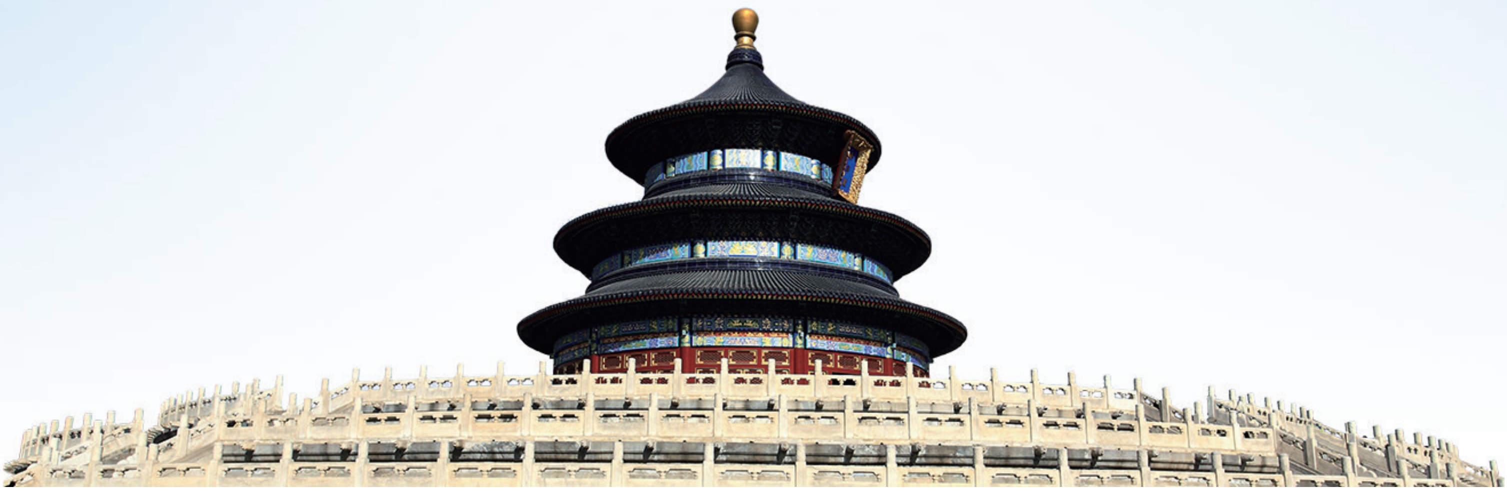
核数据2019

INTERNATIONAL CONFERENCE ON NUCLEAR DATA FOR SCIENCE AND TECHNOLOGY

May 19 - 24, 2019 • Beijing, China

CONFERENCE PROGRAM & ABSTRACT BOOK



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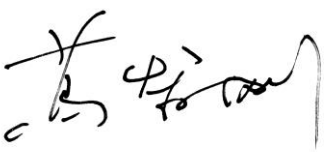
Welcome Message

Since the first symposium in Harwell (UK) in 1978, the series of International Conference on Nuclear Data for Science and Technology (ND Conference) have been the primary conference concerning nuclear data and its applications, both scientific and technical. In the forthcoming 2019, for the first time ever, the relay baton will be passed to China.

Nuclear data is a comprehensive investigational field connecting fundamental physics and nuclear applications, which has been an essence in the development of peaceful use of nuclear. In light of the increasingly paramount role of nuclear data in diverse fields of research and application, ND2019 will address many active scientific and technical fields, including: fundamental nuclear physics, astrophysics, nuclear data measurements, nuclear power and energy, nuclear medicine, nuclear non-proliferation, nuclear safety, nuclear education and public acceptance, and so on.

As the local organizers of ND2019, China Nuclear Data Center will invite all scientists and engineers interested in one of the topics above to present their achievements, share their insights and facilitate potential cooperation.



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Organizational Structure

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Mr. Zhigang Ge

LOC Secretary

Mr. Wenming Wang

Organized by

China Nuclear Data Center (CNDC)
China Institute of Atomic Energy (CIAE)
Chinese Nuclear Society (CNS)

Co-sponsored by

Nuclear Energy Agency (NEA)
International Atomic Energy Agency (IAEA）

Supported by

China Atomic Energy Authority (CAEA)
National Natural Science Foundation of China (NSFC)
China National Nuclear Corporation (CNNC)
China Center of advance science and technology world laboratory (CCAST)

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General and Practical Information

Venue and Dates

The ND2019 Conference will take place at the **China National Convention Center (CNCC)**

20 May 2019

Opening, Keynote, and Plenary session
Site: Plenary Hall B (CNCC Level 4)

20-23 May 2019

Technical Sessions
Site: CNCC Level 2 and Level 3

24 May 2019

Plenary and Closing session
Site: CNCC Level 3 Auditorium

Registration and information desk

The registration and information desk will be set-up at Level 1 Main Lobby H at CNCC during the following days and times:

May 19	09:00-22:00hrs
May 20–23	08:00-18:00hrs

Use of Internet

Wireless internet is available
Network: CNCC Free (no password)

Simultaneous Translation

For the opening and keynote sessions, the simultaneous translation will be provided. The headset will be collected at the entrance of the Plenary Hall B on May 20, 2019.

Note: Please present your valid ID to get the SI Receiver and return it after sessions.
In case of loss, a compensation of RMB 1200 for one SI Receiver will be charged.

Currency and Exchange

The currency used in China is the Renminbi Yuan (RMB or ￥) and the value is pegged to the US dollar with a current exchange rate around 6.75 (May 2019).

Euros and US Dollars can be exchanged at your hotel or at any bank. Traveler's cheques can only be exchanged at the Bank of China. Banks usually open from 9 a.m. to 5 p.m. From Monday to Friday and 9 a.m. to 4 p.m. on Saturday and Sunday.

Major credit cards are accepted at many establishments, such as American Express, Diners Club, JCB, Master Card and Visa.

ATM Machine

Beijing is a very ATM-friendly city. There are many banks with ATMs, but only about 50% of these accept foreign cards. The main foreign friendly ATMs are controlled by the Bank of China. Bank of China ATMs work in both Chinese and English (depending on your card), use the latest equipment, and are reasonably easy to find.

Weather

May is a good time to visit Beijing. It is filled with bright reds and vivid greens everywhere. Normally, the weather is very warm with the temperature remaining 10-25 Centigrade degree (50-77 Fahrenheit degree). There are usually less windy days and few sandstorms during this month. There might be some drizzle but clear and sunny days are in the majority.

Electricity

The standard voltage in China is 220 V, 50 Hz. The outlet has three prongs and you should bring your own adaptor. For a list of the outlets and plugs used in China, please check： http://electricaloutlet.org/

Insurance

Organizers of the Congress do not take any liability for personal accidents or injury or loss or damage to private property of any participant indirectly arising from travelling to Beijing and/or attending the Congress. Participants are advised to purchase adequate travel and health insurance before leaving their own countries.

Safety and Security

In general China is a very safe country. However, be aware of pickpockets and be careful when crossing the road. Passports should be kept in the hotel for safety until the departure day. Also note the serial numbers of your traveler’s checks if you carry those. We also recommend having copies of your passport and credit cards with you in case of loss or theft.

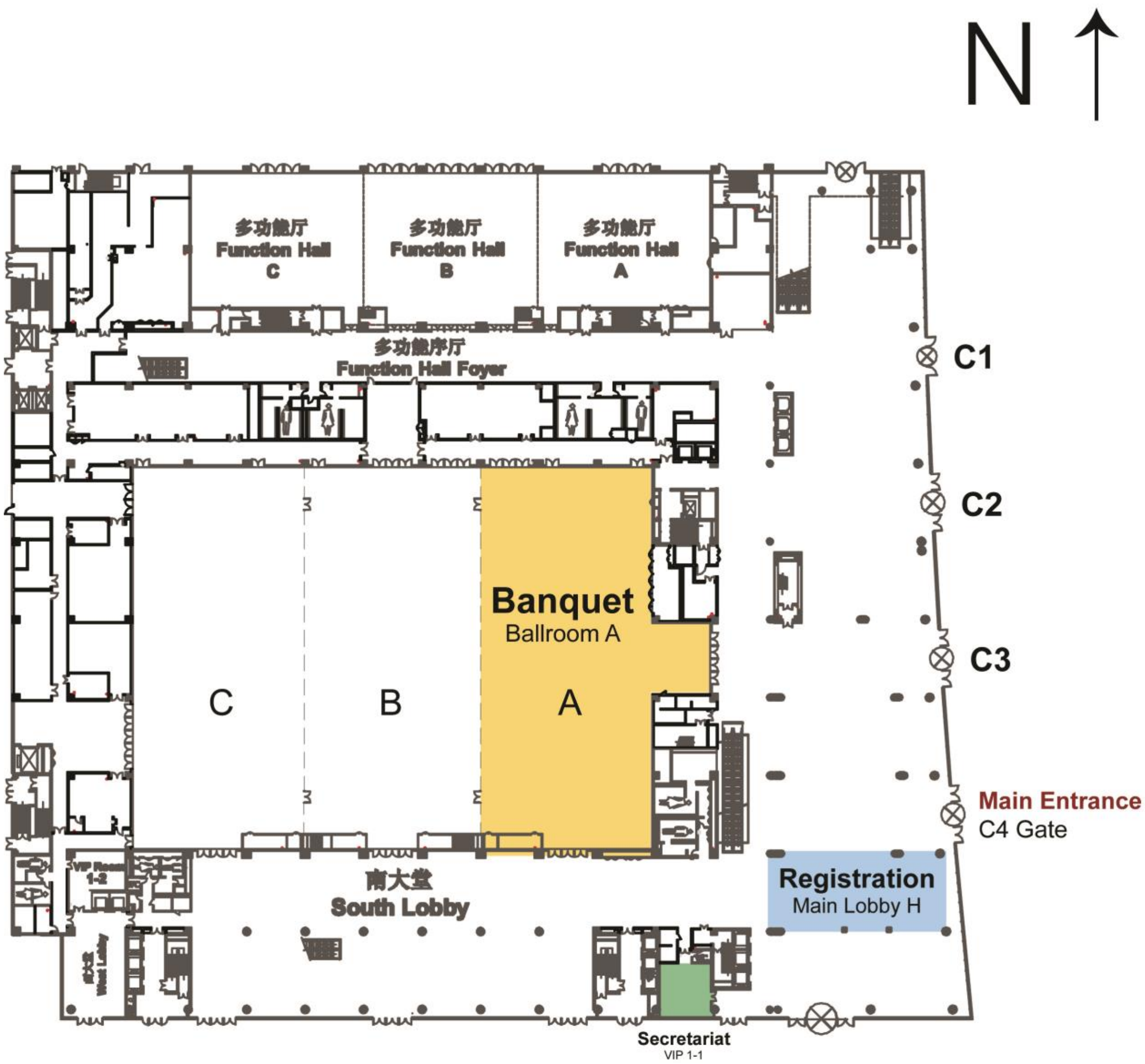
Tipping

Gratuities are not customary in China. However, in hotels and during group travels, tipping is practiced for porters, tour guides and drivers.

Smoking

Smoking in indoor public places has been banned in Beijing from June 1, 2015 following the rolling out of the toughest ever anti-smoking regulation in China. The regulation extends smoking bans to include all indoor public areas and workplaces, plus a number of outdoor areas including schools, seating areas in sports stadiums and hospitals where women or children are treated.

Level 1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多功能厅
Function Hall
C
多功能厅
Function Hall
B
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Function Hall
A
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Function Hall Foyer
C1
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Banquet
Ballroom A
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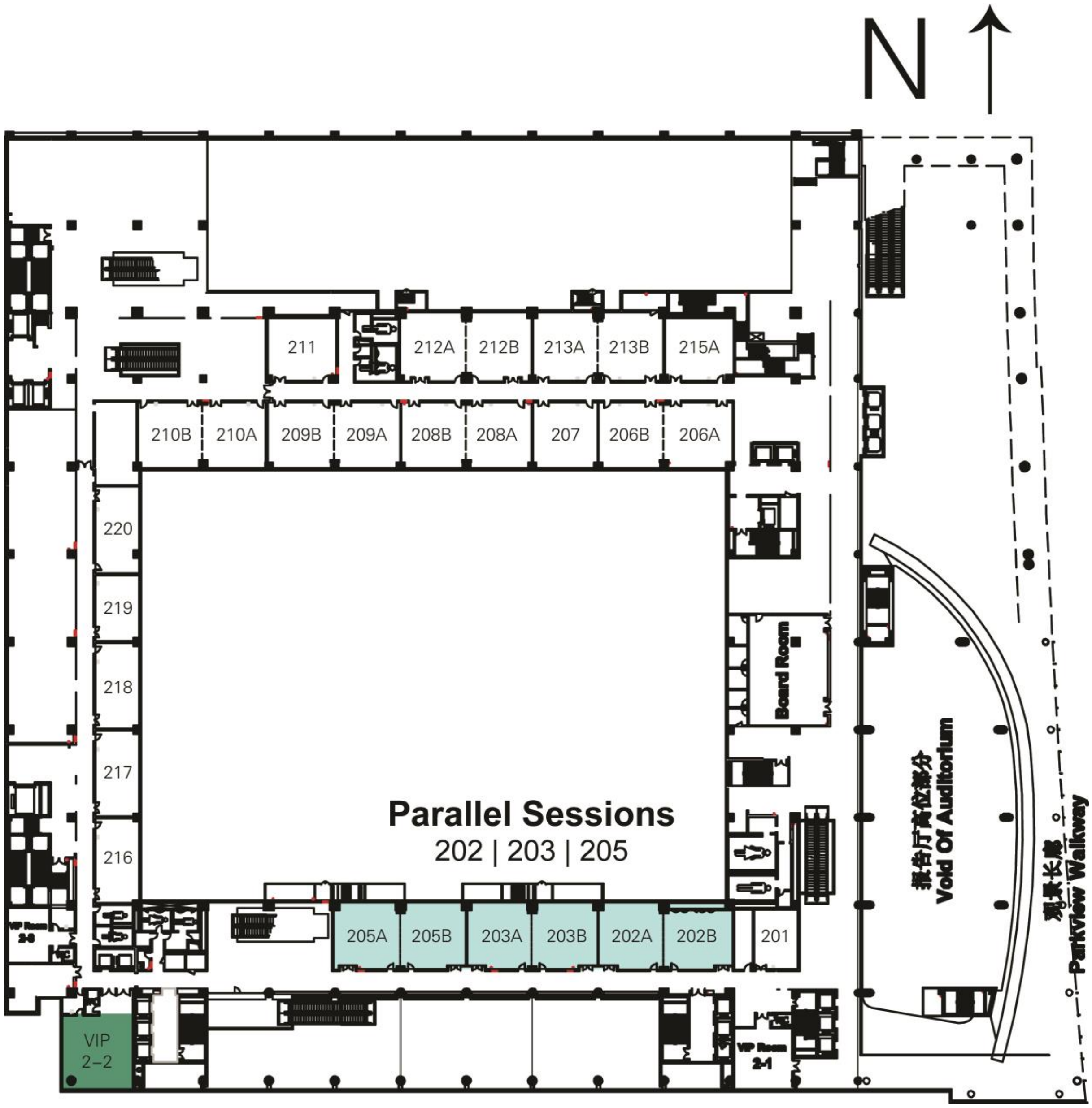
Main Entrance
C4 Gate
南大堂
South Lobby
Registration
Main Lobby H
Secretariat
VIP 1-1

Level 2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2–2
VIP Room
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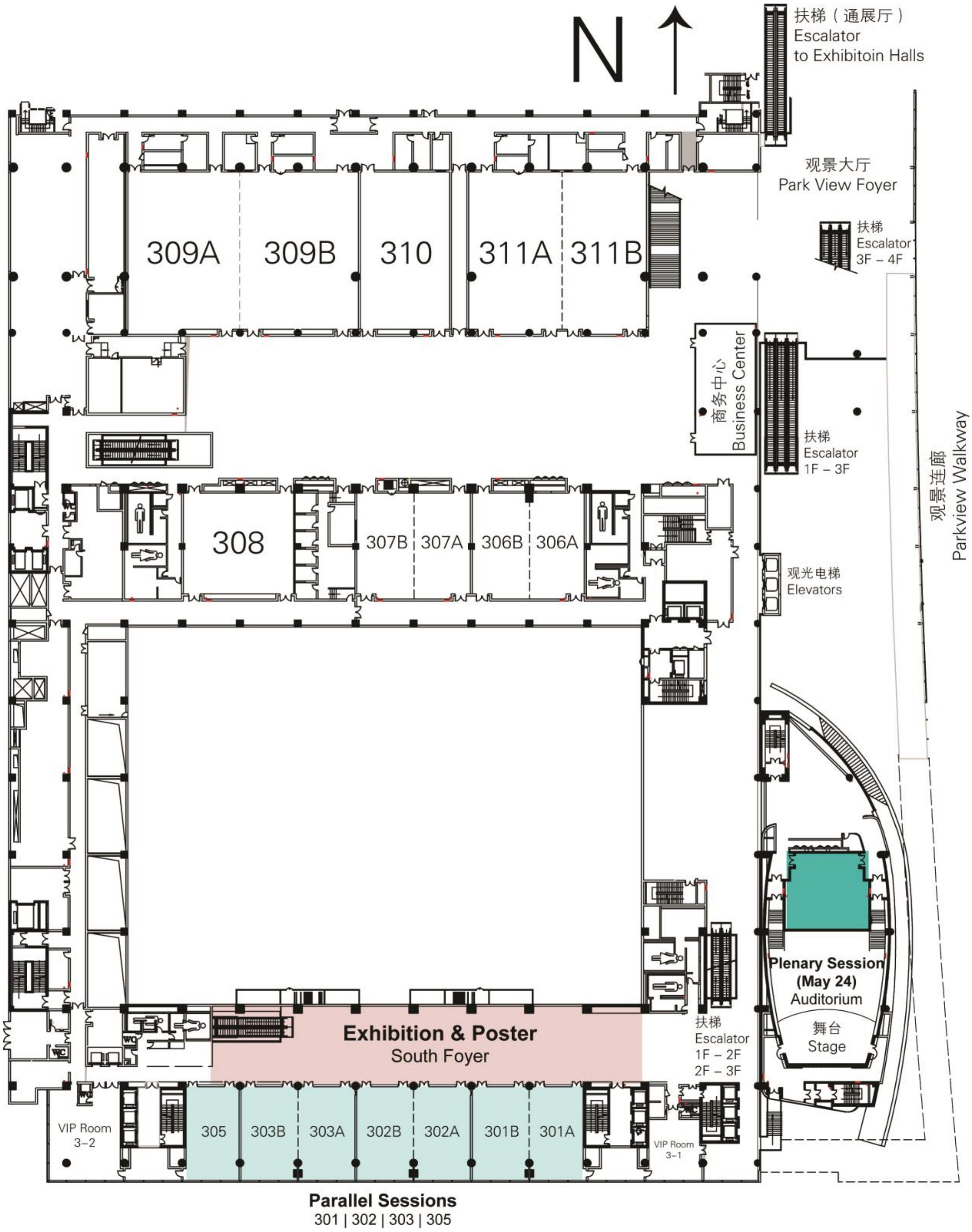
Void Of Auditorium
Parkview Walkway

Level 3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扶梯（通展厅）
Escalator
to Exhibitoin Halls
观景大厅
Park View Foyer
扶梯
Escalator
3F – 4F
309A
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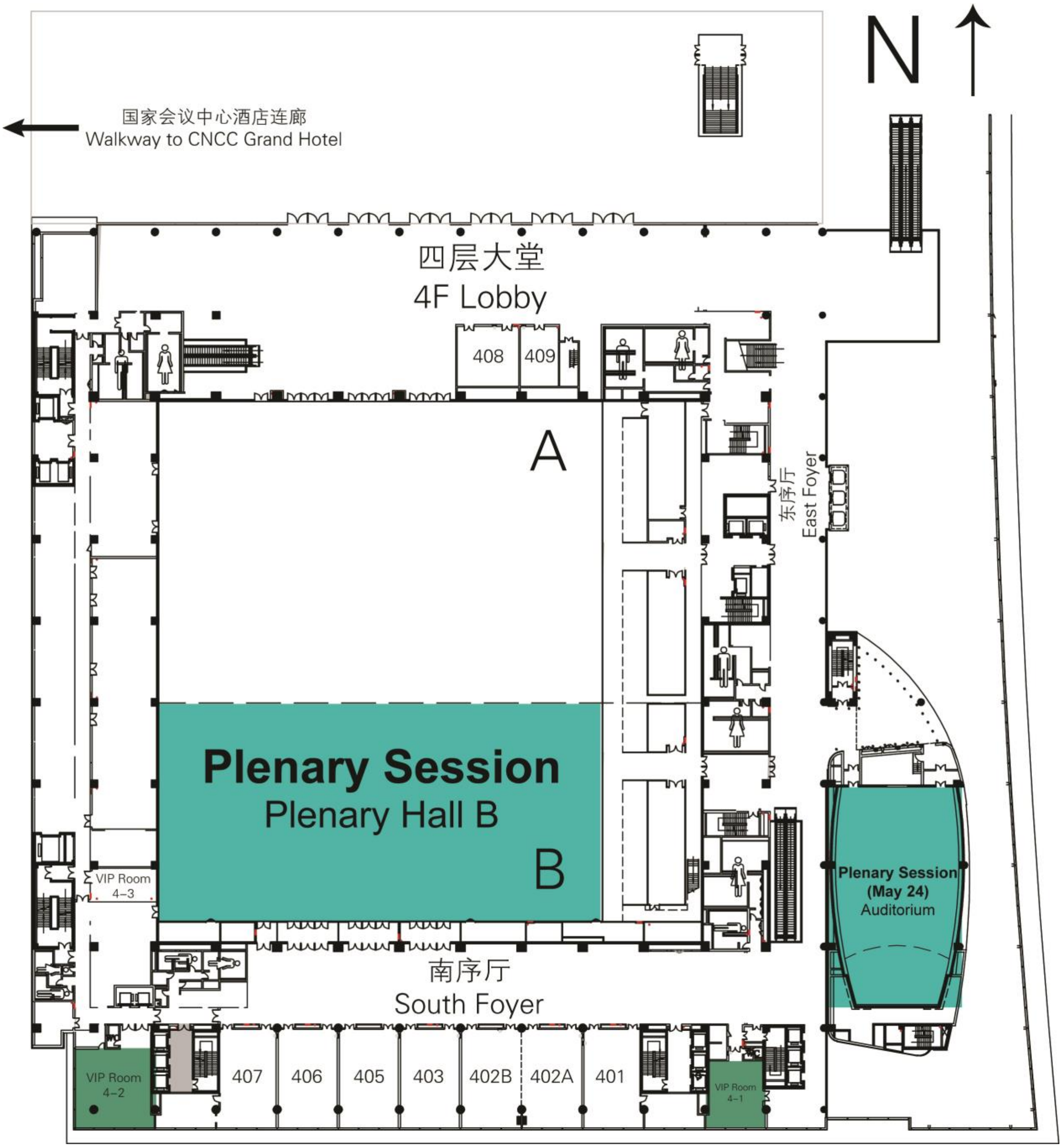
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ND2019 Agenda

Time	Site	Event
May 19		
09:00-22:00	CNCC L1 Main Lobby H	**Registration**
19:00-21:00	CNCC L4 Plenary Hall B	**Welcome Reception**
May 20		
08:00-18:00	CNCC L1 Main Lobby H	**Registration**
08:30-10:00	CNCC L4 Plenary Hall B	**Opening & Keynote Session**
10:00-10:30	To be Announced on Site	**Coffee Break & Group Photo**
10:30-12:00	CNCC L4 Plenary Hall B	**Opening & Keynote Session**
12:00-14:00	Exhibition Hall 4A	**Lunch**
14:00-18:30	CNCC L4 Plenary Hall B	**Plenary Session**
May 21		
08:00-18:00	CNCC L1 Main Lobby H	**Registration**
08:30-18:00	CNCC L3 & L2	**Parallel Session**
12:00-14:00	CNCC L3 South Foyer	**Lunch|Exhibition|Poster Networking**
May 22		
08:00-18:00	CNCC L1 Main Lobby H	**Registration**
08:30-18:00	CNCC L3 & L2	**Parallel Session**
12:00-14:00	CNCC L3 South Foyer	**Lunch|Exhibition|Poster Networking**
May 23		
08:00-18:00	CNCC L1 Main Lobby H	**Registration**
08:30-18:00	CNCC L3 & L2	**Parallel Session**
19:00-21:00	Ballroom A	**Banquet**
12:00-14:00	CNCC L3 South Foyer	**Lunch|Exhibition|Poster Networking**
May 24		
08:30-12:40	CNCC L3 Auditorium	**Plenary & Closing session**

Scientific Information

Plenary, Invited, Regular and Short Oral Contributions

Parallel sessions will take place in room 301,302,303,305,202,203,205.

- **Plenary Contributions** are indicated as “L” in the program and abstract book.
- **Invited Contributions** are indicated as “I” in the program and abstract book.
- **Regular Contributions** are indicated as “R” in the program and abstract book.
- **Short Contributions** are indicated as “S” in the program and abstract book.

Oral Presentations

- Oral presentations in all Congress programs must be given in English.
- Speaker’s Lounge is available for all speakers to submit and check the presentation files from 14:00 to 17:30 on May 19, 9:00 to 17:30 on May 20-23.
- At least 12 hours before your designated session, all technical session speakers are required to bring your presentation files with USB memory stick to the Speaker's Lounge, including your full name in the file name.
- All sessions must start on time and projectors must be utilized. Please make sure that your slides are clear and legible for all audiences.
- It is our recommendation that the speakers would arrive at least 20 minutes prior to the start of your session to communicate with your chairman about the process of your presentation. All sessions should start on time and all speakers should utilize the provided computer.

Oral Presentation Time

Presentation Type	Time
Plenary Talk	35 minutes
Invited Oral	30 minutes
Regular Oral	20 minutes
Poster/Short Oral	05 minutes

* Q & A included

Audio Visual Equipment

The following audio-visual equipment will be provided by the Congress in all technical session rooms at no charge:

i) A Laptop (Windows, 1024 x 768 standard resolution). *It is highly recommended that you save your presentation on a USB flash drive for emergency back-up.*
ii) Wireless hand hold Microphone or desk Microphone
iii) Laser Pointer
iv) Standing Lectern
v) Projector

*It is our recommendation that the speakers would arrive at least 20 minutes prior to the start of your session to communicate with your chairman about the process of your presentation. All sessions should start on time and all speakers should utilize the provided computer.

PowerPoint Slide Presentations

The following information is designed to help you prepare your visuals for a quality, professional presentation. Remember that LESS IS BETTER and all visuals *MUST BE DEVOID OF CORPORATE NAMES/LOGOS (except for title slide) AND BRAND NAMES.*

i) Prepare your PPT in the ratio of 4:3 (16:9 is available at Plenary session because LED can be Divi-Screen Displayed at 4:3 or 16:9 ratio)
ii) Design slides that can be seen from the back row of the room
iii) For the maximum effect, use 10 or fewer words on a slide
iv) Avoid using more than six words per line or eight to 10 lines of type per visual
v) Use strong, bold san serif typefaces for reading ease. Don't use all capitals; provide ample spacing between words and letters
vi) Leave space at least the height of the capital letter between line
vii) Lower case letters are more legible than capitals
viii) Vary the size of type on your visual to illustrate relative importance of information
ix) Contrast is important. In general, use dark colors for the background and light colors for text and graphics.
x) Limit each slide to one main idea
xi) Graphs and charts should be simple
xii) Include titles to supplement, not duplicate, slide data
xiii) Use duplicates if you need to refer to the same slide at different times in your presentations
xiv) Plan your slides for a good visual place in your presentation. Don't leave a slide on the screen after discussing it.

Poster Presentations

◆ **Short presentation and oral Discussions**

- Posters will have five-minute short oral talk by roughly 4-to-6 slides in the assigned sessions. Posters will be on display on the same half-day of the short oral presentation.
- Authors must be available at their posters for protracted discussions during the break of the conference on the same day.

◆ **Poster Setup, Presentation and Removal Schedule**

- Upon registration, posters need to be submitted to the local organizers on May 19, 2019.
- Posters should be less than 95cm (width)×130cm (length) in size and can be affixed to the panels using poster glue. Kindly note that the poster should be prepared by authors.
- From May 21 to 23, in parallel with the corresponding technical sessions, all posters will be on exhibition from 08:30 to 18:00 and removed roughly at 19:00.
- Without specific statements, all posters will be discarded properly and local organizers are not responsible for returning/shipping posters to authors.

Arrangements for poster exhibition

Date	Time	Event
May 19, 2019	10:00-18:00	Poster Collection
May 21, 2019	08:30-18:00	Day1 exhibition
May 22, 2019	08:30-18:00	Day2 exhibition
May 23, 2019	08:30-18:00	Day3 exhibition

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Topic Track: Plenary A
Session Title: Plenary A1
Chair: Tokio Fukahori

14:00	**L001**	**The Joint Evaluated Fission and Fusion (JEFF) Nuclear Data Library** / Arjan Plompen (European Commission - Joint Research Centre, Belgium)
14:35	**L002**	**Recent Results from the Neutron Induced Fission Fragment Tracking Experiment Using the FissionTPC** / Nathaniel Bowden (Lawrence Livermore National Laboratory, USA)
15:10	**L003**	**Correlated Transition of TKE and Mass Distribution in Nuclear Fission** / Satoshi Chiba (Tokyo Ins. of Technology, Japan)
15:45		**Break**

Topic Track: Plenary A
Session Title: Plenary A2
Chair: Arjan Koning

16:05	**L004**	**The CONRAD Code, A Tool for Nuclear Data Analysis and Nuclear Reaction Modelling** / Cyrille De Saint Jean (CEA, France)
16:40	**L005**	**Fast Neutron Capture Reaction Data Measurement of Minor Actinides for Development of Nuclear Transmutation Systems** / Tatsuya Katabuchi (Tokyo Ins. of Technology, Japan)
17:15	**L006**	**Nuclear and covariance data adjustment for nuclear data files improvement: new methods and approaches** / Massimo Salvatores (Scientific Advisor, Reactor and Fuel Cycle, France)
17:50	**L007**	**CENDL3.2: The New General Purpose Nuclear Database** / Zhigang Ge (China Nuclear Data Center, Beijing)

Tue May 21	8:30-12:30	Room 202

Topic Track: Nuclear theory, model and codes
Session Title: Nuclear reaction theory models and codes 1
Chair: Gilles Noguere

08:30	**I008**	**Novel Challenges for FLUKA: Status of the Code and A Review of Recent Developments** / Alfredo Ferrari (CERN, Switzerland)
09:00	**R009**	**Total Cross Section Model with Uncertainty Evaluated by KALMAN** / Shintaro Hashimoto (Japan Atomic Energy Agency)
09:20	**R010**	**Synergy of Nuclear Data and Nuclear Theory Online** / Andrey Denikin (FLNR, Joint Ins. for Nuclear Research, Dubna, Russian Federation)
09:40	**R011**	**Recent Progress of A Code System Deuracs Toward Deuteron Nuclear Data Evaluation** / Shinsuke Nakayama (Japan Atomic Energy Agency)
10:00	**R012**	**Systematic Formalism for the (n,p) Reaction Cross Section at 2.5, 14, 20 MeV with Explicit Description of MSC and MSD Pre-equilibrium Multiple Particle Emission** / Olumide Oluwasanmi Ige (Physics Department Nigerian Defence Academy Kaduna)
10:20		**Break**

Topic Track: Nuclear theory, model and codes
Session Title: Nuclear reaction theory models and codes 2
Chair: Alfredo Ferrari

10:40	**R013**	**Systematic Uncertainties of E1 Photon Strength Functions Extracted from Photodata** / Oleksandr Gorbachenko (Taras Shevchenko National Uni. of Kyiv, Kyiv, Ukraine) / Speaker: Stephane Goriely
11:00	**R014**	**Comparative Analysis of Neutron Activation Cross Sections of Aluminum Used As Cladding in Miniature Neutron Source Reactors** / Olumide Oluwasanmi Ige (Physics Department Nigerian Defence Academy Kaduna)
11:20	**R015**	**Nucleon-transfer Reactions for Low-energy Deuterons in FLUKA** / Salvat-pujol Francesc (on Behalf Of The Fluka Collaboration) (CERN, Switzerland)
11:40	**R016**	**Consistent Assessment of Deuteron Interactions at Low and Medium Energies** / Marilena Avrigeanu (Horia Hulubei National Ins. for Physics and Nuclear Engineering (IFIN-HH), Romania)
12:00	**R017**	**Alpha-nucleus Optical Potential Based on the Isospin-dependent DBHF** / Zhi Zhang (CIAE, China)
12:20	**S018**	**The Cross Sections and Energy Spectra of the Particle Emission in α Induced Reaction on $^{54,56,57,58,\mathrm{nat}}$Fe and $^{63,65,\mathrm{nat}}$Cu** / Xinwu Su (Shanxi Datong Uni., Datong , China) / Speaker: Yongli Xu
12:25	**S019**	**Employing Talys to Deduce Initial JRMS in Fission Fragments** / Ali Al-adili (Uppsala Uni., Sweden)

Topic Track: Nuclear theory, model and codes
Session Title: Nuclear reaction theory models and codes 3
Chair: Helmut Leeb

14:00	**I020**	**Multiband Coupling and Nuclear Softness in Optical Model Calculations for Even-even and Odd-A Actinides** / Dmitry Martyanov (Joint Ins. for Power and Nuclear Research - Sosny, Belarus)
14:30	**R021**	**Global Phenomenological Optical Model Potentials for Some Weakly Bounded Light Projectiles** / Yongli Xu (College of Physics and Electronic Science, Shanxi Datong Uni., Datong , China)
14:50	**R022**	**The Dark Side of Alpha-particle Optical Potential: Emission from Excited Nuclei** / Vlad Gabriel Avrigeanu (Horia Hulubei National Ins. for Physics and Nuclear Engineering (IFIN-HH), Romania)
15:10	**R023**	**Unified Description of Bound States and Nucleon Scattering for Double Magic Nuclei by A Lane-consistent Dispersive Optical Model Potential** / Weili Sun (Ins. of Applied Physics and Computational Mathematics, China)
15:30	**R024**	**Comparison of Practical Expressions for E1 Photon Strength Functions** / Oleksandr Gorbachenko (Taras Shevchenko National Uni. of Kyiv, Kyiv, Ukraine) / Speaker: Ihor kadenko
15:50		**Break**

Topic Track: Nuclear theory, model and codes
Session Title: Nuclear reaction theory models and codes 4
Chair: Dmitry Martyanov

16:10	**I025**	**Developments Regarding Three-body Reaction Channels Within the R-matrix Formalism** / Helmut Leeb (TU Wien, Austria)
16:40	**R026**	**Monte Carlo Simulation of Gamma and Fission Transfer Reactions Using Extended R-matrix Theory** / Olivier Bouland (CEA/DER/SPRC/LEPh, CE Cadarache, Saint-Paul-lez-Durance, France)
17:00	**R027**	**Modernization of Sammy: An R-matrix Bayesian Nuclear Data Evaluation Code** / Goran Arbanas (ORNL, USA)
17:20	**R028**	**R-matrix Analyses of Light Element Reactions** / Paris Mark (T-2, Theoretical Division, LANL, USA)
17:40	**S029**	**Theoretical Calculation of Micro Data for the Nuclear Reaction of p+^{27}Al up to 200 MeV** / Zhengjun Zhang (North West Uni. , Xi'an , China)
17:45	**S030**	**An Evaluation of the Alpha-cluster Formation Factor in (n,α) Reactions** / Odsuren Myagmarjav (Nuclear Research Center, National Uni. of Mongolia, Mongolia)

Tue May 21 | 8:30-12:20 | Room 203

Topic Track: Evaluation
Session Title: Evaluation methodology 1
Chair: Nobuyuki Iwamoto

08:30	**I031**	**New Paradigm for Nuclear Data Evaluation** / Michal Herman (LANL, USA)
09:00	**R032**	**Prompt Fission Neutron Spectra of ^{238}U(n,F) and ^{232}Th(n,F)** / Vladimir M. Maslov (Joint Ins. of Nuclear and Energy Research, 22 0109, Minsk-Sosny, Belarus)
09:20	**R033**	**Interfacing TALYS with A Bayesian Treatment of Inconsistent Data and Model Defects** / Georg Schnabel (Uppsala Uni., Sweden)
09:40	**R034**	**The RAC-CERNGEPLIS Evaluation Method for Global Fitting** / Zhenpeng Chen (Tsinghua Uni., China)
10:00	**R035**	**Theoretical Calculations and Covariance Analysis for n+^{40}Ca Reactions** / Yue Zhang (China Inst. of Atomic Energy)
10:20		**Break**

Topic Track: Evaluation
Session Title: Evaluation methodology 2
Chair: Michal Herman

10:40	**R036**	**New Reaction Evaluations for Chromium Isotopes** / Gustavo Nobre (Brookhaven National Laboratory, USA)
11:00	**R037**	**New Evaluations of W-182,184,186 General Purpose Neutron Cross-section Data up to 200 MeV Neutron Energy** / Alexander Konobeyev (Karlsruhe Ins. of Technology, Germany)
11:20	**R038**	**^{233}U Cross Section Comparison Evaluation Between SAMMY and FITWR Code Fitting Procedures** / Mohammad Alrwashdeh (Khalifah university, Jordan)
11:40	**R039**	**Evaluation of Neutron Induced Reactions on Fe-56 with CONRAD** / Maria Diakaki (CEA, DEN Cadarache, F-13 108 Saint Paul Les Durance, France)
12:00	**S040**	**Calculation of Stricken to Mortality and Incidence Cancers Due to Beyond Design Basis Accidents (BDBA) in Populations Near Nuclear Facilities** / Hadi Shamoradifar (Payam e noor university, Iran)
12:05	**S041**	**Some Ideas Need Discussion in Global Fitting for Nuclear Data Evaluation** / Zhenpeng Chen (Tsinghua university, China)
12:10	**S042**	**The Evaluations of Gamma-induced V-51** / Lin Li (China Inst. of Atomic Energy)
12:15	**S043**	**Development the Nuclear Decay Data Sublibrary for Fission Product** / Xiaolong Huang (China Nuclear Data Center)

Tue May 21	14:00-17:50	Room 203

Topic Track: Evaluation
Session Title: Evaluation methodology 3
Chair: Cyrille De Saint Jean

14:00	**I044**	**Resonance Evaluations of Gadolinium Isotopes** / Luiz Leal (Institut de Radioprotection et de Surete Nucleaire, France)
14:30	**R045**	**Measurement and Covariance Analysis of Reaction Cross-section by Using Unscented Transformation Method** / Vidya Devi (IET Bhaddal, Rupnagar, Punjab-India)
14:50	**R046**	**Unified Bayesian Evaluation of Oxygen Based on the Hybrid R-matrix Method** / Helmut Leeb (TU Wien, Austria)
15:10	**R047**	**New Perspectives in Neutron Reaction Cross-section Evaluation Using Consistent Multichannel Modeling Methodology: Application to 16-O** / Aloys Nizigama (CEA/DER/SPRC/LEPh, CE Cadarache, 13 108 Saint-Paul-lez-Durance, France) / Speaker: Olivier Bouland
15:30	**R048**	**Evaluation and Validation of ^{28,29,30}Si Cross Sections in the Resolved Resonance Region** / Roberto Capote (IAEA)
15:50		**Break**

Topic Track: Evaluation
Session Title: Evaluation methodology 4
Chair: Luiz Leal

16:10	**R049**	**On the Use of Indicator for Measuring Goodness of Bayesian Inference in Evaluation of Nuclear Data** / Cyrille De Saint Jean (CEA, France)
16:30	**R050**	**Prompt Fission Neutron Spectra of ^{237}Np(n,F) and ^{241,243}Am(n,F)** / Vladimir M. Maslov (Joint Ins. of Nuclear and Energy Research, Minsk-Sosny, Belarus)
16:50	**R051**	**Can Machine Learning Techniques Help Us to Solve Nuclear Data Problems?** / Denise Neudecker (LANL, USA) / Speaker: LA-TBD
17:10	**R052**	**The Systematics of Nuclear Reaction Excitation Function** / Jimin Wang (China Inst. of Atomic Energy)
17:30	**R053**	**New ^{23}Na Nuclear Data Evaluation Taking Into Account Both Differential and Double Differential Experiments** / Pascal Archier (CEA, France)

Tue May 21 — 8:30-12:30 — Room 205

Topic Track: Nuclear data processing and validation
Session Title: Nuclear data processing 1
Chair: Cedric Jouanne

08:30	I054	**Status of the IRSN Nuclear Data Processing System GAIA-2** / Clément Jeannesson (Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France)
09:00	R055	**Analyzing the Distribution of Scattering Angle in Ace Multigroup Library Using the Maximum Entropy Method** / Shuaitao Zhu (North China Electric Power Uni.)
09:20	R056	**Study on Consistent PN Cross Section Process Method for Fast Reactor** / Xubo Ma (North China Electric Power Uni.)
09:40	R057	**Upgrade on Neutron-gamma Coupled Multi-group Data Generation System** / Xiaofei Wu (China Nuclear Data Center)
10:00	R058	**Development of Multi-group Nuclear Engineering Computational Library for Neutronics Calculation of Light Water Reactors** / Qingming He (Xi'an Jiaotong Uni., China)
10:20		**Break**

Topic Track: Nuclear data processing and validation
Session Title: Nuclear data processing 2
Chair: Clément Jeannesson

10:40	I059	**Current Status of the GALILEE-1 Processing Code** / Cedric Jouanne (CEA Saclay, France)
11:10	I060	**Implementation of URR and NTSL in the GNDS Format Using FUDGE** / Bret Beck (Lawrence Livermore National Laboratory, USA)
11:40	R061	**New R-matrix Resonance Reconstruction in NJOY21** / Wim Haeck (LANL, USA)
12:00	R062	**Development and Verification of Resonance Elastic Scattering Kernel Processing Module in Nuclear Data Processing Code NECP-Atlas** / Jialong Xu (Xi'an Jiaotong Uni., China)
12:20	S063	**Application of hyperfine group self-shielding calculation method to lattice and whole-core physics calculation** / Wen Yin (School of Nuclear Science and Technology, Xi'an Jiaotong Uni., Xi'an, Shaanxi, China)
12:25	S064	**Updates of the Pressurized Water Reactor Burnup Nuclear Data Libraries Based on the Latest ENDF/B-VIII.0 Data** / Chao Peng (Shanghai Nuclear Engineering Research & Design Ins. CO., LTD, China)

Tue May 21 14:00-18:00 Room 205

Topic Track: Nuclear data processing and validation
Session Title: Nuclear data processing 3
Chair: Haicheng Wu

14:00	**I065**	**Progress of the Development of the Nuclear Data Processing Code NECP-Atlas** / Tiejun Zu (Xi'an Jiaotong Univerisity, China)
14:30	**I066**	**Advanced Neutronics Software SuperMC and Its Real Time Multi-temperature Cross Sections Generation Method** / Liqin Hu (Ins. of Nuclear Energy Safety Technology, Chinese Academy of Sciences, China)
15:00	**R067**	**NDPlot: A Plotting Tool for Nuclear Data** / Yongli Jin (China Nuclear Data Center, China Inst. of Atomic Energy, Beijing 10 2413, China)
15:20	**R068**	**Progress Towards International Adoption of GNDS** / Caleb Mattoon (Lawrence Livermore National Laboratory, USA)
15:40	**S069**	**On the Use of the Integral Data Assimilation Technique to Provide Feedback on Evaluated Nuclear Data: Application to the JEFF-3.1.1 Library Using Post-irradiation Examinations** / Gilles Noguere (CEA Cadarache, France)
15:50		**Break**

Topic Track: Nuclear data processing and validation
Session Title: Nuclear data adjustment 1
Chair: Tiejun Zu

16:10	**I070**	**Trends on Major Actinides from an Integral Data Assimilation** / Gerald Rimpault (CEA, DEN, DER, SPRC, Cadarache, F-St Paul-Lez-Durance, France) / Speaker: Gilles Noguere
16:40	**R071**	**Researches on Nuclear-data Adjustment for the Sodium-cooled Fast Reactor** / Chenghui Wan (Xi'an Jiaotong Uni., China)
17:00	**R072**	**Using Tanimato Measure to Assess Similarities of Different Critical Assemblies** / Kai Fan (CAEP, China)
17:20	**R073**	**Impact of Nuclear Data Evaluations on Data Assimilation for An LFR** / Pablo Romojaro (CIEMAT, Spain)
17:40	**R074**	**Towards Rigorous Integral Feedback: Computing Reference Sensitivities to Resonance Parameters** / Pierre Tamagno (CEA, France)

Tue May 21 | 8:30-12:30 | Room 301

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 1
Chair: Jan Heyse

08:30	**I075**	**Gains: Neutron Inelastic Cross Section Measurements of Interest for Applications and Reaction Studies** / Alexandru Liviu Negret (Horia Hulubei National Ins. for Physics and Nuclear Engineering, Romania)
09:00	**R076**	**Neutron Inelastic Cross Sections on ^{16}O** / Marian Boromiza (Horia Hulubei National Ins. for Physics and Nuclear Engineering, Romania)
09:20	**R077**	**Neutron Inelastic Cross Sections on ^{54}Fe** / Adina Olacel (Horia Hulubei National Ins. for Physics and Nuclear Engineering, Magurele, Romania)
09:40	**R078**	**Fast Neutron Inelastic Scattering from ^{7}li** / Roland Beyer (Helmholtz-Zentrum Dresden-Rossendorf, Germany)
10:00	**R079**	**Measurement of the Angular Distribution of Neutrons Scattered from Deuterium Below 3 MeV** / Elisa Pirovano (Physikalisch-Technische Bundesanstalt, Germany)
10:20		**Break**

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 2
Chair: Alexandru Liviu Negret

10:40	**I080**	**Nuclear Data Activities at the EC-JRC Neutron Facilities GELINA and MONNET** / Jan Heyse (European Commission - Joint Research Centre, Belgium)
11:10	**R081**	**Measurement of the ^{13}C Absorption Cross Section Via Neutron Irradiation and AMS** / Tobias Wright (Uni. of Manchester, United Kingdom)
11:30	**R082**	**Profil-2 Experiment and Neutron Capture Cross Sections of Europium Isotopes** / Shengli Chen (CEA, France)
11:50	**R083**	**^{241}Am Neutron Capture Cross Section Measured with C6D6 Detectors at the n_TOF Facility, CERN** / Andreea Oprea (Horia Hulubei National Ins. for R&D in Physics and Nuclear Engineering (IFIN-HH), Romania)
12:10	**R084**	**Filtered Neutron Capture Cross-section of Hf-180** / Ngoc Son Pham (Nuclear Research Institute, Vietnam)

Tue May 21 14:00-18:00 Room 301

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 3
Chair: Hiroaki Utsunomiya

14:00	R085	**Preliminary Results on the Neutron Induced Capture Cross Section and Alpha Ratio of ^{233}U at n_TOF with Fission Tagging** / Michael Bacak (CERN, Switzerland)
14:20	R086	**Radiative Thermal-neutron Capture on ^{139}La** / Aaron Hurst (Uni. of California, Berkeley, USA)
14:40	R087	**Measurement of the Pu-242(n,γ) Cross Section from Thermal to 500 KeV at the Budapest Research Reactor and CERN n_TOF-EAR1 Facilities** / Jorge Lerendegui-marco (Universidad de Sevilla, Spain)
15:00	R088	**Measurement of Neutron-capture Cross Sections of Radioactive Minor Actinide Isotopes with High Time-resolution Neutron Pulses at J-PARC/MLF** / Shoichiro Kawase (Japan Atomic Energy Agency)
15:20	R089	**Measurement of the Neutron Capture Cross Section of ^{237}Np Using ANNRI at MLF/J-PARC** / Gerard Rovira Leveroni (Tokyo Ins. of Technology, Japan)
15:40	S090	**Research on Neutron Total Cross-section Measurement at CSNS-WNS** / Xingyan Liu (China Academy of Engineering Physics, Mianyang , China)
15:45	S091	**Neutron Capture and Total Cross-section Measurement of Gd-155 and Gd-157 at ANNRI in J-PARC** / Atsushi Kimura (Japan Atomic Energy Agency (JAEA))
15:50		**Break**

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 4
Chair: Tatsuya Katabuchi

16:10	I092	**GDR Cross Sections Updated in the IAEA-CRP** / Hiroaki Utsunomiya (Konan Uni., Japan)
16:40	R093	**Study of Photon Strength Functions of Pu-241 and Cm-245 from Neutron Capture Measurements** / Daniel Cano-ott (CIEMAT, Spain)
17:00	R094	**New Reliabile Photoneutron Reaction Data for ^{159}Tb** / Vladimir Varlamov
17:20	R095	**Measurement and Analysis of ^{155,157}Gd(n,γ) From Thermal Energy to 1 Kev** / Cristian Massimi (INFN - Bologna, Italy)
17:40	S096	**Neutron Inelastic Cross Section Measurements on ^{58,60}Ni** / Adina Olacel (Horia Hulubei National Ins. for Physics and Nuclear Engineering, Romania)
17:45	S097	**Neutron Resonance Transmission Analysis of Cylindrical Samples Used for Reactivity Worth Measurements** / Lino Salamon (CEA, DER, DEN, Cadarache, F-Saint-Paul-les-Durance, France)
17:50	S098	**Photodisintegration Reaction Rate Involving Charged Particles: Systematic Uncertainty from Nuclear Optical Model Potential and Experimental Solution Based on ELI-NP** / Haoyang Lan (Uni. of South China)
17:55	S099	**A Compact Photo-neutron Source Driven by 15 MeV Electron Linac** / Jianlong Han (Shanghai Ins. of Applied Physics, Chinese Academy of Sciences, Shanghai , China)

Tue May 21		8:30-12:30	Room 302

Topic Track: Fission physics and observables
Session Title: Fission theory and experimental 1
Chair: Satoshi Chiba

08:30	I100	**Energy Dependent Fission Product Yields from Neutron Induced Fission of ^{235}U, ^{238}U, and ^{239}Pu** / Anton Tonchev (Lawrence Livermore National Laboratory, USA)
09:00	R101	**Fission Studies at IGISOL/JYFLTRAP: Measurements of Neutron-induced Fission Yields** / Andreas Solders (Uppsala Uni., BOX 516, Uppsala, Sweden)
09:20	R102	**Product Yields from 0.57 MeV, 1.0 MeV and 1.5 MeV Neutron Induced Fission of U-235** / Jing Feng (China Inst. of Atomic Energy)
09:40	R103	**Fission Studies at IGISOL/JYFLTRAP: Isomeric Yield Ratio Measurements from 25 MeV ^{nat}U(p,f), in the Quest for Angular Momentum Studies** / Mattias Lantz (Uppsala Uni., Sweden)
10:00	R104	**Update of EXFOR for Experimental Fission Product Yield** / Naohiko Otsuka (IAEA) / Speaker: Shin Okumura
10:20		**Break**

Topic Track: Fission physics and observables
Session Title: Fission theory and experimental 2
Chair: Anton Tonchev

10:40	I105	**Energy Dependent Fission Yield Calculations with Langevin Model, Hauser-Feshbach Statistical Decay and Beta Decay** / Shin Okumura (Internationl Atomic Energy Agency, Austria)
11:10	R106	**Fission Study in Macro-microscopic Model** / Tieshuan Fan (School of Physics, Peking Uni., China) / Speaker: Zhiming Wang
11:30	R107	**Calculation of Fission Fragment Mass Distributions by Using A Semi-empirical Method** / Jounghwa Lee (Nuclear Data Center, Korea Atomic Energy Research Institute, Daejeon , Korea)
11:50	R108	**Study of fission dynamics with a three-dimensional Langevin approach** / Lile Liu (China Inst. of Atomic Energy)
12:10	R109	**A Global Parameterization for Fission Yields** / Amy Lovell (LANL, USA)

Tue May 21	14:00-17:55	Room 302

Topic Track: Fission physics and observables
Session Title: Fission theory and experimental 3
Chair: Ali Al-adili

14:00	**I110**	**Parameter Optimization for Spontaneously Fissioning Isotopes in FREYA** / Ramona Vogt (Nuclear and Chemical Sciences Division, Lawrence Livermore National Laboratory, Livermore, CA , USA)
14:30	**R111**	**Microscopic Study on Nuclear Fission Dynamics Within Covariant Density Functional Theory** / Zhipan Li (School of Physical Science and Technology, Southwest Uni., Chongqing , China)
14:50	**R112**	**A Monte Carlo Approach for Estimating Fission Fragment Distributions** / Marc Verriere (LANL, USA)
15:10	**R113**	**Calculation of the beta-delayed fission gamma data** / Nengchuan Shu (China Inst. of Atomic Energy)
15:30	**R114**	**Study of High-energy Fission and Quasi-fission with Inverse Kinematics** / Giorgia Mantovani (INFN-LNL, Uni. of Padova, Italy)
15:50		**Break**

Topic Track: Fission physics and observables
Session Title: Fission theory and experimental 4
Chair: Ramona Vogt

16:10	**I115**	**The VERDI Spectrometer - Opportunities and Challenges** / Ali Al-adili (Department of Physics and Astronomy, Uppsala Uni., Sweden)
16:40	**R116**	**FALSTAFF, An Apparatus to Study Fission Fragment Distributions: First Arm Results** / Quentin Deshayes (CEA Irfu, France)
17:00	**R117**	**Performance of A Twin Position-sensitive Frisch-grid Ionization Chamber for Photofission Experiments*** / Marius Peck (Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany)
17:20	**R118**	**Fission Fragments Observables Measurements at the LOHENGRIN Spectrometer** / Christophe Sage (CNRS/LPSC, F-Grenoble, France)
17:40	**S119**	**DeℓFin: A Talys-based Tool for the Comparison of Fission Model Codes** / Andreas Solders (Uppsala Uni., BOX 51 6, Uppsala, Sweden, China)
17:45	**S120**	**Discussion of Atomic Number Measurement of Fission Fragment by the Nuclear Stopping Power** / Wengang Jiang (Northwest Ins. of Nuclear Technology, China) / Speaker: Quanlin Shi
17:50	**S121**	**Yield Evaluation for Several Chains of ^{235}U+n Fission with Zp Model** / Xiaoxue Zhao (Shenyang Normal Uni., China)

Topic Track: Experimental facilities, equipment techniques and methods
Session Title: Experimental facilities, equipment techniques and methods 1
Chair: Markus Nyman

08:30	I122	**RAON: Rare Isotope Accelerator Complex for On-line Experiment** / Young Kwan Kwon (Rare Isotope Science Project (RISP) / Ins. for Basic Science (IBS), Korea)
09:00	R123	**Neutron Activation Experiment of ITER Concrete Based on HINEG D-T Neutron Source** / Jun Zou (Ins. of Nuclear Energy Safety Technology, CAS• FDS Team, China)
09:20	R124	**Development of HINEG and Its Experimental Campaigns** / Fang Wang (Ins. of Nuclear Energy Safety Technology, Chinese Academy of Sciences, Hefei, Anhui, China) / Speaker: Yongfeng Wang
09:40	R125	**A New LCS γ Source- Shanghai Laser Electron Gamma Source (SLEGS) At Shanghai Synchrotron Radiation Facility (SSRF)** / Gongtao Fan (Shanghai Advanced Research Ins. Chinese Academy of Sciences, China)
10:00	R126	**Physics Design of the Next-generation Spallation Neutron Target-moderator-reflector-shield Assembly Mark-IV at LANSCE** / Lukas Zavorka (LANL, USA)
10:20		**Break**

Topic Track: Experimental facilities, equipment techniques and methods
Session Title: Experimental facilities, equipment techniques and methods 2
Chair: Young Kwan Kwon

10:40	I127	**New Equipment for Neutron Scattering Cross-section Measurements at GELINA** / Markus Nyman (European Commission, Joint Research Centre, Unit G.2 - Standards for Nuclear Safety, Security & Safeguards, Retieseweg 111, 2440 Geel, Belgium)
11:10	R128	**Current Status of KAERI Neutron Time-of-flight Facility and Its Performance Prediction Through Monte Carlo Simulations** / Jong Woon Kim (Korea Atomic Energy Research Institute)
11:30	R129	**Neutron Beam Line for TOF Measurements at the Spanish National Accelerator Lab (CNA)** / Miguel Macías Martínez (Universidad de Sevilla - Centro Nacional de Aceleradores, Spain)
11:50	R130	**Commissioning of An MRTOF-MS at IMP/CAS** / Wenxue Huang (Ins. of Modern Physics, Chinese Academy of Sciences, China)
12:10	S131	**Laser-driven Neutrons for Time-of-flight Experiments?** / Carlos Guerrero (Universidad de Sevilla (US), Spain) / Speaker: Jorge Lerendegui Marco
12:15	S132	**The Prototype Dosimetry System to Protect MPD Electronic Equipment at the New NICA Collider.** / Marcin Bielewicz (National Center for Nuclear Research, Swierk, Otwock, Poland)
12:20	S133	**Neutron Source Evaluation for the Neutron Data Production System (NDPS) At RAON** / Sangjin Lee (Ins. for Basic Science (IBS), Korea)
12:25	S134	**A Design of Transition-edge Sensor for Measuring Kinetic Energies of Fission Fragments** / Xianglei Wang (Northwest Ins. of Nuclear Technology, China)

Topic Track: Experimental facilities, equipment techniques and methods
Session Title: Experimental facilities, equipment techniques and methods 3
Chair: Heikki Penttila

14:00	**I135**	**Status and Perspectives of the Neutron Time-of-flight Facility n_TOF at CERN** / Enrico Chiaveri (European Organizatoin for Nuclear Research (CERN), Switzerland)
14:30	**R136**	**Fission Studies at IGISOL/JYFLTRAP: Simulations of the Ion Guide for Neutron-induced Fission and Comparison with Experimental Data** / Zhihao Gao (Uppsala Uni., BOX 516, Uppsala, Sweden.)
14:50	**R137**	**Discovery of New Neutron-moderating Materials at ISIS Neutron and Muon Source** / Goran Skoro (UK Research and Innovation Science and Technology Facilities, United Kingdom)
15:10	**R138**	**Development of SONATE, A Compact Accelerator Driven Neutron Source** / Loic Thulliez (IRFU, CEA, Université Paris-Saclay F-Gif-sur-Yvette France)
15:30	**R139**	**Introduction of the C6D6 Detector System of the Back-n at CSNS** / Jie Ren (China Inst. of Atomic Energy)
15:50		**Break**

Topic Track: Experimental facilities, equipment techniques and methods
Session Title: Experimental facilities, equipment techniques and methods 4
Chair: Enrico Chiaveri

16:10	**I140**	**Radioactive Ion Beam Manipulation at the IGISOL-4 Facility** / Heikki Penttila (Uni. of Jyväskylä, Finland)
16:40	**R141**	**Development of Stainless-steel Reflector for VR-1 Training Reactor** / Jan Frybort (Czech Technical Uni. in Prague, Czech Republic)
17:00	**R142**	**Characterization of Neutron Source for Nuclear Data Experiment in China** / Jie Bao (China Inst. of Atomic Energy)
17:20	**R143**	**Double-bunch Unfolding Method for the CSNS Back-n White Neutron Source** / Han Yi (Ins. of High Energy Physics, Chinese Academy of Sciences, China) / Speaker: Taofeng Wang
17:40	**S144**	**Formation of A Thermal Neutron Beam and Measurement of Its Intensity at the Tandetron Accelerator** / Konstantin Mitrofanov (Joint Stock Company "State Scientific Centre of the Russian Federation - Ins. for Physics and Power Engineering named after A.I. Leypunsky")
17:45	**S145**	**Analysis of the Systematic Errors in Determining the Time Stamp for the Digital Time-of-flight Neutron Spectrometer.** / Pavel Prusachenko (I.I. Leypunsky Ins. for Physics and Power Engineering (IPPE), Bondarenko sq. 1, Obninsk , Russia)
17:50	**S146**	**In Searching of Leakage Location of Underground High Voltage Electric Cable Using Radiotracer Method** / Sugiharto Sugiharto (Center for Isotopes and Radiation Application (CIRA), National Nuclear Energy Agency of Indonesia (BATAN))

Tue May 21 | 8:30-12:25 | Room 305

Topic Track: Nuclear Data Application
Session Title: Application in Nuclear Reactor 1
Chair: Alejandro Sonzogni

08:30	**I147**	**Assessment of Representativity of the PETALE Experiments for Validation of Swiss LWRs Ex-core Dosimetry Calculations** / Dimitri Rochman (Paul Scherrer Institut, Switzerland) / Speaker: Marco Pecchia
09:00	**R148**	**Development and Verification of WIMS-D Libraries for Advanced Self-shielding Method** / Yuechao Liang (Harbin Engineering Uni., China)
09:20	**R149**	**Study on Kinetic Characteristics of Krypton and Xenon in Molten Salt Reactor System** / Bo Zhou (Shanghai Ins. of Applied Physics (SINAP), CAS, China)
09:40	**R150**	**Development and Engineering Verification of A Multi-group Library for PWR Lattice Calculation** / Hongbo Zhang (Shanghai Nuclear Engineering Research and Design Institute, China)
10:00	**R151**	**Deacy Data for Decay Heat and Anti-neutrino Spectra Calculations** / Paraskevi Dimitriou (International Atomic Energy Agency, 1400 Vienna, Austria)
10:20		**Break**

Topic Track: Nuclear Data Application
Session Title: Application in Nuclear Reactor 2
Chair: Paraskevi Dimitriou

10:40	**R152**	**Fine Structure in Nuclear Reactors Antineutrino Spectra** / Alejandro Sonzogni (Brookhaven National Laboratory, USA)
11:00	**R153**	**Rational Function Representation of Point-wise Nuclear Cross Sections and Applications to Doppler Broadening** / Shichang Liu (North China Electric Power Uni.)
11:20	**R154**	**Radiological Assessments of the Chemical Plant of the Molten Salt Fast Reactor in the Frame of the SAMOFAR H2020 Project** / Anthony Marchix (Irfu, CEA, Université Paris-Saclay, F-91 191 Gif-sur-Yvette, France)
11:40	**R155**	**Reaction Rate of Transmutation ^{129}I, ^{237}Np, and ^{243}Am: Modeling and Comparison with the Yalina-thermal Facility Experiments** / Tamara Korbut (The Joint Ins. for Power and Nuclear Research - Sosny of the National Academy of Sciences of Belarus)
12:00	**R156**	**Optimization of neutron-energy group structure for graphite-moderated reactors in the SCALE code system** / Lukasz Koszuk (National Centre for Nuclear Research, Poland)
12:20	**S157**	**Neutronic Parameters and CPS (control and Protection System) Worth Calculation of Thermal Research Reactor Using MCNPX Code** / Hadi Shamoradifar (Payam e noor university, Iran)

Tue May 21	14:00-17:50	Room 305

Topic Track: Nuclear Data Application
Session Title: Application in Nuclear Reactor 3
Chair: Tamara Korbut

14:00	**I158**	**A New Reference Database for Beta-delayed Neutron Data for Applications** / Paraskevi Dimitriou (International Atomic Energy Agency, On behalf of the IAEA CRP, Austria)
14:30	**R159**	**On-the-fly Temperature-dependent Cross Section Treatment Under Extreme Conditions in RMC Code** / Lei Zheng (Department of Engineering Physics, Tsinghua Uni., China)
14:50	**R160**	**Evolution of the Importance of Neutron-induced Reactions Along the Cycle of An LFR** / Pablo Romojaro (CIEMAT, Spain)
15:10	**R161**	**Benchmarking the New ENDF/B-VIII.0 Nuclear Data Library for OECD/NEA Medium 1000 MWth Sodium-cooled Fast Reactor** / Donny Hartanto (Uni. of Sharjah, UAE, United Arab Emirates)
15:30	**R162**	**Measurement of Temperature-dependent Thermal Neutron Spectrum in CaH2 Moderator Material for Space Reactor Using TOF Method** / Jaehong Lee (Ins. for Intergrated Radiation and Nuclear Science, Kyoto Unversity, Japan)
15:50		**Break**

Topic Track: Nuclear Data Application
Session Title: Application in Nuclear Reactor 4
Chair: Ping Liu

16:10	**R163**	**Production and Verification of the Compressed Depletion Data Library for Neutronic Analysis** / Yunfei Zhang (Harbin Engineering Uni., China)
16:30	**R164**	**Benchmarking the New ENDF/B-VIII.0 Nuclear Data Library for the First Core of Indonesian Multipurpose Research Reactor (RSG-GAS)** / Donny Hartanto (Uni. of Sharjah, UAE, United Arab Emirates)
16:50	**R165**	**Nuclear Data Sensitivity and Uncertainty Analyses on the First Core Criticality of the RSG Gas Multipurpose Research Reactor** / Peng Hong Liem (Tokyo City Uni., Japan)
17:10	**R166**	**On the Impact of Nuclear Data Uncertainties on LWR Neutron Dosimetry Assessments** / Dimitri Rochman (Paul Scherrer Institut, Switzerland) / Speaker: Erwin Alhassan
17:30	**R167**	**Nuclear Data Sensitivity Analysis and Uncertainty Propagation in the KYADJ Whole-core Transport Code** / Qu Wu (Nuclear Power Ins. of China)

Wed May 22 8:30-12:20 Room 202

Topic Track: Nuclear theory, model and codes
Session Title: Nuclear reaction theory models and codes 5
Chair: Jutta Escher

08:30	I168	change to I171/R171 (1) ›erto Capote (IAEA)
09:00	R169	**Theoretical Calculation and Evaluation of Neutron-induced Reactions on Pu Isotopes** / Hairui Guo (Ins. of Applied Physics and Computational Mathematics, Beijing , China)
09:20	R170	**Theoretical Calculation and Evaluation for n+^{232,233,234,235,236,237,238}U Reactions** / Yinlu Han (China Inst. of Atomic Energy)
09:40	R171	**Photonuclear Data Library and Photon Strength Functions** / Paraskevi Dimitriou (IAEA)
10:00	R172	**The Evaluations of Photonuclear Data in CNDC** / Xi Tao (China Inst. of Atomic Energy)
10:20		**Break**

Topic Track: Nuclear theory, model and codes
Session Title: Nuclear reaction theory models and codes 6
Chair: Roberto Capote

10:40	I173	**Surrogate Reactions: Doorways to Cross Sections for Unstable Isotopes** / Jutta Escher (Lawrence Livermore National Laboratory, USA)
11:10	R174	**Incorporating A Two-step Mechanism into Calculations of (p,t) Reactions Used to Populate Compound Nucleus Spin-parity Distributions in Support of Surrogate Neutron Capture Measurements** / James Benstead (AWE, United Kingdom)
11:30	R175	**Statistical Theory of Light Nucleus reactions with 1p-shell light nuclei involved** / Xiaojun Sun (Guangxi Normal Uni., College of Physics, Guilin, China)
11:50	R176	**Microscopic Optical Potentials for Li Isotopes** / Wendi Chen (Graduate School of China Academy of Engineering Physics)
12:10	S177	**Coupled-channel Analysis of Deuteron Scattering on ^{56}Fe** / Yujie Liu (Graduate School of China Academy of Engineering Physics)
12:15	S178	**Studies on Neutron-Neutron Elastic Scattering** / Qianghua Wu (Tsinghua Uni., China)

Wed May 22 | 14:00-16:10 | Room 202

Topic Track: Nuclear theory, model and codes
Session Title: Nuclear reaction theory models and codes 7
Chair: Yukinobu Watanabe

14:00	**R179**	**N+d Scattering Solved with Faddeev-AGS Equations Using the Wave Packet Method** / Danyang Pang (Beihang Uni., China)
14:20	**R180**	**QRPA Predictions of the E1 and M1 Gamma-ray Strength Functions Using the D1M Gogny Interaction** / Stephane Hilaire (CEA, France)
14:40	**R181**	**A Study of Giant Dipole Resonance Parameters from Photoabsorption Cross Sections** / Yuan Tian (China Inst. of Atomic Energy)
15:00	**R182**	**Structure of Continuum States and Strength Function in the Complex Scaling Method** / Myagmarjav Odsuren (School of Engineering and Applied Sciences, National Uni. of Mongolia, Mongolia)
15:20	**S183**	**The Refractive Scattering of ^{17}F+^{12}C** / Liyuan Hu (Harbin Engineering Uni., China)
15:25	**S184**	**Simulation of Neutron Transmission Performance of Metal Spherical Shell Under Temperature Dependent Neutron Cross Section** / Yinghong Zuo (Northwest Institue of Nuclear Technology, China)
15:30	**S185**	**Improvement of Generalized Evaporation Model Based on Analysis of Isotope Production in Proton- and Deuteron-induced Spallation Reactions** / Shunsuke Sato (Kyushu Uni., Japan)
15:50		**Break**

16:10-18:00 **Workshop on Neutronics Experiment Facility HINEG and Simulation Code SuperMC**

Wed May 22 8:30-12:00 Room 203

Topic Track: Evaluation
Session Title: Evaluated libraries
Chair: Allan Carlson

08:30	**I186**	**Status of JENDL** / Osamu Iwamoto (Japan Atomic Energy Agency)
09:00	**R187**	**Completeness of Neutron-, Photo-induced and Spontaneous Fission Yields Data** / Boris Pritychenko (Brookhaven National Laboratory, USA)
09:20	**R188**	**Systematic Description of Product Mass Yields of the Neutron-induced ^{232}Th and $^{232-239}$U Fissions** / Wenjie Zhu (School of Physics, Peking Uni., China) / Speaker: Tieshuan Fan
09:40	**R189**	**Evaluation and Validation of Fe-56 Data after CENDL–3.2b1** / Haicheng Wu (China Inst. of Atomic Energy)
10:00	**R190**	**Decay Heat Uncertainty Quantification with the GNIAC Code** / Jimin Ma (Ins. of Nuclear Physics and Chemistry, China)
10:20		**Break**

Topic Track: Evaluation
Session Title: Uncertainty quantification and covariances 1
Chair: Boris Pritychenko

10:40	**R191**	**Depletion Uncertainty Analysis Performed to the Critical MYRRHA Core Configuration** / Alexey Stankovskiy (SCK-CEN, a Belgian Nuclear Research Centre, Belgium)
11:00	**R192**	**Evaluation of Neutron Reaction Cross-sections with Taking Unrecognized Experimental Errors Into Account** / Sergei Badikov (National Research Nuclear Uni. "MEPhI", Russia)
11:20	**R193**	**Covariance Evaluation of the CENDL Library** / Ruirui Xu (China Inst. of Atomic Energy)
11:40	**S194**	**Uncertainties of Calculated Coincidence-summing Correction Factors in Gamma-ray Spectrometry** / Valentina Semkova (Ins. for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria) / Speaker: Naohiko Otsuka
11:45	**S195**	**Uncertainty Quantification by Polynomial Chaos Technique for Source Driven Subcritical Experimental Systems** / Tamara Korbut (The Joint Ins. for Power and Nuclear Research - Sosny of the National Academy of Sciences of Belarus)
11:50	**S196**	**Cyclotron Production Cross Sections of ^{61}Cu Radionuclide from ^{nat}Ni(d, X)^{61}Cu Nuclear Reaction** / Ahmed Rufai Usman (Umaru Musa Yaradua Uni., Nigeria)
11:55	**S197**	**Measurement of ^{241}Am (n,2n) Reaction Cross-section Induced by 14.8 MeV Neutron** / Feng Xie (Northwest Ins. of nuclear technology, China)

Wed May 22 | 14:00-18:00 | Room 203

	Topic Track: Evaluation **Session Title: Uncertainty quantification and covariances 2** Chair: Osamu Iwamoto	
14:00	**I198**	**Reduction of Uncertainty in General-purpose Libraries Using Transport Equation Constraints** / Jan Malec (JSI, Slovenia)
14:30	**R199**	**Researches on Uncertainty Quantification Due to Nuclear-data Covariance for PWR and SFR** / Chenghui Wan (Xi'an Jiaotong Uni., China)
14:50	**R200**	**Covariance Generation for the Prompt Neutron Multiplicity on Pu-239 and U-235 Including the (n,γf) Process in the R.R.R.** / Esther Leal-cidoncha (Laboratory of Physical Studies, CEA/DEN Cadarache, F-13 108 Saint Paul Les Durance, France) / Speaker: Gilles Noguere
15:10	**R201**	**Measurement of ^{235}U(n,f) Cross Section Below 150 keV** / Simone Amaducci (INFN - Laboratori Nazionali del Sud, Italy)
15:30	**S202**	**Calculation of Electron Scattering Cross-section Using Different Theoretical Methods** / Xiazhi Li (Northwest Ins. of Nuclear Technology, Xi'an, China)
15:35	**S203**	**Improved Model for Atomic Displacement Calculation** / Shengli Chen (CEA, France)
15:50		**Break**
	Topic Track: Evaluation **Session Title: Cross section and decay standards** Chair: Jan Malec	
16:10	**I204**	**Recent Work on Neutron Cross Section Standards** / Allan Carlson (NIST, USA)
16:40	**R205**	**Updating Covariances of Experiments in the Neutron Data Standards Database** / Denise Neudecker (LANL, USA) / Speaker: LA-TBD
17:00	**R206**	**Modified Single Particle Estimate Approach for Estimation of Nuclear Resonance Fluorescence Cross-section** / Kwangho Ju (KAIST (Korea Advanced Ins. of Science and Technology))
17:20	**R207**	**Precise Measurement of the Neutron Capture Cross Section of U-235 at Thermal and Sub-thermal Energies** / Anton Wallner (Department of Nuclear Physics, Australian National Uni., Canberra, Australia)
17:40	**R208**	**Relativistic Effect on Atomic Displacement Damage** / Shengli Chen (CEA, France)

Wed May 22 — 8:30-12:40 — Room 205

Topic Track: Nuclear data processing and validation
Session Title: Nuclear data adjustment 2
Chair: Andrej Trkov

08:30	**I209**	**Integral Adjustment of Nuclear Data Libraries - Finding Unrecognized Systematic Uncertainties and Correlations** / Henrik Sjostrand (Division of Applied Nuclear Physics, Department of Physics and Astronomy, Uppsala Uni., Uppsala, Sweden)
09:00	**R210**	**In Search of the Best Nuclear Data File for Proton Induced Reactions: Varying Both Models and Their Parameters** / Erwin Alhassan (Laboratory for Reactor Physics and Thermal-Hydraulics, Paul Scherrer Institute, 5232 Villigen, Switzerland)
09:20	**R211**	**Data Assimilation with Post Irradiation Examination Experiments** / Daniel Siefman (Swiss Federal Ins. of Technology in Lausanne, Switzerland)
09:40	**R212**	**Analysis of the Prior Nuclear Data Correlation and Its Effect on the Adjustment in Bayesian Inference** / Dinesh Kumar (Uppsala Uni., Sweden)
10:00	**R213**	**Learning from Google: About A Computational EXFOR Database for Efficient Data Retrieval and Analysis** / Georg Schnabel (Uppsala Uni., Sweden)
10:20		**Break**

Topic Track: Nuclear data processing and validation
Session Title: Nuclear data validation 1
Chair: Tim Ware

10:40	**I214**	**Improved Evaluations of Neutron Induced Reactions on ^{57}Fe and ^{56}Fe Targets** / Andrej Trkov (IAEA, Austria)
11:10	**I215**	**Fusion Decay-heat Benchmark for Nuclear Data Validation: Advanced Interrogation Capabilities with FISPACT-II** / Mark Gilbert (United Kingdom Atomic Energy Authority)
11:40	**R216**	**Two Absolute Integral Measurements of the ^{197}Au(n,γg) Stellar Cross-section and Solution of the Historic Discrepancies.** / Javier Praena (Uni. of Granada (Spain))
12:00	**R217**	**Nuclear Data Verification and Validation Platform for JEFF-4** / Luca Fiorito (Nuclear Energy Agency, France)
12:20	**R218**	**New Features and Improvements in the NEA Nuclear Data Tool Suite** / Michael Fleming (OECD Nuclear Energy Agency, France)

Wed May 22 14:00-18:00 Room 205

Topic Track: Nuclear data processing and validation
Session Title: Nuclear data validation 2
Chair: Bret Beck

14:00	**I219**	**Benchmark Testing of CENDL-3.2B1** / Haicheng Wu (China Inst. of Atomic Energy)
14:30	**R220**	**Effects of Different Nuclear Evaluation Data on the RMC K-eff Calculation** / Wenxin Zhang (Nuclear Power Ins. of China)
14:50	**R221**	**Analyses of Natural Radioactivity Concentrations in Soil and Assessment of Effective Doses in Several Districts of BANTEN and West Java, Indonesia** / Makhsun Makhsun (National Nuclear Energy Agency of Indonesia)
15:10	**R222**	**Validation of Tritium Production Cross-section of Lithium in JEFF3.2 with HCPB Mock-up Experiment** / Bin Li (Ins. of Nuclear Energy Safety Technology, Chinese Academy of Sciences, China)
15:30	**R223**	**Benchmarking ENDF/B-VIII.0 Using the LANL Expanded Criticality Validation Suite for MCNP** / Ramon Arcilla (Brookhaven National Laboratory, USA)
15:50		**Break**

Topic Track: Nuclear data processing and validation
Session Title: Nuclear data validation 3
Chair: Mark Gilbert

16:10	**I224**	**Validation of JEFF-3.3 and ENDF/B-VIII.0 Nuclear Data Libraries in ANSWERS Codes** / Tim Ware (Wood, United Kingdom)
16:40	**I225**	**Advance: the ENDF Quality Assurance System** / David Brown (National Nuclear Data Center/Brookhaven National Laboratory, USA)
17:10	**R226**	**Testing of the Thorium-uranium Fuel Cycle Special Nuclear Data Library - CENDL-TMSR 1.0** / Xiaohe Wang (Shanghai Ins. of Applied Physics, China)
17:30	**R227**	**Validation of A New URR Implementation in GNDS Format** / Marie-anne Descalle (Lawrence Livermore National Laboratory, USA)
17:50	**S228**	**Ratio of Spectral Averaged Cross Sections Measured in 252-Cf(sf) and 235-U(n_{th},f) Neutron Fields** / Martin Schulc (Research Centre Rez, Czech Republic) / Speaker: R. Capote
17:55	**S229**	**Introduction of A Systematic Integral Testing Tool ENDITS** / Huanyu Zhang (China Inst. of Atomic Energy)

Wed May 22 8:30-12:30 Room 301

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 5
Chair: Maelle Kerveno

08:30	**I230**	**Measurement of (n,f) and (n,2n) Cross Sections of Actinides with the Surrogate Capture-reaction Method** / Chengjian Lin (China Inst. of Atomic Energy)
09:00	**R231**	**Measurements of Cross Sections for High Energy Neutron Induced Reactions on Co and Bi** / Peane Peter Maleka (NRF-iThemba LABS, South Africa)
09:20	**R232**	**High Precision Measurements of the ^{93}Nb(n,2n)$^{92g+m}$Nb Reaction Cross Section** / Jianqi Chen (China Inst. of Atomic Energy) / Speaker: Guangyuan Luan
09:40	**R233**	**Measurements of Differential and Angle-integrated Cross Sections for the ^{10}B(n,α)^{7}Li Reaction in the Neutron Energy Range of 1 eV $<$ En $<$ 2.5 MeV** / Haoyu Jiang (State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking Uni., Beijing , China)
10:00	**R234**	**Angular Differential and Angle-integrated Cross Section Measurement for the ^{6}Li(n,t)^{4}He Reaction from 1 eV to 3 MeV at CSNS** / Huaiyong Bai (State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking Uni., Beijing , China)
10:20		**Break**

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 6
Chair: Chengjian Lin

10:40	**I235**	**An Overview of Experimental Nuclear Science at Los Alamos** / Morgan White (LANL, USA) / Speaker: Matt Devlin
11:10	**R236**	**What Can We Learn from (n,xnγ) Cross Sections About Reaction Mechanism and Nuclear Structure ?** / Maelle Kerveno (CNRS/IPHC, France)
11:30	**R237**	**Measurement of (n,γ) Cross-section on ^{186}W Isotopes at Different Neutron Energies** / Mayur Mehta (Ins. for PLASMA RESEARCH, India)
11:50	**R238**	**Thermal Neutron Capture Cross-sections Measurements of Ti-50, V-51 and Mo-98** / Ngoc Son Pham (Nuclear Research Institute, Vietnam)
12:10	**R239**	**Measurement of the ^{244}Cm and ^{246}Cm Neutron-induced Capture Cross Sections at the n_TOF Facility** / Victor Alcayne (CIEMAT(Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas), Spain)

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 7
Chair: Guohui Zhang

14:00	**I240**	**Neutron Transmission Measurements at nELBE** / Arnd Rudolf Junghans (Helmholtz-Zentrum Dresden-Rossendorf, Germany)
14:30	**R241**	**New Experimental Data for ^{12}C(n,α)^{9}Be Reaction.** / Tatiana Khromyleva (IPPE, Russia)
14:50	**R242**	**Photoneutron Reaction Cross Sections for ^{75}As and ^{181}Ta: Systematic Uncertainties and Data Reliability** / Vladimir Varlamov
15:10	**R243**	**Photonuclear reaction study in CIAE** / Chuangye He (China Inst. of Atomic Energy, Beijing , China)
15:30	**R244**	**MCNP Modeling for Neutron-induced Charged Particle Cross-section Measurements at LANSCE** / Lukas Zavorka (LANL, USA)
15:50		**Break**

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 8
Chair: Arnd Rudolf Junghans

16:10	**I245**	**Measurements of Neutron-induced Charged-particle Emission Reactions** / Guohui Zhang (School of Physics, Peking Uni., Beijing , China)
16:40	**R246**	**Measurement of the Energy-differential Cross Section of the ^{12}C(n,p) and ^{12}C(n,d) Reactions at the n_TOF Facility at CERN** / Massimo Barbagallo (CERN, Switzerland)
17:00	**R247**	**Monte Carlo Simulations and n-p Differential Scattering Data Measured with Recoil Proton Telescopes** / Nicholas Terranova (INFN, CNAF, Bologna, Italy)
17:20	**R248**	**Measurement of Production Cross Sections of ^{22}Na and ^{24}Na in Proton Induced Reactions on Aluminum** / Sung-chul Yang (Korea Atomic Energy Research Institute)
17:40	**R249**	**Cross-section Measurement in the Reactions of ^{136}Xe on Proton, Deuteron and Carbon** / Xiaohui Sun (RIKEN Nishina Center, Japan)
18:00	**S250**	**Continuous Spectra of Light Charged Particles from Interaction of 30 MeV Energy Protons with Cooper** / Timur Zholdybayev (Ins. of nuclear physics, Kazakhstan) / Speaker: Naohiko Otsuka
18:05	**S251**	**Simulations of the Measurements of Differential Cross Sections of the n-p and n-d Elastic Scattering Reactions at CSNS Back-n White Neutron Source** / Zengqi Cui (School of Physics, Peking Uni., China)

Wed May 22 | 8:30-12:30 | Room 302

Topic Track: Fission physics and observables
Session Title: Fission theory and experimental 5
Chair: Jack Silano

08:30	**I252**	**Calculation of the Fission Observables in the Resolved Resonance Energy Region of the ^{235}U(n,f) Reaction** / Olivier Serot (French Alternative Energies and Atomic Energy Commission (CEA), France)
09:00	**R253**	**Microscopic Studies of Fission Observables of Compound Nuclei** / Junchen Pei (School of Physics, Peking Uni., China)
09:20	**R254**	**Monte-carlo Evaluation on Fission Process for Neutron-induced Actinide Nuclei Fission** / Zheng Wei (Lanzhou Uni., China)
09:40	**R255**	**Advances in Modeling and Simulation of Fast Neutron Induced Fission of ^{232}Th** / Cristiana Oprea (JINR, Russia)
10:00	**R256**	**The Scission Microscopic Structure of Fission in Actinide Nuclei** / Xin Guan (Liaoning normal university, China)
10:20		**Break**

Topic Track: Fission physics and observables
Session Title: Fission theory and experimental 6
Chair: Olivier Serot

10:40	**I257**	**Validating the Bohr Hypothesis: Comparing Fission-product Yields from Photon-induced Fission of ^{240}Pu and Neutron-induced Fission of ^{239}Pu** / Jack Silano (Lawrence Livermore National Laboratory, USA)
11:10	**I258**	**Fission Studies Using Steff at n_TOF, CERN** / Nikolay Sosnin (The Uni. of Manchester, United Kingdom)
11:40	**R259**	**Improved Neutron Multiplicity Correlations with Fission Fragment Mass and Energy from ^{239}Pu(n,f)** / Alf Göök (European Commission - Joint Research Centre, Belgium)
12:00	**R260**	**The Spatial Parity Non Conservation Effects in the Fission Induced by Thermal and Resonant Neutrons on ^{233}U** / Cristiana Oprea (JINR, Russia)
12:20	**S261**	**Shape Description in Macro-microscopic Model** / Zhiming Wang (State Key Laboratory of Nuclear Physics and Technology, Peking Uni., Beijing 10 0871, China)
12:25	**S262**	**Energy Dependence of Time Parameters of Delayed Neutrons for the Fission of U-233 by Neutrons in Energy Range from 14 to 18 MeV** / Dmitrii Gremiachkin (JSC "SSC RF-IPPE", Russia)

Topic Track: Fission physics and observables
Session Title: Prompt fission neutron spectrum
Chair: Veatriki Michalopoulou

14:00	I263	**Prompt Fission Neutron Spectra for Neutron-induced Fission of ^{239}Pu and ^{235}U** / M. Devlin (LANL, Los Alamos, NM , USA)
14:30	R264	**Prompt Fission Neutron Spectra of ^{235}U(n,F) and ^{239}Pu(n,F)** / Vladimir M. Maslov (Joint Ins. of Nuclear and Energy Research, 22 0109, Minsk-Sosny, Belarus)
14:50	R265	**Observations of Poorly-known Features of the ^{239}Pu and ^{235}U Prompt Fission Neutron Spectra** / Keegan J. Kelly (LANL, USA)
15:10	R266	**Systematic Behaviours and Correlations Between Different Quantities Characterizing the Residual Nuclei Following the Sequential Emission of Prompt Neutrons** / Anabella Tudora (Uni. of Bucharest, Faculty of Physics, Romania)
15:30	R267	**Angular Distributions and Anysotropy of Fission Fragments from Neutron-induced Fission of ^{239}Pu, ^{237}Np, and ^{nat}Pb in Intermediate Energy Range 1- 200 Mev** / Alexey Gagarskiy (B.P. Konstantinov Petersburg Nuclear Physics Ins. of National Research Center "Kurchatov Institute", Gatchina, Leningrad region, Russia)
15:50		**Break**

Topic Track: Fission physics and observables
Session Title: Fission cross section
Chair: M. Devlin

16:10	I268	**First Results of the ^{230}Th(n,f) Cross Section Measurements at the CERN n_TOF Facility** / Veatriki Michalopoulou (European Organization for Nuclear Reasearch (CERN), Switzerland)
16:40	R269	**First Results of the ^{241}Am(n,f) Cross-section Measurement at the Experimental Area 2 of the n_TOF Facility at CERN** / Zinovia Eleme (Department of Physics, Uni. of Ioannina, Greece)
17:00	R270	**Study of the Neutron Induced Fission Cross-section of ^{237}Np at CERN's n_TOF Facility Over A Wide Energy Range** / Athanasios Stamatopoulos (National Technical Uni. of Athens, Greece)
17:20	R271	**Measurement of the ^{234}U(n,f) Cross Section in the Energy Range Between 14.8 and 19.2 MeV Using Micromegas Detectors** / Sotiris Chasapoglou (National Technical Uni. of Athens, Greece) / Speaker: Antigoni Kalamara
17:40	S272	**Experiments on Nubar(A) in ^{235}U(n_{th},f) Using the Double-E Method** / Ali Al-adili (Department of Physics and Astronomy, Uppsala Uni., Sweden)
17:45	S273	**Experimental Estimation of the "scission" Neutron Yield in the Thermal Neutron Induced Fission of ^{233}U and ^{235}U** / Aleksandr Vorobev (Petersburg Nuclear Physics Ins. named B.P. Konstantinov of National Research Centre "Kurchatov Institute", Russia)

Wed May 22 8:30-12:30 Room 303

Topic Track: Experimental facilities, equipment techniques and methods
Session Title: Experimental facilities, equipment techniques and methods 5
Chair: Frank Gunsing

08:30	I274	**Measuring Independent Fission Product Yields and Other Neutron Induced Reactions with the FissionTPC** / Nicholas Walsh (Lawrence Livermore National Laboratory, USA)
09:00	R275	**Utilizing Nuclear Data in Delayed Gamma-ray Spectroscopy Inverse Monte Carlo Analysis** / Douglas Chase Rodriguez (Japan Atomic Energy Agency)
09:20	R276	**Neutron Spectrum Determination of P+be Reaction for 30 MeV Protons Using the Multi-foil Activation Technique** / Milan Stefanik (Nuclear Physics Ins. of the Czech Academy of Science, p.r.i, Rez 130, Rez 250 68, Czech Republic)
09:40	R277	**Charged Particle Activation Measurements in NPI CAS and in Future GANIL/SPIRAL2-NFS** / Jaromir Mrazek (NPI CAS, Rez, Czech Republic)
10:00	R278	**Source Preparation Techniques in Nuclear Decay Data Measurements of Alpha Emitting Radionuclides by Using DSA** / Abdullah Dirican (Turkish Atomic Energy Authority- Department of Radiaton and Accelerator Technologies, Turkey)
10:20		**Break**

Topic Track: Experimental facilities, equipment techniques and methods
Session Title: Experimental facilities, equipment techniques and methods 6
Chair: Nicholas Walsh

10:40	R279	**Micromegas-based Detectors for Time-of-flight Measurements of Neutron-induced Reactions** / Frank Gunsing (CEA Saclay, France)
11:00	R280	**Targetry of Rare Isotopes at PSI** / Emilio Andrea Maugeri (Paul Scherrer Institut, Switzerland)
11:20	R281	**Neutron-gamma Classification with Support Vector Machine Based on Tensor Decomposition** / Hanane Arahmane (ESMAR Laboratory Faculty of Sciences Mohammed V Uni., Morocco)
11:40	R282	**Development and Characterization of PPACs for Fission Studies** / Diego Tarrio (Department of Physics and Astronomy, Uppsala Uni. (Sweden))
12:00	R283	**The Light Charged Particle Detector Array at the "back-n" White Neutron Source** / Rui Fan (Ins. of High Energy Physics, CAS, China)
12:20	S284	**Evaluation of Gamma-ray Strength Function Based on Measured Gamma-ray Pulse-height Spectra in Time-of-flight Neutron Capture Experiments** / Nobuyuki Iwamoto (Japan Atomic Energy Agency)
12:25	S285	**A New 3 MV Tandem Accelerator Facilities for Materials Research and Nuclear Reaction Cross Section Measurements** / Md. Shuza Uddin (Ins. of Nuclear Science and Technology Atomic Energy Research Establishment Savar Dhaka Bangladesh)

Wed May 22	14:00-18:00	Room 303

Topic Track: Experimental facilities, equipment techniques and methods
Session Title: Experimental facilities, equipment techniques and methods 7
Chair: Nathaniel Bowden

14:00	**R286**	**Application of Similarity Analysis Method in Zero-power Experimental Validation** / Tong Ning (China Inst. of Atomic Energy)
14:20	**R287**	**A New Neutron Induced γ-ray Generator for Geant4** / Emilio Mendoza Cembranos (CIEMAT, Madrid, Spain) / Speaker: Daniel Cano-Ott
14:40	**R288**	**The ^{6}LiF-silicon Detector Array Developed for Real-time Neutron Monitoring at Back-streaming White Neutron Beam at CSNS** / Qiang Li (Ins. of High Energy Physics , China)
15:00	**R289**	**New Detection Systems at U-120M Cyclotron** / Jan Novak (Nuclear Physics Ins. ASCR, Czech Republic)
15:20	**R290**	**Collimator Design of A Recoil Proton Telescope** / Feipeng Wang (Ins. of Nuclear Energy Safety Technology, Chinese Academy of Sciences, China)
15:40	**S291**	**The Silicon-detector Array at Back-n White Neutron Facility** / Wei Jiang (Ins. of High Energy Physics , China)
15:45	**S292**	**Back-streaming White Neutron Beam for Neutron Imaging at CSNS** / Keqing Gao (Neutron Science Center, DongGuan, China)
15:50		**Break**

Topic Track: Spallation, high and intermediate energy reactions
Session Title: Spallation, high and intermediate energy reactions 1
Chair: Hiroki Iwamoto

16:10	**I293**	**Recent Progress in Nuclear Data Measurement for ADS at IMP** / Zhiqiang Chen (Ins. of Modern Physics, Chinese Academy of Sciences, China)
16:40	**R294**	**Measurement of Displacement Cross Section in J-PARC for Proton in the Energy Range from 0.4 GeV to 3 GeV** / Shin-ichiro Meigo (J-PARC/Japan Atomic Energy Agency)
17:00	**R295**	**Nuclear Charge-changing Cross Section and Interaction Cross Section Measurements on C/H Target at Intermediate and High Energies** / Baohua Sun (Beihang Uni., China)
17:20	**R296**	**Spallation Reaction Study for Long-lived Fission Products in Nuclear Waste** / He Wang (RIKEN Nishina Center, Japan)
17:40	**R297**	**Measurement of Nuclide Production Cross Section for Lead and Bismuth with Proton in Energy Range from 0.4 GeV to 3.0 GeV** / Hiroki Matsuda (J-PARC/JAEA, Japan)

Wed May 22 8:30-12:30 Room 305

Topic Track: Nuclear Data Application
Session Title: Application in Nuclear Reactor 5
Chair: Jaehong Lee

08:30	**I298**	**Study of Th-U Fuel Cycle and Nuclear Data for TMSR** / Jingen Chen (Shanghai Ins. of Applied Physics (SINAP), CAS, China)
09:00	**R299**	**Impacts of Nuclear Data Uncertainties on the Generic Safety of the Soluble-boron-free SMR ATOM Core** / Xuan Ha Nguyen (Korea Advanced Ins. of Science and Technology (KAIST))
09:20	**R300**	**Analysis of the Perturbation Experiments for Some Sensitive Isotopes Application on the Designs of the Space Nuclear Reactor** / Sanbing Wang (Ins. of Nuclear Physics and Chemistry, China Academy of Engineering Physics)
09:40	**R301**	**Impact Analysis of Model and Data Library for Iter Nuclear Calculation Based on SuperMC** / Pengcheng Long (Ins. of Nuclear Energy Safety Technology, Chinese Academy of Sciences, China)
10:00	**S302**	**The influence and analysis of background cross section for the calculation of PWR fuel pin** / Xiang Xiao (School of Nuclear science and Engineering, North China Electric Power Uni., Beijing , China)
10:05	**S303**	**Source-term and Radiological Safety Analysis of TRIGA Research Reactor of Bangladesh** / Mohammad Mizanur Rahman (Bangladesh Atomic Energy Commission)
10:10	**S304**	**Uncertainty Quantification and Sensitivity Studies on Thorium-fueled Reactors** / Eliot Party (Institut Pluridisciplinaire Hubert Curien - Université de Strasbourg, France) / Speaker: Maelle Kerveno
10:15	**S305**	**Research and Development of China Nuclear Safety Cloud Computing Platform NCloud** / Pengcheng Long (Ins. of Nuclear Energy Safety Technology, Chinese Academy of Sciences, China)
10:20		**Break**

Topic Track: Nuclear data application
Session Title: Nuclear data for astrophysics and cosmology 1
Chair: Anton Wallner

10:40	**I306**	**Extensive New Beta-delayed Neutron Measurements for Astrophysics** / Jose Luis Tain (Instituto de Fisica Corpuscular, Spain)
11:10	**R307**	**The Cosmic Ray Detector (MCORD) for the New Collider NICA** / Marcin Bielewicz (National Center for Nuclear Research, Otwock-Swierk, Poland)
11:30	**R308**	**New Reaction Rates for the Destruction of ^{7}Be During Big Bang Nucleosynthesis Measured at CERN/n_TOF and Their Implications on the Cosmological Lithium Problem** / Alberto Mengoni (ENEA, Bologna, Italy)
11:50	**R309**	**Determine the Neutron Capture Cross Section of Radionuclide with Surrogate Ratio Method** / Shengquan Yan (China Inst. of Atomic Energy)
12:10	**R310**	**The ^{154}Gd Neutron Capture Cross Section Measured at the n_TOF Facility and Its Astrophysical Implications** / Mario Mastromarco (Istituto Nazionale di Fisica Nucleare (INFN), Italy)

Wed May 22 14:00-16:55 Room 305

Topic Track: Nuclear data application
Session Title: Nuclear data for astrophysics and cosmology 2
Chair: Michael Smith

14:00	**I311**	**Impact of Fission Fragment Distribution on R-Process Nucleosynthesis in Neutron Star Mergers and Supernovae** / Toshitaka Kajino (Beihang Uni./NAOJ/Uni. of Tokyo, China)
14:30	**R312**	**Systematic Deviations of Neutron-capture Cross Sections Derived from Independent Accelerator Mass Spectrometry Measurements** / Anton Wallner (The Australian National Uni.)
14:50	**R313**	**Impact of Nuclear Data on Stellar Nucleosynthesis and Cosmology** / Boris Pritychenko (Brookhaven National Laboratory, USA)
15:10	**R314**	**Uncertainty Study in Analyzing the Reactor Neutrino Anomaly Based on the Nuclear Structure Physics** / Xiaobao Wang (Huzhou Uni., China)
15:30	**R315**	**Study of Astrophysical Nuclear Reactions in a Laser-driven Plasma Environment** / Xiaofeng Xi (Department of Nuclear Physics, China Inst. of Atomic Energy, Beijing , China)
15:50		**Break**

Topic Track: Nuclear data application
Session Title: Nuclear data for astrophysics and cosmology 3
Chair: Toshitaka Kajino

16:10	**R316**	**Gamma-ray Strength Functions for Astrophysical Applications in the IAEA-CRP** / Hiroaki Utsunomiya (Konan Uni., Japan)
16:30	**R317**	**The Unknown Site of Actinide Nucleosynthesis - Clues from Extraterrestrial Pu-244 in Deep-sea Archives** / Anton Wallner (The Australian National Uni.)
16:50	**S318**	**Direct Capture Cross Sections on Exotic Tin Isotopes*** / Shisheng Zhang (Beihang Uni., China) / Speaker: Michael Smith

Thu May 23 — 8:30-12:30 — Room 202

Topic Track: Nuclear structure and decay data
Session Title: Nuclear masses and decay data measurements
Chair: Young-sik Cho

08:30	**I319**	**Atomic Mass Evaluation** / Meng Wang (IMP, CAS, China)
09:00	**R320**	**Structure of Beta Decay Strength Function, Spin-isospin SU(4) Symmetry, and SU(4) Region** / Igor Izosimov (Joint Ins. for Nuclear Research (JINR), Russia)
09:20	**R321**	**Alpha-decay Studies on the New Neutron-deficient Np Isotopes** / Zhiyuan Zhang (Ins. of Modern Physics, Chinese Academy of Sciences, China)
09:40	**R322**	**First Results from Novel Measurement Methods of Nuclear Properties with the FRS Ion Catcher** / Israel Mardor (Soreq Nuclear Research Center, Israel) / Speaker: Samuel Ayet San Andres
10:00	**R323**	**Spectroscopy of ^{16}B from the Quasi-free (p,pn) Reaction** / Zaihong Yang (Osaka Uni., Japan)
10:20		**Break**

Topic Track: Nuclear structure and decay data
Session Title: Beta-delayed neutron
Chair: Meng Wang

10:40	**I324**	**The Latest Results of Beta-delayed Neutron and Beta-delayed Gamma Measurements with MTAS** / Bertis Rasco (ORNL, USA)
11:10	**R325**	**Strong One-neutron Emission from Two-neutron Unbound States in Beta Decays of Neutron-rich Ga Isotopes** / Rin Yokoyama (Uni. of Tennessee, USA)
11:30	**R326**	**Beta-neutron-gamma Spectroscopy of Beta-delayed Neutron Emitters Around Doubly-magic ^{78}Ni** / Krzysztof Rykaczewski (ORNL, USA)
11:50	**R327**	**A New Measurement System for Study of Nuclide Decay Schemes** / Xuesong Li (Northwest Ins. of nuclear technology, China)
12:10	**R328**	**New Results from the Modular Total Absorption Spectrometer** / Marek Karny (Uni. of Warsaw, Poland)

Thu May 23	14:00-18:05	Room 202

Topic Track: Nuclear structure and decay data
Session Title: Beta-decay
Chair: Krzysztof Rykaczewski

14:00	**I329**	**Improving reactor antineutrino spectra and decay heat calculations with Total Absorption Gamma-ray Spectroscopy** / Alejandro Algora (The Valecia-Nantes TAGS collaboration) / Speaker: Jose Luis Tain
14:30	**R330**	**How Accurate Are the Half-lives of Long-lived Isotopes?** / Dorothea Schumann (Paul Scherrer Institute, Switzerland)
14:50	**R331**	**Nuclear Mass Table in Deformed Relativistic Continuum Hartree-Bogoliubov Theory** / Eunjin In (Sungkyunkwan Uni., Korea)
15:10	**R332**	**Recent Nuclear Shell Model Study and Its Possible Role in Nuclear Data** / Cenxi Yuan (Sun Yat-sen Uni., China)
15:30	**R333**	**Analysis of the Reactor Antineutrino Spectrum Anomaly with Fuel Burnup** / Le Yang (North China Electric Power Uni.)
15:50		**Break**

Topic Track: Nuclear structure and decay data
Session Title: Decay data measurements and Nuclear structure theory models and codes
Chair: Jose Luis Tain

16:10	**I334**	**Decay Heat and Anti-neutrino Energy Spectra in Fission Products** / Krzysztof Rykaczewski (ORNL, USA)
16:40	**R335**	**Precise αK and αT Internal Conversion Coefficient Measurement As Test of Internal Conversion Theory: the Case of 39.752(6)-keV E3 Transition in ^{103m}Rh** / N. Nica (Cyclotron Institute, Texas A&M Uni., College Station, Texas , USA)
17:00	**R336**	**Experimental Study of β Spectra Using Si Detector** / Abhilasha Singh (CEA, LIST, Laboratoire National Henri Becquerel (LNE-LNHB), CEA-Saclay Gif/Yvette cedex, France)
17:20	**R337**	**Towards the First Experimental Determination of the ^{93}Mo Half-life** / Ivan Kajan (Paul Scherrer Institute, Switzerland)
17:40	**R338**	**Study of Finite Nuclei Within A Dirac-Brueckner-Hhartree-Fock** / Xiao-dong Sun (China Nuclear Data Center, China Inst. of Atomic Energy)
18:00	**S339**	**Measurements of Gamma-ray Intensities from the Decay of ^{187}W in the Reaction ^{186}W(n,γ)^{187}W** / Cheolmin Ham (Department of Energy Science, Sungkyunkwan Uni., Suwon , Korea)

Thu May 23 | 8:30-12:20 | Room 203

Topic Track: Evaluation
Session Title: Thermal scattering data 1
Chair: Jose Ignacio Marquez Damian

08:30	**I340**	**Thermal Scattering for Neutron Moderator Materials: Integrating Neutron Scattering Experiments with Density Functional Theory Simulations** / Li Liu (Rensselaer Polytechnic Institute, USA)
09:00	**R341**	**Temperature Dependent Measurement of Thermal Neutron Differential Scattering in Heavy Water** / Gang Li (Canadian Nuclear Laboratories, Canada)
09:20	**R342**	**On the Evaluation of the Thermal Neutron Scattering Cross Sections of Uranium Mono-nitride** / Iyad Al-qasir (Department of Mechanical and Nuclear Engineering, Uni. of Sharjah, Sharjah , UAE, United Arab Emirates)
09:40	**R343**	**Generation and Validation of Thermal Neutron Scattering Cross-section for Heavy Water Using Molecular Dynamics Simulations** / Haelee Hyun (Korea Atomic Energy Research Institute)
10:00	**R344**	**High-resolution Time-of-flight Measurements for Light Water at the Spallation Neutron Source (SNS), Oak Ridge National Laboratory** / Luiz Leal (Institut de Radioprotection et de Surete Nucleaire, France)
10:20		**Break**

Topic Track: Evaluation
Session Title: Thermal scattering data 2
Chair: Li Liu

10:40	**I345**	**Experimental Validation of the Temperature Behavior of the ENDF/B-VIII.0 Thermal Scattering Kernel for Light Water** / Jose Ignacio Marquez Damian (Centro Atomico Bariloche - Comision Nacional de Energia Atomica, Argentina)
11:10	**R346**	**Thermal Neutron Scattering Data for Liquid Molten Salt LiF-BeF_2** / Jia Wang (Ins. of Applied Physics and Computational Mathematics, China)
11:30	**R347**	**Analysis of the Time-of-flight Scattering Cross Section Data for Light Water Measured at the SEQUOIA Spectrometer, Spallation Neutron Source (SNS)** / Vaibhav Jaiswal (Uni. of Lille, France)
11:50	**R348**	**Measurement of the Double-differential Neutron Cross Section of U in UO_2 From Room Temperature to Hot Full Power Conditions** / Gilles Noguere (CEA, DEN Cadarache, F-Saint Paul Les Durance, France)
12:10	**S349**	**Effect of FLiBe Thermal Neutron Scattering on Reactivity of Molten Salt Reactor** / Yafen Liu (Shanghai Ins. of Apllied Physics, China)
12:15	**S350**	**Processing and Application of Nuclear Data for Low Temperature Criticality Assessment** / Tim Ware (Wood, United Kingdom)

Thu May 23 14:00-18:15 Room 203

Topic Track: Evaluation
Session Title: Thermal scattering data 3
Chair: Jia Wang

14:00	**R351**	**Validated Scattering Kernels for Triphenylmethane at Cryogenic Temperatures** / Florencia Cantargi (Neutron Physics Department- Centro Atómico Bariloche- Comisión Nacional de Energía Atómica- Argentina)
14:20	**R352**	**Measurement of the Scattering Laws of Irradiated Nuclear Graphite Using Inelastic Neutron Scattering Techniques** / Iyad Al-qasir (Department of Mechanical and Nuclear Engineering, Uni. of Sharjah, Sharjah , UAE, United Arab Emirates)
14:40	**S353**	**Development and verification of the thermal scattering law processing module in nuclear data processing code NECP-Atlas** / Yongqiang Tang (School of Nuclear Science and Technology, Xian Jiaotong Uni., Xian, Shaanxi, China)
15:50		**Break**

Topic Track: Nuclear data application
Session Title: Nuclear data for medical applications
Chair: Ulrich Fischer

16:10	**I354**	**Update of the IAEA Reference Cross Sections for Charged-particle Monitor Reactions** / Roberto Capote Noy (IAEA)
16:40	**I355**	**Radioisotope Production at the IFMIF-DONES Facility** / Rafael Rivera (Uni. of Granada (Spain)) / Speaker: Javier Praena
17:10	**R356**	**Investigation of Novel Routes for Production of the Medical Radionuclides ^{61}Cu, ^{64}Cu and ^{67}Cu** / Md. Shuza Uddin (Ins. of Nuclear Science and Technology, Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh)
17:30	**R357**	**A New Evaluation of the Nuclear Decay Data of ^{223}Ra** / Aurelian Luca (Horia Hulubei National Ins. for Research and Development in Physics and Nuclear Engineering (IFIN-HH), Romania)
17:50	**R358**	**A Feasibility Study on the ^{99m}Tc Production with Laser-compton Scattering Gamma-rays** / Kwangho Ju (Korea Advanced Ins. of Science and Technology)
18:10	**S359**	**Production of Radionuclides with Secondary Neutrons Induced by A 66 MeV Primary Proton Beam** / Mogakolodi Adolf Motetshwane (Botswana International Uni. of Science and Technology (BIUST), South Africa)

Thu May 23	8:30-12:35	Room 205

Topic Track: Nuclear data application
Session Title: Nuclear data in accelerator related applications 1
Chair: Tadahiro Kin

08:30	**I360**	**The High-energy Intra-nuclear Cascade Liège-based Residual (HEIR) Nuclear Data Library** / Michael Fleming (OECD Nuclear Energy Agency, France)
09:00	**R361**	**Study of the Li(d,xn) Reaction for the Development of Accelerator-based Neutron Sources** / Yukinobu Watanabe (Kyushu Uni., Japan)
09:20	**R362**	**Generation of Collimated Neutron Beam Using High Intensity Laser Pulses** / Tao Ye (Ins. of Applied Physics and Computational Mathematics, China)
09:40	**R363**	**Neutron Production in the Li-7(p,n) Reaction in the Energy Range 17-34 Mev** / Mitja Majerle (Nuclear Physics Ins. CAS, Czech Republic)
10:00	**R364**	**Isotope-production Cross Sections of Residual Nuclei in Proton- and Deuteron-induced Reactions on ^{93}Zr at 50 MeV/u** / Keita Nakano (Kyushu Uni., Japan)
10:20		**Break**

Topic Track: Nuclear data application
Session Title: Nuclear data in accelerator related applications 2
Chair: Michael Fleming

10:40	**I365**	**Production Method of Environmental Tracer Cs-132 by Accelerator-based Neutron** / Tadahiro Kin (Department of Advanced Energy Engineering Science, Kyushu Uni., Japan)
11:10	**R366**	**Excitation Functions of ^{3}He- Induced Nuclear Reactions on Natural Copper up to 55 Mev** / Mayeen Khandaker (Sunway Uni., Malaysia)
11:30	**R367**	**Uncertainty Quantification of Radiation Source Terms for Thorium- and Uranium-based Medical Isotope Production Targets Irradiated by 100 MeV Protons** / Alexey Stankovskiy (SCK-CEN, a Belgian Nuclear Research Centre, Belgium)
11:50	**R368**	**Calculation of Athermal Recombination Corrected Dpa Cross Sections of Materials for Proton, Deuteron and Heavy-ion Irradiations Using the PHITS Code** / Yosuke Iwamoto (Japan Atomic Energy Agency)
12:10	**R369**	**Study of ^{18}O(p,α)^{15}N Reaction at Low Energies** / Hossein Rafikheiri (Nuclear Science and Technology Research Ins. (NSTRI), Iran)
12:30	**S370**	**Evaluation of Photonuclear Reaction Data for Medical Applications** / Young-sik Cho (Korea Atomic Energy Research Institute)

Thu May 23 14:00-17:50 Room 205

Topic Track: Nuclear data application
Session Title: Nuclear data in accelerator related applications 3
Chair: Toni Koegler

14:00	I371	**Impact of the ENDF/B-VIII.0 Library on Modeling Nuclear Tools for Oil Exploration** / Marie-laure Mauborgne (Schlumberger, USA)
14:30	R372	**Total Neutron Cross-section Extracted from Transmission Experiments with Liquid Oxygen Using Neutron Energies from 18 to 34 MeV** / Martin Ansorge (Nuclear Physics Institute, CAS, Czech Republic)
14:50	R373	**Neutron Production Double-differential Cross Sections on Carbon Bombarded by 800 MeV/u ^{28}Si** / Cheolmin Ham (Department of Energy Science, Sungkyunkwan Uni., Suwon , Korea)
15:10	R374	**The Activation of ^{nat}Zr by Quasi-monoenergetic Neutrons Below 34 MeV.** / Eva šimečkova (Nuclear Physics Ins. of CAS, Czech Republic)
15:30	R375	**Cross Section Determination for TAD Materials in Quasi Mono-energetic Neutron Spectrum from P(li) Reaction** / Dusan Kral (Brno Uni. of Technology, Czech Republic)
15:50		**Break**

Topic Track: Nuclear data application
Session Title: Particle therapy and radiotherapy
Chair: Marie-laure Mauborgne

16:10	I376	**Single Plane Compton Imaging for Radionuclide and Prompt Gamma-ray Imaging** / Toni Koegler (Helmholtz-Zentrum Dresden - Rossendorf, Ins. of Radiooncology - OncoRay, Dresden, Germany)
16:40	R377	**Improvements of the Nuclear Reaction Modelling and First Radiobiological Studies in the FLUKA Monte Carlo Code for Hadron Therapy** / Giulia Arico (European Organization for Nuclear Research (CERN), Switzerland)
17:00	R378	**Production Yields of β^+ Emitters for Range Verification in Proton Therapy** / Carlos Guerrero (Universidad de Sevilla, Spain) / Speaker: Jorge Lerendegui Marco
17:20	R379	**Study of Dose Rate in the Brain Model Based on the Neutron Beam of SUT-MNSR** / Kaijian Li (Suranaree Uni. of Technology, Nakhon Ratchasima, Thailand, China)
17:40	S380	**Multiphysics Modelling of Dose Delivery in Targeted Alpha Therapy** / Gang Li (Canadian Nuclear Laboratories, Canada)
17:45	S381	**Proton-induced Prompt Gamma-ray Yield of Carbon for Range Verification in Hadron Therapy** / Toni Koegler (OncoRay - National Center for Radiation Research in Oncology, Faculty of Medicine and Uni. Hospital Carl Gustav Carus, Technische Universität Dresden, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany)

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 9
Chair: Massimo Salvatores

08:30	I382	**Experiments with Neutron Induced Neutron Emission from U-235 Pu-239 and Graphite** / Yaron Danon (Gaerttner LINAC Center, Rensselaer Polytechnic Institute, Troy, NY , USA)
09:00	R383	**New ^{209}Bi Photodisintegration Data and Physical Criteria of Data Reliability** / Vladimir Varlamov (Faculty of Physics, Lomonosov Moscow State Uni., Moscow, Russia)
09:20	R384	**Isomer Ratios for Products of Photonuclear Reactions on Rh** / Ihor Kadenko (Taras Shevchenko National Uni. of Kyiv Ukraine) / Speaker: Ihor Kadenko
09:40	R385	**Evaporation Residue Cross Section Measurements for the ^{35,37}Cl + ^{181}Ta Reactions** / Laveen Puthiya Veetil (Department of Physics, School of Physical Sciences, Central Uni. of Kerala, Kasaragod , India)
10:00	S386	**Neutron TOF Experiments for Transmission and Capture of Neutrons on ^{103}Rh in the Resonance Region** / Vivek Raghunath Chavan (Sungkyunkwan Uni., Suwon-, Republic of Korea)
10:05	S387	**Double-differential Cross Section Measurement with Low Threshold Detector for Proton Production Induced by Several Tens of MeV Protons** / Yuji Yamaguchi (Kyushu Uni., Japan)
10:10	S388	**Measurement of Gamma Ray from Inelastic Neutron Scattering for ^{56}Fe** / Zhaohui Wang (China Inst. of Atomic Energy, Beijing , China)
10:20		**Break**

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 10
Chair: Yaron Danon

10:40	I389	**Measurements of (n,2n) Spectrum-averaged Cross Sections in the Thermal-neutron Induced Fission of U-235: Fixing the High Energy Tail of the PFNS** / Roberto Capote (IAEA)
11:10	R390	**Neutron Production from Thick LiF, C, Si, Ni, Mo, and Ta Targets Bombarded by 13.4-MeV Deuterons** / Hayato Takeshita (Department of Advanced Energy Engineering Science, Kyushu Uni., Japan)
11:30	R391	**Isomeric Cross Section Study of Neutron Induced Reactions on Ge Isotopes** / Roza Vlastou-zanni (National Technical Uni. of Athens, Greece)
11:50	R392	**Recent Results and Error Propagation of the Neutron Induced Reaction Cross Section for the Nuclear Data Applications** / Surjit Mukherjee (The M. S. Uni. of Baroda, Vadodara, India)
12:10	S393	**Simulation of Nondestructive Measurement of ^{88}Kr Fission Yield Based on Gamma Ray** / Chenqing Wang (Northwest Ins. of Nuclear Technology, China)
12:15	S394	**The cross-section measurement of the ^{6}Li(n,t) reaction based on the silicon carbide detector at Back-n white neutron source** / Kang Sun (Ins. of High Energy Physics, CAS, Beijing , China,)
12:20	S395	**Measurement of the ^{16}O(n,α)^{13}C Reaction Cross-section Using A Double Frisch Grid Ionisation Chamber.** / Sebastian Urlass (European Organization for Nuclear Research, Geneva, Switzerland)

Thu May 23 14:00-18:05 Room 301

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 11
Chair: Andreas Solders

14:00	I396	**Recent Progress of Neutron Reaction Data Measurement at CIAE** / Xichao Ruan (China Inst. of Atomic Energy)
14:30	R397	**Towards Formation of Iaea Database for All Metallic Properties Useful in Radionuclides Production: Effect of Varied Titanium Densities on Excitation Functions.** / Ahmed Rufai Usman (Umaru Musa Yar'adua Uni., Katsina, Nigeria)
14:50	R398	**Light-nuclei Sub-barrier Nuclear Fusion and Screening Effect** / Kaihong Fang (Lanzhou Uiversity, China)
15:10	R399	**Cross Sections for A New Nuclear Reaction Channel on Au-197 with Dineutron Escape** / Ihor Kadenko (Taras Shevchenko National Uni. of Kyiv, Ukraine)
15:30	R400	**Development of Mc-based Error Estimation Technique of Unfolded Neutron Spectrum by Multiple-foil Activation Method** / Katsumi Aoki (Department of Advanced Energy Engineering, Kyushu Uni., Japan)
15:50		**Break**

Topic Track: Nuclear reaction measurements
Session Title: Nuclear reaction measurements 12
Chair: Xichao Ruan

16:10	I401	**Measurement of the ^{236}U(n,f) Cross-section at Fast Neutron Energies with Micromegas Detectors** / Andrea Tsinganis (CERN, Switzerland) / Speaker: Veatriki Michalopoulou-Petropoulu
16:40	R402	**Measurement of the ^{235}U(n,f) Cross Section Relative to n-p Scattering up to 1 GeV** / Alice Manna (Uni. and INFN of Bologna, Italy)
17:00	R403	**Recent Status of Fission Cross-section Measurement at Back-n White Neutron Beam of CSNS** / Yiwei Yang (Ins. of Nuclear Physics and Chemistry, CAEP, China)
17:20	R404	**Cross Section Measurements for Proton Induced Reactions on Natural Lanthanum** / K. V. Seeley (Uni. of Wisconsin, Madison, USA)
17:40	S405	**Measurement of Fission Cross Sections on ^{232}Th and ^{238}U Induced by D-T Neutrons** / Qiang Wang (Lanzhou Uni., China)
17:45	S406	**The Equivalent Efficiency Calibration Method of Radioactive Gas Source** / Gongshuo Yu (Northwest Ins. of Nuclear Technology (NINT), China)
17:50	S407	**Covariance Analysis on the Thermal Neutron Capture Cross Sections Using An Am-be Neutron Source** / Naohiko Otsuka (IAEA)
17:55	S408	**Characterization of the Differential Neutron Energy Spectrum from Proton Bombardment of Inconel-clad Lithium Conversion Targets** / Christopher Kutyreff (Uni. of Wisconsin-Madison, School of Medicine and Public Health, USA)
18:00	S409	**Measurements of the ^{33}S(n,α)^{30}Si Cross-section at n_TOF-CERN and ILL: Resonance Analysis and Implications.** / Javier Praena (Uni. of Granada (Spain))

Thu May 23 8:30-12:40 Room 302

Topic Track: Data dissemination and international collaboration
Session Title: Data dissemination and international collaboration 1
Chair: Franco Michel-sendis

08:30	**I410**	**Progress in International Collaboration on EXFOR Library** / Naohiko Otsuka (IAEA)
09:00	**R411**	**Nuclear Data Web Dissemination Efforts at the NNDC** / Tim Johnson (Brookhaven National Lab, USA)
09:20	**R412**	**MetroBeta: A European Project Providing Access to Accurate Beta Spectra** / Mark Kellett (CEA, LIST, Laboratoire National Henri Becquerel (LNHB), CEA-Saclay, 91 191 Gif sur Yvette, France)
09:40	**R413**	**The International Network of Nuclear Structure and Decay Data Evaluators** / Paraskevi Dimitriou (IAEA)
10:00	**R414**	**Overview of the OECD-NEA Working Party on International Nuclear Data Evaluation Cooperation (WPEC)** / Michael Fleming (OECD Nuclear Energy Agency, France)
10:20		**Break**

Topic Track: Data dissemination and international collaboration
Session Title: Data dissemination and international collaboration 2
Chair: Naohiko Otsuka

10:40	**I415**	**Perspectives on Nuclear Data Verification and Validation at the Data Bank Nuclear Data Service** / Franco Michel-sendis (OECD Nuclear Energy Agency, France)
11:10	**I416**	**Citizen Science in Radiation Research** / Cecilia Gustavsson (Department of Physics and Astronomy, Uppsala Uni., Sweden) / Speaker: Mattias Lantz
11:40	**R417**	**Conceptual Design, Modeling and Development of A Direction-finding Gamma Detector** / Zaheen Nasir (Military Ins. of Science & Technology, Bangladesh)
12:00	**R418**	**HPRL - International Cooperation to Identify and Monitor Priority Nuclear Data Needs for Nuclear Applications** / Emmeric Dupont (CEA-Irfu, Universitê Paris-Saclay, Gif-sur-Yvette, France)
12:20	**S419**	**Recent Dissemination Enhancements and Activities** / Tim Johnson (Brookhaven National Lab, USA)
12:25	**S420**	**Concentration of ^{137}Cs in Indonesia Marine Waters** / Mohamad Nur Yahya (National Nuclear Energy Agency of Indonesia)
12:30	**S421**	**Development of New Software for Nuclear Data Compilation** / Aiganym Sarsembayeva (Department of Physics and Technology, Al-Farabi Kazakh National Uni., Almaty , Kazakhstan)
12:35	**S422**	**Gamma Spectroscopy Methodology for Measurements of Large Amounts of Environmental Samples in Sweden 30 Years after the Chernobyl Accident** / Mattias Lantz (Department of Physics and Astronomy, Uppsala Uni., SE-Uppsala, Sweden)

Thu May 23 | 14:00-16:10 | Room 302

Topic Track: Nuclear data application
Session Title: Nuclear data in fusion application
Chair: Rafael Rivera

14:00	**I423**	**Nuclear Data Activities of the EUROfusion Consortium** / Ulrich Fischer (Karlsruhe Ins. of Technology (KIT), Germany)
14:30	**I424**	**Validation of Theory of Radiation Damage Against Experimental Data** / Olga Ogorodnikova (National Research Nuclear Uni. "MEPHI", Russia)
15:00	**R425**	**Comparison Between Measurement and Calculations for A 14 MeV Neutron Water Activation Experiment** / Mario Pillon (ENEA, Italy)
15:20	**R426**	**A Comparative Survey of Evaluated Nuclear Data Libraries for Usage in Fusion-relevant Activation Foils Spectrometry Experiments** / Prasoon Raj (Karlsruhe Ins. of Technology, Germany)
15:40	**S427**	**Cross-section and Activation Data for Long-lived Radionuclides (A $\sim$ 50-60) with Their Impact in Fusion Reactor Technology** / Bhawna Pandey (Govind Ballabh Pant Uni. of Agriculture and Technology, Pantnagar , Uttarakhand, India)
15:50		**Break**

16:10-18:00 **EG-GNDS Side-meeting**

Thu May 23	8:30-12:30	Room 303

Topic Track: Spallation, high and intermediate energy reactions
Session Title: Spallation, high and intermediate energy reactions 2
Chair: Zhiqiang Chen

08:30	**I428**	**A Comprehensive Study of Spallation Models for Proton-induced Spallation Product Yields Utilized in Transport Calculation** / Hiroki Iwamoto (Japan Atomic Energy Agency)
09:00	**R429**	**Distribution of Neutron and Proton Field in Elongated Spallation Targets** / Miroslav Zeman (Brno Uni. of Technology, Czech Republic)
09:20	**R430**	**Production Cross Sections of Long-lived Radionuclides in Proton Irradiated Pb, Ta and W Targets** / Zeynep Talip (Paul Scherrer Institute, Switzerland)
09:40	**R431**	**Neutron Energy Spectra Measurements of the Back-n White Neutron Source at CSNS** / Yonghao Chen (Ins. of High Energy Physics Chinese Academy of Science, China)
10:00	**R432**	**Neutron Imaging at the n_TOF Facility of CERN** / Federica Mingrone (European Organization for Nuclear Research (CERN), Switzerland) / Speaker: Michael Bacak
10:20		**Break**

Topic Track: Nuclear data processing and validation
Session Title: Integral experiments 1
Chair: Ivan Kodeli

10:40	**I433**	**Current Overview of ICSBEP and IRPhEP Benchmark Evaluation Practices** / John Darrell Bess (Idaho National Laboratory, USA)
11:10	**R434**	**A Study on Integral Parameters of VVER Critical Experiments of LWRS Based on Evaluated Nuclear Data Library ENDF/B-VII.0 & JENDL-3.0** / Zaheen Nasir (Military Ins. of Science & Technology, Bangladesh)
11:30	**R435**	**Combining Correlations from Multiple Criticality Benchmarks for Nuclear Data Adjustments Within A Total Monte Carlo Framework** / Erwin Alhassan (Laboratory for Reactor Physics and Thermal-Hydraulics, Paul Scherrer Institute, 5232 Villigen, Switzerland)
11:50	**R436**	**Validation of Heavy Water Cross Section Using Ambe Neutron Source** / Michal Kostal (Research Center Rez, Czech Republic)
12:10	**R437**	**Nuclear Data Implications of Tex, Ten New Critical Experiments with Plutonium and Tantalum** / Catherine Percher (Lawrence Livermore National Laboratory, USA)

Thu May 23 | 14:00-18:05 | Room 303

Topic Track: Nuclear data processing and validation
Session Title: Integral experiments 2
Chair: John Darrell Bess

14:00	I438	**National Criticality Experiments Research Center (NCERC) - Capabilities and Recent Measurements** / Nicholas Thompson (LANL, USA)
14:30	R439	**Fusion Neutronics Integral Experimental Study of Zr, W Evaluated Nuclear Data** / Suyalatu Zhang (Ins. of low-intermediate energy nuclear reactions, Inner Mongolia Uni. for Nationalities, China)
14:50	R440	**ZED-2 Reactor as a Physics Test Facility for Validating Evaluated Nuclear Data Libraries** / J.c. Chow (Canadian Nuclear Laboratories, Chalk River, Ontario, Canada, K0J 1J) / Speaker: Jimmy Chow
15:10	R441	**Contributions to Integral Nuclear Data in ICSBEP and IRPhEP Since ND2016** / John Darrell Bess (Idaho National Laboratory, USA)
15:30	R442	**Measurement of the Delayed-neutron Yield and Time Constants in the Cold Neutron Induced Fission of ^{235}U at ILL** / Olivier Serot (French Alternative Energies and Atomic Energy Commission (CEA), France)
15:50		**Break**

Topic Track: Nuclear data processing and validation
Session Title: Integral experiments 3
Chair: Nicholas Thompson

16:10	I443	**Use of Shielding Integral Benchmark Archive and Database for Nuclear Data Validation** / Ivan Kodeli (Jozef Stefan Institute, Ljubljana, Slovenia)
16:40	R444	**Bayesian Monte Carlo Assimilation for the PETALE Experimental Programme Using Inter-dosimeter Correlation** / Axel Laureau (Laboratory for Reactor Physics and Systems behaviour (LRS), Ecole Polytechnique Fdrale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland)
17:00	R445	**The Benchmark Experiment on Slab Iron with D-t Neutrons for Validation of Evaluated Nuclear Data** / Yanyan Ding (China Inst. of Atomic Energy)
17:20	R446	**Neutron Spectra Measurement and Calculation Using Last Available Version of Data Libraries CIELO, ENDF, CENDL and JEFF in Iron and Oxygen Benchmark Assemblies.** / Bohumil Jansky (Research Centre Rez, Czech republic)
17:40	R447	**Measurement of Leakage Neutron Spectra with D-t Neutrons and Validation of Evaluated Nuclear Data** / Rui Han (Ins. of Modern Physics, Chinese Academy of Sciences, China)
18:00	S448	**Research on Doppler Broadening Rejection Correction Based on 0K Nuclear Data** / Shenglong Qiang (Nuclear Power Ins. of China)

Fri May 24	8:30-12:20	Auditorium

Topic Track: Plenary B
Session Title: Plenary B1
Chair: Arjan Plompen

08:30	**L449**	**ENDF/B-VIII.0 and Beyond** / David Brown (National Nuclear Data Center/Brookhaven National Laboratory, USA)
09:05	**L450**	**Challenges in Actinides Evaluation: PFNS and the Next Pu Evaluation** / Roberto Capote (IAEA)
09:40	**L451**	**Nuclear reaction data in the next decade and the role of TALYS** / Arjan Koning (IAEA)
10:15		**Break**

Topic Track: Plenary B
Session Title: Plenary B2
Chair: David Brown

10:35	**L452**	**The Leverage of Nuclei in the Cosmos** / Michael Smith (ORNL, USA)
11:10	**L453**	**Results of the Collaborative International Evaluated Library Organisation (CIELO) Project** / Mark Chadwick (LANL, USA) / Speaker: Michael Fleming
11:45	**L454**	**CSNS Back-n White Neutron Facility and First Nuclear Data Measurements** / Jingyu Tang For The Back-n Collaboration (Ins. of High Energy Physics - Dongguan Branch, CAS, Dongguan, Guangdong, China)

Closing Ceremony
Chair: Zhigang Ge

12:20-12:40	**Summary remarks , Acknowledgement and Conference closing**

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L001 The Joint Evaluated Fission and Fusion (JEFF) Nuclear Data Library

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The JEFF Nuclear Data Library version 3.3 (referred to as JEFF-3.3) was released November 20, 2017. It represents the last of the JEFF-3 series of libraries that started with JEFF-3.0 released in April 2002. JEFF-3.3 involved a number of substantial changes compared to its predecessor JEFF-3.2: a new set of major actinides, improved gamma-production data, a new decay data file, a new fission yields file, replacement of a large set of legacy files by and complementing the existing with files from TENDL-2017 enhancing for instance decay heat estimation and allowing activation calculations directly from the transport file. JEFF-3.3 was verified and validated extensively by a large effort of members in the development community. This shows good performance for criticality estimates against ICSBEP and proprietary benchmarks.

The present focus of the JEFF community is the development of JEFF-4.0. With this new library we want to make several major steps forward taking advantage of developments that for practical reasons could not be incorporated in the latest release. First there is the increased demand on completeness. Any scientist should be able to assess the nuclear physics related aspects of his problem with the best available knowledge of reaction and decay data using a single data file (JEFF-4.0) that meets all demands. This requires a high level of completeness and quality control. Modern software development will be needed and must be combined efficiently with expert knowledge to achieve such an ambitious goal. A two-step approach will be taken towards JEFF-4.0 covering two mandates (6 years). In the first mandate the goals for its development will be set and the methods for library generation will be developed. In the second mandate the actual library will be developed and tested. Advances in our understanding of how to tackle the issues facing JEFF-4.0 with increased automation, computer power, new data formats and software interfaces were made in recent years. An example that JEFF-4.0 wants to benefit from through close collaboration is the TENDL library. In the presentation these goals and methods will be outlined.

L002 Recent Results from the Neutron Induced Fission Fragment Tracking Experiment Using the FissionTPC

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The goal of the Neutron Induced Fission Fragment Tracking Experiment (NIFFTE) is to measure neutron-induced fission cross section ratios with high precision and perform a comprehensive evaluation of systematic uncertainties in such ratio measurements. The NIFFTE Collaboration has designed and built a Time Projection Chamber, the fissionTPC, for this purpose. The detector enables charged particle tracking with full three-dimensional charge cloud reconstruction, allowing for the characterization of fission fragments and alpha particles originating from a central target. The wealth of information gained from this approach allows for a detailed understanding of fission fragment detection efficiency and systematic uncertainties relating to particle identification and target and beam spatial uniformity, amongst others.

Here we present the current status of the NIFFTE experiment, including cross section ratio measurements of U-238(n,f)/U-235(n,f), Pu-239(n,f)/U-235(n,f), and U-238(n,f)/Pu-239(n,f). Additionally, we will describe the wide variety of systematic studies being performed, including a direct measurement of the energy dependent spatial profile of the neutron beam delivered by the Los Alamos Neutron Science Center (LANSCE) to the fissionTPC apparatus.

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L003 Correlated Transition of TKE and Mass Distribution in Nuclear Fission

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We explore correlated transition of total kinetic energy and mass distribution of fission fragments ranging from A = 236 to 260 region by 4-dimensional Langevin equation. We calculate the free-energy surface by the 2-center Woods-Saxon model, and inertia and friction tensors by hydrodynamical models. We decompose the TKE-mass chart into standard mode which gives asymmetric mass distribution, and symmetric modewhich changes from super-long mode giving low TKE to super short mode, which becomes dominant, as mass increases from 256 to 258 suddenly. The symmetric mode keeps being super short, however, dominant mode goes back to the standard mode as mass number further increases. We investigated how the fragment deformations play an important role to account for this correlated transions

L004 The CONRAD Code, A Tool for Nuclear Data Analysis and Nuclear Reaction Modelling

Cyrille De Saint Jean, Pierre Tamagno, Pascal Archier, Gilles Noguere, Abdelhazize Chebbouboi
CEA

The CONRAD code is an object-oriented software tool developed at CEA since 2005. It aims at providing nuclear reactions models calculations, data assimilation procedures based on Bayesian inference and a proper framework to treat all uncertainties involved in the nuclear data evaluation process: experimental uncertainties (statistical and systematic) as well as models uncertainties. This paper will present the most recent developments concerning the theoretical and evaluation activity aspects.

Continuous efforts have been done in CONRAD to implement models for the continuum energy range: couple-channels optical model for proper inelastic channel calculation (with a first pre-equilibrium model). For the fission channel, new barrier calculation models are proposed based on Cramer-Nix simple representation as well as one dimensional general barrier representation calculated with a Numerov algorithm. In addition, a charged particle R-Matrix capability was introduced for both entrance and outgoing charged particle channels. Each development aspect is illustrated with several examples and calculations were validated by comparison with existing codes (SAMMY, REFIT, ECIS, TALYS).

New analysis can now be performed with CONRAD such as the use of Monte-Carlo Bayesian inference (instead of traditional generalized least square), multi nuclear reaction models calculations allowing the analysis of experiments covering wide energy ranges. This latter can give rise to full range covariance matrices (instead of block diagonal matrices). Furthermore, a simultaneous evaluation of neutron multiplicity and prompt fission neutron spectrum was recently introduced (generalized Madland-Nix model) giving rise to posterior cross correlation between these nuclear data after an experimental comparison. Finally, new capabilities oriented towards integral experiments data assimilation will be presented, especially the transposition of integral data assimilation to nuclear reactors.

L005 Fast Neutron Capture Reaction Data Measurement of Minor Actinides for Development of Nuclear Transmutation Systems

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Long-lived minor actinides (MA) in nuclear waste from nuclear power plants are a serious issue to continue nuclear energy production. To solve the issue, researchers have suggested nuclear transmutation, in which long-lived radionuclides are transmuted into stable or shorter-life nuclides via neutron-induced nuclear reactions. Development of nuclear transmutation systems as an accelerator-driven system requires accurate neutron nuclear reaction data. In 2017, a research project entitled "Study on accuracy improvement of fast-neutron capture reaction data of long-lived MAs for development of nuclear transmutation systems" started as a joint collaboration, including Tokyo Tech, Japan Atomic Energy Agency and Kyoto University. This project focuses on the neutron capture reaction of MAs, especially ^{237}Np, ^{241}Am and ^{243}Am, in the fast neutron energy region. The final goal of this project is to improve the accuracies of the neutron capture cross sections of ^{237}Np, ^{241}Am and ^{243}Am employing a high-intensity neutron beam from a spallation source of the Japan Proton Accelerator Research Complex (J-PARC) that reduces uncertainties of measurement. To achieve the goal, development of a neutron beam filter system in J-PARC, sample characteristic assay, and theoretical reaction model study are included in the project. The neutron beam filter is designed to solve the so-called double-bunch beam issue in J-PARC. The sample characteristic assay, particularly, precise isotope mass spectrometry lowers systematic uncertainties originating samples. The theoretical reaction model study improves MA nuclear data evaluation method based on cross sections and gamma-ray spectra measured in the J-PARC experiments. In this contribution, the overview of the project and the current progress will be presented.

This work is supported by the Innovative Nuclear Research and Development Program from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

L006 Nuclear and covariance data adjustment for nuclear data files improvement: new methods and approaches

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The WPEC Subgroup 33 final report indicated that a deeper understanding of the methodologies and of their applications implies that cross section adjustments can provide crucial feedback to evaluators and differential measurement experimentalists to improve the knowledge of neutron cross sections to be used in a wide range of applications.This new role for cross section adjustment requires to solve a new series of issues: definition of crn iteria to assess the reliability and robustness of an adjustment; requisites to assure the quantitative validity of the covariance data; criteria to identify inconsistency between differential and integral data; and definitions for consistent approaches in the use of both adjusted data and a posteriori covariance data to improve quantitatively nuclear data files. It is also crucial to provide methods and define conditions to generalize the results of an adjustment in order to evaluate the "extrapolability" of the results of an adjustment to a different range of applications (e.g., different reactor systems) for which the adjustment was not initially intended and to suggest guidelines to enlarge the experimental data base in order to meet needs that were identified by the cross section adjustment.

L007 CENDL3.2: The New General Purpose Nuclear Database

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Since 2010 the development of a new revision of Chinese Evaluated Nuclear Data Library, namely CENDL-3.2, has been started under the joint efforts of CENDL working group(China Nuclear Data Center (CNDC) and the Chinese Nuclear Data Cooperation Network). This library is built with the general purpose to provide high-quality nuclear data for the modern nuclear science and engineering. To fulfill the requirement of domestic users,five sub-libraries are specially designed in CENDL-3.2, which contain the neutron reaction data and covariance, photonuclear reaction data, fission yield, activation and decay data, and the results cover hundreds of nucleus from light to heavy concerned in applications.Comparing with CENDL-3.1, the evaluation of nuclear reaction data for several key nuclides, such as ^{235}U, ^{239}Pu, ^{233}U, ^{232}Th, ^{56}Fe et al. has been revised and improved.

The evaluation methodologies applied in CENDL-3.2 are systematically set up through along-term CENDL project study. In addition to CNDC, more than 10 Chinese universities and institutions are involvedin this project. The evaluation technique of nuclear reaction data, such as the few body calculations based on the Faddeev-AGS approach for light nuclei, the calculation system for neutron reactions with fission products and actinides with MINUIT optimization scheme, the microscopic optical model,and the empirical and microscopic methods for photon strength function et al.are developed to improve the data, and the covariance evaluation tools,COVAC and SEMAW are also established simultaneously;fission yields for ^{235}U and ^{239}Pu will be checked and evaluated with new experimental date including those measured by CIAE and its collaborations. Zp model is modified to fit both of the independent and cumulative yields with updated decay chain, which could results consistent yields and the related covariance; new decay data were evaluated by applying new mass formula and updated logFT values. All CENDL project also benefit from the international cooperation such as NRDC network, IAEA/CRP, OECD/WPEC and et al..

To assess the accuracy of the CENDL-3.2 in application, the library was tested with the criticality and shielding benchmarks collected in ENDITS-1.0. The criticality benchmarking results shows that the χ^2 of keff values decreases around 15% and close to ENDF/B-VIII.0. Shielding test shows that the nearly 40% under prediction of neutron leakage spectra from the 70cm-dia. The problem related to the IPPE iron sphere is almost solved. More detail of validation results will be presented in the nuclear data validation section this conference.

Today, many fruits of this CENDL Library have been applied in the Chinese domestic nuclear industry, including the design of CFR600 and TMSR. CNDC are participating in the international cooperation (CRP, WPEC, CIELO et al.) around data evaluation and method development for future.

I008 Novel Challenges for FLUKA: Status of the Code and A Review of Recent Developments

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FLUKA embeds sophisticated nuclear and atomic models in order to be able to perform accurate simulations of particle interactions from low up to cosmic ray energies and/or the energies reached by the most powerful accelerators. Possible projectiles include elementary hadrons, ions, lepton and neutrino beams. The code is often tasked with critical calculations for the feasibility studies and eventually the design of new projects or experiment in domains where little or no data are available. These applications put a particular strain on the extrapolation of FLUKA physics models where little or no experimental guidance exist. Therefore the code physics is constantly evolving with improvements to existing models and new features regularly added. Some of the latest developments and addition to the FLUKA code nuclear models will be presented, including examples and benchmarking. In particular the topics described in the following will be described in some details: other topics, including deuteron interactions at low-medium energies and light ion interactions at energies of relevance for hadrontherapy will be the subject of other contributions at this Conference. Significant improvements in intermediate energy hadron-nucleus interactions in energy ranges of relevance for neutrino beam production, as well as in neutrino interactions themselves will be discussed in view of future experiments.

Models for the description of deflection effects besides Coulomb scattering in very high energy muon propagation will be laso presented. Those effects are of major rlevance for future high energy accelerators beyond LHC and for their experiments. For neutrons below 20 MeV FLUKA makes use of an extensive group library based on recent evaluated nuclear data files which is suitable for most shielding and radioprotection applications. Two recent additions will be discussed:
a) the integration into the library of isomer production data aimed at better predicting radioactive inventories
b) an initial effort at implementing a fully correlated, closed kinematics pointwise approach to low energy neutron interactions.

This approachwill allow to describe event-by-event neutron interactions in the lowenergy domain with particular emphasis to neutron detector simulations and rare event, neutrino, dark matter, experiments where neutrons are sometimes a background

R009 Total Cross Section Model with Uncertainty Evaluated by KALMAN

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Particle transport simulations based on the Monte Carlo technique have been successfully applied to radiation shielding in accelerator facilities. The reliability of the simulation results can be usually evaluated by statistical uncertainties, which depend on the number of trials. In addition, the results include systemic uncertainties that are caused by unclear physical quantities such as total cross sections and reaction cross sections. Therefore, estimation of the systematic uncertainty is also required to confirm quantitatively the reliability of results.

Recently, Koning and Rochman proposed the Total Monte Carlo method [1] to estimate the systematic uncertainty. In the method, many nuclear data libraries are developed by a nuclear reaction model TALYS with varying its internal parameters. Thereafter, transport simulations are performed along with the developed libraries. The systematic uncertainty can be estimated from variance in results obtained by the simulations. Note that it is difficult to apply this method to analysis of shielding calculation induced by neutrons with energies higher than 100 MeV because huge data libraries for the energy region must be developed.

In the present study, we improved a total cross section model implemented in the Particle and Heavy Ion Transport code System (PHITS) [2] to estimate the systematic uncertainty caused by total cross sections of neutrons in the shielding calculation. We evaluated unclear quantities of internal parameters included in the model by KALMAN [3], which is Bayesian code based on the least squares technique, comparing with experimental data of the total cross section of several targets between C and Pb. The uncertainties in the total cross sections calculated by the improved model are comparable to errors of the experimental data. In the present study, transport simulations are performed varying the internal parameters within their unclear quantities instead of using many libraries required in the Total Monte Carlo method.

[1] A. J. Koning and D. Rochman, Ann. Nucl. Energy 35, 2024-2030 (2008).
[2] T. Sato et al., J. Nucl. Sci. Technol. 55, 684-690 (2018).
[3] T. Kawano and K. Shibata, JAERI-Data/Code 97-037 (1997) [in Japanese].

R010 Synergy of Nuclear Data and Nuclear Theory Online

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The NRV web knowledge base on low-energy nuclear physics has been created in the Joint Institute for Nuclear Research. This knowledge base working through the Internet integrates a large amount of digitized experimental data on the properties of nuclei and nuclear reaction cross sections with a wide range of computational programs for modeling of nuclear properties and various processes of nuclear dynamics which run directly in the browser of a remote user. Today, the NRV knowledge base is both a powerful tool for nuclear physics research and an educational resource. The system is widely used, as evidenced by the large number of user queries to its resources and the number of references to the knowledge base in the articles published in scientific journals. The basic principles of the NRV knowledge base are covered, and a brief description of its structure is given. The practical usage of the NRV knowledge base for both scientific and educational applications is demonstrated in detail.

R011 Recent Progress of A Code System Deuracs Toward Deuteron Nuclear Data Evaluation

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Intensive neutron sources using deuteron accelerators have been proposed for various applications such as irradiation test for fusion reactor materials and production of radioisotopes for medical use. In addition, transmutation system using deuteron-induced spallation reactions has been recently proposed for several long-lived fission products (LLFPs). Accurate and comprehensive deuteron nuclear data are indispensable in the design study of such facilities. However, currently available experimental and evaluated data of deuteron-induced reactions are not necessarily enough for the requirement.

Under the above situations, we have been developing a code system dedicated for deuteron-induced reactions, which is called DEURACS. DEURACS consists of several calculation codes based on theoretical models to describe respective reaction mechanisms. The breakup processes, namely elastic breakup and non-elastic breakup are calculated using the codes based on the continuum-discretized coupled-channels (CDCC) theory and the Glauber model, respectively. The (d,n) and (d,p) transfer reactions to bound states in the residual nuclei are calculated by a conventional zero-range distorted wave Born approximation (DWBA) using the DWUCK4 code. In addition, the pre-equilibrium and the compound nucleus processes are calculated using the two-component exciton model and the Hauser-Feshbach model implemented in the CCONE code. For the better prediction of composite particle emission, the Iwamoto-Harada model of cluster emission is incorporated with the exciton model, and the pickup and inelastic scattering processes in direct reaction are also taken into account by the semi-empirical model by Kalbach.

So far DEURACS was applied successfully to prediction of double-differential cross sections (DDXs) for (d,xn) and (d,xp) reactions up to 100 MeV. In the present work, calculations using DEURACS are compared with available experimental data up to 200 MeV such as DDXs for emission of neutron or light charged particles up to $A = 4$. We also analyze isotopic production cross sections of residual nuclei in the deuteron-induced spallation reactions on several LLFPs. Validation of the present modelling in DEURACS is discussed through comparison with the experimental data.

This work was partially supported by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

R012 Systematic Formalism for the (n,p) Reaction Cross Section at 2.5, 14, 20 MeV with Explicit Description of MSC and MSD Pre-equilibrium Multiple Particle Emission

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Semi - empirical systematic formalisms for the calculations of (n,p) reaction cross sections within the Pre-equilibrium Multistep MSC and MSD models has been developed with relevance for cases of scarce experimental and unreliable evaluated data. The formalisms provide very explicit account for the significant impact of non-equilibrium component of Multiple Particle Emission in the (n,p) reaction cross-section for light, medium and heavy nuclei within $24 \leq A \leq 209$; $13 \leq Z \leq 83$ at 2.5, 14 and 20 MeV. The analytic study shows the dependence of the (n,p) reaction cross section on nucleonic composition and on asymmetric nuclear parameters.

R013 Systematic Uncertainties of E1 Photon Strength Functions Extracted from Photodata

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Experimental data for photoabsorption cross-section above neutron separation energies S from EXFOR database [1] do not include contribution of the cross-section from gamma-gamma channels. This contribution is very large at gamma-ray energies below S+dE, where dE is a small positive energy below the threshold of the photo-reaction with emission of two neutrons or, in some cases, other reactions with large cross-sections; typically dE $<$ 1.5 MeV. The absence of this contribution leads to incorrectly small values of the photon strength functions [2] extracted from photodata in above mentioned gamma-ray energy range.

In this contribution, the specific intervals dE for nuclei were calculated using simulations of the photo cross-sections by the nuclear reaction code TALYS 1.6 [3]. These intervals were found from the condition of ten percent contribution of the cross-section from gamma-gamma transitions to total photoabsorption cross-section. New database for electric dipole photon strength functions were prepared with systematic uncertainty less than 10% by discarding the PSF values in the gamma-energy range from S to S+dE.

This work is partially supported by the IAEA through a CRP on Updating the Photonuclear Data Library and generating a Reference Database for Photon Strength Functions (F41032).

[1] EXFOR database; https://www-nds.iaea.org/exfor/exfor.html.
[2] R.Capote, M.Herman, P.Oblozinsky, P.G.Young, S.Goriely, T.Belgya, A.V.Ignatyuk, A.J.Koning, S.Hilaire, V.A.Plujko et al., Nucl. Data Sheets, 110 (2009) 3107 (http://www-nds.iaea.org/RIPL-3/. RIPL-3).
[3] A.J. Koning, S. Hilaire, M.C. Duijvestijn, in: O. Bersillon et al. (Eds.), TALYS-10, Proc. Intern. Conf. Nuclear Data for Science and Technology, April 22-27, 2007, Nice, France, EDP Sciences, 2008, pp. 211-214, http://www.talys.eu

R014 Comparative Analysis of Neutron Activation Cross Sections of Aluminum Used As Cladding in Miniature Neutron Source Reactors

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Theoretical calculations has been carried out for the stable isotope of Al to predict the (n,p), (n,2n) and (n,α) activation cross sections completely from threshold up to 20 MeV using both a singular multi step pre equilibrium code EXIFON 2.0 which is a global and standard minimum model description without explicit account for higher-order effects and a modular code EMPIRE 3.2 which is a versatile multi model code with capacity for implementing several higher order effects. Results from both efforts provide adequate data for application within the reactor energy spectrum and compares fairly with recent measurements and evaluations. The observed differences however gives a measure for deviation from an average nuclear behavior for the isotope within the energy range studied and points to the improvements made possible when higher-order effects are accounted for in the optical, compound nucleus and Pre-equilibrium models.

R015 Nucleon-transfer Reactions for Low-energy Deuterons in FLUKA

Salvat-pujol Francesc (on Behalf Of The Fluka Collaboration)
CERN

Low-energy (<200 MeV) deuteron interactions with nuclei remain a topic of ongoing research, with practical interest as sources of mostly forward-scattered neutrons and protons, with a variety of applications in detector technology, accelerator shielding design, etc. The inclusion of these interaction mechanisms in a general-purpose Monte-Carlo code for the simulation of radiation transport is not straightforward due to the idiosyncrasies of the deuteron: low binding energy and predominantly direct nature of its nuclear interactions in the considered energy domain.

We address here nucleon-transfer reactions for deuterons on a selection of target nuclei of particular relevance for neutronics. Nucleon transfer from the deuteron to a target nucleus leads to the formation of a recoiling final nucleus in the ground sate or in a low-lying excited state: a series of sharp and discrete peaks appear in the energy spectrum of the emitted nucleon, at energies correlating with the excitation-energy spectrum of the final nucleus. The angular distribution of the emitted nucleon exhibits a characteristic oscillatory behavior suited for an effective description based on the distorted-wave Born approximation.

Distorted waves were determined by numerically solving the radial Schroedinger equation using the RADIAL subroutine package, using the Han and the Koning+Delaroche optical-potential model for the deuteron and the emitted nucleon, respectively. The potential in which the transferred nucleon is bound is modelled as a real Woods-Saxon with a spin-orbit coupling term; its depth was varied until a binding energy was obtained in agreement with the final-state excitation energy. The radial integrals arising in the calculation of the transition-matrix element are quickly converging (the bound-nucleon radial function drops quickly outside of the nuclear radius). The evaluation of the differential cross section for the emitted nucleon follows naturally. The DWBA yields reasonable angular distributions of the emitted nucleon. The practical difficulty lies in the adjustment of the naturally arising spectroscopic factors. Experimental angular distributions have been used to gauge the normalization of our DWBA differential cross sections in as broad a deuteron-energy range as the published data allow. The resulting database of DWBA differential cross sections has been adapted for sampling in FLUKA.

R016 Consistent Assessment of Deuteron Interactions at Low and Medium Energies

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Enlarged deuteron-data needs follow the demands of on-going strategic research programs (ITER, IFMIF, SPIRAL2-NFS) using deuteron beams, while the corresponding experimental and evaluated data are less extensive and accurate than for neutrons. Also, there are currently many efforts to improve the description of deuteron reactions due to the use of (d,pf) surrogate reactions for neutron capture (n,γ) and induced fission (n,f) studies. Consequently, this work concerns the deuteron interaction analysis by unitary account of the contributing reaction mechanisms.

Specific non-compound processes as breakup (BU) and direct reactions (DR) make the deuteron-induced reactions substantially different from reactions with other incident particles. The deuteron interaction with low and medium mass target nuclei at incident energies below and around the Coulomb barrier proceeds largely through stripping and pick-up DR mechanisms, while pre-equilibrium emission (PE) and evaporation from fully equilibrated compound nucleus (CN) become important at higher energies. Moreover, the deuteron BU is quite important along the whole incident-energy range. Thus, significant discrepancies with measured cross sections follow the scarce consideration of only PE and CN processes while microscopic calculation of inclusive BU and DR cross sections are yet numerically tested.

However, whereas the associated DR, PE, and CN models are already settled, an increased attention should be paid to the theoretical description of the BU components, namely the elastic BU, with no further interaction of BU nucleons, and inelastic BU where one of the deuteron constituents interacts non-elastically with the target nucleus. This is why a comparative assessment of measured data and results of BU microscopic description, as well as current parametrization [1] already involved within recent systematic studies [2,3] is equally useful to basic studies and improved nuclear data calculations. Actually, missing of suitable BU+DR analysis leads to still large disagreement between the experimental and evaluated deuteron-activation excitation functions, and forms the object of this work.

[1] M. Avrigeanu and V. Avrigeanu, Phys. Rev. C 95, 024607 (2017).
[2] M. Avrigeanu et al., Phys. Rev. C 94, 014606 (2016).
[3] E. Simeckova et al., Phys. Rev. C 98, 034606 (2018).

R017 Alpha-nucleus Optical Potential Based on the Isospin-dependent DBHF

Zhi Zhang, Ruirui Xu, Zhongyu Ma, Zhigang Ge
CIAE

The alpha-nucleus optical potential is an interesting topic in the fundamental research and application of nuclear reactions. In the previous work, the microscopic nucleon-nucleus optical potential (CTOM) based on the isospin-dependent Dirac-Brueckner-Hartree-Fock (DBHF) has been successfully described the scattering between nucleons and finite nuclei. Based on the CTOM, this work continue using the same nuclear force correction factor and combine with the double-folding model and improved local density approximation (ILDA) to give the alpha-nucleus optical potential. Then we have been systematically calculated the optical potentials and elastic scattering cross sections of the ^{12}C - ^{208}Pb target with the incident energy in the range of 40 - 400MeV. In order to give a better description of the scattering sections, this work introduced the correction factor NR and NI to adjust the real parts and imaginary parts of the optical potentials, meanwhile the variation of the parameters with the element charge, mass, and incident energy have been discussed. The calculation system have constrained the parameters of NR and NI, and give a better description the experimental results of alpha-nucleus elastic scattering angular distributions and final establish a basis for conducting relevant nuclear reaction study.

S018 The Cross Sections and Energy Spectra of the Particle Emission in α Induced Reaction on $^{54,56,57,58,\mathrm{nat}}$Fe and $^{63,65,\mathrm{nat}}$Cu

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Nuclear data for alpha particle induced reactions on $^{54,56,57,58,\mathrm{nat}}$Fe and $^{63,65,\mathrm{nat}}$Cu plays an important role in the application of nuclear techniques like charged particle activation analysis, medical isotope production, estimation of neutron yield and residual activity of accelerator components or simulation of radiation damage. All cross sections of α-induced reactions, angular distributions, energy spectra and double differential cross sections of neutron, proton, deuteron, triton, helium and α-particle emissions for $^{54,56,57,58,\mathrm{nat}}$Fe and $^{63,65,\mathrm{nat}}$Cu are consistently calculated and analyzed at incident energy below 200 MeV. The optical model, the intra-nuclear cascade model, direct reaction theories, the unified Hauser-Feshbach and exciton model which includes the improved Iwamoto-Harada model are used. Theoretically calculated results are compared with the existing experimental data. Good agreement is generally observed between the calculated results and the experimental data. Since the improved Iwamoto-Harada model has been included in the exciton model for the light composite particle emissions, the theoretical models provide the good description of the shapes and magnitude of the energy spectra and double differential cross section of emission deuteron, triton, helium and alpha. The evaluated data are given in the format of ENDF. Therefore, these data can be effectively used in different practical applications.

S019 Employing Talys to Deduce Initial JRMS in Fission Fragments

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Fission fragments carry a considerable amount of angular momentum (J). Despite numerous fission studies, models do not fully explain the generation of J. Measurements of isomeric yield ratios (IYR) for proton-induced fission reactions are performed at the IGISOL-JYFLTRAP facility in Finland. The root-mean-square (rms) of the spin distribution is deduced from the measured IYR by utilizing the TALYS nuclear-reaction code. Here we describe this method in detail and assess it using IYR data from well-known reactions; ^{235}U(n_{th},f) and ^{252}Cf(sf). In addition, we investigate the advantages and limitations of the method.

The population of high-spin states (excited or ground states) as a function of initial nuclear spin is studied in TALYS. Isomeric yield ratios found in the literature are compared to IYR calculations in TALYS, by changing the angular momentum distribution of the initial fragments (in terms of Jrms).

The study was performed on the following fission products: ^{84}Br, ^{90}Rb, ^{128,130,132}Sb, ^{132,134,136}I, ^{133,135}Xe, ^{133,135}Te, ^{138}Cs, and ^{146}La. The overall results showed a consistent performance of TALYS, both in comparison to reported literature values and to the fission code GEF. A few discrepant Jrms values were found in the literature, highlighting the possible need to re-examine these deduced literature Jrms values.

A sensitivity analysis showed that poorly known level structure data affects the accuracy of the calculations significantly. Moreover, reducing the number of levels taken into account in the calculations enhances the agreement with the literature results since level density models are used instead. Calculations were also performed on the reaction studied at IGISOL, ^{238}U($p_{25\mathrm{MeV}}$,f), where multiple fission chances are possible. According to GEF, each channel contributes differently to the fragment angular momentum, and thus to the population of IYR. This stresses the importance of proper weighting.

In the future, the method will be improved by considering more realistic excitation energy distributions and energy-dependent spin distribution.

I020 Multiband Coupling and Nuclear Softness in Optical Model Calculations for Even-even and Odd-A Actinides

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A model was recently proposed[1] that introduces a general concept of inter-band coupling in optical model calculations for strongly statically deformed nuclei. A crucial part of the model - effective deformations - that define the strength of band couplings were taken as fitting parameters that allowed performing simplified optical calculations.

Additional nuclear structure information was considered[2] by using the soft-rotator nuclear model[3] allowing to derive the required effective deformations for even-even actinides, thereby reducing the number of effective parameters in the model, as well as improving the predictive power for nuclei where poor experimental data exist. This model extension also accounted for the nuclear stretching and dynamic volume conservation effects in coupled channels calculations.

A spectator model was used that describe nucleon scattering on odd-A targets by treating them as a single particle coupled to an even-even core. Collective motion is defined by the even-even core allowing to derive the effective deformations for odd-A targets. This approach allows the coupling of all nuclear states which are built on the same unpaired nucleon single-particle wave function and different collective excitations of the core using the soft-rotator model.

This work describes a complete and unified framework for coupled channels optical model calculations of nucleon scattering on both even-even and odd-A actinides with the account of multiple-band coupling and nuclear softness. Calculations performed for ^{233}U and ^{238}U show that the direct excitation cross sections from non-ground state bands are comparable to the nucleon scattering cross sections on the third level of the GS band.

Therefore, a coupling scheme is still far from saturation when only GS band is accounted for using a rigid rotor model[4], and multiband coupling is required to calculate accurate reaction cross sections. Softness effects are shown to change the estimated compound nucleus formation cross-section by 5-15% below 100 keV, with non-vanishing difference up to 200 MeV.

[1] E. S. Soukhovitski et al, Phys. Rev. C 94, 064605 (2016).
[2] D. Martyanov et al, EPJ Web Conf. 146, 12031 (2017).
[3] Y. V. Porodzinskij et al, Phys. At. Nucl. 59, 228 (1996).
[4] F. S. Dietrich et al, Phys. Rev. C 85, 044611 (2012).

R021 Global Phenomenological Optical Model Potentials for Some Weakly Bounded Light Projectiles

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The global phenomenological optical model potentials for the weakly bounded projectiles isotopic chain ^{6,7,8,9,10}Li are constructed by simultaneously fitting experimental data of the elastic scattering angular distributions and the reaction cross sections. Based on the obtained global optical model potential of ^{7}Li projectile, the global phenomenological optical model potentials for the isotopic chain ^{8,10,11}B projectiles are also derived. All the calculations are compared with the available experimental data. The performance shows that the global phenomenological optical model potentials for isotopic chain of lithium and boron can give a satisfactory description for elastic scattering of these projectiles.

R022 The Dark Side of Alpha-particle Optical Potential: Emission from Excited Nuclei

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The alpha-particle interaction with nuclei and the corresponding optical model potential (OMP) were of special interest from the earliest days of nuclear physics. The widely-used phenomenological OMP parameters were derived from the analysis of either elastic-scattering or alpha-induced reaction data while then are used to describe also the alpha-particle emission from hot nuclei excited in nuclear reactions. However the later studies are also subject of various assumptions and quantities. Thus, the alpha-particle OMP for the incident channel seems similar to the familiar side of the Moon which is facing always the Earth, but for the alpha-emission it is like the dark side of the Moon. Moreover, there is a so-called alpha-potential mystery [1] of the account at once of both absorption and emission of alpha particles, of equal interest for nuclear astrophysics and nuclear technology.

A former search for new physics in potentials to describe nuclear de-excitation made use of the assumption that particle evaporation occurs from a transient nuclear stratosphere of the emitter nucleus ([2] and Refs. therein). However, the question of a real difference between the OMPs which describe either alpha-particle elastic scattering and induced reactions [3] or alpha-emission from excited compound nuclei [4] could be answered only following definite conclusions concerning the incident channel. Thus, while better results provided by potential [3] within large-scale nuclear-data evaluation [5] led to its adoption as the default option within the latest version of the code TALYS [6], the need to use or not use the same potential for emitted alpha particles [7,8] makes the object of this work.

[1] T. Rauscher, Phys. Rev. Lett. 111, 061104 (2013)
[2] M. Avrigeanu, W. von Oertzen, and V. Avrigeanu, Nucl. Phys. A764, 246 (2006).
[3] V. Avrigeanu et al., Phys. Rev. C 90, 044612 (2014).
[4] V. Avrigeanu, P.E. Hodgson, and M. Avrigeanu, Phys. Rev. C 49, 2136 (1994).
[5] A. J. Koning, Report EFFDOC-1271, OECD/NEA Data Bank, Paris, 2015.
[6] A. J. Koning et al., v. TALYS-1.9, 2017, http://www.talys.eu
[7] V. Avrigeanu and M. Avrigeanu, Phys. Rev. C 91, 064611 (2015).
[8] V. Avrigeanu and M. Avrigeanu, Phys. Rev. C 94, 024621 (2017).

R023 Unified Description of Bound States and Nucleon Scattering for Double Magic Nuclei by A Lane-consistent Dispersive Optical Model Potential

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Both zirconium and lead are important materials for nuclear applications widely used in reactor cladding (Zr) and cooling (lead) as well as for shielding. An improved optical model describing nucleon scattering on these nuclei is needed to meet nuclear data requirements of new reactor designs. A unified description of bound states and nucleon scattering on double-magic target nuclei ^{90}Zr and ^{208}Pb is presented, in terms of a spherical Lane-consistent dispersive optical model potential that considers non-localities both in the real and imaginary volume potentials and is valid from -50 up to 200 MeV. The non-locality is considered in the real potential as proposed by Perey-Buck [1]; for imaginary potential the non-locality induces asymmetric imaginary volume potential for large values of $|$ E-E$_f$$|$[2-4]. Realistic parameterization of imaginary potentials W$_v$(E) and W$_s$(E) are used forcing them to be zero in the region of width 2E$_p$ near the Fermi energy [4,5]. The gap E$_p$ is the average energy of the single-particle levels, being very important to describe nucleon scattering on magic-nuclei due to the large shell gaps observed in their excitation spectra. New potential parameters are obtained by fitting both the single-particle states and scattering states data. A consistent description of all bound and scattering observables is achieved.

[1] F. Perey and B. Buck, Nucl. Phys. 32 (1962) 353.
[2] C. Mahaux and H. Ngo, Nucl. Phys. A431 (1984) 486.
[3] C. Mahaux and R. Sartor, Nucl. Phys. A458 (1986) 25.
[4] C. Mahaux and R. Sartor, Nucl. Phys. A528 (1991) 253.
[5] A. Molina et al, Phys. Rev. C65 (2002) 034616.

R024 Comparison of Practical Expressions for E1 Photon Strength Functions

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The description of photoabsorption cross-sections by closed-form Lorentzian models of photon strength functions for photoexcitation by electric dipole gamma-rays is considered. The experimental photoabsorption data are compared with theoretical calculations for even-even nuclei using criteria of minimum of least-square factor and root-mean-square deviation factor. The following models are used: Standard Lorentzian, Simplified Modified Lorentzian model, Generalized Lorentzian model [1,2] and Triple Lorentzian Model [3,4]. It was shown that the Simplified Modified Lorentzian model can be considered as the best one for simulating of the E1 PSF at the gamma-ray energies below $\sim$ 30 MeV for simple description of photoabsorption data.

This work is partially supported by the IAEA through a CRP on Updating the Photonuclear Data Library and generating a Reference Database for Photon Strength Functions (F41032).

[1] R.Capote, M.Herman, P.Oblozinsky et al., Nuclear Data Sheets, 110, 3107 (2009).
[2] V.A.Plujko, O.M.Gorbachenko, R.Capote, P. Dimitriou, At. Data Nucl. Data Tables,123-124, 1 (2018).
[3] Y.Alhassid, B.Bush, S.Levit Phys. Rev. Lett., 61, 1926 (1988).
[4] A.R. Junghans, G. Rusev, R. Schwengner et al., Phys. Lett. B, 670, 200 (2008).

I025 Developments Regarding Three-body Reaction Channels Within the R-matrix Formalism

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At low incident energies the reaction cross sections show striking resonance structures which cannot properly be reproduced by (semi-)microscopic nuclear models. Usually R-matrix theory is applied to obtain a sufficiently accurate but phenomenological description of the resonance region. However, the concept of standard R-matrix theory is only based on two-particle reaction channels. Thus three- and many-body channels cannot be described by standard R-matrix theory and are usually treated in an approximate way [1] by sequential processes. A similar problem also occurs for capture channels (e.g. (n,γ)) for which perturbative approaches are frequently applied.

In 1974 Glöckle [2] proposed an R-matrix formulation based on Faddeev equations for reactions with three particles of equal mass. In this contribution we extend this formalism to three particles with unequal masses in s-wave states. In addition we reformulated the expressions in order to be suited for numerical implementation in the environment of an R-matrix code.

The availability of an R-matrix treatment of three- and many-body channels is particularly important for light nuclear systems in which breakup channels may open in the resonance regime. Therefore we apply the formalism first to schematic examples in light nuclear systems in order to show the feasibility of the formalism and to study its properties.

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[1] A.M. Lane, R. Thomas, Rev.Mod.Phys. 30, 257 (1958)
[2] W. Glöckle, Z. Phys. 271, 31 (1974)

R026 Monte Carlo Simulation of Gamma and Fission Transfer Reactions Using Extended R-matrix Theory

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The idea to supplement neutron-induced fission cross-section database with particle-transfer-induced reactions has been raised a long time ago. Analytical simulations of these measured direct-reaction induced fission probabilities were performed under several simplifications from which is stated the surrogate-reaction method. Major limitations in surrogate data conversion were promptly noticed with the difficulty to estimate compound nucleus formation cross section, possible differences of angular momentum distribution between neutron capture and direct reactions and the assumption of fission decay probability spin-parity independence. Referring to Weisskopf-Ewing (WE) approximation was justified in the seventies because of computer restrictions, lack of precise information on nuclear level densities across deformation and difficulties for achieving confident optical model calculations over a large range of nuclides. Nowadays the bulk of those approximations can be left aside even if difficulties remain. Present theoretical approach is portrayed and subsequent results can be compared for one of the first times with experimental gamma-decay probabilities; thanks to very recent simultaneous ^{238}U(^{3}He,^{4}He)^{237}U* [DOI: 10.1051/epjconf/34201003], ^{240}Pu(^{3}He,^{4}He)^{239}Pu* and ^{240}Pu(^{4}He,^{4}He')^{240}Pu* gamma and fission surrogate measurements. This work is supported by recent R-matrix simulations [PRC88,054612 (2013); PRC97,064601(2018)] of low-energy neutron-induced fission cross sections over the whole Pu isotope family that have enlightened the actual possibility to carry extended R-matrix fission barrier calculations accurate enough to make predictions of neutron-induced cross sections for the family isotopes for which no neutron spectroscopy measurements exist. This conference presentation is willing to show how well extended R-matrix can fit low nuclear excitation energy (from 4 to S_n+2 MeV) fission and gamma decay probabilities without referring to the surrogate-reaction method. Direct reaction population calculation in terms of pickup (^{3}He,^{4}He) reactions has been attempted whereas the estimation of direct inelastic (^{4}He,^{4}He') population prior to our Monte Carlo simulation of gamma and fission decays has been insured by the TALYS (ECIS) code. Final pretty reasonable simulation-measurement agreement that will be demonstrated, opens a new era for neutron cross section evaluation of heavy isotopes on the ground of combined experimental cross section and decay probability databases.

R027 Modernization of SAMMY: An R-matrix Bayesian Nuclear Data Evaluation Code

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SAMMY is a standard nuclear data evaluation code developed at the Oak Ridge National Laboratory (ORNL) for Bayesian fitting of R-matrix resonance parameters to neutron, proton, and α-particle differential cross sections data in resolved and unresolved resonance energy ranges of medium and heavy nuclides. We will provide an overview of SAMMY's extant features and will report on progress of SAMMY modernization into a modern software framework, development of new features inside SAMMY, adoption of modern software quality assurances methods, and near- and long-term plans for expansion of SAMMY's capabilities.

SAMMY's extant features include facility-specific multi-component experimental resolution functions, resolution functions of several commercially available detectors, Doppler broadening of cross sections, and multiple scattering effects, among others. SAMMY has been established as the foremost tool worldwide for R- matrix resonance parameter evaluations of medium and heavy nuclides, contributing many evaluated resonance parameter sets and their covariance matrices to evaluated nuclear data libraries.

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R028 R-matrix Analyses of Light Element Reactions

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We give an overview of the status of light-element evaluations of nuclear reactions using the phenomenological R matrix approach. We will detail recent work including the extension of the NN evaluation to higher energy, observable covariances, and the importance of unitarity in determining the detailed behavior of light-element cross sections, such as the role of the inter-ference cross section NI in dt elastic scattering. We also discuss the importance of light-element evaluations in a range of applciations such as the early universe and in the determination of actinide cross sections.

S029 Theoretical Calculation of Micro Data for the Nuclear Reaction of p+^{27}Al up to 200 MeV

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Using optical model theory, an optimal set of optical model potential parameters is obtained in order that the theoretical values of non-elastic scattering cross sections and elastic scattering angular distributions are consistent with experimental values for the reaction of p+^{27}Al; The direct inelastic scattering angular distributions to discrete levels are calculated with the distorted wave Born approximation; The intra nuclear mechanism, exciton model, evaporation model, Hauser-Feshbach theory with the width fluctuation correction and pick-up mechanism of compound particles emission are applied all reaction cross sections p+^{27}Al reactions. The theoretical results are compared with experimental data.

S030 An Evaluation of the Alpha-cluster Formation Factor in (n,α) Reactions

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Cluster formation effect in nuclei is one of important subjects of the modern nuclear physics study for understanding of light nuclear structure, alpha and heavy cluster decays, cluster transfer and emission reactions. Many authors have been considering for a long time the clustering effect in nuclei using different approaches to this problem. However, the results of these studies are not consistent and a common explanation of the α-clustering in a nucleus and unified method to obtain the α-clustering probability are not up to now available. Results of such investigations are varied in the wide range depending on theoretical models used in calculations.

In this work we suggest some methods based on the statistical and knock-on models for evaluation of the α-clustering factor or α-clustering probability in (n,α) reactions induced by slow and fast neutrons.

The main purpose of this study is to compare the values of the α-clustering factors obtained by the compound and direct mechanisms for the same nuclear reactions. Also, our results are compared with values estimated by other authors.

I031 New Paradigm for Nuclear Data Evaluation

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Building on the results of a series of NEA WPEC Subgroups, IAEA led International Nuclear Data Evaluation Network, US Recovery Act projects, and recent progress in nuclear reaction modeling and machine learning, we propose a change in the evaluation procedure to produce adjusted libraries which eventually would allow for to account consistently for the total of differential and integral experiments. The two key features of the new paradigm will be:
- Using a set of clean, reliable and representative integral experiments in the evaluation process.
- Developing an infrastructure enabling quick adjustment of the relevant part of the library to changes in the evaluation for a given material.

The first point will extend the evaluation procedure to account for integral experiment on the same footing as the differential ones and will provide comprehensive covariance matrix including cross-correlations among different materials/reactions that are critical for realistic propagation of data uncertainties to integral quantities.

The second point will reduce error-cancellation issue by removing a condition when eliminating an error in a new evaluation degrades performance of the library due to a compensating error left in another evaluation(s). The new infrastructure will also facilitate updating of the library to account for new or corrected experiments and advances in the reaction modeling.

The new paradigm will involve:
- selecting a set of integral experiments with related input decks,
- storing ENDF evaluation inputs and procedures in a form that allows for a quick modification of the evaluation maintaining physical constraints,
- building sensitivities for cross sections and integral experiments,
- using proven adjustment and machine learning methods to perform global library adjustment each time any evaluation is changed,
- employing machine learning to facilitate analysis of results of each global adjustment.

The project is scalable and can be started with a limited core of nuclei, e.g., those considered in the CIELO exercise. Key to the success will be physically sound reaction modeling needed to ensure that physics constraints are fully observed while dependable covariances with cross-correlations will play crucial role in the adjustment. Some specific results showing feasibility of the approach will be presented.

R032 Prompt Fission Neutron Spectra of ^{238}U(n,F) and ^{232}Th(n,F)

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Prompt fission neutron spectra of ^{238}U(n,F) and ^{232}Th(n,F) were many times modified in data libraries like ENDF/B-VIII, JEFF-3.3, JENDL-4.0. A number of discrepancies as concerns spectra shape variation with the increase of E_n from thermal up to 20 MeV still remains. The consistent model prediction is based on reliable measured data which are available only in between 2.9 and 17.7 MeV. Different model estimates of (n,xnf) chances in (n,F) are discrepant 1.5-3 times. The next complication is due to TKE decrease with E_n in case of ^{238}U(n,F)[1,2] and increase in case of ^{232}Th(n,F) for $E_n<E_{nnf}$. Local maxima and minima observed as correlated with (n,xnf) thresholds of ^{238}U(n,F) and ^{232}Th(n,F)[3], respectively, are reproduced within our approach[4] as for v_p. The TKE for first-chance fission of ^{239}U and ^{233}Th could be fixed, that much influences the high energy tail of PFNS. The decomposition of the PFNS into pre-fission neutrons and neutrons evaporated in ^{238}U(n,F) and ^{232}Th(n,F), reactions[4-6]is provided. Exclusive pre-fission neutron spectra are calculated with Hauser-Feshach fitting of (n,F), (n,xn) data. The PFNS shape at 2.9 MeV is fitted with the model[4-6]. That leads to softening of calculated PFNS. Consistent description of PFNS, TKE, (n,F) and (n,xn) cross sections helps to distinguish the signatures of (n,nf) and first and second neutrons of (n,2nf) reaction as dependent on the fissility of the CN. The sensitivity to the competition of fission, neutron and gamma-emission in the vicinity of (n,xnf) thresholds could be captured only via consistent analysis of (n,F) and (n,xn) data. That defines the shape of hard tail of the PFNS. Matrices of prompt fission neutrons of ^{238}U(n,F) and ^{232}Th(n,F), describing the measured data shapes within data errors in a uniform approach are obtained. The discrepancies between evaluated data of ENDF/B-VIII, JEFF-3.3, JENDL-4.0 and with the measured data base of 1960-2018 are explained.

[1] C.M. Zoller e.a., Report IKDA 95/25, June 1995.
[2] D.L. Duke e.a., Phys.Rev. 94,054604(2016)
[3] J. King e.a., Eur.Phys.J. A53,238(2017).
[4] V.M. Maslov e.a., Phys.Rev.C69,034607(2004).
[5] N.V. Kornilov e.a., Phys.At.Nucl. 62,173(1999).
[6] V.M. Maslov e.a., Journal of Kor.Phys. Soc., 59, 2,1337(2011).

R033 Interfacing TALYS with A Bayesian Treatment of Inconsistent Data and Model Defects

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TENDL is today the most complete ND library in terms of evaluated isotopes and available uncertainty information. It is built using the TALYS based T6 code package [1] and contains thus model-based evaluations. Model-based evaluations often yield very stiff covariance matrices and are sensitive to model defects. Also inconsistent experimental data jeopardize the statistical consistency of ND evaluations. It has been shown that model defects can be modeled by Gaussian processes [2], a powerful machine learning technique. Recently, an empirical Bayesian approach has been developped to deal with inconsistent experimental data [3]. These developments are complementary and can be combined within the framework of Bayesian statistics. We present details about interfacing TALYS with analysis code that implements the aforementioned theoretical developments. Moreover, we discuss the impact of the novel Bayesian treatment on evaluations. Particular emphasis is put on the effect on uncertainties and correlations. Results from selected isotopes, e.g., Fe-56, are presented and compared to JEFF 3.3, TENDL2017 and ENDF/B-VIII.0.

[1] A. J. Koning and D. Rochman, Nuclear Data Sheets 113 (2012) 2841-2934
[2] G. Schnabel, H. Leeb, Differential Cross Sections and the Impact of Model Defects in Nuclear Data Evaluation, Proc of Wonder-2015, 2016
[3] G. Schnabel, Fitting and Analysis Technique for Inconsistent Nuclear Data, Proc. of MC2017, 2017

R034 the RAC-CERNGEPLIS Evaluation Method for Global Fitting

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The R-matrix Analysis Code(RAC) with CERNGEPLIS Evaluation Method has been used to do Global Fitting for ^{7}Li, ^{11}B system, the obtained results have been used to do the Neutron Standard of IAEA, and for ^{20}O system to get the astrophysical S factor of ^{12}C (α, γ) ^{16}O with high accuracy(5%), and for ^{7}Be system with perfect fitting results, which is the common test sample of the cooperation program about "R-matrix Codes for Charged-particle Reactions in the Resolved Resonance Region" of IAEA, for 2 nuclei system n+p and p+p to get neutron-neutron scattering cross section; and ^{4}He, ^{17}O system. These practices explain that the Code RAC and the CERNGEPLIS Evaluation Method is a powerful tool for nuclear data evaluation.

The RAC-CERNGEPLIS evaluation method means that: RAC-R-matrix Analysis Code with multi-levels and multi-channels theory with Lane1958);
C-Covariance statistics and 'Generalized Least-squares Method' are used;
E-Law of Error propagation is used to get accurate Covariance Matrix;
R-Relativistic calculation for energy;
N-Normalizing data-set relative to the evaluated values;
G-Global database for a nuclear system is fitted;
E-Elimination of channel is used to expend analysis energy range;
P-Smith-PPP modification method is considered;
L-Lett's criteria is used to minimize the effect from occasional 'outliers';
I-Iterative fitting procedure is used to get the best evaluated values
S-Systematic error is updated according to the errors of fitted values.

The work about ^{11}B system will be taken as the sample to explain these problems.

R035 Theoretical Calculations and Covariance Analysis for n+^{40}Ca Reactions

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Calcium is a commonly existing element in environment and living organisms. Accurate evaluated nuclear data and covariance for ^{40}Ca (natural abundance 96.94%) has been a particular topic in nuclear engineering and nuclear technique application. All the experimental data for n+^{40}Ca up to 200 MeV are collected and analyzed, including cross sections, angular distributions, energy spectra, and double differential cross sections. And as experimental data rich reactions, (n,tot), (n,α) cross sections are evaluated. By using nuclear theoretical models, including the optical model, the distorted wave Born approximation theory, and pre-equilibrium and equilibrium reaction theories, all the neutron data for ^{40}Ca are calculated. Theoretical results agree with observed experimental data. Making use of the evaluated ^{40}Ca(n,tot), ^{40}Ca(n,α) cross sections, adopting the lease square method, covariance for some important cross sections are obtained up to 20 MeV. Results are given in ENDF/B format, and are compared with popular evaluations.

R036 New Reaction Evaluations for Chromium Isotopes

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Detailed knowledge of the interaction between neutrons and nuclei from structural materials is essential for any nuclear application such as shielding, reactor design, stockpile stewardship and waste management. The main structural component is stainless steel, which is in reality a combination of mostly iron and other different materials like chromium, manganese, nickel, etc. A new evaluation of the isotopes in natural iron has been performed recently [1-3] which, despite all advances and successes, could not fully explain experimental observations of some integral benchmarks which are sensitive to chromium. In addition to that, the existing evaluations of chromium isotopes in the ENDF/B library, dated from 1997 (fast region) and 2010 (resonances), are in need of updates due to limitations in the angular distributions and in the description of low-energy cross-section fluctuations, among other issues. The current work presents the main developments, improvements and results of the new evaluations for the major and minor chromium isotopes, as part of the International Nuclear Data Evaluation Network (INDEN) collaboration and aiming for the next release of the ENDF/B library.

[1] M.Herman, A.Trkov, R.Capote, G.P.A.Nobre et al., Nuclear Data Sheets 148, 214-253 (2018)
[2] D.A.Brown, M.B.Chadwick, R.Capote et al., Nuclear Data Sheets 148, 1-142 (2018)
[3] M.B.Chadwick, R.Capote, A.Trkov et al., Nuclear Data Sheets 148, 189-213 (2018)

R037 New Evaluations of W-182,184,186 General Purpose Neutron Cross-section Data up to 200 MeV Neutron Energy

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In the frame of the Power Plant Physics and Technology (PPPT) of EUROfusion, new evaluations of general purpose neutron cross-section data were performed for the ^{182,184,186}W isotopes covering the neutron energy up to 200 MeV. A special version of the TALYS nuclear model code implementing the geometry dependent hybrid (GDH) model supplied with models for the non-equilibrium cluster emission was applied for calculations of the nuclide production and the energy distribution of the emitted particles. The parameters of the GDH model were properly estimated using measured data for individual tungsten isotopes. The neutron cross-sections were evaluated making use of available experimental data, systematics including estimated A-dependence of components of gas production cross-sections, and covariance information produced as part of the evaluation process. The BEKED code package, developed at KIT, was applied for calculations of co-variances using a dedicated Monte Carlo method. The evaluated data were processed into standard ENDF data format using the TEFAL code and the FOX module of the BEKED system. The evaluated data files were checked for errors and inconsistencies, processed with the NJOY code into ACE data format, and benchmarked against available integral experiments with MCNP neutron transport calculations.

R038 ^{233}U Cross Section Comparison Evaluation Between SAMMY and FITWR Code Fitting Procedures

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The aim of this study is to investigate the availability and accuracy of the cross-section data for ^{233}U to perform the calculations of the critical system. Two evaluated data libraries are available, the U.S. data bank (ENDF) and the Japanese data bank (JENDL). The pre-calculations were performed by SAMMY code with the assistance of two methods of fitting procedure, the first one is Bayes method which is available in the SAMMY code, and the second one is weighted least square method with nonlinear regression available in FITWR code developed in Tsinghua University. A computer program FITWR has been developed and applied to the experimental total cross sections for MeV incident energy particles such as "neutron, proton...etc.". The program FITWR utilizes least square method with weighted form by using linear regression method with high order polynomial, in order to meet the growing demands of the nuclear data, FITWR program deals with variance and covariance data provided along with experimental data and yield those for the evaluated ones

R039 Evaluation of Neutron Induced Reactions on Fe-56 with CONRAD

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Experimental and theoretical efforts were performed on Iron in the framework of the working group SG40 (CIELO) of the Working Party on International Nuclear Data Evaluation Co-operation (WPEC) [1]. Several institutes contributed to produce new evaluated files for ^{56}Fe. Neutron cross sections were revisited from thermal to MeV energy ranges.

Comparisons with microscopic data and experimental validations using integral benchmarks pointed out some remaining issues in the evaluations of the Iron isotopes [2]. A new evaluation of ^{56}Fe is in progress at the CEA of Cadarache in order to solve problems identified in the resolved resonance range and in the "continuum" part of the neutron cross sections. Model parameters involved in the theoretical description of the neutron cross sections (resonance parameters and high energy model parameters) were determined with the CONRAD code, by using nuclear models of CONRAD and those available in the ECIS and TALYS codes. In the resonance range, transmission, capture, elastic and inelastic data were analyzed simultaneously by introducing experimental corrections, such as the time-resolution of the facilities. Angular distributions for the elastic and inelastic scatterings can be reconstructed with the CONRAD code via the Blatt-Biedenharn formalism. The CONRAD code also allows computing a covariance matrix between low and high model parameters for producing full covariances between all the neutron cross sections of interest for the nuclear applications.

First results obtained from thermal to MeV energy ranges will be presented. Their consistencies will be discussed with the integral benchmark PERLE carried out at the zero-power reactor EOLE, located at the CEA of Cadarache.

[1] M. Herman et al., Nucl. Data Sheets 148, 214 (2018)
[2] R. Capote and A. Trkov, Improvement of the CIELO evaluation of neutron induced reactions on natural iron, Int. Workshop on nuclear data evaluation for reactor applications (WONDER), Aix en provence, 2018.

S040 Calculation of Stricken to Mortality and Incidence Cancers Due to Beyond Design Basis Accidents (BDBA) in Populations Near Nuclear Facilities

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Payam E Noor University

In this investigation the amount of absorbed doses by the different pathways of Cloud shine, Ground shine, deposition of radioactive materials on skin and cloths, ingestion, inhalation, and the consequences of radioactive materials releases due to Beyond Design Basis Accidents such as fire, explosion, criticality and earthquake in Populations near Nuclear Facilities by the residents are evaluated. The calculations related to atomic cloud distribution, estimation of delivered dose and decay chains are performed by PCCOSYMA dose. These computations are based on radioactive source terms, distribution height of radioactive materials, actions for reducing the absorbed dose, human body physiological characteristics, metrological condition and population distribution. Finally, the number of peoples who are stricken to mortality and incidence cancers and risk values are calculated for 1 year and 50 years. The results show that for short term and long term effects there is no risk for stricken to cancers.

S041 Some Ideas Need Discussion in Global Fitting for Nuclear Data Evaluation

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Tsinghua University

The 'global fitting' means that with one set R-matrix parameter to fit all kinds of available and useful experimental data for one nuclear system in a wide energy range (maybe from 1.0e-7 MeV to 20 MeV) simultaneously, some different ideas maybe need discussion as follow. The 'General Least Square' (GLS) method should be used to get an accurate Covariance matrix which well matched to evaluation data, using the 'Conversional Least Square' (CLS) method is hard to get accurate Covariance matrix; the normalized target should be the experimental data, not the calculation value; the whole data-base used is not a pure statistic sample, which must include non-compound component and some non-physical discrepancy; so not any reason to limit the R-matrix parameters used, and all R-Matrix parameter should to be searched freely; never to think that only the levels with obvious physical mean can be used; and never to think that only the levels listed in Existing energy level diagram can be used. With the Reduced R-Matrix theory (Lane1958) has a possibility to do evaluation from 1.0E-07 MeV to 20 MeV for some nuclear system, if only there exist a very good data-base. In the paper of C. R. Brune, it is definitely pointed out that the Brune transform is suitable only for real physical resonance, So the Brune formulae is not suitable to do transform for the Standard R-matrix parameters of a global fitting. The basic criteria for a good fitting is that the calculation value closed to the data value, and the most of calculation value for a data-group located in the error bar.

The work about ^{7}Li system will be taken as the sample to explain these problems.

S042 The Evaluations of Gamma-induced V-51

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1. China Institute Atomic Energy
2. Shenyang Normal University

Photonuclear data are important to radiation damage, reactor dosimetry, accelerator shielding etc. IAEA has started a new CRP (No.20466) form 2016 to 2019, and V-51 is one of the targets elements in the Chinese contract. In this work, photon absorption cross section for V-51 is calculated by the function of SMLO under the assistance of experimental neutron emission reactions evaluation and the theoretical charged particle emission cross sections. In order to obtain the charged particle emission cross sections, theoretical F factor was used by MEND-G with the default physics parameters. Then, the level density and pair energy parameters of MEND-G were adjusted. The (γ,2n), (γ,3n) et al. cross sections of V-51 are finally obtained agree with the experimental data available. All the theoretical results were given in ENDF-6 format.

S043 Development the Nuclear Decay Data Sublibrary for Fission Product

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China Nuclear Data Center

Accurate and reliable nuclear decay data libraries are essential for calculation and design of the advanced nuclear systems. To meet the requirements of decay heat calculation, burn-up calculation, analysis neutrino spectra anomaly and the other related studies, the evaluated nuclear decay data sublibrary for fission product named CDDL1.0 has been developped and constituted based on the several main national evaluated data libraries in the world. About 1415 nuclides were included in the first version. And two major data format, that's ENSDF and ENDF were provided. Some decay heat calculation, reactor neutrino spectra analysis and decay chain design needed in fission yield evaluation were performed to test the accuracy and reliability of the nuclear decay data sublibrary.

I044 Resonance Evaluations of Gadolinium Isotopes

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2. Oak Ridge National Laboratory
3. Italian National Agency for New Technologies, Energy and Sustainable Economic Development
4. Chalk River National Laboratory

New evaluation of Gadolinium isotopes, Gd-152, Gd-154, Gd-155, Gd-156, Gd-157, Gd-158, and Gd-160, in the resolved resonance region has been performed with the code SAMMY. The main objective of revising the resonance evaluations of these isotopes is to address issues in connection to critical benchmark results and reactor physics analysis of power reactors. Trends on the k-eff for thermal benchmark system as a function of the gadolinium concentration indicate an issue with existing evaluations. A combination of the codes SAMMY and SAMINT, which permits incorporation of differential and integral data in the evaluation process, was used to observe which resonance parameters were sensitivity to changes in the k-eff. Benchmark sensitivity calculations and analysis were done based on the MACSENS code. The evaluation process indicates a strong correlation of the neutron capture cross section, Westcott factor, and the capture resonance integral with the observed trend of the k-eff with Gadolinium concentration. The isotopes, Gd-155 and Gd-157, have capture cross section of about $\sim$ 60,000 barns and $\sim$ 250,000 barns, respectively. The differential data used in the evaluation are transmission and capture cross section data available in the EXFOR database. Critical benchmarks accessible in the ICSBEP collection and critical reactor configurations based on ZED-2 experiments in CNL (Chalk River) were included in the analysis and evaluations. In addition to the resonance parameter evaluation, the resonance parameter covariance matrix was also derived and the results for the uncertainties of Gd capture cross sections were obtained.

A detailed description of the methodology used in the evaluation process and results of new evaluation performance in thermal benchmarks will be presented in the full paper.

R045 Measurement and Covariance Analysis of Reaction Cross-section by Using Unscented Transformation Method

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This study presents a novel approach for uncertainty propagation of the neutron induced cross-section measurement using unscented transformation method. The UT technique is completely defined by the moments of random process and hence produces better results for error propagation in non-linear case with large uncertainties. The UT method is to implement and give result accurate as Sandwich formula and Monte-Carlo techniques. Monte-Carlo method provides the probability distribution for the cross sections that contains much more information but it can be difficult to extract that information. UT method do not require much computational power and give results same as that of MC method in very short computing time. Whenever non-linearity is high, Jacobian matrix is hard to calculate or micro-correlations are difficult to assign, these methods can serve as a great alternate to first order sensitivity analysis method for propagating uncertainty in nuclear science field.

R046 Unified Bayesian Evaluation of Oxygen Based on the Hybrid R-matrix Method

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TU Wien

The generation of a complete evaluated nuclear data file is usually based on several, rather different nuclear models as a-priori information. Especially, the R-matrix theory, suitable for the resonance region, together with the Statistical Model, applicable only at higher energies, are frequently used for the generation of a complete evaluated file. In general the two energy regions are treated rather disjunct and mutual correlations are ignored because of the conceptual differences of the nuclear models.

In this contributions we propose a statistically consistent procedure to combine both models in a Unified Bayesian Evaluation taking into account mutual dependences of both models. This feature yields a unified a-priori covariance matrix and consequently after Bayesian update a unified a-posteriori covariance matrix over the whole energy range of the evaluation. Thus discontinuities at the interfaces of the validity ranges of the nuclear models will not occur in the associated evaluated data file.

The Unified Bayesian Evaluation method was used to generate an evaluated nuclear data file of oxygen in order to demonstrate the feasibility of the proposed method. Especially, we consider the reactions of the ^{17}O compound nuclear system which are described by the recently developed Hybrid R-Matrix method [1]. The Hybrid R-Matrix method ensures a smooth transition of reaction cross sections between R-matrix and Statistical Model calculations and makes use of physically reasonable matching radii.

The work was partly supported by EUROfusion grants, WP Materials and Matching Grants of the Austrian Academy of Sciences. The views and opinions expressed herein do not reflect necessarily those of the European Commission.

[1] T. Srdinko, H. Leeb, R-matrix approach at the intersection with the statistical model regime, EPJ Web of Conferences 146, 12030 (2017)

R047 New Perspectives in Neutron Reaction Cross-section Evaluation Using Consistent Multichannel Modeling Methodology: Application to 16-O

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The traditional methodology of nuclear data evaluation is showing its limitations in reducing significantly the uncertainties in neutron cross sections below their current level. This suggests that a new approach should be considered. This presentation aims at establishing that a major qualitative improvement is possible by changing the reference framework historically used for evaluating nuclear model data. The central idea is to move from the restrictive framework of the incident neutron and target nucleus to the more general framework of the excited compound nucleus. Such a change, which implies the simultaneous modeling of all the reactions leading to the same compound nucleus, opens up the possibility of direct comparisons between nuclear model parameters, whether those are derived for reactor physics applications, astrophysics or basic nuclear spectroscopy studies. This would have the double advantage of bringing together evaluation activities performed separately, and of pooling experimental databases and basic theoretical nuclear parameter files. A consistent multichannel modeling methodology using the CONRAD code is demonstrated across the evaluation of differential and angle-integrated neutron cross sections of ^{16}O by fitting simultaneously incident-neutron direct kinematic reactions and incident-alpha inverse kinematic reactions without converting alpha data into the neutron laboratory system. The modeling is fulfilled within the R-matrix formalism and a unique set of fitted resonance parameters related to the ^{17}O* compound nucleus. This new Resonance Region evaluation is based on a large set of experimental measurements and attempts are made to answer the surviving questions that have been raised by the CIELO project regarding the evaluated neutron cross sections of the ^{16}O.

R048 Evaluation and Validation of ^{28,29,30}Si Cross Sections in the Resolved Resonance Region

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Performed at Oak Ridge National Laboratory in 2002, the set of resonance parameter evaluations of the three stable silicon isotopes ^{28,29,30}Si was restored from the archives. These evaluations also accounted for the contribution of the direct component of the capture cross sections computed over the neutron resonance range. For the most abundant isotope ^{28}Si, the value of the thermal capture cross sections was increased by 10% on the basis of an IAEA evaluation published by the EGAF project devoted to re-evaluate the thermal radiative neutron capture cross sections. For all isotopes the contribution of the direct capture cross sections was recomputed using a CUPIDO code and its energy-dependent behaviour improved. Results of benchmark calculations performed at the International Atomic Energy Agency showed an excellent greement with targeted integral measurements. These evaluations demonstrate that better physics result in improved evaluation performance for critical applications.

R049 On the Use of Indicator for Measuring Goodness of Bayesian Inference in Evaluation of Nuclear Data

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2. Uppsala University

The evaluation of nuclear data is mainly based on nuclear reaction model comparisons with experiments within a Bayesian inference mathematical framework. Very few statistical discussions arise from this inference. Especially, the notion of goodness of the fit is not clearly exposed. Various potential Bayesian indicator can be proposed for evaluating the correctness of the adjustment. In addition, the complexity of the adjusted model that is traduced by its parameters (and the associated covariance matrix) is never really assessed: definition of a proper set of effective parameters to be adjusted. This paper will review a set of potential Bayesian indicators that may be standard in the Bayesian inference community but not really used in the framework of nuclear data assimilation. Furthermore, these indicators (Akaike information criteria, Bayesian information criterion, deviance information criterion, cook's distance$\cdots$) will give some common framework for addressing general questions such as, model complexity, overfitting, effectiveness of the parameters... Another important aspect that will be investigated is the comparison of complex models in the Bayesian framework to infer a possible best choice.

The use of Monte-Carlo Bayesian inference (instead of traditional generalized least square) implemented in the CONRAD code is a suitable mathematical framework for calculating these indicators.

R050 Prompt Fission Neutron Spectra of ^{237}Np(n,F) and ^{241,243}Am(n,F)

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Experimental investigations of prompt fission neutron spectra (PFNS) of ^{235}U(n,F), ^{239}Pu(n,F) ^{232}Th(n,F), ^{238}U(n,F) already in late 1950th allowed to reveal pre-fission neutrons[1] at 14.3 MeV. However, only soft pre-fission neutrons were detected, while the net effect was almost the same as in later measurements, except ^{239}Pu(n,F). Actual database at thermal 2.9 MeV up to 20 MeV contains a number of pre- and post-fission neutron signatures as dependent on the incident neutron energy and target nuclide fissility. Parameterizing post-fission prompt neutron spectra[2] reproduces shape of PFNS above (n,xnf) threshold with exclusive pre-fission and post-fission neutrons, emitted from (x+1) fissioning nuclides[3]. The contributions are unambiguously defined by consistent fits of (n,F) and (n,2n), (n,3n) cross sections. Similar approach is applied for the reactions ^{237}Np(n,F) and ^{241,243}Am(n,F). In case of ^{237}Np(n,F) and ^{241}Am(n,F) weights of (n,xnf) reactions are fixed via ^{237}Np(n,2n) ^{236m}Np and ^{241}Am(n,2n) cross section fits. Some turmoil comes from the data on ^{240}Am(n,F)[4], emerging from the ratio of fission probabilities in reaction (p,tF), though the energy dependence of that cross section is quite compatible with ^{241}Am(n,F) data. PFNS of ^{241,243}Am(n,F) and ^{237}Np(n,F)[5] on the web[6], are modified due to TKE data[7], predicting local maxima as correlated with (n,xnf). Measured data[8] for ^{241,243}Am(n,F) PFNS permit detailed investigation both of post-fission and pre-fission neutrons. Contribution of (n,2nf)[1,2] neutrons, as for ^{239}Pu(n,F) at 14.7 MeV only weakly influences the shape of PFNS, unlike ^{235}U(n,F) reaction. The trend of PFNS[8] at thermal energy of ^{242m}Am(n,F) seems to be compatible with the measured PFNS data for ^{235}U(n,F) and ^{239}Pu(n,F). Borrowing PFNS data from other libraries one should note the obvious correlations of observed PFNS and fission cross sections.

[1] Yu. S. Zamyatnin et al., Sov. J. At. Energy, 4, 443 (1958).
[2] N. V. Kornilov et al., Phys.At.Nucl. 62, 173 (1999).
[3] V. M. Maslov et al., Journal of Korean Phys. Soc., 59, 2, 1337 (2011).
[4] R. J. Casperson et al., Phys. Rev. C90 034601, 2014.
[5] https://www-nds.iaea.org/minskact/, 2011.
[6] V. M. Maslov et al., INDC(BLR)-021, IAEA, 2010.
[7] F.-J. Hambsch et al. Nucl. Phys.A,679,3,2000.
[8] L. V. Drapchinsky, Report ISTC-1828-01, 2004.

R051 Can Machine Learning Techniques Help Us to Solve Nuclear Data Problems?

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There is currently a world-wide 'hype' of applying machine learning techniques to big data problems ongoing. Different machine learning techniques are applied to address questions from big on-line shops to solving difficult scientific problems. Here, we explore whether machine learning techniques can help us solve problems in nuclear data evaluation which cannot be satisfactorily addressed by conventional nuclear data methodology.

For instance, one major issue is the subjectivity of selecting differential and integral experimental data for nuclear data evaluation and validation. Due to the sheer amount of measurement and—in some cases nuclear data—information, it is often impossible to take into account all hidden inter-dependencies across a suite of experiments when selecting data for evaluations or validation. Here, we will show how machine learning techniques can be applied to address this issue and show in how far the algorithms are able to find physics motivated clusters of data and capture the inter-dependencies of data correctly.

R052 The Systematics of Nuclear Reaction Excitation Function

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The excitation function for the reactions induced by neutron are very important for evaluation of nuclear data, which is quite useful in nuclear engineering and technology applications. Based on the nuclear reaction theoretical model, under some assumptions and approximations, parameterized formulas of excitation functions for the reactions induced by neutron have been established. Only the most sensitive parameters are included in the formulas. For getting the parameters, the available experimental data of these reactions were analyzed and fitted by means of the nonlinear least squares method. The fitted results agree fairly well with the measured data at some energy and nucleus region. On the basis of the parameters of every nuclei, the correlations between the parameters and some quantity of the target nucleus can be expressed as simple functions. Using the regional parameters, more accurate systematics prediction for unmeasured nucleus or energy range may be provided.

R053 New ^{23}Na Nuclear Data Evaluation Taking Into Account Both Differential and Double Differential Experiments

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CEA

In 2012 CEA produced a entire new evaluation of sodium nuclear data for the release of the JEFF-3.2 evaluated nuclear data library. During the evaluation process performed with the CONRAD code, several differential measurements (total and discrete inelastic cross-sections) have been used. However double differential data (elastic angular distribution) that were yet available in the EXFOR database were not incorporated in the analysis at that time because it was impossible to obtain a correct agreement for both angle-integrated cross-sections and double differential data. The underlying cause of this disagreement was mainly due to the attribution of quantum numbers to resonance and related channel amplitudes. Indeed these numbers are imposed during the analysis but impact differently angular distributions and angle-integrated cross-sections. An automated search for an accurate set of quantum numbers has been implemented in order to produce a reliable quantum numbers set. In this paper we present a new evaluation of ^{23}Na taking into account both differential and double differential measurements. The analysis performed with the CONRAD code reached the level of agreement with experimental data for the total and inelastic cross-sections but this time with a significant improvement for the elastic angular distributions. This new evaluation produced in the ENDF-6 format has then been tested and validated on critical facilities calculation (MASURCA and ZPPR) in different configurations (nominal and voided) in order to assess its performances.

I054 Status of the IRSN Nuclear Data Processing System GAIA-2

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The Institut de Radioprotection et de Sûreté Nucléaire (IRSN) has been developing capabilities for nuclear data processing, that is the GAIA-2 code system. GAIA-2 aims at producing continuous-energy ACE files for Monte-Carlo codes such as MCNP or MORET, for criticality safety applications. GAIA-2 was initiated in 2012 in which the code first release included features such as resonances reconstruction in the resolved resonance range, with full R-matrix formalism capabilities. Cross section temperature effects are accounted for on the basis of a Fourier transform methods. The code has been extensively validated with comparisons with codes such as NJOY, AMPX and SAMMY.

Recently, some important steps have been achieved toward the development of a fully operational system. First, a nuclear data handler has been implemented as a generic set of functions meant to store the nuclear data involved between the continuous-energy processing steps. Secondly, the processing of the unresolved resonance range (URR) has been implemented within GAIA-2. This paper will more especially focus on the methods which have been developed to process the URR. In this range, resonance parameters are only given as average values on a set of reference energies in the Single-Level Breit-Wigner formalism. Average cross sections can be calculated from the average resonance parameters distributions. Then, probability tables are constructed based on Monte-Carlo methods, from which self-shielded cross sections can be derived.

Several statistic methods to compute the probability tables have been developed within the same framework, in order to estimate the biases introduced by the method only. Thus, the sampling of pseudo-resonances has been achieved on arbitrary ranges in the URR, or by defining pairs of resonances around reference energies. In order to determine the number of resonances to sample, autocorrelation functions based on adjacent levels correlation has been explored. Questions related to possible ways to accelerate the algorithms such has a combination of half sampling and renormalizations have been investigated. Average cross sections from the tables have been compared to results from direct computations and ACE files have been produced to compare results with other codes such as NJOY or AMPX.

R055 Analyzing the Distribution of Scattering Angle in Ace Multi-group Library Using the Maximum Entropy Method

Shuaitao Zhu, Xubo Ma, Hui Tang, Le Yang, Bo Cao
North China Electric Power University

Abstract: To describe the angular distribution for a group-to-group scattering event, the coefficients of a truncated Legendre series are usually used in multi-group cross-section sets. However, the truncated expansion can be negative for some scattering angles. In this study, probability density function (PDF) of scattering angle is calculated using the maximum entropy method to avoid the negative probabilities of some scattering angles and ACE multi-group library is generated. The multi-group library is verified by the computation of RBEC-M benchmark using RMC code. The differences between two methods generating scattering data, the maximum entropy method and discrete angle method, are also studied. The calculation results using ACE multi-group library are in good agreement with the results of benchmark report. It shows that multi-group library including the scattering angle data computed by the maximum entropy method is credible.

R056 Study on Consistent PN Cross Section Process Method for Fast Reactor

Xubo Ma, Hui Tang, Ruomeng Qiu
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A code named MGGC was developed to process the MATXS format nuclear data library for fast reactor. In order to obtain the multigroup group cross section (33 groups) from the ultrafine group cross section (2082 groups), flux solvers was developed based on consistent P1, consistent P1 extended N and consistent PN. Interference between isotopes has been taken into account through background cross section iteration when calculate the problem depended macroscopic cross section. The methods were verified by using the fast reactor RBEC-M and ZPR6A7 benchmark. The results show that the consistent PN approximation has no obvious advantages in fast reactor flux calculation comparing with the other methods, and the power distribution was given, for the RBEC-M benchmark problem, the maximum power deviation of single component power distribution is 0.57%. For the ZPR6A7 benchmark problem, the maximum power deviation is 4.38%.

R057 Upgrade on Neutron-gamma Coupled Multi-group Data Generation System

Xiaofei Wu
China Nuclear Data Center

NPLC-2 is a neutron-gamma coupled multi-group data generation system developed by China Nuclear Data Center, which can produce AMPX format library for SCALE system. NPLC-2 has several drawbacks, for example the number of temperatures cannot exceed 10 and it cannot handle multi-temperature scattering matrix. Shielding benchmarks suggests that there are errors in gamma data produced by NPLC-2. This work updated the NPLC-2 system, replaced miler4 with CMiler and added support for njoy2016. Tests show that updated system works well.

R058 Development of Multi-group Nuclear Engineering Computational Library for Neutronics Calculation of Light Water Reactors

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Multi-group (MG) cross section (XS) library plays an important role in MG neutronics calculation. Specifically, factors greatly impacts the precision and efficiency of the MG neutronics calculation are: energy group structure, Goldstein-Cohen (GC) factors, subgroup parameters, etc. This paper focuses on the procedure of generating Multi-Group Nuclear Engineering Computational Library (NECL-MG) and improvements made in several aspects. These improvements include: 1. Optimization of the energy group structure based on the contributon theory; 2. Computation of new group-wise GC factors; 3. Generation of subgroup parameters based on heterogeneous resonance integral tables. The numerical results show that NECL-MG is suitable for high-fidelity neutronics calculation of light water reactors.

I059 Current Status of the GALILEE-1 Processing Code

Cedric Jouanne, Mireille Coste-delclaux
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GALILEE-1 is the new verification and processing system for evaluated data, developed at CEA. Three main components are under development:
- GALION component (GALilée Input Output for Nuclear data) is dedicated to read (resp. write) input (resp. produced) data. Input format can be ENDF-6 or GNDS formats while output format is ENDF-Type (GNDS-Type is under development)
- GALVANE component (GALilée Verification of the Accuracy of Nuclear Evaluation) is dedicated to the verification of nuclear evaluations that are the GALILEE-1 input data. This verification is partly carried out by comparison with structure data available in NUBASE or ENSDF database.
- GTREND component (Galilé Treatment of Evaluated Nuclear Data) is developed to provide continuous-energy, multigroup and probability tables data.

A fourth component which development will begin later is an automated chain for producing consistent libraries for transport and depletion codes. Nowadays, GALION can read evaluated data in ENDF-6 (GNDS will be available soon) format as well as structure data in ENSDF or NUBASE format. All these data are stored in C++ objects, named GBASE objects. GALVANE and GTREND components work on these GBASE objects, which allows the same verification and processing stages, whatever the type of evaluation format. GALVANE can diagnose inconsistencies in resonance parameters, Q reaction values, excited level schemes, kinetic data, thermal scattering laws... GTREND can reconstruct pointwise cross-sections over the whole energy range, provide a linearization grid, broaden linearized cross-sections, provide thermal data for various TSLs and calculate moment based probability tables.

In the unresolved domain, resonances are not separable and identifiable and the representation of cross sections in the form of probability tables has been used. Two main channels of representation are considered:
- Pointwise probability tables, used for example by MCNP and constructed by the PURR module of NJOY
- Multigroup probability tables, used by TRIPOLI-4 in the URR and by APOLLO2-3 in the whole energy range. At the present time, these PT are built by CALENDF

In the near future, GTREND will produce these two types of representation using common functionalities. Comparative Monte Carlo calculations with MCNP and TRIPOLI-4 will be shown.

I060 Implementation of URR and NTSL in the GNDS Format Using FUDGE

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A new format for storing evaluated and processed nuclear data dubbed the Generalized Nuclear Data Structure (GNDS) has been developed by the Working Party on Evaluation Co-operation (OECD/NEA/WPEC) Sub-group 38. GNDS is a modern replacement for the ENDF-6 format that has served the nuclear data community for nearly 50 years.

Lawrence Livermore National Laboratory (LLNL) has updated its nuclear data codes to read, write and process nuclear data stored in GNDS. For processing, LLNL has updated its FUDGE (For Updating Data and Generating Evaluations) package to read GNDS data, recast the data into forms more suitable for deterministic and Monte Carlo transport (e.g., heat cross section, multi-group data) and save the processed data into a GNDS file. FUDGE can also translate GNDS data into an ACE formatted file for use with the MCNP6 Monte Carlo transport code.

FUDGE is written in Python which facilitates its use by evaluators and processors, but is not well suited for accessing nuclear data by transport codes. For efficient access by transport codes, LLNL has developed a C++ library dubbed GIDI (General Interaction Data Interface). GIDI has been implemented in LLNL's Monte Carlo (Mercury) and deterministic (Ardra) transport codes. A C++ library dubbed MCGIDI (Monte Carlo GIDI) has been developed to aid in cross section lookup and sampling of GNDS data by Monte Carlo transport codes. MCGIDI extracts data from a GIDI instance and is used by Mercury.

We have recently updated FUDGE to generate Unresolved Resonance Region (URR) probability tables, and added support for them in GIDI and MCGIDI. We are also working on support for Neutron Thermal Scattering Law (NTSL) data. We will describe FUDGE, GIDI and MCGIDI with a focus on URR probability tables and NSTL additions. We will also present the status of these codes and future work.

R061 New R-matrix Resonance Reconstruction in NJOY21

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LANL

The NJOY Nuclear Data Processing System developed at Los Alamos National Laboratory is a comprehensive computer code used to produce point-wise and multigroup nuclear data application libraries from evaluated nuclear data. An essential step in the production of these nuclear data application libraries is the resonance reconstruction in which the evaluation's resonance parameters (resonance energies with associated resonance widths for each reaction channel considered in the compound system) are interpreted using a predefined formalism to produce cross section values. Within NJOY, this is the task of the RECONR module.

LANL is currently working on modernising NJOY with NJOY21, a complete rewrite of NJOY from the ground up to respond to the development of the GNDS nuclear data format but also to extend and update some of the basic functionalities of NJOY such as resonance reconstruction by adding new resonance formalisms. NJOY21 currently has the capability for resonance reconstruction using ENDF resonance formalisms such as the Single-level Breit-Wigner, Multi-level Breit-Wigner and Reich-Moore formalisms.

With this work, we have extended this capability to the ENDF R-matrix limited (RML) formalism which allows for using an arbitrary number of reaction channels, including outgoing charged particle channels. Keeping in mind the goals of NJOY21, the underlying coding of this new R-matrix capability was designed to allow for flexibility and ease of extension. It currently only supports the Reich-Moore formalism for incident neutron channels (using an eliminated capture channel) but work is currently underway to extend this to include a generalised R-matrix formalism and different types of incident channels (including charged particles).

Another option available in this R-matrix capability is the customisation of the boundary condition for a channel to allow for multiple options (such as using a constant value or using the option in which the boundary condition cancels out the shift of the channel). Additional options for this boundary condition or the resonance formalism will be added as they are proposed in the new GNDS nuclear data format.

R062 Development and Verification of Resonance Elastic Scattering Kernel Processing Module in Nuclear Data Processing Code NECP-Atlas

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Some efforts have been made to exactly consider the effect of neutron up-scattering caused by thermal motion of target nuclei and resonance elastic scattering on the multi-group and continuous-energy data (i.e. S(α,β) tables). The resonance elastic scattering kernel (RESK) formulations for anisotropic scattering up to any Legendre order has been adopted to represent the exact Doppler broadened energy transfer kernels. A semi-analytical integration method is applied to perform the RESK calculations for getting the differential moments. Combining with the RESK calculations, an algorithm named multi-point linearization algorithm is proposed to generate the incident energy grids of RESK interpolation tables. The RESK data can be interpolated precisely based on the interpolation tables to reduce the calculation burden. To generate the multi-group data, a neutron slowing-down equation solver is developed based on the RESK instead of the conventional asymptotic scattering kernel, by which the effect of the neutron up-scattering on the neutron energy spectrum can be exactly considered. To generate the continuous-energy data, the differential moments are used for evaluating the equally probable cosines included in S(α,β) tables. All the methods mentioned above have been implemented into the nuclear data processing code called NECP-Atlas. Numerical results show that the proposed methods are capable of producing accurate multi-group and ACE-format libraries for downstream calculations. The fuel Doppler coefficients and eigenvalues of the real problems will be improved if the up-scattering effect is incorporated into the multi-group and ACE-format libraries. The numerical results also show that the impact on eigenvalues caused by the RESK can be correctly taken account by the Monte Carlo calculations using the S(α, β) tables. The results based on the S(α, β) tables match with those based on the Doppler broadening rejection correction (DBRC) approach used in OpenMC code.

S063 Application of hyperfine group self-shielding calculation method to lattice and whole-core physics calculation

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Hyperfine group method is a direct, simple and accurate method for resonance calculation. Because the hyperfine group method uses hundreds of thousands of energy groups to solve the neutron slowing-down equation, the calculation speed of this method is relatively slow. In order to reduce the computation time of hyperfine group method, two types of acceleration methods are summarized and three types of interpolation schemes are proposed in this paper. Accelerations for source item calculation and collision probability calculation are summarized and used in hyperfine group method based on Dancoff factor equivalence. Source item calculation in hyperfine group method can be accelerated using recursive formula. Collision probability calculation in hyperfine group method can be accelerated using collision probability pre-tabulation. Dancoff-factor-based interpolation scheme, burnup-based interpolation scheme and fuel-temperature-based interpolation scheme are proposed and applied to lattice and whole-core resonance calculation. The microscopic multi-group effective cross sections are calculated in several typical pin cells and tabulated into multi-group effective cross sections table online. The microscopic multi-group effective cross sections in each fuel rod will be obtained by interpolating Dancoff factor, burnup and fuel temperature. Numerical results show that the hyperfine group resonance calculation time after acceleration is reduced significantly so that the hyperfine group method can be applied to lattice and whole-core physics calculation and get accurate and stable results.

S064 Updates of the Pressurized Water Reactor Burnup Nuclear Data Libraries Based on the Latest ENDF/B-VIII.0 Data

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The pressurized water reactor (PWR) burnup libraries for ORIGEN-S based on the latest ENDF/B-VIII.0 have been extensively updated in this paper. The ORIGEN-S nuclear data libraries consist of three parts, such as decay data, neutron cross section and fission product yields data. The CARDSDEC and CARDCSFPY, which are developed by our team, are used to update decay data and fission product yields data for 30 fissionable actinides. Neutron cross section data updating is firstly processed into fine multigroup data using a continuous-energy neutron flux spectrum that is representative of typical pressurized water reactor fuel and pointwise cross section evaluations from ENDF/B-VIII.0, and then the fine multigroup data is collapsed into the basic three-energy-group structure used by ORIGEN-S and update the previous basic ORIGEN-S library by the CARDCSFPY. Preliminary verification are performed with PWR benchmark published by OECD/NEA. Comparisons between the previous basic ORIGEN-S libraries and the updated libraries developed in this work are also presented.

I065 Progress of the Development of the Nuclear Data Processing Code NECP-Atlas

Tiejun Zu, Jialong Xu, Yongqiang Tang, Huchao Bi, Fei Zhao, Qichen Teng, Ning Xu, Liangzhi Cao, Hongchun Wu
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A new nuclear data processing code called NECP-Atlas is under development at Xi'an Jiaotong University in China. The motivation for the development is to establish a platform to carry out deeper researches on nuclear data processing methods to satisfy the demands on accurate cross sections in the fields of high-fidelity transport simulation and advanced reactor design. Some methods to improve the accuracy of cross sections used in the neutronics analysis have been implemented in to the NECP-Atlas code, eg. the treatment of resonance elastic scattering. NECP-Atlas is capable of processing the ENDF-6 format evaluations including ENDF/B-VIII.0, ENDF/B-VII.1, ENDF/B-VII.0, CENDL-3.1, JEFF-3.2 and JENDL-4.0, to multigroup and continuous energy cross sections. The code can also generate various data for different application aspects, and it has been connected with three neutronics analysis codes NECP-Bamboo, NECP-SARAX and NECP-X which are respectively designated for light water cooled reactor analysis, fast reactor analysis and high-fidelity whole-core neutronics analysis. This paper describes the main characters of NECP-Atlas and demonstrates the performance and accuracy of the code on a variety of benchmarks.

I066 Advanced Neutronics Software SuperMC and Its Real Time Multi-temperature Cross Sections Generation Method

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Super Multi-functional Calculation Program for Nuclear Design and Safety Evaluation, SuperMC, is a large-scale integrated software system for neutronics design, which can be used for the design and safety evaluation of nuclear energy systems, as well as nuclear technology application fields including radiation medicine, nuclear detection and so on. The latest version, SuperMC3.3, supports the whole process neutronics simulation including n, γ transport, isotope depletion, material activation and dose calculation, and it has advanced capabilities including CAD-based accurate automatic modeling for complex irregular geometry, feature-accelerated high-efficiency calculation, multi-style visualized analysis and collaborative nuclear and multi-physics design based on cloud computing.

Due to the Doppler broadening phenomenon, it needs to generate cross section libraries at different temperatures to make accurate reactor neutronics simulation. In SuperMC, real time multi-temperature cross sections generation method for Monte Carlo simulations is developed. It considered features of a wide energy region of incident neutron, including resolved resonance energy region, thermal energy region and unresolved resonance energy region. Optimal double-exponential (DE) method was proposed and adopted for resolved resonance region to improve the efficiency of cross section generation while keeping the precise of the cross section. According the features of thermal scattering nuclear data, i.e. S(α,β), at different temperature intervals, the Neville interpolation based thermal scattering data generation method is proposed, by which the high generation efficiency and data accuracy can be obtained. For the unresolved resonance energy region, considering the features of probability table data, the common expression for nuclear data of unresolved resonance energy region, at different temperature intervals, piecewise interpolation cross section generation method is proposed. BN-600 benchmark was used to verify the correctness and availability of theNeutronics Software developed real time multi-temperature cross sections generation method. The calculation results indicated that the proposed method can generate neutron cross sections at the desired temperature with high efficiency and accuracy. It showed the capability of the developed method for application in reactor multi-physics coupling simulation.

SuperMC has been adequately verified and validated by benchmark models and experiments and has been applied in more than 40 mega nuclear engineering projects, such as ITER, E-DEMO, HPR1000.

R067 NDPlot: A Plotting Tool for Nuclear Data

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NDPlot is an efficient plotting tool for nuclear data. It is not only a plotting tool for nuclear data, but also integrated application software. We have released the beta version of NDPlot with an NDPlot server on the internet. NDPlot can plot experimental and evaluated data of reaction cross sections, angular distributions of secondary particles, energy distributions of secondary particles and energy-angle distributions of products. Since September 2018, it has been able to draw the chain yields and energy dependent fission product yields, including experimental data and evaluated data. NDPlot also provides tools to filter fission yield data and correct the data with new gamma data.

R068 Progress Towards International Adoption of GNDS

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The Generalized Nuclear Database Structure (GNDS) was approved in 2017 by the Working Party for Evaluation Cooperation (WPEC) as the new international standard for storing and exchanging nuclear data [1]. GNDS is a modern and flexible replacement for the previous standard, ENDF-6. Unlike ENDF-6, GNDS is not limited to evaluated nuclear data, but also provides a standardized structure for exchanging processed data (e.g., multi-group representations of the evaluated data) as well as nuclear structure and decay information. GNDS is designed to be easily expanded to handle more types of nuclear data as the needs of users evolve.

Although GNDS has been approved by the WPEC, more work is needed before it can be fully adopted by the international nuclear data community. Tasks include translating nuclear data libraries into GNDS, providing nuclear data evaluators with tools for generating GNDS evaluations, updating format and physics checking codes to support GNDS data, and updating processing codes to handle reading and writing GNDS.

This presentation will provide an overview of progress on all of these tasks, along with an overview of open-source software like FUDGE and GIDI that have been released to help ease the transition to using GNDS data.

[1] https://www.oecd-nea.org/science/wpec/gnds/

S069 On the Use of the Integral Data Assimilation Technique to Provide Feedback on Evaluated Nuclear Data: Application to the JEFF-3.1.1 Library Using Post-irradiation Examinations

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2. Orano Cycle

DARWIN2.3 is the French reference package used for fuel cycle applications. It solves the Boltzmann and Bateman equations in a coupling way to compute fuel cycle parameters, at any irradiation and cooling times. The quantities of interest for the fuel cycle are the fuel inventory, masses, residual decay heat, neutron, α, β, γ sources and spectra, and radiotoxicity. A package is defined by a nuclear data library, one or several computer codes, and one or several calculation schemes (for instance: routine dedicated to either Light Water Reactors or Fast Reactors). For DARWIN2.3, the nuclear data comes from the JEFF-3.1.1 library.

DARWIN2.3 includes the APOLLO2 deterministic transport code for LWR calculations, which provides self-shielded and energy-collapsed cross sections and multi-group neutron flux to the DARWIN/PEPIN2 depletion solver, both of them were developed by CEA/DEN with the support of its industrial partners AREVA and EDF.

The DARWIN2.3 experimental validation is based on the analysis of French Post-Irradiated Experiments; it points out some nuclides for which the depleted concentration calculation can be improved. A work plan to improve DARWIN2.3 calculations has been established. One step of it consists in improving the nuclear data implied in the calculation of the production of such nuclides. Integral Data Assimilation (IDA) based on the experimental validation of the DARWIN2.3 package has been investigated here for Caesium and Europium isotopes, whose respective concentration are underestimated for $^{133-134-137}$Cs, and slightly overestimated for ^{154}Eu.

To do so, the CYRUS code was first used to perform monokinetic sensitivity analyses on isotopic concentrations. Then, the APOLLO2 code was used to perform multi-group sensitivity analyses.

The IDA process has been carried out thanks to the CONRAD code: nuclear data adjustments were performed using a generalized least square method and marginalization techniques to take uncertainties on model parameters into account. Results suggest an increase of both $^{133-137}$Cs cumulative thermal fission yields for ^{235}U, and a decrease of ^{153}Eu capture cross-section.

I070 Trends on Major Actinides from an Integral Data Assimilation

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Nuclear data constitute the main source of uncertainty in neutronic calculations. The objective is to revisit integral data assimilation for a better prediction of the characteristics of SFR cores. ICSBEP, IRPhE and MASURCA critical masses, PROFIL irradiation experiments and the FCA-IX experimental programme (critical masses and spectral indices) with well-mastered experimental technique have been used. As calculations are performed without modelling errors (with as-built geometries) and without approximations with the TRIPOLI4 MC code, highly reliable C/E are achieved. Trends on the JEFF3.1.1 nuclear data are obtained in a way that minimize the possibility of creating compensating errors. Marginalization technique has been used for light and structural isotopes for which approximations in the integral data assimilation technique are high. This was achieved with the CONRAD code solving the Bayes equation.

Assimilation results suggest up to a 2.5% decrease for ^{238}U capture from 3 keV to 60 keV, and a 4-5% decrease for ^{238}U inelastic in the plateau region. For this energy range, uncertainties are respectively reduced from 3-4 to 1-2% and from 6-9% to 2-2.5% for ^{238}U capture and ^{238}U inelastic. Results on ^{239}Pu fission cross sections are included in posterior uncertainties. The increase trends on ^{239}Pu capture cross section of around 3% in the [2 keV-100 keV] energy range come from a low PROFIL ^{240}Pu/^{239}Pu ratio C/E. For ^{240}Pu fission cross section, results are mainly driven by JEZEBEL ^{240}Pu critical mass. For ^{240}Pu capture cross section, the increase trend of around 4% in the [3 keV-100 keV] energy range suggested by PROFIL C/E goes in the same direction as the recent ENDF/B.VIII evaluation though at a much lower level.

The nuclear data uncertainty associated to SFR ASTRID critical mass is reduced from 1558 pcm to 470 pcm. Hence, the integral data assimilation greatly reduces uncertainties associated to nuclear data and provides relevant feedback on nuclear data complementary to differential measurements.

R071 Researches on Nuclear-data Adjustment for the Sodium-cooled Fast Reactor

Chenghui Wan, Youqi Zheng, Liangzhi Cao, Hongchun Wu
Xi'an Jiaotong University

In this paper, the technique of nuclear-data adjustment has been studied and implemented for the sodium-cooled fast reactor. With application of the nuclear-data covariance generated from ENDF/B-VII.1 and the experimental data of the existing sodium-cooled fast reactors provided in the ICSBEP handbook, the nuclear-data library of the Monte-Carlo code has been adjusted. For the nuclear-data adjustment, the basic techniques and methodologies have been studied, including sensitivity analysis, uncertainty analysis and adjustment based on the Generalized Linear Least-Square Method. Through the numerical results, it can be observed that the biases between Monte-Carlo simulations and corresponding experimental data are reduced notably, and also the uncertainties of the simulation results due to nuclear data are reduced notably. Moreover, detailed comparisons between the nuclear-data adjustments and the version improvements from ENDF/B-VII.1 to ENDF/B-8.0 are given in this paper.

R072 Using Tanimato Measure to Assess Similarities of Different Critical Assemblies

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CAEP

Combined use information of integral experiments and covariance data could help improve evaluated nuclear data files, or adjust multi-group cross sections for using in specific sort of assemblies. There are lots of integral experiments have been done and documented. How to choose integral experiments should be considered carefully depend on the aim of the adjustment. For improving evaluated nuclear data files, the chosen integral experiments should have dissimilarities, or the information of the experiments are repetitive. If the aim of the adjustment is to improve the calculation accuracy of specific sort of assemblies, experiments which similar to this sort of assemblies should be chosen. There are several similarity measures used to assess similarities of different critical assemblies, such as E similarity, G similarity and C similarity. But in practice, several experiments which assessed similar to each other by E similarity and G similarity have large difference in C/E values, which is hard to explain. The reason of this phenomenon could be underestimating the experiment error or misunderstanding of E similarity and G similarity. Based on the formula, these E and G similarities have large none-linear when the similarity is larger than 0.9. Even when the similarity between two experiments is larger than 0.95, the divergence of the sensitivity vectors is not small as the similarity indicated. So, we studied Tanimato Measure and used it to assess similarities of different critical assemblies. The results show that the linear of Tanimato Measure is much better than E or G similarity, and is a better choice to assess similarity of critical assemblies. But in some cases, Tanimato Measure still indicates disagreement of similarity and C/E values, and needs more integral experiments to solve the diverge.

R073 Impact of Nuclear Data Evaluations on Data Assimilation for An LFR

Pablo Romojaro, Francisco álvarez-velarde
CIEMAT

The Lead-cooled Fast Reactor (LFR) is one of the three technologies selected by the Sustainable Nuclear Energy Technology Platform that can meet future European energy needs. The main drawbacks for the industrial deployment of LFR are the lack of operational experience and the impact of uncertainties. In nuclear reactor design the uncertainties mainly come from material properties, fabrication tolerances, operation conditions, simulation tools and nuclear data. The uncertainty in nuclear data is one of the most important sources of uncertainty in reactor physics simulations. Furthermore, it is known that the uncertainties in reactor criticality safety parameters are severely dependent on the nuclear data library used to estimate them. However, the impact of using different evaluations while performing data assimilation to constraint the uncertainties in the criticality parameters has not been properly assessed yet.

In this work, a data assimilation for the main isotopes contributing to the uncertainty in keff of the ALFRED lead-cooled fast reactor has been performed with the SUMMON system using JEFF-3.3, ENDF/B-VIII.0 and JENDL-4.0u2 state-of-the-art nuclear data libraries, together with critical mass experiments from the International Criticality Safety Benchmark Evaluation Project that are representative of ALFRED, in order to assess the impact of using different nuclear data evaluation for data assimilation.

R074 Towards Rigorous Integral Feedback: Computing Reference Sensitivities to Resonance Parameters

Pierre Tamagno, Elias Vandermeersch
CEA

Integral experiments on reactors such as criticality configurations, spectral indices or oscillation reactivity worth measurements claim to have very small experimental and technological uncertainties. Therefore these latter are considered valuable as experimental data input in nuclear data evaluation. Because of their integral nature they are mostly expected to constrain normalization or other experimental parameters present in the assimilation process of usual microscopic time-of-flight experimental data. To perform rigorous nuclear model parameters $\vec{p}$ adjustment, for instance on measured k-eff the related sensitivities $\vec{S} = \partial$ k-eff$\partial\vec{p}$ must be obtained. In usual integral feedback, sensitivity to multi-group cross sections are obtained with deterministic code using perturbation theory. These multi-group cross section sensitivity are then convoluted with parameter sensitivity in order to provide the sensitivity on nuclear model parameter. Recently stochastic approach have been elaborated in order to obtain cross-section sensitivities thus avoiding the multi-group discretization. In the present work we used the recent Iterated Fission Probability method of the TRIPOLI4 code in order to obtain directly score sensitivity nuclear physics parameters. We exemplify the method on the computation of sensitivity on Pu-239 and O-16 resonance parameters for the ICSBEP benchmark PST001. The underlying nuclear model describing resonant cross sections are based in the R-matrix formalism that provides not only the interaction cross sections but also the angular distribution of the scattered neutrons. Therefore in order to use accurate parameter sensitives both contributions (on cross section and on angular distributions) must be included. The IFP perturbation method has thus been updated in order to include perturbation to angular distribution laws thus yielding true resonance parameter sensitives.

I075 Gains: Neutron Inelastic Cross Section Measurements of Interest for Applications and Reaction Studies

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3. EC-JRC-Geel, Belgium

We will give an update on the measurements performed using GAINS at GELINA (JRC-Geel, Belgium) during the last years. While undergoing a series of significant upgrades, the setup continued to produce highly precise cross sections. Our measurements are primarily driven by technological needs with an emphasise on structural materials used in the development of nuclear facilities. However, most cases offered the opportunity to investigate various reaction mechanism and/or nuclear structure issues. The presentation will concentrate on several specific experiments describing the particular difficulties we met and the solutions we adopted to infer reliable data and to draw significant conclusions.

R076 Neutron Inelastic Cross Sections on ^{16}O

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A (n,n'γ) experiment was performed at the Geel Electron LINear Accelerator (GELINA) of the European Commission-Joint Research Center (EC-JRC) to measure neutron inelastic scattering cross-sections on ^{16}O with high precision. In order to detect the radiation of interest Gamma Array for Inelastic Neutron Scattering (GAINS) spectrometer was employed. It consists of twelve HPGe detector with 100% relative efficiency placed at 110°, 125° and 150° relatively to the direction of the neutron beam. The incident neutrons, which had energies ranging from 0.5 to 20 MeV, were scattered on a SiO_2 target: 32.30(4)-mm thickness and 76.26(4)-mm diameter. A fission chamber with ^{235}U deposits was used for data normalization. We will shortly present the data analysis procedure, the most important experimental particularities and the extracted results: the angle-integrated γ-production cross sections for all the observed transitions coming from the inelastic channel.

R077 Neutron Inelastic Cross Sections on ^{54}Fe

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A ^{54}Fe(n,n'γ) cross section measurement was performed at the Geel Electron Linear Accelerator of EC-JRC, Geel using the Gamma Array for Inelastic Neutron Scattering spectrometer and a ^{235}U fission chamber for flux normalization. The experimental results are presented in comparison with previous reported results and also with TALYS 1.9 default and tuned calculations. The tuned calculation, employing modifications of the optical model parameters, improved significantly the description of the experimental results and led to interesting conclusions regarding the interaction of the ^{54}Fe nucleus with neutrons.

R078 Fast Neutron Inelastic Scattering from ^{7}li

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The inelastic scattering of fast neutrons from ^{7}Li nuclei was investigated at the nELBE neutron-time-of-flight facility. This process has technological implications in fusion and fission reactors. In the former it could create an intense γ-ray field causing heating and radiation damage, in the latter it could strongly influence the neutron energy spectrum and therefore the neutronics of e.g. novel reactor concepts like the molten salt reactor. Furthermore the γ-ray production cross section of ^{7}Li is a very good case to be used as an alternative for neutron fluence determination to enable relative measurements of neutron-induced reactions. Inelastic neutron scattering on ^{7}Li leads to the production of a 478 keV γ-ray from the first excited state of ^{7}Li. The next higher lying state in this nucleus at 4630 keV already undergoes break up into an α-particle and a triton. The angular distribution of the γ-rays after inelastic neutron scattering is isotropic and has negligible internal conversion. The threshold energy is low enough to be able to cover a large range of neutron energy and the cross section of about 0.2 barn is reasonably high to enable good statistics within a feasible measurement time.

At nELBE the photon production cross section was determined by irradiated a disc of LiF with a neutrons of energies ranging from 100 keV to about 10 MeV. The target position was surounded by a setup of 7 $LaBr_3$ scintillation detectors and 4 high-purity germanium detectors to detect the 478 keV de-excitation γ-rays. A ^{235}U fission chamber was used to determine the incoming neutron flux. All details of the experiment and the data analysis will be explained. The final results will be compared to previous measurement done e.g. at the GELINA facility.

R079 Measurement of the Angular Distribution of Neutrons Scattered from Deuterium Below 3 MeV

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Accurate experimental data describing the angular distribution of neutron elastic scattering on deuterium are of interest for both fundamental research, for understanding quantum-mechanical few-body systems, and nuclear applications, e.g. for metrology, detector development, and reactor engineering. Below 3 MeV of incident energy, however, the available measurements are scarce and partially inconsistent. The data in the evaluated nuclear libraries have been found to cause inconsistencies when trying to reproduce heavy-water moderated criticality benchmarks, and the re-evaluation of the angular distribution below 1 MeV figures on the High Priority Request List for nuclear data maintained by the OECD/NEA.

A new measurement of the differential cross section of n-d scattering was therefore carried out. Monoenergetic neutrons in the energy range from 400 keV to 2.5 MeV were employed to irradiate a proportional counter filled with mixtures of deuterated gases, which served as both neutron target and detector for the recoil deuterons. As the deuteron recoil energy is directly related to the neutron scattering angle, the experimental pulse-height was analysed to reconstruct the neutron angular distributions over a large angular range. Interferences due to photon-induced events were minimized by means of passive shielding and an active rise-time discrimination scheme. To account for the finite resolution of the detector, incomplete energy deposition (wall effect), and multiple scattering events, a dedicated Monte Carlo model was implemented simulating neutron and deuteron transport in the detector. The coefficients of the Legendre expansion of the differential cross section were obtained from the comparison of simulations to measurements using an iterative procedure. The experimental results are compared to evaluated cross sections from the main nuclear data libraries and theoretical ab-initio calculations.

I080 Nuclear Data Activities at the EC-JRC Neutron Facilities GELINA and MONNET

Jan Heyse, Alf Göök, Stefan Kopecky, Markus Nyman, Stephan Oberstedt, Carlos Paradela Dobarro, Arjan Plompen, Peter Schillebeeckx, Gašper žerovnik
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The European Commission's (EC) Joint Research Centre (JRC) operates two neutron facilities at its site in Geel (BE). The first, GELINA [1], is a 150 MeV electron accelerator-driven pulsed white neutron source, allowing neutron time-of-flight measurements with high energy resolution covering the energy range from thermal up to 15 MeV. GELINA also allows use of the high radiation field in the neutron production hall. The second facility, MONNET, is a high-intensity quasi mono-energetic fast neutron source, driven by a 3.5 MV Tandem accelerator which produces continuous or pulsed beams of protons, deuterons and alpha particles. In combination with lithium, deuterium and tritium targets, these beams allow producing quasi mono-energetic neutrons in the energy region 0 - 24 MeV. MONNET has been installed recently as the replacement of a Van de Graaff accelerator.

The neutron facilities in Geel are used for neutron cross section measurements related to criticality safety and innovative nuclear systems, measurements of nuclear data standards, basic physics and fission studies. Other applications include material studies, cultural heritage, dosimetry, medical applications and development, testing and calibration of electronics, detectors and measuring methods. In the framework of JRC's open access program, these facilities are open to people working in academia and research organizations, small and medium enterprises and more in general to the public and private sector.

An overview of recent measurements will be given, including examples of measurements carried out in the framework of open access.

[1] W. Mondelaers and P. Schillebeeckx, Notiziario Neutroni e Luce di Sincrotrone 11, 19 - 25 (2006).

R081 Measurement of the ^{13}C Absorption Cross Section Via Neutron Irradiation and AMS

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The radionuclide ^{14}C is present in irradiated graphite and quantifying this relies on accurate knowledge of the two main production routes: ^{13}C(n,γ)^{14}C and ^{14}N(n,p)^{14}C. The former has been recently measured by prompt gamma ray activation analysis and the measured value of 1.496±0.018 mb [1] is over 40% larger than the results of older neutron activation-based experiments [2-4].

Work has been performed to accurately measure the ^{13}C(n,γ)^{14}C cross section for slow neutrons, first by irradiating ampoules of enriched ^{13}C powder at the PF1b cold neutron beam line at the high-flux reactor of ILL, Grenoble. The ^{14}C/^{13}C isotopic ratio of multiple irradiated ampoules was then measured at the VERA AMS facility, Vienna. AMS is a powerful tool for cross section measurements where the activated product is stable or long lived, such as ^{14}C. However, in this case care must be taken to estimate the level of any ^{14}C produced from auxiliary paths such as ^{14}N(n,p). Preliminary results show good agreement with the value from reference [1] confirming that the evaluated thermal cross section in JEFF 3.3 should be increased by $\sim$ 9%. The experimental procedure, analysis and results of this measurement shall be presented.

[1] R. B. Firestone and Zs. Revay, Phys. Rev. C, 93, 054306 (2016)
[2] G. Henning, Phys. Rev., 95, p.92, (1954)
[3] P. Campion et al., AECL Reports, 36 (1957)
[4] H. Motz and E. Jurney, Washington AEC Office Reports, 1044 40 (1963)

R082 PROFIL-2 Experiment and Neutron Capture Cross Sections of Europium Isotopes

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Neutron-induced cross section is one of the key quantities in nuclear physics and nuclear engineering. The integral experiment can give good feedback to the cross sections with low uncertainties. Using the optical model and statistical model, the neutron-induced total and capture cross sections of ^{153}Eu are revaluated according to the experimental microscopic total cross sections and the PROFIL-2 integral experiment. The corresponding uncertainties and covariances are determined with the data assimilation method implemented in CONRAD code. On the other hand, the previous interpretation of the PROFIL-2 experiment showed that JEFF-3.1 overestimates the neutron-induced capture cross section of ^{151}Eu by a factor of 2. Further analysis performed in the present work points out that the large difference between calculation and experimental data is mainly due to the lack of ^{152m1}Eu in ERANOS code, which is used to interpret the PROFIL-2 experiment. The correction of ^{152m1}Eu on the interpretation largely reduces the difference between JEFF-3.1 and PROFIL-2 and shows the agreement between the PROFIL-2 integral experiment and other microscopic measurements. The revaluated neutron-induced total and capture cross sections of ^{151}Eu and ^{153}Eu correspond well with both the microscopic experimental measurements and the PROFIL-2 integral experiment.

R083 ^{241}Am Neutron Capture Cross Section Measured with C6D6 Detectors at the n_TOF Facility, CERN

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Neutron capture on ^{241}Am plays an important role in nuclear energy production and also provides valuable information for the improvement of nuclear models and the statistical interpretation of nuclear properties. A new experiment to measure the ^{241}Am(n,γ) cross section at energies below 300 eV and in particular the thermal region and the first few resonances below 10 eV has been carried out at EAR2 of the n_TOF facility at CERN. Four neutron-insensitive C6D6 detectors have been used to measure the gamma cascade and then deduce the neutron capture yield. Preliminary results will be presented and compared with previously obtained results at the same facility in EAR1. In EAR1 the gamma-ray background at thermal energies was about 90% of the signal while in EAR2 we took full advantage of the much more favorable signal to noise ratio. We also extended the low energy limit down to subthermal energies. This measurement will allow a comparison with neutron capture measurements conducted at reactors and using a different experimental technique.

R084 Filtered Neutron Capture Cross-section of Hf-180

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The neutron capture cross-sections of ^{180}Hf(n,γ)^{181}Hf reactions have been measured at filtered neutron energies of 24, 59, 133 and 148 keV. The mono-energetic neutron beams have been created at the horizontal channels of Dalat research reactor by means of the neutron filtered technique. The present neutron capture cross sections of ^{180}Hf were obtained relative to the standard capture cross sections of ^{197}Au by the activation method. The corrections for multi-scattering, self-shielding, and resonance capture effects by neutron background were taken into account. The results of neutron capture cross-section obtaining in this work are compared with the previous experimental and evaluated values.

R085 Preliminary Results on the Neutron Induced Capture Cross Section and Alpha Ratio of ^{233}U at n_TOF with Fission Tagging

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^{233}U is of key importance among the fissile nuclei in the Th-U fuel cycle for Generation IV nuclear energy systems. In the particular case of^{233}U the capture cross-section is on average about one order of magnitude lower than the fission cross-section. An efficient capture-fission discrimination is therefore crucial for the accuracy in the measurement of the capture cross-section. Thus, a combined set-up of fission and γ-detectors is needed to allow tagging of the fission γ-rays. A measurement of the ^{233}U capture cross-section and α-ratio was performed at the CERN n_TOF facility. The Total Absorption Calorimeter (TAC) of n_TOF , a 4π array made of 40 BaF_2 crystals, was employed as γ-detector. The TAC was coupled with a novel compact ionisation chamber as fission detector, which was optimised for fast timing needed for alpha-fragment separation. In the present contribution the experimental set-up will be described and essential parts of the analysis procedure will be discussed, like the determination of the fission chamber efficiency and the background subtraction. Monte Carlo simulations of the full experimental set-up were compared to the experimental capture response and used to calculate the detection efficiency, pile-up and dead-time corrections. Finally, preliminary results on the capture response, cross section and α-ratio will be presented.

R086 Radiative Thermal-neutron Capture on ^{139}La

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The nucleus ^{139}La is an abundant fission product in thermal- and fast-neutron induced fission of ^{233,235}U and fast-neutron induced fission of ^{239}Pu. Accordingly, neutron-capture cross sections for ^{139}La provide an important ingredient for reactor-fuel related applications. To address this need, prompt partial γ-ray cross sections and the total radiative neutron-capture cross section were measured for the $^{139}La(n,\gamma)$ reaction using a guided beam of thermal neutrons at the Prompt Gamma Activation Analysis facility of the Budapest Research Reactor. A variety of photon strength function and nuclear level-density models have been used to assess the statistical-model γ decay of the compound nucleus ^{140}La, providing insight into the quality and completeness of the measured data. New spin-parity assignments have also been determined for several of the low-lying levels populated in ^{140}La from the measured reaction cross sections, together with the statistical-model analysis and an evaluation of the available nuclear structure data.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Numbers DE-NA0003180 and DE-NA0000979. This work is also supported by the Lawrence Berkeley National Laboratory under Contract No. DE-AC02-05CH11231 for the US Nuclear Data Program, and the Lawrence Livermore National Laboratory under Contract no. DE-AC52-07NA27344. Additional support was received through the Undergraduate Research Apprentice Program and the Nuclear Science and Security Consortium. The access to the Budapest PGAA facility was supported by Project No. 124068 of the National Research, Development and Innovation Fund of Hungary, financed under the K17 funding scheme.

R087 Measurement of the Pu-242(n,γ) Cross Section from Thermal to 500 KeV at the Budapest Research Reactor and CERN n_TOF-EAR1 Facilities

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The future of nuclear energy points to the use of innovative nuclear systems, such as Accelerator Driven Systems and Generation-IV reactors, aimed at the reduction of the nuclear waste. The design and operation of these innovative systems requires a better knowledge of the capture and fission cross sections of the Pu isotopes. This is clearly stated in the WPEC-26 report. For the case of ^{242}Pu capture, a reduction of the uncertainty in the fast region from the current 35% down to 8-12% is required. Moreover, aiming at improving the evaluation of the fast energy range in terms of average parameters, the OECD NEA "High Priority Request List" requests high-resolution capture measurements with improved accuracy below 2 keV. The uncertainties also affect the thermal point, where previous experimental results deviate from each other by 20%.

In collaboration with JGU Mainz and HZ Dresden-Rossendorf, we produced a ^{242}Pu sample consisting of a stack of seven fission-like targets making a total of 95(4) mg of ^{242}Pu electrodeposited on thin (11.5 μm) aluminium backings. This contribution presents the results of a new measurement of the ^{242}Pu(n,γ) cross section from thermal to 500 keV combining different neutron beams and techniques. The thermal point was determined at the Budapest Research Reactor by means of Neutron Activation Analysis and Prompt Gamma Analysis, and the resolved (1 eV - 4 keV) and unresolved resonance regions (1 - 500 keV) were measured using a set of four Total Energy detectors at n_TOF-EAR1. A brief overview of the facilities, experimental set-ups and analysis techniques will be given, and the final results and the accuracy achieved in each energy region will be discussed.

R088 Measurement of Neutron-capture Cross Sections of Radioactive Minor Actinide Isotopes with High Time-resolution Neutron Pulses at J-PARC/MLF

Shoichiro Kawase, Atsushi Kimura, Hideo Harada, Nobuyuki Iwamoto, Osamu Iwamoto, Shoji Nakamura, Mariko Segawa, Yosuke Toh
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Minor actinides (MA) are generated in nuclear power plants through the reaction chains of neutron captures and beta and/or alpha decays starting from uranium. To reduce the long-lasting radiotoxicity of MAs in the spent fuels, some innovative reactors such as Accelerator Driven Systems (ADS) and associated fuel cycles are intensively investigated. For this purpose, accurate neutron-capture cross section data on MAs are needed. Curium-244 is one of the most important MA isotopes in the treatment of radioactive waste because of its significant share in the source of decay heat and large neutron emission rate in spent fuels. Despite its importance, the accuracy of neutron capture cross section of ^{244}Cm is still not enough, since the measurements have been highly challenging due to the high specific activities.

In this study, the neutron capture cross sections of ^{244}Cm (half-life: 18 years) and ^{246}Cm (half-life: 4760 years) were measured for the neutron energy range from 1 up to a few hundred eV via the neutron time-of-flight method with Accurate Neutron-Nucleus Reaction measurement Instrument (ANNRI) at Material and Life Science Experimental Facility (MLF) of the Japan Proton Accelerator Research Complex (J-PARC). The activities of ^{244}Cm and ^{246}Cm samples at the measurement time were 1.2 GBq and 1.1 GBq, respectively. The world's most intense neutron pulses from the Japan Spallation Neutron Source (JSNS) enable us to perform the accurate measurement of neutron capture cross sections. In addition, the use of single-bunched neutron pulse allows the analysis in higher neutron energy region than previous measurements at ANNRI.

R089 Measurement of the Neutron Capture Cross Section of ^{237}Np Using ANNRI at MLF/J-PARC

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Precise nuclear data for neutron capture reactions of minor actinides (MA) have become a primary research topic for their preponderant role in the study and design of transmutation methods in nuclear waste management. Present nuclear evaluated data libraries can be used in the early stages of the design of transmutation nuclear systems. Nonetheless, the exhaustive engineering designs and safety assessments require more precise and complete nuclear data.

^{237}Np possesses a half-life of 2.14×10^6 years and it is one of the most abundant MA in spent nuclear fuel. ^{237}Np is also one of the main components of the Accelerator-Driven Systems (ADS) core, a sub-critical reactor facility for nuclear transmutation. Currently available nuclear data for the neutron capture rection of ^{237}Np is an important contributor to the ADS criticality uncertainty. JENDL-4.0 includes uncertainties from 6% up to 10% in the region of interest for the core design (0.5-500 keV), much higher than the requirements of less than 5%. Hence, it is essential to accurately determine the neutron capture cross section at such energy range along with the resonance parameters for examining the nuclear transmutation of ^{237}Np.

The measurements were performed using the Accurate Neutron-Nucleus Reaction Measurement Instrument (ANNRI) at the Japan Proton Accelerator Research Complex (J-PARC). Intense pulsed neutrons were produced using the 3 GeV proton beam of the J-PARC facility with energy ranging from thermal energy to several hundred keV. A Time of Flight (TOF) method using a NaI(Tl) detector was employed for this measurement and the data were analyzed based on a pulse-height weighting technique in order to derive a neutron capture yield.

A 200mg capture sample of ^{237}Np (5 MBq) was used for the measurements. The neutron spectrum was reconstructed using the 478 keV gamma-rays from the ^{10}B(n,α)^{7}Li reaction with a boron sample containing enriched ^{10}B up to 90%. A final value for the capture cross section of ^{237}Np is presented alongside with a resonance analysis using the Refit fitting program. The capture data was normalized at the first resonance using JENDL-4.0.

S090 Research on Neutron Total Cross-section Measurement at CSNS-WNS

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The high accuracy neutron total cross-section measurement is important to the design of nuclear device and related nuclear physics. The first experiment on the total cross section was researched by using the Neutron TOtal Cross Section Spectrometer (NTOX) at the White Neutron Source on China Spallation Neutron Source (CSNS-WNS). The White neutrons were produced by spallation of the 1.6 GeV proton beam with a beam power of 20 kW and pulse frequency 25Hz incident on a tungsten target. In order to support the experiment, the neutron transmission and scattering in a series of samples were simulated and evaluated when the diameter of the neutron beam was 60 mm at End Station 1 and 30 mm at End Station 2. Measurements of neutron total cross sections of natural graphite and high purity aluminum with a diameter of 70 mm in the wide neutron energy region up to 20MeV have been performed by using the time-of-flight method, and the time-of-flight path was about 76 m long. A multi-layer fast fission chamber with ^{235}U and ^{238}U was employed as neutron detectors. The signal waveforms were collected by the DAQ system provided by Back-n Collaboration. The neutron time-of-flight spectra and transmission were obtained by off-line data processing. The neutron total cross-sections and their uncertainty were analyzed.

S091 Neutron Capture and Total Cross-section Measurement of Gd-155 and Gd-157 at ANNRI in J-PARC

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Gadolinium (Gd) is used as a burnable poison to compensate for the decrease in reactivity under operations of commercial light water reactors, since two nuclides, Gd-155 and Gd-157, have large capture cross sections for thermal neutrons. It is essential for safe and reliable operation of nuclear power plants to know accurate values of neutron capture cross-sections of these nuclides.

Neutron capture and total cross section of Gd-155 and Gd-157 were measured in the energy region from 5 meV to 1 eV with the neutron time-of-flight method at Accurate Neutron-Nucleus Reaction measurement Instrument (ANNRI) at Material and Life Science Experimental Facility (MLF) of the Japan Proton Accelerator Research Complex (J-PARC) using both the NaI (Tl) spectrometer at the flight length of 28 m and Li-glass detectors at the flight length of 29 m. In the neutron capture cross-section measurement, two samples with different thickness for each nuclide were used. By taking ratios of capture yields of the thick and those of thin samples, uncertainties due to neutron intensity and detection efficiency of the spectrometer were cancelled out, thus neutron capture cross sections are deduced with high accuracy. The derived cross sections at neutron energy of 25.3 meV agreed with evaluated values and the experimental results by Moller but were not consistent with those by Leinweber.

The neutron experiments at the Materials and Life Science Experimental Facility of the J-PARC were performed under the user program (Proposal No. 2016P1001 and 2015P1001). Present study includes the result of "Research and Development for accuracy improvement of neutron nuclear data on minor actinides" entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

I092 GDR Cross Sections Updated in the IAEA-CRP

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We aim to resolve the long-standing discrepancy between the Livermore and Saclay data of GDR partial photoneutron cross sections in the Coordinated Research Project of the International Atomic Energy Agency with the code F41032 [1]. A series of experiments were performed by using the quasi-monochromatic gamma-ray beam produced in the laser Compton scattering at the NewSUBARU synchrotron radiation facility. We have finished the data acquisition for 11 nuclei from 9Be to ^{209}Bi in the IAEA-CRP by the direct neutron-multiplicity sorting with a flat-efficiency detector [2]. We will perform the data reduction, evaluation, and documentation for the new data before publishing an updated photonuclear data library in 2020. We present the current status of the project and GDR cross sections updated in the IAEA-CRP, including those for ^{209}Bi[3], ^{159}Tb, ^{197}Au etc.

[1] https://www-nds.iaea.org/CRP-photonuclear/
[2] H. Utsunomiya et al., Nucl. Instrum. Meth. A871, 135 (2017).
[3] I. Gheorghe et al., Phys. Rev. C 96, 044604 (2017).

R093 Study of Photon Strength Functions of Pu-241 and Cm-245 from Neutron Capture Measurements

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We have measured the γ-rays following neutron capture on ^{240}Pu and ^{244}Cm at the n_TOF facility at CERN with the Total Absorption Calorimeter. This detector is made of 40 BaF_2 crystals operating in coincidence and covering almost the entire solid angle. This allows to obtain information concerning the energy spectra and the multiplicity of the measured capture γ-ray cascades. We have analyzed the measured data in order to draw conclusions about the E1 and M1 Photon Strength Functions of ^{241}Pu and ^{245}Cm below their neutron separation energies. In particular, we have investigated different Lorentzian-like shapes for the E1 strength functions (Standard Lorentzian, Enhanced Generalized Lorentzian, Modified Lorentzian $\cdots$) and searched for resonant structures in the M1 strength functions, corresponding to the scissors mode. The results are compared with theoretical predictions.

R094 New Reliabile Photoneutron Reaction Data for ^{159}Tb

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Data for partial (γ, 1n), (γ, 2n), and (γ, 3n) photoneutron reactions cross sections and those for total photoneutron $\sigma(\gamma$, tot) and yield $\sigma(\gamma$, Sn) reactions were obtained for ^{159}Tb at Livermore (USA) and Saclay (France). The ratios of integrated cross sections R_S^{int}/R_L^{int} for reactions (γ, 1n), (γ, 2n), (γ, tot) and (γ, Sn) are equal, correspondingly, to 1.37, 0.68, 0.98 and 1.07. The reason could be the systematic uncertainties of the method for determination of neutron multiplicity because of noticeably difference in efficiency of one and two neutrons detection. The new measurements were carried out using the quasi-monochromatic laser Compton-scattering (LCS) γ-ray beam and the novel technique of direct neutron-multiplicity sorting with a flat-efficiency detector. New experimental cross sections are significantly different from both cross sections. The new cross sections are in good agreement with data evaluated using experimental-theoretical method

$$\sigma^{eval}(\gamma, in) = F_i^{th}\sigma^{exp}(\gamma, Sn) = [\sigma^{th}(\gamma, in)/\sigma^{th}(\gamma, Sn)]\sigma^{exp}(\gamma, Sn)$$

and data reliability criteria,

$$F_i = \sigma(\gamma, in)/\sigma(\gamma, Sn)$$

It means that reliable partial reaction cross section data free from shortcomings typical for the method of neutron multiplicity sorting could be obtained using the new experimental method . The work is supported by the Research Contracts (ROM-20476, RUS-20501, JPN-20564) of the IAEA Coordinated Research Project No F41032.

R095 Measurement and Analysis of ^{155,157}Gd(n,γ) From Thermal Energy to 1 Kev

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The large capture cross section of gadolinium has considerable influence on applications in nuclear technologies and has significant impact in neutrino physics, hadron therapy and nuclear astrophysics. Sizable discrepancies present in literature motivated a new measurement on the isotopes with the largest cross section, ^{155}Gd and ^{157}Gd, which were recently measured at the neutron time-of-flight facility n_TOF at CERN.

The capture events were recorded by an array of 4 C6D6 detectors, and the capture yield was deduced exploiting the total energy detection system in combination with the Pulse Height Weighting Techniques. Because of the large cross section around thermal neutron energy, metallic samples of different thickness were used to prevent problems related to self-shielding. The samples were isotopically enriched, with a cross contamination of the other isotope of less than 10%.

The capture yield was analyzed with the R-Matrix code SAMMY to describe the cross section in terms of resonance parameters. The results are significantly different from evaluations and from previous TOF experiments, in particular at neutron thermal energy. The capture cross section from this work is consistent with an integral measurement performed in 2012 at the Canadian Zed-2 reactor. An overview of the experiment and of the analysis will be presented, together with a comparison of the present results with evaluations and literature data.

S096 Neutron Inelastic Cross Section Measurements on ^{58,60}Ni

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A natural nickel sample was used at the GELINA neutron source of the EC-JRC, Geel to measure the neutron inelastic cross sections. The GAINS spectrometer was employed to detect the emitted gamma rays while a ^{238}U fission chamber monitored the neutron flux. Our preliminary results will be presented in comparison with previous reported data and TALYS 1.9 calculations performed using the default input parameters.

S097 Neutron Resonance Transmission Analysis of Cylindrical Samples Used for Reactivity Worth Measurements

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The reactivity worth of hundreds of cylindrical samples containing actinides and non-fissile isotopes of interest for reactor applications was measured by the oscillation technique in the MINERVE reactor at CEA Cadarache (France) [1]. For some of the nuclides, discrepancies between the calculated and experimental values (C/E) cannot be explained by the use of erroneous nuclear data in the neutronic calculations. Although the sample composition provided by the manufacturer was determined by well established radiochemical analysis, bias effects due to the sample composition were not excluded. Therefore, an experimental program was proposed to characterize the MINERVE samples by Neutron Resonance Transmission Analysis (NRTA) [2] at the time-of-flight facility GELINA of JRC-Geel (Belgium).

NRTA is a non-destructive analysis technique that consists of measuring the neutron transmission through a given material. Accurate transmission measurements require the use of thin disks with a diameter larger than the neutron beam diameter. The cylindrical geometry of the MINERVE samples do not fulfil these conditions. New data reduction and resonance shape analysis techniques were developed to account for the characteristics of the MINERVE samples. The feasibility of such analysis was investigated on silver samples. First, transmission and capture measurements were performed on thin natural silver discs in order to extract reliable ^{107,109}Ag resonance parameters. Then, transmission measurements were performed with UO_2, Al_2O_3 and liquid MINEVRE samples doped with silver. The volume densities of the main components, ^{238}U and ^{107,109}Ag, derived from the NRTA data confirm within 2% the values provided by the manufacturer. The NRTA data also reveal a substantial tungsten contamination that was not reported by the manufacturer. The tungsten contamination is related to the manufacturing process of the sample pellets by compacting powder. The impact of the observed tungsten contamination can lead to non-negligible increases of the C/E ratios up to 5.7%. Since the tungsten contamination varies from sample to sample, NRTA should be applied to other MINERVE samples, especially those designed for the Burn-up Credit program.

[1] A. Gruel et al., Nucl. Sci. Eng., vol. 169, p. 229 (2011).
[2] P. Schillebeeckx et al., JRC Science and Policy Reports, Report EUR 26848 EN (2014).

S098 Photodisintegration Reaction Rate Involving Charged Particles: Systematic Uncertainty from Nuclear Optical Model Potential and Experimental Solution Based on ELI-NP

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Photodisintegration reaction rates involving charged particles are of relevance to the p-process nucleosynthesis that aims at explaining the production of the stable neutron-deficient nuclides heavier than iron. In this study, taking into account both reaction mechanisms of compound and pre-equilibrium, cross sections and astrophysical rates of (γ,p) and (γ,α) reactions for about 3000 target nuclei with $10 < Z < 100$ ranging from stable to proton dripline are computed with TALYS software, in which the phenomenological Wood-Saxon and microscopical folding potentials are both used. Systematic comparison of the calculated results are performed, and it is found that these reaction rates, especially for (γ,α), are sensitive to the optical model potential (OMP). Thus better determination of OMP is crucial to reduce the uncertainties of photodisintegration reaction rates involving charged particles. A γ-beam facility in Extreme Light Infrastructure-Nuclear Physics (ELI-NP) will provide great opportunity to experimentally study the photodisintegration reactions involving charged particles, combining with the Extreme Light Infrastructure Silicon Strip Array (ELISSA) for charged particles detection. Therefore, measurement of photodisintegration reaction based on ELI-NP and ELISSA is proposed, and the experimental results can be used to constrain the OMPs of charged particles that are crucial to the reaction rate predictions. Furthermore, energy spectrum and total reaction yield of the emitted charged particles from the photodisintegration reaction of astrophysics interest are obtained by GEANT4 simulation. Simultaneously satisfying the detection threshold of experimental yield and the particle identification of proton and α particle, the minimum energies of inducing γ-beam for measuring (γ,p) and (γ,α) reactions are predicted, and it is found that the studied reactions of astrophysics interest can be directly measured in the energy range of their Gamow windows. It is expected that the present study could eventually guide the promising photonuclear measurements at ELI-NP.

S099 A Compact Photo-neutron Source Driven by 15 MeV Electron Linac

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A electron linac-driven neutron source is constructed at the Shanghai Institute of Applied Physics, Chinese Academy of Sciences (SINAP-CAS). The neutron source is designed for key nuclear data measurements for Thorium Molten Salt Reactor (TMSR) project. The linac delivers an electron beam of 15 MeV, with a beam current of 0.1 mA, and a repetition rate variable from 1 to 266 Hz. The electron pulse width is arranged from 1 ns to 3 ms for different experimental objectives. A thick tungsten target is mounted at the end of beam line, where the electrons generate bremsstrahlung photons which in secondary (γ, n) reactions on tungsten release neutrons. A water-cooled copper pedestal is welded to the tungsten target to dissipate the thermal load deposited by the electron beam. A high suppression of the electrons and photons is obtained by using the neutrons emitted perpendicularly from the electron beam. A collimator inserted in the shield creates a well-defined neutron beam that enters the vacuum transport piping. Polythene moderator is installed in the piping for neutron thermalizing. A thermal neutron flux of 4000 n/cm^{2}s from a 10 cm thickness moderator surface is evaluated. A Time of Flight (ToF) spectrometer is built at the end of the transport piping with a flight path of 6 m, where a thermal neutron flux of 300 n/cm^{2}s is presented.

I100 Energy Dependent Fission Product Yields from Neutron Induced Fission of ^{235}U, ^{238}U, and ^{239}Pu

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We have begun to provide self-consistent, high-precision, and time-dependent FPY data for ^{235}U, ^{238}U,and ^{239}Pu isotopes using monoenergetic and pulsed neutron beams with energies from 0.1 to 15 MeV. Monoenergetic and tunable neutron beams were produced by four different charged particle reactions [1] while the neutron flux was monitored by fission ionization chambers [2]. Using irradiations of varying duration, we measured the energy dependence of the absolute yields for more than two dozen fission products, with half-lives ranging from minutes to months, on these targets of interest. The results confirm the progression towards symmetric fission at higher incident neutron energy, i.e., 14.8 MeV. However, at lower energies (En$<\sim$4 MeV) the experimental data reveal an unexpected energy dependence of some of the fission-product yields from neutron-induced fission of ^{239}Pu: a positive slope up to about 4-5 MeV which then turns negative as the incident neutron energy increases [3]. This latter finding at low-energy is in conflict with present theoretical predictions. A new experimental campaign to determine the cumulative and short-lived (seconds to minutes) fission-product yield data will be presented for fast neutron induced fission.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.

[1] M. Gooden et al., Nucl. Data Sheets 131, 319 (2016).
[2] C. Bhatia et al., Nucl. Instr. Meth. Phys. Res. A 757, 7 (2014).
[3] A. Tonchev et al., 6thIntern. Conf. on Fiss. and Prop. of Neutron-Rich Nuclei, p.381 (2017).

R101 Fission Studies at IGISOL/JYFLTRAP: Measurements of Neutron-induced Fission Yields

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The fission product yield is an important characteristic of the fission process. For nuclear energy applications good knowledge of neutron induced fission yields is crucial and the IAEA has pointed to that most fissioning systems need to be further investigated. With the introduction of Generation IV nuclear power, the change in composition of the fuel and neutron spectrum will alter the yields of fission products. This will affect the reactor criticality, through beta delayed neutrons and reactor poisons, and the decay heat as well as burn-up monitoring.

With the aim of high precision measurements of fission yields a beryllium proton-to-neutron converter has been developed, installed and characterised at the IGISOL facility at the University of Jyväskylä. The produced neutron field irradiates a fissionable target and the fission products are collected online using a custom designed ion guide. Using a series of mass separating elements, culminating with the JYFLTRAP Penning trap, fission products can be separated and counted on a nuclide basis.

A first measurement of neutron induced fission yields has been performed for the reaction ^{nat}U(n,f). We here present the relative cumulative isotopic yields of tin and the relative independent isotopic yields of antimony, as well as isomeric yield ratios for five of the nuclides. We also present the ongoing work to optimise the production, collection and separation of the fission products.

R102 Product Yields from 0.57 MeV, 1.0 MeV and 1.5 MeV Neutron Induced Fission of U-235

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The chain yields of more than 30 fission products, are obtained for the fission of ^{235}U induced by 0.57 MeV, 1.0 MeV and 1.5 MeV neutrons. Absolute fission rate is monitored by a double-fission chamber while fission product activities are measured via HPGe γ-ray spectrometry. MCNP IVB is applied to simulate neutron spectrum in the Uranium samples, and the effects of 4 kinds of secondary neutrons on fission yield data are discussed.

R103 Fission Studies at IGISOL/JYFLTRAP: Isomeric Yield Ratio Measurements from 25 MeV ^{nat}U(p,f), in the Quest for Angular Momentum Studies

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The mechanism for the generation of large angular momentum in fission fragments is far from understood, and different theories compete on giving an explanation. There is no direct way of measuring the angular momentum, but it can be derived from fission observables, such as the isomeric yield ratio. Isomeric yield ratios have earlier been measured through gamma-ray spectroscopy. Such methods may have limitations, such as inadequate knowledge of decay schemes or overlapping gamma transitions. These difficulties can be overcome with the Ion Guide Isotope Separator On-Line (IGISOL) technique, where reaction products from a thin target can be collected and mass separated before being analysed.

We have used the IGISOL-JYFLTRAP facility at the Univesity of Jyväskylä for measurements of isomeric yield ratios from 25 MeV proton-induced fission on natU. The IGISOL techniqe is coupled to the JYFLTRAP double Penning trap, which enables separation of the isomer and the ground state by mass. The implementation of the novel Phase-Imaging Ion-Cyclotron-Resonance technique allows isomeric states excited by 140 keV, and with half-lives of the order of 0.5 s, to be resolved from the ground state.

We compare measured isomeric yield ratios for the odd-A isotopes of $^{119-127}$Cd and $^{119-127}$In with other experiments and the GEF fission model. The measured isomeric yield ratios have been used to derive the root-mean-square angular momentum (Jrms) of the related primary fragments, by employing the nuclear reaction code TALYS. The results for the Cd and in isotopes show a dependency of the angular momentum on the number of unpaired protons and neutrons, where the odd-Z in isotopes carry larger angular momenta. The deduced values of Jrms display a strong correlation with the electric quadrupole moments of the fission products, and its interpretation will be discussed. A forthcoming experiment for further measurements of isomeric yield ratios on both sides of the nuclear shell closures Z = 50 and N = 82 may shed more light on the underlying mechanisms.

R104 Update of EXFOR for Experimental Fission Product Yield

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The fission product yield (FPY) was not within the scope of EXFOR compilation when Four Neutron Centres started data exchange in 1970s. FPY evaluators have compiled experimental data by themselves, and their evaluated data files contain not only evaluated FPY but also experiential FPY used for evaluation. They are compiled in their own format, and it is not easy to access to the source files. Under this situation, EXFOR should serve as the central storage of experimental FPY to assist evaluators and other researchers dealing with FPY in the world. In order to improve the EXFOR completeness for FPY, we assessed the completeness of EXFOR against experimental FPY databases developed by FPY evaluators. The result of the assessment and future plan will be presented.

I105 Energy Dependent Fission Yield Calculations with Langevin Model, Hauser-Feshbach Statistical Decay and Beta Decay

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The fission yield data are one of the key ingredients for studying nuclear energy applications. Due to an increasing demand for the high quality fission yield data in these applications, the available evaluated data in the current nuclear data libraries are insufficient. Particularly, the data for minor actinides or the energy-dependent properties have become of great interest. A complete calculation of fission yields involves three stages; (1) the nuclear fission process from a compound nucleus formation to scission, (2) the statistical decay of excited complementary fission fragments, and (3) beta-decay. At each stage, the fission observables need to be calculated simultaneously and they should be consistent each other. We have developed the Hauser-Feshbach statistical decay model for the fission fragment pairs at the stage (2), and the model outputs are concatenated with the beta decay process (3).

In this study, we demonstrate a seamless calculation from (1) to (3) with the Langevin model, the Hauser-Feshbach statistical decay and the beta-decay. The Langevin model produces some important ingredients for inputs of the Hauser-Feshbach statistical decay model, and the seamless calculation provides the fission yields as well as some other fission-related observables for various actinides in an energy dependent manner. We discuss the results of our calculation and compare them with available experimental data.

R106 Fission Study in Macro-microscopic Model

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New calculations of fission barrier heights in a five-dimensional (5D) deformation space for actinide nuclei have been performed based on a macro-microscopic (MM) model. To calculate potential energy surface (PES), we use the 5D generalized Lawrence shape (GLS) realistic parameterization as the shape description, Lublin-Strasbourg Drop (LSD) model for the macroscopic energy and folded-Yukawa potential as the single-particle potential. A method to use double center oscillator bases on any kind of shape description was presented. For the pairing energy, we use the SBCS model. Finally, Strutinsky method is used to calculate the microscopic correction energy. To find the fission barriers and fission paths, some concepts from geography are extended to 5D PES, and we assume that the fission path follows the line of steepest descent. The scission barriers of U and Pu isotopes are calculated, which are consistent with other theoretical and experimental results. Besides the fission barriers and fission paths, we also obtained the most-probable fission fragment distributions of several systems.

We use the Brownian shape motion (BSM) on the PESs and combine the BSM with the concept of random neck rupture (RNR). As our shape description cannot depict the shape where two fragments appear, we use the Rayleigh criterion to determine where the compound nucleus suddenly scission. With concept of random neck rupture, the rupture should occur around the neck with some distribution. So we add a Gaussian random number with standard error of 4 amu to each mass splitting. Combining BSM and RNR together, we use the PES to calculate the thermal neutron induced fission of U-234 and U-236, and also fast neutron induce and other higher energy results. The transition from symmetric fission to asymmetric fission of Th and Pa isotopes is well reproduced in our model. In 2010, a new asymmetric fission area was found by beta-delay fission. Our model can also reproduce this asymmetric fission yields, and the peak position and the width of yield are closer to the experimental results.

R107 Calculation of Fission Fragment Mass Distributions by Using A Semi-empirical Method

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Fission product yield data are important for applications of nuclear technology such as the estimation of decay heat, operation of nuclear reactors and handling of spent fuels. However, due to the short life-time, a large part of fission fragment yield data cannot be obtained from measurements. Therefore, models of fission fragment yields are needed for such unmeasured cases. Though many theoretical fission models are developed, the calculation results are not necessarily accurate enough to reproduce the fission observables quantitatively. On the other hand, semi-empirical models may be useful in describing fission product yields in a simple way but with a relatively good accuracy.

We developed a semi-empirical fission model based on the saddle point fission model of Itkis [1] and Schmidt [2]. It is assumed that fission product yields are determined by the fission barrier to some extent whereas values of the effects of detailed nuclear dynamics from saddle to scission are included in our model parameters. The parameters for our empirical model are deduced by fitting the evaluated fission yields to the ENDF data, and we found that the parameters can be expressed in simple forms. The calculated fission product yields from our model which has 10 parameters can reproduce the yields nearly as well as GEF.

[1] Itkis et al., Z. Phys. A 320 (1985) 433. [2] K.-H. Schmidt et al., Nucl. Data Sheets 131 (2016) 107.

R108 Study of fission dynamics with a three-dimensional Langevin approach

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The fission fragment mass distribution and total kinetic energy distribution were studied within three dimensional Langevin model. As one of the important transport parameters, the temperature dependent potential energy surface was calculated with Macroscopic-Microscopic model based on the Finite Range Liquid Drop Model and Two Center Shell Model. The Werner-Wheeler approximation was used to calculate the inertia tensor and one body model was adopted to calculate the friction tensor, and both of them are dependent on the nuclear shapes. The influence of the starting position for the Langevin calculation, level density parameter and shell damping parameter on the fragment mass distribution were studied. The calculated fragment mass distributions of ^{235}U, ^{233}U, and ^{232}Th induced by neutron at 14 MeV have a good agreement with the evaluated data, which is a good basis to do the further research. In the last, the total kinetic energy distributions for several values of friction strength were also calculated.

R109 A Global Parameterization for Fission Yields

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Developing a consistent picture of fission observables, in particular prompt fission quantities, is important for a variety of applications including energy, non-proliferation, and defense. Often, each of these observables is calculated using a separate model, however, with Monte Carlo codes, such as CGMF, it is possible to calculate prompt fission observables in a consistent framework. Beginning with yields in mass, charge, kinetic energy, spin, and parity, a Hauser-Feschbach statistical decay is used to calculate the number of prompt neutrons and gamma rays, along with their energy and momentum. Many of the models within CGMF responsible for these decays are parameterized and must be constrained using experimental data, which can be scarce for some isotopes of interest. It is therefore important to have global models, instead of creating a separate parameterization for each isotope. In this contribution, we have begun to develop a global model for mass and kinetic energy yields. We use the Brosa model parameterization for Y(A,TKE) [U. Brosa, et. al., Phys. Rep. 197, 4 (1990)], and construct each parameter within the model as a function of mass, charge, and incident neutron energy of the fissioning system. A Markov Chain Monte Carlo is used to optimize these parameters. The yields and resulting prompt neutron and gamma observables are then compared to calculations from the default parameterization in CGMF as well as experimental data.

I110 Parameter Optimization for Spontaneously Fissioning Isotopes in FREYA

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For many years, the state of the art for handling fission in radiation transport codes has involved sampling from average distributions. However, such "average" fission models have limited interaction-by-interaction capabilities. Energy is not explicitly conserved and no correlations are available because all particles are emitted isotropically and independently. However, in a true fission event, the energies, momenta and multiplicities of emitted particles are correlated. Recently, several Monte Carlo codes have become available that calculate complete fission events. Event-by-event techniques are particularly useful because it is possible to obtain the fission products as well as the prompt neutrons and photons emitted during the fission process, all with complete kinematic information. It is therefore possible to extract any desired observables, including correlations.

The fast event-by-event fission code FREYA (Fission Reaction Event Yield Algorithm) generates large samples of complete fission events. FREYA employs only a few physics-based parameters. We discuss recent results on optimization of these parameters and compare results with the optimized parameters to available data on prompt neutron and photon emission. The work of R.V. was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. The work of J.R. and L.A.B. was performed under the auspices of the U.S. Department of Energy by Lawrence Berkeley National Laboratory under Contract DE-AC02-05CH11231. This work was supported by the Office of Defense Nuclear Nonproliferation Research & Development (DNN R&D), National Nuclear Security Administration, U.S. Department of Energy.

R111 Microscopic Study on Nuclear Fission Dynamics Within Covariant Density Functional Theory

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Nuclear fission plays crucial roles in the energy application, military, industry, agriculture, medical, and other fields. Fission presents a unique example of a non-equilibrium large-amplitude collective motion in a multi-dimensional space where all nucleons participate with complex correlation effects. Recently, the time-dependent Generator Coordinate Method (TDGCM) has been extended to the study of nuclear fission dynamic properties based on covariance density functional theory (CDFT). The new model is applied to the induced fission of Th isotopes and ^{240}Pu. It provides reliable multi-dimensional potential energy surfaces and acceptable agreement for the fission observables: charge and mass distributions of the fragments; total kinetic and excitation energy distributions, the average number of neutrons emitted and the average neutron energy.

R112 A Monte Carlo Approach for Estimating Fission Fragment Distributions

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The theoretical description of the fission process is still a challenge eighty years after its discovery. For the particular case of fission fragment distributions, current calculations are based on a two-step process. One first determines the most probable scission configurations. This first step can be done by using one of several existing approaches such as the macroscopic-microscopic method or the nuclear energy density functional theory. The second step is the simulation of nuclear dynamics through, e.g. the time-dependent generator coordinate method, time-dependent density functional theory, or semi-classical approaches such as Langevin or random-walk. These give the probability to populate a given scission configuration. The problem with this overall methodology is that scission configurations are almost always characterized by non-integer numbers of particles in the fragment. As a result, current models fail to reproduce the odd-even staggering of charge distributions and neglect the dispersion of the fragmentation distributions associated with each scission configuration. In this work, we describe a novel approach to estimate the full fragmentation distribution for fragments with integer numbers of particles. In the first part of this presentation we will briefly describe the formalism of the method and illustrate it with the limiting case of two well-separated fragments. In the second part, we will present the results we have obtained for the charge and mass distributions on selected actinides using a macroscopic-microscopic approach for the potential energy surface together with a Langevin description of the dynamics.

R113 Calculation of the beta-delayed fission gamma data

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The beta-delayed fission gamma data is defined as the number of gammas emitted per unit time per unit gamma energy after a certain fission event, which is a function of the time after fission. ENDF/B-VII includes the data of n+^{235}U and ^{239}Pu fissions evaluated in 2004 or so. A program is created to calculate the gamma data with the database from ENSDF-2018. The result shows that most of the gamma data agree with those in ENDF/B-VII. However, quite a few obviously have difference. And moreover, the gamma spectrum shapes are not same for different incident neutron energies, should be given individually. Integrated gamma spectrum is also simulated, and compared with the experimental data measured by CIAE, most of the gamma rays are in consistent and the discrepancy implicated we should check the related database, such as the yield and decay data. The data for series of fissions are calculated and convert to ENDF/B6 format, and will be compiled into new CENDL library.

R114 Study of High-energy Fission and Quasi-fission with Inverse Kinematics

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Since its discovery, fission appeared as a complex process where different nuclear properties interplay shaping the characteristics of the emerging fission fragment distributions. In general, the influence of the shell effects is expected to decrease with increasing excitation energy of the fissioning nucleus, making the process driven by almost pure liquid-drop properties. Recently, some features in the total kinetics energy and in the N/Z distributions of the fragments, commonly associated with shell effects, came out in a series of experiments with high excitation energy fusion fission reactions in inverse kinematics. Indeed, fusion-induced fission in inverse kinematics has proved to be a powerful tool to investigate nuclear fission, giving access to other observables with respect to a direct kinematics approach and thereby adding new information on the fission fragments.

The use of inverse kinematics with the VAMOS magnetic spectrometer at GANIL (France) coupled with the SPIDER telescope allows the identification of the fissioning system and permits to extract properties such as the total kinetics energy, and the mass and atomic number distributions of the emitted fragments. With these kind of measurement, the neutron-to-proton ratio of the fragments can also be obtained, which is an observable extremely sensitive to the shell structure effects, as it has been shown in previous experiments within the same campaign.

In the latest experiment of this campaign, a study of high-energy fission and quasi-fission between a ^{238}U beam and a series of light targets was carried out by using the aforementioned technique, in order to probe the role of the shell structure in these processes. This contribution will be focused on the latest results and on the ongoing analysis of the yields of the fragment mass and charge distributions, as well as of the neutron-to-proton ratio, and their link with possible structure effects.

I115 The VERDI Spectrometer - Opportunities and Challenges

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Accurate fission yield (FY) data are essential to develop successful fission models. They also serve to infer properties of potential energy landscapes and scission shapes. Correlation studies on neutron multiplicity and FY disclose how excitation energy is shared in the fission process. However, correlation data are sparse at thermal and especially at higher excitation energies. Therefore, there is a strong international effort to fill the data libraries with high-quality correlated data. Several double-energy, double-velocity (2E-2v) instruments are being developed worldwide, in order to augment the data libraries needs and to suppress uncertainties in the fission fragment (FF) mass distribution; e.g. the SPIDER, STEFF and FALSTAFF spectrometers.

In this work, we focus on the VERDI spectrometer (VElocity for Direct particle Identification) which is a (2E-2v) setup, currently under development at JRC-GEEL. VERDI has two Time-Of-Flight (TOF) sections equipped with 16 Silicon detectors each, in which the FF energies are measured (2E). The FF velocities are also measured by means of their TOF (2v), determined from the times of a MCP (Micro-Channel Plate) and the silicon detectors.

The studies performed on the spontaneous fission of ^{252}Cf(sf) are promising and show a seemingly better mass resolution compared to conventional measurements. The prompt fission neutron multiplicity as a function of FF mass verifies earlier experiments, performed with other techniques. However, the correlation between neutron multiplicity and the Total Kinetic Energy (TKE) has been a challenge to reproduce. This has been linked to the Plasma Delay Time (PDT) effect in the Silicon detectors and the insufficient corrections applied in the analysis procedure. Therefore, the PDT challenge is now subject of a dedicated measurement. A first experiment using a thermal neutron beam is planned.

Moreover, a dedicated simulation study performed on the (2E-2v) method revealed some inherent problems with the deduced neutron multiplicity shape. The often-made assumption of unchanged fragment velocity biases the results. The neutron emission introduces a spread in the velocity distribution and hence in the calculated mass, affecting the neutron multiplicity curve. Therefore, the resolution response function needs to be accounted for and we present a correction procedure.

R116 FALSTAFF, An Apparatus to Study Fission Fragment Distributions: First Arm Results

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Nuclear fission is a complex process that still need fundamental studies. New measurements, particularly of correlated observables, could allow to develop more sophisticated theoretical models to eventually have truly predictive capabilities for the physics of fission. Moreover, the next generation reactors concepts are mostly foreseen to operate in the fast-neutron energy domain and new high quality nuclear data are needed. In this context, a new experimental setup, called FALSTAFF, dedicated to the study of fission is under development.

The FALSTAFF setup aims to investigate the fission of actinides in the fast-neutron energy domain (from a few hundred of keV to a few MeV). Once completed, this two-arm spectrometer will detect both fragments in coincidence and allow to measure their time of flight (ToF) and kinetic energy. The determination of the velocity of the two fragments (2V method) will allow us to reconstruct the mass before neutron evaporation and the measure of the energy will permit to determine the mass of the fragment after neutron evaporation (EV method). By combining the two methods, one will have access to the average neutron multiplicity as a function of the fission fragment mass.

The first arm of the FALSTAFF spectrometer was built. It is composed of two main parts: first, two SED-MWPC (Multi-Wire Proportional Counter) detectors are used to measure the time-of-flight as well as the position of the fragments, thus reconstructing their velocity. Second, an axial ionization chamber gives their kinetic energy and the energy loss profile.

This paper will describe the FALSTAFF setup. Then a study of fission fragments will be presented, exhibiting kinetic energy, velocity and post-evaporation mass distributions obtained with the first arm of FALSTAFF. These observables will be shown for both ^{252}Cf spontaneous fission and ^{235}U neutron induced fission studied at the Orphe reactor. We will also compare those data to both simulation and data from literature.

R117 Performance of A Twin Position-sensitive Frisch-grid Ionization Chamber for Photofission Experiments

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Twin Frisch-grid ionization chambers for the study of fission-fragment properties have been established as accurate and reliable detectors in the last decades. Fission-fragment mass and energy distributions are determined using the double kinetic energy technique, based on the conservation of mass and linear momentum in the process of fission. The polar angle of the collinear fission fragments is determined from the time that free electrons, created by decelerating fission fragments in the counting gas, need to drift from the location of their creation to the anode plates.

Recently, a position-sensitive twin Frisch-grid ionization chamber for fission-fragment and prompt-neutron correlation experiments was designed by Göök et al.. By exchanging the anode plates in the standard chamber on both sides by an array of grid- and strip-anodes, which are rotated by 90° relative to each other and read out by means of resistive charge division, a position sensitivity is achieved that allows the azimuthal fragment emission angle to be determined, too. The performance of a twin position-sensitive Frisch-grid ionization chamber, recently constructed at TU Darmstadt, for future photofission experiments at ELI-NP has been studied using the well-known ^{252}Cf(sf) decay. First results will be presented. Supported by BMBF (05P2018RDEN9).

R118 Fission Fragments Observables Measurements at the LOHENGRIN Spectrometer

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Nuclear fission yields are key data for reactor studies, such as decay heat, criticality or spent fuel radiotoxicity, and for our understanding of the fission process. Despite significant efforts allocated for measuring fission yields during the last decades, the recent evaluated libraries still need improvements in particular in the reduction of the uncertainties. Moreover, some discrepancies between these libraries must be explained.

Additional measurements provide complementary information and estimations of experimental correlations, and new kinds of measurements enable to test the models used in the nuclear data evaluation. A common effort by the CEA, the LPSC and the ILL aims at tackling these issues by providing precise measurements of isotopic and isobaric fission yields as well as the related variance-covariance matrices. Additionally, the experimental program involves a large range of observables requested by the evaluations, such as the kinetic energy dependence of isotopic yields and odd-even effect in order to test the sharing between the two fission fragments of the total excitation energy. Another example is the complete range of isotopic distribution per mass that allows the determination of the charge polarization, which has to be consistent for complementary masses (pre-neutron emission). This information is a key ingredient for the evaluation of isotopic yields.

All of these measurements were carried out at the Institut Laue Langevin in Grenoble with the Lohengrin mass spectrometer by studying thermal neutron induced fission of ^{241}Pm. Methods, results and comparison to models calculations will be presented corresponding to a status on fission fragments observables reachable with this facility.

S119 DeℓFin: A Talys-based Tool for the Comparison of Fission Model Codes

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Many different computer models have been developed to describe fission observables. These models make assumptions on the state of the fragment after scission and simulate the de-excitation through neutron and photon emission until ending up in a stable, or meta-stable, state. The assumptions made on the initial conditions, the excitation energy and angular momentum of the fragments, are different for different codes. However, also the de-excitation process is handled differently and many times model parameters are tuned in order to reproduce measured data.

The aim of this work is to provide a comparison of the model assumptions by decoupling the evaporation process from the de-excitation. This is done by taking the properties of the fragments from the respective code and run the de-excitation through the nuclear reaction code TALYS. The generation of the input files for TALYS, based on the fission fragment properties, as well as the extraction of the fission observables, have been bundled into a dedicated code, DEℓFIN. Hence, a comparison can made between the results of the standalone codes with what is obtained using DEℓFIN, as well as with experimental data. We here present the performance of five different models; GEF, FIFRELIN, CGMF, FREYA and PbP in the prediction of the prompt neutron emission as a function of mass, and highlight features of the respective model code.

S120 Discussion of Atomic Number Measurement of Fission Fragment by the Nuclear Stopping Power

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Atomic number measurement of fission fragment is very important for the research on the fission of actinide nuclei, but now there isn't reliable technique for measuring atomic number. This paper tries to explore a new measurement technique which is based on the theory that the nuclear stopping power is directly proportion to the atomic number. The current signal of Frisch-grid ionization chamber can be used to characterize the specific energy losses of fission fragment in working gas. So the specific energy losses in isobutene of fission fragments emitting from ^{252}Cf have been experimentally measured, and rough partition of the atomic number of light or heavy fragments has been preliminarily obtained. This proves that this new measuring technique is feasible. However this is only a primarily attempt work, for it is found that measurement of nuclear stopping power is mainly affected by the grid inefficiency, and the signal processing method and the preamplifier performance must be improved, too.

S121 Yield Evaluation for Several Chains of ^{235}U+n Fission with Zp Model

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Independent and cumulative yields are evaluated for chains A=95, 99 and 140 from n+^{235}U fission, wherein the ratios are adopted preferably. Decay chain is updated with ENSDF and used to convert cumulative yield from independent yields. The evaluated yields on the same chain are adjusted with Zp model with least square fit method, and consequently, the model parameters, as well as all the yields and covariance on one chain are produced.

I122 RAON: Rare Isotope Accelerator Complex for On-line Experiment

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RAON is under active construction at Daejeon, Republic of Korea. Based on a 400 kW heavy-ion linear accelerator, RAON will deliver a variety of stable and rare isotope beams with wide range of energy (a few keV/nucleon to a few hundreds MeV/nucleon) and high intensity to experimental areas for researches in fields of basic and applied science. Now the fabrication of major components for accelerator systems is under process. In this talk, the status of RAON including progress on accelerator and experimental systems will be presented.

R123 Neutron Activation Experiment of ITER Concrete Based on HINEG D-T Neutron Source

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Institute of Nuclear Energy Safety Technology, CAS• FDS Team

It has been drawn to the attention of ITER that the presence of trace elements in concrete is predicted to lead to an increase in the shutdown dose rate by about 30% after 106 seconds cooling. The main isotopes of interest are Terbium (^{106}Tb), Europium (^{152}Eu and ^{154}Eu) and Tantalum (^{181}Ta). The fractional contribution will increase with time. During ITER nuclear analysis, the concentration of Terbium, Europium and Tantalum are set to the chemical detection limit (e.g. 0.0003 for Eu) and they are predicted to make a contribution to the shutdown dose rate. But this may be erroneous. A better solution, a neutron activation experiment is being carried out to measure the concentration of the three interested elements (Eu, Tb, Ta) in concrete.

In this experiment, the High Intensity D-T Fusion Neutron Generator HINEG was used as a neutron source. A mock-up made of lead and polyethylene was designed in such a way to reproduce as close as possible the neutron energy spectra occurring on the inner wall of the tokamak pit in ITER. The thermal neutron and the 14MeV neutron are important in the neutron energy spectra. A concrete sample (Diameter: 6 cm, thickness: 1.5 cm, about 0.1 kg) was enveloped by the mock-up. In order to measure the concentration of the trace elements (Eu, Tb and Ta) in concrete, reference activation foils of Eu, Tb and Ta were placed in the front and rear ends of the concrete sample, respectively. If we get the activities of Eu, Tb and Ta in concrete and foils, and the concentrations of Eu, Tb and Ta in foils are also known, then the concentration of Eu, Tb and Ta in concrete can be easily obtained. The mock-up will be irritated by HINEG for 10 hours with neutron source of about 10^{12} n/s. After the irradiated sample is cooled for 10 days, 30 days and 90 days, the concentrations of mother nucleus of Eu, Tb and Ta can be measured by HPGe spectrometer.

R124 Development of HINEG and Its Experimental Campaigns

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Advanced nuclear energy becomes essential to solve the problem of increasing energy demands. More research work is needed on nuclear technology and safety before application of advanced nuclear energy. A high intensity D-T fusion neutron generator is keenly needed for the research and development (R&D) of advanced nuclear technology.

The Institute of Nuclear Energy Safety Technology (INEST), Chinese Academy of Sciences (CAS) has launched the High Intensity D-T Fusion Neutron Generator (HINEG) project. The R&D of HINEG includes three phases: (I) HINEG-I has been constructed and successfully produced a D-T fusion neutron yield of up to 6.4×10^{12} n/s. HINEG-I is an important research platform for basic research on neutronics such as validation of neutronics theory and software, measurement and validation of nuclear data, radiation shielding and protection, etc. (II) HINEG-II aims at a high neutron yield via high speed rotating tritium target system and high intensity ion source, which could be used to support the research on validation of advanced nuclear technology, such as materials irradiation, component neutronics performance. The preliminary design and research on key technologies are on-going. (III) HINEG-III is a fusion volumetric neutron source. The integration testing of nuclear system engineering could be performed.

Recently, a series of experiments have been carried out on HINEG facility, such as measurement and validation of nuclear data, neutronics performances of fusion reactor blanket, biological effects of neutron irradiation, fast neutron radiography, and so on. In order to assess the evaluated neutron data for Pb and LBE, FDS team performed the neutron leakage spectra measurement experiment. In this experiment, pulse neutron source was used to irradiate the Pb and LBE samples, and TOF method was used for leakage spectra measurement. The measure result and simulation results with different data library were compared, and it showed that the LBE simulation result with ENDF/B-VII.1 has some discrepancy from measurement result. Base on sensitivity analysis, the discrepancy is caused by the angular distribution data of ^{209}Bi in ENDF/B-VII.

R125 A New LCS γ Source- Shanghai Laser Electron Gamma Source (SLEGS) At Shanghai Synchrotron Radiation Facility (SSRF)

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A new Laser Compton Scattering (LCS) γ source - Shanghai Laser Electron Gamma Source (SLEGS) is under construction in Shanghai Synchrotron Radiation Facility (SSRF) located at Shanghai Institute of Applied Physics. SLEGS produces nearly monochromatic, highly polarized gamma-ray beams from 0.4 to 20 MeV, with its peak performance of total flux up to about 1E8 ph/s. Based on the method of photonuclear reaction, SLEGS aims to basic physics researches, such as nuclear data, nuclear physics and nuclear astrophysics. In addition, SLEGS also tends to carry out the applied research relating to aerospace and nuclear energy, such as space radiation effect research of the aerospace electronic components. A summary of the Technical Design Report for the SLEGS and the associated experimental setup will be discussed in the presentation.

R126 Physics Design of the Next-generation Spallation Neutron Target-moderator-reflector-shield Assembly Mark-IV at LANSCE

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We present the physics design of the next-generation spallation neutron target-moderator-reflector-shield (TMRS) assembly for the Manuel Lujan Jr. Neutron Scattering Center at LANSCE. The new TMRS was developed to improve the neutronic performance of the Lujan Center in the intermediate energy range (keV-MeV) enabling a variety of new nuclear physics experiments. The keV-MeV range is key for a large number of basic and applied nuclear science efforts, particularly related to neutron capture and resonance total cross-section measurements. For many astrophysical applications, the superior generation of keV-MeV neutrons opens the door to a wider range of measurements on unstable targets. These measurements are expected to have an improved signal-to-background ratio, which will help reduce experimental uncertainties significantly. The results of our Monte Carlo study indicate that the new TMRS will generate keV-MeV neutrons with higher intensity and improved energy resolution. At the same time, the new TMRS largely maintains its current performance in the cold and thermal ranges supporting materials research. In summary, the new TMRS has the potential to enhance Lujan Center's experimental capability in a wider interval of neutron energies - cold to intermediate - after its scheduled installation in 2020.

I127 New Equipment for Neutron Scattering Cross-section Measurements at GELINA

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High-resolution measurements of elastic neutron scattering differential cross sections are of interest in nuclear engineering and applications. Furthermore, neutron scattering data are necessary for the determination of parameters describing nucleon-nucleon potentials. A scintillator array for high-quality measurements of elastic neutron scattering has been developed at European Commission's Joint Research Centre (JRC) in Geel, Belgium. The array consists of 32 liquid organic scintillators (16 EJ301 and 16 EJ315) and a digitizer-based data acquisition system. The system has been installed on flight path one, 30-m measurement station, at the GELINA neutron source operated by JRC Geel. Time-of-flight technique is used for incident neutron energy determination, and pulse-shape analysis allows the separation of neutron events from photons. Inelastic scattering can also be separated from elastic scattering by determining the scattered neutron energy from the time-of-flight dependent light-output distributions. The experimental setup and data analysis procedure were validated by performing measurements using carbon and iron samples.

Inelastic neutron scattering is the main neutron energy loss mechanism in a nuclear reactor. For that reason accurate knowledge of inelastic neutron scattering cross sections is crucial, especially for the design of advanced reactors such as the Generation IV concepts. While usually inelastic neutron scattering can be measured using the gamma rays emitted, there are important cases where this is not feasible because of high internal conversion. One such example is the 45-keV transition from the first excited state to the ground state in ^{238}U. To access transitions like this, a conversion-electron spectrometer DELCO (Detector for Electrons from Internal COnversion) has been designed. Preliminary tests have been carried out at JRC Geel. The spectrometer has been tested in different configurations consisting of silicon detectors and a planar germanium detector. The necessity of detecting very low-energy electrons over background caused by the radioactivity of the sample makes these measurements extremely challenging. The current status of the spectrometer, results from the first tests, and future prospects will be discussed.

R128 Current Status of KAERI Neutron Time-of-flight Facility and Its Performance Prediction Through Monte Carlo Simulations

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The neutron time-of-flight facility construction project was started in December 2011 by establishing a Nuclear Data Center at the Korea Atomic Energy Research Institute (KAERI). The project consists of three main parts. The first is a superconducting electron accelerator that needs to be repaired today. The expected operating conditions are 17 MeV, an average current of 0.08 mA, and a 20ps pulse width with 200 kHz. The second is a photo-neutron source that uses liquid lead to produce neutrons and needs to change its arrangement of components. The final step is to construct a measurement building where experiments are performed to measure nuclear data.

Unlike equipment manufacturing and repair, construction of the nTOF measurement building was considerably delayed due to budget and various licensing issues. However, the construction eventually began in May 2018 and be completed by the end of the year. A building simply consists of a big hall (6m $\times$ 6m $\times$ 10m) for the measurement experiments and three rooms for processing the data obtained from the experiments.

We estimated the expected performance of our nTOF facility through Monte Carlo simulations. The expected neutron production rate is about 4.0×1011 neutrons/s, the neutron energy range is about 7 MeV to 100 KeV, and the flight path length is between 5m and 15m.

In this presentation, the current status of KAERI neutron time-of-flight facility and its predicted performance through Monte Carlo simulations will be presented.

R129 Neutron Beam Line for TOF Measurements at the Spanish National Accelerator Lab (CNA)

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Few years ago the Spanish National Accelerator Lab (CNA) developed the first accelerator-based neutron facility in Spain, HiSPANoS (Hispalis Neutron Source). The first applications of the line were related to integral measurements applied to nuclear astrophysics, dosimetry and single event effects produced by neutrons in electronic devices.

The successful of HiSPANoS pushed the enhancement of the facility. A new line of the Tandem accelerator was designed for neutron time-of-flight (TOF) experiments. In collaboration with the NEC Company, two devices were designed for pulsing ion beams (chopper) and for compressing in time (buncher) the pulsed beams, both located in the pre-acceleration stage.

The beam chopper consists of a pair of electrically deflecting plates, mounted in parallel to the initial ion beam. One plate is normally polarized with dc voltage deflecting the beam on an absorbing beam catcher. The second plate is connected to an electronic switch, which with a desired repetition rate provides a voltage that compensates the previous one producing an oscillation of the beam in the transverse direction, thus creating a beam pulse (60 ns). The buncher consists of a pair of tubular electrodes. It is mounted coaxially to the ion beam, after the chopper. The electrodes are supplied with locked radiofrequency voltage phase. The entrance and the exit gaps of the tubular bunching electrodes are used for the time compression of the beam pulse to 1 ns.

The chopper-buncher system has been already installed and commissioned. Proton beams are delivered with repetition rates from 62.5 kHz to 2 MHz and 1 ns pulse width.

In order to check the performance of the whole TOF system, we have carried out the measurement of the neutron spectrum produced by ^{7}Li(p,n)^{7}Be reaction at Ep = 1912 keV. Such spectrum has been measured by TOF few times and it can be considered a standard neutron field, in particular en nuclear astrophysics. We will show the results of such experiment performed at CNA. The excellent performance of the accelerator, the chopper-buncher system and the acquisition system allows us to offer the TOF line at HiSPANoS-CNA to the neutron community.

R130 Commissioning of An MRTOF-MS at IMP/CAS

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The multi-reflection time-of-flight mass spectrometer (MRTOF-MS) has been developed as a new device in recent years for mass spectrometry and isobaric separation with ion bunches with kinetic energies in the range of a few hundreds of electron-Volts to a few kilo-electron-Volts. Up to now, many MRTOF-MSs have been commissioned or under construction.

An MRTOF mass analyzer is being constructed at IMP/CAS (Institute of Modern Physics, Chinese Academy of Sciences). A new method including two sub-procedures, global search and local refinement, has been developed for the design of MRTOF-MS. The method can be used to optimize the parameters of MRTOF-MS both operating in mirror-switching mode and in in-trap-lift mode. By using this method, an MRTOF mass analyzer, in which each mirror consists of five cylindrical electrodes, has been designed. With a total time-of-fight of 6.5 ms for the ion species of ^{40}Ar^{1+}, the maximal mass resolving power has been achieved to be 1.3×10^5 in the mirror-switching mode, and 1.5×10^5 in the in-trap-lift mode. The simulation also reveals the relationships between the resolving power and the potentials applied on the mirror electrodes, the lens electrode and the drift tube. This MRTOF-MS has been constructed and is being commissioning now. The preliminary test results show that it works fine. In this conference, we will present the design details, optimization method and the test results obtained.

S131 Laser-driven Neutrons for Time-of-flight Experiments?

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Pulsed neutron beams entail a powerful probe in nuclear physics with applications in a wide variety of fields. Nowadays, these neutron beams are produced in conventional accelerator facilities in which the time-of-fight technique is used to determine the kinetic energy of the neutrons.

In the last decades, the development of ultra-short (femtosecond) and ultra-high power (> 1019 W/cm2) lasers has opened the door to a vast number of new applications, among others the production and acceleration of ions. The use of these ion beams for neutron production has allowed us to reach fluxes per pulse which are competitive with more conventional neutron sources; this kind of laser source could be a promising alternative for the community of pulsed neutron beam users. Nevertheless, these laser-driven neutrons have not been used in a nuclear physics experiment so far.

In this context, our research team from Universidad de Sevilla, in collaboration with other research teams with a large experience in pulsed neutron beams, intends to carry out a series of experiments. The main goal is to produce and characterize laser-driven neutrons but optimizing the analysis, diagnostic and detection techniques currently used in conventional neutron sources to implement them in this new environment. This way, we can lay down the viability of carrying out nuclear physics experiments in this kind of sources by identifying the advantages and disadvantages of this production method.

To achieve this purpose, we expect to perform experiments in different laser facilities in Spain (L2A2 in Santiago de Compostela and CLPU in Salamanca) and Europe (CILEX in Paris and LEX Photonics in Munich).

S132 The Prototype Dosimetry System to Protect MPD Electronic Equipment at the New NICA Collider.

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In time of the work the Multi-Purpose Detector (MPD), which is a part of the new Nuclotron-based Ion Collider fAcility (NICA) located in Dubna (Russia), can burst in an accidental irradiation caused by the NICA's or MPD failure or its abnormal functioning. It can result in the presence of the radiation exposure in the Platform, where the Slow Control electronic equipment will be installed. The Platform is located a few meters from the MPD. There is a risk of destroying the electronics Slow Control System and Data Acquisition System. The article describes the method of prevention of such situation by the continuous dosimetry monitoring on the Slow Control Platform and alarming when the radiation threshold is overrun.

S133 Neutron Source Evaluation for the Neutron Data Production System (NDPS) At RAON

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As NDPS at RAON is neutron data production facility, it can produce various neutron sources from the multiple targets such as C, Li, Co, and W by $\sim$ 88 MeV, 600 MeV protons and $\sim$ 53 MeV deuteron beams. The design of a neutron facility and source will depend on the users' requirements and the users' demands. A key point to evaluate these sources in relation to a given purpose is to answer the following questions: 1) what kind of spectrum we can provide? 2) what other particles we have? 3) what are the physical properties of this source 4) how accurate this estimate is? We evaluate several neutron sources using MCNP, PHITS, and ADVANTG. In this study, we discuss several types of neutron sources available at RAON. This evaluation is based on the actual facility layout of NDPS at RAON.

S134 A Design of Transition-edge Sensor for Measuring Kinetic Energies of Fission Fragments

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It is necessary to accurately measure the kinetic energies of fission fragments when using the time-of-flight method to measure the mass of fission fragments. The ionization chamber and the Au-Si surface barrier detector are common kinetic energy detectors. However, the energy loss of the entrance window of the ionization chamber is difficult to calibrate, and the Au-Si surface barrier detector has a serious recombination effect, which make it very hard to accurately measure the kinetic energy of fission debris. The transition-edge sensor (TES detector) is a cryogenic calorimeter that can be used to measure the energy deposition by measuring the temperature variation induced by absorbing the energy of the incident particle. There is no energy loss of the entrance window and recombination effect. The highest resolution of TES detector achieved in references is 0.02%. In this paper, we designed a TES detector for measuring kinetic energies of fission fragments. The energy deposition processes of fission fragments in TES detectors made of different materials and structures were simulated. The heat conduction processes of TES detectors with different volume, shapes and materials were calculated. The thermal diffusion time and thermal recovery time of those detectors were obtained. The design of TES detector for kinetic energy measurement of fission debris was preliminarily completed.

I135 Status and Perspectives of the Neutron Time-of-flight Facility n_TOF at CERN

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Since the start of operation in 2001, based on an idea of Prof. Carlo Rubbia, and thanks also to the construction of a second experimental area in 2014, n_TOF has become one of the most forefront neutron facilities in the world, providing a wealth of new data on neutroninduced reactions of interest for Nuclear Astrophysics and applications to various fields in Nuclear Technology. The unique features of the facility will continue to be exploited in the future, to perform challenging new measurements addressing the still open issues and longstanding quests in the field of neutron physics. This contribution will outline the main characteristics of the n_TOF facility, and their relevance for neutron studies in different areas of research, such as Nuclear astrophysics, Nuclear energy and medical applications. Finally, the future perspectives of the facility will be presented, including the upgrade of the spallation target, the setup of an imaging installation and the construction of a new irradiation area.

R136 Fission Studies at IGISOL/JYFLTRAP: Simulations of the Ion Guide for Neutron-induced Fission and Comparison with Experimental Data

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For the production of exotic nuclei at the IGISOL facility an ion guide for neutron induced fission has been developed and put in use in experiments. Fission fragments are produced inside the ion guide and collected using a helium buffer gas. Meanwhile, a GEANT4 model has been developed to simulate the transportation and stopping of the charged fission products. In a recent measurement of neutron induced fission yields, implantation foils were located at different positions in the ion guide. The gamma spectra from these foils and the fission targets are compared to the result from the GEANT4 simulation.

In order to allow fission yield measurements in the low yield regions, towards the tails and the in symmetric part of the mass distribution, the stopping and extraction efficiency of the ion guide has to be significantly improved. This objective can be achieved by increasing the size while introducing electric field guidance using a combination of static electrodes and an RF-carpet. To this end, the GEANT-model is used to optimise the design of such an ion guide.

R137 **Discovery of New Neutron-moderating Materials at ISIS Neutron and Muon Source**

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The way to identify and characterize potentially interesting neutron-moderating materials is to measure their neutronic properties: total cross-section and vibrational density of states (VDoS) and use the obtained results for the creation of the so-called scattering kernels. These scattering kernels linked with contemporary Monte Carlo radiation transport codes are used then to perform "virtual" experiments and test effectiveness of new materials for neutron moderation.

In this paper, the possibility of performing such a neutronic characterization at the ISIS Neutron and Muon Source [1] using two of its instruments, VESUVIO [2] and TOSCA [3], will be described. VESUVIO is an indirect-geometry spectrometer mainly employed for the determination of nuclear quantum effects in materials using Deep Inelastic Neutron Scattering. However, in recent years, VESUVIO has become an experimental station for Epithermal and Thermal Neutron Analysis (ETNA - for more details see reference [4]), where, for example, the energy range accessible for neutron transmission experiments (total cross-section determination) spans 8 orders of magnitude, from a fraction of meV to tens of keV. Recently upgraded [5] TOSCA instrument is an indirect-geometry inelastic neutron spectrometer optimized for high resolution vibrational spectroscopy in the energy transfer region between -24 and 4000 1/cm which makes it a perfect tool for the determination of vibrational density of states of moderator material candidates. As an illustration of the ISIS Neutron and Muon Source capability to significantly improve and accelerate the process of identification and characterization of new neutron-moderating materials, the results of recent measurements of neutronic properties of one of the possible moderator materials, triphenylmethane, using VESUVIO and TOSCA, will be discussed.

[1] https://www.isis.stfc.ac.uk/Pages/home.aspx.
[2] https://www.isis.stfc.ac.uk/Pages/vesuvio.aspx.
[3] https://www.isis.stfc.ac.uk/Pages/tosca.aspx.
[4] C. Andreani, M. Krzystyniak, G. Romanelli, R. Senesi and F. Fernandez-Alonso, "Electron-volt neutron spectroscopy: beyond fundamental systems", Advances in Physics, 2017,
http://dx.doi.org/10.1080/00018732.2017.1317963.
[5] R. Pinna et al, Nuclear Inst. and Methods in Physics Research, A 896 (2018) 68-74,
https://doi.org/10.1016/j.nima.2018.04.009.

R138 Development of SONATE, A Compact Accelerator Driven Neutron Source

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Today facilities providing high brilliance neutron beams at thermal energy (several meV) are of primary importance for various research topics such as medical applications (neutron capture therapy, radioisotope production), condensed matter neutron scattering experiments, neutronography and nuclear physics experiments.

Most of these experiments are currently performed at nuclear reactors. However these facilities are aging and the political context does not favored the building of new ones. This is the case in CEA-Saclay (France), where the Orphee reactor used by the neutron scattering community is planned to shutdown in 2019. Consequently, another local facility being able to provide high brilliance neutron beam has to be developed.

Fission, spallation and fusion reactions based facilities could be a solution but are not suited as local facilities because of respectively political choices, their high costs, the need of heavy radiation shielding and their low neutron yields. The recent development of high intensity accelerators makes nuclear reaction involving proton/deuteron impinging on a light target (beryllium, lithium) facilities competitive with nuclear reactors in term of brilliance and cost.

At CEA-Saclay, a compact accelerator driven neutron source (CANS), named SONATE, is being developed in taking advantage of the IPHI proton injector which is able to deliver an intensity up to 100 mA. With this high intensity accelerator, the remaining challenges to maximize the source brilliance mostly concern the optimization of the target-moderator-reflector (TMR) configuration (materials, geometries) impacting the neutron yields and the neutron focusing during the slowing-down stage. This optimization problem is tackled with a Geant4 simulation.

After recalling the needs and the challenges associated to CANS developments, I will present the latest Geant4 TMR configuration optimizations. A special attention will be paid to nuclear models and nuclear data used to describe the proton/target, with beryllium and lithium targets, and neutron/material interactions. The latest experimental results will be also reported.

R139 Introduction of the C6D6 Detector System of the Back-n at CSNS

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The Back-n white neutron source (Back-n) at China Spallation Neutron Source (CSNS) is the first spallation white neutron source in China,and it can be used to do neutron capture cross section measurement. A C6D6 detector system was built in the Back-n experimental station, and the pulse height weight technique (PHWT) was used to determine the detection efficiency. A few of experiments were carried out to measure the characteristics of the neutron beam, such as the flux, time resolution and the beam profile. And the neutron radiative capture cross section of ^{197}Au was measured to testify the C6D6 system and the neutron beam line.

I140 Radioactive Ion Beam Manipulation at the IGISOL-4 Facility

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The IGISOL-4 facility [1] in the JYFL Accelerator Laboratory of the University of Jyväskylä (JYFL-ACCLAB) produces low-energy radioactive ion beams utilizing an ion-guide based, ISOL-type mass separator. The speciality of the ion-guide technique employed at the IGISOL is that it is based on the survival of recoil ions in noble gas following a nuclear reaction in a thin target, which mechanism is applicable for all elements, in particular for the refractory ones. Combined with charged particle-induced fission, IGISOL provides a wide selection of neutron-rich beams.[2] Neutron-deficient beams are produced via fusion-evaporation reactions[3]. Laser ionization techniques have been developed for particular cases, e.g., a hot cavity laser ion source for silver production[4].

The presentation will concentrate on the ion manipulation techniques utilised at IGISOL-4 facility. The JYFLTRAP Penning trap is used to both precision mass measurements and as a high MRP filter to produce monoisotopic source. [5] Advanced techniques such as Ramsey cleaning allow separation of low-lying isomeric states, 233 keV ^{133m}Xe as an example [6]. More demanding separation is reached via PI-ICR technique [7]. In the near future, a MR-TOF device [8] will be commissioned. It is utilised as pre-separator for JYFLTRAP, and for radioactive sample production as such. It is expected become in routine operation by 2020. In addition to IGISOL, the recoil separators RITU and MARA produce radioactive ion beams. The new vacuum mode recoil separator MARA [9] has proven as an effective tool for the production of proton-rich isotopes. Its expansion, MARA-LEB, the low energy branch of MARA, will utilize the gas cell (ion guide) technique and laser ionization, providing means to convert MeV-scale radioactive beams to low energy ones[10].

In the presentation, the capability of ion manipulation techniques at the IGISOL and MARA will be discussed.

[1] I.Moore, et al, NIMB, 317(2013)208.
[2] H.Penttila, et al, EPJA, 52(2016)104.
[3] T.Eronen, et al., PRC, 95(2016)025501.
[4] M.Reponen, et al., Rev. Sci. Instrum. 86(2015)123501.
[5] T.Eronen, et al., EPJA, 48(2012)46.
[6] K.Perajarvi, et al., Applied Rad. Isotopes, 71(2013)34.
[7] D.Nesterenko, et al., EPJA, 54(2018)154
[8] R.N.Wolf, et al., NIMA, 686 (2012) 82.
[9] J.Saren, Ph.D.Thesis, JYFL Res. Report 7/2011, https://jyx.jyu.fi/bitstream/handle/123456789/40107/1/978-951-39-4512-1.pdf
[10] P.Papadakis, et al, Hyp. Int. 237(2016)152.

R141 Development of Stainless-steel Reflector for VR-1 Training Reactor

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Light-water reactor cores are commonly surrounded by a stainless-steel and water reflector. Reflectors are improving power distribution in the core, reducing leakage of neutrons and thus also protecting pressurized vessel from neutron irradiation and following embrittlement. Contrary to standard procedures utilized for generation of fuel assembly data, reflector elements require a special approach. The major difficulty with reflectors is represented by an absence of neutron sources in the reflector elements. Some artificial neutron source simulating the realistic source of neutrons from neutron leakage from surrounding fuel assemblies must be added in the calculation model. Reflector data in the full-core calculations have a great impact on power distribution in the reactor core. Research in this field is usually focused on square geometry, and therefore accurate data for hexagonal geometry are lacking. Improvements in this area are needed.

Training Reactor VR-1 is used for measurements related to nuclear engineering. Department of Nuclear Reactors operating this reactor at Czech Technical University in Prague is currently designing reflector elements containing stainless-steel in order to provide measurable characteristics that can be compared to calculations realized by either Monte-Carlo codes or PARCS. This article summarizes the methodology of development of the reflector assemblies to improve their similarity with VVER-1000 reflector. Impact of evaluated nuclear data will be assessed.

R142 Characterization of Neutron Source for Nuclear Data Experiment in China

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Before 2000, The mono-/quasi mono-energy neutron provided by the reactor, 600kV Crocraft-Walton Generator, 4.5MV Van de Graaff Accelerator and Tandem Accelerator for nuclear data experiment in China, which in general below 30MeV include thermal neutron, 2.5MeV, 5MeV, 14MeV etc. Although characters of the neutron source clearly known, but that can not fully satisfy the requirments from neutron data measurment. In 2018, China Spallation Neutron Source-White Neutron Source platform completed, the primary neutron beam characteristic parameters obtained by experiment, covering the energy range eV-100MeV, which basically met the data measurement needs. The development of a narrow beam(2.6ns)- white neutron platform based on 100MeV cyclotron is currently underway and is expected to be accomplish in 2020, which will provide high qulity fast neutron beam for nuclear data experiment in future.

R143 Double-bunch Unfolding Method for the CSNS Back-n White Neutron Source

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The nominal operation mode of the CSNS accelerator complex has two bunches per pulse. The two bunches have a time interval of 410 ns. For experiments using the time-of-flight method to measure the neutron energy, the double-bunch property reduces the TOF measurement accuracy of high-energy neutrons, causing errors in the energy determination. In order to improve the measurement accuracy of TOF, the double-bunch spectrum needs to be unfolded. In this study, the Bayesian algorithm is used to develop a program to unfold the double-bunch spectrum. Through the simulation data test, the unfolding algorithm is proven feasible and effective, and the unfolding error caused by the algorithm is less than 1%. The unfolding program is now applied to the data treatment of different experiments, as one example, the data of a neutron energy spectrum measurement is used here.

S144 Formation of A Thermal Neutron Beam and Measurement of Its Intensity at the Tandetron Accelerator

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Joint Stock Company "State Scientific Centre of the Russian Federation - Institute for Physics and Power Engineering named after A.I. Leypunsky"

The need to calibrate the tested gas-discharge detectors suggests the presence of neutron beams with well-known parameters. To this end, work was carried out on the formation of a thermal neutron beam and the measurement of the spatial distribution of its intensity. The ^{7}Li(p,n) nuclear reaction on metallic lithium installed in a cooled target device of the Tandetron accelerator was used as a neutron source. The beam was formed using a moderator block. The intensity of the thermal neutron beam was measured by the activation method.

S145 Analysis of the Systematic Errors in Determining the Time Stamp for the Digital Time-of-flight Neutron Spectrometer.

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In [1-3] was shown that there is the systematic shift in the time stamp from gamma-rays, depending on the pulse amplitude. At the same time, the analysis of such the time shift for the signals from neutrons was not made, and the correction value for neutrons was taken the same as for gamma-rays. The aim of the work was the analysis the systematic errors that occur in determining the time stamp for the neutron signals, as well as their possible influence on the results of the neutron spectra measurements by the time-of-flight method. A digital neutron spectrometer based on a stilbene crystal was used as a detector.

As a result of the measurements carried out on the Tandetron accelerator, it was shown that the amplitude dependence of the time shift for signals from neutrons and gamma-rays is noticeably different. It was shown that the use of the time shift correction obtained from the analysis of the prompt gamma-rays peak for the neutron signals can lead to a significant distortion of the shape of the measured spectrum. This is especially actual for the time-of-flight measurements using the short flight path.

[1] N.V. Kornilov, I. Fabry, S. Oberstedt, F.-J. Hambsch, Nuclear Instruments and Methods in Physics Research Section A 599 (2009) 226.
[2] A. Gook, F.-J. Hambsch and M. Vidali, Physical Review C 90 (2014) 064611.
[3] A.S. Vorobyev, O.A. Shcherbakov, Yu.S. Pleva, A.M. Gagarski, et al., Nuclear Instruments and Methods in Physics Research Section A 598 (2009) 795.

S146 In Searching of Leakage Location of Underground High Voltage Electric Cable Using Radiotracer Method

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A radiotracer technique has been applied for searching the leakage location of underground high voltage electric cable which spand along 7 km approximately from Manggarai to Jatinegara electric stations. The electric cable which burried at the depth of 2.5-3 meter underground was designed to provide electric power of 150 kV voltage for housing, shopping mall, street lighting and public facilities consumptions. A 20 ml of bromine-82 isotope with activity around 5 mCi in form of para-dibromobenzene (C_6H_4-Br_2) compound solution has been injected at the injection point which located around at the middle length of the spanned cable. Both ends of the cable one at the Manggarai station and the other one at the Jatinegara station were blocked to facilitate that the oil flow in the cable is only possible from the injection point to the point of leakage. Prior to injection, four scintilllation detectors had been placed on the cable line around the injection point with the positions were two detectors at Manggarai direction and the other two detectors were at Jatinegara direction, respectively. To accelerate the time of measurement, a high air pressure from air compressor was utilized to push the oil to make it able to flow easier into the cable through the injection point. The recorded radiation intensity by the detectors were used for searching the direction of the oil flow in the cable which in turn it is used to determine the leak location. The measurement results showed that the direction of oil flow in the cable was from the injection point to Manggarai and the location of leakage was identified at the area in front of Manggarai train station as justified by accumulation of oil around the cable in that area.

I147 Assessment of Representativity of the PETALE Experiments for Validation of Swiss LWRs Ex-core Dosimetry Calculations

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The international experimental program PETALE will be carried out by LRS/EPFL team at the CROCUS research reactor in collaboration with CEA Cadarache. The program aims at performing new measurements appropriate for validation of the neutron deep penetration simulations through the materials composing the reactor pressure vessel, as well as for evaluation of their reflector properties.

In the given paper the representativity of the PETALE experimental set up and planned measurements with respect to operational LWR reactors dosimetry and activation evaluations is assessed based on the application of the PSI in-house tool NUSS. The NUSS tool allows realization of stochastic sampling of the nuclear data using the covariance matrices available in the modern nuclear data libraries. The representativity and systems similarity can be assessed then based on the resulting Pearson correlation coefficients.

The ultimate goal of the work is first of all to assess if the planned PETALE measurements could be applicable for extension of the validation database for the PSI calculation methodology for LWR reactor dosimetry applications. Secondly, provided that the PETALE measurements are found potentially useful for the task above, the information on the correlations between the PETALE neutron detectors' responses and the reactor dosimetry quantities of interest, including the measured data from Swiss NPPs, shall be presented and discussed.

R148 Development and Verification of WIMS-D Libraries for Advanced Self-shielding Method

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Specialized WIMS-D nuclear data libraries have been developed to meet the requirement of the advanced lattice code MOCHA, which Embed Self-Shielding Method (ESSM), an advanced self-shielding method is applied in. Recent WIMS-D libraries based on WIMS-69 or XMAS-172 energy group structures split the resonant groups and the thermal groups at 4.0eV, which ignores some resonance reactions distributed in the thermal groups. A more rational and scientific energy group structure meshing scheme has been employed in these specialized WIMS-D libraries. Ultra-fine multigroup library is also required in the ESSM lattice code. The variety of isotopes contained in the ultra-fine multigroup library has been enriched in order to meet the explicit treatment in the burnup calculation. Moreover, a nuclear data library production system, written in the Python language, was developed to automate the production, modification and management of WIMS-D library.

R149 Study on Kinetic Characteristics of Krypton and Xenon in Molten Salt Reactor System

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A numerical code for the dynamic distribution calculation of krypton and xenon in primary loop system was developed for molten salt reactor (MSR) based on Mathematica7.0, involving the function of dealing with flow and on-line removing. Results for the static burnup using this code was in good agreement with ORIGEN-S, with deviation less than 10%. Distribution and dynamic characteristics of krypton and xenon in the primary loop were obtained in case of flow reginalzation and online removal. Results show that there is a 6.61% underestimate of the total ^{135}Xe activity for static burnup model and a 1.46% underestima of the total activity of krypton and xenon in the system. The total activity of krypton and xenon in the exhaust gas system is 1.84 × 1016Bq with the maximum removal fraction, of which ^{83m}Kr, ^{85m}Kr, ^{87}Kr, ^{88}Kr, ^{133}Xe, ^{135}Xe and ^{138}Xe account for about 95.6%. The total activity of krypton and xenon in the primary loop system is 2.64 × 1014Bq with the maximum removal fraction, of which ^{138}Xe, ^{135m}Xe, ^{134m}Xe, ^{87}Kr and ^{83m}Kr account for about 93.6%.Compared with static burnup model, more accurate results could be achieved for dynamic distribution of krypton, xenon and these precursor in the molten salt of primary loop. The analysis results can provide a theoretical basis for the management scheme of Krypton Xenon and Iodine source terms, the cooling design of the radioactive exhaust system and the source term analysis in accident conditions for the molten salt reactor.

R150 Development and Engineering Verification of A Multi-group Library for PWR Lattice Calculation

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A multi-group library is developed for the PWR lattice code PANDA in Shanghai Nuclear Engineering Research and Design Institute (SNERDI). The library is designed based on engineering requirements and owns some unique features. It is mainly processed by the NJOY code, and some auxiliary tools are utilized to improve the efficiency and accuracy. Verifications are performed which demonstrate the good applicability for engineering applications.

R151 Deacy Data for Decay Heat and Anti-neutrino Spectra Calculations

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An assessment and overall review has been undertaken of the decay data needs for both decay-heat and antineutrino spectral calculations. This extensive study has been performed under the auspices of the IAEA Nuclear Data Section, and has covered the following activities:

(1) Assessments of the decay schemes of the fission fragments that contribute significantly to the decay heat of fifteen different fission systems. The impact of irradiating these systems by means of highly specific energies of neutron pulse as a function of the cooling time after irradiation has been determined by means of systematic calculations with the FISPACT inventory code [1]. An ordered total of 104 fission products were identified as the most important contributors from the tables generated [1], and a series of thorough assessments of their evaluated decay data as adopted from ENSDF was performed [2]. These studies generated recommendations for measurements by means of high-resolution gamma-ray spectroscopy (HRGS) and/or total absorption gamma-ray spectroscopy (TAGS) that arose as a consequence of particular nuclides being defined with inadequate decay schemes, along with the potential existence of the Pandemonium effect[3]. Revision of an existing evaluation might also be merited.

(2)A comprehensive listing of all the TAGS measurements performed by the Valencia-Nantes and ORNL groups since the publication of the NEA/WPEC-25 priority list [4], including all measured beta feedings.

(3)Systematic studies of the impact of the above measured beta feeding intensities on decay heat calculations, based on different evaluated libraries, such as ENDF/B-VIII.0, JEFF-3.3 and JENDL-4.0. The aim of this work is to provide a clear assessment of the impact of all the recent TAGS measurements in calculations of decay-heat and antineutrino spectra for a wider range of fissioning systems, and to re-assess the remaining needs for TAGS and/or HRGS measurements.

[1] M. Fleming, J.-Ch. Sublet, Report CCFE-R(15)28/S1, June 2015.
[2] ENSDF: Evaluated Nuclear Structure Data File. Available online at: www.nndc.bnl.gov/ensdf/
[3] J.C. Hardy, L.C. Carrez, B. Jonson, P.G. Hansen, Phys. Lett. 71B, 307-310 (1977).
[4] M.A. Kellett, A.L. Nichols, O. Bersillon, et al., NEA/WPEC-25, OECD/NEA, Paris, 2007, ISBN 978-92-64-99034-0.

R152 Fine Structure in Nuclear Reactors Antineutrino Spectra

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Nuclear reactors are copious sources of electron antineutrinos, with about 10^21 antineutrinos emitted per second for a typical power reactor. These electron antineutrinos are produced by the beta-minus decay of the more than 800 neutron-rich fission fragments, which are the debris from the main source of energy generation in a reactor, the neutron induced fission of actinide nuclides. Recently, the transformation of electron antineutrinos into the other two flavors was measured by three large-scale experimental collaborations, Daya Bay, Double Chooz and RENO. These experiments also confirmed a deficit of antineutrinos of about 5% at short distances put in evidence in 2011 following a re-assessment of the conversion procedure to obtain antineutrino spectra from the measured electron spectra. This intriguing deficit, as well as a spectrum distortion, has triggered a number of short distance reactor experiments; additionally, new projects will explore the possibility of monitoring the performance of nuclear reactors and tracking ^{239}Pu for non-proliferation treaty verification.

Electrons and antineutrinos produced in beta-minus decay, unlike their sharp-peaked gamma-ray counterparts, have broad energy distributions. In this work, an investigation using the highest-fidelity nuclear databases to date shows that the signature from individual fission products could be disentangled from the total spectrum. To achieve that, a novel yet simple numerical procedure has been developed. In the analysis of the Daya Bay antineutrino spectrum, this new tool allows for the identification of just 4 nuclides, ^{95}Y, ^{98,102}Nb and ^{102}Tc. A similar analysis performed on the ^{235}U electron spectrum reveals also the presence of ^{96}Y and ^{92}Rb. The reason beyond this ability to identify individual products is that the emission of antineutrinos in a nuclear reactor is not a purely statistical process: out of the 800 fission products, a smaller number of them will contribute considerably to the sum antineutrino spectrum. Finally, we explore the possibility that using these individual contributions can rule out parameters in the 3+1 model, that is, a fourth sterile neutrino.

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R153 Rational Function Representation of Point-wise Nuclear Cross Sections and Applications to Doppler Broadening

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Direct Doppler broadening of nuclear cross sections in Monte Carlo codes play an important role in multi-physics coupling considering thermal-hydraulics feedback. The windowed multipole representation method proposed by CRPG group from MIT provides an analytical way of Doppler broadening with high efficiency. However, the resonance parameters are required by this method such that only 2/3 of the ENDF/B-VII.1 nuclides can be processed. Some important nuclides needed in reactor applications such as Oxygen-16 and Hydrogen-1 are directly represented in point-wise form in the evaluation nuclear data library hindering the practicality of this approach. This paper presents a new fitting method for nuclear point-wise cross sections data that yields a rational function form analogous to the multipole representation. The Vector Fitting technique which originates from the field of signal processing was applied to the fitting of point-wise cross sections. Poles and residues from Vector Fitting were generated for Oxygen-16, Hydrogen-1, Boron-10 and Boron-11 and processed in the windowed multipole format. These new libraries were tested by direct comparison of the microscopic cross sections before and after Doppler Broadening, and by integral comparisons using a typical PWR pin cell from the BEAVRS benchmark. Results indicate that the new libraries are equivalent to the point-wise representation with the added benefit of allowing on-the-fly Doppler broadening without the need for temperature interpolation. Runtimes are approximately 28% slower using the multipole representation on this example problem compared to a single temperature ACE file.

R154 Radiological Assessments of the Chemical Plant of the Molten Salt Fast Reactor in the Frame of the SAMOFAR H2020 Project

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The Molten Salt Fast Reactor (MSFR) is a reactor concept that is able to operate by using a liquid fuel based on LiF-ThF_4-UF_4 molten salt at temperatures ranging between 650 and 750°C. One of his advantages is that it can be operated in the same time as a burner and a breeder. Since August 2015, the safety aspects of the overall MSFR concept are studied within the project SAMOFAR (Safety Assessment of the Molten Salt Fast Reactor) in the Horizon 2020 EC/Euratom research programme. The objectives of the SAMOFAR project are to prove the innovative safety of the MSFR concept by advanced experimental and numerical techniques, to deliver a breakthrough in nuclear safety and optimal waste management, and to create a consortium of stakeholders to demonstrate the MSFR beyond the project. The present work is part of the Workpackage 5, aiming to assess the safety issues related to the chemical plant.

The proposed chemical plant consists of several separation and/or storage stages in order to clean-up the fuel salt from the fission products and to recycle the actinides to the reactor core. Its objective is to treat 40 liters a day of used fuel collected into the core. Due to the unstable isotopes contained into the molten salt, the evolution of the extracted inventory has to be performed in each stage of the plant. For this purpose, new developments have been addressed to solve the Bateman equations, which are required to treat the evolution of the radioactive inventory, in coupling with the chemical separation of specific isotopes along the chemical loop. The evolution of radioactivity and residual heat have been assessed in each stages of the chemical plant, including the long-term storage zones. The criticality hazard and the required shielding have also been evaluated.

First, the objectives of the project SAMOFAR will be introduced, including the main features of the MSFR. Secondly, the methodology used to treat the evolution of the inventory along the chemical loop will be presented. A specific focus on the nuclear data used and their associated uncertainties in the safety observables will be discussed.

R155 Reaction Rate of Transmutation ^{129}I, ^{237}Np, and ^{243}Am: Modeling and Comparison with the Yalina-thermal Facility Experiments

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The purpose of the present work is Monte-Carlo simulation of the neutron field and reaction rate of transmutation of the long-lived fission product and minor actinide and corporation with experimental data obtained on the Yalina-Thermal facility. The Yalina-T facility is a zero-power subcritical assembly driven by a high-intensity neutron generator. Measurements of keff were performed in static and pulsed modes at Yalina-T.

The spatial and energy distribution of neutrons and reaction rate of transmutation were calculated by MCU and MCNP. The system calculations were carried out using nuclear data libraries from various origins since there can be significant differences in cross sections for various reaction processes including fission. The libraries JEFF and ENDF/B were used in this work. Calculation results were compared with experimental values in this work. Obtained results are interesting for estimation of nuclear data, for the development of models and codes using for ADS development.

S157 Neutronic Parameters and CPS (control and Protection System) Worth Calculation of Thermal Research Reactor Using MCNPX Code

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One of the main attributes of reactor core design is finding the best distribution of the core controls and protection systems. Nuclear reactors have several distinctive types of control and protection elements, such as control rods, shimming rods and emergency rods. Each of these elements performs a separate task in a control procedure. The distribution of these elements in the core contributes to their worth and expense, therefore finding the best location and distribution of the control protection system (CPS) elements is very important from the viewpoint of nuclear reactor design and safety. The scope of this paper is to present the neutronic parameters such as effective multiplication factor (K-eff), Neutron Spectrum and CPS worth calculation of research heavy water reactor using MCNPX code. In order to reduce the possible systematic errors due to inexact geometry, a very exact three-dimensional model of Reactor was developed. The MCNPX2.6 input file was prepared in such a way that a very quick setup of any desired core configuration with an adequate position of all Control and Protection Systems (CPS) is possible. Utilizing the appropriate material cross-sections in an MCNP calculation is essential to obtain reliable results. The MCNP neutron interaction tables used in this study are processed from ENDF/B-VII evaluated data file at room temperature. The thermal scattering treatment was used for light and heavy water, and polyethylene.

The obtained computational data showed that when all the emergency rods are fully inserted in the core, or when all the emergency channels are filled by light water, the negative imposed reactivity is more than the clean core excess reactivity (5% ΔK/K) plus 1%. Therefore, the emergency system satisfies the nuclear safety regulations.

I158 A New Reference Database for Beta-delayed Neutron Data for Applications

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The field of beta-delayed neutron emission has been of interest since the discovery of nuclear fission. In nuclear power reactors, delayed-neutron (DN) data play a crucial role in reactor kinetics calculations and safe operation. Summation calculations to determine the decay heat or the anti-neutrino spectra produced as a result of the beta-decay of fission products in the reactor depend strongly on the accurate description of neutron and γ-ray emission processes. Beta-delayed neutron data also have a significant impact in the field of nuclear structure and astrophysics.

During the last decade there has been a renewed interest in the experimental and theoretical study of neutron-rich nuclei far from stability at the next generation of radioactive beam facilities, leading to a wealth of new data. Many new beta-delayed neutron branching ratios have been measured for exotic nuclides. The impact of all these new data has been explored by an IAEA Coordinated Research Project (CRP) which was held from 2013 to 2017. The CRP has produced a Reference Database for beta-delayed neutron emission that includes the following:
- compilation and evaluation of $T_{1/2}$, P_n for all measured DN emitters
- new systematics and model predictions,
- compilation of macroscopic total DN yields, decay curves, group parameters (ai,Ti) in 6-and 8-groups re-presentation and aggregate DN spectra,
- benchmarking of microscopic data (P_n, spectra) against macroscopic data
- recommendation of macroscopic DN data for fissile materials of interest.

We present the results of the validation of the new microscopic ($T_{1/2}$, P_n) data against the recommended total delayed neutron yields and a series of integral benchmark measurements. Time-dependent integral DN energy spectra have been measured for thermal neutron-induced fission of ^{235}U and we demonstrate the consistency of these spectra with those obtained from summation calculations over the microscopic data ($T_{1/2}$, P_n). Finally, the total delayed neutron yields have been measured in the energy range from 0.3 to 5 MeV for nuclides of importance to reactor technology and applications. We present new recommendations for the temporary DN groups in 6- and 8-group models based on these new experimental data.

R159 On-the-fly Temperature-dependent Cross Section Treatment Under Extreme Conditions in RMC Code

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Extreme conditions involved in Inertial Confinement Fusion (ICF) including extremely high temperatures ($\sim 10^7$K), extremely high velocities of target motion (10^6m/s) and extremely high neutron densities (10^{23}n/cm^3). The effect of extremely high temperatures on Monte-Carlo neutron transport was considered, and the target motion sampling (TMS) method with elevated basis cross section and the improved on-the-fly probability table interpolation method were developed based on the on-the-fly temperature-dependent cross section treatment capacity in Reactor Monte-Carlo Code (RMC), which was developed by REAL group at Tsinghua University. The free gas model was adopted to treat the thermal scattering in the thermal energy region, and the effect of high energy above the unresolved resonance region was neglected in present work. The proposed method was validated by Godiva and Jezebel benchmarks, results showed that the method has high efficiency and satisfactory fidelity compared with these of the NJOY-based reference results.

R160 Evolution of the Importance of Neutron-induced Reactions Along the Cycle of an LFR

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CIEMAT

The Lead-cooled Fast Reactor (LFR) is one of the three technologies selected by the Sustainable Nuclear Energy Technology Platform that can meet future European energy needs. Several LFR concepts are now in design phase, such as MYRRHA and ALFRED, and accurate nuclear data are required for the neutronic and safety assessment of the fast reactor designs. However, the impact of nuclear data on the criticality safety parameters changes along the reactor cycle, and, consequently, so does nuclear data needs.

In this work, an assessment of the evolution of the importance of neutron-induced reactions along the cycle of a reference LFR design (i.e., ALFRED) with the state-of-the-art JEFF-3.3 nuclear data library is performed. Sensitivity analyses have been carried out with MCNP6 code in order to identify the most relevant isotopes and reactions from the neutronic point of view at Beginning of Life, Beginning of Cycle and End of Cycle. Furthermore, an uncertainty quantification has been performed with the SUMMON system to study the evolution of uncertainties in the effective neutron multiplication factor along the reactor cycle.

The results from this work provide an exhaustive picture of the influence of nuclear data on core criticality performance, identifying key quantities and nuclear data needs relevant to achieve an improved safety level for LFR.

R161 Benchmarking the New ENDF/B-VIII.0 Nuclear Data Library for OECD/NEA Medium 1000 MWth Sodium-cooled Fast Reactor

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This paper presents the benchmark evaluation of the new ENDF/B-VIII.0 nuclear library for the OECD/NEA Medium 1000 MWth Sodium-cooled Fast Reactor (SFR). There are 2 SFR cores: metallic fueled (MET-1000) and oxide fueled (MOX-1000). The continuous-energy Monte Carlo codes Serpent 2 will be used as the calculation tools. Several nuclear libraries such as ENDF/B-VII.1 and JENDL-4.0 will be included to be compared with the newest ENDF/B-VIII.0. The evaluated parameters are k-eff, beta-eff, sodium void reactivity ($\triangle\rho$Na), Doppler constant ($\triangle\rho$Doppler), control rod worth ($\triangle\rho$CR), and radial power distribution.

R162 Measurement of Temperature-dependent Thermal Neutron Spectrum in CaH2 Moderator Material for Space Reactor Using TOF Method

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In order to power the space exploration such as human missions to the moon and Mars, the small high-temperature nuclear reactor using a solid moderator has been proposed as a space power system. As a solid moderator, the calcium-hydride (CaH2) having a high melting point, 816 °C, is suggested for the high-temperature operation.

Because neutronics characteristics is changed by the increase of temperature, the reactivity of the CaH2 moderated space reactor is greatly contributed to the temperature-dependent thermal neutron spectrum in the moderator. Nevertheless, the evaluated nuclear data and experimental data of the CaH2 is not satisfied in quality and quantity. Therefore, in order to accurately design the reactor, it is necessary to experimentally confirm the temperature-dependent thermal neutron spectrum in the CaH2.

In the present study, we have focused on the measurement of the temperature-dependent thermal neutron spectrum in the CaH2. To obtain the temperature-dependent thermal neutron spectrum, we have carried out the neutron scattering experiment using the time-of-flight (TOF) method at the Kyoto University Institute for Integrated Radiation and Nuclear Science - Linear Accelerator (KURNS-LINAC). In present experiment, we raised the temperature of the CaH2 from a room temperature to 500 °C, and obtained the change of the thermal neutron spectrum for the increase of temperature.

The obtained temperature-dependent thermal neutron spectrum in the CaH2 is compared with the calculated result using the Monte-Carlo simulation with JENDL-4.0.

R163 Production and Verification of the Compressed Depletion Data Library for Neutronic Analysis

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The depletion calculation based on the explicit depletion library can accurately describe the revolution of reactor composition, However, it requests large computing cost in reactor physics calculation. In this paper, a high-fidelity compression depletion library is produced based on quantitative significance analysis. In PWR problem, the effects of each unit compression operation on neutron absorption, neutron output, and target nuclide nuclear number density are investigated. For the compressed library, a series of benchmark problems are used to verification. The results show that the simplified library can significantly reduce the burn-up chain scale and save computing resources, while meeting the calculation accuracy requirement.

R164 Benchmarking the New ENDF/B-VIII.0 Nuclear Data Library for the First Core of Indonesian Multipurpose Research Reactor (RSG-GAS)

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The Indonesian Multipurpose Research Reactor namely Reaktor Serba Guna G.A. Siwabessy (RSG GAS) is a 30 MWth (max.) pool-type reactor loaded with plate-type low-enriched uranium fuel, using light water as coolant and moderator, and beryllium as reflector. The benchmark of the 1st criticality core of RSG GAS using different nuclear data libraries such as JENDL-4.0, JENDL-3.3, ENDF/B-VII.0, and JEFF-3.1 have been performed in the previous work and compared with the experiment result. In this work, the newly released ENDF/B-VIII.0 neutron reaction and thermal neutron scattering libraries will be used and the important neutronics parameters such as multiplication factor, kinetics parameters, and fission reaction rate will be calculated using Monte Carlo code MCNP6.2 and compared against the previous work and the experiment result.

R165 Nuclear Data Sensitivity and Uncertainty Analyses on the First Core Criticality of the RSG Gas Multipurpose Research Reactor

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The results of criticality, sensitivity and uncertainty (S/U) analyses on the first core criticality of the Indonesian 30 MWth Multipurpose Reactor RSG GAS (MPR-30) using the recent nuclear data libraries (ENDF/B-VII.1 and JENDL-4.0) and analytical tools available at present (WHISPER-1.1) are presented. Two groups of criticality benchmark cases were carefully selected from the experiments conducted during the first criticality approach and control rod calibrations. The C/E values of effective neutron multiplication factor (k) for the worst case was found around 1.005. Large negative sensitivities were found in (n,γ) reaction of H-1, U-235, Al-27, U-238 and Be-9 while large positive sensitivities were found in U-235 (total nu and fission), H-1 (elastic), Be-9 (free gas, elastic) and H-1 S(α,β) (lwtr.20t, inelastic). The energy dependency of the sensitivities were also presented and discussed in detail. The S/U analysis results concluded that the uncertainties of k originated from the nuclear data were found around 0.6% which covered well the [C/E-1] values. Differences in the sensitivities amongst the two nuclear data libraries were also identified, and recommendation for improving the nuclear data library was given.

R166 On the Impact of Nuclear Data Uncertainties on LWR Neutron Dosimetry Assessments

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In this work, an overview on the relevance of the nuclear data (ND) uncertainties with respect to the Light Water Reactors (LWR) neutron dosimetry is presented. The paper summarizes findings and observations accumulated on the basis of several studies realized at the LRT (former LRS) laboratory of the Paul Scherrer Istitute over the past decade. The studies were done using the base LRT calculation methodology for dosimetry assessments, which involves the neutron source distribution representation, obtained based on validated CASMO/SIMULATE calculation models, and the consequent neutron transport simulations with the MCNP code. The methodology was validated using as the reference data the results of numerous measurement programs realized at Swiss NPPs and at PSI Hotlab. Namely, the following experimental programs are considered in the given overview: PWR RPV scraping tests and PWR "gradient probes" post irradiation examination (PIE) data and BWR reactor fast neutron fluence monitors dosimetry PIE data.

The assessment of the nuclear data related uncertainties was performed with the help of calculation tools and methodologies developed and maintained at LRT, which in principle can cover the complete calculation chain from the cycle-specific core-follow calculations to the neutron transport and finally to the dosimetry reaction rates calculations. However, so far the above uncertainty components were mainly analyzed separately from each other in order to facilitate the separate tools development and associated V&V studies. When appropriate, the results of the cross-verification of the different ND uncertainty quantification tools and techniques realized at LRT will be discussed too.

Furthermore, the findings on which particular neutron induced reactions contribute dominantly to the overall ND-related uncertainties will be presented. In addition, the magnitude of the ND-related uncertainties will be assessed against other types of typical modeling and experimental uncertainties based on the information available at LRT. Thus, the collected results should be sufficiently representative to assess the overall impact of the various nuclear data uncertainties with respect to the practical reactor dosimetry applications and provide relevant feedback to the nuclear data evaluators.

R167 Nuclear Data Sensitivity Analysis and Uncertainty Propagation in the KYADJ Whole-core Transport Code

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Nuclear data sensitivity analysis and uncertainty propagation has been extensively applied to nuclear data adjustment and uncertainty quantification in the field of nuclear engineering. Sensitivity and Uncertainty (S&U) analysis is developed in the KYADJ whole-core transport code in order to meet the requirement of advanced reactor design. KYADJ aims to use the two-dimension Method of Characteristic (MOC) and the one-dimension discrete ordinate (SN) coupled method to solve the neutron transport equation and achieve one-step direct transport calculation of reactor core. Developing sensitivity and uncertainty analysis module in KYADJ can minimize deviations caused by modeling approximation and enhance calculation efficiency. This work describes the application of the classic perturbation theory to the KYADJ transport solver. In order to obtain uncertainty, a technique is proposed for processing a covariance data file in 45-group energy grid instead of 44-group SCALE 6.1 covariance data which is extensively used in various codes. Numerical results for Uncertainty Analysis in Modelling (UAM) benchmarks are presented and compared to RMC. The results agree well with the reference and the capability of S&U analysis in KYADJ is verified.

I168 Fission Cross Sections of Plutonium Isotopes

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New data evaluations for the neutron induced reactions on Plutonium isotopes are of interest for ongoing international research projects such as INDEN [1]. This paper presents our preliminary results of the reaction model calculations for the $^{238-242}$Pu targets in the neutron incident energy range starting above the unresolved resonance region and extended up to 30 MeV. The calculations are performed with the statistical model code EMPIRE 3.2 Malta [2] following the same approach as for the Uranium isotopic chain [3,4]. Except for the fission channel, the experimental data are very scarce, therefore we rely on the description and predictive power of the regional dispersive coupled channel optical model potential [5] and on the optical model for fission [6,7] to provide reliable theoretical information where experimental data lack. As in the Uranium case, a consistent set of fission barrier parameters is established along the isotopic chain. The same parameters are used for a given isotope, irrespective of the fission chance. For validation, they have been also used for photon induced fission cross section calculations in the energy range 5-20 MeV. By adopting this procedure, a very good description of the experimental fission is achieved allowing for reliable predictions of inelastic, (n,2n) and (n,3n) cross sections. The consistent set of fission barrier parameters is also of interest for the IAEA CRP RIPL [8].

[1] INDEN: International Nuclear Data Evaluation Network, A. Trkov and R. Capote, IAEA coordinators; online at https://www-nds.iaea.org/index-meeting-crp/TM_IAEACIELO/
[2] M. Herman, R. Capote, B.V. Carlson, et al, Nucl. Data Sheets 108, 2655-2715 (2007).
[3] R. Capote, A. Trkov, M. Sin, et al., Nucl. Data Sheets 148, 254-292 (2018).
[4] M. Sin, R. Capote, M. W. Herman, and A. Trkov, Nucl. Data Sheets 139, 190-203 (2017).
[5] R. Capote, S. Chiba, E. Sh. Soukhovitskiy, J. Nucl. Sci. Technol. 45, 333 (2008).
[6] M. Sin and R. Capote, Phys. Rev. C77, 054601 (2008).
[7] M. Sin, R. Capote, M. W. Herman, and A. Trkov, Phys. Rev. C93, 034605 (2016).
[8] IAEA CRP on Recommended Input Parameter Library (RIPL) for Fission Cross Section Calculations.

R169 Theoretical Calculation and Evaluation of Neutron-induced Reactions on Pu Isotopes

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In order to reduce the uncertainties in the design and operation of accelerator-driven systems (ADSs), high-precision nuclear data for neutron- and proton-induced reactions on a variety of isotopes in the energy range below 200 MeV are necessary. As the important component of the spent fuel of current nuclear power plants, Pu isotopes will be loaded into ADSs to produce energy and neutrons. Therefore, accurate nuclear data for neutron-induced reactions on Pu isotopes are needed in the calculation of neutron and energy balance and the prediction of transmutation rates of the various radioactive species. To meet this requirement, all cross sections, angular distributions, energy spectra, double differential cross sections of neutron, proton, deuteron, triton, helium-3 and alpha emissions and the number of neutron per fission for n+Pu reactions are consistently calculated and analyzed by theoretical nuclear models in the energy range of En $\leq$ 200 MeV. The theoretical models include the optical model, the distorted wave born approximation theory, the Hauser-Feshbach theory, the fission model, the evaporation model, the exciton model and the intranuclear cascade model. The calculated results reproduce the experimental data well. In addition, the variation tendency of reaction cross sections related to the target mass numbers is obtained, which is very important for the prediction of nuclear data on neutron-actinides reactions because the experimental data are lacking.

R170 Theoretical Calculation and Evaluation for n+^{232,233,234,235,236,237,238}U Reactions

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In order to reduce the uncertainties in the design and operation of accelerator-driven systems (ADSs), high-recision nuclear data for neutron- and proton-induced reactions on a variety of isotopes in the energy range below 200 MeV are necessary. As the important component of the spent fuel of current nuclear power plants, U isotopes will be loaded into ADSs to produce energy and neutrons. Therefore, accurate nuclear data for neutron-induced reactions on Pu isotopes are needed in the calculation of neutron and energy balance and the prediction of transmutation rates of the various radioactive species. To meet this requirement, all cross sections, angular distributions, energy spectra, double differential cross sections of neutron, proton, deuteron, triton, helium-3 and alpha emissions and the number of neutron per fission for n+^{232,233,234,235,236,237,238}U reactions are consistently calculated and analyzed by theoretical nuclear models in the energy range of En $\leq$ 200 MeV. The optical model, the unified Hauser-Feshbach theory and the exciton model, the linear angular momentum dependent exciton state density model, the fission model, the intranuclear cascade model, the distorted-wave Born approximation and the coupled channel theory. The calculated results reproduce the experimental data well, and the variation tendency of reaction cross sections related to the target mass numbers is obtained.

R171 Photonuclear Data Library and Photon Strength Functions

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International Atomic Energy Agency

On behalf of the IAEA CRP on Updating the Photonuclear Data Library and generating a Reference Database for Photon Strength Functions: Photon strength functions (PSF) describe the average response of the nucleus to an electromagnetic probe, and are thus important quantities for the theoretical modelling of nuclear reactions. As such they are relevant sources of input information for other databases such as the IAEA Reference Input Parameter Library (RIPL), and evaluated data files such as Evaluated Gamma Activation File (EGAF), Evaluated Nuclear Structure and Decay File (ENSDF), and transport files in ENDF-6 format, which are also used by the broader scientific community.

In the past two decades, there has been considerable growth in the amount of reaction data measured to determine photonuclear cross sections or photon strength functions. Quite often the different experimental techniques lead to discrepant results and users are faced with the dilemma of trying to decide which (if any) amongst the divergent data they should adopt. It is therefore important that all these experimental data are evaluated by experts who will recommend the most reliable data for use in the various applications. The evaluation of nuclear data consists of several systematic steps. These include a bibliographic compilation, a compilation of experimental data, followed by a critical analysis of the measurement techniques used, together with evaluations based on theoretical modelling.

We describe the work that is performed under the IAEA CRP (2016-2020) which aims at providing updated photonuclear data and recommend reliable experimental and evaluated photon strength functions to the basic and applied sciences community.

The scope of the project for both photonuclear cross-section data and photon strength functions covers
- measurements,
- compilation of existing data,
- assessment / recommendation of data,
- evaluation of data (on the basis of models),
- dissemination (data library/database).

Some examples of new evaluations of photonuclear reaction cross sections and recommendations of photon strength functions will be discussed.

R172 The Evaluations of Photonuclear Data in CNDC

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Photonuclear data are important to reactor design, accelerator, medical treatment and nuclear astrophysics. In recent years, with the development of new experimental devices such as LCS gamma ray source, the International Atomic Energy Agency (IAEA) has started a new international cooperation CRP project since 2016, in order to develop the evaluation methods of photonuclear reaction and photon strength function on the basis of new measurement data and update the database of photonuclear reaction. The energy range should be increased to 200MeV. On the basis of code MEND used for the low and medium energy nuclear reaction, MEND-G has been developed, which can be used to calculate the heavy nuclear reaction in the photon incident region below 200 MeV. GLUNF was developed for light nucleus. 7 models were considered in PSF calculation and parameters have been updated. Be, V, Cr, Zr, W, Bi, etc were calculated and evaluated, and the results have been submitted to IAEA. As an example, the evaluation of Cr will be used to introduce the evaluation of photonuclear data in CNDC. The experimental data of gamma-induced Cr-52 reaction were analyzed and evaluated. The differences between absorption cross section and neutron and proton emission cross sections were clarified. A set of absorption cross sections which can be used for fitting calculation of photon intensity function were given. SMLO method was adopted to calculate photon absorption cross section of Cr-52. The absorption cross-section was used as input of MEND-G. The neutron and proton emission cross-sections were given by adjusting the parameters of level density and pair energy, which were in accordance with the experimental data. A complete set of data in ENDF-6 format was given. Other isotopes of Cr lacked experimental data. Based on the absorption cross section of Cr-52, the absorption cross sections of each element of Cr were calculated by SMLO method, and the complete data of Cr-50, Cr-53 and Cr-54 were given by MEND-G.

I173 Surrogate Reactions: Doorways to Cross Sections for Unstable Isotopes

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Obtaining reliable data for nuclear reactions on unstable isotopes remains an extremely important task and a formidable challenge. Cross sections for neutron-induced reactions – crucial ingredients for models of astrophysical processes and for applied science – are particularly elusive, as both projectile and target in the reaction are unstable. Calculations of compound cross sections, at the same time, are often quite limited in accuracy due to uncertainties in the nuclear physics inputs needed.

Various methods have been proposed for determining unknown cross sections from indirect measurements. The 'surrogate reaction method' [1] uses inelastic scattering or transfer ('surrogate') reactions to produce the compound nucleus of interest and measure its subsequent decay. In principle, this data provides constraints for the models describing the decay of the compound nucleus, which dominate the uncertainties of the cross section calculations. Past applications of the surrogate approach assumed the decay to be independent of the mechanism that formed the compound nucleus. This approximation works reasonably well for (n,f) cross sections [2], but has long been known to break down for capture reactions [3].

At the heart of the problem is the need for a better understanding of doorway states which link the direct (surrogate) reaction with the compound nucleus of interest. I will demonstrate that a proper theoretical description of the surrogate reaction mechanisms is key to overcoming the limitations encountered previously. Specifically, theoretical descriptions of the (p,d) and (d,p) transfer reaction have been developed to complement recent measurements in the Zr-Y-Mo region. The procedure for obtaining constraints for unknown capture cross sections is illustrated and indirectly extracted cross sections for both known (benchmark) and unknown capture reactions are presented [4]. The method makes no use of auxiliary constraining quantities, such as neutron resonance data, or average radiative widths, which are not available for short-lived isotopes; thus it can be applied to isotopes away from stability.

These recent successes point towards new opportunities: I will discuss the use of inelastic scattering as a potential surrogate mechanism, the feasibility of determining (n,2n) and other desired cross sections, and, finally, possible experiments at radioactive-beam facilities.

R174 Incorporating A Two-step Mechanism into Calculations of (p,t) Reactions Used to Populate Compound Nucleus Spin-parity Distributions in Support of Surrogate Neutron Capture Measurements

James Benstead
AWE

The surrogate reaction method may be used to determine the cross section for neutron-induced reactions not accessible through standard experimental techniques by creating the same compound nucleus which the desired reaction would pass through, but via a different entrance channel. A variety of direct reactions have been employed in order to generate the required compound nuclei for surrogate studies.

In this work, a previously developed (p,t) reaction model has been extended to incorporate a two-step reaction mechanism, which can take the form of either sequential neutron transfer or an additional inelastic, possibly collective, excitation of the compound nucleus. This updated model is applied to ^{90,92,94,96}Zr target nuclei and is found to modify the strengths of the previously predicted populated levels. A comparison against available experimental data is also performed.

It is planned that this improved (p,t) model will be used to attempt to constrain cross section predictions for a number of (n,γ) reactions in future, as well as provide a possible comparison against other surrogate studies utilising different direct reactions such as (p,d).

R175 Statistical Theory of Light Nucleus reactions with 1p-shell light nuclei involved

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The 1p-shell light elements (Li, Be, B, C, N, and O) had long been selected as the most important materials for improving neutron economy in thermal and fast fission reactors and in the design of accelerator-driven spallation neutron sources. A Statistical Theory of Light Nucleus reactions (STLN) is proposed to describe the double-differential cross sections for both neutron and light charged particle induced nuclear reactions with 1p-shell light nuclei involved. The dynamics of STLN is described by the unified Hauser-Feshbach and exciton model, in which the angular momentum and parity conservations are strictly considered in equilibrium and pre-equilibrium processes. The Coulomb barriers of the incoming and outgoing charged particles, which significantly influence the open channels of the reaction, can be reasonably considered in the incident channel and different outgoing channels. In kinematics, the recoiling effects in various emission processes are strictly taken into account. The analytical double-differential cross sections of the reaction products in sequential and simultaneous emission processes are obtained in terms of the new integral formula proposed in our recent paper [Phys. Rev. C 92, 061601(R) (2015)]. We calculate the double-differential cross sections of outgoing neutrons and charged particles using the PUNF code in the frame of STLN. The existing experimental double-differential cross sections of neutrons and charged particles at different incident energies can be remarkably well reproduced. So it is suggested that the PUNF code is a powerful tool to set up "file-6" in the reaction data library for light charged particle induced nuclear reactions with 1p-shell light nuclei involved.

R176 Microscopic Optical Potentials for Li Isotopes

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The microscopic optical potentials for Li isotopes(A = 6,7,8) without free parameter are obtained by folding the microscopic optical potentials of their internal nucleons with density distributions generated from corresponding internal wave functions of Li isotopes. An isospin-dependent nucleon microscopic optical potential based on the Skyrme nucleon-nucleon effective interaction is used as the nucleon optical potential. Two different nuclear structure models, shell model and cluster model, are employed separately to construct the internal wave functions of Li isotopes(A = 6,7,8) and derive their density distributions of internal nucleons. (In addition, the microscopic optical potentials for ^{9}Li and ^{1}1Li are also calculated in similar way but with measured nucleon density distributions.) The Li microscopic optical potentials are used to calculate the elastic-scattering angular distributions and reaction cross sections. The results reproduce experimental data well and are comparable to those calculated by phenomenological optical model potentials in many cases.

S177 Coupled-channel Analysis of Deuteron Scattering on ^{56}Fe

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An optimal set of deuteron optical potential parameters for Fe-56 are obtained based on the elastic and inelastic scattering experimental data and available global deuteron OMPs. The coupled-channel method based on rigid-rotator model with only ground-state rotational band is employed to calculate the scattering angular distributions. And the deformation parameters from RIPL-3 are compared with those from the fitting of experiments. The contributions from deuteron breakup effects are discussed.

S178 Studies on Neutron-Neutron Elastic Scattering

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In neutron-neutron (N+N) scattering studies, direct experimental data (N+N) have not been available up to now due to the difficulty in producing effective neutron targets. However, there are many accurate experimental data and mature theoretical results about the scattering of neutron-proton (n+p) and proton-proton (p+p). In this work, the comprehensive R-matrix analysis program RAC was used to systematically fit and analyze the experimental data related to (n+p) and (p+p) below 50MeV, and the accurate fitting values of (n+p) and (p+p) elastic scattering (removing the long-term coulomb effect) below 50MeV were obtained. Based on the quark level of nucleon, the elastic scattering cross sections of (N+N), (N+p) and (p+p), are deduced, and they can be expressed as N(N,N)N, p(N,N)p and p(p,p)p respectively. It is found that with the change of incident nucleon energy, p(N,N)p and p(p,p)p have a good inverse symmetric change relative p(N,N)p. Using the above fitting values (n+p) and (p+p), the elastic scattering cross section (n + n) is derived. This calculation value is close to the system's optical model (N+N) analysis calculation value and the (N+N) recommended value in ENDF/B-VIII.0.

R179 n+d Scattering Solved with Faddeev-AGS Equations Using the Wave Packet Method

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We present the results of elastic scattering and breakup reactions of the n+d three-body system solved with the Faddeev-AGS equations using the wave packet method with realistic nucleon-nucleon interactions. Comparisons are made with results using other methods. These results will be integrated in the CNDC database.

R180 QRPA Predictions of the E1 and M1 Gamma-ray Strength Functions Using the D1M Gogny Interaction

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Within the framework of a global microscopic approach, all the nuclear input required for nuclear reaction predictions are being, step by step, derived from a sole nucleon-nucleon effective interaction, namely the D1M Gogny force [1]. Nuclear masses [1], deformations, radial densities and level densities [2] have already been obtained and have shown a rather good agreement with experimental data either directly or when used, for instance, to derive optical models [3]. We now focus on the radiative strength functions within the Gogny-QRPA approach whose predictive power has been established with respect to photoabsorption experimental data up to heavy actinide targets [4]. The current status of this project, aiming at producing tables of gamma-ray strength functions for both E1 and M1 transitions, will be discussed with a particular emphasis on the consequences on capture cross section modelling. In particular, it will be shown that the current approach is able to solve the longstanding problem related to the simultaneous description of photoabsorption and capture cross sections.

[1] S. Goriely et al., First Gogny-Hartree-Fock-Bogoliubov Nuclear Mass Model, Phys. Rev. Lett 102, (2009) 242501.
[2] S. Hilaire et al., Temperature-dependent combinatorial level densities with the D1M Gogny force, Phys. Rev. C 86, (2012) 064317.
[3] S. Hilaire et al., Nuclear reaction inputs based on effective interactions, Eur. Phys. J. A 52 (2016) 336.
[4] S. Péru et al., Giant resonances in ^{238}U within the quasiparticle random-phase approximation with the Gogny force, Phys. Rev. C 83 (2011) 014314.

R181 A Study of Giant Dipole Resonance Parameters from Photoabsorption Cross Sections

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It is believed that decay properties of medium-weight and heavy nuclei at excitation energies above the pairing gap are not governed by structural effects but more likely by statistical properties that can be described via so-called Photon Strength Functions (PSF) for different multipolarities. These quantities are directly related to photoabsorption cross section (σ_γ). It is well known that PSFs/σ_{abs} are dominated by electric Giant Dipole Resonance (GDR) at $\epsilon_\gamma \leq 40$ MeV. In this paper, we construct two kinds of systematic GDR parameters by fitting the photoabsorption cross section of the experimental data. One is based on microscopic approach, the other is estimated by the phenomenological models. They both can be used to predict the photoabsorption cross section for nuclei from medium to heavy.

R182 Structure of Continuum States and Strength Function in the Complex Scaling Method

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A virtual state plays an important role in reaction cross sections just above the breakup threshold energy [1,2]. However, the virtual state in the complex scaling method (CSM) [3,4] cannot be directly solved as an isolated pole solution since the scaling angle in the CSM does not cover the position of the virtual state pole on the negative imaginary axis of the complex momentum plane. Therefore, it has been desired to find a new approach for the CSM to describe the virtual state.

In 2015, we studied the $1/2^+$ state of ^{9}Be and the photodisintegration cross section applying the CSM to the α+α+n three-cluster model [1]. The results indicate that there is no sharp resonant state corresponding to the distinct peak observed just above the 8Be+n threshold in the photodisintegration cross section of ^{9}Be. We concluded that the first excited $1/2^+$ state in ^{9}Be is a ^{8}Be+n virtual state but not resonant one. Recently, we proposed a useful approach to find the pole position of the vitual state using the continuum level density, the scattering phase shifts and scattering length calculated in the CSM [5].

In this report, we present our recent results of the mirror nuclei ^{5}He and ^{5}Li obtained by analyzing structure of contiuum states in the complex scaled α+N two-body model Decomposed scattering cross section and continuum level density of α+N system are discussed.

[1] M.Odsuren, Y.Kikuchi, M.Aikawa, T.Myo, K.Kato, Phys.Rev.C92, 014322 (2015)
[2] Y.Kikuchi, M.Odsuren, T.Myo, K.Kato, Phys.Rev.C93, 054605 (2016)
[3] Y.K.Ho, Phys.Rep.99, 1 (1983)
[4] S.Aoyama, T.Myo, K.Kato, K.Ikeda, Prog.Theor.Phys. 116, 1 (2006)
[5] M.Odsuren, Y.Kikuchi, T.Myo, G.Khuukhenkhuu, H.Masui, K.Kato, Phys.Rev.C95, 064305 (2017)

S183 The Refractive Scattering of ^{17}F+^{12}C

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Based on the cluster description of the proton riched nucleus ^{17}F, the experimental data of the elastic scattering angular distribution of ^{17}F+^{12}C at 10 MeV/nucleon is reanalyzed by the optical model. In our calculations, ^{17}F is treated as an ^{16}O core plus a valence proton. The optical potential of ^{17}F+^{12}C is obtained by folding the interactions of ^{16}O+^{12}C and p+^{12}C both at $\sim$ 10 MeV per nucleon. These interactions are chosen carefully and their reliability has been verified. The existing experimental differential cross sections of ^{17}F+^{12}C are at smaller angles (the diffractive part) and reproduced well by the present calculations. While at larger angles, a typical refractive phenomenon (nuclear rainbow) is observed in the calculated angular distribution. Two Airy minima are clearly seen, which is quite different from the results of the optical model calculations performed in the original literature of this data set. This refractive effect should arise from the contribution of the core ^{16}O during the collision process. The optical potential of ^{16}O+^{12}C shows the dominance in the refractive scattering while the calculated angular distribution is not sensitive to the choice of p+^{12}C interaction. The global optical potential of p+^{12}C could be used safely in the calculation. The CDCC calculation is also performed and it is found that the positions of the Airy minima are nearly not affected by the breakup coupling. These facts indicate the possibility to analyze the rainbow pattern of ^{17}F+^{12}C systematically with the optical model.

S184 Simulation of Neutron Transmission Performance of Metal Spherical Shell Under Temperature Dependent Neutron Cross Section

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To study the effect of temperature dependent neutron cross section on the neutron transmission performance of typical metal spherical shells, this paper generated the temperature dependent neutron cross section data by using NJOY program, and established the physical and computational model of interaction of neutron with iron and aluminium spherical shell. The temperature evolutions of energy spectrum of transmitted neutron and secondary gamma ray, and the number ratios of transmitted neutrons to secondary gamma rays have been studied by using Monte Carlo simulation method at different neutron energies. The conclusions drawn in this study are as follows: (1) the influence of temperature on neutron cross section data is different in different neutron energy intervals. For example, when the neutron energy is in the range of 0.01 MeV to 1 MeV, the change of temperature has significant effect on the total cross section and gamma ray production cross section of the interaction between neutrons and iron atoms, while it has little effect on the cross section when the neutron energy exceeds 1 MeV. (2) For different type of metals, the transmitted neutron spectrum and the secondary gamma ray spectrum will be significantly affected when the temperature increases to different high values. (3) For the spherical shell of iron or aluminium with thickness of 2 cm, the number of transmitted neutrons decreases slightly with the increase of temperature, and the number ratio of transmitted neutrons to secondary gamma rays decreases with the increase of temperature when the incident neutron energy is 0.1 MeV. (4) The variation trend of the number of secondary gamma ray with temperature is related to the type of shell material. For iron, it increases with the increase of temperature, and for aluminium, it decreases with the increase of temperature.

S185 Improvement of Generalized Evaporation Model Based on Analysis of Isotope Production in Proton- and Deuteron-induced Spallation Reactions

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Cross section measurements of isotope production cross sections in proton- and deuteron-induced spallation reactions on long-lived fission products (e.g., ^{93}Zr and ^{107}Pd) have been performed for R & D of nuclear transmutation systems. To evaluate the transmutation efficiency by simulation, it is of essential importance to use theoretical models that reproduce the measured nuclear data with high accuracy. However, there are some discrepancies between the measured production cross sections and theoretical calculations with PHITS in which INCL-4.6 and Generalized Evaporation Model (GEM) are implemented. To resolve these discrepancies, we have improved the GEM by the following ways in the present work.

First, the PHITS calculation underestimates the measured cross sections in the neutron deficient region of the produced isotopes adjacent to the target nucleus. It is expected that the underestimation is caused by suppression of neutron emission by using the empirical formula of Dostrovsky et al. as the inverse reaction cross section. Since there is a discrepancy between the formula and the experimental data and/or optical model calculation in the low energy region, we have made a new systematics based on the optical model calculation for proton and neutron. The underestimation was improved by using the new systematics.

Second, the odd-even staggering (OES) was clearly seen in the calculated isotopic distribution of production cross-sections, while no appreciable OES was observed in the experimental data. We have found that OES is due to ignorance of the discrete levels in GEM in which Gilibart-Cameron (G-C) formula is used as the level density. Since the pairing correction is not sufficient in this approach, it is expected that the calculation shows the strong OES. This situation was improved by using a back-shifted Fermi gas model with energy dependence instead of the G-C formula.

Finally, competition between particle and gamma-ray emissions from unbound states of excited nuclei in the evaporation process was ignored in the original GEM. Introduction of the competition to GEM resulted in further improvement of agreement with the experimental data.

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I186 Status of JENDL

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Two special-purpose files were released recently. One is the JENDL Photonuclear Data File 2016 (JENDL/PD-2016) which contains the data of photonuclear reaction cross sections for various nuclei from H-2 to Lr-266 covering a wide area of the nuclear chart. The other one is the JENDL Activation Cross Section File for Nuclear Decommissioning 2017 (JENDL/AD-2017) which provides production cross sections of radioactive nuclei by neutrons. It is intended to help accurate evaluation of activation inventory in decommission of nuclear power reactors.

Regarding the general-purpose file, we are planning to release the next version of JENDL-4.0 opened in 2010, which would be made available by 2022 as JENDL-5. To contribute to the important problems concerning the nuclear energy in Japan such as nuclear waste and nuclear safety as well as various application fields of nuclear data, it is intended to raise reliability of simulation calculation of nuclear reactors and neutron transportation in structure materials. New data evaluation and revision are in progress. The first test version of the JENDL-5 called JENDL-51 has been created by updating neutron reaction data for about 100 nuclides. A new Japanese evaluation of thermal scattering law data is also adopted for light water. The benchmark tests for nuclear reactors and shielding are being performed. Recent progress and future plan of the JENDL project will be presented.

R187 Completeness of Neutron-, Photo-induced and Spontaneous Fission Yields Data

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Nuclear data collection, evaluation and dissemination activities have been performed worldwide for many years. It is absolutely essential for the overall progress of science and technology to create the complete collections of experimental data sets and associated publications, and store these data in publicly accessible databases. Due to many historical and technological reasons not all published data have been identified and compiled. These "missing data" manifest themselves via scientific publications, data evaluations and nuclear databases comparisons. The detailed analysis of Nuclear Science References (NSR) and Experimental Nuclear Reaction (EXFOR) databases shows thousands of previously missed nuclear reaction experiments and creates a roadmap for creation of complete data records for fission cross sections, yields and covariances. The National Nuclear Data Center (NNDC) program for identification, compilation and storage of missing data sets is described, and recommendations for improving the databases fission yields completeness are given.

R188 Systematic Description of Product Mass Yields of the Neutron-induced ^{232}Th and $^{232-239}$U Fissions

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The study of fission product yields plays an important role in the understanding of the fission process and the development, design and safety analysis of advanced nuclear energy systems such as the Th-U cycle. It is essential to study the mass distributions and energy dependence of the fission yield because the neutron energy in the environment of generated fission products is not single. In this work, a systematics of fission product mass yields of ^{232}Th and $^{232-239}$U was established and the mass distribution can be estimated from thermal to 20 MeV, which is very usefully unmeasured data. We also find that the systematics of Katakura and Wahl recommended by IAEA's CRP project are distorted when they calculate the fission yield of ^{232}Th and ^{233}U. A new proposed systematic formula for the neutron-induced ^{232}Th and ^{23U}U fission can accurately calculate the mass distributions and energy dependence of the fission yield. A quantitative description of the fission mass distribution from thermal neutrons to 14 MeV was achieved. Prompt neutrons are one of the main participants in the fission process of the Th-U cycle. The fission prompt neutron spectra for neutron induced fissions of ^{232}Th and ^{233}U in the incident neutron energy below 6 MeV were calculated by the combining of the multi-modal Los Alamos model and the systematic method in this work.

R189 Evaluation and Validation of Fe-56 Data after CENDL–3.2b1

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The SSL is served as fuel cladding and shielding material in CFR-600. The nuclear data of Fe-56 plays an important role in the neutronics calculations of physics and shielding design. However, both the evaluations from CENDL-3.2beta1 and ENDF/B-VIII.0 show serious under predictions of neutron leakage spectra in thick shielding benchmarks. An improved revision needs to be done for CFR-600 design.

Since previous validations and sensitivity analysis show that the ^{56}Fe(n,inl) cross section is main source of under prediction, a re-evaluation of the ^{56}Fe(n,inl) and ^{56}Fe(n,n'γ) experimental cross sections has been performed. The experiments since 1970 have been reviewed. The same corrections of partial cross sections for gamma-ray anisotropy were applied to the gamma production cross sections below 2MeV. The gamma production cross sections from threshold to 20MeV for 847keV gamma-ray were evaluated based on the experiment work by Voss(1971), Dickens(1991) and Neslon(2004). A set of total cross sections for ^{56}Fe(n,inl) reaction was also deduced based the recommended experimental data and reaction ratio between total inelastic and partial gamma production cross sections for 847 keV gamma-ray evaluated by V. Pronyaev.

Based on the C32b1 version of Fe-56 data, the re-evaluated cross sections for (n,inl) reactions were applied to create a new beta version. The new data were tested against the shielding and criticality benchmarks. Very good benchmarking result was obtained for the IPPE iron sphere irradiated by the Cf-252 neutron source, which confirms the new cross sections for (n,inl) reaction. Some C/E values of keff for the fast and intermediate spectra criticality benchmarks sensitive to Fe-56 were also improved, but some still need more work to do.

R190 Decay Heat Uncertainty Quantification with the GNIAC Code

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Decay heat plays an important role in nuclear engineering, such as the safety of nuclear facilities and nuclear fuel waste management. Many codes such as FISPACT, CYRUS, URANIE/MENDEL, ACAB, ORIGEN have functions to estimate decay heat. GNIAC is a new general nuclide inventory analysis code developed at INPC in China. GNIAC has applied many new features such as the Chebyshev Rational Approximation Method (CRAM), direct use of library in ENDF-6 format, XML format for input/output and so on, which make the code a useful nuclide inventory analysis tool for nuclear applications.

In this paper, decay heat uncertainty quantification has been implemented in GNIAC code with deterministic approach. Uncertainty in decay heat, which are due to the propagation of variance and covariance data of fission yields and radioactive decay data, are calculated with the sensitivity analysis and uncertainty propagation method. Two preliminary applications which are U-235 thermal fission pulse and Pu-239 fast fission pulse has been used to validate GNIAC code. The results show good agreement with the reference results, ensuring the reliability of the GNIAC code.

R191 Depletion Uncertainty Analysis Performed to the Critical MYRRHA Core Configuration

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Neutron-induced nuclear data covariances are one of the most important sources of uncertainty in reactor physics simulations. Thus, it is of great importance to quantify the impact that such covariances would have in the design and criticality safety analysis of advanced fast reactors such as the MYRRHA (Multi-purpose hYbrid Research Reactor for High-Tech Applications) accelerator driven system (ADS). Moreover, such study should be performed along the irradiation-cycle via a depletion analysis. MYRRHA, a flexible lead-bismuth cooled experimental facility, is foreseen to operate both in critical and sub-critical ADS mode. Regarding the most recent design of its critical core configuration, the beginning-of-life (BOL) has been chosen to have 18 fuel batches with the appropriate excess of reactivity and a pre-discharge burnup of interest that, after 90 EFPDs of operation, would lead to a discharge burnup of about 57 MWd/kg iHM.

In this work, the objective is to propagate the most recent covariance evaluations of important nuclides related to MOX fuel and its fission yields along a cycle-depletion analysis of the critical MYRRHA core. Therefore, it is also expected to perform a comparison of the impact that covariances of modern evaluated major libraries (such as the ones encountered in JEFF-3.3 and ENDF/B-VIII.0) would have, in the criticality safety and inventory prediction along the BOL-cycle of a certain MYRRHA fuel burnup batch. For this purpose, the SCK?CEN in-house depletion code ALEPH2 (with SERPENT code as neutron transport module) is intended to be employed, where the different many-randomized continuous-energy reaction libraries used as ALEPH2 inputs and based on the different neutron-reaction covariances will be computed by the SANDY code. The statistical approach for uncertainty and sensitivity analysis is expected to be performed in order to quantify the effect on observables of interest as a function of burnup, and by employing the most updated MYRRHA critical core configuration.

R192 Evaluation of Neutron Reaction Cross-sections with Taking Unrecognized Experimental Errors Into Account

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Underestimation of the evaluated neutron reaction cross-section uncertainties calculated within strict statistical methods is an important problem of modern statistics and its application to the neutron data evaluation. Last neutron standards evaluation fixed this problem as an unresolved one [1]. There are a few reasons of the underestimation. One of them is inadequate processing of unrecognized experimental errors.

The attempts to resolve the problem have been undertaken earlier. In particular, the method described in [2] is intended for an estimation of the average variance (over experiment) of unrecognized experimental errors. The approach presented in this paper allows to construct a complete covariance matrix of the experimental errors including the unrecognized ones. It is based on applying the classical statistical methods (generalized least squares method and Bayes approach) in iterative way. The evaluated curve and the covariances of measured cross-sections are calculated at each iteration. The input data for the calculations are the results of measurements. The covariances of measured cross-sections are determined on the basis of deviations of the evaluated curve from the results of measurements. Special procedures for a refinement of the calculated matrices from unphysical structures (to avoid the problems induced by the non-positive definiteness and the Peelle's Pertitent Puzzle [3]) are used. An original approximation is calculated in assumption of independent experimental errors.

The method was applied for the evaluation of dosimetry reaction cross-sections. It provides more reliable uncertainty information for the evaluated cross-sections compared to the calculations where the traditional approach is used for the calculation of the experimental covariances (on the basis of the components of total experimental errors).

[1] Carlson, A.D., et al., Evaluation of the Neutron Data Standards, Nuclear Data Sheets p. 143 - 188, v.148, 2018.
[2] S.A.Badikov, "A new technique for dosimetry reaction cross-section evaluation", ASTM Special Technical Publications 1550 STP, p.131-140, 2012.3. International Evaluation of Neutron Cross-Section Standards, STI/PUB/1291, Vienna, IAEA, 2007.
[3] International Evaluation of Neutron Cross-Section Standards, STI/PUB/1291, Vienna, IAEA, 2007.

R193 Covariance Evaluation of the CENDL Library

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The uncertainties and correlations of nuclear data are very concerned in the recent nuclear engineering study. In order to provide the complete covariance files to the reaction cross sections in CENDL, the non-model dependent and model dependent approaches are specially developed at CNDC to produce the covariance files based on the deterministic least square method. In this work, the status of method and the data results for actinides and structure materials for CENDL will be presented.

S194 Uncertainties of Calculated Coincidence-summing Correction Factors in Gamma-ray Spectrometry

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The gamma-ray spectrometry is a measurement technique widely applied for activity measurements in many fields of science and applications. The detection limits in case of low activity concentrations can be improved by measurements in "close" sample-detector geometry and detectors with high detection efficiency. However, such measurements are affected by coincidence-summing effects caused by the simultaneous deposition in the detector of the energy of the gamma-rays emitted in a cascade. In addition the coincidence-summing effects need to be taken into account in efficiency calibrations utilizing multiple gamma-rays standard sources.

The evaluation of the coincidence-summing effects requires knowledge of the probability per decay that coincidences between two or more transitions occur, determined by the decay properties; total and full energy peak efficiencies for the entire spectrum. Many algorithms and computer programs have been developed for identification of the coincident gamma transitions, calculation of the coincidence probability and coupling with the peak or total efficiencies. However, in most of the cases proper uncertainty propagation is not provided. Uncertainty analysis in order to provide reliable confidence level of the reported values is required nowadays in view of the more stringent quality assurance criteria.

For calculation of the gamma-ray peak area in presence of coincidence summing effects we have chosen the general method proposed by Andreev et al. [1] and developed to a matrix formulation by Semkow et al. [2]. The method is based on recursive formulae in which the decay data and efficiencies are coupled. The decay scheme is represented by a matrix and the summing-in and summing-out effects for all gamma transitions are simultaneously calculated in a consistent way. Methods for propagation of the decay data, peak and total efficiencies to the measured gamma-ray peak intensities in presence of coincidence-summing will be described and applied for the Cs-134 decay scheme.

[1] D.S. Andreev, K.I. Erokhina, V.S. Zvonov and I.Kh. Lemberg, Instr. Exp. Tech (USSR) 15 (1972) 1358

[2] T.M. Semkow, G. Mehmood, P.P. Parekh, , M. Virgil, Nucl. Instrum. Meth. A290 (1990) 437.

S195 Uncertainty Quantification by Polynomial Chaos Technique for Source Driven Subcritical Experimental Systems

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The improvement of the computational methods used for the uncertainty analysis of source driven subcritical experiments makes it possible to obtain more realistic estimates of the accuracy of results. This is important for the further improvement of the calculation codes and cross-section libraries used to justify the ADS-systems nuclear safety and characteristics. Standard methods for estimating uncertainties (Monte-Carlo, sensitivity analysis, etc.) have disadvantages associated with a significant increase in the demand for computational resources for their use in nonlinear problems with a large number of input parameters that contribute to the overall subcriticality and reaction rate uncertainties. In this connection, the spectral methods of uncertainty analysis, in particular, the method of polynomial chaos attracts growing attention.

In this work, polynomial chaos approach has been adapted to estimate the uncertainties of the results of subcritical experiment performed on Yalina facility. Yalina is subcritical assembly driven by a neutron generator. It is operating at the Joint Institute for Power and Nuclear Research - Sosny of the National Academy of Sciences of Belarus for investigation the static and dynamic neutronics properties of ADS-system.

S196 Cyclotron Production Cross Sections of ^{61}Cu Radionuclide from ^{nat}Ni(d, X)^{61}Cu Nuclear Reaction

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The ^{61}Cu is in important radionuclide in nuclear medicine as well as industrial applications. In the present work, production cross sections of ^{61}Cu were measured in the ^{nat}Ni(d,x)^{61}Cu nuclear reaction. The target irradiation was done using 24 MeV deuteron energy to the production threshold of the ^{61}Cu. The well-established stacked-foil activation technique was combined with HPGe γ-ray spectrometry for the irradiation and measurement of the induced activities, respectively. The results were compared with the available experimental data and also with the evaluated data in the TENDL library. Our results agree with some of the earlier reported experimental data while a partial agreement is found with the evaluated data from the TENDL library. The results would help to understand the discrepancies among the earlier measurements.

S197 Measurement of ^{241}Am (n,2n) Reaction Cross-section Induced by 14.8 MeV Neutron

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The measurement of the cross section of the reaction ^{241}Am(n,2n)240Am at 14.8 MeV neutron, has been performed by the activation method. The neutron beam was produced at the Cock-croft Accelerator in China Institute of Atomic Energy, by the ^{3}H(d,n)^{4}He reaction, using a Ti-tritiated target. The radioactive target consisted of a 201 MBq ^{241}Am solution enclosed in a polypropylene tube. A natural Au solution containing about 1 mg Au, was mixed with ^{241}Am solution as reference materials for the neutron flux determination. After the end of the irradiation, the samples were placed into lead shield tube. The activity induced at the ^{241}Am target and the reference materials Au, was measured off-line by a well-type HPGe detector whose efficiency was calibrated by ^{240}Am and ^{241}Am activity standard source. ^{241}Am(n,2n)^{240}Am cross section at En = 14.8 MeV is calculated. The result is 269(39) mb.

I198 Reduction of Uncertainty in General-purpose Libraries Using Transport Equation Constraints

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There is a long-standing controversy between the users, who would like the evaluated nuclear data libraries to predict small uncertainties in the multiplication factors k-eff of critical assemblies and the evaluators, who derive the covariance information from measured differential data that predict relatively large uncertainties, in spite of the observation that in many cases the differences between the measured and the calculated k-eff are small. If the calculated values are aligned, it means that the benchmarks are correlated, and not that the actual uncertainties are small. The average number of neutrons per fission cannot be measured to better than about 0.5∼% and the uncertainty in the fission cross section of ^{235}U, which is a standard, is about 1.5∼%. From the differential experimental point of view these two quantities are practically uncorrelated. Consider a simple 1-group form of the transport equation:

$$k_{eff} = \frac{\overline{\nu}}{\Sigma_f \Sigma_a + \Sigma_f + L} \tag{1}$$

where Σ are the cross sections and subscripts a and f stand for absorption and fission, respectively, while L is the leakage. The uncertainty of $\overline{\nu}$ is directly propagated to k-eff. The propagation of the uncertainty in Σ_f is diminished slightly because it appears in the numerator and the denominator and depends on the relative magnitude of Σ_a, but it is obvious that the uncertainty due to nuclear data alone cannot be much smaller than about 1∼%. Assuming that the above equation is universally valid and that the typical uncertainty reachable in critical experiments is 0.3∼%, then we can derive strong anti-correlations between $\overline{\nu}$ and Σ_f.

Considering the above, simple generic correlation coefficients are derived using spectrum-averaged $\overline{\nu}$, Σ_f, and Σ_a values for a thermal Maxwellian spectrum and ^{235}U prompt fission neutron spectrum and the constraint that the uncertainty of critical experiments is about 0.3∼%.

Derived correlations are not related to any particular reactor system and can be added to the covariance information to reduce the calculated k-eff uncertainty without artificially reducing the uncertainty of $\overline{\nu}$ and Σ_f. The approach is compared to the results of a rigorous GLS procedure for a highly-enriched uranium bare sphere and a bare highly-enriched uranium solution.

R199 Researches on Uncertainty Quantification Due to Nuclear-data Covariance for PWR and SFR

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In this paper, uncertainty quantification has been implemented to both PWR and SFR, propagating the nuclear-data uncertainties to the significant reactor simulation results. For the nuclear-data uncertainty propagation, the UNICORN code has been applied, which utilizes the Direct Numerical Perturbation Method for sensitivity analysis and Statistical Sampling Method for uncertainty analysis. The nuclear-data covariance library is generated from ENDF/B-VII.1, with different energy-group structures and weighting spectrums applied for PWR and SFR. For uncertainty propagation to PWR, the BEAVRS benchmark has been analyzed, quantifying the uncertainties of the reactor keff and power distributions. For uncertainty propagation to SFR, the experiments launched on JOYO and ZPPR facilities have been analyzed, quantifying the reactor keff, reactivity and power distributions. From the numerical results, it can be observed that the nuclear data introduces about 500pcm and 1200pcm to the keff of PWR and SFR. For the relative uncertainties of the power distributions, the maximum uncertainty can be about 4% and 2% for PWR and SFR. All these uncertainties introduced by the nuclear data are significant for reactor-physics modeling and simulations.

R200 Covariance Generation for the Prompt Neutron Multiplicity on Pu-239 and U-235 Including the (n,γf) Process in the R.R.R.

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Fission cross sections of U-235 and Pu-239 can be seen as a sum of the "direct" fission and "two-step" (n,γf) reactions. In the Resolved Resonance Range (R.R.R.) of the reaction cross sections, the contribution of the (n,γf) process has an impact on the determination of the partial widths involved in the Reich-Moore approximation of the R-matrix theory. The present work aims to investigate this impact by using the CONRAD code and the partial width γf for the (n,γf) reaction calculated by Bouland et al. [1]. A method, similar to the one presented in [2], will be used. This method was succesfully applied to describe the prompt neutron multiplicity of Pu-239 up to 50 eV. A spetial attention will be paid to the covariance matrix obtained on p, and correlations with cross sections will be discussed.

[1] J. E. Lynn, P. Talou and O. Bouland. Phys. Rev. C 97, 064601 (2018).
[2] E. Leal-Cidoncha, G. Noguere, O. Bouland and O. Serot. WONDER-2018 Proceedings (to be submitted to) EPJ Web of Conferences (2018).

R201 Measurement of ^{235}U(n,f) Cross Section Below 150 keV

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Presented by Simone Amaducci on behalf of n_TOF collaboration

The ^{235}U(n,f) cross section is established as a standard reference at thermal energy and in the range between 150 keV and 200 MeV. This reaction is widely employed to measure the neutron flux, or as reference in measurements of neutron induced reaction cross sections, in particular fission reactions of actinides of interest for nuclear technologies and for the modeling of fission recycling in r-process nucleosynthesis. Recent experimental data have hinted to a possible overestimation, by some evaluations, of the ^{235}U(n,f) cross section between 10 and 30 keV, where it is often employed although not considered as a standard in this energy range. Hence any correction to the values adopted in evaluated libraries will have an immediate impact on all the results of experiments using the ^{235}U fission as reference.

For such reasons an accurate measurement of ^{235}U(n,f) cross section has recently been performed at the n_TOF facility at CERN, where a suitable neutron beam with a remarkable energy resolution and high instantaneous flux is available. A new experimental setup has been used, consisting of a stack of six single pad silicon detectors and pairs of ^{235}U, ^{10}B and ^{6}Li targets, with the ^{10}B(n,α) and ^{6}Li(n,t) reactions used as reference. The stack has been placed along the beam line in order to detect the forward and backward products, with large angle coverage. This measurement is the first in which silicon detectors has been used to detect fission products at the n_TOF facility. It confirms the overestimation in the 10-30 keV range by major evaluated data libraries, further improves the knowledge of the uranium fission cross section at low energies. In the talk the customized experimental apparatus and the data analysis with the final results will be presented.

S202 Calculation of Electron Scattering Cross-section Using Different Theoretical Methods

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Aiming at the simulation of the fine process of the electron transportation in gamma detectors, we calculate electron differential scattering cross-section (DCS) of several typical materials including Fe, ethylene and polyethylene. Based on three different calculation methods, which are partial wave methods based on Dirac equation and R-matrix theory, we find discrepant differences of DCS at low energy region. The result indicates that both partial wave method and R-matrix theory associated with independent atom method (IAM) are not suitable for low energy electron impacting on strong coupled molecule, for example, electron-ethylene. For high energy electron interacting with atom and molecule, the result shows no critical difference because the kinetic energy of the incident electron is severely higher than the electron bound energy in molecule or the excitation energy of a certain atom.

S203 Improved Model for Atomic Displacement Calculation

Shengli Chen, David Bernard, Jean Tommasi, Cyrille De Saint Jean
CEA

Atomic displacement is one of the key factors that influence the behaviors of material properties during and after irradiation. For example, the life of a nuclear reactor is determined by the irradiation resistance of the reactor pressure vessel. Many models, including the international standard metric Norgett-Robinson-Torrens model (NRT), have been developed to calculate the Displacement per Atom (DPA) using the energy of Primary Knocked-on Atom (PKA) as a major parameter. However, extensive experiments and simulations indicate that the NRT-DPA model seriously overestimates (about 3 times) the actual DPA. Nordlund recently developed the Athermal Recombination-Corrected DPA (ARC-DPA) model. The ARC-DPA model shows that the Molecular Dynamics (MD) simulations can be directly used to compute DPA by fitting the simulated data for each isotope. We have developed an improved expression for the efficiency function to calculate the DPA without requiring fitting parameters as needed in the ARC-DPA model. Our DPA calculation results utilizing the improved efficiency function are validated against the experimental data for the Fe, Ni, and Cu. The applications in fast breeder nuclear reactors show good agreement with the ARC-DPA metric for ^{56}Fe.

I204 Recent Work on Neutron Cross Section Standards

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An evaluation of the neutron standards was recently completed. That evaluation included each of the following: the neutron cross section standards (the H(n,n), ^{6}Li(n,t), ^{10}B(n,α_1C), ^{10}B(n,α), C(n,n), Au(n,γ), ^{235}U(n,f) and ^{238}U(n,f) cross sections); the ^{252}Cf spontaneous prompt fission neutron spectrum; the ^{235}U thermal neutron-induced prompt fission neutron spectrum; reference γ-ray production cross sections and the low energy gold capture cross section. Also included in the neutron cross section standards evaluation process were the ^{238}U(n,γ) and ^{239}Pu(n,f) cross sections. Those data were included since there are many ratio measurements of those cross sections with the standards and absolute data are available for them. Thus the evaluation process produced, in addition to the standard cross sections, evaluations for the ^{238}U(n,γ) and ^{239}Pu(n,f) cross sections.

It is important to maintain experimental programs to increase the quality and extend the database for these standards in order to improve evaluations of the standards. In this presentation work will be reported on new or continuing efforts on the cross section standards including that on the 30 keV Maxwellian averaged cross section for Au(n,γ) that is used in neutron capture cross section measurements as a reference for reactions important for astrophysics. Also reference γ-ray production cross section work and efforts to improve the source intensity of the US national standard neutron source, NBS-I, that has been used in cross section measurements will be discussed.

R205 Updating Covariances of Experiments in the Neutron Data Standards Database

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The Neutron Data Standards project co-ordinated by the IAEA provides high-fidelity mean values and covariances of specific observables—the ^{6}Li(n,t), ^{10}B(n,α), ^{235,238}U(n,f) and ^{239}Pu(n,f) cross-sections among them. Nuclear data measurements of other observables are often measured as a ratio to standard observables. And, hence, the Neutron Data Standard project data influence evaluated quantities apart from the data provided by standard project (and included in, for instance, ENDF/B-VIII.0) through these ratio measurements relative to many other observables.

In the recent release of the standards data, the evaluated uncertainties of some observables were significantly increased using the method of 'unrecognized systematic uncertainties'. For instance, the ^{235}U(n,f) and ^{239}Pu(n,f) cross-section uncertainties were increased by a factor of two in some energy ranges. This significant increase leads to increased evaluated uncertainties of other observables and, in turn, of application quantities calculated using Neutron Data standards data or evaluated data taking into account implicitly these new standards data. The reason for increasing these uncertainties were that it was assumed that uncertainty sources of specific experiments, correlations between uncertainties of different experiments and unrecognized uncertainties across measurements using the same technique are missing for experimental data in the standards database.

Here, ^{239}Pu(n,f) cross-section uncertainties of experiments in the standards database are updated to account for missing uncertainties of single experiments and missing correlations between uncertainties of different experiments. This update is undertaken by applying a template of expected uncertainties and correlations for (n,f) cross-section measurements consistently across all data sets. It will be discussed how the evaluated ^{239}Pu(n,f) cross-section and uncertainties change due to that update. It will be also shown how ^{6}Li(n,t), ^{10}B(n,α) and ^{235,238}U(n,f) cross-section uncertainties are influenced due to cross-correlations and ratio measurements in the standards database.

R206 Modified Single Particle Estimate Approach for Estimation of Nuclear Resonance Fluorescence Cross-section

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This paper describes a theoretical approach to calculate nuclear resonance fluorescence (NRF) cross-section. The accurate theoretical evaluation of NRF cross section is important as the experimentally measure data is available only for the limited number of excited states and fewer number of isotopes. In this work, the conventional transition strength based on the single particle estimate (SPE) model is adjusted using experimental data of U-238 and Pu-239 to overcome the limitation of the model. The strength has been adjusted according to the type and multipolarity of transition strength which are determined by quantized values of excited and ground states. The results are partially acceptable compared to the known experimental data in the view of benchmarking the process. This method will be particularly useful if many experimental NRF cross-section are accumulated.

R207 Precise Measurement of the Neutron Capture Cross Section of U-235 at Thermal and Sub-thermal Energies

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The recommended -highly precise- cross-section value for ^{235}U neutron-capture at thermal energies is largely based on the difference from total and competing cross-sections of ^{235}U. Despite its importance and high value (100 barn), direct measurements of (n,γ) are rare (only two exist for thermal energies) and exhibit large uncertainties. The reason is the difficulty to measure the characteristic radiation of the reaction product ^{236}U within a dominant fission background (^{236}U has a long half-life of 23.4 Myr).

Capture of ^{235}U may exhibit a deviation from a pure 1/v-behaviour around thermal energies. Additional energy-dependent data are required to provide information about the cross section and of α, i.e. the capture-to-fission ratio. Measurements at different beam temperatures provide directly the shape of the correction-factor as a function of energy. For this reasons, we started a project with a new method utilizing different neutron fields to evaluate its energy dependence in the low energy region. We use a combination of neutron activation and subsequent accelerator-mass-spectrometry (AMS) for direct atom counting of the reaction product U.

Activations of several $\sim$ 50mg pellets (natural uranium-oxide powder with well-known stoichiometry and low ^{236}U content) have been performed: with an almost pure Maxwellian spectrum at room temperature at BR1 (Mol) and with cold neutrons at MLZ (Munich); more irradiations are planned at ILL (Grenoble) for lower energies. The main quantity measured in AMS is the isotope ratio of the reaction product relative to the target nuclide, this is ^{236}U/^{235}U for ^{235}U(n,γ)^{236}U. Using AMS, the capture cross-section is then simply this isotope ratio divided by the neutron fluence. Simultaneously, we measure the ^{236}U/^{239}Pu ratio in the irradiated ^{nat}U sample giving directly the cross-section ratio of ^{235}U(n,γ) relative to ^{238}U(n,γ). A measurement relative to fission is possible, too. The latter cases are completely independent of the neutron fluence. AMS will allow for an accurate determination of ^{235}U(n,γ)^{236}U. Based on our experience in neutron cross-section measurements and by combining the results from different AMS labs, we expect an AMS-uncertainty <2%.

We will present our new measurement approach, its potential for independent highly precise nuclear data and we will give preliminary results.

R208 Relativistic Effect on Atomic Displacement Damage

Shengli Chen, David Bernard, Cyrille De Saint Jean
CEA

Displacement per Atom (DPA) is one of the most important parameters that measure the mechanical behaviors of materials after irradiation. However, the relativistic effect is not accounted for in typical calculations of DPA cross sections and Primary Knock-on Atom (PKA) spectra. Recent work shows the computation of relativistic recoil energy for neutron scattering reactions. The relativistic corrections are not important for incident energy below 20 MeV but significant for high incident energies, such as 200 MeV. Both positive and negative relativistic corrections on recoil energy leads to the broadening of PKA spectra. The influence of relativistic effect on atomic displacement damage will be presented for particle emission reactions, including (n,p) and (n,α) reactions, which are not negligible at high incident energy.

I209 Integral Adjustment of Nuclear Data Libraries - Finding Unrecognized Systematic Uncertainties and Correlations

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To reduce the uncertainties and obtain a better predictive power, integral adjustment of nuclear data libraries is one powerful option. Databases with integral experiments, such as the ICSBEP contain a large amount of data. When adjusting nuclear data using these integral experiments, it is important to not only include reported experimental uncertainties but also to account for the possibility of unreported experimental uncertainties and correlations between experiments, and calculation uncertainties[1]. Unreported uncertainties and correlations can be identified and possibly quantified using marginal likelihood optimization (MLO)[2]. MLO has previously been tested for integral adjustment [3]. In this paper, a method for including more information from the full likelihood space is pursued.

It is shown that MLO can be an effective tool in addressing unknown uncertainties and correlations for a selected number of integral experiments. Results in terms of obtained parameter estimates as well as of posterior uncertainties and correlations are reported. The results are validated against an independent set of integral experiments.

The findings are important for large-scale ND evaluations that heavily rely on automatization, such as TENDL, but also for any integral adjustment where a complete knowledge of all uncertainty components is out of reach. The authors believe that this is always the case.

[1] E.Alhassan et al. On the use of integral experiments for uncertainty reduction of reactor macroscopic parameters within the TMC methodology Progress in Nuclear Energy, 88, pp. 43-52. (2016)
[2] G. Schnabel, Fitting and Analysis Technique for Inconsistent Nuclear Data, Proc. of MC2017, 2017
[3] H. Sjöstrand et al. Monte Carlo integral adjustment of nuclear data libraries - experimental covariances and inconsistent data, WONDER 2018.

R210 In Search of the Best Nuclear Data File for Proton Induced Reactions: Varying Both Models and Their Parameters

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A lot of research work has been done in fine tuning model parameters to reproduce experimental data for neutron induced reactions. This however is not the case for proton induced reactions where large deviations still exist between model calculations and experiments for some cross sections. In this work, we present a method for searching both the model and model parameter space in order to identify the 'best' nuclear reaction models with their parameter sets that reproduces carefully selected experimental data. Three sets of experimental data from EXFOR are used in this work: (1) cross sections of the target nucleus (2) cross sections of the residual nuclides and (3) angular distributions. A sensitivity and correlation analysis was carried out to identify the relationships and sensitivities of different models as well as their parameters to cross sections. The selected models and their parameters were then varied simultaneously to produce a large set of random nuclear data files. The goodness of fit between our adjustments and experimental data was achieved by computing a global (weighted) chi square which took into consideration the above listed experimental data. The method has been applied for the adjustment of proton induced reactions on Co-59 between 1 to 100 MeV. The adjusted files obtained are compared with available experimental data and evaluations from other nuclear data libraries.

R211 Data Assimilation with Post Irradiation Examination Experiments

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Burnup calculations to predict the nuclide compositions of spent fuel are subject to uncertainties created by nuclear data. These uncertainties include cross sections, neutron multiplicities, fission spectra, and fission yields. This can create uncertainties and biases in predicted nuclide compositions. Data assimilation methods can be extended to burnup calculations by treating the nuclides in the spent fuel as integral parameters. Then, the nuclide compositions can be adjusted along with the nuclear data. We present here adjustments to nuclide compositions and fission yield data with simulations of the post-irradiation examination experiments from the LWR-Proteus Phase II campaign. The adjustments are done through the stochastic sampling of the input nuclear data in order to account for non-linear effects in the coupling of the Bateman and Boltzmann equations.

R212 Analysis of the Prior Nuclear Data Correlation and Its Effect on the Adjustment in Bayesian Inference

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High-quality nuclear data is of prime importance while considering the design of advanced fast reactors. The quantification of nuclear data uncertainties is always required for the safety calculations of nuclear power plants. Using reliable nuclear data and its correlation are of great importance for the quality of uncertainty analysis. Nuclear data is usually evaluated using mathematical models and is improved by using integral experiments. To utilize the past critical experimental data to the reactor design work, a typical procedure for the nuclear data adjustment is based on the Bayesian theory (least-square technique or Monte-Carlo). Using Bayesian theorem, the nuclear model parameters are optimized by the inclusion of experimental information. The posterior data and its covariance are evaluated from the optimized model parameters. In this process, the prior data, its covariance and the integral experimental data are provided to the optimizer as input. The selection of integral experiments is based on the availability of well-documented specifications and experimental uncertainties.

The prior covariance matrix used for the adjustment is usually very large as it contains correlation information between energy groups, nuclear reactions and isotopes considered for the adjustment. Often, due to the choices made for adjustment; the prior correlation matrix is encountered as negative definite or singular. These situations affect the accuracy of the adjustment heavily. Hence, in the adjustment process, it is very important to avoid the prior matrix as singular or negative definite.

In this work, using principal component analysis, the size of the prior nuclear data (and its correlation) is first reduced to ensure the non-singularity in the prior. Further, the reduced parameters are used in Bayesian inference for the posterior calculation. Furthermore, the influence of each individual ingredient (experiment/nuclear data) will be analyzed using the concept of Cook's distance. First, JEZEBEL (^{239}Pu, ^{240}Pu and ^{241}Pu) will be considered and the transposition of the result on ASTRID Fast reactor concept will be discussed.

R213 Learning from Google: About A Computational EXFOR Database for Efficient Data Retrieval and Analysis

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High-level languages, such as Python and R, find broad adoption for data science and machine learning due to their expressive power and the many community-contributed packages to apply sophisticated algorithms in just a few lines of code. Despite the fast progress in these fields in recent years, the field of nuclear data evaluation remained relatively unaffected by these developments. An essential reason for this observation may be the fact that the original EXFOR format is cumbersome to deal with in high-level languages. In this contribution, I present details about the successful conversion of the complete original EXFOR database to a NoSQL database as, e.g., employed by Google, discuss the advantages of this database architecture for nuclear data evaluation, and provide examples demonstrating the ease and flexibility of data retrieval. Finally, I show some possibilities of quick data visualization and manipulation, such as the inversion of huge experimental covariance matrices (e.g., 105×105 including correlations between data sets), underpinning the benefits of performing nuclear data evaluation in a high-level language. Conversion codes and program packages will be made available for everyone. The availability of these codes will also enable outsiders of the nuclear data field, e.g., mathematicians, statisticians, and data scientists, to test their ideas and contribute to the field.

I214 Improved Evaluations of Neutron Induced Reactions on ^{57}Fe and ^{56}Fe Targets

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Nuclear reaction data of iron are important in reactor physics and shielding applications and have been addressed within the Subgroup-40 (CIELO) of the OECD/NEA Data Bank. The resulting evaluated data files from the BNL/IAEA collaboration for the iron isotopes were included in the ENDF/B-VIII.0 library and performed well in criticality benchmarks. Unfortunately, inadequate performance of the ^{56}Fe evaluation was discovered for shielding benchmarks just before the release of the ENDF/B-VIII.0 library: the leakage spectra from thick iron shells with a ^{252}Cf source in the centre were significantly under-predicted in the energy range 1-8 MeV.

To correct the deficiency, additional analysis was performed. The root cause of the problem was traced to the non-elastic cross section, which seemed to be too high. This hypothesis was confirmed by new measurements of the elastic cross section. A compromise between the measured elastic and the inelastic cross section was sought such that unitarity with the total cross section was preserved. In addition, a slight tuning of the total cross section was made just above the resonance range and the elastic cross section was increased in the resonance interference minima around 300 keV, guided by the measured leakage spectra from thick iron shells with a ^{252}Cf source in the centre. Changes to the ^{57}Fe evaluation in the resonance region were needed to increase the average inelastic cross section in agreement with recently published values.

The resulting evaluated data files were extensively tested. The previously observed deficiency of under-predicting the leakage spectra from thick iron shells with a ^{252}Cf source was avoided. Similar benchmark experiments with a D-T source also showed an improvement. In a benchmark involving 40 MeV neutrons the new evaluation performed much better than the ENDF/B-VII.1 library. At the same time, performance in criticality benchmarks was not compromised. The benchmarking exercise illustrates how integral benchmarks can be used to discriminate between discrepant differential data to produce evaluated data files that perform well in situations that are critical for the safe operation of nuclear installations. Details of the changes to the differential data will be given and selected representative benchmark results will be presented.

I215 Fusion Decay-heat Benchmark for Nuclear Data Validation: Advanced Interrogation Capabilities with FISPACT-II

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The validation of nuclear data used to predict compositional changes in materials under neutron irradiation is an important factor in determining the quality and robustness of "production" simulations to model materials in real applications. The FISPACT-II inventory code, developed by UKAEA, is a modern and efficient code that has undergone rigorous testing. However, while the computational techniques may be verified, the quality and accuracy of transmutation and activation predictions are largely determined by the validity of input nuclear data. Hence, FISPACT-II development has been paralleled by extensive efforts to devise, produce, analyze, and automate a suite of data validation benchmarks that test the code in a variety of scenarios with different nuclear data libraries.

Of importance for UKAEA's fusion research (at the Culham Centre for Fusion Energy, CCFE) is the fusion decay-heat benchmark that makes use of an invaluable experimental database produced in Japan at the turn of the 21st century. A wide range of different materials were irradiated for either 5 minutes or 7 hours at the fusion neutron source (FNS) facility of the Japan Atomic Energy Agency (JAEA), and the decay heat was subsequently measured as a function of time with high accuracy. The experimental characteristics (measurement times, sample compositions, etc.) were well documented and this has allowed simulations to be designed to faithfully reflect the irradiation and measurements.

This benchmark has been performed with the latest versions of major international nuclear data libraries, including TENDL-2017, JEFF-3.3, CENDL-3.1, JENDL/AD, and ENDF/B-VIII.0. Novel analysis techniques have been developed to probe the subtleties in each individual measurement set; for example, graphical visualization of the time-evolving contributions to decay-heat from different radionuclides - a capability afforded by FISPACT-II's detailed inventory outputs - offers new insight into the proficiency of the simulated decay profiles, both quantitatively and qualitatively. For many materials, the code predictions are a good match to measurements, but for some important cases (and cooling times) the comparison between simulation and experiment is not so favourable. Various examples, both good and bad, will be discussed in this paper, highlighting the detailed interrogation techniques developed within the FISPACT-II (https://fispact.ukaea.uk/) framework.

R216 Two Absolute Integral Measurements of the ^{197}Au(n,γg) Stellar Cross-section and Solution of the Historic Discrepancies.

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The Au(n,γ) cross-section is the most used reference in time-of-flight (TOF) and integral experiments, in particular in those for nuclear astrophysics, although the energy range above thermal to 0.2 MeV, the most important in astrophysics, is not included as standard. It was not included neither in the extension of neutron standards performed in 2014 nor in the work for the new evaluation (2018), in which it is only recommended a linear interpolation above thermal to 0.2 MeV. The main reason is the structure of the cross-section in this energy range and the historic and important discrepancy between the Maxwellian Average Cross Section at kT = 30 keV (MACS-30) calculated from the standards evaluations and the experimental integral value of Ratynski and Köppeler (R&K).

R&K obtained an accurate value of the MACS-30 of (582±9) mb by means of spectrum average cross section (SACS) at kT=25 keV with a quasi Maxwellian Neutron Spectrum (MNS) at kT=25 keV. However, the R&K value of the MACS-30 is has been about 6% lower than all standards evaluations since the 2006. We have carried out two integral experiments with different methods of neutron production for the absolute determination of the Au(n,γ) stellar cross-section at kT = 30 keV. The first experiment mimics the R&K but using a gold flat sample. The second experiment is based on the production of a neutron spectrum which resembles much better a Maxwellian than those of R&K. The analysis includes new and improved corrections for flat sample and neutron spectrum. The obtained results agree with TOF measurements and recent IAEA evaluation. We suggest the revision of the most important cross-section data for nuclear astrophysics taken into account these corrections. In addition, we will discuss the origin of the historic discrepancy.

R217 Nuclear Data Verification and Validation Platform for JEFF-4

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Nuclear Energy Agency

In 2018, the Joint Evaluated Fission and Fusion (JEFF) project extended its mandate with a focus on the delivery of a new nuclear data library, JEFF-4. The requirements for the JEFF-4 advancement include: a) enhanced quality control; b) the use of modern systems to support production; and c) a higher level of task automatization. In particular, the complete automation of a verification and validation (V&V) sequence for nuclear data libraries was identified as the cornerstone to ensure quality, transparency and reproducibility to the whole project. Not only should individual files be automatically tested for consistency with the underlying physics, but also the processing and benchmarking of the whole library must be addressed.

A git-based development platform installed and maintained by the NEA Data Bank was adopted as a collaborative space for the JEFF-4 library production. This platform allows close collaboration amongst JEFF evaluators and nuclear data end-users. Thanks to its built-in continuous integration framework a V&V sequence was put in place to automatically test, process and benchmark evaluated nuclear data files. This sequence summarizes the best knowledge of the JEFF community in terms of nuclear data processing and benchmarking and includes all the most widespread dedicated code such as the ENDF checking and utility tools, NJOY and MCNP. In this work, the development platform and its implications with the JEFF-4 progress are described.

R218 New Features and Improvements in the NEA Nuclear Data Tool Suite

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The OECD Nuclear Energy Agency (NEA) has developed and maintains several products that are used in the verification and validation of nuclear data, including the Java-based Nuclear Data Information System (JANIS) and the Nuclear Data Sensitivity Tool (NDaST). These integrate other collections of the NEA, including the International Handbooks of benchmark experiments on Criticality Safety and Reactor Physics (ICSBEP and IRPhEP) and their supporting relational databases (DICE and IDAT). Recent development of the JANIS, DICE and NDaST systems have resulted in the ability to perform uncertainty propagation utilising Legendre polynomial sensitivities, calculation of case-to-case covariances and correlations, use of spectrum weighting in perturbations, calculation of statistical results with suites of randomly sampled nuclear data files and new command-line interfaces to automate analyses and generate XML outputs. All of the most recent, major nuclear data libraries have been fully processed and incorporated, along with new visualisation features for covariances and sensitivities, an expanded set of reaction channel definitions, and new EXFOR data types defined by the NRDC. Optimisation of numerical methods has also improved performance, with over order-of-magnitude speed-up in the case of sensitivity-uncertainty calculations.

This presentation will highlight the most salient improvements to the NEA nuclear data tools and discuss how they are used in a variety of nuclear data verification, validation and feedback processes.

I219 Benchmark Testing of CENDL-3.2B1

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The nuclear reaction data for several important actinides and structure materials are continuing revised for CENDL-3.2. A new beta version of CENDL library, CENDL-3.2beta1, was prepared. To test the performance of the new version and supplying feedbacks for further revising, the library was tested with 1261 criticality benchmarks from the ICSBEP2006 handbook, by using the first version of the Evaluated Nuclear Data Testing System (ENDITS-1.0). The C/E trends against the EALF values of the criticality benchmarks sensitive to the same material are studied. The benchmarking results shows the data for U-235, Pu-239, Th-232 and Fe-56 have been improved comparing with CENDL-3.1. The overall 2 have decreased significantly by the improvement of Pu data. A list of isotopes need to be improve was also suggested.

R220 Effects of Different Nuclear Evaluation Data on the RMC K-eff Calculation

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Neutron cross section data is the basis of nuclear reactor physical calculation and has a decisive influence on the accuracy of calculation results.AFA3G assemble is widely used in nuclear power plants. CENACE is an ACE format multiple-temperature continuous energy cross section library that developed by China Nuclear Data Center.In this paper , we calculated the AFA3G assemble by RMC.We respectively used ENDF6.8/,ENDF/7 and CENACE data for calculation.The impact of nuclear data on RMC calculation is studied by comparing the results of different nuclear data.

R221 Analyses of Natural Radioactivity Concentrations in Soil and Assessment of Effective Doses in Several Districts of BANTEN and West Java, Indonesia

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Natural radioactivity contents in soil significantly affect the gamma radiation levels. Analyzes the natural radioactivity concentrations may be used to calculate the effective dose rates accepted by the people in an area. This study carried out analyzes of natural radioactivity concentrations in soil and assess the effective dose rates accepted by the people in several districts of Banten and West Java. Analyzes the natural radioactivity concentrations that include ^{226}Ra, ^{232}Th and 40K were conducted to the samples of surface soils. The soils that were collected from several areas were brought to the laboratory to be prepared and measured the radioactivity concentration using a gamma spectrometry. The results show that the average activity concentrations of ^{226}Ra, ^{232}Th and 40K range from 17.59 to 47.81, 24.41 to 73.55 and 18.16 to 248.97 Bqkg^{-1}, respectively. The calculated value of total average absorbed dose rate in air of Banten and West Java are 37.85 $\pm$ 3.99 and 34.34 $\pm$ 3.75 nGy/h, average radium equivalent activity 82.75 $\pm$ 8.72 and 75.06 $\pm$ 8.20 Bqkg^{-1}, average value of external hazard index 0.23 $\pm$ 0.02 and 0.20 $\pm$ 0.02 as well as outdoor annual effective doses vary from 134.77 to 372.36 and 136.25 to 236.75 mSv.

R222 Validation of Tritium Production Cross-section of Lithium in JEFF3.2 with HCPB Mock-up Experiment

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In the D-T fueled fusion reactors, it is a pre-condition for maintaining their sustainable operation to assure tritium self-sufficiency merited by tritium breeding ratio (TBR). In such reactors, the tritium is produced via reaction between lithium and neutrons. The high precision tritium production cross-section of lithium is crucial to high prediction of TBR in the design of fusion reactors. In this work, the tritium production cross-section of lithium in the JEFF3.2 was validated with HCPB mock-up experiment using SuperMC which is a nuclear design and safety evaluation software system developed by FDS Team.

The HCPB mock-up was irradiated on the 14 MeV fusion neutron source FNG. In the experiment, the 8 stacks of Li2CO3 pellets which were used to measure the tritium production rate (TPR) were symmetrically placed at the two layers of breeder to reduce systemic error. In calculation, a detail model including geometry and neutron source was built in the SuperMC. In this work, the TPR of lower 4 stacks of pellets were compared with calculated ones due to model symmetry.

The statistical calculation error (1) of these results ranged from 0.0002 to 0.0024. It was found that C/E for these 4 stacks ranged from 0.80$\sim$0.97 (the average C/Es were found to be 0.85, 0.92, 0.92 and 0.91), which means that calculated TRP gave underestimation by 3% $\sim$20 %. The above underestimation results indicate that calculated TRP using JEFF3.2 data library could be considered as conservative for reactor applications. And it also indicated that SuperMC could be applied in neutronics simulation of fusion reactors.

R223 Benchmarking ENDF/B-VIII.0 Using the LANL Expanded Criticality Validation Suite for MCNP

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Brookhaven National Laboratory

For many years, the Los Alamos National Laboratory (LANL) expanded criticality validation suite has been used as one of the effective indicators of the overall performance of each ENDF/B library. With the release of new versions of MCNP and NJOY, the ENDF/B-VIII.0 neutron and thermal scattering sublibraries were re-validated using the 119 problems comprising the aforementioned validation suite. This activity is an integral part of the National Nuclear Data Center's continuous nuclear data quality assurance process. The ACE files were generated using NJOY21 (LANL), the latest production version of the NJOY nuclear data processing system. The MCNP 6.2 (LANL) code, which contains the latest code enhancements and bug fixes, then used these ACE files to calculate the k-eff for each problem. Eigenvalue C/E values were calculated and compared with those obtained with ENDF/B-VII.1, JEFF-3.3 and JENDL-4.0.

I224 Validation of JEFF-3.3 and ENDF/B-VIII.0 Nuclear Data Libraries in ANSWERS Codes

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Wood

The JEFF-3.3 and ENDF/B-VIII.0 evaluated nuclear data libraries were released in December 2017 and February 2018 respectively. Both evaluations represent a comprehensive update to their predecessor evaluations. The ANSWERS Software Service produces the MONK® and MCBEND Monte Carlo codes, and the WIMS deterministic code for nuclear criticality, shielding and reactor physics applications. MONK and MCBEND can utilise continuous energy nuclear data provided by the BINGO nuclear data library and MONK and WIMS can utilise broad energy group (172 group XMAS scheme) via the WIMS nuclear data library. To produce the BINGO library, the BINGO Pre-Processor code is used to process ENDF6 format evaluations. This utilises the RECONR-BROADR-PURR sequence of NJOY2016 to reconstruct and Doppler broaden the free gas neutron cross sections together with bespoke routines to generate cumulative distributions for the$S(\alpha,\beta)$ tabulations and equi-probable bins or probability functions for the secondary angle and energy data. To produce the WIMS library, NJOY2016 is again used to reconstruct and Doppler broaden the cross sections. The THERMR module is used to process the thermal scattering scatter. Preparation of data for system-dependent resonance shielding of some nuclides is performed. GROUPR is then used to produce the group averaged data before all the data are then transformed into the specific WIMS library format.

The MONK validation includes analyses based on around 800 configurations for a range of fuel and moderator types. The WIMS validation includes analyses of zero-energy critical and sub-critical, commissioning, operational and post-irradiation experiments for a range of fuel and moderator types. The MCBEND validation includes neutron and gamma dosimetry for iron, water and graphite shielding in proximity to nuclear fuel material and irradiation sources. This paper presents and discusses the results of MONK, MCBEND and WIMS validation benchmark calculations using the JEFF-3.3 and ENDF/B-VIII.0 based BINGO and WIMS nuclear data libraries.

I225 Advance: the ENDF Quality Assurance System

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The ENDF/B library is the United States' most important nuclear data library for neutronics and other nuclear applications, so ensuring the overall quality of the library is paramount. The Cross Section Evaluation Working Group (CSEWG) now uses the ADVANCE quality assurance system to automate testing of the ENDF/B nuclear data library. ADVANCE is a continuous integration system, such as commonly used in software development: ADVANCE continually monitors the source code repository containing the ENDF/B library and any changes to ENDF/B are automatically subjected to a battery of tests including processing through customer codes. The results are published on the NNDC website (see http://www.nndc.bnl.gov/endf/b7.dev/qa/index.html). In this contribution, we will explain how ADVANCE works and detail recent updates to ADVANCE including:
Updated processing codes (FUDGE, PREPRO, NJOY21 and others)
New resonance report
Upgrade of system to Python3 and the latest BuildBot

We will also detail plans for future upgrades to ADVANCE and overall improvements to the quality assurance regime of ENDF/B. Finally, we will also provide details about how to obtain and deploy ADVANCE in other institutions.

R226 Testing of the Thorium-uranium Fuel Cycle Special Nuclear Data Library CENDL-TMSR 1.0

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Thorium-Uranium fuel cycle in Thorium based Molten Salt Reactor (TMSR) has the advantages of high conversion ratio, good performance of Non-proliferation and low production of long life & high radioactive fission products. Improving the confidence and reliability of Thorium-Uranium fuel cycle nuclear data is one of the important ways to enhance the physical design accuracy. China Nuclear Data Center commissioned by Shanghai Institute of Applied Physics developed a thorium-uranium fuel cycle special nuclear data library (CENDL-TMSR-V1.0) which can be used in critical calculation and shielding design of TMSR. In order to validate and qualify the reliability and applicability of CENDL-TMSR-V1.0, a serious of integral benchmark experiments from the International Criticality Safety Benchmark Experiment Handbook were chosen according to the characteristics of TMSR. At the same time, the sensitivity and uncertainty of CENDL-TMSR-V1.0 were evaluated in the key physics parameters for TMSR liquid experimental reactor (TMSR-LF). The benchmark results show that the relative errors between the calculated values and the experimental values of k-eff in most experiments are within 0.5% and the total uncertainty in keff is less than 1%. It ensures the accuracy and reliability of CENDL-TMSR-V1.0, which could be applied in the physical design of TMSR.

R227 Validation of A New URR Implementation in GNDS Format

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The Generalized Nuclear Data Structure (GNDS) is a modern, flexible nuclear data format meant to replace the half-century-old Evaluated Nuclear Data Format (ENDF-6). The specifications have been defined by the Working Party on Evaluation Co-operation (OECD/NEA/WPEC) Sub-group 38, except for the treatment of the Unresolved resonances region. Lawrence Livermore National Laboratory has developed a suite of codes to handle GNDS formatted data, a processing code named FUDGE, and two GNDS API's named GIDI and MCGIDI. These API's are in use in two of LLNL's radiation transport codes Mercury and Ardra. FUDGE (For Updating Data and Generating Evaluations) supports translation of ENDF-6 formatted data to and from GNDS. It also processes GNDS data for use in Monte Carlo and deterministic transport codes, including reconstructing cross sections and angular distributions from resonance parameters. FUDGE can also translate data from GNDS into the ACE format, for use with the MCNP6 Monte Carlo transport code. GIDI (General Interaction Data Interface) is a C++ library for accessing GNDS data and is implemented in LLNL's Monte Carlo, Mercury, and deterministic, Ardra, particle transport codes. MCGIDI (Monte Carlo GIDI) is a C++ library that extracts data from a GIDI instance and is used by Mercury to sample from the data.

We present results from criticality benchmark simulations run with Mercury and using ENDF/B-VIII.0 evaluated nuclear data to test the implementation of the Unresolved Resonance Region probability tables in FUDGE and GIDI/MCGIDI. We compare k-effective values obtained with the Mercury code and data in the GNDS format to those calculated using MCNP6 and ACE files. We demonstrate the new processing and simulation capabilities of GNDS/GIDI/MCGIDI, as well as explore the impact of URR on criticality benchmark simulations. Initial results of the ongoing implementation of thermal scattering laws in LLNL codes will also be reported. Finally, we will generate ACE files from GNDS files using FUDGE and compare them to NJOY generated ACE files using MCNP6. Prepared by LLNL under Contract DE-AC52-07NA27344.

S228 Ratio of Spectral Averaged Cross Sections Measured in 252-Cf(sf) and 235-U(n_{th},f) Neutron Fields

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The results of systematic evaluations of spectrum averaged cross section (SACS) measurements in the fission neutron fields of 252-Cf and 235-U are presented. The data form a complete database of high-threshold experimental SACS measured in the same installation under the same conditions and using the same high purity germanium gamma spectrometer. This is crucial to reduce the uncertainty of the ratio and the data scattering and therefore, to minimize discrepancies compared to cross section measured under different conditions in different laboratories. This new dataset complements and extends earlier experimental evaluations.The total emission of the 252-Cf neutron source during the experiments varied from 9.5E8 to 4.5E8 neutrons per second. The emission was derived in accordance to the data in the Certificate of Calibration involving absolute flux measurements in a manganese sulphate bath. Concerning 235-U fission neutron field, the irradiations were carried out in a specifically designed core assembled in the zero power light water LR-0 reactor. This special core has well described neutron field. After the irradiation, the low volume irradiated samples to be measured by gamma spectrometry were placed directly on the upper cap of a coaxial high purity germanium (HPGe) detector in a vertical configuration (ORTEC GEM35P4). High volume samples were homogenized and strewn into the Marinelli beaker. HPGe detector is surrounded by the lead shielding box with a thin inner copper cladding and covered with rubber for suppression of background signal and bremsstrahlung. The experimental reaction rates were derived for irradiated samples from the Net Peak Areas (NPA) measured using the semiconductor HPGe detector. The measured reaction rates are used to derive the spectrum-averaged cross sections. Furthermore, measured reaction rates are also compared with MCNP6 calculations using various nuclear data libraries, in particular IRDFF evaluations.

S229 Introduction of A Systematic Integral Testing Tool ENDITS

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In recent years, China Nuclear Data Center has gradually established a set of systematic integral testing system,ENDITS-1.0. This system can be use in systematically management of the validation of nuclear data, to achieve the standardization and informatization at operational and analytical level. A large number of benchmarks were collected and sorted out, and a database of characteristic parameters of experiments containing more than 6,000 benchmark experiments was been established. The information of experiment age, structure, materials and other parameters were collected for the retrieval and trend analysis. Through a lot of geometric modeling work, a standard physical model library is established. This library includes ENDITS-MCNP database for MCNP calculation and ENDITS-SCALE database for NPLC program calculation. At present, more than 2500 standard physical models are available. These benchmarks cover shielding and critical benchmarks and capture cross-section integral experiments, which can be used in integral testing of the nuclear data. The ENDITS-1.0 system has been applied to integral tests of CENDL-TMSR and CENDL-NP.

I230 Measurement of (n,f) and (n,2n) Cross Sections of Actinides with the Surrogate Capture-reaction Method

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The surrogate reaction method is an indirect approach to measure the cross sections of neutron induced reactions replacing with charged-particle induced ones. In generally, the peripheral reactions, such as inelastic scattering or transfer reactions are chosen as the surrogate reactions. As a result, the angular momenta involved in these reactions are far larger than the neutron induced reactions, which causes difficulty in theoretical corrections. Considering this, we proposed to use light-ion capture reaction as the surrogate reaction. In this case, the spin of compound nuclei in the surrogate reaction is similar to that in the direct neutron reaction. Therefore, the difficulty of spin corrections can be effectively avoided. Based on this idea, the ^{235}U(n,2n) cross sections have been checked through the ^{232}Th(α,2n) reactions. As a further application, the ^{239}Pu(n,f) and (n,2n) cross sections were successfully extracted by using ^{236}U(α,f) and (α,2n) reactions as the surrogate reaction. The results coincide well with the data of ENDFB7 within the error range. In conclusion, this surrogate capture-reaction method can be extensively applied for the measurement of (n,f) and (n,2n) cross sections of other actinides.

R231 Measurements of Cross Sections for High Energy Neutron Induced Reactions on Co and Bi

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There are missing experimental data for neutron cross-section libraries of (n,xn) reactions in various materials. At neutron energies below 30 MeV, the cross section for these nuclear reactions are considered to be well-known. At high energies (above 20 MeV), these set of (n,xn) reactions are important for neutron fluence monitoring and spectra unfolding at the future IV generation Nuclear Fast reactors (FR) (e.g. accelerator driven systems (ADS)). Cross-sections for neutron-induced reactions on natural cobalt and bismuth were measured at incident neutron energies of about 90 MeV and 140 MeV. These measurements were made using quasi-monoenergetic neutrons (QMN) obtained from the ^{7}Li(p,n) reaction at iThemba LABS. Corrections are made for the contribution of the low energy tail (continuum) in the incident neutron spectrum of these measurements. For another two energies (63 MeV and 95 MeV) we performed similar experiments for natural Yttrium with the QMN at the The Svedberg laboratory (TSL) in Uppsala, Sweden. The measured cross-sections are compared with some of the few available cross-section measurements for neutron-induced reactions at high energies.

R232 High Precision Measurements of the ^{93}Nb(n,2n)$^{92g+m}$Nb Reaction Cross Section

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China Institute of Atomic Energy

The ^{93}Nb(n,2n)$^{92g+m}$Nb cross section is of interest because ^{93}Nb is often used as an element of superconduct alloy in Reactor in which a significant portion of fission neutron spectrum lies above the threshold of ^{93}Nb(n,2n)$^{92g+m}$Nb reaction. Such a cross section has been measured using different neutron detection schemes by many groups in the past 60 years, but the results gained still have a great degree of discrepancy ranging from 800 mb to 2000 mb. In this paper, the ^{93}Nb(n,2n)$^{92g+m}$Nb cross section has been remeasured at En=14.72±0.5 MeV, by means of a new detector based on 110 ^{3}He tubes embedded a spherical polyethelene moderator, relative to the ^{169}Tm(n,2n)^{168}Tm and ^{59}Co(n,2n)^{58}Co reference cross sections. The new experiment result based on Tm (1418±76 mb) agrees fairly well with the result based on Co (1513 $\sim$ 40 mb) within the range of uncertainty, which indicating that this experiment successfully measured the ^{93}Nb(n,2n)$^{92g+m}$Nb reaction cross section. This present paper will describe the experimental procedure and review the different corrections needed to obtain accurate cross sections.

R233 Measurements of Differential and Angle-integrated Cross Sections for the ^{10}B(n,α)^{7}Li Reaction in the Neutron Energy Range of 1 eV $<$ En $<$ 2.5 MeV

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Differential and angle-integrated cross sections for the ^{10}B(n,α)^{7}Li reaction have been measured at CSNS Back-n white neutron source in the incident neutron energy range from 1 eV to 2.5 MeV (71 energy points). Two back-back enriched (90%) ^{10}B samples 5.0 cm in diameter and $\sim$ 85.0 μg/cm^2 in thickness each with a common aluminum backing were prepared. The experiments were conducted using the silicon-detector array of the Light-charged Particle Detector Array (LPDA) system. With 15 silicon detectors, the angular distributions of α-particles were measured from $\sim$20° to $\sim$160°. Fitted by Legendre polynomials, the (n,α) cross-sections were obtained through integration. The absolute cross sections were normalized using the standard cross-sections of the ^{10}B(n,α)^{7}Li reaction in 0.3 - 0.5 MeV neutron energy region. The separating cross sections of the two reaction channels, ^{10}B(n,α_0) and ^{10}B(n,α_1), were obtained for neutron energies up to 1 MeV. All results were compared with existing measurements and evaluations.

R234 Angular Differential and Angle-integrated Cross Section Measurement for the ^{6}Li(n,t)^{4}He Reaction from 1 eV to 3 MeV at CSNS

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As the first experimental research on neutron-induced charged-particle emission reaction at CSNS Back-n white neutron source, angular differential and angle-integrated cross sections for the ^{6}Li(n,t)^{4}He reaction have been measured from 1 eV to 3 MeV at 80 neutron energy points. The LPDA (Light charged Particle Detector Array) setup, placed at Endstation#1 of CSNS Back-n white neutron source, was built and used as the charged particle detector which was mainly consisted with 15 silicon detectors and a vacuum chamber at the first stage. Two enriched (90%) ^{6}LiF samples were prepared with 50 mm in diameter and $\sim$ 800 μg/cm^2 in thickness. Angular differential cross sections (at 15 detection angles ranging from $\sim$ 20° to $\sim$160°) and angle-integrated cross sections were obtained, which are normalized to the standard cross section in 0.1 - 0.4 MeV region where a big resonance peak exists. Measurement results are compared with existing measurements and evaluations. The present cross sections accord well with the recommended standard below 0.5 MeV. However, the present results are somewhat lower than those of most evaluations in the 0.5 - 3.0 MeV region.

I235 An Overview of Experimental Nuclear Science at Los Alamos

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The very first manuscript at Los Alamos was a report on the measurement of the prompt fission neutron spectra. Nuclear science has been at the core of Los Alamos since its inception. Despite this, about a decade ago it was recognized that the nuclear data measurements program at Los Alamos had significantly atrophied and that substantial new efforts were required. This lead to a significant investment in fission research much of which is only now coming to its full fruition. This talk will review the recent history of our experimental programs and highlight many of the advances that have been made, or are still to come.

R236 What Can We Learn from (n,xnγ) Cross Sections About Reaction Mechanism and Nuclear Structure ?

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Inelastic reactions are key reactions in reactor cores as they influence the slowing down of the neutron by reducing the neutron energy, therefore moving neutrons between different energy groups. Therefore, the keff and the radial power distribution of reactor are sensitive to the inelastic scattering. This is especially true for major core components like ^{238}U and the corresponding material in the Th-U fuel cycle, the ^{232}Th nucleus. Since several years, it has been shown that the knowledge of the inelastic cross section in nuclear databases is still need to be improved to accurately simulate reactor cores and a strong demand for new measurements has emerged with very tight target uncertainties (only a few percent) on inelastic scattering cross section. To bypass the well-known experimental difficulty to detect neutrons, the prompt gamma ray spectroscopy method is an indirect yet powerful way to obtain inelastic cross sections.

Our collaboration has developed the GRAPhEME setup (GeRmanium array for Actinides PrEcise MEasurements) at the GELINA facility and uses prompt gamma ray spectroscopy method to measure (n,n'γ) cross sections. GRAPhEME has been optimized for measurement on actinides. The measurements on these nuclei are particularly challenging as their nuclear structure presents low lying levels, a high density of levels even at low excitation energy and moreover, the concurrent neutron-induced fission reaction contaminates the g-energy distribution. For all these reasons, the need of modeling is essential to deduce the total inelastic scattering (n,xn) cross section from the measured partial (n,xnγ) ones.

In this contribution we propose to review the work performed with theoreticians to test the predictive power of reaction nuclear codes like TALYS, EMPIRE and CoH, on the following nuclei studied with GRAPhEME: ^{238}U, ^{232}Th and W isotopes. We will highlight what are the needed/expected improvements concerning the reaction mechanisms description but also the impact of the nuclear structure knowledge. A discussion about uncertainties issues in this kind of measurements will be also presented as the target uncertainty of a few percent on the (n,n') cross sections requested by the reactor applications (HPRL) is a real challenge.

R237 Measurement of (n,γ) Cross-section on ^{186}W Isotopes at Different Neutron Energies

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In fusion reactors a large number of high energy neutrons around 14 MeV generated by D-T reaction. These neutrons escape from the plasma and interact with the first-wall and Plasma Facing Materials which cause atomic displacements within the materials, leading to the generation and accumulation of radiation defects and also initiates the nuclear reactions that alter the transmutation, changes the chemical composition of materials, leading in turn to measurable changes in structural and mechanical properties. The cross-section data of reactions induced by neutrons plays an important role for the study of interaction mechanism, induced activity, nuclear transmutation, radiation damage and other studies. For the study of nuclear reactor, there is a need of high accuracy in reaction cross-section data for reactor materials. There is a large discrepancies and non-availability of the neutron induced reaction cross-section data around 14 MeV for plasma facing materials.

Tungsten is consider as a prime Plasma Facing Material used as divertor components in ITER like fusion reactor. This paper provides the detailed measurement study of ^{186}W(n,γ)^{187}W reaction cross-section at average neutron energies (En) of 5.85±0.33, 10.62±1.0, 13.77±0.95, 16.72±0.85 and 19.33±1.23 MeV using neutron activation and off-line γ-ray spectrometric technique. The neutrons were generated using ^{7}Li(p,n)^{7}Be reaction using 14UD BARC-TIFR Pelletron facilities at Mumbai, India. The experimentally measured reaction cross-sections have been compared with the predicted reaction cross-sections theoretically using nuclear reaction model codes TALYS-1.8 and EMPIRE-3.2.2. The present data are also compared with the values from the latest available evaluated nuclear data libraries and found to be in agreement with the data of ENDF/B-VIII.0,JENDL-4.0.

R238 Thermal Neutron Capture Cross-sections Measurements of Ti-50, V-51 and Mo-98

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Thermal neutron capture cross sections for ^{50}Ti, ^{51}V and ^{98}Mo were measured by the activation method using the filtered thermal neutron beam at the channel No. 2 of Dalat research reactor. An optimal composition of Si and Bi single crystals has been used as neutron filters to create the high purity filtered thermal neutron beam with Cadmium ratio up to 420. The cyclic activation mode was applied for the cases of ^{50}Ti and ^{51}V because of short half lives of their neutron capture products. The induced activities in the irradiated samples were measured by a high resolution HPGe digital gamma-ray spectrometer. The present results of thermal neutron capture cross sections have been obtained relative to the reference values of ^{197}Au standard, with $\sigma_\circ = 98.65 \pm 0.09$ barn. The necessary correction factors for thermal neutron self-shielding and multi-scattering effects were taken into account in the determinations. The present results are discussed and compared with previous measurements.

R239 Measurement of the ^{244}Cm and ^{246}Cm Neutron-induced Capture Cross Sections at the n_TOF Facility

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Accurate neutron capture cross section data for minor actinides (MAs) are required to estimate the production and transmutation rates of MAs in light water reactors with a high burnup, critical fast reactors like Gen-IV systems and other innovative reactor systems such as accelerator driven systems (ADS). Capture reactions of ^{244}Cm and ^{246}Cm isotopes open the path for the formation of heavier Cm isotopes and of heavier elements such as Bk and Cf. In addition, ^{244}Cm shares nearly 50% of the total actinide decay heat in irradiated reactor fuels with a high burnup, even after three years of cooling.

Experimental data for these isotopes are very scarce due to the difficulties of providing isotopically enriched samples and because the high intrinsic activity of the samples requires the use of neutron facilities with high instantaneous flux. The only two previous experimental data sets for these neutron capture cross sections have been obtained in 1969 using a nuclear explosion and, more recently, at J-PARC in 2010.

Both neutron capture cross sections have been measured at n_TOF with the same samples that the previous experiments in J-PARC. The samples were measured at Experimental Area 2 (EAR-2) with three C6D6 detectors and also in Experimental Area 1 (EAR-1) with the Total Absorption Calorimeter (TAC). Preliminary results assessing the quality and limitations of these new experimental datasets are presented for the experiments in both areas. Preliminary yields of both measurements will be compared with evaluated libraries for the first time.

I240 Neutron Transmission Measurements at nELBE

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Neutron total cross sections are an important source of experimental data in the evaluation of neutron-induced cross sections. The sum of all neutron-induced reaction cross sections can be determined with a precision of a few precent in a relative measurement. The transmission is determined from the count rates of the neutron beam transmitted through a target sample relative to the count rate without sample and is independent of the neutron detection efficiency. The neutron spectrum of the photoneutron source nELBE extends in the fast region from about 100 keV to 10 MeV and has favourable conditions for transmission measurements due the low instantaneous flux of neutrons and low gamma-flash background. Several materials of interest (in part included in the CIELO evaluation or on the HPRL of OECD/NEA) have been investigated: ^{197}Au[1,2],^{nat}Fe[2], ^{nat}W[2], ^{238}U, ^{nat}Pt, ^{4}He, ^{nat}O, ^{nat}Ne, ^{nat}Xe. For gaseous targets high pressure gas cells have been built that hold up to 200 bar pressure. The experimental setup will be presented including results from several transmission experiments and the data analysis leading to the total cross sections will be discussed.

This work has been supported by the EURATOM FP7 project CHANDA and by the German Federal Ministry of Education and Research (03NUK13A).

[1] R. Hannaske et al., Eur. Phys. J. A (2013) 49: 137
[2] R. Beyer et al., Eur. Phys. J. A (2018) 54: 81

R241 New Experimental Data for ^{12}C(n,α)^{9}Be Reaction.

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The work is devoted to the experimental study of the reaction cross section ^{12}C(n,α)^{9}Be. Interest in this reaction is due to the fact that carbon is widely used in reactors as a moderator and reflector of neutrons. In addition, organic scintillators containing carbon are widely used to register fast neutrons. The ^{12}C(n,α)^{9}Be reaction can significantly affect the efficiency of fast neutron detection. Carbon is one of the main elements of organic tissue and the reactions taking place on it are interesting from the point of view of dosimetric applications.In this work, a Frisch grid ionization chamber filled with a mixture of Krypton and carbon dioxide was used. The carbon atoms of the working gas contained used as the target for the reaction under investigation. The signals from the chamber electrodes were digitized and information about the energy of the particles, the type of particles, and their place of birth was extracted using special computer processing. The neutron flux was monitored by registering fission fragments from a ^{238}U layer with a known number of nuclei. The data for the reaction cross section ^{12}C(n,α)^{9}Be were obtained in the energy range from 7.5 to 9.6 MeV.

R242 Photoneutron Reaction Cross Sections for ^{75}As and ^{181}Ta: Systematic Uncertainties and Data Reliability

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There is well-known problem of significant systematic disagreements between data for reactions (γ, 1n) and (γ, 2n), obtained at Livermore (USA) and Saclay (France) using the method of photoneutron multiplicity sorting. The averaged ratios S/L of integrated cross sections for 19 nuclei from ^{51}V to ^{239}U are equal to 0.84 for (γ, 2n) and 1.07 for (γ, 1n) reactions [1]. For ^{75}As S/L ratios for both partial reactions are very close (1.22 and 1.21)) but for ^{181}Ta - quite different (0.89 and 1.25).

Partial reaction cross-section data were analyzed using the physical data reliability criteria [2],

$$\sigma^{eval}(\gamma, in) = F_i^{th}\sigma^{exp}(\gamma, Sn) = [\sigma^{th}(\gamma, in)/\sigma^{th}(\gamma, Sn)]\sigma^{exp}(\gamma, Sn)$$

There are serious doubts in reliability of Saclay data. The Livermore data are in general definitely unreliable. Using the experimental-theoretical method for partial reaction cross section evaluation [2],

$$\sigma^{eval}(\gamma, in) = F_i^{th}\sigma^{exp}(\gamma, Sn) = [\sigma^{th}(\gamma, in)/\sigma^{th}(\gamma, Sn)]\sigma^{exp}(\gamma, Sn)$$

where $\sigma^{exp}(\gamma, Sn) = \sigma^{exp}[(\gamma, 1n) + 2(\gamma, 2n) + 3(\gamma, 3n) + ...]$, the new reliable partial reaction cross sections were evaluated.

The main reason of definite unreliability of Livermore data is erroneous normalization of results of measurements in the cases of both nuclei and the loss of many neutrons from the 1n channel in the case of ^{181}Ta [3]. The reason of Saclay and Livermore data unreliability is erroneous sorting of photoneutrons between "1n" and "2n" channels. The newly evaluated cross-section data for both nuclei disagree with experimental data obtained at both Livermore and Saclay and for ^{181}Ta agree with data obtained bremsstrahlung and activation method [4]. The work is supported by the Research Contract 20501 of the IAEA Coordinated Research Project No F41032.

[1] V.V.Varlamov, et. al., Eur. Phys. J. A 50 7 (2014) 114.
[2] V.V.Varlamov, et. al., Bull. Rus. Acad. Sci. Phys. 74 (2010) 842.
[3] V.V.Varlamov, et. al., Phys. Atom. Nucl. 76 (2013) 1403.
[4] B.S.Ishkhanov, et. al., Phys. Atom. Nucl. 75 (2012) 253.

R243 Photonuclear reaction study in CIAE

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The ways used to produce high energy gamma rays are laser-electron Compton scatter, (p, γ) resonance reaction, positron annihilation in flight, Bremsstrahlung etc. One of which (p, γ) resonance reaction is a good way for producing gamma source. Two experiments, ^{13}C(p, γ)^{14}N and ^{7}Li(p, γ)^{8}Be, have been done to produce 9.17 MeV, 14.8 MeV and 17.6 MeV gamma rays. The cross section of ^{197}Au(γ,n)^{196}Au was measured under the energy of 9.17 MeV. Our result is similar to the result which was done by the laser-electron Compton scatter gamma source. It indicates that the method of photonuclear reaction study has been successfully built in our lab.

R244 MCNP Modeling for Neutron-induced Charged Particle Cross-section Measurements at LANSCE

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We developed a detailed MCNP6® model of the LENZ (Low Energy NZ-neutron induced charged particle detection) instrument at the Los Alamos Neutron Science Center (LANSCE) to reduce experimental uncertainties in measurements of nuclear data important for nuclear applications. The model enables to calculate the response function of the instrument with high accuracy, to distinguish between a primary signal and various components of the beam-induced background, and to optimize the instrument for future experiments. For our calculations we improved the double differential cross sections of (n,p) and (n,α) reactions using the LANL-developed Hauser-Feshbach code CoH3. These cross sections were either flat angular distributions for discrete levels and for continuum or they were completely missing from the latest release of the ENDF/B-VIII library. We show the impact of the improved reaction evaluations on our results. We also show key advantages of the MCNP6® post-processing using the PTRAC card.

The results will advance the forward propagation analysis (FPA) of the LENZ measurements, which have been focusing on determining the high-precision cross sections of (n,p) and (n,α) reactions. We will present the progress of the LENZ FPA with the advanced modeling and data evaluations on materials including O-16, Ni-58, Ni-60, and nat-Ni in the neutron energy range of 0.5 - 20 MeV, which reflects the anticipated fast neutron spectrum in future nuclear facilities, such as molten-salt reactors or fusion devices.

This work benefits from the LANSCE accelerator facility and is supported by the U.S. Department of Energy under contracts DE-AC52-06NA25396.

I245 Measurements of Neutron-induced Charged-particle Emission Reactions

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In the past two decades cooperating with Frank Laboratory of Neutron Physics (FLNP), Joint Institute for Nuclear Research (JINR), measurements of (n,α) reaction cross sections for ^{6}Li, ^{10}B, ^{35}Cl, ^{39}K, ^{40}Ca, ^{54,56,57}Fe, ^{58}Ni, ^{63}Cu, ^{64,67}Zn, ^{95}Mo, ^{143,144}Nd and ^{144,147,149}Sm nuclei were performed in the MeV neutron energy region based on the 4.5 MV Van de Graaff accelerator of Peking University. In recent years, our measurements were extended in three aspects. Firstly, measurements were expanded from two-body reactions to three-body reactions such as ^{10}B(n,t2α). Secondly, the neutron energy region was extended from below 7 MeV to 8 - 11 MeV by using the HI-13 tandem accelerator of China Institute of Atomic Energy (CIAE), with which cross sections of ^{54,56}Fe(n,α) reactions were obtained. Thirdly, based on the newly built China Spallation Neutron Source (CSNS), differential and angle-integrated cross sections were measured for ^{6}Li(n,t) and ^{10}B(n,α) reactions in the neutron energy region from 1 eV to 3 MeV. Outline and results of our previous measurements are presented, as well as the future measurement plan.

R246 Measurement of the Energy-differential Cross Section of the ^{12}C(n,p) and ^{12}C(n,d) Reactions at the n_TOF Facility at CERN

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CERN

As part of the challenging n_TOF program on (n,cp) nuclear reactions studies, the energy differential cross-sections of the ^{12}C(n,p)^{12}B and ^{12}C(n,d)^{11}B reactions have been measured at CERN from the reactions thresholds up to 30 MeV neutron energy. The cross section of the ^{12}C(n,p)^{12}B reaction is of interest in several fields of basic and applied Nuclear Physics: in radioprotection and hadrontherapy, as well as in the design of shields and collimators at accelerator facilities, spallation neutron sources and irradiation facilities for fusion materials. Furthermore, it is crucial for simulations of the response of diamond detectors to high-energy neutrons, in view of the increasing importance of these detectors in neutron irradiation studies. Finally, reliable cross section data on this reaction may help re?ne theoretical models of light charged particle emission from light nuclei.

The energy-dependent cross section of the ^{12}C(n,p)^{12}B reaction is at present highly uncertain, large discrepancies are indeed observed between the experimental data available in EXFOR and between various evaluated nuclear data libraries. The same applies for ^{12}C(n,d)^{11}B cross-section, for which no data below 20 MeV exist in literature while evaluations based on calculations or indirect measurements show sizable discrepancies.

The ^{12}C(n,p)^{12}B and ^{12}C(n,d)^{11}B measurements have been recently performed at the long flight-path (185 m) experimental area EAR1 of the n_TOF facility at CERN using a pure (99.95%) self-sustaining graphite target and two silicon telescopes placed at different angles. This experimental setup guarantees both identification of the charged particles emitted in the reactions and the measurement of their angular distribution. In addition, the correlations between neutron time of ?ight and proton/deuteron energy deposition allow to disentangle the contribution of other competing (n,cp) reactions. An overview of the measurement, the analysis and the preliminary results obtained in comparison with previous data will be presented.

R247 Monte Carlo Simulations and n-p Differential Scattering Data Measured with Recoil Proton Telescopes

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The ^{235}U neutron-induced fission cross section, a standard at thermal energy and between 0.15 MeV and 200 MeV, plays a crucial role in nuclear technology applications. The long-standing need of improving cross section data above 20 MeV and the lack of experimental data above 200 MeV motivated a new experimental campaign at the n_TOF facility at CERN. The measurement has been performed in 2018 at the experimental area 1 (EAR1), located at 185 m from the neutron-producing target (the experiment is presented by A. Manna et al. in a contribution to this conference). The ^{235}U(n,f) cross section from 20 MeV up to about 1 GeV has been measured relative to the ^{1}H(n,n)^{1}H reaction, which is considered the primary reference in this energy region.

The neutron flux impinging on the ^{235}U sample (a key quantity for determining fission events) has been obtained by detecting recoil protons originating from n-p scattering in a C_2H_4 sample. Two Recoil Proton Telescopes (RPT), consisting of several layers of solid-state detectors and fast plastic scintillators, have been located at proton scattering angles of 25° and 30°, out of the neutron beam. The RPTs exploit the DeltaE-E technique for particle identification, a basic requirement for the rejection of charged particles from neutron-induced reactions in carbon. Extensive Monte Carlo simulations were performed to characterize proton transport through the different slabs of silicon and scintillation detectors, to optimize the experimental set-up and to deduce the efficiency of the whole RPT detector. In this work we compare measured data collected with the RPTs with a full Monte Carlo simulation based on the Geant-4 toolkit.

R248 Measurement of Production Cross Sections of ^{22}Na and ^{24}Na in Proton Induced Reactions on Aluminum

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The cross sections for the production of ^{22}Na and ^{24}Na from the ^{27}Al(p,x) reactions were measured using a stacked-foil activation technique with a proton energy of 57 MeV at the 100 MeV proton linac of the Korea multi-purpose accelerator complex (KOMAC). The induced activity of sample was determined by a HPGe detector. The proton energy along the stack foils was calculated using the SRIM code. The measured cross sections were compared with the experimental data of available literature and the data from the TENDL-2017 library.

R249 Cross-section Measurement in the Reactions of ^{136}Xe on Proton, Deuteron and Carbon

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Spallation/fragmentation reaction plays an important role in the production of the unstable nuclei. In order to optimize the yield of the radioactive ions, a good understanding of the reaction mechanisms is of great importance, in particular, the energy and target dependence is essential. Many experiments have been performed to investigate on the reaction mechanisms of the spallation, particularly for the reactions on the stable nuclei ^{136}Xe (N=80,Z=54). Because it is used as a primary beam in worldwide for radioactive beam generation. However, present study of the ^{136}Xe on deuteron and heavy-ion is limited, only the reactions at high energy is performed. In order to add more information on the energy dependence of deuteron- and heavy-ion- induced reactions, and to investigate the target dependence, we have studied the reactions of ^{136}Xe induced by proton, deuteron and carbon at 168 MeV/u.

The experiment was performed at the RIKEN Radioactive Isotope Beam Factory. The secondary beams were produced by the in-flight fission of ^{238}U beam at 345 MeV/u incident on a ^{9}Be target. The particles in the secondary beams were identified event by event in the BigRIPS separator. CH_2, CD_2 and C targets were used to induce the secondary reactions. The reaction products were analyzed and identified unambiguously by the ZeroDegree spectrometer. The cross sections for the reactions of ^{136}Xe on proton, deuteron and carbon will be presented as well as the target dependence. The energy dependence was also investigated by the comparison of these experimental results to previous studies for ^{136}Xe at higher reaction energies. These results were compared with the theoretical calculations including both the intra-nuclear cascade/dynamical and evaporation processes using PHITS, and with empirical SPACS and EPAX parameterization. These data can be used as benchmark for the spallation models.

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S250 Continuous Spectra of Light Charged Particles from Interaction of 30 MeV Energy Protons with Cooper

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In recent decades along with the technical developments there are intensive researches of physical aspects of accelerator driven system (ADS). For correct simulation of the neutron flux data on the spectral composition and angular distribution of secondary protons and light charged particles produced in the quenching of the primary beam of protons in the target device are needed for the establishment of such units (accelerator + subcritical reactor). Consequently, it is extremely important to obtain experimental cross sections of the reactions used as benchmarks in constructing and development of models of nuclear reaction mechanisms, and to improve their predictive power.

The experimental data were obtained on the proton beam of isochronous cyclotron U-150M at the Institute of Nuclear Physics of Kazakhstan. The copper was chosen because it is a widely used constructional material. The self-supporting foil of thickness of 3.5 mg/cm^2 with natural cooper was used as target. Systematic errors of measured cross sections were mainly due to the uncertainty in the thickness of the target determination ($<5\%$), the current integrator calibration (1%) and the solid angle of the spectrometer (1.3%). The total systematic error did not exceed 10%. The statistical error, the value of which depended on the type and energy of the detected particles, was 1 - 4% for protons and 1 - 8% for α-particles.

An analysis of the experimental results of reactions (p,xp) and (p,xα) on the nucleus ^{nat}Cu at Ep = 30 MeV was done within the the exciton model code TALYS, which had been optimized for this case. In addition to the calculations within exciton model, the calculations in the framework of other mechanisms of nuclear reactions (direct and equilibrium) were carried out. The obtained experimental results complete the base of nuclear reaction cross-section data and can be used in the designing of safe and wasteless hybrid nuclear power plants.Y. Kucuk was supported by TUBITAK under the project 118R029.

S251 Simulations of the Measurements of Differential Cross Sections of the n-p and n-d Elastic Scattering Reactions at CSNS Back-n White Neutron Source

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Differential cross-section data of the n-p and n-d elastic scattering reactions (^{1}H(n,el),^{2}H(n,el)) are collected and analyzed from EXFOR library. For $E_n > 20$ MeV, the experimental results are scarce and have large uncertainties and discrepancies in general. For En $\leq$ 20 MeV, the results lack systematicness, most of which were measured around $E_n = 14$ MeV even though the differential cross sections of n-p scattering in 1 keV $\leq$ En $\leq$ 20 MeV region are recommended as standard. Taking these facts into account, more accurate and systematic measurements are planned. The experiments will be conducted using $\triangle$E-E detector array of the Light-charged Particle Detector Array (LPDA) system at China Spallation Neutron Source (CSNS) Back-n white neutron source, and simulations of the experiments are carried out. Using polyethylene and deuterated polyethylene of 200 μm in thickness as samples, the 2-D spectra of both n-p and n-d scattering reactions are simulated along with the background reactions from ^{12}C in the samples, and the counting rates of the $\triangle$E-E detectors are obtained. According to the simulations, the applicable neutron energy range and positions of the detectors are recommended, and the beam durations for the event and background measurements are suggested.

I252 Calculation of the Fission Observables in the Resolved Resonance Energy Region of the ^{235}U(n,f) Reaction

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In recent years, JRC-Geel institute has measured mass yields and kinetic energy distributions of the fission fragments (i.e. before prompt neutron emission), in the resolved resonance energy region (up to 45 eV) for the ^{235}U(n,f) reaction. Thanks to a scintillation detector array (SCINTIA), the average prompt neutron multiplicity was also determined for the main resonances. From this experimental work, fluctuations of several fission observables (mass yields, average total kinetic energy <TKE>, average prompt neutron multiplicity ($<\nu_P>$) were clearly observed in the resonances region.

In the present work, these experimental pre-neutron mass yields and kinetic energies were used as input data for our Monte Carlo code 'FIFRELIN' (FIssion FRagment Evaporation Leading to an INvestigation of nuclear data). By adopting the Hauser-Feshbach statistical model, the code simulates the de-excitation of fission fragments. Four free parameters are available: two of them (called R_T^{min} and R_T^{max}) govern at the scission point the sharing of the total available excitation energy between the two nascent fission fragments, while the two others (called σ_L and σ_H) are dedicated to the initial fission fragment spins assignment. Usually, these four free parameters are tuned in order to reproduce one known fission observable ($<\nu_P>$, for example). In this way, fission observables (prompt particles energy spectra and multiplicities, delayed neutrons multiplicity,$\cdots$) and correlations between them can be deduced.

Two different approaches will be presented and discussed here. The first one consists in tuning the four free parameters in order to reproduce the well-known total prompt neutron multiplicity at the thermal incident neutron energy ($<\nu_P> = 2.42$, according to JEFF-3.3 library). Then, the free parameters are kept constant for each investigated ^{235}U resonances. The calculated fluctuations of $<\nu_P>$ in the resonances are only due to the fluctuations of the pre-neutron mass yields and kinetic energy. The second approach consists in tuning the free parameters for reproducing the experimental $<\nu_P>$ for each resonance. In this way, all calculated fission observables fluctuations can be highlighted and correlations between the spin of the resonances and the fission observables can be investigated.

R253 Microscopic Studies of Fission Observables of Compound Nuclei

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The fission of compound nuclei are of great interests regarding studies of induced fission, synthesis of superheavy nuclei and astrophysical r-process. Based on the temperature dependent Skyrme-Hartree-Fock+BCS calculations of fission barriers, we firstly studied the fission rates. The SHF equations are solved in the axially symmetric coordinate-spaces. We pointed out that the curvatures of fission barriers and valleys are now can be self-consistently obtained. We also employed the temperature dependent calculations of mass parameters. The thermal fission rates are calculated by the imaginary free energy method. Therefore, the survival probabilities of superheavy compound nuclei can be given without free parameters. We also carried out large scale calculations of the two-dimensional potential energy surfaces (β_2 and β_3) for studies of fission fragments. The modified broyden method is implemented to accelerate the SHF calculations. Other new theoretical progresses related to fission studies are also discussed.

R254 Monte-carlo Evaluation on Fission Process for Neutron-induced Actinide Nuclei Fission

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Based on the systematic model, a global potential-driving model with well-determined parameters is proposed by uniting the empirical asymmetric fission potential and the empirical symmetric fission potential, which can precisely calculate the potential energy distributions and the pre-neutron-emission mass distributions for neutron-induced actinide nuclei fission with incident-neutron-energies up to 160 MeV. Taking the shell-correction terms and the energy-dependence of evaporation neutrons for the reactions (n,xnf) into account, the results obtained from the potential-driving model are in good agreement with the experimental data. Compared with the GEF, TALYS and PYF code, the potential-driving model shows a significant advance with regard to accuracy.

Based on the developed potential-driving model, Monte-Carlo code calculates the characteristics of fission reaction process for neutron-induced actinide nuclei fission. Typical calculated results, including yields, kinetic energy distributions, fission neutron spectrum and decay γ-ray spectrum, are compared with experimental data and evaluated data. It shows that the Monte-Carlo calculated results agree quite well with the experiment data, which indicate that Monte-Carlo code with the developed potential-driving model can reproduce and predict the characteristics of fission reaction process at reasonable energy ranges.

Given the well predictions on the characteristics of fission reaction process, Monte-Carlo code with the developed potential-driving model should well evaluate the yields, kinetic energy distributions, fission neutron spectrum and decay γ-ray spectrum for neutron-induced actinide nuclei fission, which will guide for the physical design of nuclear fission engineering.

R255 Advances in Modeling and Simulation of Fast Neutron Induced Fission of ^{232}Th

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Nuclear data obtained in the neutron induced fission of 232-Thorium are of a great importance for advanced fast reactors based on Th fuel cycle. Fission cross sections, mass and charge distributions, prompt emission in fission including neutron multiplicities, yields of some isotopes of interest, and associated uncertainties were obtained. This paper presents the theoretical predictions and the first results on ^{232}Th(n,f) by applying Talys, and an author's computer code, dedicated to nuclear reaction mechanisms and structure of nuclei calculations. Uncertainties induced by nuclear data were quantified using preliminary, energy-dependent relative covariance matrices evaluated with ENDF nuclear data and processed for the studied fission process. Theoretical evaluations obtained here are compared with existing experimental data. The present researches on ^{232}Th(n,f) reaction are realized in the frame of nuclear data program running at JINR basic facilities IREN and MT-25 Microtron.

R256 The Scission Microscopic Structure of Fission in Actinide Nuclei

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Based on the Two center shell model plus the pairing interaction approach for the description of fission potential energy surface, fission potential barrier, and the scission for nuclei fission in actinide regions, we will analyze the effect on the microscopic structure of the scission and the subsequent dynamics process induced by the competition of deformed mean-field and the pairing interaction, especially the role of pairing interaction.

I257 Validating the Bohr Hypothesis: Comparing Fission-product Yields from Photon-induced Fission of ^{240}Pu and Neutron-induced Fission of ^{239}Pu

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The Bohr Hypothesis, one of the most fundamental assumptions in nuclear fission theory, states that the decay of a compound nucleus with a given excitation energy, spin and parity is independent of its formation [1]. Using fission product yields (FPYs) as a sensitive probe, we have performed new high precision test of the combined effects of the entrance channel, spin and parity on the fission process. Two different reactions were used in a self-consistent manner to produce a compound ^{240}Pu nucleus with the same excitation energy: neutron induced fission of ^{239}Pu at $E_n = 4.5$ MeV and photon-induced fission of ^{240}Pu at $E_\gamma = 11.2$ MeV. The FPYs from these two reactions were measured using quasimonoenergetic neutron beams from the TUNL's FN tandem Van de Graaff accelerator [2] and quasimonenergetic photon beams from the HIGS facility. The first results comparing the FPYs from these two reactions will be presented. Implications for validating the Bohr hypothesis will be discussed.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.

[1] N. Bohr and J. A. Wheeler, "The Mechanism of Nuclear Fission." Physical Review 56, 426 (1939).
[2] M. E. Gooden et al., "Energy Dependence of Fission Product Yields from ^{235}U, ^{238}U and ^{239}Pu for Incident Neutron Energies Between 0.5 and 14.8 MeV." Nuclear Data Sheets 131, 319 (2016).

I258 Fission Studies Using Steff at n_TOF, CERN

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SpecTrometer for Exotic Fission Fragments (STEFF) has been built at the University of Manchester to perform prompt fission gamma-ray energy and multiplicity measurements in correlation with the fission fragments (FF). The measurements are performed at the Neutron Time-of-Flight (n_ToF) facility at CERN, where measurements are made using a beam of neutrons produced through the spallation of a 20 GeV/c pulsed proton beam impinging on a lead target. The neutron beam covers a wide range of energies from thermal to ∼300 MeV and travels to the fissile material target through a 20 m beamline. An array of NaI and LaBr 3 scintillators surround the target and perform gamma-ray measurements. STEFF also features four arms with FF time-of-flight detectors and ionization chambers for FF energy and charge measurement. Two campaigns of measurements were conducted in 2015 and 2016 on ^{235}U targets with different beam collimators and target sizes. A campaign of measurements of ^{239}Pu fission was conducted in 2018. These measurements are in response to a high priority request [1], which was issued by the NEA [2] for information on neutron-induced fission prompt gamma ray energies and multiplicities for these two isotopes. The results of the STEFF experiment are of particular interest due to the ability to measure these fission properties, along side the nuclear charge and mass distributions, as a function of neutron energy. The capabilities of STEFF at n_TOF will be presented as well as the analysis procedures and preliminary results from the experimental campaigns.

[1] Rimpault, G., Courcelle, A., and Blanchet, D.: Needs for accurate measurements of spectrum and multiplicity of prompt γ emitted in Fission, NEA HPRL, 2006.
[2] OECD HEA, NEA Nuclear Data High Priority Request List, HPRL, http://www.oecd-nea.org/dbdata/hprl/hprlview.pl,ID = 421, 2006.

R259 Improved Neutron Multiplicity Correlations with Fission Fragment Mass and Energy from ^{239}Pu(n,f)

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We present experiments carried out to determine prompt neutron multiplicity correlations with fission fragment masses and total kinetic energies in the reaction ^{239}Pu(n,f). The experiment has been performed at the GELINA facility at JRC-Geel. A twin position-sensitive Frisch-grid ionization chamber is used for fission fragment identification via the double kinetic enery technique. An array of scinitillation detectors is employed for neutron counting. Correlations between average neutron multiplicities and fission fragment properties have been measured with improved resolution in both mass and TKE, compared to data from the literature.

There exists experimental evidence for strong fluctuations of the average neutron multiplicity from resonance to resonance in ^{239}Pu(n,f). These fluctuations have been shown to impact nuclear reactor benchmarks by reducing the criticality. The fluctuating neutron multiplicity can be explained as a consequence of the competition between direct fission and the (n,γf) process. However, there is also evidence for fluctuations of the fission fragment mass yields from resonance to resonance. The mass yield fluctuations may also contribute to fluctuations of the neutron multiplicity averaged over all fission fragment masses. In order to model the contribution to the neutron multiplicity fluctuations by the fission fragment mass yield fluctuations new data on the correlations between fission fragment properties and neutron multiplicities are in need.

R260 The Spatial Parity Non Conservation Effects in the Fission Induced by Thermal and Resonant Neutrons on ^{233}U

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Neutron induced fission is a complex process and spatial symmetry breaking effects are considered to happen in the cold phase of the compound nucleus. For some Uranium isotopes as ^{233}U forward - backward (FB), left - right (LR) and parity non conservation effects (PNC) experimentally were observed. They were described in the frame of mixing states of compound nucleus with the same spin and opposite parities resonant - resonant formalism. For incident neutrons up to some tens of electron volts in the case of fissionable nuclei many close resonances are present. Usually, in neutron reactions, the presence of a large number of resonances cancels the asymmetry and parity violation (PV) effects due to the random signs of phases in the incident and emergent channels. In order to explain such effects for fission it is necessary to state that the sign of phases are not random. This statement implies the evaluation of a series of phases and widths for each new P resonance. In the atlases for neutron resonances parameters, P resonances for fissionable nuclei are not indicated which means the necessity to extract them from some experiments. Introduction of new parameters makes the calculations more complicated. The interferences of compound states with the same spins and opposite parities are analyzed. In this research new P resonance parameters from FB and LR effects in order to explain the observed asymmetries and PNC effect have been derived. By using the multilevel Breit - Wigner formalism it was demonstrated that the resonance states observed in FB and LR measurements are just a result of multilevel interference between S resonances. Only new P resonances, not indicated in nuclear data atlases for neutron resonance parameters, are able to describe the observed asymmetry effects.

A new approach in which the neutrons are captured by S resonant process in the incident channels followed by non resonant fission fragments emission due to the weak non leptonic interaction is proposed.

S261 Shape Description in Macro-microscopic Model

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There are three main parts in the macro-microscopic model, and one of them is the shape description. A set of shape parameters should be able to describe the shape evolution of the fission nucleus. And to calculate the potential energy surface on a five-dimensional deformation space, we need to discretize the value of the shape parameters. As it is not known what kind of the shape evolution a nucleus would really experience, an exploration on the choice of shape evolution is valuable and noteworthy.

In this report, we compare the potential energy surface (PES) and some relevant results obtained by those PESs based on two different sets of shape parameters, including the generalized Lawrence shape and the three quadrature connected surface. By changing the shape description, we recalculated the fission barriers and fission path. Along the path, the shape evolution can be presented step by step. Furthermore, based on the random walk and the random neck rupture model in the simulation of fission process, we calculated the fission fragment mass distributions of U-233 for different excitation energies, from thermal neutron to nearly 5 MeV injection energy. After a comparison, we can conclude that the three quadrature connect surfaces is a better choice near the scission area as the fission barrier heights and fission fragment mass distributions are closer to the experimental results.

S262 Energy Dependence of Time Parameters of Delayed Neutrons for the Fission of U-233 by Neutrons in Energy Range from 14 to 18 MeV

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Analysis of the existing data on the relative abundances of delayed neutrons and half-lives of their precursors measured for the fission of heavy nuclei by neutrons in the energy range from 14 MeV and higher has shown, that for many important nuclides, from the point of nuclear fuel cycle, such data are missing and existing data significantly differ from each other.

In the present work the procedure of the measurement of the time dependence of delayed neutron flux intensity decay for the fission of ^{233}U by neutrons in energy range from 14 to 18 MeV generated in the reaction T(d,n)^{4}He on the accelerator of SSC RF-IPPE. Used experimental technique is based on the cyclic irradiation of the sample in the well-known neutron flux with the consequent measurement of the time dependence of delayed neutron flux intensity decay. In the processing of obtained decay curves there were taking into account the effects, affecting the shape of the decay curves, appearing when the reaction T(d,n)^{4}He is used as a neutron source. The comparison with the data obtained by summation technique has been done.

I263 Prompt Fission Neutron Spectra for Neutron-induced Fission of ^{239}Pu and ^{235}U

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We report the results of a large effort to accurately measure the Prompt Fission Neutron Spectra (PFNS) for neutron-induced fission of ^{235}U and ^{239}Pu. The Chi-Nu experiment at the Los Alamos Neutron Science Center (LANSCE) used an unmoderated, white spectrum of neutrons to induce fission and a double time-of-flight technique to determine the incoming and outgoing neutron energies. The actinide samples were placed inside a parallel plate avalanche counter, providing a fast fission signal. Two neutron detector arrays, one with 54 liquid scintillators and another with 22 lithium glass detectors, were then used to detect the outgoing neutrons and measure the PFNS distributions over a wide range in outgoing energy. Extensive Monte Carlo modeling was used to understand the experiment response and extract the PFNS. Systematic errors and uncertainties in the method have been examined and quantified. A summary of these results for incoming energies from 1 to 20 MeV will be presented.

R264 Prompt Fission Neutron Spectra of ^{235}U(n,F) and ^{239}Pu(n,F)

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Matrices of prompt fission neutrons spectra of ^{235}U(n,F) and ^{239}Pu(n,F), describing data shapes, TKE, average number of prompt fission neutrons and (n,F) and (n,xn) data up to 20 MeV are provided. PFNS of ^{235}U(n,F) and ^{239}Pu(n,F) in libraries ENDF/B-VIII, JEFF-3.3 and JENDL-4.0 are discrepant in shapes and average energies. Sometimes fragments of other libraries, discrepant with data[1-3] are borrowed.

At E_{th} we fitted as in the model-independent GMA-estimate of PFNS[4-6]. Its shape is consistent with measured PFNS of ^{233}U(n,f), ^{242m}Am(n,f), ^{245}Cm(n,f), ratios of ^{235}U/^{239}Pu, and ^{252}Cf(sf), ^{240,242}Pu(sf), ^{244,246,248}Cm(sf) data. At higher E_n the model fits ratios of PFNS for ^{235}U(n,F) and ^{239}Pu(n,F) and PFNS data below E_{nnf}. That comprises the basis to add the (n,xnf) neutrons.

Local maxima observed in TKE[7,8] correlated with (n,nf) and (n,2nf) thresholds of ^{235}U(n,xnf) and ^{239}Pu,xnf), respectively, are reproduced. That helps to fix the TKE values of $^{235-x}$U and $^{239-x}$Pu, =0,1,2. within our approach[4]. In v_p contributions of v_{pre} and v_{post} help to define the pre-neutron emission TKE of ^{239}Pu(n,F) for the TKE[8] . Consistent description of TKE of fission fragments, PFNS, (n,F) and (n,xn) helps to distinguish the (n,nf) and 1st and 2nd neutrons of (n,2nf) in the observed PFNS as dependent on the fissility. Comparison with the data[1-3] shows that the contribution of pre-fission neutrons to the PFNS diminishes with the increase of the fissility. The contribution of the (n,2nf) neutrons in case of ^{235}U(n,F), pronounces only slightly in the PFNS of ^{239}Pu(n,F) at E=14.7 MeV, as predicted in[9]. Explicit decomposition of observed PFNS into exclusive pre-fission neutrons and neutrons emitted from fragments is quite compatible with the data[1,2], as it is for the calculations[6,9].

[1] M. Devlin e.a., Nucl. Data Sheets, 148,322(2018)
[2] K. J. Kelly e.a., LA-UR-18-21453, 2018
[3] A. Chatillon e.a., Phys. Rev. C89,014611,2014)
[4] V. M. Maslov e.a., Journal of Korean Phys. Soc., 59, 2, 1337(2011)
[5] N. V. Kornilov e.a., Phys.At.Nucl. 62,173(1999)
[6] V. M. Maslov e.a., Nucl. Phys. A760,274(2005)
[7] D. L. Duke e.a., Nucl. Phys. A970,65(2018)
[8] K. Meierbachtol e.a., Phys. Rev. C94,034611(2016)
[9] V. M. Maslov, At.Energy,103,633 (2007)

R265 Observations of Poorly-known Features of the ^{239}Pu and ^{235}U Prompt Fission Neutron Spectra

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Prompt fission neutron spectrum (PFNS) evaluations use available nuclear data to predict the PFNS across a wide range of incident and outgoing neutron energies. However, these data are sparse, inconsistent, and incomplete with respect to the desired energy coverage. As such, evaluations sometimes predict features of the PFNS, such those relating to multi-chance fission and pre-equilibrium pre-fission neutron emission, without any experimental verification. The Chi-Nu experiment at Los Alamos National Laboratory has recently obtained high-precision results for the ^{239}Pu and ^{235}U PFNS which, for the first time in most cases, have shed light on multi-chance fission and pre-equilibrium contributions to the observed fission neutron spectrum. In addition to providing the first experimental data on some of these fission properties, the angular coverage of the Chi-Nu experiment allowed for the extraction of angular distributions of pre-equilibrium pre-fission neutrons. PFNS results of multi-chance fission and pre-equilibrium pre-fission neutron emission will be presented in terms of the observed neutron spectrum, the average PFNS energies, and observed angular distributions.

R266 Systematic Behaviours and Correlations Between Different Quantities Characterizing the Residual Nuclei Following the Sequential Emission of Prompt Neutrons

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A deterministic treatment of sequential neutron emission, based on recursive equations of the residual temperatures (see Ref.[1] for details about), is applied to numerous fission cases (i.e. 49 cases implying nuclei fissioning spontaneously or induced by thermal and fast neutrons) for which reliable experimental Y(A,TKE) distributions exist. This fact emphasizes systematic behaviours and correlations between different average quantities characterizing the initial and residual fission fragments and the sequential prompt neutron emission. The ratios of the average residual temperature following the emission of each neutron to the average temperature of initial fragments ($<Tk>/<Ti>$) are almost constant for all studied fission cases and do not depend on the prescriptions used for the compound nucleus cross sections of the inverse process and the level density parameters of initial and residual fragments. This finding allows the determination of a general triangular form for the residual temperature distribution of each emission sequence Pk(T) with the maximum temperature related only to the average temperature of initial fragments. Consequently the sequential emission can be included into the Los Alamos model, i.e. a prompt neutron spectrum in the center-of-mass frame corresponding to each emission sequence is calculated by integrating over Pk(T). The systematic behaviours of the ratios of average residual temperatures and energies to the initial ones together with other linear correlations between different prompt emission and residual quantities allow to obtain indicative values of different average prompt emission quantities in the absence of any prompt emission model.

[1] A.Tudora, F.-J.Hambsch, V.Tobosaru, Eur. Phys. J. A 54 (2018) 87

R267 Angular Distributions and Anysotropy of Fission Fragments from Neutron-induced Fission of ^{239}Pu, ^{237}Np, and ^{nat}Pb in Intermediate Energy Range 1- 200 Mev

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This work continues a series of experiments aimed at the investigation of energy dependence of anisotropy of fission fragments in intermediate neutron energy range. Angular distributions of fission fragments from the neutron-induced fission of ^{239}Pu, ^{237}Np, and natPb have been measured in the energy range 1-200 MeV at the neutron TOF spectrometer GNEIS based on the spallation neutron source at 1 GeV proton synchrocyclotron of the NRC "Kurchatov Institute" - PNPI (Gatchina, Russia). The anisotropy of fission fragments deduced from the data on measured angular distributions is presented. In the neutron energy range above 20 MeV present data have been obtained for the first time.

I268 First Results of the ^{230}Th(n,f) Cross Section Measurements at the CERN n_TOF Facility

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The study of neutron-induced reactions on actinides is of considerable importance for the design of advanced nuclear systems and alternative fuel cycles. Specifically, ^{230}Th is produced from the -decay of ^{234}U as a byproduct of the ^{232}Th/^{233}U fuel cycle, thus the accurate knowledge of its fission cross-section is strongly required. However, few experimental datasets exist in literature with large deviations among them, covering the energy range between 0.2 to 25 MeV.

In addition, the study of the ^{230}Th(n,f) cross-section is of great interest in the research on the fission process related to the structure of the fission barriers. Previous measurements have revealed a large resonance at $E_n = 715$ keV and additional fine structures, but with high discrepancies among the cross-section values of these measurements.

This contribution presents preliminary results of the ^{230}Th(n,f) cross-section measurements at the CERN n_TOF facility. The high purity targets of the natural, but very rare isotope ^{230}Th, were produced at JRC-Geel in Belgium. The measurements were performed at both experimental areas (EAR-1 and EAR-2) of the n_TOF facility, covering a very broad energy range from thermal up to at least 30 MeV. The experimental setup was based on Micromegas detectors with the ^{235}U(n,f) and ^{238}U(n,f) reaction cross-sections used as reference.

R269 First Results of the ^{241}Am(n,f) Cross-section Measurement at the Experimental Area 2 of the n_TOF Facility at CERN

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Feasibility, design and sensitivity studies on innovative nuclear reactors (Accelerator Driven Systems-ADS [1], or Generation IV fast neutron reactors), that could address the issue of transmutation of nuclear waste using fuels enriched in minor actinides, require high accuracy cross-section data for a variety of neutron-induced reactions from thermal energies to several tens of MeV. The isotope ^{241}Am ($_{1/2}$= 433 years) is present in high-level nuclear waste (HLW), representing about 1.8% of the actinide mass in spent PWR UOx fuel [2]. Its importance increases with cooling time due to additional production from the beta-decay of ^{241}Pm with a half-life of 14.3 years. Both the net production of ^{241}Am in conventional reactors, including its further accumulation through the decay of ^{241}Pm and its destruction through transmutation/incineration are very important for the design of any recycling solution.

In the present work, the ^{241}Am(n,f) reaction cross-section was measured with Micromegas detectors at the Experimental Area 2 of the n_TOF facility at CERN using the time of flight technique. For the measurement, the ^{235}U(n,f) and ^{238}U(n,f) reference reactions were used for the absolute normalization of the experimental fission fragment yields. This contribution gives an overview of the detector-sample configuration, the experimental setup, the adopted data analysis techniques, and presents preliminary results.

[1] A. Stanculescu, Annals of Nuclear Energy 62, 607-612, (2013)
[2] A. Plompen, Minor Actinides, Major Challenges, the Needs for and Benefits of International Collaboration, Nucl. Data Sheets (2014), DOI: 10.1016/j.nds.2014.04.007

R270 Study of the Neutron Induced Fission Cross-section of ^{237}Np at CERN's n_TOF Facility Over A Wide Energy Range

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The accurate knowledge of fission cross-sections induced by neutrons of isotopes involved in the nuclear fuel cycle is vital for the design and safe operation of advanced nuclear systems. Such experimental data can provide additional constraints for the adjustment of nuclear model parameters used in the evaluation process, resulting in the further development of fission models. In the present work, the ^{237}Np(n,f)) cross-section was studied at the EAR2 vertical beam-line at CERN's n_TOF facility, over a wide range of neutron energies, from meV to MeV, using the time-of-flight technique and a set-up based on Micromegas detectors, in an attempt to provide accurate experimental data of a reaction that is frequently used as a reference one in many measurements related to feasibility and design studies for advanced nuclear systems. Preliminary results as well as the experimental procedure, including a description of the facility and the data handling and analysis, are presented.

R271 Measurement of the ^{234}U(n,f) Cross Section in the Energy Range Between 14.8 and 19.2 MeV Using Micromegas Detectors

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The accurate knowledge of neutron induced fission cross sections of actinides leads to the optimization of the design of new generation reactors as well as Accelerator Driven Systems (ADS). Especially ^{234}U, is involved in the thorium cycle where it builds up from neutron capture in ^{233}U. In this work, the ^{234}U(n,f) cross section has been measured by using a Micromegas detector assembly, at incident neutron energies of 14.8, 16.5, 17.8 and 19.2 MeV, where only a few available discrepant data exist in literature leading to poor evaluations. The ^{235}U(n,f) and ^{238}U(n,f) reactions were used as reference ones. The actinide targets and the Micromegas detectors were placed in a chamber filled with a Ar:CO_2 gas mixture at atmospheric pressure. The quasi- monoenergetic neutron beams were produced at the 5.5 MV Tandem Accelerator Laboratory at the National Center for Scientific Research "Demokritos" implementing the ^{3}H(d,n)^{4}He reaction. Due to the fact that the monochromaticity of the neutron beams was affected by parasitic reactions with the materials of the experimental area, as well as from the beam line itself, a detailed study of the neutron spectra was carried out by coupling both NeuSDesc and MCNP5 codes. Monte-Carlo simulations were also performed by using FLUKA and GEF codes for the estimation of the fission fragments detection efficiency. Finally, a methodology is introduced for the compensation of the parasitic neutron contribution to the experimental fission yield, which can be applied in facilities without time-of-flight capabilities.

S272 Experiments on Nubar(A) in ^{235}U(n_{th},f) Using the Double-E Method

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Prompt fission neutrons carry valuable information on how excitation energy is shared between fragments in nuclear fission. In order to improve the knowledge about the neutron emission, correlation measurements between fragment mass and prompt neutron characteristics are needed, especially as a function of excitation energy. Precise fission data helps improving both the fission modeling and the safety of future generations of nuclear technology.

In this work we present experiments performed at JRC Geel. A Twin Frisch-Grid Ionization Chamber was used in conjunction with liquid-scintillator detectors of the NE-213 type. Both fission fragments were detected back-to-back, allowing the determination of energy and emission angle relative to the chamber axis. The pre-neutron mass distribution was calculated using the conservation of mass and momentum. The coincidence rate of the chamber and the neutron detectors was measured as a function of fragment mass, to allow the deduction of average neutron emission quantities.

We present results on the average prompt fission neutron multiplicity, nubar from ^{252}Cf(sf) and ^{235}U(n_{th},f). The average neutron emission was derived both as a function of mass and Total Kinetic Energy (TKE). The results agree very well with previous measurements measured at JRC-GEEL and improve the knowledge about the so-called "saw-tooth shape" in fission neutron emission. Both nubar shapes confirm the strong fluctuations, correlated with nuclear structure effects in the nascent fragments (near magicity at A $\sim$ 78 and A $\sim$ 132). The correlation between the neutron multiplicity and the TKE, nubar(TKE), confirms the newly found slope of -13 MeV/n, in contrast to earlier deviating literature values.

Moreover, experimental effects related to shielding and target corrections are discussed. The U-data were measured with two different target thicknesses, to allow assessing the influence of fragment energy loss in the target layer on the nubar data. In addition, the ^{252}Cf(sf) case was measured with and without the detector shielding assembly, which allows us to study the effect of neutron scattering on the nubar(A,TKE) data.

S273 Experimental Estimation of the "scission" Neutron Yield in the Thermal Neutron Induced Fission of ^{233}U and ^{235}U

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The analysis of angular and energy distributions of prompt neutrons from the thermal neutron induced fission of ^{233}U and ^{235}U measured recently in the WWR-M research reactor (Gatchina, Russia) have been performed. The yield of "scission" neutrons has been estimated by comparing the measured distributions with calculations within the model of emission of neutrons from completely accelerated fragments. Besides taking into account "scission" neutrons, for the best description of measured angular and energy distributions of fission neutrons, the calculation should be performed under the assumption that neutrons with a higher (about 6-8%) probability are emitted along the fission axis in the center-of-mass system of fission fragments.

I274 Measuring Independent Fission Product Yields and Other Neutron Induced Reactions with the FissionTPC

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The NIFFTE collaboration built the fission Time Projection Chamber (fissionTPC) as an instrument to precisely measure neutron induced fission cross section ratios from actinide targets. This detector provides 2π coverage to charged particles in two independently instrumented volumes with a dynamic range spanning protons to heavy fission fragments. The TPC is able to provide track-level detail from complex events including vertices, direction, energy, and ionization profiles. This capability enables the fissionTPC to perform other measurements beyond the original focus of actinide cross section ratios. In this presentation we will describe two such additional measurements in detail.

First, we have begun a program to measure the Independent Fission Product Yield of ^{239}Pu as a function of incident neutron energy. The strength of using the fissionTPC for this measurement is its ability to identify particle mass and charge using the detailed information in the ionization profile. We will also investigate the uncertainties related to energy loss, pulse height defect, and pile-up effects. Second, working with collaborators in the evaluation community, we are exploring the use of the $^{1}H(n,el)$ and $^{6}Li(n,\alpha)t$ reactions as references to the $^{239}Pu(n,f)$ cross section. This works includes the development of experimental techniques and evaluations of the precision that could be achieved. We have found that a precise measurement in ratio to $^{1}H(n,el)$ using the fissionTPC would be best performed at a mono-energetic neutron beam. Additionally, we have shown the the fissionTPC is well suited to use the $^{6}Li(n,\alpha)t$ reaction in a ratio measurement and that this could have a significant impact on both the actinide and lithium cross section evaluations. These measurements would be performed in the energy range of 0.2 MeV to 20 MeV.

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R275 Utilizing Nuclear Data in Delayed Gamma-ray Spectroscopy Inverse Monte Carlo Analysis

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Safeguards verification of uranium and plutonium in high-radioactivity nuclear material (HRNM) is currently performed using destructive analysis techniques. However, the preparation method is a time burden on both the safeguards inspectors and facility operators. While nondestructive assay (NDA) techniques would improve the efficiency and time, there are no passive NDA techniques available to directly verify the U and Pu content. As an alternative, the JAEA and JRC are collaboratively developing the Delayed Gamma-ray Spectroscopy (DGS) active-interrogation NDA technique to evaluate the fissile composition from the unique fission product yield distributions. To analyze the data, we are developing an Inverse Monte Carlo (IMC) method that simulates the interrogation and evaluates the individual contributions from the mixed nuclear material to the composite spectrum. While the current nuclear data affects the ability to evaluate the composition, the IMC analysis method can be used to determine the systematic uncertainty contributions and has the potential to improve the nuclear data. We will present the current status of the DGS collaborative work as it relates to the development of the DGS IMC analysis.

R276 Neutron Spectrum Determination of P+be Reaction for 30 MeV Protons Using the Multi-foil Activation Technique

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Nuclear Physics Institute (NPI) of the Czech Academy of Sciences (CAS) operates the accelerator-driven fast neutron generators of white and quasi-monoenergetic spectra using the charged particle beams (protons and deuterons) delivered by the isochronous cyclotron U-120M. In standard operation, proton induced reactions on thick beryllium or thin lithium targets are used for neutron field production within the fusion related research applications (e.g. cross-sections measurement and validation for IFMIF-DONES research program). Recently, the p + Be source reaction was investigated for 30 MeV proton beam and thick beryllium target at the NPI CAS in Rez near Prague, and new intensive neutron field of white spectrum up to 28 MeV was successfully developed. For neutron field determination of the p(30)+Be source reaction in close source-to-sample distances, the multi-foil activation technique was utilized. Sets of ten activation materials (Au, Co, Lu, Ti, In, Al, Y, Fe, Ni, Nb) were irradiated by neutrons from the p(30)+Be source, and activated dosimetry foils were analyzed by means of the nuclear gamma-ray spectrometry method (HPGe detectors). From measured reaction rates, white neutron spectrum was reconstructed utilizing the modified version of SAND-II unfolding code. The study of Be(p,xn) source reaction with 30 MeV proton beam provided new spectral data for energy range that is characterized by a lack of empirical data (above 20 MeV). Obtained neutron field extends the utilization of cyclotron-based fast neutron sources at the NPI and provides new experimental opportunities for future intensive irradiation experiments such as nuclear data validation, fast neutron activation analysis, radiation hardness tests of electronics and materials for nuclear energetics and aerospace industry.

R277 Charged Particle Activation Measurements in NPI CAS and in Future GANIL/SPIRAL2-NFS

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The proton, deuteron and alpha induced reactions are of a great interest for the assessment of induced radioactivity of accelerator components, targets and beam stoppers as well as isotope production for medicine and also to nuclear astrophysics. We present the proton and deuteron induced reaction cross sections on cobalt, titan and copper investigated by stacked-foil activation technique with 20 MeV energy beams in NPI CAS Rez and compare the results to the other author's data and to predictions of evaluated data libraries. A new irradiation chamber for activation measurements will be presented. The chamber is based on an airlock system and is coupled to a pneumatic transfer system developed in KIT Karlsruhe. This system is installed in GANIL/SPIRAL2-NFS and will be used for proton, deuteron and alpha particle activation measurements wtith long- and short-lived isotopes.

R278 Source Preparation Techniques in Nuclear Decay Data Measurements of Alpha Emitting Radionuclides by Using DSA

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Alpha-particle counting at Defined Solid Angle (DSA) spectrometers have been used to determine alpha emission probabilities, relative half-lives, branching factors and energies. This technique was used in the case of primary standardization and mostly performed by ion-implanted silicon (PIPS) detectors. The most important features of this technique are geometrically calculated efficiency, low background and energy spectra of each alpha decaying nuclide. This paper describes techniques for the preparation of sources suitable for alpha spectrometric measurements are presented. These techniques are electrodeposition, direct evaporation, self-deposition, direct precipitation and the use of solvents and spreading agents. The relative principles, advantages of each technique and the application to high and low levels of activity are considered.

R279 Micromegas-based Detectors for Time-of-flight Measurements of Neutron-induced Reactions

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CEA Saclay

Micromegas detectors are versatile gaseous detectors which can also be used for neutron detection. They consist of a two-stage parallel-plate avalanche chamber with an ionization drift region and an amplification region. The use of the microbulk technique allows the use of printed circuit board techniques to produce a very thin, radiation resistant, and low-mass detector with an amplification gap of typically 50~micrometer. Such Micromegas detectors have been developed for use in combination with neutron time-of-flight measurements for in-beam neutron-flux monitoring, fission and light-charged particle reaction cross section measurements, and for neutron-beam imaging. An overview of MicroMegas detectors for neutron detection and neutron reaction cross section measurements and related results and developments will be presented.

R280 Targetry of Rare Isotopes at PSI

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Production and characterization of rare isotopes targets at the Paul Scherrer Institut is presented describing the used preparation methods, such as molecular plating, casting and ion implantation. Different methods, partially or totally developed at PSI, for target characterization, in terms of deposited activities and spatial distributions, are introduced as well. In particular, two methods, based on alpha spectrometry coupled with the advanced alpha-spectroscopy simulation program, and radiographic imaging, respectively, are presented.

R281 Neutron-gamma Classification with Support Vector Machine Based on Tensor Decomposition

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The development of digital signal processing plays an effective role to achieve fast and accurate techniques for neutron-gamma discrimination. This research work tackled a novel combination between supervised and unsupervised machine learning in order to perform neutron and gamma discrimination of the pulses from a stilbene organic scintillation detector. This combination represents the application of tensor decomposition techniques and support vector machine which have been proven to be a powerful method from a viewpoint of data analysis and for the detection of various assortments of radiations. We proposed a three steps procedure that highly qualified the discrimination task: First, the output signals of the used detector have been considered as mixtures of several unknown sources which we tried to extract using tensor decomposition models. Second, the continuous wavelet transform is used to characterize the extracted original source signals. Finally, to improve the accuracy of neutron-gamma discrimination we developed a new approach that considers the neutron-gamma configuration as a segmented image. Then, a vector of most significant features is fed into a nonlinear support vector machine model to perform the neutron-gamma discrimination in mixed radiation field. Furthermore, the proposed method provides the classification precision for each radiation.

R282 Development and Characterization of PPACs for Fission Studies

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Despite long efforts on experimental and theoretical studies of nuclear reactions, it is still not possible to predict most of the cross sections from first principles, and accurate measurements are still necessary to improve evaluated nuclear data files. In particular, neutron-induced fission cross sections of ^{235}U and ^{238}U are widely used as standards for monitoring of neutron beams, but only a few measurements exist above 20 MeV versus the primary neutron standard H(n,n).

To resolve the structures present in the cross sections, a neutron beam with a continuous energy range is required. The neutron energy is measured by its time-of-flight using the signals from the radio-frequency of the accelerator and from the detection of a fission fragment.

PPACs (Parallel Plate Avalanche Counters) present a high detection efficiency for fission fragments and a good time resolution. An experimental setup combining PPACs with the pre-existing setup "Medley", is being developed to measure the fission cross sections of ^{235}U and ^{238}U, using H(n,n) as a reference. The three reactions are studied in a single measurement, thus canceling out most of the systematic uncertainties. The setup can be used at a white neutron beam, thus opening for usage at different neutron facilities, e.g. at the upcoming Neutrons for Science (NFS) at GANIL (France) where a neutron energy range from 1 to 40 MeV is expected.

PPACs will detect the fission fragments, whereas the protons will be identified using ΔE-ΔE-E telescopes. The first Silicon detectors in the telescopes, located at different angles, will provide with fission fragment angular distributions.

Extensive studies on production of single-gap PPACs have been done, and new electrodes have been produced by evaporation of Aluminum on thin mylar foils. Several PPACs have been built and characterized thoroughly using alpha particles and fission fragments from decays of ^{241}Am and ^{252}Cf. PPAC time and energy resolutions have been investigated, as well as their detection efficiency for several bias voltages and gas pressures. Their performance has been analyzed according to theoretical descriptions of gas-filled detectors.

In this contribution, the status of the PPAC development is presented, as well as the results on their characterization.

R283 The Light Charged Particle Detector Array at the "back-n" White Neutron Source

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"Back-n" is a high luminosity white neutron source at the China Spallation Neutron Source (CSNS). A Lighted charged Particle Detector Array (LPDA) is designed for general (n,x) reaction experiment, including three different detectors and some support system. The LPDA finished first experiment of ^{6}Li (n,α) measurement while the "Back-n" first running. From the preliminary results, the detectors give an excellent particle identification. A series of precise double differential cross sections of ^{6}Li (n,α) reaction is achieved.

S284 Evaluation of Gamma-ray Strength Function Based on Measured Gamma-ray Pulse-height Spectra in Time-of-flight Neutron Capture Experiments

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Gamma-ray strength function (GSF) as well as nuclear level density is important ingredients to calculate neutron capture cross sections, since it gives energy-dependent transition strength of gamma-rays from a capture state and directly relates to spectrum of emitted gamma-rays. Therefore, the improvement of GSF is essential to enhance the reliability of neutron capture cross sections.

The shape of GSF has been determined by experiments of neutron capture reactions, (p,p') reactions and nuclear resonance fluorescence. In addition, the use of the information of gamma-ray spectrum (i.e., pulse-height (PH) spectrum) measured by time-of-flight experiments is effective to evaluate the GSF. A lot of PH spectra have been measured by the Ge and NaI(Tl) detectors of the ANNRI installed at the Material and Life Science Experimental Facility in J-PARC. However, those spectra have not been actively used to extract the information of GSF so far.

In the present study, we measured the PH spectrum of gold by using the NaI(Tl) detectors in ANNRI and used it for the evaluation of GSF. The gamma-ray spectrum for gold was calculated by a nuclear reaction model code CCONE. The obtained gamma-ray spectrum was applied to the Monte Carlo particle transport simulation code PHITS to derive PH spectrum comparable with the measured data. After this evaluation, we obtained GSF, which reasonably explained the measured PH spectrum. The details of the measurements, evaluation method and evaluated results of GSF and neutron capture cross sections in the fast neutron energy region will be presented.

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S285 A New 3 MV Tandem Accelerator Facilities for Materials Research and Nuclear Reaction Cross Section Measurements

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The BAEC 3 MV Tandem Accelerator was recently installed in the campus of Atomic Energy Research Establishment, Savar, Bangladesh. It has two ion sources; duoplasmatron, and negative sputter ion sources. A new experimental vacuum chamber was incorporated in this accelerator, whose major function is to allow use of standard ion beam analysis (IBA) techniques such as proton induced X-ray emission (PIXE), Rutherford backscattering spectrometry (RBS with channeling capability), proton induced gamma-ray emission (PIGE), etc. with millimeter-sized beam. Since installation the irradiation facility has been utilized for proton irradiations only. The IBA technique allows determination of composition and depth profile of constituents near the surface of a material. The chamber has also been adapted to nuclear reaction analysis (NRA). An experimental study of the (p,n) and (p,γ) reactions thus appears worthwhile because the available cross section database for those reactions in the low-energy range is rather weak. Some work on cross section measurements has already been done using the modified chamber.

further interesting area of investigation using a tandem accelerator is the production and utilization of neutrons. For this purpose, a Be-target holder has been constructed. The characterization of the generated neutron spectrum is in progress. After its characterization, the neutron field will be used for activation of materials. Furthermore, integral measurements of cross sections of some (n,p) reactions will be performed. These are important for fusion reactor technology and also serve as neutron dosimetry reactions in fission and fusion systems. The results are expected to contribute to the validation of available excitation functions of the dosimetry reactions.

Details on the irradiation facility and the characterization of the available beam will be given. Some typical results obtained by IBA analysis and some results on few (p,x) reaction cross sections measured by the activation technique will be presented. The status of development of the p(Be) neutron field will be described.

R286 Application of Similarity Analysis Method in Zero-power Experimental Validation

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New advanced reactors require zero-power experiments to validate the correctness of design. In order to ensure sufficient validation strength, certain similarity of physical properties between zero-power experiment reactor and the target reactor is required. Based on sensitivity and uncertainty analysis techniques, three indexes for evaluating the physical similarity between reactor systems were introduced. Based on the Monte Carlo transport program MONK, a coupled similarity analysis program MCS was compiled. The results of MCS were compared with TSUNAMI's and the two programs showed good agreement. Finally, the similarity between the CEFR in MOX fuel loading design and the BFS-119-2 zero-power experiment scheme given by IPPE was calculated by MCS. The results showed that the two systems were very similar to each other, and the physical properties of the CEFR-MOX loading design could be validate by the zero-power experiment.

R287 A New Neutron Induced γ-ray Generator for Geant4

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Evaluated nuclear data libraries written in ENDF-6 format are used by Monte Carlo codes such as Geant4, MCNP6 or FLUKA for the transport of low energy neutrons (up to 20 MeV). The format in which the production of γ-rays after neutron induced reactions is provided do not allow, in general, to generate these γ-ray cascades in a correlated way. This is not a problem for most of the calculations needed in reactor applications or dose calculations. However, difficulties arise when simulating electromagnetic calorimeters, detectors in coincidence, or the response of a detector to neutron induced reactions produced near or inside the detector. For this reason we have developed and implemented into Geant4 a model for generating neutron induced γ-ray cascades in a correlated way. The model uses the known level schemes and branching ratios of the different nuclei provided by RIPL-3 and ENSDF. The unknown part of the level schemes and branching ratios are generated using statistical models, in a similar way as the DICEBOX [1] and the DECAYGEN [2] codes. The electron conversion factors have been obtained from BrIcc. The resulting γ-ray cascades have been compared with other models and with the prompt thermal capture γ-ray databases provided by the IAEA (EGAF) and the Brookhaven National Laboratory (CapGam).

[1] F. Becvár, Nucl. Instrum. Methods A 417, 434 (1998).
[2] J.L. Taín and D. Cano-Ott, Nucl. Instrum. Methods A 571, 719 (2007).

R288 The ^{6}LiF-silicon Detector Array Developed for Real-time Neutron Monitoring at Back-streaming White Neutron Beam at CSNS

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A white neutron source for nuclear data measurement has been built and put into operation on the China Spallation Neutron Source (CSNS). We developed a beam monitor for real-time online monitoring of neutron flux on the white neutron sources. The beam monitor work simultaneously with other nuclear data measurement detectors to provide neutron flux for data analysis. To minimize beam disturbances and reduce the background generated by the monitor, a structure in which neutron conversion layer and Si detectors are separated is employed: A ^{6}LiF film with 360 μg/cm^2 was deposited on a 10μm aluminum foil and placed in the beam, eight 20×20 mm Si-detectors were placed around the film outside the beam to maximize the reception of secondary particles from the conversion layer and to avoiding neutron beam irradiation. The simulation of the beam monitor (count rate, energy spectrum, interference, etc.), construction and performance testing are detailed in the text. The monitor obtained good performance in the CSNS white neutron source test run in March 2018: Its count rate at 10kw power operation of the accelerator is about 45cps, the count rate stability is better than 1%, and the beam disturbances is less than 0.1%. These are well consistent with the simulation results.

R289 New Detection Systems at U-120M Cyclotron

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Intensive, high energy neutron beams with energies up to 33 MeV are produced using cyclotron driven broad-spectrum and quasi-monoenergetic neutron generators at the NPI. The neutron beams are well characterized with the TOF and PRT measurements.

The segmented Fe-CH2 collimator is used to collimate the neutron beam and two detection systems are being developed for the studies of the reaction with neutrons. The first one is the evacuated chamber for the detection of the charged particles at different angles from the (n,cp) reactions, the second is the array of four HPGe detectors for the detection of direct and delayed gammas produced in the reaction of the studied material with neutrons.

The advanced bunching system is also being developed at the U120M cyclotron. It will allow to direct a short (few ns long) pulse of accelerated particles to the neutron converter with the 1 us delay between bunches. Together with 7 m long flight path this extension will open new possibilities in the cross section measurements.

R290 Collimator Design of A Recoil Proton Telescope

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Proton recoil telescope is a perfect instrument to perform precise absolute neutron flux measurements above 1MeV which based on standard H (n,p) elastic scattering cross section. As for the accelerator neutron sources, proton recoil telescope is a neutron flux monitor which stand along from the target system.

A recoil proton telescope system for neutron flux monitoring of high intensity D-T fusion neutron generator (HINEG) has been developed by the Institute of Nuclear Energy Safety Technology (INEST), Chinese Academy of Sciences (CAS). This system mainly consists of a collimator, a vacuum vessel, a polyethylene converter and two silicon detectors. The length, aperture and shading effects of this collimator were optimized by Super Multi-functional Calculation Program for Nuclear Design and Safety Evaluation (SuperMC). The collimator structure is combined with 300mm thick copper, 680mm thick iron, and 20mm thick lead. And the diameter of copper is 300mm, iron is a staircase structure which has two size 300mm and 600mm, the diameter of lead is 600mm. The aperture was designed with a round shaded hole and coned-shaded hole. With this structure the irradiation damage of the silicon detector was reduced and detectors' service life is benefit from these optimized. The recoil proton signal was highlighted and the interference of Si(n,p) and Si (n,α) reactions was decrease, which is benefit for the debugging of recoil proton telescope.

Recoil proton telescope was installed at the position back to the D+ beam line to increase of the experimental space efficiency. Distance from the target to telescope system is 1.3m, and the angle between the recoil proton telescope and the beam line is 11.5 degree. The detection efficiency of the recoil proton telescope was 3.1762×10^{-10}. The results show that the recoil proton telescope is suitable for the high neutron yield measuring of the high intensity D-T fusion neutron generator.

S291 The Silicon-detector Array at Back-n White Neutron Facility

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In order to detect the light charged particles produced in (n,lcp) reactions at Back-n white neutron facility, a silicon-detector array(SDA) is set up in LPDA spectrometer. The SDA is composed of 16 PIN silicon detectors, with thickness of 500 μm. The active area of each detector is 20 mm×25 mm. The SDA is placed 200 mm away from the center of the target and can detect the emerging particles from 18 degree to 90 degree. Using the SDA, several experiments was carried out at Back-n. The SDA has shown good performance in experiments.

S292 Back-streaming White Neutron Beam for Neutron Imaging at CSNS

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In 2018, the CSNS back-streaming white neutron source (Back-n) has been built and starts commissioning. The Back-n beam has a wide energy spectrum ranging from 1 eV to 200 MeV and high neutron flux. We can use the characteristic peaks of neutron resonance structure to achieve a good identification of the nuclides. Based on the characteristics of the existing Back-n beam, we estimated the qualitative influences due to the proton time structure, beam spot uniformity and flux. The nuclide identification range and position resolution are given within the Back-n white neutron radiography.

I293 Recent Progress in Nuclear Data Measurement for ADS at IMP

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Recent progress in nuclear data measurement for ADS at Institute of Modern Physics is reviewed briefly. Based on the cooler storage ring of the Heavy Ion Research Facility in Lanzhou, nuclear data terminal was established. The nuclear data measurement facility for the ADS spallation target has been constructed, which provides a very important platform for the experimental measurements of spallation reactions. A Neutron Time-of-Flight (n_TOF) spectrometer was developed for the study of neutron production from spallation reactions related to the ADS project. A number of experiments have been conducted in the nuclear data terminal.

R294 Measurement of Displacement Cross Section in J-PARC for Proton in the Energy Range from 0.4 GeV to 3 GeV

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For damage estimation of structural materials in the accelerator facility, displacement per atom (DPA) is widely employed as an index of the damage calculated based on the displacement cross section obtained with the calculation model. Although the DPA is employed as the standard index of material damage, the experimental data of displacement cross section are scarce for a proton in the energy region above 20 MeV. Among the calculation models, the difference about 8 times exists for tungsten so that experimental data of the displacement cross section is crucial. To obtained the displacement cross section, which can be obtained by the change of resistivity of the sample under irradiated with proton with cryogenic temperature, we have started the experiment in J-PARC to measure the displacement cross section between 0.4 and 3 GeV. As a preliminary result, the displacement cross-section of copper was successfully obtained for 3-GeV proton. The present results showed that the widely utilized Norgertt-Robinson-Torrens (NRT) model overestimates the cross section as suggested by the previous experiment in the lower energy region. It is also found that the calculation with a recently proposed model by Nordlund et al.shows good agreement with the present data.

R295 Nuclear Charge-changing Cross Section and Interaction Cross Section Measurements on C/H Target at Intermediate and High Energies

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Precise measurements of charge-changing cross sections and interaction cross sections of exotic nuclei at intermediate and high energies have been one of the frontiers in radioactive ion beam physics. In the last decades, rich experimental data on p- and sd-shell nuclei have been accumulated. These data are valuable in modeling nuclear reactions and in constraining heavy ion radiation protection, hadron therapy and cosmic ray propagations in space. On the other hand, they carry important information on the proton and nucleon distributions in the projectile nuclei and thus can be used to extract the proton-distribution and matter-distribution radii. In this contribution, I will review the experimental data on the charge-changing and interaction cross sections of both stable and unstable nuclei on hydrogen and carbon targets. The energy-, isotope- and isospin-dependence will be discussed. Moreover, I will introduce our recent experimental progress on the charge-changing cross section on the sd-shell at around 300 MeV/u on a C target performed at the HIRFL-CSR, Lanzhou.

R296 Spallation Reaction Study for Long-lived Fission Products in Nuclear Waste

He Wang
RIKEN Nishina Center

Reduction in the quantity of high-level radioactive waste in the spent fuel is one of the major issues for the use of a nuclear power plant. Research and development into the reduction and recycling of radioactive waste using partitioning and transmutation technology has been performed over recent decades. Transmutation on the long-lived fission products (LLFPs), however, has been slow. The LLFP nuclei have large radiotoxicities and long lifetimes, and they can be produced continuously even in the accelerator driven systems and next-generation nuclear reactors in addition. It is essential to find effective reactions for the LLFP transmutation. However, experimental reaction data are currently lacking.

Nuclear physics plays an essential role in addressing the treatment on LLFP, because the reliable reaction data and models are necessary for LLFP transmutation. Aiming at bringing a new invention to the nuclear transmutation on LLFP, we have studied the proton- and deuteron-induced spallation reactions for the long-lived fission products (^{137}Cs, ^{90}Sr, ^{107}Pd, ^{93}Zr, ^{126}Sn and ^{79}Se) at different reaction energies ranging from 50 to 200 MeV/u at the RIKEN RI beam factory. The LLFP beams were produced by in-flight fission of a ^{238}U primary beam at 345 MeV/nucleon in the BigRIPS in-flight fragment separator. The reaction residues were analyzed by the Zero Degree spectrometer. Both the LLFP beams and reaction products were unambiguously identified event-by-event.

The present work focuses on ^{137}Cs, ^{90}Sr and ^{107}Pd. Cross sections on proton and deuteron were successfully obtained for these three LLFP nuclei. Both target and energy dependences of reactions were systematically investigated. The new data were compared with theoretical calculations with intra-nuclear cascade and evaporation processes by using the PHITS framework. In the presentation, the results on the LLFP nuclei ^{137}Cs, ^{90}Sr and ^{107}Pd. as well as the potential of spallation reaction on the LLFP transmutation will be discussed.

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R297 Measurement of Nuclide Production Cross Section for Lead and Bismuth with Proton in Energy Range from 0.4 GeV to 3.0 GeV

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For the Accelerator-Driven nuclear transmutation System (ADS), nuclide production yield estimation in a lead-bismuth target is important to manage the target. However, experimental data of nuclide production yield by spallation and high-energy fission reactions are scarce. In order to obtain the experimental data, we carried out an experiment in J-PARC using natPb and natBi samples. The samples were thin foils with a thickness of $\sim$ 0.1 mm and irradiated with protons at various kinematic energy points between 0.4 and 3.0 GeV. After the irradiation, nuclide production cross section was determined by spectroscopic measurement of decay gamma-rays from the samples with HPGe detectors.

The present experimental results were compared with the evaluated data (JENDL-HE/2007) and the calculated values by the PHITS code. In the PHITS calculation, INCL4.6 and the Bertini model were utilized as the intra-nuclear cascade models. Also, GEM, Original-GEM developed by Furihata and Modified-GEM with Prokofiev's systematics were employed as the statistical decay models. It was found that cross sections of fission products disagreed between the experiments and the calculations except some products. For spallation products, both calculation and the evaluated data underestimated the data over the whole range. However, by using Original-GEM and Modified-GEM, cross sections were close to the experiments.

In this paper, experimental details and results, comparison of cross sections, and discussion will be presented.

I298 Study of Th-U Fuel Cycle and Nuclear Data for TMSR

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Closing Th-U fuel cycle is the ultimate goal of Thorium-based Molten Salt Reactor (TMSR) nuclear energy system program. A series of Th-U fuel cycle studies have been conducted for different types of MSR at different development stages. An innovative "three-step" strategy with thorium utilization achieving respective $\sim$20%, $\sim$40% and $\sim$80% was proposed for the Small modular Molten Salt Reactor (rapidly deployed) by considering the technology readiness of fuel reprocessing and comprehensive evaluation results. Engineering designs verifying Th-U conversation were conducted for the experimental MSR, and studies of Th-U transition and TRU transmutation were implemented for Molten Salt Breeding Reactor and Molten Salt Fast Reactor, respectively. To provide a base for TMSR Th-U fuel cycle designs and researches, basic physical rules of Th-U fuel cycle were deeply investigated and a series of in-housed calculation codes dedicated to MSR were developed. At the same time, the Th-U fuel cycle nuclear data which is important to enhance the physical design accuracy of TMSR was developed jointly by Shanghai Institute of Applied Physics and China Nuclear Data Center. A photoneutron source (PNS) driven by a 15 MeV electron LINAC had been built to provide neutron cross section measurements and benchmark for some key nuclides concerning TMSR. A Th-U fuel cycle special nuclear data library (CENDL-TMSR-V1.0) based on several international leading nuclear data libraries was developed and tested through a serious of integral benchmark experiments from the International Criticality Safety Benchmark Experiment Handbook. The thermal neutron scattering data of liquid molten salt was generated and added for improving the precision of physical design. All above study activities will contribute to obtain a high performance of TMSR Th-U fuel cycle.

R299 Impacts of Nuclear Data Uncertainties on the Generic Safety of the Soluble-boron-free SMR ATOM Core

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The qualification of the nuclear data uncertainty on the reactor safety parameters is critically important, especially for a system with a self-controllability, even though a certain design safety parameter uncertainty can be absorbed by its inherent negative feedback. The significant design uncertainty may limit the self-controllable margin of the system. In this paper, impacts of nuclear data uncertainty on the genetic safety features of the autonomous transportable on-demand reactor module (ATOM) are evaluated. The ATOM, a soluble-boron-free (SBF) small modular reactor (SMR), are designed to for autonomous operation utilizing its highly negative feedback and by allowing inlet coolant temperature variation. Several nuclear data libraries, such as ENDF, JENDLE, JEFF and etc., are considered for the uncertainty qualification in term of the fuel and coolant temperature coefficients, kinetic parameters, xenon worth, and etc. To obtain the design parameters, several CSBA-loaded fuel assemblies of the ATOM are simulated by the Monte Carlo Serpent 2 code. Consequently, the assessment of the genetic safety of the ATOM core induced nuclear data uncertainty is analyzed by a modified balance of reactivity method accounting for xenon dynamics.

R300 Analysis of the Perturbation Experiments for Some Sensitive Isotopes Application on the Designs of the Space Nuclear Reactor

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space nuclear reactor (SNR) was considered as the priority power source to enble the future human space exploration missions. And the various metal isotopes, such as beryllium, molybdenum, tungsten, and so on, had extensively applied on the designs of SNR to improve their performance, espacially for the criticality safety. But the past researches had pointed out that the cross section uncertainty of these isotopes seriously affecting the designs of SNR. IN order to estimate the influence from the integral cross sections of these nuclides, this paper firstly prepared a group of some typical metal samples for the perturbation experiments, including Fe, Ni, Cr, Be, Gd, W, Re, and Mo, and measured their reactivity worth at the upper surface center of a cylinderical highl enriched uranium reactor by the inverse kinetic method; secondly, the experiment results were compared from the theory value caculated by Keno VI and MCNP5, based on ENDF/BV,ENDF/BVI, and ENDF/BVII, respectivly. The standard uncertainties for the experiments values were less than 0.05, and the errors for the determination value were less than 4. Overally, the caculation results were consistent with the experiments, but there were a little difference among three neutron cross section database. These experiment results were very helpful to select the suitable neutron cross section database in the designs of SNR with the hard neutron spectrum.

R301 Impact Analysis of Model and Data Library for ITER Nuclear Calculation Based on SuperMC

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The ITER Organization maintains neutronics reference models. Series of tokamak sector models has progressed over many years from Benchmark model to the C-lite V1 model released at the end of 2013. Since then several model updates have been continuously implemented. The latest release, C-Model represents the tokamak up to the bioshield with central upper, equatorial and lower ports, i.e. an even-port configuration. C-Model, as previous C-lite models, is based on a modular concept of model envelopes which fill all space of the torus sector. This envelope block structure has been adopted to facilitate model update management on the basis of single standalone models, which can be easily replaced in the model assembly. C-Model has been significantly improved with respect to C-lite in terms of specific system model design status and level of detail, focused on in-vessel and vessel components.

SuperMC (Super Multi-functional Calculation Program for Nuclear Design and Safety Evaluation) is a general, accurate and efficient software system for neutronics design and analysis, developed by INEST (Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences)FDS Team. Taking neutron, photon transport calculation as the core, SuperMC supports the whole process neutronics calculation including depletion, material activation and transmutation and dose calculation. Besides, based on the cloud computing framework, it integrates accurate automatic modeling, visualized analyses and comprehensive data libraries as a whole. It has been as the reference code by ITER IO, and supported to establish ITER 3D basic neutronics models.

As we know, many nuclear analysis of ITER has been performed based on previous ITER models and data library FENDL 2.1. In this paper, the whole space neutron flux calculation based on SuperMC has been performed on two condition: (1) with ITER benchmark model and FENDL 2.1, and (2) with the latest ITER C model and FENDL 3.0. The deviation on model structure and composition, data library and neutron flux distribution has been analyzed and specified, and the area with large deviation has been indicated. The results are useful to decide that which area's nuclear analysis of ITER should be reviewed based on the latest model.

S302 The influence and analysis of background cross section for the calculation of PWR fuel pin

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With the development of resonance theory, the accuracy of multi-group cross section data is increasing gradually. It should be analyzed for the impact of background cross section data in PWR fuel pin. In the early designation of nuclear reactor, the ENDF/B-VI.3 library had reached so many engineering experimental data. Therefore, this paper using the new version of NJOY2016 code based on the evaluated nuclear data library ENDF/B-VI.3 and the crucial nuclides (^{235}U and ^{nat}Zr) of PWR fuel are choose. Through analyzing the background cross section data and the number of background cross section, the influence of these parameters on the multi-group cross section data and the k$_{inf}$ value in the PWR fuel pin are determined. Finally, the production process of multi-group library is improved.

S303 Source-term and Radiological Safety Analysis of TRIGA Research Reactor of Bangladesh

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A precise modeling methodology for atmospheric dispersion and radiological safety analysis has been performed to predict the radiological consequences in terms of accidental radionuclides release from the 3 MW TRIGA Mark-II research reactor of Bangladesh. To calculate the source-term that was generated from the inventory of peak radioisotope activities released from TRIGA research reactor, isotope generation and depletion code ORIGEN2.1 has been used. The source-term was evaluated with the reactor original operational data for 800 MWD burnup until 31st December, 2016. This corresponds to average burnup of initial ^{235}U content of about 10 percent in the core and leads to total core inventory of 2.44E-18 Bq for 50 important radionuclides. To estimate the releases of various radionuclide groups at various downwind distances, a health physics computer code HotSpot was used. The code resulted radiation dose profile in and around the investigated area and calculated the Total Effective Doses (TEDs) for various atmospheric Pasquill stability classes (categories A-F) with site-specific averaged meteorological conditions. The meteorological data, such as, average wind speed, frequency distribution of wind direction, etc. have also been analyzed based on the data collected near the reactor site. Two hypothetical accident scenarios were selected, assuming that the activities were released to the atmosphere after the design basis accident. The results indicate that a person located adjacent to 5.5 km of downwind distance from reactor, would receive the TED value of about 0.1 Sv under both analyzed accidental scenarios.

S304 Uncertainty Quantification and Sensitivity Studies on Thorium-fueled Reactors

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In order to conceive innovant reactor systems or ease the operation of current reactors, computational simulation has been widely used. To ensure accuracy and relevance of results from these calculations, necessary to prove the respect of the stringent safety criteria, significant efforts are made on uncertainty quantification. Amongst sources of uncertainty, nuclear data have been shown to have an important impact. Significant progress have been made in recent years to propagate these uncertainties for point-wise cross sections using Monte Carlo codes. Cross sections responsible for most of the final uncertainty can be pointed in these studies. If final uncertainty obtained after propagation is not satisfactory for the application, it also allows to determine accuracy needed on these cross sections and ask for an update of their evaluation or new measurements, possibly by adding it in OECD-NEA High Priority Request List.

In this work, a study of uncertainties in ^{232}Th/^{233}U-fueled reactors, arising from these two isotopes nuclear cross sections will be presented. ^{232}Th/^{233}U-fuel is considered as an alternative to ^{235}U (standard fuel) or ^{239}Pu (MOX). As it has not been used on an industrial scale yet, data on its behaviour is scarcer. In this poster, first will be shown current uncertainties on these cross sections for neutron energy range relevant to nuclear reactors. Then, effects of these cross sections on reactor parameters keff, βeff and on radial power will be outlined, as well as their associated consequences, for both thermal and fast neutron reactors. Methods used are: first, Total Monte Carlo method, where change in calculated parameters are computed for each change in cross sections, is used as a reference; second, uncertainty propagation using sensitivity tools integrated in transport codes MCNP and SERPENT is a faster method but is approximate and needs to be checked. Selected problems encountered along this process will be mentionned. Finally, maximum uncertainties on cross sections required to mitigate these consequences will be assessed.

S305 Research and Development of China Nuclear Safety Cloud Computing Platform NCloud

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Nuclear safety is the lifeline of the development of nuclear energy and nuclear technology utilization. It is great significant to improve the safety level of nuclear power plants through comprehensive numerical simulation technology. The nuclear database, nuclear software and simulation platform are the basic of nuclear safety study and application. China Nuclear Safety Cloud Computing Platform (NCloud) has been developed by the Institute of Nuclear Safety Technology, Chinese Academic of Sciences • FDS Team. It provided four main functions:
a) Nuclear safety data pool and data services. The database includes experimental nuclear reaction libraries, evaluated nuclear data libraries, application nuclear data libraries, nuclear material data libraries, reliability libraries, nuclear emergency public data libraries, etc. furthermore, data customization, forecasting of nuclear material properties, reliability data correction, reliability analysis of reactor components, visualization analysis have been provided.
b) Nuclear safety calculation and analysis software pool. More than 20 nuclear safety analysis software have been collected in this platform, include comprehensive simulation tools, neutron transport calculation programs, burn-up calculation codes, activation calculation codes, irradiation damage calculation codes, hydromechanics calculation codes, reactor system analysis programs, nuclear emergency decision support system and accurate model programs.
c) Integrated simulation for normal working condition. In this module, whole space accurate modeling of reactor and building can be done on-line. And multi-physics coupling simulation of burn-up, activation and dose have been provided based on SuperMC (Super-functional Calculation Program for Nuclear Design and Safety Evaluation). Furthermore, it provides scenario evaluation such as maintenance scenarios, assembly scenarios, etc.
d) Integrated simulation for accident condition. It provides accident source term inversion, accident evolution process prediction, full-scale simulation of radionuclides diffusion and intelligent decision support.
e) The scientific research community. In this module, users can create team workspace and share documents in it, discussion via video conference and remote collaboration.

Up to now, some core functions of NCloud has been used in more than 60 countries and applied in many mega nuclear engineering projects.

I306 Extensive New Beta-delayed Neutron Measurements for Astrophysics

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Soon after the discovery of fission, the emission of delayed neutrons was identified and associated to the decay of neutron-rich fission products [1]. Its key role in controlling the progress of chain reactions in nuclear reactors was also recognized. In the seventies the important role of beta-delayed neutron emission in the description of rapid neutron capture (r-) processes occurring in explosive stellar scenarios with large neutron abundances was first pointed out [2]. However, most of the very neutron-rich nuclei synthetized along the r-process reaction path have eluded until now direct experimental investigation [3].

The BRIKEN project [4] was launched to extend significantly our knowledge of beta-delayed neutron emission probabilities (Pn) and half-lives ($T_{1/2}$) into this region, combining the very high beam intensity achieved at the RIBF accelerator complex in RIKEN [5] and the selection/identification capabilities for reaction products of the BigRIPS in-flight spectrometer [6], together with state-of-the-art ion implant-and-decay detectors and moderated neutron counters [7]. The experimental program started in 2017 and envisages the measurement of over 250 new beta-delayed neutron emitters, and 100 new half-lives covering the region from mass A $\sim$ 70 to A $\sim$ 200 with a direct impact in r-process nucleosynthesis calculations [8]. Lighter mass (A = 30-70) nuclei will also be investigated. The wealth of new data will allow a thorough benchmarking of nuclear structure dependent beta-strength calculations [9] and the study of the competition between gamma-emission and different multi-neutron emission channels [10]. In this presentation we will review the status of the experimental program and show some initial results.

[1] N. Bohr and J.A. Wheeler, Phys. Rev. 56 (1939) 426.
[2] T. Kodama and K. Takahashi, Phys. Lett. B 43 (1973) 167.
[3] https://www-nds.iaea.org/beta-delayed-neutron/
[4] J. L. Tain et al., Acta Phys. Pol. B 49 (2018) 417.
[5] H. Okuno et al., Prog. Theor. Exp. Phys. 2012, 03C002 (2012).
[6] T. Kubo et al., Prog. Theor. Exp. Phys. 2012, 03C003 (2012).
[7] A. Tolosa et al., arXiv:1808.00732.
[8] M. R. Mumpower et al., Prog. Nucl. Part. Phys. 86 (2016) 86.
[9] P. Moeller et al., Phys. Rev. C 67 (2003) 055802.
[10] M. R. Mumpower et al., Phys. Rev. C 94 (2016) 064317.

R307 **The Cosmic Ray Detector (MCORD) for the New Collider NICA**

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Multi-Purpose Detector (MPD) is a part of Nuclotron-based Ion Collider fAcility (NICA) located in Dubna, Russia. For full functionality, the MPD needs an additional trigger system for off-beam calibration of MPD sub-detectors and for rejection of cosmic ray particles (mainly muons). The system could also be very useful for astrophysics observations of cosmic showers initiated by high energy primary particles. The consortium NICA-PL comprised of several Polish scientific institutions has been formed to define goals and basic assumptions for MPD Cosmic Ray Detector (MCORD). This article describes the early stage design of the MCORD detector based on plastic scintillators with silicon photomultiplier photodetectors (SiPM) for scintillation readout and electronic system based on MicroTCA crate. Some simulations for MCORD detector performance are also presented.

R308 New Reaction Rates for the Destruction of ^{7}Be During Big Bang Nucleosynthesis Measured at CERN/n_TOF and Their Implications on the Cosmological Lithium Problem

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A few neutron-induced reactions are important in the processes leading to the formation of the first nuclides at the very beginning of our universe, during the so-called big bang nucleosynthesis (BBN). Amongst these, the (n,p) and (n,α) reactions on ^{7}Be play a key role, in particular for the determination of the abundance of primordial lithium.

New measurements of the ^{7}Be(n,α)^{4}He and ^{7}Be(n,p)^{7}Li reaction cross sections from thermal to keV neutron energies have been recently performed at CERN/n_TOF [1], [2]. High purity ^{7}Be material was produced at the Paul Scherrer Institute (PSI) and, in the case of the (n,p) experiment, implanted at CERN/ISOLDE and irradiated with the neutron beam of the EAR2 experimental area at n_TOF, demonstrating the feasibility of neutron measurements on samples produced at radioactive ion beam facilities. The cross sections turned out to be higher than previously known, in particular at low energies.

Based on the n_TOF experimental results, new astrophysical reaction rates have been derived for both reaction mechanisms, including a proper evaluation of their uncertainties in thermal energy range of interest for BBN studies. The new estimate of the ^{7}Be destruction rate based on these new results yields a decrease of the predicted cosmological ^{7}Li abundance which turned out to be insufficient to provide a viable solution to the cosmological Lithium problem (CLiP).

A full account of the implications on the BBN of the new n_TOF nuclear data measurements will be presented, in particular whether the present results can finally rule out neutron-induced reactions as a potential explanation of the CLiP, leaving all alternative physics and astronomical scenarios.

[1] M Barbagallo et al. (The n_TOF Collaboration), Phys. Rev. Lett. 117 (2016) 152701
[2] L A Damone et al. (The n_TOF Collaboration), Phys. Rev. Lett. 121 (2018) 042701

R309 Determine the Neutron Capture Cross Section of Radionuclide with Surrogate Ratio Method

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Whether for nuclear reactors on the earth or massive stars in the universe, there are many radionuclides mixed in their fuels, and neutron radiative capture reactions of such radionuclides play an important role in the energy generation and nucleosynthesis. Due to difficulty of the manufacture of radioactive target, it is hard to measure the neutron capture cross section directly. We investigate the indirect method, surrogate ratio method(SRM), to determine the (n,γ) cross section of radionuclides. The relative γ-decay probability ratios of the neutron resonance states in ^{94}Zr and ^{92}Zr populated via two-neutron transfer reactions, ^{92}Zr(^{18}O,^{16}O)^{94}Zr and ^{90}Zr(^{18}O,^{16}O)^{92}Zr, have been measured. The cross sections of the ^{93}Zr(n,γ)^{94}Zr reaction are derived from the experimentally obtained ratios and the cross sections of the ^{91}Zr(n,γ)^{92}Zr reaction in the equivalent neutron energy range of En = 0-8MeV. The deduced cross sections of ^{93}Zr(n,γ)^{94}Zr reaction agree with the directly measured ones in the low-energy region, and with the evaluated ENDF/B-VII.1 data at higher energies of En > 3MeV. The agreement supports the concept of the SRM method to indirectly determine the (n,γ) reaction cross sections. After the validity check, We measure the cross section of ^{95}Zr(n,γ)^{96}Zr reaction.

R310 The ^{154}Gd Neutron Capture Cross Section Measured at the n_TOF Facility and Its Astrophysical Implications

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The (n,γ) cross sections of the gadolinium isotopes play an important role in the study of the stellar nucleosynthesis. In particular, among the products heavier than Fe, ^{154}Gd together with ^{152}Gd have the peculiarity to be mainly produced by the slow capture process, the so-called s process, since they are shielded against the β-decay chains from the r-process region by the stable samarium isobars. Such a quasi pure s-process origin makes them crucial for testing the robustness of stellar models in galactic chemical evolution (GCE). According to recent models, the ^{154}Gd and ^{152}Gd abundances are expected to be 15-20% lower than the reference branched s-process ^{150}Sm isotope. The close correlation between stellar abundances and neutron capture cross sections prompted for an accurate measurement of ^{154}Gd cross section in order to reduce the uncertainty attributable to nuclear physics input and eventually rule out one of the possible causes of present discrepancies between observation and model predictions. To this end, the neutron capture cross section of ^{154}Gd was measured in a wide neutron energy range (from thermal up to some keV) with high resolution in the first experimental area of the neutron time-of-flight facility n_TOF (EAR1) at CERN. In this talk, after a brief description of the motivation and of the experimental setup used in the measurement, the preliminary results of the ^{154}Gd neutron capture reaction as well as their astrophysical implications will be presented.

I311 Impact of Fission Fragment Distribution on R-Process Nucleosynthesis in Neutron Star Mergers and Supernovae

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GW170817/SSS17a was an event of the century that opened a new window to multi-messenger astronomy and nuclear astrophysics. In addition to the detections of gravitational wave (GW) and gamma-ray burst, optical and near-infrared emissions among many other observables strongly suggest that this event was triggered by binary neutron star merger (NSM) and that the total energy release is consistent with radiative decays of lanthanoids, as predicted theoretically, although no specific r-process element was identified observationally.

Theoretical calculation of the r-process nucleosynthesis in NSMs indicates that the 2ndpeak elements around A$\sim$130 (Te-I-Cs) are produced if the symmetric fission occurs (to two double magic nuclei ^{132}Sn plus neutrons) from extremely neutron-rich actinides around Z$\sim$100 and A$\sim$180 [1]. The 2^{nd} peak structure is however smeared out due to the fission recycling if the fission-fragment-distribution (FFD) is asymmetric [2,3]. Another serious astrophysical problem is that NSMs could not contribute to the early Galaxy for cosmologically long merging time-scale for too slow GW radiation. Core-collapse supernovae (both MHD Jet-SNe and ν-driven wind SNe) are viable candidates for these r-process elements because they can explain the "universality" at the 2^{nd} through 3^{rd} peak r-process elements found in old metal-deficient halo stars.

We propose a novel solution to this twisted problem by carrying out both NSM and SN nucleosynthesis calculations by taking account of both symmetric and asymmetric FFDs in the fission-recycling r-process nucleosynthesis in Galactic chemo-dynamical evolution [4].

[1] T. Suzuki, T. Kajino et al., ApJ 859 (2018), Issue 2, article id. 133, 9 pp.
[2] S. Shibagaki, T. Kajino et al., ApJ 816 (2016), 79.
[3] T. Kajino & G. J. Mathews, Rep. Prog. Phys. 80 (2017), 084901.
[4] Y. Hirai, T. Kajino et al., ApJ 814 (2015), 41; MNRAS 466 (2017), 2472-2487.

R312 Systematic Deviations of Neutron-capture Cross Sections Derived from Independent Accelerator Mass Spectrometry Measurements

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The detection of long-lived radionuclides through ultra-sensitive isotope ratio measurements via accelerator mass spectrometry (AMS) offers opportunities for precise measurements of neutron capture cross sections, e.g. for nuclear astrophysics. For specific reactions AMS provides a unique tool to pin down uncertainties which is important to address existing discrepancies. This approach directly counts the number of reaction products present in the sample after the neutron activation rather than measuring the associated γ-radiation or the emitted particles during the irradiation.

A series of samples was irradiated at Karlsruhe Institute of Technology (KIT) with neutrons simulating a Maxwell-Boltzmann distribution of 25 keV, and also with quasi-monoenergetic neutrons of energies up to 500 keV and at thermal energies. In this way precise neutron-capture cross section data were obtained for a series of isotopes, among them ^{9}Be, ^{13}C, ^{35}Cl, ^{40}Ca, ^{54}Fe, ^{235,238}U, and for ^{14}N(n,p) by AMS.

Using AMS, the respective spectrum-averaged cross section is simply the product of two quantities, the neutron fluence and the isotope ratio of reaction product and educt; the latter quantity the direct result obtained from AMS. The reaction ^{197}Au(n,γ) was used as fluence monitor for all activations. From these data, Maxwellian average cross sections (MACS) are derived by normalizing the known cross-section to energy dependence.

The reaction products were measured as isotope ratios relative to their respective individual AMS standards that are completely independent for different nuclides. Thus, this technique represents a truly complementary approach, completely independent of any other experimental method (such as time-of-flight method or decay counting); in addition the AMS results are also fully uncorrelated for different reactions.

When compared with existing data from complementary techniques, cross sections obtained through AMS suggest a small but consistent systematic difference. Potential reasons for this discrepancy and potential unknown systematic uncertainties will be discussed.

R313 Impact of Nuclear Data on Stellar Nucleosynthesis and Cosmology

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Recent gravitational waves detection from a binary neutron star merger (GW170817)energized the astrophysical community and encouraged the further research for determination of nuclear physics observables. Comprehensive studies of atomic nuclei in the cosmos provide a unique information on stellar nucleosynthesis processes that is necessary to validate using the latest nuclear data. Evaluated Nuclear Data File (ENDF) libraries contain complete collections of reaction cross sections, angular distributions, fission yields and decay data. These data collections have been used worldwide in nuclear industry and national security applications. It represents a great interest to explore the recently-released ENDF/B-VIII.0 library for nuclear astrophysics purposes and compare findings with the predictions of Talys Evaluated Nuclear Data Library (TENDL-2015) and Karlsruhe Astrophysical Database of Nucleosynthesis in Stars (KADoNiS).

The Maxwellian-averaged cross sections (MACS) and astrophysical reaction rates were calculated using the ENDF/B-VIII.0 and TENDL-2015 evaluated data sets. The calculated cross sections were combined with the solar system abundances and fitted using the classical model of stellar nucleosynthesis. Astrophysical rapid- and slow-neutron capture, r- and s-processes, respectively, abundances were extracted from the present data and compared with available values. Further analysis of MACS reveals thepotential astrophysical data deficiencies and strong needs for new measurements. The current results demonstrate large nuclear astrophysics potential of evaluated libraries and mutually beneficial relations between nuclear industry and research efforts.

R314 Uncertainty Study in Analyzing the Reactor Neutrino Anomaly Based on the Nuclear Structure Physics

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The Daya Bay (DB) reactor neutrino experiments confirm the "reactor neutrino anomaly" in that the measured value of σ_f is about 5.1% below that predicted by the model spectra of Huber and Mueller (H-M). Such anomaly could be potentially extremely important for the possible existence of sterile neutrino. Thus, extensive recent literature appears, to study the origin of the anomaly.

In this talk, I would like to discuss some topic related to the uncertainties of the antineutrino spectra. To obtain the antineutrino spectra theoretically, so-called summation method or by the conversion method can be used. For both methods, all corrections to decay that can affect the spectra at the few percent level are normally included. There are four subdominant corrections to decay that must be considered in calculating the antineutrino spectra. These are the recoil, radiative, finite-size, and weak magnetism corrections. The recoil correction is quite small, and the radiative correction has been taken from the work of Sirlin, both before and since the occurrence of the anomaly. In all cases, the finite-size and weak magnetism corrections that were applied involve some level of approximation. We have checked the validity of the nuclear structure assumption, particularly for allowed fission-fragment β decays.

R315 Study of Astrophysical Nuclear Reactions in a Laser-driven Plasma Environment

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The nuclear reaction cross-sections measured in laboratory at room temperature and pressure are hard to apply to the extreme astrophysical plasma environment, because two corrections on electron screening and plasma screening are needed for the experimental data[1]. In the recent years, it is possible to simulate astrophysical plasma environment and study nuclear physics and nuclear astrophysics questions following the rapid development of high-intensity laser technology. Laser nuclear physics becomes a new interdisciplinary area[1-2]. In this work we present the measurements of astrophysical reactions D(d, p)^{3}He and ^{7}Li(p,α)^{4}He at energies of several keV where the coulomb screening effects are very important and compared the results with the reaction cross-section data at laboratory environment.

[1] M. Arnould, and K. Takahashi, Rep. Prog. Phys. 62, 395 (1999).

[4] Perspectives in nuclear physics. NuPECC long range plan 2017.

R316 Gamma-ray Strength Functions for Astrophysical Applications in the IAEA-CRP

Hiroaki Utsunomiya[1], Stephane Goriely[2], Therese Renstrøm[3], Gry Tveten[3], Takashi Ari-izumi[1], Shuji Miyamoto[4], Yiu-wing Lui[5], Ann-cecilie Larsen[3], Sunniva Siem[3], Stephane Hilaire[6], Sophi Péru[6], Arjan Koning[7]

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5. Texas A&M University
6. CEA, DAM, DIF
7. International Atomic Energy Agency

We have investigated the γ-ray strength function (γ SF) in the Coordinated Research Project with the code F41032 launched by the International Atomic Energy Agency [1]. The (γ,n) and (n,γ) cross sections are interconnected through the γ-ray strength function (γ SF). The recent systematic study across the chart of nuclei [2] has revealed the presence of the zero-limit strength of both E1 and M1 components only in the photo-deexcitaiton mode, indicating the violation of the Brink hypothesis [3,4] which is the equality of the γSF in photo-excitation and de-excitation modes. Within the framework of the γ-ray strength function method [5], we use (γ,n) cross sections as experimental constraints on the γSF with the zero-limit strength from the Hartree-Fock-Bogolyubov plus quasiparticle-random phase approximation based on the Gogny D1M interaction for E1 and M1 components. The (n,γ) cross sections calculated with the experimentally constrained γSFs are compared to existing data. We present the latest development of the γSF study for astrophysical applications in the IAEA-CRP, including the nickel [6] and thallium [7] isotopic chains.

[1] https://www-nds.iaea.org/CRP-photonuclear/
[2] S. Goriely, S. Hilaire, S. Péru, K. Sieja, Phys. Rev. C 98 (2018) 014327.
[3] D.M. Brink, Ph.D Thesis, Oxford University, 1955.
[4] P. Axel, Phys. Rev. 126, 671 (1962).
[5] H. Utsunomiya et al., Phys. Rev. C 82, 064610 (2010).
[6] H. Utsunoiya et al., Phys. Rev. C, submitted.
[7] H. Utsunomiya et al., Phys. Rev. C, to be submitted.

R317 The Unknown Site of Actinide Nucleosynthesis - Clues from Extraterrestrial Pu-244 in Deep-sea Archives

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3. Australian Nuclear Science and Technology Organisation (ANSTO), Sydney
4. Hebrew University, Jerusalem, Israel

Half of the heavy elements are produced in r-process nucleosynthesis, which is exclusively responsible for actinide production. The r-process itself is far from being fully understood; in particular its sites and history remain a mystery.

The abundance of long-lived actinides in today's interstellar medium (ISM) results from the interplay between production and decay. Their presence would establish that their production was recent. In particular ^{244}Pu ($t_{1/2}$ = 81 Myr) can place strong constraints on r-process frequency and production yields over the last few 100 Myr [1,2]. Detection of ISM-^{244}Pu in deep-sea archives would complement the positive detection of interstellar and supernova-produced ^{56}Fe [3-6]. However, the low concentrations measured suggest an unexpectedly low abundance of interstellar Pu [7]. It signals actinide r-process nucleosynthesis is rare, which is incompatible with the rate and expected yield of supernovae as the predominant actinide-producing sites, but compatible with neutron-star mergers.

Here we present new results for ^{244}Pu measured at ANSTO with unprecedented sensitivity and background-free detection of Pu. We measured anthropogenic Pu in deep-sea samples and searched older layers for extraterrestrial signals. These data provide new insights into their ISM concentrations for the last 11 Myr. ^{244}Pu was present in the early solar system. Our results suggest it must have been subject to a rare r-process nucleosynthesis event shortly before formation.

[1] M. Paul et al. ApJL558,2001
[2] C. Wallner et al. NAstrRev48,2004
[3] K. Knie et al., PRL83,1999, PRL93
[4] A. Wallner et al., Nature532,2016
[5] L. Fimiani et al., PRL116,2016
[6] P. Ludwig et al., PNAS113,2016
[7] A. Wallner et al., Nature Comm.6, 2015

S318 Direct Capture Cross Sections on Exotic Tin Isotopes*

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Neutron capture rates on exotic n-rich Sn isotopes have been shown by sensitivity studies to alter the late-time r-process reaction pathway and final synthesized r-process abundances. Recent estimates of the direct neutron capture cross section for these isotopes have, however, exhibited significant differences in their value, their neutron-number dependence, and their magnitude in comparison to compound nuclear capture. We used recent experimental information on bound levels of ^{125,127,129,131,133}Sn, and new co-variant density functional theory predictions for bound level properties in ^{135,137,139}Sn, as input for direct neutron capture cross section calculations for ^{124}Sn - ^{138}Sn. A comparison with recent predictions and potential impacts on the r-process will be discussed.

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I319 **Atomic Mass Evaluation**

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3. ANL, USA
4. RIKEN, Japan
5. MPIK, Germany

As a fundamental property of nuclei, atomic masses are widely used in many domains of science and engineering. A reliable atomic mass table derived from the experimental data, where the atomic masses and the relevant experimental information can be found conveniently, is in high demand by the research community. To meet the demands, the Atomic Mass Evaluation (Ame) was created and now serves the research community by providing the most reliable and comprehensive information related to the atomic masses. The last complete evaluation of experimental atomic mass data Ame2016 was published in 2017. In this contribution, general aspects of the development of Ame2016 and the current status of AME will be presented and discussed.

R320 **Structure of Beta Decay Strength Function, Spin-isospin SU(4) Symmetry, and SU(4) Region**

Igor Izosimov
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The β-decay strength function S_β(E) governs [1,2] the nuclear energy distribution of elementary charge-exchange excitations and their combinations like proton particle (πp)-neutron hole (νh) coupled into a spin-parity I^π : $[\pi \mathrm{p} \times \nu h]^\pi_I$ and neutron particle (νp)-proton hole (πh) coupled into a spin-parity I^π : $[\nu \mathrm{p} \times \pi h)]^\pi_I$. The strength function of Fermi-type β-transitions takes into account excitations $[\pi \mathrm{p} \times \nu h]^+_0$ or $[\nu \mathrm{p} \times \pi h]^+_0$. The strength of the Fermi-type transitions is concentrated in the region of the isobar-analogue resonance (IAR). The strength function for β-transitions of the Gamow-Teller (GT) type describes excitations $[\pi \mathrm{p} \times \nu h]^+_1$ or $[\nu \mathrm{p} \times \pi h]^+_1$. Residual interaction can cause collectivization of these configurations and occurrence of resonances in S_β(E)). In heavy and middle nuclei, because of repulsive character of the spin-isospin residual interaction, the energy of GT resonance is larger than the energy of IAR (EGT > EIAR). One of the consequence of the Wigner spin-isospin SU(4) symmetry is EGT = EIAR. SU(4) symmetry-restoration effect induced by the residual interaction, which displaces the GT towards the IAR with [1,2] increasing (N-Z)/A. In ^{6}Li nucleus (g.s. is the tango [3] halo state, IAR is the Borromean halo resonance) for low energy GT phonon (reduced GT strength B(GT) $\approx 5g^2_A/4\pi$ ($\sum$(Ikeda sum rule) = $6g^2_A/4\pi$) we have EGT < EIAR, EGT-EIAR = -3562.88 keV, and (N-Z)/A=0.33 for ^{6}He (^{6}He g.s. is the parent Borromean halo state). Such situation may be connected with contribution of the attractive component [4] of residual interaction in this nucleus. It will be very interesting to find a region of atomic nuclei, where the EGT $\approx$ EIAR and spin-isospin SU(4) symmetry determine the nuclear properties (SU(4) region). Our estimation shows that the value Z/N $\approx$ 0.6 corresponds to the SU(4) region. Different manifestations of the SU(4) symmetry are discussed.

[1] I.N. Izosimov, Phys. of Part. and Nucl. 30, 131 (1999).
[2] I.N. Izosimov, V.G. Kalinnikov and A.A. Solnyshkin, Phys. of Part. and Nucl. 42, 963 (2011).
[3] I.N. Izosimov, Phys. of At. Nucl. 80, 867 (2017).
[4] Y.Fujita, et al., Phys. Rev. Lett. 112, 112502 (2014).

R321 Alpha-decay Studies on the New Neutron-deficient Np Isotopes

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Alpha decay, as a crucial decay mode of unstable nuclei, has been proven to be a powerful experimental tool to identify the new superheavy elements and investigate the nuclear structure of exotic nuclei near the proton drip line. In the vicinity of the doubly magic nucleus ^{208}Pb, alpha-decay study provides an opportunity to disclose the intriguing nature of nuclear structure moving away from the closed shells.

Recently, we performed a series of experiments on the gas-filled recoil separator SHANS (IMP, Lanzhou) aimed at the alpha-decay studies in the region of the heaviest N = 126 isotones. Four new isotopes ^{219,220,223,224}Np have been produced, which allow us to establish the systematics of the alpha-decay properties for this isotopic chain for the first time. In my presentation, the status of our setup and the new decay data on the Np isotopes will be presented. Based on these measurements, the stability of the N = 126 shell closure on Np will be discussed.

R322 First Results from Novel Measurement Methods of Nuclear Properties with the FRS Ion Catcher

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5. IFIN-HH/ELI-NP
6. FRS Ion Catcher Collaboration Affiliations

We have developed novel methods to measure nuclear half-lives and decay branching ratios of exotic nuclei, and fission yield distributions and isomer yield ratios, all based on simultaneous identification of reaction products by direct mass measurements. The methods were implemented and tested at the Fragment Separator (FRS) Ion Catcher (IC) at GSI (Darmstadt, Germany), which comprises a cryogenic stopping cell (CSC), a radio frequency quadrupole (RFQ) mass filter and beam line, and a multiple-reflection time-of-flight mass-spectrometer (MR-TOF-MS).

Half-lives are obtained by counting the amount of precursor and recoil nuclei as a function of containment time in the CSC, branching ratios are determined by counting the relative quantities of recoil nuclei in a given decay, and fission yield distributions and isomer ratios are also extracted from the relative counts of the fission fragments. Isotope identification is performed by direct mass measurement, for which the FRSIC MR-TOF-MS mass resolving power enables isobar and isomer separation.

By using the above methods, we measure directly for the first time the high-fission-peak isotope yield distribution in spontaneous fission of ^{252}Cf and some of its isomer yield ratios, re-measured several nuclear half-lives, and demonstrated the branching ratio method for isomer internal transition. Identification by direct mass measurement circumvents systematic uncertainties and backgrounds that impair methods based on gamma de-excitation. Furthermore, the method does not require prior knowledge of nuclear properties, since all are measured during the experiment. This point is highlighted in the current contribution, where in the process of demonstrating our method, we measured directly for the first time the mass of the isomer ^{119n}Sb ($t_{1/2}$= 850(90) msec), perhaps offering a resolution to a long-existing conflict regarding its exact excitation energy and quantum numbers.

R323 Spectroscopy of ^{16}B from the Quasi-free (p,pn) Reaction

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The spectroscopy of neutron-rich nuclei lying at the limits of stability is very important for the development of our knowledge of nuclear interactions and understanding of the exotic phenomena recently observed when approaching the neutron drip line such as halo and clusters [1,2]. The spectroscopy of ^{16}B is also critical for unraveling the neutron-neutron correlation in the Borromean nucleus ^{17}B in which the neutron halo has been observed. But up to now, very limited knowledge has been obtained for ^{16}B beyond the ground state [3].

We have carried out new measurements of ^{16}B at RIBF (RIKEN Nishina Center) by employing the quasi-free (p,pn) reaction on ^{17}B, followed by kinematically complete measurement. The verterx-tracking liquid hydrogen target MINOS [4] has been used in the present measurement. The charged fragments and decay neutron were detected by SAMURAI spectrometer and the associated neutron detector array NEBULA [5]. The relative energy of ^{16}B is then reconstructed with the invariant-mass method. By detecting prompt gamma rays in coincidence using the in-beam gamma-ray spectrometer DALI [6], identification of the final state of the ^{15}B core was achieved for the first time. The level scheme of ^{16}B and decay patterns have been constructed and compared to modern theoretical calculations.

[1] P. Navratil, et al., Phys. Rev. C 62 (2000) 054311.
[2] I. Tanihata, et al., Prog. Part. Nucl. Phys. 68 (2013) 215.
[3] J. L. Lecouey, et al., Phys. Lett. B 672 (2009) 6
[4] A. Obertelli, et al., Eur. Phys. J. A 50 (2014) 8.
[5] Kobayashi et al., Nucl. Inst. Meth. B 317 (2013) 294.
[6] S.Takeuchi, et al., Nucl. Instr. Meth. Phys. Res., Sect. A 763 (2014) 596.

I324 The Latest Results of Beta-delayed Neutron and Beta-delayed Gamma Measurements with MTAS

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ORNL

The Modular Total Absorption Spectrometer (MTAS) is a 1 ton NaI based 4 pi total absorption spectrometer detector. MTAS is capable of measuring the beta feeding intensities from the decay of neutron rich nuclei, including ground state to ground state decays, decays to excited states, and decays to neutron unbound states. Recent results include measurments of beta-decays of dominant fission products including beta-delayed neutron emitters. The latest results will be presented including an overview of the analysis techniques used to extract the various decay channels.

R325 Strong One-neutron Emission from Two-neutron Unbound States in Beta Decays of Neutron-rich Ga Isotopes

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2. Oak Ridge National Laboratory
3. Instituto de Fisica Corpuscular
4. RIKEN, Nishina Center
5. BRIKEN Collaboration

Beta-delayed one-neutron and two-neutron branching ratios (P1n and P2n) have been measured in the decay of neutron-rich Ga isotopes A = 84 to 87 at the RI-beam Factory at the RIKEN Nishina Center using a high-efficiency array of ^{3}He neutron counters (BRIKEN). Two-neutron emission was observed in the decay of ^{84,85,87}Ga for the first time. P1n values are also obtained with higher precision than previous measurements. The observation of the large P1n values compared to the P2n values in the Ga isotopes are interpreted as a signature of dominating one neutron emission from the two-neutron unbound excited states in Ge daughters. Hauser Feshbach statistical model calculations reproduces our experimental results, which demonstrate the relevance and importance of a statistical description of neutron emission for the prediction of the decay properties of multi-neutron emitters and that it must be included in the r-process modeling.

The author will present the result on behalf of BRIKEN Collaboration.

R326 Beta-neutron-gamma Spectroscopy of Beta-delayed Neutron Emitters Around Doubly-magic ^{78}Ni

Krzysztof Rykaczewski
Oak Ridge National Laboratory
Krzysztof P. Rykaczewski for the BRIKEN collaboration

The spectroscopic studies focused on beta-neutron-gamma spectroscopy of βn-emitters nuclei around ^{78}Ni was performed at RIKEN by BRIKEN collaboration. Nuclei around ^{78}Ni were created with the 345 MeV/u ^{238}U beam reaching nearly 70 part*nanoAmp and separated by means of BigRIPS spectrometer. The spectroscopy of radiation emitted by the beta-delayed neutron precursors was performed using BRIKEN array [1] modified to achieve larger gamma efficiency. The fragment implantation and decay array were consisting of four smaller double-sided Si-strip counters of WASABI [2] and was complemented by a position sensitive YSO scintillator developed at the UTK. The BigRIPS setting was maximized for the transmission of ^{82}Cu. Isotopes between ^{61}V-^{69}V up to ^{95}Br-^{97}Br were produced and identified. The total rate of identified ^{78}Ni ions was around 65,000, with about 35,000 ions implanted for decay study. This measurement clearly identified for the first time the gamma transitions following neutron emission to the excited states in ^{77}Cu, compare [3]. It points to the discovery potential and selectivity of experiments adding efficient neutron detection to the beta-gamma counting.

Together with new beta-delayed (multi) neutron branching ratios and half-lives, new data beta-n-gamma correlations help us to analyze the nuclear structure evolution at and beyond N = 50 shell closure.

[1] A. Tarifeno-Saldivia et al., J. Instrum. 12, 04006, 2017.
[2] S. Nishimura S., Prog. Theor. Exp. Phys. 3C006, 2012.
[3] E. Sahin et al., Phys. Rev. Lett. 118, 242502, 2017.

R327 A New Measurement System for Study of Nuclide Decay Schemes

Xuesong Li, Quanlin Shi, Tao Bai, Feng Xie, Yihua Dai, Jianzhong Ni, Gongshuo Yu, Wengang Jiang, Jianfeng Liang
Northwest institute of nuclear technology

Considering all kind of rays and their cascading relations in nuclide decay process, a new measurement system for study of nuclide decay schemes was designed in this paper. There were three units in this system: absolute activity measurement unit, $\alpha/\beta/$X coincidence measurement unit and X/γ coincidence measurement unit. According to the first unit which can work in two-three coincidence and β-γ coincidence modes, we can get the absolute activity and the emitting probabilities of the main γ rays. According to the second unit, we can get the α,β, X cascading relations and emitting probabilities. According to the third unit, we can get X/γ, γ/γ cascading relations. The above measurement can provide rich data for nuclide decay schemes.

R328 New Results from the Modular Total Absorption Spectrometer

Marek Karny
University of Warsaw

Total Absorption Spectrometers (TAS) capable of detecting most of the gamma transitions occurring during the decay process are perfect tools for establishing a true beta feeding pattern. TAS-aided experiments are particularly important for neutron-rich nuclei, where the beta strength is highly distributed over many final states. Knowledge of the correct beta feeding pattern is important for the analysis of the structure of parent and daughter activities as well as for the determination of the decay heat released by fission products during nuclear fuel cycle. The Modular Total Absorption Spectrometer (MTAS) was operating at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory. It consists of 19 NaI(Tl) hexagonal shape modules, with a full energy gamma ray efficiency exceeding 81% around 500 keV [1].

In this talk we will present the unpublished results on the evaluation of ^{87}Br, ^{87}Kr, ^{135}Te,^{136}I and ^{139}Cs. Impact on the decay heat calculation of the presented results together with the previously published data [2] will be discussed. Performance of the new segmented Central detector and its foreseen impact on the data evaluation will also be discussed.

[1] M. Karny et al, , Nucl. Instr. Meth. A836 (2016) 83-90
[2] A.Fijałkowska et al. Phys.Rev.Lett. 119 (2017) 052503

I329 Improving reactor antineutrino spectra and decay heat calculations with Total Absorption Gamma-ray Spectroscopy

Alejandro Algora, Muriel Fallot, Victor Guadilla
The Valecia-Nantes TAGS collaboration

Total absorption spectroscopy is the only technique available that provides beta decay data (feedings) free from the Pandemonium systematic error [1-3]. In this contribution we will present results from the research work performed by our collaboration employing this technique, which is relevant for reactor applications. The measurements, we are presenting here, have been performed at the University of Jyväskylä IGISOL IV Facility [4] using trap-assisted spectroscopy that provided radioactive beams of very high isotopic purity [5].

In this presentation we will emphasize mainly on new results coming from an experiment performed in 2014 and recently analysed [6,7]. This data have been shown to be of relevance in calculations of the decay heat and in calculations of the antineutrino spectrum from reactors. The impact of the new measurements in nuclear structure and astrophysics will be also discussed. Some of the studied cases are beta delayed neutron emitters, for which gamma competition above the neutron separation energy has been also determined. The impact of all the measurements performed until now by our collaboration in reactor applications will be also discussed [8-13] and future perspectives presented.

R330 How Accurate Are the Half-lives of Long-lived Isotopes?

Dorothea Schumann
Paul Scherrer Institute

Isotopes with comparable long half-lives are of special interest for nuclear scientists due to a number of reasons: Depending on the kind and intensity of the emitted radiation, long-lived isotopes can have a high radiological impact during operation of nuclear installations (reactors, accelerators). Correspondingly high attention has to be paid in case of intermediate and/or final disposal of the corresponding nuclear waste. The so-called "Branching points" in the nuclear s-process as well as several other long-lived isotopes are of high relevance for the understanding of the element synthesis in the Early Solar System and the development of our Universe. Some of these isotopes are used for nuclear dating of environmental samples in order to reconstruct climate changes, material circulations and other processes relevant in Geoscience and climate research.

The exact knowledge of the nuclear properties, in particular half-lives and branching ratios as well as cross sections of a variety of nuclear reactions (mainly neutron- and charged-particle-induced) of these isotopes is a precondition for the evaluation of any of these impact factors. But how accurate are the presently known data on the decay properties of such isotopes? In the contribution, with the help of some prominent examples, we will display the current state-of-the-art, especially pointing on some of the recent new measurements and the consequently performed re-evaluations. We are going to discuss the impact of inaccurate or wrong data, detect obvious lacks of data, explain the reasons and give some ideas for future improvement.

R331 Nuclear Mass Table in Deformed Relativistic Continuum Hartree-Bogoliubov Theory

Eunjin In, Seung-woo Hong
Sungkyunkwan University

In exotic nuclei, particularly those close to neutron drip lines, pairing correlations between the bound states and the continuum should be treated carefully. We have studied the properties of even-even nuclei in a Relativistic Continuum Hartree-Bogoliubov (DRHB) theory for deformed nuclei which provides a proper treatment of paring correlations. With the relativistic density functional PC-PK1, the deformed RHB equations are solved in a Woods-Saxon basis. We study the deformation effect on the position of the neutron drip line. Also, halo properties in deformed nuclei are investigated through the analysis of two neutron separation energies, neutron Fermi energy, quadrupole deformation parameters, root-mean-square radii, and nucleon density distributions. We will show our recent results from the DRHB theory with PC-PK1, including halo effects. Also, a nuclear mass table under construction will be presented.

R332 Recent Nuclear Shell Model Study and Its Possible Role in Nuclear Data

Cenxi Yuan
Sun Yat-sen University

Atomic nuclei are complicated quantum many-body system. To understand the underlying physics in nuclei, the essential knowledge is the understanding of nuclear force and nuclear model. Unfortunately, none of these two are exactly understood up to now. On the other hand, there are huge amount of nuclear data, including masses, levels, EM properties, alpha and beta decay half-lives. It is worth to know the uncertainties between these observed data and calculations within one model and one nuclear force. In this talk, I will introduce the nuclear shell model and its applications on light, medium, and heavy nuclei from Be to Np. Some preliminary results on the uncertainties of nuclear models will be presented. Systematic investigation on the uncertainty of shell model is helpful for important nuclear data for astrophysics and reactor physics. The universe is a huge reactor, while many small reactors around the world provide electric power for us. Nuclear data, including masses, levels, decay energies, neutron separation energies, and ratio of delay neutron decay, are important for understand the nuclear synthesis in universe and physics in reactor.

R333 Analysis of the Reactor Antineutrino Spectrum Anomaly with Fuel Burnup

Le Yang, Xu-bo Ma
North China Electric Power University

Almost all of the neutrinos in the reactor are derived from the fission of four nuclides of ^{235}U, ^{238} U, ^{239}Pu, and ^{241}Pu. Recently, the reactor antineutrino spectrum were measured at Daya Bay reactor neutrino experiment and RENO, more than 10% discrepancies of the spectrum in the energy region 5-7 MeV were found. In this study, the antineutrino spectrum is evaluated using ab initial method with ENDF/B-VII.1 nuclear database and RMC (Reactor Monte Carlo code) simulation. The results are compared with the Daya Bay experiment measurement results, and it is shown that no bump is found with this method and the results of middle of cycle are great well with the experiment than that of begin of cycle and end of cycle.

I334 Decay Heat and Anti-neutrino Energy Spectra in Fission Products

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Fission process of heavy nuclei ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu generates energy in power reactors. Part of this energy generation originates from the decay energy of fission products. Major advances in understanding of the emission following the decay of fission products most abundant during the nuclear fuel cycle have been made following the measurements performed with the Modular Total Absorption Spectrometer (MTAS) [1-4]. MTAS array of about 1 ton total weight constructed from 19 NaI(Tl) modules packed in a close geometry has been commissioned and used for the decay studies of nearly 80 fission products at ORNL [5,6]. Analysis of MTAS spectra resulted in the modification of beta-gamma decay schemes and following beta-strength distribution. It was found that the average beta energy per decay is reduced and the average gamma energy is increased. The increase of respective decay heat up to 3% was deduced after the analysis of about ten studied most abundant fission products [2]. The respective anti-neutrino spectra associated with analyzed decays were found to have substantially reduced high energy part, with respect to the ENSDF/ENDF references. It resulted in a redefinition of the reference antineutrino flux in power reactors, and following reduction of the anti-neutrino anomaly [7,8] to about 97(2)% level. The status of the analysis of MTAS data and their impact on the decay heat and anti-neutrino spectra properties will be presented.

[1] B. C. Rasco et al., Phys. Rev. Lett. 117, 092501, 2016.
[2] A. Fijałkowska et al., Phys. Rev. Lett. 2017.
[3] B. C. Rasco et al., Phys. Rev. C 95, 054328, 2017.
[4] M. Woliska-Cichocka et al., Eur. Phys. Jour. Web of Conf., 146, 10005, 2017.
[5] B. C. Rasco et al., Nucl. Instr. Meth. Phys. Res. A 788, 137, 2015.
[6] M. Karny et al., Nucl. Instr. Meth. Phys. Res. A 836, 83, 2016.
[7] G. Mention et al., Phys. Rev. D 83, 073006, 2011.
[8] P. Huber, Phys. Rev. C 84, 024617, 2011.

R335 Precise αK and αT Internal Conversion Coefficient Measurement As Test of Internal Conversion Theory: the Case of 39.752(6)-keV E3 Transition in ^{103m}Rh

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During the past decade we have completed eight precise measurements (±2%) of α_K Internal Conversion Coefficients (ICC's) in order to guide theoretical calculations in dealing with the electronic vacancy. In the past the vacancy was either ignored or included, but no reliable discrimination was possible based on the existing data. This ambiguity affected the quality of nuclear data that relied on ICC calculations, and especially impacted those applications where precision was critical. The advent of our precise measurements showed unambiguously that theories including the vacancy were in agreement with measurements, while those ignoring the vacancy disagreed. Here we report α_K (and α_T) measurements done by the γ- to x-ray ratio method for the 39.752(6)-keV E3 transition in ^{103m}Rh, which we populated by both the β- decay of ^{103}Ru and the ε decay of ^{103}Pd. From the ^{103}Ru decay we extracted both αK and αT, while the ^{103}Pd decay provided a relationship between α_K and α_T, which we used as a consistency check. Sources of ^{103}Ru and ^{103}Pd were activated by thermal neutrons and each was measured for several months, from which we extracted $\alpha_K = 141.1(23)$ and $\alpha_T = 1428(13)$. Dirac-Fock calculations that include the effect of the K-shell atomic vacancy yield K $= 135.3(1)$ and $\alpha_T = 1404(1)$ while those that exclude the vacancy yield $\alpha_K = 127.5(1)$ and $\alpha = 1388(2)$. In fact, our results are in disagreement with both types of calculations, albeit less so for the calculations that include the vacancy. However if a tiny 0.04% M4 admixture is included, as allowed by the measurement that assigned the E3 multipolarity for this transition in the first place, good agreement is reestablished with the theory including the vacancy, while the disagreement with the theory ignoring the vacancy persists.

R336 Experimental Study of β Spectra Using Si Detector

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The shape of beta spectra was originally studied during the 1950s, 60s and 70s and is now experiencing a rebirth due to emerging needs. Studies performed so far have been focused mainly on allowed and first forbidden non-unique transitions. However, several applications in nuclear energy industries, nuclear medicine, ionizing radiation metrology and scientific communities of fundamental physics are lacking the precise knowledge of beta spectra with well-established uncertainties.

The LNHB has developed an almost 4π measurement system for beta spectra based on two Si detectors in coincidence. This tight detection geometry allows scattering to be minimized, and in particular the backscattering of the electron, a physical phenomenon which distorts the measured spectrum shape.

In this contribution, the experimental technique and the measured spectra from ^{36}Cl, ^{14}C, ^{99}Tc and ^{151}Sm decays will be discussed, along with the Monte Carlo study using PENELOPE (2014). From the preliminary simulations performed, remaining distortions are still to be expected. The planned methodology to unfold them, in order to extract experimental shape factors, will be discussed in light of these results.

R337 Towards the First Experimental Determination of the ^{93}Mo Half-life

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The molybdenum ^{93}Mo isotope is a long lived electron capture radionuclide produced by neutron activation of molybdenum containing compounds. The half-life of ^{93}Mo was never directly measured and the currently used value is 4000 a with an uncertainty of 20% solely based on systematical trends and general considerations. The presented work is focused on the measurement of the ^{93}Mo half-life by means of high resolution mass spectroscopy measurements to determine the total number of atoms in the sample combined with high energy resolved X-ray spectroscopy utilizing high purity single crystal germanium detectors to measure the absolute activity of the radioactive isotope. ^{93}Mo for this work was produced by irradiating high purity niobium disc with 72 MeV protons at PSI's proton accelerator facility. After the irradiation, ^{93}Mo was extracted and purified by means of extraction chromatography using TBP resin and alumina in order to separate molybdenum from niobium with sufficiently high decontamination factors (10E11). Based on the preliminary results we were able to determine first ever experimentally the half-life of ^{93}Mo. The presentation explains the methodological challenges in chemical separations of both elemental and radiological pure molybdenum as well as key issues caused by interferences in X-ray spectroscopy originating from the ingrowth of ^{93m}Nb as decay daughter of ^{93}Mo. It was observed that the precision of the result is strongly influenced by the available data regarding the decay properties of ^{93}Mo as well as the X-ray emission probabilities of ^{93}Nb.

R338 Study of Finite Nuclei Within A Dirac-Brueckner-Hhartree-Fock

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Starting from the realistic nuclear force, the Dirac-Brueckner-Hartree-Fock (DBHF) approach can provide an effective in-median nuclear interaction which is able to well reproduce the nuclear matter saturation properties. Through the improved local density approximation (ILDA), based on the new DBHF nucleon scalar and vector self-energies obtained by the subtracted T matrix (STM) projection, the Dirac equations of every single particle level in finite nuclei are self-consistently solved. The density, isospin and momentum dependence of scalar and vector potentials are considered to investigate the nuclei structure. With few parameters the binding energies and radius of finite nuclei are described.

S339 Measurements of Gamma-ray Intensities from the Decay of ^{187}W in the Reaction ^{186}W(n,γ)^{187}W

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The International Atomic Energy Agency (IAEA) provides nuclear structure and decay database such as Evaluated Nuclear Structure Data File (ENSDF), which includes half-lives, decay schemes, gamma-ray intensities, etc. These data play an important role for nuclear engineering, nuclear safety, medical sciences, and nuclear sciences. Tungsten and its alloys are used as targets, shielding materials, and nuclear fusion applications. ^{186}W(n,γ)^{187}W is a reaction often used for the activation foil method to measure the neutron flux. The gamma-ray intensities are measured precisely for a quantitative analysis.

Neutrons over a wide range of energies are produced by bombarding a 1.05 cm thick beryllium target with protons delivered by the MC-50 Cyclotron of the Korea Institute of Radiological and Medical Sciences (KIRAMS). Natural tungsten was irradiated by a continuous energy beam of neutrons to produce ^{187}W via ^{186}W(n,γ)^{187}W reaction. ^{186}W has a high neutron capture cross-section. The gamma-rays from the decay of ^{187}W ($T_{1/2}$=24.0h) to ^{187}Re were measured by a High Purity Germanium detector. The gamma-ray emission intensities from the decay of ^{187}W were measured and were compared with previous published data. The measured gamma-ray intensities were found in good agreement with the previous published data except the gamma-ray peak at Eγ = 582 keV.

I340 Thermal Scattering for Neutron Moderator Materials: Integrating Neutron Scattering Experiments with Density Functional Theory Simulations

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Improvements in determination of the thermal scattering law of moderator materials (measuring, calculating, and validating) are important for accurate prediction of neutron thermalization in nuclear systems. In this work a new methodology for producing thermal scattering libraries from the experimental data for polyethylene $(C2H4)_n$ is discussed and expanded to other systems such as Lucite and water. Double differential scattering cross section (DDSCS) experiments were performed at the Spallation Neutron Source of Oak Ridge National Laboratory (SNS ORNL). New scattering kernel evaluations, based on phonon spectrum for $(C2H4)_n$, are created using the NJOY2016 code.

Two different methods were used: direct and indirect geometry neutron scattering at ARCS and SEQUOIA, and VISION instruments, respectively, where the phonon spectrum was derived from the dynamical structure factor S(Q, omega) obtained from the measured DDSCS. In order to compare and validate the newly created library, the experimental setup was simulated using MCNP6.1. Compared with the current ENDF/B-VII.1, the resulting Rensselaer Polytechnic Institute (RPI) $(C2H4)_n$ libraries improved both double differential scattering and total scattering cross sections. A set of criticality benchmarks containing $(C2H4)_n$ from HEU-MET-THERM resulted in an overall improved calculation of Keff , although the libraries should be tested against benchmarks more sensitive to $(C2H4)_n$. The Density Functional Theory (DFT)+oClimax (a package provided by ORNL) method is used and is shown to be most comprehensive method for analysis of moderator materials. The importance of DFT+oClimax method lies in the fact that it can be validated against all data measured at VISION, ARCS and SEQUOIA, and experimental total scattering cross section measurements.

R341 Temperature Dependent Measurement of Thermal Neutron Differential Scattering in Heavy Water

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Heavy water (D2O) is used as the moderator in Pressurized Heavy Water Reactor (PHWR) designs, with about 50 commercial reactors operated in several countries. Accurate nuclear data for heavy water is important for the design and safety considerations of PHWR power and research reactors.

The thermal neutron differential scattering cross section for heavy water has been measured from 23 to 80°C at atmospheric pressure to cover the common moderator conditions of PHWR reactors (65-70°C and 1 atm pressure). The measurement was performed using a triple-axis spectrometer at the National Research Universal reactor located in Chalk River, Canada. The measured results are compared with the D2O data libraries from the Evaluated Nuclear Data Files ENDF/B-VII.1 and ENDF/B-VIII.0. Significant improvements are observed comparing the measured data to the recently released ENDF/B-VIII.0 evaluated data.

Simulations were performed using both MCNP (Monte Carlo N-Particle code) and GEANT4 (GEometry and Tracking toolkit) software, with new data libraries processed from ENDF/B-VIII.0. Comparisons between simulations and the experiments will be presented, and the effects of data library processing on the simulation results will be discussed.

R342 On the Evaluation of the Thermal Neutron Scattering Cross Sections of Uranium Mono-nitride

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Since the Fukushima-Daiichi nuclear power plant complex event in 2011, developing fuels and claddings with accident tolerant characteristics for use in commercial light water reactors becomes a central goal. Therefore, there has been a growing interest in using ceramic fuels other than UO_2 in the next generation light water reactors. The use of uranium mono-nitride (UN) fuel in light water reactors has recently received an increasing interest.

In this work, the thermal neutron scattering law and the inelastic and coherent elastic scattering cross sections of UN are calculated at different temperatures starting from the phonon density of states obtained from first-principles electronic structure calculations. The main aim of this work is to present a detailed investigation and deep understanding of the thermal neutron interactions with UN with natural nitrogen natN ($U^{nat}N$) and with the isotopically fully enriched ^{15}N ($U^{15}N$) as an alternative fuel. In addition to highlighting the main differences between the inelastic thermal neutron scattering cross sections of $U^{nat}N$ and $U^{15}N$, the following topics will be presented and discussed:
i-The multi-phonon process between the thermal neutrons and acoustic and optic phonons in UN.
ii- The atomic mass effect on the behavior of the total inelastic scattering cross section.
iii- The coherent elastic scattering cross section of $U^{nat}N$ and $U^{15}N$.

R343 Generation and Validation of Thermal Neutron Scattering Cross-section for Heavy Water Using Molecular Dynamics Simulations

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Recently, the thermal scattering libraries of ENDF/B-VIII.0 for light and heavy water were released with a new water model (CAB model) proposed by Damian. For the CAB model, the molecular dynamics code GROMACS was used to more accurately describe the realistic motions of water molecules. In this paper, to consider the coherent component we also generated the thermal scattering cross-section of the deuterium and oxygen bound in the heavy water molecules using the GROMACS code and EPSR code. In addition, the frequency spectrum was also calculated using the GROMACS code. Thermal scattering cross sections based on the newly calculated Skööld correction factor and the frequency spectrum were generated by NJOY2016 code. Finally, the performance of the generated thermal scattering cross sections was validated by performing an ICSBEP benchmark simulation using MCNPX code.

R344 High-resolution Time-of-flight Measurements for Light Water at the Spallation Neutron Source (SNS), Oak Ridge National Laboratory

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Series of light water inelastic neutron scattering experiments were made at the Oak Ridge National Laboratory (ORNL), Spallation Neutron Source (SNS) covering temperatures ranging from 293 K to 600 K and pressures of 1 bar and 150 bar. The temperatures and pressures ranges correspond to that of pressurized light water reactors. The inelastic scattering measurements will serve in the analysis and evaluation of light water thermal scattering kernels, also known as $S(\alpha,\beta)$ thermal scattering law (TSL), in a consistent fashion given the amount and quality of the measured data.

Light water thermal scattering evaluations available in existing nuclear data libraries has certain limitations and pitfalls. The present paper introduces the state of the art of the light water thermal scattering cross section data for light water not only for room temperature but as well as for reactor operating temperatures, i.e. $\sim$ 550 - 600 K. During the past few years there has been a renewed interest in reinvestigating the existing models and utilize the recent experimental data or performing molecular dynamics simulations. It should be pointed out that no single TSL evaluation is based fully on experimental data and one has to rely on models.

The full paper will be devoted to the detailed description of the experimental setup, measurement and data correction methodology to obtain the double differential data, frequency spectrum and the derived total scattering cross sections. The analysis of the experimental data would help us in validating the existing approach based on old experimental data or based on molecular dynamic simulations using classical water models, knowledge of which is very important to generate TSL libraries at reactor operating conditions.

I345 Experimental Validation of the Temperature Behavior of the ENDF/B-VIII.0 Thermal Scattering Kernel for Light Water

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The Neutron Physics Department at Centro Atomico Bariloche developed new models for the interaction of thermal neutrons with water [1] which have been validated against experimental data, including new thermal scattering experiments [2], and were adopted for the release of ENDF/B-VIII.0 [3]. Although the older models are in general good for most applications, some discrepancies had appeared in the case of heavy water, and this motivated new measurements [4] that validated the new model.

In the case of light water, the new model predicts a reduction of the total cross section around 25 meV when the temperature is increased from room temperature. This reduction is not predicted by the existing models, and potentially affects the calculation of temperature reactivity coefficients in nuclear reactors. This reduction has been traced to a shift in the frequency spectrum of liquid water.

The only experimental data previously available is one experiment performed at the Demokritos reactor in the '60s [5] at 200 °C and 20 °C, which validates the new model when ratios are computed. In order to verify this effect at a lower temperature range, a transmission experiment was carried out at the VESUVIO spectrometer in the ISIS facility in the UK in June 2018, measuring the total neutron cross section in the range from 10 °C to 80 °C. In this contribution we will present this new experimental data, and its comparison with the models.

[1] Marquez Damian, JI, J. R. Granada, and D. C. Malaspina. Ann. of Nucl. Ener. 65 (2014): 280-289.
[2] Dawidowski, J., LA Rodríguez Palomino, JI Márquez Damián, J. J. Blostein, and G. J. Cuello. Ann. of Nucl. Ener. 90 (2016): 247-255.
[3] Brown, D, et al. Nuclear Data Sheets 148 (2018): 1-142.
[4] Marquez Damian, JI, J. R. Granada, D. Baxter, S. Parnell, and D. Evans. In V UCANS Meeting, Il Nuovo Cimento-C. 2015.
[5] M. Dritsa, A. Kostikas. Report EANDC (OR) 63 "L" (1967)

R346 Thermal Neutron Scattering Data for Liquid Molten Salt LiF-BeF_2

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The molten salt LiF-BeF_2 are widely used in Thorium Molten Salt Reactor Nuclear Energy System (TMSR) and therefore the thermal neutron scattering data for liquid molten salt LiF-BeF_2 are needed to be considered in the reactor design and safety analysis of TMSR. In this work, ab initio molecular dynamics methods are used to calculate the phonon density of states of liquid molten salt LiF-BeF_2 (2:1) in different temperatures. Egelstaff and Schofield "effective width model" are used to obtain the diffusion-type spectrum of the density of states and the corresponding partial s (α, β). Thermal neutron scattering data for liquid molten salt LiF-BeF_2 are given and the influence of this data in neutron Transport calculation are analysed.

R347 **Analysis of the Time-of-flight Scattering Cross Section Data for Light Water Measured at the SEQUOIA Spectrometer, Spallation Neutron Source (SNS)**

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Thermal scattering cross section data for light water available in the major nuclear data libraries observes major differences especially at reactor operating temperatures, for instance 550 K - 600 K. During the past few years there has been a renewed interest in reviewing the existing thermal scattering models and generating more accurate and reliable thermal scattering cross sections using existing experimental data and in some cases based on Molecular Dynamics (MD) simulations. Due to lack of available experimental thermal scattering data at high temperatures, there is a need for performing new time-of-flight experiments, to have a better understanding of the scattering process, which is presently difficult to model using classical MD simulations at high temperatures. New experimental data would facilitate the development of a model free thermal scattering evaluation, thus avoiding approximations utilized presently while generating cross sections based on the LEAPR module of the NJOY code.

Lack of experimental thermal scattering data for light water at high temperatures lead to a new measurement campaign within the INSIDER project at the Institut de radioprotection et de sûreté nucléaire (IRSN). Double differential scattering cross section for light water have been measured at the SEQUOIA spectrometer based at the Spallation Neutron Source (SNS), Oak Ridge National Laboratory, United States. Several experiments have been carried out at different temperatures and pressures corresponding to liquid light water. Measurements at five different incident neutron energies (8, 60, 160, 280 and 800 meV) have been carried out to help exploring different regions of the frequency spectrum of light water. The full paper will present the results obtained after the experimental data correction of the double differential data and the derived frequency spectrum of light water. The analysis of the experimental data would provide one with better confidence, the behavior of thermal scattering cross sections for light water at high temperatures, knowledge of which is very important for the design of novel reactors as well as existing pressurized water reactors.

R348 Measurement of the Double-differential Neutron Cross Section of U in UO_2 From Room Temperature to Hot Full Power Conditions

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Over the last 40 years, new methodologies for measuring and evaluating double differential cross sections have emerged. Better-measured and evaluated data are produced nowadays. However, the working group WPEC/SG-42 of the NEA data bank has pointed out the lack of experimental data for the major (uranium and plutonium) and minor (americium and neptunium) actinides.

The NAUSICAA project of the Institute Laue-Langevin (Grenoble, France) aims to measure double differential cross sections and produce S(a,b) tables for evaluated neutron data libraries. A multi-year program on actinides is needed in order to provide a complete set of reliable data over a broad temperature range for UOX and MOX fuels, from room temperature to Hot Full Power (HFP) conditions. HFP conditions correspond to an average temperature of 900 K that accounts for the temperature profile in the fuel. The temperature profile is nearly parabolic with a minimum close to 600 K (periphery of the pellet) and a maximum of about 1000 K (centre of the pellet).

The first step of the multi-year program consisted of measuring the double-differential neutron cross sections for UOX fuel up to HFP conditions at the ILL facilities. The sample had a cylindrical shape. It was composed of a stack of four UO2 pellets, sealed under vacuum in a glass tube. The experiments were carried out at the IN4 (l=0.85 Å and 1.11 Å) and IN6 (l = 5.12 Å) spectrometers at 294 K, 600 K and 900 K.

Experimental data will be compared with Monte-Carlo calculations based on earlier models relying on experimental phonon spectrum and with results provided by more advanced ab initio simulations. We also aim to convert the dynamic structure factors S(q,w), derived from the data sets, to S(a,b) tables. For UOX fuel, a special attention will be paid to the work of Pang [1] that reports valuable experimental and calculated phonon density of states for UO_2 at 295 K and 1200 K

[1] J.W.L. Pang et al., Phonon density of states and anharmonicity of UO_2, Phys. Rev. B 89, 115132 (2014)

S349 Effect of FLiBe Thermal Neutron Scattering on Reactivity of Molten Salt Reactor

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Thermal neutron scattering data has an important influence on the calculation and design of reactor with a thermal spectrum. However, as the only liquid fuel in the Gen-IV reactor candidates, the research on the thermal neutron scattering effect of coolant and somewhat moderator FLiBe has not been carried out sufficiently either experimentally or theoretically. The effect of FLiBe thermal neutron scattering on reactivity of TMSR-LF (thorium molten salt reactor - liquid fuel), TMSR-SF (thorium molten salt reactor - solid fuel) and MSRE (molten salt reactor experiment) were investigated and compared. Results show that the effect of FLiBe thermal neutron scattering on reactivity depends to some extent on the fuel-graphite volume ratio of core. Calculations indicate that FLiBe thermal neutron scattering of MSRE (with the hardest spectrum) has the minimum effect of 41 pcm on reactivity, and FLiBe thermal neutron scattering of TMSR-SF (with the softest spectrum) has the maximum effect of -94 pcm on reactivity, and FLiBe thermal neutron scattering of TMSR-LF has an effect of -61 pcm on reactivity.

S350 Processing and Application of Nuclear Data for Low Temperature Criticality Assessment

Tim Ware, David Hanlon, Tara Hanlon, Richard Hiles, Ray Perry, Simon Richards
Wood

Until recently, codes used for criticality safety assessment have had a lower limit to the temperature range for which calculations can be performed. Where criticality assessment has been required for lower temperatures, indirect methods, including reasoned argument or extrapolation of results, have been required to assess reactivity changes at these temperatures.

The ANSWERS Software Service MONK® version ^{10}B Monte Carlo criticality code, issued in 2017, is capable of performing criticality calculations at any temperature, within the temperature limits of the underlying nuclear data. The temperature range of the BINGO continuous energy nuclear data library used by MONK has been extended below the traditional lower temperature limit of 293.6∼K to include temperatures down to 193∼K. The main data source for this prototype library is JEFF-3.1.2.

This extension required development of the thermal bound scattering data for the key moderator materials on the library. The majority of the bound data in JEFF-3.1.2 was derived from studies by Institut für Kernenergetik und Energiesysteme (IKE). Therefore, for some materials including graphite, the temperature-independent frequency spectra parameters published by IKE were reprocessed by the NJOY LEAPR module to produce S(α,β) tabulations for the extended temperature range. For ^{1}H in H_2O, the IKE continuous frequency spectrum was extrapolated to 273.15∼K (the freezing point of water) which allowed the other parameters to be recalculated for 273.15∼K. LEAPR was again used to regenerate the S(α,β) tabulations. For ^{1}H in CH_2, ^{1}H in ice(Ih) and ^{16}O in ice(Ih), the data published in ENDF/B-VIII.0 was used.

The extended BINGO library was created using the BINGO Pre-Processor code. This utilises NJOY to reconstruct the free gas cross sections and bespoke routines to generate cumulative distributions for the S(α,β) tabulations and equi-probable bins or probability functions for the secondary angle and energy data.

A number of MONK criticality calculations have been performed to assess the effect of the low temperature nuclear data, in particular that of ice, for nuclear fuel transport flask configurations. The results obtained demonstrate good agreement between extrapolation methods and direct calculation as well as a discernible difference in the use of ice and liquid water bound scattering data.

R351 Validated Scattering Kernels for Triphenylmethane at Cryogenic Temperatures

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Cold neutrons are widely used in different fields of research such as the study of the structure and dynamics of solids and liquids, the investigation of magnetic materials, biological systems, polymer science, and a rapidly growing area of industrial applications. In a pulsed neutron source where the pulse width is an important parameter to be consider, hydrogenated materials are often used because of its high energy transfer in each collision. Triphenylmethane is a protonated molecular compound formed by three phenyl groups connected through a central carbon atom. It has already been proposed of being of potential interest as a cold neutron moderator.

Following the research line started in 2015 as part of the IAEA CRP "Advanced Moderator for Intense Cold Neutron Beams in Materials Research" we presented in the ND2016 conference a preliminary kernel for triphenylmethane. We now present a new model for the generation of the scattering kernels of this material, together with transmission experiments of total cross section performed in 2017.

The thermal scattering kernel was generated using the NJOY Nuclear Data Processing system with a model based on calculations performed using the harmonic approximation and forces calculated by density functional theory. Neutron transmission experiments were carried out at the VESUVIO instrument from the ISIS Neutron Source at the Rutherford Appleton Laboratory, U.K, to measure the total neutron cross section over a wide range of incident energy (10^{-3} to 10^{2} eV) at room temperature and different cryogenic temperatures.

The very good agreement found by comparing measurements with our model validates the scattering kernel construction and the cross section library which was produced in ENDF and ACE formats.

R352 Measurement of the Scattering Laws of Irradiated Nuclear Graphite Using Inelastic Neutron Scattering Techniques

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Research studies into the subject of radiation damage and effect in graphite began in the early 1940's as a part of the development of nuclear weapons and nuclear power. Extensive measurements were performed to study changes to the macroscopic thermal and mechanical properties of irradiated graphite. Many of these properties such as thermal expansion coefficient, heat capacity, thermal conductivity, bulk modulus and elastic constants have some level of dependency on the lattice vibrational properties.

In this work, a series of measurements of the scattering laws of different samples of irradiated nuclear graphite were performed at room temperature using the state-of-art Wide Angular-Range Chopper Spectrometer (ARCS) at the neutron spallation source in Oak Ridge National Laboratory. The samples were exposed to different levels of neutron damage (up to $\sim$ 30 dpa) and irradiation temperature1 (300 °C-750 °C). The main differences in the measured scattering laws and corresponding phonon densities of states for samples with different irradiation conditions (damage and/or temperature) will be identified and compared with first-principles calculations.

The irradiation of the specimens was performed at the Oak Ridge National Laboratory (ORNL) and sponsored by Tokai Carbon Co., Ltd. (NFE-09-02345) with the U.S. Department of Energy. A portion of this research at ORNL's High Flux Isotope Reactor and the Spallation Neutron Source was sponsored by the Scientific User Facilities Division, Office of Basic Energy Sciences, US Department of Energy. Oak Ridge National Laboratory is managed by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725 for the U.S. Department of Energy. Travel and time of I. I. Al-Qasir was supported by the University of Sharjah, UAE. This material is based upon work that was conducted by I. I. Al-Qasir while a Visiting Research Fellow at the Shull Wollan Center-the University of Tennessee and Oak Ridge National Laboratory's Joint Institute for Neutron Sciences.

[1] Campbell, A.A., Y. Katoh, M.A. Snead, and K. Takizawa, "Property changes of G347A graphite due to neutron irradiation", Carbon, 109, 860-873. (2016)

S353 Development and verification of the thermal scattering law processing module in nuclear data processing code NECP-Atlas

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Cold neutrons are widely used in different fields of research such as the study of the structure and dynamics of solids and liquids, the investigation of magnetic materials, biological systems, polymer science, and a rapidly growing area of industrial applications. In a pulsed neutron source where the pulse width is an important parameter to be consider, hydrogenated materials are often used because of its high energy transfer in each collision. Triphenylmethane is a protonated molecular compound formed by three phenyl groups connected through a central carbon atom. It has already been proposed of being of potential interest as a cold neutron moderatoIn this paper, method researches on the thermal scattering law data have been implemented. At thermal energies, the cross sections and the angular and energy distributions of scattered neutrons are affected by the chemical binding of the scattering nucleus in solid, liquid, or gas. In this case, the arising of interface effects due to the interaction between thermal neutrons and the scattering system must be considered. The elastic and inelastic scattering include both coherent and incoherent parts. Based on the theory of the thermal neutron scattering law, a new module in nuclear data processing code NECP-Atlas is developed to produce the thermal scattering law data in ENDF-6 format. In this work, the results are compared to the conventional thermal neutron scattering code LEAPR which is a module in NJOY code system. Then, WLUP(WIMS Library Update Project) and ICSBEP(International Criticality Safety Benchmark Evaluation Project) benchmarks are calculated. The numerical results show that the thermal scattering law processing module in NECP-Atlas has comparable accuracy with LEAPR in NJOY.

I354 Update of the IAEA Reference Cross Sections for Charged-particle Monitor Reactions

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Evaluated cross sections of beam-monitor reactions are required for accurate cross-section measurements for the production of radionuclides in accelerators over a very broad energy range. Beam-monitor reactions were defined in a pioneering IAEA project back in 2001. The present work reviews a recent update coordinated by the IAEA of beam-monitor reactions released in 2018. Accurate cross-section data were recommended with corresponding uncertainties over a wide range of targets and projectiles, based on selection of existing measurements and complementary evaluations of the decay data of specific radionuclides. Least-square evaluations including uncertainty quantification using Pade approximations of monitor-reaction cross sections have been undertaken for charged-particle beams of protons, deuterons, ^{3}He- and ^{4}He particles. Recommended beam monitor reaction data with their uncertainties are available at the IAEA-NDS medical portal www-nds.iaea.org/medical/monitor_reactions.html.

I355 Radioisotope Production at the IFMIF-DONES Facility

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The International Fusion Materials Irradiation Facility - Demo Oriented NEutron Source (IFMIF-DONES) is a single-sited novel Research Infrastructure for testing, validation and qualification of the materials to be used in a fusion reactor. Recently, IFMIF-DONES has been declared of interest by ESFRI (European Strategy Forum on Research Infrastructures) and its European host city would be Granada (Spain).

In spite the first and most important application of IFMIF-DONES must be related to fusion technology, the unprecedented neutron flux available could be exploited without modifying the routine operation of DONES. Thus, it is already planned an experimental hall for other applications in which neutrons will be used for different purposes. One of the applications that can help DONES to be more sustainable is the radioisotope production with neutrons. On the other hand, it is also under discussion the possibility to deflect 1/100 pulses of deuterons after the whole acceleration, at an energy of 40 MeV, to a new experimental hall.

We present here the possible production of different radioisotopes with both, deuterons and neutrons, at DONES. Some of the radioisotopes we will discuss are: ^{177}Lu, ^{99}Mo, ^{90}Y, ^{103}Pd, ^{64}Cu and ^{153}Sm. The results show the viability to use DONES for such production in terms of sustains the needs of a small-medium region.

R356 Investigation of Novel Routes for Production of the Medical Radionuclides ^{61}Cu, ^{64}Cu and ^{67}Cu

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Three radionuclides of copper, namely ^{61}Cu($T_{1/2}$ = 3.3 h), ^{64}Cu($T_{1/2}$ = 12.7h) and ^{67}Cu($T_{1/2}$ = 2.58 d), are of considerable medical interest, the first two as non-standard PET radionuclides and the latter as a therapeutic radionuclide. Several methods have been reported for their production. We investigated a few novel routes using three accelerators and a nuclear reactor. Excitation functions of the ^{nat}Ni(α,x)^{60,61,67}Cu and ^{nat}Ni(p,x)^{60,61,64}Cu reactions were measured using the stacked-foil activation technique over the energy ranges up to 45 MeV α-particles and 17 MeV protons, respectively. The experimental data achieved were compared with literature data as well as with nuclear model calculations performed using the code TALYS-1.8.

In α-particle irradiation, $>$ 95% pure ^{61}Cu can be produced using the energy window of E_{α}=20®17 MeV with the impurities level of 5% ^{60}Cu and 0.009% ^{67}Cu. In this energy range, the ^{61}Cu yield would be 116 MBq/μA.h, which is enough for clinical scale production. The excitation function of the ^{64}Ni(p,n)^{64}Cu reaction commonly used in the production of ^{64}Cu was known. However, our new measurements have strengthened the database in the low energy range below 5 MeV. Furthermore, it was shown that the nuclear model calculation cannot reproduce the low-energy part of the excitation function without a proper choice of the input parameters. The fast neutron spectrum of the TRIGA Mark-II reactor at Savar, Dhaka, Bangladesh was characterized via multiple foil activation technique. Integral cross sections of the ^{64}Zn(n,p)^{64}Cu and 67Zn(n,p)^{67}Cu reactions were measured radiochemically and for the fast time by TRIGA reactor neutrons. The results were found to be 28.9±2.0 mb and 0.84±0.07 mb, respectively. These results are slightly lower than those for a pure fission spectrum. It is possible to produce ^{64}Cu in GBq quantities (with ^{67}Cu-impurity $<$0.1%) by irradiating a ^{nat}Zn target for 6 h with fast neutrons of a TRIGA reactor. The simultaneous production of ^{64}Cu and ^{67}Cu for theranostic studies would be possible if irradiations could be done at a high flux reactor.

R357 A New Evaluation of the Nuclear Decay Data of ^{223}Ra

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Since 2013, the radionuclide ^{223}Ra is used in nuclear medicine to prepare radiopharmaceuticals for targeted radiotherapy in bone metastases and bone palliation in prostate cancer of patients from European countries and the USA. ^{223}Ra is a member of the natural radioactive series of Actinium and decays by alpha-particle emission (100%), populating the excited nuclear levels of ^{219}Rn. According to the 2011 nuclear decay data evaluation within the Decay Data Evaluation Project (DDEP), by V.P. Chechev, the half-life of ^{223}Ra is (11.43 ± 0.03) days; the decay scheme is not considered as fully complete, because of the disagreement between the measured and calculated probabilities of some alpha-transitions and incomplete information on several (possible) gamma-ray transitions.

New high quality measurements of ^{223}Ra nuclear decay data were performed and numerous results have been published since 2012 and, consequently, an updated nuclear decay data evaluation was undertaken, according to the DDEP procedures. The new recommended nuclear data have significantly reduced uncertainties, compared with the previous evaluated data. For example, the new recommended half-life value is (11.437 ± 0.003) days (all uncertainties reported correspond to a coverage factor k=1); the new uncertainty is 10 times lower than the uncertainty of the evaluation published in 2011. Similarly, the proposed absolute emission intensity of the 154.2 keV gamma-ray following the decay of ^{223}Ra is now (0.0603 ± 0.0003), compared to the previous value of (0.0584 ± 0.013). Using the results of this new evaluation, the decay energy value (Q) published in the AME2016 atomic mass evaluation was tested using the Q-testing tool in the SAISINUC software (developed by the LNE-LNHB), to allow the consistency of the ^{223}Ra decay scheme to be verified. All the results obtained are presented and discussed in this paper.

R358 A Feasibility Study on the ^{99m}Tc Production with Laser-Compton Scattering Gamma-rays

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This paper describes the potential application of the (γ,n) and (γ, γ') reactions for the production of ^{99m}Tc using laser-Compton scattering (LCS) gamma rays source. These photo-transmutation based methods are regarded as alternative options to the production of ^{99m}Tc in research reactors which will complete their operating lives in the near future. In this study, the LCS gamma rays source is optimized in the multi-MeV region to enhance the effectiveness of the giant dipole resonance (GDR) based ^{100}Mo(γ, n)^{99}Mo reaction and the nuclear resonance fluorescence (NRF) based ^{99}Tc(γ, γ')^{99m}Tc reaction. These methods are particularly suitable in terms of minimizing the secondary nuclear waste as compared to the reactor based method. The results show that the use of these photonuclear reactions seem to be plausible option only if much higher intensity of LCS beam is realized.

S359 Production of Radionuclides with Secondary Neutrons Induced by A 66 MeV Primary Proton Beam

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In this work, a small activation chamber was specially designed to facilitate the irradiation of selected samples with secondary neutrons behind a radionuclide production target in the vertical-beam target station (VBTS) at iThemba LABS. The main aim was to assay the radionuclides formed in the samples, with a special interest in those of medical importance. The experiment was performed simultaneously with a routine radionuclide production run, during which a target was bombarded with a 66 MeV proton beam. Twenty-two different samples, ranging from ^{7}Be to ^{209}Bi, were assayed for their gamma-ray emissions by means of a high-purity germanium (HPGe) detector. Based on these activation data, physical yields were determined for all uniquely identified reaction products.

The experimental yields are compared with corresponding predictions based on neutron fluxes obtained from Monte Carlo simulations with the radiation transport code MNCP 6.1 in conjunction with evaluated cross sections for neutron-induced reactions from the TENDL-2015 and TENDL-2017 nuclear data libraries. Six different physics selections were employed in the Monte Carlo simulations, leading to several sets of predicted results.

Activation products from a total of 104 nuclear reactions/processes have been observed cleanly, several of which are used in medical applications. In some cases the yields are too low for this method to be profitably exploited in a routine radionuclide production facility. In several other cases the specific activities of the radionuclides will be too low for use in medical applications. In a few cases, however, the use of secondary neutrons clearly has potential. Six medically interesting radionuclides have been singled out for further scrutiny, namely ^{46}Sc, ^{59}Fe, ^{103}Ru, ^{141}Ce, ^{161}Tb and ^{203}Hg. Although the production rates are generally low, the produced yields are nevertheless sufficient for some research purposes, such as radiochemical separation studies, the development of methods for radiolabeling of biomolecules, calibration sources for radiation detectors, and preclinical trials.

I360 The High-energy Intra-nuclear Cascade Liège-based Residual (HEIR) Nuclear Data Library

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It is standard practice for nuclear data files to include tabulated data for distinct reaction channels for incident energies up to 20-30 MeV. Above these energies, the assumptions implicit in the definition of individual channels break down and event generators are typically used within codes that simulate nuclear observables in applications. These offer robust simulation of the physics but increase the computational burden. So-called 'high-energy' nuclear data files have been produced, but the well-known libraries are more than a decade old and rely upon models developed many years before their release. This presentation describes a modern library with a high level of production automation that offers regular updates as the models it is based upon are improved.

The most recent versions of the intra-nuclear cascade and de-excitation models available within Geant4 were used to generate tabulated data of residual nuclide production. For the first released library, the INCL++5.3 and ABLA version within Geant v10.3 were used to calculate over 1012 incident protons over 2095 target isotopes with incident energies up to 1 GeV. These were collated into tabulated data in the international-standard ENDF-6 format and processed with PREPRO-2017. The resulting files were provided as group-wise files and were distributed as HEIR-0.1 with the FISPACT-II version 4.0 release.

A second library, HEIR-0.2, has been generated using the new INCL++6.0 and C++ translation of the ABLA07 model available within Geant4 v10.4. Simulations were performed using incident protons, neutrons, deuterons and pions. Comparisons with experimental data will be shown that demonstrate improved agreement with experiment not only between the two versions, but against the other well-known high-energy nuclear data files and models available within Geant4. These include distributions in mass and isotope, as well as incident-energy dependent cumulative and independent cross sections from the EXFOR database.

R361 Study of the Li(d,xn) Reaction for the Development of Accelerator-based Neutron Sources

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Accelerator-based neutron sources induced by deuteron beams are attractive for study of nuclear transmutation of radioactive waste as well as radiation damage for fusion reactor materials. Neutron production data from various materials bombarded by deuterons are required for optimized design of such neutron sources. However, the experimental data, e.g. double-differential neutron production cross section (DDX), are not sufficient. In the present work, therefore, we have carried out a DDX measurement for Li at 200 MeV in the Research Center for Nuclear Physics (RCNP), Osaka University.

The experiment was carried out at the N0 course in RCNP. A deuteron beam accelerated to 200 MeV was transported to the neutron experimental hall and focused on a thin Li target foil (1 mm thick) placed in the beam swinger magnet. Emitted neutrons from the target were detected by two different-size EJ301 liquid organic scintillators (2" in dia$\times$2" thick and 5" in dia$\times$5" thick) located at two distances of 7 m and 20 m, respectively. The neutron DDXs were measured at six angles (0°, 5°, 10°, 15°, 20° and 25°) by moving the target along the beam trajectory in the swinger magnet. The two-gate integration method was adopted to eliminate gamma-ray background. The neutron energy was determined by a conventional time-of-flight method. The neutron detection efficiencies of the detectors were calculated by SCINFUL-QMD code.

We will present the results of the present DDX measurement and compare them with theoretical model calculations with DEURACS and PHITS. In addition, the incident energy dependence of the Li(d,xn) reaction will be discussed using the other data measured at 25, 40, and 100 MeV. This work was funded by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

R362 Generation of Collimated Neutron Beam Using High Intensity Laser Pulses

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Ultra-intensive laser beam can accelerates ions efficiently via Radiation Pressure Acceleration (RPA) mechanism on thin target, and quasi-monoenergetic high-energy neutrons are produced later by collisions between the boosted ions and the converter nuclei. When it is shaped initially in the transverse direction to match the laser intensity profile, the target can be uniformly accelerated for a longer time compared to a usual flat one. Undesirable plasma heating is effectively suppressed. The energy spectrum of accelerated ions in the acceleration region will be improved, and the collimated quasi-monoenergetic ion beams can be obtained. Then, the final neutrons will be also collimated. The 2-D particle-in-cell simulations are employed to study ion acceleration from a thin target irradiated by ultra-intense laser pulse. And nuclear reaction models, such as DWBA method and the exiton model, are used to calculate the nuclear data such as, neutron energy spectrum and the emission angle distribution, for neutron production analysis.

R363 Neutron Production in the Li-7(p,n) Reaction in the Energy Range 17-34 Mev

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Two neutron targets are in operation at the NPI. The cyclotron U120M provides protons in the energy range 20-35 MeV that are directed to thin Li (2 mm) or thick Be (8 mm) targets for the production of quasi monoenergetic and continuous neutron spectra. The experimental data on the neutron production were collected during several irradiation campaigns on the Li target. Time-Of-Flight method was used to measure the number of the peak neutrons in the forward direction, and the number of produced ^{7}Be nuclei was determined with the gamma-spectrometry. The ratio of the forward directed peak neutrons agrees well with the formula introduced by Uwamino (NIM A389 (1997) 463-473). More studies of the angular distribution of the peak neutrons were done by the TOF measurements at angles 0-15 degrees. The available experimental data on the angular distribution were collected and angular systematics covering the energy interval from the NPI energy range up to 80 MeV was created.

R364 Isotope-production Cross Sections of Residual Nuclei in Proton- and Deuteron-induced Reactions on ^{93}Zr at 50 MeV/u

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In recent years, systematic cross section measurement of proton- and deuteron-induced reactions on long-lived fission products (e.g. ^{79}Se, ^{93}Zr, ^{107}Pd, ^{126}Sn, and ^{135}Cs) has been performed to provide fundamental data necessary for nuclear waste transmutation. As for 93Zr, isotope-production cross sections have been measured at the reaction energies of 100 and 200 MeV/u and theoretical model analyses with the intra-nuclear cascade model and evaporation model have been performed so far. Thus, the extension to the low incident energy, where spallation reaction is no more dominant, is currently of interest for systematic study. In the present work, a measurement of isotope-production cross sections for ^{93}Zr has been conducted at the energy of 50 MeV/u by using the inverse kinematics method. The measured cross sections are discussed in terms of the energy dependence. Also, the theoretical models are employed to calculate the cross sections and the reproducibility is investigated in the low energy region.

The measurement of isotope-production cross sections of proton- and deuteron-induced reactions on ^{93}Zr was conducted at RIKEN RIBF using BigRIPS RI Beam separator and ZeroDegree Spectrometer (ZDS). First, a ^{238}U beam accelerated up to 345 MeV/u irradiated a 9Be production target and consequently the secondary beam was generated via the in-flight fission of ^{238}U. Next, the secondary beam was separated and identified by using BigRIPS. Then the secondary beam bombarded a cooled gas hydrogen or deuterium reaction target located at the entrance of ZDS. The fragments produced at the reaction target and their charge-states were also identified event-by-event by using ZDS thanks to its high-resolution capability. The fragments had a wide range of magnetic rigidity because they easily pick up electrons through the beamline materials. Thus, the different seven magnet settings for ZDS were adopted to cover the wide range of magnet rigidity. We present the measured isotope-production cross sections and the comparison with the model calculations using the PHITS code in which the Liege Intra-Nuclear Cascade (INCL) model and the Generalized Evaporation Model (GEM) are implemented.

This work was funded by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

I365 Production Method of Environmental Tracer Cs-132 by Accelerator-based Neutron

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Cesium-137 has been well-known as the most problematic nuclide in a nuclear accident. For instance, in the Fukushima Daiichi nuclear power accident, large amounts of radioactive nuclides were released into the environment. There are three dominant nuclides; ^{137}Cs, ^{134}Cs, and ^{131}I. Among all, ^{137}Cs is the dominant radiation source of the environment in these days because of its long half-life ($T_{1/2}$ = 30 y). Huge effort has devoted to the study on the dynamics of cesium in soil to develop decontamination method or investigate pollution of agricultural crops and so on. In these study, short-time dynamics of cesium in soil is very important. Nevertheless, long half-life radioactive cesium; ^{137}Cs has been using, because no short half-life radioactive cesium is available. Moreover, using unsealed ^{137}Cs source requires careful management to avoid environmental pollution for long time. Although such difficulties are existing, it is clear that further study on cesium dynamics in the environment is important. To enhance these study, we have proposed a new environmental tracer, ^{132}Cs. The dynamics in the environment is completely same as ^{137}Cs, and the gamma-ray energy of ^{137}Cs (662 keV) and ^{132}Cs (668 keV) is very close. Cesium-132 can be produced via the ^{133}Cs(n,2n) reaction by accelerator-based neutron. We have conducted a production experiment of the accelerator-based production method at CYRIC, Tohoku University, Japan. The accelerator-based neutron was generated by the C(d,n) reaction in thick carbon neutron converter by 30-MeV deuteron. A raw material made of Cs_2CO_3 was irradiated by the neutron and produced radioactivity of ^{132}Cs was measured by a HP Ge detector. Then, to demonstrate its feasibility, the simple dynamics in a few spices of soil was investigated by using a NaI(Tl) detector. We found that sufficient radioactivity of ^{132}Cs can be produced by a few μA of deuteron beam, and the dynamics can be clearly measured.

R366 Excitation Functions of ^{3}He- Induced Nuclear Reactions on Natural Copper up to 55 Mev

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Excitation functions for the ^{nat}Cu(^{3}He,x)^{66,67}Ga,^{65}Zn,^{57,58,60}Co nuclear reactions were measured from the respective threshold up to 55 MeV incident energy by using the conventional stacked foil activation technique combined with HPGe γ-ray spectrometry. Measured data were critically compared with the relevant earlier experimental data and also with the evaluated data in the TENDL-2018 library, and show a partial agreement among them. From the measured cross-section data integral production yields were calculated. The measured data are useful for reducing the existing discrepancies in the literature, to improve the nuclear reaction model codes, and to enrich the experimental database towards various applications. The application of the deduced data in the field of beam monitoring and thin layer activation is discussed.

R367 Uncertainty Quantification of Radiation Source Terms for Thorium- and Uranium-based Medical Isotope Production Targets Irradiated by 100 MeV Protons

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In the framework of Phase I of the MYRRHA project implementation, a section of the superconducting linear accelerator continuously delivering up to 5 mA of 100 MeV protons will be constructed. A part of the beam (up to 0.5 mA) will be directed on the ISOL (Isotope Separation On-Line) target station dedicated to medical isotope production and fundamental physics research. A thorium carbide (or alternatively uranium carbide) target is considered, mostly focusing on the production of Ac-225. Beyond the isotopes to be extracted on-line, plenty of other radioactive species will be produced mainly due to primary proton interactions with heavy nuclei of the target material. To evaluate the radiological consequences of both routine operation and accidental radioactivity release, and ultimately to license this target station, an accurate prediction of radiation source terms, including uncertainty quantification, is required.

Nuclear data files for Thorium and Uranium up to 100 MeV have been produced based on elementary proton-nucleus interaction calculations with various physics models. A set of 10 physics models allowed to obtain best estimate values and corresponding energy covariance information for excitation functions describing production of residual nuclei, including fission products. The available proton induced experimental data for the radioactive nuclide production lie within the obtained uncertainty bands.

Uncertainties on nuclide concentrations that determine radiation source terms have been propagated using the Monte Carlo sampling of nuclide yields from calculated energy covariance information. Since there is no feedback from the particle transport calculation, it was possible to evaluate the convergence rate as a function of the number of randomly generated excitation functions for each residual nuclide. It was demonstrated that the minimum number of samples to get the variance-of-the-variance below 1% for all residual nuclides is around 300. The nuclides contributing the most to the source terms of both Thorium- and Uranium-based targets are predicted with uncertainties 15-60% (one standard deviation).

R368 Calculation of Athermal Recombination Corrected Dpa Cross Sections of Materials for Proton, Deuteron and Heavy-ion Irradiations Using the PHITS Code

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The displacement damage calculation method in the Particle and Heavy Ion Transport code System (PHITS) has been developed using the screened Coulomb scattering to evaluate the energy of the target Primary Knock on Atom (PKA) created by the projectile and the "secondary particles" which include all particles created from the sequential nuclear reactions [1]. This method enables us to calculate displacement cross sections of materials for various particle such as proton, deuteron and heavy-ion in the wide energy range. To calculate the number of displaced atoms, the conventional Norgett-Robinson-Torrens (NRT) model has been used. Recently, K. Nordlund et al. provided the athermal recombination corrected (arc) displacement per atom (dpa) function obtained from MD simulations providing more physically realistic descriptions of primary defect creation in materials [2]. Therefore, the arc-dpa will be used for efficient predictions of the usable lifetime of materials in various accelerator facilities.

In this work, to provide the arc-dpa cross sections for proton, deuteron and heavy-ion irradiations, the arc-dpa function related with the defect production efficiency was implemented in the radiation damage model in PHITS. The parameters included in the arc-dpa function were taken from the paper by K. Nordlund et al. [2] for Fe, Cu, Ni, Pd, Pt and W. For the displacement cross sections of Cu and W under proton irradiations with the energy range between 100 MeV and 3 GeV, the NRT-dpa cross sections are larger than the arc-dpa cross sections by a factor of 3 and the arc-dpa cross sections give good agreements with the experimental data [3].

We will present the arc-dpa cross sections of the selected materials (Fe, Cu, Ni, Pd, Pt and W) for proton, deuteron and heavy-ion (C and Ca) irradiations in the high-energy region between 100 MeV/u and 3 GeV/u and compare them with the NRT-dpa cross sections for discussions about particle and material dependencies of the athermal recombination correction.

[1] Y. Iwamoto et al., Nucl. Instrum. Methods B 269 (2011) 353.
[2] K. Nordlund et al., Nature Communications 9 (2018) 1084.
[3] Y. Iwamoto et al., J. Nucl. Mater. 508 (2018) 195.

R369 **Study of $^{18}O(p,\alpha)^{15}N$ Reaction at Low Energies**

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In this research, an attempt was made to improve our knowledge of the cross section for the $^{18}O(p,\alpha)^{15}N$ reaction so as to be utilized in Nuclear Reaction Analysis (NRA) and other low-energy nuclear physics applications, such as nuclear astrophysics. The differential cross section values of the $^{18}O(p,\alpha)^{15}N$ reaction were measured for $E_{d,lab}$ = 600-2100 keV, at three scattering angles, namely at 135°, 150° and 165° with an uncertainty of 5%. The cross section values were collected with an energy step of ∼ 10 keV. Although, the detailed measurements were carried out with an energy step of ∼ 2 keV around the resonances. The results were compared with the previous studies and the similarities and differences were discussed. Also an attempt was made to evaluate this cross-section in the framework of R-matrix calculation.

Solid ^{18}O-enriched target was prepared by anodizing silicon substrate, a technique which is known to produce stable target with highly homogenous thickness. Proton beam from the 3 MeV Van de Graaff accelerator of NSTRI was employed with an energy resolution of ± 1 keV. Proton beam with a spot size of 1×1mm^2 was irradiated on the target with the current of 40 nA, resulting in a small dead time less than 10% during the data acquisition. Numerical values of the measured data will soon be available in the EXFOR/IBANDL data base.

[1] Amsel, Georges, and David Samuel. "Microanalysis of the stable isotopes of oxygen by means of nuclear reactions." Analytical Chemistry 39.14 (1967): 1689-1698.
[2] Sellin, David L., Henry W. Newson, and Edward G. Bilpuch. "High resolution investigation of resonances in ^{19}F." Annals of Physics 51.3 (1969): 461-475.
[3] Caciolli, A., et al. "Preparation and characterisation of isotopically enriched Ta2O5 targets for nuclear astrophysics studies." The European Physical Journal A 48.10 (2012): 144.
[4] Rafi-kheiri, Hossein, Omidreza Kakuee, and Mohammad Lamehi-Rachti. "Differential cross section measurement of ^{16}O(d, p0,1) reactions at energies and angles relevant to NRA." Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 371 (2016): 46-49.

S370 **Evaluation of Photonuclear Reaction Data for Medical Applications**

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Certain nuclides can be used for the production of medical radioisotopes via photonuclear reactions. These include Ca-48, Cu-65, Mo-100, Er-166 and Re-187, each producing Ca-47, Cu-64, Mo-99, Er-165 and Re-186. In this study the photonuclear cross sections of these nuclides were evaluated based on the existing experimental data. The optical model parameters, level density parameter, GDR parameters and pre-equilibrium parameters were adjusted up to 20% of their default values, with some up to 30%, to fit to the experimental data. Most procedures involved in the nuclear data evaluations were automatically carried out using the specially developed tuning tool. To accelerate the tuning procedure, the MPI technique was used for running the multiple codes simultaneously.

I371 Impact of the ENDF/B-VIII.0 Library on Modeling Nuclear Tools for Oil Exploration

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In the oilfield, exploration of the subsurface is essential to answer questions regarding the location, quantity, type, and producibility of hydrocarbons. Well logging provides measurements of the characteristics of rock formations and the fluids in their pore spaces to help identify and evaluate interesting reservoirs. Downhole nuclear measurements focus on formation properties such as natural radioactivity, formation density and hydrogen content, as well as the identification of the elemental and mineralogical composition of the rock through spectroscopy.

Accurate nuclear modeling is a fundamental part of nuclear well logging tool development, from concept through design to response characterization. At the concept stage, modeling is used to explore novel tool geometries, materials, and measurements. Few if any experiments are available to benchmark the modeling, so the predictions must be reliable to avoid expensive design. During development, modeling enables rapid determination of the optimal balance between physics, mechanical, and electrical constraints without extensive experimentation. The mechanical constraints can be severe: logging-while-drilling (LWD) tools must operate at temperatures and pressures that may exceed 175 °C and 2000 atmospheres, survive repeated shocks of 100 g or more, yet deliver accurate and reliable measurements. Lastly, tool response characterization requires good modeling to complement experimental data and to expand the database to include situations, which are difficult or impossible to reproduce in the lab.

Underlying the accuracy of nuclear modeling is a good knowledge of nuclear cross sections of the elements found in tool, borehole and subsurface formations. The recent focus on replacing tools based on radioisotopic sources with those based on d-t neutron generators opens many opportunities for new measurements but highlights the deficiencies of current cross sections. For example, in neutron-induced inelastic and capture gamma-ray spectroscopy, major obstacles come from a lack of or inaccuracies in the cross sections of essential materials.

In this presentation, we will examine the impact of the new ENDF/B-VIII.0 library on the modeling of nuclear logging tools. We will show examples of the benchmarking of modeling results against experimental data obtained during tool characterization, discuss the discrepancies encountered, and describe the differences with the previous library version.

R372 Total Neutron Cross-section Extracted from Transmission Experiments with Liquid Oxygen Using Neutron Energies from 18 to 34 MeV

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Fast neutron generators driven by isochronous cyclotron U-120M developed at Nuclear Physics Institute are used for various neutron cross-section measurements in recent years. In this case specifically the target station with 2 mm thin lithium was used to produce pulsed beams of fast quasi-monoenegretic neutrons in ^{7}Li(p,n) reaction. Time-of-Flight technique was used to determine exact neutron energy spectra. The transmission measurements on liquid oxygen were conducted for several kinetic energies between 18 and 34 MeV and the total cross-sections for the reaction ^{nat}O(n,tot) were derived.

R373 Neutron Production Double-differential Cross Sections on Carbon Bombarded by 800 MeV/u ^{28}Si

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Heavy ion beams are generated and used for many purposes including studies of nuclear structures and reactions, and medical therapy. A heavy-ion facility RAON is under construction in Korea to provide radioactive ion beams, which will be generated by using both In-flight Fragment (IF) method and Isotope Separation On-Line (ISOL) method. Nuclear data due to the heavy ion beams are needed in the analysis of experimental data and safety of the facilities, etc. For the development of shielding design for safety, it is important to measure secondary neutrons from heavy-ion reactions and compare the data with simulation results. In the Monte Carlo simulations related to heavy ions, one of the physics models most often used is the quantum molecular dynamics (QMD). For the verification of various physics models, such as QMD, experimental data of heavy-ion reactions are needed.

Double-differential cross sections from a carbon target bombarded with 800 MeV/u silicon ion beam were measured at HIMAC facility in Japan. Neutron spectra were measured at 6 different angles (15°, 30°, 45°, 60°, 75°, and 90°) by the time-of-flight technique using NE213 liquid scintillators. The experimental results were compared with the simulation results obtained by the PHITS. The PHITS code deals with heavy-ion reactions by means of JQMD (JAERI QMD) model. The simulation results were found in good agreement with our experimental data of the secondary neutrons.

R374 The Activation of ^{nat}Zr by Quasi-monoenergetic Neutrons Below 34 MeV.

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Good knowledge of the cross section for neutron-induced reactions on Zr becomes of importance due to the use of zirconium as a structural material in reactors, applicability in neutron dosimetry and for theoretical models testing. Thin Zr foils (0.25 mm thickness, 99.9% purity, Goodfelow product) were irradiated in the quasi-monoenergetic p-Li neutron field. For the production of the neutron fields, the proton beams from NPI energy-variable cyclotron U120M at proton energies 20.33, 22.44, 24.69, 27.64, 30.06, 32.31 and 35.1 MeV. ^{7}Li (2 mm) target with carbon stopper were used. The reaction 7Li(n,p) produces the high-energy quasi-monoenergetic neutrons with the tail to lower energies. The flux density and neutron spectra were evaluated by MCNPX code and validated with sets of measurements including neutron Time-Of-Flight and Proton Recoil Telescope and additional activation monitors (Au). The pneumatic post enabled the investigation of short living isotopes. The foil activity determination was performed by the nuclear gamma-spectrometry method employing two HPGe detectors. The reaction rates for ^{89m,89,95,97}Zr, ^{87m,87,88,90m,91m,92,93,94,95}Y and ^{87m,91,92}Sr were obtained and cross-sections were extracted. The preliminary results are discussed.

R375 Cross Section Determination for TAD Materials in Quasi Mono-energetic Neutron Spectrum from P(li) Reaction

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The threshold activation detectors are of great importance for determination of neutron's energy and flux density. For different sources and set ups it is necessary to choose the right combination of materials which cover the estimated spectra. Several different materials were irradiated in the quasi-monoenergetic neutron field with peak energy of neutrons 28.2 MeV in CANAM facility. Neutrons were produced in p + Li reaction in thin target and the foils were situated in proton beam axis and in close geometry to the Li target. Integral number of protons was established from accelerator telemetry and lithium target activation measurement after experiment. During experiment one long irradiation was done for following foils: Al, Au, Bi, Co, Cu, Fe, In, Mn, Pb, Ta, V, Y and four short irradiations for those foils: Cu, Fe, In, Ta, V, W, Y. The foils were irradiated as sandwich sorted by cross section where the materials with higher cross section were placed in back of sandwich. The short irradiations were done due to need to measure short living reaction products. Neutrons produced in the p + Li reaction have quasi mono-energetic spectrum which provide the suitable basis for cross section determination. Experimental results were calculated for (n,xn), (n,γ), (n,p) and (n,α) reactions via the dosimetry foils activation method including gamma-ray spectroscopy method. Several important spectroscopic corrections have to be applied for higher accuracy of obtained results, including neutron background suppression. Experimental data will be used for design alloy which consists from different threshold materials and can be used for evaluation of different neutron fields. Besides, the obtained cross section will be added into the EXFOR database.

I376 Single Plane Compton Imaging for Radionuclide and Prompt Gamma-ray Imaging

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The contribution reports on first attempts to prove the concept of Single Plane Compton Imaging (SPCI), which was recently proposed in [1]. SPCI combines electronic collimation as known from conventional Compton cameras with a much simpler detector design: Multiple scintillator pixels are arranged alongside in a single detection plane. Imaging information is encoded in a set of 'conditional' spectra meaning energy deposition distributions in single pixels obliged with the condition of a coincident detection in another (adjacent) pixel. The activity distribution is iteratively reconstructed from the measured projections (the bin contents of the conditional spectra) by using the Maximum Likelihood Expectation Maximization (MLEM) algorithm.

This concept has been approached experimentally with three distinct setups addressing the application fields of radionuclide imaging in nuclear medicine, and of prompt-gamma based range verification in radiooncology with proton beams. The first setup consists of two Directional Gamma-Ray Detectors [2], each consisting of two monolithic $CeBr_3$ scintillators of 2"×1" and 2"×2", arranged facing each other in close geometry. Those were exposed to prompt gamma radiation produced by a 90 MeV proton beam in a beam-stopping polymethyl acrylate (PMMA) target. The third setup, aiming to be applied in radionuclide imaging, is a combination of a 4×4 pixel array of about $7 \times 7 \times 20$ mm^3 GAGG scintillator pixels read out with a Philips STEK module comprising 44 digital silicon photomultiplier dies. Data were taken with radioactive point sources arranged in few-cm distance from the scintillator pixels. Though data analyses are not yet finished, the effects enabling imaging are clearly visible. Preliminary plots exemplify the applicability of SPCI in both applications. The experimental activities have been closely accompanied with appropriate imaging methods and modeling using the Geant4 toolkit.

[1]G. Pausch et al., 'A Novel Scheme of Compton Imaging for Nuclear Medicine,' in IEEE Nuclear Science Symposium, Medical Imaging Conference and Room-Temperature Semiconductor Detector Workshop (NSS/MIC/RTSD), Strasbourg, 2016.
[2]A. Gueorguiev et al., "A novel method to determine the directionality of radiation sources with two detectors based on coincidence measurements," in IEEE Nuclear Science Symposuim & Medical Imaging Conference, Knoxville, 2010.

R377

Improvements of the Nuclear Reaction Modelling and First Radiobiological Studies in the FLUKA Monte Carlo Code for Hadron Therapy

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This work envisages to improve and develop the nuclear reaction and fragmentation models embedded in the FLUKA Monte Carlo code, for medical purposes. FLUKA is exploited for clinical studies at the Heidelberg Ion Beam Therapy (HIT) and Marburg Ion-Beam Therapy (MIT) centers in Germany, and at the National Centre of Oncological Hadrontherapy (CNAO) in Italy. It is used to generate the basic input data for the treatment planning systems (TPS), and to validate the dose calculations performed with commercial TPSs.

Angular and energy distributions of the fragments originated from the irradiation of materials of interest for medical applications (e.g. C, O, Ti, Au) with carbon ion beams have been investigated. Comparison of FLUKA simulations with experiments enables the identification of the factors in the FLUKA nuclear reaction and fragmentation models that need further refinements. Considerable improvements in the prediction of the angular yields have been achieved, especially concerning secondary protons, lithium and boron ions.

Measurements of the production cross sections of ^{10}C, ^{11}C, ^{15}O generated from carbon ion beams in graphite and oxygen were performed at MIT. The results were compared with FLUKA simulations and used to improve the accuracy of FLUKA. These radioisotopes activity, measurable with positron emission tomography, are used at CNAO for in-vivo range verification during the treatments, and FLUKA is used as reference for the measured activity distributions.

Radiobiological studies are performed interfacing FLUKA to the BIophysical ANalysis of Cell death and chromosome Aberration model (BIANCA), developed in Pavia. In BIANCA cell deaths are directly linked to chromosome aberrations. This research allows simulation of cell survival curves and relative biological effectiveness for different energies and particle types (e.g. protons, helium and carbon ions) in FLUKA. Complementary information to that provided by other radiobiological models can be obtained, such as the probability of chromosome aberrations, which are indicators of normal tissue damage.

This research focuses on the FLUKA accuracy improvement, especially regarding the prediction of the physical and biological properties of the secondary radiation produced during hadron therapy treatments. A general overview of the developments recently achieved will be provided.

R378 Production Yields of β^+ Emitters for Range Verification in Proton Therapy

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In protontherapy, there is an intensive research program focused on in-vivo range verification. In-vivo PET range verification relies on the comparison of the measured and estimated activities from β^+ emitters induced by the proton beam on the most abundant elements in the human body, right after (long-lived β^+ emitters ^{11}C, ^{13}N and ^{15}O) or during (short-lived β^+ emitters ^{29}P, ^{12}N, ^{38m}K and ^{10}C) the irradiation. The accuracy of the estimated distribution depends on the accuracy of the corresponding Monte Carlo simulations, which depends on the underlying cross section data available. However, a revision of the experimental data available in EXFOR indicates that the reaction cross sections of interest have not been measured in the full energy range (up to 230 MeV) and that there are sizeable discrepancies between the different data sets. Indeed, several studies confirm the need for more accurate measurements, especially in the case of the short-lived β^+ emitters, for which there are no data above 55 MeV.

In this context, an ambitious experimental program has been launched for expanding and improving the knowledge of the production yields of the reactions resulting in the mentioned long- and short-lived β^+ emitters. For long-lived isotopes, a new method has been developed combining a multi-foil technique with the measurement of the induced activity with a PET scanner. This has successfully been tested below 18 MeV at CNA (Spain) and will be used at a clinical beam during 2019 to obtain data up to 230 MeV. The method, however, is not suitable for measuring short-lived positron emitters, since the decay is produced before one can place the films in the PET scanner. Therefore, a set-up combining a stack of targets sandwiched between converter/degrader foils with an array of $LaBr_3$ detectors is being designed. The technique is being tested at CNA below 18 MeV and will be tested at higher energies at KVI-CART. In both cases, for short- and long-lived positron emitters, it is crucial the availability of the new IAEA evaluated monitor reactions, in particular the reaction ^{nat}Cu(p,x)^{63}Zn which is used for normalization purposes.

R379 Study of Dose Rate in the Brain Model Based on the Neutron Beam of SUT-MNSR

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Boron neutron capture therapy (BNCT) is tumor-cell targeted radiotherapy that has significant superiority over conventional radiotherapies. Since Japanese scientists treated a patient with head and neck cancer with BNCT in1960s, so far, some clinical trials used by BNCT have been finished by reactor source. The most neutron beams used for BNCT are from the reactors with high power, the Miniature Neutron Source Reactor(MNSR) with 30kW was designed and biult by China institute of Atomic Energy in 1984, new design MNSR with BNCT beam for Suranaree University of Technology(SUT) is being designed and built. According to SUT-MNSR physics design, SUT-MNSR will have the epithermal neutron beam for BNCT treatment. The dose rate distribution in the body should be estimated before SUT-MNSR is used for BNCT clinical trials (Brain tumor). This paper introduces the simulation for SUT-MNSR neutron beams by Monte Carlo N-Particle Transport Code (MCNP), the establishment of human brain model and physics dose rate distribution in brain tumor. The calculating results at the epithermal neutron beam exit are that the epithermal neutron flux rate at the exit is 1.39×10^{9}n$\cdot$cm$^{-2}\cdot$n^{-1}, the ratio of Gamma dose rate to epithermal neutron flux rate is 3.74×10^{-14}Gy$\cdot$cm$^{2}\cdot$n^{-1}, the ratio of epithermal neutron flux rate to thermal neutron is 17.8, the data meets the request for BNCT treatment. The brain model is established according to the different element in the skin, skull and tissue, the distribution of neutron dose and Gamma dose in the brain model were calculated.

S380 Multiphysics Modelling of Dose Delivery in Targeted Alpha Therapy

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Targeted Alpha Therapy (TAT) is an encouraging option for cancer treatment due to high linear energy transfer and short range of α particles, resulting in a highly-localized dose. However, characterization is challenging for both of the alpha-immunoconjugate (AIC) delivery process and the radiation transport process, due to the complex in vivo vascular system and the microscopic level of particle interactions. To better understand the AIC target delivery process and its toxicity effects to endothelial cells, biokinetic and microdosimetry models were developed at Canadian Nuclear Laboratories. The biokinetic model uses computational fluid dynamics to study the AIC delivery in blood flow through a two-dimensional vasculature embedded in a tumour or normal cell. The microdosimetry model based on Monte Carlo simulation evaluates the alpha particle transport and energy deposition. The results of the transient AIC delivery and dose absorption to endothelial cells will be presented, along with discussion of efforts to couple the biokinetic and microdosimetry models into a general framework. The goal of this work is to improve the modelling capability of AIC delivery in blood vessels, in order to support the preclinical study of TAT.

S381 **Proton-induced Prompt Gamma-ray Yield of Carbon for Range Verification in Hadron Therapy**

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With particle therapy, more and more patients around the world are benefiting from precise dose deposition in the tumor. Due to the characteristic depth dose distribution, however, hadron therapy is particularly susceptible to range inaccuracies. Particle range verification is the subject of current research, but not yet a clinical standard. To circumvent this problem, safety margins are currently being defined around the tumor volume, which nullify the potential precision of particle compared to conventional photon therapy.

The use of the prompt gamma radiation resulting from the deceleration of hadrons in tissue for range verification is a promising approach here. At present, various methods exist (for example, prompt gamma-ray imaging, prompt gamma-ray spectroscopy, prompt gamma-ray timing, prompt gamma-ray peak integration), which attempt to obtain information regarding the range from the temporal and/or spatial distribution of these high-energy photons. However, all methods are based directly or indirectly on the results of particle transport calculations. But their results show significant discrepancies compared to the experimental data. Photon production cross sections are particularly important for range verification with prompt gamma radiation, although there is hardly any experimental data for the clinically relevant isotopes to check and optimize the underlying models.

At the University Proton Therapy Dresden, the prompt emission spectrum of homogeneous graphite targets of different thickness was determined by irradiation with 90, 150 and 226 MeV protons. The detector response of the $CeBr_3$ scintillation detectors (placed below 55 degree, 90 degree and 125 degree with respect to the beam axis) was determined by Geant 4 simulations and verified by measurements with radioactive emitters. The emission spectrum was then obtained by unfolding the detector response using two different deconvolution algorithms (gold deconvolution and spectrum stripping). Scattered protons, which were detected in a YAP/BGO-Phoswich detector below 35 degree, were used to determine the incident proton fluence. The yields thus obtained are in good agreement with the available experimental data.

I382 Experiments with Neutron Induced Neutron Emission from U-235 Pu-239 and Graphite

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A neutron induced neutron emission experiment was conducted as the Los Alamos Neutron Science Center (LANSCE) facility at Los Alamos National Laboratory (LANL). In this experiment, a sample was placed in a well collimated neutron beam and was surrounded by and array of 28 fast neutron detectors (EJ-309). The experiment was performed with a neutron flight path of 21.5 m from the source to the sample, and 1 m from the sample to the detectors. The neutron emission from the sample was measured as a function of neutron time of flight covering an incident energy range from 0. - 20 MeV. The samples included U-235, Pu-239, graphite, and a blank that matched the encapsulation of the sample. The measured samples were constantly cycled in and out of the neutron beam.

This type of experiment measures neutron emission from all reactions occurring in the sample such as fission and elastic and inelastic scattering. Similar to the methodology previously developed at RPI [1], the measurements were compared with detailed simulations of the experiment using different cross section evaluations for the sample. The observed differences can be attributed to the evaluated neutron cross section and angular distributions. The graphite sample was used as a reference to validate both the experiment and simulation methodology and showed good agreement between experiments and simulations. A review of the experimental setup, analysis methods, and some of the results will be presented.

R383 New ^{209}Bi Photodisintegration Data and Physical Criteria of Data Reliability

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Data for partial photoneutron reactions (γ,1n), (γ,2n), and (γ,3n) cross sections obtained for many nuclei using the method of neutron multiplicity sorting at Livermore (USA) and Saclay (France) were analyzed using the experimental-theoretical method for evaluation and the physical criteria. The experimental neutron yield cross-section was decomposed into the partial reaction cross sections using the transitional neutron multiplicity functions calculated within the framework of the Combined Model of Photonuclear Reactions. Experimental data do not satisfy the criteria of reliability and differ noticeably from the evaluated data. For ^{181}Ta, ^{196}Au and ^{209}Bi evaluated data are consistent with the experimental data obtained using bremsstrahlung beams and activation method.

To investigate the problem of data reliability in detail, (γ,1n), (γ,2n), (γ,3n), and (γ,4n) cross sections evaluated for ^{209}Bi were compared with the new experimental data obtained using quasi-monochromatic laser Compton-scattering (LCS) γ-ray beams and the novel technique of direct neutron-multiplicity sorting with a flat-efficiency detector. Photoneutron cross-section measurements were performed for ^{209}Bi(γ, in) reactions with i = 1-4 using LCS γ-ray beams at the NewSUBARU synchrotron radiation facility. A flat response neutron detector with the detection efficiency of 36.5 $\pm$ 1.6 % was developed. The new experimental F_i^{exp} data are in good agreement with F_i^{th}, assuring the reliability of the new data. The work is supported by the Research Contracts (ROM-20476, RUS-20501, JPN-20564) of the IAEA Coordinated Research Project No F41032.

R384 Isomer Ratios for Products of Photonuclear Reactions on Rh

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The use of high-energy gamma-quanta as projectiles in nuclear reactions has some significant advantages for studying the structure of the nuclei and nuclear reactions. Indeed, gamma-quanta do not introduce a large angular momentum and do not cause an additional contribution to the excitation energy of the compound nucleus due to the absence of the binding energy of the projectile. In addition, precise nondiscrete control of the incident energy of gamma quanta is possible. Very limited experimental data for photonuclear reactions in the energy range (30-100) MeV for testing new and available theoretical models were the main motivation for this work.

Experimental measurements and calculations of isomer ratios for the products of photonuclear reactions on rhodium with escape of several particles were performed with application of bremsstrahlung with 74.9 MeV endpoint energy. Metallic rhodium targets to study the reaction ^{103}Rh (γ,4n) ^{99m,g}Rh were irradiated. The LU-40 linear electron accelerator was used as the source of bremsstrahlung radiation. The method of measuring the induced radioactivity was used and the HPGe spectrometer with the GC 2019 detector was applied for counting of gamma spectra. The energy resolution of the electron beam was about 1%, and the average current was within (3.8 - 5.3) μA. For the nuclear reaction ^{103}Rh(γ, 4n)^{99m,g}Rh the isomer ratio equals 1.60 $\pm$ 0.19. For theoretical calculations of the isomer ratio for this reaction the TALYS code was selected and the obtained experimental value of the isomer ratio is in good agreement with theoretical estimate.

R385 Evaporation Residue Cross Section Measurements for the ^{35,37}Cl + ^{181}Ta Reactions

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Heavy ion fusion reactions are particularly important as the most successful mechanisms for the synthesis of super heavy elements (SHEs). SHE up to Z = 118 have been synthesized in the lab. SHE are ideally evaporation residues (ER). The formation probability of a compound nucleus (CN) and its survival against fission decay are two important aspects in SHE research. The intricacies of the fusion process and the microscopic stabilization of the CN or ER against fission are not fully known till date. Though shell closure is speculated to enhance the survival probability of the fused system, experimental data are rather scarce, particularly for the neutron shell closure at N = 126. In this back ground, we have carried out ER measurements using ^{35,37}Cl and ^{181}Ta targets to explore the role of shell stabilization at high excitation energies.

ER cross sections have been measured for the ^{35,37}Cl + ^{181}Ta reactions in the energy range 169.7-235.9 MeV (for ^{35}Cl beam) and 170.3-236.6 MeV (for ^{37}Cl beam) using HYbrid Recoil Mass Analyzer facility of Inter University Accelerator Centre, New Delhi. Obtained cross sections were compared with the results of theoretical studies using dinuclear system model and statistical model calculations. The experimental total ER cross sections are well reproduced by the model calculations except at the higher excitation energies. Fusion probability of ^{216}Th compound nucleus with N = 126 and ^{218}Th compound nucleus with N = 128 was estimated.

S386 Neutron TOF Experiments for Transmission and Capture of Neutrons on ^{103}Rh in the Resonance Region

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Transmission measurements have been performed at the time-of-flight facility GELINA to determine neutron resonance parameters for ^{103}Rh. The measurements have been carried out at a 10 m transmission station at a moderated neutron beam using a Li-glass scintillator with the accelerator operating at 800 Hz and 50 Hz. This report provides the experimental details required to deliver the data to the EXFOR data library which is maintained by the Nuclear Data Section of the IAEA and the Nuclear Energy Agency of the OECD. The experimental conditions and data reduction procedures are described. In addition, the full covariance information based on the AGS concept is given such that nuclear reaction model parameters together with their covariances can be derived in a least squares adjustment to the data.

S387 Double-differential Cross Section Measurement with Low Threshold Detector for Proton Production Induced by Several Tens of MeV Protons

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Double-differential cross sections (DDXs) for charged particle production in energetic proton-nucleus reactions are required to estimate spatial distributions of energy deposition and radiation damage in devices used for accelerator driven system and particle radiation therapy. Since the estimation is performed using model calculation, it is necessary that nuclear reaction models have high predictive power for DDXs. Two-stage model, which consists of the intra-nuclear cascade (INC) model and the generalized evaporation model (GEM), generally well describes proton production for intermediate energy proton-nucleus reactions, except for low energy proton production from a heavy target. The emission of low energy proton after INC stage is calculated by GEM as evaporation from an excited nucleus with considering Coulomb barrier. To improve GEM, new series of experimental data covering low energy region down to 2 MeV for various targets and angles are required because systematic data are not available in this energy region due to threshold energy of conventional detector with DE-E particle identification. To obtain the data, we develop a low threshold detector consisting of Bragg curve counter (BCC) and two built-in solid-state detectors (SSDs). The experiment was performed at cyclotron facility of National Institute of Radiological Sciences for 70-MeV incident protons on natC, ^{27}Al, ^{nat}Cu, ^{197}Au targets. DDXs for secondary particle production were measured at 15, 60, and 120 degrees in the laboratory system with the low threshold detector and a counter telescope consisting of the SSD and the BGO scintillator. The threshold energy of 1.3 MeV was obtained for proton production DDXs because of the thin entrance window and self particle identification capability of the BCC. The calculated proton spectra using our INC model, INC-ELF, plus GEM and nuclear data library of JENDL-4.0/HE are compared with present DDXs and show good agreement except for the ^{197}Au target.

S388 Measurement of Gamma Ray from Inelastic Neutron Scattering for ^{56}Fe

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In nuclear reactors,neutron inelastic scattering is an important energy loss mechanism that affects reactor calculations and radiation shielding.Iron is an important material in reactor,but there are obverious divergence for inelastic scattering cross section and related gamma production sections.So the precise measurements are urgent for satisfing the demanding of new nuclear reactor(fast reactor),ADS and nuclear apparatus. We builded the Array of HPGe detectors,electronics and acquisition system.The shielding and collimator had been established.Experiments had been carried out on CIAE high voltage multiplier,CIAE 2×1.7 MV accelerator and CSNS Back-n white neutron source.We studied the prompt gamma ray method and give out the gamma-ray production cross-sections from inelastic neutron scattering for ^{56}Fe.The measurement error is less than 10%. The item aim to establish the experiment method by using iron target. After measuring methods are proved to be feasible,we can measure other crucial nuclide in reactor fuels.

I389 Measurements of (n,2n) Spectrum-averaged Cross Sections in the Thermal-neutron Induced Fission of U-235: Fixing the High Energy Tail of the PFNS

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A deeper understanding of nuclear fission is of great importance to nu-clear physics applications. The prompt fission neutron spectra (PFNS) plays an important role in many nuclear applications. The nuclear science community continues to face the situation that existing measured PFNS, model calculations and evaluations are often discrep-ant [1]. Different models as well as evaluations yield predictions that differ significantly [1], especially at outgoing neutron energies below 500 keV or above 8 MeV. The high-energy region above 8 MeV is relevant for neutron dosimetry applications and estimations of radiation damage. Given the importance of ^{235}U fission neutrons for energy applications the in-stigation of further experimental and theoretical studies was highly recom-mended; [1]. The IAEA requested recently new measurements of high threshold, e.g., (n,2n) reactions, in the ^{235}U(n_{th},f) PFNS to uniquely define the PFNS high-energy behavior [1]. PFNS are difficult to measure above 8 MeV due to very low neutron yields, therefore, also the measured and evaluated spectrum-averaged cross section data (SACS) are discrepant or nonexistent above 8-10 MeV. In particular, integral measurements are needed and SACS measurements of high-threshold reactions are strongly encouraged in the ^{235}U(n_{th},f) and ^{252}Cf(sf) neutron fields.

An irradiation of the primary ^{235}U foil at the ILL thermal-neutron high-flux reactor (PF1b channel) was undertaken for the ^{235}U(n_{th},f) PFNS production and SACS measurements in a fission-foil sandwich geometry. SACS for several well-validated dosimetry reactions were measured by gamma spectrometry: ^{89}Y(n,2n), ^{169}Tm(n,2n), ^{127}I(n,2n), ^{55}Mn(n,2n), and ^{93}Nb(n,2n)^{92m}Nb using ^{197}Au(n,γ), ^{54}Fe(n,α), reactions on titanium, and ^{58}Ni(n,p) as flux monitors. ^{56}Fe(n,2n), ^{54}Fe(n,2n) and Fe-54(n,p) were also measured, the latter to assess the additional contribution to the ^{55}Mn(n,2n). Additionally, the ^{27}Al(n,2n) reaction with a neutron threshold at 13.55 MeV was measured by AMS. Measured cross sections are compared to results obtained from the convolution of the evaluated PFNS and well-validated dosimetry evaluations to validate the evaluated PFNS.

[1] R. Capote et al, Nucl. Data Sheets 131 (2016) 1-106

R390 Neutron Production from Thick LiF, C, Si, Ni, Mo, and Ta Targets Bombarded by 13.4-MeV Deuterons

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Neutron production from deuteron-induced reactions has been proposed as a candidate of accelerator-based neutron source for various applications such as transmutation of radioactive waste and production of medical radioisotopes. For the design of such neutron sources, comprehensive knowledge of deuteron-induced reactions is essential. So far, experimental data of thick target neutron yields (TTNYs) have been obtained at deuteron energies below 10 MeV and theoretical model analyses have been performed in Kyushu University. On the other hand, M. Drosg et al. have focused on neutron production with triton irradiation and recently measured triton-induced TTNYs (t-TTNYs) from some target materials by 20.22-MeV triton irradiation. To compare deuteron-induced TTNYs (d-TTNYs) with t-TTNYs at the same incident energy per nucleon and the same target materials, we have conducted a new measurement of d-TTNYs at the incident energy of 13.4 MeV, or 6.7 MeV/nucleon, and analyzed them with theoretical models.

The experiment was performed with 8-MV Tandem accelerator at Center for Accelerator and Beam Applied Science (CABAS), Kyushu University. The deuteron beam accelerated to 13.4 MeV was irradiated on the targets (LiF, C, Si, Ni, Mo, and Ta) with enough thickness to stop deuterons (2mm for C, and 1mm for the others). Emitted neutrons were detected by an EJ301 organic liquid scintillator (5.08 cm by 5.08 cm in diameter and length) placed at 2.4 m from the target position. The measured angles were 0, 3.5, 15, and 30 degrees for C, 0, 15, and 30 for LiF, and 0 degree for the other targets, respectively. Neutron spectra were obtained from the acquired data of light output signals by using the unfolding technique.

Total neutron yields were derived by integrating TTNYs over the neutron energies more than 2 MeV. It was found that neutron production by deuteron depends more strongly on the atomic number of target nuclei than that by triton. In addition, theoretical model analyses with PHITS and DEURACS codes are also presented. This work was funded by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

R391 Isomeric Cross Section Study of Neutron Induced Reactions on Ge Isotopes

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Studies of neutron induced reactions are of considerable interest, not only for their importance to fundamental research in Nuclear Physics, but also for practical applications such as fusion reactor technology. Concerning Ge, besides its importance as semi-conducting material, (n,2n) reactions on even-even Ge isotopes present high cross sections of hundreds of millibarns, thus increasing considerably the number of neutrons in neutron fields. In addition, Ge is expected to exhibit structure change and possible shape transition, having isotopes within the region of neutron number N = 40 and furthermore, some of the residual nuclei following (n,2n) and (n,α) reactions on Ge isotopes, are produced in an isomeric state. The experimental determination of isomeric cross sections is of fundamental interest for studying the spin distribution of level density in the compound nucleus. Therefore, more experimental data are needed both for reliable practical applications as well as for testing theoretical calculations and improving the systematic development of model parameters.

In this respect, cross sections for the ^{70,76}Ge(n,2n) and ^{72,74}Ge(n,α) reactions have been measured at the 5.5 MV tandem T11/25 Accelerator Laboratory of NCSR "Demokritos", using the activation technique. Monoenergetic neutron beams have been produced in the $\sim$ 15-20 MeV energy region, by means of the ^{3}H(d,n)^{4}He reaction. The maximum flux has been determined to be of the order of 10^5-10^6n/cm^{2}s, while the flux variation of the neutron beam was monitored by using a BF3 detector. The cross section has been deduced with respect to the ^{27}Al(n,α)^{24}Na, ^{197}Au(n,2n)^{196}Au and ^{93}Nb(n,2n)^{92m}Nb reference reactions. After the end of the irradiations, the activity induced by the neutron beams at the targets and reference foils, has been measured by HPGe detectors. Statistical model calculations using the EMPIRE code and taking into account pre-equilibrium emission, were performed on the data measured in this work as well as on data reported in literature.

R392 Recent Results and Error Propagation of the Neutron Induced Reaction Cross Section for the Nuclear Data Applications

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The neutron induced reaction cross-sections are vital for various current and modern reactor applications like Accelerator Driven Subcritical systems, International Experimental Thermonuclear Reactor and Nuclear Data. We have made an attempt to understand the nature of the cross-section data for reactor fuel materials (^{238}U, ^{232}Th) and structural materials (Sn, Tb, W, Gd) within the neutron energies 5-20 MeV. In addition to this, we have also measured the production cross-sections for the most demanding medical isotope ^{99m}Mo using the ^{100}Mo(n,2n)^{99m}Mo reaction for the fast neutrons energies 10-22 MeV . The experiments were carried out at the 14UD BARC-TIFR Pelletron accelerator utilizing the activation and off-line γ-ray measurement technique. The quasi-monoenergetic neutrons of desired energies were generated using the ^{7}Li(p, n) reaction. The nuclear model codes like, TALYS-1.9, ALICE-2014 and EMPIRE-3.2.3 were used for the theoretical calculations. In each of the experiments, the neutron flux was measured using a suitable monitor reaction. The target samples were counted using the similar detector geometry in each experiment. Therefore, large correlation comes among the measured cross-sections at different neutron energies. The use of various neutron monitor reactions may also lead to the large uncertainties. Therefore, to calculate the optimum uncertainty in each measured data the error propagation method was utilized. The uncertainties together with the correlation coefficients were calculated for each case and were found to be within the range of 10-20%. The recent work emphasis the vitality of the nuclear reaction cross-section data for the reactor based applications.

S393 Simulation of Nondestructive Measurement of ^{88}Kr Fission Yield Based on Gamma Ray

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In this paper, experimental conditions for the gamma-ray nondestructive measurement of yields of ^{88}Kr in thermal neutron induced fission of ^{239}Pu are simulated, and the feasible measurement scheme was recommended. Firstly, gamma-ray emission probabilities of each fission product in ^{239}Pu fission are calculated by the self-developed program. Then, the gamma-ray spectra of HPGe detector with the relative efficiency 60% were calculated by Geant4 program in direct mode and absorber mode. The results indicates that it's difficult to determine the yields of ^{88}Kr precisely in direct mode because of high counting rate, large dead time and high low-energy background. But after adding the absorber, the total counting rate of the detector and the counting rate of low-energy gamma ray decreased significantly which meets the measuring conditions of the detector very well and the measurement data is reliable. The latest literature shows that the uncertainty of high-energy gamma ray of ^{88}Kr is less than 2%, so it is feasible to use absorption mode to accurately measure the fission yield of ^{88}Kr with high-energy gamma ray.

S394 The cross-section measurement of the ^{6}Li(n,t) reaction based on the silicon carbide detector at Back-n white neutron source

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Back-n white neutron source at China Spallation Neutron Source (CSNS) was put into operation in 2018, providing a good platform for measuring cross sections of neutron induced light charged particle (lcp) emission (n,lcp) reactions. Currently, a silicon detector array and △E-E telescopes are used to detect and identify the reaction product particles at Back-n. Nevertheless, silicon detector suffers from the effect of irradiation damage and needs to be away from the beam center. Thus, the detectors cover a small spatial solid angle and it takes a long time to measure the reaction cross section during experiments. Taking advantage of a good radiation hardness, Silicon Carbide (SiC) detectors are suitable for cross-section measurements of (n, lcp) reactions at 0^0 angle. In this work, a SiC detector was placed in the beam for the cross-section measurement of ^{6}Li(n, t) reaction. This experiment has been completed and data analysis is going on.

S395 Measurement of the $^{16}O(n,\alpha)^{13}C$ Reaction Cross-section Using A Double Frisch Grid Ionisation Chamber.

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The role of the $^{16}O(n,\alpha)^{13}C$ reaction cross-section is pivotal for a diversity of applications, ranging from nuclear technologies to nuclear astrophysics. On the one hand, as pointed out by the CIELO Collaboration, discrepancies present in the measured and evaluated cross-section data affect in particular the prediction of the effective multiplication factor (keff) and of helium production for current and innovative reactors. On the other hand, measuring the $^{16}O(n,\alpha)^{13}C$ reaction is a valuable indirect method to acquire information of its inverse reaction, the $^{13}C(\alpha,n)^{16}O$, which is the main source of neutrons to feed the nucleosynthesis chain of the slow neutron capture process in light Asymptotic Giant Branch stars ($M/M_{\odot} \leq 4$). As direct measurements are extremely challenging to perform, precious information on the reaction rate can be inferred by measuring the inverse reaction, which is crucial to correctly model the nucleosynthesis processes and to predict the abundances of heavy elements ($A < 204$) produced in AGB stars.

An experimental method has been developed using an ionisation chamber in which the working gas - a mixture of Kr(95%)+CO_2(5%) - acts as the sample itself. To this purpose, a Double Frisch Grid Ionization Chamber was designed and has been built at Helmholtz-Zentrum Dresden-Rossendorf, and the $^{16}O(n,\alpha)^{13}C$ cross-section measurement has been performed at the neutron time-of-flight facility (n_TOF) of CERN in November 2018. Thanks to the wide neutron energy spectrum provided by the facility, together with the excellent neutron energy resolution, the results could give access to important information such as the reaction cross-section and the level parameters of the compound nucleus ^{17}O. The outcome of the measurement will be presented, focusing on the performance of the detector and electronics in the high-energy region of the neutron spectrum.

I396 Recent Progress of Neutron Reaction Data Measurement at CIAE

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In this report, the nuclear data measurement activities at China Institute of Atomic Energy(CIAE) in recent years are presented. The secondary neutron emission DX and DDX measurement, the integral experiment for nuclear data benchmarking, the excitation function measurement, the neutron induced fission yields measurement and the gamma production yields measurement carried out in recent years are introduced. Furthermore, the progress of some new facilities and proposed plans (e.g. A Gamma ray Total Absorption Facility (GTAF) for (n,γ) reaction cross section measurement, A ^{3}He detector array for (n,2n) reaction cross section measurement, the back streaming white neutron beam for nuclear data measurement at China Spallation Neutron Source (CSNS) are also presented.

R397 Towards Formation of Iaea Database for All Metallic Properties Useful in Radionuclides Production: Effect of Varied Titanium Densities on Excitation Functions.

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The production optimization of medical radionuclides for various applications requires careful analysis of all production parameters. The importance and delicacy of such radionuclides in nuclear medicine cannot be overemphasized. During cross section calculations, scientists sometimes find more than one reported literature value of a certain parameter, each leading to a different effect on the overall cross sections. In the present work, we considered the effect of slight variations of density values of titanium reported the literature on the experimental cross sections. Several reported density values (4.50, 4.506, 4.507 and 4.54 g/cm^3) were found in the literature, but only the lowest and highest values (4.50 and 4.54 g/cm^3) were considered. The said densities were used to calculate the cross sections of Ti(α, x)^{51}Cr,^{46}Sc radionuclides. The corresponding trends of the excitation functions of ^{51}Cr and ^{46}Sc were thus analyzed for the selected density values. The calculated cross sections from the different density values have been analyzed and compared graphically to show the level of variations, as well as comparison with theoretical TALYS code calculated cross sections. Following the observed slight variation effect of the various density values, we recommend that IAEA could update its database with recommended density values for all metals.

R398 Light-nuclei Sub-barrier Nuclear Fusion and Screening Effect

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Light-nuclei fusion reactions occurred in sub-Coulomb barrier energy region, playing an important role in fusion energy utilization, astrophysical application and nuclear weapons designs, their reaction cross sections and the environmental effects should be experimentally measured precisely. The 'abnormal' screening effect on fusion-reaction rate in metallic environment under a sub-barrier energy region has been reported by several laboratories [1-3], but the screening mechanism is not fully understood yet.

As a systematic research work, we have performed: a). The d-D reactions occurred in more than 30 kinds of hosts in 2-20 keV region; b). The p/d-$^{7/6}$Li reactions occurred in solid/liquid Li/LiNO$_3$ and LiF targets in 25-100 keV region; c). The p/d-^{9}Be reactions in metallic Be target in 18-100 keV region. The experiments were performed at a low-energy high-current ion beam generator at Research Center for Electron Photon Science of Tohoku University.

The results [4-7] show:
a). Most metallic environments provide 'abnormal' screening energies;
b). Phase (solid/liquid) of hosts affects on the reaction rate;
c). Temperature of host would affect the reaction rate also;
d). Species of beam (ion/molecular) lead to a different reaction rate.

[1] F. Raiola, et al., Eur. Phys. J. A 19, 283.
[2] J. Kasagi, Surf. Coat. Tech. 201, 8574.
[3] K. Czerski, et al., Europhys. Lett. 54 449.
[4] T. S. Wang, et al., J. Phys. G: Nucl. Part. Phys. 35, 068001
[5] Fang Kaihong, et al., Phys. Rev. C 94, 054602.
[6] Fang Kaihong,et al., Europhys. Lett. 109, 22002.
[7] Fang Kaihong, et al., J. Phys. Soc. Jap. 80, 084201.
[8] Fang Kaihong, et al., Phys. Let. B, 785, 262.

R399 Cross Sections for A New Nuclear Reaction Channel on Au-197 with Dineutron Escape

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A new nuclear reaction channel was studied with neutrons and Au-197 in the input channel and a bound dineutron with Au-196g in the outgoing channel. It was observed for the first time, that this reaction takes place for incident neutron energies which are about 2 MeV below the threshold of the corresponding (n,2n) nuclear reaction. Two experiments have been carried out employing the neutron activation technique. Au foils of 99.99% purity were irradiated with neutrons and then the activated foils were counted with application of HPGe spectrometers.

The first irradiation with MGC-20 cyclotrone was conducted for the [6.1 $\div$ 6.39] MeV neutron energy region using two Au foils of 12.2 mm diameter and 150μm thickness and one more Au foil of the same diameter and 200 μm thickness. All Au foils were placed in 1 mm Cd shielding. The cross-section value was calculated for $E_\gamma = 355.73$ keV ($I_\gamma = 87\%$) gamma peak of 6.4 σ statistical significance and equals 0.037$\pm$0.008 mb. The other neutron activation experiment was carried out for the [5.5 - 6.4] MeV neutron energy region. A stack of three Au foils with 13 mm diameter and 200 μm nominal thickness was irradiated in a Cd case with 1 mm wall thickness too. The 333.03 kev gamma peak ($I_\gamma = 22.9\%$) was observed with 3.3 σ statistical significance and the 355.73 keV gamma line due to Au-196g decay was detected with 9.3 σ statistical significance in the instrumental gamma spectrum. The calculated cross section is 0.18 $\pm$ 0.06 mb.

Based on these results and earlier available data, published by the authors, it seems reasonable to introduce a new nuclear reaction channel into EXFOR database and other nuclear data libraries.

R400 Development of Mc-based Error Estimation Technique of Unfolded Neutron Spectrum by Multiple-foil Activation Method

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Accelerator-based neutrons by deuterons have been proposed as a new system for radioisotopes (RIs) production. In the system, the accelerator-based neutron is produced via the (d,n) reaction by deuteron irradiation on thick neutron converter made of C or Be. Raw materials are irradiated by the neutrons to produce a target RI by an activation reaction.

Simulation study is necessary to estimate the accurate product amount and purity of a target RI, and to design the irradiation system. For the simulation, accurate thick-target neutron yields (TTNYs) are required. The multiple-foil activation method is appropriate for TTNY measurement because activation power of the neutron source can be measured directly. In the method, unfolding process is necessary to derive TTNY from measured radioactivity of the irradiated foils. We derived number of produced atoms from measurement of gamma-ray emitted from the foils. However, accurate estimation of the error of experimental TTNY is difficult. In the unfolding process, we do not know clearly what kind of activation reaction influence what part of neutron energy range of TTNY. Hence, derivation of the error of TTNY is hard. The purpose of this study is to develop a new technique of estimating the error of TTNY.

The experimental data of number of atoms produced by activation reaction was obtained at Cyclotron and Radioisotope Center (CYRIC), Tohoku University, and we used it as input data in unfolding process. Deuterons were accelerated to 16 MeV and bombarded a thick carbon target. Multiple foils were irradiated by the neutrons generated by the C(d,n) reaction.

We developed a new unfolding program to derive the error of TTNY, the correlation between each activation reaction, and TTNY. The program combines the GRAVEL algorithm and Monte-Carlo technique. The GRAVEL based on the iterative approximation method requires the number of atoms produced by activation reaction, production rate function and initial guess spectrum. The input value of the number of atoms is generated randomly following Gaussian distribution around the number of produced atoms. We derived the correlation between individual activation reactions and the unfolded neutron spectrum. Moreover, we evaluated the error of TTNY.

I401 Measurement of the ^{236}U(n,f) Cross-section at Fast Neutron Energies with Micromegas Detectors

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The accurate estimation of the neutron-induced fission cross-section of actinides is of great importance for the design of advanced nuclear reactors and accelerator-driven systems. Specifically, ^{236}U is produced as a by-product in the ^{232}Th/^{233}U fuel cycle from neutron capture in ^{235}U, requiring the knowledge of the corresponding fission cross-section with high accuracy. However, few experimental data in the 4-10 MeV energy range exist in literature, resulting in discrepancies in the latest evaluated libraries. Thus, new measurements are essential for the improvement of the evaluations.

In the present work, the measurement of the ^{236}U(n,f) cross-section was performed, using the ^{238}U(n,f) and ^{235}U(n,f) reference reactions. The measurements were carried out at the neutron beam facility of the National Centre for Scientific Research 'Demokritos' (Greece) and the quasi-monoenergetic neutron beams in the 4-10 MeV energy range were produced via the ^{2}H(d,n)^{3}He reaction. Five actinide targets ($2\times^{236}$U, $2\times^{238}$U and $2\times^{235}$U) and the corresponding Micromegas detectors for the detection of the fission fragments were placed in a chamber filled with an Ar:CO_2 (80:20) mixture kept at approximately atmospheric pressure.

Detailed Monte Carlo simulations were performed for the study of the neutron flux and neutron energy distribution at the position of each target, as well as for the study of the energy deposition of the fission fragments in the active volume of the detector. The mass and homogeneity of the actinide targets were experimentally determined via alpha spectroscopy and Rutherford Backscattering Spectrometry, respectively. The experimental procedure, the analysis, the methodology used to correct for the presence of parasitic neutrons and the cross section results are presented and discussed.

This research is implemented through the IKY scholarships programme and co-financed by the European Union (European Social Fund - ESF) and Greek national funds through the action entitled Reinforcement of Post-doctoral Researchers, in the framework of the Operational Programme Human Resources Development Program, Education and Lifelong Learning of the National Strategic Reference Framework (NSRF) 2014-2020.

R402 Measurement of the ^{235}U(n,f) Cross Section Relative to n-p Scattering up to 1 GeV

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Neutron cross section standards are fundamental ingredients for both measurement and evaluations of neutron-induced reaction cross sections. However, no cross section standard exists for neutron energies above 200 MeV. This led the International Atomic Energy Agency to issue a request for a new absolute measurement of neutron induced fission cross sections, relative to n-p scattering, to establish a fission cross section standard above 200 MeV. An effective choice for the reaction to be studied is the ^{235}U(n,f) reaction, already one of the most important standard cross section at thermal neutron energy and between 0.15 MeV and 200 MeV. Despite its importance in fundamental nuclear physics and its widespread use as reference for neutron fluence measurements, only two data sets are available in the energy range between 20 and 200 MeV and there are no experimental data above 200 MeV. Moreover the fission process at high excitation energy is an important topic as it is related to fundamental quantities of excited nuclear matter.

The CERN n_TOF facility offers the possibility to improve the situation thanks to the wide neutron energy spectrum available in its experimental areas, ranging from thermal to 1 GeV. A dedicated measurement campaign was carried out with the aim of providing accurate and precise cross section data of the ^{235}U(n,f) reaction in the high energy region.

The experimental setup consisted of two fission detectors and three detectors to measure the neutron flux. Fission fragments were detected using both a Parallel Plate Avalanche Counter - particularly suited for neutron energies above 200 MeV - and a Parallel Plate Ionization Chamber - designed for the energy region from 10 MeV to 200 MeV. The number of neutrons impinging on the ^{235}U samples was measured by detecting recoil protons emitted from Polyethylene samples placed downstream with respect to the fission counters. Three different Proton Recoil Telescopes were used to cover the entire neutron energy region, from 10 MeV to 1 GeV.

An overview of the experimental setup will be presented, together with the results of the preliminary analysis in the high-energy region.

R403 Recent Status of Fission Cross-section Measurement at Back-n White Neutron Beam of CSNS

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To reduce fission data uncertainty and provide independent nuclear data relevant for new reactors, a fast ionization chamber for fission cross section measurement (called FIXM) was constructed at Back-n beam line of the newly built China Spallation Neutron Source (CSNS). Based on the classical theory of ionization chamber and relative measurement, careful calculation and Monte-Carlo simulation were carried out in spectrometer design and sample preparation. FIXM was used in the first measurement campaign at Back-n, in which three ^{235}U cells, three ^{238}U cells and one ^{236}U cell were mounted for (n,f) reaction measurement in 1eV-200MeV energy range. The design performance was tested and verified, especially the fast response, clear fission event discrimination, high neutron utilization and fission detection efficiency. A careful analysis of the waveform data acquired via public DAQ of Back-n has been performed to determine the Time-of-Flight spectrum and relative fission cross-section. The ^{235}U(n,f) Time-of-Flight spectrum measured in this work was compared with ENDF/B-VII.1 and ENDF/B-VIII.0 and showed good agreement in resonances in eV energy range. The measured fission cross section ratio of ^{235}U and ^{238}U also has good agreement with ENDF/B-VIII.0 within 3% between 1-20 MeV. A comprehensive study of the construction and experiment is presented.

R404 Cross Section Measurements for Proton Induced Reactions on Natural Lanthanum

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Cross sections were measured for radionuclides produced via proton irradiation on a stacked ^{nat}La foil target at the Isotope Production Facility located at Los Alamos National Laboratory. Incident proton energies were approximately 100 MeV and measuremets were made for ten energy positions ranging from about 30 Mev to 90 MeV. Residuals were identified using HPGe gamma spectrometry at both LANL and UW-Madison. Of particular interest was the cross section measurement of ^{134}Ce due to its potential as the imaging component of a theranostic pair with therapy isotope ^{225}Ac. Theoretical values from TENDL (2017) libraries were then compared with the experimental cross section measurements.

S405 Measurement of Fission Cross Sections on ^{232}Th and ^{238}U Induced by D-T Neutrons

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The fission nuclear reactions of ^{232}Th and ^{238}U induced by D-T neutrons were investigated with the neutron activation technique. The fission cross sections of ^{232}Th and ^{238}U induced by 14 MeV neutrons were measured precisely using low-background gamma spectrometer. Neutron flux was tested by accompanying α particle in the irradiation and the neutron energies were given by the cross section ratio of ^{90}Zr(n,2n)^{89}Zr to ^{93}Nb(n,2n)^{92m}Nb reaction. The cross sections of ^{232}Th(n,f)$^{A}_{Z}$X and ^{238}U(n,f)$^{A}_{Z}$X, which leading to ^{89}Rb, ^{138}Cs, ^{138}Xe, ^{134}Te, ^{134}I, ^{131}In, ^{84}Br, ^{142}Ba, and so on, were deduced at 14.1±0.3, 14.5±0.3 and 14.8±0.3 MeV, respectively. The results were compared with previous cumulative fission-yield measurements which shown some obvious difference.

S406 The Equivalent Efficiency Calibration Method of Radioactive Gas Source

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The accurate calibration of the detection efficiency of radioactive gas source is the key to the accurate measurement of radionuclide activity. In view of the problem that the existing calibration method is rather tedious, an efficiency calibration method using the planar source to be equivalent to the gas source was proposed. Refer to the stainless steel gas source box with a volume of 50 ml, the plane source box is designed, and the optimal equivalent scheme was selected through Monte Carlo Simulations. The planar source of filter paper was prepared by using radio nuclides with known specific activities such as Co-60, Ba-133, Eu-152, Se-75, Cs-134, Sb-124 and Na-24. Then the characteristic gamma energy peak efficiency of these nuclides, at a position 25 cm away from the surface of HPGe detector, was calibrated.The full energy peak efficiency curve was obtained by the least square method. In order to verify the accuracy of the efficiency curve above, Ar-41, Xe-133 and Kr-87 gases were produced by irradiation, and their specific activity was measured absolutely by proportional counter tube, respectively. The full energy peak efficiency of the above three gas sources at 25 cm distance from the detector was absolutely calibrated. The deviation between interpolation and absolute calibration is less than 2.5%, which proves the accuracy of the equivalent efficiency calibration method.

S407 Covariance Analysis on the Thermal Neutron Capture Cross Sections Using An Am-be Neutron Source

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We have recently measured the thermal cross sections of ^{71}Ga(n,γ)^{72}Ga and ^{104}Ru(n,γ)^{105}Ru using an Am-Be neutron source having strength of 4×107 neutrons/sec, which was used in our previous study to measure the thermal neutron capture cross section and resonance integrals of ^{138}Ba, ^{141}Pr, ^{139}La and ^{140}Ce[1,2]. The experimental technique and data reduction formalism of our present study are available in the previous publications[1,2].

The thermal cross section of ^{71}Ga was measured using the two monitor reactions ^{55}Mn(n,γ)^{56}Mn and ^{197}Au(n,γ)^{198}Au. The thermal neutron cross section of ^{104}Ru was derived with the ^{105}Ru activity, which was determined from the gamma spectrum analysis of the^{105}Ru 724.2 keV gamma line and its beta decay product ^{105}Rh 319.1 keV gamma line.

For each case, we obtained two cross sections (from two monitors or two gamma lines), and their average was adopted as the final value. Some parameters adopted in our cross section derivation (e.g., nuclear data, sample weight, detector efficiency) are correlated between the two values in our present work. Therefore we had to use the off-diagonal weighted mean instead of the conventional weighted mean [3] to avoid underestimation of the uncertainty in the weighted mean value [4]. Detailed covariance analysis of our measurement result will be presented.

[1] Priyada Panikkath and P. Mohanakrishnan, Eur. Phys. J. A 52 (2016) 276.
[2] Priyada Panikkath and P. Mohanakrishnan, Eur. Phys. J. A 53 (2017) 46.
[3] W, Mannhart, INDC(NDS)-0558 Rev., International Atomic Energy Agency, 2013.
[4] N. Otuka and D.L. Smith, Nucl. Data Sheets 120 (2014) 281.

S408 Characterization of the Differential Neutron Energy Spectrum from Proton Bombardment of Inconel-clad Lithium Conversion Targets

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We report first efforts to produce a quasi-monoenergetic neutron (QMN) beam using the Lawrence Berkeley 88 cyclotron. Protons at energies of 15, 22, and 40 MeV were impinged onto a lithium conversion target with a thickness of 0.2 cm. The ^{7}Li(p,n)^{7}Be nuclear reaction produces a forward-directed secondary flux of neutrons with energy $\sim$1.8 MeV lower than the incident proton energy and a more isotropic distribution of lower energy neutrons in a process that is well-described [McMurray et al, 1993]. First efforts to characterize the lithium target's differential neutron energy spectrum were made using activation foils (μA proton intensities) at 0° and 20° relative to the primary beam axis and EJ-309 liquid scintillator detectors (nA proton intensities). Selected for their (n,γ), (n,2n), (n,3n), (n,p), (n,pn), and (n,α) nuclear reaction channels, monitor foils of natural aluminum, cobalt, gold, indium, nickel, and zirconium foils were irradiated. Neutron reactions were confirmed via HPGe spectrometry of the residual radionuclides in each foil. Future efforts are planned to expand the energy range and spectroscopic characterization capability.

McMurray, W. R., Aschman, D. G., Bharuth-Ram, K., & Fearick, R. W. (1993).The Faure cyclotron neutron source and a particle spectrometer for neutron induced emission of charged particles at energies between 60 and 200 MeV. Nuclear Inst. and Methods in Physics Research, A, 329(1-2), 217-222. https://doi.org/10.1016/0168-9002(93)90939-F

S409 Measurements of the ^{33}S(n,α)^{30}Si Cross-section at n_TOF-CERN and ILL: Resonance Analysis and Implications.

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The ^{33}S(n,α)^{30}Si was proposed as a cooperative target to ^{10}B in neutron capture therapy (NCT) for tumours growing to the skin. Also this reaction is important in nuclear astrophysics due to the unresolved puzzle of the ^{36}S production in the solar system. Previously to these experiments the situation of the data was: at thermal point discrepancies of more than 30% could be found between the available EXFOR data; from the thermal point to 10 keV there were no data at all; from 10 keV to 300 keV there was only one (n,alpha) measurement able to resolve resonances. However, the description of the (n,α) resonances showed important discrepancies in comparison with the unique transmission measurement. In particular, and extremely important for NCT, the alpha width of the most important resonance (13.5 keV) was a factor 2 lower for the (n,α) experiment compared to the transmission measurement.

Here we present three experiments have been performed covering the whole energy range of interest in astrophysics and NTC. These experiments have solved all the issues remaining for this reaction. The most important results are briefly descibed in the following. The high-resolution measurement at Experimental Area 1 of the n_TOF-CERN facility has provided accurate data from 10 to 300 keV. The description of the 13.5 keV resonance agrees with the transmission measurement and disagrees with the (n,α) measurement. The high-flux measurement at Experimental Area 2 of the n_TOF-CERN facility has provided data for the first time from the thermal energy to 10 keV and also the analysis confirms an 1/v behaviour of the cross-section. Finally, the thermal point was also obtained in the PF1b experimental area of the nuclear reactor at ILL (Grenoble) as a double check of its value.

With all these data, a resonance analysis of the whole energy range has been carried out. The importance the new data as well as the new analysis of the resonances in NCT and astrophysics will be discussed.

I410 Progress in International Collaboration on EXFOR Library

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The EXFOR library has served as the unique repository of experimental nuclear reaction data. The Nuclear Reaction Data Centres (NRDC) have compiled and exchanged data for almost 50 years, and now the data sets from more than 22000 experimental works are freely available from the data centres. Recent efforts on improvement of completeness and quality assurance are presented. Three tools for digitization of numerical data from figure images developed by three centres and adopted by NRDC for EXFOR compilation are also introduced.

R411 Nuclear Data Web Dissemination Efforts at the NNDC

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The National Nuclear Data Center, located in Brookhaven National Laboratory, is responsible for dissemination of nuclear structure and reaction data and offers a wide variety of online services. Included online are applications such as NuDat 2.0, Wallet Cards, ENSDF/XUNDL search and file retrievals for obtaining detailed nuclear structure information, and ENDF/EXFOR searches for nuclear reaction cross sections, fission yields, and decay data. One of the most heavily used services, NuDat 2.0 presents a rich and easy-to-use interface to explore many aspects of nuclear and decay properties.

Evaluated Nuclear Structure (ENSDF) files upon which this interface is largely based are available from the ENSDF database using an online search and retrieval web interface from which it is possible to quickly locate supporting literature and determine the latest dates on which evaluations are based. Complementary to this is the web interface used to search and retrieve experimental unevaluated nuclear data (XUNDL), which has the latest experimental results for nuclear structure measurements. Nuclear reaction data, including fission yields, can be accessed through Sigma or ENDF/EXFOR search and retrieval interfaces.

At the foundation, the Nuclear Science References (NSR) interface enables finely tuned searches for research papers and facilitates evaluation efforts. Online tools are available to calculate important quantities such as logft values or Q values. The nuclear data available online has been put together through years of collaborative efforts of those in the nuclear data community and the National Nuclear Data Center hosts the GForge server to support these efforts. GForge provides file versioning, bug tracking, and Wiki documents and the new ADVANCE system interfaces with GForge to provide real time quality control and checking of both codes and ENDF data. Although not exhaustive, presented are a few of the online services available along with effective, sometimes not well-known, ways to utilize these resources. Recent enchancements to online services, such as NuDat, ENSDF Retrieval, and EXFOR are presented and future directions are explored.

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R412 MetroBeta: A European Project Providing Access to Accurate Beta Spectra

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The EMPIR project MetroBeta, is coming to a close following three years' work. The project has led to an improvement in the knowledge of beta spectra, by making progress in theoretical calculations and through innovative measurements. The theoretical developments are based on improvements to the BetaShape code, and include an improved radiative correction, with a specific correction for forbidden unique transitions, and the uncertainty propagation has been modified to better treat the cases where uncertainty information is missing in the input file. For improved use, the code is able to read and write ENSDF files.

The innovative measurement technique using metallic magnetic calorimeters (MMCs), cryogenic detectors operated below 20 mK, have been further developed and used for the precise measurement of beta spectra. Specifically designed MMCs, where the beta emitter is embedded in a metallic absorber with an appropriate heat capacity for optimal energy sensitivity, have been used to measure four spectra from mostly pure beta emitters. Four representative radionuclides were selected and have been measured, covering a wide range of beta endpoint energies: Sm-151 (Q = 76.3 keV, but also has a small beta decay branch to an excited state), C-14 (Q = 156.5 keV), Tc-99 (Q = 293.8 keV) and Cl-36 (Q = 709.5 keV).

Further measurements were undertaken using solid scintillator crystals for two representative radionuclides: Rb-87 (Q = 282.2 keV) and Lu-176 (Q = 1192.8 keV). The measured beta spectra endpoint energies are consistent with the Atomic Mass Evaluation, validating the technique, and the spectral shapes are comparable with spectra calculated using BetaShape.

A magnetic spectrometer is also being implemented and has been used to measure the beta for the 2nd forbidden non-unique transition of Cl-36 (Q = 709.5 keV). The resulting measured spectra is consistent with BetaShape and follows that expected from a 1st forbidden unique transition. The systematic comparison of the measured spectra with the theoretical spectra validates the advances made with BetaShape code which has been further developed within the project. Beta spectra are available from the LNHB website which hosts the Decay Data Evaluation Project (DDEP) recommended decay schemes available at: http://www.lnhb.fr/nuclear-data/nuclear-data-table/

R413 The International Network of Nuclear Structure and Decay Data Evaluators

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The Evaluated Nuclear Structure data File (ENSDF) is the most comprehensive and complete nuclear structure and decay data database in the world. It contains recommended data on all the nuclear structure and decay properties that have been measured. The maintainance and development of ENSDF is carried out by an international group of experts from the USA, Europe, India, China, Japan and Australia who form the international network of Nuclear Structure and Decay Data evaluators (NSDD). The ENSDF database management and maintenance resides with the National Nuclear Data Centre, BNL. Since 1974 the International Atomic Energy Agency has been coordinating the network, organising the biennial meetings, training workshops and providing technical support where needed [1].

In this paper we present the current challenges and future directions of the NSDD network and the impact this work has both in nuclear sciences and applications.

[1] NSDD network web page, http://www-nds.iaea.org/nsdd/

R414 Overview of the OECD-NEA Working Party on International Nuclear Data Evaluation Cooperation (WPEC)

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11. IAEA Nuclear Data Section
12. Lawrence Livermore National Laboratory
13. National Nuclear Laboratory
14. Idaho National Laboratory
15. European Commission, Joint Research Centre
16. Oak Ridge National Laboratory

The OECD Nuclear Energy Agency (NEA) Working Party on International Nuclear Data Evaluation Cooperation (WPEC) was established in 1989 to facilitate collaboration in nuclear data activities. Over its thirty year history, fifty different subgroups have been created to address topics in nearly every aspect of nuclear data, including: experimental measurements, evaluation, validation, model development, quality assurance of databases and the development of software tools.

WPEC has recently completed activities on fission yield evaluation, the general nuclear database structure (GNDS) to replace the ENDF-6 format, methods to provide feedback to evaluation, studies of specific capture cross sections, new methods in thermal scattering kernel evaluation and the Collaborative International Evaluated Library Organisation (CIELO) Pilot Project. Ongoing activities in GNDS application programming interface (API) development, methods for covariance evaluation and quality assurance in nuclear data validation using the International Criticality Safety Benchmark Evaluation Project (ICSBEP) database are complemented by the work of two Expert Groups that oversee the High-Priority Request List (HPRL) for Nuclear Data and the continuous development of the GNDS. New activities on the use of integral experiments for nuclear data validation and adjustment, as well as the use of the Shielding Integral Benchmark Archive and Database (SINBAD) for validation have begun and will be coordinated alongside future subgroups.

After three decades we will review the status of WPEC, how it integrates other collections and activities organised by the NEA and how it dovetails with the initiatives of the IAEA and other bodies to effectively coordinate international activities in nuclear data.

I415 Perspectives on Nuclear Data Verification and Validation at the Data Bank Nuclear Data Service

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Since its creation in 1978, one of the core missions of the NEA Data Bank is to support the production of high quality nuclear data for the international scientific and technical community. At the core of enhancing nuclear data services, a verification and validation effort of evaluated nuclear data is continuing at the Data Bank with the implementation of a sistematized workflow of processes under the so-called Nuclear Data Evaluation Cycle (NDEC) for the verification, testing and benchmarking of neutron data libraries. This paper will present an overview of our nuclear data activities while highlighting most recent progresses.

I416 Citizen Science in Radiation Research

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A growing trend in science is that research institutions reach out to members of the public for participating in research. The reasons for outreach are many, spanning from the desire to collect and/or analyse large sets of data efficiently, to the idea of including the general public on a very fundamental level in science-making and ultimately decision-making. The latter aims at enhancing the publics understanding and interest in science and scientific methods by involving and listening to members of the public. An important premise is that science is a collective endeavour concerning all humans and that scientifically founded decisions have the potential for building and organizing a sustainable society.

The presented project is curriculum-based and carried out in 240 lower secondary school classes (pupils of age 13-16). The task, as designed by the participating universities, is to collect mushroom, soil and animal droppings from different parts of Sweden, do preliminary sample preparation and analyses and send the samples to the university institutions for radioactivity measurement. Behind the project is a desire to compare today's levels of 137-Cs with those deposited right after the Chernobyl accident in 1986, but also to study the exchange of caesium between organisms as well as the impacts of biological and geological processes on uptake and retention. The scientific outcome is a geodatabase with the 137-Cs activity (Bq/m^2) present in the Swedish environment, where radioactivity data can be linked to the species (fungi, competing species, animals foraging), forest type, land type, land use and other environmental factors. The science question is of interest to the general public as foraging for mushroom, as well as spending recreational time in forests is widely popular in Sweden.

In this article, we will discuss the current status of the project and the observations we have made about how well the public can participate in scientific research. Focus will be on organization of the project, such as logistics, preparation of supportive material, feedback and communication between researchers and schools. We will present observations about the impact the project has had on the participants, based on quantitative and qualitative evaluations.

R417 Conceptual Design, Modeling and Development of A Direction-finding Gamma Detector

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This paper describes our first undergraduate project report and findings on the subject matter. Basing on our everyday interaction with ionizing radiation of the sorts which needs to be detected, a gamma detector with which one can detect radiation only is very common. To make one of these kinds of detector doesn't take much and can be prepared at a fairly low cost being very common project in nuclear science arena. But energy dependence of these kinds of detectors are very poor. So, detecting the radiation doesn't accomplish much if we can't determine the responsible radionuclide for it or at least where it is located. As a result of which eventually our project was focused on developing a device having directional radiation detection capability. A compass capable of detecting and finding out the direction from where the radiation is coming, named RADCOM-1 has been developed. The paper unfolds the simple physics behind it and as well as design, model, materials used, tests and results etc.

R418 HPRL - International Cooperation to Identify and Monitor Priority Nuclear Data Needs for Nuclear Applications

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2. OECD-NEA, Boulogne-Billancourt, France
3. IAEA-NAPC-NDS, Vienna, Austria
4. NIST, Gaithersburg, MD, USA
5. RPI, Troy, NY, USA
6. CIAE-CNDC, Beijing, China
7. JAEA, Tokai-mura, Japan
8. INFN & University of Bologna, Bologna, Italy
9. EC-JRC, Geel, Belgium
10. University of Granada, Granada, Spain
11. PI Atomstandart, State Corporation Rosatom, Moscow, Russia
12. KIT, Karlsruhe, Germany
13. SCK-CEN, Mol, Belgium
14. Http://www.oecd-nea.org/science/wpec/hprl

The OECD-NEA High Priority Request List (HPRL) is a point of reference to guide and stimulate the improvement of nuclear data for nuclear energy and other nuclear applications. The HPRL is application-driven and the requests are submitted by nuclear data users or representatives of the user's communities. A panel of international experts reviews and monitors the requests in the framework of an Expert Group mandated by the NEA Nuclear Science Committee Working Party on International Nuclear Data Evaluation Cooperation (WPEC). After approval, individual requests are classified to three categories; high priority requests, general requests, and special purpose requests (e.g., dosimetry, standard). The HPRL is hosted by the NEA in the form of a relational database publicly available on the web. This contribution provides an overview of HPRL entries, status and outlook. Examples of requests successfully completed will be given and new requests will be described with emphasis on updated nuclear data needs in the fields of nuclear energy, neutron standards, dosimetry, and medical applications.

S419 Recent Dissemination Enhancements and Activities

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The National Nuclear Data Center, located in Brookhaven National Laboratory, is responsible for dissemination of nuclear structure and reaction data and offers a wide variety of online services to retrieve and download this data. These include applications such as NuDat 2.0, Wallet Cards, ENSDF/XUNDL search and file retrievals for obtaining detailed nuclear structure information, and ENDF/EXFOR searches for nuclear reaction cross sections, fission yields, and decay data. One of the most heavily used services, NuDat 2.0 presents a rich and easy-to-use interface to explore many aspects of nuclear and decay properties. Although heavily used, there are many new and not as well known useful features in NuDat 2.0 that are shown here. Recently added features are also presented for retrieval of Evaluated Nuclear Structure Files (ENSDF) and the latest experimental data through Experimental Unevaluated Nuclear Data (XUNDL) retrieval. For nuclear reaction data dissemination, recent enhancements to the EXFOR interface from collaboration with the IAEA are demonstrated. The nuclear data available online has been put together through years of collaborative efforts of those in the nuclear data community and, in addition to the previously mentioned services, the National Nuclear Data Center hosts the GForge server to facilitate this work. Some of the available features, such as file versioning and bug tracking are discussed.

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S420 Concentration of ^{137}Cs in Indonesia Marine Waters

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Following the Eastern Japanese Earthquake and following the tsunami that occurred on March 11, 2011, the Fukushima Dai-ichi Nuclear Power Plant (1F NPP) of the Tokyo Electric Power Company (TEPCO) was damaged and released ^{137}Cs and ^{134}Cs radionuclides into the surrounding areas. The total amounts of ^{137}Cs that were directly released into the sea were estimated to equal up to 27 $\pm$ 15 PBq. The estimated that 160 PBq ^{131}I and 15 PBq of ^{137}Cs were discharged into the atmosphere from the 1F NPP reactors (No. 1, No. 2 and No. 3). On other hand estimated that more than 80% of the atmospherically released ^{137}Cs entered the atmosphere offshore from Fukushima, followed by deposition in the Pacific Ocean. Due to their chemical properties, the ^{137}Cs radionuclides can be soluble in seawater, which allows them to spread over long distances by marine currents and dissipate throughout the oceanic water masses . Oceanic currents (e.g., the Oyashio and Kuroshio currents) will transport radionuclides quickly from the western North Pacific Coast off Japan and undergo advection and mixing. Pacific water that is transferred into the Indian Ocean through this association is well known as Indonesian Through Flow (ITF). Thus, the ^{137}Cs and ^{134}Cs radionuclides potentially entered the Indonesian sea from Fukushima through ITF.

S421 Development of New Software for Nuclear Data Compilation

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Nuclear reaction data is essential for research and development in nuclear physics, astrophysics, nuclear engineering, radiation ecology, and radiation medicine. These fields require a variety of nuclear reactions data in the form of the database accessible to nuclear data users around the world. NRDC network uses a special format of nuclear data EXFOR (EXchangeFORmat) containing extensive data on nuclear reactions with photons, neutrons, charged particles, heavy ions, the properties and structure of atomic nuclei [1]. Today EXFOR contains data from more than 20,000 experiments [2].

Maintenance of such a massive array of various data requires specialized tools with the possibility to compile, input and digitize numerical and graphical information. Al-Farabi Kazakh National University in collaboration with the National University of Mongolia is developing a new user-friendly software for nuclear data input with the possibility of output in EXFOR [3, 4]. We give the description and analysis of available software for nuclear data compilation.

[1] Nuclear Data Services. Available from: https://www-nds.iaea.org/
[2] EXFOR Database. Available from: https://www-nds.iaea.org/exfor/exfor.htm
[3] A. Sarsembayeva et al.: IAEA Proceedings of the Seventh Workshop on Asian Nuclear Reaction Database Development. China Institute of Atomic Energy, Beijing, China, November 8-11, 2016. P.69.

[4] A. Sarsembayeva et al.: Proceedings of the 2015 Symposium on Nuclear Data. Ibaraki Quantum Beam Research Center, Tokai-mura, Ibaraki, Japan, 19-20 November 2015. P.81

S422 Gamma Spectroscopy Methodology for Measurements of Large Amounts of Environmental Samples in Sweden 30 Years after the Chernobyl Accident

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In a Swedish citizen science project, 250 elementary school classes participate in collecting fungi, related soil samples, and droppings from deer and wild boar, from all over Sweden. The samples are sent to a laboratory at Uppsala University where they are analyzed through gamma spectroscopy with a shielded HPGe detector with 30 percent relative efficiency. The main objective is to scan the samples for ^{137}Cs from the Chernobyl accident and compare the data with measurements from 1986, but uptake of naturally occuring radionuclides like 40K and Radon daughters will also be determined. Together with the soil samples, transfer factors will be derived, and correlations for these factors will be sought for different species of fungi and soil types. The potential for correlating the results with different biological processes will also be investigated, in part through the collected animal droppings. Here we present the experimental setup and methodology. Corrections for geometry, self-shielding and true coincidence summing will be explained. Preliminary results will be presented and compared with earlier data.

I423 Nuclear Data Activities of the EUROfusion Consortium

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Within the Power Plant Physics and Technology (PPPT) programme of EUROfusion, extensive development works are conducted on a fusion power demonstration plant (DEMO) and the high intense neutron source IFMIF-DONES (International Fusion Material Irradiation Facility- DEMO Oriented NEutron Source) for the material qualification. Neutronics simulations play a fundamental role for the design and optimisation of these facilities including the evaluation and verification of their nuclear performances. Accurate data need to be provided to predict the tritium breeding capability, assess the shielding efficiency, estimate the nuclear power generated in the system, and produce activation and radiation damage data for the irradiated materials/components. Likewise this applies for the radiation dose fields to be provided after shut-down or during maintenance periods. The availability of high quality nuclear data is thus a pre-requisite for reliable design calculations affecting the nuclear design and performance of the facilities, as well as safety, licensing, waste management and decommissioning issues.

Accordingly, the EUROfusion consortium has implemented a dedicated activity on the development of high quality nuclear data to support neutronics in the PPPT programme. This includes the evaluation of general purpose neutron cross-section data as required for design calculations using particle transport codes, the generation of new activation and displacement damage cross-section data libraries, and evaluation of deuteron cross-sections as required for the IFMID-DONES accelerator. This work is complemented by extensive benchmark, sensitivity and uncertainty analyses to check the performance of the evaluated cross-section data and libraries against integral experiments.

The paper provides an overview of the related nuclear data activities conducted in the PPPT programme since 2017. The focus is on the achievements obtained in the area of nuclear data evaluations, benchmarking and validation, activation and radiation damage, nuclear model and method improvements, and sensitivity/uncertainty assessments.

I424 Validation of Theory of Radiation Damage Against Experimental Data

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Tungsten (W) is a leading candidate of plasma-facing material in ITER and DEMO reactors. Reduced activated ferritic-martensitic (RAFM) steels are one of priority candidate materials for advanced fission and fusion structural materials. In this regards, a fundamental understanding of radiation damage in W and Fe is critical for the design of materials in extreme environment, for example, for fusion reactors. However, working on irradiated materials is costly. To simulate neutron-induced damage in nuclear materials, ion beams are widely used. However, it is not always clear if the mechanisms under the ion irradiation are relevant to lower dose rate and the primary knock-on atom (PKA) spectrum under neutron irradiation. In order to simulate the real experimental conditions of irradiation of reactor materials for reliable predictions of radiation damage in fusion reactors, it is necessary to establish the adequacy of the resulting damage produced by different types of irradiation. For this reason, we compare radiation-induced defects in W and Fe created by protons with an energy of 22.5 MeV and neutrons with continuous spectrum up to 35 MeV. Study of different distributions of radiation-induced vacancies and vacancy clusters of different sizes created by different types of irradiation allows us an experimental validation of the value of "displacement per atom" (dpa) when comparing different types of irradiation. Radiation-induced defects have been studied by well-established method of positron-annihilation lifetime-spectroscopy (PALS). New experimental data in combination with data available from the literature provide an evidence that the classical Norgett-Robinson-Torrens (NRT_dpa) model describes well experimental data for W. On the other hand, the recently developed athermal recombination corrected (arc_dpa) model [1] describes well experimental data in the case of Fe. Reasons are discussed.

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[1] K. Nordlund et al., Nature communications, 9 (2018), 1-8

R425 Comparison Between Measurement and Calculations for A 14 MeV Neutron Water Activation Experiment

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The loads due to gamma rays emitted from the decay of ^{16}N and delayed neutrons from N-17, generated by the activation of water in cooling circuits, are critical for ITER design. The assessment of nuclear loads from activated water is complex, it requires temporal and spatial dependent transport and activation calculations taking into account variation of irradiation, water flow conditions and cooling circuits parameters. A Water Activation Experiment has been recently conducted at the Frascati Neutron Generator (FNG) in order to validate the methodology for water activation assessment used for ITER and to reduce the safety factors applied to the calculations results which have large impact on the schedule, commissioning and licensing. Water circulating inside a ITER First Wall (FW) mock-up was irradiated with 14 MeV D-T neutrons and then measured using a large CsI scintillator detector. The system consists of a closed water loop where the cooling water, transiting through an ITER FW mock-up, is irradiated by the FNG D-T neutron generator. The induced ^{16}N activity via 14 MeV neutrons interactions with ^{16}O via the ^{16}O(n,p)^{16}N reaction is measured in a dedicated counting station via an expansion volume and after several ^{16}N half-lives decay time the water is exposed again at the neutron flux. The measured ^{16}N activity is obtained measuring the emitted characteristic 6.13 MeV gamma-ray. Calculations were performed in an accurate model of the FW mock-up using the MCNP Monte Carlo code and FENDL3.1d nuclear data library to obtain the predicted flux impinging on the water. The FISPACT-II inventory code with the most recent versions of FENDL, TENDL, IRDFF and EAF database was used to predict the ^{16}N activity. A comparison between measurements and calculations is reported and discussed.

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R426 A Comparative Survey of Evaluated Nuclear Data Libraries for Usage in Fusion-relevant Activation Foils Spectrometry Experiments

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The neutron energy spectrum in nuclear fusion devices is frequently determined with activation foil measurements and employing the obtained reaction rates to adjust a computationally-guessed input spectrum in the so-called unfolding codes. Recently, we have utilized this methodology in the post-analyses of experiments performed at the Joint European Torus (JET) machine, Technical University of Dresden Neutron Generator (TUD-NG) and Nuclear Physics Institute (NPI) of Rez. MAXED, a maximum-entropy unfolding code, and STAYSL-PNNL least-squares adjustment software are selected among a wide variety of tools available to us. Limited a-priori information and numerous sources of error make the spectral-adjustment a rather complex and uncertain procedure. Its careful streamlining and evaluation is necessary. Nuclear cross-section data, their uncertainties and covariance matrices hold a very vital position in this. In this paper, a survey of common reactions and available cross-section and covariance files is presented. The IRDFF.V.1.05 library is most up-to-date and recommended source of data for this purpose. In fusion applications however, many interesting dosimetry reactions are found missing in this, leading us to investigate other standard sources like ENDF/B-VIII.0, EAF-2010, JEFF-3.3, TENDL-2017, etc. Data processing toolkit NJOY-2016 is implemented to extract data and format them to prepare response functions based on these files. Then, the unfolding is performed for three experiments- with D-D (approx. 2.5 MeV peak) neutrons at JET and TUD-NG and white neutron field (approx. 33 MeV endpoint neutron energy) at NPI, each with between three and ten reaction channels, and four sets of input response functions. The total integrated fluences can vary by around 30% on changing the data source. The sensitivity of the unfolding regimes to the choice of nuclear data library, in different experiments and for different energy regions, is reported here. Combining the experiences of the data-processing, results of unfolding, and comparison of individual data to experimental values, some qualitative conclusions are made to improve the activation spectrometry procedure implemented in our fusion experiments.

S427 Cross-section and Activation Data for Long-lived Radionuclides (A $\sim$ 50-60) with Their Impact in Fusion Reactor Technology

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Long-lived radionuclides in the mass region 50-60 requires great concern as radioactive nuclear waste, enhancement of extra helium and hydrogen generation during reactor operation, which can affect the nuclear analysis of the fusion reactor. Present study highlights the need, impact and first time experimental measurement of cross-section study performed specially for the long-lived radionuclides in the medium mass region. Landmark step has been taken in this direction which includes; (i) the measurement of neutron induced cross-section of radionuclides ^{55}Fe(n,xp), ^{59}Ni(n,xp) by surrogate ratio method, (ii) estimation of the radionuclides formed in a fusion reactor environment through different pathways using activation calculations (iii) impact of radionuclides on reactor material i.e. primary knock on atom spectra, DPA calculations, number of He and H atom produced at the critical components of a fusion reactor and (iv) simulation of neutron induced damage by charged particle using code SDTrim.SP (Static and Dynamic Trim for Sequental and Parallel computer).

Important outcomes drawn from the above study are: (i) The surrogate reaction ratio technique has been used for the first time for the charged particle emission reaction important to D-T fusion. Because of the discrepancy in the available nuclear data libraries more experimental measurements are required. The surrogate ratio method can be benchmarked with the reaction that have direct measurement. The accuracy of the deduced cross-section is now well known for certain ranges of incident neutron energy. Further, because of the anomalous behaviour of the (n,p) and (n,α) reaction for ^{55}Fe and ^{59}Ni at lower energies, it is recommended to include the lower energy neutron induced cross-section calculation in nuclear reaction modular code TALYS and EMPIRE. Parallel to this, there is a requirement of the charged particle induced inventory in the present available activation code, because any reaction channel either neutron induced or charged particle induced (p,α,d) can breed radionuclides during reactor operation. Inclusion of the charged particle inventory in the activation code would be able to complete the real activation scenario.

I428 A Comprehensive Study of Spallation Models for Proton-induced Spallation Product Yields Utilized in Transport Calculation

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In the design of high-energy accelerator facilities such as accelerator-driven systems (ADSs), spallation models play an important role in predicting the radiation dose and identifying the radioactive sources. A recent benchmark study of the Particle and Heavy-Ion Transport code System (PHITS) [1] and experiments conducted at J-PARC [2] revealed that there are considerable discrepancies in the spallation product yields between the calculation results with the PHITS default model, a combination of INCL4.6 and GEM (INCL4.6/GEM), and the experimental data.

To understand the trends of these disagreements and compare with the latest various spallation models, we conducted a comprehensive study of the spallation models, focusing on the spallation product yields including neutron yields. The calculations were performed for proton-induced reactions using the spallation models utilized in the Monte Carlo particle transport simulation codes such as PHITS, MCNP, and Geant4 (i.e. INCL4.6/GEM, Bertini/GEM, JQMD2/GEM, JQMD2/SMM/GEM, CEM03.03, INCL++/GEMINI++, INCL++/ABLA07, etc.). The calculated spallation product yields were compared with experimental data available from the EXFOR experimental nuclear reaction database. The most recent data measured at J-PARC (activation cross sections and spallation neutron yields emitted from the J-PARC mercury target) were also used in the comparisons. This paper will present the results and discuss the necessary modifications to the spallation models.

[1] Y. Iwamoto et al. "Benchmark study of the recent version of the PHITS code", J. Nucl. Sci. Technol., 2017, 54[5], 617-635.
[2] H. Matsuda et al. "Proton-induced activation cross section measurement for aluminum with proton energy range from 0.4 to 3 GeV at J-PARC", J. Nucl. Sci. Technol., 2018, 55[8], 955-961.

R429 Distribution of Neutron and Proton Field in Elongated Spallation Targets

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Analysis of neutron spatial and energy distribution was carried out for two elongated targets. The targets have a cylindrical shape and are made of lead and carbon, respectively. The dimensions are approximately one meter in length and 19 cm in diameter. The targets were irradiated by 660 MeV proton beam at Phasotron accelerator facility at Joint Institute for Nuclear Research in Dubna. A total number of high energy protons impacted on target was 2.52(19)E15 for the carbon target experiment and 2.3(2)E15 for the lead target experiment. Produced neutron field was monitored by threshold activation detectors (Al, Bi, Co) in various positions. The irradiated detectors were measured by means of gamma spectrometry using HPGe detectors. Reaction rates of different radionuclides production in the activation detectors were determined and the results from both experiments were compared. The ratio of the reaction rates shows in general that the number of residual nuclei with higher threshold energies is higher for experiment with carbon target than for experiment with lead target. The ratios were calculated for 7 reactions produced in cobalt detectors, 6 reactions in bismuth detectors, and 3 reactions in aluminum detectors.

R430 Production Cross Sections of Long-lived Radionuclides in Proton Irradiated Pb, Ta and W Targets

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In this study, proton irradiated Pb, Ta and W targets, which are considered to use for spallation neutron facilities (SNF) and accelerator driven systems (ADS), were investigated for the purpose of the cross-sections determination. Cross section database of long-lived radionuclides is especially important for the licensing, safe operation and decommissioning of these facilities. In addition, these data are important to evaluate and improve the existing computer simulation codes.

Radiochemical separation methods were developed for the separation of the long-lived -emitters ^{129}I, ^{36}Cl and α-emitters ^{154}Dy, ^{148}Gd, ^{150}Gd, and ^{146}Sm from proton irradiated Pb, Ta, and W targets up to 2.6 GeV. Measurements of ^{129}I/^{127}I and Cl/^{36}Cl ratios were performed using accelerator mass spectrometer. Molecular plating technique was used to prepare thin lanthanides samples to obtain a good quality -spectrum with high resolution and small low energy tail contribution. Autoradiography and focused ion beam/scanning electron microscopy techniques were used for the characterization of the lanthanide deposited layer.

The experimental results were compared with the previous theoretical studies and calculations obtained with the combination of Lige intra-nuclear cascade (INCL++) and de-excitation phase (ABLA07) codes. The comparisons showed a satisfactory agreement for the ^{148}Gd, ^{129}I, and ^{36}Cl cross-section results. It was clearly shown that radiochemical separation has a high impact on improving the accuracy of the results. However, theoretical ^{154}Dy cross sections data were underestimated, which could be due to the high uncertainty of the accepted half-life value of ^{154}Dy (3 ± 1.5 My).

R431 Neutron Energy Spectra Measurements of the Back-n White Neutron Source at CSNS

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4. Back-n Collaboration

A back streaming white neutron beam line (Back-n) at China Spallation Neutron Source (CSNS) was built mainly for nuclear data measurements and the commissioning and user program has started since the beginning of 2018. The white neutron source can provide neutrons from 0.5 eV up to hundreds of MeV by impinging 1.6 GeV protons onto a thick tungsten target that is shared with neutron scattering applications. There are two experimental halls along the Back-n beam line: End Station 1 (ES♯1) with a flight path of about 55 m and End Station 2 (ES♯2) with about 76 m. The neutron energy spectra at both ES♯1 and ES♯2 were measured with a multi-layer fission ionization chamber and other detectors by the time-of-flight method. The first results measured by the fission chamber are given here. The energy spectra are in a good agreement with the Monte Carlos simulations.

R432 Neutron Imaging at the n_TOF Facility of CERN

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Neutron imaging techniques are a well-known tool for non-destructive analysis, which use the peculiar interaction of neutrons with matter to penetrate thick-walled samples. Neutron radiographies are obtained both exploiting the different material densities - i.e. sensitivity to the neutron elastic scattering - and the neutron-induced reaction cross-sections. In this sense, the mass attenuation coefficient is complementary to that of X-rays, making the technique a valid alternative to X-ray radiographs when metal-shielded samples - as engineering parts or fine art artefacts - should be investigated.

In this context, the neutron time-of-flight facility (n_TOF) of CERN could enter in the number of facilities available for neutron radiography and inspection of materials thanks to the very high neutron flux in its second experimental area. In particular, the characteristics of the n_TOF spallation neutron source lead to a pulsed neutron beam of exceptionally high instantaneous intensity, with about 1.1×10^7 neutrons per 30ms-long bunches with a 4-cm diameter beam spot. About 20% of the neutrons fall in the thermal energy range ($E_n < 1$ eV). This feature helps to improve the image contrast for radioactive targets, making the facility particularly suited for inspecting irradiated materials.

The feasibility of the neutron imaging method has been proven with two different in-beam tests. Following the successful proof-of-concept, a full characterisation of several irradiated targets has been completed, successfully inspecting their inner structure and assessing potential damages.

The technique will be here presented together with the results obtained, and possible upgrades involving the optimisation of the beam-line and of the detection system assembly will be discussed. In particular, the possibility to exploit the time-of-flight technique to perform material characterisation and material-selective radiographs will be explored.

I433 Current Overview of ICSBEP and IRPhEP Benchmark Evaluation Practices

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Two projects sanctioned by the Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) have over two decades of experience developing established and comprehensive data sets in handbooks supporting criticality safety and reactor physics. The International Criticality Safety Benchmark Evaluation Project (ICSBEP) and the International Reactor Physics Experiment Evaluation Project (IRPhEP) serve as examples of quality and excellence in preserving our experimental data heritage and establishing integral benchmark standards upon which current and future modeling, validation, and safety efforts can be supported. Evaluation practices have evolved with each year of these projects to include additional benchmark experiment data, establish more comprehensive techniques for evaluation of uncertainties and biases, and encourage established high-quality peer-review efforts. This paper will summarize the current format of the handbooks, best-practices for a comprehensive benchmark evaluation, recent activities and protocol within these projects, and a look into future identified needs and activities.

R434 A Study on Integral Parameters of VVER Critical Experiments of LWRS Based on Evaluated Nuclear Data Library ENDF/B-VII.0 & JENDL-3.0

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This work focuses on the study of integral parameters for the purpose of validation of the lattice transport code WIMSD-5B through benchmarking VVER critical experiments based on nuclear data files ENDF/B-VII and JENDL-3. In integral measurements, these lattices are considered as standard benchmarks for testing reactor physics method (code) as well as nuclear data files. The integral parameters of the said lattice were attained by using the WIMSD-5B of the lattice transport code WIMS based on the previously mentioned libraries.

The selected integral parameters were compared with the measured values for numerical benchmarking and as well as for comparison between libraries. It was found that in most cases, the values of integral parameters demonstrate a good agreement with the experiment values. In addition, the group constants in WIMS format for the isotopes U-235 and U-238 between two data files have been compared using WIMS library utility code WILLIE and it was found that the group constants are identical with very insignificant difference. This analysis reflects the validation of the lattice transport code WIMS as well as evaluated nuclear data files ENDF/B-VII and JENDL-3 through benchmarking integral parameters of VVER critical experiments.

Besides, the group constants study also enriches this validation study. Additionally, few experiments' results with least variation from standard output have been used to compare energy versus cross section as well as energy versus neutron flux trend with the standard one for better comprehending the code's inner workings. This enables us to better understand the code's problem dependent approximation process while solving as well as provides some insight in estimating the deviation from actual physical solution. This also enriches the validation study as well as provides necessary reasonableness to select the code for further studies. Therefore, this study can also be essential to implement further neutronic analysis of VVER reactor which is going to be established in Rooppur Bangladesh.

R435 Combining Correlations from Multiple Criticality Benchmarks for Nuclear Data Adjustments Within A Total Monte Carlo Framework

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The use of criticality benchmarks for a posteriori adjustment of nuclear data in order to reproduce integral benchmark experimental data is common within the nuclear data community. Data adjustments are normally carried out by globally fitting benchmark calculational results to available criticality experiments. These benchmarks are usually correlated since similar instruments and methods were employed in their measurement and analyses. Additionally, benchmarks are also correlated in nuclear data since they share similar characteristics such as material and isotopic composition, as well as in neutron spectrum. If all these correlations are not taken into account, the resulting covariances used for data adjustments could introduce an additional source of uncertainty. While this is not a problem for single benchmarks, it becomes increasingly important when multiple benchmarks are used for adjustments. in this work, a Total Monte Carlo based method for combining correlations from different sources is presented. The combined correlations are used to build variance-covariance matrices used for the adjustment of ^{208}Pb within a Bayesian framework using a selected number of lead sensitive benchmarks. The results from this work are compared with available experimental data from the EXFOR database as well as with benchmark experimental results and other nuclear data libraries.

R436 Validation of Heavy Water Cross Section Using Ambe Neutron Source

Michal Kostal[1], Nicola Burianova[1], Martin Schulc[1], Evzen Novak[1], Tomas Czakoj[1], Zdenek Matej[2], Frantisek Cvachovec[3], Filip Mravec[2], Luiz Leal[4]
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Physical quantities derived from integral experiments can usually be measured much more accurately than that from differential nuclear data. The accurate knowledge of integral parameters provide excellent grounds for testing and tuning differential data such as, for instance, cross sections. Measurement of neutron leakage spectra with ^{252}Cf neutron source located at sphere center is often used as integral experiments. While this type of experiments provide information for cross section tuning, however, care must be taken to avoid misleading interpretation namely at high energies due to the very low portion of high energy neutrons in ^{252}Cf spectra. This issue can be alleviated by the use of point source with different spectra shape. For that purpose one suitable candidate seems to be the AmBe neutron source which has a relatively high average energy and peak character of emitted neutrons.

Indeed, AmBe seems an interesting option because the calculated neutron spectra are not very sensitive to the shape of the neutron spectra. Thus the neutron leakage spectra calculated using tabulated ISO spectra is nearly the same as those measured using the AmBe spectra as input. Fast neutron leakage spectra were measured in heavy water benchmark sphere with diameter of 50 cm. The measurement was carried out with a stilbene scintillation detector in the energy range of 1 - 10 MeV. Due to peak character of AmBe spectra, the detector arrangement was successfully tested in LVR-15 light water reactor silicon filtered field. The resulted spectra were compared with calculations performed with MCNP6 using various libraries, namely ENDF/B-VII.I, JENDL-4, and an ISRN evaluation. The results show disagreement for AmBe neutron source oppositely to case with ^{252}Cf point source in center of heavy water sphere benchmark of diameter 50 cm. The full paper will describe the details concerning the experimental data and also the benchmark results.

R437 Nuclear Data Implications of Tex, Ten New Critical Experiments with Plutonium and Tantalum

Catherine Percher, David Heinrichs, Soon Kim, Jesse Norris
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Ten new plutonium integral critical experiments have been completed as part of the Thermal Epithermal eXperiments (TEX) at the National Critical Experiments Research Center in the United States. The goal of the TEX Program is to address identified integral data needs by executing critical experiment series that span a wide range of fission energy spectra, from thermal (below 0.625 eV), through the intermediate energy range (0.625 eV to 100 keV), to fast (above 100 keV), and can be easily modified to include other test materials. The ten configurations were fueled with plutonium metal plates that were excessed from the Zero Power Physics Reactor (ZPPR) program. Five of the experiments were designed to provide a plutonium baseline and used only plutonium ZPPR plates, arranged in alternating layers with varying thicknesses of polyethylene for moderation to tune the fission neutron spectrum from fast to thermal. Based on the preliminary results of the baseline cases, it is clear that there is significant (1% in k-eff) over-prediction using the ENDF/B-VII.1 and ENDF/B-VIII.0 libraries for the more intermediate energy baseline configurations. The other five experiments were variations on the baseline configurations and incorporated a tantalum layer on top of each plutonium layer, providing a test of the tantalum cross sections in different energy regimes. There is currently a lack of experimental benchmarks for tantalum in the International Criticality Safety Benchmark Evaluation Project (ICSBEP) handbook. Adding tantalum to the baseline configurations worsened the over-prediction bias to 1.5-2% in k_{eff}. This result points to an issue with the underlying intermediate and fast neutron scattering cross sections for tantalum.

I438 National Criticality Experiments Research Center (NCERC) - Capabilities and Recent Measurements

Nicholas Thompson, David Hayes, William Myers, Joetta Goda, Rene Sanchez, Travis Grove, Jesson Hutchinson, Theresa Cutler, John Bounds, George Mckenzie, Derek Dinwiddie, Rian Bahran, Alex Mcspaden, Jennifer Arthur, Robert Little, Avneet Sood, Morgan White, Robert Margevicius
Los Alamos National Laboratory

The National Criticality Experiments Research Center (NCERC) located at the Device Assembly Facility (DAF) at the Nevada National Security Site (NNSS) and operated by Los Alamos National Laboratory (LANL) is home to four critical assemblies which are used to support of range of missions, including nuclear criticality safety and nuclear nonproliferation. Additionally, subcritical systems can also be assembled at NCERC. NCERC is providing critical and subcritical experiments valuable to the nuclear data community and experiments performed at NCERC are often published as benchmarks in the International Criticality Safety Benchmark Evaluation Project (ICSBEP) Handbook. This presentation will give a broad overview of recent experiments performed at NCERC, upcoming experiments, and why integral measurements are important and useful to the nuclear data community.

The four critical assemblies are GODIVA IV, FLATTOP, COMET, and PLANET. GODIVA IV is a cylindrical metal fast burst reactor, the fourth in the GODIVA series that dates back to the 1950's. FLATTOP is an HEU or Pu core reflected by natural uranium. COMET and PLANET are vertical lift assemblies, where one half of the reactor can be lifted to the upper half of the reactor to create a critical system.

Some recent experiments measurements include various critical intermediate energy assemblies with lead, and subcritical measurements of plutonium reflected by copper, tungsten, and nickel. Work is also underway to make a better measurement of the critical mass of neptunium, using a neptunium sphere surrounded by nickel shells. Additionally, measurements will be performed next year with HEU shells from Rocky Flats. These HEU shells will be stacked together to make larger and larger systems. Other upcoming measurements include an HEU critical assembly sensitive to intermediate energy neutrons.

R439 Fusion Neutronics Integral Experimental Study of Zr, W Evaluated Nuclear Data

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Integral neutronics experiments have been a powerful tool and method for examining the reliability of evaluated nuclear data. In present report, the accuracy of evaluated nuclear data for W, Zr has been validated by comparing measured leakage neutron spectra with calculated ones. Leakage neutron spectra from the irradiation of D-T neutrons on W, Zr samples were experimentally measured at 60° and 120° by using a time-of-flight method. Theoretical calculations are carried out by Monte Carlo neutron transport code MCNP-4C with evaluated nuclear data of the ENDF/B-VII.0, ENDF/B-VII.1, JENDL-4.0 and CENDL-3.1 libraries. We will discuss the reason may cause the disagreement between the measurements and calculated results.

R440 ZED-2 Reactor as a Physics Test Facility for Validating Evaluated Nuclear Data Libraries

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ZED-2 (Zero Energy Deuterium) is a heavy-water moderated, zero power critical facility at the Chalk River site of Canadian Nuclear Laboratories. ZED-2 has contributed to over 58 years of thermal reactor physics research, and continues to be a crucial and unique facility for such work. There are few proving grounds with which to conduct modern experiments to explore reactor physics phenomena relevant for advanced reactor applications, and validate the evaluated nuclear data libraries used in designing such reactors. In ZED-2, the large vessel (3.3 m in both height and diameter) and the flexibility of configurations (including materials in core, fuel type, and to some extent, coolant and fuel temperature), make this facility useful to perform such meaningful measurements, for both critical (stationary) cores with thermal neutron spectrum and compound-fuels, and reactor kinetic (time-dependent) configurations.

In this work, we present the current capabilities of ZED-2 and review available and prospective ZED-2 benchmarks (in ICSBEP/IRPhEP databases and other open sources). To discuss the performance of recent releases of evaluated nuclear data libraries, such as ENDF/B-VIII.0 (2018) and JEFF-3.3 (2017), and in particular, the improvements in thermal scattering sub-libraries (TSL) of these evaluations, we review the capabilities of ZED-2 to validate the TSLs for light and heavy water, uranium dioxide, reactor graphite, etc., at different temperatures. Finally, we demonstrate the capabilities of the ZED-2 model generator software developed at CNL that allows us to generate consistent ZED-2 models for well-known Monte Carlo neutron transport codes, such as MCNP, SERPENT, and KENO .

R441 Contributions to Integral Nuclear Data in ICSBEP and IRPhEP Since ND2016

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The contributions to the International Criticality Safety Benchmark Evaluation Project (ICSBEP) and the International Reactor Physics Experiment Evaluation Project (IRPhEP) was last discussed directly with the international nuclear data community at the International Conference on Nuclear Data for Science and Technology in 2016. Since ND2016, integral benchmark data that are available for nuclear data testing has continued to increase. The status of the international benchmark efforts and the latest contributions to integral nuclear data for testing is discussed. Select benchmark configurations that have been added to the ICSBEP and IRPhEP Handbooks since ND2016 are highlighted. The 2018 edition of the International Handbook of Evaluated Criticality Safety Benchmark Experiments (ICSBEP Handbook) now contains 574 evaluations with benchmark specifications for 4,916 critical, near-critical, or subcritical configurations, 45 criticality alarm placement/shielding configuration with multiple dose points apiece, and 215 configurations that have been categorized as fundamental physics measurements that are relevant to criticality safety applications. The 2018 edition of the International Handbook of Evaluated Reactor Physics Benchmark Experiments (IRPhEP Handbook) contains data from 159 different experimental series that were performed at 54 different nuclear facilities. Currently 156 of the 159 evaluations are published as approved benchmarks with the remaining four evaluations published in draft format only. Measurements found in the IRPhEP Handbook include criticality, buckling and extrapolation length, spectral characteristics, reactivity effects, reactivity coefficients, kinetics, reaction-rate distributions, power distributions, isotopic compositions, and/or other miscellaneous types of measurements for various types of reactor systems. The most recent annual Technical Review Group (TRG) meetings for both projects were held in October 2018; additional approved benchmark evaluations will be included in the 2019 editions of these handbooks. These handbooks continue to represent the standard for neutronics benchmark experiment evaluation.

R442 Measurement of the Delayed-neutron Yield and Time Constants in the Cold Neutron Induced Fission of ^{235}U at Ill

Olivier Serot[1], Daniela Foligno[1], Pierre Leconte[1], Benoit Geslot[1], Gregoire De Izarra[1], Abdelhazize Cheboubbi[1], Annick Billebaud[2], Nathalie Marie[4], Fran?ois Lecolley[4], Jean-luc Lecouey[4], Ulli K?ster[5], Torsten Soldner[5], Ludovic Mathieu[3]

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Delayed neutron data is essential in inherent reactor safety and in reactor control since it is used to estimate the reactivity. Nowadays, discrepancies among the data in the international databases (JEFF, ENDF, JENDL) are very large and bring excessive conservatism in the safety margins. The quantities of interest related to delayed neutrons are the average delayed neutron yield, the mean precursors' half-life, and the kinetic parameters.

The ALDEN experiment, built in a collaboration of CEA, CNRS, and IRSN, is aimed to measure the delayed-neutron activity for several fissioning systems and to derive the previously mentioned quantities. The detector consists of a polyethylene matrix with a central hole for the target and neutron beam passage and with 16 ^{3}He proportional counters for neutron detection. It has been calibrated at NPL (National Physical Laboratory, UK) with accurately-known neutron sources to estimate the absolute efficiency and at the AMANDE accelerator (IRSN, France) to estimate the relative efficiency as a function of the neutron energy.

The first experimental campaign with a fission target took place at ILL (Institut Laue-Langevin) at the beginning of September 2018. The fissile material, a deposit of ^{235}U, was installed in an active fission chamber at the center of the polyethylene matrix. The collimated neutron beam provided a cold neutron capture flux of about 8· 108 n/cm^2 s at the target position. After defined irradiation lengths, during which fission occurred and precursors built up, the beam was interrupted by a fast shutter and the delayed neutrons emitted by the precursors were detected. Optimal cycles of irradiation and decay phases had been previously chosen to stimulate specific groups of precursors. The data analysis as well as the procedure for the estimation of uncertainty will be presented, together with preliminary results for the average delayed-neutron yield, the mean precursors' half-life, and the kinetic parameters.

I443 Use of Shielding Integral Benchmark Archive and Database for Nuclear Data Validation

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Shielding benchmarks were extensively used for the validation and improvement of nuclear data since many years. Recent evaluations however mostly rely on the validation using critical benchmarks, which can introduce biases and compensation effects. A new Working Party on International Nuclear Data Evaluation Co-operation Subgroup 47 (WPEC SG47) entitled "Use of Shielding Integral Benchmark Archive and Database for Nuclear Data Validation" was formed in spring 2018 with the main objective to contribute to the diversification of the nuclear data validation practice by including more extensively other types of integral measurements, such as shielding benchmarks, in the validation and evaluation procedure. Use of shielding benchmarks is expected to provide a wider-scope test of the performance of the evaluated nuclear data and would ultimately contribute to a production of more general-purpose cross-section evaluations. WPEC SG47 will work in close coordination with other NEA activities such as EGRTS, WPEC SG45, SG46, CIELO, JEFF, and in particular the SINBAD project. The latest version of Shielding Integral Benchmark Archive and Database (SINBAD), distributed by the NEA and RSICC, includes over 100 shielding benchmark experiments covering fission reactor shielding (48 benchmarks), fusion blanket neutronics (31), and accelerator shielding (23) applications. SG47 will provide feedback on the existing database, and promote further development and provide recommendations on the SINBAD evaluations based on the experience, needs and expectations of the nuclear data community. Examples of the (miss)use of the SINBAD benchmark experiment data will be presented.

R444 Bayesian Monte Carlo Assimilation for the PETALE Experimental Programme Using Inter-dosimeter Correlation

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The PETALE experimental programme in the CROCUS reactor at EPFL intends to contribute to the improvement of neutron cross sections in the MeV energy range for stainless steel, particularly in the prospect of heavy reflector elements of PWRs. It mainly consists in several transmission experiments with metallic plates interleaved with thin dosimeter foils. These metal plates are composed of nuclear-grade stainless steel, and its elemental components of interest - iron, nickel and chromium separately to avoid compensation effects. After irradiation, the dosimeter activities are measured in HPGe gamma spectrometers to be compared with calculation results. In this frame, the experiments were first prepared and optimized using Total Monte Carlo (TMC) uncertainty propagation in association with a Correlated Sampling (CS) technique using a modified version of the Serpent2 Monte Carlo code. This first step highlighted the high correlation level between the dosimeters regarding the effect of the nuclear data uncertainties.

This article will first present the methodology developed using the TMC-CS approach to generate dosimeter covariances and to estimate the nuisance parameters. In anticipation of the final experimental results, this work investigates different approaches to consider these experimental correlations in the Bayesian assimilation process on nuclear data, as two dosimeters with similar cross sections should not over-constrain the BMC assimilation. Finally, the choice of the observables that might be used to perform the assimilation is also discussed, such as the absolute dosimeter activities, the ratios of these activities to simplify the HPGe calibration source uncertainty, or using the same dosimeter material but at different positions to limit the calibration uncertainty directly.

R445 The Benchmark Experiment on Slab Iron with D-T Neutrons for Validation of Evaluated Nuclear Data

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An experimental system for benchmark validation of nuclear data with slab samples has been setup at China Institute of Atomic Energy (CIAE). Neutron leakage spectra in the range of 0.8 to 16 MeV from iron slab samples were measured by time-of flight technique using a D-T neutron source with the measured angle at 60 degree and 120 degree. The thicknesses of the slabs were chosen to be 5cm, 10cm and 15cm. The experimental results were compared with the calculated ones by MCNP-4c simulation, using the evaluated data of iron from the CENDL-3.1, ENDF/B-VII.1 and JENDL-4.0 libraries.

From the comparison of neutron spectra and the C/Es between the measured and the calculated results, it was found that some discrepancies in the major reaction channels including (n,p), (n,n') and (n,2n) are existing. Detailed information on the neutron product distribution with the evaluated data was presented to explain the discrepancies which turn out to the data of the above three libraries needed to be improved as required in different energy ranges.

R446 Neutron Spectra Measurement and Calculation Using Last Available Version of Data Libraries CIELO, ENDF, CENDL and JEFF in Iron and Oxygen Benchmark Assemblies.

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The leakage neutron spectra measurements have been done on benchmark spherical assemblies - iron spheres with diameter of 30, 50 and 100 cm, light and heawy water spheres with diameters of 30 and 50 cm. The Cf-252 neutron source was placed into the centre of iron and water sphere. The proton recoil method was used for neutron spectra measurement using spherical hydrogen proportional counters with pressure of 400 and 1000 kPa and stilbene detector. The paralel calculations were provided using last available version of data libraries CIELO, ENDF, CENDL and JEFF. The evaluated cross section data of iron and oxygen were validated on comparisons between the calculated and experimental neutron spectra.

R447 Measurement of Leakage Neutron Spectra with D-t Neutrons and Validation of Evaluated Nuclear Data

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Benchmarking of evaluated nuclear data libraries was performed for $\sim$ 14.8 MeV neutrons on the several targets, such as gallium, graphite, silicon carbide, uranium, tungsten and granular tungsten samples. The experiments were performed at China Institute of Atomic Energy (CIAE). The leakage neutron energy spectra from the samples were measured at 60 degree and 120 degree by a TOF technique with a BC501A scintillation detector. The measured spectra are rather well reproduced by MCNP-4C simulations with the CENDL3.1, ENDF/B-VII.1, ENDF/B-VIII.1, JENDL-4.0, JEEF3.2, TENDEL2015 evaluated nuclear data libraries and so on. There have some difference between experiments and simulations for the inelastic contributions around E_n = 10-12MeV. And the discrepancies of the leakage neutron spectra in the MCNP simulations originate simply from the differences in the spectra distributions of the neutron reaction channels in the evaluated nuclear data libraries.

S448 Research on Doppler Broadening Rejection Correction Based on 0K Nuclear Data

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Many Monte Carlo programs use the Doppler Broadening Rejection Correction (DBRC) method to consider the effect of resonance elastic scattering in temperature feedback.DBRC can be studied based on 0K nuclear data.Based on 0K nuclear data, this paper will study the effect of DBRC on temperature feedback calculation results in the Monte Carlo program.The important nuclear data were selected according to the calculation results, and further demands were put forward for further research on nuclear data.

L449 ENDF/B-VIII.0 and Beyond

David Brown
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On Friday, February 2, 2018, the Cross Section Evaluation Working Group (CSEWG) released ENDF/B-VIII.0, the latest ENDF/B library. ENDF/B is the most important library for neutronics and shielding calculations in the United States and ENDF/B-VIII.0 marks roughly 50 years from the very first ENDF/B library release. ENDF/B-VIII.0 builds on experimental and theoretical work from across the United States and the international nuclear science community including new developments since 2011. The many improvements include the new Nuclear Data Standards evaluations, and the CIELO project evaluations for neutron reactions on ^{16}O, ^{56}Fe, ^{235}U, ^{238}U and ^{239}Pu and a nearly completely new thermal neutron scattering sublibrary. Other notable advances include updated evaluated data for light nuclei, structural materials, actinides, fission energy release, prompt fission neutron and gamma-ray spectra, decay data and charged-particle reaction data. ENDF/B-VIII.0 is the highest quality and best performing ENDF/B library to date as shown by overall performance in simulations of ICSBEP critical assemblies and shielding benchmarks. The library is issued in the traditional ENDF-6 format, as well as in the new Generalized Nuclear Database Structure (GNDS) format. In this contribution, we will review the highlights of ENDF/B-VIII.0 and note many of its remaining shortcomings. We will lay out CSEWG's path forward for the next library release which, among other things, will include new Fission Product Yields, decay data, evaluations for Plutonium isotopes and major revisions to structural materials. Much of this work will be coordinated through the INDEN and continuing CIELO collaborative projects.

L450 Challenges in Actinides Evaluation: PFNS and the Next Pu Evaluation

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Lessons learned during the IAEA CIELO evaluations of ^{235,238}U targets are reviewed. Preliminary updates of the ^{239,240}Pu evaluation within the IAEA INDEN project are discussed with focus on the impact of the IAEA evaluation softer PFNS at the thermal point on critical Pu solutions. The impact of new PFNS evaluation on fast critical benchmarks is also considered. Possible updates of resonance parameters are discussed. Information learned from benchmark calculations and differential data measurements are combined trying to improve the evaluation consistency.

L451 Nuclear reaction data in the next decade and the role of TALYS

Arjan Koning
International Atomic Energy Agency

The nuclear model code TALYS was originally designed to analyse and predict nuclear reactions. TALYS has been extensively validated over the past 20 years, by the authors and thousands of users, in fields ranging from fundamental nuclear reaction studies to nuclear data evaluation for applications. It has been decided to turn more capabilities related to TALYS to open source software. A major upgrade will be released in 2019, TALYS-2.0, comprising among others further development towards microscopic nuclear structure ingredients, full capabilities regarding Bayesian Monte Carlo based uncertainty quantification (this was not open source so far), complete ENDF data library production (this was not open source so far), integration of EXFOR database and all world data libraries for direct comparison and optimization, a complete rewrite in modular Fortran-95, unprecedented documentation of all its options.

Besides the usual role of TALYS as an analysis and prediction tool for new measurements and for reactions important for applications, TALYS users will now be able to produce complete evaluated nuclear data libraries including uncertainty quantification, enabling them to extend their work to fields as Total Monte Carlo, TENDL-like nuclear data libraries and more efficient testing of the latest physics models with experimental data.

L452 The Leverage of Nuclei in the Cosmos

Michael Smith
Oak Ridge National Laboratory

Astrophysical simulations can be improved through quantifying the uncertainties in their predictions and performing meaningful comparisons to astrophysical observations. Examples of techniques for propagating nuclear physics input uncertainties through a variety of astrophysical simulations will be presented, from simple min-max approaches to Monte Carlo and more advanced methods. Comparisons with other contributions to astrophysical simulation predictions will be given, and suggestions for improved uncertainty quantification will be discussed.

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L453 Results of the Collaborative International Evaluated Library Organisation (CIELO) Project

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7. Japan Atomic Energy Agency
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Simulation of nuclear systems requires complete data that represents the relevant nuclear physics. This requires many types of experimental measurements, theoretical physics, semi-empirical models and software systems, as well as experts to integrate and guide the process. This discipline is collectively known as nuclear data, and separate programmes within various European countries, the USA, Japan, Russia, and other OECD Nuclear Energy Agency (NEA) member countries have been operating for many decades. The NEA Working Party on International Nuclear Data Evaluation Co-operation (WPEC) exists to improve the quality and completeness of nuclear data by bringing together representatives of the major nuclear data evaluation projects of NEA member countries and selected Invitees. The Sub- and Expert Groups of the WPEC typically focus on specific technical topics, while the Collaborative International Evaluated Library Organisation Pilot Project (CIELO) was established to generate complete evaluations for a selection of the most important isotopes for criticality in nuclear technologies: ^{235,238}U, ^{239}Pu, ^{56}Fe, ^{16}O and ^{1}H.

project stimulated numerous activities, resulting in, directly or indirectly, an entire Special Issue of the Nuclear Data Sheets journal (issue 148, 2018) and the production of a suite of new nuclear data evaluations that have been incorporated in major nuclear data libraries. The outcomes of these evaluations include significant harmonisation of discrepancies between the independent programmes, improvement in the performance for international standard nuclear criticality and neutron transmission benchmarks, complete uncertainties for nearly all parameters and the utilisation of modern data storage technologies. This work has leveraged the considerable, parallel experimental work in collecting improved experimental measurements to support nuclear data and highlighted high-priority areas for further study. A productive and durable framework for international evaluation has been established which will build upon the lessons learned. These will continue through new WPEC groups and a new IAEA evaluation network, which has been initiated in response to the success of the CIELO project.

This talk will summarize some performance feedback on the CIELO evaluations, including recent results, and will describe ongoing and future, planned CIELO-related collaborations to further advance our understanding.

L454 CSNS Back-n White Neutron Facility and First Nuclear Data Measurements

Jingyu Tang For The Back-n Collaboration
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CSNS (China Spallation Neutron Source) is a large scientific facility just completed in 2018, aiming for multidisciplinary research. Taking the high proton power of 100 kW at Phase-I and 500 kW at Phase-II at CSNS, a white neutron facility (Back-n) was added and the construction was completed simultaneously. It makes use of the back-streaming neutrons at the spallation target, which have the typical characteristics as a white neutron beam, very intense flux of 10^7 n/cm^2/s at a flight distance of 55 m, very wide energy spectrum of 0.3 eV to 200 MeV, good time resolution of a few per mille. Together with the beamline, four spectrometers for nuclear data measurements have been built and put in operation, including FIXM for fission cross-section measurements, C6D6 detectors for neutron capture measurements, LPDA for light-particle emission measurements, and NTOX for total cross-section measurements. Other types of spectrometers are in construction or in planning. The first years operation of the Back-n includes eight nuclear data experiments by using the four spectrometers. The initial experimental results will be presented.

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