

**2024 年度核データ研究
会/Symposium on Nuclear
Data 2024**

Report of Contributions

Contribution ID: 5

Type: **not specified**

Proton beam irradiation for space use at 3NBT and proton beam irradiation facility plan in J-PARC/宇宙利用のための J-PARC 3NBT および陽子ビーム利用施設における陽子利用

Thursday, 14 November 2024 16:00 (2 hours)

The Japan Aerospace Exploration Agency (JAXA) plans to develop the charged particle spectrum in space to observe the radiation dose for astronauts for Artemis programs. Also, the National Institute of Information and Communications Technology (NICT) plans to develop a spectrum to observe solar flares precisely. Both spectrometers based on Cherenkov radiation are aimed to observe the charged particles up to about 1 GeV. Those institutions want to examine the spectrometers using J-PARC accelerators. To match their requirements and fulfill the safety without disturbing the accelerator operation, a method using beam scattering at the window was developed in J-PARC, which gives us quasi-monoenergetic protons by placing the device at a small angle regarding the incident proton directions. This technique allows us to use the double differential cross sections in several GeV regions, which is explained in this session.

Also, many small space satellites have been planned for future communications. The need for protons for space use has drastically increased, as the need to test the semiconductor devices mounted on the satellites in space environments against failures due to single-event Effects (SEEs). Therefore, the needs are expected to increase drastically worldwide.

For the study of material damage under the beam irradiation circumstance of accelerator-driven systems (ADS), the Japan Atomic Energy Agency (JAEA) had planned to construct a Transmutation Experimental Facility Target Facility (TEF-T) using J-PARC Linac 400 -MeV proton beams and the LBE spallation target. The task force for evaluating partitioning and transmutation technology in the MEXT concluded that the facility should be considered to maximize the advantages of using Linac to meet users' various needs. The proton irradiation facility, a successor of TEF-T, will be constructed to supply the proton beam applications for space use as one of the purposes. In this session, the beam facility, including another purpose, will be explained.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 6

Type: **not specified**

中性子放射化分析による中性子捕獲断面積の高精度測定手法の開発

Session Classification: Presentation by Award of Nuclear Data Division/核データ部会賞
受賞者講演

Contribution ID: 7

Type: **not specified**

4次元 **Langevin** 模型を用いた即発崩壊過程に伴う核分裂観測量の体系的計算のための枠組みの構築

Session Classification: Presentation by Award of Nuclear Data Division/核データ部会賞
受賞者講演

Contribution ID: 8

Type: **not specified**

Status and plans for critical facility modified-STACY/臨界集合体 STACY 更新炉の現状と 今後の計画

Friday, 15 November 2024 12:50 (30 minutes)

In the TEPCO's Fukushima Daiichi Nuclear Power Plant accident, fuel debris was formed by fuel melting and mixing with in-core structures. Although the detailed properties of the fuel debris are still unknown, it is thought to contain materials such as iron and concrete. Then, in order to understand the criticality characteristics of fuel debris, JAEA is conducting a comprehensive numerical analysis assuming the composition of fuel debris containing concrete and iron. However, integral experimental data including these materials are scarce, and the validation of the analytical results has not been fully investigated. Thus, JAEA modified the criticality facility STACY in order to obtain experimental data that will contribute to the validation. This report describes the outline and status of the modified-STACY, and the plan is also presented.

The modified-STACY core is assembled in the open-top core tank using fuel rods and light water moderator. Each fuel rods consists of a zirconium alloy clad tube (9.5 mm outer diameter) and UO₂ pellets. Experimental apparatus can be loaded inside the core within the scope of the license. The water level controls the core reactivity, and the critical water level data are obtained. The modification of the STACY was completed in December 2023 and its first criticality was achieved in April 2024. Experimental campaign for investigation of characteristics of the fuel debris was started in August 2024, and the experiments are currently being conducted in the core consisting only of fuel rods and light water moderators.

Experiments on the core containing the structural materials will be conducted in January 2025. In these experiments, stainless steel rods of the same size as the fuel rods and Al cladding tubes of the same size filled with a concrete simulant will be used as the experimental apparatus to simulate the structural materials. By using them, the effects of contaminants such as iron, silicon, and calcium on criticality will be investigated. In addition, the presentation will also report on plans after the debris experiment is completed.

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Session Classification: Status of Nuclear Reactor Facilities/原子炉施設の現状

Contribution ID: 9

Type: **not specified**

New Approaches in Nuclear Data Evaluation through Bayesian Machine Learning/ベイズ機械学習 による核データ評価の新たなアプローチ

Friday, 15 November 2024 10:20 (30 minutes)

Nuclear data are essential for the research and development of nuclear energy systems and accelerator facilities, and applications involving radioactive isotopes. However, the increasing complexity of theoretical models and the demands of large-scale computations have made sustainable nuclear data evaluation challenging with limited human resources. To overcome these difficulties and continue providing reliable nuclear data, it is crucial to advance nuclear data evaluation methods.

In this talk, I will explore possible solutions to these issues through Bayesian machine learning, using examples from our recent work. [1,2].

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- [2] H. Iwamoto, M. Niikura, R. Mizuno, “Comprehensive Bayesian machine learning approach to estimating the total nuclear capture rate of a negative muon”, *Phys. Rev. C* (submitted).

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Session Classification: Recent Topics/最近のトピックス

Contribution ID: 10

Type: not specified

Construction of a framework for the systematic calculation of prompt fission observables using a four-dimensional Langevin model/4次元 Langevin 模型を用いた即発崩壊過程に伴う核分裂観測量の体系的計算のための枠組みの構築

Thursday, 14 November 2024 13:40 (30 minutes)

Fission observables such as neutron multiplicity, the spectrum, and the mass/charge distributions of fission fragments/products play an important role in evaluating safety and effectiveness for nuclear applications. However, these types of data are limited due to the difficulties of experiments and their associated factors. Moreover, theoretical calculations for these observables are also challenging since the fission process is rooted in several different physical mechanisms.

We proposed a new framework for the systematic calculation of the prompt fission observables and applied it to a series of Pu isotopes [1]. This framework consists of calculations of deformation up to the scission of a nucleus (before the prompt decay) and the process of the prompt decay. The mass distribution of fission fragments and the total kinetic energy of the fragments before prompt decay were calculated using a four-dimensional Langevin model [2], which is a nuclear physics-based approach. We calculated accurate mass distributions of fission fragments by superposing two Langevin calculations, taking into account the influence of different magic shells. Then, fission observables after prompt decay were calculated in a consistent manner using the Hauser-Feshbach statistical decay model. We employed a nuclear reaction code TALYS [3,4] and used the obtained Langevin results as the inputs.

In the presentation, we will compare the calculated fission observables with the previous Langevin results, as well as experimental and evaluated data, and show that our results successfully capture the known trends and reasonably reproduce the data.

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Session Classification: Presentation by Award of Nuclear Data Division/核データ部会賞

受賞者講演

Contribution ID: 11

Type: **not specified**

Differential Cross-Section Measurements for Thermal Neutron Scattering Law at J-PARC/J-PARC における熱中性子散乱則のための微分断面積測定

Thursday, 14 November 2024 14:50 (30 minutes)

Thermal neutron scattering law (TSL) is one of the important nuclear data that affect reactor characteristics such as criticality in the core design of thermal reactors. TSL describes neutron scattering due to atomic and molecular dynamics within materials. Evaluated nuclear data files include the latest TSLs, which were derived by molecular dynamics calculations [1]. The derived TSLs are verified using double-differential cross sections (DDSCSs) and total cross sections, which include thermal-neutron scattering. For this purpose, studies on measuring DDSCSs and/or total cross sections in the neutron energy range from thermal to a few meV have been carried out at the Materials and Life Science Experimental Facility in the Japan Proton Accelerator Research Complex (J-PARC). Preliminary results of graphite, NaCl, KCl, CaH₂, ZrH₂, and YH₂ were obtained [2]. This presentation reports on the current status and future plans for DDSCS and total cross section measurements in J-PARC.

Acknowledgment

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- [2] A. Kimura et al., “Total and Double Differential Scattering Cross-Section Measurements of Isotropic Graphite”, EPJ Web of Conferences 294, 01002 (2024).

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Session Classification: Current Status and Issues of the Thermal Neutron Scattering Law / 熱中性子散乱則データの現状と課題

Contribution ID: 12

Type: **not specified**

Gamma ray spectroscopy for event out of phase of pulsed neutron source for short lived fission products/パルス中性子源に同期しない γ 線のスペクトル測定による短寿命 FP 放射能評価

Friday, 15 November 2024 14:30 (30 minutes)

Delayed gamma ray assay (DGA) is a promising technique for estimating fission rate ratio of uranium (U) and plutonium isotopes contained in spent nuclear fuel [1]. The accuracy of DGA relies on that of the data of fission product yield and decay (FPY & FPD). To enhance the accuracy of the FPY & FPD data, differential measurements have been conducted in the LINAC neutron source facility in KURNS. In the facility, pulsed electron beam with time width of $5 \mu\text{s}$ is periodically injected onto a tantalum target with frequency of 30 Hz. In the target, neutrons are radiated by the photo-nuclear reactions. The neutrons are moderated in a water jacket surrounding the target.

An U-aluminum sample placed 11.4 m from the target was irradiated by the moderated neutrons and γ rays generated by fission and capture reactions were measured with the HPGe detector together with time of flight (TOF) data conventionally to determine incident neutron energy. In the period of 33 ms, there is an out of phase (OOP) time region where the thermal neutrons decay away. γ rays radiated in the OOP region are not prompt ones but those from radio-isotopes with half lives. Then we decided to study the out of phase event spectroscopy (OOPS) to estimate the radio-activities of FPs. The advanced points of OOPS are 1) major discrete energy γ rays for DGA are measurable, 2) decay γ rays can be distinguished from the prompt ones with the TOF data, 3) FPs with half lives shorter than a second are measurable, and 4) the sample and the γ ray detector have never been displaced. In the OOP region, discrete energy γ rays from 1 MeV to 5.5 MeV were detected.

Radio-activities of FPs and emission rates of γ rays were calculated based on the JENDL/FPY&FPD-2011 data base [2] by solving the Bateman equation. By comparing the calculated and the measured γ ray spectra, FP nuclides with half-lives from 0.5 s to 2.6 h were identified, such as $^{95,96,97,98}\text{Y}$, $^{89,90,90m,91}\text{Rb}$, ^{86}Br , ^{95}Sr , etc. Estimation scheme of the detection efficiency and the estimation of radio-activity considering the time spectrum of thermal - neutron induced fission are now under development. However, even currently, OOPS is very promising to give data for validation of FPY & FPD data.

References

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Session Classification: Applications of Nuclear Data/核データの応用

Contribution ID: 13

Type: **not specified**

Development of accurate measurement method for neutron capture cross-sections by neutron activation analysis/中性子放射化分析による中性子捕獲断面積の高精度測定手法の開発

Thursday, 14 November 2024 13:10 (30 minutes)

Neutron activation analysis is a highly sensitive and convenient method for qualitative analysis, but it was thought to be unsuitable for quantitative analysis. However, we have applied this method to quantitative analysis and have succeeded in measuring neutron capture cross-sections with high accuracy. By paying careful attention to uncertainty factors related to measurements, such as sample preparation in the experimental process, the neutron irradiation field, the use of Gd shielding material instead of a conventional Cd material, the development of neutron flux monitors, and the nuclear data used for analysis, we have developed a highly accurate measurement method for neutron capture cross-sections. Using this technique, we have been able to carry out systematic measurements of long-live fission products [1-3], minor actinides [4-8] and isotopes [9-13], and have succeeded in deriving cross-section data. When it was difficult to obtain a single element sample, impurities in a sample were used, and their abundance ratio was examined by mass spectrometry to quantify the amount of the target sample, resulting in successful irradiation experiments [14]. Furthermore, when a daughter nuclide is a stable one, it is impossible to derive the cross-section by conventional activation method. However, by combining activation analysis with mass spectrometry. However, by combining activation analysis and mass spectrometry, we succeeded in deriving the cross-sections, demonstrating that mass spectrometry is a very powerful method for measuring cross-sections [15]. This presentation will provide some examples of the experiments and outline how the cross-section data were derived.

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Session Classification: Presentation by Award of Nuclear Data Division/核データ部会賞
受賞者講演

Contribution ID: 14

Type: **not specified**

Remarks on Activation Analyses for Decommissioning/廃止措置のための放射化計算にお ける注意点

Friday, 15 November 2024 09:30 (45 minutes)

Activation analyses are essential in planning and execution of reactor decommissioning, where the ORIGEN-2 and ORIGEN-S codes are often used in Japan. This presentation points out problems in these codes and introduces the ORIGEN code, which is bundled in the US nuclear safety analysis code system SCALE6.2 [1] or later. ORIGEN solves most of the problems but SCALE6.2 bundles only the libraries from the nuclear data library ENDF/B-VII.0 or later. Thus I produced new libraries [2] for the ORIGEN code from JENDL-5. I also present remarks on calculations with the two-dimensional Sn code DORT [3] which is often used to calculate neutron spectra for activation analyses.

References

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Session Classification: Tutorial/チュートリアル

Contribution ID: 15

Type: **not specified**

Current status and issues of evaluation of thermal neutron scattering law for nuclear reactor moderators/原子炉用減速材の熱中性子散乱則評価の現状と課題

Thursday, 14 November 2024 15:20 (30 minutes)

This talk will introduce and discuss the current status and issues of the evaluation of thermal scattering laws (TSL) in the development of the Japanese Evaluated Nuclear Data Library, JENDL.

In thermal neutron reactors, the TSL of the moderator has a significant impact on core calculations. In the JENDL series, the latest version, JENDL-5, is the first to include an original evaluation of TSL. In this evaluation, the TSL of water, a typical moderator, and hydrogen-containing organic compounds such as methane, which is used as a moderator in neutron sources, were evaluated based on molecular dynamics calculations.

However, data for crystalline materials was obtained from the ENDF/B-VIII.0 library. Crystalline materials are often used as moderators in thermal neutron reactors. Such examples are graphite in high-temperature gas-cooled reactors and molten salt reactors, and calcium hydride (CaH₂) in small reactors.

Under these circumstances, we have started to establish a method for evaluating the TSL of crystalline materials with the aim of enhancing the TSL data in JENDL. As a result, we have obtained results that reproduce the experimental values of neutron scattering at J-PARC well for graphite and CaH₂ by using an evaluation method based on first-principles calculations.

In addition, further improvements are underway for the TSL of light water. In order to improve reliability under high-temperature and high-pressure conditions such as reactor operation conditions, we are developing a method for evaluating TSL using molecular dynamics calculations with potentials based on first-principles calculations, which are considered to have high predictability for changes in temperature and pressure. We will also discuss the progress of evaluating TSL for light water using this method.

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Session Classification: Current Status and Issues of the Thermal Neutron Scattering Law / 熱中性子散乱則データの現状と課題

Contribution ID: 16

Type: **not specified**

Development of a gamma-ray detector sensitive to only high-energy gamma-rays/高エネルギーガンマ線にのみ感度を持つ検出器の開発

Thursday, 14 November 2024 16:00 (2 hours)

Measurement of high-energy gamma radiation in high-dose-rate environments is difficult due to problems such as the dead time of a detector. However, there is a need for measurement techniques under high dose rates, such as radiation detection and nuclear data measurement inside nuclear reactors and in radiation contaminated areas. In particular, this issue must be solved in applications such as critical monitoring in handling nuclear debris and neutron cross section measurement of radionuclides. Major component of gamma-rays in these applications is relatively low energy gamma-rays (several hundred keV). Thus, this research project is to solve the issue by developing a gamma-ray detector that is sensitive to only high energy gamma-rays based on a new detection principle that employs electron-positron pair production induced by high-energy gamma-rays and detects annihilation gamma-rays. The detector system consists of a pair-production target and a pair of gamma-ray detectors which detect annihilation gamma-rays from the pair production target. In the present work, the geometrical configuration and the pair production target were optimized by Monte Carlo simulation.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 17

Type: **not specified**

Searching for saddle points on fission energy surfaces using Cassini parameters/Cassini パラメータを用いた核分裂エネルギー曲面でのサドルポイントの探索

Thursday, 14 November 2024 16:00 (2 hours)

The mass and total kinetic energy (TKE) distribution of fission fragments brings essential information on fission dynamics. The fission dynamics have been investigated theoretically with the multi-dimensional Langevin approach, in particular, for actinide nuclei [1]. In this approach, the deformation potential plays a key role in determining the fragment distribution. In order to understand the results of multi-dimensional Langevin calculations, a specific analysis of the structure of the deformation potential is essential. In general, double-humped barrier structures are known for actinide nuclei, but triple-humped barriers are predicted for some nuclides. Identification of the positions and heights of saddle points corresponding to second and third barriers in the multi-dimensional potential space will explain the mass-TKE distributions obtained by Langevin calculations and contribute to the understanding of the origin of various fission modes.

In this study, to investigate the structure of the energy surface in a multi-dimensional deformation space, we focus on the positions and heights of minima and saddle points. The deformation space is described by the Cassini parameter, which is composed of an overall elongation α and deformation parameters α_n , and can flexibly describe various nuclear shapes. We used $\alpha, \alpha_1, \alpha_3, \alpha_4, \alpha_6$ and investigated the structure of the energy surface in a 5-dimensional deformation space. The deformation potential was calculated by adding the microscopic shell correction energy to the macroscopic droplet energy. The saddle points are searched for using the water immersion method. In a multi-dimensional space, there may be many saddle points, and the dam method is used to find them [2]. The 5-dimensional energy surface described by the Cassini parameter is complex, with many saddle points. This is the first attempt to analyze their distribution and height.

In this presentation, the results for Fm isotopes will be presented, since it is known that the mass distribution changes from asymmetric to symmetric between $A = 256$ and 258 in Fm. In ^{256}Fm , an asymmetric third saddle point arises which induces asymmetric splitting. In contrast, in ^{258}Fm , we obtain the symmetric splitting at the third saddle point. It was found that the third saddle point is higher than the second saddle point at ^{256}Fm , whereas the second saddle point is higher than the third saddle point at ^{258}Fm . The changes in the barrier structure in response to the neutron number are thought to lead to changes in the mass distribution.

References

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 18

Type: **not specified**

Problems on Processing of Thermal Scattering Law Data with AMPX-6/AMPX-6 を使った熱中性子散乱則データの処理に関する問題

Thursday, 14 November 2024 16:00 (2 hours)

The US nuclear safety analysis code system SCALE6.2 [1] is also widely used in Japan, but the bundled AMPX continuous energy libraries are produced only from the US nuclear data library ENDF/B. Thus I produced an AMPX continuous energy library of JENDL-5 with the AMPX-6 code [2] bundled in SCALE6.2. In this nuclear data processing I found out that several produced AMPX continuous energy files of the thermal scattering law data in JENDL-5 had strange cross section data. I examined reasons why the strange cross section data were produced in detail and specified that an inadequate processing method of the thermal scattering law data in AMPX-6 caused the strange cross section data. I improved AMPX-6 and obtained adequate AMPX continuous energy files of the JENDL-5 thermal scattering law data.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 19

Type: **not specified**

Comparison of CsI(Tl) and NE213 responses to high-energy neutrons using PHITS simulation/PHITS による高エネルギー中性子に対する CsI(Tl) and NE213 の応答特性評価

Thursday, 14 November 2024 16:00 (2 hours)

A shielding experiment campaign using NE213 liquid scintillator was conducted to measure high-energy neutrons at the CHARM facility located in CERN [1]. From the neutron spectra obtained with the NE213 scintillator, it was observed that the high-energy components originated from nuclear reactions between the Cu target and 24 GeV/c proton beam.

However, significant discrepancies between measured and calculated data were observed, not only in their shapes but also in integrated values within the high-energy region above 100 MeV. The reason is that the maximum proton energy to fully stop within 12.7 cm thickness of the NE213 scintillator is about 124 MeV according to the SRIM calculation. Thus, the recoil protons having more than this energy pass through the scintillator, with depositing only a portion of their energies. There is a need to develop a new detector that is more sensitive to energies above 124 MeV.

Using PHITS simulation, the response differences between CsI(Tl) and NE213 scintillators were evaluated to clarify the high-energy neutron detection. The dimension of the CsI(Tl) crystal and NE213 are 5 cm x 5 cm x 30 cm-length and ϕ 12.7 cm x 12.7 cm-length, respectively. Additionally, a 3x3 assembly of CsI(Tl) crystal was modeled to increase the effective area for absorbing secondary particles from the high-energy neutron interaction. It is expected that the maximum deposition energy by neutrons can reach more than 400 MeV. This study enables a more accurate characterization of the energy distribution of high-energy neutrons that are mainly present in high-energy accelerator facilities.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 20

Type: not specified

Selection of activation foil for error reduction of benchmark experiment on large angle elastic scattering reaction cross section of Li by 14 MeV neutron/リチウムの 14MeV 中性子大角度散乱断面積ベンチマーク実験における誤差低減のための放射化箔の選定

Thursday, 14 November 2024 16:00 (2 hours)

In high-energy and high-intensity neutron environments, such as the fusion reactor blanket, large angle scattering reaction cross sections significantly affect neutron transport calculation results. C. Konno has identified discrepancies between experimental and calculated values in the blanket benchmark experiments in Japan Atomic Energy Agency (JAEA) [1]. Therefore, benchmarking studies for large angle scattering cross sections are indispensable. The authors' group developed a benchmark experimental system utilizing the foil activation method to validate these cross sections [2]. Four experiments for a certain sample were conducted using two shadow bars composed of conical irons with and without the sample to extract large angle scattering neutrons.

In the previous study, we performed a benchmark experiment for lithium using hafnium as the activation foil. However, due to lithium's low mass, detecting large angle scattering neutrons was challenging, leading to considerable experimental errors caused by neutrons scattered from walls and other surrounding materials. In that study, to investigate whether large angle scattered neutrons from lithium could be detected, the counts obtained with the Ge detector and the associated statistical errors were calculated when various elements were used as the activation foil, concluding that hafnium was the best activation foil. However, the statistical error estimation did not account for background contributions, a significant factor in the experiment. Furthermore, the cooling and measurement times required further optimization.

In this study, we recalculated the statistical error by considering background effects and recalibrating the cooling time, and obtained statistical errors at various measurement times. Six isotopes were selected for measurement based on factors such as isotope abundance, activation cross section, threshold value, and half-life. The reaction rate for each activation reaction was calculated using MCNP5, the Ge detector counts were determined, and the statistical error was recalculated. Our results indicated that using the $^{24}\text{Mg}(n, p)^{24}\text{Na}$ reaction with magnesium as the activation foil the lowest statistical error was obtained, i.e., approximately one-third of that obtained when using hafnium. In addition, it was found that modifying the thickness of the activation foil further reduced the statistical error.

In the future we will develop an experimental system that could further minimize statistical errors by optimizing the materials and configurations of surrounding components of the experimental assembly, and carry out benchmark experiments with the assembly for large angle scattering cross section for lithium using magnesium as the activation foil to obtain highly accurate experimental results.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 21

Type: **not specified**

Study of INC model for alpha inelastic scattering at 230 MeV/u/230MeV/u の α 粒子の非弾性散乱に関する INC 模型の研究

Thursday, 14 November 2024 16:00 (2 hours)

The Intranuclear Cascade model has been improved for calculating alpha induced reaction. Alpha inelastic reaction is dominant for the alpha incident reaction, so that its cross section must be calculated accurately. However, it is difficult to optimize the inelastic reaction and fragmentation reaction for all fragment channel in parallel. Therefore, in this study, we focus on the inelastic reaction only and calculate the cross section for alpha particles using the break-up model having dependency of target mass density. The calculation results were compared with experimental data of double differential cross sections for the alpha particle at incident energy of 230 MeV/u on ^{27}Al . As a result, good agreements are obtained.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 22

Type: **not specified**

Production of Medical Radioisotopes at RIKEN RI Beam Factory/理研 RI ビームファクトリーにおける医療用ラジオアイソトープの製造

Friday, 15 November 2024 15:00 (30 minutes)

Radioisotopes (RIs) are widely used as tracers and radiation sources in basic research in physics, chemistry and biology, as well as in medical, agricultural and industrial applications. We are developing production technologies for useful RIs and promoting RI application research in various research fields using the heavy-ion accelerators in the RIKEN RI Beam Factory [1–3]. More than 100 RIs covering almost the entire periodic table of elements, from beryllium (Be) to element 107, bohrium (Bh) have been produced with the RIKEN AVF cyclotron and the RIKEN linear accelerator. On the other hand, RIs of a large number of elements (multitracer) are simultaneously produced from metallic targets such as ^{nat}Ti , ^{nat}Ag , ^{nat}Hf , and ^{197}Au irradiated with a 135-MeV/nucleon ^{14}N beam from the RIKEN Ring Cyclotron. RIKEN RIs are used for applied research in various fields ranging from chemistry of new elements to diagnosis and therapy of cancer, in collaboration with researchers in the world. In this symposium, the development and application of ^{211}At [4–6] and ^{225}Ac [7,8] will be discussed, especially from the viewpoint of their nuclear data and potential application to targeted α -particle therapy.

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Session Classification: Applications of Nuclear Data/核データの応用

Contribution ID: 23

Type: **not specified**

Study of INC model for proton induced reaction near 0 degrees/0 度近傍における陽子入射反応に対する INC 模型の研究

Thursday, 14 November 2024 16:00 (2 hours)

The intranuclear cascade model has been improved for calculating proton-induced reactions; the calculation results near 0 degrees remain unsatisfactory. It is known that several types of giant resonances exist near 0 degrees. In this study, giant resonances were incorporated, and comparisons with experimental data were conducted to examine mass and energy dependencies. The experimental data includes the double differential cross-section for the reactions, for example, $^{208}\text{Pb}(p,n)$ at 78 MeV and $^{208}\text{Pb}(p,p')$ at 295 MeV. As a result, good agreement was achieved.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 24

Type: **not specified**

Evaluation of Nuclear Decay Data to Revise ENSDF and Verification of JENDL-5 Decay Data File for Burnup Calculation/ENSDF の更新に向けた崩壊データの評価と燃焼計算のための JENDL-5 Decay Data File の検証

Thursday, 14 November 2024 16:00 (2 hours)

To calculate reliably and accurately concentrations and activities for nuclides generated or depleted by fission and radioactive decay in nuclear fuel, it is necessary to use the updated nuclear decay data such as half-lives, branching ratios, and γ -ray spectra. The Evaluated Nuclear Structure Data File (ENSDF) contains required decay data for all nuclides, which is periodically revised by evaluating all available experimental data. However, the latest revision of ENSDF was more than 10 years ago for many nuclides, and the evaluated data for them are old. Therefore, we are performing new evaluations of decay data for these nuclides. This presentation gives a few examples of our evaluation and compares the newly evaluated values and those in the present ENSDF.

An example is the β -decay half-life of ^{129}I , which is crucial nuclear data for managing nuclear waste because this nuclide is one of the long-lived fission products. We carefully read the references that have reported the half-life measurements of ^{129}I so far to determine whether their values can be adopted. Also, a statistical analysis, such as the χ^2 -test, was conducted on these values. After these procedures, we have determined that the value in the latest reference, $1.614(12) \times 10^7$ y, should be the recommended value rather than the average, including other older values. The present ENSDF value, revised in 2014, is $1.57(4) \times 10^7$ y.

JENDL-5 Decay Data File (DDF) is one of the sub-libraries of JENDL-5 and was publicized in 2021. Most of the data in JENDL-5 DDF were taken from ENSDF. We verified the values in JENDL-5 DDF by using our newly evaluated values. For example, the half-life of ^{129}I in JENDL-5 DDF is 1.5711×10^7 y \pm 4.0027×10^5 y. This uncertainty is considerably larger than that of the newly evaluated value. Regarding the Q-values of β -decay, our evaluation takes the values from the latest atomic mass evaluation AME2020 [1], while JENDL-5 DDF adopted the values from the former version, AME2016. The Q-value for each nuclide, especially for shorter half-lived ones, is slightly different between versions of AME.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 25

Type: **not specified**

Possibility of Synthesizing New Superheavy Elements using ^{51}V , ^{54}Cr Projectiles/ ^{51}V , ^{54}Cr 入射核を用いた新超重元素の合成可能性

Thursday, 14 November 2024 16:00 (2 hours)

In recent years, the synthesis of new superheavy element(SHE) as been paid attention around the world. When synthesizing SHEs, hot fusion using ^{48}Ca as projectile and actinides as targets is successful for many SHEs up to Og ($Z=118$) [1,2]. In synthesizing SHEs after $Z=119$ by hot fusion, if ^{48}Ca is used as projectile, it is necessary to use nuclides after Es ($Z=99$) as targets. However, nuclides after Es ($Z=99$) have so short half-lives, it is not practical to use them as targets. Therefore, to synthesize SHEs after $Z=119$, it is necessary to use projectile with a higher number of protons than ^{48}Ca . This allows the target to be determined relatively stable nuclide in actinides. The synthesizing of SHEs includes touching process, formation process, and decay process. We calculate evaporation residue cross section by combining three probabilities of these processes. The touching probability is calculated by coupled channel model [3,4]. The formation probability of compound nucleus is calculated by dynamical model with Langevin equation [3]. And the survival probability of excited compound nucleus is calculated by statistical model [5]. In this study, we calculated the evaporation residue cross sections using ^{51}V and ^{54}Cr , which have more protons than ^{48}Ca , as projectiles and actinides as targets. And we analyzed the effect of difference in combination of projectiles and targets on cross sections.

In this presentation, we mainly discuss the effect of Q -value, that depends on the mass tables, on rising positions of cross sections' excitation functions and the associated difference in evaporation residue cross sections.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 26

Type: **not specified**

Development of a detection technique for nuclear fuel materials using photonuclear reactions/光核分裂反応を利用した核燃料物質検知技術の開発

Thursday, 14 November 2024 16:00 (2 hours)

Nuclear security at nuclear reactor facilities is a significant concern, particularly with regards to the theft and smuggling of nuclear material, as well as sabotage of the facilities. One crucial task to prevent these security incidents is the development of non-destructive detection techniques for identifying nuclear material. Although numerous techniques have been proposed, further study is still needed to meet the necessary requirements.

Previous research has proposed to employ a photon beam from the inverse Compton scattering using a large accelerator [1]. However, this approach requires a large accelerator facility.

In comparison to previous research, the present research aims to develop a new system using a small accelerator. This research uses the nuclear reaction ${}^7\text{Li}(p, \gamma){}^8\text{Be}$ that has never been focused upon in nuclear security fields. A non-destructive detection system using this high-energy γ -ray source is under development. When a high-energy photon interacts with nuclear material, such as uranium or plutonium, it induces nuclear fission and emits fast neutrons. In this way, the amounts of nuclear materials can be identified by measuring neutrons. Neutrons possess a high power of penetrability, enabling the detection of nuclear material even if it is concealed within a container made of high-Z materials [1]. As the first step, a neutron detection technique employing ${}^7\text{Li}(p, \gamma){}^8\text{Be}$ photon source is being studied. ${}^{197}\text{Au}$ sample is used for a test experiment and neutrons from the photonuclear reaction are detected. When ${}^{197}\text{Au}$ is irradiated with γ -rays, it produces both neutrons and γ -rays. To separate neutrons and γ -rays, the pulse shape discrimination technique is employed. Time-of-flight (TOF) can also be used for reducing background. The project outline and preliminary results of the study will be presented.

References:

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 27

Type: **not specified**

Development of a neutron resonance analysis technique for nondestructive fissile material assay and nuclear data/核分裂性物質を非破壊分析するための中性子共鳴分析法の技術開発と核データ

Friday, 15 November 2024 14:00 (30 minutes)

The Japan Atomic Energy Agency (JAEA) has been developing various non-destructive assay (NDA) techniques [1] to verify nuclear materials. However, one major challenge in NDA is measuring highly radioactive materials. To address this, neutron resonance analysis (NRA) has been proposed as a promising active neutron NDA technique. NRA combines neutron resonance transmission analysis (NRTA) [2] with neutron resonance capture analysis (NRCA) [2, 3] and the newly introduced neutron resonance fission neutron analysis (NRFNA) [4]. In an NRA system, a pulsed neutron beam, in conjunction with the neutron time-of-flight (TOF) method [2], is used to measure transmitted neutrons, capture gamma-rays, and fission neutrons from a fissile material sample. The system employs a GS20 glass scintillator for detecting transmitted neutrons, while a pulse shape discrimination (PSD) plastic scintillator is used to detect and discriminate between capture gamma-rays and fission neutrons. The positions and depths of resonance peaks or dips in the TOF spectra are determined by the neutron cross sections of nuclides and their amount in the sample. Therefore, to accurately identify and quantify fissile materials based on these spectra, the use of the evaluated nuclear data library is essential. This presentation will provide a detailed overview of the NRA project and discuss the critical role of accurate nuclear data in its success.

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Session Classification: Applications of Nuclear Data/核データの応用

Contribution ID: 28

Type: **not specified**

Generation of JENDL-5 Covariance Libraries and their Application on the Nuclear Data Uncertainties for the Indonesian RSG GAS Multipurpose Research Reactor/JENDL-5 共分散ライブラリの作成及びインドネシア RSG GAS 多目的研究炉の核データによる臨界性の不確かさ評価への応用

Thursday, 14 November 2024 16:00 (2 hours)

The JENDL-5 [1] covariance library, covering 105 nuclides, was generated using the AMPX-6 code system [2]. Additionally, a covariance library was also generated from ENDF/B-VIII [3] for JENDL-5 nuclides lacking covariance data. These covariance libraries facilitated the estimation of keff uncertainty attributable to the nuclear data of the Indonesian RSG GAS Multipurpose Research Reactor (clean first core criticality experiments). The RSG GAS is a material testing reactor, characterized by its beryllium reflector, light-water moderator, and low-enriched uranium (19.75 wt.%) fuel. Sensitivity coefficients for the ten dominant reaction types required for uncertainty evaluation were derived using the MCNP6 code [4]. The estimated keff uncertainties due to nuclear data are 620 pcm, 644 pcm, and 637 pcm for JENDL-5 only, JENDL-5 & ENDF/B-VIII.0, and ENDF/B-VIII.0 covariance libraries, respectively, which are comparable with the keff $([C/E-1])$ values.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 29

Type: **not specified**

Analysis of angular momentum of produced nuclei and particle emission angles in multinucleon transfer reactions/多核子移行反応における生成核の角運動量と粒子放出角度の解析

Thursday, 14 November 2024 16:00 (2 hours)

The analysis of the properties of nuclei in the neutron-rich region, one of the challenges in nuclear reactions, is very important in the study of superheavy element synthesis and the r-process in astrophysics. However, most nuclei in this region are not yet known [1]. As a means of reaching this region, a method based on multinucleon transfer reactions has been proposed [2].

At present, experimental studies on multinucleon transfer reactions have intensified with the development of accelerators and other experimental techniques [3]. However, the physical mechanism of the multinucleon transfer reaction itself has not been completely clarified. In this respect, it is essential to contribute to experimental studies through theoretical approaches.

In this study, a theoretical dynamical model applying the Langevin equation was used to analyze multinucleon transfer reactions targeting a spherical nucleus. Correlations between the particle emission angle and the number of transferred nucleons, which can be measured experimentally, and the angular momentum of the product nucleus, which cannot be measured experimentally, were investigated. This is important for multinucleon transfer reactions because the survival probability depends on the angular momentum of the produced nuclei. We report on the correlation of each parameter since the calculations were performed in a reaction using an Xe beam and a target nucleus.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 30

Type: **not specified**

Development of a measurement system for the surrogate reaction method/代理反応法測定用測定装置の開発

Thursday, 14 November 2024 16:00 (2 hours)

We are developing a measurement system for the simultaneous determination of (n,γ) , (n,f) , (n,n') , and $(n,2n)$ reaction cross sections using the surrogate reaction method. The system consists of $\text{LaBr}_3(\text{Ce})$ scintillators for high-energy γ rays, Ge detectors for low-energy discrete γ rays, Si detectors for scattered particles, and solar cell charged-particle detectors for fission fragment measurements. To investigate the performance of the measurement system, ^3He beams were irradiated to a ^{243}Am target at the JAEA-Tokai tandem accelerator facility to observe the scattered particles from the target, and γ -rays and fission fragments emitted from the compound nuclei produced by the ^3He -induced reaction. In this poster presentation, the details of the measurement system and the results of the experiment will be discussed

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 31

Type: not specified

Measurement of neutron capture cross-sections of ^{99}Tc at ANNRI of J-PARC MLF/J-PARC MLF ANNRI を用いた ^{99}Tc の中性子捕獲断面積の測定

Thursday, 14 November 2024 16:00 (2 hours)

Technetium-99 is a long-lived fission product (LLFP) which undergoes γ -decay with a half-life of 211,100 years. This long-lived nature and relative abundance of production (approximately 6% of fission events produce ^{99}Tc) and environmental mobility makes long term waste storage challenging. As such it is a possible candidate for being reduced via nuclear transmutation. The $^{99}\text{Tc}(n, \gamma)^{100}\text{Tc}$ produces ^{100}Tc which undergoes γ -decay to the stable ^{100}Ru with a half-life of 15.46 min. To design systems that could drive these reactions, more accurate neutron capture cross-section data is required. There are large differences between experimental data of the neutron capture cross-sections, especially in the keV neutron energy range [1][2][3][4]. This motivated the present measurement of the neutron capture cross-sections of ^{99}Tc .

The experiment was conducted at the Accurate Neutron-Nucleus Reaction measurement Instrument (ANNRI) beamline at the Materials and Life Science Experimental Facility (MLF) at the Japan Proton Accelerator Research Complex (J-PARC). Capture γ -rays from neutron capture events were measured using a NaI(Tl) detector placed at a 90 degree angle to the neutron beam axis. The total mass of the ^{99}Tc sample was 78 mg with a diameter of 6.3 mm and an activity of 1.4 mCi at time of preparation and was contained in an aluminum sample case. The sample was placed at a neutron flight distance of 27.9 m and capture γ -rays were measured from thermal to the keV energy range. The time-of-flight (TOF) method was employed to determine the incident neutron energy. The incident neutron spectrum was determined by placing a sample of boron enriched with ^{10}B at the sample position and detecting 478-keV γ -rays from the $^{10}\text{B}(n, \gamma)^7\text{Li}$ reaction. A blank run, a dummy case and a carbon sample were also measured for the purposes of background subtraction. From this raw TOF spectrum the neutron capture yield was calculated using the pulse height weighting technique. Self-shielding and multiple scattering were accounted for using PHITS simulation code. The neutron capture-cross section of ^{99}Tc from the thermal to keV energy region were derived. This presentation will compare present results with past data and provide a discussion.

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Trajectory analysis of the 4-D Langevin model using principal component analysis/主成分分析による 4 次元ランジュバンの軌道解析

Thursday, 14 November 2024 16:00 (2 hours)

The four-dimensional Langevin model [1,2,3] is a nuclear physics model that allows for the independent treatment of each fission fragment and accurately reproduces the total kinetic energy (TKE). However, due to the multidimensional nature of the model, it is challenging to quantitatively determine which physical quantities exhibit a strong correlation with nuclear fission. In this study, we applied Principal Component Analysis (PCA) [4] to project the fission trajectory data obtained from the four-dimensional Langevin model onto a space defined by principal component vectors, aiming to identify the most significant physical quantities. Specifically, we used 1000 events for each of the standard and super-short fission modes of ^{258}Fm to obtain the variance for the PCA analysis. Based on these findings, our results indicate that contributions from components different from those typically assumed became more prominent.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 33

Type: **not specified**

Angular momentum distribution and mechanisms of evaporation residue produced in multi-nucleon transfer reaction/多核子移行反応で生成した蒸発残留核の角運動量分布とメカニズムの解明

Thursday, 14 November 2024 16:00 (2 hours)

Recently, multi-nucleon transfer (MNT) reactions have attracted attention as a method of producing neutron-rich nuclei [1]. However, the reaction mechanism is not yet well understood due to its novelty and complexity. In this study, we construct a dynamical model that describes the dynamics of the MNT reaction and verify the model by comparing it with experimental data to clarify the reaction mechanism.

As a first step, to clarify the reaction mechanism, the angular momentum of the evaporation residue (ER) produced by MNT reaction and the emission angle of projectile-like nuclei were investigated. It is known that the fission process of ERs depends on their angular momentum, and the information of angular momentum is important to know the survival probability of the ER [2]. The emission angles of projectile-like nuclei are also experimentally observable data, which is necessary information for angular momentum prediction. There is a correlation between angular momentum and the emission angle of projectile-like nuclei. The present study aims to deal with the production of neutron-rich nuclei in the heavy and superheavy elemental regions. In this work, MNT reaction in the $^{86}\text{Kr} + ^{166}\text{Er}$ system is calculated. The collision angles were then taken into account along with the deformed target nuclei.

The theoretical model we use is based on the two-center shell model to describe the configuration of nuclei [3]. The time evolution of the configuration is described by the multidimensional Langevin equation [4]. In this presentation, we show the effect of the collision angle in the case of a deformed target nuclei and discuss its influence on the reaction mechanism. The effect of the angular momentum of ERs on the following fission process is also discussed.

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Study of fission modes in ^{258}Md with six-dimensional Langevin equation/6次元 Langevin 方程式を用いた ^{258}Md 核分裂モードの研究

Thursday, 14 November 2024 16:00 (2 hours)

Understanding nuclear fission is critical for updating and improving the nuclear data. In particular, significant questions remain regarding fission near the mass number $A = 257$, where the dramatic changes in fragment mass distribution due to variations in neutron number are observed. These phenomena are generally attributed to shell effects, although a detailed explanation has yet to be provided. Moreover, it is important to clarify the dependence of excitation energy on the shell effects.

Recently, measurements of the fragment mass and total kinetic energy (TKE) distributions for the fission of ^{258}Md , which is produced in the $^4\text{He} + ^{254}\text{Es}$ reaction and conducted at JAEA, indicate the coexistence of multiple distinct fission modes: short symmetric, asymmetric, and super-long symmetric fission [1]. To understand these observations, the analysis of fission paths obtained from dynamical calculations using high-dimensional Langevin equations plays an important role. These calculations explore the origins of the observed distributions, shedding light on the mechanisms driving each fission mode.

In this study, we calculate the fission process of ^{258}Md with the multi-dimensional Langevin equation with the Cassini shape parameterization [2]. To describe various fission modes, we use the six Cassini shape parameters $\{\alpha, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5\}$, and apply them to the six-dimensional Langevin equation. The combination of these shape parameters can flexibly describe deformed nuclear shapes. This is the first attempt to calculate the Langevin dynamics in the six-dimensional collective coordinates. The resulting fragment mass and TKE distributions show the existence of three types of fission modes, consistent with the measurement data. Furthermore, by increasing the excitation energy from 15 MeV to 18 MeV, the relative contribution of each mode is changed. With higher excitation energy, the short symmetric fission mode decreases significantly, and the asymmetric fission mode becomes dominant. It is considered that the shell effect corresponding to short symmetric fission is largely damped by the increase in excitation energy. Through analysis of fission paths obtained from these six-dimensional Langevin calculations, we expect to elucidate the physical origins and mechanisms of each fission mode.

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Session Classification: Poster presentation/ポスターセッション

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Decay branching ratios of ^{197m}Hg and ^{195m}Hg determined by decay curve analysis/崩壊曲線分析による ^{197m}Hg と ^{195m}Hg の崩壊分岐比の決定

Thursday, 14 November 2024 16:00 (2 hours)

We studied the decay branching ratios of ^{197m}Hg (24 h) and ^{195m}Hg (42 h) by offline γ -ray spectroscopy of a natural platinum foil irradiated by α -particles at 29 MeV. We observed strong cooling time dependence in the isomeric ratios of ^{197}Hg and ^{195}Hg determined by the conventional activation cross section formula. To eliminate the cooling time dependence, we performed decay curve analysis with the decay branching ratios of these metastable states as adjustable parameters assuming that the isomeric ratios do not depend on the cooling time. We resolved the time dependence by adjusting the isomeric transition branching ratios to $94.5\pm 0.7\%$ and $48.9\pm 1.8\%$ for ^{197m}Hg and ^{195m}Hg , respectively. The ^{197m}Hg decay branching ratio obtained by us is very close to $94.68\pm 0.09\%$ published by Lebeda et al. in 2020 [1].

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Session Classification: Poster presentation/ポスターセッション

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Type: **not specified**

Reevaluation of Neutron Energy Spectrum in Kyoto University BNCT Irradiation Field Using Multifoil Activation Method/多重箔放射化法による京大炉のBNCT 照射場の中性子エネルギースペクトルの再評価

Thursday, 14 November 2024 16:00 (2 hours)

The Heavy-Water Thermal Neutron Facility at the Kyoto University Research Reactor (KUR) has been used for boron neutron capture therapy (BNCT) since 1974. After facility upgrades in 1996, it was renamed the Heavy-Water Neutron Irradiation Facility (HWNIF), and the neutron energy spectrum was measured using the multifoil activation method. In 2010, KUR switched from high- to low-enrichment fuel, but the neutron spectrum in the KUR-HWNIF has not been reevaluated precisely since then. Detail of neutron energy spectrum data in BNCT irradiation fields is essential for various purposes, such as comparing irradiation characteristics across BNCT facilities, developing detectors and spectrometers, and calculating absorption dose.

This study aimed to reevaluate the neutron energy spectrum for the standard epithermal-neutron irradiation mode at KUR-HWNIF using the multifoil activation method. The previous evaluation irradiated the multifoil at 5 MW for 10 hours. Currently, KUR operates at 1 MW for 47 hours and 5 MW for only 6 hours each week. Due to limited 5 MW operation time, we utilized 1 MW power to irradiate the multifoil. With a lower thermal operation power, some foils used in the previous evaluation yielded lower counts during the measurements. In this study, the types of foils used for irradiation, the irradiation time, and the irradiation setup were adjusted from a previous study to obtain measurable results from the irradiated foils. \par

The neutron energy spectrum was evaluated using selected foils and optimized irradiation times, suited for measuring the spectrum in the epithermal and fast neutron ranges, which are predominant in the standard epithermal-neutron irradiation mode. The neutron energy spectrum unfolding process was performed by UMG package which included MAXED and GRAVEL unfolding code [2]. The previous evaluated nominal neutron energy spectrum [1] data was used as initial guess for unfolding process. Comparing with two different unfolding result of UNG package, GRAVEL gave a better evaluation result without any irregularities. Based on the reevaluated results from GRAVEL unfolding code, the epithermal- and fast-neutron fluxes increased by approximately 34% and 19%, respectively. The neutron absorption dose rate at evaluation point was approximately 17% lower than the previous one; however, it remained acceptable from the perspective of BNCT biological irradiation.

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keV-neutron capture cross section measurement of ^{129}I using a Si-filter neutron beam/Si フィルターを用いた ^{129}I の keV 中性子捕獲断面積測定

Thursday, 14 November 2024 16:00 (2 hours)

Diminishing the amount of high-level nuclear waste accumulated through reactor operation has always been a one of the most important obstacles regarding the long-term implementation of nuclear technologies. While the main efforts have been targeting minor actinides (MAs), long-lived fission products (LLFPs) remain another clear target for which several solutions have already been proposed. Among these solutions is the nuclear transmutation of LLFPs by means of fast nuclear reactors, the feasibility of which has been proven in recent studies [1,2]. For this approach, accurate nuclear data in the keV-neutron region are required for most LLFPs such as ^{129}I , ^{126}Sn , ^{93}Zr and ^{79}Se . In particular, iodine-129 poses an environmental threat for geological disposals in comparison with other LLFPs due to being soluble [3]. Moreover, ^{129}I uncertainties in the keV-neutron capture cross section that were estimated to be of 20-29% due to the lack of experimental data [3]. Hence, in order to improve the accuracy of the nuclear data for ^{129}I , further experimental efforts are required.

Neutron filter experiments were performed using the NaI(Tl) spectrometer of the ANNRI beamline at J-PARC to determine the neutron capture cross section at the neutron energies of 51.5 and 127.7 keV. A sample containing 404 mg of ^{129}I was measured, while having the incident neutron flux stream through a 20-cm-thick natSi filter to remove the influence of the double-bunch mode of J-PARC. In addition, a ^{197}Au sample was also measured to normalize the cross-section results. In this study, the results of the ^{129}I neutron capture cross-section at the neutron energies of 51.5 and 127.7 keV are presented. These results were determined relative to the ^{197}Au neutron capture yield measured in the present experiment and the evaluated nuclear data from JENDL-5. This work complements a past experiment using the time-of-flight methodology, in which the neutron capture cross-section of ^{129}I was measured from 10 meV to about 30 keV [4].

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Development of a calculation system contributing to the consideration of production methods for Auger electron emitters/オージェ電子放出核種の生成法の検討に資する計算システムの開発

Thursday, 14 November 2024 16:00 (2 hours)

Recently nuclear medicine therapy using nuclides emitting α rays and Auger electrons is gathering attention [1]. α rays and Auger electrons have a higher linear energy transfer than β rays and are expected to enable the therapy with little damage to normal cells surrounding the tumor. Especially Auger electron emitters have an advantage that their daughter nuclei are less likely to decay compared to α ray emitters. Since there are many Auger electron emitters, and their production reactions and paths are diverse, the best nuclide for practical use and its production method have not been established at present. We are also working for improving the accuracy of nuclear data considering three-body nuclear forces. Based on the above situation, we have developed a system to calculate and illustrate nuclide production cross sections and Thick Target Yield (TTY) from various nuclear reactions for contributing to the consideration of wide range of possibilities on production for Auger electron emitters.

The developed system can calculate and illustrate arbitrary nuclide production cross sections and TTYs from light particle ($n, p, d, t, {}^3\text{He}, \alpha, \gamma$) injection reactions. The nuclear reaction model calculation code CCONE [2] is used to calculate reaction cross sections. In addition, when illustrating, the CCONE calculated values are converted to ENDF-6 format. Therefore, existing nuclear data library values in ENDF-6 format, such as JENDL and TENDL, can also be illustrated and compared. Injection particles, incident energies, and targets including natural compositions can be selected, and the sum of multiple nuclide production cross sections (e.g., ${}^{77}\text{Br}+{}^{77}\text{Kr}$ (decays to ${}^{77}\text{Br}$ with a half-life of 1.24 hours)) can also be output.

Using this system, we investigated the optimal production method for Auger electron emitters. For example, when the incident energy is from 1 to 50 MeV and a natural composed target is used, the production cross section of ${}^{77}\text{Br}$, which is one of the Auger electron emitters, is the largest for $\alpha+{}^{75}\text{As}$ around 25 MeV, while TTY of ${}^{77}\text{Br}$ is the largest for $p+{}^{nat}\text{Se}$ when isotope separation is considered. In this poster presentation, we will also report the results of other Auger electron emitters. Furthermore, we will refer about the evaluation of unwanted nuclides that may be produced, time variation of TTY, and comparison with experimental values and other libraries. In the future, we plan to apply this system to nuclides other than Auger electron emitters to improve the accuracy of nuclear data.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 39

Type: **not specified**

Improvement of dynamical model considering neutron emission effect during fission process/核分裂過程での中性子放出効果を考慮した動力学モデルの改良

Thursday, 14 November 2024 16:00 (2 hours)

The experiments at JAEA have produced a wide variety of nuclei and various excited states through multi-nucleon transfer reactions and successfully observed their fission [1]. The fission fragment mass distributions (FFMDs) obtained in this experiment show a mass asymmetry even in the high excitation energy region. This phenomenon can be explained by multi-chance fission (MCF). In a previous study [2], the neutron emission multiplicity was obtained by the GEF code [3] and then the fission process was calculated by the dynamical model method to incorporate the MCF effect and reproduce the experimental data of FFMDs with high accuracy. However, the above method does not take into account neutron emission during the fission process. Therefore, our group has been developing a model that can describe neutron emission in the fission process by incorporating the neutron evaporation process in the dynamical model [4]. In fact, FFMD calculations can be performed taking into account the decrease in excitation energy due to neutron emission and the accompanying change in the shell correction energy. In this study, we have further improved the model so that it can also take into account variation in the liquid drop model potential due to neutron emission, and we report the results.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 40

Type: **not specified**

Cross section measurement of the $^{nat}\text{W}(p,X)$ reactions by an activation method/放射化法を用いた $^{nat}\text{W}(p,X)$ 反応断面積測定

Thursday, 14 November 2024 16:00 (2 hours)

Tungsten is applied to a target at proton accelerator facilities, e.g., ESS and COMET (J-PARC). Additionally, tungsten is used as a shielding material, such as the ADS facility by JAEA [1]. Thus, activation of tungsten by high-energy protons receives attention because residual γ -ray dose rate has impact on a maintenance schedule. To derive the dose rate, nuclide production cross section is required. Although there are previous studies of the $^{nat}\text{W}(p,X)$ reactions [2,3], there remain nuclides which have not measured yet. Also, nuclear reaction models can predict the nuclide production cross sections. However, the prediction accuracy is not fully understood currently. Hence, further measurement of the reactions in question should be performed. Then, we did an activation experiment of the $^{nat}\text{W}(p,X)$ reactions with GeV-energy proton incidence (0.4, 1.3, 2.2, and 3.0 GeV) at J-PARC following the same manner in Ref. [4].

As a result, a total of 140 nuclides via the $^{nat}\text{W}(p,X)$ reactions were acquired. In this poster, some of the results are presented. According to the average C/E values for obtained nuclides, JENDL/HE-2007 [5] reproduces our Exp. data within 30% for heavy nuclides. In our poster, comparison with nuclear reaction models in PHITS [6] is also presented.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 41

Type: **not specified**

Experimental study of Multinucleon Transfer reaction using JAEA-RMS/JAEA/反跳生成核分離装置を用いた多核子移行反応の研究

Thursday, 14 November 2024 16:00 (2 hours)

Multinucleon transfer (MNT) reactions have attracted attention in the field of nuclear physics and astronomical nucleosynthesis as a reaction which produces neutron-rich nuclei as evaporation residues (ER). But detailed feature of reaction mechanism is not understood. Detailed experimental data are necessary to develop a model to guide an optimal reaction and experimental condition. We have started the measurement of ER cross sections in various conditions. Experiments were carried out using the JAEA Recoil Mass Separator (JAEA-RMS[1]). As a first attempt, we studied the reaction $^{30}\text{Si}+^{209}\text{Bi}$. The production cross sections for each produced isotopes are determined as a function of recoil angle and recoil energy (thus Q-value), where identification of nuclides were achieved by the on-line alpha-decay measurement of the implanted ERs at the focal plane Si detector. The result is the first to realize the on-line decay measurement produce in the MNT reaction at a finite angle.

References

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 42

Type: **not specified**

Understanding the complex dynamics of fusion reactions/融合反応における複雑なダイナミクスの解明

Thursday, 14 November 2024 16:00 (2 hours)

At present, using the fusion reaction between the projectile and target nuclei, up to Og has been successfully synthesized and projects to synthesis of new superheavy elements (SHEs) are underway at several facilities around the world. However, the synthesis probability of SHEs is extremely low, and most of them undergo quasi-fission, which cannot sustain a compound nucleus after contact. Therefore, this study aims to elucidate the complex dynamics of quasi-fission by systematically investigating the reaction mechanism.

To understand the dynamics of the fusion process, we focused on the correlation between fragment mass and its emitting angle of quasi-fission [1]. Our group has succeeded in reproducing the mass angular distribution (MAD) of the emitted nuclei by using a dynamical model, considering the deformation of the target nuclei [2]. The dynamical model is based on the liquid drop model and the shell effect to determine the shape of the nucleus and its potential at that time, and the time evolution of the shape from fusion to fission can be traced by solving the Langevin equation. Calculations of fusion reactions require fitting of indefinite parameters from experimental data, such as energy dissipation due to friction between nuclei and the transition from diabatic to adiabatic potentials, which are suitable for equilibration of the system.

In this study, we calculated the 42 systems experimented in Ref. [1] under identical conditions except for the number of nucleons and summarized the MAD. Among these, we correct the uncertain parameters and systematically evaluate $^{64}\text{Ni}+^{170}\text{Er}$, $^{48}\text{Ti}+^{186}\text{W}$, and $^{32}\text{S}+^{202}\text{Hg}$, which form the compound nucleus of ^{234}Cm .

References

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 43

Type: **not specified**

Feedback on neutron capture cross-section of ^{133}Cs from analysis of measured inventories of ^{133}Cs and ^{134}Cs of UO_2 fuel irradiated in TMI Unit 1/TMI 1 号炉
において照射された UO_2 燃料の ^{133}Cs 及び ^{134}Cs の核種組成測定値の解析から得られた ^{133}Cs の中性子捕獲断面積の知見

Thursday, 14 November 2024 16:00 (2 hours)

Nuclide inventory calculations with MVP-BURN and JENDL-4.0 were performed for the twelve fuel samples taken from two 15×15 PWR fuel assemblies irradiated in Three Mile Island (TMI) Unit 1[1,2]. The calculated results of ^{134}Cs for the one-cycle-irradiation fuel samples and those of ^{133}Cs for the two-cycle-irradiation fuel samples were compared with the measured data. The averaged C/E-1s of ^{134}Cs and ^{133}Cs were -11.2% and 2.9% , respectively. They were similar to those with the previous studies. The C/E-1s were also compared with those with SCALE 5.1 (ENDF/B-V)[1] for ^{134}Cs and those with SCALE 6.1.2 (ENDF/B-VII.0)[2] for ^{133}Cs . The differences in the C/E-1s were mainly attributed to the differences in the neutron capture resonance integrals ($\text{RI}\gamma$ s) of ^{133}Cs in the nuclear data libraries. The C/E-1s of ^{133}Cs and ^{134}Cs in the present study both indicated that a larger $\text{RI}\gamma$ of ^{133}Cs than that in JENDL-4.0 would bring the C/Es closer to 1.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 44

Type: **not specified**

Criticality data of the modified STACY and evaluation results of nuclear data libraries/定常臨界実験装置 STACY 更新炉の臨界データと核データライブラリの評価結果

Thursday, 14 November 2024 16:00 (2 hours)

To develop technologies for criticality safety management during the fuel debris retrieval at the Fukushima Daiichi Nuclear Power Plant, we conduct experiments under various core conditions assumed for fuel debris. JAEA modified the Static Experiment Critical Facility (STACY) from a solution fuel system to a light-water moderated heterogeneous system for critical experiments to study the criticality characteristics of fuel debris. After the modification, STACY was operated to inspect its designed performance on reactor operation, and the first criticality was achieved on April 22, 2024.

In this study, we performed criticality calculations of STACY's critical cores using several nuclear data libraries and compared their results. The five core patterns in a series of performance testing were calculated neutron multiplication factor with the measured critical water levels: (1) 277 fuel rods with a water level of about 70 cm, (2) 253 fuel rods with a water level of about 110 cm, (3) 253 fuel rods with an irradiation sample in the center of the core for thermal power calibration with a water level of about 120 cm, (4) 241 fuel rods with a water level of about 70 cm, and (5) 213 fuel rods with a water level of about 110 cm. Fuel rods are cylindrically loaded on a grid plate with grid intervals of 1.50 cm for cores (1), (2) and (3), and of 1.27 cm with skipping one by one to achieve fuel intervals of 2.54 cm for cores (4) and (5).

We calculated neutron effective multiplication factors of each core using MVP2 with JENDL-4.0, JENDL-5, and ENDF/B-VII.1. Furthermore, in order to analyze the differences between libraries, a comparison was made for representative nuclides by replacing the nuclear data of each nuclide with JENDL-5 in the calculations using JENDL-4.0.

The result using JENDL-4.0 showed that the effective neutron multiplication factor correspond within 3σ for cases of (1), (2), and (3). However, it overestimated about 69 pcm for case (4) and about 33 pcm for case (5). JENDL-5 overestimated all patterns, 195 pcm in maximum.

In this presentation, detailed critical data for all pattern cores and evaluated trends for each nuclide will be presented.

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 45

Type: **not specified**

Development of Neutron Activation Method Using UV Curable Resin Scintillator/紫外線硬化型シンチレーターを用いた中性子放射化法の研究

Thursday, 14 November 2024 16:00 (2 hours)

Strontium-88, which has a neutron magic number of 50, is important in s-process nucleosynthesis because it acts as a bottleneck in the s-process reaction network due to the small (n, γ) cross section. Therefore, the neutron captures cross sections need to be known with high precision for the reliable determination of the s-process abundances. However, there is disagreement between previous experiments. The Maxwellian-averaged neutron capture cross section at 30 keV was 6.13 ± 0.18 mb in Ref. [1] while 5.46 ± 0.45 in Ref. [2]. The two measurements were conducted with different methods: neutron activation method for Ref. [1] and time-of-flight (TOF) method for Ref. [2]. In general, the activation method is a well-established method but the measurement in Ref. [1] is different from the traditional activation method, in which γ -rays from the activated sample are counted with a Ge detector after irradiation. They detected electrons from β -decay with semiconductor detectors because the activated product ^{89}Sr ($T_{1/2} = 50.5$ days) does not emit γ -rays in the β -decay process. Although the β -ray spectrum was not shown in Ref. [1], the result may suffer from low signal-to-background ratio due to the low counting rate, causing overestimation of the cross section. Thus, the purpose of the present study is to improve the neutron activation analysis with a larger detector efficiency achieved by the plastic scintillator made of UV curable resin. The experimental plan and preliminary results will be presented in the presentation.

References

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Session Classification: Poster presentation/ポスターセッション

Contribution ID: 46

Type: **not specified**

Progress in Muon Nuclear Data/ ミュオン核データの 進展

Friday, 15 November 2024 10:50 (30 minutes)

The negative muon (μ^-), which is the second generation of charged lepton and has a 200 times heavier mass than an electron, forms an exotic atom with a nucleus in materials. After the atomic cascade, some of the muons are captured to the nucleus, $\mu^- + p \rightarrow n + \nu_\mu$, with competing for the decay in the atomic orbit, $\mu^- + \rightarrow e^- + \nu_\mu + \nu_e$. The nucleus absorbing a muon is in a unique excited state because the muon has a mass of $105.6 \text{ MeV}/c^2$ and is captured from its $1s$ state, resulting in the highly excited state being generated with low angular momentum, unlike the nuclear collision. In addition to the interest in nuclear physics, the reaction induced by the negative muon has been attracting interest in various fields of study year by year for this decade. The X-rays emitted in the atomic cascade make non-destructive elemental analysis possible, which can apply to archaeological artifacts, etc. The muon-to-nuclear capture can control the artificial transmutation of the nucleus. The basic and application studies using the negative muon are one of the major fractions in the users' programs of the muon facility in J-PARC MLF. However, the series of reactions after muon injection has not been understood comprehensively, and one has to rely on the empirical models, though it has a sort of risk like unexpected radioactivation. To promote the applications of the negative muon, the muon nuclear data is essential and under development [1]. The muon nuclear data will consist of the following four sub-libraries:

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Session Classification: Recent Topics/最近のトピックス

Contribution ID: 51

Type: **not specified**

三体核力～原子核物理の新しい物質観～核データにつ
なげたいという思い

Friday, 15 November 2024 11:20 (30 minutes)

In preparation

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Session Classification: Recent Topics/最近のトピックス

Contribution ID: 52

Type: **not specified**

Present Status and Future Plans of KURN/複合研原子 炉施設の現状と今後の計画

Friday, 15 November 2024 13:20 (30 minutes)

Institute for Integrated Radiation and Nuclear Science, Kyoto University (KURNS) has been operated two research reactors, namely, Kyoto University Research Reactor (KUR) and Kyoto University Critical Assembly (KUCA).

KUR whose maximum power is 5MW starts its operation in 1964 and it has been utilized mainly for supplying fast and thermal neutron in various kinds of research field, however, Kyoto University decided to stop its operation in May-2026 because of several reasons; treatment of spent fuels, facility aging problem, increasing operation cost and so on. After shutdown, we will soon submit decommissioning application of KUR to Nuclear Regulation Authority (NRA) and, firstly, all spent fuels are planning to ship to U.S.A.

KUCA whose maximum power is 100W starts its operation in 1974 and it has been utilized for basic reactor physics experiments and nuclear human resources development through student education experiments. It had used highly enriched uranium (HEU) fuels both at the solid moderated core and the light water moderated core, and according to the reduced enrichment program for research reactors conducted by U.S.A., all HEU fuels was sent back to U.S.A. until 2022 and new low enriched uranium (LEU) fuels have been prepared for KUCA including obtaining license from NRA. For light water moderated core, uranium silicide plate type fuels have been already fabricated in a foreign fuel company and some of them were just transported to KUCA last month. For solid moderated core, world-first uranium-molybdenum alloy coupon type fuels are now under fabrication. We are planning to restart operation of KUCA in 2025 and will utilize it for research and student education.

KURNS owns other radiation facilities such as a hot laboratory where unsealed radioactive material and nuclear materials can be handled for research purpose and operates accelerators; the electron linear accelerator, the proton cyclotron and so on. After shutdown of KUR, we will continue to utilize those unique radiation facilities as joint use research center.

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Session Classification: Status of Nuclear Reactor Facilities/原子炉施設の現状

Contribution ID: 53

Type: **not specified**

EXFOR workshop の報告

Friday, 15 November 2024 16:10 (15 minutes)

In preparation

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Session Classification: Various Reports/各種報告

Contribution ID: 54

Type: **not specified**

日本原子力学会シグマ調査専門委員会の活動

Friday, 15 November 2024 16:25 (15 minutes)

In preparation

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Session Classification: Various Reports/各種報告

Contribution ID: 55

Type: **not specified**

ポスター賞贈呈式, サマリー・総合討論

Friday, 15 November 2024 16:40 (20 minutes)

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Session Classification: Closing remarks/閉会挨拶

Contribution ID: 56

Type: **not specified**

開会挨拶・事務連絡

Thursday, 14 November 2024 13:00 (10 minutes)

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Session Classification: Opening address

Contribution ID: 57

Type: **not specified**

Measurement of residual nuclei with active-target TPCs and Si detectors/アクティブ標的 TPC および Si 半導体検出器を用いた残留核の測定

Friday, 15 November 2024 15:30 (30 minutes)

Time Projection Chambers (TPCs) and silicon (Si) semiconductor detectors are useful to examine residual nuclei in nuclear reaction.

We developed MAIKo and MAIKo+, which are TPC-based active target systems [1]. They enable tracking of low-energy charged particles over a large solid angle by using gas as both the detection medium and target. We utilize them to study triple-alpha reaction, which is one of the most important in nucleosynthesis in the universe. We inject a neutron beam into the MAIKo(+) active targets filled with a detection gas containing carbon, and measure 3 alpha particles emitted from excited states of residual carbon nuclei. A test measurement was conducted at the OKTAVIAN neutron beam facility in Osaka University, and it showed significant potential to measure residual nuclei in nuclear reactions [2].

We also developed a Si detector array SAKRA to detect decay particles from residual nuclei. It has particle-identification capabilities via pulse shape analysis. We demonstrated that SAKRA is capable to distinguish protons from alpha particles at $E > 2$ MeV and alpha particles from carbon nuclei at $E > 5$ MeV, and useful to examine decay processes of residual nuclei and to clarify their internal structures. We employed SAKRA to search for alpha cluster states in ^{24}Mg [3].

In this talk, we will report the performance of MAIKo(+) and SAKRA, and present their application in our recent experimental works.

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Importance and issues of CaH₂ TLS data for reactivity coefficient and core characteristics of MoveluXTM /超小型炉 MoveluXTM における CaH₂ の温度反応度特性と炉心特性における熱中性子散乱則データの重要性と課題

Thursday, 14 November 2024 14:20 (30 minutes)

To realize a decarbonized society, various organizations are developing small modular reactors and micro-reactors [1]. Toshiba Energy Systems & Solutions has been developing a MoveluXTM reactor system with 10 MWt and 3-4 MWe power output. The MoveluXTM core uses less than 5% LEU as the nuclear fuel. Furthermore, calcium hydride (CaH₂) is also used as the solid-state neutron moderator. The hydrogen in CaH₂ dissociated above 800 °C; thus, this temperature is the operation limitation temperature of the core. From the viewpoint of the core characteristics, the CaH₂ moderator shows a positive temperature reactivity coefficient from room temperature to near the operation temperature [2].

The MoveluXTM core utilizes this positive temperature reactivity coefficient to assure critical safety during transport [3]. To evaluate this core characteristic, the TSL of CaH₂ is very important input data for the core calculation. However, only JEFF published TSL data on the CaH₂, and it was based on one experiment's data.

On the other hand, the Toshiba Energy Systems & Solutions Corporation measured TSL of CaH₂ in the past research with Tokyo Tech and Kyoto University. Additionally, JAEA also evaluates this TSL based on the simulation. The MoveluXTM core had around 200 pcm between these TLS data, furthermore, more than a 2% difference in temperature reactivity coefficient was confirmed. These differences were not small, thus, improvement of the CaH₂ TSL data will be required.

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