# 2025 年度核データ +TOMOE プロジェクト合同研究会/Joint Symposium on Nuclear Data and ERATO TOMOE project in 2025

Wednesday, 19 November 2025 - Friday, 21 November 2025

JAEA Tokai Mirai Base

# Book of Abstracts

# Contents

**Opening Plenary / オープニングプレナリー / (1/2)**

## Present and future of JENDL-5/JENDL-5 の現在と将来

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The latest version of the Japanese Evaluated Nuclear Data Library, JENDL-5, was released at the end of 2021. JENDL-5 integrated the nuclear data released as the general-purpose and special-purpose files to meet the growing needs in various fields of nuclear energy and radiation applications [1]. The library consists of 8 nuclear related sub-libraries and 3 atomic related ones. While the atomic related data were adopted from ENDF/B-VIII.0, a large part of the nuclear related data originates from the JENDL libraries. So far, the fission product yields and thermal scattering law in JENDL were adopted from other libraries such as ENDF and JEFF, JENDL-5 includes the originally evaluated ones for those. The neutron reaction data, the most important data in the nuclear data library, was updated and increased in the wide range of nuclides from light to heavy ones. The number of nuclides increased to nearly double the previous version JENDL-4.0, and the incident neutron energy range was extended from 20 MeV to 200 MeV for many nuclides. In the viewpoints of the performance of reactor calculations, the benchmark results for those showed significant improvements from ones of the JENDL-4.0 especially for plutonium-related cores.
For the next version of JENDL-5, the uncertainty of the evaluated data, i.e. covariance, is focused on for revision due to the lack of those data for many nuclides. They are important to evaluate the uncertainties due to the nuclear data for the neutronics calculations especially for new types of nuclear reactor systems. In addition, new measurements of nuclear reactions and thermal neutron scattering with ANNRI and other facilities in J-PARC are in progress. They will be considered for updates. Other efforts about muon nuclear data and nuclear three-body forces have been launched. They would progress the data of JENDL.

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**Opening Plenary / オープニングプレナリー / (2/2)**

## History of JENDL Development and Future/JENDL の開発の歴史と未来

**Author:** Tokio/智生 Fukahori/深堀[1]

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I was pleased to hear Drs. Osamu Iwamoto, Nobuyuki Iwamaoto and Ken-ichi Tada has been gotten the Awards for Science and Technology (Development Category), the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology in last April. This report is for its celebration lecture.
The Japanese Evaluated Nuclear Data Library (JENDL) has been being developed over 60 years. The JENDL-1 and -2 were developed for fast reactor design, and fusion reactors were added as a purpose of JENDL-3.x while JENDL-4.0 and JENDL-5 are general purpose files. According to version of JENDL, the file capacities have increased exponentially. Evaluation codes have been changed time by time. In this presentation, history of JENDL development is introduced as well as perspective of future appearance of nuclear data file.

This work is (partly) supported by JST ERATO Grant No. JPMJER2304, Japan.

**TOMOE Project Session 1 / TOMOE プロジェクトセッション 1 / (1/3)**

## Introduction of ERATO Three-Nucleon Force Project TOMOE

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The JST-ERATO Sekiguchi Three-Nucleon Forces Project (TOMOE Project) is currently ongoing. This project aims to determine three-nucleon forces based on chiral effective field theory using high-precision scattering data from few-nucleon experiments. Establishing a quantum many-body calculation to describe nuclear properties with high predictive power is within the scope. I will present an overview of this project.

**TOMOE Project Session 1 / TOMOE プロジェクトセッション 1 / (2/3)**

## Gaussian Expansion method and its application to the ground and the first excited states in Atomic physics/ガウス関数展開法と原子分野における基底状態および第 1 励起状態の推定

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Many important problem in physics can be attributed to solving accurately Schroedinger equation for 3- and 4-body problem.By solving the equation, i) we can predict various observable before measurement, and ii) we can obtain new understandings by comparing the observed data and our theoretical prediction. For this purpose, it is necessary 1) to develop the method to calculate 3- and 4-body problems precisely, and 2) to apply to various fields such as nuclear physics as well as atomic physics.
I have been developing ‘Gaussian Expansion Method (GEM)’ which is one of few-body calculation method. Here, I explain GEM simply and its application 4He atomic systems.
Indeed, it is interesting to find ‘universality’ in 4He bosonic systems with large scattering length of 4He-4He potential. In this talk, I show the universality for the binding energies of the ground and the first excited states in three- to five- 4He atomic systems.

**TOMOE Project Session 1 / TOMOE プロジェクトセッション 1 / (3/3)**

## Density functional approaches to nuclear response and reaction/密度汎関数計算による原子核応答・反応計算へのアプローチ

**Author:** Takashi/孝 Nakatsukasa/中務[1]

[1] *University of Tsukuba/筑波大*

It is not trivial to quantitatively reproduce nuclear saturation, the most fundamental property of atomic nuclei, which is often discussed together with the necessity of three-body forces. The density functional theory is known to reproduce the saturation property and gives quantitative descriptions from light to heavy nuclei with a single universal energy density functional. For instance, it is able to provide quantitative descriptions of physical quantities of the ground states, such as mass and charge radius. The nuclear masses are reproduced with mean errors below 3 MeV. Methods based on time-dependent density functional theory are adequate for describing excited states. Using the linear responses around the ground state, information about excited states can be obtained. Furthermore, it

can be applied to the microscopic derivation of the collective Hamiltonian. Extending these methods enables applications to nuclear reactions, which leads to calculations of transition densities for direct reactions and the microscopic derivation of low-energy nuclear reaction models.

This presentation briefly reviews recent developments in nuclear density functional theory and introduces approaches and computational results concerning nuclear structure and reactions.

**Measurement and evaluation (1) / 測定・評価（1） / (1/2)**

# Measurement of Interaction Cross Sections in the RIKEN TRIP-S3CAN program/理研 TRIP-S3CAN プログラムにおける相互作用断面積測定

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RIKEN Transformative Research Innovation Platform of RIKEN Platforms (TRIP) project was launched in FY2023. The main objective of the TRIP project is to establish a next-generation research DX (digital transformation) platform by accumulating and integrating high-quality data to interconnect all RIKEN platforms. One of the experimental programs in the field of nuclear physics within the TRIP project is called Symbiotic Systematic and Simultaneous Cross-section measurements for All over the Nuclear chart ($S^3CAN$). In the TRIP-$S^3CAN$ program, we are measuring interaction cross sections of various nuclei that have not yet been measured, aiming to efficiently accumulate comprehensive nuclear data. It is known that measurements of interaction cross sections provide an effective method to extract nuclear size properties such as density distributions and matter radii. The experiments are conducted at the Radioactive Isotope Beam Factory (RIBF) at RIKEN, which is an accelerator facility capable of producing a wide variety of nuclei. Thanks to recent improvements in the data acquisition system and rapid beam tuning at RIBF, it is now possible to measure interaction cross sections of approximately ten nuclei within about three hours under a single beam setting. So far, we have measured about 150 nuclei in FY2024, and another 150 nuclei in FY2025, covering atomic numbers in the range $Z$ = 14 60. In this talk, we will present the details of these measurements and an overview of the recent results obtained from the TRIP-$S^3CAN$ program.

**Measurement and evaluation (1) / 測定・評価（1） / (2/2)**

## Scattering experiment using polarized deuteron beam and polarized proton target/偏極重陽子ビームと偏極陽子標的の衝突実験

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The study of three-nucleon forces (3NFs) is essential for clarifying various nuclear phenomena. The 3NFs arise naturally in the meson exchange model as well as in the framework of chiral effective field theory (EFT) [1]. In this framework, consistent two-, three- and many nucleon forces are derived on the same footing. The first non-vanishing 3NF diagrams appear at the third order, so called next-to-next leading order. At high orders, there are variety of spin and iso-spin dependent term of 3NFs as well as short range interaction terms. These short-range interactions involve unknown low energy constants determined from the experimental data. Few-nucleon scattering is one of a good probe to investigate in detail the properties of nuclear forces including 3NFs. The TOMOE project aims to pin down the chiral-EFT-based 3NFs from three nucleon scattering and establish the high-precision nuclear potential. We plan to measure the complete set of spin-correlation coefficients for deuteron-proton ($d$-$p$) elastic scattering at intermediate energies (approximately 100 MeV/nucleon). The measurement of spin-correlation coefficients for $d$-$p$ elastic scattering will be performed at RIKEN RI beam factory (RIBF). This measurement requires both the beam and the target to be polarized. At RIKEN RIBF, the highly polarized deuteron beam with the arbitrary spin control is available [2]. We developed the polarized proton target based on the dynamic nuclear polarization using photo-excited triplet electron (triplet-DNP) [3,4]. The triplet-DNP enables the mild operating conditions such as a low magnetic field (about 0.1 T) and high temperatures (about 100 K or more). The scattered particles are detected by the KuJyaku detector system [5] which is consisted of four multi-wired drift chambers and plastic scintillation counters. The KuJyaku system covers the scattering angles $\theta_{\mathrm{lab.}} = 10°–60°$ in the laboratory system. Using these experimental devices, we plan to perform the high-precision measurement of spin correlation coefficients.
In this talk, we explain our research backgrounds and report the details and recent developments of our experimental system.

**Experience in the development and use of systems that utilize nuclear data / 核データを利用するシステムの整備と利用経験 / (1/2)**

## Development of SWAT-X -Efforts for Burnup Calculations using Latest Nuclear Data- /SWAT-X の開発 -最新の核データを用いた燃焼計算に向けた取り組み-

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The Japan Atomic Energy Agency (JAEA) has developed and maintained several burnup calculation codes, such as SWAT4 [1] and MVP-BURN [2], which have been widely used for research and various nuclear evaluations. However, recent updates and expansions of evaluated nuclear data libraries have made it difficult to apply new nuclear data to these codes because of limitations in the number of nuclides, nuclear reactions, and decay modes that can be treated.
To address this issue, JAEA has been developing a new burnup calculation code system called SWAT-X. To enable flexible utilization of modern nuclear data, SWAT-X is being developed from scratch using Python 3. As a first step, a basic burnup calculation function was implemented by coupling burnup calculations with CRAMO [3] and neutron transport calculations with MVP3 [4]. The validity of this function was confirmed through comparisons between the burnup calculation results of SWAT-X and SWAT4.
At present, SWAT-X includes a function that can automatically construct arbitrary depletion chains using data from evaluated nuclear data libraries. In this function, detailed depletion chains are generated by reading ENDF-6 formatted decay and fission yield data. For cross sections, reaction paths are defined using the SWAT-X library, which contains multi-group infinite-dilution cross-section data derived from GENDF files produced by FRENDY v2 [5]. One-group cross sections for user-selected major nuclides are obtained by MVP3 using continuous-energy data, while those for other nuclides are calculated by collapsing the multi-group cross sections with neutron fluxes from MVP3. The depletion chain can be systematically simplified by selecting specific nuclides to be included or by applying half-life thresholds to determine whether certain decays are considered. This function enables burnup calculations using a detailed burnup chain based on JENDL-5, comprising approximately 4,070 nuclides.
In parallel, we are developing a fast burnup calculation capability using neutron spectrum reconstruction, as an improved approach to the one-point calculation method of ORIGEN2 [6]. This method employs a reduced-order model (ROM) constructed from neutron spectrum snapshots using the proper orthogonal decomposition and regression models. The ROM allows rapid neutron spectrum estimation at each burnup step, greatly reducing computation time by eliminating repeated neutron transport simulations.
This presentation will introduce the SWAT-X system, describe its calculation capabilities, and present verification results.
This work was supported in part by JSPS KAKENHI Grant Number JP24K08300.

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**Experience in the development and use of systems that utilize nuclear data / 核データを利用するシステムの整備と利用経験 / (2/2)**

## Example of JENDL-5 Application/JENDL-5 の使用経験

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JENDL-5 has been utilized in many fields including nuclear engineering since its release, and results of validation works have been also reported. Generally, validation of the evaluated nuclear data libraries is carried out using the measurement data on the integral parameters obtained at nuclear facilities. In the field of nuclear engineering, the radioactive decay data play important roles mainly in reactor kinetics problems and nuclear fuel burnup (or depletion) problems. Some examples of validation works for the JENDL-5 decay data using the relevant benchmark problems are presented. The integral data, which are sensitive to the decay data, are generally sensitive to other nuclear data also, and this is discussed using some examples of the post-irradiation examination data. Finally, the explicit fission model, which uses the decay data of fission products directly, is also briefly explained as an example of application of the decay data to the nuclear engineering problems.

**Measurement and evaluation (2) / 測定・評価 (2) / (1/2)**

## Overview of Nuclear Data Production System: The Neutron Experimental System at RAON

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A neutron experimental system, called Nuclear Data Production System (NDPS) [1,2], has been constructed at RAON (Rare Isotope Accelerator complex for ON-line experiments) in Republic of Korea. It is designed to produce both white and mono-energetic neutrons, utilizing ion beams and proton beams with thick graphite and thin lithium targets, respectively. Neutrons are generated in the target room and guided to the TOF room via a 4-meter-long neutron collimator composed of iron and 5% borated polyethylene. The neutron flight path from the production target to the detectors can be adjusted from 5 to 50 meters, depending on the experimental requirements. At the downstream end of the experimental room, a neutron beam dump is installed to absorb neutrons and reduce scattered backgrounds.
In 2024, the first beam test of NDPS was conducted using 16 MeV/u 40Ar18+ ion beams to generate neutrons. The emitted neutrons are measured using EJ-301 liquid scintillators and activation foils to evaluate the neutron energy spectrum. This presentation will provide an overview of NDPS, along with its current status.

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**Measurement and evaluation (2) / 測定・評価 (2) / (2/2)**

## Overview of Neutron-Induced Cross-Section Measurements at ANNRI/ANNRI における核データ測定の現状

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Accurate nuclear cross-section data are essential for the design, safety assessment, and optimization of innovative nuclear reactor systems. Neutron-capture cross sections of minor actinides (MAs) and long-lived fission products (LLFPs) are particularly important for evaluating transmutation, production rates, and fuel-cycle sustainability in advanced nuclear systems [1-3]. However, precise measurements are challenging due to intense radioactivity and the limited availability of the target nuclides. To overcome these challenges, the Accurate Neutron-Nucleus Reaction measurement Instrument (ANNRI) was constructed in 2008 through a collaboration among Hokkaido University, Institute of Science Tokyo, and Japan Atomic Energy Agency. ANNRI is installed on Beam Line No. 04 of the Materials and Life Science Experimental Facility at J-PARC, which provides high-intensity pulsed neutrons over a wide energy range. Since its commissioning, a series of measurements have been conducted to obtain neutron-induced cross-sections of MAs and LLFPs using high-intensity pulsed neutrons. Capture and/or total cross sections of $^{244}$Cm, $^{246}$Cm, $^{241}$Am, $^{243}$Am, $^{237}$Np, $^{99}$Tc, $^{107}$Pd, $^{129}$I, and many stable isotopes were reported [5-9]. These results at ANNRI are expected to play a key role in advancing the development of innovative nuclear systems and sustainable nuclear fuel cycles. This presentation provides an overview of the ANNRI facility, experimental achievements, and ongoing efforts.

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核データの妥当性の検証のためのシステムの整備

## STACY Critical Experiments to Clarify Fuel Debris Criticality Characteristics/燃料デブリの臨界特性を明らかにする STACY 臨界実験


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The details of the fuel debris generated in the Tokyo Electric Power Company Holdings' Fukushima Dai-ichi Nuclear Power Station accident are still not fully understood, and its critical properties are being evaluated using nuclear calculations with various parameters. On the other hand, criticality experiments are required to validate these computations because the fuel debris contains materials such as concrete for which nuclear data is not well evaluated and has heterogeneous and nonuniform compositions. For this purpose, the critical assembly STACY was modified from a solution fuel system to a light water-moderated heterogeneous system. This modification was completed at the end of 2023, and the operation restarted in the spring of 2024. To simulate the criticality characteristics of the fuel debris, 70 rod-shaped samples of concrete composition and stainless steel with the same diameter as the $UO_2$ fuel rods were prepared, and equipment was also installed to prepare pellet-shaped samples and load them into the experimental core. We will report the results of these experiments, plans for making benchmarks, and expected contributions of the modified STACY to the Fukushima Dai-ichi decommissioning work.

Acknowledgments
The modification of the STACY critical assembly and their experimental activities were performed under the auspices of the Secretariat of Nuclear Regulation Authority (S/NRA/R) of Japan.

**TOMOE Project Session 2 / TOMOE プロジェクトセッション 2 / (1/3)**

## Radioisotope production at RARiS/RARiS での RI 製造

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At the Research Center for Accelerator and Radioisotope Science (RARiS), Tohoku University, we operate and maintain an electron linear accelerator (LINAC) and an AVF cyclotron, selecting between these accelerators according to the production purpose and the nuclide of interest. Through our joint-use program as a shared user facility, we carry out routine production and supply of radioisotopes to support basic research and related activities.
Within the TOMOE project, our group is responsible for producing radioisotopes and supplying them to the Radiopharmaceutical Group. At present in TOMOE, copper-64 ($^{64}$Cu) is produced in the $^{68}$Zn($\gamma$,pn) reaction with bremsstrahlung generated by the electron linac, and bromine-77 ($^{77}$Br) is produced in the $^{nat}$Se(p,xn) reaction with protons accelerated by the AVF cyclotron. These productions are implemented as part of the project's routine operations at RARiS.
In this presentation, we will briefly introduce the supply of these radioisotopes and examine the nuclear reaction pathways for producing the intended radioisotopes. For example, in addition to the $^{68}$Zn($\gamma$,pn) route used for $^{64}$Cu, this nuclide can also be produced in the $^{64}$Ni(p,n) reaction or the $^{64}$Zn(n,p) reaction. We will compare candidate production routes by evaluating production efficiency in terms of the incident particle and cross-section, while also considering target availability.

**TOMOE Project Session 2 / TOMOE プロジェクトセッション 2 / (2/3)**

## Evaluation of RI production yield using the CCONE-based framework/CCONE ベースのフレームワークを用いた RI 製造量の評価

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Currently, a framework is required to examine the production method of a target nuclide while considering various boundary conditions based on nuclear reaction calculation codes and evaluated nuclear data libraries. To address this, we have developed a framework based on CCONE [1, 2], which had not been previously established. This framework enables the easy investigation of reactions that maximize the production cross-section or thick target yield [3] of the target nuclide. Furthermore, improvements of this framework enable yield calculations for incident particles with continuous energy distributions.
Tohoku University RARiS Mikamine site (hereafter RARiS-Mikamine) has been manufacturing and supplying the Auger-electron emitter $^{64}$Cu via the $\gamma$+$^{66}$Zn reaction. In contrast, the production yield of $^{64}$Cu exhibits significant variation among experimental days, making it difficult to say that a stable supply has been achieved. To identify the cause of this variability, we applied this framework to evaluate the $^{64}$Cu production yield.
Evaluating the $^{64}$Cu production yield at RARiS-Mikamine requires the bremsstrahlung spectrum and the $^{64}$Cu production cross-section (excitation function). The bremsstrahlung spectrum was obtained by reproducing the RARiS-Mikamine experimental setup and irradiating a Ta converter with an electron beam in the radiation transport code PHITS [4]. The excitation function was acquired from CCONE and evaluated nuclear data libraries, including JENDL-5 [5]. Based on past experiments and calculations using the framework and PHITS, it was found that the misalignment of the electron beam position and the thickness of the Ta converter significantly affect the $^{64}$Cu production yield. A comparison between the experimental and calculated $^{64}$Cu production yields, incorporating these findings, suggested that the calculation using the JEFF-3.3 [6] excitation function best reproduces the experimental values. Currently, we are investigating other potential factors that might influence the $^{64}$Cu production yield. Furthermore, manufacturing experiments for the Auger-electron emitter $^{77}$Br have begun at the Tohoku University RARiS Aobayama site, and preparations for the evaluation of the $^{77}$Br production yield are also underway.

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**TOMOE Project Session 2 / TOMOE プロジェクトセッション 2 / (3/3)**

# Radioisotopes for Diagnosis and Therapy in Nuclear Medicine/核医学における診断・治療用放射性同位体

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The use of radioactive isotopes (RIs) in medicine enables both the diagnosis and treatment of diseases, referred to as nuclear medicine imaging and nuclear medicine therapy, respectively. For example, drugs labeled with RIs can be administered to visualize or destroy cancer cells that selectively accumulate the compound. The physical and chemical properties required for RIs differ between diagnostic and therapeutic applications. In each case, the energy of the emitted radiation and the half-life of the isotope must be carefully optimized. Furthermore, since many diseases progress rapidly and cannot wait for isotope production, a stable and reliable supply of the required RI is essential. Because the amount of radiopharmaceutical administered to patients is extremely small, there are few elemental restrictions on the composition of the compound.

In nuclear medicine imaging, the radiation emitted from the administered radiopharmaceutical must be detected externally. Therefore, isotopes emitting γ-rays or X-rays with sufficient tissue penetration are used. For therapeutic applications, particle-emitting isotopes are employed. Traditionally, $\beta^-$-emitters have been widely used due to their relatively long range and established production routes. However, in recent years, α-emitting isotopes with high linear energy transfer (LET) have attracted significant attention. In addition, isotopes that emit Auger electrons are now being investigated for achieving even more localized irradiation at the nanometer scale.
A variety of diagnostic and therapeutic RIs are currently used in clinical practice. Nonetheless, the discovery or production of new isotopes with more favorable properties would further advance the field. Hopefully, three-body nuclear forces could lead to the creation of new nuclear data that are directly useful for medical applications.

**Plenary Talk / プレナリートーク / (1/2)**

## Reflecting on Over Forty Years of Nuclear Data Research at Kyushu University/九大における核データ研究 40 数年を振り返る

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As I approach retirement at the end of this fiscal year, I would like to take this opportunity to review my research journey in the fields of nuclear physics and nuclear data. I will begin by looking back on the history of education and research in the Department of Nuclear Engineering, Faculty of Engineering, at Kyushu University, where I spent my early academic years. I will then trace the development of nuclear data research at Kyushu University, highlighting its evolution and key milestones. In particular, I will present my own studies on important "pre-equilibrium reaction processes" within this research lineage and reflect on how collaborations and interactions with many researchers in the nuclear physics community have shaped and enriched my work.

**Plenary Talk / プレナリートーク / (2/2)**

## Memorial Lecture for Mr. Tsuneo Nakagawa - JENDL File Developments and Mr. Tsuneo Nakagawa -San / 中川庸夫さん追悼講演ー JENDL 開発と中川庸雄さん

**Author:**

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In memory of Mr. Tsuneo Nakagawa, who passed away in May of this year, we would like to express our sincere gratitude to Mr. Nakagawa for his highly technical and skillful editing efforts And also in swiftly disseminating and exchanging of information in the community through the regular publication of Nuclear Data News. It would be OK Mr. Nakagawa MR.JENDL

**TOMOE Project Session 3 / TOMOE プロジェクトセッション 3 / (1/3)**

## Nuclear Fission and the Nonequilibrium Green's Function Method :A Novel Microscopic Approach/核分裂と非平衡グリーン関数法：

# 新しい微視的記述法

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To describe nuclear fission, phenomenological approaches, including statistical models and the Langevin method, have been widely employed. On the other hand, microscopic theories of nuclear fission are still under development and contain many aspects that require improvement. In particular, no method has been established for deriving nuclear fission cross sections from a microscopic nuclear Hamiltonian.
To address this issue, we have developed a microscopic nuclear fission model based on the Non-equilibrium Green's Function (NEGF) method, which is widely used to simulate electronic currents in nano-devices. Using the NEGF method, we first discuss the microscopic origin of the Porter Thomas fluctuations in 235U(n,f)[1]. We then analyze the fission cross sections of 235U(n,f) and 236U(γ,f) and examine the quantitative performance of the NEGF fission model[2]. In particular, we focus on the applicability of the theory in the tunneling region. Finally, we introduce the probability current in the nuclear fission model space spanned by Slater determinants labeled by different deformations and excitation energies. This allows us to microscopically clarify the transition dynamics of nuclear fission and to compare them with the Langevin picture.

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**TOMOE Project Session 3 / TOMOE プロジェクトセッション 3 / (2/3)**

# Microscopic description of deuteron-induced inclusive reactions and its implications to nuclear data evaluation/包括的重陽子入射反応の微視的記述と核データ評価への展開

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Previous studies have revealed the importance of introducing surface correction into a phenomenological model for inclusive $(n, xn)$ and $(p, xp)$ reactions [1]. These findings have contributed significantly to the improvement of nuclear data evaluation. However, the necessity for the surface correction in an inclusive $(d, xd)$ reaction has hardly been investigated.
The purpose of this study is to investigate the difference in the peripherality of the $(p, xp)$ and $(d, xd)$ reactions by a theoretical analysis using a quantum mechanical model, and to obtain a theoretical basis on the $(d, xd)$ reaction. The energy spectra and their radial distributions for the $(p, xp)$ and $(d, xd)$ reactions are calculated by the one-step semiclassical distorted wave model (SCDW) [2-4]. In this presentation, we will explain the description of the $(d, xd)$ reaction with the SCDW and discuss the effect of the difference in the peripherality of the $(p, xp)$ and $(d, xd)$ reactions on a phenomenological model for nuclear data evaluation.

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**TOMOE Project Session 3 / TOMOE プロジェクトセッション 3 / (3/3)**

## Application of Nuclear Structure Theories to Nuclear Data Evaluation/核構造理論の核データへの応用

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Reliable nuclear data are essential for both basic research and practical applications in nuclear science and technology. Recent advances in microscopic nuclear reaction theories have enabled a more unified and consistent description of nuclear structure and reaction dynamics. In this work, we present applications of such theoretical frameworks to nuclear data evaluation. In particular, we focus on the use of the subtracted second random-phase approximation (SSRPA) and pre-equilibrium reaction models to describe particle-emission spectra and transition strengths in compound and pre-equilibrium processes [1,2]. These approaches allow a microscopic treatment of two-particle two-hole configurations and two-body external fields, providing deeper insight into complex nuclear responses. Furthermore, we introduce recent developments in the study of the antisymmetric spin orbit components of three-nucleon forces and their impact on nuclear structure [3]. This approach offers a path toward more accurate and physically grounded nuclear data evaluations. Prospects for incorporating such microscopic insights into next-generation evaluated nuclear data libraries will also be discussed.

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**Measurement and evaluation(3)/測定・評価 (3) / (1/2)**

## Nuclear Data Measurements at J-PARC 3NBT/J-PARC 3NBT における核データ測定の取り組み

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We are performing nuclear data measurements at the 3NBT facility of J-PARC. In this symposium, we will present an overview of a series of experiments, including measurements of (1) neutron energy spectra at 180 degrees from the beam direction from the mercury target at the MLF, (2) nuclide production cross sections induced by the proton beam, (3) proton scattering spectra through an aluminum window.

**Poster Session / ポスターセッション**

# Study of keV-Range Neutron-Capture Cross Sections of Chromium Isotopes/クロム同位体の keV 中性子捕獲断面積の研究

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Chromium (Cr) matters from two perspectives. In reactors, Cr is a major alloying element in stainless steels throughout cores and internals. Its 1–100 keV neutron-capture cross section directly affects reaction rates and $k_{\mathrm{eff}}$ [1]. In astrophysics, accurate MACS are crucial for modeling nucleosynthesis [2]. However, current datasets and evaluations show discrepancies in this energy window, so high accuracy with small uncertainties cross section of Chromium is needed.

We plan to carry out measurements of the neutron capture cross section $^{50}\mathrm{Cr}$ and $^{53}\mathrm{Cr}$ at the Institute of Science Tokyo. Neutrons are produced via the $^{7}\mathrm{Li}(p,n)^{7}\mathrm{Be}$ reaction by bombarding a lithium target with a proton beam from the Pelletron accelerator. Prompt $\gamma$-rays from the neutron capture reactions are detected with a $\mathrm{NaI(Tl)}$ detector. The incident neutrons are monitored with a $^{6}\mathrm{Li}$ glass detector and the incident neutron energy is determined with the time-of-flight (TOF) method. Measurements are conducted in the two energy regions: 15–100 keV and around 550 keV. The flight paths from the neutron source to the sample are 120 mm for the low energy experiment and 200 mm for the high energy one. The $\mathrm{NaI(Tl)}$ detector is shielded with multiple shielding materials to reduced $\gamma$-ray and neutron backgrounds. The $\mathrm{NaI(Tl)}$ scintillator is surrounded with an anti-Compton annular detector to reduce the Compton-scattering events in the detector. The TOF and the pulse-height of events are recorded sequentially in the list-format data. After background subtraction, the pulse-height weighting technique is applied to derive the neutron capture yield from the pulse height spectrum. The cross section is obtained in ratio to the $^{197}\mathrm{Au}(n,\gamma)^{198}\mathrm{Au}$ reaction. The result is normalized to the standard cross section of $^{197}\mathrm{Au}(n,\gamma)^{198}\mathrm{Au}$.

The plan and feasibility of the present study will be given in this contribution.
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**Poster Session / ポスターセッション**

# Theoretical interpretation of experimental double differential cross-section data for photoneutron emission

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This study used the $\mathrm{CoH_3}$ code [1] to perform a theoretical interpretation of neutron double-differential cross-sections (DDXs) for two nuclei, Tantalum (Ta) and Bismuth (Bi) [2-3], with the goal of investigating the underlying reaction mechanisms. We modified the exciton model by introducing a phenomenological factor to govern the transition rate from the initial, simple configuration to more complex ones. Appropriate values of the factor determined by considering the experimental

data revealed contrasting results: the factor was less than unity for Bi, suggesting enhanced pre-equilibrium neutron emission, and greater than unity for Ta, indicating suppressed emission. These findings provide new evidence for nuclear-structure effects on pre-equilibrium neutron emission. While this modified model improved the high-energy description, it did not accurately reproduce the emission region corresponding to discrete residual nucleus levels, highlighting the necessity for further refinement of pre-equilibrium models.

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**Poster Session** / ポスターセッション

## Evaluation of Time resolution in the KURNS-LINAC Pulsed Neutron Source with a 170 mm Diameter Cylindrical Moderator/KURNS-LINAC パルス中性子源（170mm 径減速材）の時間分解能評価

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The electron linear accelerator at the Institute for Integrated Radiation and Nuclear Science, Kyoto University (KURNS-LINAC) is an L-band accelerator installed in 1965. In nuclear data measurements at KURNS-LIAC, pulsed neutron sources consisting of a water-cooled tantalum target as a photo-neutron source and light water moderators were used. The time resolutions of those pulsed neutron sources had been evaluated through numerical calculation [1] and experiment [2]. In recent years, an improved cylindrical moderator vessel called the 170 mm diameter moderator was implemented. The moderator vessel has been modified for improvement of the Ta target installation. Thus, time resolution of the 170 mm diameter moderator was evaluated by the PHITS3.31A [3] with the JENDL-5 [4] in this study. As the result, it was obtained that the time resolutions at a neutron flight path of 12.7 m are approximately 0.6 % for TOF times between 30 - 100 μsec. This work was supported by JSPS KAKENHI Grant Number JP25K15764.

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**Poster Session** / ポスターセッション

## Systematic evaluation toward predicting low-energy heavy-ion reactions using dynamical model/動力学模型を用いた低エネルギー重イオン反応の予測に向けた系統的な評価

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The history of element synthesis (Z>92) began with the discovery of $_{93}$Np in 1940. Since then, elements up to $_{118}$Og have been officially recognized. The superheavy elements from $_{114}$Fl to $_{118}$Og were first successfully synthesized directly using a $^{48}$Ca projectile. However, this approach is considered impractical for element 119 due to the extreme difficulty in producing a viable target of $_{99}$Es. Therefore, reactions with new projectiles ($_{22}$Ti, $_{23}$V, $_{24}$Cr) must be explored. However, the fusion mechanisms for these reactions remain poorly understood largely due to the complexity of the compound nucleus formation process. As these dynamics cannot be directly observed experimentally, indirect methods are required. D. J. Hinde et al. offered such an approach, gaining insights from the Mass-Angle Distribution (MAD)　the correlation between fission fragments and their scattering angles[1]. Our research aims to theoretically reproduce these MADs. This will facilitate a systematic evaluation of heavy-ion reactions and ultimately allow for predictions in unexplored reaction systems.

For this analysis, we employ a dynamical model that determines the nuclear shape and its corresponding potential based on the liquid drop model and shell effects. By solving the Langevin equation, this model traces the time evolution of the nuclear shape from fusion through to fission[2,3]. We perform calculations to reproduce the experimental results of ref. [4] and analyze the shape evolution leading to compound nucleus formation.

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**Poster Session / ポスターセッション**

## Nuclear Data Evaluation of Se Isotopes and its Application to Se-79 Capture Cross Section/Se 同位体核データ評価及び Se-79 捕獲断面積への応用

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Se-79 produced during the operation of nuclear reactors needs to be disposed with transmutation technology due to its high radioactivity and geological migration. For developing reasonable transmutation scheme, it is important to improve the accuracy of Se-79 neutron capture cross section. Despite its importance, there is still almost no experimental data available for capture cross section evaluation. This is because the cumulative fission yield of Se-79 is very low which makes it difficult to gain enough amount of sample for data measurement. As an alternative method, the capture cross sections of stable isotopes such as Se-77, 78, and 80 can be applied for the evaluation. Their similar systematics to that of Se-79 make parameters suitable for use in estimating the Se-79 capture cross section. The present research aims to improve the reliability of Se isotopes' capture cross sections, so they become applicable for Se-79 data evaluation.

For evaluation, nuclear reaction model code system CCONE[1] was used. The optical potentials

were evaluated so they reproduce the experimental total cross section data of both elemental Se and stable Se isotopes. For evaluating data below 20 [MeV], the compound reaction calculation was done based on Hauser-Feshbach statistical model. The level densities were improved from the previous work of JENDL-5 (2021)[2] by fitting to the average level spacings of s-wave neutron resonances least affected by the lack of measured resonances. The modified Lorentzian model type 1 (MLO1)[3] was chosen for E1 gamma-ray strength functions, since they align better with the experimental capture reaction data than GLO model used in the previous evaluation. In addition to the default giant dipole resonance parameters, the transition strengths from the capture state to the discrete levels were adjusted to achieve the best reproduction of capture gamma-ray spectrum derived by Igashira et al.[4].
The results for Se-77, 78, and 80 capture gamma-ray spectrum showed better fit with the experimental data than that of JENDL-5. The capture cross sections for Se-77, 78 and 80 derived from improved level densities and gamma-ray strength functions reproduced the experimental data within 26% range. Since the precision is better than JENDL-5, it is concluded that the reliability of the capture cross sections has improved. Furthermore, the Se-79 capture cross section was calculated using the systematics of the improved parameters. The result was 20% smaller than JENDL-5. The preliminary result predicts lower transmutation rate in keV to MeV region than the value predicted from JENDL-5.

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**Poster Session** / ポスターセッション

## Activation Foil Selection for High-Precision Benchmark Experiments on Large-Angle Elastic Scattering of Lithium by 14 MeV Neutrons/14 MeV 中性子によるリチウム大角度弾性散乱ベンチマーク実験の高精度化に向けた放射化箔の選定

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In fusion reactors, large angle neutron scattering reactions significantly affect neutronics calculations, particularly for the reactor blanket. Previous integral experiments for large angle scattering cross section data at JAEA/FNS revealed discrepancies between experimental and calculated values [1]. Therefore, benchmarking studies on large angle scattering cross sections were indispensable. The authors' group has developed a benchmark experimental system using two shadow bars composed of conical irons to validate large angle scattering cross sections [2].
In a previous study, a benchmark experiment for lithium was performed using hafnium as the activation foil. However, the statistical error was considerable due to neutrons scattered from walls and surrounding materials.
In this study, new candidate activation foils were examined to reduce statistical error by considering reaction cross section, threshold energy, half-life, and γ-ray intensity based on the data from JENDL-5. Subsequently, the activation reaction rate for each candidate foil was calculated using the neutron flux obtained from MCNP5 simulations and the activation cross sections. The expected γ-ray count detected by a Ge detector was also estimated, and the corresponding statistical error was evaluated. As a result, magnesium showed the lowest statistical error through the $^{24}$Mg(n, p)$^{24}$Na

reaction. However, the result was still insufficient for achieving a high-precision benchmark experiment. To further reduce the statistical error, additional activation foils with lower threshold energies were considered, and recalculations were performed. It was found that using an indium foil with the $^{115}$In(n, n′)$^{115m}$In reaction could further reduce the statistical error. However, in this case, background neutrons with energies above approximately 1 MeV also activated the indium foil, making it difficult to deduce only the large angle scattered neutrons.
In the future, further improvements will be required to suppress the contribution of the background neutrons when using indium foils. In addition, we plan to develop an experimental system that minimizes statistical errors by optimizing the materials and configurations of the surrounding components of the experimental assembly, and carry out benchmark experiments on the large angle scattering cross section of lithium.

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**Poster Session** / ポスターセッション

# Evaluation of Nuclear Decay Data to Revise ENSDF and Verification of JENDL-5 Decay Data File for Burnup Calculation (II)/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

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To calculate reliably and accurately concentrations and activities for nuclides generated or depleted by neutron reactions and radioactive decays in nuclear fuel, it is necessary to use the updated nuclear decay data such as half-lives, branching ratios, and $\gamma$-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. A few examples of our evaluations were reported in the last year’ s symposium. This presentation gives our evaluations performed in this year.
An example is the ⊠-decay half-life of 120gI. We carefully read all of the references regarding the measurements of this half-life, and accumulated reliable data from them. The statistical analyses of these data were made, and the recommended value has been determined to be 81.8 (2) min. Similar procedures were taken to determine the recommended values of the half-lives of 120gCs and 120gXe to be 64 (3) s and 46 (6) min, respectively. Another example is the excitation energy of the metastable state 120mI. We adopted the excitation energy from a recent reference of the sensitive $\gamma$-ray measurement.
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. In case of the A=120, the latest revision of ENSDF was made in 2014. We verified the values in JENDL-5 DDF by using our newly evaluated values. For example, the half-lives of 120gI, 120gCs and 120gXe in JENDL-5 DDF were taken from old references, and have been changed to the new values as mentioned above. Also, the excitation energy of 120mI in JENDL-5 DDF has been revised by the present evaluation. The old value had large uncertainty because it was adopted from a reference of low-resolution⊠⊠-ray spectra measurements.

**Poster Session** / ポスターセッション

## Analysis with JENDL-5 on TCA critical experiments of PWR-type fuel assembly loaded with B4C neutron absorber rods/B4C 中性子吸収棒を装荷した PWR 型燃料集合体に関する TCA 臨界試験の JENDL-5 による解析

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A series of critical experiments was implemented on a mockup PWR-type fuel assembly loaded with B4C neutron absorber rods (B4C rods) in a tank-type critical assembly (TCA) in 1983 [1]. The mockup assembly was a 15x15 lattice consisting of 204 UO2 fuel rods with 3.2 wt% enrichment and 21 water holes. It was surrounded by a driver lattice region composed of 2.6 wt% enrichment UO2 fuel rods. In the experiments, critical water levels were measured by varying the number of B4C rods inserted into the water holes of the mockup assembly. The core radial fission rate distributions in the mockup assembly and driver region were also measured by fuel rod gamma-scanning. In the present study, the experimental results were analyzed using a continuous-energy Monte Carlo code MVP3 [2] with a JENDL-5-based nuclear library. The analysis results were also compared with those with a JENDL-4.0-based nuclear library. The effective neutron multiplication factors (keffs) with JENDL-5 ranged from 0.9998 to 1.0006, exhibiting an increasing trend with the critical water levels, while those with JENDL-4.0 were around 0.9997. The reactivity effects by the updated neutron cross-sections of 1H in H2O, 16O in H2O, 16O in the materials other than water, 235U, and 238U in JENDL-5 were estimated by derivative calculations with the cross-sections in JENDL-5 partly replaced by those in JENDL-4.0. As a result, the differences in the trends in keffs between JENDL-5 and JENDL-4.0 were mainly attributed to the updated cross-section of 1H in water. The C/E-1s in the comparison between the calculated and measured relative fission rates of the fuel rods were obtained for the mockup assembly and driver region. The root-mean-squares (RMSs) of the C/E-1s with JENDL-5 and JENDL-4.0 for the mockup assembly increased with the number of B4C rods and ranged from 1.3% to 2.3%. Those for the driver region were almost independent of the number of B4C rods and ranged from 1.1% to 1.4%. The RMSs with JENDL-5 for the driver region were slightly larger than those with JENDL-4.0.

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**Poster Session** / ポスターセッション

## A New Cross Sections Database for the Simulation of MSRs within the NMB Code

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The Nuclear Material Balance [1] (NMB) code is a nuclear fuel cycle simulator developed by the former Tokyo Institute of Technology (present Institute of Science Tokyo) and the Japanese Atomic Energy Agency. The code allows the simulation of the full nuclear fuel cycle, including front-end, reactor and back-end operations for an extended number of reactor designs, fuels, reprocessing and disposal strategies. Presently, the burn-up matrix used in the NMB depletion calculations, is constructed through microscopic cross sections catalogues analogue to the ORLIBJ40 [2] database, where the data is tabulated for various isotopes, nuclear reactions, types of nuclear reactors and fuel burn-up, nor requiring therefore to perform neutron transport calculations.
While this approach is perfectly suitable for the simulation of solid fuel reactors, it is limited for the simulation of Molten Salt Reactors (MSRs), where online fuel treatment is typically a requirement, and should be tracked during burn-up. A few examples of material flows include the removal of volatile fission products from the fuel, the removal of insoluble fission products through fuel treatment, and the refueling. Different codes were developed for the investigation of MSR fuel cycles, as EQL0D [3], a MATLAB-based wrapper for Serpent2 developed at the Paul Scherrer Institute with the scope of studying MSRs fuel cycles. While front and back-end are not simulated, such codes provide high detail reactor calculations and databases, such as burn-up dependent depletion matrices including modifications for online reprocessing streams.
A valid option for MSRs depletion calculations in the NMB routine, is to construct the burn-up and material-flows dependent burn-up matrices with the support of codes specialized in MSR fuel cycle calculations, and include them directly in NMB. To do so, EQL0D was used to simulate the fuel cycle of several MSR types until equilibrium, for several burn-up steps and several material exchange rates for gaseous FP removal, soluble FP removal, and refueling patterns. For each of these calculations, the EQL0D burn-up matrices were extracted, and analyzed, and formatted for NMB compatibility. On top of having a new cross section catalogue for the deployment of MSRs in NMB, the production of the present database allowed to study the influence of refueling patterns and burn-up for specific isotopes and reactions.

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**Poster Session /** ポスターセッション

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

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Ensuring the security of nuclear reactor facilities is one of the most pressing challenges in the nuclear field. Theft or illegal transport of nuclear materials, and sabotage of nuclear facilities, are serious threats to safety and stability. Addressing these risks requires technologies that can detect and identify nuclear materials without damaging them. However, existing approaches have been constrained by the absence of practical photon sources that are simultaneously compact, affordable, and produce minimal background radiation.
To overcome this limitation, the present study makes use of high-energy gamma rays produced

through the 7Li(p, γ)8Be reaction as a novel photon source [1]. When these photons strike nuclear materials, they can induce photonuclear fission, generating fast neutrons in the process. By measuring the emitted neutrons, the presence and quantity of nuclear material can be inferred [2]. Based on this principle, this research proposes a new detection concept that utilizes photonuclear reactions for non-destructive nuclear material identification.
In the present experiment, 14.6 MeV and 17.6 MeV high-energy gamma rays were generated via the 7Li(p, γ)8Be reaction and irradiated onto a gold target to induce the 197Au(γ, n)196Au reaction. The emitted photonuclear neutrons were successfully observed. We found that a major issue encountered during the gamma-ray irradiation was the strong background radiation produced by the 0.478 MeV gamma rays from the (p, p') reaction in the Li target. To reduce this inelastic scattering background, an experiment was performed at a proton energy of 0.5 MeV, which is lower than the reaction threshold energy of the inelastic reaction, i.e. 0.546 MeV. Furthermore, the feasibility of the proposed non-destructive detection method based on the 7Li(p, γ)8Be reaction was evaluated using neutron transport simulations with the MCNP code. Because we are not authorized to handle nuclear fuel materials in our accelerator facility, we plan to use a $^{237}$Np sample as a substitute material to test the present method to detect photofission neutrons. The experimental feasibility was evaluated in calculations with the MCNP code.

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**Poster Session** / ポスターセッション

## Derivation of the DD Neutron Source Term Considering 3D Scattering/3 次元散乱を考慮した DD 中性子源項の導出

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In this study, we evaluated and improved the simulation method of the DD neutron field in the OKTAVIAN facility at Osaka University, aiming to establish it as a standard neutron field. In previous studies [1], discrepancies were observed between the experimental angular distribution of DD neutron intensity and simulation results. To address this issue, we developed a new 3D simulation method for calculating the neutron source term, considering the scattering behavior of the incident deuterium beam in the target.
In the conventional 2D model, the relationship between the deuteron scattering angle η and the neutron emission angle φ was simplified, however, this approximation could not accurately reproduce the particle behavior. To solve this problem, we employed 3D calculation model by introducing two azimuthal parameters, α andβ, representing the orientations of the incident and scattered particles. The relationship amongη, φ, and the beam angle θ is expressed as
$\cos\varphi=\cos\eta\cos\theta+\sin\eta\sin\theta\cos(\alpha-\beta)$
A 3D Monte Carlo simulation based on this equation was performed to evaluate the neutron emission probability density under various conditions. As a result, an improvement was observed at large neutron emission angles.
In future, we will perform the theoretical verification of this simulation method.

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**Poster Session** / ポスターセッション

## Measurement of charge-state distributions of unstable nuclear beam around $^{136}$Xe at the RIKEN RIBF/理化学研究所 RIBF における 136Xe 近傍の不安定核ビームでの荷電状態分布測定

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In heavy-ion beam experiments, the charge-state distribution of ions after passing through materials is an important quantity for improving the accuracy of beam transmission efficiency and interaction cross-section measurements. In the transmission method for measuring interaction cross sections, precise prediction or measurement of the charge-state distribution is essential to ensure accuracy. We performed systematic measurements of charge-state distributions for heavy ions in the TRIP-S3CAN experiment.
In this study, radioactive isotope beams of nuclei around $^{136}$Xe were produced using a primary beam of $^{238}$U at the RIKEN Radioactive Isotope Beam Factory (RIBF). Their charge-state distributions after passing through target materials were measured with the BigRIPS spectrometer and the Zero Degree Spectrometer. In particular, for isotopes with atomic numbers $Z$ = 54 61, the $Z$ dependence of the fractions of H-like and He-like charge states was investigated and compared with predictions from simulation codes such as CHARGE and GLOBAL[1]. Furthermore, we also evaluated the energy dependence of the charge-state distributions.

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**Poster Session** / ポスターセッション

## Concept and Design of a Two-Layer Scintillator Detector for Neutron-Gamma Discrimination/中性子・ガンマ線弁別に向けた二層型シンチレータ検出器の検討

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Fast neutron detection plays an essential role in various fields, including nuclear data measurement, radiation shielding design and dose evaluation. In fast neutron measurements, gamma-rays are typically accompanied by neutrons in the radiation field, requiring effective neutron-gamma (n-g) discrimination. For this reason, organic scintillators are widely used because of their fast response and capability of n-g identification by using pulse shape discrimination (PSD). PSD-capable plastic scintillators like EJ-276 and EJ-299-33 have been developed recently to improve n-g discrimination performance. However, the pulse shapes of neutrons and gamma-rays become similar and overlap at the low-energy region, resulting in reduced PSD performance when using conventional charge integration methods with plastic scintillators [1, 2].
To overcome this limitation, we propose a new approach based on a two-layer scintillator detector. In this detector, Compton-scattered photons that deposit a small amount of energy and escape from the plastic scintillator are detected by a second scintillator with different scintillation properties. Signal shape differences from the two scintillators are utilized to discriminate gamma-ray events in the low-energy region. Consequently, this configuration is expected to enhance n-g discrimination and improve neutron detection efficiency in mixed radiation fields.
In this presentation, we present the conceptual design of the proposed two-layer scintillation detector and report on preliminary simulation results performed using Monte Carlo simulations with the Particle and Heavy Ion Transport code System (PHITS) [3] to evaluate the energy deposition characteristics of neutrons and gamma-rays in this configuration.

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**Poster Session** / ポスターセッション

## Study on 35Cl(n, p) Reactions Using Sample-Added Scintillator/試料添加シンチレーターを用いた 35Cl(n, p) 反応の研究

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The cross sections of neutron-induced charged-particle emission reactions such as (n,p) and (n,α) for many nuclides have not been measured as well as those of the neutron capture reaction. In the present work, building upon our previous confirmation of the feasibility of the sample-added scintillator technique for detecting neutron-induced charged-particle emission reactions, we plan to extend this approach to a specific target nucleus, 35Cl. The aim is to measure the 35Cl(n, p) reactions with improved accuracy by a new kind of method. The new method uses plastic scintillator added with sample material for measurement which is a cube with a length of 60 mm. The sample-added scintillator attached on a photomultiplier tube (PMT), which PMT is placed at 90 degrees to the neutron beam, is irradiated with neutrons and charged-particles emitted from neutron-induced reactions are detected at the same time. In order to collect as much photon as possible from the

scintillator, a device is used to reflect the light onto the surface of the PMT. Scintillators including sample materials were fabricated and the fabricated scintillators will be tested in irradiation test experiments conducted with the Pelletron of the Institute of Science Tokyo. Boron nitride (BN), lithium fluoride (LiF), gold (Au) and lithium chloride (LiCl) were chosen as sample materials to mix with scintillator for the test experiments. The 10B(n,α)7Li, 6Li(n,t)4He, 197Au(n, $\gamma$)198Au and 35Cl(n, p)35S reactions occur in scintillators added with BN, LiF, Au and LiCl respectively. The cross sections of the reactions are high and the Q-values are also high. Thus, charged particles from the reactions are easy to detect and these reactions are good for test. To identify charged particles, the pulse shape discrimination (PSD) was also employed. The pulse shape discrimination technique is based on the property of organic scintillators that the decay constant of light output changes depending on the mass and charge of charged particles. Signals from the photomultiplier tube were fed into the CAEN waveform digitizer V1720 that enables us to process signal onboard for the PSD parameter. In addition to the PSD parameter, the time-of-flight and the pulse heights of events were recorded sequentially. We have already simulated different sample-added scintillators using PHITS. From the simulation results, we can distinguish different charged particles successfully. Therefore, we can use this method to identify the proton produced by 35Cl(n, p)35S in the future experiment. The present contribution will report the results of the PHITS result.

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**Poster Session** / ポスターセッション

## Polarization measurement of polarized deuteron beam for deuteron-proton elastic scattering experiment/重陽子-陽子弾性散乱実験に向けた偏極重陽子ビームの偏極度測定


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The three-nucleon force (3NF) is crucial for understanding various nuclear properties, including the binding energy of light nuclei and observables in few-nucleon scattering. In few-nucleon scattering, 3NF effects have been observed in the cross section for deuteron-proton elastic scattering at around 100 MeV/nucleon [1]. 3NF effects have been observed in the cross section for deuteron-proton elastic scattering at around 100 MeV/nucleon.Meanwhile, spin observables, e.g. deuteron analyzing powers, are not always described by the 3NF models. To investigate 3NFs, we extend measurements to the complete set of spin correlation coefficients for deuteron-proton scattering at 100 MeV/nucleon. These observables are obtained by using a polarized deuteron beam and a polarized proton target. In this study, we measured the polarization of the deuteron beam using a newly installed beamline polarimeter.

We conducted the experiments at the RIKEN RI Beam Factory. The polarized deuteron beam was accelerated by an AVF cyclotron up to 14 MeV. The polarimetry was made by using the reaction of $^{12}\mathrm{C}(d,p)^{13}\mathrm{C}_{\mathrm{gnd.}}$ [2]. The beam bombarded the polyethylene target with thickness of 10 $\mu$m. Scattered protons were detected by a dE-E detector consisting of a plastic scintillator and a NaI(Tl) detector.

In the conference, we report the experimental procedure and the obtained results.

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**Poster Session / ポスターセッション**

## Prediction of Energy Dependence of Fission Yield using BNN/BNNを用いた核分裂収率のエネルギー依存性予測

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Accurate fission product yield (FPY) data are essential for reactor design and safety studies. Existing nuclear data libraries provide FPY only at limited neutron energies, leaving large gaps in the intermediate region that affect predictions for accelerator-driven systems (ADS) and advanced reactors. We developed a physics-informed machine-learning model using a Bayesian Neural Network (BNN) combined with a nuclear shell-structure factor and optimized by the Widely Applicable Information Criterion (WAIC). This approach [1,2] reproduces both global and fine structures of FPY distributions while maintaining physical consistency. The predicted energy dependence agrees well with recent experimental data [3], confirming the model' s reliability. Independent yields were used to calculate the production of delayed-neutron precursors and the energy-dependent delayed neutron yield (DNY). For key minor actinides such as 241Am, reliable DNY values were obtained for the first time, improving the understanding of reactivity control and safety margins in subcritical systems. The proposed framework demonstrates that integrating physical insight into machine learning can provide accurate and continuous nuclear data, enhancing the predictive capability of reactor simulations for next-generation nuclear systems.

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**Poster Session / ポスターセッション**

## Performance evaluation of multi-wire drift chambers for spin-correlation coefficient measurements in deuteron-proton elastic scattering/重陽子－陽子弾性散乱のスピン相関係数測定に向けたマルチワイヤ — ドリフトチェンバーの性能評価

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The nuclear force that forms the nuclei is described as interactions between nucleons. The three-nucleon force (3NF) acting among three nucleons is essential to provide descriptions for various nuclear phenomena with high precision. Among the components of the 3NF, the spin-dependent part is still insufficiently understood [1]. To investigate spin-dependent parts of 3NFs, we are planning the measurement of the complete set of spin correlation coefficients, where a polarized deuteron beam is applied on a polarized proton solid target. The measured observables are compared with the rigorous numerical calculations to pin down the 3NF effects.
In the experiment the scattered deuterons and recoil protons from deuteron-proton elastic scattering are measured at the wide angles of 14° 54° in the laboratory system. The detector system consists of the multi-wire drift chambers (MWDCs) and the plastic scintillators. The MWDCs are used to reconstruct the trajectories of the scattered deuterons and recoil protons. The plastic scintillators provide coincidence triggers to ensure the simultaneous detection of the scattered deuteron and recoil proton, which allows the identification of d-p elastic scattering events.
In this study, we evaluated the performance of the MWDCs by measuring their detection efficiency and position resolution. The detection efficiency was evaluated using a $^{90}$Sr $\beta$ source. The voltage ratio applied to the cathode and anode wires was optimized to achieve the best operational condition. The position resolution was measured using cosmic rays, which have higher mass and energy and are less affected by multiple scattering.

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**Poster Session** / ポスターセッション

## Development of a Short Flight-Path Z-Identification System using Fast Plastic Scintillators and an Ionization Chamber for Charge-Changing Cross Section Measurements/荷電変化断面積測定に向けた高速プラスチックシンチレータとイオンチェンバーを用いた短距離用の原子番号識別システムの開発

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Charge-changing cross section ($\sigma_{\mathrm{CC}}$) measurements play an essential role in advancing our understanding of nuclear structure. In heavy-ion beam experiments, atomic number ($Z$) identification is performed by combining the measurement of energy loss ($\Delta E$) with that of the particle velocity ($\beta$). Under typical conditions, the flight path is long enough to determine $\beta$ with high precision, and therefore the achievable $Z$ resolution is mainly limited by the $\Delta E$ resolution. However, in the $\sigma_{\mathrm{CC}}$ measurements, where $Z$-identification is required for all particles downstream of the reaction target, the flight path between the target and the downstream magnetic analyzer is too short to measure time-of-flight (TOF). To address this problem, we attempted $Z$-identification downstream of the target by using the combination of $\Delta E$ from an ionization chamber and $\beta$ measured precisely under a short flight path of approximately 2 m using fast plastic scintillators.
The experiment was carried out at RIKEN RIBF. Secondary beams, such as Sn isotopes, were produced from a primary beam of $^{238}$U and irradiated onto a reaction target placed at the F8 focal plane. The $Z$-identification of the reaction products downstream of the target was performed using the ionization chamber in combination with a newly developed short flight-path TOF measurement system. This system employs fast plastic scintillators together with a processing circuit configured for high-precision time measurement.
In this study, we investigated the timing resolution and its position dependence of the developed plastic detectors, as well as the achieved $Z$-identification capability when combined with the ionization chamber. The result will be discussed in detail.

**Poster Session / **ポスターセッション

## Measurement of Interaction Cross Sections Near Stable Nuclei in TRIP-S3CAN/TRIP-S3CAN における安定核近傍の相互作用断面積測定

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The interaction cross section (σI) is a fundamental observable that provides valuable information about the spatial extent of atomic nuclei and can be used to derive the nuclear matter radius. By determining nuclear radii, we can improve our understanding of nuclear structure and how nuclear size changes across the nuclear chart.
Traditionally, nuclear charge radii have been obtained from electron scattering and laser spectroscopy experiments. However, nuclear matter radii have not yet been widely determined from interaction cross sections over a wide range of mass numbers.
The TRIP-S3CAN experiment in 2025 at RIKEN' s Radioactive Isotope Beam Factory (RIBF) aims to systematically investigate approximately 300 isotopes over a wide range of atomic numbers Z = 25 60. In this experiment, the magnetic rigidity (Bρ), time of flight (TOF), and energy loss (ΔE) of the particles were measured to determine Z and mass-to-charge ratio (A/Q), and to identify the isotopes contained in the secondary beam. In this study, we determined the experimental interaction cross sections for nuclei near the line of stability. These results were compared with theoretical model predictions to clarify the structure of stable and near-stable nuclei and to elucidate nuclear reaction mechanisms more precisely.

**Poster Session** / ポスターセッション

## One-proton Removal Cross Section of $^{90}$Sr Using a Thick Solid Deuteron Target/厚い固体重水素標的を用いた$^{90}$Sr の 1 陽子剥離断面積

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In Accelerator-Driven systems (ADS), reliable cross-section data for fast neutron interacting with radioactive waste are essential for improving the prediction accuracy of transmutation performance [1]. Due to the high radiotoxicity of the waste, it is difficult to use it directly as a target; therefore, a neutron target is desired. However, the fabrication of a stable neutron target is not feasible. A recent theoretical study suggests that neutron reaction cross sections can be indirectly extracted by combining those measured with deuteron and proton targets [2]. There¬fore, a deuteron target has the potential to provide such data and is important. We are develop¬ing a thick solid deuterium target (SDT) for reaction cross-section measurements. Thick targets are advantageous for these measurements, as they improve statistical uncertainty and reduce measurement time due to the increased number of reactions within the target.

By further developing the existing solid hydrogen target production system [3], we fabricated a thick, large-aperture SDT with a length of 50 mm and a diameter of 50 mm. To check the system, we performed an ion beam irradiation experiment using the SDT.
The experiment was carried out at the BigRIPS beamline of RIKEN RIBF. A primary $^{238}$U beam at 345 MeV/u was incident on a $^{9}$Be production target to produce a cocktail beam that included $^{90}$Sr at 235 MeV/u via projectile-fission reactions. The sec¬ondary beam was irradiated onto the SDT, which was located at the entrance of the ZeroDegree spectrometer (ZDS). The time of flight (TOF) was measured by two plastic scintillation coun¬ters. The magnetic rigidity ($B\rho$) was determined by the trajectory reconstruction using the positions and angels of particles measured by parallel-plate avalanche counters (PPACs) in¬stalled at each focal plane. The energy loss ($\Delta E$) was measured by an ionization chamber. The particles in both upstream and downstream of the SDT were identified event by event via the TOF $B\rho$-$\Delta E$ method. In this study, we evaluated the performance of our SDT system by comparing the one-proton removal cross sections of $^{90}$Sr with the data reported in Ref. [4]. We will report the experimental setup and the results.

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**Poster Session** / ポスターセッション

## Analysis of Neutron-Induced Gamma-ray Background for BNCT Dose Evaluation System Using a LaBr3 Detector/$LaBr_3$ 検出器を用いた BNCT 線量評価システムの中性子誘起ガンマ線バックグラウンドの解析

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Currently, several approaches have been investigated for dose evaluation in the boron neutron capture therapy (BNCT). (1) In clinical practice, the absorbed dose is typically evaluated using the gold wire activation technique combined with pre-treatment PET scans, which provide both the neutron flux and boron concentration. (2) Another approach introduces MRI-sensitive structures, such as Gd-containing compounds, into boron agents, allowing boron concentration to be inferred from MRI [1]. (3) A more direct method, known as PG-SPECT (Prompt Gamma SPECT) [2], detects the 478 keV prompt gamma rays emitted from the $^{10}$B(n, $\alpha$)$^{7}$Li reaction, thereby estimating the actual reaction rate and corresponding dose. The advantage of PG-SPECT is that it eliminates the need for gold wire activation measurement, providing a direct and online assessment of the treatment dose.
In our previous studies, PG-SPECT has faced several challenges. One major issue is the large neutron-induced gamma-ray background. Because the neutron fluence in BNCT experiments in the lab system can reach the order of $10^9\ \mathrm{n/cm^2/s}$, extensive neutron interactions occur within the detection system, producing a substantial and complex gamma-ray background that interferes with the measurement of the $478\ \mathrm{keV}$ gamma-ray signal. Our previous findings suggest that these secondary gamma rays are mainly generated by neutron interactions within the material inside the PMT. Therefore, in this study, we employ PHITS simulations to investigate and validate this hypothesis.
Another challenge lies in the trade-off between lightweight system design and background shielding. Conventional clinical SPECT systems typically detect the $140\ \mathrm{keV}$ gamma rays emitted by $^{99m}$Tc, requiring only a few millimeters of lead shielding. In contrast, PG-SPECT must detect $478\ \mathrm{keV}$ prompt gamma rays, which necessitates significantly thicker shielding layers. This results in increased system volume and weight, making compact and clinically practical designs more difficult. Therefore, an optimal balance must be achieved between shielding performance and mechanical lightweight-

ing.
In this study, PHITS simulations are conducted to clarify the origin of neutron-induced gamma-ray background and to explore optimized shielding and collimator configurations that reduce these backgrounds while minimizing overall system weight. This work aims to support the development of a clinically feasible PG-SPECT system for BNCT dose monitoring.

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**Poster Session** / ポスターセッション

## Production cross sections of 44g,mSc from GeV-energy proton incidence/GeV エネルギー陽子入射による 44g,mSc 生成断面積

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Isomer production is important in nuclear applications, such as radiation safety and radioactive waste management, and theoretical nuclear physics, such as level structure. Although the isomer production can be described by EBITEM [1] in PHITS [2], the number of reactions used as benchmarks is limited. Thus, further verification of the EBITEM's performance is essential. To confirm the availability of EBITEM, we selected the $^{44g,m}$Sc production cross sections and the isomeric ratios of $^{44}$Sc as benchmarks due to following reasons: 1) the decay from the parent ($^{44}$Ti, $T_{1/2}$ = 59.1 y) is minuscule, 2) the de-excitation from $^{44m}$Sc ($T_{1/2}$ = 58.61 h) to $^{44g}$Sc ($T_{1/2}$ = 4.042 h) is negligible, and 3) $^{44m}$Sc ($E_\gamma$ = 271.25 keV) has the unrelated $\gamma$-line to $^{44g}$Sc ($E_\gamma$ = 1157.02 keV). We have been measuring the nuclide production cross sections of GeV-energy proton incidence on the targets with the atomic number 21 to 30 by an activation technique at J-PARC. For the measurement of $^{45}$Sc, $^{nat}$V, $^{55}$Mn, $^{59}$Co, $^{nat}$Ni, and $^{nat}$Cu targets, we acquired both $^{44g,m}$Sc production cross sections. However, for the measurement of $^{nat}$Ti, $^{nat}$Cr, $^{nat}$Fe, $^{nat}$Zn targets, some of the objective cross sections have not been reported. Thus, the purpose of this study is to analyze the data measured at J-PARC to obtain the missing cross sections. We successfully acquired the cross sections of interest (5 reactions and 13 data points). In this poster, we compared our present data with the results of previous studies and the combination of nuclear reaction model and EBITEM. We also discuss the proton energy dependence and target-Z dependence of an isomeric ratio of $^{44}$Sc.

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**Poster Session** / ポスターセッション

## Measurement of charge-changing cross sections of 38-43Ca/38-43Ca の荷電変化断面積測定

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The charge radius of an atomic nucleus is an important physical quantity representing its size. By considering the charge distribution of nucleons, it can be converted into the radii of the proton density distribution within the nucleus. Charged radii have been derived from measurements of electron scattering and isotope shifts; however, due to experimental limitations, the measurable nuclides are restricted to stable nuclei and some unstable nuclei. Since charge change in nuclear reactions involves a change in proton number before and after the reaction, the charge-changing cross section is known to be sensitive to the proton density distribution of the incident nucleus. In principle, the charge-changing cross section can be measured for any nucleus, provided the beam intensity is experimentally feasible, making it applicable to many unstable nuclei.
This study focused on Ca isotopes and measured the charge-changing cross section around stable nuclei, including regions with proton excess. Since charge-changing cross sections for Ca isotopes in the neutron-rich region ($^{42-51}$Ca) have been measured previously [1], this study systematically discusses charge-changing cross sections including the proton-rich region. The experiments were conducted at RIKEN RIBF as part of the TRIP project. A $^{70}$Zn beam with an energy of 345 MeV/u was irradiated onto a Be production target to produce unstable nuclei via the incident nucleus spallation reaction. The unstable nuclei separated by the RI beam separation production apparatus BigRIPS and irradiated onto a carbon target (1.5g/cm$^2$). The average incident energy of Ca isotopes is 180 230 MeV/u. To obtain charge-changing cross sections, we counted the number of incident particles and the number of Ca isotopes (Z=20) downstream of a carbon target with a transmission method.
In this study, we measured the charge-changing cross sections of $^{38-43}$Ca on a carbon target. In this presentation, we will describe the experimental details and analysis methods, and discuss the systematics of charge-changing cross sections of Ca isotopes.

References
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**Poster Session** / ポスターセッション

## Measurement of displacement cross section using 440-GeV protons at CERN HiRadMat/CERN HiRadMat における 440 GeV 陽

# 子を用いたはじき出し断面積測定

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As a material-damage index due to the radiation, displacement per atom (dpa) is used widely, which is given by the particle fluence and the displacement cross section, which can be obtained by the electrical resistivity change of target materials due to the proton irradiation by the Matthiessen rule. The sample had to be cooled at cryo-temperature to observe the very small resistivity change and sustain the damage. To obtain the cross section data, J-PARC and JAEA conducted experiments using protons in the kinetic energy range from 100 MeV to 120 GeV. The experimental results were compared with the calculation based on the Norgett-Robinson-Torrens model (NRT-dpa), which is widely utilized to determine the dpa. It was found that the NRT-dpa overestimated the experiment by a factor of 3-8, depending on the target materials. A recent model based on athermal recombination corrected model (arc-dpa) showed good agreement with the experiment. It is of interest to compare the experimental cross section with the calculation model at high energy, such as 440 GeV, where the energy deposition increases due to relativistic effects. To obtain the experimental data, we conducted an experiment at CERN HiRadMat using the 440 GeV protons. In this session, the preliminary displacement cross sections results are shown compared with the calculation results. It was found that PHITS calculations with arc-dpa reproduced the experiment well. On the contrary, the NRT-dpa calculation overestimates the experimental data.

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**Poster Session** / ポスターセッション

# Preliminary Benchmark Study on the Large-Angle Neutron Scattering Cross Section of Liquid Nitrogen ($LN_2$)./液体窒素 ($LN_2$) の大角度中性子散乱断面積に関する予備ベンチマーク研究

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A preliminary benchmark study has been conducted to investigate the large-angle neutron scattering cross section of liquid nitrogen ($LN_2$). This work is motivated by the crucial role of nitrogen as a constituent nuclide in several materials used for the blanket and shielding systems of fusion reactors. Despite its importance, existing nuclear data for nitrogen remain insufficiently accurate, particularly in the high-energy neutron range. Hence, an experimental benchmark is essential to validate and improve these data.
The benchmark experiment was performed at the OKTAVIAN facility, Osaka University, Japan, employing the two-shadow-bar technique previously established by the author's group [1]. Four irradiation configurations were conducted, corresponding to two shadow-bar sizes (S1 and S2) with and

without the target, denoted as S1t, S1nt, S2t, and S2nt. Unlike previous studies using solid targets, the present work utilized a liquid nitrogen target enclosed by Styrofoam to sustain the cryogenic condition during irradiation.
Monte Carlo simulations using MCNP5 [2] was carried out among major evaluated nuclear data libraries: JENDL-4.0 [3], JEFF-3.3 [4], and ENDF/B-VIII.0 [5]. The results indicated considerable discrepancies between experimental and calculated values. This large statistical error mainly attributed to target instability caused by $LN_2$ evaporation during irradiation. So that, several technical improvements are being developed, including optimization of container design, enhancement of thermal insulation, and selection of highly effective activation foils.

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