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Book of Abstracts

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Neutron Capture Cross Section Measurement of Minor Actinides in Fast Neutron Energy Region for Study on Nuclear Transmutation System

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A research project entitled Study on accuracy improvement of fast-neutron capture reaction data of long-lived MAs for development of nuclear transmutation systems has been ongoing since 2017. The project aims at improving accuracies of neutron capture cross sections of long-lived minor actinides (^{237}Np, ^{241}Am, ^{243}Am) in the fast neutron energy region which are very important for development of nuclear transmutation systems. In order to improve the capture reaction data of MAs, measurements using an intense pulsed neutron beam from a spallation neutron source of the Japan Proton Accelerator Research Complex (J-PARC) are planned. The project consists of four parts: (1) development of neutron beam filter system in J-PARC, (2) neutron capture cross section measurement, (3) sample characteristic assay, and (4) theoretical reaction model study. The neutron beam filter system is designed to solve the so-called double bunch issue of a neutron beam in J-PARC. This allows for measuring neutron capture cross sections using the high-intensity neutron beam of J-PARC. The sample characteristic assay, particularly, precise isotope mass spectrometry lowers systematic uncertainties originating the samples. In the theoretical reaction model study, a nuclear reaction model is employed to analyze not only cross sections but also γ-ray spectra measured in experiments, and then improve accuracies of evaluated nuclear data. The outline of the project and the current progress will be presented.
This work is supported by the Innovative Nuclear Research and Development Program from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

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Recent progress and future plan on the JENDL project

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The latest version of JENDL general purpose file, i.e. JENDL-4.0 was released in 2010. It focused on improvements of the data of fission products and minor actinides that would be important for research and development on light water reactors with high burn-up and MOX fuels, and also for innovative reactors such as ones for accelerator driven system. After that, many special purpose files have been released: JENDL FP Decay Data File 2011 (JENDL/FPD-2011), JENDL FP Fission Yields Data File 2011 (JENDL/FPY-2011), JENDL-4.0 High Energy File (JENDL-4.0/HE), JENDL Decay Data File 2015 (JENDL/DDF-20215), JENDL Photonuclear Data File 2016 (JENDL/PD-2016), JENDL Activation Cross Section File for Nuclear Decommissioning 2017 (JENDL/AD-2017), JENDL LLFP Transmutation Cross Section File 2018 (JENDL/ImPACT-2018). These files were developed to meets needs from expanding fields of applications such as backends of nuclear energy and accelerator utilizations. In addition to the special purpose files, development of the next version of general purpose file JENDL-5 is in progress. For JENDL-5, we are aiming at increasing completeness and reliability from JENDL-4.0 in viewpoints of target nuclide species and data uncertainties by taking into accounts the current knowledge of cross section measurements, nuclear theory and integral benchmark tests. A new R-matrix theory code AMUR has been developed and applied to the resonance analysis for light nuclides. Structure

materials and medium-heavy nuclides have been evaluated using the modern nuclear reaction model codes CCONE. Minor actinides data was updated using the TOF measurements with ANNRI installed at MLF in J-PARC. The first test library JENDL-5α1 was created last year and its integral benchmark tests was performed. The next version of the test files JENDL-5α2 will be made in this year. JENDL-5 is planned to be released in 2022. At the symposium, progress and future plan of JENDL-5 and summary of the recently released special purpose files will be presented.

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A Consideration on Nuclear Data Needs for 1F Decommissioning

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After 8 years from the accident at TEPCO Fukushima Daiichi Nucleat Power Station (1F), the “on-site” R&D situation has been changed into new phase. It can be considered like from understanding to predicting by many direct and indirect measurements and analyses. In this presentation, nuclear data needs for 1F decommishioning are revisited according to these situation. The needs for accident evolution characteristcs, criticality management, deburis strage, waste management, etc. are considered with the view point of R&D on prediction what is going on and will be happened in each stage of decommisioning.

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Fundamental physics using neutron at J-PARC and accelerator-driven compact neutron source

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Precise measurements using low energy neutron give a complementary information to the collider experiments using high energy accelerators. Moreover, it is also sensitive to a new physics in high energy regions where the collider experiments may not reach. High quality neutron beam can be provided to an experimental apparatus by using the neutron optics which has been gratly advanced in recent years. A beamline BL05, which is intended for the fundamental physics using low energy neutron, has been constructed at the J-PARC/MLF, and successfully started the operation in the end of 2008. In this talk, the experiments using low energy neutron conducted at the J-PARC/MLF/BL05 will be given. In addition, recent situation of accelerator-driven compact neutron source will be also presented in this talk.

Poster Session - Board: 1 / **26**

Production cross sections of ^{45}Ti via deuteron-induced reaction on ^{45}Sc

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The nuclide ^{45}Ti has a half-life of 184.8 min and is a positron emitter (E^{+}= 439 keV, I^{+}= 84.8%)suitable for positron emission tomography (PET). The deuteron-induced reaction on a scandium-45 target is a possible route to produce this radionuclide at cyclotrons. In this study, the cross sections of the ^{45}Sc(d,2n)^{45}Ti reaction were measured using stacked foil activation method and -ray spectrometry up to 24 MeV.
The experiment was performed at the AVF cyclotron of the RIKEN RI Beam Factory. The stacked target consisted of pure metallic foils of ^{45}Sc (7.71 and 76.0 mg/cm^2 thickness, 99.0% purity), ^{27}Al (4.99 mg/cm^2, 99.6%) and ^{nat}Ti (9.13 mg/cm^2, 99.6%). The stack was irradiated for 30 min by a 24-MeV deuteron beam of an average intensity of 180.3 nA. The incident beam energy was measured by time-of-flight method. The energy degradation in the stacked foils was calculated by the SRIM code[1].

https://www.jcprg.org/temp/45Ti.png

Figure 1: Fig. 1. The excitation function of the ^{45}Sc(d,2n)^{45}Ti reaction.

The excitation function of the ^{45}Sc(d,2n)^{45}Ti reaction is shown in Fig. 1 in comparison with the previous data[2] and the theoretical estimation of TENDL-2017[3]. The derived excitation function of the ^{45}Sc(d,2n)^{45}Ti reaction is almost consistent with the data reported by Hermanne et al.[2]. The TENDL-2017 data show that the peak position is slightly shifted to the lower energy compared to the two experimental data sets. The experiment was carried out at RI Beam Factory operated by RIKEN Nishina Center and CNS, University of Tokyo, Japan. This work is supported by JSPS KAKENHI Grant Number 17K07004. Ts.Z was granted a scholarship by the Mongolian-Japan Engineering Education Development Program, M-JEED project J11B16.
References:

1. Ziegler JF, Ziegler MD, Biersack JP. SRIM - The stopping and range of ions in matter (2010). Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms. 2010;268:18181823.

2. Hermanne A, Adam Rebeles R, Tarkanyi F, et al. Cross sections of deuteron induced reactions on 45Sc up to 50 MeV: Experiments and comparison with theoretical codes. Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms [Internet]. 2012;270:106115. Available from: http://dx.doi.org/10.1016/j.nimb.2011.09.002.

3. Koning AJ, Rochman D, Sublet JC, et al. TENDL: Complete Nuclear Data Library for Innovative Nuclear Science and Technology. Nucl. Data Sheets. 2019;155:155.

Poster Session - Board: 2 / **43**

Production of ^{169}Yb by the proton-induced reaction on ^{169}Tm

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The radionuclide ^{169}Yb ($T_{1/2}$ = 32 d) decays with emission of Auger electrons and X-rays, which can be used for brachytherapy. We have systematically investigated the production routes of ^{169}Yb through charged-particle induced reactions. Deuteron- and alpha-induced reactions on ^{169}Tm and alpha-induced reactions on ^{nat}Er have already been studied. Recently an experiment of the proton-induced reaction on ^{169}Tm was performed. In this paper, we report the preliminary result of this experiment.
The experiment was performed using the MGC-20E cyclotron at Institute for Nuclear Research (ATOMKI), Hungary. The stacked foil activation technique and the high-resolution gamma-ray spectrometry were used. Pure metallic foils of ^{169}Tm (21.0 mg/cm^2, 99.0% purity) and ^{nat}Ti (9.1 mg/cm^2, 99.6% purity) were stacked as a target. The target was irradiated for 30 min by an 18 MeV proton beam with 210 nA. Gamma-ray spectra were collected for the irradiated foils by a HPGe detector.
Our preliminary result of the ^{169}Tm(p,n)^{169}Yb reaction is shown in Fig. 1 in comparison with the previous experimental data [1-3] and the TENDL-2017 data [4]. The peak amplitude of the result is normalized to the data of Birattari et al. (1973) 1. The detailed analysis is being performed.

https://www.jcprg.org/temp/fig-169Yb.png

Figure 2: Cross sections of the ^{169}Tm(p,n)^{169}Yb reaction with the previous data and the TENDL-2017 data.

Reference

1. C. Birattari et al., Nucl. Phys. A 201 (1973) 579.
2. I. Spahn et al., Appl. Radiat. Isot. 63 (2005) 235.
3. F. Tarkanyi et al., Appl. Radiat. Isot. 70 (2012) 309.
4. A. Koning and D. Rochman, Nucl. Data Sheets 113 (2012) 2841.

Poster Session - Board: 3 / **69**

Proton-induced reactions of 93Zr using the OEDO beamline

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Estimation of reaction cross sections using existing nuclear data libraries is difficult at a low energy where compound reaction and pre-equilibrium reaction compete with each other. Accumulation of experimental data in such an energy range, therefore, helps to establish a developed library as a testing ground of novel theories of reaction mechanism. On the other hand, ^{93}Zr, one of the long-lived fission products (LLFP) produced by nuclear reactors, has been well studied to find an optimal pathway as nuclear transmutation. This research aims to measure the cross sections of the products of the proton-induced reactions of ^{93}Zr at 30 MeV/u in inverse kinematics on purpose of accumulating nuclear data as well as of investigating suitability of such a reaction for nuclear transmutation. Note that this is the part of the first physics experimental campaign using OEDO, the low energy beamline employing the slowing-down method. In this presentation, we will show the experimental setup, analysis, and preliminary results with the estimations.

Poster Session - Board: 4 / **25**

Measurements of nuclear cross section data for proton-induced reactions on Bi and Pb targets at intermediate energy

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Nuclear cross sections data of 209Bi(p, xn)207,206,205,204,203Po, 209Bi(p, pxn)207,206,205,204,203,202Bi, and natPb(p, xn) 206,205,204,203,202,201Bi reactions were measured using the well-known stack-foil activation technique and gamma-ray spectrometry over the 40 to 100 MeV proton energy range. The targets were arranged in different stacks consisting of Bi, Pb, Al, Au foils and Pb plates. The proton beam intensity was determined by activation analysis method using 27Al(p, 3pn)24Na, 197Au(p, pn)196Au, and 197Au(p, p3n)194Au monitor reactions. Around 90 nuclear cross section data points were totally measured in this work.
Furthermore, excitation functions of the mentioned reactions were calculated by using the theoretical models based on the TALYS code and compared to the measured data in this work as well as with other data in the literature. To investigate the effects of various nuclear models on the reaction excitation functions, combinations of the nuclear input parameters of different level density models, optical model potentials, and -ray strength functions were considered. It was concluded that the level density models influenced the reaction cross sections significantly.

Poster Session - Board: 5 / **59**

Measurement of nuclide production cross sections for Z = 26-30 elements irradiated with 0.4 - 3.0 GeV proton in J-PARC

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For the design of Accelerator-Driven nuclear transmutation System (ADS), accurate cross section data are required to estimate the number of radioactive nuclides for treating radioactive wastes in the ADS plant. Although much effort has been devoted to obtaining the nuclide production cross section irradiated by protons in the energy region utilized for the ADS at several facilities so far, data with systematic uncertainties of ~10% exist. Furthermore, no experimental data still exist around for protons in a few GeV region. In order to validate the calculation code and the evaluated data utilized for the ADS, we started the experiment to obtain the cross section at 3-GeV synchrotron in J-PARC.
In this study, we obtained nuclide production cross section for targets with Z numbers from 26 to 30 (i.e. ^{nat}Fe, ^{nat}Ni, and ^{nat}Zn), which are important regions for the estimation of the radioactivity of the ADS structural materials. Furthermore, we investigated the incident energy dependency on the cross section from several hundred MeV to 3 GeV using the present and

the previous experimental data, comparing with different intra-nuclear cascade and evaporation models of INCL4.6/GEM, INCL++/ABLA07, and Bertini/GEM, and evaluated nuclear data of JENDL-HE2007.

Poster Session - Board: 6 / **57**

Study of an angular correlation of γ-rays emitted by 117Sn(n,γ) reactions for T-violation search

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The breaking of parity symmetry and charge conjugation (CP-violation) is necessary to explain a difference between the number of matter and that of antimatter in the current universe. Assuming the CPT theorem, CP-violation means the violation of time reversal invariance. It is theoretically suggested that T-violation could be enhanced in compound nuclear reactions by an interference between an amplitude of a s-wave resonance and that of a p-wave resonance. This theory predicts that one of key parameters for T-violation search is a spin factor κ(J) which corresponds to experimental sensitivity. The value of κ(J) depends on nuclear species and can be determined by measuring an angular correlation of γ-rays produced by (n,γ) reactions which compound nuclear state in a p-wave resonance decays to a specific state. If a nucleus has large κ(J), it becomes a candidate for T-violation search. To determine the value of κ(J) of 117Sn, which is easy to measure angular correlation because its p-wave resonance ca be clearly observed, we measured the angular correlation of γ-rays emitted from the compound states at J-PARC MLF BL04. The angular correlation was observed clearly when the compound state decays to a ground state. In addition, we conducted an experiment for determining a branching ratio which the compound state decays to the ground state in the (n,γ) reaction. In this poster, we will report the experimental result and analysis status.

Poster Session - Board: 7 / **62**

Measurement of ray angular distribution to come from 4.53 eV p-wave resonance of 111Cd in compound nuclear reaction

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In order to explain our universe, the existence of unknown CP violation is necessary. CP violation is equivalent to time reversal violation by assuming CPT invariance. We are planning to search for a new source of time reversal violation using compound nuclear reactions, in which a nucleus absorbs neutron and emits ray. It is experimentally observed that enhancement of parity violation by compound nuclear reactions is amplified by a factor of 10ˆ6 compared to proton-proton scattering. This effect is considered due to s-p mixing, which is interference between tails of s-wave and p-wave. It is theoretically suggested that similarly enhancement mechanism can be applied to time reversal violation. In the theory, the magnitude of the enhancement for time reversal violation depends on a spin factor (J,) which has a different value for each nucleus, whose is a parameter of partial neutron width with j = 1/2, and j = 3/2. We performed a measurement to determine the (J,) of 111Cd in J-PARC MLF BL04. 111Cd is a strong candidate for a search for time reversal violation since it has a large enhancement factor for parity violation. We can determine (J,) using parameter , which is only determined by comparing calculation and experiment of shape change of p-wave resonance relying on the angle of emitted ray. We studied the shape change using ray energy measuring the angular distribution of rays emitted by compound nuclear reaction by using germanium detectors, and neutron energy acquired by using time of flight technique. We will present the result of the analysis for the determination of (J,) of 111Cd.

Poster Session - Board: 8 / **28**

Measurement of photon strength function in In-115 at gELBE facility

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The photon strength function (PSF) is an important quantity to estimate the neutron capture cross section for the understanding of astrophysical processes and applications to nuclear engineering. In the last half century, the giant dipole resonance (GDR) has been studied well. Recently, the PSF on the low-energy tail of the GDR below the neutron threshold is of particular interest because of the appearance of an extra enhancement of E1 strength called Pygmy dipole resonance (PDR), or M1 strength in addition. The nuclei heavier than iron are mainly produced via s-, r-, or p- processes. The origin of p-nuclei is said to be production via photodisintegration in the O/Ne layers of core-collapse of massive stars explosions of supernovae type I or II, or/and s-, r- processes. However, one of the p-nuclei, ^{115}Sn still cannot be explained with its production abundance. Recently, the s-process contribution is tried to be explained at the branching point of neutron capture reaction and -decay at ^{113}Cd^{m} by the following reactions: ^{112}Cd(n,g)^{113}Cd^{m}(-)^{113}In(n,g)^{114}Sn(n,g)^{115}Sn. It was found that an s-process contribution from ^{113}Cd^{m} is not sufficient to explain the production problem of ^{115}Sn. In this study, we would like to shift the viewpoint to the ^{115}In region, which is produced via the main s-process. In this region, 3 possible reactions compete between ^{115}In(g,n)(n,g)^{114}In(-)^{114}Sn(g,n)^{115}Sn. However, both the photodisintegration rate for ^{115}In and the neutron capture rate for ^{114}In have not been known experimentally well. Hence, we measured the ^{115}In(g,g)^{115}In reaction to estimate the photodisintegration rate and the rate of the inverse ^{114}In(n,g)^{115}In reaction.

Poster Session - Board: 9 / **50**

Comparison between experimental and calculation neutron spectra of the 197Au (γ,n) reaction for 17 MeV polarized photon

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Until now, neutron spectra were measured for 17MeV polarized photons on a thick Au target at angles from 30 to 150 degrees 1. The result shows two components of neutrons, evaporation and direct. The angular distribution of the evaporation shows isotropic and that of the direct shows dependence on angle between photon polarization and neutron emission. These spectra are useful to evaluate models and parameters in theoretical calculation, however, comparison between of experiment and calculation has not been done. For this comparison, double differential cross section (DDX) is more preferable than thick target neutron spectra, because cumulative effect in the target can be eliminated. Therefore, we measured the DDX of the 197Au(g,n) for 17 MeV polarized photons on a thin target and compared the results with that of PHITS calculation. The experimental setup was identical except for target thickness, the reduction of which decreases the attenuation of photon and neutron. The polarization direction of photon was set to horizontal, that was parallel to the floor. The neutron detector, a NE213 organic liquid scintilla tor (12.7 cm x12.7 cm L), was placed at 90 degrees horizontally with respect to photon beam axis and 60 cm away from the target. PHITS code (version 3.12) has been used to calculate the double differential cross section. The result shows neutron spectrum only from evaporation model although two components were observed in experiment. The quantitative comparison and discussion will be presented at the symposium.
Keywords: differential double cross section photon neutron , 17MeV polarized photon, Au, PHITS calculation.

Poster Session - Board: 10 / **44**

Measurement of total neutron cross section of Niobium at J-PARC MLF ANNRI

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Niobium(Nb)-93, which is mono isotope, is one of the material elements to strengthen stainless steel and is used for structural materials of nuclear reactors. Since Nb is also used as an element of superconductor alloys, it has been used in fields such as fusion reactor and accelerator development. Determination of neutron total cross section with high accuracy is therefore required in the field of nuclear technology. The cross sections of Nb were measured by T. Wang(2011), N. J. Drindak(2006) and so on. However, the resonance parameters determined by them have discrepancies up to about 10% each other. In order to determine the more precise values of resonance parameters, transmission measurements were performed to evaluate total cross section of ^{93}Nb at the ANNRI of MLF in J-PARC in June of 2019. The ANNRI is one of beamlines in

MLF, and Germanium gamma-ray detectors and the Liglass neutron detectors are installed to measure nuclear reactions. A target was natural Nb plate of 25 mm × 25 mm × 10 mm^t whose size was determined from necessary statistic. Since the target size was big and the thermal-neutron capture cross-section is small (about 1.1 barns), the effect of neutron diffraction was observed in low neutron energy region. When discussing reactions to a single nucleus, the effect of diffraction resulting from crystal structure is unnecessary information. Thus, this effect must be estimated and removed to determine the total cross section as nuclear data for a single nucleus. In this poster, I will present preliminary results of the experiment and the estimated effects of neutron diffraction. This work has been supported in part by Grants-in-Aid for Scientific Research (JP17H01076).

Poster Session - Board: 11 / **37**

High-Energy Measurement of the Neutron Capture Cross Section of ^{237}Np

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Precise nuclear data for neutron capture reactions of minor actinides (MA) have become a primary research topic for their preponderant role in the study and design of transmutation methods in nuclear waste management. Accurate nuclear data are necessary in order to examine their production and long term burn-up characteristics. Present nuclear evaluated data libraries can be used in the early stages of the design of transmutation nuclear systems. Nonetheless, the exhaustive engineering designs and safety assessments require more precise and complete nuclear data and a significant reduction in terms of their uncertainties.

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

The neutron capture cross section measurements were performed using the Accurate Neutron Nucleus Reaction Measurement Instrument (ANNRI) at the Materials and Life Science Facility (MLF) of the Japan Proton Accelerator Research Complex (J-PARC). A Time of Flight (TOF) method using a NaI(Tl) detector was employed for this measurement and the data were analyzed based on a pulseheight weighting technique in order to derive a neutron capture yield.

A capture sample of ^{237}Np with a mass of 200 mg was used for the measurements. The sample consisted of 227 mg of neptunium dioxide (NpO_2) powder together with 624.5 mg of Al powder, used as a binder, and it possessed an activity of 5 MBq. The neutron spectrum was reconstructed using the 478 keV gamma-rays from the ^{10}B (n,) ^{7}Li reaction with a boron sample containing enriched 10B up to 90%.

A final value for the capture cross section of ^{237}Np is presented using two normalization techniques. The capture data was normalized at the first resonance using JENDL-4.0 and also using the total neutron flux obtained from a ^{197}Au sample measurement in which the first resonance was completely saturated. This measurement results were complemented with calculations using CCONE code to estimate the PH spectrum under the detection threshold.

Alongside these results, an analysis of the high-energy capture cross-section with CCONE was performed. An evaluated cross-section is presented using the experimental results.

Poster Session - Board: 12 / **63**

New Methods to Reduce Systematic Uncertainties of Capture Cross Section Measurement Using a Sample Rotation System

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Accurate nuclear data for neutron-induced reactions are essential for the design of nuclear transmutation system. However uncertainties of nuclear data such as Minor actinides (MA) do not fulfill requirement for the design of transmutation facilities. Measurement of the neutron capture cross section is ongoing at the Accurate Neutron Nucleus Reaction Measurement Instrument (ANNRI) in the Materials and Life Science Experimental Facility of the Japan Proton Accelerator Research Complex (J-PARC). The determination of the absolute values of cross sections is one of the main causes that affect the final uncertainties of cross section results.
In the present work, we suggest two new methods to reduce systematic uncertainties of capture cross section measurement. Both methods employ change of the self-shielding effect with sample rotation angle. The first method is for thickness determination of a B-10 sample which is used for measurement of the incident neutron spectrum. In capture cross section measurements in ANNRI, we place B-10 sample and determine the incident neutron spectrum by counting the 478 keV -rays from the B-10(n,)Li-7 reaction. The uncertainty of the B-10 sample thickness, more precisely the area density that is usually calculated from the mass and the area, introduces the uncertainty of the shape of the incident neutron spectrum. In this method, the B-10 sample is tilted with respect to the neutron beam direction, thereby changing the effective thickness. The neutron self-shielding effect increases with the effective thickness. This results in change of the shapes of time-of-flight (TOF) spectrum of 478 keV -ray counts from the B-10(n,)Li-7 reaction with the tilted angle. Comparing the difference of the TOF spectra at different angles and assuming the 1/v energy dependence of cross section of the B-10(n,)Li-7 reaction, the area density of the B-10 sample can be determined without using sample mass and area.
The second method suggested in this work is for absolute determination of the capture cross section. For absolute determination of capture cross section. a typical and often-used technique is the saturated resonance method that is based on the fact that the number of neutron capture events becomes equal to the number of the incident neutrons at a large resonance when the sample is very thick and the resonance is fully saturated. The principle of our method is similar to the saturated resonance method but this method does not require a fully saturated resonance. In this method, the neutron self-shielding factor is determined from change of resonance peak height with sample tilted angle. The self-shielding factor at the resonance peak is used for normalization to give the absolute capture cross section.
Theoretical and experimental studies on the methods are ongoing. Calculations using Monte Carlo simulation code PHITS were carried out to study the feasibility of the present methods. Test experiments using a sample rotation system at ANNRI were also performed. We used Np-237 sample in the measurements. Preliminary results will be given in this contribution.

Poster Session - Board: 13 / **47**

Proton Spectra with Low-Energy-Threshold from 40- and 70-MeV Proton-Induced Reactions

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Energy and angular distributions of secondary particles from energetic proton-nucleus reactions are required to estimate the spatial distributions of energy deposition and radiation damage for the engineering design of an accelerator driven system and a particle radiation therapy. Because the estimation is performed using a Monte Carlo simulation code such as PHITS, the nuclear reaction models must have high predictive power for energy and angular distributions. A two-stage model comprising the intra-nuclear cascade (INC) model and the generalized evaporation model (GEM) generally well describes proton production for intermediate energy proton-nucleus reactions, except for low-energy proton production from a heavy target. The emission of low-energy proton from an excited nucleus is calculated by the GEM after INC stage with considering Coulomb barrier. To improve the GEM, new experimental data covering the low-energy range down to 2 MeV are required for various targets and angles from forward to backward because systematic data are not available in this energy range because of threshold energy of conventional detector with dE-E particle identification. To obtain the data, we develop a low-energy-threshold detector consisting of a Bragg curve counter (BCC) and two silicon-surface barrier detectors (SSDs), and a bismuth germanate (BGO) scintillator. The experiment was performed at cyclotron facility of National Institute of Radiological Sciences for 40- and 70-MeV incident protons on C, Al, Cu, Au targets. Secondary particle spectra were measured at 60, 120, and 150 degrees in the laboratory system using the low-energy-threshold detector. The resultant spectra are compared with results of nuclear data library of JENDL-4.0/HE and prediction from the two-stage models.

Poster Session - Board: 14 / **64**

Charged particle emission reactions induced by 100-MeV/u 12C ions

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Even though carbon-ions provide highly conformal dose distributions thanks to the Bragg peak and the high straightness of the track, they will induce undesired dose outside the primary beam field. The undesired dose arises from secondary particles produced through beam interactions with the patient's body. Despite intensive studies, lateral dose distributions are not understood well, because there are no energy-angle double-differential cross sections (DDXs) of heavy-charged particle productions at large angles. The purpose of this study was to measure DDXs of carbon-ion nuclear reactions to improve accuracy of secondary dose estimation in carbon-ion radiotherapy. The measurement was performed at the Heavy Ion Medical Accelerator in Chiba (HIMAC), National Institute for Radiological Sciences, Japan. The carbon-ions were accelerated to 100 MeV/u and bombarded the target (C, Al, and Co). Emitted charged particles were detected by counter-telescopes installed at the PH2. Light particles (p, d, t. 3He and) were detected with two dE-E telescopes comprising two silicon-surface-barrier detectors (SSDs), a GSO(Ce) crystal and four PWO crystals. Particles heavier than were detected with two dE-E telescopes consisting of two SSDs and a CsI(Tl) crystal. Thanks to their high energy resolutions, isotope separation was achieved for many of detected particles. This report describes experimental results obtained during 2018-2019 at HIMAC.

Poster Session - Board: 15 / **42**

Neutron Production Double-differential cross section from Carbon and Niobium targets bombarded with 290 MeV/u ^{136}Xe ions

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Neutron production double-differential cross sections from thin C and Nb targets bombarded by 290 MeV/u ^{136}Xe ions were measured by using the HIMAC (Heavy Ion Medical Accelerator in Chiba) facility of National Institute of Radiological Sciences, Japan. We used the inverse time-of-flight method using NE213 liquid organic scintillators. NE213 liquid organic scintillators were at the angles of 15ř, 30ř, 45ř, 60ř, 75ř, 90ř. For measuring the background, iron bars were set for each flight path. In order to shield scattering particles from a beam dump, iron and concrete blocks were placed between the detectors and the beam dump. The experimental results were compared with Monte Carlo codes PHITS and GEANT4. Monte Carlo results generally agree with the measured ones within a factor of two.

Poster Session - Board: 16 / **70**

Measurement of Neutron Energy Spectra of 345 MeV/u ^{238}U Incidence on a Cu Target

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Radioactive Isotope Beam Factory (RIBF) at RIKEN accelerates ^{238}U ions up to 345 MeV/u. The operational maximum beam current of ^{238}U is about 70 particle nA now. The maximum permitted intensity of ^{238}U beam at RIBF is 300 particle nA. Optimization of the radiation shielding design is desired for upgrade of beam current to more than 1 particle A in the future. Neutron production thick target yields (TTY) by 345 MeV/u ^{238}U beam is essential as a source term in shielding design. However, there is no data of this reaction. In this study, neutron TTY by ^{238}U beam on a copper target is measured.
The experiment was carried out at Zero Degree Spectrometer beam line of RIBF. The 345 MeV/u ^{238}U beam was induced on a Cu target of 10 mm thick, which was longer than the range of incident ions. Neutrons produced in the target were measured with NE213 liquid organic scintillators, which was set at 0°, 45° and 90° from the beam axis. Time-of-Flight technique was applied to determine the kinetic energies of neutrons. The comparison between measured TTY and simulation results by PHITS will be discussed.

Poster Session - Board: 17 / **52**

Measurement of the energy spectra of hydrogen isotopes from nuclear muon capture in natSi

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Soft errors induced by cosmic ray have been recognized as a major threat for the electronics used at the ground level. The soft error is caused by an upset of the memory information induced by the energy deposition in devices by energetic ionizing radiation. Recently, cosmic-ray muon-induced soft errors have attracted much attention due to the reduction of soft error immunity on static random access memories. Our previous work reported that the negative muon has much more serious effect on the occurrence of SEUs compared to the positive one because of the emission of the light ions from the nuclear muon capture reaction on Si. However, no experimental data of the energy spectra of the light ions from the capture reaction on Si has been reported until now. Therefore, there is an uncertainty in the estimation of the muon-induced soft error rate. To overcome this situation, we newly performed the experiment to measure the energy spectra of the hydrogen isotopes generated via the muon capture reaction on the Si nucleus. The experiment was performed using the MuSIC-M1 muon beam line at RCNP, Osaka University. A 100-ţm thick silicon target was irradiated by the muon beam and the emitted ions from the target was measured by using a E-E telescope that consists of a 325-ţm thick silicon detector (E) and a 25-mm thick CsI(Tl) detector (E). The hydrogen isotopes (proton, deuteron and triton) were detected and their energy spectra were successfully measured. At the poster presentation, the detail of the experiment, results and comparison with the theoretical model will be discussed.

Poster Session - Board: 18 / **56**

Detailed examination of benchmark experimental method for large angle scattering reaction cross section at 14MeV for a flake target

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1.Introduction
The elastic scattering reaction cross section data commonly show smaller in backward angles compared to those of forward angles when the energy of the incident neutron is high. However, in the case of gap streaming phenomenon in the neutronics design of the fusion reactor, the reaction cross section value of back scattering may have a large influence on the calculation result. Until now, there was a difference reported between experimental and calculated values of neutron benchmark experiments using a DT neutron source. The cause is not yet clear, however it has been pointed out that the reaction cross section value of large angle scattering could be uncertain. For this problem, the authors group developed a benchmark method for large angle scattering cross sections and has carried out experiments with an iron sample for the last few years. In the next step, we will consider benchmark experiments for other elements contained in fusion structural materials like W, Si and so on. In this case we expect that it may be required to cope with non-solid samples such as powders, e.g., Si flake. In this study, we propose a method to realize an accurate large angle scattering cross section benchmark that can eliminate the influence of the case of the sample and the wall of the irradiation room when conducting experiments with powder samples filled in the case.

2.Experimental method
In this experiment, a shadow bar is positioned in front of the DT neutron source, and a silicon target filled in a cylindrical case is placed behind it. A Nb foil that detects neutrons is placed on the edge of the shadow bar. The shadow bar has the role of shielding neutrons that are directly incident on the Nb foil from the radiation source. We use two shadow bars, the one of which

is thin, and the other is thick. The thin shadow bar (S1) measures the contribution of large angle scattering neutrons, and the thick shadow bar (S2) measures the contribution of neutrons reflected by the wall. For each of these two shadow bars, two experiments are conducted with and without flake silicon in the case, and in total four experimental results are carried out. The four results are used to estimate the contribution of neutrons from the wall and the contribution of large angle scattering neutrons from the silicon target accurately.

3.Result and discussion
Based on the above experimental principle, we performed numerical simulations using MCNP-5 in order to extract only the contribution of large angle scattering neutron. To clarify the neutron path incident on Nb, we flagged five cells, i.e., shadow bar, wall, Si target, container, and its lid, then examined the contribution of 31 pathways (=5C1 + 5C2 + 5C3 + 5C4 + 5C5). As a result of physical consideration, it was found that 19 paths were needed to be considered in detail because we could remove several paths through which neutrons cannot physically pass. The large angle scattering neutron contribution by the route through lid and target, PATH, is the value we want to obtain as the final experimental result. It was found that the contribution of large angle scattering neutrons can be estimated from the measured Nb reaction rates of four experiments using the following equation.
PATH =(S1tc) -(S1c) -((S2tc) -(S2c)), where tc : Experiment with Si target in the case, c : Experiments with only the case (without Si target).

4.Future plan
The next step is to carry out experiments with the present method and then to find a way to feedback the obtained results to the evaluated nuclear data.

Poster Session - Board: 19 / **54**

Integration test with a Gaseous Detector and a Solenoidal Magnet for the Precise Neutron Lifetime Measurement

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The neutron lifetime, =879.4ś0.6 sec, is an important parameter for particle/nuclear physics and cosmology. There is, however an 8.6 sec(4.0) deviation between the measured values of the neutron lifetime using two methods. A new method with a Time Projection Chamber(TPC) is being implemented at BL05 MLF J-PARC using a pulsed cold neutron beam. A TPC records both the electrons from neutron beta decay and protons from the neutron-3He capture reactions in order to estimate the neutron flux. However, electron background signals require the largest correction and are source of uncertainly for this type experiment. It is confirmed by Monte Carlo simulation that an uniform magnetic field generated by solenoidal magnet along the neutron beam can greatly reduce this background. The detector has been constructed and the integration test with a magnet has been finished and we are now preparing for the operation with neutron beam. We will present the status of this experiment.

Poster Session - Board: 20 / **61**

HUNS upgrade; Simulation of the beam profile for a thermal neutron source in HUNS-2

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The electron linear accelerator in Hokkaido University Neutron Source (HUNS 1) was recently upgraded toward HUNS-2 to increase the electron beam current. The HUNS-2 is an accelerator-driven neutron source that is equipped with a cold-, thermal- and fast-neutron type of sources. Experiments such as a small angle neutron scattering [2], neutron transmission imaging [3] and neutron irradiation test have been currently conducted using HUNS-2 for studies of material science and developments of measurement method.
In this work, the neutron beam profile for the HUNS-2 thermal neutron source was calculated with the Monte Carlo simulation code PHITS [4] to improve a target, moderator and reflector assembly (TMRA) of the present thermal neutron source system [5]. The TMRA consists mainly of a neutron production target with a tungsten disc, lead blocks and water channels, a polyethylene moderator and graphite reflectors. Through the simulations, a position and size of TMRA was designed for increasing the intensity of thermal neutron beam.
1 M. Furusaka, et al., Phys. Proc. 60 (2014) 167. [2] T. Ishida, et al., ISIJ Int. 57 (2017) 1831. [3] K.Y. Hara, et al., EPJ Web Conf. 146 (2017) 03032. [4] T. Sato, et al., J. Nucl. Sci. Technol. 55 (2018) 684. [5] T. Kamiyama, et al., Nuovo Ciemento 38 C (2015) 187.

Poster Session - Board: 21 / **65**

Preliminary experiment on characterization of RANS-II neutron production via the ^{7}Li(p, n)^{7}Be reaction with 2.49 MeV proton injection

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RANS-II, which aims to be the prototype of a compact neutron system for diagnostics of infrastructure, has recently completed in the construction and proton beam of 2.49 MeV successfully was accelerated and injected onto a Li target for neutron production. As the performance of the RANS-II neutron production target is one of most important keys from the neutronics point of view, we firstly set an experimental program to investigate the neutron characteristics with the RANS-II conditions based on the ^{7}Li(n, p)^{7}Be reaction. To measure neutrons below 1 MeV due to the maximum, we have examined two methods; a long counter with ^{3}He which has a thick cylinder moderator for high energetic neutrons surrounded by low energy neutron absorber of B_4C, and the foil activation using the ^{115}In(n, n)^{115m}In reaction which has a low threshold energy of 336 keV. These reaction rates were calculated by the particle transport calculation code, PHITS, and compared with measurements. It was found that there are considerably large discrepancies between experiments and calculations, systematically, and analyses are undertaken taking accounts of possible uncertainties in terms of numbers of proton, detector to source geometry, geometrical model relevant to the transport calculations, and so one. Discussions on nuclear data associated with the p-Li neutron production, such as detection cross sections are to be given.

Poster Session - Board: 22 / **66**

Development of a neutron beam monitor for nuclear data measurement using spallation neutron source

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Highly precise neutron nuclear data is required in nuclear transmutation research of long life minor actinides (MA) in nuclear waste. It has been difficult to measure neutron-induced reaction cross sections of MAs due to large background of the decay γ-rays from the radioactive samples. In recent years, with the advent of spallation neutron sources, the qualities of cross section measurements of MAs were significantly improved. The Japanese Spallation Neutron Source (JSNS) in the Japan Proton Accelerator Research Complex (J-PARC) was started in operation in 2008. In order to utilize a high-intensity pulsed neutron beam from JSNS for nuclear data measurement, the Accurate Neutron Nucleus Reaction Measurement Instrument (ANNRI) was built and has been used for the past ten years.
In neutron capture cross section measurement, the number of the incident neutrons is necessary to derive the neutron capture cross section. To normalize the detected γ -ray yield to the number of the incident neutrons, the neutron count is usually monitored by detecting the incident neutrons with a neutron detector. However, in measurement with ANNRI, neutron monitoring detection has not been employed and, instead, the number of proton beam pulses injected into the spallation target has been used based on the assumption that the number of proton beam pulses is proportional to the number of incident neutrons. This assumption is mostly plausible but could fail when the conditions of the proton accelerator or the neutron source change. To avoid possible failure of the proton pulse counting method and make measurement with ANNRI more robust, an additional neutron beam monitor is under development.
To develop a neutron beam monitor for ANNRI, there are two issues to overcome. First, very high intensity neutron beam from JSNS requires a fast detector system that can process signals at a high counting rate. Second, γ -flash, an intense γ -ray burst produced when the proton beam pulse bombards the spallation target, can paralyze a detector. Thus, γ -ray sensibility of the neutron monitor should be low. In order to fulfill the requirements, a thin sheet-type plastic scintillator combined with thin ^{6}Li layer on a Mylar film is adopted for the present neutron monitor. The incident neutrons react with ^{6}Li and the ^{6}Li(n,t)^{4}He reaction occurs. The emitted particles, tritons and alphas, are detected with the plastic scintillator. The short ranges of tritons and alphas allow for using a thin plastic scintillator film, and the thin detector leads to low γ -ray sensibility. Another requirement for fast detection is achieved by the fast response property of plastic scintillator. Simulation studies using Monte Carlo simulation code PHITS was performed to optimize the detector design, especially thickness of the ^{6}Li layer. A test detector system was built to study the feasibility. Test experiments were carried out at ANNRI. Preliminary results will be given in this contribution.

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Model analysis of isotope-production cross sections for proton- and deuteron-induced reactions on Zr-93

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A treatment of High-Level Radioactive Waste (HLW) is one of the crucial issues for nuclear energy developments because of the long-term radiotoxicity of long-lived fission products (LLFPs) included in HLW. Nuclear transmutation technology has received much attention as a possible method of the burden reduction of its disposal by converting LLFPs into stable and/or short-lived nuclei. So far, measurements of isotope production cross sections for proton- and deuteron-induced reactions on Zr-93 at 50, 105, and 209 MeV/nucleon have been performed. As the next step,

investigation of energy dependence and systematic benchmark tests of theoretical models are required. In the present work, we focus on the inter-comparison among them and benchmark tests of theoretical models. The inter-comparison is performed from the aspects of the mass number distribution of the production cross sections. Also, the theoretical model calculations by PHITS code and INCL++/ABLA07 code are analyzed based on the differences from the experimental data. The detailed analysis and results are presented in the poster.

Poster Session - Board: 24 / **45**

Dependence of the potential energy surface of U-236 system on effective nucleon-nucleon interactions

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The potential energy surface (PES) is one of the most important quantity to understand fission mechanisms. Valley in PES originating from the ground state defines the most-favorable path toward the scission. Microscopic models such as Hartree-Fock theory are known to be powerful tools to obtain the PES of fissionning nuclei. However, the effective interactions to be used in such calculations are normally determined to reproduce ground-state mass, deformation and radius, single-particle levels, properties of infinite nuclear matter, and so on. On the other hand, the fission barriers were not considered enough except for SKM* Skyrme interaction which was designed to reproduce fission barrier of Pu-240 and it is usually recognized that reproduction of fission barriers is not satisfactory for other systems. In this work, we tested 3 kinds of Skyrme effective interactions in terms of the Hartree-Fock+BCS method, and obtained PESs of U-236 (compound nucleus of n+U-235 system) up to scission configuration as a function of quadrupole and octupole deformations. From this calculation, we will elucidate the dependence of fission path on effective interactions, and afterward we will try to extract information which leads to properties of production of the fission fragments such as charge polarization and mass distribution.

Poster Session - Board: 25 / **51**

Fission study using four-dimensional Langevin model - Nuclear shape of fission fragments

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The precise data on prompt neutron multiplicity and prompt neutron spectrum of nuclear fission are necessary for nuclear reactor designs. We plan to calculate these data by simulation based on 4D Langevin Model. The excitation energy of each fission fragment at scission directly determines the prompt neutron multiplicity. Deformation energy should be the main term of excitation energy. In this study, we make it posible to precisely calculate the deformations, Quadrupole Moment (Q_{20}) and Octupole Moment (Q_{30}), of each fission fragment at scission by using 4D Langevin Model. After systematic survey of Actinides, we find that the deformations of light fragments are larger than heavy fragments. Also, the mass number dependence of deformations of fission fragments shows a sawtooth structure which is similar to prompt neutron multiplicity.

Poster Session - Board: 26 / **49**

Systematical calculation of probabilities of beta-delayed neutron emission and fission in the entire region of nuclear chart

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In the very neutron-rich nuclei, the beta-decay occurs with some accompanying process as neutron emissions, and fission. The beta-decayed neutron process is an important phenomenon for manipulating nuclear reactor, and the beta-delayed fission critically affects the termination of the r-process nucleosynthesis in stars. We performed a systematical calculation of probabilities of beta-delayed neutron and beta-delayed fission with the improved gross theory of beta-decay [1,2] and the KTUY mass model [3,4] in the entire region of nuclear chart. The calculated probabilities of beta-delayed neutron emissions are compared with experimental ones for over 200 nuclides. Regarding the delayed fission, we only give calculated ones because there are no experimental data. In the landscape of fission-barrier height with the KTUY mass model in super- and extremely super-heavy mass region, the conventional island of stability is found near nuclei with Z=114 and N=184, while there is peninsula along N=228 [5]. The N=228 peninsula is caused by single-particle shell gap of N=228 appears in Ref [4]. The beta-delayed fission probabilities are calculated with the fission barriers and a beta-decay model, the gross theory. There are some regions with large fission probabilities as avoided along N=228. These fission probabilities affect the abundance from the r-process and also determines the creation of super-heavy element in nature. This work was financially supported by the Japan Society for the Promotion of Science KAKENHI (Grants No. 18K03631 and No. 17H06090) as a program Effects of fission to isotopic abundances on the r-process synthesis in star and Study of the origin of heavy elements using an innovative mass spectrograph.
References 1 H. Koura and S. Chiba, Phys. Rev. C 95, 064304 (2017). [2] F. Endo and H. Koura, Phys. Rev. C 99, 034303 (2019). [3] H. Koura, et al., Prog. Theor. Phys. 113, 305 (2005) [4] H. Koura and S. Chiba, J. Phys. Soc. Jpn. 82, 014201 (2013). [5] H. Koura, Prog. Theor. Exp. Phys. 2014, 113D02 (2014).

Poster Session - Board: 27 / **40**

Estimation of covariance of the neutron cross section of the long-lived fission product

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Estimation of covariance of the neutron cross sections of the long-lived fission product (LLFP) nuclides is important for the design of an innovative LLFP transmutation system utilizing a fast reactor. Estimation of uncertainty of the cross-section data produces quantitative evaluation of errors of the reactor constants such as nuclear transmutation rate. We estimated the covariances of neutron cross sections of LLFP nuclides (79Se, 93Zr, 99Tc, 107Pd, 129I, and 135Cs) using the nuclear data evaluation code system T6.

Poster Session - Board: 28 / **48**

Estimation of Covariance of Neutron Cross Sections for Decommissioning

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To optimize disposal of low-level radioactive waste generated from decommissioning of nuclear facilities, required are 1) reliable assessment of radioactivity level by calculation and measurement and 2) a good estimate of the uncertainty of those results for the classification of radioactive waste. However, uncertainties due to errors in cross-section data, one of the important input data for the calculations, have not been estimated in previous studies because of a lack of covariance data in many nuclei stored in JENDL-4. In this study, we estimated the covariance of neutron cross sections of ^{59}Co and ^{62}Ni, which are important nuclides for decommissioning, using a nuclear data evaluation code system T6 based on parameter distributions determined by a Bayesian Monte Carlo method. Special efforts were taken to adjust resonance and nuclear model parameters to reproduce cross sections of important reactions given in JENDL-4 so that we can estimate possible fluctuation around JENDL-4, and uncertainties of thermal cross sections given by Mughabghab.

Poster Session - Board: 29 / **34**

Development of multi-group neutron activation cross-section library from JENDL/AD-2017

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JENDL Activation Cross Section File for Nuclear Decommissioning 2017 (JENDL/AD-2017) 1 was released in 2018. This file includes neutron-induced nuclear reaction cross-sections of 311 nuclides from 10-5 eV to 20 MeV. Dr. Okumura et al. developed a multi-group neutron activation cross-section library (MAXS2015) based on the nuclear data libraries JENDL-4.0 and JEFF-3.0/A for activation calculations in nuclear facility decommissioning [2]. Thus a multi-group neutron activation cross-section library (MAXS/AD-2017) with the same format as MAXS-2015 has been developed from JENDL/AD-2017 for activation calculations in nuclear facility decommissioning.

MAXS-2015 was produced with the NJOY2012 [3] code. However it was found that the groupr module in NJOY2012 could not treat the production cross sections for radionuclides. Then the PREPRO 2018 [4] code was adopted for producing a group-wise file of JENDL/AD-2017. The following modules in PREPRO 2018 were used; *ENDF2C, LINEAR, RECENT, SIGMA1, ACTIVATE, FIXUP, DICTIN, GROUPIE.* The calculation conditions are as follows,

- Temperature : 300 K
- Group structure : VITAMIN-B6 (199 groups)
- Weight function : Maxwell+1/E+Fission
- Infinite dilution

The produced group-wise file of JENDL/AD-2017 was converted to MAXS/AD-2017 of the MAXS format [2] with a small program.

MAXS/AD-2017 will be converted to an ORIGEN-S library and be tested with the JPDR decommissioning data. Then MAXS/AD-2017 will be released.

References
1 https://wwwndc.jaea.go.jp/ftpnd/jendl/jendl-ad-2017.html
[2] K. Okumura, K. Kojima, K. Tanaka, Development of multi-group neutron activation cross-section library for decommissioning of nuclear facilities, Proc. of 2014 Symposium on Nuclear Data, p. 43, JAEA-Conf 2015-003(2016).
[3] R. E. MacFarlane, D. W. Muir, R. M. Boicourt, A. C. Kahler, The NJOY Nuclear Data Processing System, Version 2012, LA-UR-12-27079, Los Alamos National Laboratory (2012).
[4] https://www-nds.iaea.org/public/endf/prepro2018/

Poster Session - Board: 30 / **71**

Quantification of Integral Data Effectiveness Using the Concept of Active Sub-Space in Nuclear Data Testing

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In the field of nuclear and radiation engineering, a huge amount of experimental data related to the reactor physics and the radiation shielding have been obtained at various facilities in the world, and some of them have been released to the public as open data to validate numerical tools solving the reactor physics and radiation shielding problems. Experimental data which can be utilized to validate nuclear data are referred to as integral data in the field of nuclear data, and so many integral data have been accumulated through projects such as ICSBEP and IRPhEP. Those integral data have been efficiently utilized to validate the evaluated nuclear data files. The number of the available integral data has become huge, so it is important to choose a proper set of integral data when validating the evaluated nuclear data files. To do so, dependency of integral data should be carefully examined, and a procedure how to choose proper integral data should be invented. We have proposed to adopt the concept of the active sub-space to this problem in our previous study and have tested our method against a set of fictitious integral data in the past. In the present work, results newly obtained with actual integral data will be presented.

Poster Session - Board: 31 / **60**

Uncertainty estimation of conventional neutron-spectrum unfolding codes with Monte Carlo based method

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Unfolding method has been applied for neutron spectra derivation of Bonner sphere experiment, multiple-foil activation method and so on. Many types of unfolding techniques such as iterative approximation method, maximum entropy method, and stochastic methods have been developed. However, some of unfolding codes cannot analytically give uncertainty of the derived neutron spectrum. To overcome this situation, we have developed uncertainty estimation method based on Monte Carlo technique. For validation of the method, we applied our developing method to analysis of multiple-foil activation method. Experimental data was obtained at Cyclotron and Radioisotope Center (CYRIC), Tohoku University. Deuterons were accelerated to 20 MeV and bombarded on a thick carbon target to produce neutrons via the C(d, n) reaction. Multiple foils made of Al, Co, Fe, Mo, Ni, Zn, Zr, were irradiated by the neutrons to induce various activation reactions. In the multiple-foil activation method, an unfolding code derives a neutron spectrum from radioactivity induced by neutron irradiation and production rate functions of activation reactions. In our uncertainty estimation method, we considered only statistical uncertainty propagation of measured activity. First, measured activity is randomly changed by Gaussian

distribution having statistical uncertainty, and then a neutron spectrum is derived by an unfolding code. This process is calculated iteratively and derived spectra. The spectra are statistically analyzed to estimate the uncertainty propagation. This method was applied to a few conventional unfolding codes, and we compared the propagated uncertainty to know properties of the unfolding codes. The details of developed program to estimate uncertainty of unfolded spectrum and the comparison result between codes will be reported in the presentation.

Poster Session - Board: 32 / **32**

The Influence of B Burnable poison and T Production Li rod on Effective Multiplication Factor in the HTGR

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Tritium (T) is required for engineering tests and the demo reactor first fuel load of fusion reactor, which uses DT reaction. In order to establish a T procurement method, it was proposed that T production method by loading Li in the high temperature gas-cooled reactor (HTGR). A loaded unit called Li rod replaces to the B burnable poison (BP) and produces T. There is a possibility that it causes differences in an effective multiplication factor (keff) by the BP atom change. This presentation shows the keff difference of the High Temperature engineering Test Reactor (HTTR) is evaluated. A cause is discussed if the keff characteristic changes. In addition, the same evaluation about the Gas Turbine High Temperature Reactor 300 (GTHTR300) is conducted and it is revealed whether the HTGR types influence the results.

Poster Session - Board: 33 / **39**

Evaluation of radioactive concentration produced in electric equipments and materials on the decommissioning of nuclear power plants

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A various cables used in nuclear power plants are treated as wastes in decommissioning. If part of them is treated as non-radioactive wastes, the amount of radioactive waste can be reduced. Furthermore, valuable resources such as copper can be recycled, and that contributes to the efficient use of resources. In this study, we have evaluated the produced nuclides in representative PWR cables by neutron irradiation calculated with the activation cross section data. As the results of evaluation, we have confirmed the possibility of the Ni-63 concentration exceeding the criterion for clearance near reactor vessel. To improve the inventory evaluation, the uncertainty evaluation of activation cross section will be important.

Poster Session - Board: 34 / **38**

Evaluation of scattered radiation on the contralateral breast in breast-conserving therapy

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Breast-conserving therapy is a standard local treatment for breast cancer up to stage II after breast-conserving surgery. In this treatment, the occurrence of contralateral breast cancer has been reported as a late adverse event. One of the possible reasons is the effect of low-dose exposure to contralateral breasts by scattered radiation. While treatment planning is carefully conducted, a detailed evaluation of the dose distribution has not been performed yet. In this study, we evaluated the effect of scattered radiation on the contralateral breast by the difference in irradiation conditions on the affected breast using Monte Carlo simulation code PHITS. In the calculation, a model for the breast was created using the ICRP110 phantom. For the irradiation condition, 4-6 MV X-rays were used and the dose distribution of scattered radiation was evaluated. The contralateral dose was less than the target dose farther away from the inner edge of the affected breast. In addition, the larger the breast size, the effect of scattered radiation increased.

Poster Session - Board: 35 / **53**

Burnup calculation with different fission yield data

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Fission yield is an important physical quantity to evaluate the amount of fission products after irradiation. The fission yield used in Japanese Evaluated Nuclear Data Library (JENDL) employs ENDF/B data. The fission yield has recently been evaluated in Japan based on the various theories. In order to evaluate the effect of different fission yield data on burnup calculation, burnup chain and/or fission yield data used in a burnup calculation is to be modified so as to obtain reasonable results because different/additional isotopes are stored among the data, especially for isomers. The comparison between JENDL/FPY2011 and new fission yield evaluated by Tokyo Tech. was performed with SWAT4.0 for the PIE data: BM5 sample of Swiss Beznau-1 PWR, and the results shows that there is relatively large impact on the results. This shows the importance in burnup calculation how to handle the burnup chain and/or fission yield data on the comparison among different fission yield data.

Poster Session - Board: 36 / **41**

Improvement of fuel ion ratio diagnostics performance using anisotropic neutron emission spectrum in NBI heating deuterium-tritium plasma

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For the stable operation of the deuterium-tritium (DT) fusion reactor, it is important to measure fuel ion ratio (nT/nD). A method to determine nT/nD from the emission ratio of 14 MeV neutron by DT reaction and 2.45 MeV neutron by DD reaction is being studied. This method has a serious problem that the detection of 2.45 MeV neutron by DD reaction is interfered by slowing-down component of 14 MeV neutron by DT reaction. As a solution to this problem, the technic using the rise in the fraction of the DD to DT reaction rate and modification of neutron emission spectrum by NBI-heating has been studied. Owing to this technic, the measurement was possible even in nT/nD = 1.0. However, the measurable plasma condition is still limited, and further improvement is required. In this study, we consider neutron measurement using the anisotropic neutron spectrum for further improvement of the diagnostics performance. We indicate the effectiveness of the proposed method by discussing the range of measurable plasma condition.

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Recent R&D of HTGR and Requirement for Nuclear Data

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Recently, HTGR attracts a particular attention due to the outstanding safety features especially after the Fukushima Daiichi nuclear disaster, and the R&D is significantly promoted. In this presentation, we introduce the R&D plan of HTGR and the activities related to relating reactor physics and nuclear data including an experiment by using KUCA. Furthermore, requirement for nuclear data to the HTGR design is discussed.

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Performance of a gas-cooled reactor as a tritium production device for fusion reactors

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To start up an initial fusion reactor and for technical tests for tritium circulation and blanket system, it is necessary to provide sufficient amount of tritium from an outside device. We have proposed tritium production using a high temperature gas-cooled reactor [1,2]. The gas turbine high-temperature reactor of 300MWe nominal capacity (GTHTR300) [3] and high temperature engineering test reactor (HTTR) [4] have been assumed as typical calculation targets of gas-cooled reactor. On the basis of the continuous-energy Monte Carlo transport code MVP-BURN [5], the burn-up calculations for whole-core region have been carried out considering its unique double heterogeneity structure. The effectiveness of the use of the high-temperature gas-cooled reactor for tritium production for fusion reactors is presented.
To realize a proposed system, tritium handling technique in the reactor core is also important. If we can keep the Li-rod temperature below 800 K during the operation, the tritium outflow from the Li rods to He coolant can be suppressed to less than 1% of the amount of the tritium produced. When we attempt to operate the reactor at a higher temperature range (e.g. 1100-1200 K) from the viewpoint of electric power generation efficiency, the outflow will be increased. It is important to devise a way to reduce the outflow to further low level. The current status for development of Li-loading rod structure for tritium production and future plan for demonstration test are also shown.
1 H. Matsuura, et al., Nucl. Eng. Des., 243 (2012) 95. [2] H. Matsuura, J. Plasma Fusion Res., 93 (2017) 457. (in Japanese) [3] X. Yan, et al., Nucl. Eng. Des., 222 (2003) 247. [4] S. Saito, et al, JAERI 1332 (1994). [5] Y. Nagaya, et al., JAERI 1348 (2005).

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Research and development of an innovative transmutation system of LLFP by fast reactors

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Transmutation of long-lived fission products (LLFPs: ^{79}Se, ^{93}Zr, ^{99}Tc, ^{107}Pd, ^{129}I, and ^{135}Cs) into short-lived or non-radioactive nuclides by fast reactors without isotope separation nor even-odd separation has been proposed as a solution to the problem of radioactive wastes disposal[1,2].

Despite investigation of many methods, such transmutation remains technologically difficult. To establish an effective and efficient transmutation system, we propose a novel neutron moderator material, yttrium deuteride (YD_2), to soften the neutron spectrum leaking from the reactor core as well as YH_2. Special care has been taken to avoid thermal spike/peaking in reactor heat distribution. Neutron energy spectra and effective halflives of LLFPs, transmutation rates, and support ratios were evaluated with the continuous-energy Monte Carlo code MVP-II/MVP-BURN and the JENDL4.0 cross section library. The effective half-lives of the 6 LLFPs will be drastically decreased from the order of 10^6 to 10^2 years, and the support ratios exceed 1.0 for all six LLFPs. This successful development and implementation of a transmutation system for LLFPs without isotope separation contributes to an ability of fast reactors to reduce radioactive waste by consuming their own LLFPs.

This study comprises the results of Research and development of an innovative transmutation system of LLFP by fast reactors (18K03642) entrusted to the Tokyo Institute of Technology by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

1 S.Chiba, T.Wakabayshi, Y.Tachi, N.Takaki, A.Terashima, S.Okumura and T.Yoshida, Scientific Reports 7, 13961(2017).
[2] T.Wakabayashi, M.Takahashi, S.Chiba, N.Takaki, Y.Tachi and Y.Tahara, Nucl. Eng. Design 352(2019)110208.

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Nuclear Data Activities and Related Database Services at the IAEA Nuclear Data Section

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The Nuclear Data Section (NDS) of IAEA assembles, develops and disseminates nuclear data and related databases for basic science and nuclear applications. This presentation will give an overview of the activities at IAEA-NDS, which aimed to develop nuclear data libraries and to disseminate and maintain databases such as Ion Beam Analysis Nuclear Data Library (IBANDL), Evaluated Nuclear Structure and Decay Data File (ENSDF), and Experimental Reaction (EXFOR) database, and to develop data retrieval system such as Isotope Browser as well as a brand-new product of Medical Isotope Browser. This presentation will focus primarily on EXFOR database, which is maintained by the International Network of Nuclear Reaction Data Centres (NRDC) network under the auspices of the IAEA. The published experimental nuclear reaction data are compiled in the EXFOR database. Currently, the database contains more than 20,000 experiments and more than 150,000 numerical datasets.
A recent increase in interests on the nuclear fission product yield (FPY) for various nuclear application fields and fundamental physics stresses the importance to develop the new evaluated FPY data libraries and to share the complete set of experimental data as a common basis. The current evaluated libraries comprise the evaluation of the experimental data as well as some empirical models. Such evaluations have been done before the 2000s and only a few additions and corrections have been done. The IAEA-NDS plans to launch a new Coordination Research Project (CRP) in early 2020 to update the evaluated FPY data for the neutron-induced fission of several important actinides. Prior to launch the CRP, IAEA-NDS finished the completeness assessment of FPY data in the EXFOR database by comparison with the datasets that used for the evaluation of two major evaluated libraries, i.e. ENDF/B-VI and UKFY-3. This presentation will review the current status of completeness assessment and future plans of further quality improvement of the FPY and fission related experimental data.

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Status of the OECD NEA Data Bank Services for Nuclear Data and Computer Program

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The Organisation for Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) Data Bank (DB) is responsible for the coordination of the Joint Evaluated Fission and Fusion (JEFF) Nuclear Data Library project, which is a collaboration between NEA Data Bank participating countries. The JEFF library combines the efforts of its participating institutions to produce sets of evaluated nuclear data, for fission and fusion applications, and is mostly used as one of the reference evaluated nuclear data library of many European countries, in particular by the French nuclear industry. Besides the Nuclear Data Services (NDS), the Computer Program Services (CPS) of the DB is in charge of providing direct services to the end users by collecting and disseminating computer programs in the Data Bank participating countries and organising training courses on the most widely used codes. The DB also supports other Standing Technical Committees (STC) of the NEA. For example, the DB has been developing the Thermochemical Database (TDB) Project since 1984 following the recommendation of the NEA Radioactive Waste Management Committee (RWMC) on the need of a database of high-quality thermochemical data for species relevant to performance assessments of deep geological repositories.
This presentation will focus on the status of NDS activities and its new strategy following the release of the latest JEFF library, i.e., JEFF-3.3 in 2017. Additionally, other topics under the Data Bank scope of activities will be presented, notably the new computer code licensing framework, i.e., the Data Bank Single User (SUL) licence.The presentation will also be the opportunity to adress any comments and questions related to the services of the Data Bank.

References

1 F. MICHEL-SENDIS, L. FIORITO and M. FLEMING, Perspectives on nuclear data activities at the Data Bank: Enhancing the validation function, NEA News, 36.2, pp.4-8 (2018).
[2] A. DUFRESNE, E. POPLAVSKAIA, and K. SUYAMA, Overview of the Activities of the OECD Nuclear Energy Agency Data Bank Computer Program Services, Proceedings of the International Conference on Mathematics and Computational Methods applied to Nuclear Science and Engineering (M&C 2019), 25-29 August 2019, Portland, Oregon USA.
[3] M.E. Ragoussi and D. Costa, Fundamentals of the NEA Thermochemical Database and its influence over national nuclear programs on the performance assessment of deep geological repositories, J. Environ. Radioact. 2019, 196, 225.

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From the resonance theory to the statistical model

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When a fast-energy neutron (in the keV to MeV region) interacts with a nucleus, the reaction cross section no longer shows a distinct resonating shape because the compound states are strongly overlapped. Under this circumstance, each of the resonances cannot be resolved anymore, and the energy-average cross section is only meaningful. The average cross section can be related to statistical properties of resolved resonances, namely the average resonance spacing and decay widths. In this talk, theories for the neutron resonance are first summarized, paying a special attention to a nuclear-technology viewpoint. Then the statistical properties of the resonances are discussed by applying the Gaussian Orthogonal Ensemble (GOE) implemented in the S and K

matrices. Although this is an old problem, our recent development on the GOE Monte Carlo technique sheds a new light on some compound nuclear reaction problems.

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Current status of search for new element 119

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The 7th period of periodic table was completed with newly named four elements from nihonium (Z=113 1) to oganesson (Z=118). In superheavy nuclei/atoms with huge atomic and mass numbers, physical and chemical properties are modified by the strong Coulomb field. Discovery and production of those superheavy elements are essentially important in extending the field of such research and in searching for the limit of existence of heavy atom and nucleus.
Recently, search for element 119 has been started by the international collaboration consisting of RIKEN, ORNL, Kyushu Univ., etc. For the synthesis of new element with the highest atomic number, the recoil separator GARIS was redesigned and newly constructed. The upgrade of the linear accelerator is going on. A radioactive Cm target was developed in collaboration with ORNL. The talk will cover the current status of the search for new element 119 and the recent activities of the Research Center for SuperHeavy Elements newly founded in Kyushu University.
1 K. Morita et al., Journal of the Physical Society of Japan 73, pp. 2593-2596 (2004).

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Application of CDCC to many-body breakup reaction

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The continuum-discretized coupled-channels method (CDCC) 1 is a reliable method for describing breakup reactions involving weakly-binding nuclei. So far, CDCC has been used successfully to reproduce experimental data for nucleon scattering from Li-isotopes [2, 3, 4], which are an important material in fusion energy development. Furthermore, CDCC can apply to analyses of four-body breakup reactions with a three-body projectile. Thus CDCC is useful for nuclear data evaluation including light nuclei. In this talk, some results of CDCC analyses will be given.
1 Masanobu Yahiro, Kazuyuki Ogata, Takuma Matsumoto, Kosho Minomo Prog. Theor. Exp. Phys. (2012), 01A206.
[2] T. Matsumoto, D. Ichinkhorloo, Y. Hirabayashi, K. Kat, and S. Chiba Phys. Rev. C 83, 064611 (2011).
[3] Hairui Guo, Yukinobu Watanabe, Takuma Matsumoto, Kohei Nagaoka, Kazuyuki Ogata, and Masanobu Yahiro, Phys. Rev. C 99, 034602 (2019).

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Topics from Radiation Safety Design of J-PARC

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The J-PARC (Japan Proton Accelerator Research Complex) is a high-intensity and high-energy proton accelerator complex which consists of the accelerator components of a 400-MeV linac, a 3 GeV synchrotron with 1 MW power and a 30-GeV synchrotron with a few tenth of kW

power. These accelerators are providing 3 GeV beam of 1 MW to the Material and Life science Experimental Facility and 50 GeV beam of a few tenth of kW to the Hadron Experimental and the Neutrino Experimental Facilities. Because of its very high beam power and its energy as well as the large-scale accelerator complex, we encountered some very difficult radiation problems on radiation safety design. The shielding study revealed that the facilities required very thick shielding, resulting in shielding required large portion of the total construction cost. Therefore, the radiation safety design was carried out in various characteristics ways, such as combining simple and detailed design methods. In this presentation, I will introduce the activity confinement system, the use of low- activationaized concrete, and the environmental impact assessment as examples in the various ways. In addition, as new issues found during the 10 years after the completion of construction, the activity caused by muons, and the effects of and particles on radiation transport will be presented.

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Present Status and Outlook of IFMIF and A-FNS

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The International Fusion Materials Irradiation Facility (IFMIF) is an accelerator-based D-Li neutron source, in which 40-MeV CW deuteron beam with total current of 250-mA produced by two accelerators impact on a liquid Li stream flowing at 15 m/s (Li target). In the IFMIF/EVEDA project under the Broader Approach (BA) agreement, the Li target was continuously operated with the cold trap and satisfied the stability requirement throughout the continuous operation. The linear IFMIF prototype accelerator (LIPAc) is currently under development in Rokkasho, Japan, to demonstrate the 9 MeV/125 mA D-beam acceleration. Recently, the first proton beam was injected into the RFQ with more than 90 % transmission, followed by the achievement of a major project milestone in July 2019: 125 mA Deuteron beam accelerated at 5 MeV. The superconducting RF linac necessary for the 9-MeV D+ beam is nearing completion of the manufacturing phase and will be assembled in Rokkasho. Based on the results from the IFMIF/EVEDA project, a conceptual design of the Advanced Fusion Neutron Source (A-FNS) for its construction in Rokkasho is underway in order to obtain material irradiation data necessary for a fusion DEMO reactor. The A-FNS is composed of an accelerator with a 40-MeV and 125-mA deuteron beam, a test facility with neutron intensity of 6.8 x1016 n/s including a liquid Li target system and a post irradiation examination facility. Additionally, A-FNS is designed to be able of multipurpose utilizations for neutron application including nuclear data study and RI (radio isotopes) production.

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Construction status and future plan for RAON and its nuclear data production system

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The Institute for Basic Science (IBS), located in Daejeon, Korea, was established in 2011 by the Korean government. The IBS has 28 Research Centers, one of which is the Rare Isotope Science Project (RISP). The accelerator complex for RISP was named RAON, which is a Korean word

meaning joy or happiness. The goal of the RISP is to produce a variety of stable and rare isotope beams which can be used in a variety of basic scientific research and applications. The RAON can deliver ions from protons to uranium. Proton and Uranium beams are accelerated up to 600 MeV and 200 MeV/u, respectively. The RAON will produce isotopes by using both In-Flight (IF) fragmentation and Isotope Separation On-Line (ISOL) methods. The IF system uses a driver linac which consists of superconducting ECR ion sources, a low energy beam transport (LEBT) section, a 500 keV/u RFQ, a medium energy beam transport (MEBT) section, a superconducting (SC) linac for a 400 kW in-flight fragmentation facility. The ISOL system uses a proton cyclotron as a driver, which accelerates protons to 70 MeV at 1 mA for ISOL facility. The ISOL facility uses an SC linac for post-acceleration of rare isotopes up to about 18.5 MeV/u, while the SC linac of IF facility is capable of accelerating uranium beams up to 200 MeV/u at 8 pμA.
There are seven experimental systems that are under construction, which include KOBRA, LAMPS, MMS, CLS, muSR, BIS, and NDPS. The Nuclear Data Production System (NDPS) is an experimental system for measuring nuclear data by use of neutron Time-of-Flight detection systems. The RAON provides deuterons and protons up to 53 MeV and 88 MeV, respectively. They are accelerated by a superconducting driver LINAC (SCL3) and are delivered to the neutron production target to produce neutrons. Pulsed beams with up to ~12 μA can be used to measure neutron-induced cross sections. By using high energy neutrons, nuclear data such as fission cross section of actinides and (n, xn) cross sections can be measured. The range of the beam repetition rate is to be 1 kHz ~ 1 MHz. The beam width of the pulsed beams is an important factor determining the accuracy of nuclear data and is aimed to be as small as 1~2 ns.
This presentation will discuss the present status of RAON and its NDPS system, and would like to promote international collaboration.