Japanese Activities in Nuclear Data Measurement

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Japan Atomic Energy Agency
Nuclear Data Measurement in Japan

Nuclear data measurements are being performed at several accelerator and reactor facilities in Japan:

- RIBF@RIKEN
- TIARA@JAEA
- CYRIC@Tohoku
- New SUBARU
- RCNP
- OKTAVIAN
- KUTL
- KUR
- KURRI-LINAC
- TIT
- ANNRI/MLF/J-PARC@JAEA
- Tandem@JAEA
- JRR-3@JAEA
- HIMAC@NIRS
- Cyclotron@NIRS

Operation Restarted in Aug. 2017
Activities by J-PARC/MLF/ANNRI collaboration in 2017

Japan Atomic Energy Agency
Tokyo Institute of Technology
Kyoto Univ.

Contact :
Nuclear Data Center
Nuclear Data and Reactor Engineering Division
Nuclear Science and Engineering Center
Japan Atomic Energy Agency
Neutron capture and Total cross sections are being measured at BL04 of J-PARC MLF.
**J-PARC Materials and Life Science Experimental Facility**

- **Building dimension:**
  - Width: 70m
  - Length: 146m
  - Height: 30m
  - Exp. Hall Height: 22m

- **Target remote handling room**

- **Cooling systems (Basement)**

- **1MW Spallation Target Station (Mercury Target)**

- **Experimental hall**

- **BL04: Nuclear Data Beam Line**

- **Spallation Mercury target**

- **Proton beam line**

- **3GeV, proton beam**

- **23 neutron beam lines will be installed in experimental halls under present design.**

- **J-PARC MLF, Taken from HP of J-PARC**
ANNRI (Accurate Neutron Nucleus Measurement Instrument)

Graph showing neutron intensity versus neutron energy for different scenarios:
- ANNRI 300kW
- ANNRI 1MW (Future)
- n_TOF (EAR-1)
- DANCE

Diagram of the experimental area showing the layout of experimental areas, beam, and detectors.
Ge Spectrometer

- Flight length: 21.5m
- 2 cluster-Ge detectors
  8 coaxial-Ge detectors
- Peak efficiency for 1.33MeV γ-rays: 3.64 ± 0.11 %
- New DAQ System (CAEN 1724,1720) is installed in 2017.

- Measurements of neutron capture cross sections of $^{241,243}$Am, $^{137,135}$Cs, $^{244,246}$Cm and stable isotopes have been finished.
- Data analysis is in progress.

TOF spectra for $^{243}$Am Samples
Nal(Tl) spectrometer

- Flight length: 28m
- Size: 330 mm\(\Phi\) 203 mmL 90°
  203 mm\(\Phi\) 203 mmL 125°

- Pulse-height weighting technique
- Measurement in the high energy region
Neutron capture cross section of $^{237}$Np

**Np-237 sample**

5 MBq
Sealed in Al container

Preliminary results
Self-shielding and multiple scattering corrections have not been applied yet.

Normalized to thermal cross section of JENDL-4.0
High energy region

The graph shows the cross section (in barns) as a function of neutron energy (in keV) for various sources and models:

- Semon (1976)
- Weston (1981)
- Lindner (1976)
- Esch (2008)
- Present
- Ju. N. Trofimov (1983)
- JENDL-4.0 (n, g)
- EDNF (n, g)
- JENDL-4.0 (n, f)
Measurement of neutron total cross sections

Li-Glass detectors for neutron total cross section is installed.

- A $^6\text{Li}$-glass scintillation detector for neutron and a $^7\text{Li}$-glass scintillation detector for B.G. were installed at the flight length of 28.7m.
- Measurements of neutron total cross sections of $^{241,243}\text{Am}$ and $^{155,157}\text{Gd}$ have been finished.
- Data analysis is in progress.

DAQ (CAEN V1720)

TOF spectra for $^{241}\text{Am}$
Activities at JAEA Tandem Accelerator Facility
(surrogate reaction)

Contact:
Katsuhisa Nishio
Advanced Science Research Center
Japan Atomic Energy Agency

20 MV
Radioactive materials can be used Th, U, Np, Pu, Am, Cm, Bk, Cf, Es
Surrogate Reactions for Fission Data

Method

- Populate excited compound nuclides using multi-nucleon transfer reactions. Identification of fissioning nucleus and its excitation energy is given by silicon \( \Delta E-E \) detectors by detecting ejected nucleus.
- Detect both fission fragments (double-velocity measurement) using multi-wire proportional counters and micro-channel plate (MCP) based timing detectors.
- Coincidence with prompt neutrons (liquid scintillation detectors with n/g discrimination technique).

Obtained Data

- Fission cross sections
- Fission fragment mass distribution
- Prompt neutron multiplicity and energy spectra

Array of 33 liquid scintillators (d5”x t2”) around the fission chamber (Planning to add 12 detectors.)

Role of Multichance Fission in the Description of Fission-Fragment Mass Distributions at High Energies


Selected Results from surrogate fission setup
Surrogate Reactions for Capture Cross Sections

Method

- Populate excited compound nuclides using multi-nucleon transfer reactions. Identification of excited nucleus and its excitation energy is given by silicon ΔE-E detectors.
- Gamma-rays emitted in the deexcitation process are detected by two anti-Compton LaBr₃(Ce) spectrometers.

Selected Results

In collaboration with China institute of Atomic Energy

The $^{95}\text{Zr}(n, \gamma)^{96}\text{Zr}$ Cross Section from the Surrogate Ratio Method and Its Effect on s-process Nucleosynthesis


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Japan Atomic Energy Agency, Tokai, Naka, Ibaraki 319-1195, Japan

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Monash Centre for Astrophysics, School of Physics and Astronomy, Monash University, Clayton, VIC 3800, Australia

Activities at Konan Univ.

Photo-excitation and neutron emission cross section measurement at Spring-8

Hiroaki Utsunomiya
Konan University
NewSUBARU
MeV $\gamma$ are produced with Laser Compton scattering
Flat-efficiency neutron detector

Experiments at NewSUBARU in 2017

July 17 - 30 : $(\gamma, xn)$ for $^{197}$Au, $^{169}$Tm, and $^{89}$Y

November 6 - 20: $(\gamma, xn)$ for $^{197}$Au, $^{169}$Tm, and $^{89}$Y

December 4 – 18: $(\gamma, n)$ for $^{184}$W, $^{183}$W, $^{182}$W, $^{68}$Zn, $^{66}$Zn, and $^{64}$Zn

Experiments at NewSUBARU in 2018

May 11 – June 9 : $(\gamma, xn)$ for $^{159}$Tb, $^{139}$La, and $^{103}$Rh

July 17 – 31: $(\gamma, n)$ for $^{156}$Gd, $^{157}$Gd, $^{158}$Gd, $^{160}$Gd
Publications

1. Neutron-multiplicity sorting
   2017

2. $^{209}\text{Bi} (\gamma, xn)$
   2017

3. Photon-flux determination
   2018
Activities at National Institutes for Quantum and Radiological Science and Technology (QST)

LCS Gamma-Ray Research Group
Contact: Toshiyuki Shizuma
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Measurements of nuclear resonance fluorescence (NRF) using polarized photon beams

Facilities:

NewSUBARU (Univ. of Hyogo), HIγS (Duke University)

NRF takes place via only electro-magnetic interaction:

- Model independent extraction of transition strength
- Selective excitation of dipole states
- Unambiguous parity determination (1− or 1+) using a polarized photon beam
Example

Electrons

- Energy: 600-1500MeV
- Current: Max. 250mA

Laser

- Nd:YVO₄, λ=1064nm
- Power: 20W

LCS γ-ray beam

- Max. energy: 6-39MeV
- Ave. flux: ~6 × 10⁵ /s
Results of NRF measurements for $^{52}$Cr

Typical NRF spectrum

Measured M1 strength compared with RPA calculations

Measured M1 strength compared with RPA calculations:

- $\Sigma B(M1) = 5.8(3) \mu_N^2$
- $\Sigma B(M1) = 5.4 \mu_N^2$

Measurement of double-differential neutron production cross sections for deuteron-induced reactions@ RCNP, Osaka U.

Team:
Dept. of Advanced Energy Engineering Science, Kyushu University
Japan Atomic Energy Agency
High Energy Accelerator Research Organization (KEK)
Research Reactor Institute, Kyoto University
Research Center for Nuclear Physics (RCNP), Osaka University

Contact person:
Yukinobu Watanabe, Kyushu University
Systematic measurement of double-differential \((d,xn)\) cross sections at 200 MeV using conventional TOF method

- **Experimental Facility:** Neutron TOF facility at RCNP, Osaka U.
- **Targets:** Li, Be, C, Al, Cu, Nb, In, Ta, Au
- **Emission angles:** 0, 5, 10, 25, 20, 25 degrees
- **Detector:** Liquid Scintillator EJ301
Result

Double-differential (d,xn) cross sections

- Incident energy: 200 MeV
- Targets: Li, Be, C, Al, Cu, Nb, In, Ta, Au
- Emission angles: 0, 5, 10, 25, 20, 25 degrees

Ref.) H. Sadamatsu et al., presented at 2017 Symp. on Nuclear Data, Tokai, Japan, Nov. 16-17, 2017.
Neutron Production DDX from Heavy-Ion Interactions @ NIRS-HIMAC

Team:
   a) Department of Applied Quantum Physics and Nuclear Engineering, Kyushu University
   b) Japan Atomic Energy Agency
   c) Hiroshima University
   d) High Energy Accelerator Research Organization
   e) Shimizu Corporation
   f) National Institute of Radiological Sciences of National Institute for Quantum and Radiological Science and Technology
   g) Korea Atomic Energy Research Institute
   h) Sungkyunkwan University
   i) Myongji University

Contact:
   Nobuhiro SHIGYO, Kyushu University
Neutron DDX and TTY from Heavy-Ion Interactions @ QST-NIRS-HIMAC

- Kyushu U., Hiroshima U., QST-NIRS, Sungkyunkwan U, Myongji U

- Systematic neutron cross sections and thick target yields for shielding design

- HIMAC PH2 beam line
- Beam: 100, 290 MeV/u Si, \( \sim 10^5 \) pps
- Target: Si (2 thicknesses)
- Detection: NE213 (2 sizes) + TOF
- Direction: 0° - 90°

- PHITS and Geant4 overestimate neutron yields at 15° and underestimate at 75° and 90°