Japanese Activities in Nuclear Data Measurement

Hideo HARADA

Japan Atomic Energy Agency

on behalf of

M. IGASHIRA[1] and H. HARADA[2]

[1]*Tokyo Institute of Technology*

[2]*Japan Atomic Energy Agency*

Nuclear Data Measurement in Japan

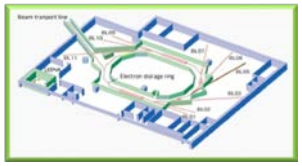
Nuclear data measurements are being performed at several accelerator and reactor facilities in Japan:

RIBF@RIKEN

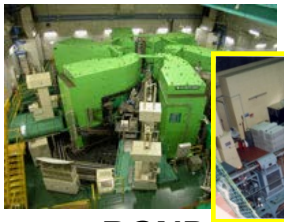
TIARA@JAEA

CYRIC@Tohoku

FNS

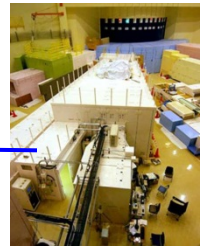


New SUBARU



RCNP

OKTAVIAN

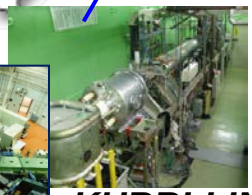


ANNRI @MLF, J-PARC

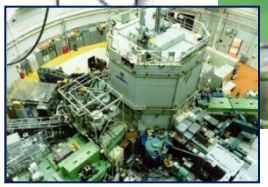
JAEA Tandem

JRR-3

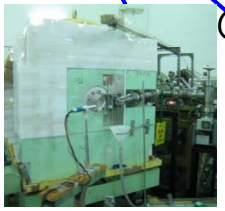
KUTL



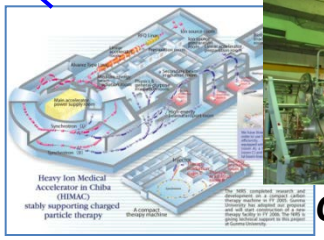
KURRI-LINAC



KUR



TIT



HIMAC @NIRS

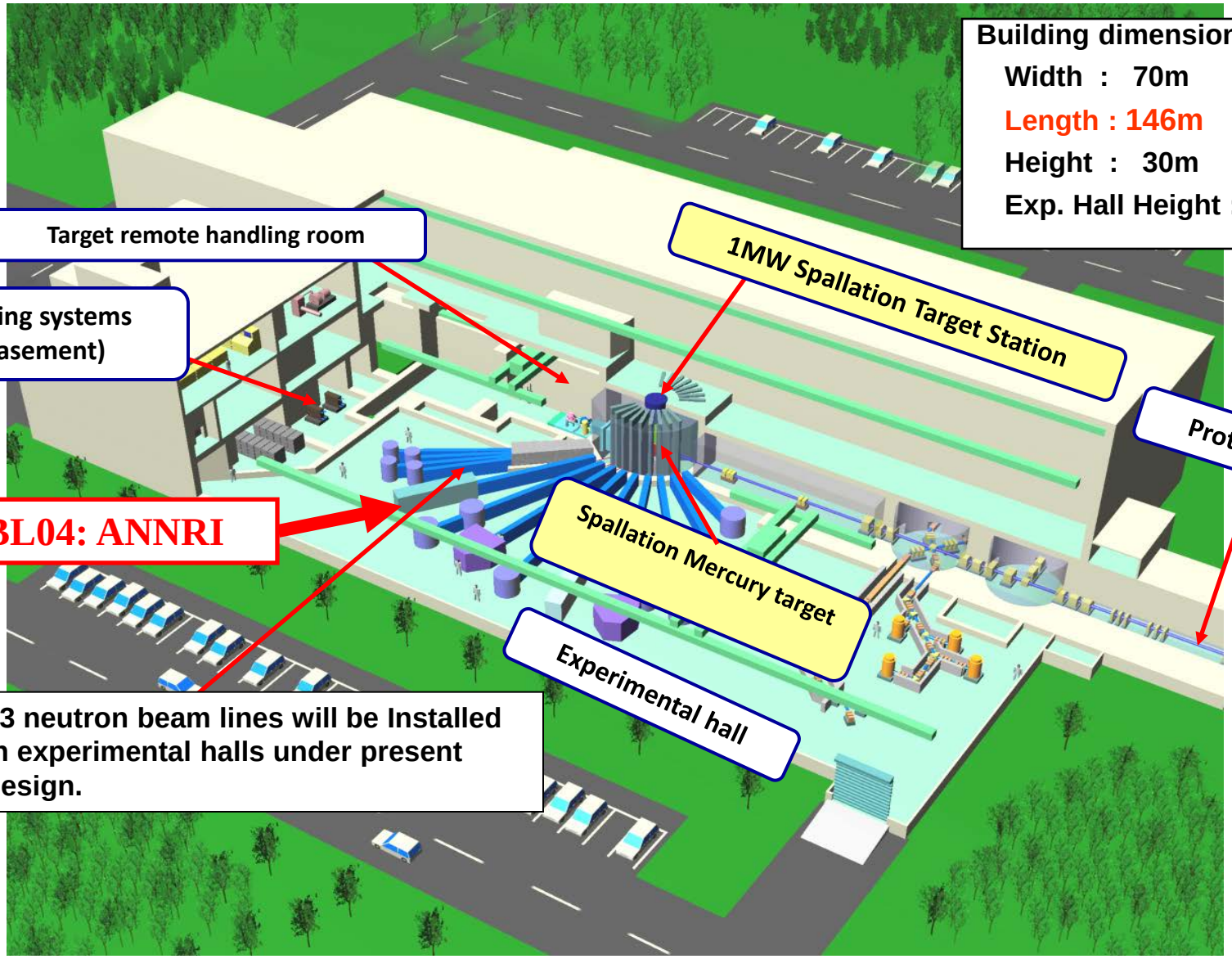
Cyclotron @NIRS

Activities by J-PARC/MLF/ANNRI collaboration

Japan Atomic Energy Agency
Tokyo Institute of Technology
Hokkaido Univ.
Kyoto Univ.

Contact :
Nuclear Data Center
Nuclear Data and Reactor Engineering Unit
Nuclear Science and Engineering Center
Japan Atomic Energy Agency

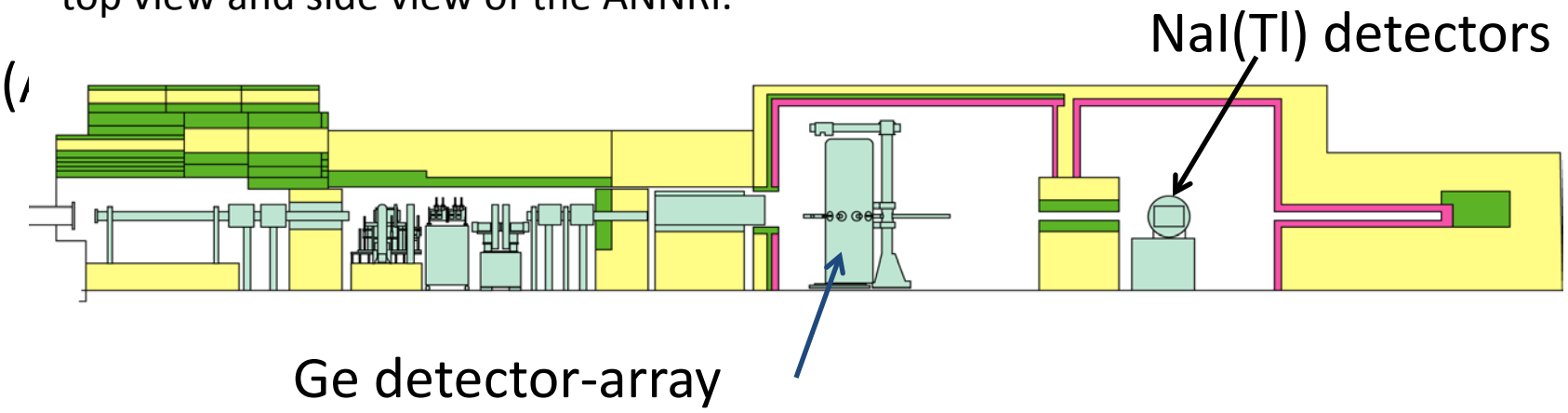
J-PARC Materials and Life Science Experimental Facility



J-PARC MLF, Taken from HP of J-PARC

Experiments@TOF facility, "ANNRI"

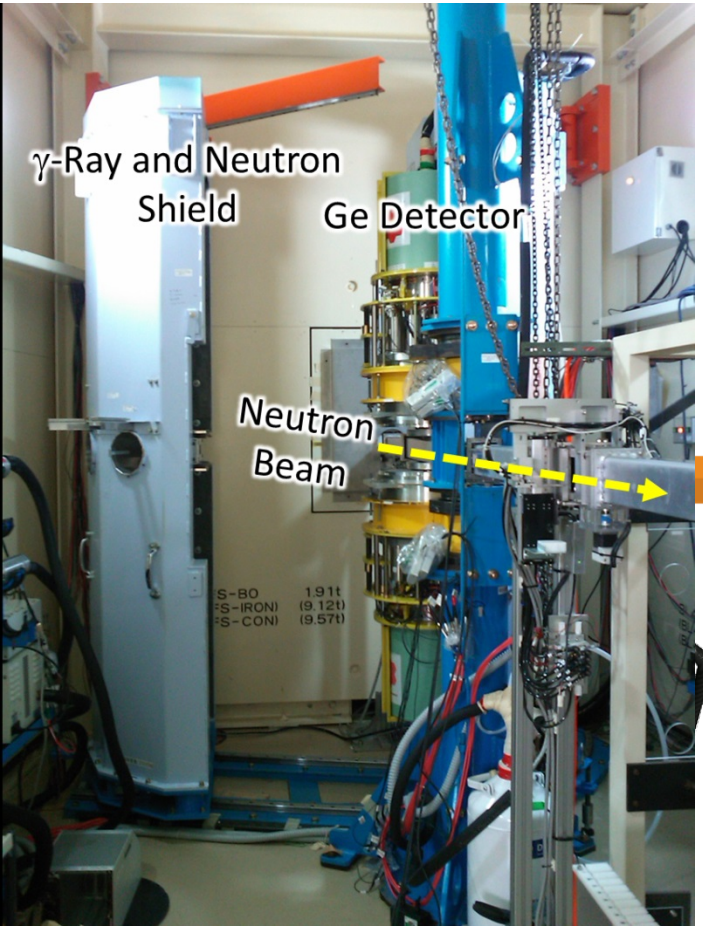
top view and side view of the ANNRI.



energy-integrated intensities	1MW (Future)	210kW
1.5-25 meV	4.3×10^7 n/s/cm^2	9.1×10^6 n/s/cm^2
0.9-1.1 keV	6.3×10^6 n/s/cm^2	1.2×10^6 n/s/cm^2

K. Kino, *et. Al.*, NIM-A, **626**, 58 -66 (2011).

Measurements using Ge Spectrometer



Our spectrometer has

- 2 cluster-Ge detectors
  (7 Ge crystals are installed in the detector)
- 8 coaxial-Ge detectors
- Compton suppressing BGO detectors

⇒22 Ge Crystals.

Energy resolution for 1.33MeV γ-rays:

5.8keV (for 200kevents/s),

2.4keV (for 20kevents/s) [1]

Peak efficiency for 1.33MeV γ-rays:

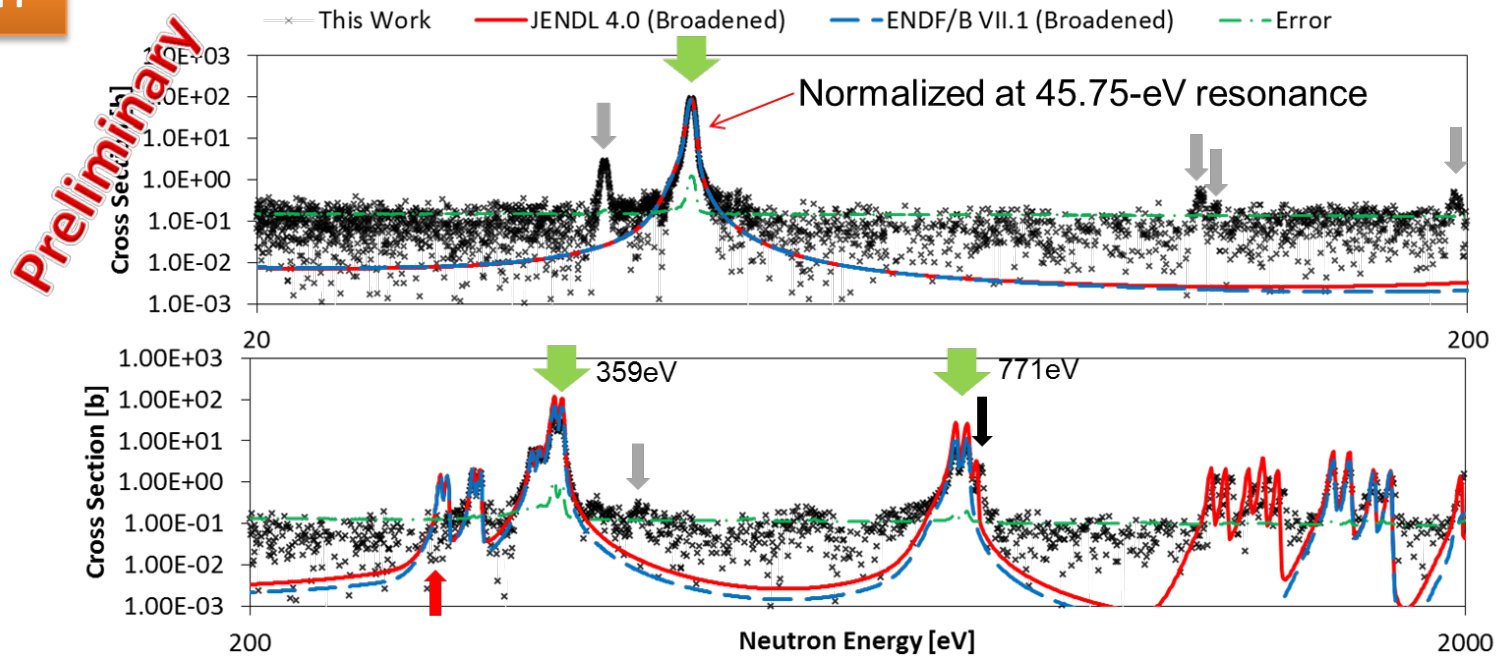
3.64 ± 0.11 %

[1] T. Kin et. al., *the 2009 NSS-MIC Conf. Rec.* , N24-2, (2009).

A. Kimura *et al.*, JAEA

~^{118}Sn and ^{nat}Gd~

^{118}Sn



➡ Resonance at 289 eV was not observed.

➡ The resonance at 784 eV is observed and listed in JENDL 4.0 but not listed in ENDF B-VII.

➡ Resonances of ^{117}Sn (0.35±0.01% contaminated)

^{nat}Gd

Our preliminary results at thermal energy
agree with the value in JENDL 4.0 and ENDF B-VII.1
but don't agree with the result by G. Leinweber [1].

[1] N.S.E. Vol. 154, 261–279 (2006)

^{107}Pd and ^{105,108}Pd

S. NAKAMURA *et al.*, JAEA

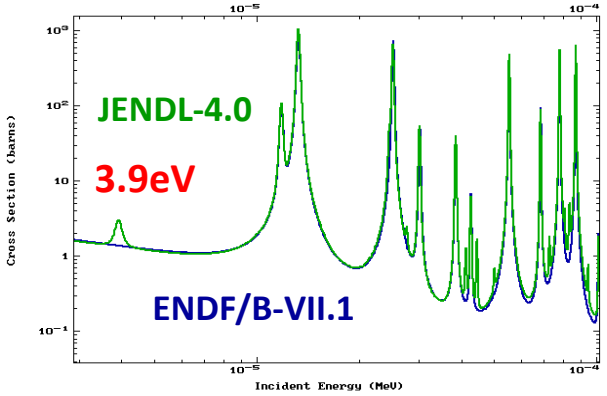
Nuclide	Energy (eV)	Year
^{107}Pd	0.01~300	2013/5(again)
^{105}Pd		2013
^{108}Pd		2013

This work obtained following insights:

- **3.9-eV resonance of ^{107}Pd was assigned.**
- **5.2-eV resonance originates to ^{109}Ag impurity in the Pd sample.**
- **This work supports the past data of the thermal-neutron capture cross-section.**

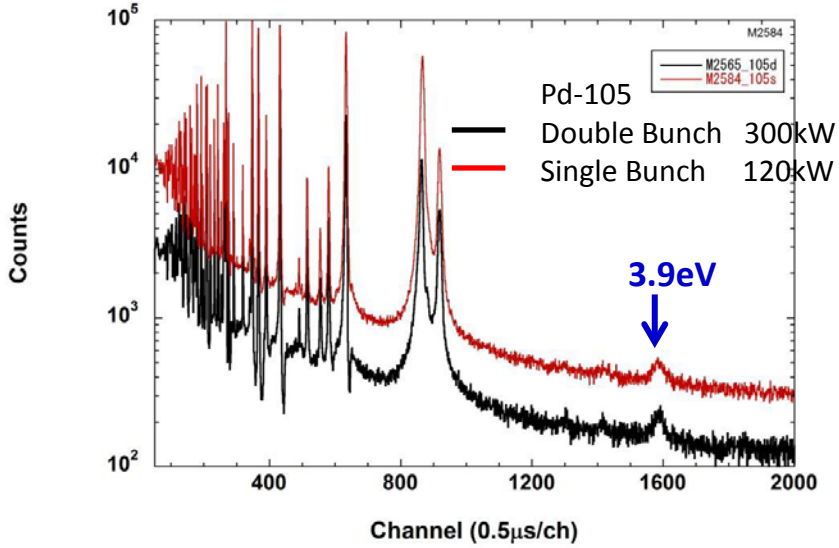
"Cross Section Measurements of the radioactive ^{107}Pd and Stable ^{105,108}Pd nuclei at J-PARC/MLF/ANNRI",
S. Nakamura, *et al.*,
to be published in Nuclear Data Sheets

^{105}Pd



Smith *et al*. reported 3.9eV res. in 2002.
So, measurements for ^{105}Pd were performed in 2013.

3.9eV res. exists for ^{105}Pd.
Our work supports JENDL-4.0 .

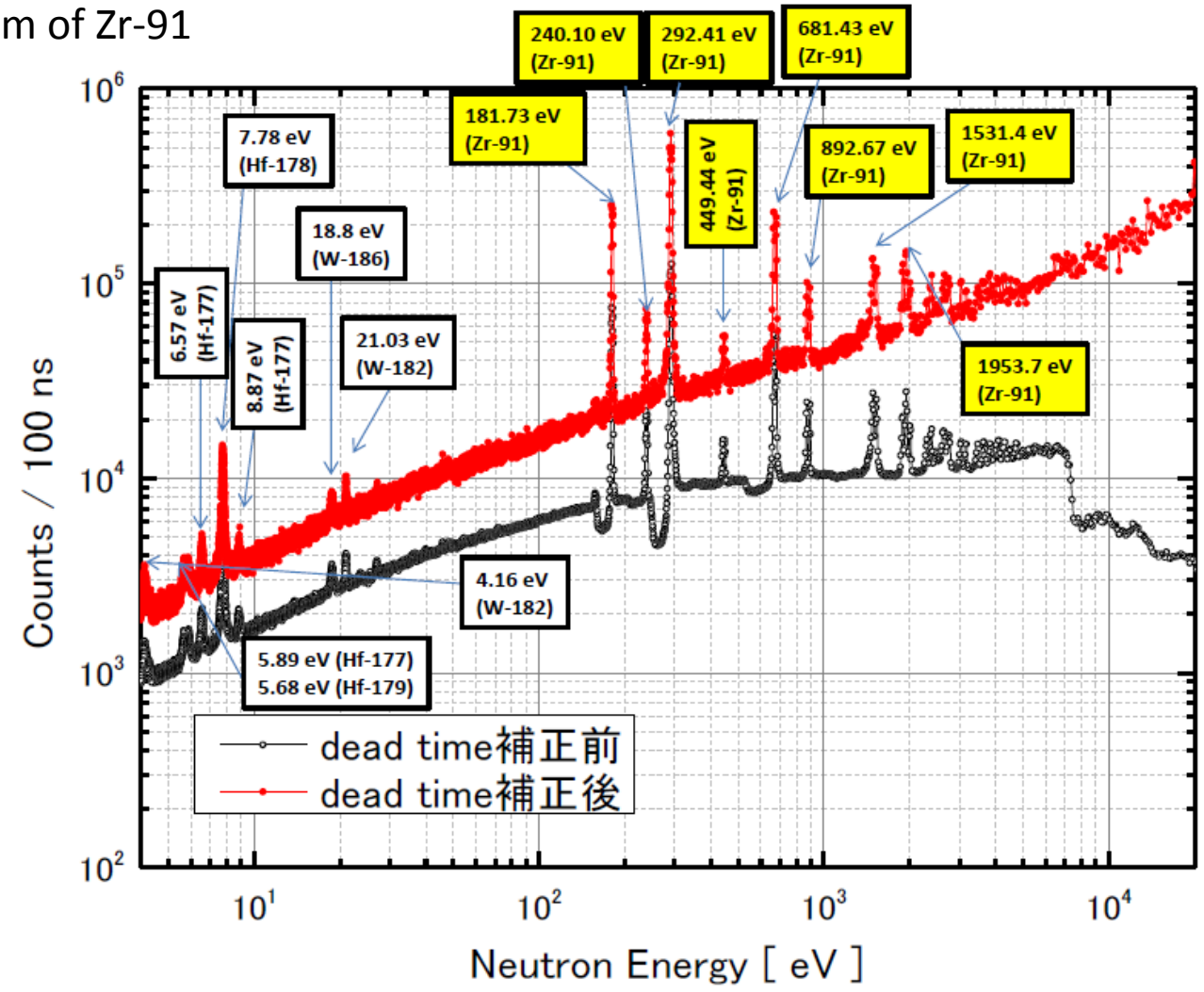


Differences between JENDL and ENDF for 41, 44, 83 and 94-eV resonance peaks.
Our work also observed these resonances.

J. Hori, et al., Kyoto Univ.

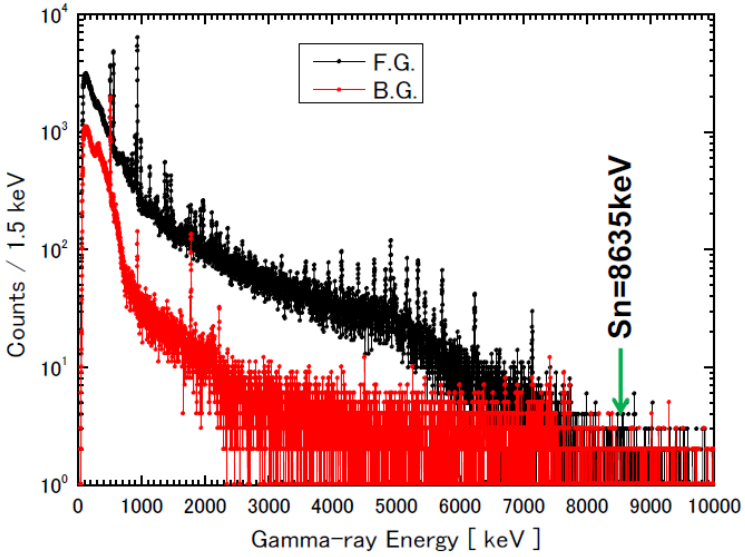
Measurements on neutron capture cross sections and gamma-ray pulse-height spectra of Zr stable isotopes using ANNRI-Ge/MLF/J-PARC

TOF spectrum of Zr-91

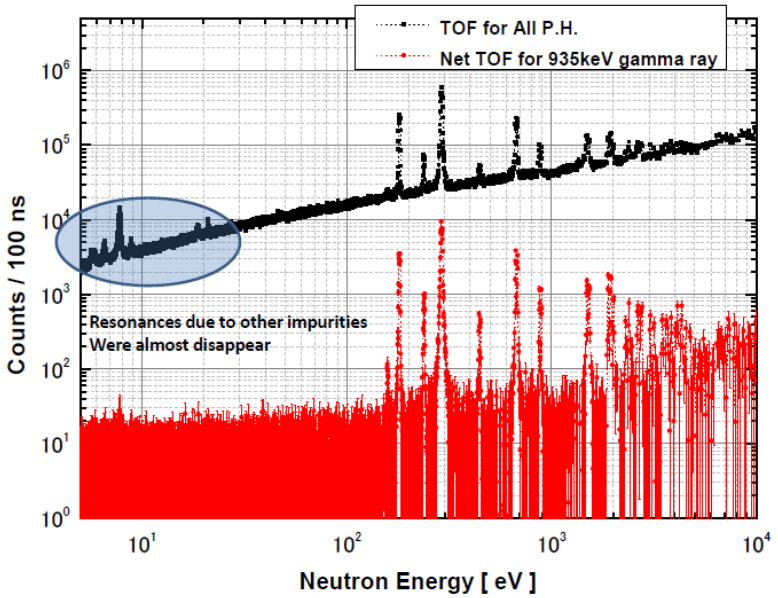


P. H. Spectra gated by resonance regions

182eV resonance region

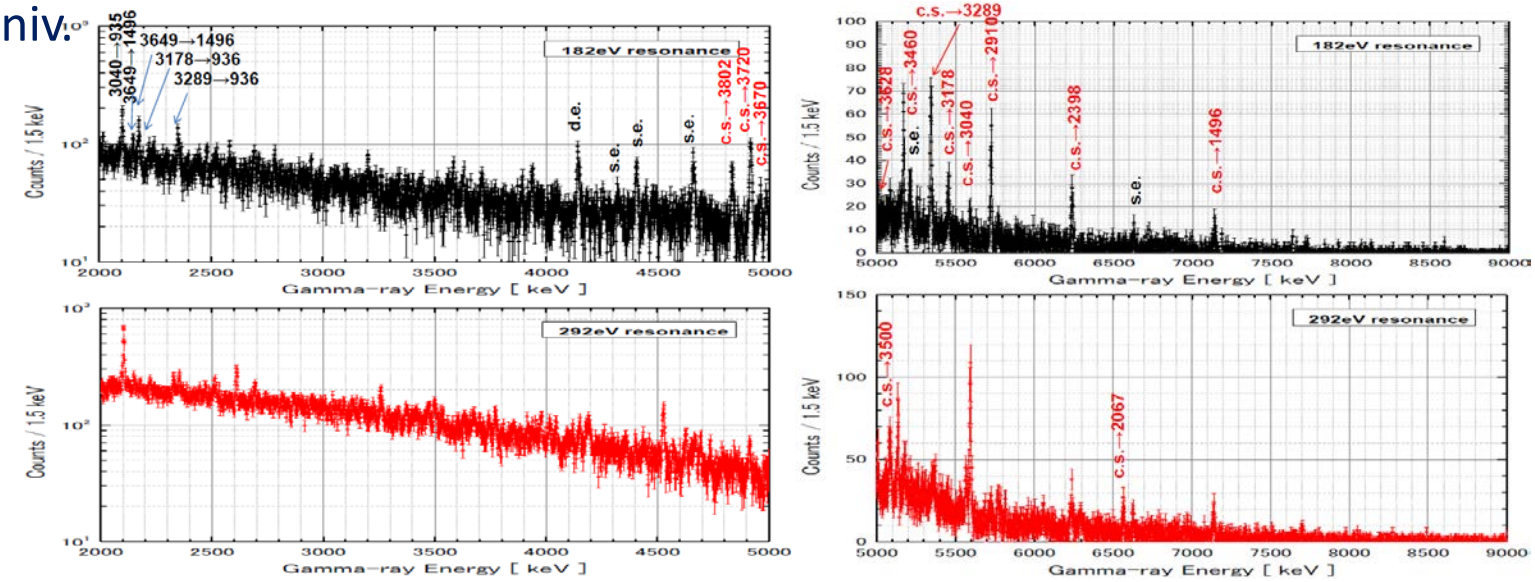


TOF spectrum gated at 935keV gamma-ray peak



J. Hori, et al., Kyoto Univ.

Comparison of net P.H. spectra between 182- and 293-eV resonances of Zr-91



Red: Primary transition peaks

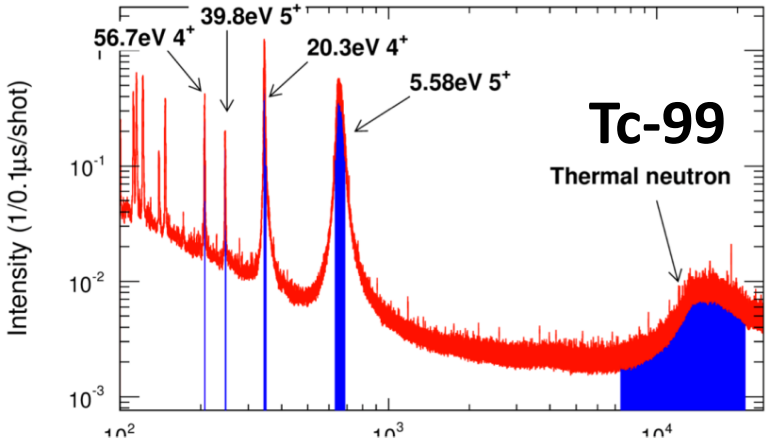
The analyses of neutron capture cross sections for Zr-91 and Zr-96 are in progress.

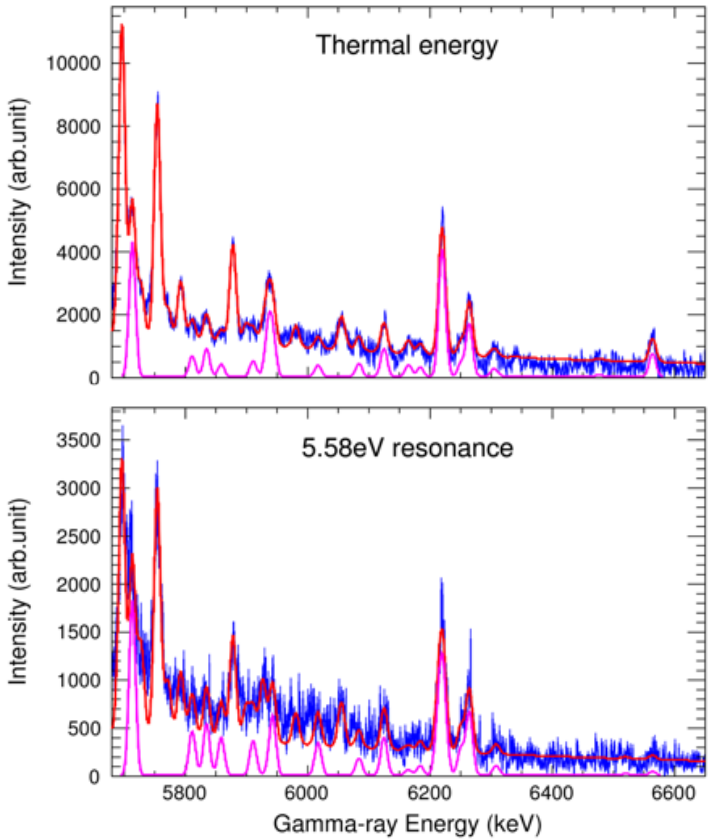
K. Kino, et al., Hokkaido Univ.

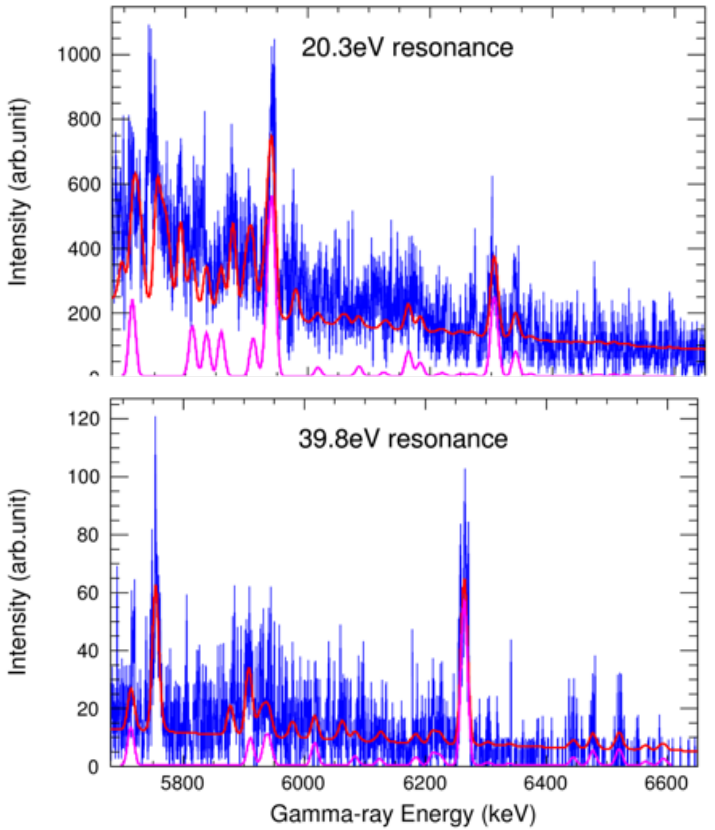
Measurement of Capture Gamma Rays from the Tc-99 Neutron Resonances at the J-PARC/ANNRI

Variations the characteristic primary gamma-rays between resonances were observed.

To be published in Nuclear Data Sheets







Red: All gamma-ray peaks + B.G. Pink: Primary gamma-ray peaks

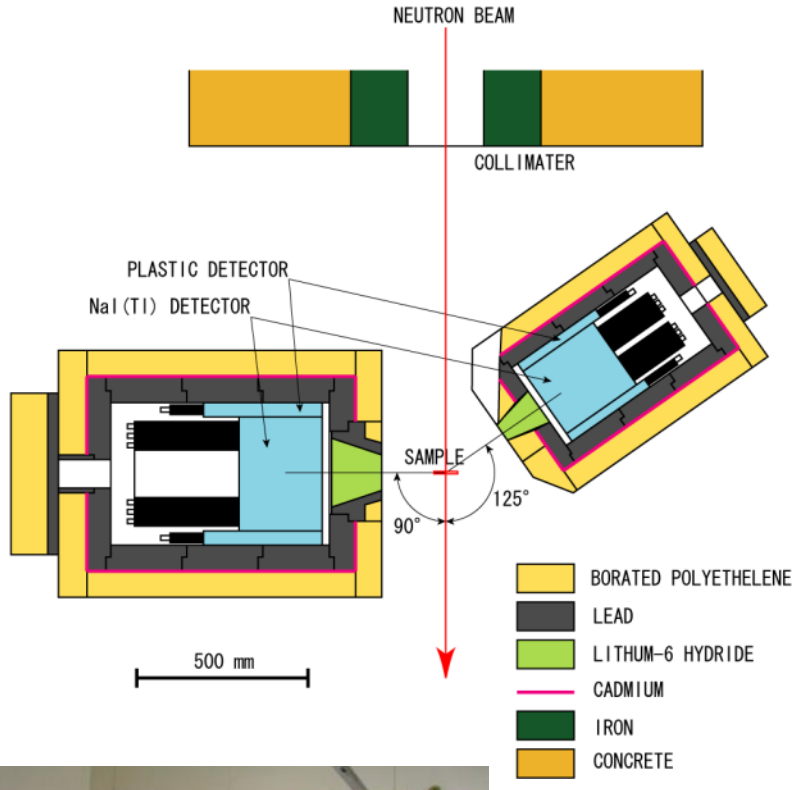
T. Katabuchi, et al.,
Tokyo Tech.

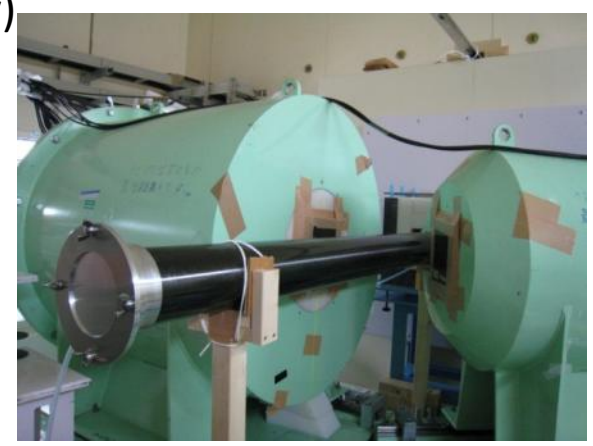
Measurements using NaI(Tl) Spectrometer

- Use for:
  - Complementary use to Ge array
  - Measurement in the high energy range
- Detectors
  - 90° detector: 13” diam. × 8” long
  - 125° detector: 8” diam. × 8” long
- Shielding
  - Borated polyethylene, Pb, ^{6}LiH, Cd
- Data acquisition

(by T. Katabuchi, Tokyo Institute of Technology)

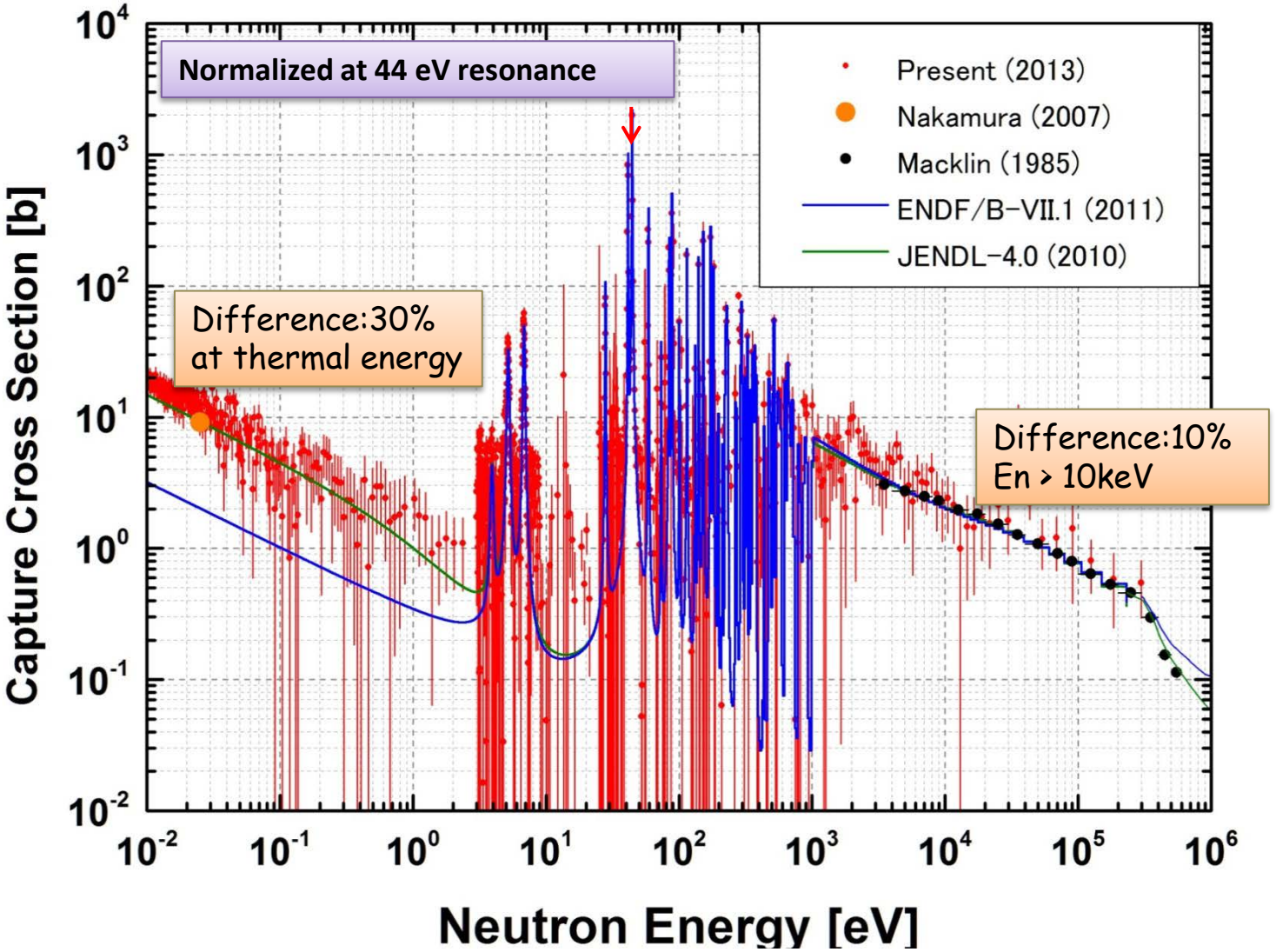
  - Multi-stop time digitizer
  - TOF, pulse height, pulse width are recorded sequentially





K. Terada, et al., Tokyo Tech.

Capture cross section of Pd-107



Presented at 4th International Symposium on Innovative Nuclear Energy Systems, INES-4, 6-8 November, 2013, Tokyo, Japan.

Activities at JAEA/FNS

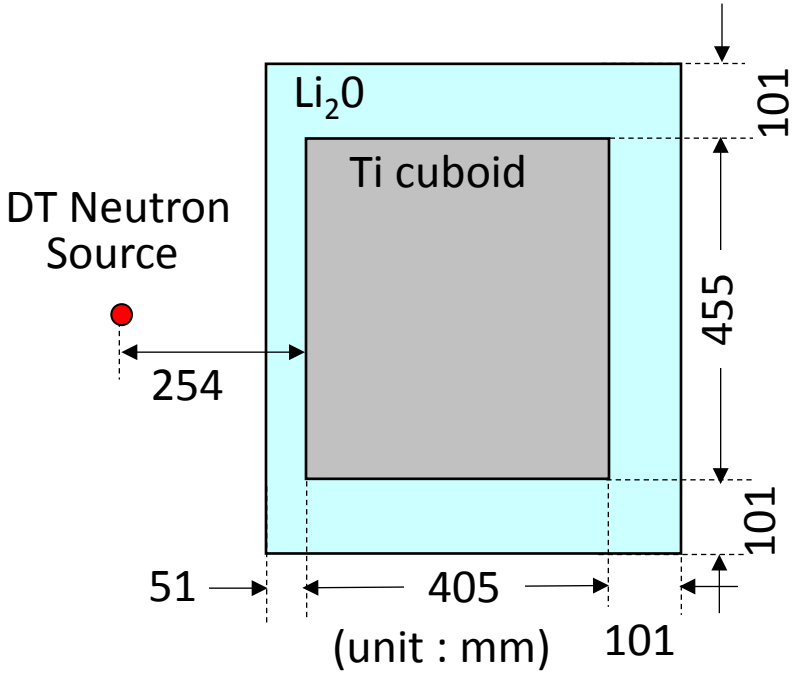
Integral experiment with DT neutron for titanium nuclear data benchmarking

Japan Atomic Energy Agency

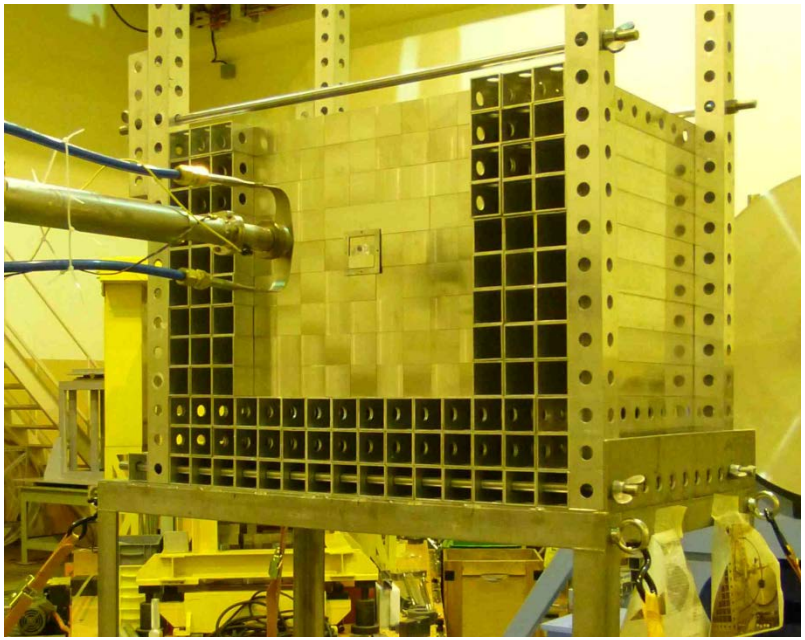
Fusion Neutronics Group

Experiment

We have carried out an integral experiment with DT neutron source for titanium nuclear data benchmarking. Reaction rates of several reactions were measured inside the titanium assembly and were compared with calculated ones with MCNP and various nuclear data libraries.



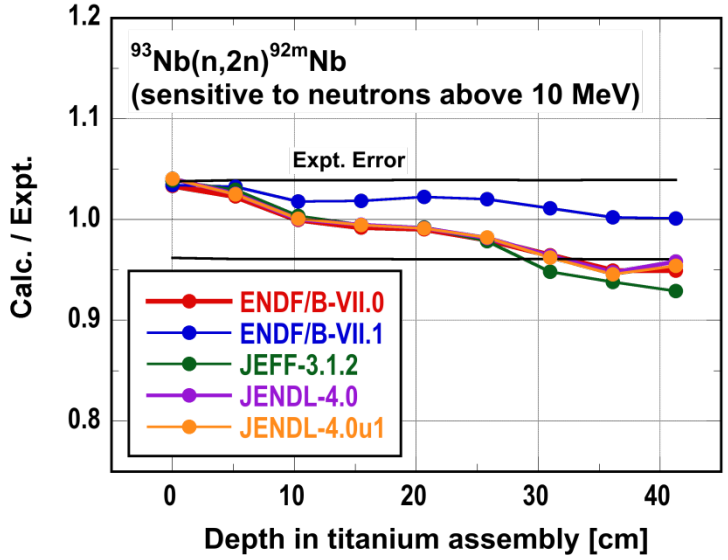
Experimental set-up

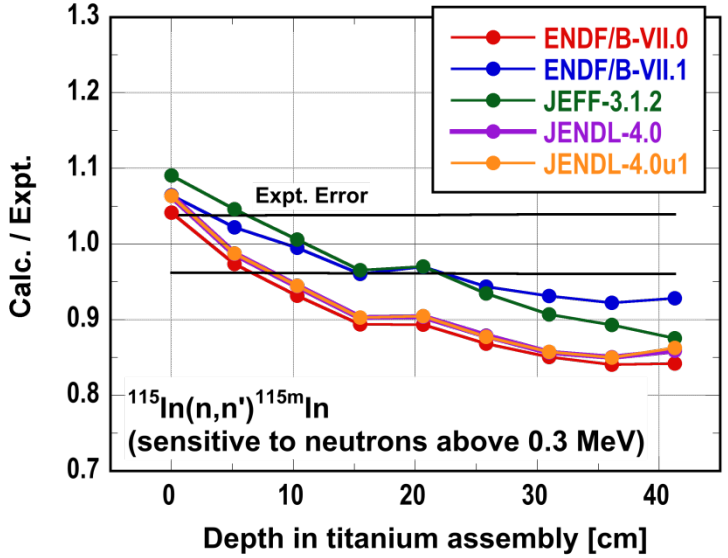


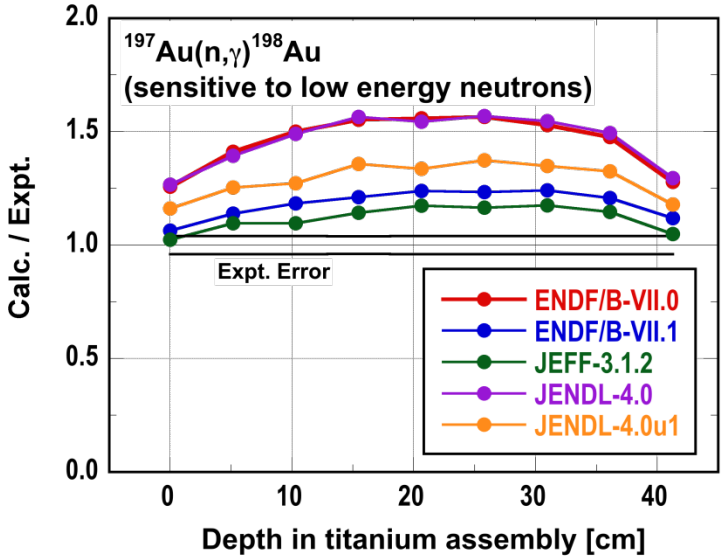
Picture of experimental set-up

Li_2O layer reduces room-returned neutrons into titanium cuboid.

Results

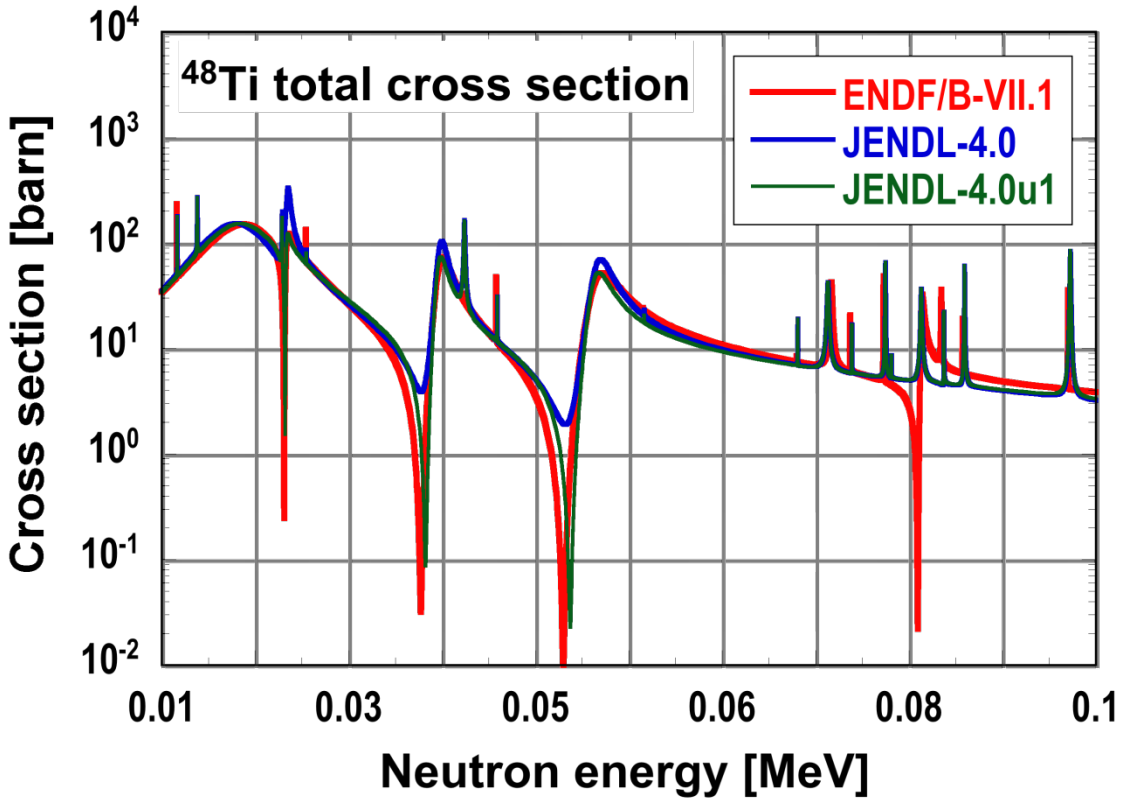






- The calculation result with ENDF/B-VII.1 agrees the measured ones the best.
- While the calculation result with JENDL-4.0 overestimates lower energy neutrons, that with JENDL-4.0u1 agrees with the measured one better.

Discussion



- **We specify that better agreement between measured and calculated results with ENDF/B-VII.1 and JENDL-4.0u1 comes from the above difference in the resonance region.**

M. Ohta, et al., "Benchmark experiment on titanium with DT neutron at JAEA/FNS ", Fusion Engineering and Design, in press.

Nuclear Data Activities at Tandem Accelerator Facility of Japan Atomic Energy Agency

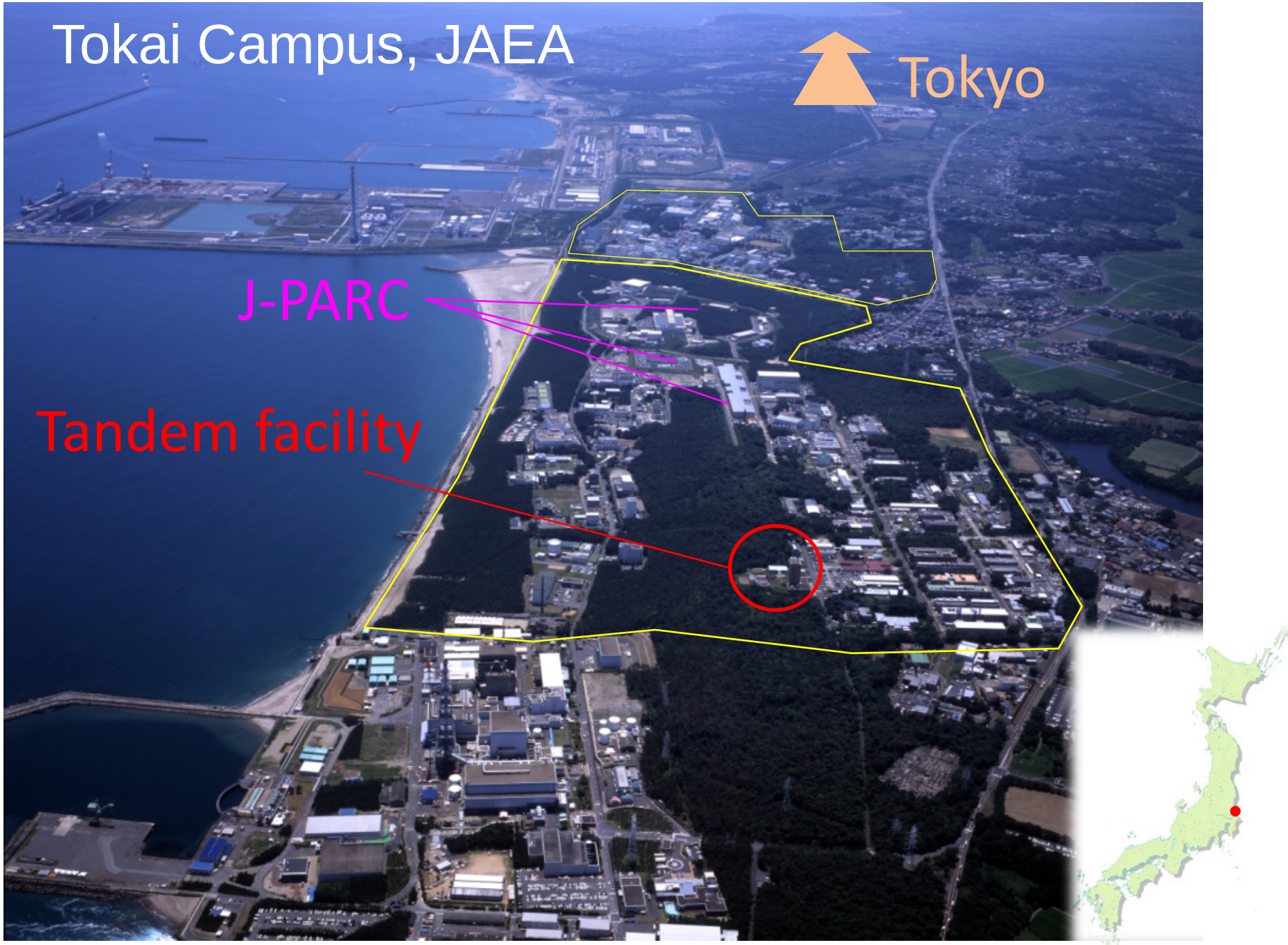
Contact :

Katsuhisa NISHIO

Advanced Science Research Center

Japan Atomic Energy Agency

nishio.katsuhisa@jaea.go.jp


Tokai Campus, JAEA
Tokyo
J-PARC
Tandem facility

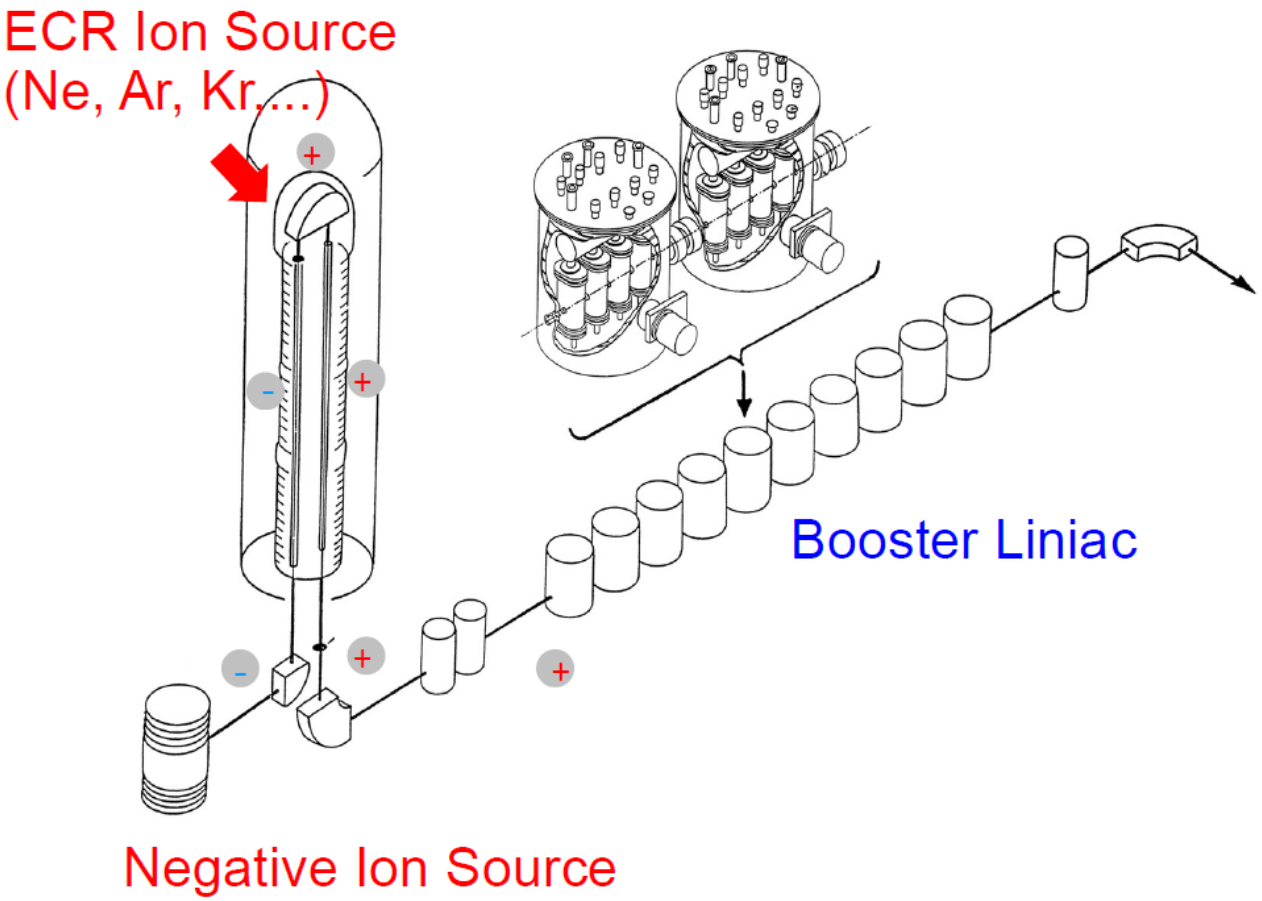
JAEA Tandem facility

Development :

1982 : 20 MV Tandem accelerator in operation

1994 : Super-conducting Booster Liniac

2008 : ECR Ion Source on the terminal



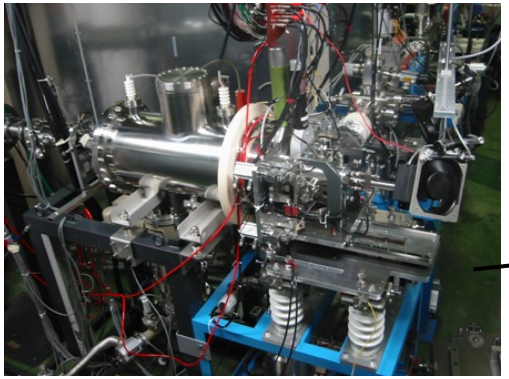
Magnetic Spectrometer

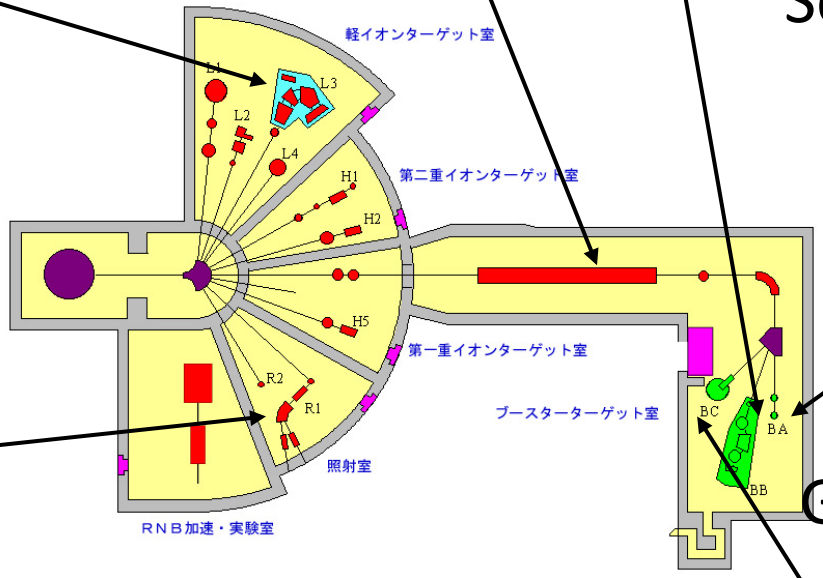
Booster Liniac

Recoil Mass Separator

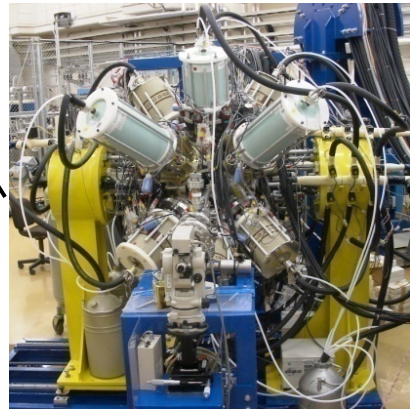
Scattering Chamber

ISOL (p + ^{238}U)



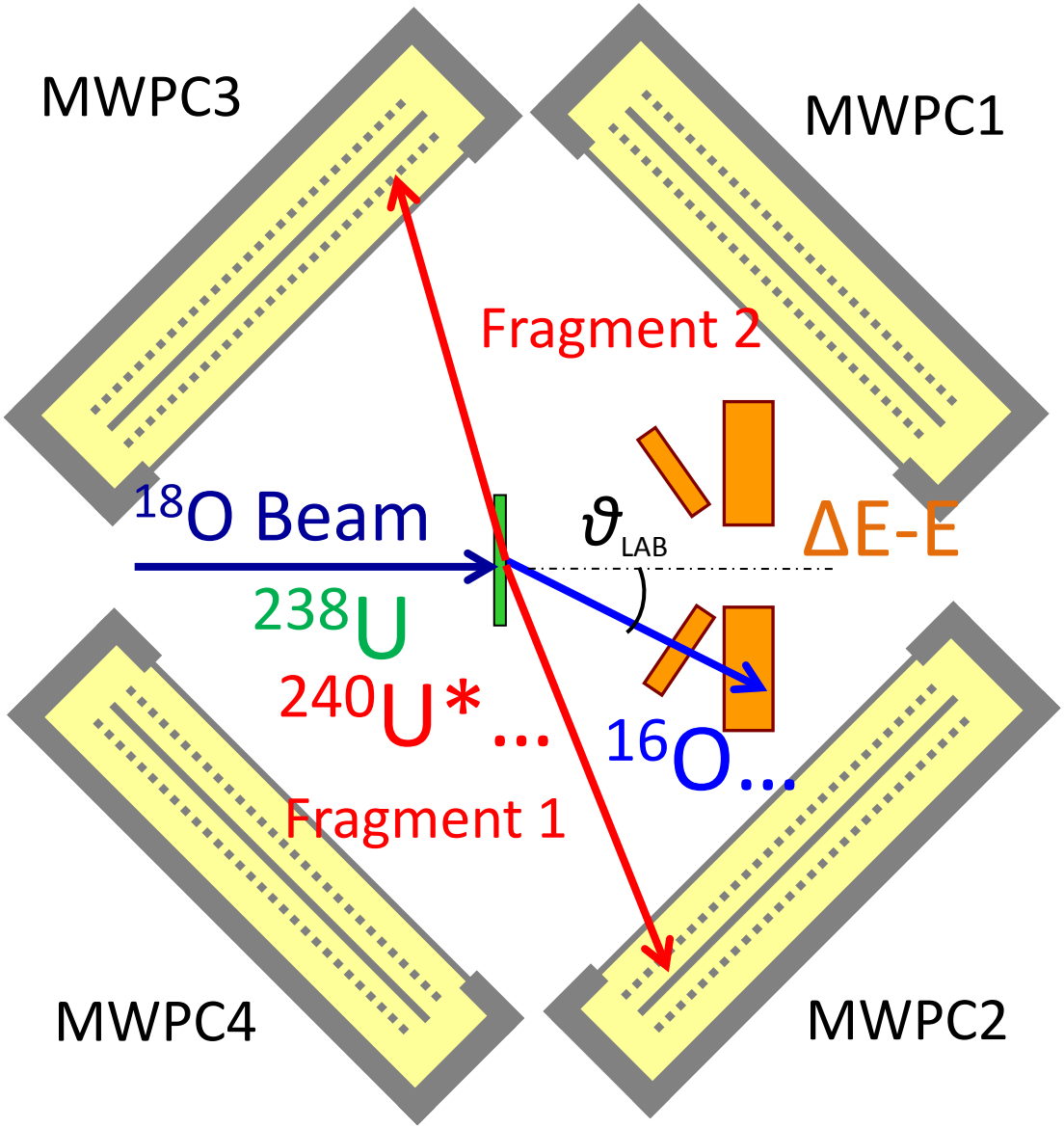


Ge-detector array

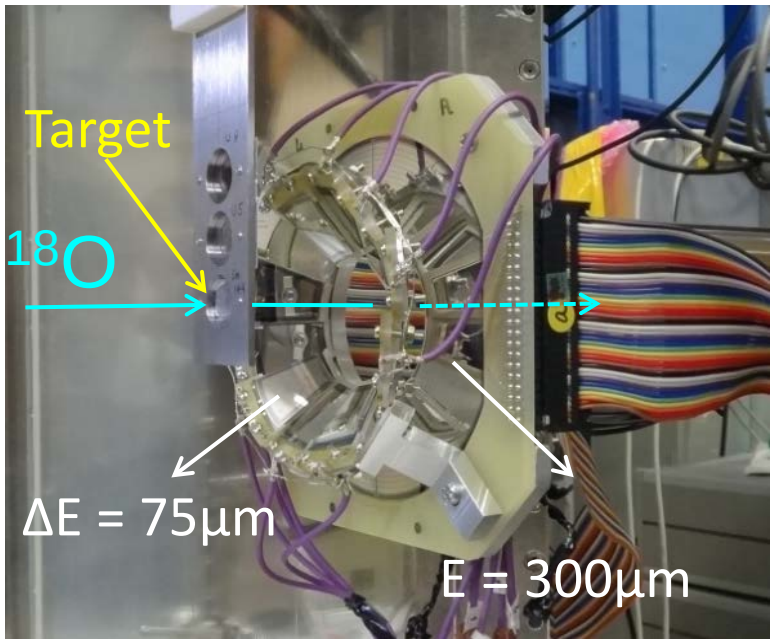


Radioactive target materials can be used
Th, U, Np, Pu, Np, Am, Cm, Cf

Fission Cross Sections

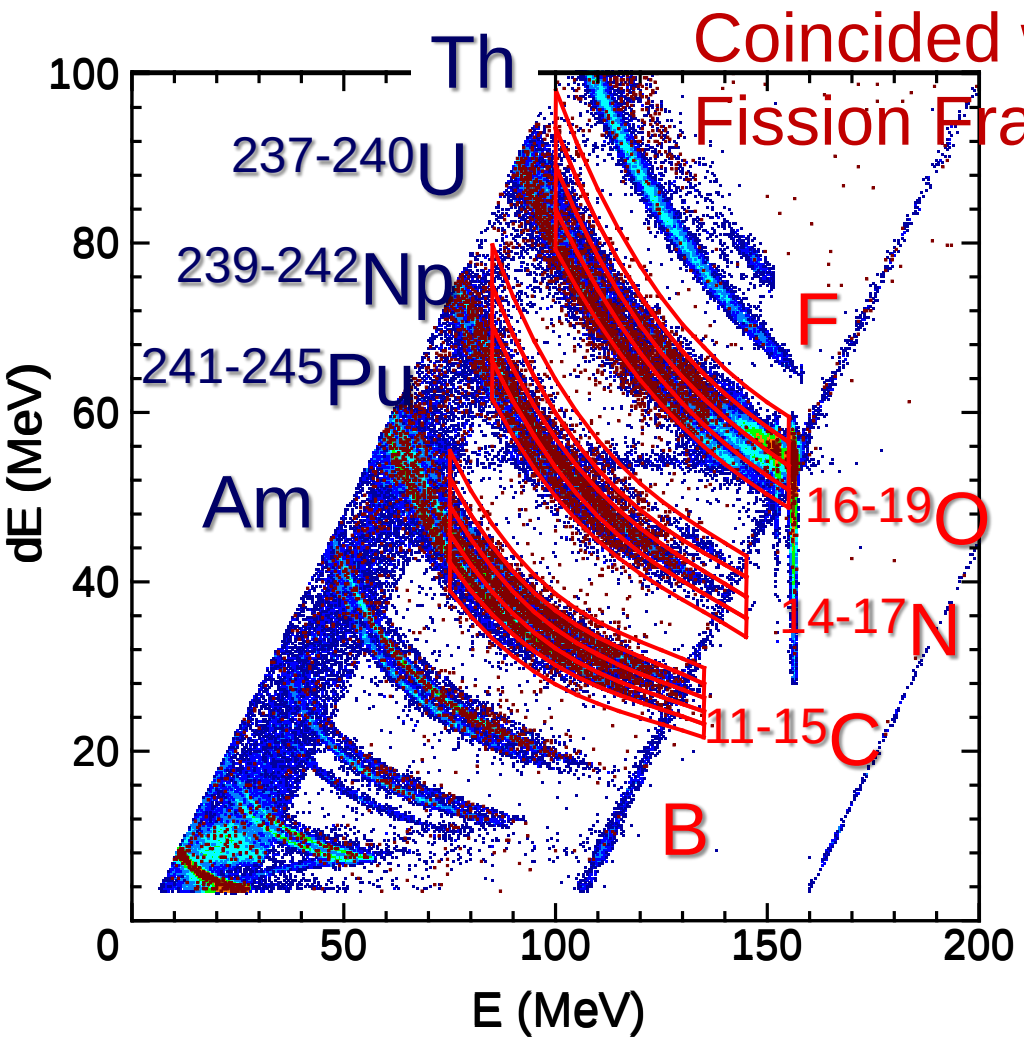


ΔE-E detector Array



Particle Identification

$^{18}O + ^{238}U$ (E=157.5 MeV)



$^{240,239,238,237}U^{*}$

n + ^{239}U (23.5 min)
n + ^{237}U (6.8 day)

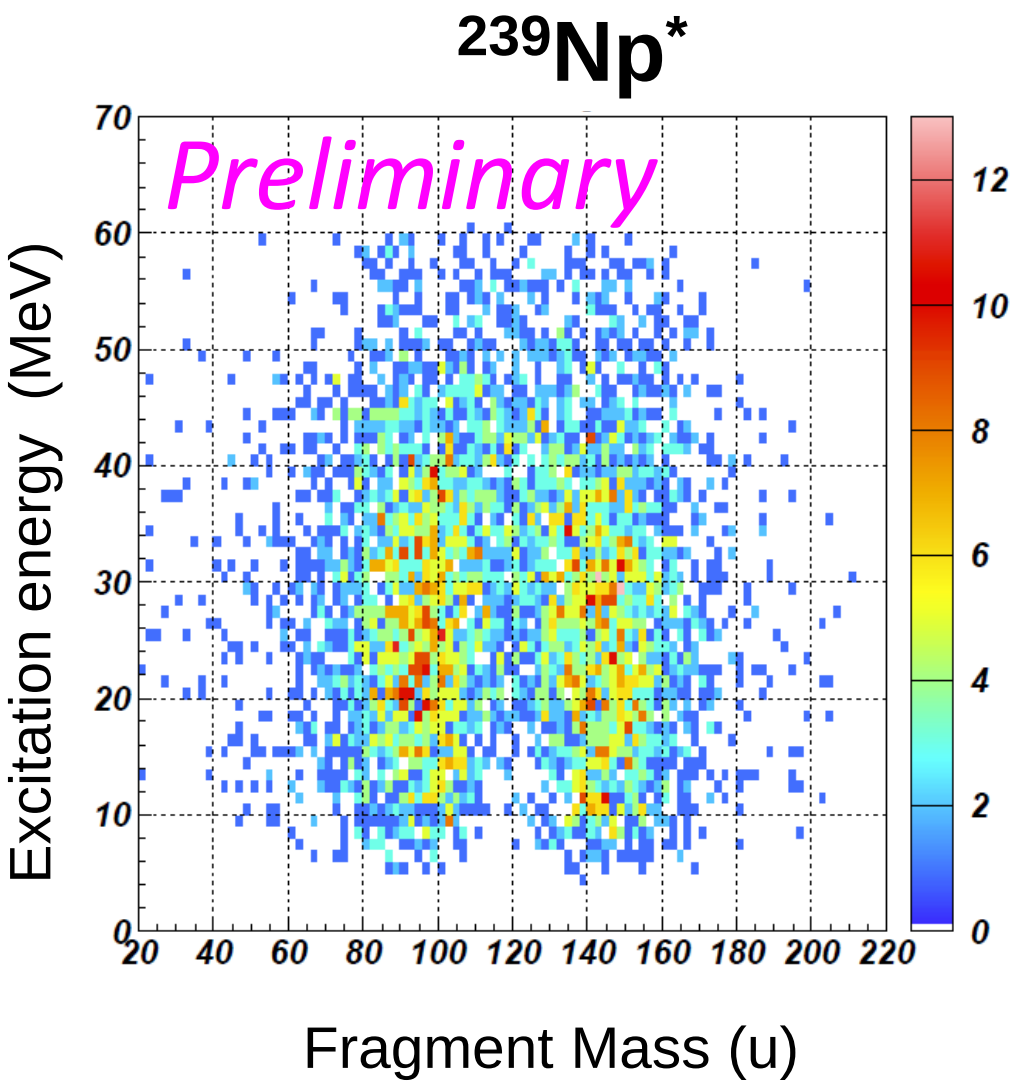
$^{242,241,240,239}Np^{*}$

n + ^{241}Np (13.9 min)
n + ^{240}Np (65 min)
n + ^{239}Np (2.4 day)
n + ^{238}Np (2.1 day)

$^{245,244,243,242,241}Pu^{*}$

n + ^{243}Pu (4.9 hr)
n + ^{241}Pu (14 yr)

Fragment Mass distributions for ^{239}Np



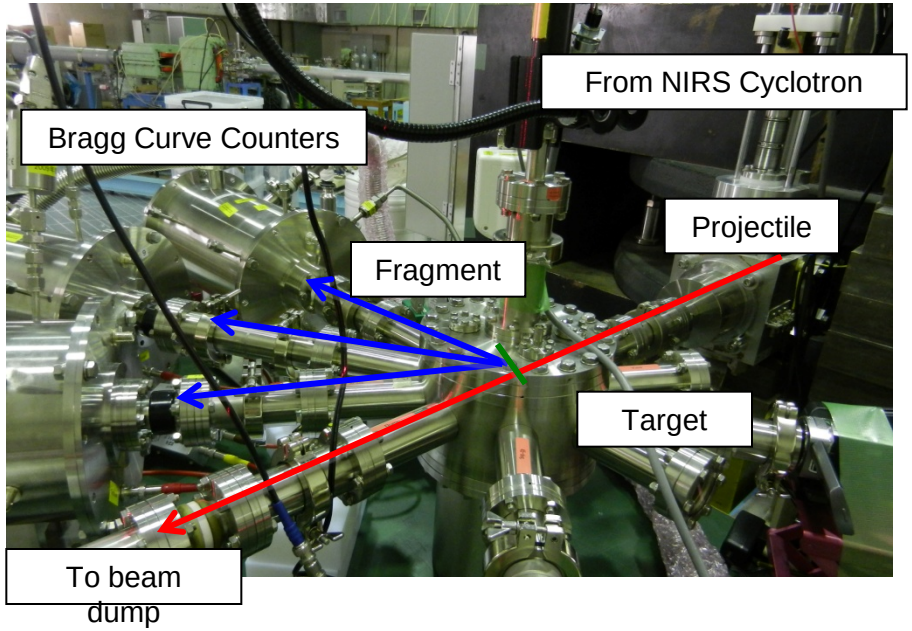
Reported in ASRC Workshop, Nuclear Fission and Structure of Exotic Nuclei,2014, Tokai

Activities at Radiation Science Center, KEK

Sanami and Hagiwara Group

Light mass fragment production DDXs of 70 MeV proton, helium and carbon induced reactions

Experimental data for different projectiles with same energy to study reaction models and parameters for fragment production induced by tens of MeV projectiles.



Facility : Cyclotron, National Institute of Radiological Sciences, Japan

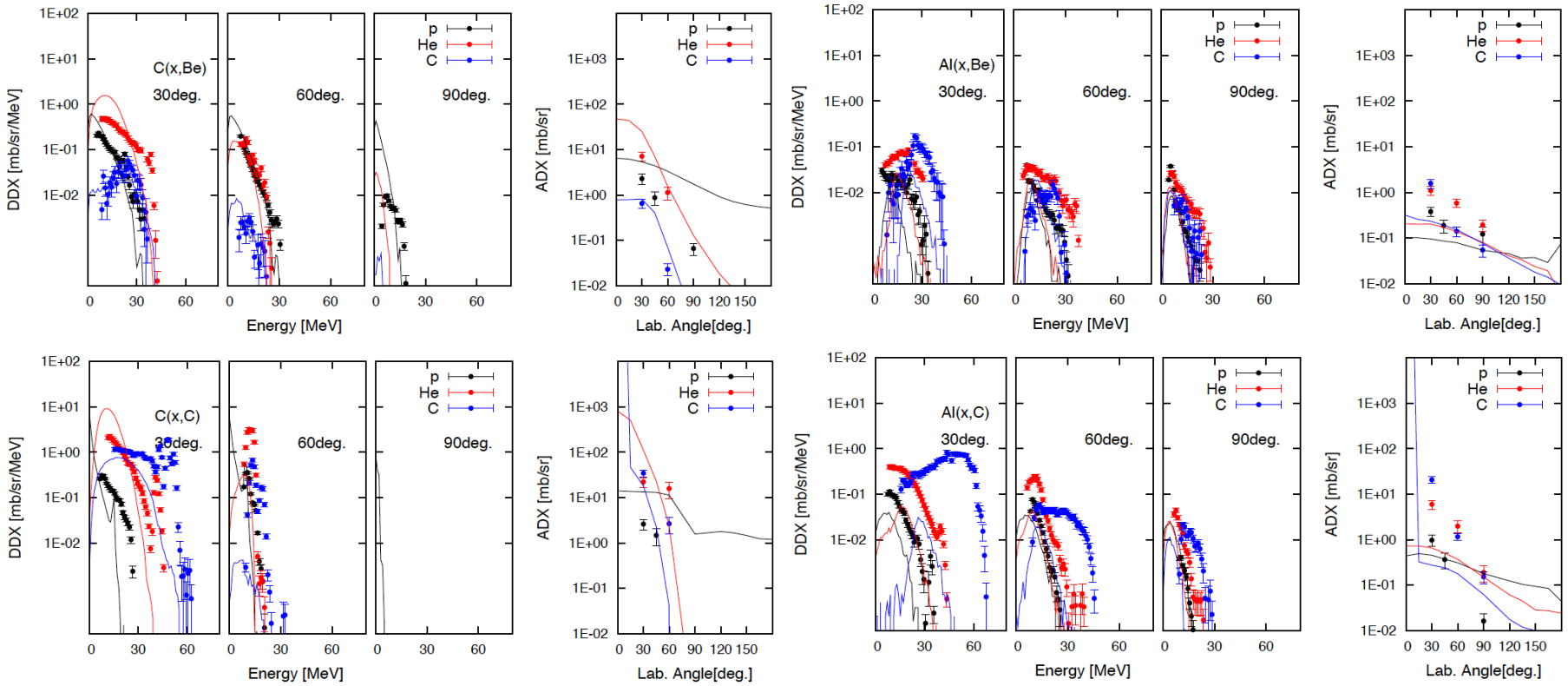
Beam : 70MeV proton, 70MeV $^{4}He^{2+}$, 6 MeV/n (72 MeV) $^{12}C^{6+}$

Targets : Be-5μm, C-200μg/cm2, Al-0.8μm, Ti-1μm, Cu-1μm

Detector : Bragg Curve Counter (BCC) at 30, 60 and 90 degrees

Nuclear data measurement activities at High Energy Accelerator Research Organization (KEK)

Beam:	Ep=70, Ed=70MeV, Ec=72MeV
Target :	C(205mg/cm^2),Al(1μm)
Fragments:	Li, Be, B, C at 30,60,90 degrees (Dots)
Calculation:	PHITS 2.62 with default option (Lines)



Activities at Tokyo Institute of Technology (Tokyo Tech)

Igashira Group

Capture Cross Sections and Gamma-ray Spectra in the keV Region

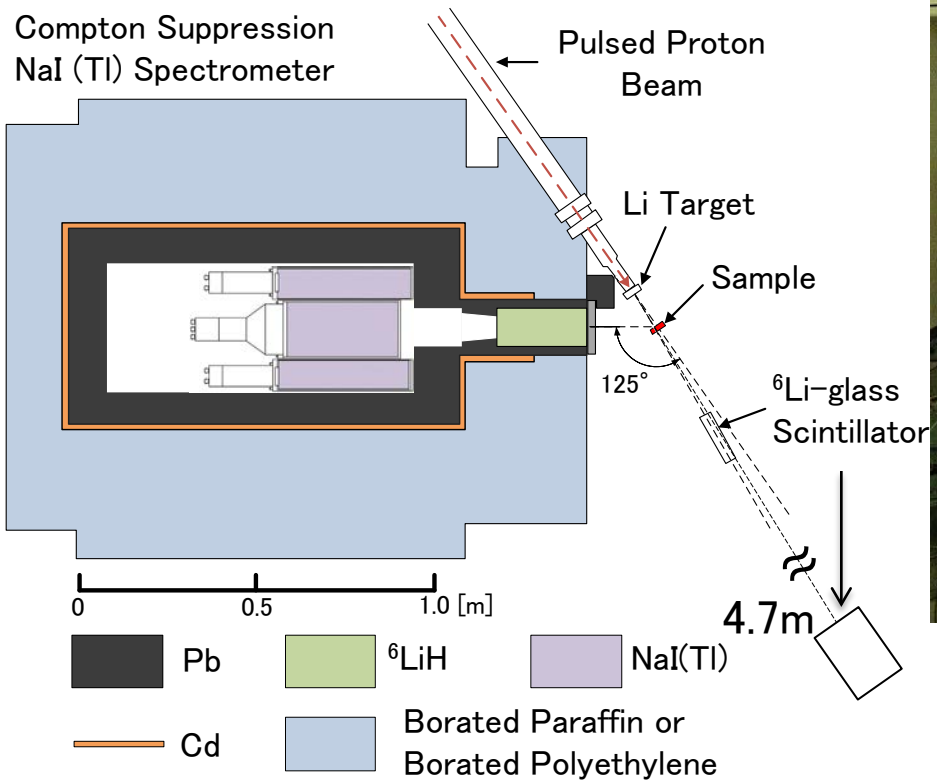
Nuclide	En = 15 - 100 keV	En = 550 keV
Pd-110	Measured in 2012	2013/5
I-127	2013/6	Not yet
Cs-133	2013/6	Not yet

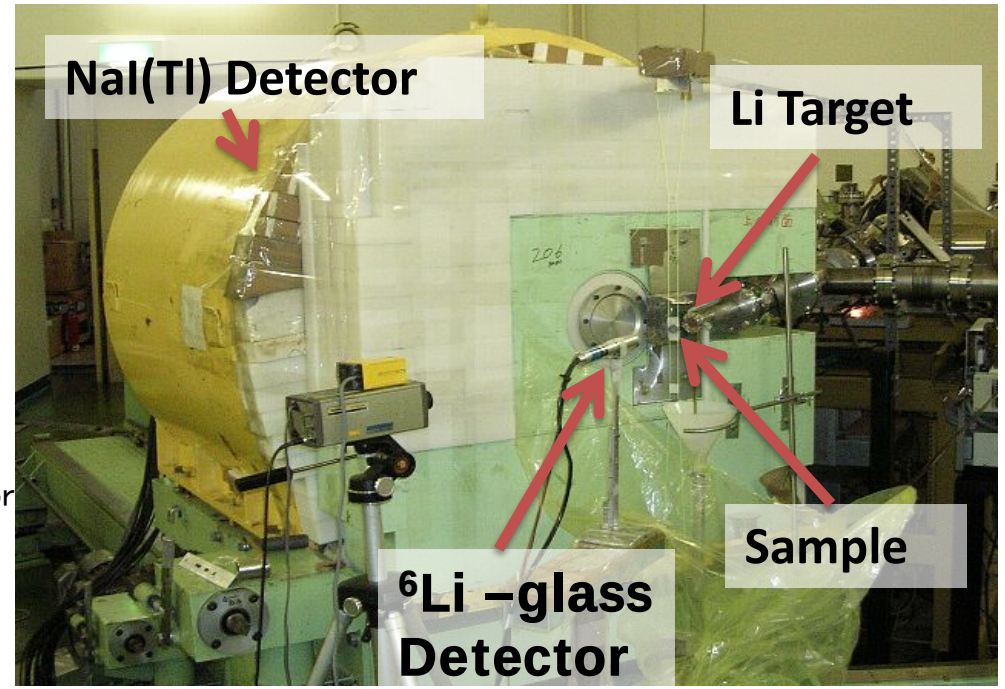
Pd-104,105,106,108 were measured by 2012.

Experimental setup

3-MV Pelletron accelerator
Pulsed proton beam
- **Repetition rate : 4 MHz**
- **Beam width : 1.5 ns**
- **Average current : 10 μA**

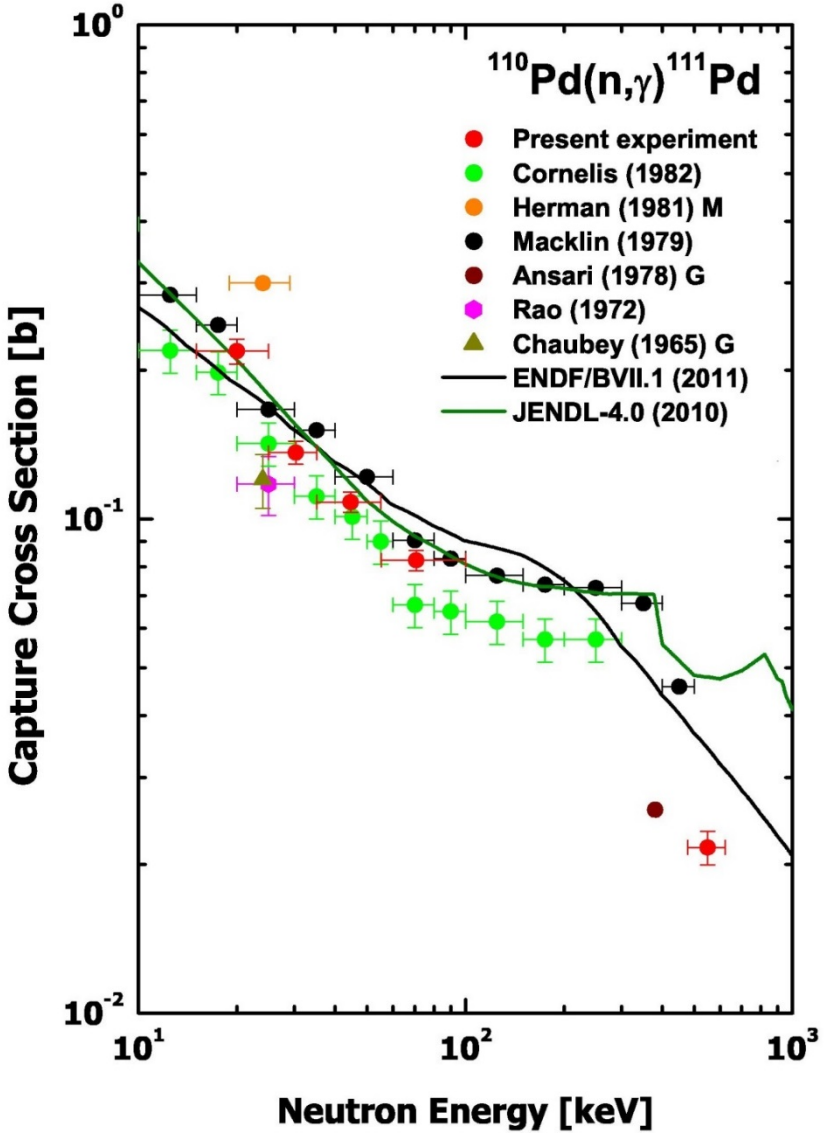
Neutron source : $^{7}Li(p,n)^{7}Be$
Flight path length :
- **12 cm for 15-100 keV neutrons**
- **20 cm for 550 keV neutrons**

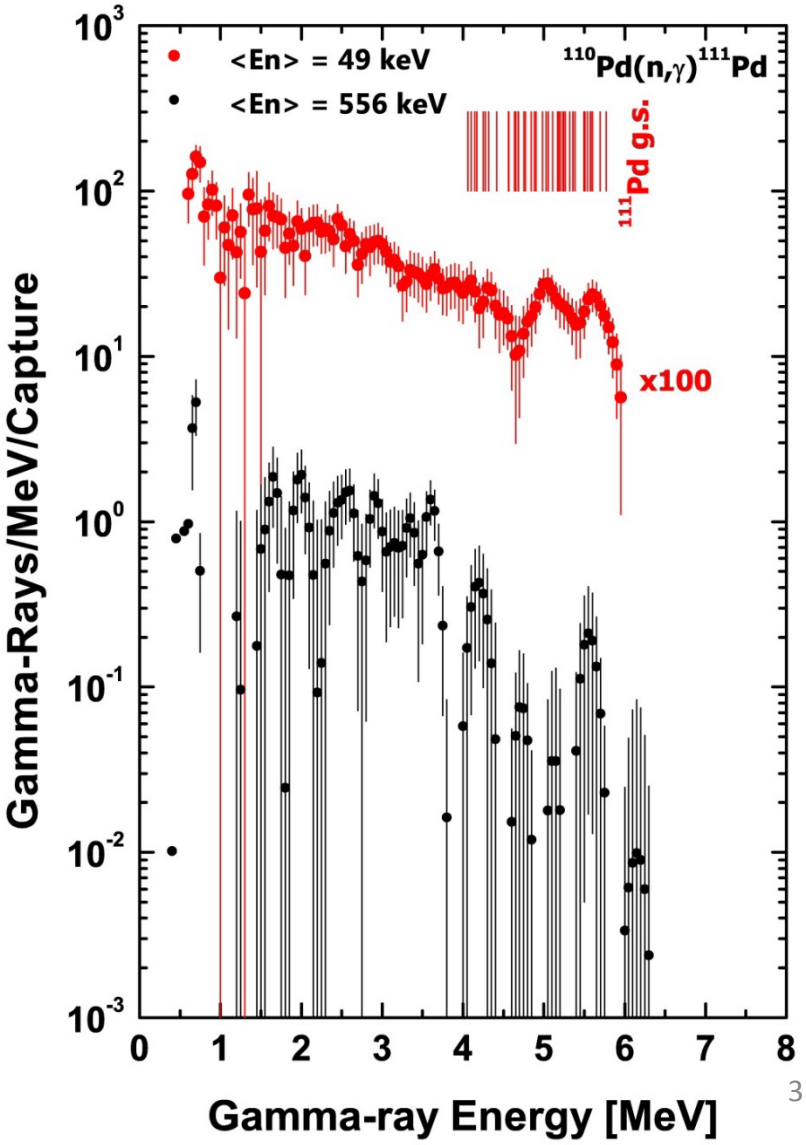




NaI(Tl) Spectrometer
- **Two Dimensional Data: TOF x PH**

Capture Cross Sections and Gamma-Ray Spectra of ^{110}Pd





Activities at Kyoto University

KURRI Group

Neutron capture cross section measurement for Th-232

Motivation : In the thorium fuel cycle, neutron capture cross section of Th-232 is important since the fissile U-233 is generated by tow successive β-decays after the capture reaction. In the JENDL-4.0, the resonance parameters were revised from the values of JENDL-3.3 as shown in Fig. 1. We started an experimental study in order to check the resonance parameters in the low energy region.
Neutron Source : KURRI-LINAC, Ta target, Flight path:12.7 m
Detector : Total absorption type BGO detectors

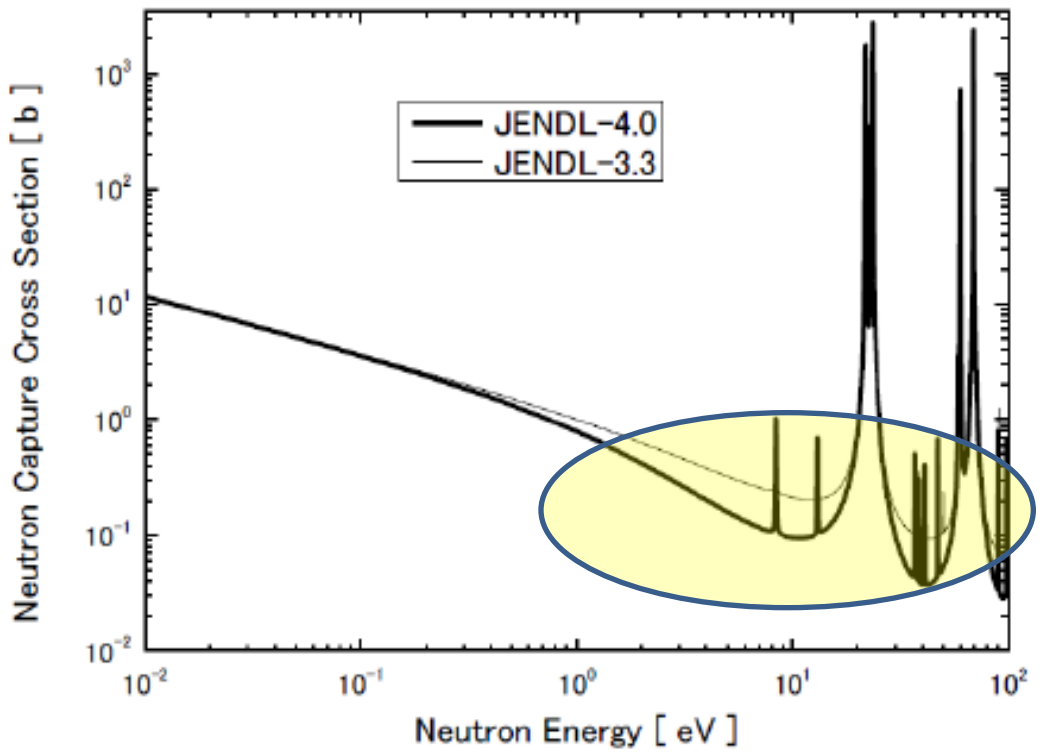
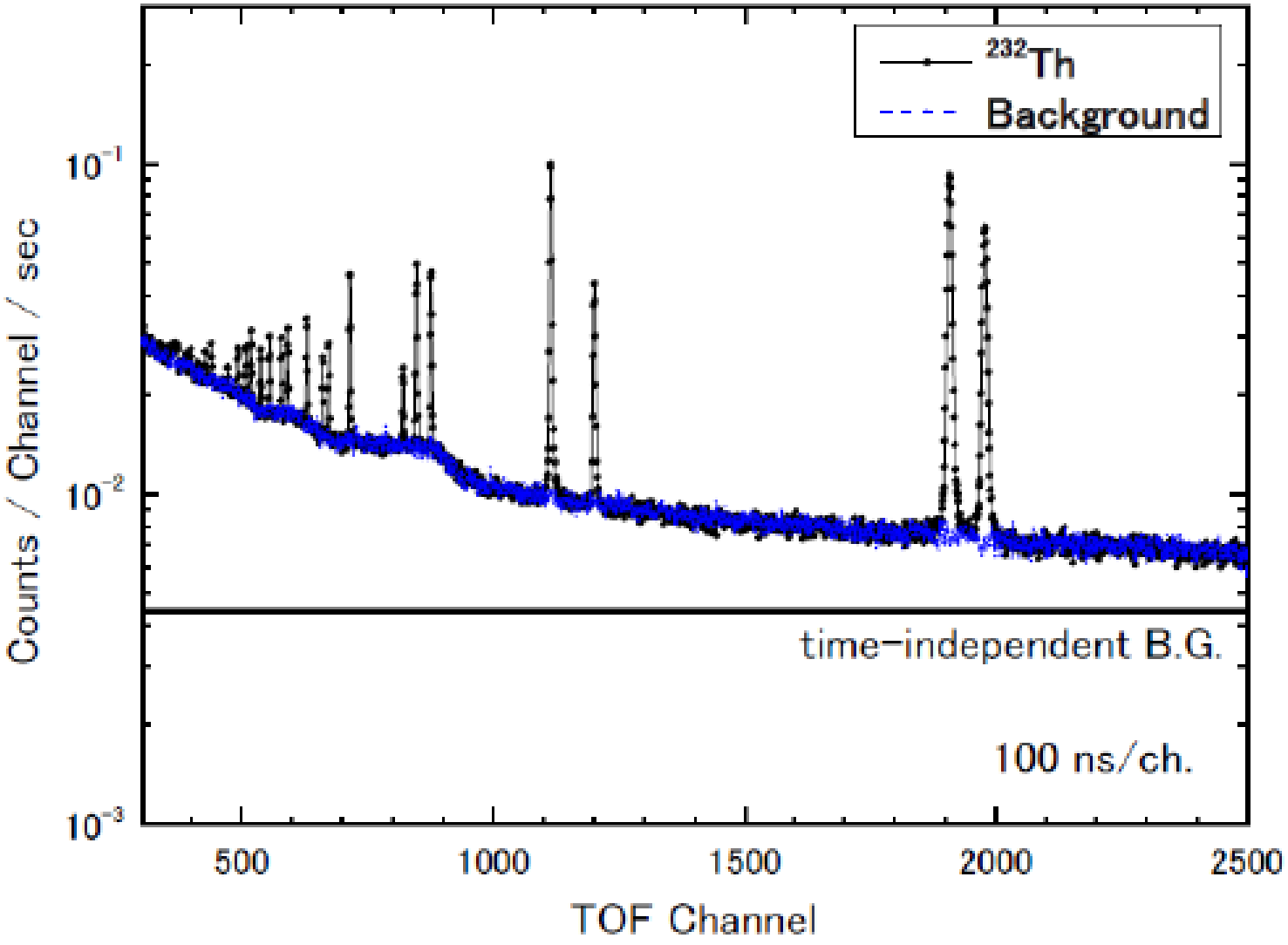


Figure 1. Comparison of Th-232 neutron capture cross sections between JENDL-4.0 and JENDL-3.3

- Th-232 Sample
  12.7 mm in diameter
  0.05 mm in thick
  Weight: ～70 mg
  Purity 99.97%

Here, a part of TOF spectrum is only shown.



Presented at the 2013 Symposium on Nuclear Data, Nov. 14-15, 2013, Tsuruga, Japan.
Final result will be presented in PHYSOR2014.

Activities at Konan University

Utsunomiya Group

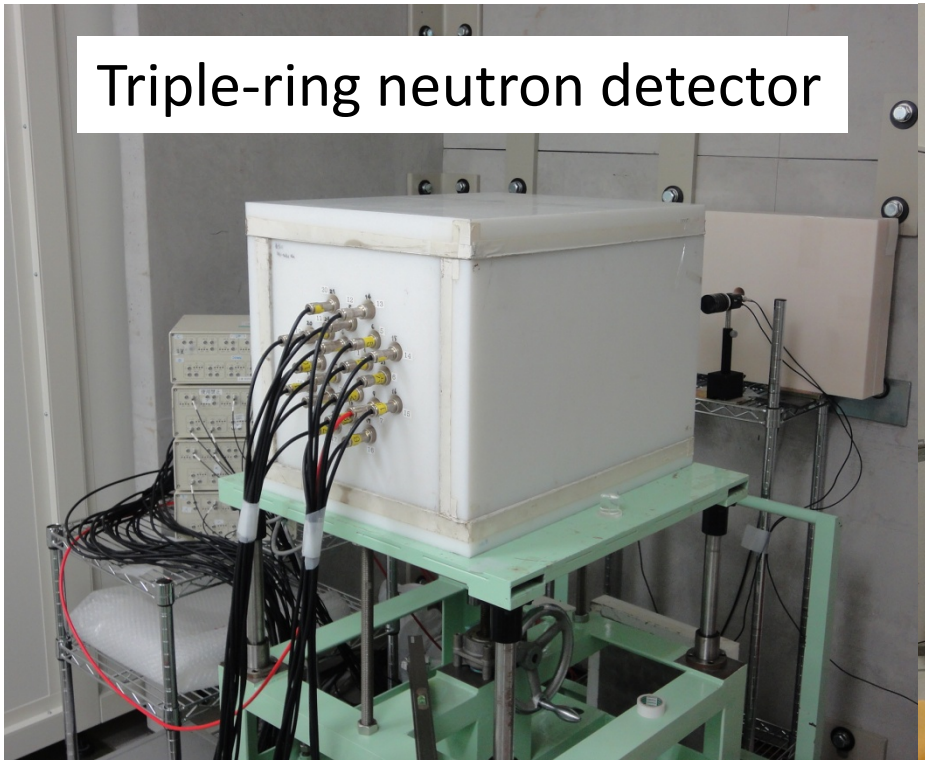
Photoneutron cross section data at NewSUBARU

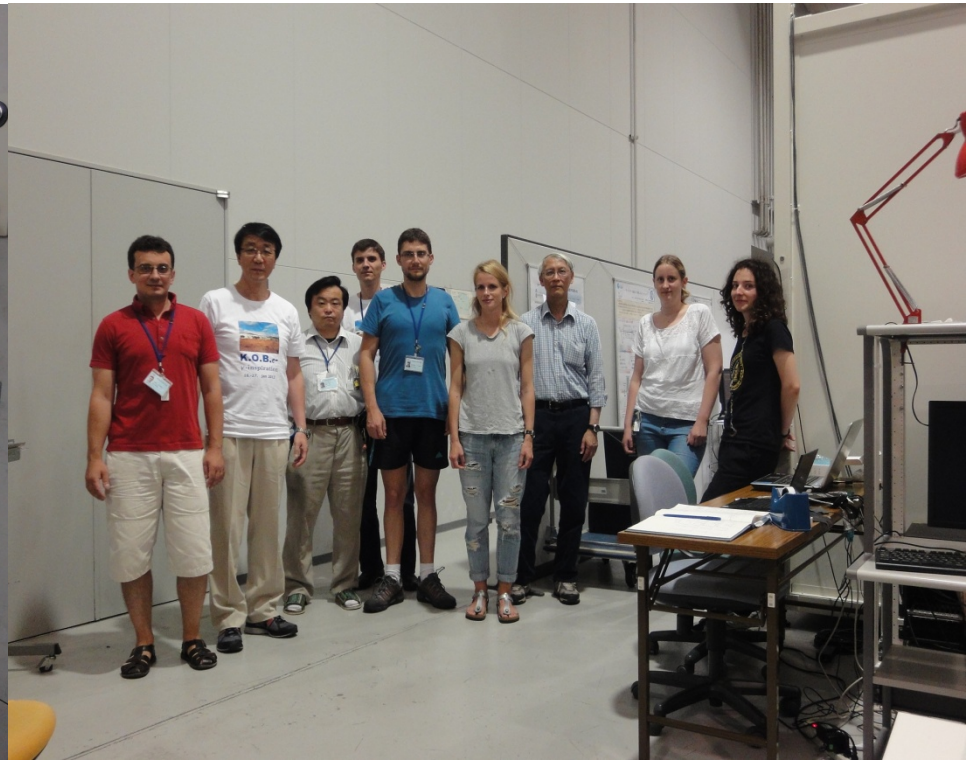
Hiroaki Utsunomiya

(Konan University)

Total (γ ,n) cross section measurements

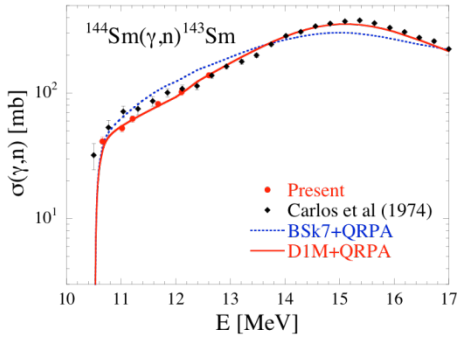
International Collaboration K.O.B.e^-
(Konan - Oslo - Bucharest - e^- beams)

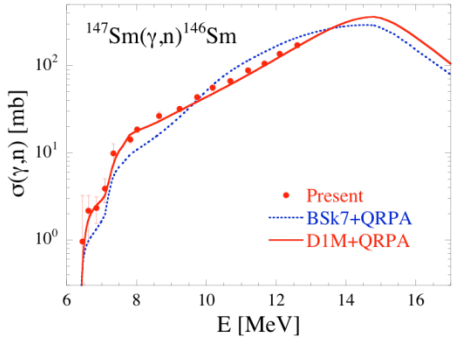


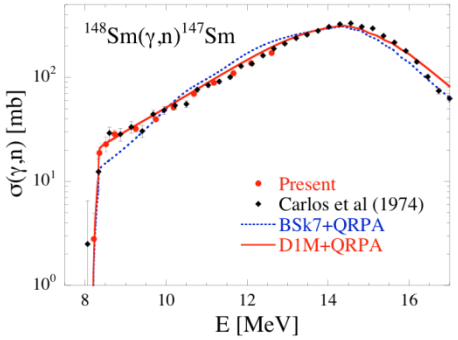


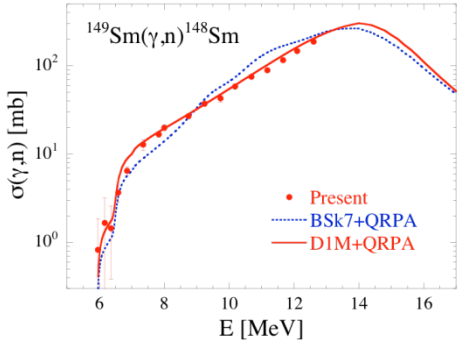
(γ,n) cross sections for Sm isotopes

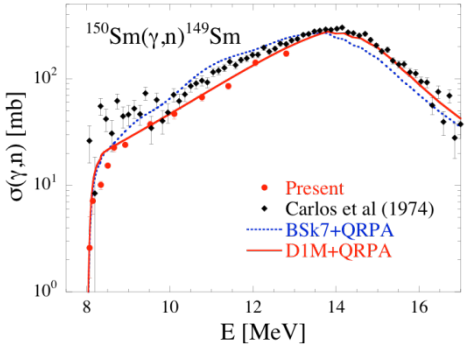
To be submitted to Physical Review C

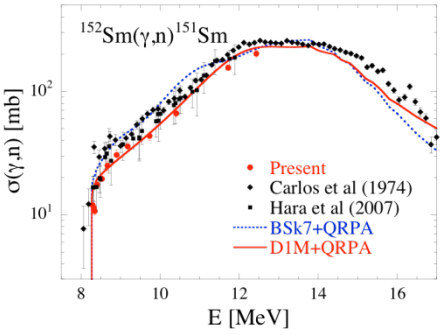


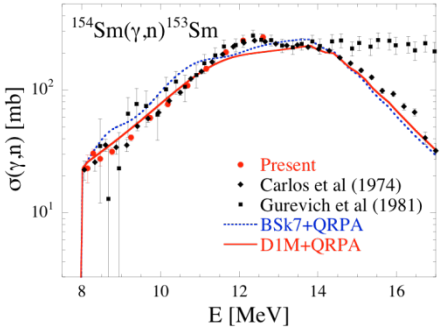






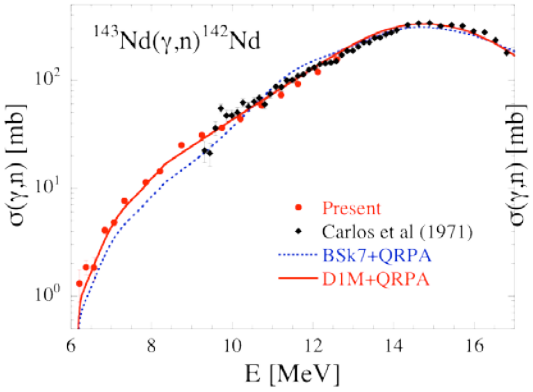


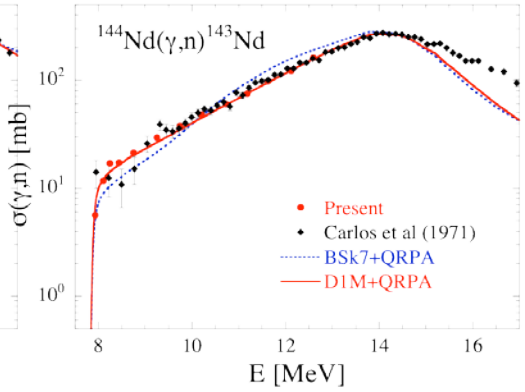


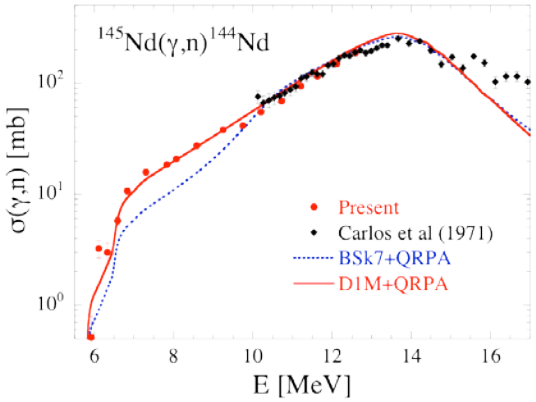


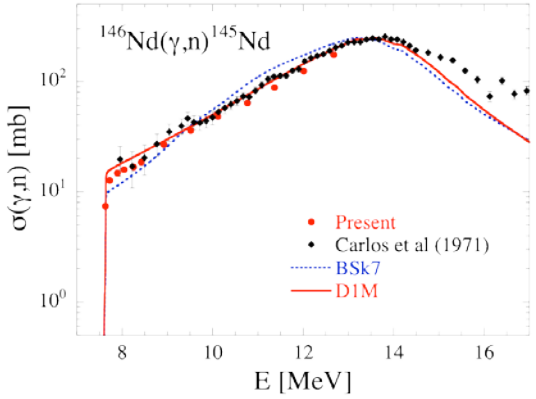
(γ,n) cross sections for Nd isotopes

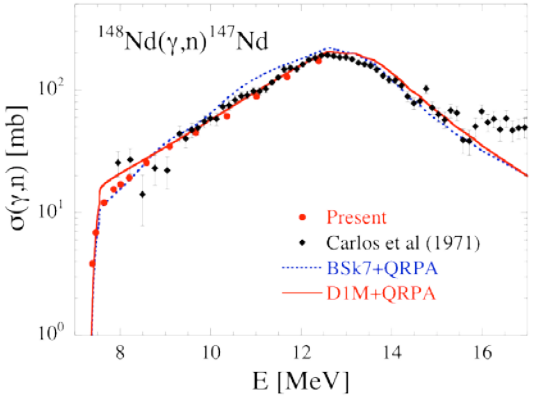
To be submitted to Physical Review C





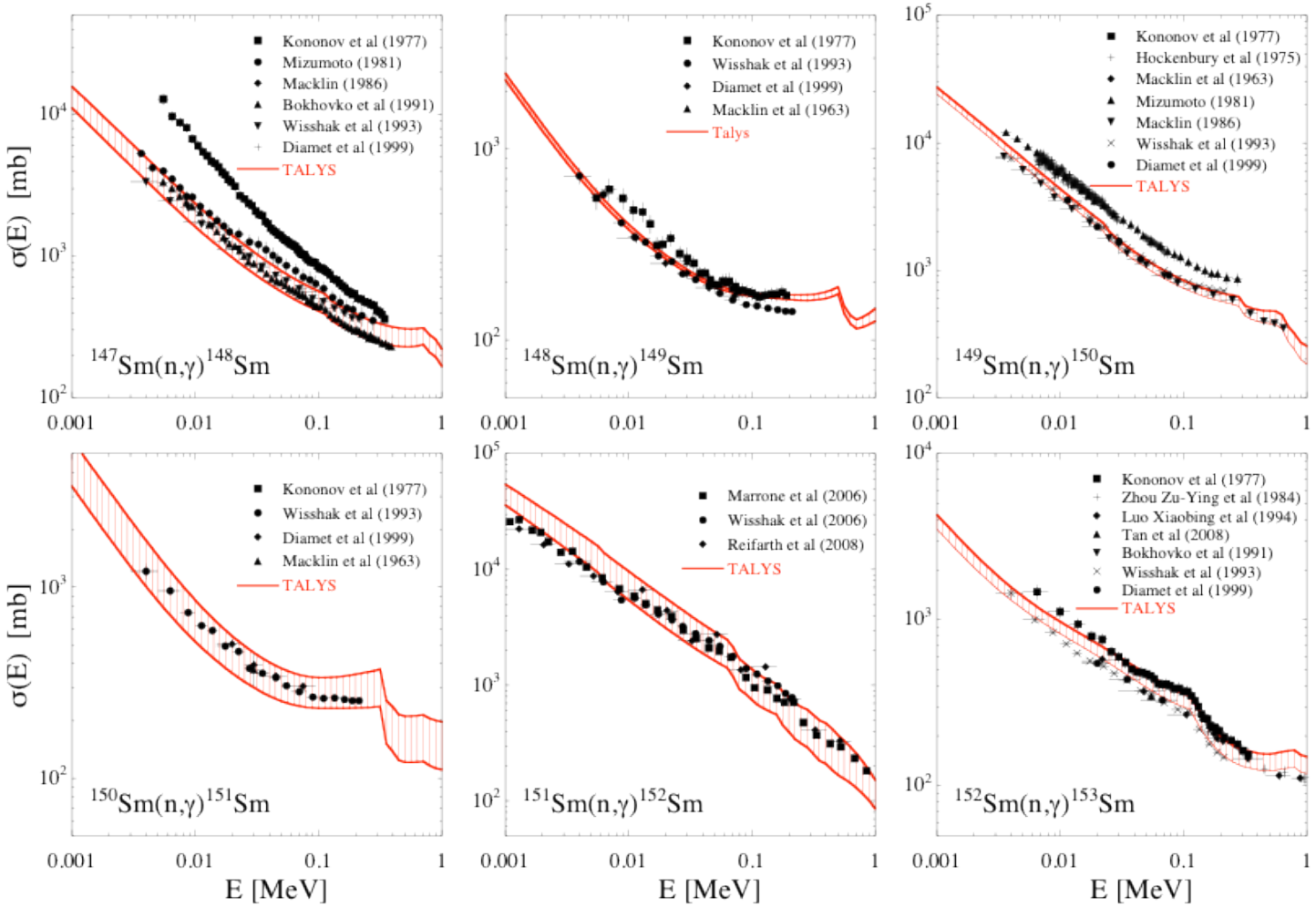






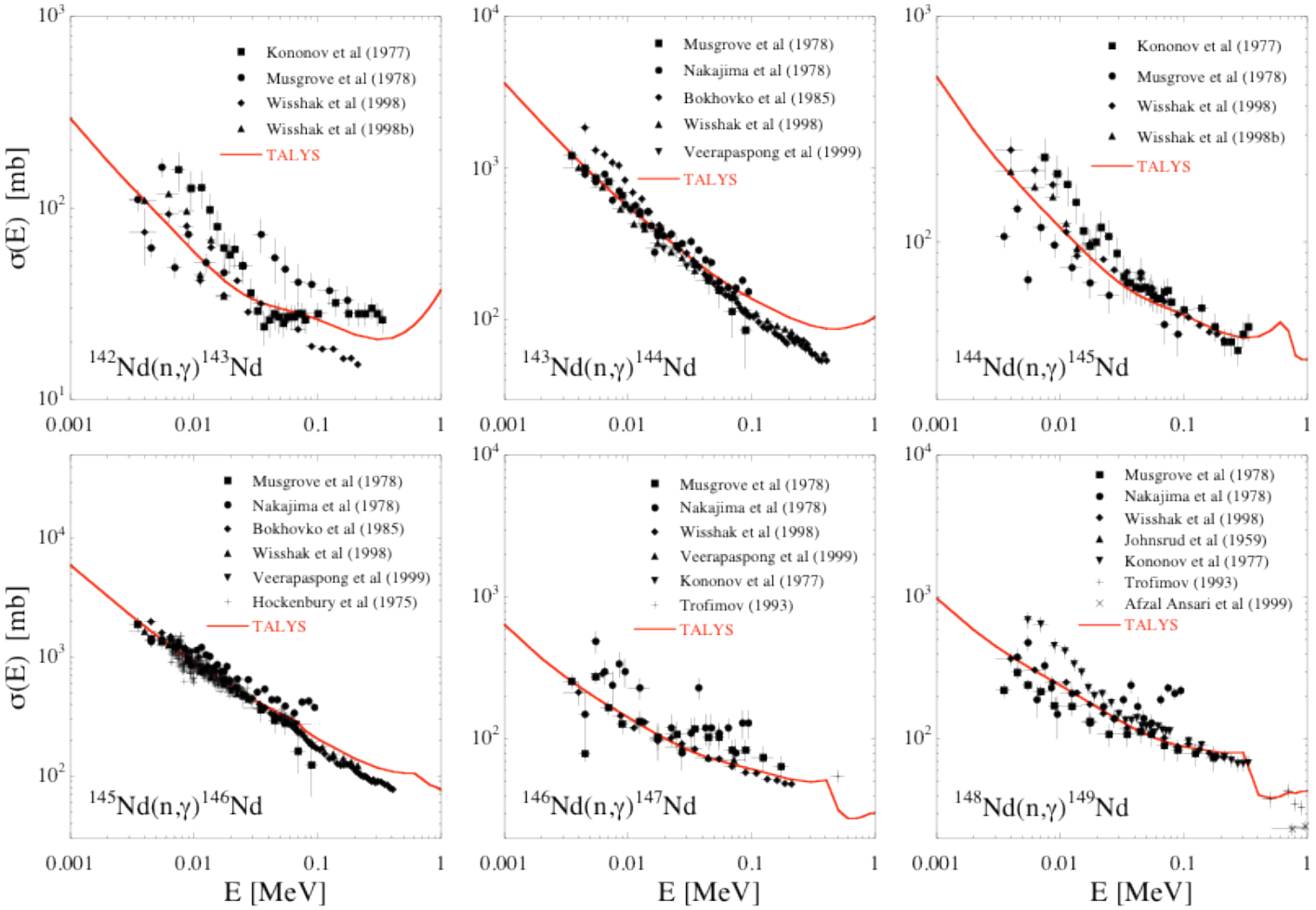
Verification of γ-ray strength functions with (n,γ) cross sections for Sm isotopes

To be submitted to Physical Review C



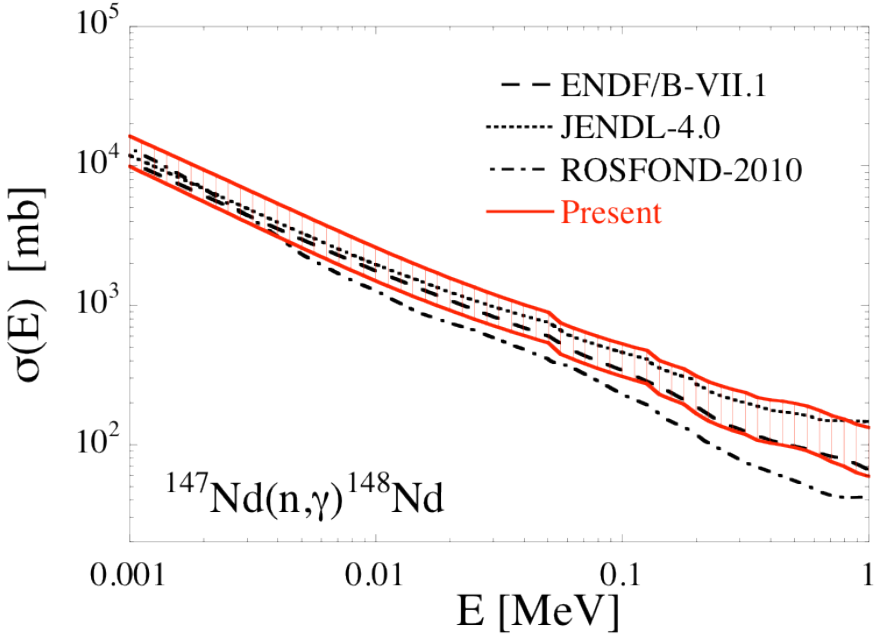
Verification of γ-ray strength functions with (n,γ) cross sections for Nd isotopes

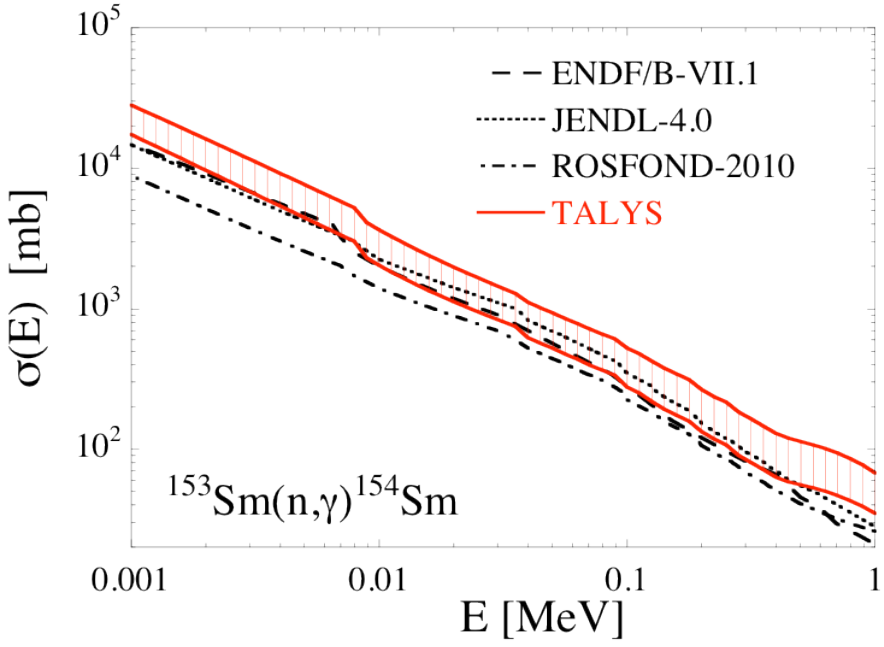
To be submitted to Physical Review C



Indirect determination of (n,γ) cross sections for ^{147}Nd (10.98 d) and ^{153}Sm (1.928 d)

To be submitted to Physical Review C





Activities at Kyushu University

Watanabe Group

Systematic Measurement of Double-Differential Neutron Yields From Thick Target Irradiated by Deuterons Below 10 MeV

九州大学
KYUSHU UNIVERSITY

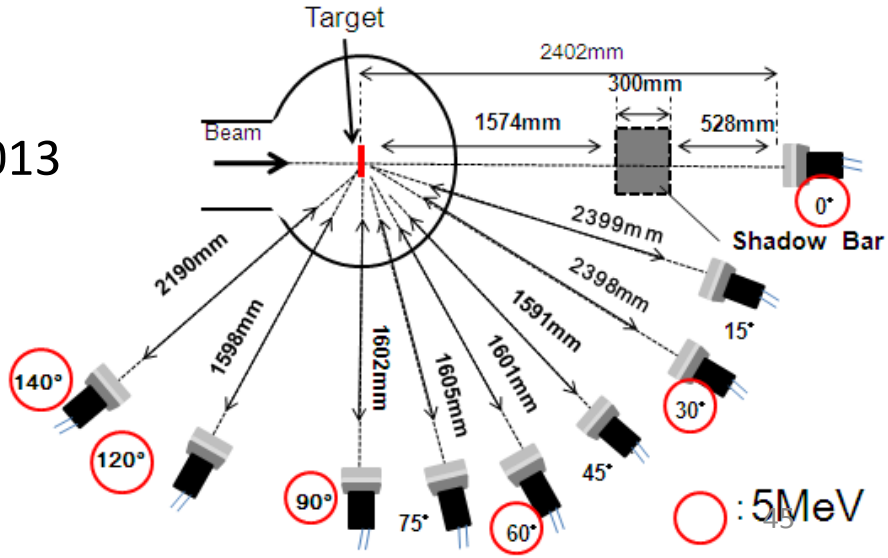
Energy Engineering Physics Laboratory
Department of Advanced Energy Engineering Science
Kyushu University

In collaboration with Ishibashi Group in the Faculty of Engineering, Kyushu University

Experiment @KUTL

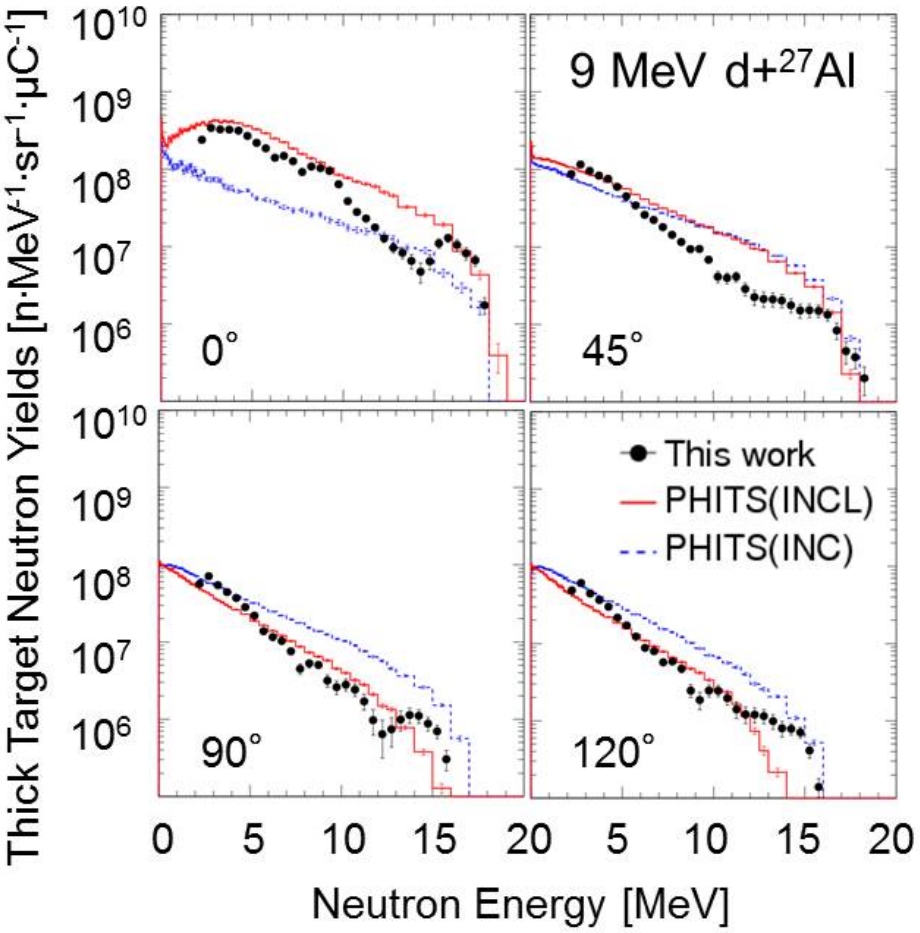
- Thick target yield（TTY）data for deuteron accelerator-based neutron sources

- Kyushu University Tandem Laboratory (KUTL)
  - Deuteron energies : 5 and 9 MeV
- Detector system
  - NE213 scintillator (50.4 mm thick and 50.4 mm in diameter)
  - Unfolding method with FORIST code
- Target
  - Al and Ta with stopping length in FY2013
- Measurment Angles
  - 0, 15, 30, 45, 60, 75, 90, 120, 140 degrees



Result

- Experimental double-differential thick target neutron yields from Al at 9 MeV
- Comparison of the measurement with PHITS calculation to validate the reaction models



The PHITS calculation using the intra-nuclear cascade of Liège (INCL) model reproduces satisfactorily well the experimental data, compared with that using the Bertini INC model.

Presented at INES-4, TIT, Japan, Nov.6-8, 2013

Activities at Kyushu University

Department of Applied Quantum Physics
and Nuclear Engineering

Ishibashi and Shigyo Group

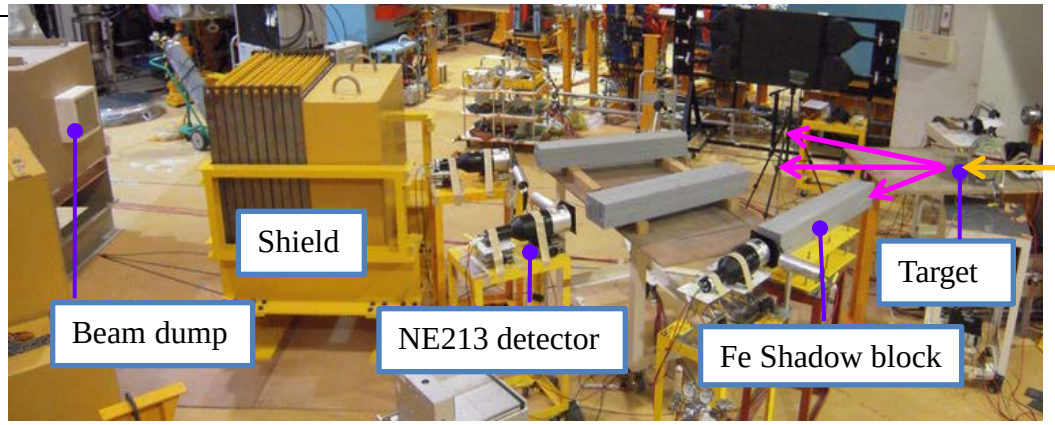
Neutron Production DDX from Heavy-Ion Interactions @ NIRS-HIMAC

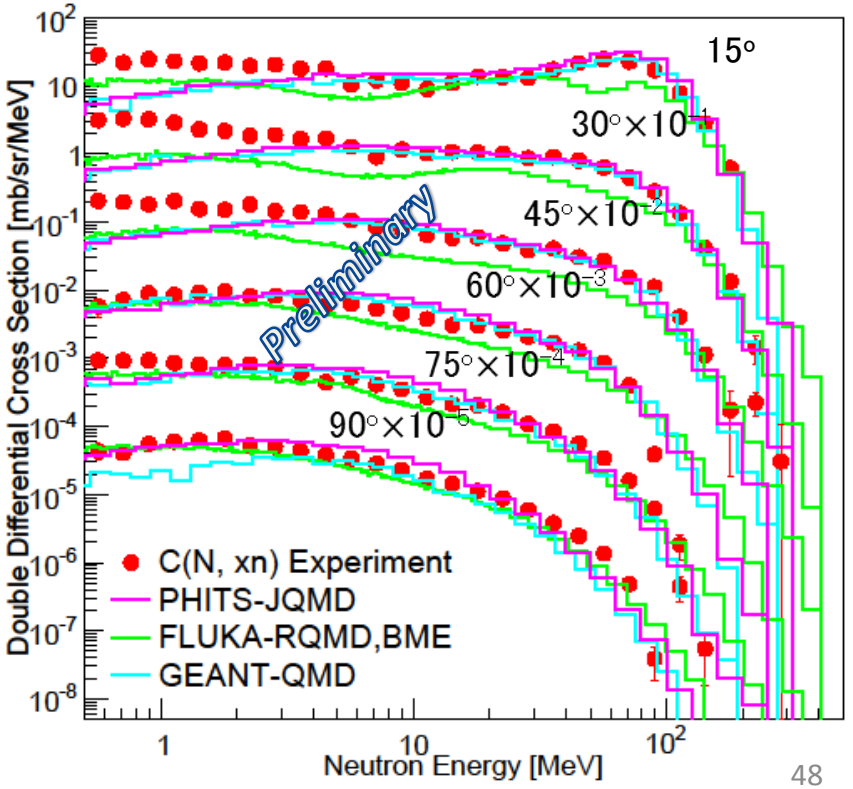
- Kyushu U., JAEA, Hiroshima U., KEK, NIRS, KAERI

- Systematic cross-section data for elements constituting a human body's tissue bombarded with heavy-ion beams

- HIMAC PH2 beam line
- Beam: 100 MeV/u O, N, 500 MeV/u Fe
- Target: C
- Detection: NE213 (2 sizes) + TOF
- Direction: 0˚, 15˚, 30˚, 45˚, 60˚, 75˚, 90˚

- Data obtained below 1 MeV of E_n
- PHITS reproduces experimental data especially above tens MeV region





100MeV/u N(C, xn) DDX

National Project related to Nuclear Data
- AIMAC project -

By JAEA & Tokyo Tech. & Kyoto Univ. team

AIMAC: Research and development for Accuracy Improvement of neutron nuclear data on Minor Actinides

Frame: Innovative Nuclear Research and Development Program by MEXT
From October 2013 to March 2017, ～ 0.3 Gyen, ～ 20 scientists

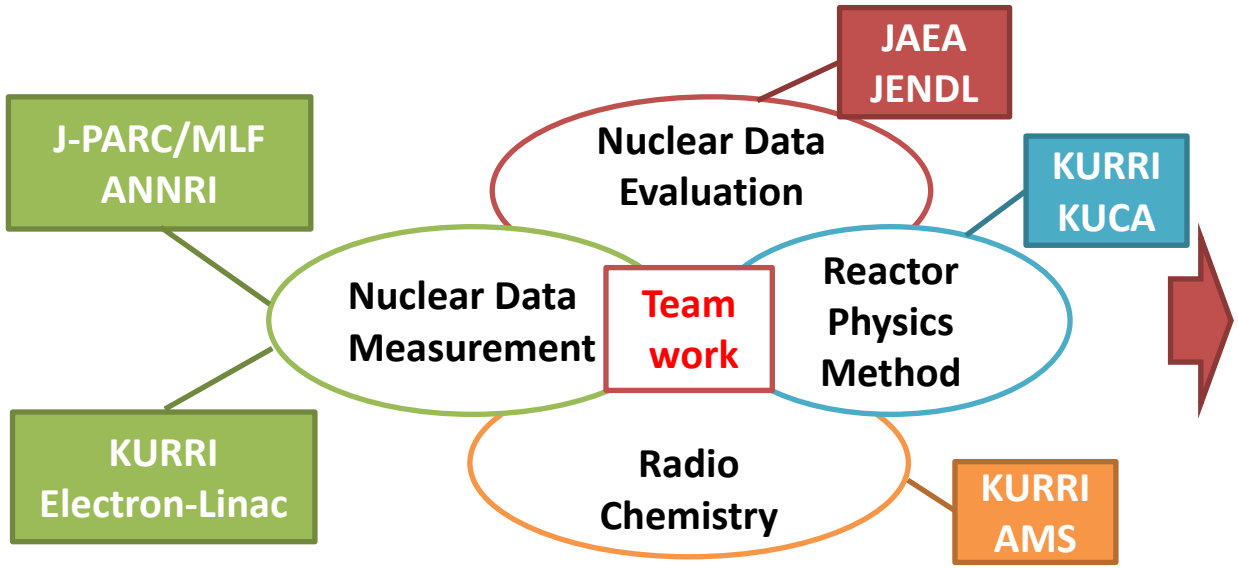
Coordinator: **Hideo Harada**
Nuclear Data and Reactor Engineering Unit
Nuclear Science and Engineering Center
Japan Atomic Energy Agency

On the AIMAC project

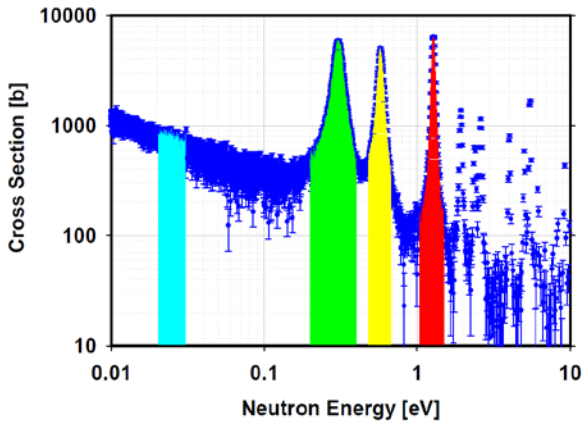
This R&D aims at improving accuracy of neutron nuclear data for minor actinides (MAs) and long-lived fission products (LLFPs), which is required for developing innovative nuclear system transmuting these nuclei.

The following research items will be conducted :

① Accurate measurements of thermal neutron capture cross-sections
② High-precision quantification of sample amount used for TOF measurement
③ Resonance parameter determination by combining total and capture cross sections
④ Extension of capture cross sections to high energy neutrons
⑤ High quality evaluation based on iterative communication with experimenters



Collaboration by researchers from 4 different research fields



Accurate Neutron Nuclear Data