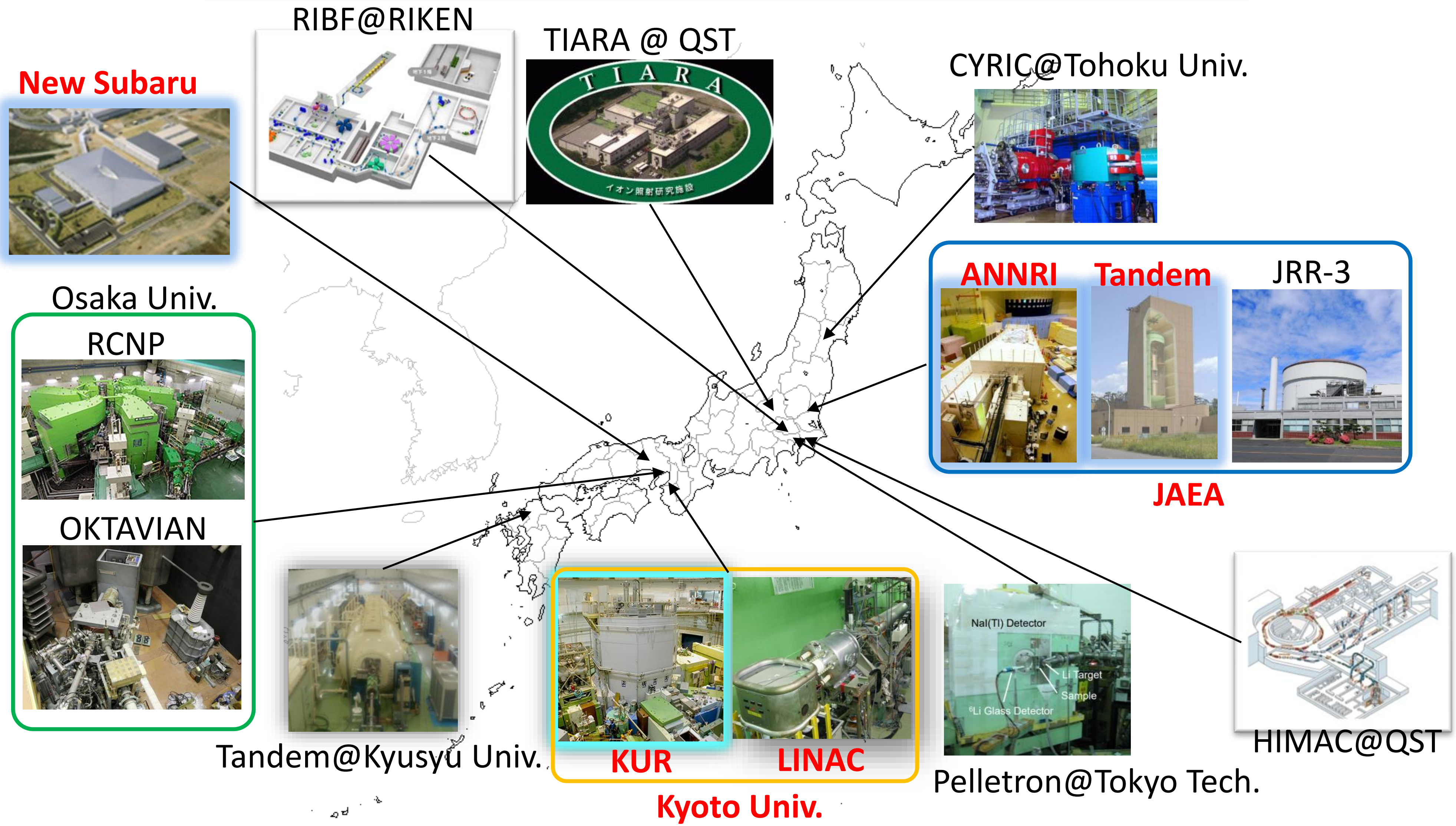
Japanese Activities in Nuclear Data Measurement

Atsushi Kimura

Japan Atomic Energy Agency

Nuclear Data Measurement in Japan

Nuclear Data Measurements have been performed at several accelerator and reactor facilities in Japan



Activities by J-PARC･MLF･ANNRI collaboration in 2020

Japan Atomic Energy Agency

Tokyo Institute of Technology

Kyoto Univ.

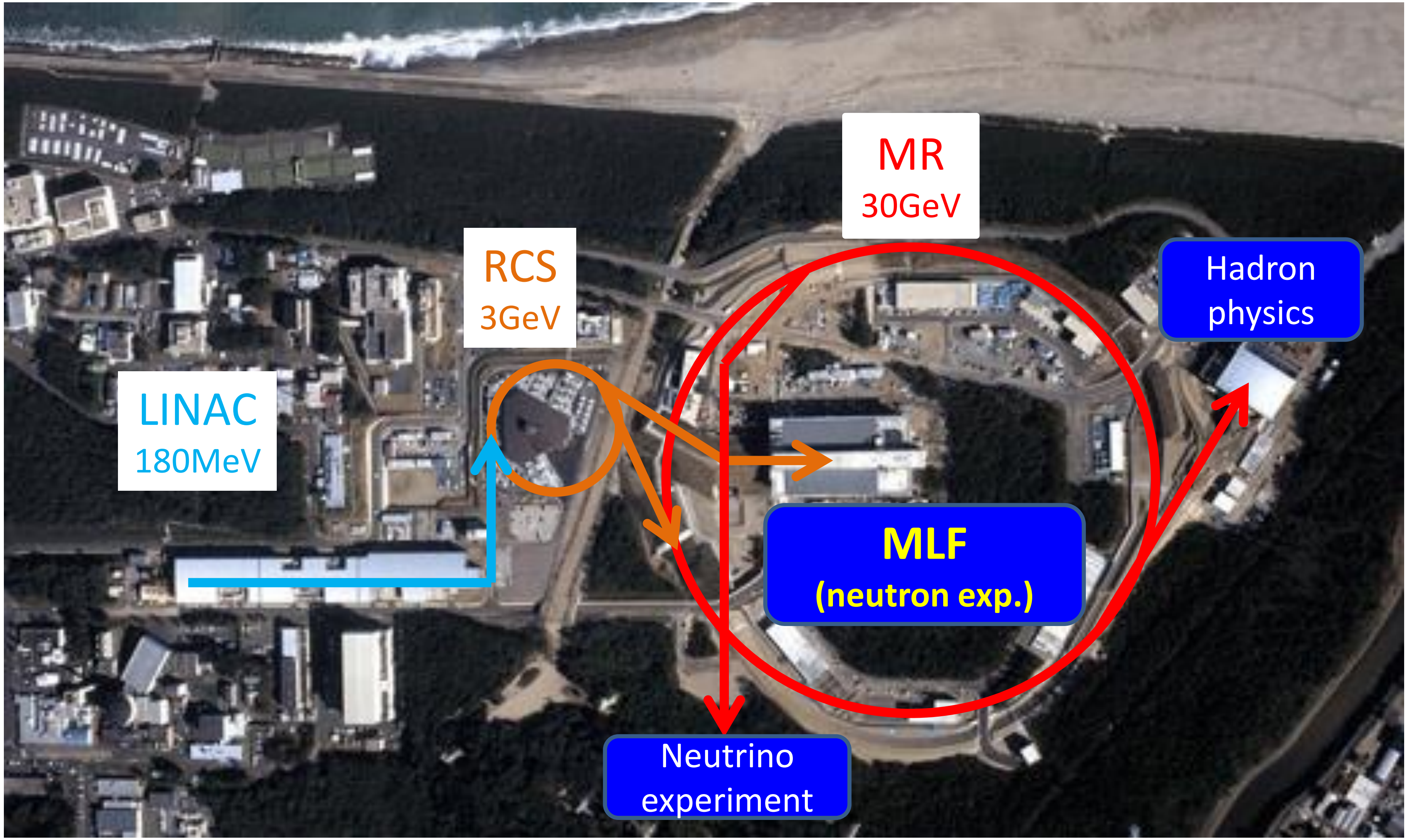
Tokyo Tech

KURNS

Contact :
Nuclear Data Center
Nuclear and LWR Engineering Division
Nuclear Science and Engineering Center
Japan Atomic Energy Agency

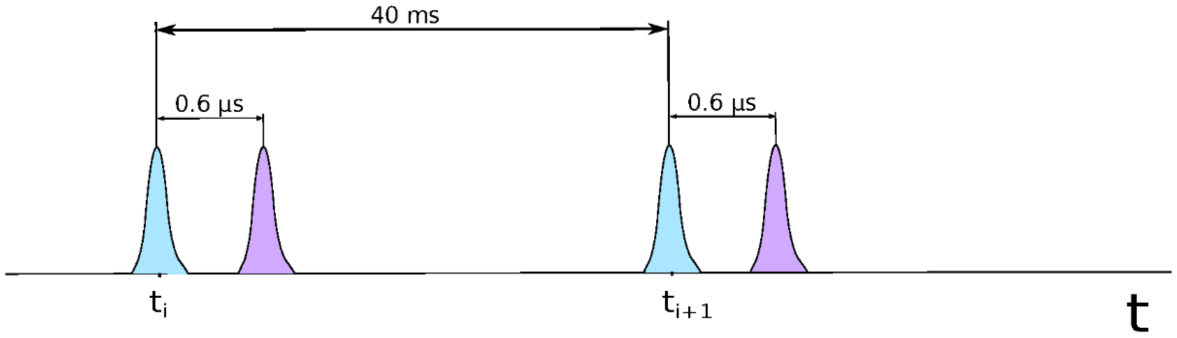
Facility

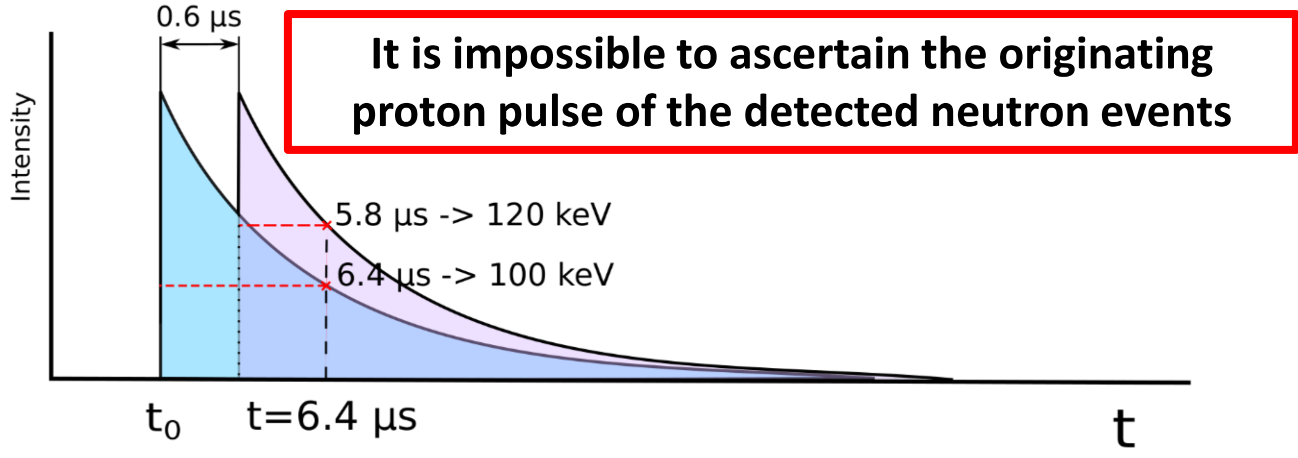
J-PARC : Japan Accelerator Research Complex



Neutron Filtering System was installed

In J-PARC, **pulsed neutrons** are generated by **pulsed protons shots** in double-bunch mode. The energy of the neutrons is determined from **timing measurements**. This technique is **not reliable** for **fast neutrons**.

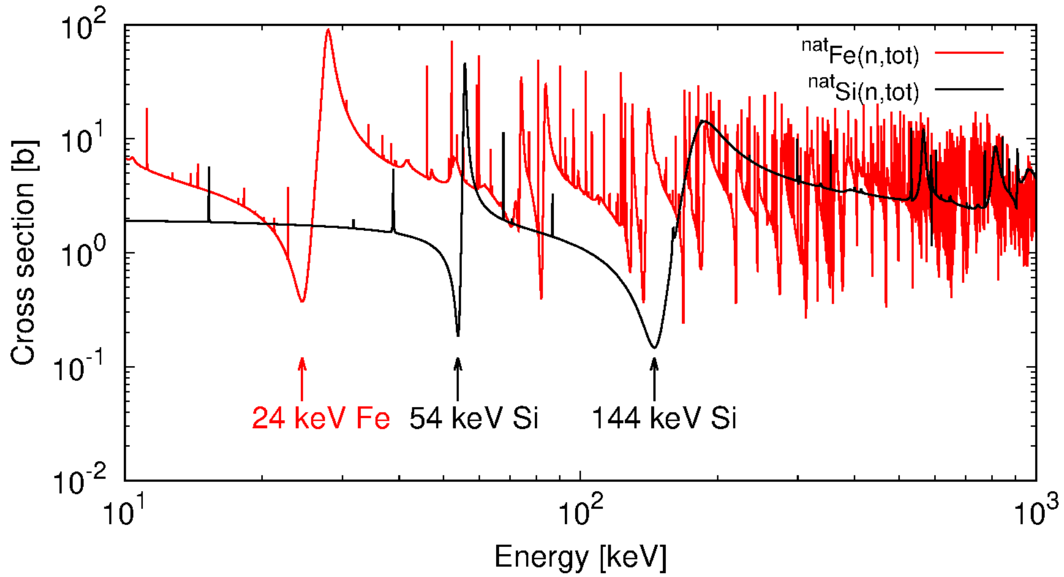


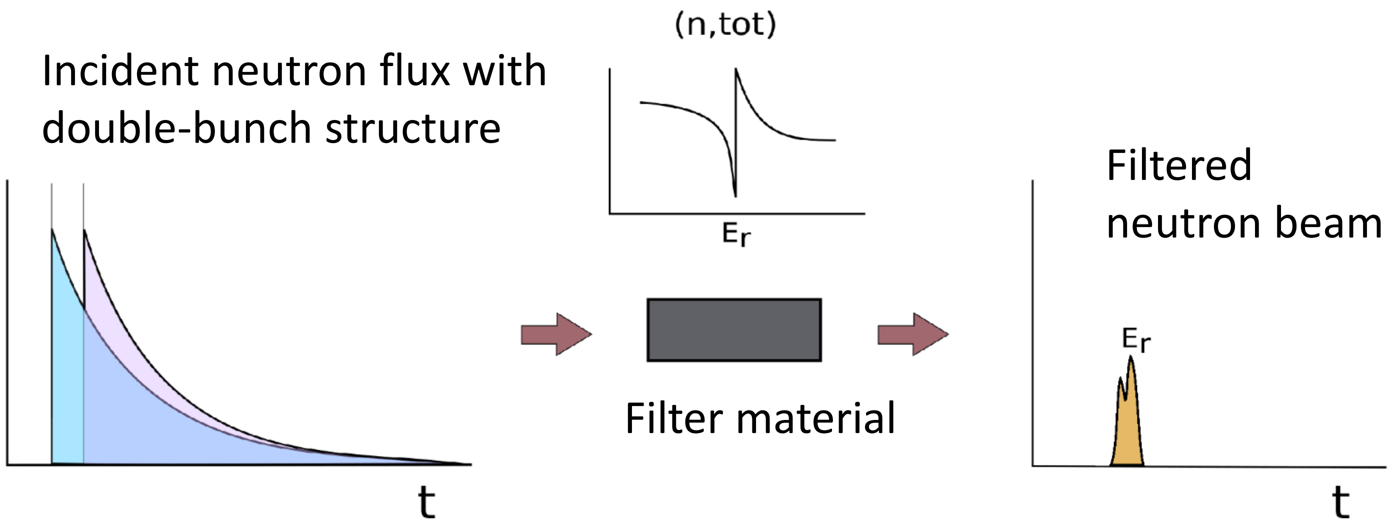


In 2020, we have installed new neutron filtering system in ANNRI.

Neutron Filtering Technique

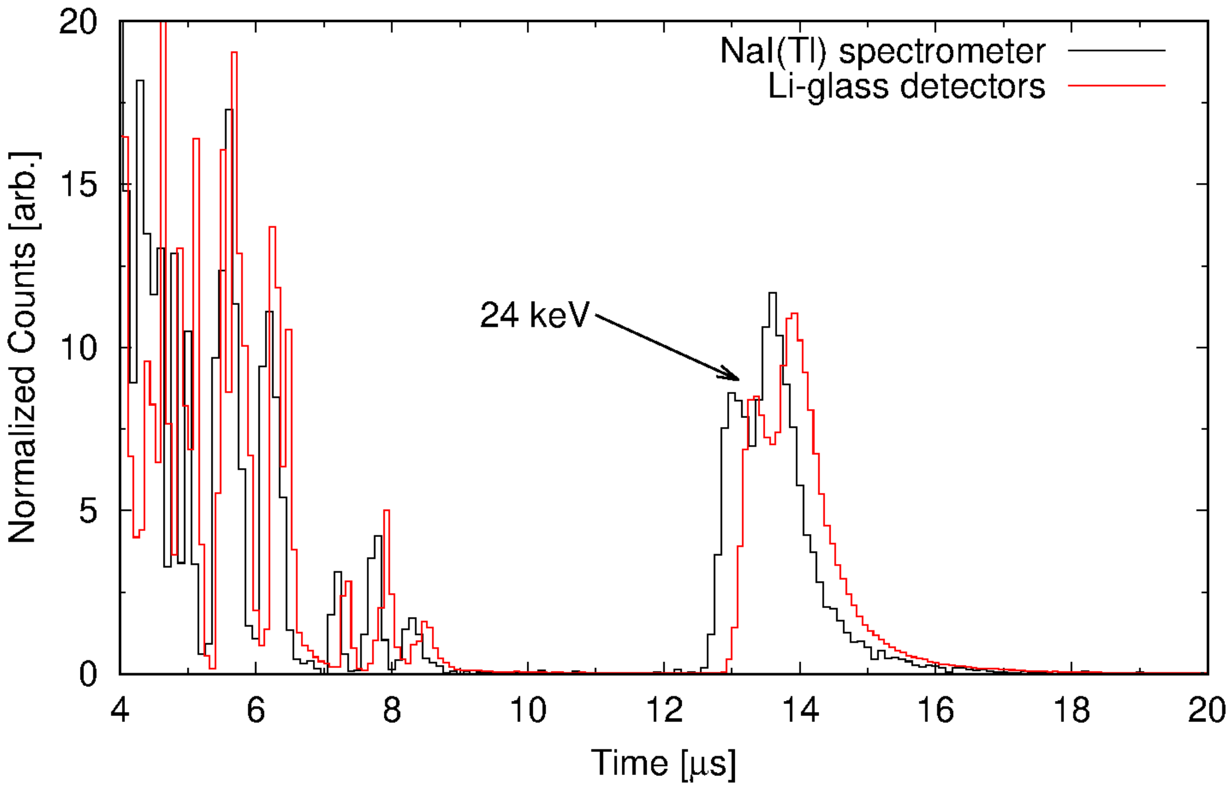
The **Neutron Filtering Technique** is applied to mitigate the effects of the double-bunch mode for fast neutrons. Common technique applied to **nuclear reactors**. Semi-monoenergetic beams can be tailored using materials that present a **sharp minimum** in the neutron total cross-section.



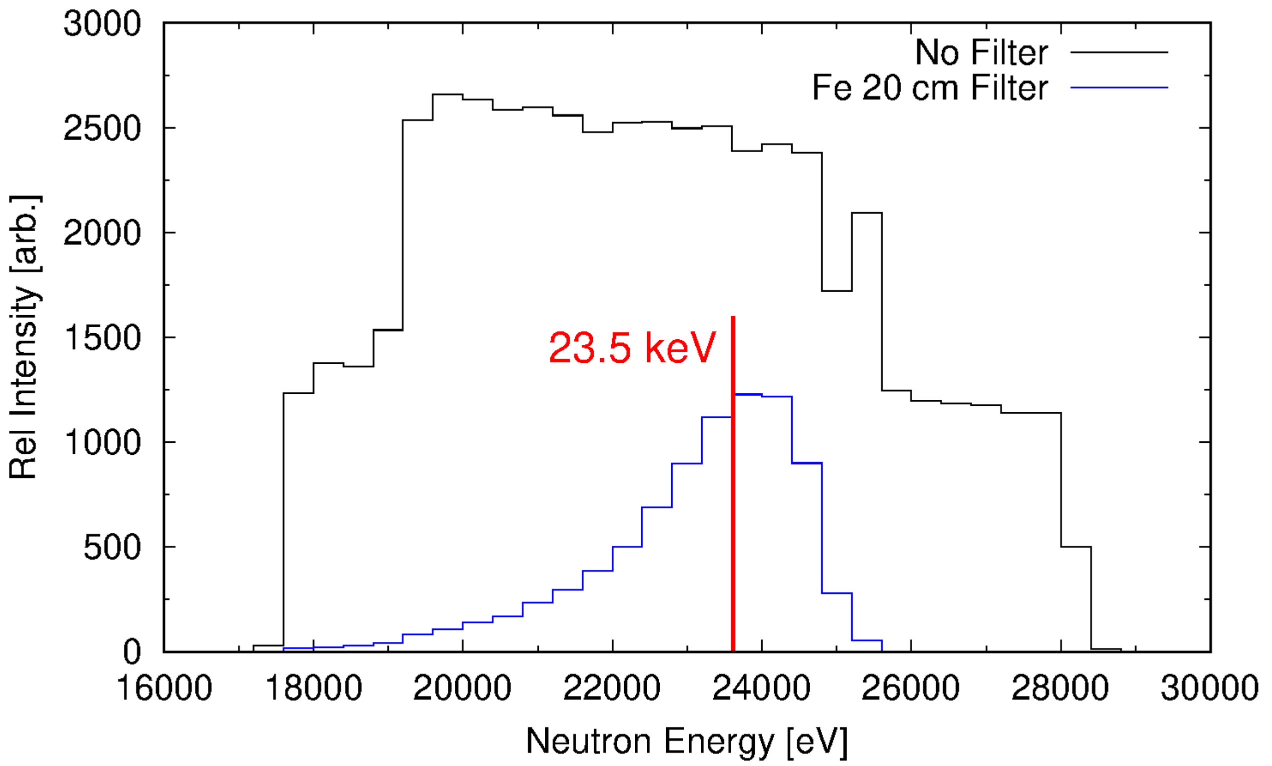


Fe(20–50cm), Si(20–50cm), Cr(10–40cm) filters are installed.

Filtered TOF spectrum (Fe 20cm)



Filtered neutron beam through **20 cm of Fe** measured by **Li-glass detectors** and a **NaI(Tl) spectrometer** (with B sample).



Energy distribution of the **filtered neutron beam (blue)** and its **energy centroid (red)** compared to the **energy distribution without filter (black)**

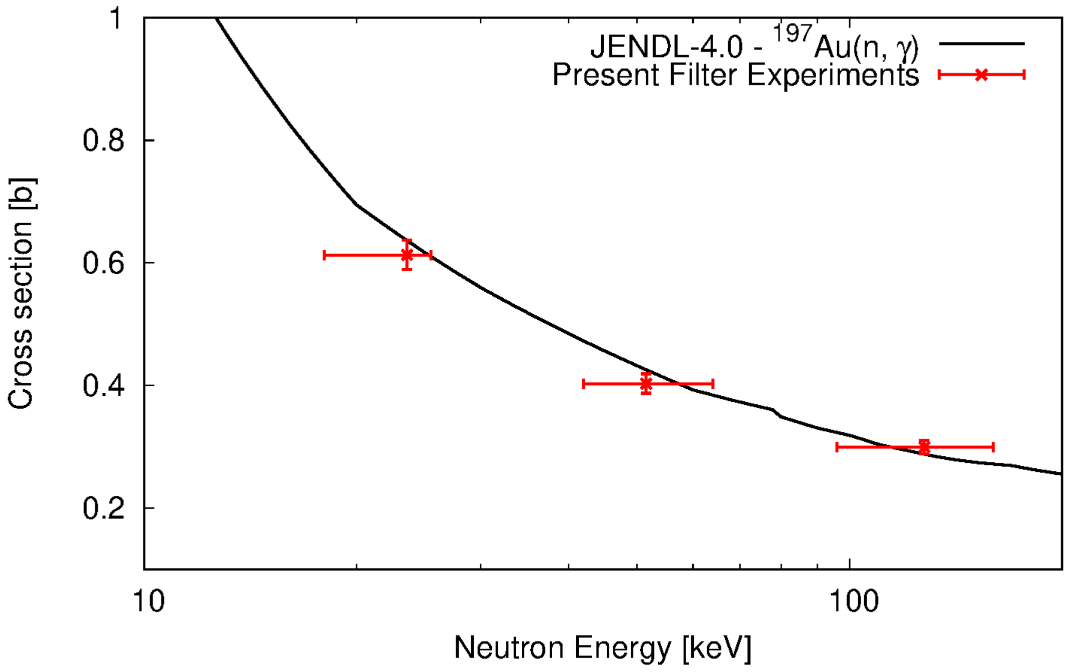
By using the neutron filtering system, shaper distribution was obtained.

Test Experiments

The ^{197}**Au(n,γ) cross-section** was determined using the three filtered peaks. Results contain **total uncertainties below 5%**.

Present results with **Fe** and **Si** as filter materials **agree within uncertainties** with the JENDL-4.0 values.

The **Neutron Filtering System** is a **viable solution** in order to bypass the double-bunch structure and measure cross-section for **fast neutrons.**



Cross-section results for the ^{197}**Au(n,γ)** reaction using the neutron filters compared to the evaluated data from JENDL-4.0

Nuclear Inst. and Methods in Physics Research, A 1003 (2021) 165318

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journal homepage: www.elsevier.com/locate/nima

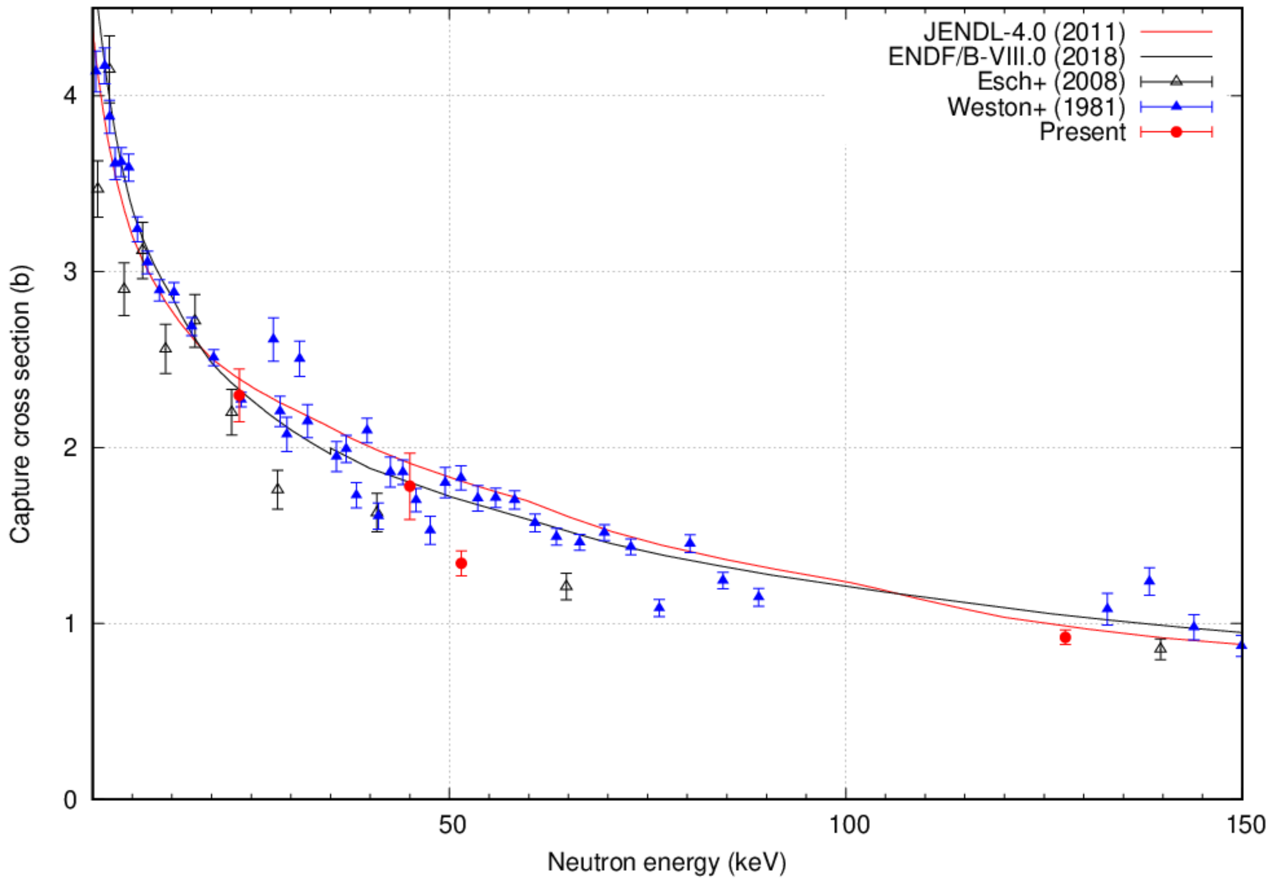
Neutron beam filter system for fast neutron cross-section measurement at the ANNRI beamline of MLF/J-PARC

Gerard Rovira [a,*], Atsushi Kimura [a], Shoji Nakamura [a], Shunsuke Endo [a], Osamu Iwamoto [a], Nobuyuki Iwamoto [a], Tatsuya Katabuchi [b], Kazushi Terada [b,1], Yu Kodama [b], Hideto Nakano [b], Jun-ichi Hori [c], Yuji Shibahara [c]

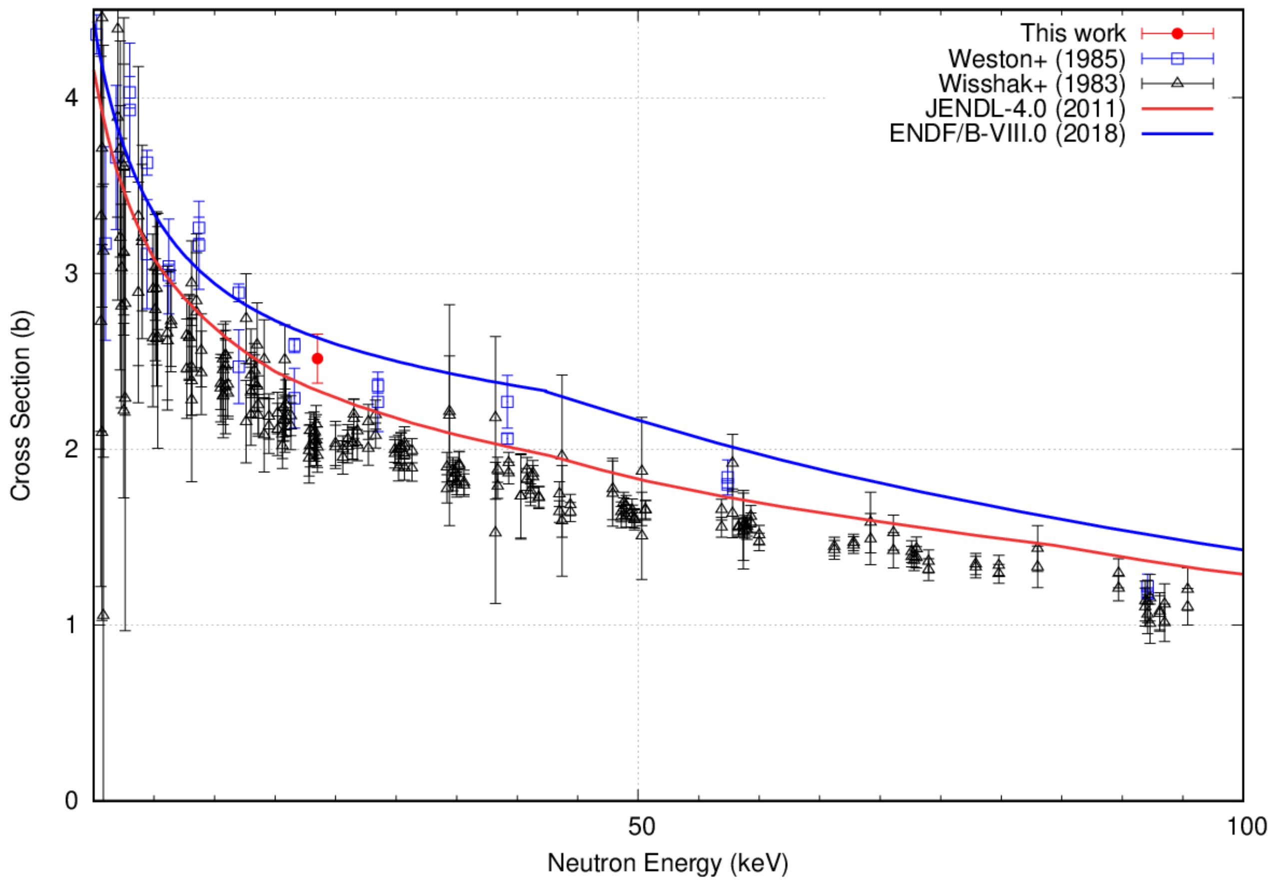
[a] Nuclear Science and Engineering Directorate, Japan Atomic Energy Agency, 2-4 Shirakata, Tokai-mura, Naka-gun, Ibaraki 319-1195, Japan
[b] Laboratory for Advanced Nuclear Energy, Institute of Innovative Research, Tokyo Institute of Technology, Ookayama 2-12-1-N1-19, Meguro-ku, Tokyo 152-8550, Japan
[c] Institute for Integrated Radiation and Nuclear Science, Kyoto University, 2 Asashiro-Nishi, Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan

Gerard Rovira, et. al.,
NIM-A, 1003(2021) 165318

Np-237



Am-243



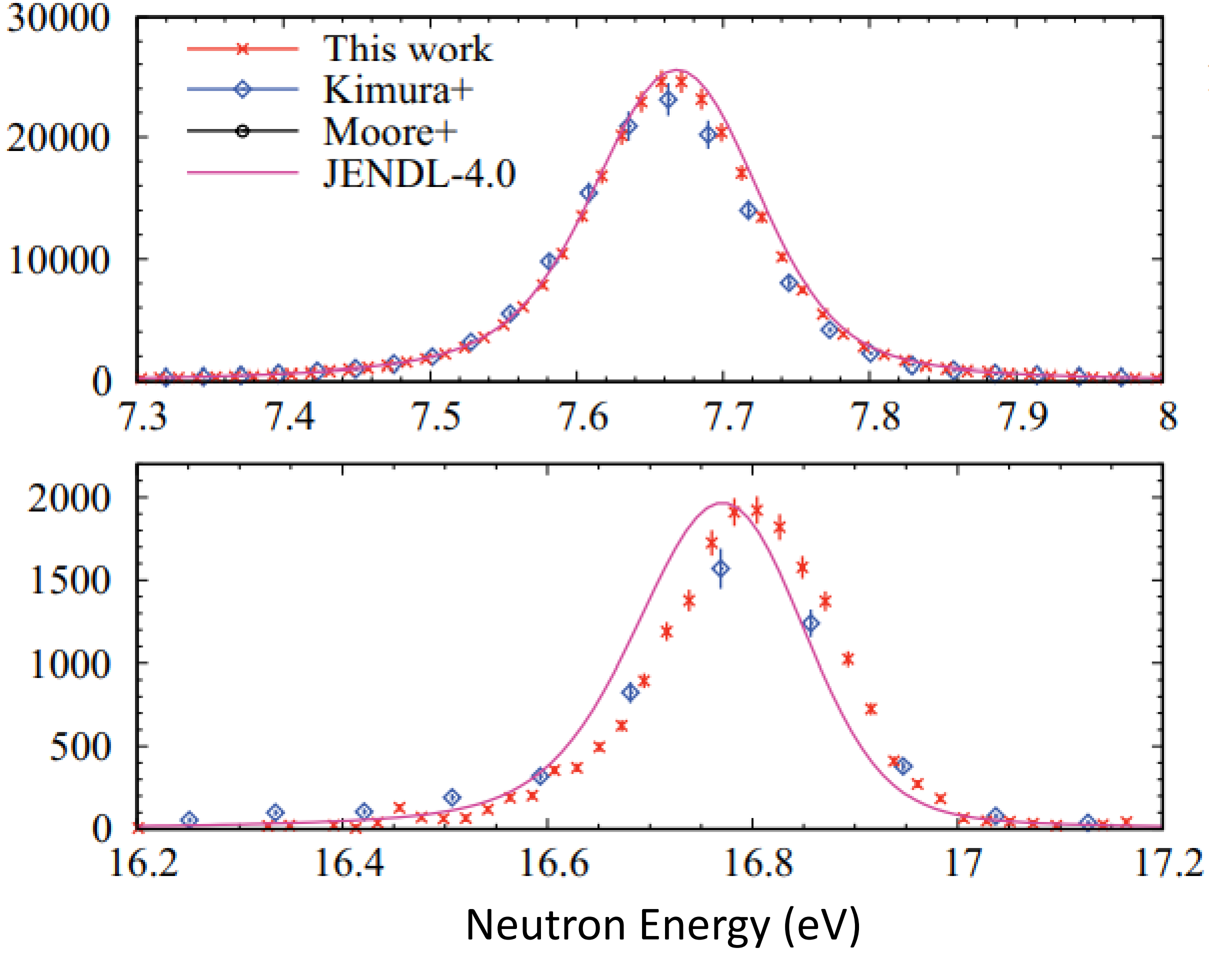
Detailed analysis is ongoing.

Neutron capture cross sections of ^{244}Cm and ^{246}Cm

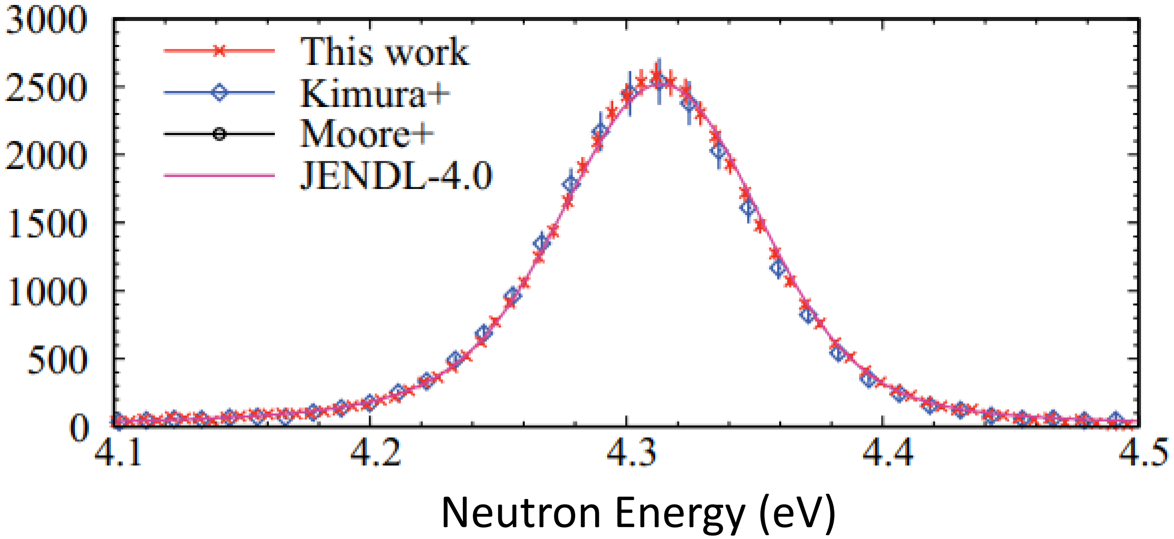
Dr. Kawase, et. al. JNST Published Online
https://doi.org/10.1080/00223131.2020.1864492

Neutron capture cross sections of ^{244}Cm and ^{246}Cm were (re-)measured in the energy range of 1 to 1000 eV with “Single-bunch mode”.

^{244}Cm



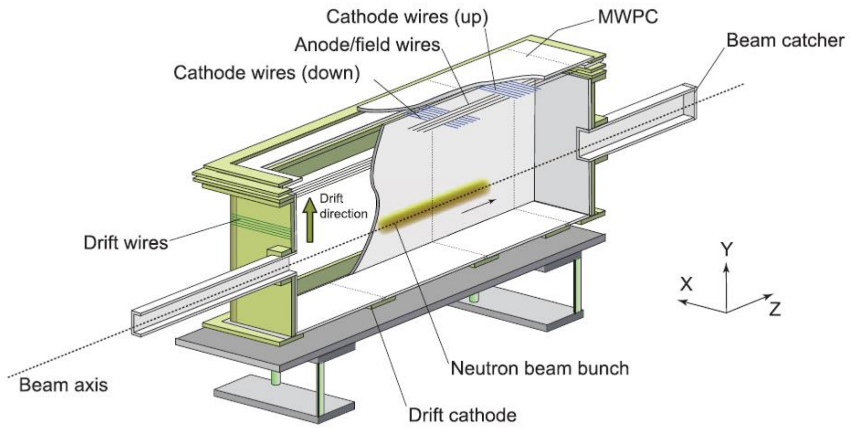
^{246}Cm



Results

- Compared to the previous data taken at the ANNRI, the uncertainties of the neutron capture cross sections were improved from 5.8% to 3.8% for the first resonance of ^{244}Cm and from 6.2% to 4.6% for the first resonance of ^{246}Cm.
- The resonance parameters for the resonances below 1 keV were extracted from the fitting of the neutron capture cross sections by using the REFIT code.
- Fifteen previously unknown resonances of ^{246}Cm were found in the energy region higher than 200 eV.

Activities at the other beam lines.

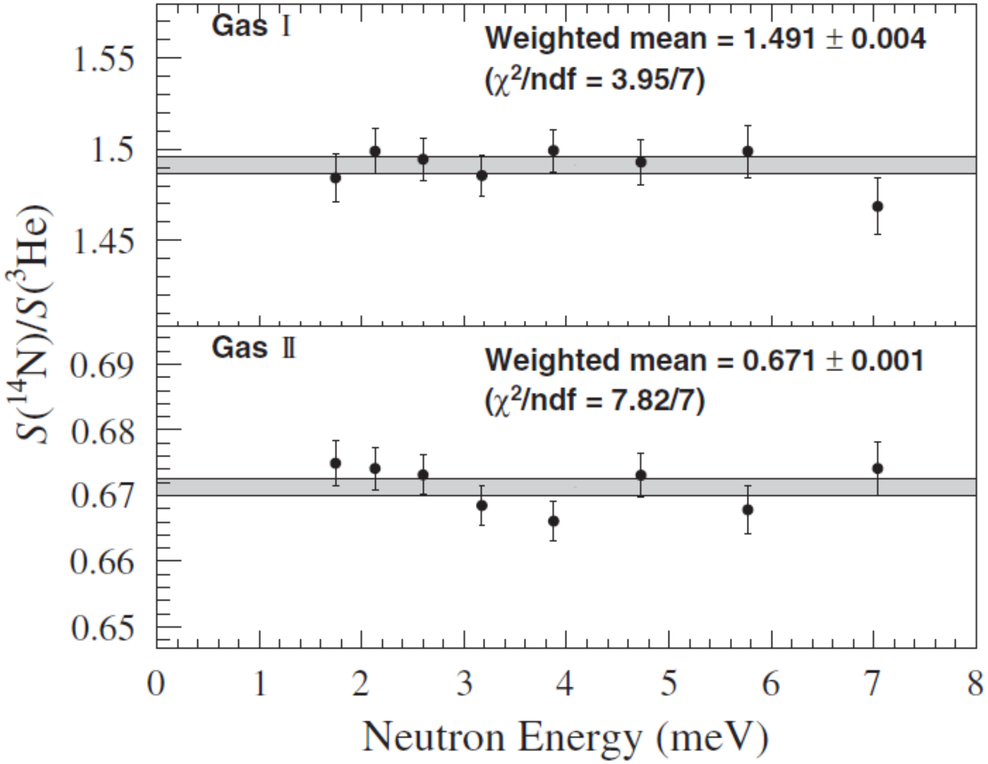


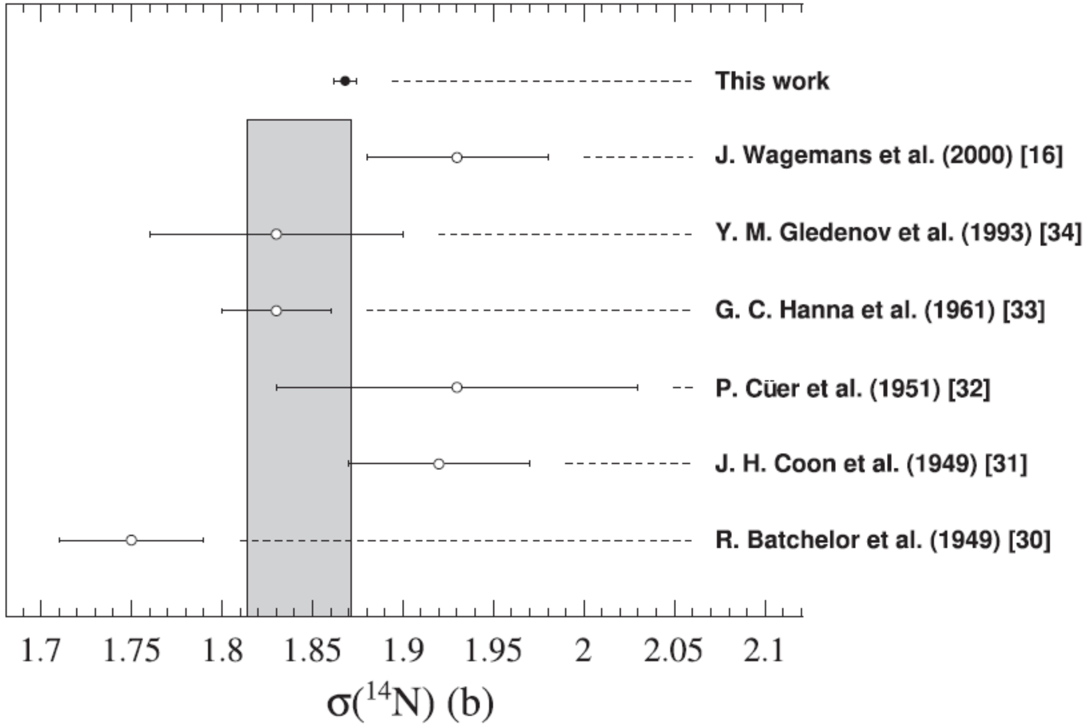
NOP(BL05)

By Dr. Kitahara, Kyoto Univ.

Prog. Theor. Exp. Phys. **2019**, 093C01
DOI: 10.1093/ptep/ptz096

Thermal cross section of $^{14}N(n, p)^{14}C$ with a gas drift chamber using N and ^3He mixed gas.





The result was 1.868 ±0.003 (stat.) ± 0.006 (sys.) b.

Activities in the other beam lines.

Neutron scattering data measurement and scattering kernel preparation of moderators and reflectors for next generation neutron sources

May 7, 2021

M. Harada (J-PARC, JAEA) harada.masahide@jaea.go.jp

Collaborated by

Y. Abe (Kyoto-Univ.)

M. Teshigawara, M. Ooi, Y. Ikeda, A. Kimura, K. Oikawa, S. Kawamura, Y. Inamura and R. Takahashi (JAEA)

Outline

- **For the design of next-generation neutron sources** such as J-PARC-MLF TS2, small neutron sources, rotating neutron sources, and so on, **scattering data (scattering kernels) of candidate materials covering from cold neutrons to thermal neutron regions are essential.**
- Although, in recent years, some scattering data has been developed by researchers in Japan, Argentina, and the United States, the Major scattering data for moderators have been measured from the 1960s to the 1980s. Accuracy, temperature range and energy range of the scattering data are not sufficient Therefore, the precise data is necessary for the design of next-generation neutron sources. And not only moderator material but also the reflector material and the structural material are indispensable data to improve the design accuracy.
- In the cold and thermal neutron region, the scattering of neutrons depends on the bonding state, motion state, and crystallinity of the atomic molecules, and are caused by down-scattering and up-scattering. Therefore, it is difficult to predict only by theory.
- In this study, we measure **total cross section, scattering cross section and capture cross section of moderator, reflector and structure materials at various temperature with BL04 (ANNRI), BL10(NOBORU) and BL14(AMATERAS) of J-PARC neutron instruments**, and prepare scattering kernels by complementing theoretical calculations.
- This study is supported by Kakenhi-C (FY2019-2021).

Measured and measurement-scheduled sample list

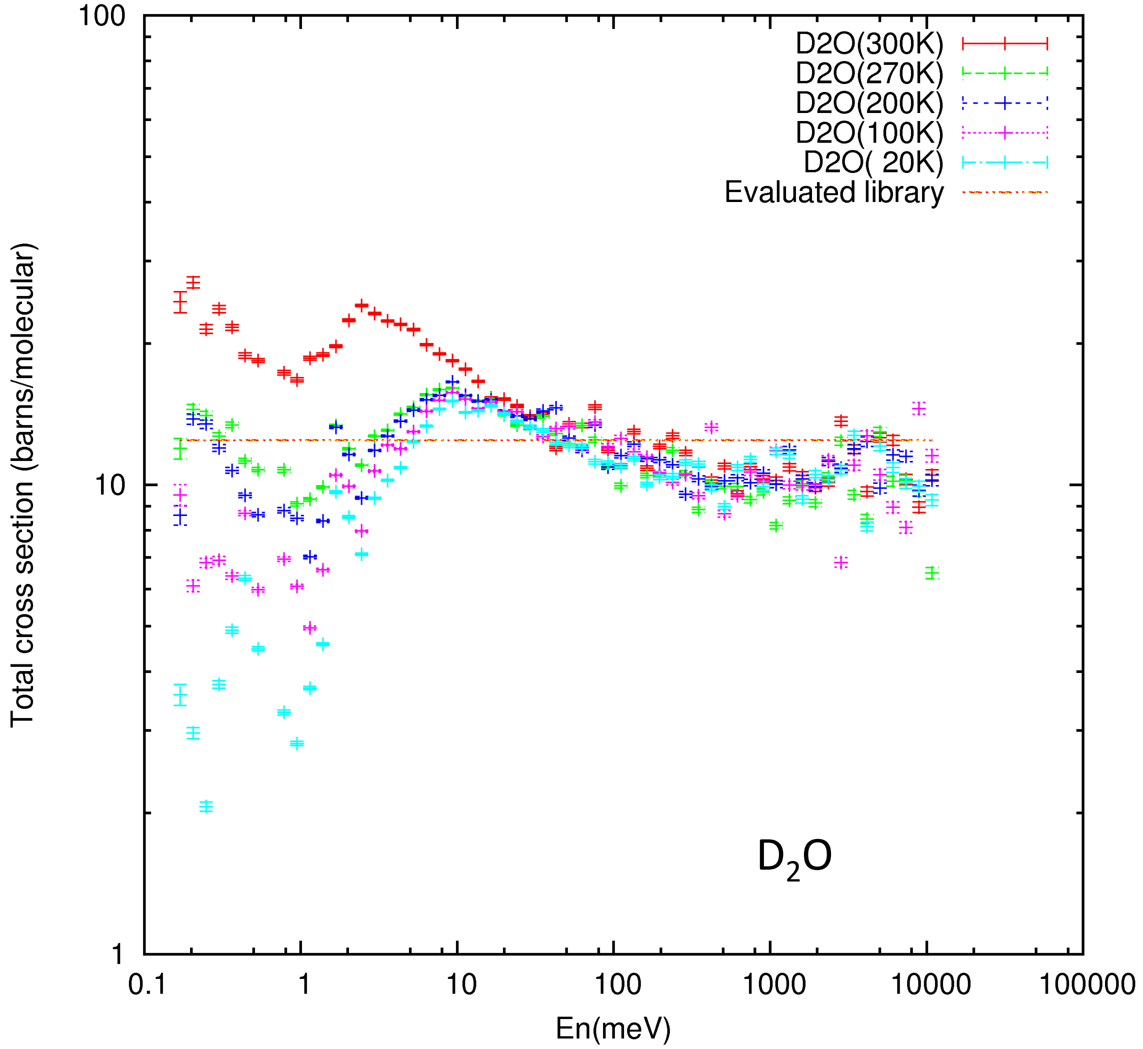
Purpose	Samples	Properties at R.T.	Capture X.S. BL04	Total X.S. BL10	Scattering X.S. BL14
Moderator materials	H2O	Liquid	FY2021	FY2018	FY2018
	D2O	Liquid	FY2021	FY2019	FY2019
	Methanol	Liquid	FY2021	FY2020	FY2020
	Ethanol	Liquid	FY2021	FY2018	FY2018
	Benzene	Liquid	FY2021	FY2019	FY2020
	Toluene	Liquid	FY2021	FY2020	FY2020
	Mesitylene	Liquid	FY2022	FY2020	FY2021
	O-Xylene	Liquid	FY2022	FY2020	FY2021
	P-Xylene	Liquid	FY2022	FY2020	FY2020
	M-Xylene	Liquid	FY2022	FY2020	FY2021
	2-butyne	Liquid	FY2022	FY2021	FY2022
	Methane	Gas	(FY 2021 @BL10)	FY2021	FY2021
	Hydrogen	Gas	(FY 2021 @BL10)	FY2021	FY2021
Reflector materials	Beryllium	Solid	FY2023	FY2022	FY2022
	Carbon	Solid	FY2023	FY2022	FY2022
	Beryllium Oxide	Solid	FY2023	FY2023	FY2023
Structure materials	A5058	Solid	FY2023	FY2022	FY2022
	A6061	Solid	FY2023	FY2022	FY2022
Moderator materials	Ethane	Gas	(FY 2023 @BL10)	FY2023	FY2023
	Methylacetylene	Gas	(FY 2023 @BL10)	FY2023	FY2023
	Polyethylene	Solid	FY2023	FY2023	FY2023

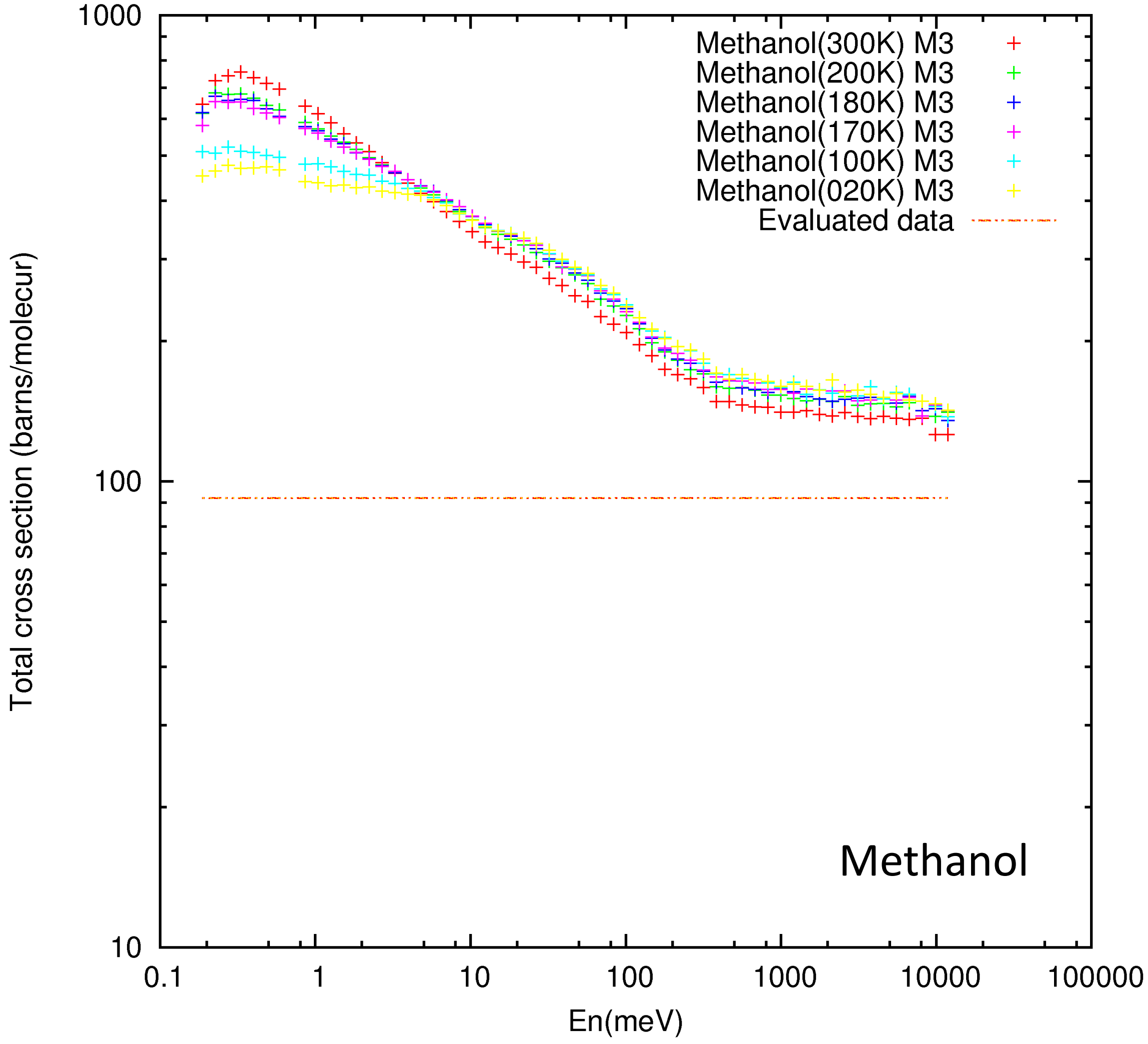
Already measured

Incident Energy : 0.1meV～10keV

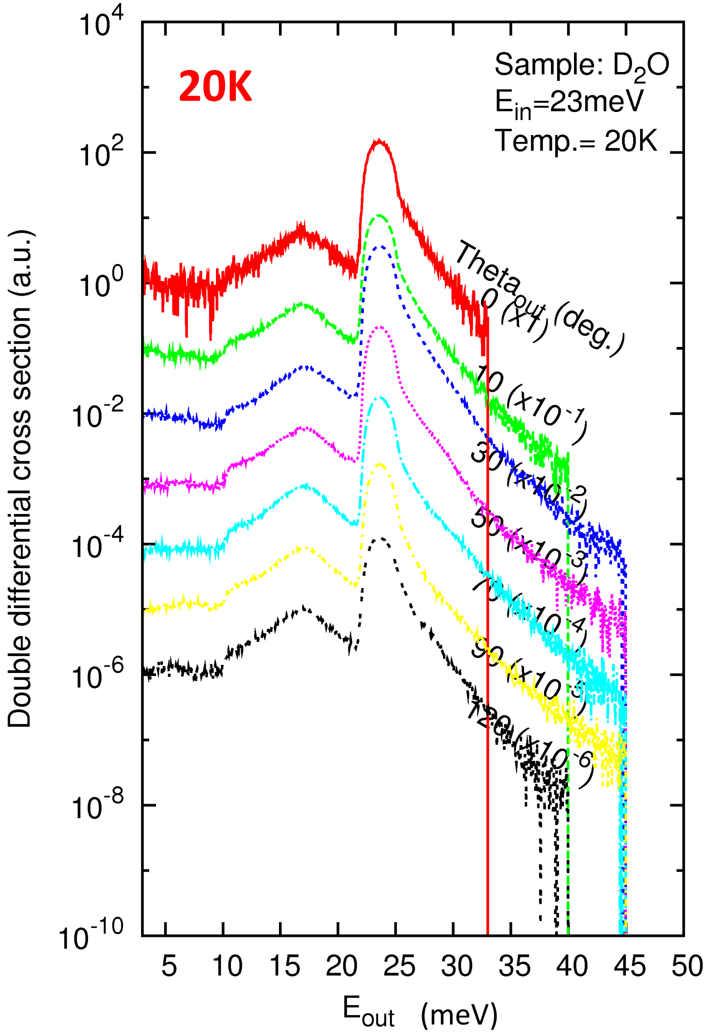
Temp.（BL10,BL14）: 20,100,200,300K+ 2points around melting points

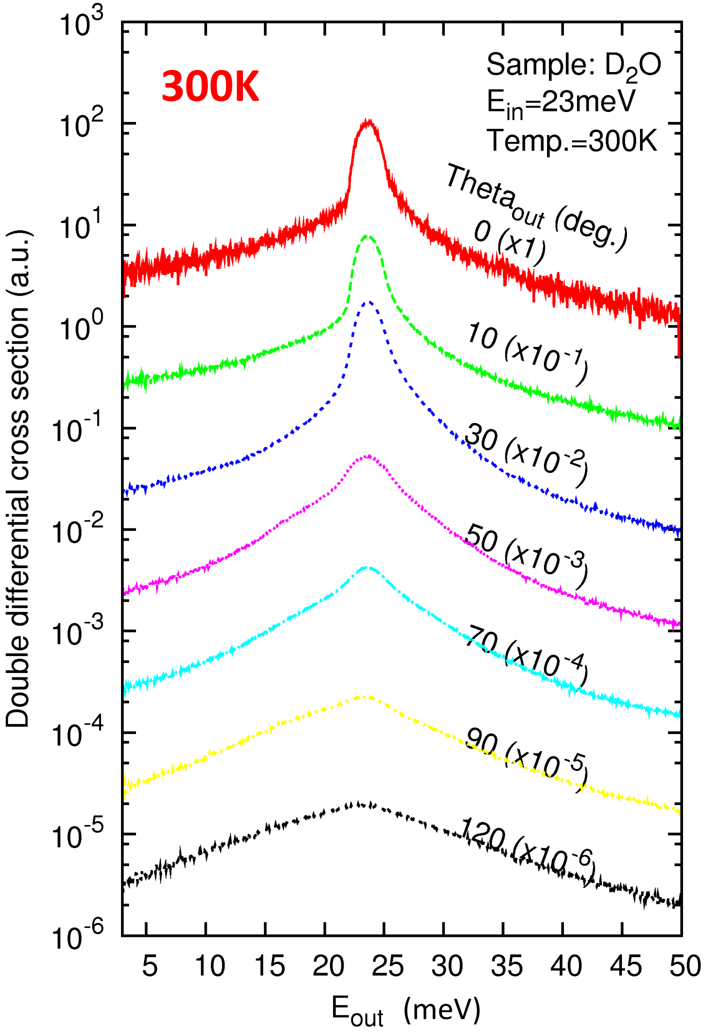
Total cross section





Double differential cross section





Detailed analysis is ongoing.

Activities at JAEA Tandem Accelerator Facility

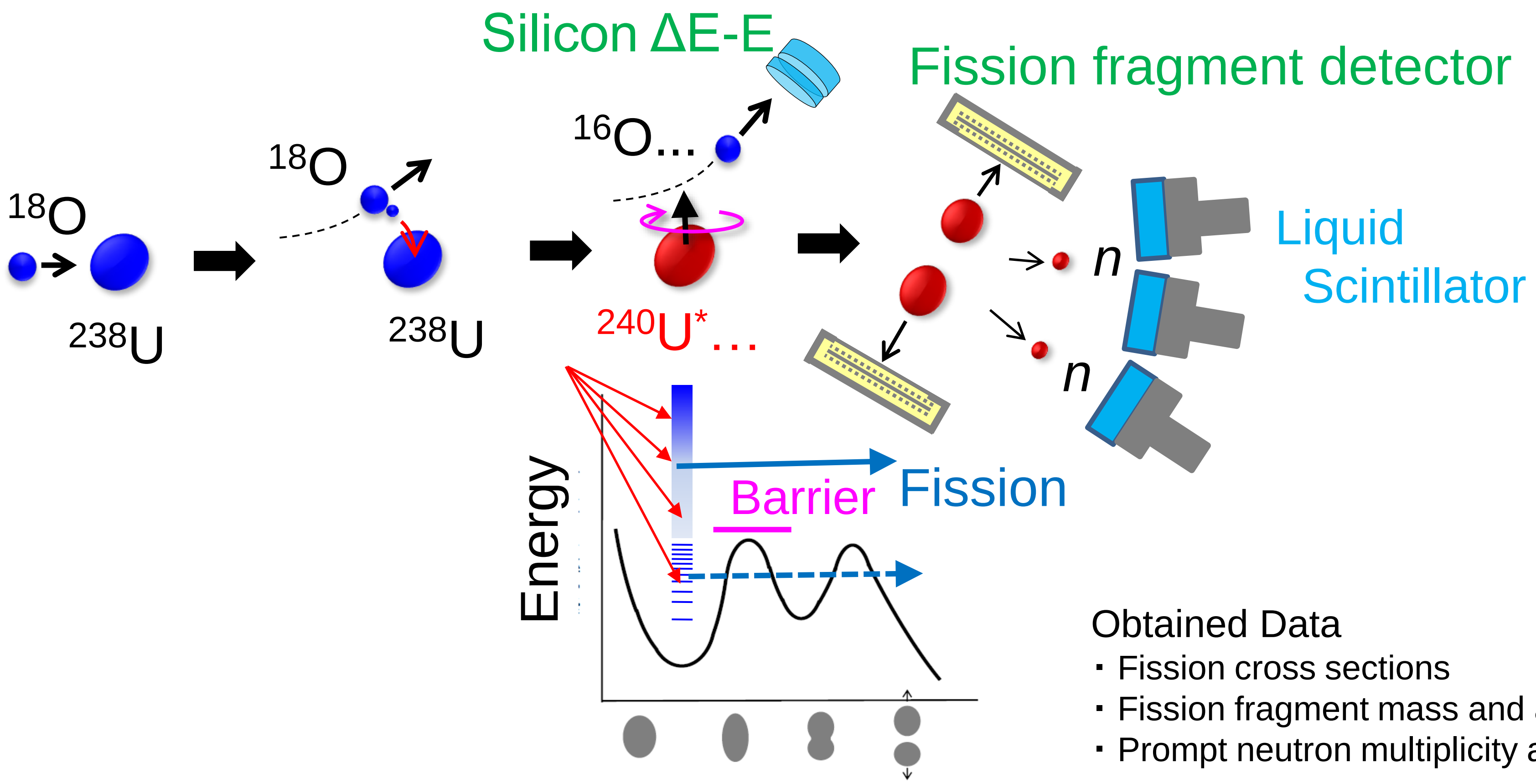
Contact :
Katsuhisa Nishio
Advanced Science Research Center
Japan Atomic Energy Agency
nishio.Katsuhisa@jaea.go.jp

20 MV

Multi-nucleon Transfer Induced Fission Study at JAEA

Method

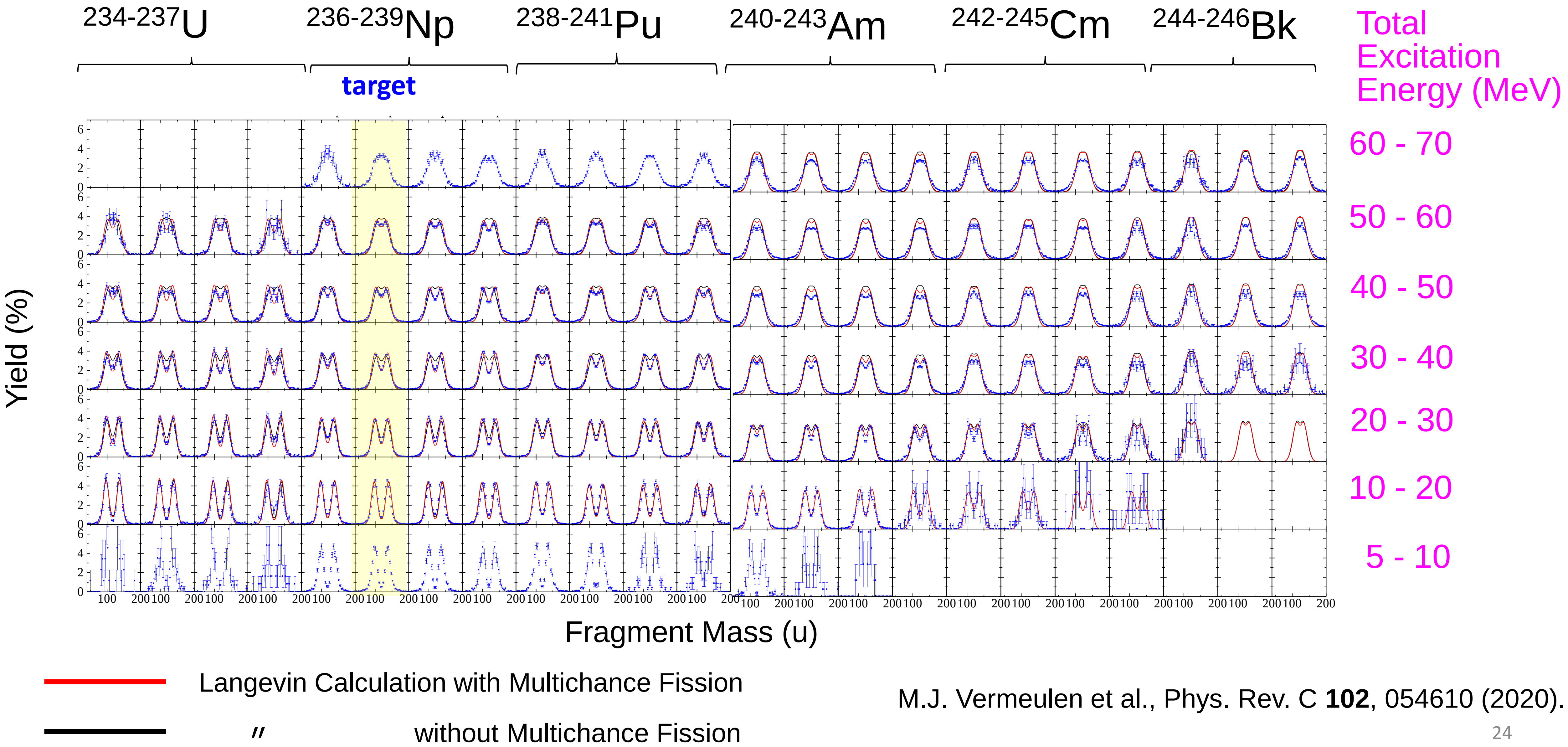
- Populate excited compound nuclides using multi-nucleon transfer reactions.
  Identification of fissioning nucleus and its excitation energy is given by silicon ΔE-E detectors.
- Detect both fission fragments (double-velocity measurement) using multi-wire proportional counters and micro-channel plate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



Obtained Data

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

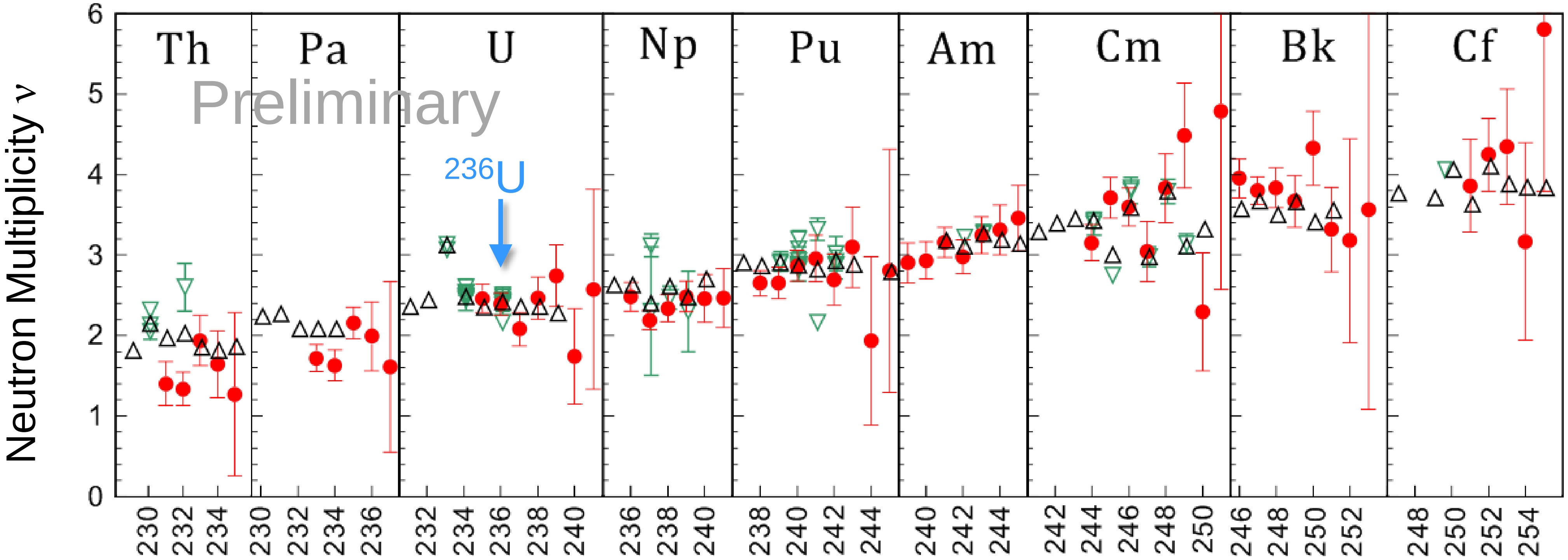
Fission Fragment Mass Distributions (FFMDs) obtained in ^{18}O + ^{237}Np



M.J. Vermeulen et al., Phys. Rev. C **102**, 054610 (2020).

Prompt neutron multiplicity for low energy fissions

Excitation energy of compound nucleus ≒ Fission barrier



Mass of Fissioning Nucleus

● Present (59 nuclei)

- $^{18}O + ^{232}Th$
- $^{18}O + ^{238}U$
- $^{18}O + ^{237}Np$
- $^{18}O + ^{243}Am$
- $^{18}O + ^{248}Cm$

▽ Experimental literature Data (19 nuclei)

△ JENDL-4.0

Activities at Kyoto University

(Institute for Integrated Radiation and Nuclear Science, Kyoto University)

KURNS

Measurement of neutron total cross sections of Sn-Pb alloys in solid and liquid states

T. Uemura, J. Hori, K. Terada, T. Sano, J. Nishiyama, R. Kimura, K. Nakajima, Symp. on Nucl. Data, 26-27 Nov., 2020.
Team: Kyoto Univ., Kindai Univ., Tokyo Institute of Technol., Toshiba Energy Systems & Solutions Corporation

Motivation： The use of a Sn-Pb alloy is considered as an emergency in-core transport medium in the design of a small modular reactor proposed by Toshiba Energy Systems & Solutions Corporation. The change of the state of the alloy during the operation will affect the core characteristics. Therefore, the thermal neutron total cross sections of the solid and liquid Sn-Pb alloys were measured by using the TOF method at KURNS-LINAC.

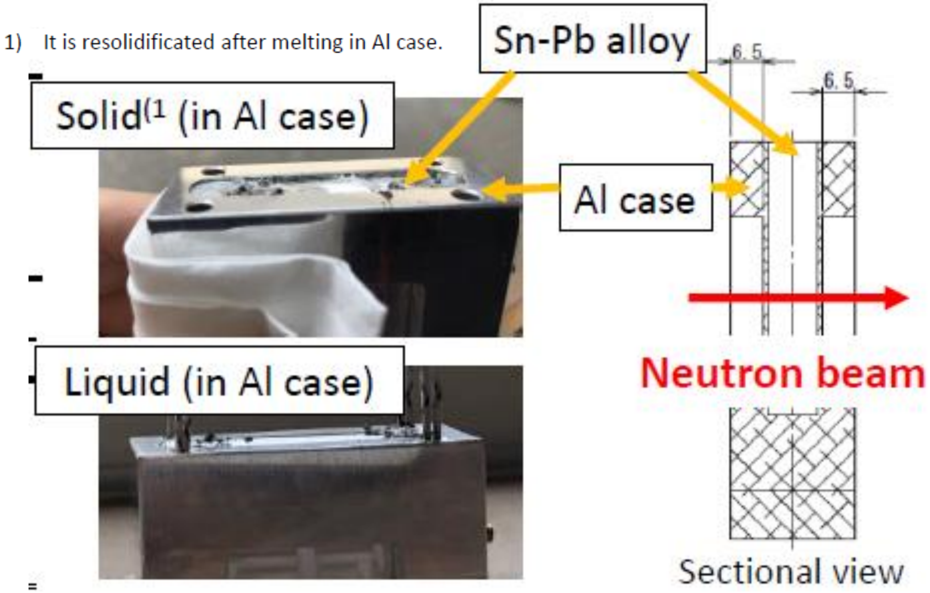


Fig. 1 Sn-Pb alloy sample

Transmission neutrons were measured by a ^{6}Li-glass detector. The flight length was 12.1 m.

The temperature of the sample was controlled.

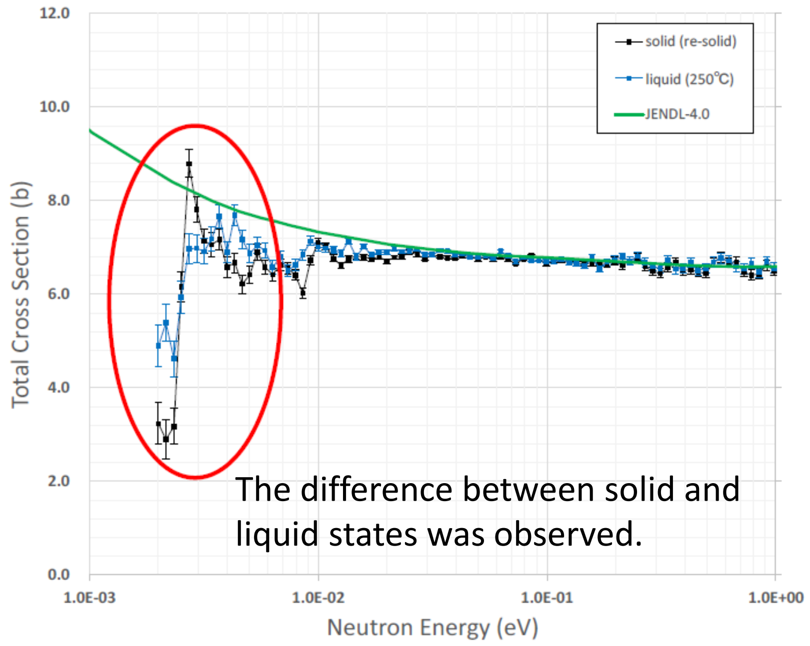


Fig. 2 Comparison of the total cross sections of Sn-Pb alloy in the solid, the liquid and JENDL-4.0(free-gas model).

Detection of gamma-rays from short-lived fission products at KUCA and KURNS-LINAC

Y. Nauchi, J. Hori, T. Sano, Y. Takahashi, K. Kosumi, H. Unesaki, Symp. on Nucl. Data, 26-27 Nov., 2020.
Team: Central Research Institute of Electric Power Industry, Kyoto Univ., Kindai Univ.

Motivation : Radioactivity of fission products (FPs) is essential for characterizing nuclear fuel & core. FP yield & decay data base have been evaluated for the calculation of the radioactivity.
In order to give reference data for validating FP-yield & decay data bases, two kinds of gamma-ray spectrum measurements are performed at Kyoto University Critical Assembly (KUCA) and the LINAC neutron source of the institute of integrated radiation and nuclear science, Kyoto university (KURNS-LINAC).

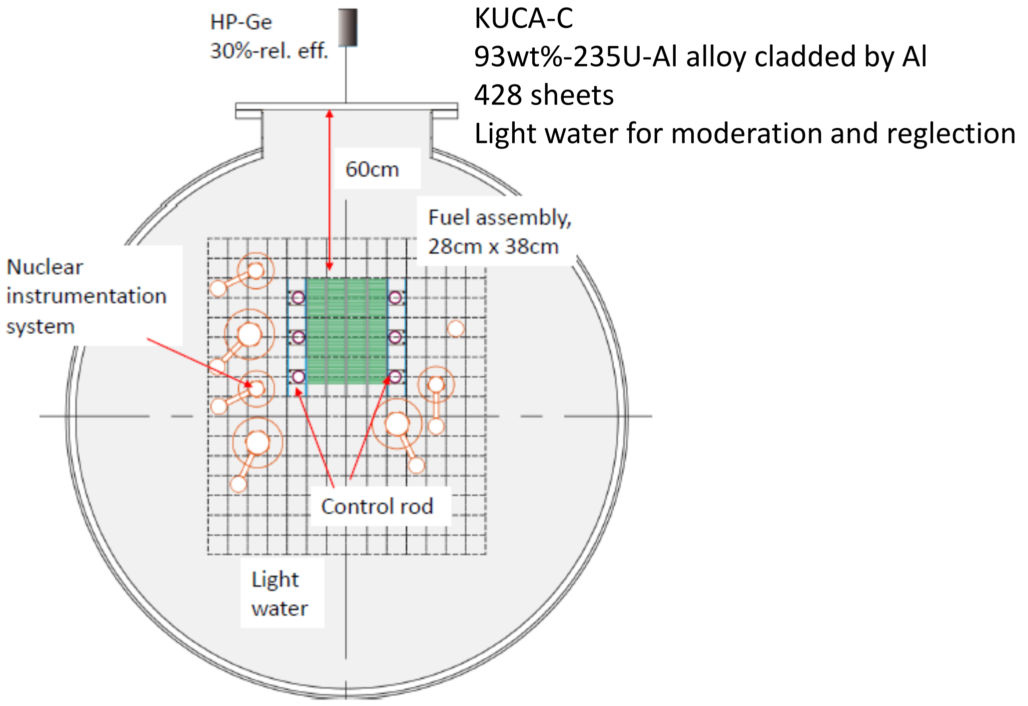


Fig. 3 experimental set-up of KUCA

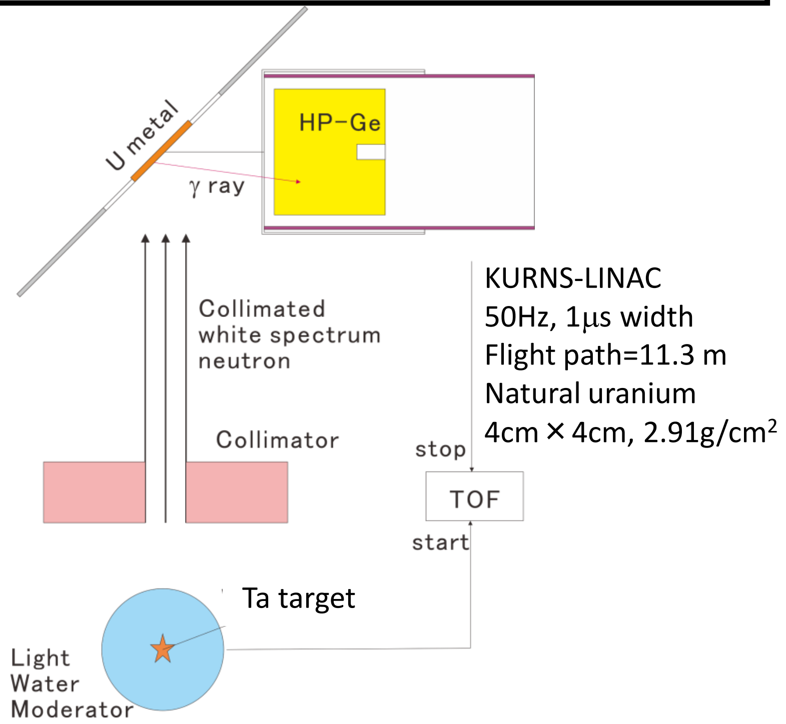


Fig. 4 experimental set-up of KURNS-LINAC

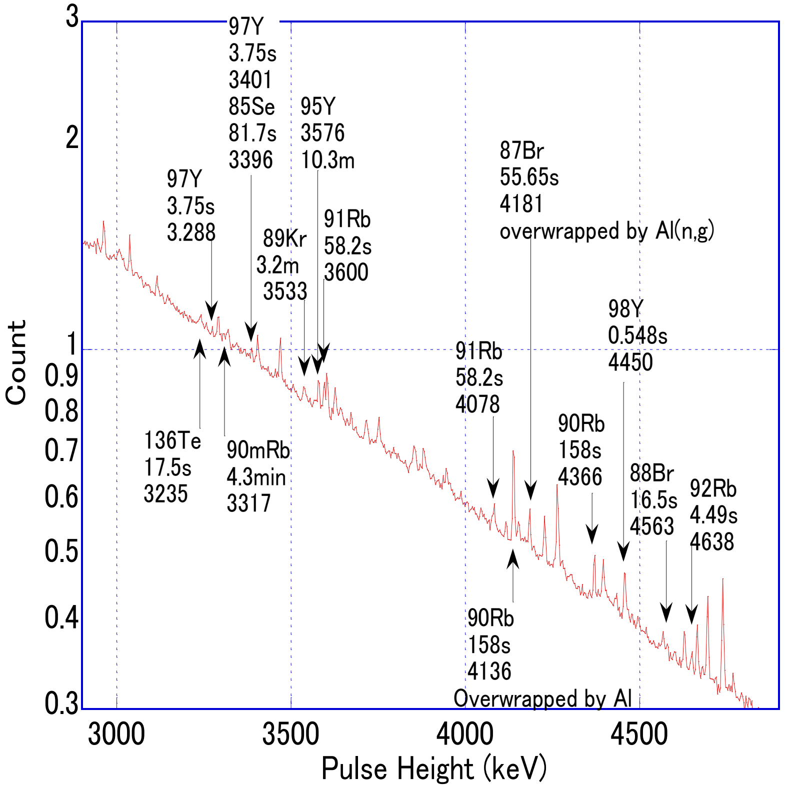


Fig. 5 Measured gamma-ray spectrum for critical core

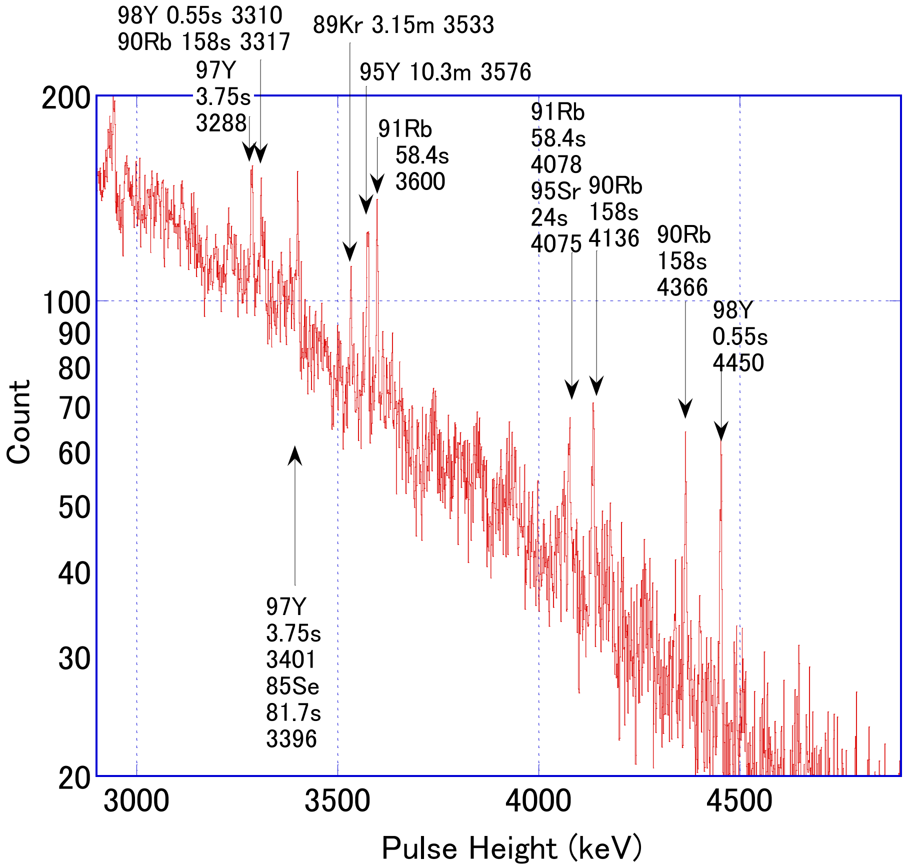


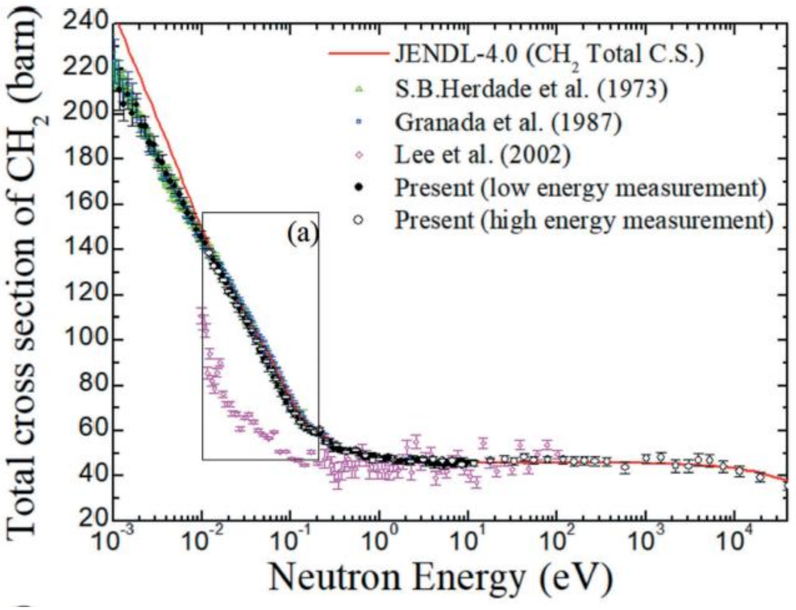
Fig. 6 Measured gamma-ray spectrum corresponding to the background TOF region in the experiment of KURNS-LINAC

Many gamma-ray peaks due to short lived FPs such as ^{87,88}Br, ^{89}Kr, ^{90,90m}Rb, ^{95,97,98}Y, ^{135}Te were observed.
By comparing the measured spectra to the numerical analysis of production and decay of isotopes originated in fission of ^{235}U, those discrete gamma rays are identified as those from decay of short-lived fission products.

Neutron total cross section measurements of polyethylene using time-of-flight method at KURNS-LINAC

J. Lee, J. Nishiyama, J. Hori, R. Kimura, T. Sako, A. Yamada, T. Sano, J. Nucl. Sci. Technol., 57, 1, 1-8 (2020).
Team: Kyoto Univ., Tokyo Institute of Technol., Kindai Univ., Toshiba Energy Systems & Solutions Corporation

Motivation : The polyethylene is well-known as one of moderator materials to produce a thermal neutron spectrum. The accurate neutron total cross sections of CH_2 in the thermal neutron energy region provide important data for the evaluation work on the CH_2 thermal neutron scattering data in the evaluated nuclear data libraries. Therefore, we have performed the transmission measurements of CH_2.



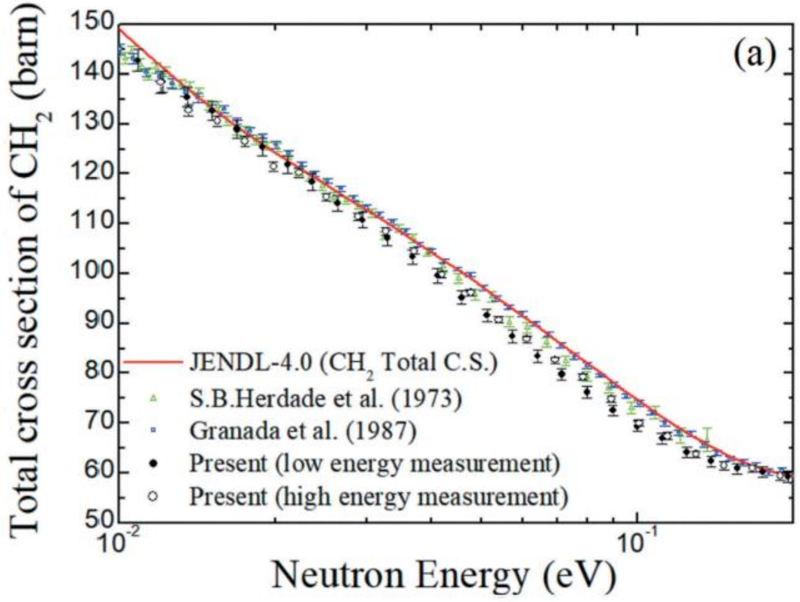


Fig. 7 Comparison of the present results with the previous measured results and the evaluated data for the neutron total cross sections of CH_2

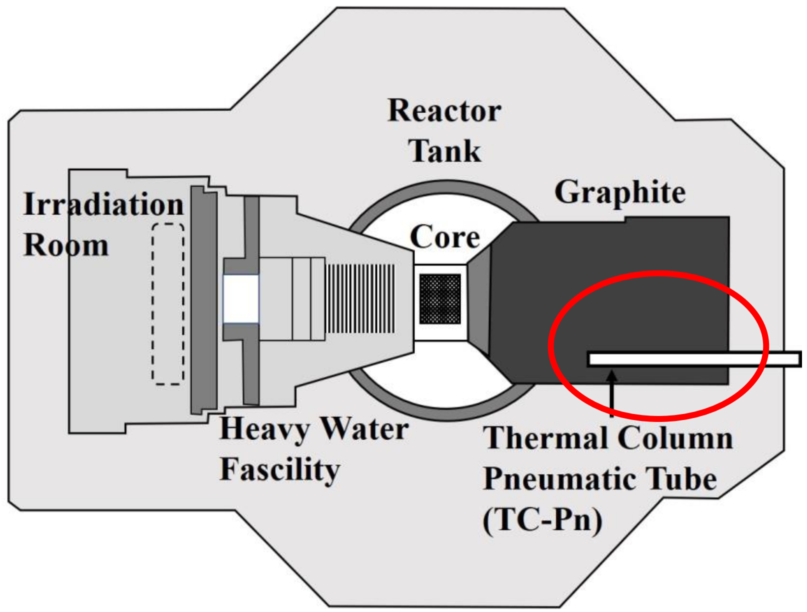
Neutron Capture Cross Section of Ta-181 with KUR

Activation method
By Dr. Nakamura (JAEA)

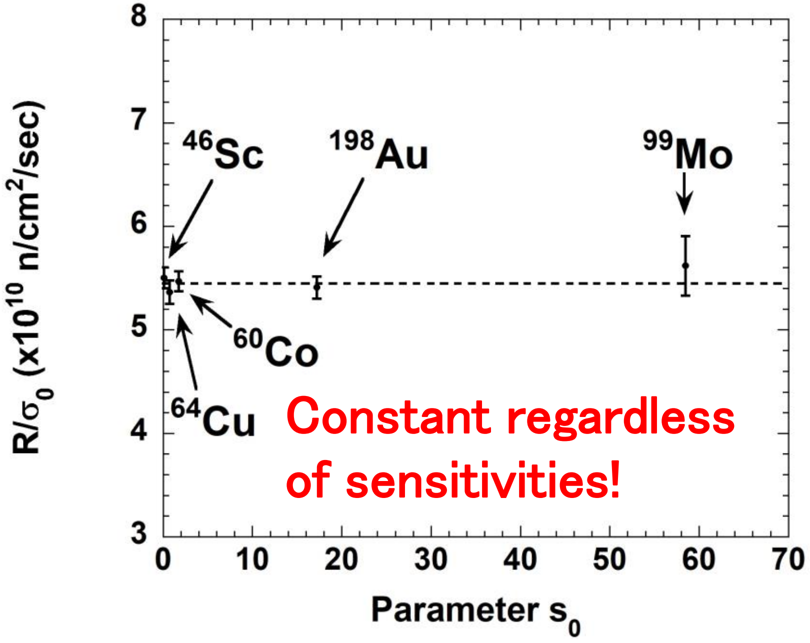
Exp. Idea

Objective：Acculately derive the thermal-neutron cross section
→ Utilize a well-thermalized neutron field
→ Graphite thermal column
→ Confirm whether or not a field is well-thermalized

Kyoto University Research Reactor (KUR)

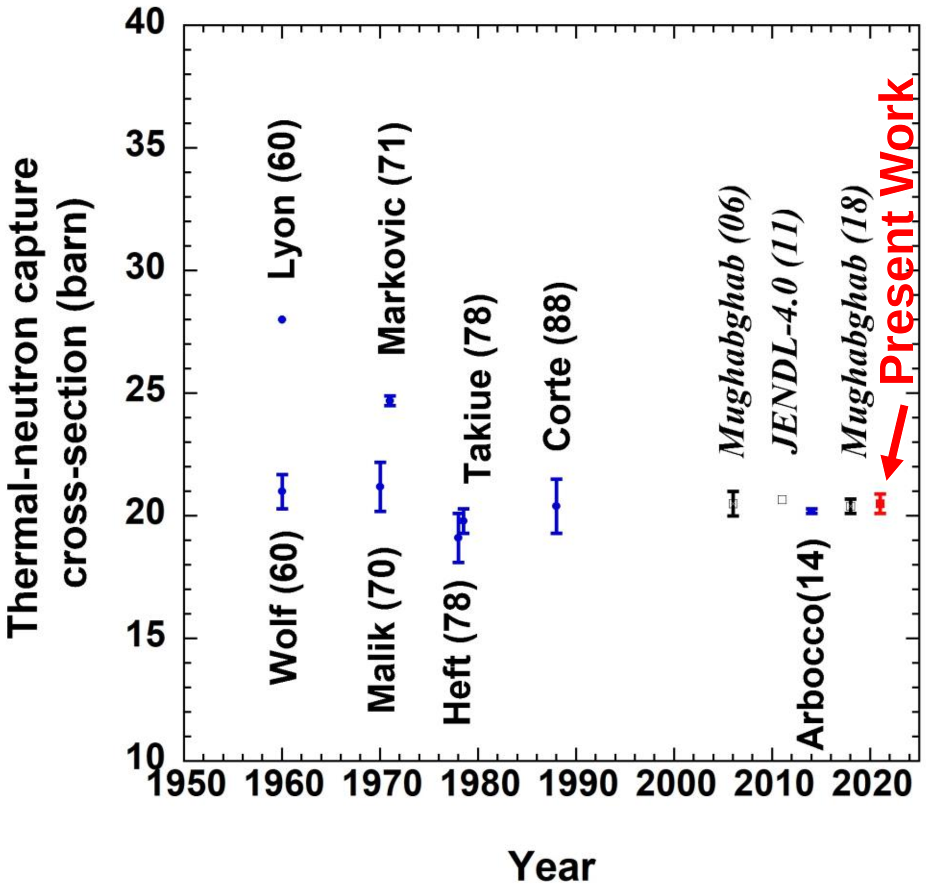


Examined the irrad. field
by Westcott method



Result (2)

Thermal–neutron capture cross section for $^{181}Ta(n,\gamma)^{182m+g}Ta$ reaction



Authors	Year	σ_0 (barn)
Present Work		20.5±0.4
Mughabghab	2018	20.4±0.3
Arbocco *et al.*	2014	20.2±0.1
JENDL-4.0	2011	20.68
Mughabghab	2006	20.5±0.5
Corte *et al.*	1988	20.4±0.22
Takiue *et al.*	1978	19.8±0.5
Heft	1978	19.1±1.0
Gryntakis	1976	27.5±1.38
Markovic *et al.*	1971	24.7±0.2
Malik *et al.*	1970	21.2±1.0
Arino *et al.*	1964	27.0
Lyon	1960	28.
Wolf	1960	21.0±0.7
Tattersall *et al.*	1960	19.0±0.2
Seren *et al.*	1947	20.6±4.1

J. Nucl. Sci. Technol. S.Nakamura *et al.*(Published on April 29, 2021)

Status of photo neutron spectrum measurement for mono-energetic polarized photon

T.Sanami[1,2]、Tran Kim Tuyet[2]、H.Yamazaki[1,2]、T.Itoga[3]、Y.Kirihara[4]、Y.Namito[1,2]、H.Nakashima[4]、S.Miyamoto[5]、Y.Asano[5]

[1]KEK、[2]SOKENDAI、[3]JASRI、[4]JAEA、[5]University of Hyogo

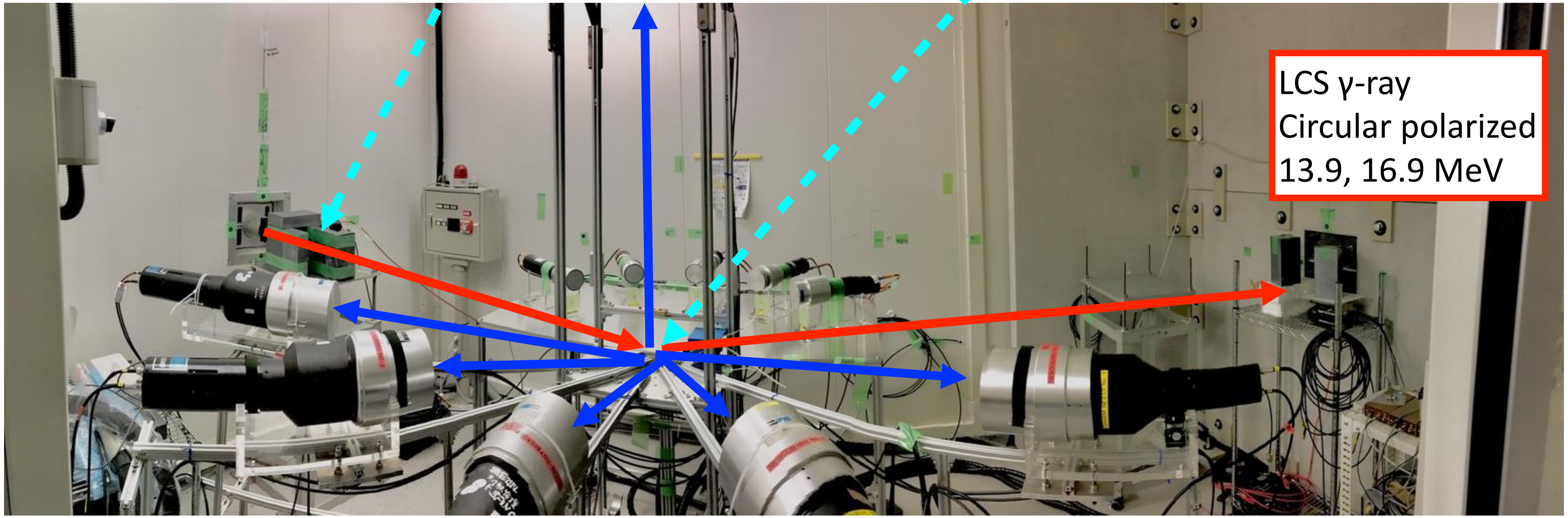
OECD/NEA/WPEC 2020

Target and detector setup

Plastic scintillator
5 mm thick with Al rad.

Targets (Au,Pb,Cu,Fe,Ti,Sn)
10 mm diam.

Optics hutch 2

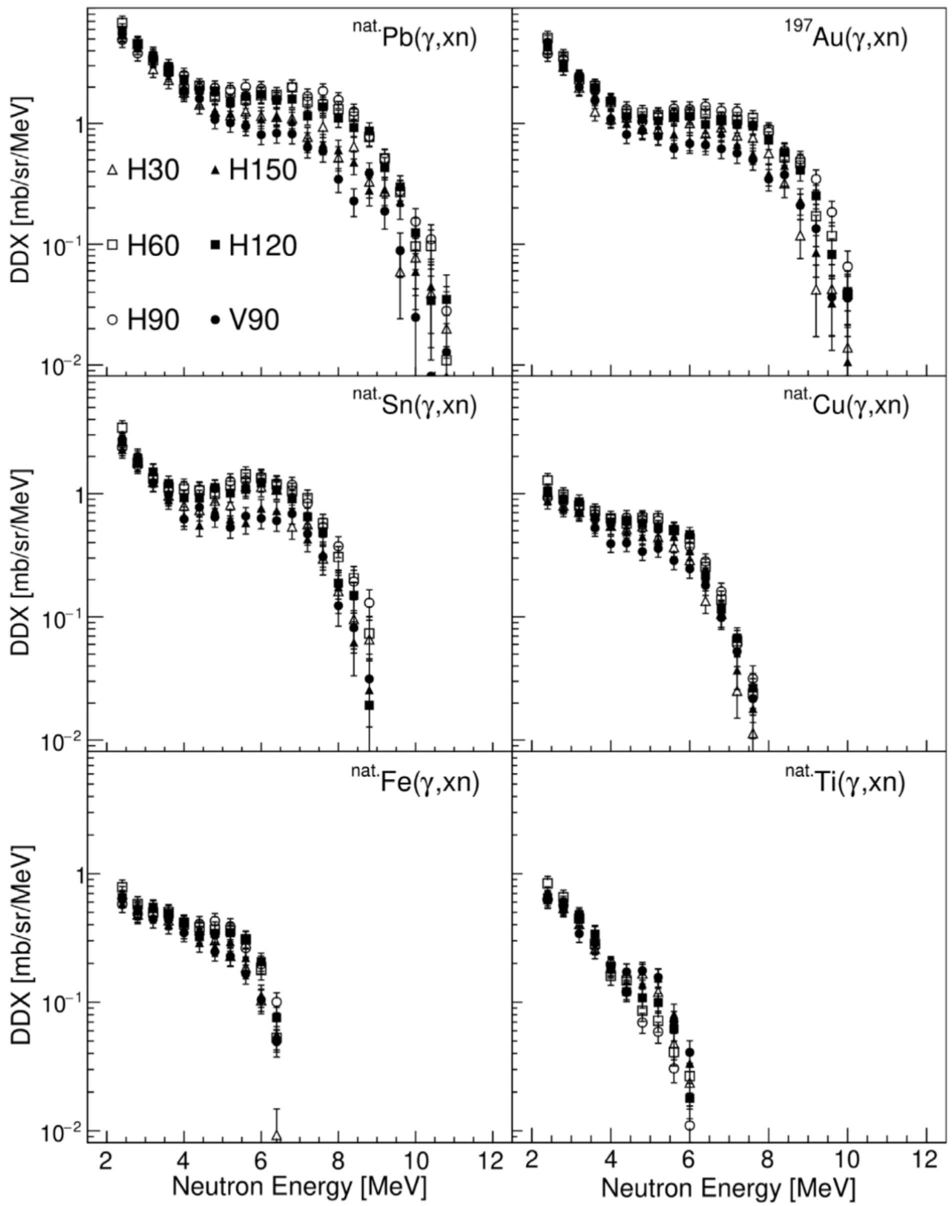


Liquid organic scintillator
5 in. diam. - 5 in. length

- https://doi.org/10.1016/j.nima.2020.164965 (2021)

Results

- Double differential cross sections (DDXs) of (γ,xn) reaction on Pb,Au,Sn,Cu,Fe, and Ti targets for horizontal 30, 60, 90, 120, 150 and vertical 90 degrees,16.6 MeV photon
- Two components, evaporation and non-evaporation, were observed
- Anisotropy was observed for non-evaporation component for all six targets



Symposium on Nuclear Data (in Japan)

- In Japan, “Symposium on Nuclear Data” is held in every third week of Nov. (Just Beaujolais Nouveau Released Day!!)
- Proceedings of the symposium are published as JAEA conference record.
- You can access the Conference Proceedings in the 2019 symposium. https://doi.org/10.11484/jaea-conf-2020-001
- The proceeding of the 2020 symposium is under reviewing process.

Thank you