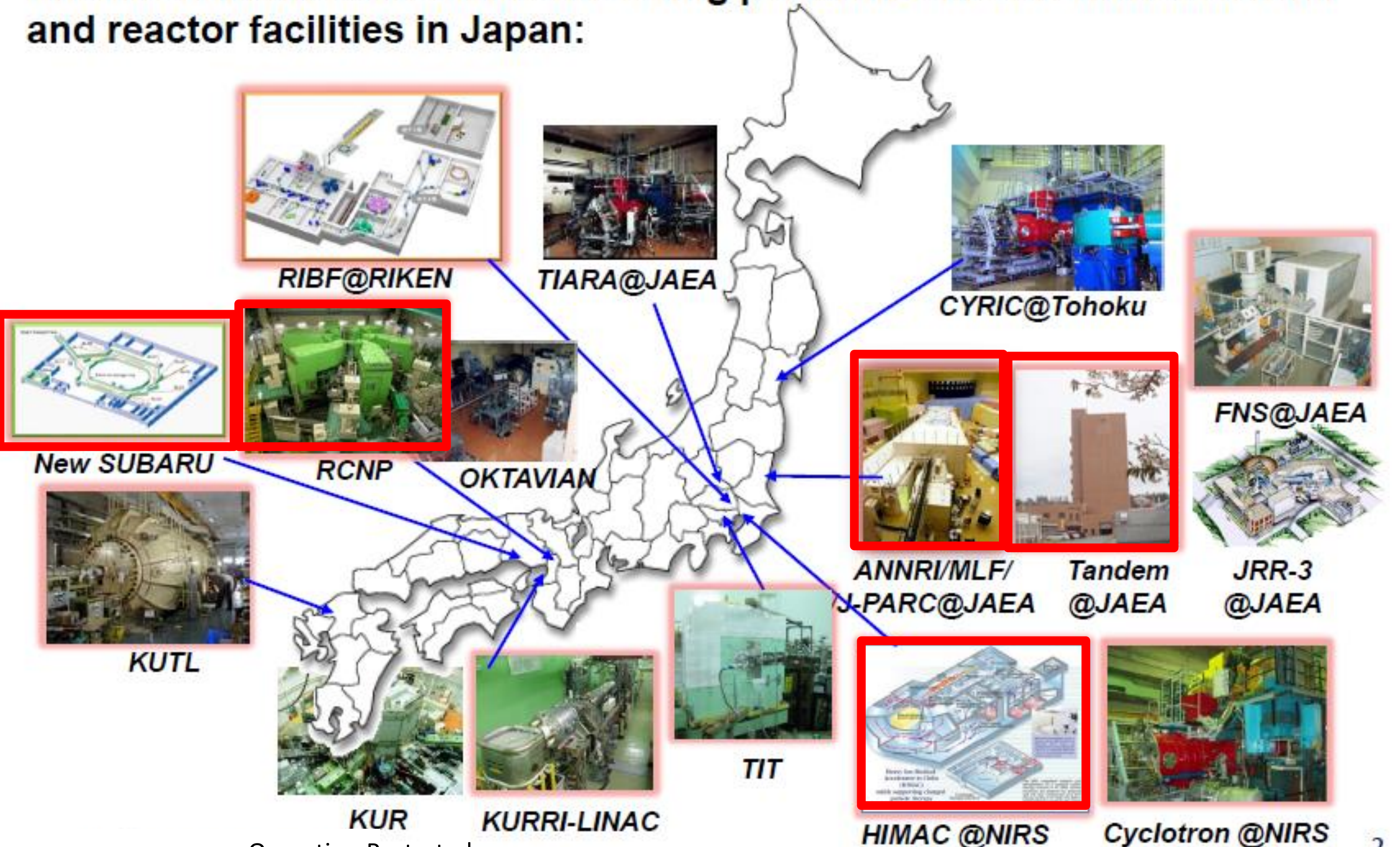
Japanese Activities in Nuclear Data Measurement

Atsushi Kimura

Japan Atomic Energy Agency

Nuclear Data Measurement in Japan

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



Operation Restarted in Aug. 2017

Activities by J-PARC/MLF/ANNRI collaboration in 2017

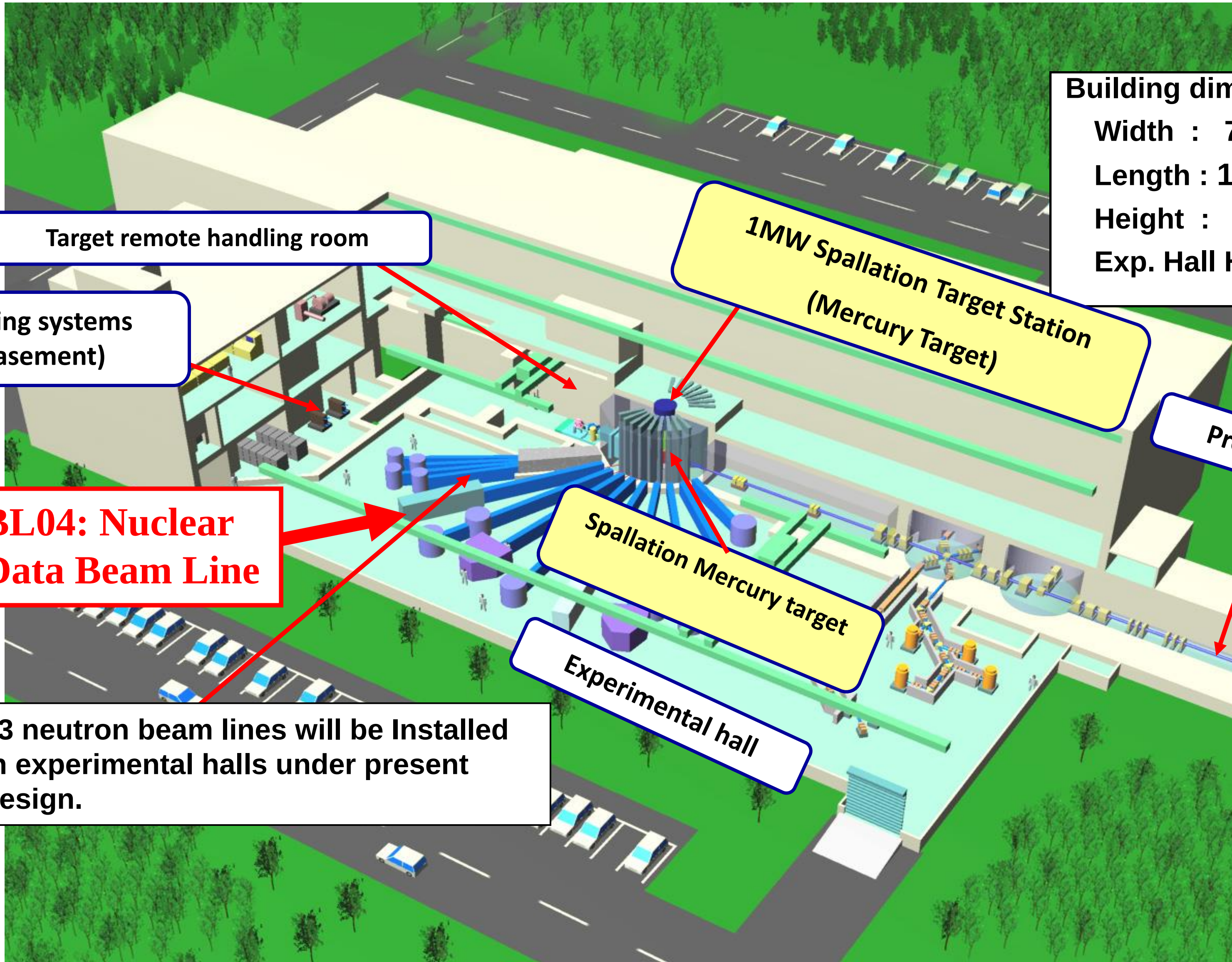
Japan Atomic Energy Agency
Tokyo Institute of Technology
Kyoto Univ.

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

Nuclear Data Projects in Japan

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

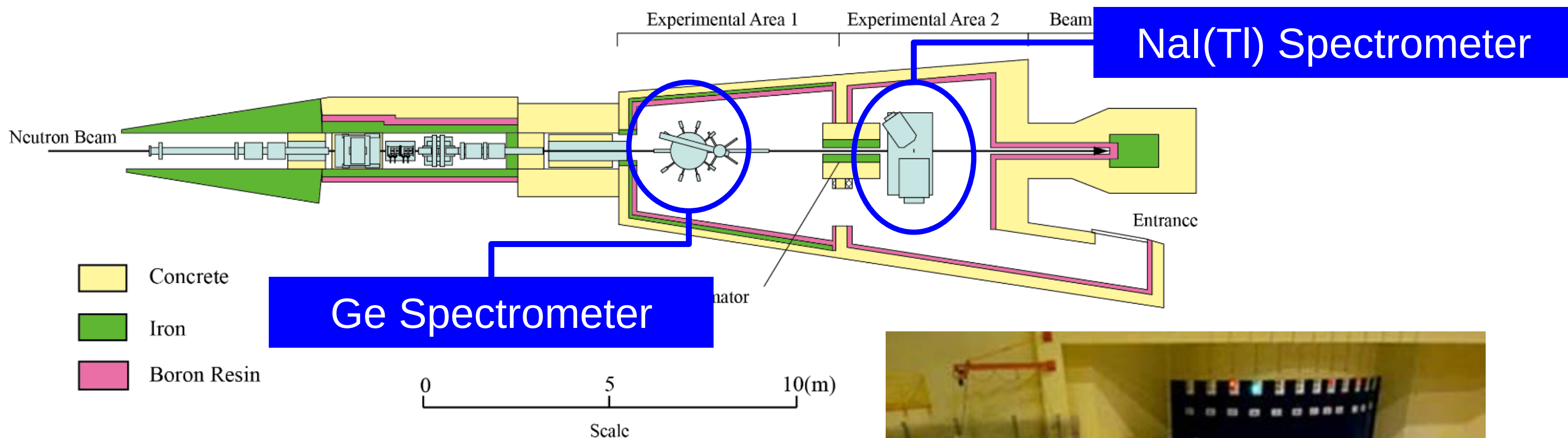
3GeV,
proton beam

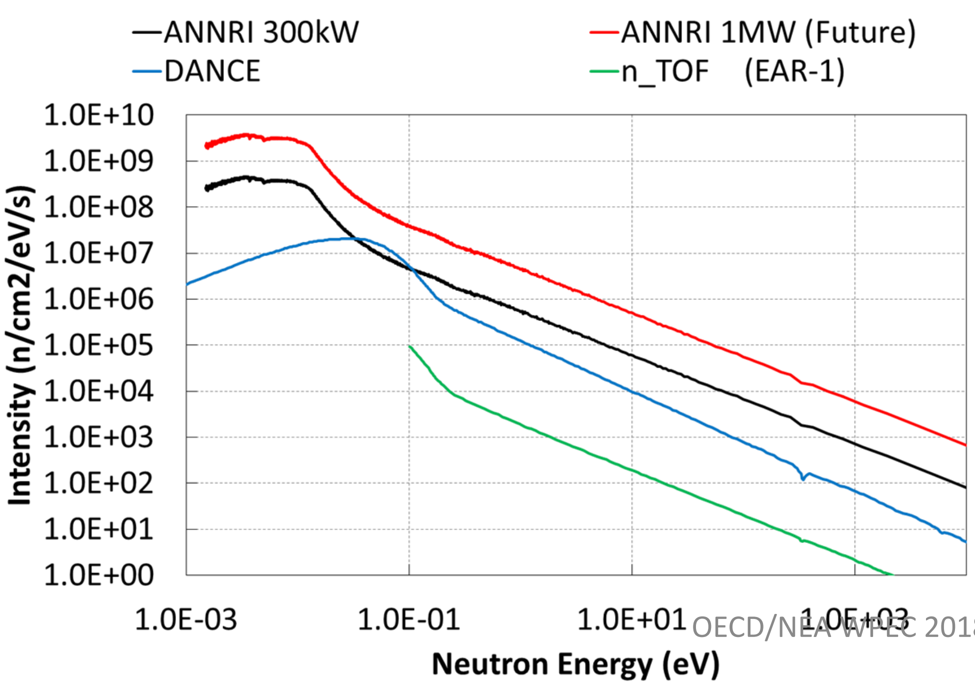
23 neutron beam lines will be Installed in experimental halls under present design.

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

ANNRI

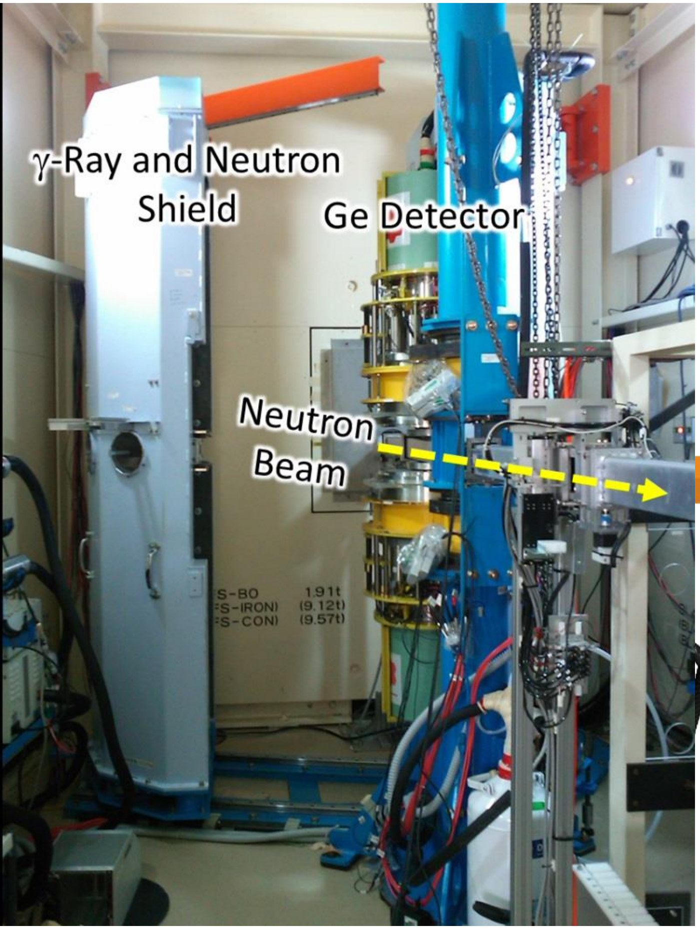
ANNRI (Accurate Neutron Nucleus Measurement Instrument)



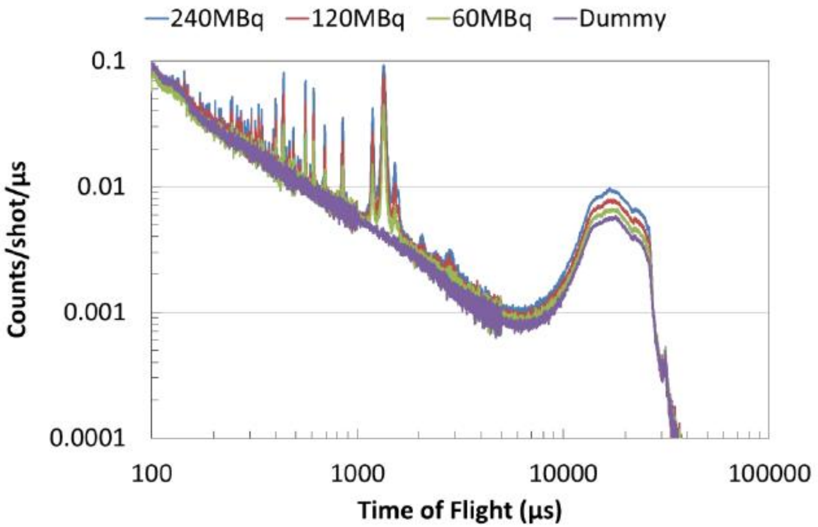


Ge Spectrometer

- 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.

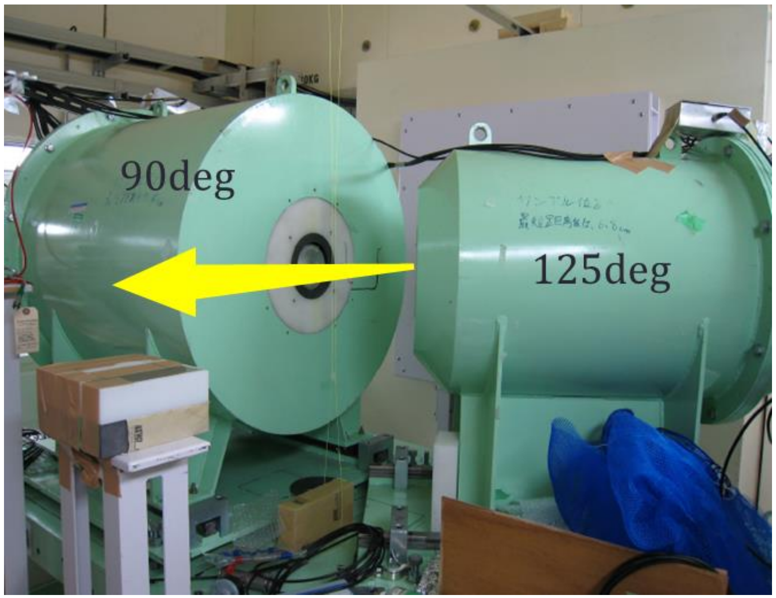


- Measurements of neutron capture cross sections of ^{241,243}Am, ^{137,135}Cs, ^{244,246}Cm and stable isotopes have been finished.
- Data analysis is in progress.



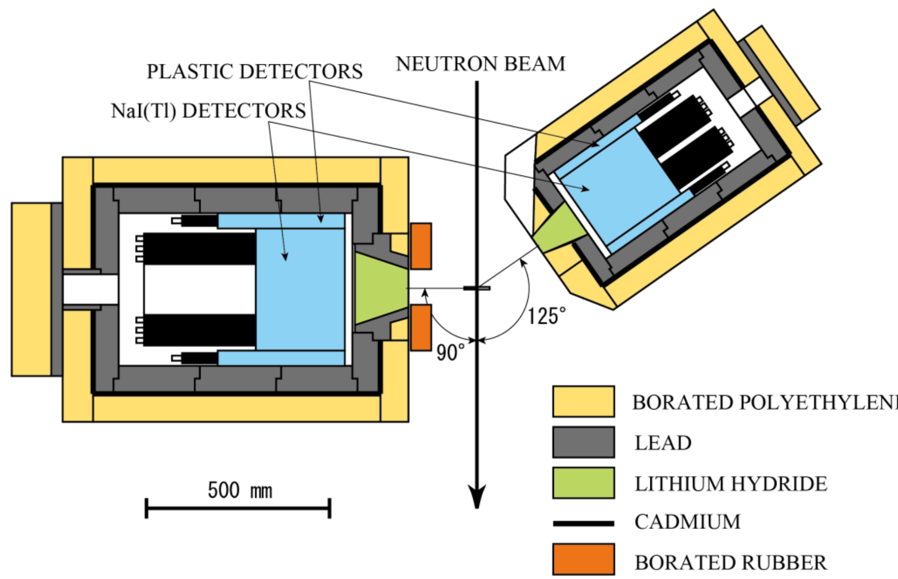
TOF spectra for ^{243}Am Samples

NaI(Tl) spectrometer



- Flight length: 28m
- Size: 330 mmΦ 203 mmL 90°
  203 mmΦ 203 mmL 125°

- Pulse-height weighting technique
- Measurement in the high energy region



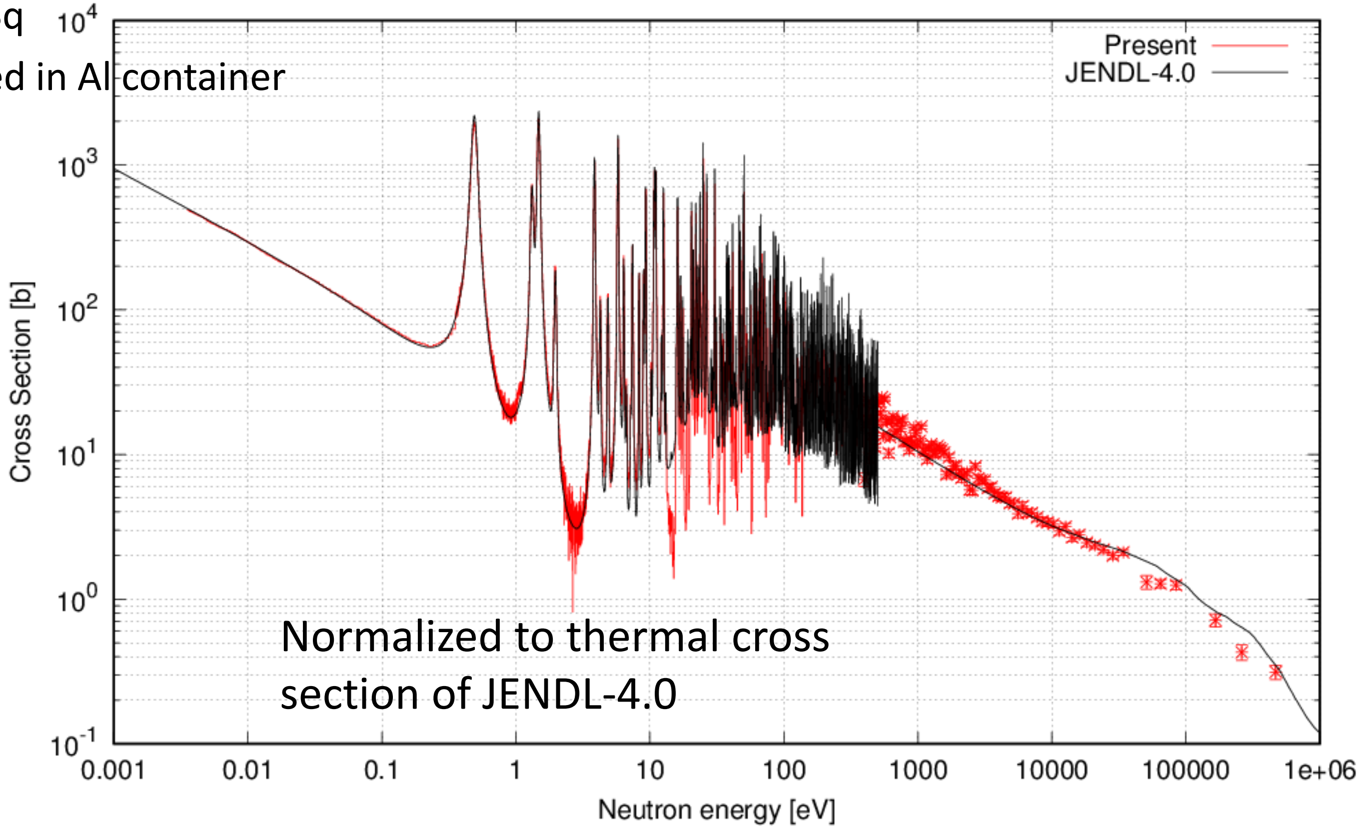
Neutron capture cross section of ^{237}Np

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

☐ Np-237 sample

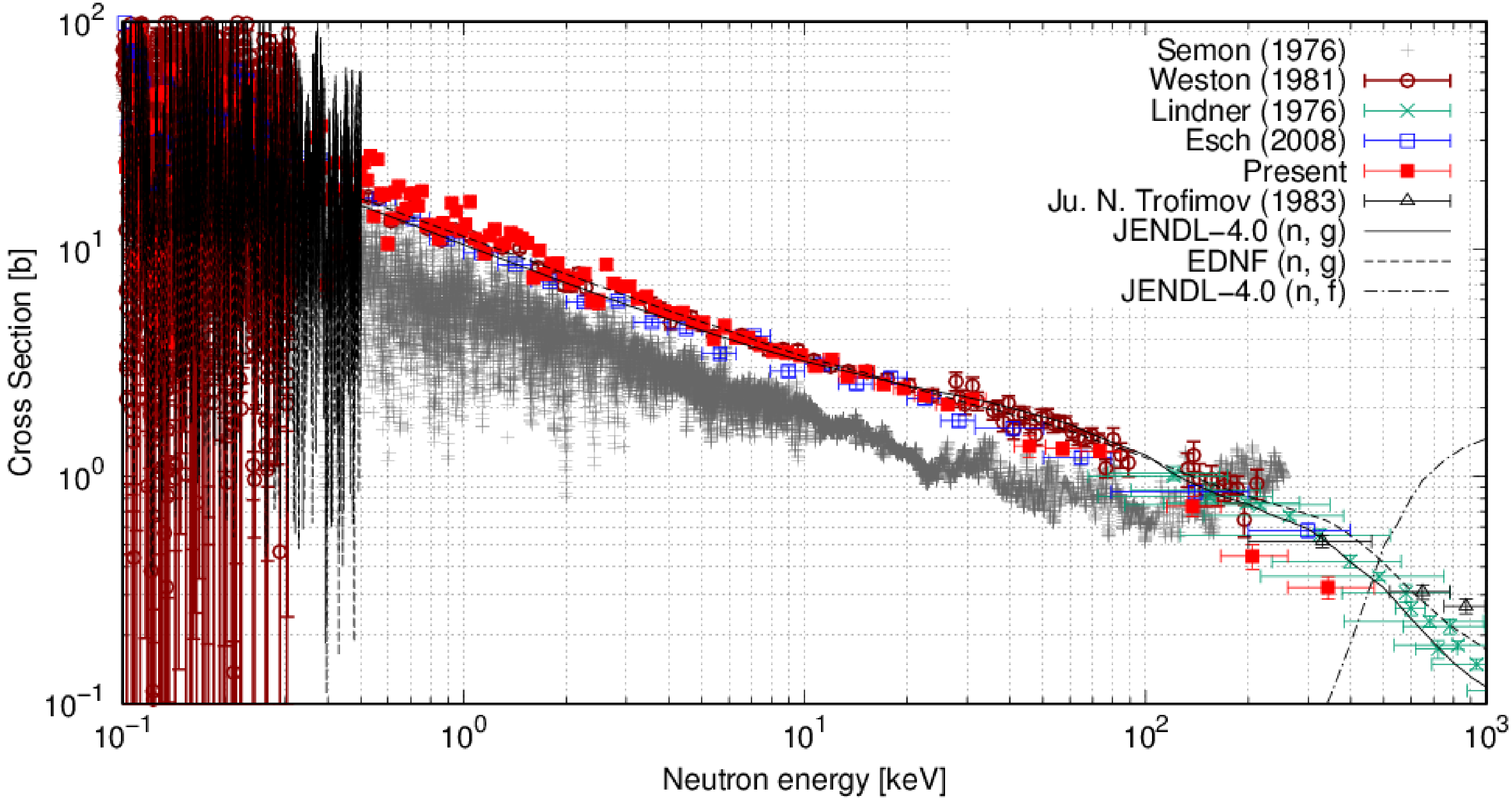
5 MBq

Sealed in Al container



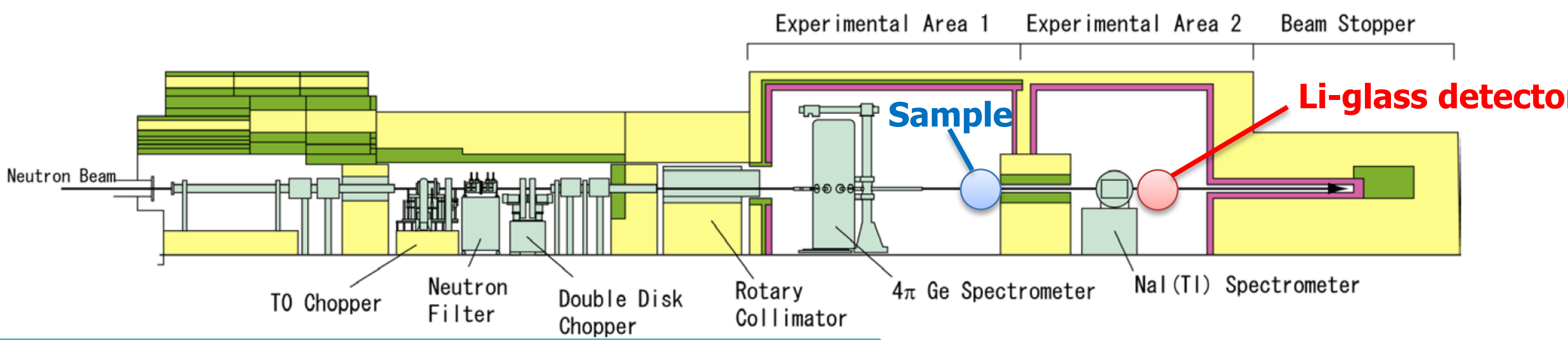
Normalized to thermal cross section of JENDL-4.0

High energy region

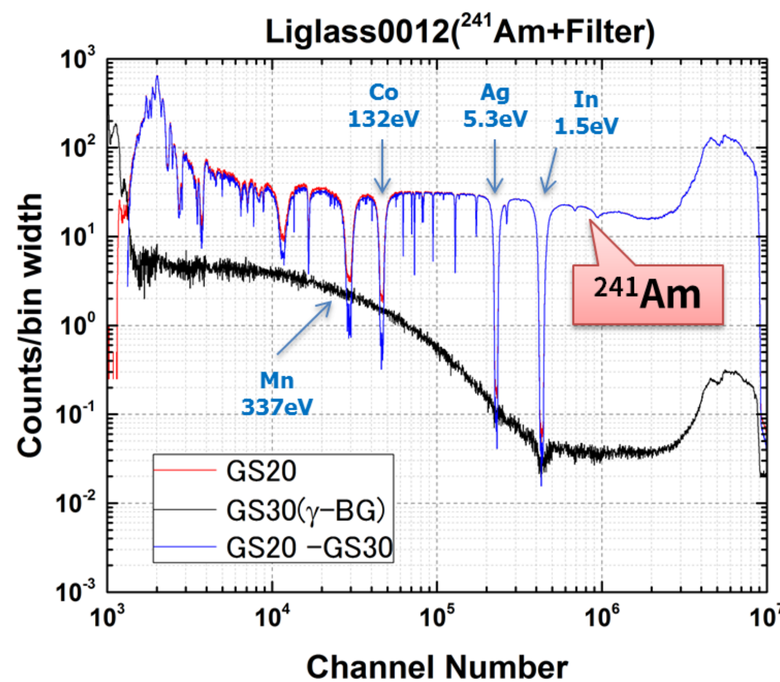


Measurement of neutron total cross sections

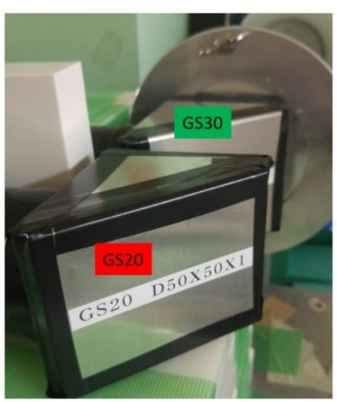
Li-Glass detectors for neutron total cross section is installed.

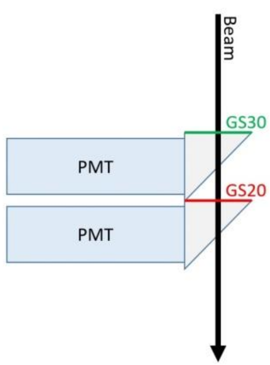


- A ^{6}Li-glass scintillation detector for neutron and a ^{7}Li-glass scintillation detector for B.G. were installed at the flight length of 28.7m
- Measurements of neutron total cross sections of ^{241,243}Am and ^{155,157}Gd have been finished.
- Data analysis is in progress.



TOF spectra for ^{241}Am





DAQ
(CAEN V1720)

Activities at JAEA Tandem Accelerator Facility

(surrogate reaction)

20 MV

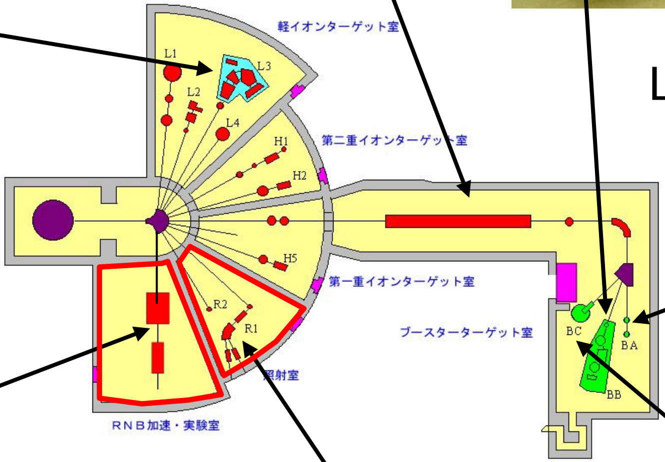
Contact :
Katsuhisa Nishio
Advanced Science Research Center
Japan Atomic Energy Agency

Equipment at the JAEA Tandem Accelerator Facility

Magnetic Spectrograph

Booster Liniac

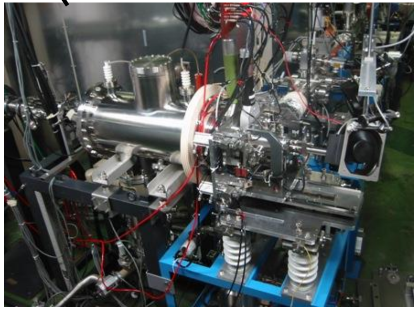
Recoil Mass Separator



Large Scattering Chamber

In-beam fission setup
(surrogate reaction)

ISOL



Ge-detector array

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

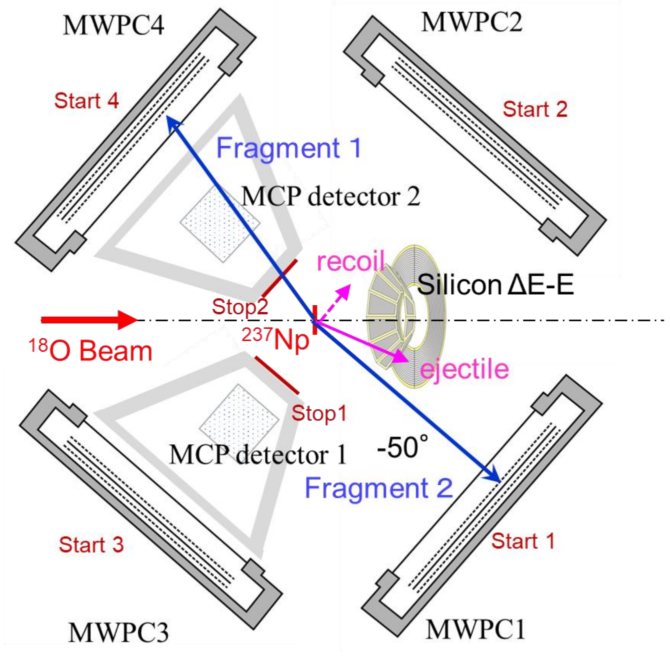
Surrogate Reactions for Fission Data

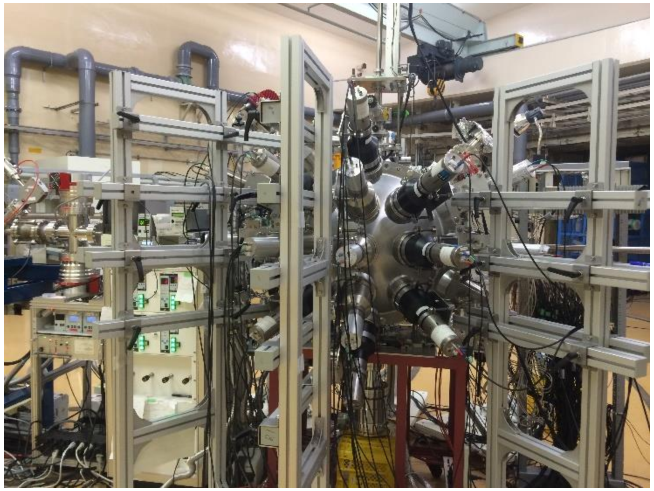
Method

- Populate excited compound nuclides using multi-nucleon transfer reactions.
  Identification of fissioning nucleus and its excitation energy is given by silicon ΔE-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.)

R. Léguillon *et al*., Phys. Lett. B **761,** 125 (2016).
K. Hirose *et al*., Phys. Rev. Lett. **119**, 222501 (2017).

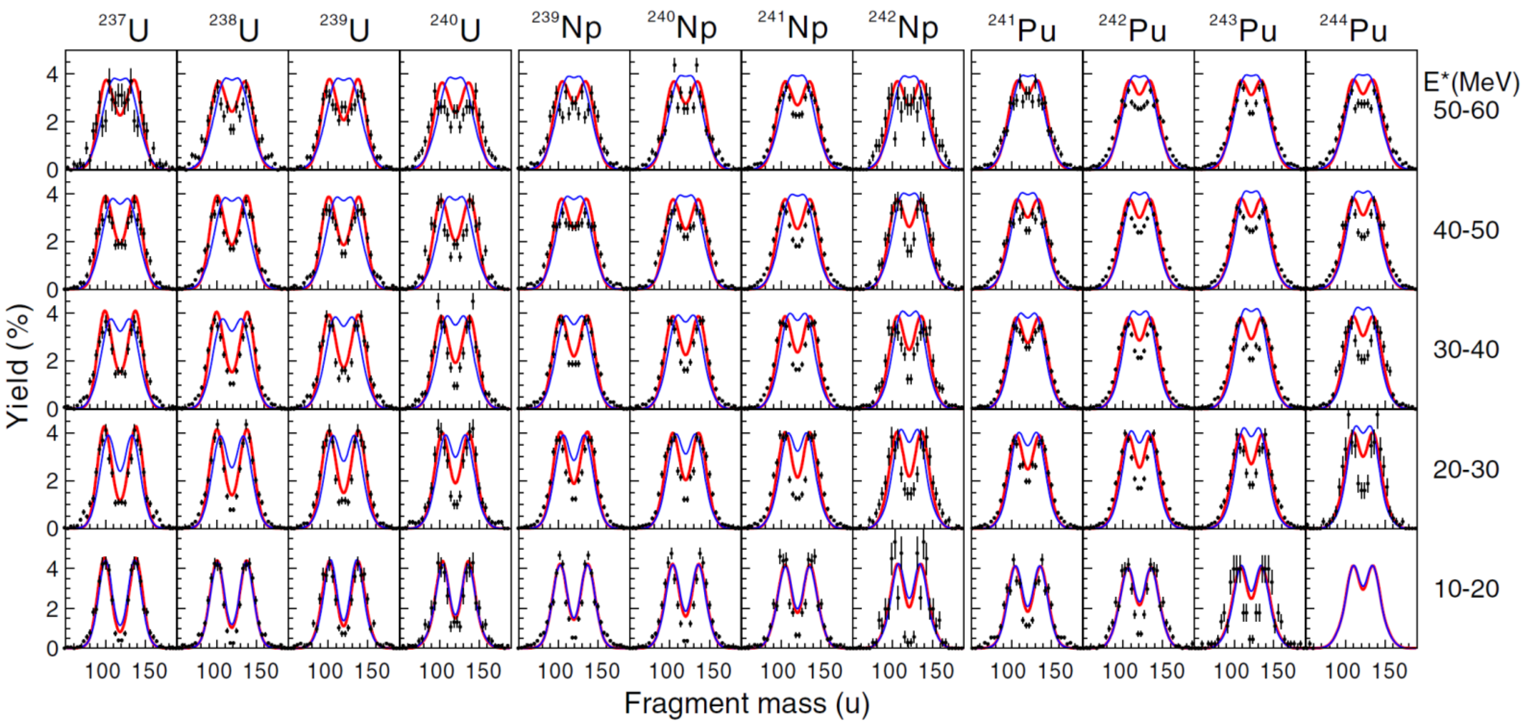
Selected Results

from surrogate fission setup

PRL **119**, 222501 (2017) PHYSICAL REVIEW LETTERS week ending 1 DECEMBER 2017

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

K. Hirose,[1,*] K. Nishio,[1] S. Tanaka,[2] R. Léguillon,[1] H. Makii,[1] I. Nishinaka,[1] R. Orlandi,[1] K. Tsukada,[1] J. Smallcombe,[3,1] M. J. Vermeulen,[1] S. Chiba,[4] Y. Aritomo,[2] T. Ohtsuki,[5] K. Nakano,[6] S. Araki,[6] Y. Watanabe,[6] R. Tatsuzawa,[7] N. Takaki,[7] N. Tamura,[8] S. Goto,[8] I. Tsekhanovich,[9] and A. N. Andreyev[10,1]

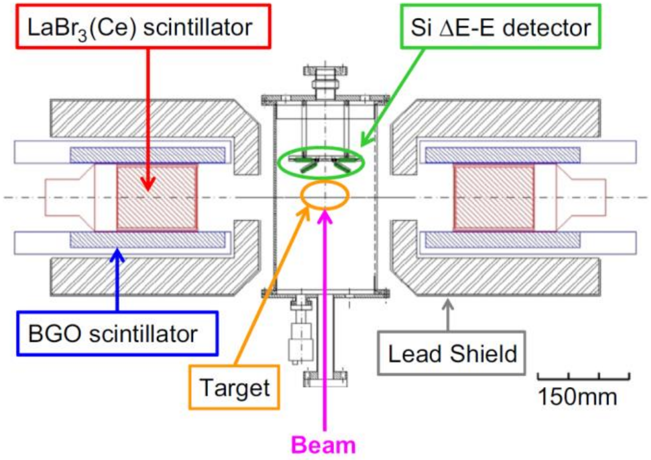


Surrogate Reactions for Capture Cross Sections

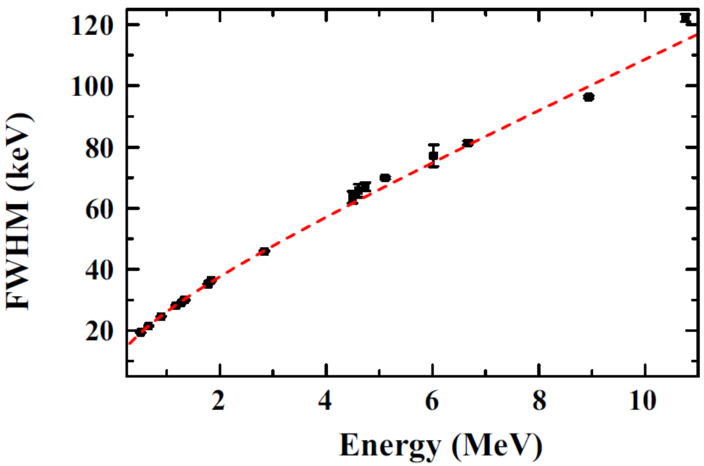
Method

- 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 $LaBr_3(Ce)$ spectrometers.

$LaBr_3(Ce)$



Detector setup for the surrogate capture measurement.



Energy Resolution

H. Makii *et al*., Nucl. Instrum. Meth. A, **797**, 83 (2015).
S. Q. Yan et al., Phys. Rev. C, **94**, 015804 (2016).

Selected Results

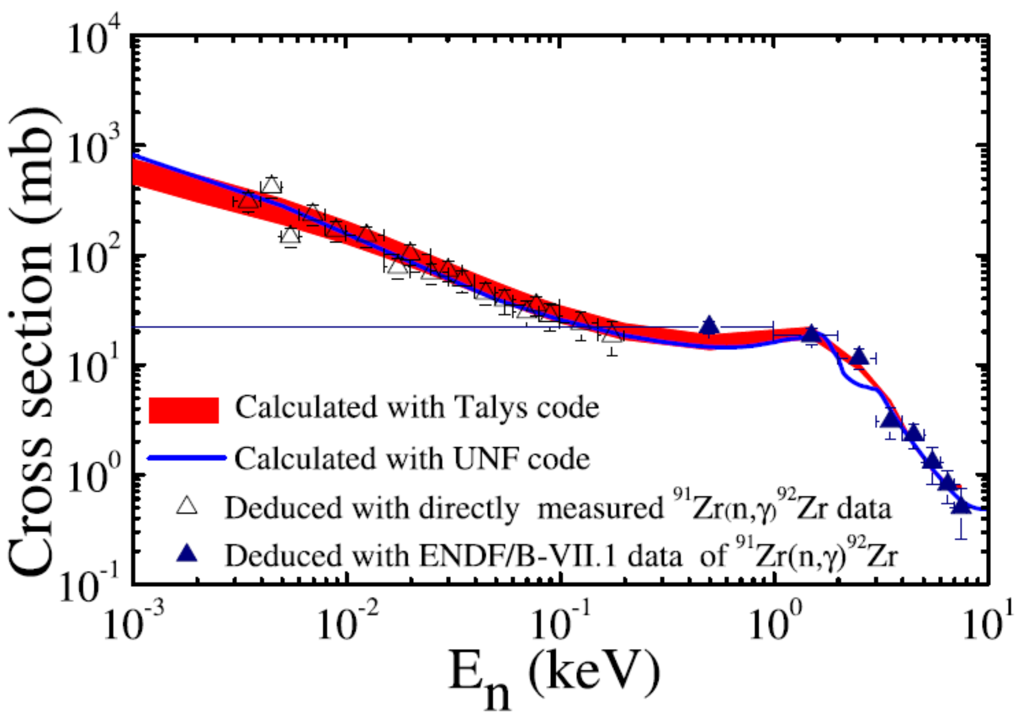
In collaboration with China institute of Atomic Energy

The Astrophysical Journal, 848:98 (8pp), 2017 October 20
https://doi.org/10.3847/1538-4357/aa8c74

CrossMark

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

S. Q. Yan (颜胜权)[1], Z. H. Li (李志宏)[1], Y. B. Wang (王友宝)[1], K. Nishio[2], M. Lugaro[3,4], A. I. Karakas[4], H. Makii[2], P. Mohr[5,6], J. Su (俊苏)[1], Y. J. Li (李云居)[1], I. Nishinaka[2], K. Hirose[2], Y. L. Han (韩银录)[1], R. Orlandi[2], Y. P. Shen (谌阳平)[1], B. Guo (冰郭)[1], S. Zeng (晟曾)[1], G. Lian (钢连)[1], Y. S. Chen (陈永寿)[1], and W. P. Liu (柳卫平)[1]
[1] China Institute of Atomic Energy, P.O. Box 275(10), Beijing 102413, P. R. China; panyu@ciae.ac.cn
[2] Japan Atomic Energy Agency, Tokai, Naka, Ibaraki 319-1195, Japan
[3] Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, 1121 Budapest, Hungary; maria.lugaro@csfk.mta.hu
[4] Monash Centre for Astrophysics, School of Physics and Astronomy, Monash University, Clayton, VIC 3800, Australia



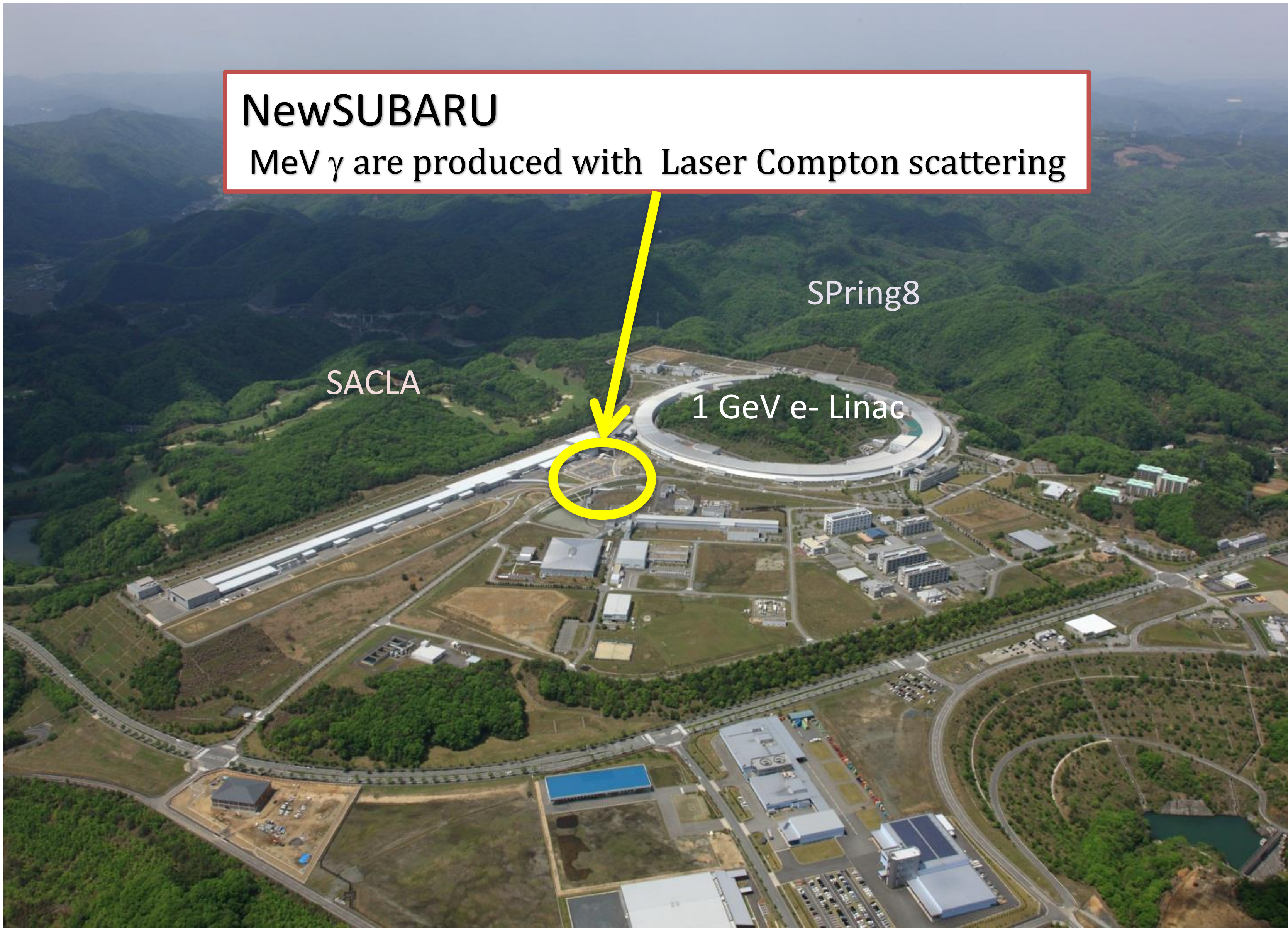
7 October 17

S. Q. Yan et al., Astrophysica J, **848**, 98 (2017).

Activities at Konan Univ.

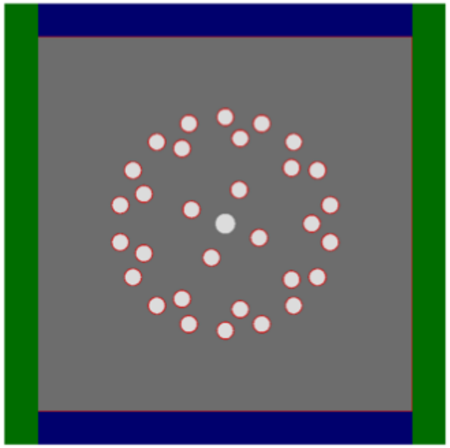
Photo-excitation and neutron emission cross section measurement at Spring-8

Hiroaki Utsunomiya
Konan University

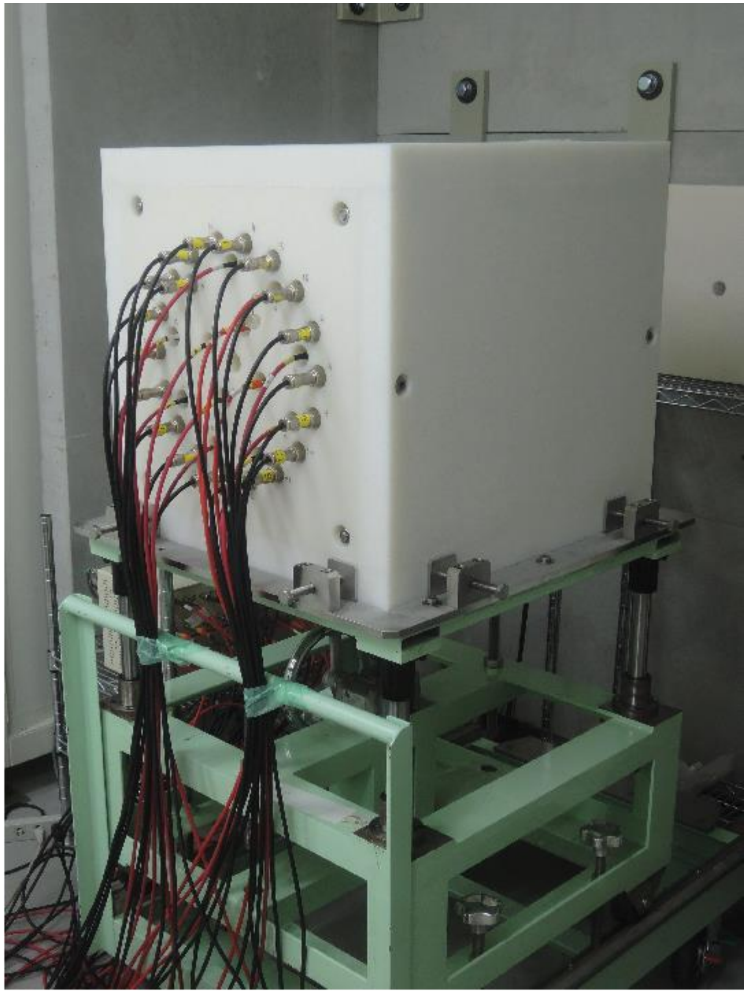

NewSUBARU
MeV γ are produced with Laser Compton scattering
SPring8
SACLA
1 GeV e- Linac

Flat-efficiency neutron detector

H. Utsunomiya et al., Nucl. Instrum. Meth. A 871 (2017) 135-141.



Configuration	^{3}He counters	Distance [cm]
Ring 1	4	5.5
Ring 2	9	13.0
Ring 3	18	16.0
Total	31	



Experiments at NewSUBARU in 2017

July 17 - 30 : (γ, xn) for 197Au, 169Tm, and 89Y

November 6 - 20: (γ, xn) for 197Au, 169Tm, and 89Y

December 4 – 18: (γ, n) for 184W, 183W, 182W, 68Zn, 66Zn, and 64Zn

Experiments at NewSUBARU in 2018

May 11 – June 9 : (γ, xn) for 159Tb, 139La, and 103Rh

July 17 – 31: (γ, n) for 156Gd, 157Gd, 158Gd, 160Gd

Publications

1. Neutron-multiplicity sorting
   2017

Nuclear Inst. and Methods in Physics Research, A 871 (2017) 135–141

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

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

Direct neutron-multiplicity sorting with a flat-efficiency detector

Hiroaki Utsunomiya[a,*], Ioana Gheorghe[b,c], Dan M. Filipescu[b], Tudor Glodariu[b], Sergey Belyshev[d], Konstantin Stopani[d], Vladimir Varlamov[d], Boris Ishkhanov[d], Seitarou Katayama[a], Daiki Takenaka[a], Takashi Ari-izumi[a], Sho Amano[e], Shuji Miyamoto[e]

2. 209Bi (γ,xn)
   2017

PHYSICAL REVIEW C 96, 044604 (2017)

Photoneutron cross-section measurements in the ^{209}Bi(γ,xn) reaction with a new method of direct neutron-multiplicity sorting

I. Gheorghe,[1,2] H. Utsunomiya,[3,*] S. Katayama,[3] D. Filipescu,[1,4] S. Belyshev,[5] K. Stopani,[6] V. Orlin,[6] V. Varlamov,[6] T. Shima,[7] S. Amano,[8] S. Miyamoto,[8] Y.-W. Lui,[9] T. Kawano,[10] and S. Goriely[11]

3. Photon-flux determination
   2018

Nuclear Inst. and Methods in Physics Research, A 896 (2018) 103–107

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

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

Photon-flux determination by the Poisson-fitting technique with quenching corrections

Hiroaki Utsunomiya[a,*], Takahumi Watanabe[a], Takashi Ari-izumi[a], Daiki Takenaka[a], Takeru Araki[a], Kazuya Tsuji[a], Ioana Gheorghe[b], Dan M. Filipescu[b], Sergey Belyshev[c], Konstantin Stopani[c], Dmytro Symochko[d], Hongwei Wang[e], Gongtao Fan[e], Therese Renstrøm[f], Gry M. Tveten[f], Yiu-Wing Lui[g], Kento Sugita[h], Shuji Miyamoto[h]

Activities at National Institutes for Quantum and Radiological Science and Technology (QST)

LCS Gamma-Ray Research Group
Contact: Toshiyuki Shizuma
shizuma.toshiyuki@qst.go.jp

Measurements of nuclear resonance fluorescence (NRF) using polarized photon beams

QST

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

Experimental Setup at NewSUBARU

Example

Electrons

Energy: 600-1500MeV

Current: Max.250mA

Laser

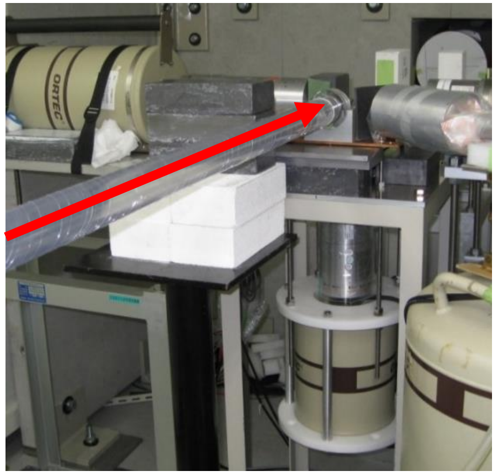
Nd:YVO_4 l=1064nm

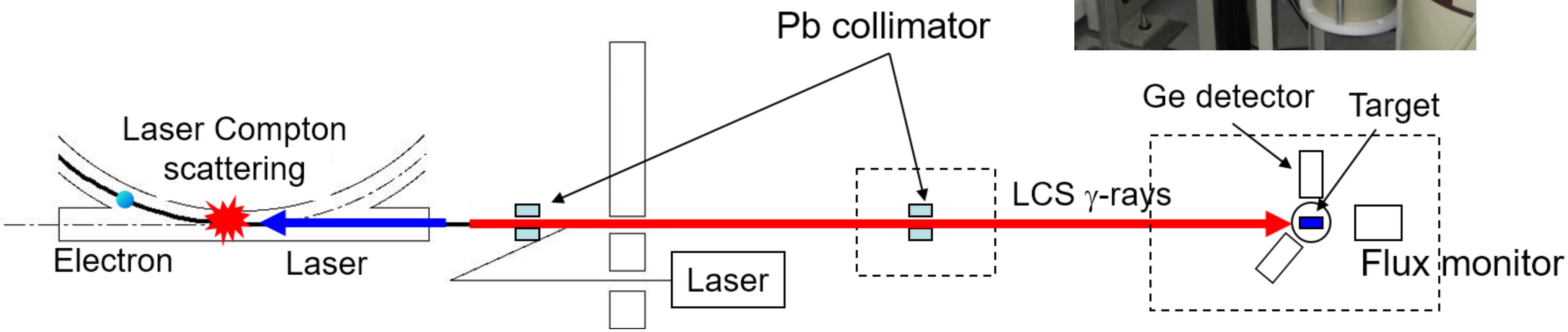
Power: 20W

LCS γ-ray beam

Max. energy: 6-39MeV

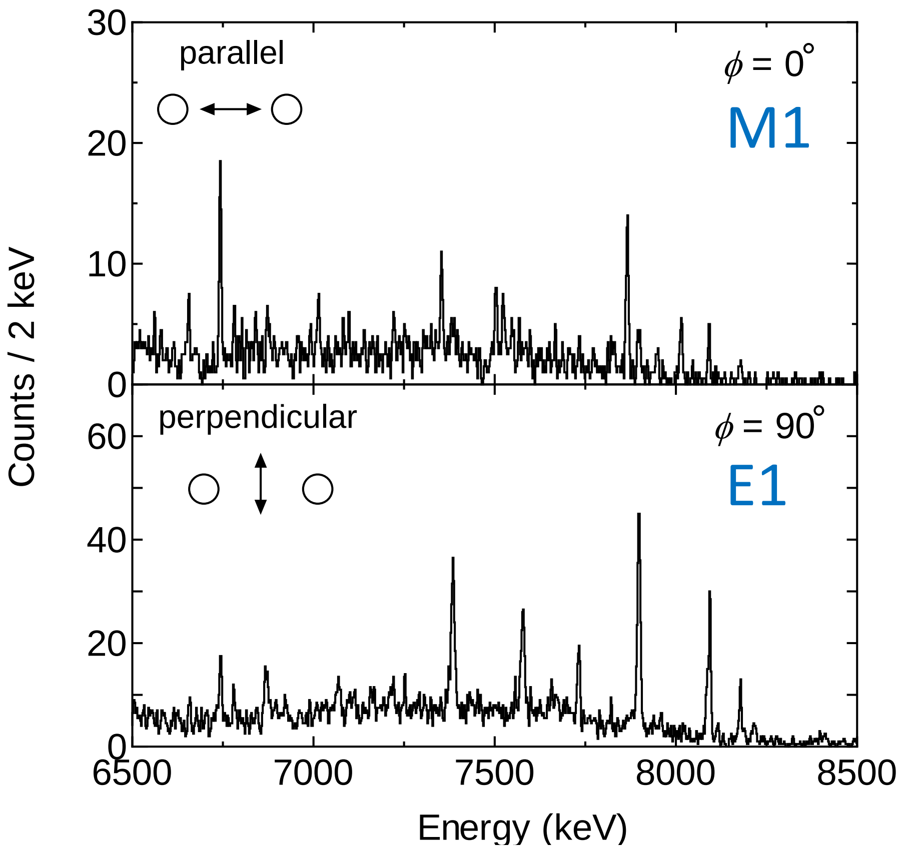
Ave. flux: ～6×10^5/s



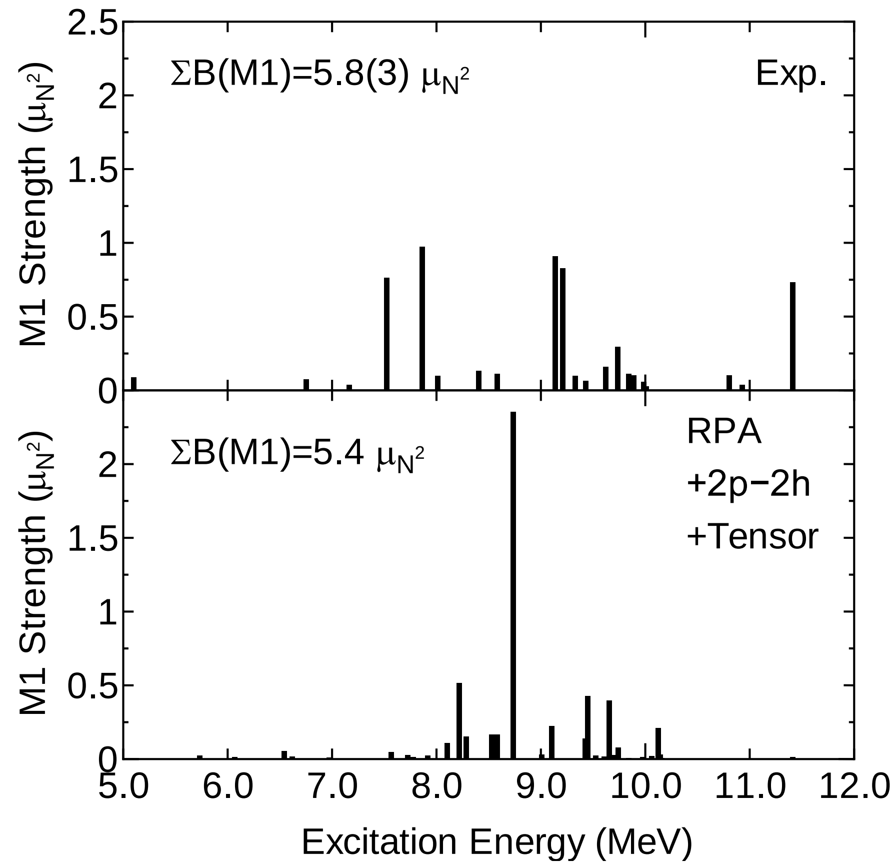


Results of NRF measurements for ^{52}Cr

Typical NRF spectrum



Measured M1 strength compared with RPA calculations



T.Shizuma et al., PRC 96, 044316 (2017).

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

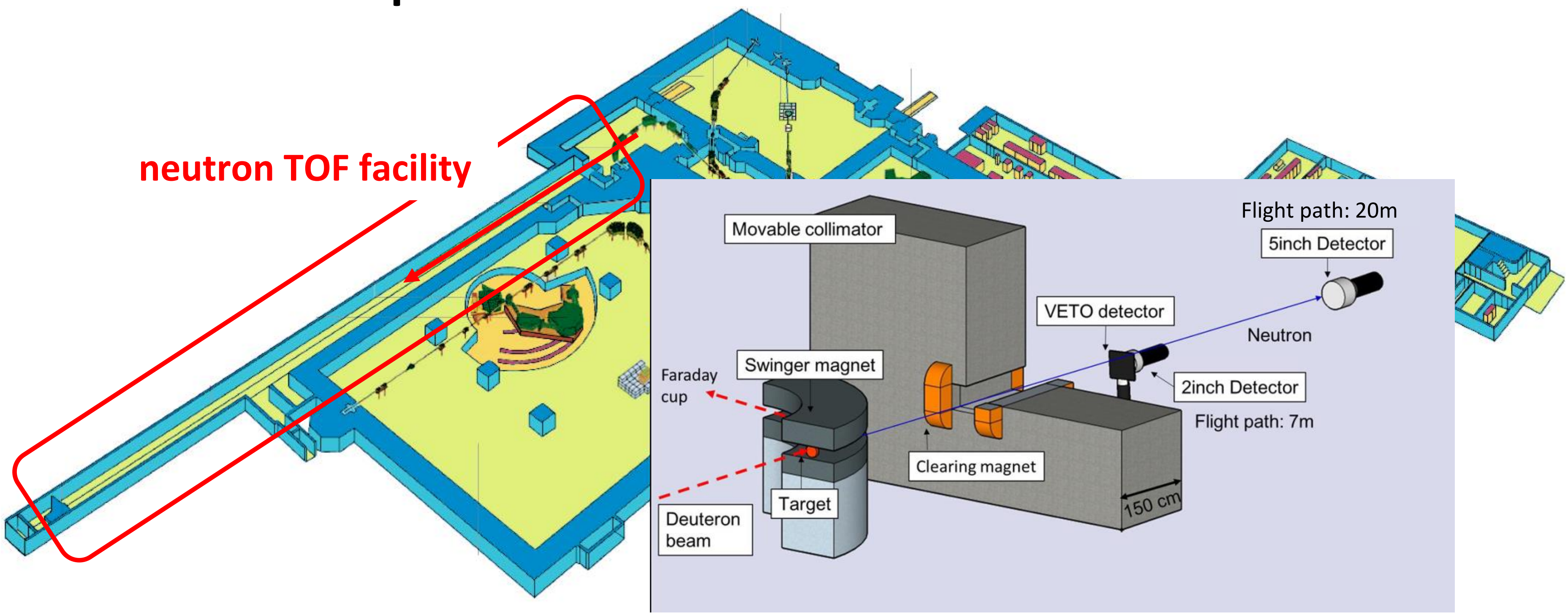
Contact person:

Yukinobu Watanabe, Kyushu University

Experiment @RCNP, Osaka U.

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**

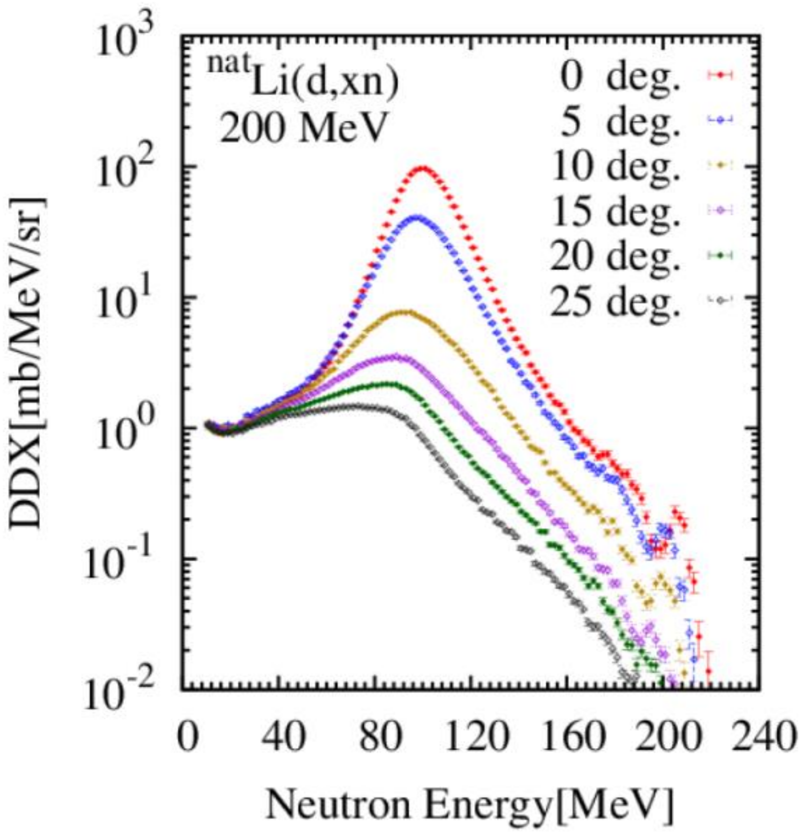


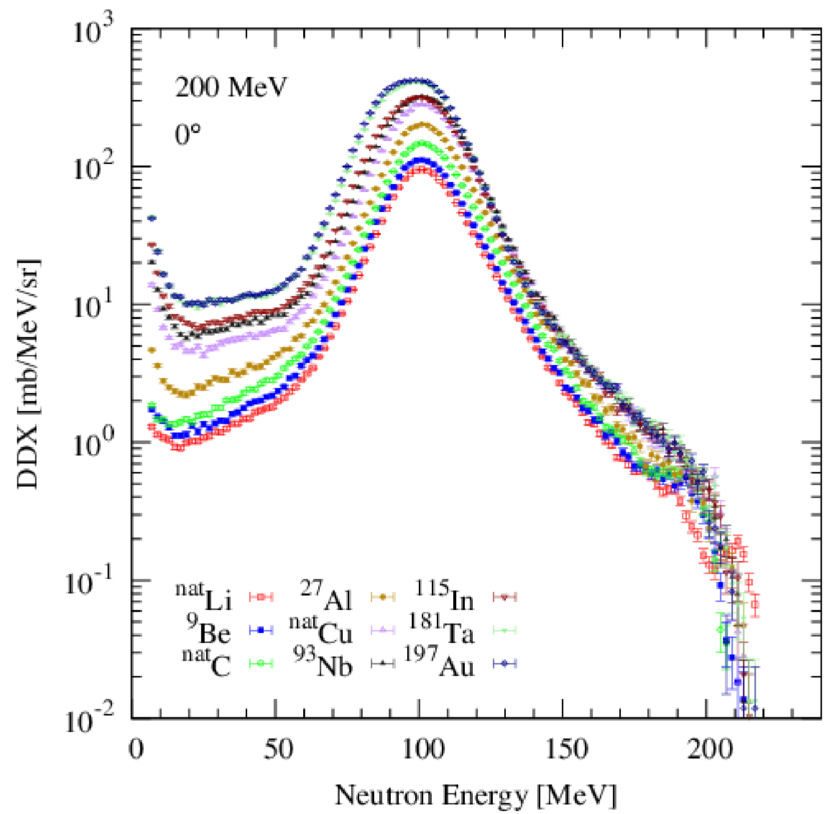
Experimental setup in the neutron TOF facility @ RCNP, Osaka U

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

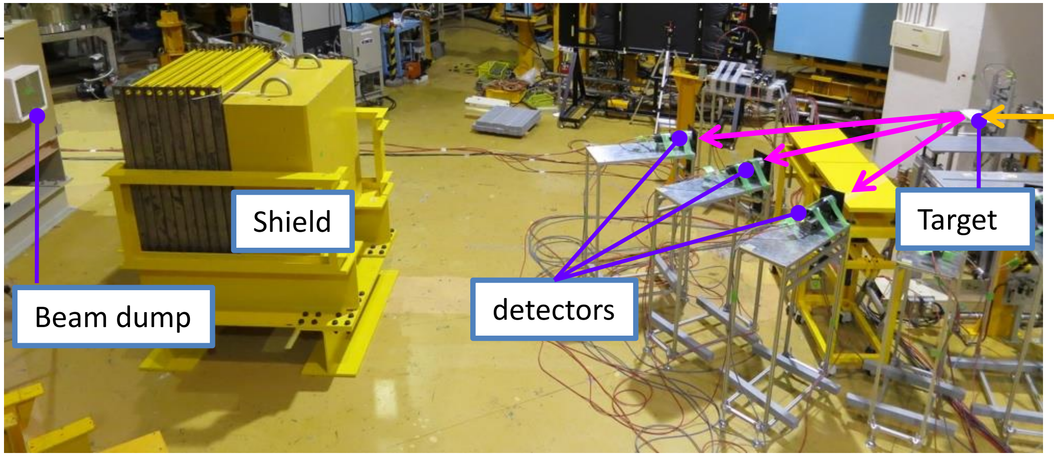
Neutron DDX and TTY from Heavy-Ion Interactions @ QST-NIRS-HIMAC

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

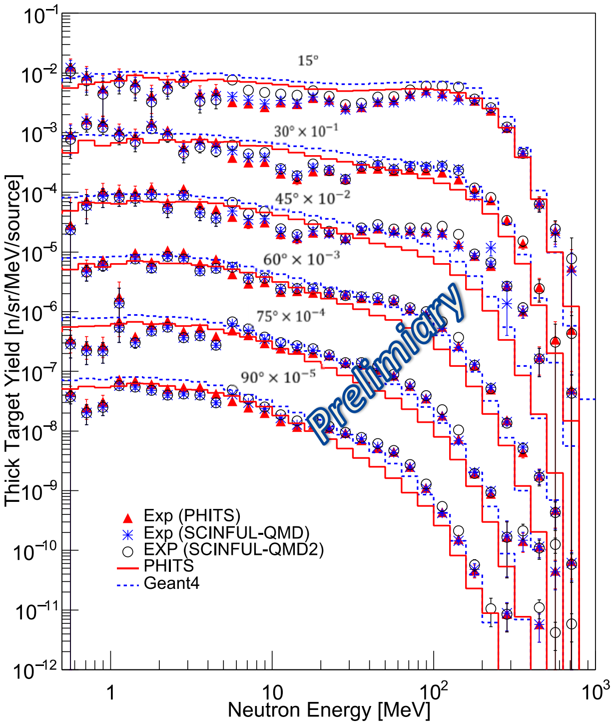
- Systematic neutron cross sections and thick target yields for shielding design

- HIMAC PH2 beam line
- Beam: 100, 290 MeV/u Si, ~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˚



Experimental setup at HIMAC



290 MeV/u Si(Si, xn) TTY