Japanese Activities in Nuclear Data Measurement

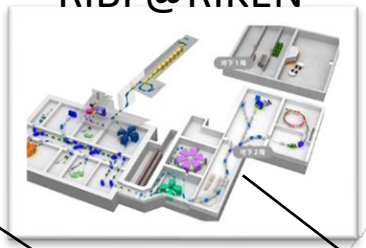
Atsushi Kimura

Japan Atomic Energy Agency

Nuclear Data Measurement in Japan

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

RIBF@RIKEN



TIARA @ QST

CYRIC@Tohoku Univ.

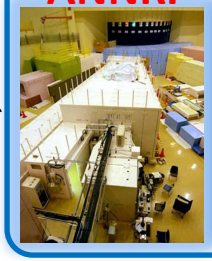
New Subaru

Osaka Univ.

RCNP

OKTAVIAN

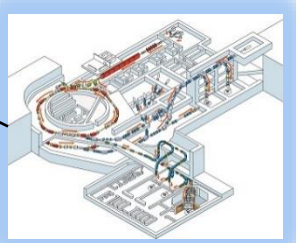
ANNRI



Tandem

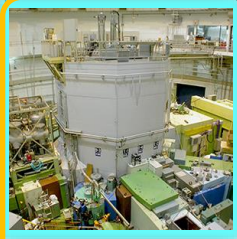
JRR-3

JAEA



HIMAC@QST

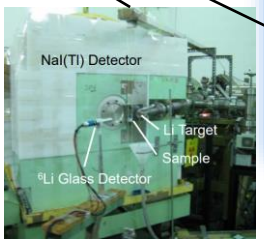
Tandem@Kyusyu Univ.



KUR

LINAC

Kyoto Univ.



Pelletron@TIT

Activities by J-PARC・MLF・ANNRI collaboration in 2019

Japan Atomic Energy Agency

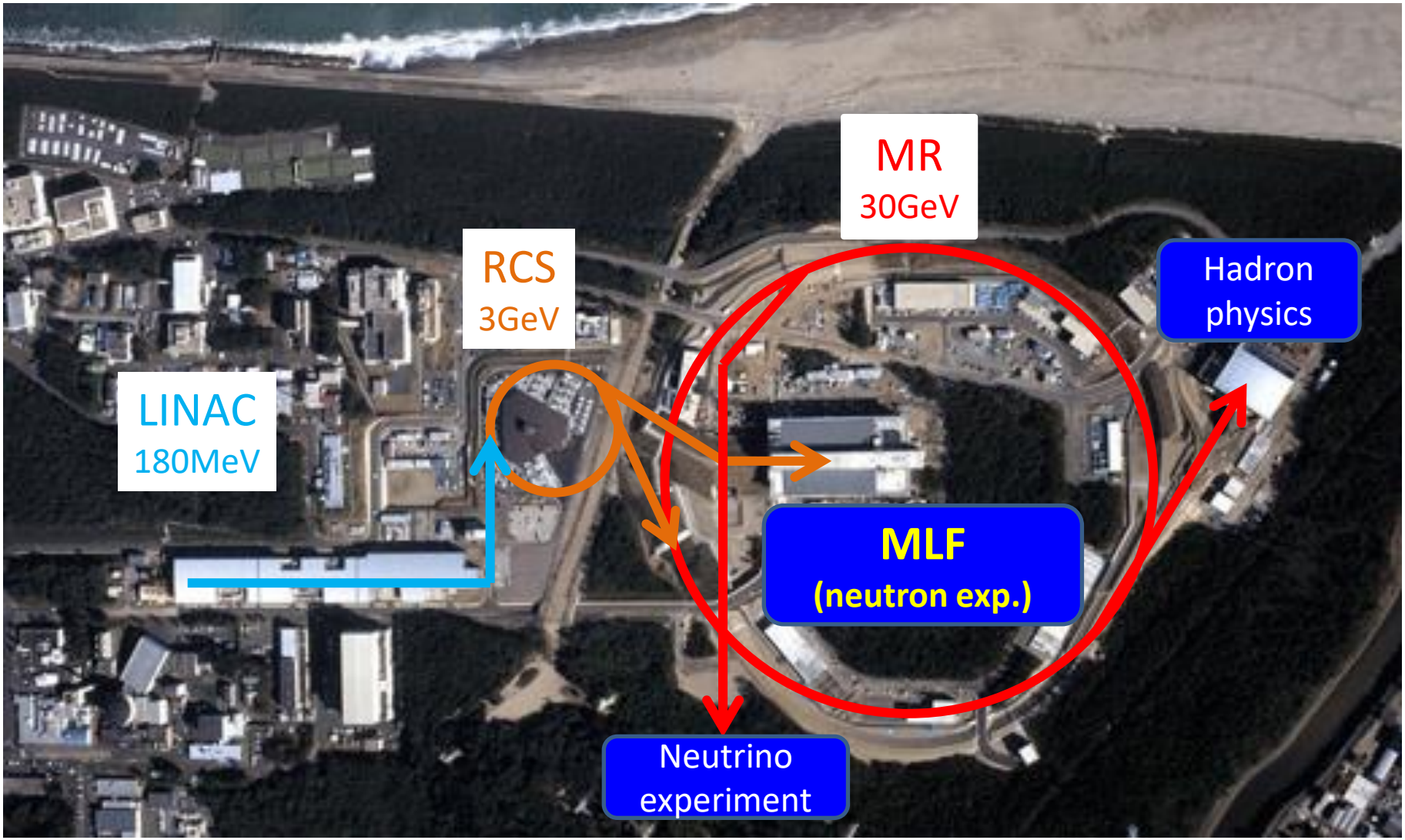
Tokyo Institute of Technology

Kyoto Univ.

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

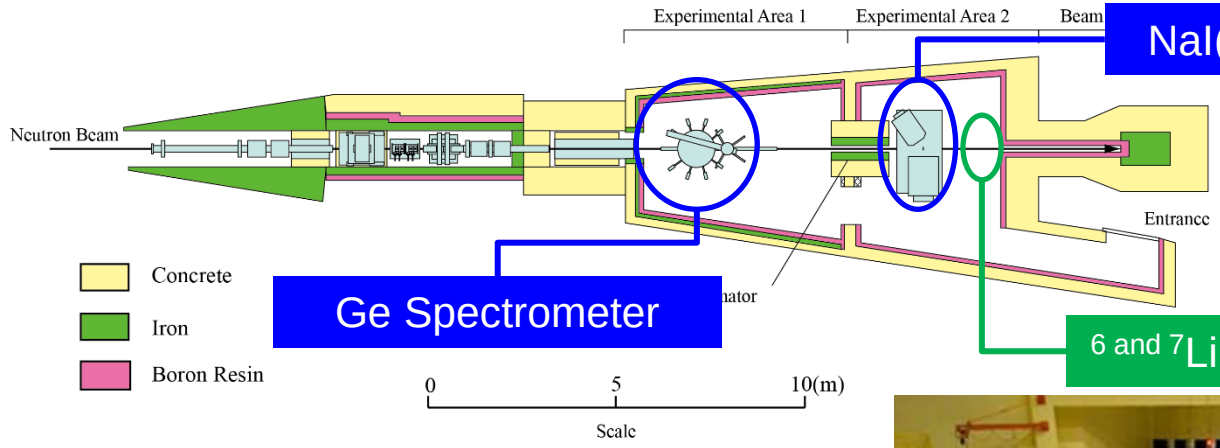
Facility

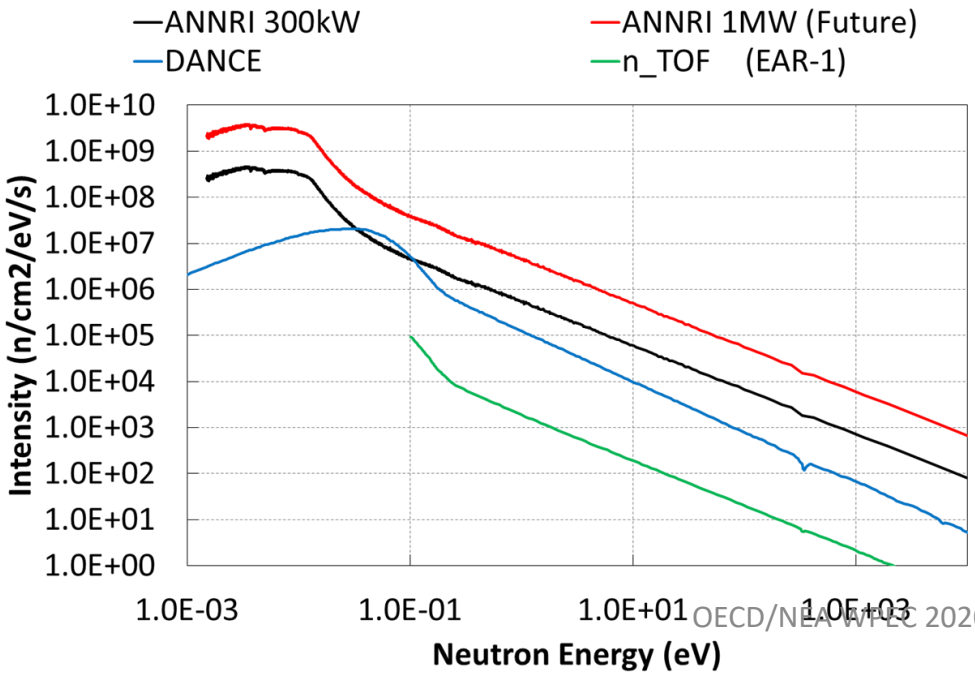
J-PARC：Japan Accelerator Research Complex



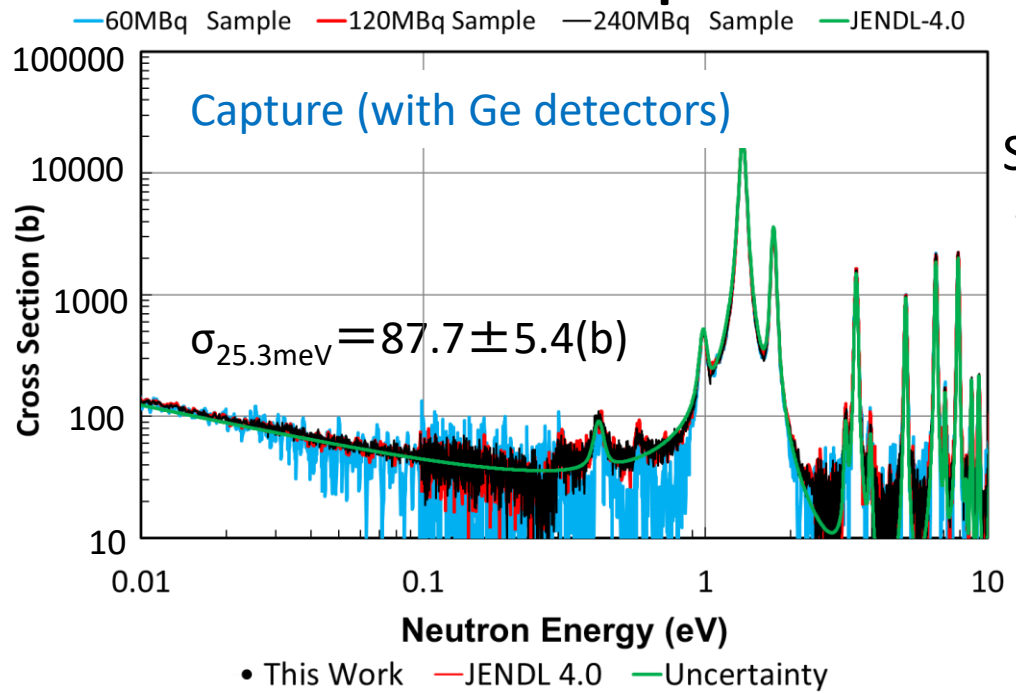
ANNRI

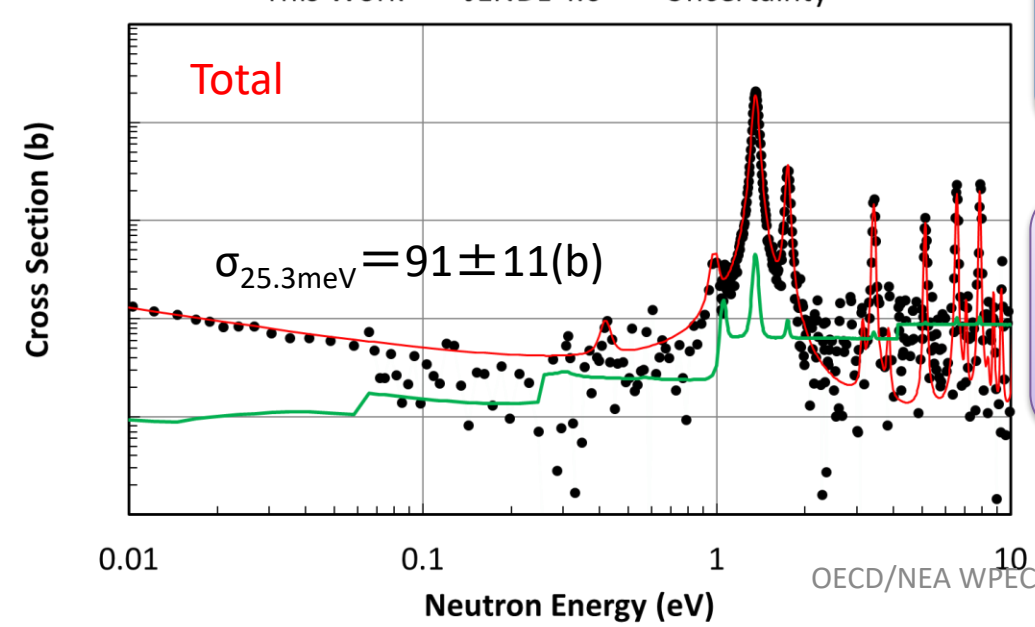
ANNRI (Accurate Neutron Nucleus Measurement Instrument)





Total and Capture cross section of ^{243}Am





A. Kimura, et. Al.,
JNST, Vol.56, No.6, pp.479-492

Sample:
^{243}Am 67.3, 155.8m, 281.8 [MBq]

Absolute capture cross section at the 1.356 eV resonance was derived by taking ratios of the capture yields.

Capture: 10meV～100eV
$\sigma_{25.3meV}$=87.7±5.4(b)
⇒10% Higher than JENDL 4.0
→Activation Experiment ongoing!

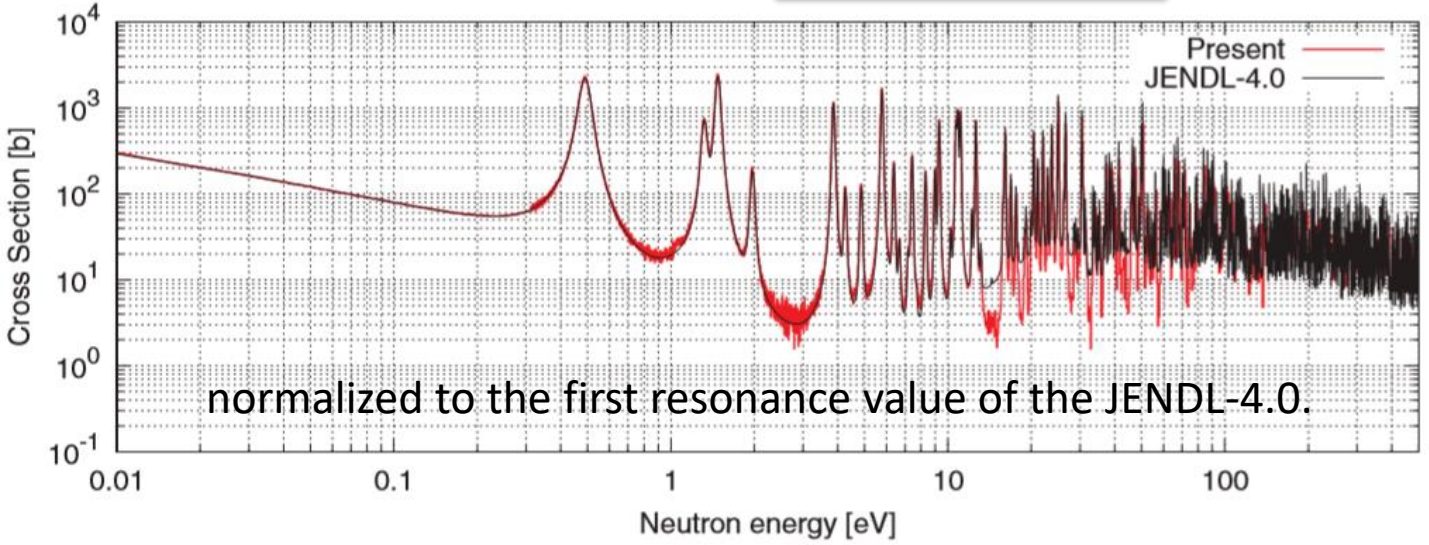
Total: 10meV~2eV
$\sigma_{25.3meV}$=91±11(b)
⇒Neutron Intensity: 7.4b

Neutron capture cross section of ^{237}Np

The capture cross-section of ^{237}Np has been measured in the energy range from 10 to 500 eV.

Sample: ^{237}Np 200mg 5[MBq]

NaI detectors



	$\sigma_{25.3meV}$ (b)
This Work	177.6±3.8
Esch (2008)	177±5
Hirose (2013)	176.6±5.3
JENDL 4.0	178.1

Averaged radiation width: 40.3±0.5meV
s-wave mean level spacing: 0.60±0.2eV
Neutron strength function (10^4S_0): 1.02±0.12

The present values are in agreement with the previous literature.

Gerard Rovira, J. Nucl. Sci. Technol., 2019, https://doi.org/10.1080/00223131.2019.1651231

Activities at the other beam lines.

Noboru (BL10)

Neutron Total cross section of powder diamond for cold neutrons

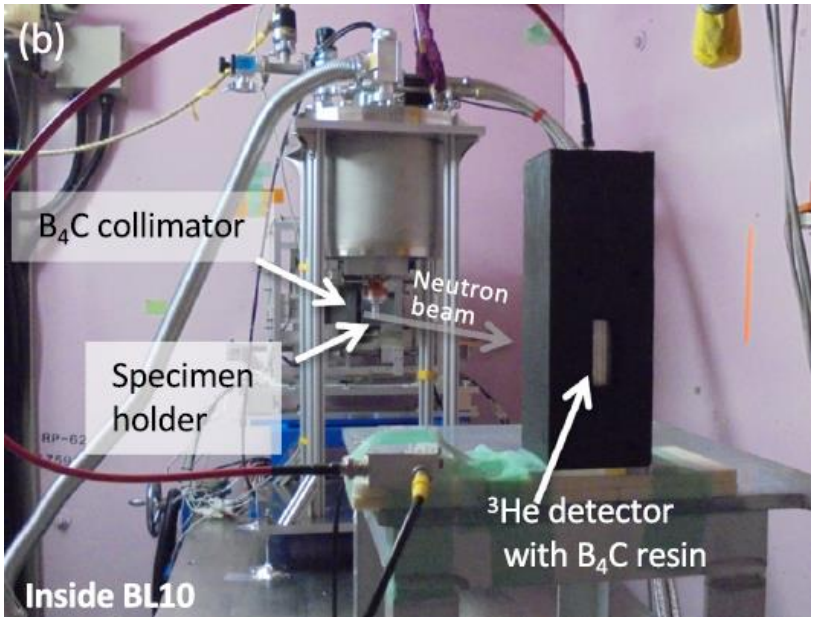
Sample:

Powder of Diamond

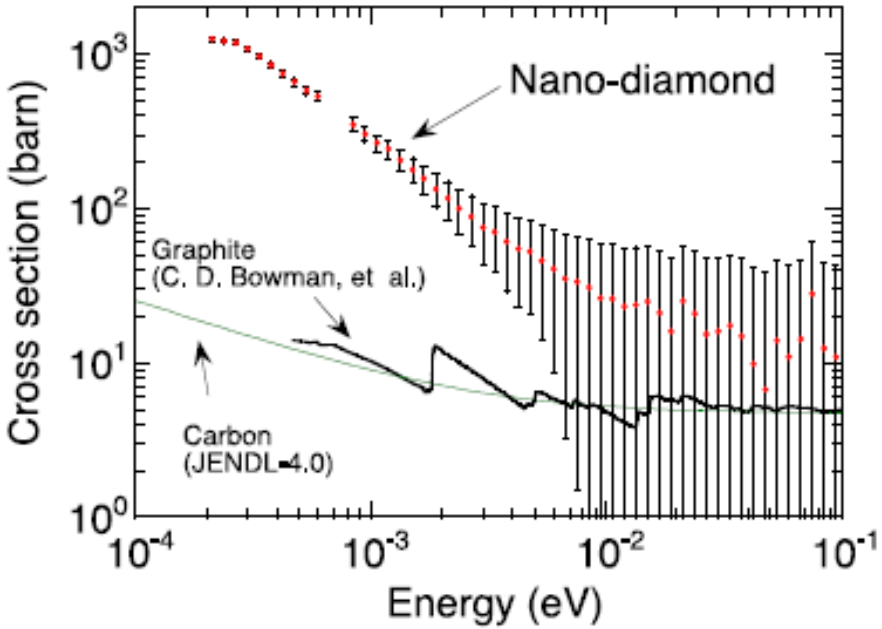
Size: 5.1nm

weight: 0.0375g

Set up:



Result:



Total cross sections of nano-diamond.
The cross sections of carbon (JENDL-4.0) and graphite (C. D. Bowman et al.) are shown for comparison.

M. Teshigawara, Y. Tsuchikawa, G. Ichikawa et al. NIM, A 929 (2019) 113–120

Activities at JAEA Tandem Accelerator Facility

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

20 MV

Equipment at the JAEA Tandem Accelerator Facility

(1) Stable, high resolution, and sharp pencil beam

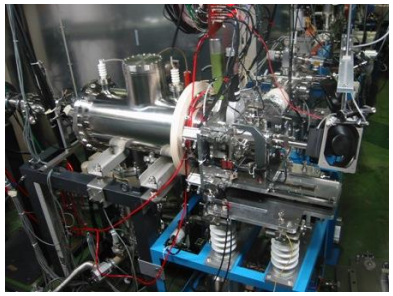
(2) Many radioactive target materials can be used

【Available】 ^{232}Th, ^{233,235,238}U, ^{237}Np, ^{239,240,244}Pu, ^{241,243}Am, ^{248}Cm, ^{249}Bk, ^{249,250,251}Cf, ^{254}Es

【Planned】 ^{226}Ra, ^{232}U, ^{252}Cf

Booster
(super-conducting linac)

(3) Unique setups



Isotope Separator On-Line

Spontaneous fission,
α-γ decay study

Recoil Mass Separator

Search for N=Z nuclei beyond ^{100}Sn

Magnetic spectrograph

Astrophysical ^{7}Li problem

Prompt Fission Setup

In-beam fission measurement

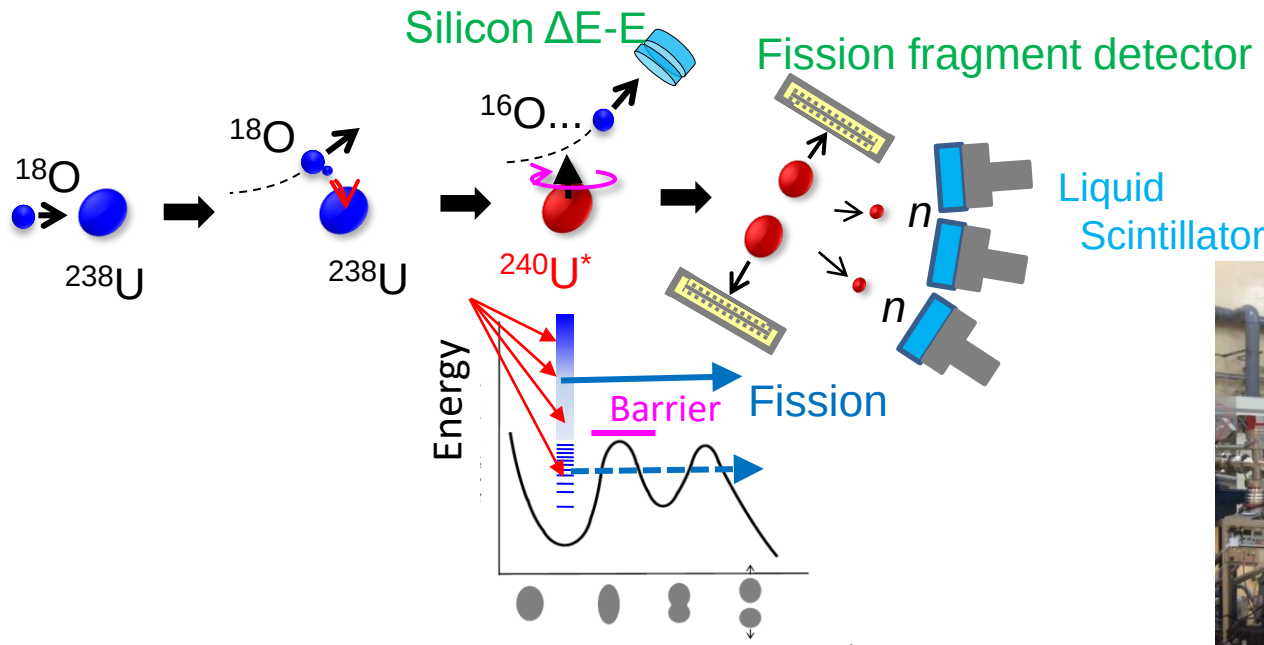
Surrogate Reactions for Fission Data

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.
- 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

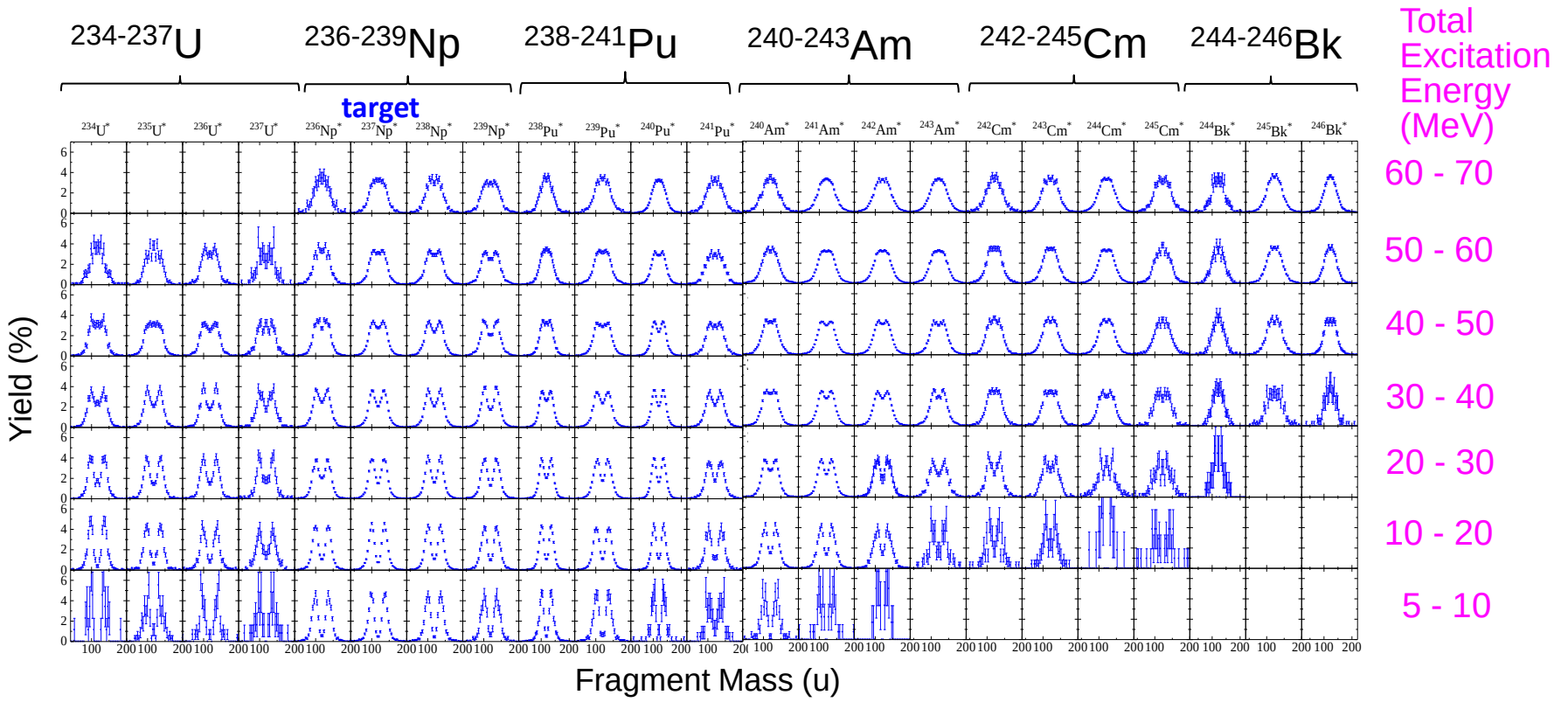
- Fission cross sections
- Fission fragment mass and angular distribution
- Prompt neutron multiplicity and energy spectra



R. Léguillon *et al*., Phys. Lett. B **761,** 125 (2016).

Selected Results

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

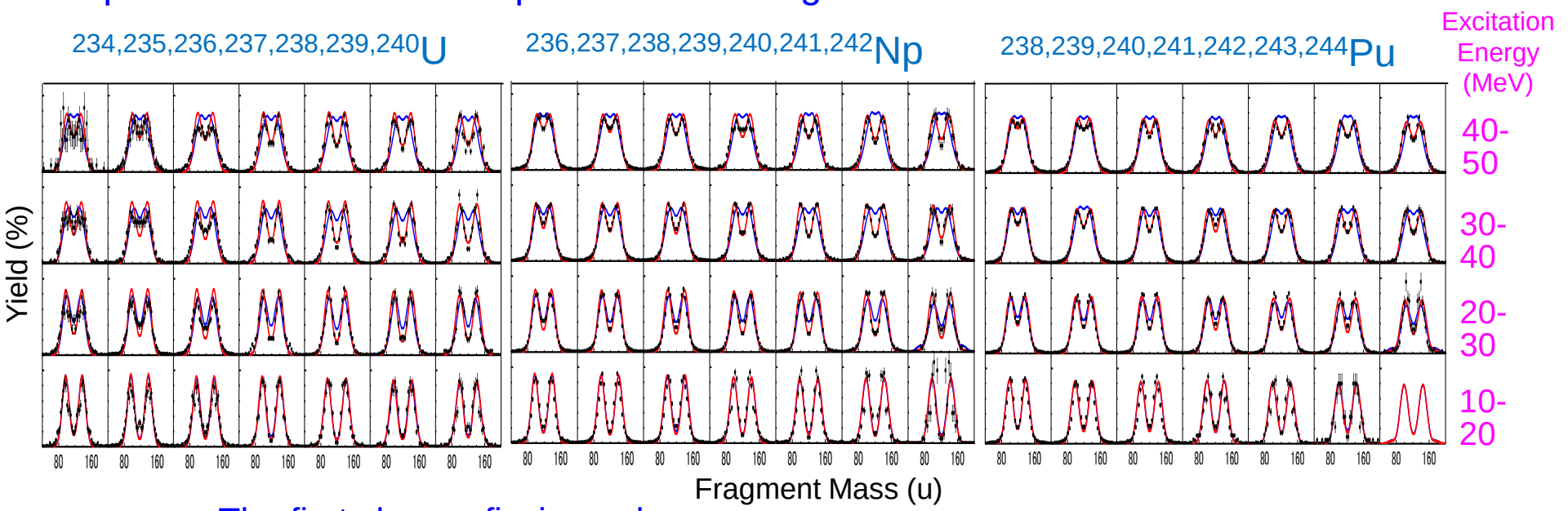


Fission data for 23 nuclides are obtained in the single experiment.

M.J. Vermeulen et al., submitted to Phys. Rev. C.

Selected Results

Experimental Data in Comparison with Langevin Calculation



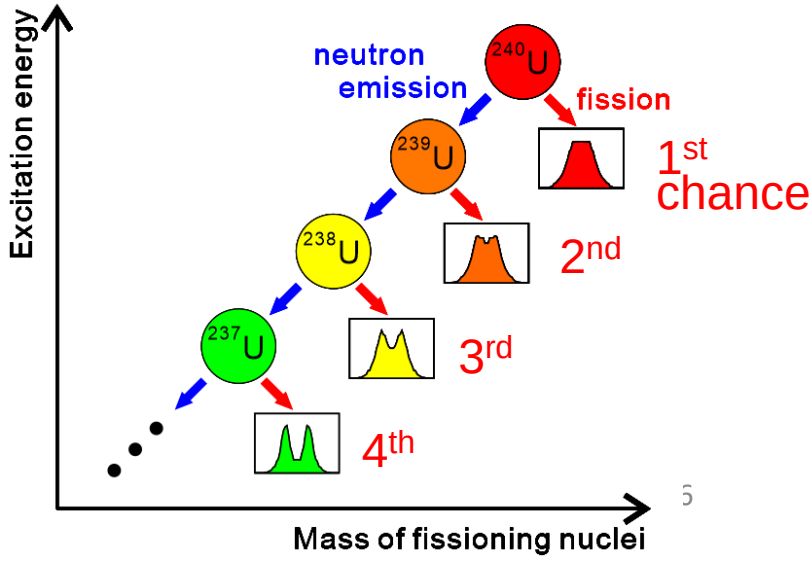
The first chance fission only

With multi-chance fission

Experimental data

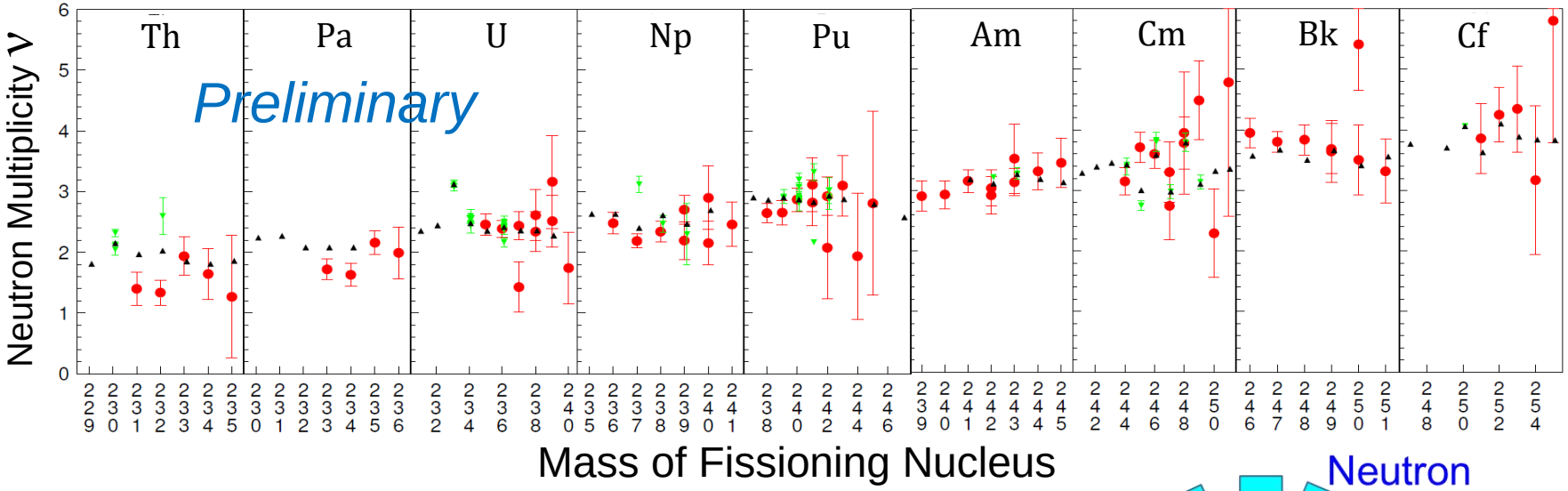
Data from $^{18}O+^{232}Th$, ^{238}U, ^{237}Np

"Effects of multichance fission on isotope dependence of fission fragment mass distribution at high energies"
S. Tanaka et al., Phys. Rev. C, **100**, 064605 (2019).

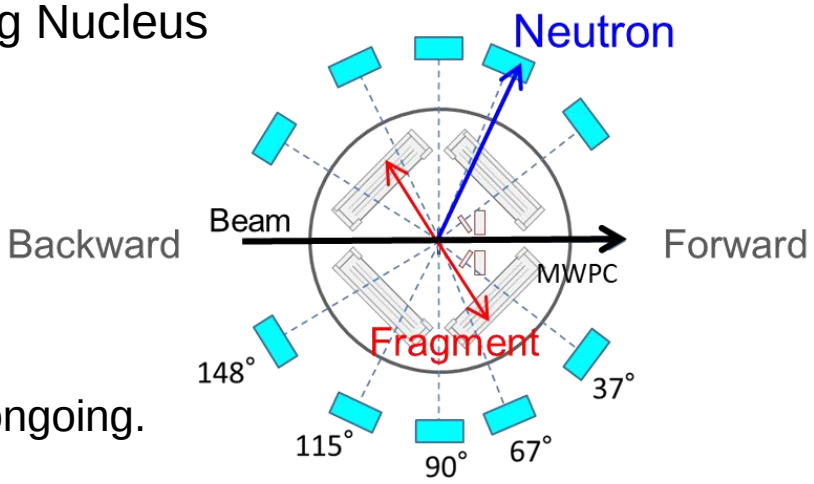


Selected Results

Prompt neutron multiplicity at low energy fissions, Eex ~ Bn



- Present
  - $^{18}O + ^{232}Th$
  - $^{18}O + ^{238}U$
  - $^{18}O + ^{237}Np$
  - $^{18}O + ^{243}Am$
  - $^{18}O + ^{248}Cm$
- JENDL-4.0
- Literature Data



33 Liquid scintillator detectors
(ø5" x t 2")

Analysis to find out the origin of prompt neutrons is ongoing.
(1) Pre-scission neutrons
(2) Neutrons from fragments.

Neutron Capture Cross Section Measurements at KURNS

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

Team:

Japan Atomic Energy Agency
Kyoto Univ.

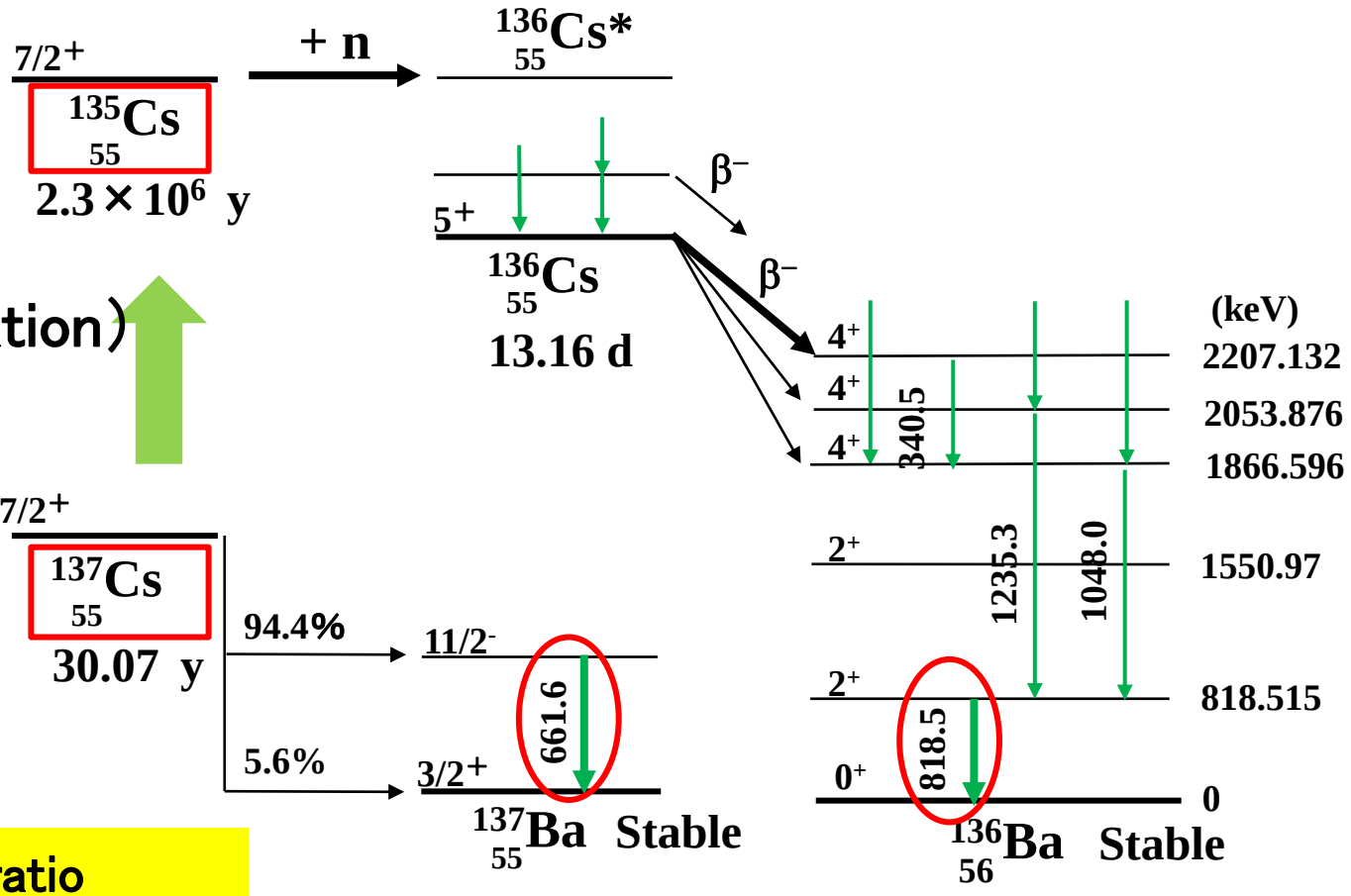
Contact:

Shoji Nakamura, JAEA

Activation Measurement of Cs-135

Utilizing Cs-135 contained in a Cs-137 standard sol.
Derive of the capture cross section of Cs-135
by measuring decay γ-rays emitted from 2 nuclides

- Cs-137 stad. sol.
(Japan RI Association)



$^{135}Cs/^{137}Cs$ Isotope ratio
0.868±0.004
0.5% Uncertainty with TIMS

Experimental Results

S.Nakamura *et al.* Journal of Nuclear Scienece and Technology, 2020, Vol.57, No.4, 388–400.

- The present result of thermal-neutron capture cross section σ_0 was in agreement with the past reported data by Katoh(1997).
- The resonance integral I_0 was 25% smaller than the evaluated value adopted in JENDL-4.0.

	Present Work	JENDL-4.0 (2010)	Katoh (1997)	Baerg (1958)	Sugarman (1949)
σ_0 (b)	8.57±0.25	8.302	8.3±0.3	8.7±0.5	14.5±4*
I_0 (b)	45.3±3.2	53.52	37.9±2.7	61.7±2.3	
Cut-off Energy (eV)	0.133	0.5	0.55	0.5	

*Effective Cross-Section

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

Team:

a) Department of Applied Quantum Physics and Nuclear Engineering, Kyushu University
b) Hiroshima University
c) National Institute of Radiological Sciences of National Institute for Quantum and Radiological Science and Technology
d) Sungkyunkwan University

Contact:

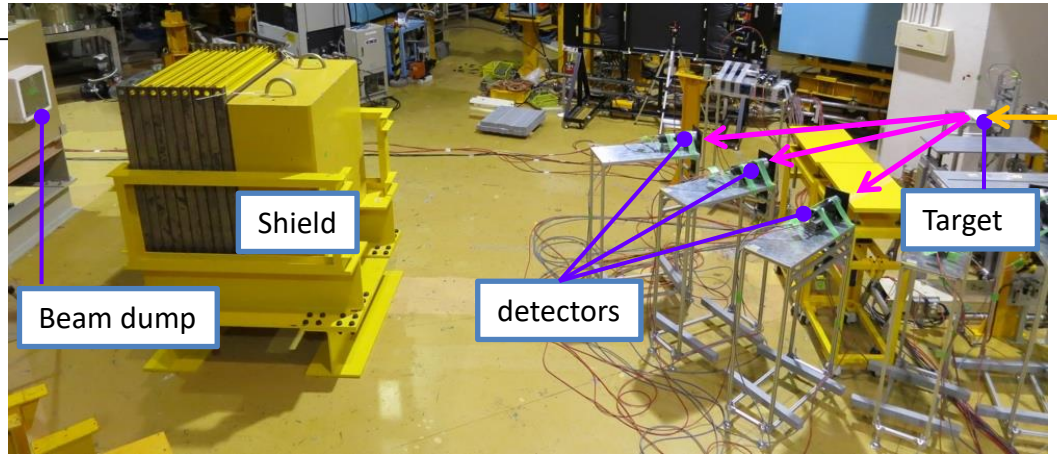
Nobuhiro SHIGYO, Kyushu University

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

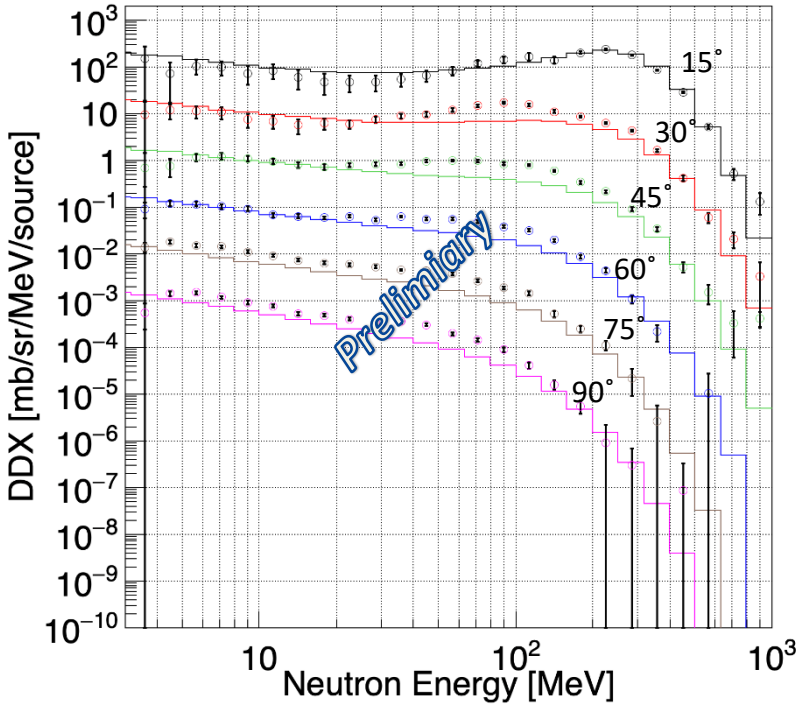
- Kyushu U., Hiroshima U., QST-NIRS, Sungkyunkwan U, Myongji U

- Systematic neutron cross sections for shielding design

- HIMAC PH2 beam line
- Beam: 290 MeV/u ^{132}Xe ~10^5 pps
- Target: Nb, Bi
- Detection: NE213, EJ301 + TOF
- Directions: 15˚ - 90˚



Experimental setup at HIMAC

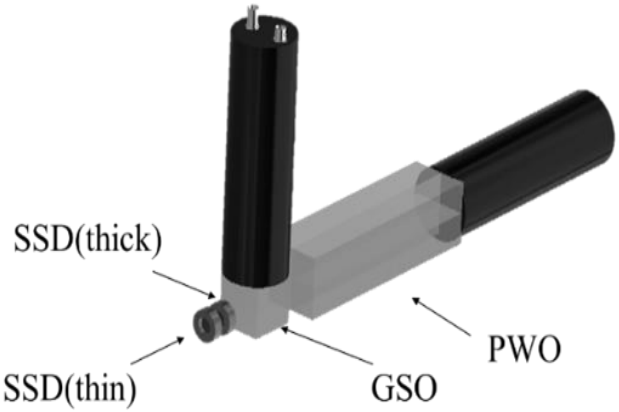


290 MeV/u ^{132}Xe(Nb, xn) DDX

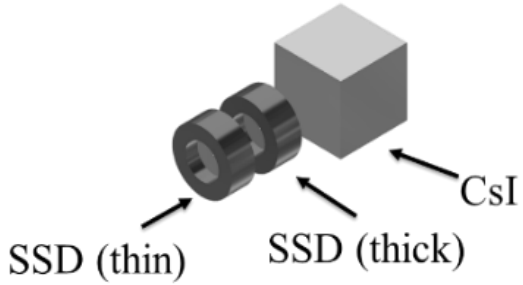
Charged particle emission reactions induced by 100-MeV/u ^{12}C ions@ HIMAC

Contact:

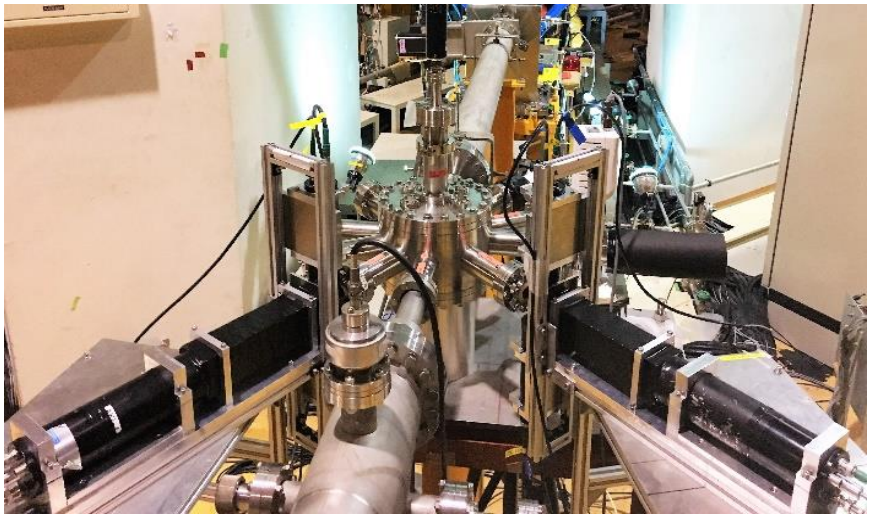
Y.Uozumi, Kyushu University



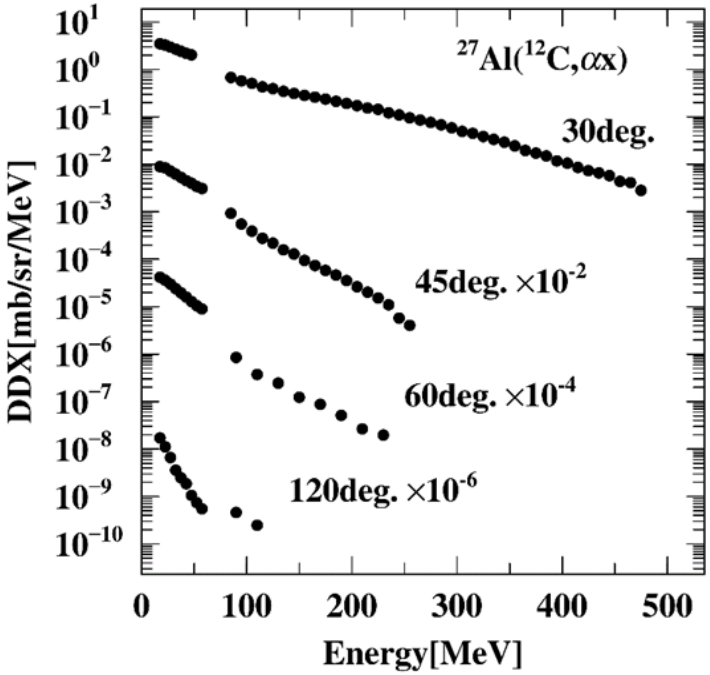
Telescope for p, d, t, ^{3}He, and α.



Telescope for particles heavier than αparticle.



Setup of vacuum chamber and detectors at PH2 course of HIMAC experimental hall.



DDXs of ^{27}Al(^{12}C, αx) reaction.

Isotope production in proton-, deuteron-, and carbon-induced reactions on ^{93}Nb at 113 MeV/nucleon in Riken RI beam

Contact person:
Yukinobu Watanabe, Kyushu University

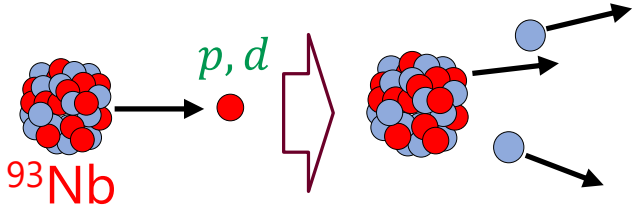
In collaboration with the members from RIKEN, Tokyo Institute of Tech., U. of Tokyo, U. of Miyazaki, Hokkaido U., and Rikkyo U., under ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan)

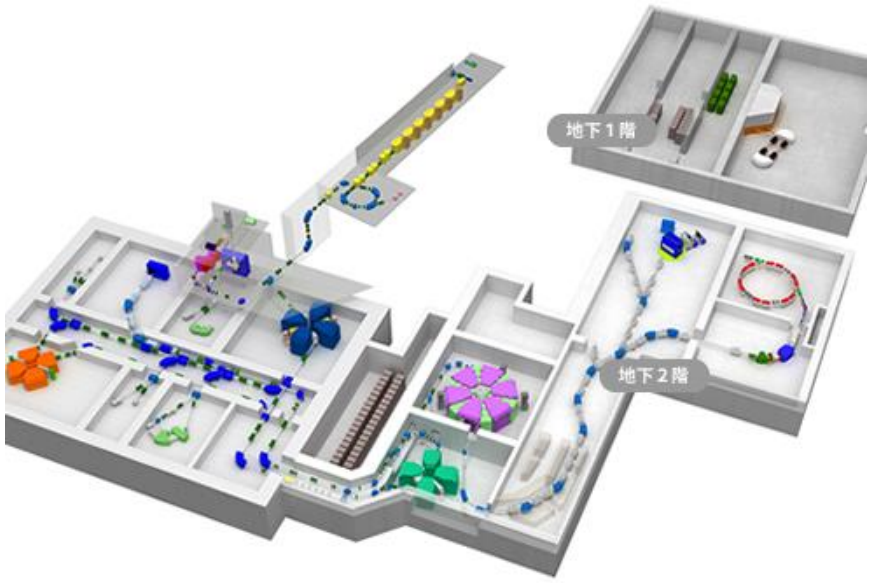
Ref.) K. Nakano, Y. Watanabe, S. Kawase et al, Phys. Rev. C **100**, 044605 (2019).
K. Nakano, Doctoral dissertation , Kyushu University (2020).

Experiment @RIKEN

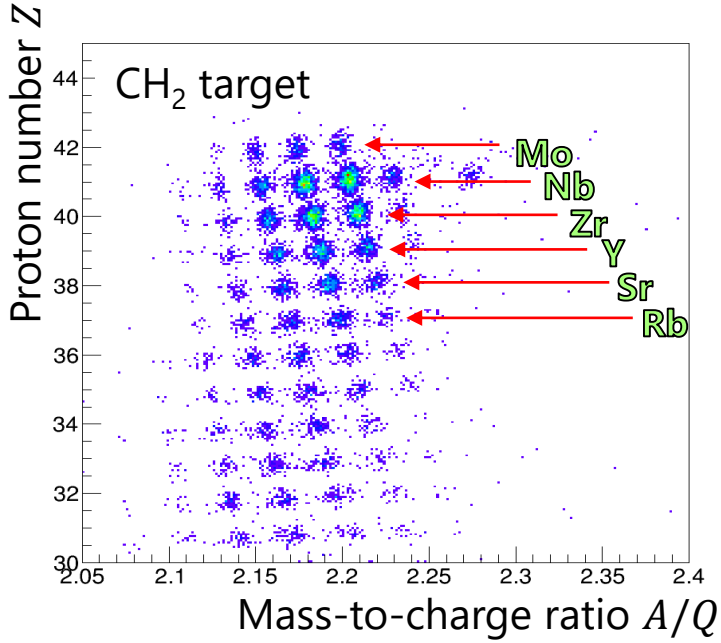
Measurement of isotope production cross section for spallation reactions using the inverse kinematic method:

- **Facility: RIKEN RI Beam Factory (RIBF)**
- **Primary beam: ^{93}Nb**
- **Secondary targets: CH_2, CD_2, C**
- **Experimental apparatus: BigRIPS, ZeroDegree Spectrometer**
- **Particle identification: TOF-Bρ-ΔE method**



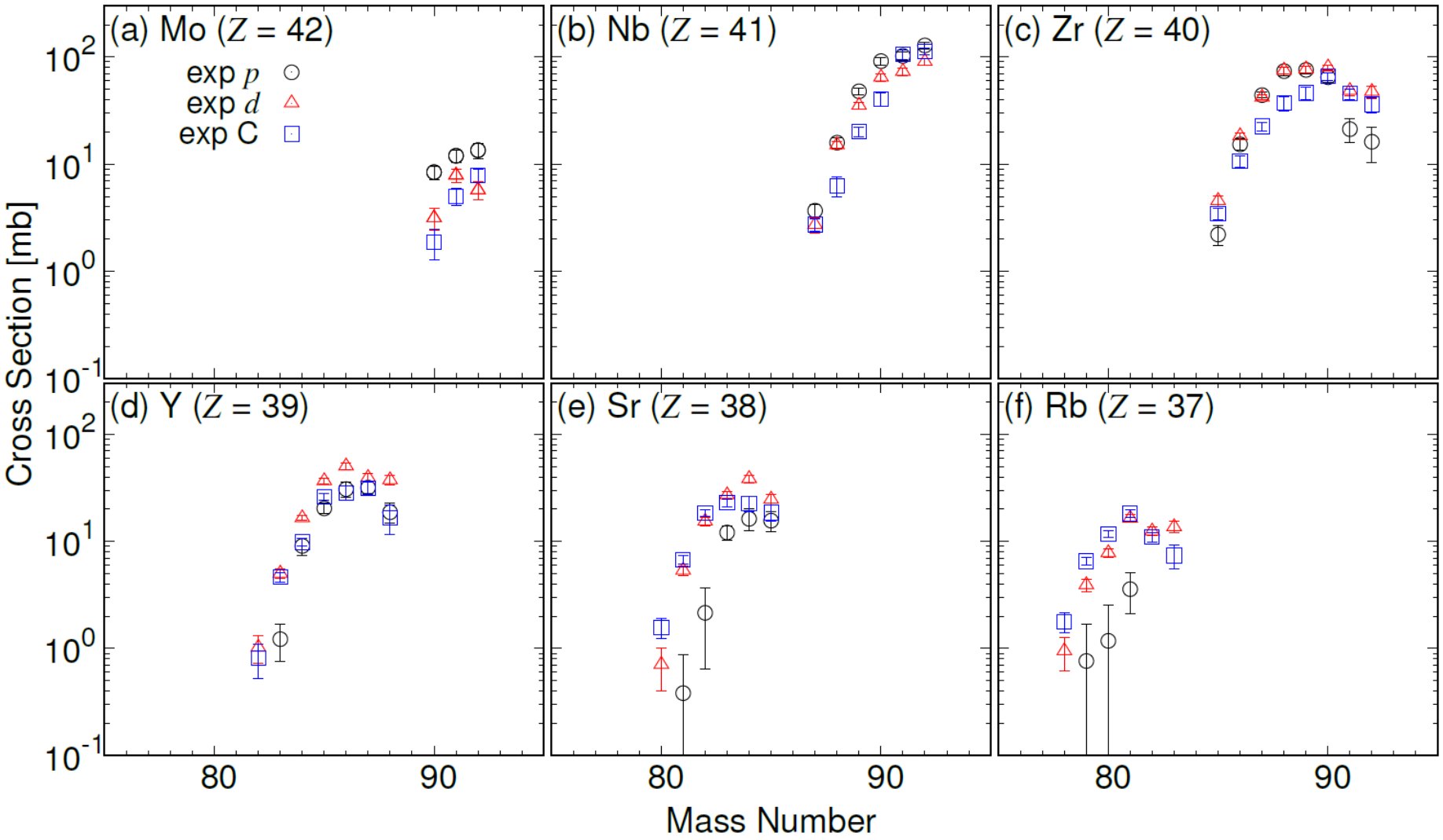


Overview of RIBF



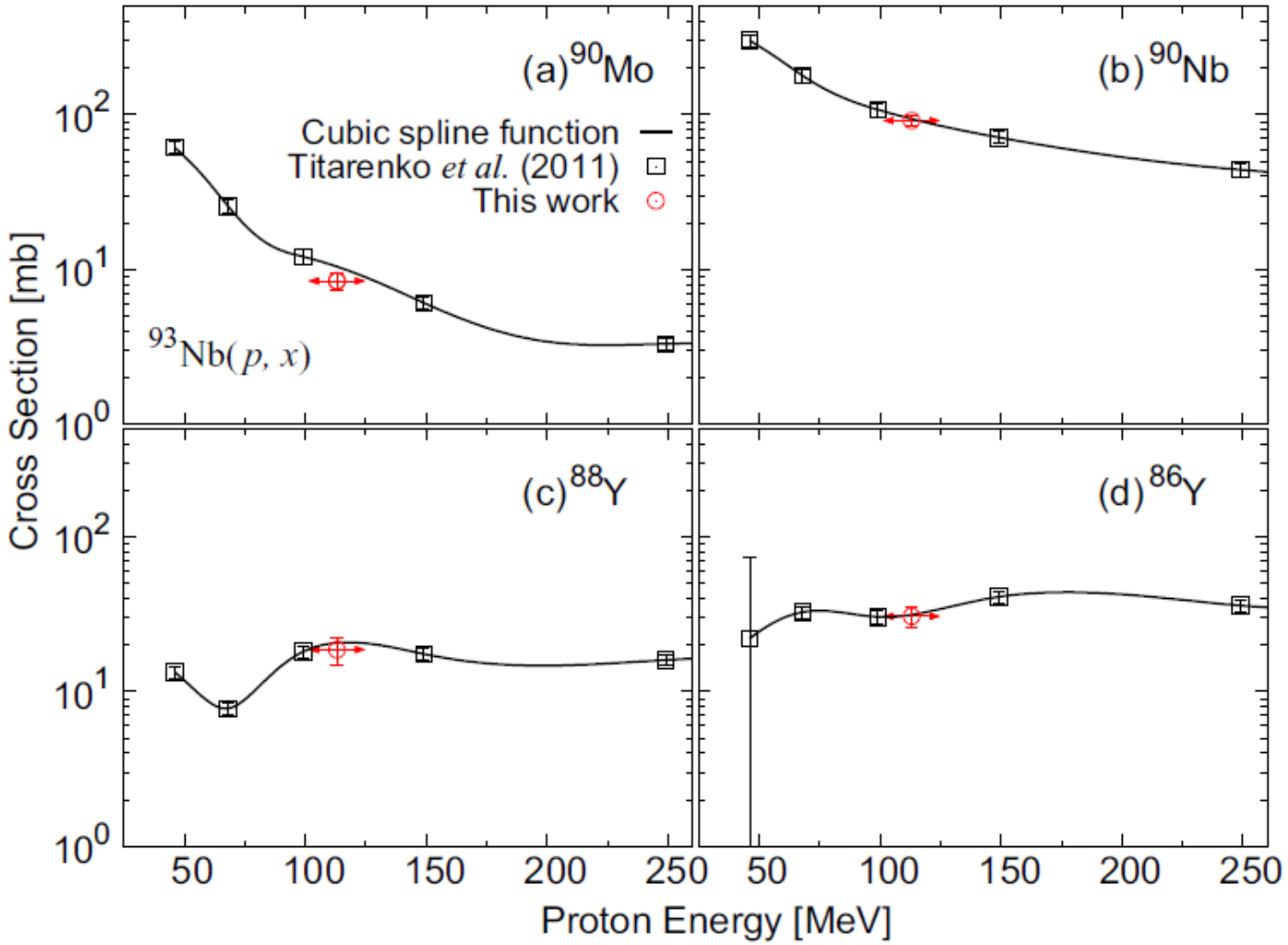
Particle identification plot for the reaction products from the CH_2 target

Experimental Result (I)



Measured isotope-production cross sections for ^{93}Nb + *p*, *d*, and C reactions at 113 MeV/nucleon

Experimental Result (II)



Comparison between data measured by the inverse kinematics method and by the activation method (Titarenko et al.) for the production cross sections of the p + ^{93}Nb reaction. The black lines connect the activation data denoted by black squares with cubic spline functions.

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 and unpolarized photon beams

Facilities:

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

NRF takes place via only electro-magnetic interaction:

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


SPring8
SACLA
1 GeV e- Linac
NewSUBARU
MeV γ

Experimental Setup at NewSUBARU

Example

Electrons

Energy: 600-1500MeV

Current: Max.250mA

Laser

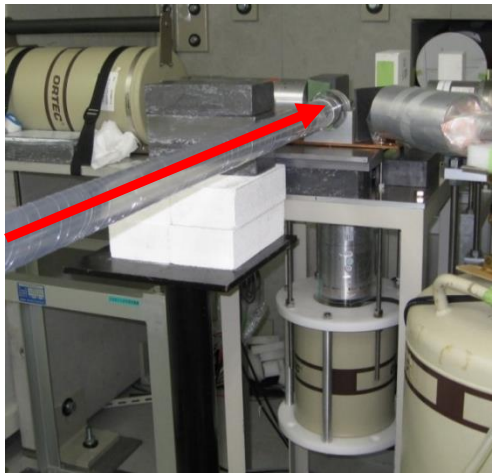
Nd:YVO_4 l=1064nm

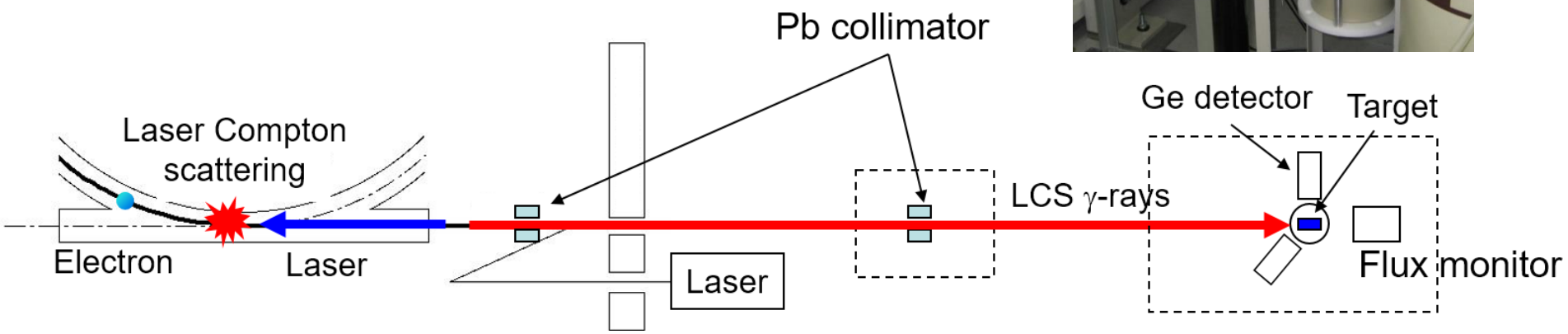
Power: 20W

LCS γ-ray beam

Max. energy: 6-39MeV

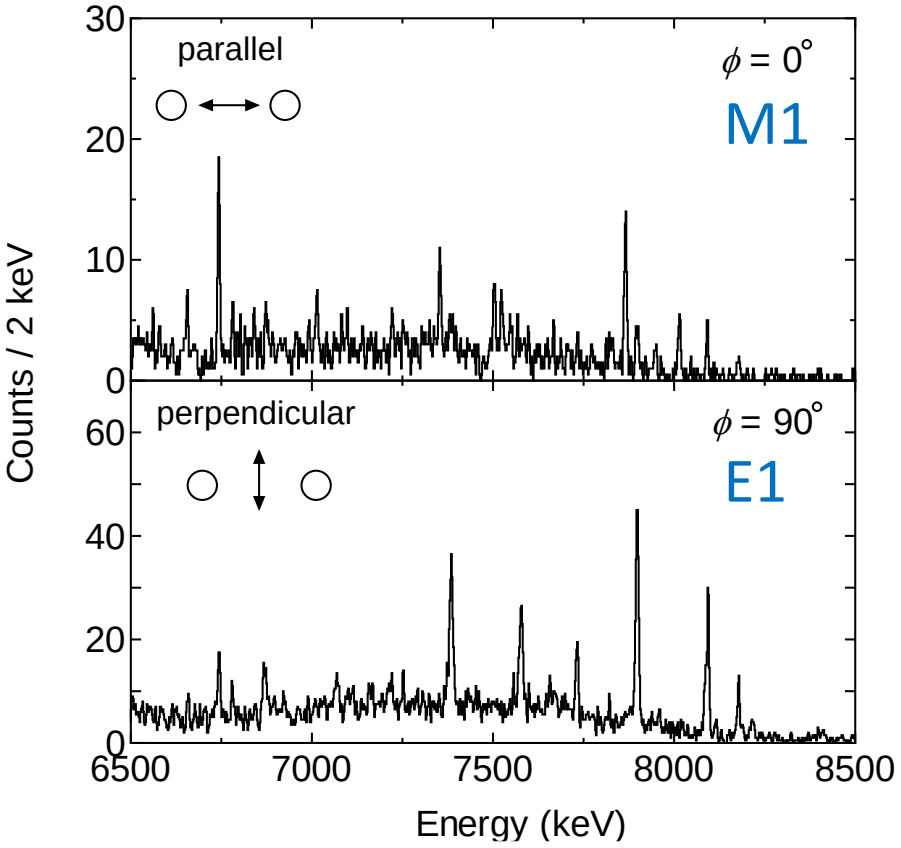
Ave. flux: ～6×10^5 /s



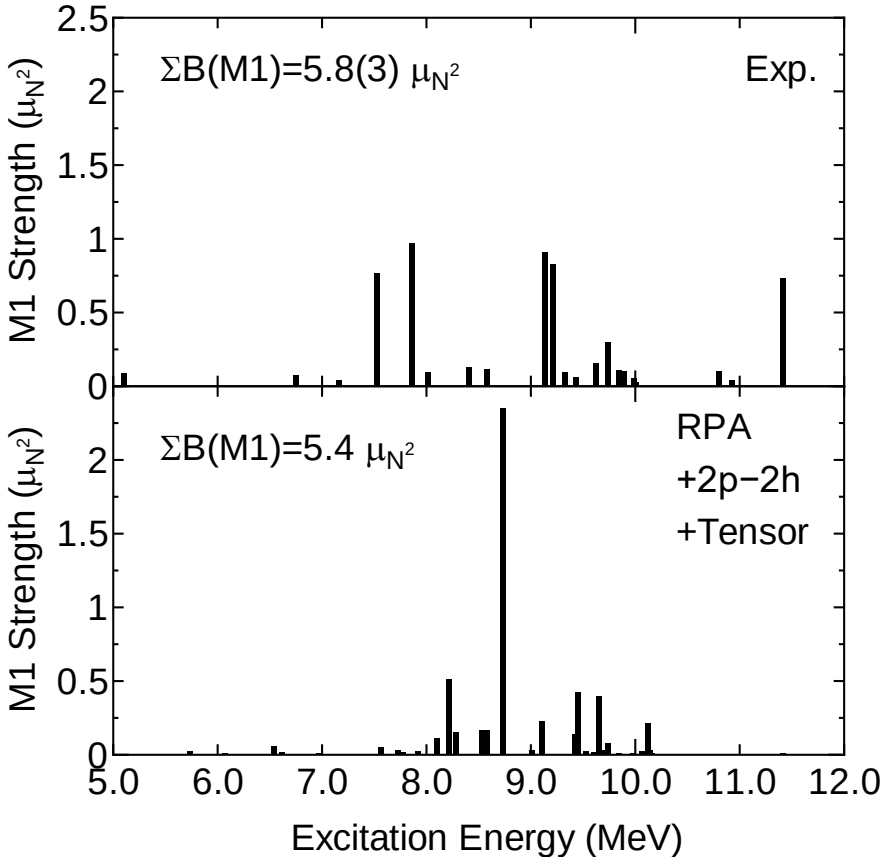


NRF measurements at NewSUBARU

Typical NRF spectrum for ^{52}Cr



Measured M1 strength compared with RPA calculations



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

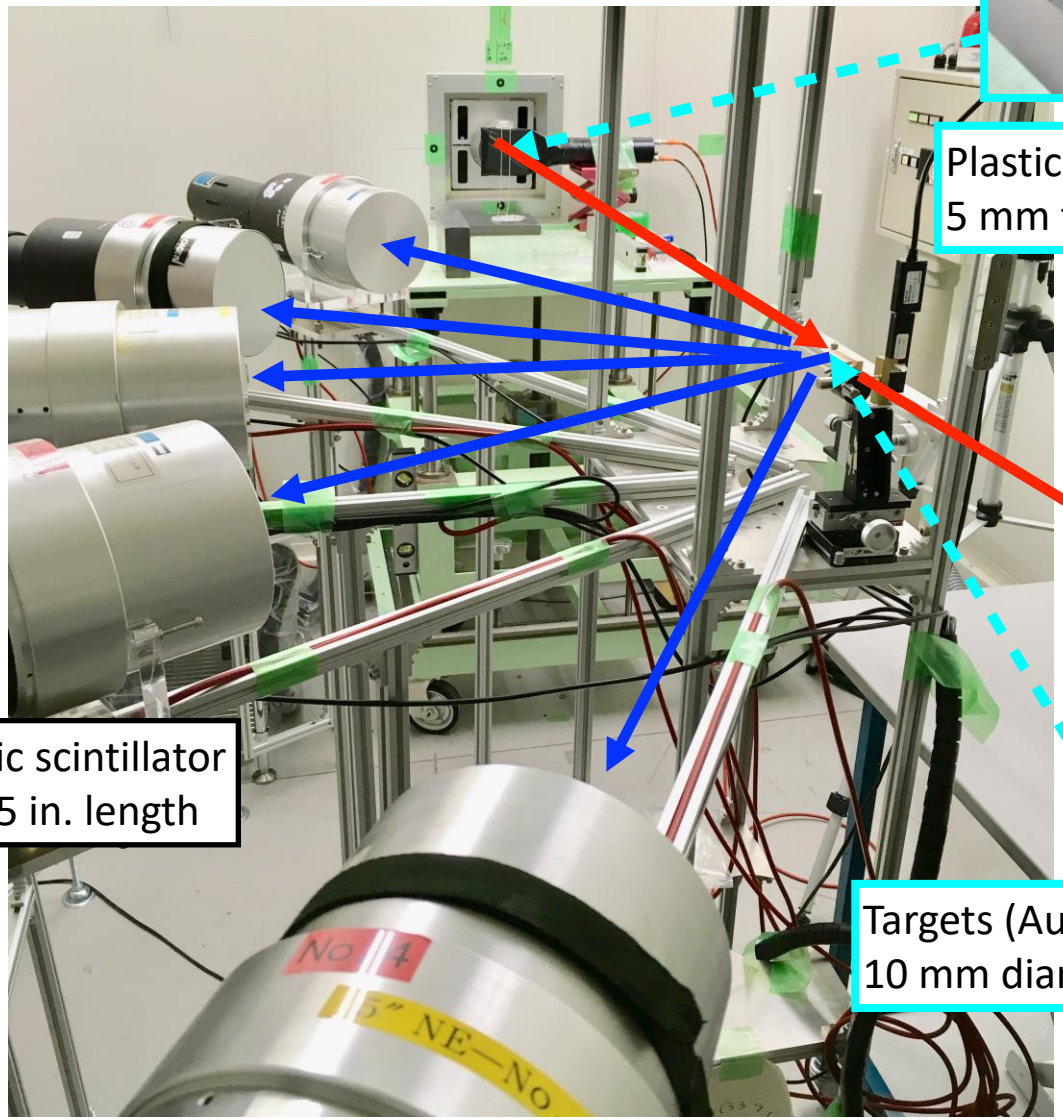
Status of photo neutron spectrum measurement for mono-energetic polarized photon

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



Optics hutch 2

90 degrees,
70 cm flight path

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

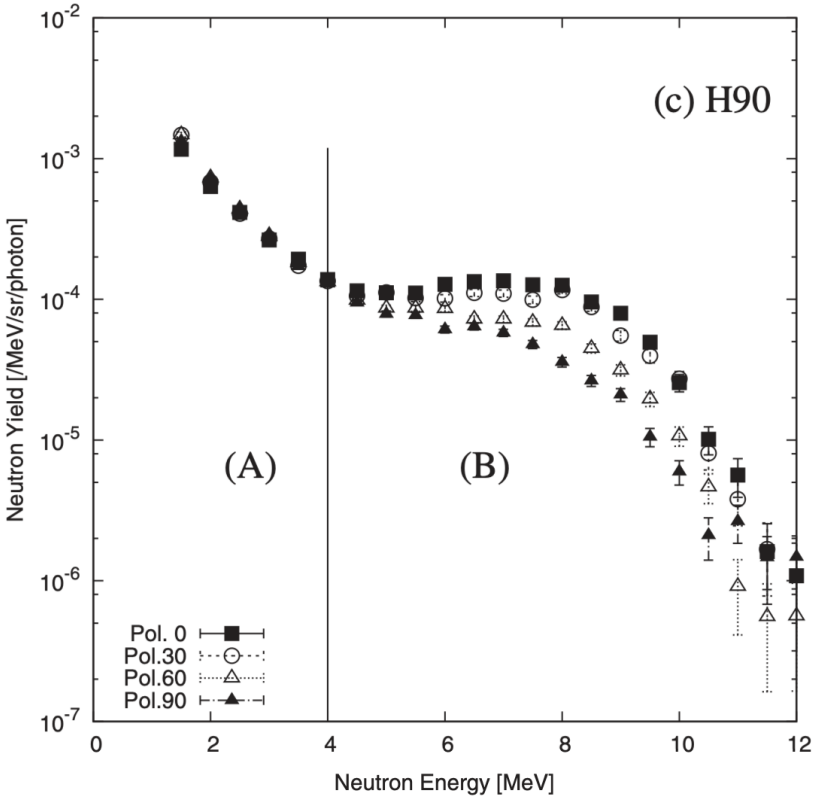
Plastic scintillator
5 mm thick with Al rad.

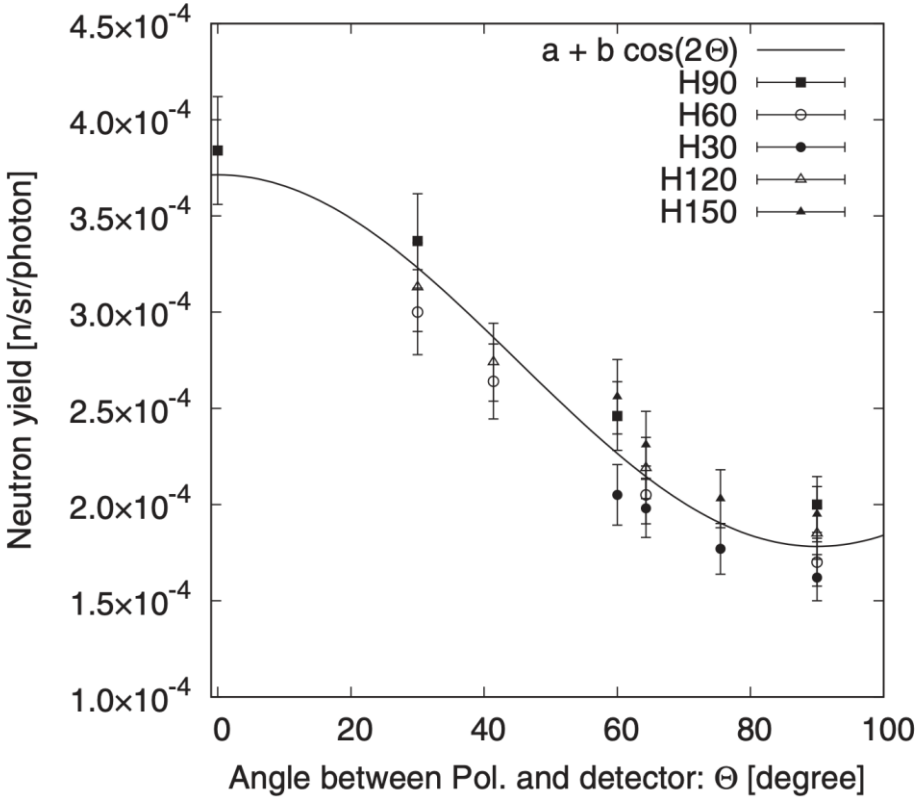
LCS γ-ray
Circular polarized
13.9, 16.9 MeV

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

- Y.Kirihara et al, https://doi.org/10.1080/00223131.2019.1691073 (2019)

Results





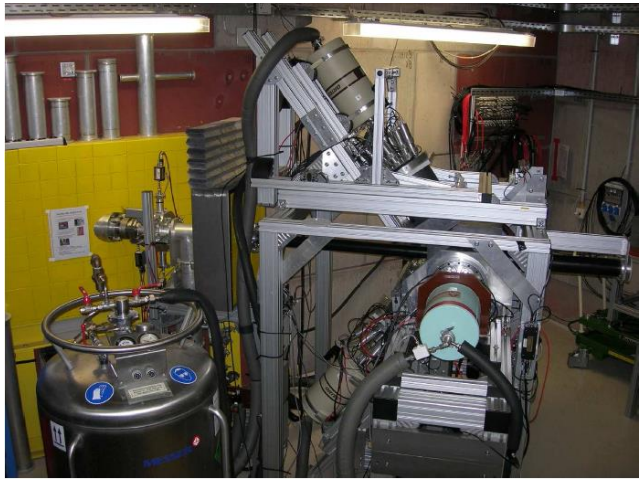
- Two components, evaporation and non-evaporation, were observed
- Strong anisotropy was observed for non-evaporation component
- The anisotropy was described as a function of angle between polarization and neutron emission

Activities at Teikyo University

Ayano Makinaga

Collaboration with Ronald Schwengner
at Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

Photon scattering cross section data at HZDR



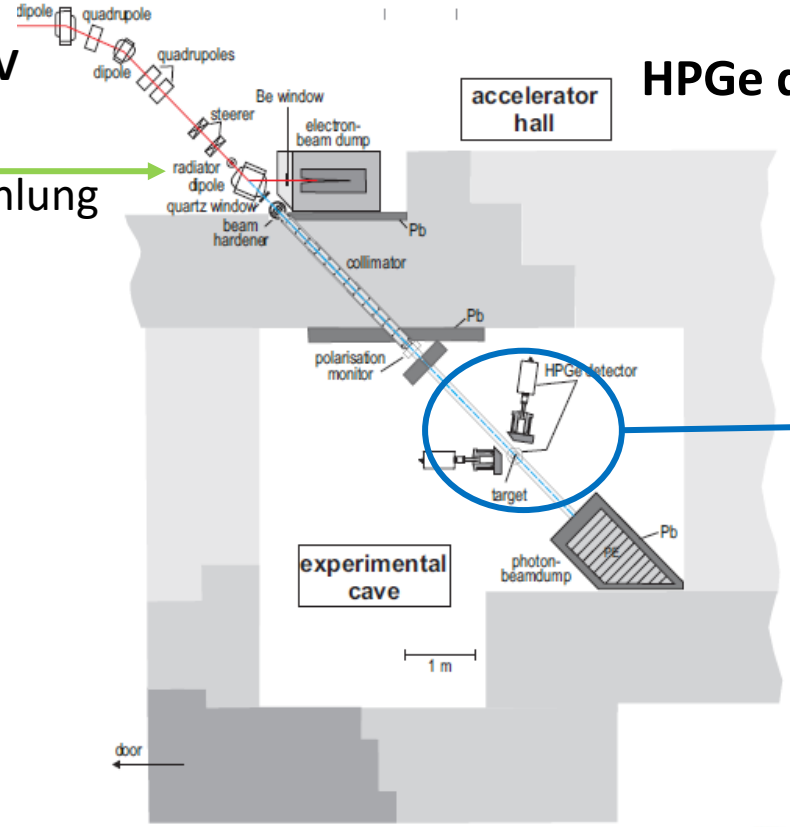
Partly supported by Hokkaido University

Experimental set up at HZDR

electron

Ee :10.3 MeV

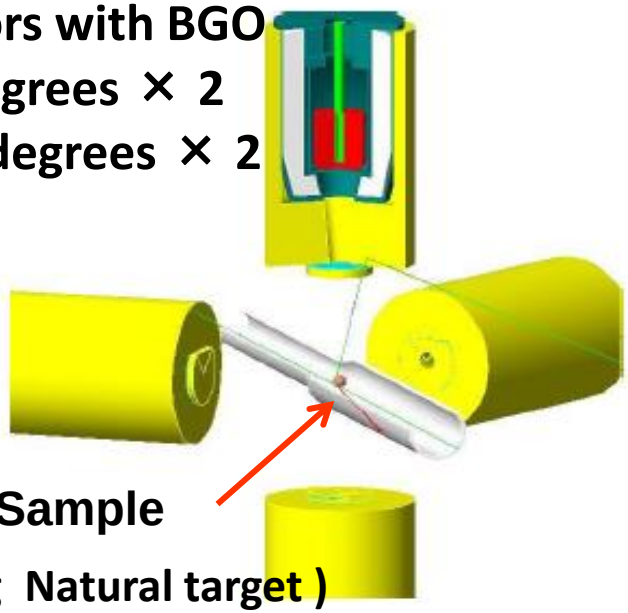
Bremsstrahlung



HPGe detectors with BGO

90 degrees × 2

127 degrees × 2



^{115}In Sample

(2.37g Natural target)

By R.Massarczyk

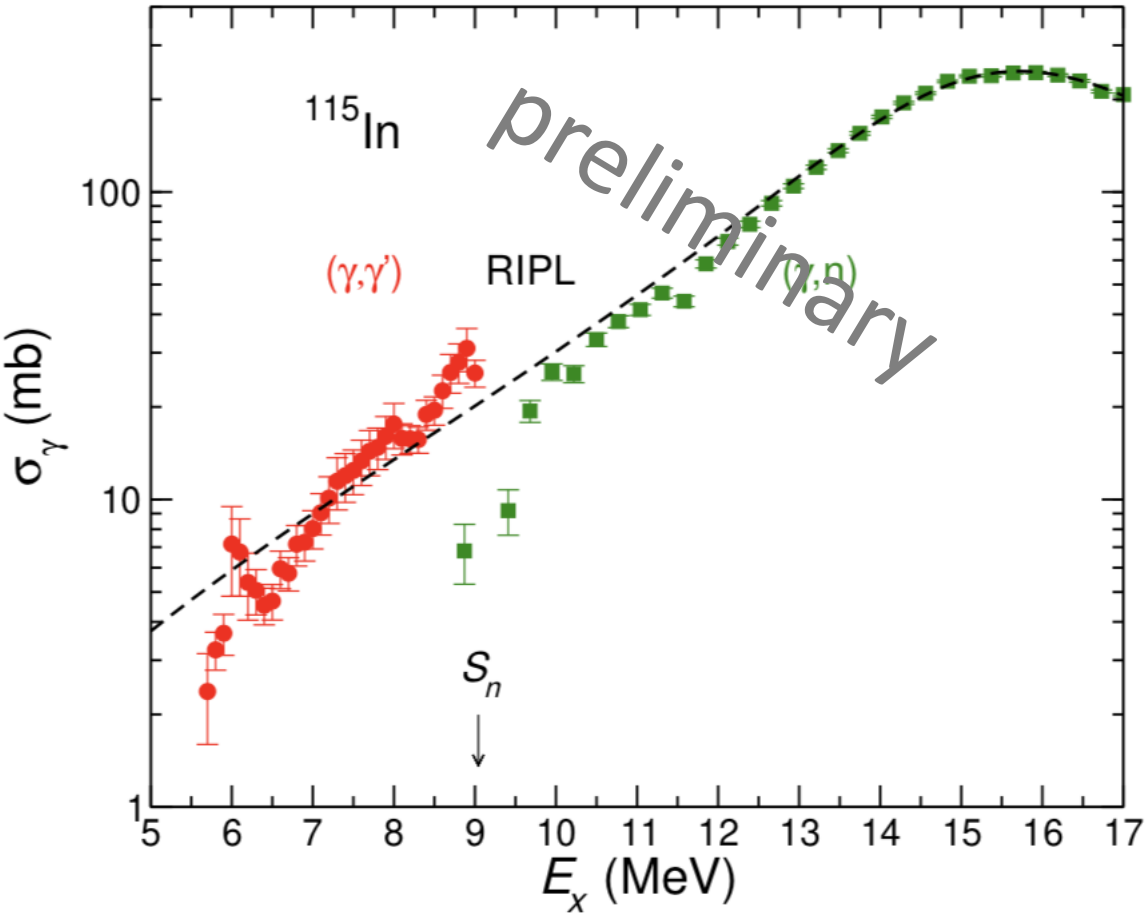
The bremsstrahlung facility at the electron accelerator gELBE

Maximum electron energy ~18MeV Maximum average current ~0.8mA

Micro-pulse rate ~13MHz Micro-pulse length ~5ps

R.Schwengner et.al., NIM A 555, 211(2005)

Result:
γSF (γ-ray strength function) for ^{115}In



● Present data

■ A. Lepretre et al., Jour. Nucl. Phys. A, **219**, 39, 7401 (1974).

There is enhanced strength around 6 MeV, 8 MeV and 9 MeV.

Thank you