Progress on Nuclear data Measurements in China

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China Institute of Atomic Energy

Progress of ND measurements in the following institutes are collected

- China Institute of Atomic Energy (CIAE)
- Shanghai Institute of Applied Physics (SINAP)
- Institute of Modern Physics (IMP)
- Inner Mongolia University for Nationalities (IMUN)

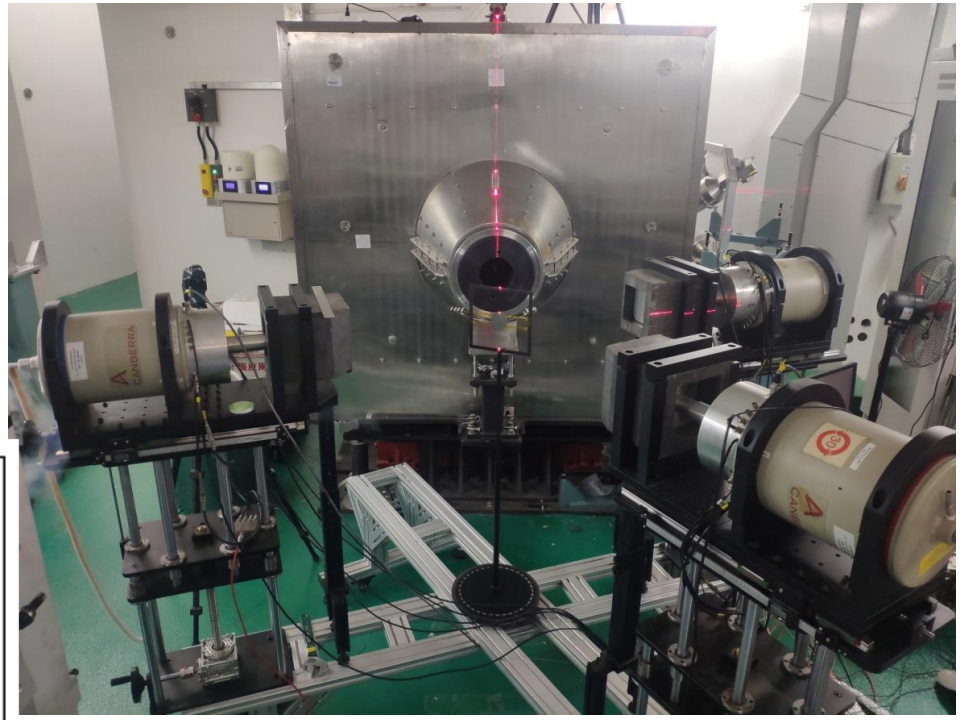
China Institute of Atomic Energy

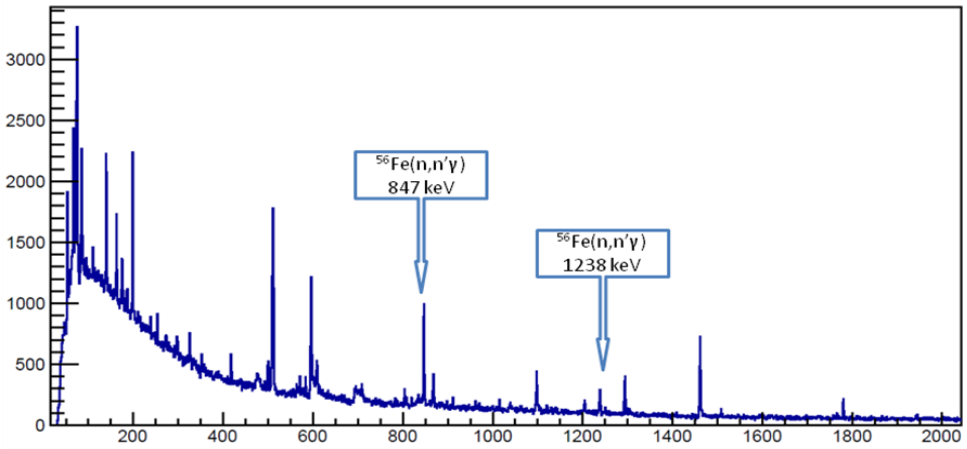
1. (n,n'g) and (n,2ng) cross section measurement

Neutron source:

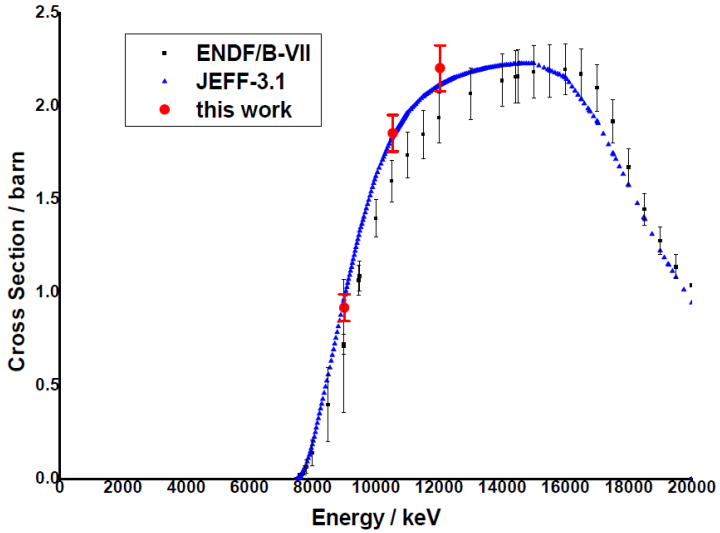
1) 2×1.7 MV tandem: 1 – 3 MeV
2) HI-13 tandem: 8 – 12 MeV
3) Neutron generator: 14 MeV

Detector:
HPGe and CLOVER detector

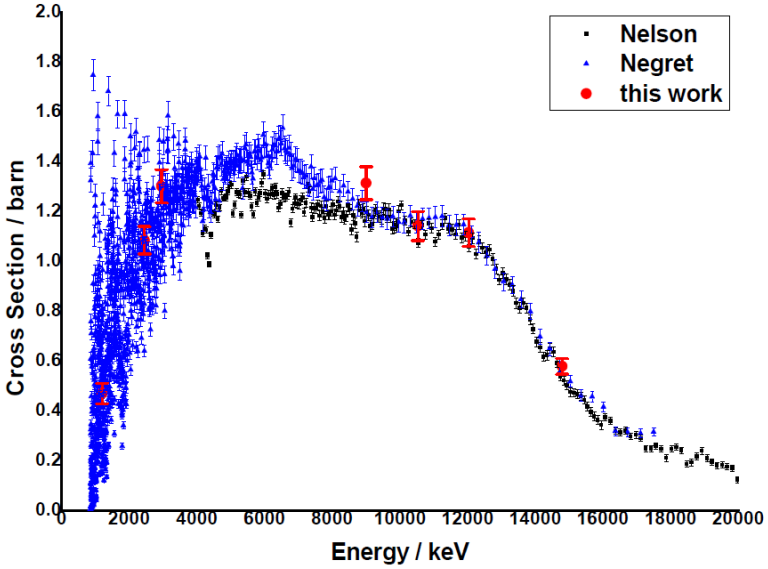




Preliminary results for (n,2ng) of ^{209}Bi and (n,n'g) of ^{56}Fe



(n,2ng) of ^{209}Bi @ 601.6 keV



(n,n'g) of ^{56}Fe

2. Neutron leakage spectrum measurement for d-D and d-T neutron sources

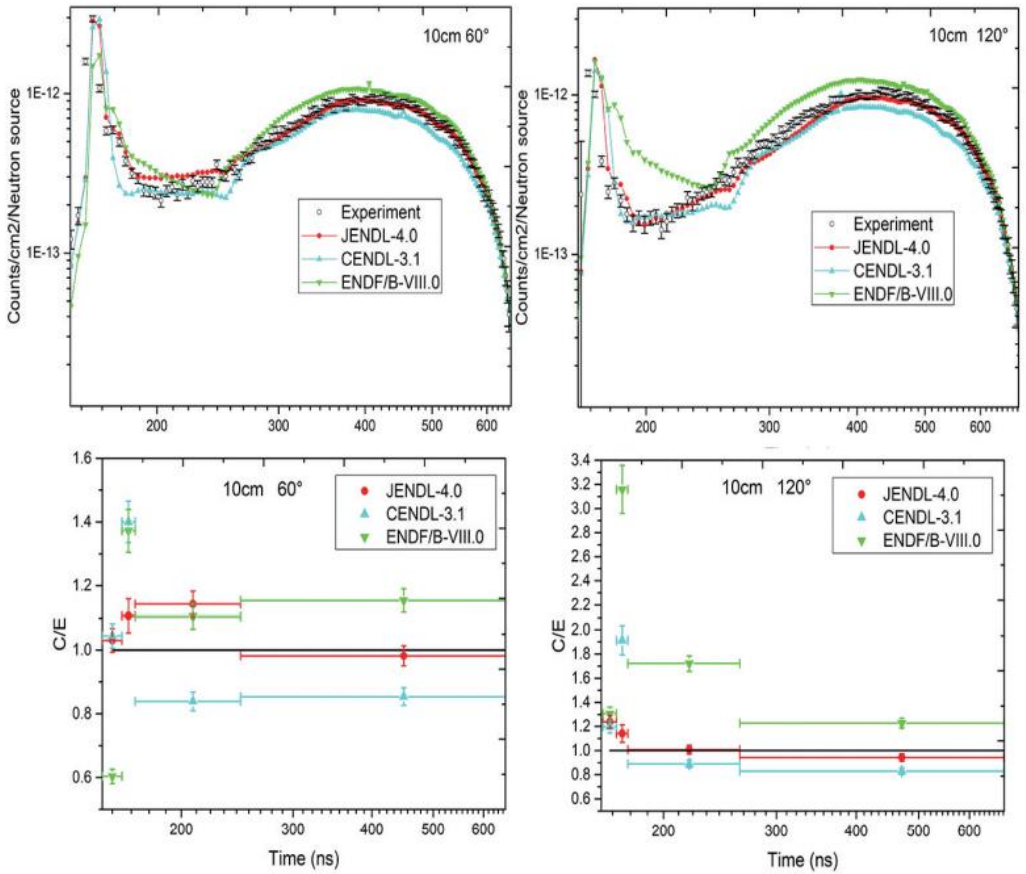


Figure 7: The results of experiment on the niobium sample with 10 cm

^{209}Bi, d-T neutrons

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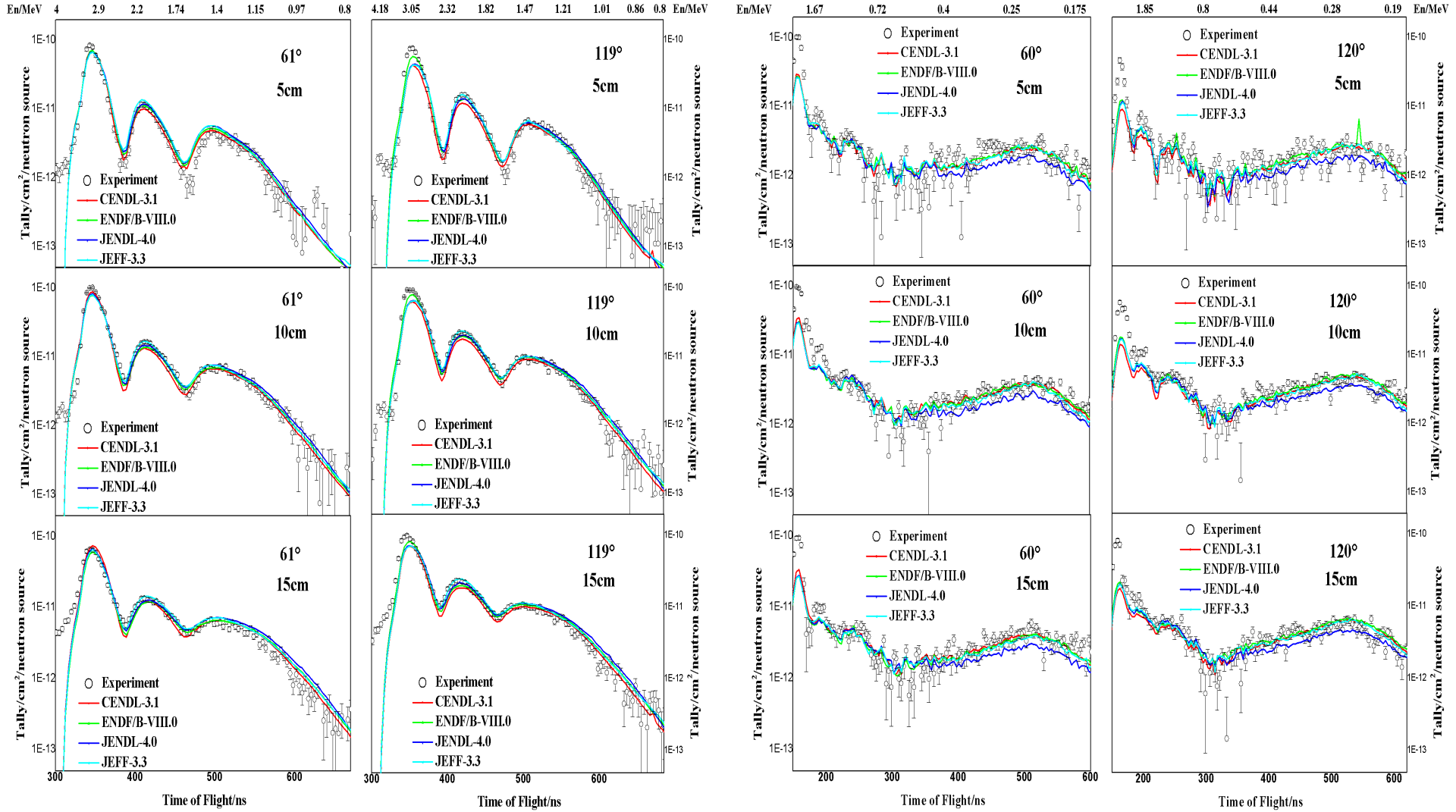
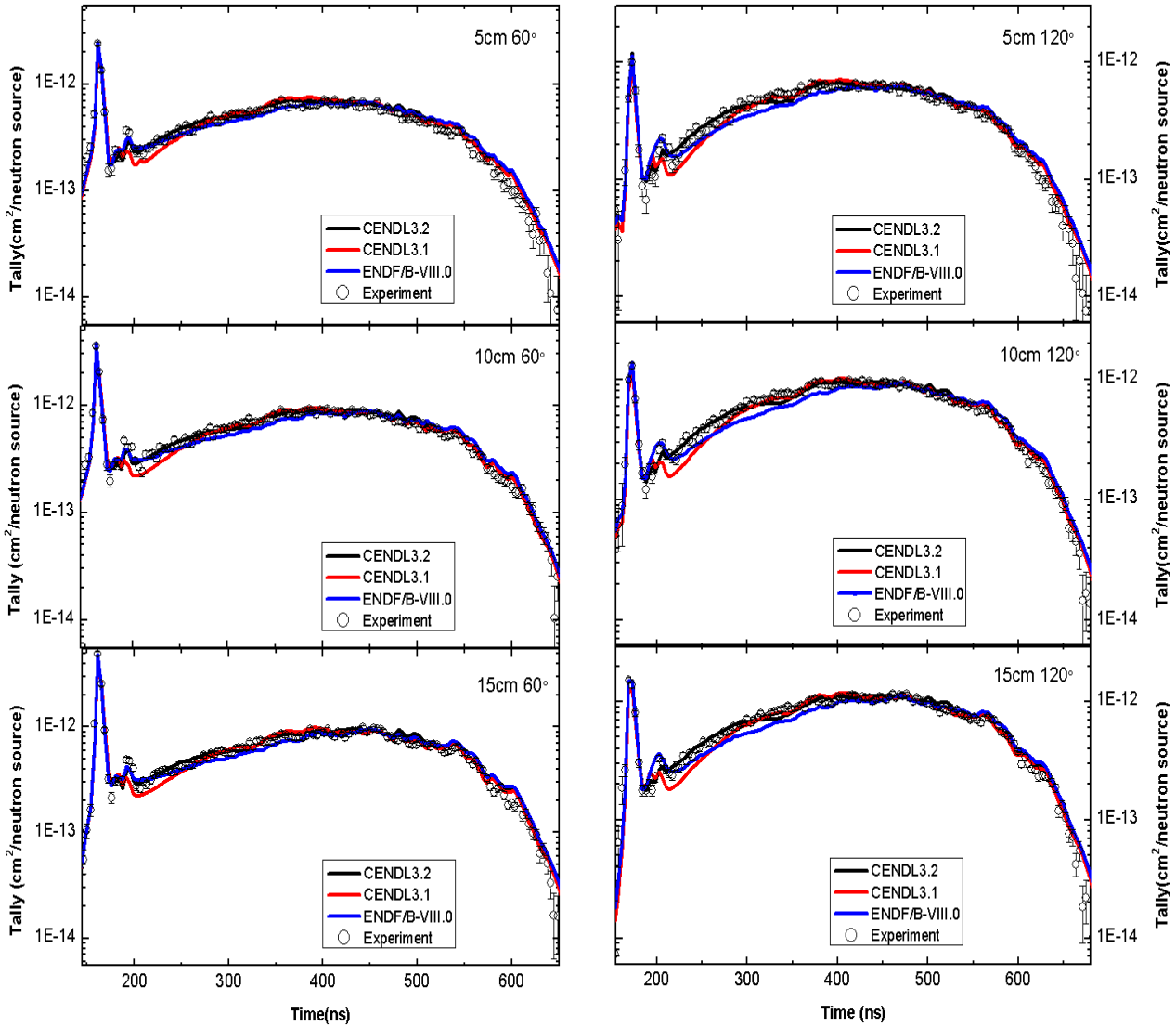
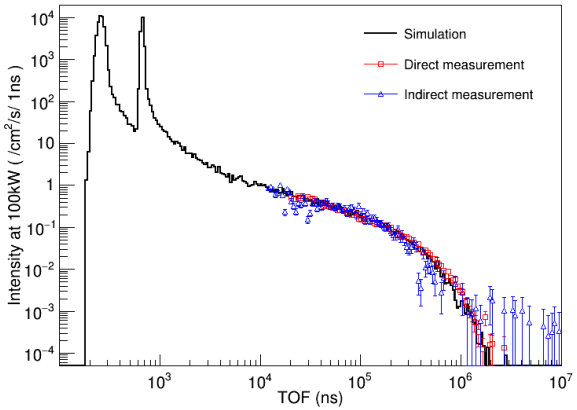


^{209}Bi, d-D neutrons（left: BC501A; right: CLYC）

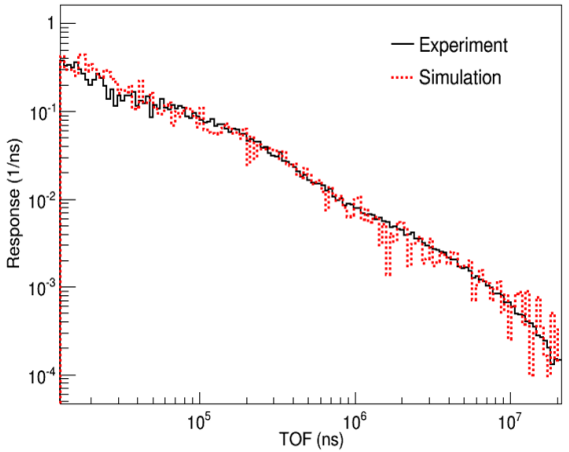


Iron data was used for improvement of CENDL data

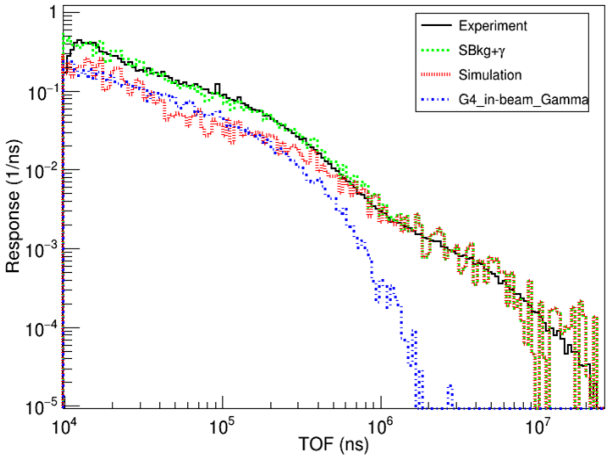
3. Neutron capture cross section measurements at CSNS
Background study



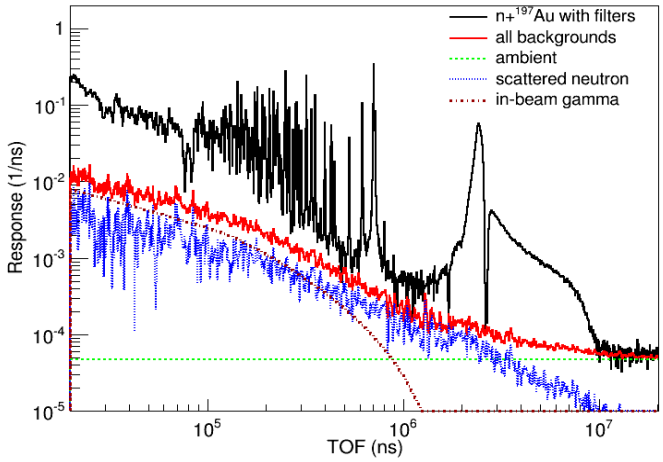
In beam gamma BG



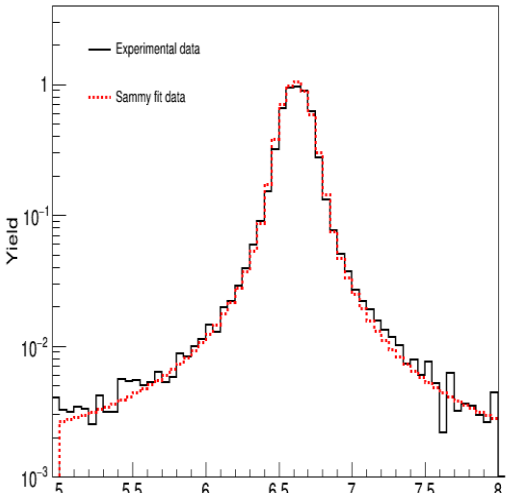
Scattered neutron BG (Carbon)

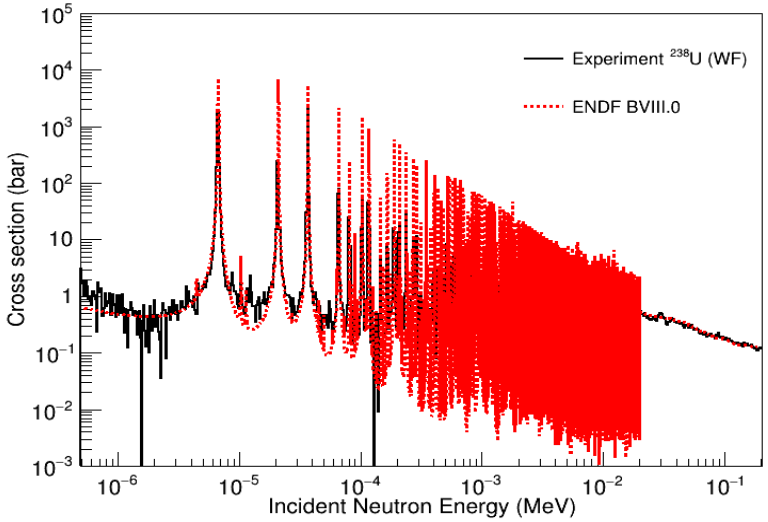


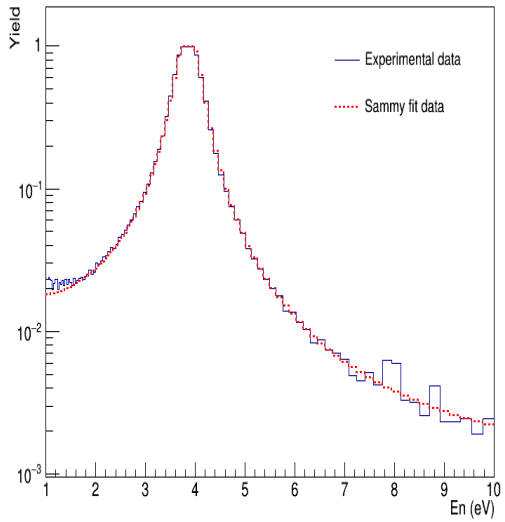
BG with Pb sample

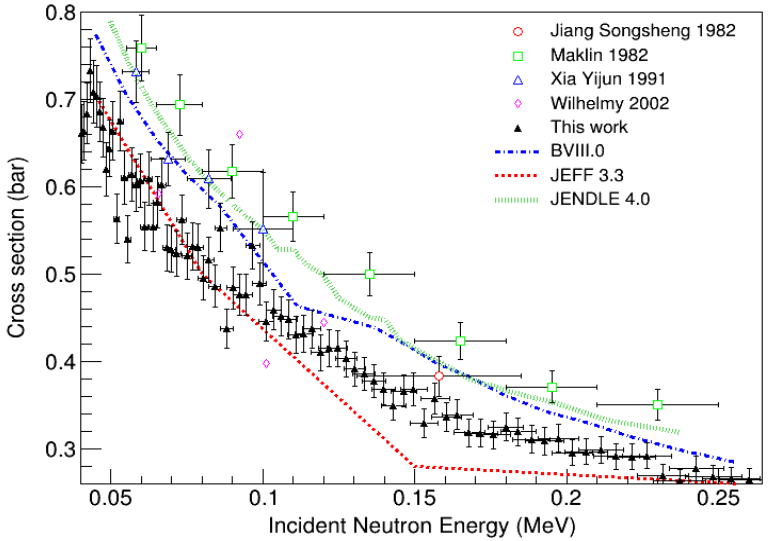


BG subtraction









^{238}U and ^{169}Tm data are nearly ready for publication

Shanghai Institute of Applied Physics (SINAP)

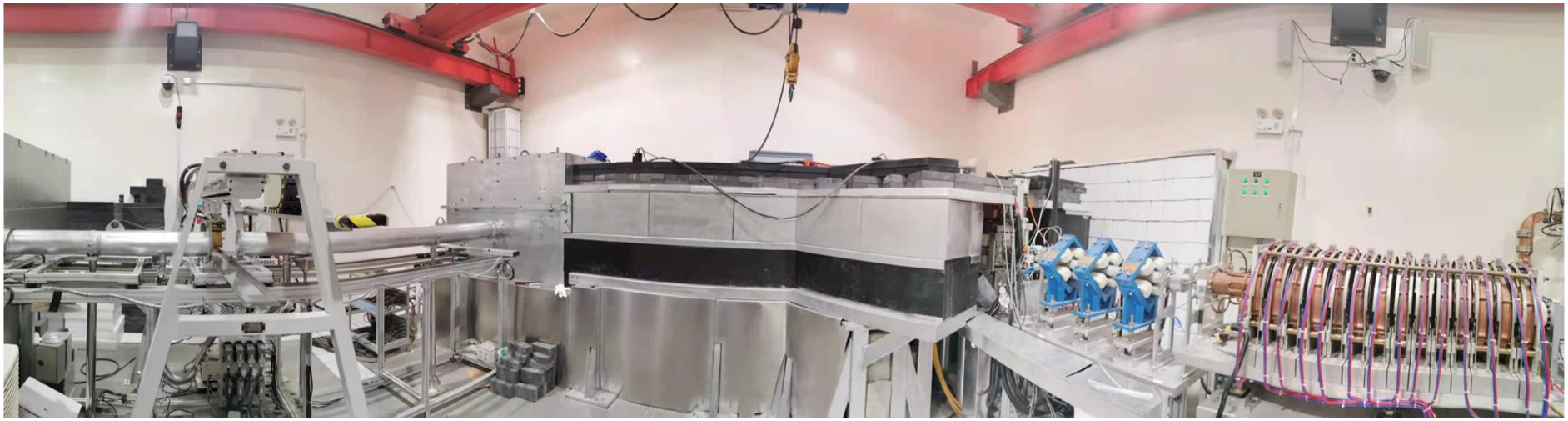
Nuclear data measurements of key nuclides for TMSR

TMSR Photo-Neutron Source (TMSR-PNS)

TMSR-PNS is a compact electron-linac-driven neutron source at the Shanghai Institute of Applied Physics, Chinese Academy of Sciences (SINAP, CAS).

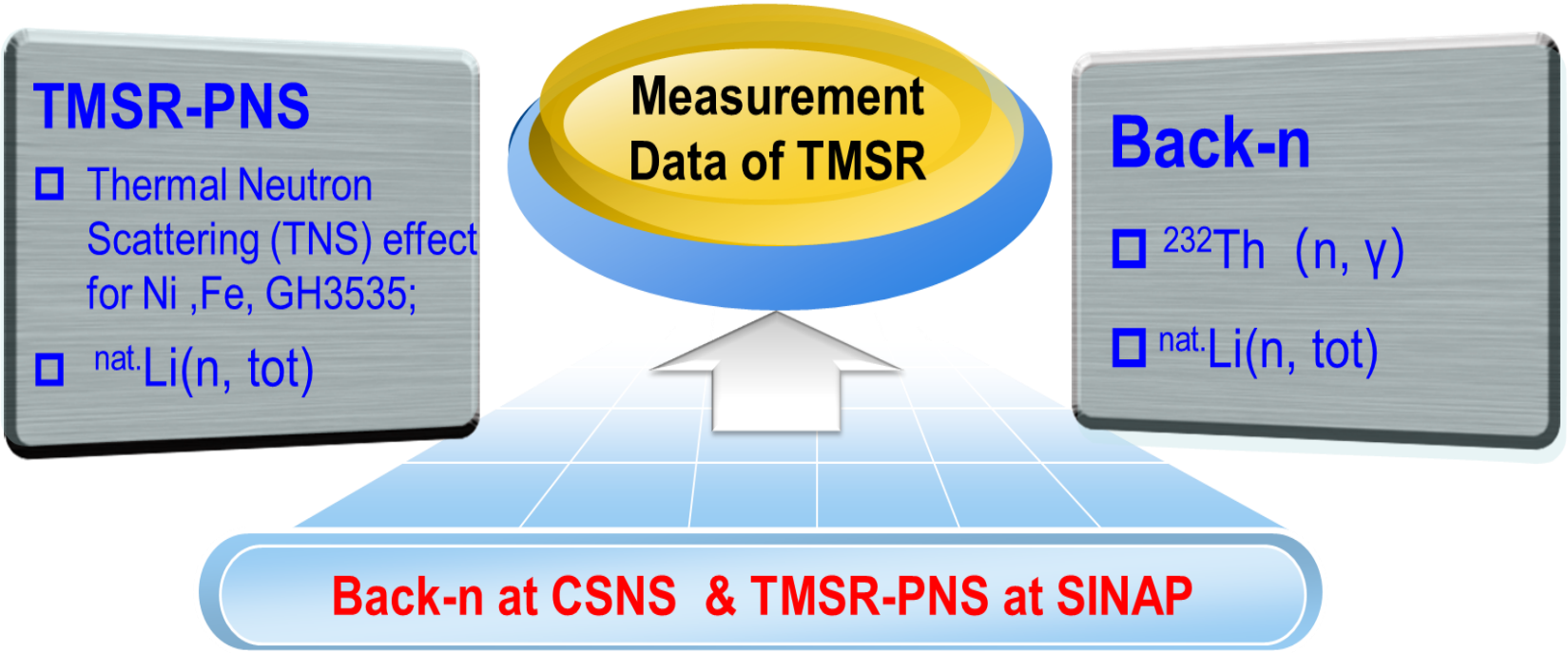
- Electron-beam energy: 15 MeV;
- Pulse width: 3-10 ns, 15-30 ns, 0.5-3 μs;
- Pulse frequency: 1-260 Hz;
- Average beam current: 0.1 mA;
- Neutron yield: ~10^{11} n/s.

- Neutron nuclear data measurements;
- Boron equivalent measurements;
- Material irradiation;
- Measurement of Th-U fuel conversion ratio.



Nuclear data measurements of key nuclides for TMSR

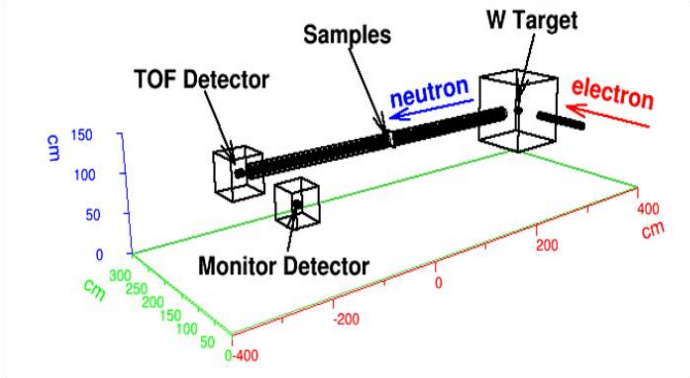
To meet the neutron nuclear data requirements of thorium-uranium fuel cycle, the key nuclear data have been measured at TMSR-PNS and Back-n facility, respectively, which provide important supports for the physical design of Thorium Molten Salt Reactor (TMSR).



Measurements of TCS for Ni ,Fe, GH3535 at TMSR-PNS

Measurements of Total Cross Section (TCS) provide important data for the study of (Thermal Neutron Scattering)TNS effect

- Spectrometer: Time-of-flight spectrometer
- Method : Transmission method
- Detector: ^{6}LiF (EJ-426)
- Samples: Ni ,Fe, GH3535

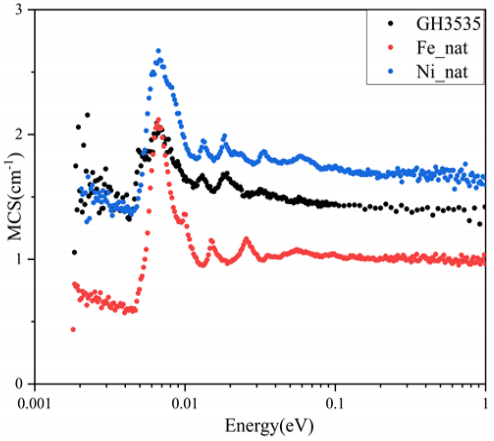


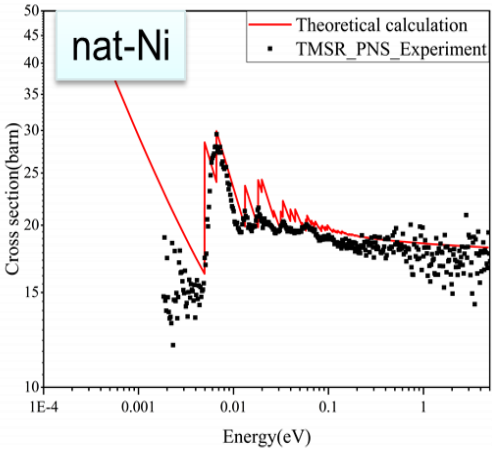
Samples	Diameter:mm	Thickness:mm	Temperature:℃
nat-Ni	60	8	20
nat-Fe	60	8	20
GH-3535	70	7.9	20/400/800

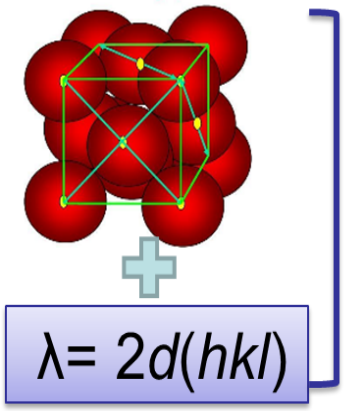
Measurements of TCS for Ni, Fe and GH3535 at TMSR-PNS

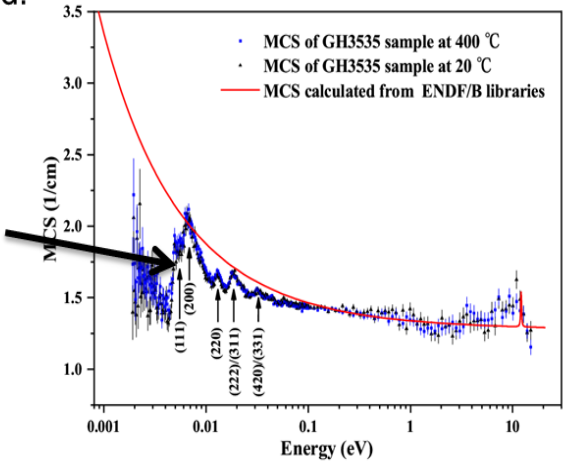
Measurement results

- The experimental data of TCS for Ni ,Fe and GH3535 are measured, respectively.
- The theoretical thermal neutron scattering cross-sections for nat-Ni are obatined from NJOY
- Comparison between the theory and the experiment was performed.







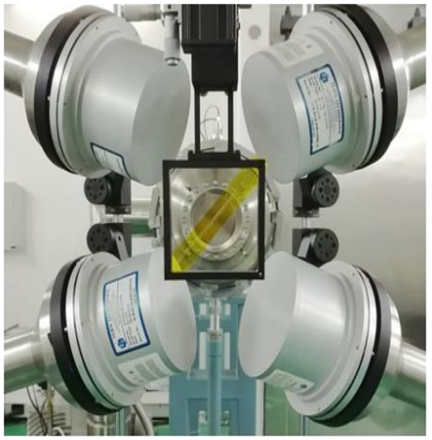


- It can be observed that the energy positions of Bragg-edges, and the Miller indices corresponding to the micro crystal structure (FCC) of the sample GH3535 are shown for each distinguishable Bragg-edge.

Measurement of ^{232}Th (n,γ) at Back-n

Experimental details

- **γ-detection**
  - ✓ **Spectrometer:** CSNS Back-n time-of-flight spectrometer
  - ✓ **Detector:** four hydrogen-free deuterated benzene C6D6 liquid scintillation detectors
  - ✓ **Method:** total energy detection principle in combination with the Pulse Height Weighting Technique (PHWT)

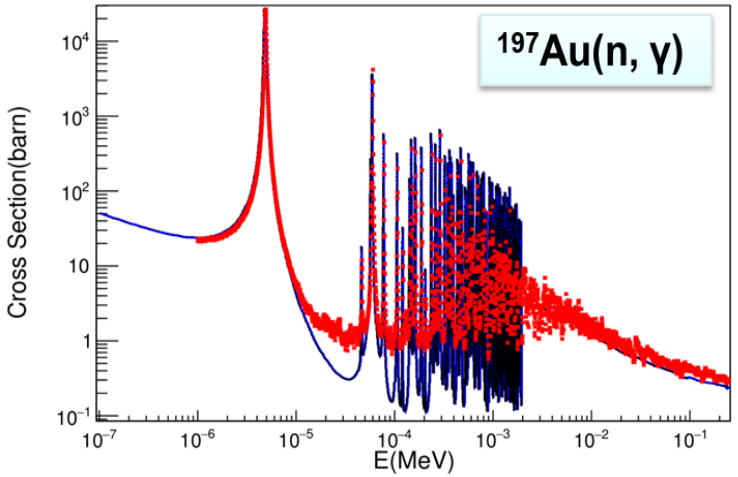


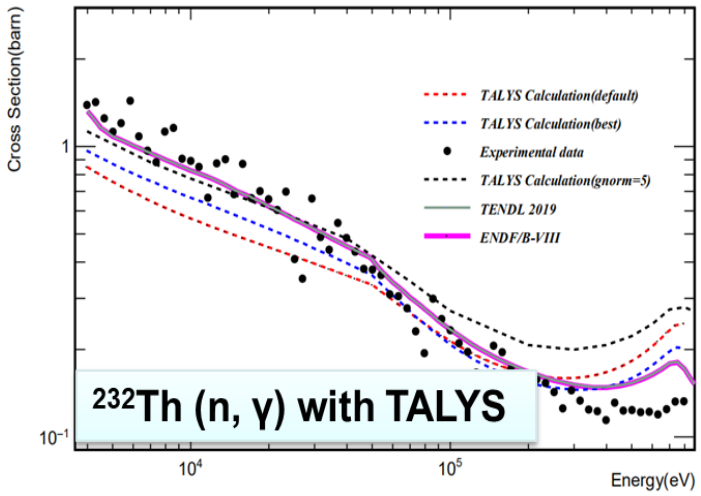
- **Samples & Background deduction**
  - ✓ **^{197}Au:** to verify the data analysis procedure and to use for normalization
  - ✓ **^{232}Th:** disk-shaped ^{232}Th sample with a diameter of 30mm and a thickness of 1mm
  - ✓ **^{nat}C:** to evaluate the background resulting from sample scattered neutrons
  - ✓ **^{nat}Pb:** to evaluate the background resulting from in-beam γ-rays
  - ✓ **Empty holder**

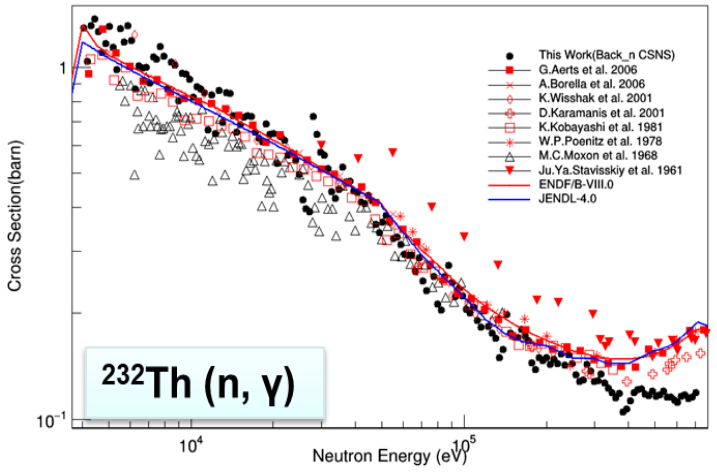
Measurement of ^{232}Th (n,γ) at Back-n

Measurement result

- Comparison of measured ^{232}Th /^{197}Au(n, γ) cross section with evaluated data from ENDF/B-VIII.0
- Calculation of ^{232}Th(n,γ) cross section with TALYS, and comparison with various measurements

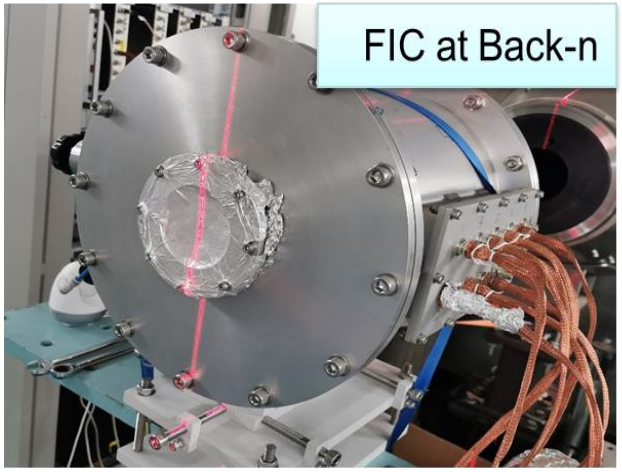


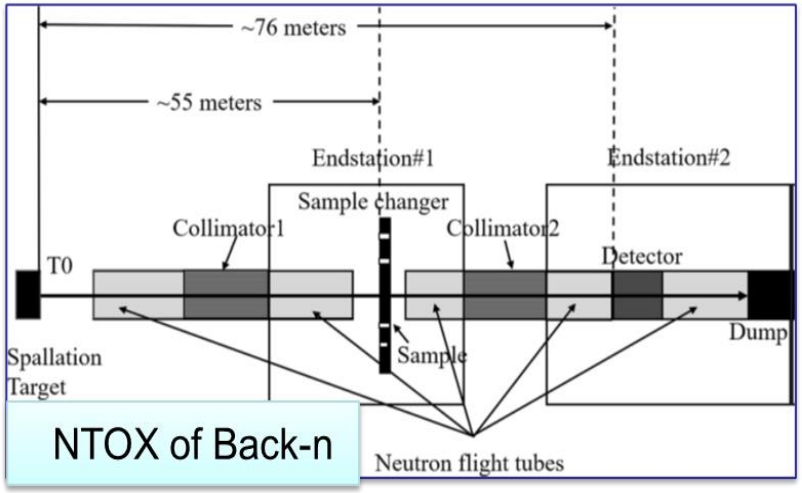




Measurement of TCS for ^{nat}Li at TMSR-PNS & Back-n

- **Spectrometer:** Time-of-flight spectrometer
- **Method :** Transmission method
- **Detector:** ^{6}LiF at TMSR-PNS， Multilayer fast ionization chamber (FIC) at Back-n
- **Samples:** Natural lithium (92.5% ^{7}Li, 7.5% ^{6}Li, Φ=50 mm, h=15 mm & 8 mm） is covered with aluminum to avoid oxidation





Measurement of TCS for ^{nat}Li at TMSR-PNS & Back-n

☐ Data analysis

◆ TMSR-PNS

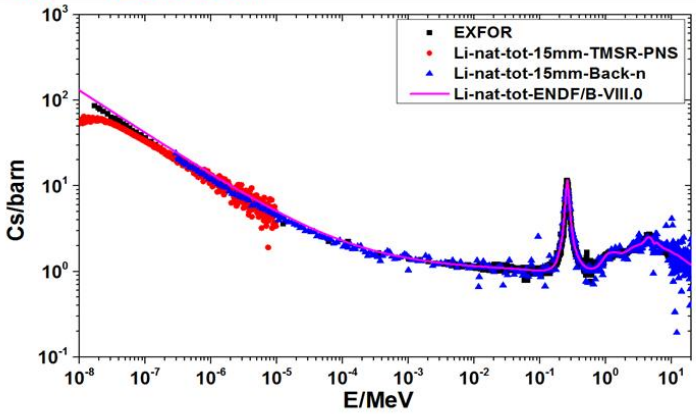
- ➢ **Background**
- ➢ **Neutron energy calibration**
- ➢ **Discrimination of n/γ : PSD**

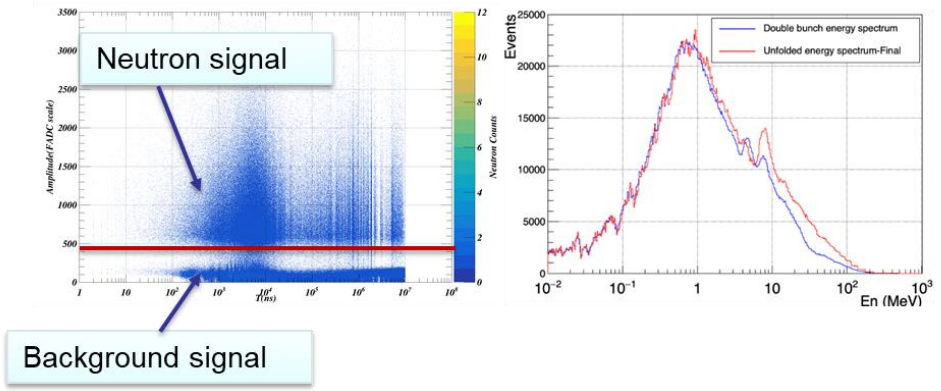
◆ Back-n

- ➢ **Neutron signal:** Threshold discrimination
- ➢ **Neutron energy calibration:** 8.77 eV resonance of ^{235}U
- ➢ **Double bunch spectrum unfolding**

☐ Measurement result:

10^{-8} ~20 MeV





Progress of nuclear data measurements at IMP,CAS

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Nuclear Safety and Nuclear Data Group
Institute of Modern Physics

Chinese Academy of Sciences(IMP,CAS)

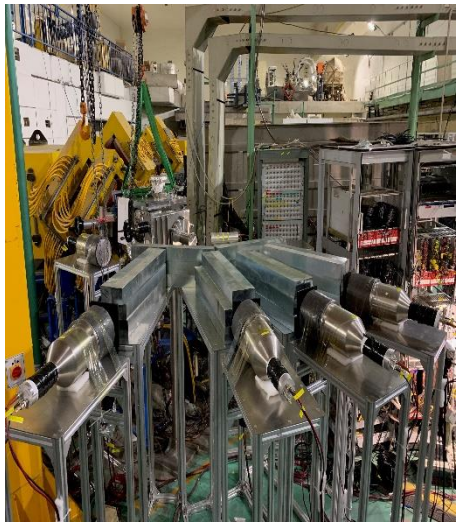
Double differential neutron yields from thick targets

- Measurements were carried out at the first Radioactive Ion Beam Line in Lanzhou (HIRFL-RIBLL1).
- BC501A liquid organic scintillator scintillation (5 inch thick and 5 inch in diameter) was used as a neutron detector.
- The experimental results were compared with GEANT4, FLUKA and PHITS calculations.

① 26.7 MeV/u ^{4}He + Be, C, Pb, W

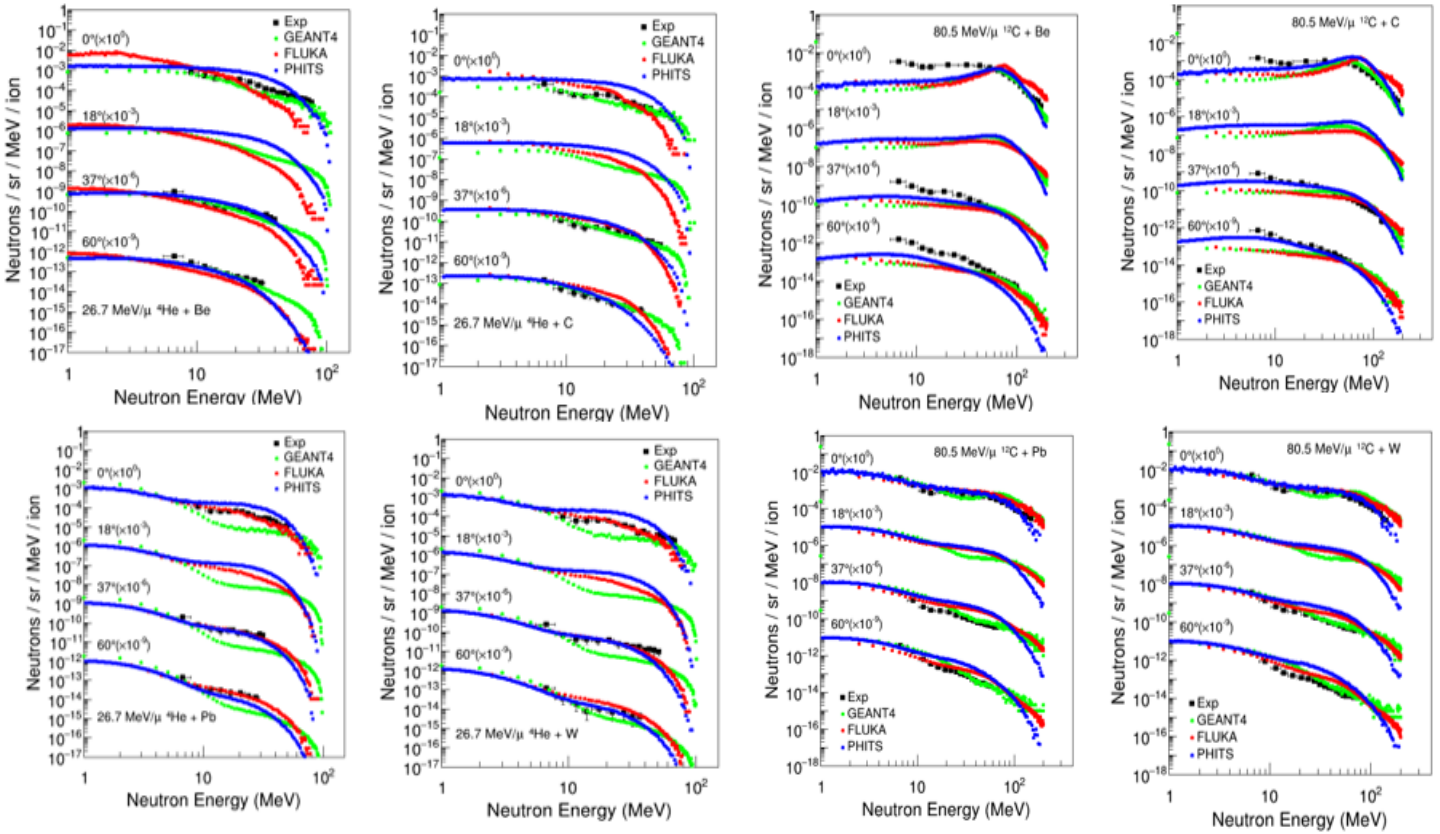
② 80.5 MeV/u ^{12}C + Be, C, Pb, W

Heavy Ion Research Facility in Lanzhou



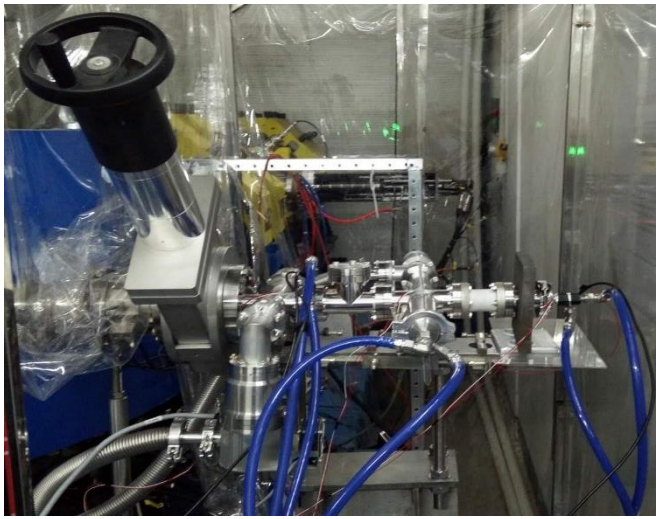
^{4}He + Be, C, Pb, W

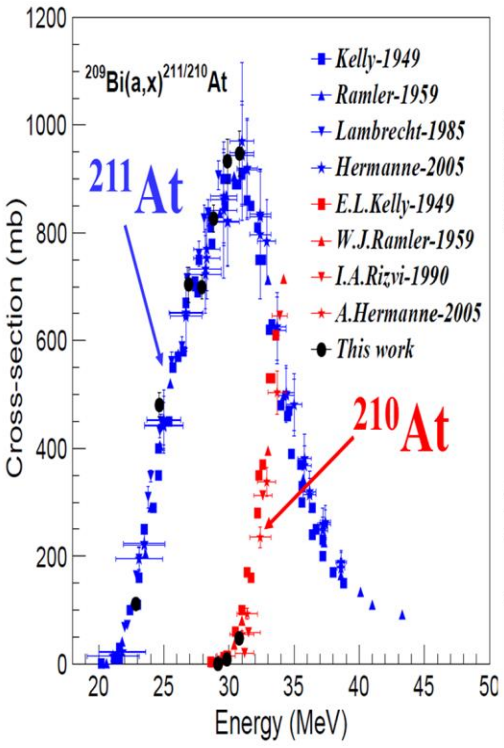
^{12}C + Be, C, Pb, W

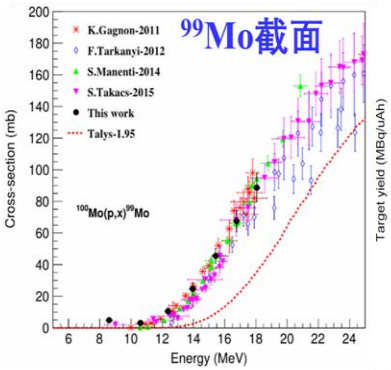


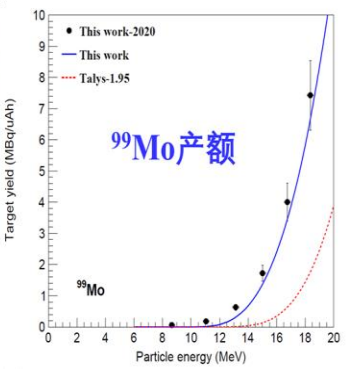
Excitation functions of ^{4}He and proton induced reactions for medical radioisotopes production

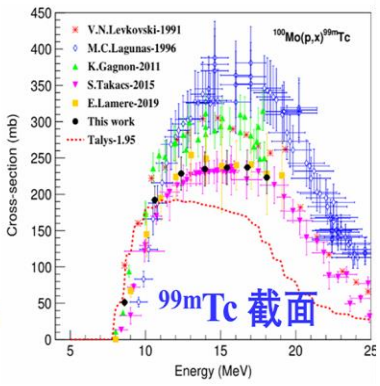
- Excitation functions of the ^{209}Bi(^{4}He, x)^{210,211}At and ^{nat}Mo(p, x) ^{99}Mo/^{99m}Tc reactions were measured.
- The irradiation was carried out at the superconducting linac at IMP,CAS.

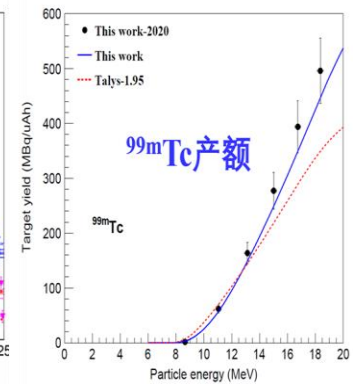






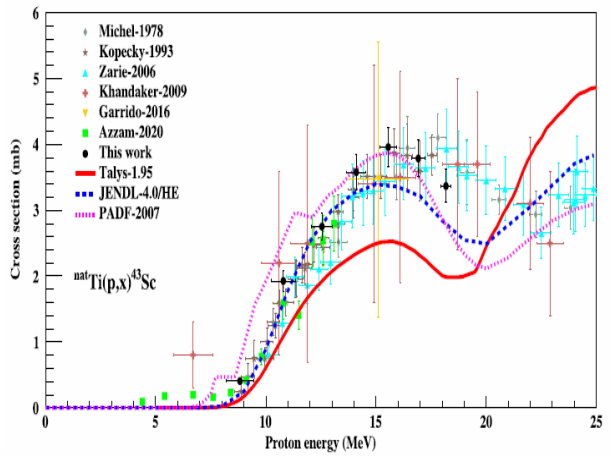


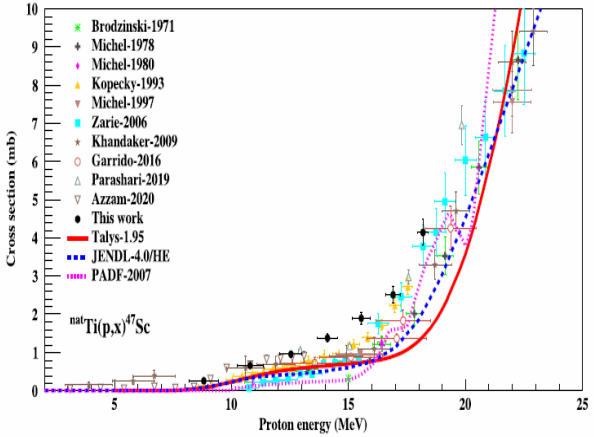


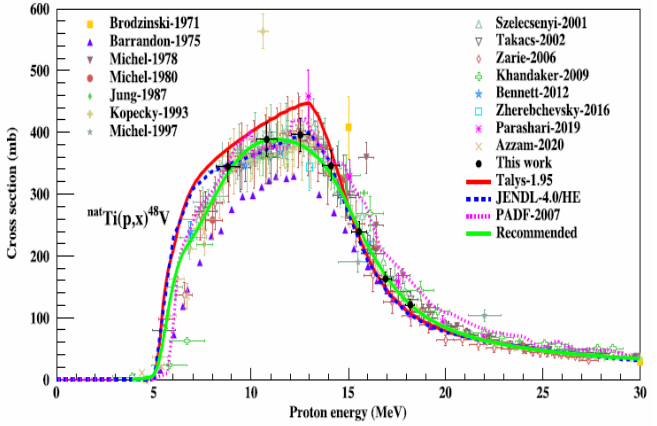


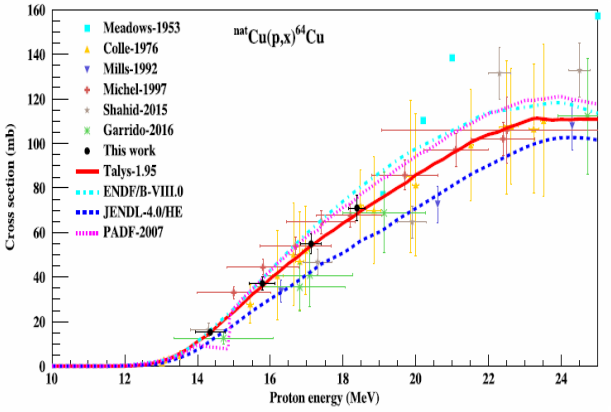
Excitation functions of proton induced reactions

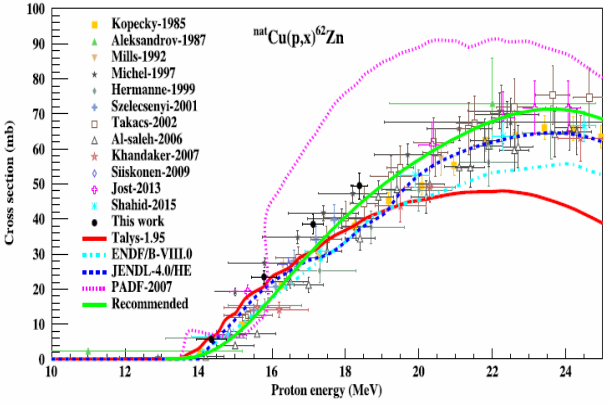
- Excitation functions of the $^{nat}Ti(p, x)^{43,47}Sc$, ^{48}V and $^{nat}Cu(p, x)^{64}Cu$, $^{62,65}Zn$ reactions were measured in the energy range of 8.8–18.4 MeV.
- The stacked-foil activation technique and off-line gamma spectroscopy were used.
- The irradiation was carried out at the superconducting linac at the Institute of Modern Physics, Chinese Academy of Sciences.
- The experimental results were compared with TALYS calculations, IAEA recommended data and evaluated nuclear data of the ENDF/B-VIII.0, JENDL-4.0/HE and PADF-2007 libraries.

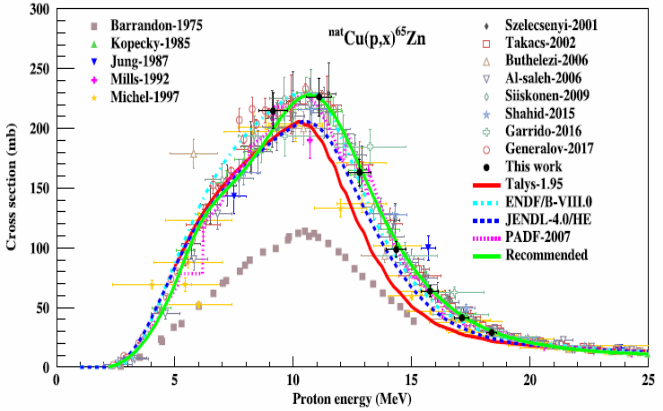












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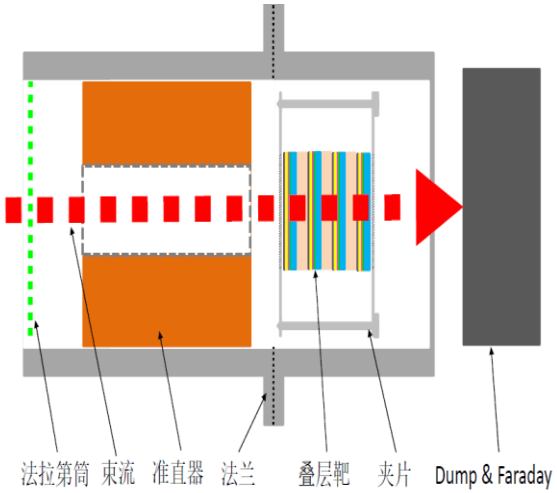
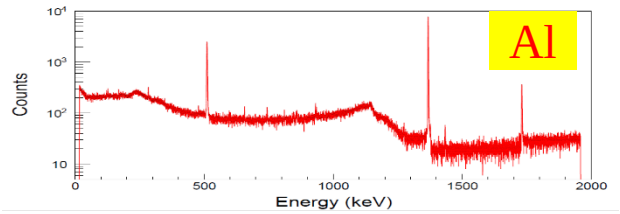
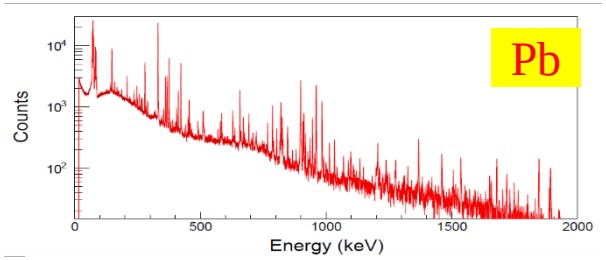
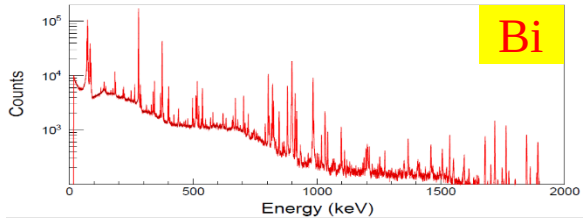
Measurements of spallation products induced by 100 MeV proton

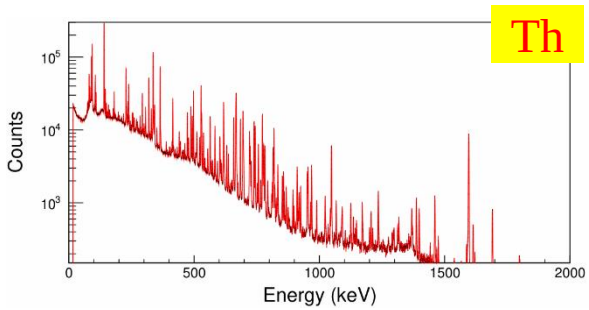
- Spallation products induced by 100 MeV proton on Pb, Bi, Th targets were measured.
- The stacked-foil activation technique and off-line gamma spectroscopy were used.
- The irradiation was carried out at HIRFL-SSC at IMP, CAS.
- The experimental data are under analyzing.

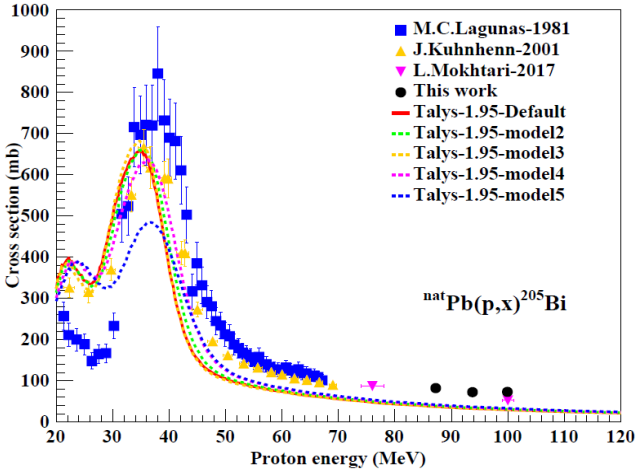


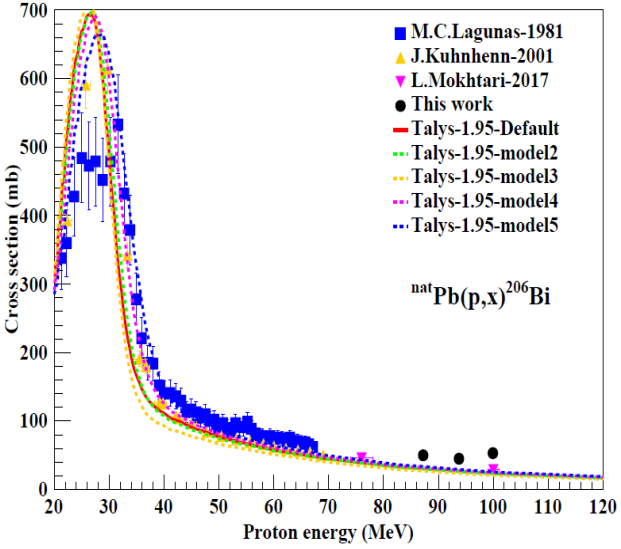












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Measurement of leakage neutron spectra for ^{nat}Zr, ^{nat}Al with D-T neutrons at CIAE

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^{nat}Zr

Measurement of leakage neutron spectra for zirconium with D-T neutrons and validation of evaluated nuclear data

S. Zhang[a,b,c,*], N. Song[a,c], J.C. Wang[a,c], Y. Nie[b], X. Ruan[b], J. Ren[b], D.X. Wang[a,c], M. Huang[a,c], L. Lu[a,c], Z. Chen[d], Y. Ding[b], K. Zhang[b], H. Chen[b], R. Wada[e], R. Han[d], Q. Sun[d]

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^{nat}Al

Measurement of leakage neutron spectra for aluminium with D-T fusion neutrons and validation of evaluated nuclear data

S. Zhang[a,b,c,*], D. Niu[a,c], D.X. Wang[a,c], Y. Nie[b], N. Song[a,c], J.C. Wang[a,c], X. Ruan[b], M. Huang[a,c], R. Wada[d], J. Ren[b], Y. Ding[b], K. Zhang[b], X. Tang[c,e], R. Han[f], B. Liu[f], L. Lu[c], W. Jiang[f]

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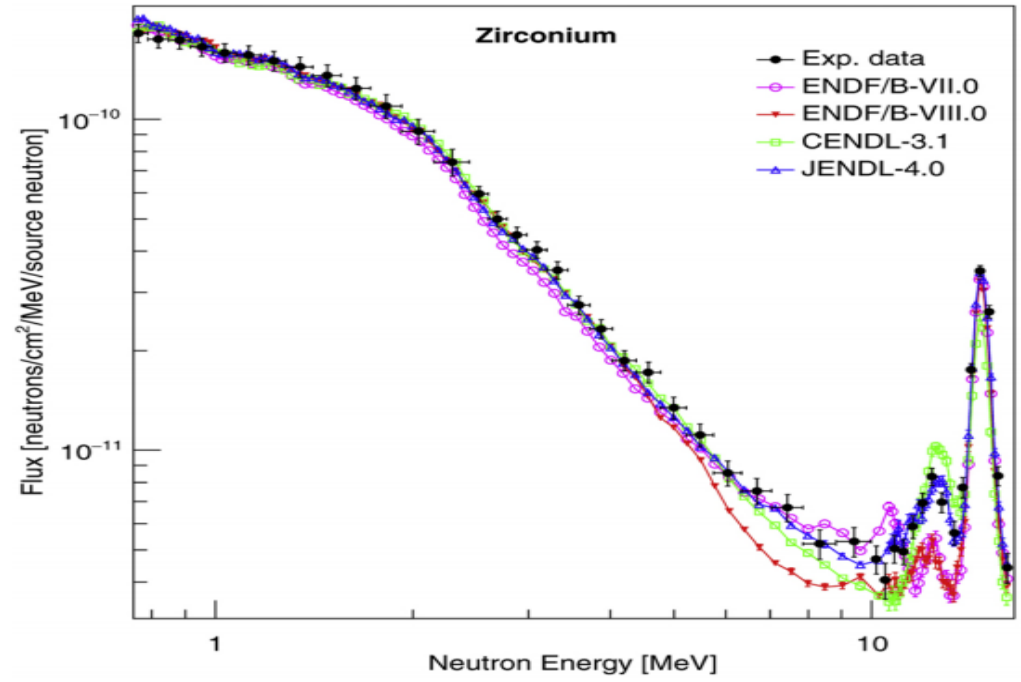
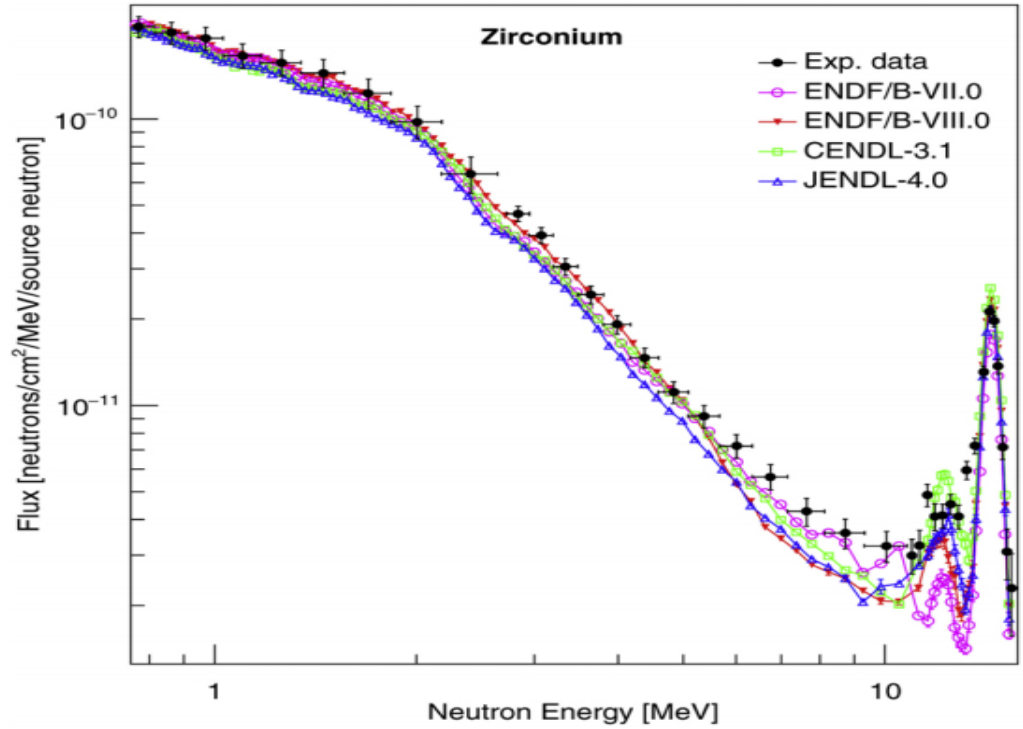
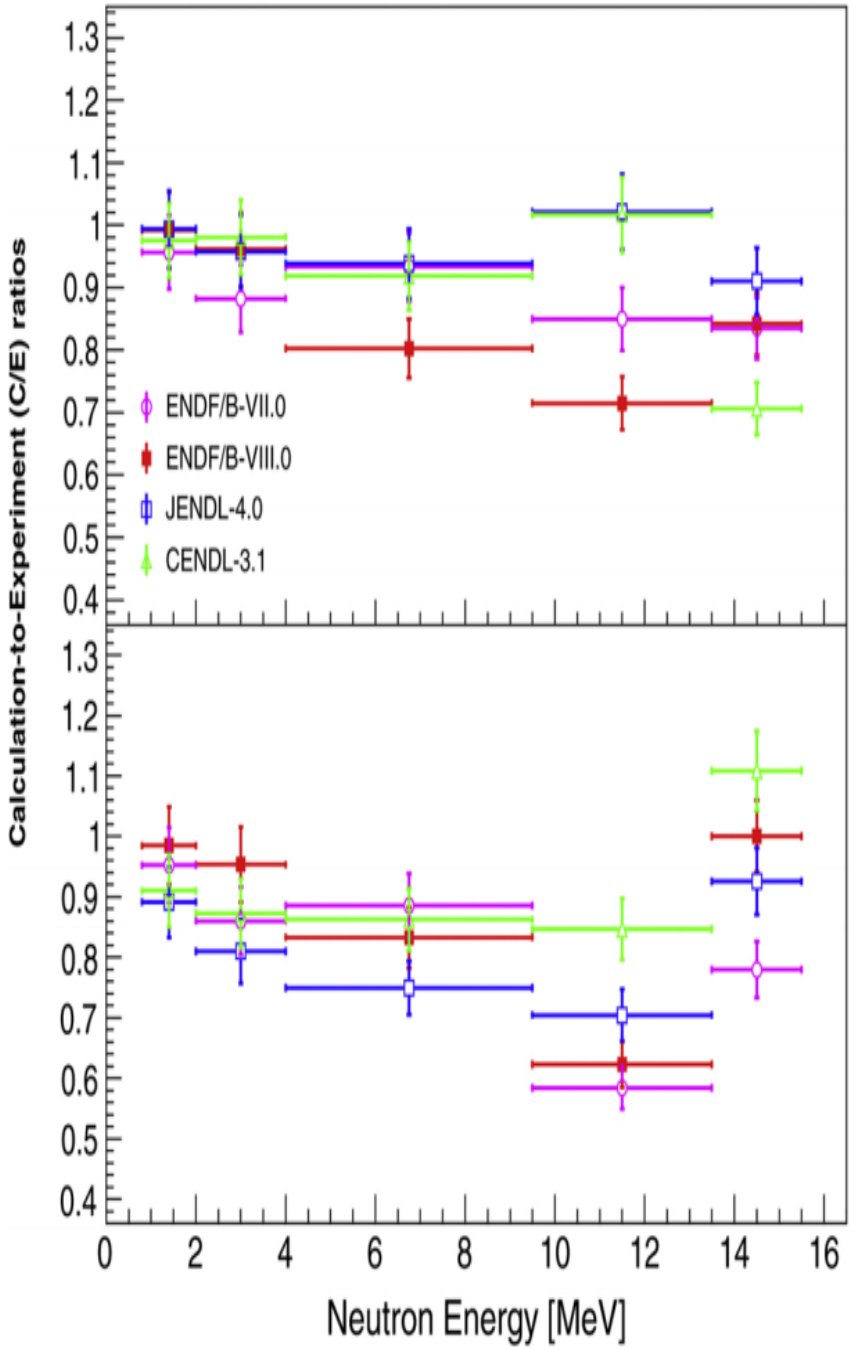
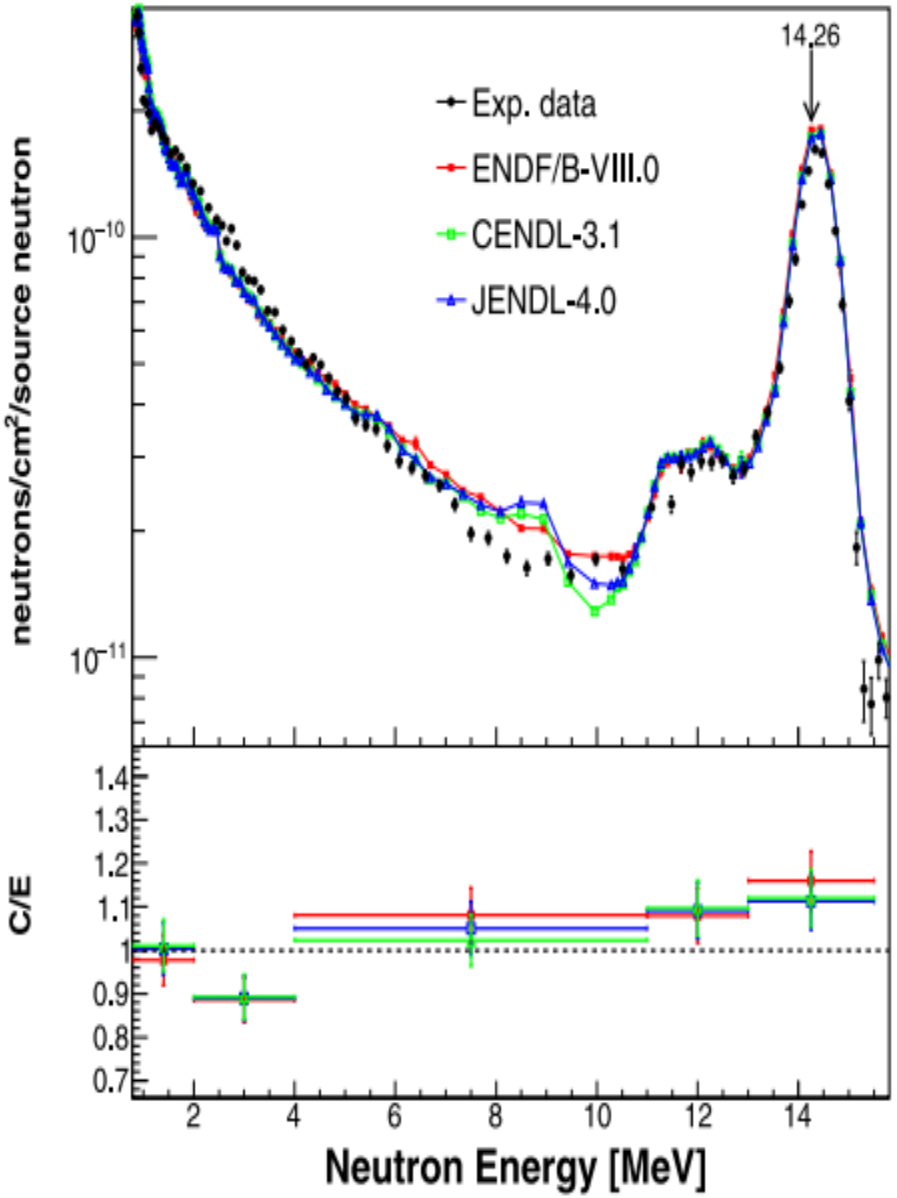
[e] College of Physics Science and Technology, Shenyang Normal University, ShenYang 110034, China
[f] Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China

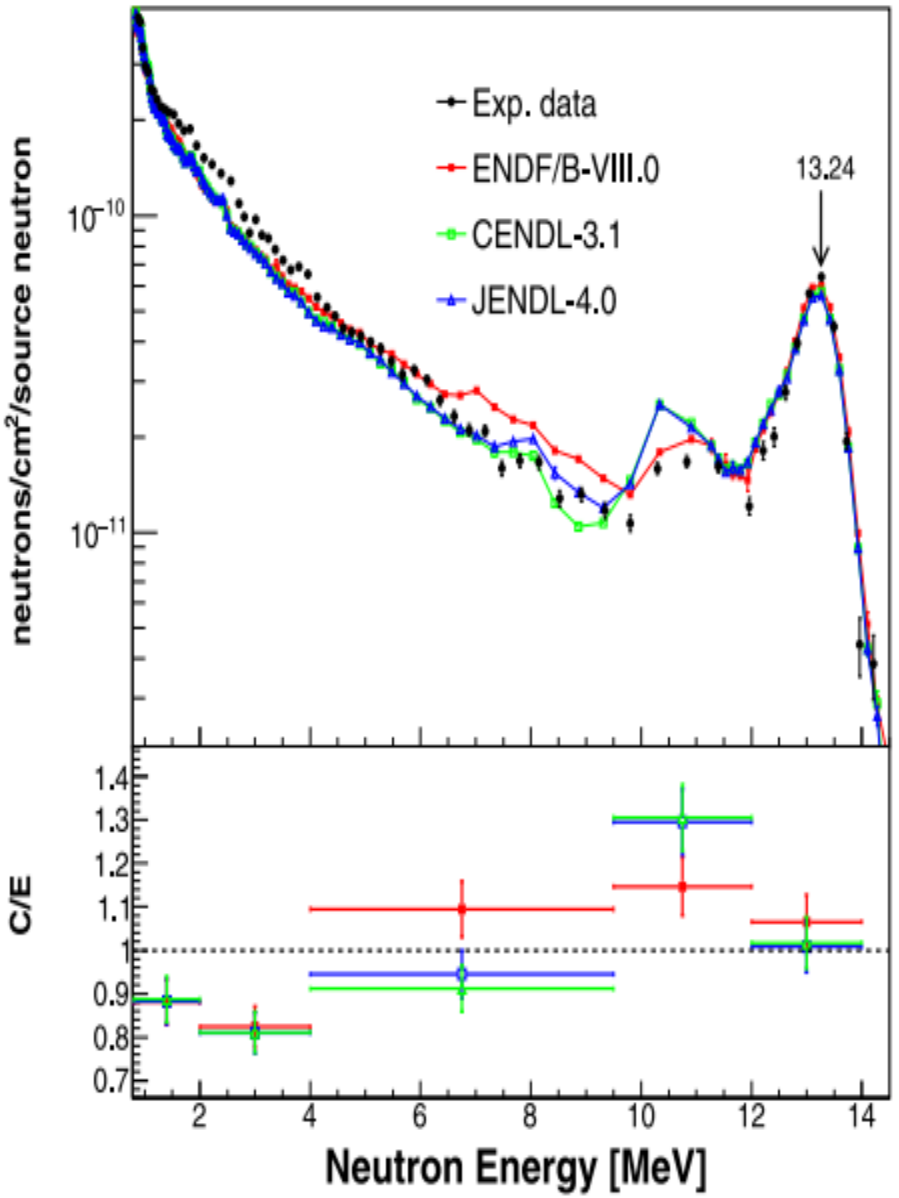

Zirconium
Exp. data
ENDF/B-VII.0
ENDF/B-VIII.0
CENDL-3.1
JENDL-4.0
Flux [neutrons/cm²/MeV/source neutron]
Neutron Energy [MeV]


Zirconium
Exp. data
ENDF/B-VII.0
ENDF/B-VIII.0
CENDL-3.1
JENDL-4.0
Flux [neutrons/cm²/MeV/source neutron]
Neutron Energy [MeV]


Calculation-to-Experiment (C/E) ratios
ENDF/B-VII.0
ENDF/B-VIII.0
JENDL-4.0
CENDL-3.1
Neutron Energy [MeV]

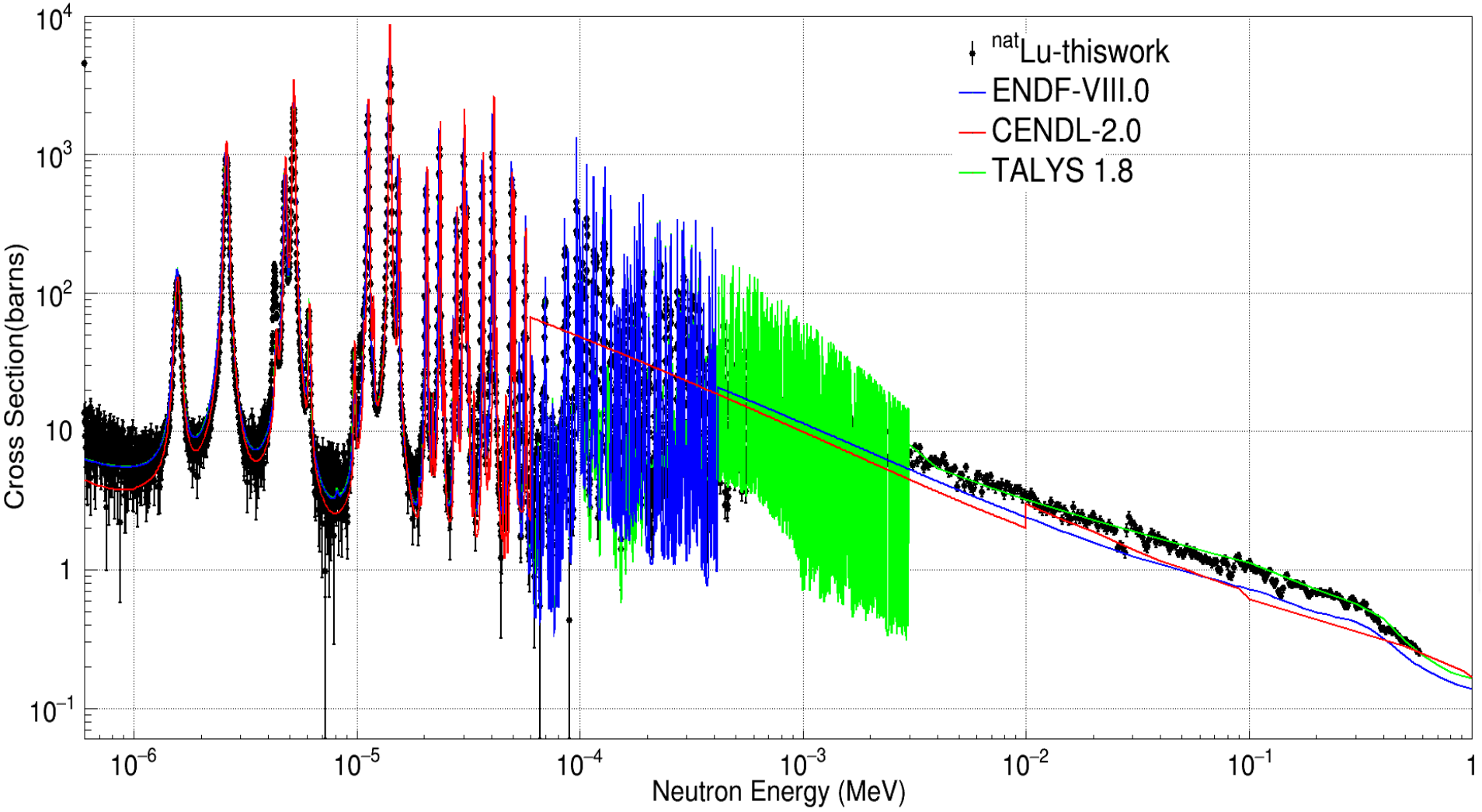
^{nat}Al case


14.26
Exp. data
ENDF/B-VIII.0
CENDL-3.1
JENDL-4.0
neutrons/cm²/source neutron
C/E
Neutron Energy [MeV]


13.24
Exp. data
ENDF/B-VIII.0
CENDL-3.1
JENDL-4.0
neutrons/cm²/source neutron
C/E
Neutron Energy [MeV]

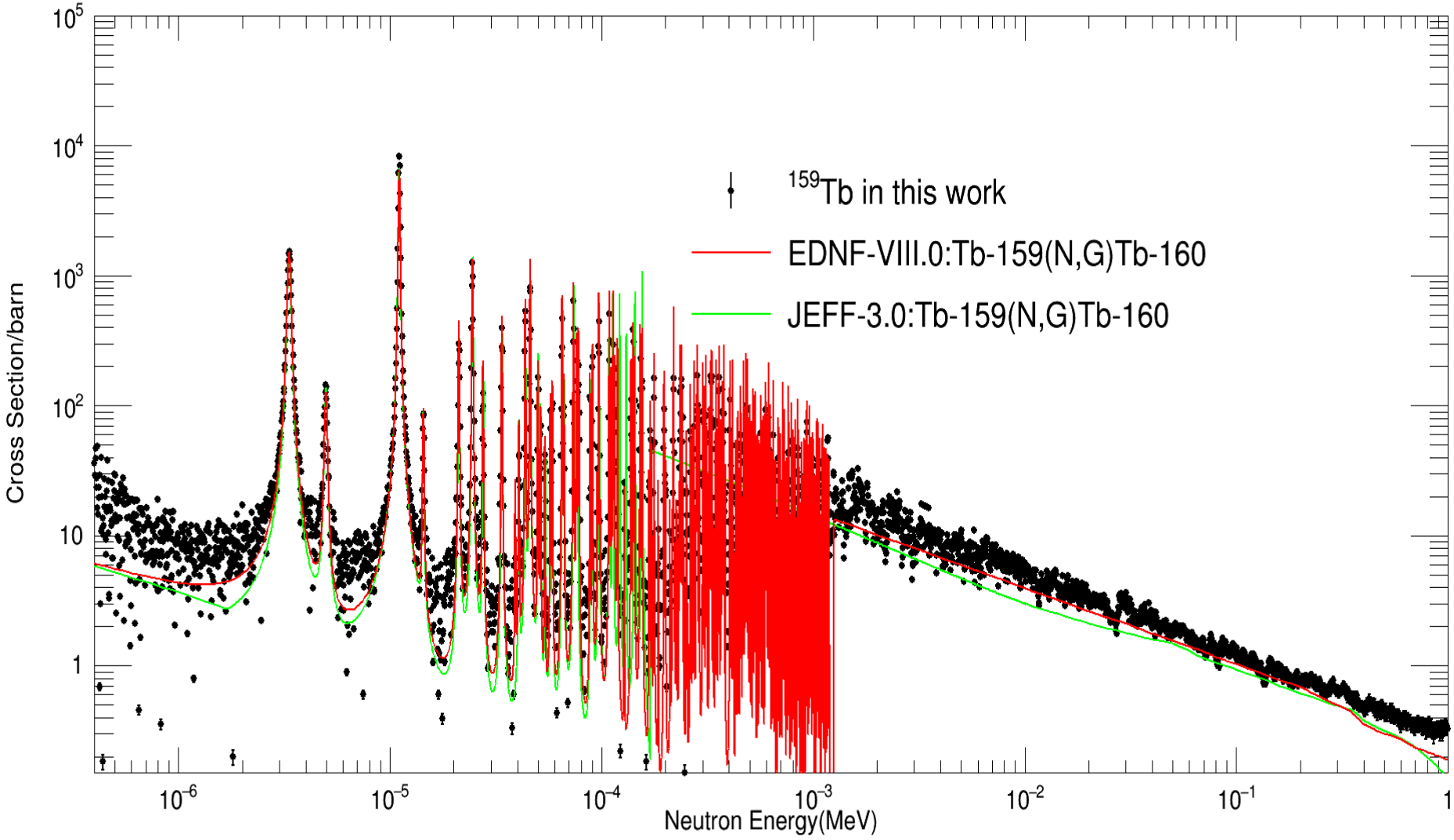
Neutron Capture Cross Section Measurement for ^{nat}Lu, ^{nat}Hf, ^{nat}Tb, ^{nat}Ho with CSNS Back-n

Preliminary result for ^{nat}Lu case



Neutron Capture Cross Section Measurement for ^{nat}Lu, ^{nat}Hf, ^{nat}Tb, ^{nat}Ho with CSNS Back-n

Preliminary result for ^{nat}Tb case



Thank you for your attention !