Problems of FENDL-3.2b

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Introduction

- We performed FENDL-3.2b benchmark tests with **TIARA and FNS experiments** and found that **FENDL-3.2b has still some problems** as shown in the FENDL-3.2b paper.
- We also carried out JENDL-5 benchmark tests# with TIARA and FNS experiments, which demonstrates that **JENDL-5 is better than FENDL-3.2b for some nuclei**.
- Recently we recognized that adequate **thermal scattering law data are important for beryllium**, though FENDL-3.2b does not have them.
- Here we explain these issues and reasons why the calculated results using FENDL-3.2b do not show the good agreement with the experimental ones.

: C. Konno, et al. JENDL-5 benchmark test for shielding applications, *J. Nucl. Sci. Technol.* 60, 1046-1069 (2023) https://doi.org/10.1080/00223131.2022.2164372

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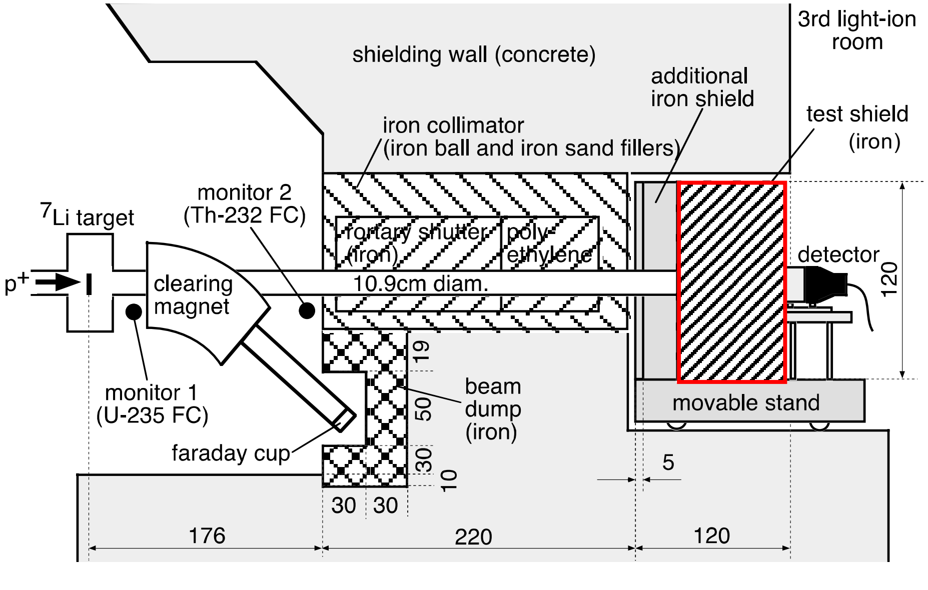
Experiment & Analysis

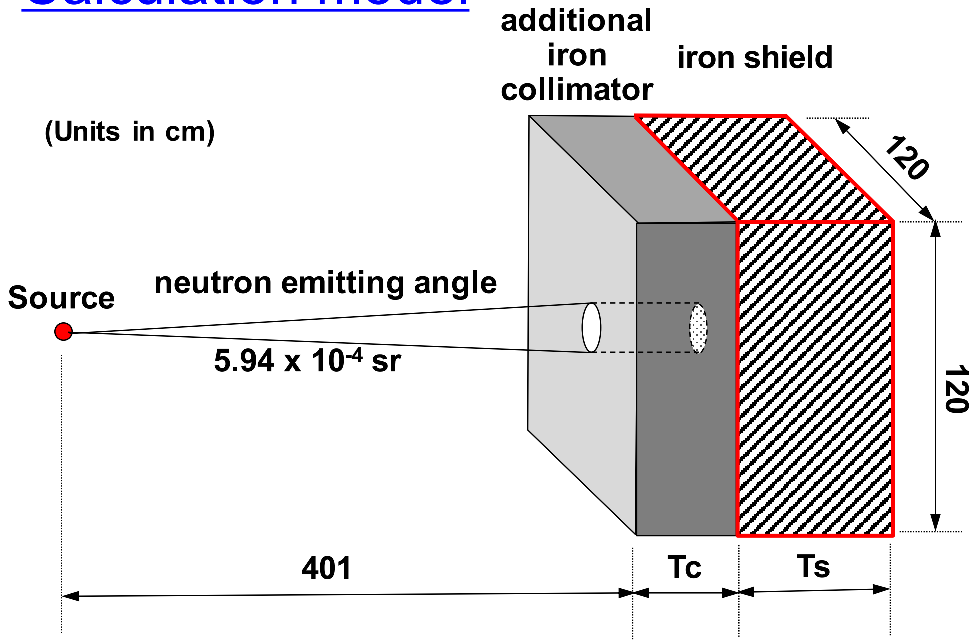
Experimental configuration



- 43 and 68 MeV of protons were bombarded on the Li-7 target.
- The generated neutrons, 40 and 65 MeV, were collimated and entered on the iron test shield.
- The neutron spectrum above 5 MeV was measured by scintillators.

See the following report for more details about the experiments and analyses:
H. Nakashima et al., JAERI-Data/Code 96-005, 1996

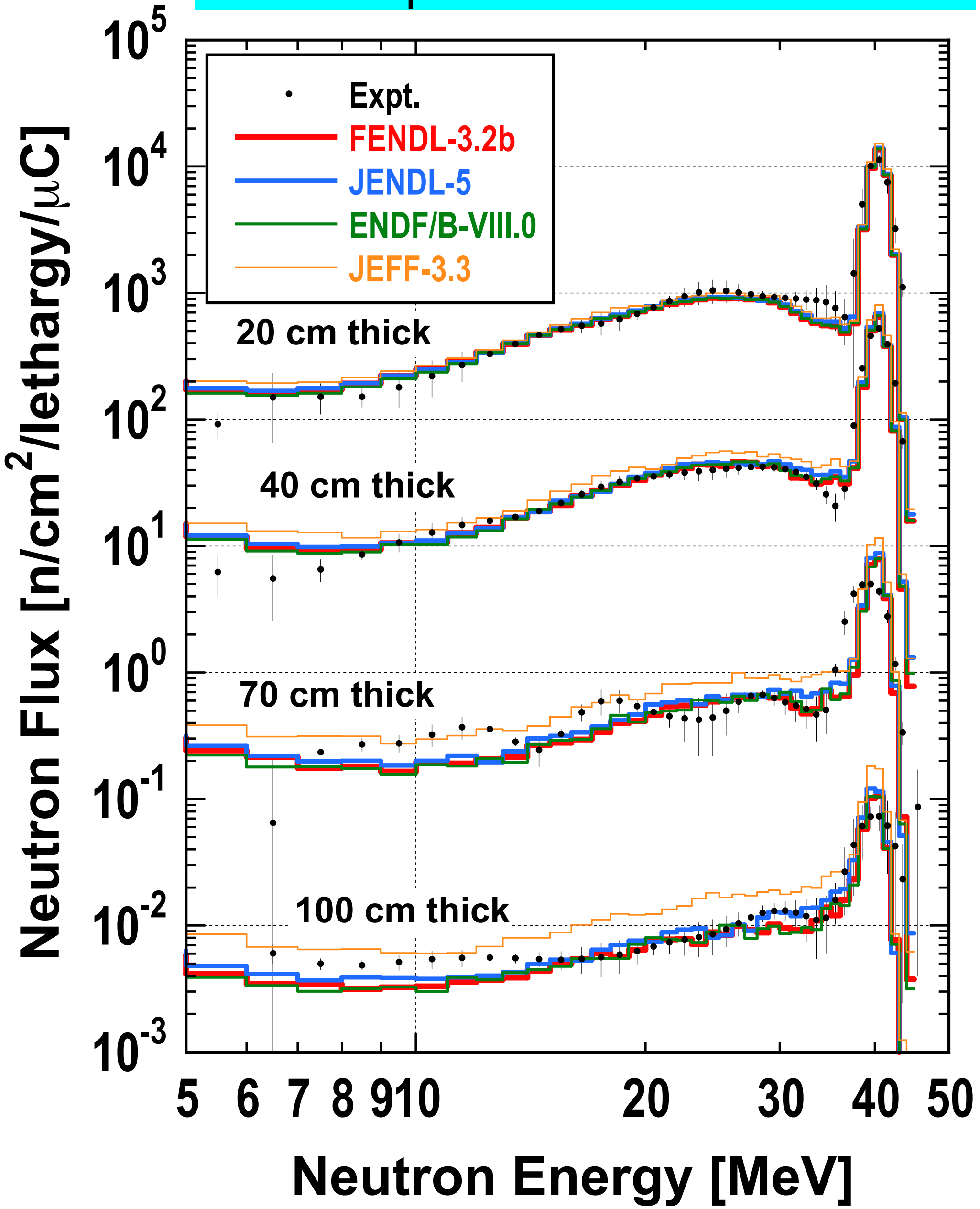
Calculation model



- Code: MCNP6.2
- Libraries:
  - FENDL-3.2b
  - JENDL-5
  - ENDF/B-VIII.0
  - JEFF-3.3
- The measured neutron spectrum was used as the source neutron in MCNP.

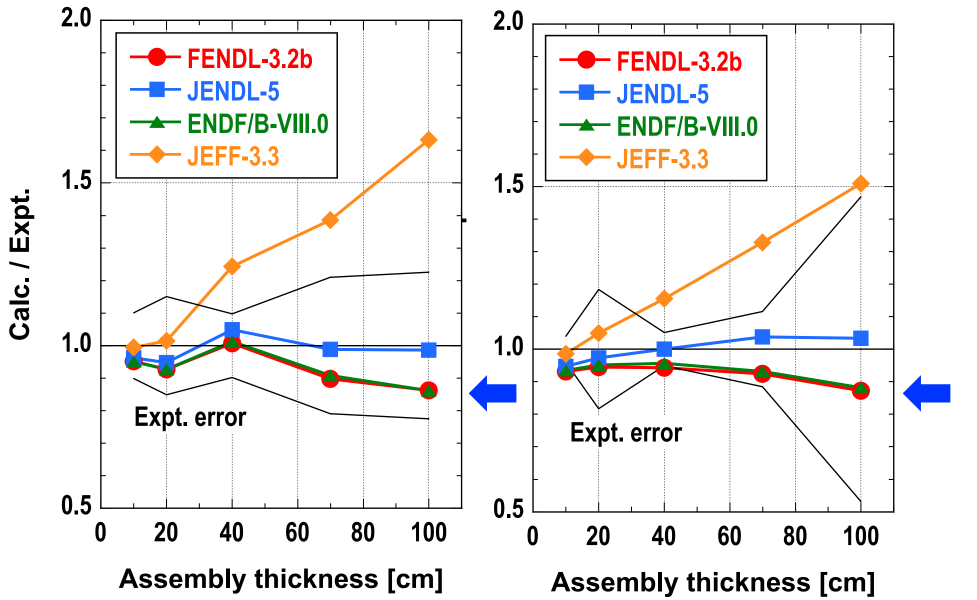
Result: 40 MeV

Neutron spectra of 40 MeV neutrons



Cont. (10 – 35 MeV)

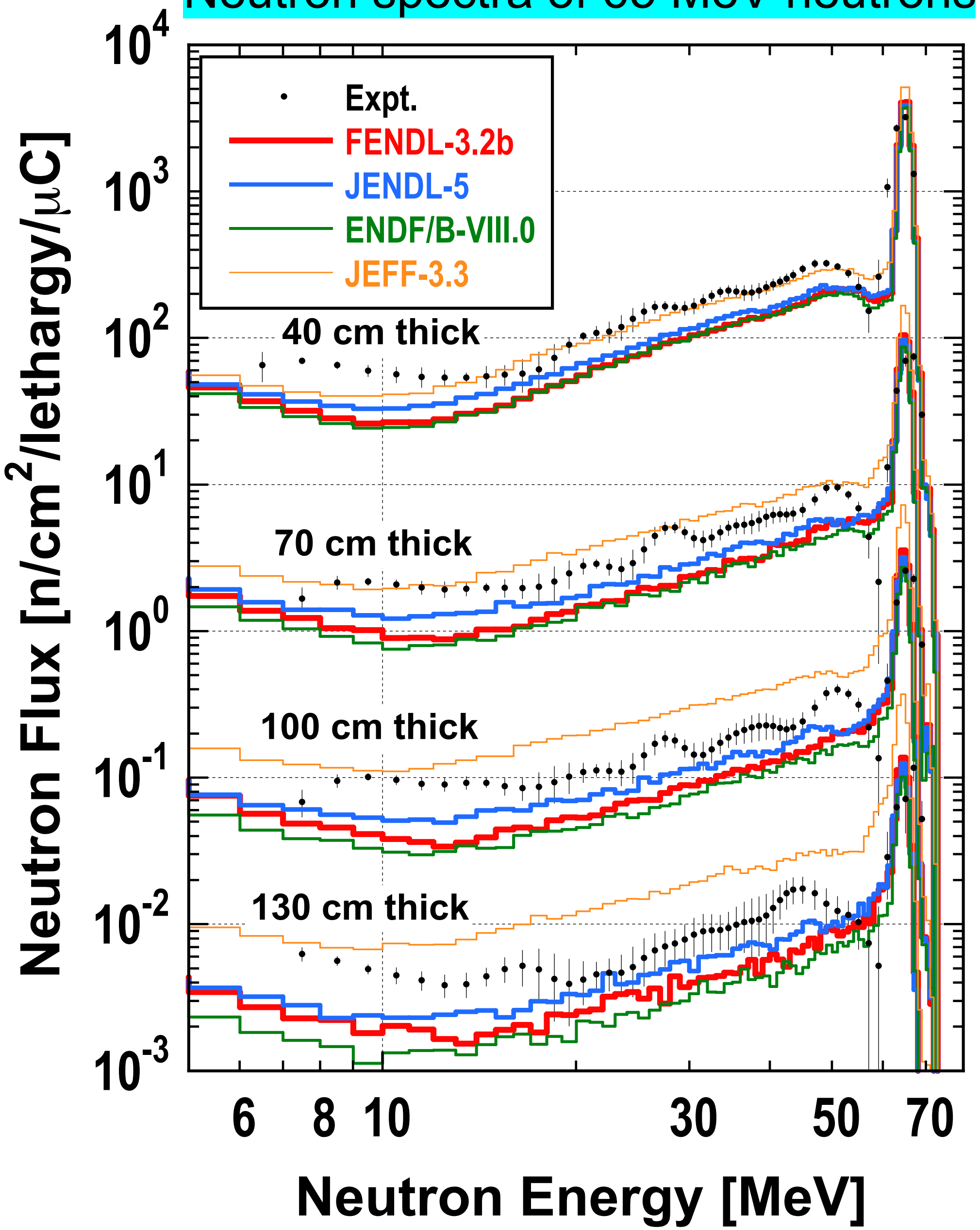
Peak (35 – 45 MeV)



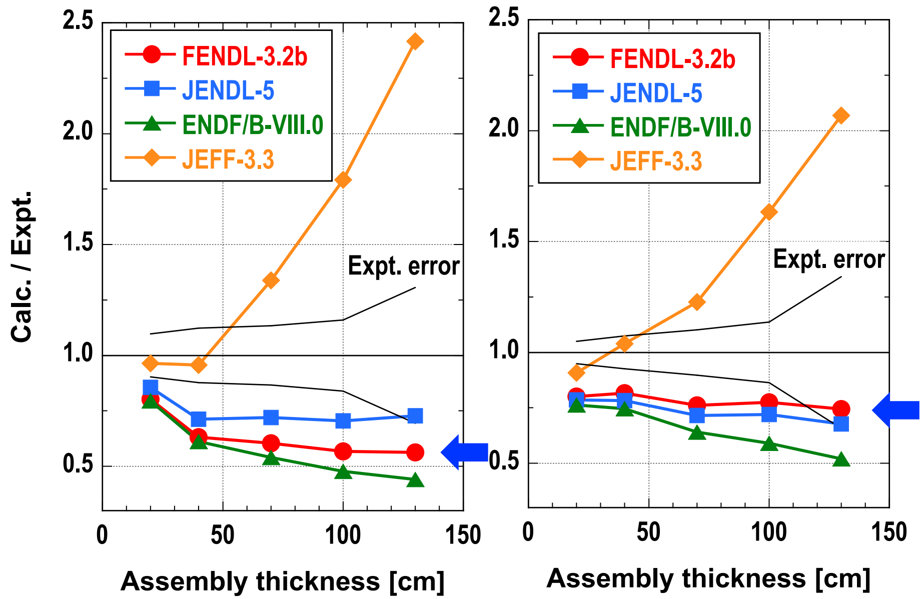
- Continuous region: FENDL-3.2b is good. JEFF-3.3 overestimates largely.
- Peak region: FENDL-3.2b is good. JEFF-3.3 overestimates largely.

Result: 65 MeV

Neutron spectra of 65 MeV neutrons



Cont. (10 – 60 MeV) Peak (60 – 70 MeV)

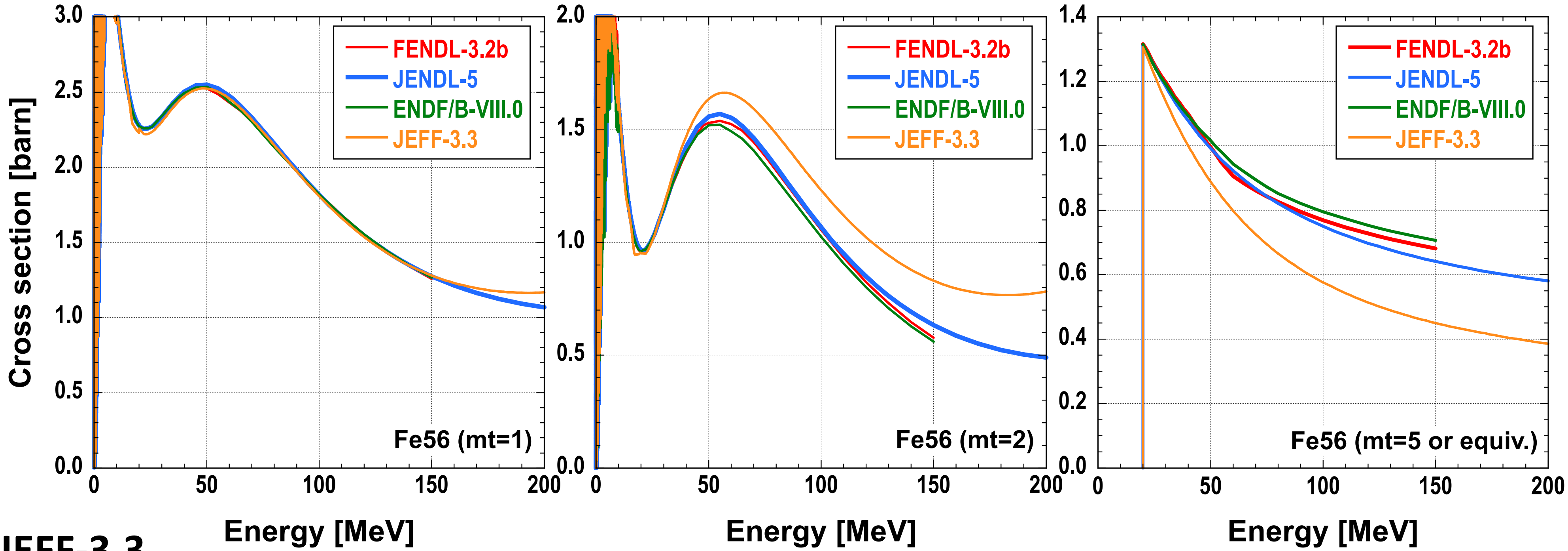


- <u>Continuous region:</u> FENDL-3.2b tends to underestimate. JENDL-5 is better than FENDL-3.2b. JEFF-3.3 overestimates largely. ENDF/B-VIII.0 underestimates.
- <u>Peak region</u>: FENDL-3.2b is the best. JEFF-3.3 overestimates largely. ENDF/B-VIII.0 underestimates.

FYI: Off the subject…

The reason of the overestimation using JEFF-3.3;

- Large elastic scattering cross section (mt=2) mt=5 equiv.
- Small non-elastic scattering cross section (mt=5 or “total – elastic”)



JEFF-3.3

- (Almost) Not changed since JEFF-3.1 (2005)
- 20 - 200 MeV extension data from NRG-2004

Next JEFF

- INDEN evaluation implemented in JEFF-4 test library, JEFF-4T2.2

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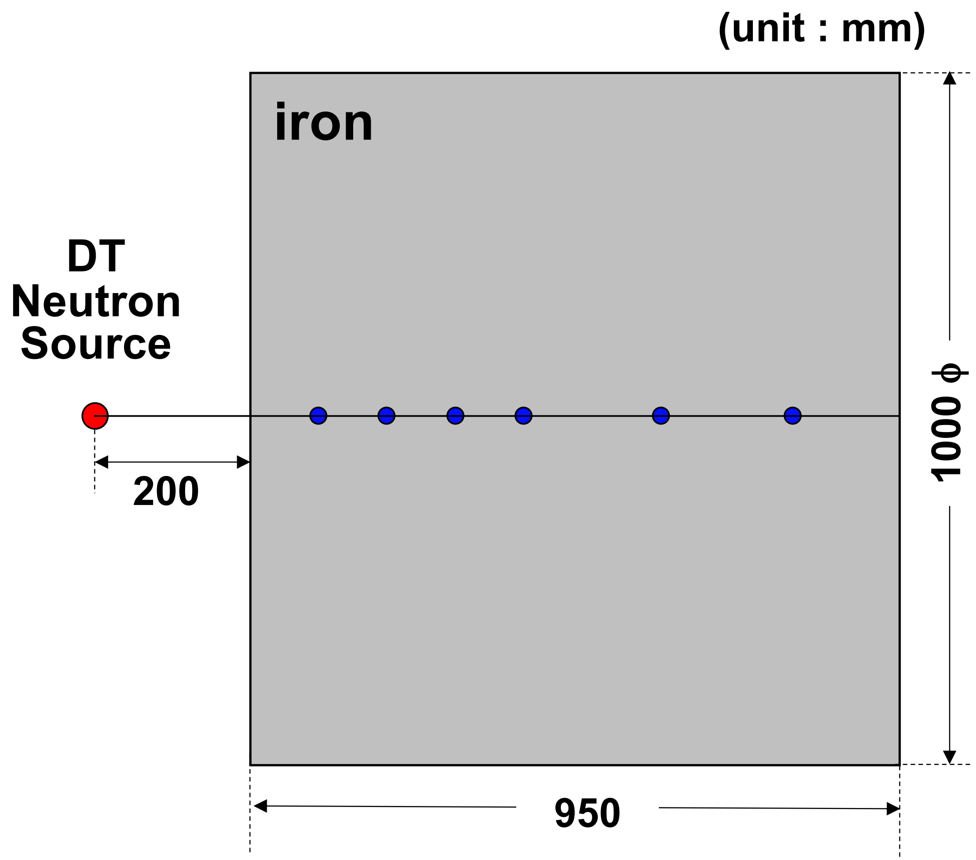
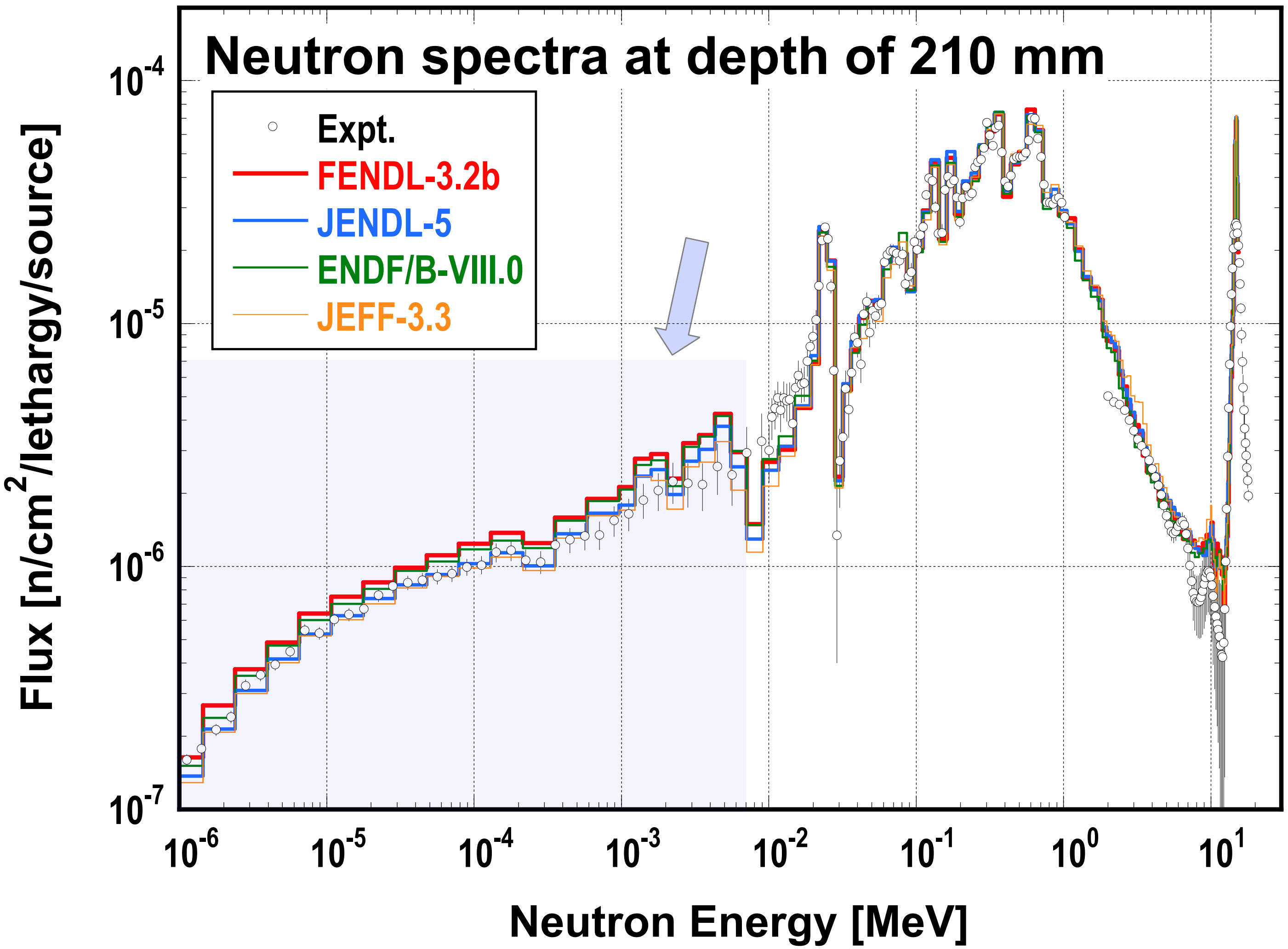


NE213, proton recoil counters, slowing down method with BF3 counter and activation foils

- **Neutron spectra** over almost the whole energy and **reaction rates** of several reactions were measured inside the iron assembly.

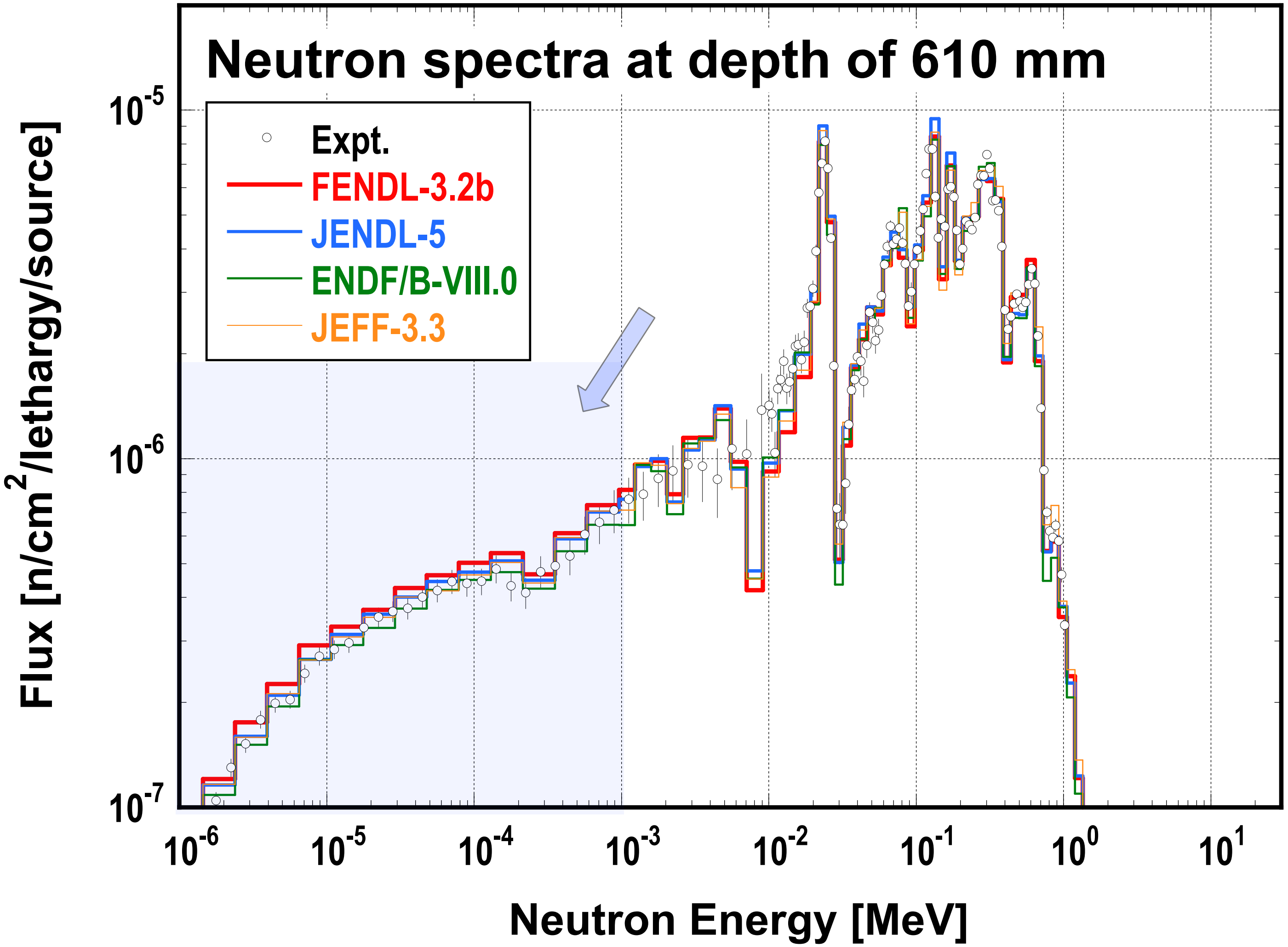
- **Code: MCNP6.2**
- **Libraries:**
  - **FENDL-3.2b**
  - **JENDL-5**
  - **ENDF/B-VIII.0**
  - **JEFF-3.3**

Result: Neutron spectra -(1)



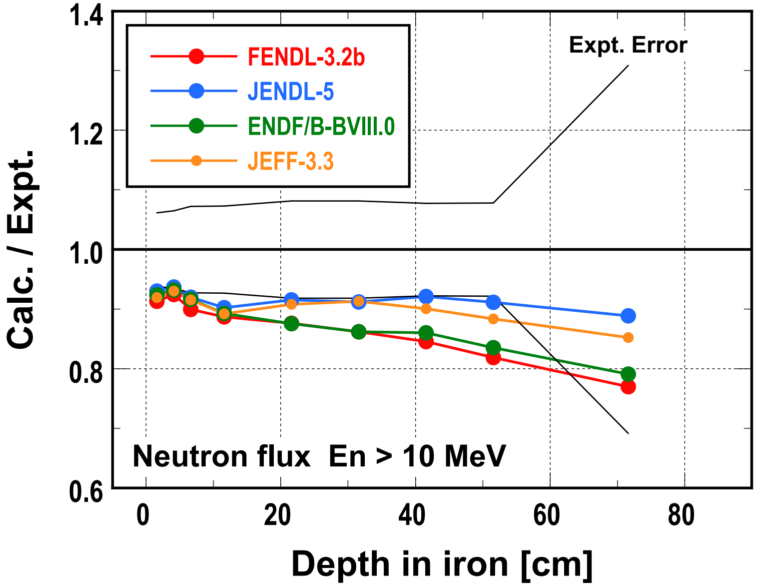
FENDL-3.2b and ENDF/B-VIII.0 overestimate the measured neutron spectrum below 10 keV!

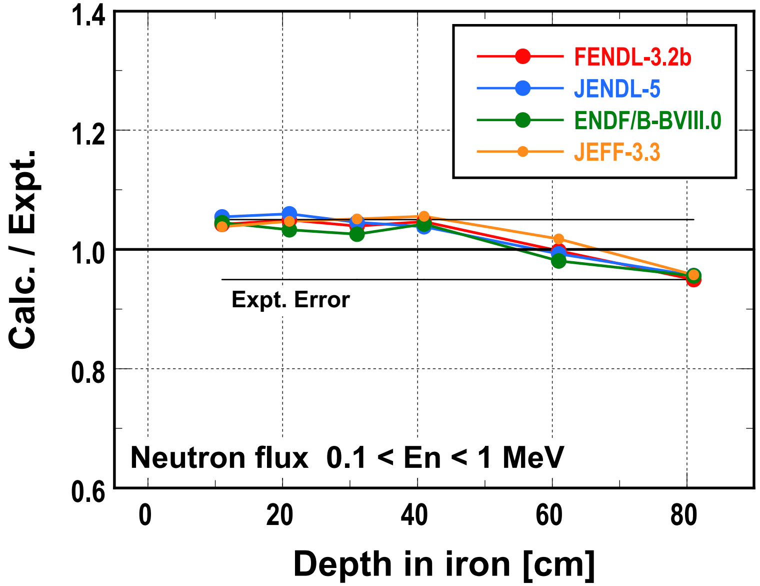
Result: Neutron spectra -(2)

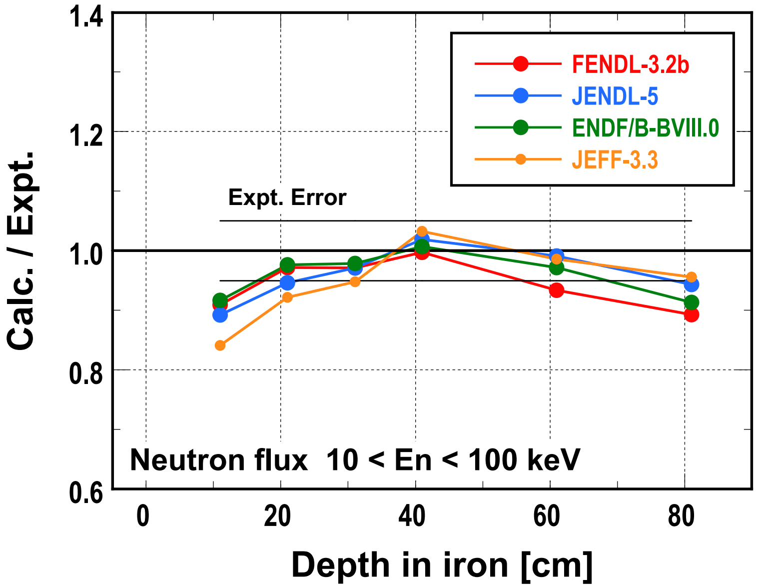


FENDL-3.2b slightly overestimates the measured neutron spectrum below 1 keV !

Result: Calc. / Expt. of neutron flux -(1)



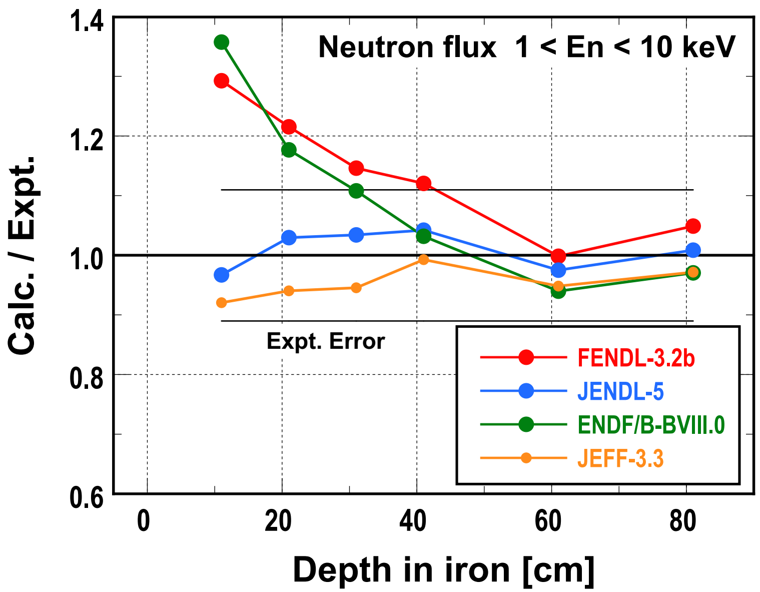


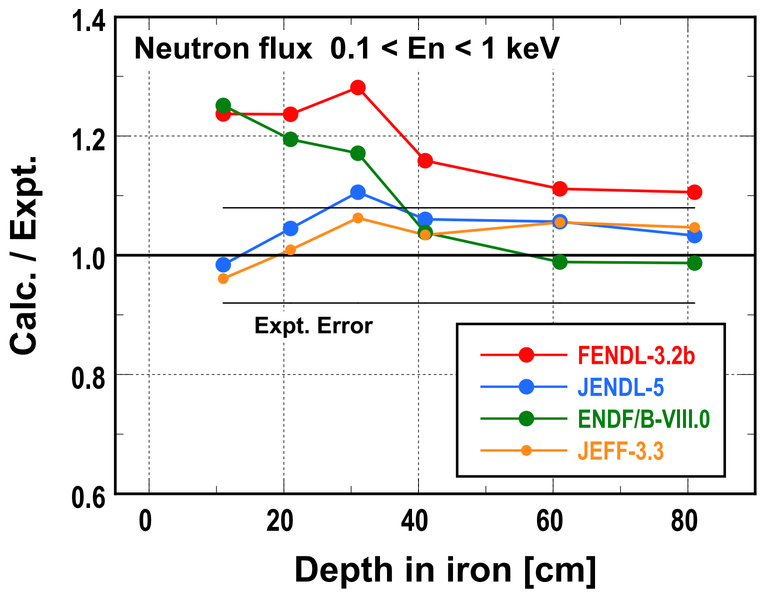


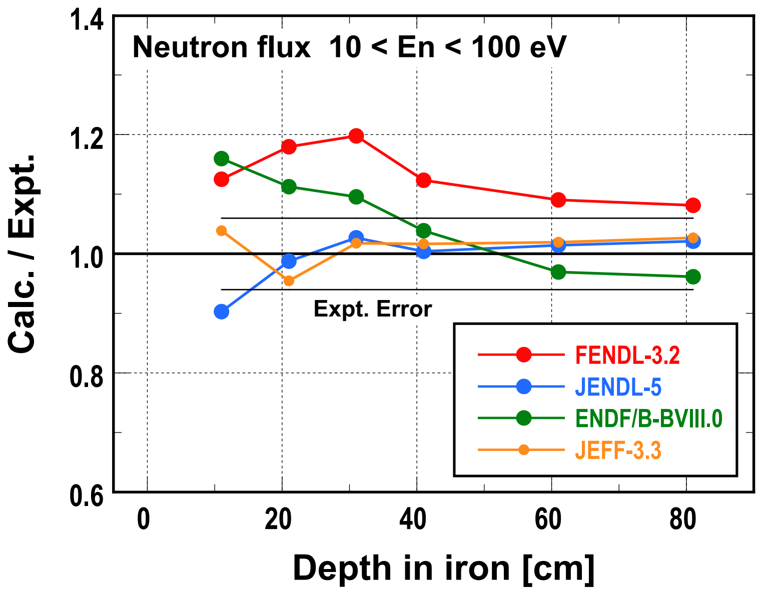
FENDL-3.2b and ENDF/B-VIII.0 tend to underestimate measured neutron flux above 10 MeV !

C. Konno and S. Kwon, Analyses of JAEA/FNS iron in-situ experiment with latest nuclear data libraries, *EPJ Web of Conferences* 284, 15010 (2023) https://doi.org/10.1051/epjconf/202328415010

Result: Calc. / Expt. of neutron flux -(2)







FENDL-3.2b and ENDF/B-VIII.0 tend to overestimate measured neutron flux below 10 keV up to depth of 60cm!

C. Konno and S. Kwon, Analyses of JAEA/FNS iron in-situ experiment with latest nuclear data libraries, *EPJ Web of Conferences* 284, 15010 (2023) https://doi.org/10.1051/epjconf/202328415010

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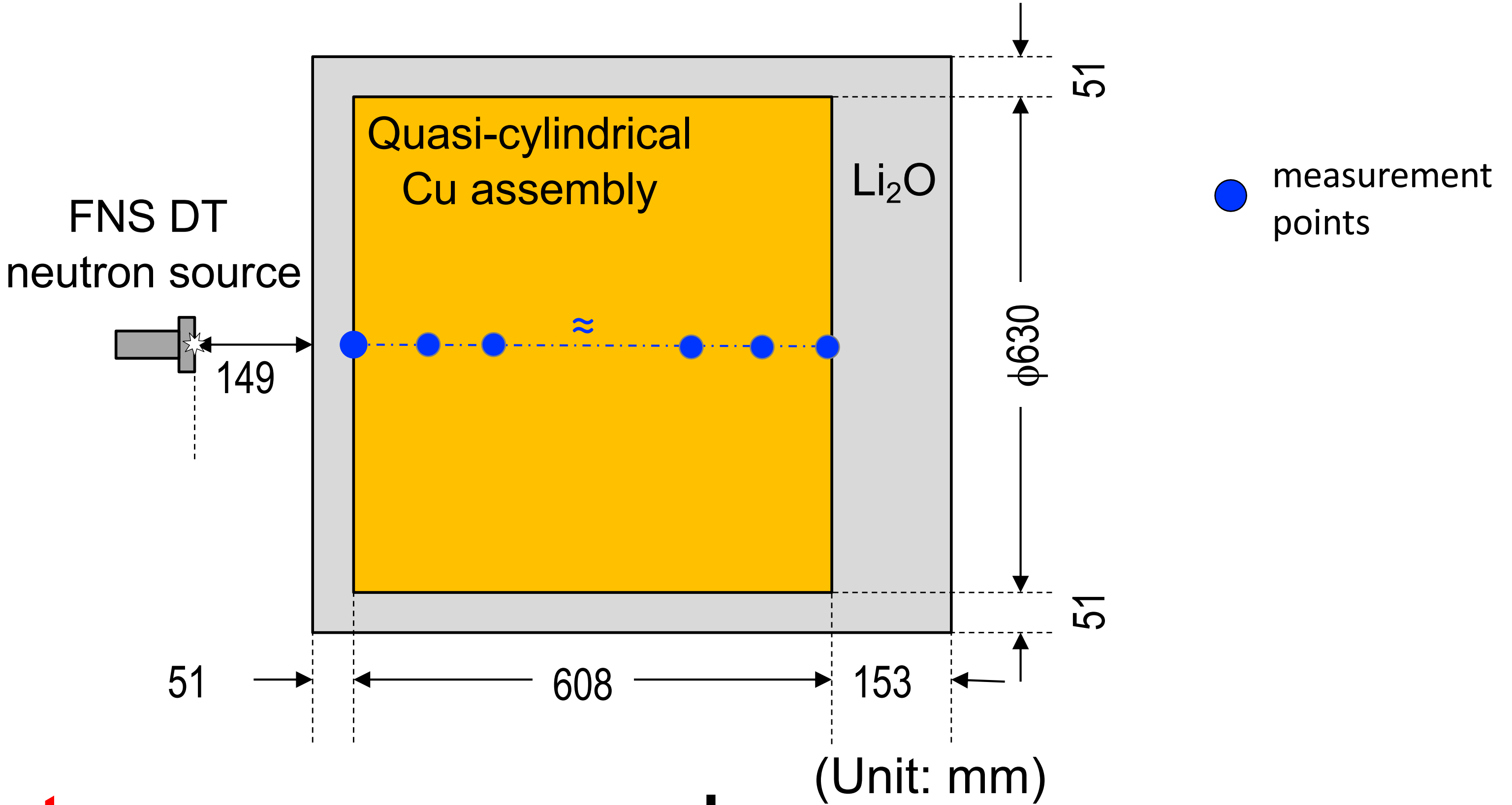


Reaction rates were measured inside the copper assembly.

- ^{93}Nb(n,2n)^{92m}Nb
- ^{27}Al(n,α)^{24}Na
- ^{115}In(n,n')^{115m}In

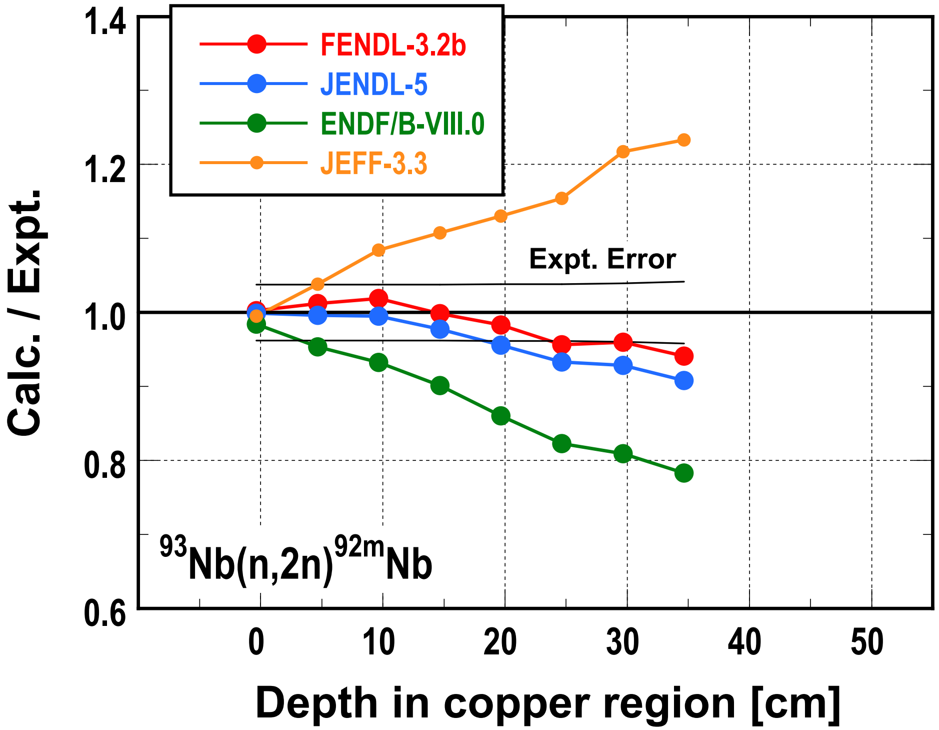
high energy neutrons

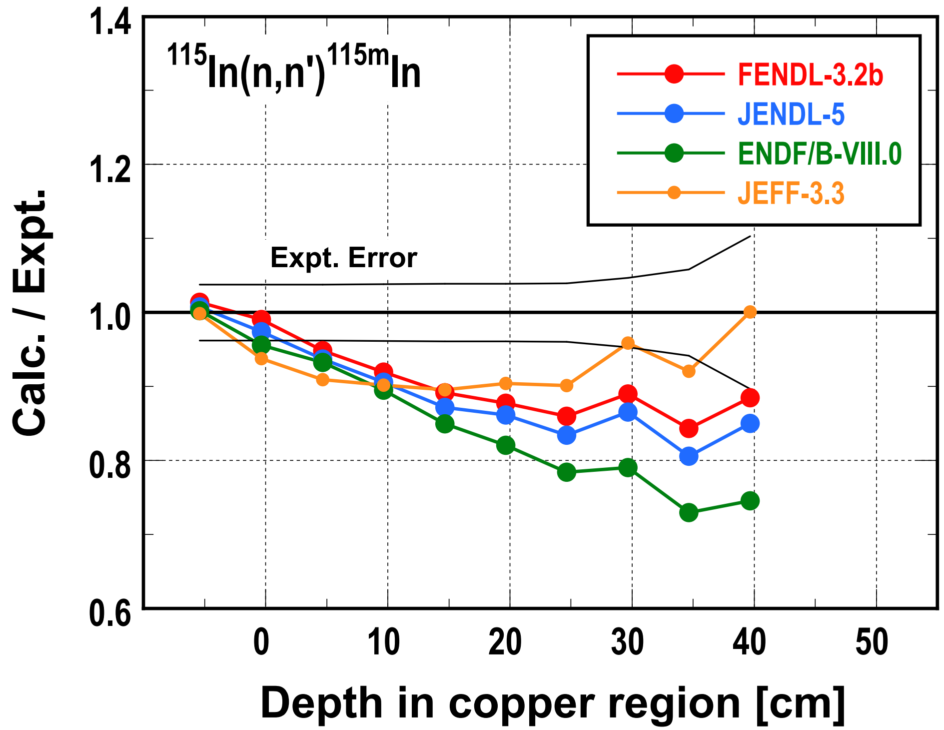
- ^{186}W(n,γ)^{187}W
- ^{197}Au(n,γ)^{198}Au

low energy neutrons

- **Code: MCNP6.2**
- **Libraries:**
  FENDL-3.2b
  JENDL-5
  ENDF/B-VIII.0
  JEFF-3.3

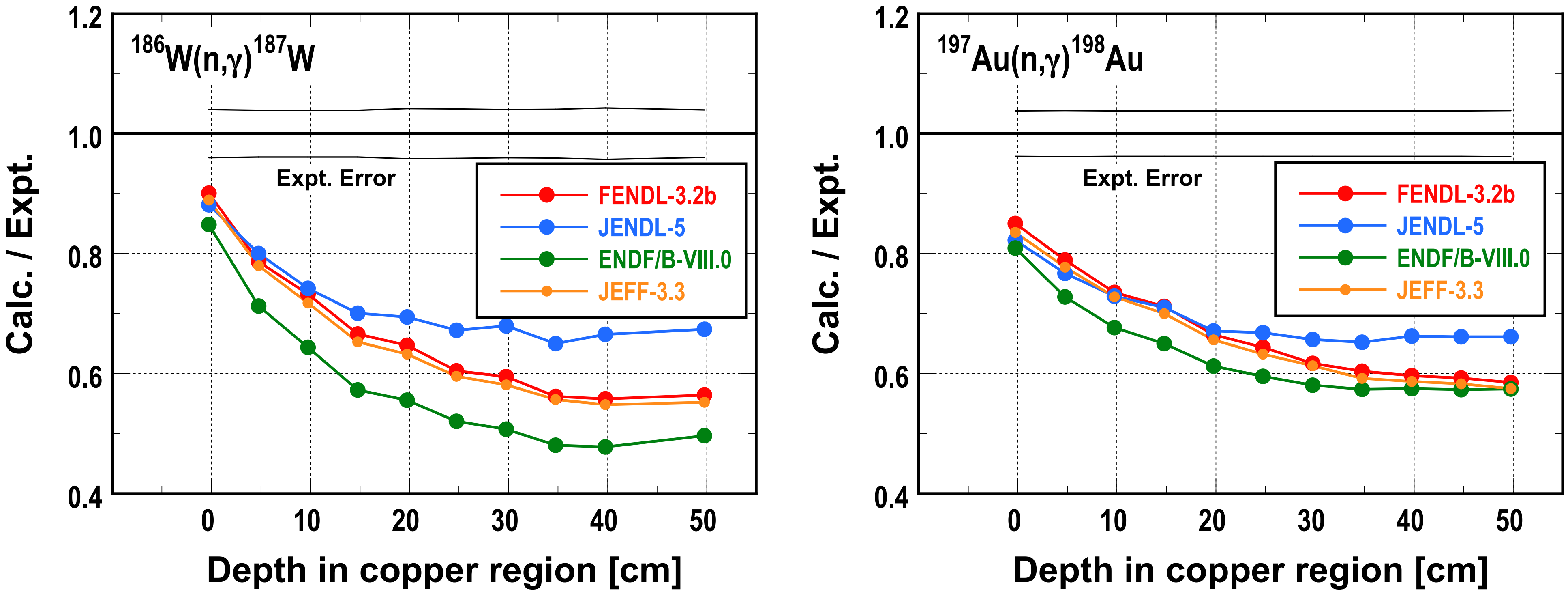
Result: Calc. / Expt. of reaction rates -(1)





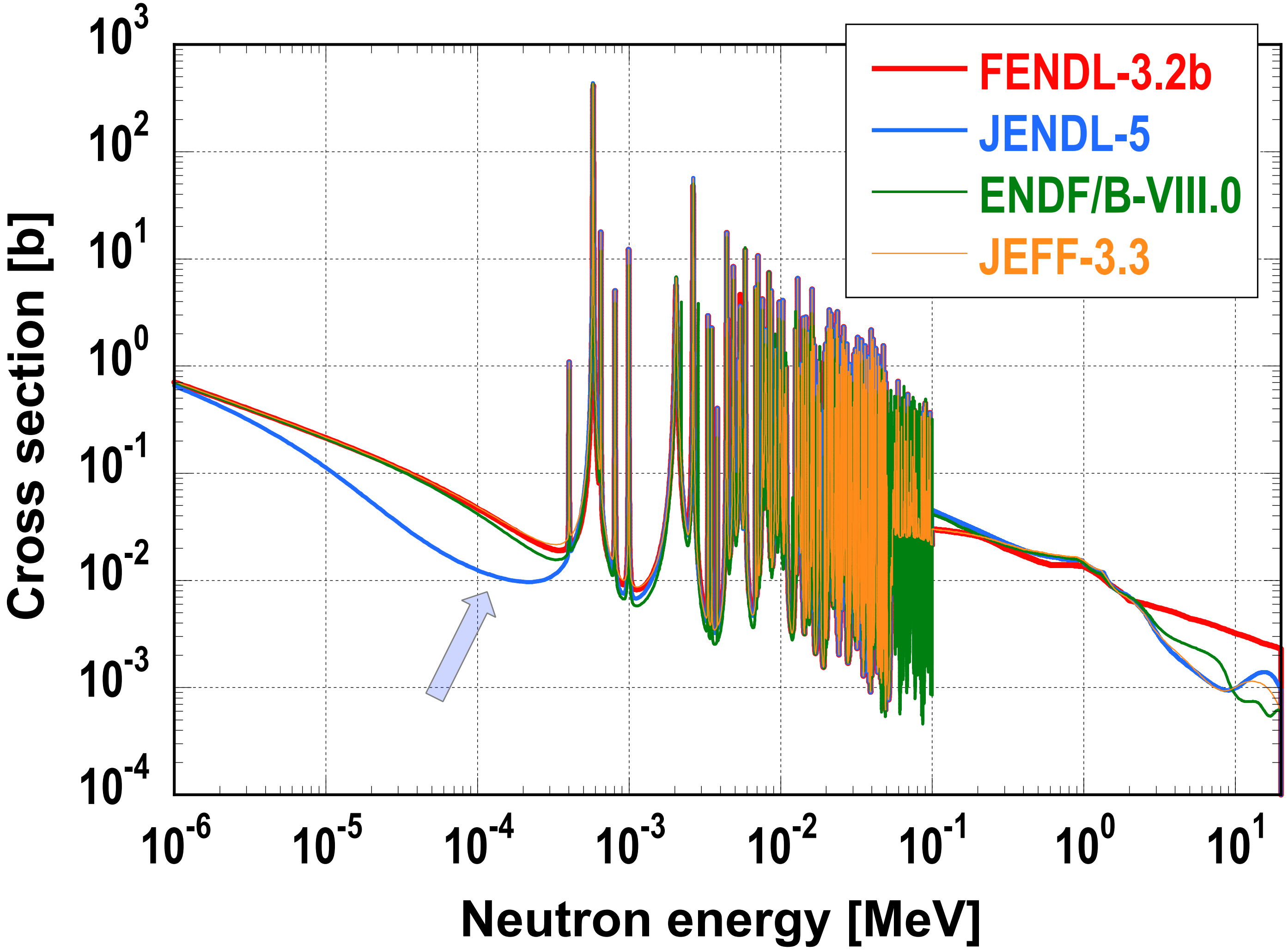
FENDL-3.2b is the best over 0.3 MeV neutrons.

Result: Calc. / Expt. of reaction rates -(2)



FENDL-3.2b tends to underestimate as same as before.
Only JENDL-5 shows the improvement.

JENDL-5 ^{63}Cu capture cross section



JENDL-5 is very different below 400 eV from other libraries.

→ Improvement of $^{186}W(n,\gamma)^{187}W$ and $^{197}Au(n,\gamma)^{198}Au$

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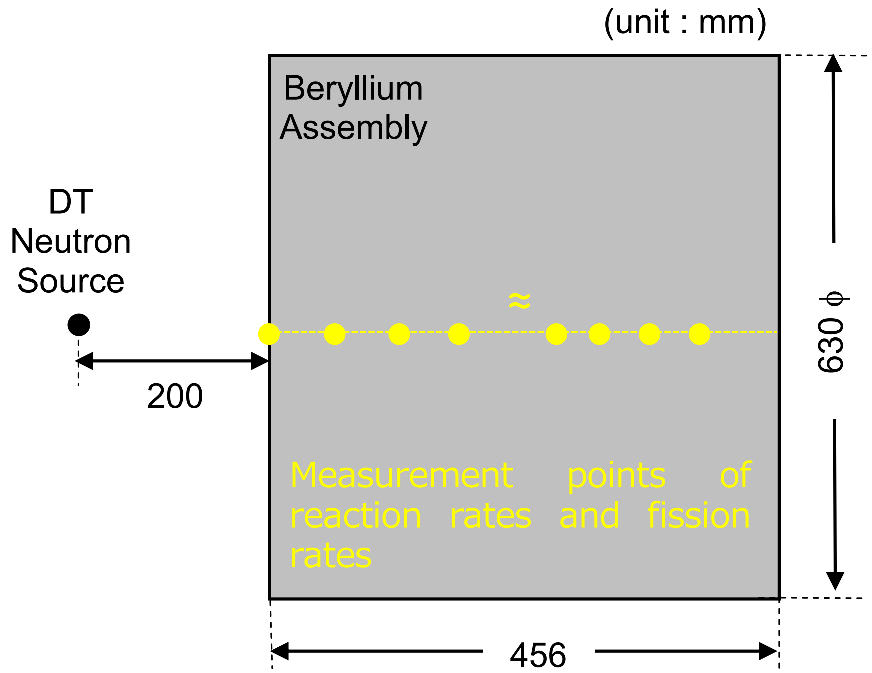


Reaction rates were measured inside the beryllium assembly.

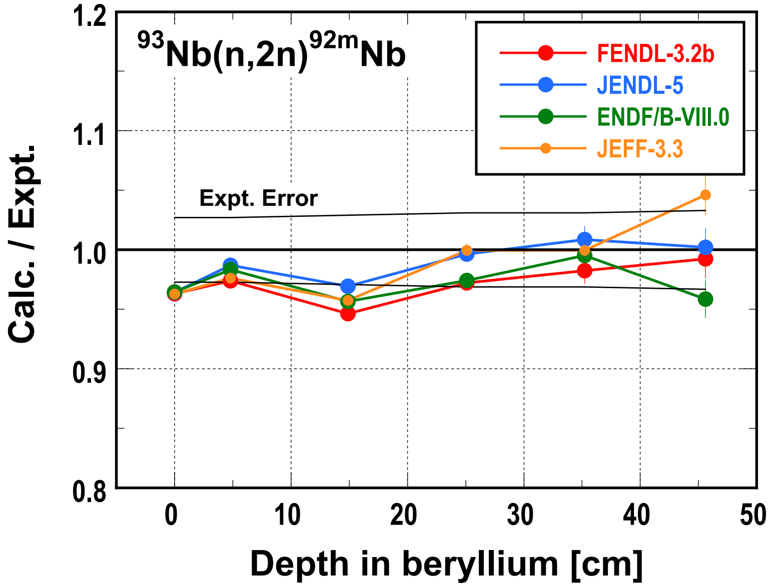
- ^{6}Li(n,α)T,
- ^{27}Al(n,α)^{24}Na,
- ^{93}Nb(n,2n)^{92m}Nb,
- ^{115}In(n,n')^{115m}In,
- ^{197}Au(n,γ)^{198}Au,
- ^{235}U(n,fission)

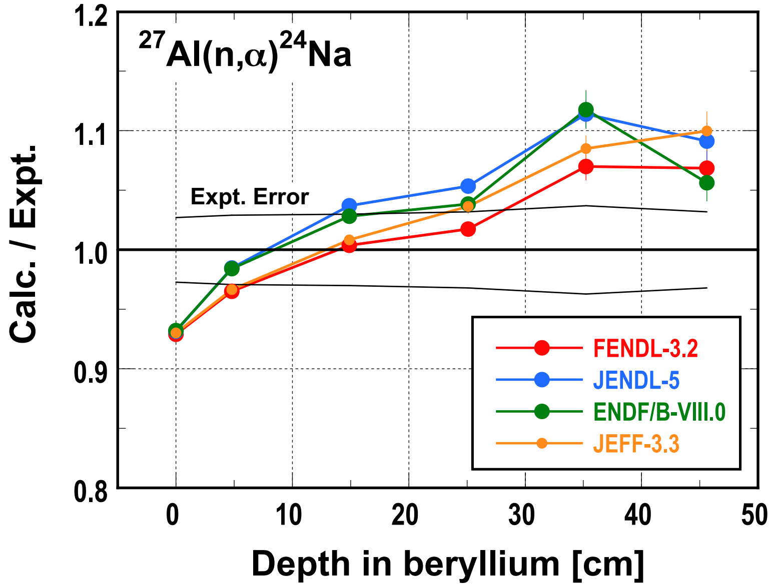
high energy neutrons

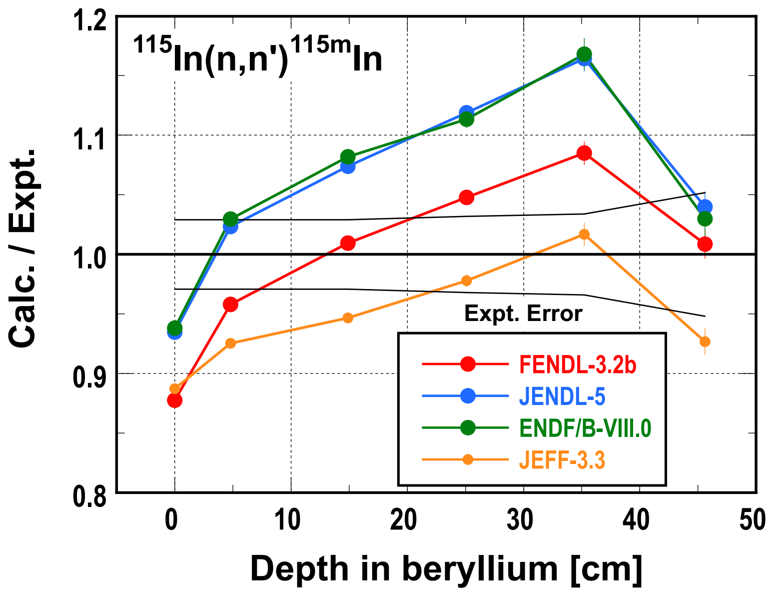
low energy neutrons

- **Code: MCNP6.2**
- **Libraries :**
  FENDL-3.2b
  (S(α,β) : ENDF/B-VIII.0)
  JENDL-5
  ENDF/B-VIII.0
  JEFF-3.3

Result: Calc. / Expt. of reaction rates -(1)

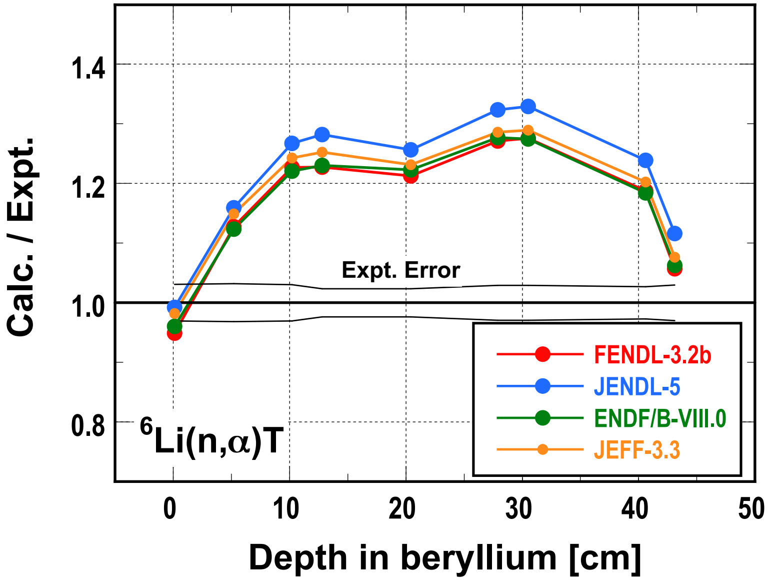


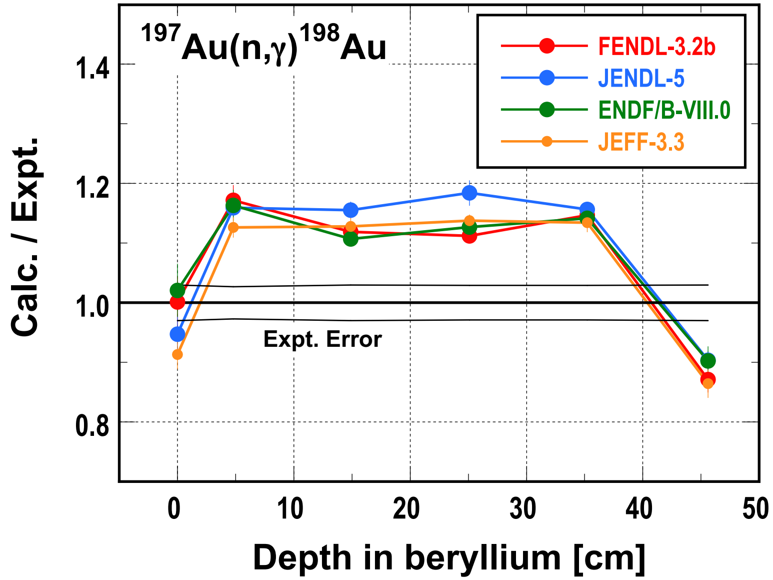


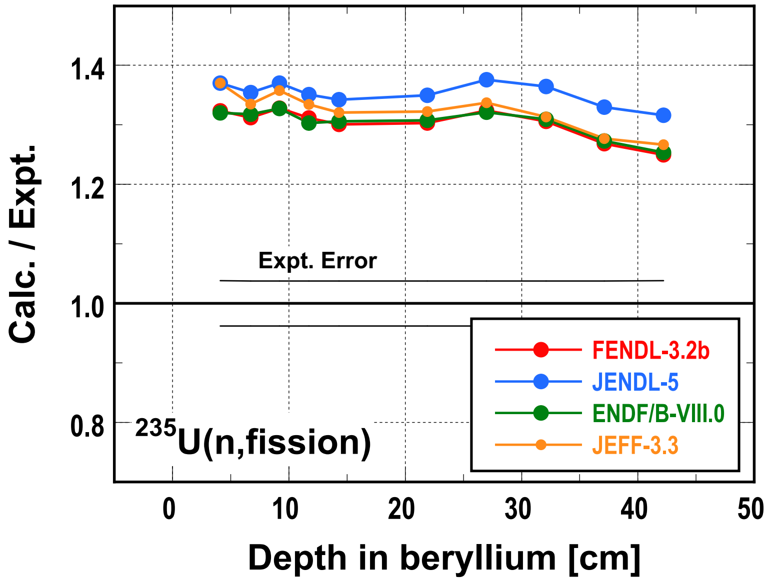


FENDL-3.2b is good!

Result: Calc. / Expt. of reaction rates -(2)







All libraries cause overestimation of reaction rates sensitive to low energy neutrons !

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Conclusion

- We carried out FENDL-3.2b and JENDL-5 benchmark tests with TIARA and FNS experiments.
- The following issues were noted.
  - ✓ Iron : JENDL-5 is better than FENDL-3.2b.
  - ✓ ^{63}Cu : JENDL-5 is better than FENDL-3.2b.
  - ✓ Beryllium : All nuclear data libraries including FENDL-3.2b overestimate low energy neutrons.

- The above issues should be investigated for the next FENDL.

Thank you for your attention!