Validation of nuclear data against accelerator experiments in SINBAD

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Experimental benchmarks in SINBAD

The validation of particle transport codes and nuclear data are necessary in the framework of the licensing process of MYRRHA installations (Phase 1: 100 MeV accelerator+irradation target stations).

- Few accelerator shielding experiments performed with the medium proton energies and target materials are relevant with the MYRRHA phase 1 project part.
- SCK & JAEA collaboration to validate Mcnp6.2, Phits codes, and nuclear data using SINBAD experiments

SINBAD abstract No.	Facility	Proton energy + target	Shielding materials
NEA-1552/03	**AVF cyclotron of the TIARA facility in JAERI**	**43 MeV and 68 MeV proton on a thin ^{7}Li target**	**Concrete, Iron**
NEA-1552/34	**Cyclotron of the Institute of Nuclear Study (INS) at the University of Tokyo**	**52 MeV proton on a thick C target**	**Graphite, Water, Concrete, Iron**
NEA-1552/31	**AVF cyclotron facility of Osaka University**	**75 MeV proton on a thick Cu target**	**Concrete**
NEA-1552/15	**Cyclotoron in the Swiss Institute for Nuclear Research (SIN)**	**590 MeV proton on a thick Pb target**	**-**
NEA-1552/23	KEK Spallation Neutron Source Facility (KENS)	500- MeV proton on a thick W target	Concrete
NEA-1552/38	Intense spallation neutron source facility, ISIS, of the Rutherford Appleton Laboratory	800- MeV proton on a thick Ta target	Concrete, Iron

Calculation condition

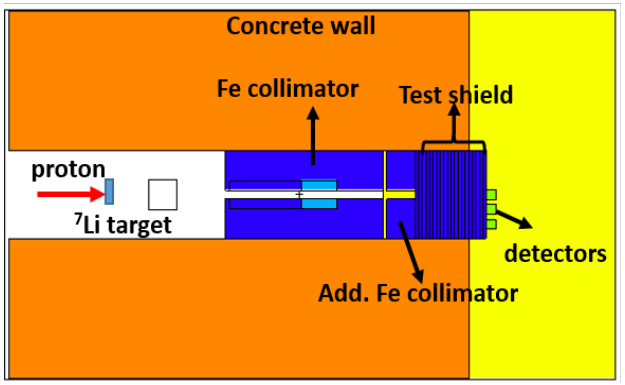
MCNP6.2 calculation configuration

Pattern ID	Proton interactions	Pattern ID	Neutron interactions
A	• different proton libraries JENDL-4.0/HE TENDL-2017 ENDF/B-VII.0 (CEM03.03 model in mix and match)	D	• JEFF-3.3 neutron library (CEM03.03 model in mix and match)
B	• JENDL-4.0/HE proton library (CEM03.03 model in mix and match)	E	• different neutron libraries JEFF-3.3 JEFF-3.1.2 JENDL-4.0/HE ENDF/B-VIII.0 ENDF/B-VII.1 JENDL-HE (CEM03.03 model in mix and match)
C	• Physics models	F	• Physics models

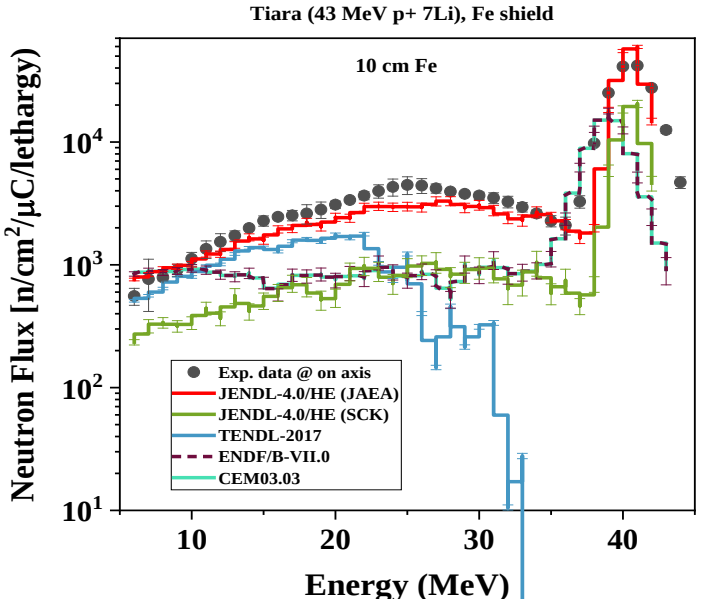
NEA-1552/03: 43-MeV proton beam, thin 7Li target

A+D configuration
(dif. proton lib.)+(JEFF-3.3 neutron lib)

Transmitted neutron flux measurement



MCNP model (B. Kos and I. Kodeli, INDC(NDS)-0785)

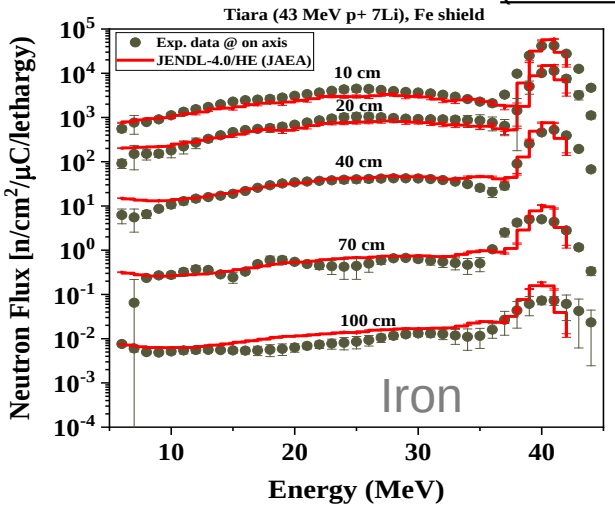


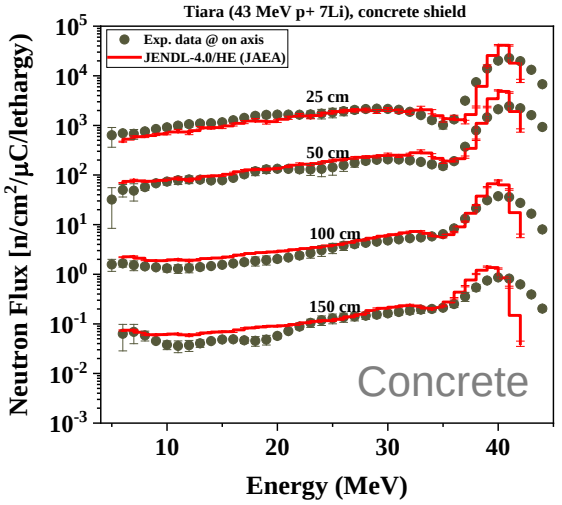
- **JENDL-4.0/HE proton library (JAEA) processed with the NJOY2016 patch, which is developed by PHITS/JENDL team, gives the perfect match with the experiment.**
- **TENDL-2017 proton library fails to produce experimental data.**
- **ENDF/B-VII.0 proton library has proton data for 7Li up to 10 MeV.**

NEA-1552/03: 43-MeV proton beam, thin 7Li target

B+D configuration

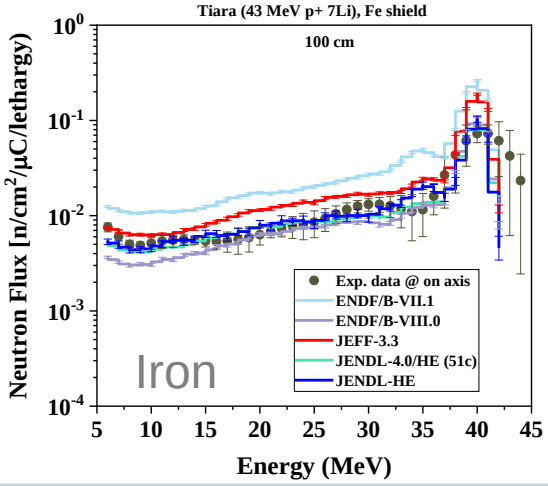
(JENDL-4.0/HE proton lib.+.)+(JEFF-3.3 neutron lib.)

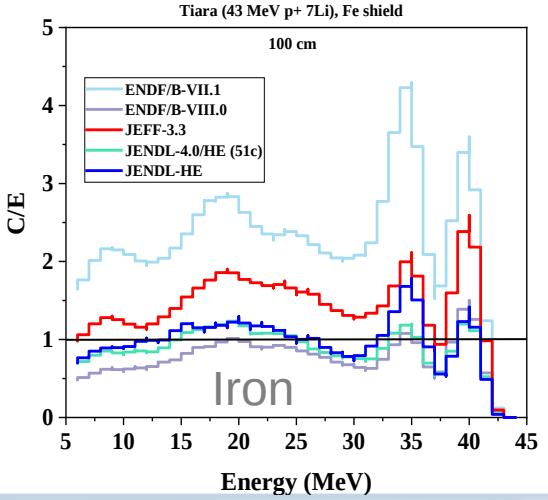


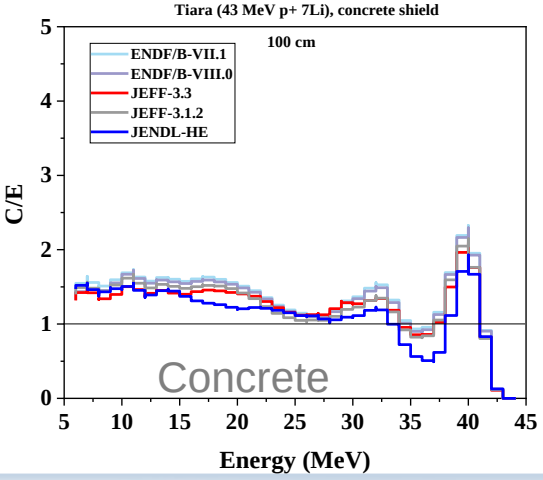


B+E configuration

(JENDL-4.0/HE proton lib.)+(diff. neutron lib.)



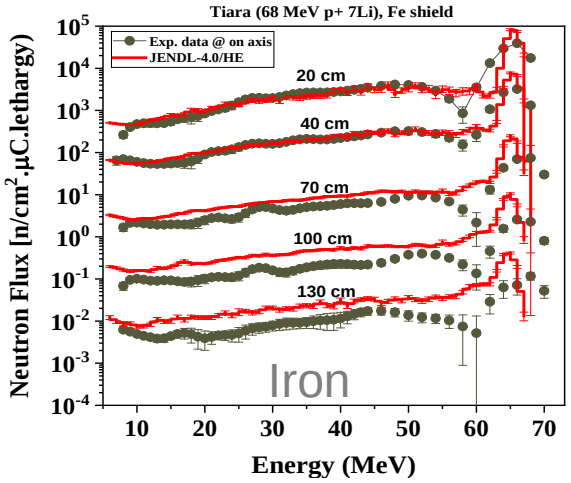


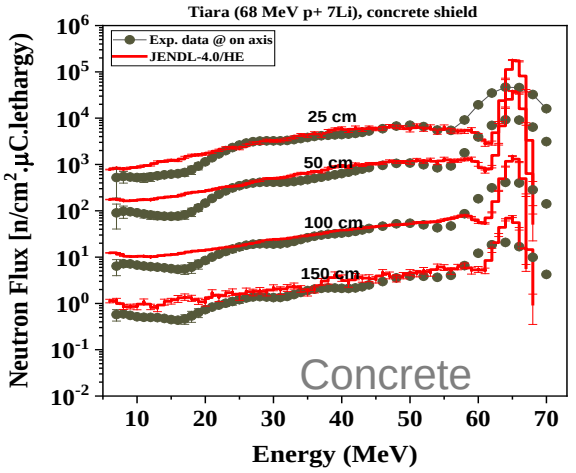


NEA-1552/03: 68-MeV proton beam, thin 7Li target

B+D configuration

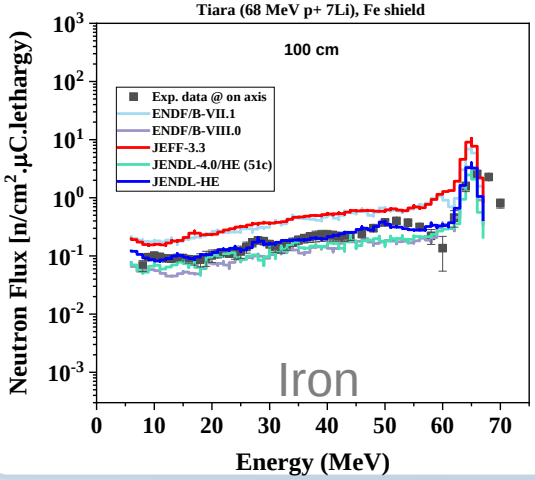
(JENDL-4.0/HE proton lib.)+(JEFF-3.3 neutron lib.)

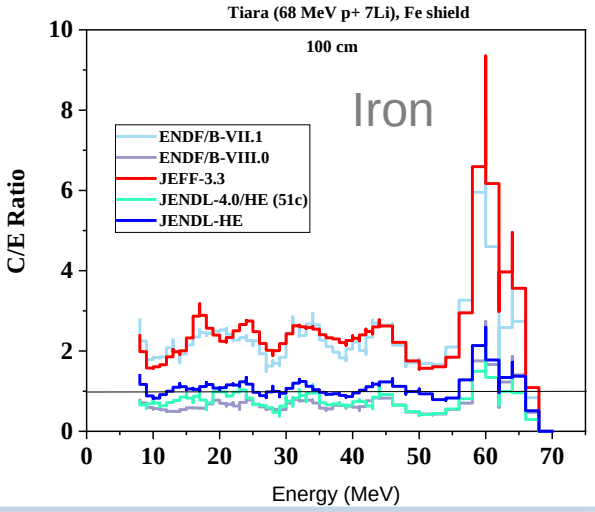


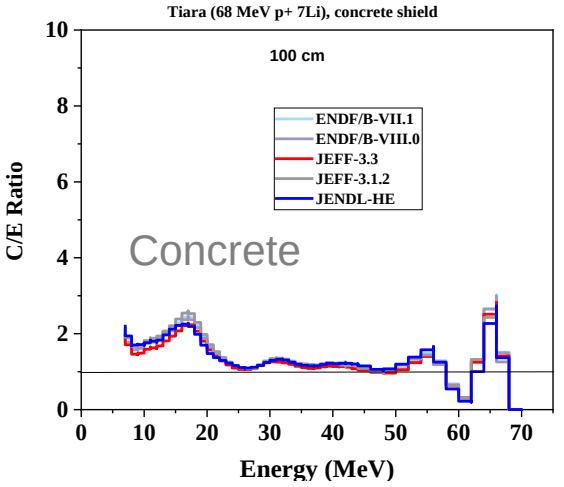


B+E configuration

(JENDL-4.0/HE proton lib.)+(diff. neutron lib.)

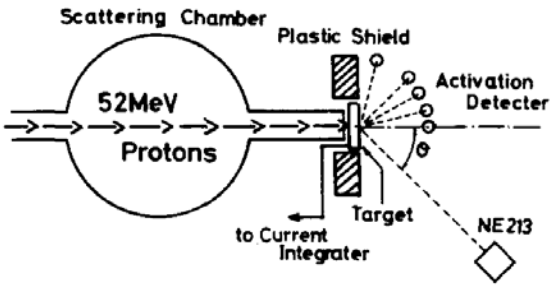


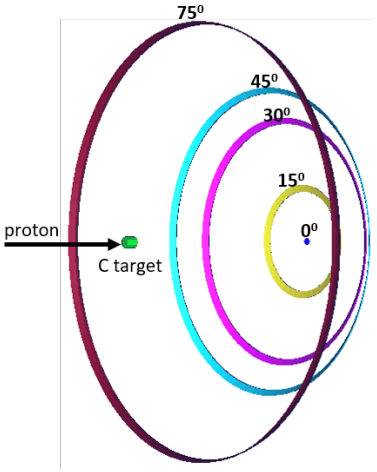




NEA-1552/34: 52-MeV proton beam, thick C target

Neutron yield measurement

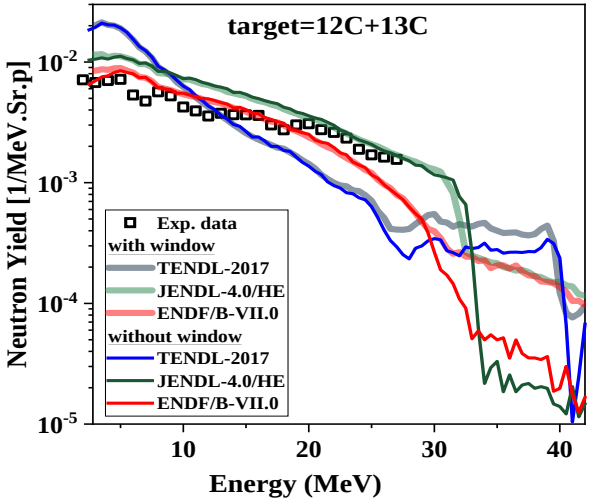


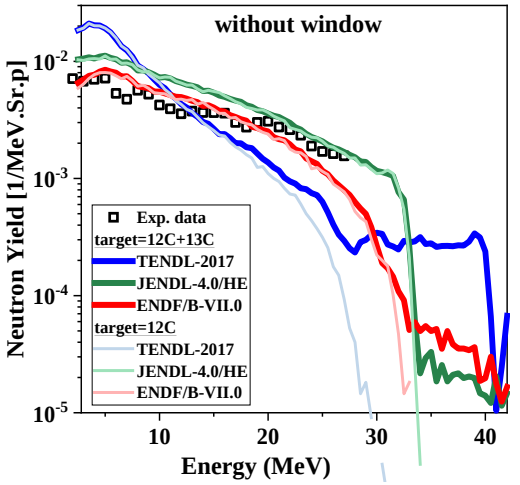


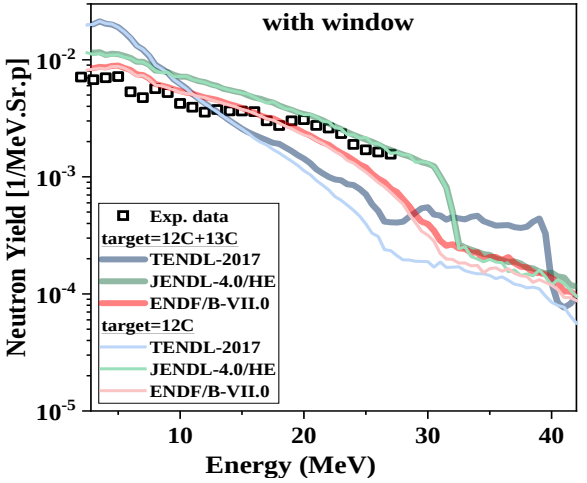
MCNP model

A+D configuration

(dif. proton lib.)+(JEFF-3.3 neutron lib)

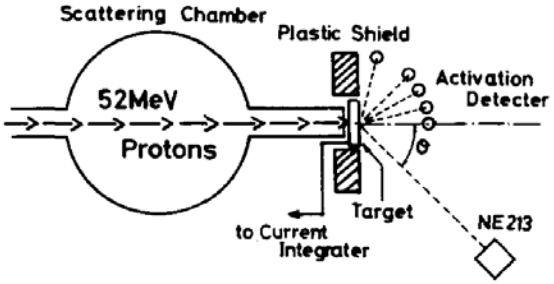


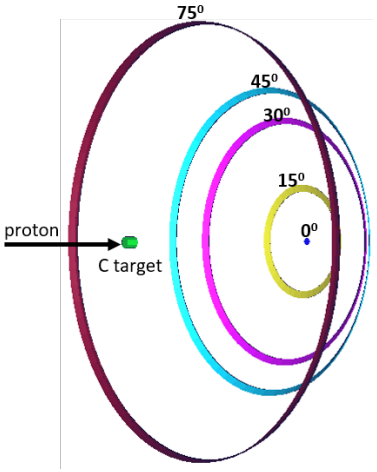




NEA-1552/34: 52-MeV proton beam, thick C target

Neutron yield measurement

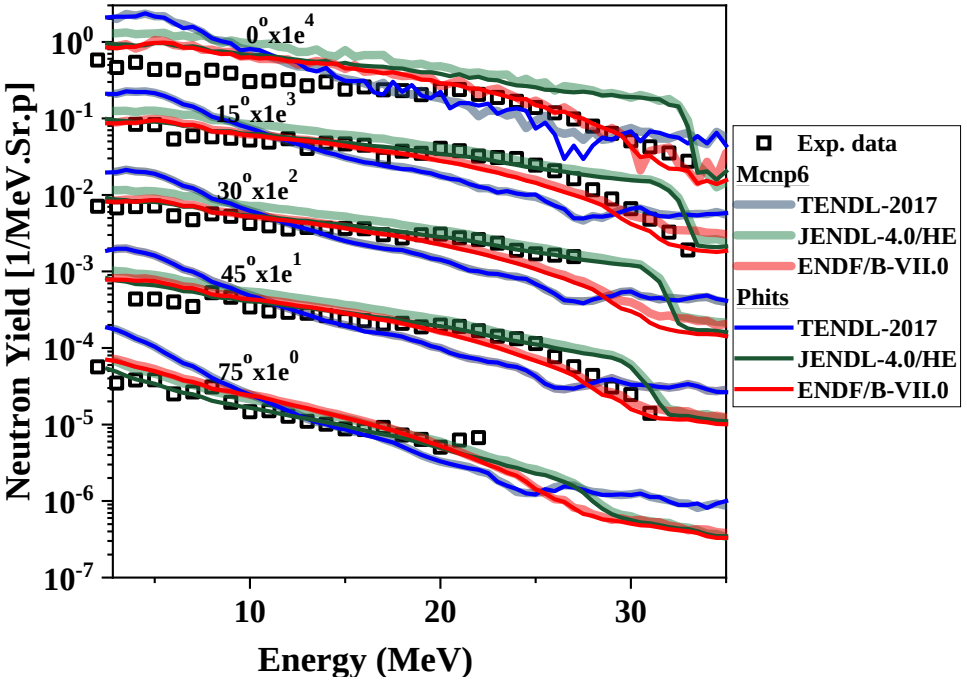




MCNP model

A+D configuration

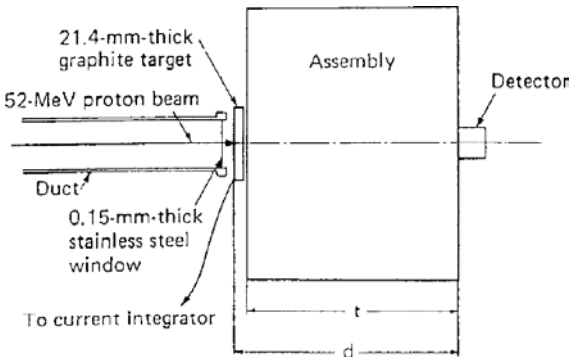
(dif. proton lib.)+(JEFF-3.3 neutron lib)

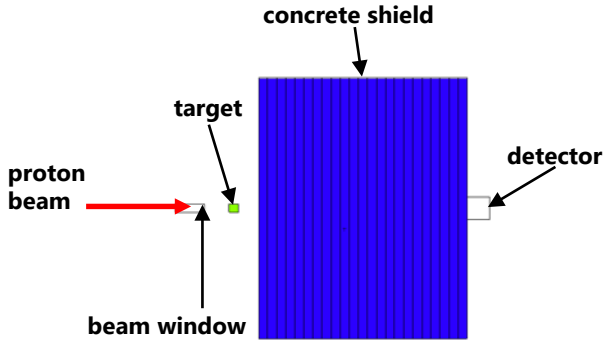


The high energy tails of experimental spectra at 30° and 75° are cut (?)

NEA-1552/34: 52-MeV proton beam, thick C target

Transmitted neutron flux measurement

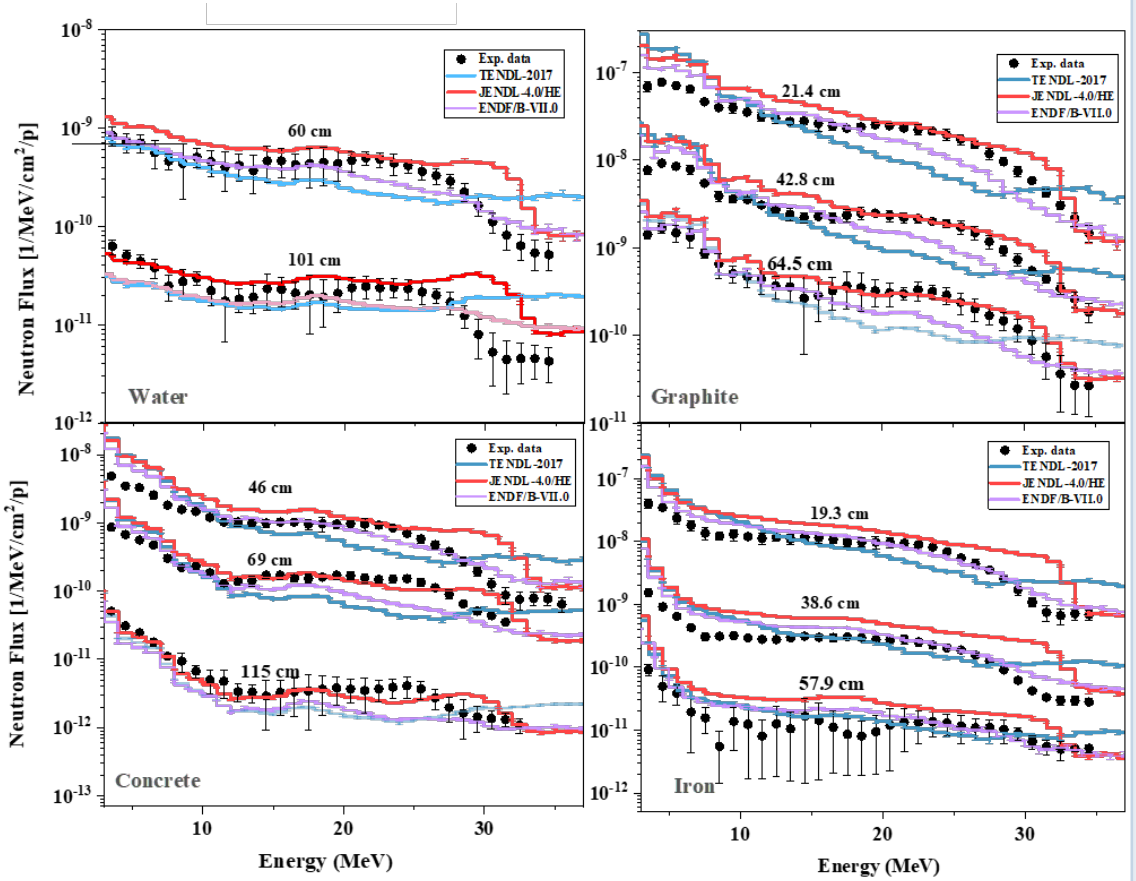




MCNP model

A+D configuration

(dif. proton lib.)+(JEFF-3.3 neutron lib)

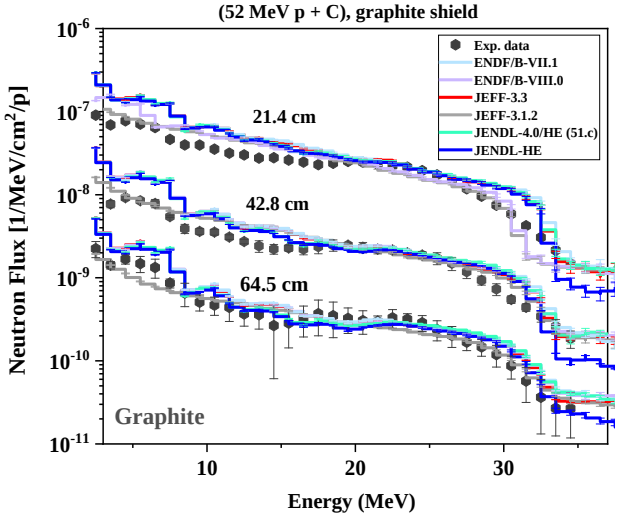


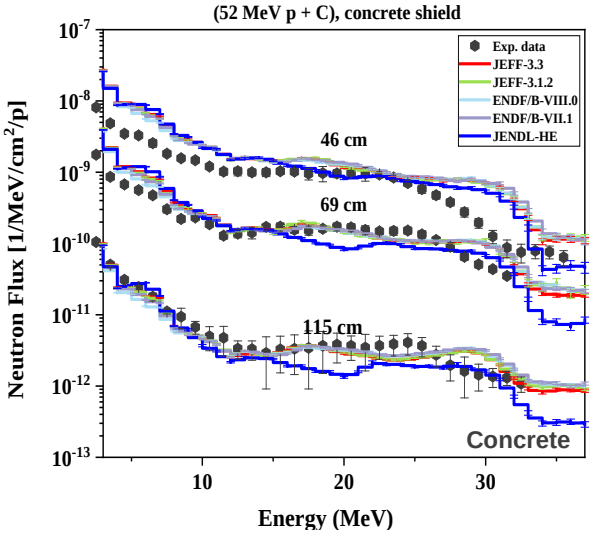
No nuclear data accurately represent the results of all considered shielding cases.

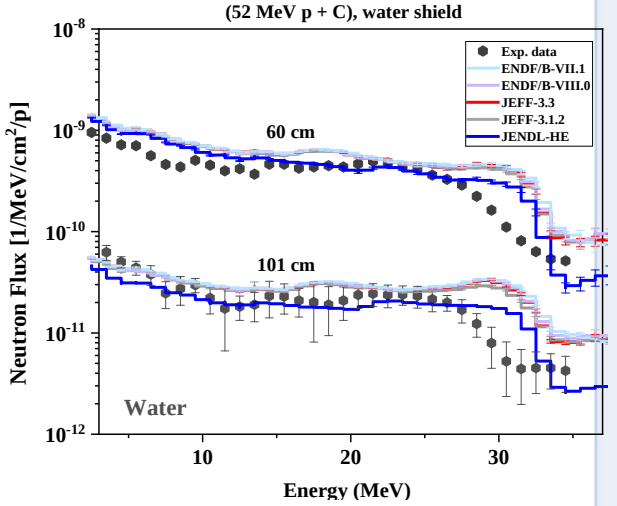
NEA-1552/34: 52-MeV proton beam, thick C target

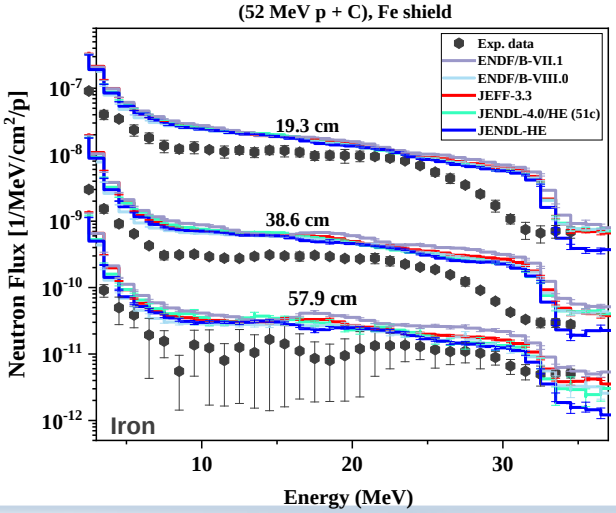
B+E configuration

(JENDL-4.0/HE proton lib.)+(diff. neutron lib.)







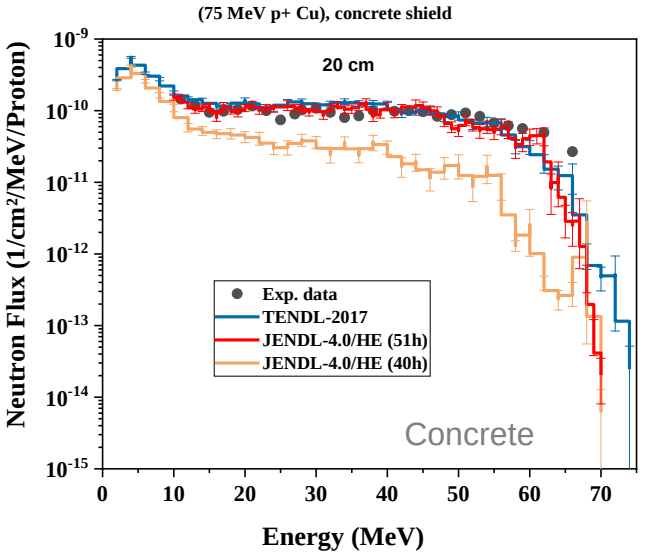


- **The shape of the transmitted neutron flux is dominantly defined by the proton induced cross sections or physics models used.**
- **Proton data are more crucial than neutron data and thus this data needs special attention.**

NEA-1552/31 : 75-MeV proton beam, thick Cu target

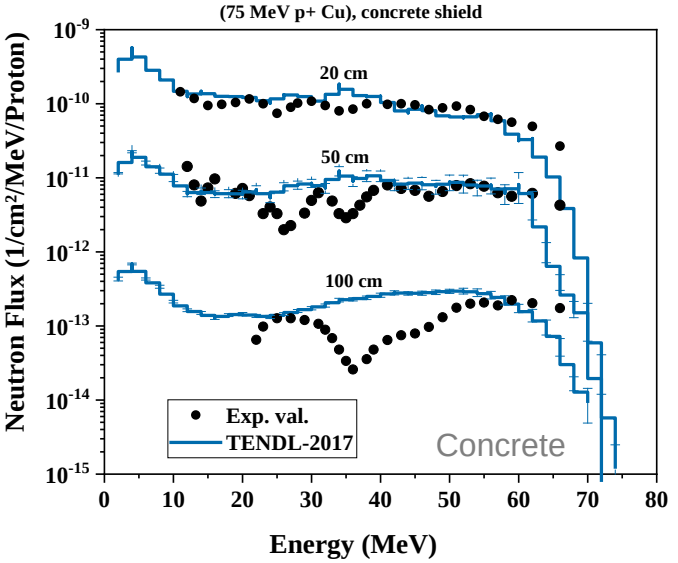
A+D configuration

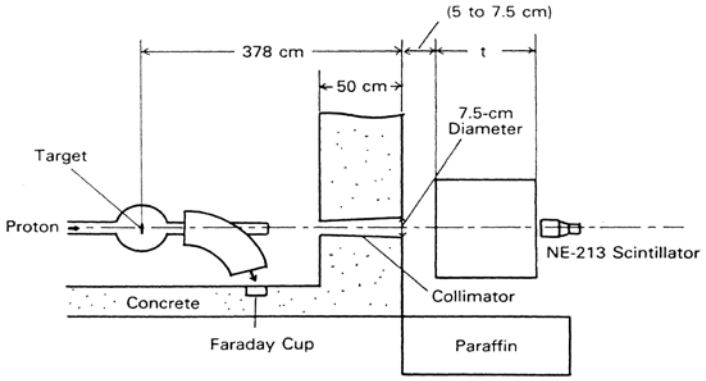
(dif. proton lib.)+(JEFF-3.3 neutron lib.)



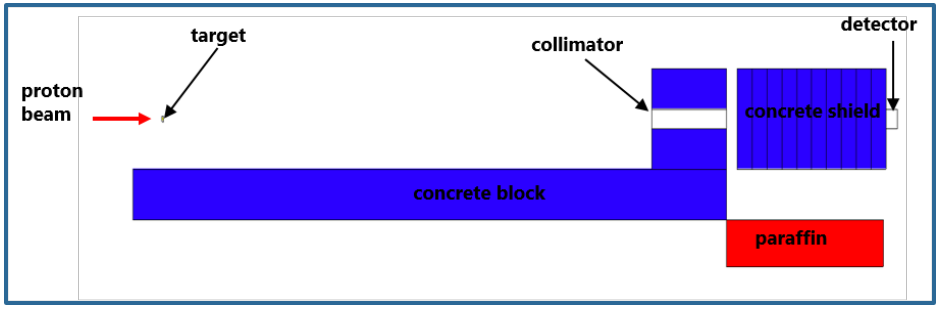
B+D configuration

(TENDL-2017 proton lib.)+(JEFF-3.3 neutron lib.)





Experimental setup for neutron penetration measurements.



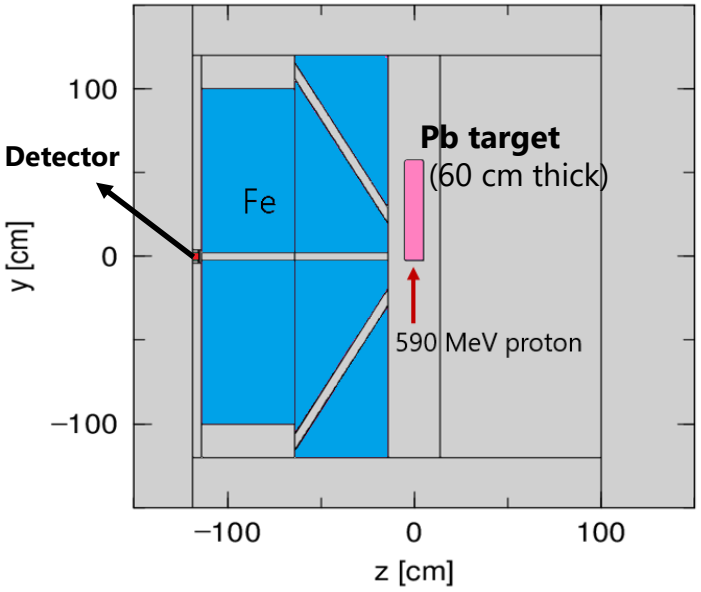
MCNP model

NEA-1552/15: 590-MeV proton beam, thick Pb target

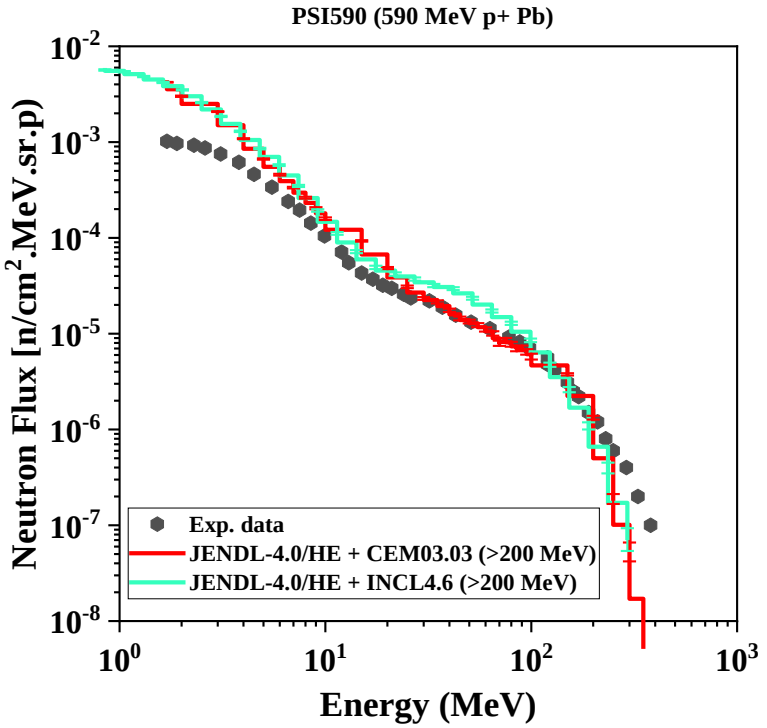
B+D configuration for MCNP
(JENDL-4.0/HE proton lib.)+(JEFF-3.3 neutron lib.)

configuration for PHITS
(JENDL-4.0/HE proton lib.)+(JENDL-4.0/HE neutron lib.)

Neutron yield measurement

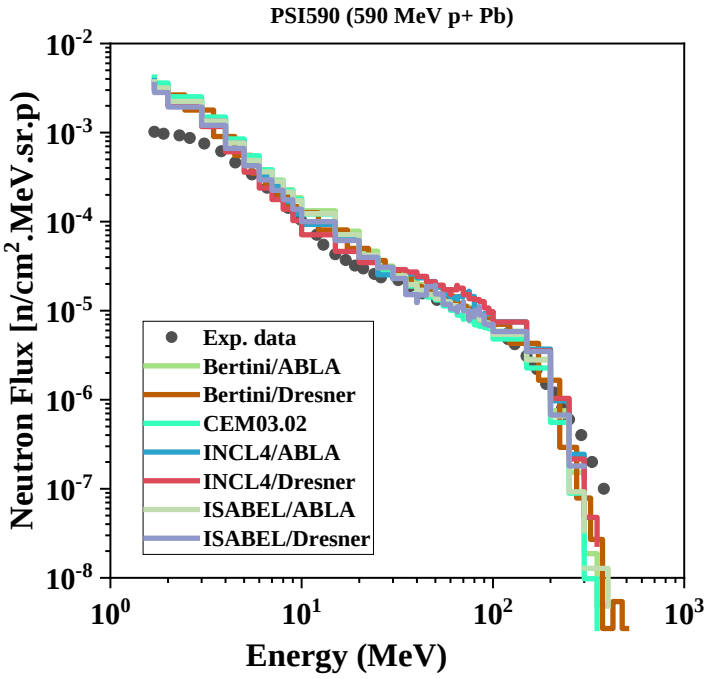


MCNP model



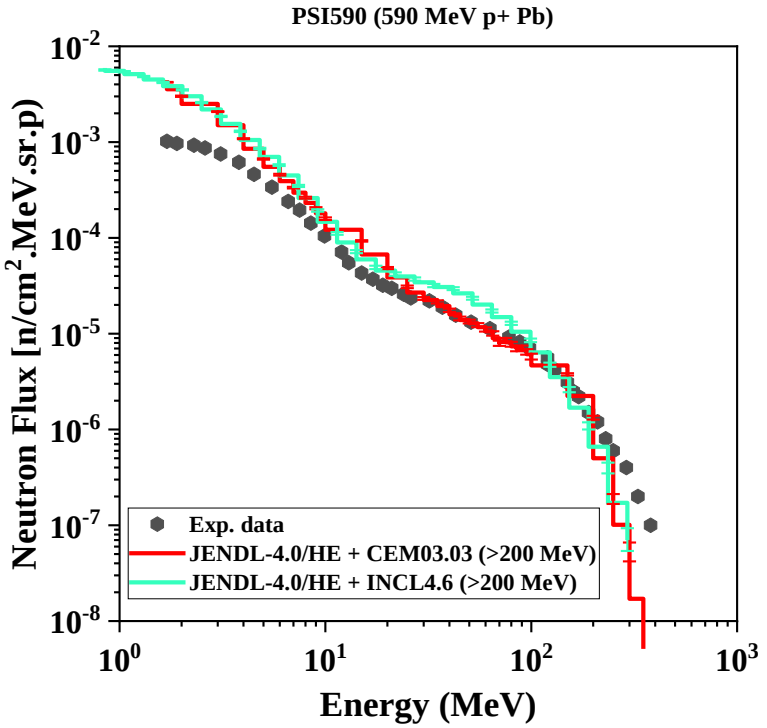
NEA-1552/15: 590-MeV proton beam, thick Pb target

C+D configuration for MCNP
(Models for proton interactions+.)+(JEFF-3.3 neutron lib.)



B+D configuration for MCNP
(JENDL-4.0/HE proton lib.)+(JEFF-3.3 neutron lib.)

configuration for PHITS
(JENDL-4.0/HE proton lib.)+(JENDL-4.0/HE neutron lib.)



- Over estimation below 5 MeV, underestimation above 200 MeV

Conclusions

- The quality of experimental data is questionable. Uncertainties for the experiments should be provided. The quality of documentation of the experiments should be increased.
- High quality proton induced library is required. Light-Z targets (Li, C) are more difficult to deal with and deserve special attention.
- Proton induced libraries are responsible for the production and spectra of the neutrons emitted from target materials.
- More experiments at different energies and different target materials are necessary.


MYRRHA