Validation of nuclear data against accelerator experiments in SINBAD

Yurdunaz Çelik
Luca Fiorito
Alexey Stankovskiy
Omar Bouhassoun
Maureen Ciccarelli
Gert Van den Eynde

ycelik@sckcen.be
SCK•CEN, Mol, Belgium

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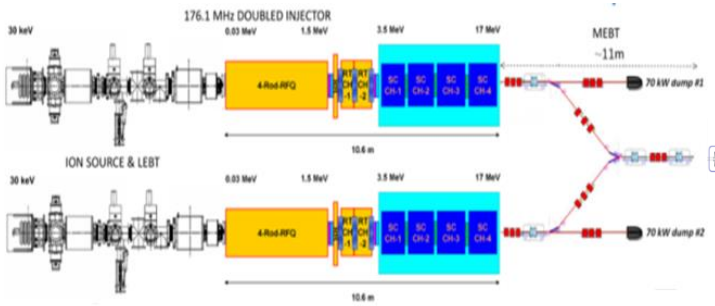
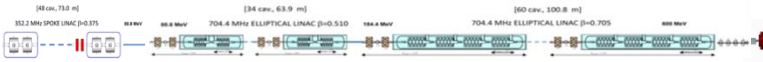
Key technical objective of the MYRRHA-project: an Accelerator Driven System

- MYRRHA – An Accelerator Driven System
  - Demonstrate the ADS concept at pre-industrial scale
    - Can operate in critical and sub-critical modes
  - Demonstrate transmutation
  - Fast neutron source → multipurpose and flexible irradiation facility

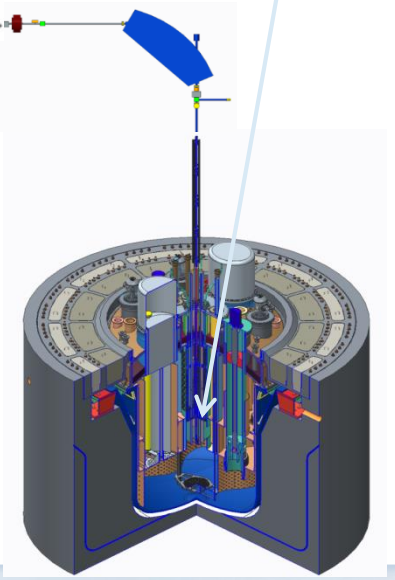




Target	
main reaction	spallation
output	$2 \cdot 10^{17}$ n/s
material	LBE (coolant)

Accelerator	
particles	protons
beam energy	600 MeV
beam current	2 - 4 mA

Reactor	
power	60 to 70 MW_{th}
k_{eff}	0.95
spectrum	fast
coolant	LBE

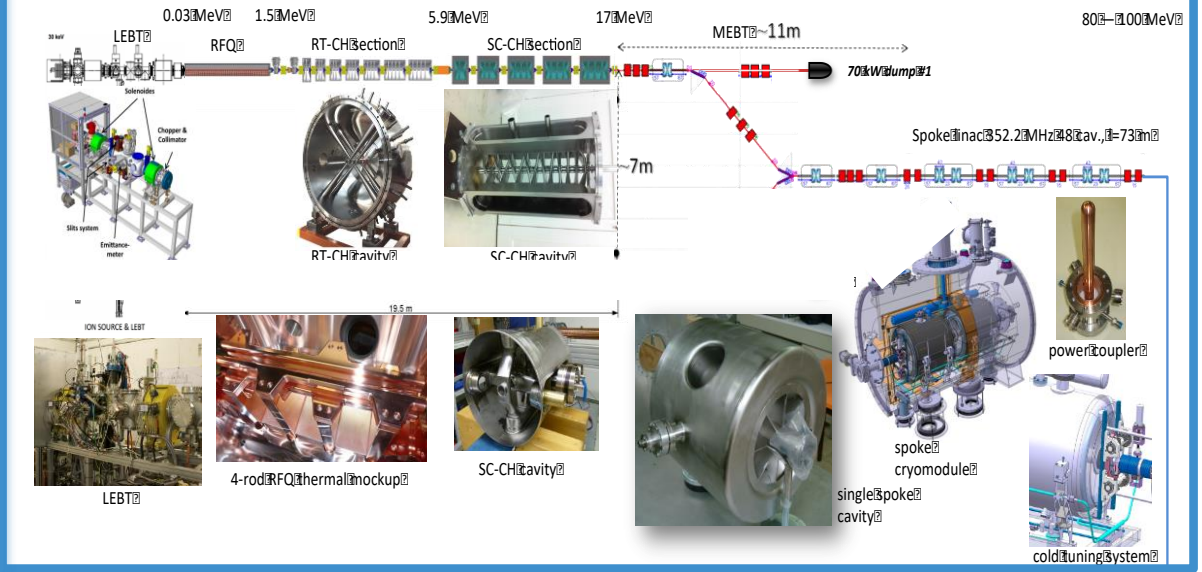


MYRRHA phased implementation strategy

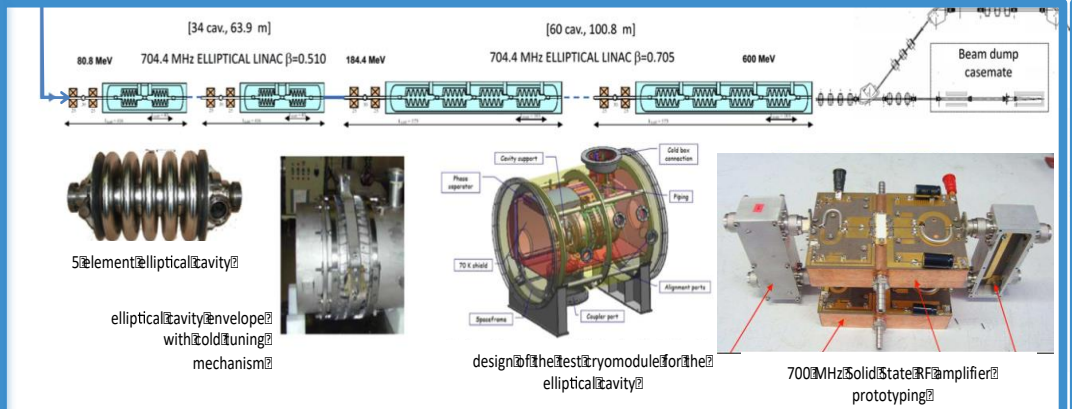
Benefits of phased approach:

- Reducing technical risk
- Spreading investment cost
- First R&D facility available in Mol end of 2024, commissioned in 2026

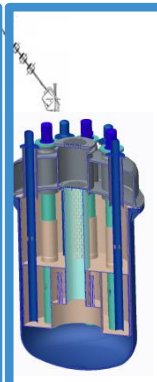
Phase 1 – 100 MeV



Phase 2 – 600 MeV

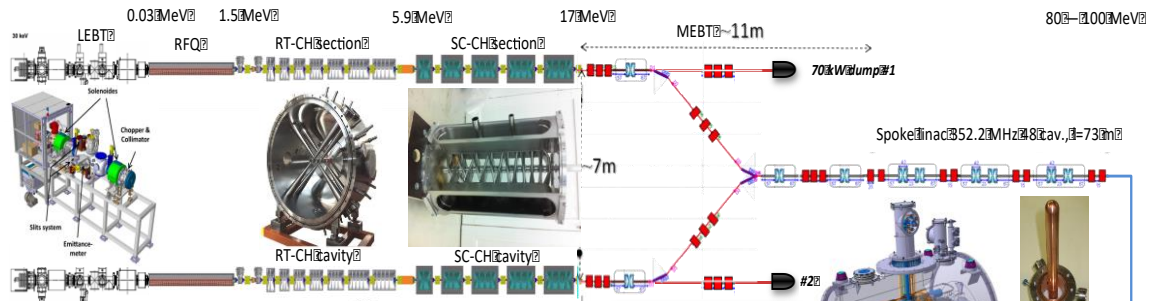


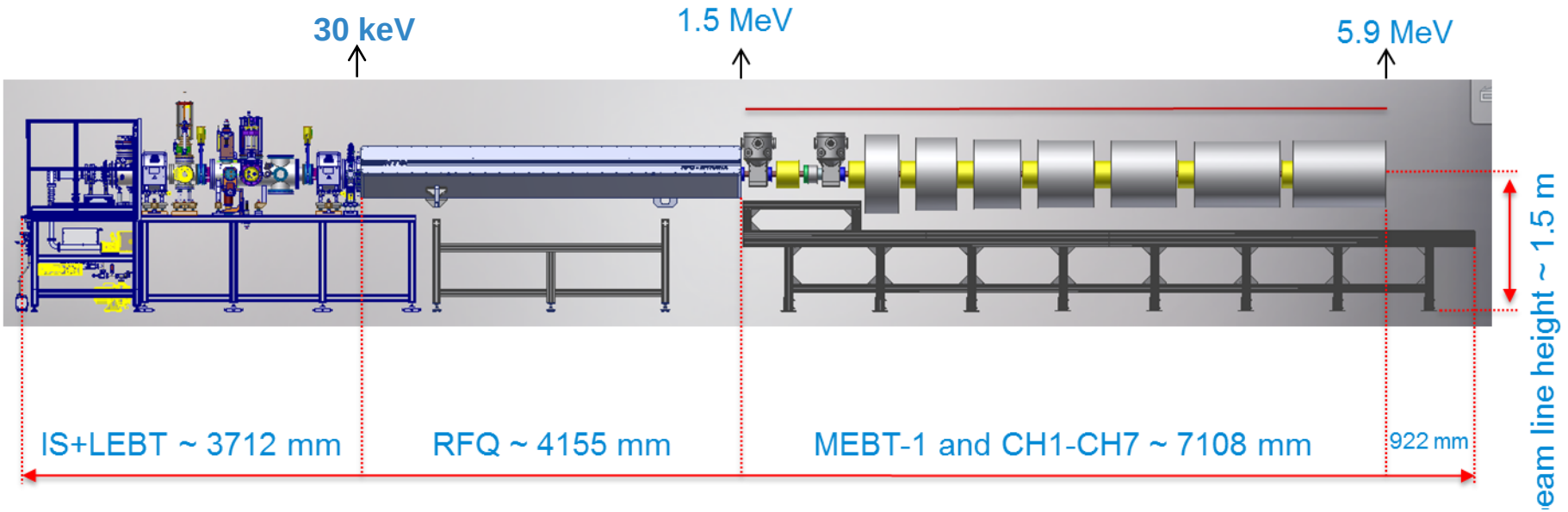
Phase 3 – Reactor



Source:SCK•CEN MYRRHA Project Team

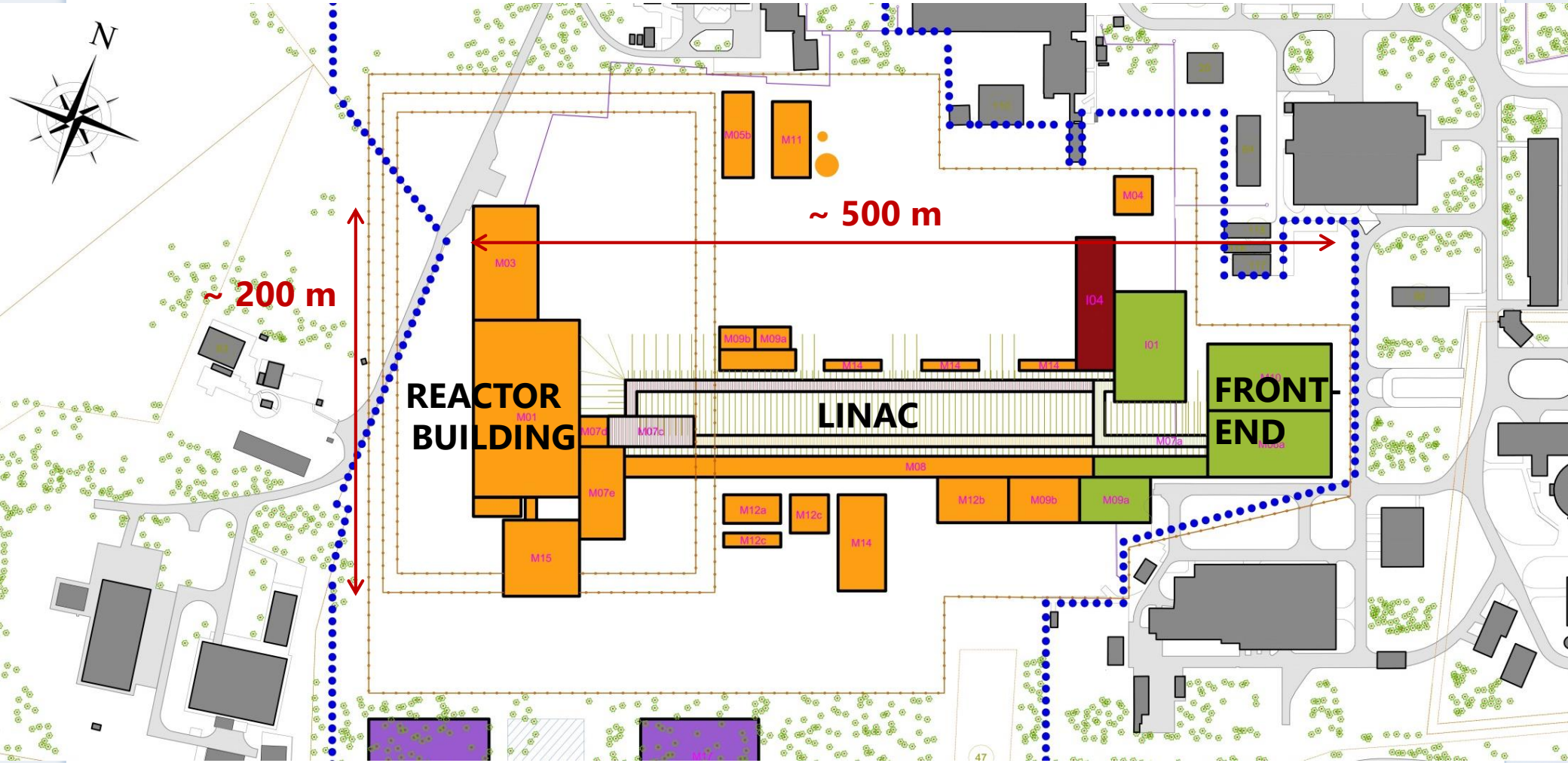
Beam line at the Cyclotron Resource Center at Catholic University of Leuven





Source:SCK•CEN MYRRHA Project Team

Masterplan Full MYRRHA

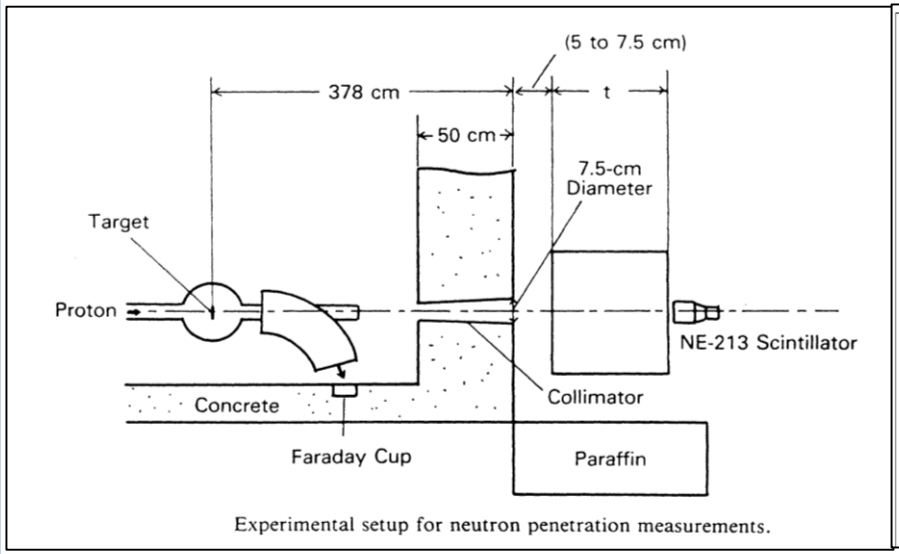


Experimental benchmarks in SINBAD

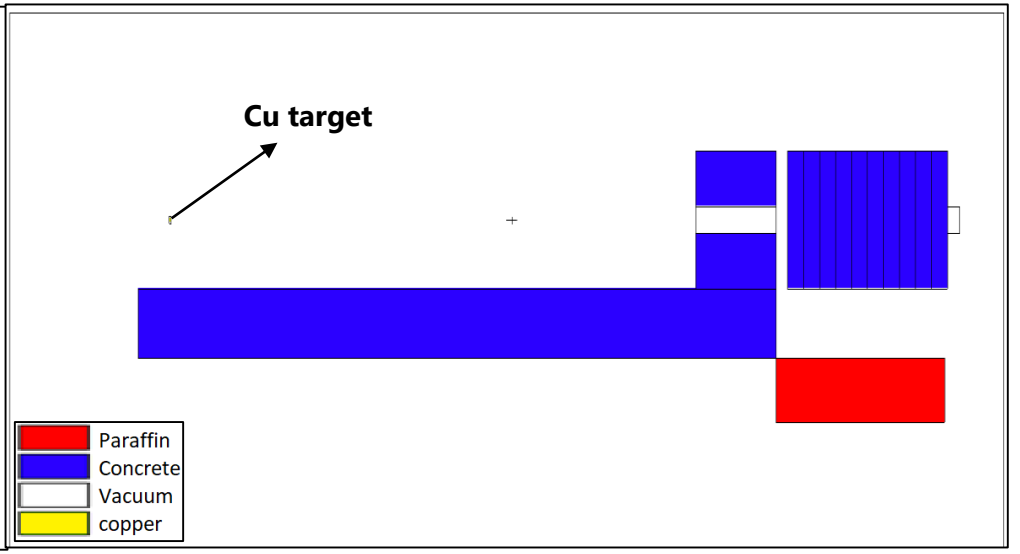
3 experiments are relevant to benchmark our codes for shielding calculations of 100 MeV accelerator and target stations:

- SINBAD-75P (NEA-1552/31) → Sinbad-experiment 1
- SINBAD-65P (NEA-1552/08)
- SINBAD-52P (NEA-1552/34) → Sinbad-experiment 2

Sinbad-experiment 1



Experimental setup for neutron penetration measurements.

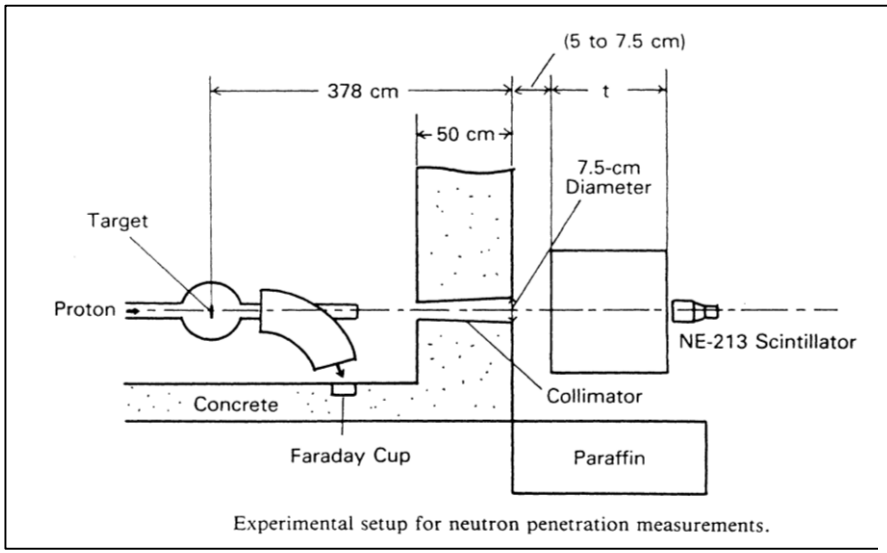


AVF cyclotron facility of Osaka University

[1] Shin K., Ishii Y., Uwamino Y., Sakai H. and Numata S.: "Transmission of Medium Energy Neutrons Through Concrete Shields," Radiation Protection Dosimetry, Vol. 37, No. 3, 175-178 (1991).

- **Detector: 7,6mm-diam x 7,6mm-long NE-213 scintillator**
- **Target: 2 cm diam x 1cm thick cupper**
- **Collimator: 7.5 cm diam x 50 cm long**
- **Concrete shielding: 40cm width x 40 cm height x 100 cm thick**

Sinbad-experiment 1



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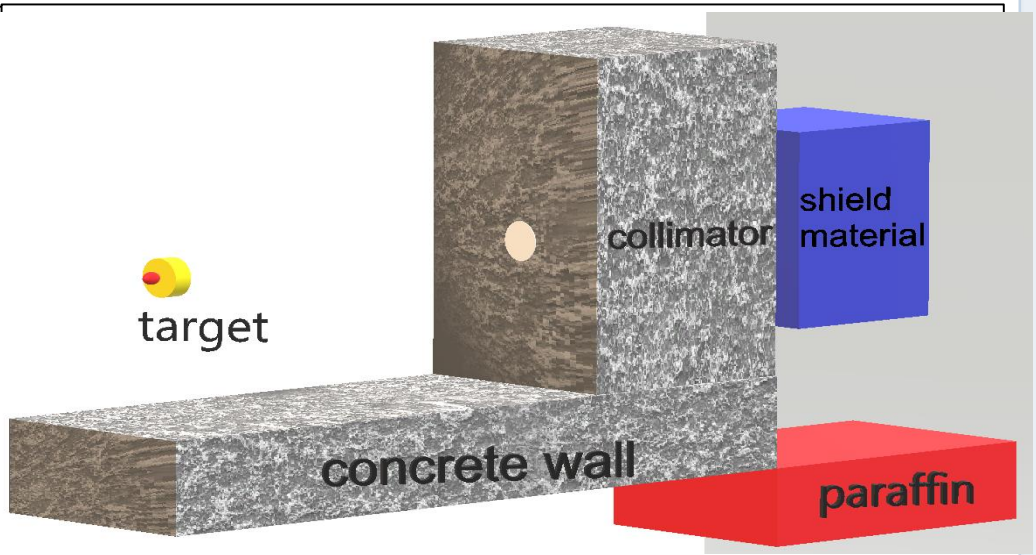

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Sinbad-experiment 1
Neutron yield measurement (75 MeV protons on Cu target)

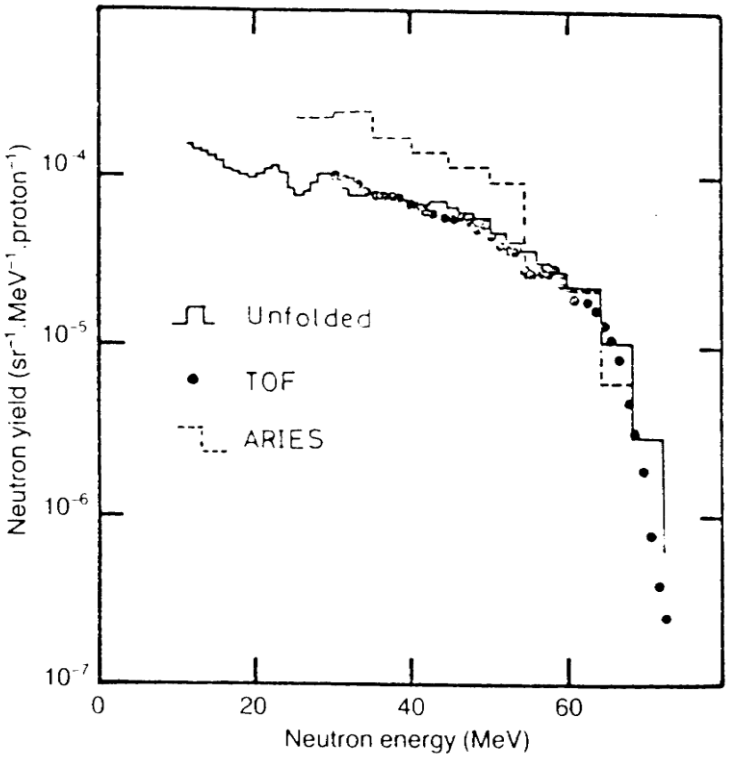
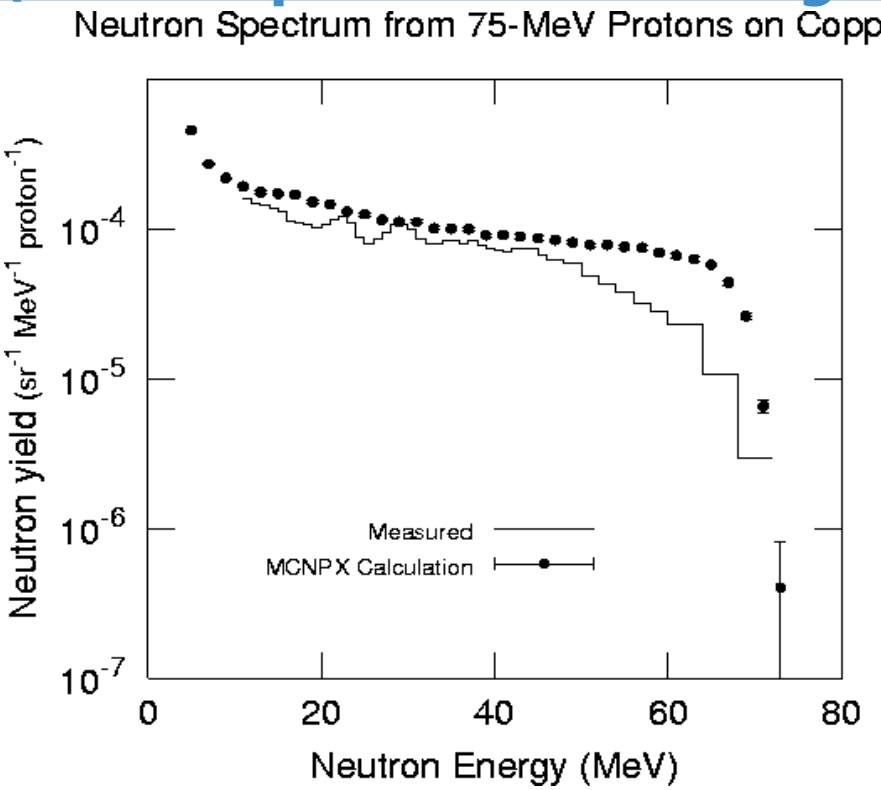


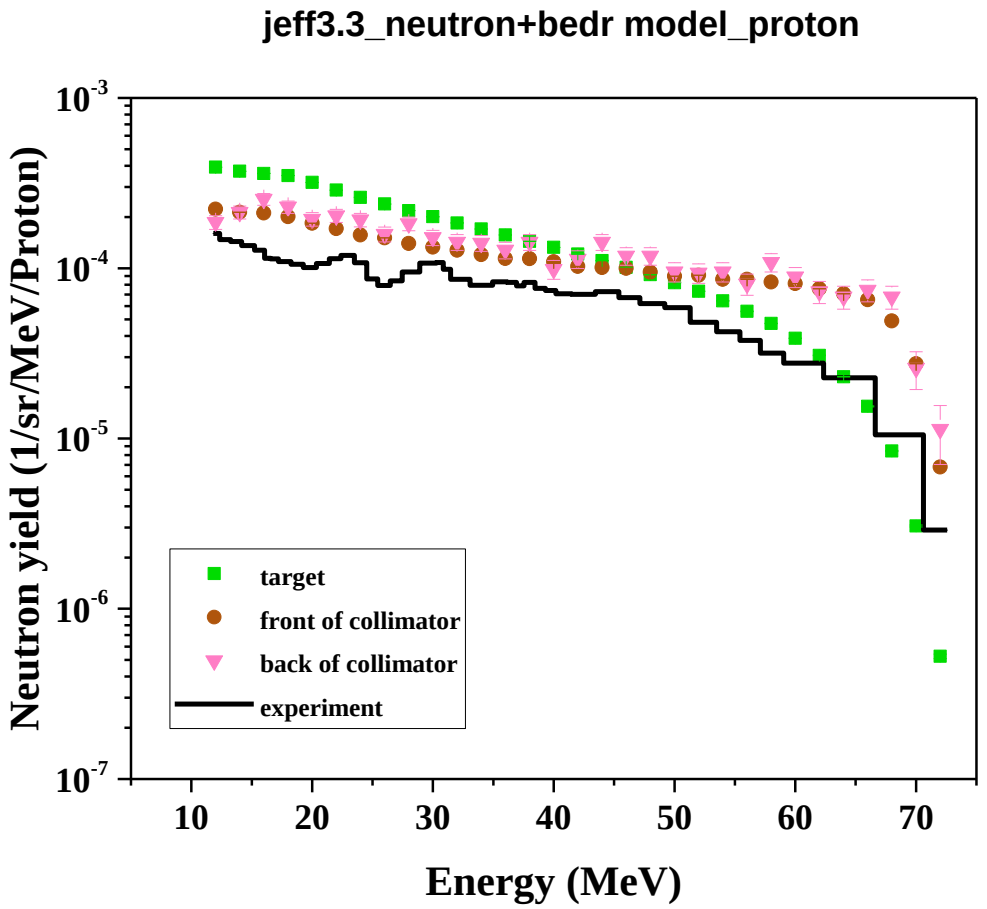
Figure -Source neutron spectra obtained by the unfolding and time of flight methods compared with ARIES calculation.

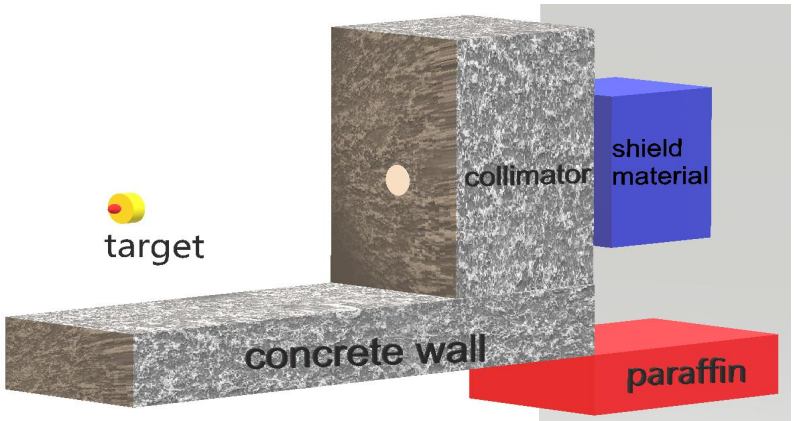


- **Default physics model for proton: Bertini/Dresner**
- **Neutron spectrum was calculated front surface of collimator**

Provided MCNPX input in SINBAD-75P for neutron yield measurement

Sinbad-experiment 1
Neutron yield measurement (75 MeV protons on Cu target)





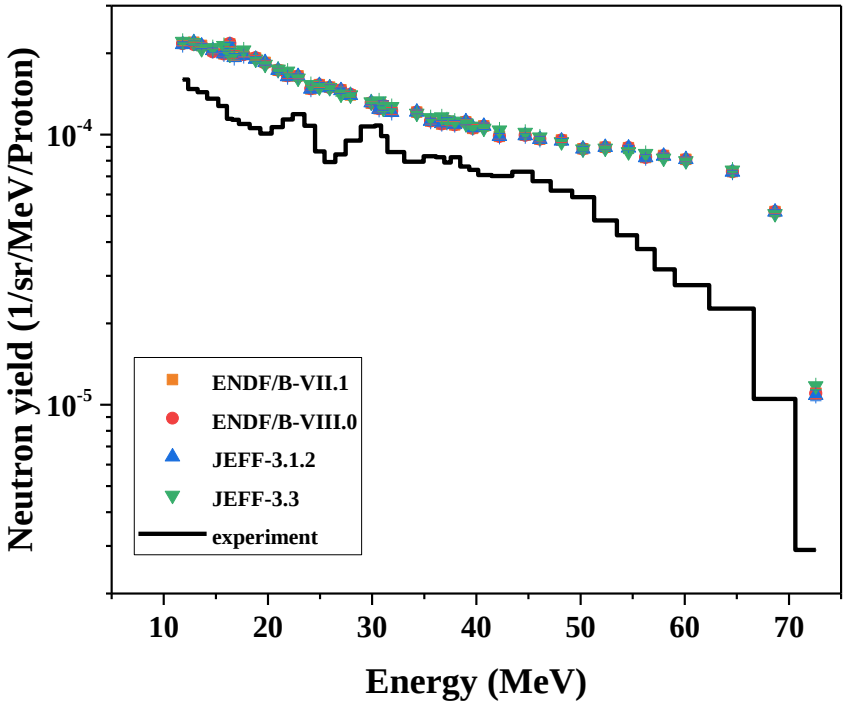
Physics model for proton:
Bertini/Dresner

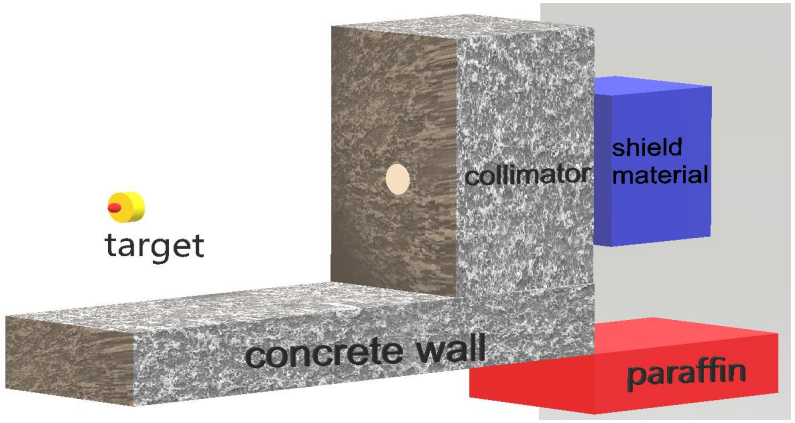
Neutron data library:JEFF3.3

Results calculated at the detector (@ 778 cm) are same with that at the back side of the collimator inside the vacuum.

Sinbad-experiment 1
Neutron yield measurement (75 MeV protons on Cu target)

Impact of neutron induced libraries





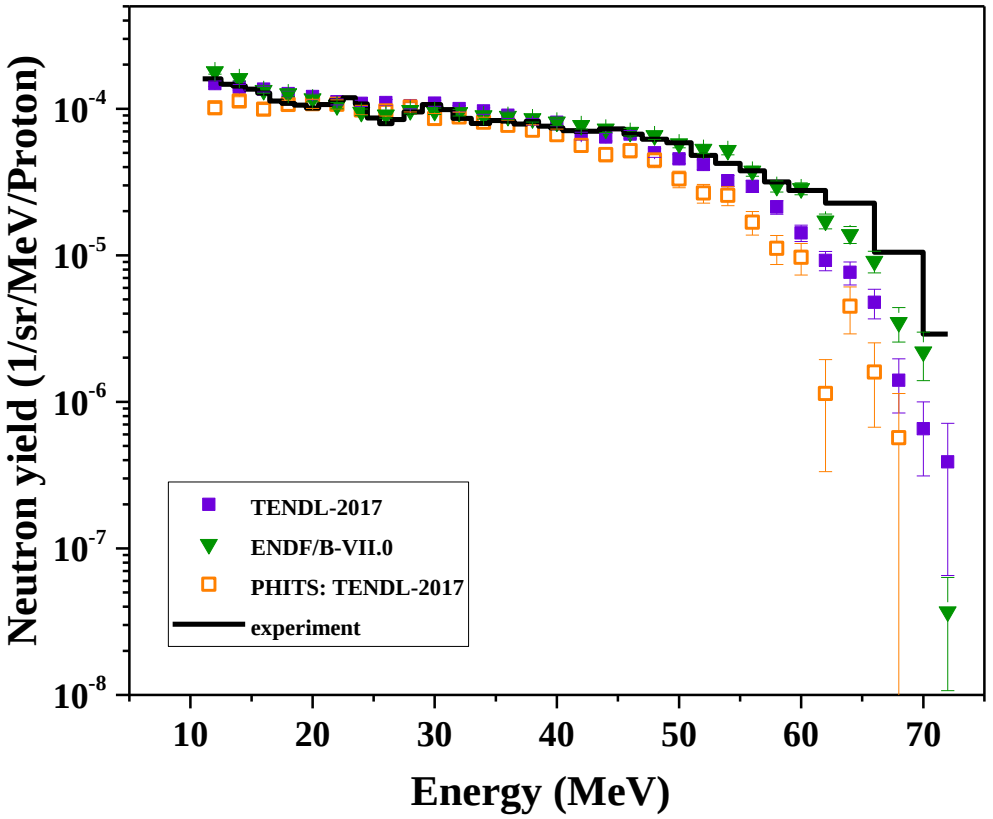
Physics model for proton:
Bertini/Dresner

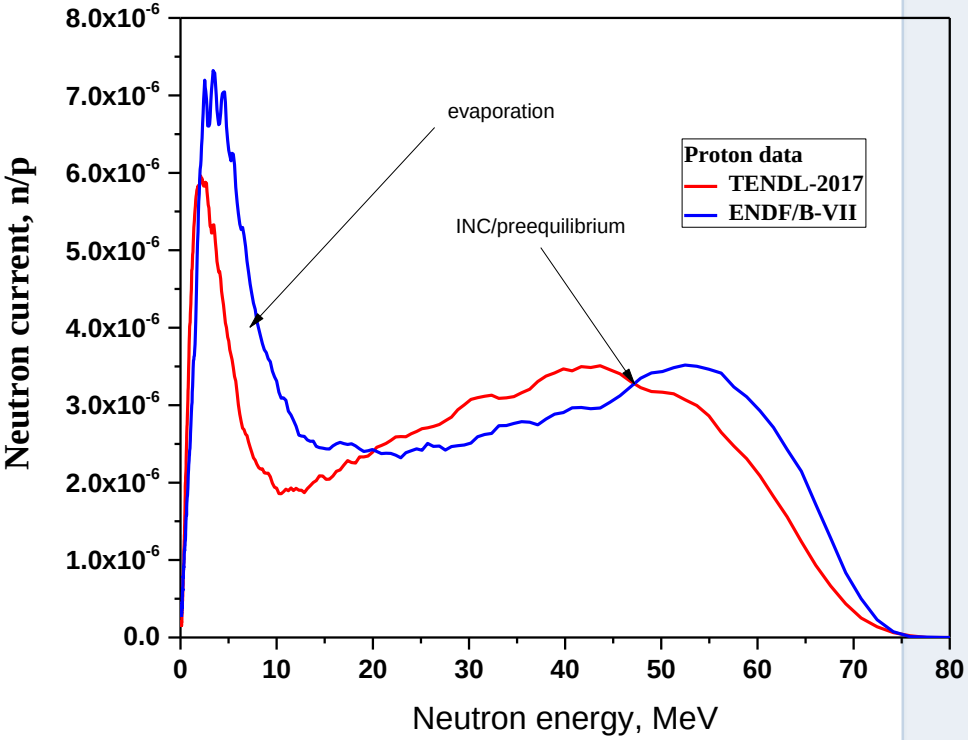
Neutron data library: **ENDF/B-VII.1**
ENDF/B-VIII.0
JEFF-3.1.2
JEFF-3.3

Neutron induced libraries do not affect the results!

Sinbad-experiment 1
Neutron yield measurement (75 MeV protons on Cu target)

Impact of proton induced libraries

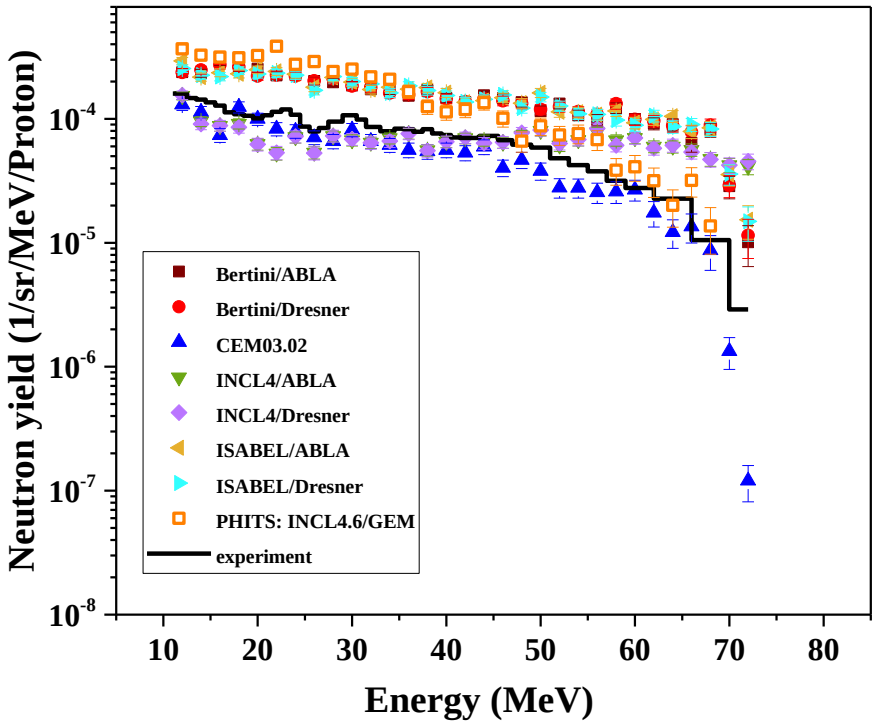


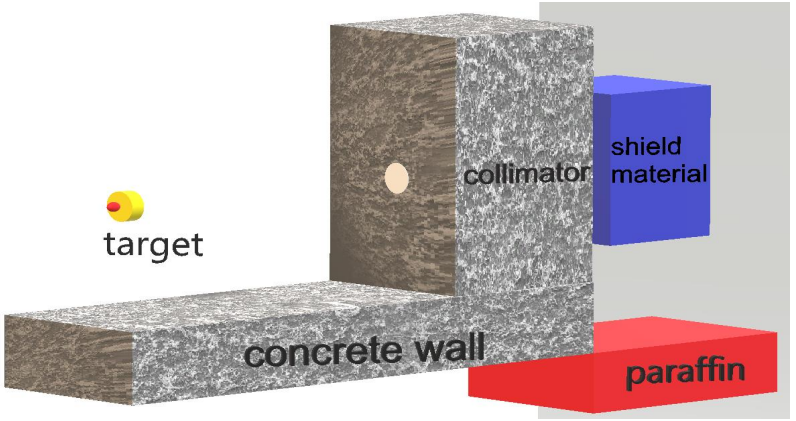


Proton induced libraries are responsible for the production and spectra of the neutrons emitted from Cu target → direct impact on the neutron spectra

Sinbad-experiment 1
Neutron yield measurement (75 MeV protons on Cu target)

Impact of physics models





Nuclear data library: JEFF-3.3

Physics models have a big impact !

Sinbad-experiment 1
Transmitted neutron spectra measurement

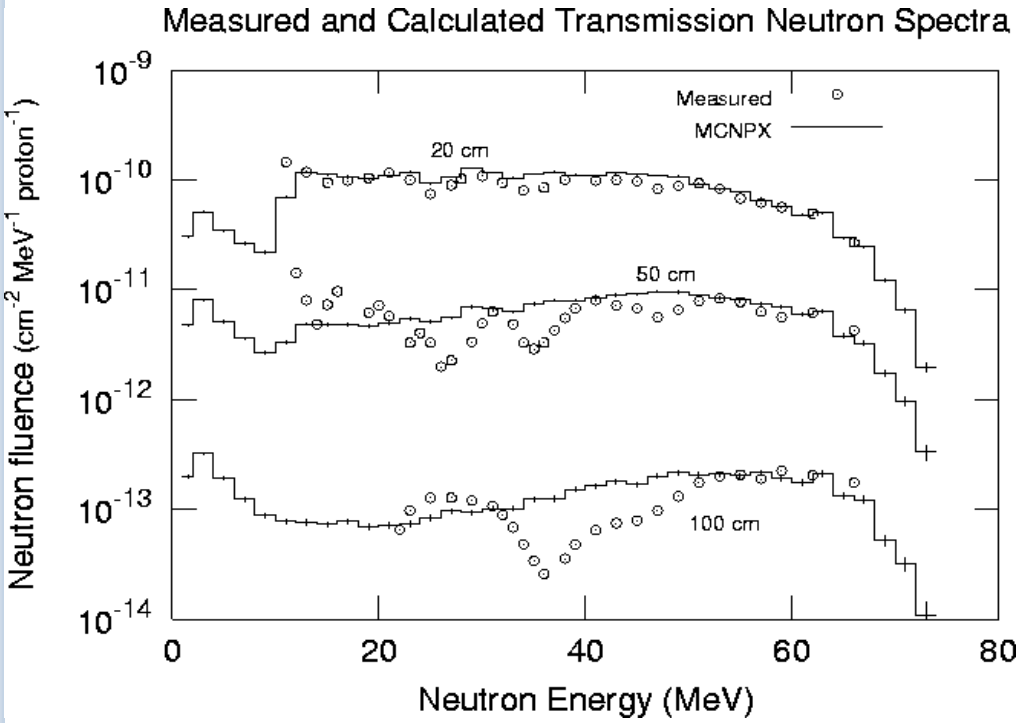


Figure -Neutron flux spectra at the detector behind the 100 cm shield.

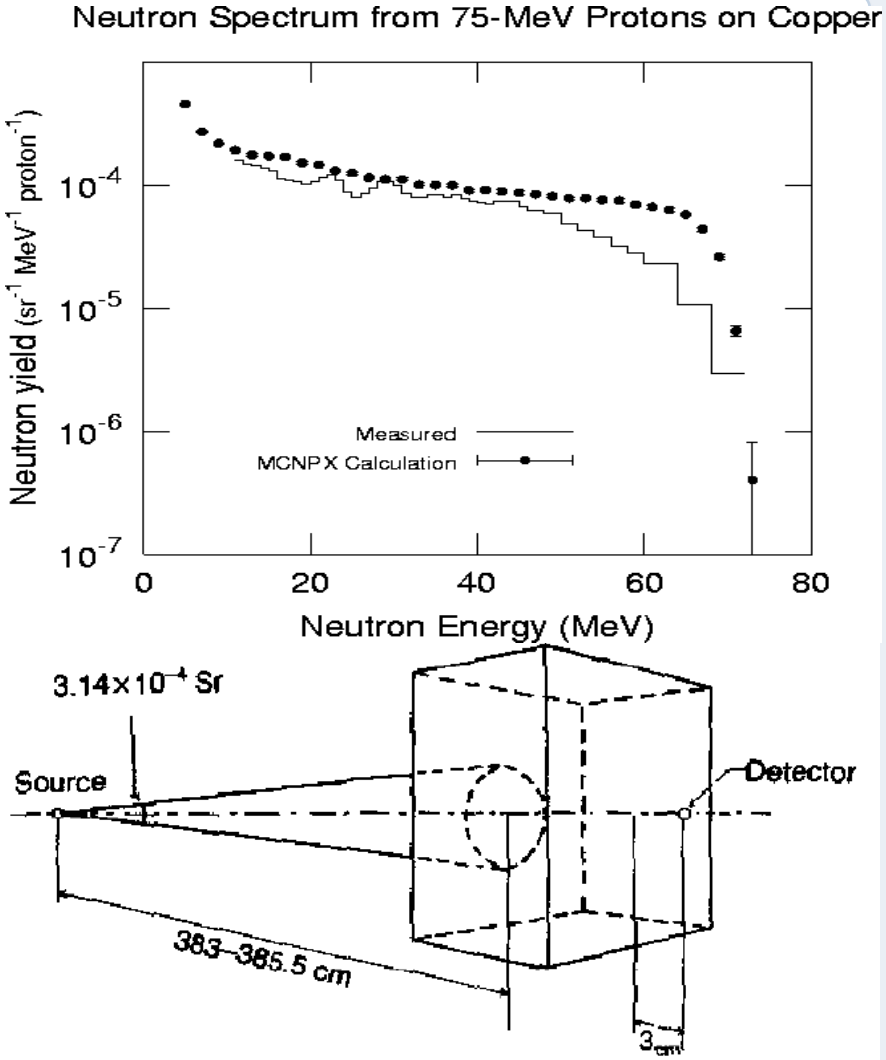
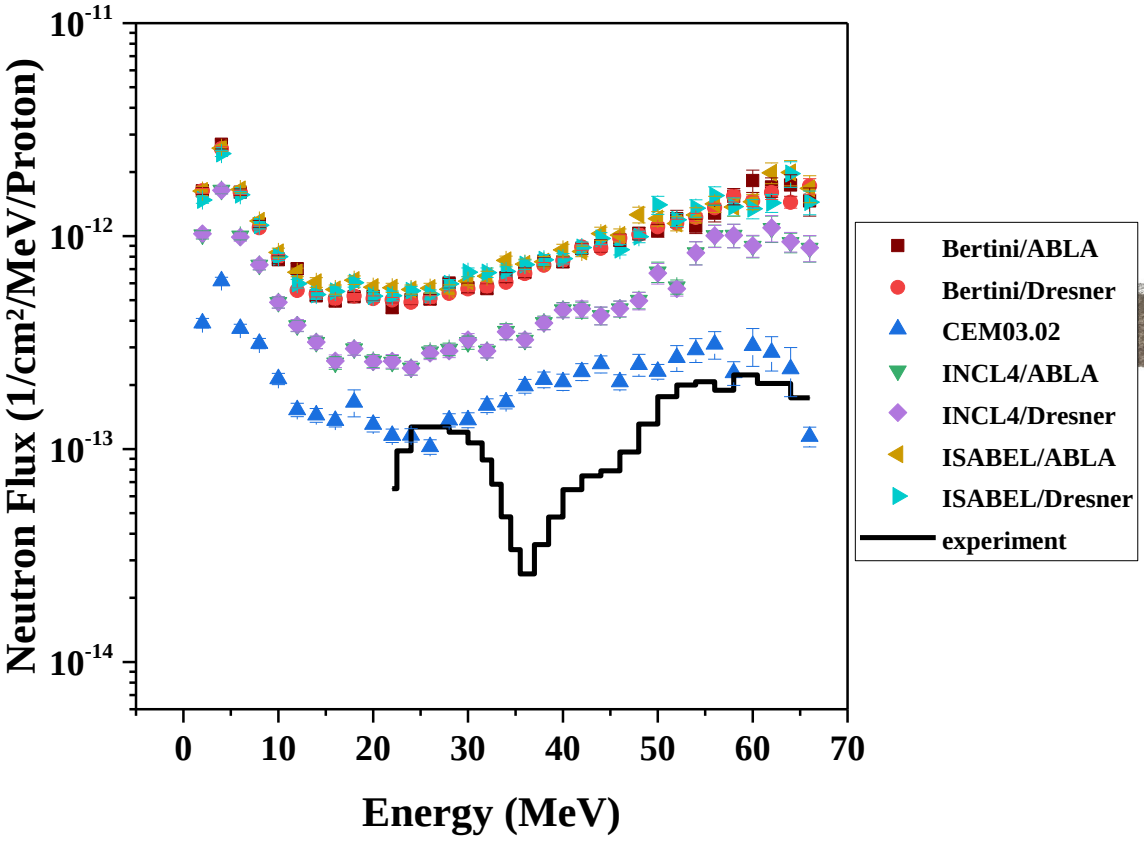
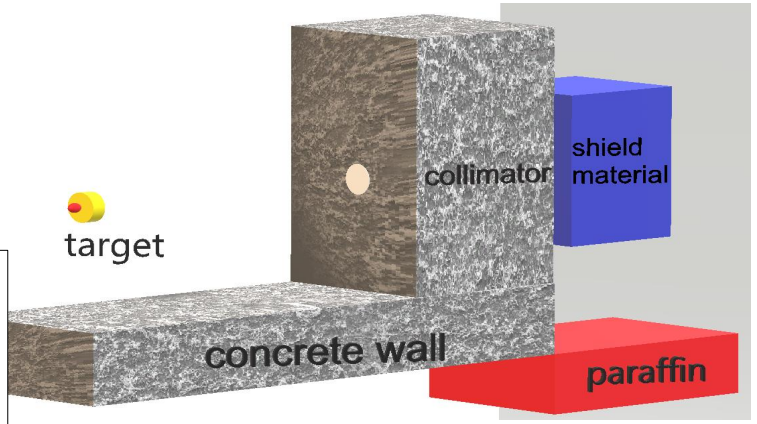


Figure 4. Geometrical model used in MORSE calculation.

Sinbad-experiment 1
Transmitted neutron spectra measurement

Impact of physics models





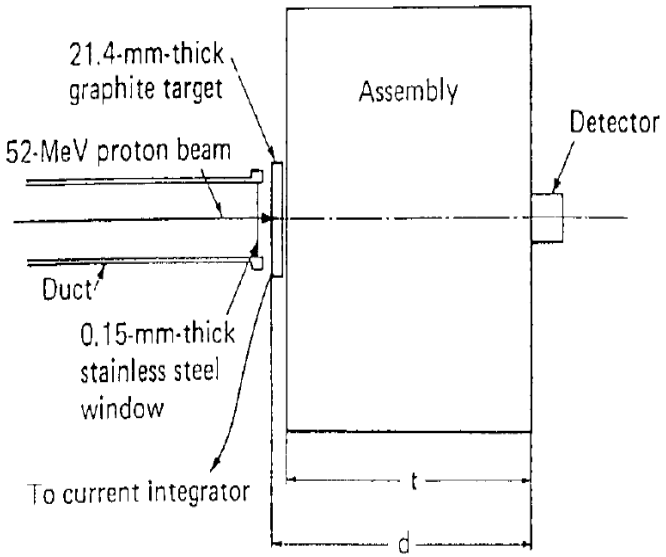
Neutron data library: JEFF-3.3

CEM03.02 gives closest results to the experiment!

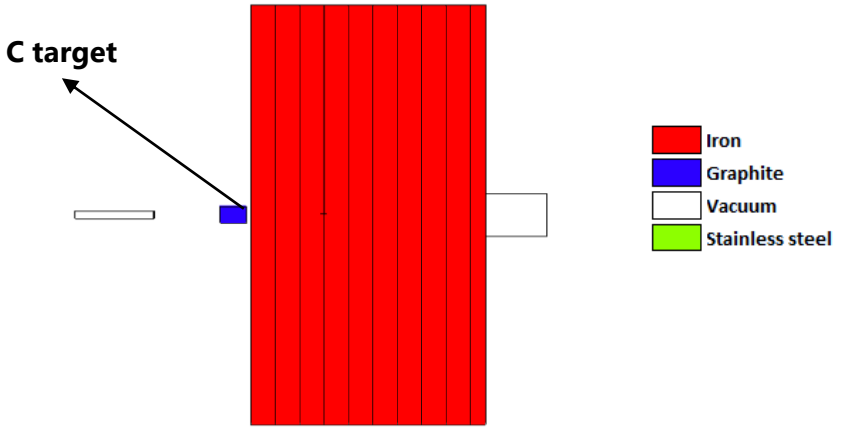
Sinbad-experiment 2
(52 MeV protons on C target)

52-MeV proton beam from FM cyclotron at the institute for Nuclear Study at the University of Tokyo on 21.4-mm graphite target (full stop). Spectra of neutrons and photons transmitted through slabs of concrete, water, graphite and iron were measured by 51x51mm NE-213 scintillator detector situated at the beam axis behind the slabs. Measurements done in 1978.

Y. Uwamino, T. Nakamura, K. Shin, Penetration Through Shielding Materials of Secondary Neutrons and Photons Generated by 52-MeV Protons, Nuclear Science and Engineering, 80 (1982° 360-369



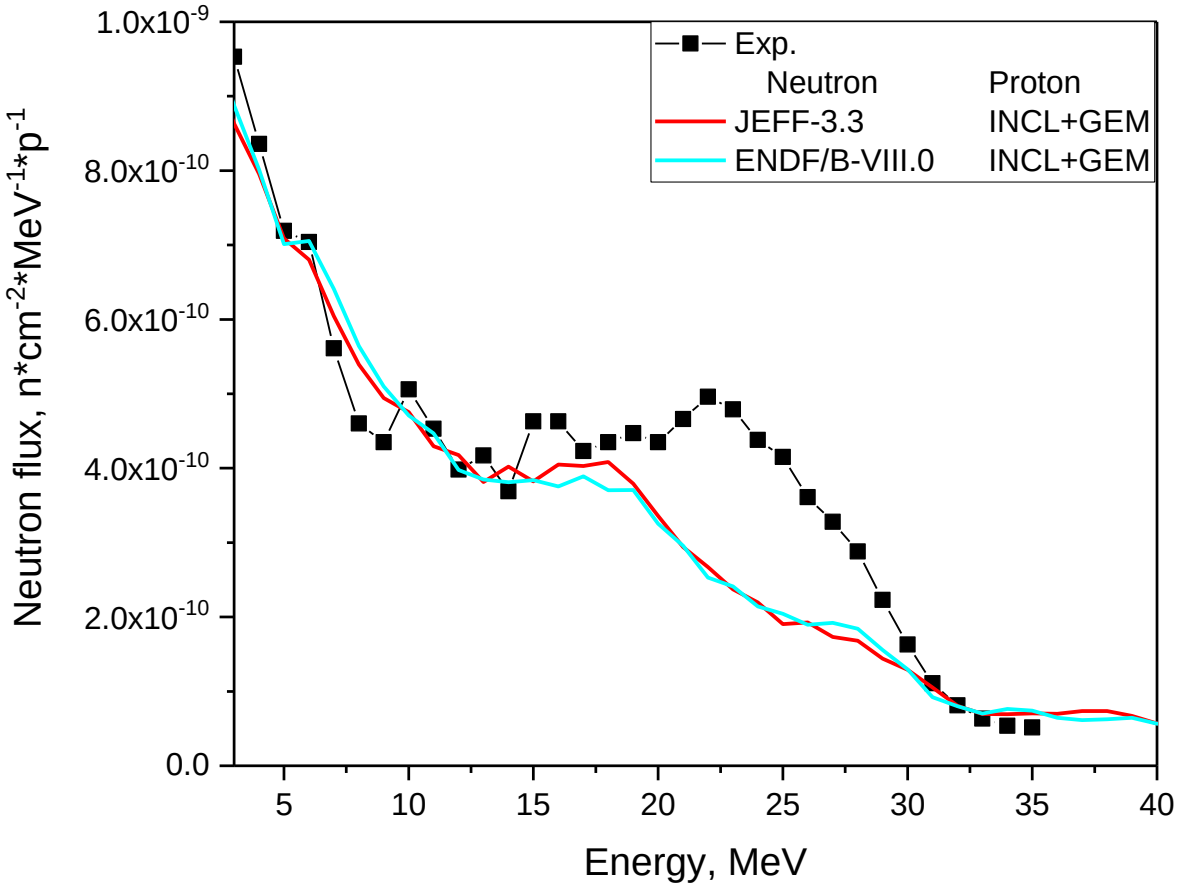
Unperturbed neutron flux (fluence) in the detector to be calculated



Geometry model for shielding calculations

Sinbad-experiment 2
Transmitted neutron spectra measurement

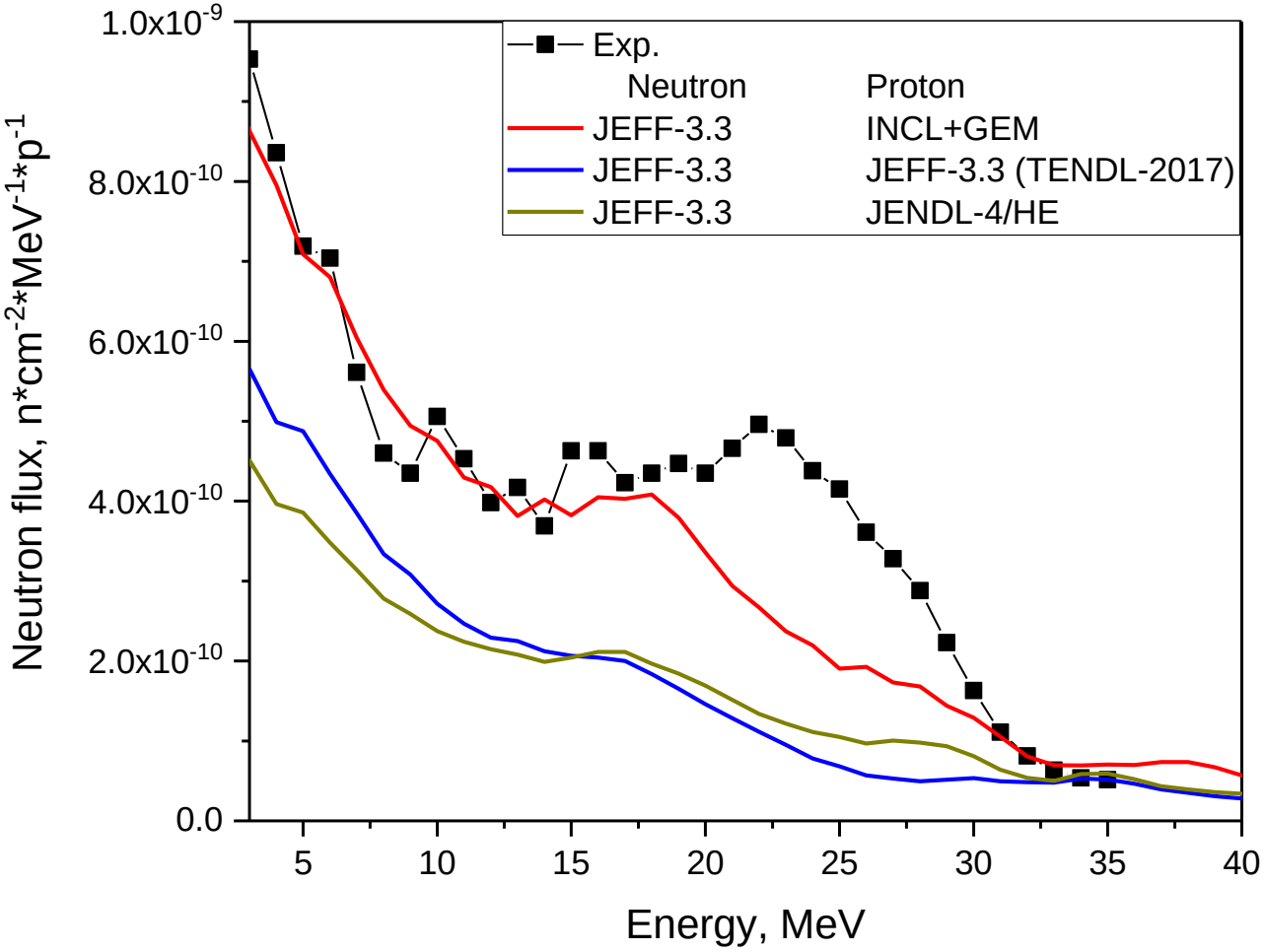
Impact of neutron induced libraries



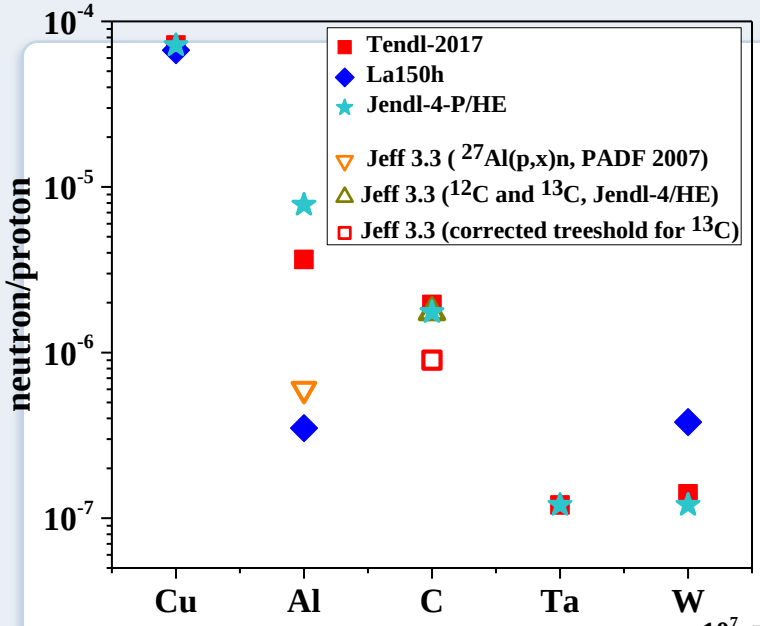
Sensitivity to neutron library is low

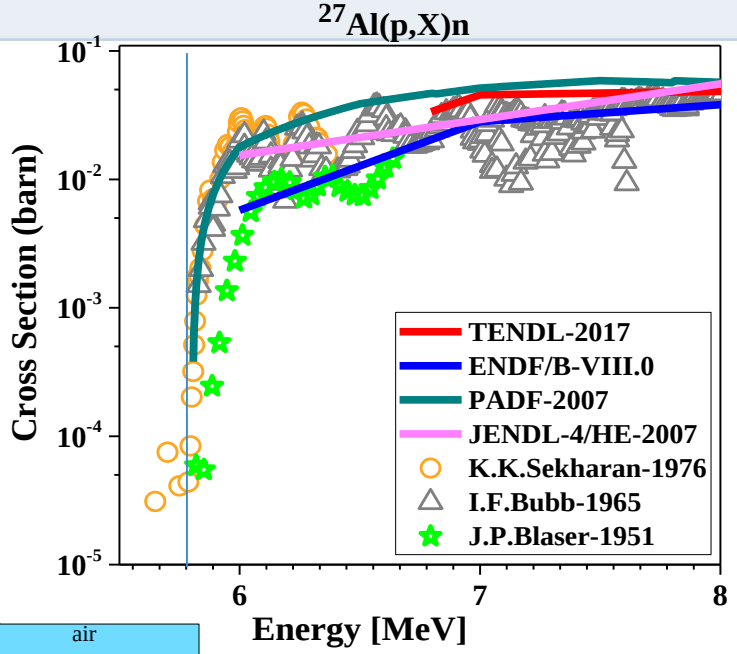
Sinbad-experiment 2
Transmitted neutron spectra measurement

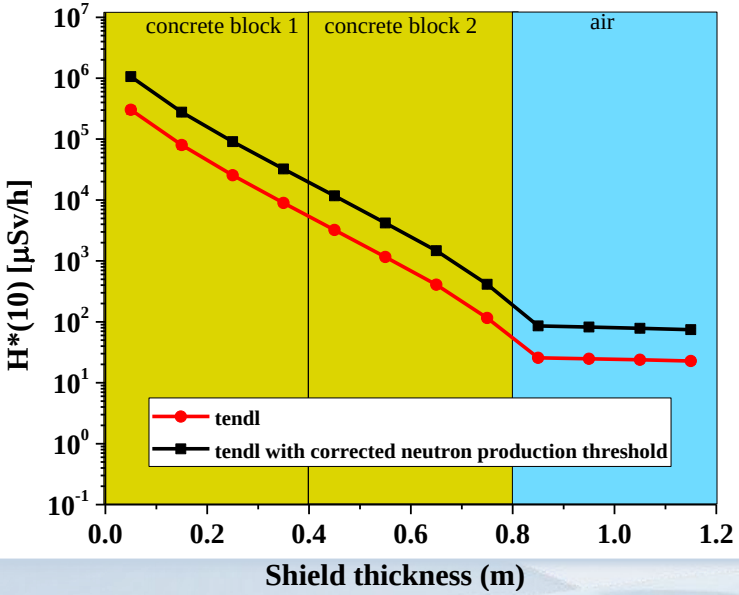
Impact of proton induced libraries



Need for the experiment at low energies!







Conclusions

- There are discrepancies between simulations and 75 MeV and 52 MeV experiments. CEM model gives closest results to the experiment.
- The quality of experimental data is questionable due to significant attenuation around 37 MeV neutron energy.
- The quality of documentation of the experiments should be increased. Uncertainties for the experiment should be provided in the SINBAD database.
- Need for the experiments at lower proton energies.
- High quality proton induced library is required.


MYRRHA

SCK•CEN
Studiecentrum voor Kernenergie
Centre d'Etude de l'Energie Nucléaire
Belgian Nuclear Research Centre

Stichting van Openbaar Nut
Fondation d'Utilité Publique
Foundation of Public Utility

Registered Office: Avenue Herrmann-Debrouxlaan 40 – BE-1160 BRUSSELS
Operational Office: Boeretang 200 – BE-2400 MOL