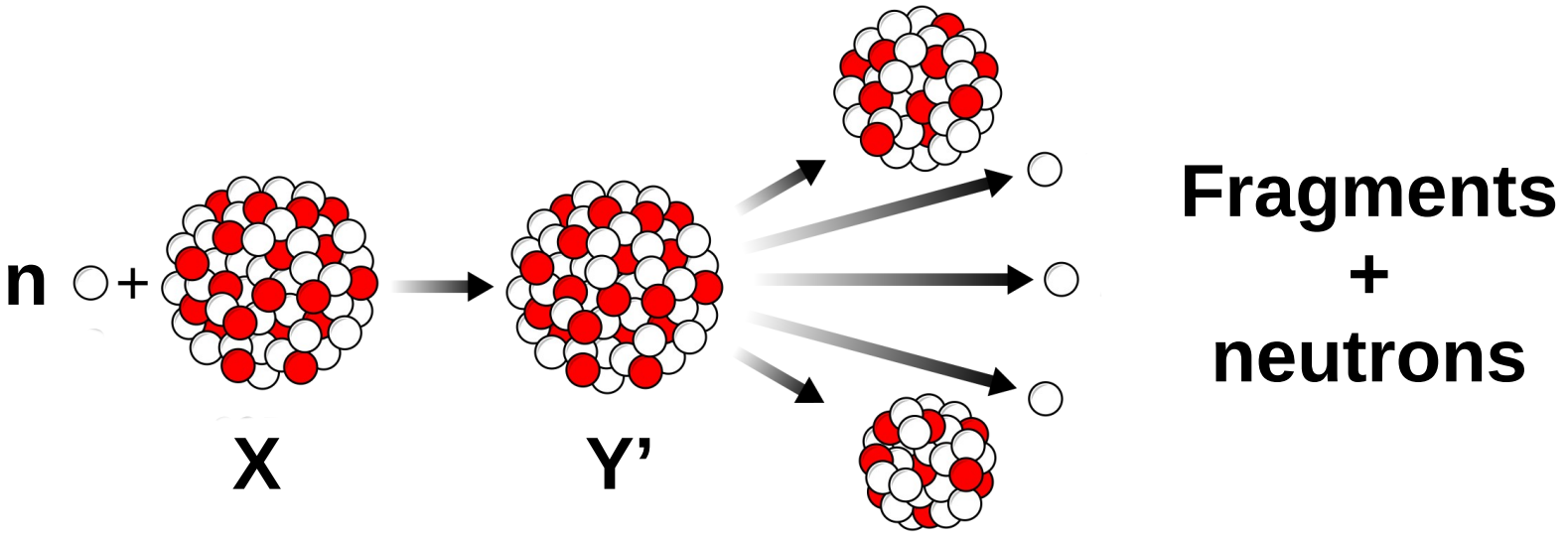
Measurement of the ^{235}U(n,f) cross section at n_TOF from thermal to 170 keV

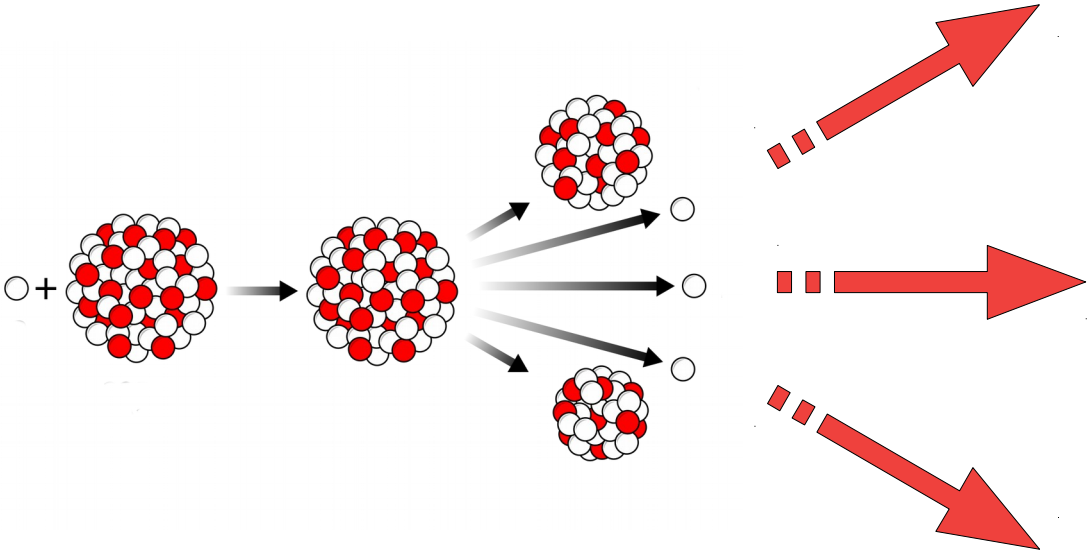
Simone Amaducci – International Conference on Application of Nuclear Techniques – Crete 9-15 June 2019

Nuclear fission

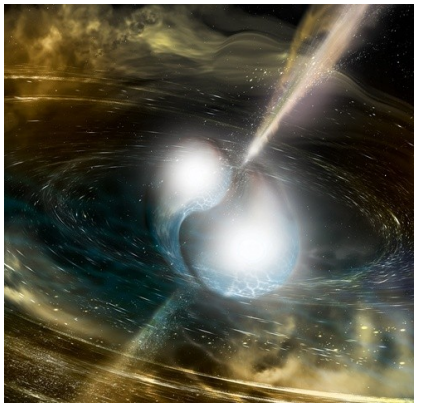


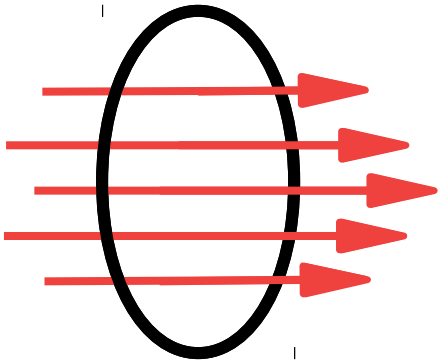
Nuclear fission

New generation fission reactors and waste burning



Heavy elements nucleosynthesis





Neutron flux measurement

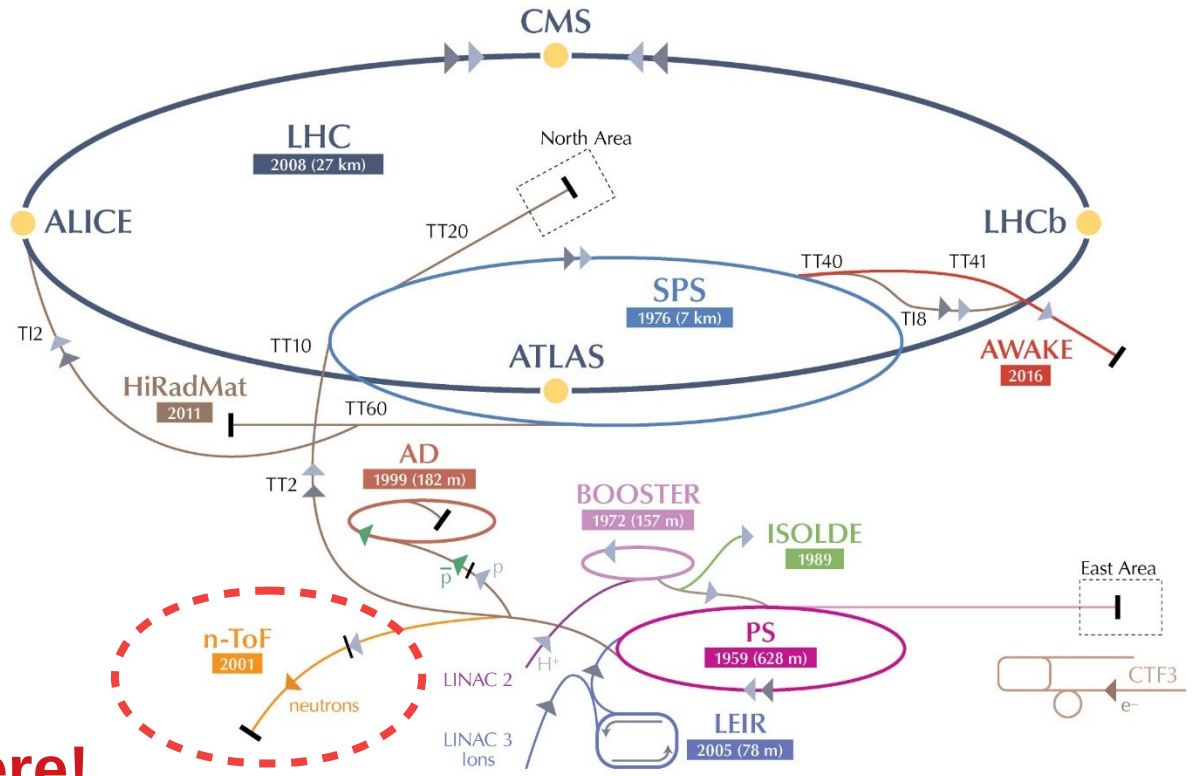
Neutron standard cross sections

Well know neutron cross section used to measure flux and as reference in other neutron cross section measurement.

Reaction	Energy interval
H(n,n)	1 keV - 20 MeV
^{3}He(n,p)	thermal - 50 keV
^{6}Li(n,t)	thermal - 1 MeV
^{10}B(n,α)	thermal - 1 MeV
^{10}B(n,α$_1$γ)	thermal - 1 MeV
C(n,n)	up to 1.8 MeV
^{197}Au(n,γ)	thermal and 0.2 MeV - 2.5 MeV
^{235}U(n,f)	**thermal and 0.15 MeV - 200 MeV**
^{238}U(n,f)	20 MeV - 200 MeV

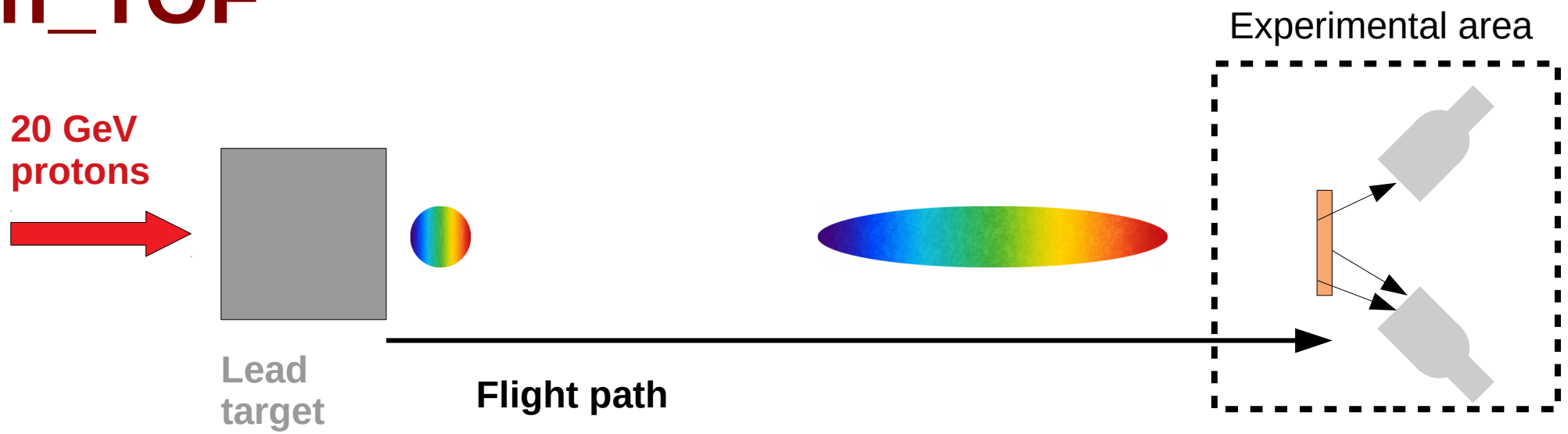
n_TOF

neutron_**T**ime**O**f**F**light

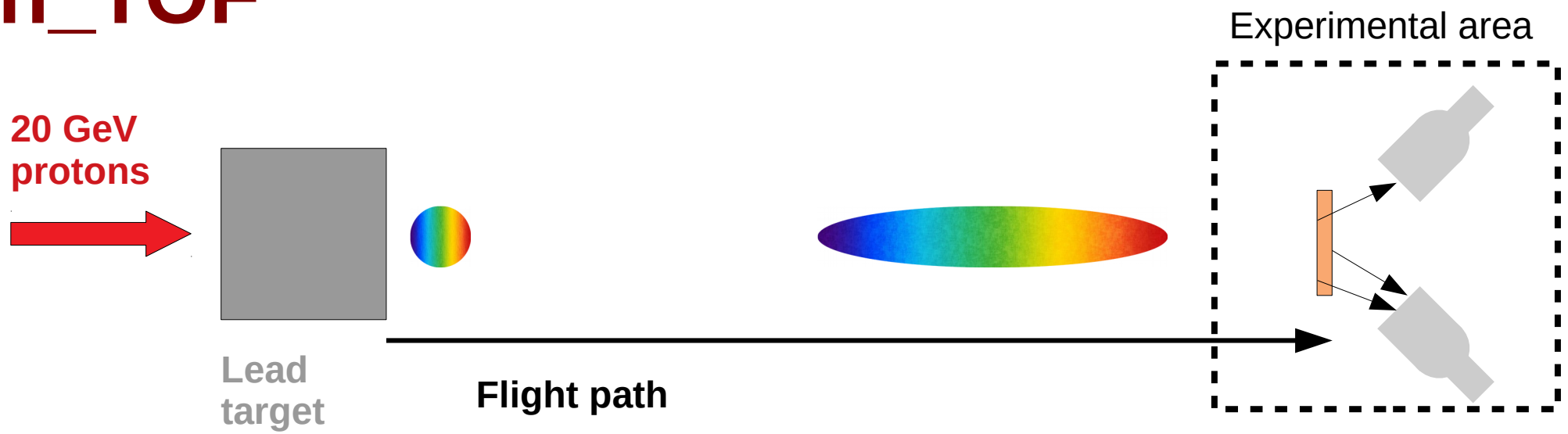


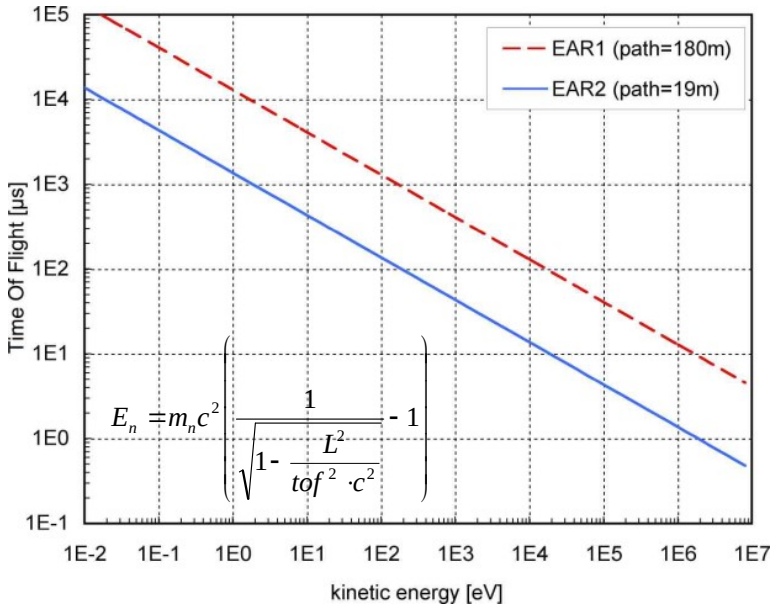
We're here!

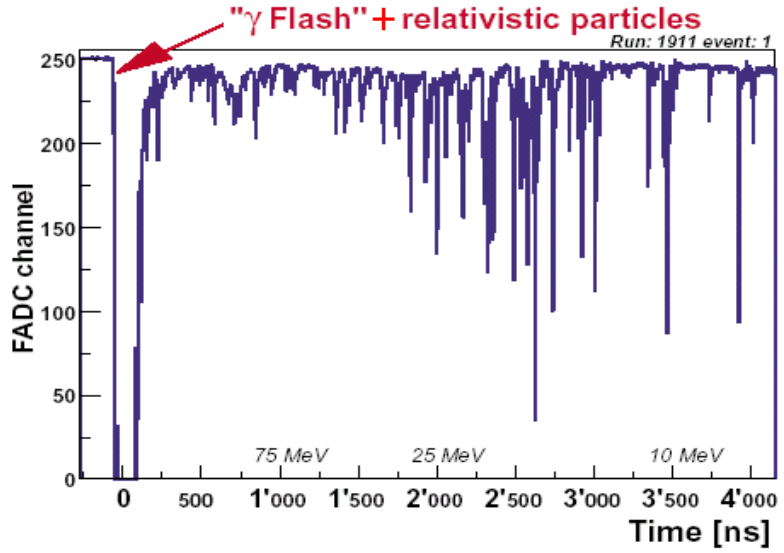
n_TOF



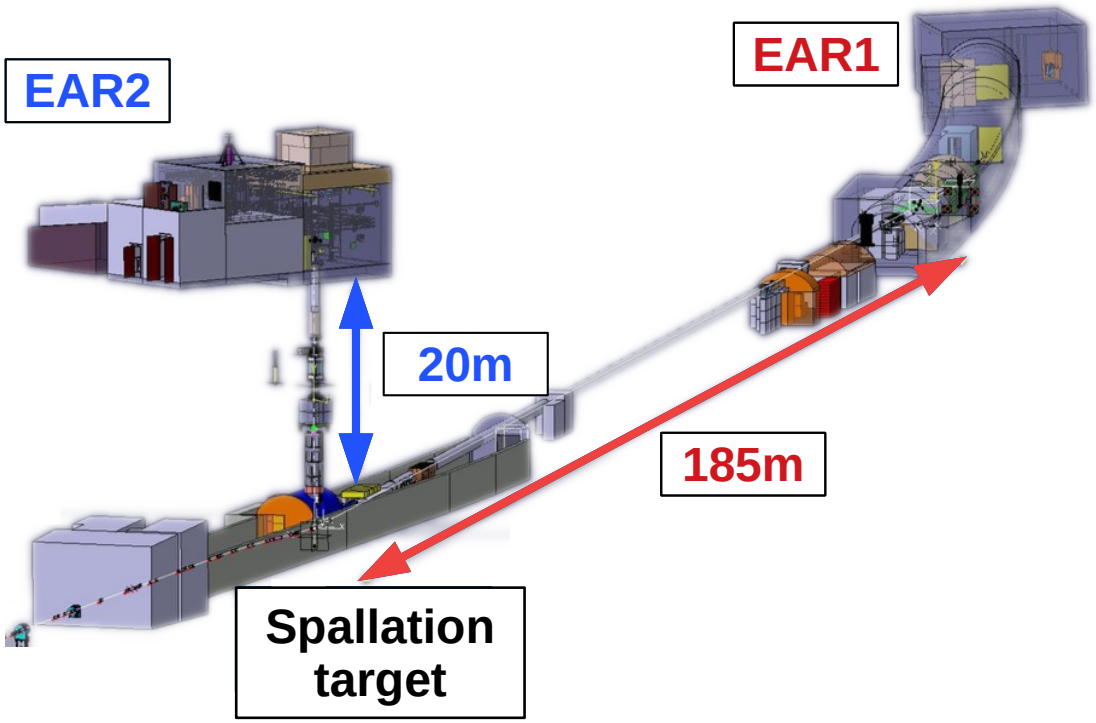
n_TOF

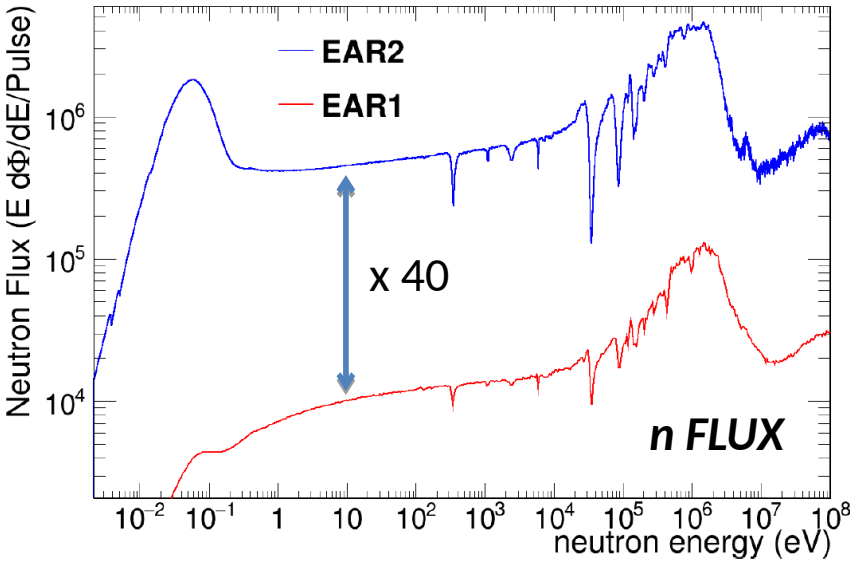

Experimental area
20 GeV protons
Lead target
Flight path


EAR1 (path=180m)
EAR2 (path=19m)
Time Of Flight [μs]
kinetic energy [eV]
$E_n = m_n c^2 \left(\frac{1}{\sqrt{1 - \frac{L^2}{tof^2 \cdot c^2}}} - 1 \right)$


"γ Flash" + relativistic particles
Run: 1911 event: 1
FADC channel
75 MeV
25 MeV
10 MeV
Time [ns]

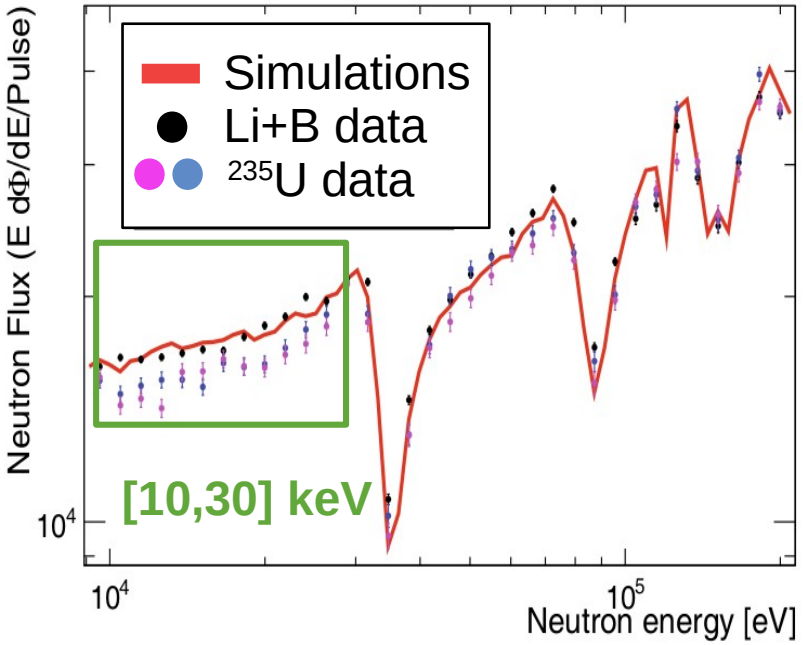
n_TOF


EAR2
EAR1
20m
185m
Spallation target


EAR2
EAR1
x 40
n FLUX
Neutron Flux (E dΦ/dE/Pulse)
neutron energy (eV)

n_TOF flux measurement

Discrepancies in the keV region were found during the last n_TOF flux measurement in EAR1.

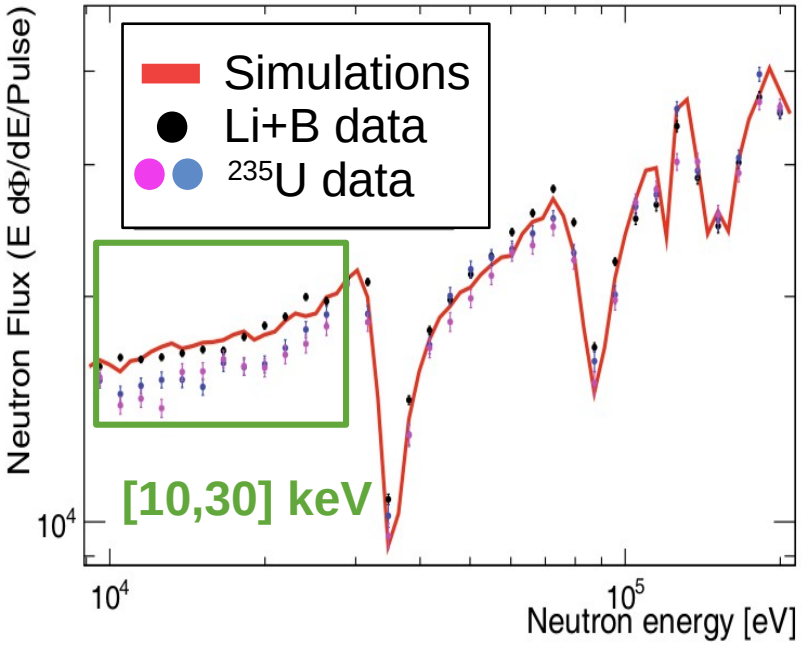


M. Barbagallo et al., Eur. Phys. J. A **49** (2013) 156

n_TOF flux measurement

Discrepancies in the keV region were found during the last n_TOF flux measurement in EAR1.

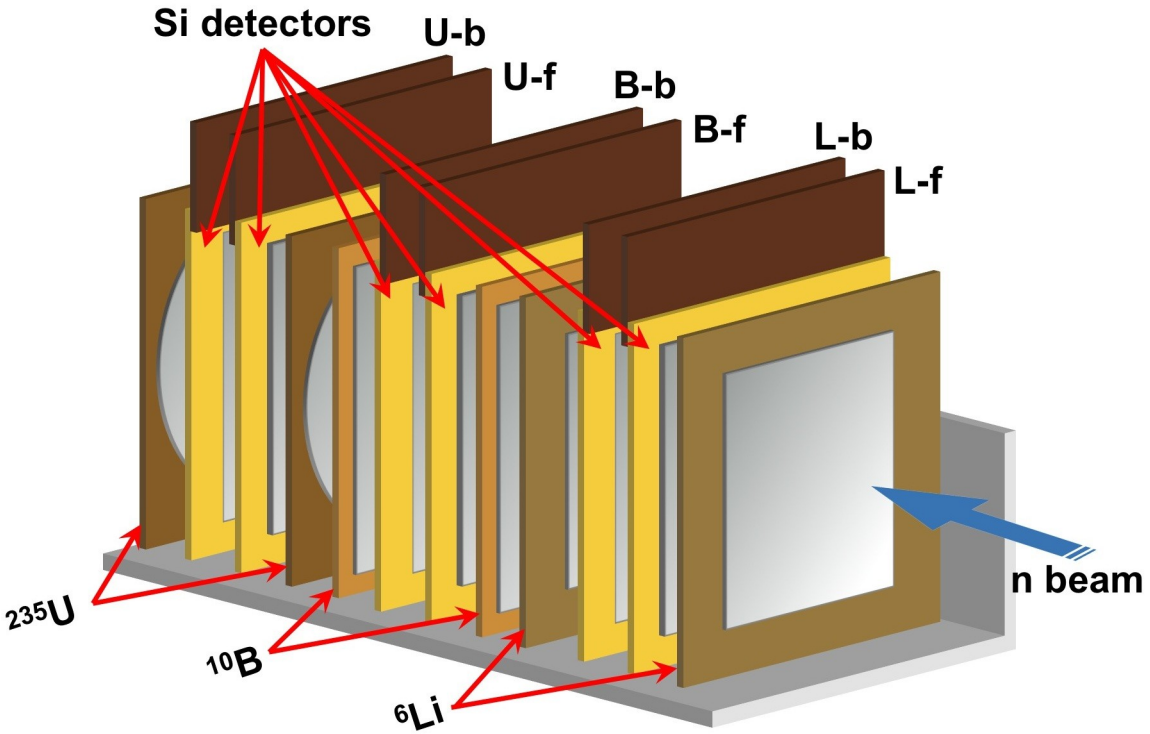
That's suspicious...

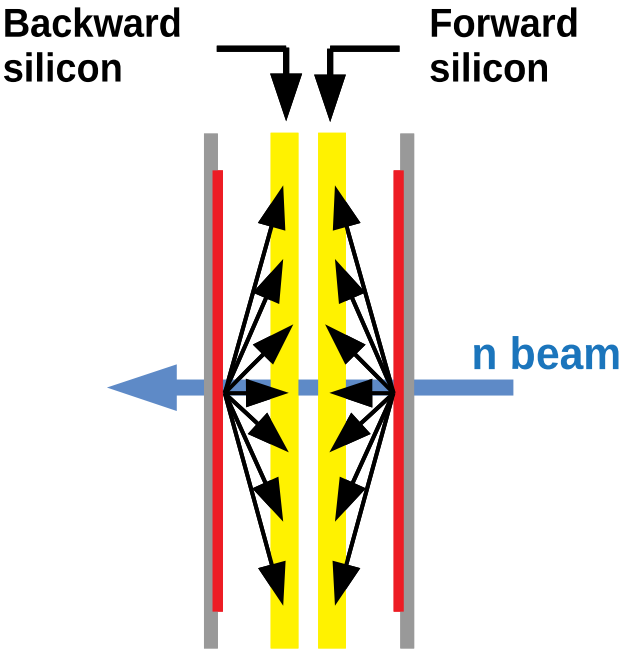


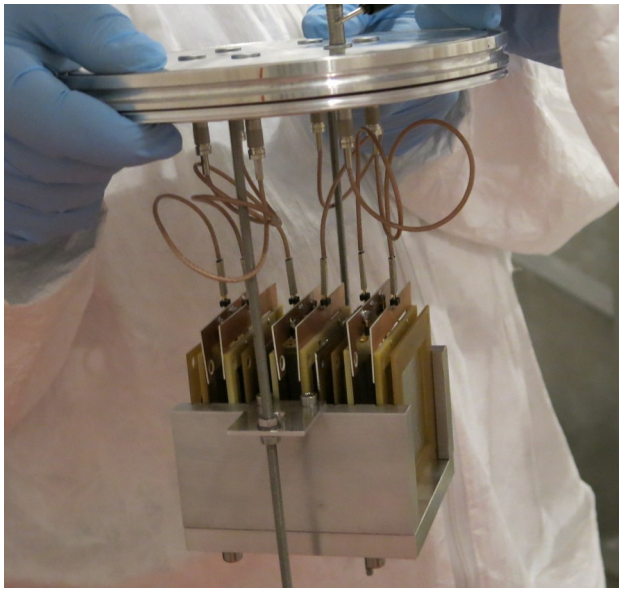
M. Barbagallo et al., Eur. Phys. J. A **49** (2013) 156

^{235}U(n,f) cross-section measurement performed at n_TOF with respect to standards ^{6}Li(n,t) and ^{10}B(n,α) in the energy range th-170 keV.

Experimental setup

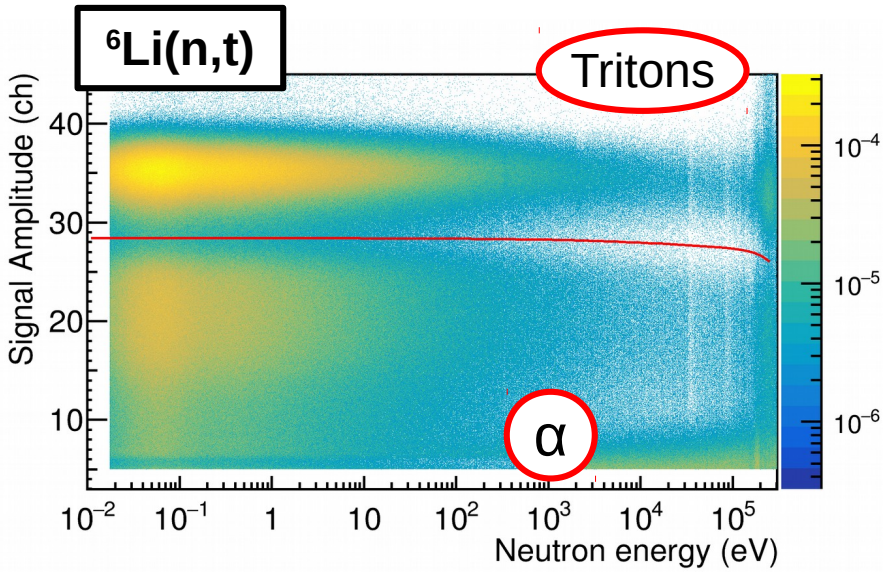


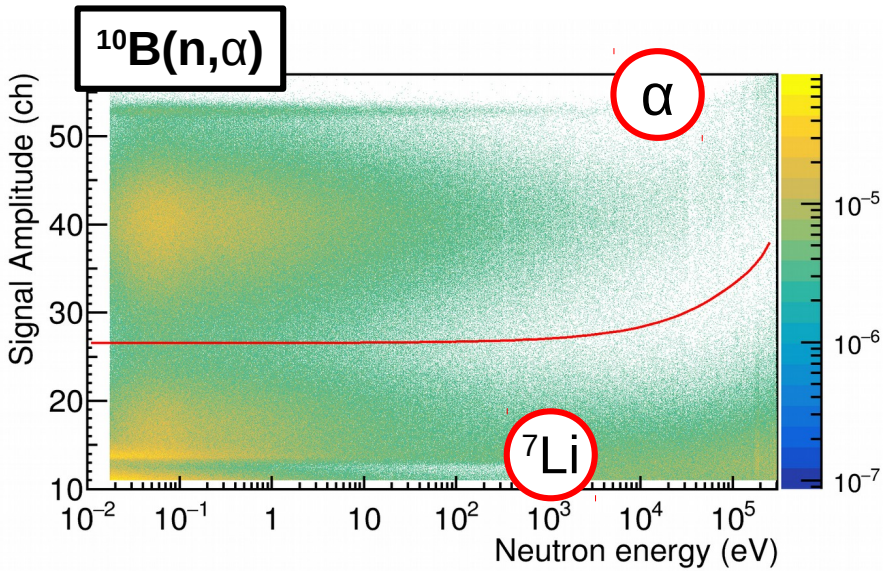




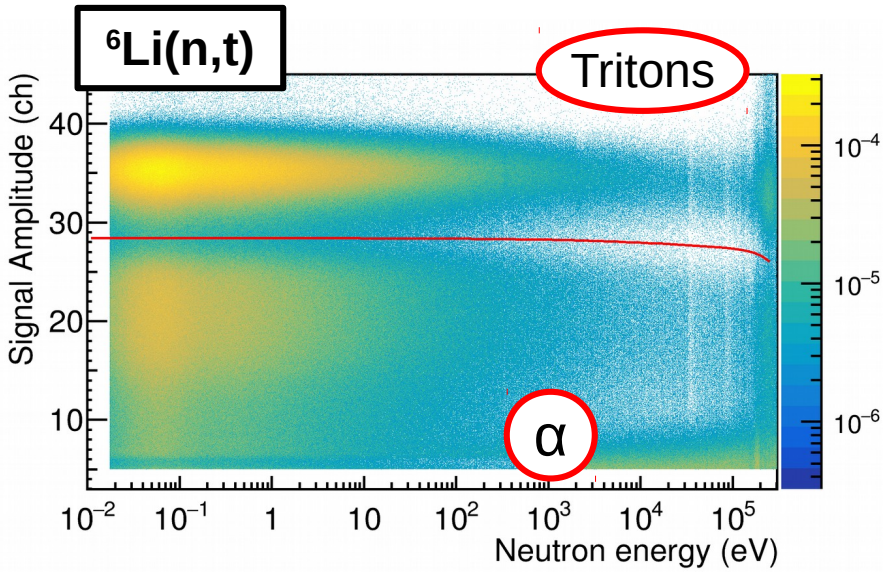
Silicon thickness: 200 um
Silicon area: 5x5 cm^2
Distance silicon-target: ~1 mm

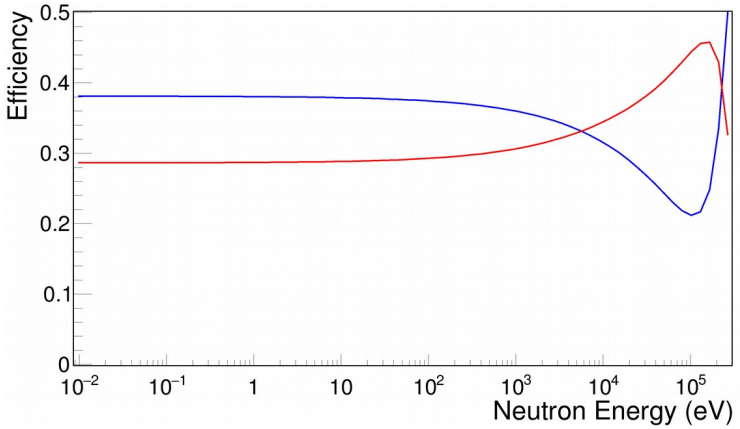
Particle identification

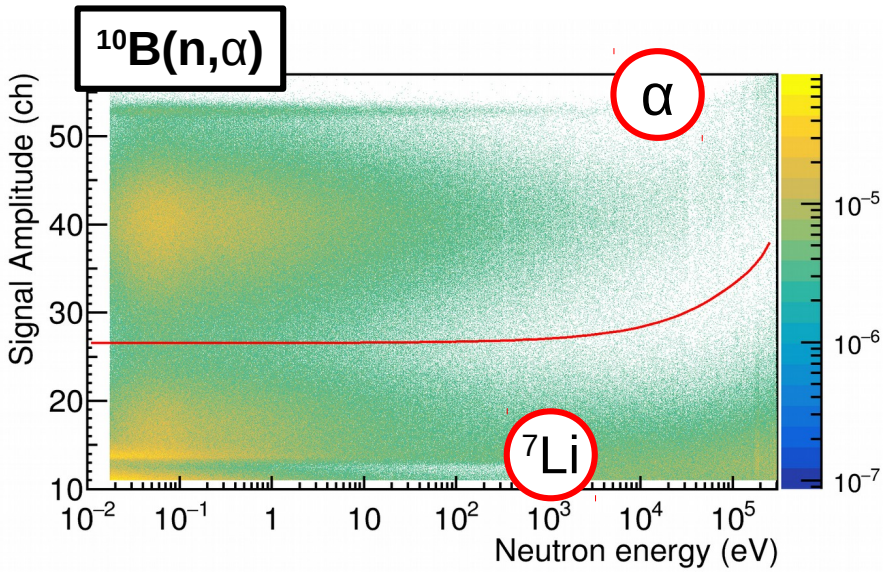




Particle identification

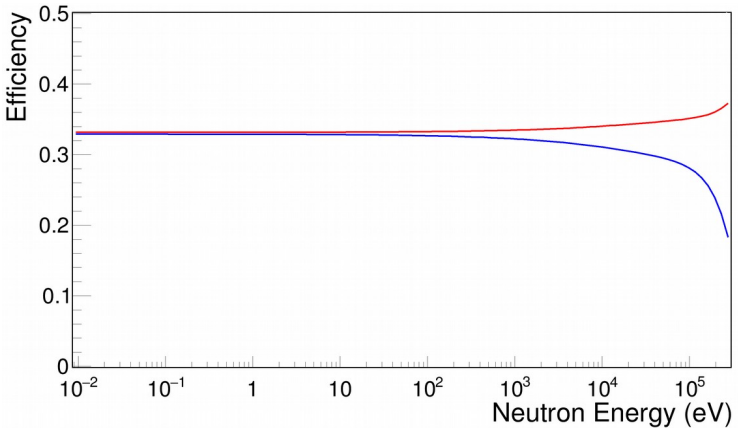




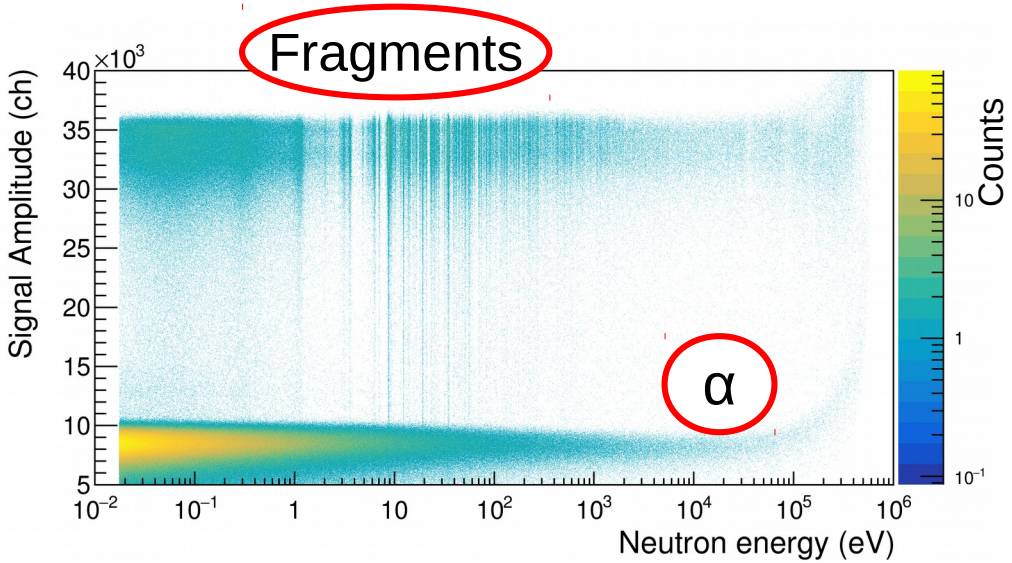


Forward direction

Backward direction



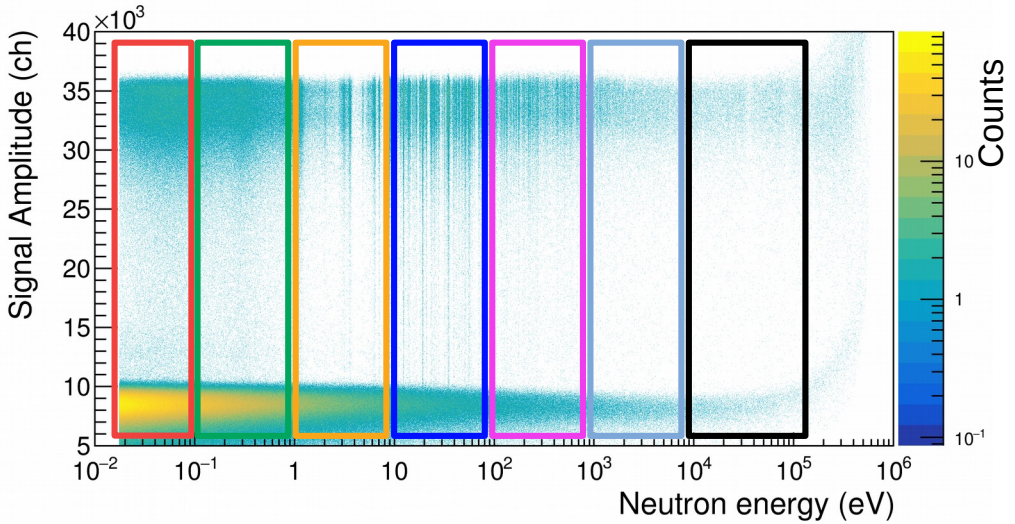
Fission Fragments discrimination



Clear separation up to hundreds of keV

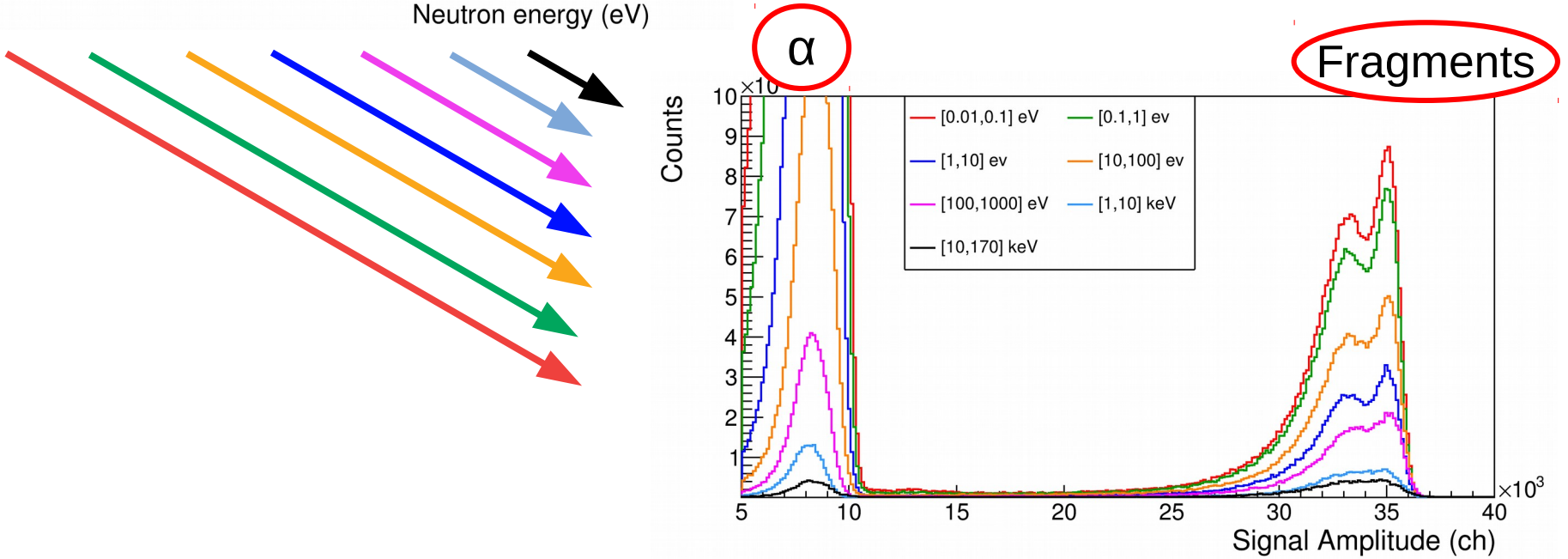
Efficiency is constant

Fission Fragments discrimination

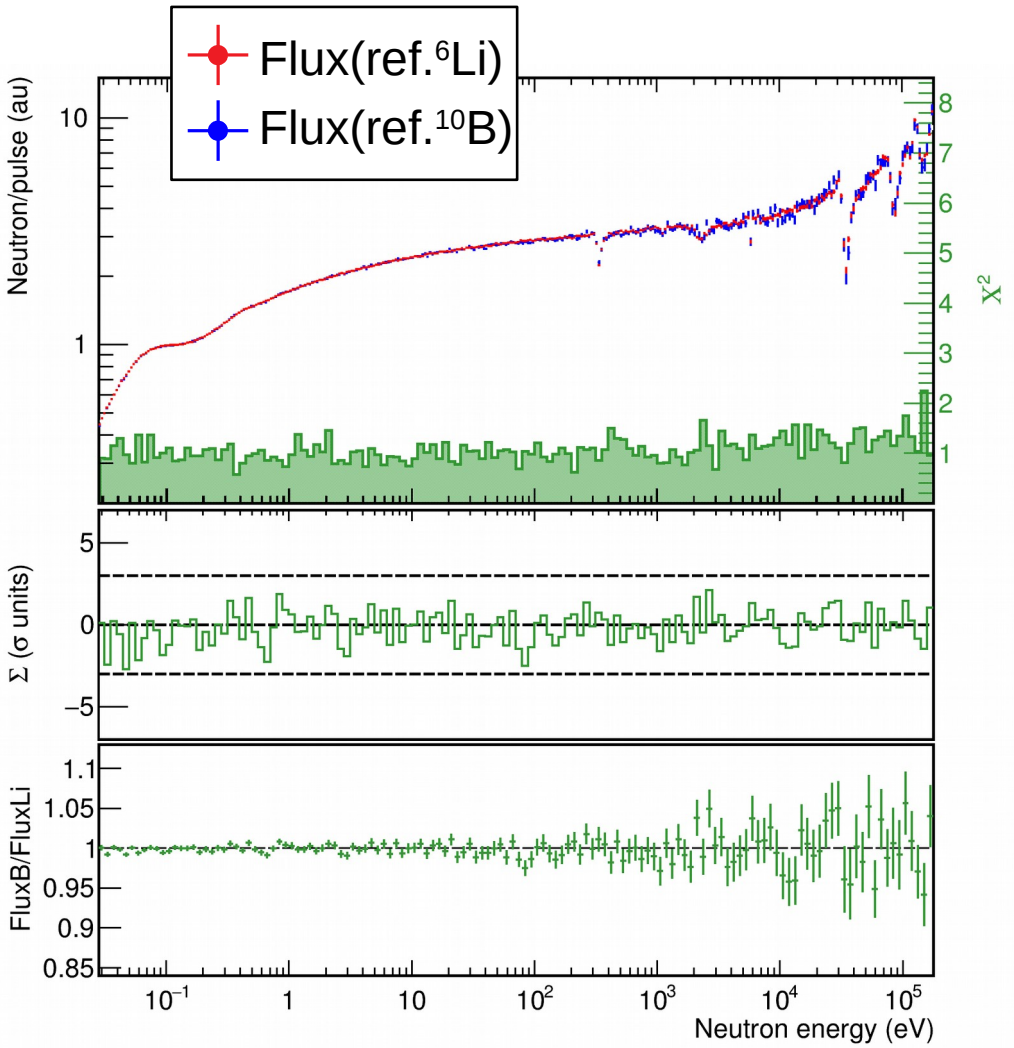


Clear separation up to hundreds of keV

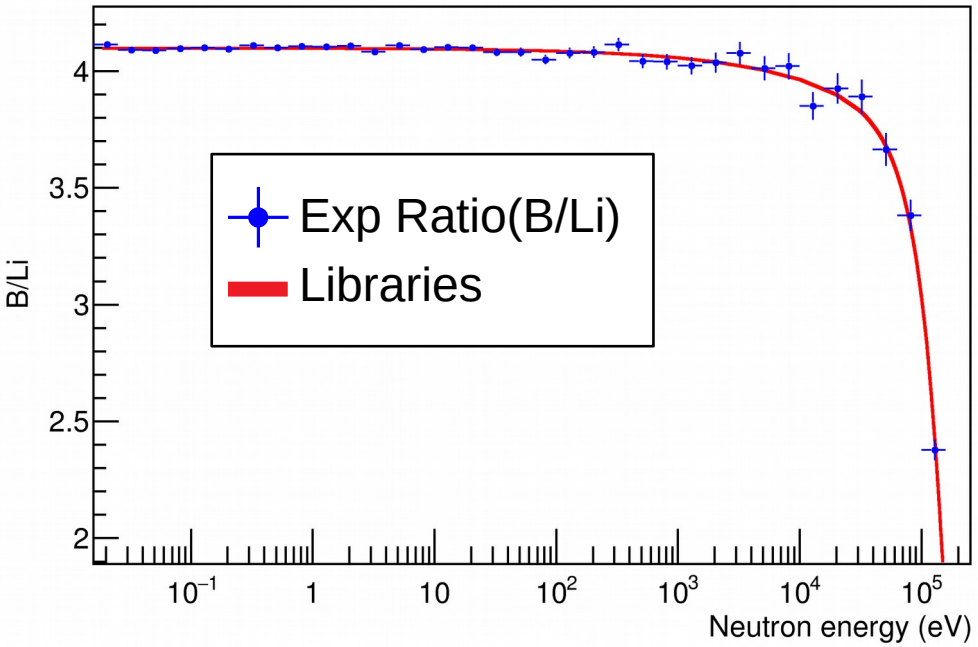
Efficiency is constant



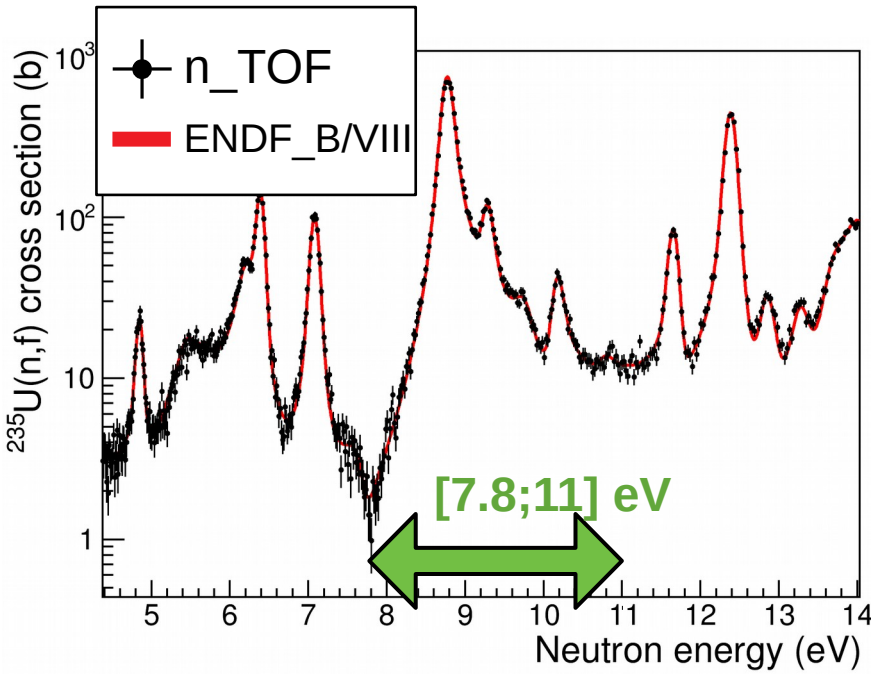
Measured flux – Ratio B/Li



Good agreement between boron and lithium data.



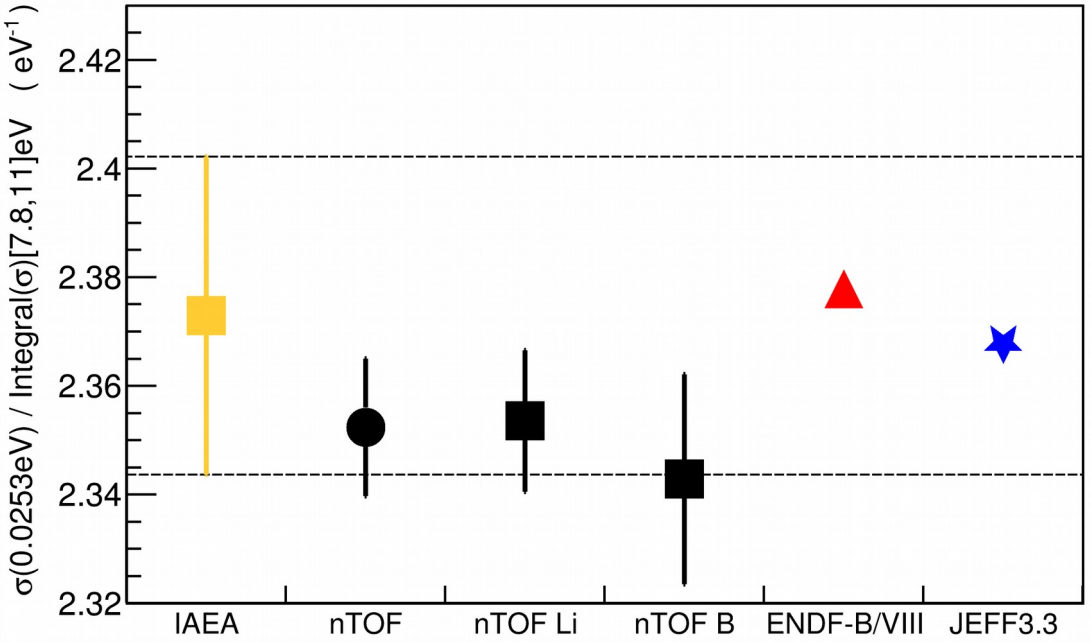
Normalization to [7.8,11]eV



⇒ Negligible border effect (two minimum)

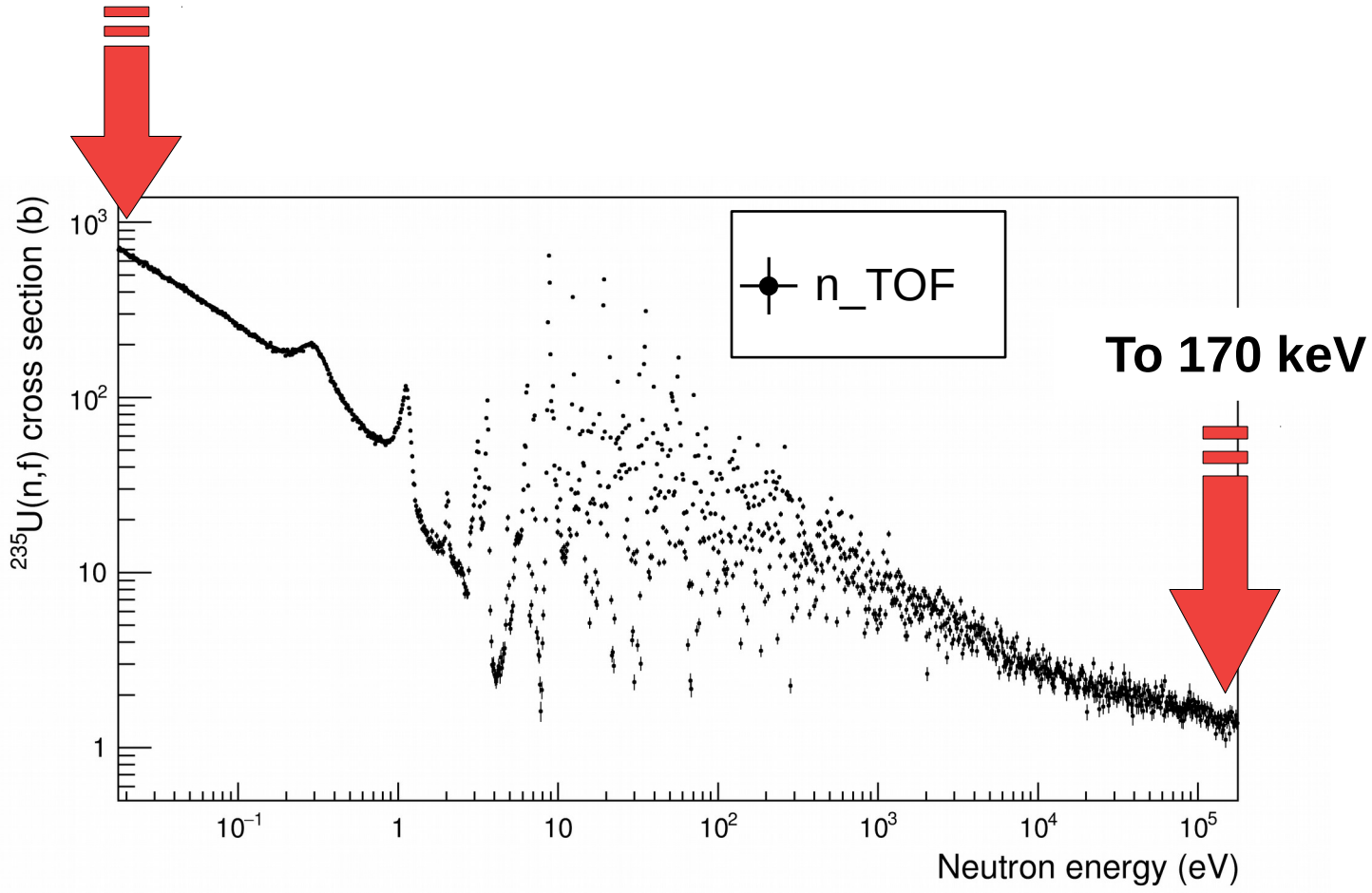
⇒ Integral [7.8,11]eV is a standard

Integral [7.8,11] eV is consistent with thermal value ⇐

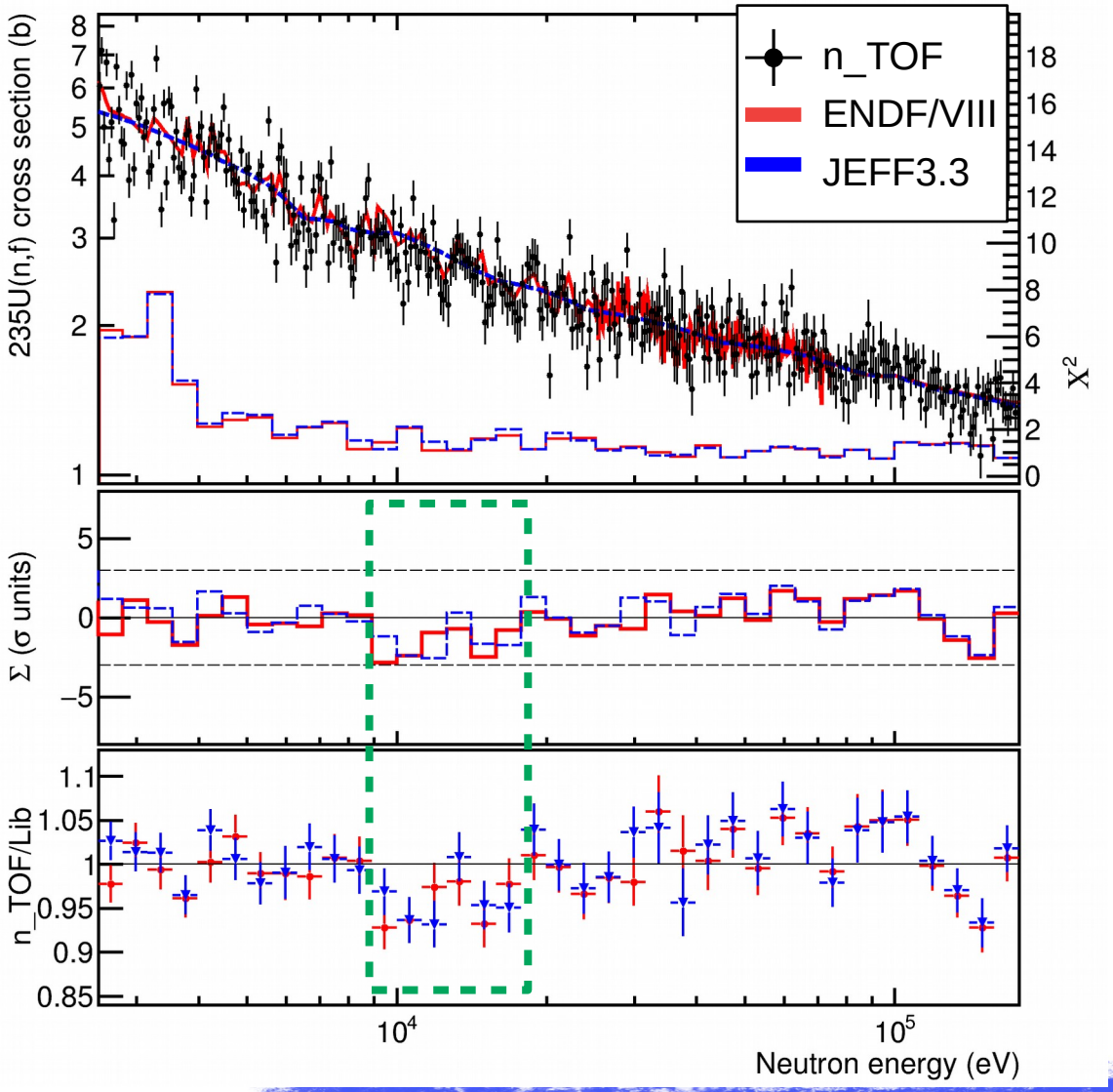


^{235}U(n,f) cross section

From thermal energy



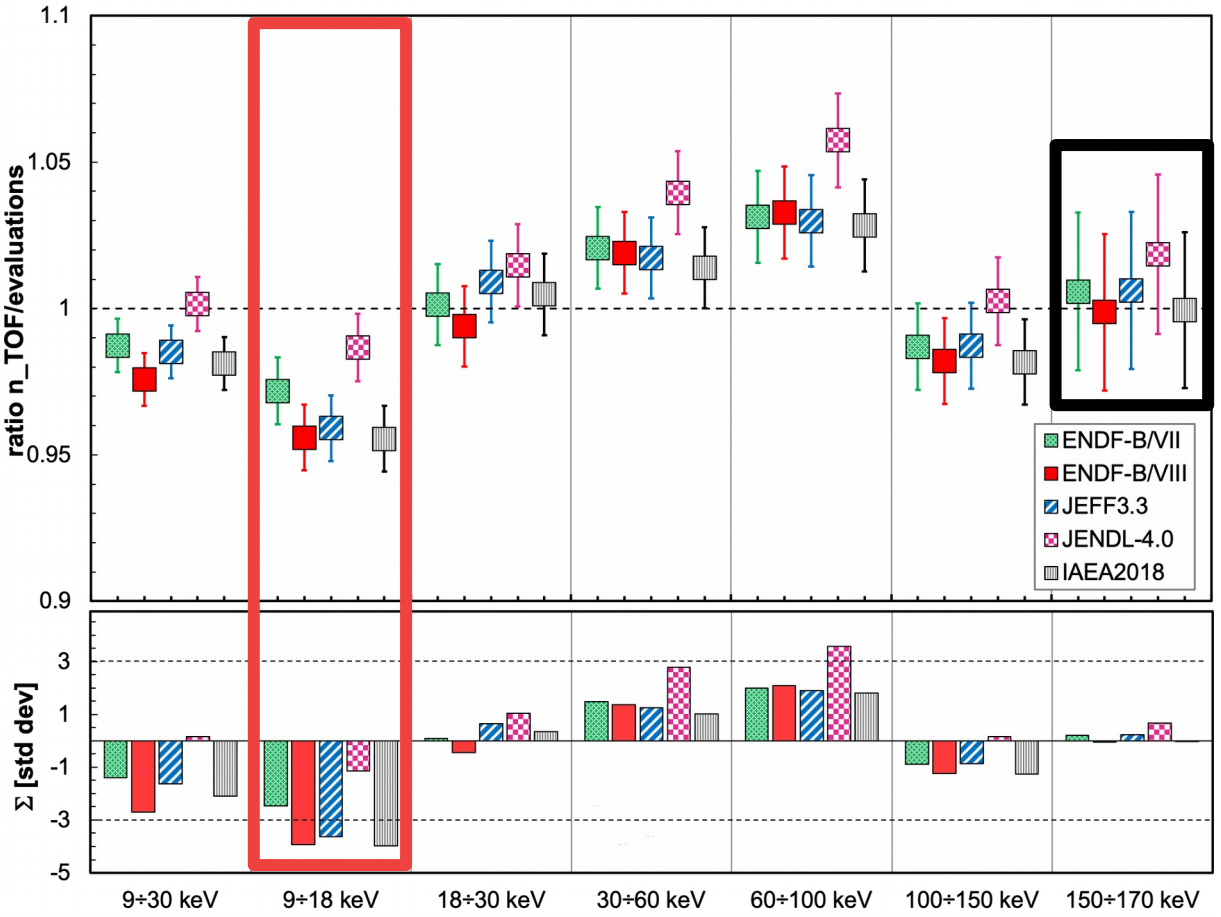
^{235}U(n,f) in the keV Region



[9,18] keV

Experimental data are systematically lower than JEFF3.3 and ENDF-B/VIII

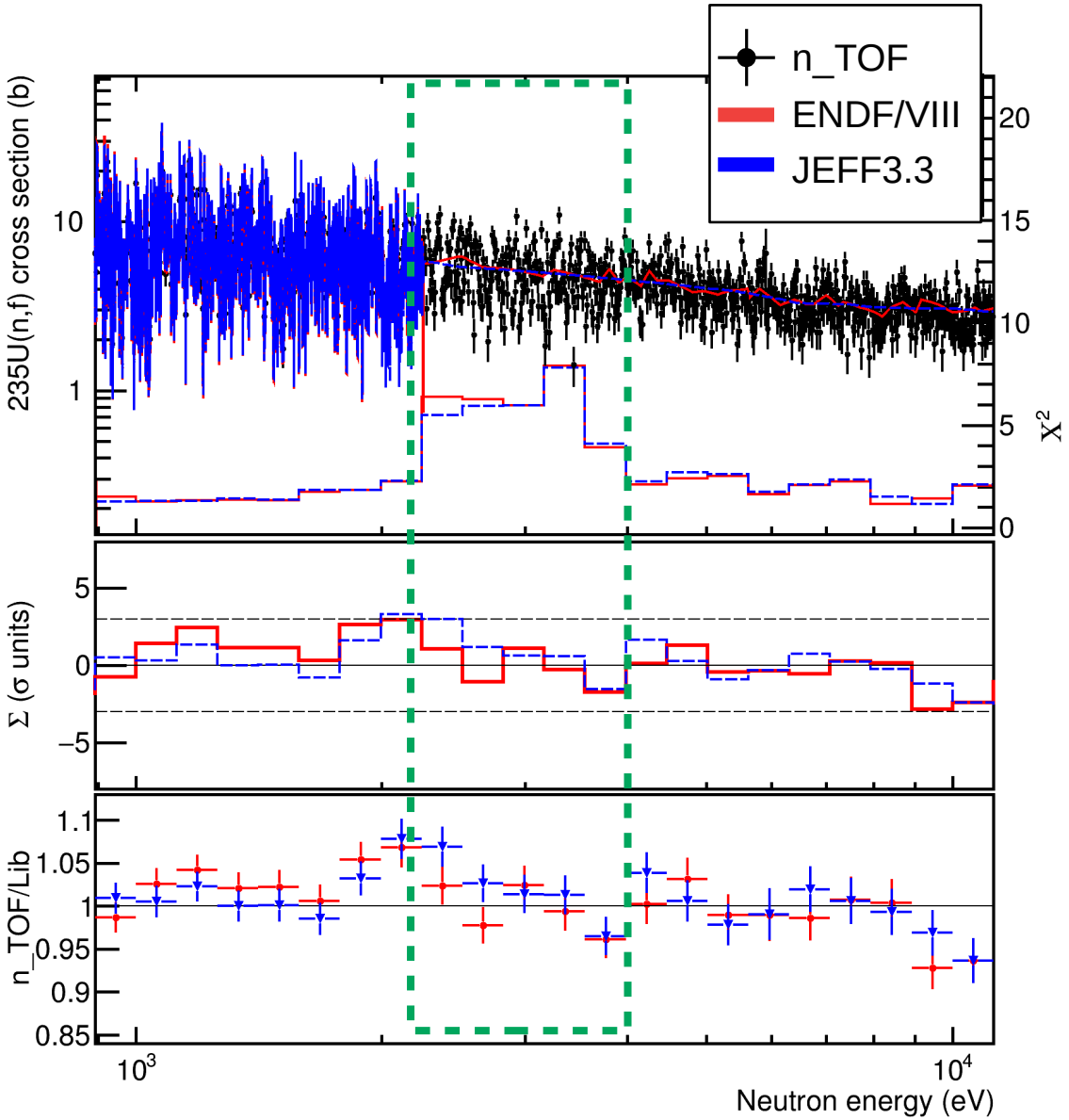
^{235}U(n,f) in the keV Region



Over 150 keV ^{235}U(n,f) is again a standard.

Most of recent the libraries overestimate ^{235}U(n,f) cross section between 9 and 18 keV.

RRR-URR limit



[2.2,4] keV

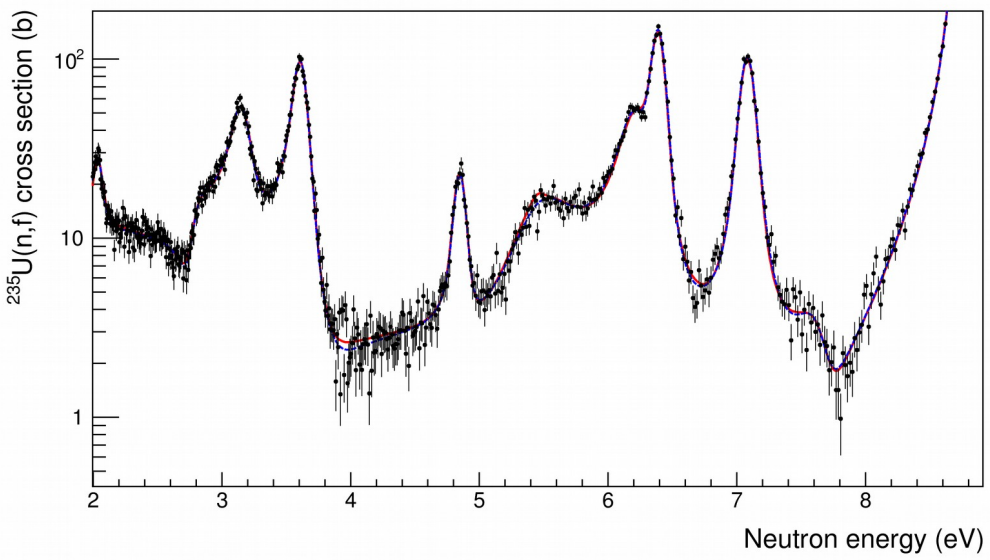
Large X² between experimental data and libraries.

No systematic deviation.

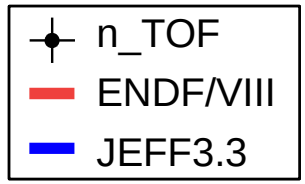
Ratio exp/libraries ~ 1

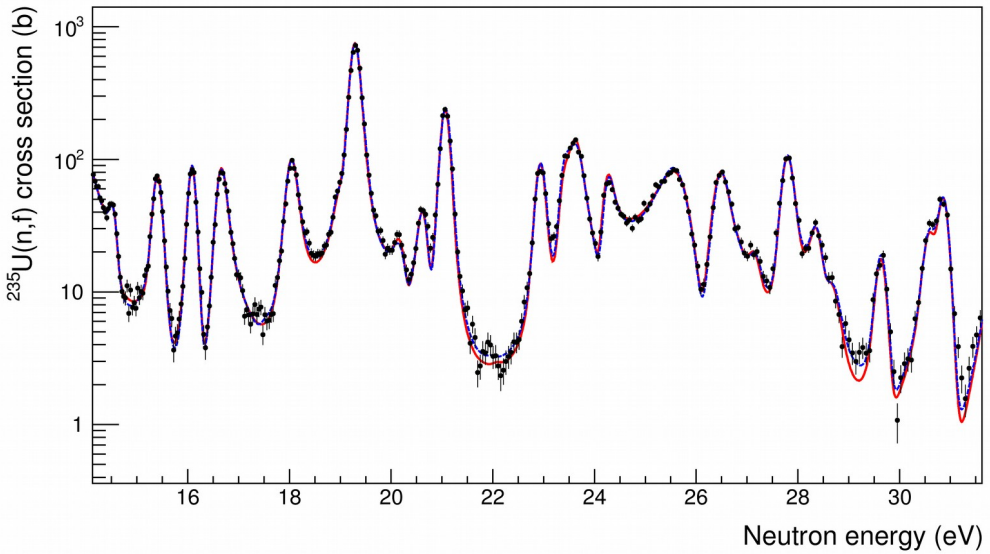
Evidences of structures in experimental data that are not present in libraries.

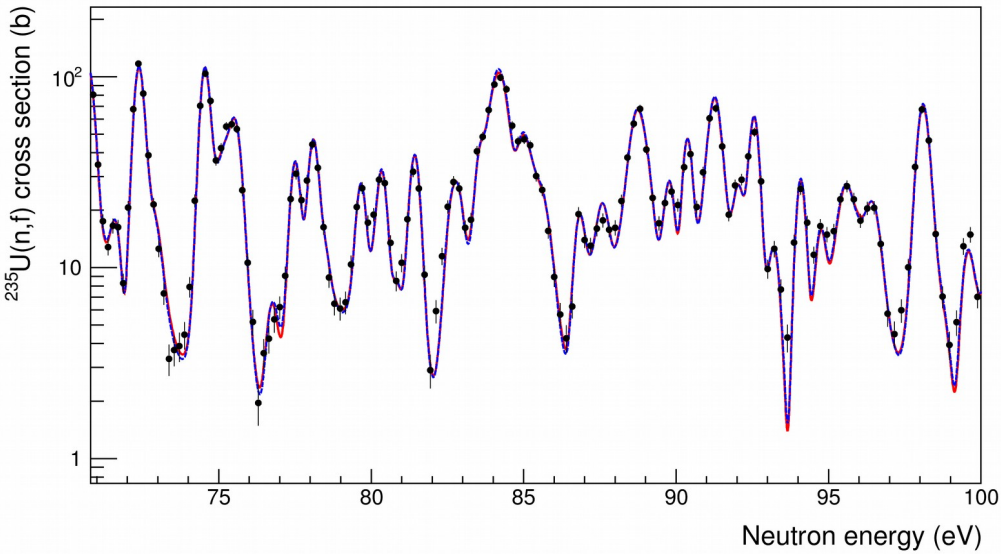
^{235}U(n,f) at lower energies



High quality data also at lower energies. A resonance analysis will be done soon.





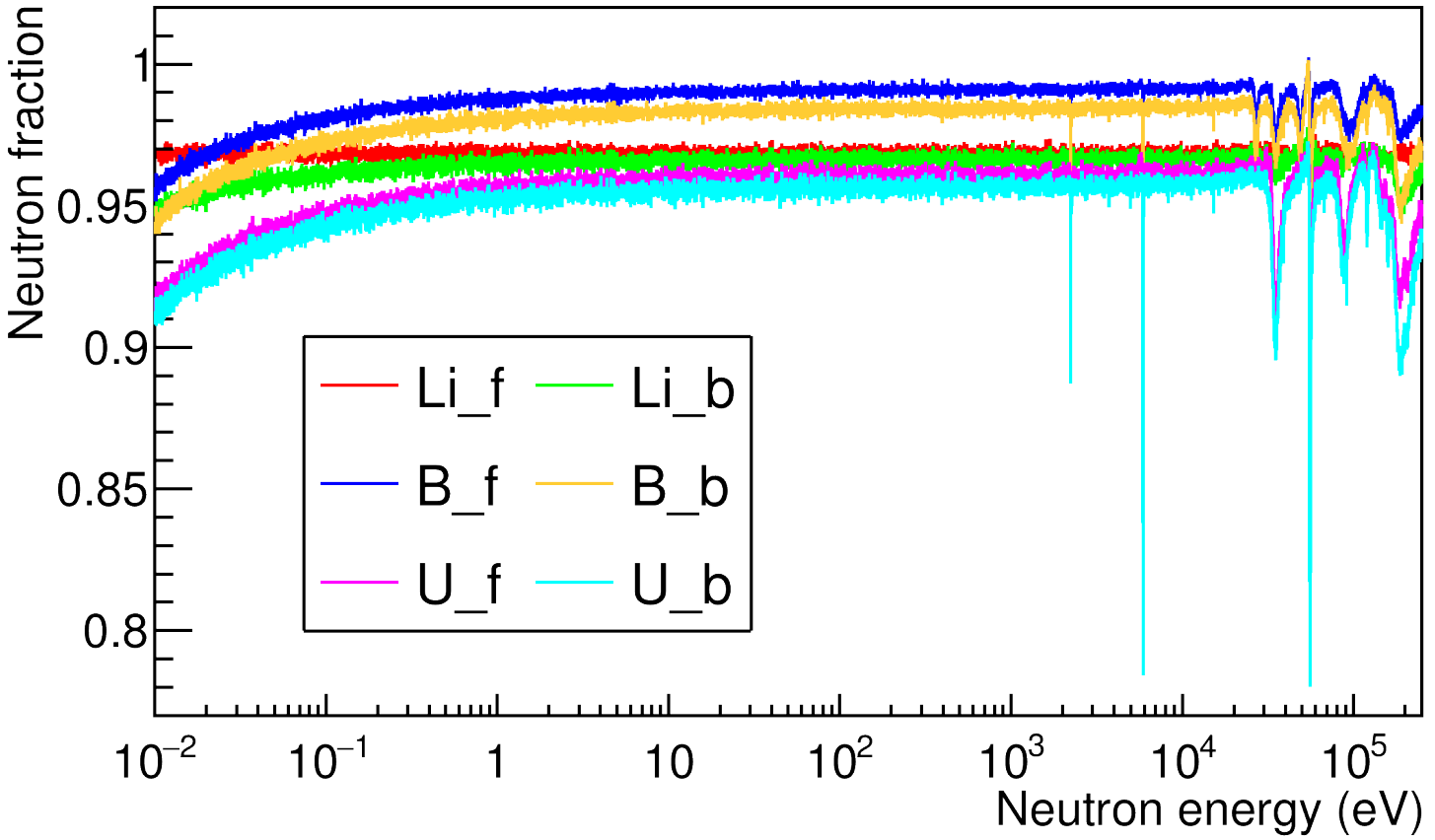


Summary

- An accurate measurement of **^{235}U(n,f) cross section with respect to ^{6}Li(n,t) and ^{10}B(n,α) standard** has been performed at n_TOF **between thermal and 170 keV** neutron energy. Paper accepted for publication on EPJ-A!
- An **overestimation** of the fission cross-section in libraries has been revealed in the **9-18 keV** neutron energy range.
- The measurement also evidences the presence of **structures in the 2.2 – 4 keV range**, just after the end of RRR of ENDF8 and JEFF3.3.
- High quality data have been collected at lower energies and a detailed resonance analysis will be performed.
- **Silicon detectors** are well suitable for high precision fission measurement at n_TOF.

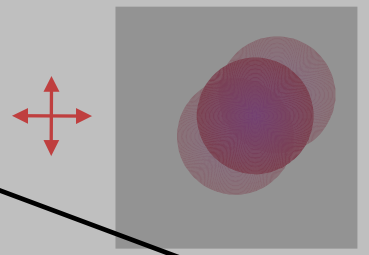
Thank you for your attention

Absorption correction



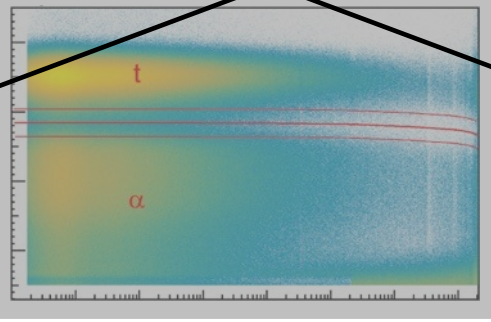
Systematic uncertainty

beam displacement ±σ



< 1%

cuts displacement ±3%
(huge change of counts)

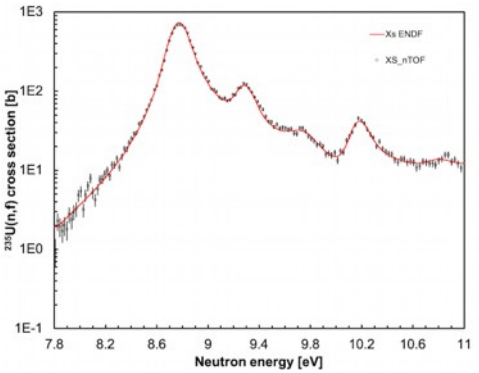


≈ 0.3% ^{6}Li

< 1% ^{10}B

≈ 0 ^{235}U

normalization (7.8÷11 eV)

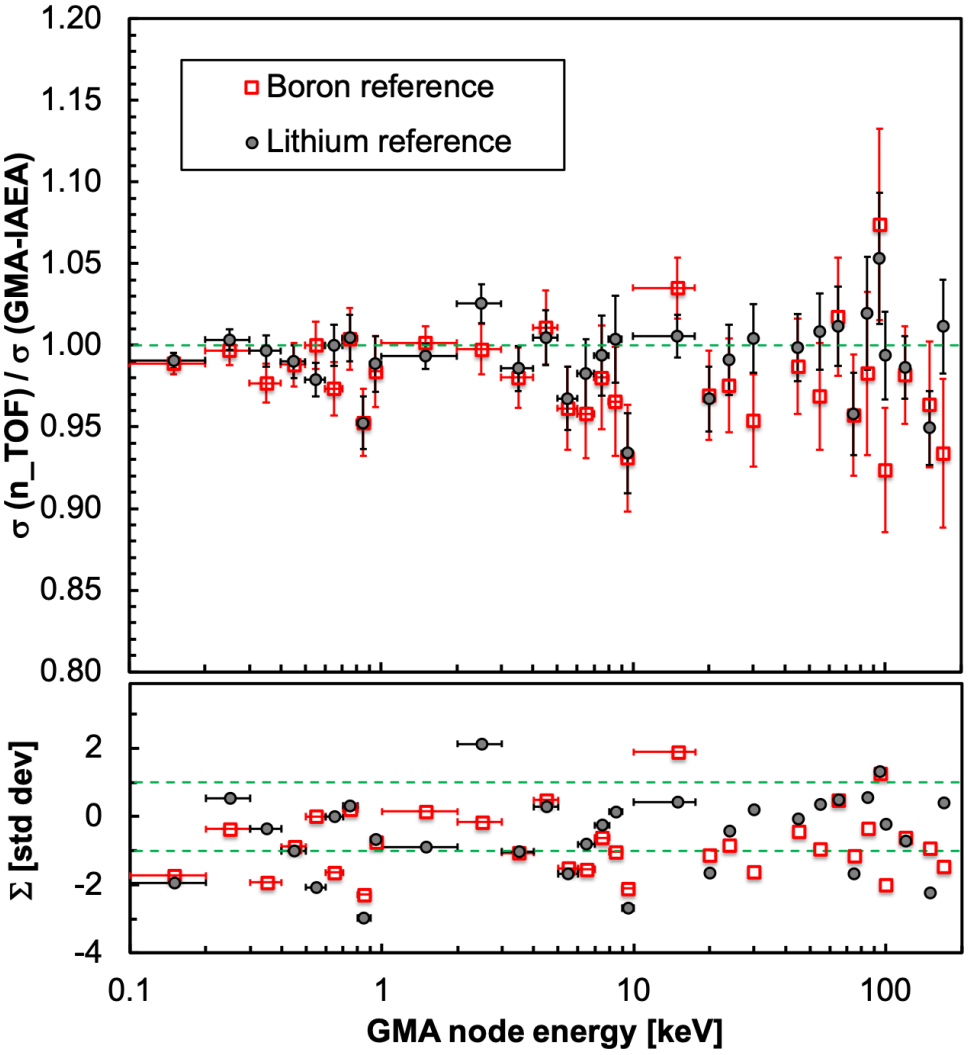


1.3% ^{6}Li

1.4% ^{10}B

1.3% total

GMA-Nodes



Overall agreement with point-wise reference provided by IAEA in 2018[1].

Differences for GMA points at 0.85 and 9.5 keV.

[1] Carlson et al., *"Evaluation of the Neutron Data Standards", Nuclear Data Sheets* ***148*** *(2018) 177*