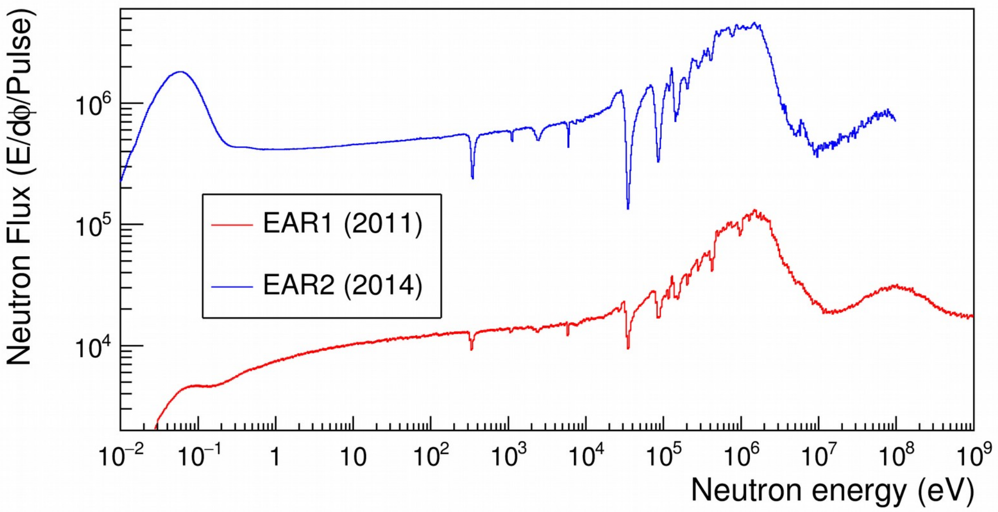
A nTD silicon based experimental apparatus for measurement of (n,cp) cross sections

Concept

n_TOF very well suited for performing the needed measurement thanks to:

- **Wide neutron energy interval**
- **High instantaneous flux**



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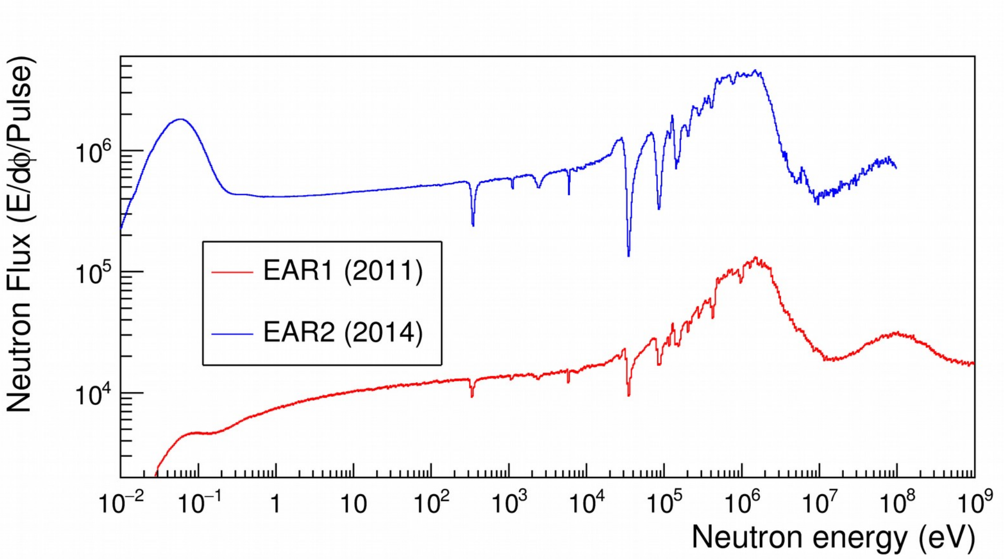
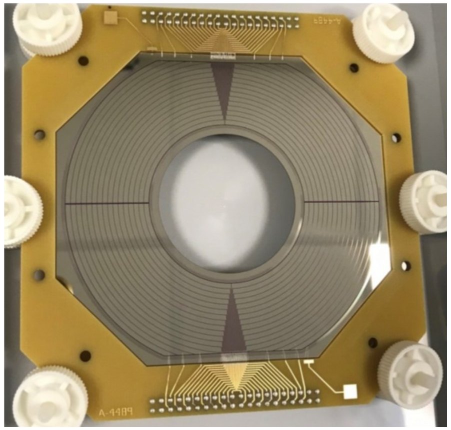
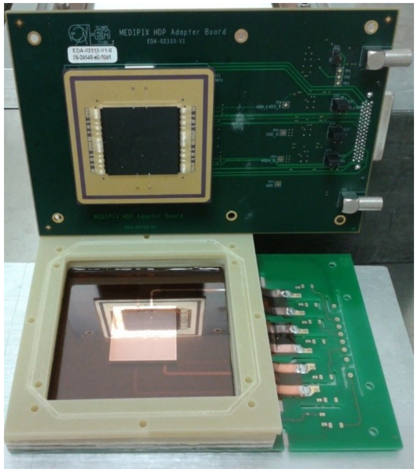


Development of **versatile experimental apparatuses** to measure (n,cp) cross section **between the threshold and tens of MeV**.



nTD silicon detectors

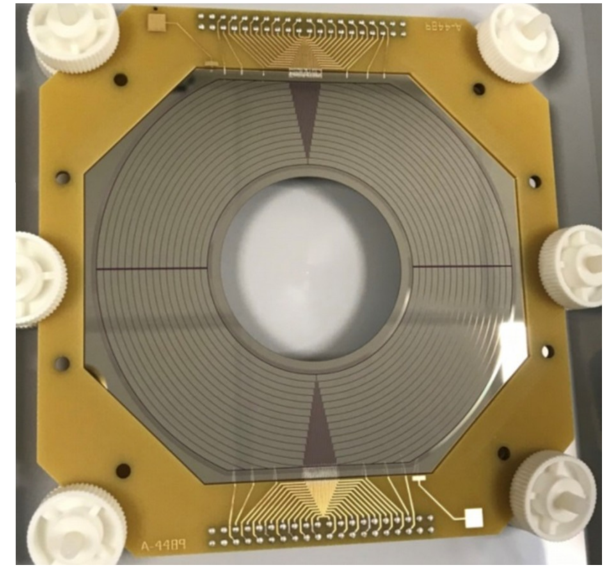


GEMPix

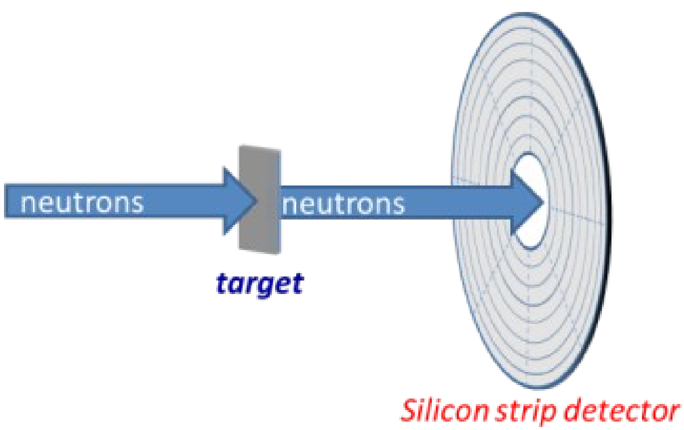
Detector concept – Silicon

Possibility to use an apparatus based on nTD annular silicon detector to **overcome the limits of telescopes**:

- **Particle discrimination based on Pulse Shape** (backside mode to enhance effects)
- **Low energy threshold** (2-3 MeV)
- Possibility to measure **angular distribution**



Basic geometry



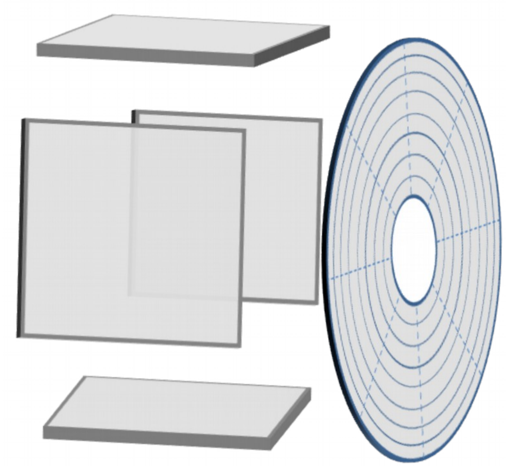
Additional sil. for large angles?

1 annular 300um @ CERN

1 nTD annular 300um @ LNS

1 square strip 5x5 cm^2 400um ordered (october?)

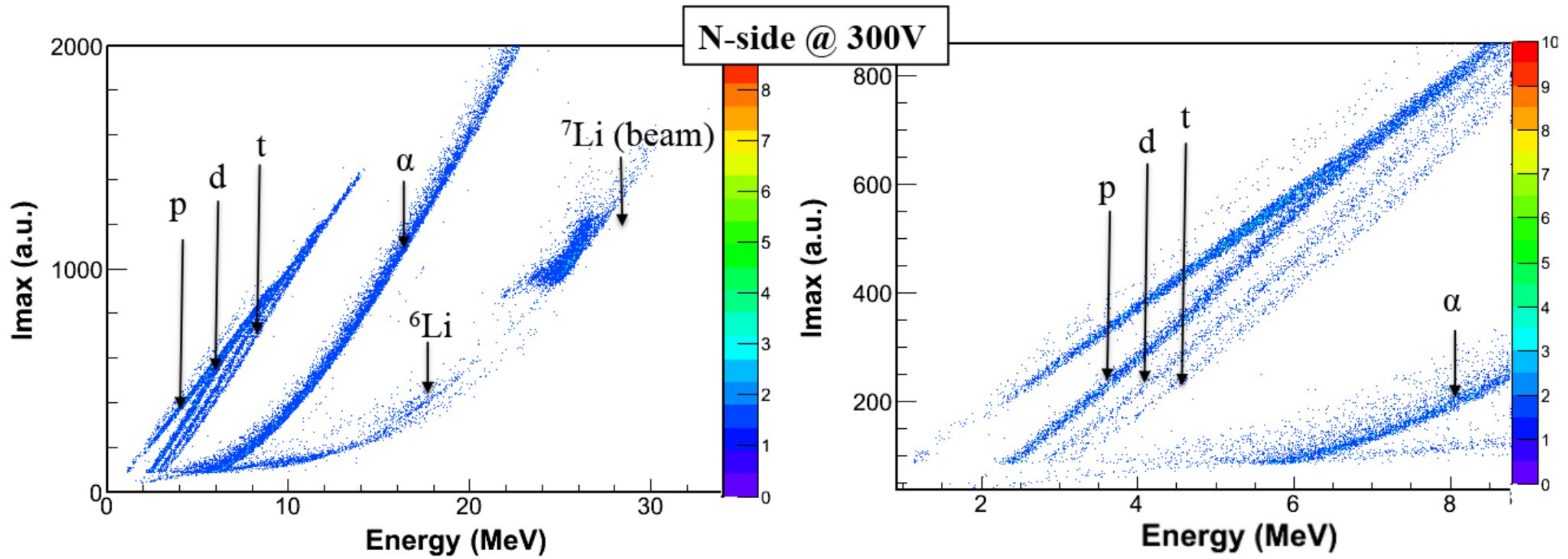
Additional silicon



Experimental technique

The pulse shape technique is a **well established** technique to perform particle identification **on the basis of the charge collection time** in a silicon detector with Vbias close to the depletion voltage and injecting from the N-side.

Avoiding the usual telescope approach we should be able to **lower the threshold**, in particular in the case of alpha particles.



M. Assié et al. Eur. Phys. J. A (2015) 51: 11 DOI 10.1140/epja/i2015-15011-6

Preliminary test

Fast test carried out in EAR1 at the very end of 2021 campaign (total beam time <6h):

- Annular detector **not nTD + in air**
- Reading directly the **signal from the preamplifier**
- 8 channels connected (1 cable not working)
- Vbias = Vdepletion

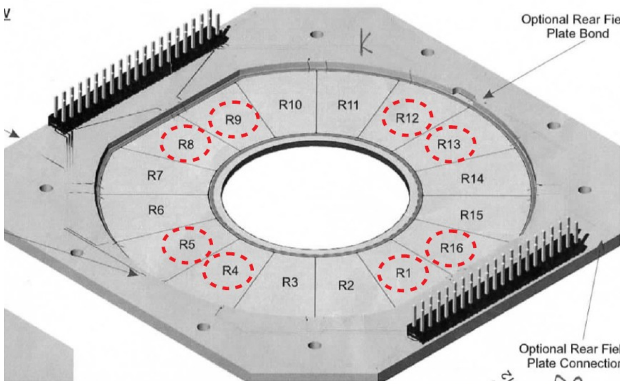
New pulse shape routine

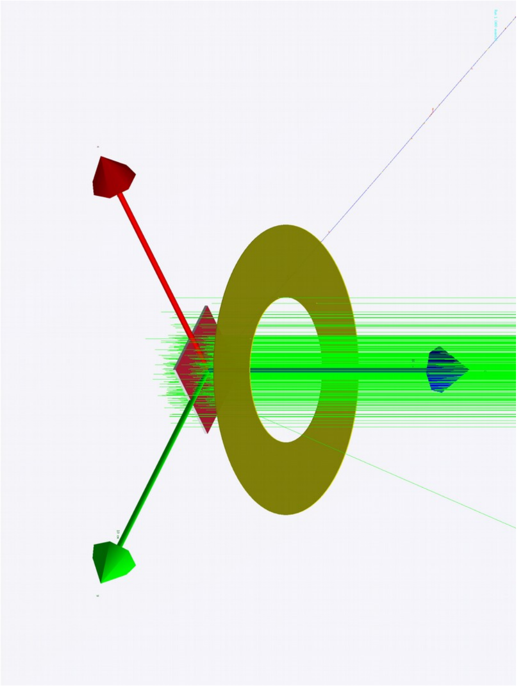
Sample configuration:

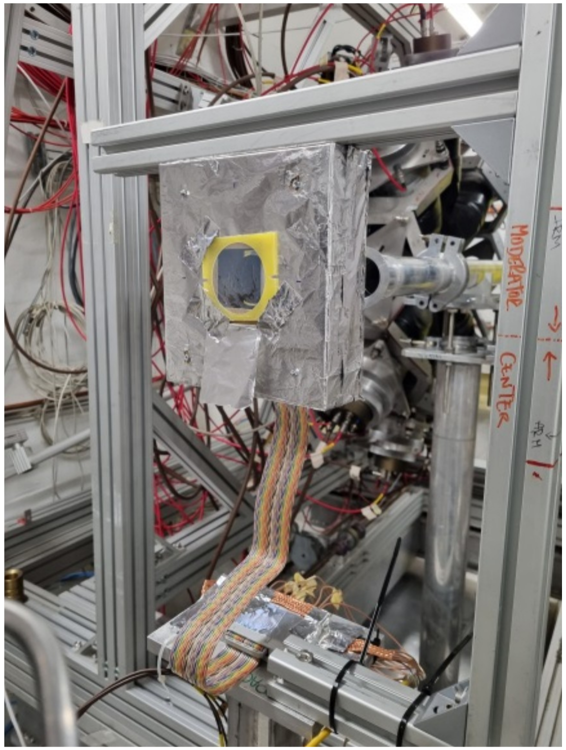
1) Thin Al

2) ^{6}LiF (1.6um) on mylar (1.5um)

3) Al + Polyethylene (1mm) + ^{6}LiF

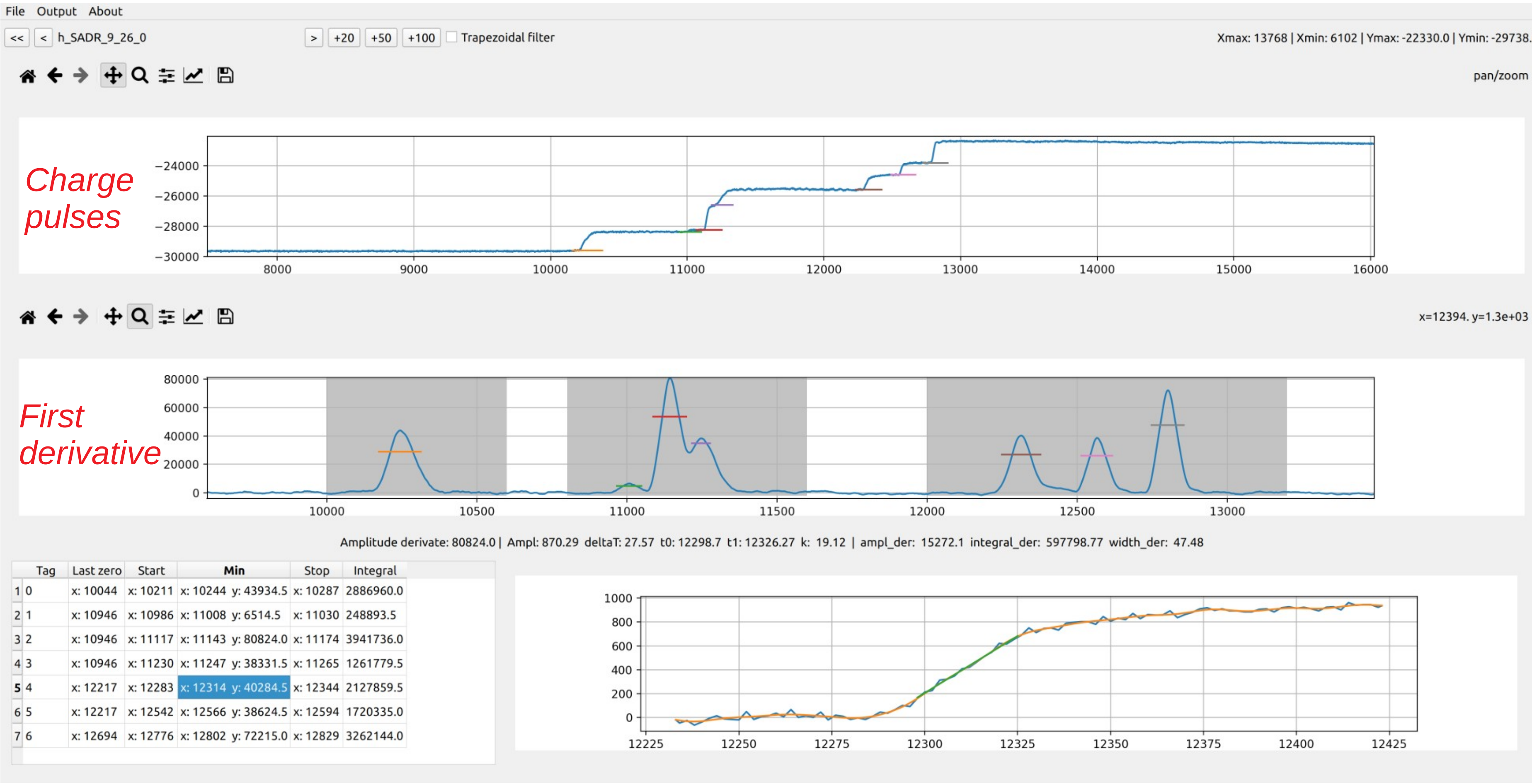






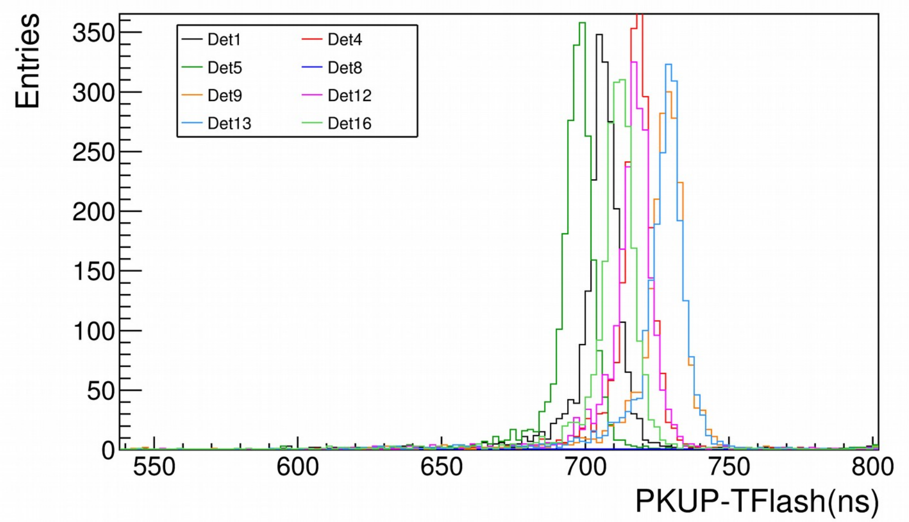
Pulse analysis

New routine build especially for this experimental apparatus, with **Python** and the possibility to use **machine learning** (CNN) to improve signal discrimination (and more).



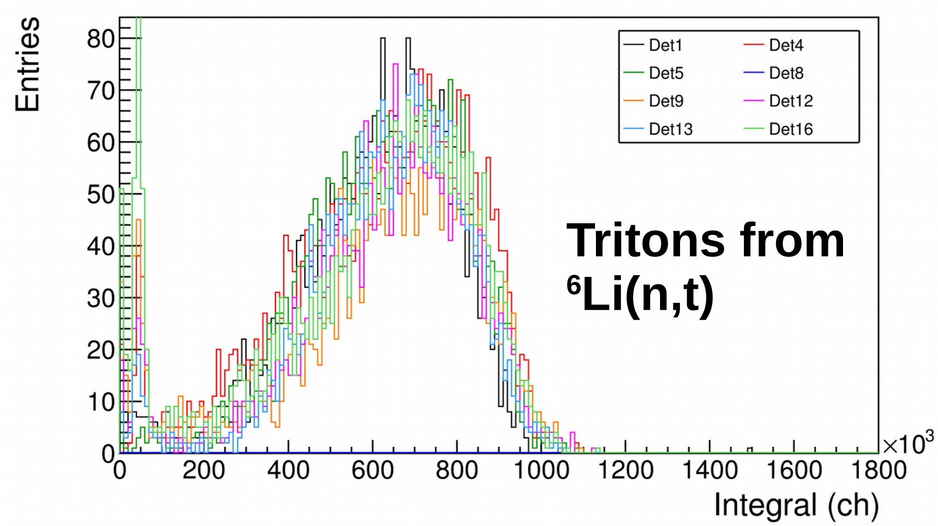
Preliminary result from test

Time difference between the gflash (identified by the new routine) and PKUP.



→ Ok for 7 ch (one dead)

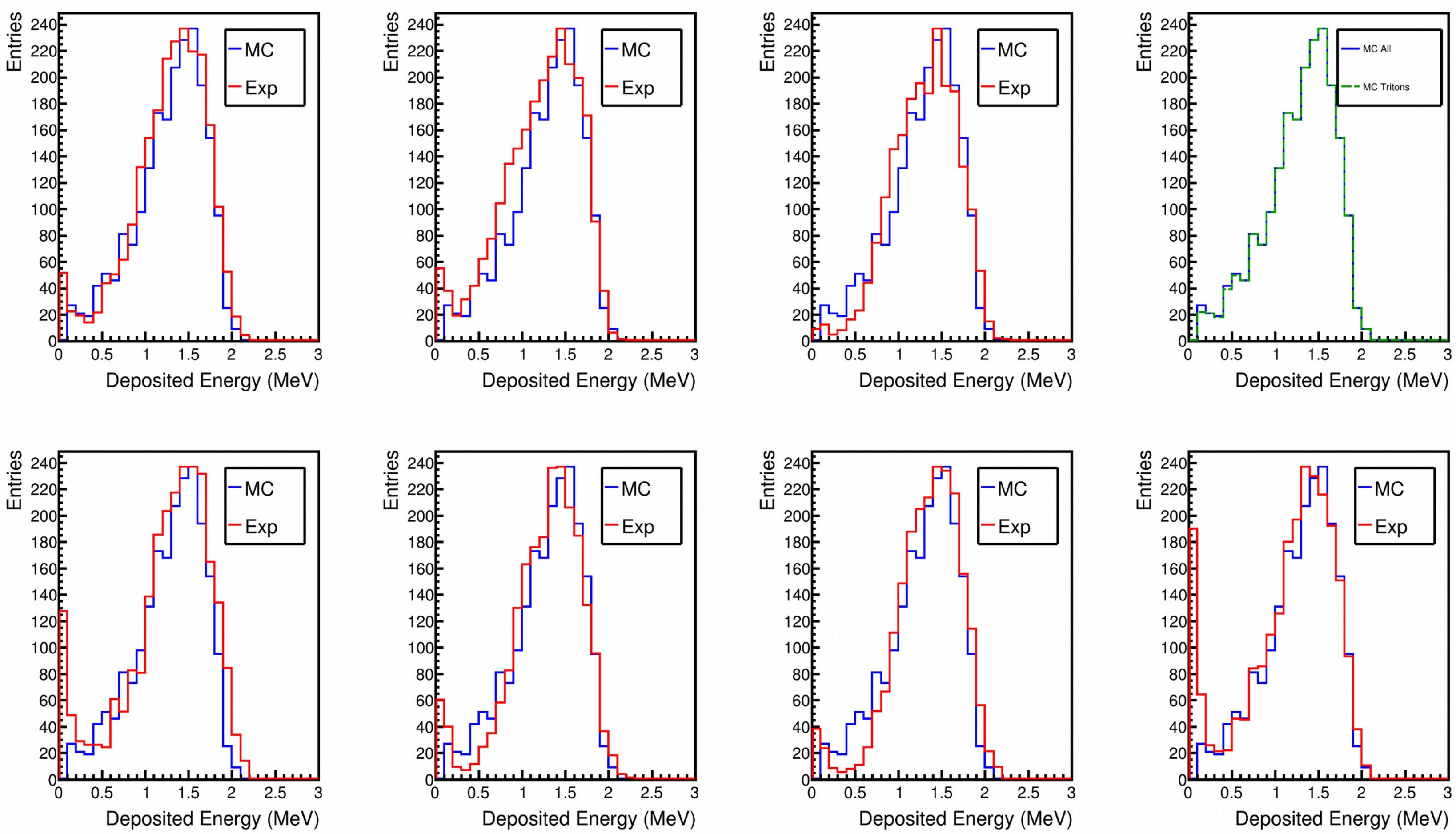
Spectroscopic information for neutron energy < 1 keV.



→ Only tritons (3cm of air)
Useful to calibrate

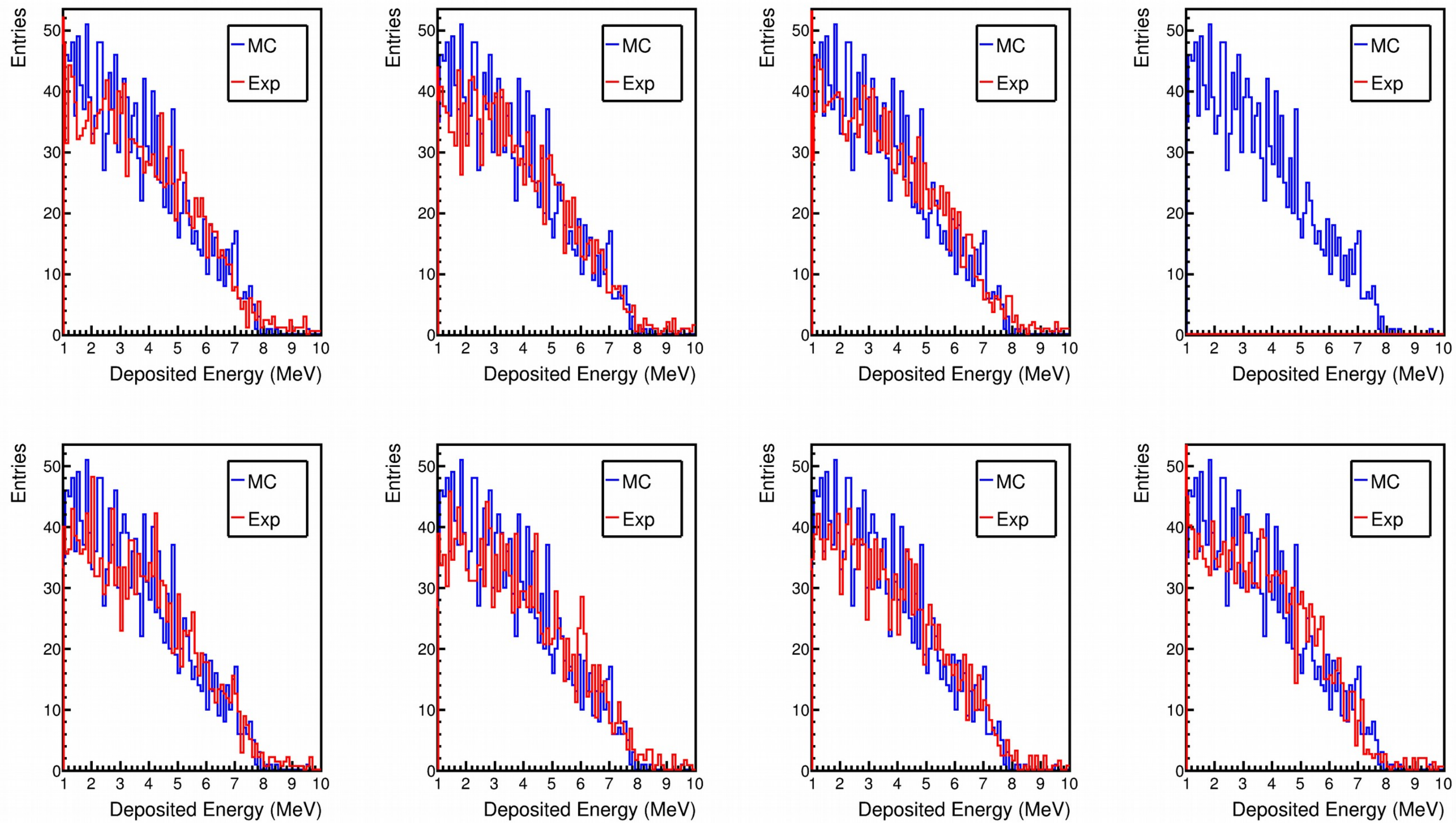
Energy Calibration

Spectra calibrated using the peak of the **tritons produced via $^{6}Li(n,t)^{4}He$ for En<1keV** (produced with 2.73 Mev but degraded in the dead layers).



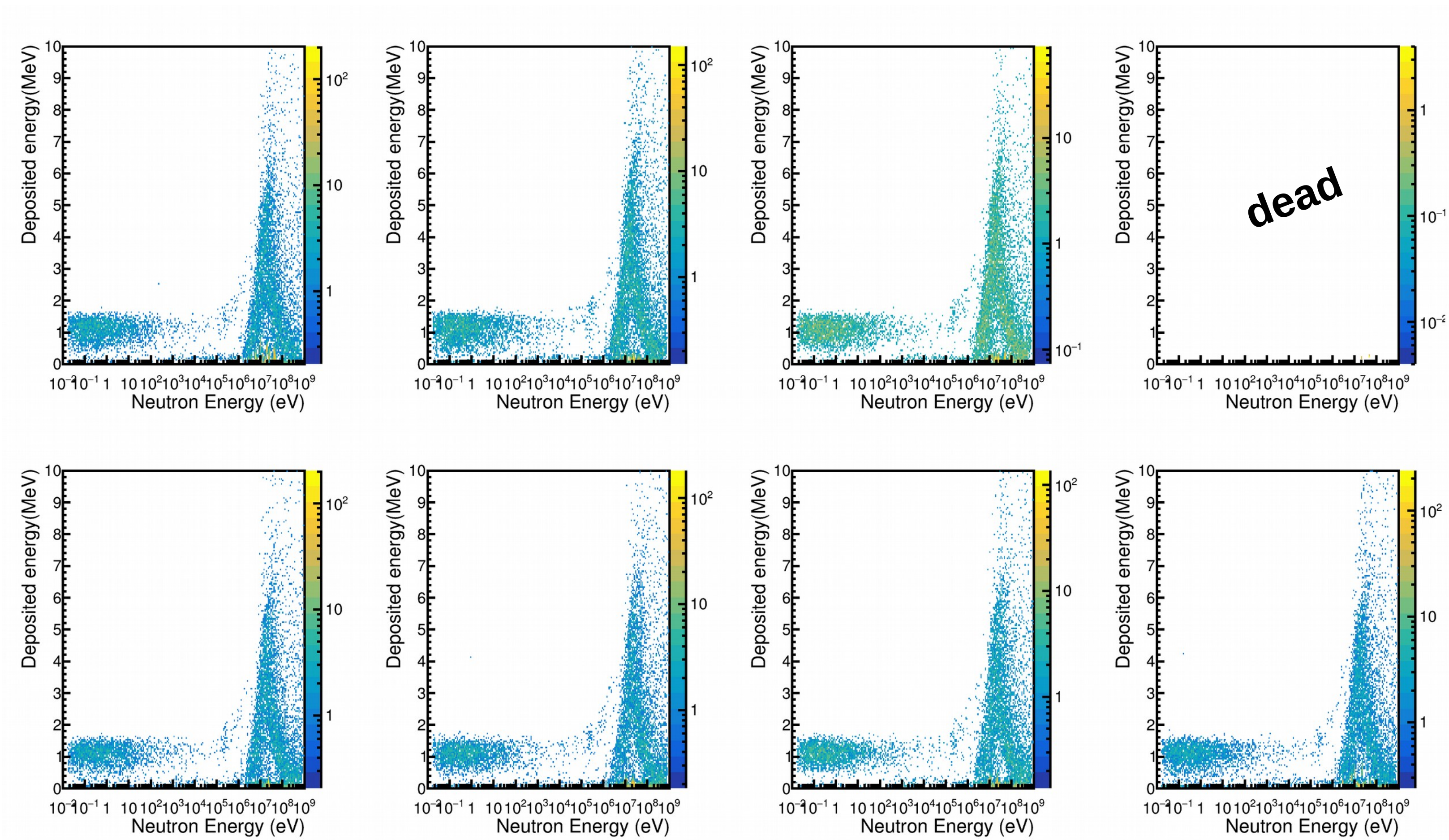
Energy Calibration

Calibration confirmed by the good agreement between experimental data and simulations for the **punch through of protons for neutron energy [1,30] MeV**.



Preliminary result from test

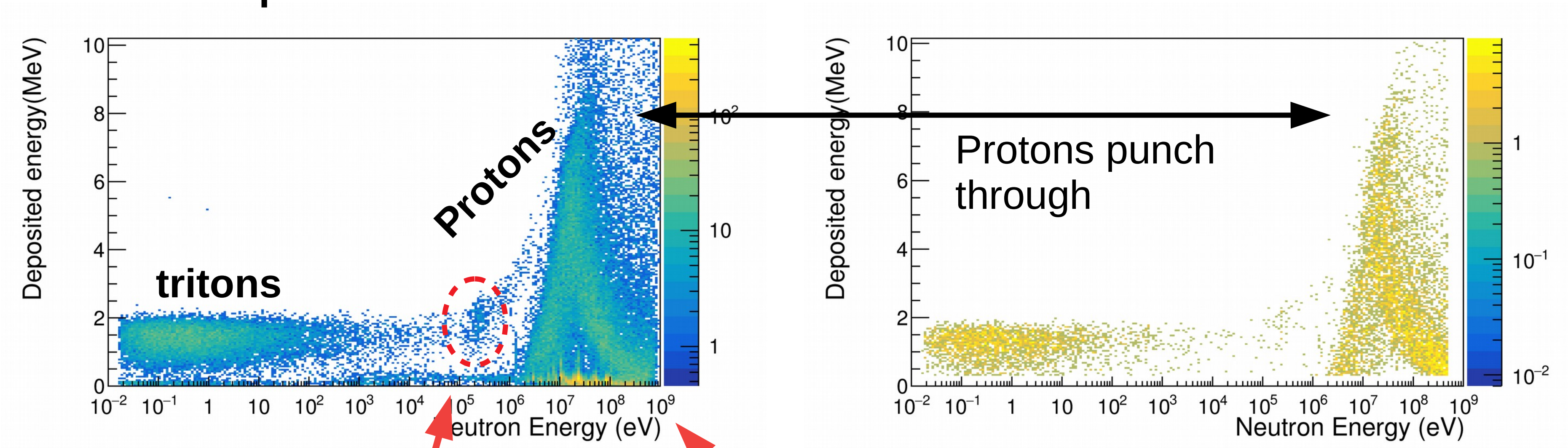
2D spectra of the deposited energy vs neutron energy for the 7 channels for the sample3 **(Al + Polyethylene (1mm) + LiF)**.



Preliminary result from test

Good agreement between the experimental and simulated 2D spectra of Deposited Energy vs Neutron Energy, despite of the not accurate calibration.

Experimental data **MC simulation**

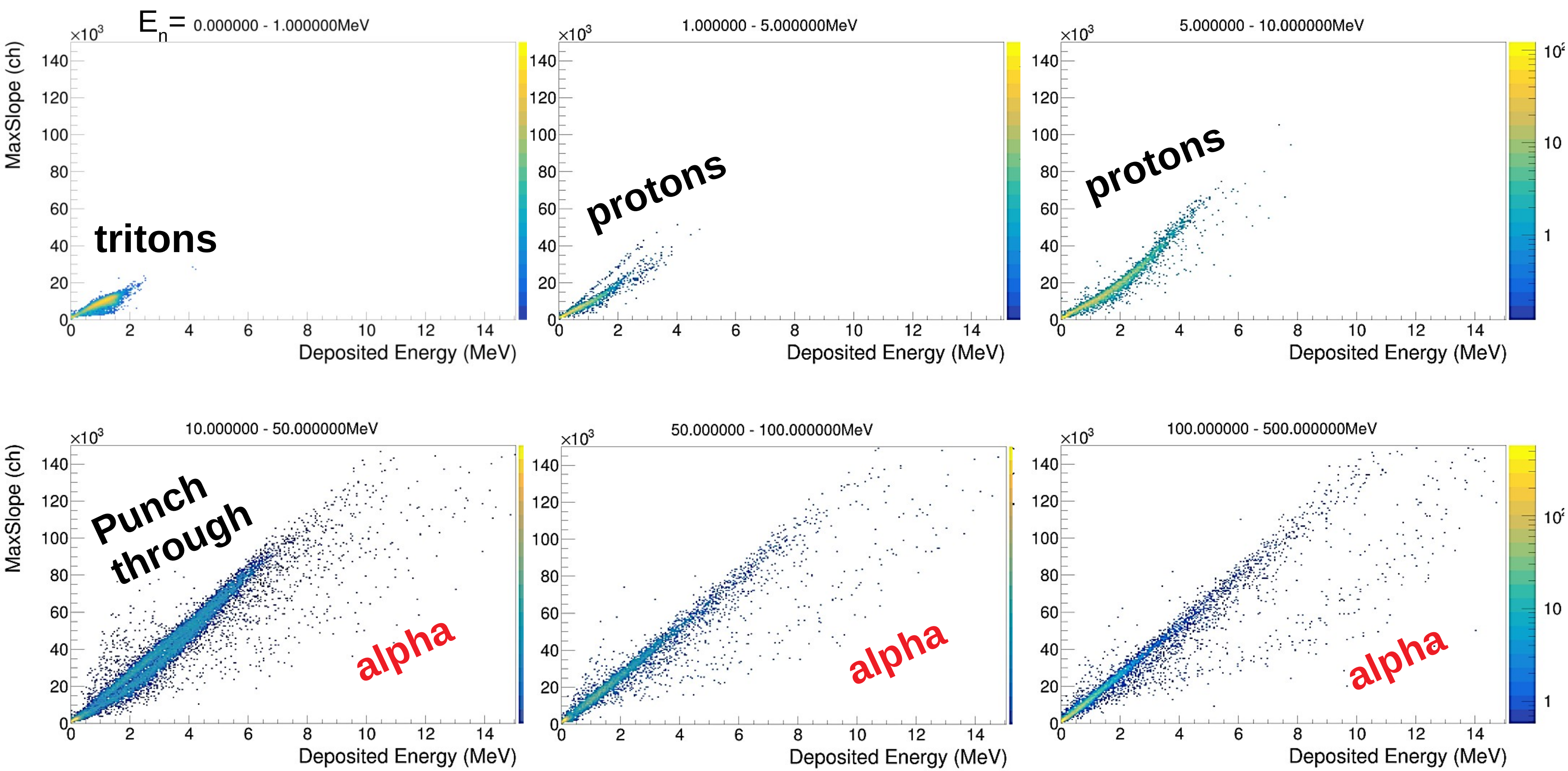


^{6}Li(n,t) resonance

Maximum neutron energy hundreds of MeV

Preliminary result from test

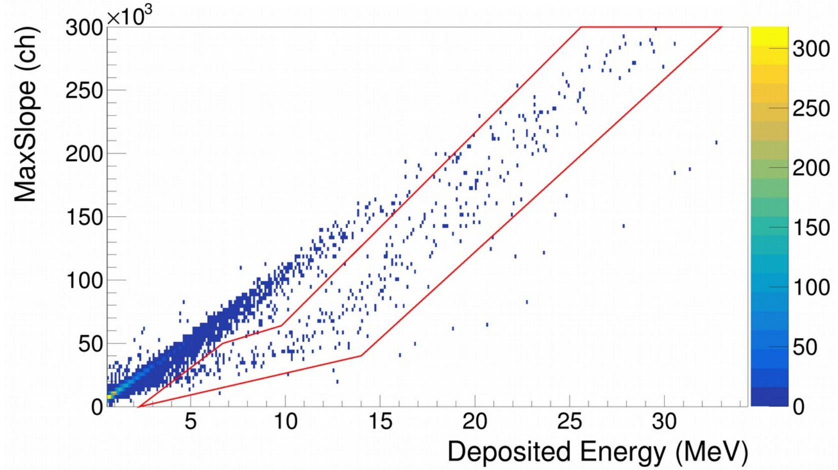
Starting from 10 MeV we start to observe a second structure, corresponding to the alpha (present detector not nTD, we expect a better separation with nTD).

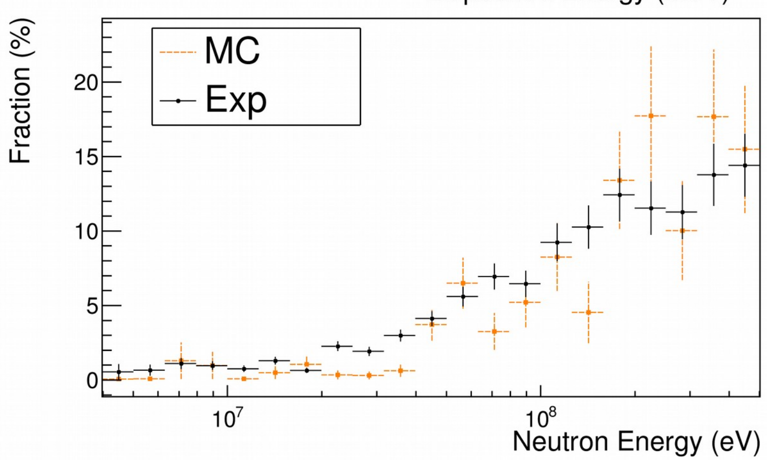


Preliminary result from test

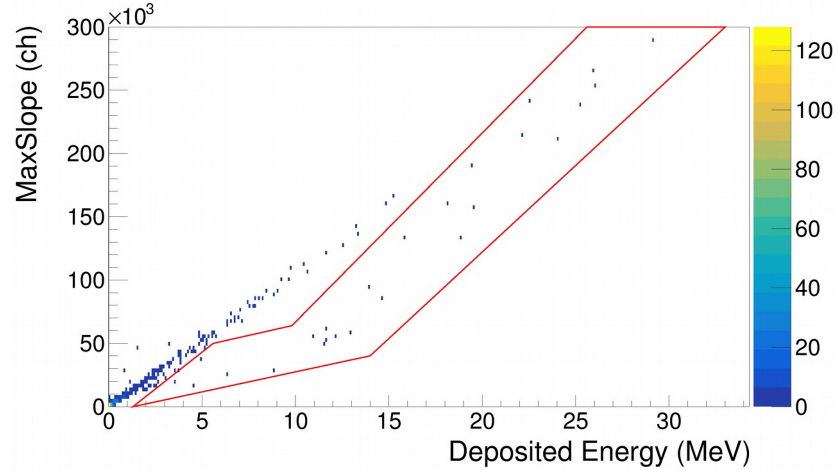
The agreement between Exp and MC for the **fraction of signals due to alpha** is good (despite a very low statistic) for both polyethylene and aluminum target.

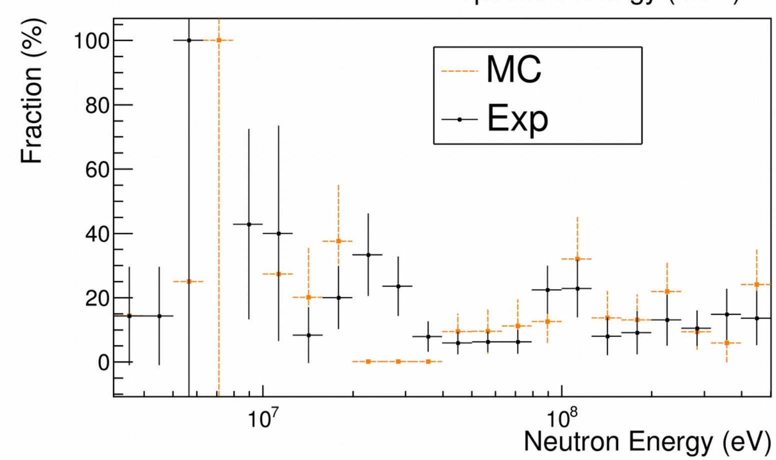
Al + Polyethylene + LiF





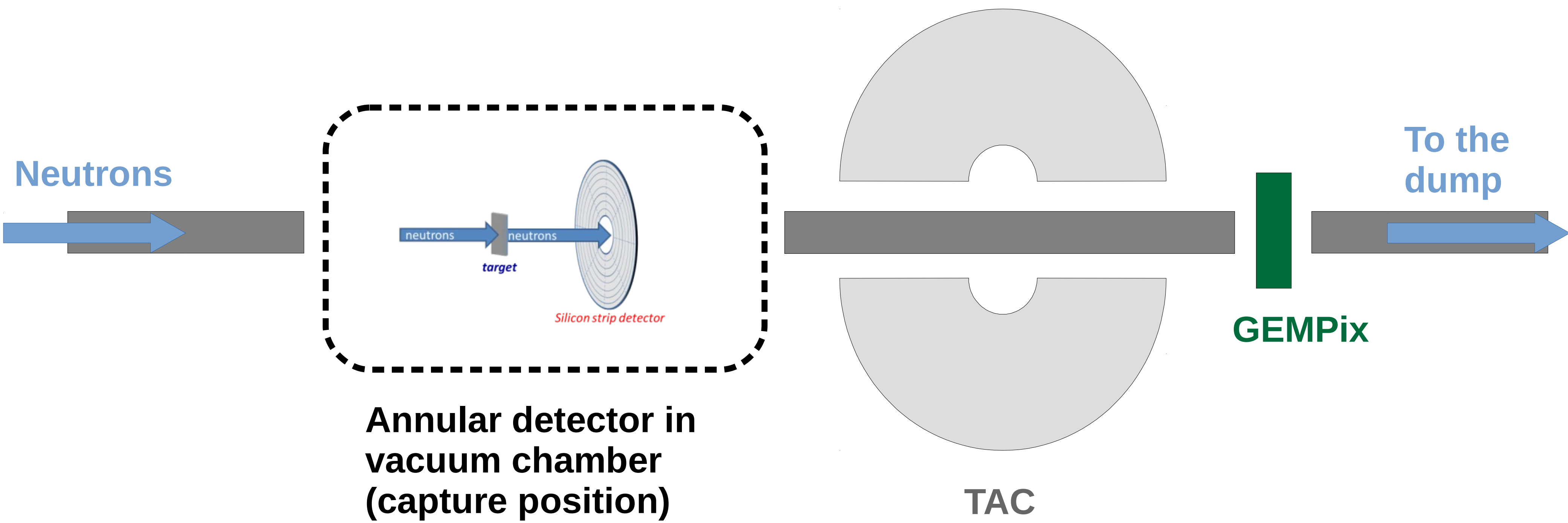
Aluminum (30' run)



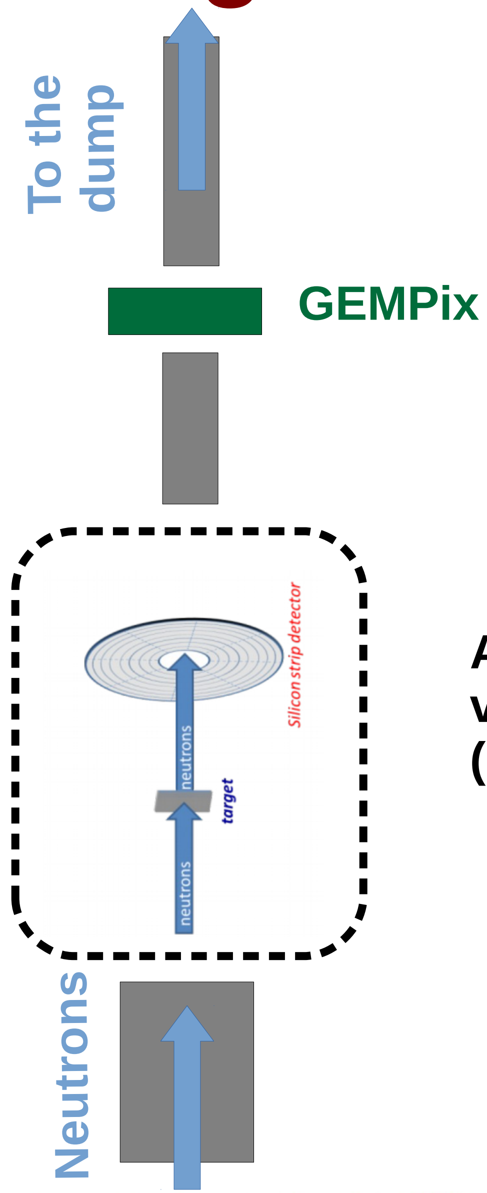


Experimental configuration - EAR1

The two apparatuses will be used in parallel in both experimental areas.



Experimental configuration - EAR2



Annular detector in vacuum chamber (SiMon2 position)

Proton request (approved by INTC)

EAR1:

Al_2O_3 and polyethylene 0.3x10^{18} protons on target to further study the pulse shape technique and to optimize the detectors

^{12}C sample (300um) 1x10^{18} protons on target full physic measurement of the $^{12}C(n,p)$ cross section, that will serve as validation for the technique and the experimental apparatus comparing with the results of the measurement already performed at n_TOF

Empty 0.2x10^{18} protons on target to measure the background during the ^{12}C measurement

Total protons EAR1: 1.5x10^{18}

EAR2:

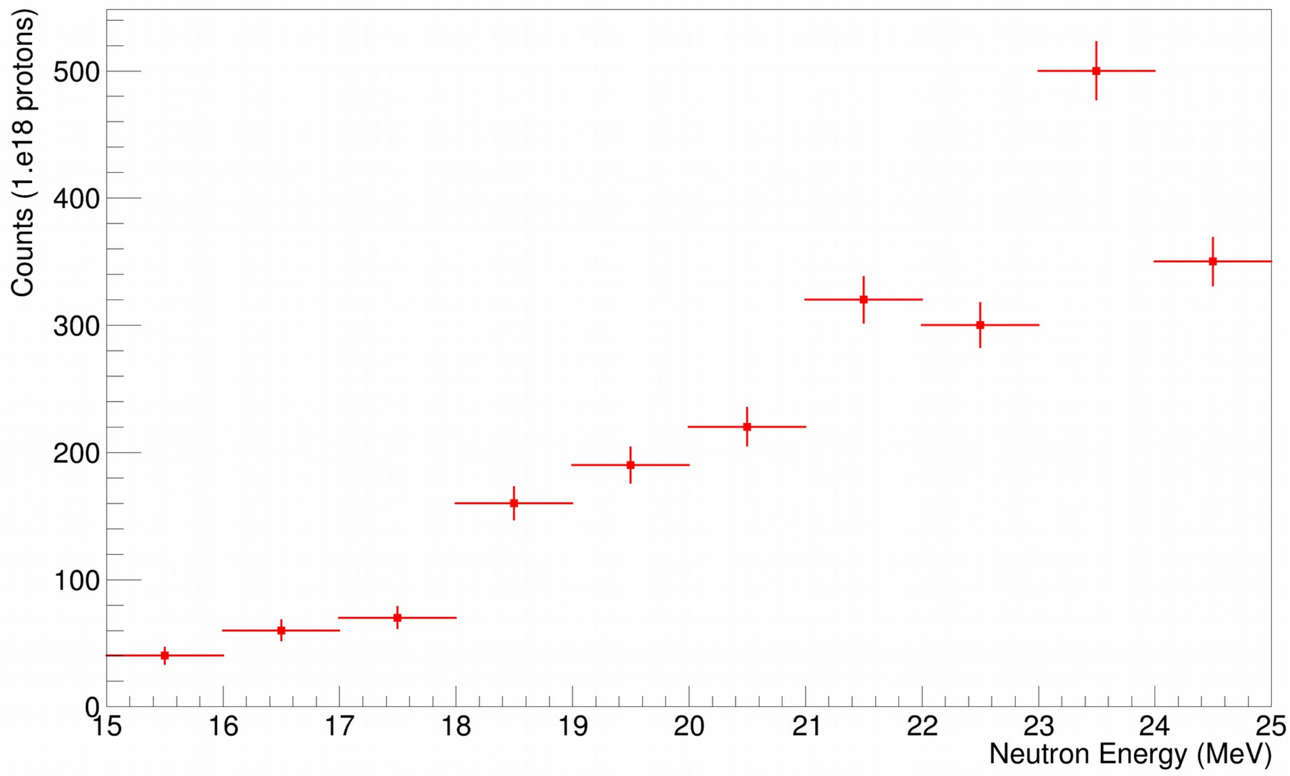
Al_2O_3 , polyethylene and metallic Al 0.5x10^{18} protons on target study the response of the detectors in EAR2 in particular the possibility to measure $^{16}O(n,\alpha)$ reaction

Total protons EAR2: 0.5x10^{18}

Yield estimation

Expected number of proton for **300 um ^{12}C sample** with a threshold of 1 MeV for **10^{18} protons on target**, simulated with Binary Cascade (total 2200).

Average statistical uncertainty 10%



Plan for this year

- Develop the mechanic support for the detector and the electronic board
- Test the not-nTD annular silicon in EAR2
- Paratistic test in the second half of November during the DDX detector test behind the TAC with the nTD silicon in vacuum
- Keep working on the analysis routines and Monte Carlo simulations

New vacuum chamber delivered last Friday

Motivation and applications

Missing (or discrepant) experimental data set for many **(n,p) and (n,α)** reactions of interest for modeling the structural material in fusion reactors (Fe, V, W).

Nuclide	Abund.	Reaction	Residual	Priority	Comment
Ne-20	90%	(n,p)	F-20	1	No data, judged measurable
Ne-22	9.2%	(n,α)	O-19	1	No data, judged measurable
Ne-22	9.2%	(n,d)	F-21	1	No data, judged measurable
S-34	4.2%	(n,d)	P-33	1	No data, judged measurable
S-34	4.2%	(n,α)	Si-31	1	Discrepant data
Cl-37	24%	(n,p)	S-37	1	Discrepant data
Ni58	68%	(n,t)	Co-56	1, A	Discrepant data
Zn-67	4.1%	(n,p)	Cu-67	1, B	Discrepant data
Ga-71	40%	(n,t)	Zn-69	1	No data, judged measurable
Kr-78	0.3%	(n,α)	Se-75	1	No data, judged measurable
Zr-90	51%	(n,p)	Y-90g	1, B	Discrepant data
Mo-92	15%	(n,d)	Nb-91	1	Discrepant data
Mo-94	9.2%	(n,p)	Nb-94	1	Discrepant data
Xe-132	27%	(n,α)	Te-129	1	No data, judged measurable
Re-187	63%	(n,t)	W-185	1	No data, judged measurable
Pt-195	34%	(n,d)	Ir-194m	1	No data, judged measurable
Pb-208	52%	(n,t)	Tl-206	1	No data, judged measurable

Nuclide	Abund.	Reaction	Comment
Ta-181	100%	(n,α)(n,p)	Lack of data below 14 MeV
W-182	26%	(n,α)(n,p)	Lack of data / No data for (n,α)
W-183	14%	(n,α)(n,p)	Lack of data / No data for (n,α)
W-184	31%	(n,α)(n,p)	Lack of data below 14 MeV
W-186	28%	(n,α)(n,p)	Lack of data below 14 MeV

(n,p) and (n,α) cause gas production, with bubble formations and embrittlement.

High energy cross section needed to correct the IFMIF data for neutrons > 14 MeV.

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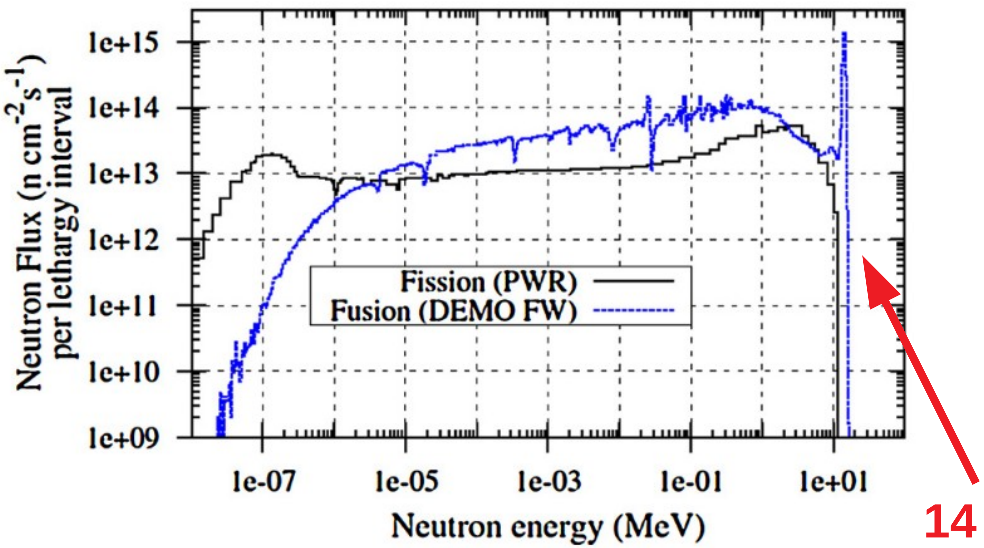
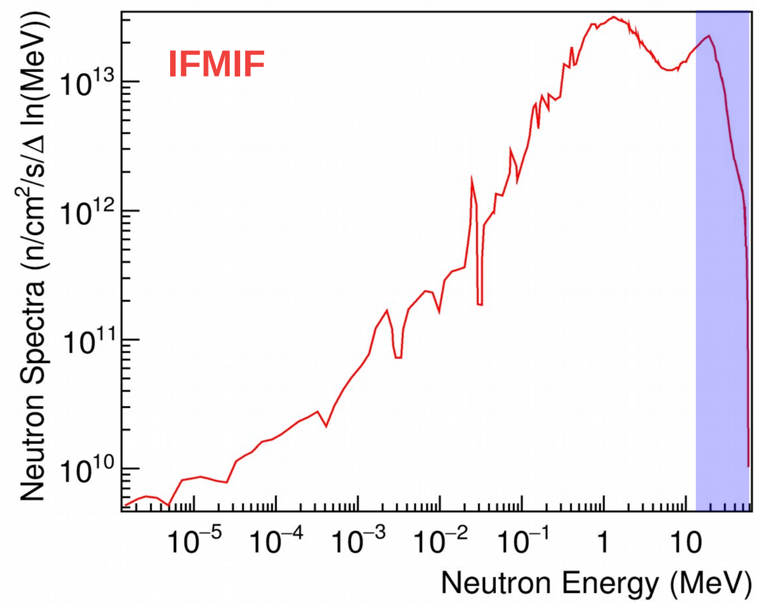


14 MeV limit

Not present in fusion



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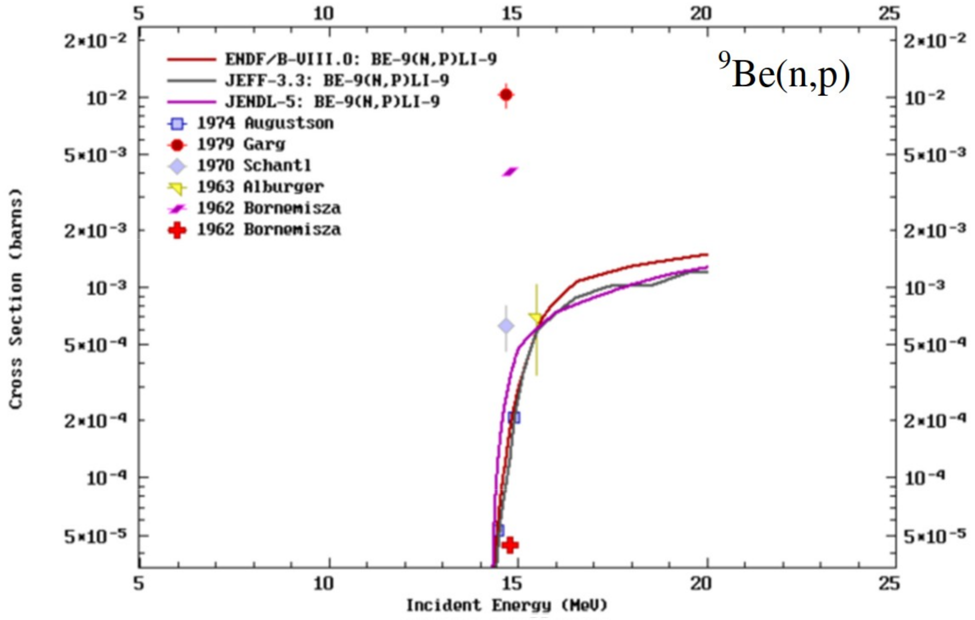
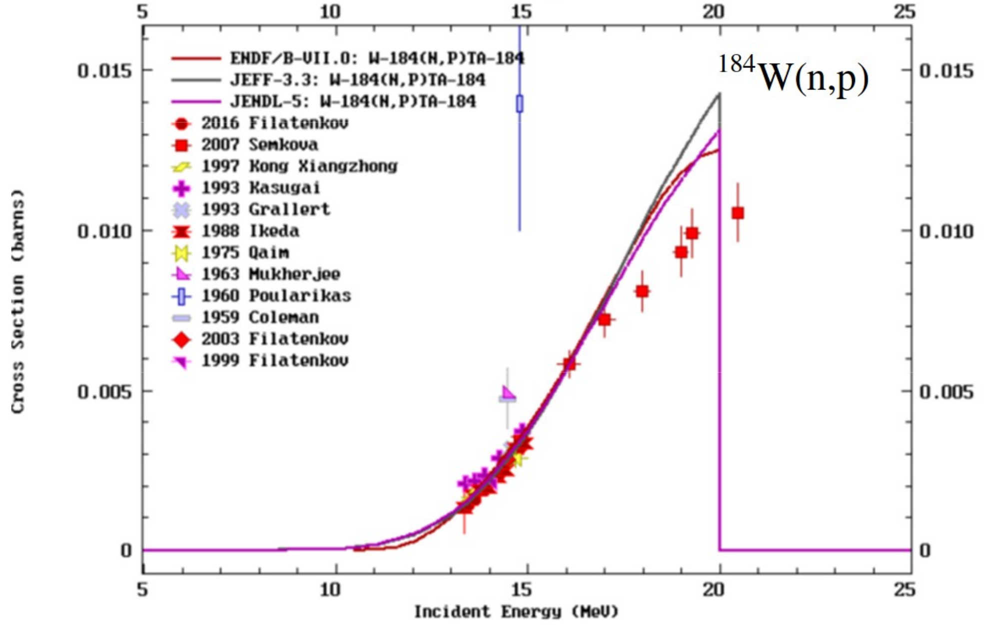
High energy cross section needed to correct the IFMIF data for neutrons > 14 MeV.

Present data and libraries

Inconsistent data for many fundamental reactions, in particular involving **beryllium and tungsten** which are largely present in the reactor walls (beryllium) and in the divertor (tungsten).





Additional reactions of interest for astrophysics (e.g. ^{41}Ca(n,p), ^{16}O(n,α), …).

Beryllium largely used in neutrino sources for many applications (mainly as a target).