Neutron-induced light-ion production experiments with Medley at GANIL-NFS

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2. NFS and experiment configuration 2023
3. Medley setup and the last experiments
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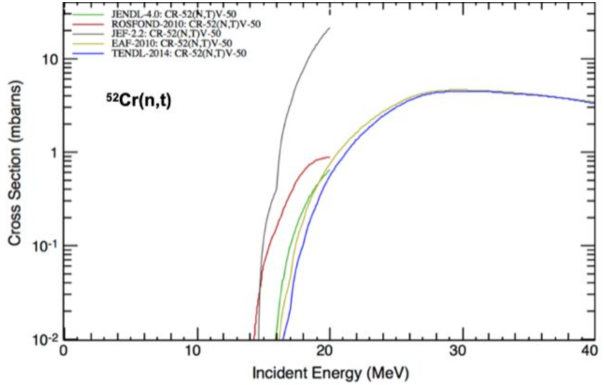
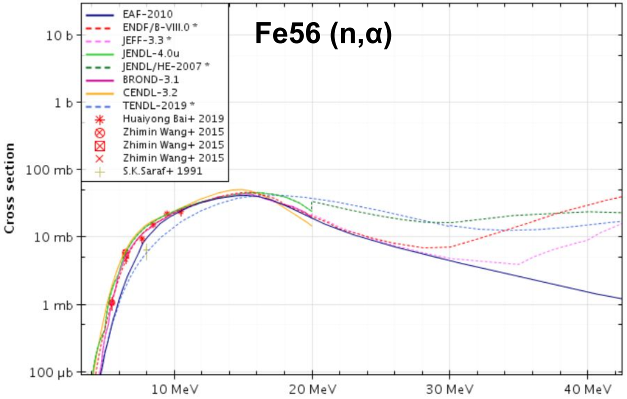
Why measuring light-ion production?

Better nuclear data regarding light-ion (p, d, t, ^{3}He, and α) production induced by neutrons are of great interest for several applications; The data are really scarce for a number of reactions;





Not all datasets are represented in the Figures

This data is important for fusion applications:

- Embrittlement of the material due to formation of gas inside it.
- Interpretation of DONES data
- Handling of tritium (decommissioning)

And more diverse applications:

- Radiation protection
- Dosimetry for aviation and spaceflight, electronics (single-event effects)

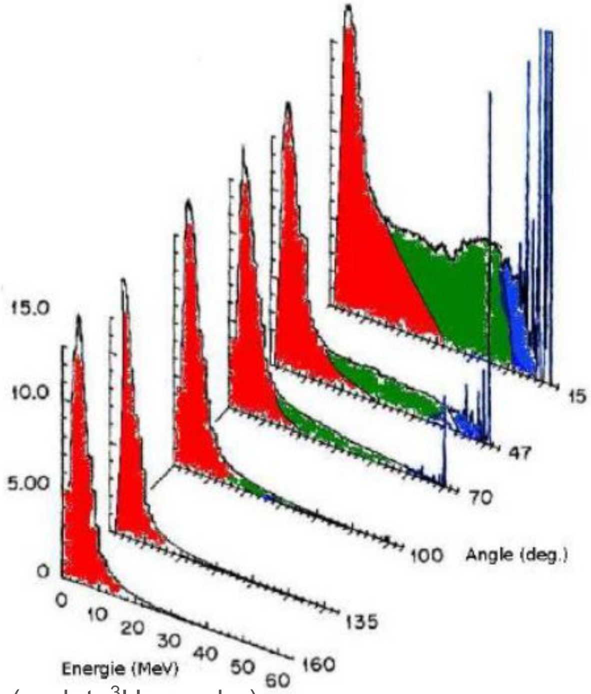
Why measuring light-ion production?

Double differential cross sections (DDX) for light charged particles (LCP) as a function of neutron energy to be measured.

From DDXs we can obtain:

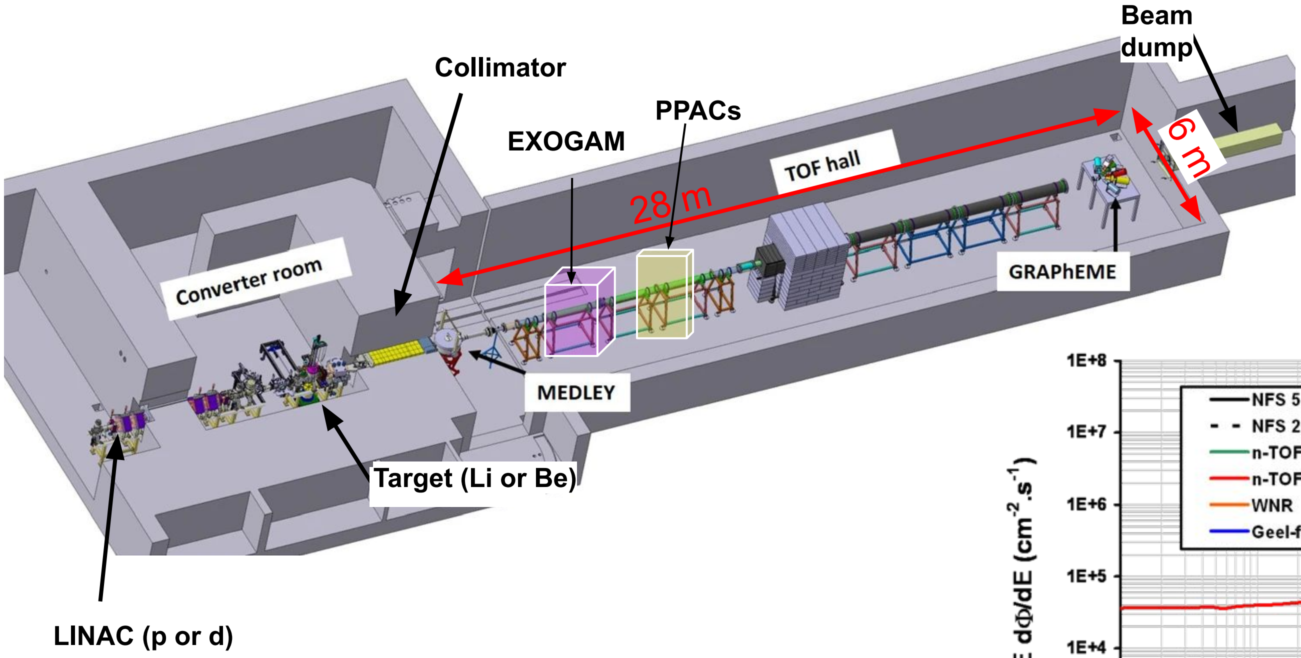
- **single-differential cross-sections** with respect to the angle of the emitted particle (for each neutron energy);
- integrated (n, LCP) **production cross sections** as a function of neutron energy.

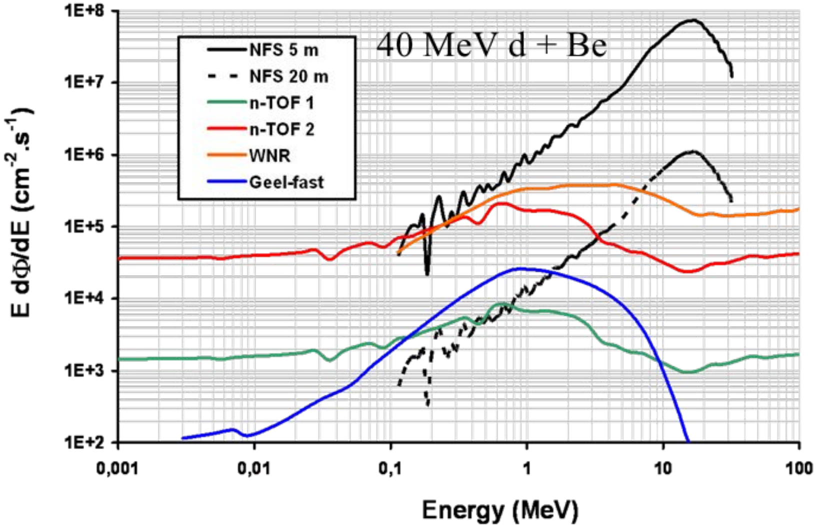
For each neutron energy:



(p, d, t, ^{3}He, and α)

Experiment configuration 2023



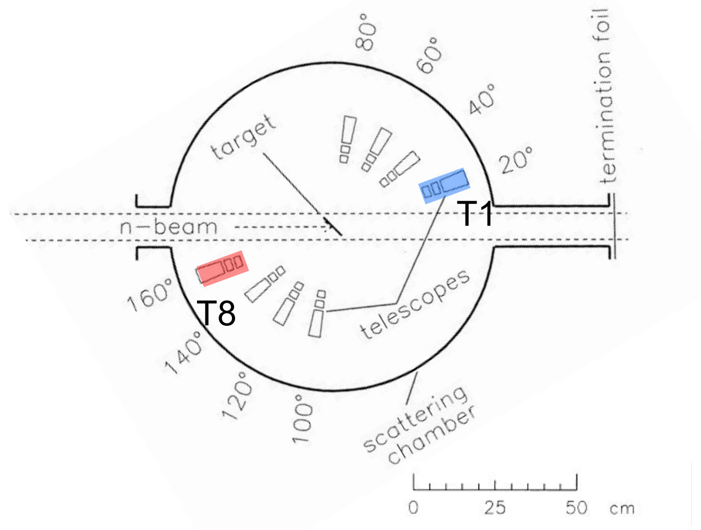


We use NFS (Neutrons for Science) new facility which provides white neutron spectra (2 MeV to 40 MeV) with reasonable flux.

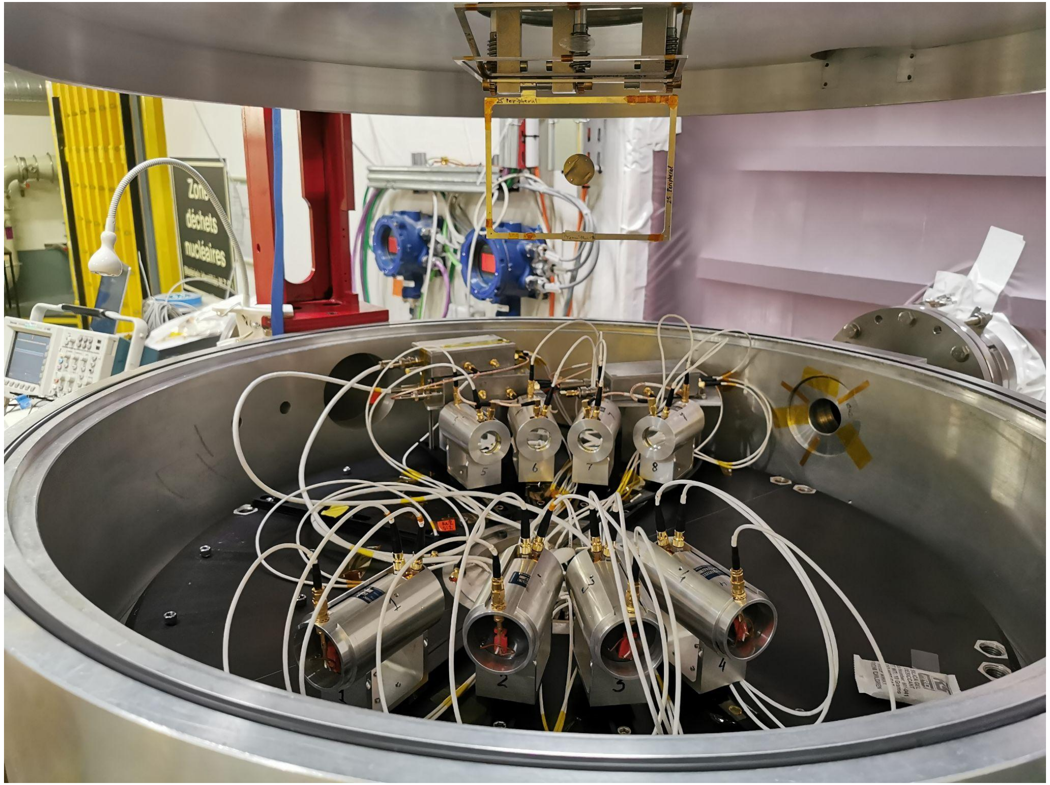
*2022 experiment was also carried out at NFS.

Medley setup for the last experiments

The objective is to measure **double differential cross sections**.

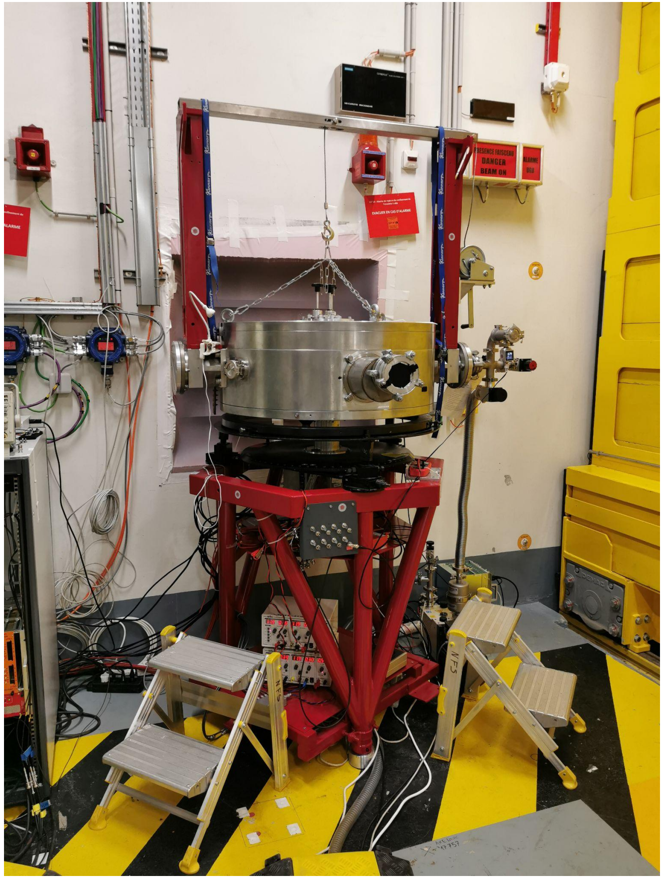


- 8 Si-Si-CsI(Tl) telescopes for light ion identification.
- coverage: 20º to 160º (20º steps); ~20 msr/telescope.
- Rotatable table allowing to cover forward and backward emission with different detectors.



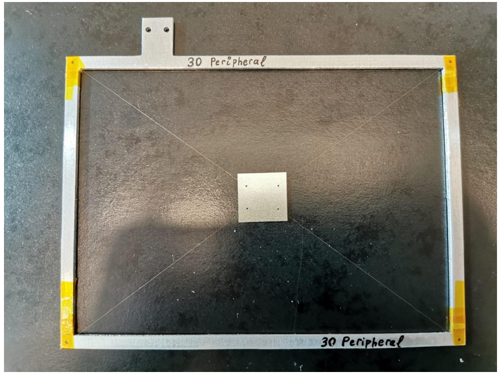
Medley (opened) chamber with Fe sample installed.

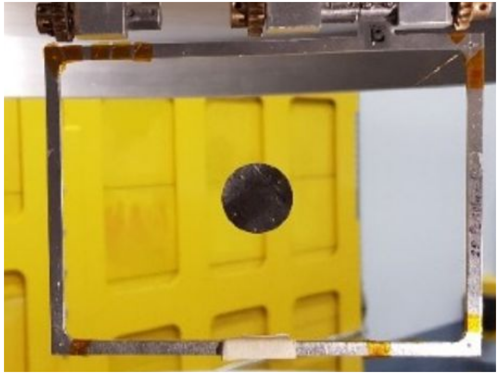
Medley setup for the last experiments



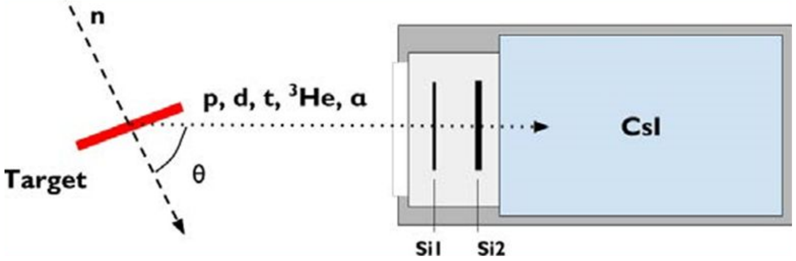
Two experiments were carried out in October-November 2023 (~ 400h of data):

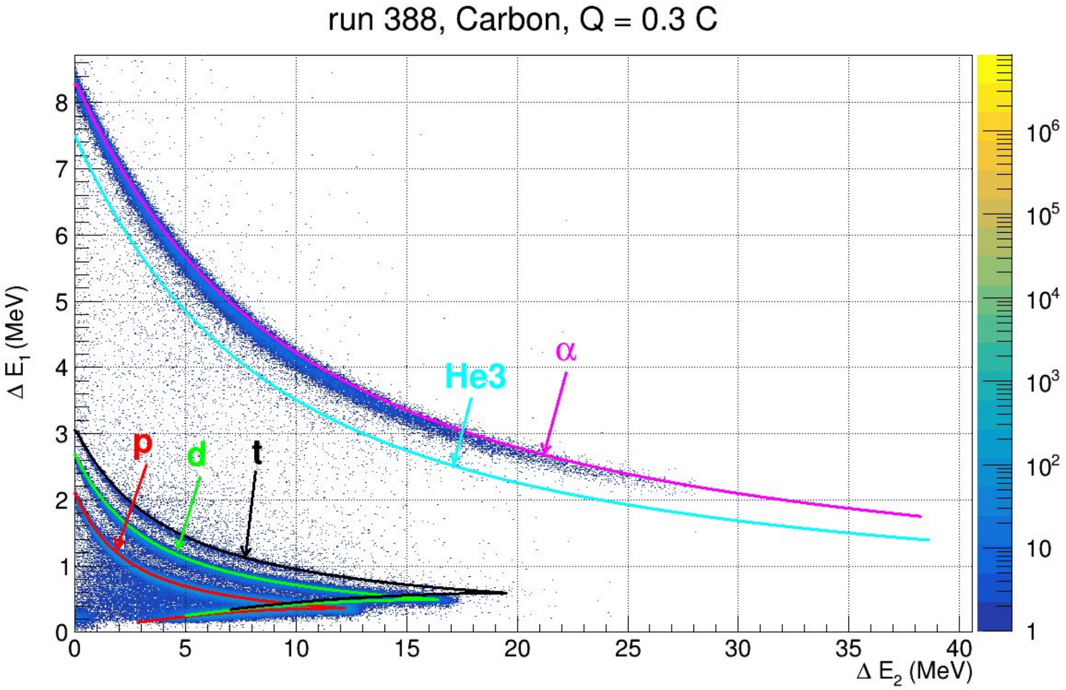
- ^{nat}Cr (~1 week beamtime to complement 2022 campaign).
  - Measurements with 75 µm and 15 µm targets, both deposited in 125 µm polyester backing.
- ^{nat}Fe (~1 week of beamtime).
  - Also measure thin (5 µm) and thick (25 µm) targets.
- CH_2 and C to obtain neutron flux from np scattering





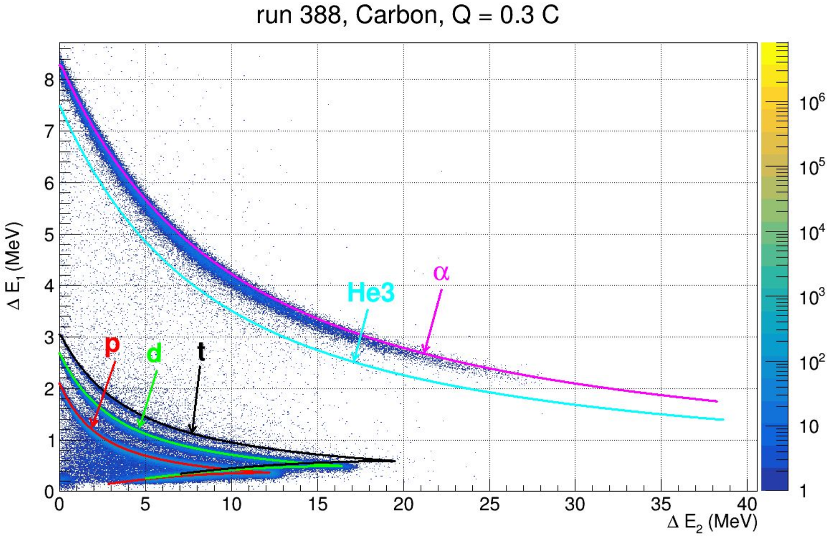
Particle identification

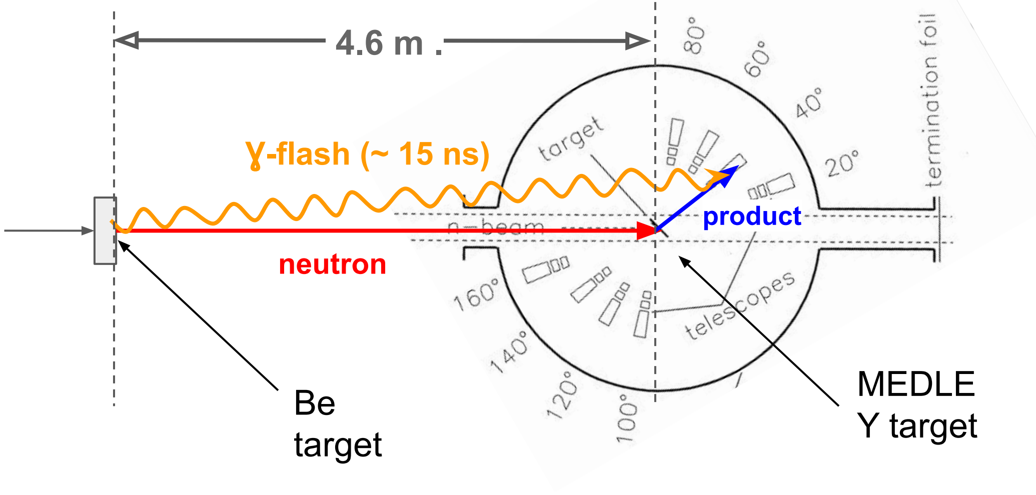




- 3 elements (Si-Si-CsI(Tl)) telescopes allow to cover a large dynamic range.
- The good resolution provides good separation between isotopes of H (p, d, t) and He (3He and α);
- Good match with KALIVEDA energy loss simulations;

Particle identification



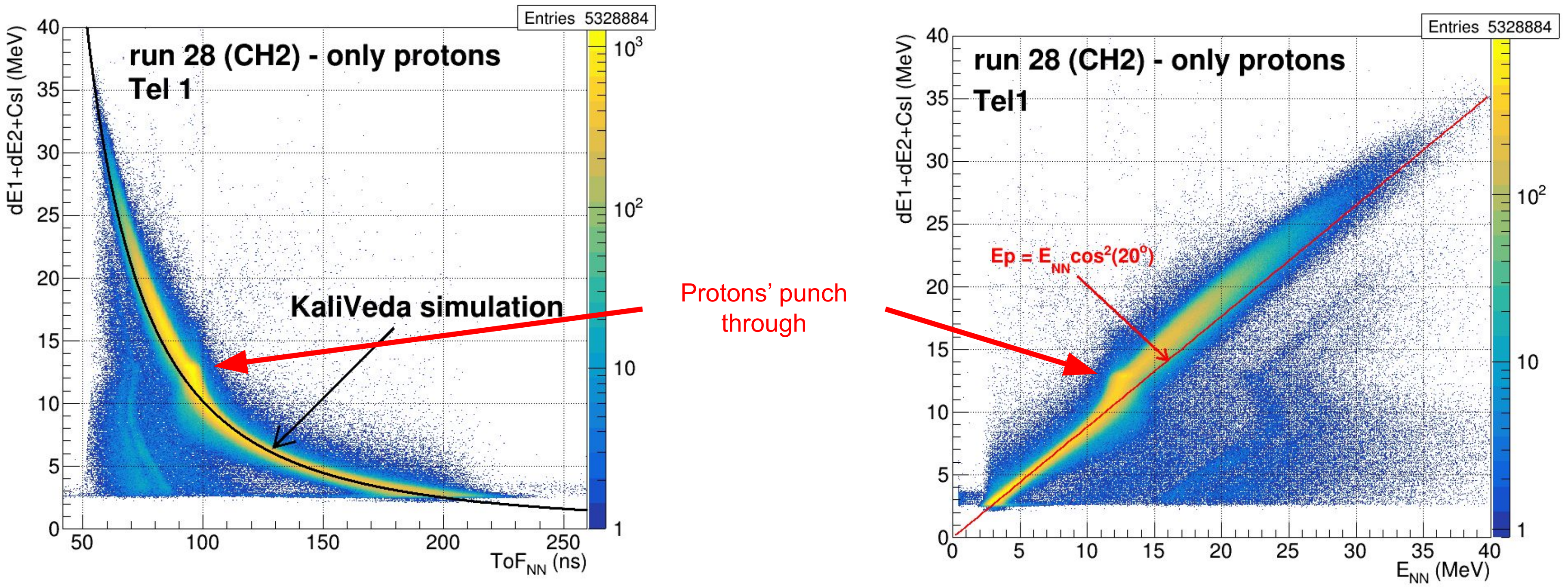


- Good calibration is also required to obtain the neutron energy (ToF technique):

$$ToF_{MEASURED} = ToF_{NEUTRON} + ToF_{PRODUCT}(E_{particle})$$

Challenges

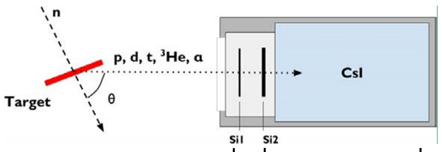
We found some deviation in the ToF measurement for energies near the punch through of the second silicon detector.



Ongoing corrections

It can be corrected, but some extra processing is necessary. He already have some ideas regarding this behaviour:

Our ToF measurements is obtained from the second Si detector:



rise time: ~ 1.2 μs

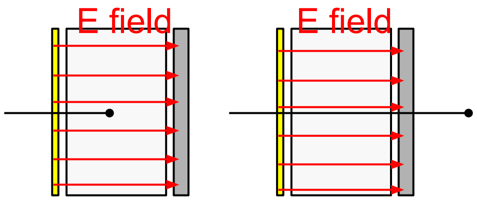
rise time: ~ 0.4 μs

rise time: ~ 2 μs

self triggered

provides ToF measurement:

(better resolution and timing characteristics, matches well GANIL's electronics)



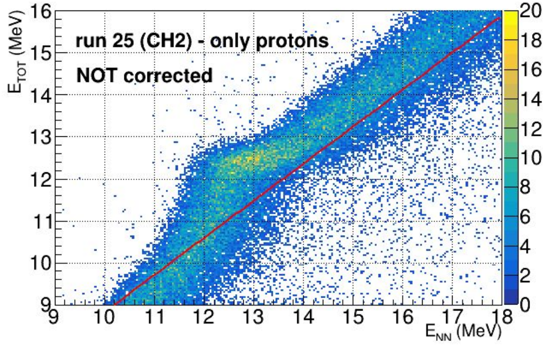
a) particle which stopped inside Si.

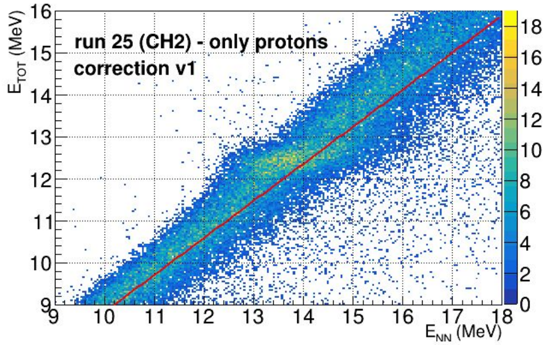
b) particle which punched through Si.

Table 11.1 Properties of Intrinsic Silicon and Germanium

	Si
Electron mobility (300 K); $cm^2/V \cdot s$	1350
Hole mobility (300 K); $cm^2/V \cdot s$	480

Electronic is still sensitive to difference probably due to signal rise time, which would lead to wrong time measurement! Deeper analysis ongoing.





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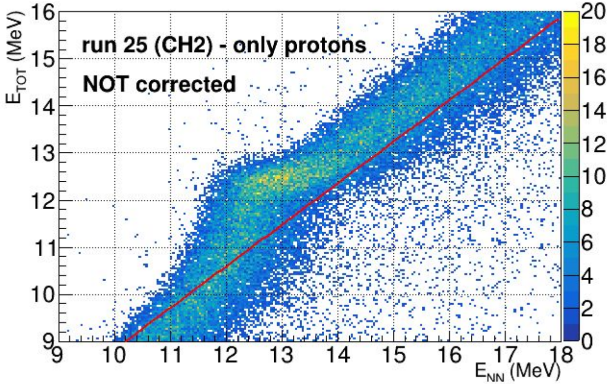
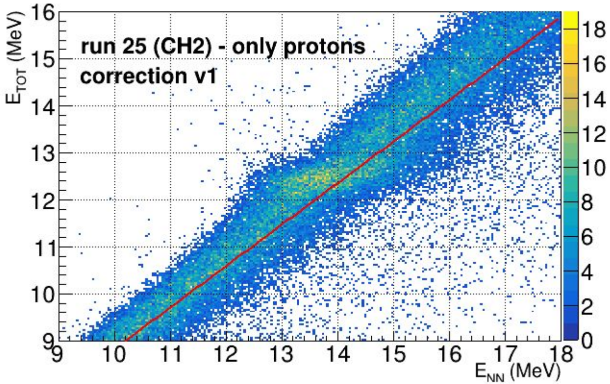
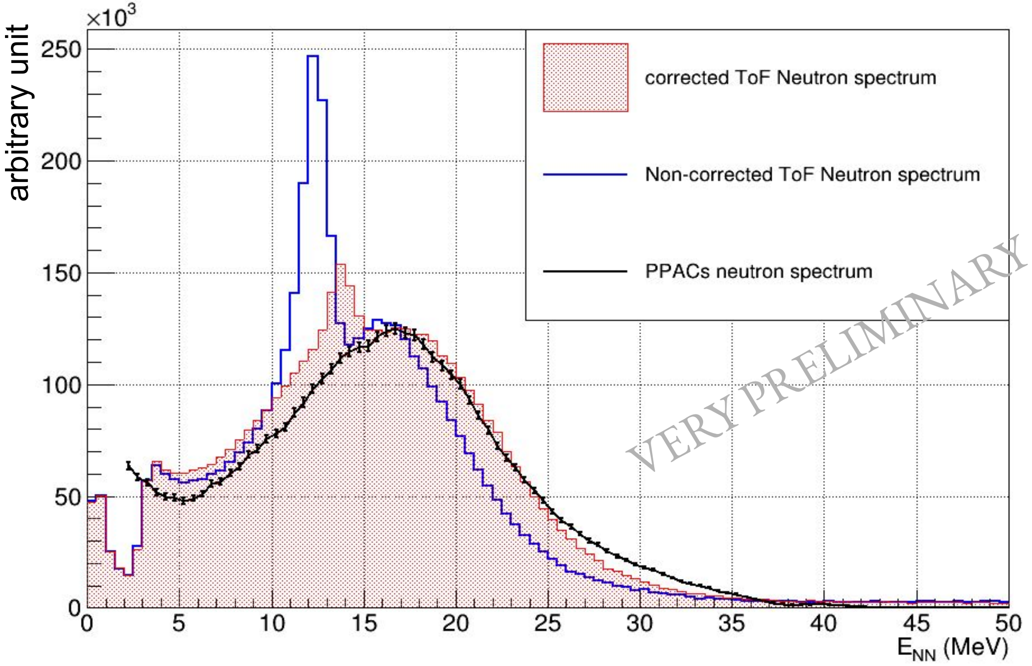
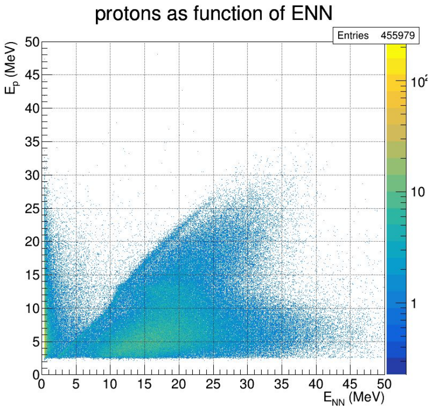


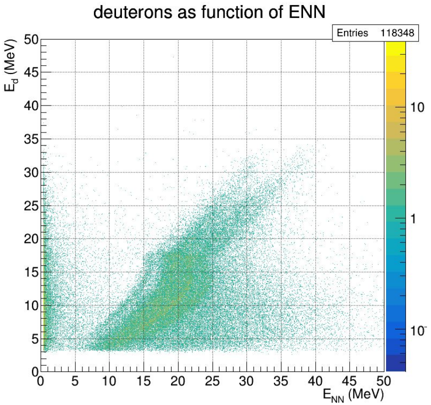


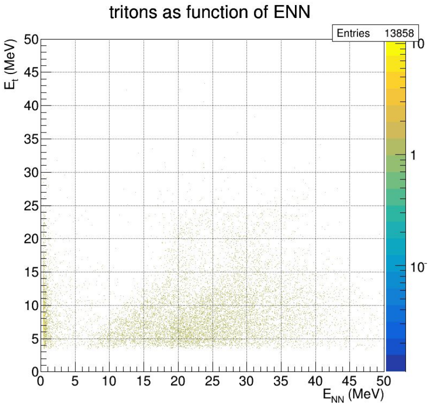


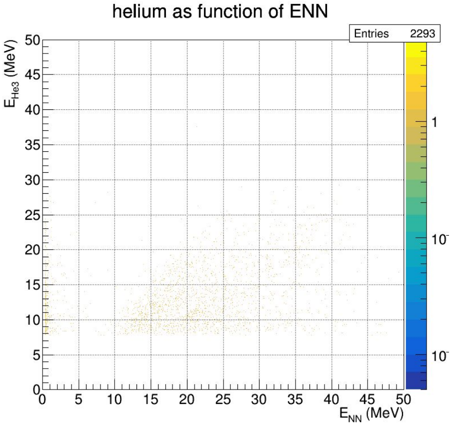
Preliminary results

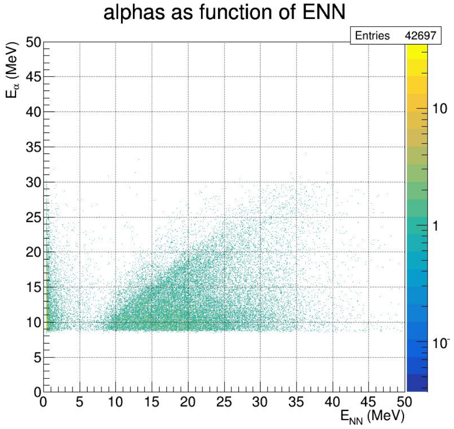
First plots of particle production as a function of neutron energy (Tel 1). Fe thin (19.8h, charge = 2.6 C)







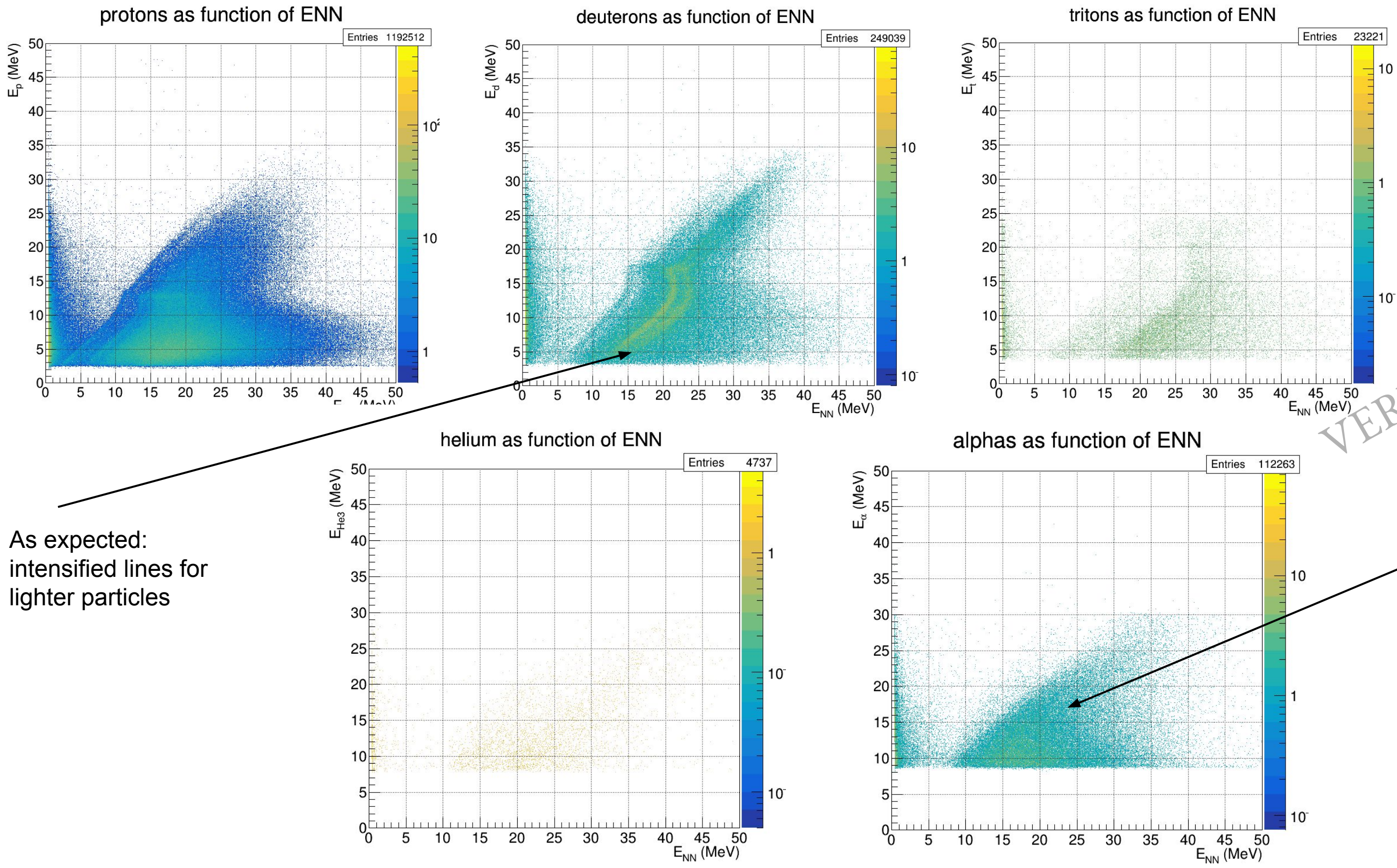




VERY PRELIMINARY

Preliminary results

First plots of particle production as a function of neutron energy (Tel 1). Fe thick (22h, Charge = 2.8 C)

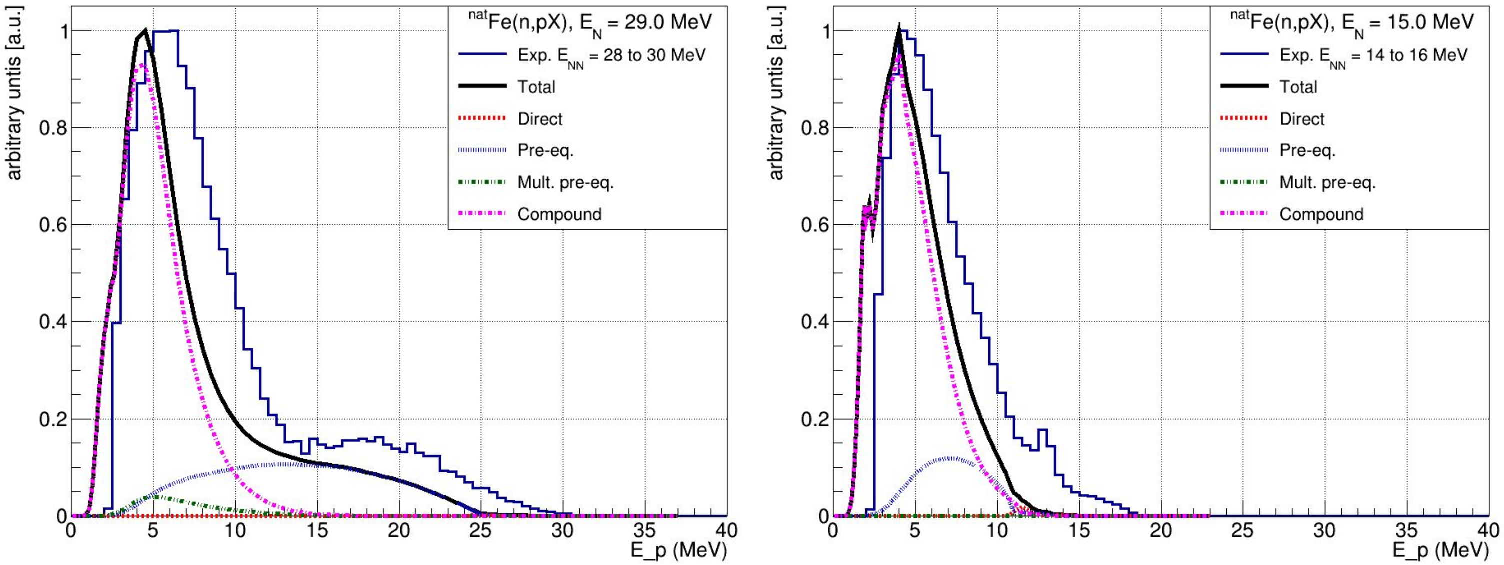


As expected: intensified lines for lighter particles

As expected: blurred spectrum for alphas (energy loss in target)

Preliminary results

As example of a **very preliminary** result:
The proton spectra from **^{nat}Fe(n,pX)** for different neutron energies using ^{nat}Fe 25 μm thick target.



Preliminary analysis indicates reasonable agreement with TALYS code (simulations does not include detector's resolutions yet).

Several steps are being implemented (such as the ToF correction for other particles and the thick target correction).

Conclusions and perspectives

- The experiments on C, Fe and Cr were successfully carried in 2022 and 2023, providing good amount of data which is being analysed.
- The setup worked well, proved to be suitable to distinguish the light ions isotopes.
- We have measured the neutron flux in the whole range of NFS (although we are working on some issues with the analysis)

  - Finish data analysis (non-trivial) for to provide double differential cross sections for (n,LCP) in C,natFe and natCr.
  - Better understand the background conditions of the experiments (NFS in a new facility, so this details are being studied in parallel). [ongoing]
  - Retrieve good ToF correction for all the particles. [ongoing]
  - Combining data for all the 8 telescopes.
  - Thick target correction (mainly for Cr data).
  - Experiment with Cu proposed by UKAEA (already approved by GANIL for this year).
  - Propose new experiments for medley in NFS for coming years.

Thank you!

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