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Measurements of high-energy neutron standards at NFS, GANIL, France

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Outline

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- High-energy neutron standards.
- NFS, GANIL.
- Our experimental setup: Medley.
- Charecteristics of Medely.

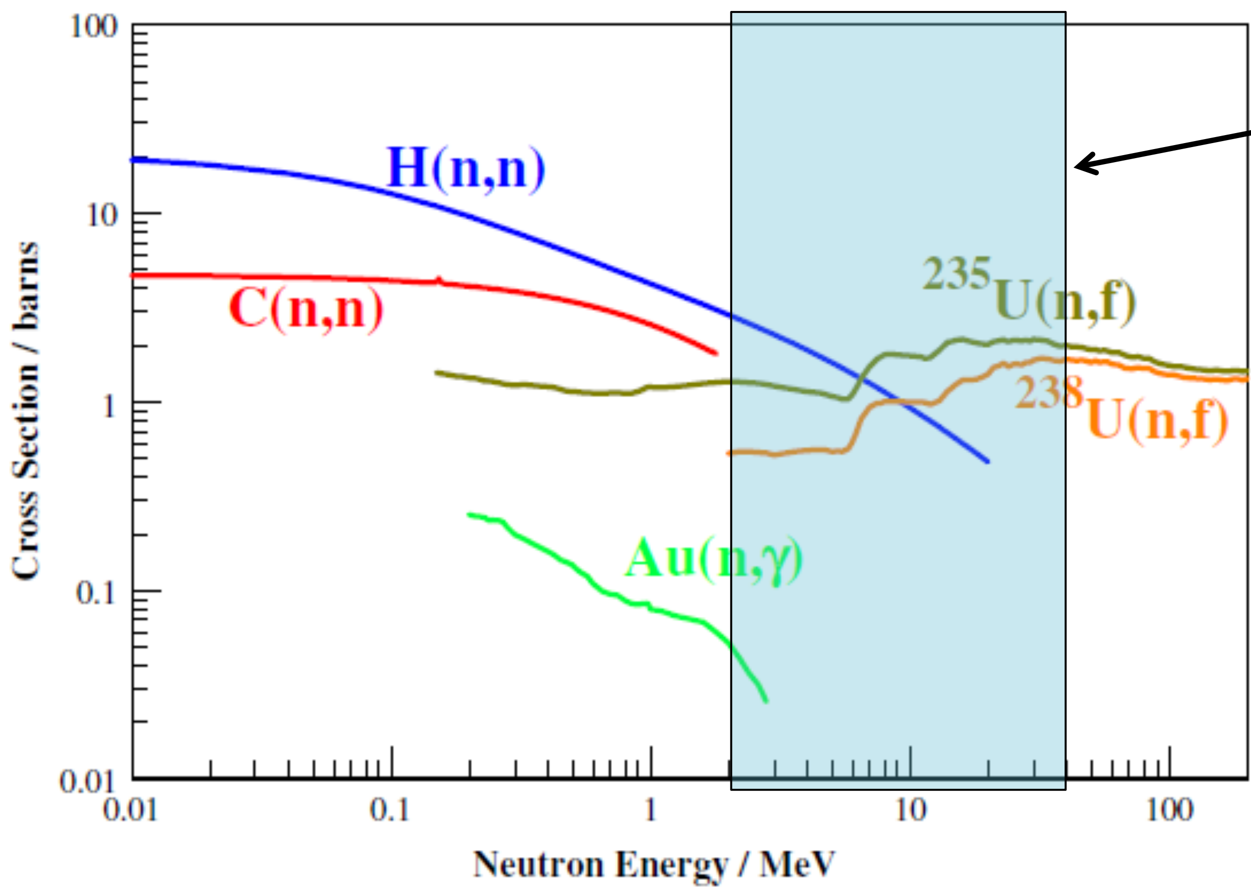
High-energy neutron standards

The use of neutron standards

- The use of standards greatly facilitates neutron cross section measurements.
- Almost all neutron cross sections in nuclear data libraries depend on standard cross sections.
- As the demand for accurate data grows…
- …there is an ongoing work to improve and extend existing standards.
- It is necessary to have several independent measurements of the neutron standards .

High-energy neutron standards

The high-energy neutron cross section standards



Energy region accessible at NFS.

3 important standards in this region (2-40 MeV):

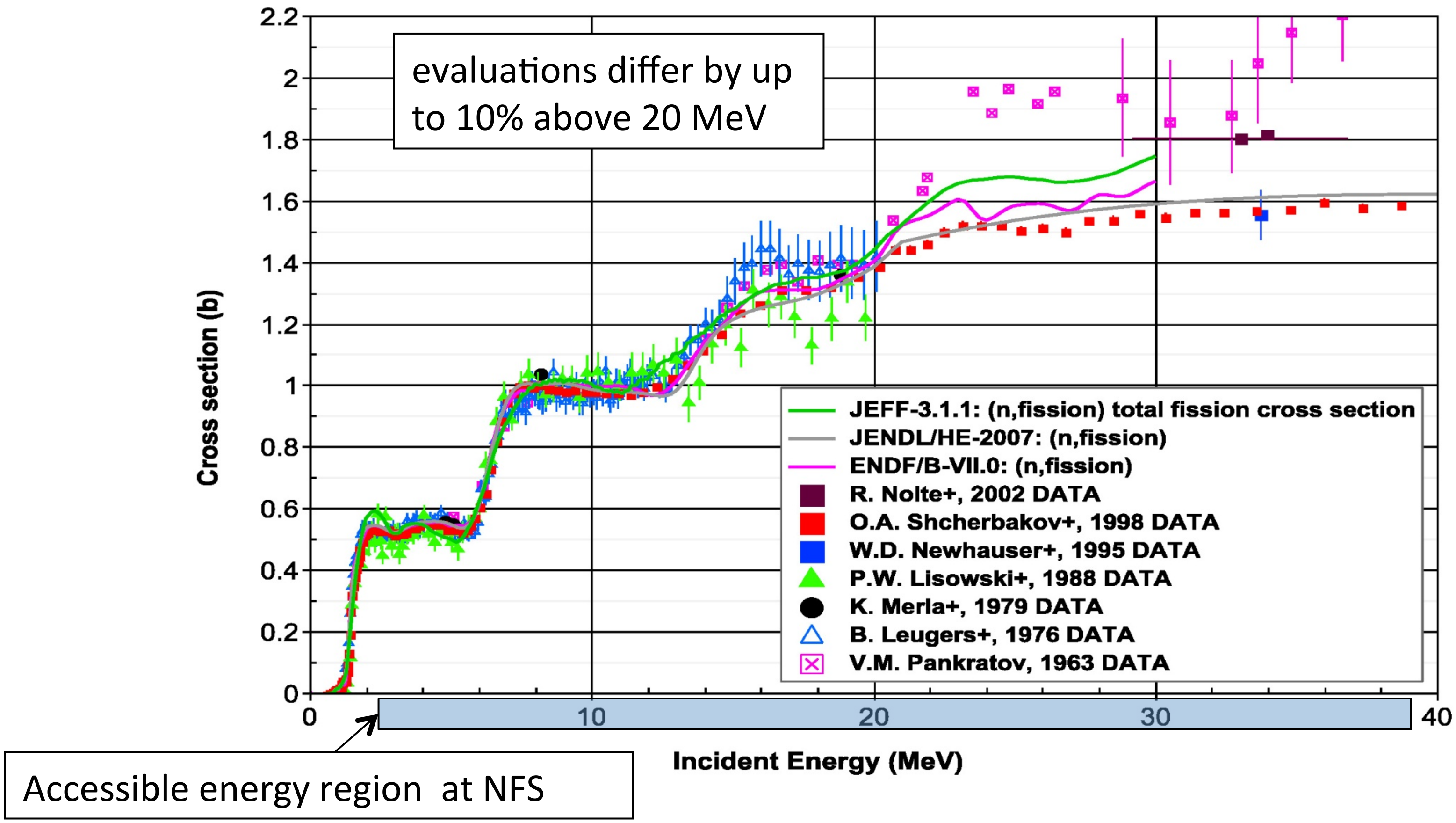
- **H(n,n)**
- **^{235}U(n,f)**
- **^{238}U(n,f)**

*A.D. Carlson, Metrologia **48**, S328 (2011).*

Neutron standards

The ^{238}U(n,f) cross section

- Used as a standard for energies 2 MeV – 200 MeV.



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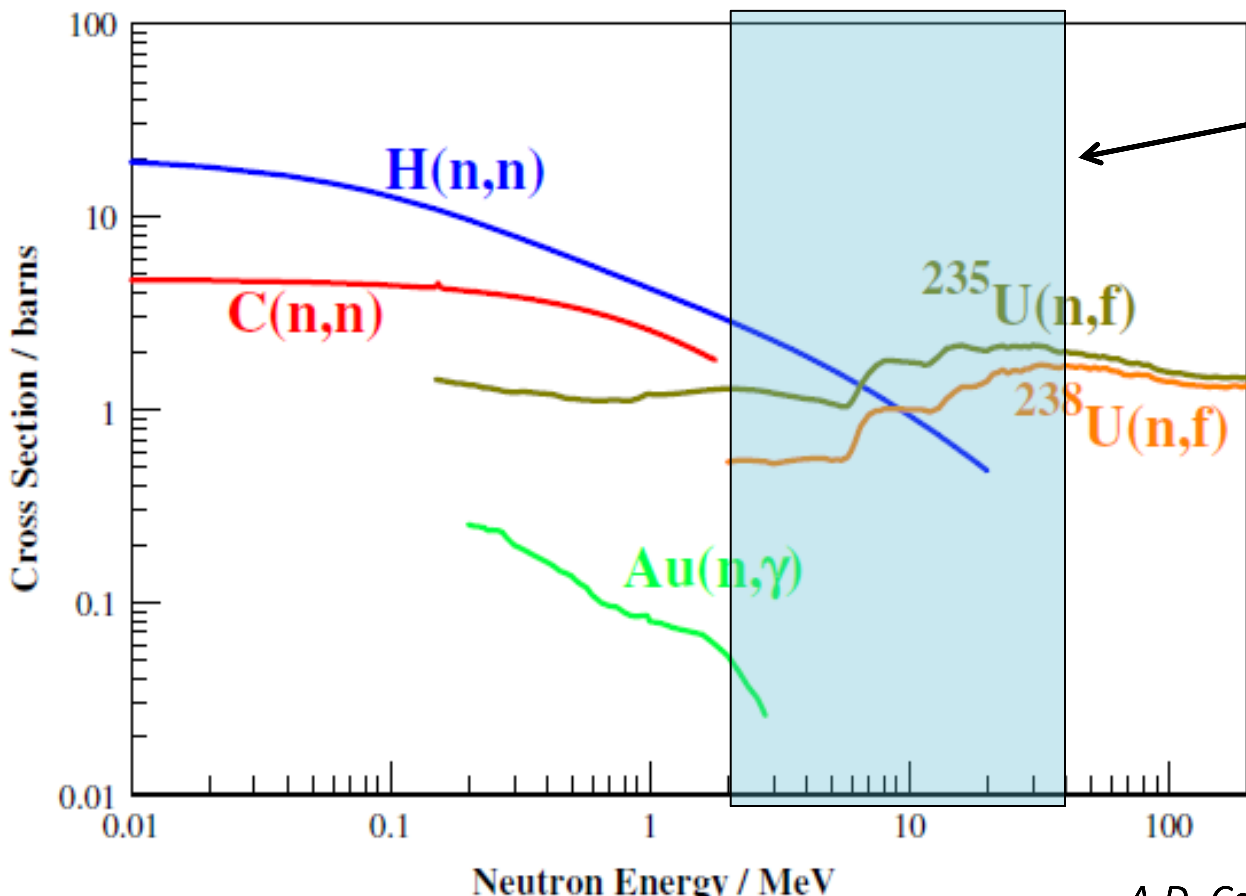
Our scientific idea

To measure all these three standards simultaneously at NFS at GANIL, France



Energy region accessible at NFS.

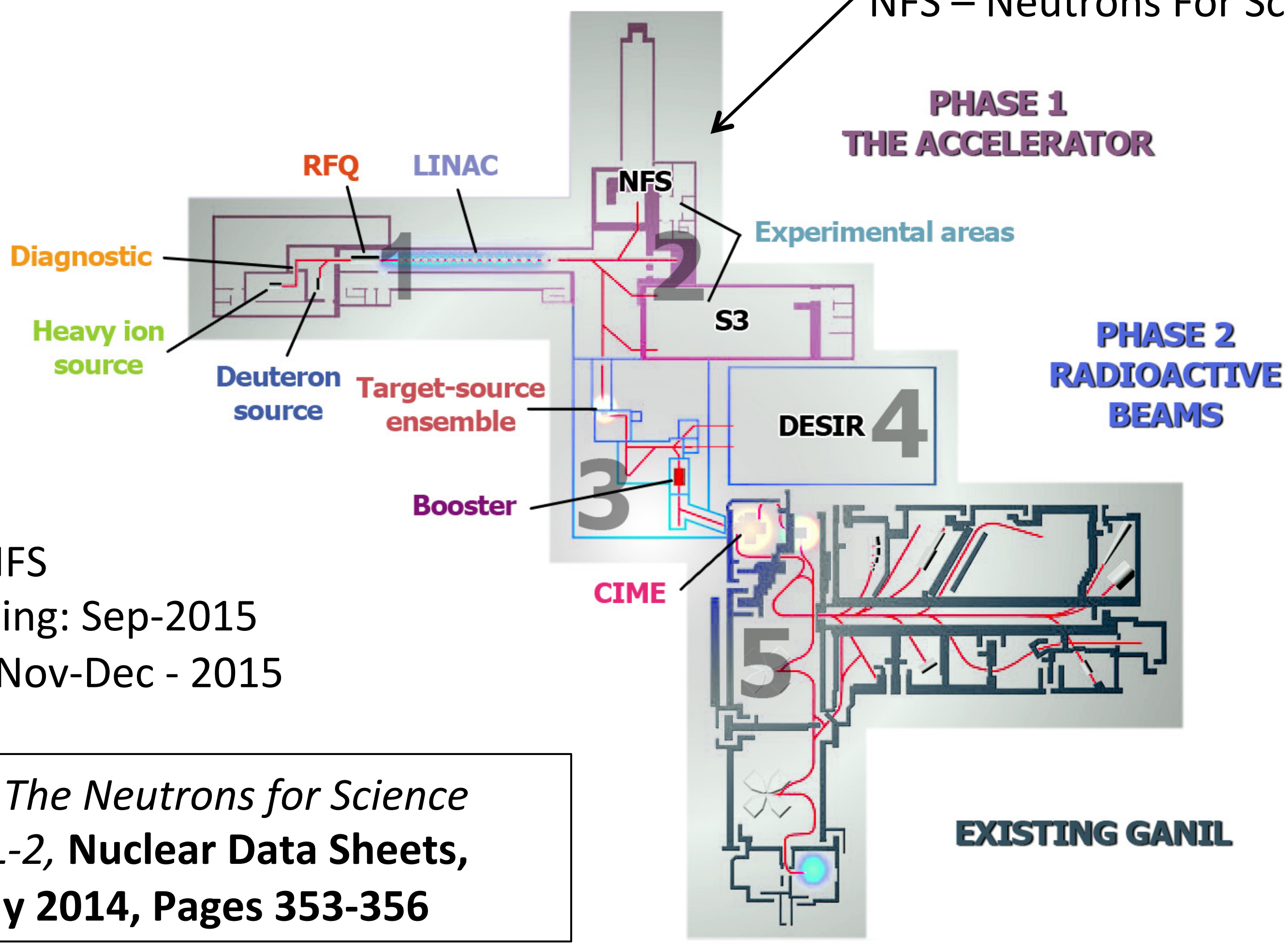
We want to measure (at the same time):

- **H(n,n)**
- **^{235}U(n,f)**
- **^{238}U(n,f)**

A.D. Carlson, Metrologia ***48****, S328 (2011).*

NFS @ SPIRAL 2 @ GANIL

NFS – Neutrons For Science

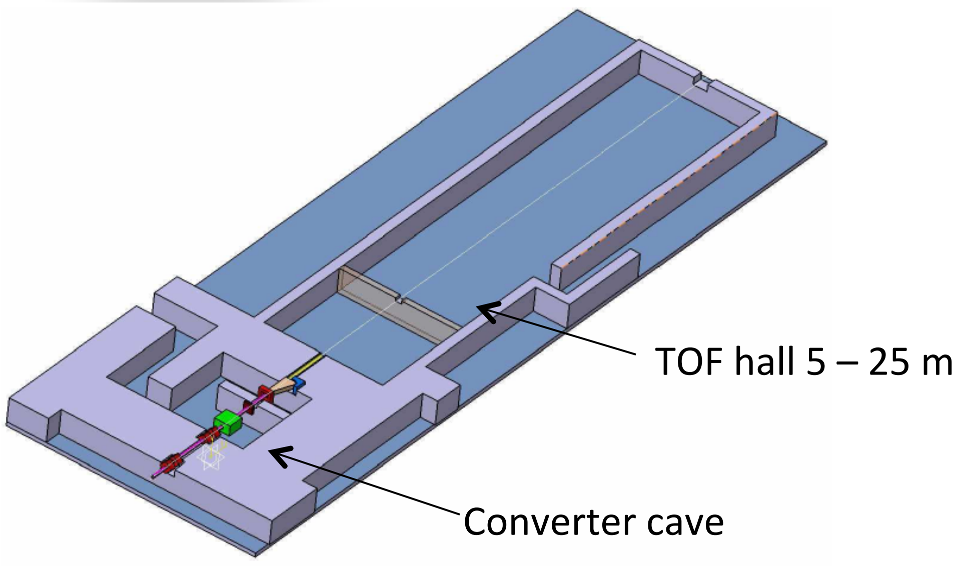


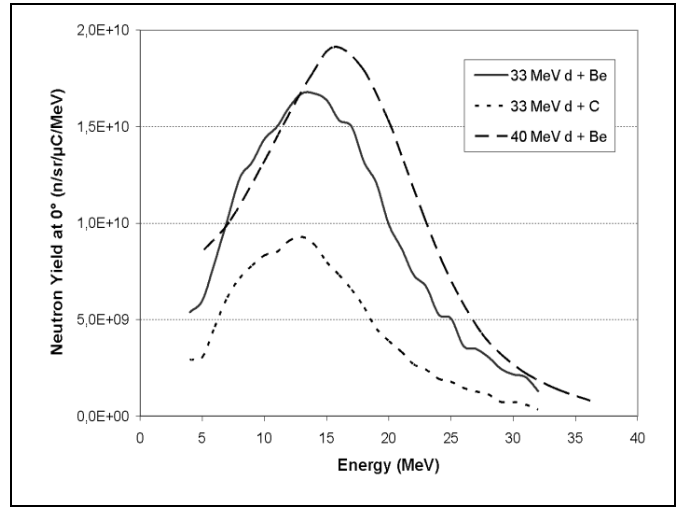
Time plan for NFS

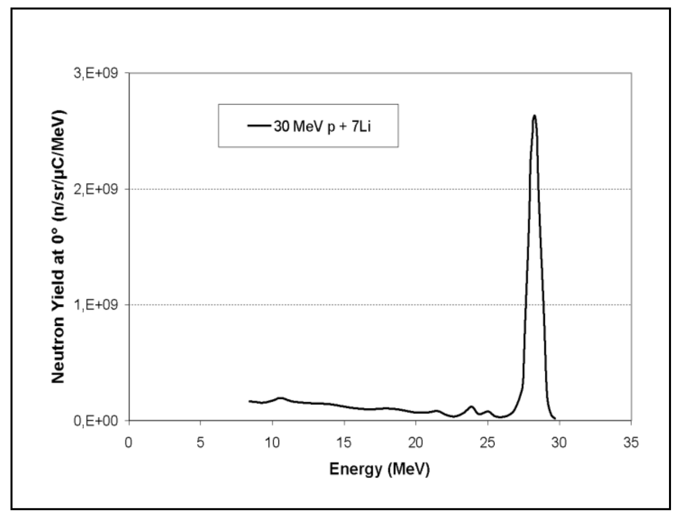
- Commissioning: Sep-2015
- First beam: Nov-Dec - 2015

X. Ledoux et al., *The Neutrons for Science Facility at SPIRAL-2,* **Nuclear Data Sheets, Volume 119, May 2014, Pages 353-356**

NFS – Neutrons For Science







- **d + Be, C** => white neutron source (1-40 MeV).
- Deuterons: maximum 40 MeV .
- **p + Li** => quasi-monoenergetic neutron beam.
- Protons: maximum 33 MeV.
- Maximum ion beam current at converter: 50 μA.
- Maximum power deposition: 2kW.
- (FWHM) of beam burst < 1 ns.

Technical Proposal NFS, http://pro.ganil-spiral2.eu/

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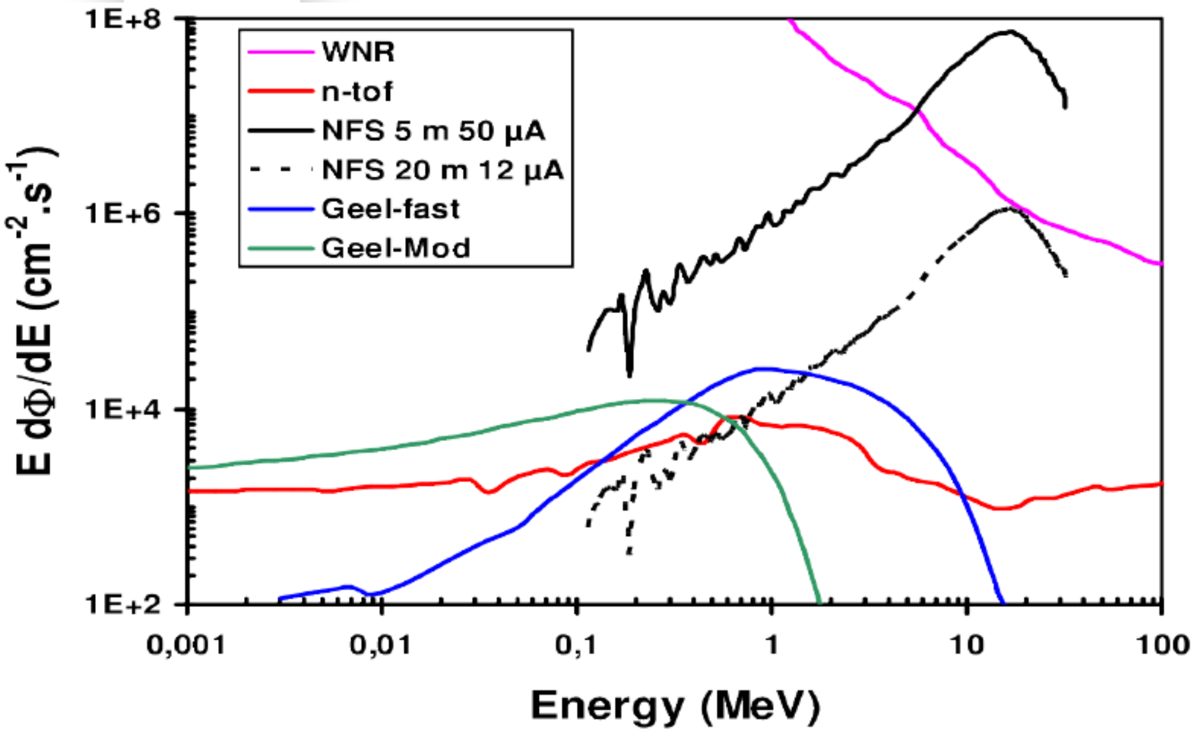
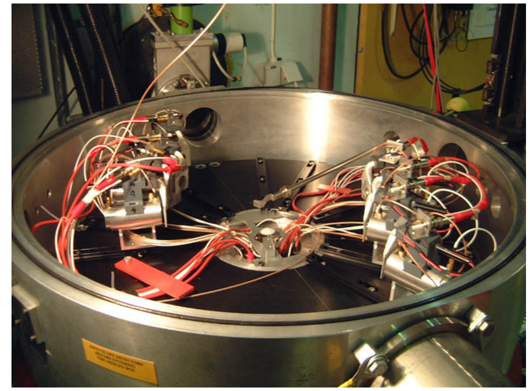
Neutron flux



Technical Proposal NFS, http://pro.ganil-spiral2.eu/

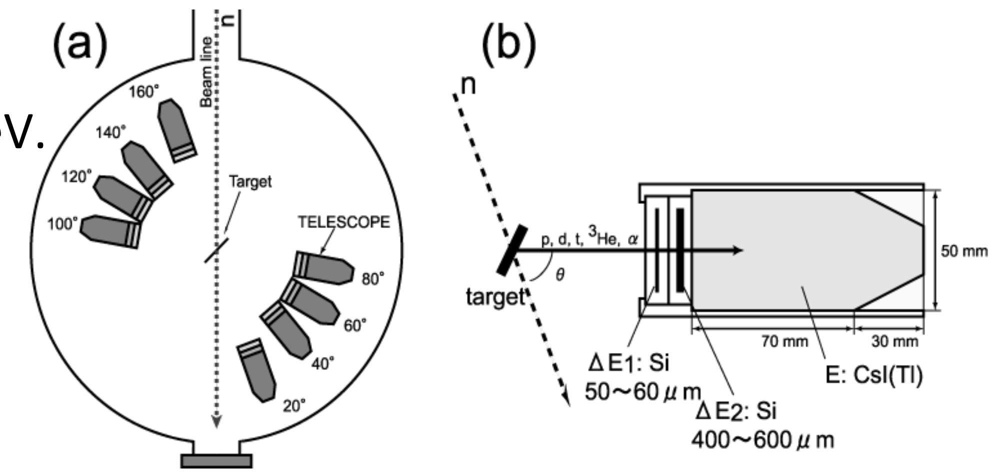
Neutron energy [MeV]	Neutron flux at Medley position [10^6 n/MeV/cm^2/s]
2	1
14	5
25	1.5
Average	2.4

Detector setup (Medley)



Original Medley (born in 2000):

- Evacuated chamber.
- 8 detector telescopes.
- ΔE-ΔE-E particle identification.
- Used for ddx of (n,light ions) reactions on C, Si, O, Fe, Bi, Pb and U at 96 MeV and/or 175 MeV.
- TSL – mono-energetic beam $^7Li(p,n)$.



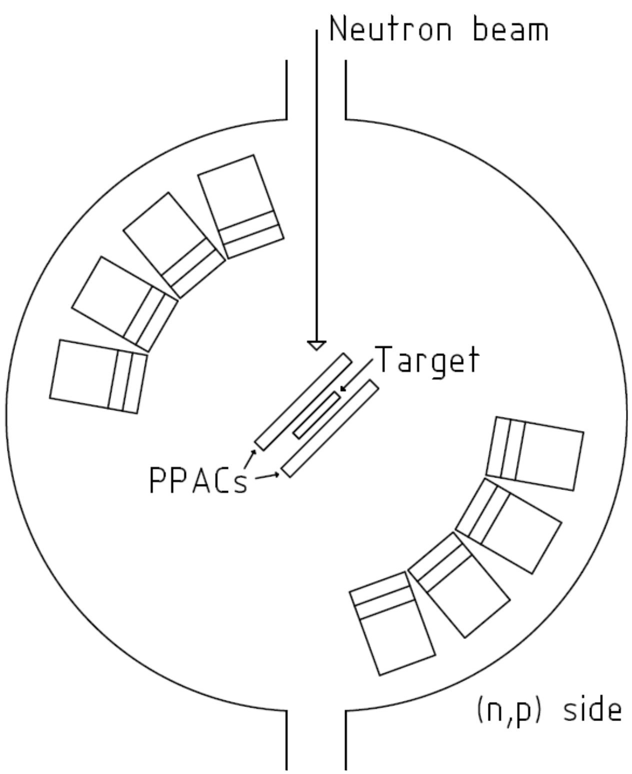
For use at NFS white beam:

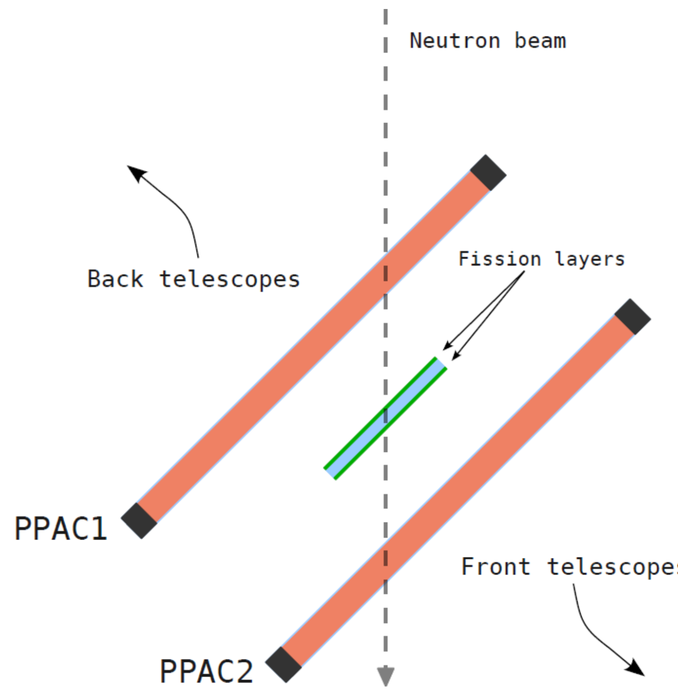
- Timing detectors, we need to determine the neutron energy for each event by measuring the neutron time-of-flight (ToF).
- Layered target: U-CH_2-U.

Upgrade of Medley setup

Upgrade will include:

- PPAC detectors for fast ToF timing for neutron energy measurement.
- Sandwich target: ^{238}U-CH_2-^{235}U for measurement relative to the *np* cross section.

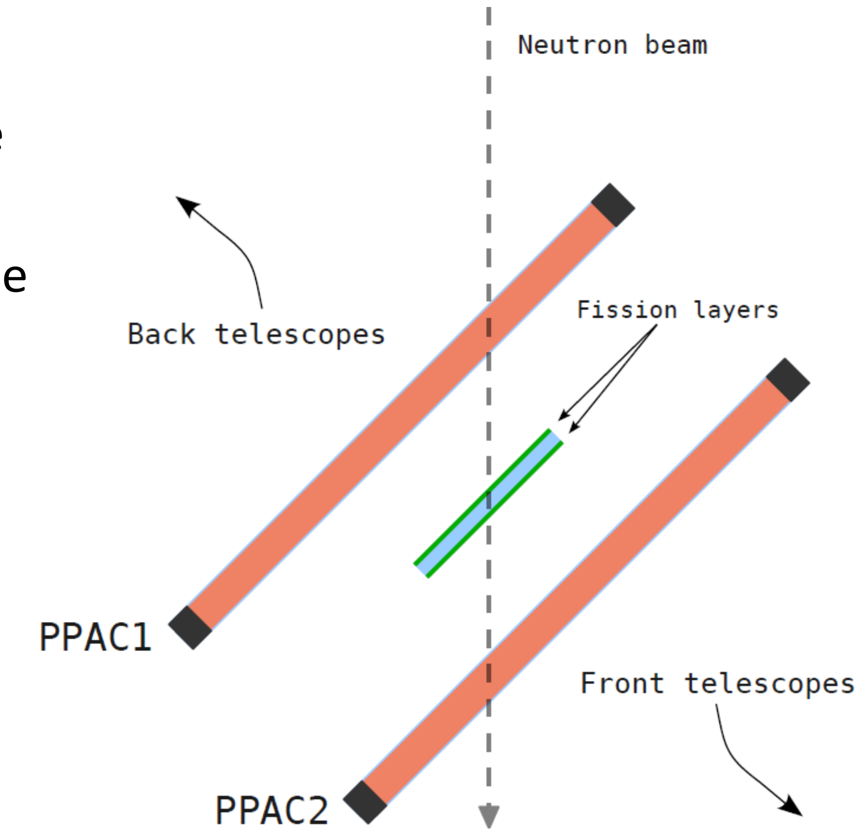




Target

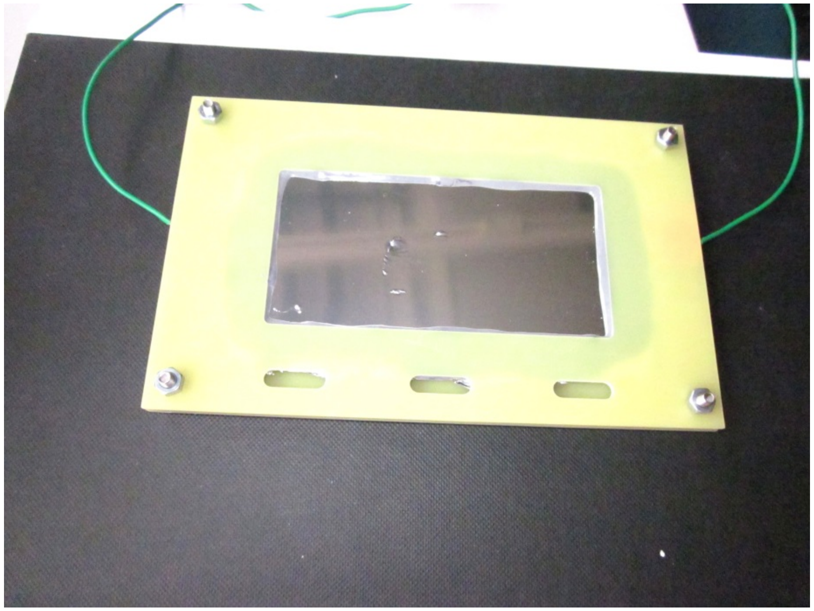
Target

- 3-layered target actinide - CH_2- actinide.
- Shape: 25 mm disc, corresponding to the opening size of the Si telescopes.
- GEANT simulations state U-layers must be < 2 μm (< 1.7 mg/cm^2).
- CH2-layer ca 100 μm to have similar statistics for all data sets.
- Targets will be manufactured IPN Orsay, Paris, France, at the CACAO laboratory within the CHANDA project.
- CHANDA -- Challenges in Nuclear Data, a EU coordinated project.



PPAC detectors

PPAC – Parallel plate avalanche counter



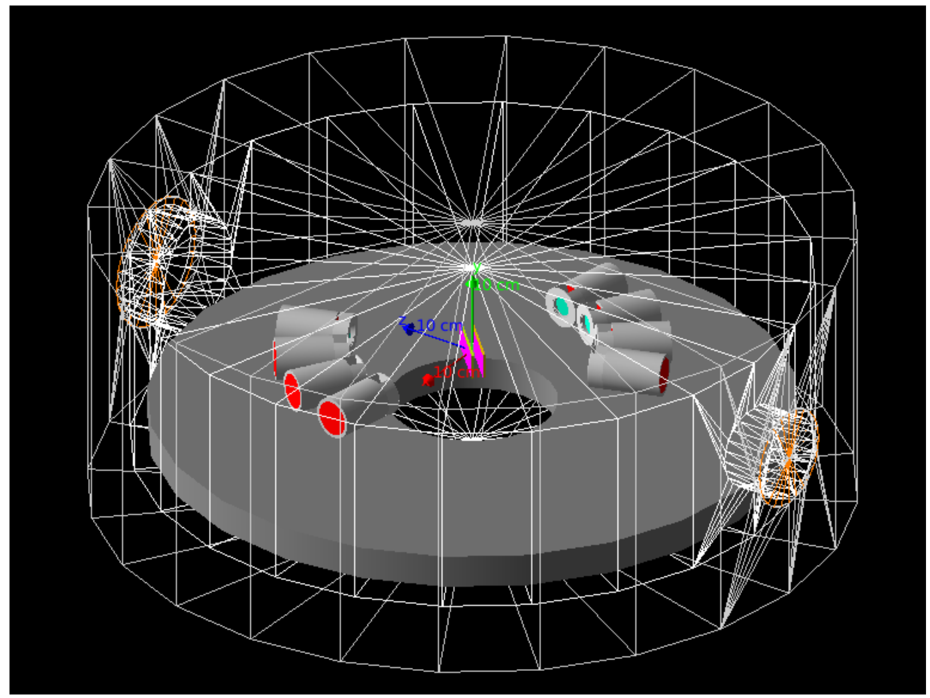
- Two thin parallel electrodes separated by a gap.
- Gas filled: low gas pressure (a few mbar).
- Widely used with heavy ions but insensitive to long-range particles.
- The particles traverse the PPAC, ionize the gas and produce an electron avalanche.
- Known to have high temporal resolution (< 0.5 ns) and low stopping power.

Our prototype PPAC is currently being tested!

GEANT4 simulations of detector system

Simulations (GEANT4)

- **Fission:** full process simulated starting with neutron spectrum.
- **Target**: 2 μm ^{238}U on each side of a 100 μm polyethylene layer
- **PPAC:** 1 μm Mylar foils, 3 mbar gas pressure, P-10 gas (90 % Ar and 10 % CH_4).

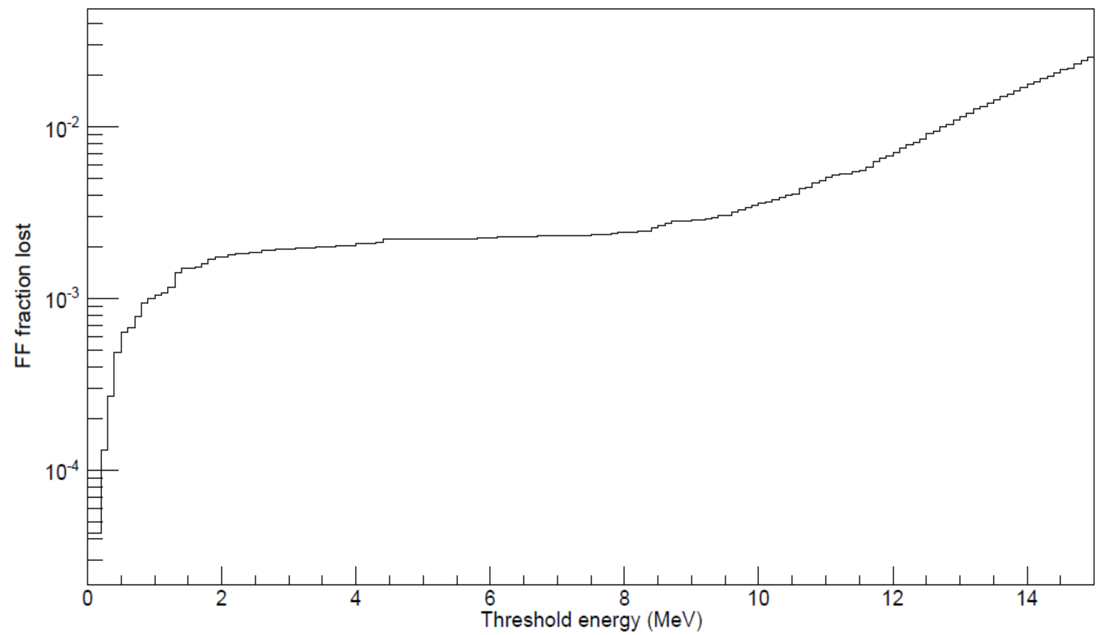


K. Jansson et al., *Measuring Light-ion Production and Fission Cross Sections Normalised to H(n,p) Scattering at the Upcoming NFS Facility*
Nuclear Data Sheets, Volume 119, May 2014, Pages 395-397

GEANT4 simulations of detector system

Fission fragments created in U-target:

- Energy loss inside 2 μm target (up to 40 MeV).
- Energy loss in PPAC and detector gas
  - Mylar foils, ca 8 MeV
  - Gas in Medley, ca 5 MeV
- Mean energy when reaching the detector telescopes = 40 MeV.



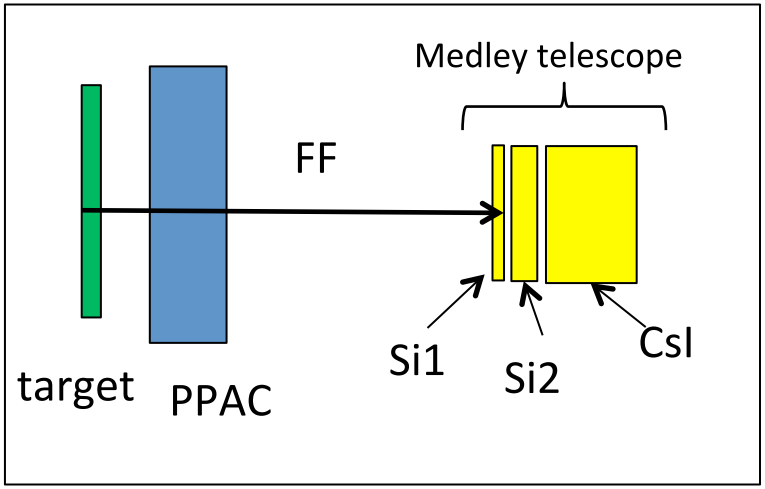
Threshold for discrimination from alpha particles in telescopes (Si_1 =50 μm) : **8 MeV**. Simulations show that only 0.1 % of the FFs have E < 8 MeV when reaching the telescopes.

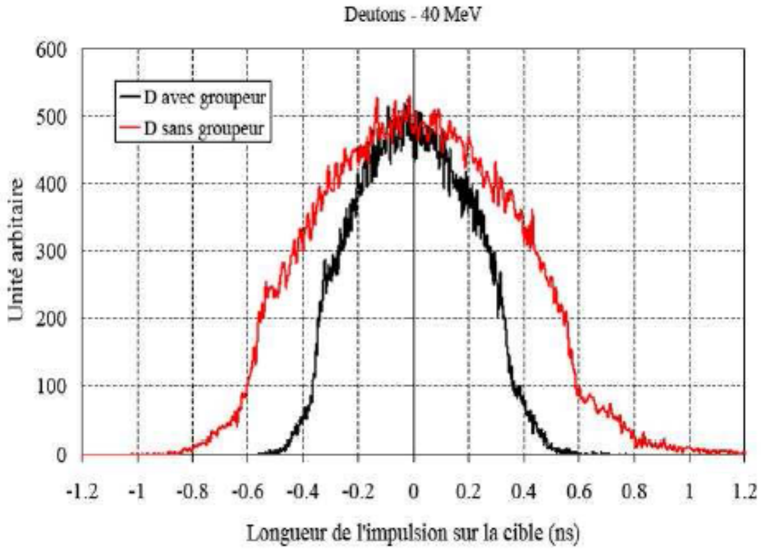
Fission fragment detection

Uncertainty in neutron energy (FF)

Contributions to energy resolution for FF detection:

- the time distribution (FWHM) of the beam burst:
  - assumed value: 0.8 ns [1]
- PPAC time resolution:
  - assumed value: 0.5 ns
- Si1 time resolution
  - assumed value: 1.0 ns





[1] Technical Proposal NFS, http://pro.ganil-spiral2.eu/

Proton detection for the *np* cross section

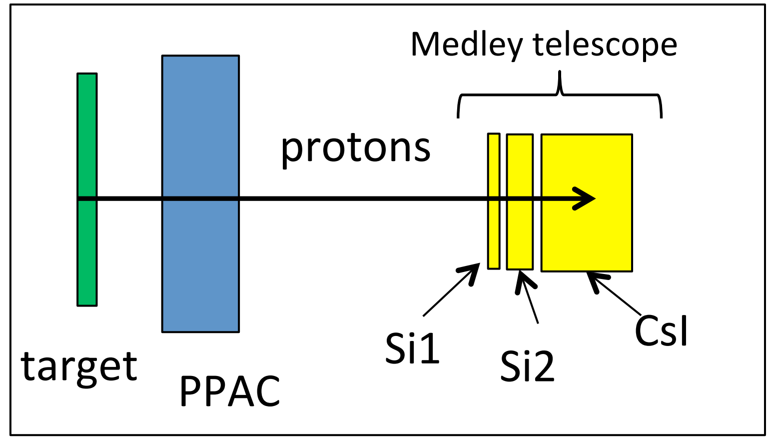
Uncertainty in neutron energy

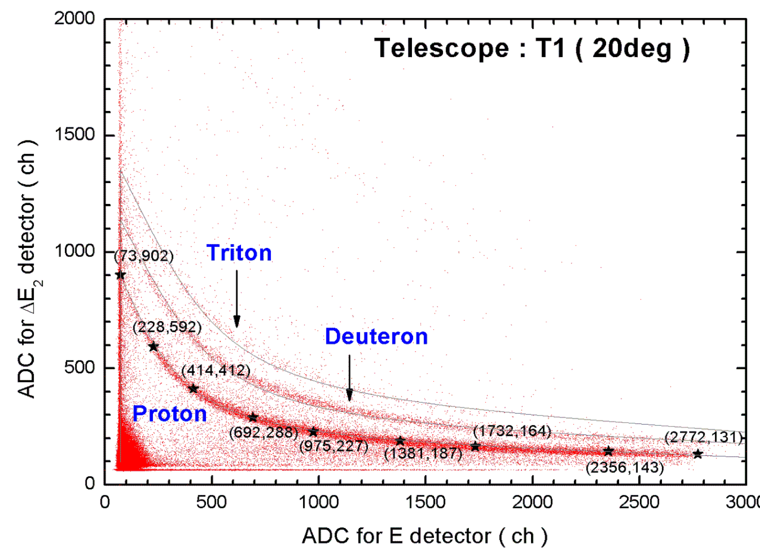
Protons will be detected by the telescopes and the first detector (Si1) will give the time signal.

The mass is always known, since protons can be identified by ΔE-ΔE-E technique.

Contributions to energy resolution for proton detection:

- the time distribution (FWHM) of the beam burst:
  - assumed value: 0.8 ns [1]
- Si1 time resolution
  - assumed value: 1.0 ns





Example of particle identification with the ΔE-ΔE-E technique

[1] Technical Proposal NFS, http://pro.ganil-spiral2.eu/

Neutron energy resolution

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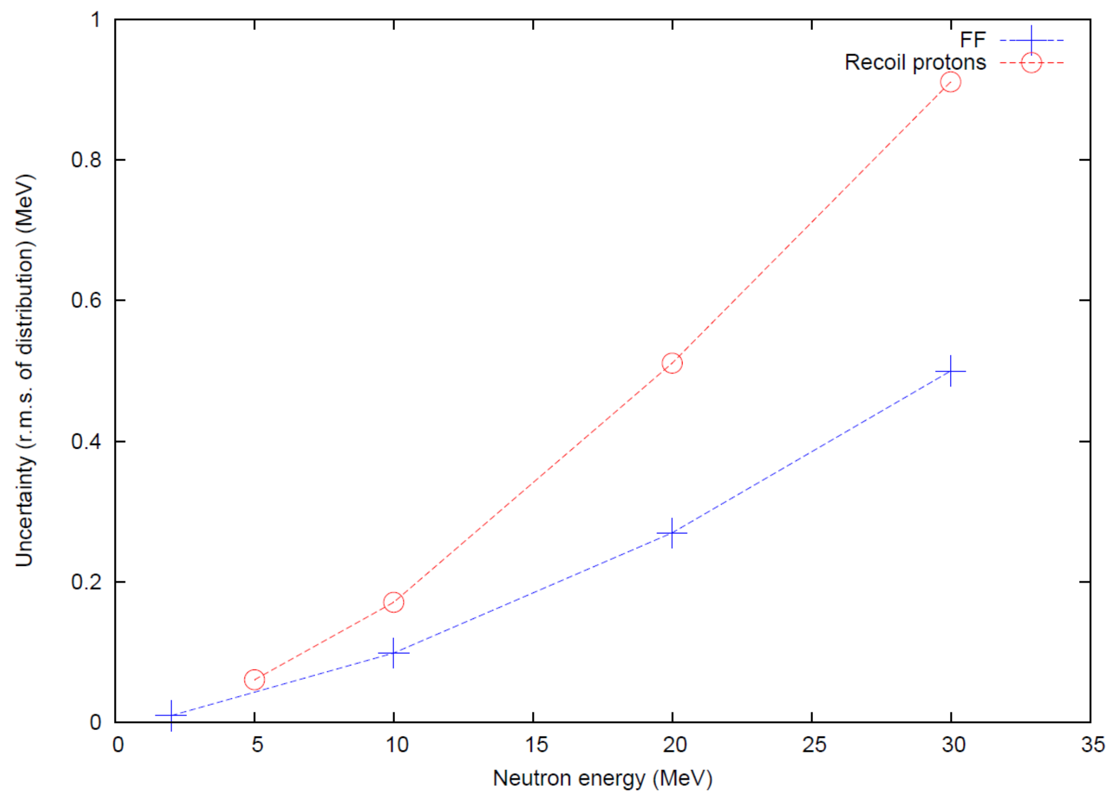
Estimates of neutron energy resolution

With our assumption we reach:

- For **fission fragments** uncertainty in neutron energy determination less than 0.5 MeV (r.m.s.) or 2 % throughout the NFS neutron range.
- For **protons** the uncertainty in neutron energy is always less than 1 MeV, or 3 % throughout the NFS neutron range.



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Thank you for your attention!