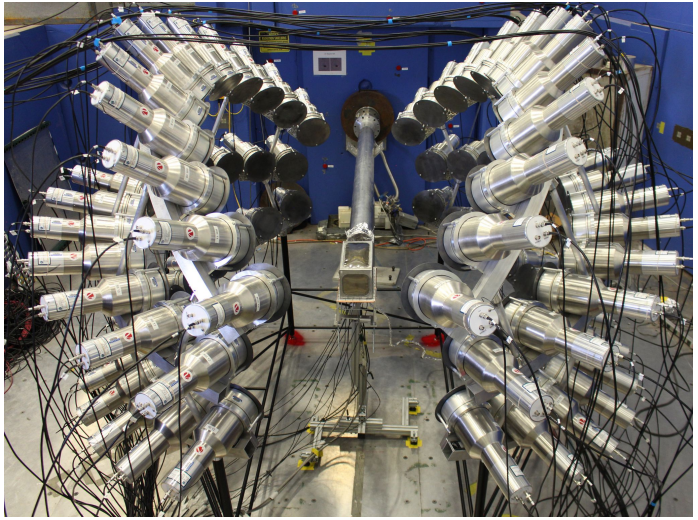


VENDETA : VErsatile Neutron DETector Array, a new high-resolution neutron time-of-flight measurement array

O. Syrett[1,2], A. Chatillon[1,2], C. Lenain[1,2], B. Mauss[1,2], P. Morfouace[1,2], J. Taieb[1,2] , M. Devlin[3], K.J. Kelly[3]

[1]CEA, DAM, DIF, Arpajon, France
[2]Universite Paris-Saclay, CEA, Laboratoire Matiere en Conditions Extremes, Bruyeres-le-Chatel, France
[3]Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

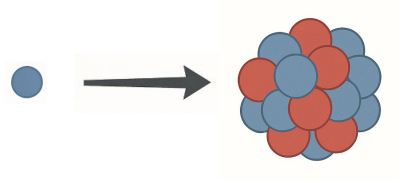
Contact information: owen.syrett@cea.fr

EuNPC 2025

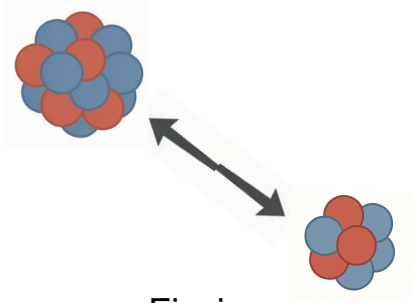
Contents

1. Prompt Fission Neutrons

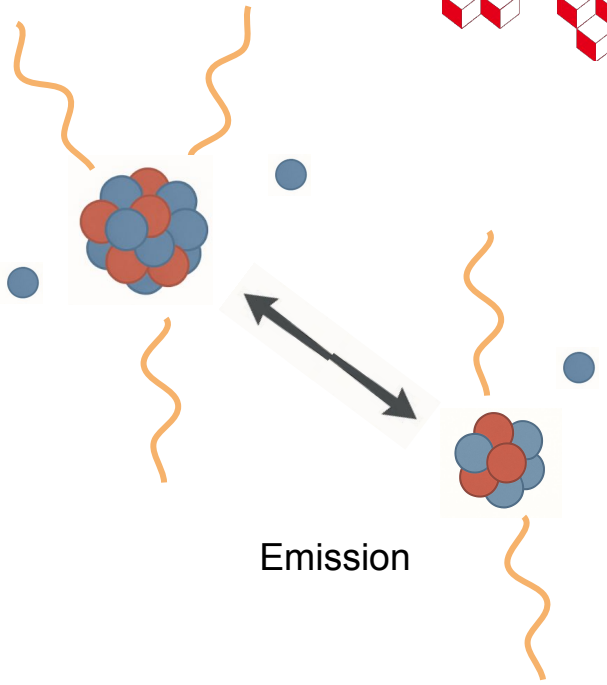
Prompt Fission Neutrons : Fission



Absorption



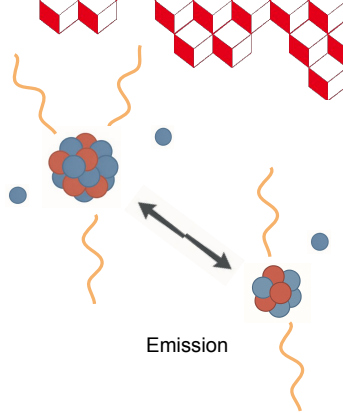
Fission



Emission

- Actinides can undergo neutron induced fission.
- Spontaneous fission is when a nucleus fissions from its ground state (such as ^{252}Cf or ^{240}Pu).

Prompt Fission Neutrons : Fragment de-excitation



- Prompt neutrons : 10^{-15}s
- Prompt γ : 10^{-14}s to µs
- Delayed neutrons : > µs (< 1% of neutrons)

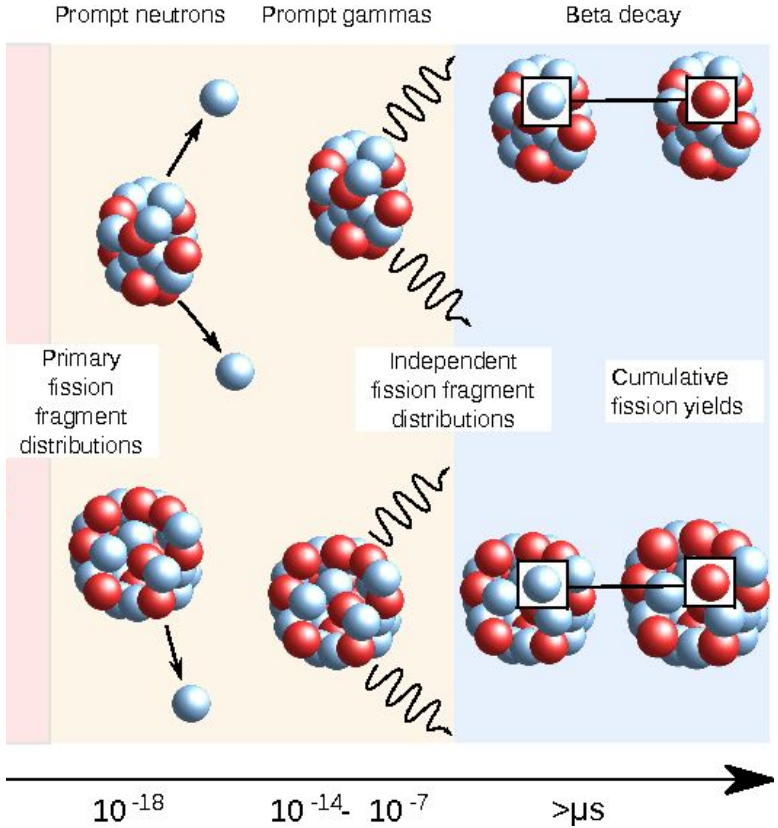
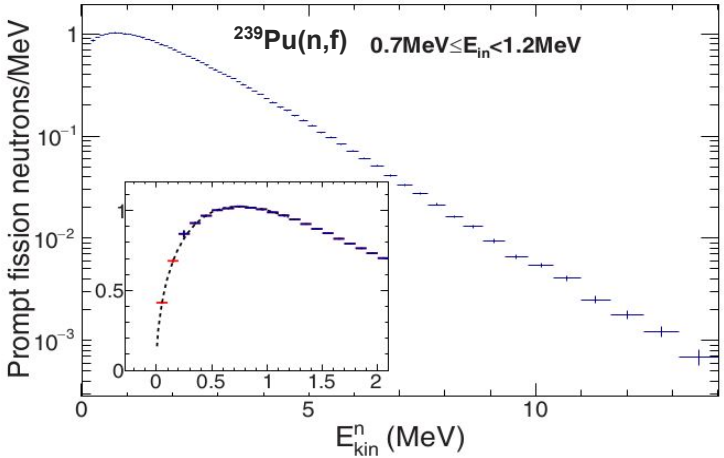


Figure from Bender et al. Future of nuclear fission theory

Prompt Fission Neutrons : Key role of neutrons

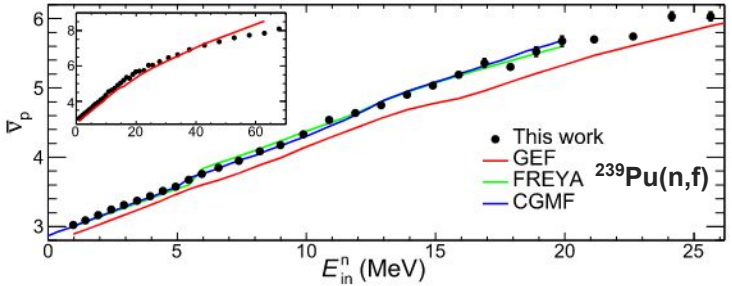
- Neutrons play a key role in the fission chain reaction.
- Neutrons emission characteristics are critical for applications (criticality calculations, neutron transport…)

Prompt fission neutron energy distribution



From P. Marini et al. (2019)

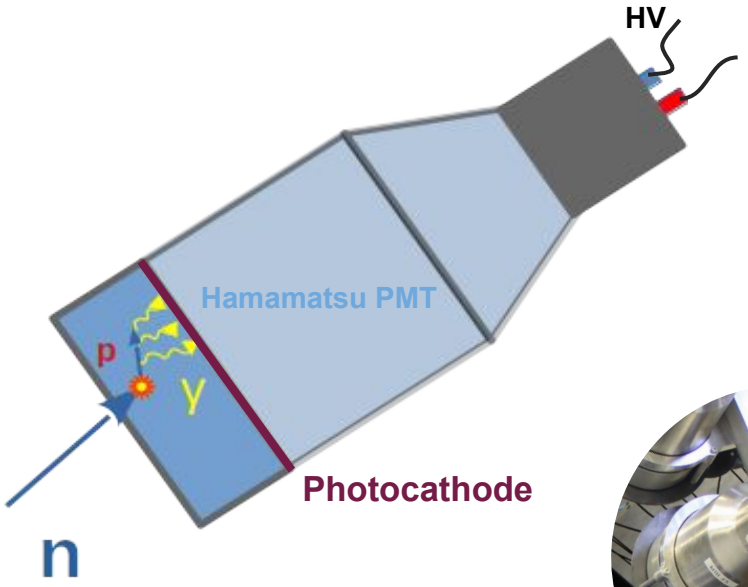
Prompt fission neutron average multiplicity



From P. Marini et al. (2022)

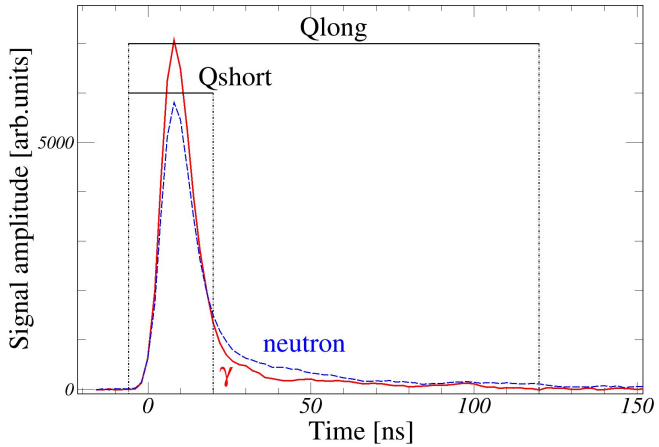
2. VENDETA : a Liquid Scintillator Array

VENDETA : a Liquid Scintillator Array : Scintillation detection



1. Charged particles resulting from the interaction of neutrons or γ with the medium's molecules.
2. Scintillation light from the excited medium.
3. Amplification into a measurable signal.

"Dual gain" electronics and FASTER DAQ *[1]* enable the sampling of signals on a wide range of light outputs (10 keVee to 5 MeVee).

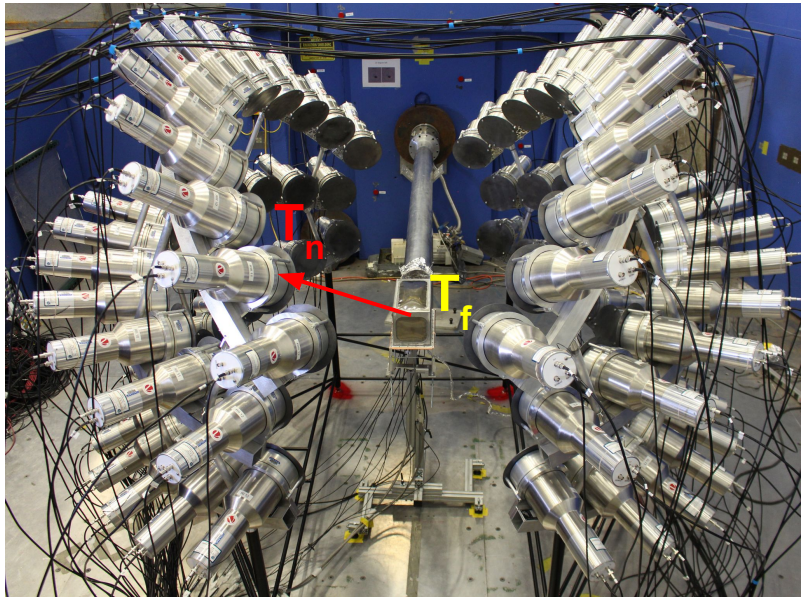


Sampled signal shapes

[1] Fast acquisition system for nuclEar research, 2025, URL https://faster.in2p3.fr.

VENDETA : a Liquid Scintillator Array : Time-of-flight technique

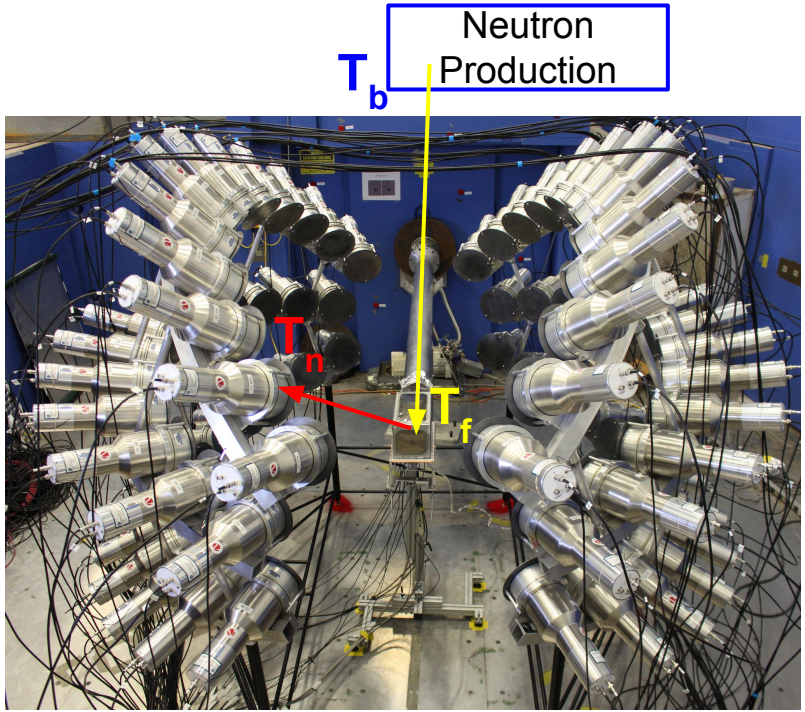
- Described in Syrett et al. in Nuclear Instruments and Methods in Physics Research A 1081 (2026).
- 72 scintillators covering 12 polar angles from 15° to 155°
- VENDETA array associated with a fission chamber containing a ^{252}Cf(*sf*) source.
- Neutron kinetic energy derived from time of flight measurement (T_n -T_f) over a 1m flight path.



Commissioning set-up at Weapon Neutron Research (WNR) facility of the Los Alamos Neutron Science Center (LANSCE).

VENDETA : a Liquid Scintillator Array : Double time of flight

- Time of flight of an incident neutron (T_f -T_b) can also be measured to study (n,f) reactions.



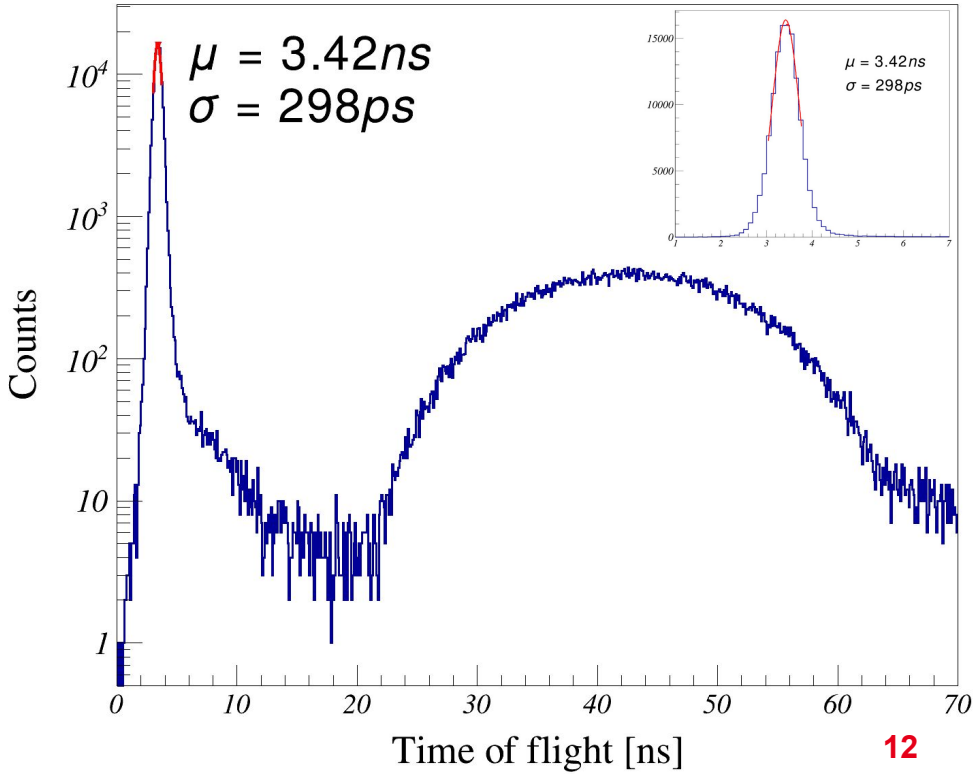
Commissioning set-up at Weapon Neutron Research (WNR) facility of the Los Alamos Neutron Science Center (LANSCE).

3. Detection characteristics

Detection characteristics : Time-of-flight resolution

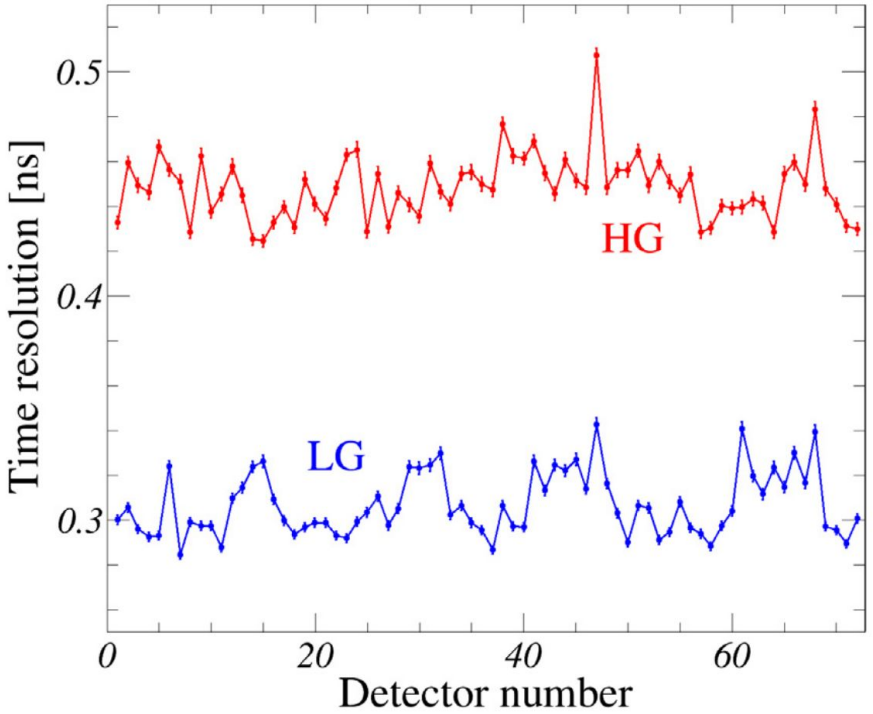
- Time resolution measured with γ-rays time of flight.
- Timing pick-up :
  - CFD algorithm on sampled signals.
  - corrected for Walk effect.

A time-of-flight spectrum



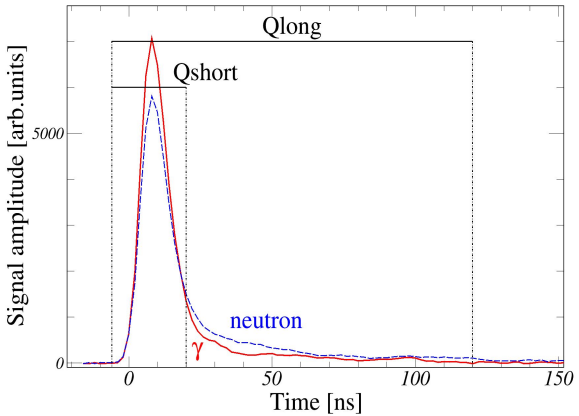
Detection characteristics : Time-of-flight resolution

- High Gain (HG) time resolution : 450 ps.
- Low Gain (LG) time resolution : 300 ps.
- Neutron kinetic energy resolution :
  - 130 keV at 4 MeV
  - 500 keV at 12 MeV.



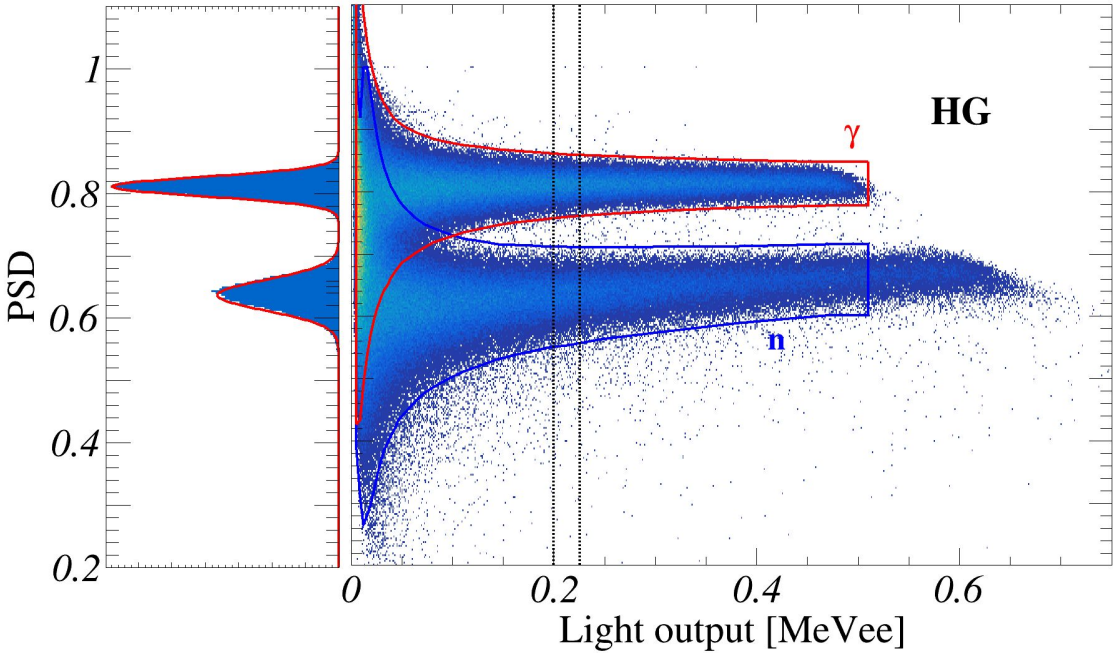
Detection characteristics : Neutron/γ discrimination

- Major challenge : identifying neutrons for low light outputs.
- Cuts defined by a gaussian fit per light output slice.



Sampled signal shapes

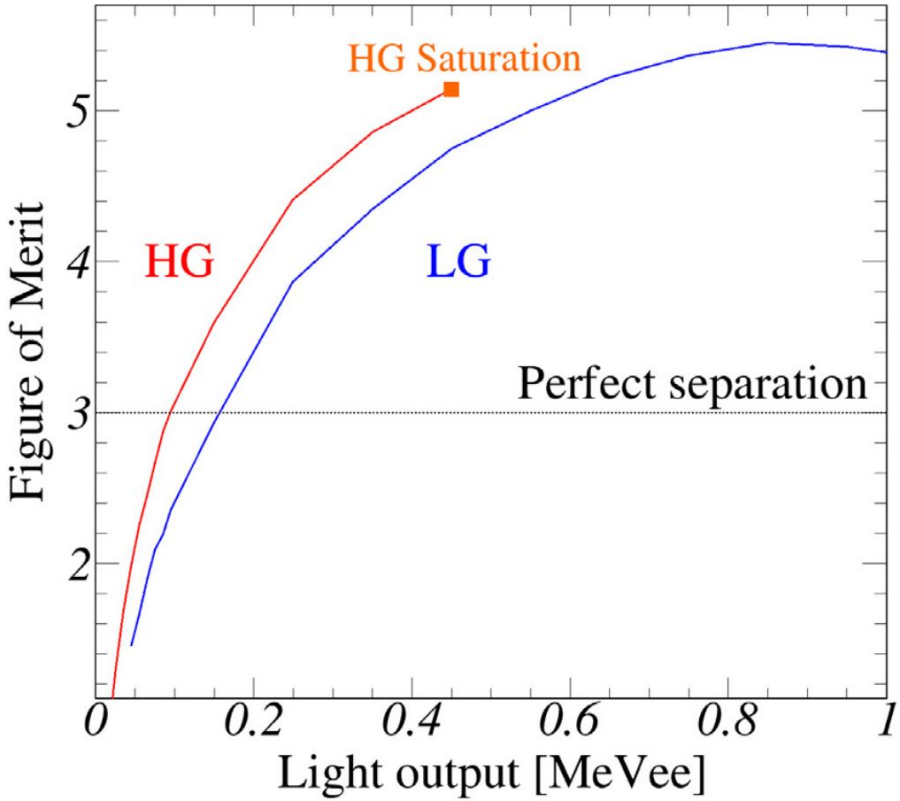
Example of a PSD plot for a VENDETA detector



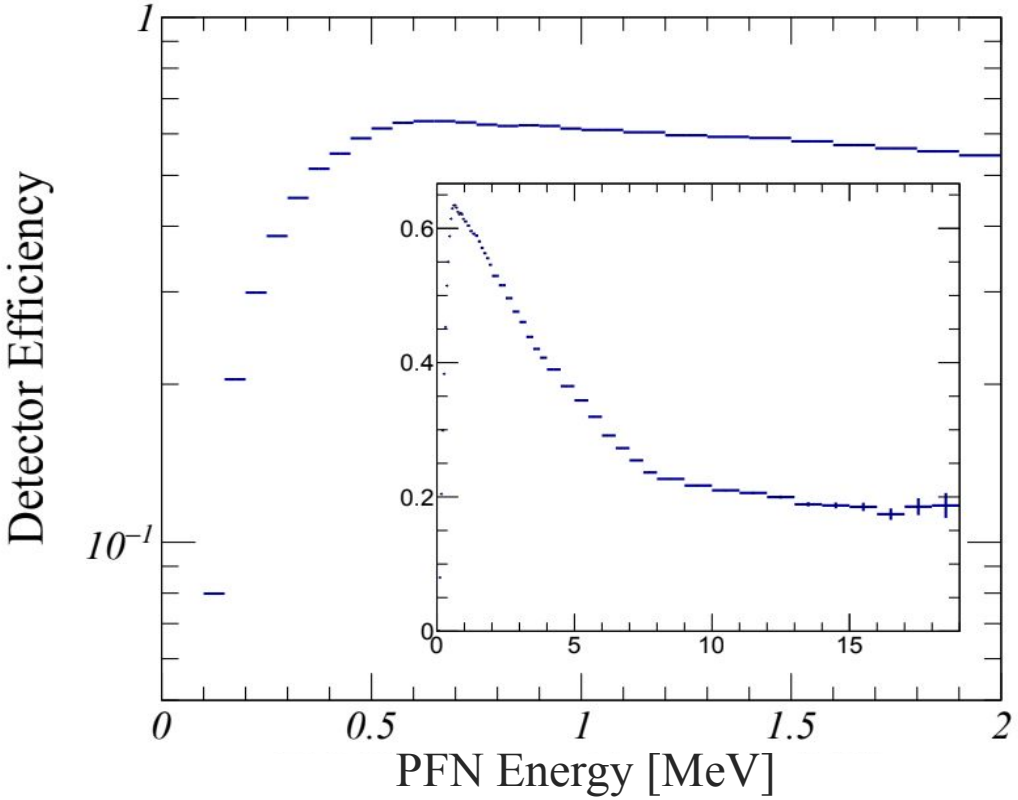
PSD = Qshort/Qlong

Detection characteristics : Neutron/γ discrimination

- The Figure of Merit is used to evaluate the discrimination.
- “Dual gain” electronics allows for discrimination on a wide range.
- Perfect discrimination down to 90 keVee.
- Some discrimination capability down to 10 keVee.



Detection characteristics : Average intrinsic efficiency



- Obtained by comparing measurement to Mannhart evaluation.
- ~ 10% down to 125 keV.
- Maximum : 65% for 650 keV neutrons.
- > 20% up to 20 MeV.

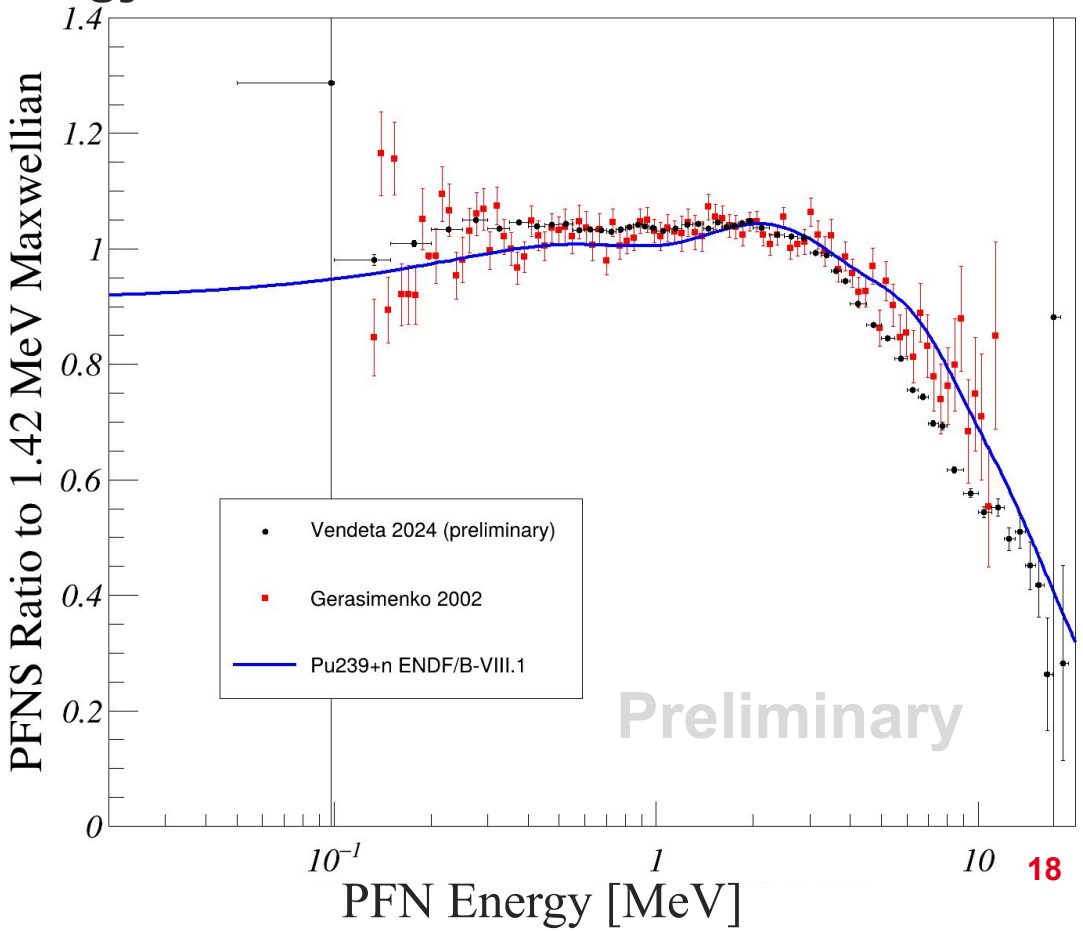
4. ^{240}Pu(sf) Measurement

^{240}Pu(sf) Measurement : Energy distribution

Average neutron energy :

$$\bar{E}_{240Pu} = 2.005 \text{ MeV} \pm 0.002$$

Compared to 2.044 MeV ± 0.036 for Gerasimenko 2002.

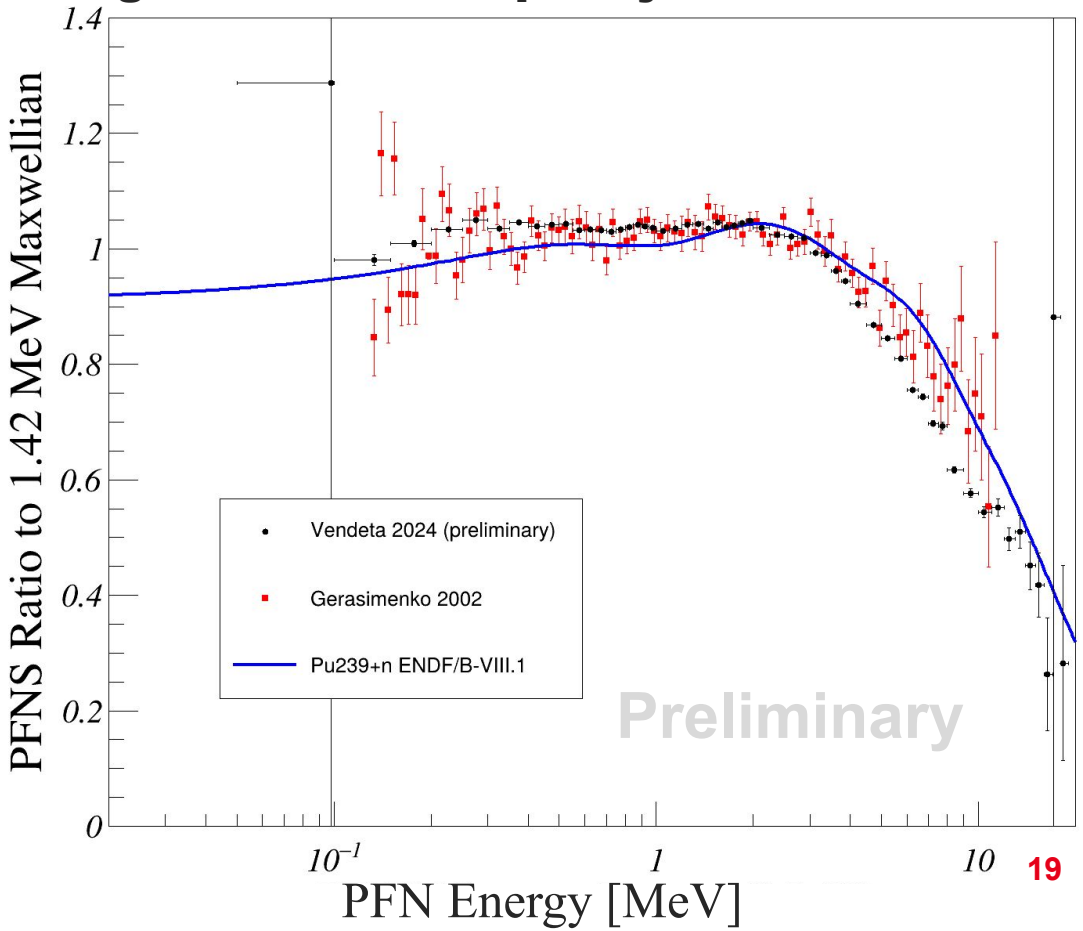


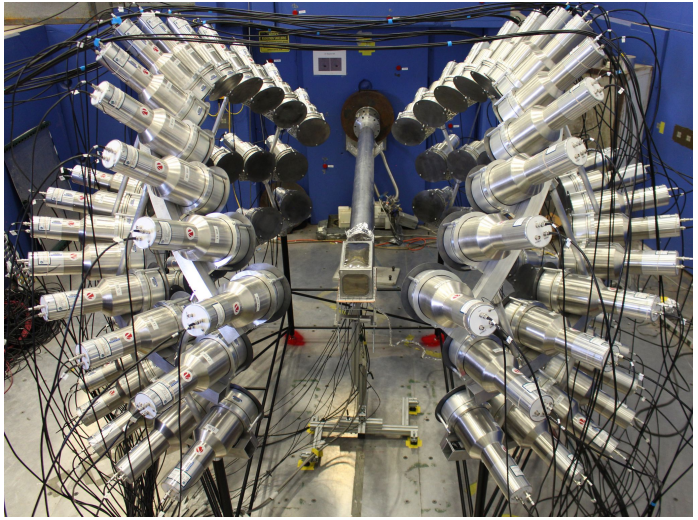
^{240}Pu(sf) Measurement : Average neutron multiplicity

Average neutron multiplicity :

$\bar{\nu}$ = 2.139 +/- 0.002

This measured value is 0.65% inferior compared to the most current ENDF/B-VIII.0 evaluation.





Thank you for your attention !
Feel free to ask any questions.

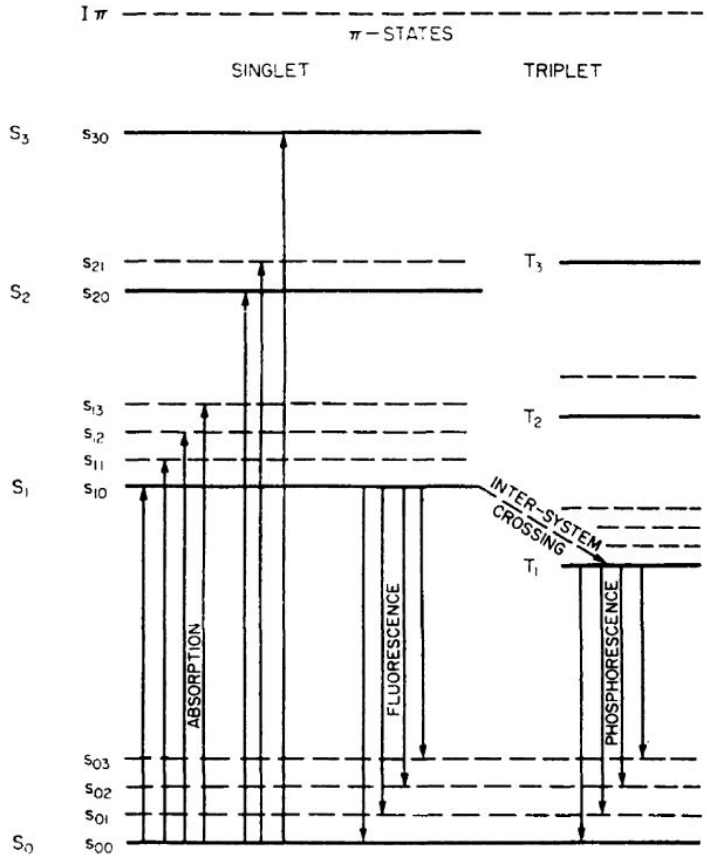
Further information : published article in Nuclear Instruments and Methods in Physics Research A 1081 (2026)

Contact information: owen.syrett@cea.fr

EuNPC 2025

A. Questions

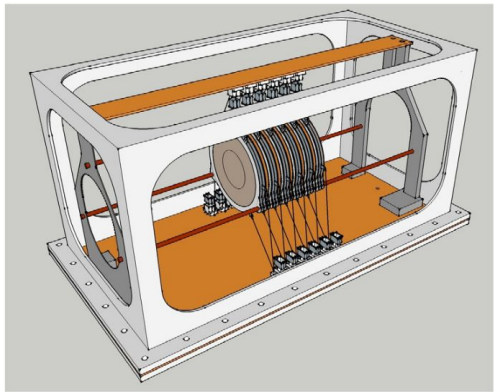
VENDETA : a Liquid Scintillator Array : organic scintillator excitation



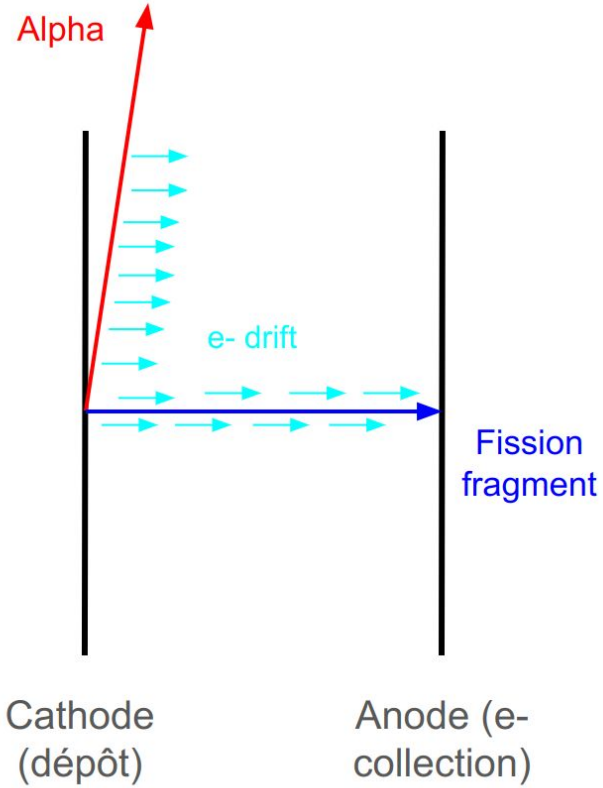
From G.F. Knoll, Radiation Detection and Measurement. Chapter 17

VENDETA : a Liquid Scintillator Array : fission detector

- Air-tight container for the studied actinide.
- Ionisation detector for fission events.
- Developed for high activity samples (100MBq).



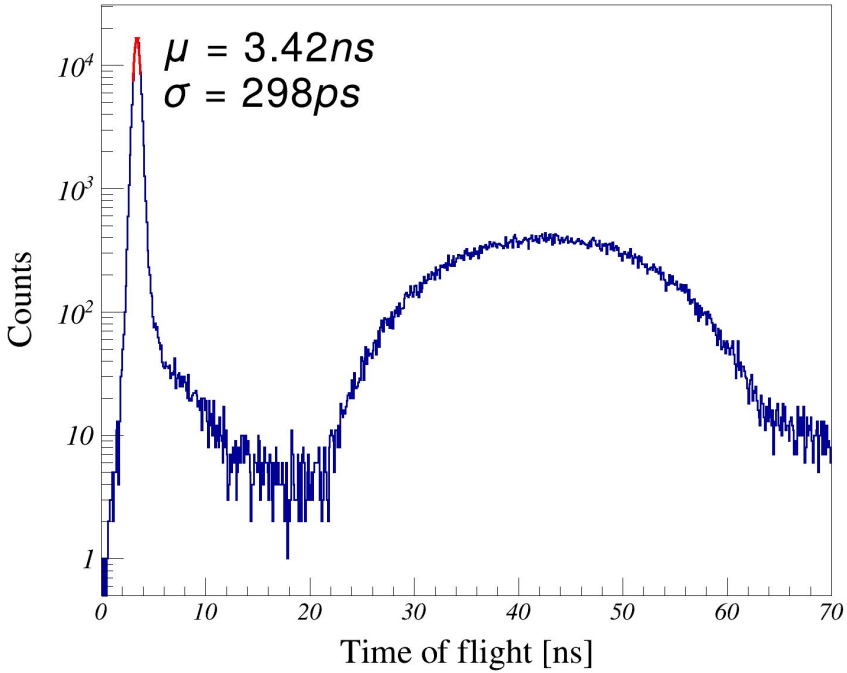
Fission chamber by B. Laurent et al.



Detection principal

Detection characteristics : Time-of-flight resolution

A time-of-flight spectrum

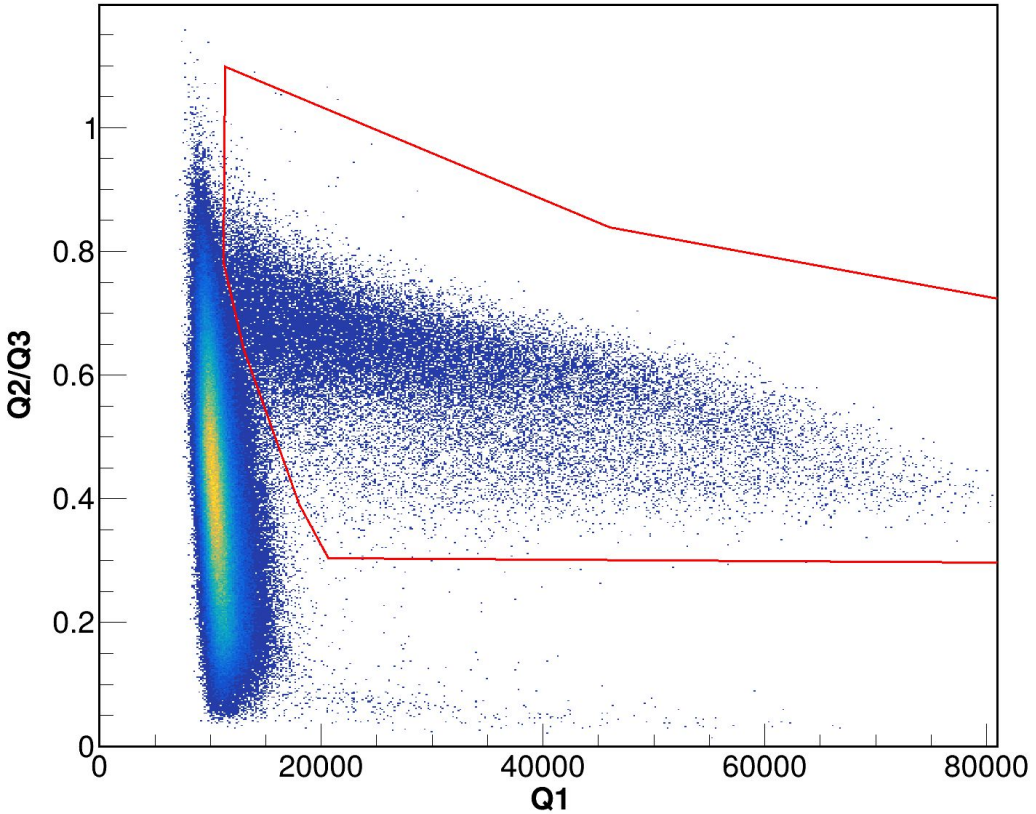


Detection characteristics : α/fission discrimination

- 100 MBq alpha activity.
- 5.7 spontaneous fission per seconde.

- Cut defined with the neutron coincidence rate in VENDETA array.

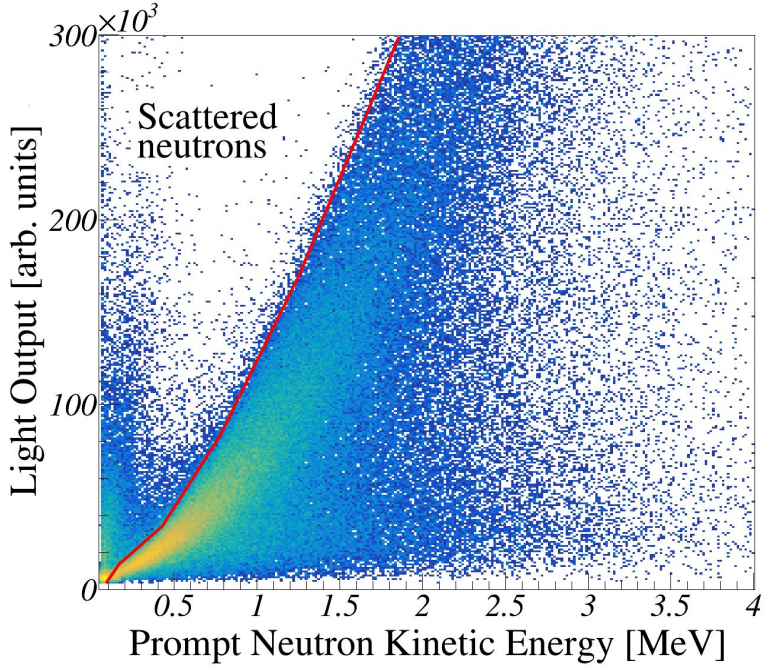
- Fission detection efficiency around 80%.



Detection characteristics : Applied corrections

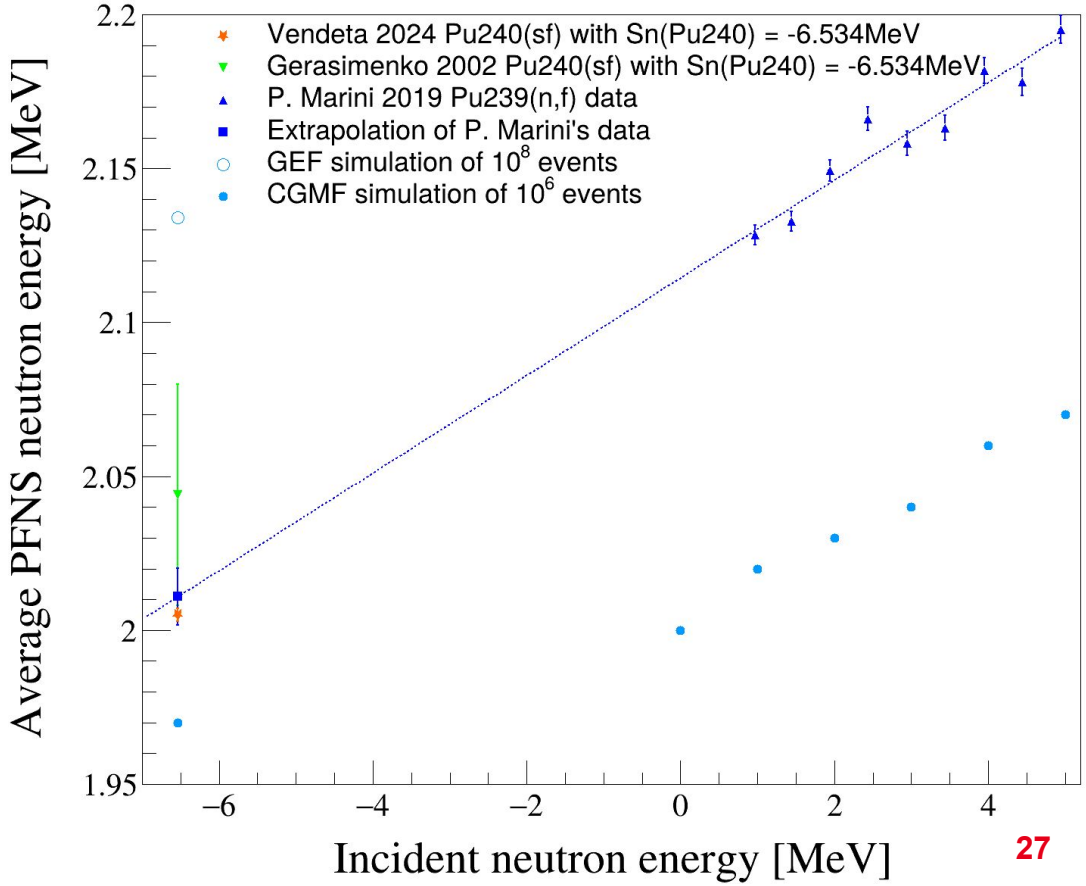
- Scattered neutrons are excluded.
- Background noise is measured with a fake trigger and subtracted.
- Detector's response is corrected for by a ^{252}Cf measurement to evaluate detector efficiency.
- Detector positions are corrected.
- Walk effect is corrected in the timing pick-up.
- Fission pile-ups are excluded.
- Losses due to VENDETA "dead-time" are taken into account.

Exemple de plot énergie/lumière pour un détecteur Vendeta



^{240}Pu(sf) Measurement : Average neutron energy ($\bar{E}$)

$\bar{E}_{240Pu} = 2.005 \pm 0.002$

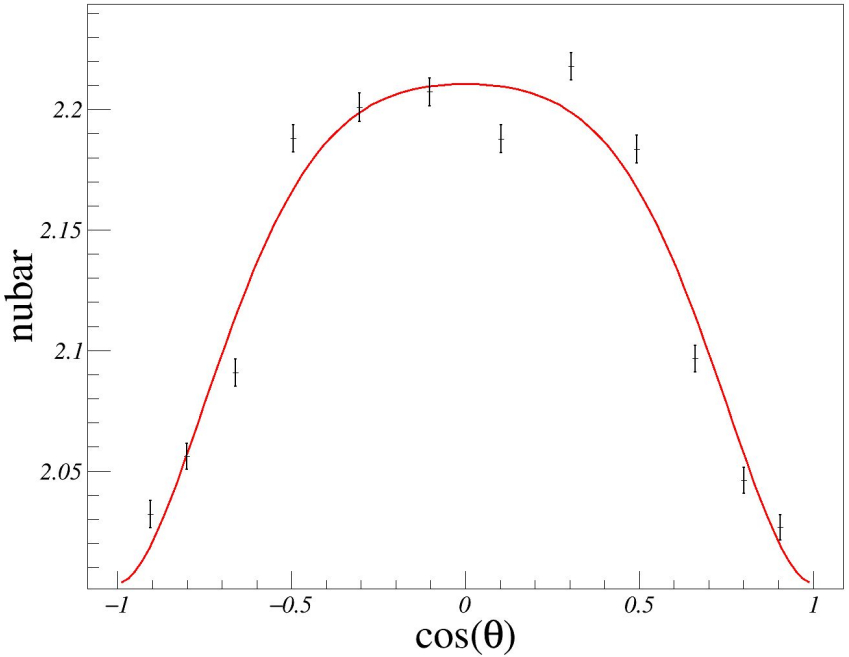


^{240}Pu(sf) Measurement : average neutron multiplicity ($\bar{\nu}$)

Latest result :

$\bar{\nu}$ = 2.139 +/- 0.002

0.65% inferior compared to ENDF evaluation.



^{240}Pu(sf) Measurement : average neutron multiplicity ($\bar{\nu}$)