Studying structure near the neutron emission threshold using the detectors TETRA and MONSTER at ALTO

Emile Cantacuzène

David Verney

Team FIIRST

Outline

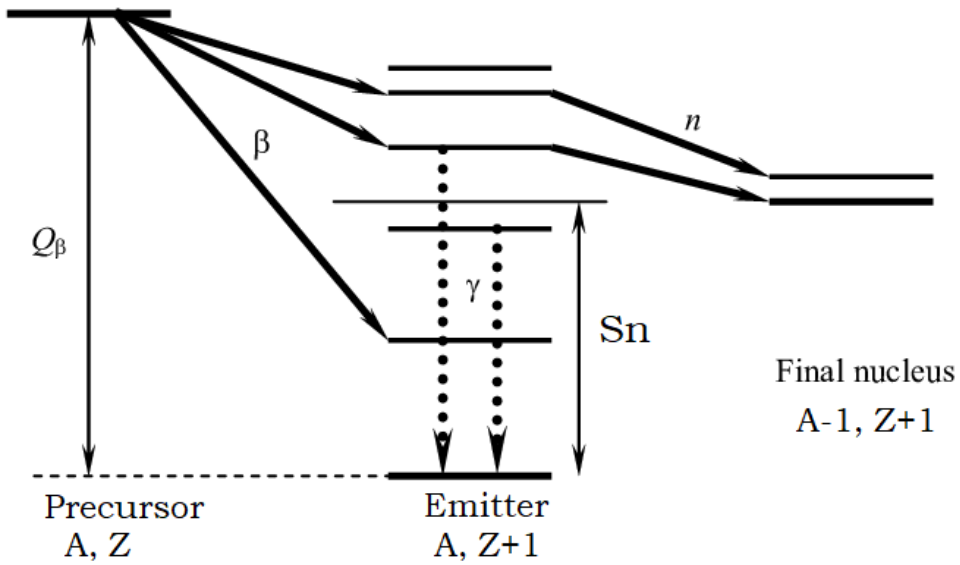
I. Structure near the neutron emission threshold

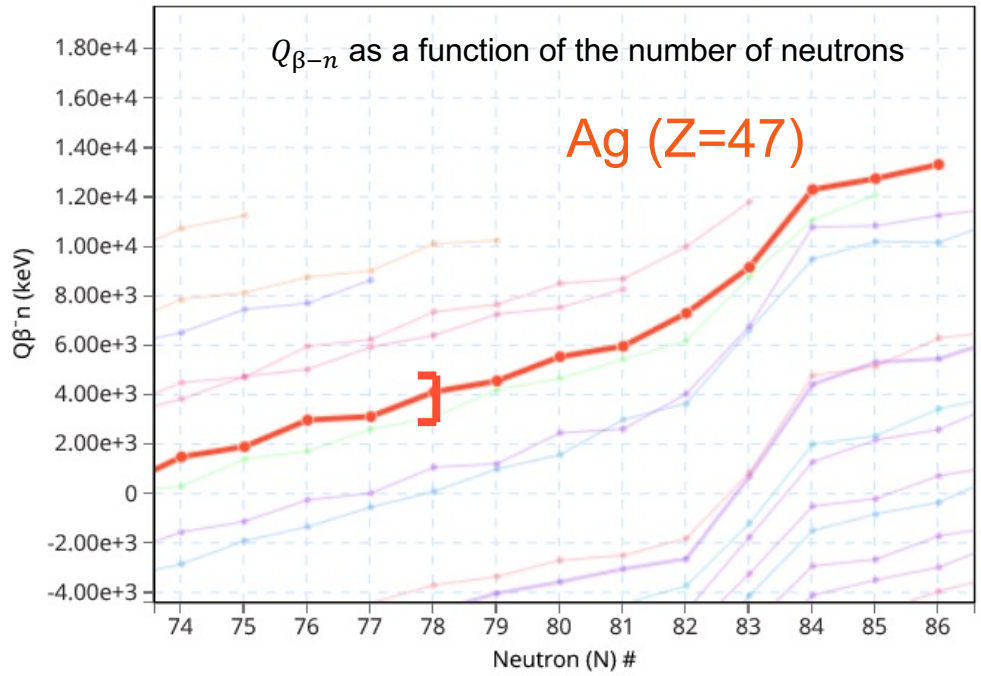
II. Experimental setup

III. TETRA simulation with Geant4

IV. TETRA data analysis from 2018 Indium experiment

Beta-delayed neutron emission

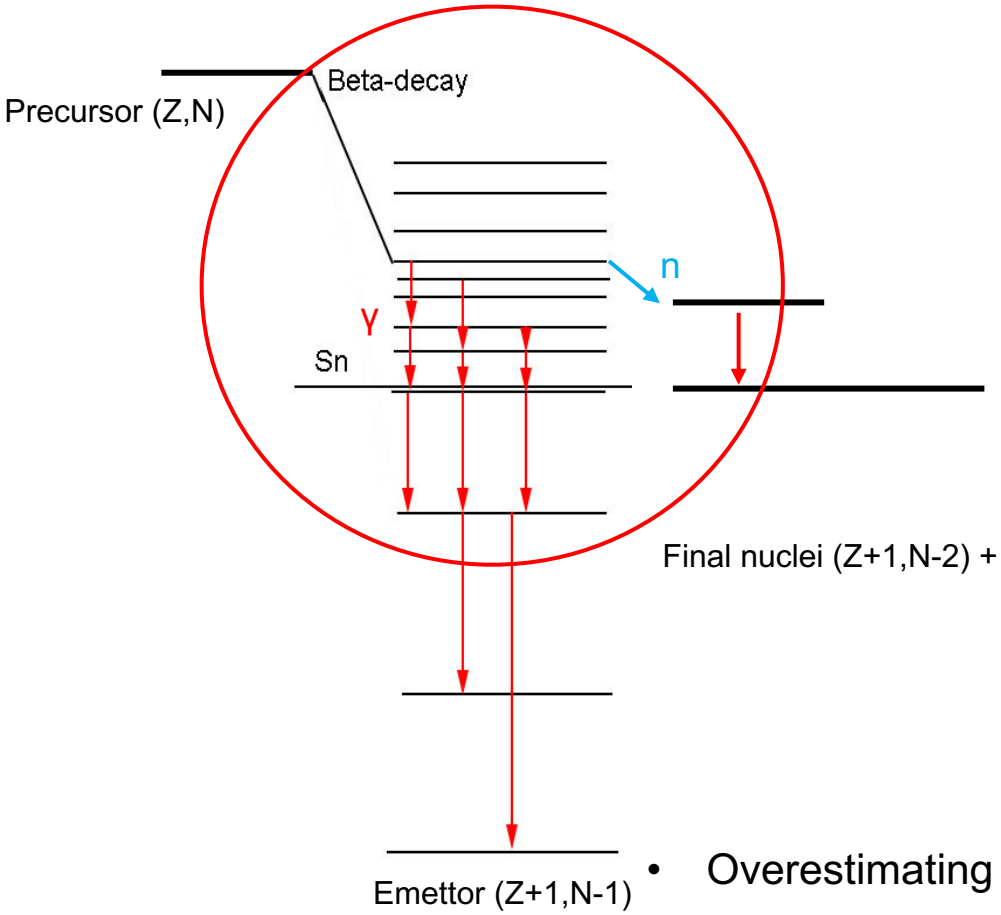




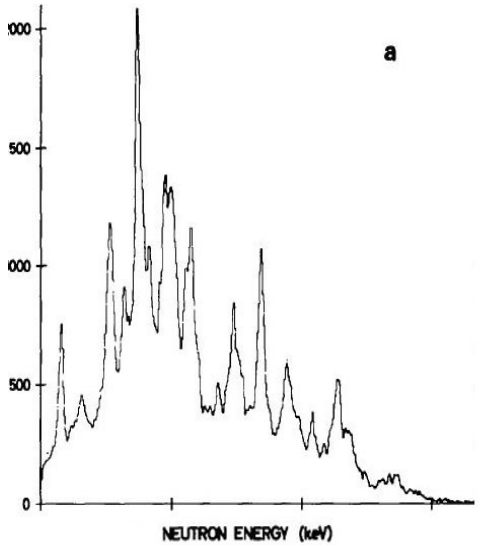
- $Q_{\beta-n} = Q_\beta - S_n$ ➡ Available energy for neutrons
- P_n: Probability for the daughter nucleus to emit a neutron after the beta decay

The statistical models

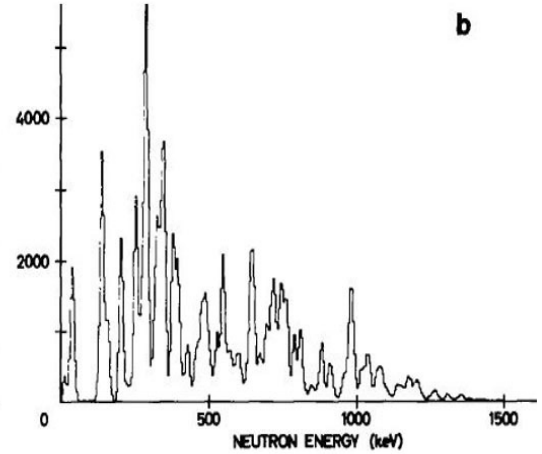
Completely statistical



Hardy et al. "The essential decay of pandemonium: β-Delayed neutrons" 1977



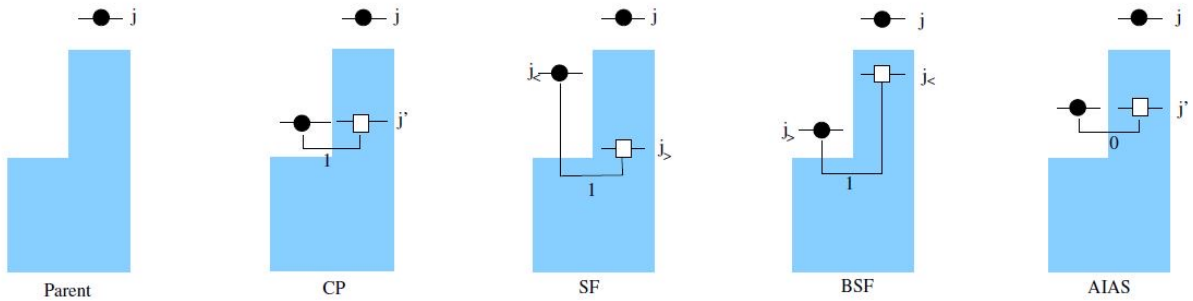
Experimental spectrum



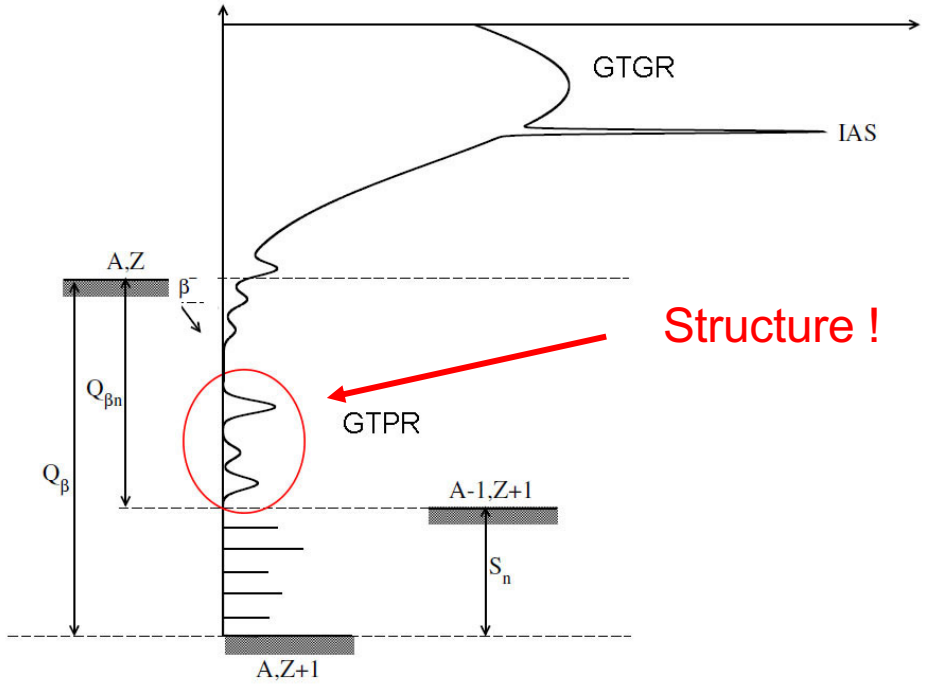
Pandemonium simulation

- Discret spectrum but bad prediction of P_n and $T_{1/2}$
- Overestimating the probability to populate levels under S_n : Pandemonium effect

Gamow-Teller « Doorway » transitions



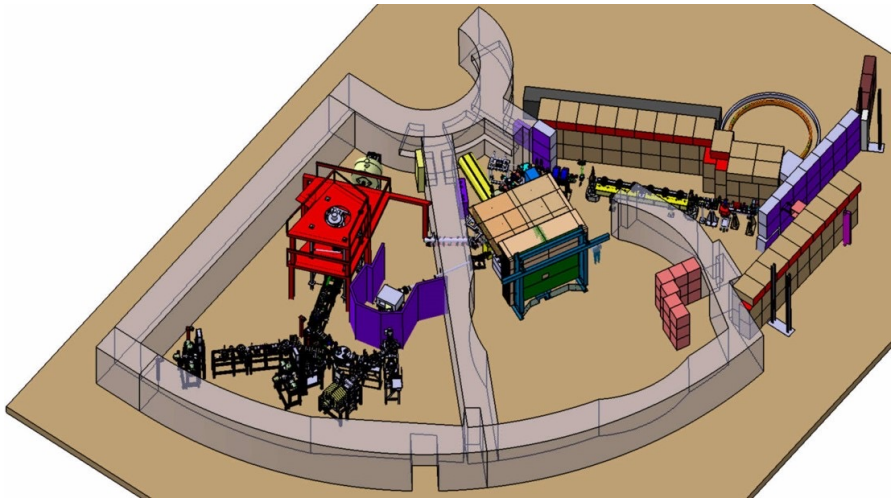
$$\Delta L = 0 \quad \Delta J = 0,1$$



- Better results for integrated properties in N = 50 region
- No overestimation of the population of levels under S_n

Statistical and Non Statistical Models for Delayed Neutron Emission : Application to nuclei near A=90 Z.M. De Oliveira (1980)

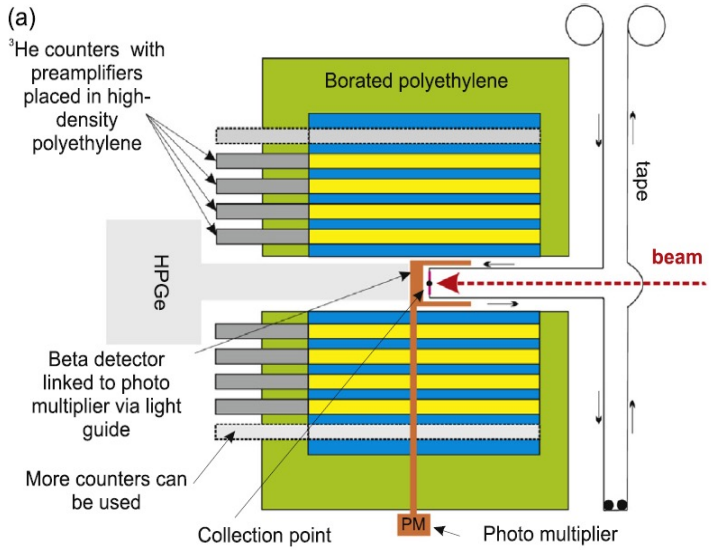
ALTO - LEB

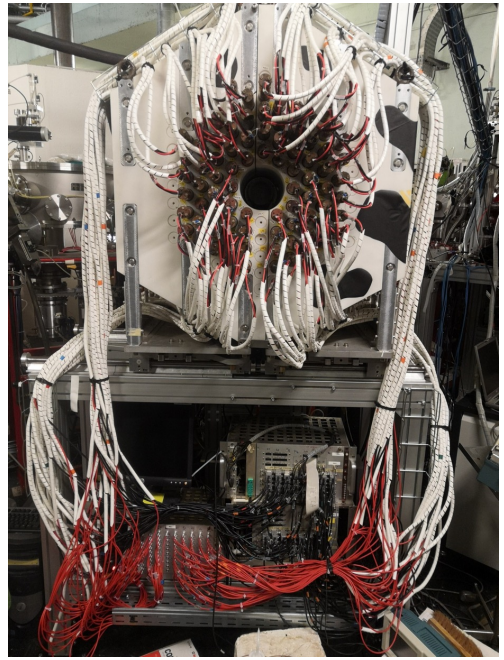


Beam production using ISOL technique

- Photofission
- Laser ionization
- Mass separation

Neutron counter : TETRA

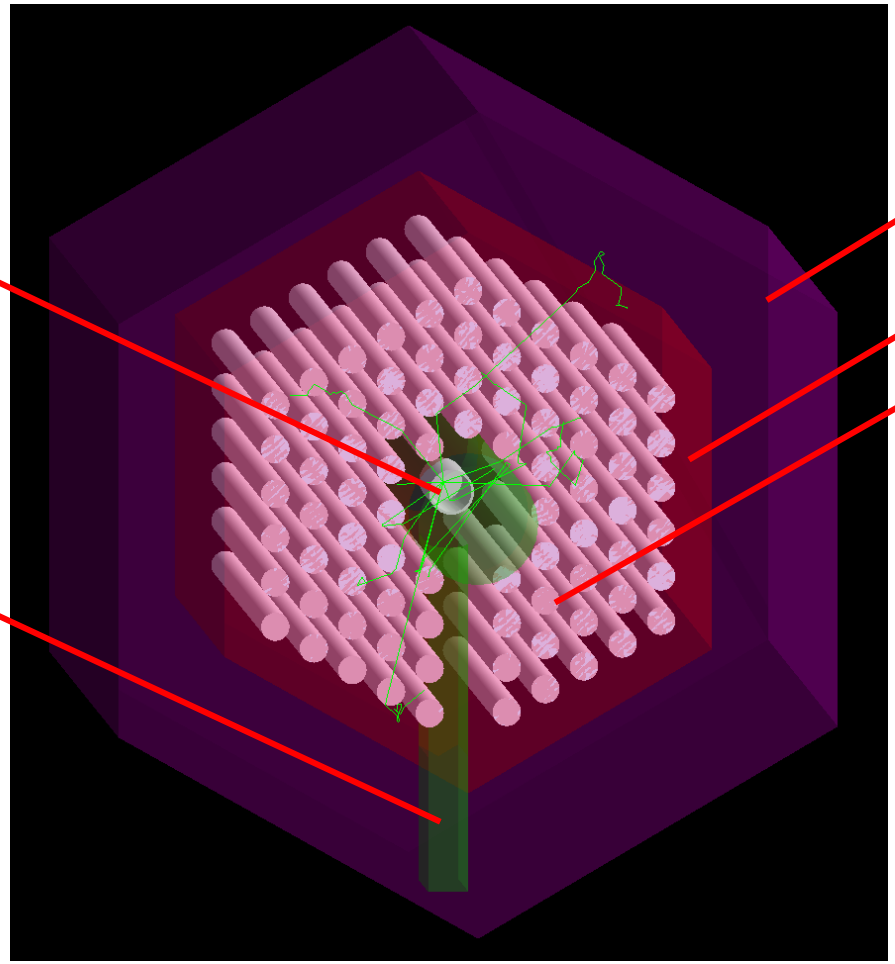




$$^3\mathrm{He} + \mathrm{n} \rightarrow {}^3\mathrm{H} + \mathrm{p} + 765\ \mathrm{keV}$$

Can TETRA provide neutron information ?

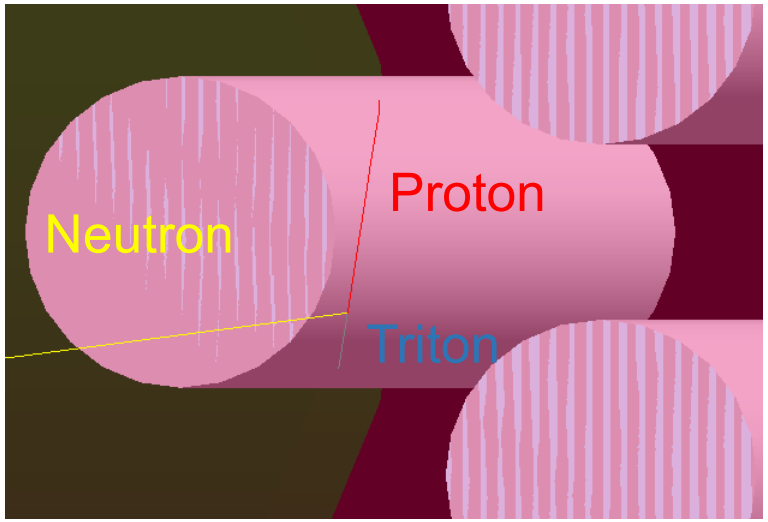
- 80 cells arranged in 4 rings
- 99% Helium 3, 1% CO2 mixture
- 7 bar in each cell



<u>Elements missing</u> :

- Germanium detector
- PMT
- Metal cover over all cells

TETRA's detection principle



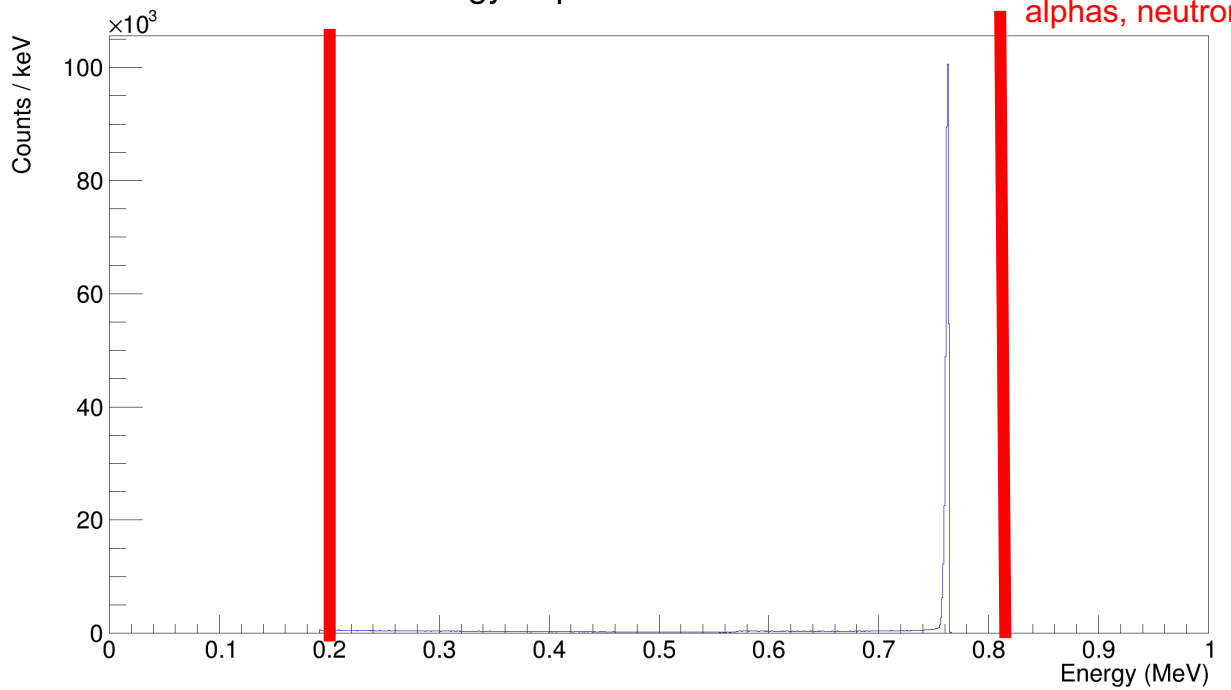
Zoom on a Helium 3 cell

$$^{3}\mathrm{He} + \mathrm{n} \rightarrow {}^{3}\mathrm{H} + \mathrm{p} + 765\ \mathrm{keV}$$

Around 5400 barns at thermal energies

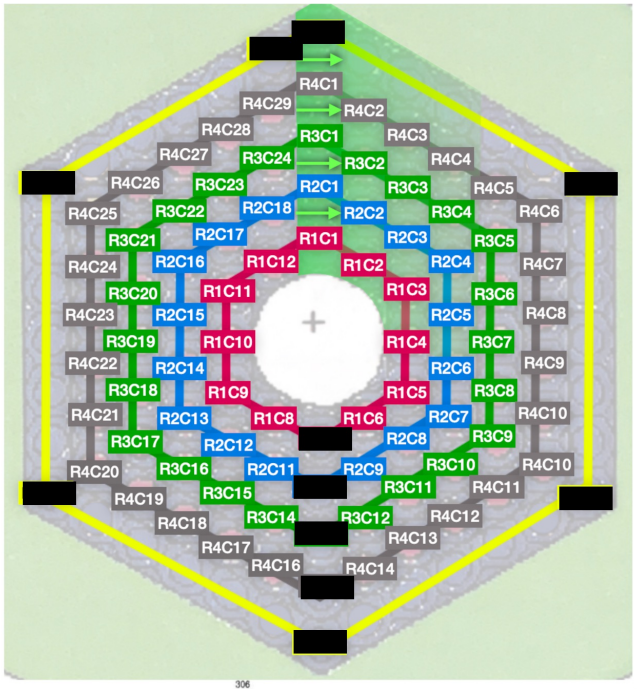
Low energy threshold: gamma pile-up, noise

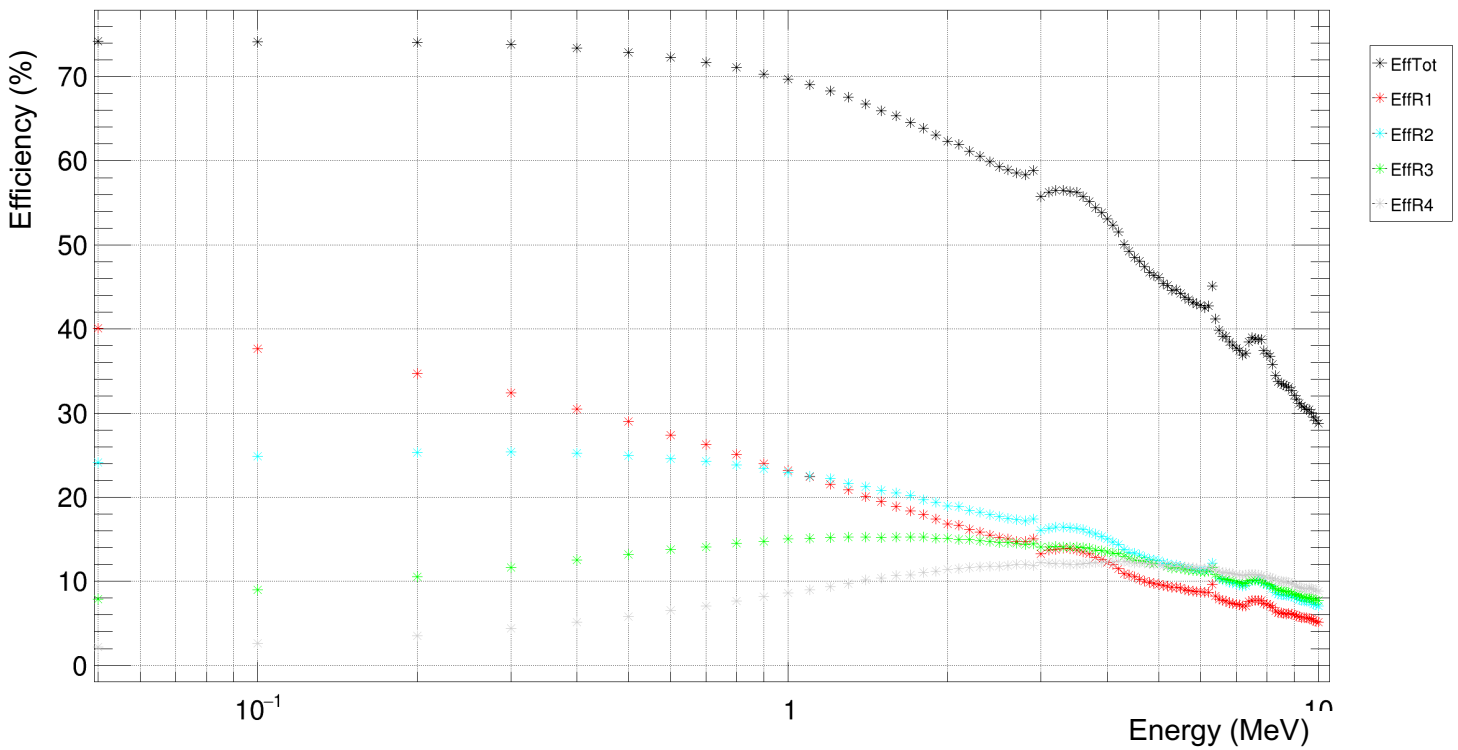
High energy threshold : Sparks, alphas, neutrons



Low energy tail ➡ Events were the secondary particles left the cell before depositing all their energy

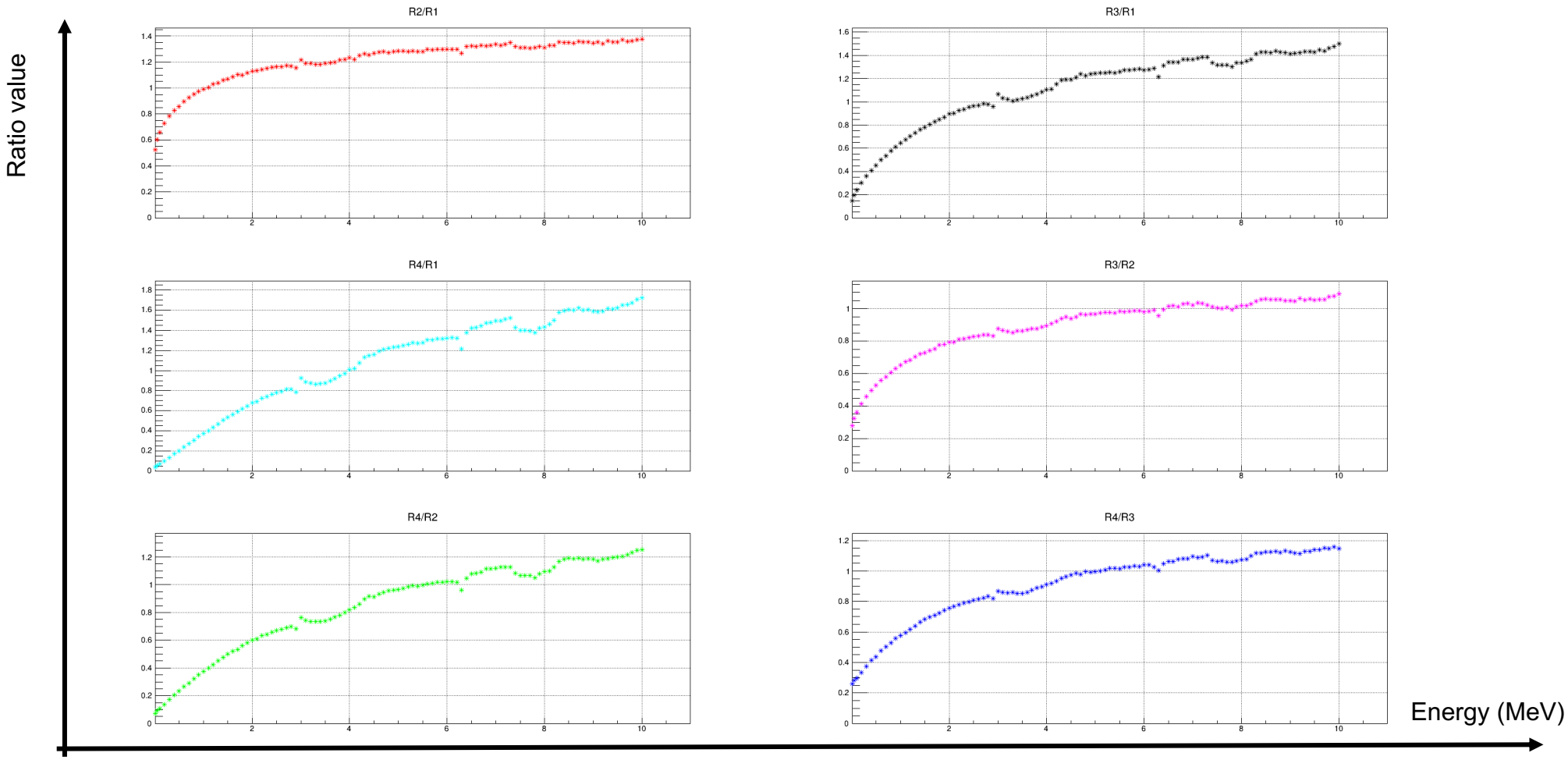
TETRA efficiency per ring





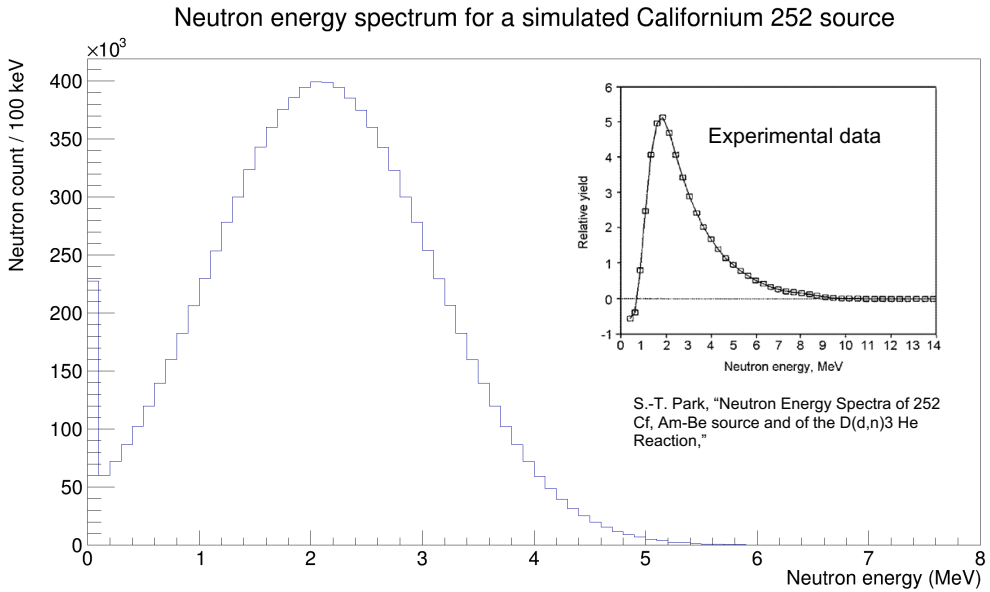
- The efficiency per ring changes with the neutron energy
- Can a link between ring efficiency and mean neutron energy be made ?

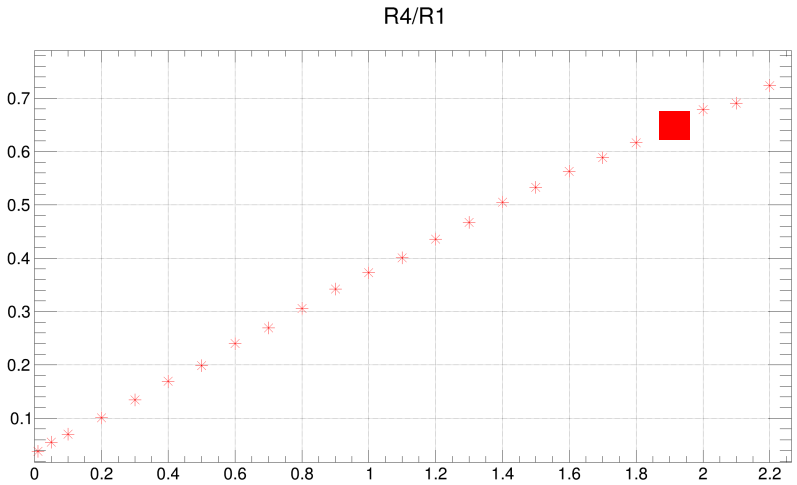
TETRA ring ratios

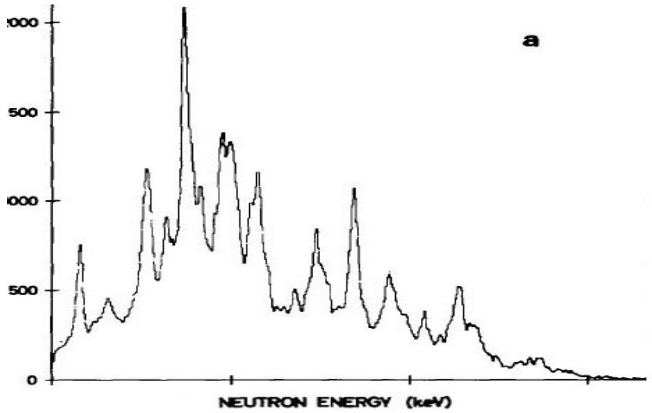


Different sensitivities for energy regions ➡ Optimize TETRA's geometry to the energy region

Different energy distributions







R4/R1 = 0.66 ➡ E = 1.95 MeV ≠ 2.1 MeV

Is an average of all ratios better ?

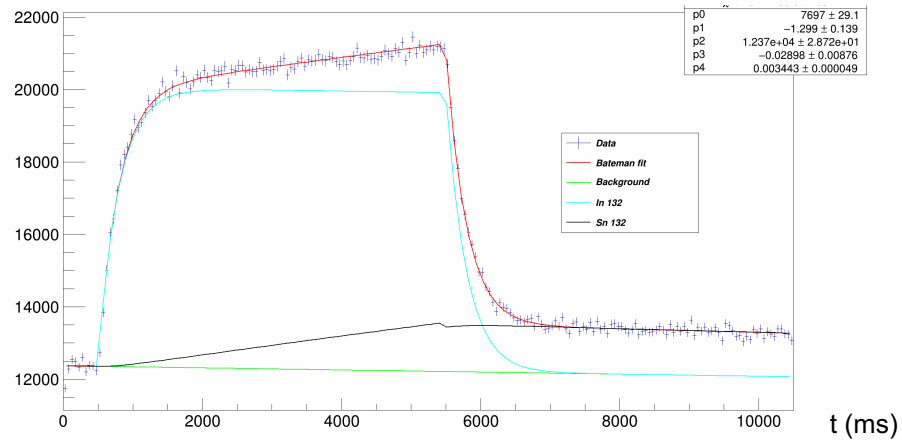
Would it work for a peak schemed distribution ?

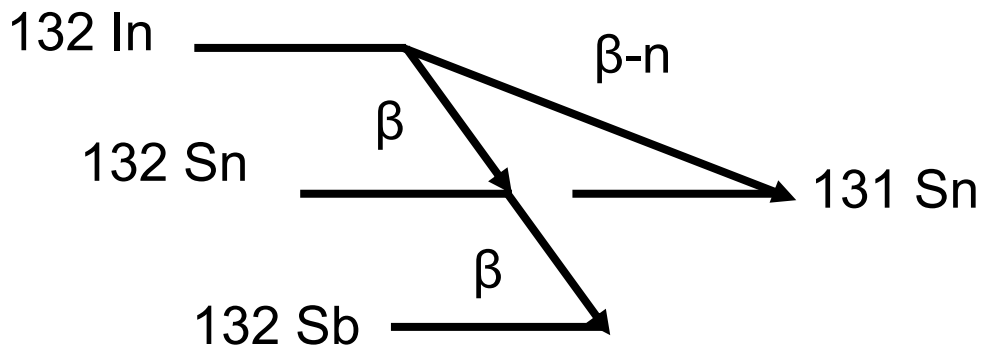
➡
- Still a lot to be tested
- Comparing to MCNP simulations would be great

Indium 132 Data analysis

Number of events

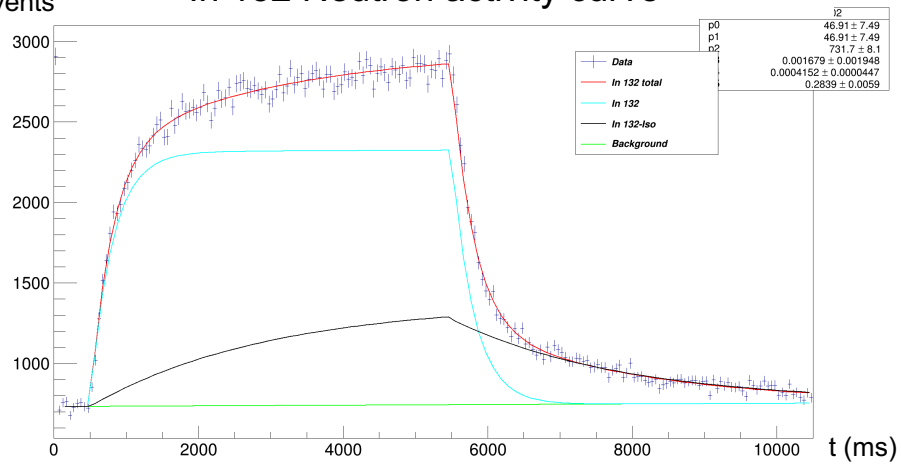
In 132 Beta activity curve





Number of events

In 132 Neutron activity curve



$$P_n = \frac{N_{tot\,n}}{N_{tot\,\beta}} = \frac{\frac{N_{\exp n}}{\varepsilon_n}}{\frac{N_{\exp \beta}}{\varepsilon_\beta}} = \frac{N_{\exp n}}{N_{\exp \beta}} \times \frac{\varepsilon_\beta}{\varepsilon_n}$$

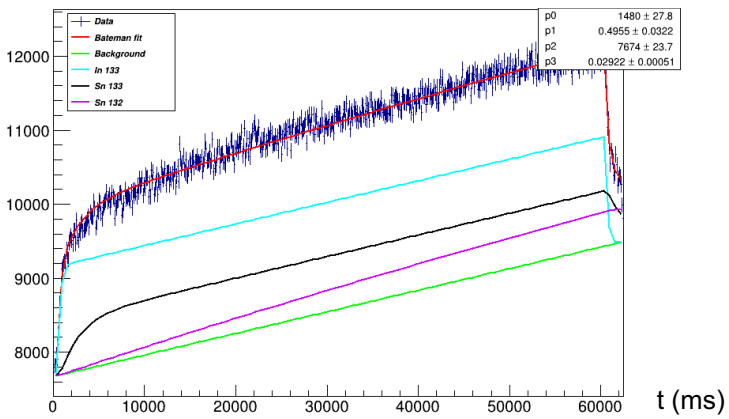
<u>By solving Bateman equations :</u>

$$P_n(In\ 132) = 17 \pm 5\%$$

Indium 133 Data analysis

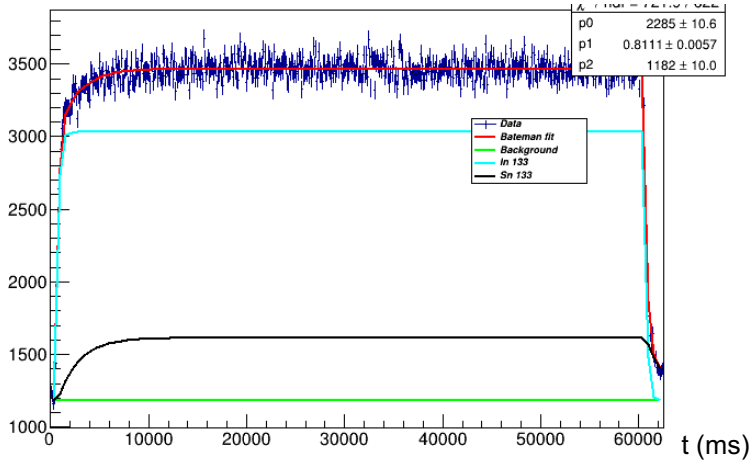
Number of events

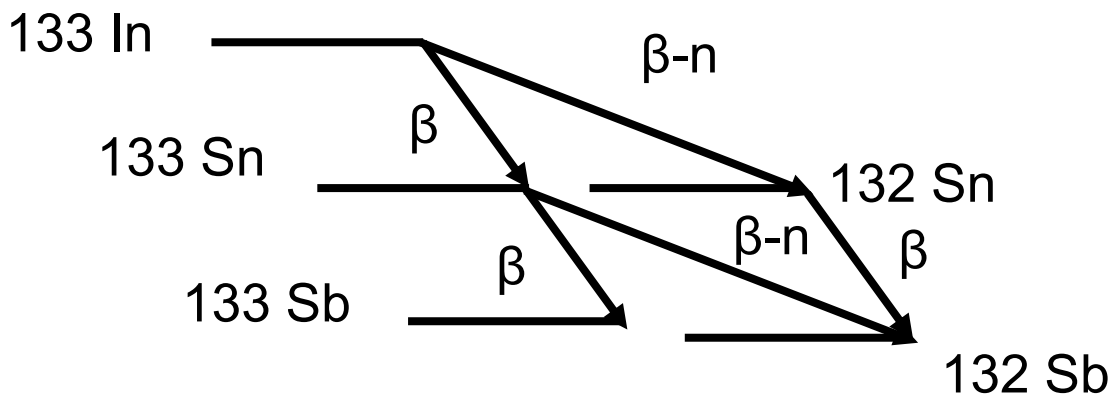
In 133 Beta activity curve



Number of events

In 133 Neutron activity curve





$$P_n(In\ 133) = 75 \pm 13\%$$

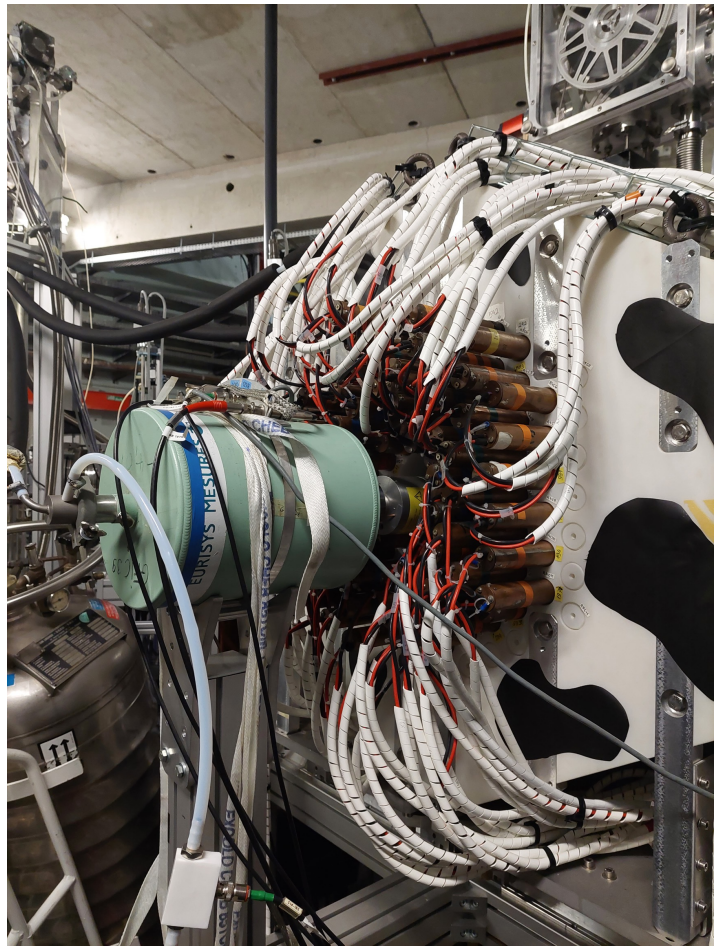
➡ Uncertainties coming mainly from TETRA efficiency

$$\frac{P_n(In\ 133)}{P_n(In\ 132)} = 4.5 < 13.5 \text{ on ENSDF}$$

Coming up

Beam time at ALTO in April for Silver 122 and more…

>COeCO and TETRA getting ready

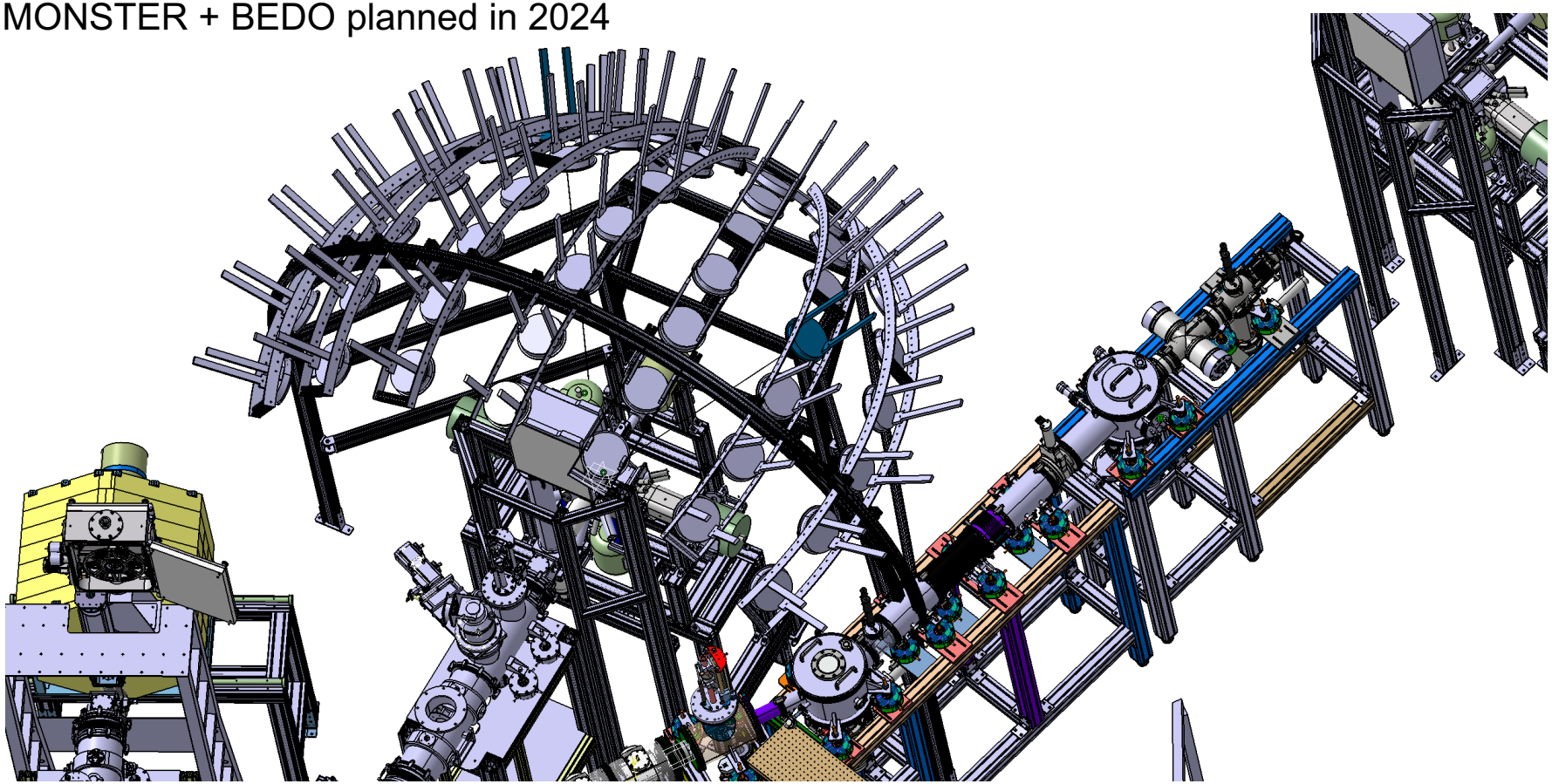


Coming up

MONSTER @ ALTO

> Structure installation in summer 2023

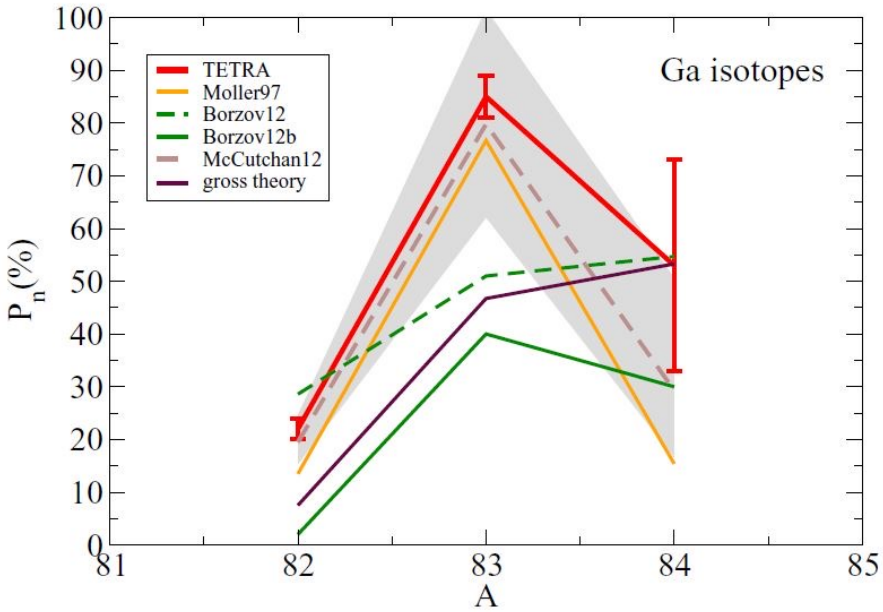
> Experiment MONSTER + BEDO planned in 2024

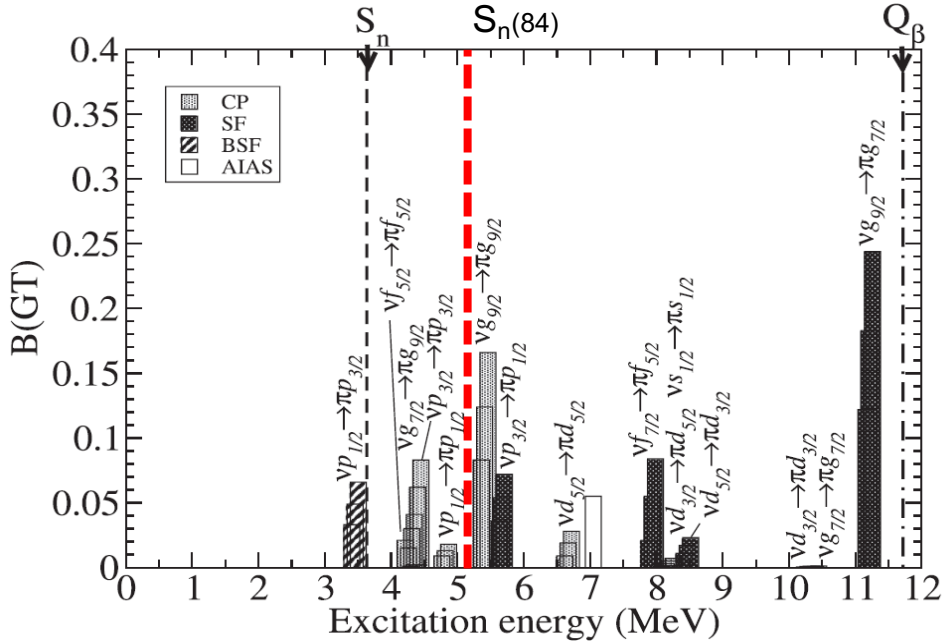


Thank you for your attention

Back up slides

Galium (Z=31) systematics





Verney et al. “Pygmy Gamow-Teller resonance in the N = 50 region: New evidence from staggering of β-delayed neutron-emission probabilities” 2017

Structure revealed