Studying structure near the neutron emission threshold using the detector TETRA at ALTO

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Outline

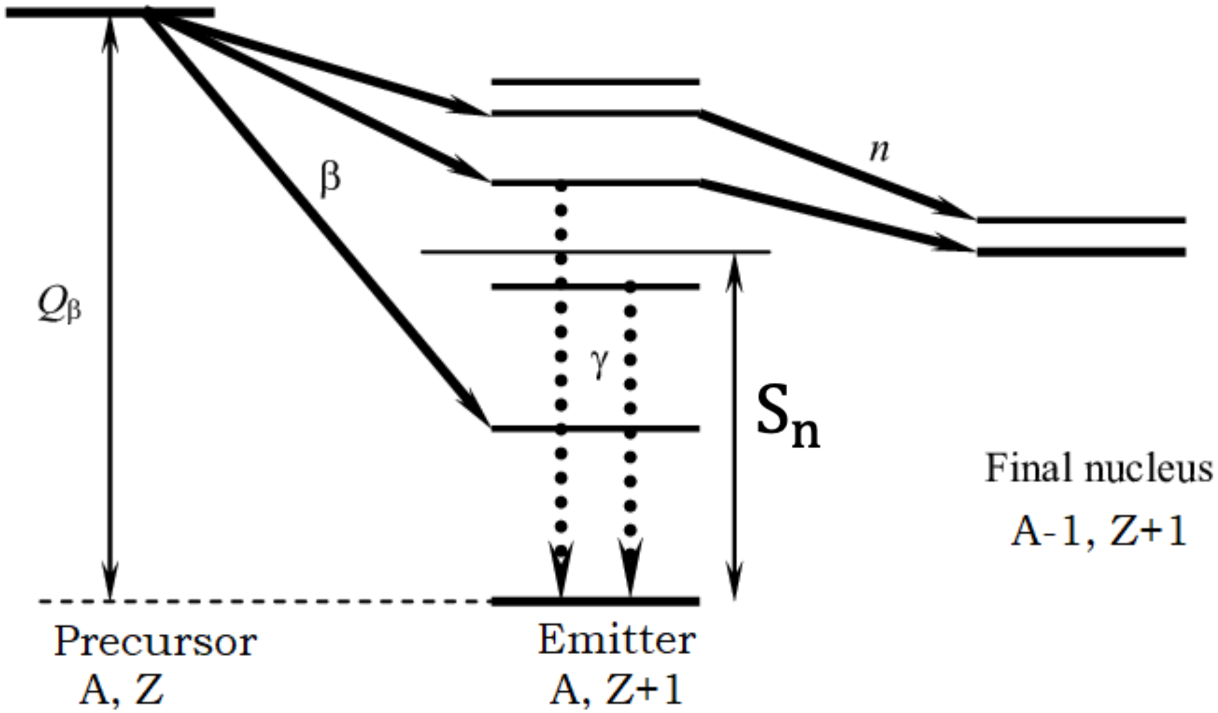
I. Structure near the neutron emission threshold

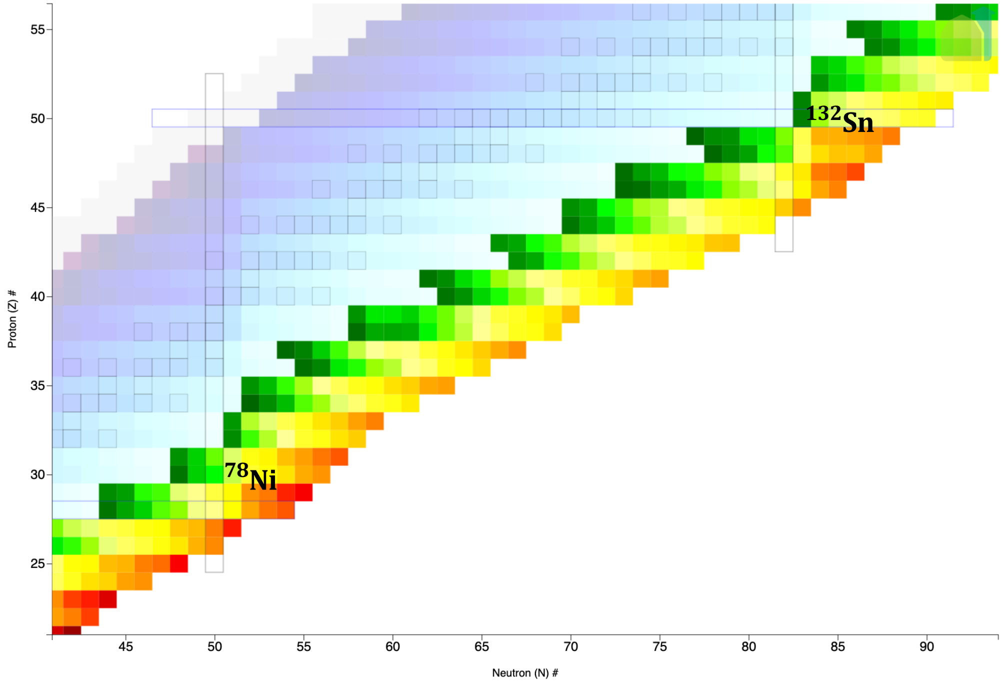
II. Experimental setup

III. Analysis of ^{82}Ga and ^{84}Ga - First results

IV. Perspectives

Beta-delayed neutron emission



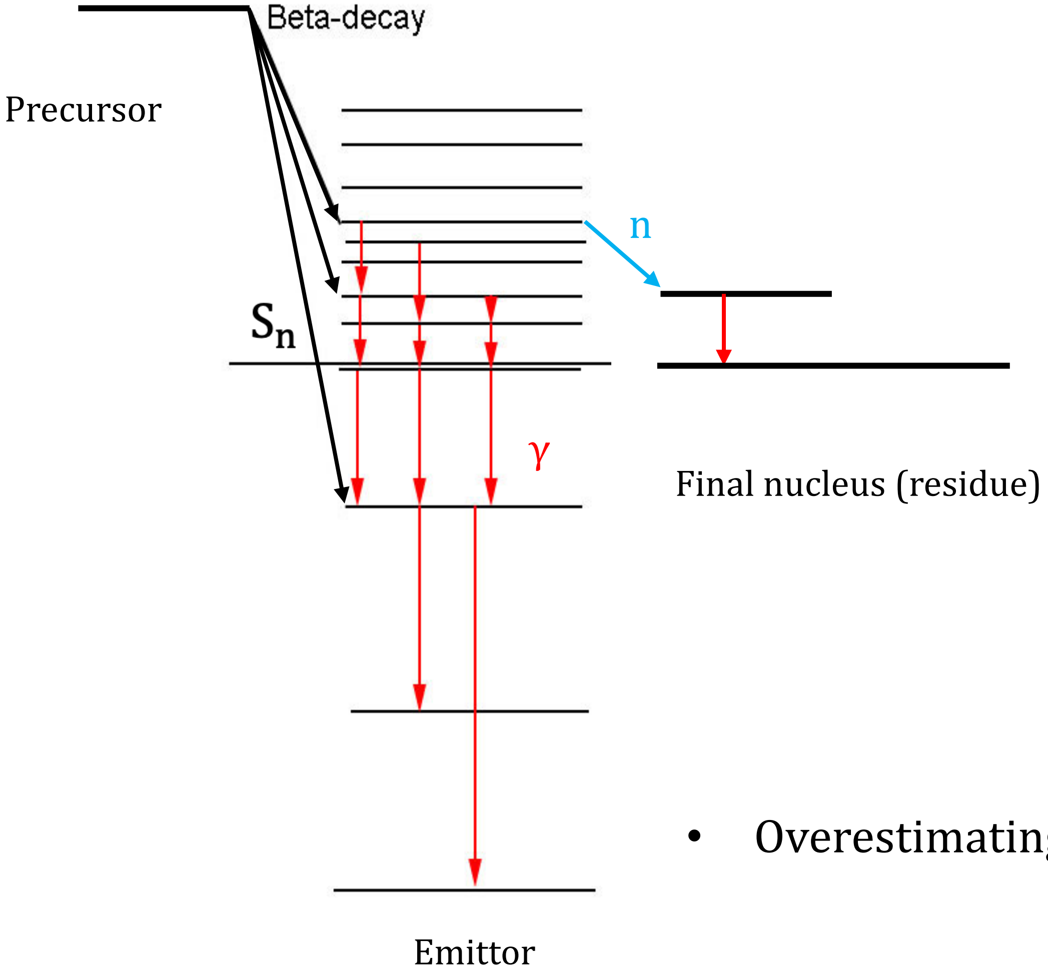


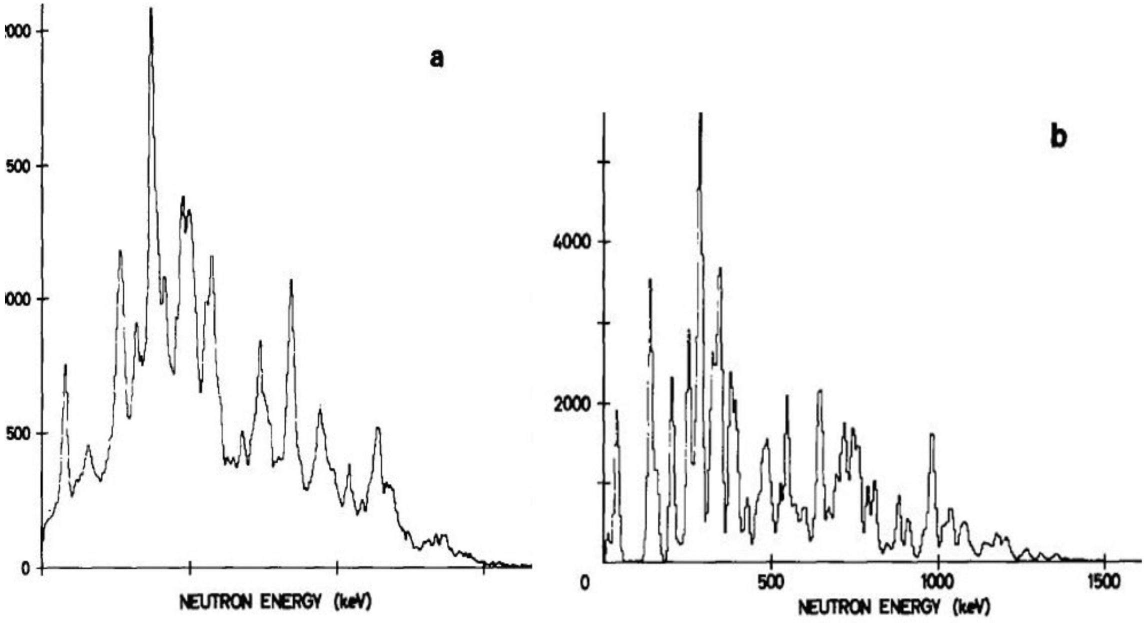
Beta-delayed neutron precursors

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

cf. "Further Observations on the Splitting of Uranium and Thorium" Roberts et al. (1939)

The statistical models



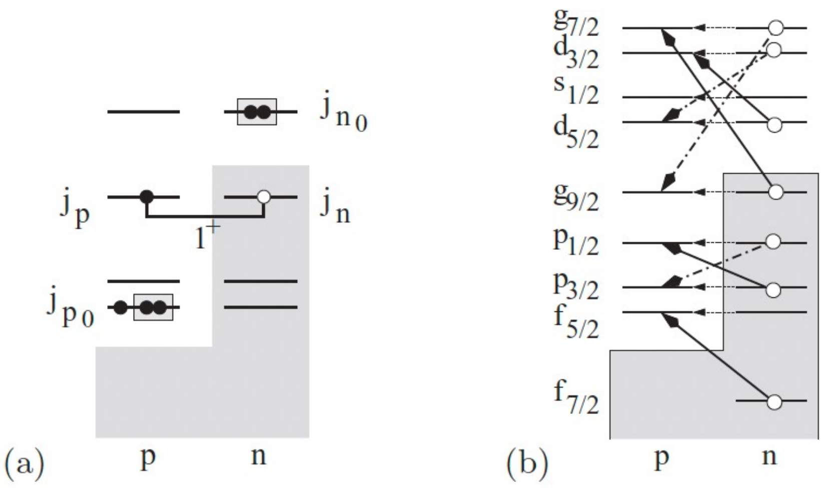


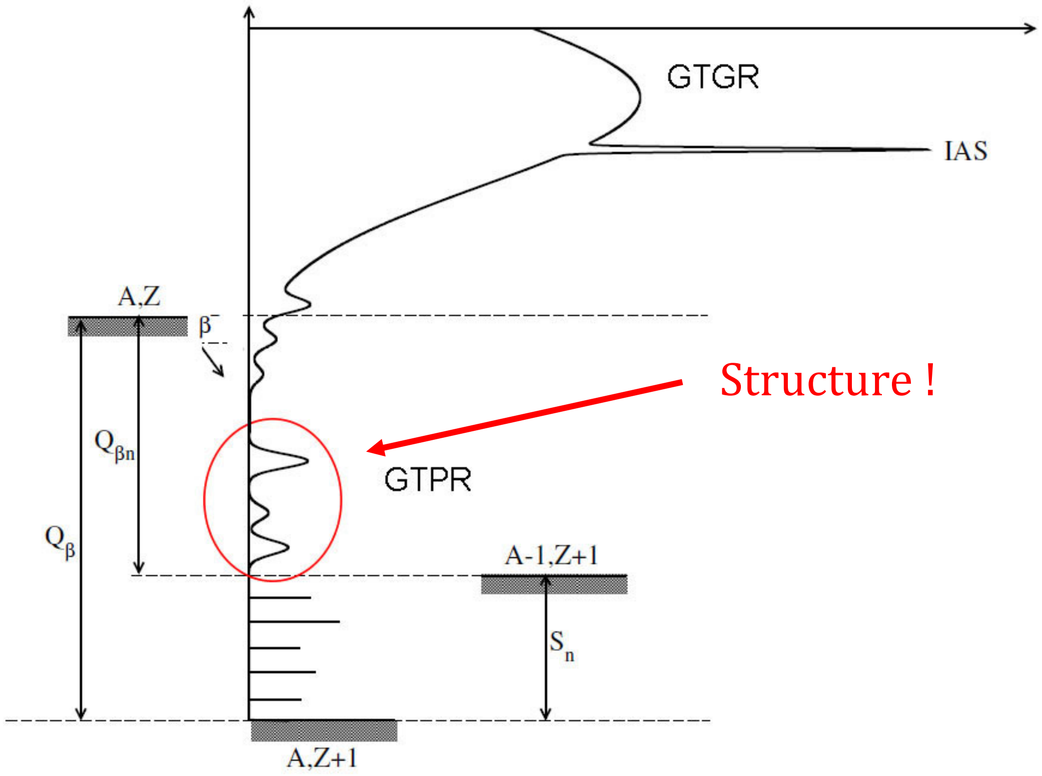
Experimental spectrum   Pandemonium simulation

- Overestimating the probability to populate levels under S_n : Pandemonium effect

cf. "The essential decay of pandemonium: β-Delayed neutrons" Hardy et al. (1977)
cf. "Calculation of delayed-neutron energy spectra in a quasiparticle random-phase approximation–Hauser-Feshbach model" Kawano et al. (2008)

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

cf. "Pygmy Gamow-Teller resonance in the N = 50 region: New evidence from staggering of β-delayed neutron-emission probabilities" Verney et al. (2017)
cf. 'Evidence of non-statistical neutron emission following β-decay near doubly magic 132Sn" Heidemann et al. (2023)
***PRL accepted** : cf. 'Compound-nucleus and doorway-state decays of β-delayed neutron emitters 51,52,53K" Xu et al. (2024)*

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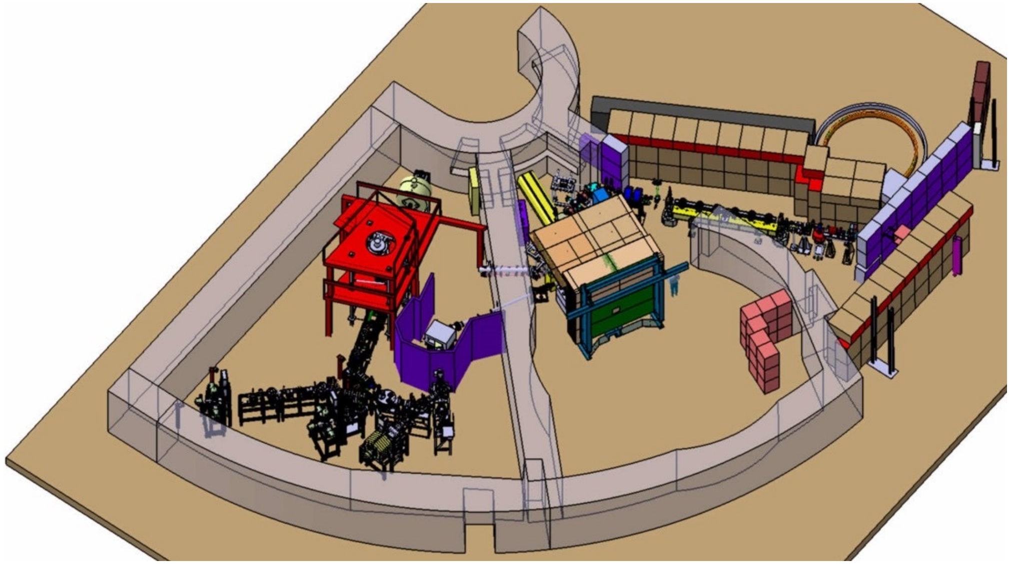
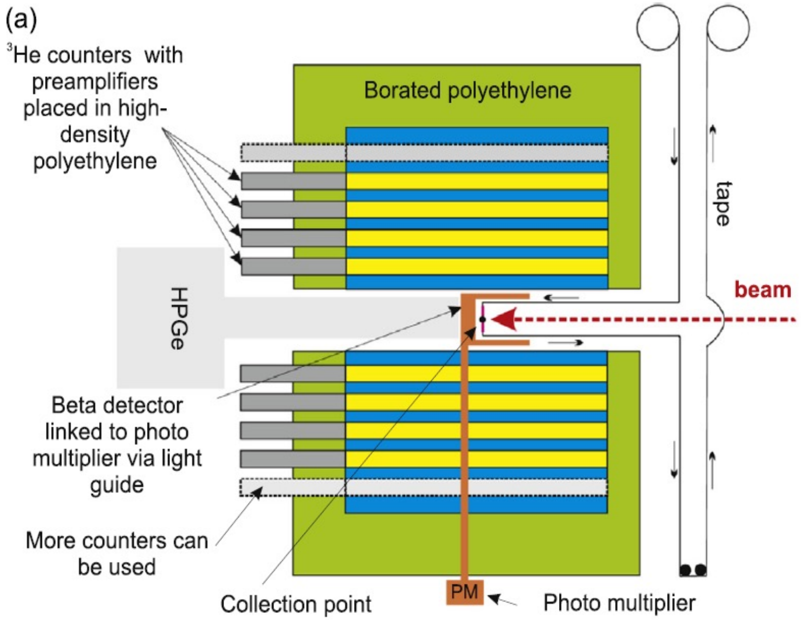
ALTO - LEB

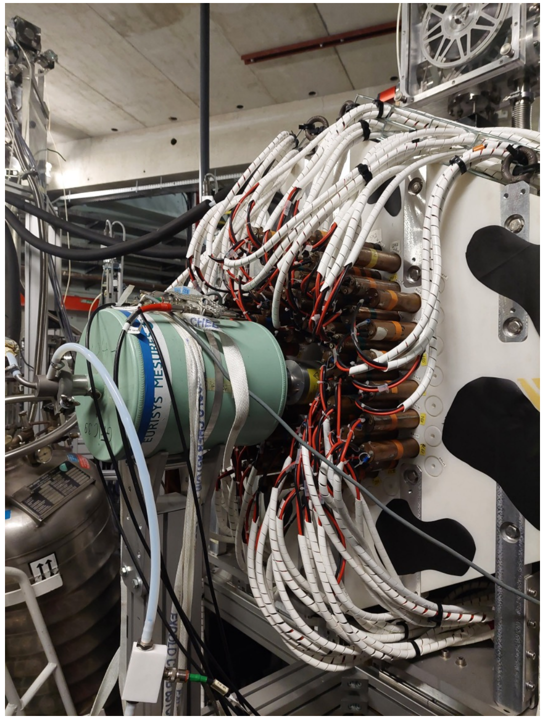


Beam production using ISOL technique

- Photofission
- Laser ionization
- Mass separation

TETRA decay station





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

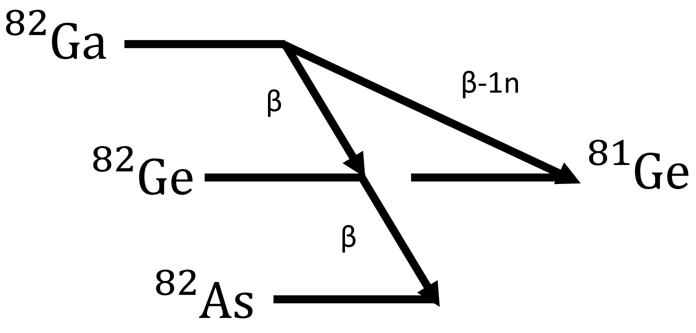
Around 5400 barns at thermal energies

Calibration isotope : ^{82}Ga

$Q_{\beta-n} = 5.290\ MeV$

$(T_{\frac{1}{2}} = 600\ ms)$

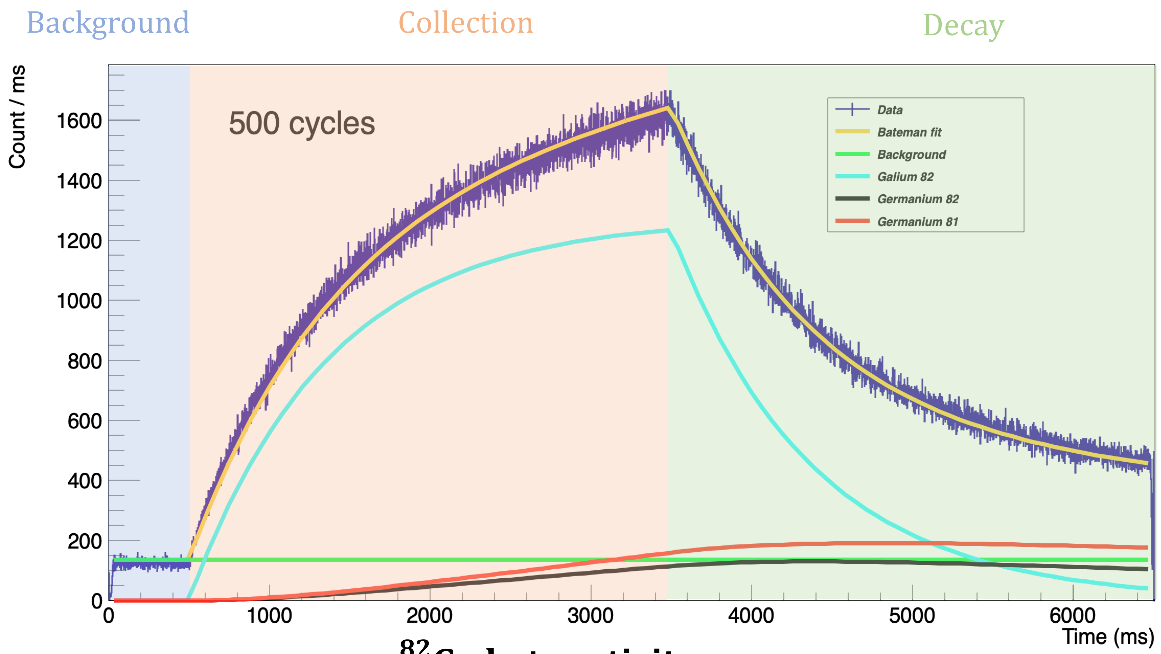
$$P_n = \frac{N_n}{N_\beta} \times \frac{\varepsilon_\beta}{\varepsilon_n} = 22.6 \pm 1\ \%$$



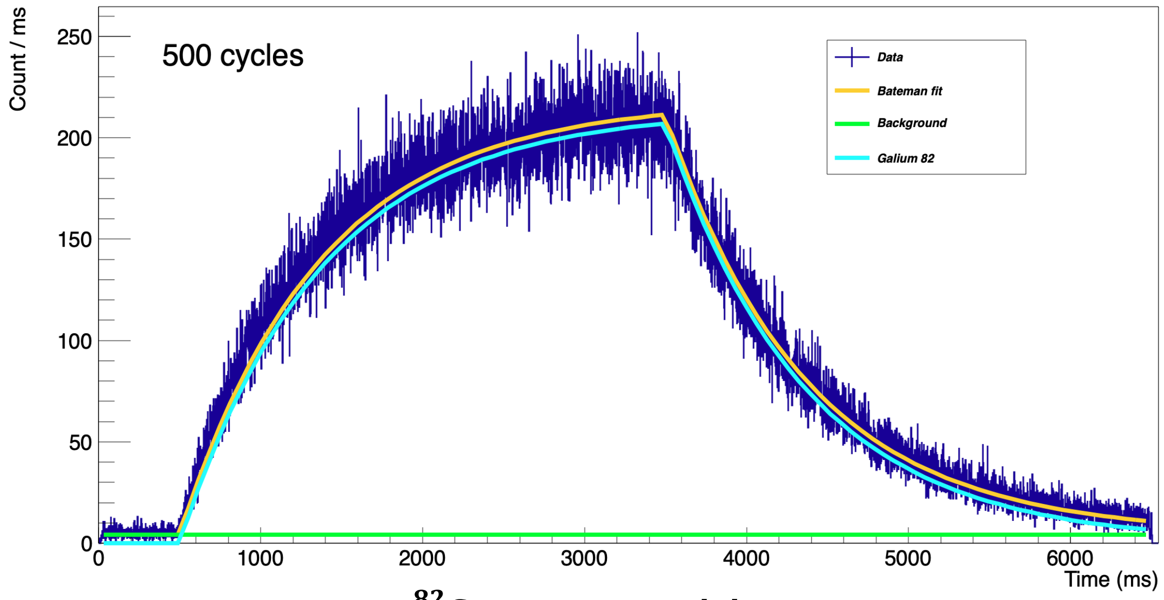
$\varepsilon_{4\pi\beta} = 73 \pm 2\ \%$

$\varepsilon_{Tetra} = 54 \pm 2\ \%$

cf. Dmitry Testov's PhD thesis (2014)



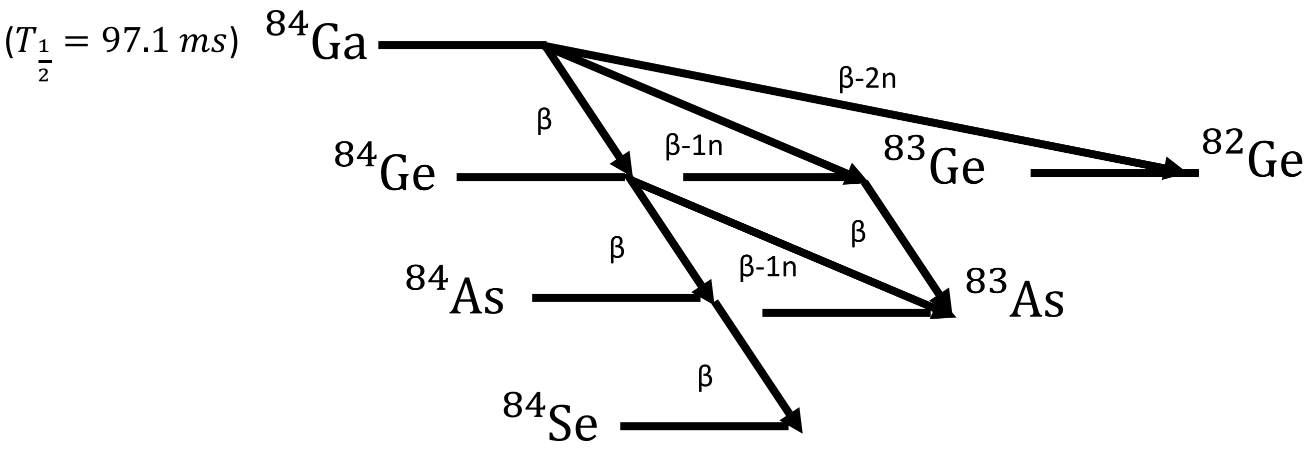
^{82}Ga beta activity

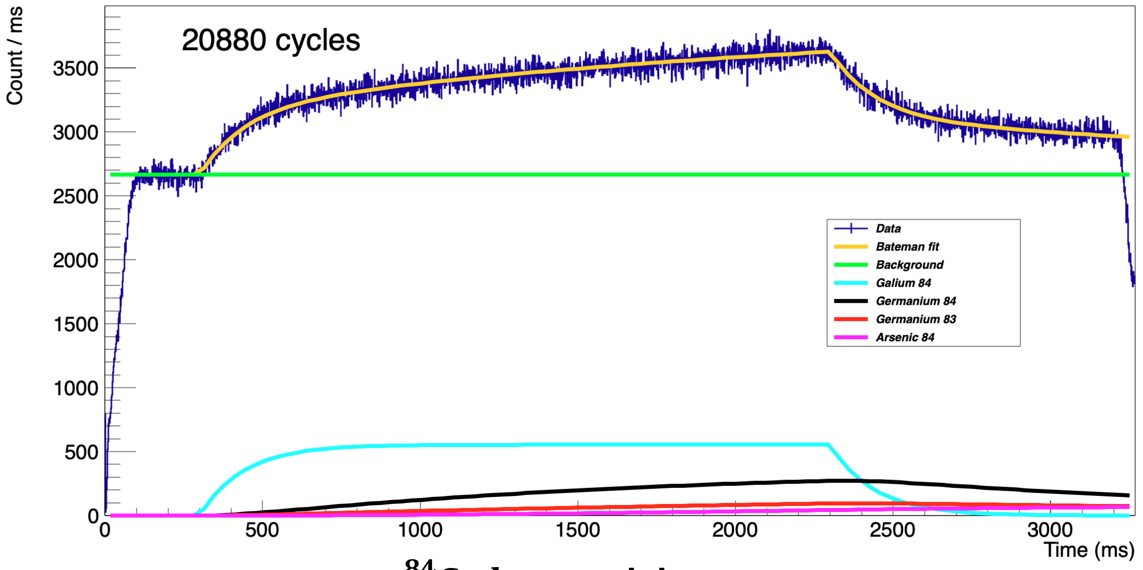


^{82}Ga neutron activity

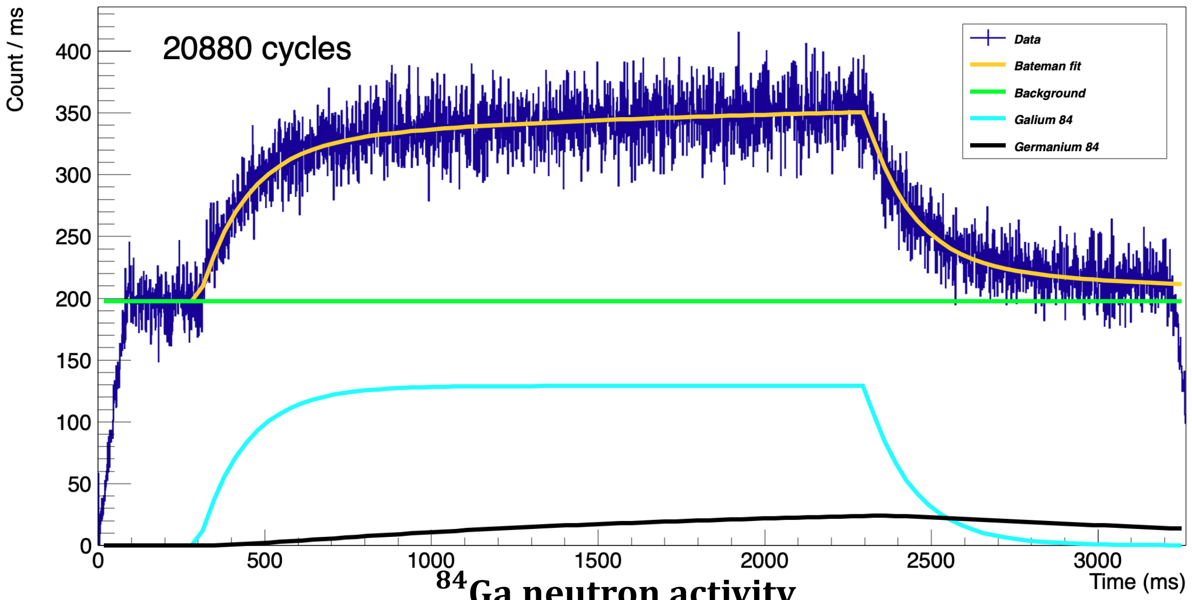
$Q_{\beta-1n} = \mathbf{8.811\ MeV}$

$P_n = P_{1n} + P_{2n} = 36.8\ \%$





^{84}Ga beta activity

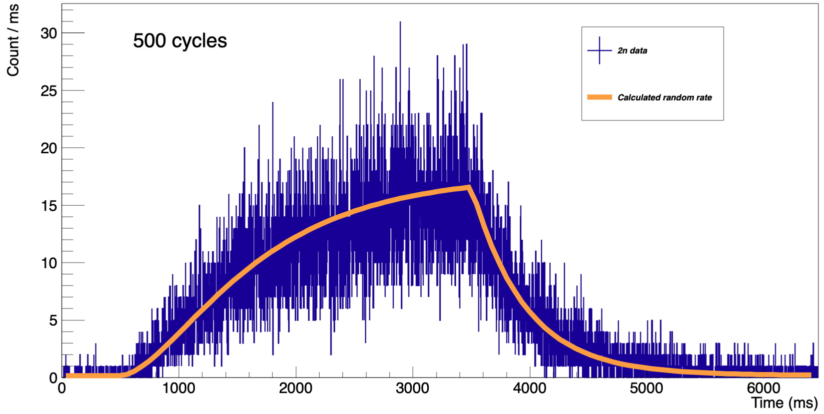


^{84}Ga neutron activity

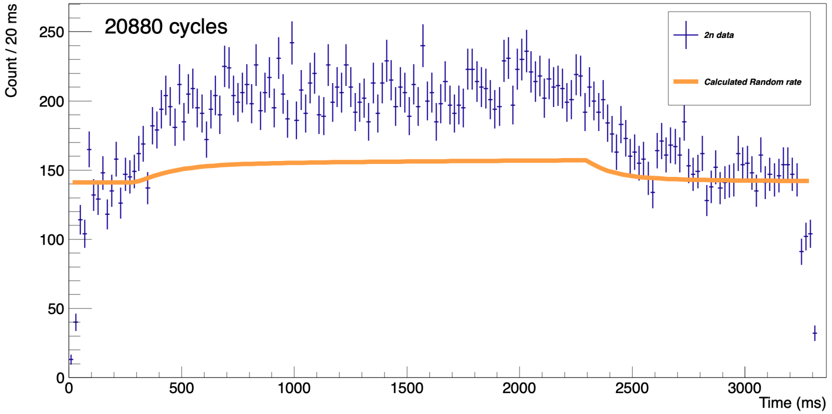
Beta-2n data analysis

Sources of 2-n background

- Fortuitous counting (grows with counting rate)
- Natural background (constant)



^{82}Ga 2-neutron activity



^{84}Ga 2-neutron activity

$Q_{\beta-2n} < 0\ MeV$

Only background 2-n counting

$Q_{\beta-2n} = 5.179\ MeV$

$$P_{2n} = \frac{\varepsilon_\beta}{\varepsilon_n^2} \times \frac{N_{2n}}{N_\beta} = 1.2\ \%$$

Preliminary

cf. "Beta-delayed two-neutrons and three-neutrons emission" Jonson et al. (1981)

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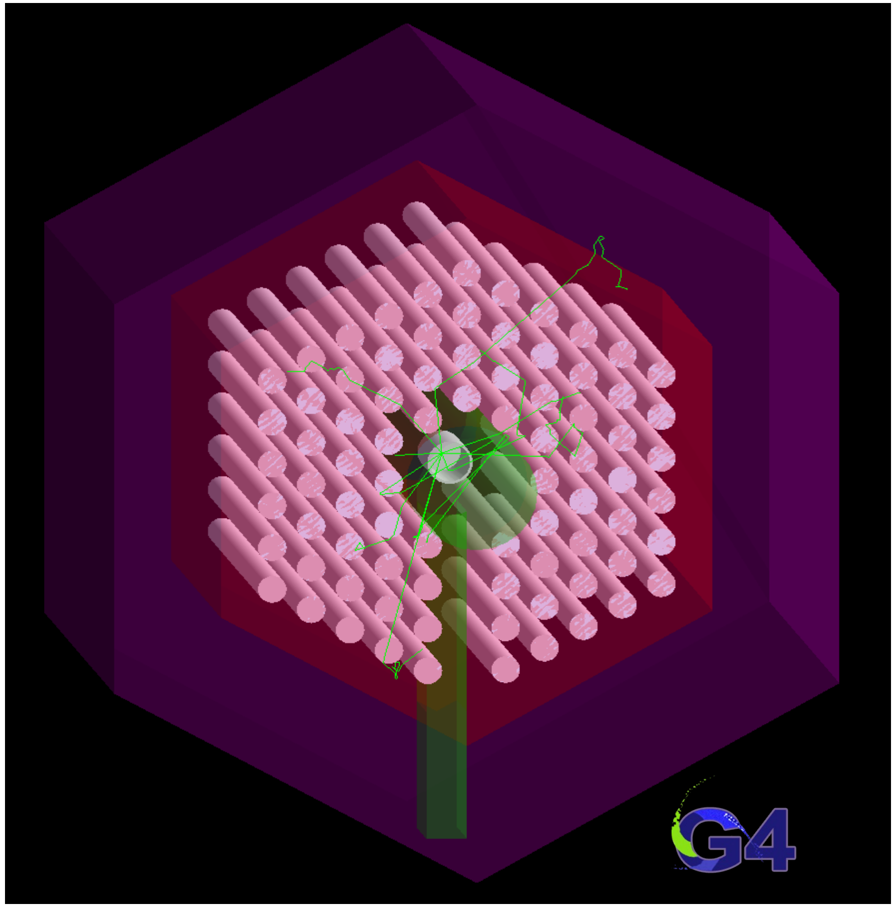
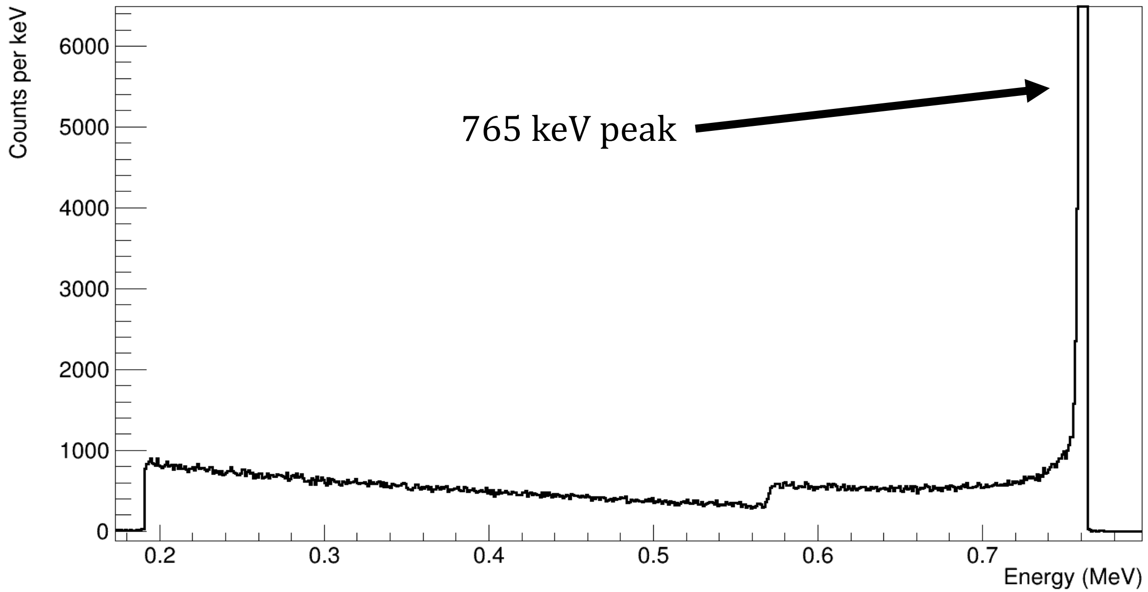
Geant4 TETRA simulation



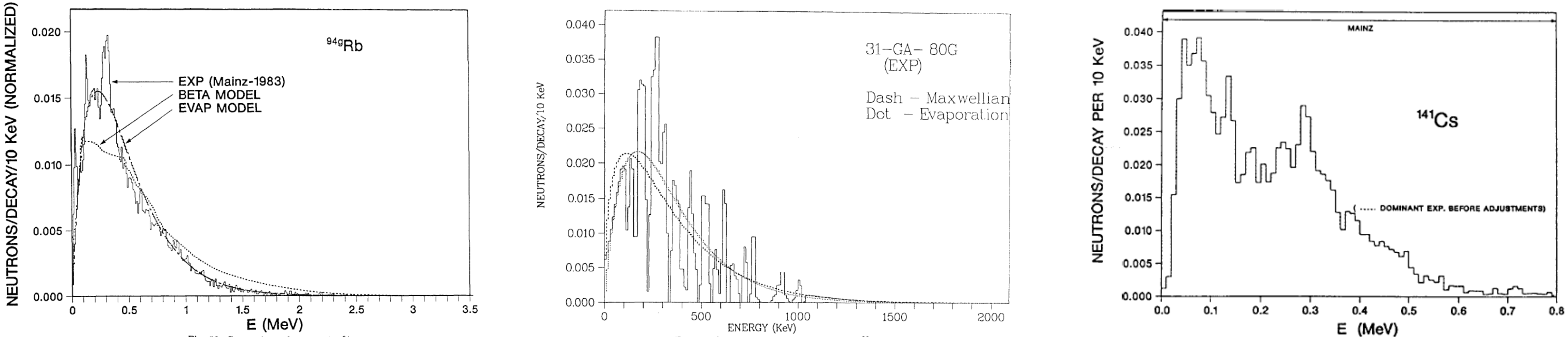


Simulated energy deposition in tetra cells

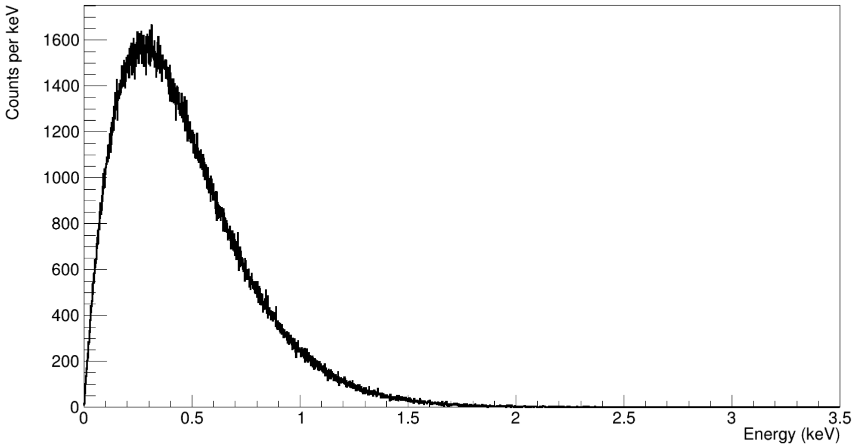
- Thermal neutrons physics list included

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

Different neutron energy distributions



A few experimental neutron energy spectra

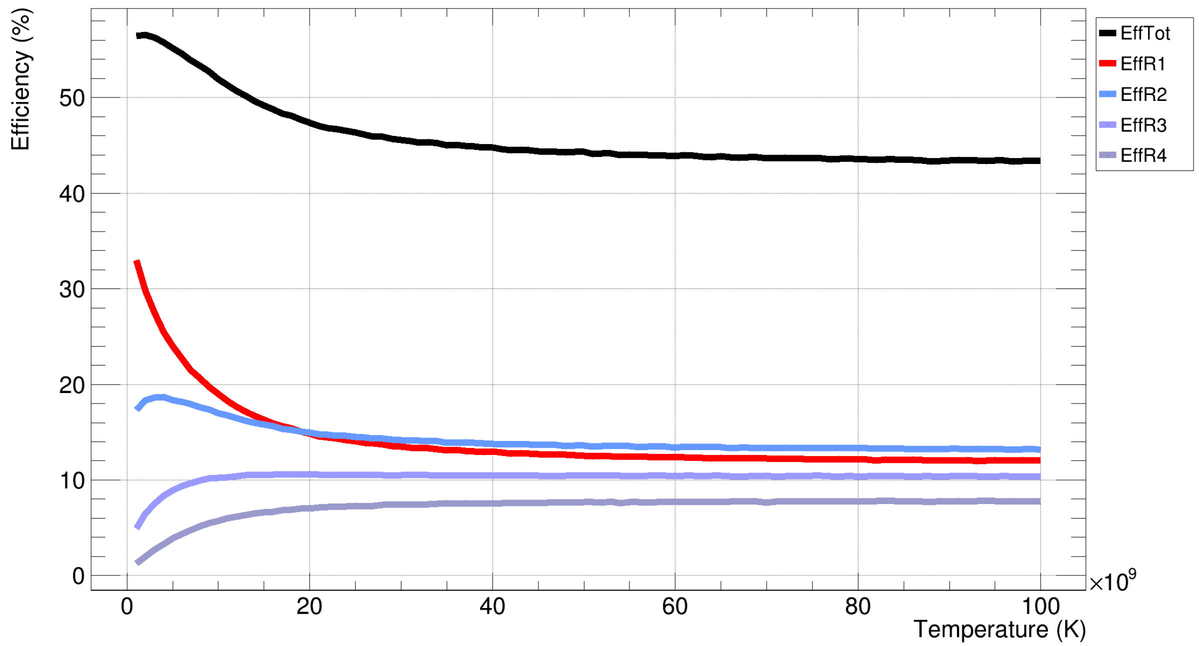


Example of simulated Maxwellian neutron source

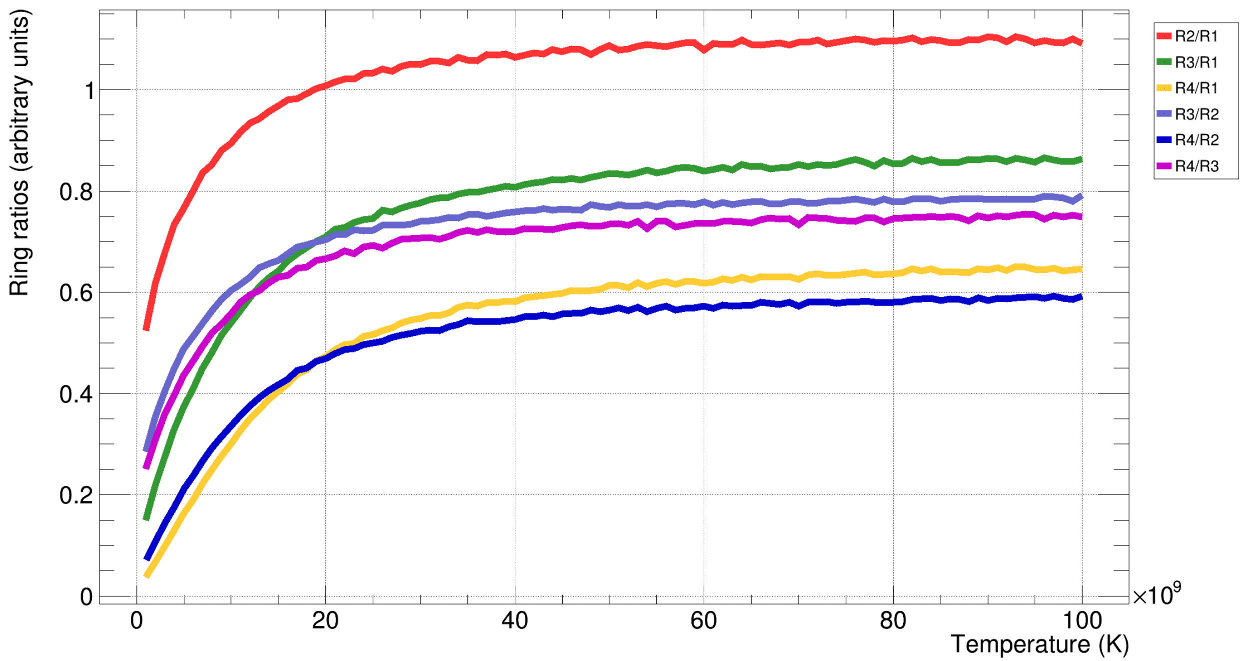
- First approximation : Maxwellian distribution
- Main parameter : Temperature

cf. "Evaluation and Application of Delayed Neutron Precursor Data" Michaele Clarice Brady

TETRA efficiency per ring

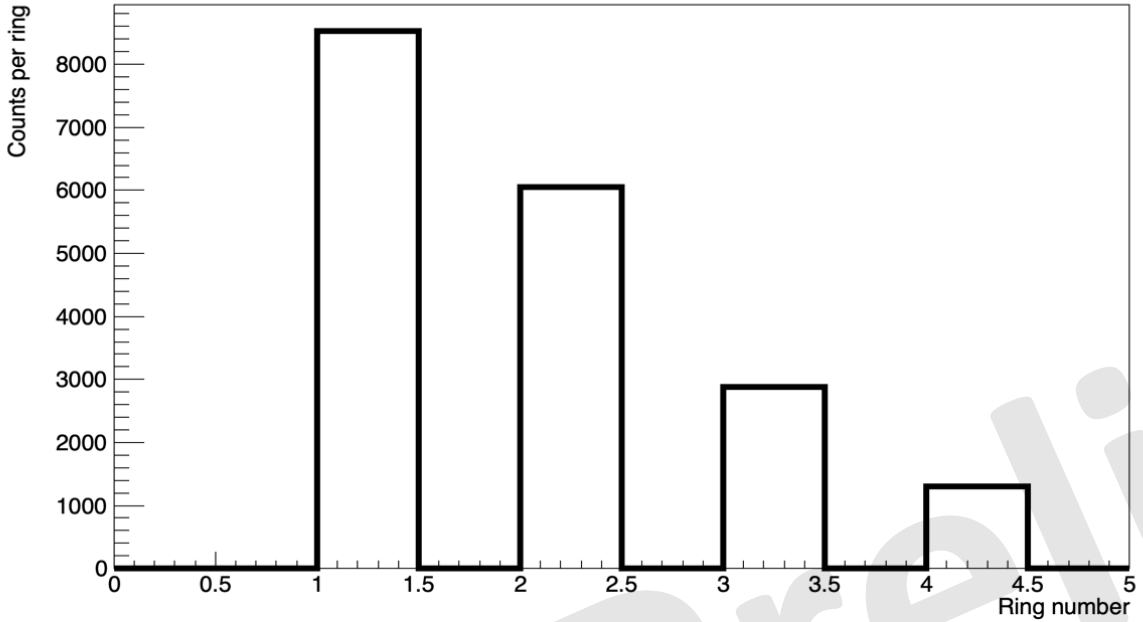


Simulated efficiency as function of Maxwellian temperature parameter

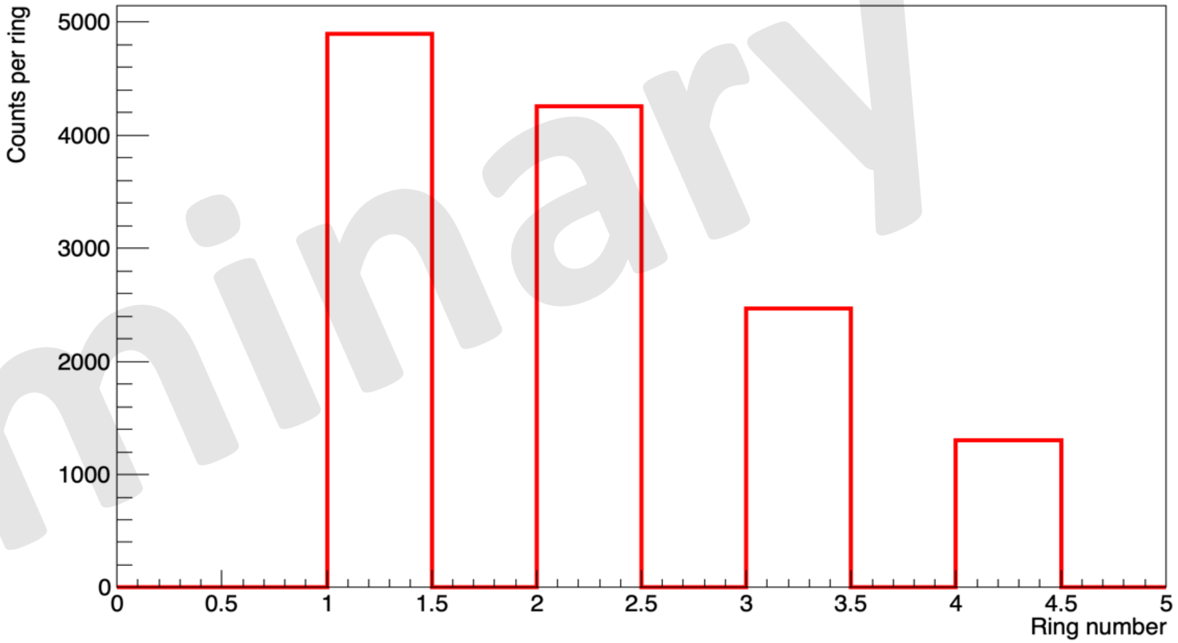


Simulated ring ratios as function of Maxwellian temperature parameter

Experimental ring ratios



^{82}Ga Ring Ratios



^{84}Ga Ring Ratios

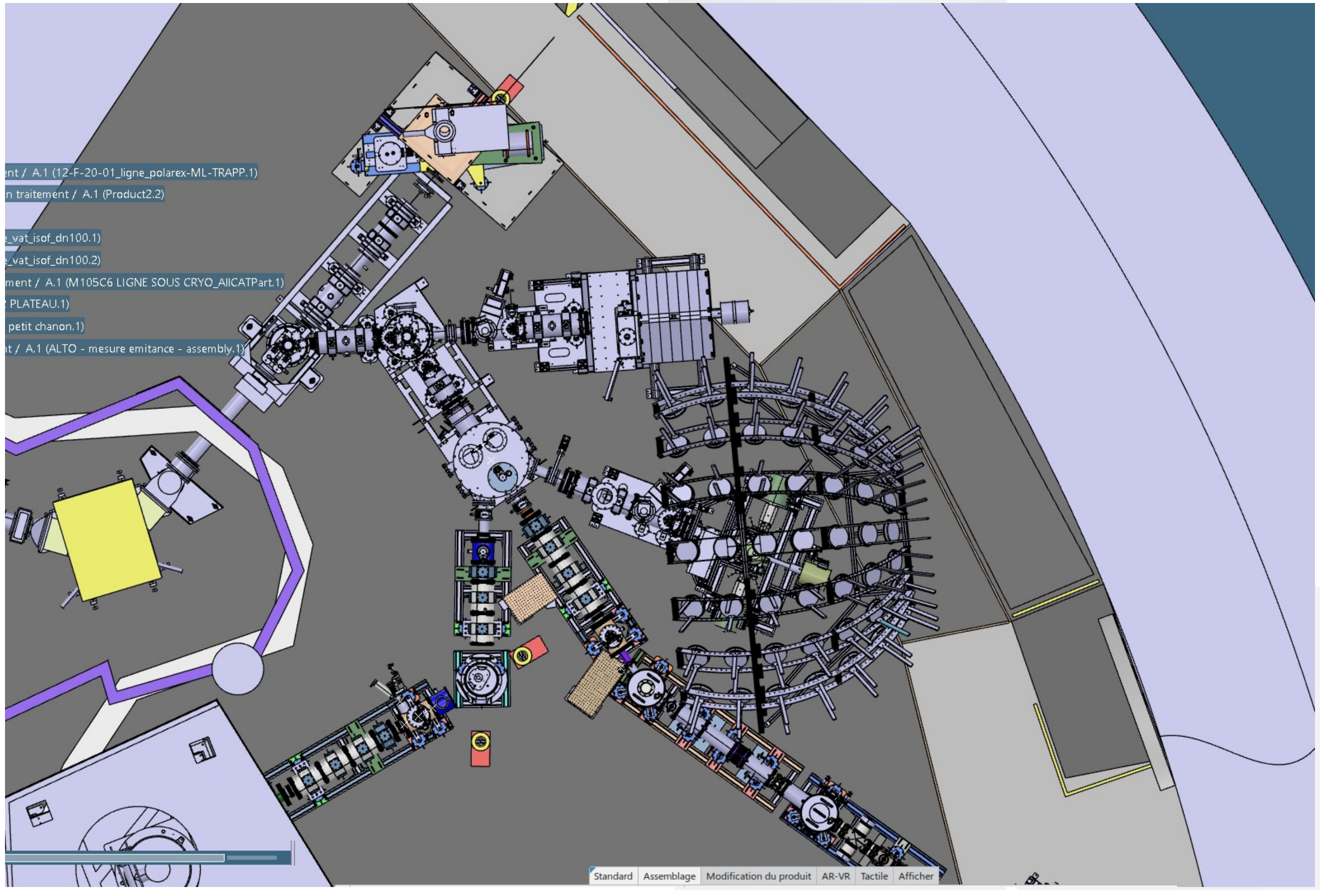
➡ 0.93 MeV mean energy

➡ 2.1 MeV mean energy

Coming up

MONSTER @ ALTO

- Structure installation in Juin 2024
- Experiment MONSTER + BEDO planned in Autumn 2024 for ^{83}Ga, ^{84}Ga and ^{81}Zn



Thank you for your attention !