

FISSION 2026

The spectroscopy of the shape isomer in ^{238}U by Nu-ball spectrometer

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Outline

- Study of the ^{238}U shape isomer
- Experimental setup and measurements
- Analysis of data
- Summary



Study of the ^{238}U shape isomer

□ Fission isomer characteristic

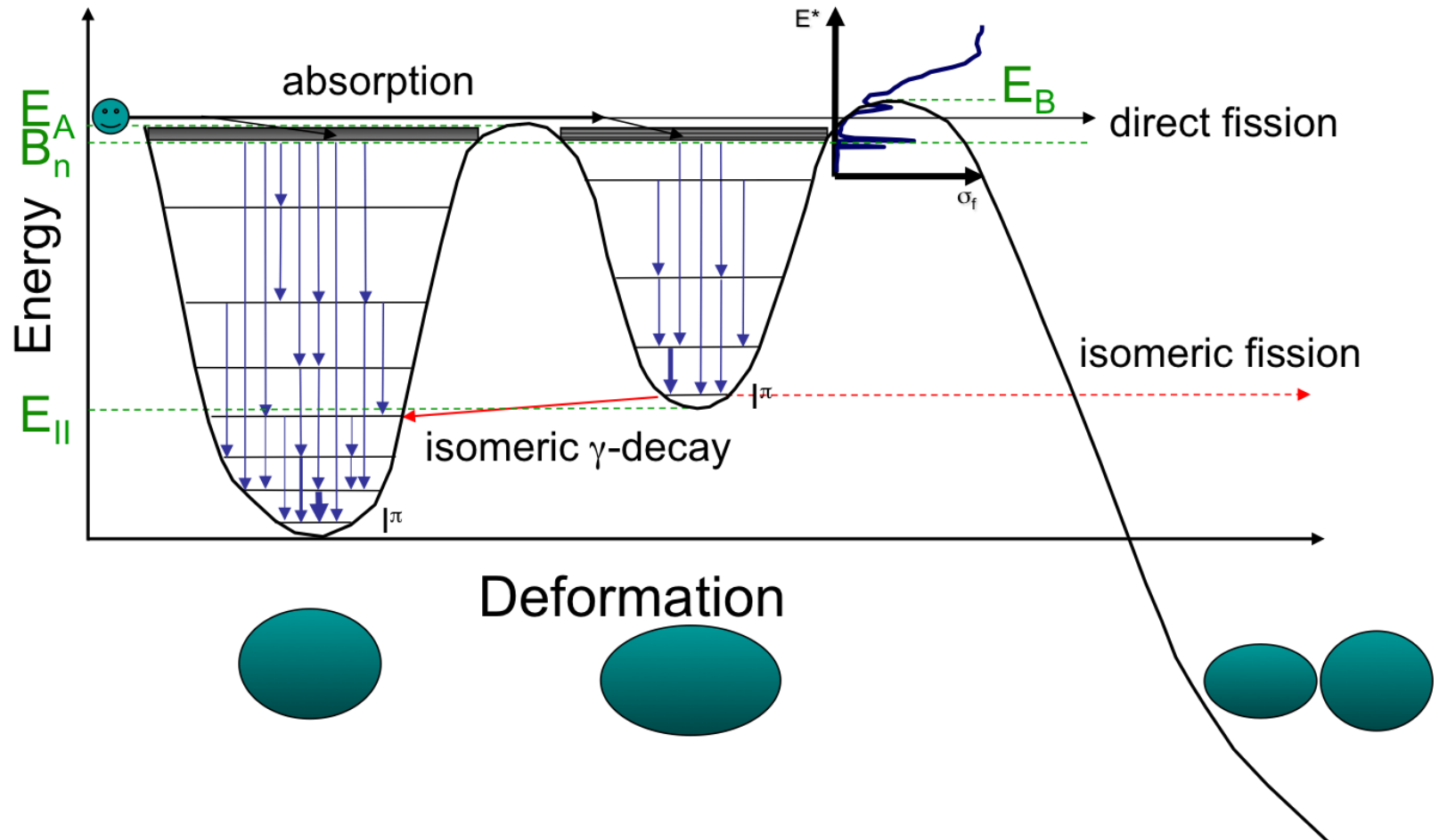
- Half-life
- Partial half-lives: isomeric fission, back-decay to 1st minimum
- Branching ration

□ Fission barrier parameters

- Barrier height
- Transmission
- Nuclear structure above super-deformed ground-state

Isomeric fission fragment characteristics

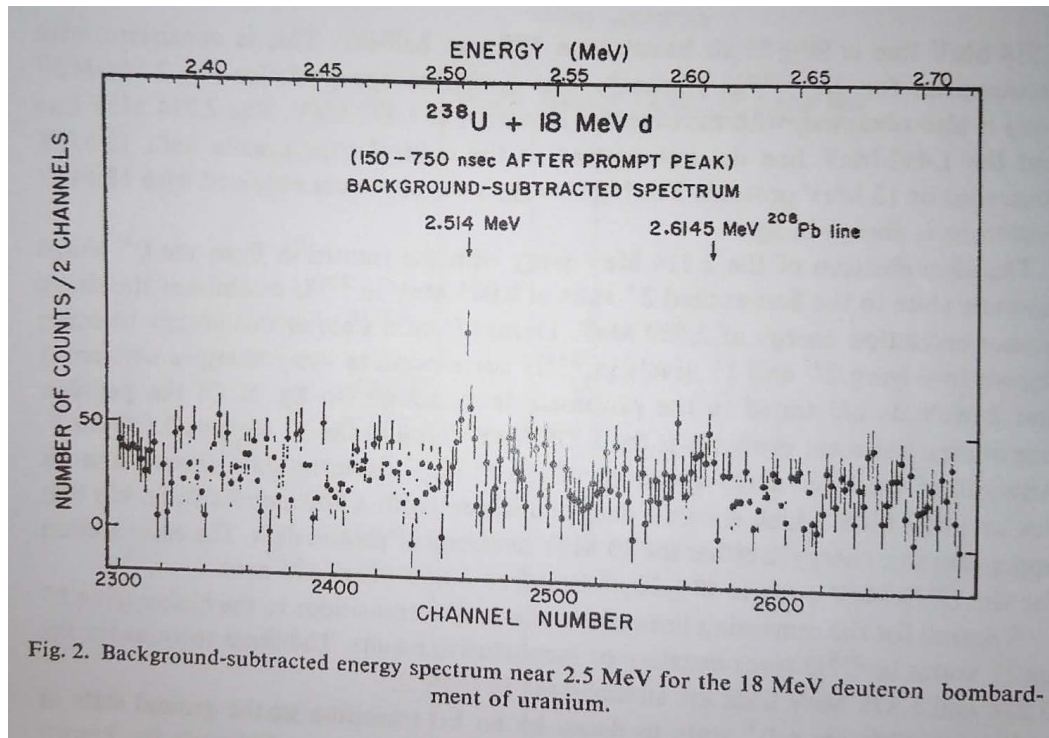
Study of the ^{238}U shape isomer



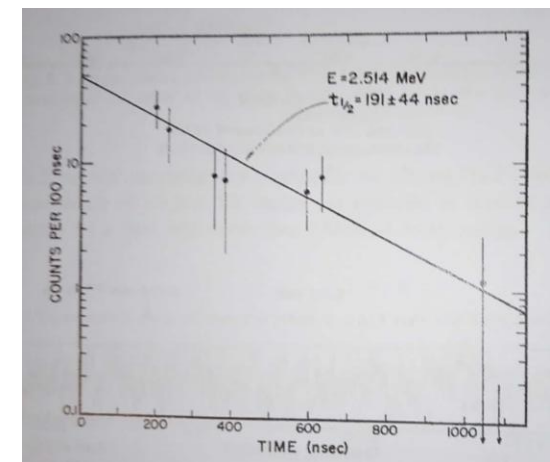
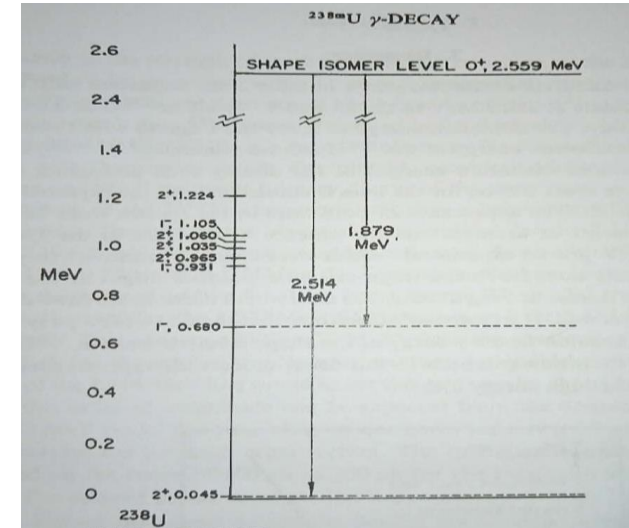
Study of the ^{238}U shape isomer – brief overview

Study of the ^{238}U shape isomer - Gamma-back decay

P.A. Russo, Nuclear Physics A 240, 1979.



Single 25 cm^3 Ge detector



Study of the ^{238}U shape isomer – brief overview

Study of the ^{238}U shape isomer - Gamma-back decay

J. Kantele, *Physical Review C*, 29 (5), 1984.

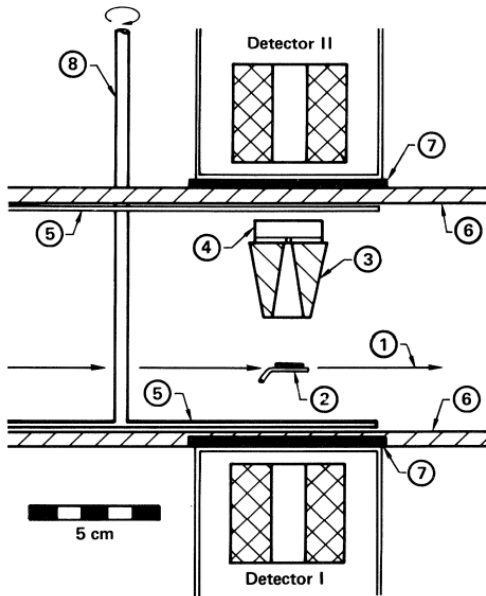


FIG. 1. Schematic cross-sectional diagram of the measurement geometry of the two-detector method: (1) beam, (2) target, (3) Hevimet conical collimator, (4) fission-fragment detector, (5) rotating disks, (6) stainless steel chamber walls, (7) 3.5-mm thick lead absorbers, (8) rotating shaft. For clarity, the thickness of the target strip is exaggerated. The shielding against the radiations from the beam stop and the floor is not shown. The shaft turning the disks is actually located above the plane of the cross section shown.

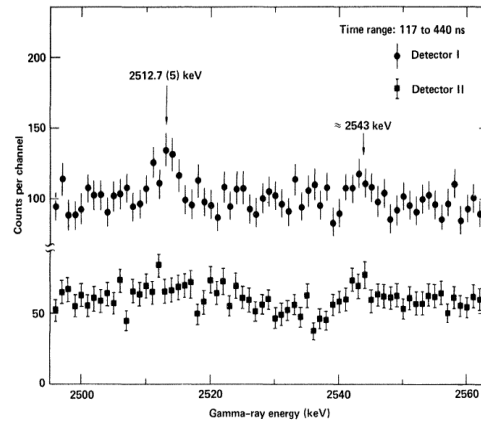
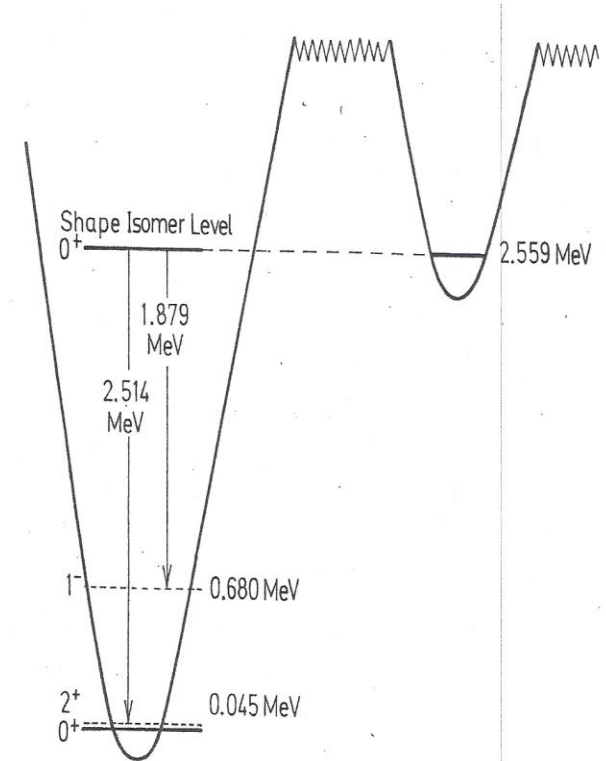


FIG. 2. Parts of γ -ray spectra recorded by the two detectors shown in Fig. 1 in the time range from 117 to 440 ns after a short burst of 18-MeV deuterons hitting a natural uranium target. The line at 2512.7 keV is present only in the upper spectrum and is, therefore, attributed to genuine target events (i.e., to the decay of the ^{238}U shape isomer). The 2543-keV line exhibited by both spectra is a typical (unidentified) room-background line.



Two 50cm^3 Ge detectors

^{238}U

Study of the ^{238}U shape isomer – brief overview

Study of the ^{238}U shape isomer - Gamma-back decay

M. Steinmayer, Z. Phys. A Hadrons and Nuclei 341, 145-154 (1992)

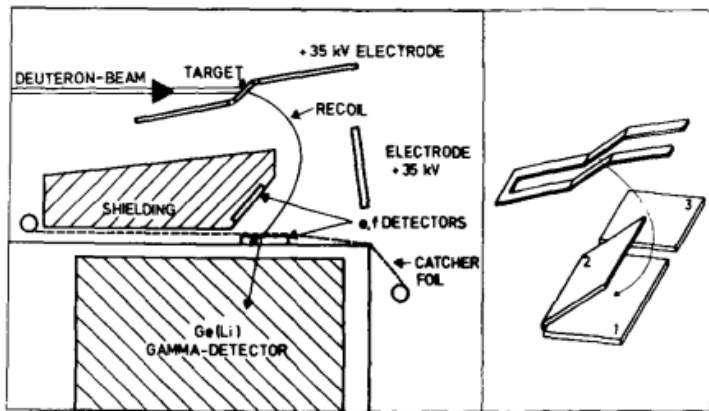


Fig. 2. Sketch of the experimental set-up to deflect the highly charged recoils near to 3 ion-implanted solid state and one Ge(Li) detector. The target and electrodes have a high voltage of 35 kV. The right part of the figure shows schematically in a perspective view the target frame and the positions of the 3 detectors

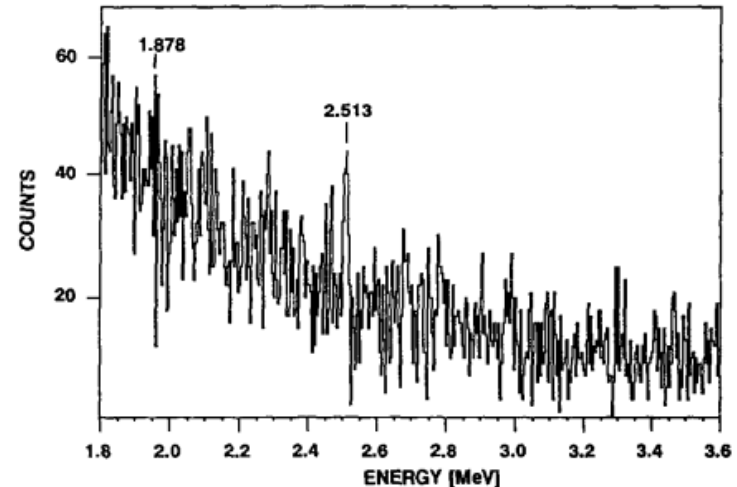
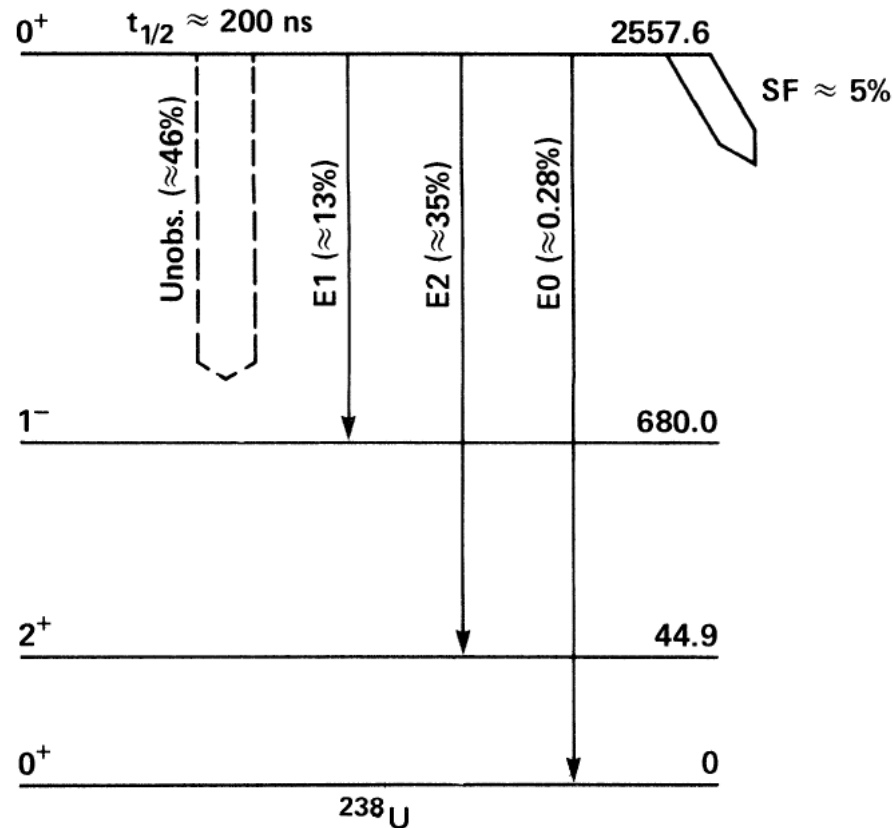


Fig. 9. Delayed coincidences of background-subtracted gamma-rays in the time window (110 to 720) ns with respect to the pulsed beam in prompt coincidence with electrons between 20 keV and 45 keV

180 cm³ coaxial Ge(Li) detector

Study of the ^{238}U shape isomer – brief overview

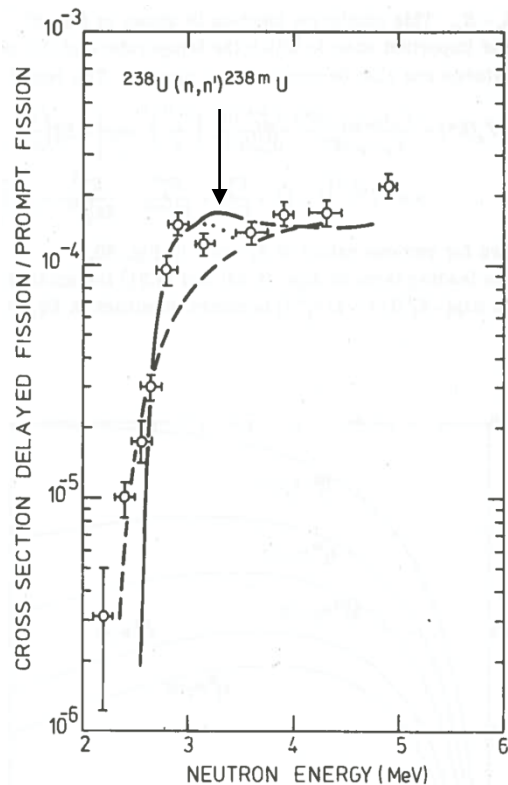
Study of the ^{238}U shape isomer - Gamma-back decay



Experimental setup and measurements

$^{238}\text{U}(n,n')$

ν -Ball + LICORNE neutron source



■ $E_n = (3.7 \pm 0.3) \text{ MeV}$

■ $\sigma_{\text{IF}} \approx 80 \mu\text{b}$

■ $\text{IT/IF} \approx 95/5$

■ $\sigma_{\text{IT}} \approx 1.5 \text{ mb}$

● Directional fast-neutron source

➤ High and pulsed neutron flux on target

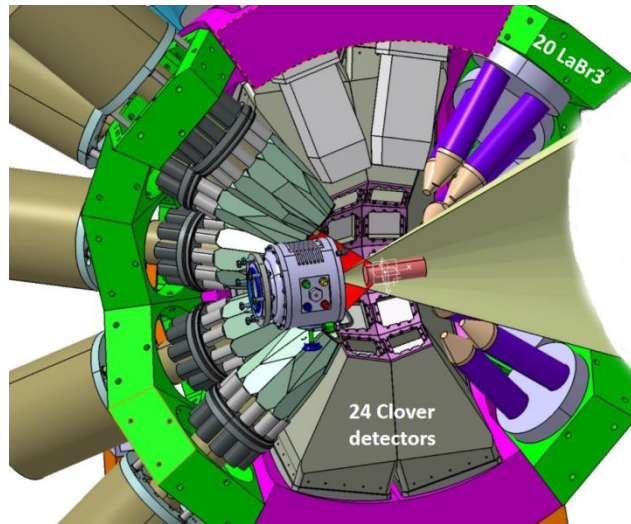
➤ Allows using a detector array

➤ High peak efficiency with ν -Ball

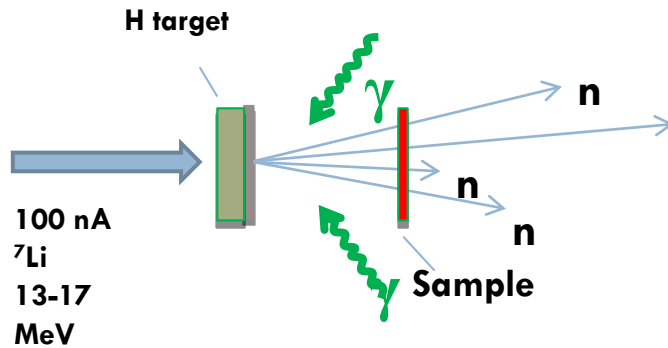
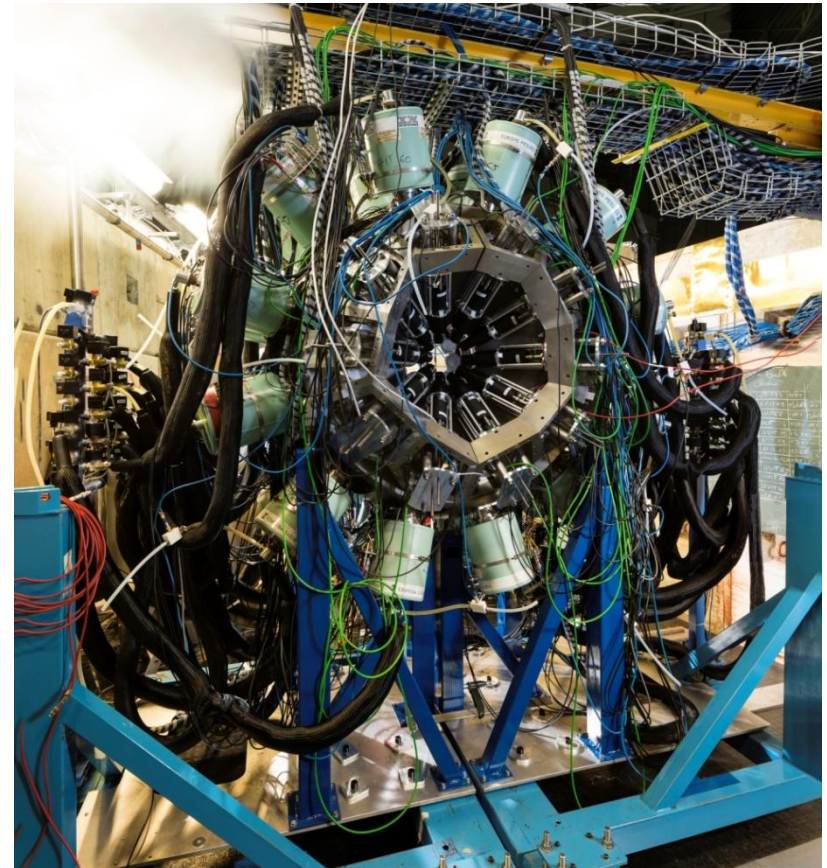
➤ High energy resolution and fast timing

Experimental setup and measurements

$^{238}\text{U}(n,n')$, LICORNE neutron source and v-Ball



+



LICORNE

Lithium Inverse Cinematiques ORsay Neutron source

v-ball

Experimental setup and measurements

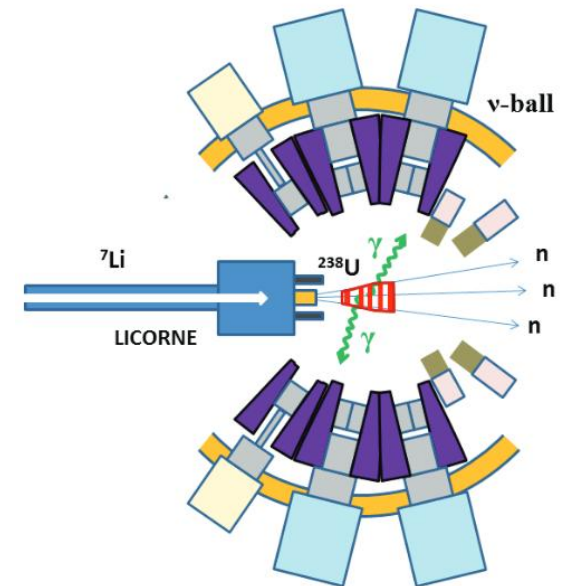
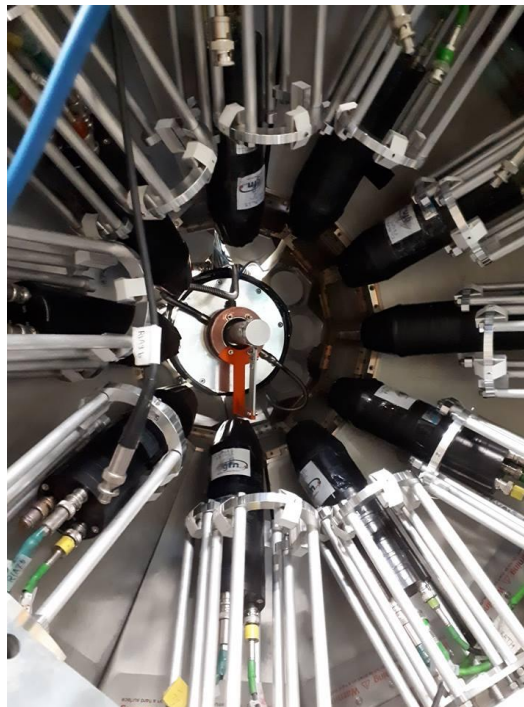
Experimental measurement
(~6 days)

- Target mass 81 g

130 hr of data

~25 Tb raw FASTER data

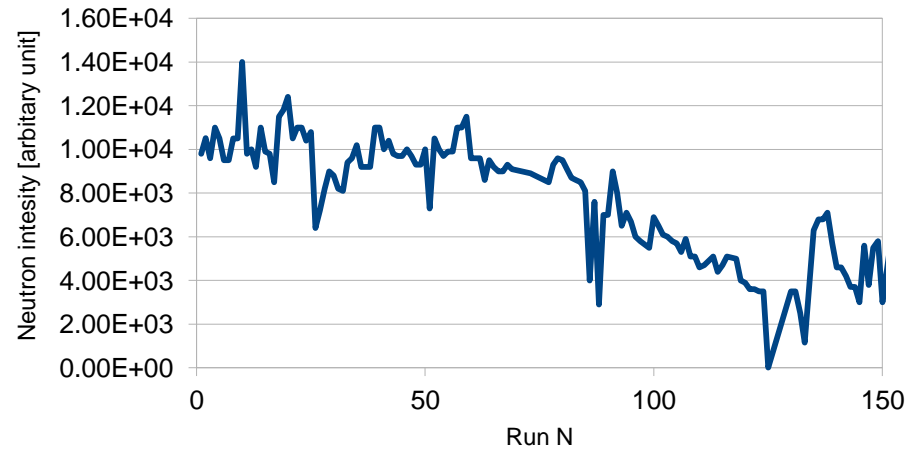
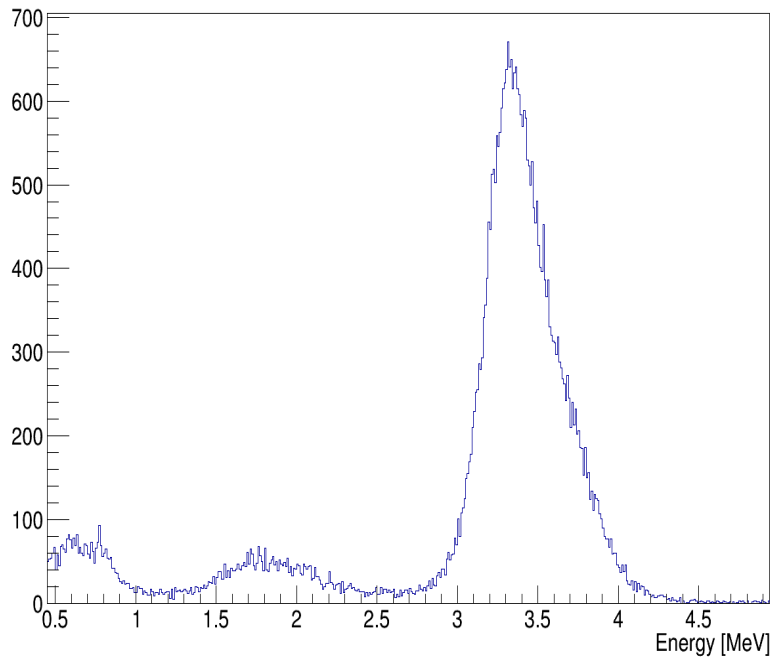
~6 Tb ROOT format data



Experimental setup and measurements

- **^7Li beam with energy of 18.5 MeV**

Neutron energy spectrum



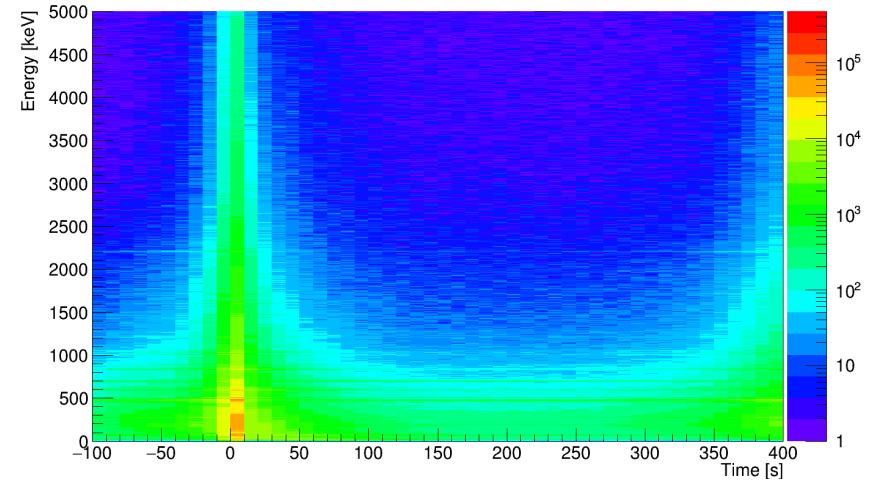
- 134 Runs

Experimental setup and measurements

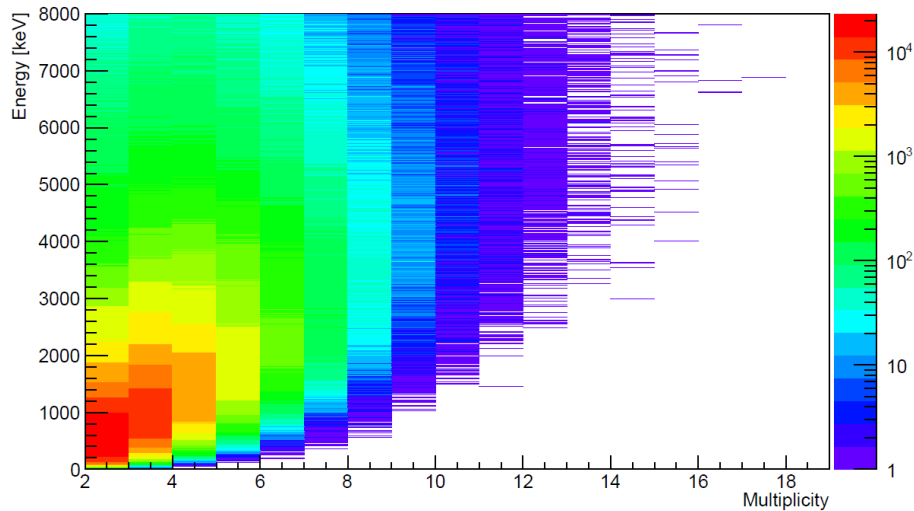
Selectivity:

- pulsed beam
- calorimetry (fission tag)
- fast timing
- $\gamma\gamma$ and $\gamma\gamma\gamma$ coincidence

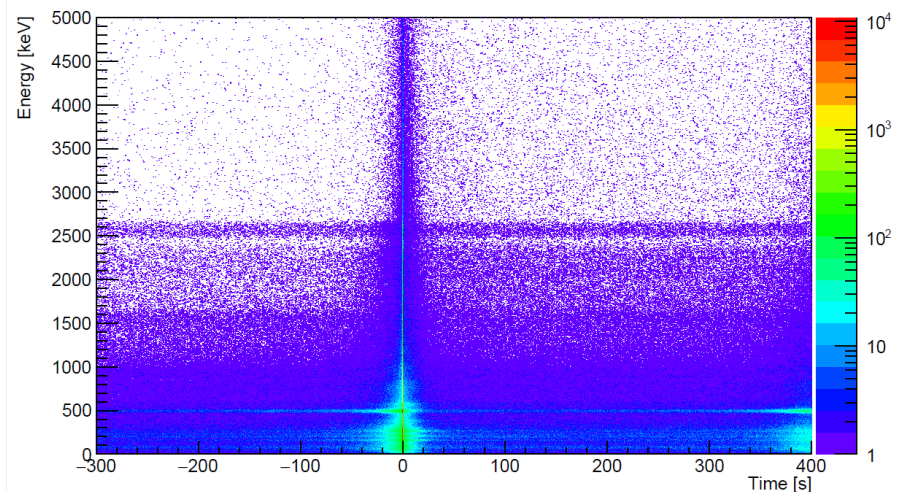
HPGe Energy vs time



Total Energy in nu-ball vs event multiplicity

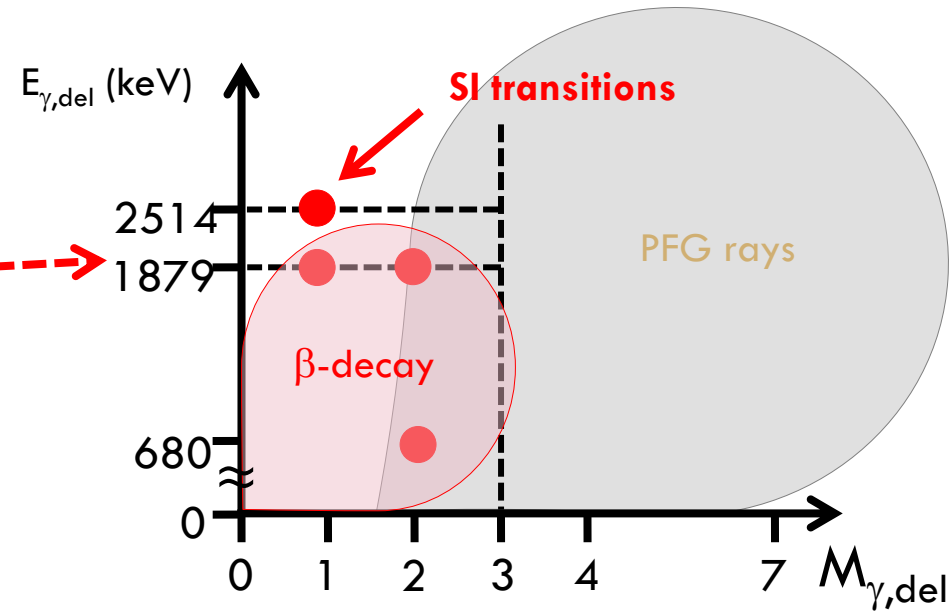
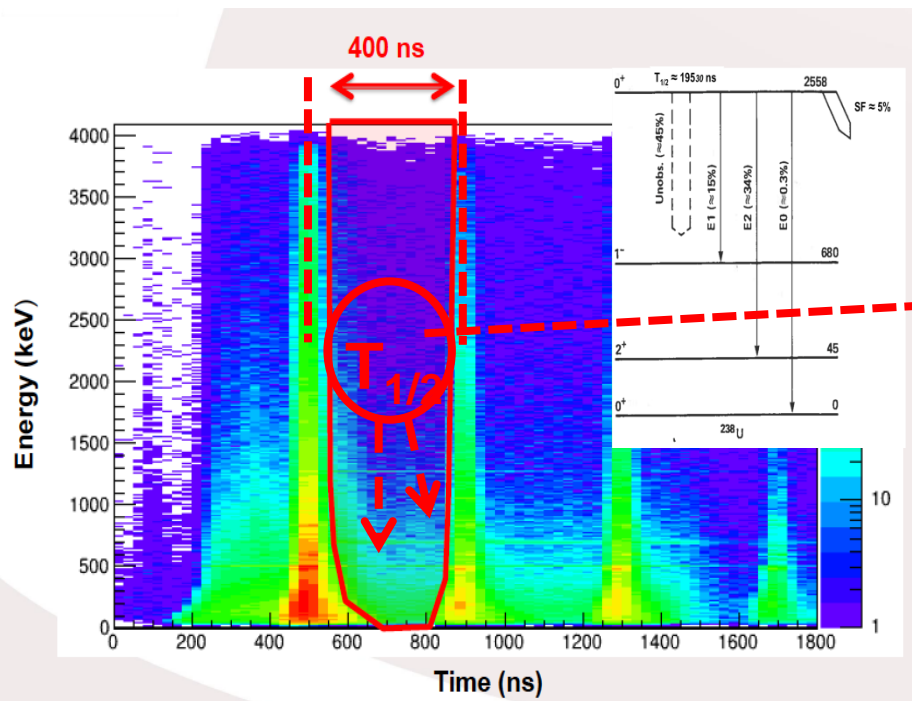


LaBr3 Energy vs time



Analysis

Data analysis scheme

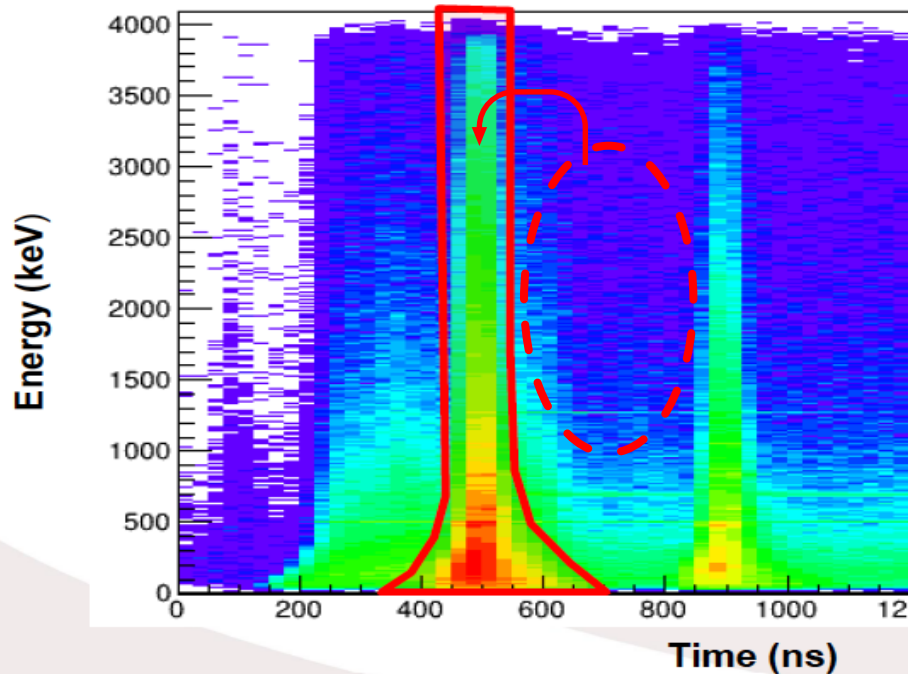


Analysis

Data analysis scheme

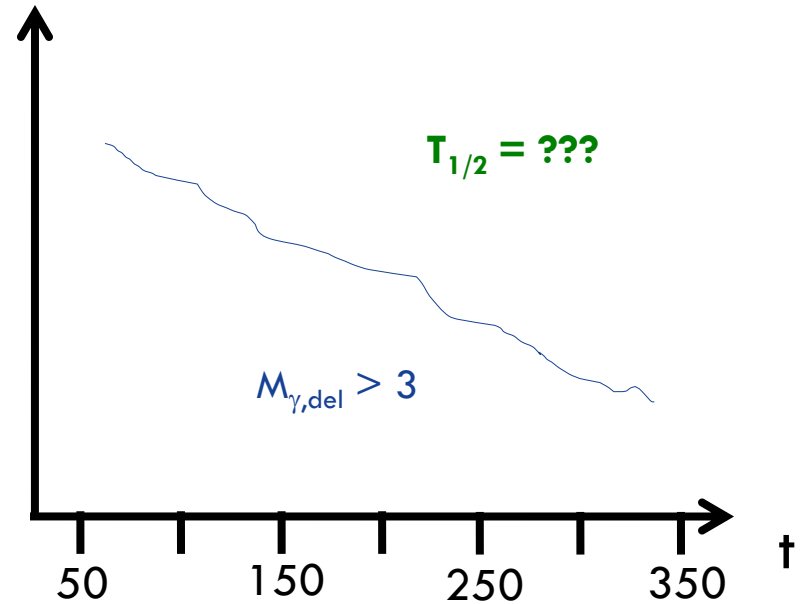
Nuclear structure above super-deformed ground-state

- Prompt – Delay coincidence



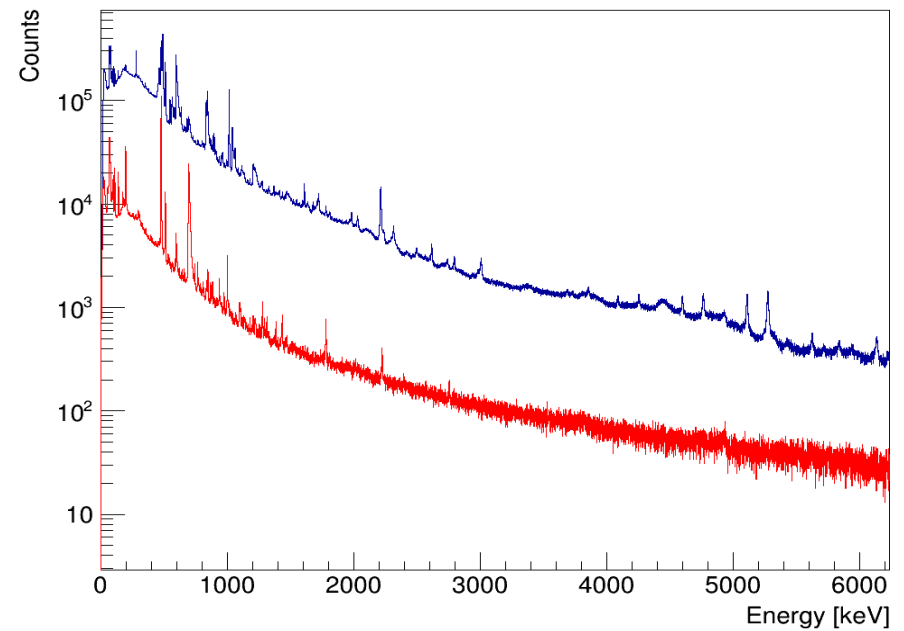
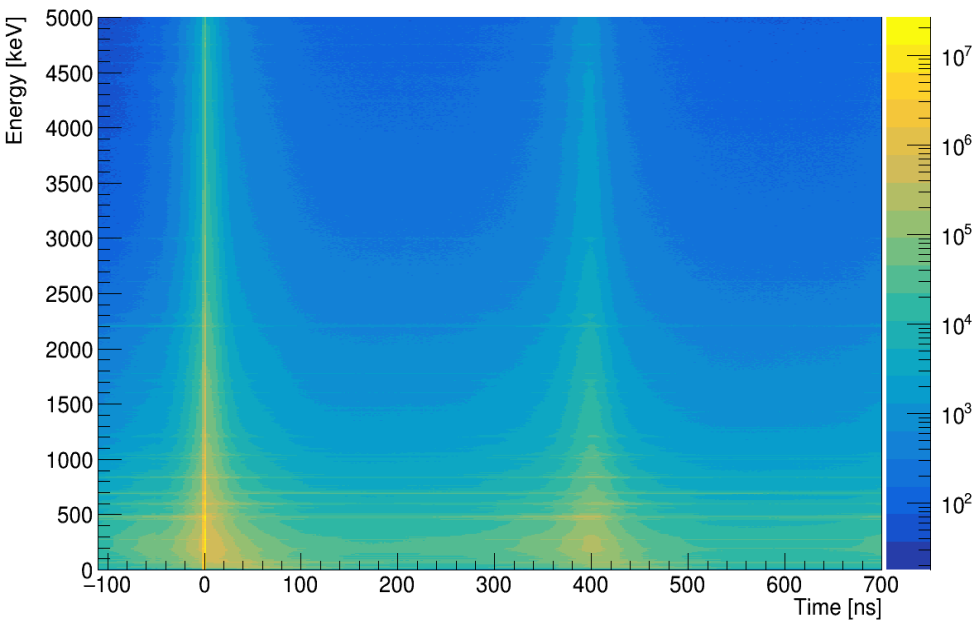
Half-life estimation

- From the $E_{g,del}(M_{g,del})$ we project $E_{g,del}$ for $M_{g,del} > 5$
- Check time distribution -> is it compatible with $T_{1/2}$



Analysis

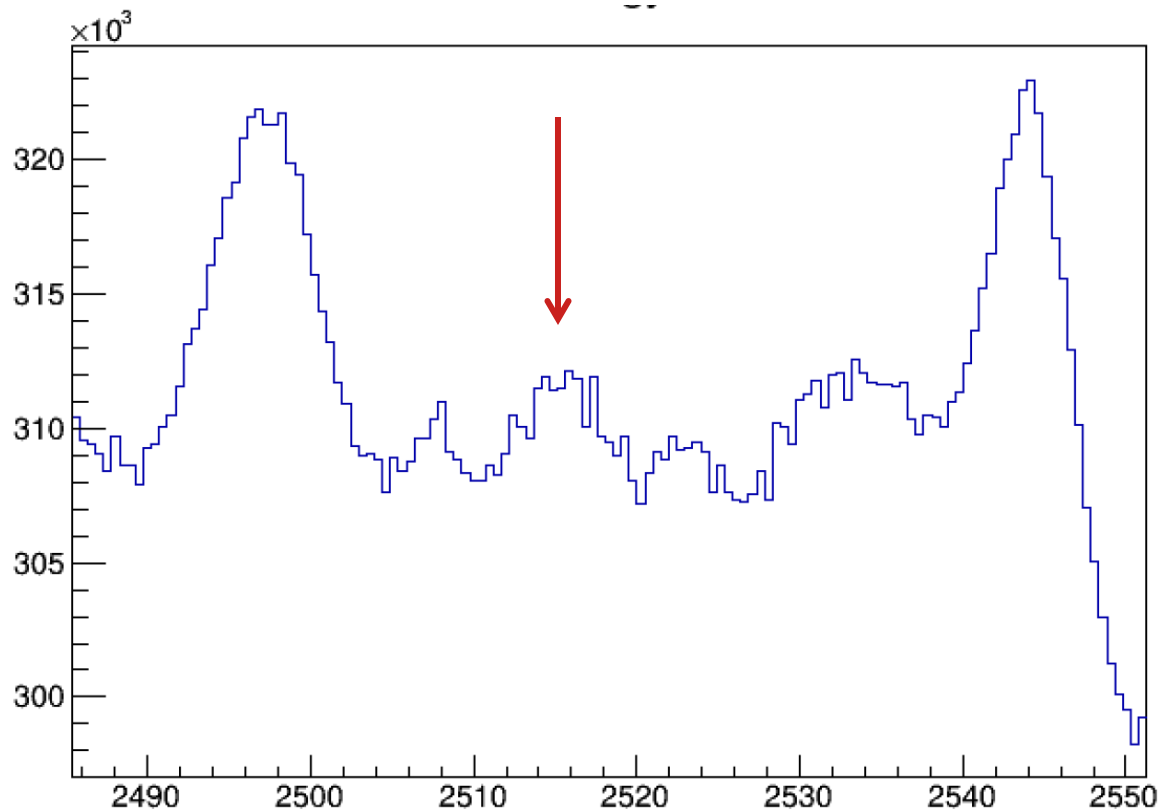
Ge detectors – time vs Energy spectrum



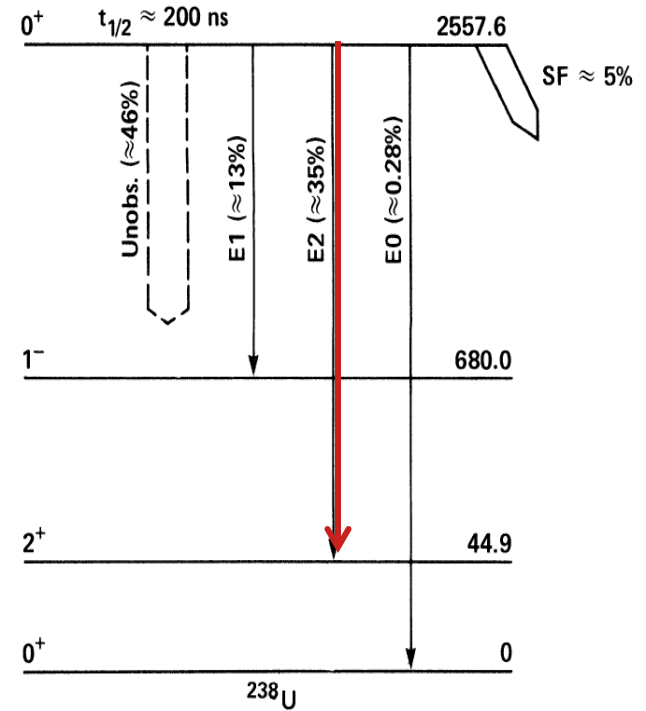
— Prompt spectrum
— Delay spectrum

Analysis

2514 keV Gamma-back decay



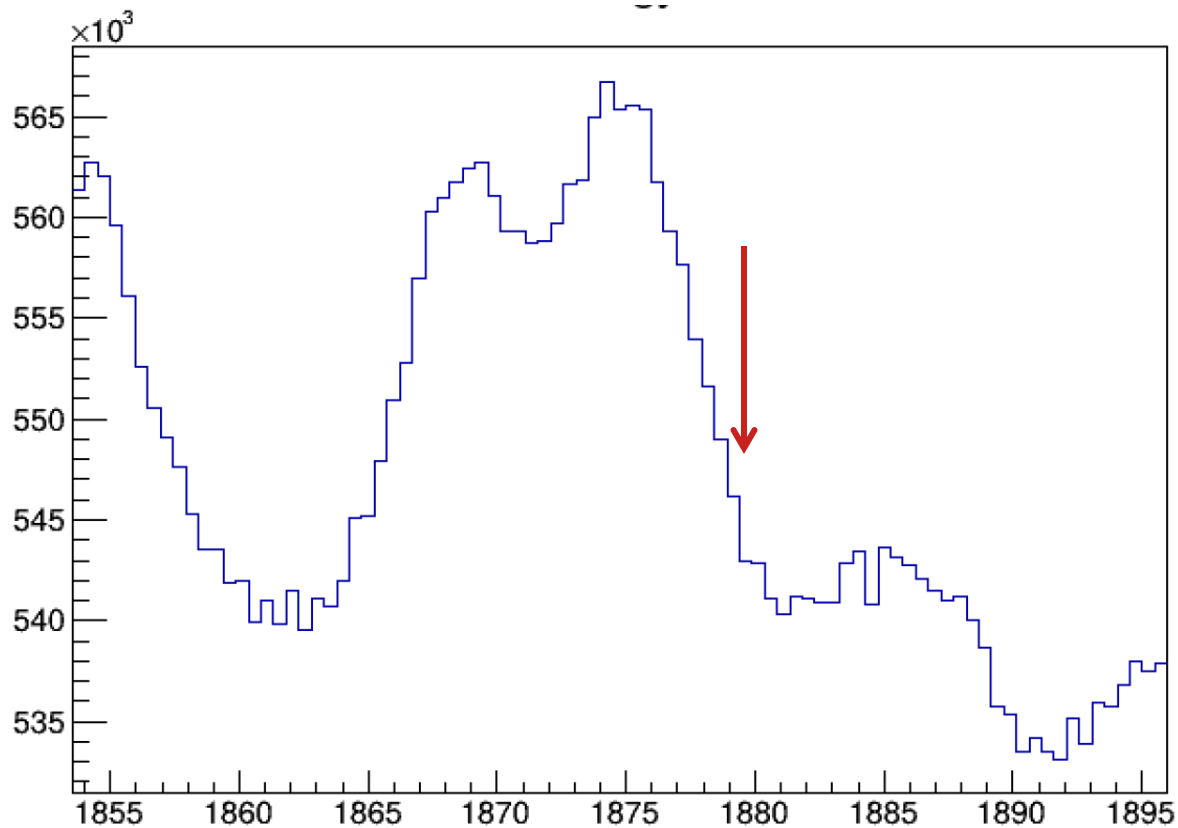
Ge detectors delay spectra - 50 ns – 350 ns after pulse



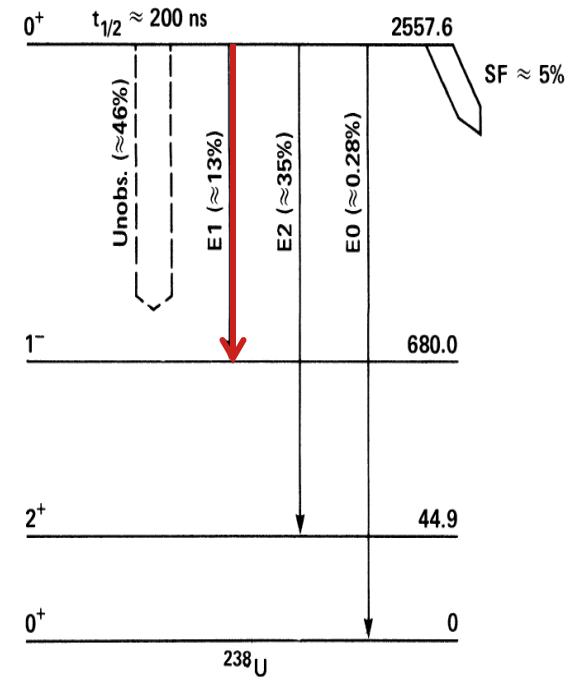
It was detected 9 times less counts than was expected.

Analysis

1878 keV Gamma-back decay



Ge detectors delay spectra - 50 ns – 350 ns after pulse

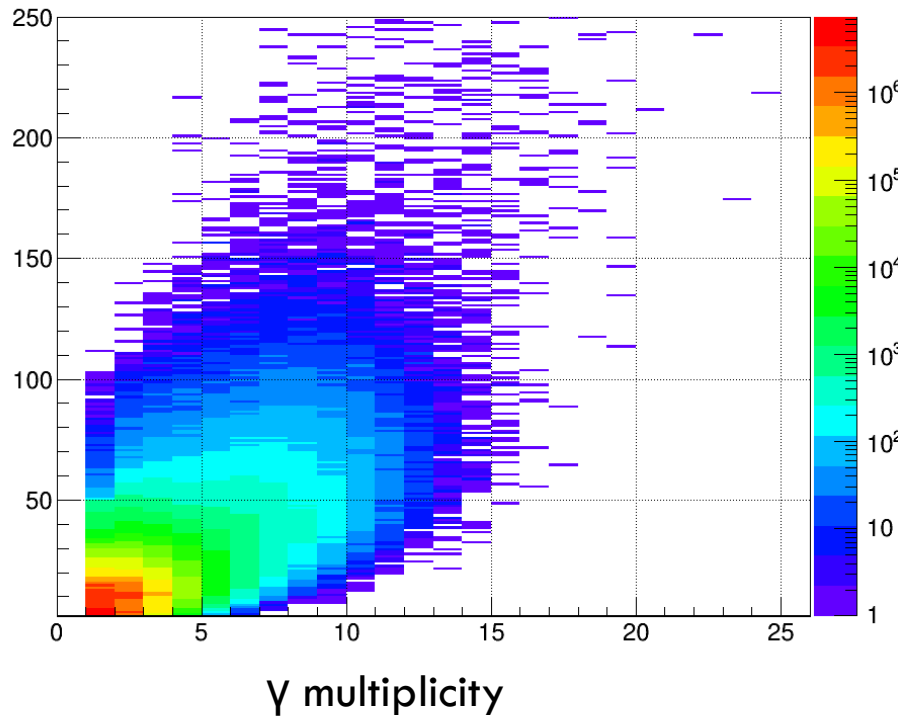


Analysis

Using ν -ball calorimetry

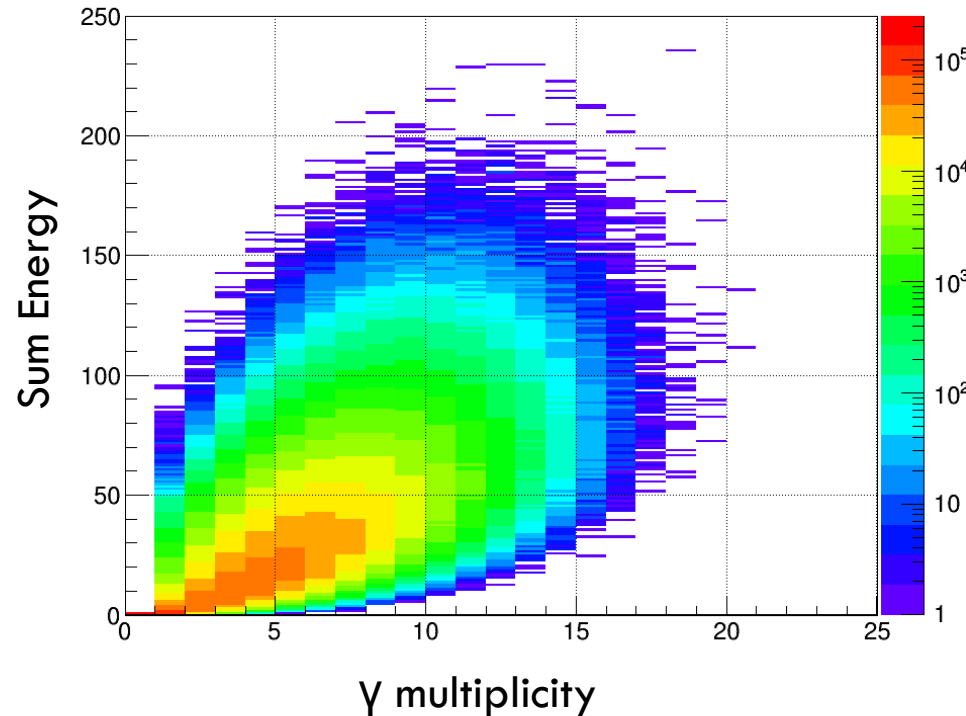
^{152}Eu beta decay events

HK



^{252}Cf fission events

HK



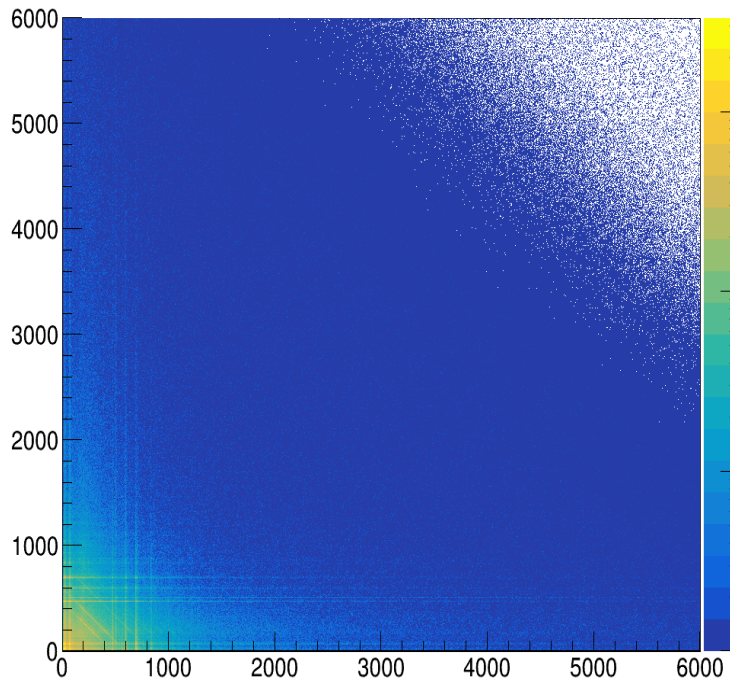
Analysis

Coincidences in delay region 50ns -350ns

Gamma-back decay

Prompt multiplicity < 3

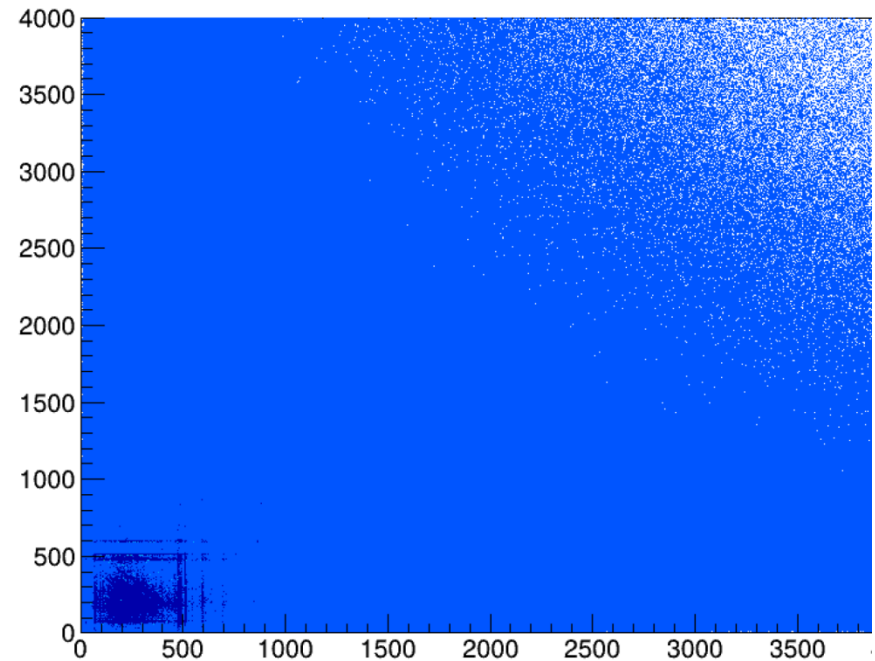
Delay multiplicity < 3



Isomeric (decay) fission

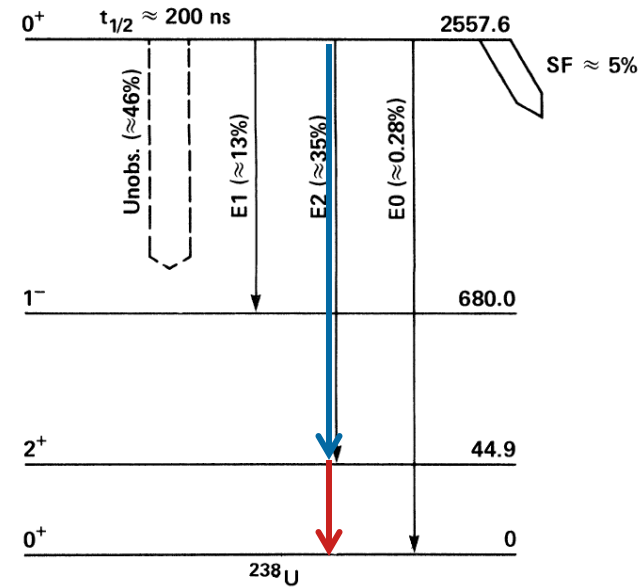
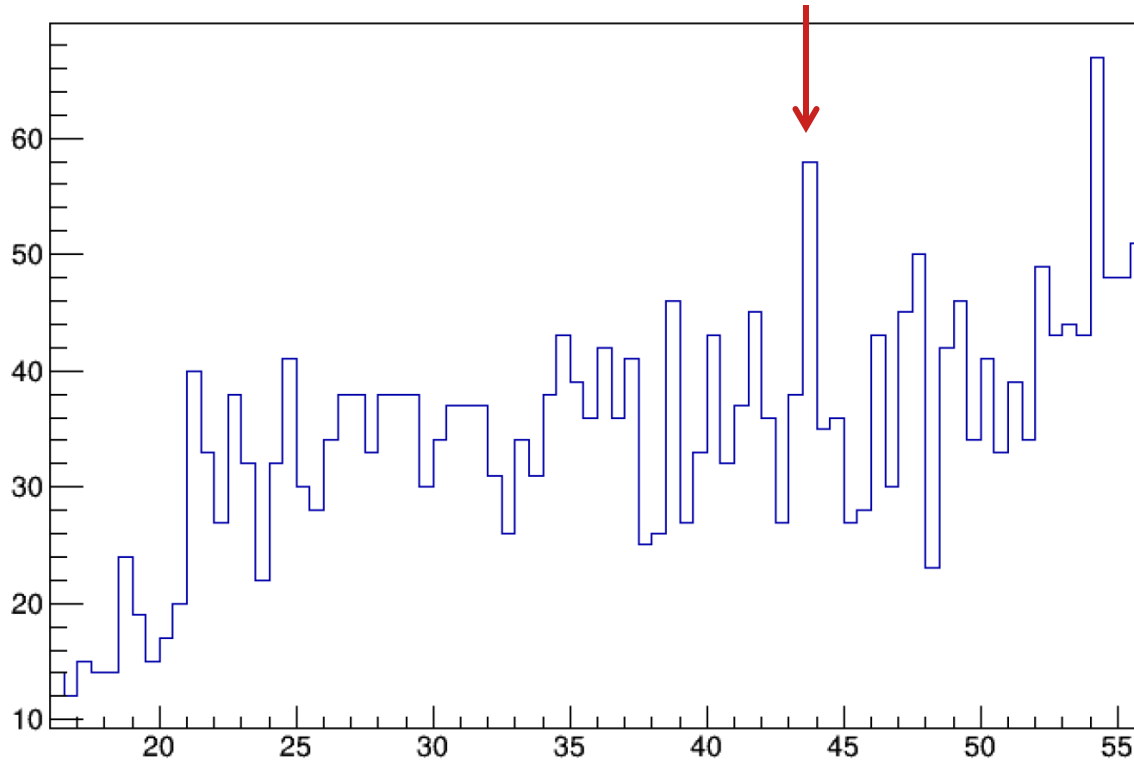
Prompt multiplicity < 3

Delay multiplicity > 3



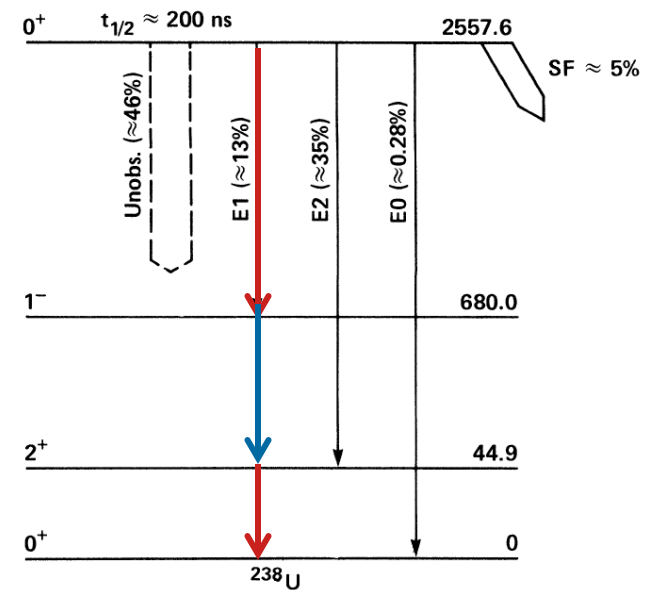
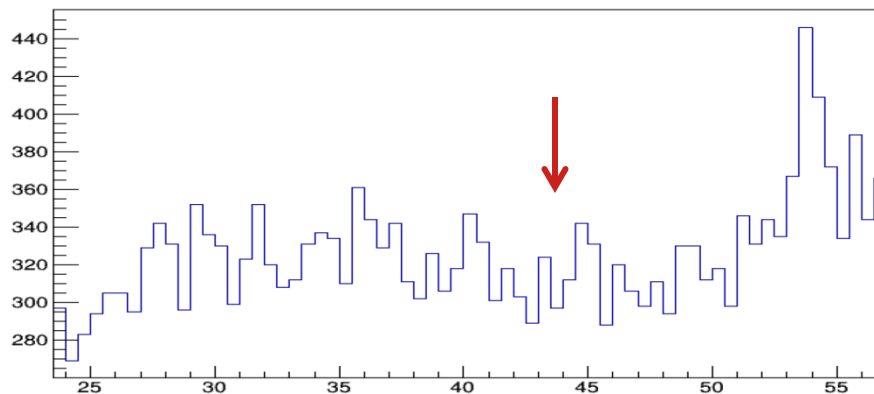
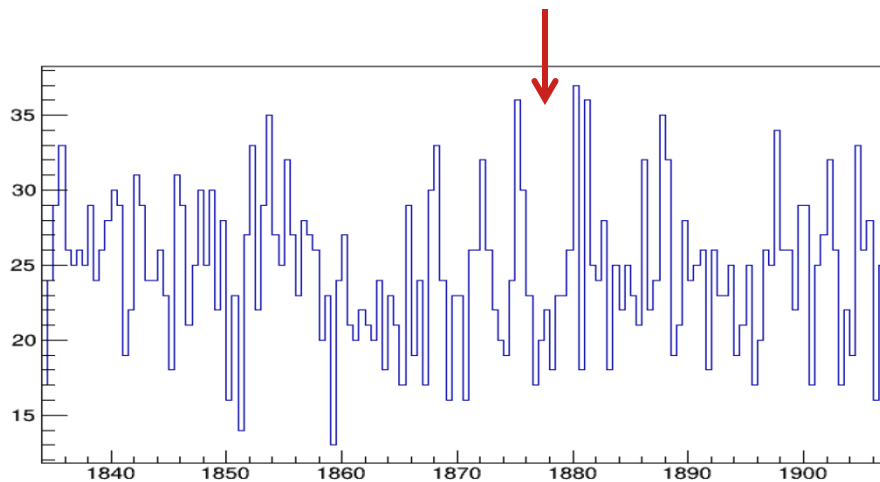
Analysis

Gate on 2515 keV expected peak at 44 keV



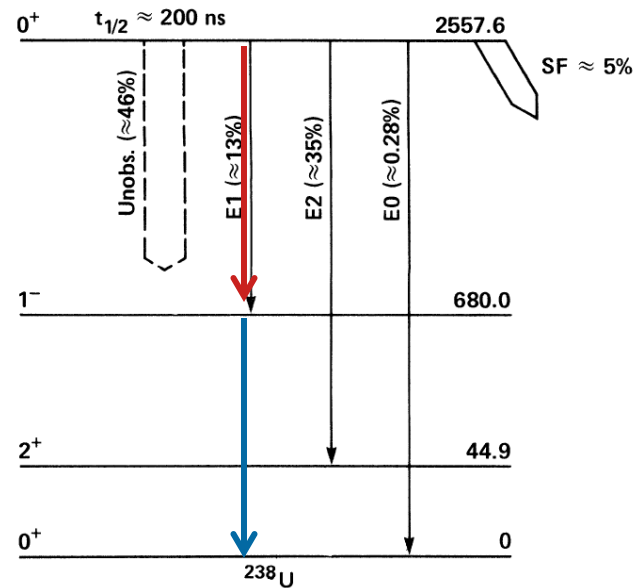
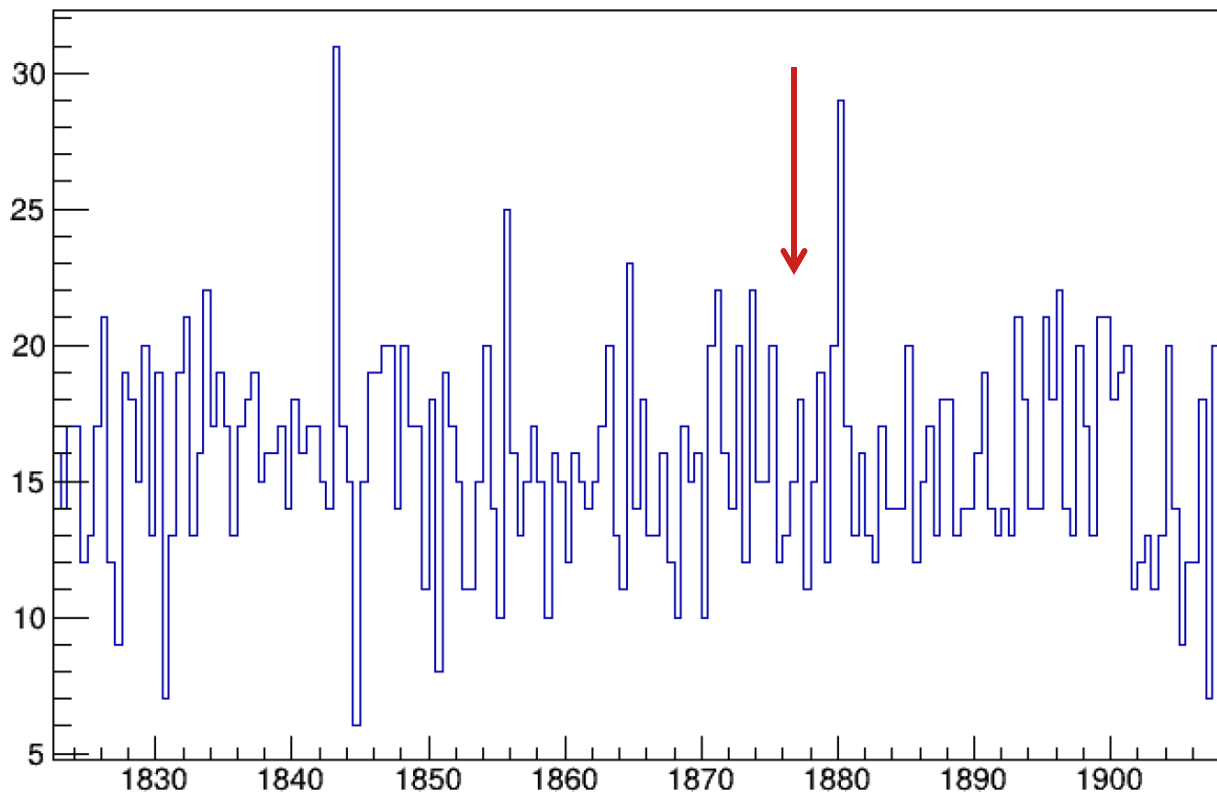
Analysis

Gate on 635 keV expected peak at 1878 keV keV and 44 keV



Analysis

Gate on 680 keV expected peak at 1878 keV

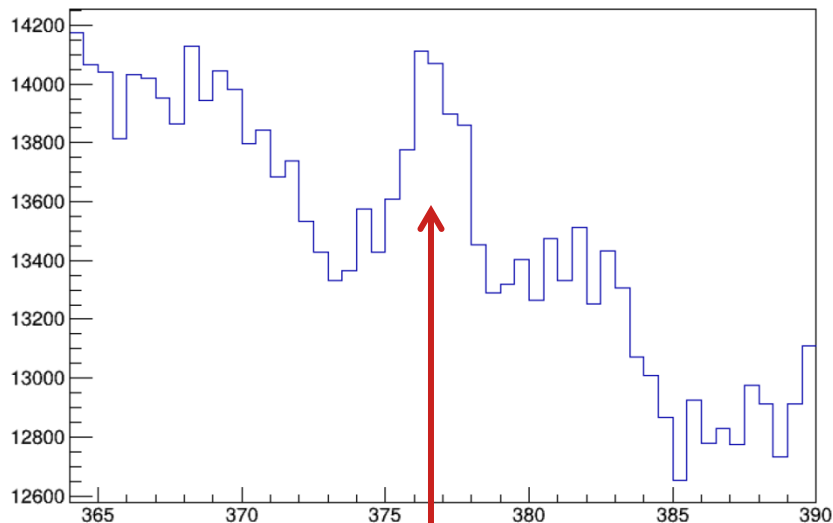


Analysis

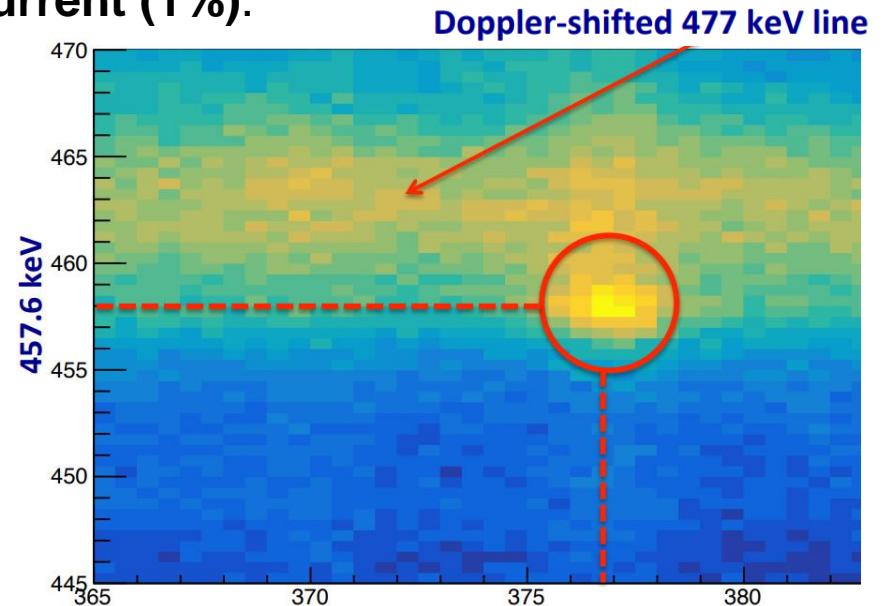
Identified fission fragment in delay region

We see fission fragments ^{140}Xe , ^{138}Xe , ^{142}Ba and ^{146}Ce
Identification through the $\{4+ \rightarrow 2+\}$ and $\{2+ \rightarrow 0+\}$ transitions
Full analyses of fission fragment yield is not completed.

Probably presence of neutron **dark current** (1%).



^{140}Xe 376.7 keV



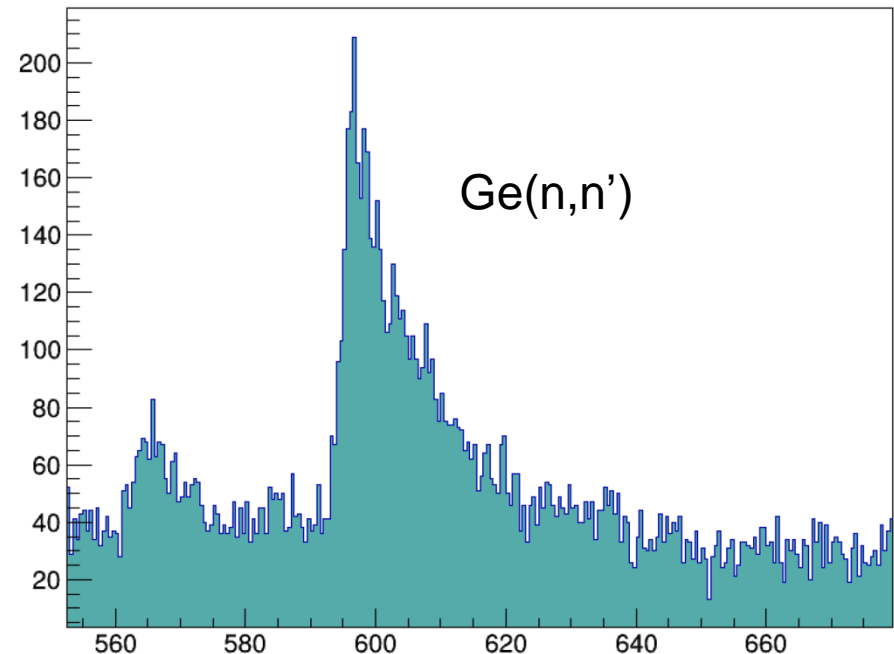
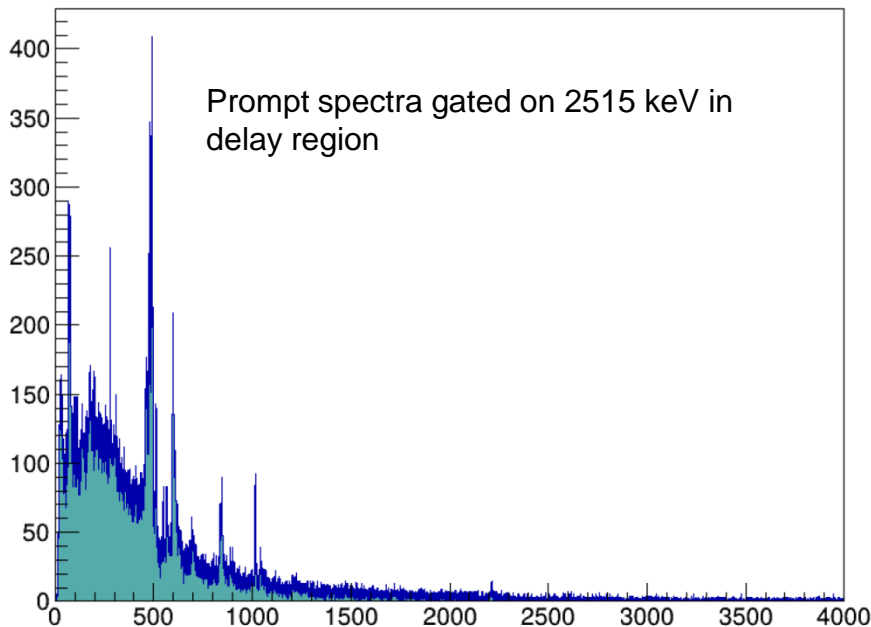
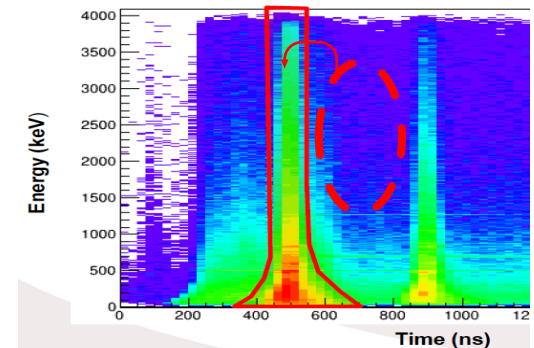
376.7 keV

^{238}U (^{140}Xe): {376.7, 457.6} keV

Analysis

Delay – prompt coincidence

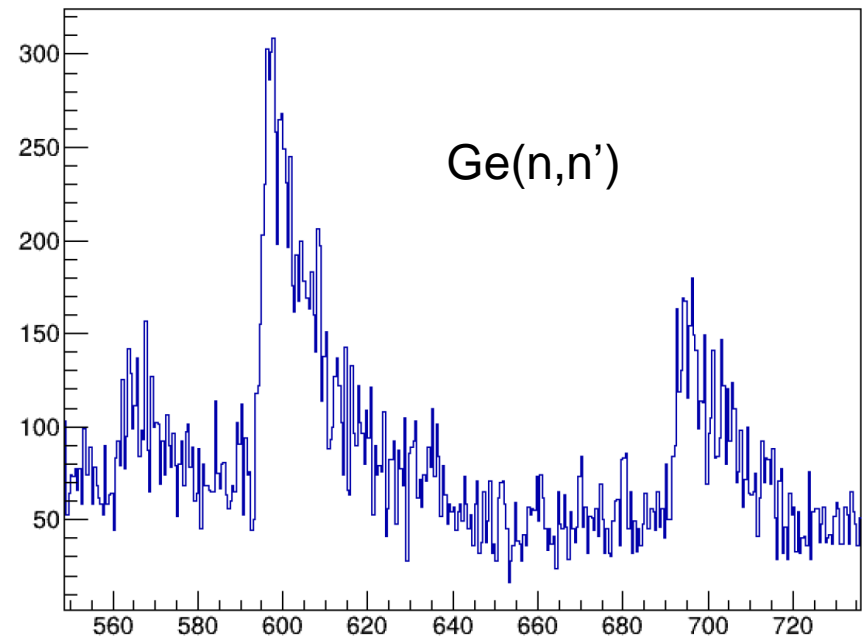
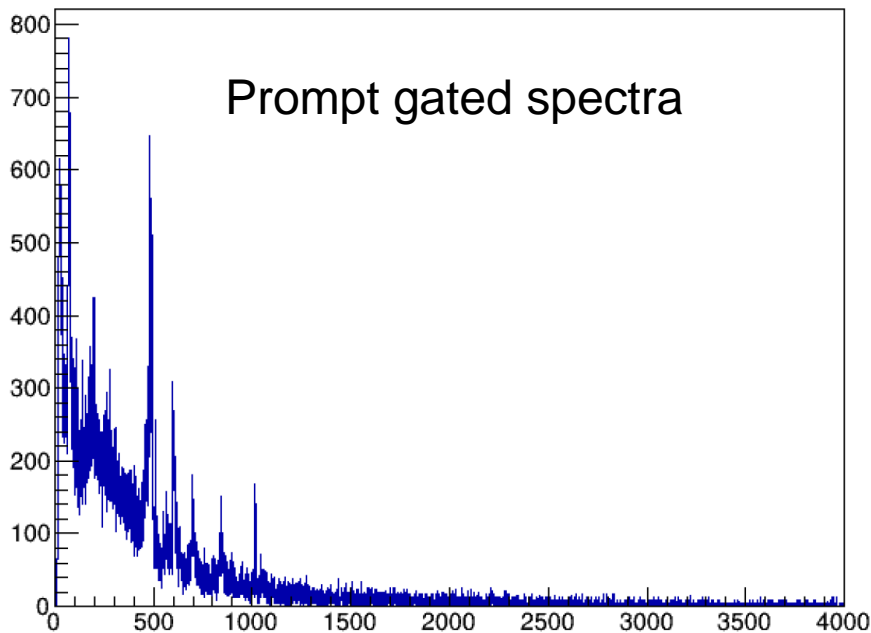
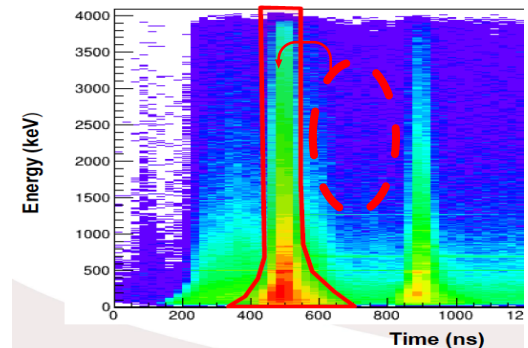
- Gated on **2515 keV** peak in delay region with **multiplicity in prompt and delay region less than 3**
- In prompt region standard background gamma peaks dominated by $\text{Ge}(n,n')$



Analysis

Delay – prompt coincidence

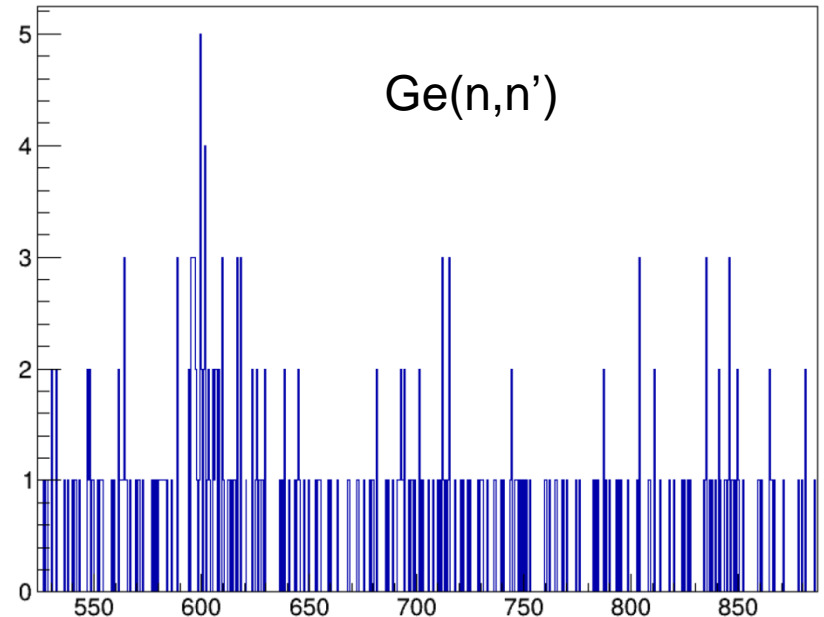
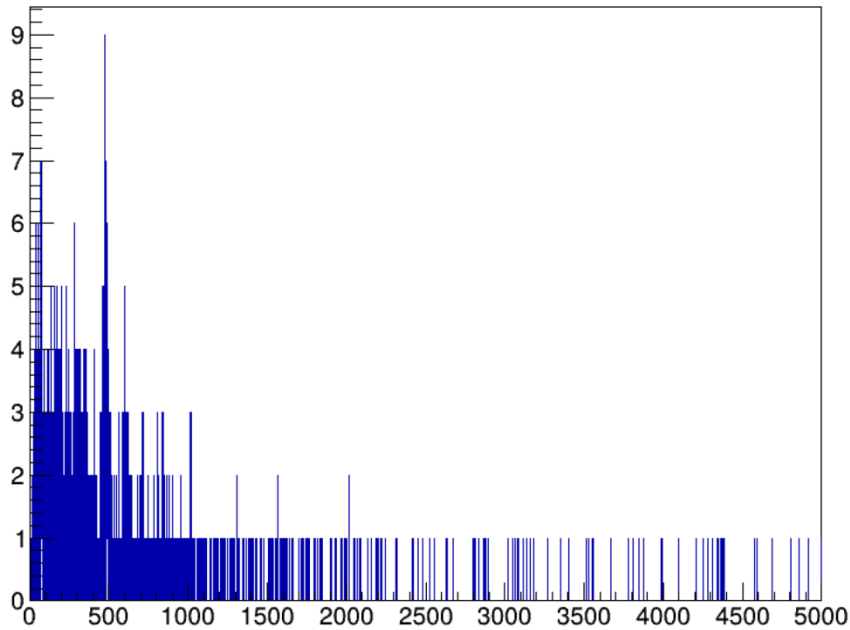
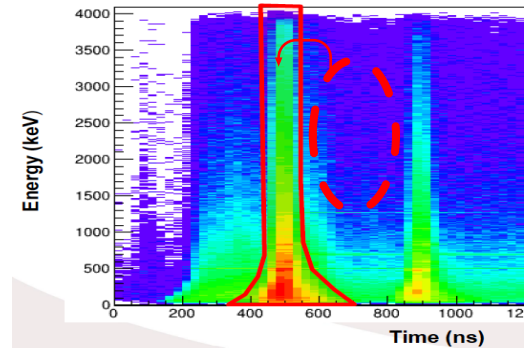
- Gated on **high multiplicity in delay region (>3)** in delay region with **multiplicity in prompt region less than 3**
- In prompt region standard background gamma peaks dominated by $\text{Ge}(n,n')$



Analysis

Delay – prompt coincidence

- Gated on ^{140}Xe peaks 377 keV and 475 keV in delay region
- In prompt region standard background gamma peaks dominated by $\text{Ge}(n,n')$

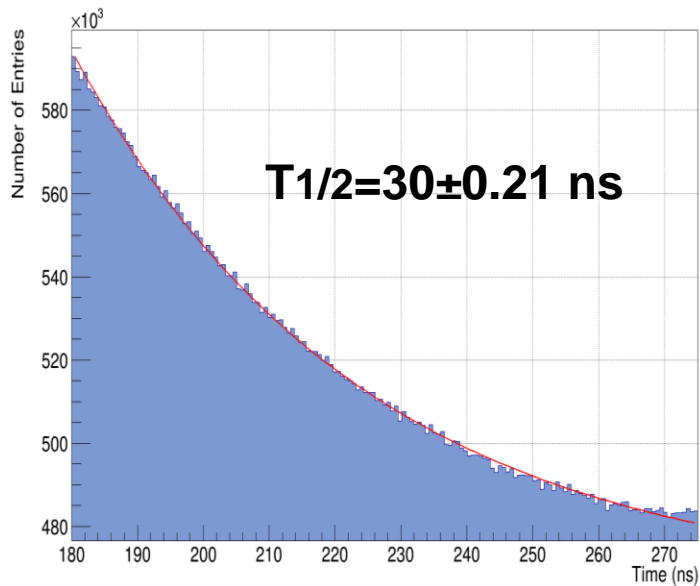


Analysis

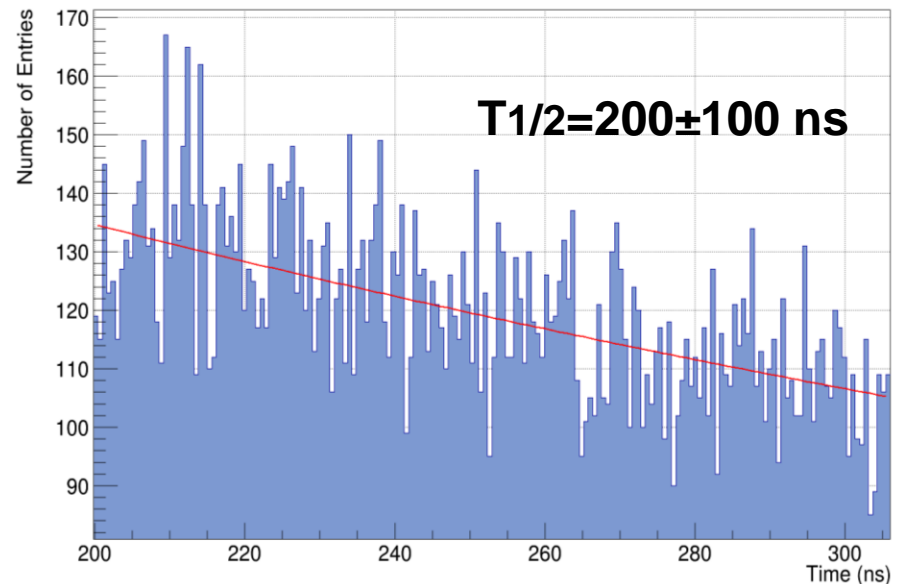
Half-life of isomeric state of 2559 keV

- Estimated from 2515 keV gamma peak from back decay: **280(144) ns**
- Estimated from ^{140}Xe 377 keV gamma peak: **257(162) ns**

Prompt Multiplicity >6



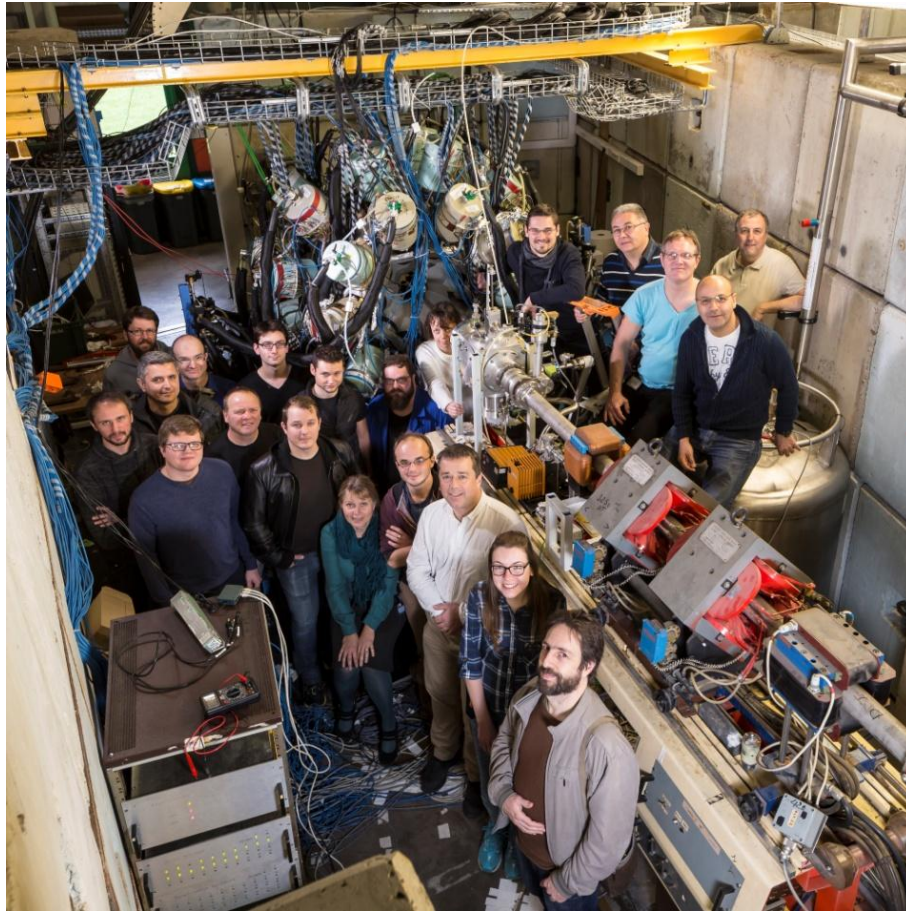
Prompt Multiplicity <3, Delay Multiplicity >4



Summary

- Spectroscopy of the shape isomer in ^{238}U was done by coupling ν -ball hybrid spectrometer with LICORNE neutron source.
- We have just 5 days of beams instead of 3 weeks.
- Higher background than was expected.

- Only gamma back decay transition of 2515 keV is detected.
- Fission fragment are detected in delay region (most probably form dark current).
- Half-life of isomeric state of 280(144) ns was measured.



Thank you