Lifetime measurements after neutron-induced fission using the FIPPS instrument at ILL

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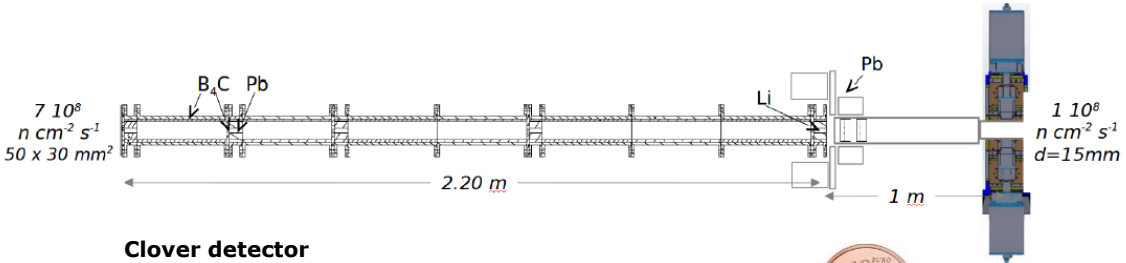
The FIPPS instrument at ILL

FIssion Product Prompt gamma-ray Spectrometer

- 8 Compton suppressed HPGe clover detectors
- Pencil-like (d=15mm) thermal neutron beam, with a flux of 10^8 n s^{-1} cm^{-2} at target position
- Possibility to add ancillary devices ($LaBr_3$, HPGe clovers...)

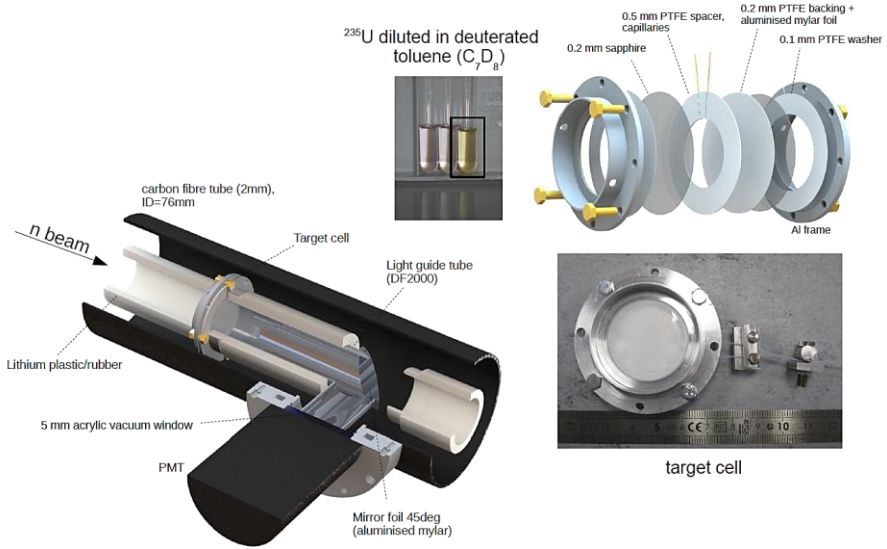


Clover detector

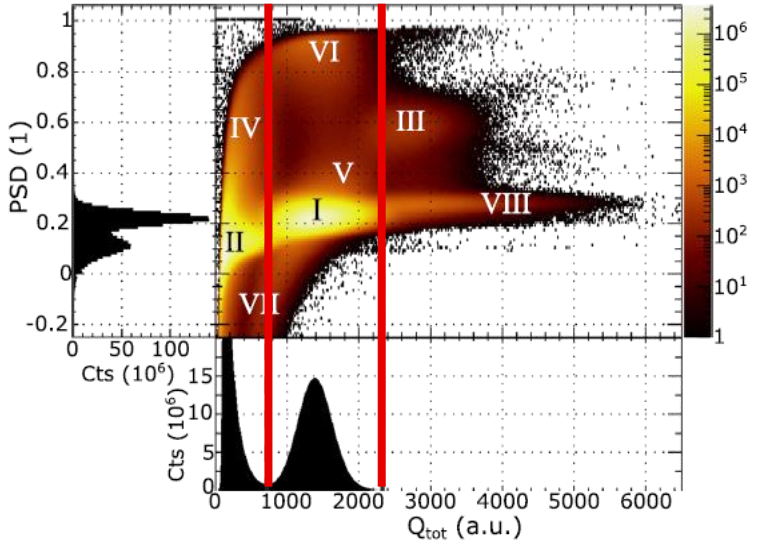
C. Michelagnoli *et al.,* EPJ Web Conf., 193 (2018) 04009
G. Colombi *et al*., Paper in preparation

The active fission target

- Campaign at FIPPS in 2018 (~32 days)
- Suppress γ-ray induced β background
- Actinide material dissolved in liquid scintillator
- 97.8(25)% fission tagging efficiency



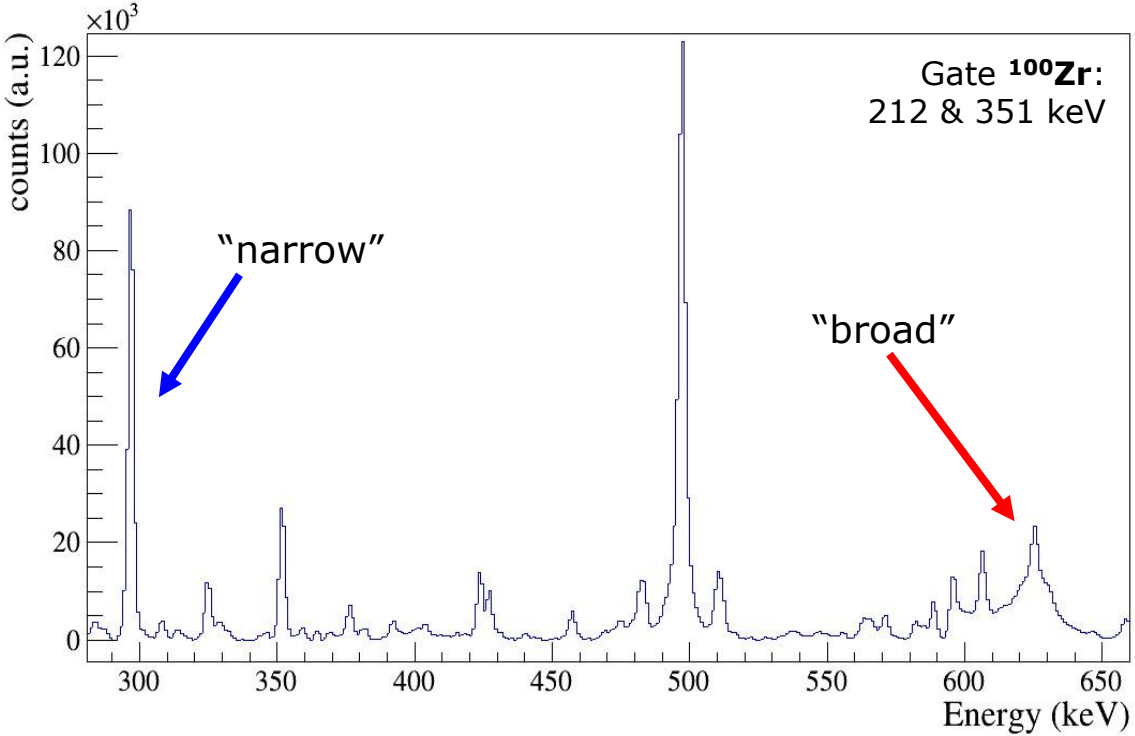
Pulse shape discrimination



I – Fission events
II – Electron events

F. Kandzia *et al.*,
Eur. Phys. J. A 56, 207 (2020)

Lineshape analysis for sub-picosecond lifetimes

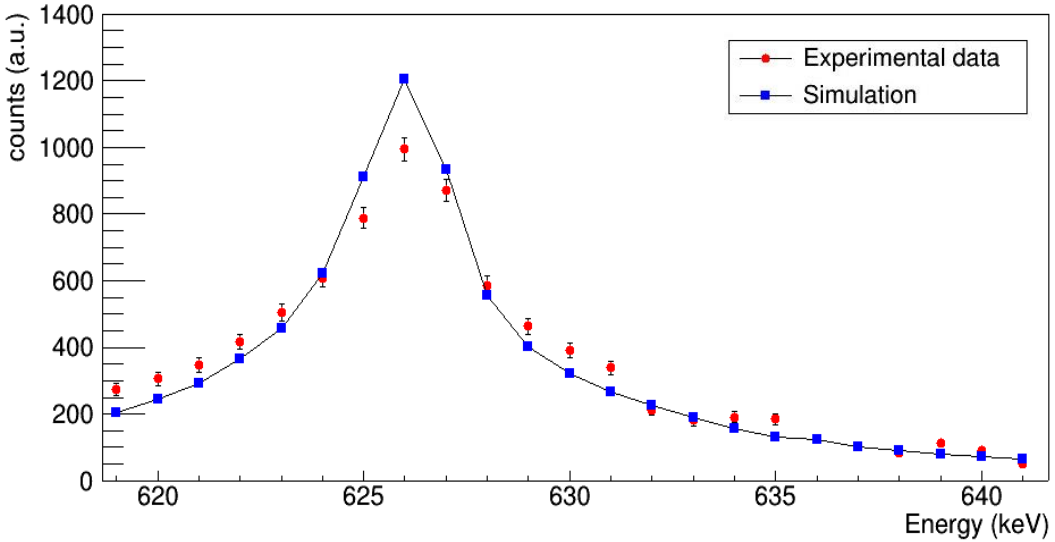


Doppler broadening of the gamma-ray peak following the de-excitation of the slowing down fission fragment (active target)

→ **Triple** gate to have major selectivity

Lineshape analysis for sub-picosecond lifetimes

^{100}Zr: $8^+ \rightarrow 6^+$



Input for Geant4 simulations:

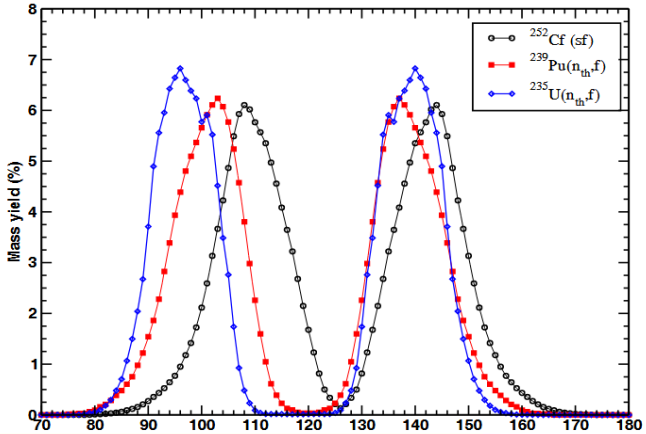
- Full FIPPS+IFIN-HH array
- Target cell geometry
- Validated stopping power
- Use FIFRELIN to describe fission
- Full gamma de-excitation (ENSDF)

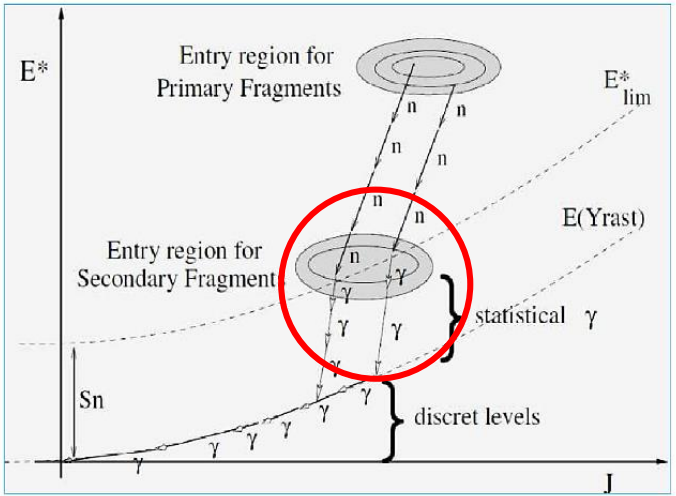
G. Colombi *et al.*,
Paper in preparation

FIFRELIN calculations

FIssion FRagment Evaporation Leading to an Investigation of Nuclear data

- Developed by CEA Cadarache
- Monte Carlo simulation
- Inputs: mass and K.E. distribution before neutron emission
- Evaluation of the repartition of the excitation energy between the fragments
- Fission fragment database with (A, Z, K.E., E*, J, π)



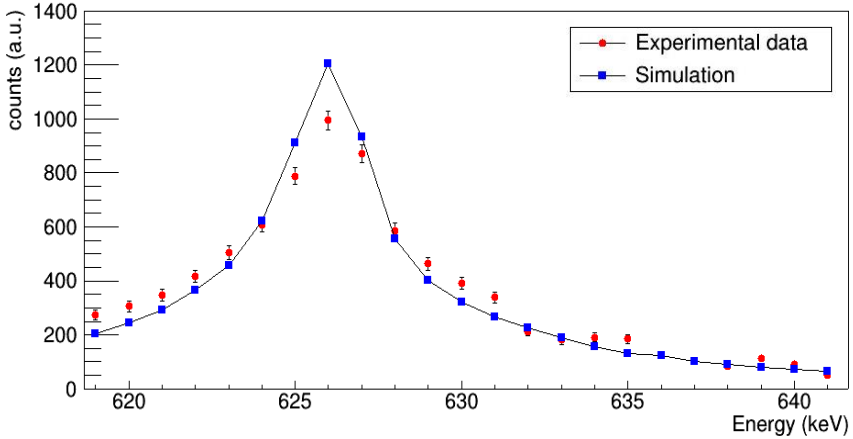


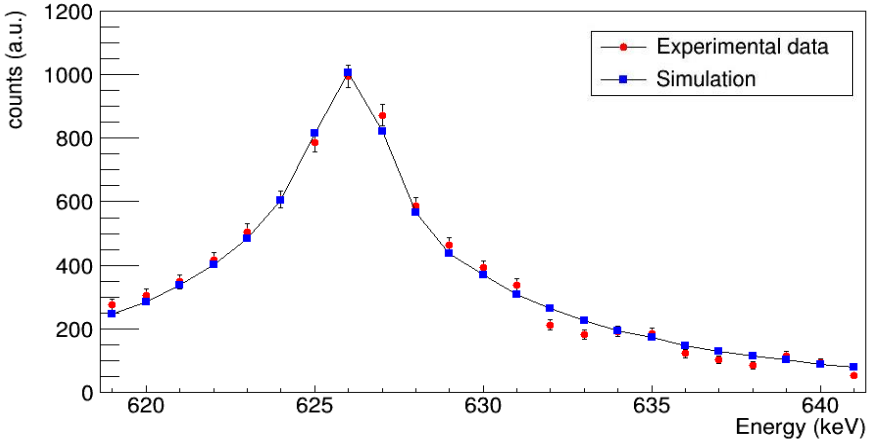
Entry point

O. Litaize, O. Serot, and L. Tamagno, EPJ A (2015), 51:177

V. Piau *et al.*, Phys. Lett. B 837 (2023) 137648

Lineshape analysis for sub-picosecond lifetimes





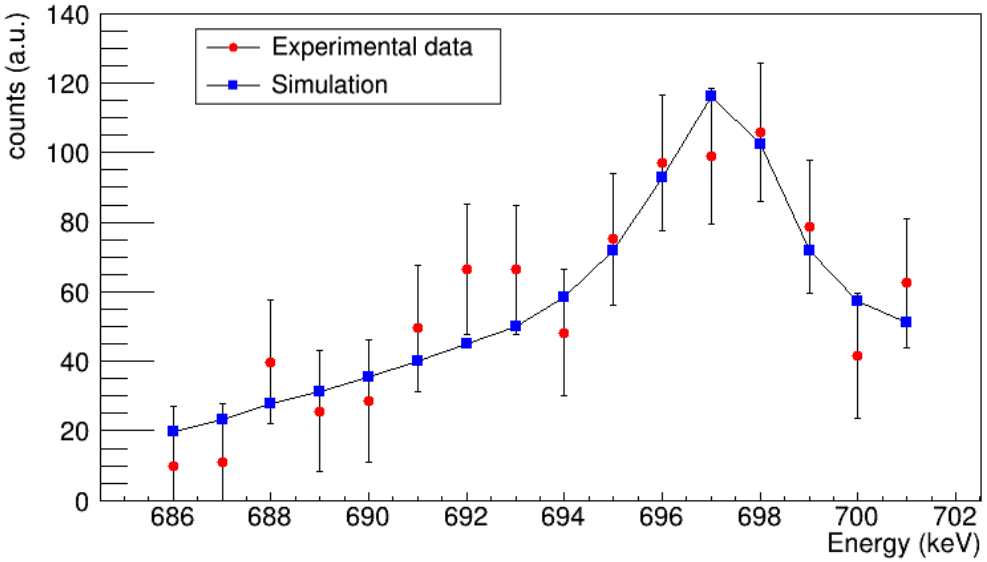
^{100}Zr: $8^+ \rightarrow 6^+$

G. Colombi *et al.*,
Paper in preparation

Lineshape analysis for sub-picosecond lifetimes

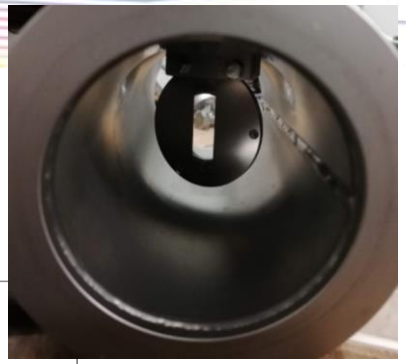
Ongoing analysis of Zr and Nb isotopes

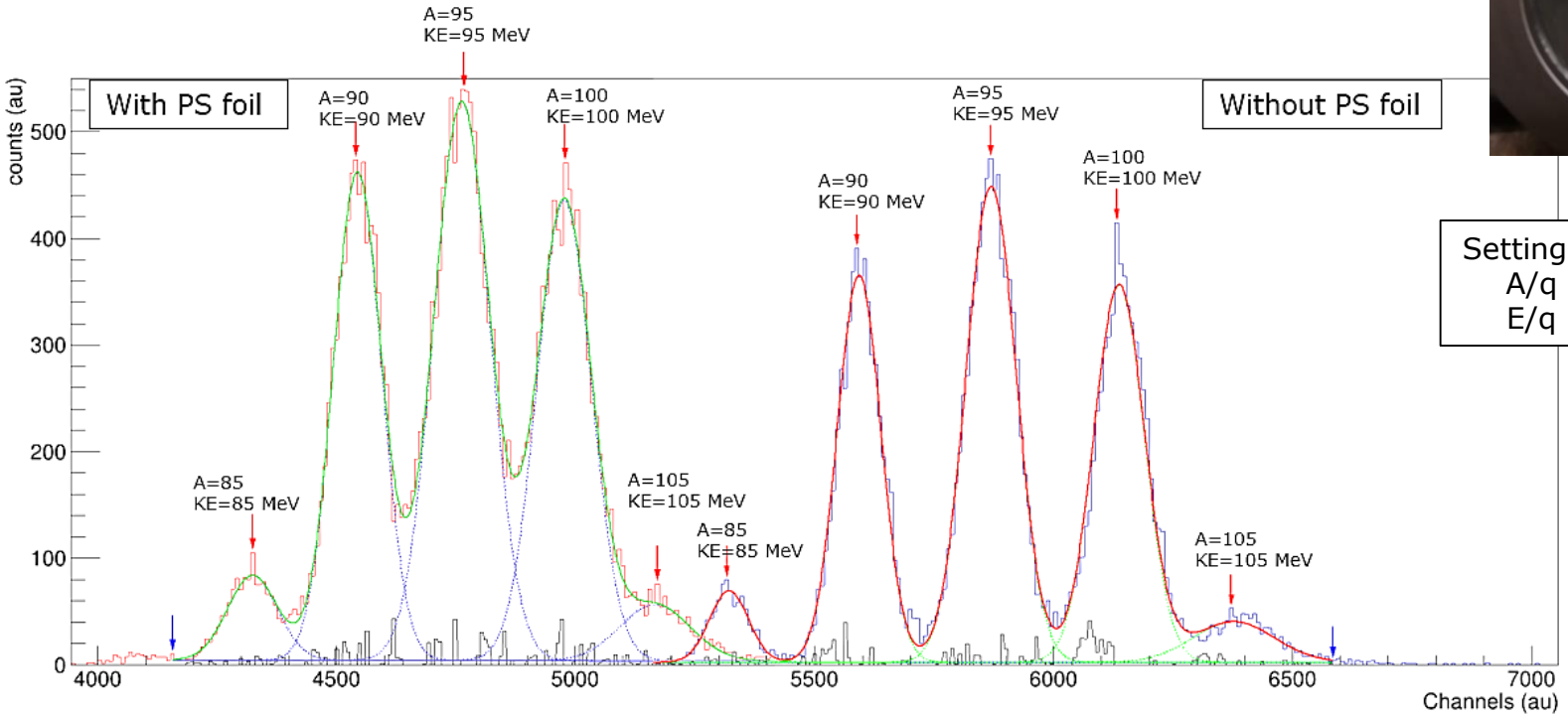
^{101}Zr: $21/2^+ \rightarrow 19/2^+$



Energy loss evaluation

- Measurement at the Lohengrin spectrometer with 2.5 µm PS foil





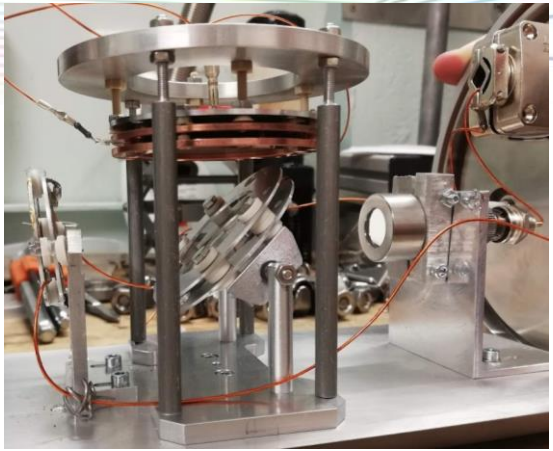
Settings Lohengrin:
A/q = 100/20
E/q = 100/20

Energy loss evaluation

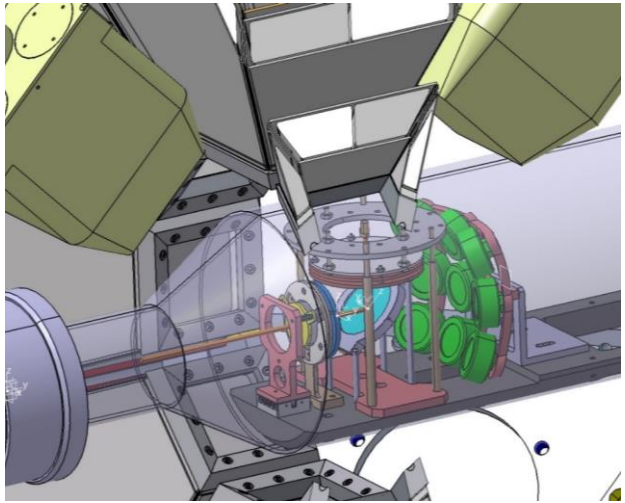
- Measurement at the Lohengrin spectrometer with 2.5 µm PS foil
- Comparison with Geant4 and SRIM-2013 calculations
  → Confidence in the Geant4 stopping power

Summary and perspectives

- New possibilities for measuring lifetimes after neutron-induced fission
- Ongoing lineshape analysis on the active target data to extract sub-ps lifetimes

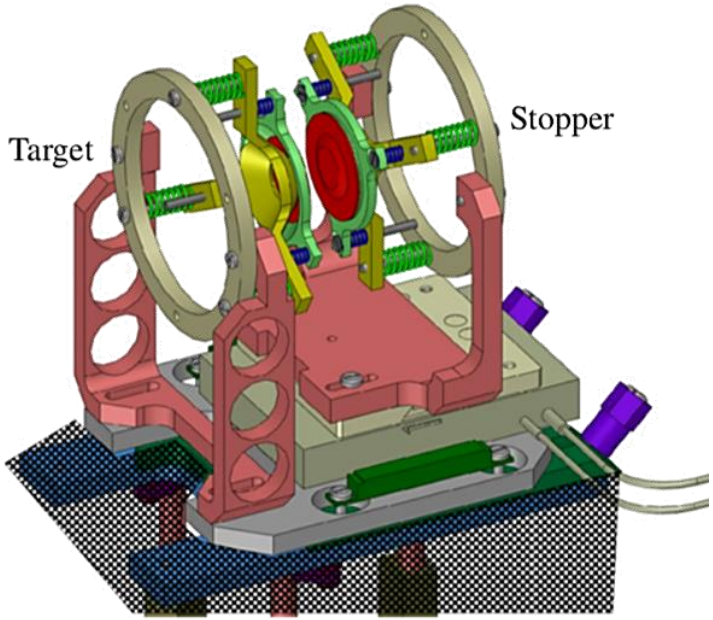


- Development of a plunger and a fission fragment identification setup for ps lifetime measurements
- The commissioning with ^{252}Cf source of the Plunger device and following experiments are foreseen in 2023




Thank you for listening!

The plunger device at a neutron beam



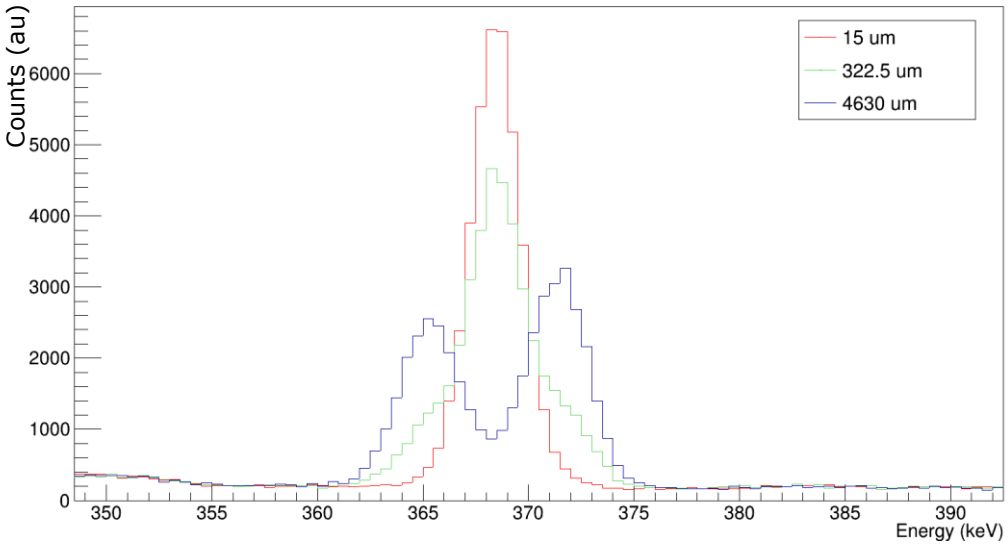
J. Ljungvall *et al.,*
NIMA 679 (2012) 61

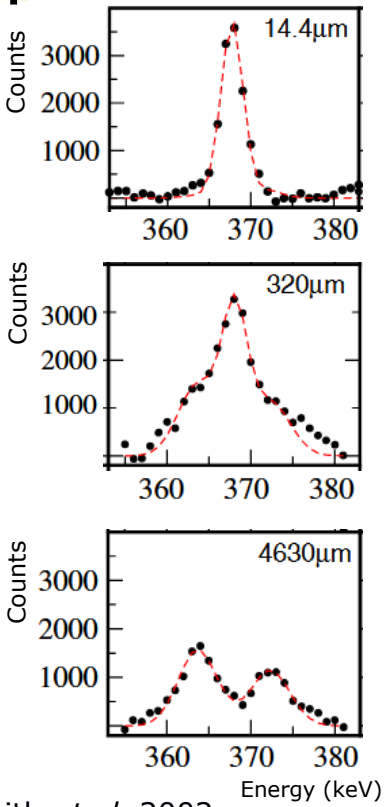
- Measurement of lifetimes in the ps to ns time range with RDDS method
- Use in neutron-induced fission reactions
- First test with a ^{252}Cf source
- Need of a mass identification setup

The plunger device at a neutron beam

Geant4 simulations of ^{104}Mo ($4^+ \rightarrow 2^+$, τ =37.7 ps)

→ Doppler corrected spectra in forward and backward detectors





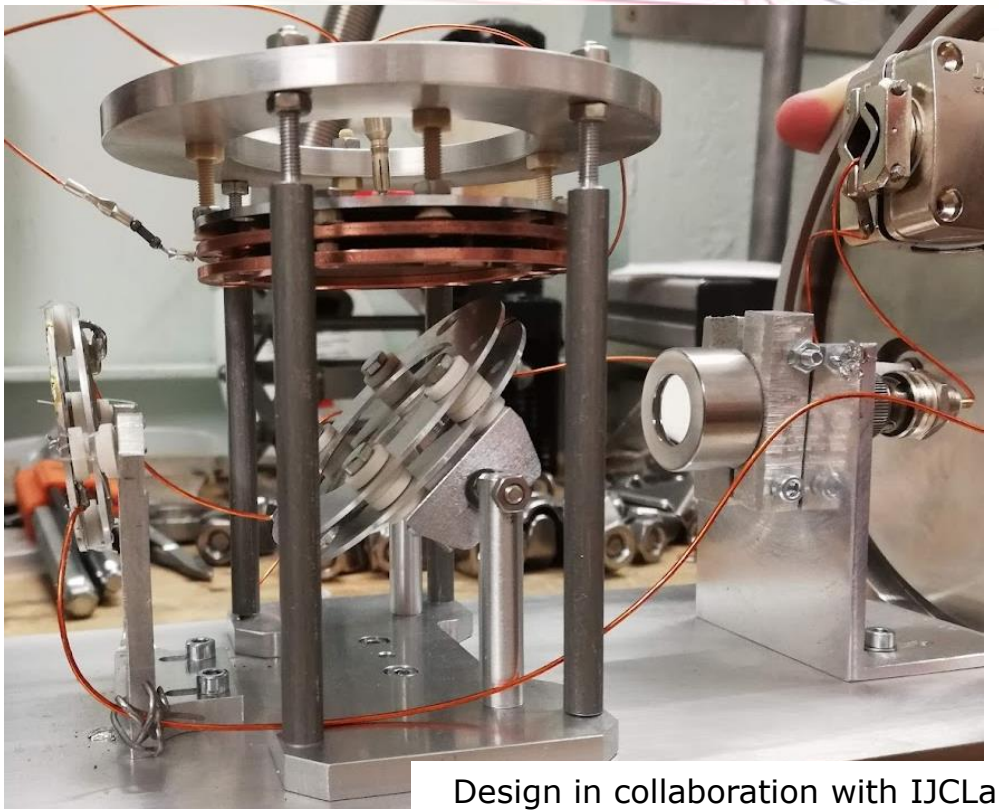
A.G. Smith *et al.* 2002,
J. Phys. G: Nucl. Part. Phys. 28 2307

The plunger device at a neutron beam

Fission fragment identification

System designed for a mass resolution of 3-5 amu, inspired by the VERDI spectrometer

Mass reconstruction with the v-E measurement



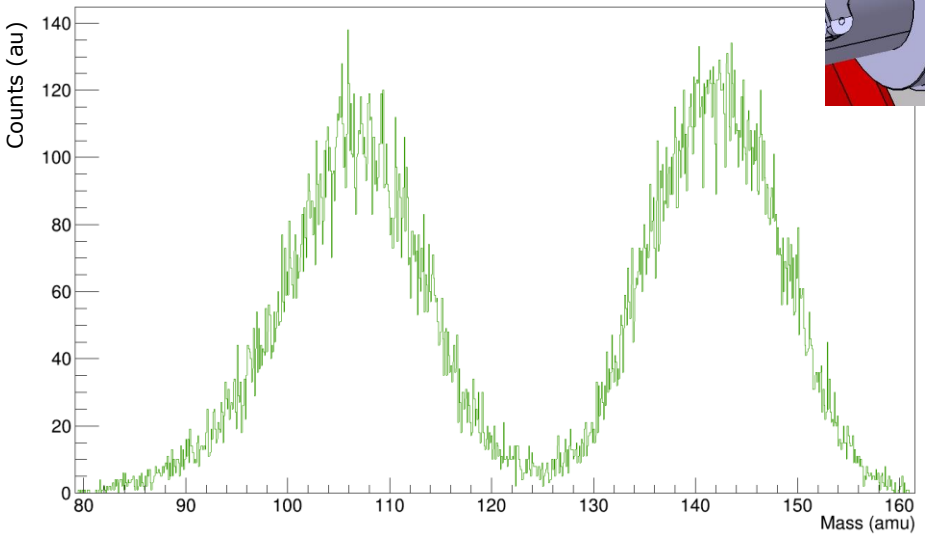
Design in collaboration with IJCLab

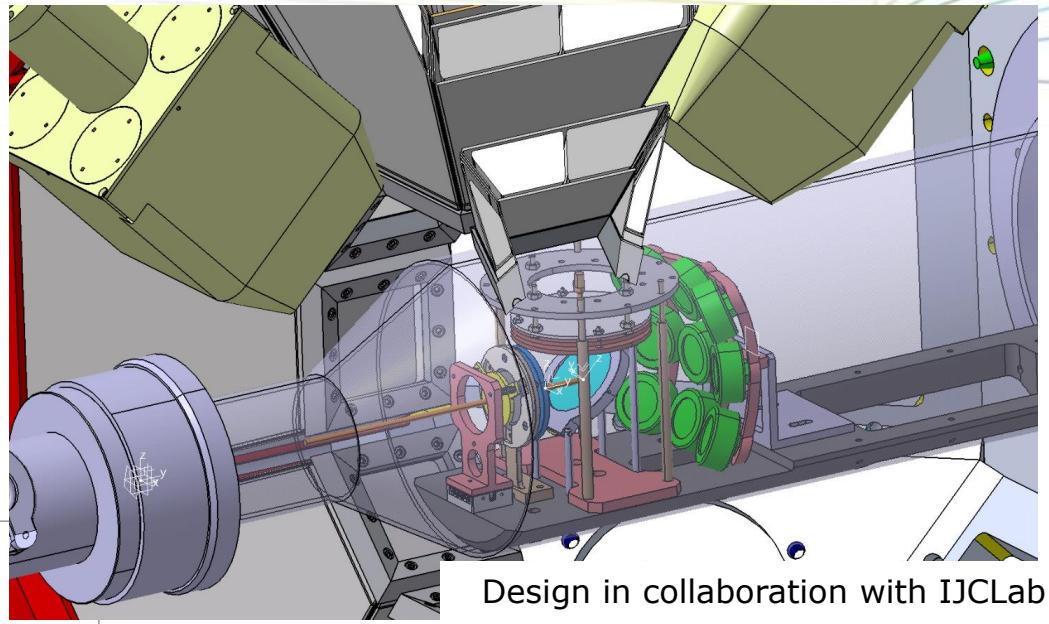
M.O. Frégeau *et al.,* NIMA 817 (2016) 35-41

The *plunger* device at a neutron beam

Fission fragment identification

Reconstructed fission fragments mass distribution from simulated ^{252}Cf source

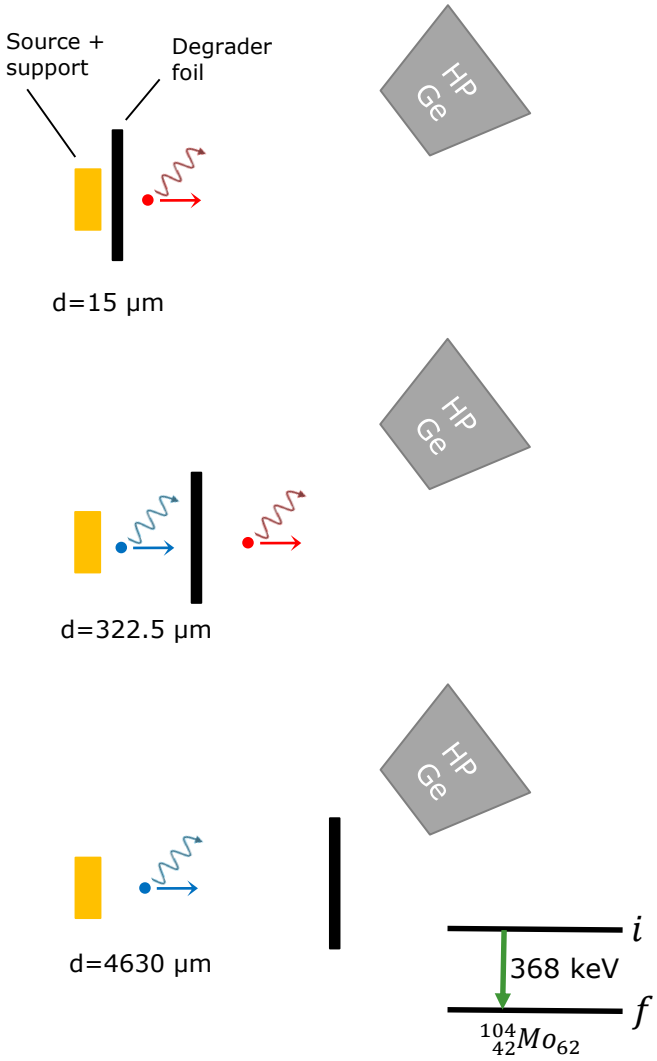


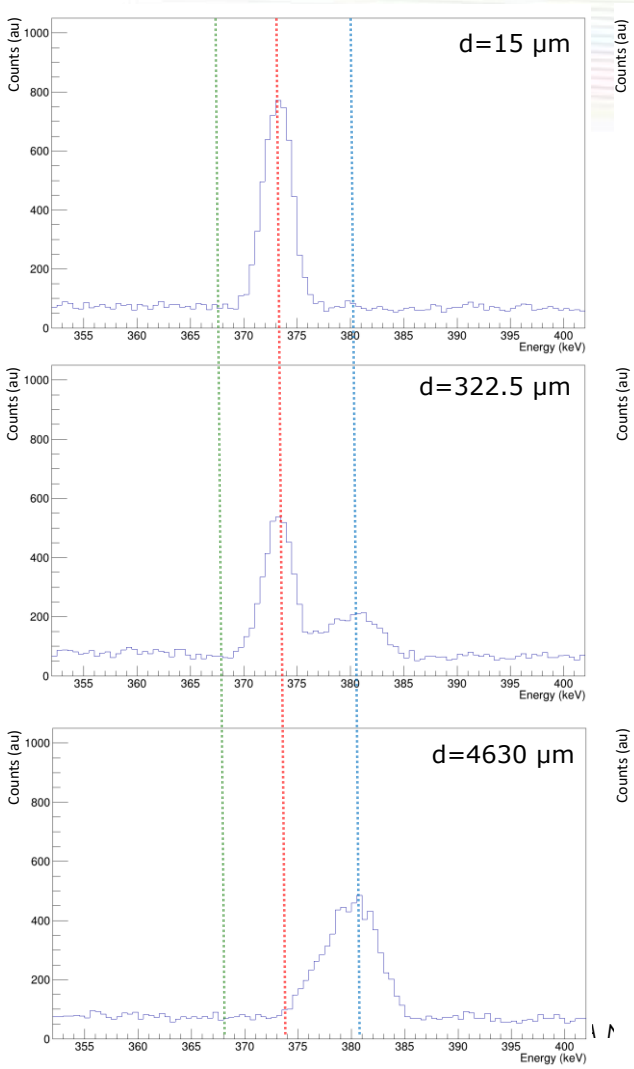


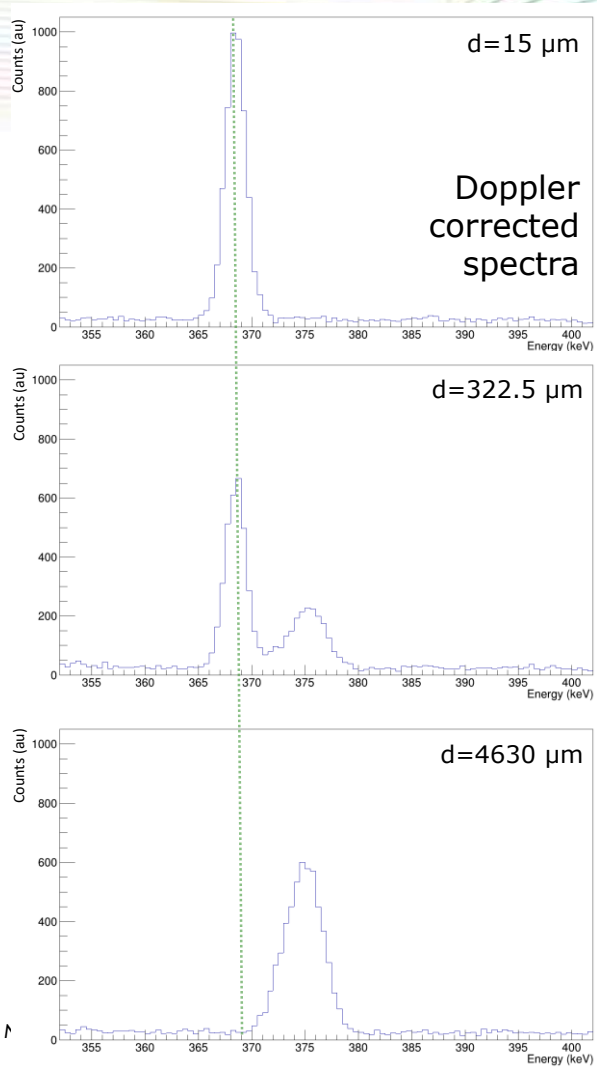
Design in collaboration with IJCLab

Design and simulation of the fission fragment detection system which allows to have a mass resolution of 3-5 amu

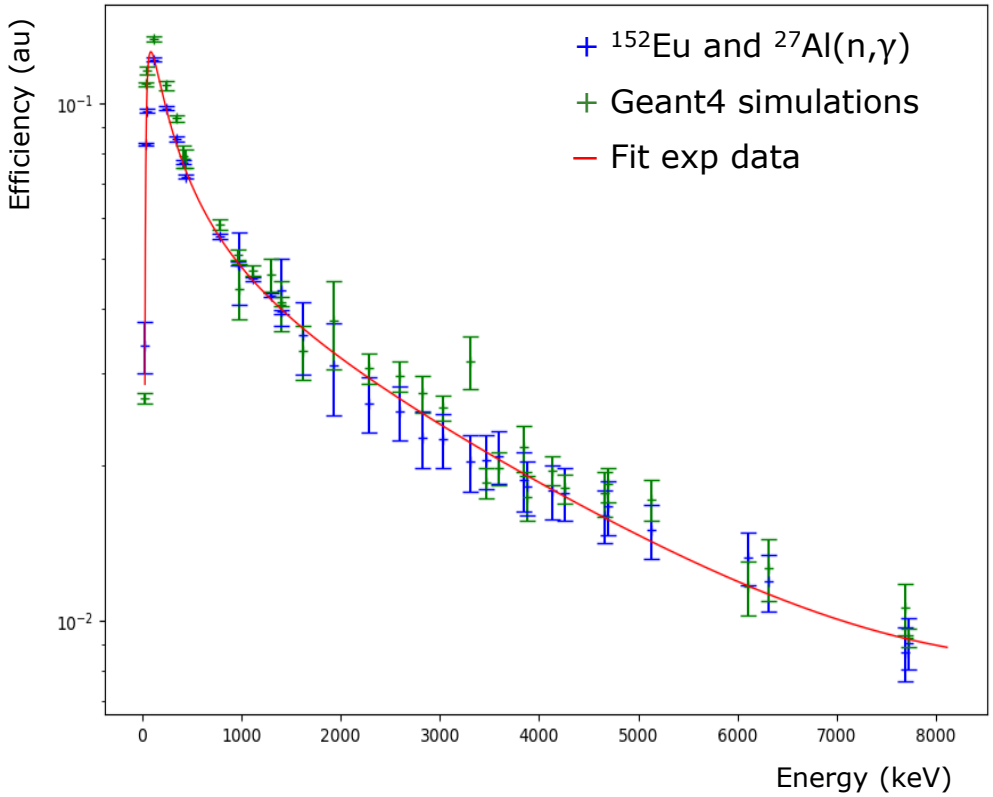
→ Study of already existing fission fragment spectrometers (VERDI, FALSTAFF, SPIDER…)


Source + support
Degrader foil
HP Ge
d=15 μm
HP Ge
d=322.5 μm
HP Ge
d=4630 μm
i
368 keV
f
$^{104}_{42}Mo_{62}$

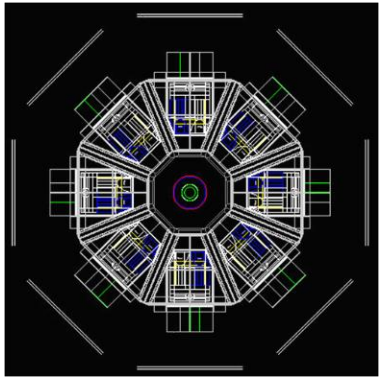

d=15 μm
d=322.5 μm
d=4630 μm
Counts (au)
Energy (keV)


d=15 μm
d=322.5 μm
d=4630 μm
Doppler corrected spectra
Counts (au)
Energy (keV)

Geant4 Monte Carlo simulations and FIPPS efficiency



- Geant4 simulations to reproduce experimental campaigns and study the feasibility of future experiments
- Validated with the ^{152}Eu efficiency curve
- Efficiency curve up to 8 MeV thanks to (n, γ) reactions

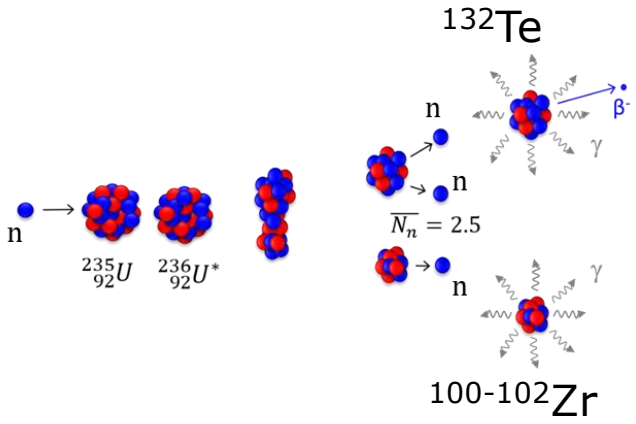


Nicolas Riggaz,
internship 2022

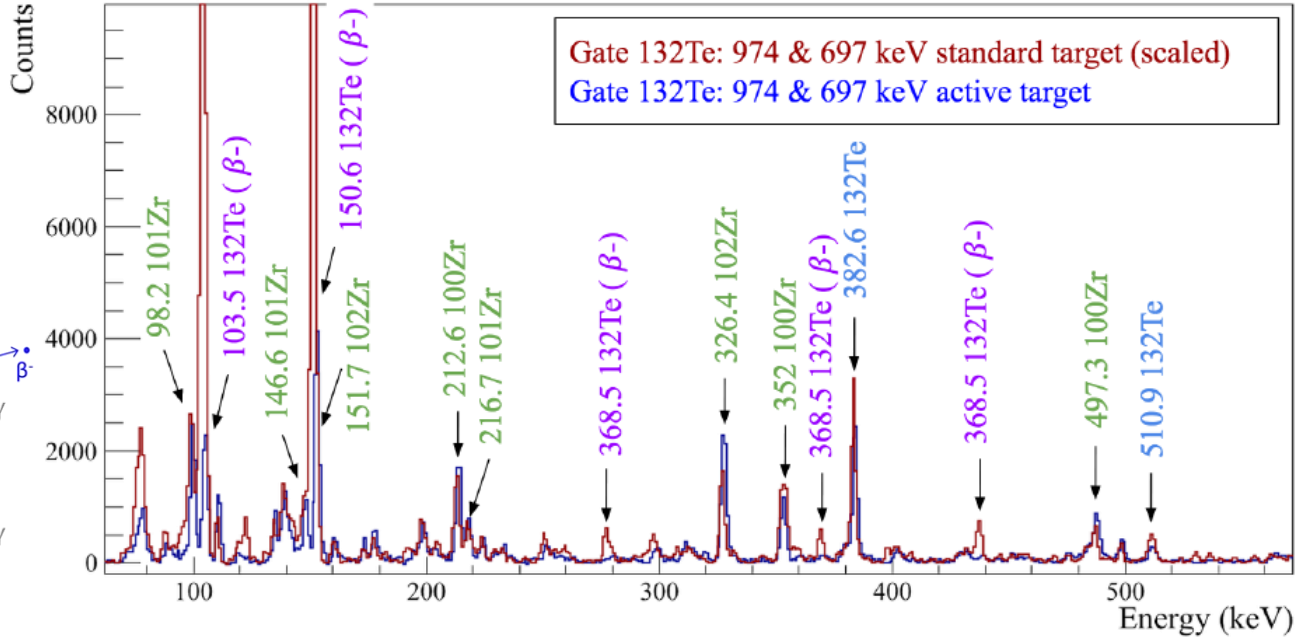
$$eff(x) = A\ ln^5(x) + \mathrm{B}\ ln^4(x) + C\ ln^3(x) + D\ ln^2(x) + \mathrm{E}\ ln(x) + F$$

Performance of the active fission target

- "Standard" metallic target at FIPPS
- Scintillator-based active target



Triple coincidence spectra



F. Kandzia *et al.*, Eur. Phys. J. A 56, 207 (2020)
D. Reygadas, PhD Thesis, October 2021