β-delayed neutron emission probability (P_{xn}) measurement test during experiment G-22-00027

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Super-FRS Experiment Collaboration Meeting

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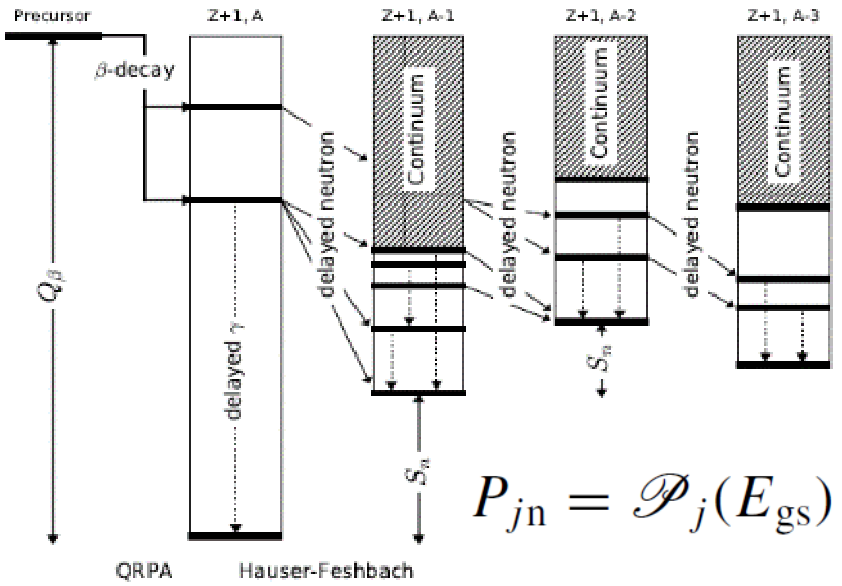
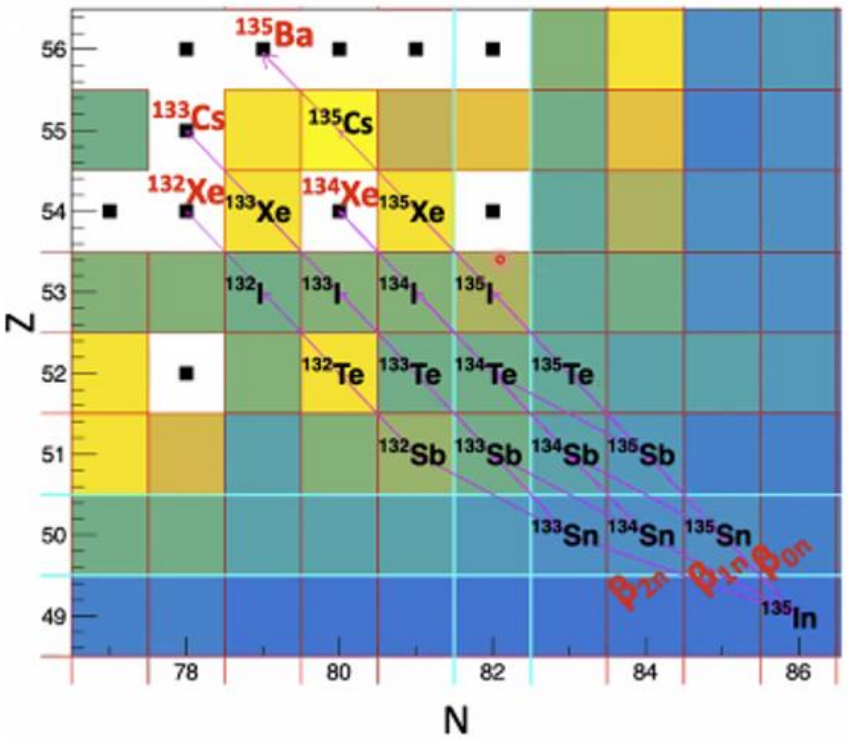
Motivation for P_{xn} measurements

- **r-process nucleosynthesis**[1]
  - Detours in β-decay chains
  - More neutrons during freeze-out
- **Nuclear physics models**[2]
  - Calculations of n-γ competition
  - Optical models for neutron transmission in the nucleus
  - Nuclear energy level schemes
- **Nuclear reactor operation**[3]
  - Next generation reactors
  - New fuel types
  - Accelerator Driven Systems
- **Worldwide βxn programs**[3]
  - Mostly using n, β, γ detectors
  - Usually, no direct recoil identification



$$P_{jn} = \mathscr{P}_j(E_{gs})$$



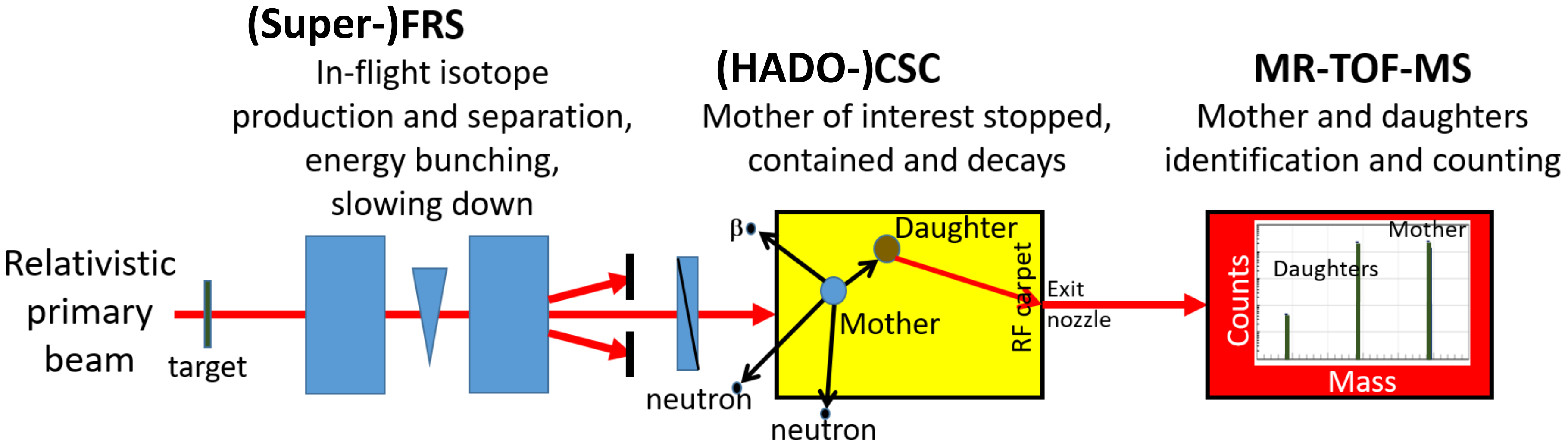
[1] R. Surman et al., JPS Conf. Proc. , 010010 (2015)

[2] M. R. Mumpower et al., Physical Review C 94, 064317 (2016)

[3] P. Dimitriou et al., Development of a Reference Database for Beta-Delayed Neutron Emission, Nuclear Data Sheets 173, 144 (2021)

P_{xn} measurement at the (Super-)FRS Ion Catcher

- A novel method for measuring **β-delayed single- and multi-neutron emission probabilities** (**P_{xn}**), simultaneously with **mass**, **$Q_{\beta xn}$**, **S_{xn}** and **$T_{1/2}$**



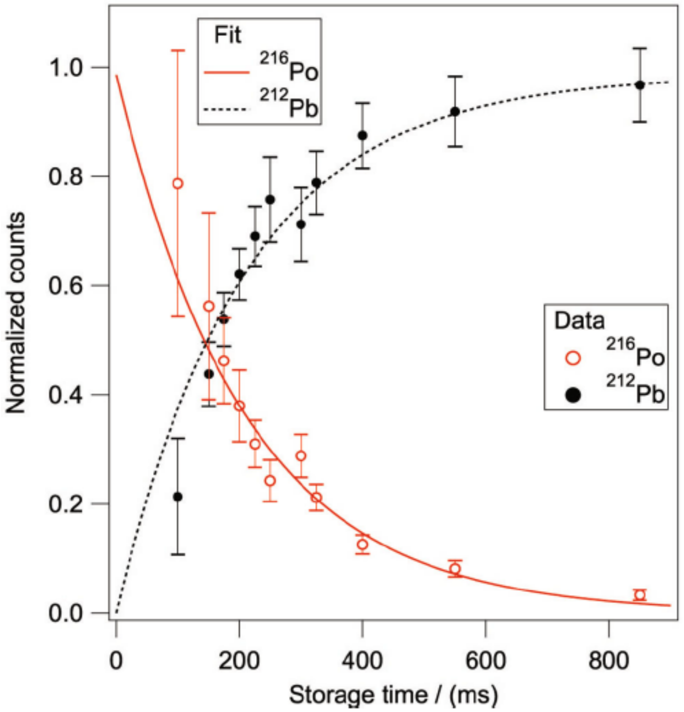
- P_{xn} is determined by the ratios between the daughters: $$P_{xn} = \frac{D_i(t_s)}{\sum D_i(t_s)}$$
- Method is **complementary** to worldwide programs
- Especially suited for **multi-neutron** emission probabilities

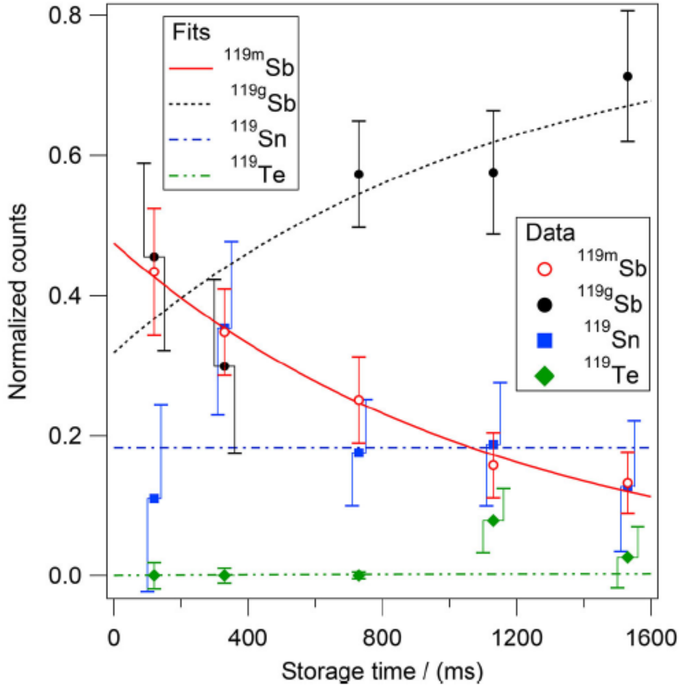
'Straight forward' analysis
Isotopes of same element
Hardly any corrections needed

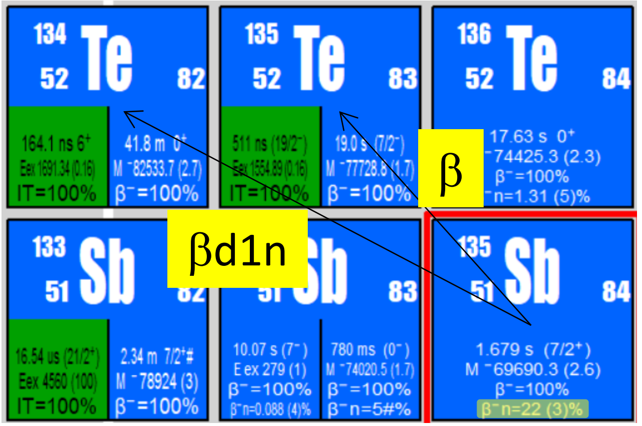
I. Miskun et al., A novel method for the measurement of half-lives and decay branching ratios of exotic nuclei, Eur. Phys. J. A (2019) 55: 148

First test of a P_{xn} measurement at the FRS-IC

- Method was demonstrated for **α-decay and isomer transition***
- Towards the **P_{xn} program at ES/FS**, our present aim was to measure **P_{1n} of ^{135}Sb**
- Performed as part of **experiment 0027 (n-skin of ^{132}Sn and ^{144}Xe)** during June 2025, for which the **FRS-IC was used for mass tagging**



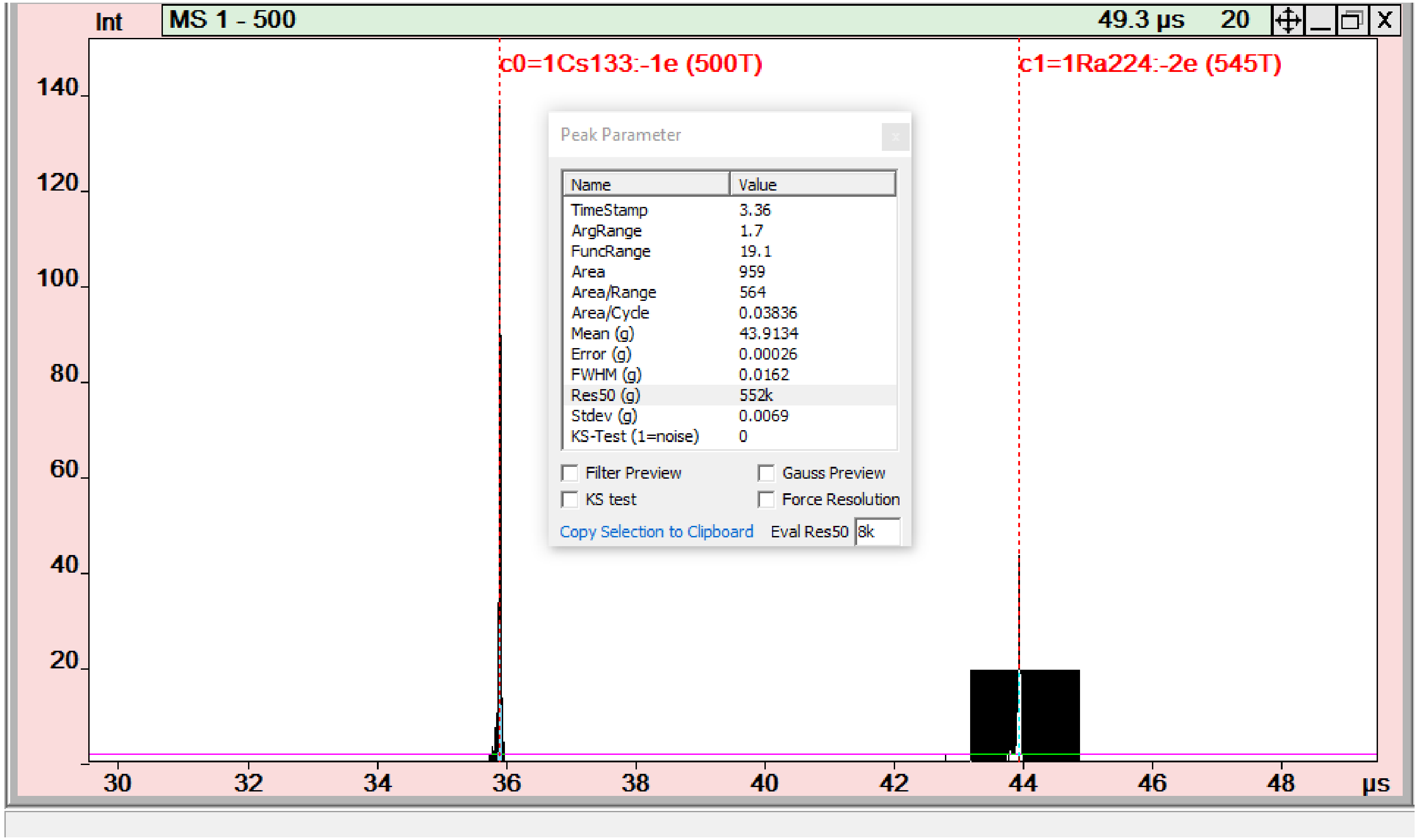




*I. Miskun et al., A novel method for the measurement of half-lives and decay branching ratios of exotic nuclei, Eur. Phys. J. A (2019) 55: 148

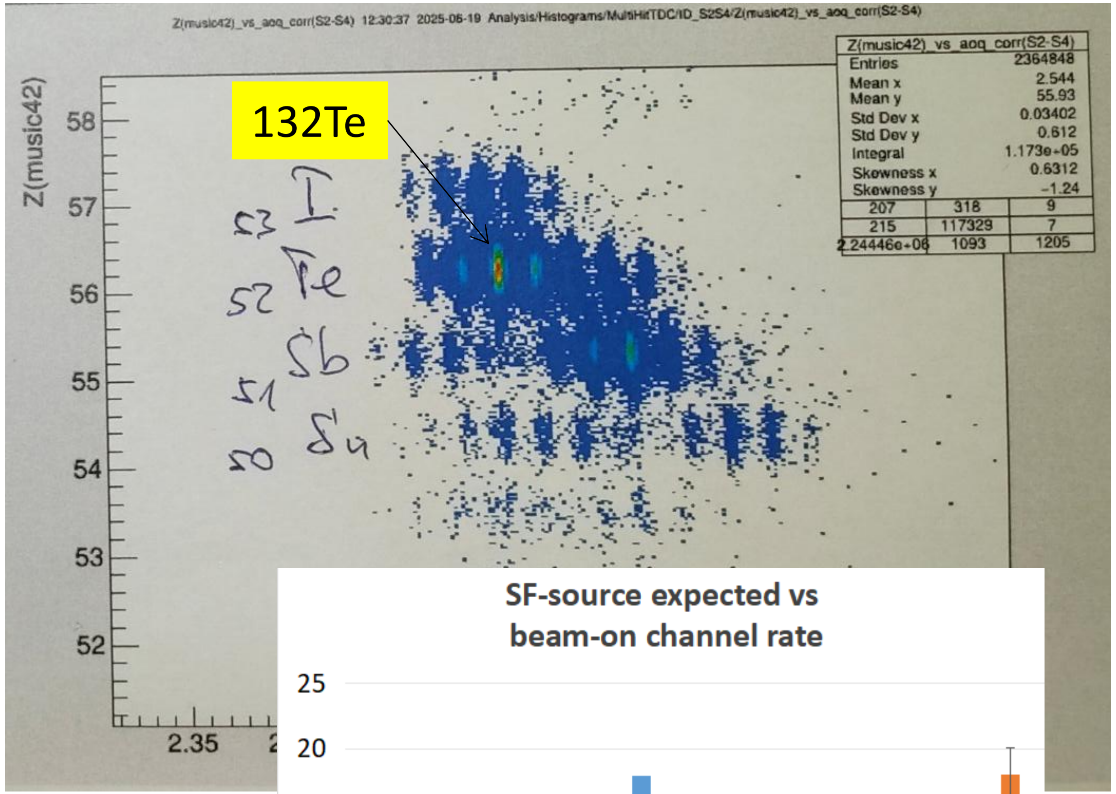
MR-TOF-MS performance towards 0027, after repair

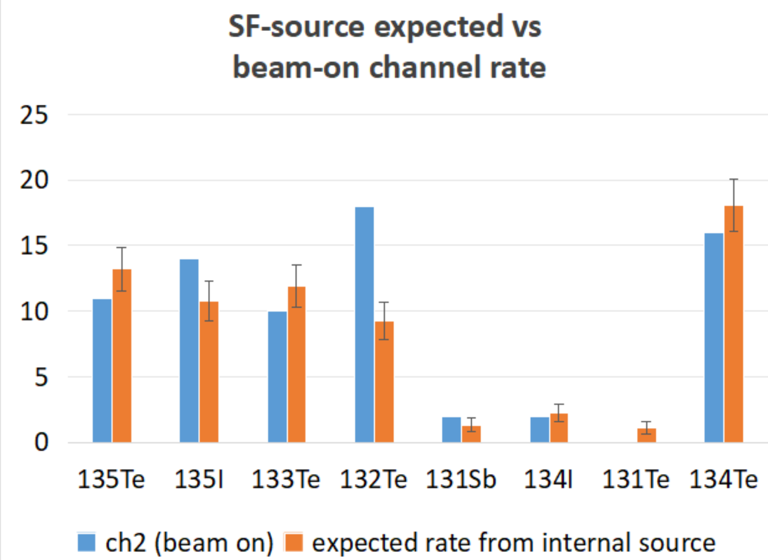
- Overnight measurements
  - $^{224}Ra^{++}$ from the a-recoil source in the CSC
  - $^{133}Cs^{+}$ from the MR-TOF-MS internal source
- Obtained expected rates with a mass resolving power (MRP) of 550,000 at 545 turns.



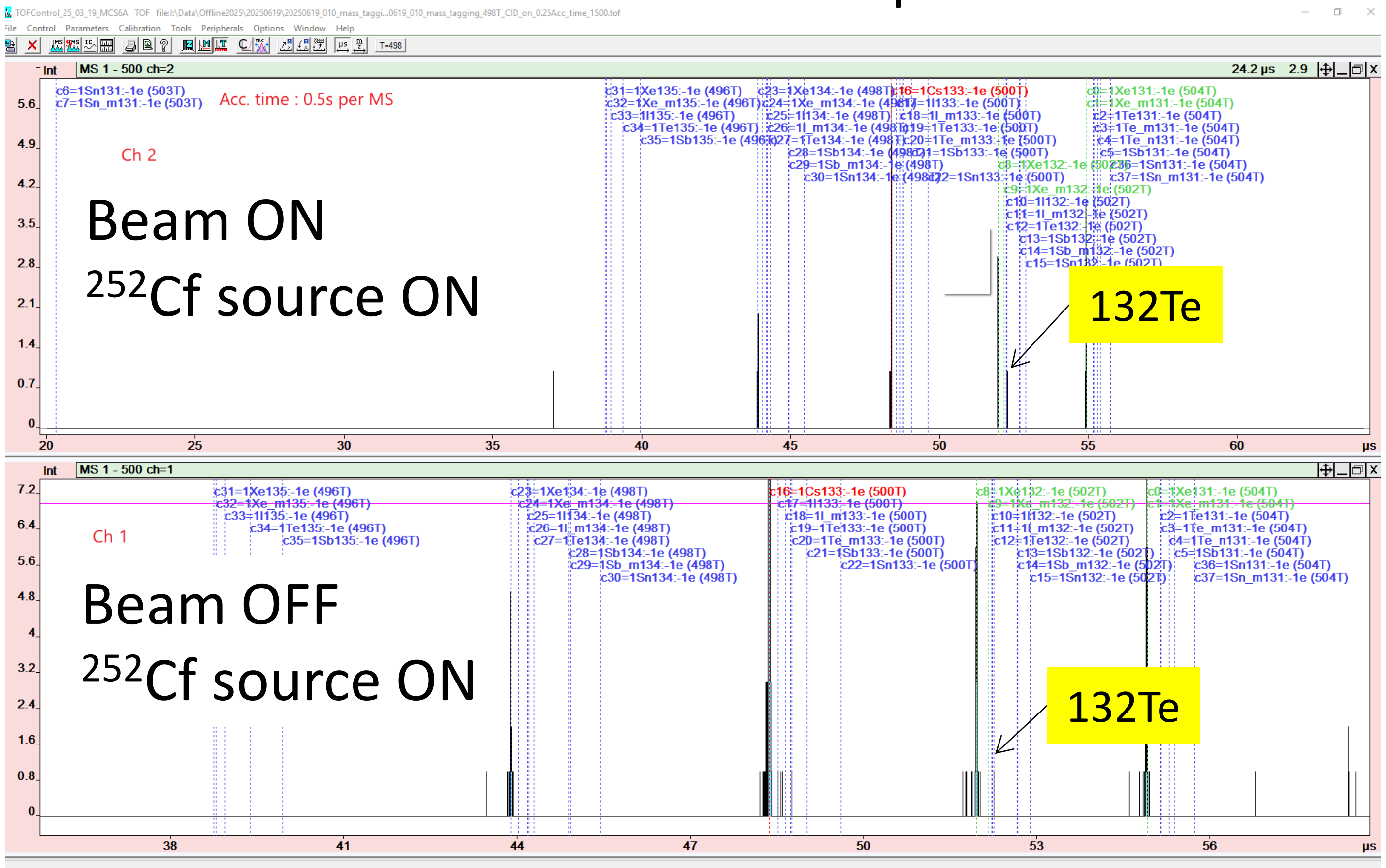
Mass tagging of ^{132}Te in FRS-IC for n-skin experiment

FRS ID plot





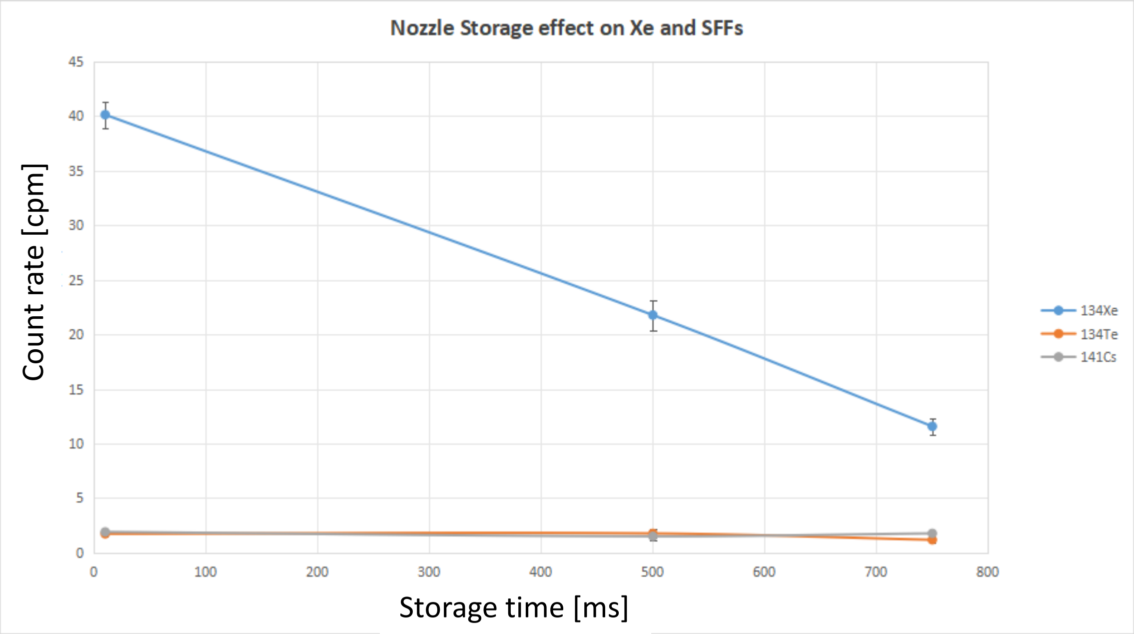
MR-TOF-MS mass spectrum

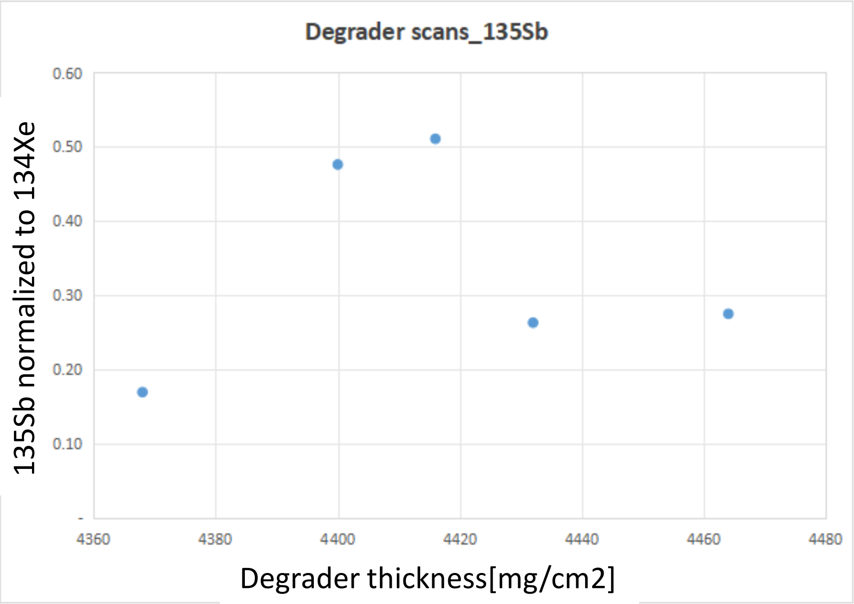


- Number of ^{132}Te counts during 'beam ON' is significantly higher than its 'beam OFF' counts.
- ^{132}Te It has the highest sigma deviation in the whole dataset
- Indicates that FRS-IC is set for ^{132}Te detection

P_{xn} test measurement of ^{135}Sb

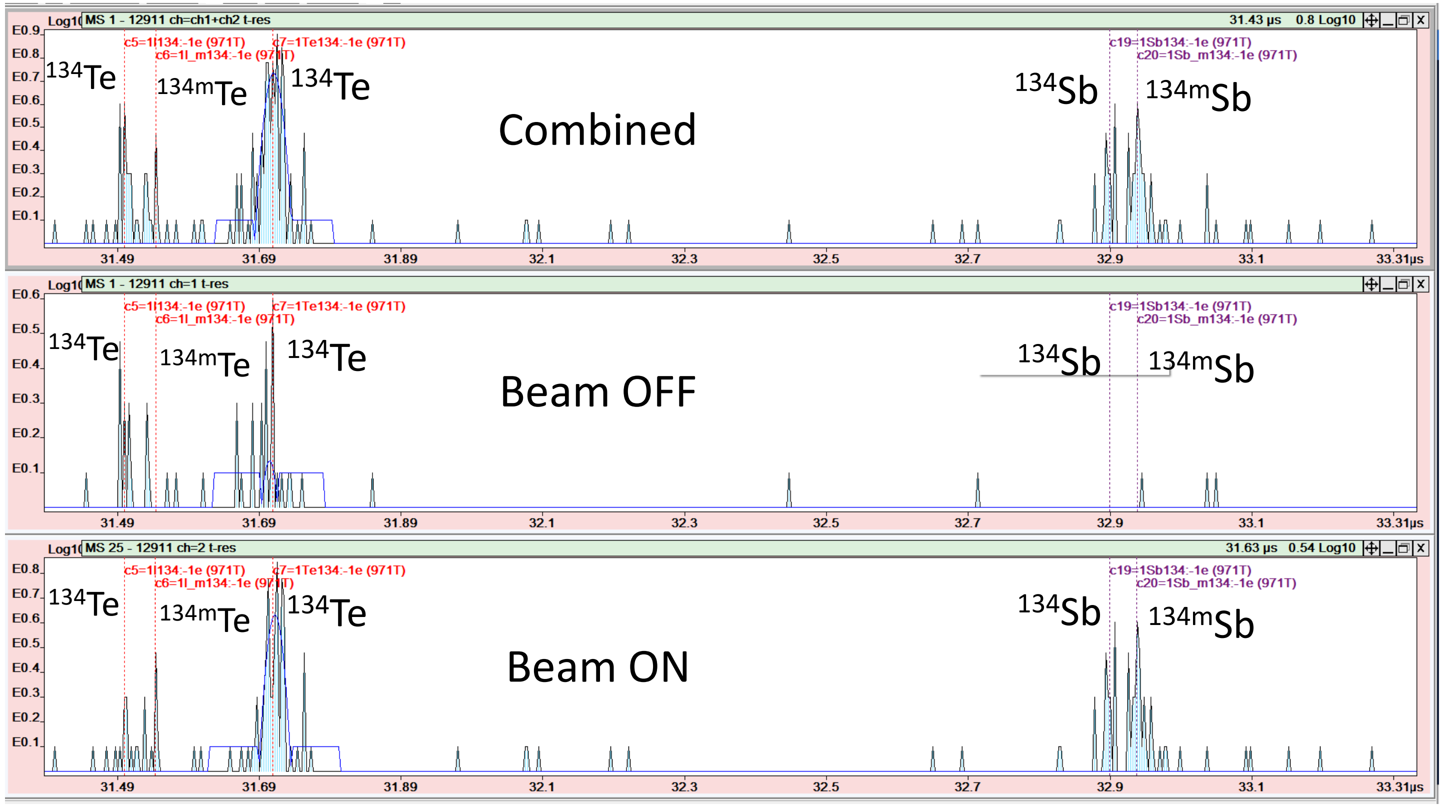
- Storage at the CSC nozzle was set up and tested successfully
- Measurements were taken with **no storage** and **2-seconds storage**
- Aim to observe between no-storage and 2-sec storage measurements:
  - **Decrease** of precursor – ^{135}**Sb**
  - **Increase** of β-decay recoil – ^{135}**Te**
  - **Increase** of β-delayed neutron recoil – ^{134}**Te**
- Compare $\frac{n(^{134}Te)}{[n(^{134}Te)+n(^{135}Te)]}$ to **literature P_{1n} (22±3%)**



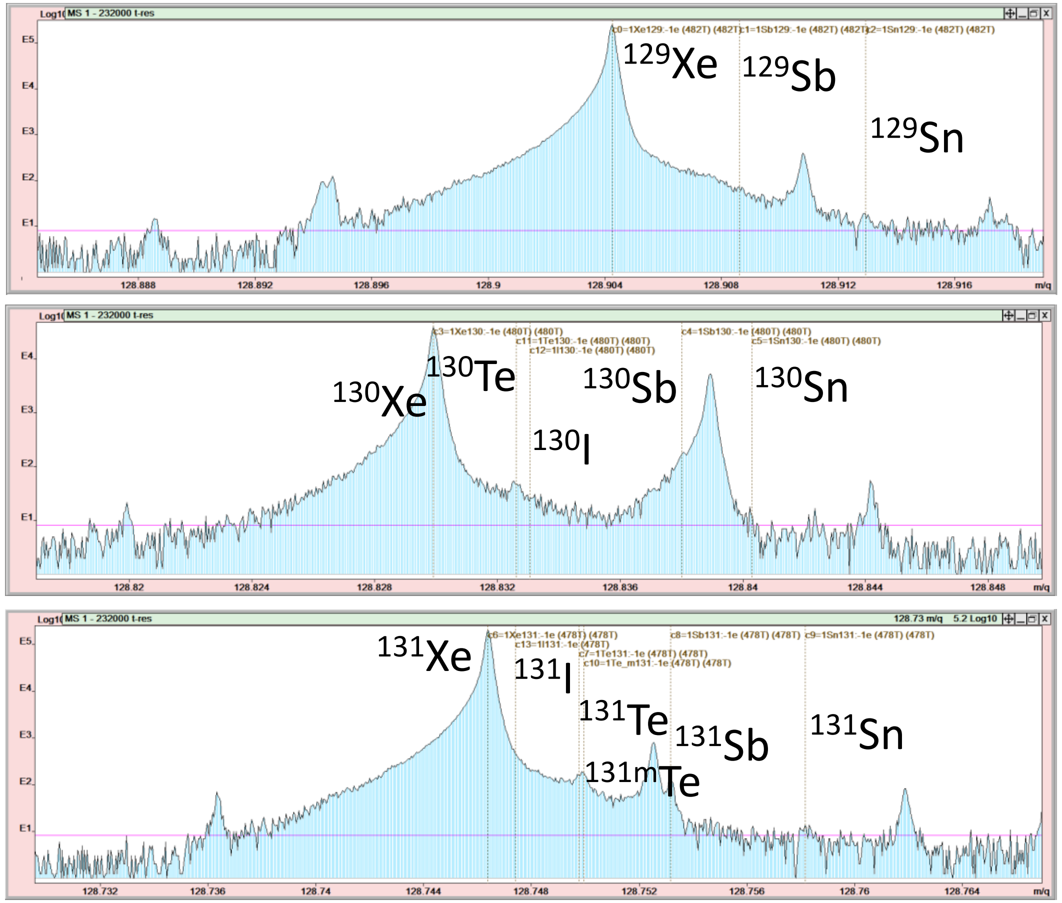


Mass measurements and isomer yield ratios from beam and ^{252}Cf SF source

^{134}Sb from beam (^{238}U inflight Coulomb fission)



129-131u from ^{252}Cf SF source



Summary

- Repaired the MR-TOF-MS and RFQ beamline, returning it to excellent performance **(MRP ≈ 550,000, beam line transmission ≈ 10-11%)**
- Performed mass tagging for experiment 0027 (^{132}Te)
- Performed a P_{1n} test experiment for ^{135}Sb, towards a P_{xn} campaign in ES and FS
- Measured several masses and isomer yield ratio from beam (^{238}U inflight Coulomb fission) and spontaneous fission (^{252}Cf SF source)
- Data analysis of all 0027 FRS-IC measurements are ongoing

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Super-FRS Experiment Collaboration

FRS Ion Catcher

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FAIR Phase 0 Research Program

FRS

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