Search for Double Alpha Decay at FRS IC: ^{224}Ra Data Analysis Status

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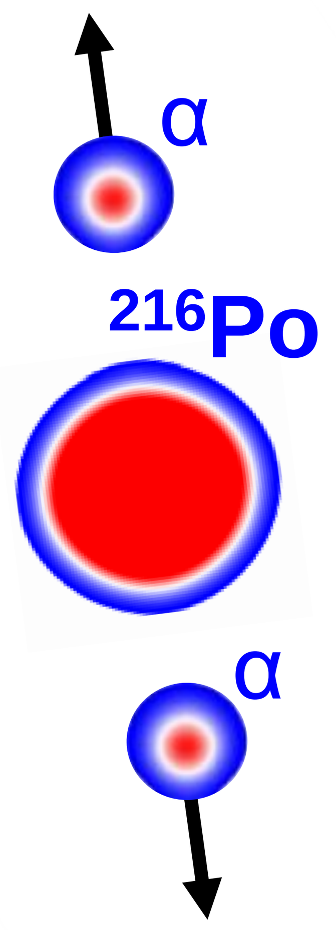
Motivation

Double alpha decay is a simultaneous emission of two α-particles, a possible rare decay mode.

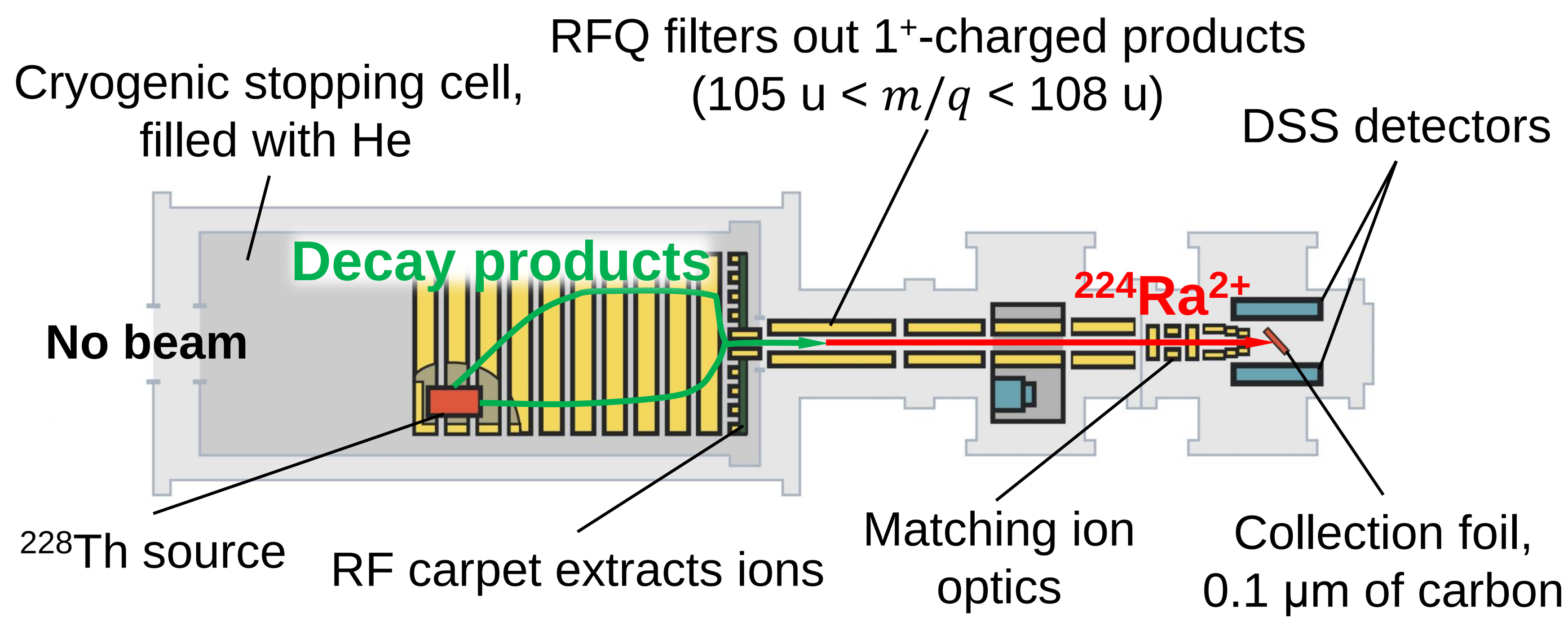
A phenomenological estimate for the **branching ratio** was found to be quite low: 10^{-23} [1]. A recent **microscopic estimate of 10^{-9}** [2] triggered experimental studies at **GSI** [3], CERN, and MSU.

Key features:
- back-to-back emission (space)
- known energy $Q_{2\alpha}/2 = 6096.8(1)$ keV (energy)
- Simultaneous emission $\Delta t < 20$ ns (time)

Experimental determination of the branching ratio relative to conventional single α-decay.

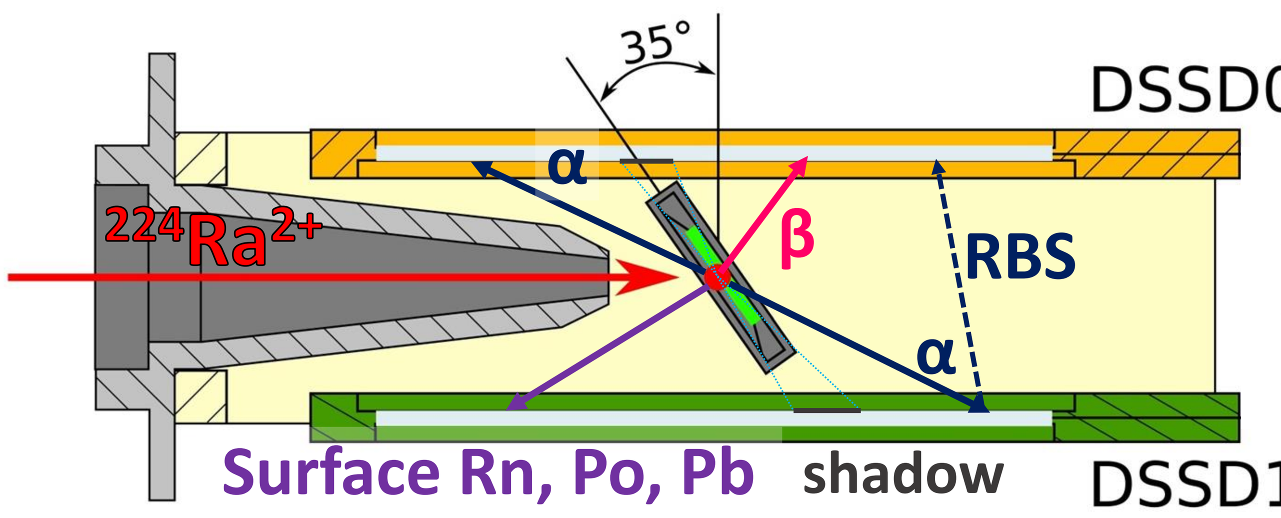


FRS Ion Catcher



The FRS Ion Catcher (GSI) is a universal system to perform decay and laser spectroscopy and mass measurements of heavy ions. **Two double-sided silicon strip detectors (DSSDs)** were used to measure charged products of ^{224}Ra during the **4-month-long measurement** in 2022.

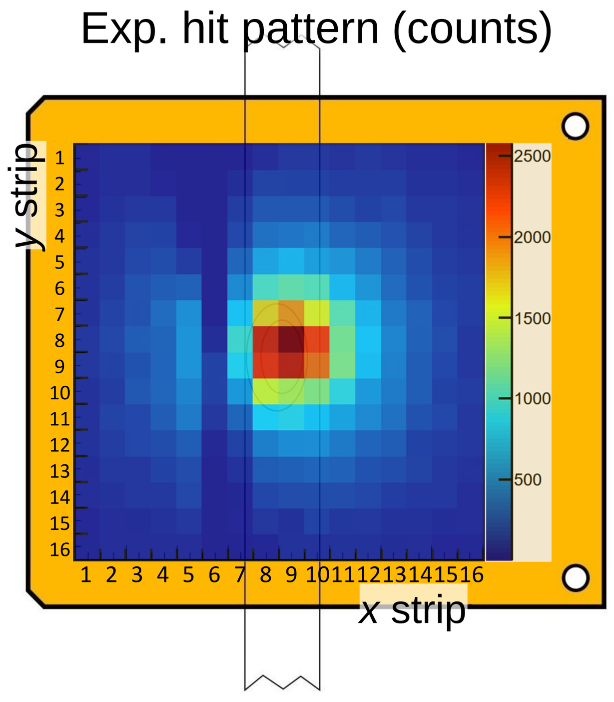
Space



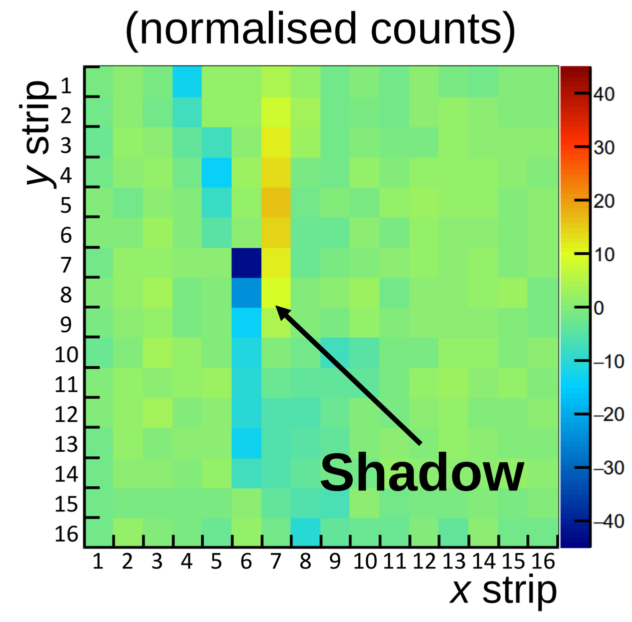
Each **DSSD** covers 33% of 4π:
- 16×16 square pixels
- Pixel 3.0 mm + gap 0.1 mm
- Active zone 49.5×49.5 mm^2

Solid angle model is used to cross-check the geometry, validate Monte Carlo simulation. The most prominent deviations are related to the shadow from the foil holder.

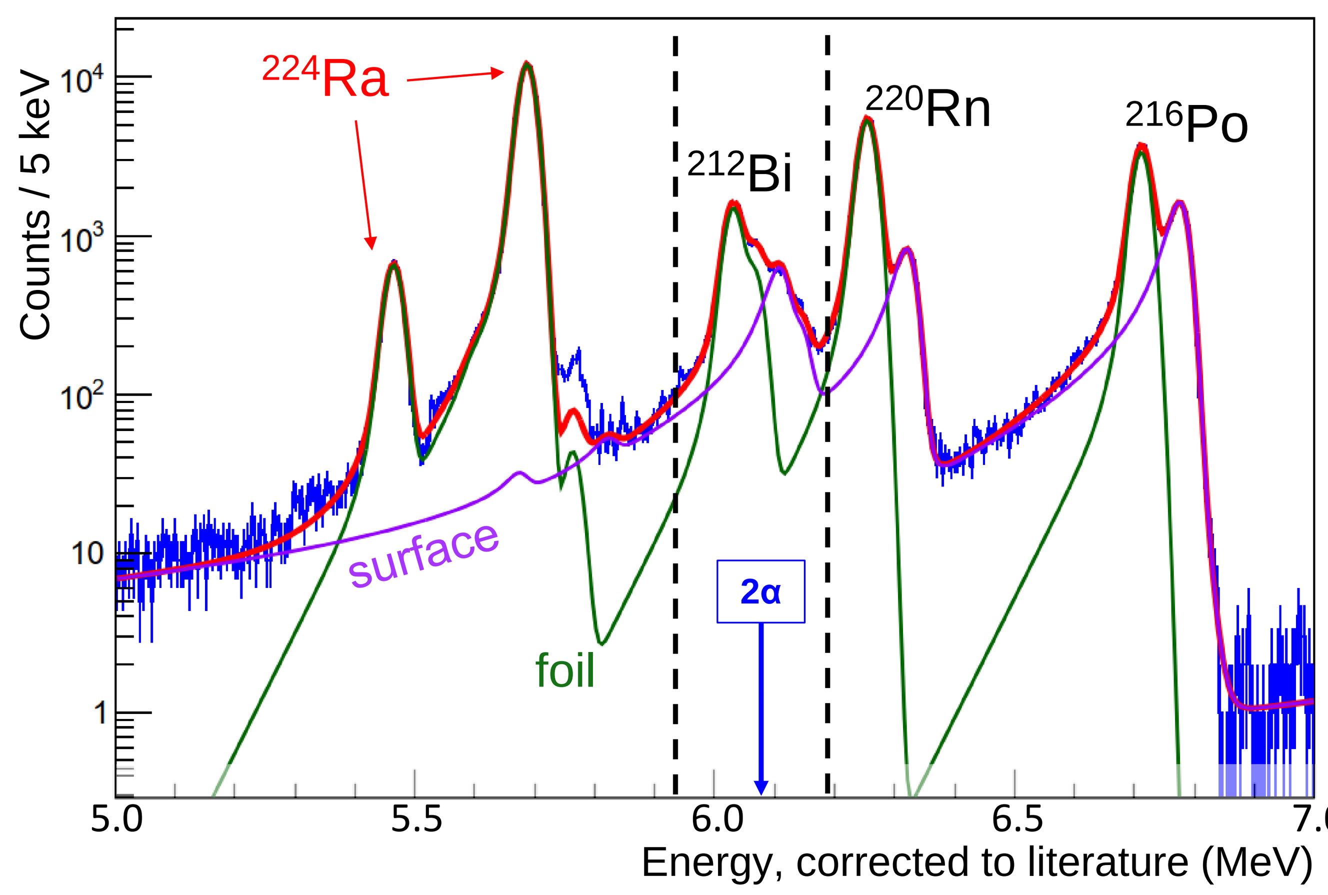
Exp. hit pattern (counts)



Deviation from exp. data, (normalised counts)



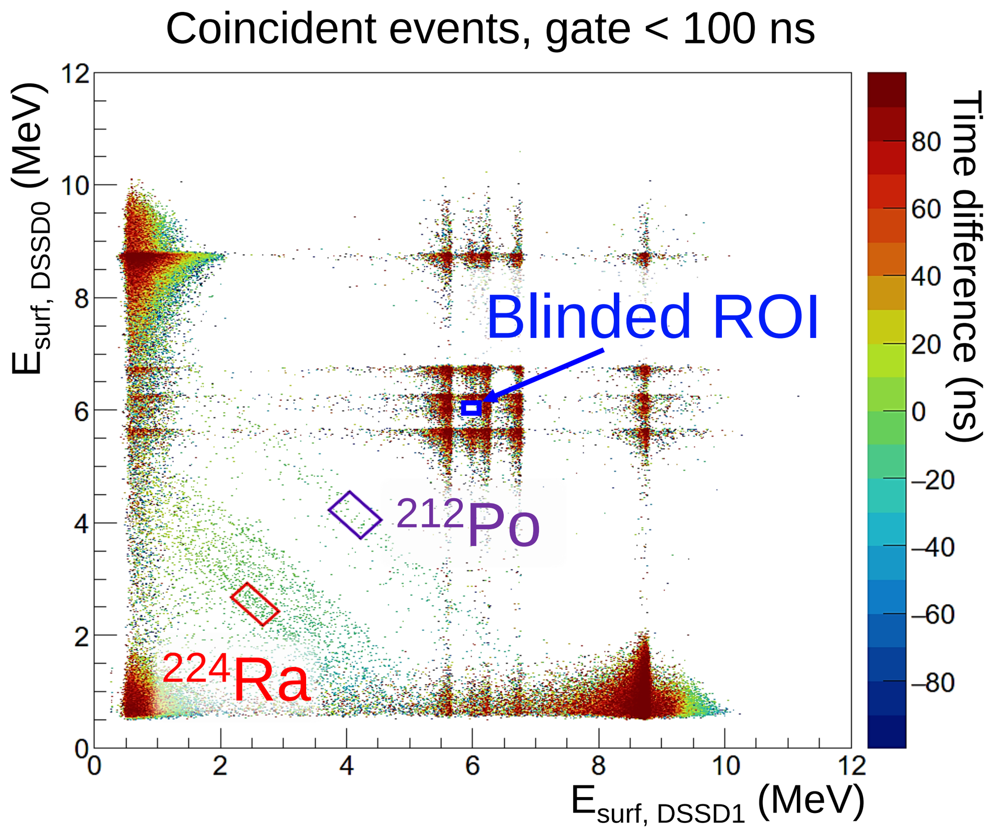
Energy



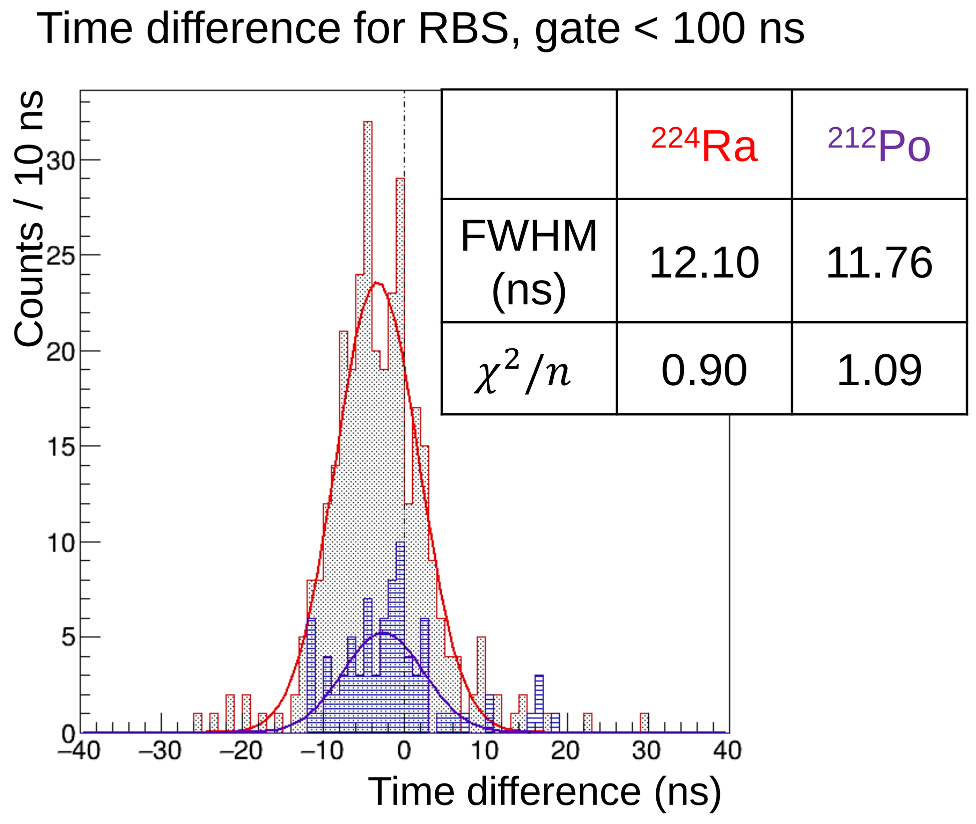
The background formed by all α-transitions needs to be described. ^{224}Ra comes from the foil only, whereas its descendants can settle on the DSSD surface and these peaks split apart. We fit each pixel to maximally constrain the decay energy in our selection.

Time

Coincident events, gate < 100 ns



Time difference for RBS, gate < 100 ns



	^{224}Ra	^{212}Po
FWHM (ns)	12.10	11.76
χ^2/n	0.90	1.09

Time resolution is estimated to be 11.9(2) ns based on true coincidence events of Rutherford backscattering, clearly visible at high statistics. The **time cut is** shown to be **independent of energy**.

Outlook

- Data: **$3\cdot10^9$ ions of ^{224}Ra decayed, 90 events for double alpha decay expected**
- Status: Effective background reduction factors achieved: energy cut × 10^{-2}, opposite pixels × 10^{-2}, time resolution × 10^{-5}, and **expected signal-to-background ratio ∼ 10**
- Goal: Unblind the data and measure the double alpha decay for the first time

References

1. D. Poenaru, M. Ivascu, J. Physique Lett. 46, 591–594 (1985).
2. F. Mercier *et al.*, Phys. Rev. Lett. 127, 012501 (2021).
3. L. Varga *et al.*, Nucl. Instrum. Methods Phys. Res. A 1063, 169252 (2024).

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