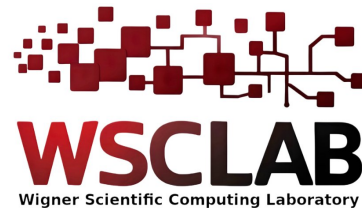


Preparation and Stability Studies for Long-Term Decay Measurements at JURLab

Franciska Sprok, Edit Fenyvesi, Gábor Gyula Kiss, Péter Lévai, Dénes Molnár, and Gergely Gábor Barnaföldi

Support: NKFIH NKKP ADVANCED 24 150038, ADVANCED 25 K153456, 2024-1.2.5-TÉT-2024 00022, 2025-1.1.5-NEMZ KI-2025-00005, 2025-1.1.5-NEMZ KI-2025-00011, WSCLAB, VLAB

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1. Motivation

2. Research Laboratory and Equipment

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4. Findings

5. Future Improvements

6. Conclusion

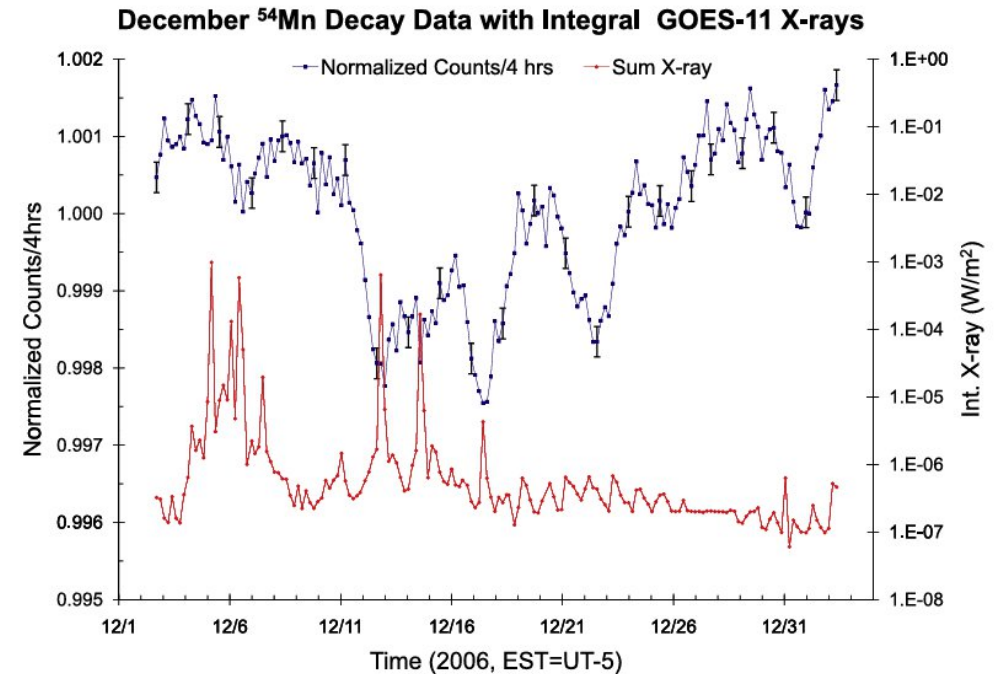
Why study long-term radioactive decay?

Are radioactive decay rates perfectly stable?

- Several studies have claimed:
 - Annual oscillations
 - Solar correlations
 - Time-dependent decay-rate anomalies
- Detector systematics can mimic tiny effects
- Gran Sasso National Laboratory (LNGS) found no evidence of time-dependent modulations

Main challenge:

- Detector and environment stability over months to years
- Changes in gain, dead-time, analysis window etc. produce variations in count rates
- Requires high precision and control



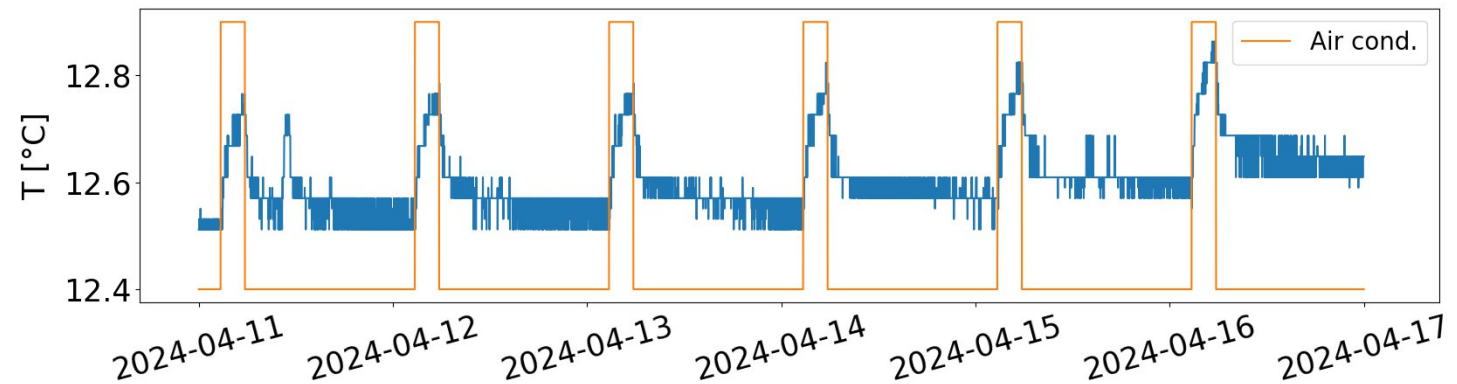
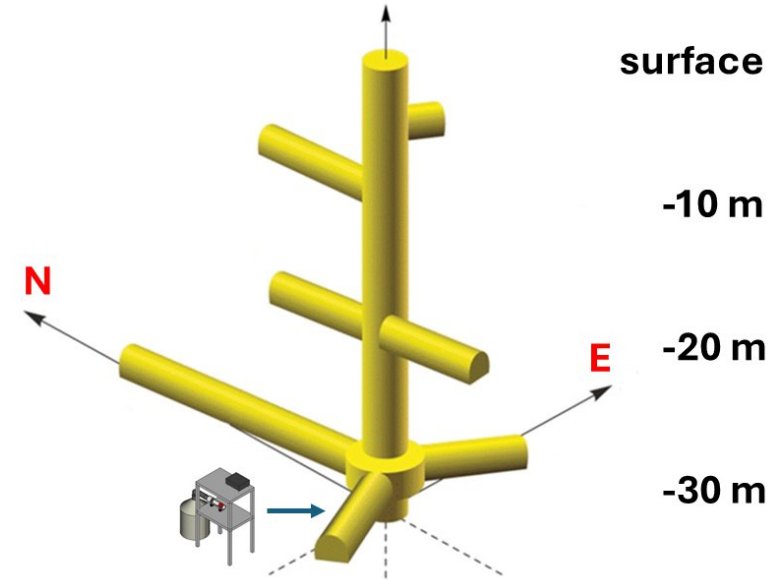
Jenkins & Fischbach, *Astropart. Phys.* 31 (2009)
Bellotti et al., *Phys. Lett. B* 710 (2012)

Jánossy Underground Research Laboratory (JURLab)

Advantages:

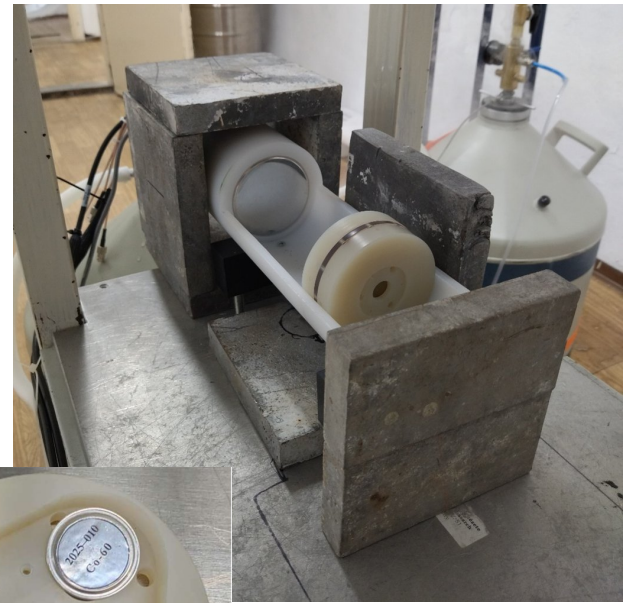
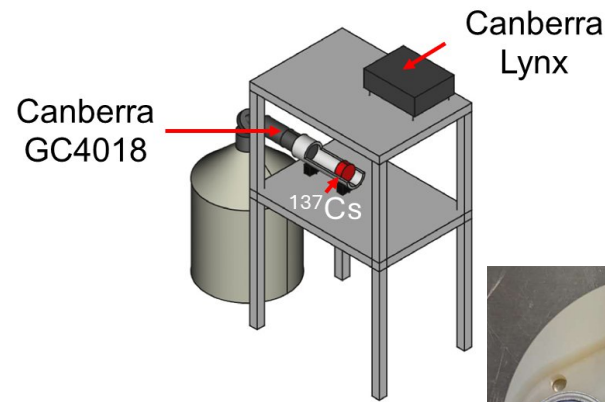
- Reduced cosmic-ray background
- More stable environmental conditions
- Lower long-term fluctuations

- Located at HUN-REN Wigner RCP
- Low-radiation background section of the Vesztergombi High Energy Laboratory (VLAB)
- Long-term monitoring campaign from 2022–2024



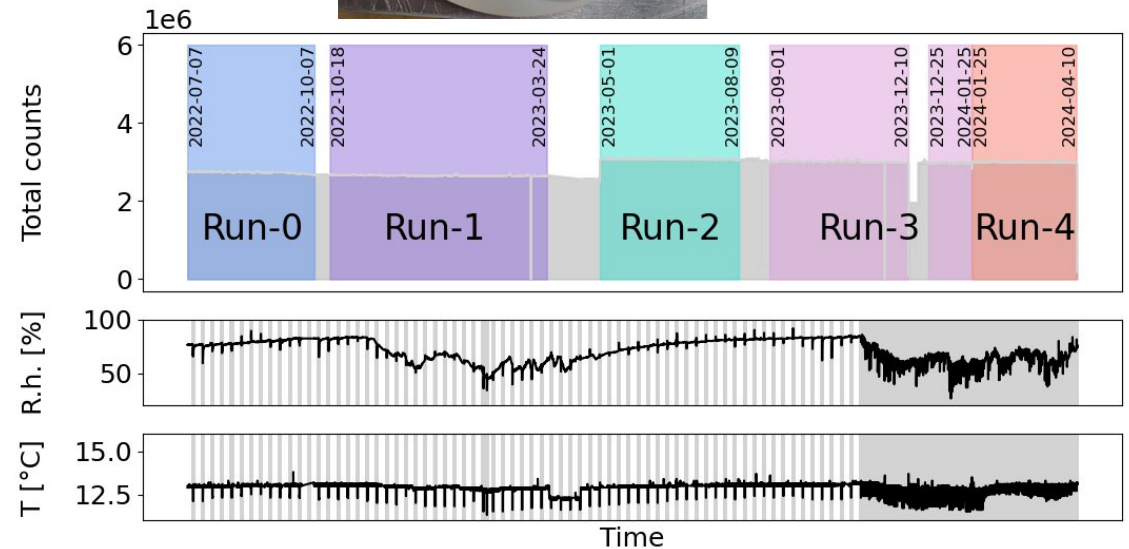
Experimental Setup

- High-purity germanium (HPGe) detector
- The data-acquisition system (DAQ)
Canberra Lynx digital signal analyzer
- Remote control
- ^{137}Cs source
- Lead shielding

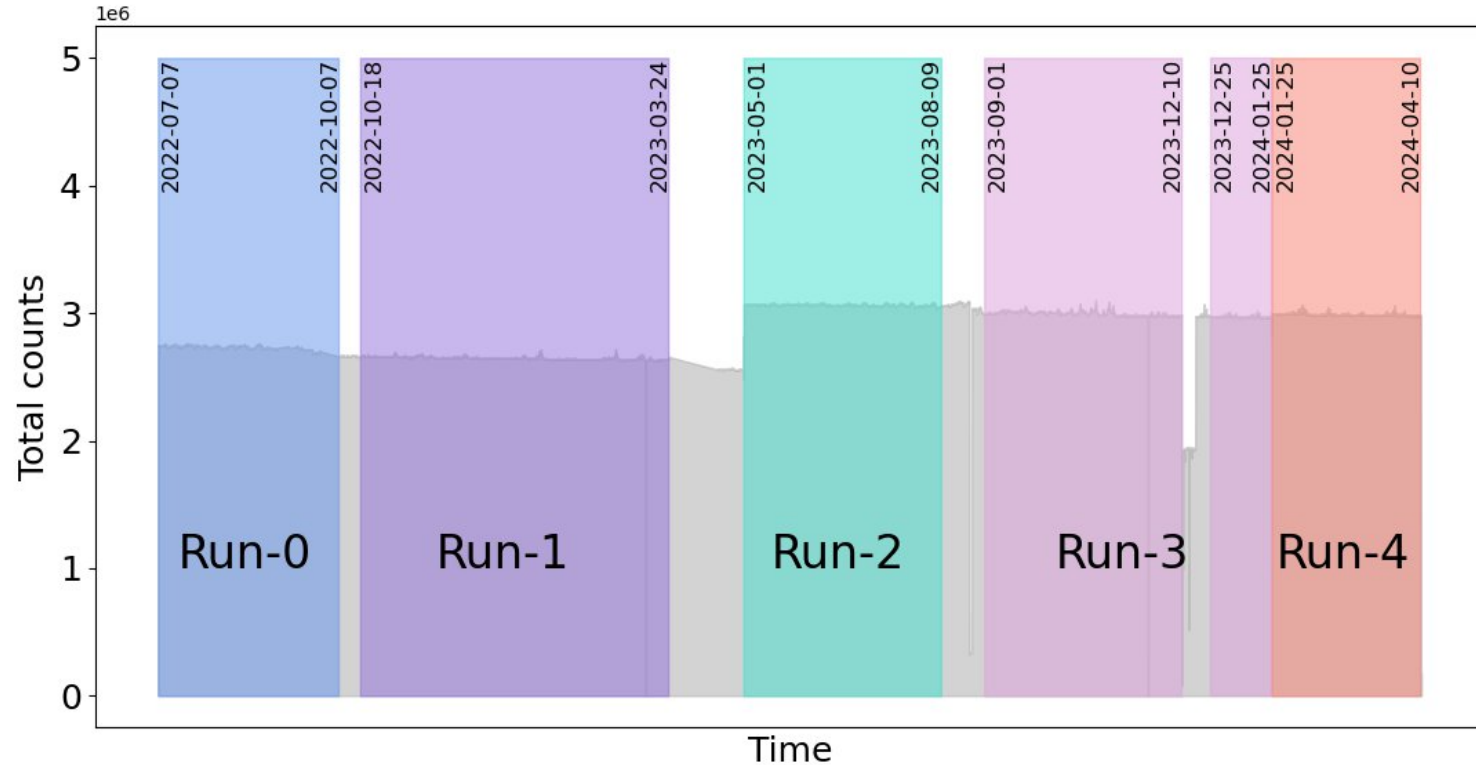


Why ^{137}Cs ?

- Long half-life $t_{1/2} = 30.08 \pm 0.09 \text{ y}$
- Strong isolated 661.7 keV gamma line
- Well suited for stability studies
- Natural background ^{40}K at 1460.8 keV used as reference $t_{1/2} = 1.248 \text{ billion y}$



Measurement Timeline



- **Data-taking periods (Runs)** between October 2022 and April 2024
- **Important practical issues:**
 - Source inspections
 - Geometry changes between runs

Run #	Start Date	End Date	Remark
Run 0	7 th July 2022	7 th Oct. 2022	Test Run – radioisotope positioning
Run 1	18 th Oct. 2022	24 th Mar. 2023	Short DAQ system interruption
Run 2	1 st May 2023	9 th Aug. 2023	Source moved closer
Run 3	1 ST Sept. 2023		Pause – signal detector connected, isotope removed for inspection
Run 4	25 th Jan. 2024	10 th Apr. 2024	End of data-taking period

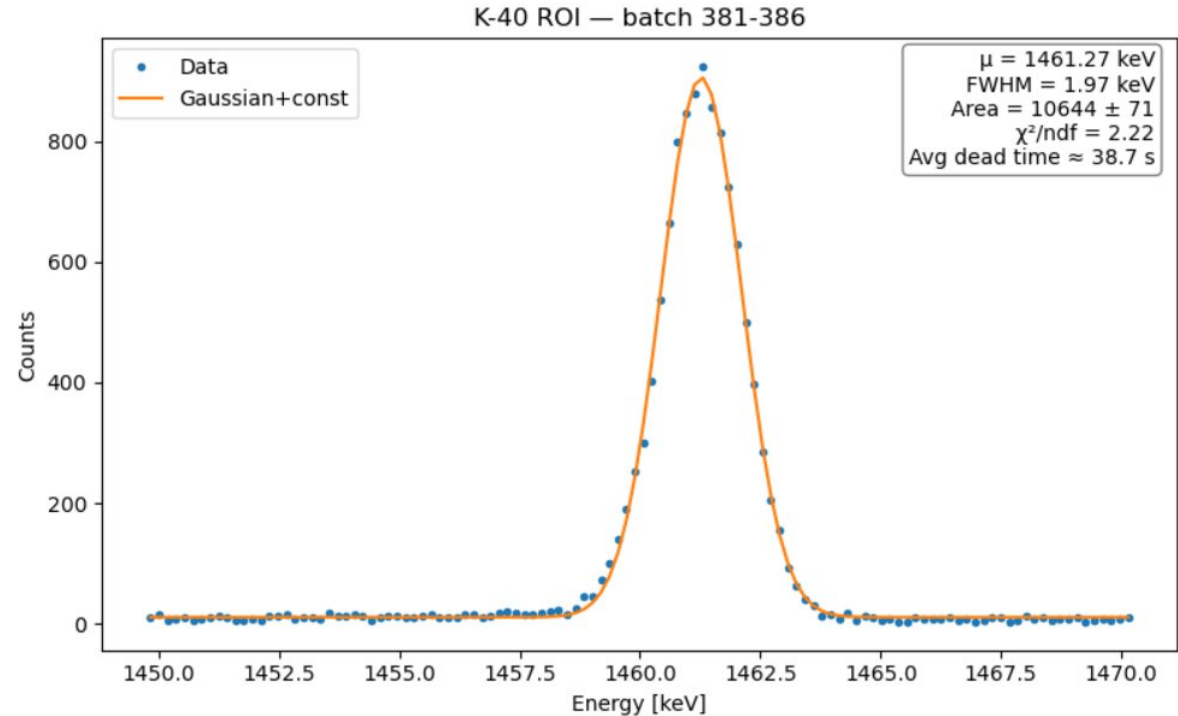
Detector Stability and Analysis

Long-term detector stability:

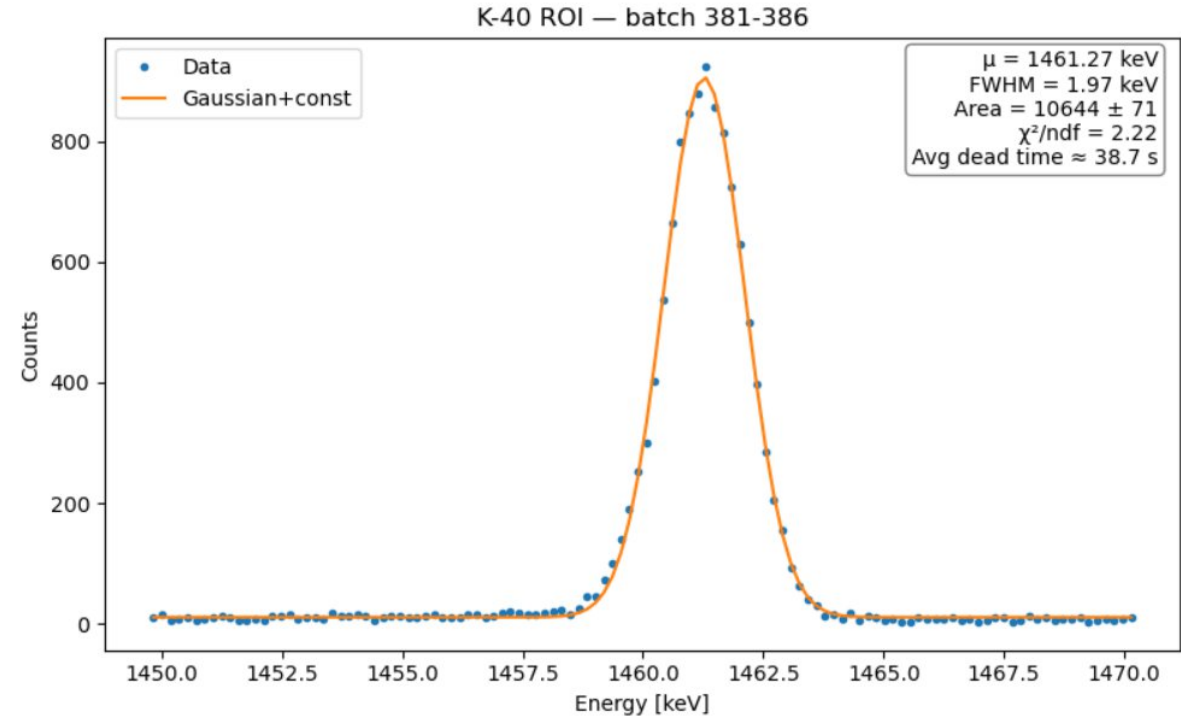
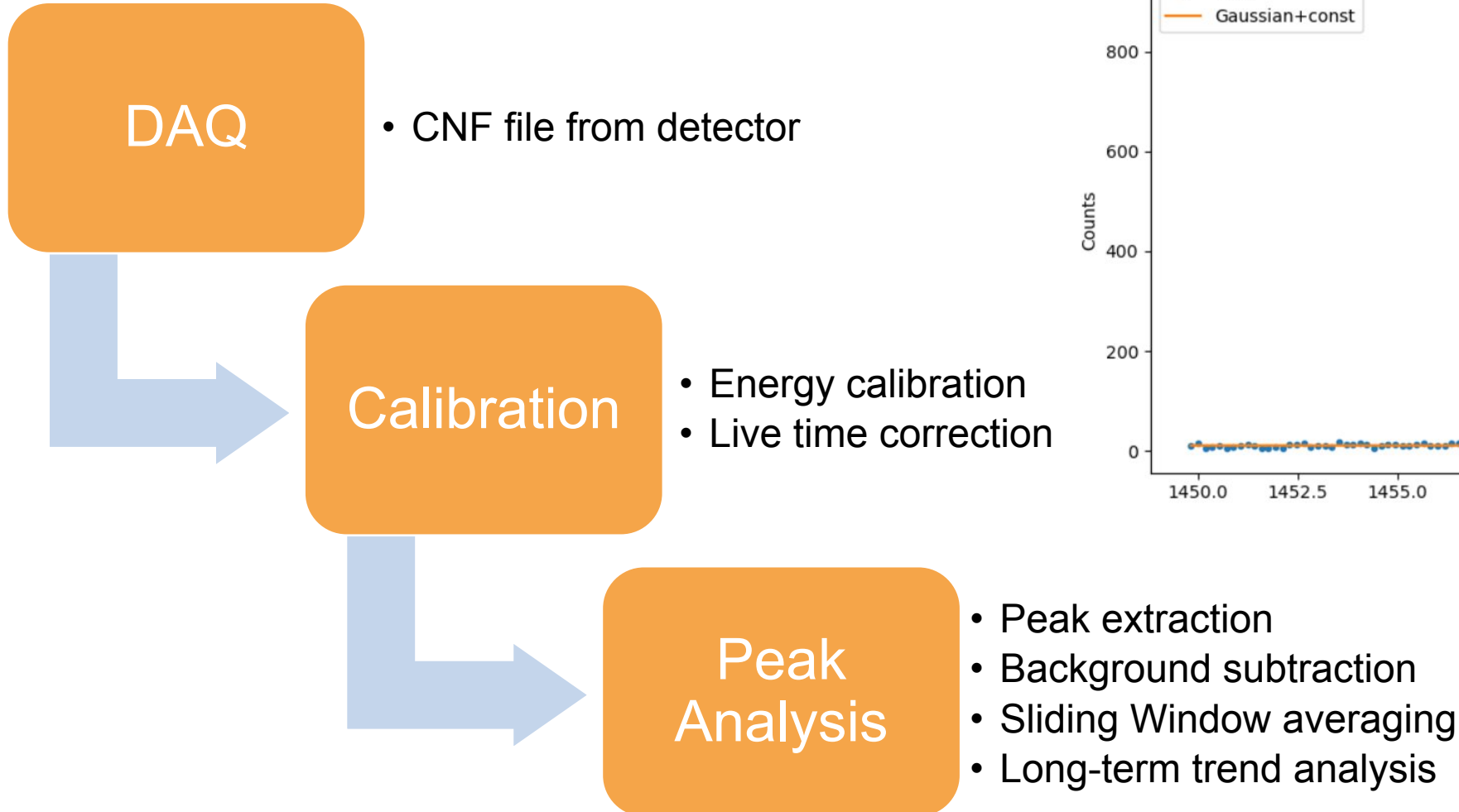
- Peak position stability
- Gain drift
- Background stability
- Count-rate consistency

Main observables:

- ^{137}Cs peak centroid
- ^{40}K peak centroid
- Peak area evolution
- Cs/K ratios



Detector Stability and Analysis

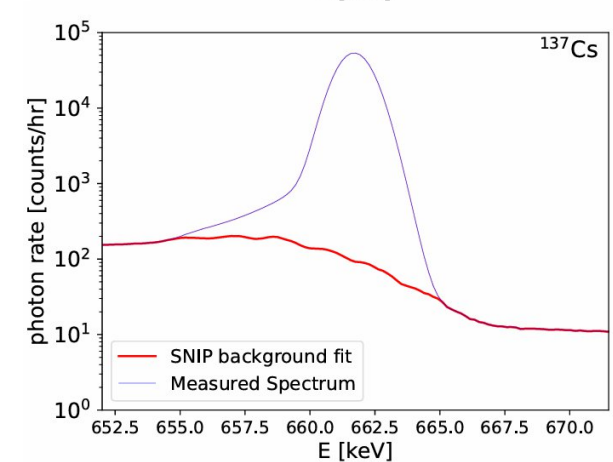
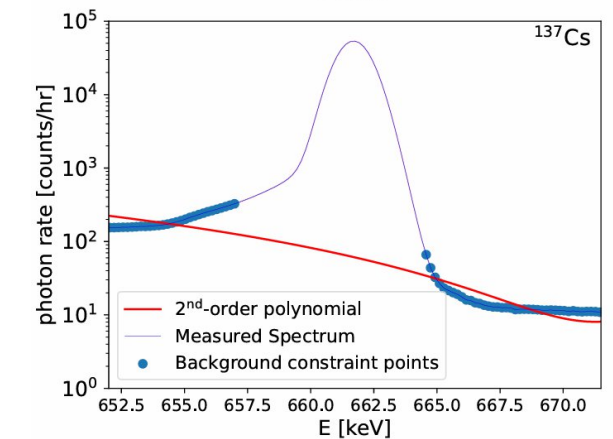
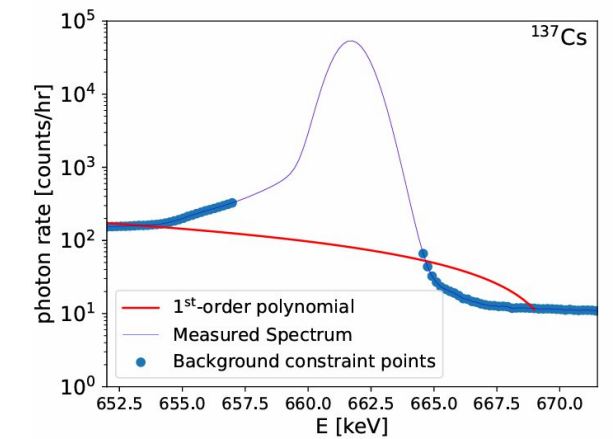
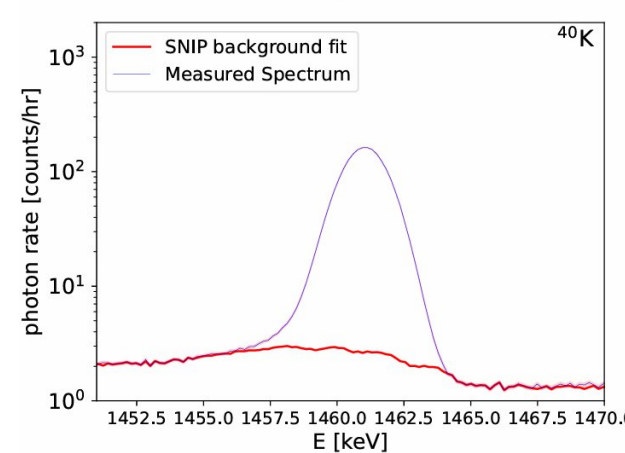
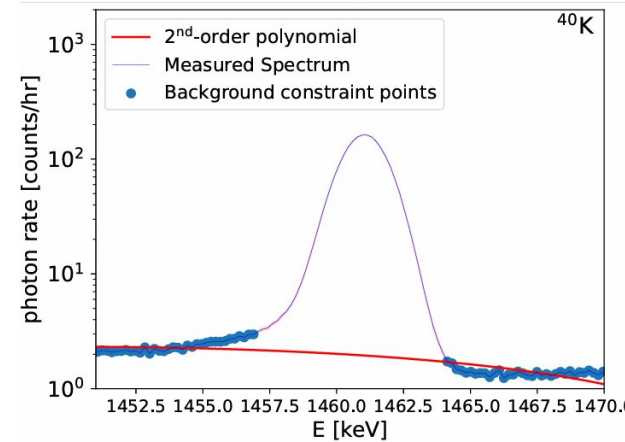
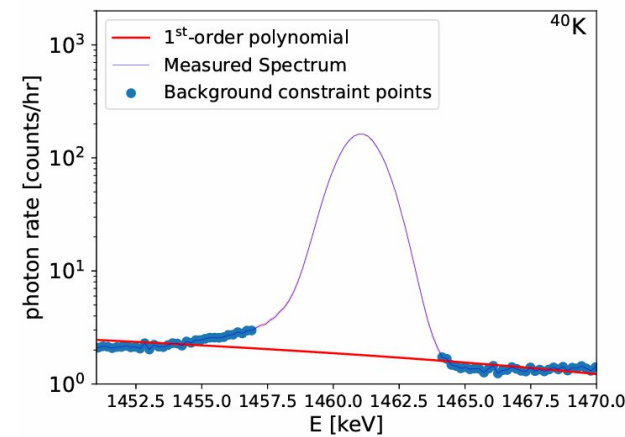


Peak Extraction

Background Subtraction:

- Polynomial background fitting (1st and 2nd order)
- SNIP background estimation
- For ^{137}Cs at 661.7 keV methods agree within $\sim 2\%$
- For ^{40}K at 1460.8 keV agreement at the level of $\sim 10\%$

Method	Purpose
Polynomial fit	Smooth local BG
Sideband interpolation	Stable local estimation - reference
SNIP algorithm	Adaptive spectral BG
Symmetric Gaussian subtraction	Cross check consistency - reference



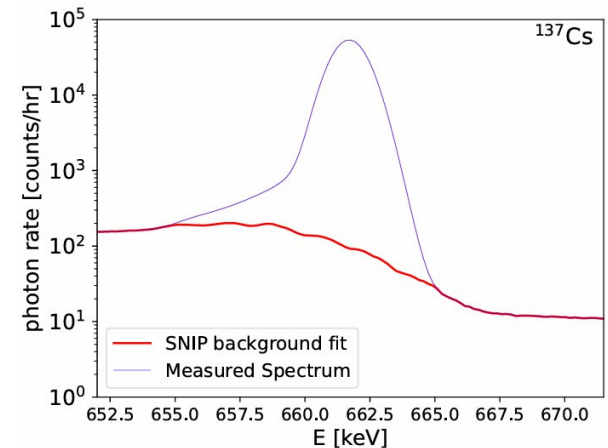
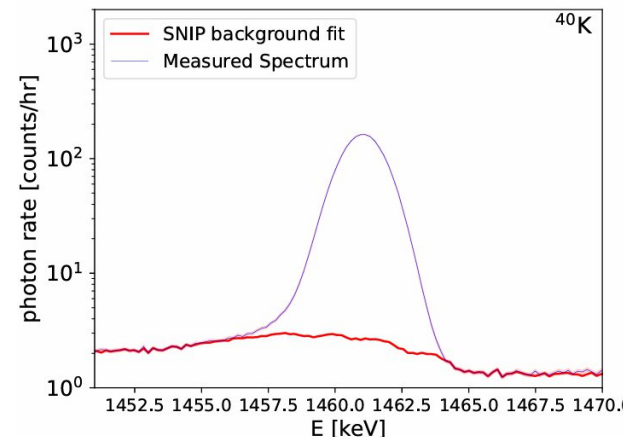
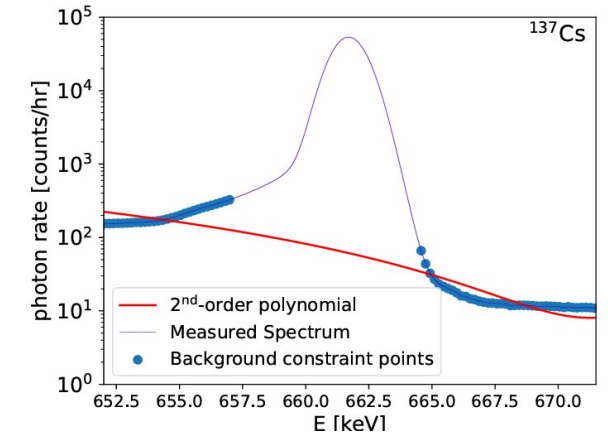
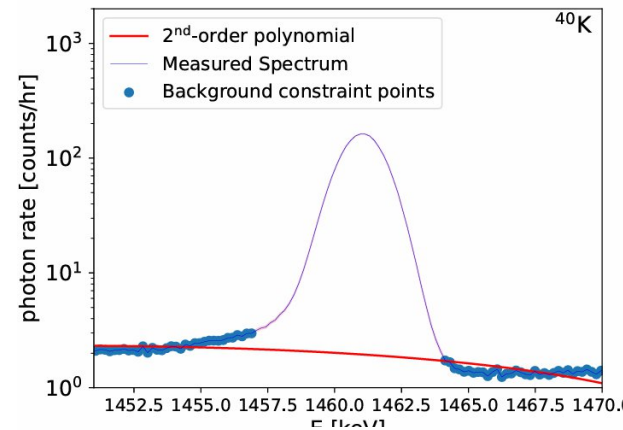
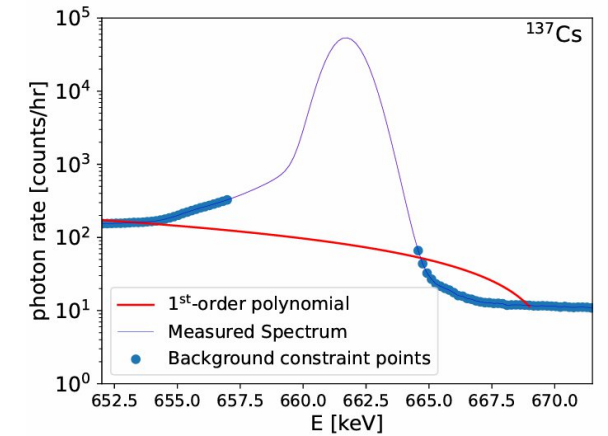
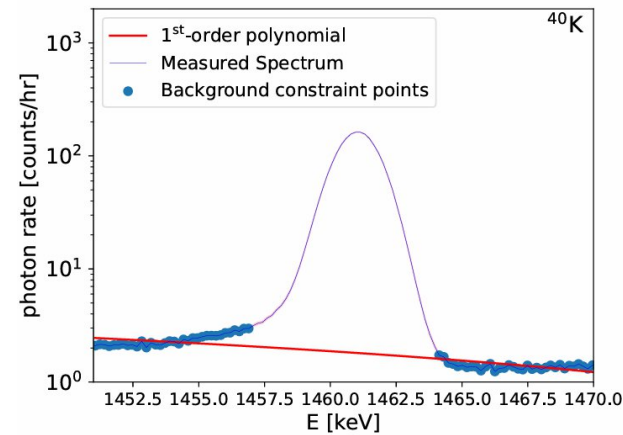
Peak Extraction

SNIP Algorithm:

Statistics-sensitive Nonlinear Iterative Peak-clipping

- Iteratively suppresses narrow peaks
- Preserves slowly varying continuum
- Produces smooth estimate of Compton background
- Used for background subtraction beneath γ peaks

Eliminates the analysis window (sideband) definition caused variations in measured counted



Detector Stability

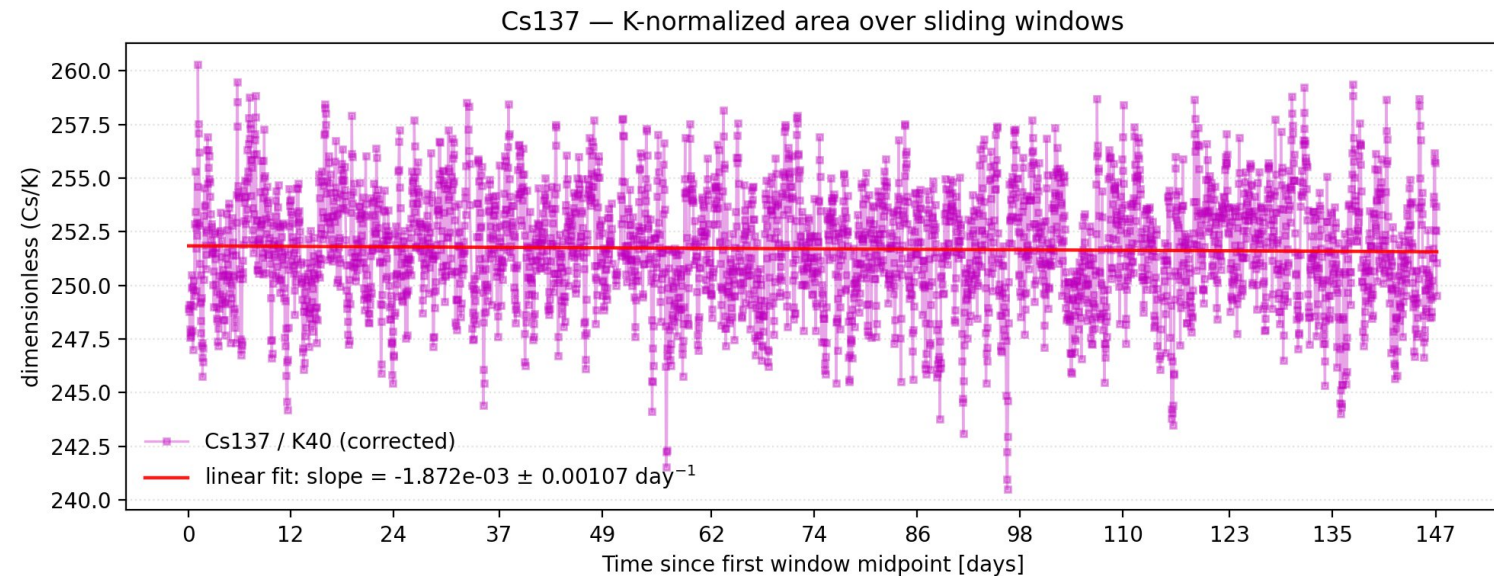
Ratio analysis:

Useful observable for relative detector response

$$\frac{{}^{137}\text{Cs}}{{}^{40}\text{K}}$$

Help reduce:

- detector efficiency effects
- common-mode gain fluctuations
- some environmental systematics



Detector Stability

^{137}Cs and ^{40}K Peak centroid evolution

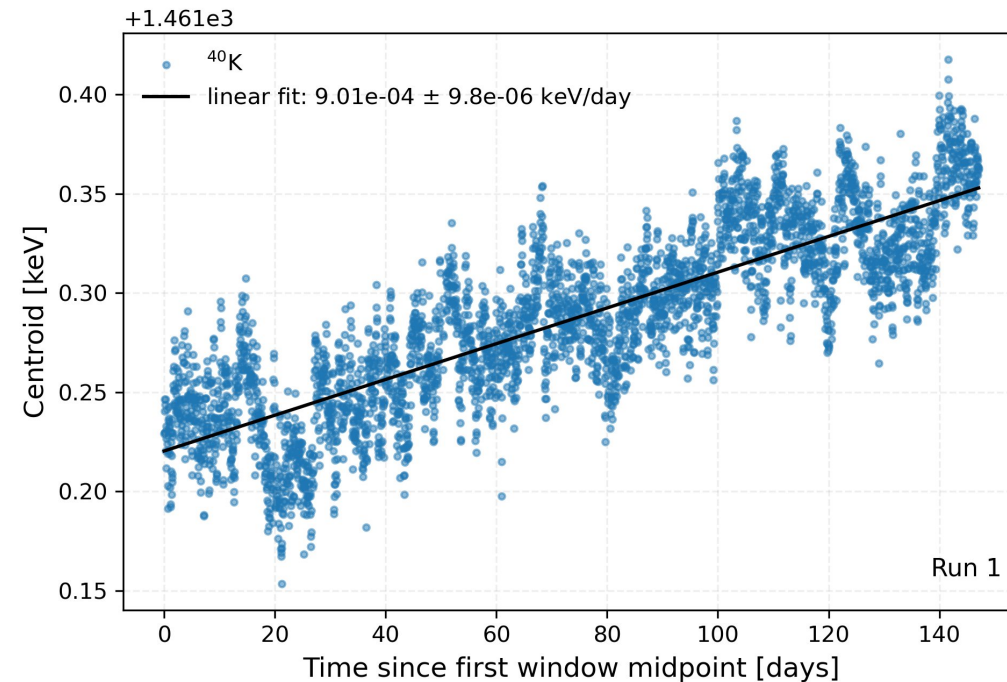
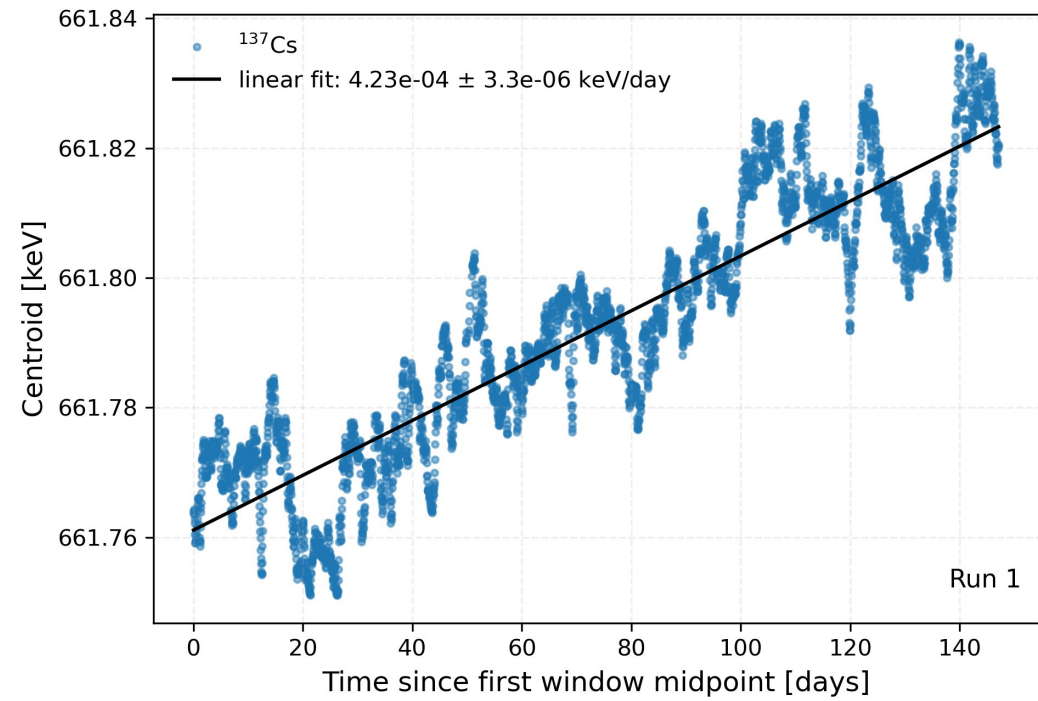
What we observed:

- Correlated centroid motion
- Indicates instrumental effect
- Consistent with calibration drift

Small systematic drift

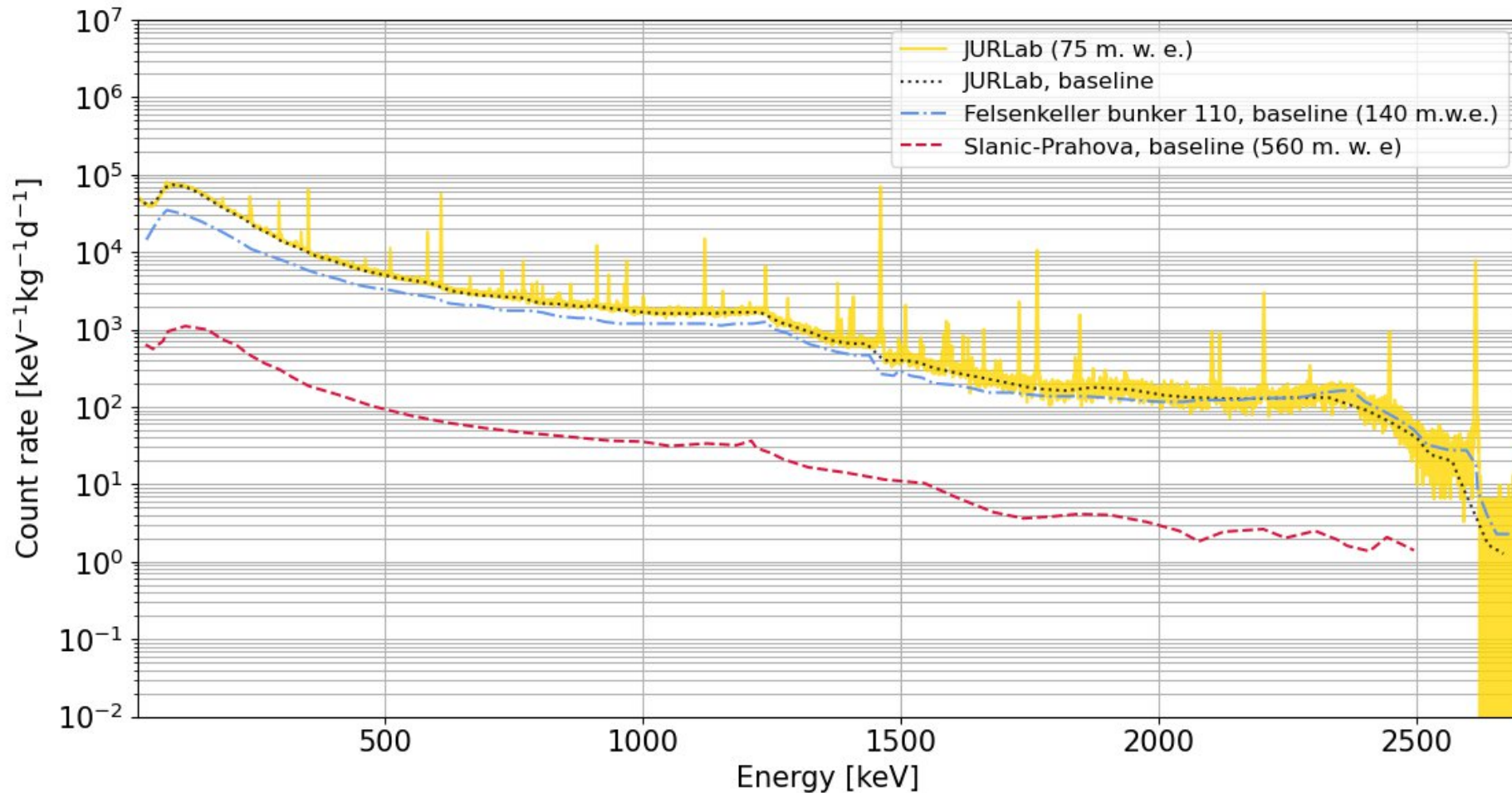


Future high-sensitivity analyses

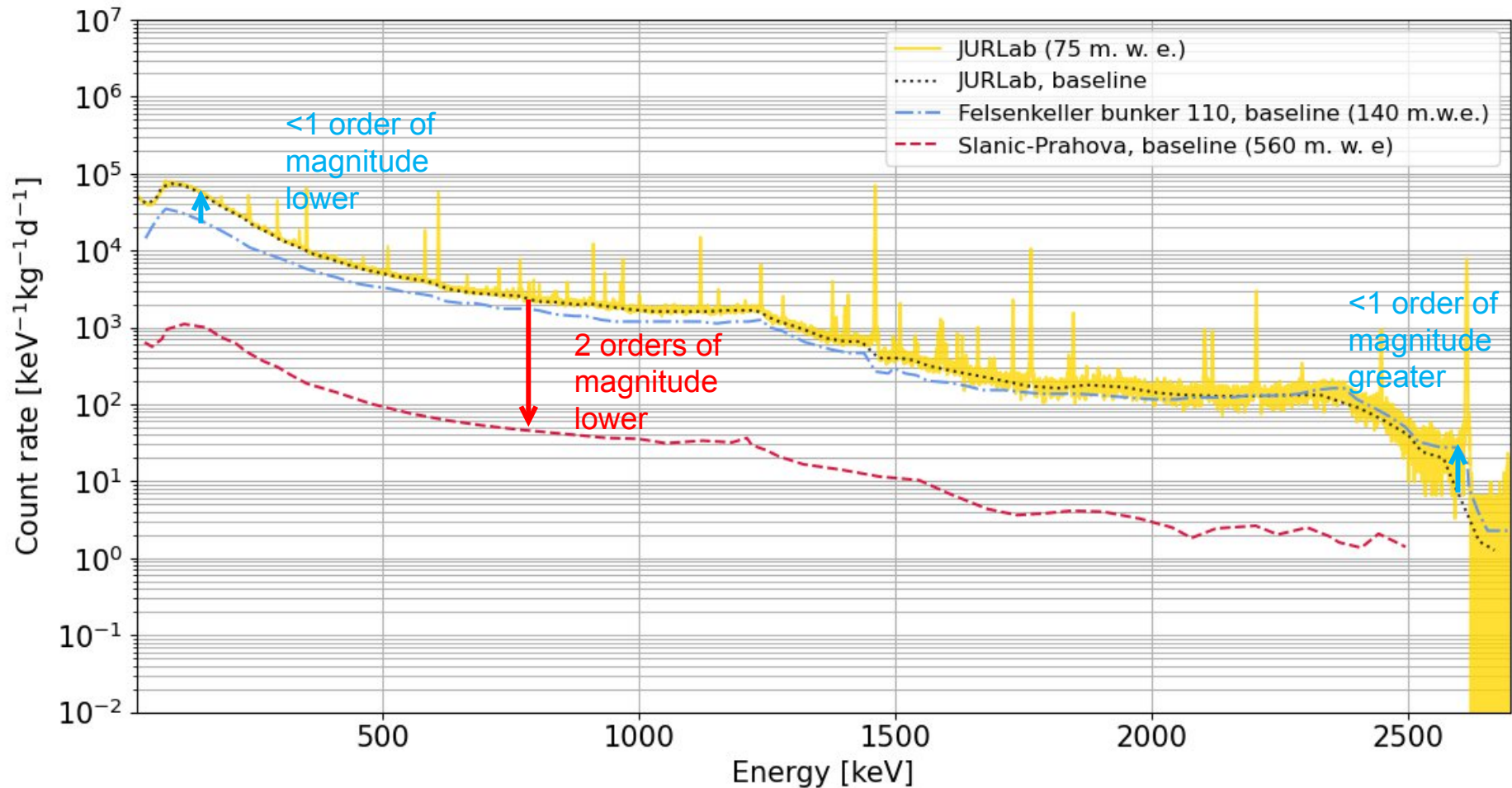


Background level Comparison

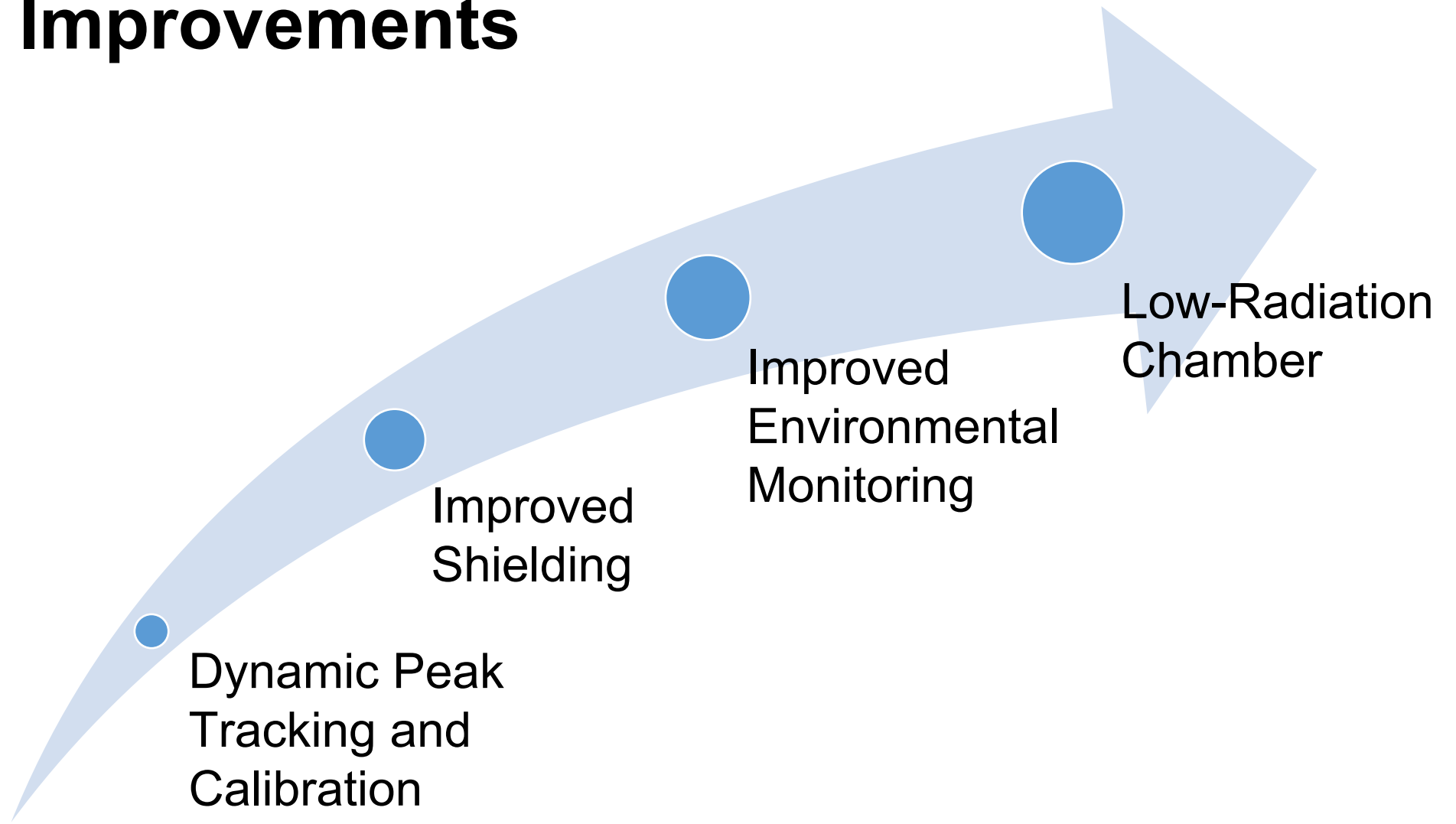
JURLab background levels are comparable to other shallow underground laboratories.



Background level Comparison



Future Improvements



Conclusion

So far we:

- Developed a long-term underground decay-measurement setup
- Characterized detector and background stability
- Successfully developed multiple peak-area extraction methods
- Established methodological groundwork for future high-sensitivity studies
- Comparable results with the best shallow-underground laboratories

Future plan:

- Systematic control must be understood at high precision
- Experimental setup improvements
- Implementing dynamic analysis



Acknowledgments

Support:

- FuSe COST Action CA24101
- NKFIH NKKP ADVANCED 24 150038
- ADVANCED 25 K153456
- 2024-1.2.5-TÉT-2024 00022
- 2025-1.1.5-NEMZ KI-2025-00005
- 2025-1.1.5-NEMZ KI-2025-0001
- WSCLAB
- VLAB

**Thank You
for your Attention!**



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