SPELS at WISArD

Spectrum of ^{32}P ELectron Shape

Anaïs Lépine, LP2i Bordeaux
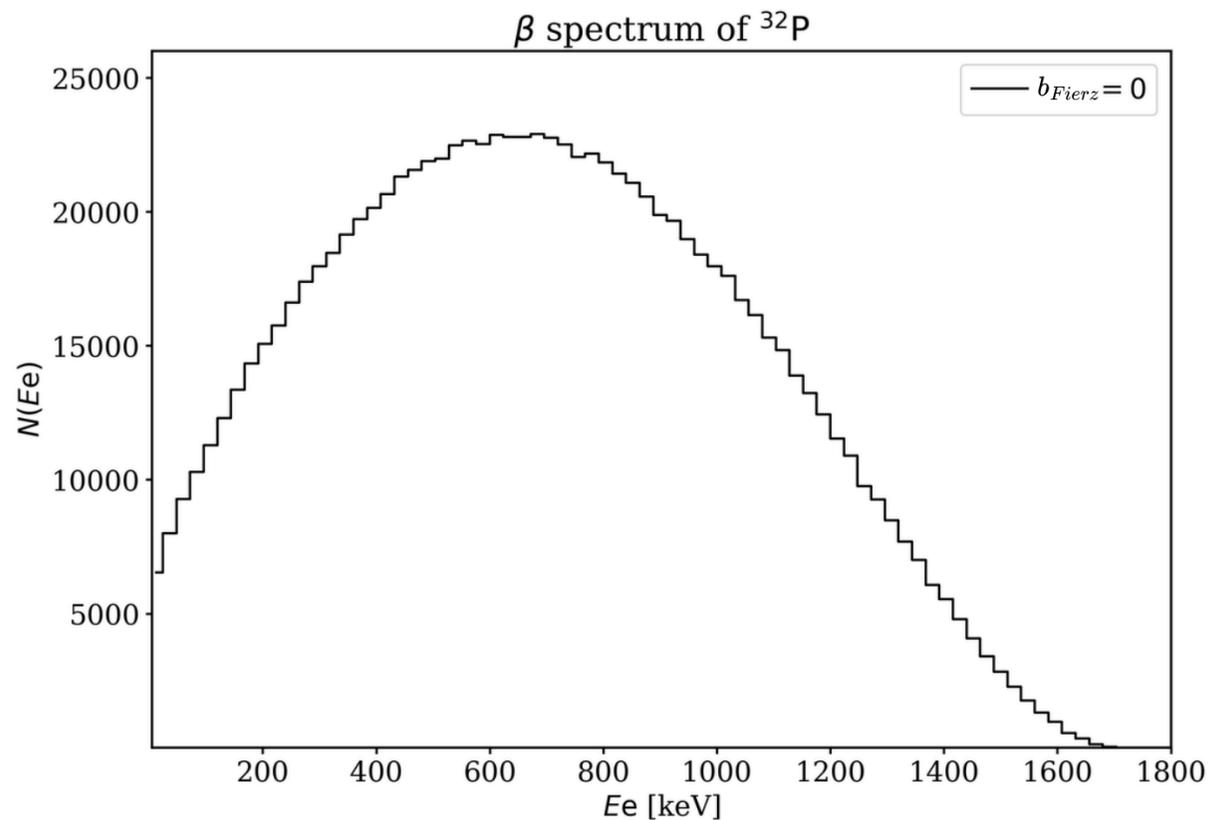2nd year PhD student

ISOL-France Workshop
17/03/2026

Bertram Blank
Maud Versteegen

The study of β-shape

The energy distribution of emitted electrons for a pure Gamow-Teller (GT) decay:

$$N(E_e) \propto F(\pm Z, E_e)\, p_e E_e (E_0 - E_e)^2 \xi \left[1 + k E_e b_{\mathrm{WM}} + \frac{m_e}{E_e} b_{\mathrm{Fierz}} \right]$$

Fermi function   Phase space   Nuclear matrix

For a high level of precision:

- b_{WM} : weak magnetism, **SM term** induced by strong interaction

- $b_{Fierz} = \dfrac{C_T + C'_T}{C_A}$ $C_{T,A}$ coupling constants for Tensor or Axial-vector current
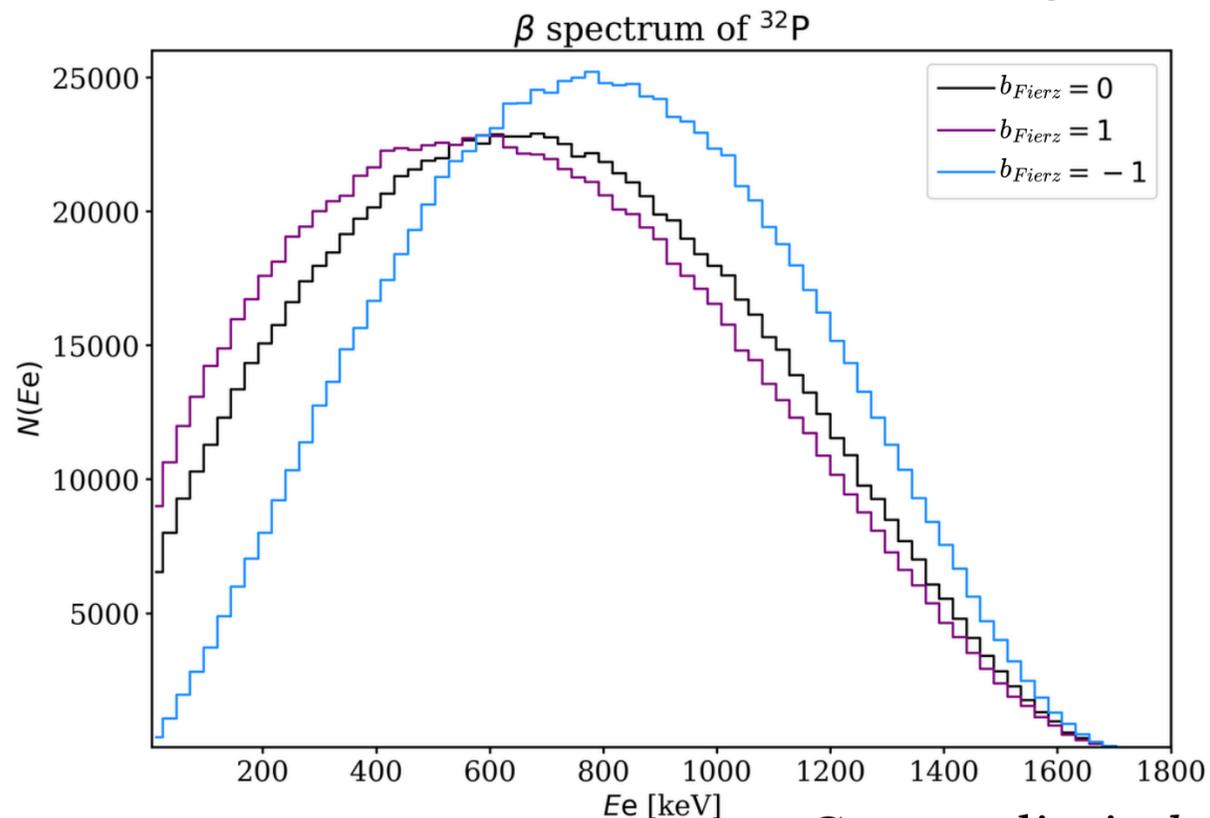
  Fierz interference, BSM term, zero in SM

A. Falkowski et al., JHEP 04, (2021)

2

The study of β-shape

The energy distribution of emitted electrons for a pure Gamow-Teller (GT) decay:

$$N(E_e) \propto F(\pm Z, E_e)\, p_e E_e (E_0 - E_e)^2 \xi \left[1 + kE_e b_{\mathrm{WM}} + \frac{m_e}{E_e} b_{\mathrm{Fierz}} \right]$$

Fermi function   Phase space   Nuclear matrix

Both terms have influence on β-shape ⟶ **Study of β-shape:**

β spectrum of ^{32}P

- Constraints on SM with weak magnetism

- Search for new physics with extraction of Fierz term

Goal: Measure the β-decay energy distribution with 10^{-3} relative precision on the Fierz term

Current limit: $b_{Fierz} < 5 \times 10^{-3}$

A. Falkowski et al., JHEP 04, (2021)

3

Isotopes candidates for new constraints
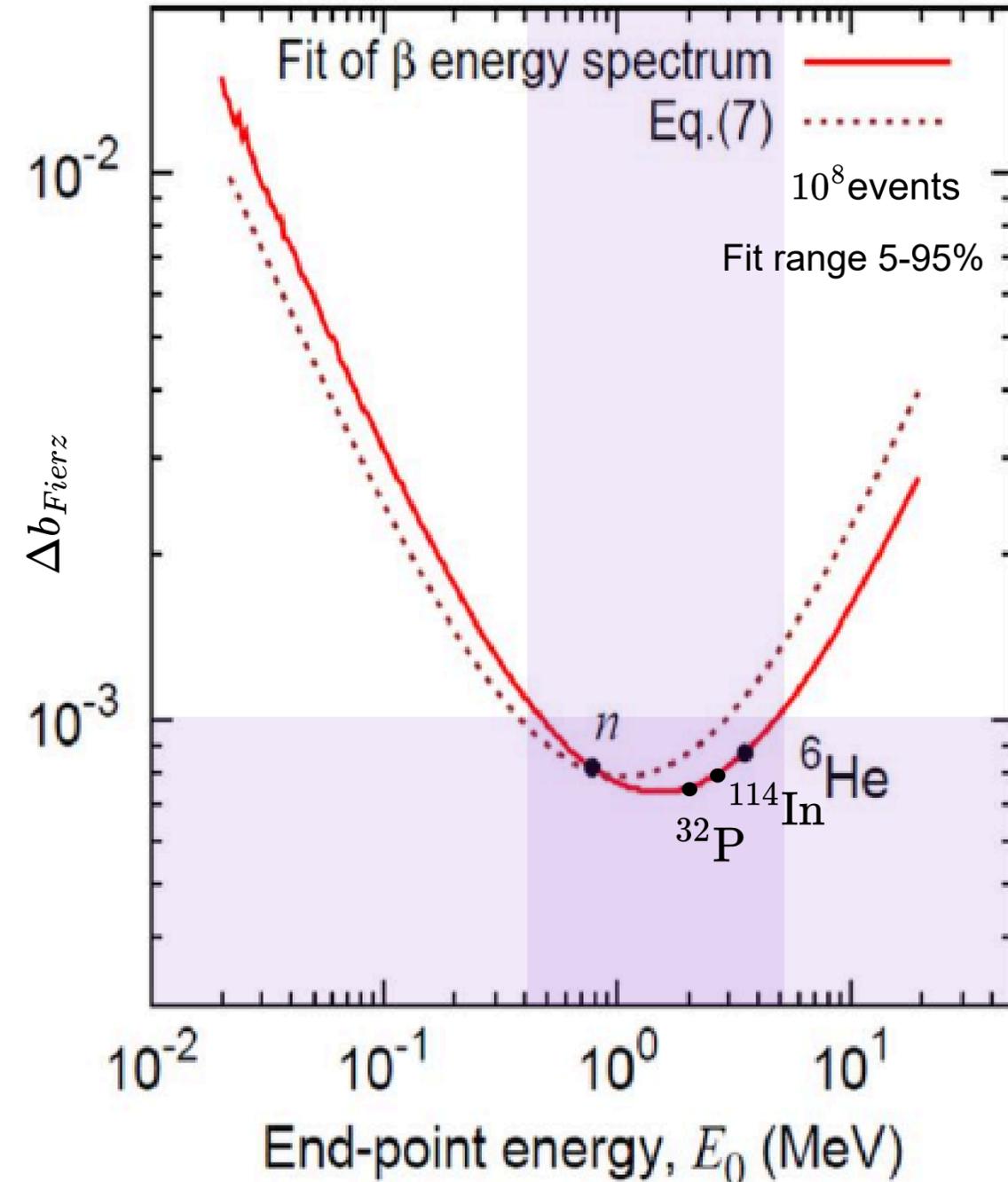
In source measurement during LS3 with:

^{114}In:
- favorable endpoint for BSM, pure GT
- Lifetime=49 days
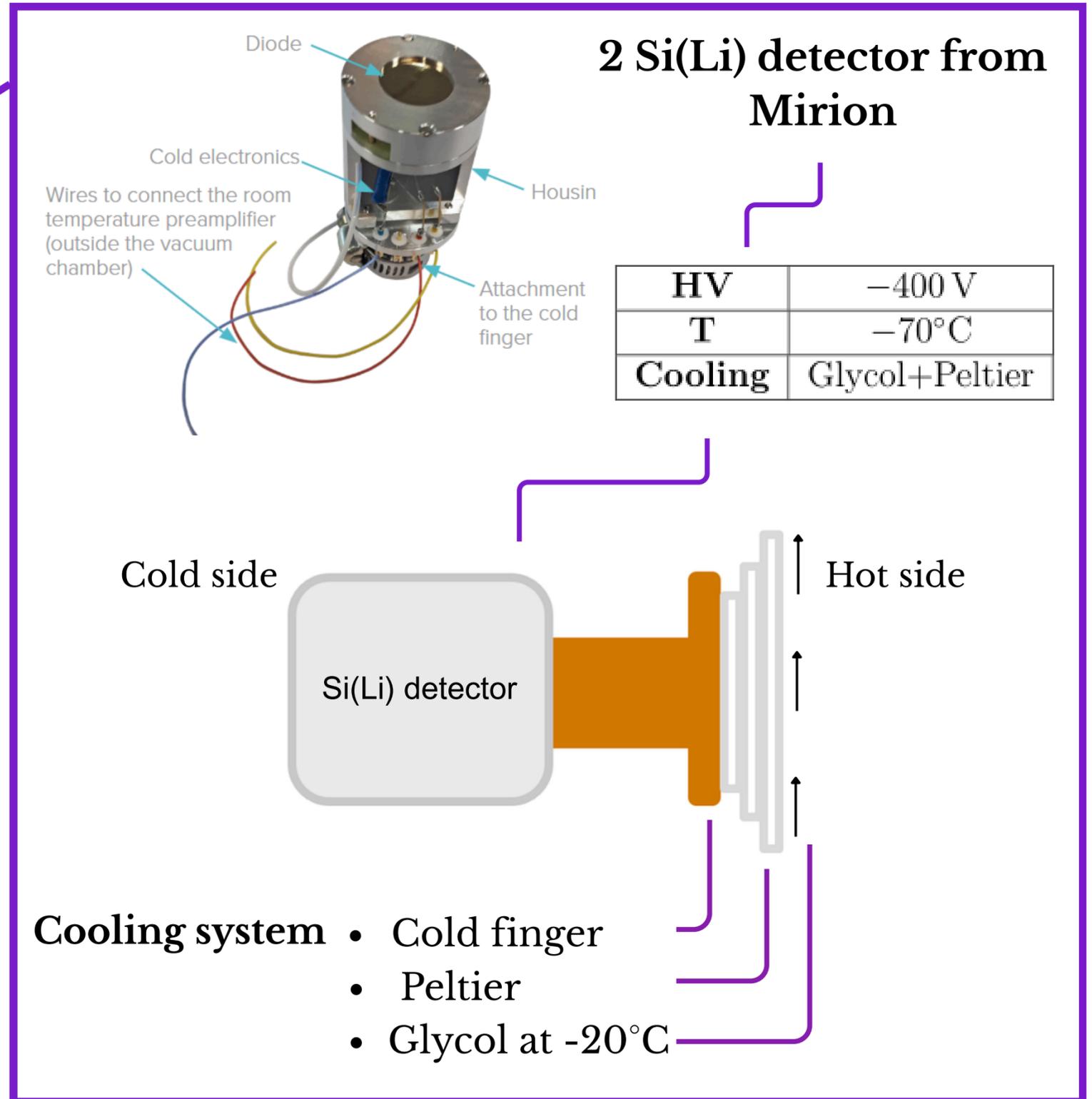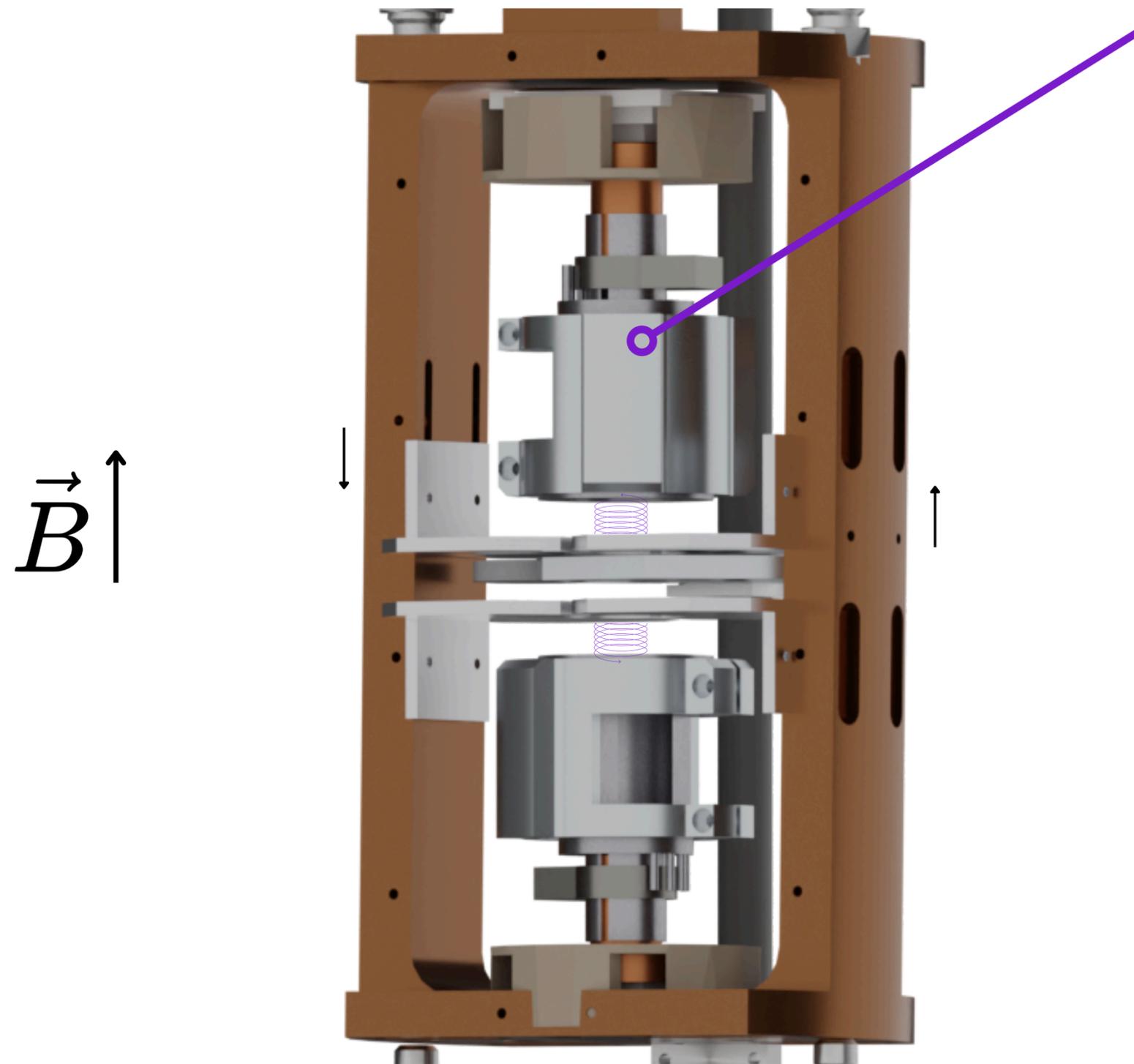- High mass region to study weak magnetism

^{32}P:
- Favorable endpoint for BSM, pure GT
- Lifetime=14.3 days
- Allowed transition with large ft value

Experimental challenges: energy loss in different layers, Bremsstrahlung and **backscattering**-> SPELS at WISArD
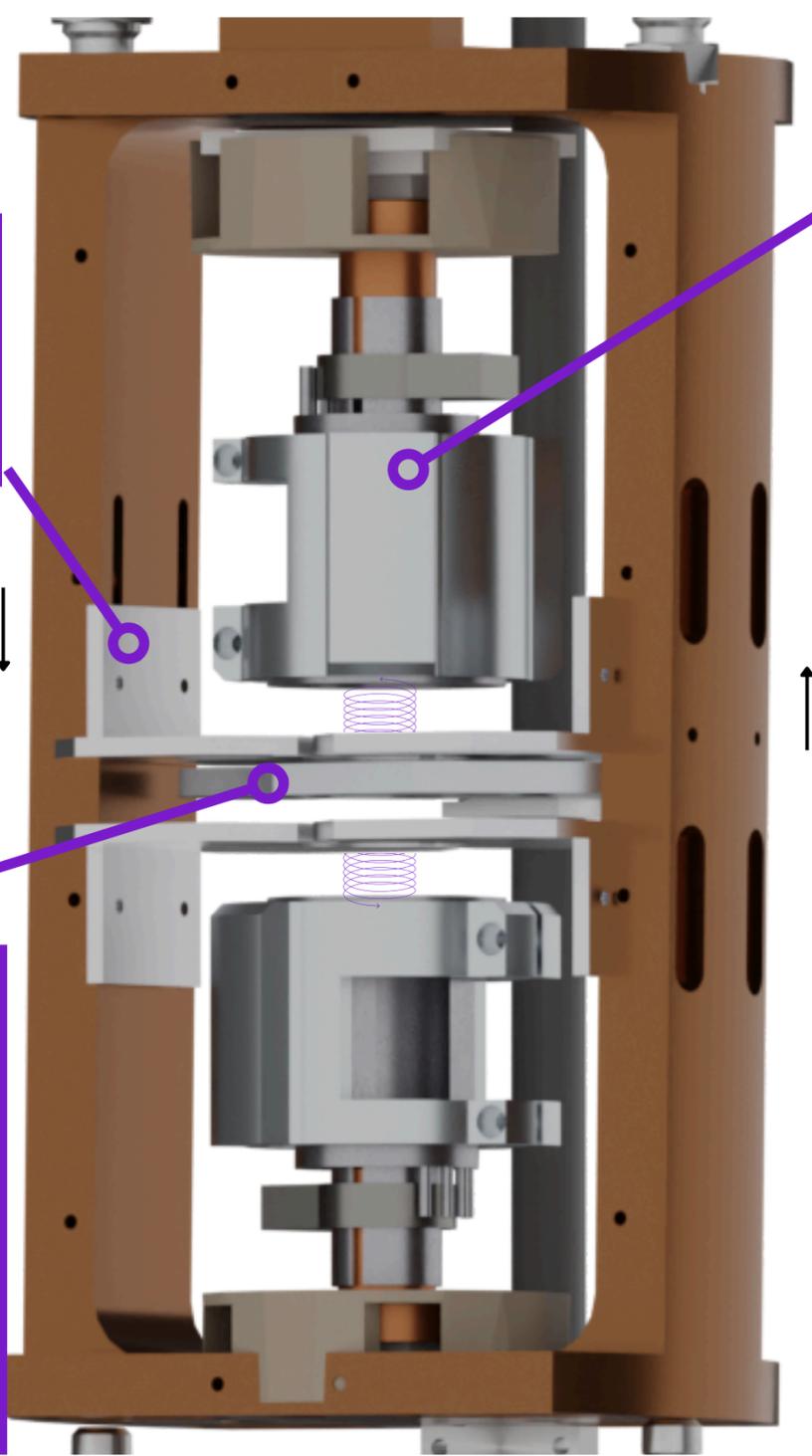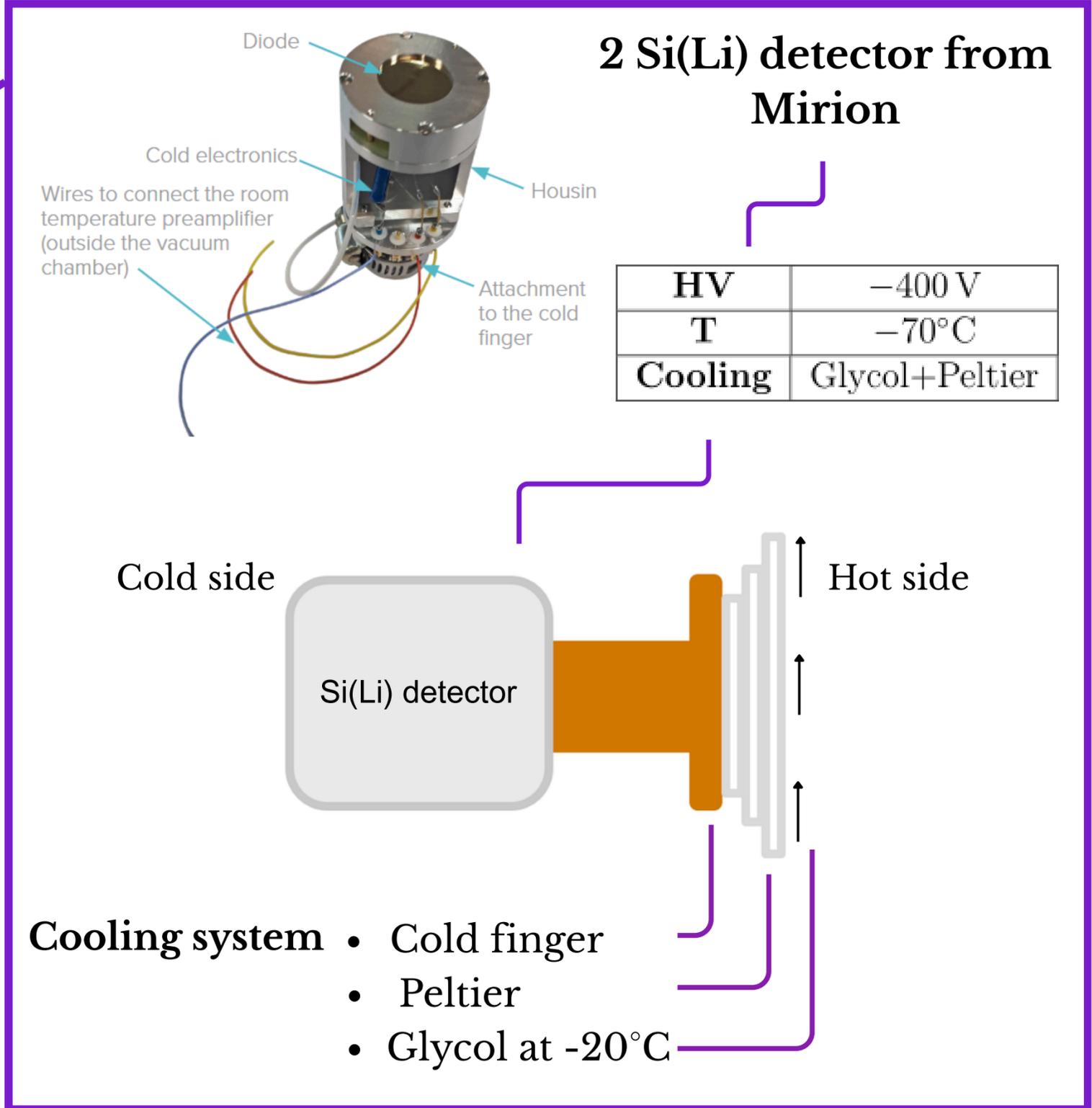

Fit of β energy spectrum ——
Eq.(7) ....
10^8 events
Fit range 5-95%

Δb_{Fierz}

End-point energy, E_0 (MeV)

n ^{32}P ^{114}In ^{6}He

4

Experimental setup

$\vec{B}$

2 Si(Li) detector from Mirion

HV	$-400\,\text{V}$
T	$-70°\text{C}$
Cooling	Glycol+Peltier

Cold side

Si(Li) detector

Hot side

Cooling system
- Cold finger
- Peltier
- Glycol at -20°C

Experimental setup

Aluminium garage + tungsten plates

Source holder

(thinner source of interest + calibration)

2 Si(Li) detector from Mirion

Diode

Cold electronics

Housin

Wires to connect the room temperature preamplifier (outside the vacuum chamber)

Attachment to the cold finger

HV	$-400\,\text{V}$
T	$-70°\text{C}$
Cooling	Glycol+Peltier

Cold side

Hot side

Si(Li) detector

Cooling system
- Cold finger
- Peltier
- Glycol at -20°C

6

First tests at ISOLDE

HV	$-400\,\mathrm{V}$
T	$-70°\mathrm{C}$
Source	$^{207}\mathrm{Bi}$

- Mechanical test
- Test of the cooling system with cooled magnet
- Energy spectra with two Si(Li) detectors
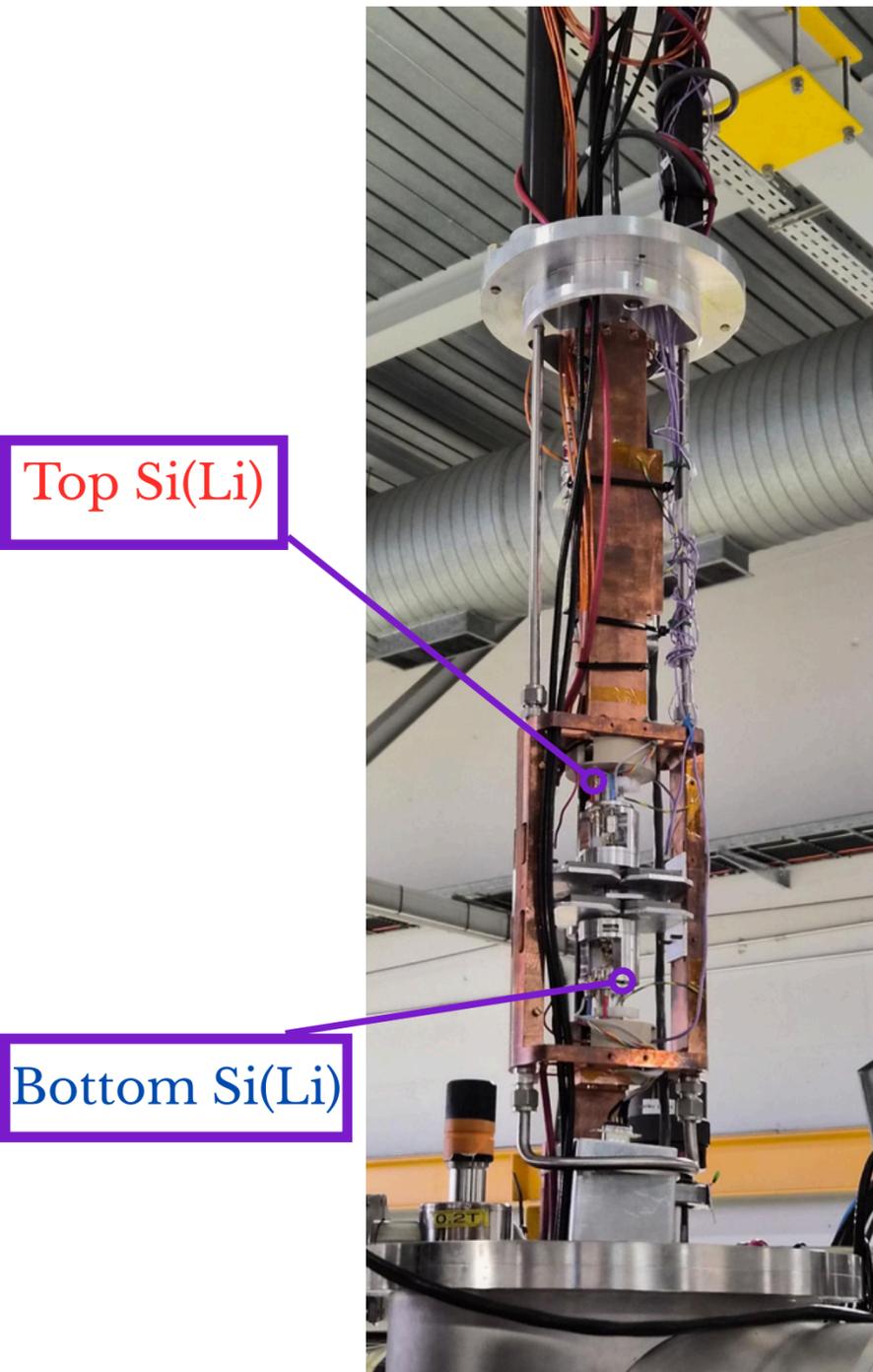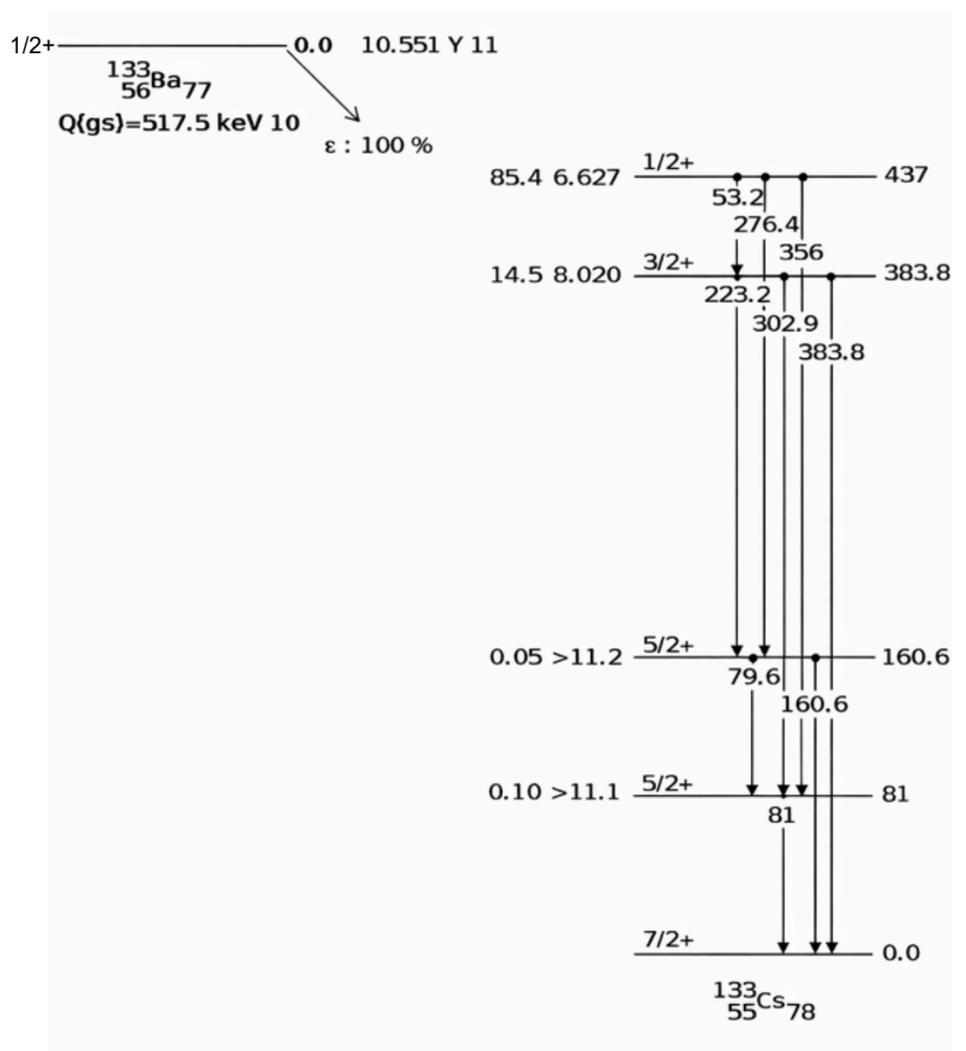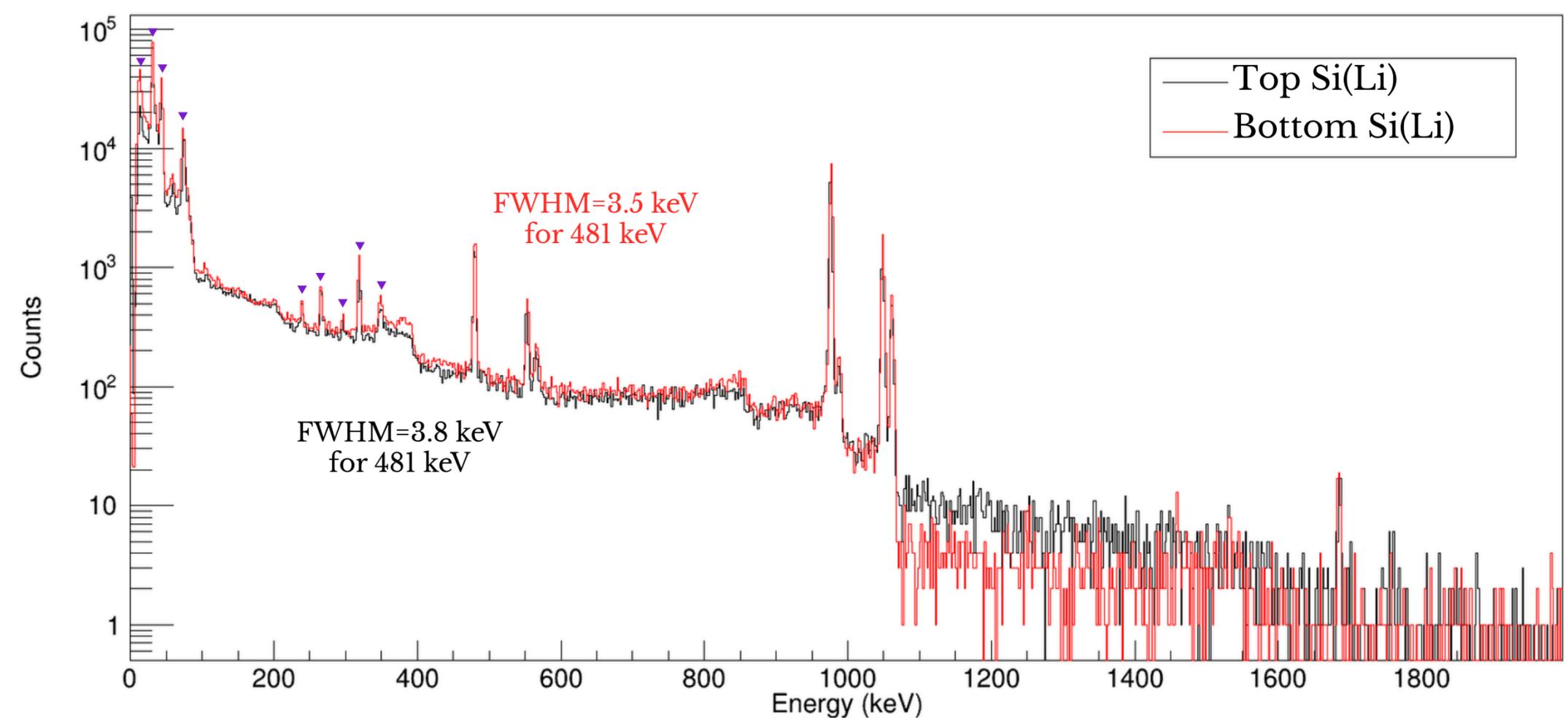

2025 Detection tower
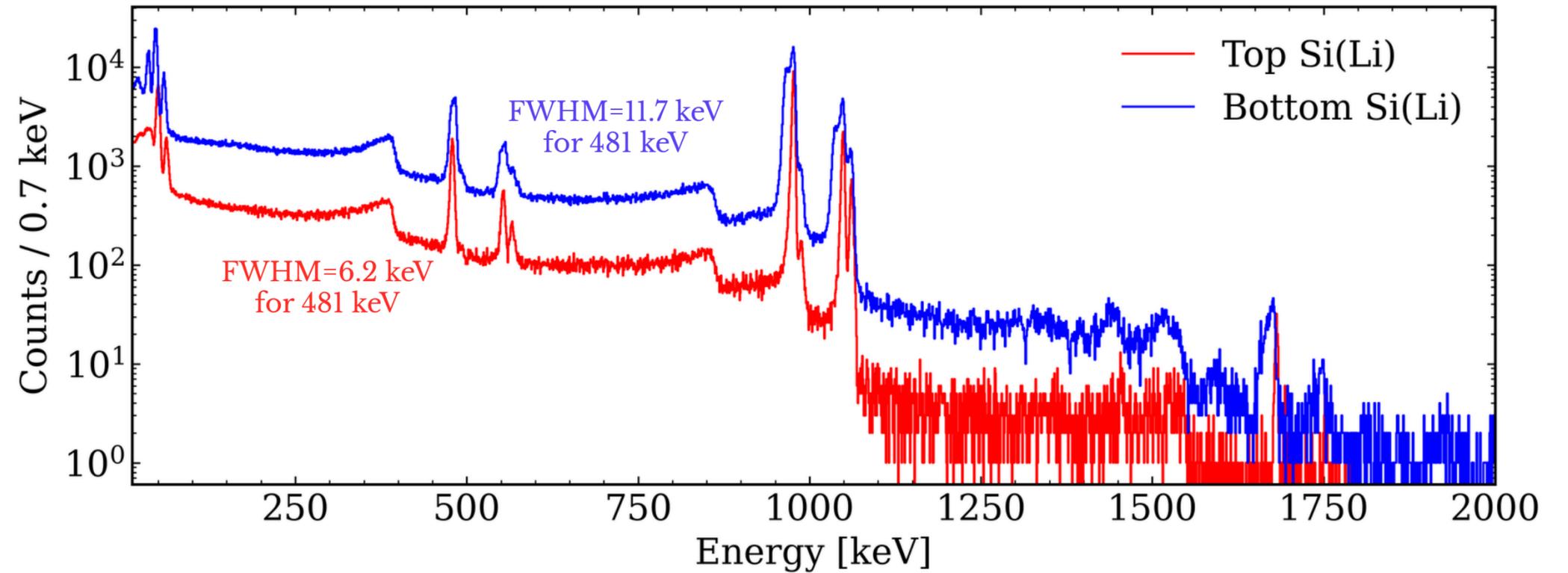
→ Investigation in Bordeaux of the differences of performances between the detectors lead to the replacement of the bottom Si(Li) by another from KU Leuven

7

First data taking

HV	$-210\,\text{V}/-395\,\text{V}$
T	$-45°\text{C}$
Source	Mixed
Activity	1 kBq

Spectrum of the mixed ($^{207}\text{Bi} + ^{133}\text{Ba}$) calibration source without pulser for 0T
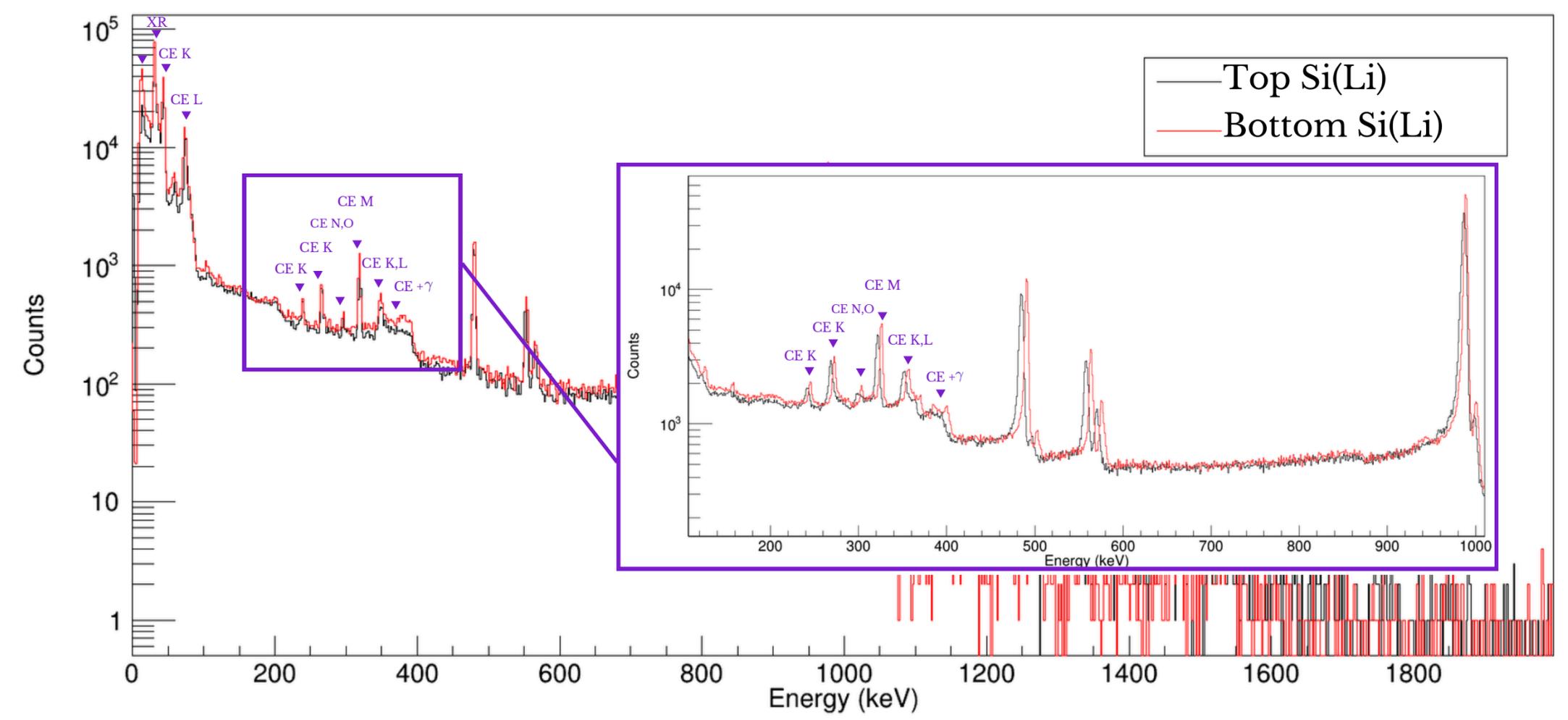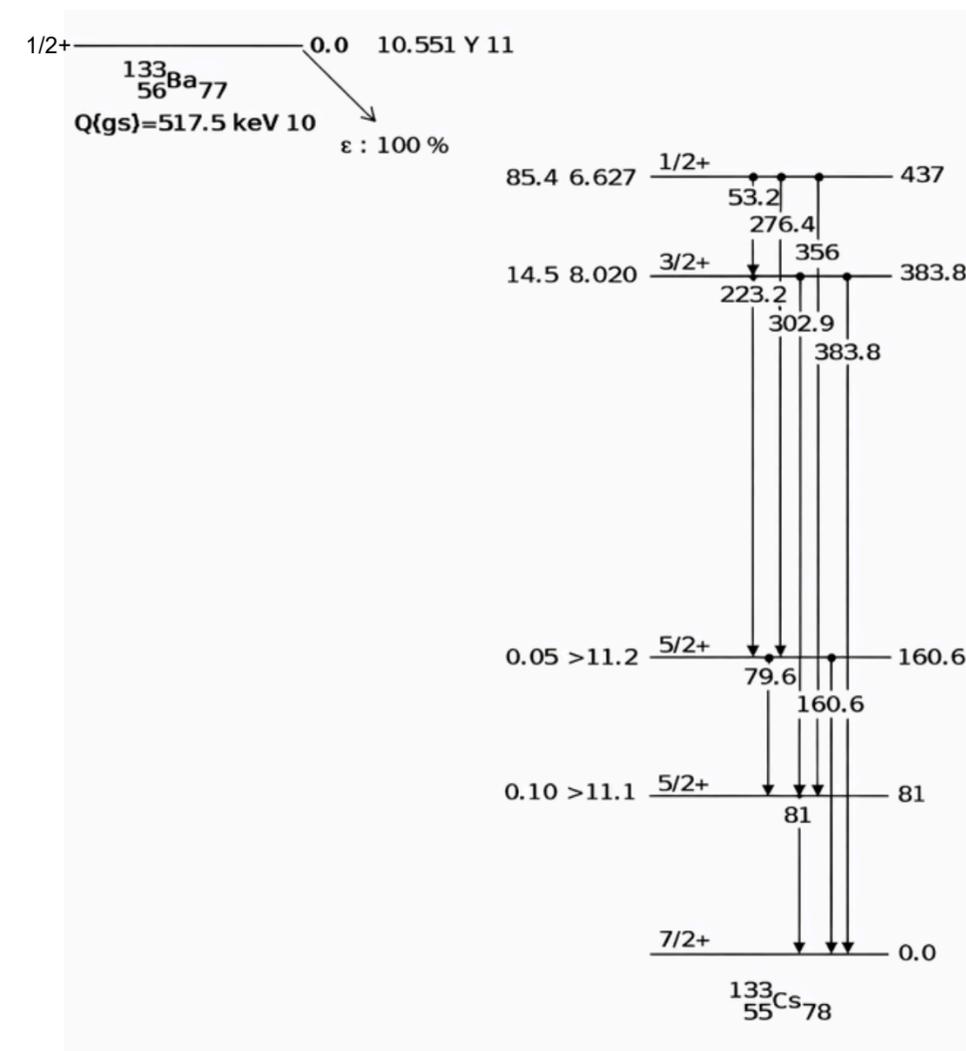

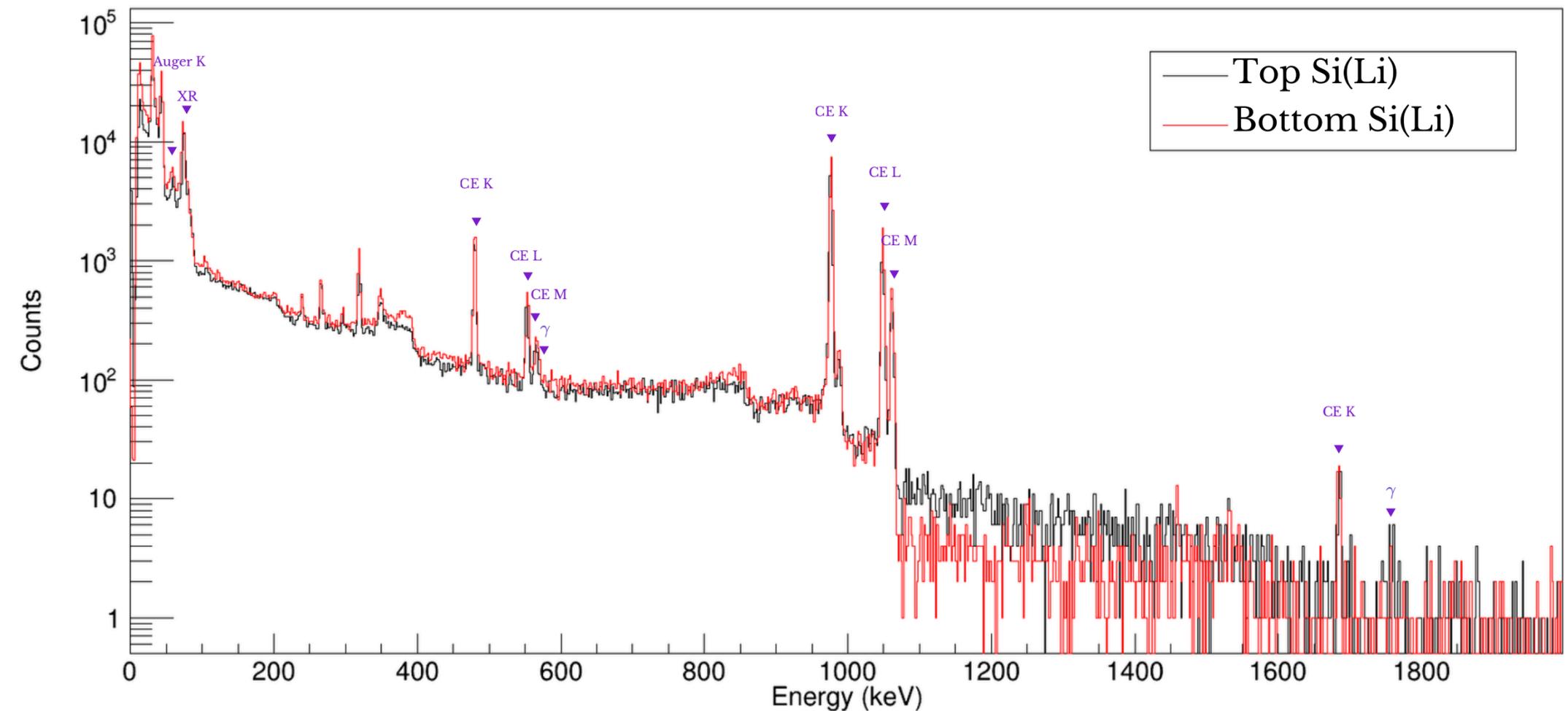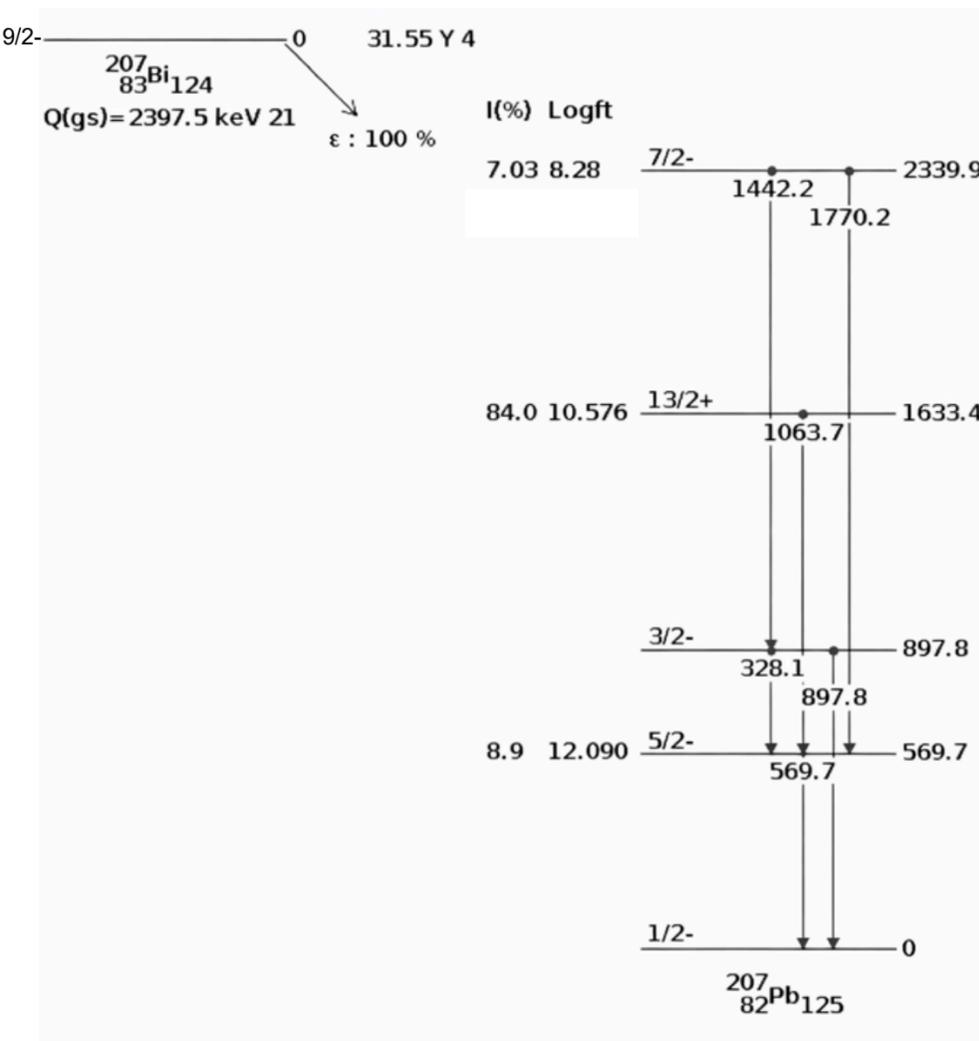Decay scheme of ^{133}Ba

⟶ HV differences and temperature measurement are being investigated back in Bordeaux

⟶ Mixed source to have a large energy range to calibrate the detectors.

8

First data taking

HV	$-210\,\text{V}/-395\,\text{V}$
T	$-45°\text{C}$
Source	Mixed
Activity	1 kBq

Spectrum of the mixed (^{207}Bi + ^{133}Ba) calibration source without pulser for 0T

Decay scheme of ^{133}Ba

→ Mixed source to have a large energy range to calibrate the detectors.

First data taking

HV	$-210\,\text{V} / -395\,\text{V}$
T	$-45°\text{C}$
Source	Mixed
Activity	1 kBq

Spectrum of the mixed (^{207}Bi + ^{133}Ba) calibration source without pulser for 0T

Decay scheme of ^{207}Bi

→ Mixed source to have a large energy range to calibrate the detectors.

First data taking

HV	$-210\,\text{V}/-395\,\text{V}$
T	$-45°\text{C}$
Source	Mixed
Activity	1 kBq

Decay scheme of ^{207}Bi

Spectrum of the mixed calibration source without pulser for 0T and 8T for bottom Si(Li)
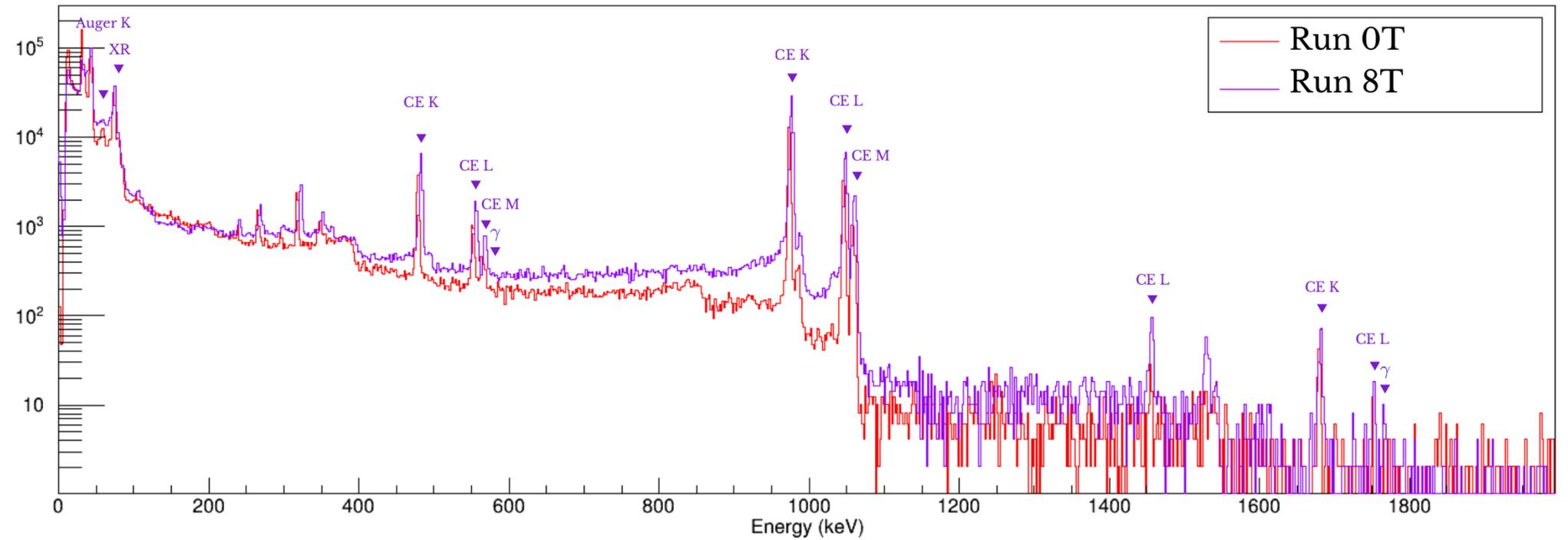
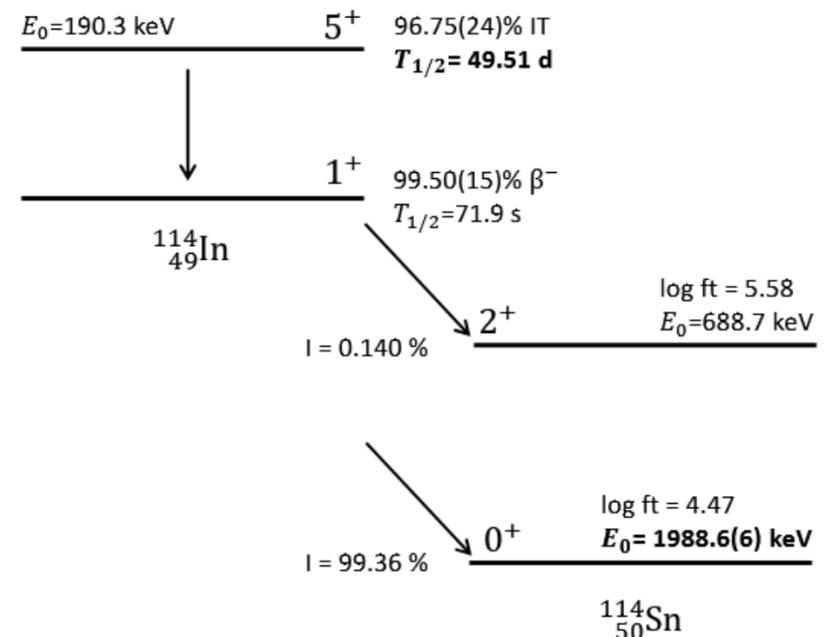⟶ Mixed source to have a large energy range to calibrate the detectors.

⟶ Effect of magnetic field : higher peak height for electron + increase of EC peaks of ^{207}Bi at high energy.
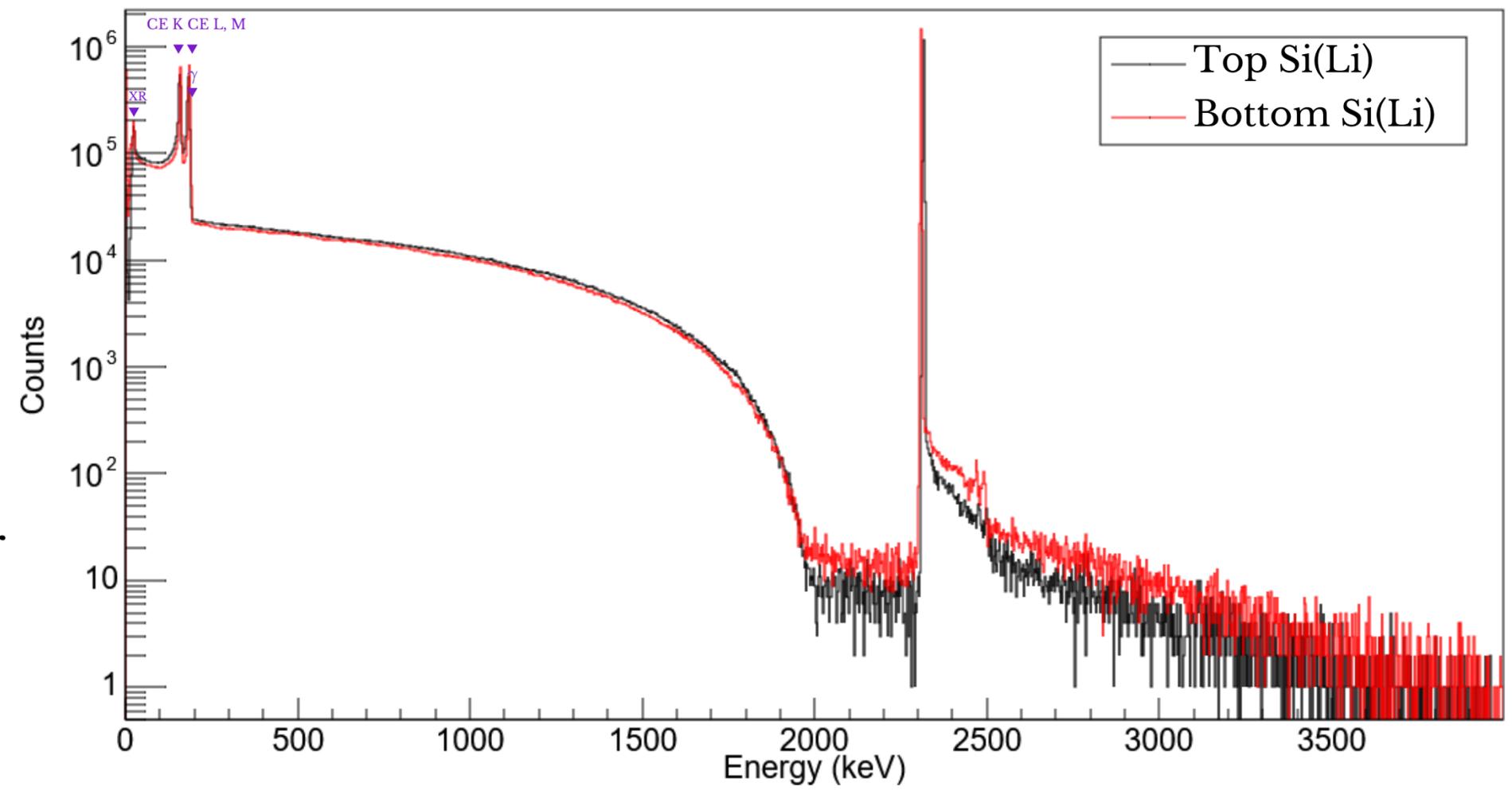
11

First data taking

HV	$-210\,\text{V}\;/-395\,\text{V}$
T	$-45°\text{C}$
Source	114In
Activity	1.5 kBq

Decay scheme of ^{114}In

Spectrum of the ^{114}In source with pulser for 8T

- 40h runs for ^{114}In with/without pulser
  - At 6T: 3.8×10^7 events
  - At 8T: 6.3×10^7 events

- 30h mixed calibration runs with/ without pulser for 6T and 8T
- Background measurement without source of ^{114}In ⟶ Added a pulser to use as a reference to correct the gain variation

12

Conclusion

- Mounting and optimization of the setup at Bordeaux and tests at KU Leuven lead to a successful first test at ISOLDE in September 2025.

- First data taking with ^{114}In and mixed calibration source in the beginning of 2026

- **Ongoing analysis:**
  - Correction of gain variation with pulser
  - Pile up model and study of coincidence events

  - Complete GEANT4 geometry → first use for calibration, then extract dead layer thickness and energy loss

  - Fit with convoluted spectra between simulation and experimental to extract b_{WM} / b_{Fierz}
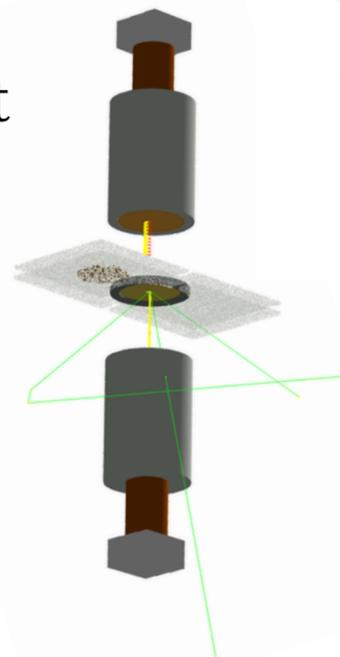
Example of cuts to erase influence of pulser for 114In spectrum at 8T
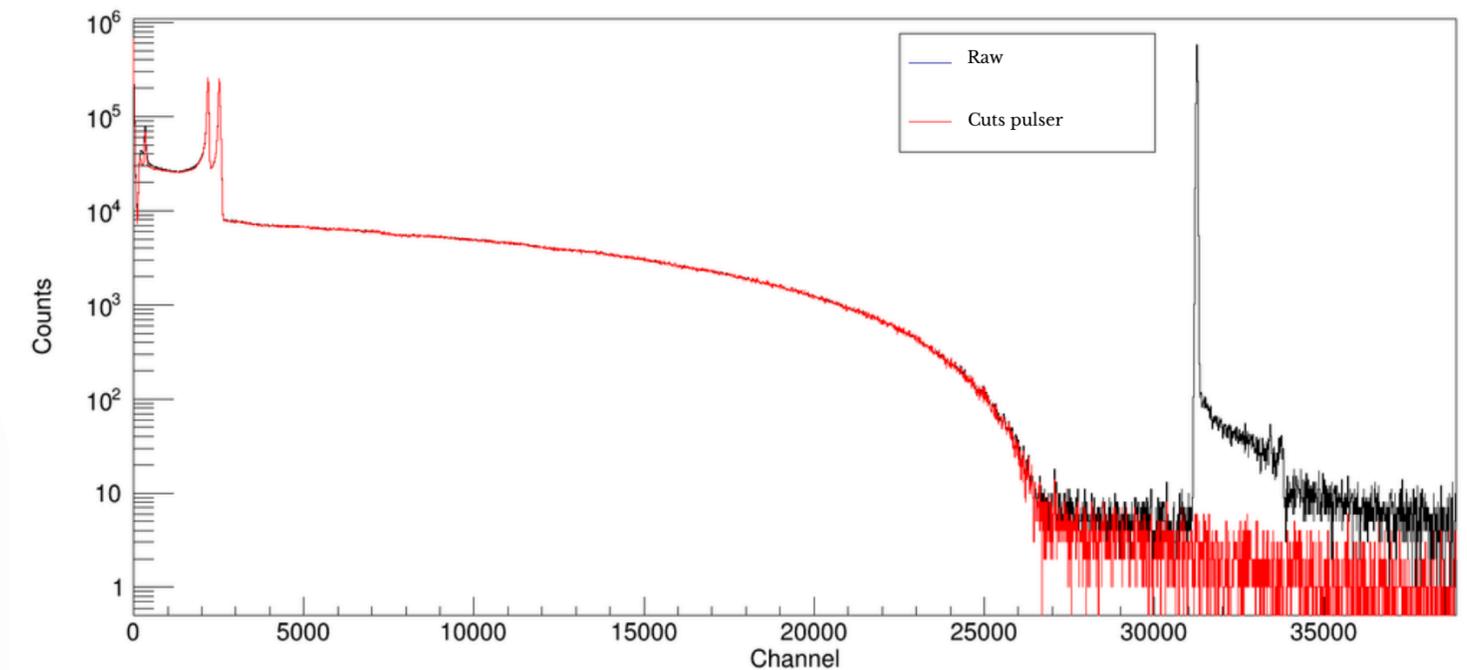
Conclusion

- Mounting and optimization of the setup at Bordeaux and tests at KU Leuven lead to a successful first test at ISOLDE in September 2025.

- First data taking with ^{114}In and mixed calibration source in the beginning of 2026

- Ongoing analysis

- **Experimental setup**

  - Ongoing improvements on the preamp settings for the HV value
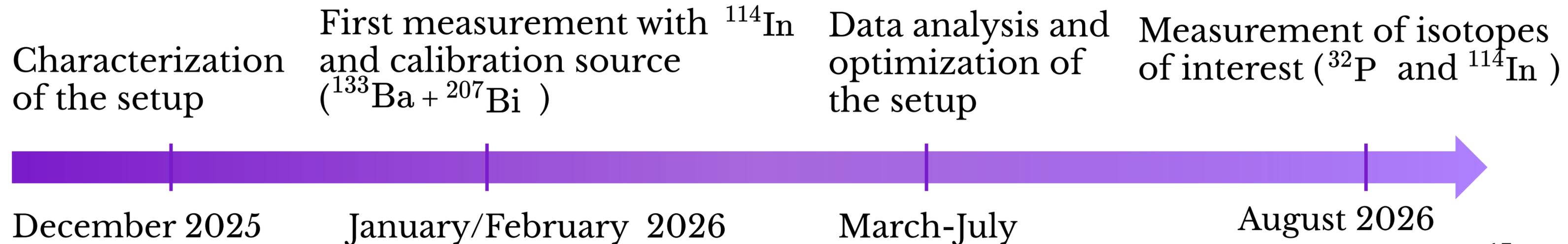
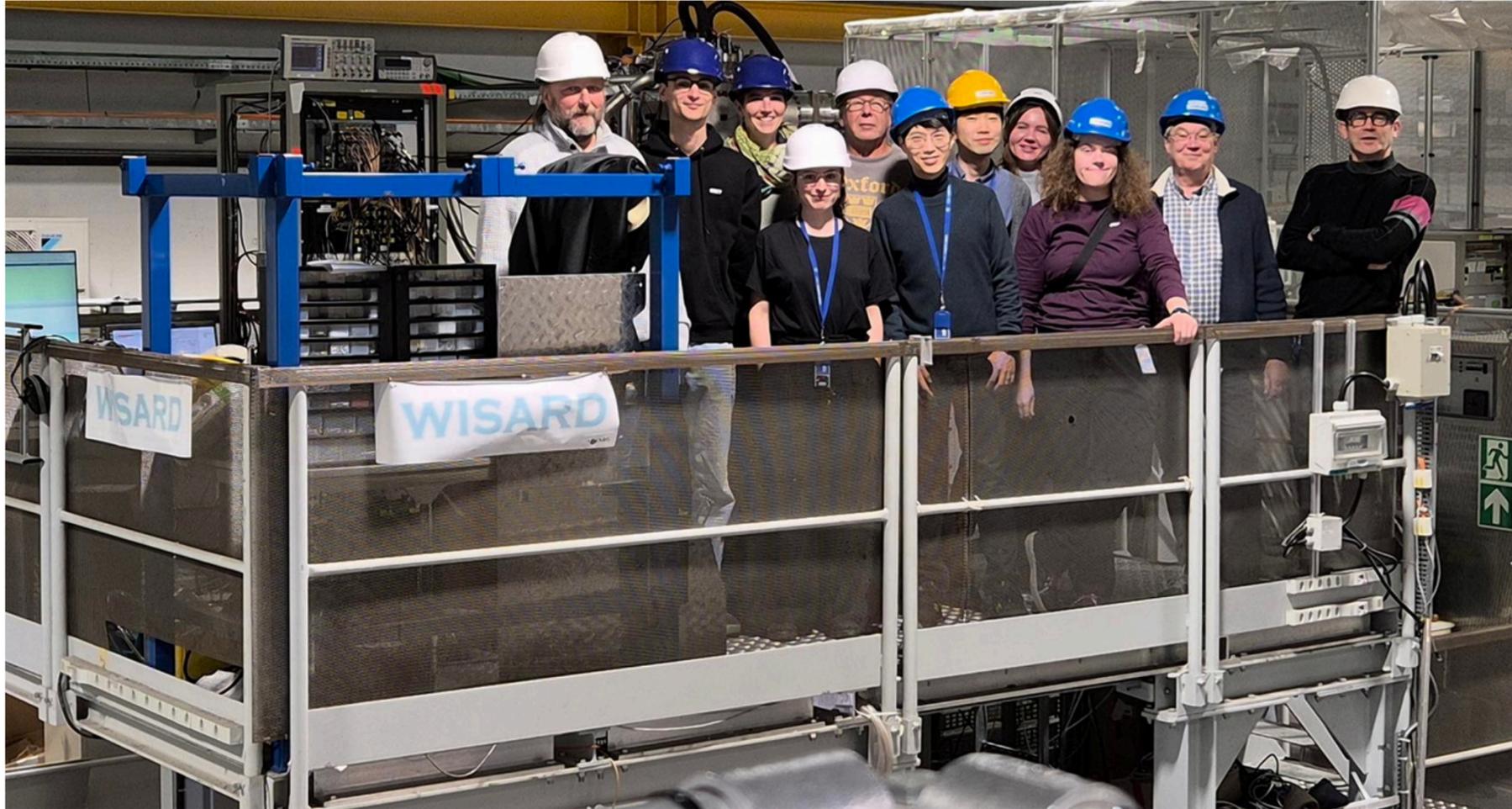 - Source characterisation with RBS measurement

Conclusion

- Mounting and optimization of the setup at Bordeaux and tests at KU Leuven lead to a successful first test at ISOLDE in September 2025.

- First data taking with ^{114}In and mixed calibration source in the beginning of 2026

- Ongoing analysis

- **Experimental setup**

Characterization of the setup

First measurement with ^{114}In and calibration source (^{133}Ba + ^{207}Bi)

Data analysis and optimization of the setup

Measurement of isotopes of interest (^{32}P and ^{114}In)

December 2025   January/February 2026   March-July   August 2026

15

Thank you for your attention!

P. Alfaurt, P. Ascher, D.Atanasov, B. Blank, A. Chekhovska, L. Daudin, X.Fléchard, M.Gerbaux, J.Giovinazzo, S.Grévy, J. Ha, C. Knapen, S.Lecanuet, R.Lica, M. Pomorski, M.Roche, N.Severijns, Y.Son, S. Vanlangendonck, M. Versteegen, D. Zakoucky

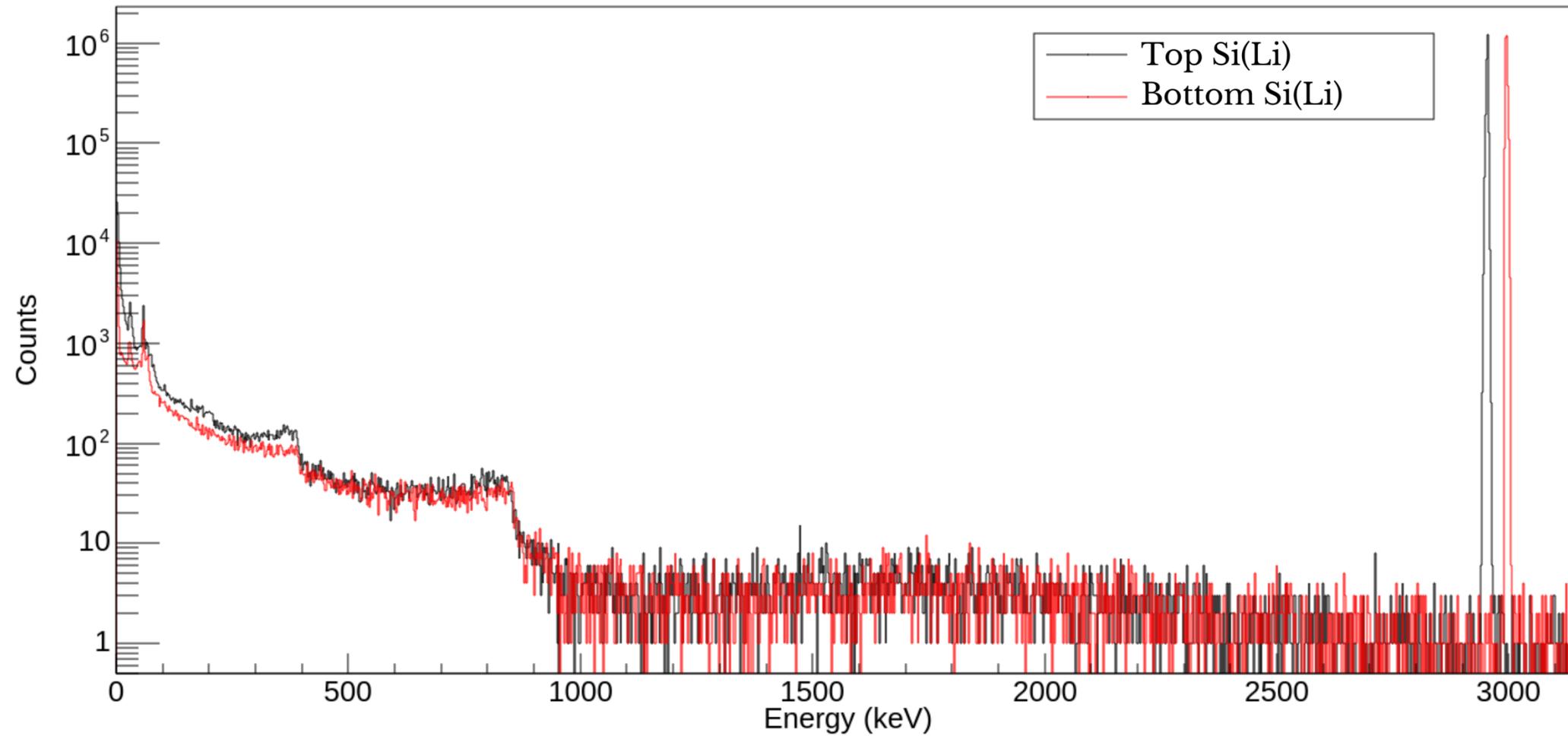# Back up

Source preparation in KU Leuven

Clear tape
Info sheet
Mylar foils
Two-sided tape
Al-ring

1.3 mm

Ø 11 mm

Ø 26 mm
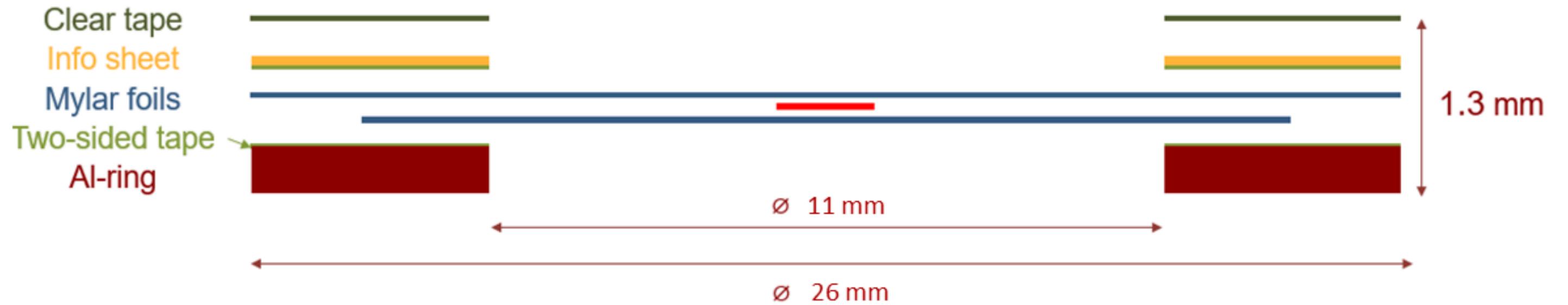
Source diameter and magnetic field value
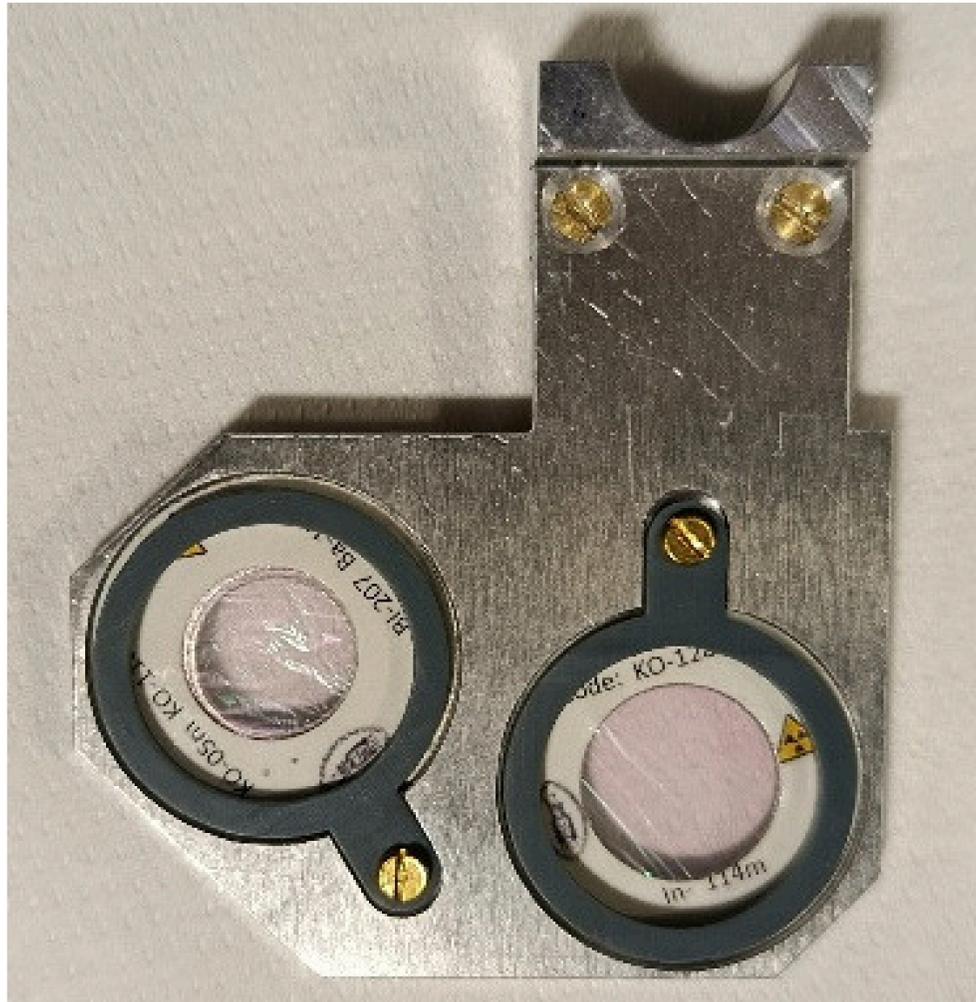
Pour E=2 MeV

B (T)	r_cyclo (mm)	r_max (mm)	r_max_backscat (mm)
4	2,05	6,01	10,19
6	1,36	4,73	7,46
8	1,02	4,05	6,01

$r_{\text{det}} = 12mm \quad r_{\text{source, }^{114}\text{In}} = 6,9mm \quad r_{\text{source, mixed}} = 6,15mm$

Background measurement

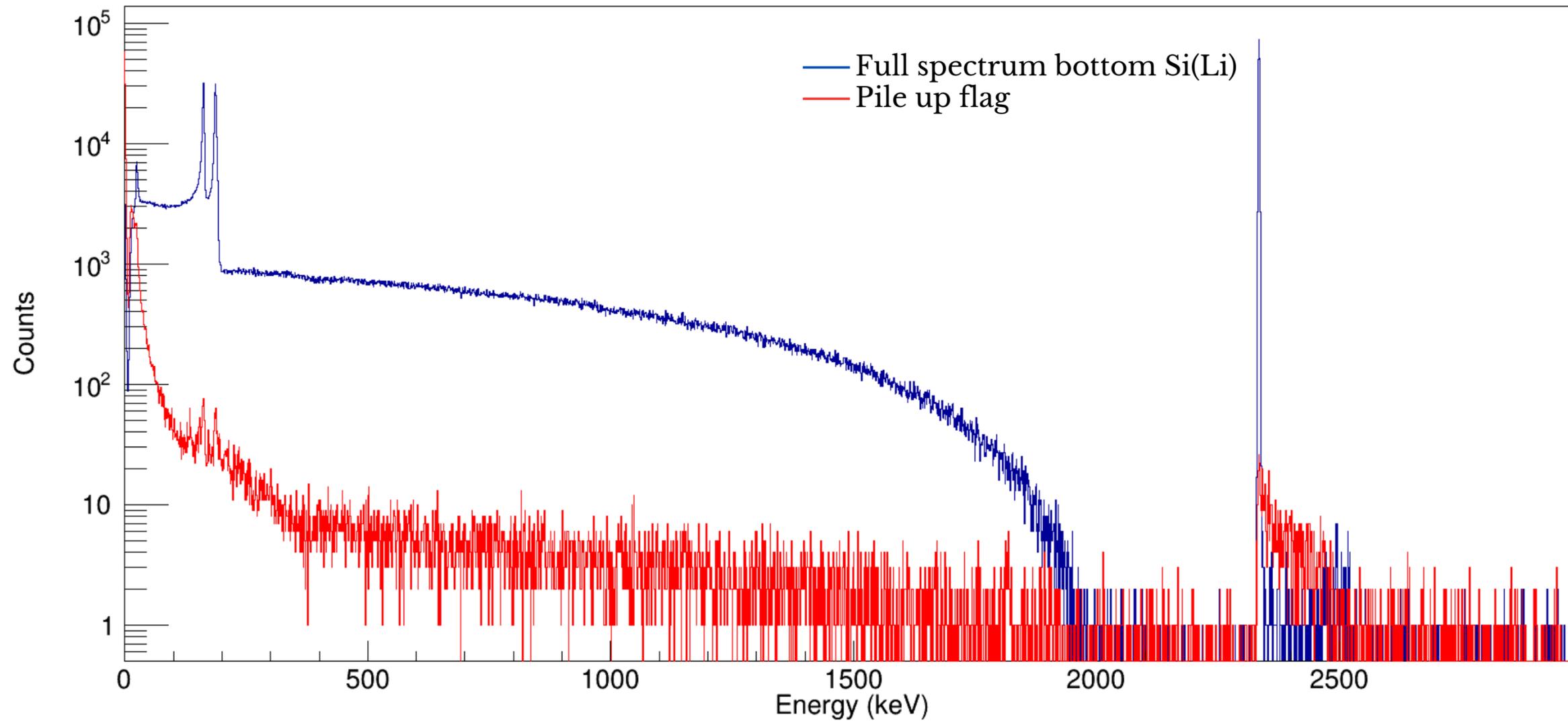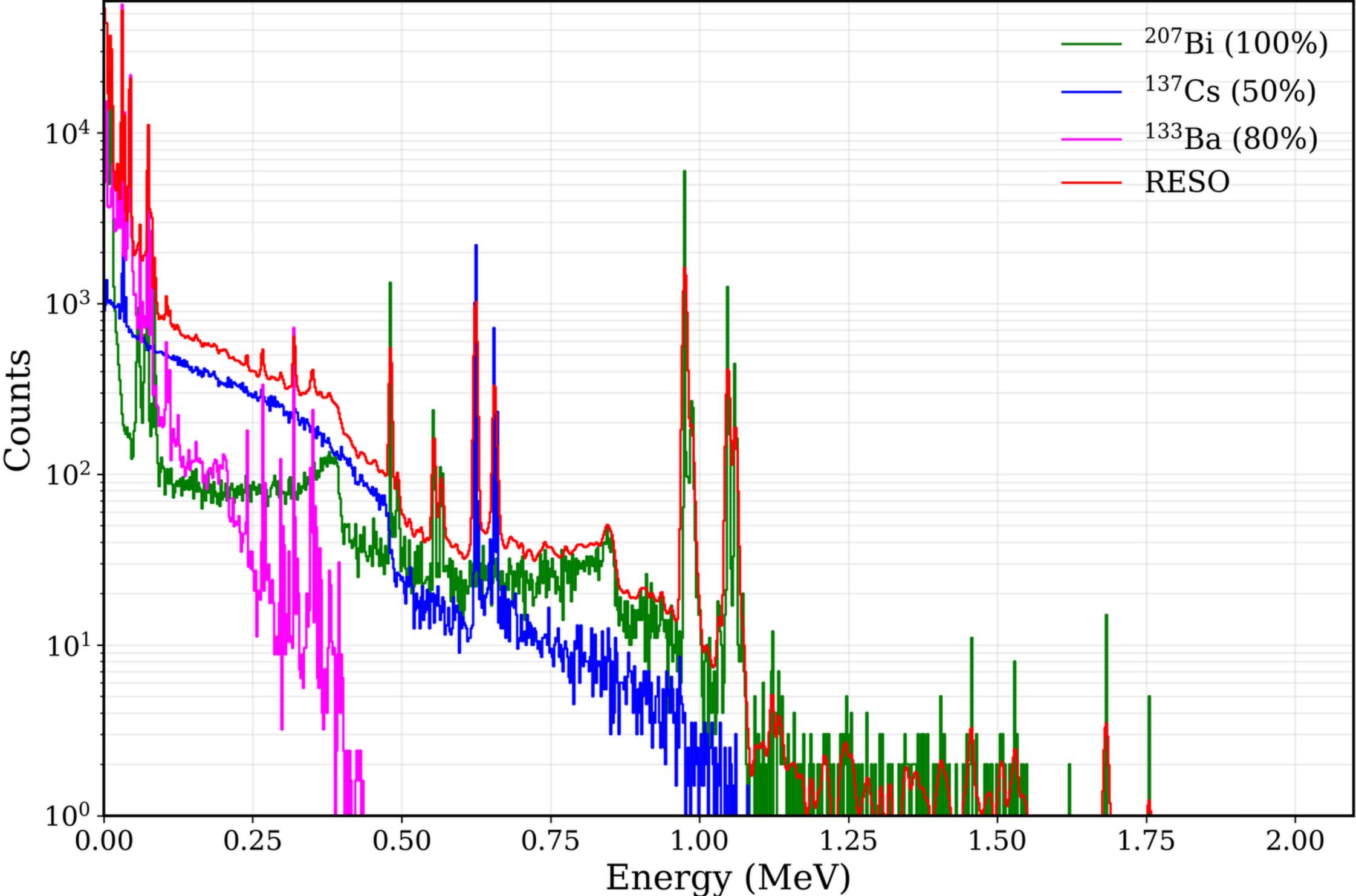| HV	$-210\,\mathrm{V}/-315\,\mathrm{V}$
T	$-45°\mathrm{C}$
Source	Mixed bgk
Activity	1 kBq

→ 60 keV XR from tungsten at low energies + 30 keV XR from ^{133}Ba

Pile up model with FASTER

Mixed calibration source (^{207}Bi, ^{133}Ba, ^{137}Cs) study

Summed Energy Histograms (Log Scale)

Legend:
- ^{207}Bi (100%)
- ^{137}Cs (50%)
- ^{133}Ba (80%)
- RESO
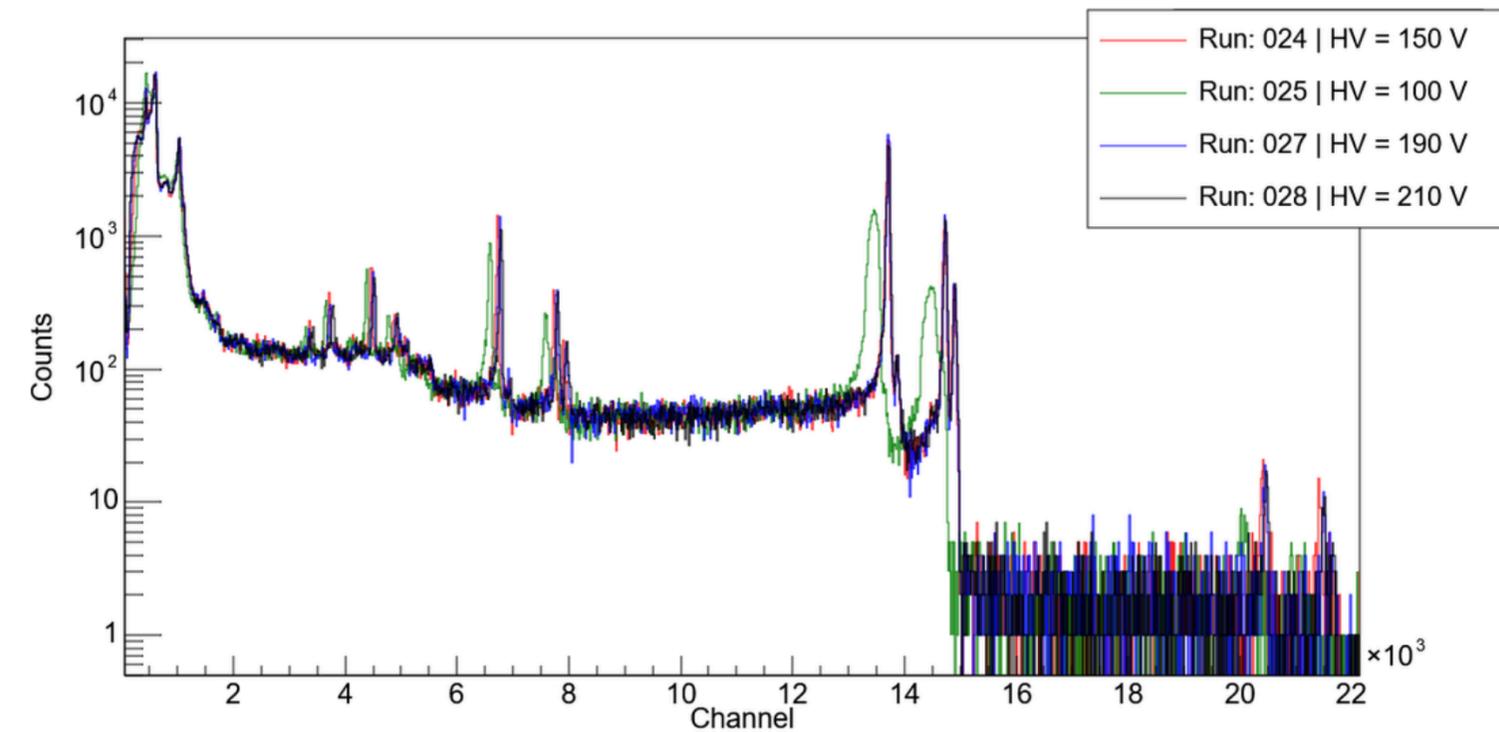
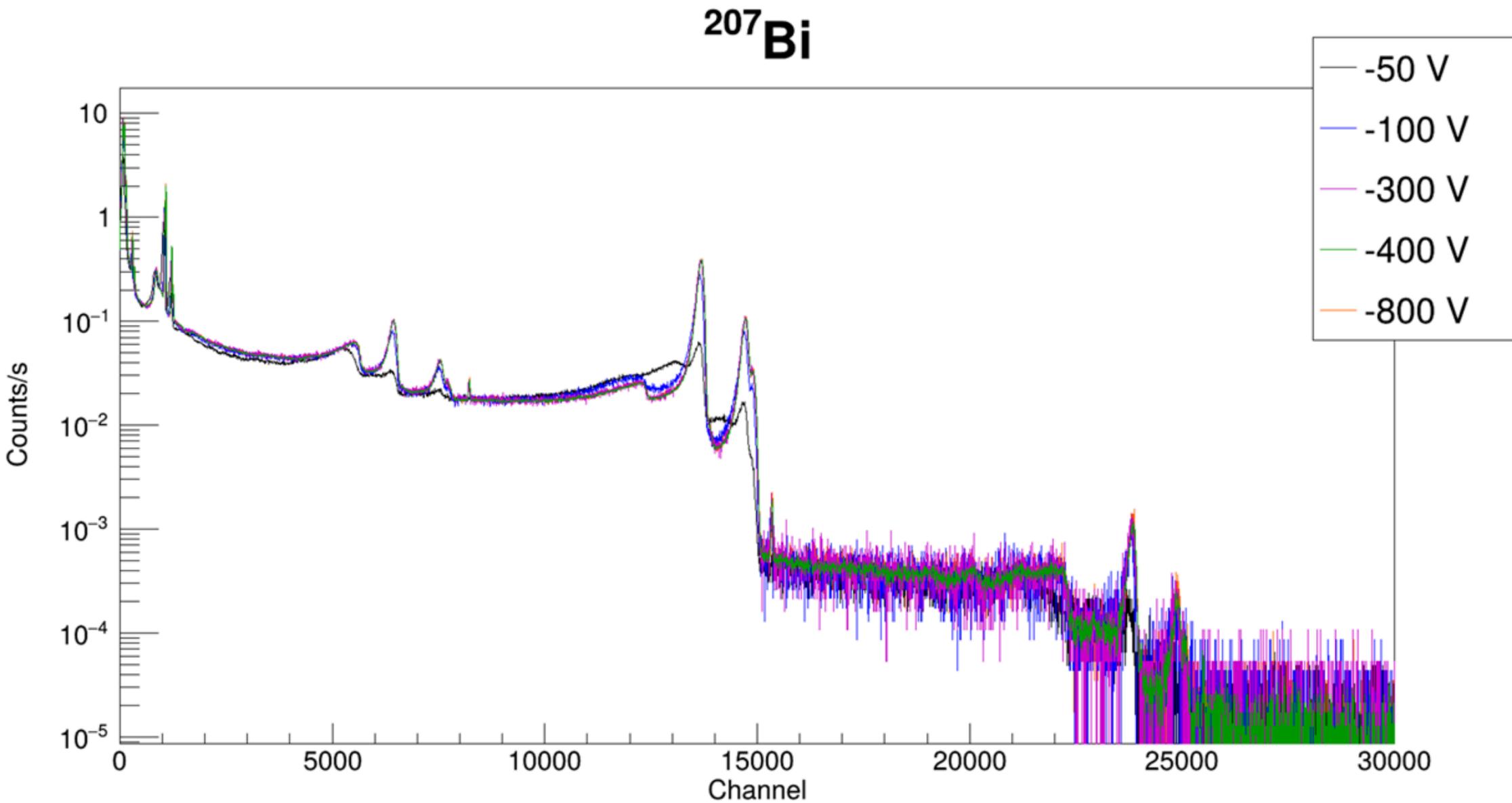# Investigation of high voltage saturation in ISOLDE
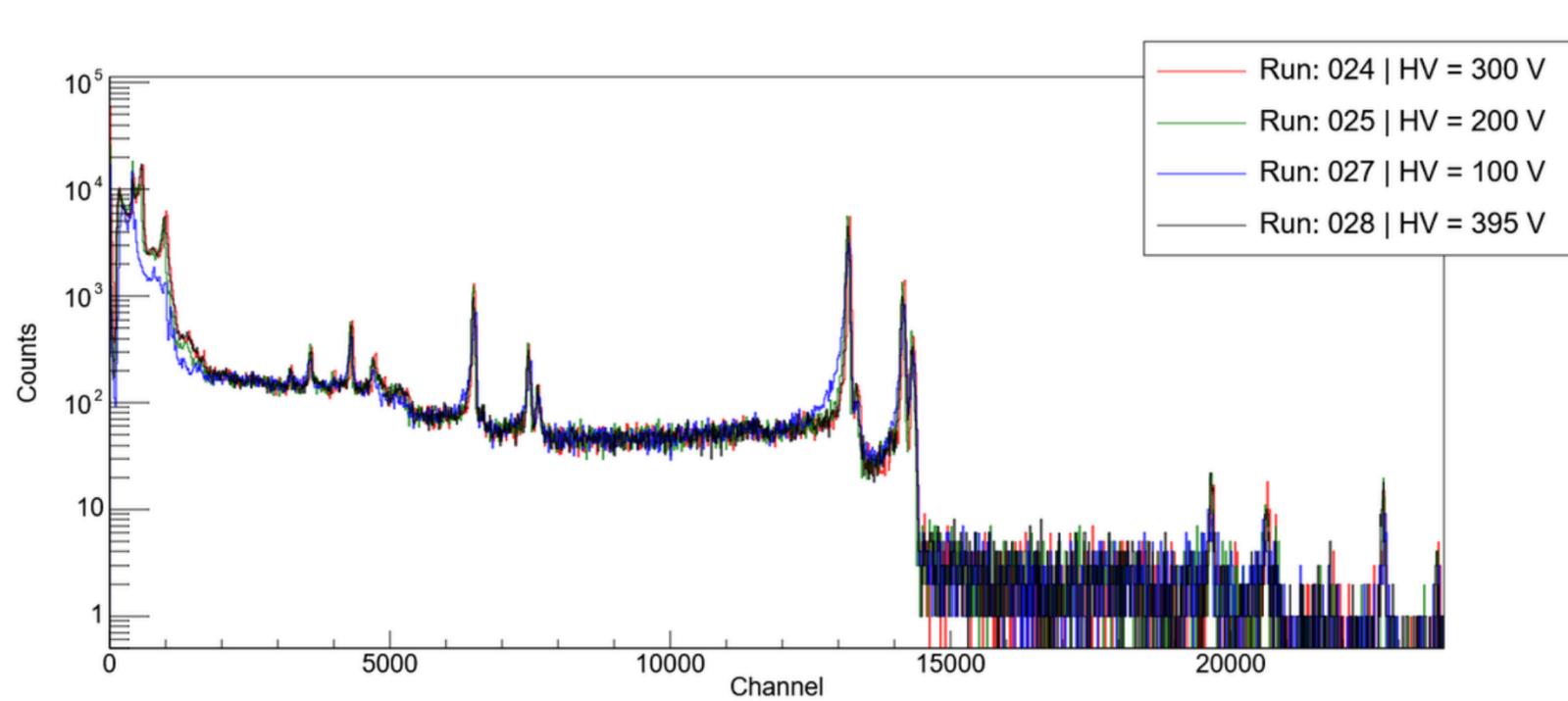
Spectra at different HV for the bottom Si(Li)

Spectra at different HV for the top Si(Li)

Completely depleted at HV=-400V? → further studies in bordeaux

Investigation of high voltage saturation in KU Leuven

- Detector cooled with LN2 + preamp outside vacuum:

-> Saturation voltage between -300 V and -400 V?

Correction of the gain variation with pulser

Gain variation

Gain first correction
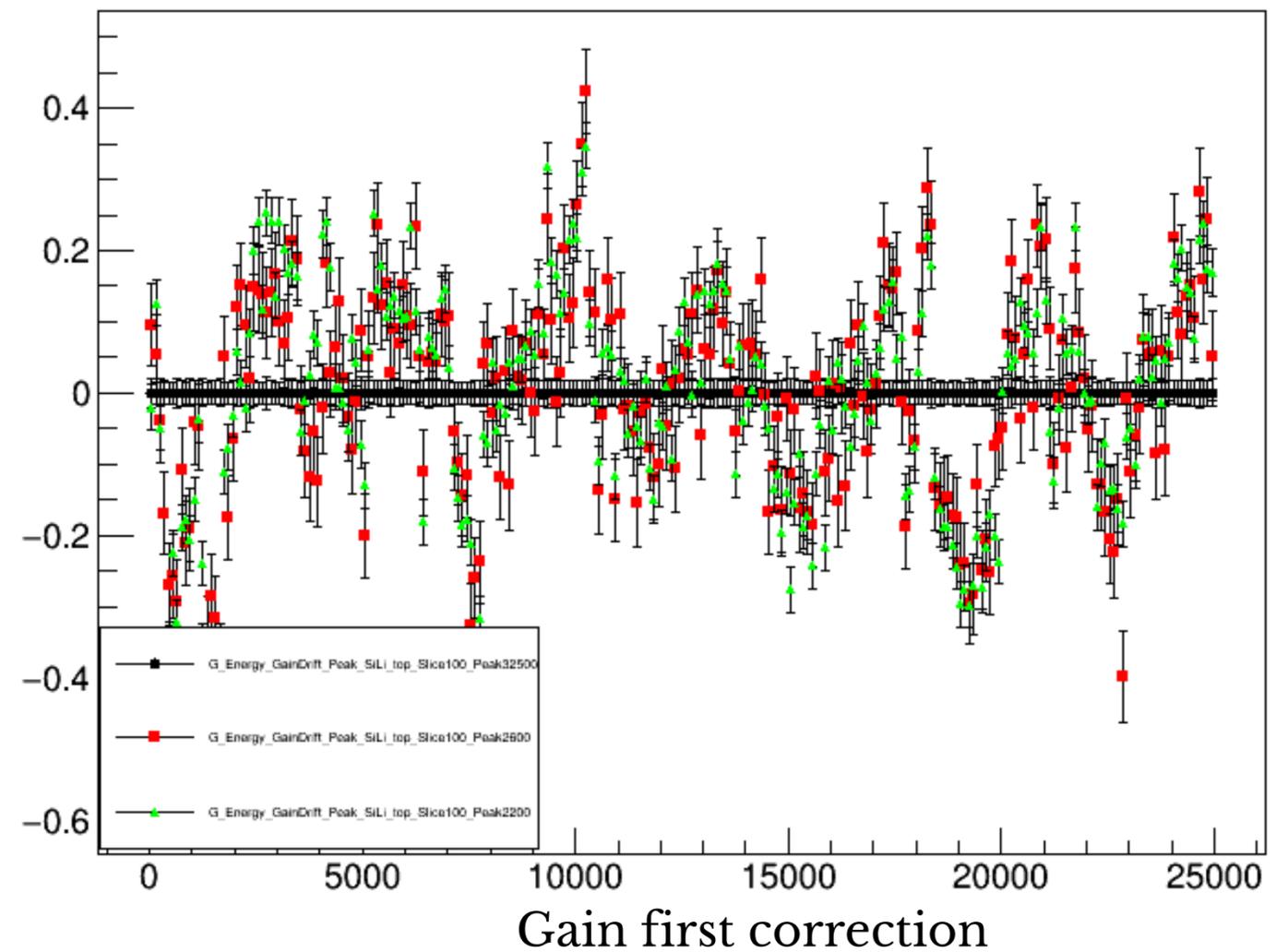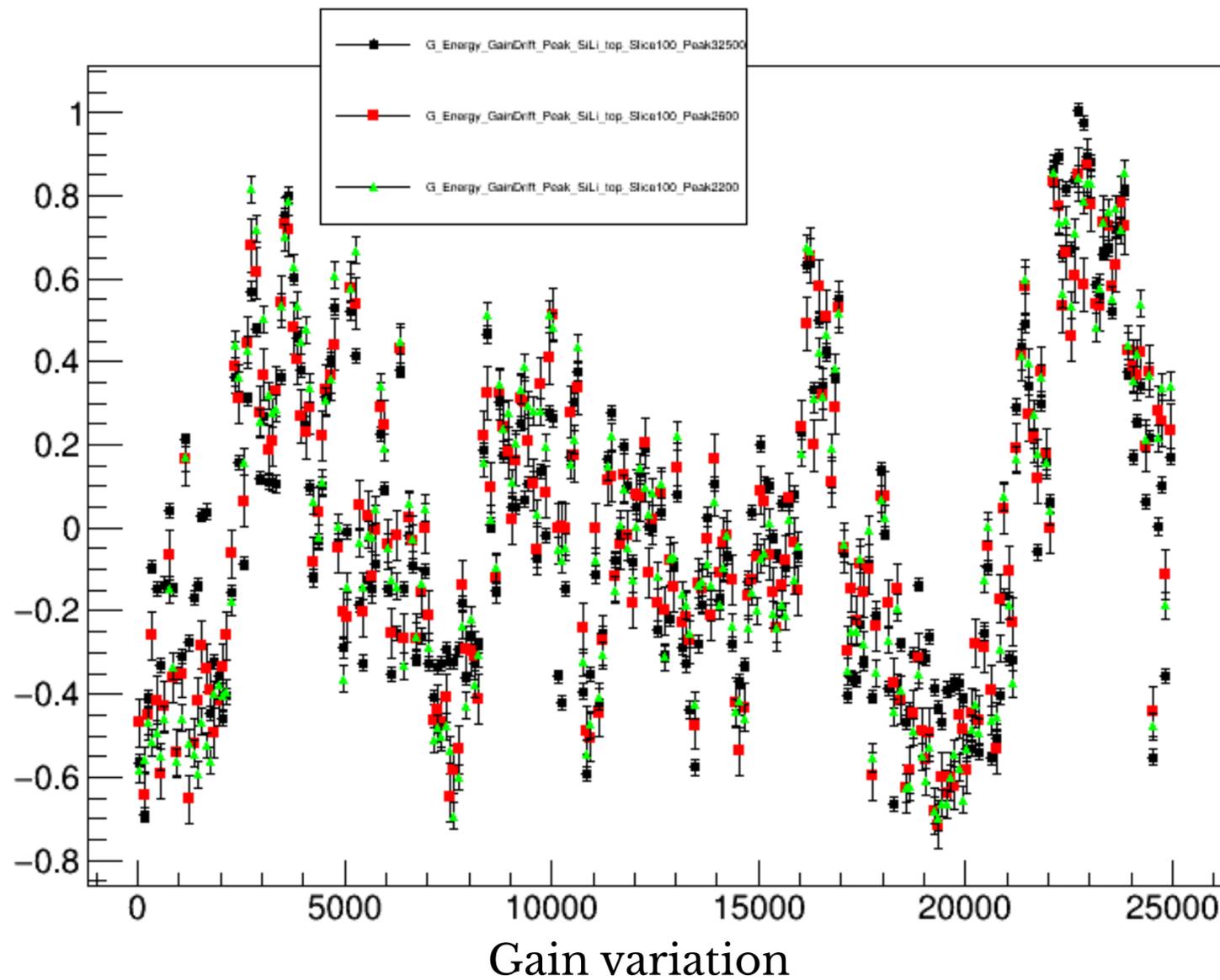
Example of gain variation for a ^{114}In run with a first correction applied with an offset by using the pulser peak as a reference.

25

Ongoing analysis to create the correction model.

Mixed calibration source (^{207}Bi , ^{32}P , ^{137}Cs) study
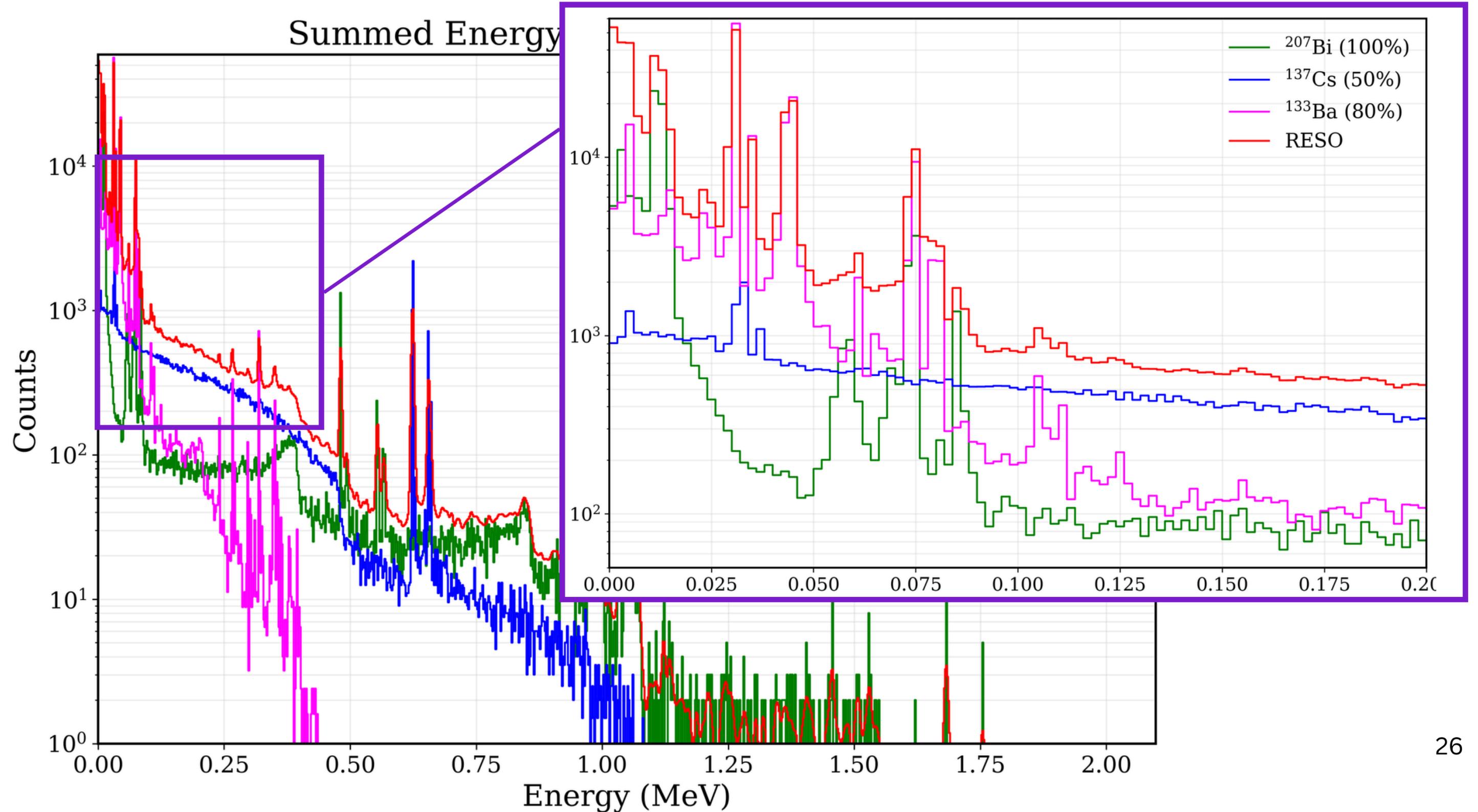
Experimental setup
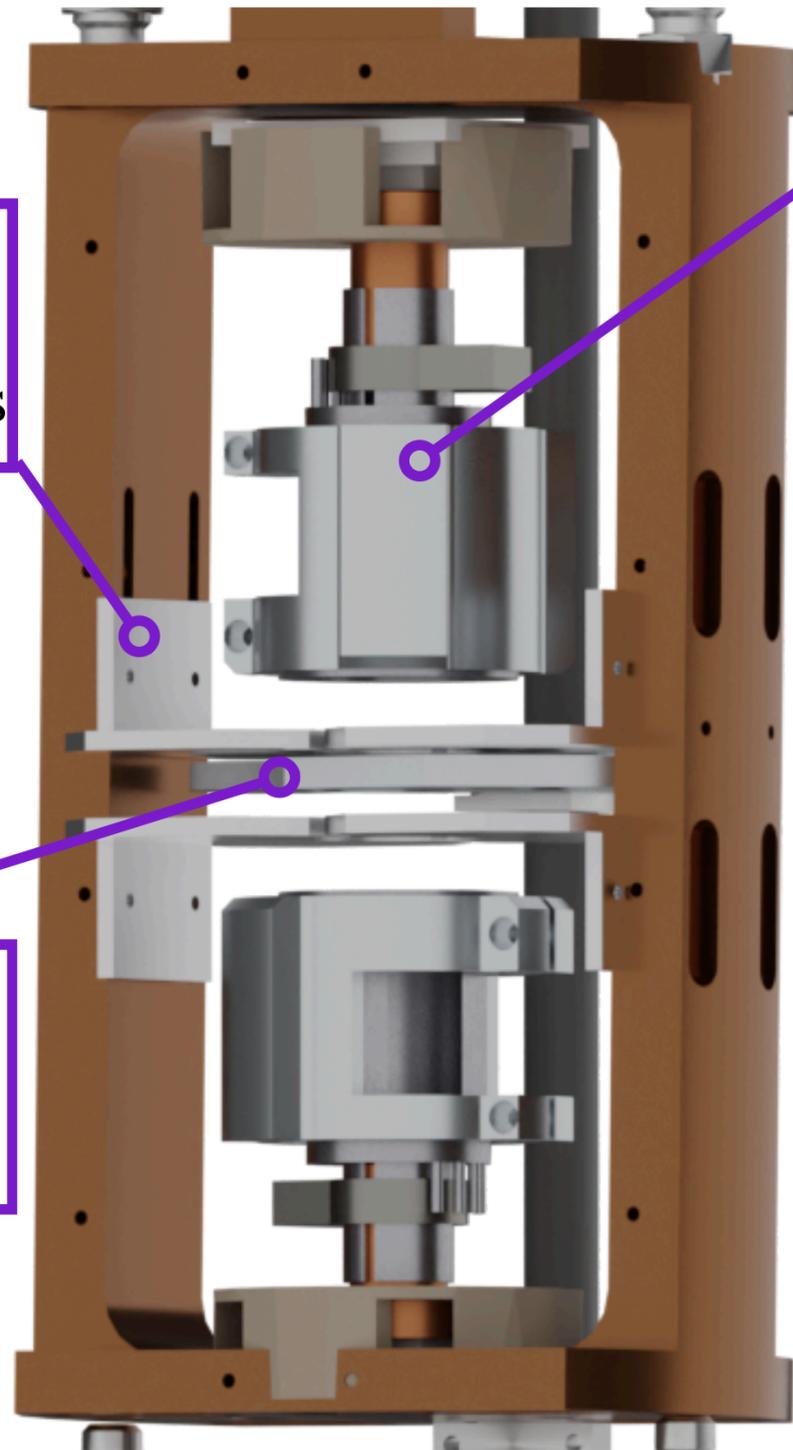
Aluminum
garage
+ tungsten plates

Source holder
(thinner source of
interest +
calibration)

Courtesy of C.Knapen

^{207}Bi

	Si(Li)
	InESS scintillators

^{207}Bi

Top Si(Li)	
Entries	42272
Mean	0.2675
Std Dev	0.2582
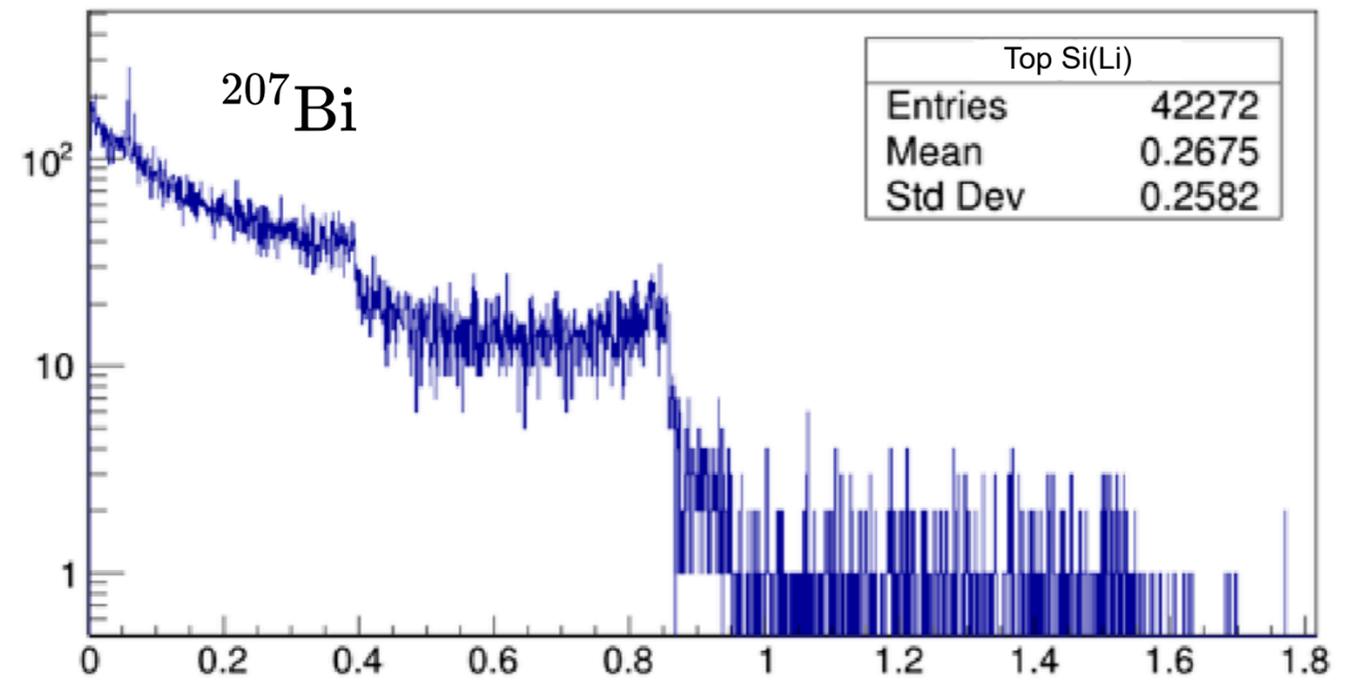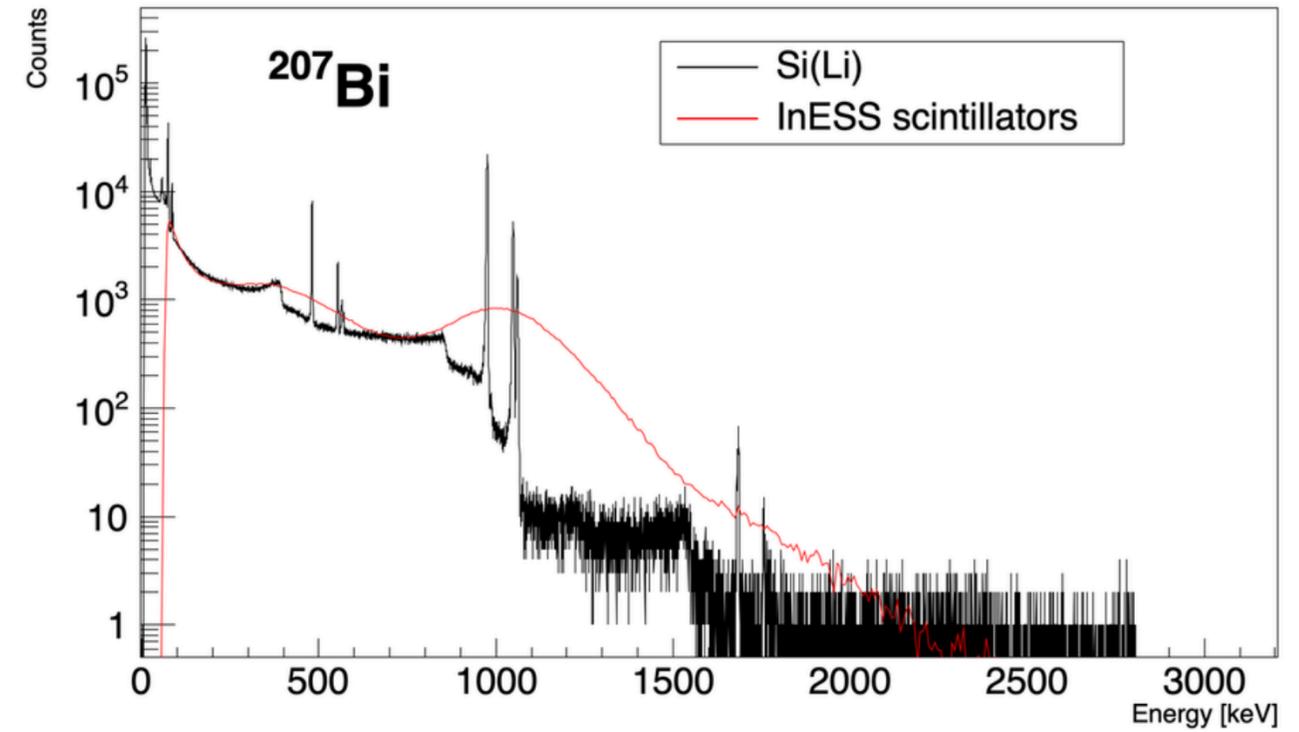
Top Si(Li) with 30 million events simulated for 5mm of tungsten

Peltier elements

A current flow applied to semiconductors arranged in a certain sequence creates a temperature gradient

Function of the peltier-technology. Dr. Neumann Peltier-Technik GmbH.

Theoretical corrections

$\overline{\nu}_e$

β
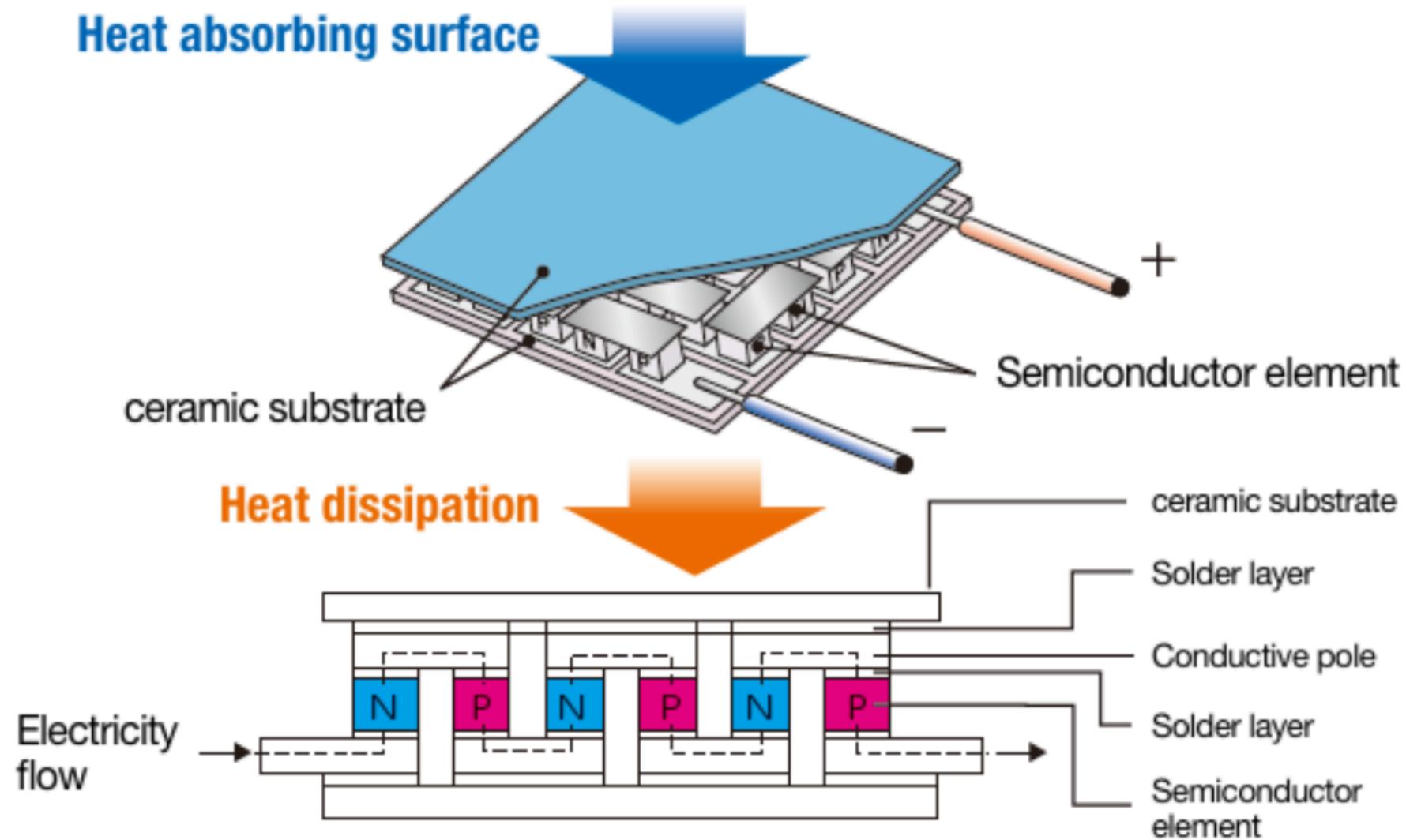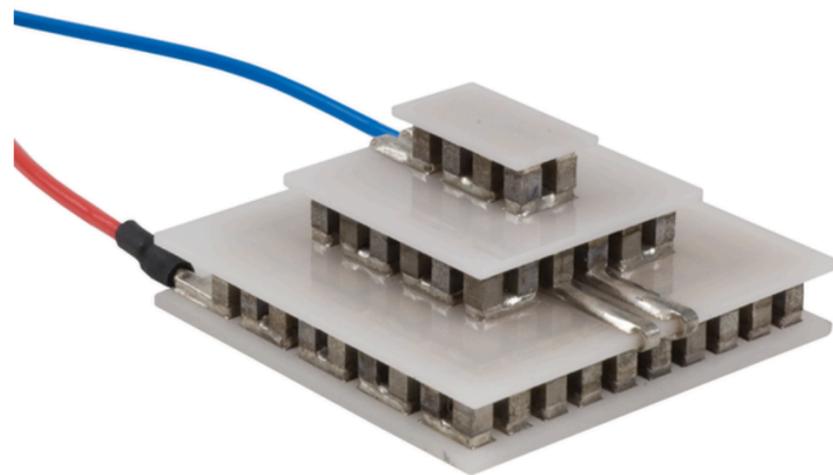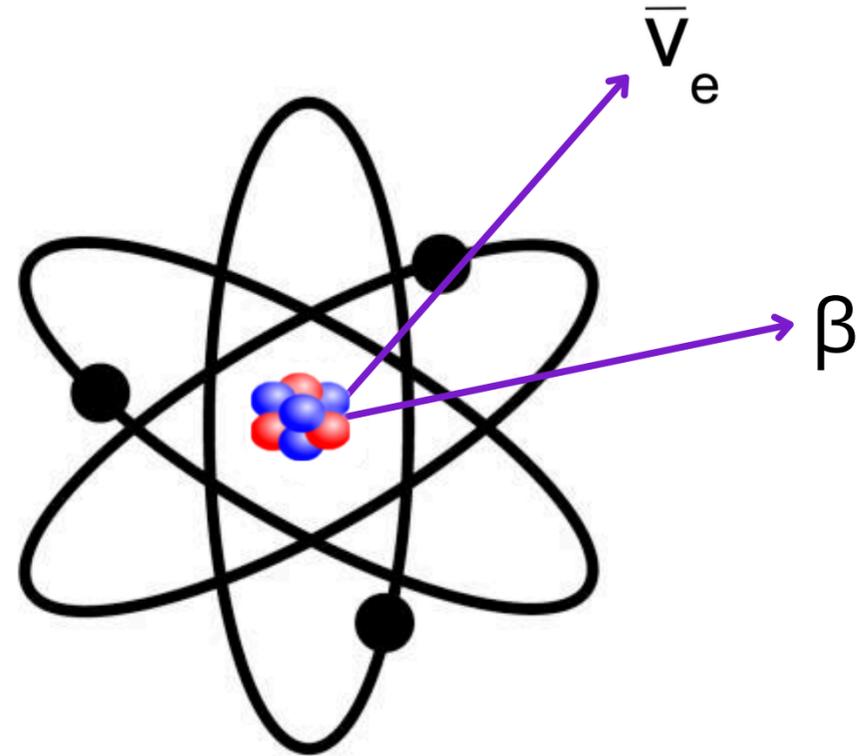
$(1 + \eta)$

- Kinematics
- Electrostatics

- Radiative corrections
- Atomic and molecular effects
- Recoil-order corrections

Beta Spectrum Generator (BSG):
High precision allowed spectrum shape generator with all theoretical corrections included

29

L.Hayen, N.Severijns and al, RMP, 2018

Lagrangian weak interaction

$$\mathcal{L}_{Lee-Yang} = \quad +\bar{p}\gamma^{\mu}n\,\bar{e}\gamma_{\mu}\left(C_V + C_V'\gamma_5\right)\nu \qquad \text{Vector current}$$

$$-\bar{p}\gamma^{\mu}\gamma_5 n\,\bar{e}\gamma_{\mu}\left(C_A\gamma_5 + C_A'\right)\nu \qquad \text{Axial-vector current}$$

$$+\bar{p}n\,\bar{e}\left(C_S + C_S'\gamma_5\right)\nu \qquad \text{Scalar current}$$

$$+\frac{1}{2}\bar{p}\sigma^{\mu\nu}n\,\bar{e}\sigma_{\mu\nu}\left(C_T + C_T'\gamma_5\right)\nu \qquad \text{Tensor current}$$

$$-\bar{p}\gamma_5 n\,\bar{e}\left(C_P\gamma_5 + C_P'\right)\nu \qquad \text{Pseudo-scalar current}$$

$$+h.\,c. \qquad C_V = 1 = C_V', C_{A=}1.27 = C_A', C_S = 0, C_T = 0$$

Weak magnetism value
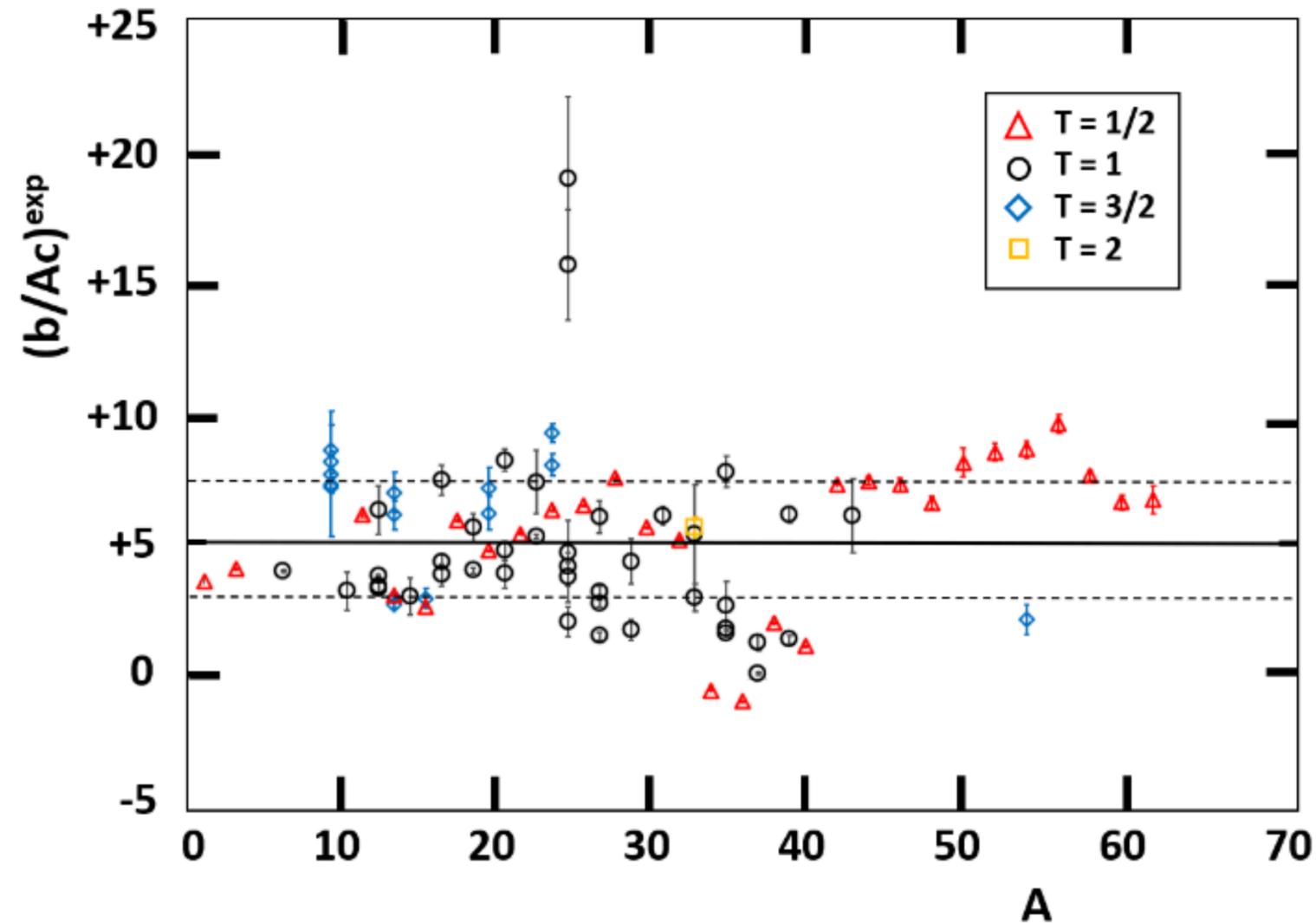
Figure 2.2: Overview of experimental b/Ac values for 85 β transitions from isotopes with $A = 3 - 61$. The unweighted average of all values shown is $b/Ac = 5.1 \pm 2.4$, not including the two strongly deviating values at mass $A = 24$. Figure reproduced from Ref. [158].

NS et al., Phys. Rev. C 107, 2023
S. Vanlangendonck, The effect of weak magnetism on the shape of the [114]In beta energy, PhD thesis, KU Leuven (2023).

Theoretical corrections

Category	Effect	Formula	Magnitude
Phase space		$pW(W_0 - W)^2$	Unity or larger
Electrostatic	Fermi function	F_0	
	Finite size nucleus	L_0	
Radiative corr.		R	
Recoil-order	Shape factor	C	
	Isovector correction	C_I	
Atomic	Atomic exchange	X	$10^{-1} - 10^{-2}$
	Atomic mismatch	r	
	Atomic screening	S	
	Shake-up & Shake-off	included in r	
Higher order	Diffuse nucl. surface	U	
	Nuclear deformation	D_{FS} & D_C	
	Recoil Coulomb corr.	Q	$10^{-3} - 10^{-4}$
	Recoiling nucleus	R_N	
	Molecular screening	ΔS_{Mol}	
	Molecular decay	Case by case	
	Bound state β decay	Γ_b/Γ_c	$< 1 \times 10^{-4}$
	Neutrino mass	negligible	

32

Systematic uncertainties on WM and 2020 results

$$\frac{b}{A_c} = 17.0(23)_{stat}(18)_{sys}$$

	Effect	Uncertainty	Δb_{WM}
Theory	Endpoint energy	0.3 keV	0.1
	ρ, R and d/Ac		None
Geant4	Detector threshold	3.75 keV	1.2
	Source position		
	Rotation	1°	0.1
	Source diameter	1 mm	0.3
	QDC time window	50 ns	None
	Foil thickness	$\pm 10\%$	None
Energy resolution	σ_1	σ_{fit}	< 0.1
	σ_2	σ_{fit}	< 0.1
SiPM non-linearity	E/pixel	0.16 keV	1.1
	$P_{crosstalk}$	Unknown	
(Auto-)calibration	a_0	σ_{fit}	< 0.1
	a_1	σ_{fit}	0.3
Total			1.7

PRELIMINARY

S. Vanlangendonck, The effect of weak magnetism on the shape of the ^{114}In beta energy, PhD thesis, KU Leuven (2023).