

SPELS at WISArD

Spectrum of ^{32}P Electron Shape



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PhD student

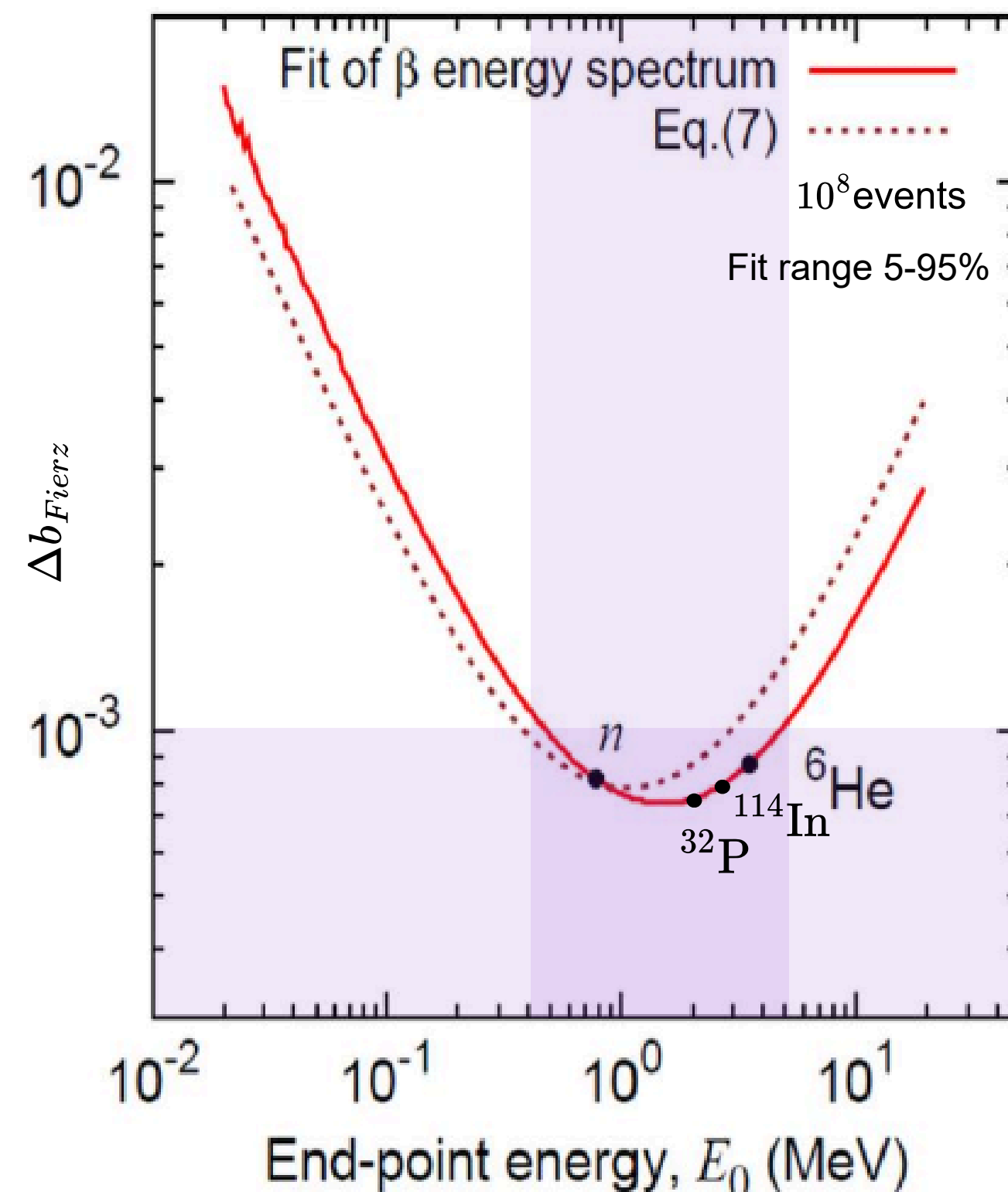
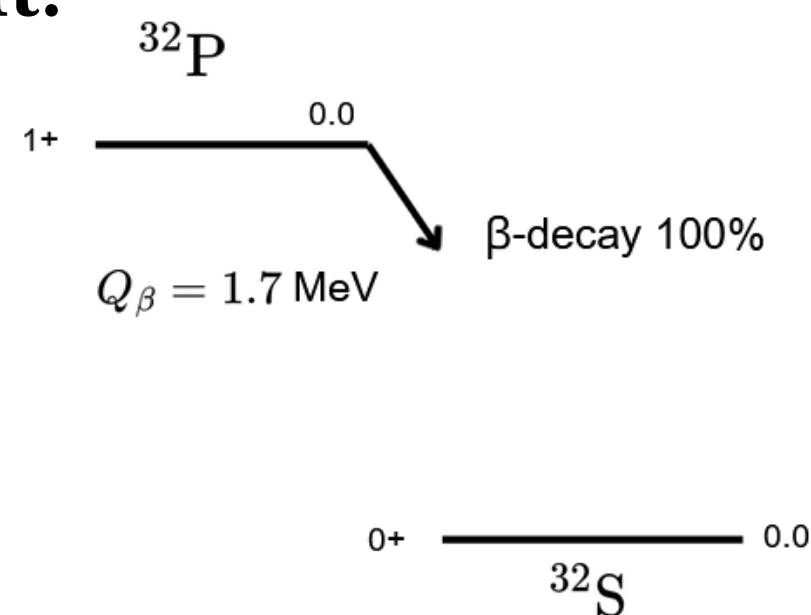
ENST Workshop
21-25/09

Bertram Blank
Maud Versteegen

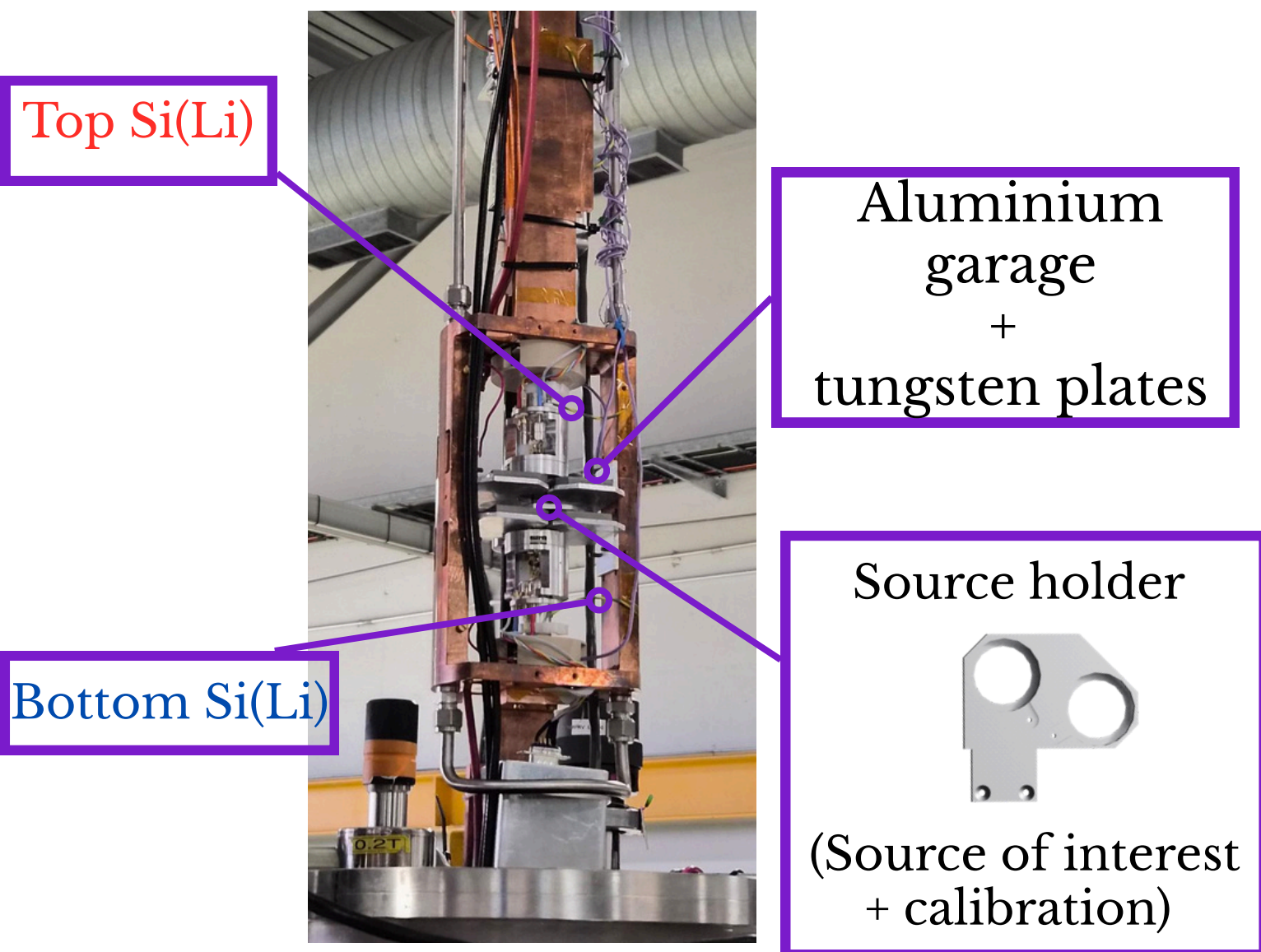
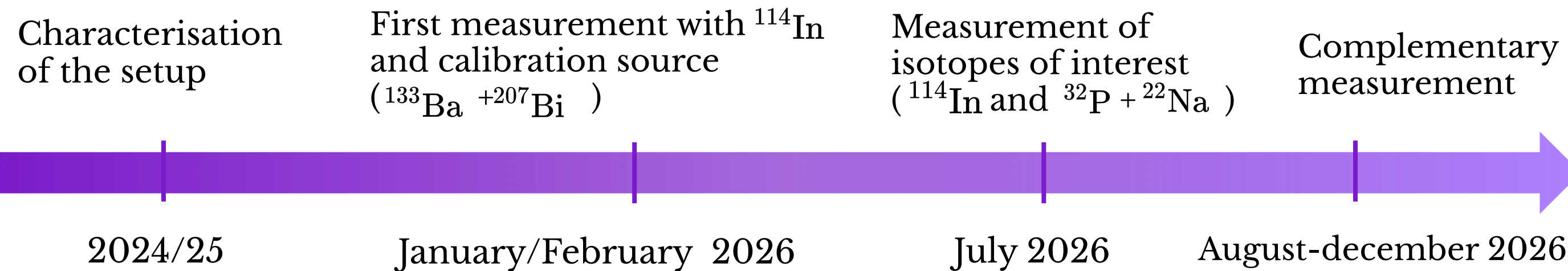
Motivations for the study of ^{32}P

^{32}P :

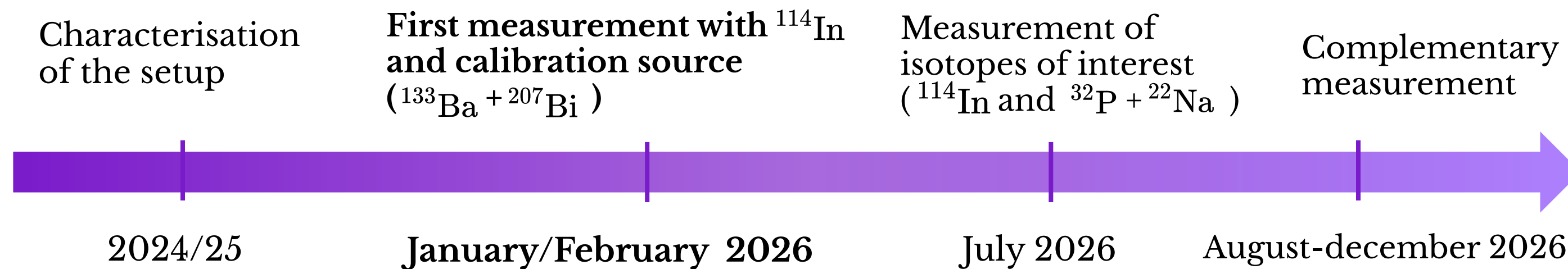
- **Weak magnetism:**
 - Allowed transition with large ft value
- **Fierz interference term:**
 - Favorable endpoint for BSM,
 - Pure GT
- **Experimental constraint:**
 - Lifetime=14.3 days



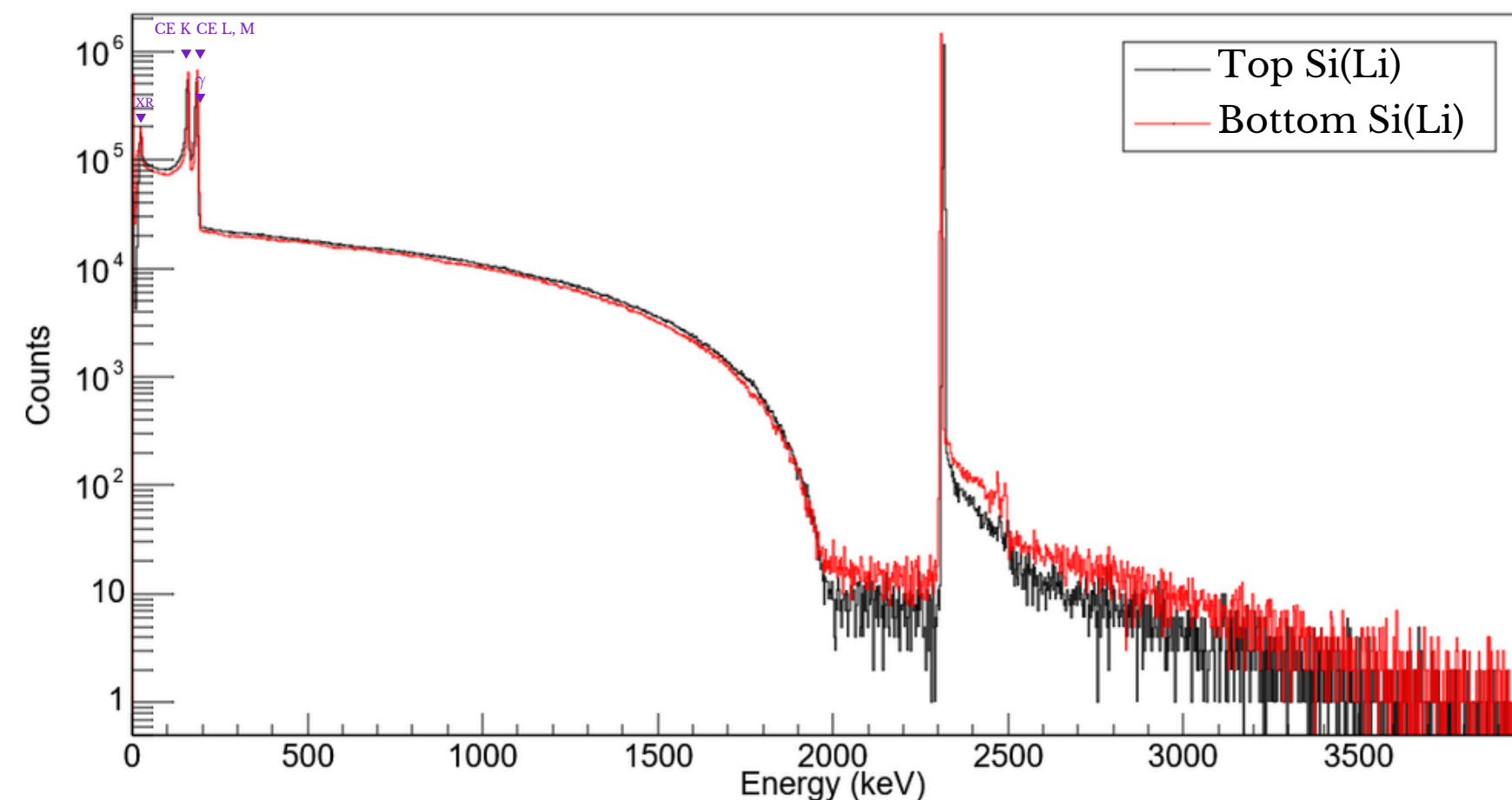
Spectra shape program at WISArD



Spectra shape program at WISArD

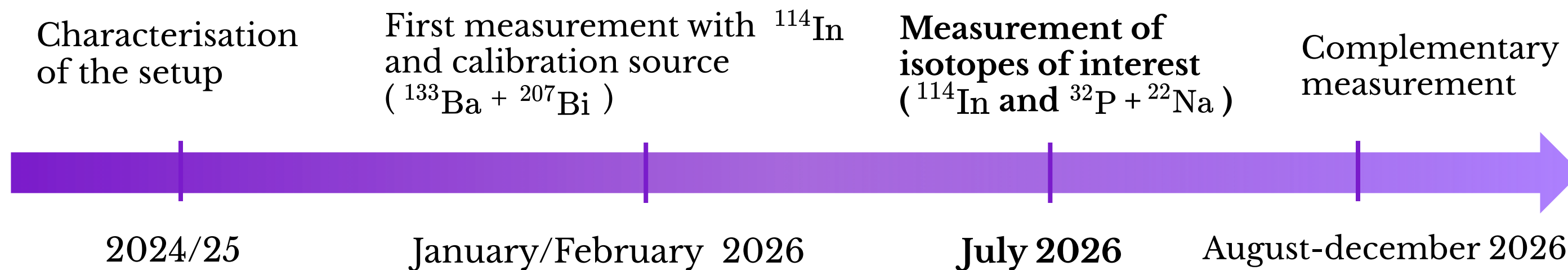


- 40h runs for ^{114}In
 - At 6T: 3.8×10^7 events
 - At 8T: 6.3×10^7 events
- 30h mixed calibration runs for 6T and 8T
- Background measurement without source of ^{114}In

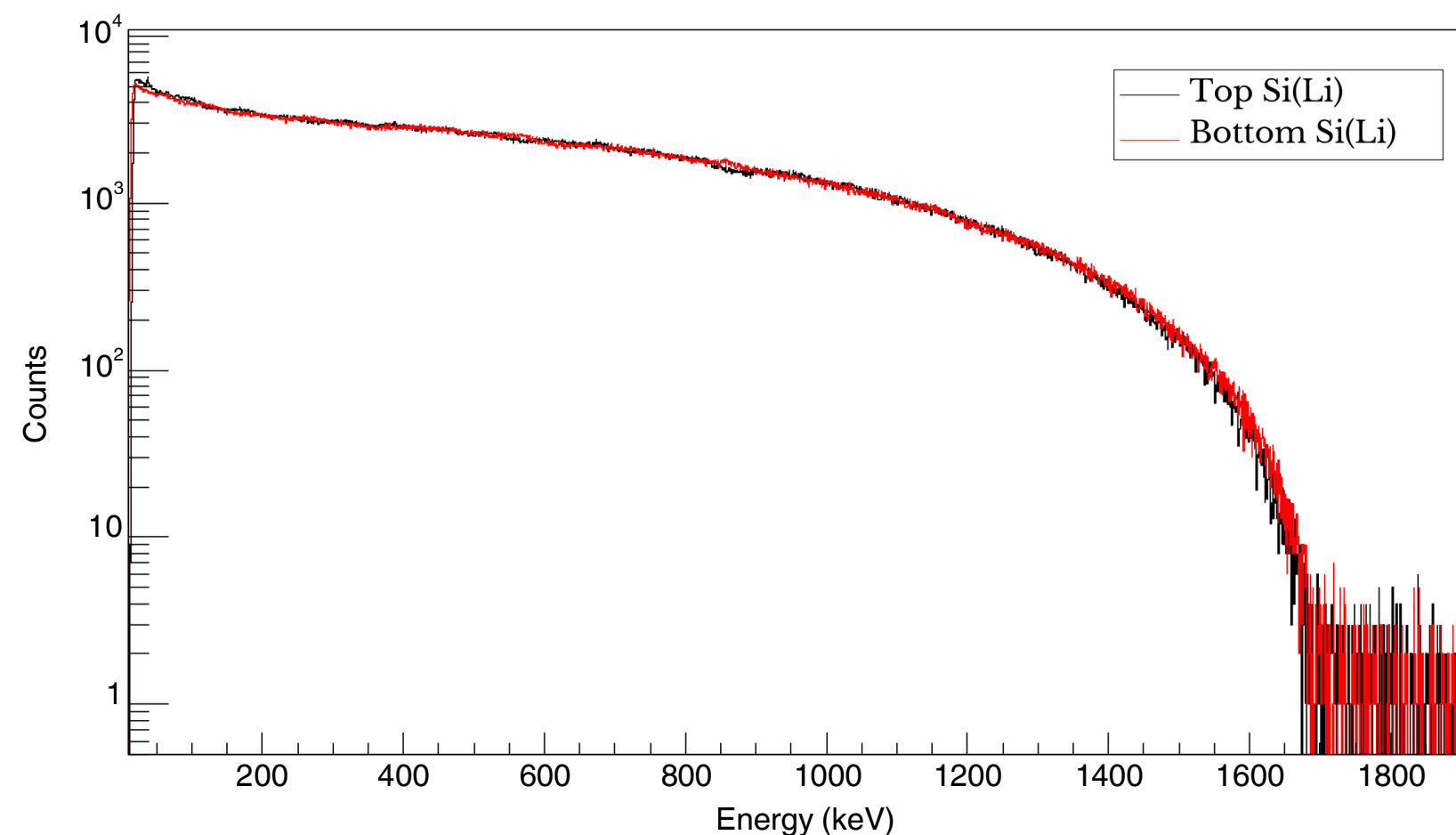


Spectrum of the ^{114}In source with pulser at 8T

Spectra shape program at WISArD



- 60h runs for ^{114}In
 - At 6T: 1.85×10^8 events
- 58h runs for ^{32}P
 - At 6T: 2.2×10^8 events
- 30h calibration runs at 6T for the measurement of ^{114}In and 35h for ^{32}P
- Background measurement without the sources of interest

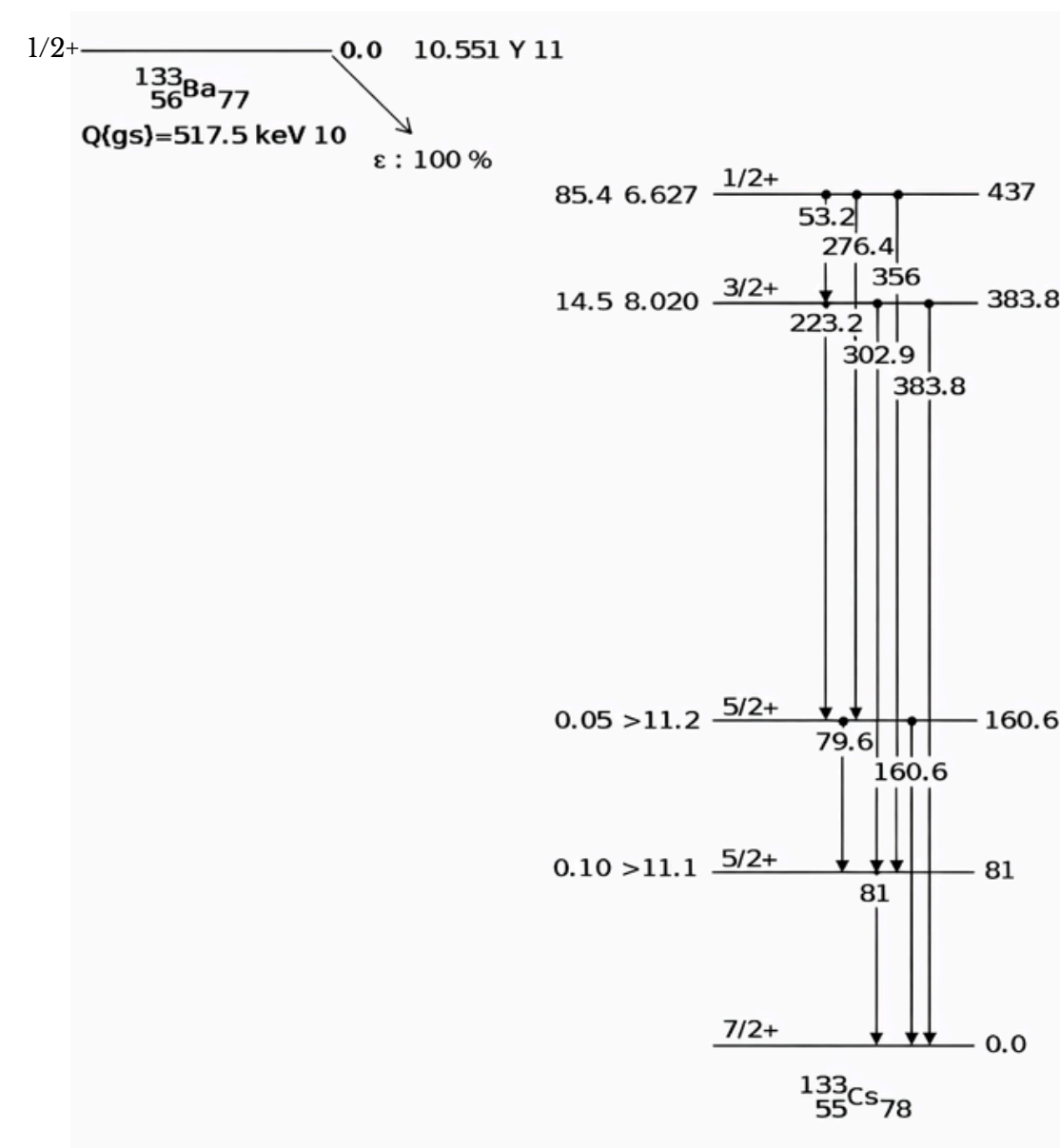


Spectrum of the ^{32}P source with pulser at 6T

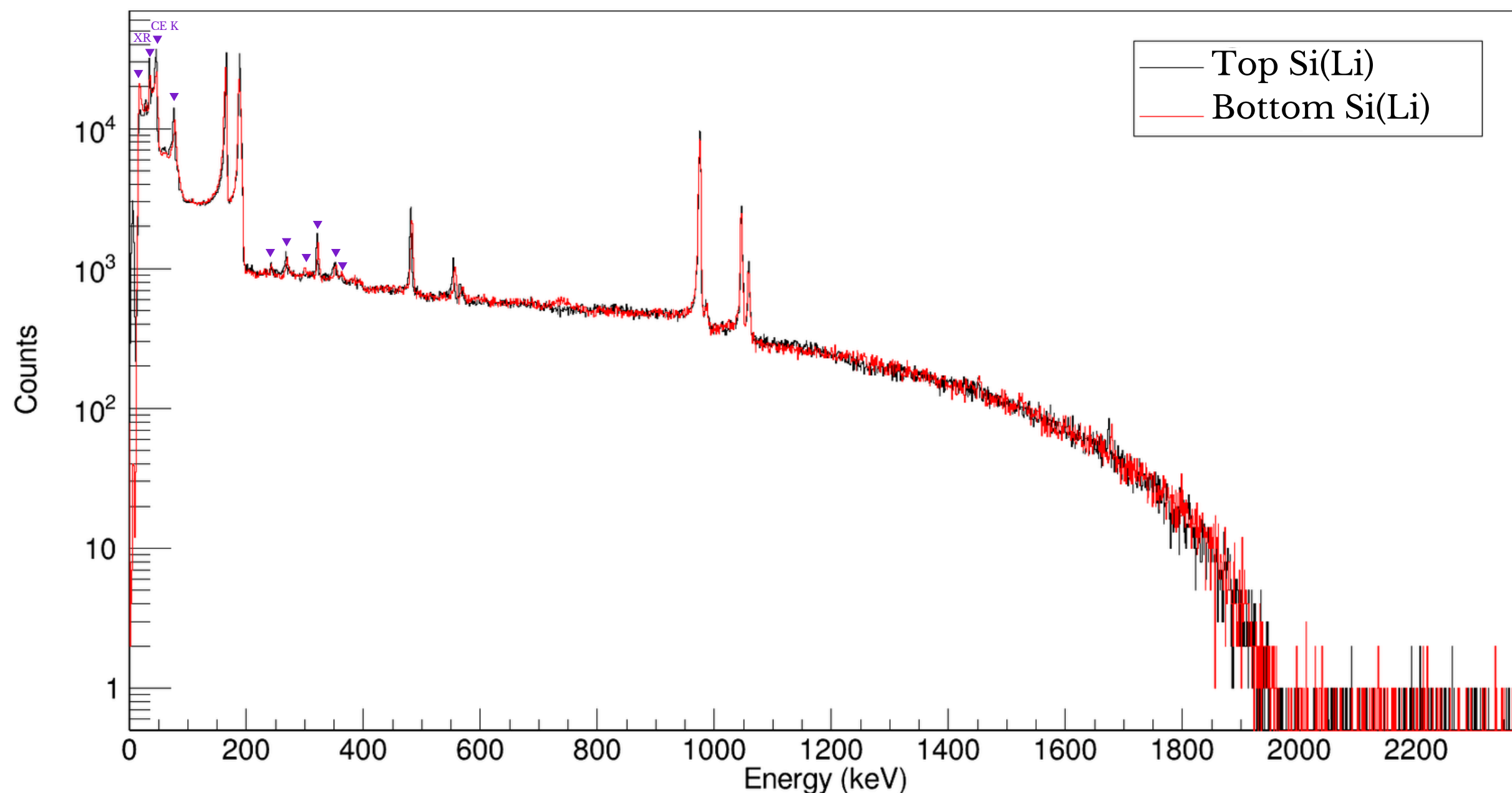
Calibration source in July

HV	−295 V / − 305 V
T	−65°C
Source	Mixed
Activity	1.2 kBq

Spectrum of the ($^{207}\text{Bi} + ^{133}\text{Ba} + ^{114}\text{In}$) source at 6T



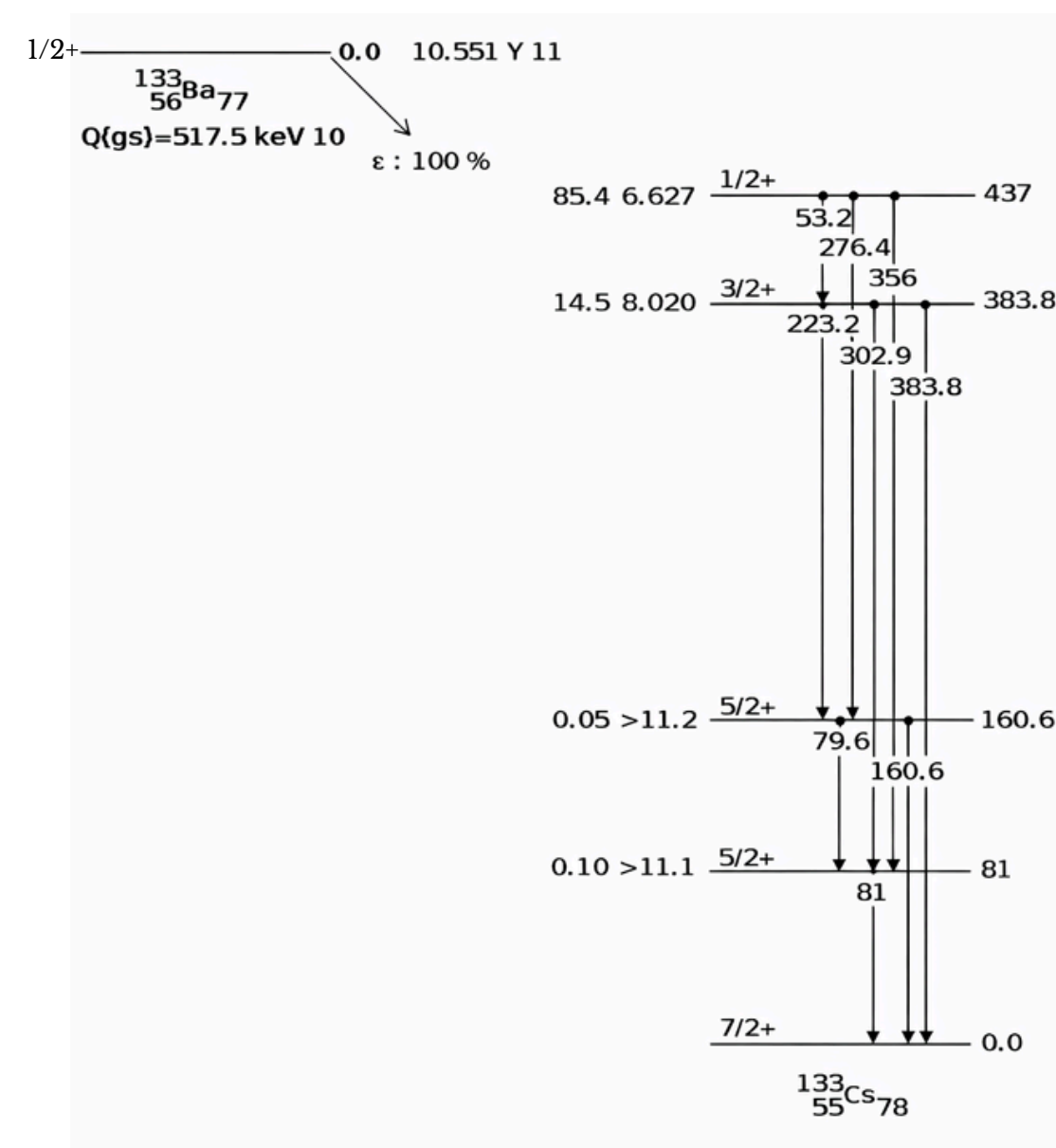
Decay scheme of ^{133}Ba



→ Mixed source to cover the 0-2 MeV energy range of the beta spectrum as much as possible

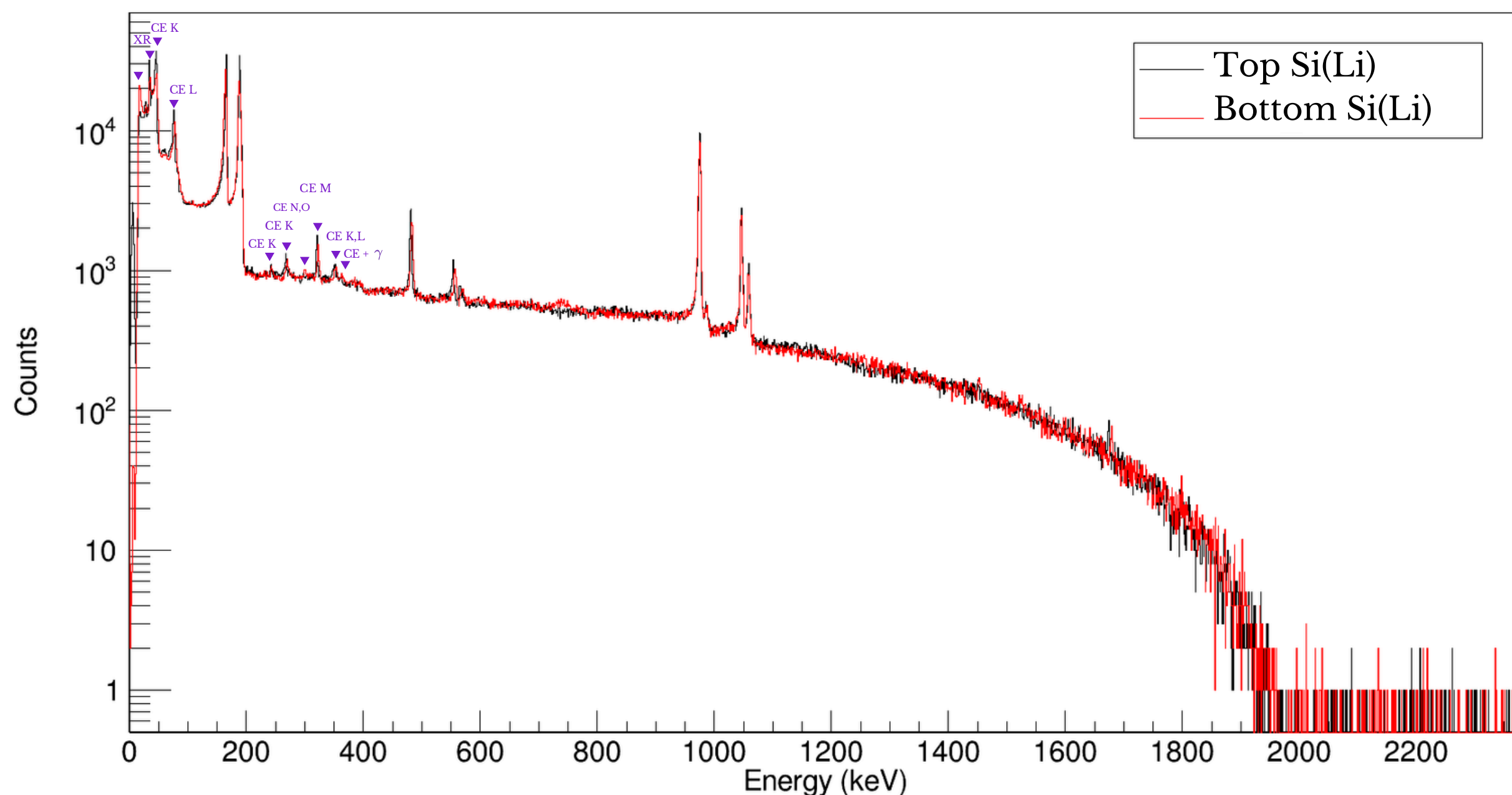
Calibration source in July

HV	−295 V / − 305 V
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Decay scheme of ^{133}Ba

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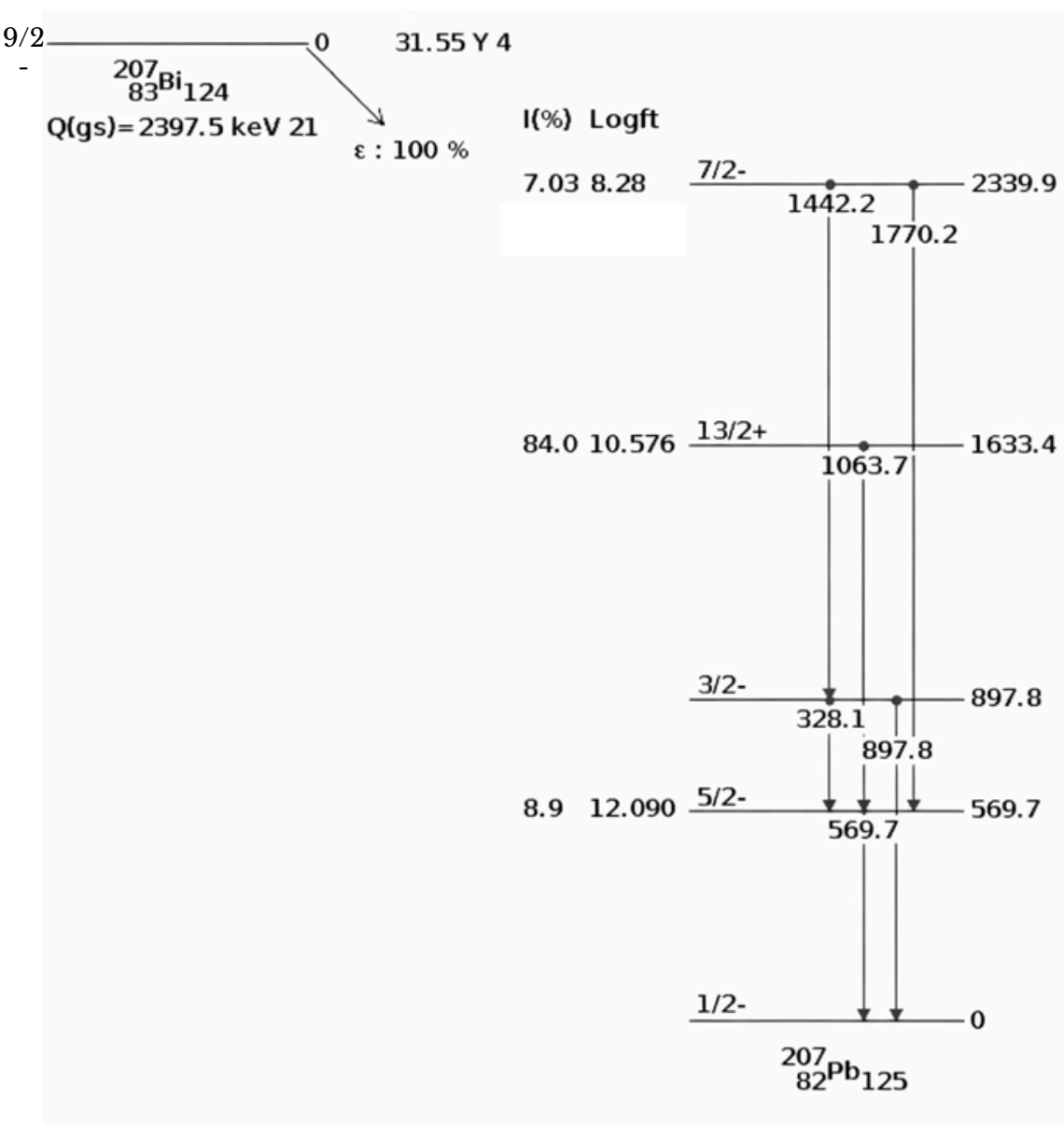


→ Mixed source to cover the 0-2 MeV energy range of the beta spectrum as much as possible

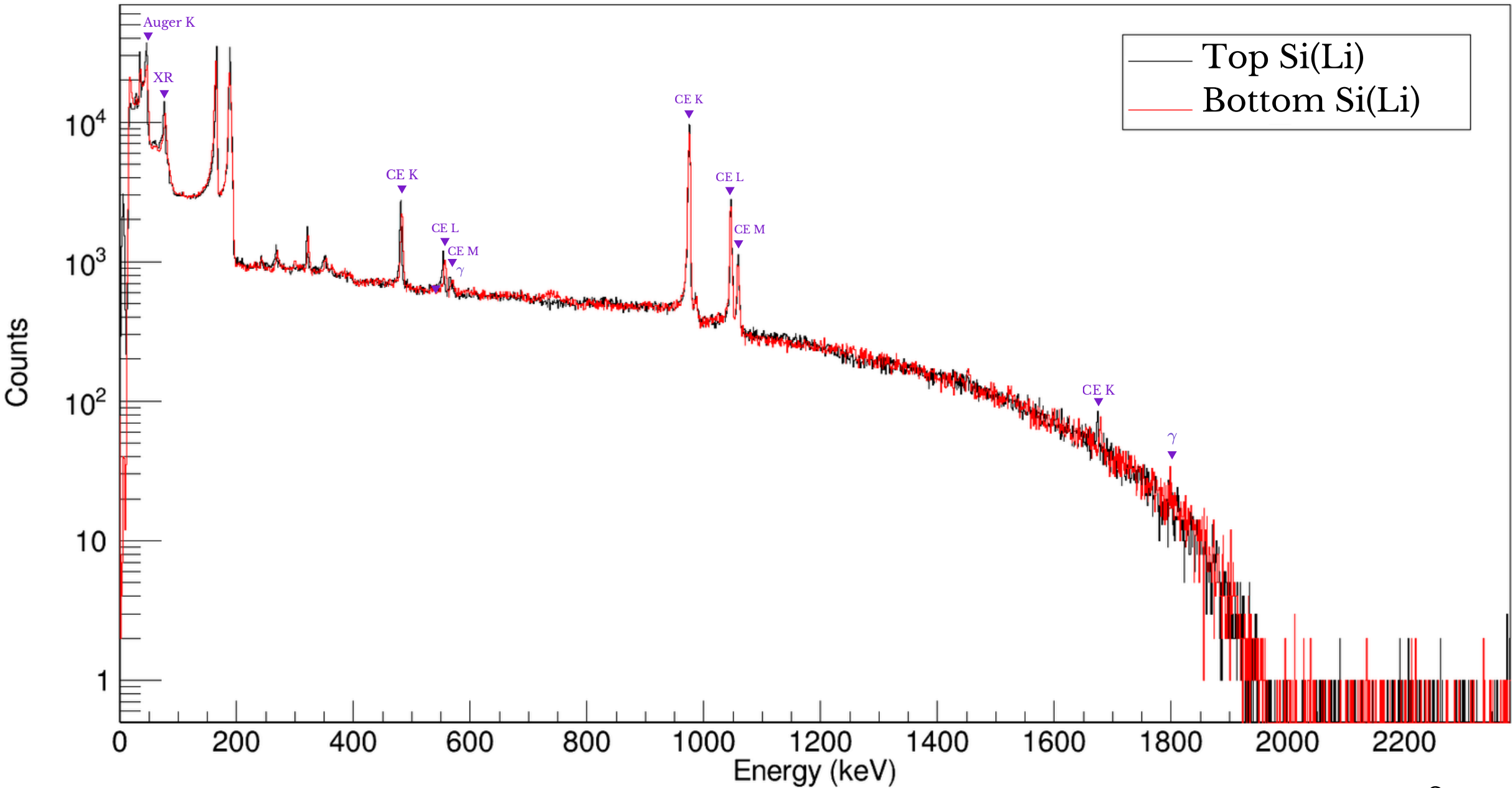
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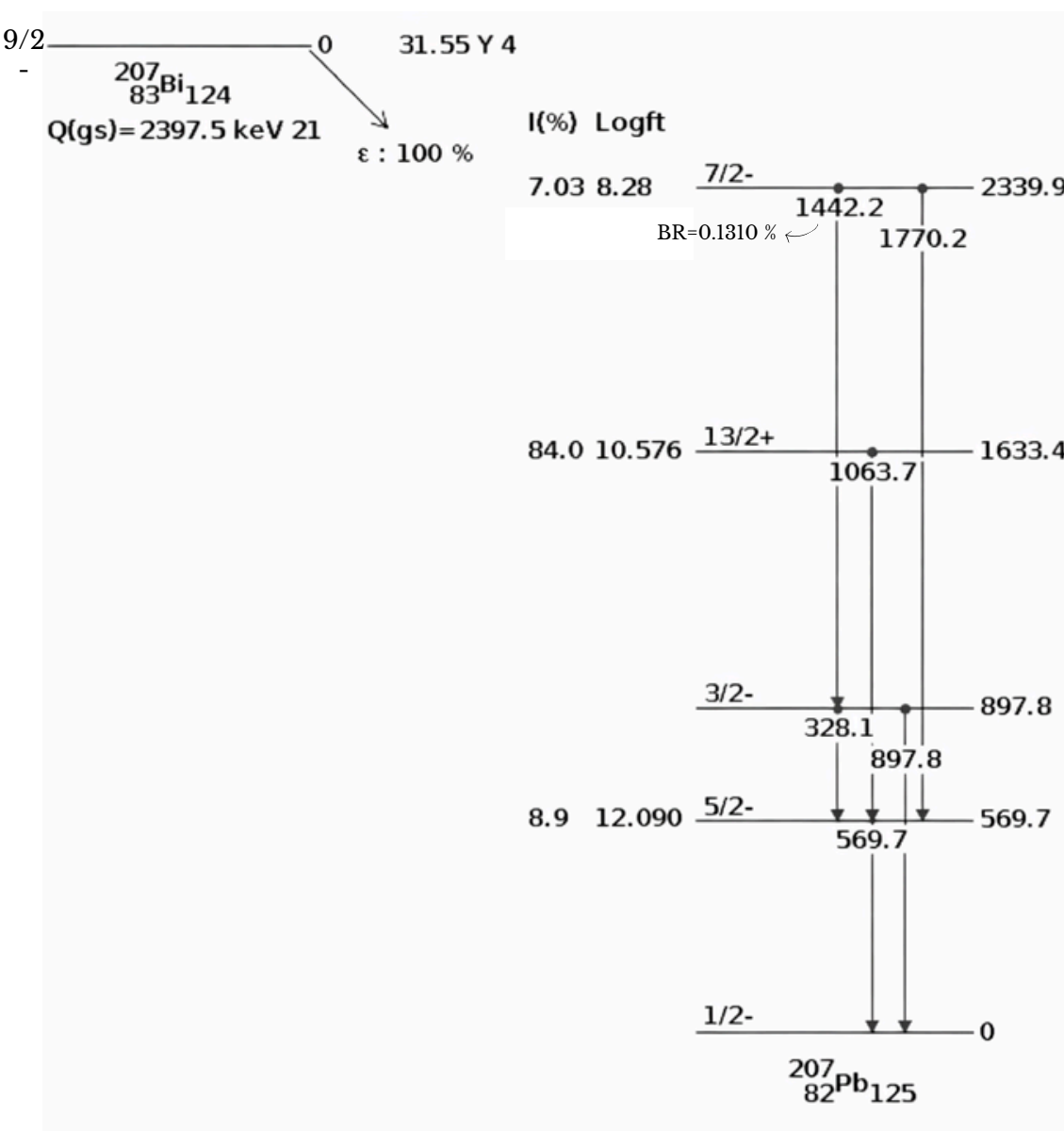
Spectrum of the ($^{207}\text{Bi} + ^{133}\text{Ba} + ^{114}\text{In}$) source at 6T



Decay scheme of ^{207}Bi

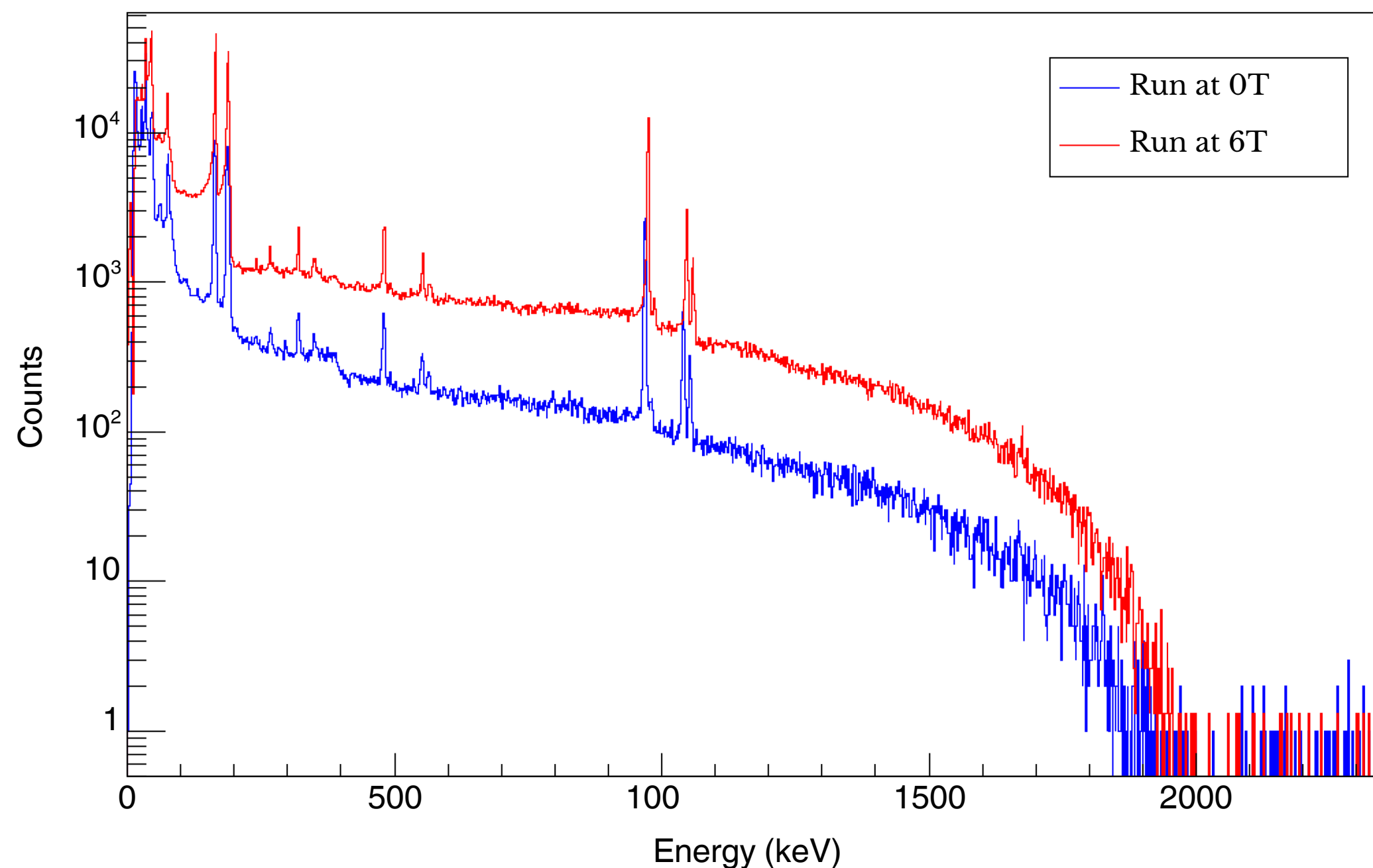


Effect of the magnetic field



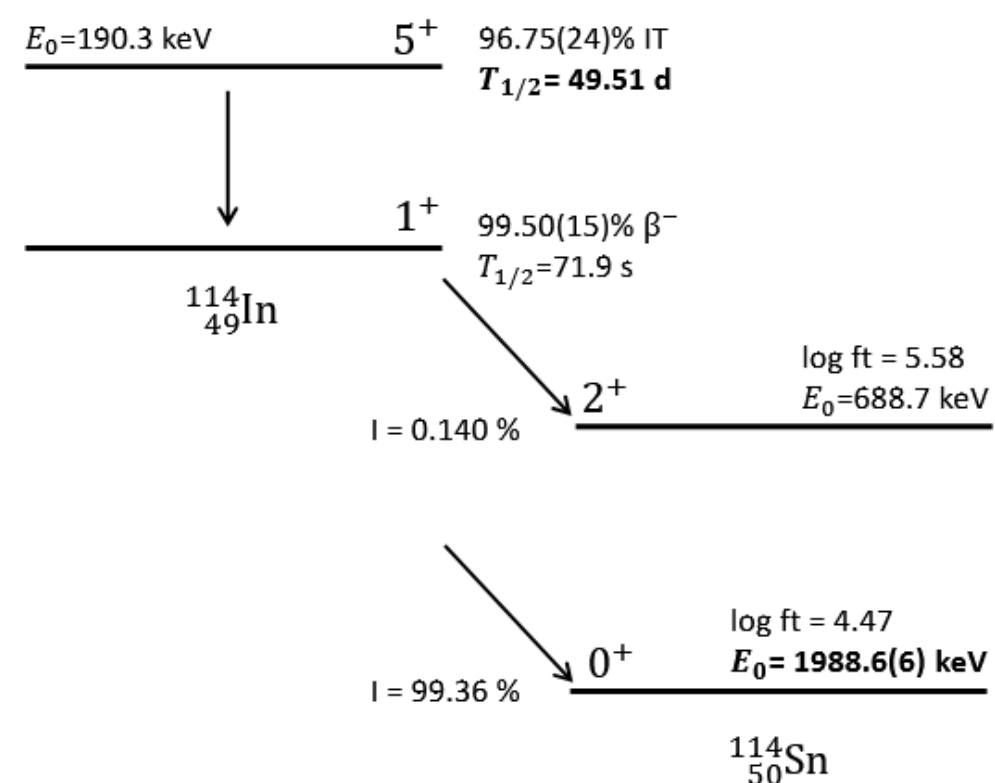
Decay scheme of ^{207}Bi

Spectrum of the ($^{207}\text{Bi} + ^{133}\text{Ba} + ^{114}\text{In}$) source at 0T and 6T



→ Effect of magnetic field : higher peak height for electron + increase of EC peaks at high energy.

Calibration sources July vs February

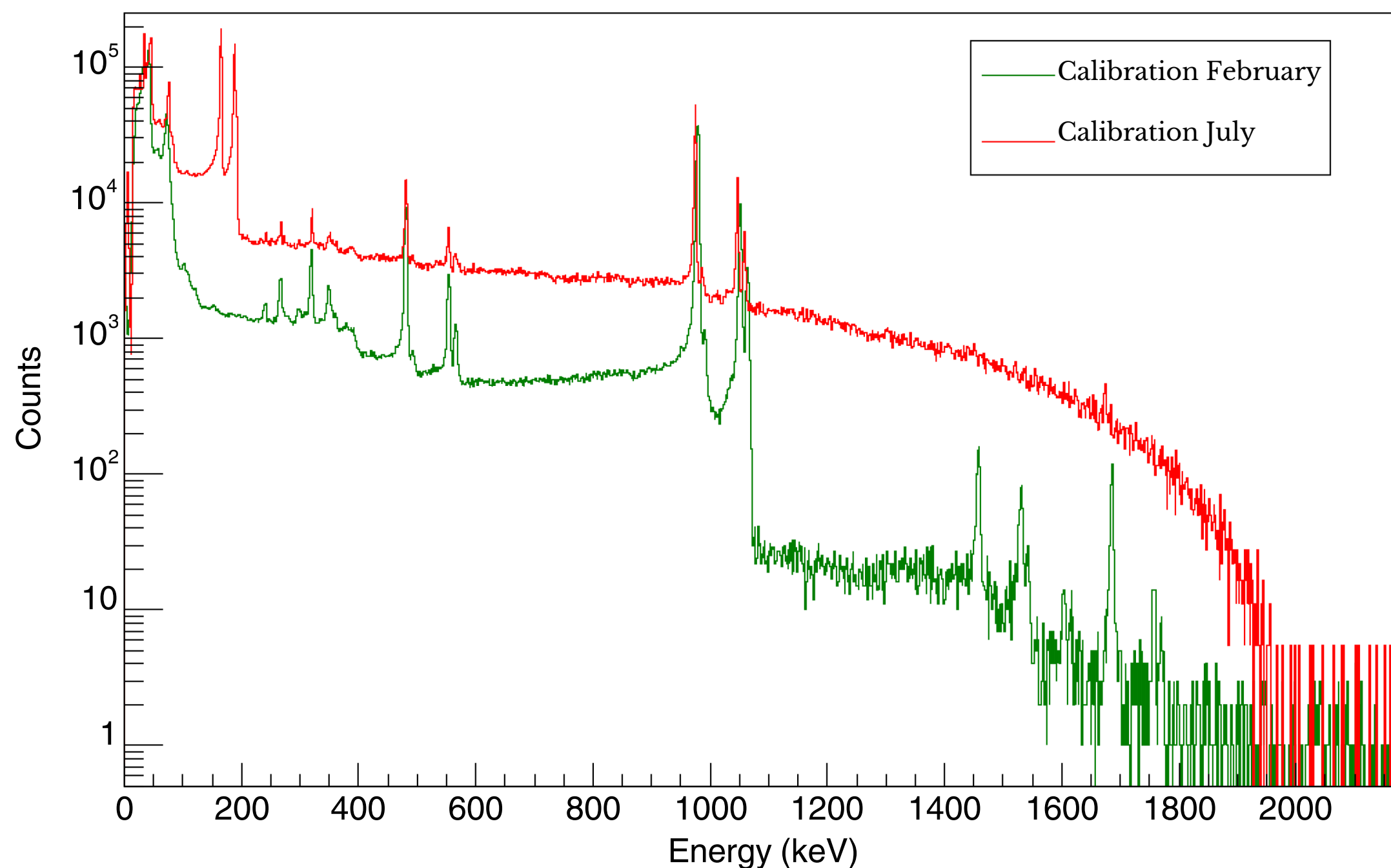


Decay scheme of ^{114}In

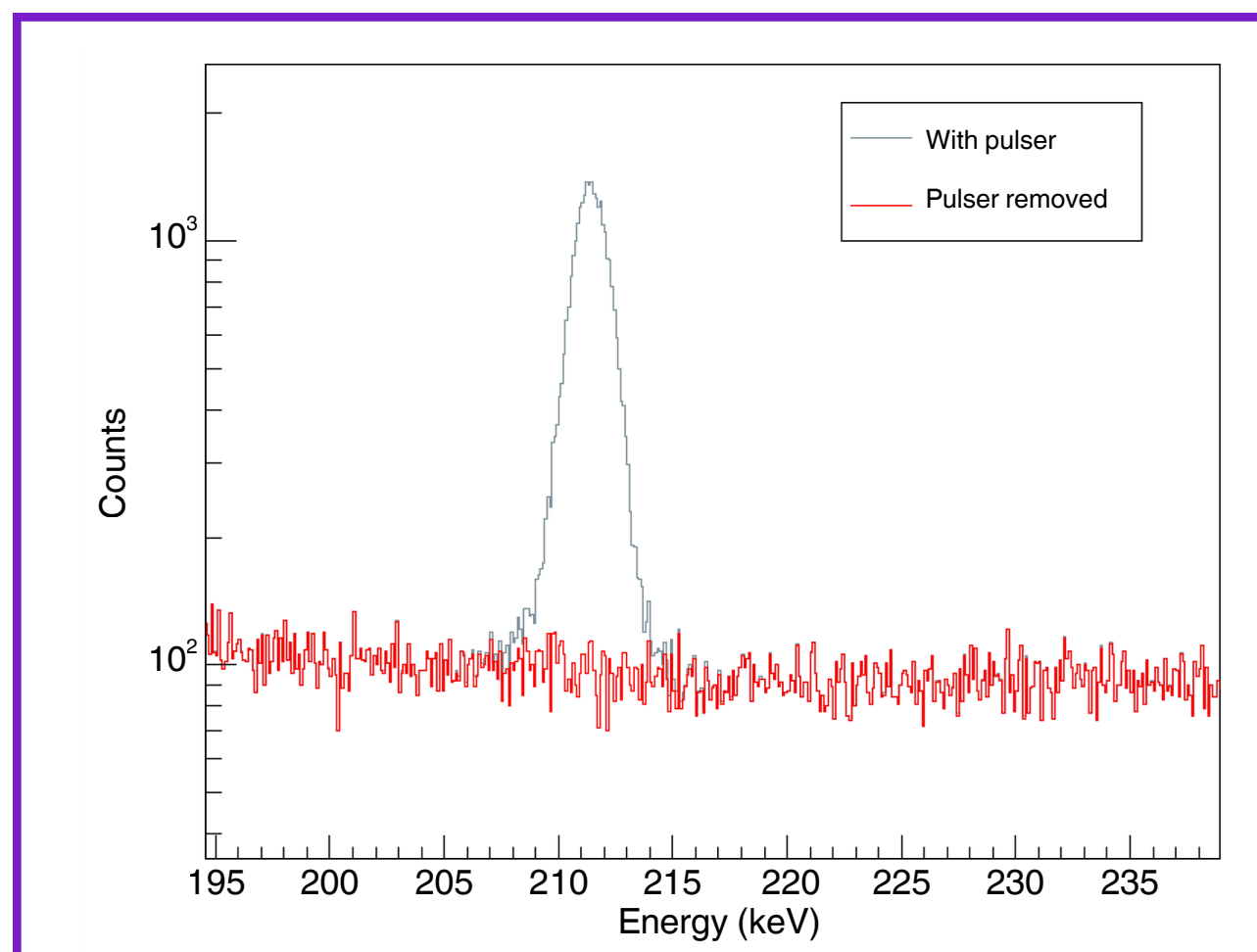
	Top Si(Li)	Bottom Si(Li)
February	$3.5 \pm 0.23 \text{ keV}$	$3.8 \pm 0.57 \text{ keV}$
July	$3.6 \pm 0.28 \text{ keV}$	$6.8 \pm 0.66 \text{ keV}$

Table 1: FWHM measured at 481 keV.

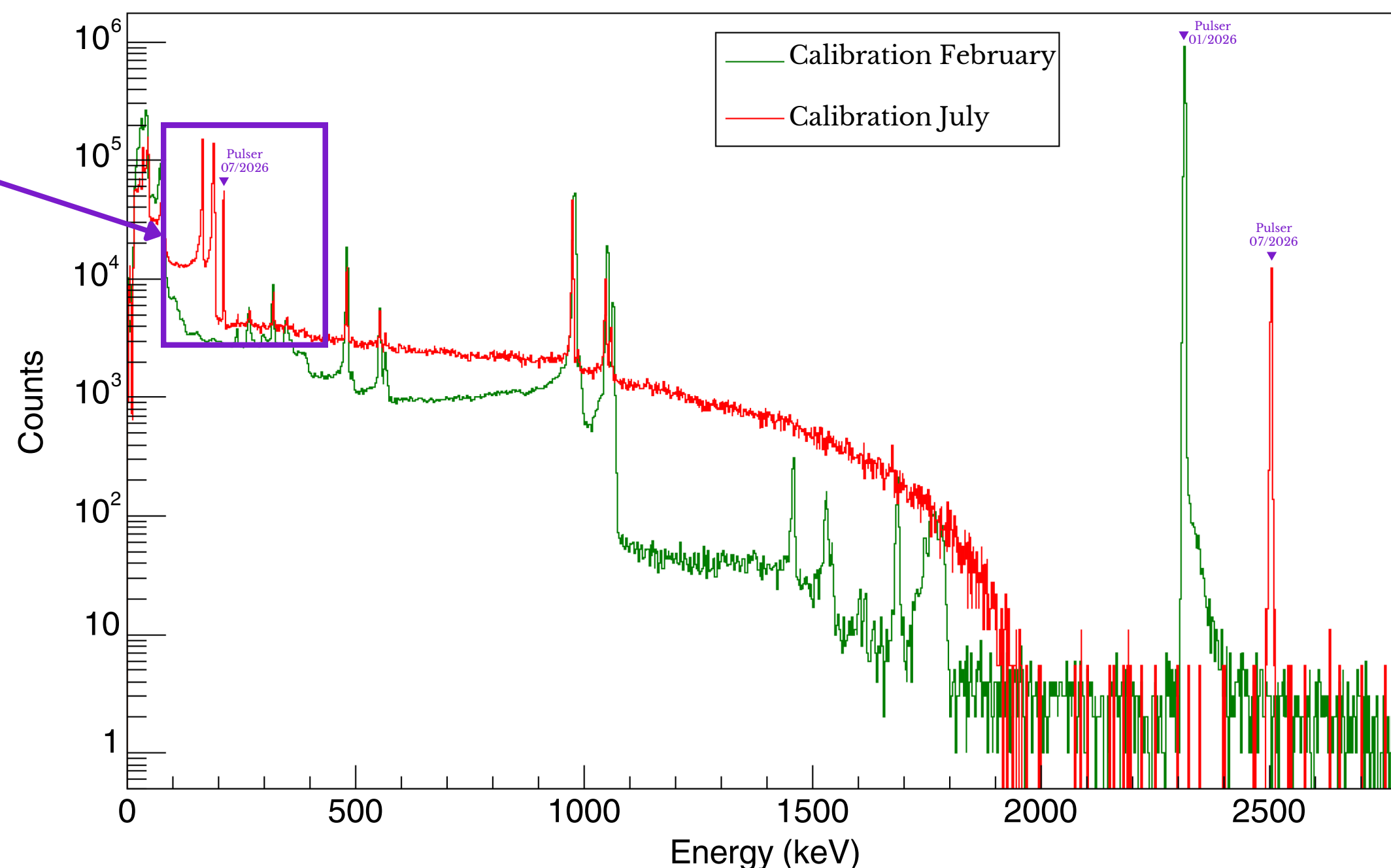
Spectra comparison of the calibration source from February ($^{207}\text{Bi} + ^{133}\text{Ba}$) and July ($^{207}\text{Bi} + ^{133}\text{Ba} + ^{114}\text{In}$) for the top detector at 6T without pulser



Adding pulser in the data



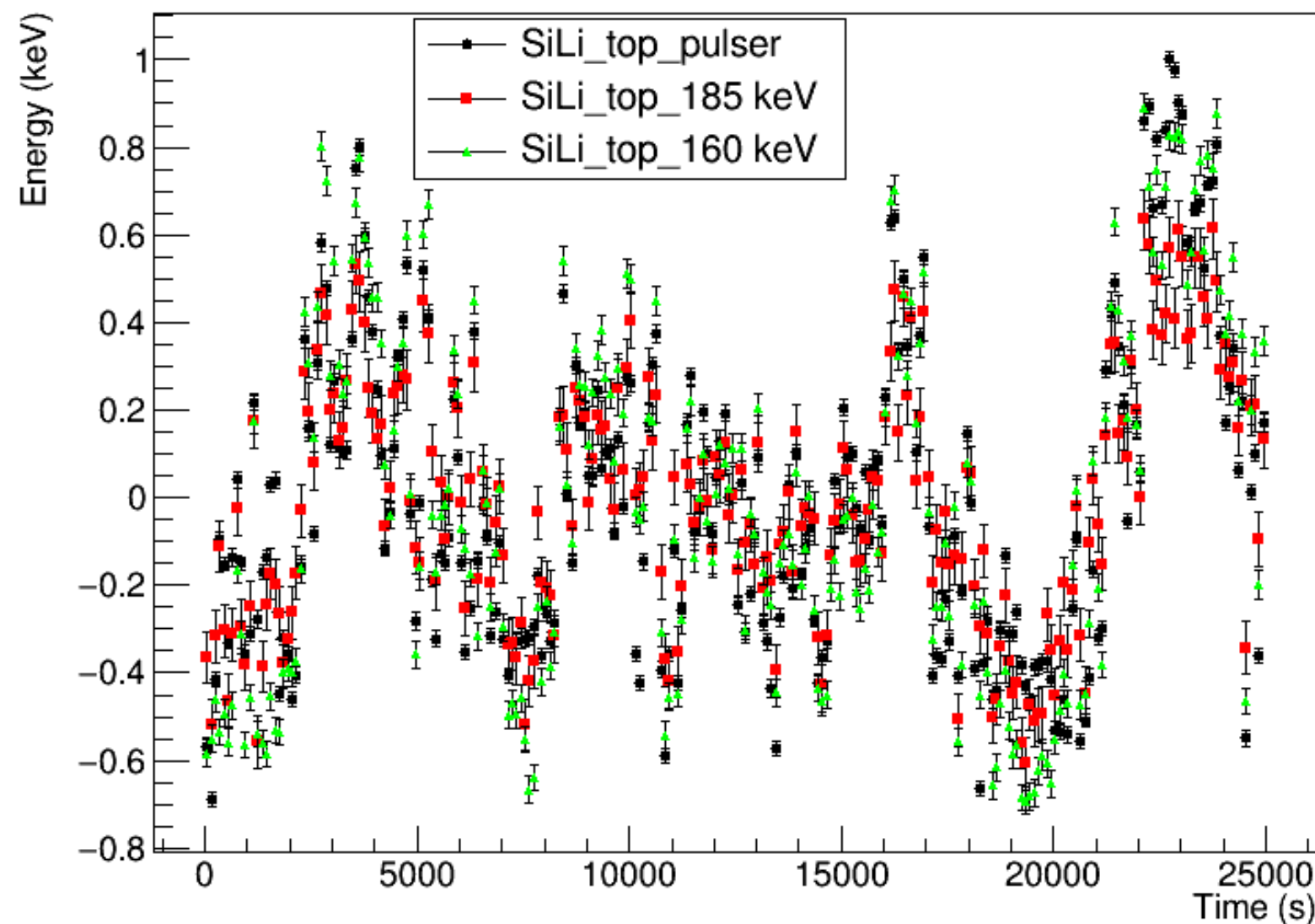
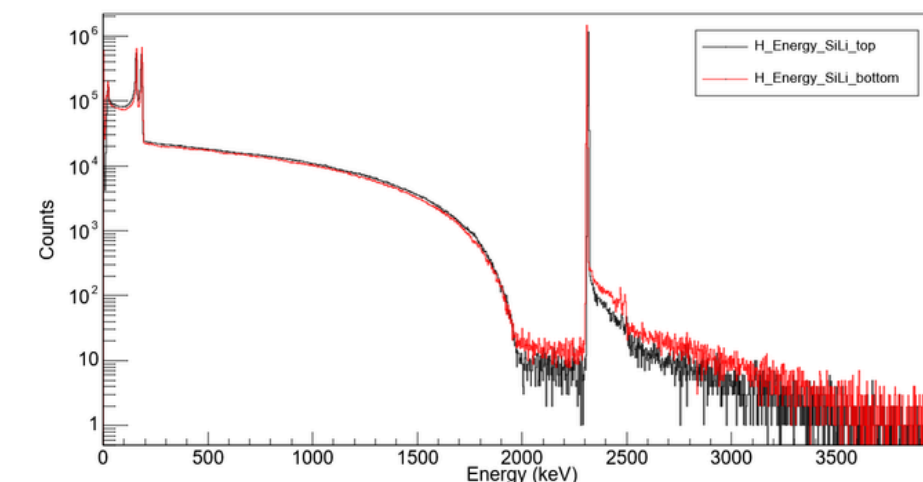
Spectra comparison of the calibration source from February ($^{207}\text{Bi} + ^{133}\text{Ba}$) and July ($^{207}\text{Bi} + ^{133}\text{Ba} + ^{114}\text{In}$) for the top detector at 6T with pulser



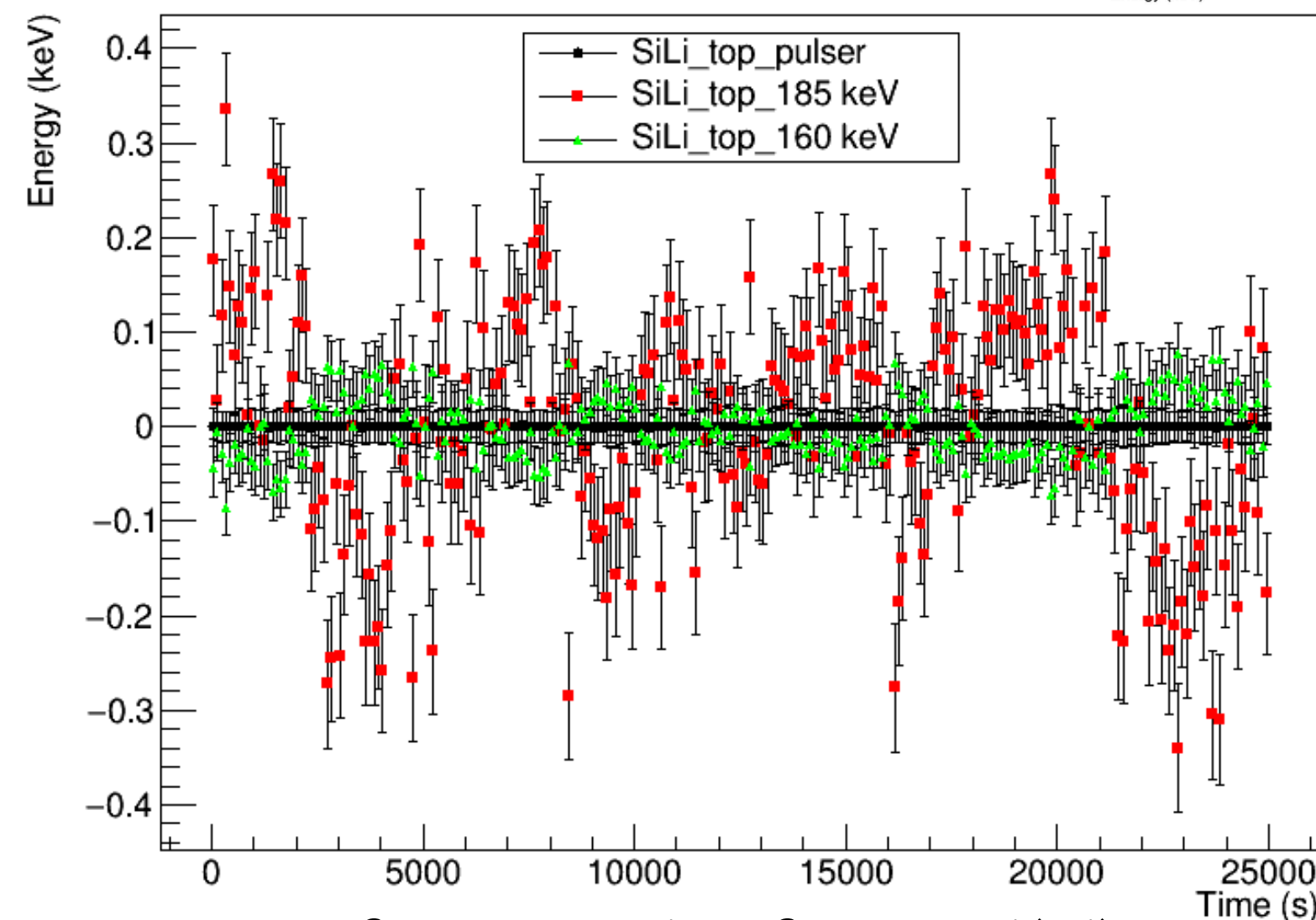
- Pulser peak and induced pile up are removable using time window cut
- Added a pulser to use as a reference to correct the gain variation, at 2.2 MeV in January and 2.5 MeV + 210keV in July.

Gain correction with pulser in February

→ Follow mean position of the peaks of 160 keV, 190 keV and pulser at 2400keV over time, with slices of 100,200,500s.



Before correction for top Si(Li)

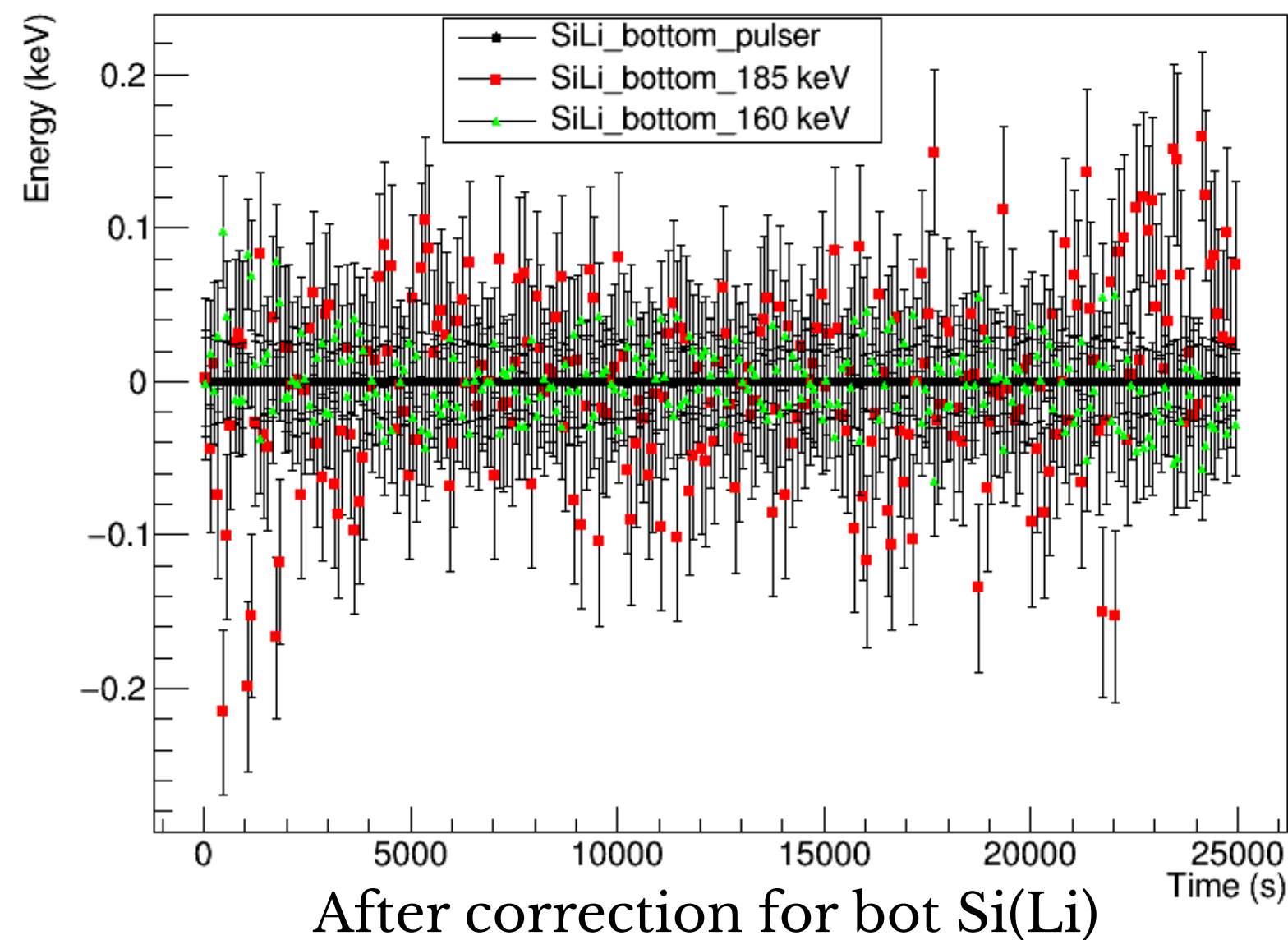
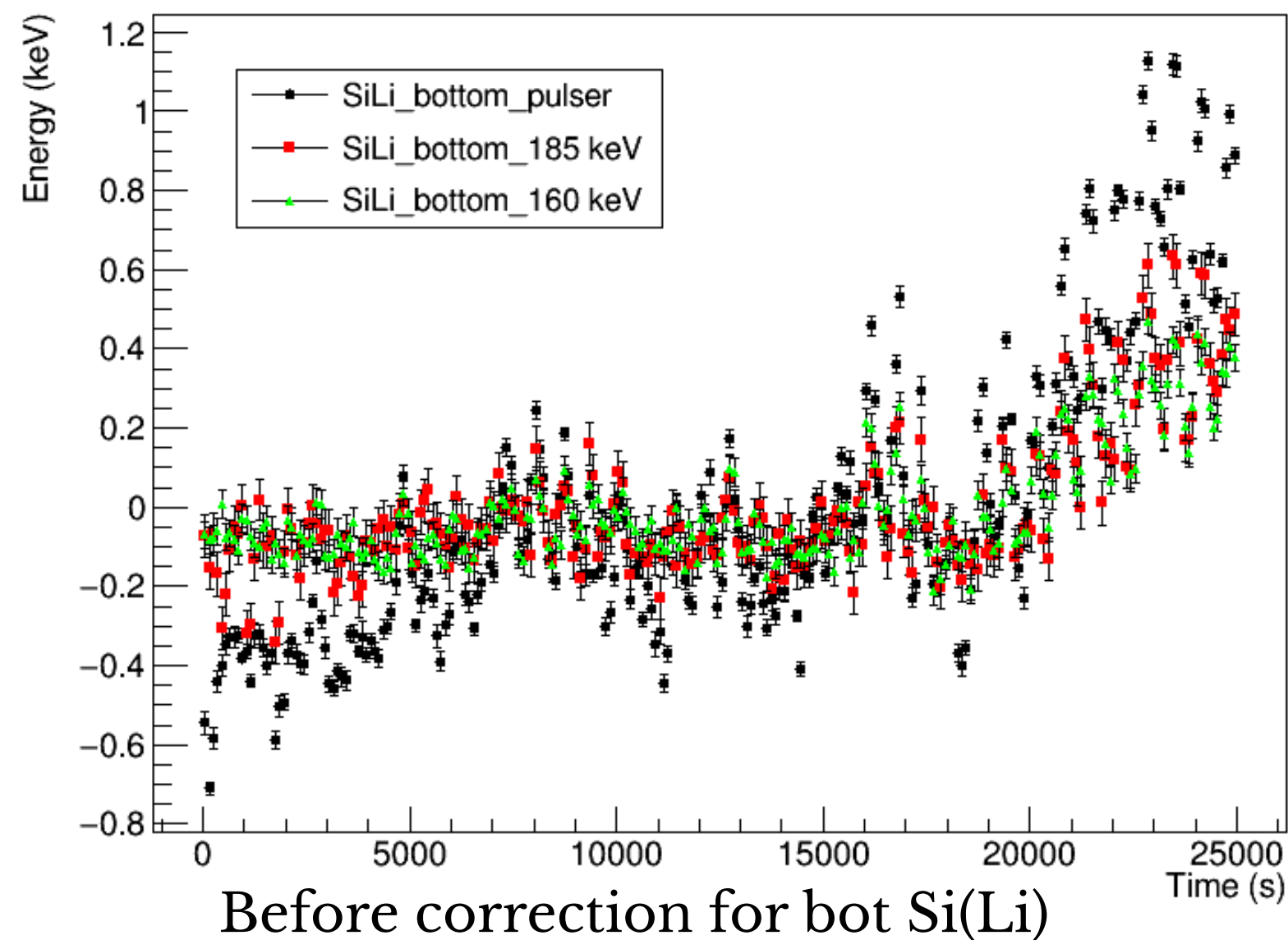
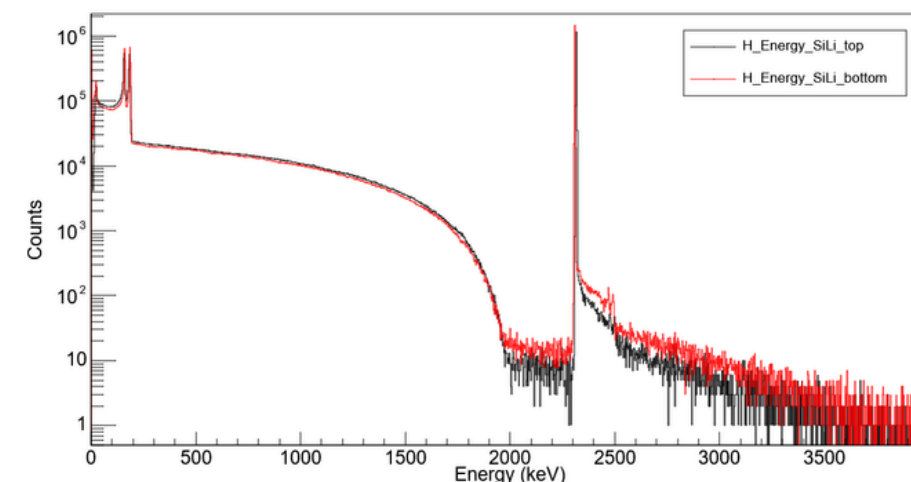


After correction for top Si(Li)

- Observed similar variation of positions during the run for physics and pulser peaks
-> can fit a linear function between the position in slice vs position in run.

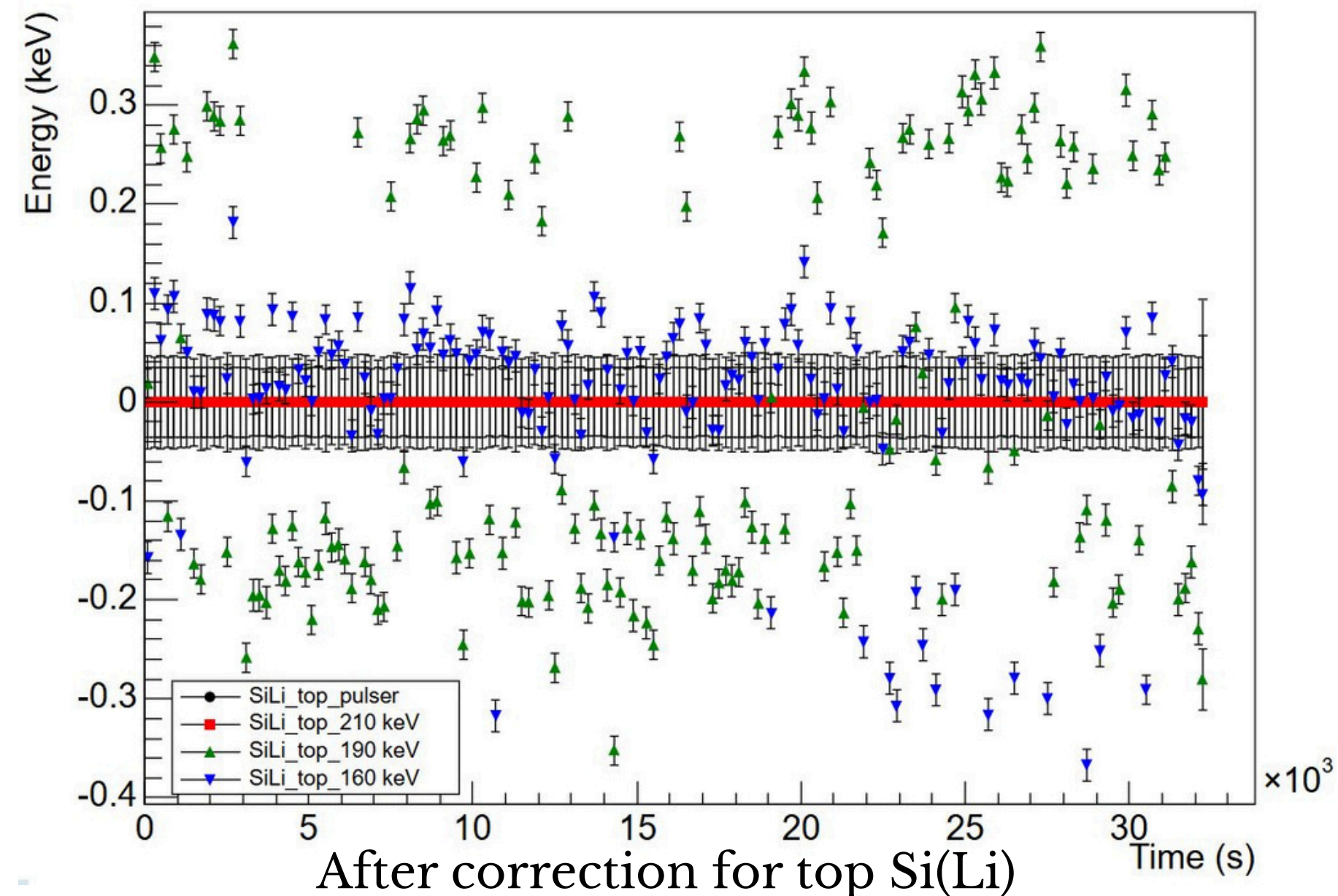
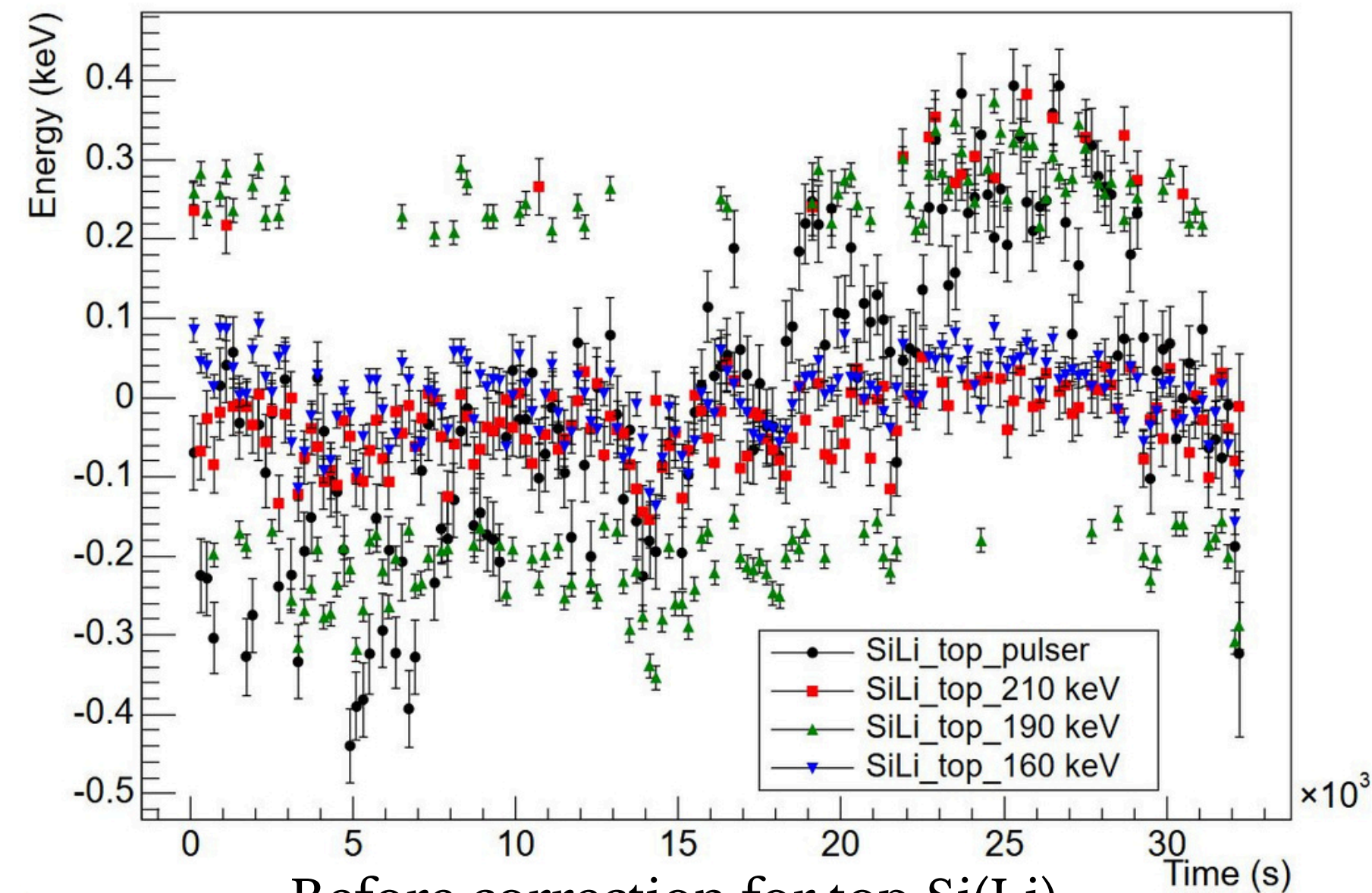
Gain correction with pulser in February

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Gain correction with pulser in July

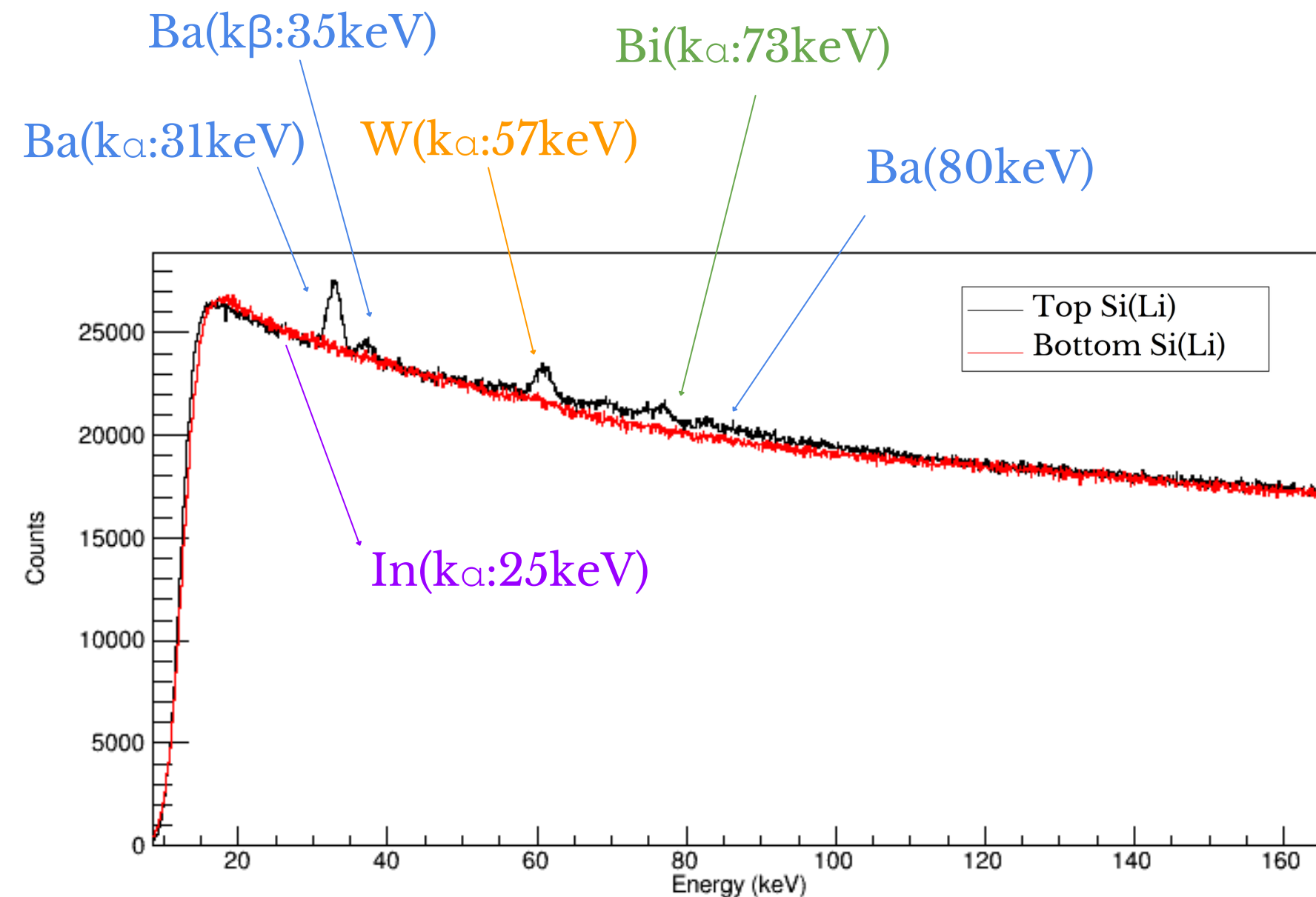
Follow mean position of the peaks of 160 keV, 190 keV from the ^{114}In and added two pulser at 210 keV and 2500keV .



- Except high variation due to work in the hall, gain more stable in July, possibly because of temperature or different preamp settings.
- ^{32}P has no physics peaks unlike ^{114}In so we added two pulser peaks

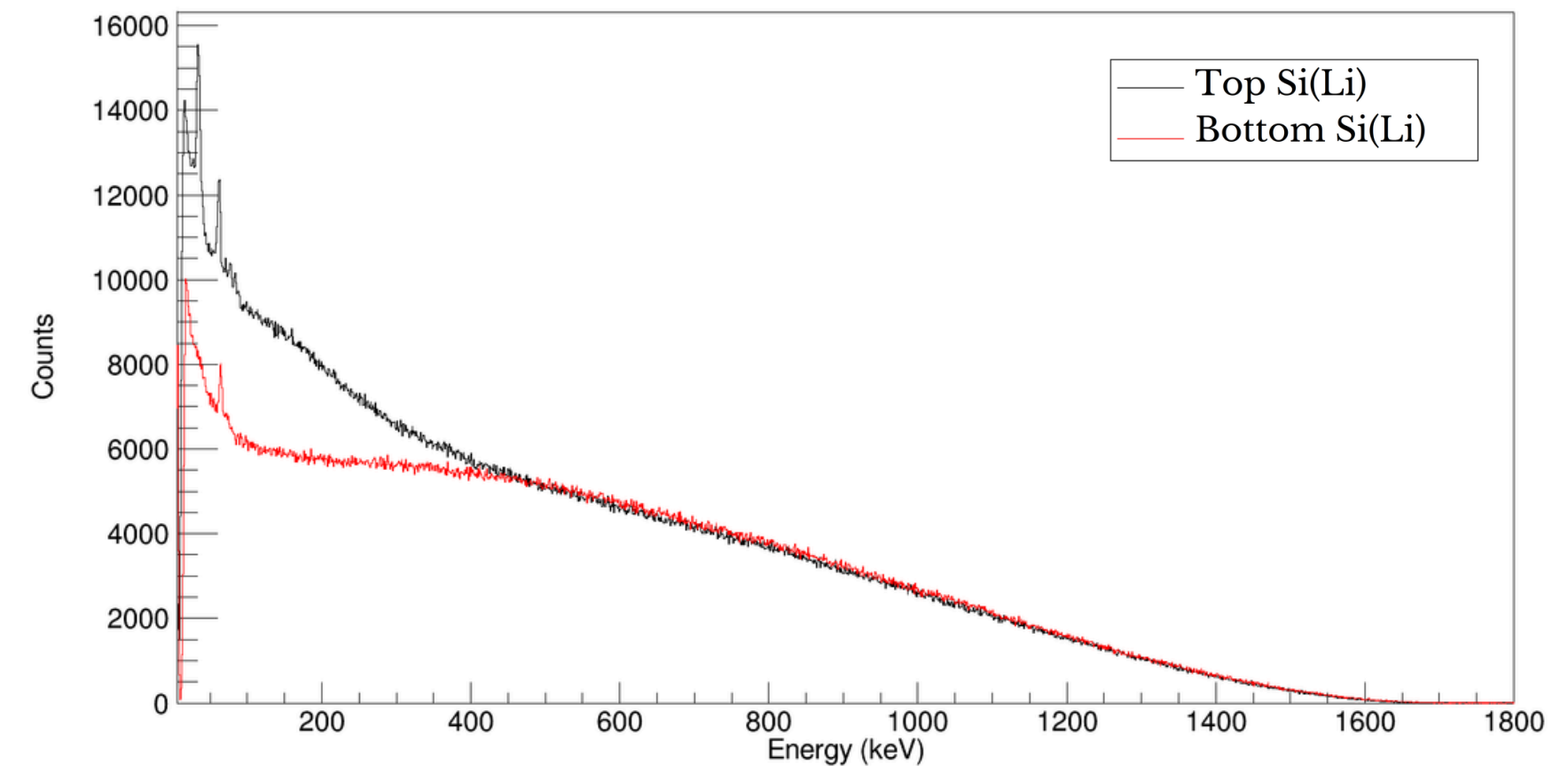
Leaking from the calibration source

We observed a discrepancy between the top and the bottom spectrum.



Spectrum of ^{32}P at 6T, several runs merged

Many peaks between [30;80] keV are in the top SiLi and not in the bottom (or many orders of magnitude less) at 6T.



Spectrum of ^{32}P at 0T, run 101

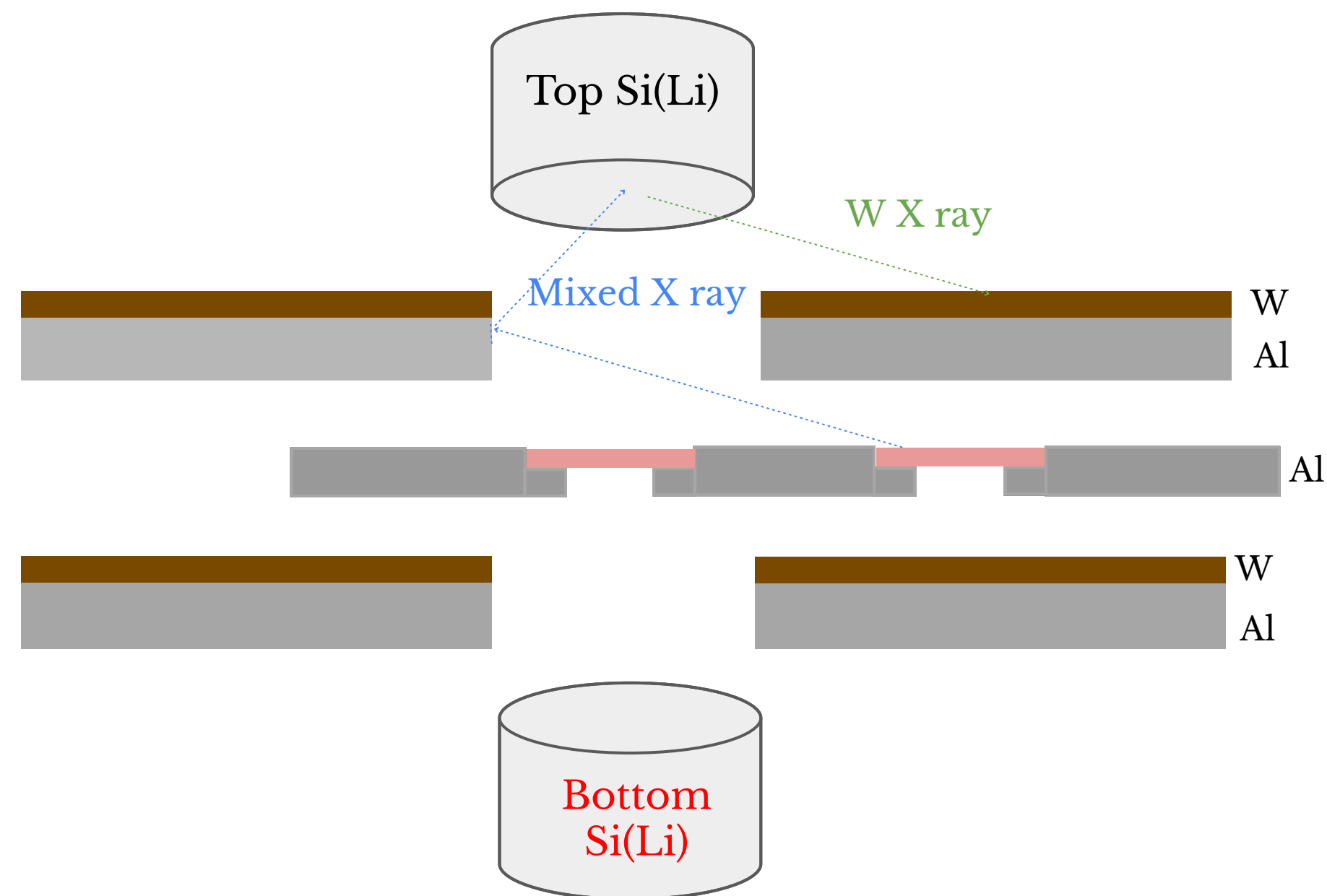
At 0T a more pronounced background until 450 keV is present in the Top detector.

Leaking from the calibration source

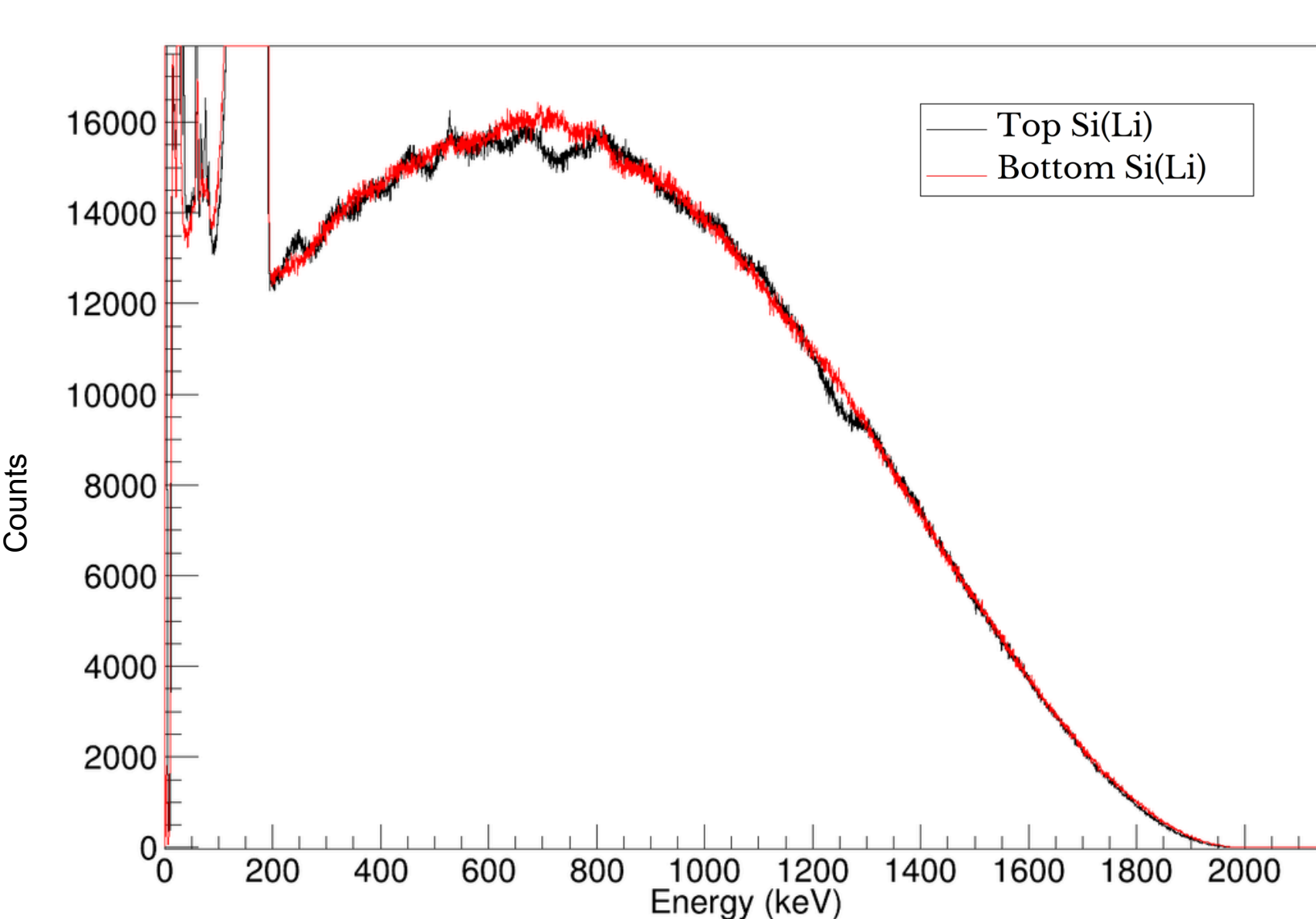
The differences between the detectors is because of the asymmetry in the geometry of the garage:

- Background at 0T and higher contribution from the calibration source: beta from mixed source enters first the aluminum (top) or the tungsten (bot).
- X-rays proportion difference: the X-rays from the tungsten can be absorbed by the Al plate before reaching the bottom Si(Li).

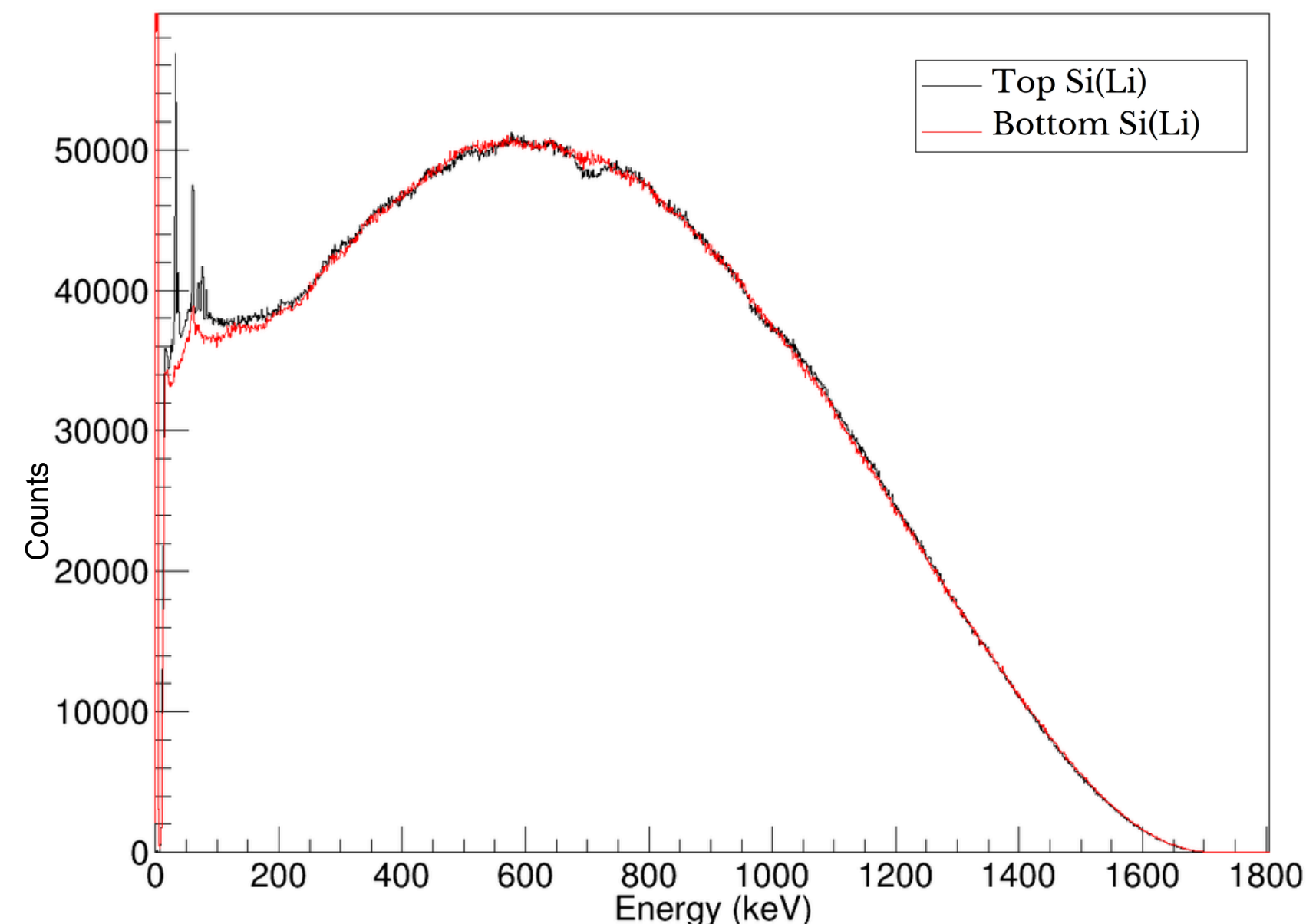
Ongoing : GEANT4 simulations to reproduce and confirm this effect



Problem: Oscillations in beta-spectrum



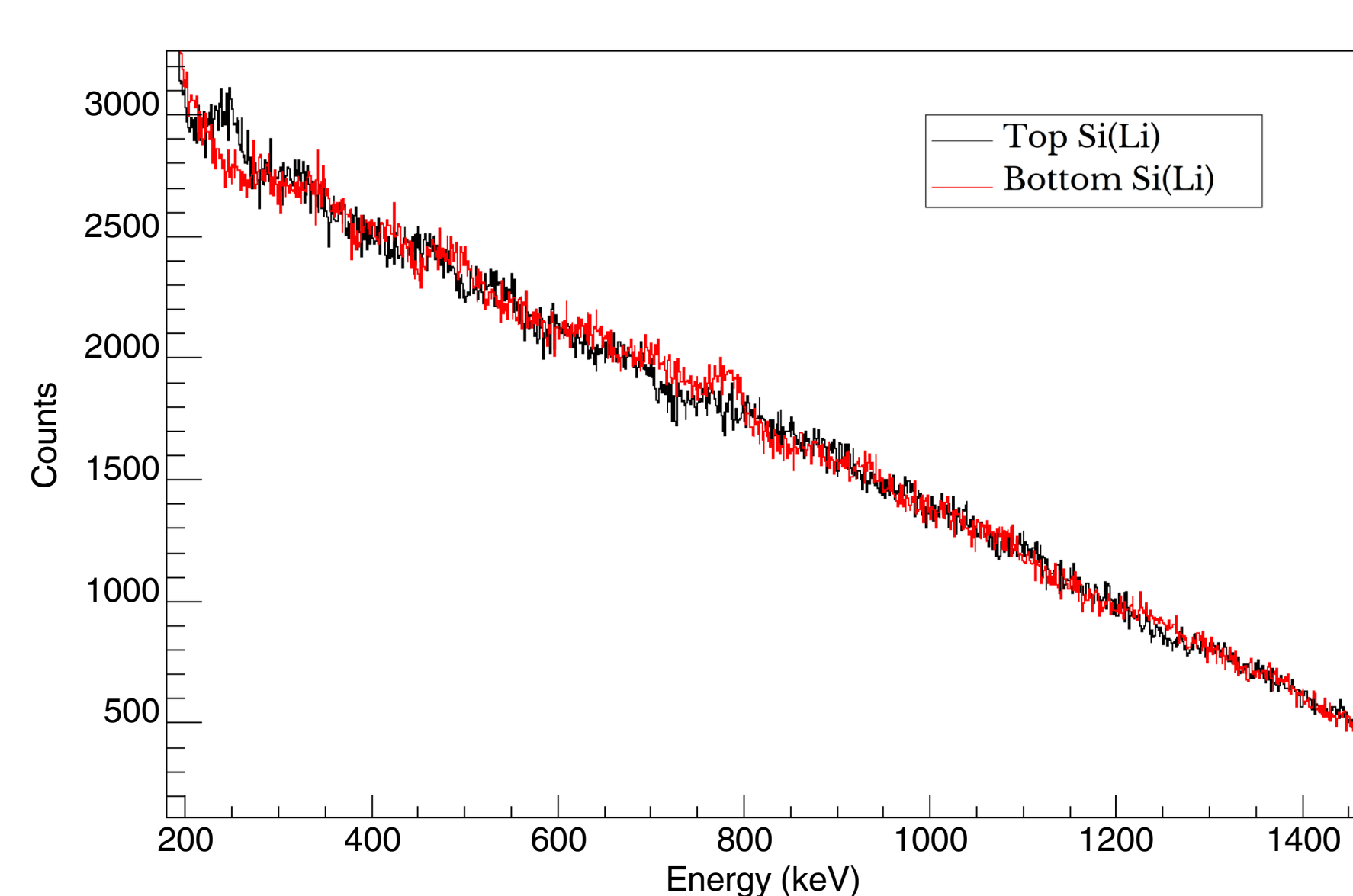
^{114}In - 6T - merged



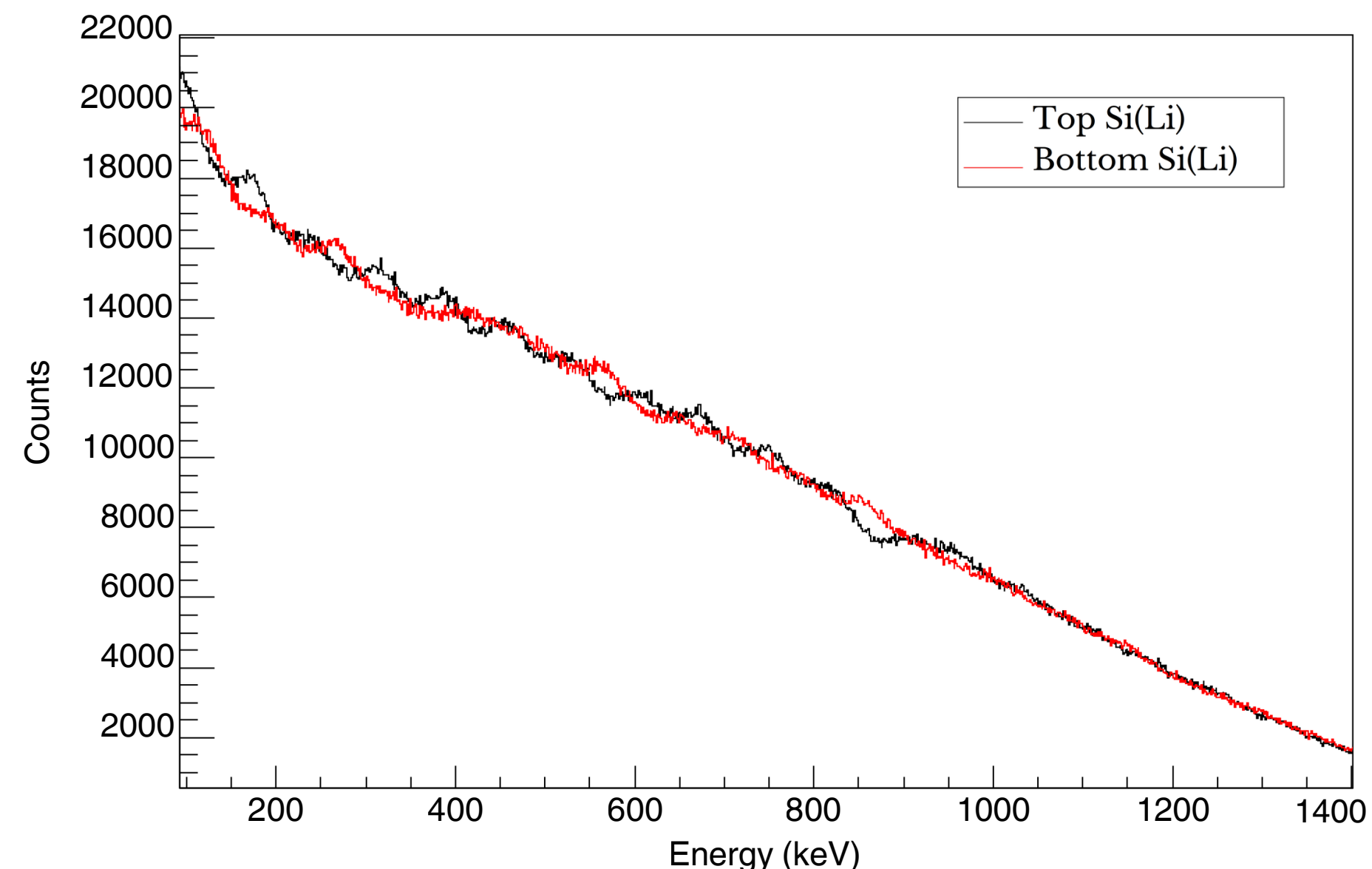
^{32}P - 6T - merged

For the three isotopes measured: we observed oscillations on the spectrum every 70-80keV.

Problem: Oscillations in beta-spectrum



Run 087, spectrum of ^{114}In , zoom on the range [200keV-1400keV]

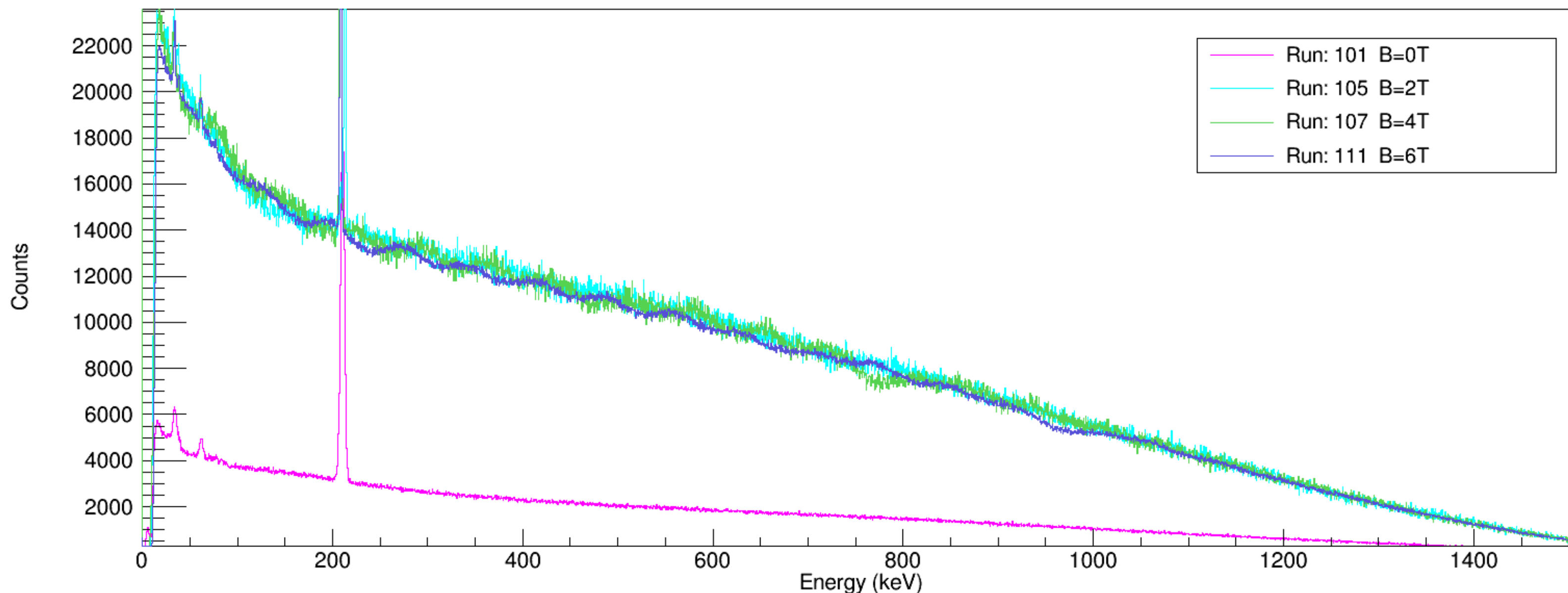


Run 119, spectrum of ^{32}P , zoom on the range [200keV-1400keV]

- For individual runs we can observe the oscillations as well but depends on the run so not constant in time.
- Zoom on a specific range but possible presence of oscillations at higher energies with enough stats
- Present in February but only visible if total stat merged.

Oscillations in beta-spectrum: magnetic field

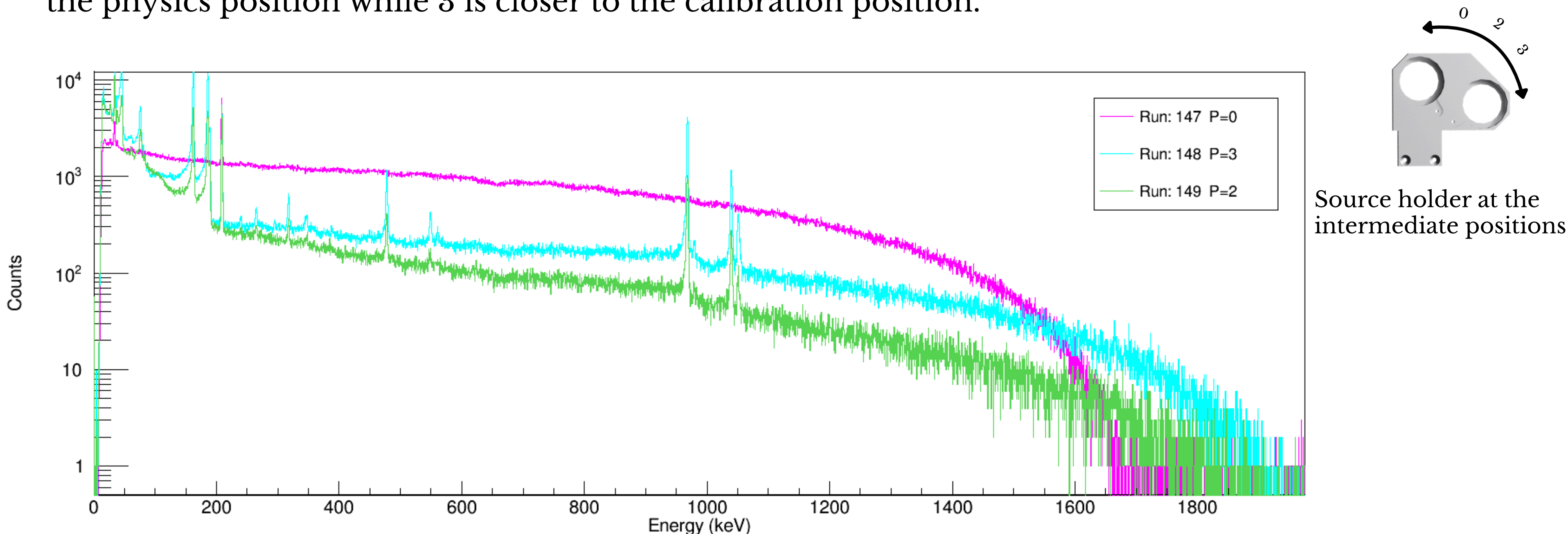
^{32}P runs at different magnetic field (0,2,4,6T) with pulser, zoom on the range below 1400keV :



→ The oscillations increase with the magnetic field but their presence at 0T is not clear yet... 19

Oscillations in beta-spectrum: source position

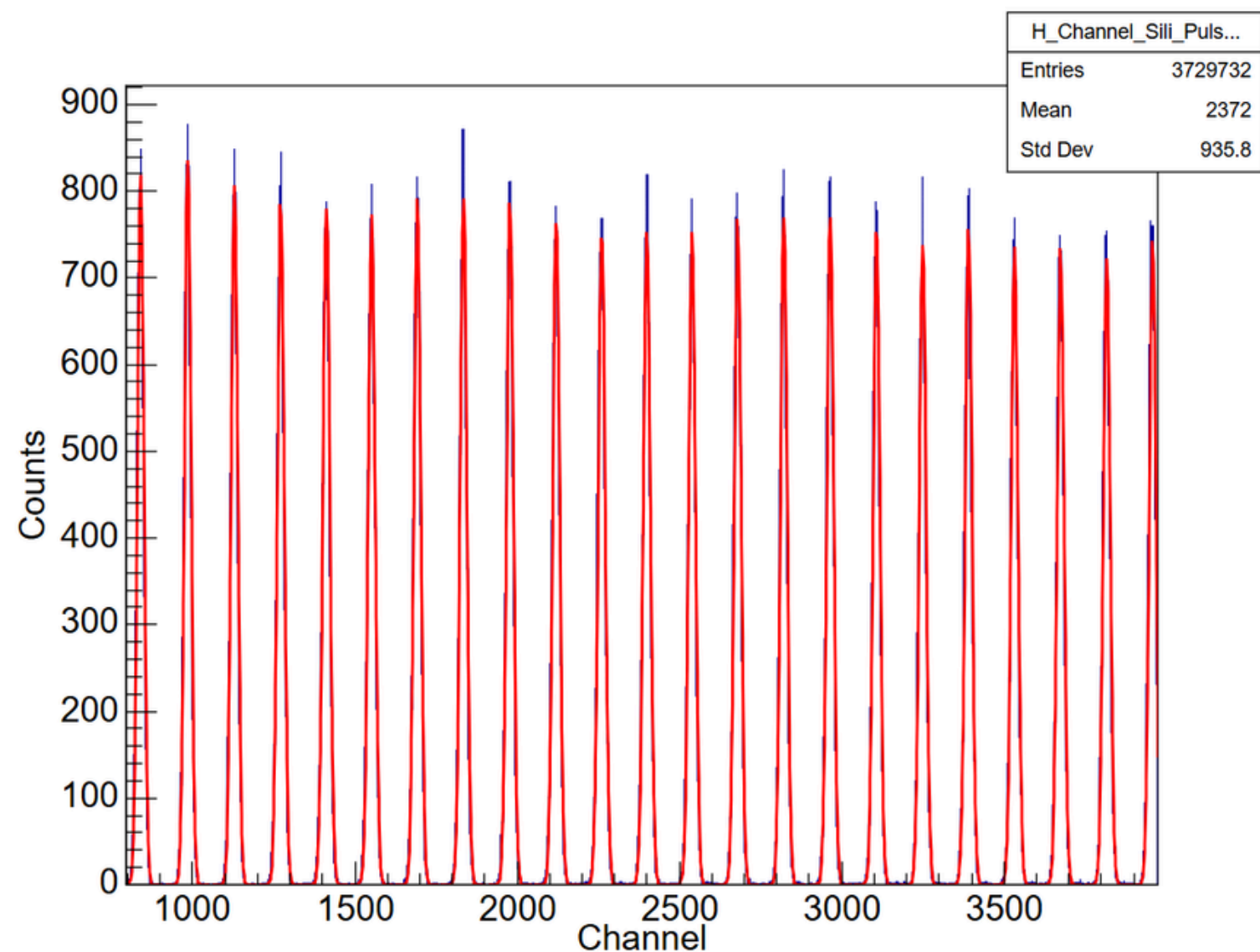
Runs with intermediate positions between the physics and the calibration, 0 being the closest to the physics position while 3 is closer to the calibration position.



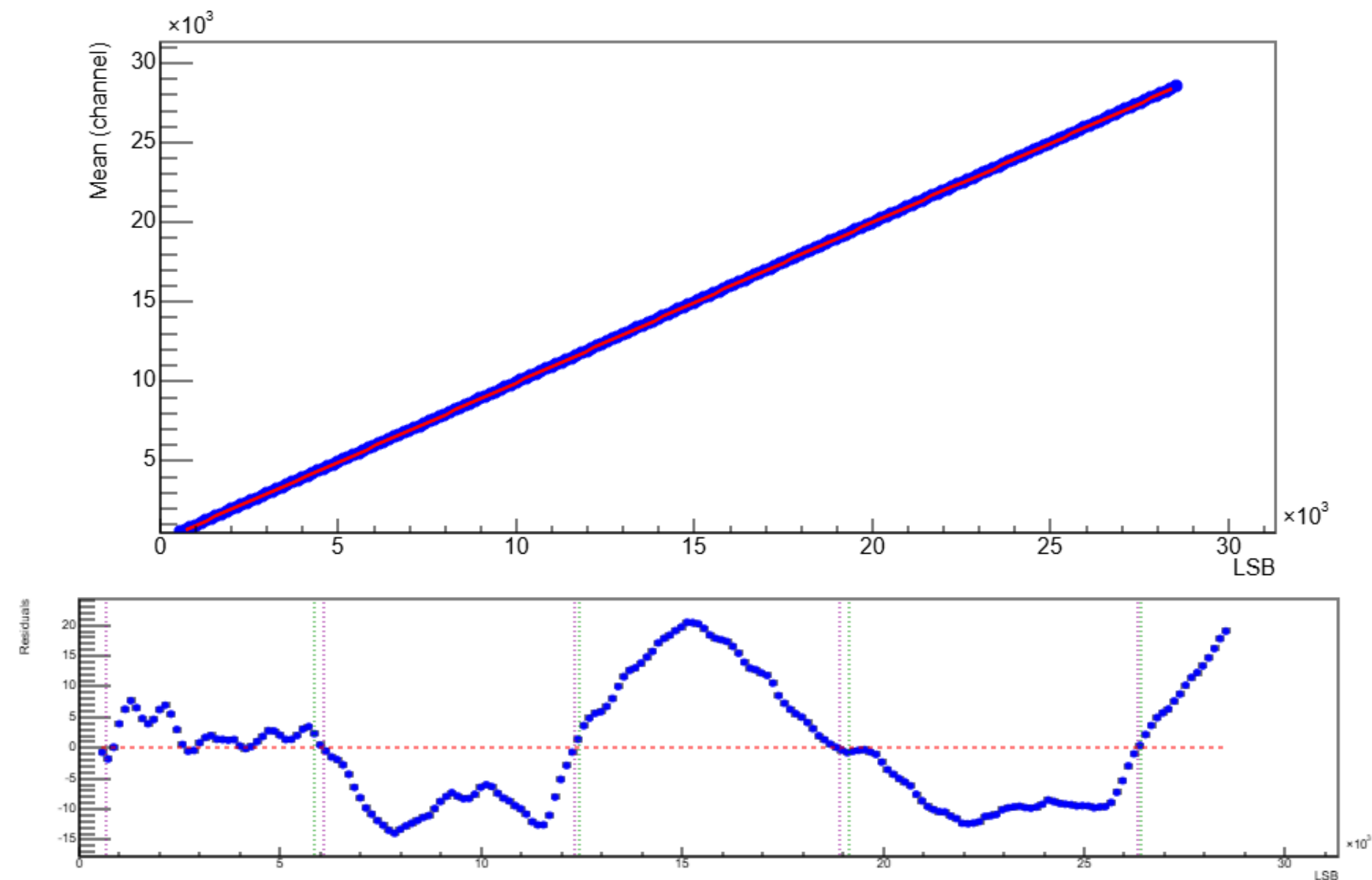
- Shorter runs so less statistics but the oscillations seem to be present no matter the position
- Additional tests performed during the data taking (HV, cooling system, cables, pulser, threshold, acquisition system... ect)

Pulser reproduction with narrow pulser scan

The goal was to see if the pulser could reproduce the oscillations so we could correct them



Zoom on a few of the 200 Gaussian fits on top Si(Li)

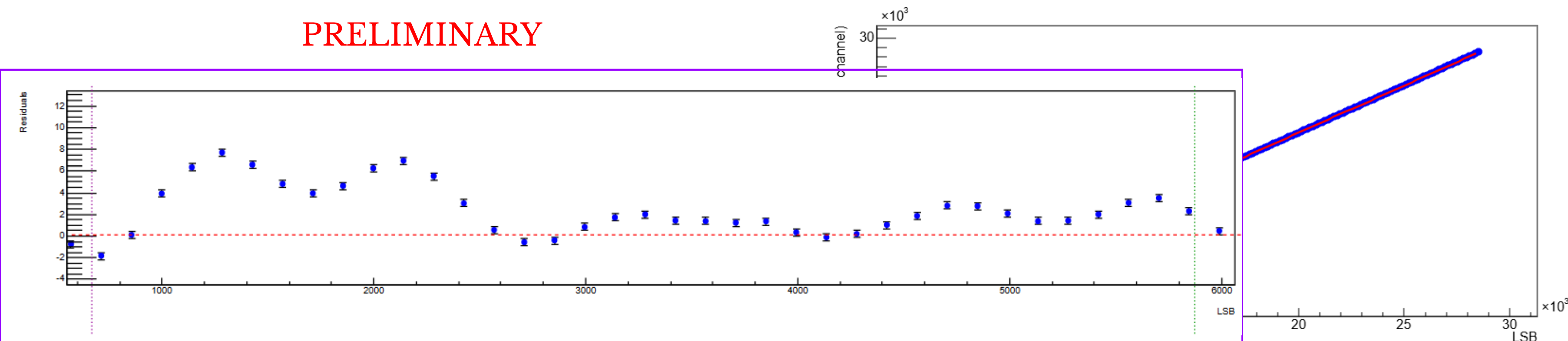


Two kinds of oscillations observed

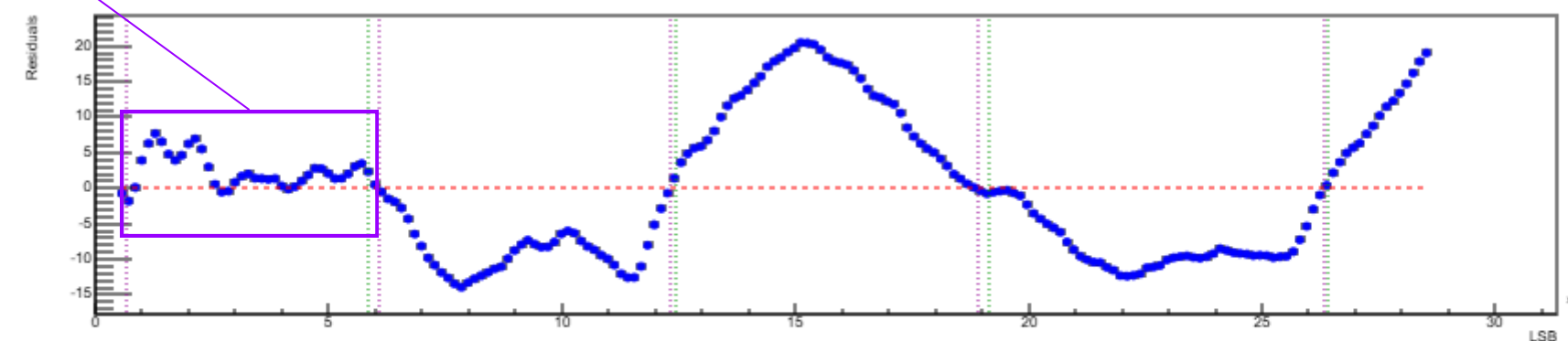
Pulser reproduction with narrow pulser scan

The goal was to see if the pulser could reproduce the oscillations so we could correct them

PRELIMINARY



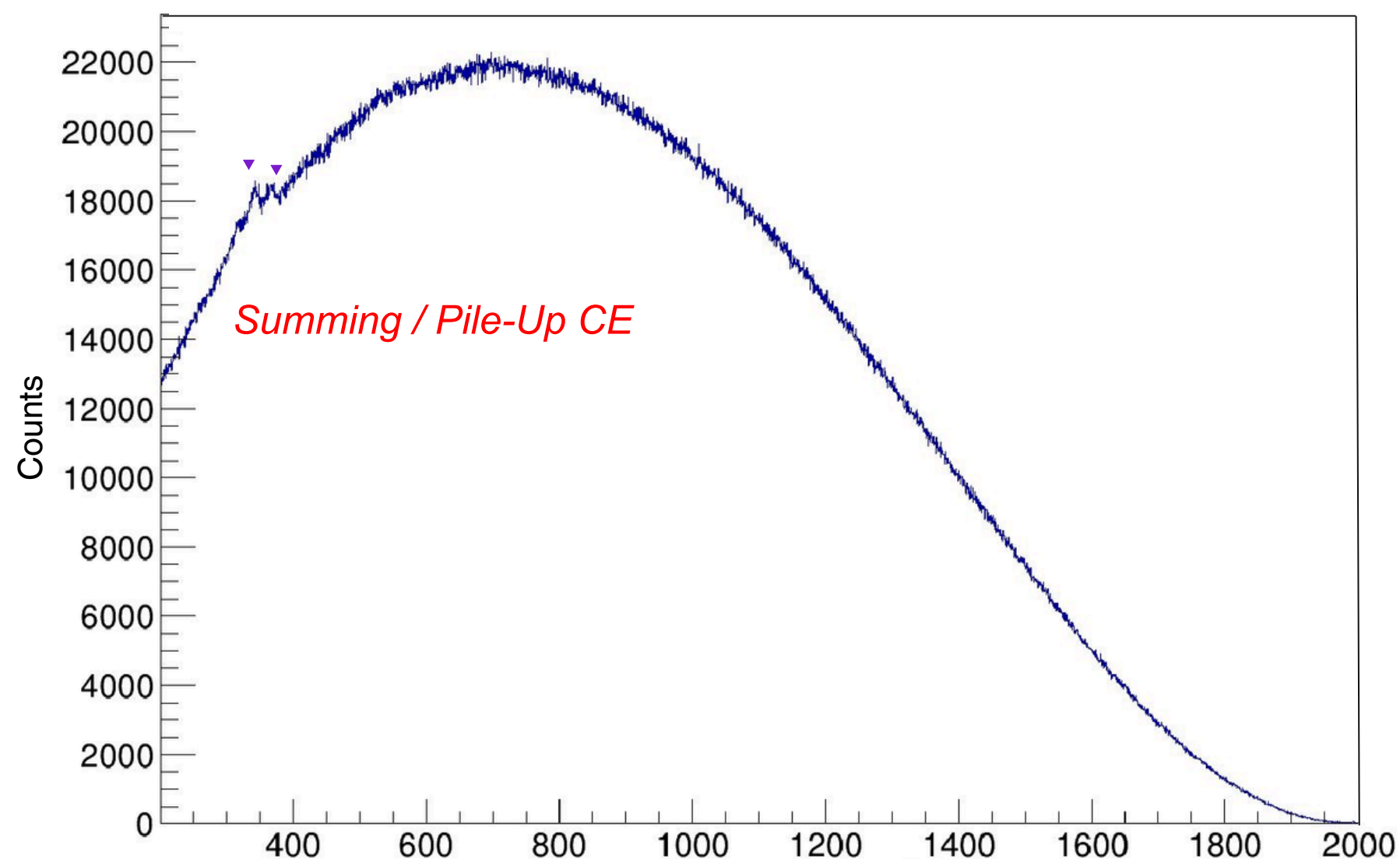
Resembles the oscillations observed on the beta spectrum, with same frequency of 70-80 keV.
To be confirmed by further analysis.



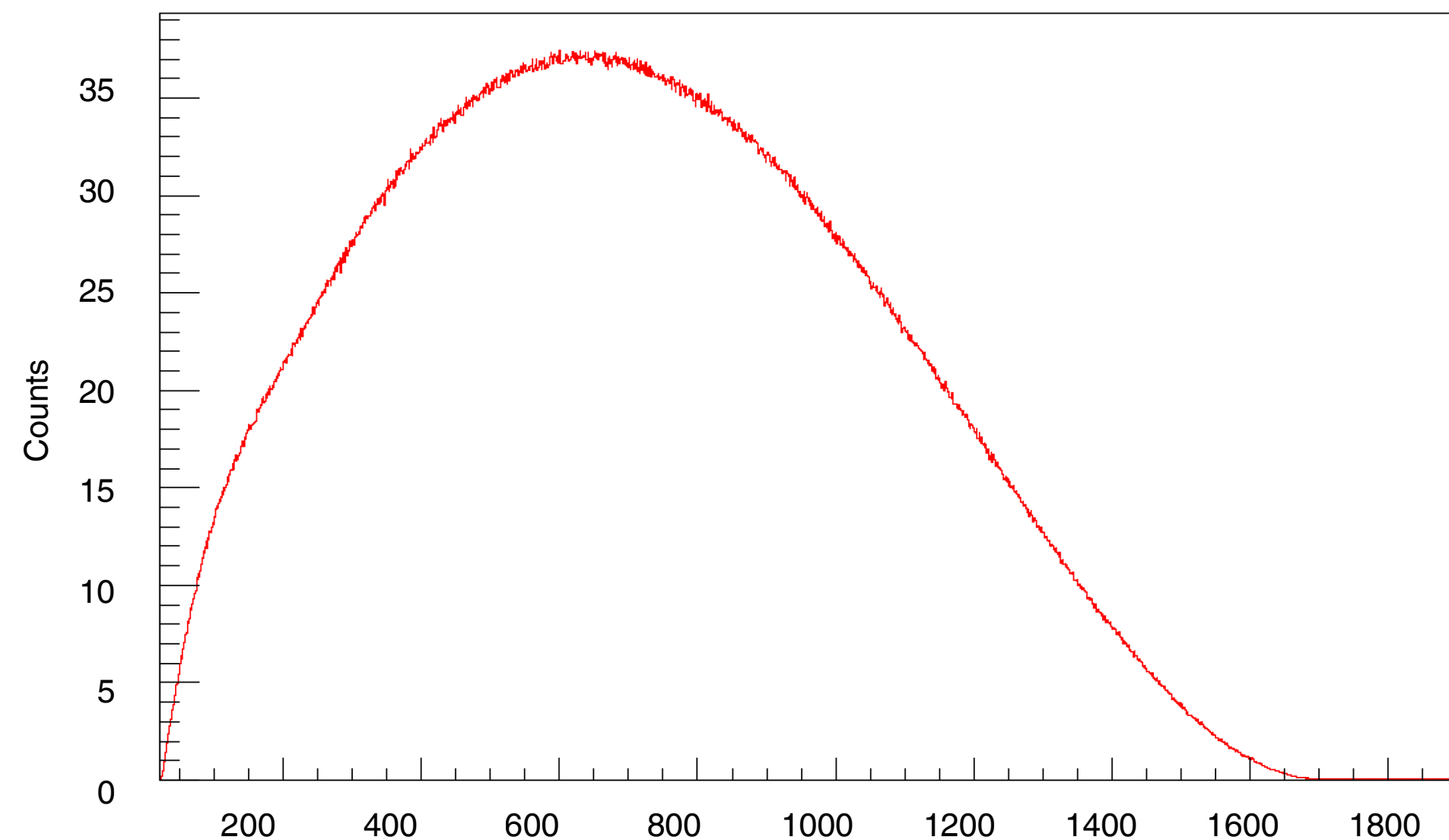
Two kinds of oscillations observed

Problem: Oscillations in beta-spectrum

The sum spectrum of the two SiLi in coincidences doesn't have oscillations.



Sum between the Si(Li) of the merged ^{114}In runs



Sum between the Si(Li) of the merged ^{32}P runs

- Next steps:
 - Ongoing experimental work to reproduce the oscillation in Bordeaux/Leuven
 - Pulser scan analysis ongoing
 - We will need to advance further in the analysis to know if the sum spectrum can be really useful

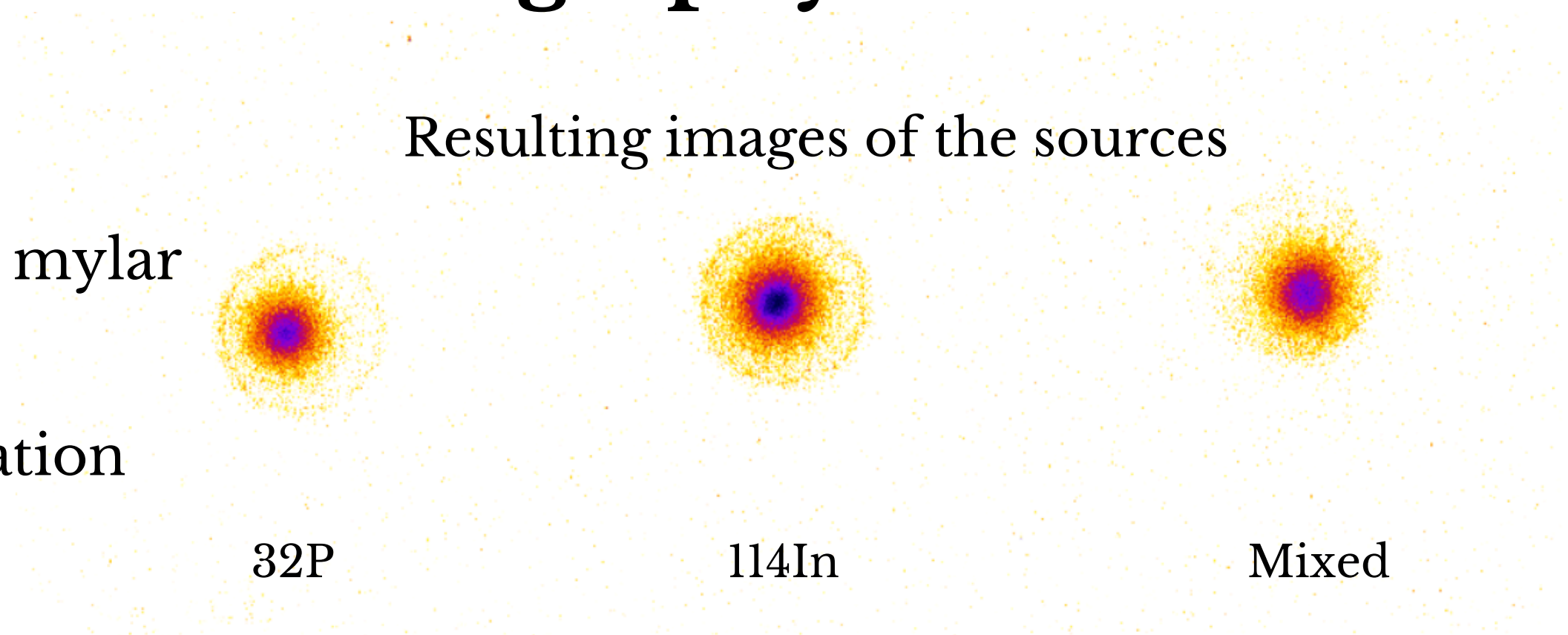
Additional measurement: autoradiography of sources

Goal of the measurement:

- Position of the radioactive spot on the mylar
- Size and uniformity of the spot

→ To include them in the GEANT4 simulation

Resulting images of the sources



Additional measurement: autoradiography of sources

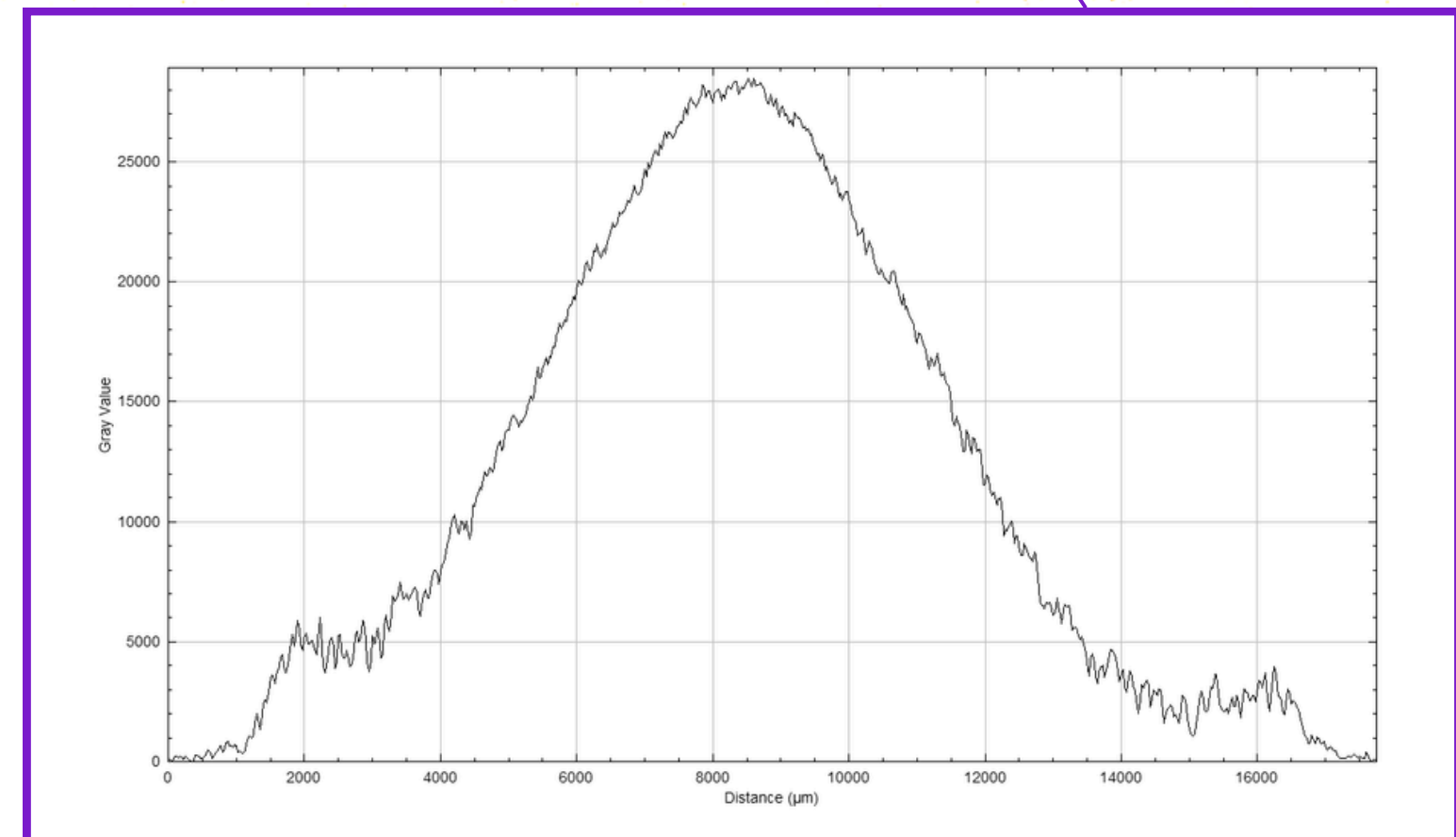
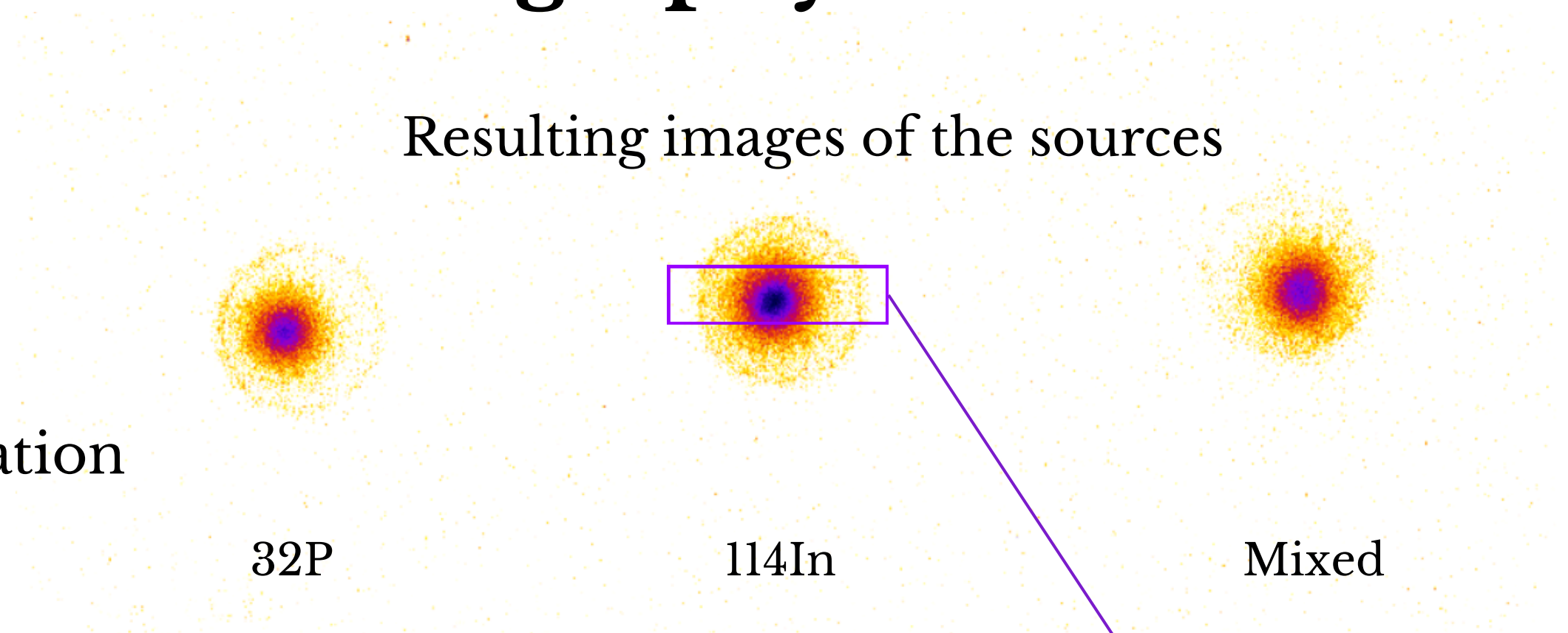
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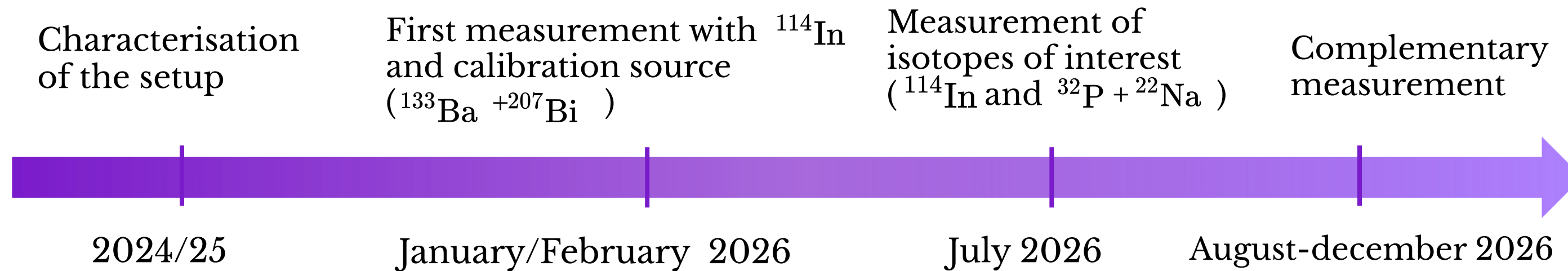
Preliminary results so far:

- Spot size =
FWHM = $7190 \pm 3.1 \mu\text{m}$ for larger gaussian
FWHM = $2624.6 \pm 1.4 \mu\text{m}$ for narrower gaussian
- Position=
Distance to the left edge = $6461 \pm 6.2 \mu\text{m}$
Distance to the right edge = $8104.2 \pm 9.3 \mu\text{m}$



Plot profile of 114In for R=25um and d=5min

Conclusion and next steps



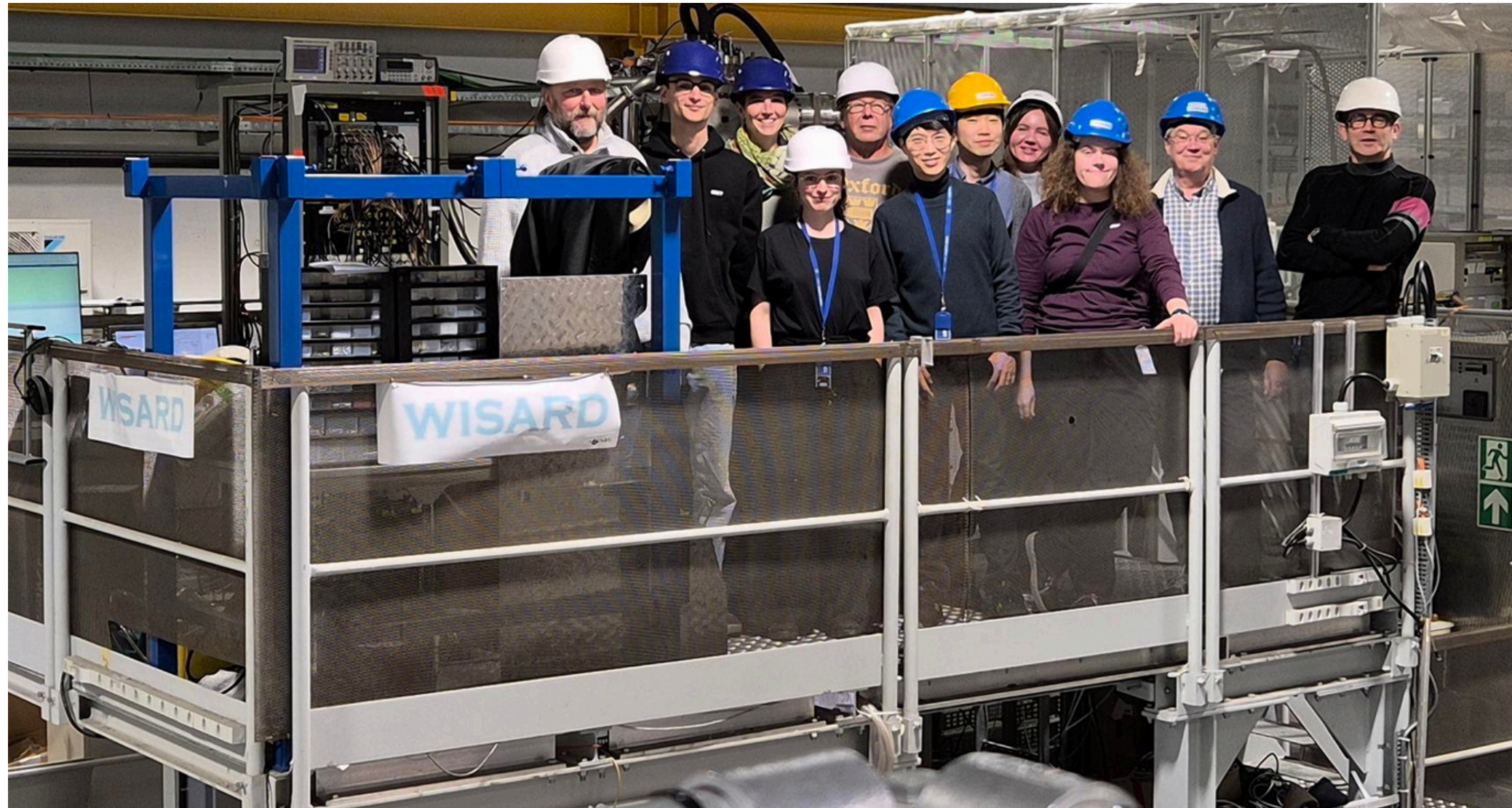
Next analysis steps:

- Auto radiography analysis
- Pulser scan possible reproduction of oscillations
- Event selection

Additional measurement:

- RBS measurement at AIFIRA: mylar thickness, homogeneity of deposit
- Si(Li) dead layer measurement at KU-Leuven

Thank you for your attention!



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

List of additional tests carried out to try to find the origin of the oscillations

- **What's we done:**
- Run without pulser
- Run with different threshold
- Run with different FASTER card
- Run at lower HV (-50V from the measurement value)
- Run with only 1 detector switch on
- Switch cables, power supply HV or LT

What's we learned:

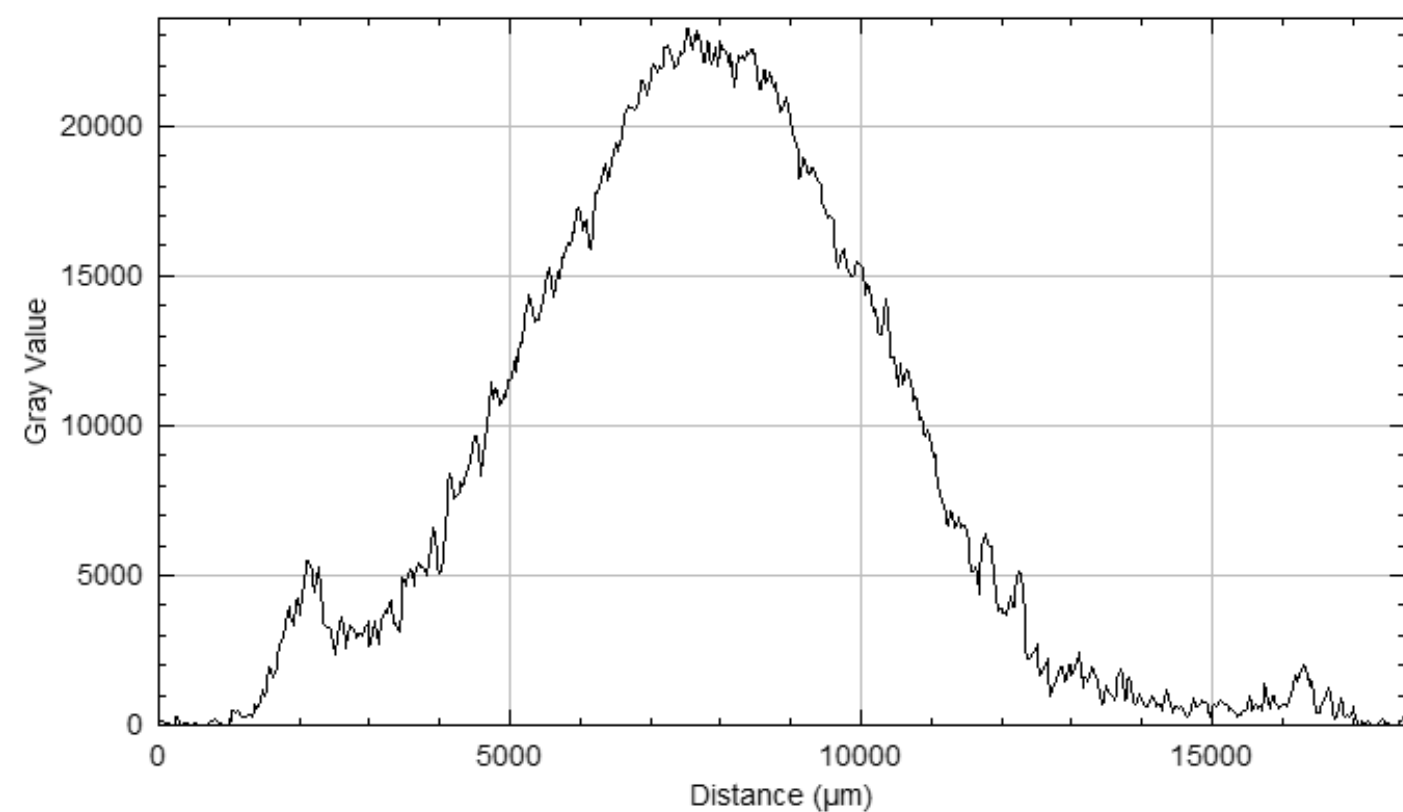
-Oscillations doesn't seems to be related to the physics. No matter the source position, the magnetic field?, the depletion region.

-Not stable in time : oscillations more or less present depending of the run+ not always on the same detector

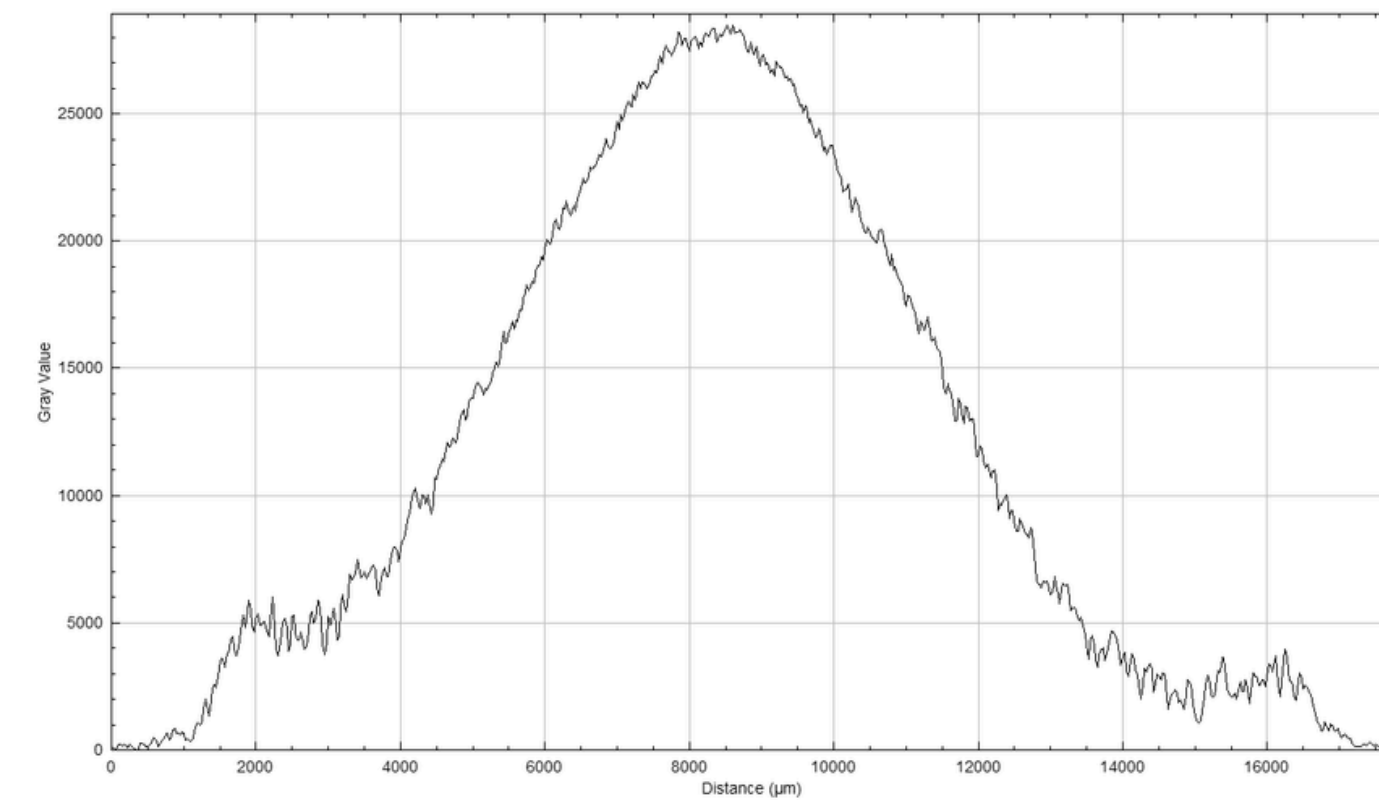
-Effect of switching off/heating the SiLi: have to wait some time to see oscillations afterwards

-Happen only when two detectors?
Oscillations in opposite phase=
crosstalk between the SiLis?

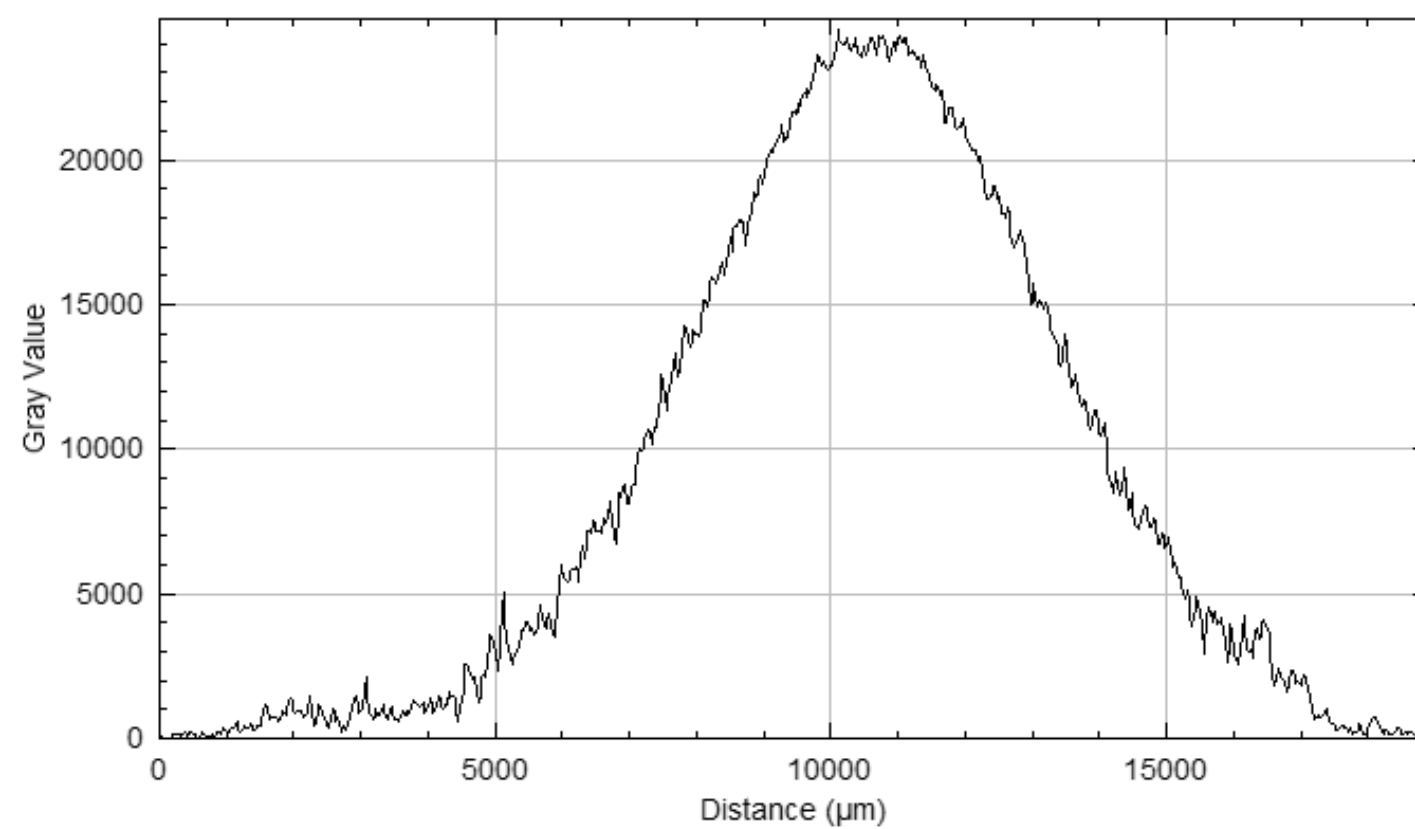
Plot profile



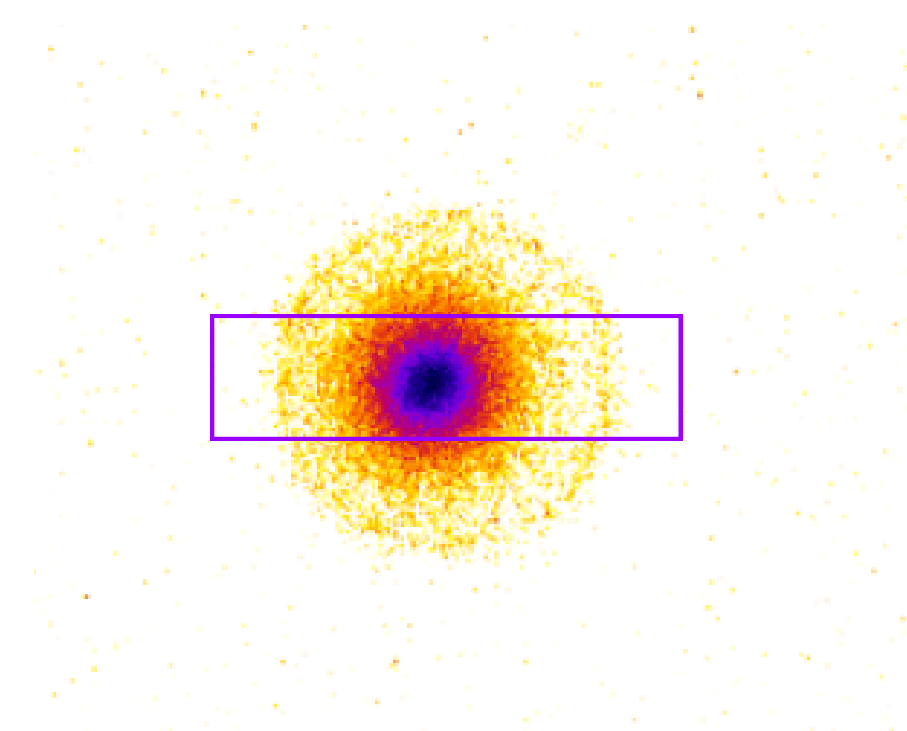
^{32}P



^{114}In

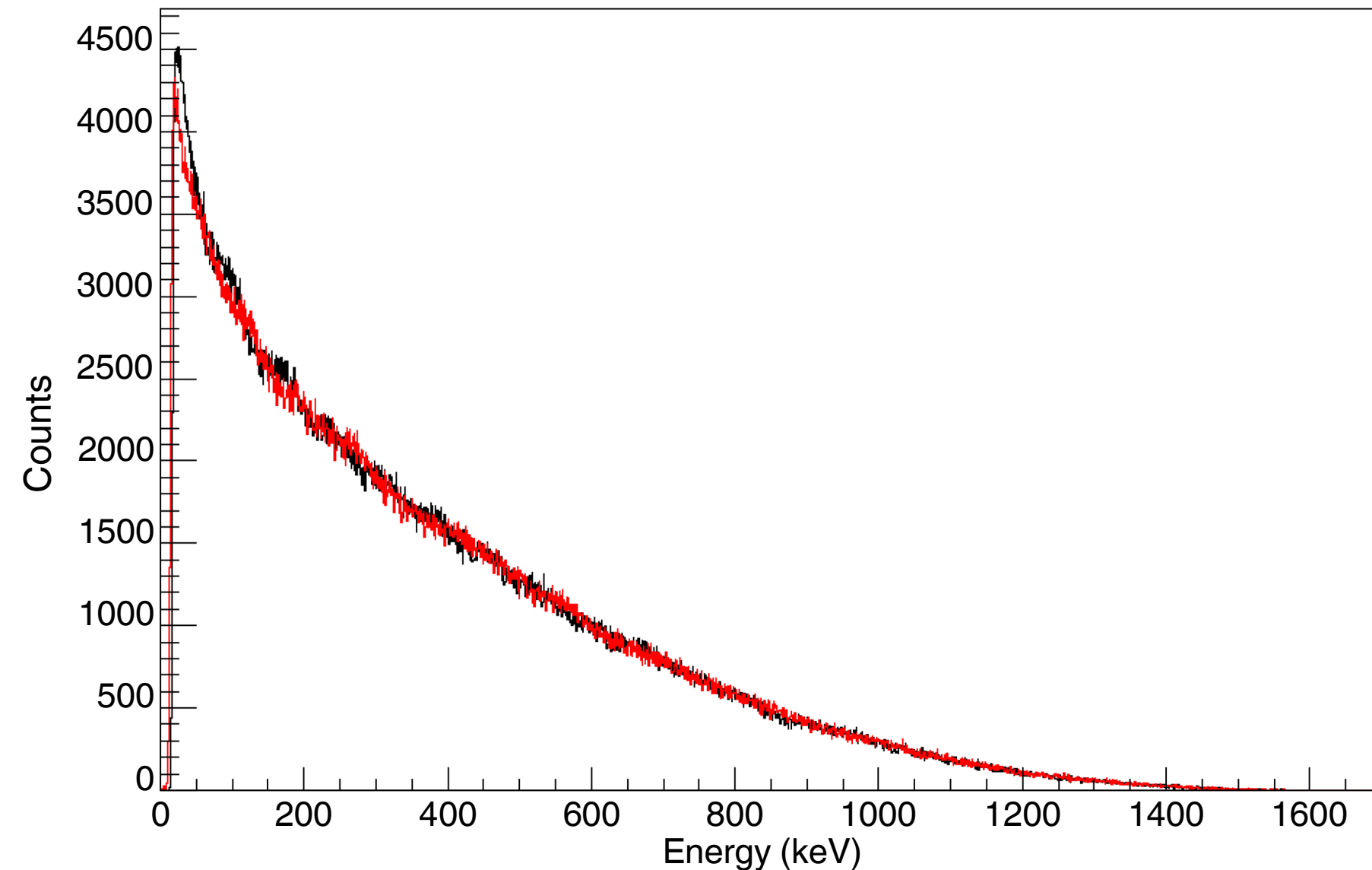


Mixed

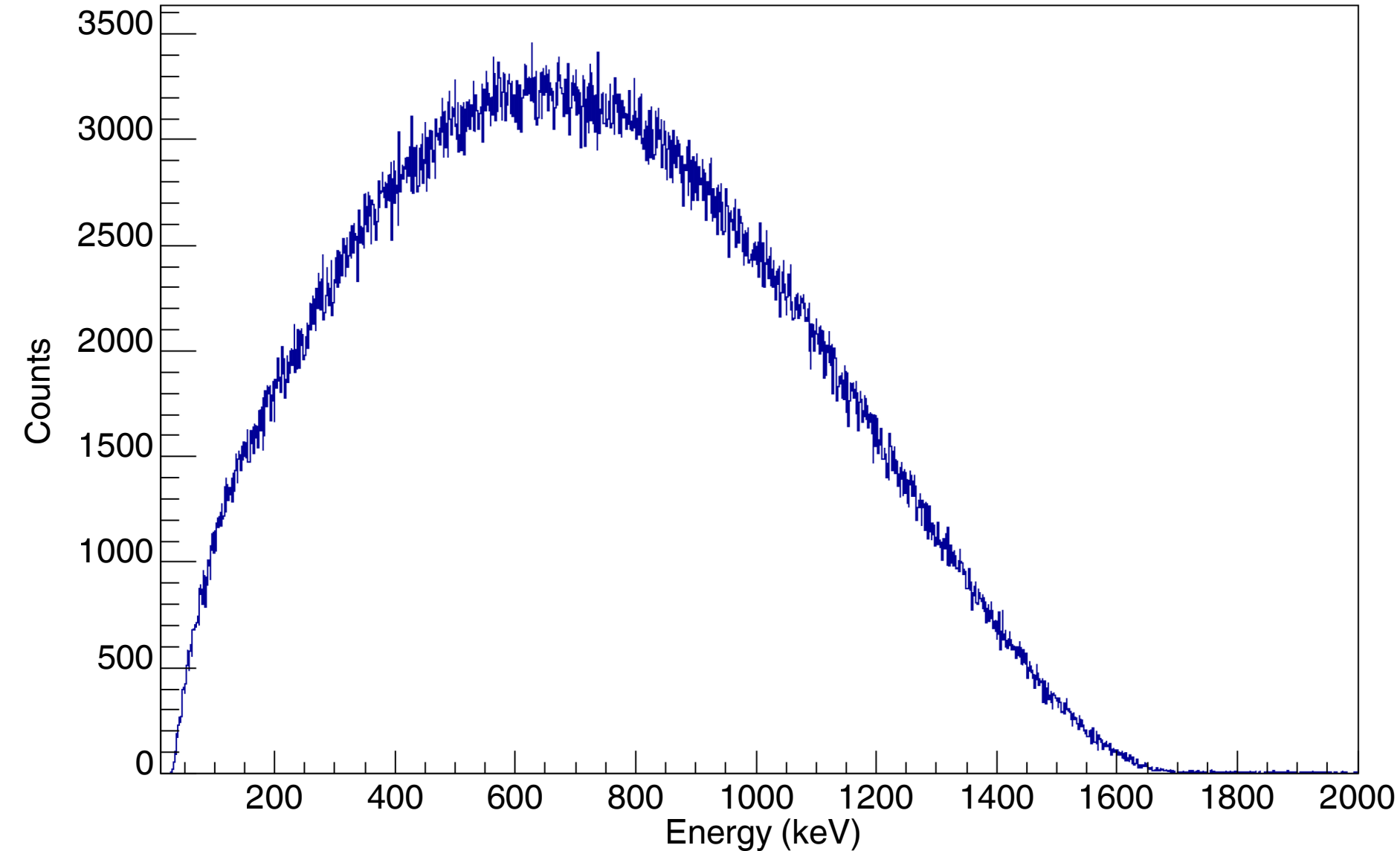


Example of larger slice used for ^{114}In : ²⁹

Oscillations in coincidence spectrum on a single run

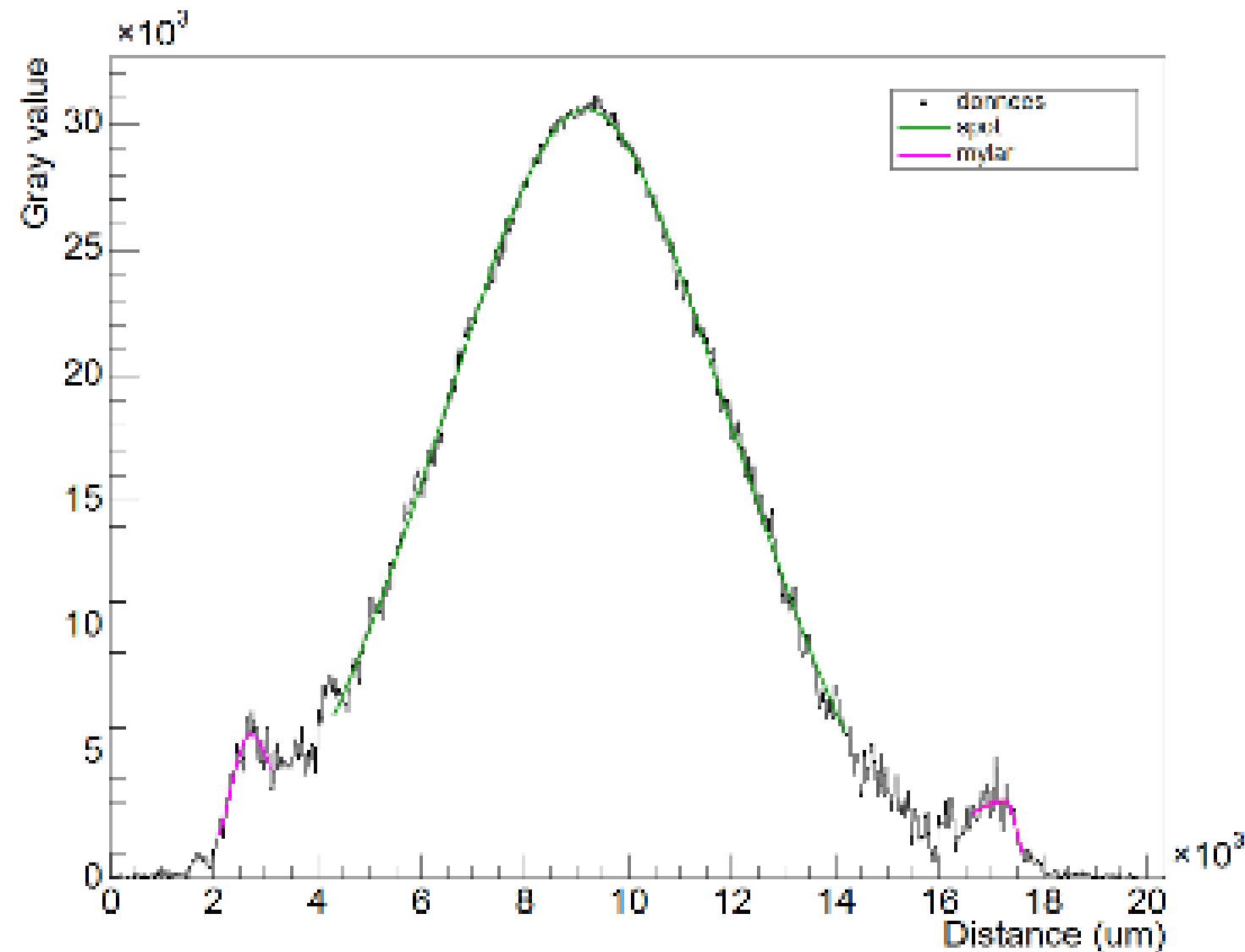


Superposed ^{32}P coincidences spectrum for both Si(Li) , run 119



Sum of the coincidences spectra for the run 119

Preliminary results



Very intermediate results so far:

-Spot size =

FWHM = $7190 \pm 3.1 \mu\text{m}$ for larger gaussian

FWHM = $2624.6 \pm 1.4 \mu\text{m}$ for narrower gaussian

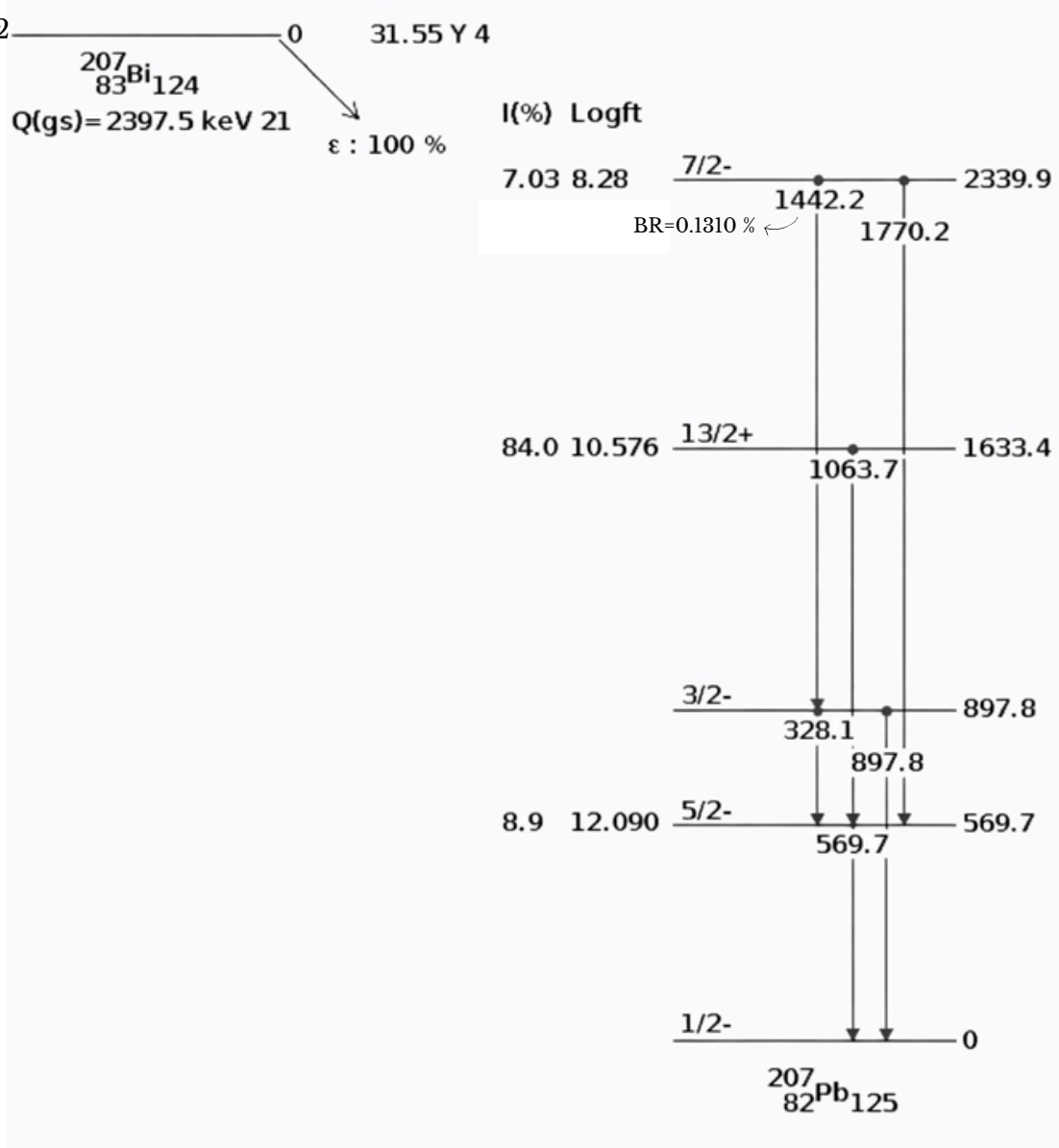
-Position:

Distance to the left edge = $6461 \pm 6.2 \mu\text{m}$

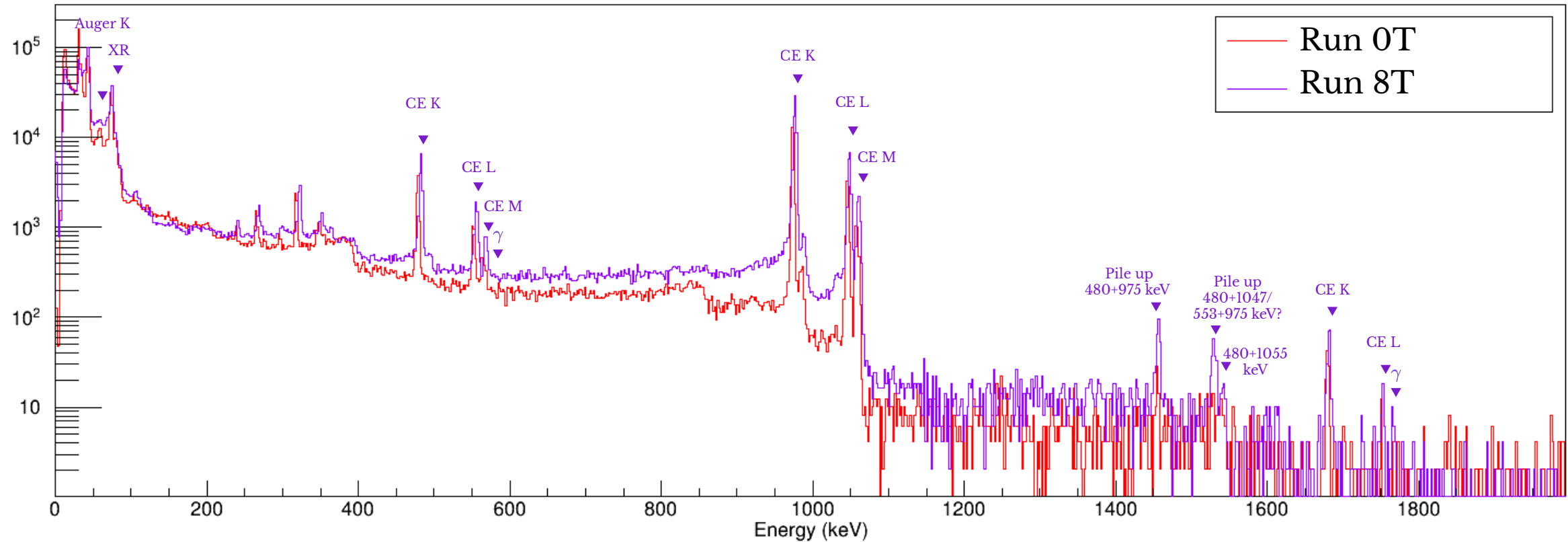
Distance to the right edge = $8104.2 \pm 9.3 \mu\text{m}$

Calibration source in February

HV	−210 V/ − 395 V
T	−45°C
Source	Mixed
Activity	1 kBq



Spectrum of the mixed calibration source without pulser at 0T and 8T for bottom Si(Li)



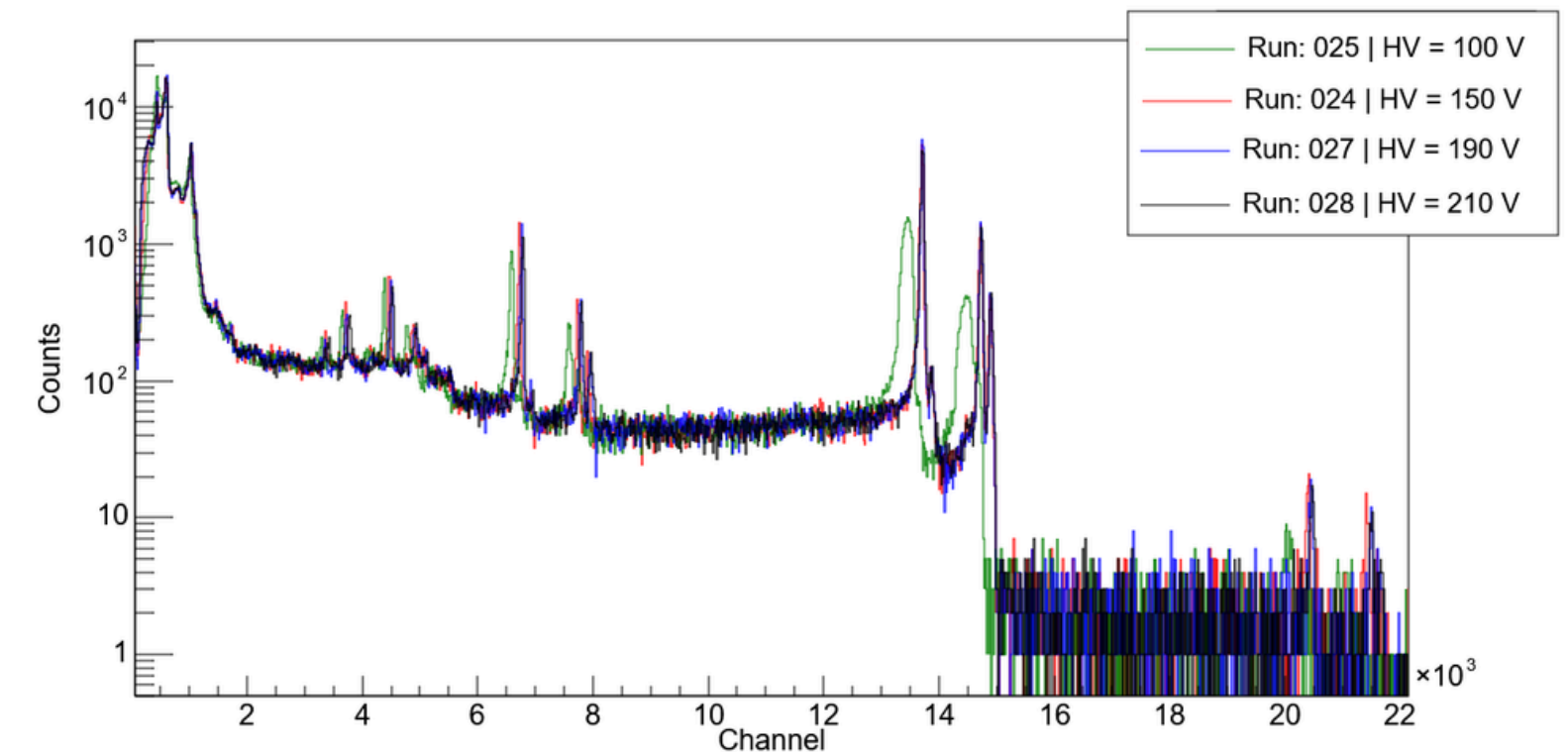
➔ Effect of magnetic field : higher peak height for electron + increase of EC peaks of ^{207}Bi at high energy.

Decay scheme of ^{207}Bi

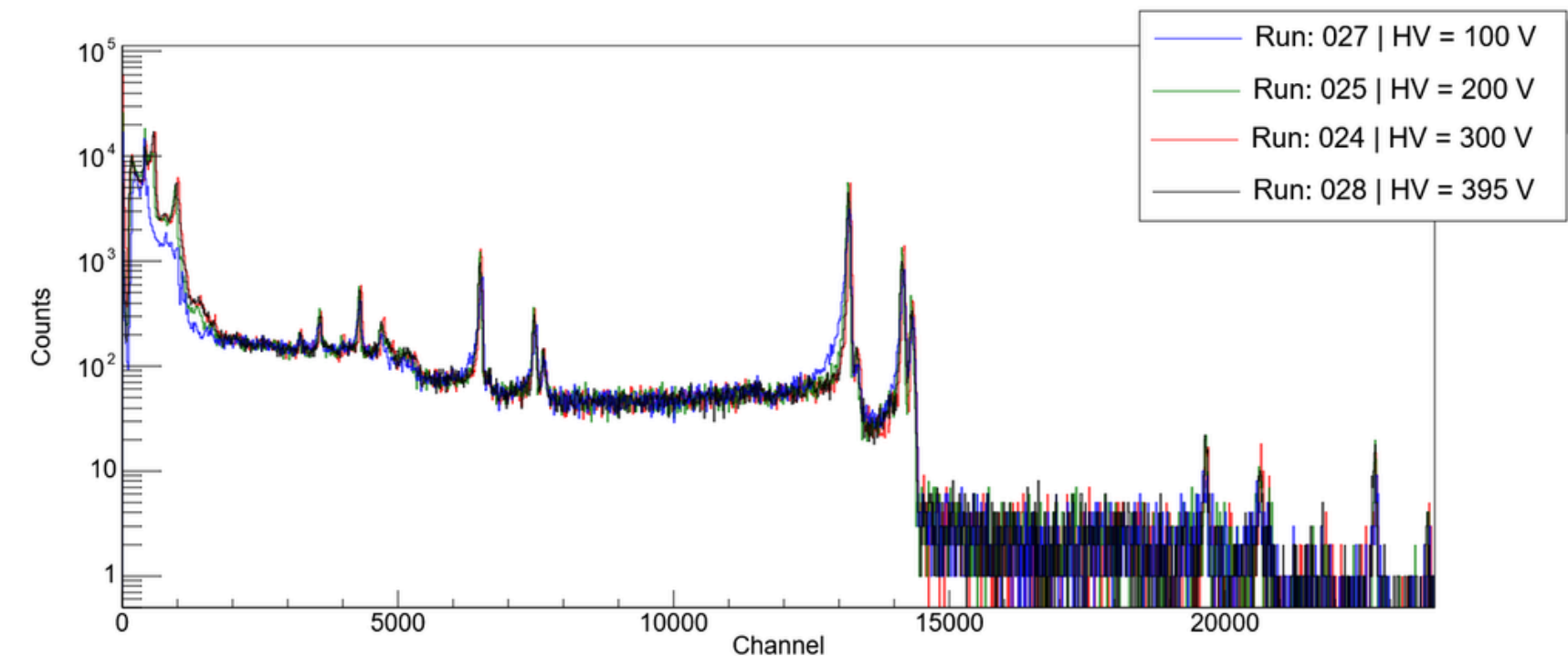
Next steps for the analysis

Priorities: finalize all setup-related tests in preparation for the July data-taking campaign, with mounting at ISOLDE planned for mid-June.

- Complete gain correction
- Analysis data runs at different HV
 - Required previous corrections (actually no)
 - Experimental optimization of the setup



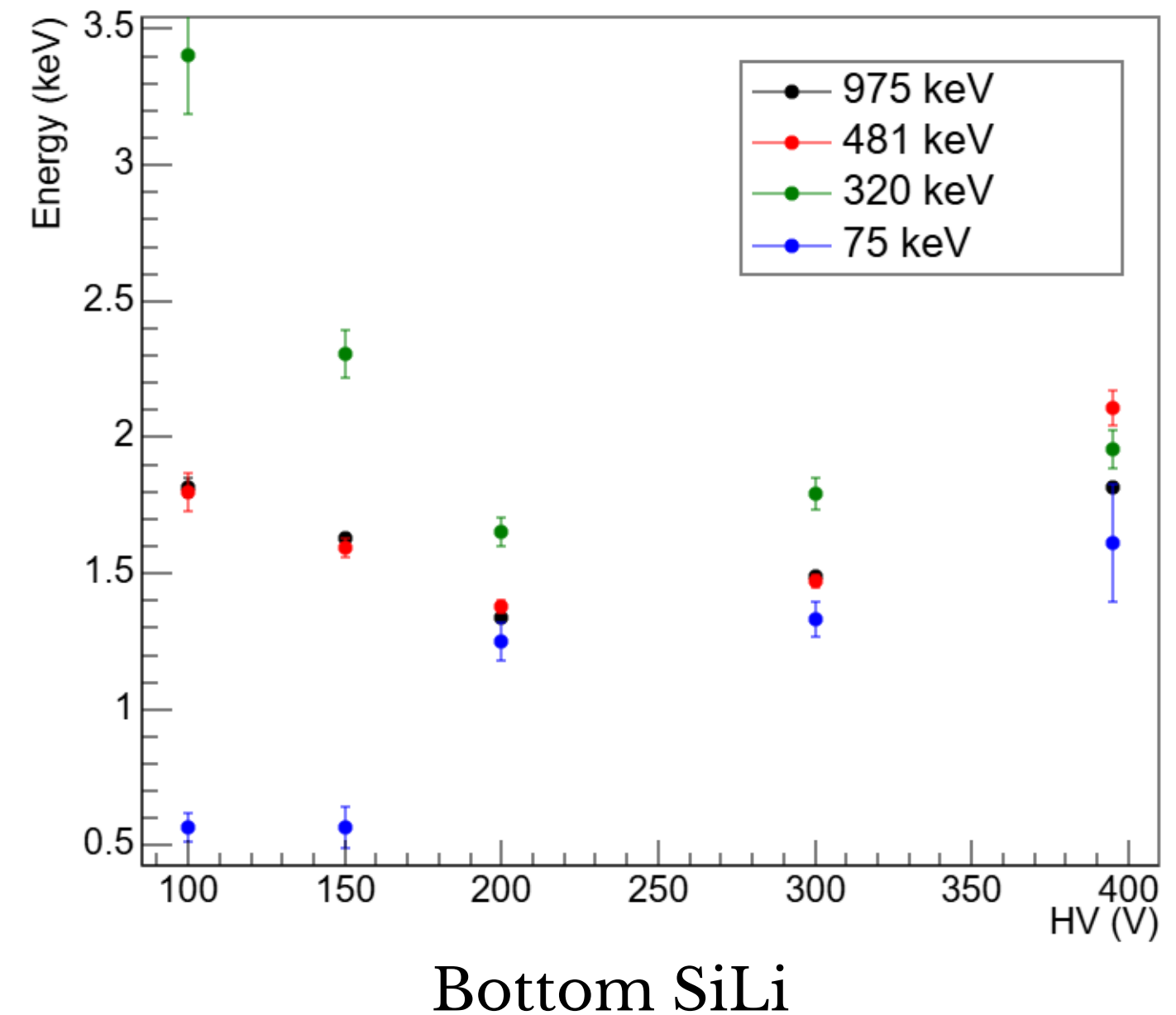
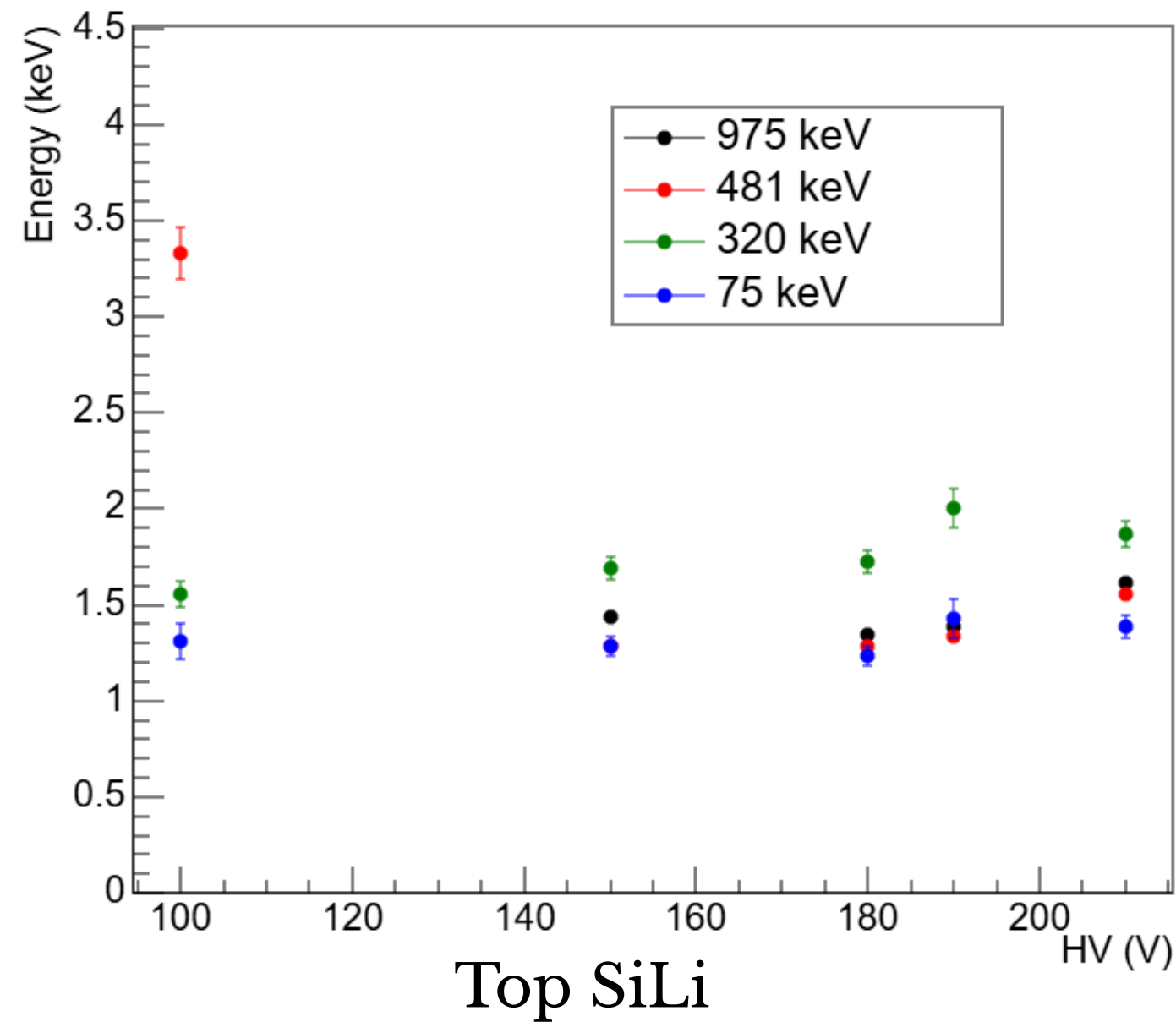
Spectra at different HV for the top Si(Li)



Spectra at different HV for the bottom Si(Li)

Analysis data runs at different HV

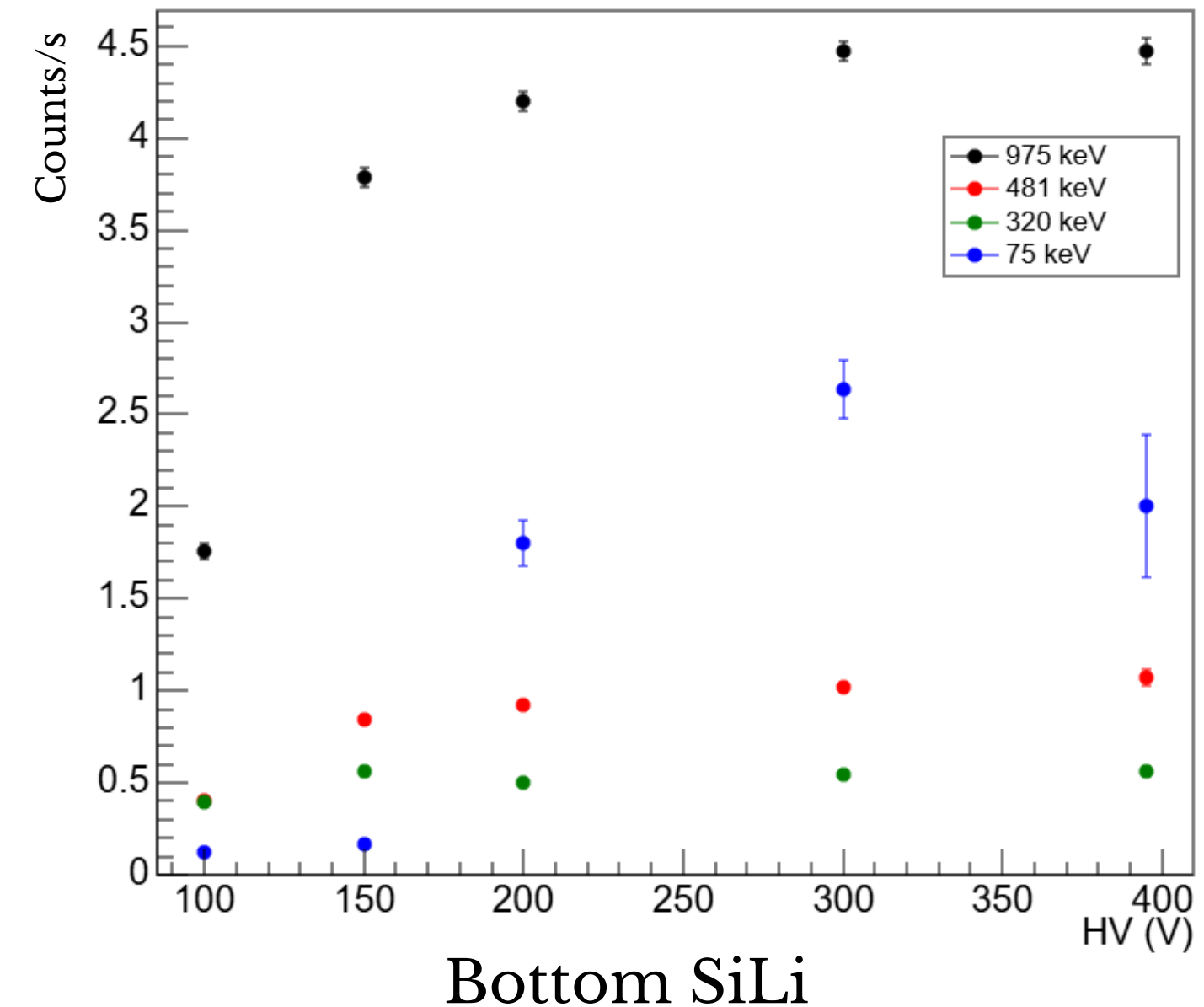
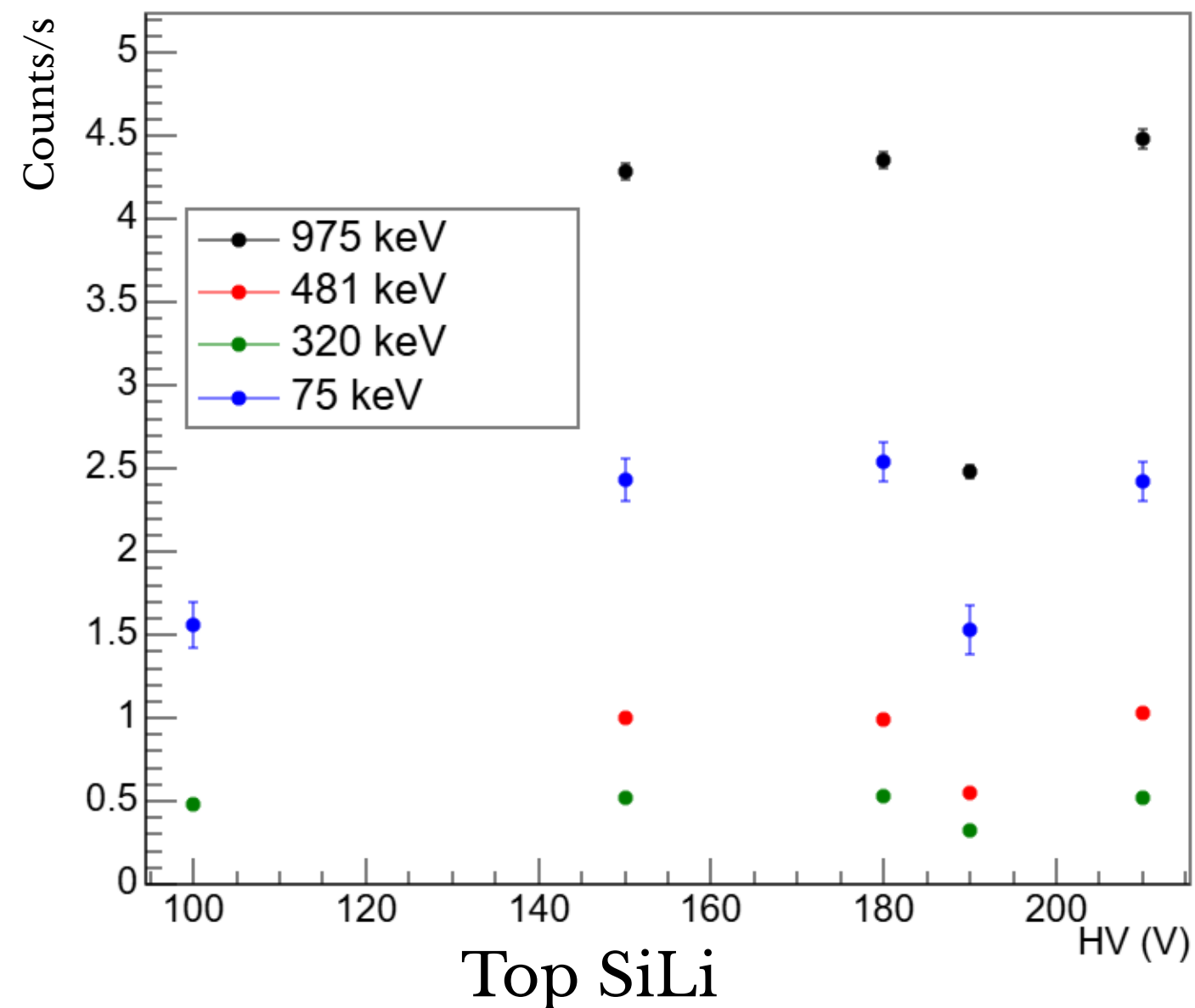
- 1/Fit gaussian on several peaks
- 2/Iteration to try to find the best chi2
- 3/Plot mean, **sigma** and height vs HV



Additional test: use diff function, change interval fit + initials parameters..

Analysis data runs at different HV

- 1/Fit gaussian on several peaks
- 2/Iteration to try to find the best chi2
- 3/Plot mean, sigma and **height (normalised)** vs HV

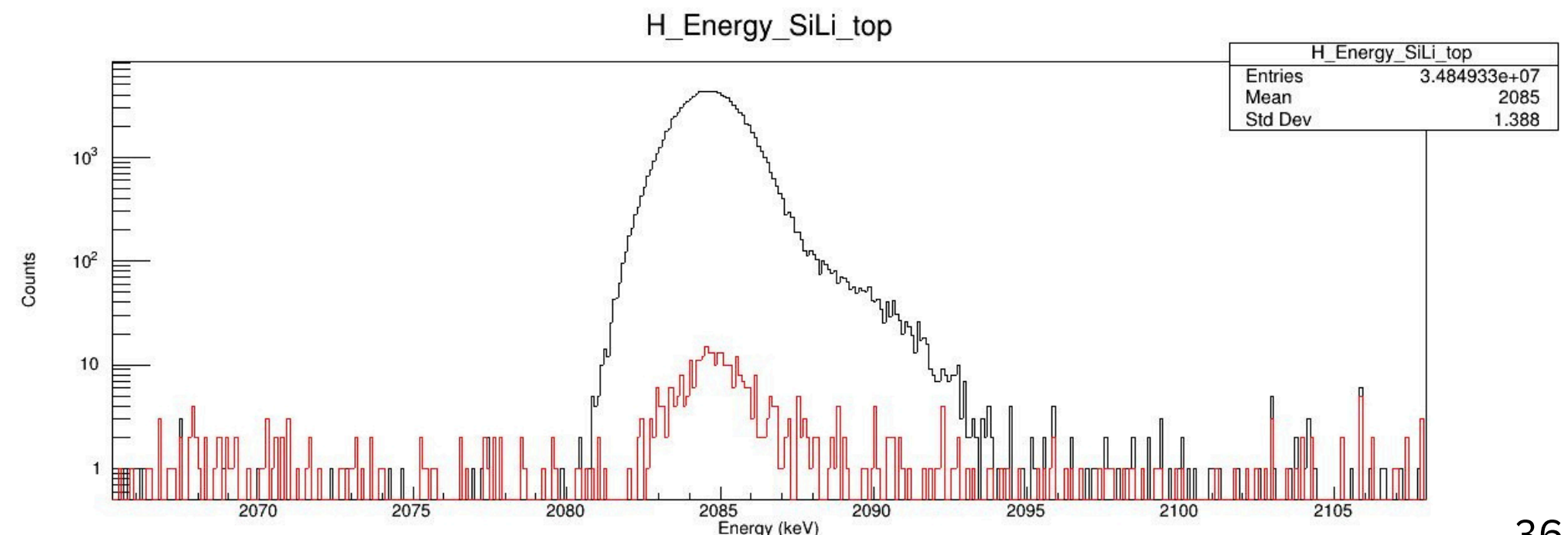


Issue fit for HV=100 for top, height normalised or not way too high-> several peaks also..
 Next steps: try to improve fit again, use gain correction with only physics peaks?

Removing Pulser

Purpose: pulser is sent at the same time in the data, to have a clean spectrum pulser has be removed from them. The pulser (113) is still in the data even if taking into account the trig of the channel 3 recording directly the pulser signal. So, in January the *removing condition* lied on a lower limit energy in the other detector to remove the remaining pulser contribution. This condition couldn't be reused be cause now a second pulser is sent at 200 keV.

Problem: Groups done by faster (trigger on 1 or 2 with 113 as a follower) does not contain the 3 signals each time the pulser is sent by the computer (~0.26%). Another cut has to be found regardless the energy.



^{32}P - run 111

Removing Pulser

Solution: Even if the pulser is not detected/triggered by faster for any reason, the frequency of the pulser should be stable and so we know when it should be in the data. A time window to remove data will be open at each period.

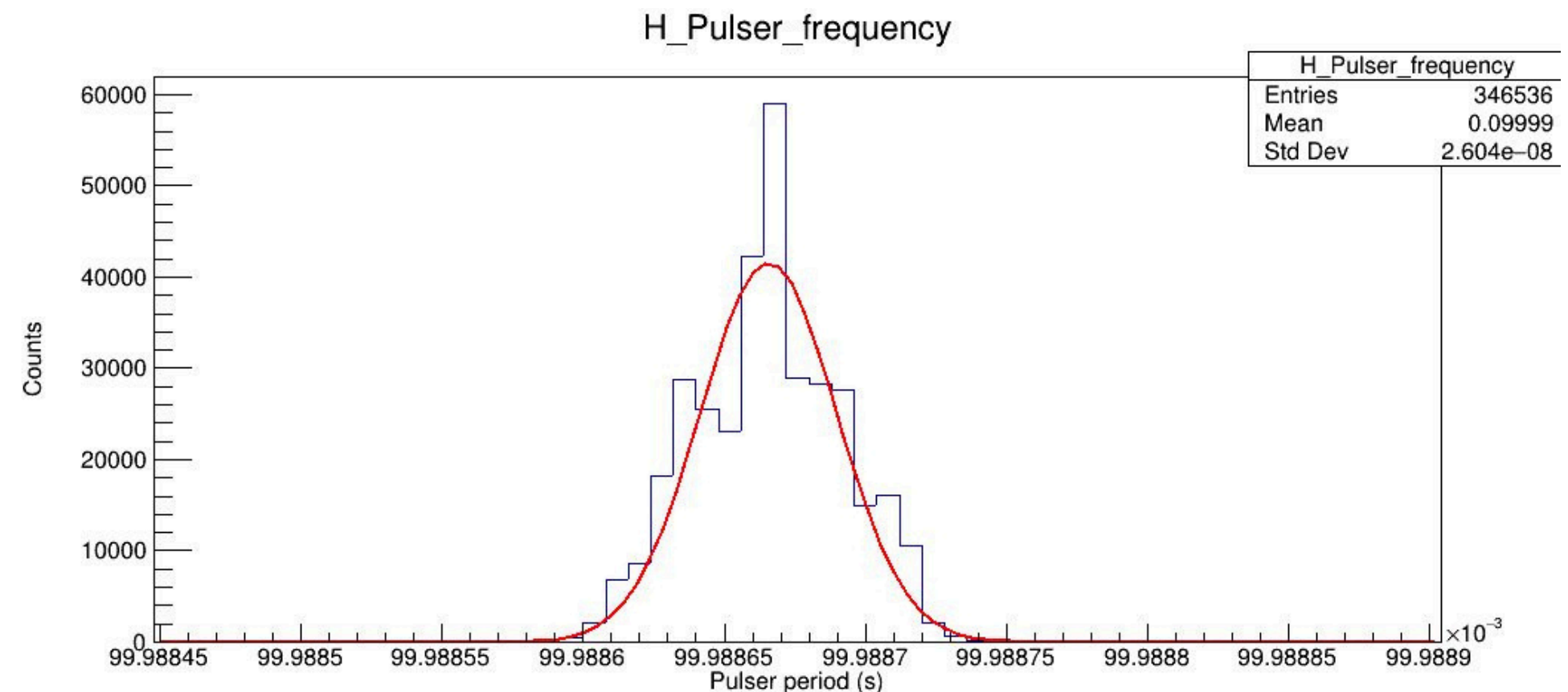
The first step of the analysis is to verify the frequency of the pulser (regardless the pulse height), the set value is 10 Hz = 100 ms. By plotting the time difference between pulser signals we obtain the pulser period/frequency:

$$T_{\text{pulser}} = 0.099\,988\,666\,(26)\text{ s}$$

$$f_{\text{pulser}} = 10.001\,133\,528\text{ Hz}$$

The uncertainty is the sigma of the distribution.

The pulser frequency which is not equal to 10 Hz strictly is not a problem but the real value and its dispersion could be important for the following.

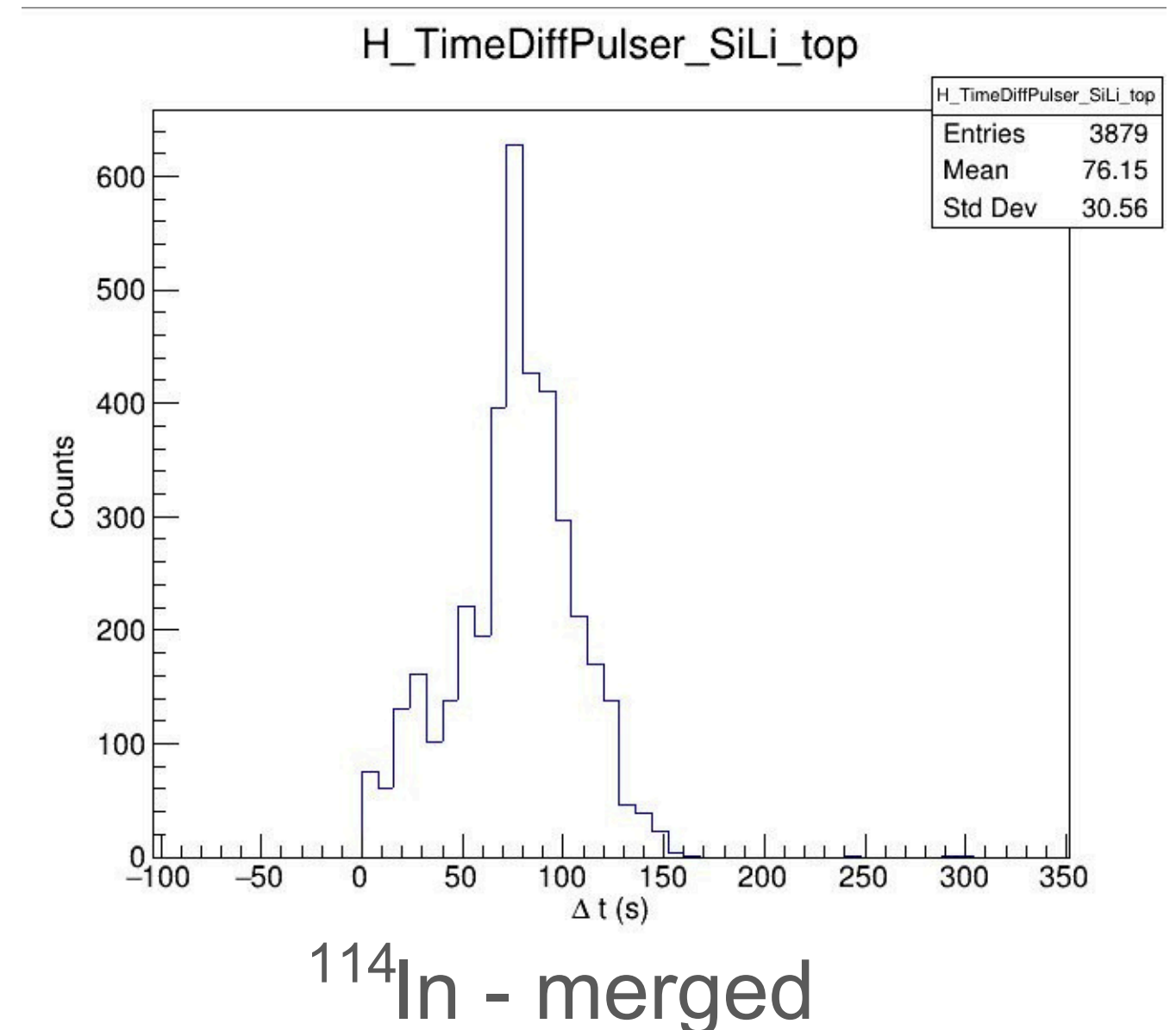


Removing Pulser

The second step consist of determining the time difference between the pulser signal detected in channel 3 and the SiLiS (driven by the walk). This estimation will determined the a part of the width of the time removing window.

By plotting the time difference between a SiLi and the pulser channel every pulser period for the remaining signals:

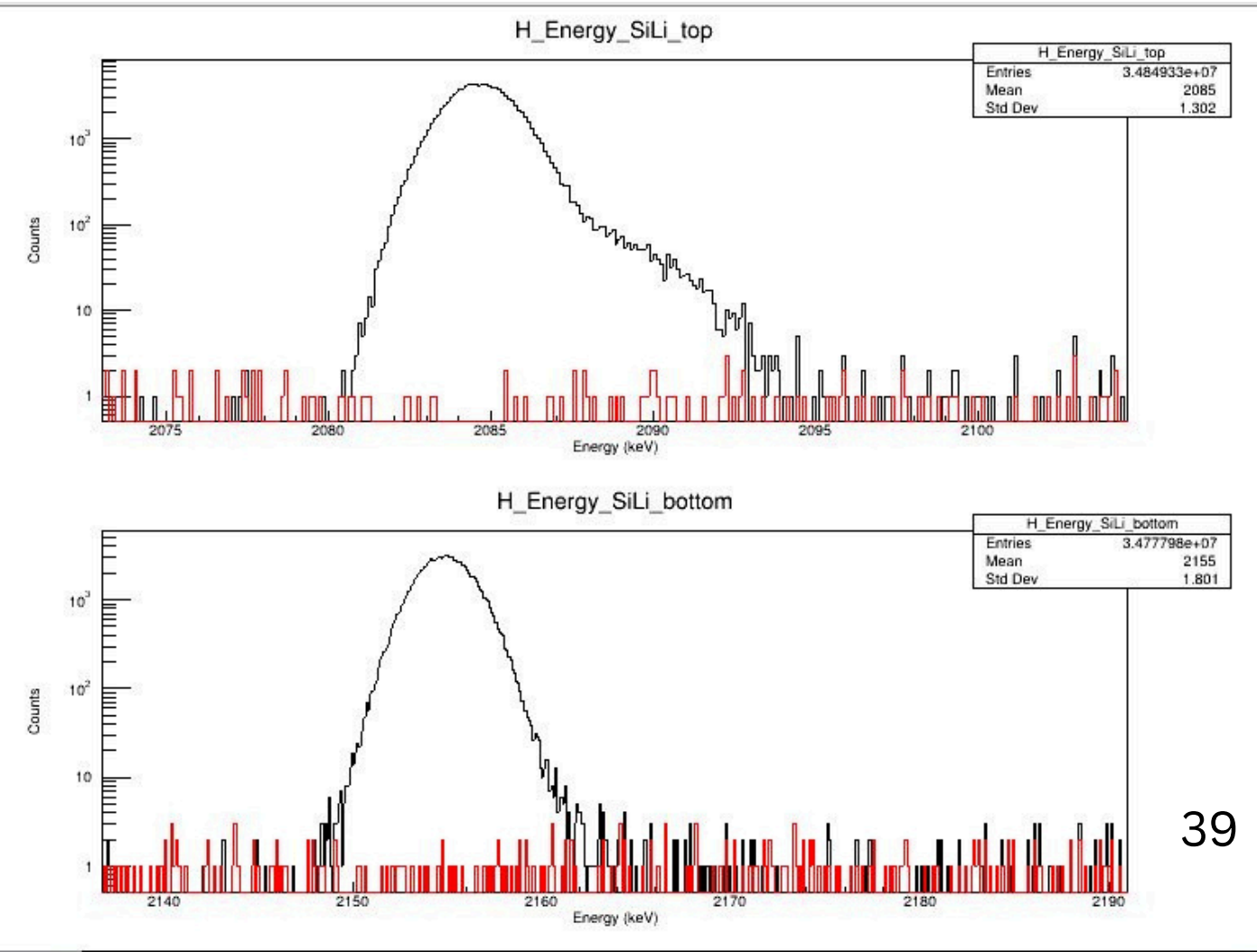
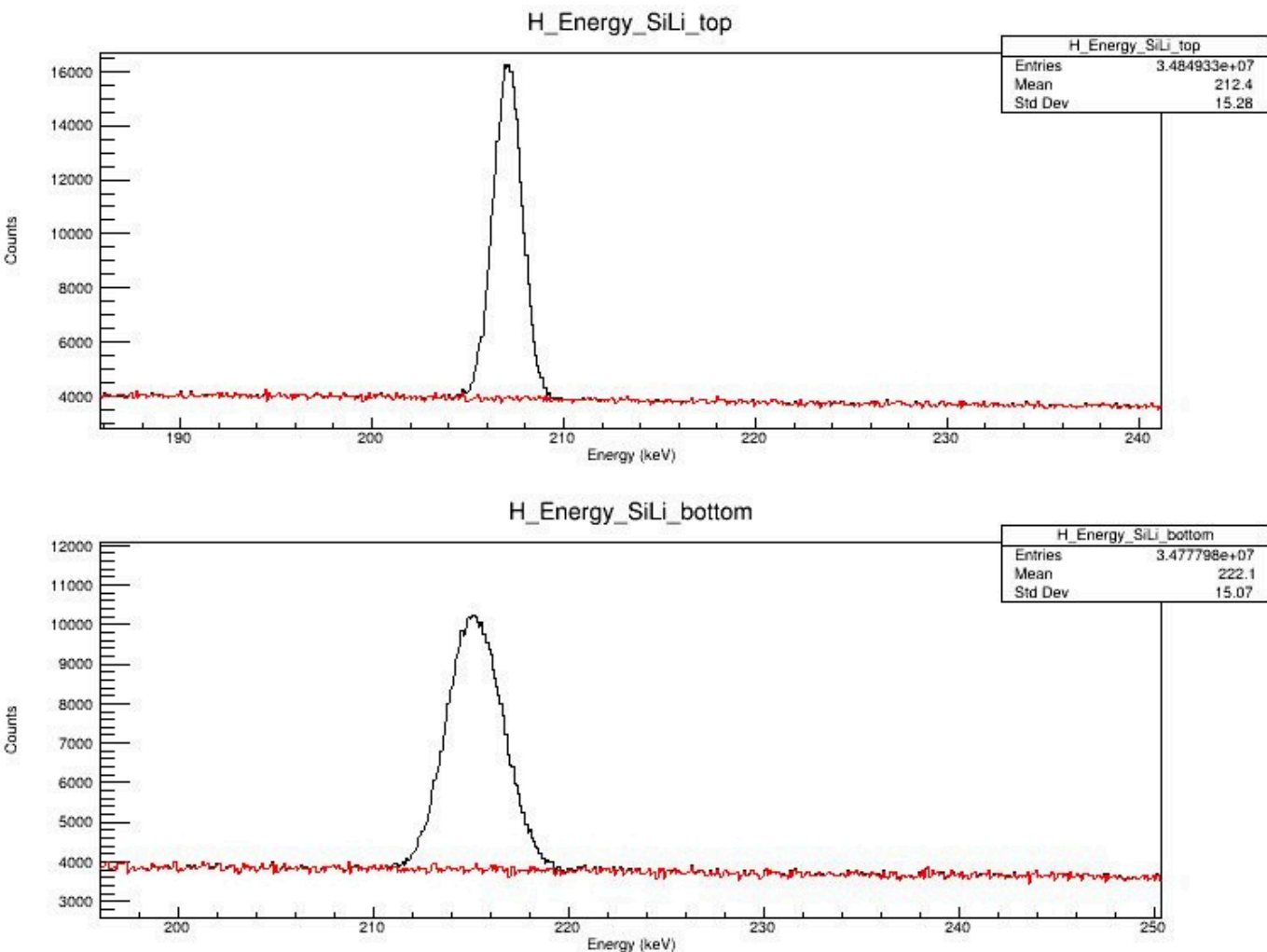
Removing window width = 400 ns
(larger window than is shown on the plot because at some point pulser channel trigger has been modified)



Removing Pulser

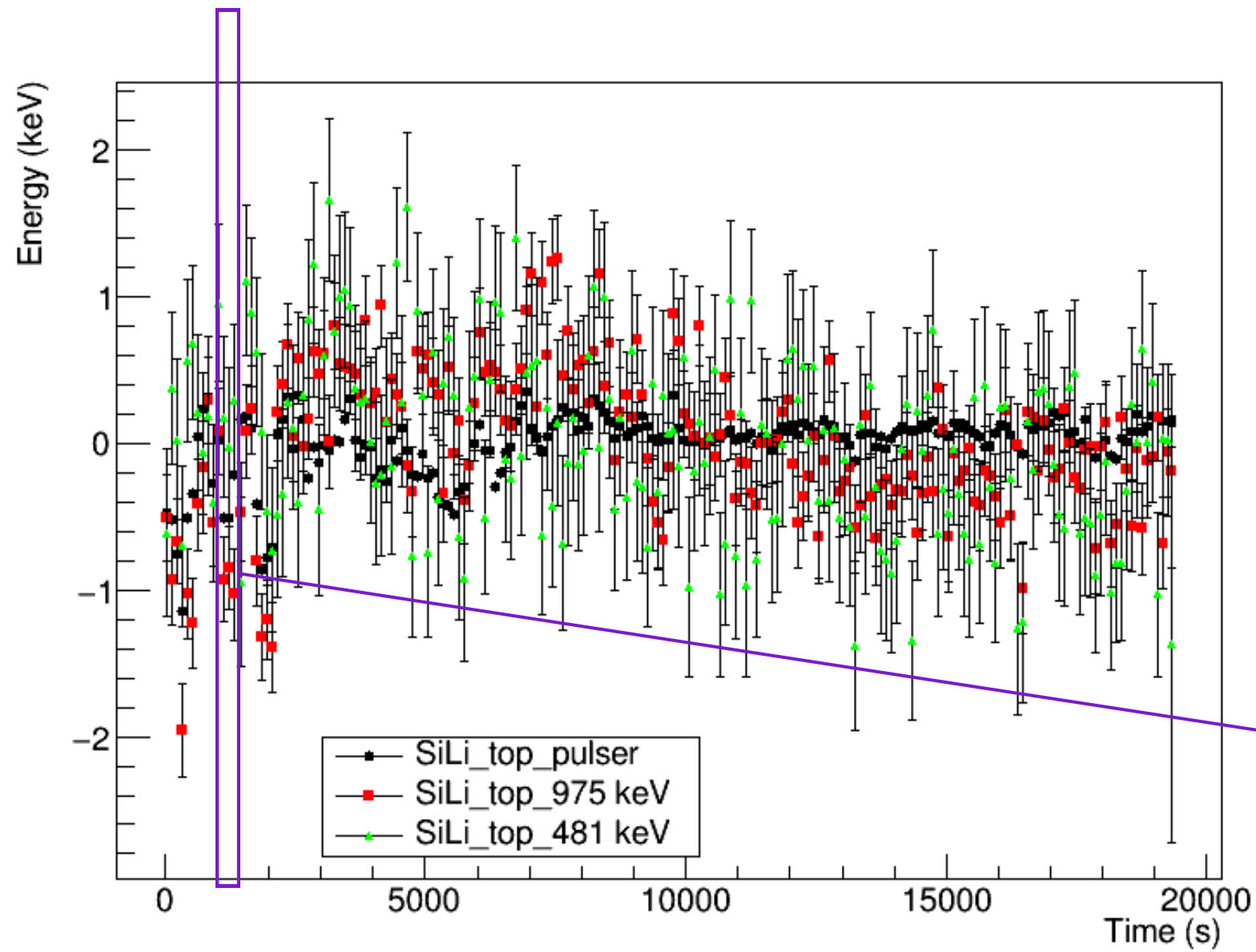
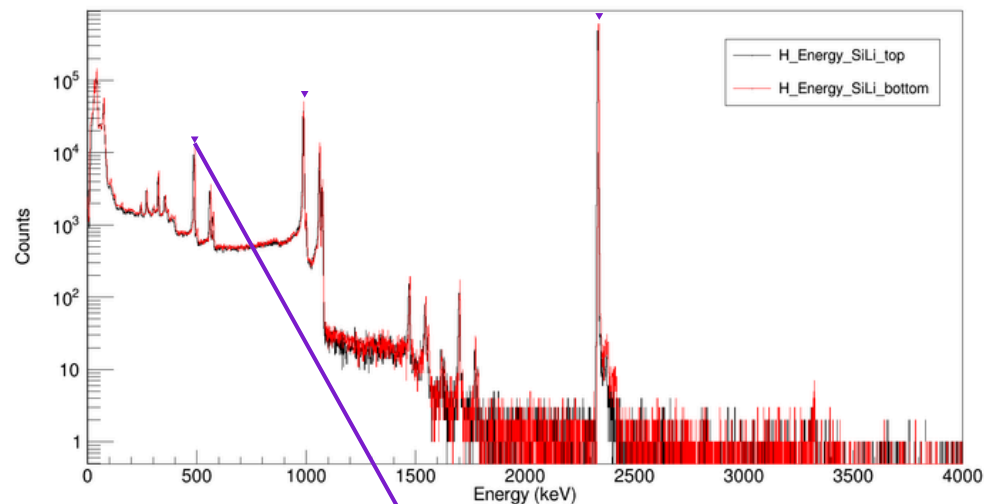
Result: Removing all the signal every pulser period in a time window of 200 ns (pileup flag is used). The full stat of 114In has also been checked and he pulser is fully removed.

No pulser in the 2 pulse regions after the cut:

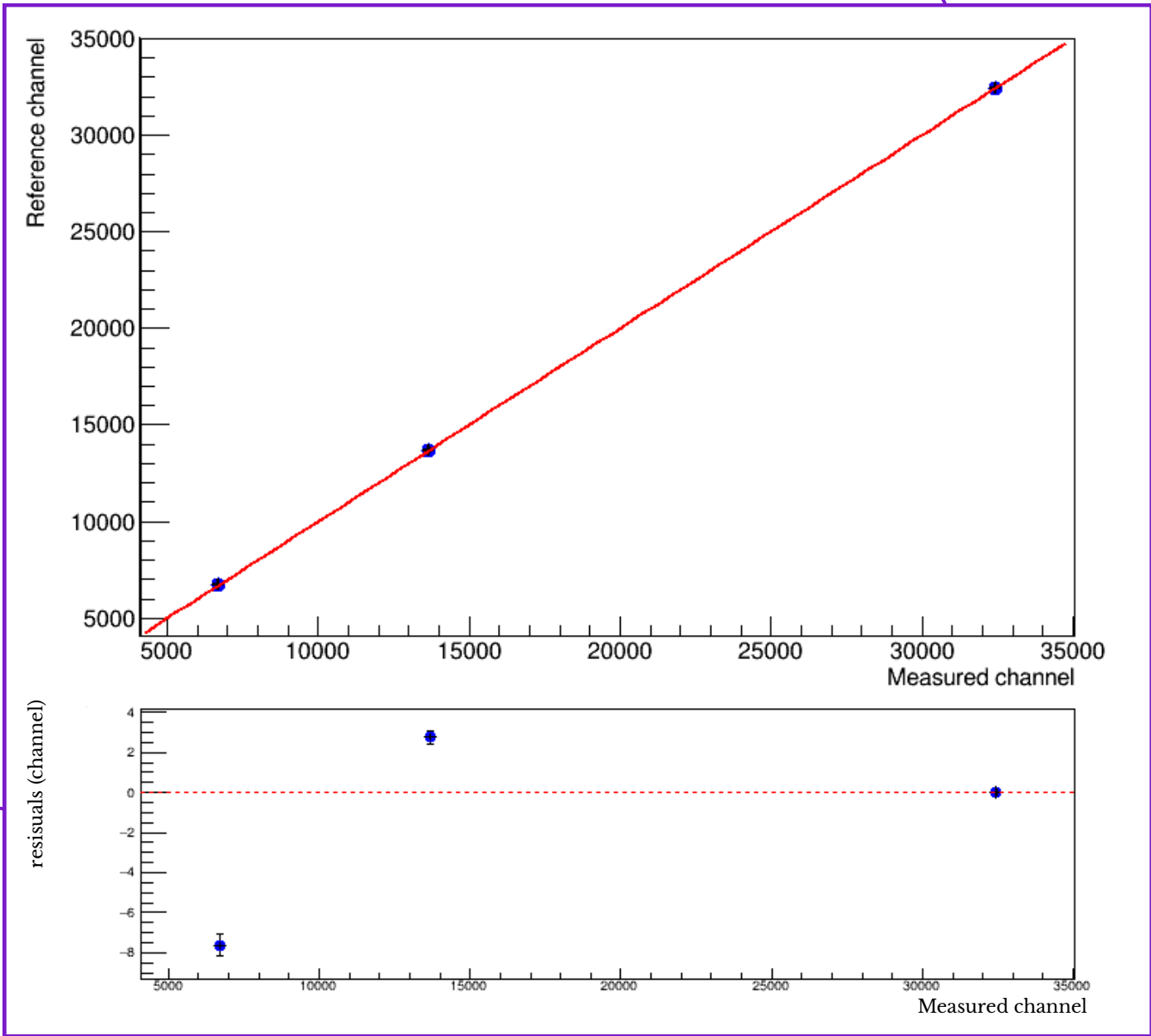


Gain correction with pulser

- 1/Use the three peaks to plot mean position in the slice vs reference position in run,
- 2/ fit with linear function
- 3/Apply function on each channel



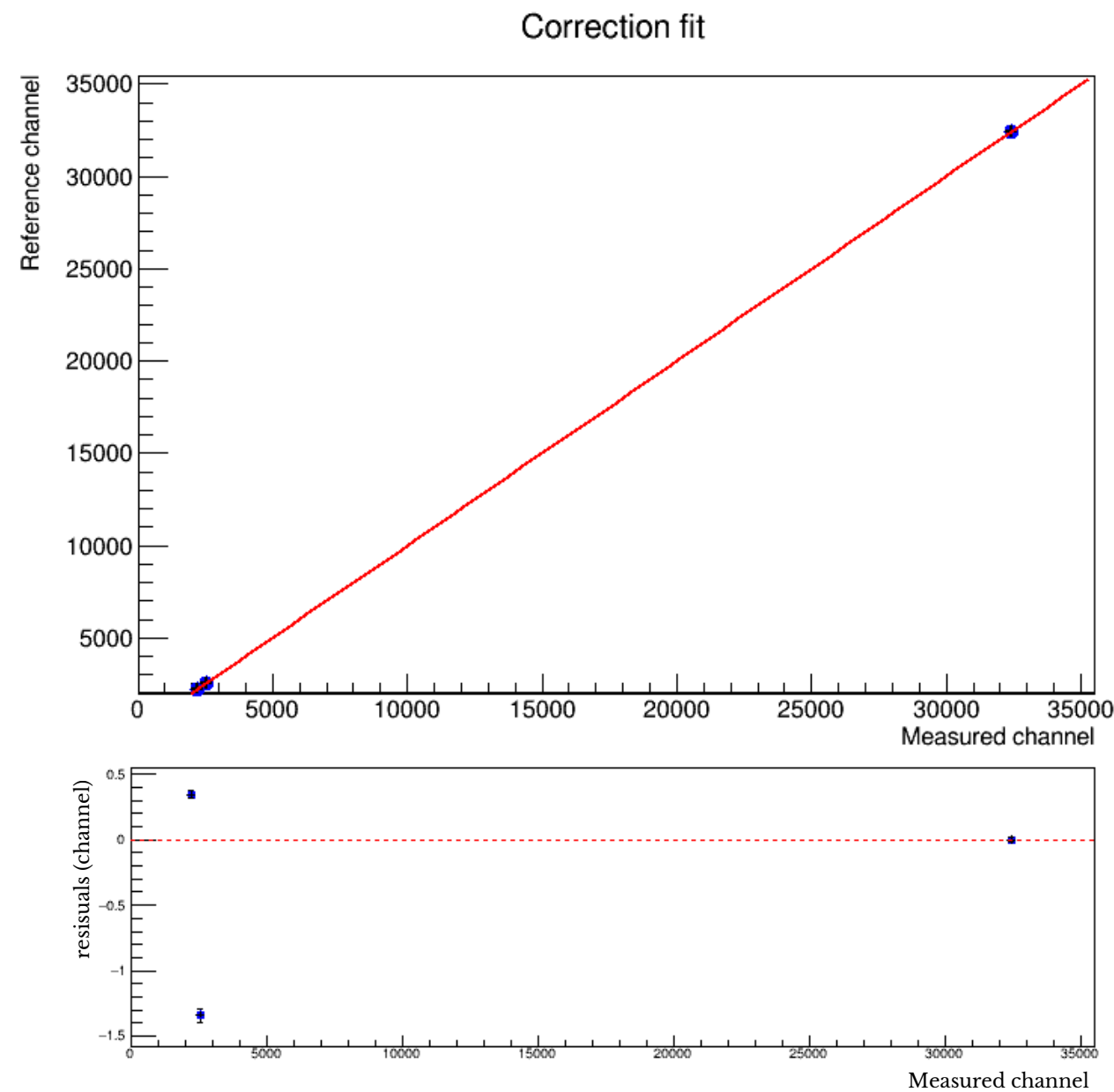
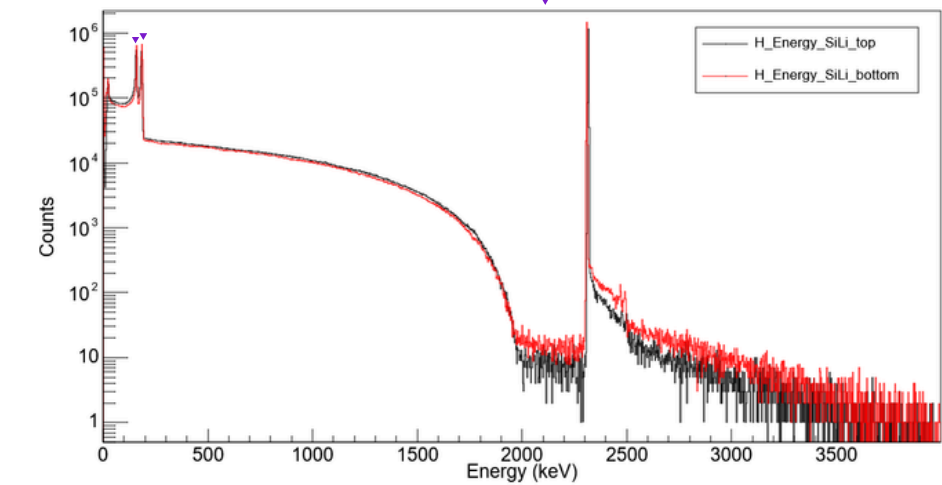
Top SiLi



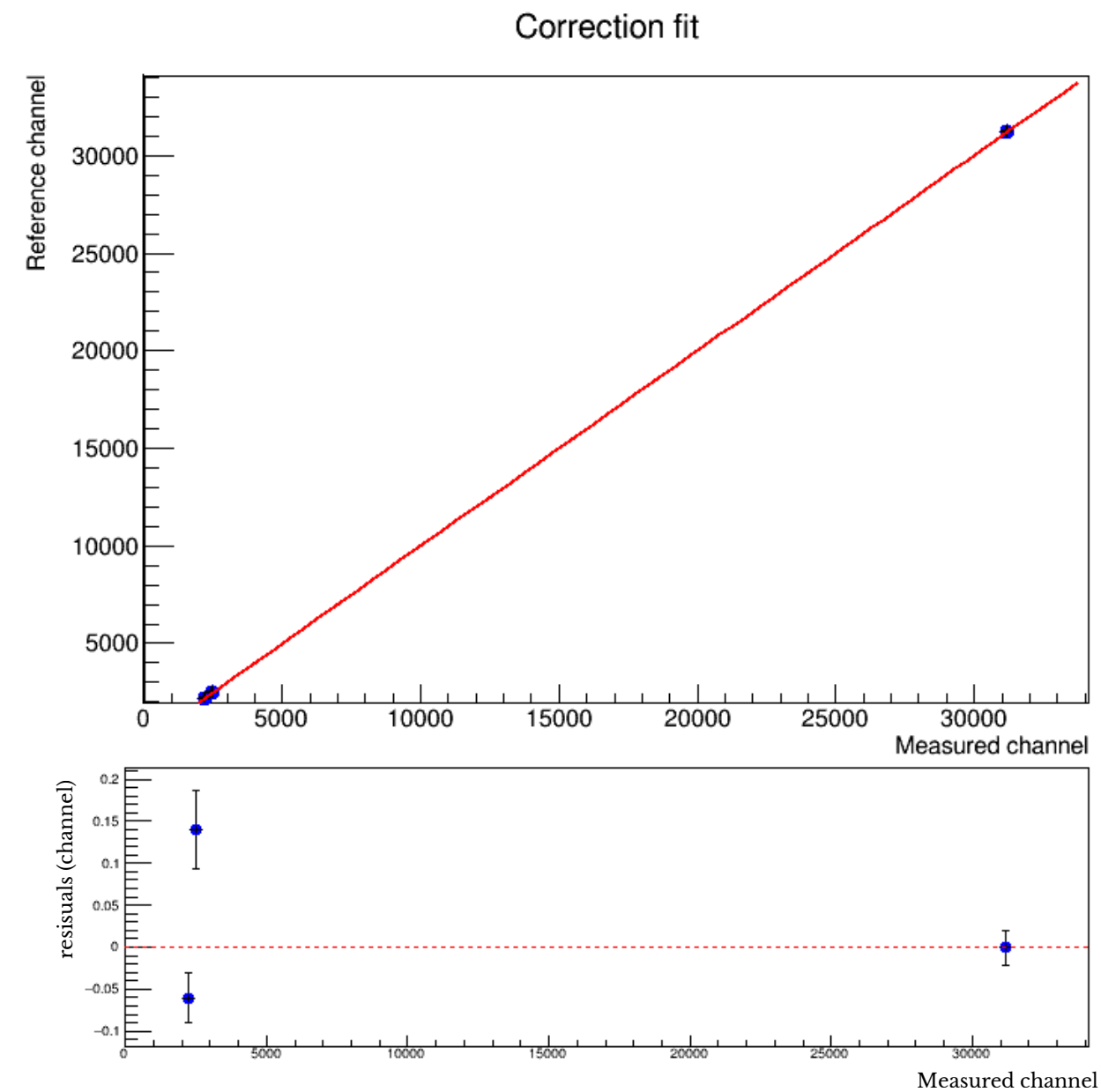
One example of correction function for slice 100s and binx=201

Gain correction with pulser

- 1/Use the three peaks to plot mean position in the slice vs reference position in run,
2/ fit with linear function
3/Apply function on each channel



Top SiLi



Bottom SiLi

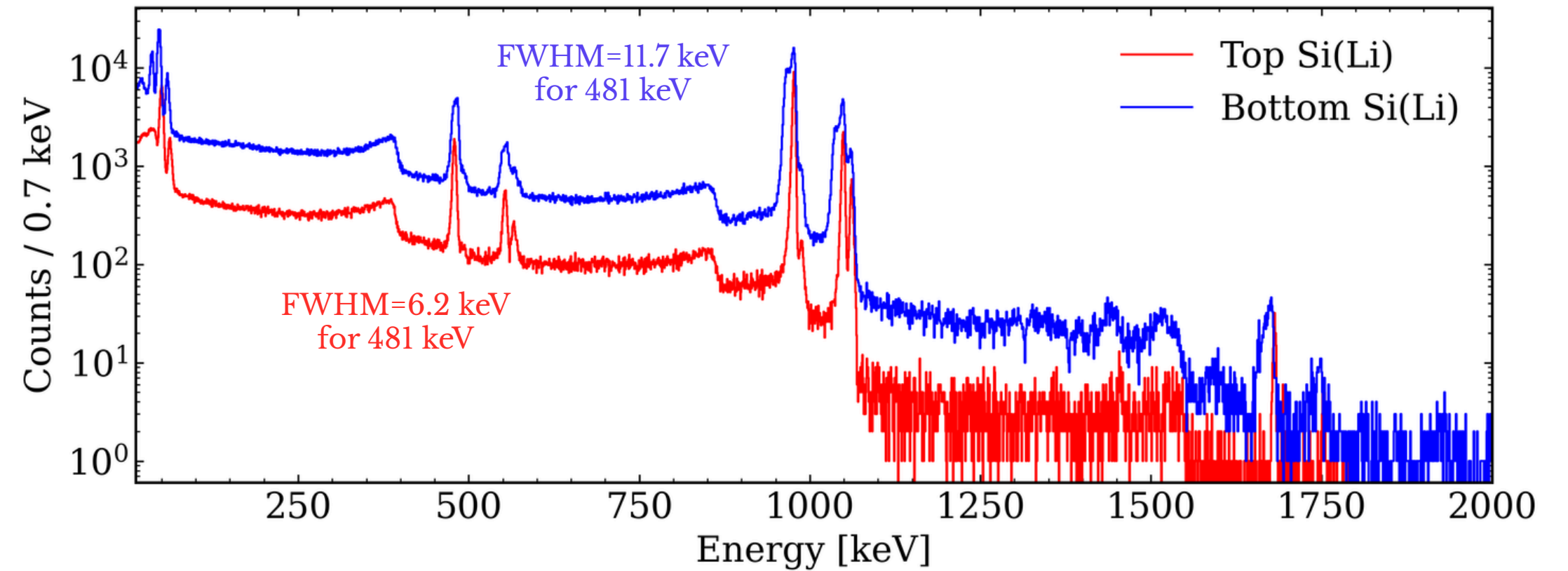
First data taking in February

Improvement of performance between September and February:

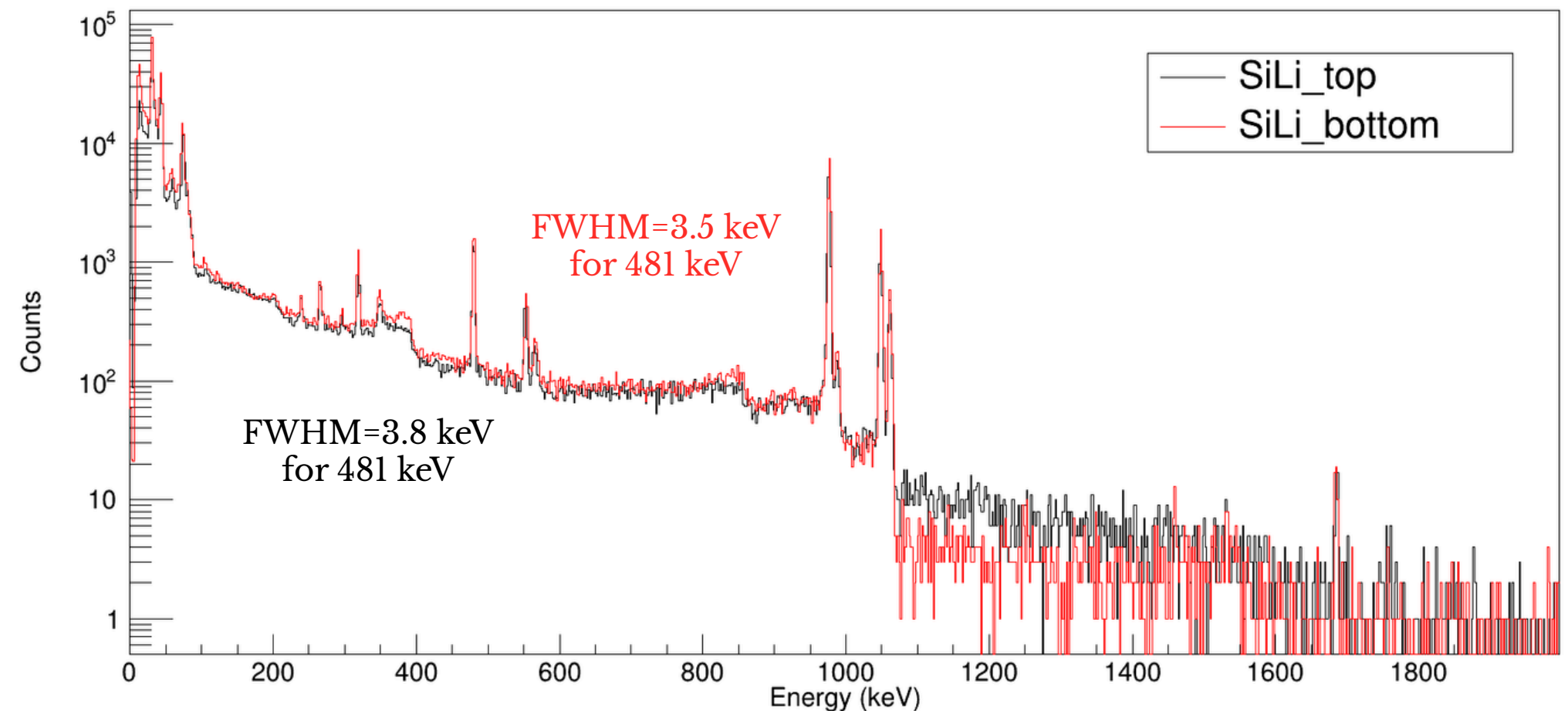
Better resolution and lower energy threshold



- Change of detectors S2->S3
- Optimization of FASTER settings (shaping time, threshold)



Spectrum of the ^{207}Bi calibration source in September 2025



Spectrum of the mixed calibration source in February 2026

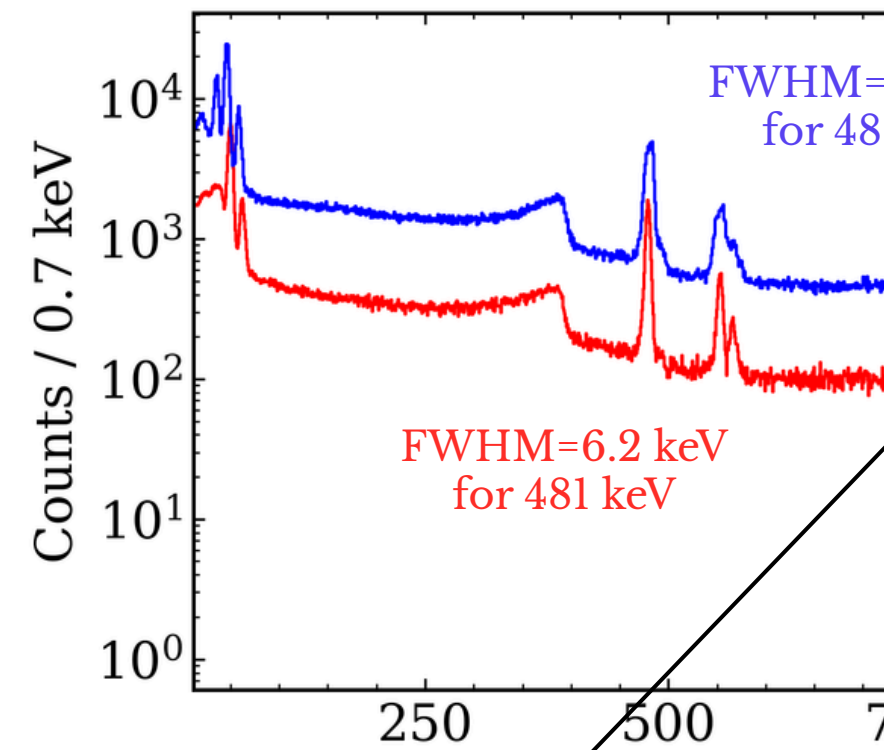
First data taking in February

Improvement of performance between September and February:

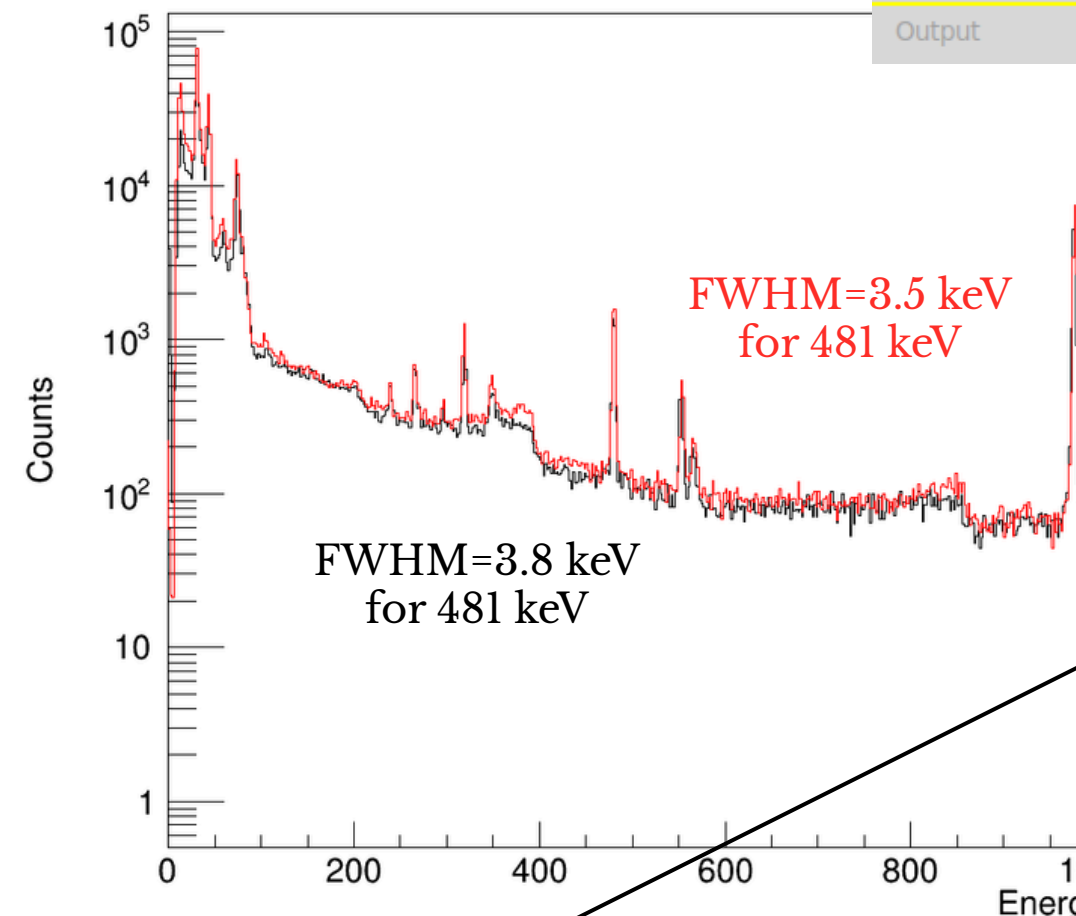
Better resolution and lower energy threshold



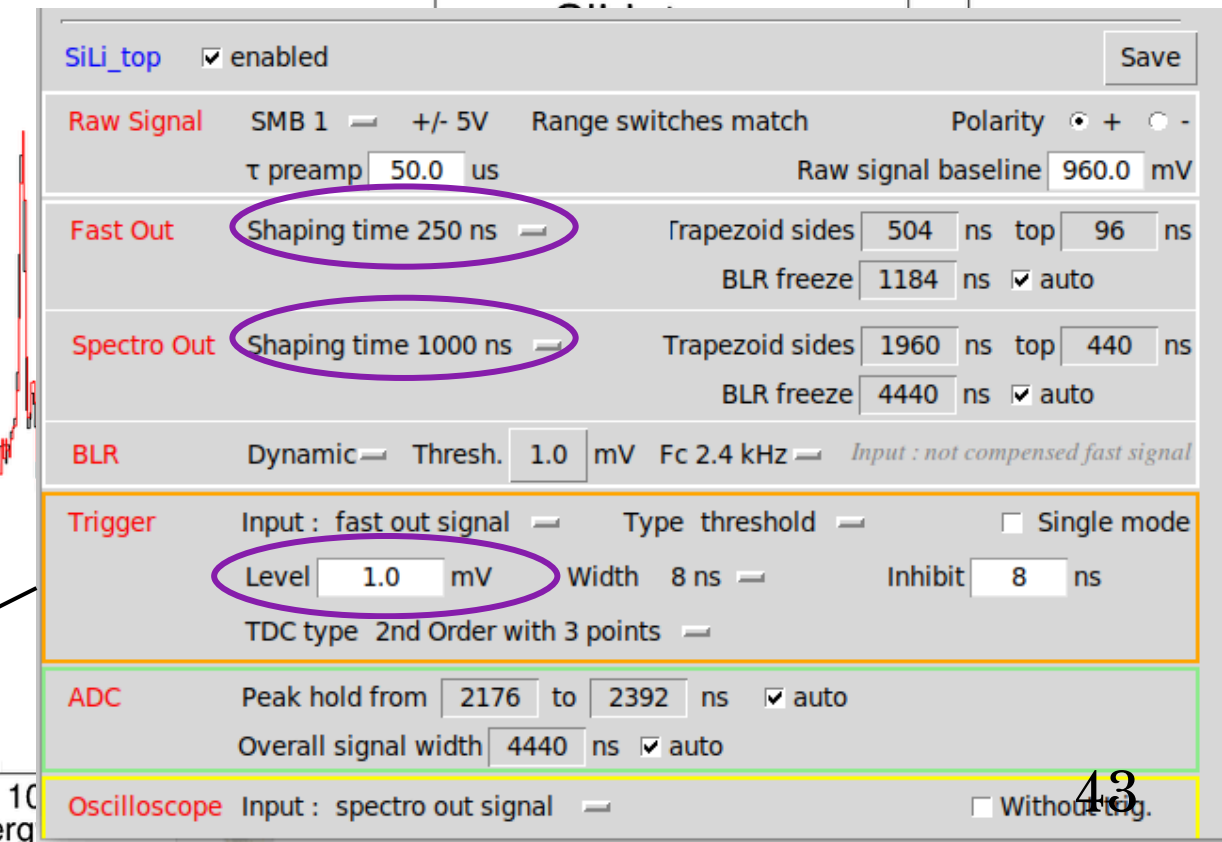
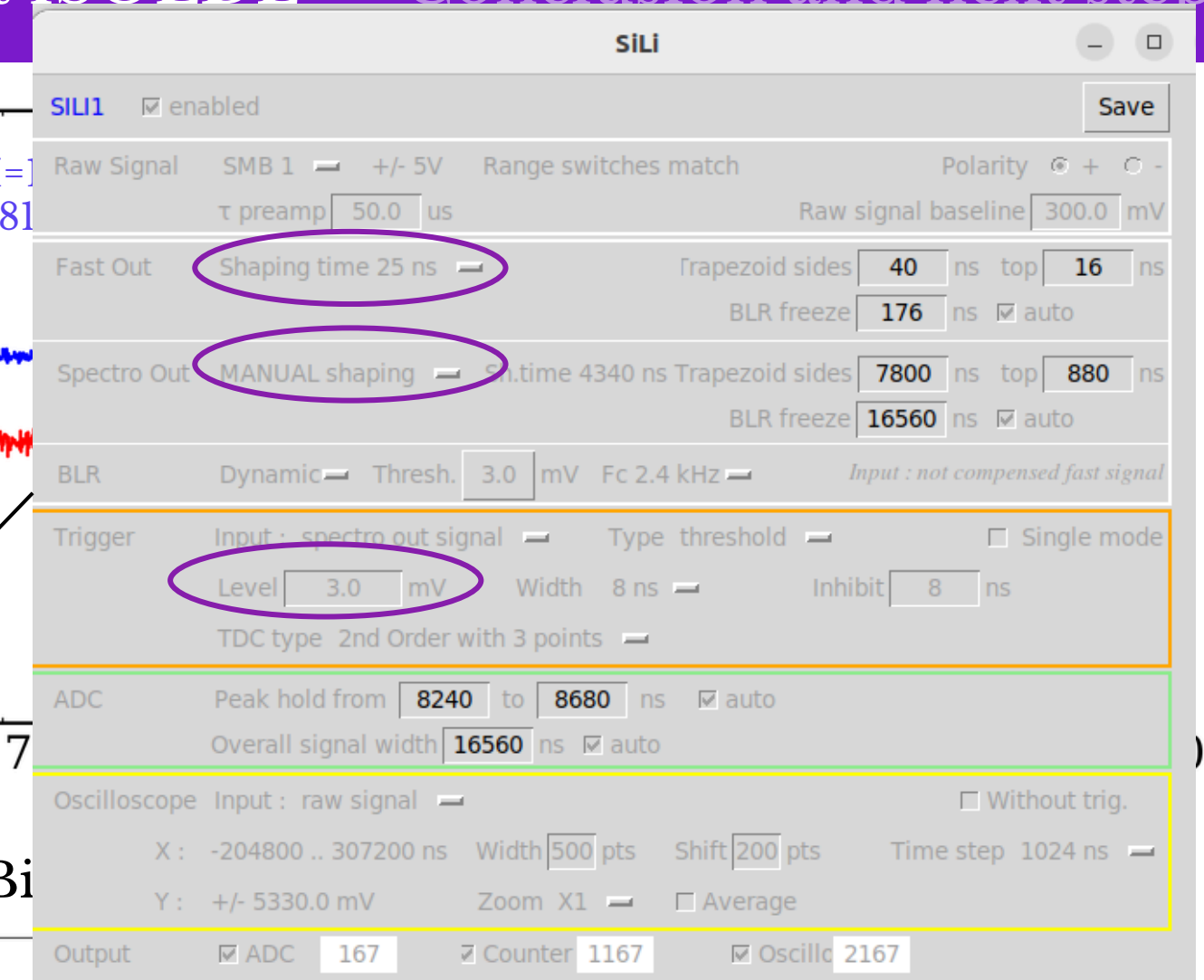
- Change of detectors S2->S3
- Optimization of FASTER settings (shaping time, threshold)

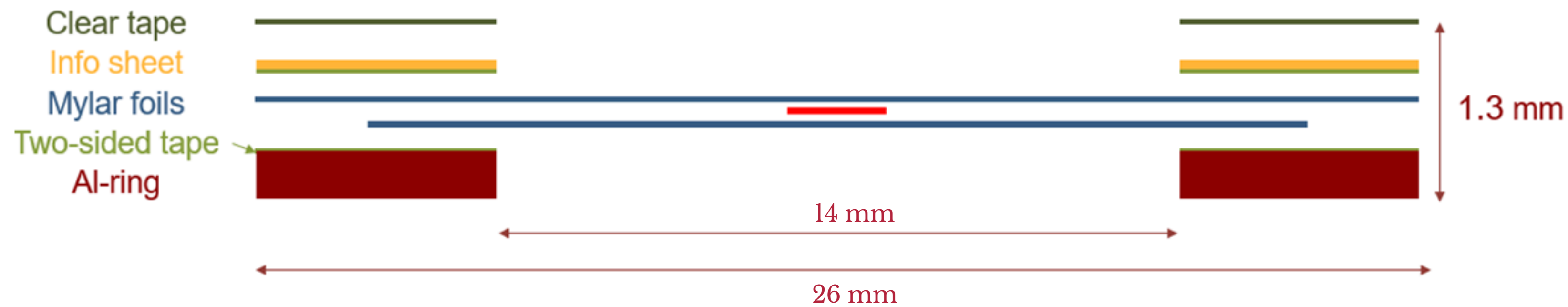


Spectrum of the 207Bi

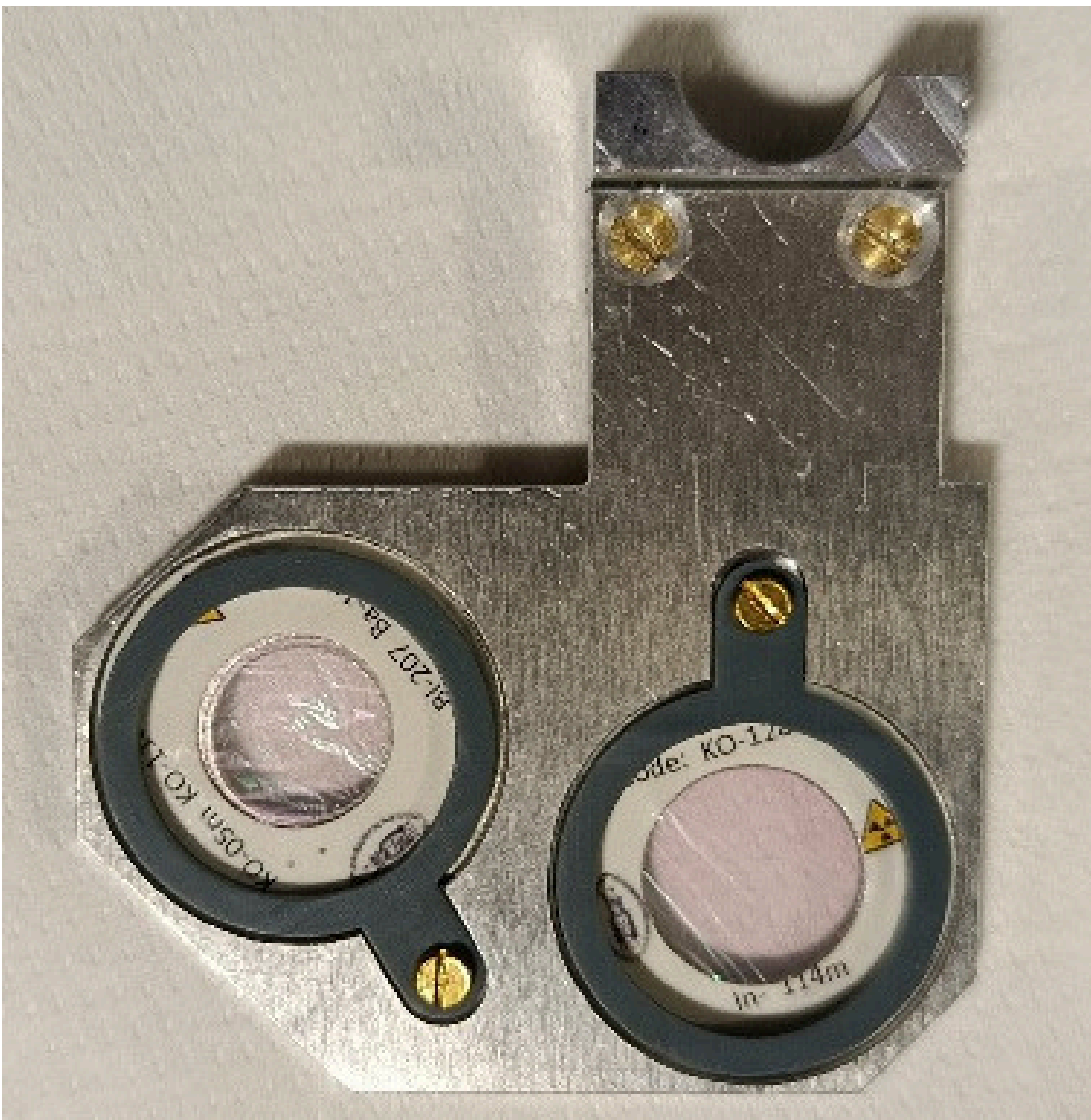


Spectrum of the mixed calibration source in February 2026





Source diameter and magnetic field value

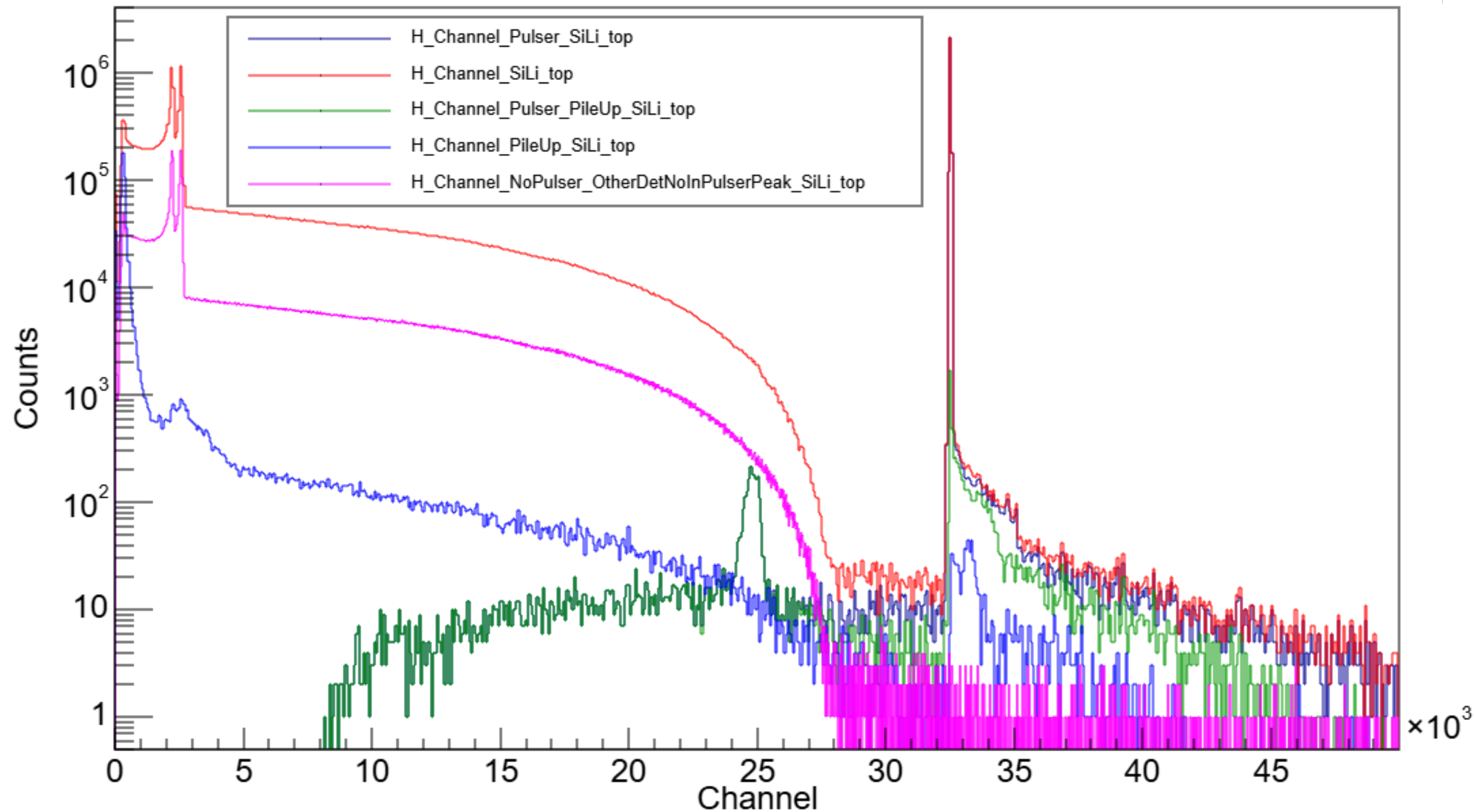


Pour E=2 MeV

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

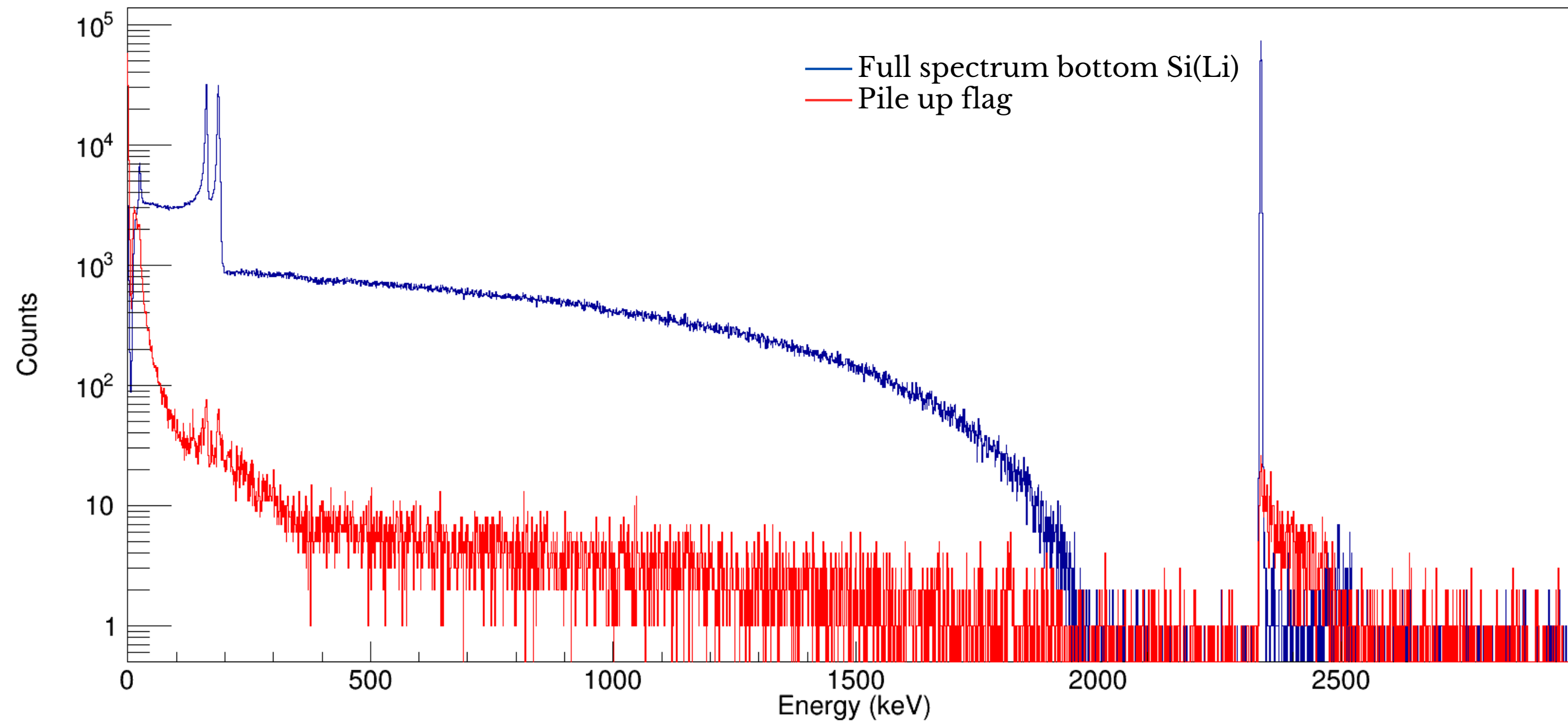
$$r_{\text{det}} = 12mm \quad r_{\text{source}, \text{}^{114}\text{In}} = 6,9mm \quad r_{\text{source, mixed}} = 6,15mm$$

Cuts Pulser details

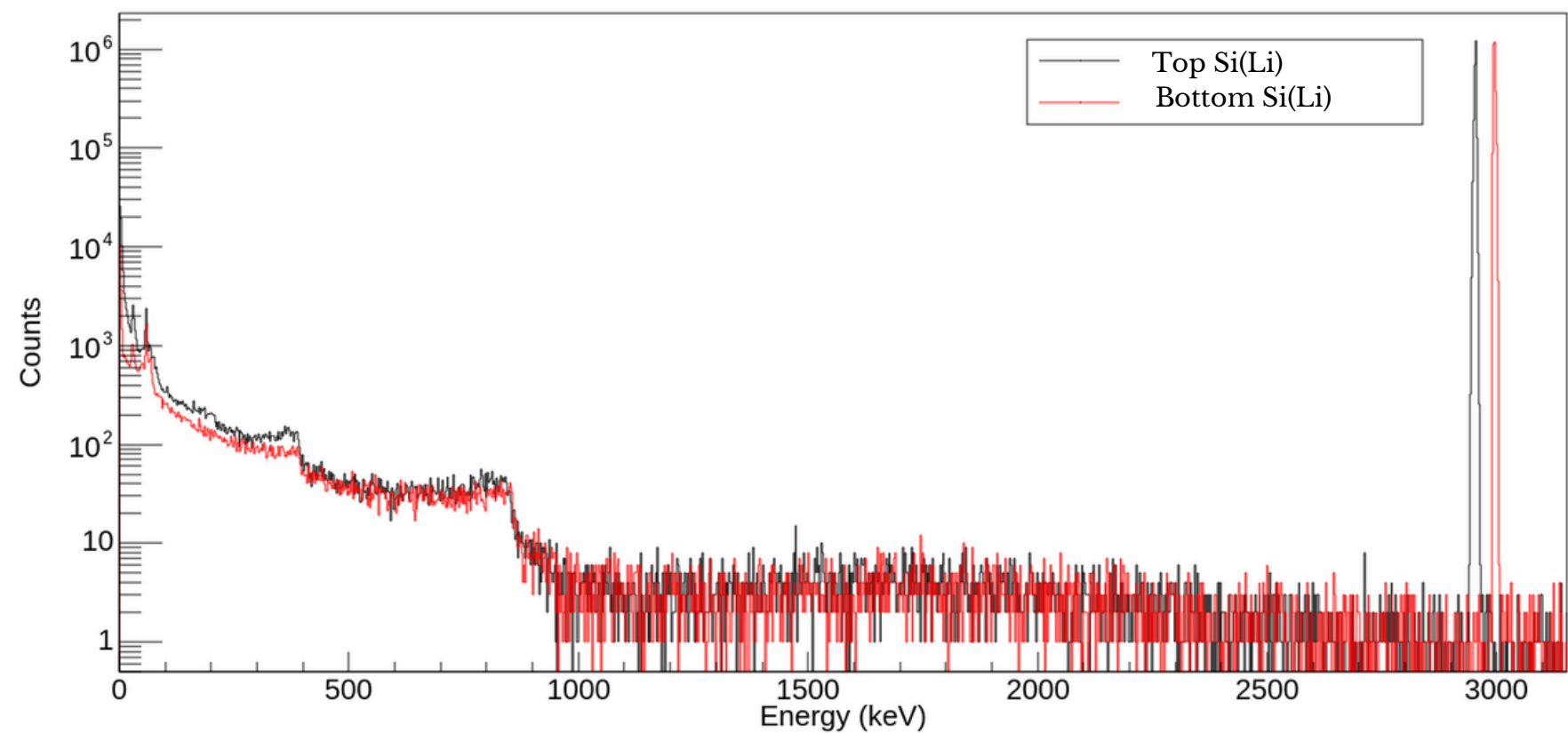


Spectrum with different cuts for pile up and pulser for top SiLi

Pile up model with FASTER

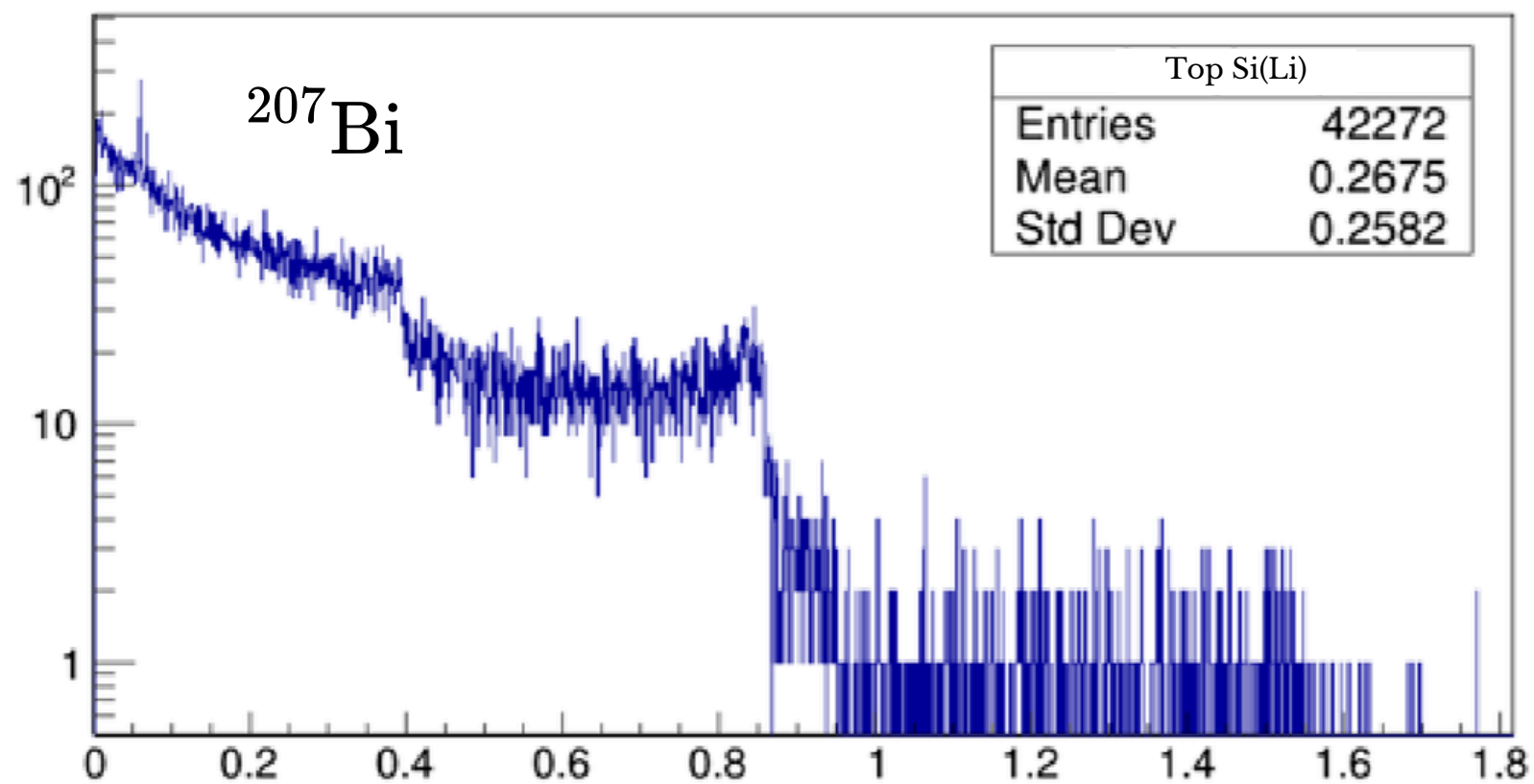


Background measurement



HV	−210 V/ − 315 V
T	−45°C
Source	Mixed bgk
Activity	1 kBq

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



Top Si(Li) with 30 million events simulated for 5mm of tungsten

Systematic uncertainties on W M 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/A_c			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		±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