Data Analysis Intercomparison

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Exercise

- Perform energy and efficiency calibration, identify radionuclides, and determine their activities

- Tasks:

  energy calibration,

  efficiency curve,

  radionuclide identification,

  activity calculation

- All data were provided

Sample

A soil sample was collected from an unspecified location. The sample was sieved through a 2 mm mesh, dried, and homogenized.
For measurement, **(475.36 ± 0.01) g of the dried soil** was packed into a polypropylene container.

The container was filled completely and then vacuum-sealed.

More than three weeks elapsed between sealing the container and performing the measurement

The container has a diameter of 92 mm, a bottom thickness of 1.3 mm, and a sidewall thickness of 1.8 mm.

The final height of the soil in the container is approximately 50 mm

Detector

High Purity Germanium detector

Planar

The detector’s entrance window is made of 0.5 mm carbon epoxy

Measurement

The sample was placed directly on top of the detector

The sample was measured for 1102549 seconds,

with a **live time of 1102212 seconds**

Background:

No sample for 855667 seconds,

with a **live time of 855522 seconds**

Energy calibration: Sample

1st iteration

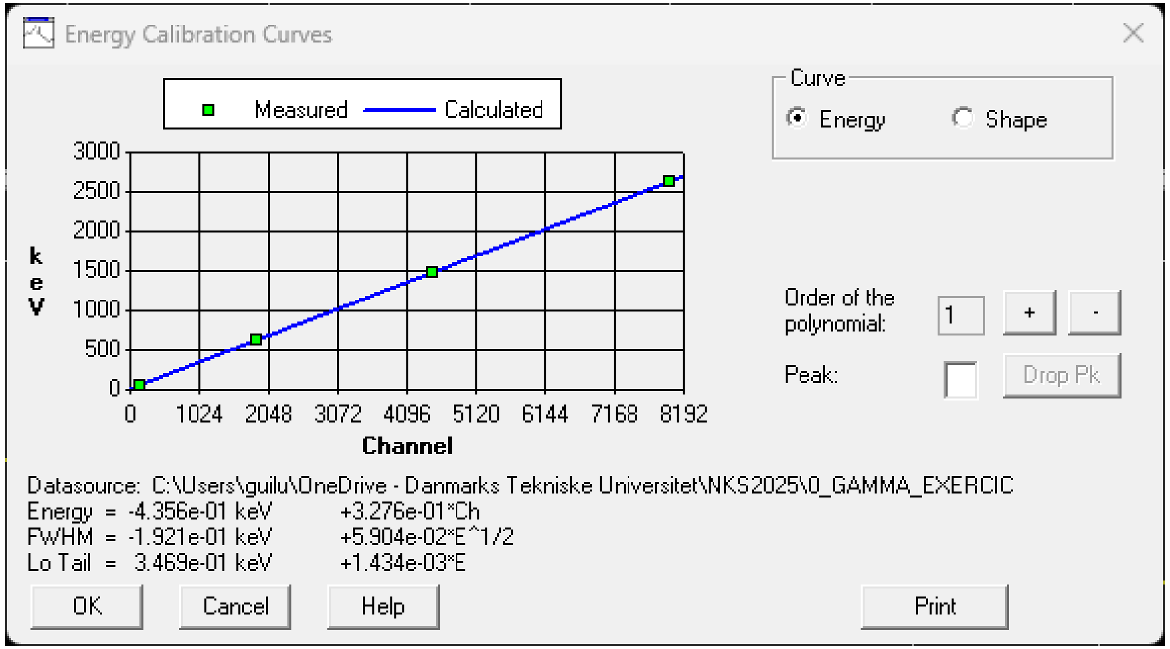
K-40: 1460.822 keV

Tl-208: 2614.511 keV

2nd iteration

Pb-210: 46.539 keV

Bi-214: 609.312 keV



Energy calibration: Background

1st iteration

Anni: 511 keV

K-40: 1460.822 keV

Tl-208: 2614.511 keV

2nd iteration

Ge-75m: 139.68 keV

Cd-114 [Cd-113(n,γ)]: 558.46 keV

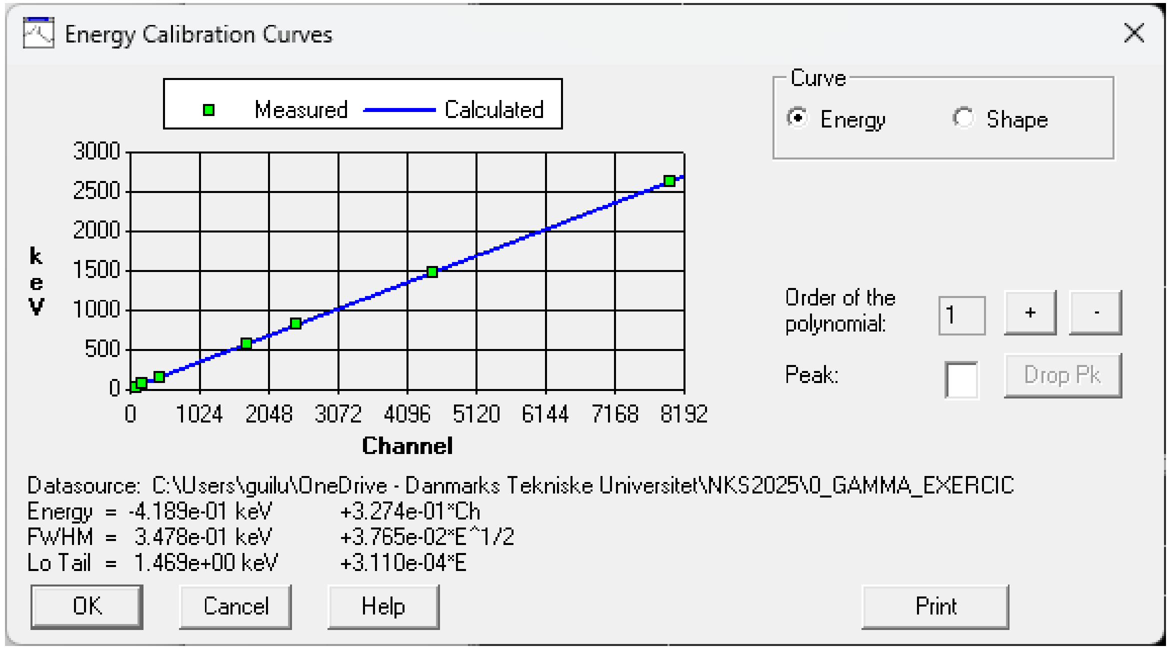
3rd iteration

Ge-73m: 53.44 keV

4th iteration

CdKα1: 23.17 keV

Pb-206 [Pb-206(n,γ)]: 803.06 keV



Full Energy peak efficiency

Nuclide	Energy [keV]	FEP Efficiency	Unc. [%]
Pb-210	46.54	0.033327	4.06
Am-241	59.54	0.046425	3.08
Cd-109	88.03	0.061718	3.08
Co-57	122.06	0.059791	3.18
Te-123m	158.97	0.052882	3.08
Sn-113	391.7	0.024004	3.08
Sr-85	514.01	0.019074	3.08
Cs-137	661.66	0.014901	3.08
Y-88	898.04	0.011741	3.08
Co-60	1173.2	0.009232	3.08
Co-60	1332.5	0.008295	3.08
Y-88	1836.1	0.006363	3.08

Several options:

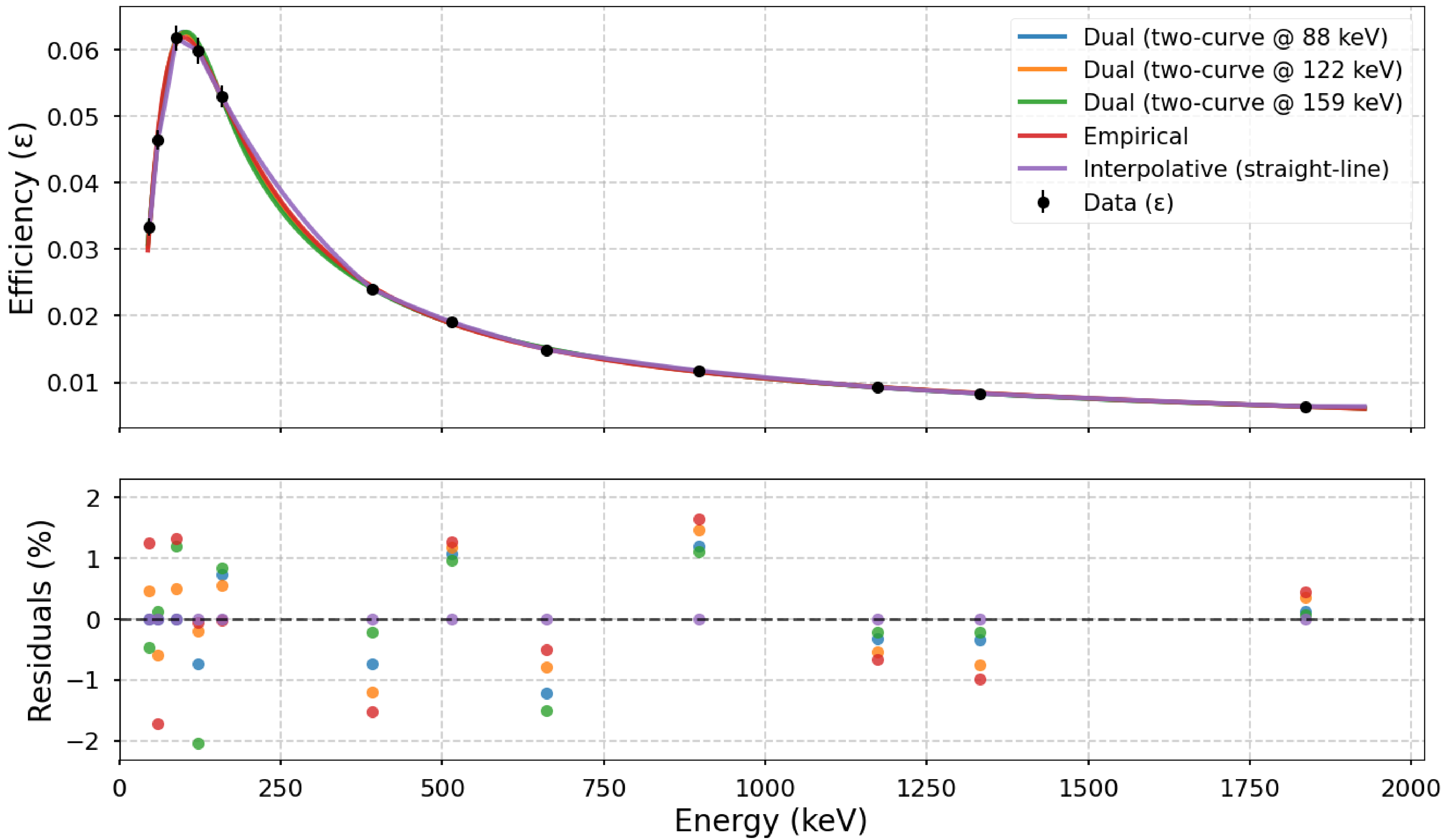
“Empirical”

“Dual”

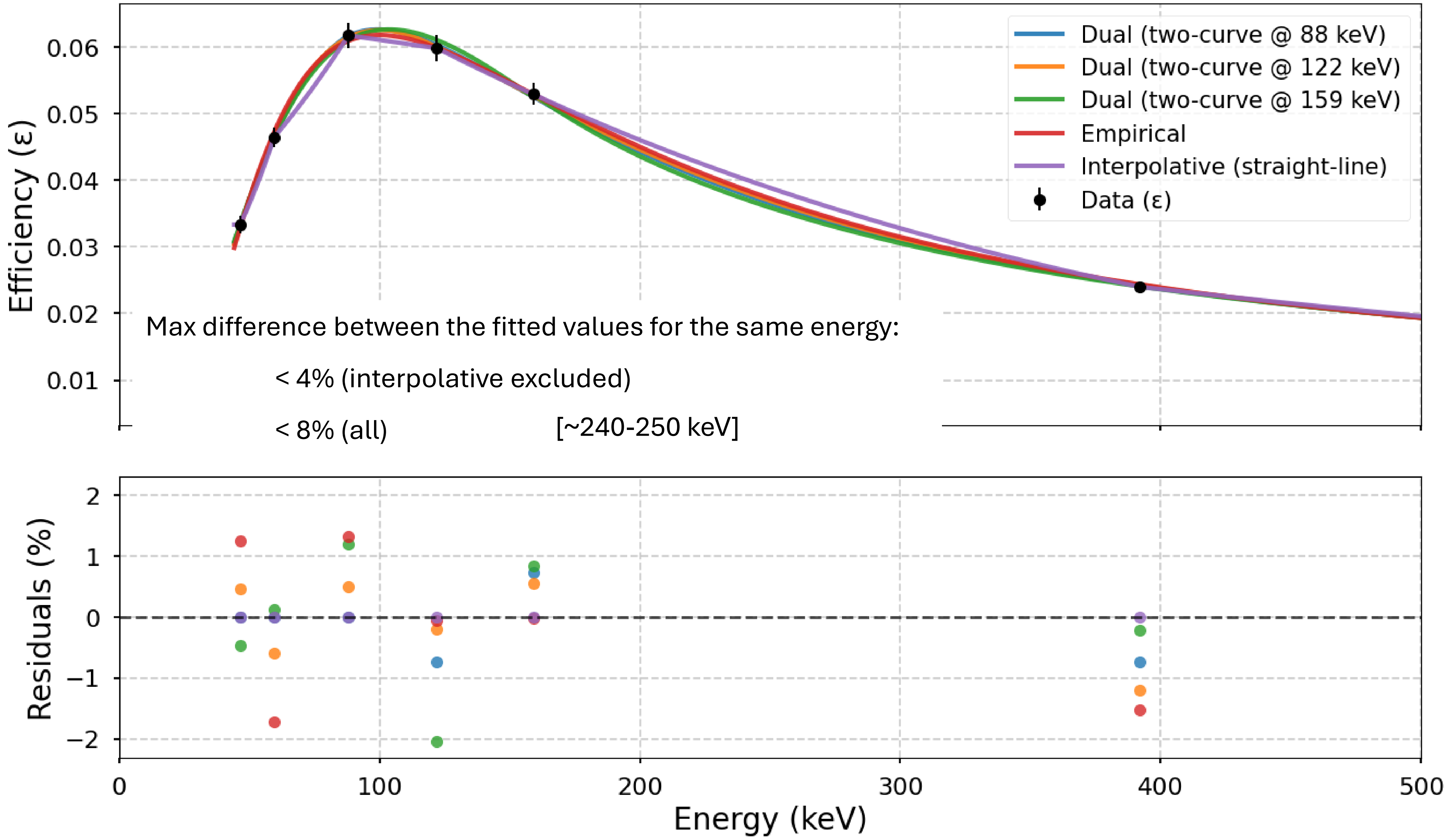
Polynomial

Interpolation

Efficiency Calibration Model Comparison



Efficiency Calibration Model Comparison



Max difference between the fitted values for the same energy:

< 4% (interpolative excluded)

< 8% (all) [~240-250 keV]

FEP efficiency curve: coincidence summing effect

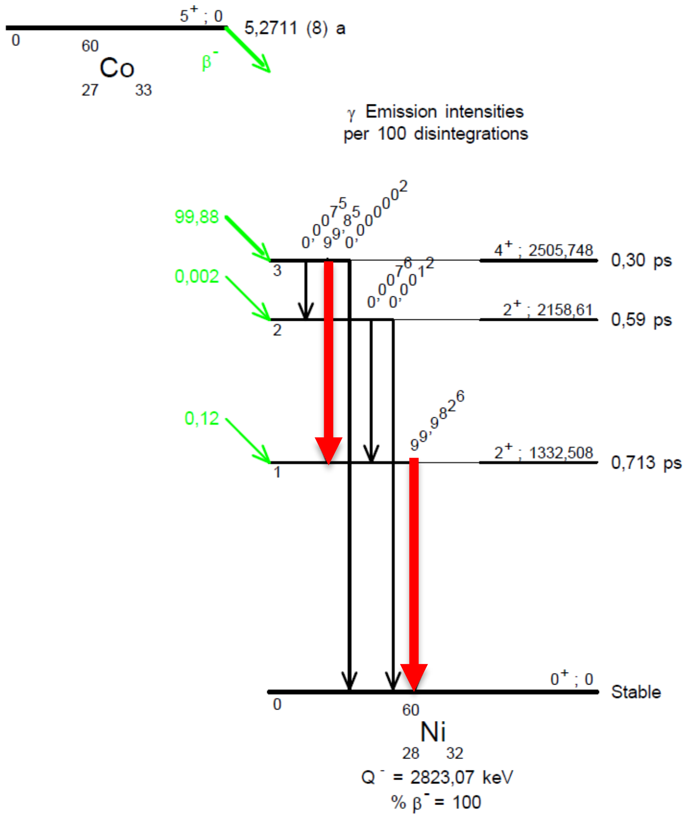
Calculated using EFFTRAN

Vidmar, T. 2005. *EFFTRAN - a Monte Carlo efficiency transfer code for gamma-ray spectrometry*.

Nuclear Instruments and Methods A 550, 603-608.

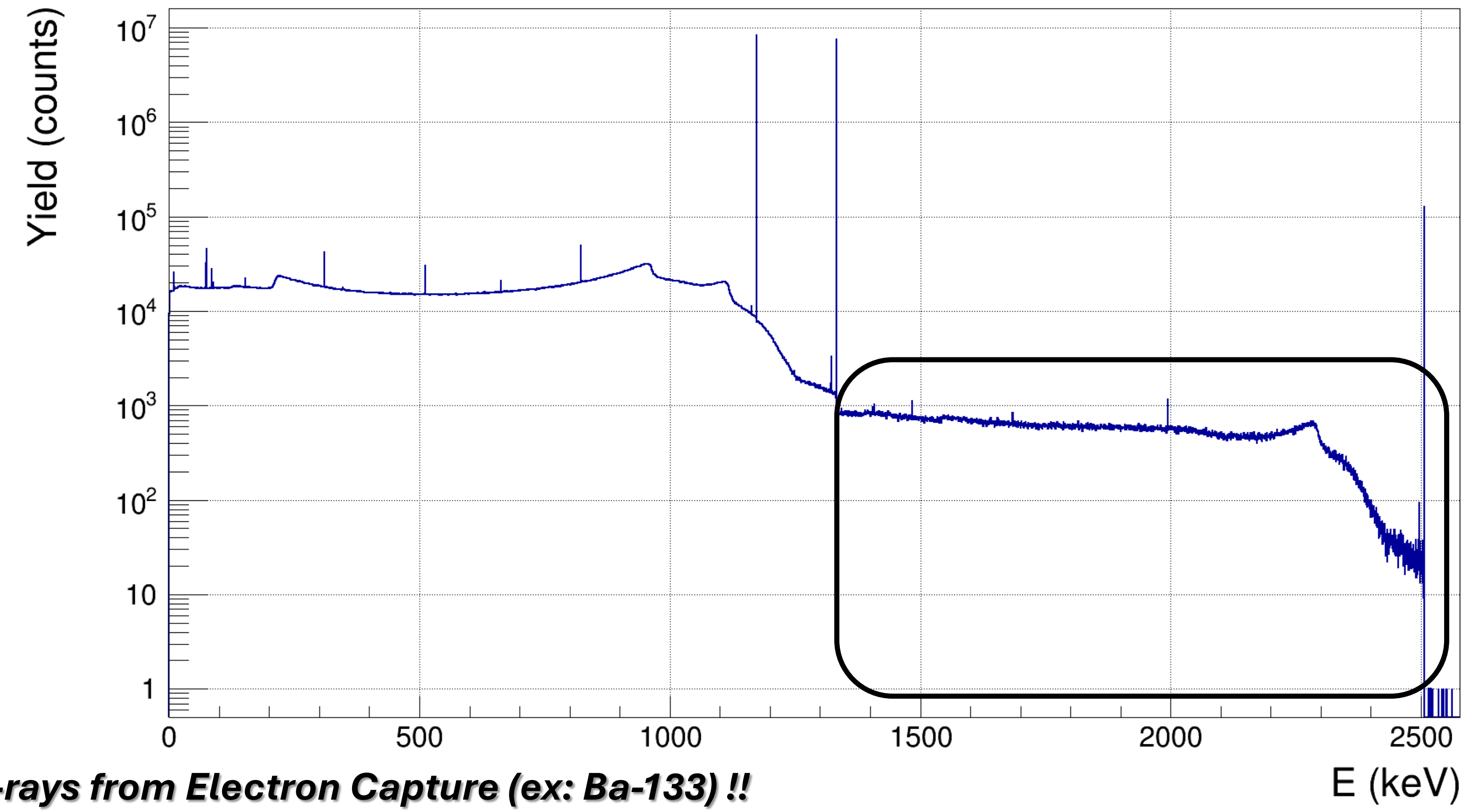
Coincidence summing corrections for the measured sample (EFFTRAN software)		
Nuclide	Energy [keV]	Correction
BE-7	477.6	1.0000
NA-22	1274.5	1.3051
K-40	1460.8	1.0002
CR-51	320.1	1.0016
MN-54	834.8	1.0019
CO-57	122.1	1.0100
CO-57	136.5	0.9866
CO-58	810.8	1.0451
CO-60	1173.2	1.1053
CO-60	1332.5	1.1101
ZN-65	1115.5	1.0053
SR-85	514.0	1.0171
Y-88	898.0	1.1149
Y-88	1836.1	1.1347
NB-94	702.6	1.1266
NB-94	871.1	1.1355
NB-95	765.8	1.0000
ZR-95	724.2	1.0000
ZR-95	756.7	1.0000
RU-103	53.3	1.2197
....		

FEP efficiency curve: coincidence summing effect



Decay data Co-60, Decay Data Evaluation Project,
http://www.lnhb.fr/nuclides/Co-60_tables.pdf

Multiple gamma-ray emitters



!! Also X-rays from Electron Capture (ex: Ba-133) !!

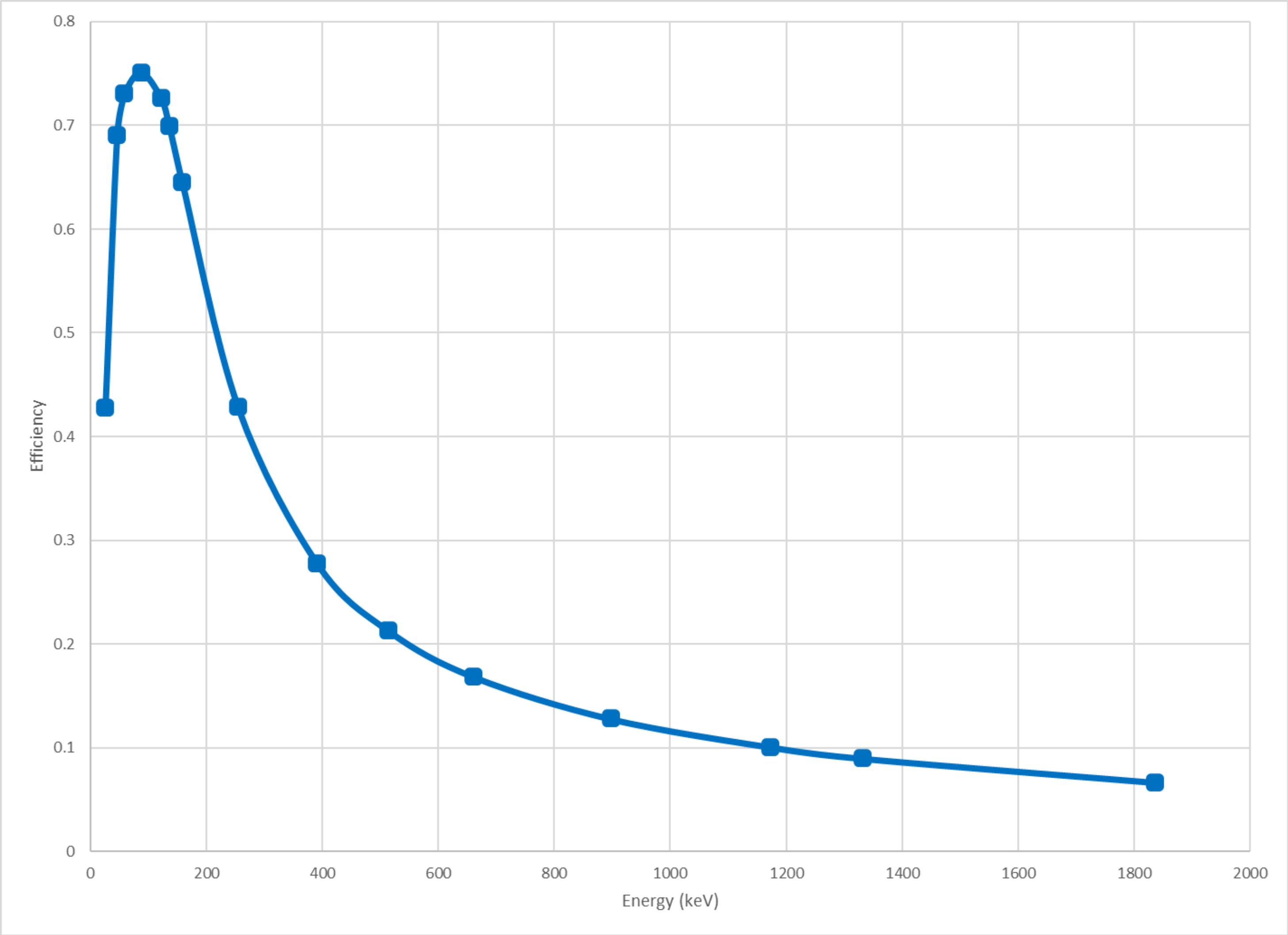
FEP efficiency curve: coincidence summing effect

Ex: Well type HPGe detector

FEP efficiencies curve

if NO coincidence summing

Am-241, Pb-210, Sr-85, Cd-109, Cs-137,
Co-57, Te-123m, Sn-113, Co-60, Y-88



FEP efficiency curve: coincidence summing effect

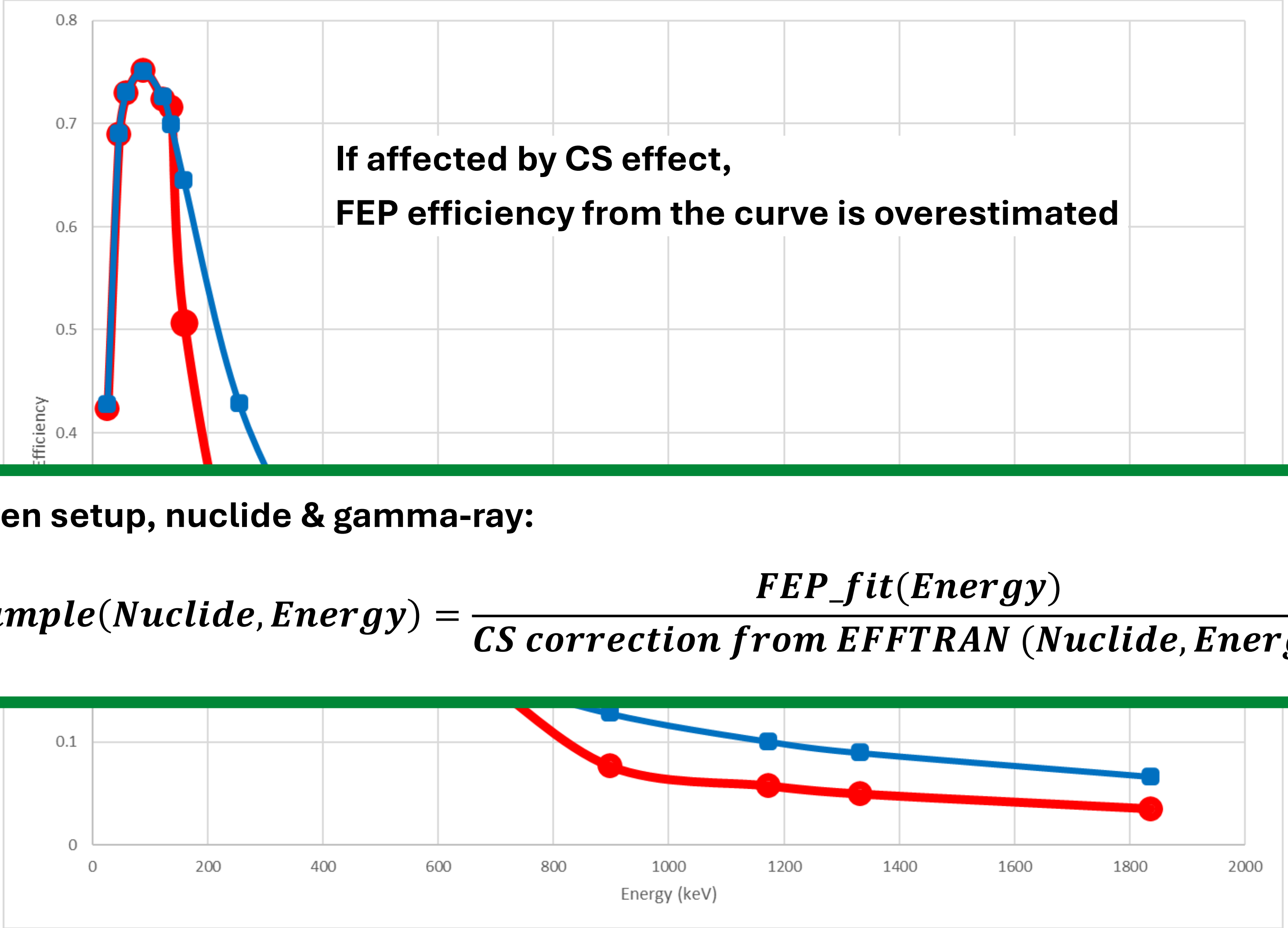
Ex: Well type HPGe detector

FEP efficiencies curve

if NO coincidence summing

With coincidence summing

Am-241, Pb-210, Sr-85, Cd-109, Cs-137,
Co-57, Te-123m, Sn-113, Co-60, Y-88



If affected by CS effect,
FEP efficiency from the curve is overestimated

For a given setup, nuclide & gamma-ray:

$$FEP\_sample(Nuclide, Energy) = \frac{FEP\_fit(Energy)}{CS\ correction\ from\ EFFTRAN\ (Nuclide, Energy)}$$

Secular equilibrium

U-238: (*U-238*), Th-234, Pa-234m
Ra-226, Pb-214 & Bi-214
Pb-210

U-235: U-235, Th-227, Ra-223 & Rn-219

Many interferences — Pa-231 (32000 y)
Low activity — Ac-227 (21 y)

Effect of equil.: within the uncertainties

Th-232: Ac-228, Ra-224, Pb-212, Bi-212, Tl-208

Th-232: (*Ra-228*), Ac-228
(*Th-228*), Ra-224, Pb-212, Bi-212, Tl-208

later

Ra-226/U-235: interference 185-186 keV

How to get the activity of Ra-226 ?

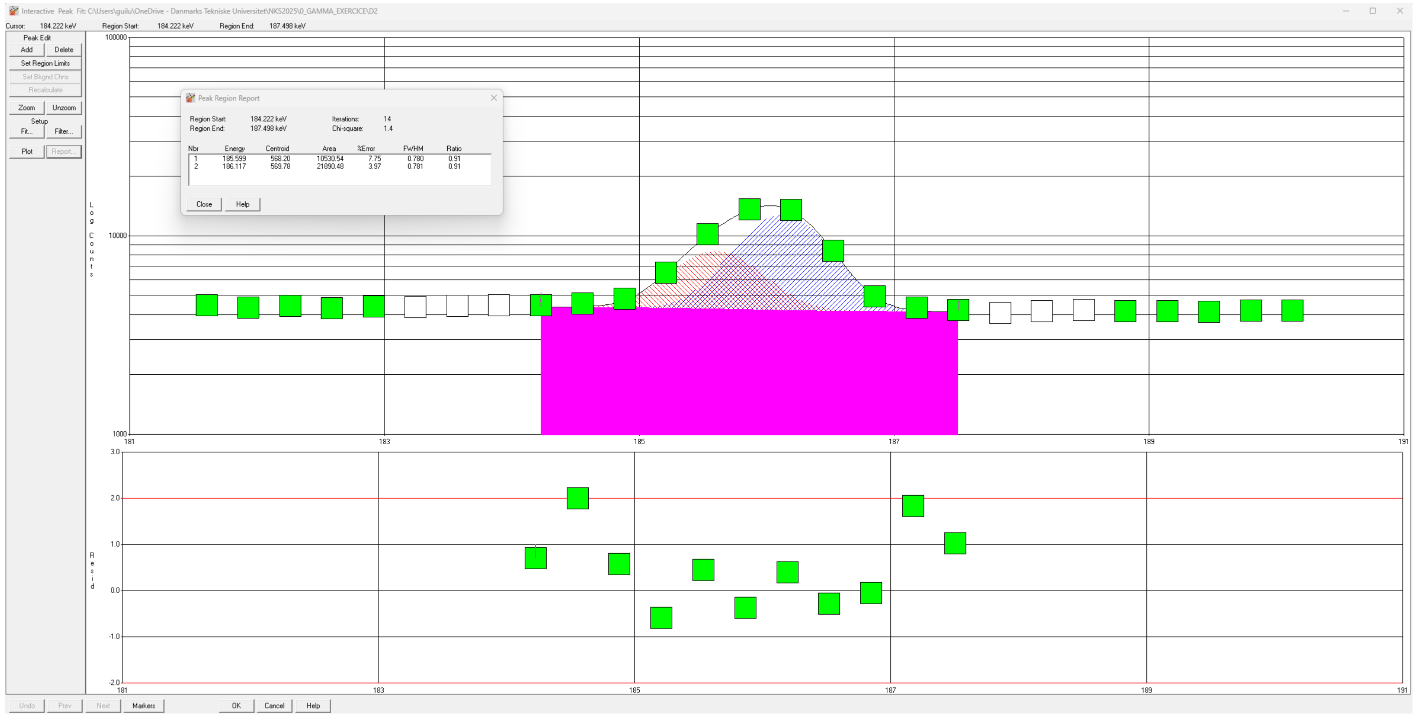
- Get activity from Ra-226 daughters: Bi/Pb-214

- Calculate U-235 activity using other peaks
then estimate the 185 keV contribution
from U-235 in the 186 keV peak

- 185 and 186 keV
can be deconvoluted

185.6 keV: 10530 ± 8% counts

186.1 keV: 21890 ± 4% counts



Ra-226/U-235: interference 185-186 keV

Ra-226 activity:

185.6 keV: 10530 ± 8% counts

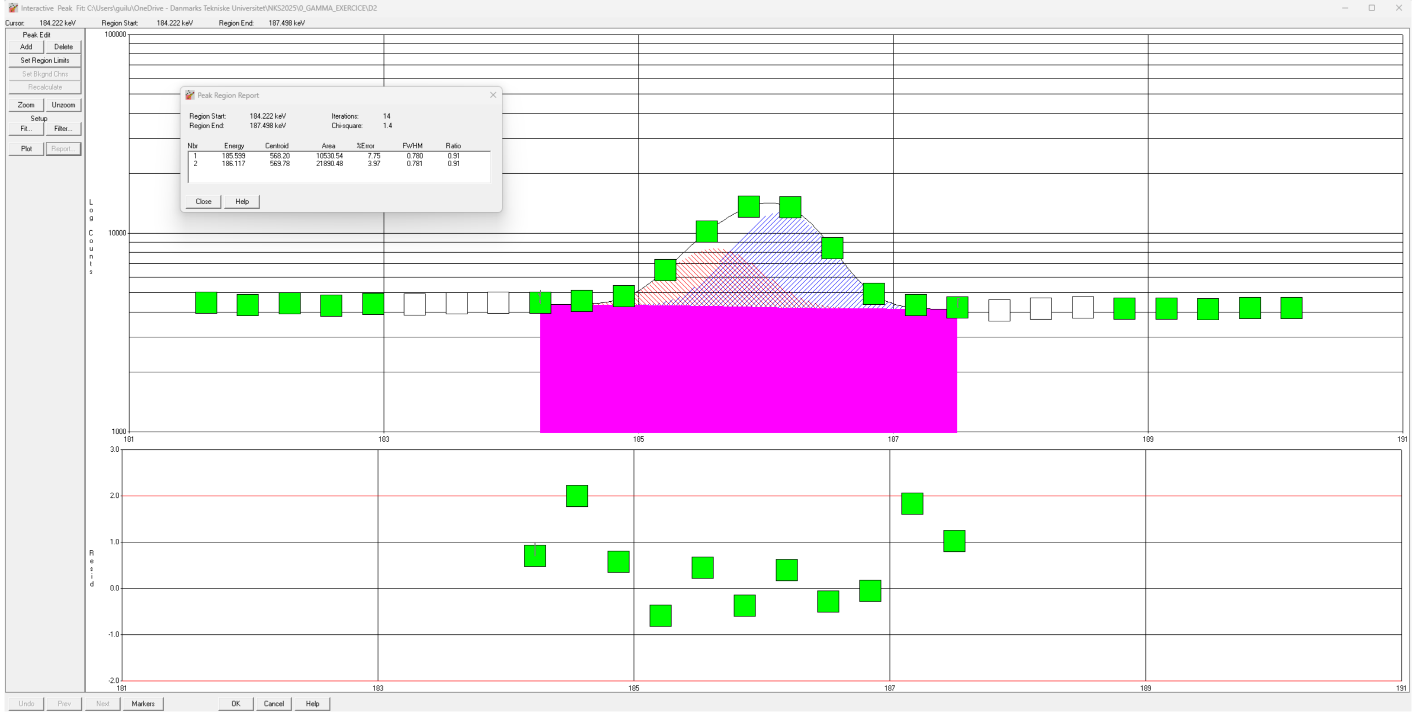
186.1 keV: 21890 ± 4% counts

- Activity from Bi/Pb-214

(23.1 ± 0.6) Bq/kg dry mass

- Activity from 186.1 keV peak

(25.7 ± 1.5) Bq/kg dry mass



Decay data

- 10 out of 12 laboratories are using DDEP decay data:

  http://www.lnhb.fr/home/nuclear-data/nuclear-data-table/
  http://www.lnhb.fr/Laraweb/

- 1 ORTEC library

- 1 Unisampo/Shaman libraries

Peak search & Nuclide identification

Peak search

- 6/12: Genie
- 3/12: GammaVision
- 1/12: Unisampo
- 2/12: FitzPeaks, *InterSpec*, HyperLab

Nuclide identification

- 6/12: Genie
- 2/12: GammaVision
- 1/12: Shaman
- 1/12: FitzPeaks, HyperLab
- 2/12: Manual

Activity calculation

Decay during the measurement

$$A = \frac{C_{sample} - C_{background}}{\varepsilon_{fit}.P_{\gamma}.t_l} . e^{\lambda t_d} . \frac{\lambda.t_r}{1 - e^{-\lambda t_r}} . K$$

Decay btw the reference date & start of the measurement

A	activity in Bq
C_{sample}	peak area
$C_{background}$	peak area in background measurement (if any peak)
t_l	live measurement time in seconds (after an interaction the detector is blind for few μs)
t_r	'real' measurement time in seconds
t_d	time difference between the measurement and the reference date in seconds
ε	efficiency for the given gamma-ray energy
P_γ	emission probability
λ	decay constant
K	additional correction(s) **= CS correction given in the exercise**

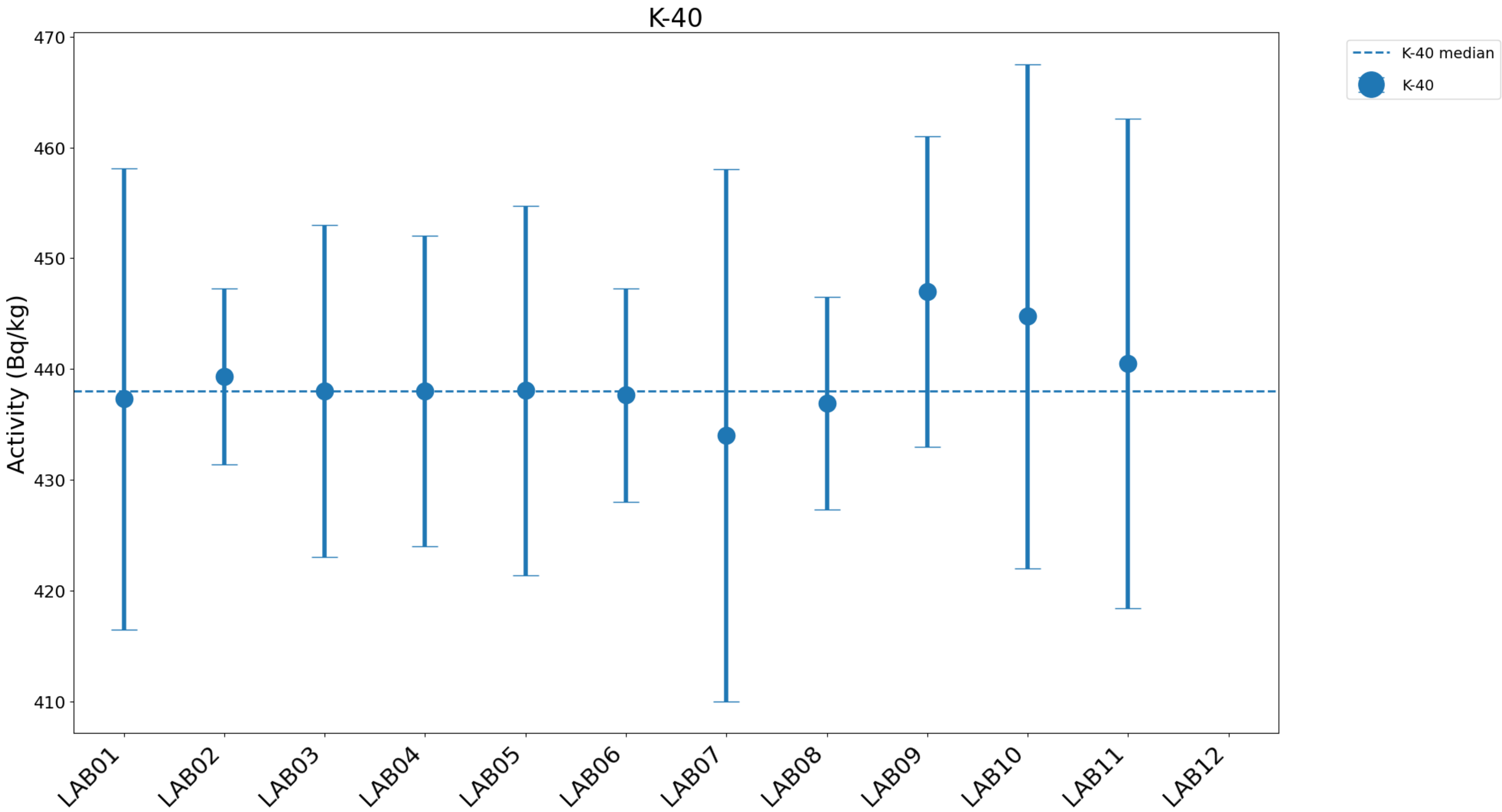
Results

- Only indicative, not an official proficiency test !
- Different ways to report results: some provide all nuclides, some only the main assuming equilibrium

Nuclide	LAB01			LAB02			LAB03			LAB04		
	Bq/kg	Unc.	Rel. Unc.	Bq/kg	Unc.	Rel. Unc.	Bq/kg	Unc.	Rel. Unc.	Bq/kg	Unc.	Rel. Unc.
K-40	437.29	20.83	4.8%	439.30	7.95	1.8%	438.00	15.00	3.4%	438.00	14.00	3.2%
Cs-137	1.02	0.05	5.2%	0.90	0.03	2.8%	1.00	0.04	4.0%	1.01	0.04	4.0%
Ba-133	0.26	0.04	13.7%	0.33	0.05	13.5%	0.27	0.01	4.4%			
U-238												
Th-234							17.80	0.90	5.1%	19.60	0.40	2.0%
Pa-234m										16.50	1.50	9.1%
U-234												
Th-230												
Ra-226				22.47	0.78	3.5%	21.00	0.80	3.8%	21.70	0.80	3.7%
Pb-214	23.22	1.11	4.8%				22.70	0.80	3.5%	22.20	0.70	3.2%
Bi-214	22.24	1.03	4.7%				22.30	0.80	3.6%	21.90	0.90	4.1%
Pb-210	32.75	2.03	6.2%	33.23	0.91	2.7%	32.50	1.50	4.6%	30.00	1.30	4.3%
Po-210												
Ac/Ra-228										19.70	0.40	2.0%
Ra-228												
Ac-228	20.91	1.22	5.8%	33.51	0.63	1.9%	20.80	1.00	4.8%			
Th-228										20.80	1.00	4.8%
Ra-224										20.80	0.70	3.4%
Pb-212	21.56	1.12	5.2%				20.90	0.80	3.8%	16.60	0.50	3.0%
Bi-212	23.20	1.24	5.3%							20.00	0.50	2.5%
Tl-208	7.76	0.36	4.7%				7.68	0.26	3.4%	7.80	0.20	2.6%
U-235				0.91	0.09	10.0%	1.01	0.02	2.4%	0.54	0.10	18.5%
Th-231												
Pa-231												
Ac-227												
Th-227										1.07	0.16	15.0%
Ra-223										1.32	0.25	18.9%
Rn-219										0.91	0.14	15.4%

Nuclide	LAB05			LAB06			LAB07			LAB08		
	Bq/kg	Unc.	Rel. Unc.	Bq/kg	Unc.	Rel. Unc.	Bq/kg	Unc.	Rel. Unc.	Bq/kg	Unc.	Rel. Unc.
K-40	438.05	16.67	3.8%	437.66	9.63	2.2%	434.00	24.00	5.5%	436.89	9.62	2.2%
Cs-137	0.99	0.04	4.0%	0.98	0.02	2.5%	1.00	0.10	10.0%	1.01	0.02	2.4%
Ba-133							0.30	0.10	33.3%	0.29	0.17	59.2%
U-238				16.75	1.47	8.8%				17.19	0.68	3.9%
Th-234	11.63	0.63	5.4%	16.75	1.47	8.8%						
Pa-234m	17.85	2.83	15.9%	16.75	1.47	8.8%	24.10	9.50	39.4%			
U-234				16.75	1.47	8.8%						
Th-230				24.17	2.13	8.8%						
Ra-226	21.05	0.89	4.2%	18.86	0.12	0.7%	23.50	6.20	26.4%	22.49	0.32	1.4%
Pb-214	23.13	0.85	3.7%	18.86	0.12	0.7%	22.40	6.20	27.7%			
Bi-214	22.32	0.83	3.7%	18.86	0.12	0.7%	20.20	2.10	10.4%			
Pb-210	21.98	1.13	5.1%	32.12	1.31	4.1%	36.00	8.30	23.1%	32.70	1.61	4.9%
Po-210				32.12	1.31	4.1%						
Ac/Ra-228												
Ra-228				24.27	0.18	0.7%				30.35	0.41	1.3%
Ac-228	20.47	0.98	4.8%	24.27	0.18	0.7%	17.90	2.30	12.8%			
Th-228				36.37	0.26	0.7%				66.34	0.89	1.3%
Ra-224												
Pb-212	21.18	0.79	3.7%	25.98	0.41	1.6%	21.20	2.40	11.3%			
Bi-212	22.54	1.04	4.6%	25.98	0.41	1.6%	19.30	2.20	11.4%			
Tl-208	7.69	0.29	3.8%	9.34	0.15	1.6%	7.00	0.10	1.4%			
U-235	1.05	0.10	9.5%	0.91	0.05	5.8%	1.10	0.30	27.3%	0.56	0.08	14.6%
Th-231				0.91	0.05	5.8%						
Pa-231				0.91	0.05	5.8%						
Ac-227				0.91	0.05	5.8%				1.14	0.09	8.1%
Th-227				0.76	0.03	3.7%						
Ra-223				0.76	0.03	3.7%						
Rn-219												

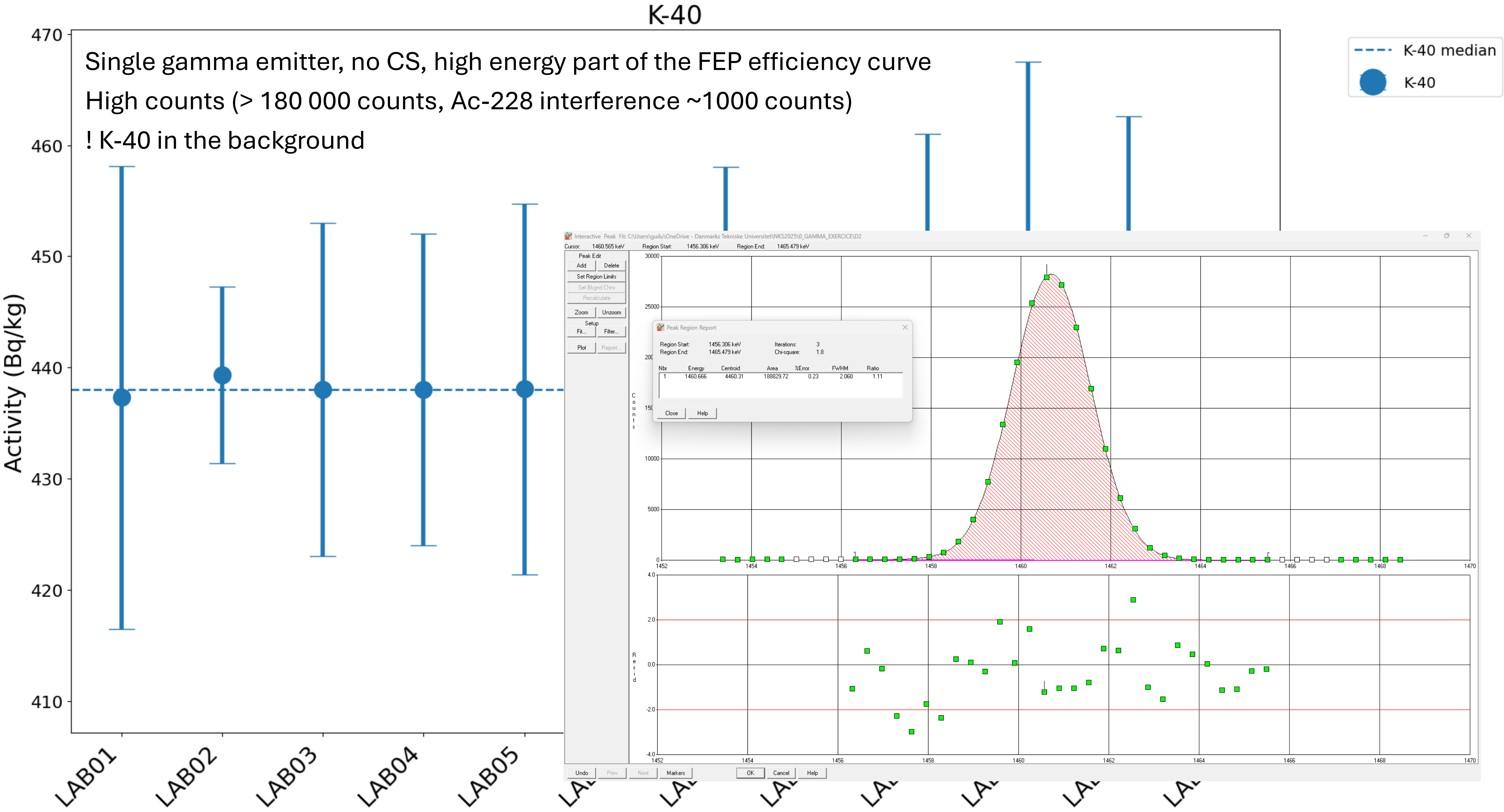
Nuclide	LAB09			LAB10			LAB11			LAB12		
	Bq/kg	Unc.	Rel. Unc.	Bq/kg	Unc.	Rel. Unc.	Bq/kg	Unc.	Rel. Unc.	Bq/kg	Unc.	Rel. Unc.
K-40	447.00	14.00	3.1%	444.76	22.74	5.1%	440.50	22.10	5.0%			
Cs-137	1.02	0.04	3.5%	1.02	0.06	5.6%	0.97	0.05	5.2%	1.39	0.10	7.1%
Ba-133				0.29	0.03	11.9%						
U-238												
Th-234	16.12	0.72	4.5%	18.53	2.87	15.5%	17.50	0.90	5.1%			
Pa-234m	14.30	1.80	12.6%	14.94	3.17	21.2%	18.70	1.60	8.6%	17.79	10.60	59.6%
U-234												
Th-230												
Ra-226	15.70	2.60	16.6%	25.70	1.34	5.2%	28.60	1.50	5.2%	23.85	0.94	3.9%
Pb-214	22.53	0.68	3.0%	23.26	0.68	2.9%	23.30	0.60	2.6%	10.61	0.40	3.8%
Bi-214	22.69	0.69	3.0%	22.66	1.14	5.0%	22.70	0.30	1.3%	19.31	0.38	2.0%
Pb-210	33.00	1.10	3.3%	33.81	5.12	15.2%	29.40	1.50	5.1%	33.21	1.29	3.9%
Po-210												
Ac/Ra-228												
Ra-228												
Ac-228	21.20	1.20	5.7%	21.10	1.24	5.9%	22.00	0.30	1.4%	21.16	0.80	3.8%
Th-228												
Ra-224				21.15	1.13	5.3%	18.80	1.00	5.3%			
Pb-212	21.06	0.68	3.2%	22.45	0.93	4.1%	22.30	0.70	3.1%	26.76	0.74	2.8%
Bi-212				23.17	1.27	5.5%	25.70	0.80	3.1%	54.19	5.65	10.4%
Tl-208	7.95	0.24	3.0%	7.76	0.33	4.2%	7.50	0.20	2.7%			
U-235	1.33	0.08	6.1%	0.83	0.04	4.8%	0.60	0.03	5.0%			
Th-231												
Pa-231												
Ac-227												
Th-227				1.05	0.10	9.2%						
Ra-223				0.95	0.09	9.7%						
Rn-219				1.14	0.13	11.5%						

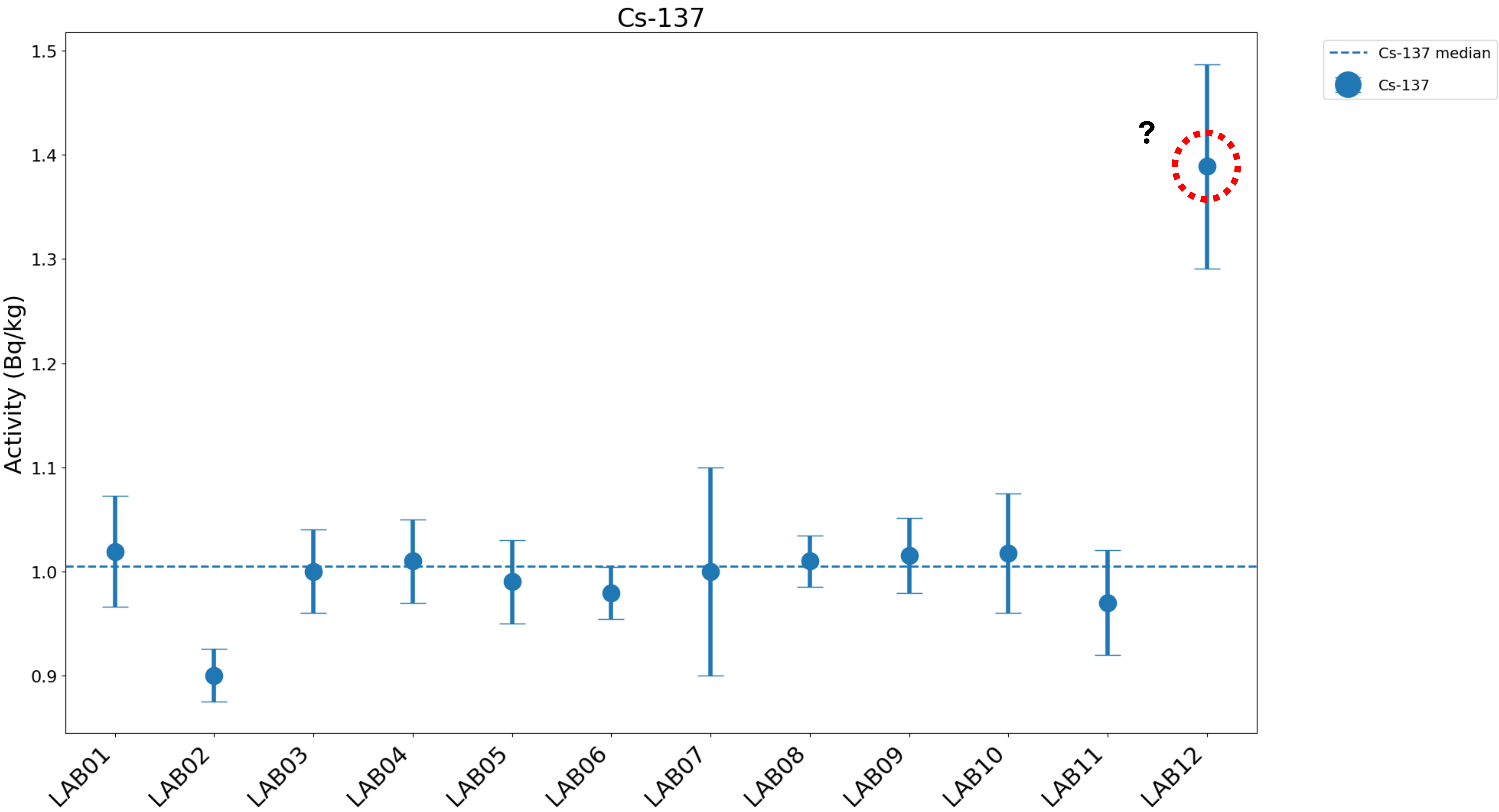

K-40
Activity (Bq/kg)
470
460
450
440
430
420
410
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
K-40 median
K-40

Single gamma emitter, no CS, high energy part of the FEP efficiency curve

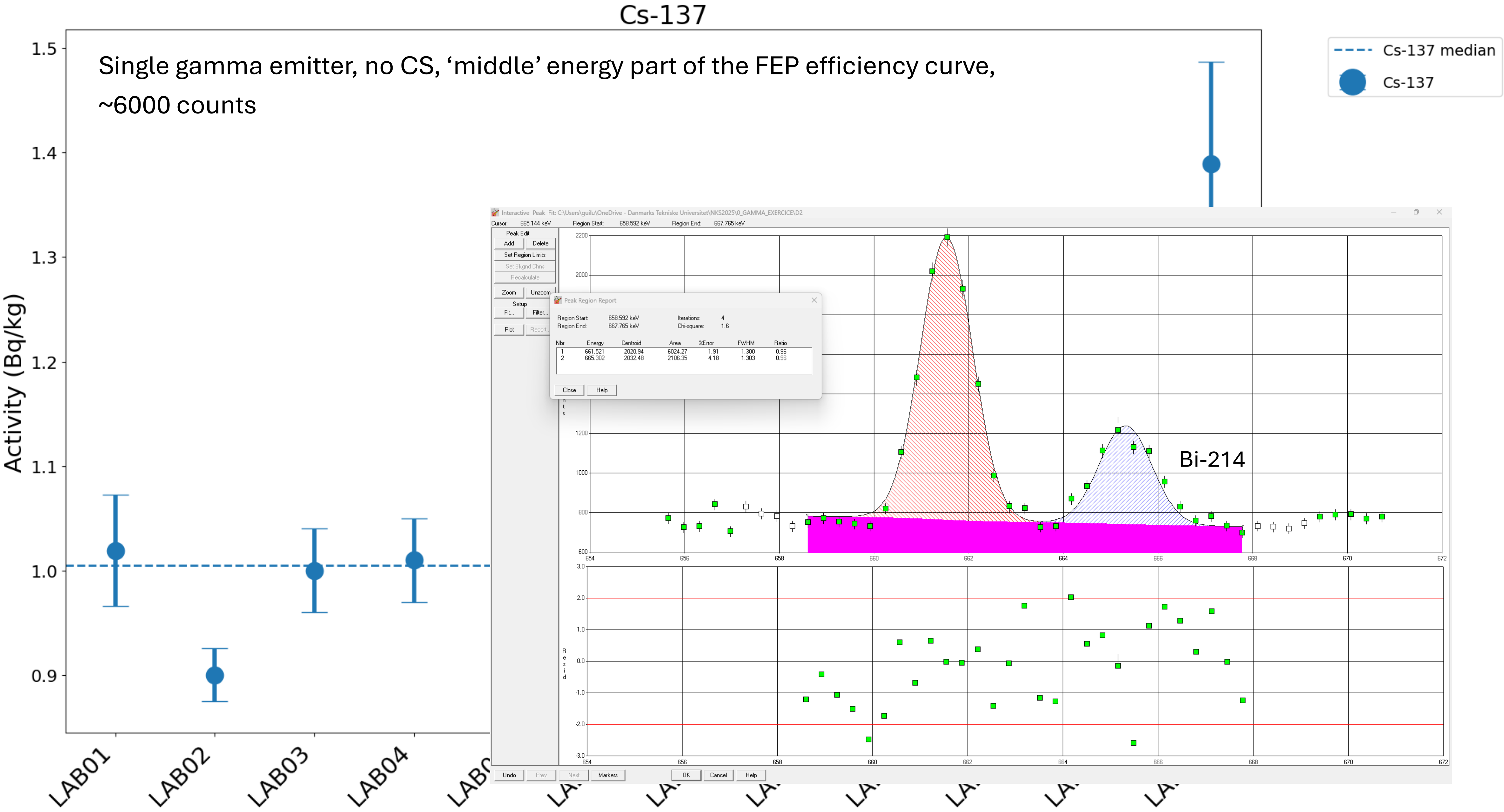
High counts (> 180 000 counts, Ac-228 interference ~1000 counts)

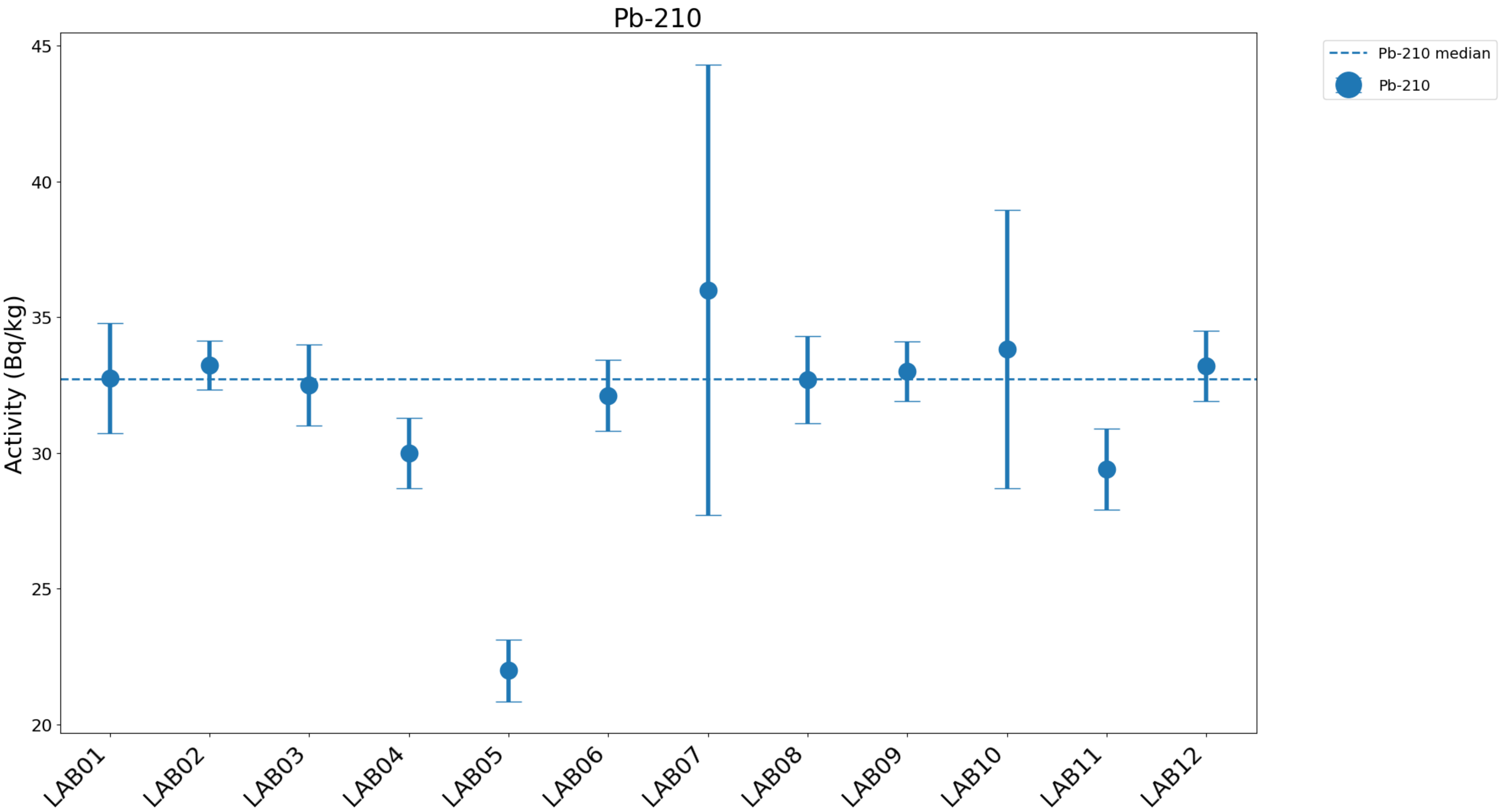
! K-40 in the background




Cs-137
Activity (Bq/kg)
1.5
1.4
1.3
1.2
1.1
1.0
0.9
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
Cs-137 median
Cs-137
?

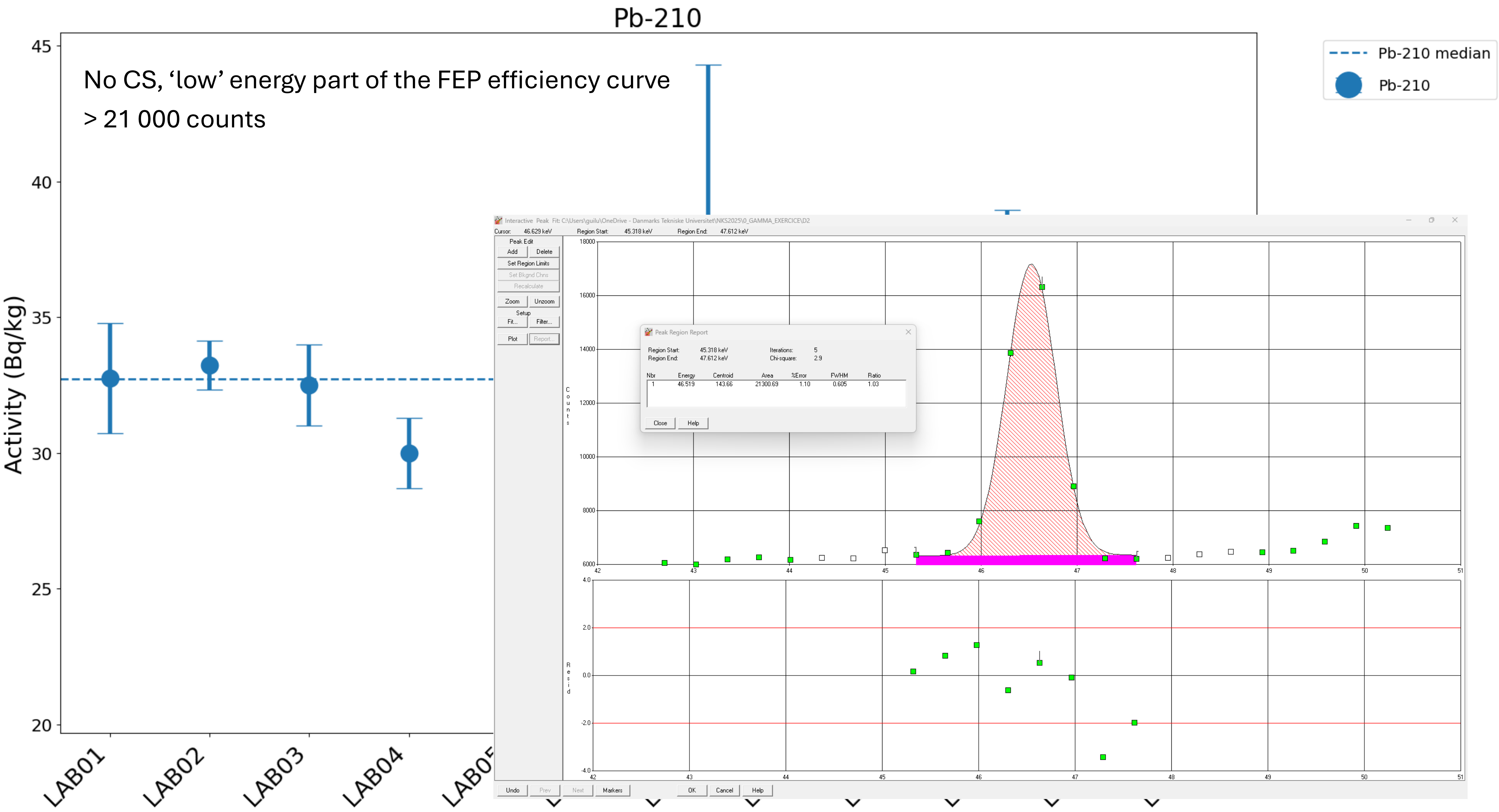
Single gamma emitter, no CS, ‘middle’ energy part of the FEP efficiency curve, ~6000 counts

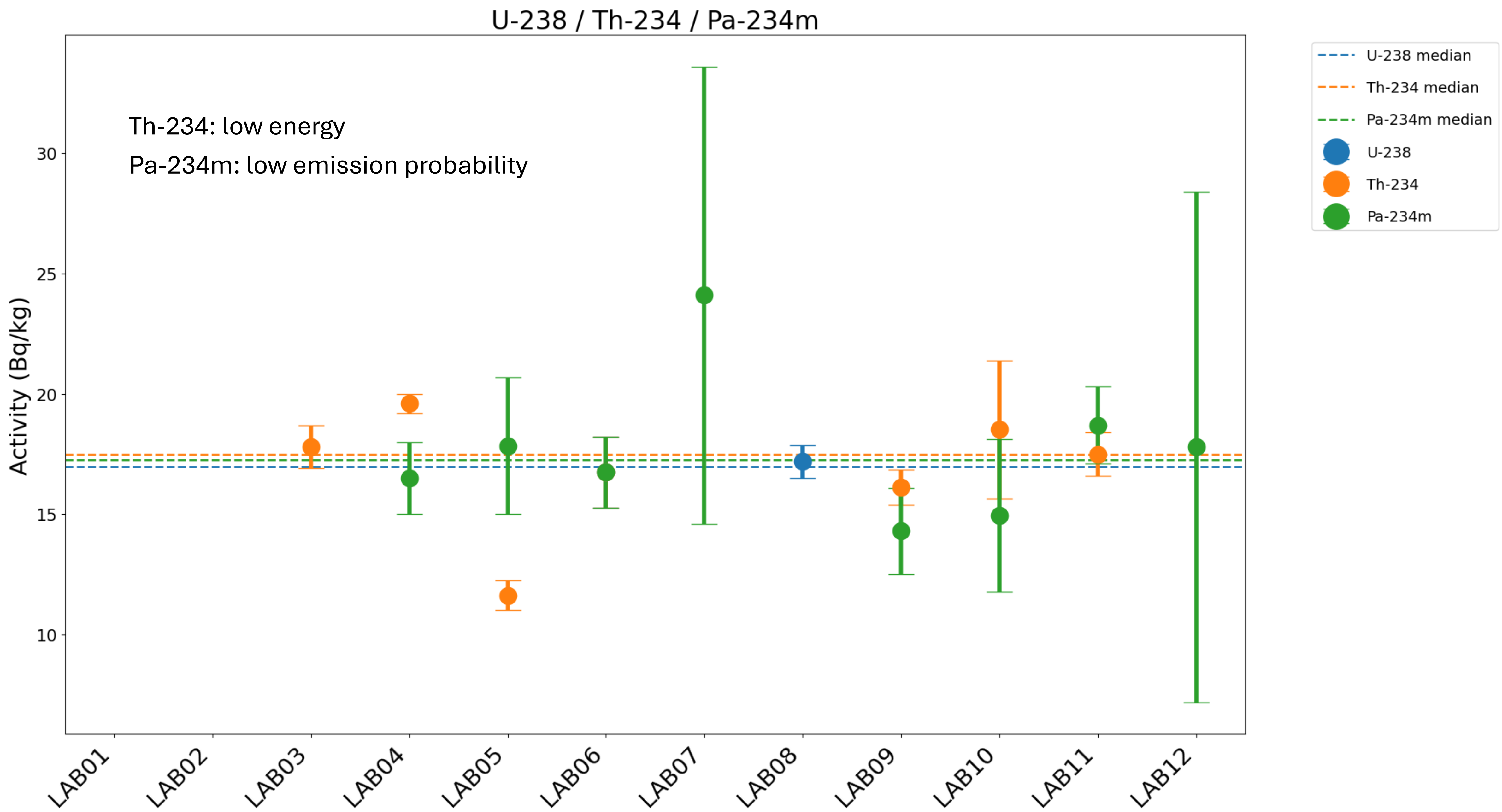



Pb-210
Activity (Bq/kg)
45
40
35
30
25
20
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
Pb-210 median
Pb-210

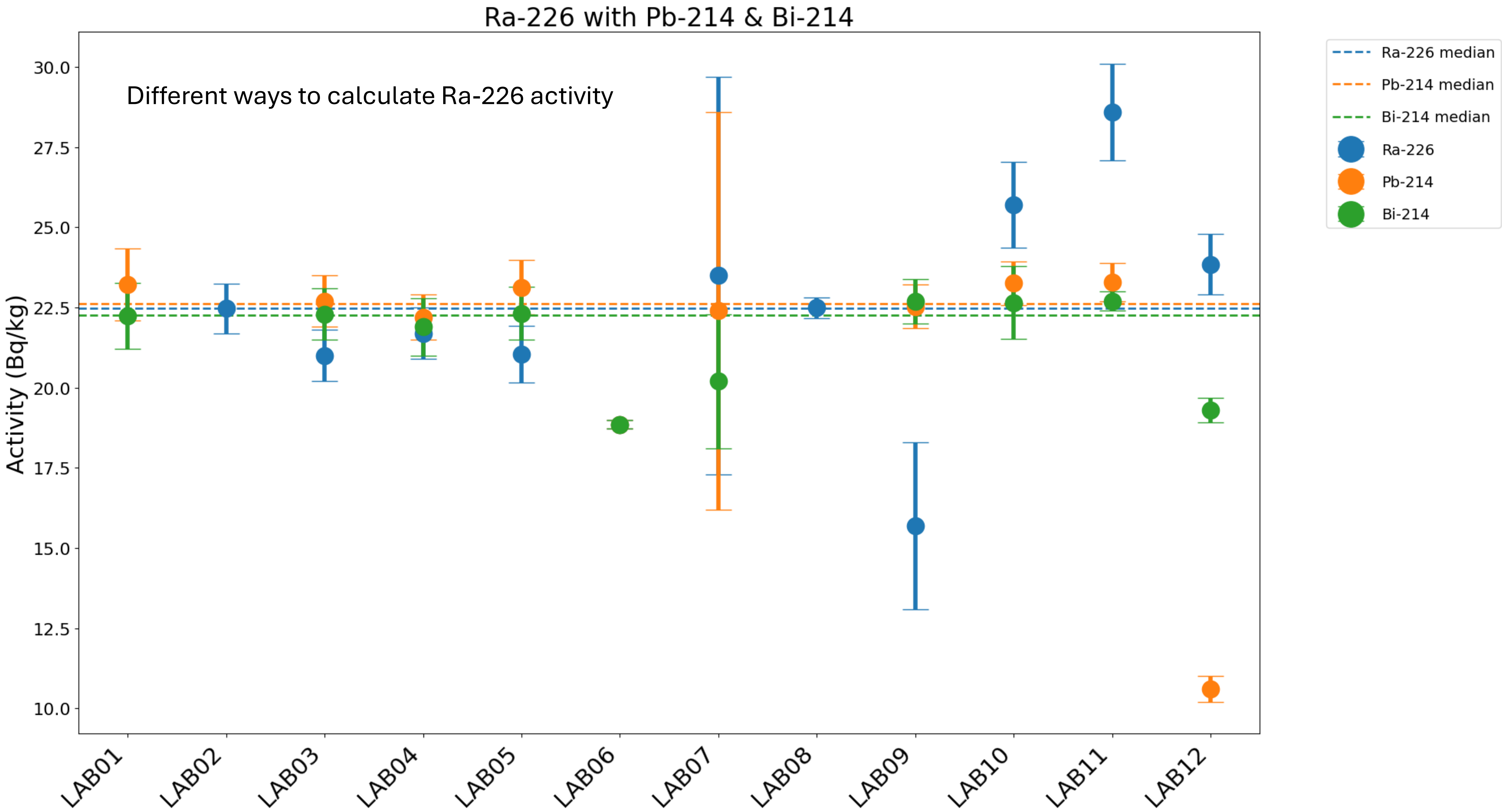
No CS, ‘low’ energy part of the FEP efficiency curve

> 21 000 counts

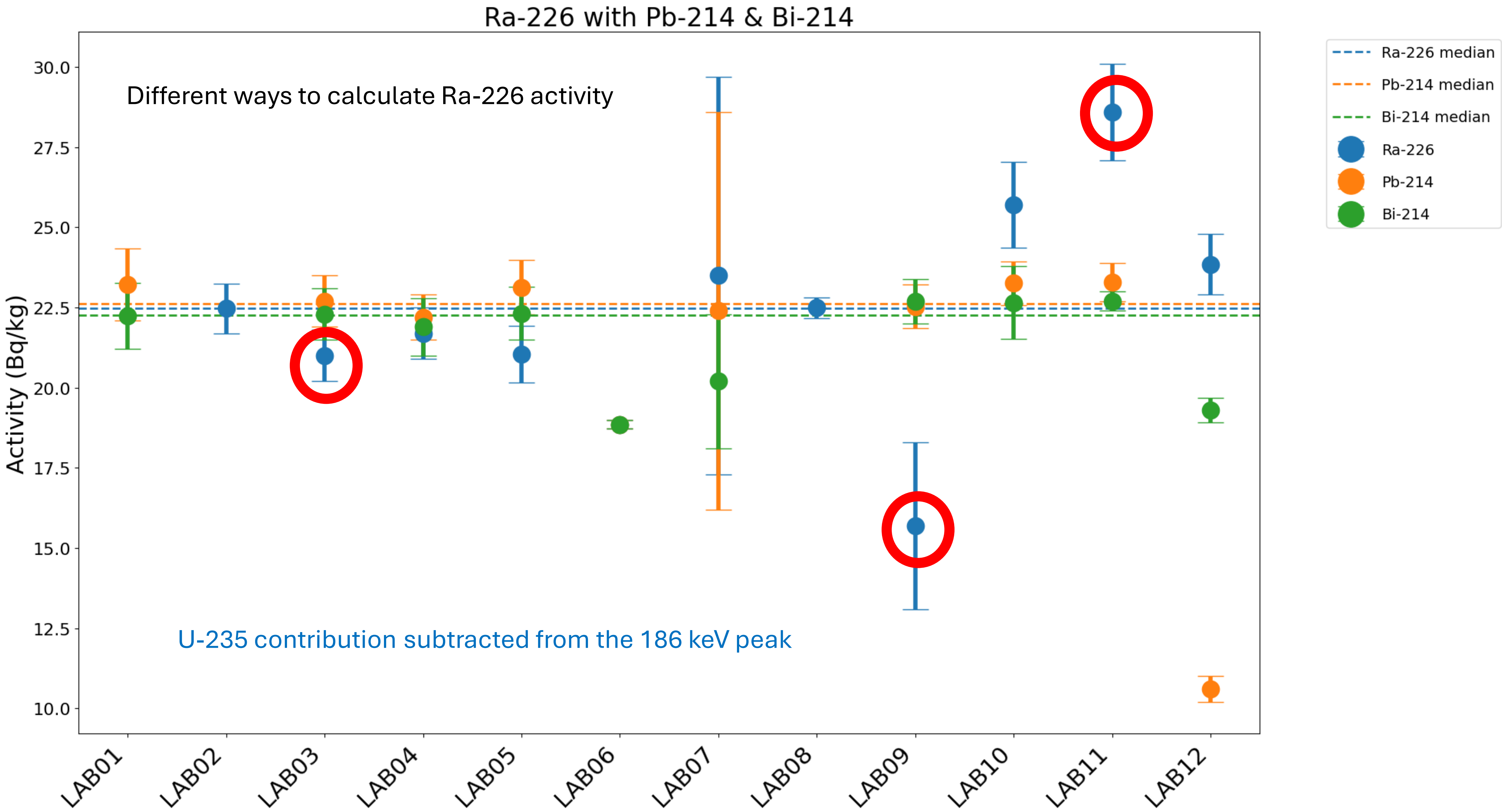




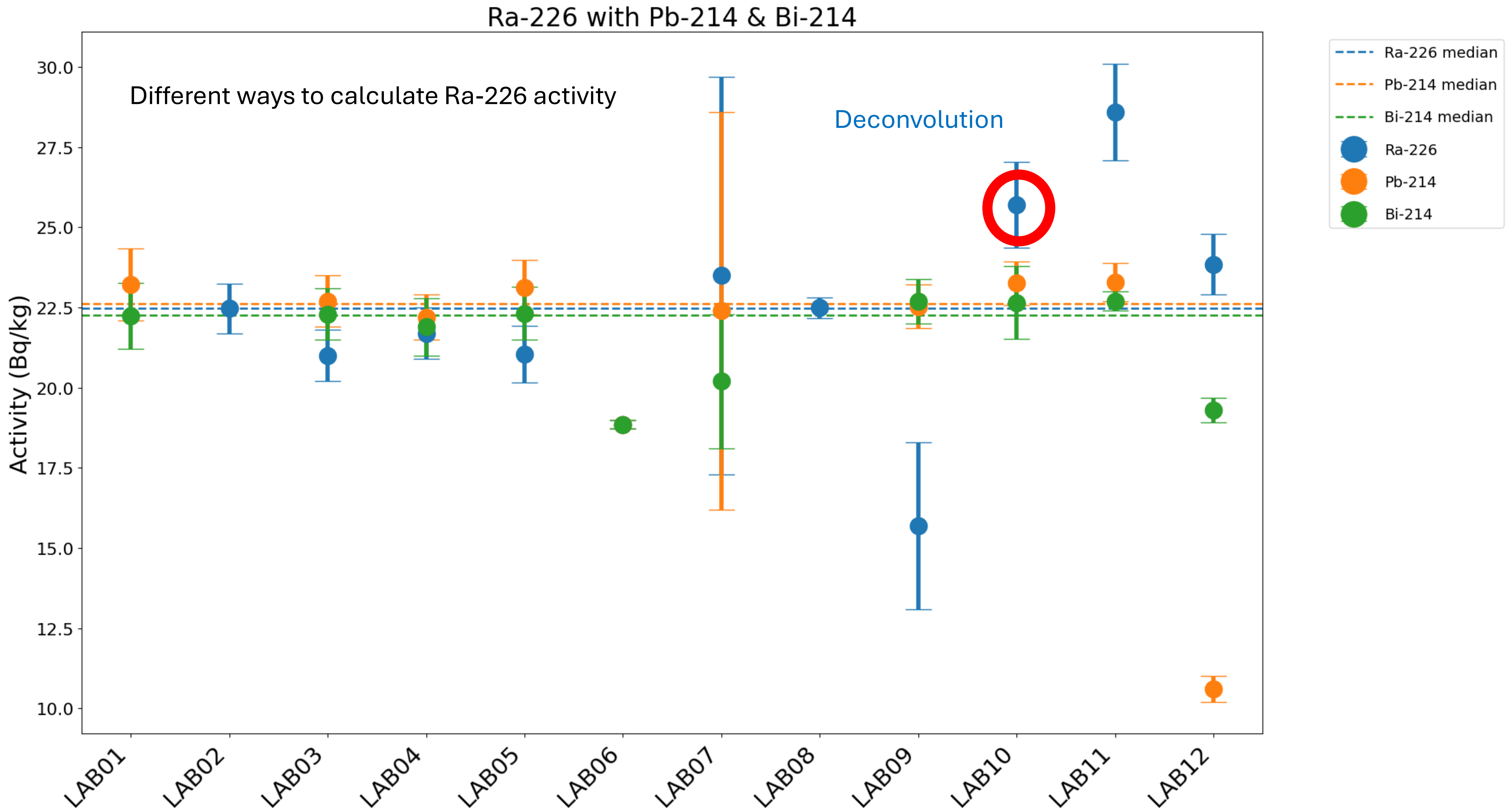
U-238 / Th-234 / Pa-234m
Th-234: low energy
Pa-234m: low emission probability
Activity (Bq/kg)
30
25
20
15
10
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
U-238 median
Th-234 median
Pa-234m median
U-238
Th-234
Pa-234m



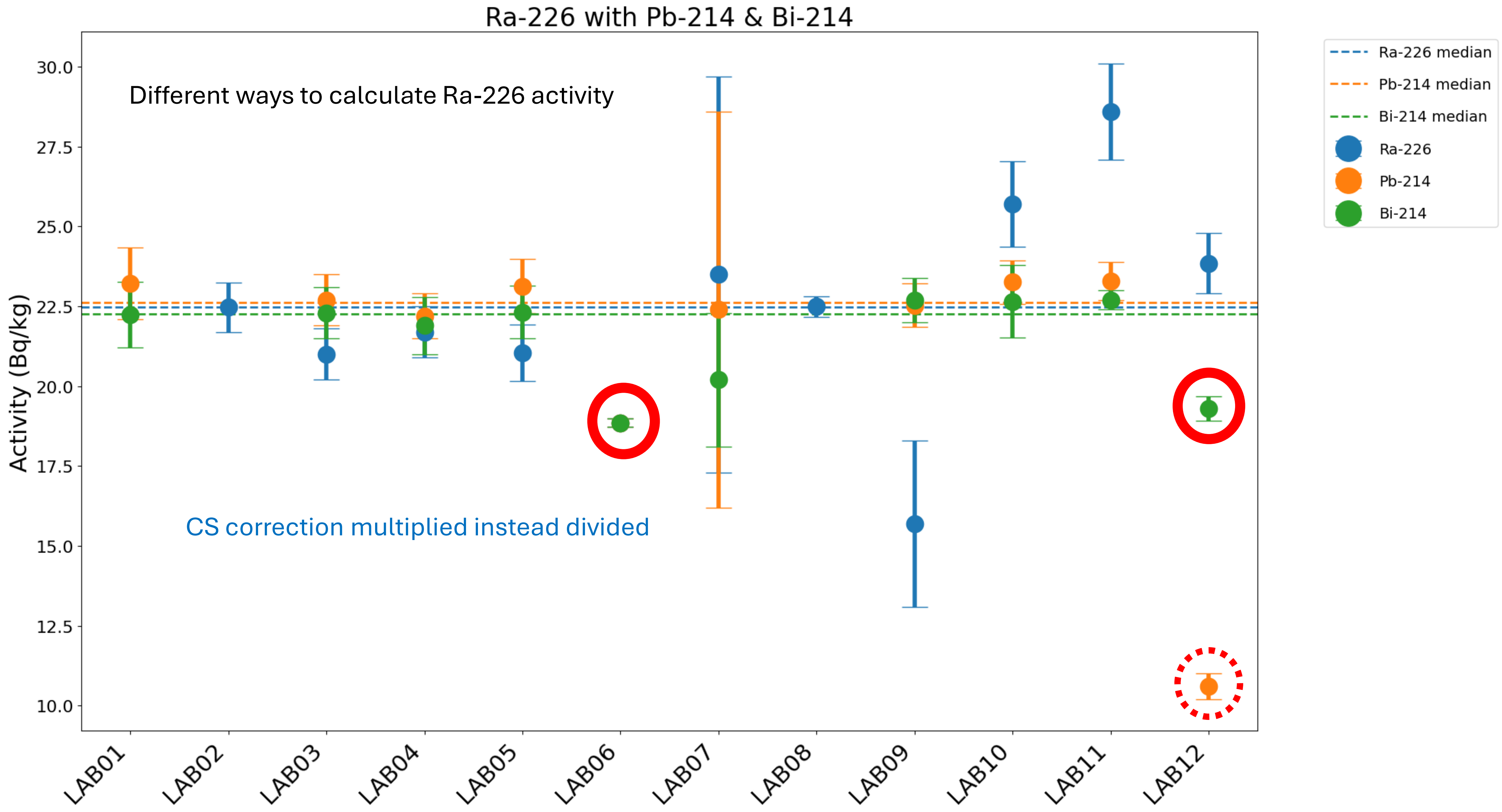
Ra-226 with Pb-214 & Bi-214
Different ways to calculate Ra-226 activity
Activity (Bq/kg)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
Ra-226 median
Pb-214 median
Bi-214 median
Ra-226
Pb-214
Bi-214

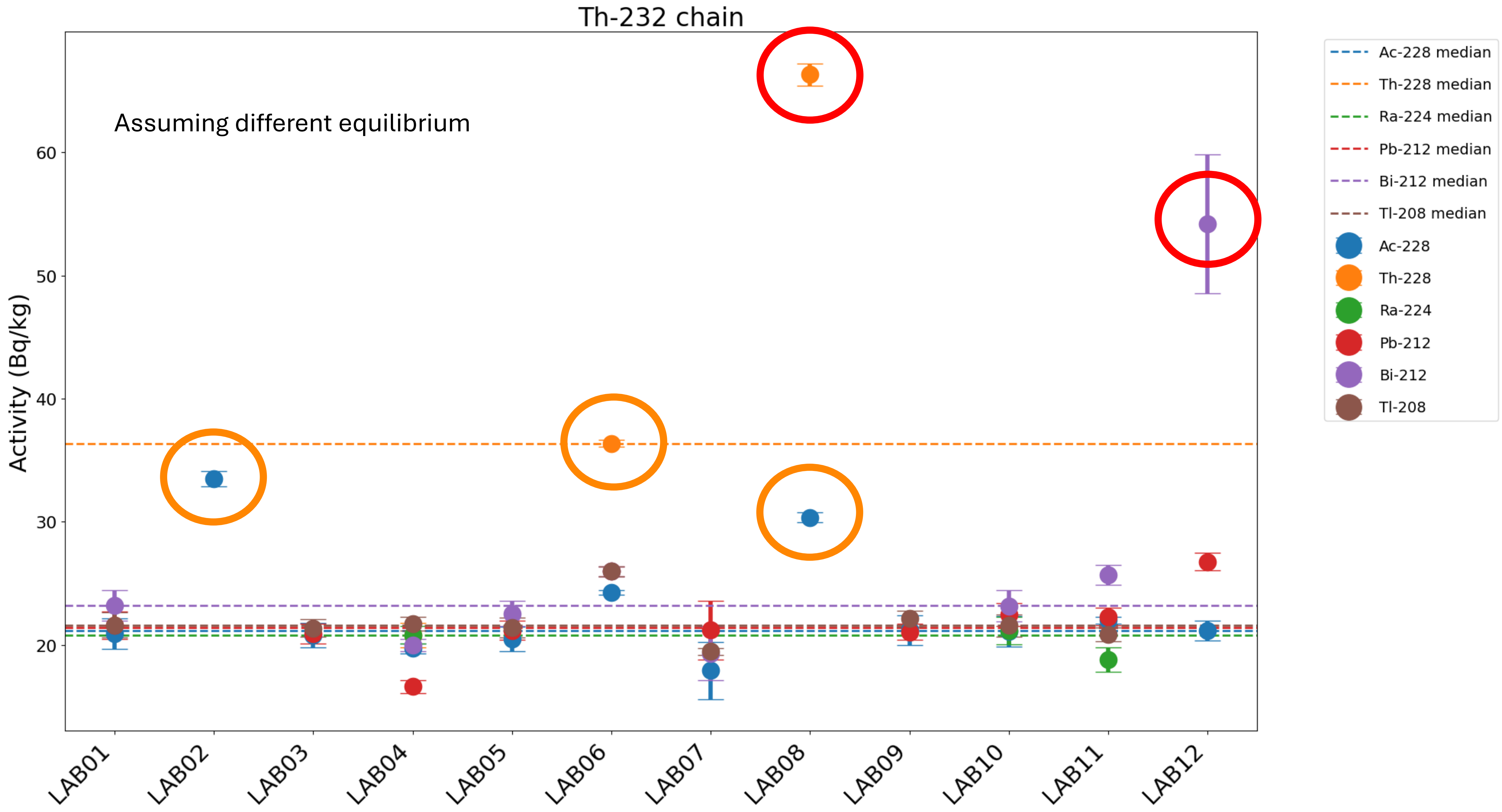


Ra-226 with Pb-214 & Bi-214
Different ways to calculate Ra-226 activity
U-235 contribution subtracted from the 186 keV peak
Activity (Bq/kg)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
Ra-226 median
Pb-214 median
Bi-214 median
Ra-226
Pb-214
Bi-214

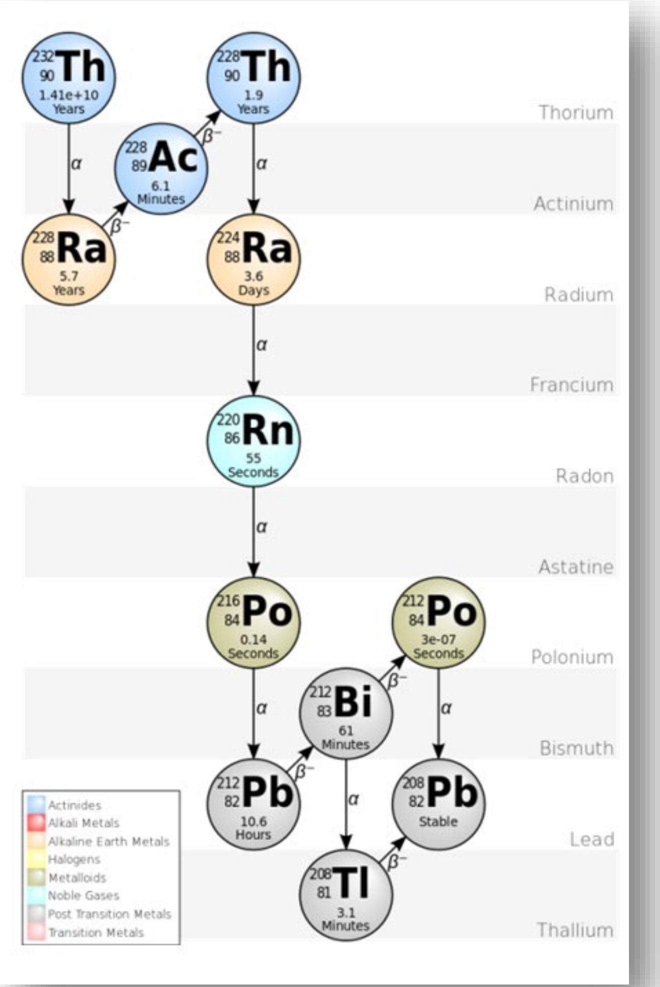


Ra-226 with Pb-214 & Bi-214
Different ways to calculate Ra-226 activity
Deconvolution
Activity (Bq/kg)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
Ra-226 median
Pb-214 median
Bi-214 median
Ra-226
Pb-214
Bi-214


Ra-226 with Pb-214 & Bi-214
Different ways to calculate Ra-226 activity
CS correction multiplied instead divided
Activity (Bq/kg)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
Ra-226 median
Pb-214 median
Bi-214 median
Ra-226
Pb-214
Bi-214


Th-232 chain
Assuming different equilibrium
Activity (Bq/kg)
60
50
40
30
20
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
Ac-228 median
Th-228 median
Ra-224 median
Pb-212 median
Bi-212 median
Tl-208 median
Ac-228
Th-228
Ra-224
Pb-212
Bi-212
Tl-208

Th-232 decay chain



Assuming equilibrium:

Ra-228 & Ac-228

Th-228→Tl-208

Reference date = measurement date

Th-232 chain

		Bq/kg	Unc.
Ra-228			
	Ac-228	21.4	0.6
Th-228			
	Ra-224	20.9	1.1
	Pb-212	22.6	0.9
	Bi-212	23.3	1.3
	Tl-208*	21.5	0.9

Reference date = 01/01/2022 00:00:00

Th-232 chain

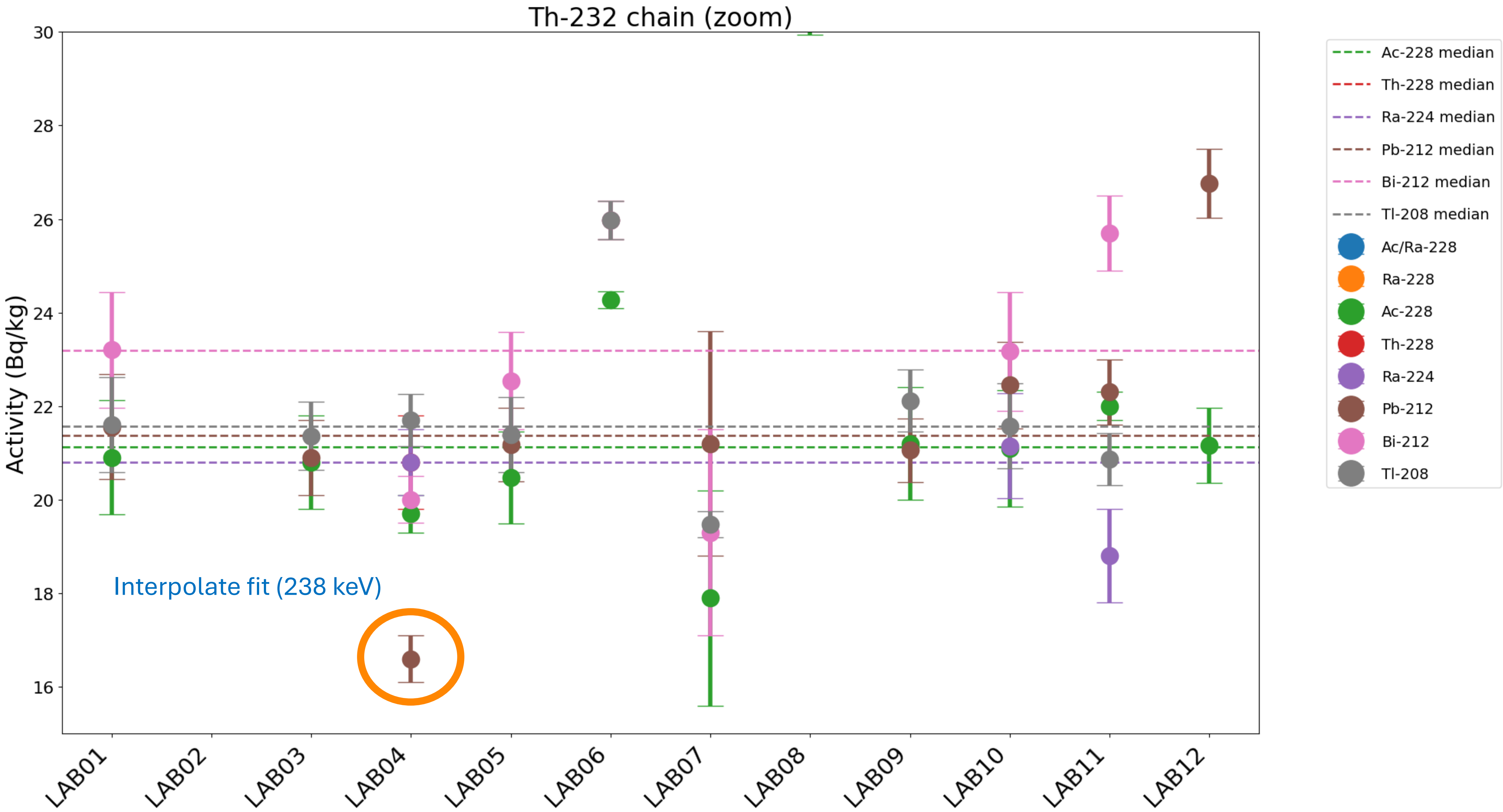
		Bq/kg	Unc.
Ra-228			
	Ac-228	31.5	0.9
Th-228			
	Ra-224	66.6	3.6
	Pb-212	71.8	3.0
	Bi-212	74.2	4.1
	Tl-208*	68.3	2.9

Ra-228 → Th-228 are in equilibrium

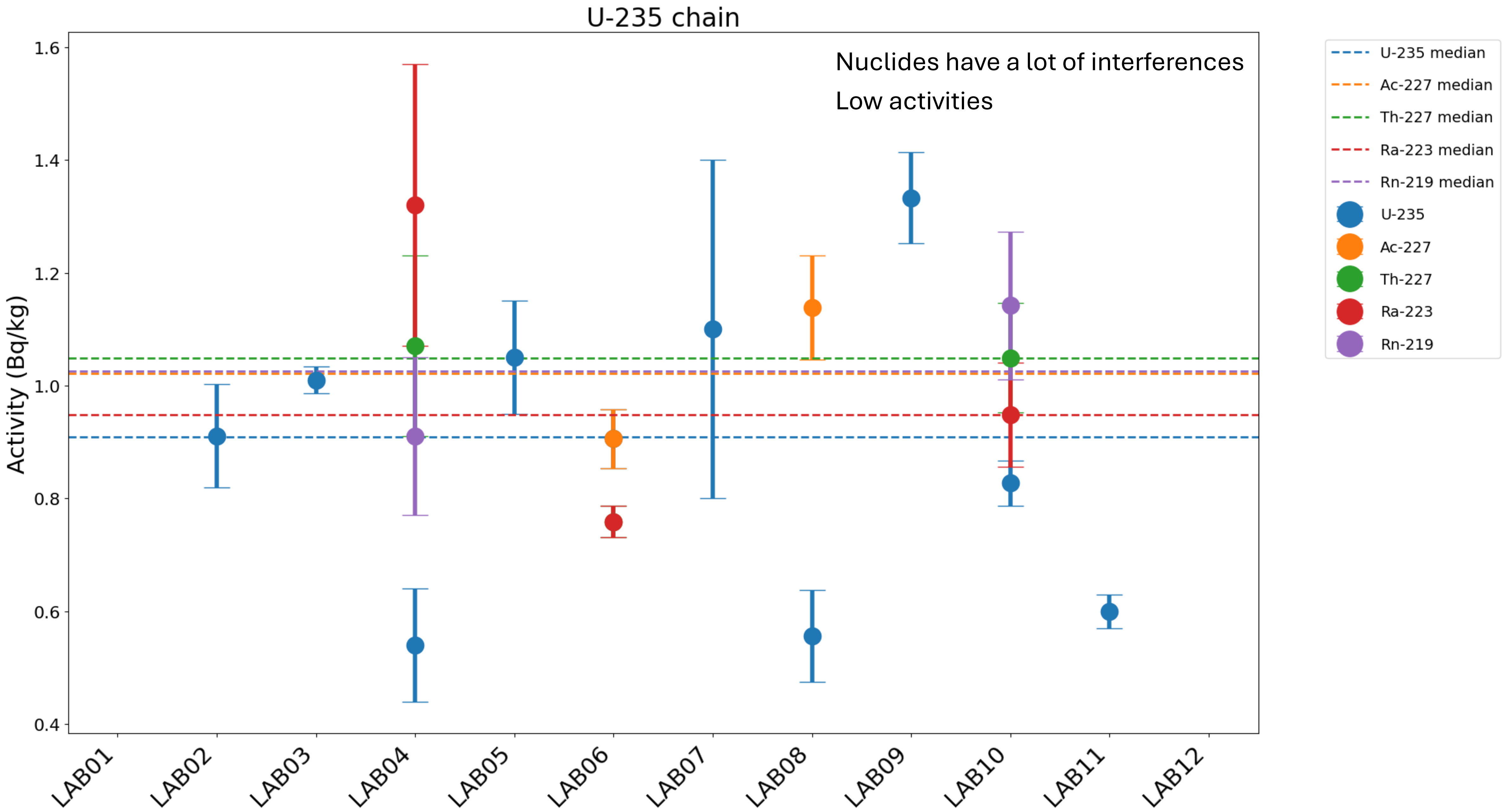
Th-232 & Ra-228 are in equilibrium ?

→ Most likely Ra is in if both 'parts'

*BR corrected



Th-232 chain (zoom)
Activity (Bq/kg)
30
28
26
24
22
20
18
16
Interpolate fit (238 keV)
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
Ac-228 median
Th-228 median
Ra-224 median
Pb-212 median
Bi-212 median
Tl-208 median
Ac/Ra-228
Ra-228
Ac-228
Th-228
Ra-224
Pb-212
Bi-212
Tl-208



U-235 chain
Nuclides have a lot of interferences
Low activities
Activity (Bq/kg)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
LAB01
LAB02
LAB03
LAB04
LAB05
LAB06
LAB07
LAB08
LAB09
LAB10
LAB11
LAB12
U-235 median
Ac-227 median
Th-227 median
Ra-223 median
Rn-219 median
U-235
Ac-227
Th-227
Ra-223
Rn-219

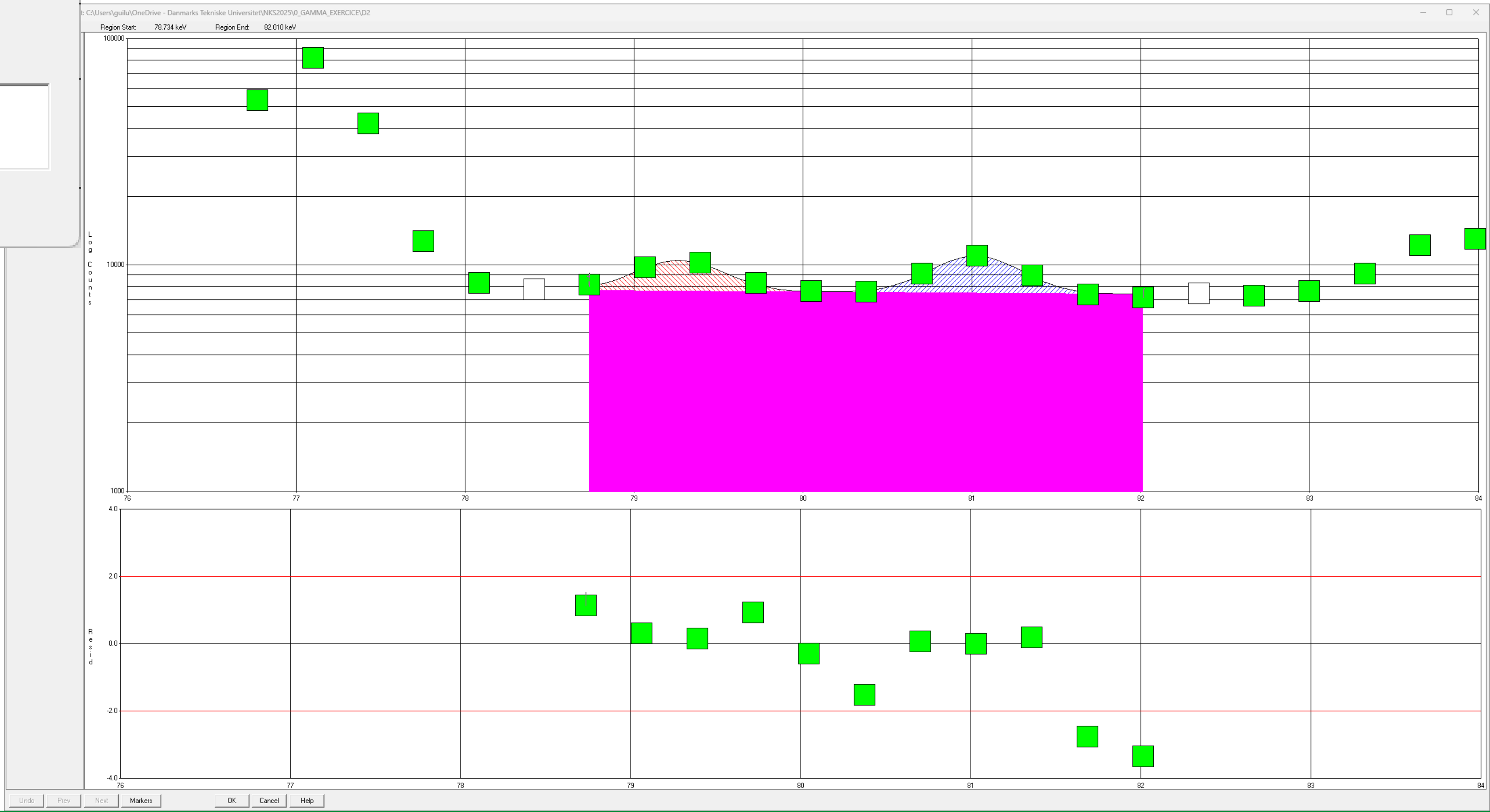
Ba-133 ?

Peak Region Report

Region Start: 78.734 keV
Region End: 82.010 keV
Iterations: 5
Chi-square: 2

Nbr	Energy	Centroid	Area	%Error	FWHM	Ratio
1	79.268	243.63	5449.02	3.81	0.594	0.89
2	81.018	248.97	6688.18	3.41	0.598	0.89

Close Help



Ba-133 ?

Peak Region Report

Region Start:	301.504 keV	Iterations:	5
Region End:	303.797 keV	Chi-square:	0.65

Nbr	Energy	Centroid	Area	%Error	FWHM	Ratio
1	302.605	925.36	732.08	18.24	0.770	0.76

Close Help

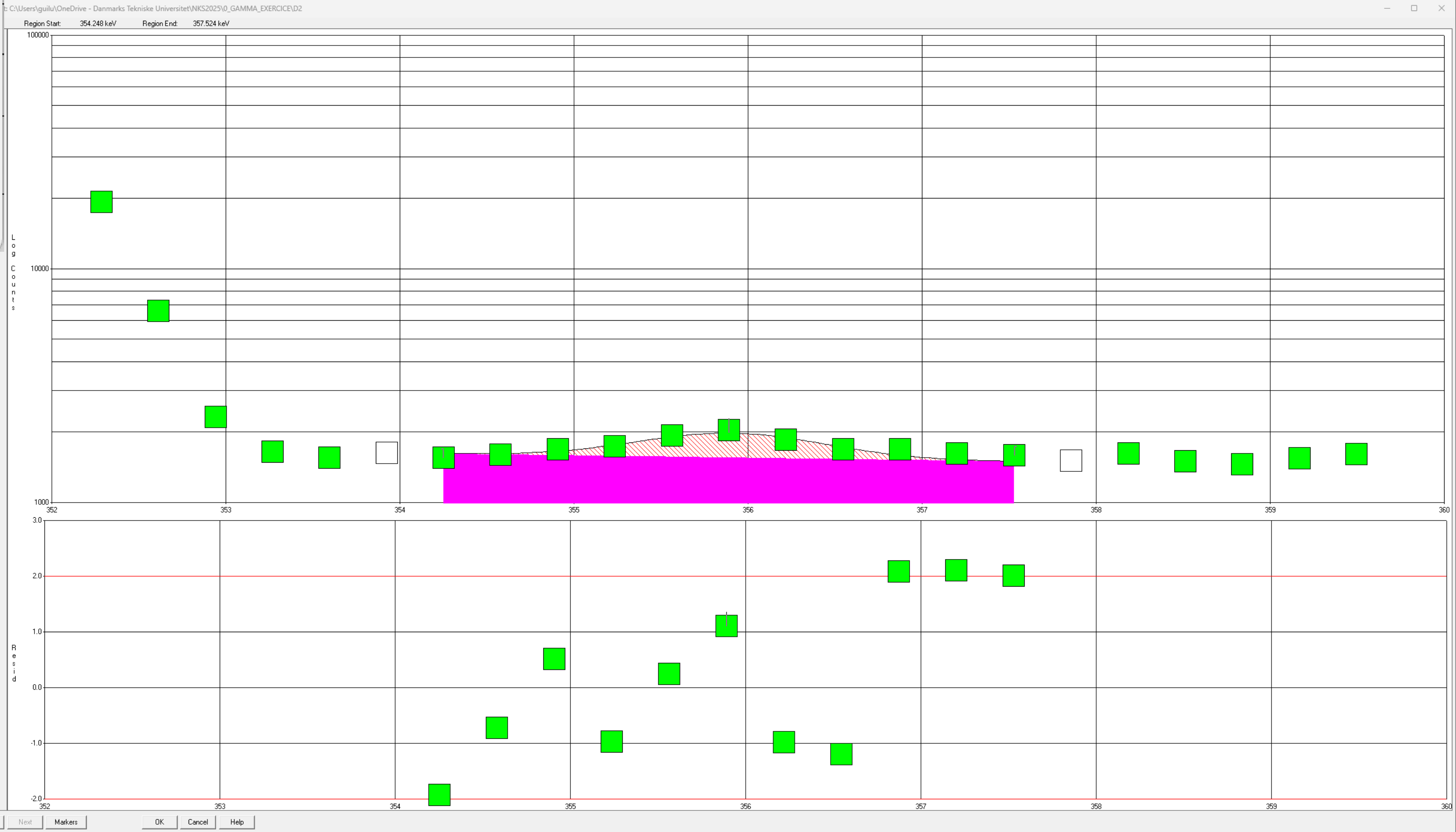
Ba-133 ?

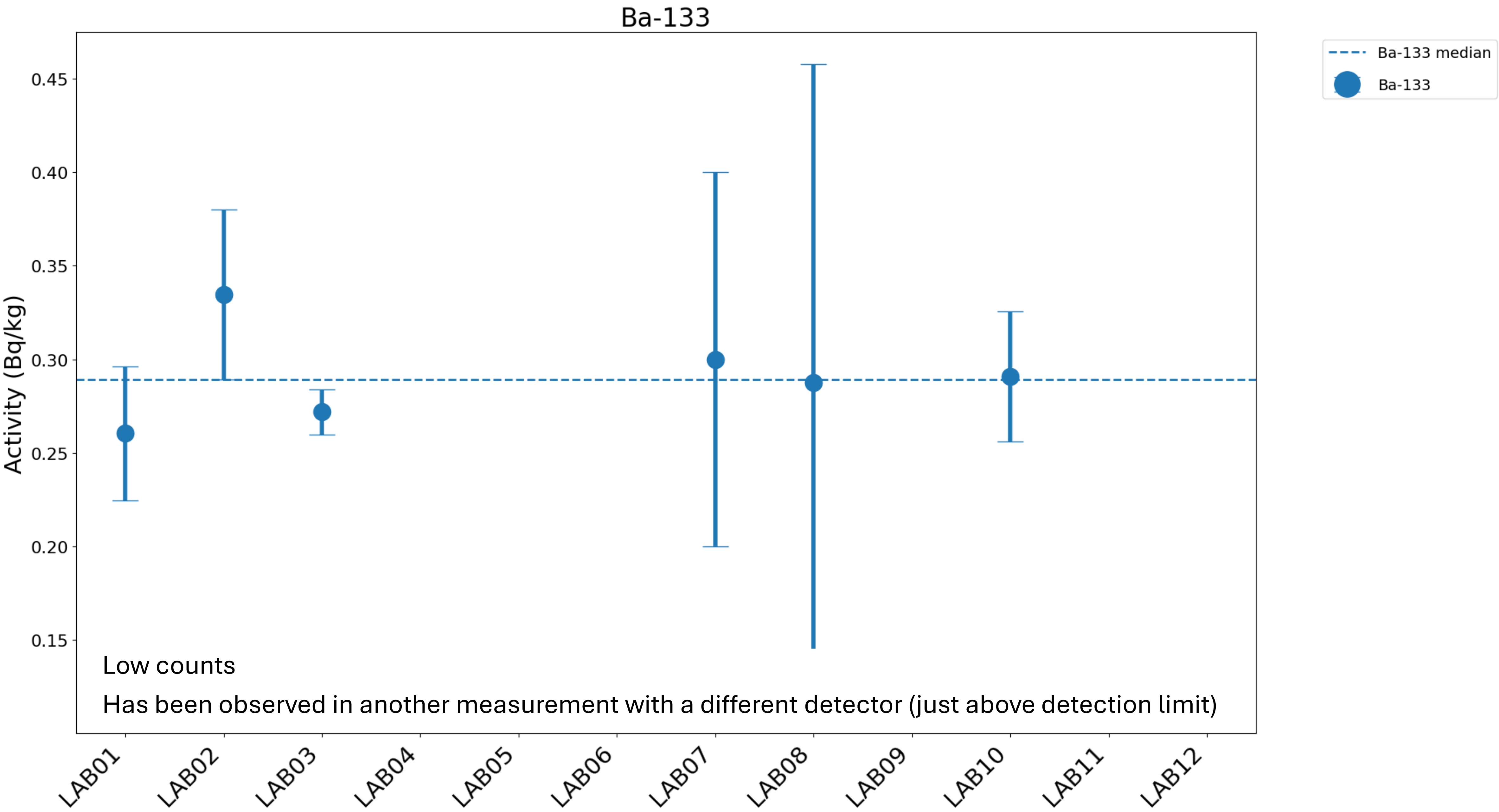
Peak Region Report

Region Start: 354.248 keV Iterations: 9
Region End: 357.524 keV Chi-square: 1.6

Nbr	Energy	Centroid	Area	%Error	FWHM	Ratio
1	355.897	1088.03	1691.98	8.45	1.213	1.13

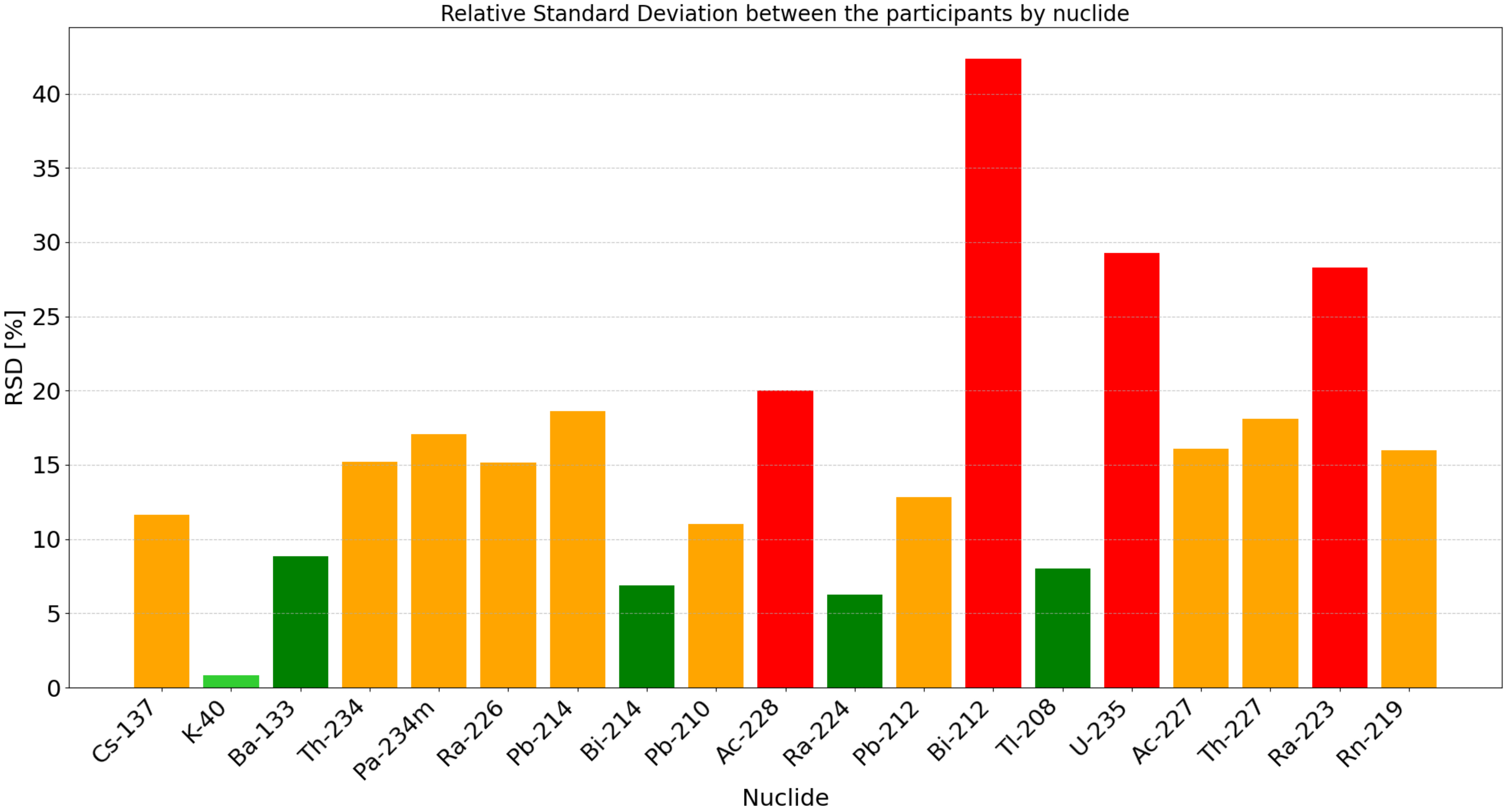
Close Help

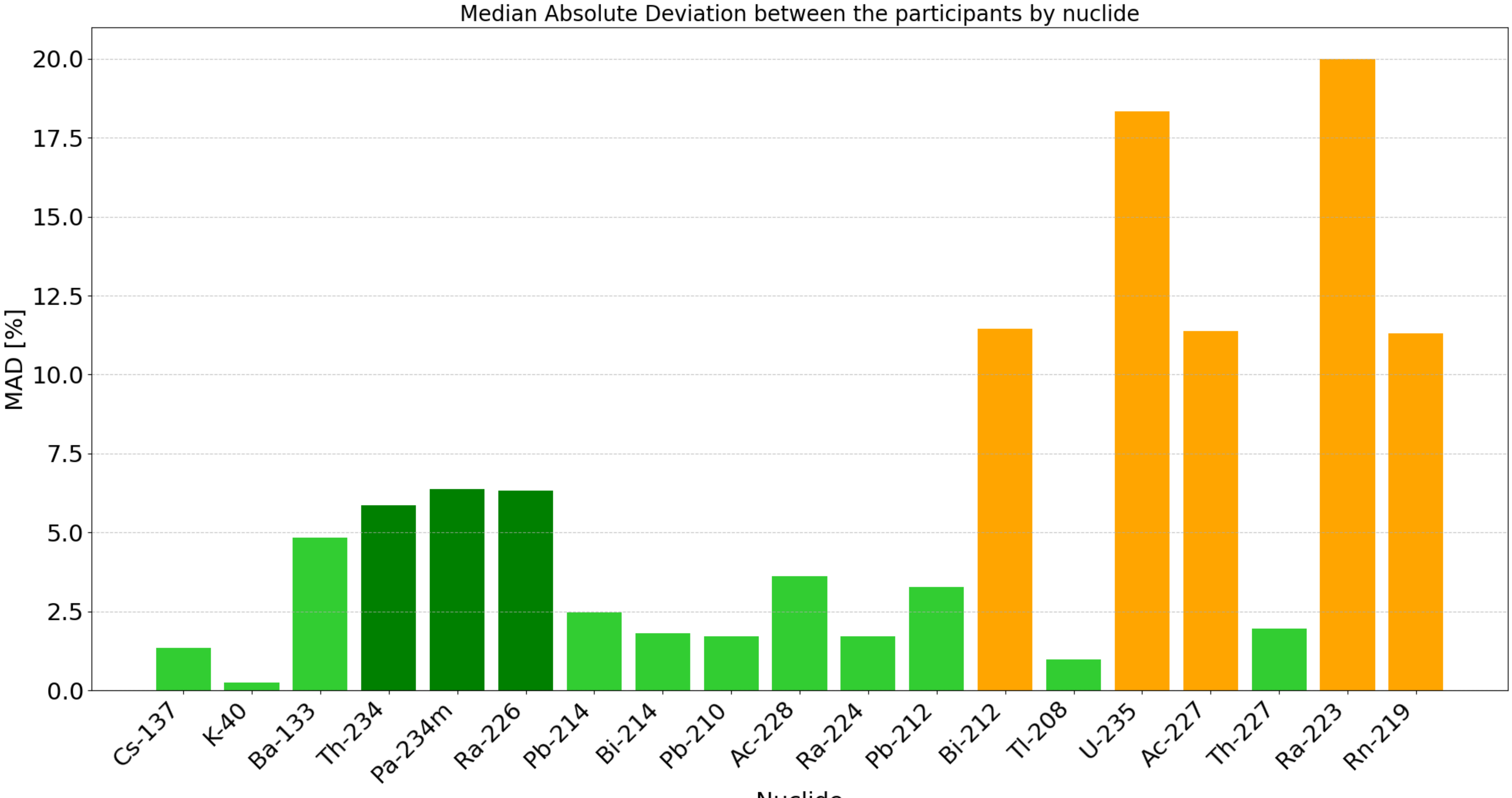




Low counts

Has been observed in another measurement with a different detector (just above detection limit)


Relative Standard Deviation between the participants by nuclide
RSD [%]
0
5
10
15
20
25
30
35
40
Cs-137
K-40
Ba-133
Th-234
Pa-234m
Ra-226
Pb-214
Bi-214
Pb-210
Ac-228
Ra-224
Pb-212
Bi-212
Tl-208
U-235
Ac-227
Th-227
Ra-223
Rn-219
Nuclide



MAD: *typical distance* of laboratories' results from the median

Conclusion

NO LAB NAME MENTIONED,
ONLY INSTRUCTIONS,
CALIBRATION DATA, CS summing corrections
& RESULTS without LAB NAMES

"The exercise shows very good interlaboratory consistency for strong gamma emitters (K-40, Cs-137). Differences become larger for weaker emitters or when decay chain equilibrium assumptions are involved. The largest variability is associated with low-intensity lines and radionuclides affected by coincidence summing or unsupported daughters."

ChatGPT 5

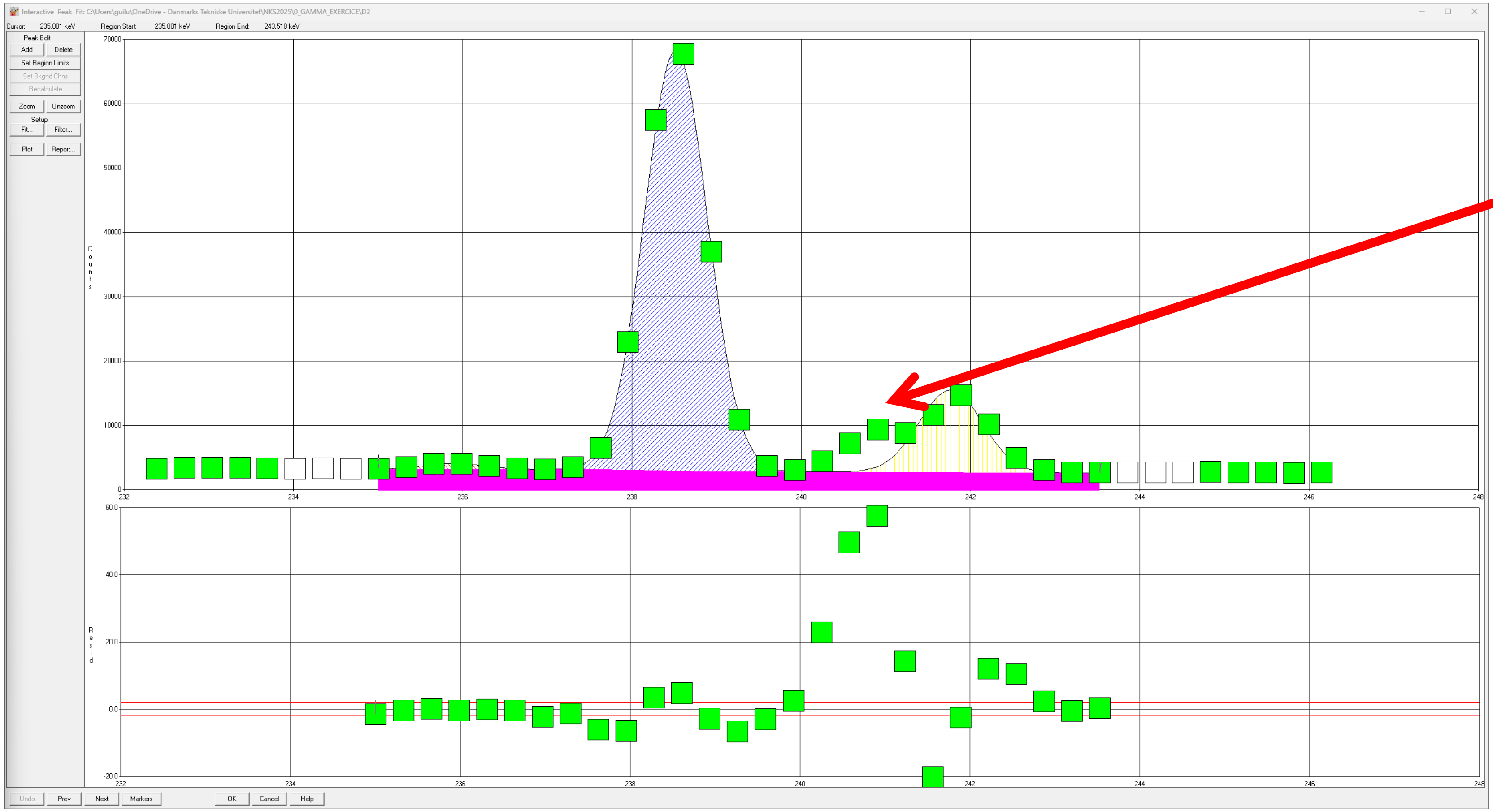
*"This intercomparison exercise was exceptionally well-designed because it successfully isolated the variability introduced by the **analysis software and the analyst's procedure** from the variability of the measurement itself.*

The key takeaway is that even when calibration and measurement are perfectly standardized, the choice of software and the specific analysis methodology remain critical sources of uncertainty and disagreement in gamma-ray spectrometry. This highlights a crucial need for harmonized analysis procedures and a thorough understanding of the software's underlying algorithms in any network of monitoring laboratories."

Gemini 2.5 Pro

Thanks to the participants !

Ra-224, 241 keV



Pb-212: 238.6 keV

Ra-224: 240.986 keV

Pb-214: 241.997 keV

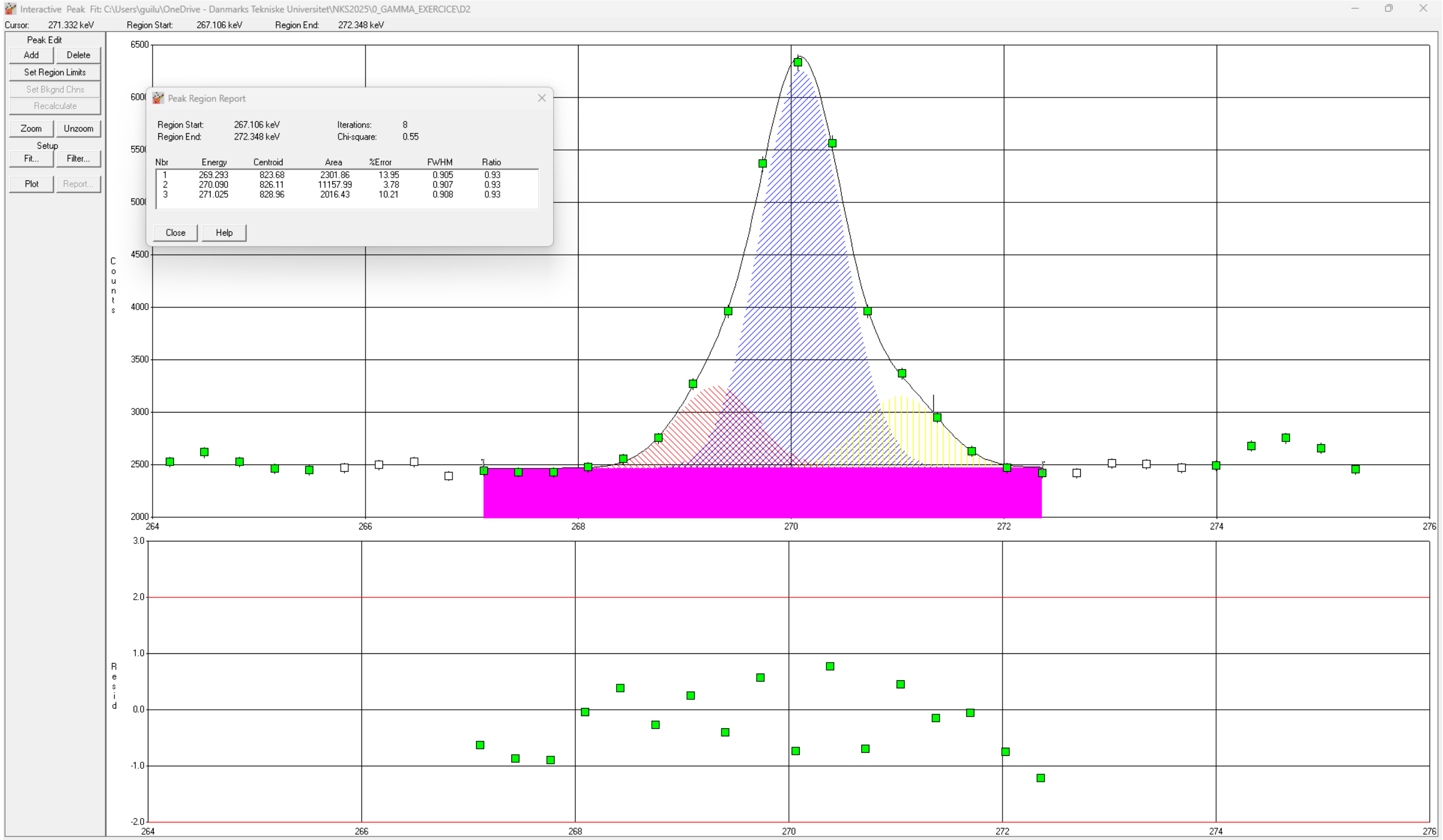
Often missed (Genie)

270 keV region

Ra-223: 269.463 keV, Pγ~14%

Ac-228:270.245 keV, Pγ~3.5%

Rn-219:271.228, Pγ~11%



Coincidence summing corrections with EFFTRAN

CS correction: EFFTRAN

Efficiency transfer and true coincidence summing corrections for environmental gamma-ray spectrometry

Free software, developed by Tim Vidmar: https://efftran.github.io/

"***EFFTRAN*** *is coded in Fortran 77 and runs on the Windows platform through an MS Excel interface written in Visual Basic for Applications.*"

Vidmar, T. 2005. EFFTRAN - a Monte Carlo efficiency transfer code for gamma-ray spectrometry. Nuclear Instruments and Methods A 550, 603-608.

CS correction: EFFTRAN

Detector

Crystal diameter	70.00	mm
Crystal length	31.00	mm
Bulletization (crystal rounding) rad	1.00	mm
Top dead layer	0.00	mm
Side dead layer	0.00	mm
Crystal hole (cavity) length	10.00	mm
Crystal hole (cavity) diameter	10.00	mm
Crystal material	Ge	

End cap (housing) diameter	88.00	mm
End cap (housing) thickness	1.00	mm
End cap (housing) material	aluminium	
Window thickness	0.50	mm
Window-to-crystal gap	5.00	mm
Window material	carbon epoxy	
Mount cup (holder) thickne	1.00	mm
Mount cup (holder) materia	aluminium	
Absorber diametre	0.00	mm
Absorber thickness	0.00	mm
Absorber material	air	

Detector

Load

Store

All numerical values must be equal to or larger than zero.

No check of the (internal) consistency of the data is performed!

The **window-to-crystal gap** is the distance between the top dead layer of the crystal and the detector window.

The **crystal diametre** includes its side dead layer. Similarly, the **crystal length** includes its top dead layer.

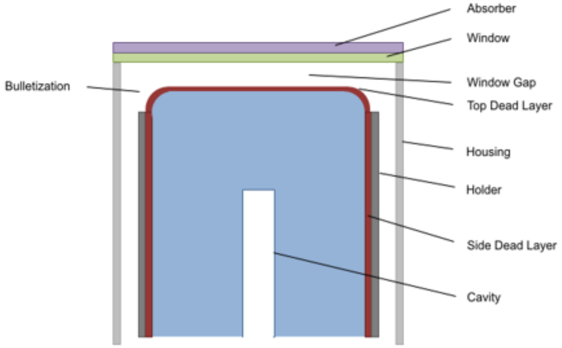
The upper edge of the crystal may be rounded. The amount of rounding is given in terms of the **bulletization (cystal rounding) radius**.

The **crystal hole** (**cavity**) is the central void drilled in the crystal, which contains the cooling pin (cold finger). The latter is not part of our model. The cavity diametre should include the surrounding germanium dead layer, which is also not modelled explicitly.

The **absorber** is assumed to be placed directly onto the detector window.

The crystal **mount cup** (**holder**) keeps the detector crystal in place.

The term **end cap** (**housing**) refers to the the detector cryostat, sometimes also called the detector can.



Source

Source filling height	50.00	mm
Source material	Sediment	
Container diameter	92.00	mm
Containier bottom thickness	1.30	mm
Container side wall thickness	1.80	mm
Container material	polypropylene	
Container-to-absorber gap*	0.00	mm

Load

Store

All numerical values must be equal to or larger than zero.

To simulate a point source, set all the numerical parameters to zero (except the container-to-absorber-gap) and all the materials to "vacuum" !

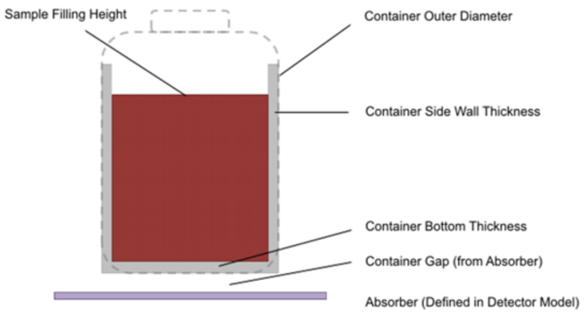
No check of the (internal) consistency od the data is performed!

The **container-to-absorber gap** is the distance between the top of the detector absorber and the bottom of the sample container.

The **sample filling height** refers to the sample material only, excluding the container bottom thickness.

The **container diametre** includes (both) its side walls.

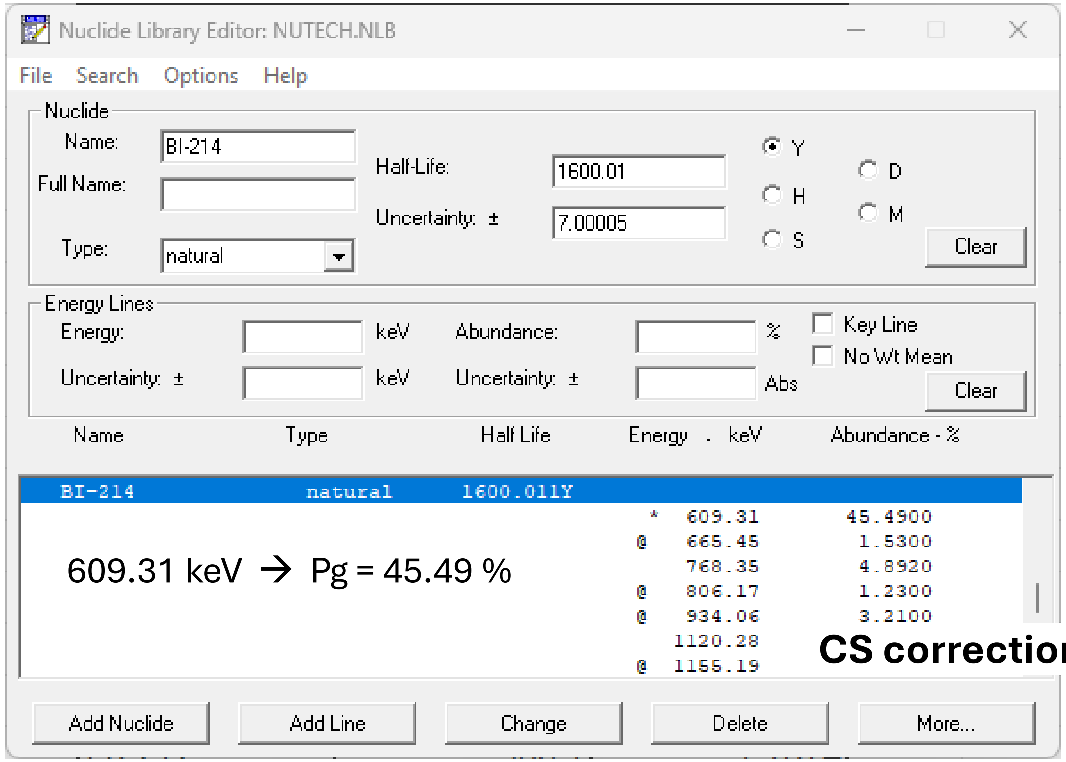
The source material is assumed to tightly fill the space in the container in its radial dimension.

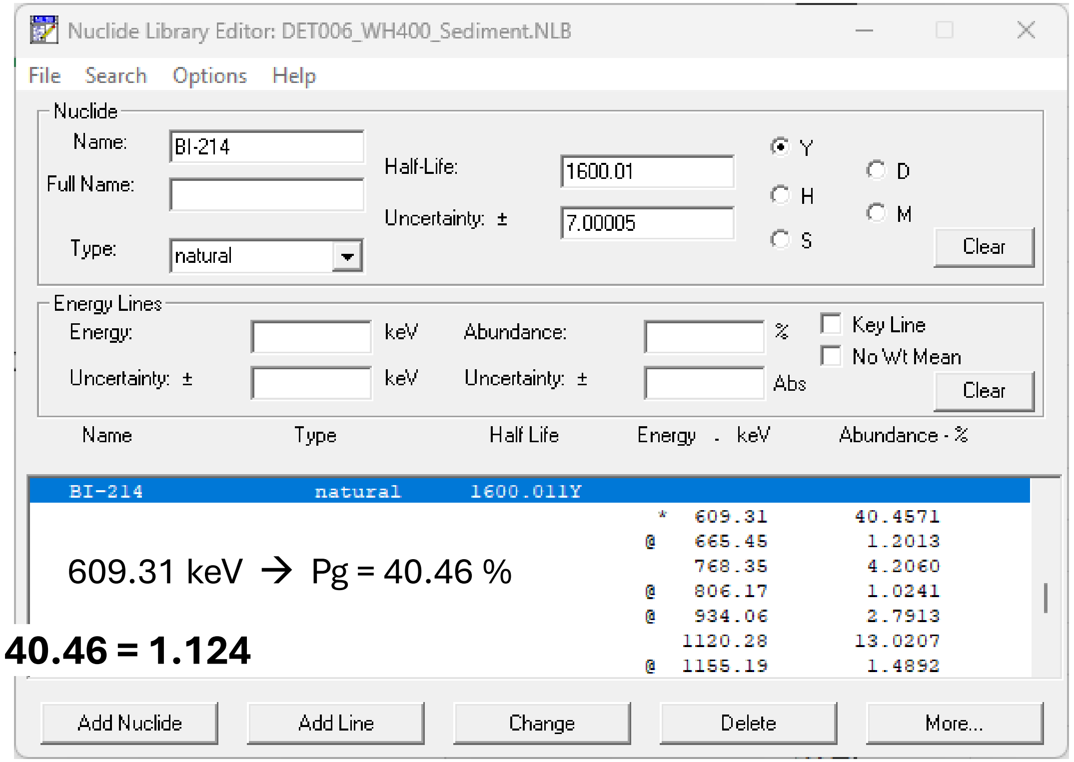


Load Genie/GammaVision library

Modify Emission probability in library

CS Corrections: EFFTRAN

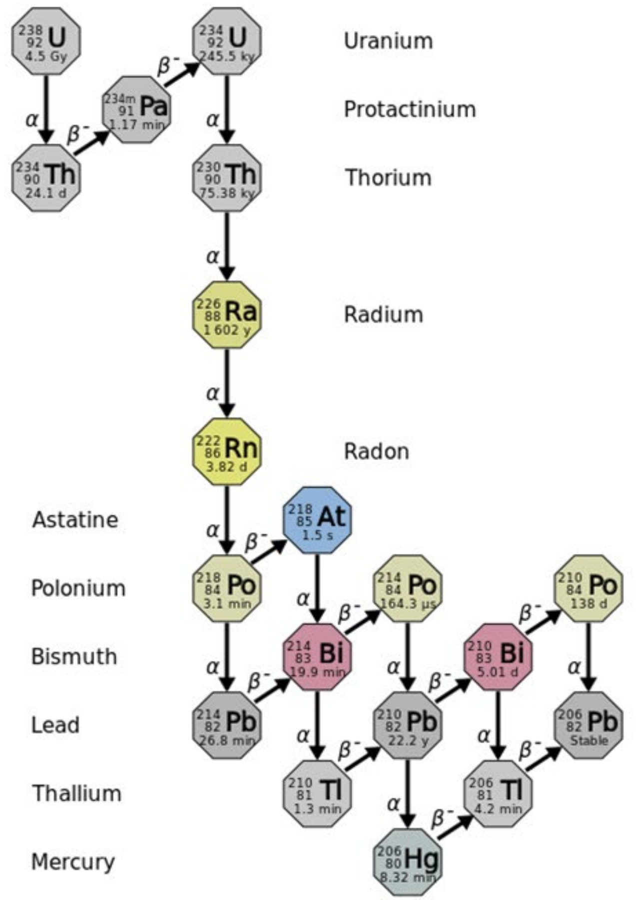


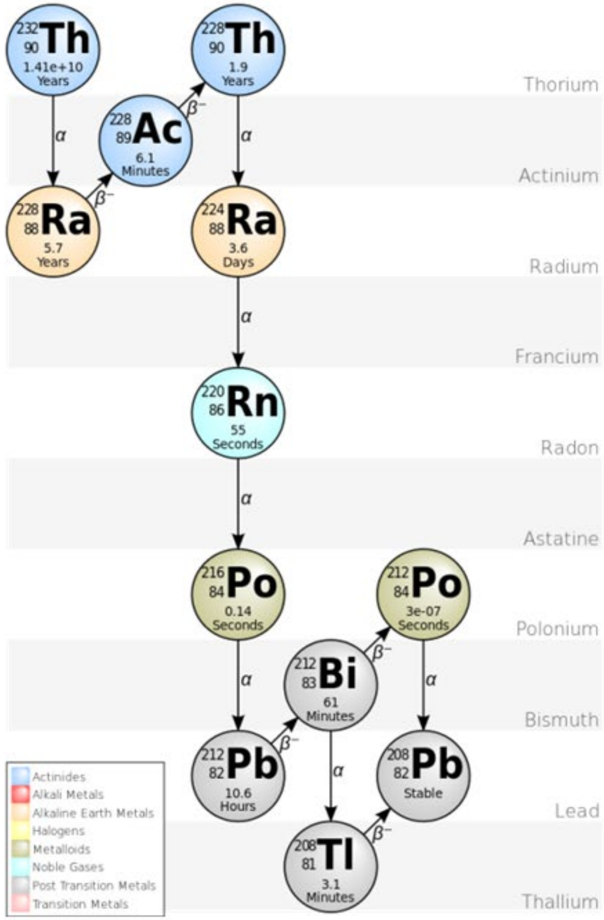


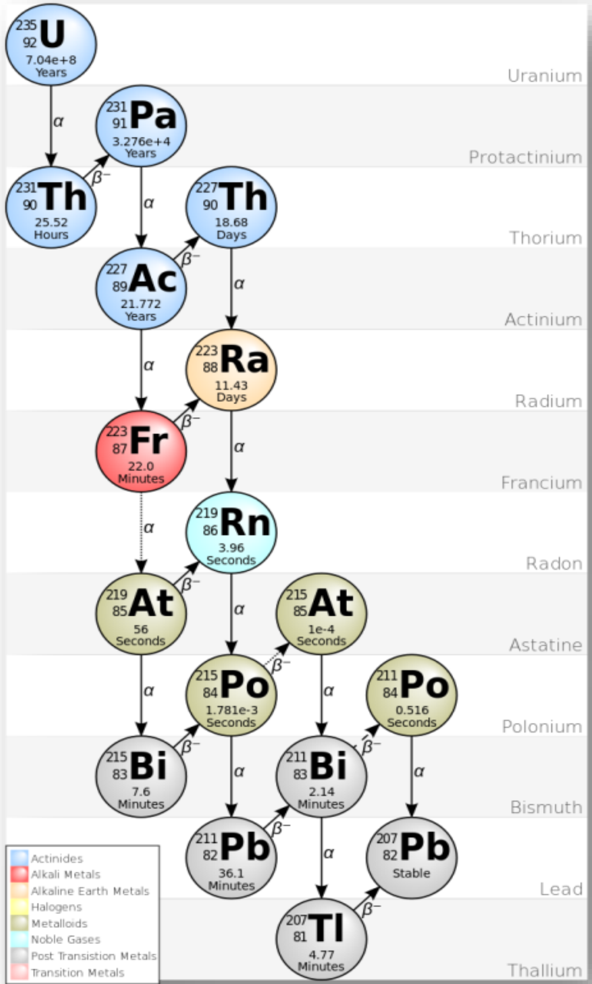
CS correction = 45.49 / 40.46 = 1.124

For a given gamma-ray:

FEP(Sample) = FEP(fit) / CS correction from EFFTRAN


Uranium
Protactinium
Thorium
Radium
Radon
Astatine
Polonium
Bismuth
Lead
Thallium
Mercury
238 92 U 4.5 Gy
234m 91 Pa 1.17 min
234 92 U 245.5 ky
234 90 Th 24.1 d
230 90 Th 75.38 ky
226 88 Ra 1 602 y
222 86 Rn 3.82 d
218 85 At 1.5 s
218 84 Po 3.1 min
214 84 Po 164.3 µs
210 84 Po 138 d
214 83 Bi 19.9 min
210 83 Bi 5.01 d
214 82 Pb 26.8 min
210 82 Pb 22.2 y
206 82 Pb Stable
210 81 Tl 1.3 min
206 81 Tl 4.2 min
206 80 Hg 8.32 min
α
β⁻


Thorium
Actinium
Radium
Francium
Radon
Astatine
Polonium
Bismuth
Lead
Thallium
232 90 Th 1.41e+10 Years
228 89 Ac 6.1 Minutes
228 90 Th 1.9 Years
228 88 Ra 5.7 Years
224 88 Ra 3.6 Days
220 86 Rn 55 Seconds
216 84 Po 0.14 Seconds
212 84 Po 3e-07 Seconds
212 83 Bi 61 Minutes
212 82 Pb 10.6 Hours
208 82 Pb Stable
208 81 Tl 3.1 Minutes
α
β−
Actinides
Alkali Metals
Alkaline Earth Metals
Halogens
Metalloids
Noble Gases
Post Transition Metals
Transition Metals


Uranium
Protactinium
Thorium
Actinium
Radium
Francium
Radon
Astatine
Polonium
Bismuth
Lead
Thallium
235 92 U 7.04e+8 Years
231 91 Pa 3.276e+4 Years
231 90 Th 25.52 Hours
227 90 Th 18.68 Days
227 89 Ac 21.772 Years
223 88 Ra 11.43 Days
223 87 Fr 22.0 Minutes
219 86 Rn 3.96 Seconds
219 85 At 56 Seconds
215 85 At 1e-4 Seconds
215 84 Po 1.781e-3 Seconds
211 84 Po 0.516 Seconds
215 83 Bi 7.6 Minutes
211 83 Bi 2.14 Minutes
211 82 Pb 36.1 Minutes
207 82 Pb Stable
207 81 Tl 4.77 Minutes
α
β−
Actinides
Alkali Metals
Alkaline Earth Metals
Halogens
Metalloids
Noble Gases
Post Transition Metals
Transition Metals