

NPL REPORT IR 56

Environmental Radioactivity Proficiency Test Exercise 2018 – Final Report

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Environmental Radioactivity Proficiency Test Exercise 2018

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ABSTRACT

The results of NPL's twenty-fourth Environmental Radioactivity Proficiency Test Exercise are reported. Six different sample types were offered: an aqueous mixture of one alpha emitter and three beta emitters (designated 'AB'), an aqueous mixture of three alpha emitters ('A1'), an aqueous mixture of three beta emitters ('B1'), an aqueous mixture of four gamma emitters ('GH'), a second aqueous mixture of four gamma emitters ('GL') and a sample of contaminated concrete ('C2'). In total, 594 results were submitted; 584 were analysed and, of these, 74% were found to be 'In Agreement' with the NPL Assigned Values.

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Approved on behalf of NPLML by Peter Ivanov,
Science Area Leader, Nuclear Metrology Group, Environment Department

Assigned Values (reference time 2018-06-01 1200 UTC)

Nuclide (AB)	Assigned Value (Bq g⁻¹)
³ H	10.47 ± 0.26
⁹⁰ Sr	8.291 ± 0.042
¹⁴⁷ Pm	18.05 ± 0.46
²⁴⁴ Cm	8.788 ± 0.058
Gross beta	22.04 ± 0.70
Nuclide (A1)	Assigned Value (Bq kg⁻¹)
²³² Th	2.724 ± 0.052
²³⁸ Pu	10.306 ± 0.050
²⁴¹ Am	7.674 ± 0.034
Gross alpha	31.7 ± 2.8
Nuclide (B1)	Assigned Value (Bq g⁻¹)
³ H	1.336 ± 0.034
¹⁴ C	0.4212 ± 0.0038
¹²⁹ I	0.3839 ± 0.0038
Nuclide (GH)	Assigned Value (Bq g⁻¹)
⁵⁴ Mn	19.06 ± 0.16
⁶⁰ Co	7.399 ± 0.041
⁶⁵ Zn	2.353 ± 0.033
¹³³ Ba	19.70 ± 0.27
Nuclide (GL)	Assigned Value (Bq kg⁻¹)
⁸⁵ Sr	5.931 ± 0.082
¹³⁴ Cs	17.14 ± 0.25
¹³⁷ Cs	6.79 ± 0.12
²¹⁰ Pb	6.30 ± 0.13
Nuclide (C2)‡	Assigned Value (Bq g⁻¹)
⁶⁰ Co	0.0705 ± 0.0022
¹³⁷ Cs	0.0565 ± 0.0019
¹⁵² Eu	7.180 ± 0.096
¹⁵⁴ Eu	0.1423 ± 0.0064

UNCERTAINTIES

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a coverage probability of approximately 95 %. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

‡ This material was coded as 'C1' in the original PTE documentation – it is coded **C2** throughout this report.

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1. SUMMARY

This environmental radioactivity Proficiency Test Exercise (PTE) was the twenty-fourth in a series of such exercises run by NPL over the last 30 years. The exercises help analysts to identify measurement problems and also support UKAS accreditations in this area; they are run on an annual basis. A range of sample types have been made available over the course of these exercises; these have been mostly aqueous in nature, although in recent years solid samples have been included.

Six sample types were made available for analysis in the 2018 PTE:

(i) **AB**: a mixture of one α -emitting radionuclide and three β -emitting radionuclides
20 g of dilute nitric acid (1 – 20 Bq g⁻¹ per radionuclide)

(ii) **A1**: a mixture of three α -emitting radionuclides
500 g of dilute nitric acid (1 – 20 Bq kg⁻¹ per radionuclide)

(iii) **B1**: a mixture of three β -emitting radionuclides
500 g of very dilute NaOH solution (0.1 – 2 Bq g⁻¹ per radionuclide)

(iv) **GH**: a 'high-level' mixture of four γ -emitting radionuclides
100 g of dilute nitric acid (1 – 20 Bq g⁻¹ per radionuclide)

(v) **GL**: a 'low-level' mixture of four γ -emitting radionuclides
500 g of dilute nitric acid (1 – 20 Bq kg⁻¹ per radionuclide)

(vi) **C2**: a contaminated concrete sample, 50 g (please note that this material was coded as 'C1' in the original PTE documentation – for administrative reasons, it is referred to as sample type C2 throughout this report)

As in previous years, the main objective was to assess the performance of the participating laboratories. This required the participants to identify (and/or measure) the activity per unit mass of the radionuclides present in the samples, whereas the tasks of NPL were to prepare and distribute the samples, to collect, analyse and interpret the results and to compile an exercise report.

Each participant was allocated by NPL a unique laboratory code number (if not already allocated in a previous PTE in this series). This was done in confidence so that no third parties could identify which participant had which code number. The participants were asked to add their code numbers to their Reporting Forms and the code numbers would be used by NPL to label the results in the final PTE report.

The activities per unit mass of the radionuclides in the aqueous sample types were traceable to national standards of radioactivity, and therefore to the international measurement system.

Each aqueous sample type was prepared (as a bulk sample) by combining weighed aliquots of standard solutions of the individual radionuclides with a weighed amount of carrier solution and then diluting the mixture further to achieve the target activity per unit mass. Dilution factors were measured gravimetrically and were verified by counting sources prepared at the various dilution levels using either liquid scintillation counting or gamma spectrometry. The Assigned Value for each nuclide was calculated by dividing the activity per unit mass of the original standard solution by the dilution factor(s). The bulk solution was subdivided into (typically) 50 bottles and homogeneity was checked by gamma spectrometry where applicable. Solution stability was checked by counting one or more bottles of each Sample Type at NPL at regular intervals throughout the course of the PTE; all solutions were found to be stable.

The bulk concrete sample consisted of contaminated material of low activity concentration procured from a nuclear site (the donor organisation is confidential). The bulk sample was powdered and homogenised before being subdivided into 45 x 50 g samples in plastic bottles. The homogeneity of the material was determined by gamma spectrometry of a subset of the bottles. Other samples in the set were analysed by pyrolysis and LSC (to determine nominal ^3H and ^{14}C concentrations), by ICP-MS (to determine nominal actinide concentrations) and by radiochemical separation and LSC (to determine the nominal ^{90}Sr concentration). These particular radionuclides (or radioelements) were suspected as being present based on information provided by the supplier or from previous experience of analysing contaminated concrete. Some needed to be quantified to aid compliance with radionuclide transport regulations. These nominal activity concentrations were not used as Assigned Values.

Note that the analysis of participants' data for measurements other than gamma measurements for Sample Type C2 does not fall under the scope of NPL's current accreditation to ISO17043 for solid samples.

After receipt of the results from the participants, the Power-Moderated Weighted Mean (PMWM, Pommé, 2012) was calculated for each radionuclide / radionuclide type. This provides a more robust estimate than the weighted mean in the event of discrepant data sets. For mutually consistent data, the method approaches the weighted mean, the weights being the reciprocals of the variances associated with the measured values. For data suspected of inconsistency, the weighting is moderated by augmenting laboratory variances by a common amount and/or by decreasing the power of weighting factors. For increasingly discrepant data sets, there is a smooth transition from the weighted mean to the arithmetic mean. The PMWM was also calculated for the following quantities:

- Sample Type AB gross beta
- Sample Type A1 gross alpha
- Sample Type B1 gross beta
- All radionuclides in Sample Type C2

For cases where no Assigned Value was available from NPL measurements, a decision was made in each case as to whether or not to use the PMWM as the Assigned Value. Note that consensus values based on the PMWM are not traceable to national standards of radioactivity.

The NPL data analysis method is described in Section 2 and the Assigned Values and PMWM values are summarised in Section 3. The PMWM values for nuclides other than gamma emitters for Sample Type C2 are summarised in the appendix, along with plots showing the deviation from the PMWM, in each case.

The dispatch of the samples was subcontracted to the following organisations:

The Courier Company (UK) Limited
11 James Way
Marshall Court
Milton Keynes MK1 1SU

DG Global Forwarding
Legacy House
Hanworth Trading Estate
Hampton Rd West
Feltham TW13 6DH

Circle Express
Unit 1
Polar Park
Bath Rd
West Drayton UB7 0EX

Note that, unless otherwise stated, all uncertainties quoted in this report are combined standard uncertainties (note that, while coverage factors are only meaningful if greater than 1, this is equivalent to applying a coverage factor of $k = 1$, providing a level of confidence of approximately 68 %).

2. TREATMENT OF DATA

The data were analysed using the same methods as in the 2017 exercise (Dean et al., 2018). The deviation 'D' from the assigned value from each laboratory value was calculated from:

$$D = \frac{L - N}{N} = \left(\frac{L}{N} - 1 \right) \quad [1]$$

The standard uncertainty ($k=1$) ' u_D ' of the deviation was calculated from:

$$u_D = \frac{L}{N} \sqrt{\left(\frac{u_L}{L} \right)^2 + \left(\frac{u_N}{N} \right)^2} \quad [2]$$

The quantities zeta (ζ), the relative uncertainty of a laboratory's value (R_L) and the z-score were calculated from:

$$\zeta = \frac{L - N}{\sqrt{u_L^2 + u_N^2}} \quad [3]$$

$$R_L = \frac{u_L}{L} \quad [4]$$

$$z = \frac{L - N}{\sigma_p} = \frac{L - N}{0.05823 N} \quad [5]$$

where:

L is the participant's value;

N is the Assigned Value;

u_L is the standard uncertainty of the participants' value;

u_N is the standard uncertainty of the Assigned Value;

σ_p is the standard uncertainty for proficiency assessment.

The value of the standard uncertainty for proficiency assessment σ_p is chosen by perception (viz. ISO 13528:2005 paragraph 6.3). It corresponds to a level of performance that NPL would wish laboratories to be able to achieve. It corresponds to a deviation D of 15 % (at a 99 % confidence level). In other words, any result with a deviation D smaller than ± 15 % will pass the z-test.

Note that the z-score presented is as defined in ISO 13528:2005 rather than the commonly understood z-score and is used to reject results on the basis of a maximum percentage deviation.

The zeta and z-scores were used to determine whether the difference between the participant's value and the Assigned Value was significantly different from zero. The Interquartile Range outlier test (Harms and Gilligan, 2011) was used to determine whether the relative uncertainty R_L was significantly larger than the other values in the data set. Note that this test is unable to identify outliers if the data set is smaller than 7.

Results for which the absolute values of the zeta score and the z-score are both ≤ 2.576 and for which R_L is not significantly larger than the other values in the data set are taken to mean that the participant's value is 'in agreement' with the Assigned Value. These results are plotted in white in this report.

If (i) R_L is significantly larger than the other values in the data set, or (ii) the result passes the zeta test but not the z-test (i.e., there is a large deviation from the Assigned Value combined with a large uncertainty), or (iii) the result passes the z-test but not the zeta test (where there is a small deviation from the Assigned Value and a small uncertainty), the participant's value is classified as 'questionable' (plotted in yellow).

If the absolute values of both the zeta score and the z-score are greater than 2.576, then the participant's value is classified as 'discrepant' from the Assigned Value (plotted in red), regardless of the value of R_L .

Table 1 Summary of data classification criteria

zeta test	R_L test	z test	Classification
pass	pass	pass	in agreement
pass	fail	pass	questionable
fail	pass	pass	questionable
pass	-	fail	questionable
fail	-	fail	discrepant

3. SUMMARY OF PARTICIPANTS' RESULTS

The reference time is 2018-06-01 1200 UTC.

Table 2 AB summary

Nuclide (AB)	NPL Assigned Values (Bq g ⁻¹)	PMWM (Bq g ⁻¹)	Deviation %	Zeta	Critical Value
³ H	10.47 ± 0.13	10.615 ± 0.069	1.4	0.98	2.58
⁹⁰ Sr	8.291 ± 0.021	8.17 ± 0.11	-1.5	-1.08	2.86
¹⁴⁷ Pm	18.05 ± 0.23	14.19 ± 0.99	-21.4	-3.80	3.71
²⁴⁴ Cm	8.788 ± 0.029	8.78 ± 0.17	0.0	-0.02	2.88

Table 3 A1 summary

Nuclide (AL)	NPL Assigned Values (Bq kg ⁻¹)	PMWM (Bq kg ⁻¹)	Deviation %	Zeta	Critical Value
²³² Th	2.724 ± 0.026	2.643 ± 0.042	-3.0	-1.63	2.71
²³⁸ Pu	10.306 ± 0.025	10.28 ± 0.12	-0.3	-0.25	2.79
²⁴¹ Am	7.674 ± 0.017	7.34 ± 0.19	-4.4	-1.72	2.78

Table 4 B1 summary

Nuclide (B1)	NPL Assigned Values (Bq g ⁻¹)	PMWM (Bq g ⁻¹)	Deviation %	Zeta	Critical Value
³ H	1.336 ± 0.017	1.3100 ± 0.0059	-1.9	-1.44	2.58
¹⁴ C	0.4212 ± 0.0019	0.4095 ± 0.0067	-2.8	-1.67	2.85
¹²⁹ I	0.3839 ± 0.0019	0.4103 ± 0.0092	6.9	2.81	2.85

Table 5 GH summary

Nuclide (GH)	NPL Assigned Values (Bq g ⁻¹)	PMWM (Bq g ⁻¹)	Deviation %	Zeta	Critical Value
⁵⁴ Mn	19.062 ± 0.081	18.86 ± 0.12	-1.1	-1.37	2.68
⁶⁰ Co	7.399 ± 0.020	7.366 ± 0.044	-0.4	-0.68	2.74
⁶⁵ Zn	2.353 ± 0.017	2.362 ± 0.026	0.4	0.28	2.69
¹³³ Ba	19.70 ± 0.13	19.28 ± 0.15	-2.1	-2.06	2.65

Table 6 GL summary

Nuclide (GL)	NPL Assigned Values (Bq kg ⁻¹)	PMWM (Bq kg ⁻¹)	Deviation %	Zeta	Critical Value
⁸⁵ Sr	5.931 ± 0.041	7.80 ± 0.43	31.5	4.33	2.95
¹³⁴ Cs	17.14 ± 0.12	17.04 ± 0.14	-0.6	-0.57	2.64
¹³⁷ Cs	6.788 ± 0.062	6.893 ± 0.055	1.5	1.27	2.58
²¹⁰ Pb	6.300 ± 0.067	6.29 ± 0.35	-0.2	-0.03	2.86

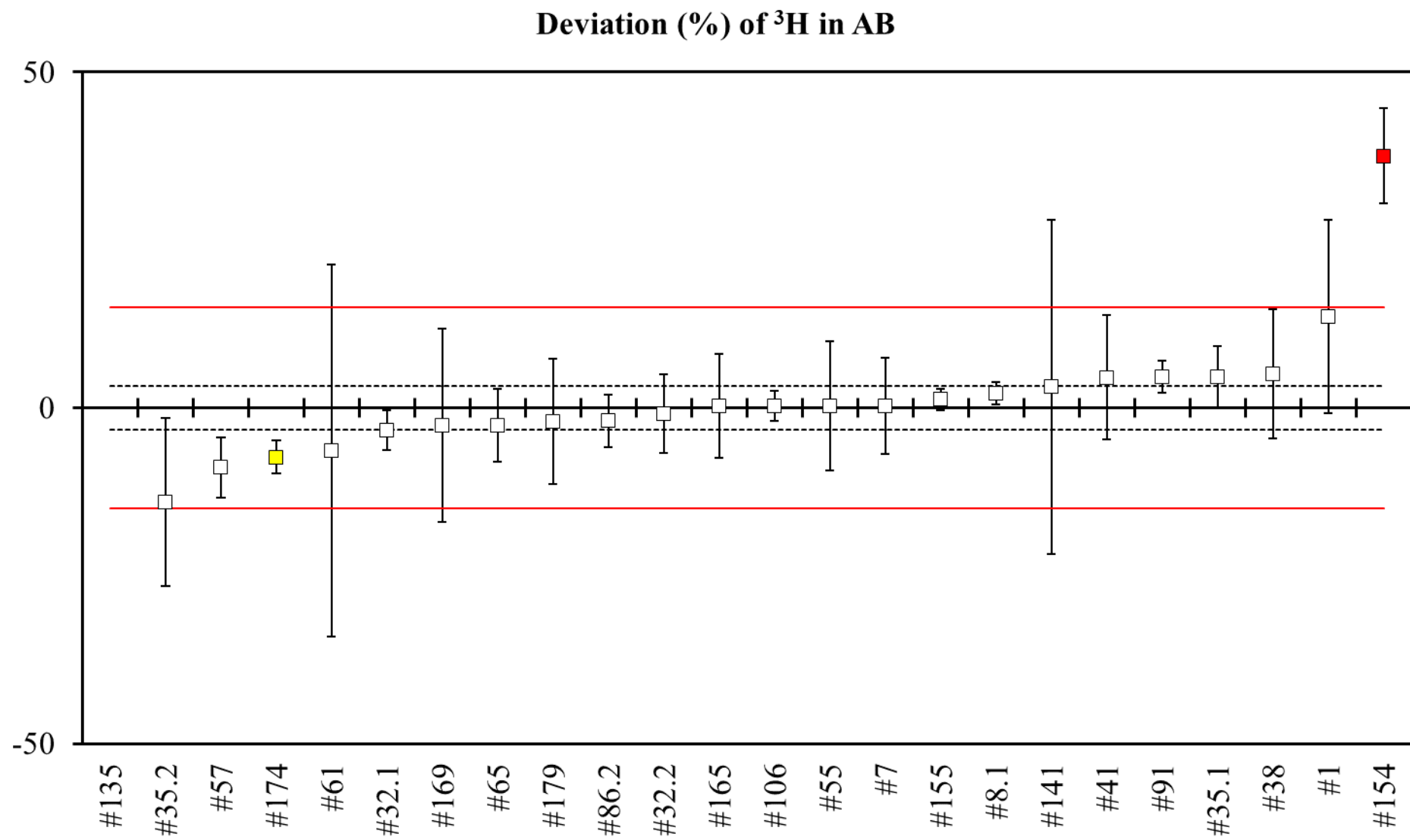
Table 7 C2 summary (⁶⁰Co, ¹³⁷Cs, ¹⁵²Eu and ¹⁵⁴Eu only)

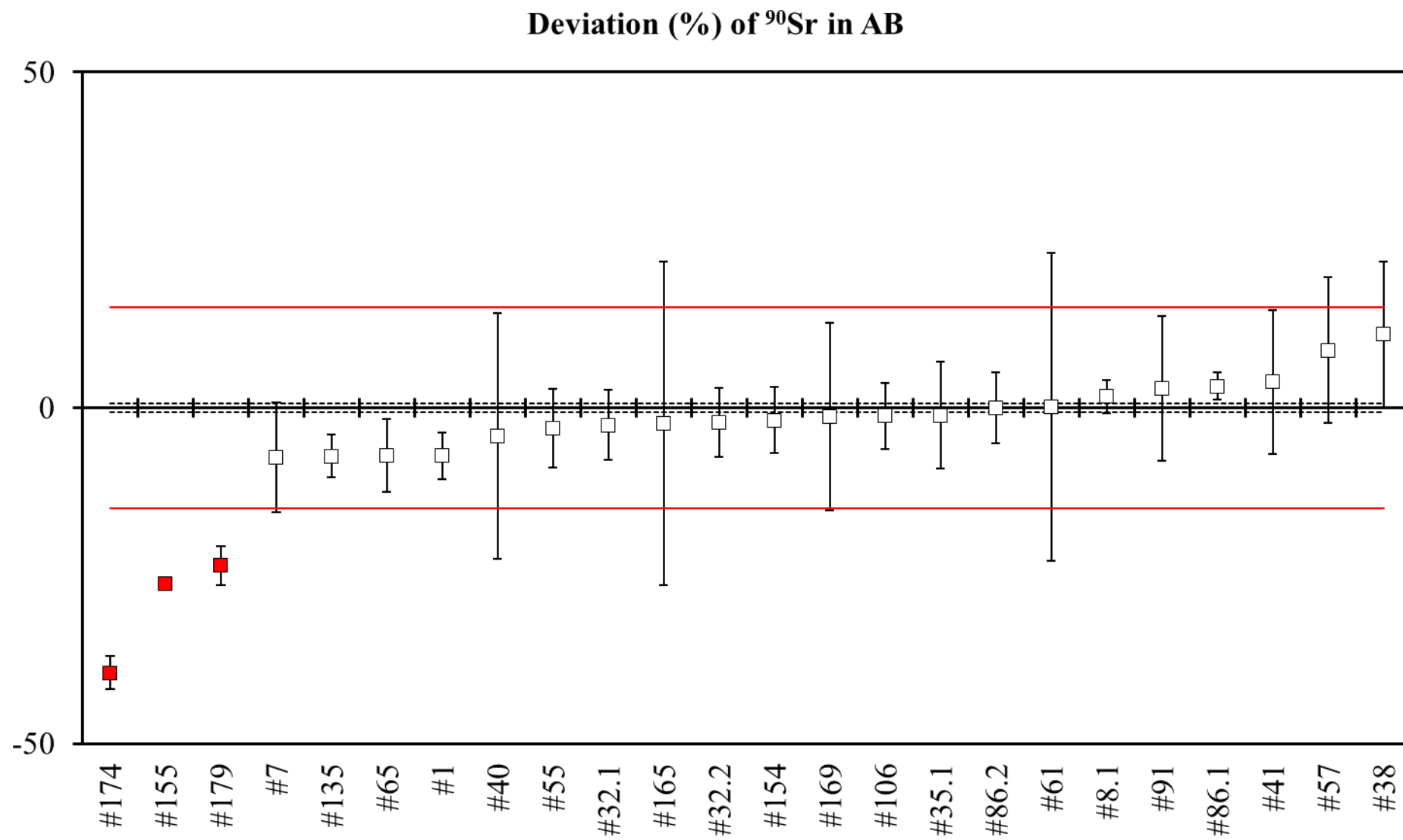
Nuclide (C2)	PMWM (Bq g ⁻¹)
⁶⁰ Co	0.0705 ± 0.0011
¹³⁷ Cs	0.05647 ± 0.00096
¹⁵² Eu	7.180 ± 0.048
¹⁵⁴ Eu	0.1423 ± 0.0032

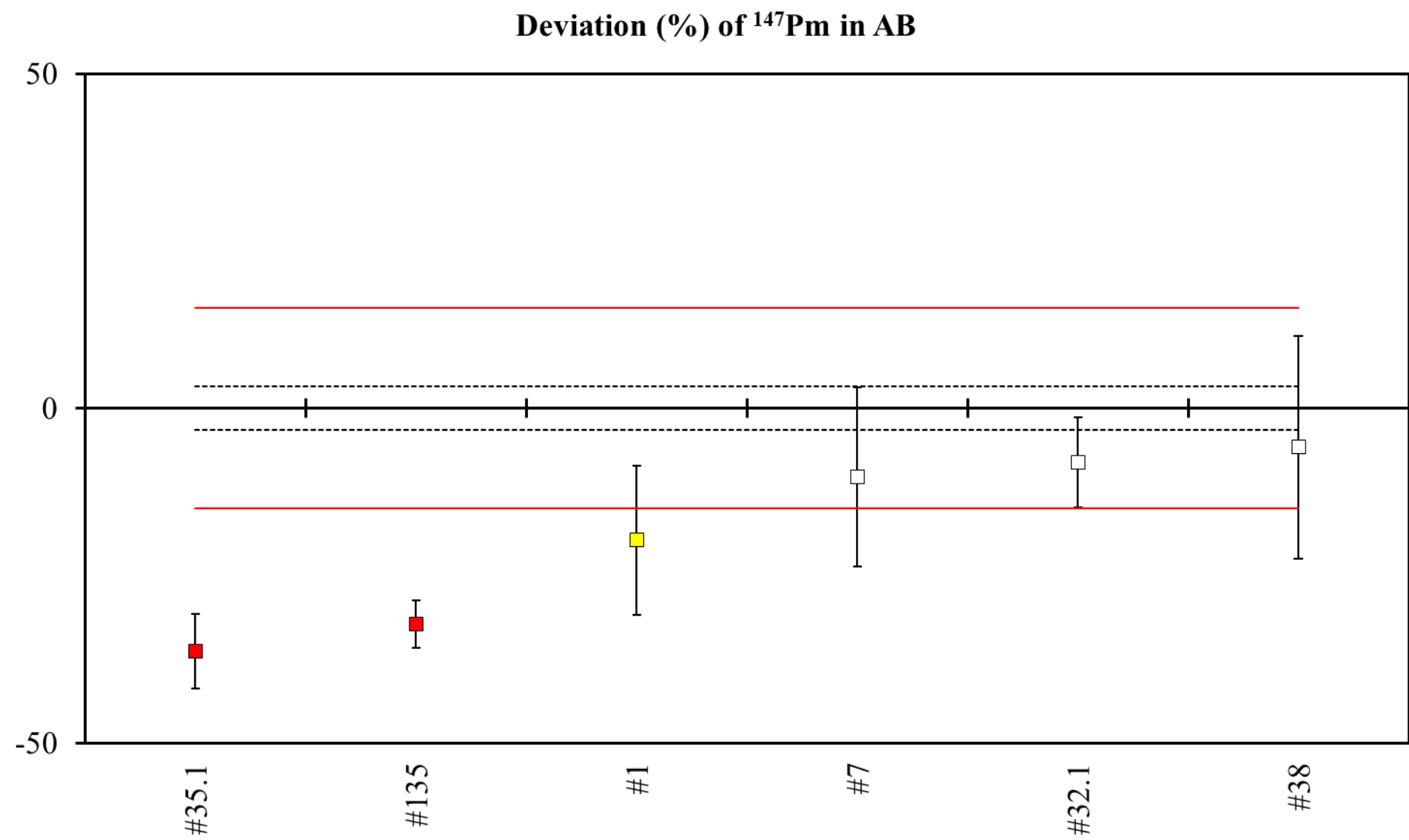
Table 8 Gross nuclide measurements summary

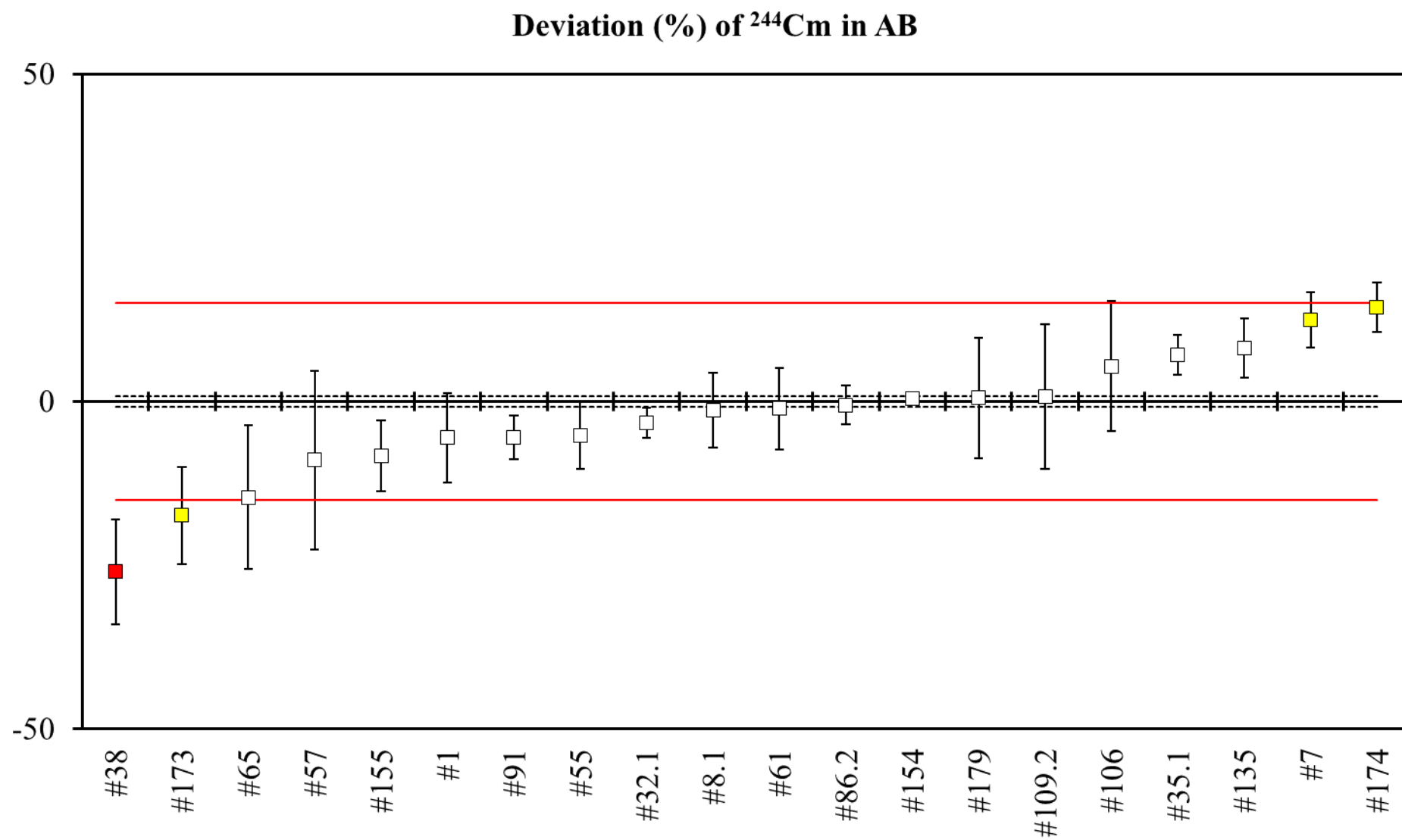
Nuclides	PMWM
Gross beta (AB)	(22.04 ± 0.35) Bq g ⁻¹
Gross alpha (A1)	(31.7 ± 1.4) Bq kg ⁻¹
Gross beta (B1)	Value not used (see Section 11)

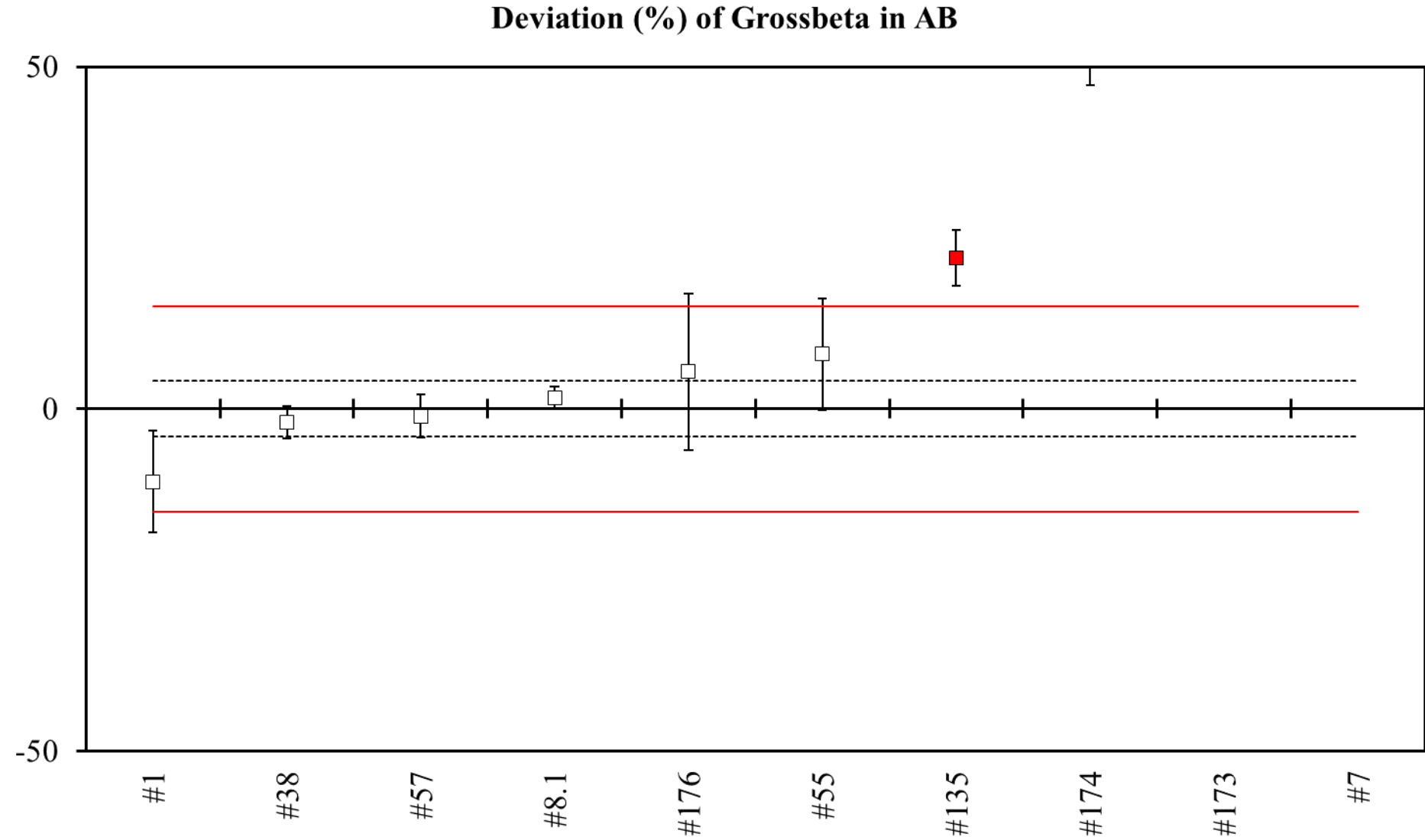
4. Alpha Beta (AB) Deviation Plots



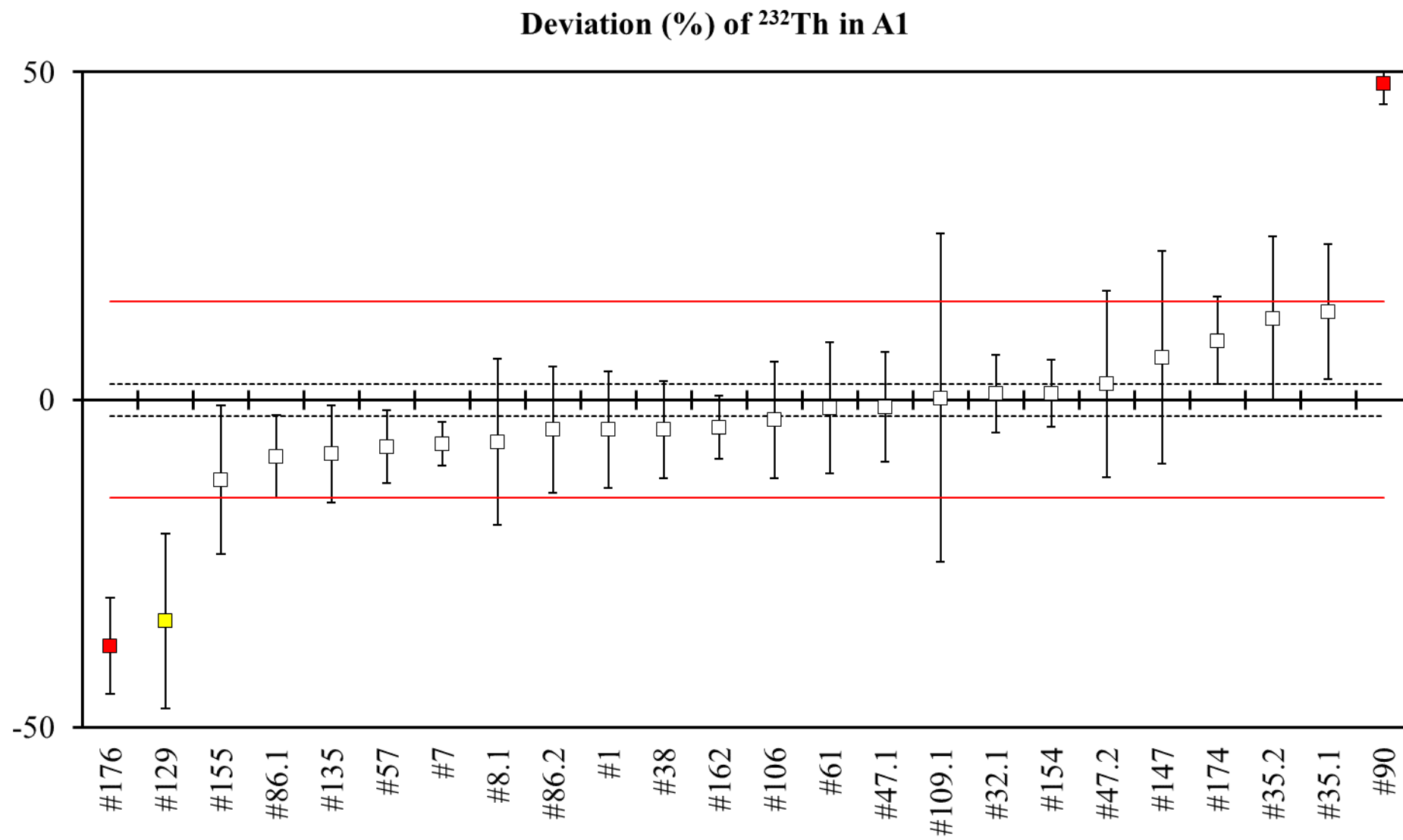


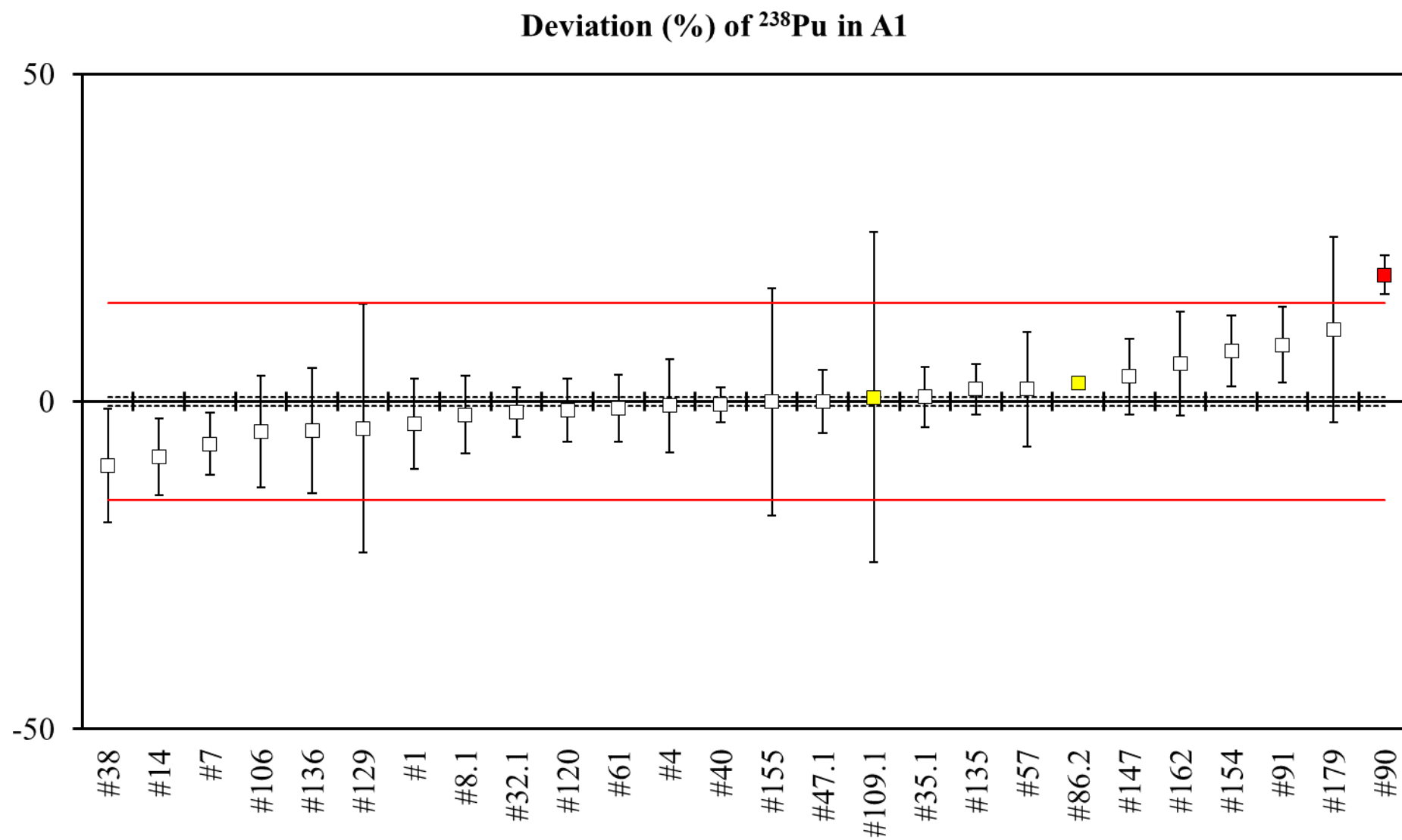


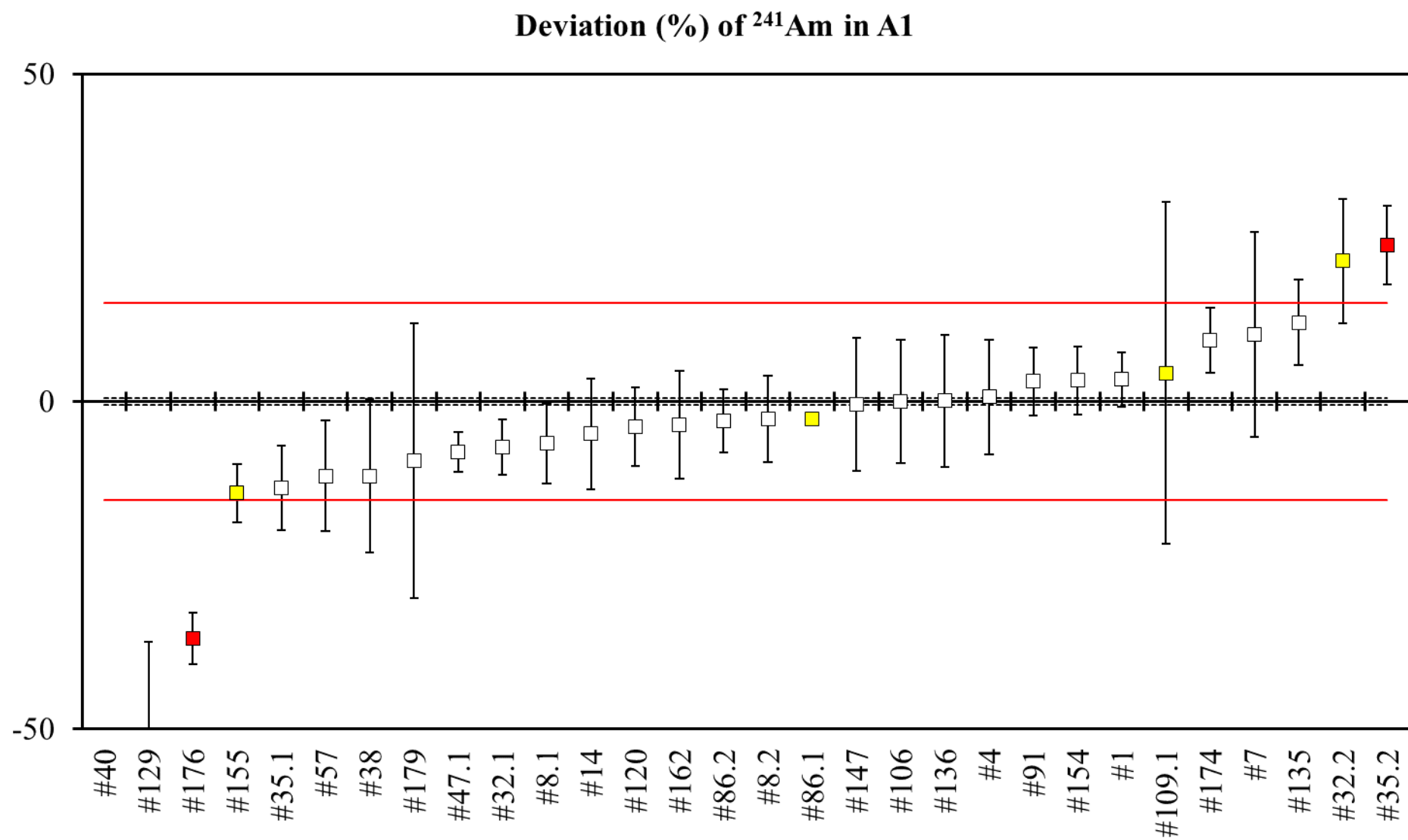


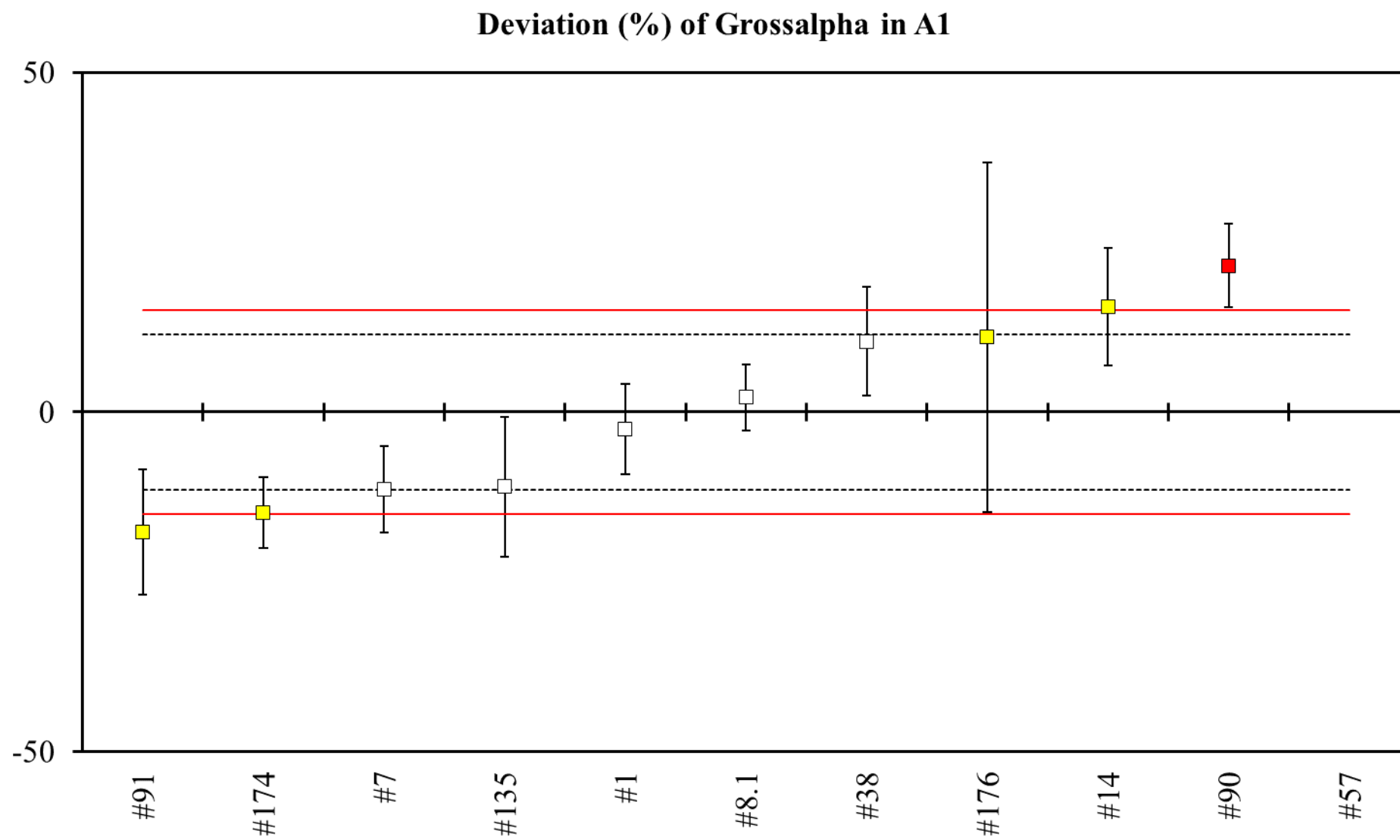


5. Alpha One (A1) Deviation Plots

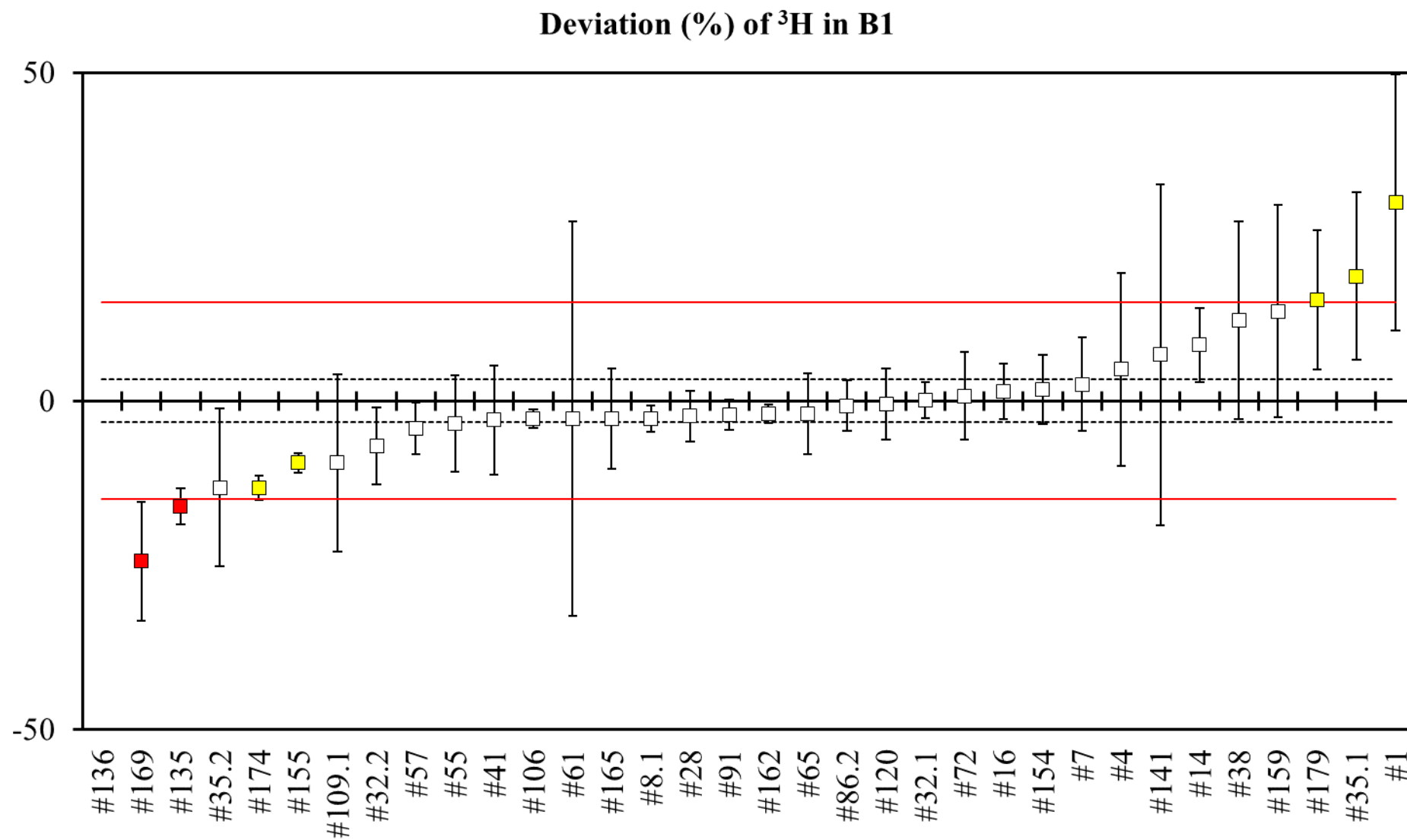


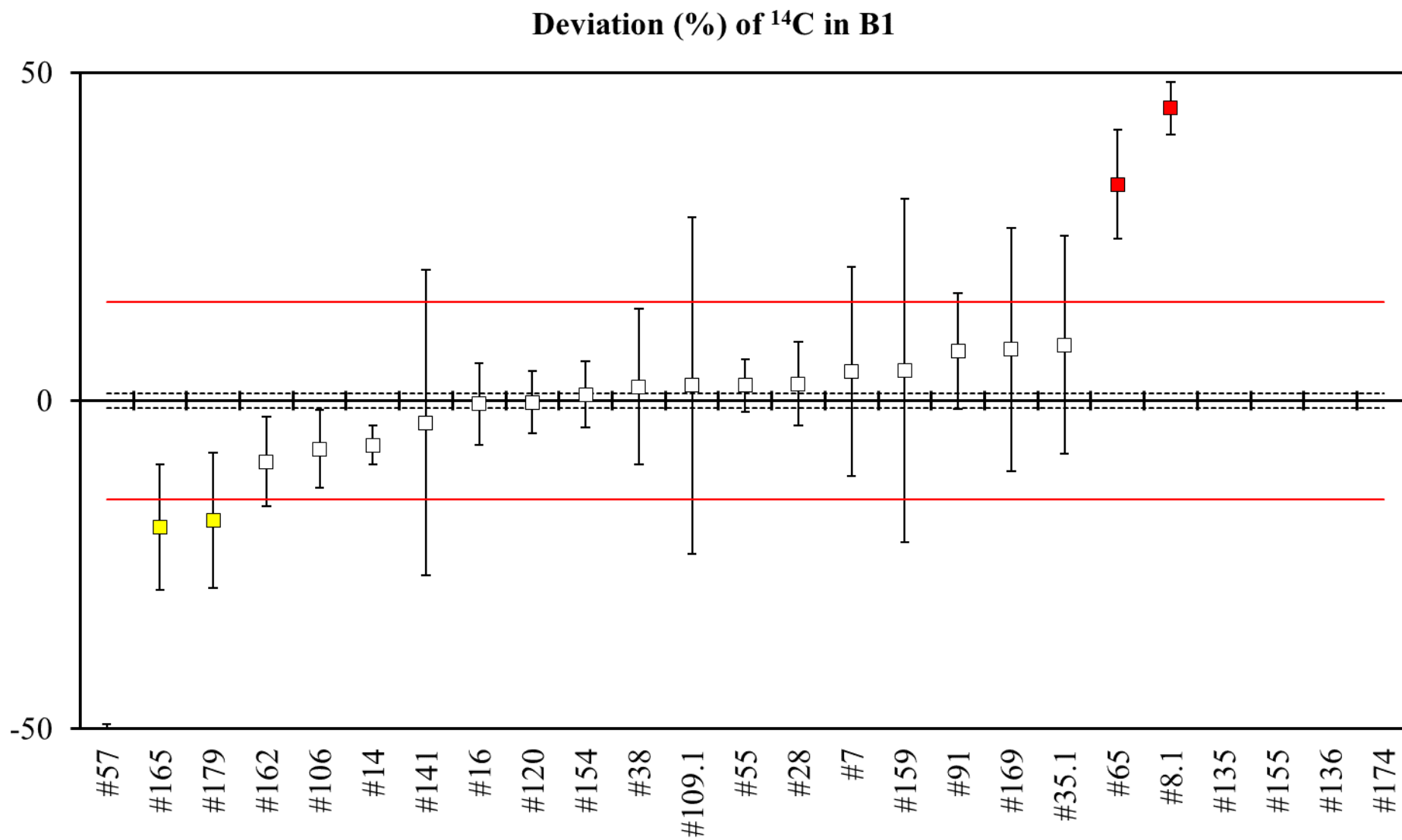


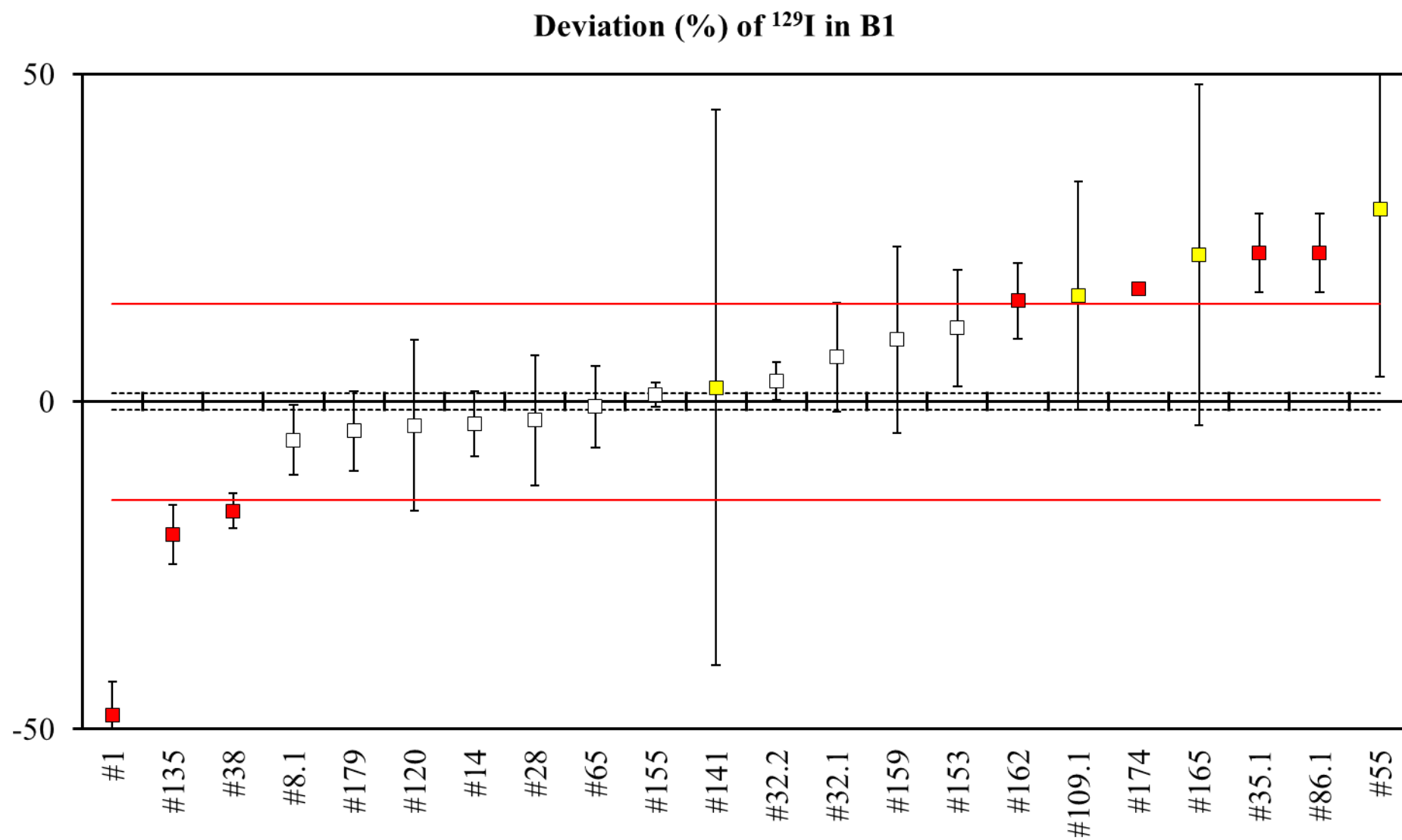




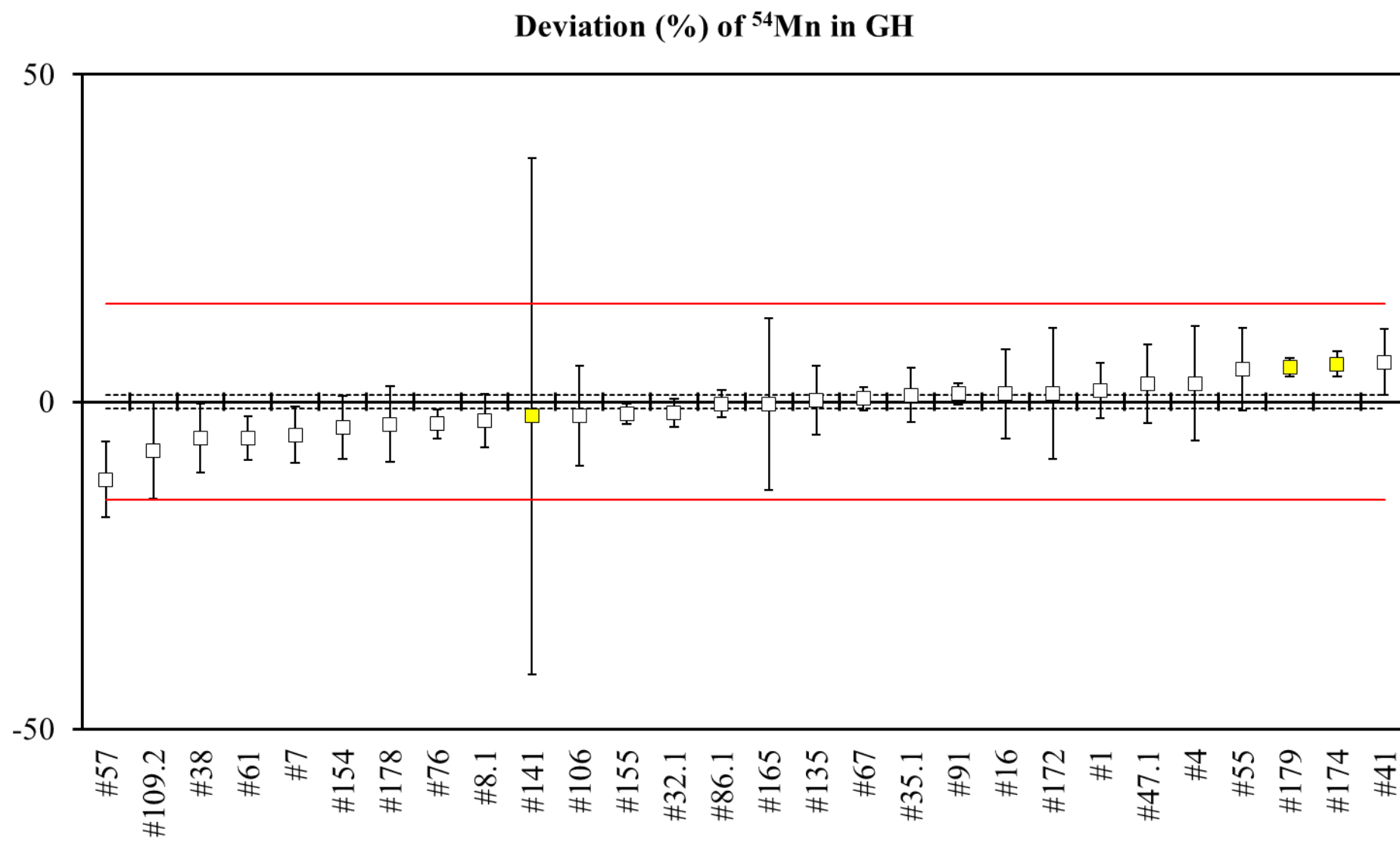
6. Beta One (B1) Deviation Plots

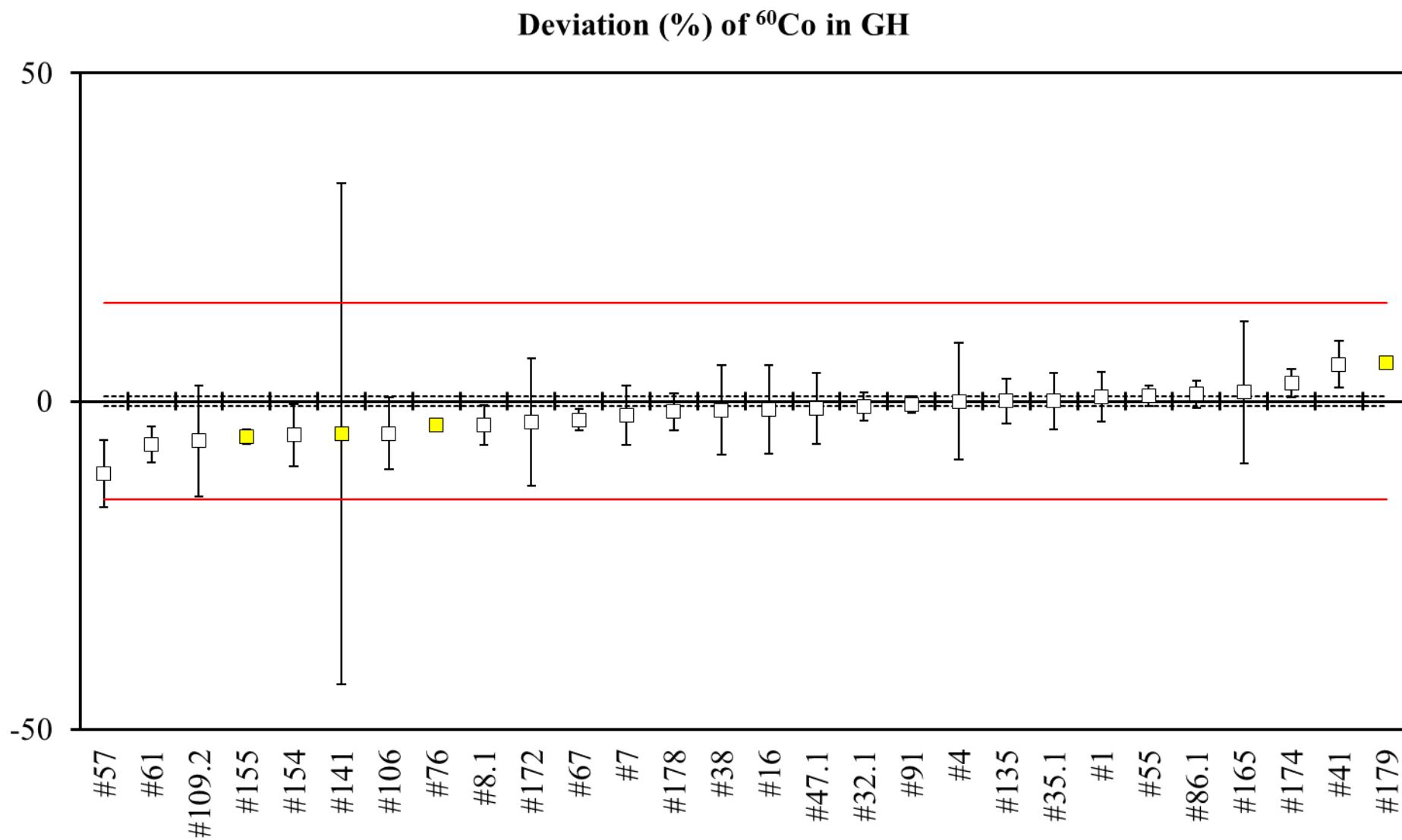


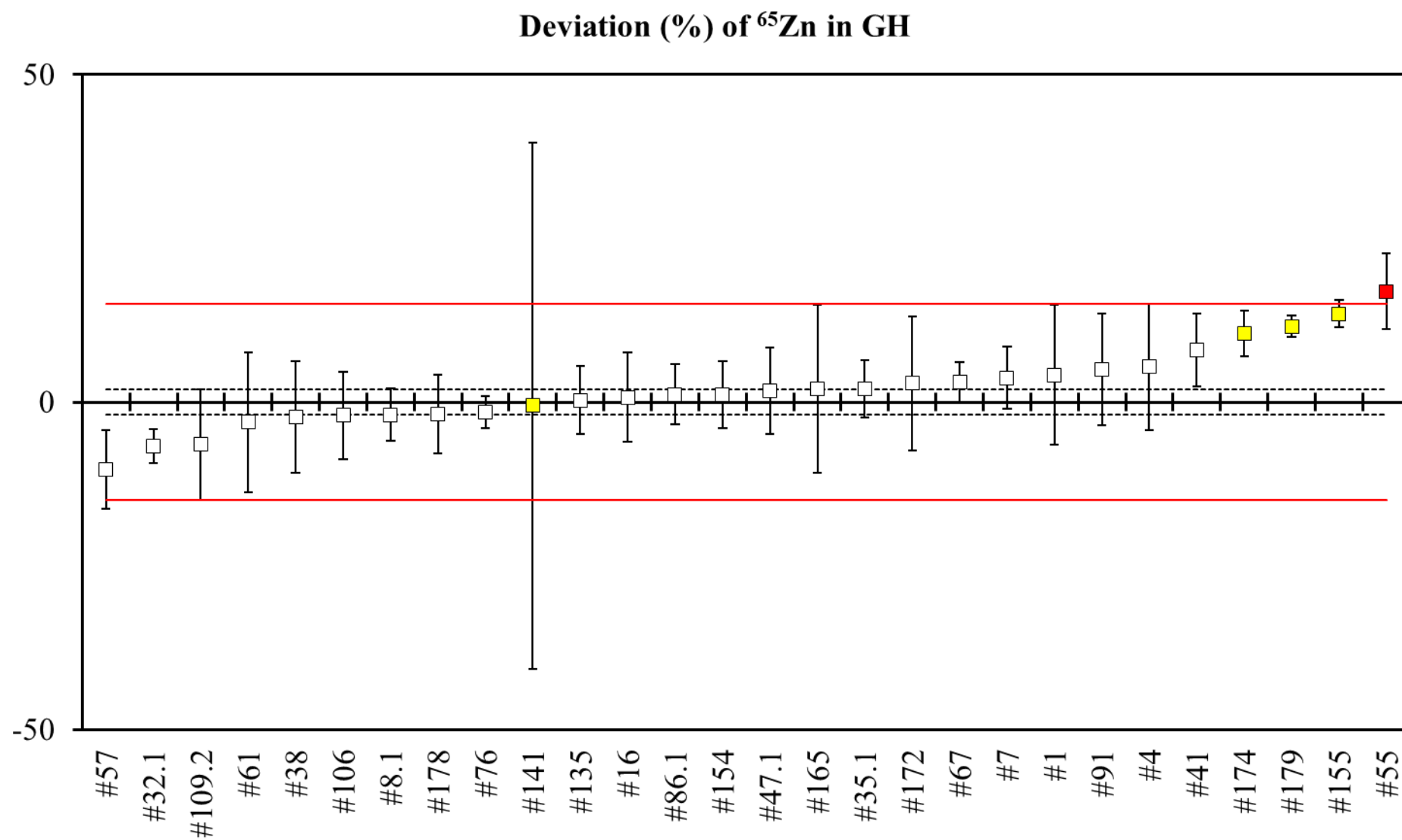


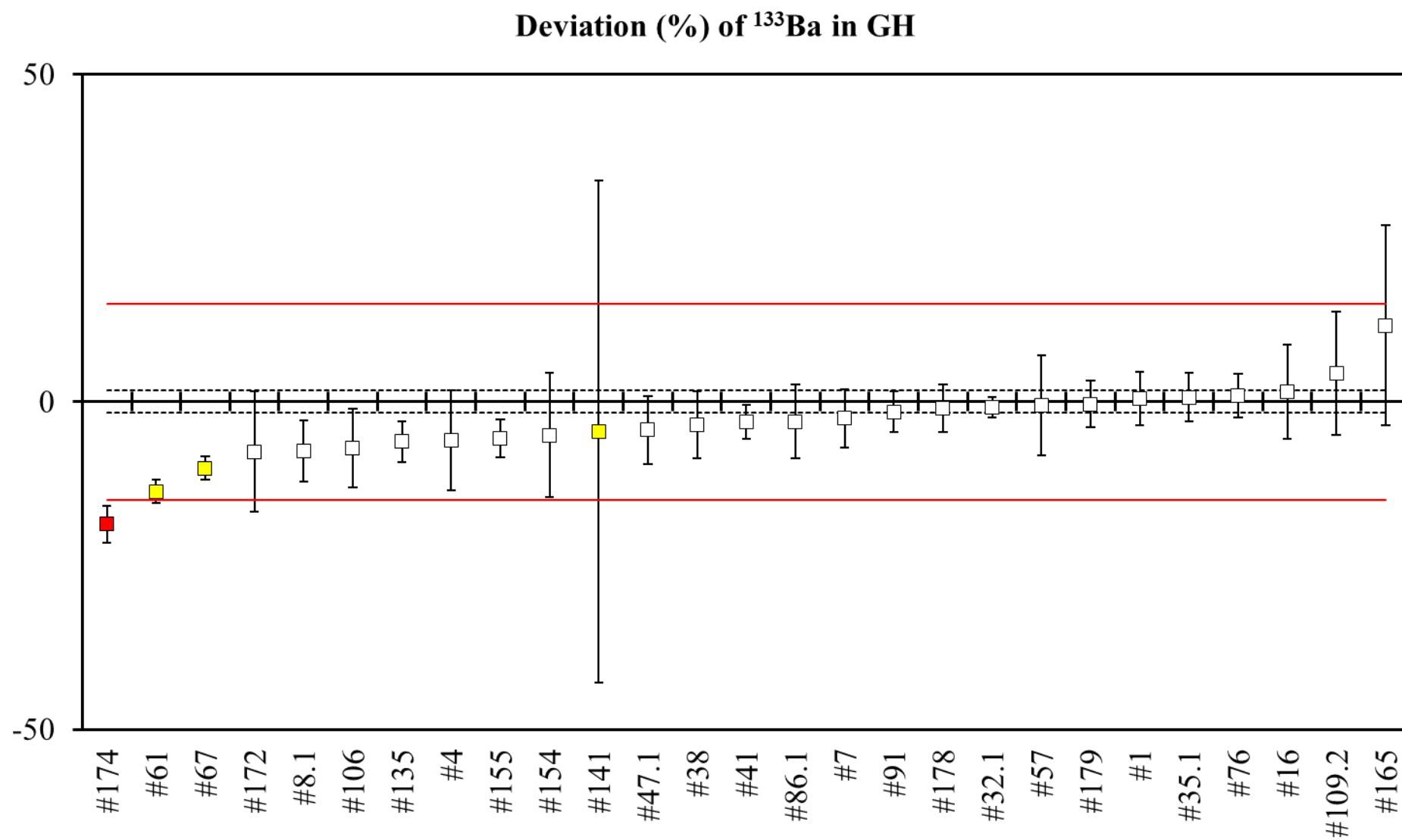


7. Gamma High (GH) Deviation Plots

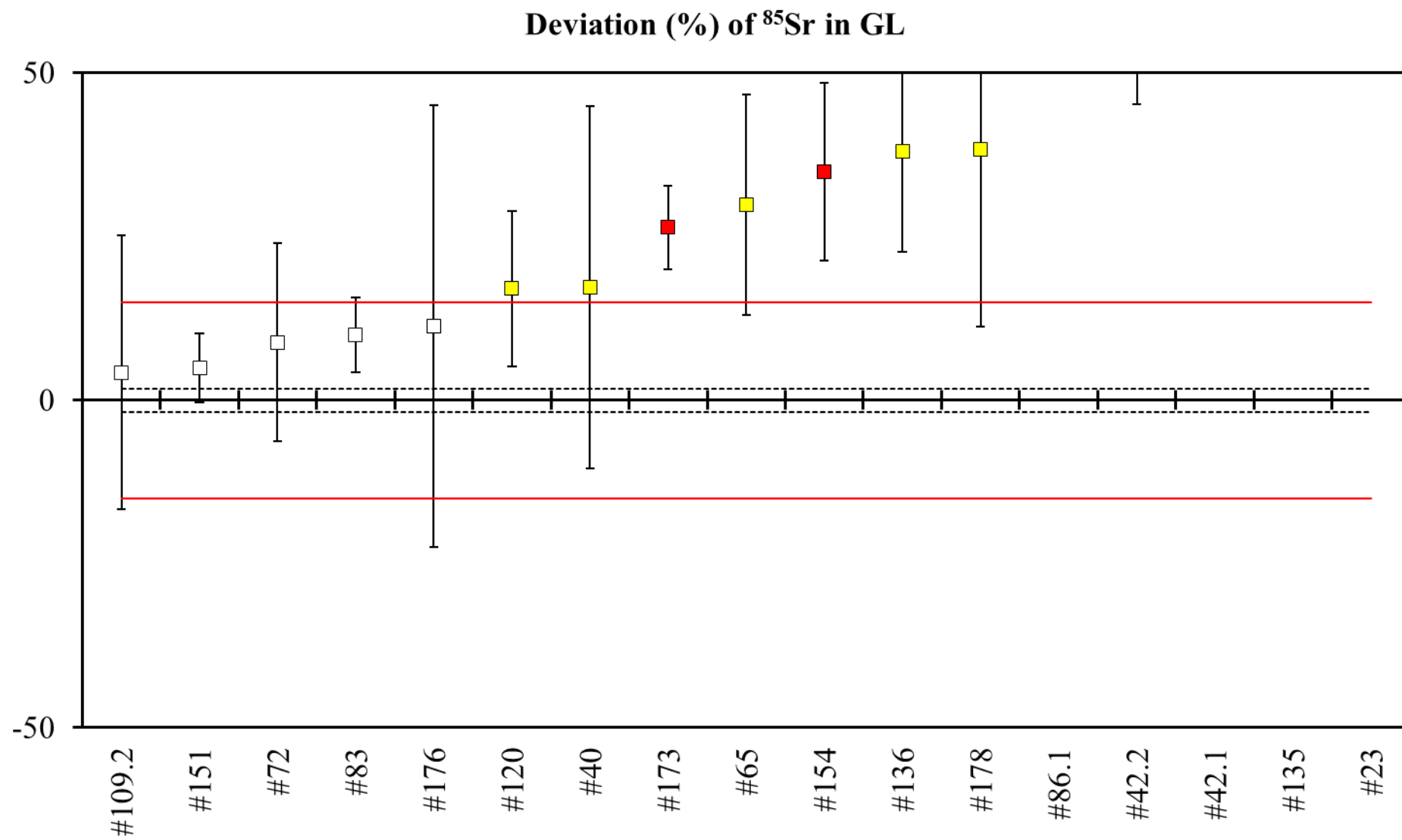


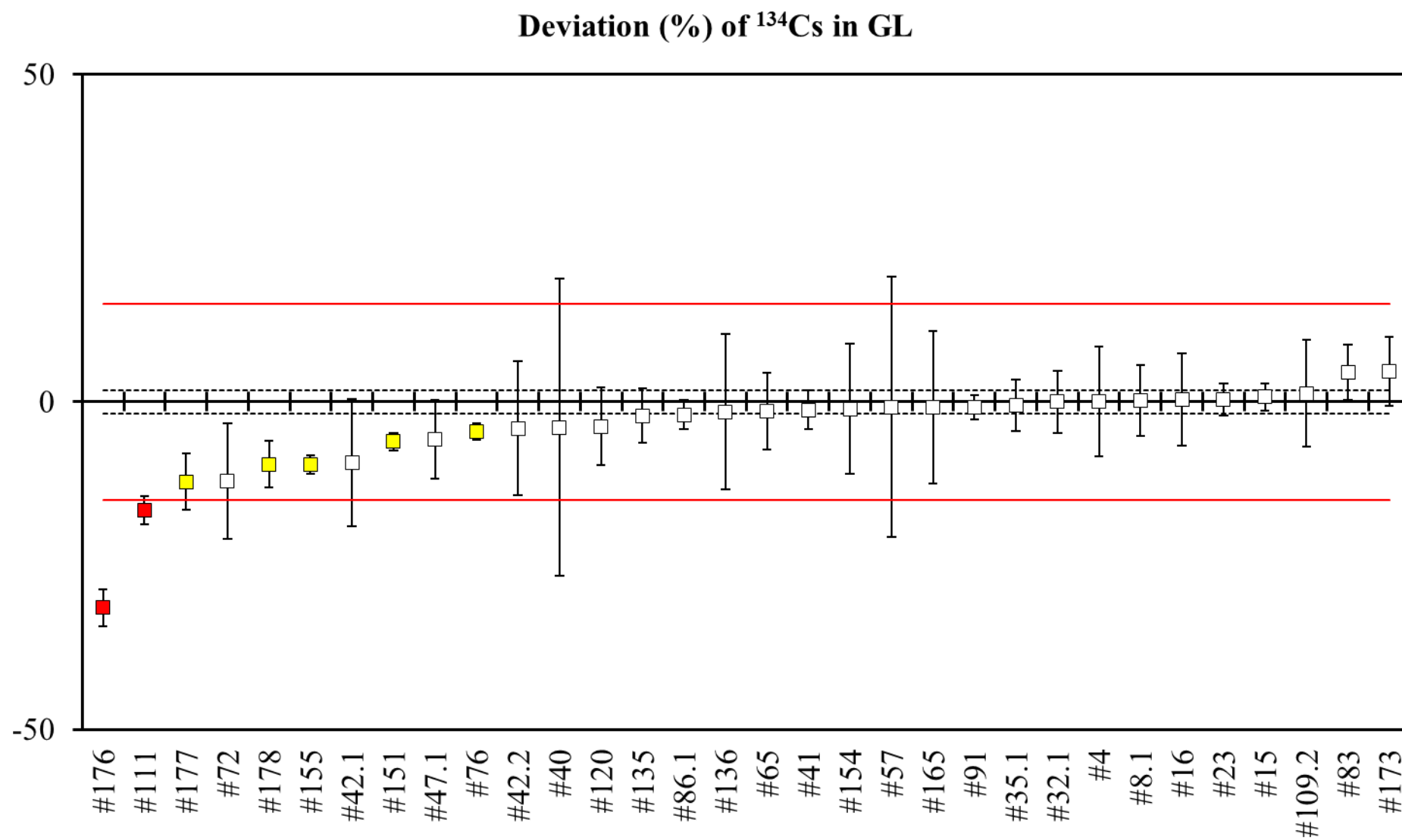


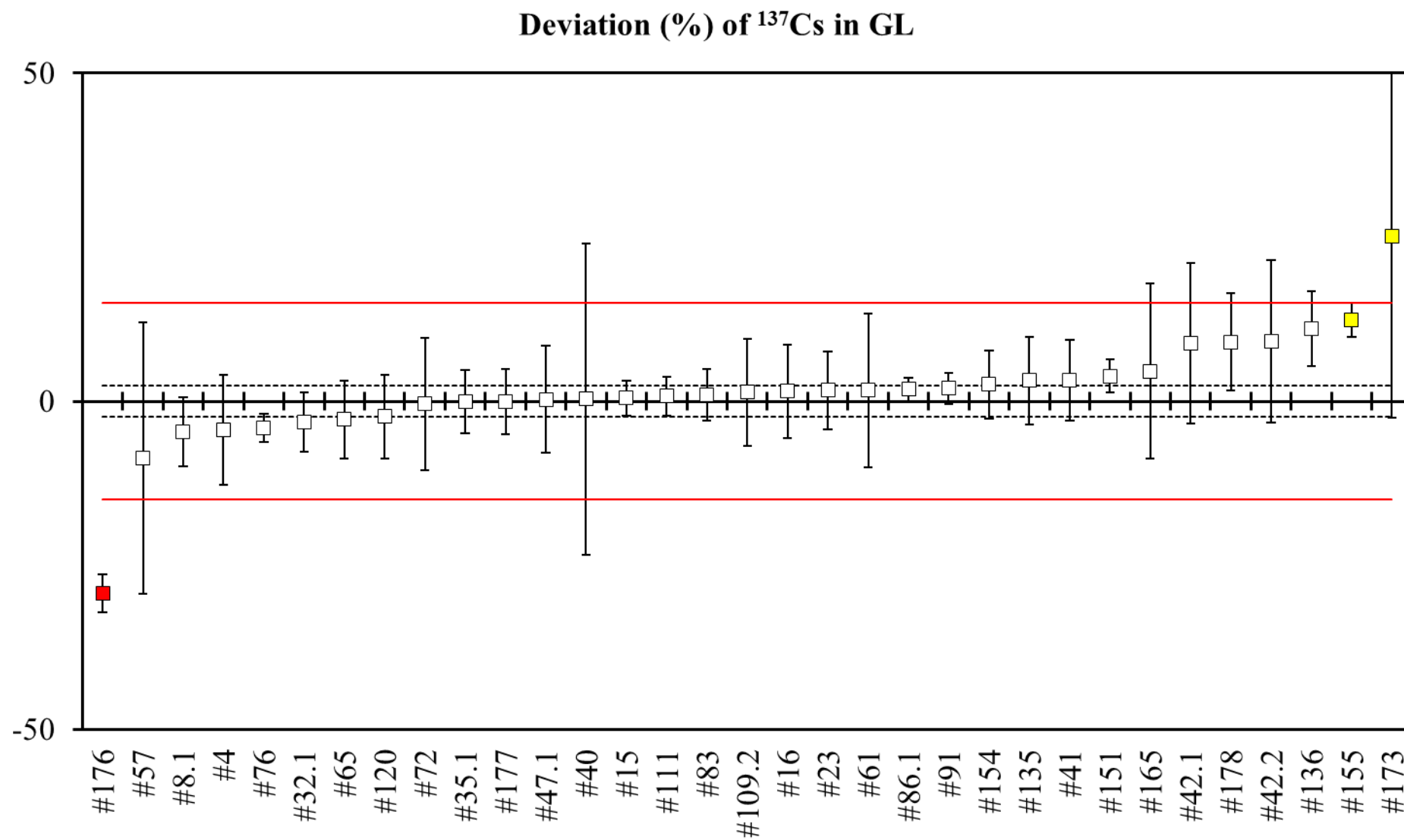


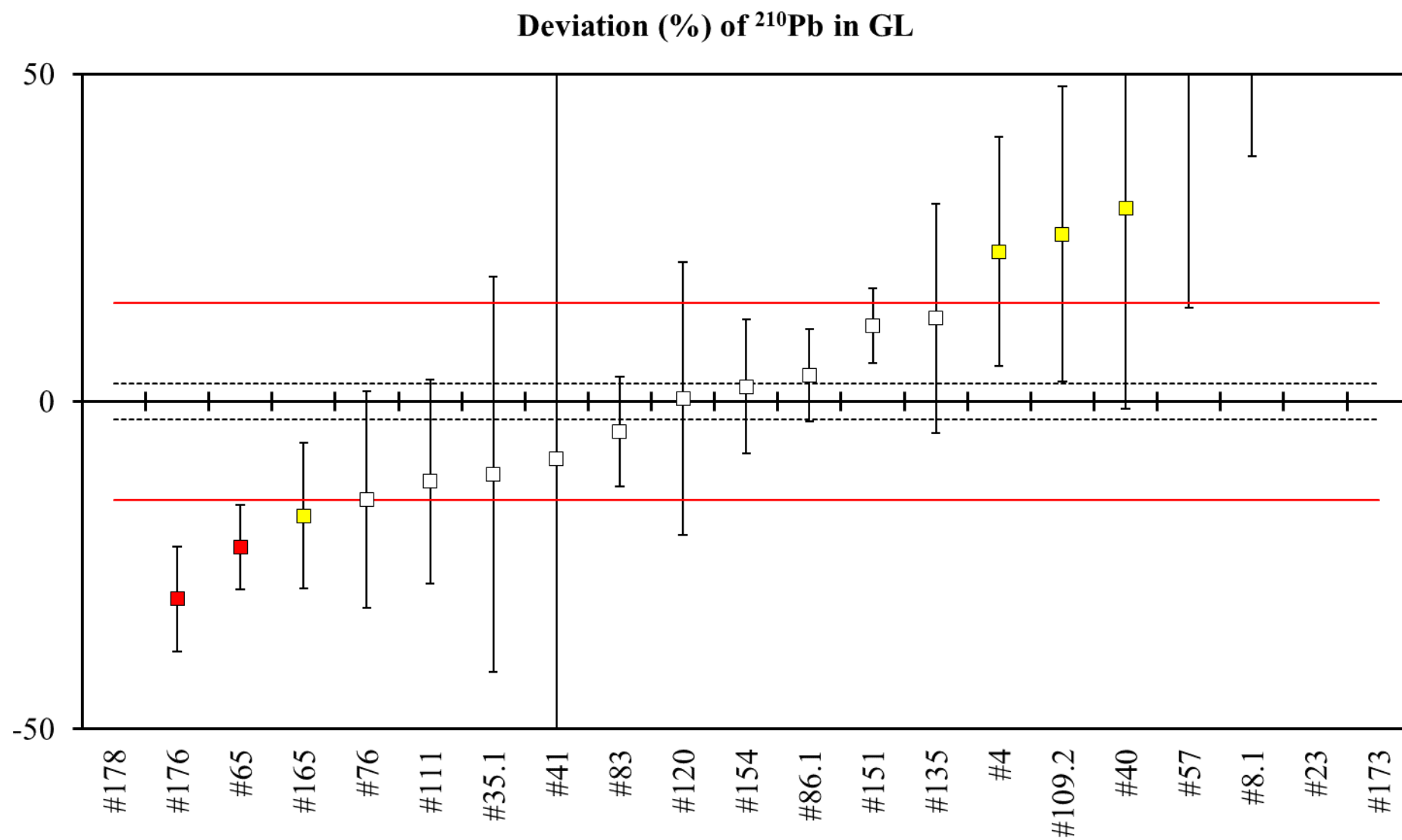


8. Gamma Low (GL) Deviation Plots

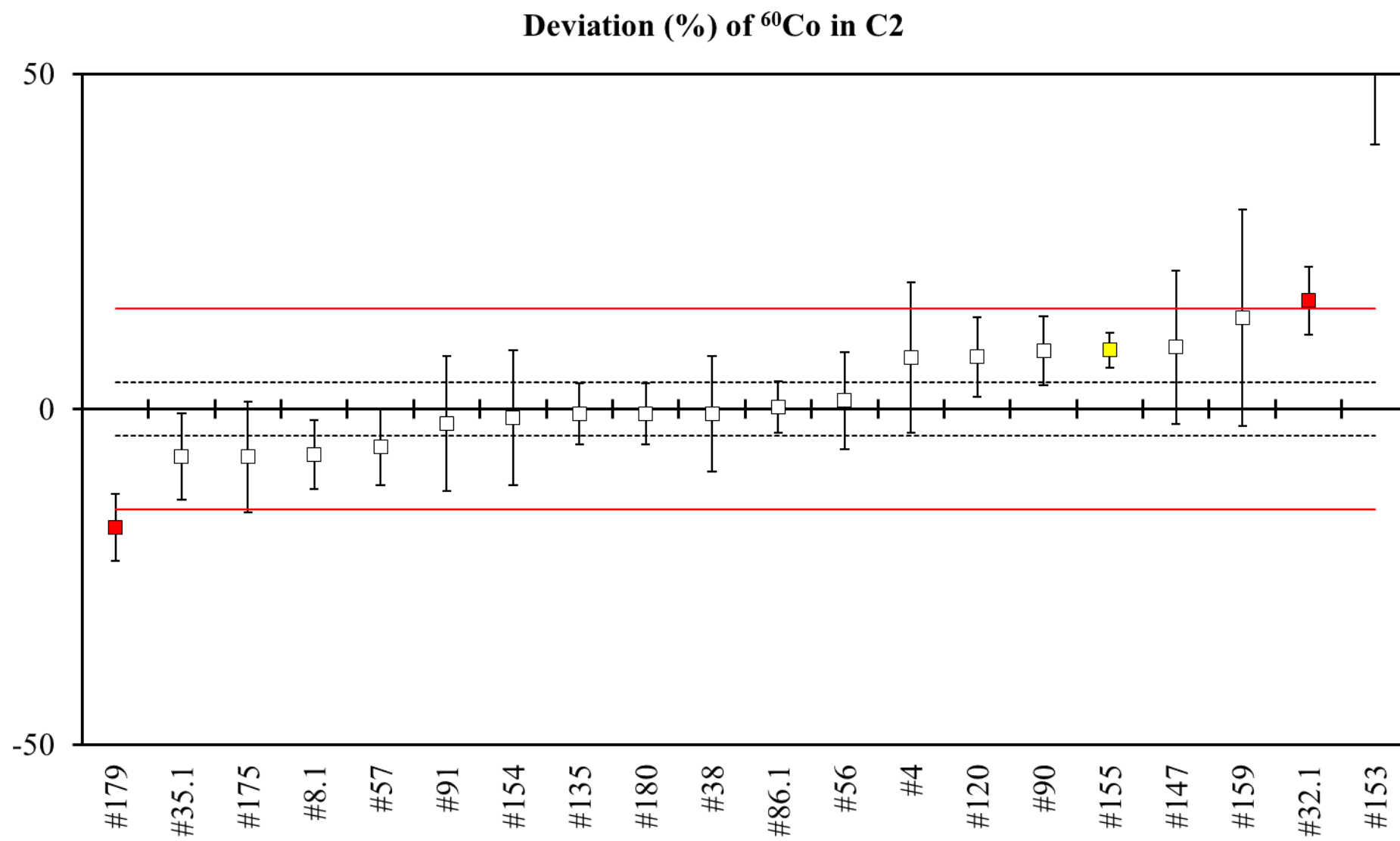


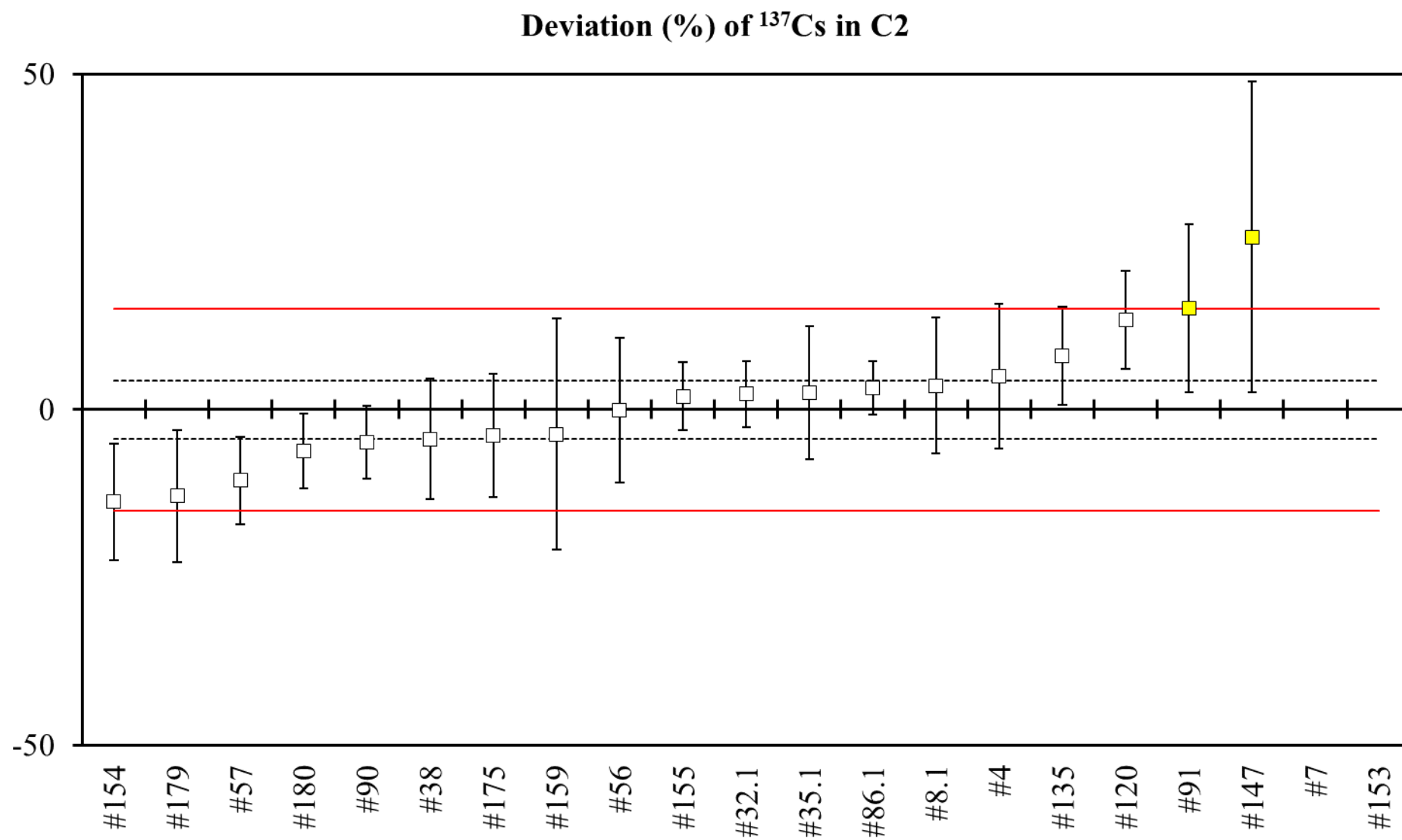


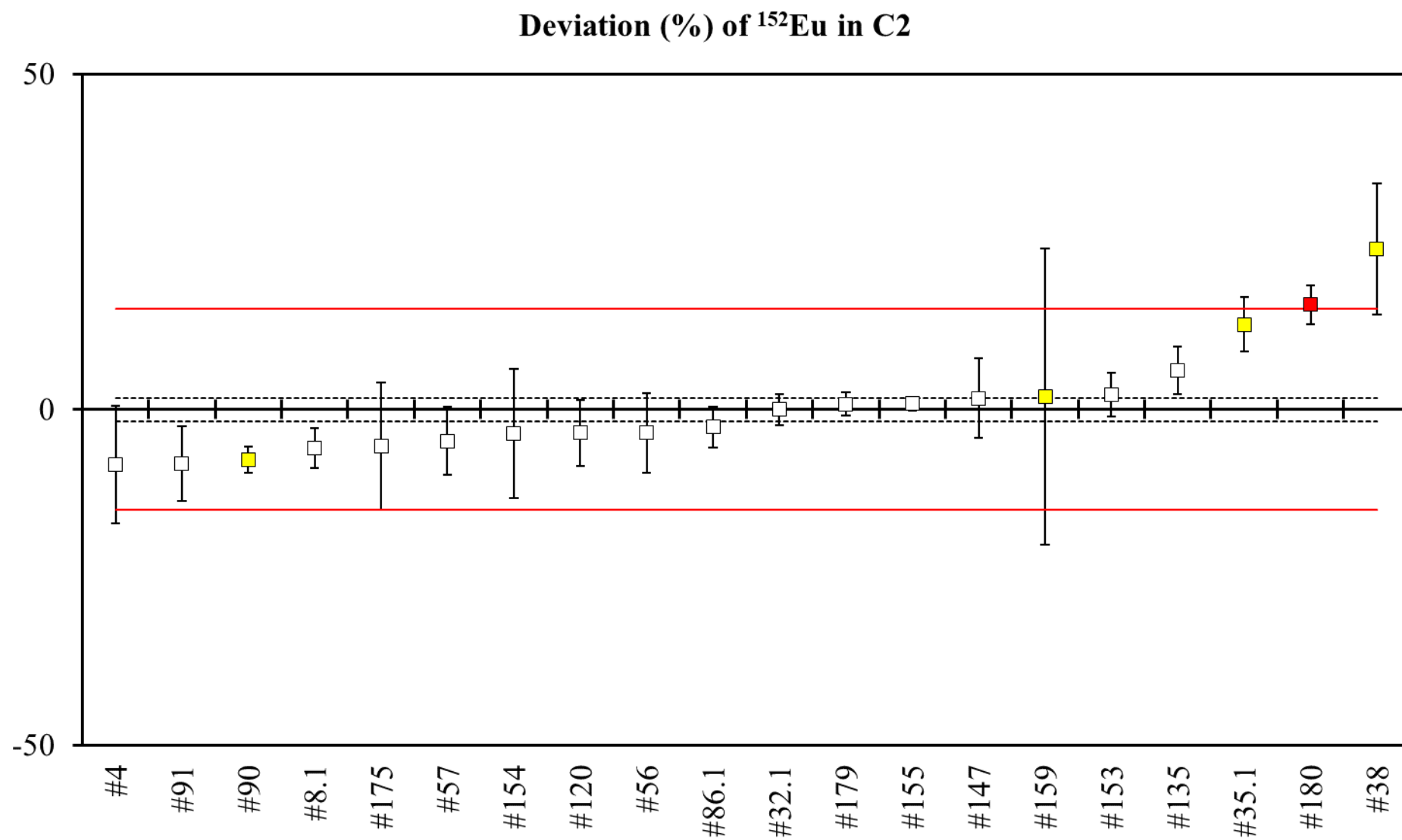


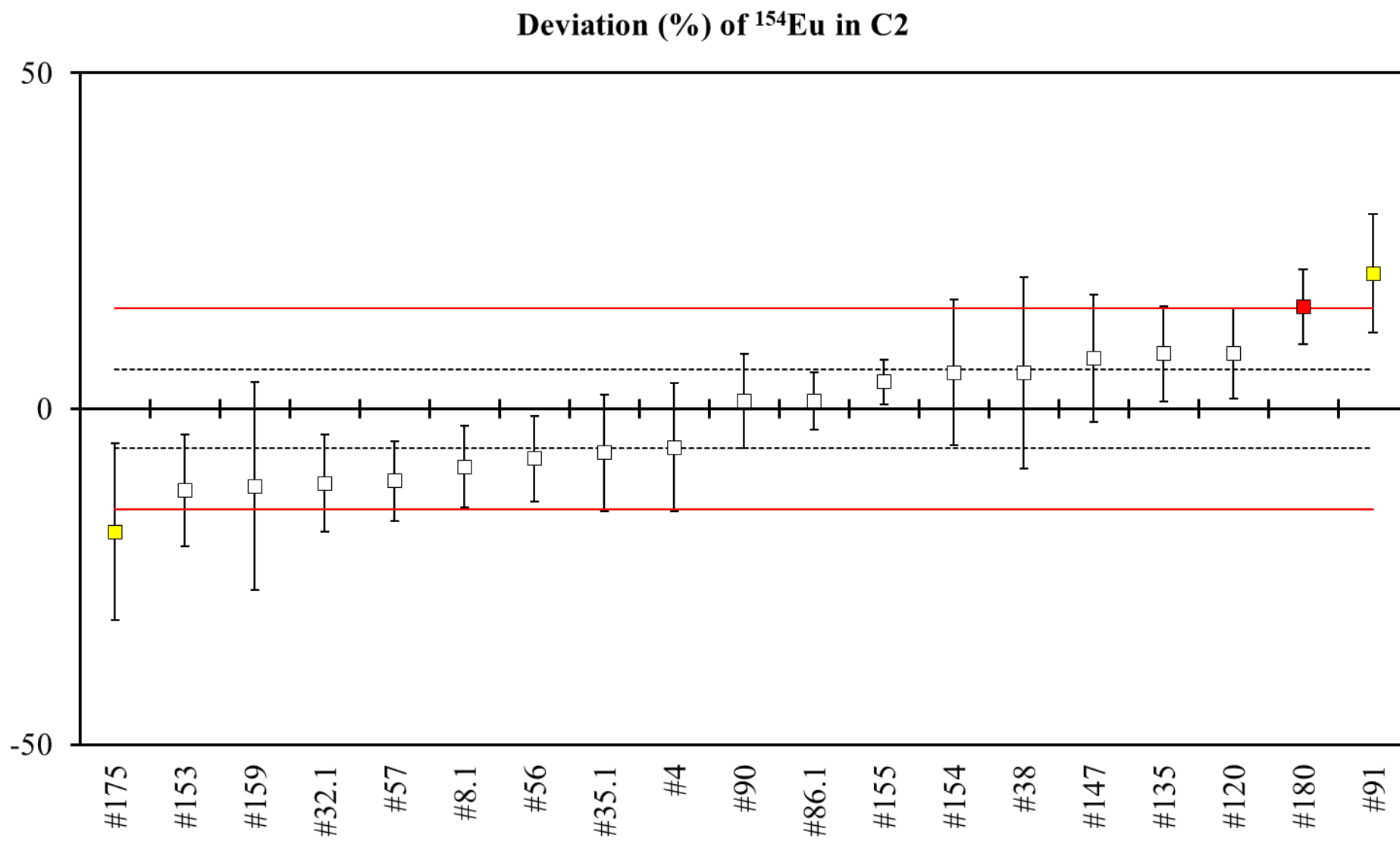


9. Concrete (C2) Deviation Plots







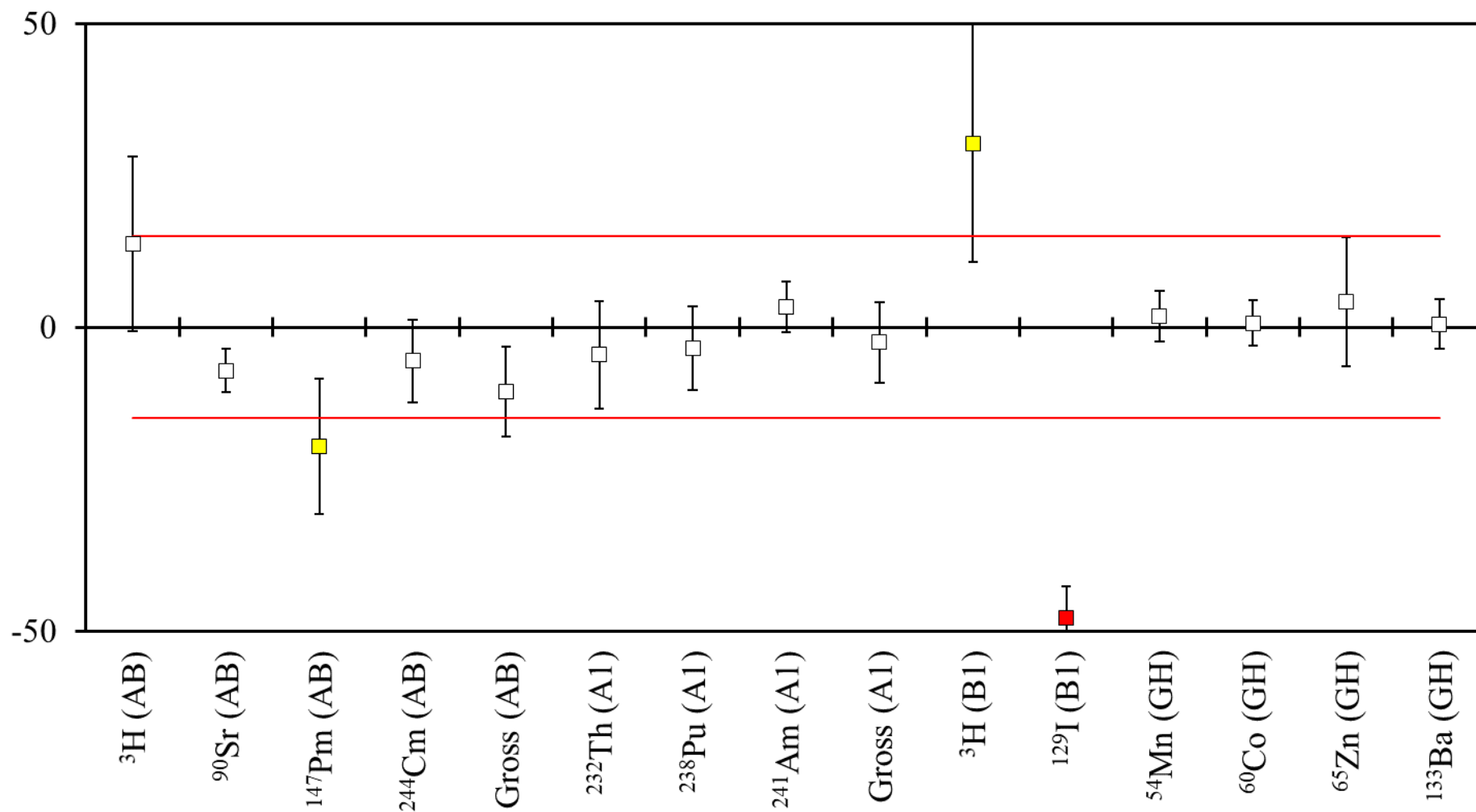


10. Deviation Plots and Tabulated Results Arranged by Lab Number

NOTE:

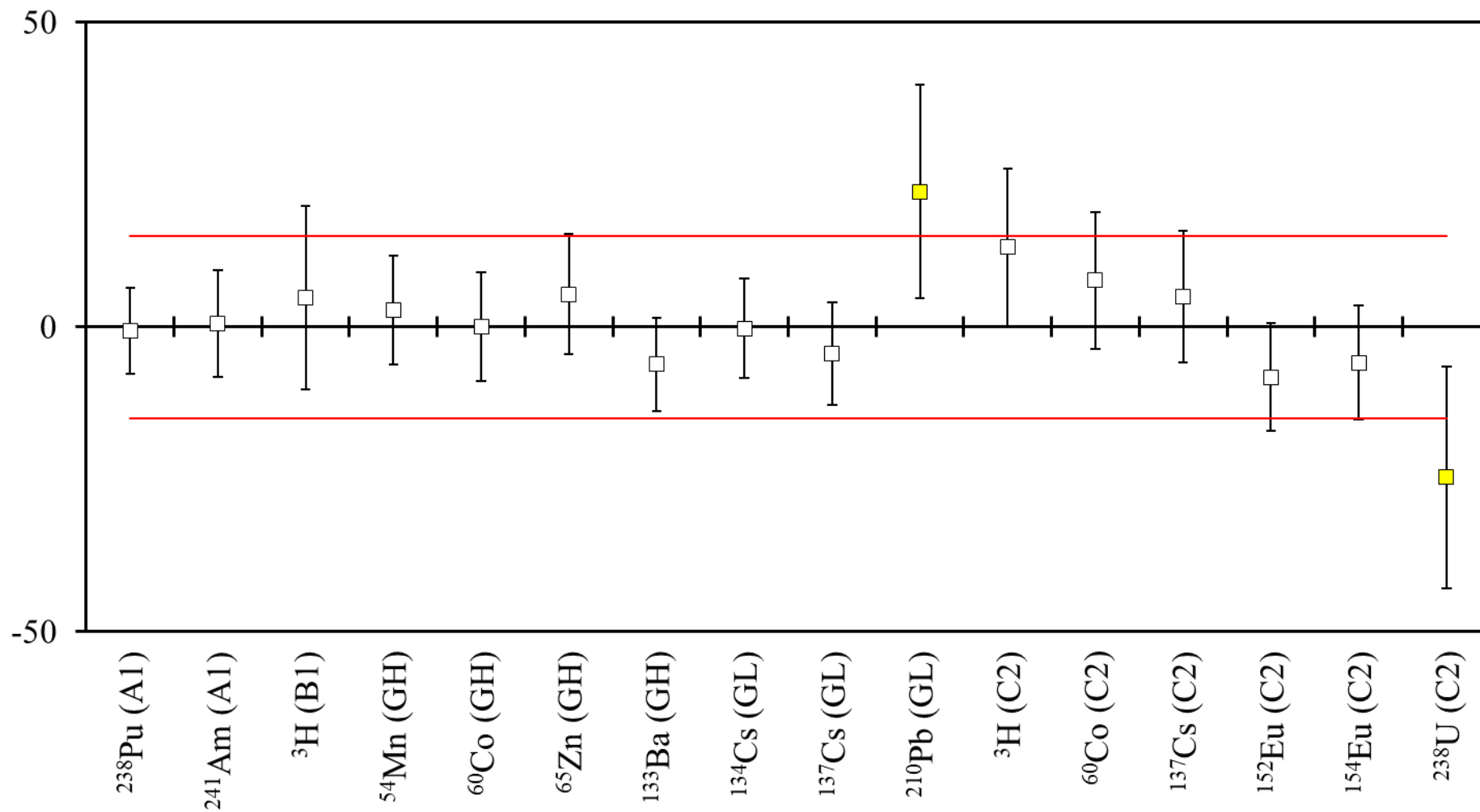
1. Data are quoted rounded, at $k=1$ (standard uncertainty). Data analysis was carried out on data as reported (i.e. before rounding). Uncertainties have been rounded to two significant figures.
2. Units of the Assigned Values and the reported results are as follows:
 - a. AB – Bq/g
 - b. A1 – Bq/kg
 - c. B1 – Bq/g
 - d. GH – Bq/g
 - e. GL – Bq/kg
 - f. C2 – Bq/g

Deviation (%) of Laboratory 1



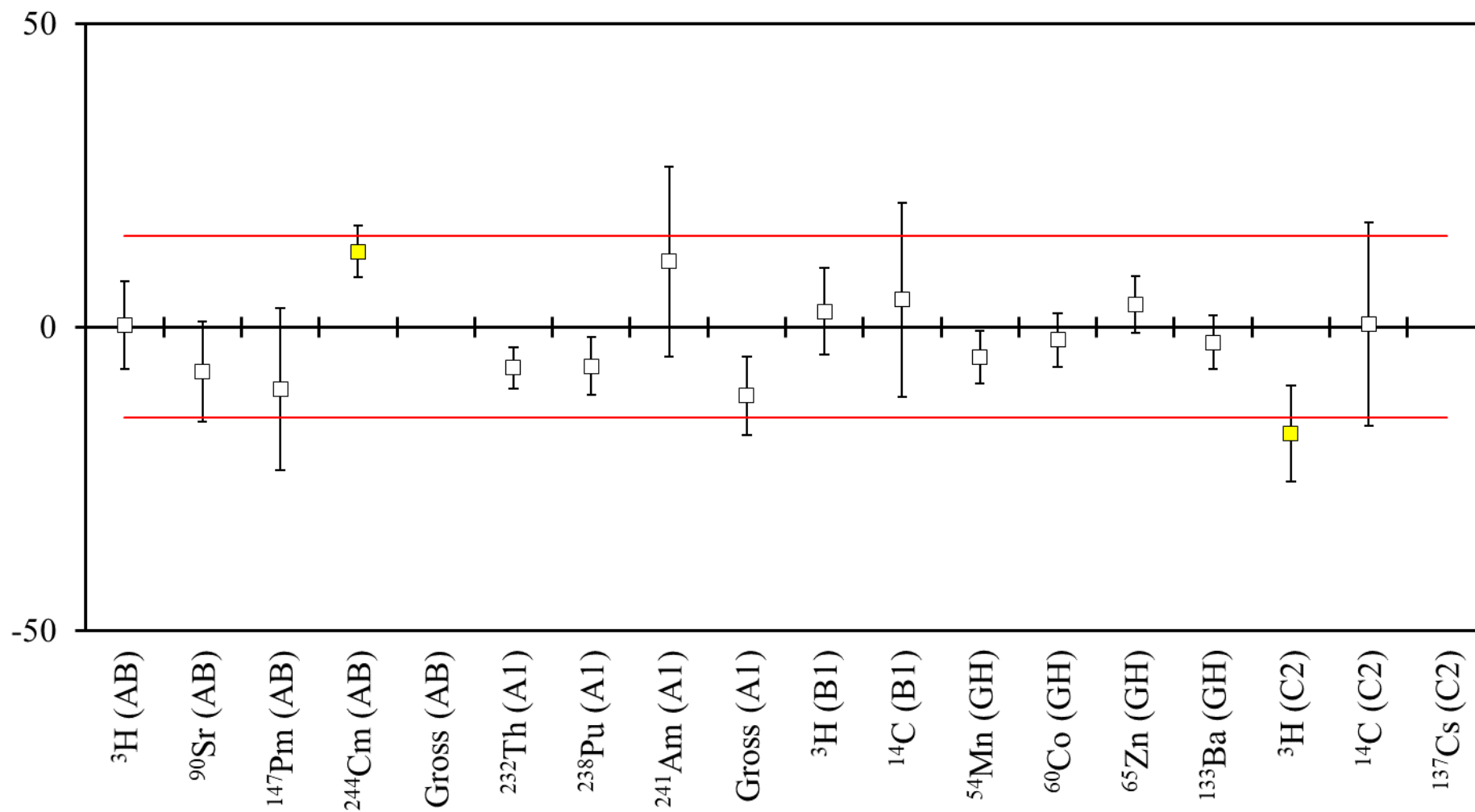
Radionuclide	Laboratory 1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	11.9 ± 1.5	10.47 ± 0.13	13.7	0.95	2.35
^{90}Sr (AB)	7.70 ± 0.29	8.291 ± 0.021	-7.1	-2.03	-1.22
^{147}Pm (AB)	14.5 ± 2.0	18.05 ± 0.23	-19.7	-1.76	-3.38
^{244}Cm (AB)	8.3 ± 0.6	8.788 ± 0.029	-5.6	-0.81	-0.95
Gross beta (AB)	19.7 ± 1.6	22.04 ± 0.35	-10.6	-1.43	-1.82
^{232}Th (A1)	2.60 ± 0.24	2.724 ± 0.026	-4.6	-0.51	-0.78
^{238}Pu (A1)	9.95 ± 0.71	10.306 ± 0.025	-3.5	-0.50	-0.59
^{241}Am (A1)	7.93 ± 0.32	7.674 ± 0.017	3.3	0.80	0.57
Gross alpha (A1)	30.9 ± 1.6	31.7 ± 1.4	-2.5	-0.38	-0.43
^3H (B1)	1.74 ± 0.26	1.336 ± 0.017	30.2	1.55	5.19
^{129}I (B1)	0.200 ± 0.020	0.3839 ± 0.0019	-47.9	-9.15	-8.23
^{54}Mn (GH)	19.40 ± 0.80	19.062 ± 0.081	1.8	0.42	0.30
^{60}Co (GH)	7.45 ± 0.28	7.399 ± 0.020	0.7	0.18	0.12
^{65}Zn (GH)	2.45 ± 0.25	2.353 ± 0.017	4.1	0.39	0.71
^{133}Ba (GH)	19.80 ± 0.80	19.70 ± 0.13	0.5	0.12	0.09

Deviation (%) of Laboratory 4



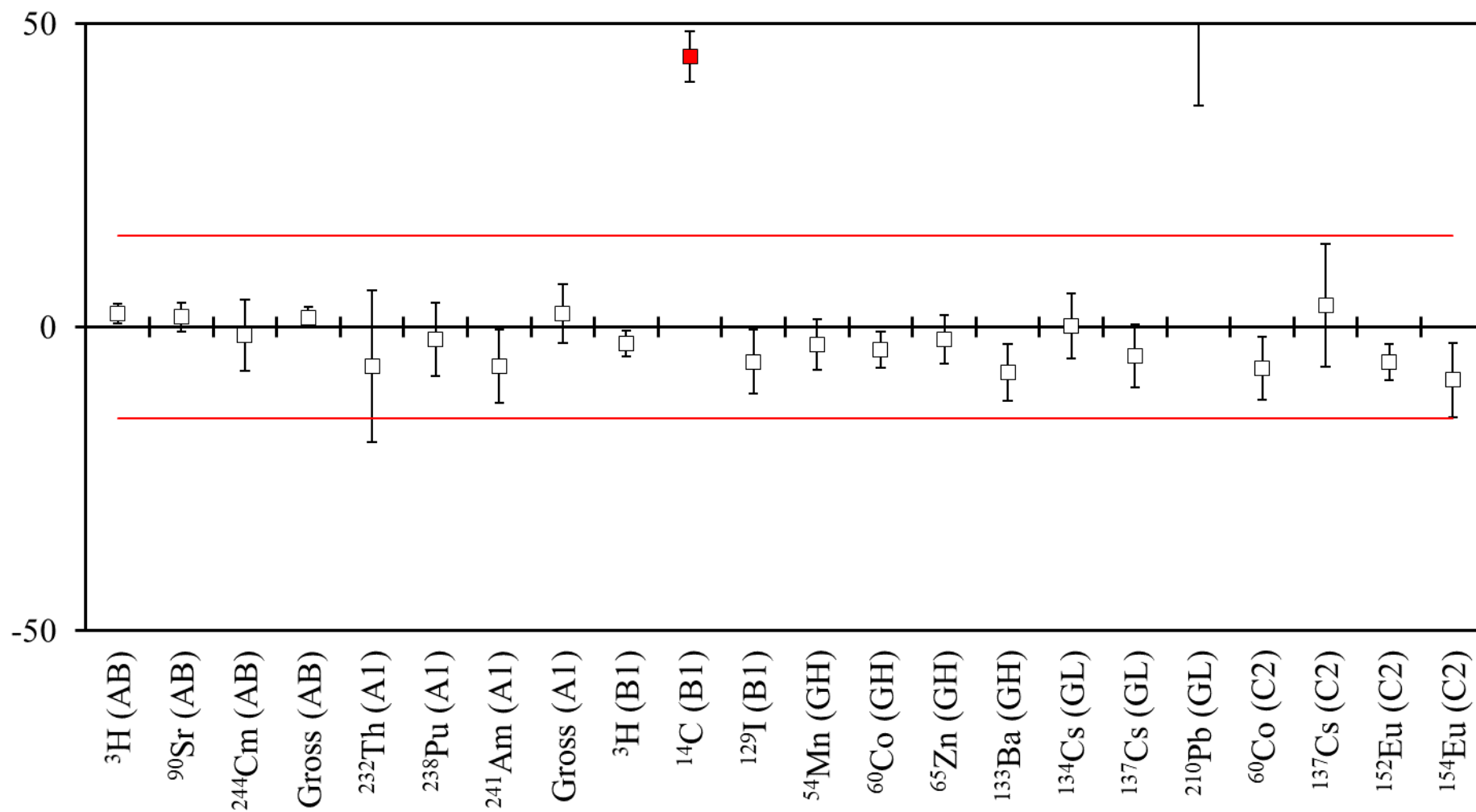
Radionuclide	Laboratory 4	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³⁸ Pu (A1)	10.24 ± 0.73	10.306 ± 0.025	-0.6	-0.09	-0.11
²⁴¹ Am (A1)	7.72 ± 0.67	7.674 ± 0.017	0.6	0.07	0.10
³ H (B1)	1.40 ± 0.20	1.336 ± 0.017	4.8	0.32	0.82
⁵⁴ Mn (GH)	19.6 ± 1.7	19.062 ± 0.081	2.8	0.32	0.48
⁶⁰ Co (GH)	7.40 ± 0.66	7.399 ± 0.020	0.0	0.00	0.00
⁶⁵ Zn (GH)	2.48 ± 0.23	2.353 ± 0.017	5.4	0.55	0.93
¹³³ Ba (GH)	18.5 ± 1.5	19.70 ± 0.13	-6.1	-0.80	-1.05
¹³⁴ Cs (GL)	17.1 ± 1.4	17.14 ± 0.12	-0.2	-0.03	-0.04
¹³⁷ Cs (GL)	6.49 ± 0.57	6.788 ± 0.062	-4.4	-0.52	-0.75
²¹⁰ Pb (GL)	7.7 ± 1.1	6.300 ± 0.067	22.2	1.27	3.82
³ H (C2)	32.8 ± 3.0	29.0 ± 2.0	13.1	1.05	2.25
⁶⁰ Co (C2)	0.0759 ± 0.0078	0.0705 ± 0.0011	7.7	0.69	1.32
¹³⁷ Cs (C2)	0.0593 ± 0.0060	0.05647 ± 0.00096	5.0	0.47	0.86
¹⁵² Eu (C2)	6.59 ± 0.63	7.180 ± 0.048	-8.2	-0.93	-1.41
¹⁵⁴ Eu (C2)	0.134 ± 0.013	0.1423 ± 0.0032	-5.8	-0.62	-1.00
²³⁸ U (C2)	0.0088 ± 0.0020	0.01168 ± 0.00097	-24.7	-1.30	-4.23

Deviation (%) of Laboratory 7



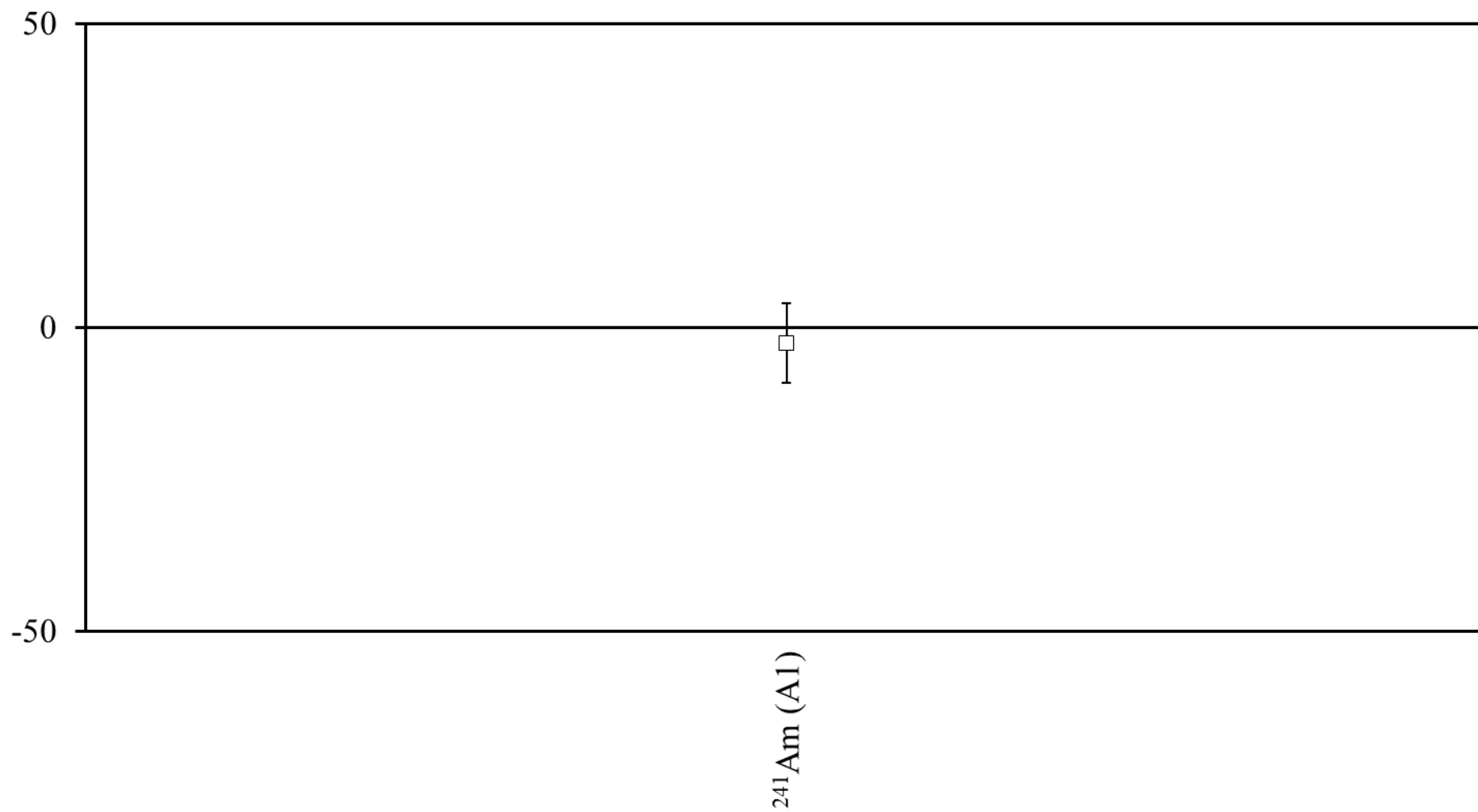
Radionuclide	Laboratory 7	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.50 ± 0.74	10.47 ± 0.13	0.3	0.04	0.05
^{90}Sr (AB)	7.68 ± 0.68	8.291 ± 0.021	-7.4	-0.90	-1.27
^{147}Pm (AB)	16.2 ± 2.4	18.05 ± 0.23	-10.2	-0.77	-1.76
^{244}Cm (AB)	9.88 ± 0.37	8.788 ± 0.029	12.4	2.94	2.13
Gross beta (AB)	51.4 ± 4.0	22.04 ± 0.35	133.2	7.31	22.88
^{232}Th (A1)	2.540 ± 0.088	2.724 ± 0.026	-6.8	-2.01	-1.16
^{238}Pu (A1)	9.64 ± 0.49	10.306 ± 0.025	-6.5	-1.36	-1.11
^{241}Am (A1)	8.5 ± 1.2	7.674 ± 0.017	10.8	0.69	1.85
Gross alpha (A1)	28.1 ± 1.6	31.7 ± 1.4	-11.4	-1.69	-1.95
^3H (B1)	1.370 ± 0.094	1.336 ± 0.017	2.5	0.36	0.44
^{14}C (B1)	0.440 ± 0.067	0.4212 ± 0.0019	4.5	0.28	0.77
Gross beta (B1)	2.01 ± 0.16	-	-	-	-
^{54}Mn (GH)	18.10 ± 0.82	19.062 ± 0.081	-5.0	-1.17	-0.87
^{60}Co (GH)	7.24 ± 0.33	7.399 ± 0.020	-2.1	-0.48	-0.37
^{65}Zn (GH)	2.44 ± 0.11	2.353 ± 0.017	3.7	0.78	0.63
^{133}Ba (GH)	19.20 ± 0.87	19.70 ± 0.13	-2.5	-0.57	-0.44
^3H (C2)	23.9 ± 1.6	29.0 ± 2.0	-17.6	-1.99	-3.02
^{14}C (C2)	0.226 ± 0.035	0.225 ± 0.014	0.4	0.03	0.08
^{137}Cs (C2)	0.478 ± 0.031	0.05647 ± 0.00096	746.5	13.59	128.19

Deviation (%) of Laboratory 8.1



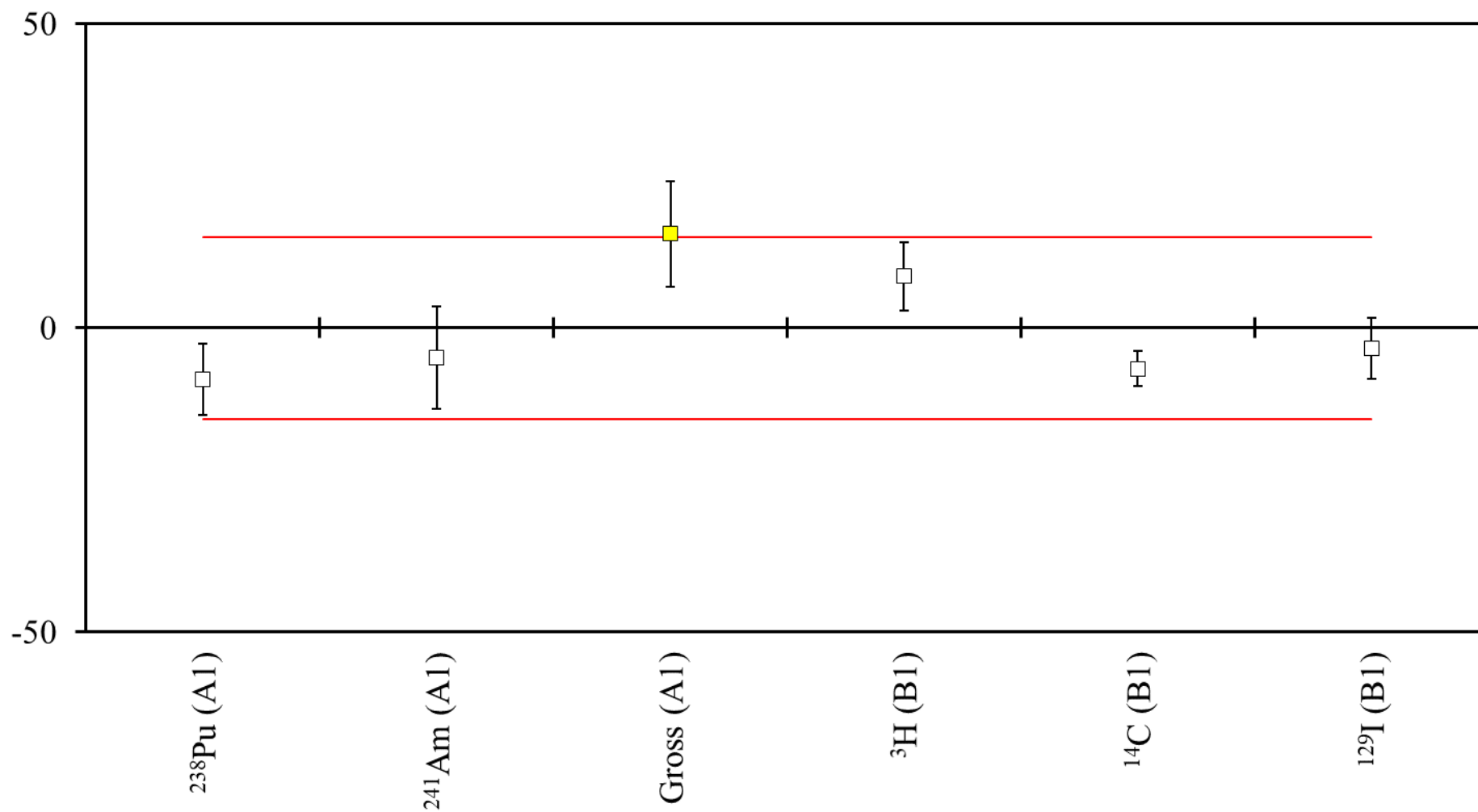
Radionuclide	Laboratory 8.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.70 ± 0.11	10.47 ± 0.13	2.2	1.35	0.38
^{90}Sr (AB)	8.43 ± 0.20	8.291 ± 0.021	1.7	0.69	0.29
^{244}Cm (AB)	8.67 ± 0.51	8.788 ± 0.029	-1.3	-0.23	-0.23
Gross beta (AB)	22.400 ± 0.085	22.04 ± 0.35	1.6	1.00	0.28
^{232}Th (A1)	2.55 ± 0.34	2.724 ± 0.026	-6.4	-0.51	-1.10
^{238}Pu (A1)	10.10 ± 0.62	10.306 ± 0.025	-2.0	-0.33	-0.34
^{241}Am (A1)	7.18 ± 0.46	7.674 ± 0.017	-6.4	-1.07	-1.11
Gross alpha (A1)	32.40 ± 0.57	31.7 ± 1.4	2.2	0.46	0.38
^3H (B1)	1.300 ± 0.022	1.336 ± 0.017	-2.7	-1.29	-0.46
^{14}C (B1)	0.609 ± 0.017	0.4212 ± 0.0019	44.6	10.98	7.66
^{129}I (B1)	0.362 ± 0.020	0.3839 ± 0.0019	-5.7	-1.09	-0.98
^{54}Mn (GH)	18.52 ± 0.78	19.062 ± 0.081	-2.8	-0.69	-0.49
^{60}Co (GH)	7.13 ± 0.22	7.399 ± 0.020	-3.6	-1.22	-0.62
^{65}Zn (GH)	2.307 ± 0.092	2.353 ± 0.017	-2.0	-0.49	-0.34
^{133}Ba (GH)	18.22 ± 0.91	19.70 ± 0.13	-7.5	-1.61	-1.29
^{134}Cs (GL)	17.18 ± 0.92	17.14 ± 0.12	0.2	0.04	0.04
^{137}Cs (GL)	6.47 ± 0.35	6.788 ± 0.062	-4.7	-0.89	-0.80
^{210}Pb (GL)	11.6 ± 3.0	6.300 ± 0.067	84.1	1.77	14.45
^{60}Co (C2)	0.0657 ± 0.0035	0.0705 ± 0.0011	-6.8	-1.31	-1.17
^{137}Cs (C2)	0.0585 ± 0.0056	0.05647 ± 0.00096	3.6	0.36	0.62
^{152}Eu (C2)	6.77 ± 0.21	7.180 ± 0.048	-5.7	-1.90	-0.98
^{154}Eu (C2)	0.1300 ± 0.0082	0.1423 ± 0.0032	-8.6	-1.40	-1.48

Deviation (%) of Laboratory 8.2



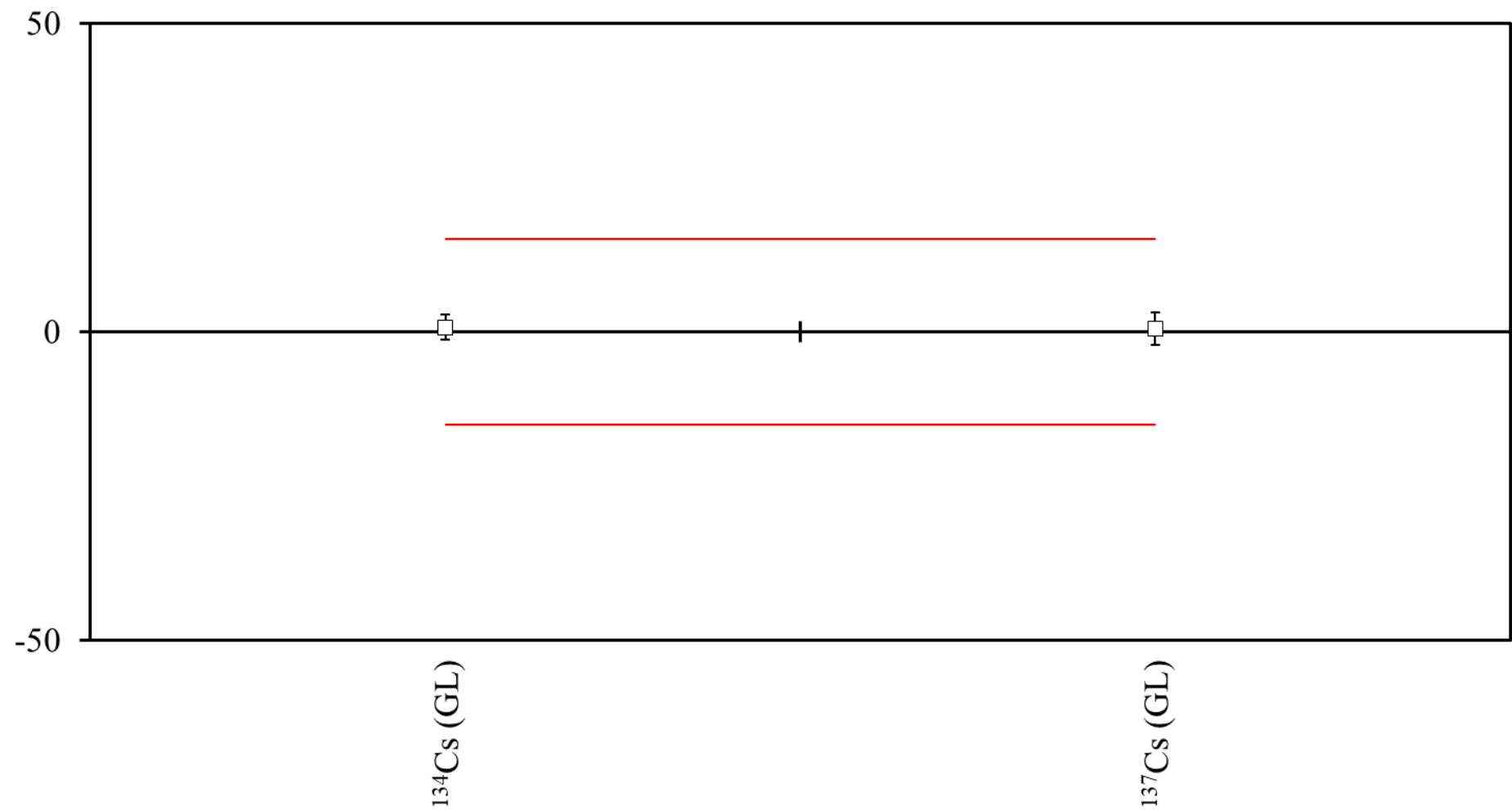
Radionuclide	Laboratory 8.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
²⁴¹ Am (A1)	7.47 ± 0.50	7.674 ± 0.017	-2.7	-0.41	-0.46

Deviation (%) of Laboratory 14



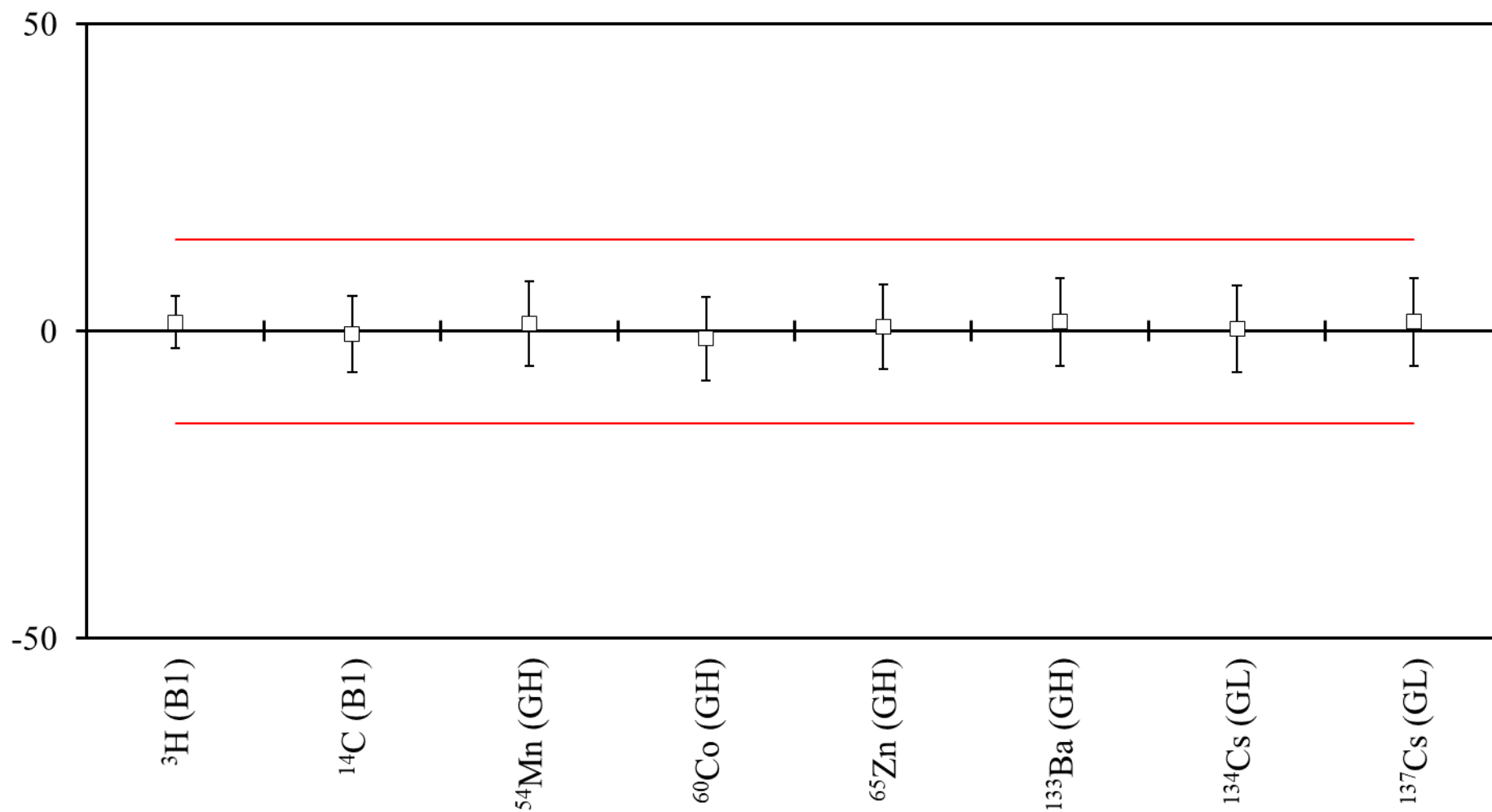
Radionuclide	Laboratory 14	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³⁸ Pu (A1)	9.44 ± 0.60	10.306 ± 0.025	-8.4	-1.44	-1.44
²⁴¹ Am (A1)	7.30 ± 0.65	7.674 ± 0.017	-4.9	-0.58	-0.84
Gross alpha (A1)	36.6 ± 2.2	31.7 ± 1.4	15.5	1.88	2.65
³ H (B1)	1.450 ± 0.073	1.336 ± 0.017	8.5	1.52	1.47
¹⁴ C (B1)	0.393 ± 0.012	0.4212 ± 0.0019	-6.7	-2.32	-1.15
¹²⁹ I (B1)	0.371 ± 0.019	0.3839 ± 0.0019	-3.4	-0.68	-0.58
Gross beta (B1)	0.764 ± 0.023	-	-	-	-

Deviation (%) of Laboratory 15



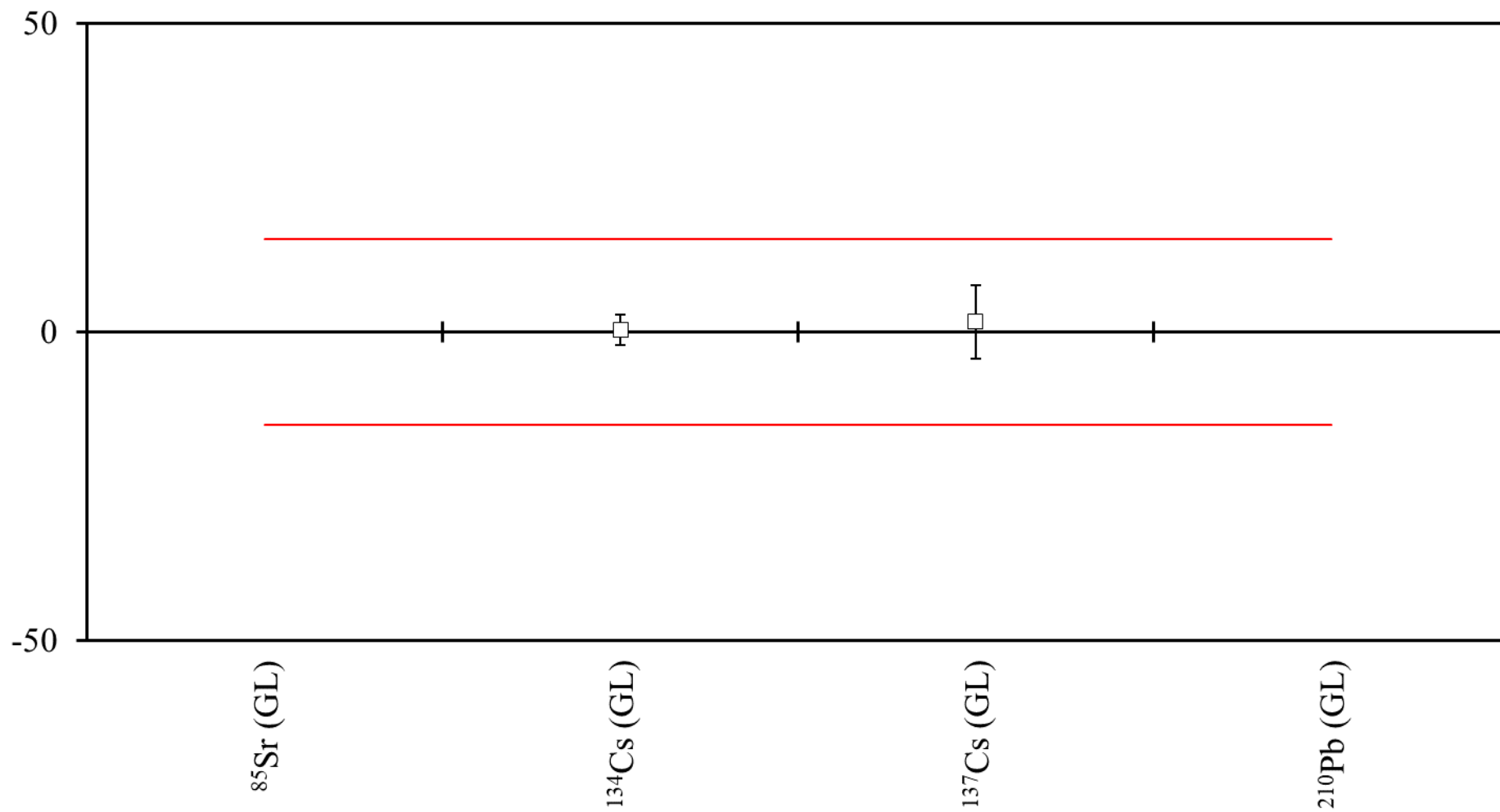
Radionuclide	Laboratory 15	NPL Assigned Value	Deviation /%	Zeta	Z Score
¹³⁴ Cs (GL)	17.27 ± 0.33	17.14 ± 0.12	0.8	0.37	0.13
¹³⁷ Cs (GL)	6.82 ± 0.17	6.788 ± 0.062	0.5	0.18	0.08

Deviation (%) of Laboratory 16



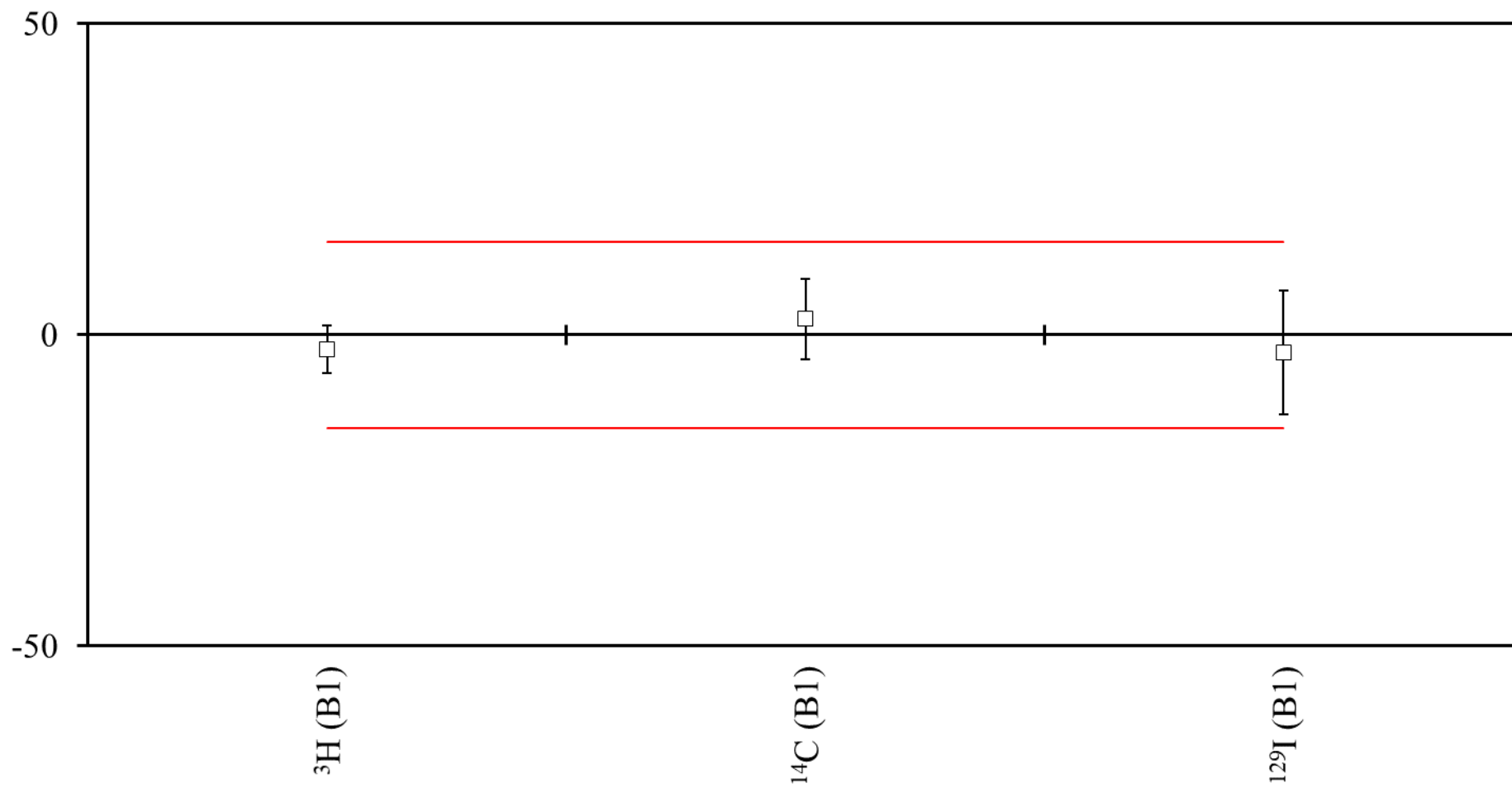
Radionuclide	Laboratory 16	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (B1)	1.355 ± 0.054	1.336 ± 0.017	1.4	0.34	0.24
^{14}C (B1)	0.419 ± 0.026	0.4212 ± 0.0019	-0.5	-0.08	-0.09
^{54}Mn (GH)	19.3 ± 1.3	19.062 ± 0.081	1.2	0.18	0.21
^{60}Co (GH)	7.31 ± 0.50	7.399 ± 0.020	-1.2	-0.18	-0.21
^{65}Zn (GH)	2.37 ± 0.16	2.353 ± 0.017	0.7	0.11	0.12
^{133}Ba (GH)	20.0 ± 1.4	19.70 ± 0.13	1.5	0.21	0.26
^{134}Cs (GL)	17.2 ± 1.2	17.14 ± 0.12	0.4	0.05	0.06
^{137}Cs (GL)	6.89 ± 0.48	6.788 ± 0.062	1.5	0.21	0.26

Deviation (%) of Laboratory 23



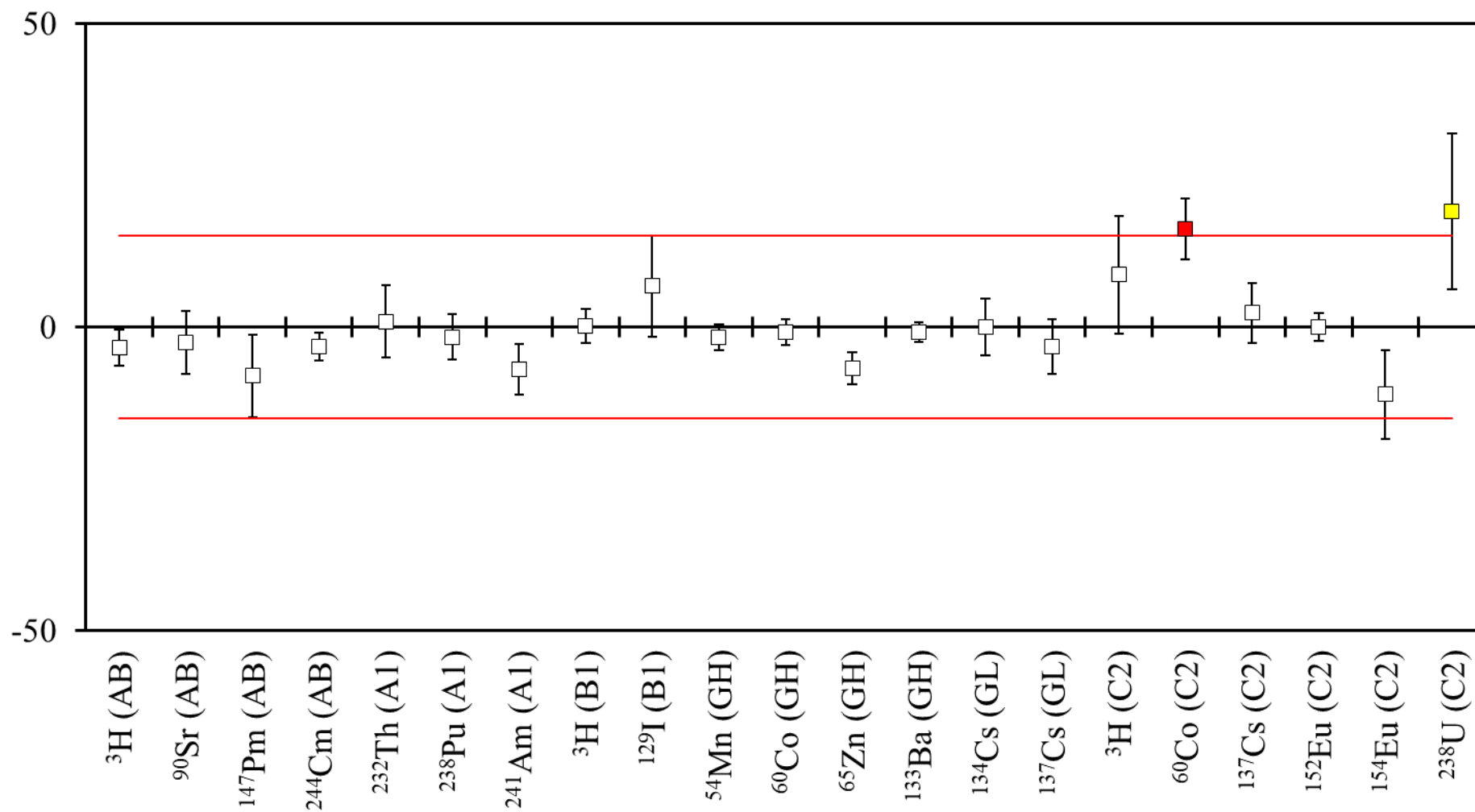
Radionuclide	Laboratory 23	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁸⁵ Sr (GL)	13.2 ± 1.9	5.931 ± 0.041	122.6	3.82	21.05
¹³⁴ Cs (GL)	17.20 ± 0.40	17.14 ± 0.12	0.4	0.14	0.06
¹³⁷ Cs (GL)	6.90 ± 0.40	6.788 ± 0.062	1.6	0.28	0.28
²¹⁰ Pb (GL)	14.0 ± 4.0	6.300 ± 0.067	122.2	1.92	20.99

Deviation (%) of Laboratory 28



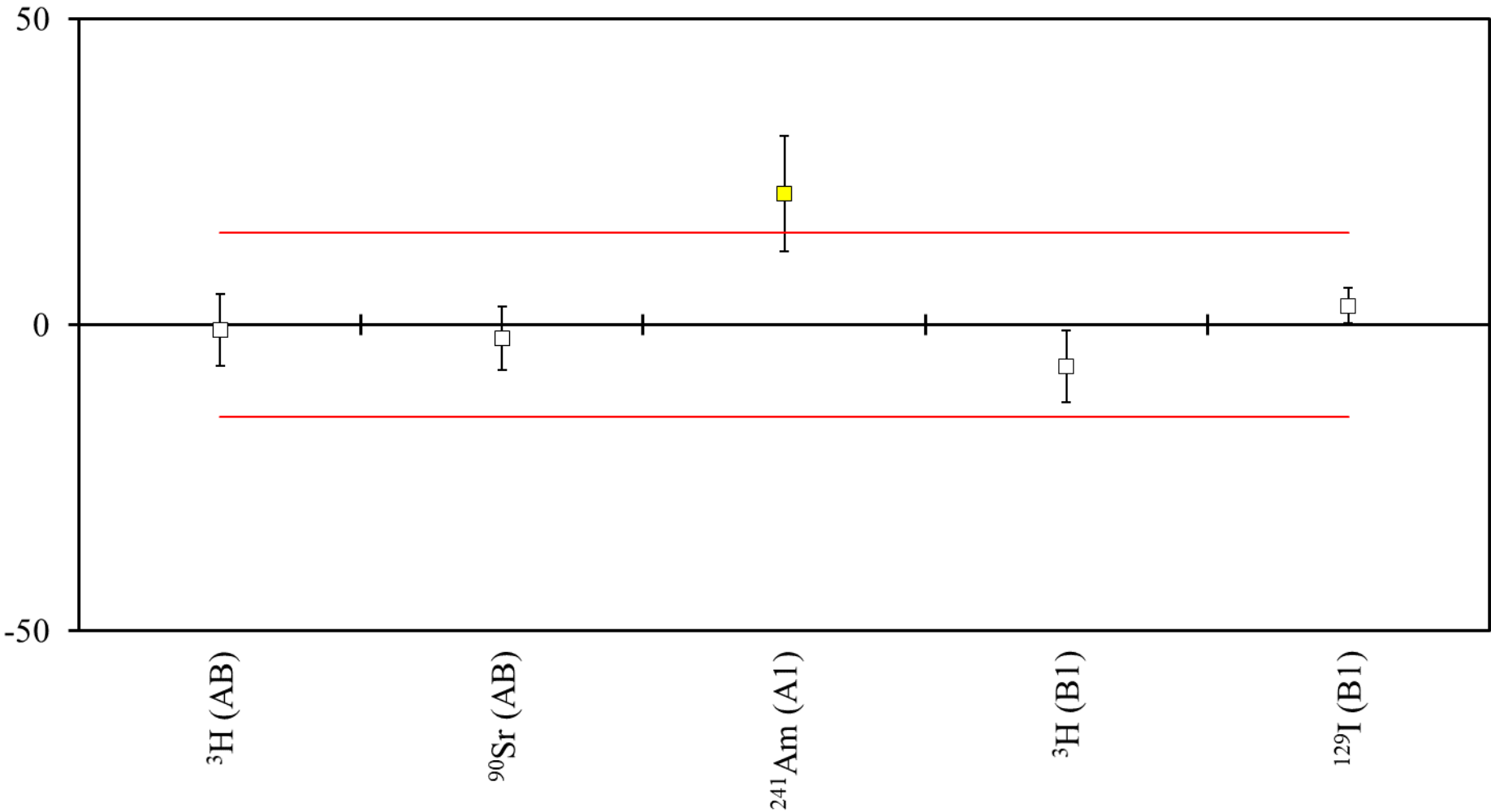
Radionuclide	Laboratory 28	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (B1)	1.305 ± 0.048	1.336 ± 0.017	-2.3	-0.61	-0.40
^{14}C (B1)	0.432 ± 0.027	0.4212 ± 0.0019	2.6	0.40	0.44
^{129}I (B1)	0.373 ± 0.038	0.3839 ± 0.0019	-2.8	-0.29	-0.49

Deviation (%) of Laboratory 32.1



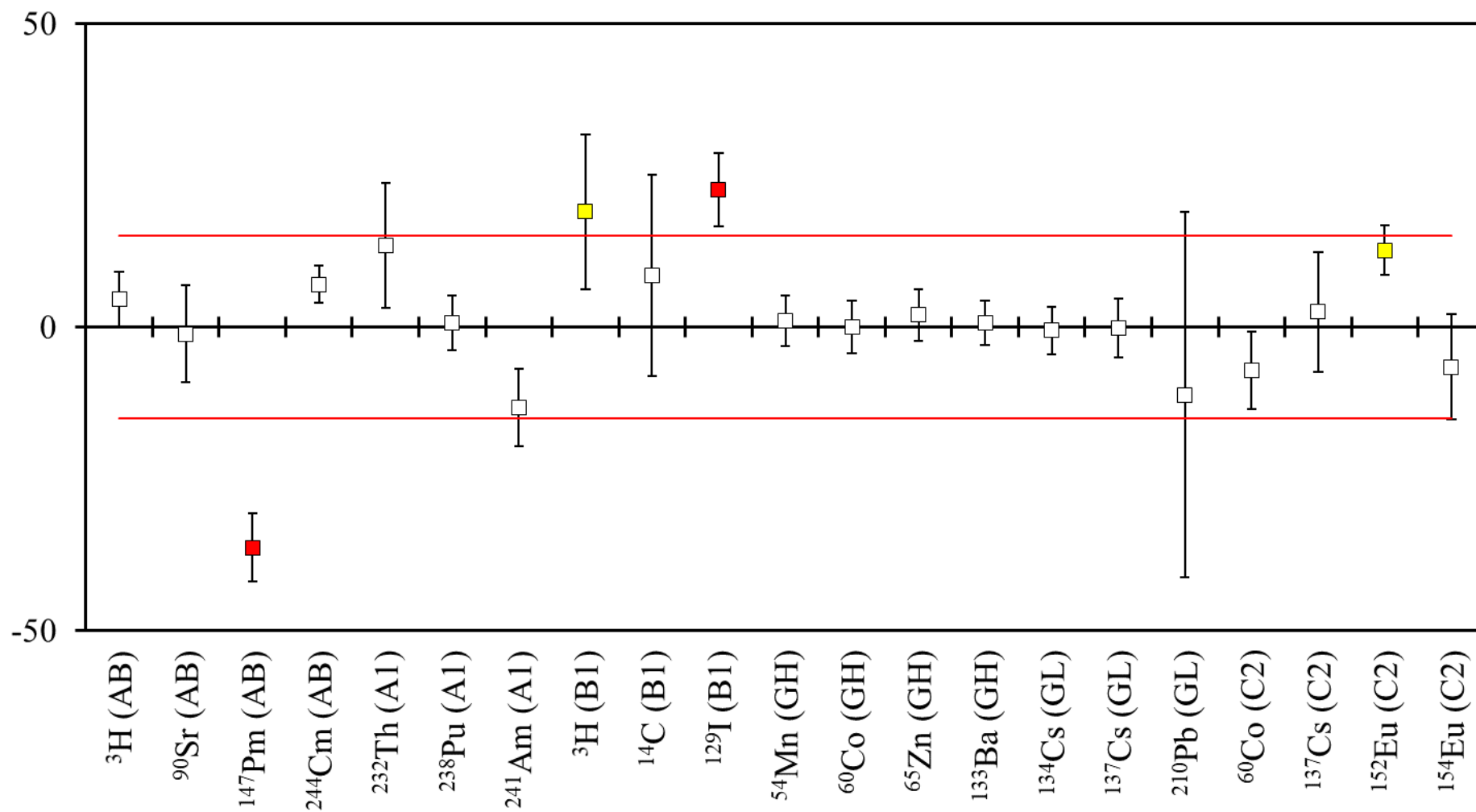
Radionuclide	Laboratory 32.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	10.12 ± 0.29	10.47 ± 0.13	-3.3	-1.10	-0.57
⁹⁰ Sr (AB)	8.08 ± 0.43	8.291 ± 0.021	-2.5	-0.49	-0.44
¹⁴⁷ Pm (AB)	16.6 ± 1.2	18.05 ± 0.23	-8.0	-1.19	-1.38
²⁴⁴ Cm (AB)	8.50 ± 0.20	8.788 ± 0.029	-3.3	-1.43	-0.56
²³² Th (A1)	2.75 ± 0.16	2.724 ± 0.026	1.0	0.16	0.16
²³⁸ Pu (A1)	10.14 ± 0.39	10.306 ± 0.025	-1.6	-0.42	-0.28
²⁴¹ Am (A1)	7.14 ± 0.32	7.674 ± 0.017	-7.0	-1.67	-1.20
³ H (B1)	1.338 ± 0.033	1.336 ± 0.017	0.1	0.05	0.03
¹²⁹ I (B1)	0.410 ± 0.032	0.3839 ± 0.0019	6.8	0.81	1.17
⁵⁴ Mn (GH)	18.74 ± 0.41	19.062 ± 0.081	-1.7	-0.77	-0.29
⁶⁰ Co (GH)	7.34 ± 0.16	7.399 ± 0.020	-0.8	-0.37	-0.14
⁶⁵ Zn (GH)	2.1950 ± 0.06	2.353 ± 0.017	-6.7	-2.53	-1.15
¹³³ Ba (GH)	19.54 ± 0.28	19.70 ± 0.13	-0.8	-0.52	-0.14
¹³⁴ Cs (GL)	17.14 ± 0.80	17.14 ± 0.12	0.0	0.00	0.00
¹³⁷ Cs (GL)	6.570 ± 0.3	6.788 ± 0.062	-3.2	-0.71	-0.55
³ H (C2)	31.5 ± 1.8	29.0 ± 2.0	8.6	0.93	1.48
⁶⁰ Co (C2)	0.0819 ± 0.0033	0.0705 ± 0.0011	16.2	3.28	2.78
¹³⁷ Cs (C2)	0.0578 ± 0.0026	0.05647 ± 0.00096	2.4	0.48	0.40
¹⁵² Eu (C2)	7.18 ± 0.16	7.180 ± 0.048	0.0	0.00	0.00
¹⁵⁴ Eu (C2)	0.1265 ± 0.0099	0.1423 ± 0.0032	-11.1	-1.52	-1.91
²³⁵ U (C2)	0.000644 ± 0.000048	-	-	-	-
²³⁸ U (C2)	0.01391 ± 0.00095	0.01168 ± 0.00097	19.1	1.64	3.28

Deviation (%) of Laboratory 32.2



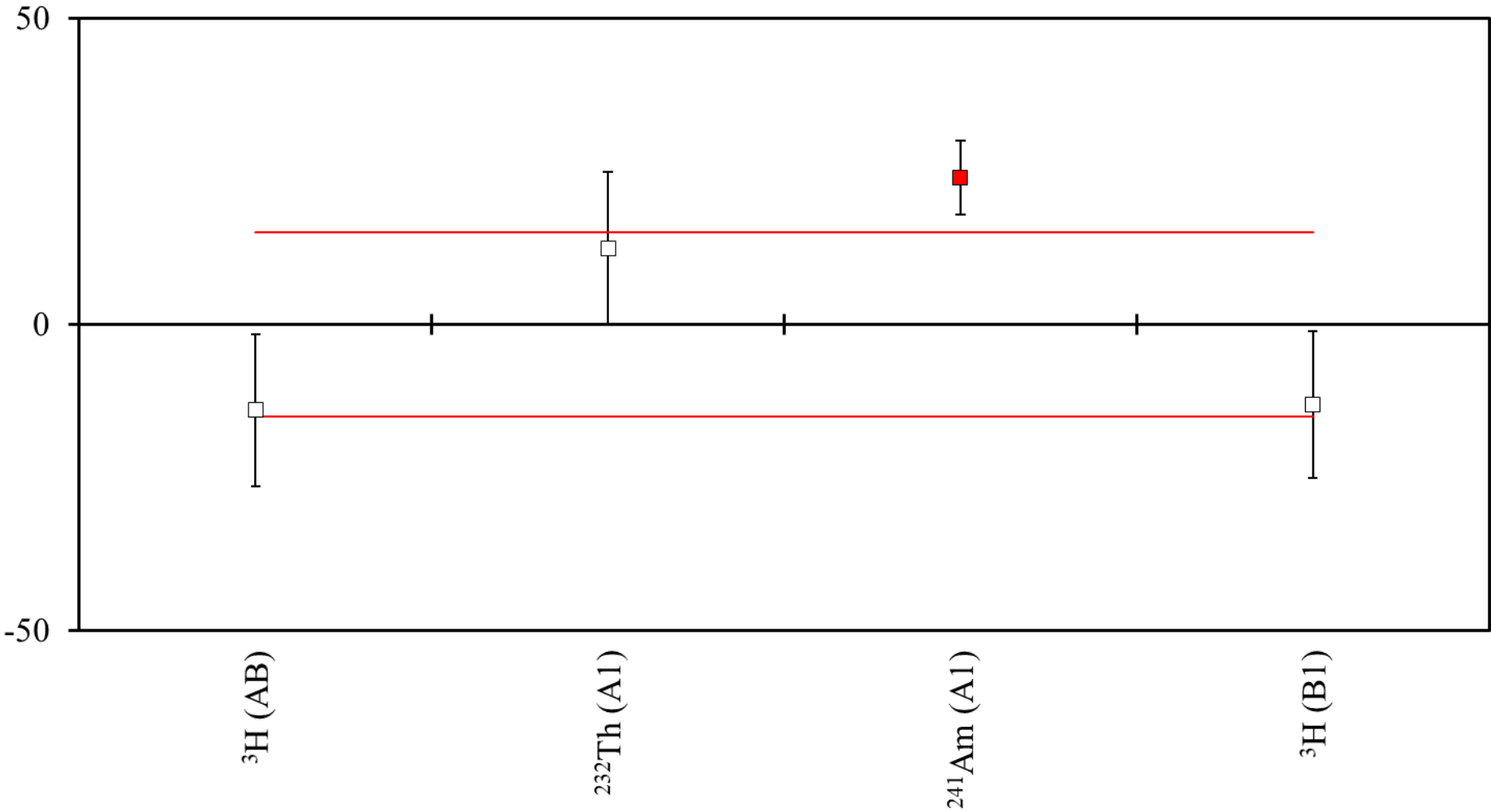
Radionuclide	Laboratory 32.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.38 ± 0.60	10.47 ± 0.13	-0.9	-0.15	-0.15
^{90}Sr (AB)	8.11 ± 0.43	8.291 ± 0.021	-2.2	-0.42	-0.37
^{241}Am (A1)	9.32 ± 0.73	7.674 ± 0.017	21.4	2.25	3.68
^3H (B1)	1.245 ± 0.077	1.336 ± 0.017	-6.8	-1.15	-1.17
^{129}I (B1)	0.396 ± 0.011	0.3839 ± 0.0019	3.2	1.08	0.54

Deviation (%) of Laboratory 35.1



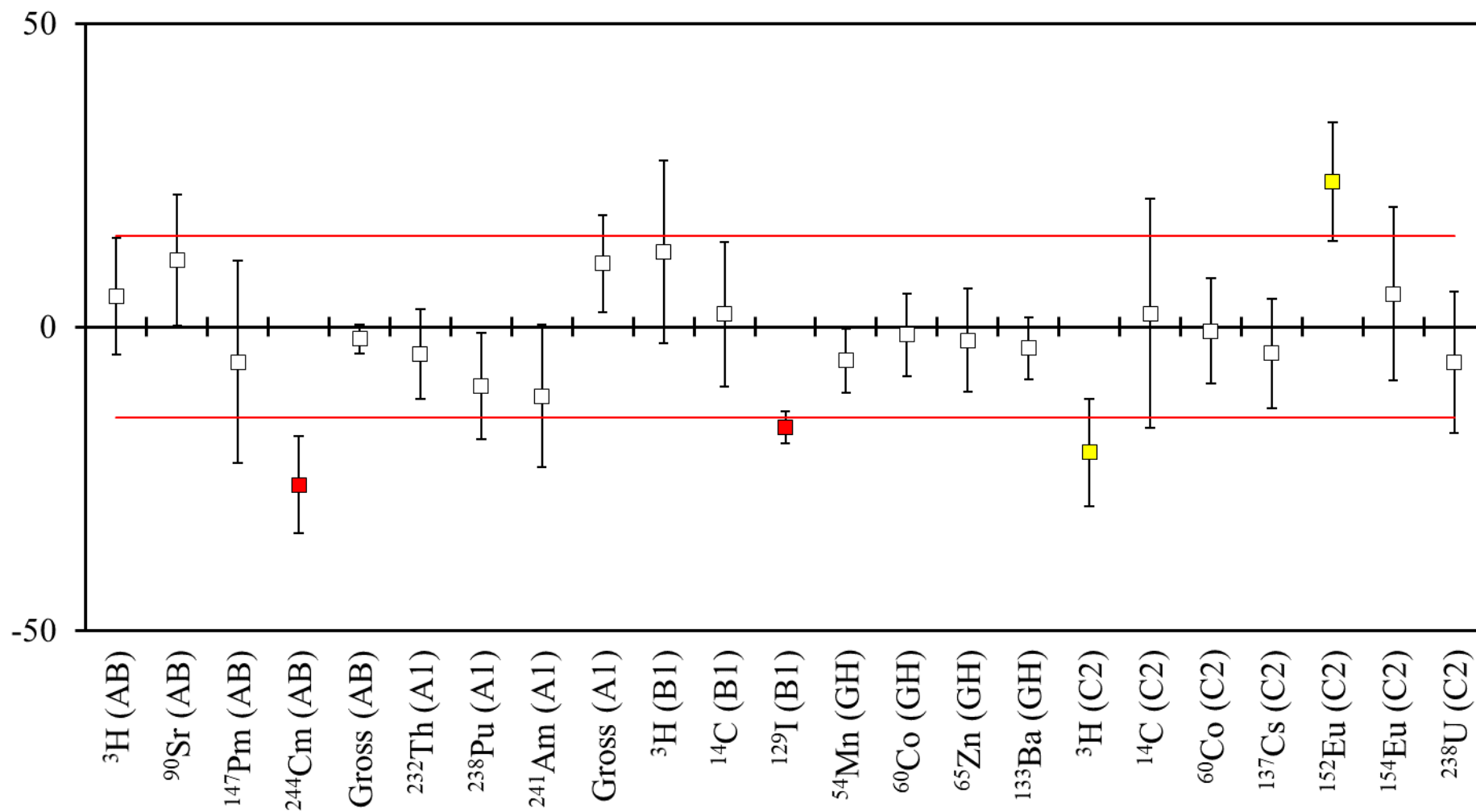
Radionuclide	Laboratory 35.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.95 ± 0.46	10.47 ± 0.13	4.6	1.00	0.79
^{90}Sr (AB)	8.20 ± 0.66	8.291 ± 0.021	-1.1	-0.14	-0.19
^{147}Pm (AB)	11.5 ± 1.0	18.05 ± 0.23	-36.3	-6.38	-6.23
^{244}Cm (AB)	9.41 ± 0.27	8.788 ± 0.029	7.1	2.29	1.22
^{232}Th (A1)	3.09 ± 0.28	2.724 ± 0.026	13.4	1.30	2.31
^{238}Pu (A1)	10.38 ± 0.47	10.306 ± 0.025	0.7	0.16	0.12
^{241}Am (A1)	6.66 ± 0.49	7.674 ± 0.017	-13.2	-2.07	-2.27
^3H (B1)	1.59 ± 0.17	1.336 ± 0.017	19.0	1.49	3.26
^{14}C (B1)	0.457 ± 0.070	0.4212 ± 0.0019	8.5	0.51	1.46
^{129}I (B1)	0.471 ± 0.023	0.3839 ± 0.0019	22.7	3.77	3.90
^{54}Mn (GH)	19.26 ± 0.79	19.062 ± 0.081	1.0	0.25	0.18
^{60}Co (GH)	7.40 ± 0.32	7.399 ± 0.020	0.0	0.00	0.00
^{65}Zn (GH)	2.40 ± 0.10	2.353 ± 0.017	2.0	0.46	0.34
^{133}Ba (GH)	19.84 ± 0.72	19.70 ± 0.13	0.7	0.19	0.12
^{134}Cs (GL)	17.05 ± 0.66	17.14 ± 0.12	-0.5	-0.13	-0.09
^{137}Cs (GL)	6.78 ± 0.32	6.788 ± 0.062	-0.1	-0.02	-0.02
^{210}Pb (GL)	5.6 ± 1.9	6.300 ± 0.067	-11.1	-0.37	-1.91
^{60}Co (C2)	0.0655 ± 0.0044	0.0705 ± 0.0011	-7.1	-1.10	-1.22
^{137}Cs (C2)	0.0579 ± 0.0055	0.05647 ± 0.00096	2.5	0.26	0.43
^{152}Eu (C2)	8.09 ± 0.29	7.180 ± 0.048	12.7	3.10	2.18
^{154}Eu (C2)	0.133 ± 0.012	0.1423 ± 0.0032	-6.5	-0.75	-1.12

Deviation (%) of Laboratory 35.2



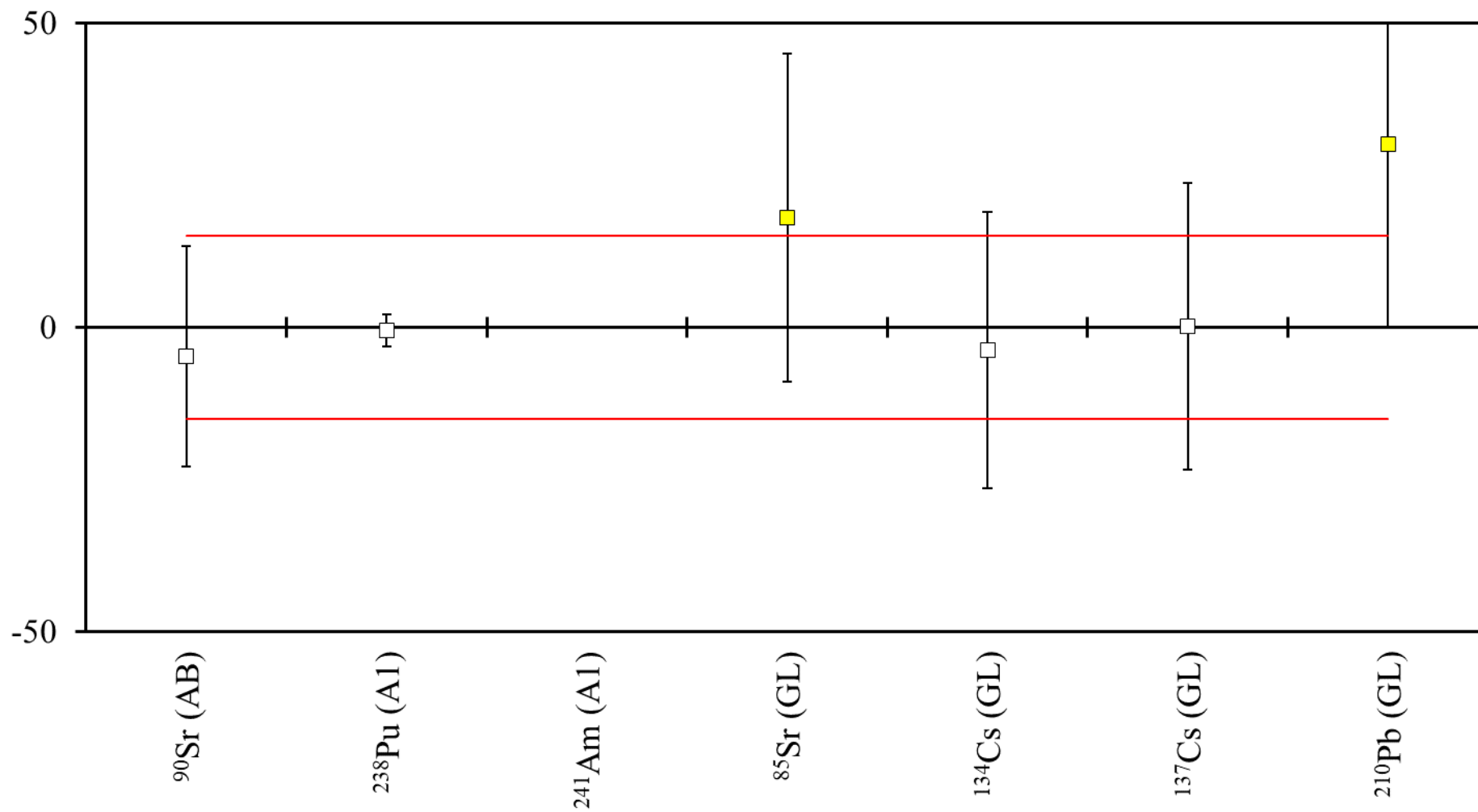
Radionuclide	Laboratory 35.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	9.0 ± 1.3	10.47 ± 0.13	-14.0	-1.13	-2.41
^{232}Th (A1)	3.06 ± 0.34	2.724 ± 0.026	12.3	0.99	2.12
^{241}Am (A1)	9.51 ± 0.46	7.674 ± 0.017	23.9	3.99	4.11
^3H (B1)	1.16 ± 0.16	1.336 ± 0.017	-13.2	-1.09	-2.26

Deviation (%) of Laboratory 38



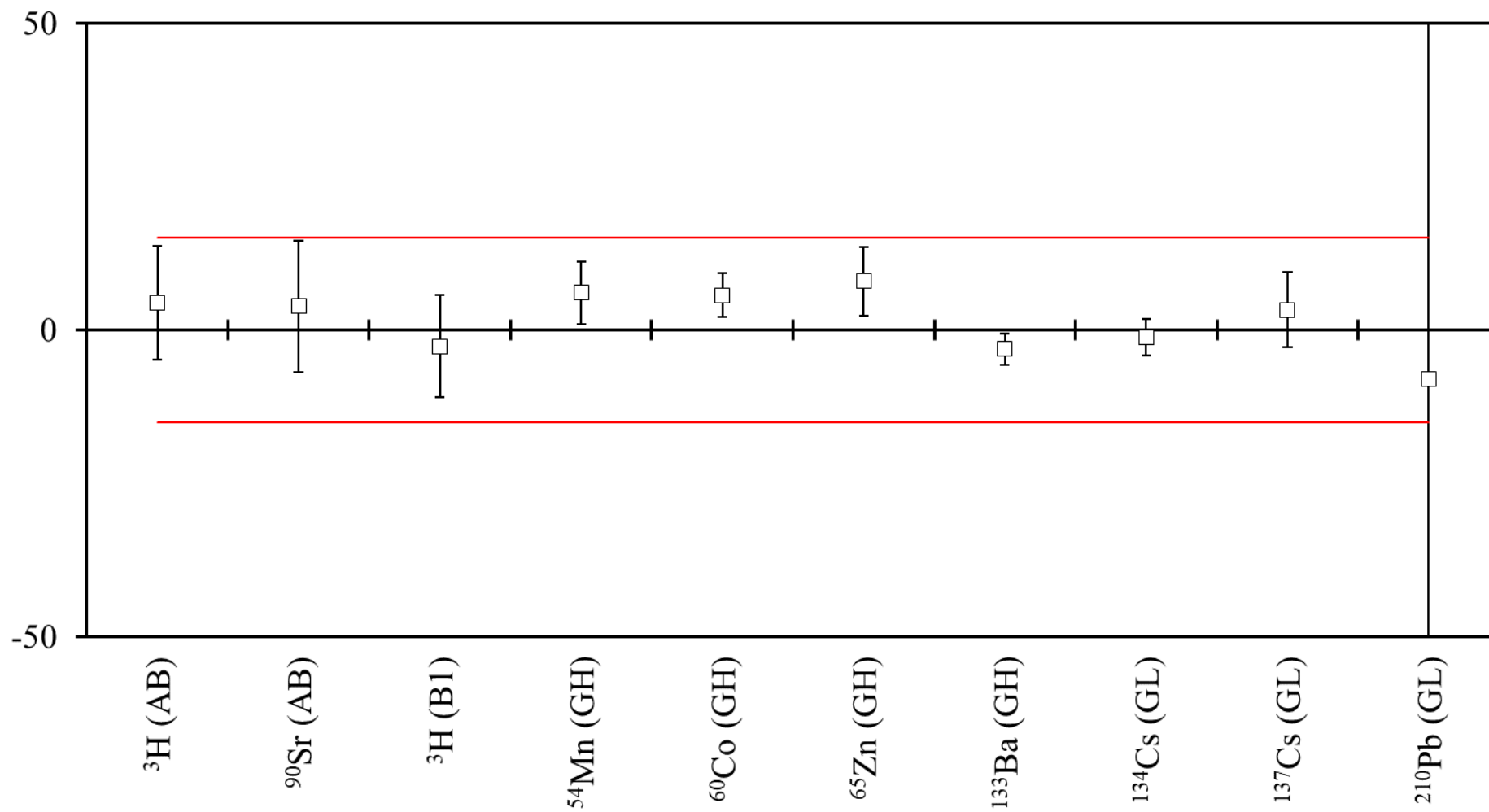
Radionuclide	Laboratory 38	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	11.0 ± 1.0	10.47 ± 0.13	5.1	0.53	0.87
⁹⁰ Sr (AB)	9.20 ± 0.90	8.291 ± 0.021	11.0	1.01	1.88
¹⁴⁷ Pm (AB)	17.0 ± 3.0	18.05 ± 0.23	-5.8	-0.35	-1.00
²⁴⁴ Cm (AB)	6.5 ± 0.7	8.788 ± 0.029	-26.0	-3.27	-4.47
Gross beta (AB)	21.60 ± 0.40	22.04 ± 0.35	-2.0	-0.83	-0.34
²³² Th (A1)	2.60 ± 0.20	2.724 ± 0.026	-4.6	-0.61	-0.78
²³⁸ Pu (A1)	9.30 ± 0.90	10.306 ± 0.025	-9.8	-1.12	-1.68
²⁴¹ Am (A1)	6.80 ± 0.90	7.674 ± 0.017	-11.4	-0.97	-1.96
Gross alpha (A1)	35.0 ± 2.0	31.7 ± 1.4	10.4	1.35	1.79
³ H (B1)	1.50 ± 0.20	1.336 ± 0.017	12.3	0.82	2.11
¹⁴ C (B1)	0.430 ± 0.050	0.4212 ± 0.0019	2.1	0.18	0.36
¹²⁹ I (B1)	0.320 ± 0.010	0.3839 ± 0.0019	-16.6	-6.28	-2.86
⁵⁴ Mn (GH)	18.0 ± 1.0	19.062 ± 0.081	-5.6	-1.06	-0.96
⁶⁰ Co (GH)	7.30 ± 0.50	7.399 ± 0.020	-1.3	-0.20	-0.23
⁶⁵ Zn (GH)	2.30 ± 0.20	2.353 ± 0.017	-2.3	-0.26	-0.39
¹³³ Ba (GH)	19.0 ± 1.0	19.70 ± 0.13	-3.6	-0.69	-0.61
³ H (C2)	23.0 ± 2.0	29.0 ± 2.0	-20.7	-2.12	-3.55
¹⁴ C (C2)	0.230 ± 0.040	0.225 ± 0.014	2.2	0.12	0.38
⁶⁰ Co (C2)	0.0700 ± 0.0060	0.0705 ± 0.0011	-0.7	-0.08	-0.12
¹³⁷ Cs (C2)	0.0540 ± 0.0050	0.05647 ± 0.00096	-4.4	-0.49	-0.75
¹⁵² Eu (C2)	8.9 ± 0.7	7.180 ± 0.048	24.0	2.45	4.11
¹⁵⁴ Eu (C2)	0.150 ± 0.020	0.1423 ± 0.0032	5.4	0.38	0.93
²³⁸ U (C2)	0.0110 ± 0.0010	0.01168 ± 0.00097	-5.8	-0.49	-1.00

Deviation (%) of Laboratory 40



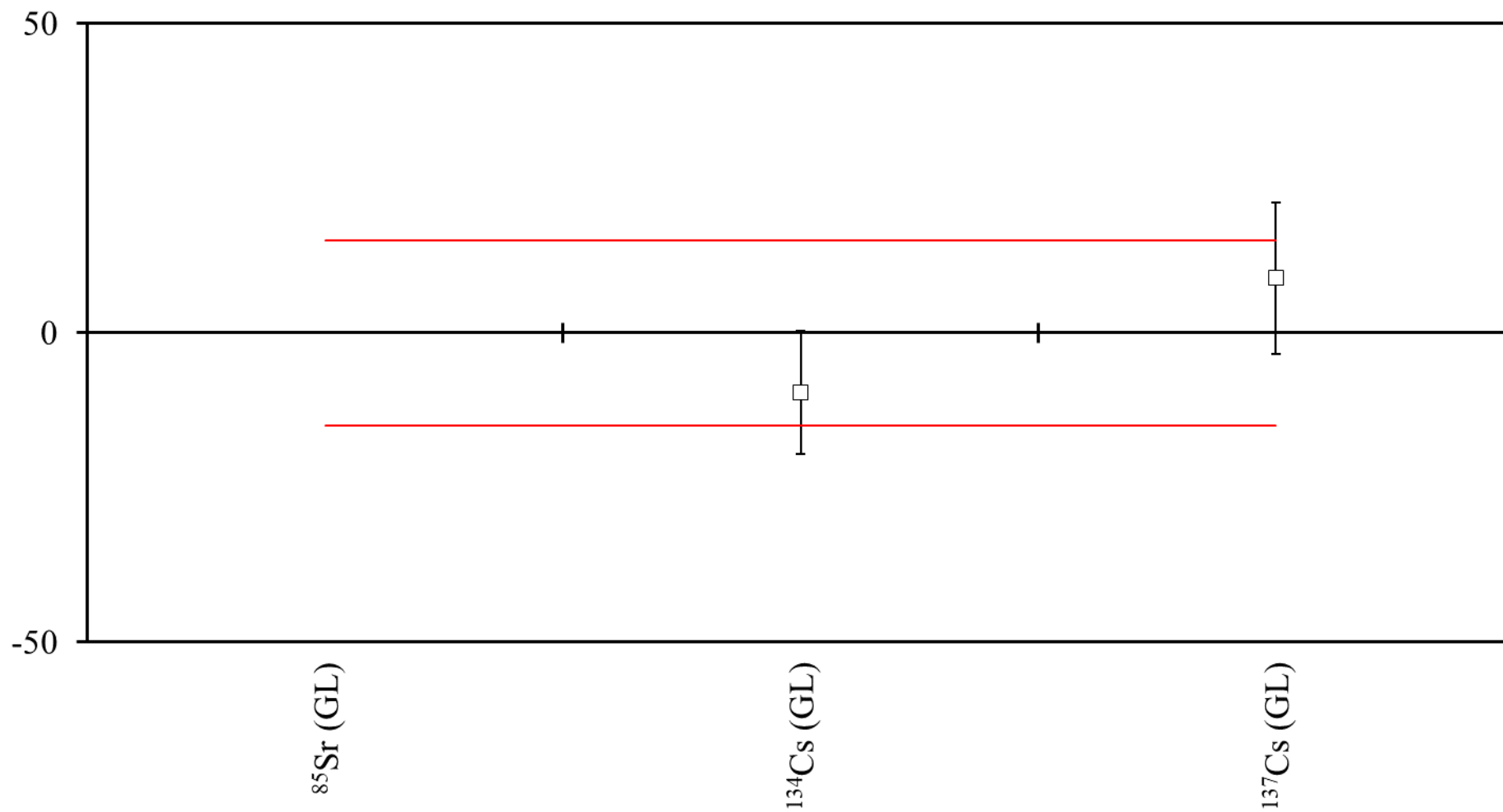
Radionuclide	Laboratory 40	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁹⁰ Sr (AB)	7.9 ± 1.5	8.291 ± 0.021	-4.7	-0.26	-0.81
²³⁸ Pu (A1)	10.26 ± 0.27	10.306 ± 0.025	-0.4	-0.17	-0.08
²⁴¹ Am (A1)	3.669 ± 0.098	7.674 ± 0.017	-52.2	-40.27	-8.96
⁸⁵ Sr (GL)	7.0 ± 1.6	5.931 ± 0.041	18.0	0.67	3.10
¹³⁴ Cs (GL)	16.5 ± 3.9	17.14 ± 0.12	-3.7	-0.16	-0.64
¹³⁷ Cs (GL)	6.8 ± 1.6	6.788 ± 0.062	0.2	0.01	0.03
²¹⁰ Pb (GL)	8.2 ± 1.9	6.300 ± 0.067	30.2	1.00	5.18

Deviation (%) of Laboratory 41



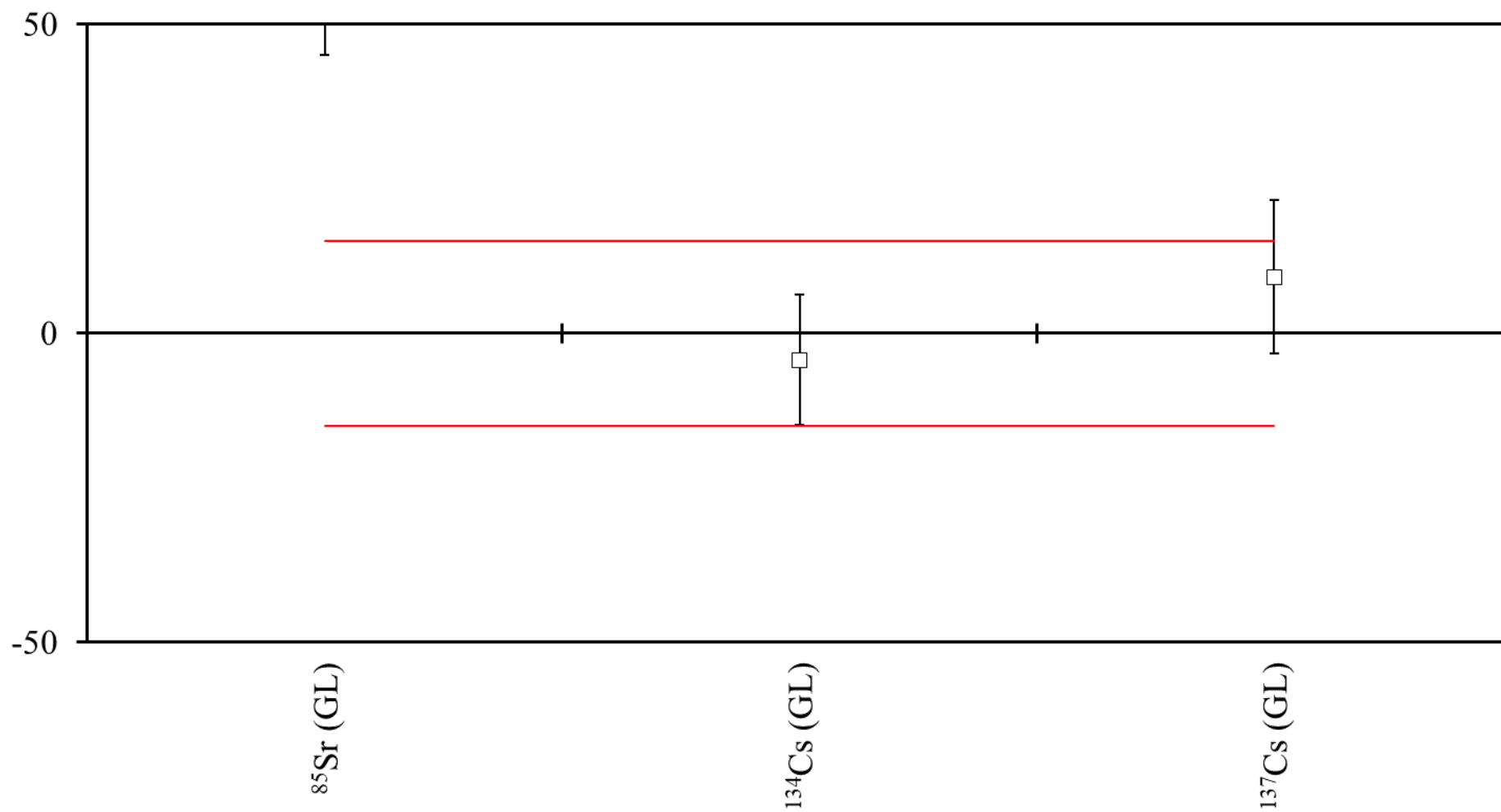
Radionuclide	Laboratory 41	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.94 ± 0.96	10.47 ± 0.13	4.5	0.49	0.77
^{90}Sr (AB)	8.61 ± 0.89	8.291 ± 0.021	3.8	0.36	0.66
^3H (B1)	1.30 ± 0.11	1.336 ± 0.017	-2.7	-0.32	-0.46
^{54}Mn (GH)	20.22 ± 0.96	19.062 ± 0.081	6.1	1.20	1.04
^{60}Co (GH)	7.82 ± 0.26	7.399 ± 0.020	5.7	1.61	0.98
^{65}Zn (GH)	2.54 ± 0.13	2.353 ± 0.017	7.9	1.43	1.36
^{133}Ba (GH)	19.09 ± 0.49	19.70 ± 0.13	-3.1	-1.20	-0.53
^{134}Cs (GL)	16.93 ± 0.50	17.14 ± 0.12	-1.2	-0.41	-0.21
^{137}Cs (GL)	7.01 ± 0.41	6.788 ± 0.062	3.3	0.54	0.56
^{210}Pb (GL)	5.8 ± 3.9	6.300 ± 0.067	-7.9	-0.13	-1.36

Deviation (%) of Laboratory 42.1



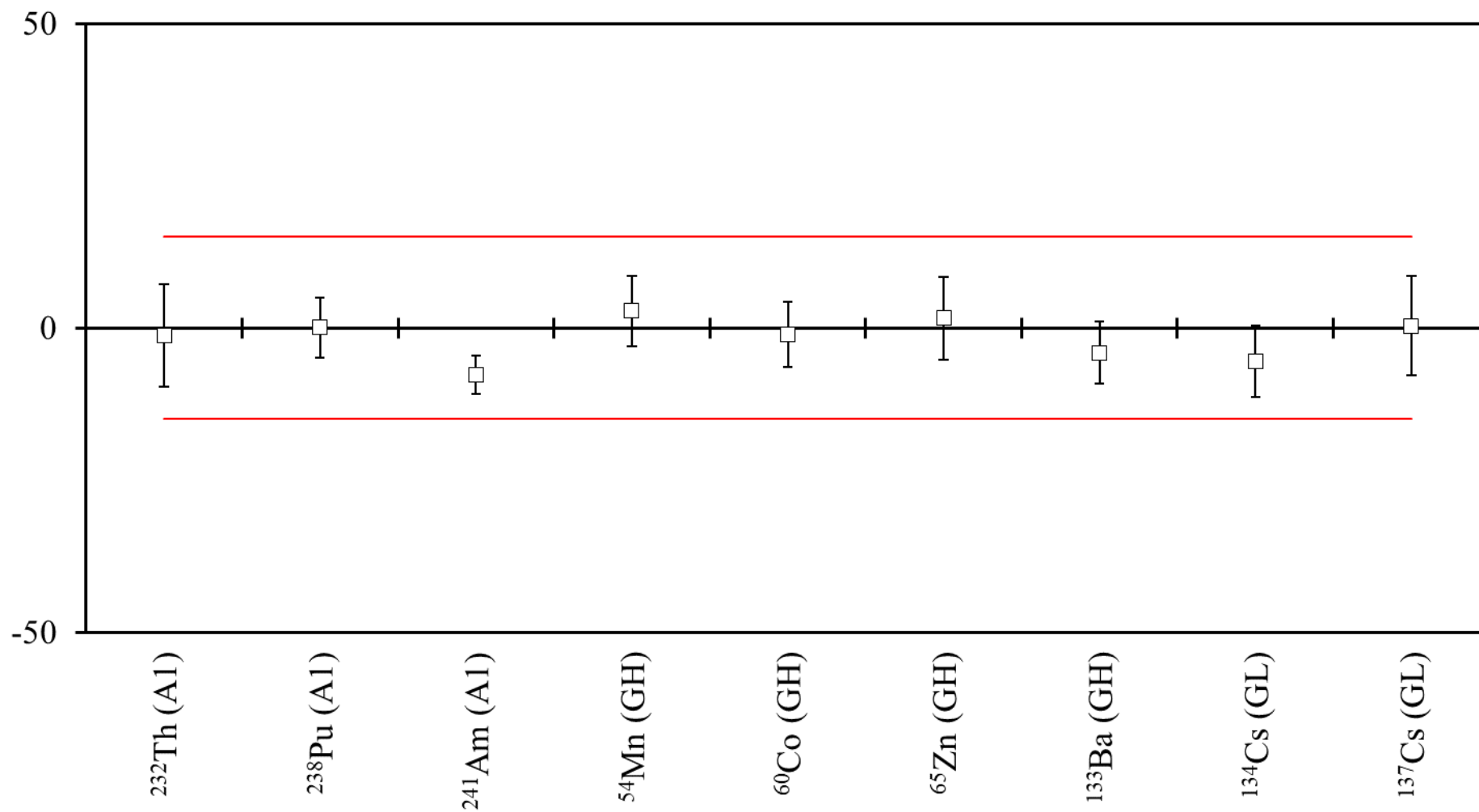
Radionuclide	Laboratory 42.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁸⁵ Sr (GL)	11.8 ± 2.3	5.931 ± 0.041	99.0	2.55	16.99
¹³⁴ Cs (GL)	15.5 ± 1.7	17.14 ± 0.12	-9.6	-0.96	-1.64
¹³⁷ Cs (GL)	7.39 ± 0.83	6.788 ± 0.062	8.9	0.72	1.52

Deviation (%) of Laboratory 42.2



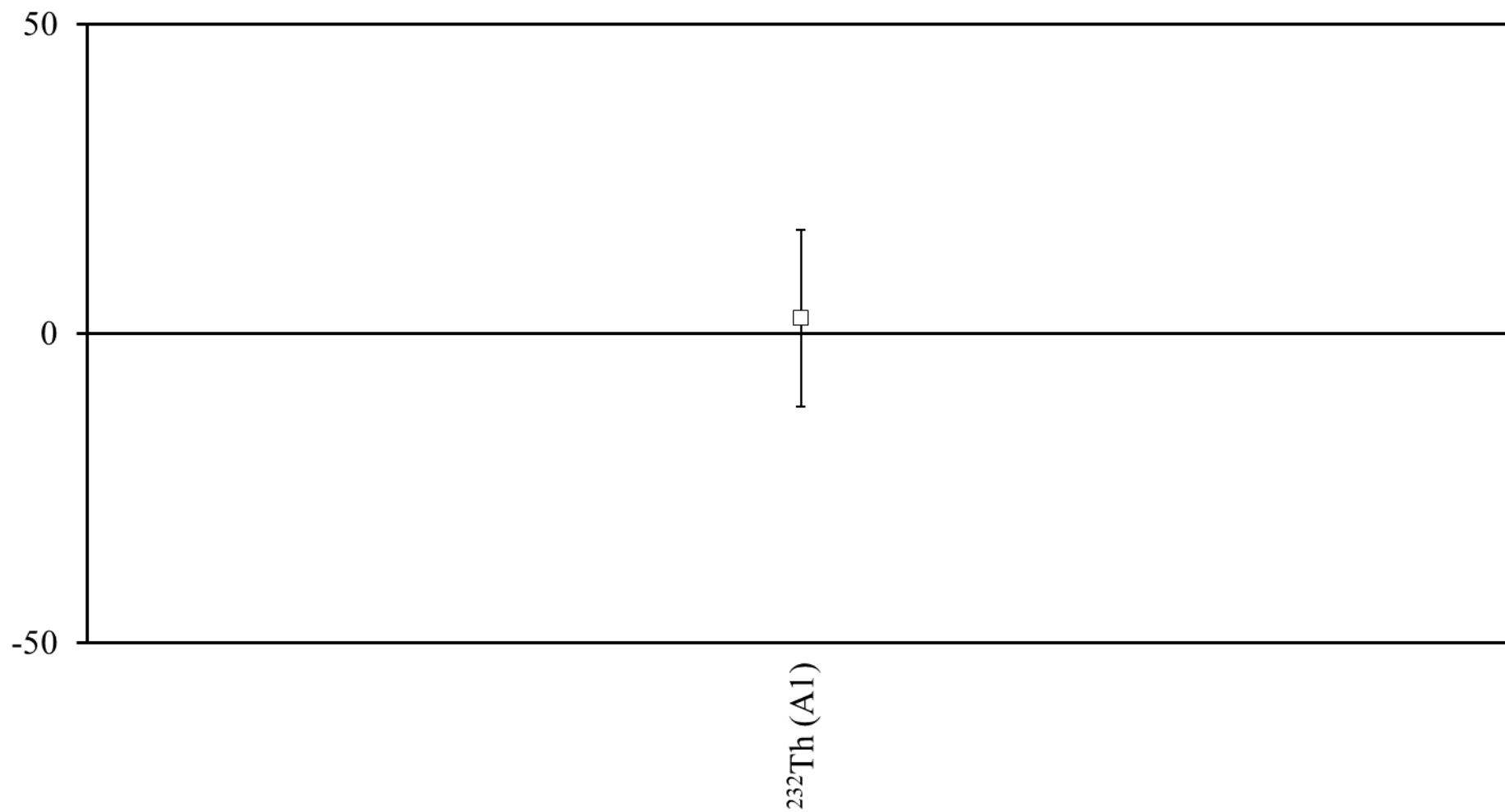
Radionuclide	Laboratory 42.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁸⁵ Sr (GL)	10.7 ± 2.1	5.931 ± 0.041	80.4	2.27	13.81
¹³⁴ Cs (GL)	16.4 ± 1.8	17.14 ± 0.12	-4.3	-0.41	-0.74
¹³⁷ Cs (GL)	7.41 ± 0.84	6.788 ± 0.062	9.2	0.74	1.57

Deviation (%) of Laboratory 47.1

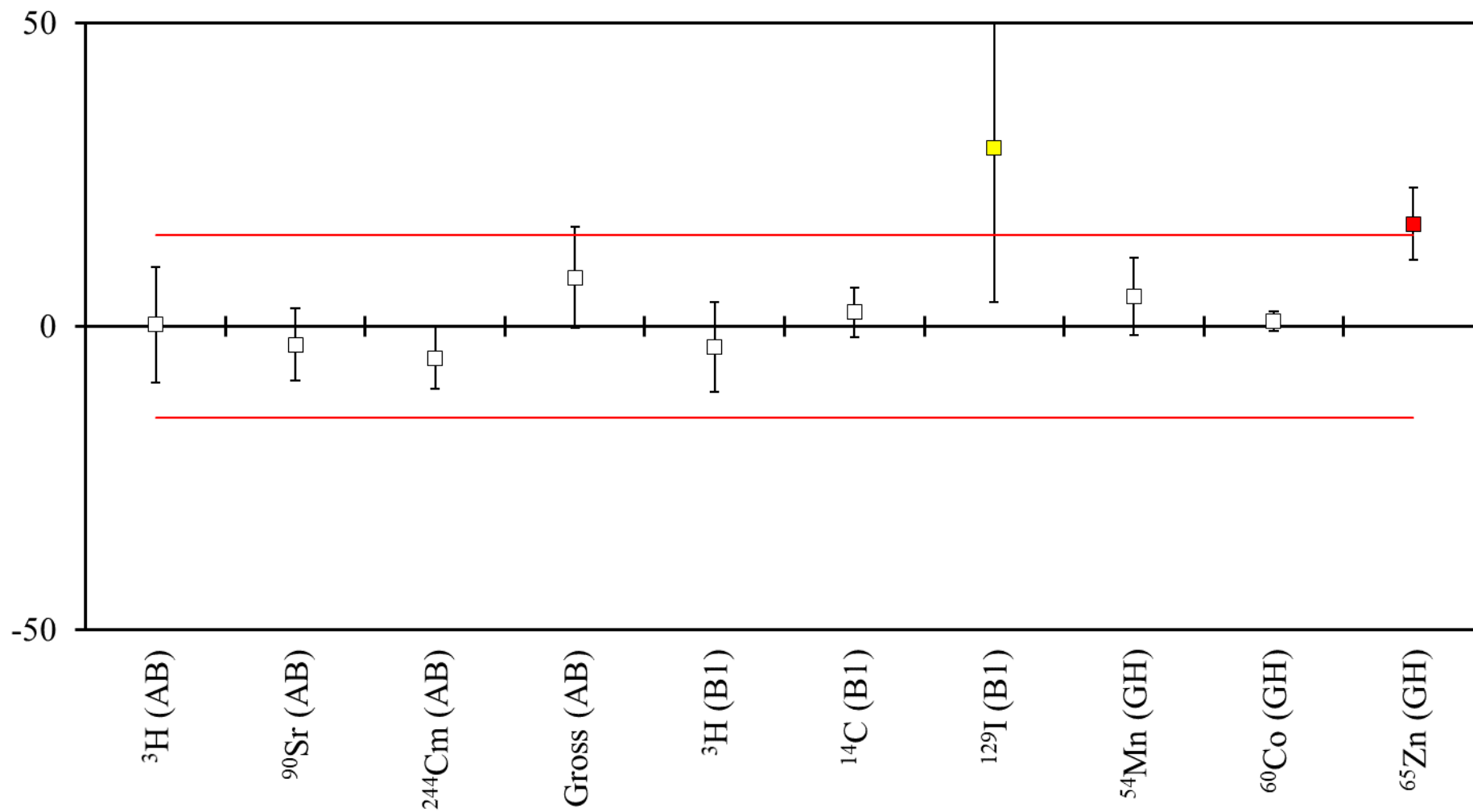


Radionuclide	Laboratory 47.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³² Th (A1)	2.69 ± 0.23	2.724 ± 0.026	-1.2	-0.15	-0.21
²³⁸ Pu (A1)	10.31 ± 0.50	10.306 ± 0.025	0.0	0.01	0.01
²⁴¹ Am (A1)	7.08 ± 0.24	7.674 ± 0.017	-7.7	-2.47	-1.33
⁵⁴ Mn (GH)	19.6 ± 1.1	19.062 ± 0.081	2.8	0.49	0.48
⁶⁰ Co (GH)	7.32 ± 0.40	7.399 ± 0.020	-1.1	-0.20	-0.18
⁶⁵ Zn (GH)	2.39 ± 0.16	2.353 ± 0.017	1.6	0.23	0.27
¹³³ Ba (GH)	18.9 ± 1.0	19.70 ± 0.13	-4.1	-0.79	-0.70
¹³⁴ Cs (GL)	16.2 ± 1.0	17.14 ± 0.12	-5.5	-0.93	-0.94
¹³⁷ Cs (GL)	6.81 ± 0.55	6.788 ± 0.062	0.3	0.04	0.06

Deviation (%) of Laboratory 47.2

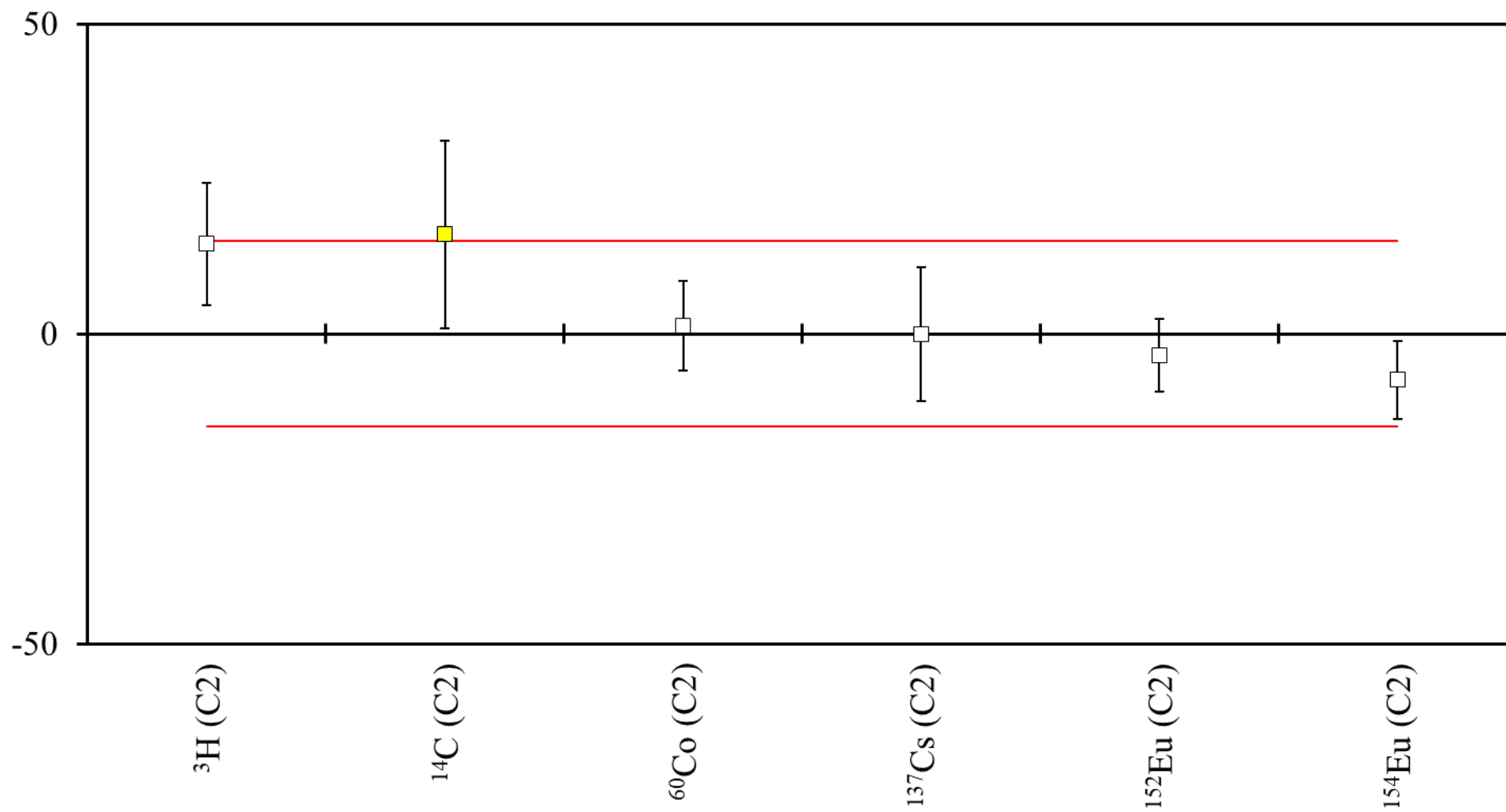


Radionuclide	Laboratory 47.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³² Th (A1)	2.79 ± 0.39	2.724 ± 0.026	2.4	0.17	0.42

Deviation (%) of Laboratory 55

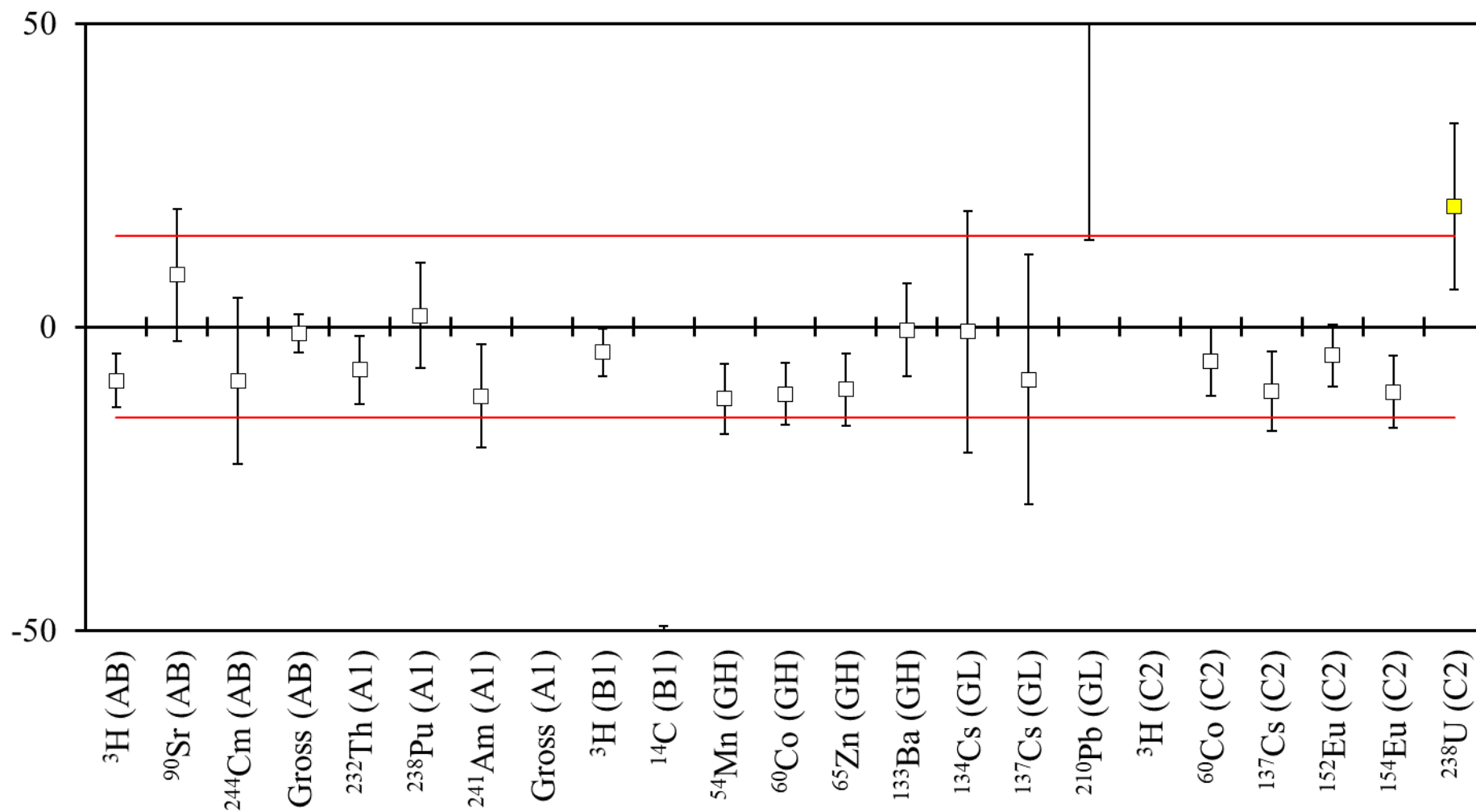
Radionuclide	Laboratory 55	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.50 ± 0.99	10.47 ± 0.13	0.3	0.03	0.05
^{90}Sr (AB)	8.04 ± 0.49	8.291 ± 0.021	-3.0	-0.51	-0.52
^{244}Cm (AB)	8.33 ± 0.45	8.788 ± 0.029	-5.2	-1.02	-0.90
Gross beta (AB)	23.8 ± 1.8	22.04 ± 0.35	8.0	0.96	1.37
^3H (B1)	1.290 ± 0.097	1.336 ± 0.017	-3.4	-0.47	-0.59
^{14}C (B1)	0.431 ± 0.017	0.4212 ± 0.0019	2.3	0.57	0.40
^{129}I (B1)	0.497 ± 0.098	0.3839 ± 0.0019	29.5	1.15	5.06
^{54}Mn (GH)	20.0 ± 1.2	19.062 ± 0.081	4.9	0.78	0.85
^{60}Co (GH)	7.46 ± 0.12	7.399 ± 0.020	0.8	0.50	0.14
^{65}Zn (GH)	2.75 ± 0.14	2.353 ± 0.017	16.9	2.82	2.90

Deviation (%) of Laboratory 56



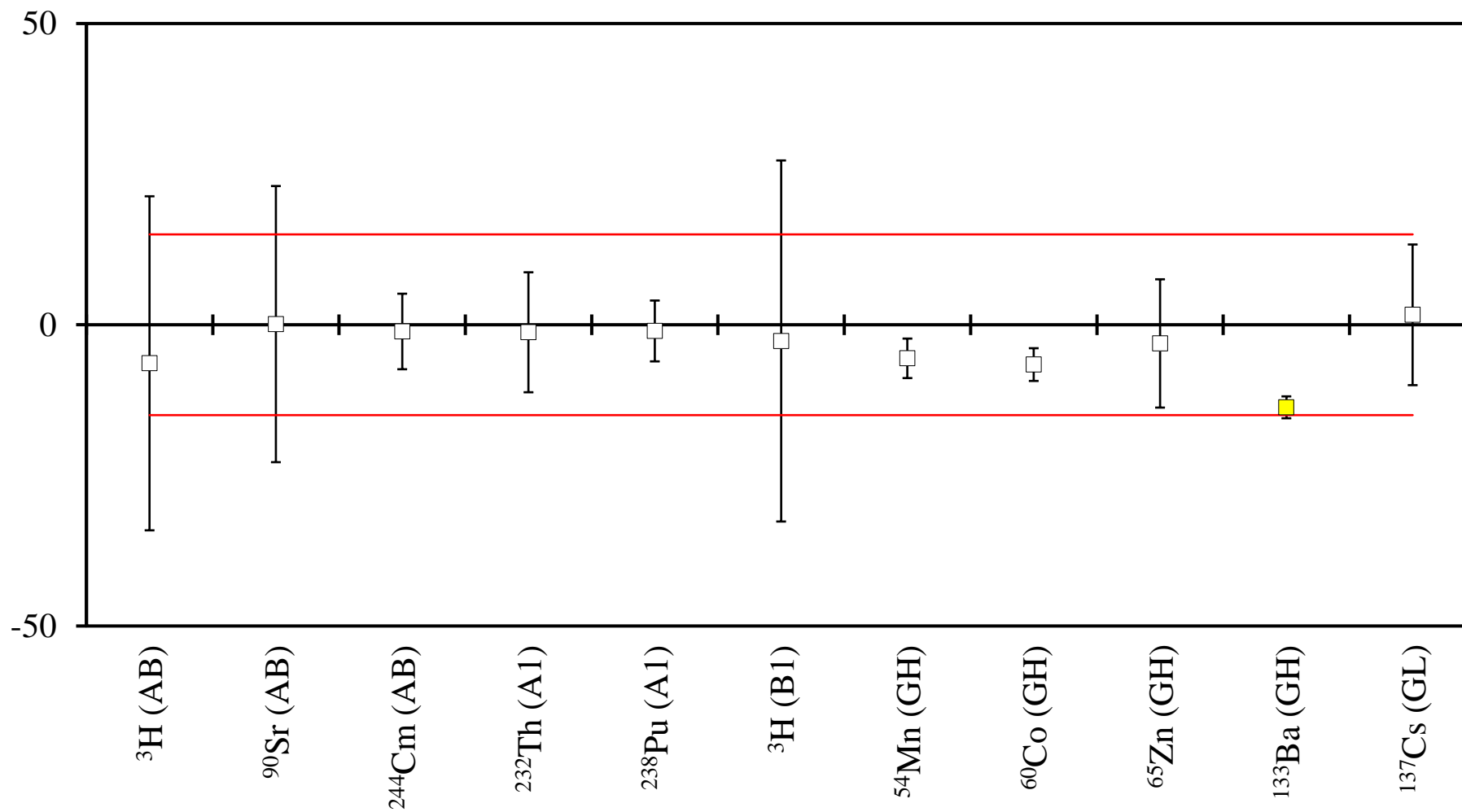
Radionuclide	Laboratory 56	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (C2)	33.2 ± 1.7	29.0 ± 2.0	14.5	1.60	2.49
^{14}C (C2)	0.261 ± 0.030	0.225 ± 0.014	16.0	1.09	2.75
^{60}Co (C2)	0.0714 ± 0.0050	0.0705 ± 0.0011	1.3	0.18	0.22
^{90}Sr (C2)	32.0 ± 2.8	-	-	-	-
^{137}Cs (C2)	0.0564 ± 0.0060	0.05647 ± 0.00096	-0.1	-0.01	-0.02
^{152}Eu (C2)	6.93 ± 0.42	7.180 ± 0.048	-3.5	-0.59	-0.60
^{154}Eu (C2)	0.1317 ± 0.0085	0.1423 ± 0.0032	-7.4	-1.17	-1.28

Deviation (%) of Laboratory 57



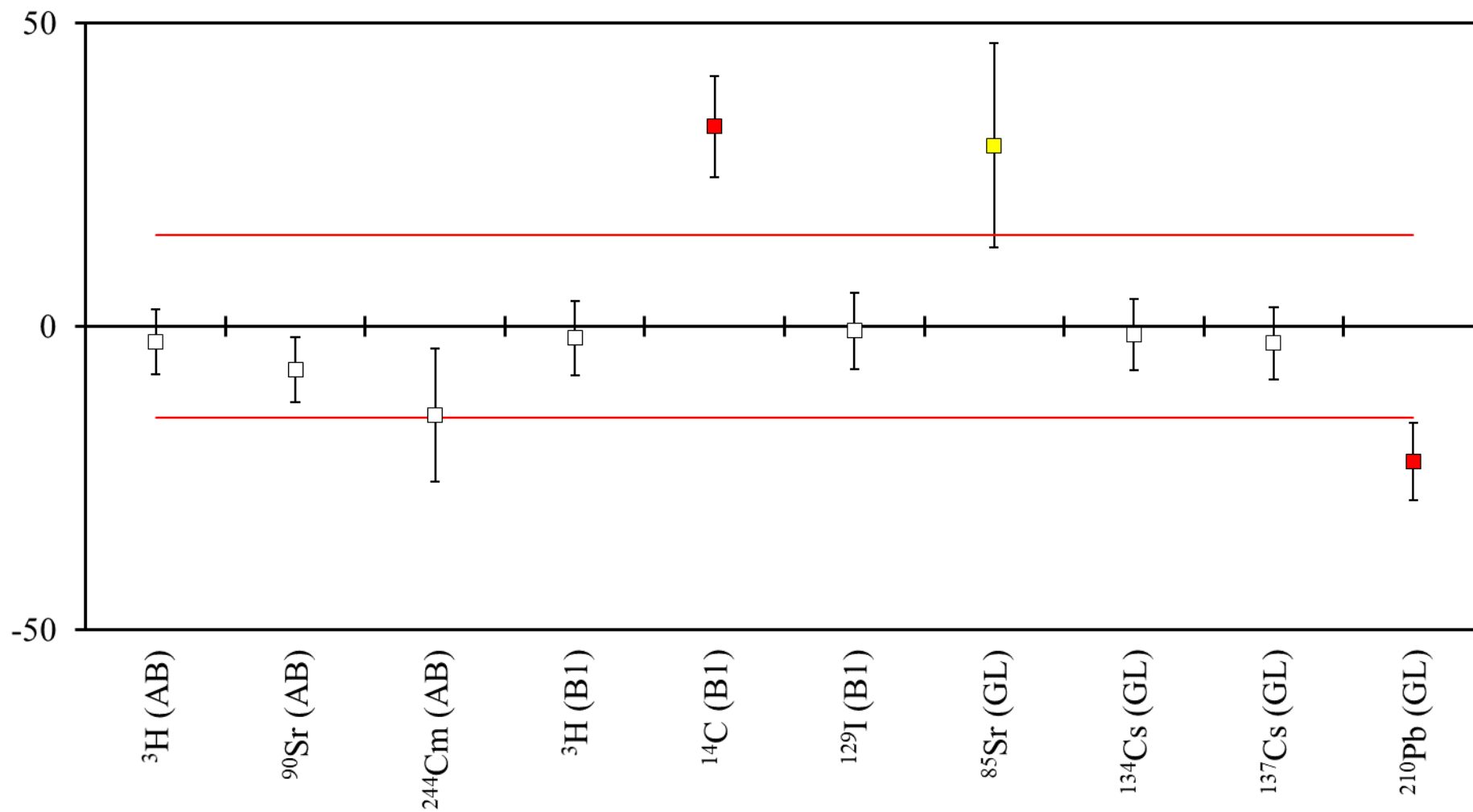
Radionuclide	Laboratory 57	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	9.54 ± 0.45	10.47 ± 0.13	-8.9	-1.99	-1.53
⁹⁰ Sr (AB)	9.00 ± 0.90	8.291 ± 0.021	8.6	0.79	1.47
²⁴⁴ Cm (AB)	8.0 ± 1.2	8.788 ± 0.029	-9.0	-0.66	-1.54
Gross beta (AB)	21.8 ± 0.6	22.04 ± 0.35	-1.1	-0.35	-0.19
²³² Th (A1)	2.53 ± 0.15	2.724 ± 0.026	-7.1	-1.27	-1.22
²³⁸ Pu (A1)	10.50 ± 0.90	10.306 ± 0.025	1.9	0.22	0.32
²⁴¹ Am (A1)	6.80 ± 0.65	7.674 ± 0.017	-11.4	-1.34	-1.96
Gross alpha (A1)	374.0 ± 2.5	31.7 ± 1.4	1079.8	119.46	185.44
³ H (B1)	1.280 ± 0.050	1.336 ± 0.017	-4.2	-1.06	-0.72
¹⁴ C (B1)	0.2080 ± 0.0055	0.4212 ± 0.0019	-50.6	-36.64	-8.69
Gross beta (B1)	0.1788 ± 0.0048	-	-	-	-
⁵⁴ Mn (GH)	16.8 ± 1.1	19.062 ± 0.081	-11.9	-2.05	-2.04
⁶⁰ Co (GH)	6.58 ± 0.38	7.399 ± 0.020	-11.1	-2.15	-1.90
⁶⁵ Zn (GH)	2.11 ± 0.14	2.353 ± 0.017	-10.3	-1.72	-1.77
¹³³ Ba (GH)	19.6 ± 1.5	19.70 ± 0.13	-0.5	-0.07	-0.09
¹³⁴ Cs (GL)	17.0 ± 3.4	17.14 ± 0.12	-0.8	-0.04	-0.14
¹³⁷ Cs (GL)	6.2 ± 1.4	6.788 ± 0.062	-8.7	-0.42	-1.49
²¹⁰ Pb (GL)	9.8 ± 2.6	6.300 ± 0.067	55.6	1.35	9.54
³ H (C2)	11.00 ± 0.55	29.0 ± 2.0	-62.1	-8.68	-10.66
⁶⁰ Co (C2)	0.0665 ± 0.0039	0.0705 ± 0.0011	-5.7	-0.99	-0.97
¹³⁷ Cs (C2)	0.0505 ± 0.0036	0.05647 ± 0.00096	-10.6	-1.60	-1.82
¹⁵² Eu (C2)	6.84 ± 0.36	7.180 ± 0.048	-4.7	-0.94	-0.81
¹⁵⁴ Eu (C2)	0.1270 ± 0.0080	0.1423 ± 0.0032	-10.8	-1.78	-1.85
²³⁵ U (C2)	0.00061 ± 0.00015	-	-	-	-
²³⁸ U (C2)	0.0140 ± 0.0011	0.01168 ± 0.00097	19.9	1.58	3.41

Deviation (%) of Laboratory 61



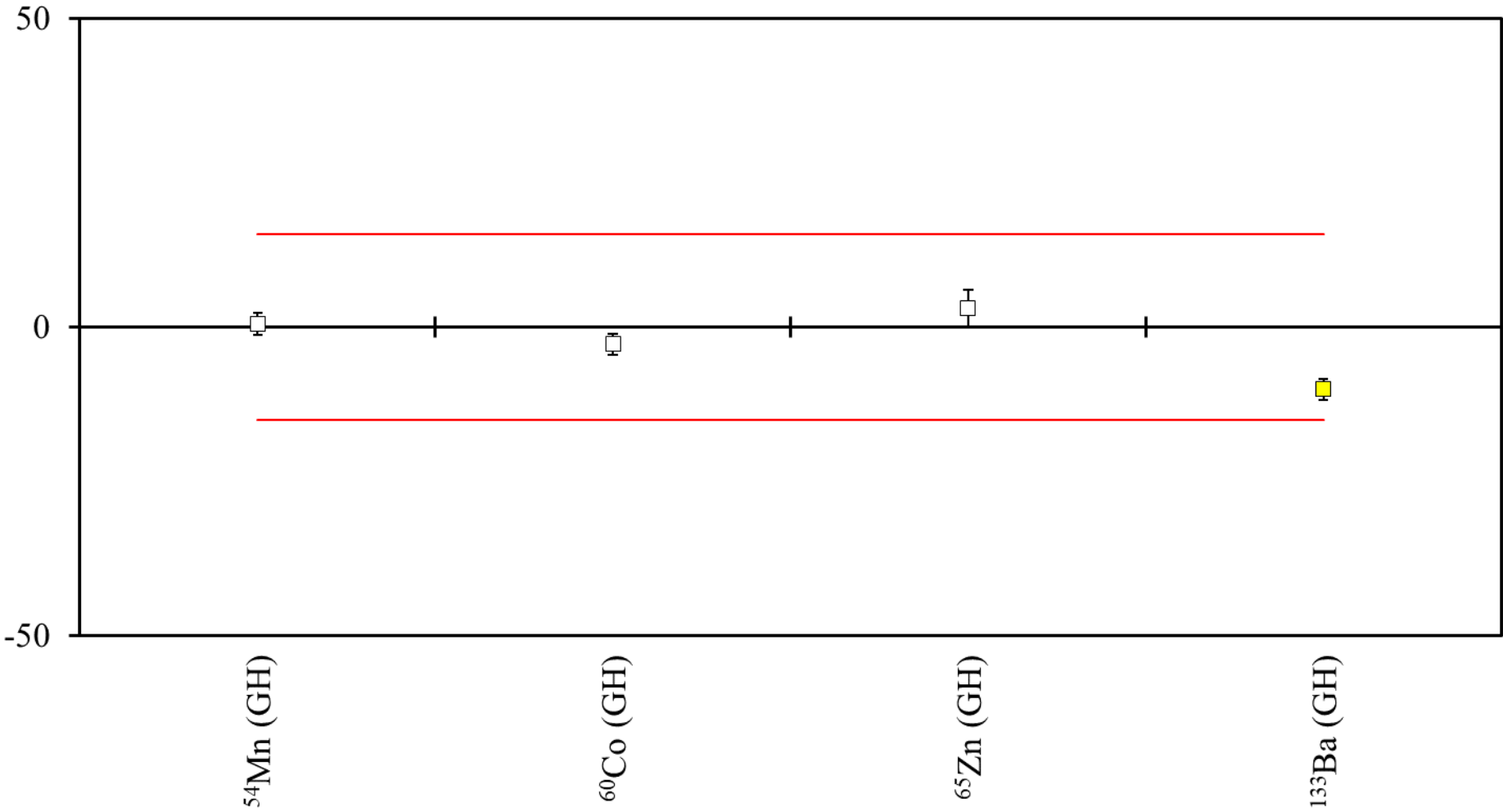
Radionuclide	Laboratory 61	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	9.8 ± 2.9	10.47 ± 0.13	-6.4	-0.23	-1.10
^{90}Sr (AB)	8.3 ± 1.9	8.291 ± 0.021	0.1	0.00	0.02
^{244}Cm (AB)	8.69 ± 0.55	8.788 ± 0.029	-1.1	-0.18	-0.19
^{232}Th (A1)	2.69 ± 0.27	2.724 ± 0.026	-1.2	-0.13	-0.21
^{238}Pu (A1)	10.20 ± 0.52	10.306 ± 0.025	-1.0	-0.20	-0.18
^3H (B1)	1.30 ± 0.40	1.336 ± 0.017	-2.7	-0.09	-0.46
^{54}Mn (GH)	18.00 ± 0.62	19.062 ± 0.081	-5.6	-1.70	-0.96
^{60}Co (GH)	6.91 ± 0.20	7.399 ± 0.020	-6.6	-2.43	-1.13
^{65}Zn (GH)	2.28 ± 0.25	2.353 ± 0.017	-3.1	-0.29	-0.53
^{133}Ba (GH)	17.00 ± 0.34	19.70 ± 0.13	-13.7	-7.42	-2.35
^{137}Cs (GL)	6.90 ± 0.79	6.788 ± 0.062	1.6	0.14	0.28

Deviation (%) of Laboratory 65



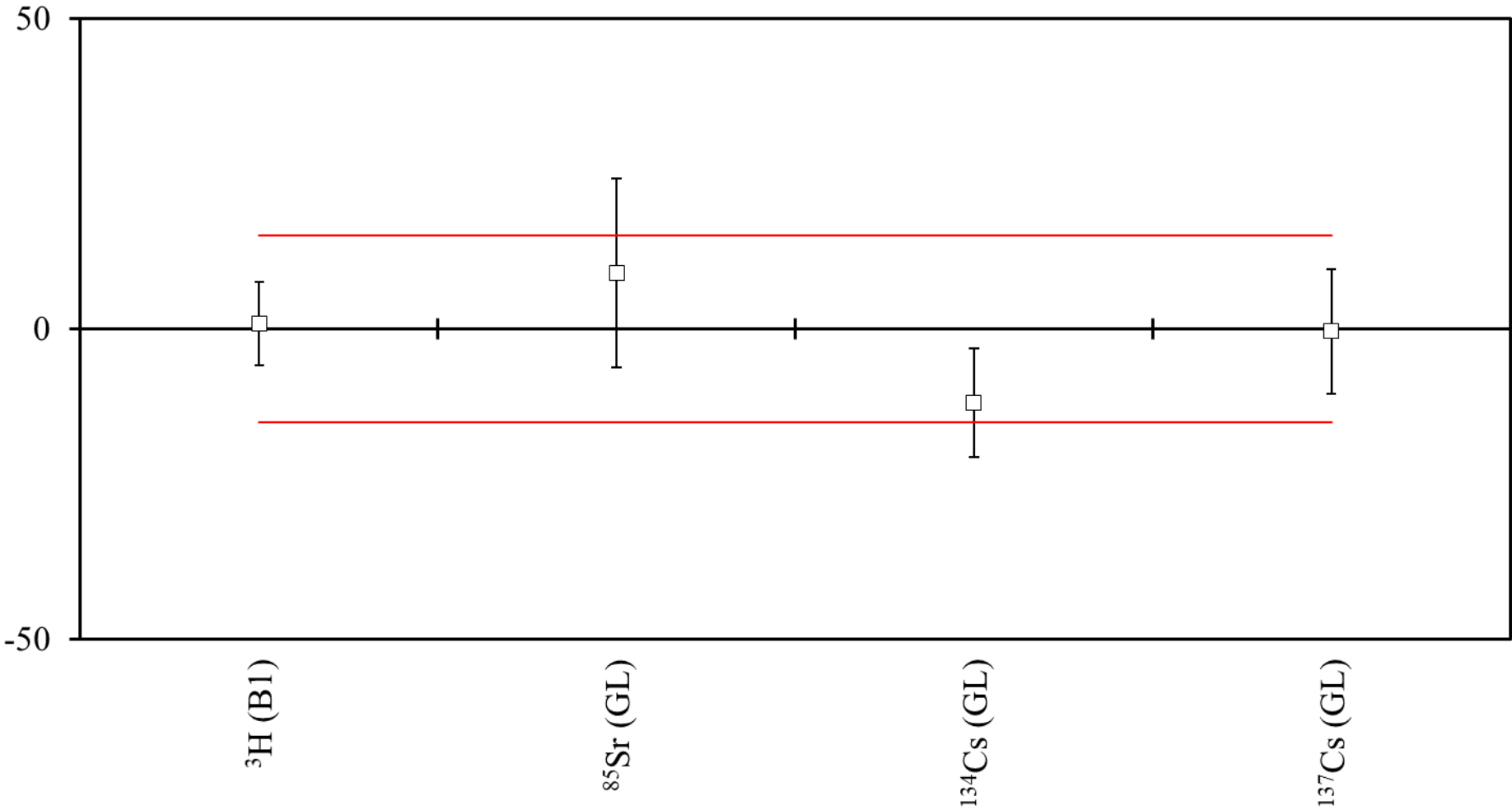
Radionuclide	Laboratory 65	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.20 ± 0.55	10.47 ± 0.13	-2.6	-0.48	-0.44
^{90}Sr (AB)	7.70 ± 0.45	8.291 ± 0.021	-7.1	-1.31	-1.22
^{244}Cm (AB)	7.50 ± 0.96	8.788 ± 0.029	-14.7	-1.34	-2.52
^3H (B1)	1.310 ± 0.080	1.336 ± 0.017	-1.9	-0.32	-0.33
^{14}C (B1)	0.560 ± 0.035	0.4212 ± 0.0019	33.0	3.96	5.66
^{129}I (B1)	0.381 ± 0.024	0.3839 ± 0.0019	-0.8	-0.12	-0.13
^{85}Sr (GL)	7.7 ± 1.0	5.931 ± 0.041	29.8	1.77	5.12
^{134}Cs (GL)	16.9 ± 1.0	17.14 ± 0.12	-1.4	-0.24	-0.24
^{137}Cs (GL)	6.60 ± 0.40	6.788 ± 0.062	-2.8	-0.46	-0.48
^{210}Pb (GL)	4.90 ± 0.40	6.300 ± 0.067	-22.2	-3.45	-3.82

Deviation (%) of Laboratory 67



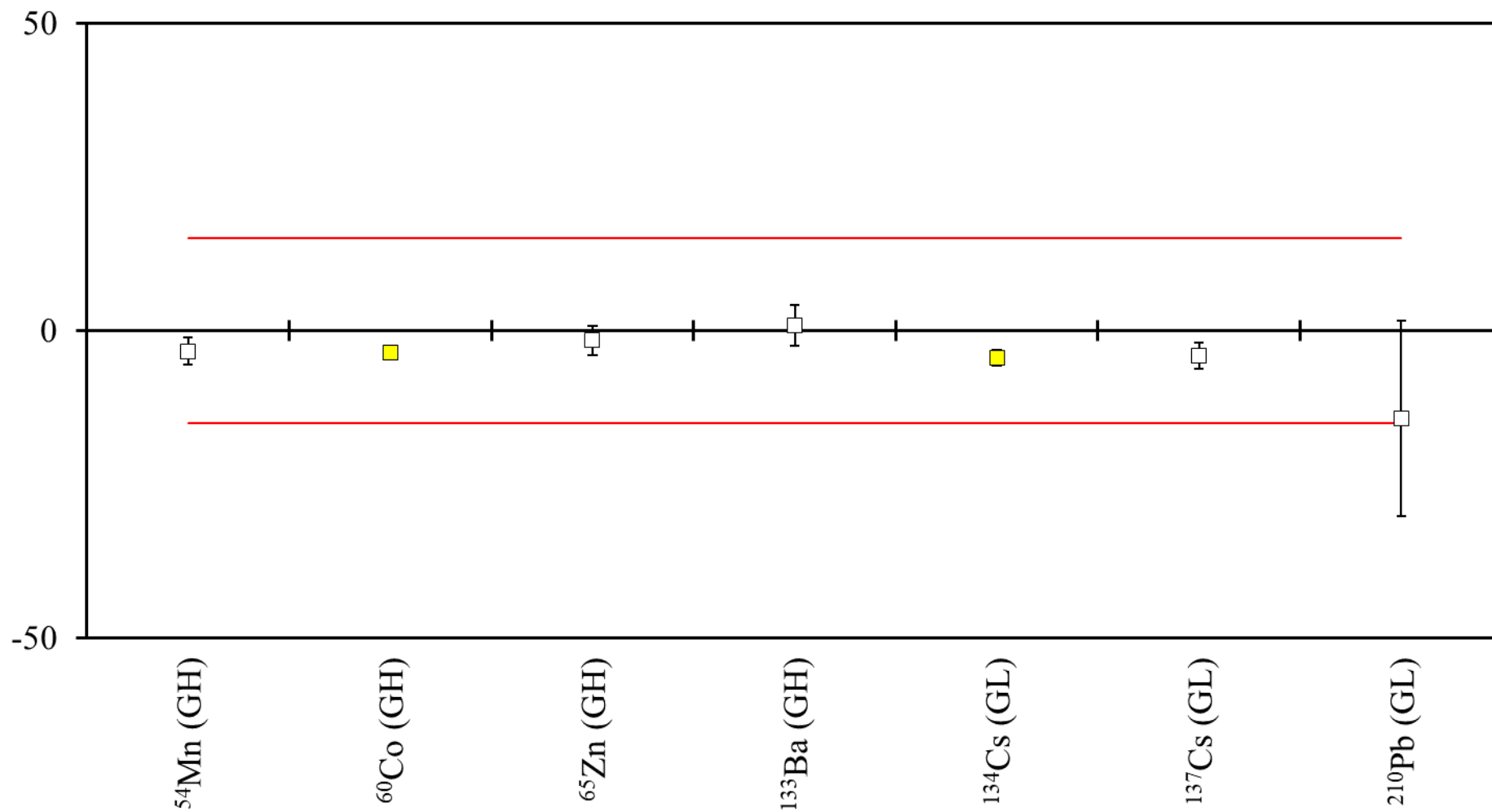
Radionuclide	Laboratory 67	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	19.15 ± 0.33	19.062 ± 0.081	0.5	0.26	0.08
⁶⁰ Co (GH)	7.19 ± 0.12	7.399 ± 0.020	-2.8	-1.72	-0.49
⁶⁵ Zn (GH)	2.425 ± 0.069	2.353 ± 0.017	3.1	1.01	0.53
¹³³ Ba (GH)	17.70 ± 0.32	19.70 ± 0.13	-10.2	-5.79	-1.74

Deviation (%) of Laboratory 72



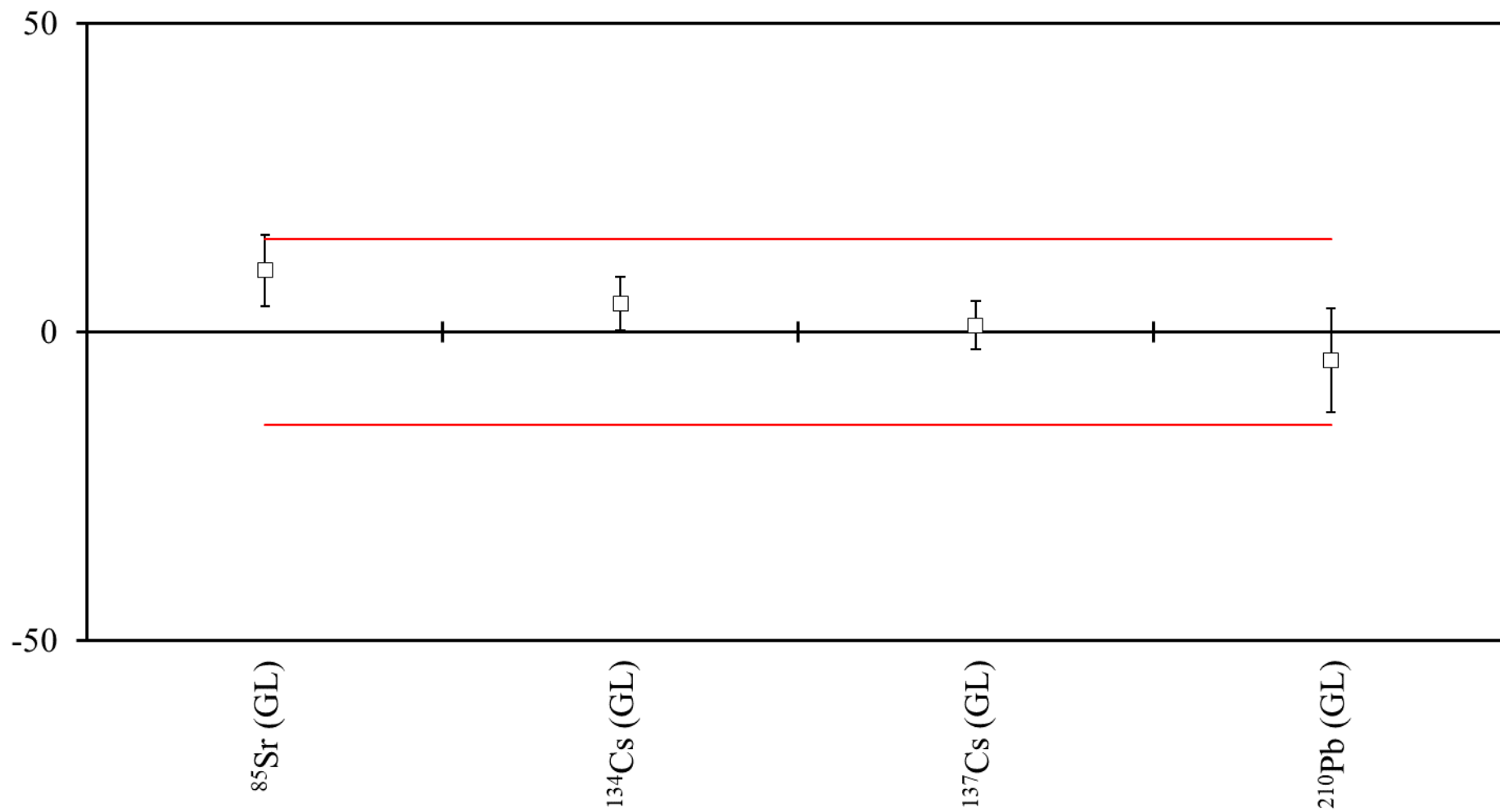
Radionuclide	Laboratory 72	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (B1)	1.346 ± 0.088	1.336 ± 0.017	0.7	0.11	0.13
^{85}Sr (GL)	6.46 ± 0.90	5.931 ± 0.041	8.9	0.59	1.53
^{134}Cs (GL)	15.1 ± 1.5	17.14 ± 0.12	-11.9	-1.36	-2.04
^{137}Cs (GL)	6.76 ± 0.68	6.788 ± 0.062	-0.4	-0.04	-0.07

Deviation (%) of Laboratory 76



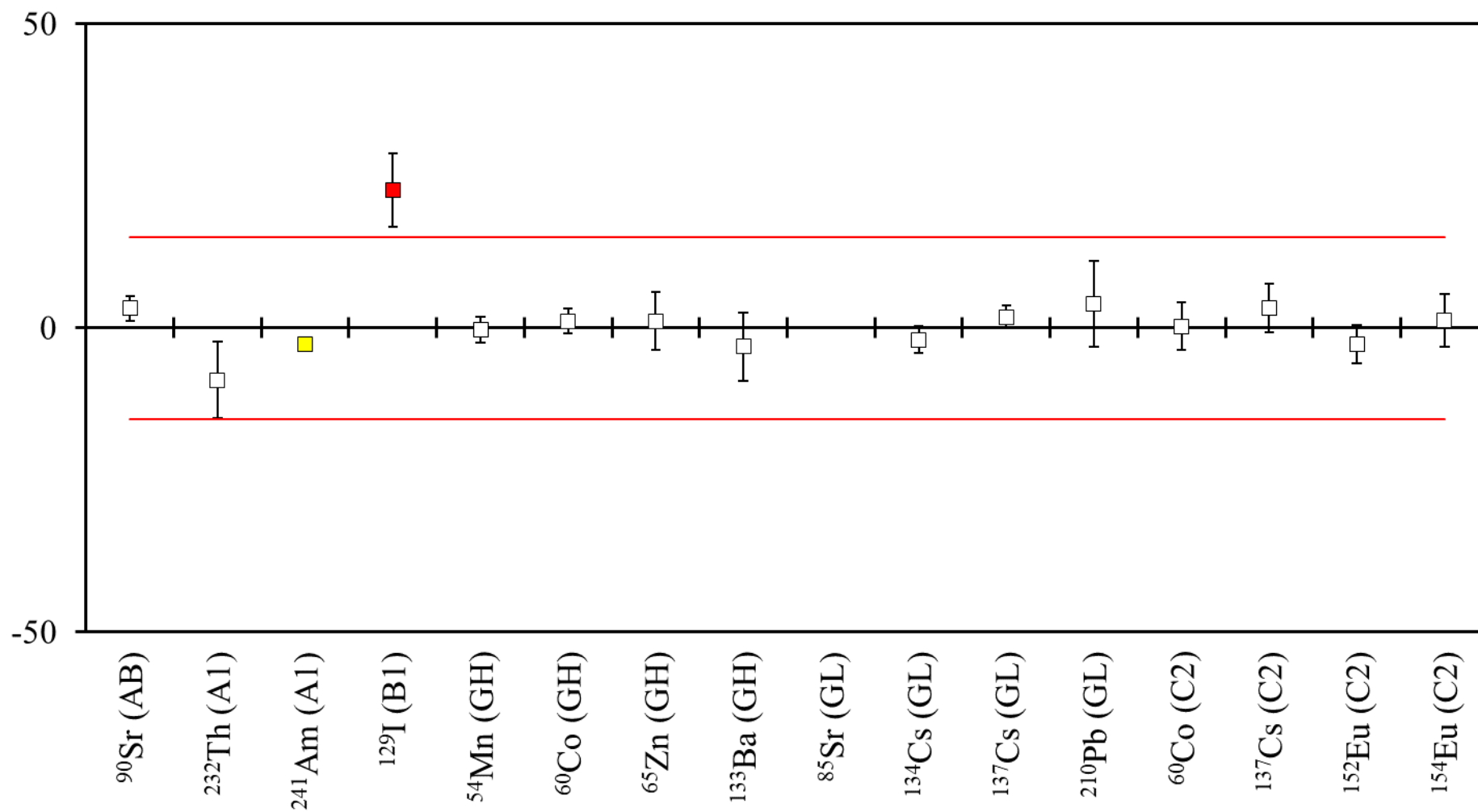
Radionuclide	Laboratory 76	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	18.42 ± 0.42	19.062 ± 0.081	-3.4	-1.50	-0.58
⁶⁰ Co (GH)	7.129 ± 0.042	7.399 ± 0.020	-3.6	-5.80	-0.63
⁶⁵ Zn (GH)	2.316 ± 0.054	2.353 ± 0.017	-1.6	-0.65	-0.27
¹³³ Ba (GH)	19.87 ± 0.64	19.70 ± 0.13	0.9	0.26	0.15
¹³⁴ Cs (GL)	16.37 ± 0.19	17.14 ± 0.12	-4.5	-3.43	-0.77
¹³⁷ Cs (GL)	6.51 ± 0.13	6.788 ± 0.062	-4.1	-1.93	-0.70
²¹⁰ Pb (GL)	5.4 ± 1.0	6.300 ± 0.067	-14.3	-0.90	-2.45

Deviation (%) of Laboratory 83



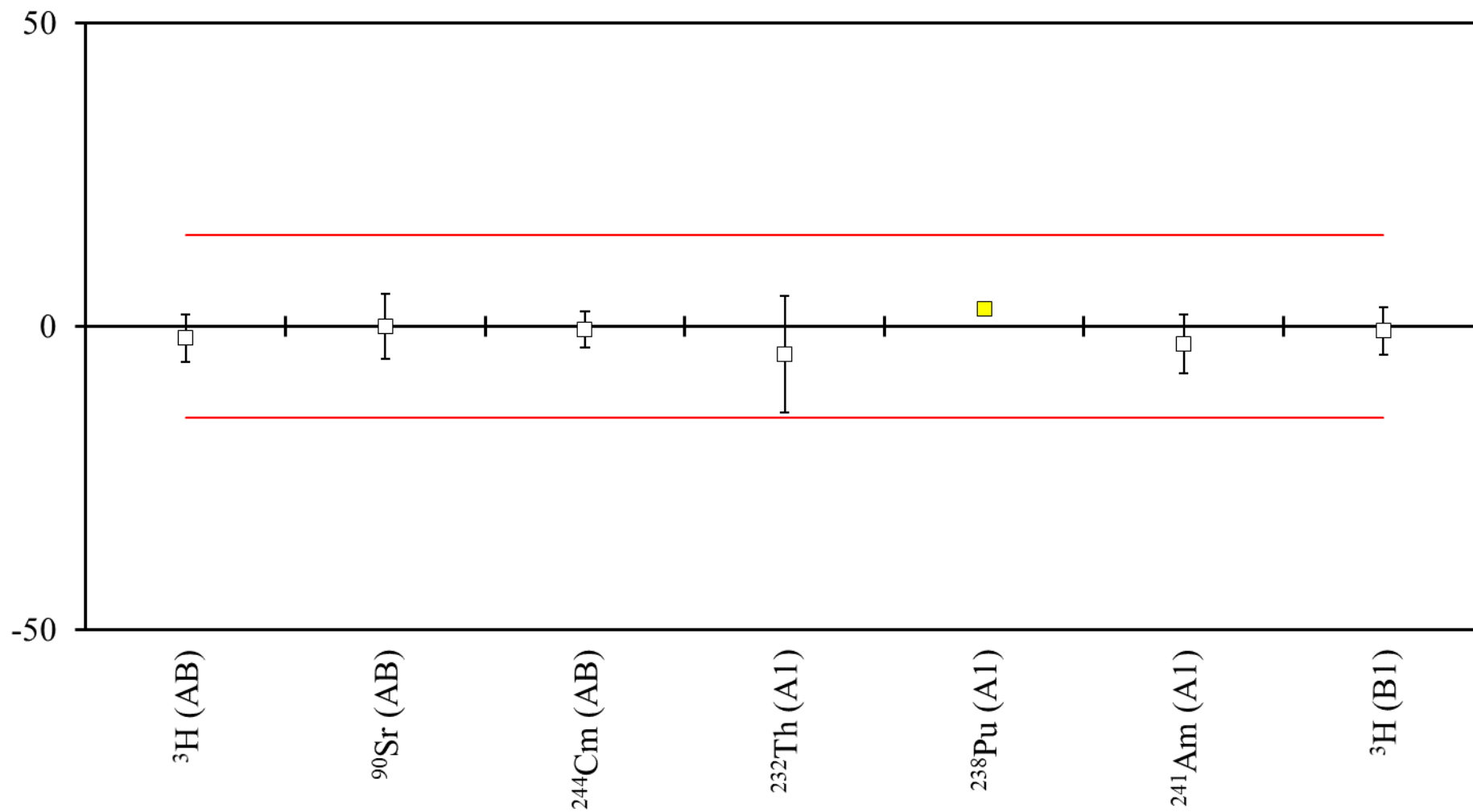
Radionuclide	Laboratory 83	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁸⁵ Sr (GL)	6.52 ± 0.34	5.931 ± 0.041	9.9	1.72	1.71
¹³⁴ Cs (GL)	17.92 ± 0.72	17.14 ± 0.12	4.6	1.07	0.78
¹³⁷ Cs (GL)	6.86 ± 0.26	6.788 ± 0.062	1.1	0.27	0.18
²¹⁰ Pb (GL)	6.01 ± 0.53	6.300 ± 0.067	-4.6	-0.54	-0.79

Deviation (%) of Laboratory 86.1



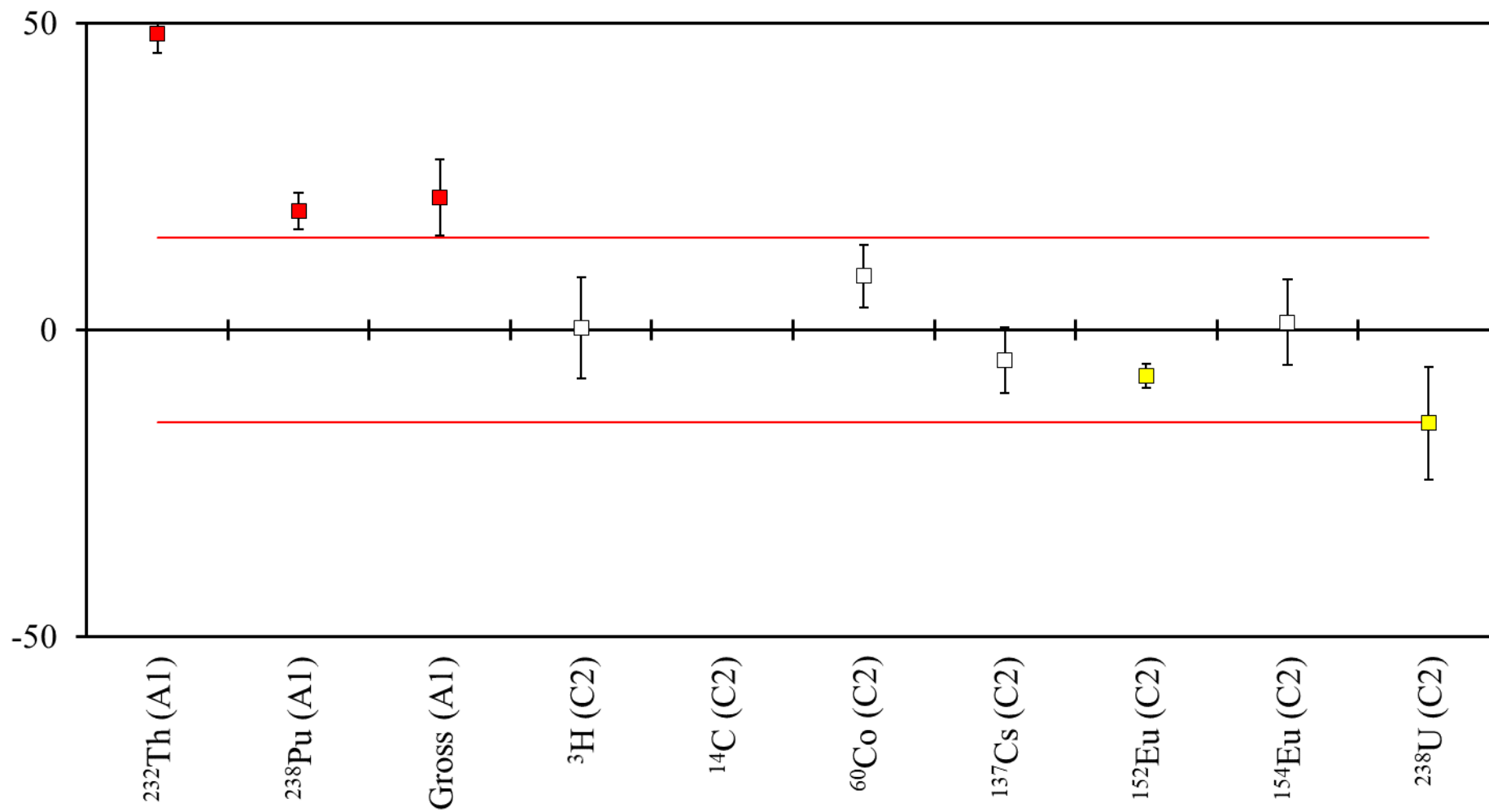
Radionuclide	Laboratory 86.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁹⁰ Sr (AB)	8.56 ± 0.17	8.291 ± 0.021	3.2	1.57	0.56
²³² Th (A1)	2.49 ± 0.17	2.724 ± 0.026	-8.6	-1.36	-1.48
²⁴¹ Am (A1)	7.47 (No reported uncertainty)	7.674 ± 0.017	-2.7	-12.00	-0.46
¹²⁹ I (B1)	0.471 ± 0.023	0.3839 ± 0.0019	22.7	3.77	3.90
⁵⁴ Mn (GH)	19.00 ± 0.39	19.062 ± 0.081	-0.3	-0.16	-0.06
⁶⁰ Co (GH)	7.48 ± 0.15	7.399 ± 0.020	1.1	0.54	0.19
⁶⁵ Zn (GH)	2.38 ± 0.11	2.353 ± 0.017	1.1	0.24	0.20
¹³³ Ba (GH)	19.1 ± 1.1	19.70 ± 0.13	-3.0	-0.54	-0.52
⁸⁵ Sr (GL)	10.30 ± 0.43	5.931 ± 0.041	73.7	10.11	12.65
¹³⁴ Cs (GL)	16.80 ± 0.36	17.14 ± 0.12	-2.0	-0.90	-0.34
¹³⁷ Cs (GL)	6.91 ± 0.11	6.788 ± 0.062	1.8	0.97	0.31
²¹⁰ Pb (GL)	6.55 ± 0.44	6.300 ± 0.067	4.0	0.56	0.68
⁶⁰ Co (C2)	0.0707 ± 0.0025	0.0705 ± 0.0011	0.3	0.07	0.05
¹³⁷ Cs (C2)	0.0583 ± 0.0020	0.05647 ± 0.00096	3.2	0.82	0.56
¹⁵² Eu (C2)	6.99 ± 0.22	7.180 ± 0.048	-2.6	-0.84	-0.45
¹⁵⁴ Eu (C2)	0.1440 ± 0.0052	0.1423 ± 0.0032	1.2	0.28	0.21

Deviation (%) of Laboratory 86.2



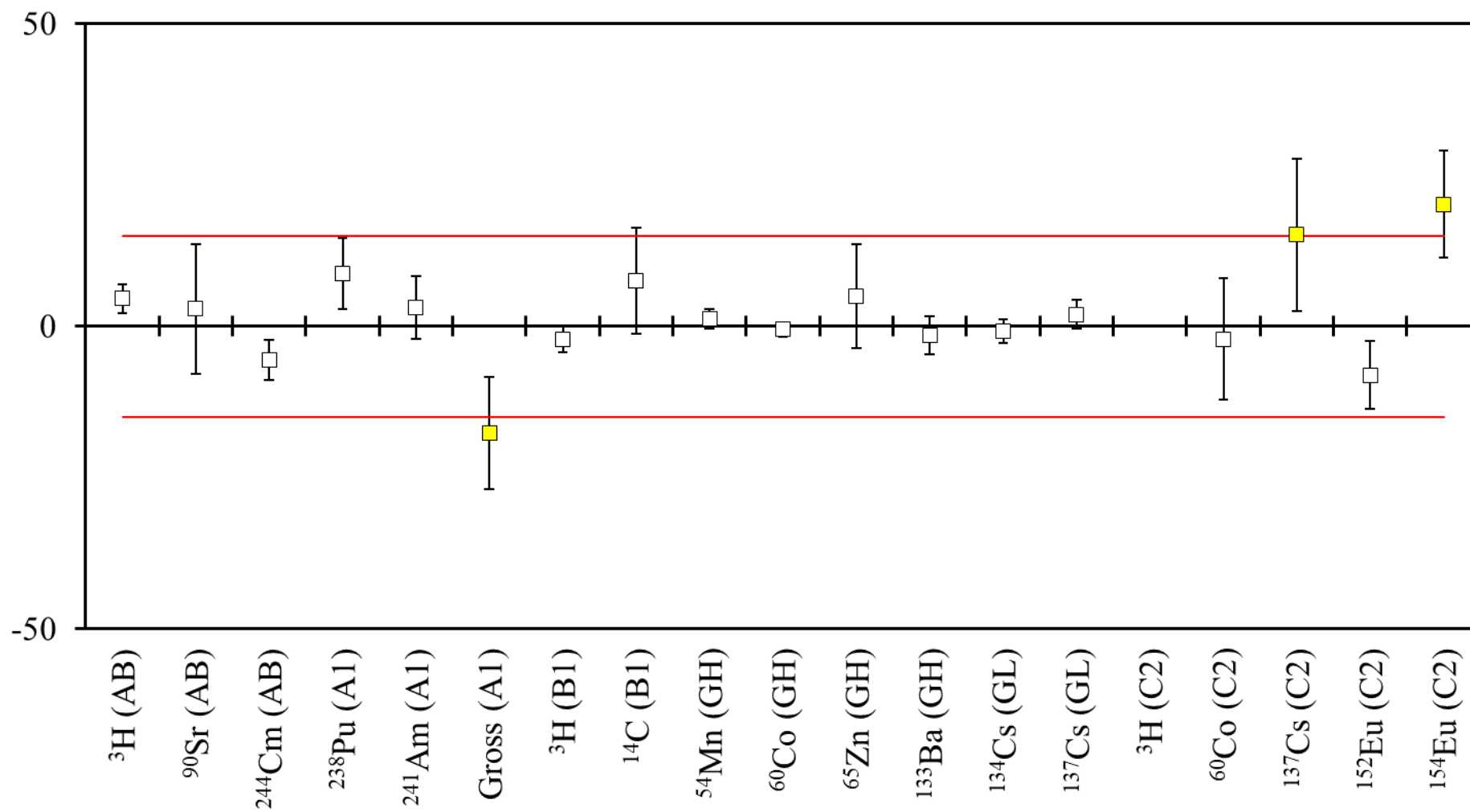
Radionuclide	Laboratory 86.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.27 ± 0.39	10.47 ± 0.13	-1.9	-0.49	-0.33
^{90}Sr (AB)	8.29 ± 0.44	8.291 ± 0.021	0.0	0.00	0.00
^{244}Cm (AB)	8.74 ± 0.26	8.788 ± 0.029	-0.5	-0.18	-0.09
^{232}Th (A1)	2.60 ± 0.26	2.724 ± 0.026	-4.6	-0.47	-0.78
^{238}Pu (A1)	10.600 ± 0.050	10.306 ± 0.025	2.9	5.26	0.49
^{241}Am (A1)	7.45 ± 0.37	7.674 ± 0.017	-2.9	-0.60	-0.50
^3H (B1)	1.326 ± 0.049	1.336 ± 0.017	-0.7	-0.19	-0.13

Deviation (%) of Laboratory 90



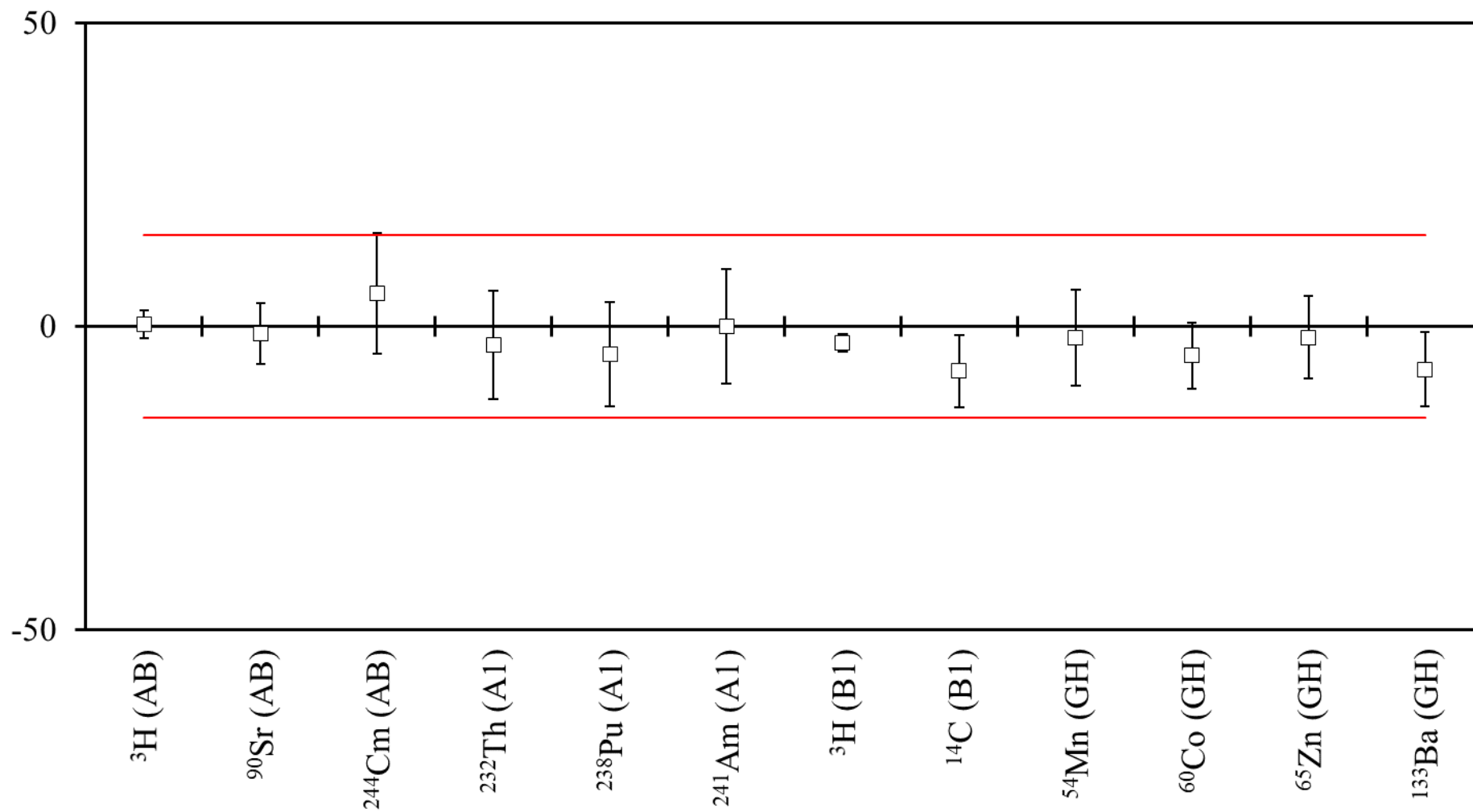
Radionuclide	Laboratory 90	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³² Th (A1)	4.040 ± 0.080	2.724 ± 0.026	48.3	15.64	8.30
²³⁸ Pu (A1)	12.3 ± 0.3	10.306 ± 0.025	19.3	6.62	3.32
Gross alpha (A1)	38.54 ± 0.96	31.7 ± 1.4	21.6	4.03	3.71
³ H (C2)	29.1 ± 1.3	29.0 ± 2.0	0.3	0.04	0.06
¹⁴ C (C2)	0.520 ± 0.055	0.225 ± 0.014	131.1	5.20	22.52
⁶⁰ Co (C2)	0.0767 ± 0.0034	0.0705 ± 0.0011	8.8	1.73	1.51
¹³⁷ Cs (C2)	0.0537 ± 0.0029	0.05647 ± 0.00096	-4.9	-0.91	-0.84
¹⁵² Eu (C2)	6.64 ± 0.13	7.180 ± 0.048	-7.5	-3.90	-1.29
¹⁵⁴ Eu (C2)	0.1440 ± 0.0094	0.1423 ± 0.0032	1.2	0.17	0.21
²³⁸ U (C2)	0.0099 ± 0.0007	0.01168 ± 0.00097	-15.2	-1.49	-2.62

Deviation (%) of Laboratory 91

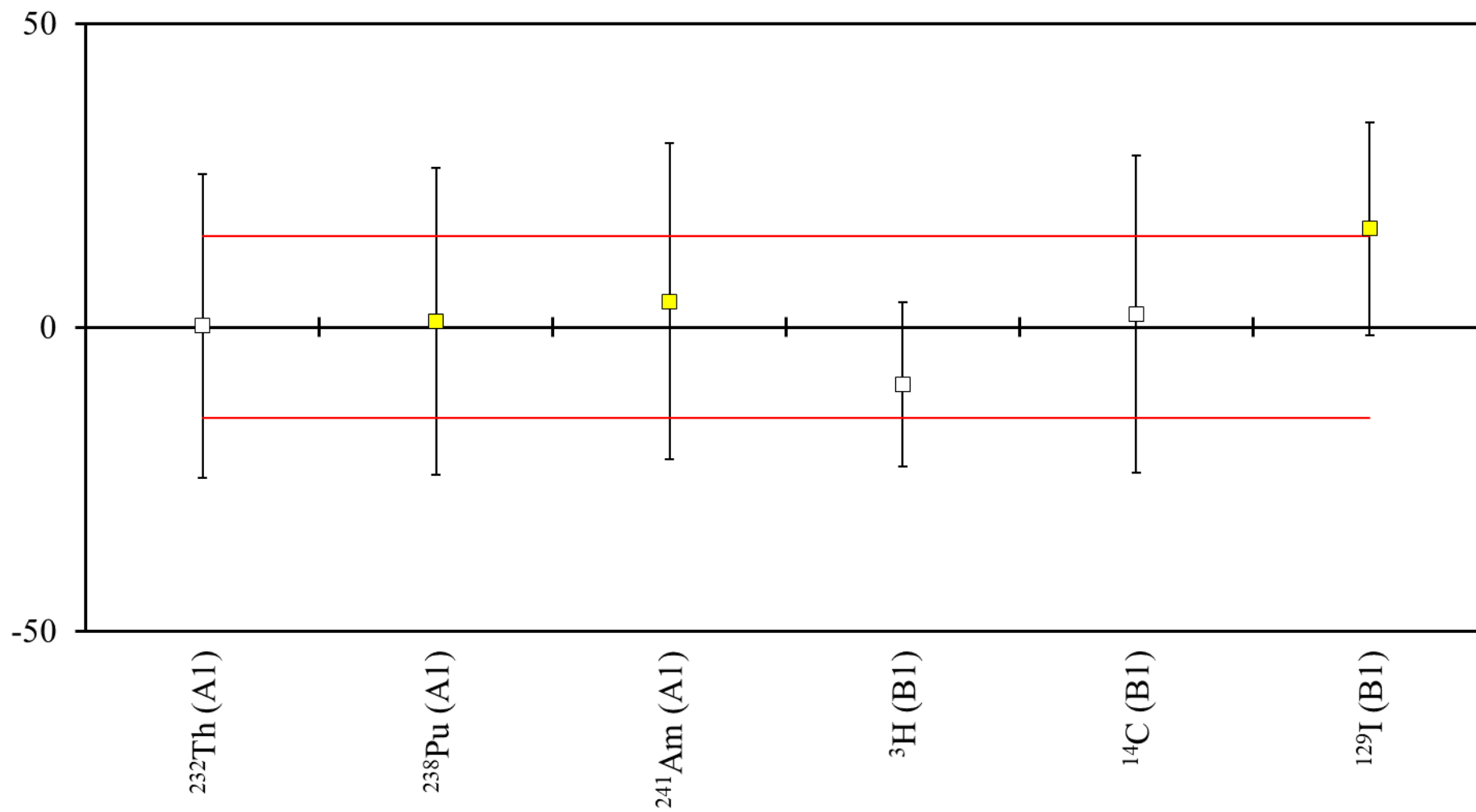


Radionuclide	Laboratory 91	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.95 ± 0.21	10.47 ± 0.13	4.6	1.94	0.79
^{90}Sr (AB)	8.53 ± 0.89	8.291 ± 0.021	2.9	0.27	0.50
^{244}Cm (AB)	8.30 ± 0.29	8.788 ± 0.029	-5.6	-1.67	-0.95
^{238}Pu (A1)	11.2 ± 0.6	10.306 ± 0.025	8.7	1.49	1.49
^{241}Am (A1)	7.91 ± 0.40	7.674 ± 0.017	3.1	0.59	0.53
Gross alpha (A1)	26.1 ± 2.7	31.7 ± 1.4	-17.7	-1.84	-3.03
^3H (B1)	1.308 ± 0.025	1.336 ± 0.017	-2.1	-0.93	-0.36
^{14}C (B1)	0.453 ± 0.037	0.4212 ± 0.0019	7.5	0.86	1.30
^{54}Mn (GH)	19.3 ± 0.3	19.062 ± 0.081	1.2	0.77	0.21
^{60}Co (GH)	7.36 ± 0.09	7.399 ± 0.020	-0.5	-0.42	-0.09
^{65}Zn (GH)	2.47 ± 0.20	2.353 ± 0.017	5.0	0.58	0.85
^{133}Ba (GH)	19.4 ± 0.6	19.70 ± 0.13	-1.5	-0.49	-0.26
^{134}Cs (GL)	17.0 ± 0.3	17.14 ± 0.12	-0.8	-0.43	-0.14
^{137}Cs (GL)	6.92 ± 0.15	6.788 ± 0.062	1.9	0.81	0.33
^3H (C2)	0.570 ± 0.050	29.0 ± 2.0	-98.0	-14.21	-16.84
^{60}Co (C2)	0.0690 ± 0.0070	0.0705 ± 0.0011	-2.1	-0.21	-0.37
^{137}Cs (C2)	0.0650 ± 0.0070	0.05647 ± 0.00096	15.1	1.21	2.59
^{152}Eu (C2)	6.60 ± 0.40	7.180 ± 0.048	-8.1	-1.44	-1.39
^{154}Eu (C2)	0.171 ± 0.012	0.1423 ± 0.0032	20.2	2.31	3.46

Deviation (%) of Laboratory 106

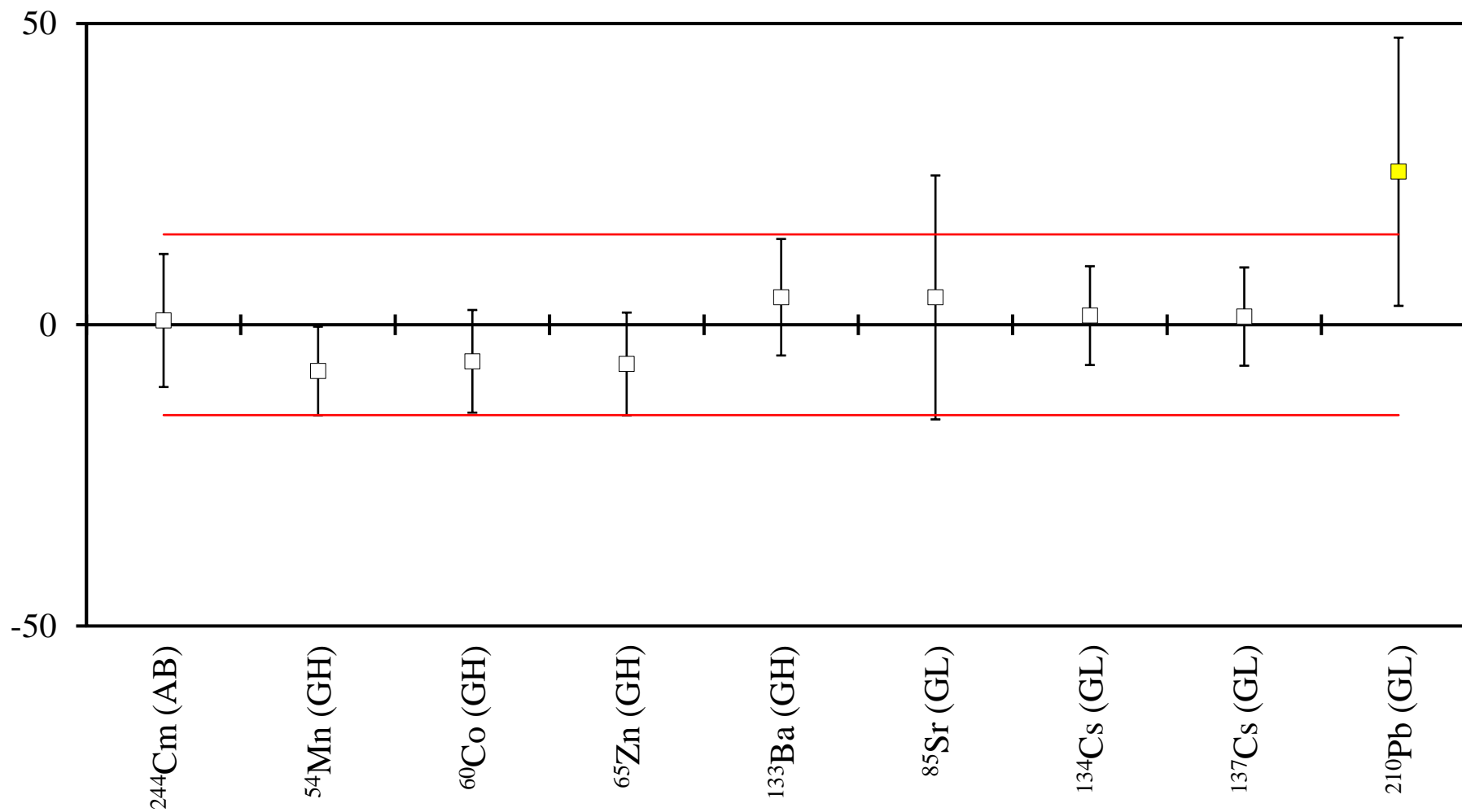


Radionuclide	Laboratory 106	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.50 ± 0.20	10.47 ± 0.13	0.3	0.13	0.05
^{90}Sr (AB)	8.19 ± 0.41	8.291 ± 0.021	-1.2	-0.25	-0.21
^{244}Cm (AB)	9.26 ± 0.87	8.788 ± 0.029	5.4	0.54	0.92
^{232}Th (A1)	2.64 ± 0.24	2.724 ± 0.026	-3.1	-0.35	-0.53
^{238}Pu (A1)	9.83 ± 0.88	10.306 ± 0.025	-4.6	-0.54	-0.79
^{241}Am (A1)	7.67 ± 0.72	7.674 ± 0.017	-0.1	-0.01	-0.01
^3H (B1)	1.300 ± 0.010	1.336 ± 0.017	-2.7	-1.83	-0.46
^{14}C (B1)	0.390 ± 0.025	0.4212 ± 0.0019	-7.4	-1.24	-1.27
^{54}Mn (GH)	18.7 ± 1.5	19.062 ± 0.081	-1.9	-0.24	-0.33
^{60}Co (GH)	7.04 ± 0.40	7.399 ± 0.020	-4.9	-0.90	-0.83
^{65}Zn (GH)	2.31 ± 0.16	2.353 ± 0.017	-1.8	-0.27	-0.31
^{133}Ba (GH)	18.3 ± 1.2	19.70 ± 0.13	-7.1	-1.16	-1.22

Deviation (%) of Laboratory 109.1

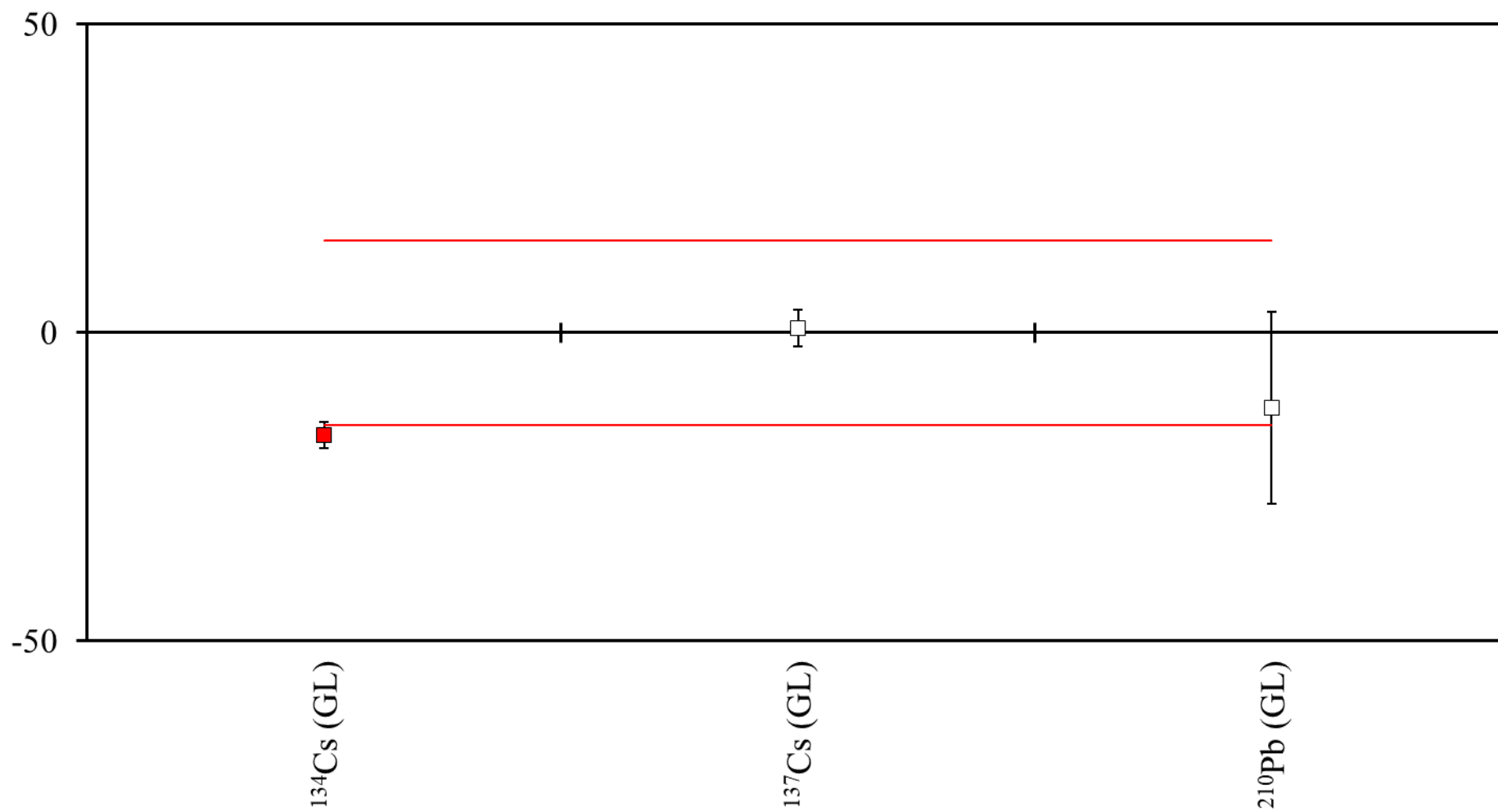
Radionuclide	Laboratory 109.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³² Th (A1)	2.73 ± 0.68	2.724 ± 0.026	0.2	0.01	0.04
²³⁸ Pu (A1)	10.4 ± 2.6	10.306 ± 0.025	0.9	0.04	0.16
²⁴¹ Am (A1)	8.0 ± 2.0	7.674 ± 0.017	4.2	0.16	0.73
³ H (B1)	1.21 ± 0.18	1.336 ± 0.017	-9.4	-0.70	-1.62
¹⁴ C (B1)	0.43 ± 0.11	0.4212 ± 0.0019	2.1	0.08	0.36
¹²⁹ I (B1)	0.446 ± 0.067	0.3839 ± 0.0019	16.2	0.93	2.78
Gross beta (B1)	0.80 ± 0.12	-	-	-	-

Deviation (%) of Laboratory 109.2



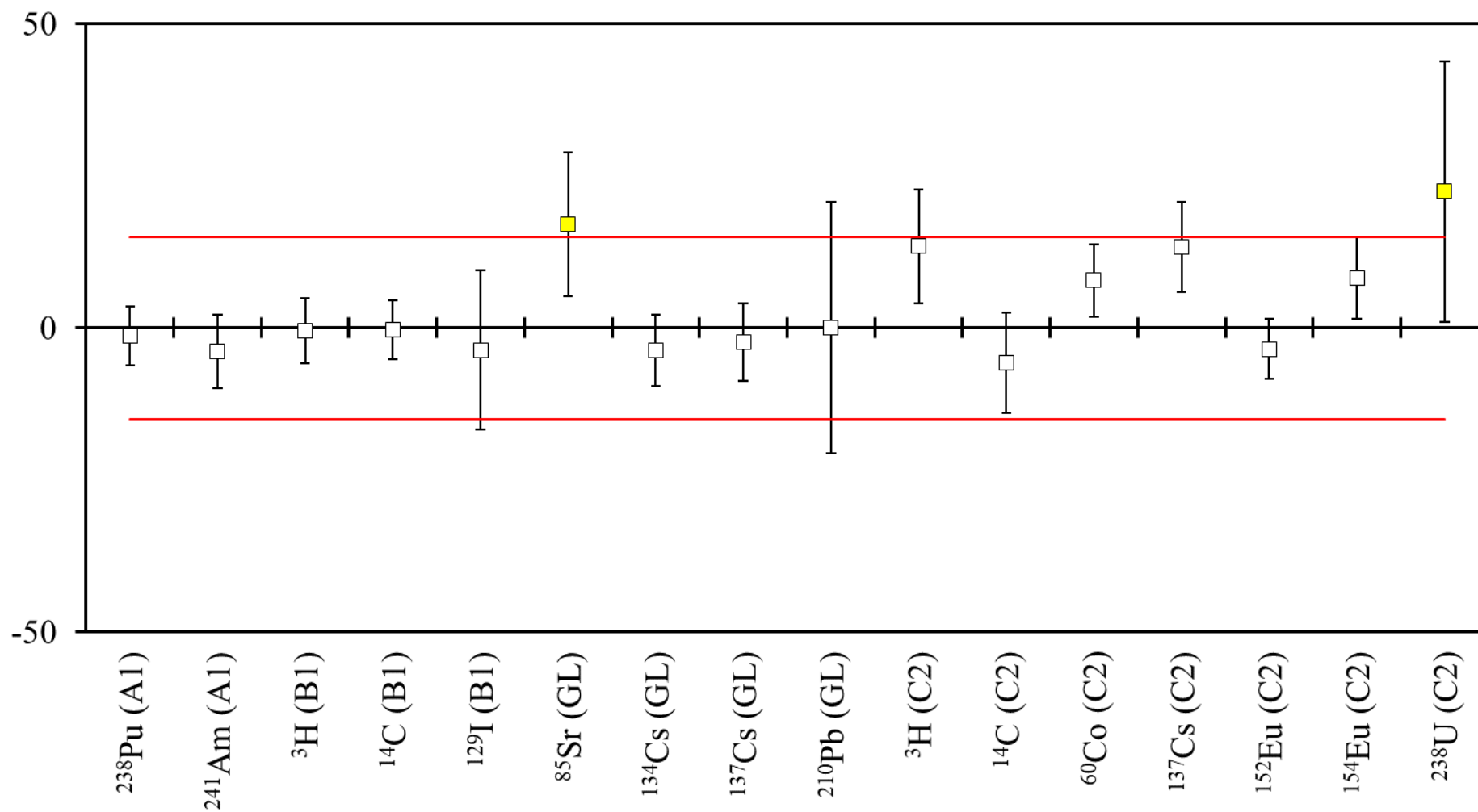
Radionuclide	Laboratory 109.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
²⁴⁴ Cm (AB)	8.85 ± 0.97	8.788 ± 0.029	0.7	0.06	0.12
⁵⁴ Mn (GH)	17.6 ± 1.4	19.062 ± 0.081	-7.7	-1.04	-1.32
⁶⁰ Co (GH)	6.95 ± 0.63	7.399 ± 0.020	-6.1	-0.71	-1.04
⁶⁵ Zn (GH)	2.20 ± 0.20	2.353 ± 0.017	-6.5	-0.76	-1.12
¹³³ Ba (GH)	20.6 ± 1.9	19.70 ± 0.13	4.6	0.47	0.78
⁸⁵ Sr (GL)	6.2 ± 1.2	5.931 ± 0.041	4.5	0.22	0.78
¹³⁴ Cs (GL)	17.4 ± 1.4	17.14 ± 0.12	1.5	0.19	0.26
¹³⁷ Cs (GL)	6.88 ± 0.55	6.788 ± 0.062	1.4	0.17	0.23
²¹⁰ Pb (GL)	7.9 ± 1.4	6.300 ± 0.067	25.4	1.14	4.36

Deviation (%) of Laboratory 111



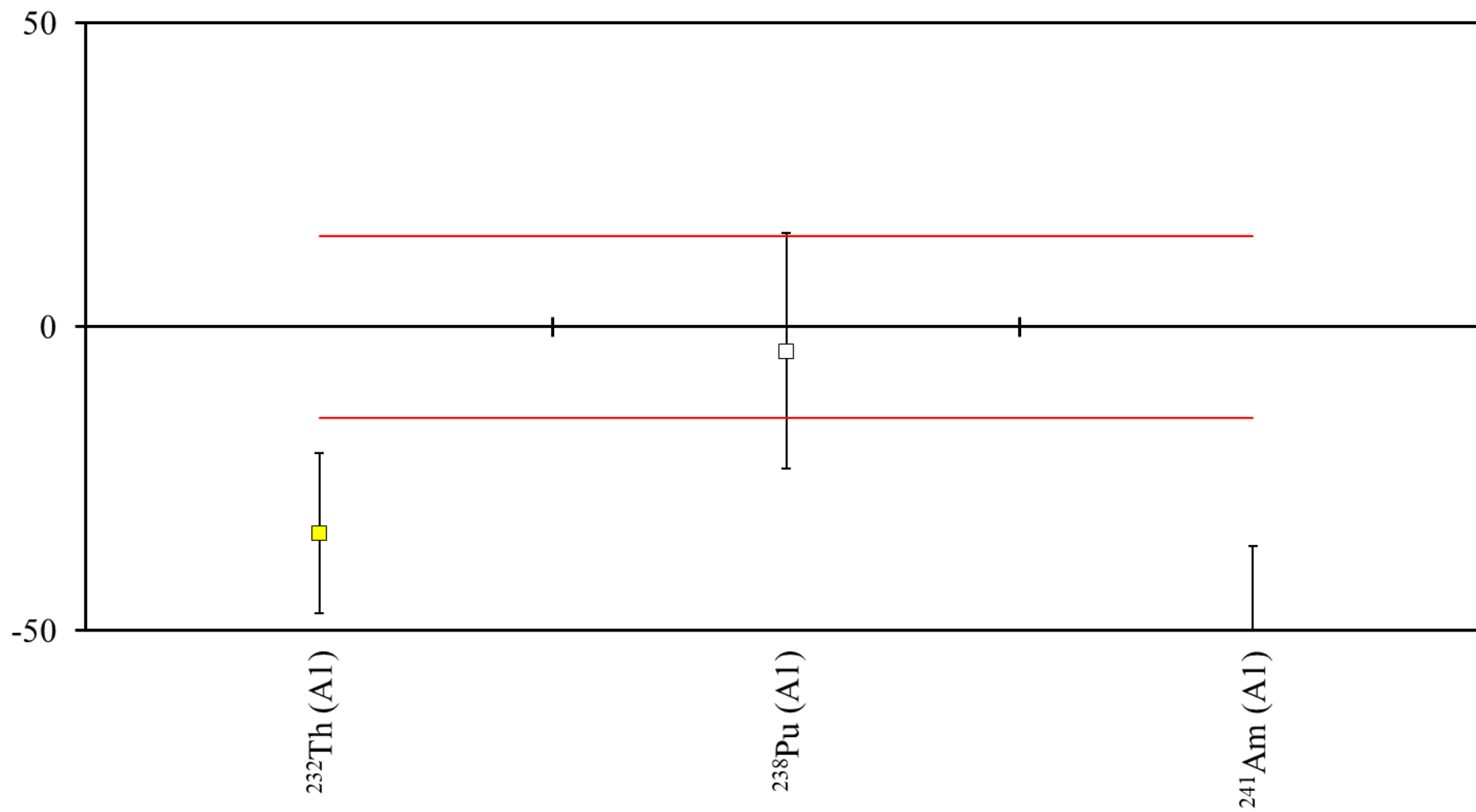
Radionuclide	Laboratory 111	NPL Assigned Value	Deviation /%	Zeta	Z Score
¹³⁴ Cs (GL)	14.30 ± 0.35	17.14 ± 0.12	-16.6	-7.68	-2.85
¹³⁷ Cs (GL)	6.84 ± 0.19	6.788 ± 0.062	0.8	0.26	0.13
²¹⁰ Pb (GL)	5.53 ± 0.98	6.300 ± 0.067	-12.2	-0.78	-2.10

Deviation (%) of Laboratory 120



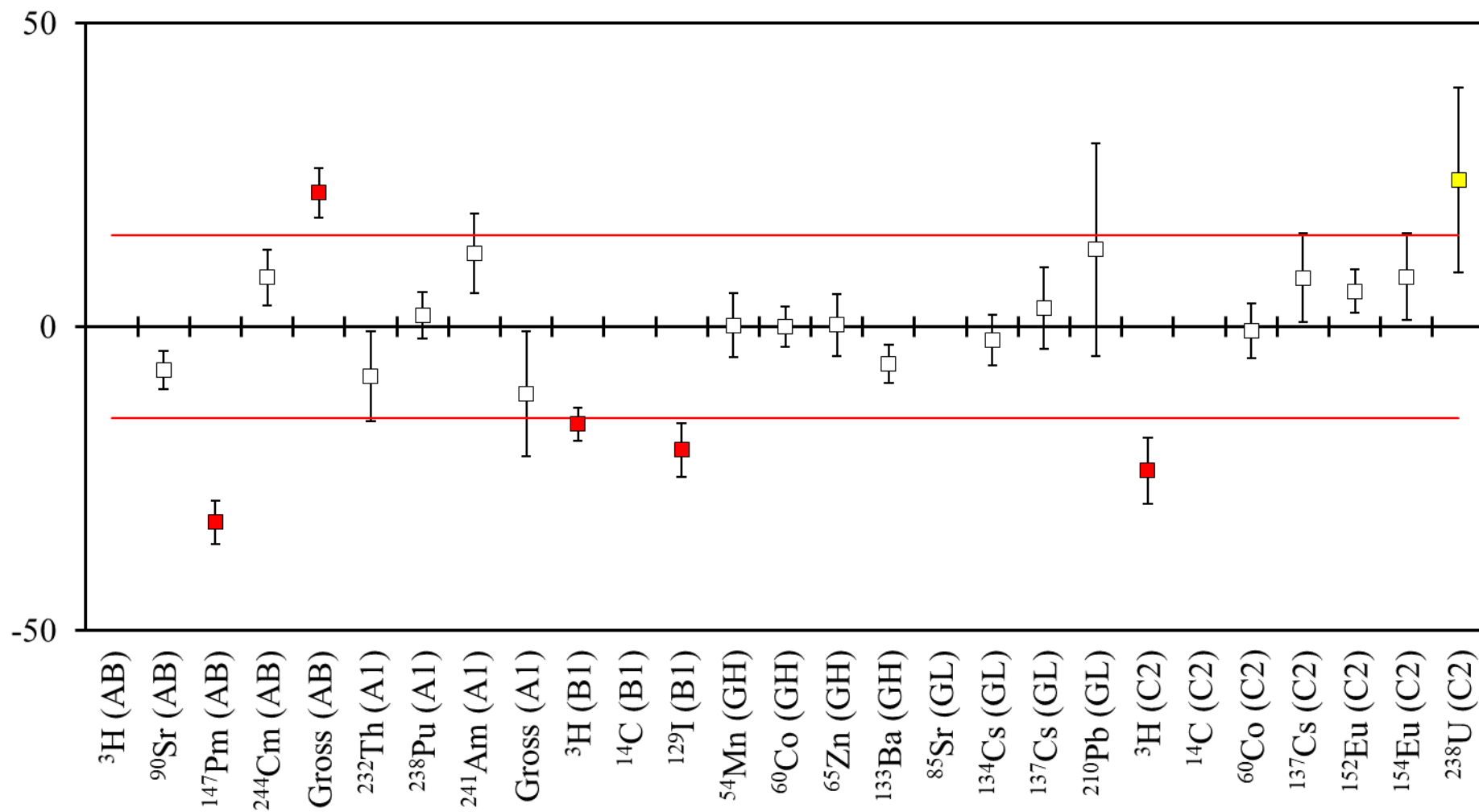
Radionuclide	Laboratory 120	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³⁸ Pu (A1)	10.17 ± 0.50	10.306 ± 0.025	-1.3	-0.27	-0.23
²⁴¹ Am (A1)	7.38 ± 0.46	7.674 ± 0.017	-3.8	-0.64	-0.66
³ H (B1)	1.33 ± 0.07	1.336 ± 0.017	-0.4	-0.08	-0.08
¹⁴ C (B1)	0.420 ± 0.020	0.4212 ± 0.0019	-0.3	-0.06	-0.05
¹²⁹ I (B1)	0.370 ± 0.050	0.3839 ± 0.0019	-3.6	-0.28	-0.62
⁸⁵ Sr (GL)	6.94 ± 0.70	5.931 ± 0.041	17.0	1.44	2.92
¹³⁴ Cs (GL)	16.5 ± 1.0	17.14 ± 0.12	-3.7	-0.64	-0.64
¹³⁷ Cs (GL)	6.63 ± 0.43	6.788 ± 0.062	-2.3	-0.36	-0.40
²¹⁰ Pb (GL)	6.3 ± 1.3	6.300 ± 0.067	0.0	0.00	0.00
³ H (C2)	32.9 ± 1.5	29.0 ± 2.0	13.4	1.56	2.31
¹⁴ C (C2)	0.212 ± 0.013	0.225 ± 0.014	-5.8	-0.68	-0.99
⁶⁰ Co (C2)	0.0760 ± 0.0040	0.0705 ± 0.0011	7.8	1.33	1.34
¹³⁷ Cs (C2)	0.0640 ± 0.0040	0.05647 ± 0.00096	13.3	1.83	2.29
¹⁵² Eu (C2)	6.93 ± 0.35	7.180 ± 0.048	-3.5	-0.71	-0.60
¹⁵⁴ Eu (C2)	0.154 ± 0.009	0.1423 ± 0.0032	8.2	1.22	1.41
²³⁸ U (C2)	0.0143 ± 0.0022	0.01168 ± 0.00097	22.4	1.09	3.85

Deviation (%) of Laboratory 129

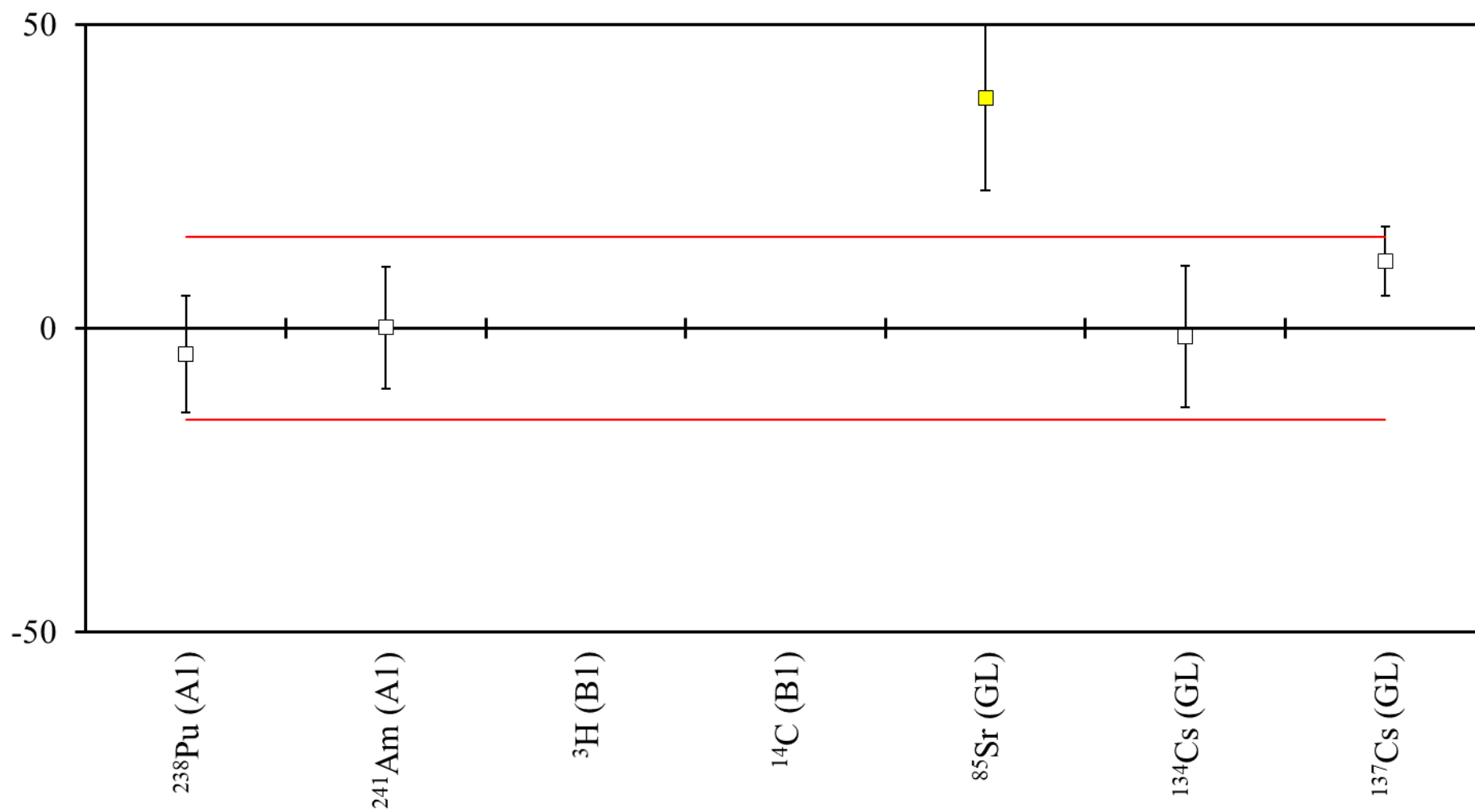


Radionuclide	Laboratory 129	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³² Th (A1)	1.80 ± 0.36	2.724 ± 0.026	-33.9	-2.56	-5.83
²³⁸ Pu (A1)	9.9 ± 2.0	10.306 ± 0.025	-3.9	-0.20	-0.68
²⁴¹ Am (A1)	3.8 ± 1.1	7.674 ± 0.017	-50.5	-3.52	-8.67

Deviation (%) of Laboratory 135

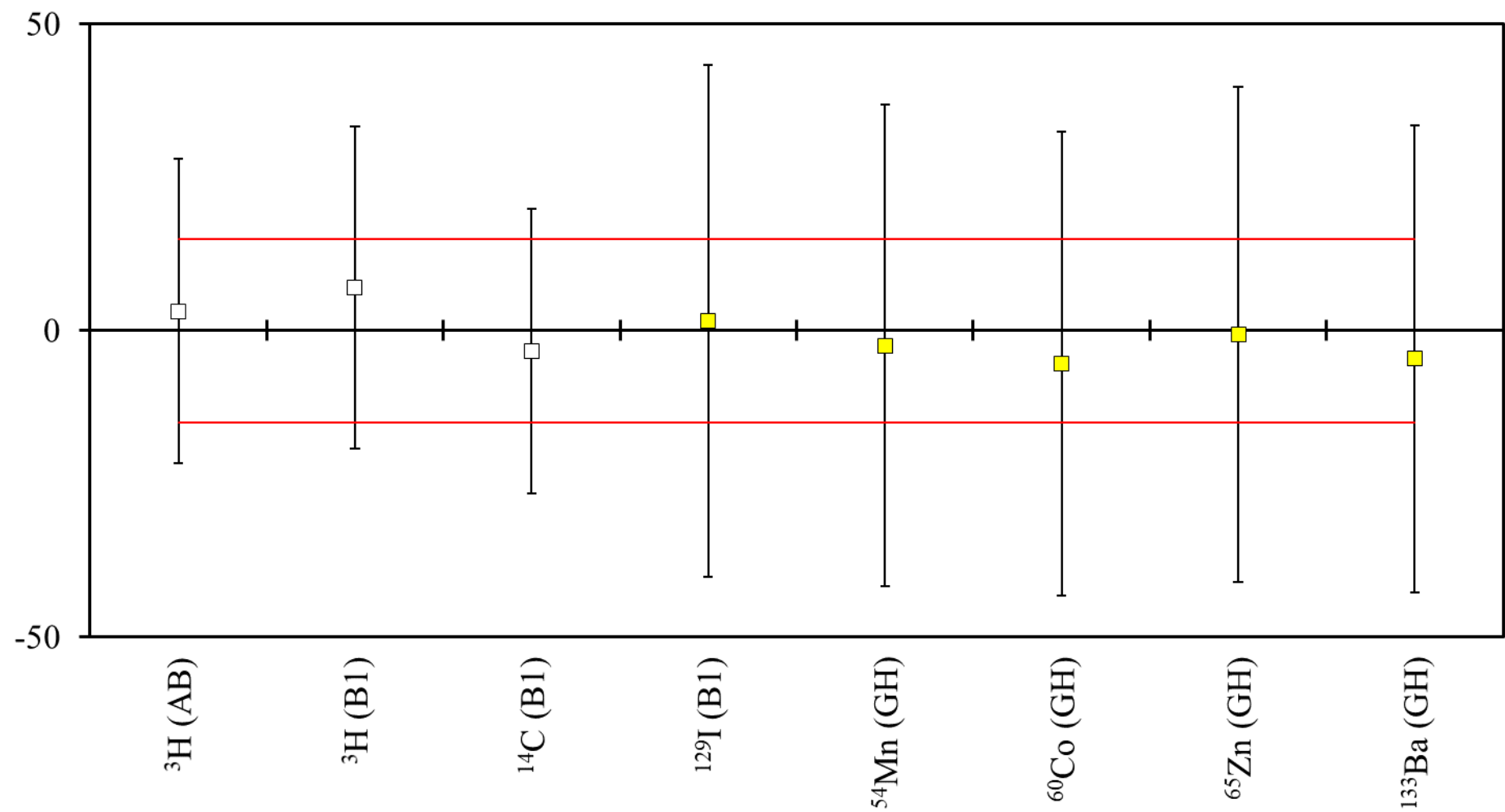


Radionuclide	Laboratory 135	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	0.0990 ± 0.0035	10.47 ± 0.13	-99.1	-79.75	-17.01
⁹⁰ Sr (AB)	7.70 ± 0.26	8.291 ± 0.021	-7.1	-2.27	-1.22
¹⁴⁷ Pm (AB)	12.24 ± 0.63	18.05 ± 0.23	-32.2	-8.66	-5.53
²⁴⁴ Cm (AB)	9.50 ± 0.40	8.788 ± 0.029	8.1	1.78	1.39
Gross beta (AB)	26.90 ± 0.80	22.04 ± 0.35	22.1	5.57	3.79
²³² Th (A1)	2.50 ± 0.20	2.724 ± 0.026	-8.2	-1.11	-1.41
²³⁸ Pu (A1)	10.50 ± 0.40	10.306 ± 0.025	1.9	0.48	0.32
²⁴¹ Am (A1)	8.60 ± 0.50	7.674 ± 0.017	12.1	1.85	2.07
Gross alpha (A1)	28.2 ± 3.0	31.7 ± 1.4	-11.0	-1.06	-1.90
³ H (B1)	1.122 ± 0.034	1.336 ± 0.017	-16.0	-5.63	-2.75
¹⁴ C (B1)	0.792 ± 0.023	0.4212 ± 0.0019	88.0	16.07	15.12
¹²⁹ I (B1)	0.306 ± 0.017	0.3839 ± 0.0019	-20.3	-4.55	-3.48
⁵⁴ Mn (GH)	19.1 ± 1.0	19.062 ± 0.081	0.2	0.04	0.03
⁶⁰ Co (GH)	7.40 ± 0.25	7.399 ± 0.020	0.0	0.00	0.00
⁶⁵ Zn (GH)	2.36 ± 0.12	2.353 ± 0.017	0.3	0.06	0.05
¹³³ Ba (GH)	18.5 ± 0.6	19.70 ± 0.13	-6.1	-1.95	-1.05
⁸⁵ Sr (GL)	12.2 ± 2.0	5.931 ± 0.041	105.7	3.13	18.15
¹³⁴ Cs (GL)	16.770 ± 0.7	17.14 ± 0.12	-2.2	-0.52	-0.37
¹³⁷ Cs (GL)	7.00 ± 0.45	6.788 ± 0.062	3.1	0.47	0.54
²¹⁰ Pb (GL)	7.1 ± 1.1	6.300 ± 0.067	12.7	0.73	2.18
³ H (C2)	22.13 ± 0.40	29.0 ± 2.0	-23.7	-3.37	-4.07
¹⁴ C (C2)	1.590 ± 0.048	0.225 ± 0.014	606.7	27.30	104.18
⁶⁰ Co (C2)	0.0700 ± 0.0030	0.0705 ± 0.0011	-0.7	-0.16	-0.12
¹³⁷ Cs (C2)	0.0610 ± 0.0040	0.05647 ± 0.00096	8.0	1.10	1.38
¹⁵² Eu (C2)	7.60 ± 0.25	7.180 ± 0.048	5.8	1.65	1.00
¹⁵⁴ Eu (C2)	0.1540 ± 0.0095	0.1423 ± 0.0032	8.2	1.17	1.41
²³⁸ U (C2)	0.0145 ± 0.0013	0.01168 ± 0.00097	24.1	1.74	4.15

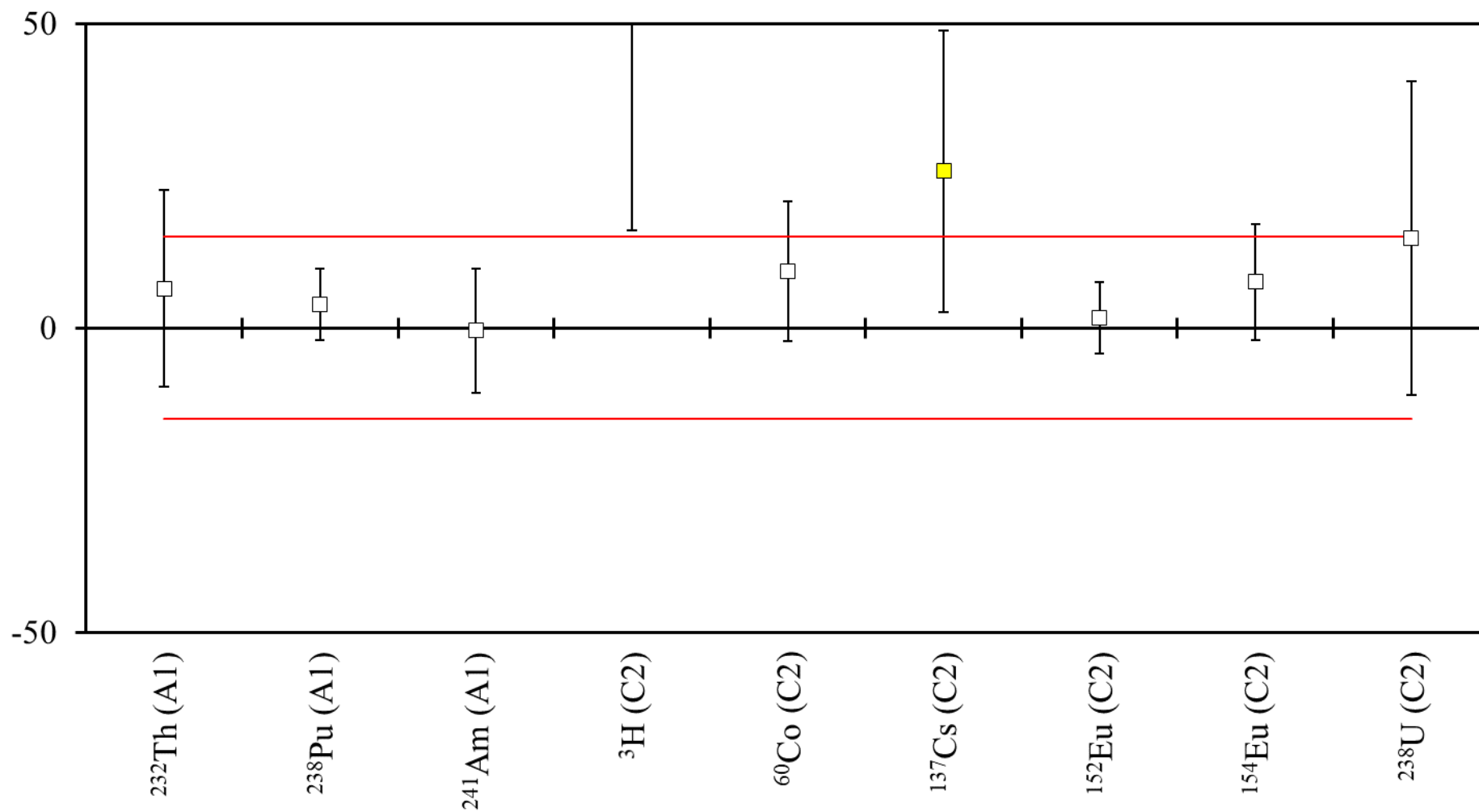
Deviation (%) of Laboratory 136

Radionuclide	Laboratory 136	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³⁸ Pu (A1)	9.86 ± 0.99	10.306 ± 0.025	-4.3	-0.45	-0.74
²⁴¹ Am (A1)	7.68 ± 0.77	7.674 ± 0.017	0.1	0.01	0.01
³ H (B1)	0.39 ± 0.03	1.336 ± 0.017	-70.8	-27.43	-12.16
¹⁴ C (B1)	1.43 ± 0.09	0.4212 ± 0.0019	239.5	11.21	41.13
⁸⁵ Sr (GL)	8.18 ± 0.90	5.931 ± 0.041	37.9	2.50	6.51
¹³⁴ Cs (GL)	16.9 ± 2.0	17.14 ± 0.12	-1.4	-0.12	-0.24
¹³⁷ Cs (GL)	7.54 ± 0.38	6.788 ± 0.062	11.1	1.95	1.90

Deviation (%) of Laboratory 141

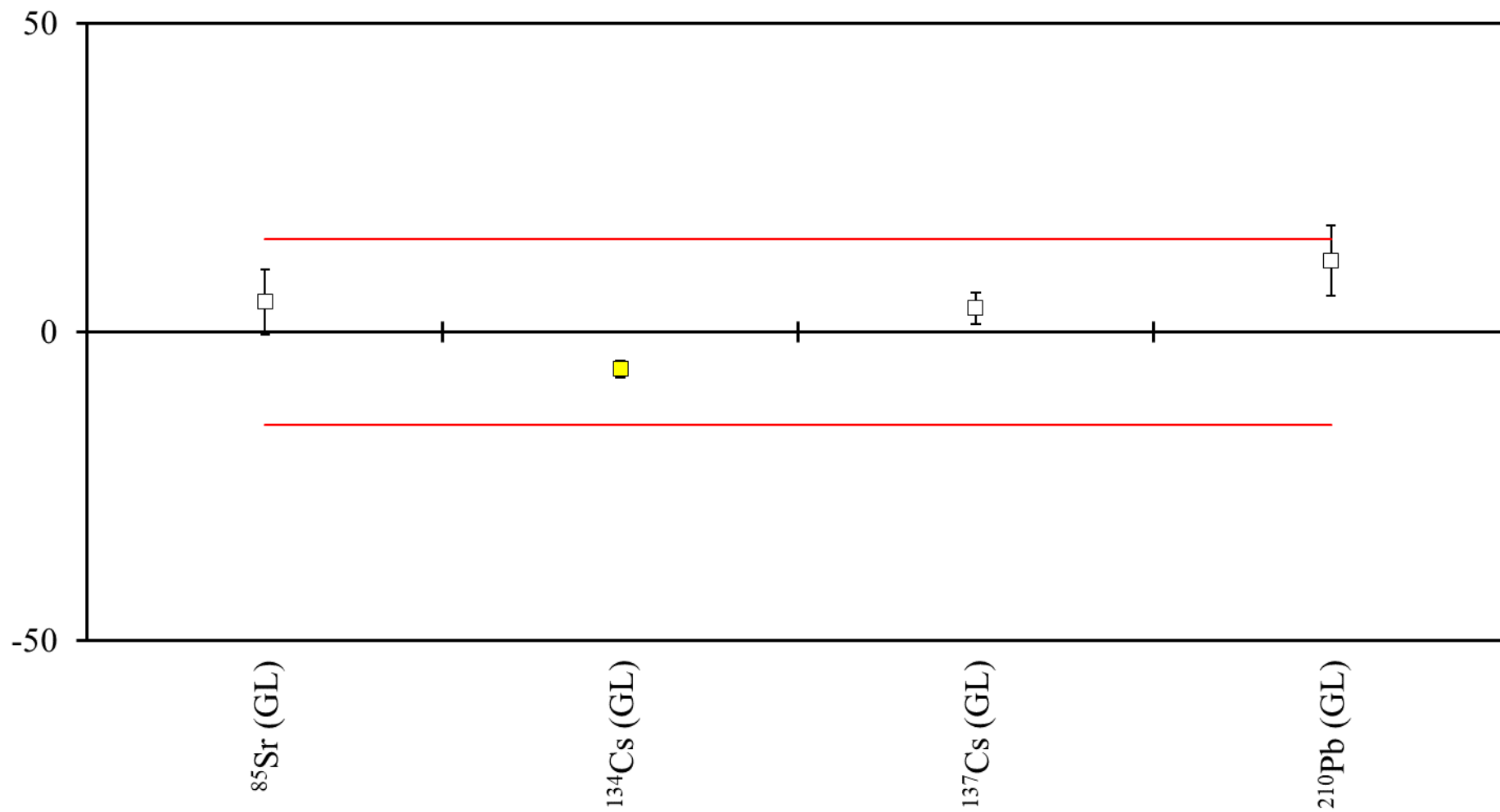


Radionuclide	Laboratory 141	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.8 ± 2.6	10.47 ± 0.13	3.2	0.13	0.54
^3H (B1)	1.43 ± 0.35	1.336 ± 0.017	7.0	0.27	1.21
^{14}C (B1)	0.407 ± 0.098	0.4212 ± 0.0019	-3.4	-0.14	-0.58
^{129}I (B1)	0.39 ± 0.16	0.3839 ± 0.0019	1.6	0.04	0.27
^{54}Mn (GH)	18.6 ± 7.5	19.062 ± 0.081	-2.4	-0.06	-0.42
^{60}Co (GH)	7.0 ± 2.8	7.399 ± 0.020	-5.4	-0.14	-0.93
^{65}Zn (GH)	2.34 ± 0.95	2.353 ± 0.017	-0.6	-0.01	-0.09
^{133}Ba (GH)	18.8 ± 7.5	19.70 ± 0.13	-4.6	-0.12	-0.78

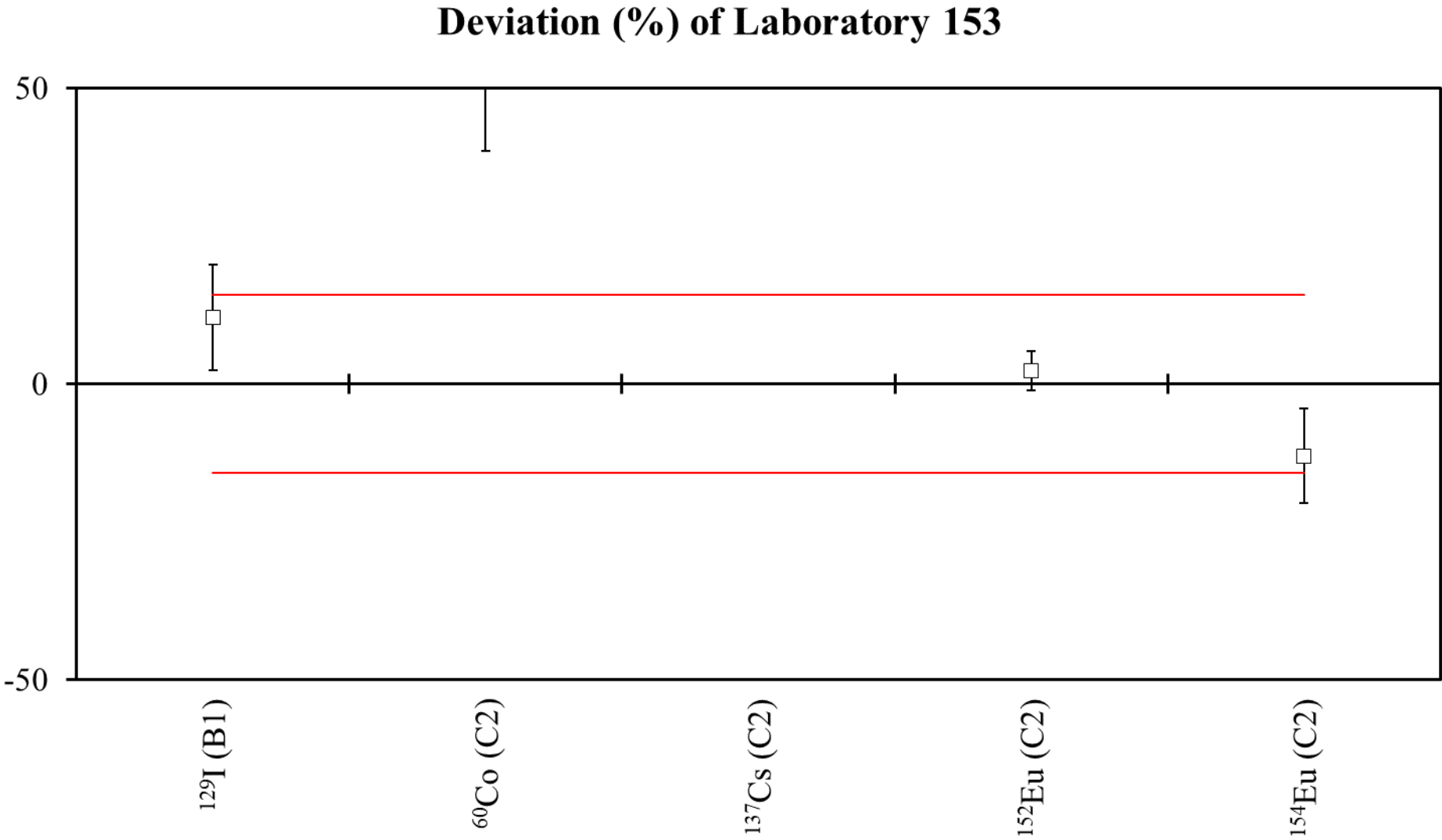
Deviation (%) of Laboratory 147

Radionuclide	Laboratory 147	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³² Th (A1)	2.90 ± 0.44	2.724 ± 0.026	6.5	0.40	1.11
²³⁸ Pu (A1)	10.7 ± 0.6	10.306 ± 0.025	3.8	0.66	0.66
²⁴¹ Am (A1)	7.64 ± 0.78	7.674 ± 0.017	-0.4	-0.04	-0.08
³ H (C2)	49 ± 15	29.0 ± 2.0	69.0	1.32	11.84
⁶⁰ Co (C2)	0.0770 ± 0.0080	0.0705 ± 0.0011	9.2	0.80	1.58
⁹⁰ Sr (C2)	20.6 ± 1.2	-	-	-	-
¹³⁷ Cs (C2)	0.071 ± 0.013	0.05647 ± 0.00096	25.7	1.11	4.42
¹⁵² Eu (C2)	7.30 ± 0.42	7.180 ± 0.048	1.7	0.28	0.29
¹⁵⁴ Eu (C2)	0.153 ± 0.013	0.1423 ± 0.0032	7.5	0.80	1.29
²³⁸ U (C2)	0.0134 ± 0.0028	0.01168 ± 0.00097	14.7	0.58	2.53

Deviation (%) of Laboratory 151

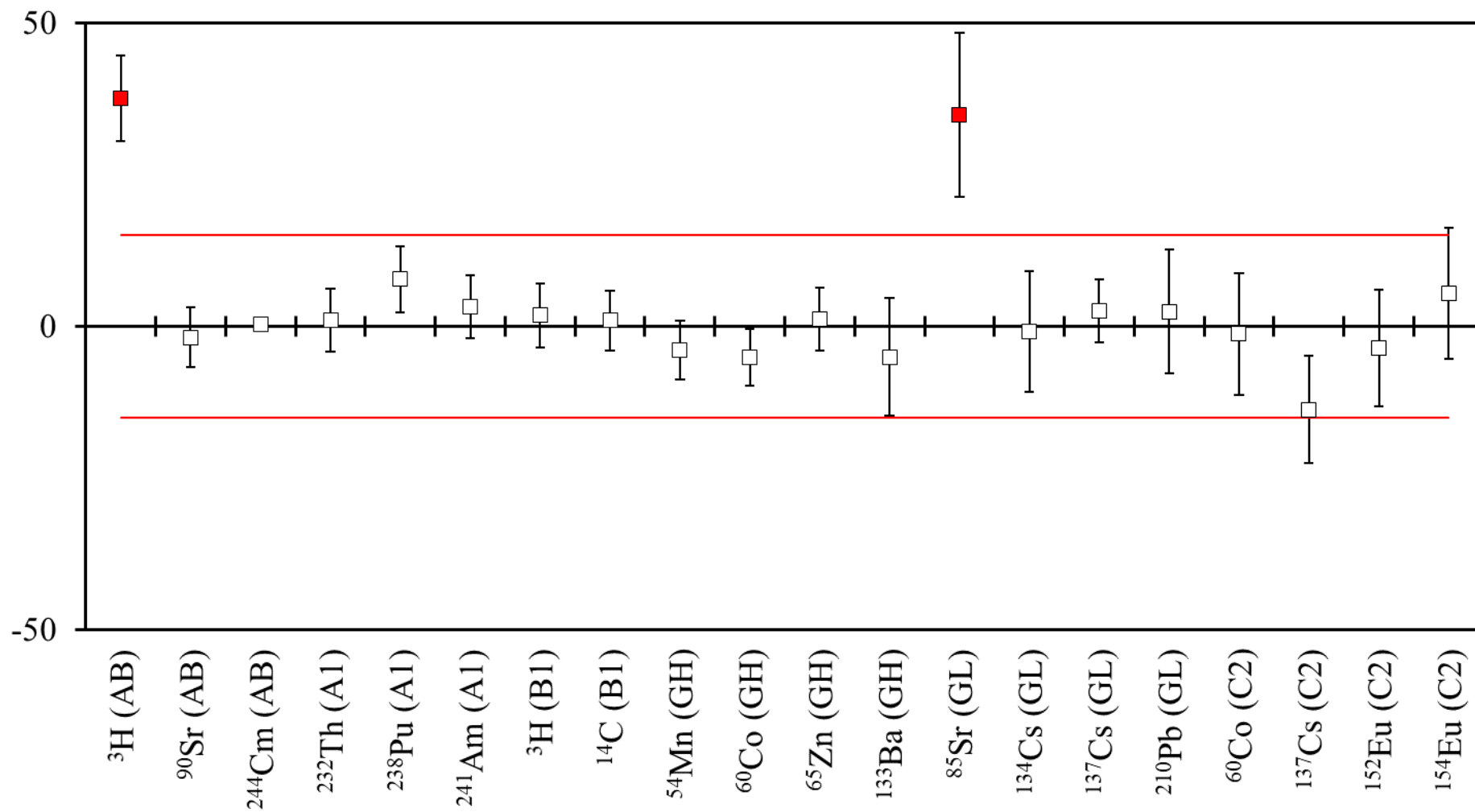


Radionuclide	Laboratory 151	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁸⁵ Sr (GL)	6.22 ± 0.31	5.931 ± 0.041	4.9	0.92	0.84
¹³⁴ Cs (GL)	16.10 ± 0.20	17.14 ± 0.12	-6.1	-4.46	-1.04
¹³⁷ Cs (GL)	7.05 ± 0.16	6.788 ± 0.062	3.9	1.53	0.66
²¹⁰ Pb (GL)	7.03 ± 0.35	6.300 ± 0.067	11.6	2.05	1.99



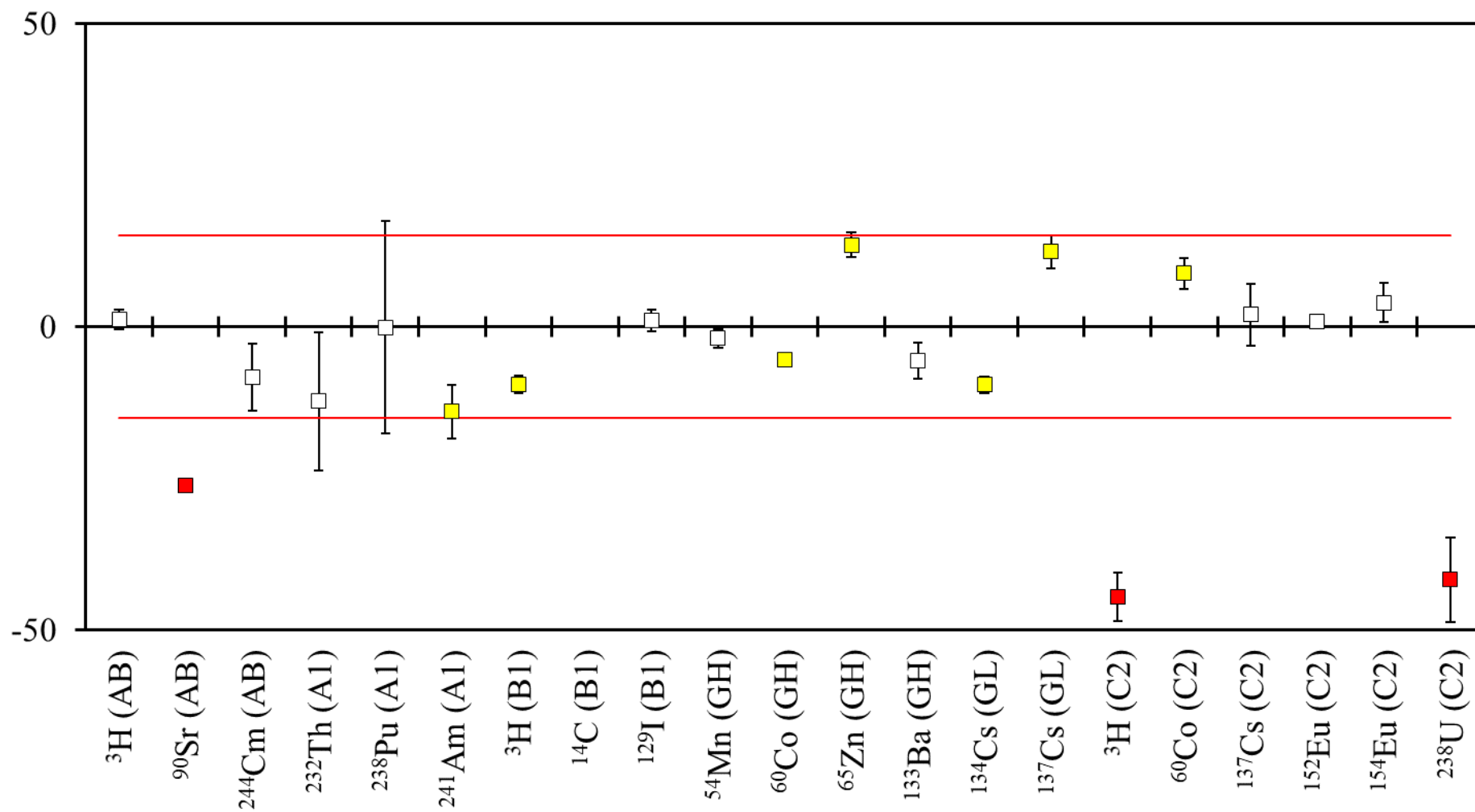
Radionuclide	Laboratory 153	NPL Assigned Value	Deviation /%	Zeta	Z Score
¹²⁹ I (B1)	0.427 ± 0.034	0.3839 ± 0.0019	11.2	1.27	1.93
⁶⁰ Co (C2)	0.1060 ± 0.0075	0.0705 ± 0.0011	50.4	4.68	8.65
¹³⁷ Cs (C2)	0.704 ± 0.065	0.05647 ± 0.00096	1146.7	9.96	196.92
¹⁵² Eu (C2)	7.34 ± 0.23	7.180 ± 0.048	2.2	0.68	0.38
¹⁵⁴ Eu (C2)	0.125 ± 0.011	0.1423 ± 0.0032	-12.2	-1.51	-2.09

Deviation (%) of Laboratory 154



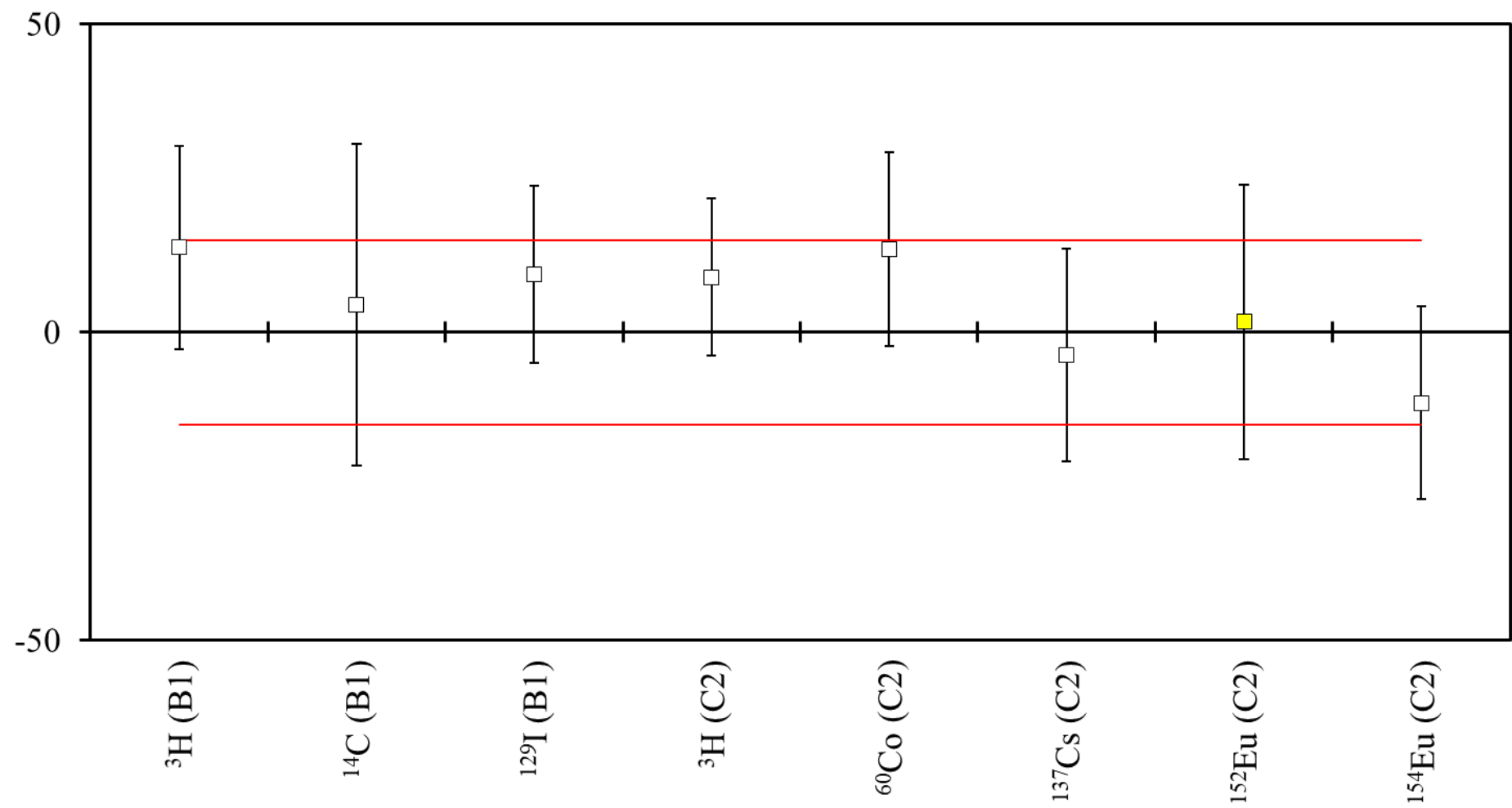
Radionuclide	Laboratory 154	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	14.40 ± 0.72	10.47 ± 0.13	37.5	5.37	6.45
⁹⁰ Sr (AB)	8.14 ± 0.41	8.291 ± 0.021	-1.8	-0.37	-0.31
²⁴⁴ Cm (AB)	8.82 (No reported uncertainty)	8.788 ± 0.029	0.4	1.10	0.06
²³² Th (A1)	2.75 ± 0.14	2.724 ± 0.026	1.0	0.18	0.16
²³⁸ Pu (A1)	11.10 ± 0.56	10.306 ± 0.025	7.7	1.42	1.32
²⁴¹ Am (A1)	7.92 ± 0.40	7.674 ± 0.017	3.2	0.61	0.55
³ H (B1)	1.360 ± 0.068	1.336 ± 0.017	1.8	0.34	0.31
¹⁴ C (B1)	0.425 ± 0.021	0.4212 ± 0.0019	0.9	0.18	0.15
⁵⁴ Mn (GH)	18.30 ± 0.92	19.062 ± 0.081	-4.0	-0.83	-0.69
⁶⁰ Co (GH)	7.02 ± 0.35	7.399 ± 0.020	-5.1	-1.08	-0.88
⁶⁵ Zn (GH)	2.38 ± 0.12	2.353 ± 0.017	1.1	0.22	0.20
¹³³ Ba (GH)	18.7 ± 1.9	19.70 ± 0.13	-5.1	-0.53	-0.87
⁸⁵ Sr (GL)	8.00 ± 0.80	5.931 ± 0.041	34.9	2.58	5.99
¹³⁴ Cs (GL)	17.0 ± 1.7	17.14 ± 0.12	-0.8	-0.08	-0.14
¹³⁷ Cs (GL)	6.96 ± 0.35	6.788 ± 0.062	2.5	0.48	0.44
²¹⁰ Pb (GL)	6.45 ± 0.64	6.300 ± 0.067	2.4	0.23	0.41
⁶⁰ Co (C2)	0.0696 ± 0.0070	0.0705 ± 0.0011	-1.3	-0.13	-0.22
¹³⁷ Cs (C2)	0.0487 ± 0.0049	0.05647 ± 0.00096	-13.8	-1.56	-2.36
¹⁵² Eu (C2)	6.92 ± 0.69	7.180 ± 0.048	-3.6	-0.38	-0.62
¹⁵⁴ Eu (C2)	0.150 ± 0.015	0.1423 ± 0.0032	5.4	0.50	0.93

Deviation (%) of Laboratory 155

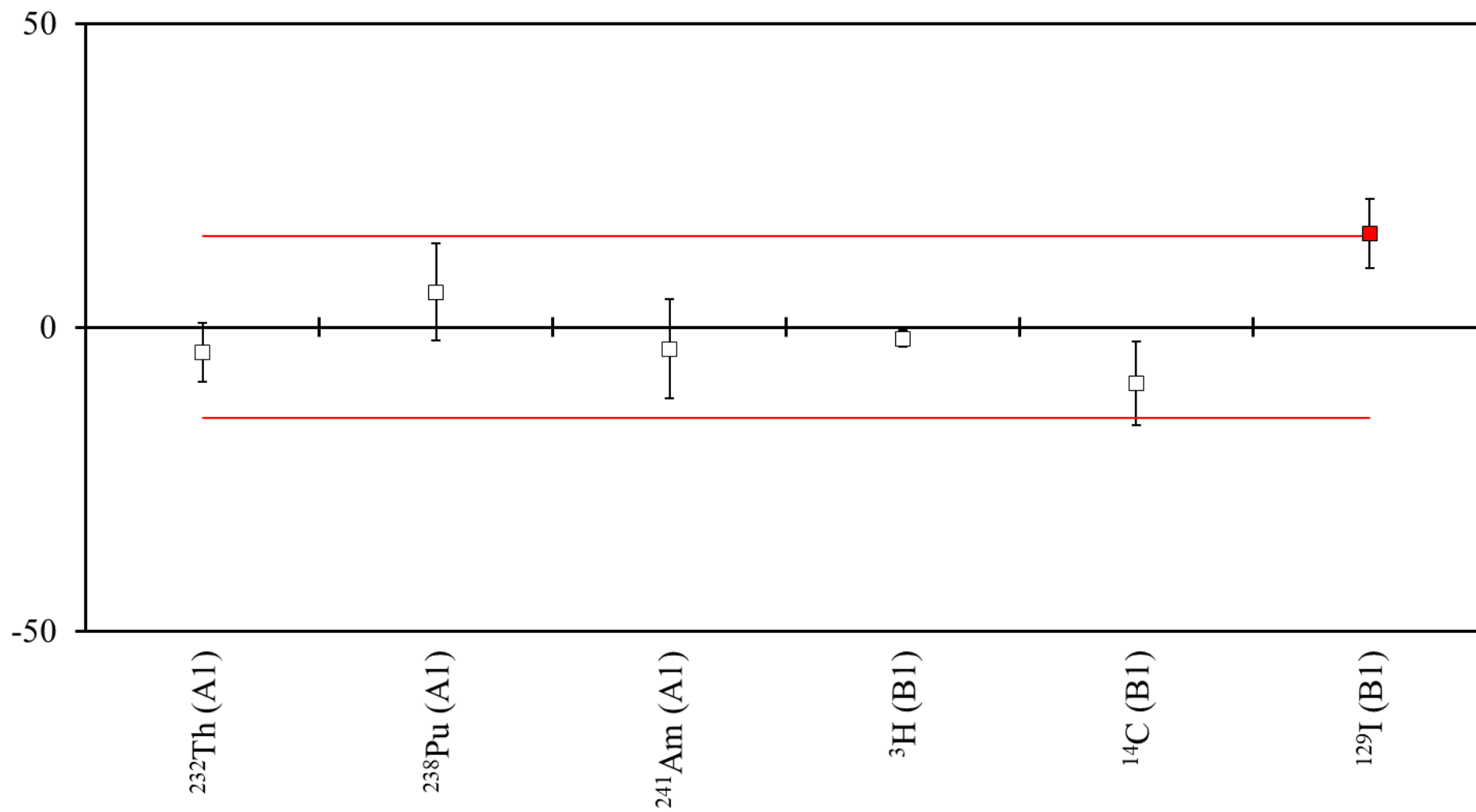


Radionuclide	Laboratory 155	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.60 ± 0.11	10.47 ± 0.13	1.2	0.76	0.21
^{90}Sr (AB)	6.120 ± 0.044	8.291 ± 0.021	-26.2	-44.53	-4.50
^{244}Cm (AB)	8.06 ± 0.48	8.788 ± 0.029	-8.3	-1.51	-1.42
^{232}Th (A1)	2.39 ± 0.31	2.724 ± 0.026	-12.3	-1.07	-2.11
^{238}Pu (A1)	10.3 ± 1.8	10.306 ± 0.025	-0.1	0.00	-0.01
^{241}Am (A1)	6.60 ± 0.34	7.674 ± 0.017	-14.0	-3.15	-2.40
^3H (B1)	1.210 ± 0.012	1.336 ± 0.017	-9.4	-6.06	-1.62
^{14}C (B1)	0.8570 ± 0.0061	0.4212 ± 0.0019	103.5	68.21	17.77
^{129}I (B1)	0.3880 ± 0.0067	0.3839 ± 0.0019	1.1	0.59	0.18
^{54}Mn (GH)	18.70 ± 0.29	19.062 ± 0.081	-1.9	-1.20	-0.33
^{60}Co (GH)	7.000 ± 0.081	7.399 ± 0.020	-5.4	-4.78	-0.93
^{65}Zn (GH)	2.670 ± 0.044	2.353 ± 0.017	13.5	6.72	2.31
^{133}Ba (GH)	18.60 ± 0.56	19.70 ± 0.13	-5.6	-1.91	-0.96
^{134}Cs (GL)	15.50 ± 0.22	17.14 ± 0.12	-9.6	-6.54	-1.64
^{137}Cs (GL)	7.63 ± 0.17	6.788 ± 0.062	12.4	4.65	2.13
^3H (C2)	16.10 ± 0.29	29.0 ± 2.0	-44.5	-6.38	-7.64
^{60}Co (C2)	0.0767 ± 0.0014	0.0705 ± 0.0011	8.8	3.48	1.51
^{137}Cs (C2)	0.0576 ± 0.0027	0.05647 ± 0.00096	2.0	0.39	0.34
^{152}Eu (C2)	7.24 ± 0.06	7.180 ± 0.048	0.8	0.78	0.14
^{154}Eu (C2)	0.1480 ± 0.0033	0.1423 ± 0.0032	4.0	1.24	0.69
^{238}U (C2)	0.00681 ± 0.00059	0.01168 ± 0.00097	-41.7	-4.29	-7.16

Deviation (%) of Laboratory 159

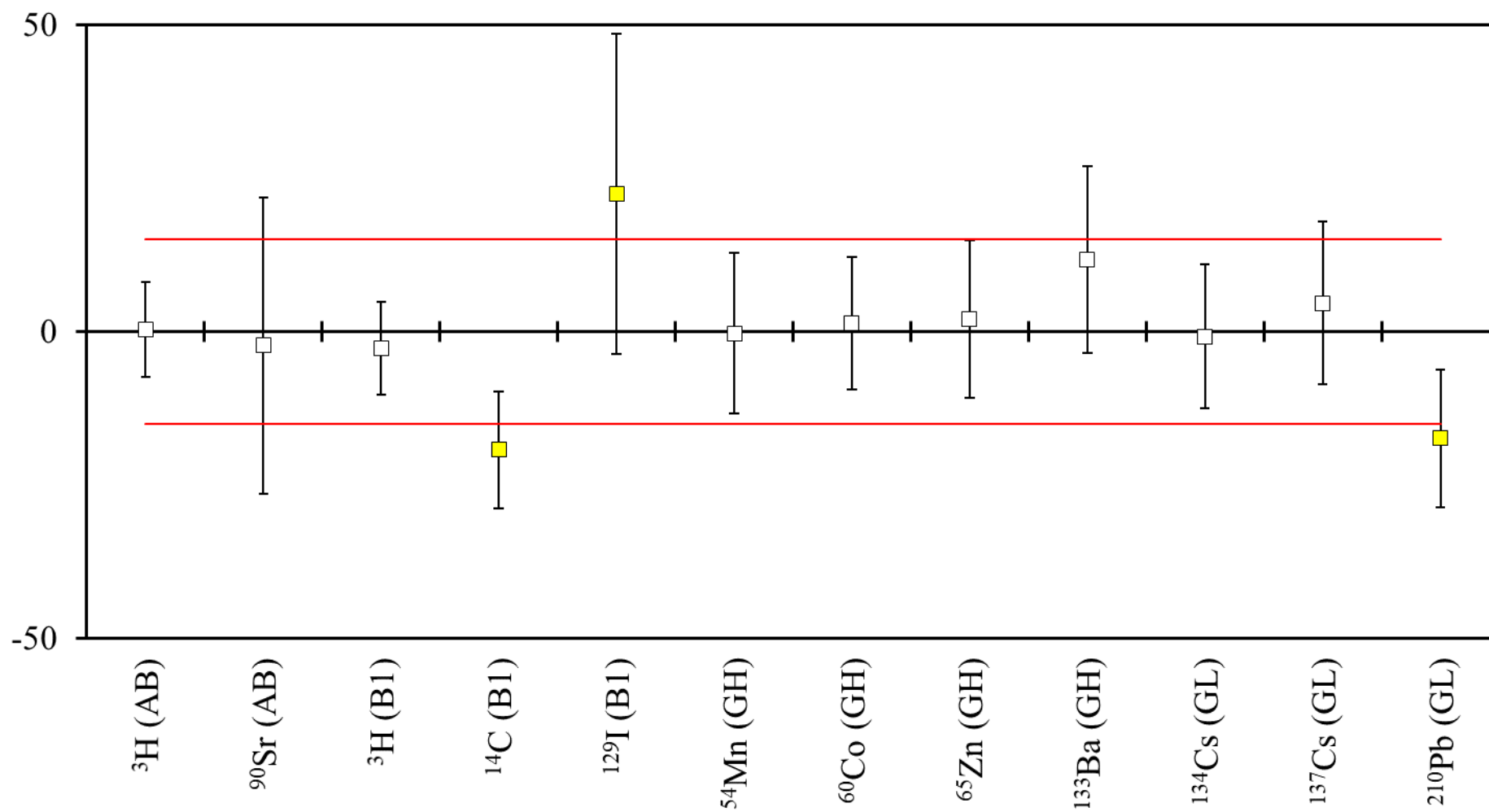


Radionuclide	Laboratory 159	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (B1)	1.52 ± 0.22	1.336 ± 0.017	13.8	0.83	2.37
^{14}C (B1)	0.44 ± 0.11	0.4212 ± 0.0019	4.5	0.17	0.77
^{129}I (B1)	0.420 ± 0.055	0.3839 ± 0.0019	9.4	0.66	1.61
^3H (C2)	31.6 ± 3.0	29.0 ± 2.0	9.0	0.72	1.54
^{60}Co (C2)	0.080 ± 0.011	0.0705 ± 0.0011	13.5	0.86	2.31
^{137}Cs (C2)	0.0544 ± 0.0097	0.05647 ± 0.00096	-3.7	-0.21	-0.63
^{152}Eu (C2)	7.3 ± 1.6	7.180 ± 0.048	1.7	0.07	0.29
^{154}Eu (C2)	0.126 ± 0.022	0.1423 ± 0.0032	-11.5	-0.73	-1.97

Deviation (%) of Laboratory 162

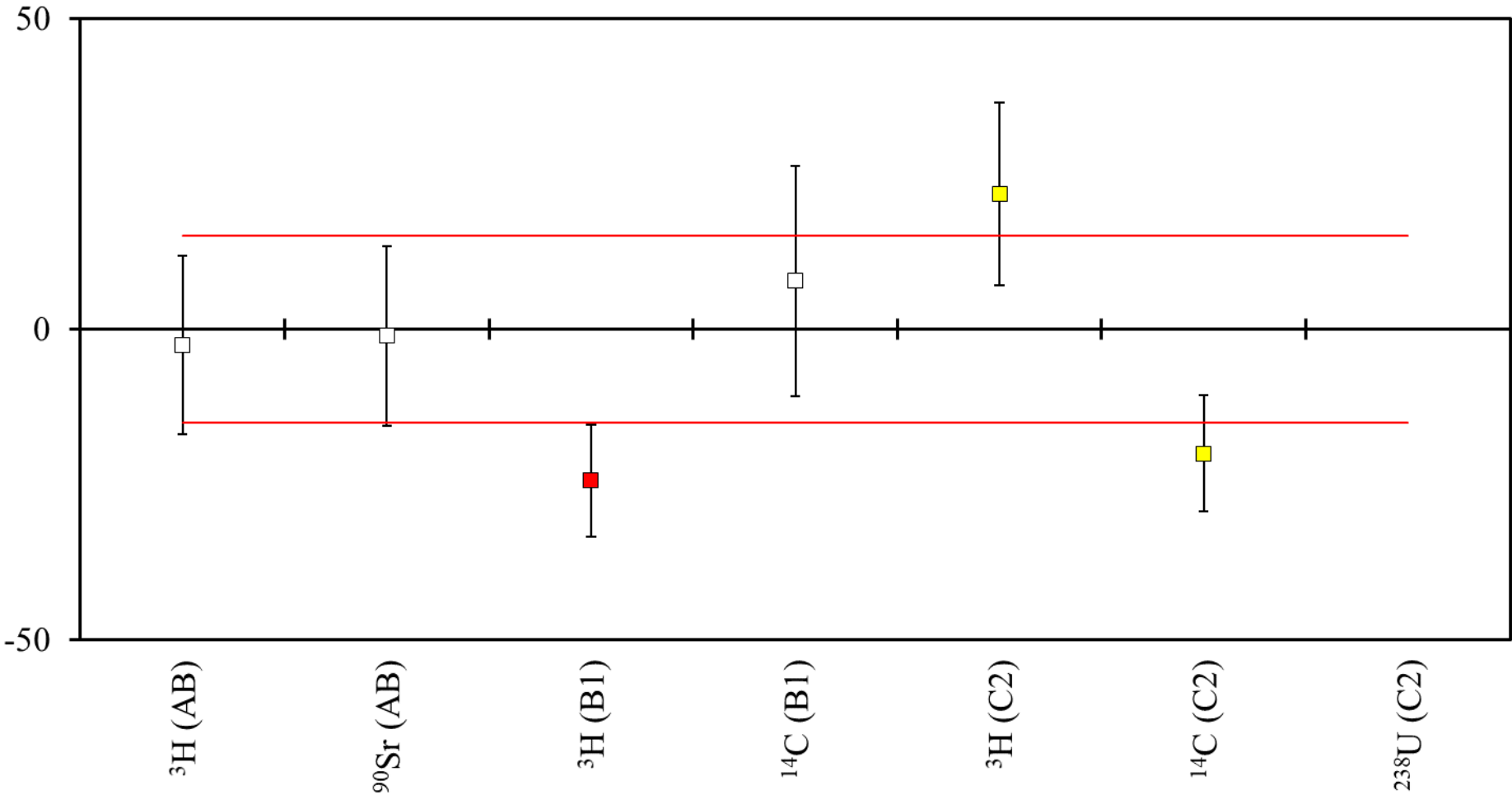
Radionuclide	Laboratory 162	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³² Th (A1)	2.61 ± 0.13	2.724 ± 0.026	-4.2	-0.86	-0.72
²³⁸ Pu (A1)	10.90 ± 0.82	10.306 ± 0.025	5.8	0.72	0.99
²⁴¹ Am (A1)	7.40 ± 0.63	7.674 ± 0.017	-3.6	-0.43	-0.61
³ H (B1)	1.3100 ± 0.0072	1.336 ± 0.017	-1.9	-1.41	-0.33
¹⁴ C (B1)	0.382 ± 0.029	0.4212 ± 0.0019	-9.3	-1.35	-1.60
¹²⁹ I (B1)	0.443 ± 0.022	0.3839 ± 0.0019	15.4	2.68	2.64

Deviation (%) of Laboratory 165



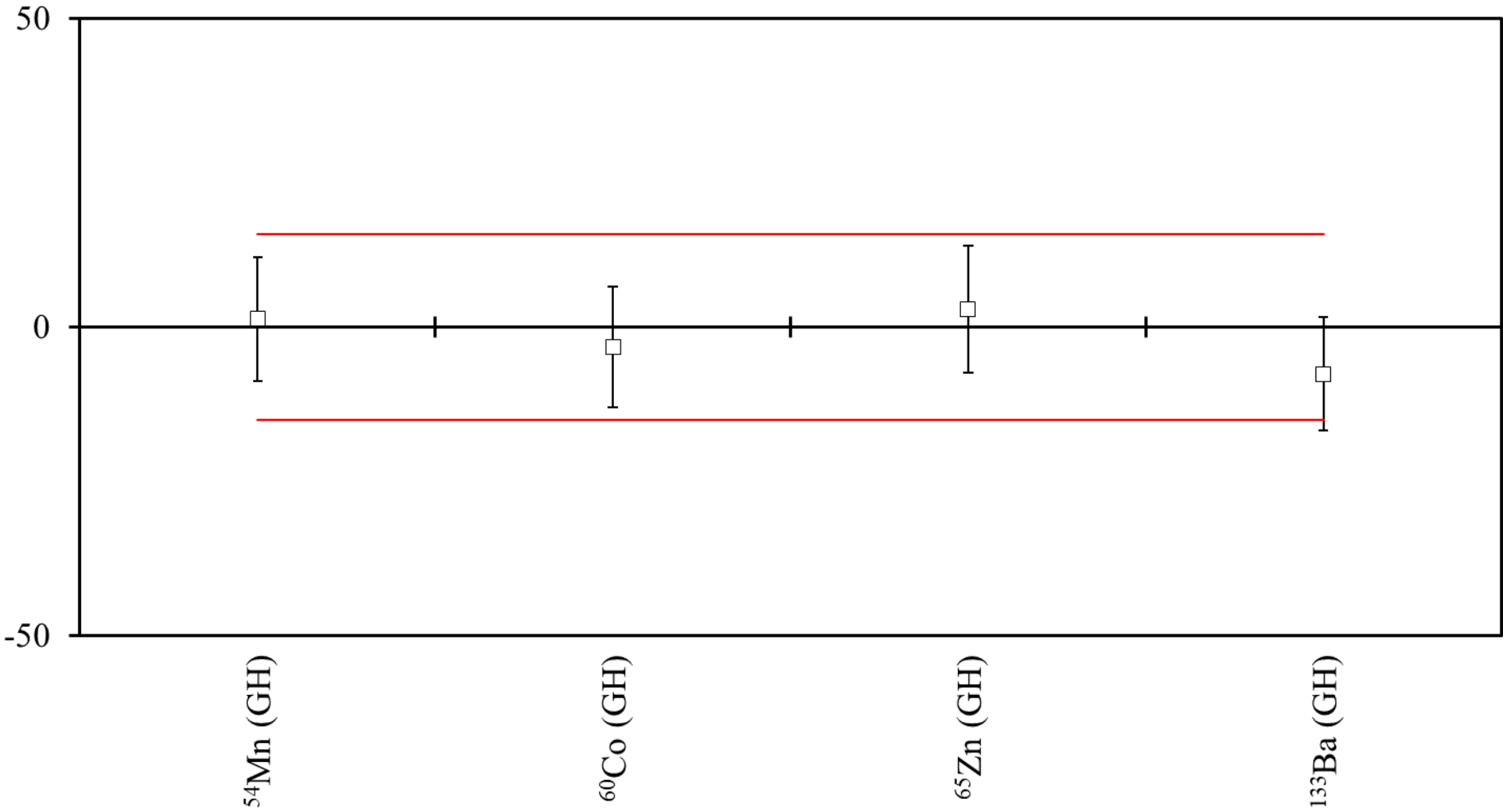
Radionuclide	Laboratory 165	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.50 ± 0.80	10.47 ± 0.13	0.3	0.04	0.05
^{90}Sr (AB)	8.1 ± 2.0	8.291 ± 0.021	-2.3	-0.10	-0.40
^3H (B1)	1.30 ± 0.10	1.336 ± 0.017	-2.7	-0.35	-0.46
^{14}C (B1)	0.340 ± 0.040	0.4212 ± 0.0019	-19.3	-2.03	-3.31
^{129}I (B1)	0.47 ± 0.10	0.3839 ± 0.0019	22.4	0.86	3.85
^{54}Mn (GH)	19.0 ± 2.5	19.062 ± 0.081	-0.3	-0.02	-0.06
^{60}Co (GH)	7.50 ± 0.80	7.399 ± 0.020	1.4	0.13	0.23
^{65}Zn (GH)	2.4 ± 0.3	2.353 ± 0.017	2.0	0.16	0.34
^{133}Ba (GH)	22.0 ± 3.0	19.70 ± 0.13	11.7	0.77	2.01
^{134}Cs (GL)	17.0 ± 2.0	17.14 ± 0.12	-0.8	-0.07	-0.14
^{137}Cs (GL)	7.10 ± 0.90	6.788 ± 0.062	4.6	0.35	0.79
^{210}Pb (GL)	5.2 ± 0.7	6.300 ± 0.067	-17.5	-1.56	-3.00

Deviation (%) of Laboratory 169

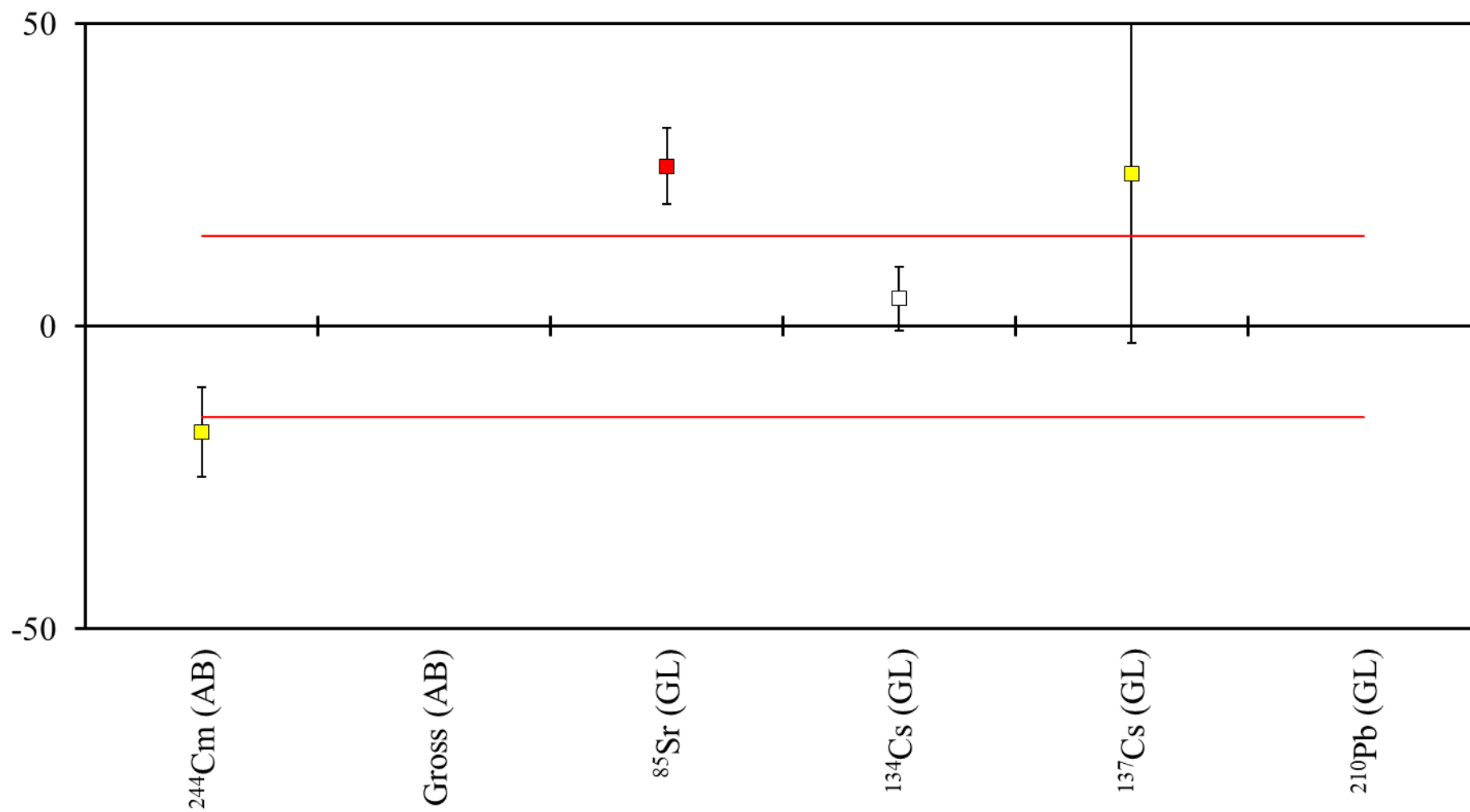


Radionuclide	Laboratory 169	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.2 ± 1.5	10.47 ± 0.13	-2.6	-0.18	-0.44
^{90}Sr (AB)	8.2 ± 1.2	8.291 ± 0.021	-1.1	-0.08	-0.19
^3H (B1)	1.01 ± 0.12	1.336 ± 0.017	-24.4	-2.69	-4.19
^{14}C (B1)	0.454 ± 0.078	0.4212 ± 0.0019	7.8	0.42	1.34
^3H (C2)	35.3 ± 3.5	29.0 ± 2.0	21.7	1.56	3.73
^{14}C (C2)	0.180 ± 0.018	0.225 ± 0.014	-20.0	-1.97	-3.43
^{235}U (C2)	0.00529 ± 0.00049	-	-	-	-
^{238}U (C2)	0.113 ± 0.010	0.01168 ± 0.00097	867.5	10.08	148.97

Deviation (%) of Laboratory 172

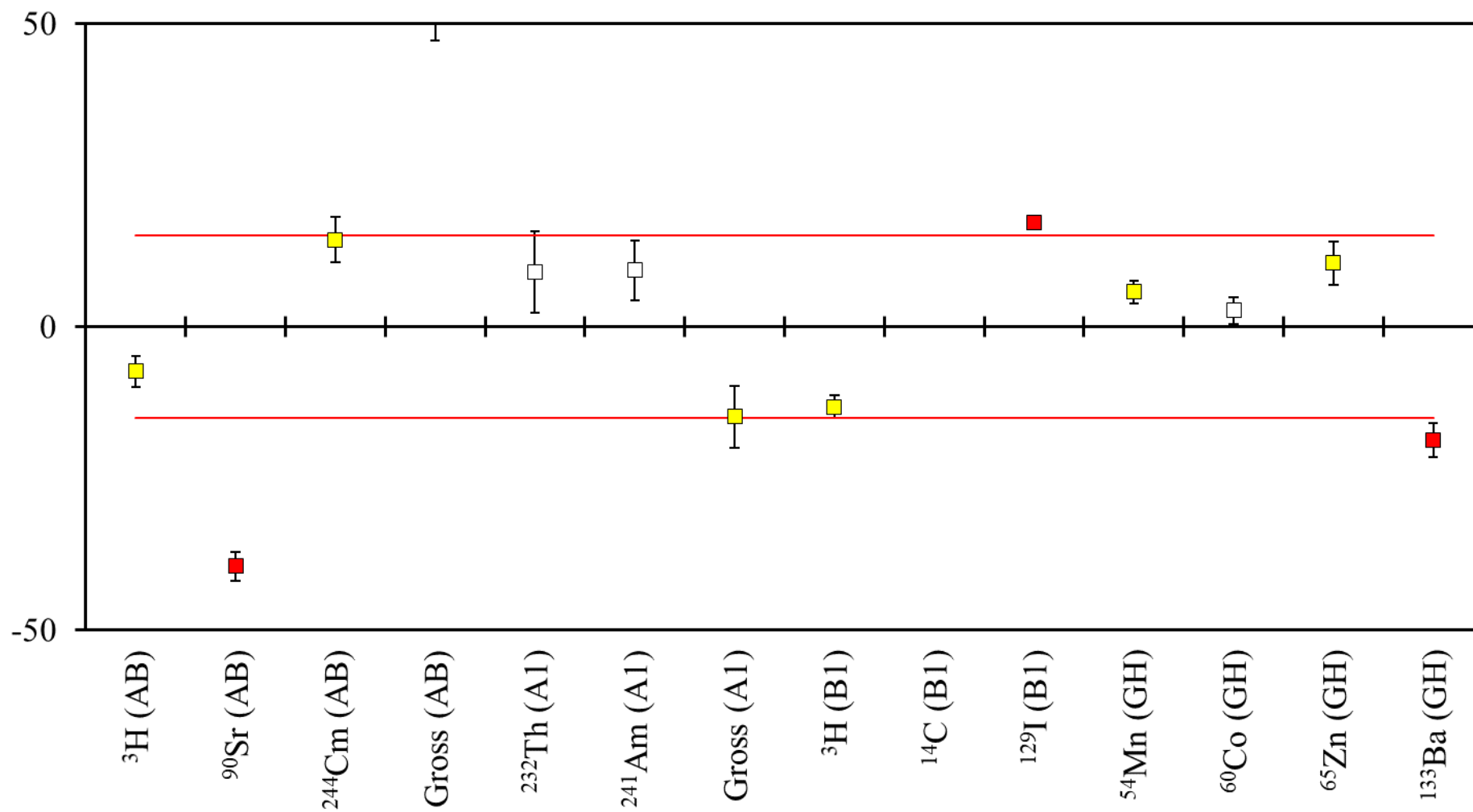


Radionuclide	Laboratory 172	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	19.3 ± 1.9	19.062 ± 0.081	1.2	0.13	0.21
⁶⁰ Co (GH)	7.16 ± 0.72	7.399 ± 0.020	-3.2	-0.33	-0.55
⁶⁵ Zn (GH)	2.42 ± 0.24	2.353 ± 0.017	2.8	0.28	0.49
¹³³ Ba (GH)	18.2 ± 1.8	19.70 ± 0.13	-7.6	-0.83	-1.31

Deviation (%) of Laboratory 173

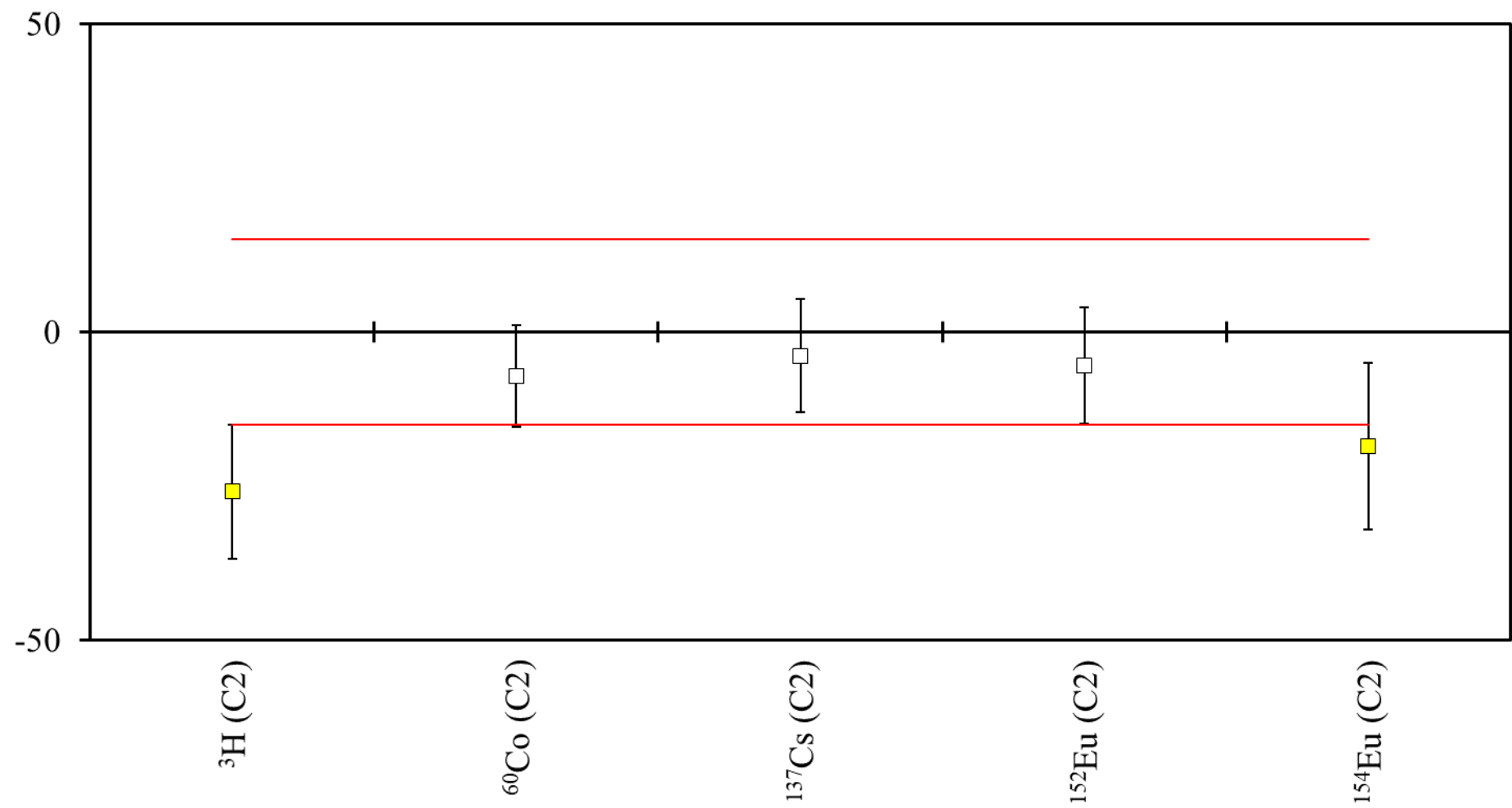
Radionuclide	Laboratory 173	NPL Assigned Value	Deviation /%	Zeta	Z Score
²⁴⁴ Cm (AB)	7.26 ± 0.65	8.788 ± 0.029	-17.4	-2.35	-2.99
Gross beta (AB)	45.7 ± 5.0	22.04 ± 0.35	107.4	4.72	18.44
⁸⁵ Sr (GL)	7.50 ± 0.37	5.931 ± 0.041	26.5	4.21	4.54
¹³⁴ Cs (GL)	17.93 ± 0.90	17.14 ± 0.12	4.6	0.87	0.79
¹³⁷ Cs (GL)	8.5 ± 1.9	6.788 ± 0.062	25.2	0.90	4.33
²¹⁰ Pb (GL)	38 ± 12	6.300 ± 0.067	503.2	2.64	86.41

Deviation (%) of Laboratory 174



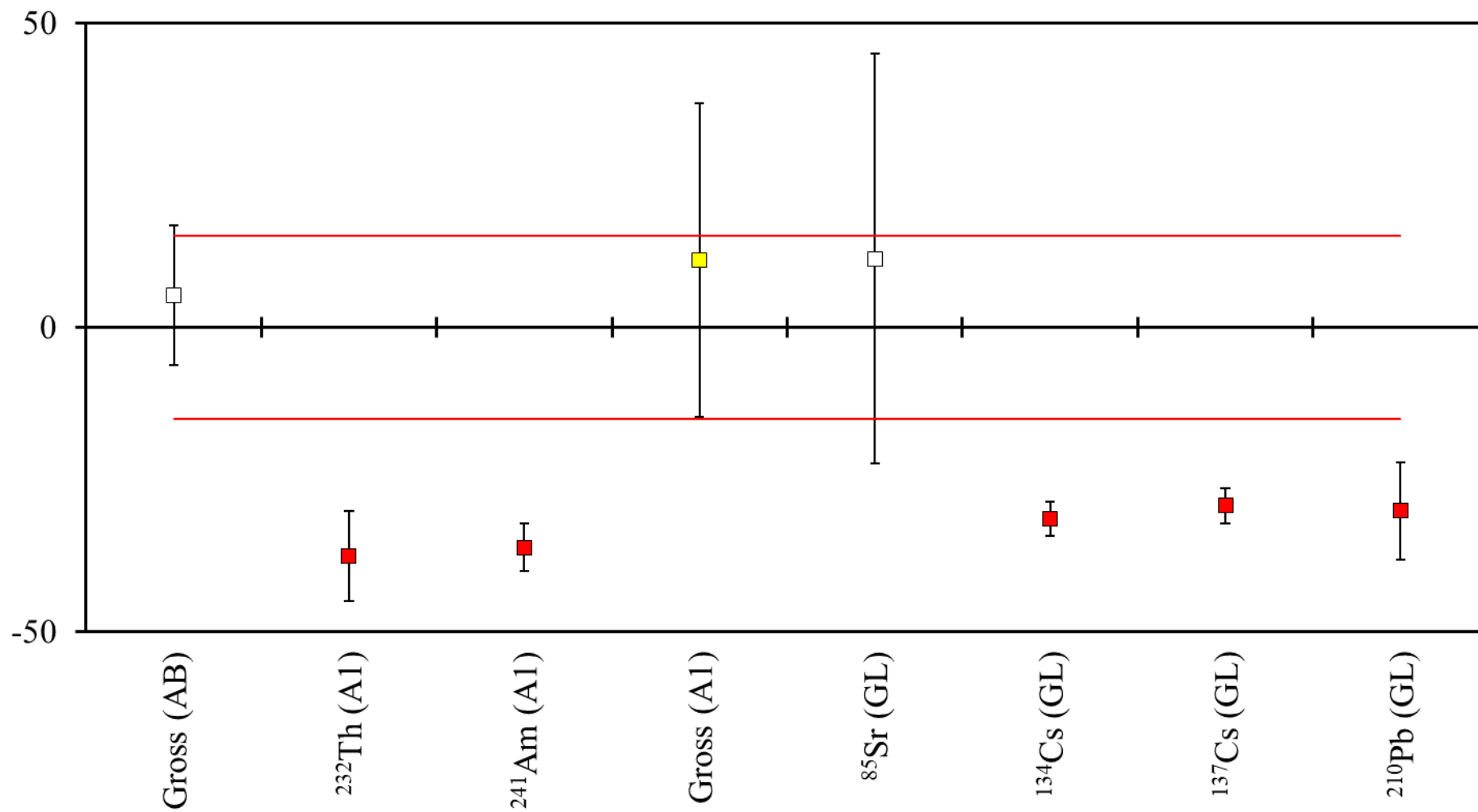
Radionuclide	Laboratory 174	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	9.70 ± 0.23	10.47 ± 0.13	-7.4	-2.91	-1.26
⁹⁰ Sr (AB)	5.02 ± 0.20	8.291 ± 0.021	-39.5	-16.27	-6.78
²⁴⁴ Cm (AB)	10.05 ± 0.33	8.788 ± 0.029	14.4	3.81	2.47
Gross beta (AB)	33.15 ± 0.45	22.04 ± 0.35	50.4	19.49	8.66
²³² Th (A1)	2.97 ± 0.18	2.724 ± 0.026	9.0	1.35	1.55
²⁴¹ Am (A1)	8.39 ± 0.38	7.674 ± 0.017	9.3	1.88	1.60
Gross alpha (A1)	27.0 ± 1.1	31.7 ± 1.4	-14.8	-2.64	-2.55
³ H (B1)	1.160 ± 0.020	1.336 ± 0.017	-13.2	-6.71	-2.26
¹⁴ C (B1)	1.710 ± 0.050	0.4212 ± 0.0019	306.0	25.76	52.55
¹²⁹ I (B1)	0.4500 ± 0.0020	0.3839 ± 0.0019	17.2	23.96	2.96
Gross beta (B1)	1.000 ± 0.020	-	-	-	-
⁵⁴ Mn (GH)	20.16 ± 0.35	19.062 ± 0.081	5.8	3.06	0.99
⁶⁰ Co (GH)	7.60 ± 0.16	7.399 ± 0.020	2.7	1.25	0.47
⁶⁵ Zn (GH)	2.600 ± 0.080	2.353 ± 0.017	10.5	3.02	1.80
¹³³ Ba (GH)	16.02 ± 0.55	19.70 ± 0.13	-18.7	-6.51	-3.21

Deviation (%) of Laboratory 175



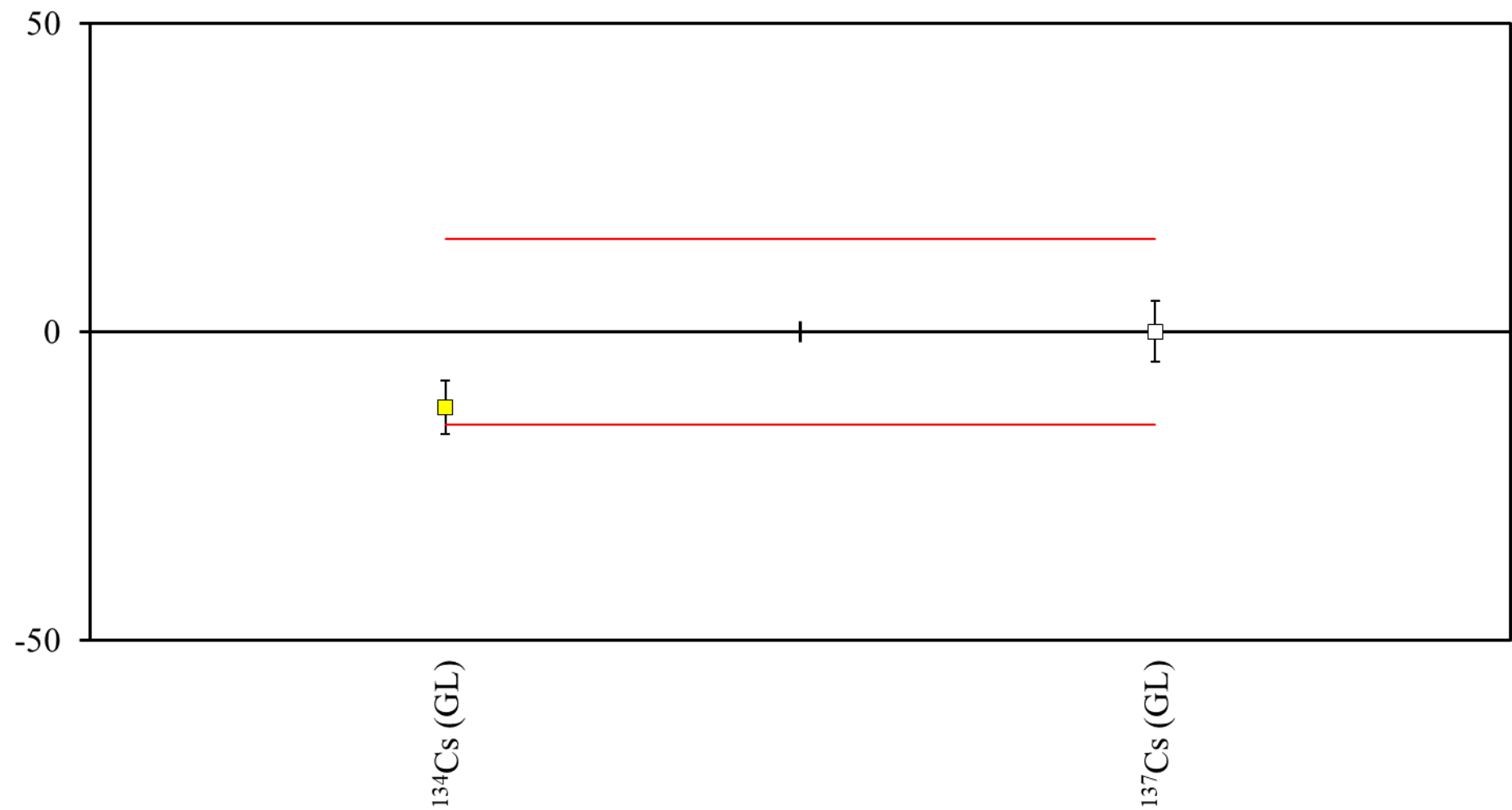
Radionuclide	Laboratory 175	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (C2)	21.5 ± 2.8	29.0 ± 2.0	-25.9	-2.18	-4.44
⁶⁰ Co (C2)	0.0655 ± 0.0057	0.0705 ± 0.0011	-7.1	-0.86	-1.22
¹³⁷ Cs (C2)	0.0543 ± 0.0051	0.05647 ± 0.00096	-3.8	-0.42	-0.66
¹⁵² Eu (C2)	6.79 ± 0.68	7.180 ± 0.048	-5.4	-0.57	-0.93
¹⁵⁴ Eu (C2)	0.116 ± 0.019	0.1423 ± 0.0032	-18.5	-1.36	-3.17

Deviation (%) of Laboratory 176



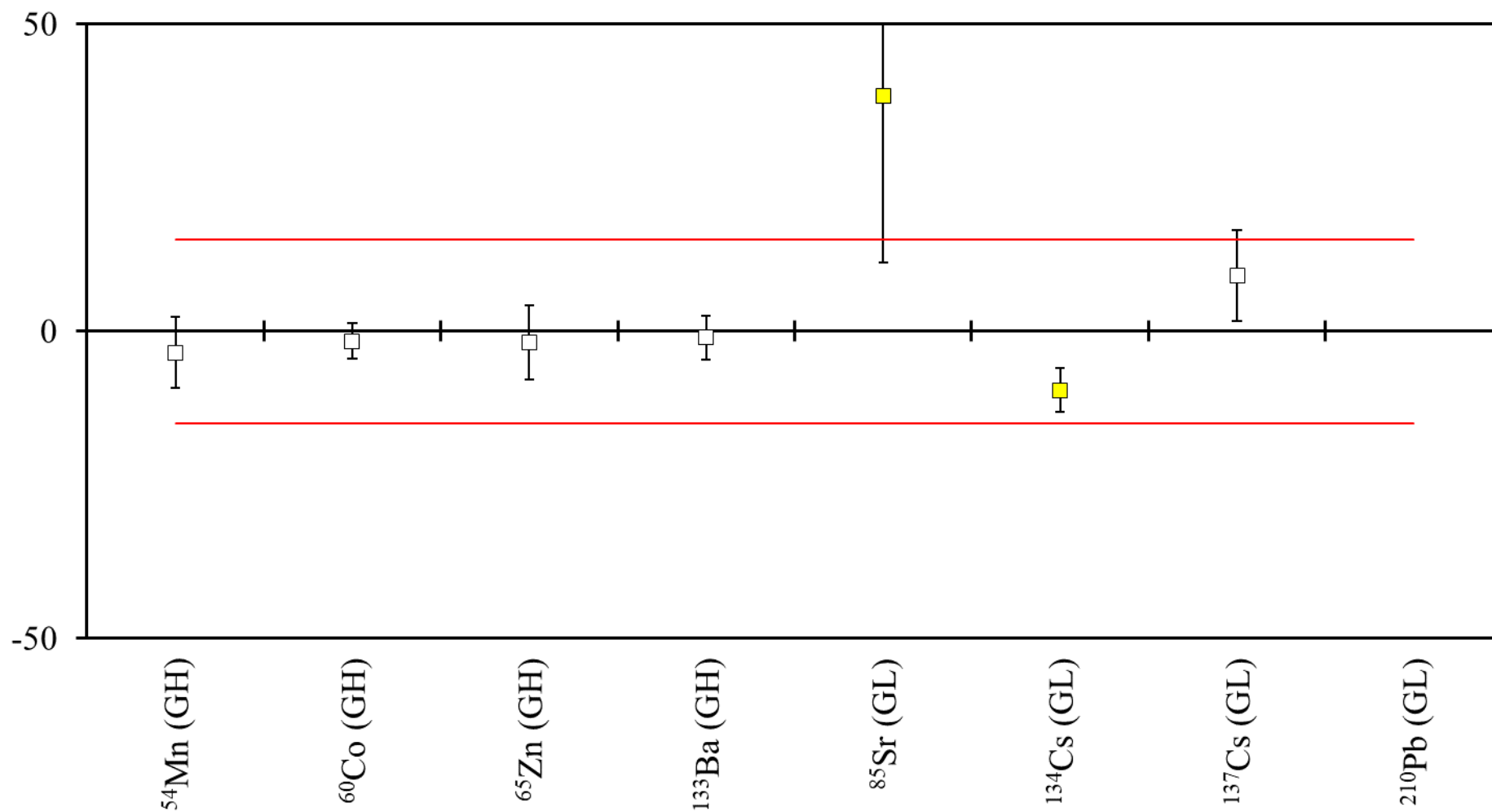
Radionuclide	Laboratory 176	NPL Assigned Value	Deviation /%	Zeta	Z Score
Gross beta (AB)	23.2 ± 2.5	22.04 ± 0.35	5.3	0.46	0.90
²³² Th (A1)	1.70 ± 0.20	2.724 ± 0.026	-37.6	-5.08	-6.46
²⁴¹ Am (A1)	4.9 ± 0.3	7.674 ± 0.017	-36.1	-9.23	-6.21
Gross alpha (A1)	35.2 ± 8.0	31.7 ± 1.4	11.0	0.43	1.90
⁸⁵ Sr (GL)	6.6 ± 2.0	5.931 ± 0.041	11.3	0.33	1.94
¹³⁴ Cs (GL)	11.75 ± 0.48	17.14 ± 0.12	-31.4	-10.89	-5.40
¹³⁷ Cs (GL)	4.80 ± 0.19	6.788 ± 0.062	-29.3	-9.95	-5.03
²¹⁰ Pb (GL)	4.40 ± 0.50	6.300 ± 0.067	-30.2	-3.77	-5.18

Deviation (%) of Laboratory 177



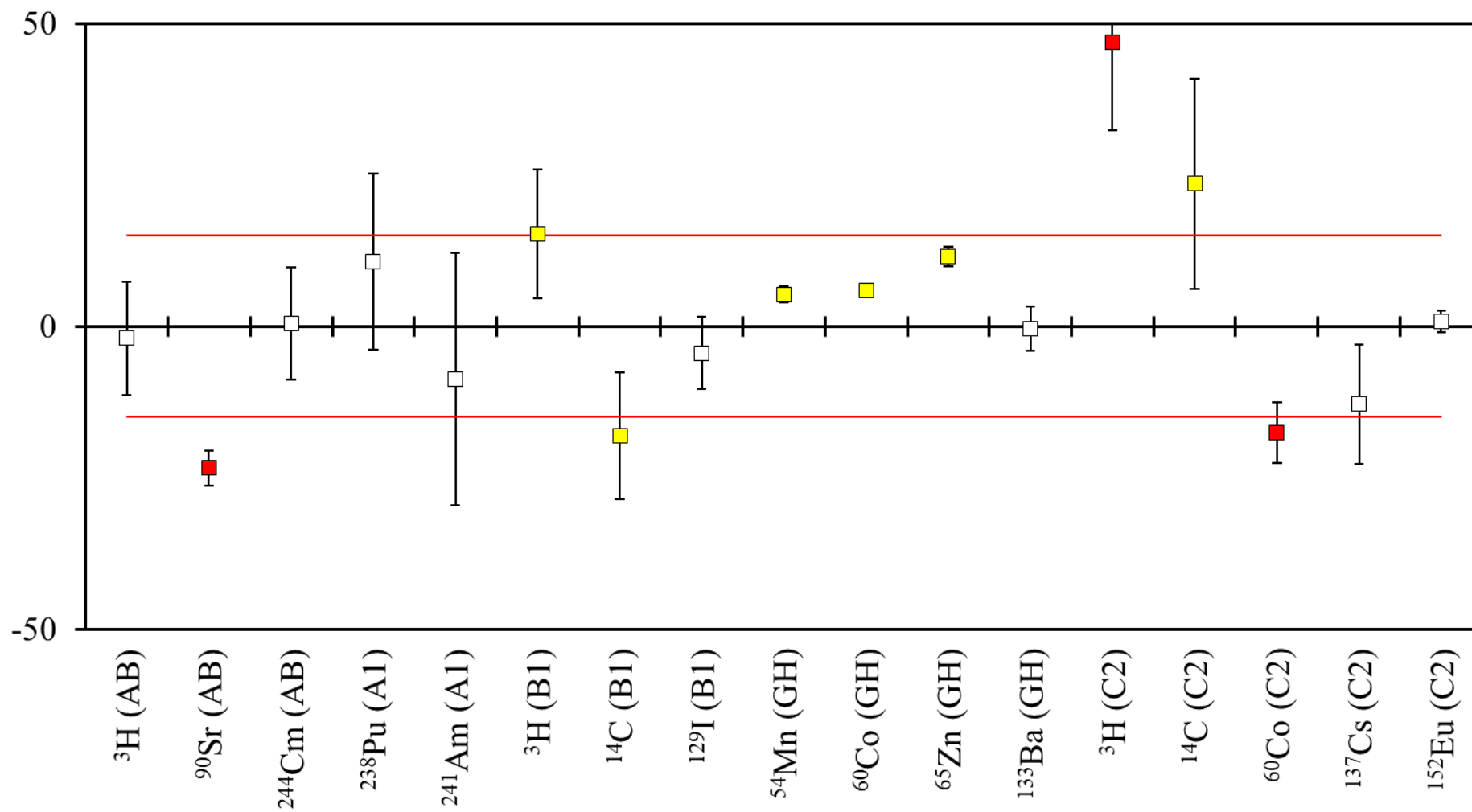
Radionuclide	Laboratory 177	NPL Assigned Value	Deviation /%	Zeta	Z Score
¹³⁴ Cs (GL)	15.05 ± 0.74	17.14 ± 0.12	-12.2	-2.79	-2.09
¹³⁷ Cs (GL)	6.79 ± 0.33	6.788 ± 0.062	0.0	0.01	0.01

Deviation (%) of Laboratory 178

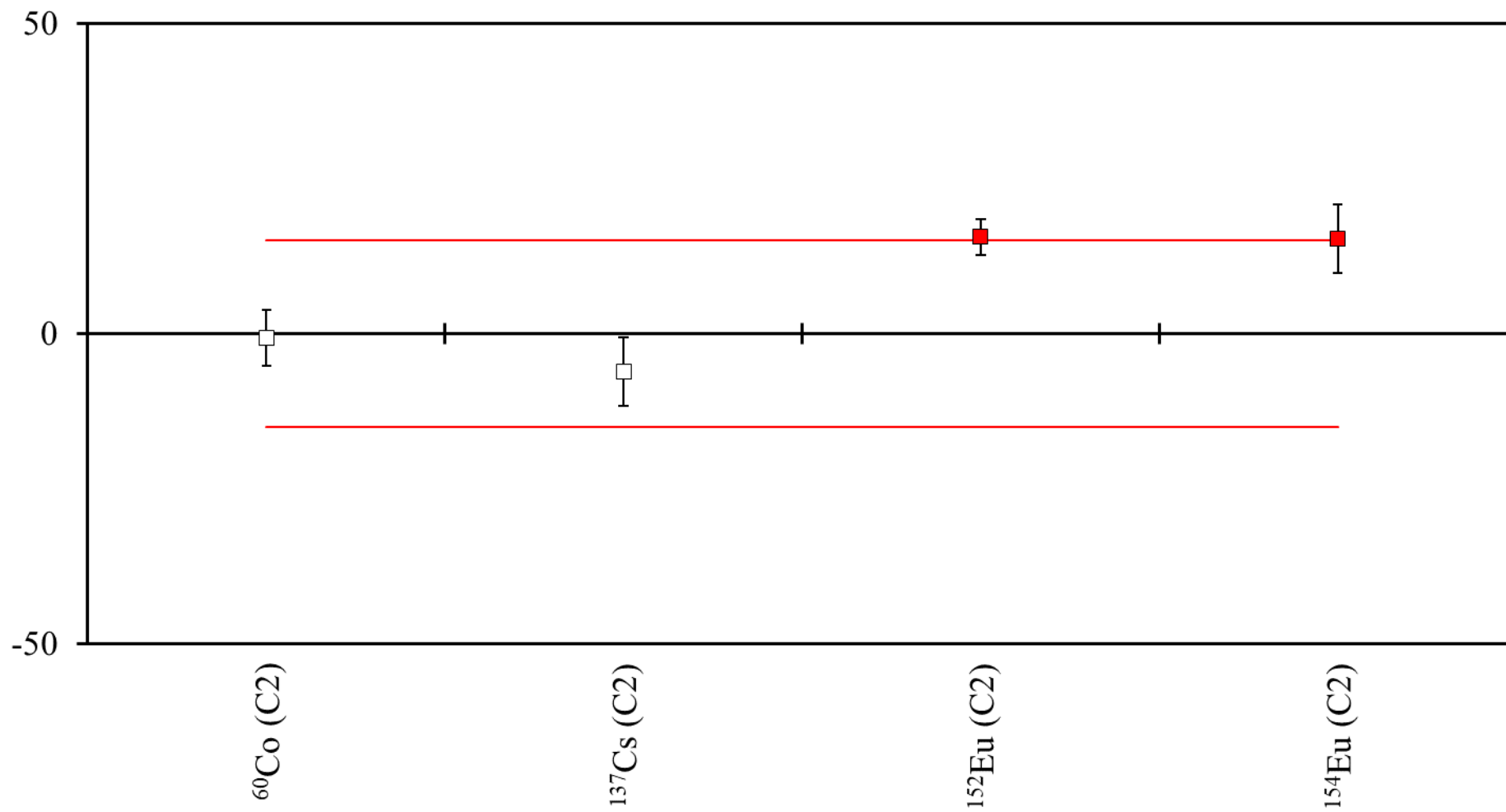


Radionuclide	Laboratory 178	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	18.4 ± 1.1	19.062 ± 0.081	-3.5	-0.60	-0.60
⁶⁰ Co (GH)	7.28 ± 0.21	7.399 ± 0.020	-1.6	-0.56	-0.28
⁶⁵ Zn (GH)	2.31 ± 0.14	2.353 ± 0.017	-1.8	-0.30	-0.31
¹³³ Ba (GH)	19.5 ± 0.7	19.70 ± 0.13	-1.0	-0.28	-0.17
⁸⁵ Sr (GL)	8.2 ± 1.6	5.931 ± 0.041	38.3	1.42	6.57
¹³⁴ Cs (GL)	15.5 ± 0.6	17.14 ± 0.12	-9.6	-2.68	-1.64
¹³⁷ Cs (GL)	7.40 ± 0.50	6.788 ± 0.062	9.0	1.21	1.55
²¹⁰ Pb (GL)	2.40 ± 0.20	6.300 ± 0.067	-61.9	-18.49	-10.63

Deviation (%) of Laboratory 179



Radionuclide	Laboratory 179	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	10.26 ± 0.97	10.47 ± 0.13	-2.0	-0.21	-0.34
^{90}Sr (AB)	6.35 ± 0.24	8.291 ± 0.021	-23.4	-8.06	-4.02
^{244}Cm (AB)	8.83 ± 0.81	8.788 ± 0.029	0.5	0.05	0.08
^{238}Pu (A1)	11.4 ± 1.5	10.306 ± 0.025	10.6	0.73	1.82
^{241}Am (A1)	7.0 ± 1.6	7.674 ± 0.017	-8.8	-0.42	-1.51
^3H (B1)	1.54 ± 0.14	1.336 ± 0.017	15.3	1.45	2.62
^{14}C (B1)	0.345 ± 0.044	0.4212 ± 0.0019	-18.1	-1.73	-3.11
^{129}I (B1)	0.367 ± 0.023	0.3839 ± 0.0019	-4.4	-0.73	-0.76
^{54}Mn (GH)	20.07 ± 0.25	19.062 ± 0.081	5.3	3.84	0.91
^{60}Co (GH)	7.834 ± 0.054	7.399 ± 0.020	5.9	7.55	1.01
^{65}Zn (GH)	2.625 ± 0.033	2.353 ± 0.017	11.6	7.33	1.99
^{133}Ba (GH)	19.630 ± 0.7	19.70 ± 0.13	-0.4	-0.10	-0.06
^3H (C2)	42.6 ± 3.0	29.0 ± 2.0	46.9	3.77	8.05
^{14}C (C2)	0.278 ± 0.035	0.225 ± 0.014	23.6	1.41	4.05
^{60}Co (C2)	0.0581 ± 0.0034	0.0705 ± 0.0011	-17.6	-3.47	-3.02
^{137}Cs (C2)	0.0492 ± 0.0055	0.05647 ± 0.00096	-12.9	-1.30	-2.21
^{152}Eu (C2)	7.24 ± 0.12	7.180 ± 0.048	0.8	0.46	0.14

Deviation (%) of Laboratory 180

Radionuclide	Laboratory 180	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁶⁰ Co (C2)	0.0700 ± 0.0030	0.0705 ± 0.0011	-0.7	-0.16	-0.12
¹³⁷ Cs (C2)	0.0530 ± 0.0030	0.05647 ± 0.00096	-6.1	-1.10	-1.06
¹⁵² Eu (C2)	8.30 ± 0.20	7.180 ± 0.048	15.6	5.45	2.68
¹⁵⁴ Eu (C2)	0.1640 ± 0.0070	0.1423 ± 0.0032	15.2	2.82	2.62

11. DISCUSSION

Please note that in some cases the participants did not report methods and / or standards and tracers used. The comments on methods and standards below refer, therefore, to the subset of participants (for each nuclide) who did report this information.

11.1 ^3H in AB and B1

The overall performance level for ^3H in B1 was similar to that seen in the 2017 PTE, with 26 out of the 34 results submitted being in agreement with the Assigned Value (AV). All the participants who reported methods used Liquid Scintillation Counting (LSC) to measure this radionuclide. In the vast majority of cases, the nuclide was separated from the mixture by distillation, combustion or pyrolysis. One participant calibrated their detector using an Amersham International standard, four used Eckert and Ziegler standards, three used Perkin Elmer standards, one used an IRE standard and the other participants did not specify the provenance of the standard used. The dataset for ^3H in AB was smaller (24), with 21 being in agreement with the AV, and the above comments on methods apply. Some of the above standards suppliers were again cited. Many participants measured ^3H in both sample types AB and B1, with some achieving markedly different performance levels for this nuclide extracted from the two different sample types.

11.2 ^{90}Sr in AB

Twenty-four results were submitted for this nuclide, 21 being in agreement with the AV – a similar overall level of performance than in the 2017 PTE. A wide range of specific separation methods were used, including precipitation, oxidation, ion- exchange chromatography and extraction chromatography. LSC (11 participants), Cerenkov counting (4 participants), proportional counting (4 participants) and a non-specified alpha/beta counting technique (one participant) were all reported as methods.

The Power-Moderated Weighted Mean values (PMWM) of the LSC, Cerenkov and proportional counting results were as follows:

LSC:	$(8.13 \pm 0.18) \text{ Bq g}^{-1}$
Cerenkov:	$(7.87 \pm 0.72) \text{ Bq g}^{-1}$
Proportional counting:	$(8.15 \pm 0.18) \text{ Bq g}^{-1}$

These results suggest there is no significant difference between the three datasets, but these are small sets, each with variations of the specific method used (e.g. different separation techniques and calibration standards), so it is difficult to draw conclusions on the basis of these results alone.

Five ^{90}Sr standards providers were cited (Amersham International, Cerca LEA, CMI, Eckert and Ziegler and NPL) although in some cases the supplier was not specified. Five participants used a ^{85}Sr yield tracer.

11.3 ^{147}Pm in AB

Only six results were reported for this nuclide, three being in agreement with the AV. All participants reporting a method used LSC, four of them using ion-exchange or extraction chromatography. Overall, the results show a significantly low bias (-21.4%); although this is a small dataset, the bias is of concern. No specific information on standards used was provided.

11.4 ^{244}Cm in AB

Twenty results were submitted for ^{244}Cm ; 16 were in agreement with the AV. Alpha spectrometry was used by all but three of the participants who reported methods (two using LSC and one using ICP-MS). Again, a range of separation methods were reported, including ion-exchange chromatography, extraction chromatography and precipitation. Twelve participants used a ^{243}Am tracer and two used ^{241}Am , in most cases from unspecified suppliers.

11.5 ^{232}Th in A1

In total 24 results were submitted for ^{232}Th ; of those, 21 were in agreement with the AV. The adopted measurement techniques were provided by 20 of the 24. This year's results included analysis by gamma spectrometry, alpha spectrometry and non-radiometric techniques including both ICP-MS and ICP-OES. Of those measurements, 11 were by alpha spectrometry 3 by gamma spectrometry, 5 by ICP-MS and 1 by ICP-OES.

A range of separation methods were reported, including ion-exchange chromatography, extraction chromatography and precipitation for samples being measured by alpha spectrometry. Gamma spectrometry of ^{232}Th was done indirectly through the ingrowth of ^{228}Ac . ICP-MS (and ICP-OES) samples were measured directly with no (or limited) sample preparation with two laboratories stating that they diluted prior to analysis.

The PMWM values reported for each method were as follows:

Alpha:	$(2.669 \pm 0.078) \text{ Bq kg}^{-1}$
Gamma:	$(2.90 \pm 0.15) \text{ Bq kg}^{-1}$
ICP-MS:	$(2.581 \pm 0.073) \text{ Bq kg}^{-1}$

The PMWM for each technique was in agreement with the AV and with the PMWM values for the other techniques. The deviation from the AV for alpha spectrometry (-2.0%) and ICP-MS (-5.3%) improved as compared to the equivalent datasets in 2017 when the deviations were -9.6% and -11.5% respectively; possibly this is due in part to the activity concentration of ^{232}Th in the A1 sample being approximately 4 times higher than in 2017. Also, the deviation for ICP-MS may be due in part to matrix effects (for example, the use of non-matrix matched standards). The gamma spectrometry PMWM showed the largest deviation from the AV (6.6%).

11.6 ^{238}Pu in A1

In total 26 results were submitted for ^{238}Pu in A1, with 23 results being in agreement with the AV. All laboratories who reported methods stated that they used alpha spectrometry, with most opting for ^{242}Pu as a tracer with the exception of one laboratory who opted for ^{236}Pu . Three standards providers were cited: NPL, NIST and Eckert and Ziegler. Some standards providers were not specified. Separation prior to measurement by alpha spectrometry was achieved using either ion-exchange or extraction chromatography. All laboratories that reported techniques opted to prepare sources using electrodeposition with two laboratories opting to use precipitation procedures as well.

11.7 ^{241}Am in A1

In total 30 results were submitted for ^{241}Am in A1; 22 were in agreement with the AV. Measurement techniques were provided by 25 of the 30 laboratories; 19 used alpha spectrometry and 6 used gamma spectrometry. The alpha spectrometry results show a significantly low bias (-6.9%) with a high spread (-52% to +24%), whilst the gamma spectrometry show a high bias (5.7%) with a smaller spread (-3% to +21%).

Alpha: $(7.14 \pm 0.12) \text{ Bq kg}^{-1}$
 Gamma: $(8.11 \pm 0.29) \text{ Bq kg}^{-1}$

The PMWM values obtained for the alpha spectrometry results and the gamma spectrometry results were not in statistical agreement.

11.8 ^{14}C in B1

In total, 25 results were submitted for this nuclide, with only 16 agreeing with NPL, a lower level of performance than in the 2017 PTE. The spread of the data is of concern (e.g. the deviations of the 6 highest results were in the range +33% to +306%). It is worth noting there is no apparent bias between the AV and the PMWM. All participants who reported a method used LSC; precipitation and combustion methods were often cited for sample pre-treatment. One participant each cited using standards from Amersham International, Cerca LEA, Eckert and Ziegler and G E Healthcare, two cited Perkin Elmer standards and four cited non-specified standards. Insufficient information was provided to explain the questionable or discrepant results.

11.9 ^{129}I in B1

Twenty-two results were returned for this nuclide, with only 11 being in agreement with NPL. Four participants reported using LSC and twelve used gamma spectrometry; many of the latter reported using a mixed gamma standard to calibrate their detector.

The PMWM values of the reported results for each method were as follows:

LSC: $(0.323 \pm 0.045) \text{ Bq g}^{-1}$
 Gamma: $(0.4501 \pm 0.0030) \text{ Bq g}^{-1}$

The gamma emission of ^{129}I at 40 keV is lower in energy than common calibration radionuclides such as ^{241}Am (60 keV) and ^{210}Pb (47 keV). The higher results obtained by gamma spectrometry could be as a result of extrapolation beyond the lowest efficiency calibration point; this practice is discouraged in BS ISO 20042:2019.

11.10 Gross alpha and gross beta results for AB, A1 and B1

In each case, the PMWM of the submitted results was calculated. Due to the large uncertainty on the PMWM of the reported values for gross beta activity in Sample Type B1, it was decided not to declare an Assigned Value for this quantity. For the other quantities (gross alpha in AB and gross alpha in A1), the PMWM was adopted as the AV.

For AB gross beta, 10 results were submitted (6 being in agreement with the AV) and the spread of results was very wide. In interpreting this dataset, it should be noted that NPL did not specify a standard method for gross beta analysis and the participants were free to use

any method they wished. In four cases, participants reported using proportional counters or GM counters (some calibrated using ^{90}Sr / ^{90}Y or ^{137}Cs standards) whereas in three cases LSC was used. Three other participants did not state the method used. The LSC results were all significantly higher than the PMWM, but this may be because the dataset was dominated by proportional counter / GM results; when LSC is used, the sensitivity to the lower-energy betas will be greater, and one would expect a result similar to the summed AVs of all the nuclides present (taking detection efficiencies into account), and this may explain at least one of the discrepant results observed.

11.11 Sample Types GH, GL and C2

All measurements were carried out using high-resolution gamma spectrometry. One participant measured ^{210}Pb in GL using a low-level beta counter and obtained a questionable result; another used acid digestion and fusion to pre-treat C2 prior to ^{137}Cs measurement and obtained a discrepant result. Participants calibrated their detectors using mixed radionuclide standards from CERCA LEA, CMI, Eckert and Ziegler, INER, NPL, or from unspecified suppliers. Four participants used Mirion Technologies' 'LabSOCS' calibration software.

Twenty-eight datasets were submitted for GH. The numbers of results in agreement with the AV by nuclide were: ^{54}Mn (25 out of 28 results submitted), ^{60}Co (24 out of 28), ^{65}Zn (23 out of 28) and ^{133}Ba (23 out of 27).

For GL, 33 datasets were submitted. The numbers of results in agreement with the AV by nuclide were: ^{85}Sr (5 out of 17 results submitted), ^{134}Cs (25 out of 32), ^{137}Cs (30 out of 33) and ^{210}Pb (10 out of 21). The radionuclide ^{210}Pb is difficult to measure at low energies due to the high presence in background, the need to extrapolate from ^{241}Am in most cases, and matrix/density corrections required compared with the standard. Measurement of ^{85}Sr may be biased by interference from the 511 keV annihilation radiation, although this effect tends to lead to underestimates of the ^{85}Sr activity rather than the overestimates observed.

Very little information on methods and standards was reported for the C2 sample. The results in agreement with the AV by nuclide were: ^{60}Co (16 out of 20 results submitted), ^{137}Cs (17 out of 21), ^{152}Eu (15 out of 20) and ^{154}Eu (16 out of 19).

12. REFERENCES

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APPENDIX – DATA FOR RADIONUCLIDES IN C2 OTHER THAN GAMMA EMITTERS

Table 9 C2 nuclides summary

Nuclides	PMWM (Bq g ⁻¹)
³ H	29.0 ± 2.0
¹⁴ C	0.225 ± 0.014
²³⁶ U	No data reported
²³⁸ U	0.01168 ± 0.00097

