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ENVIRONMENTAL RADIOACTIVITY PROFICIENCY TEST EXERCISE 2015

JULIAN DEAN, PARIS AITKEN-SMITH, SEAN COLLINS, MARIA GARCIA MIRANDA AND SELINA WOODS

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Environmental Radioactivity Proficiency Test Exercise 2015

Julian Dean, Paris Aitken-Smith, Sean Collins, Maria Garcia Miranda and Selina Woods
Acoustics and Ionising Radiation Division

ABSTRACT

The results of NPL's twenty-first Environmental Radioactivity Proficiency Test Exercise are reported. Six different sample types were offered: an aqueous mixture of two alpha emitters and two beta emitters (designated 'AB'), an aqueous mixture of four 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 powdered cement sample containing a mixture of α-emitting, β-emitting and γ-emitting radionuclides ('C1'). A total of 467 results were submitted; 450 of the results were analysed, and of these 76 % were in agreement with the Assigned Values.

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National Physical Laboratory
Hampton Road, Teddington, Middlesex, TW11 0LW

Approved on behalf of NPLML by Steven Judge, Radioactivity Group Leader,
Acoustics and Ionising Radiation Division

Assigned Values

Nuclide (AB)	Assigned Value (Bq g^{-1})
^{63}Ni	5.30 ± 0.12
^{90}Sr	9.546 ± 0.084
^{239}Pu	1.3347 ± 0.0058
^{241}Am	5.034 ± 0.022
^{244}Cm	10.778 ± 0.078
Gross alpha	18.3 ± 3.0
Gross beta	19.3 ± 2.2
Nuclide (A1)	**Assigned Value (Bq kg^{-1})**
^{232}Th	4.025 ± 0.076
^{234}U	15.22 ± 0.52
^{235}U	0.727 ± 0.030
^{238}U	15.22 ± 0.52
Gross alpha	40.5 ± 3.6
Nuclide (B1)	**Assigned Value (Bq g^{-1})**
^{3}H	1.898 ± 0.048
^{14}C	1.015 ± 0.013
^{99}Tc	0.5377 ± 0.0096
Nuclide (GH)	**Assigned Value (Bq g^{-1})**
^{65}Zn	17.52 ± 0.26
^{134}Cs	3.390 ± 0.048
^{137}Cs	9.26 ± 0.13
^{154}Eu	12.93 ± 0.20
Nuclide (GL)	**Assigned Value (Bq kg^{-1})**
^{60}Co	9.937 ± 0.052
^{210}Pb	3.362 ± 0.070
^{241}Am	17.623 ± 0.078
Nuclide (C1)	**Assigned Value (Bq g^{-1})**
^{137}Cs	66.8 ± 1.7

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.

CONTENTS

1. SUMMARY

This environmental radioactivity Proficiency Test Exercise (PTE) was the twenty-first in a series of such exercises run by NPL over the last 27 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 2015 PTE:

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

(ii) **A1:** a mixture of four α-emitting radionuclides
500 g of dilute nitric acid (0.5 – 25 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 three γ-emitting radionuclides
500 g of dilute nitric acid (1 – 20 Bq kg^{-1} per radionuclide)

(vi) **C1**: a powdered cement sample containing a mixture of α-emitting, β-emitting and γ-emitting radionuclides
100 g (up to 200 Bq g^{-1} per radionuclide)

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 concentrations 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 activity concentrations of the radionuclides in the aqueous sample types were traceable to national standards of radioactivity, which in turn provide traceability at an international level to the ultimate reference point of all measurements (the SI reference value maintained by the Bureau International des Poids et Mesures (BIPM)).

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 concentrations. 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 concentration of the original standard solution by the dilution factor(s). The bulk solution was subdivided into (typically) 40 bottles and homogeneity was checked by gamma spectrometry where applicable. Solution

stability was checked by counting one or more bottles at NPL at regular intervals throughout the course of the PTE.

The Power-Moderated Weighted Mean (PMWM) (Pommé, 2012) of the participants' values for each nuclide (and for combined nuclides) in the aqueous sample types was also calculated. This method can provide an efficient and robust mean from any data set. 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 bulk cement sample consisted of contaminated material of low activity concentration procured from a waste management facility (the donor organisation is confidential). At NPL, the bulk sample was milled and sieved to a particle size of < 0.3 mm before being homogenised and divided into sub-samples in 100 ml plastic bottles. The homogeneity of the batch was determined by gamma spectrometry. Selected sub-samples were analysed by gross alpha and gross beta counting, and by radiochemical separations followed by alpha spectrometry. The results of these analyses were used only to derive guideline activity concentrations for the participants. After receipt of the results from the participants, the PMWM was calculated for each nuclide / nuclide type and a decision was made in each case as to whether or not to use the PMWM as the Assigned Value.

Note that the analysis of participants' data for measurements other than gamma measurements for Sample Type C1 does not fall under the scope of NPL's current accreditation to ISO17043 for solid samples.

PMWM values of participants' results were also calculated for each of the following, and a decision made in each case as to whether or not to use the PMWM as the Assigned Value:

- Sample Type AB gross alpha
- Sample Type AB gross beta
- Sample Type A1 gross alpha
- Sample Type B1 gross beta

The NPL data analysis method is described in Section 2 and the Assigned Values and PMWM values are summarised in Section 3 (except for 'non-gamma' measurements for Sample Type C1, which are summarised in Appendix 1).

Note that, unless otherwise stated, all uncertainties quoted in this report are standard uncertainties multiplied by 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 2014 exercise (Dean et al., 2015). The deviation 'D' from the assigned value from each laboratory value was calculated from:

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

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

$$u_{\mathrm{D}} = \frac{L}{N}\sqrt{\left(\frac{u_{\mathrm{L}}}{L}\right)^2 + \left(\frac{u_{\mathrm{N}}}{N}\right)^2} \qquad [2]$$

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

$$\zeta = \frac{L - N}{\sqrt{u_{\mathrm{L}}^2 + u_{\mathrm{N}}^2}} \qquad [3]$$

$$R_L = \frac{u_{\mathrm{L}}}{L} \qquad [4]$$

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

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 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}. The factor of 0.05823 used to calculate the *z*-score is the ratio of 0.15 (i.e. a deviation of 15%) to 2.576. In other words, a participant value with a deviation *D* having an absolute value of ≤ 15% will pass the *z*-test.

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

Table 2 AB summary

Nuclide (AB)	NPL Assigned Values (Bq g^{-1})	PMWM (Bq g^{-1})	Deviation %	Zeta	Critical Value
^{63}Ni	5.298 ± 0.058	5.00 ± 0.62	-5.6	-0.47	3.11
^{90}Sr	9.546 ± 0.042	9.52 ± 0.12	-0.2	-0.18	2.82
^{239}Pu	1.3347 ± 0.0029	1.380 ± 0.017	3.4	2.69	2.88
^{241}Am	5.034 ± 0.011	5.118 ± 0.055	1.7	1.50	2.86
^{244}Cm	10.778 ± 0.039	10.59 ± 0.25	-1.7	-0.72	2.88

Table 3 A1 summary

Nuclide (AL)	NPL Assigned Values (Bq kg^{-1})	PMWM (Bq kg^{-1})	Deviation %	Zeta	Critical Value
^{232}Th	4.025 ± 0.038	3.807 ± 0.099	-5.4	-2.06	2.90
^{234}U	15.22 ± 0.26	15.30 ± 0.15	0.5	0.26	2.58
^{235}U	0.727 ± 0.015	0.680 ± 0.017	-6.6	-2.09	2.66
^{238}U	15.22 ± 0.26	15.38 ± 0.15	1.0	0.52	2.58

Table 4 B1 summary

Nuclide (B1)	NPL Assigned Values (Bq g^{-1})	PMWM (Bq g^{-1})	Deviation %	Zeta	Critical Value
^{3}H	1.898 ± 0.024	1.867 ± 0.017	-1.6	-1.07	2.58
^{14}C	1.0146 ± 0.0066	1.014 ± 0.015	0.0	-0.01	2.85
^{99}Tc	0.5377 ± 0.0048	0.5151 ± 0.0089	-4.2	-2.23	2.77

Table 5 GH summary

Nuclide (GH)	NPL Assigned Values (Bq g^{-1})	PMWM (Bq g^{-1})	Deviation %	Zeta	Critical Value
^{65}Zn	17.52 ± 0.13	17.78 ± 0.20	1.5	1.14	2.67
^{134}Cs	3.390 ± 0.024	3.239 ± 0.037	-4.5	-3.46	2.68
^{137}Cs	9.264 ± 0.066	9.269 ± 0.063	0.0	0.05	2.58
^{154}Eu	12.93 ± 0.10	12.59 ± 0.13	-2.6	-2.04	2.65

Table 6 GL summary

Nuclide (GL)	NPL Assigned Values (Bq kg^{-1})	PMWM (Bq kg^{-1})	Deviation %	Zeta	Critical Value
^{60}Co	9.937 ± 0.026	9.99 ± 0.16	0.5	0.34	2.80
^{210}Pb	3.362 ± 0.035	4.9 ± 1.4	44.3	1.09	3.11
^{241}Am	17.623 ± 0.039	17.990 ± 0.300	2.1	1.23	2.78

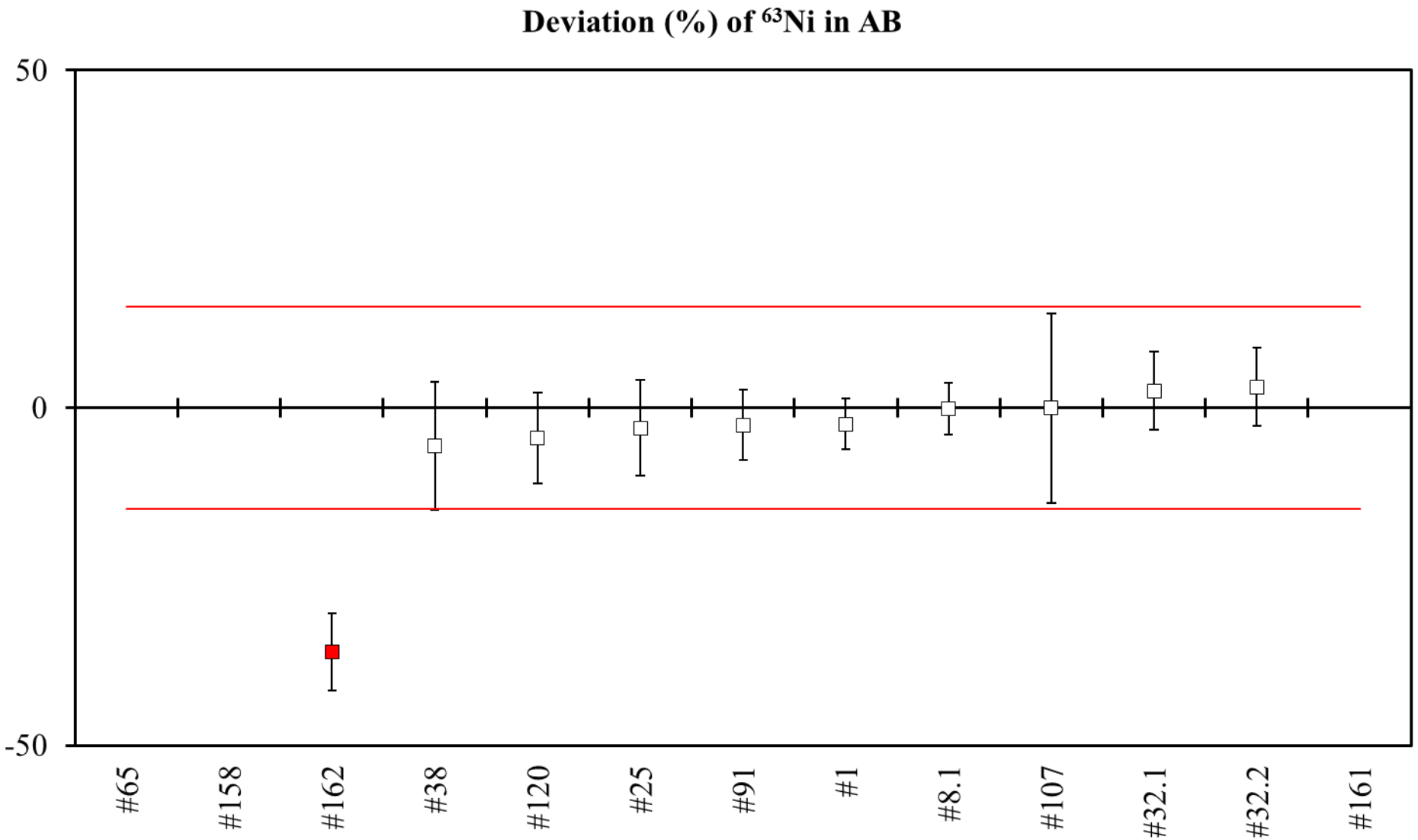
Table 7 C1 summary (^{137}Cs only)

Nuclide (C1)	PMWM (Bq g^{-1})
^{137}Cs	66.81 ± 0.87

Table 8 Gross nuclide measurements summary (excluding C1)

Nuclides	PMWM
Gross alpha (AB)	(18.3 ± 1.5) Bq g^{-1}
Gross beta (AB)	(19.3 ± 1.1) Bq g^{-1}
Gross alpha (A1)	(40.5 ± 1.8) Bq kg^{-1}
Gross beta (B1)	Value not used (see Section 11)

4. Alpha Beta (AB) Deviation Plots


Deviation (%) of 63Ni in AB
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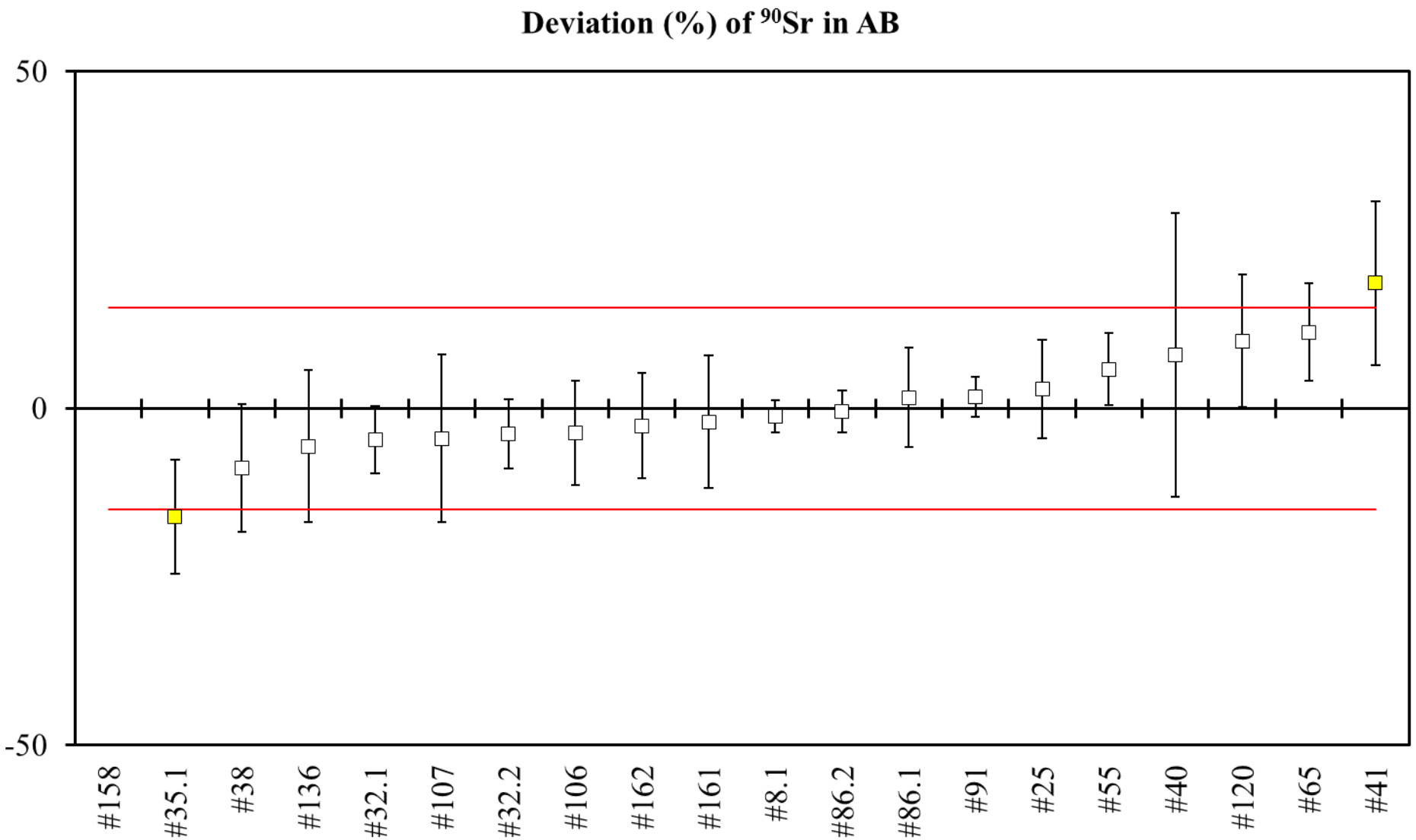
#107
#32.1
#32.2
#161


Deviation (%) of 90Sr in AB
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#35.1
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#32.2
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#161
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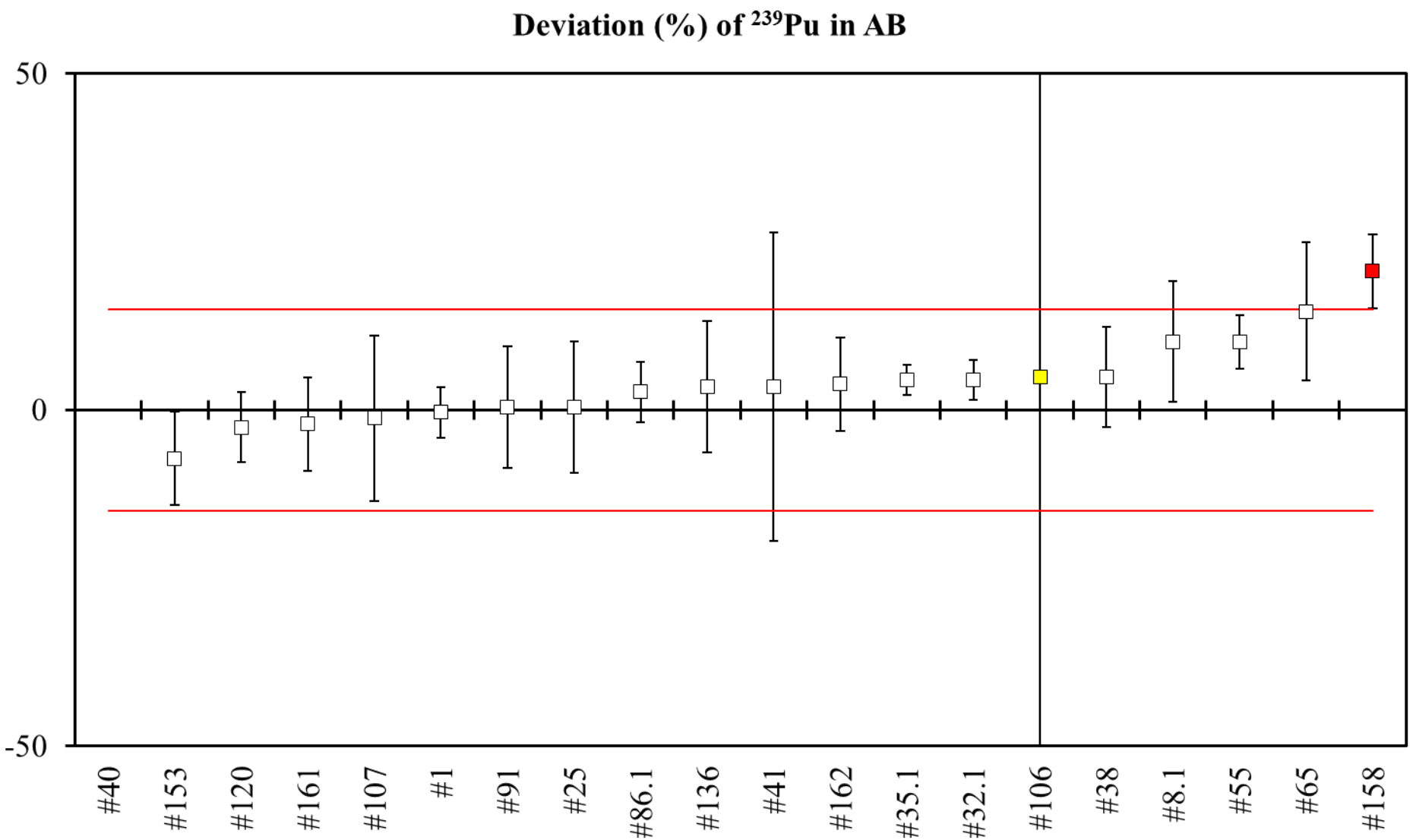
#86.2
#86.1
#91
#25
#55
#40
#120
#65
#41


Deviation (%) of 239Pu in AB
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#120
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#107
#1
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#25
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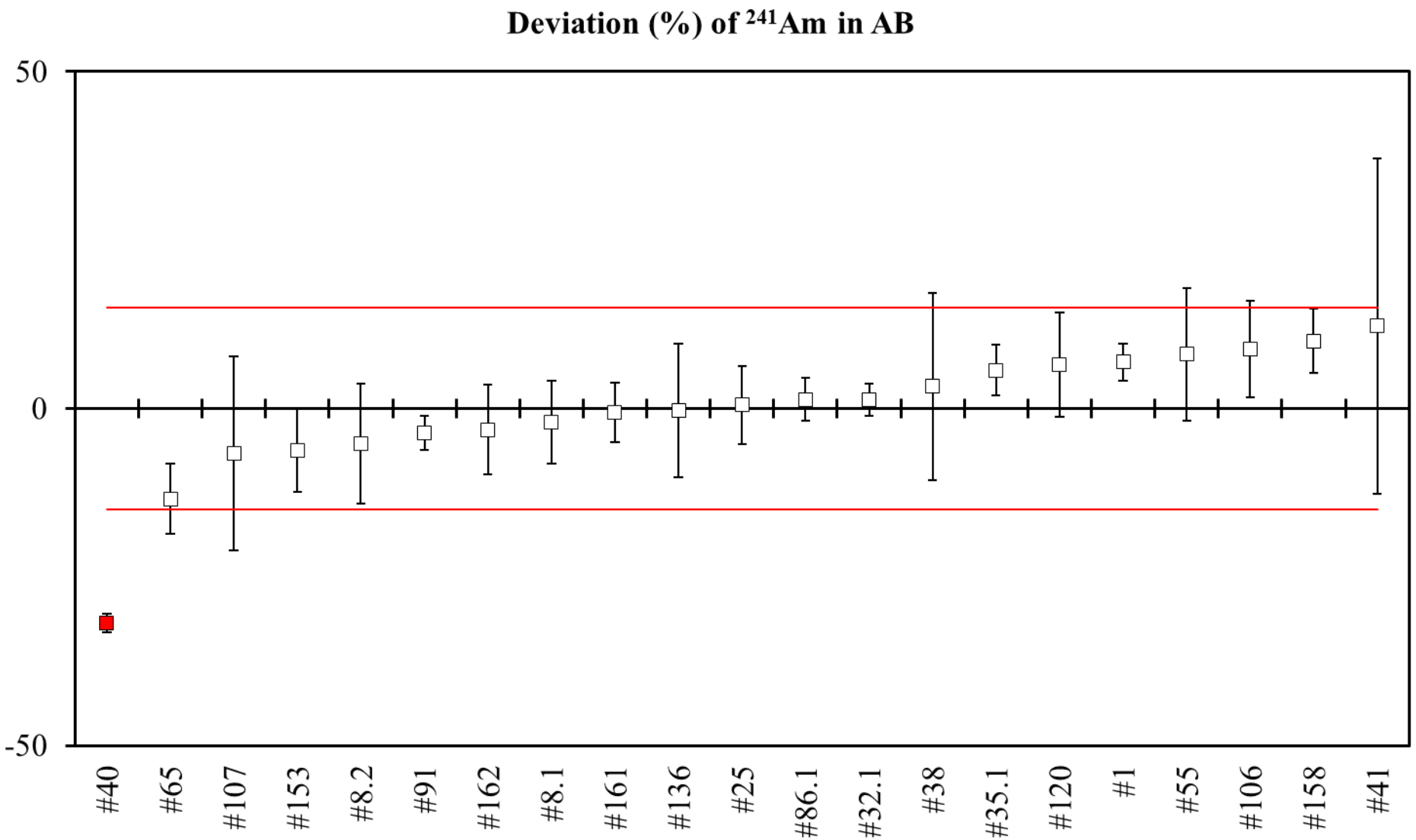
#136
#41
#162
#35.1
#32.1
#106
#38
#8.1
#55
#65
#158


Deviation (%) of 241Am in AB
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#65
#107
#153
#8.2
#91
#162
#8.1
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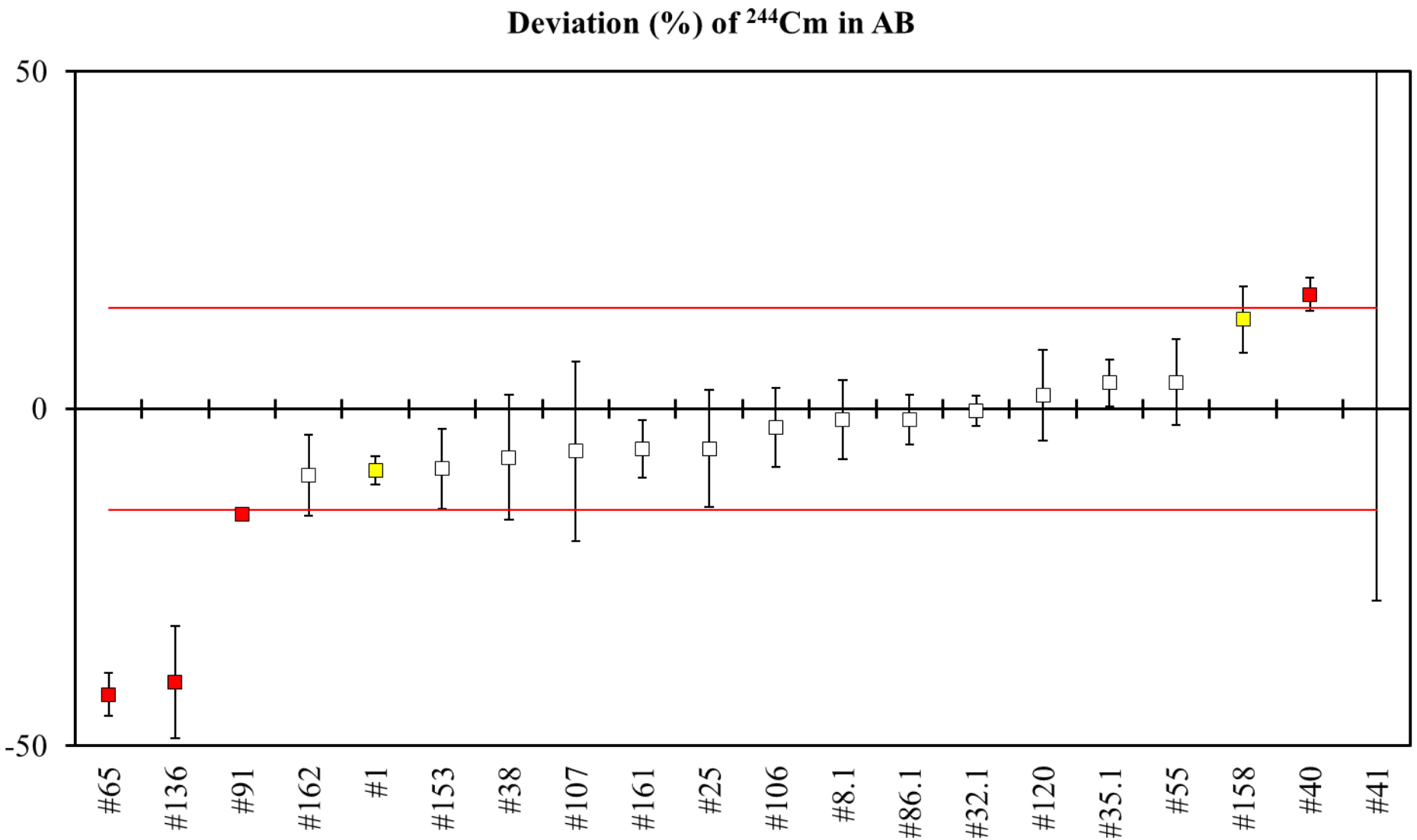
#38
#35.1
#120
#1
#55
#106
#158
#41


Deviation (%) of 244Cm in AB
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#91
#162
#1
#153
#38
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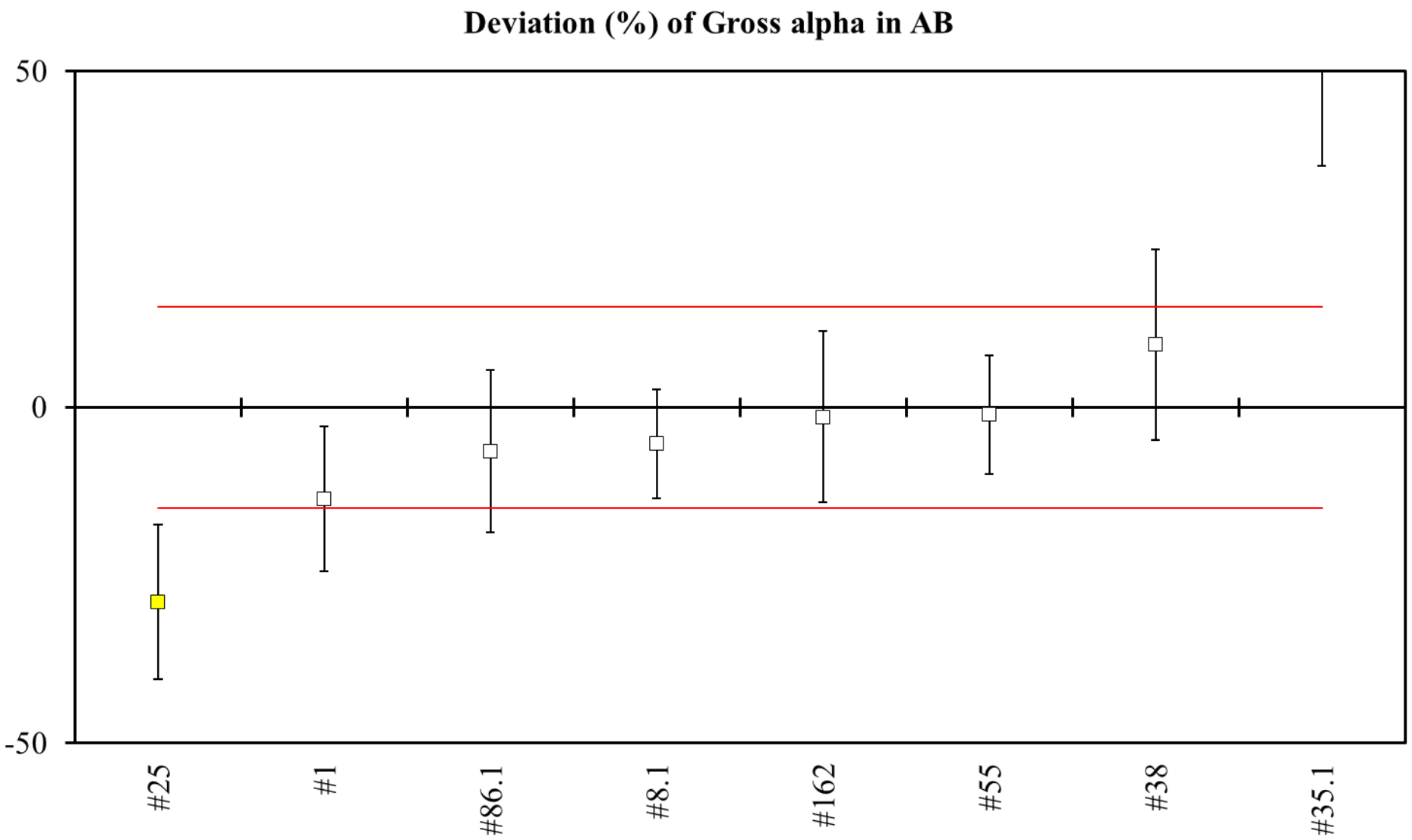
#32.1
#120
#35.1
#55
#158
#40
#41


Deviation (%) of Gross alpha in AB
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#8.1
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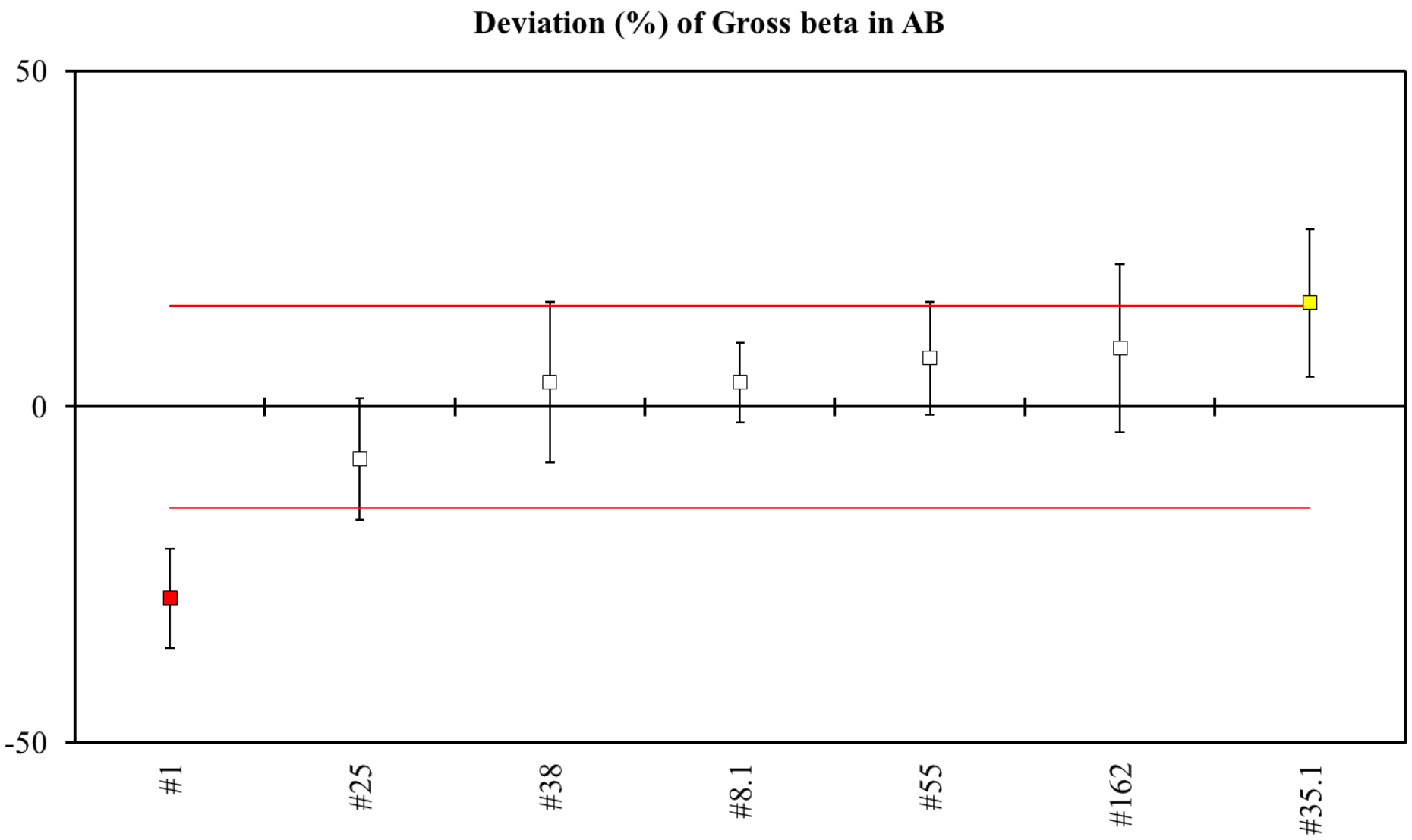
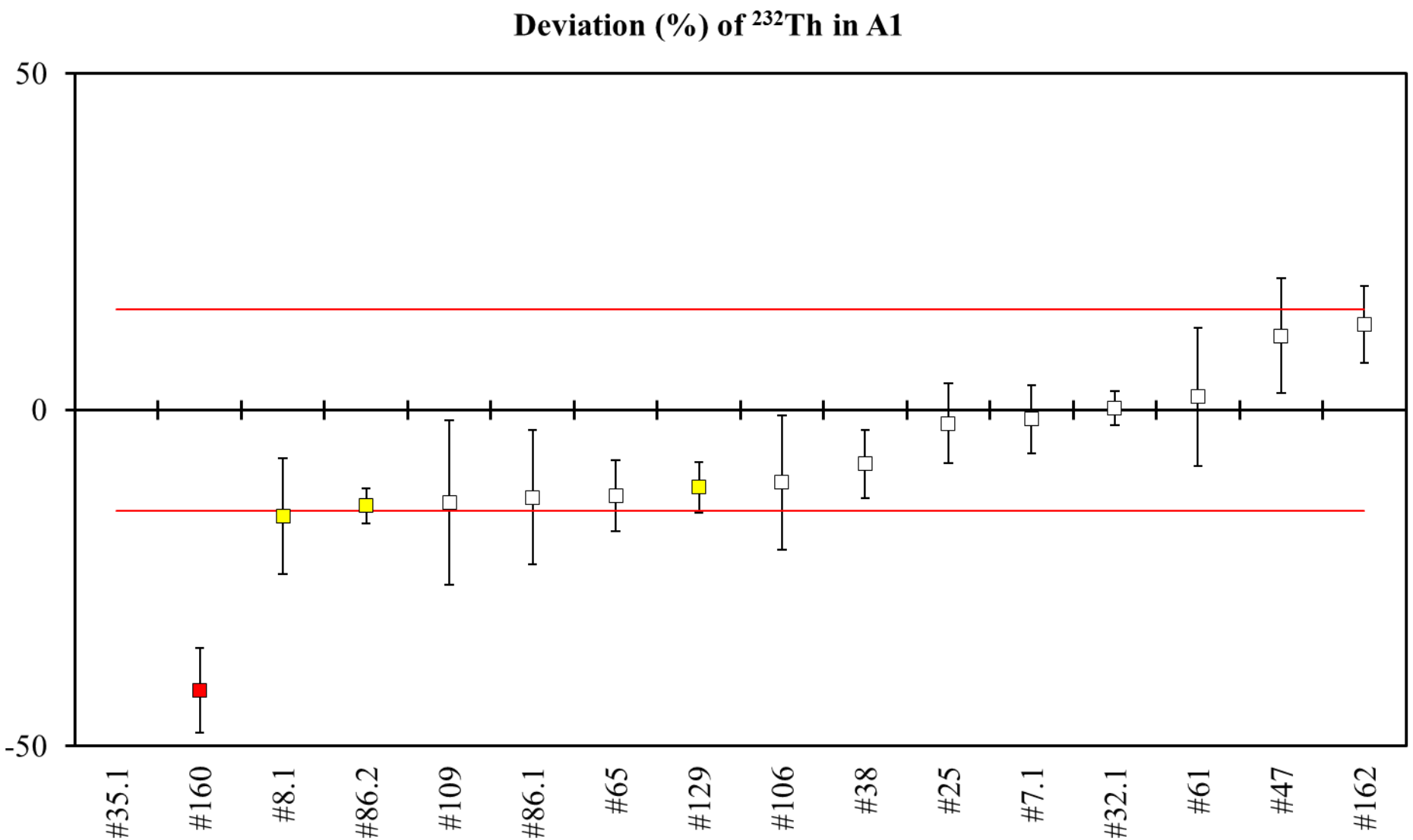
#55
#38
#35.1


Deviation (%) of Gross beta in AB
50
0
-50
#1
#25
#38
#8.1
#55
#162
#35.1

5. Alpha One (A1) Deviation Plots


Deviation (%) of 232Th in A1
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#160
#8.1
#86.2
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#86.1
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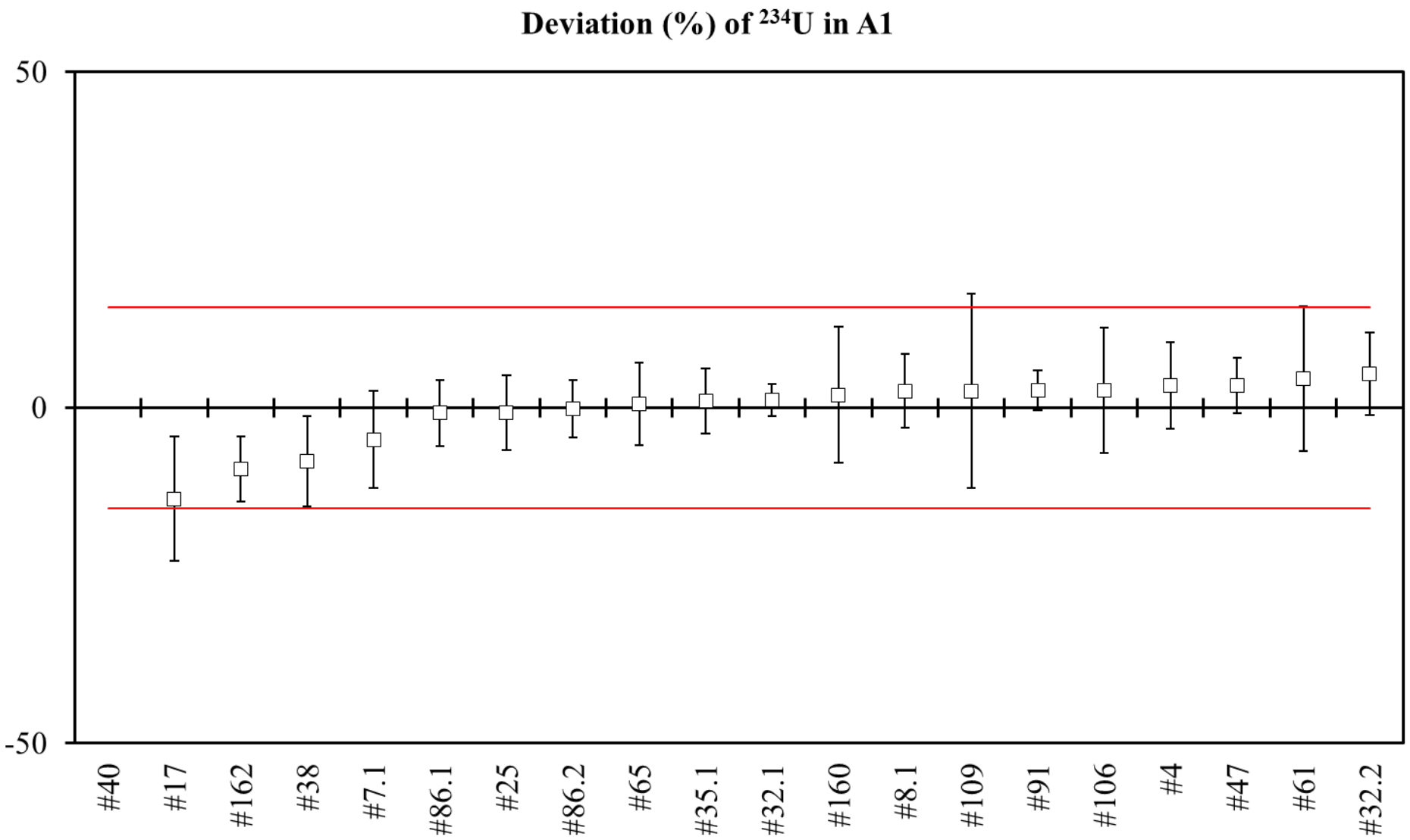
#106
#38
#25
#7.1
#32.1
#61
#47
#162


Deviation (%) of 234U in A1
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#162
#38
#7.1
#86.1
#25
#86.2
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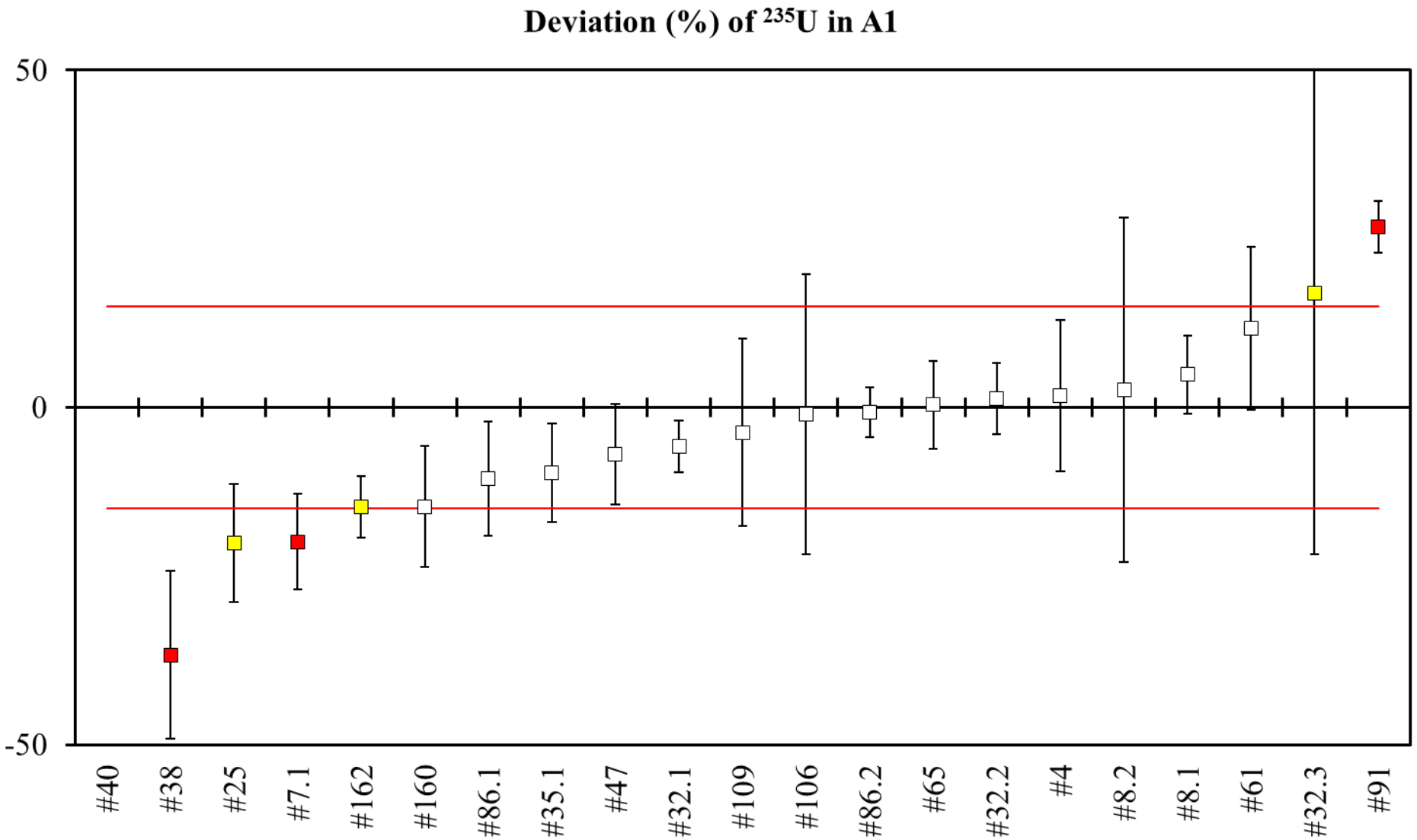
#109
#91
#106
#4
#47
#61
#32.2


Deviation (%) of 235U in A1
50
0
-50
#40
#38
#25
#7.1
#162
#160
#86.1
#35.1
#47
#32.1
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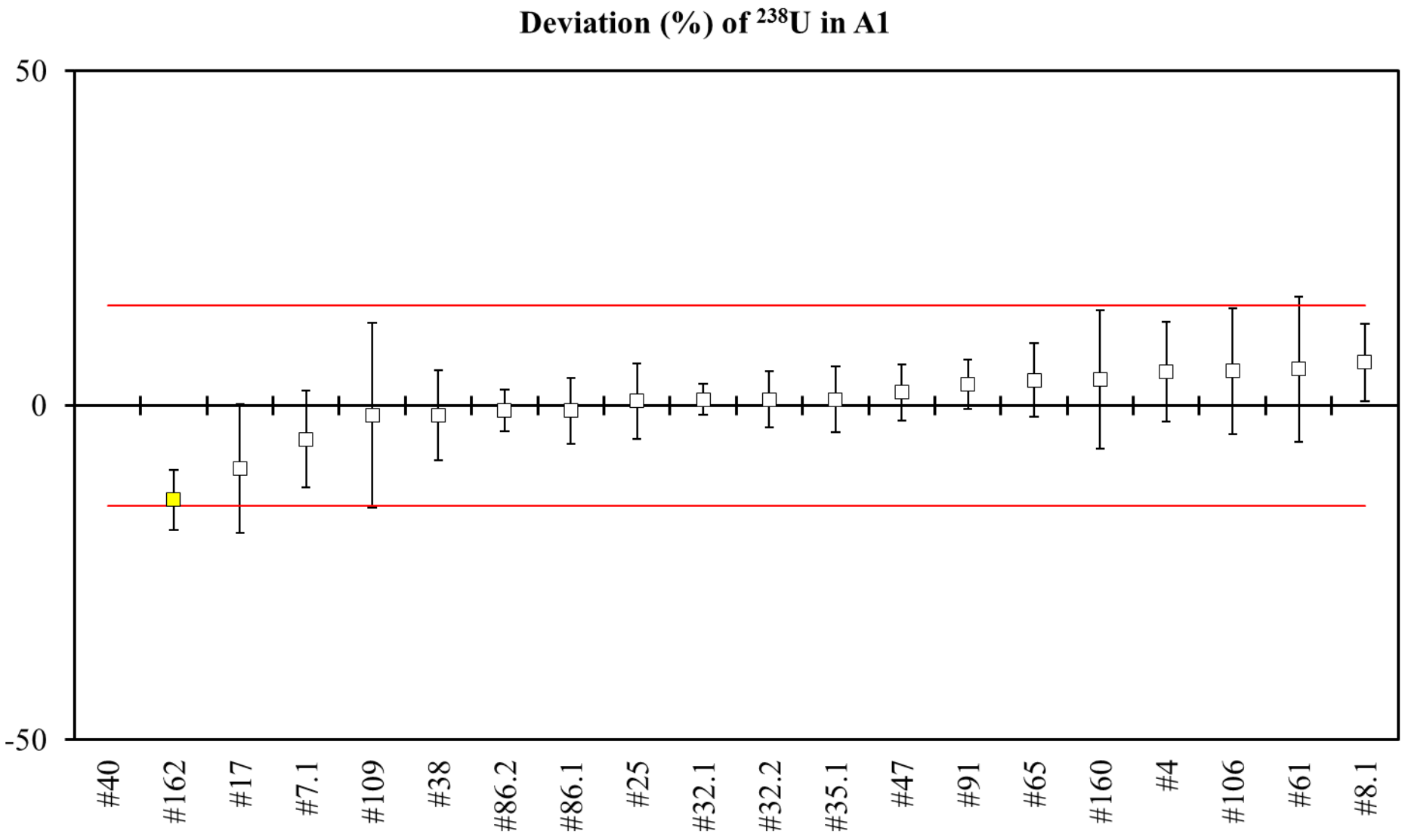
#32.2
#4
#8.2
#8.1
#61
#32.3
#91


Deviation (%) of 238U in A1
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-50
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#162
#17
#7.1
#109
#38
#86.2
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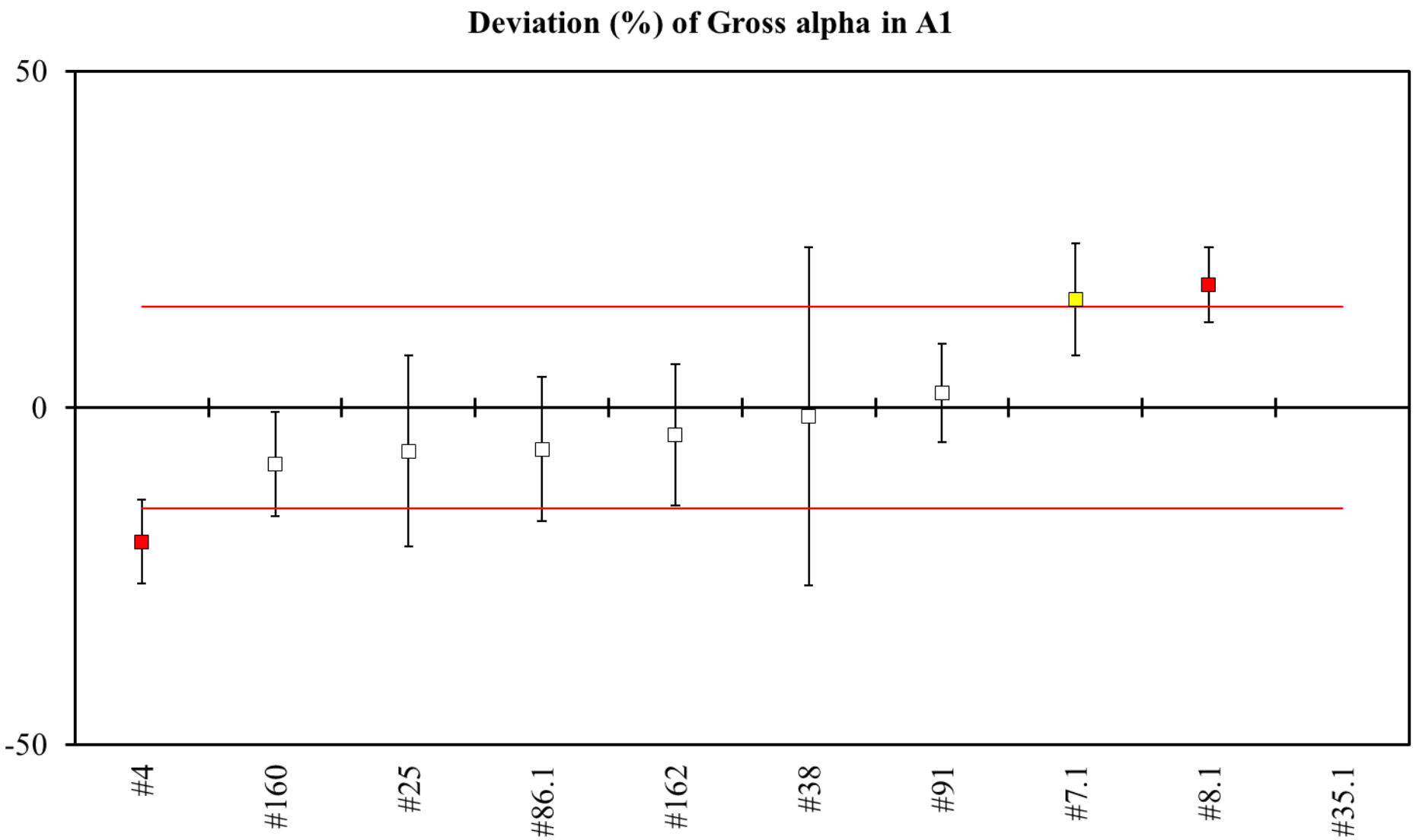
#91
#65
#160
#4
#106
#61
#8.1


Deviation (%) of Gross alpha in A1
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-50
#4
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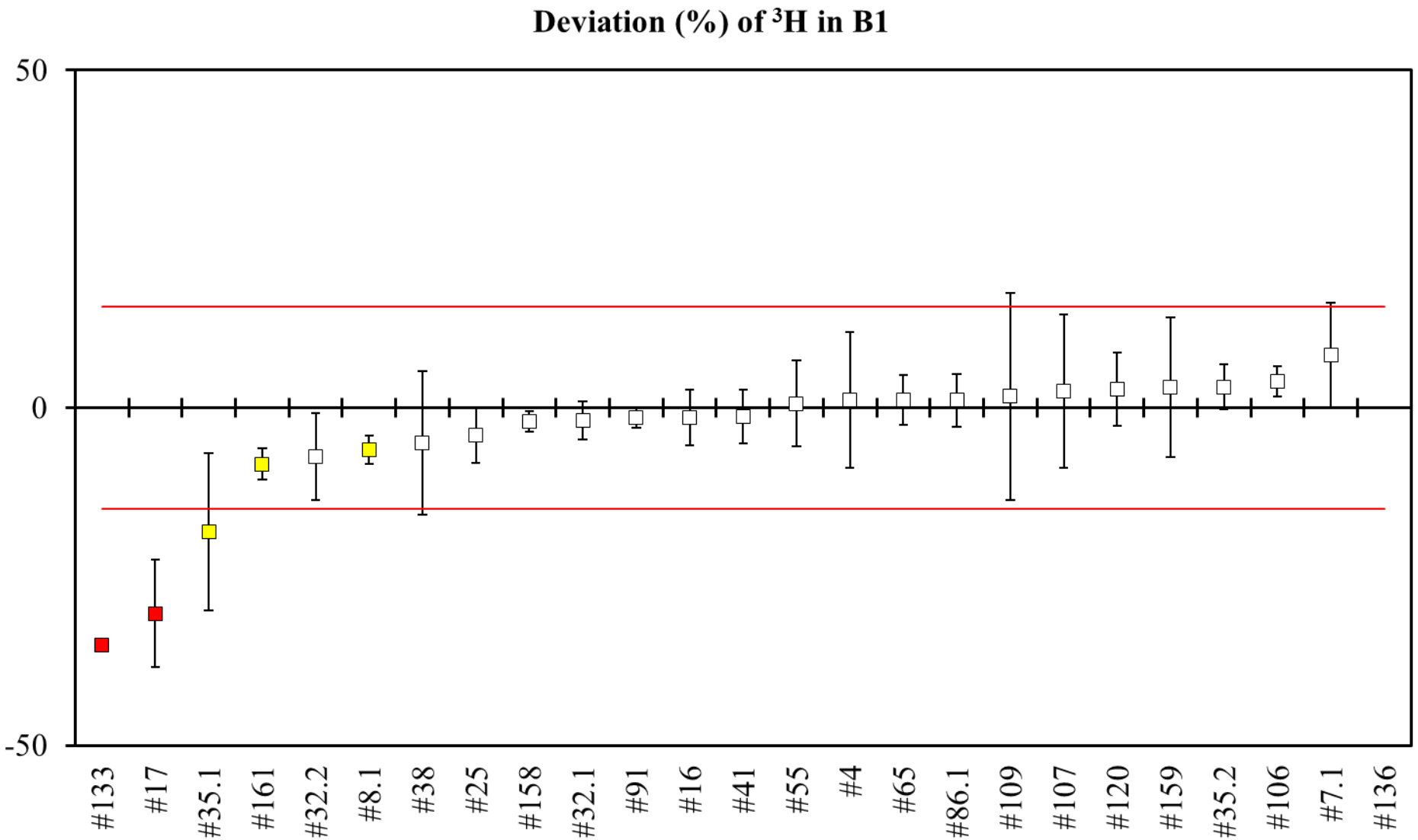
#8.1
#35.1

6. Beta One (B1) Deviation Plots


Deviation (%) of ³H in B1
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#32.2
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#32.1
#91
#16
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#120
#159
#35.2
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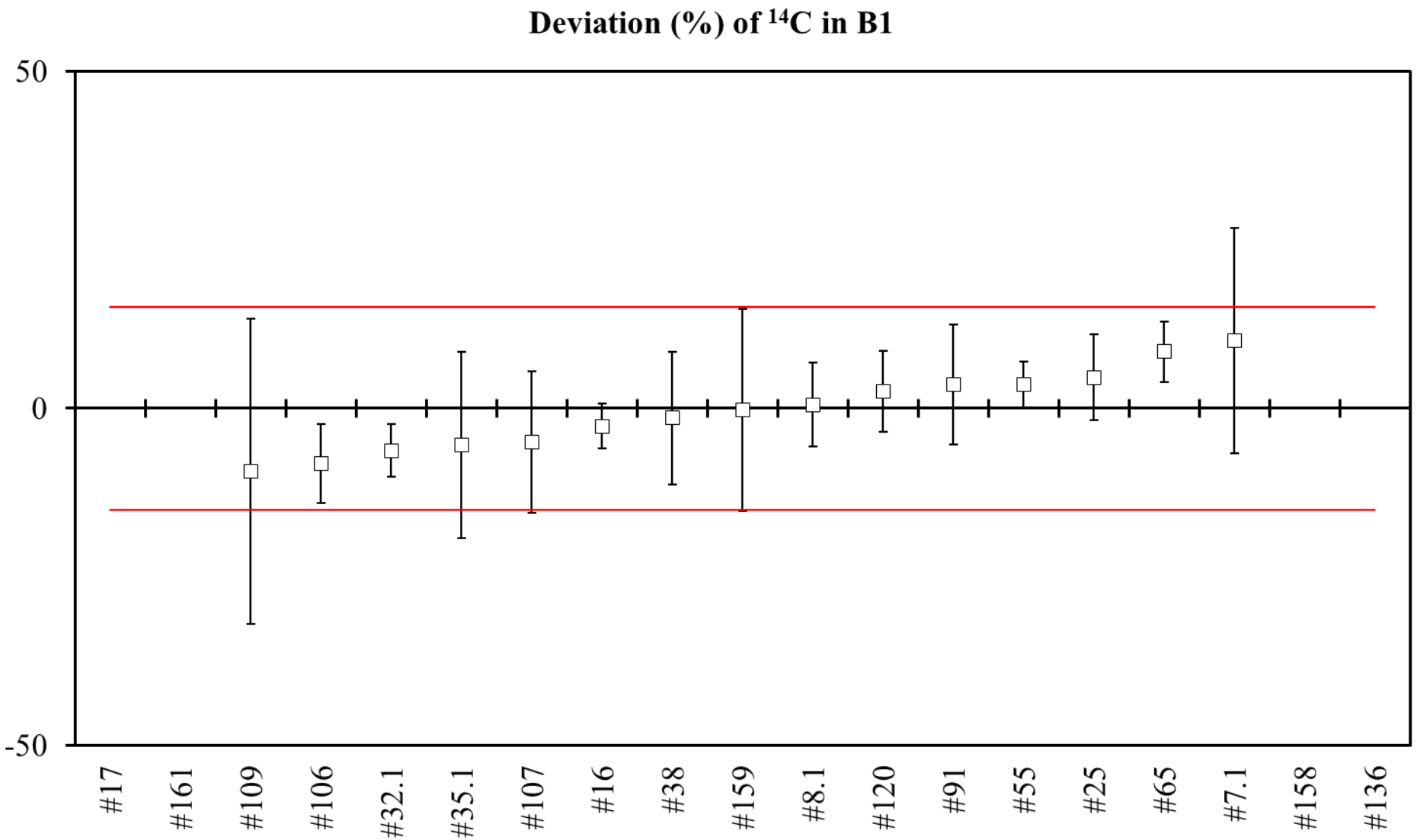
#7.1
#136


Deviation (%) of ^{14}C in B1
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0
-50
#17
#161
#109
#106
#32.1
#35.1
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#8.1
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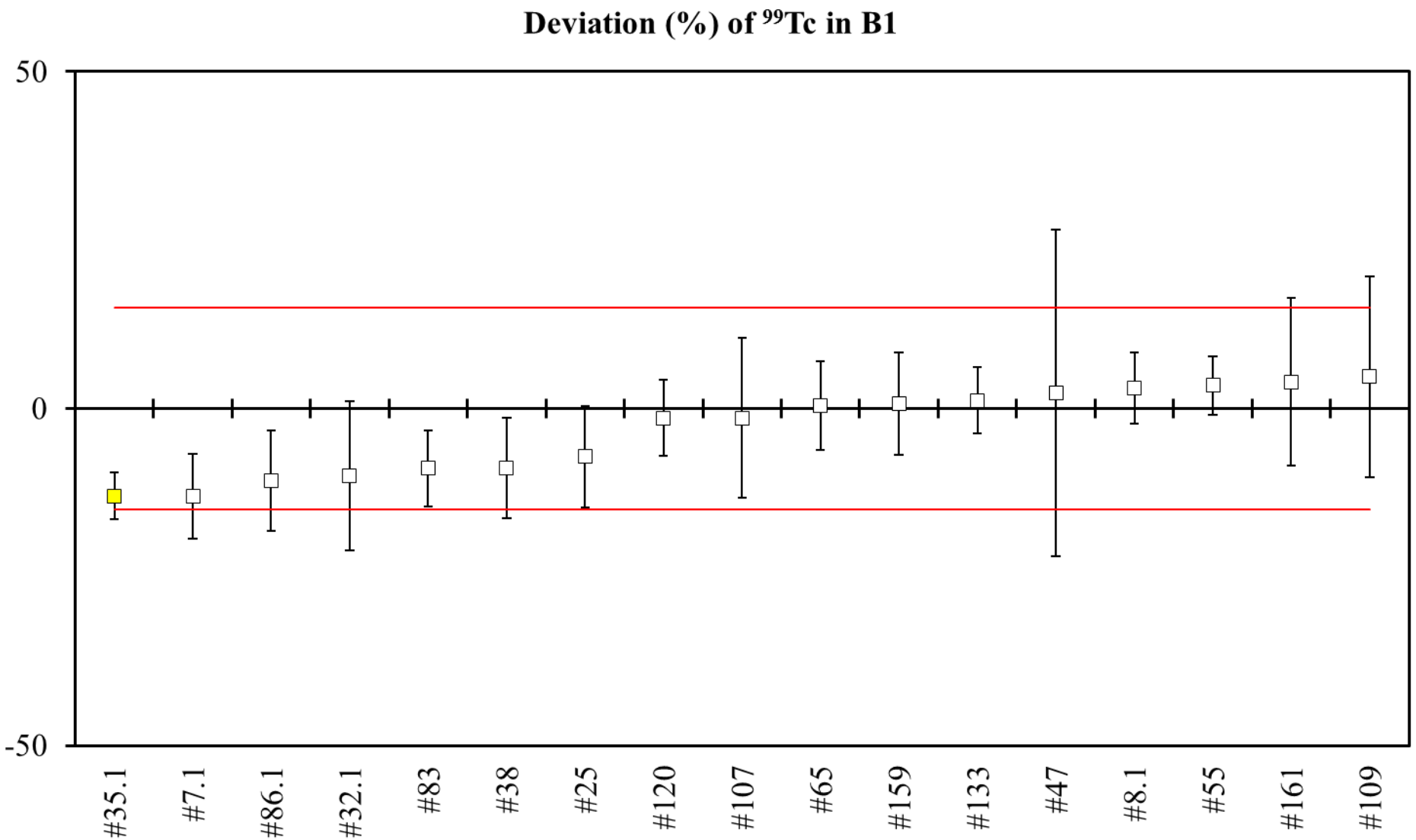
#55
#25
#65
#7.1
#158
#136


Deviation (%) of 99Tc in B1
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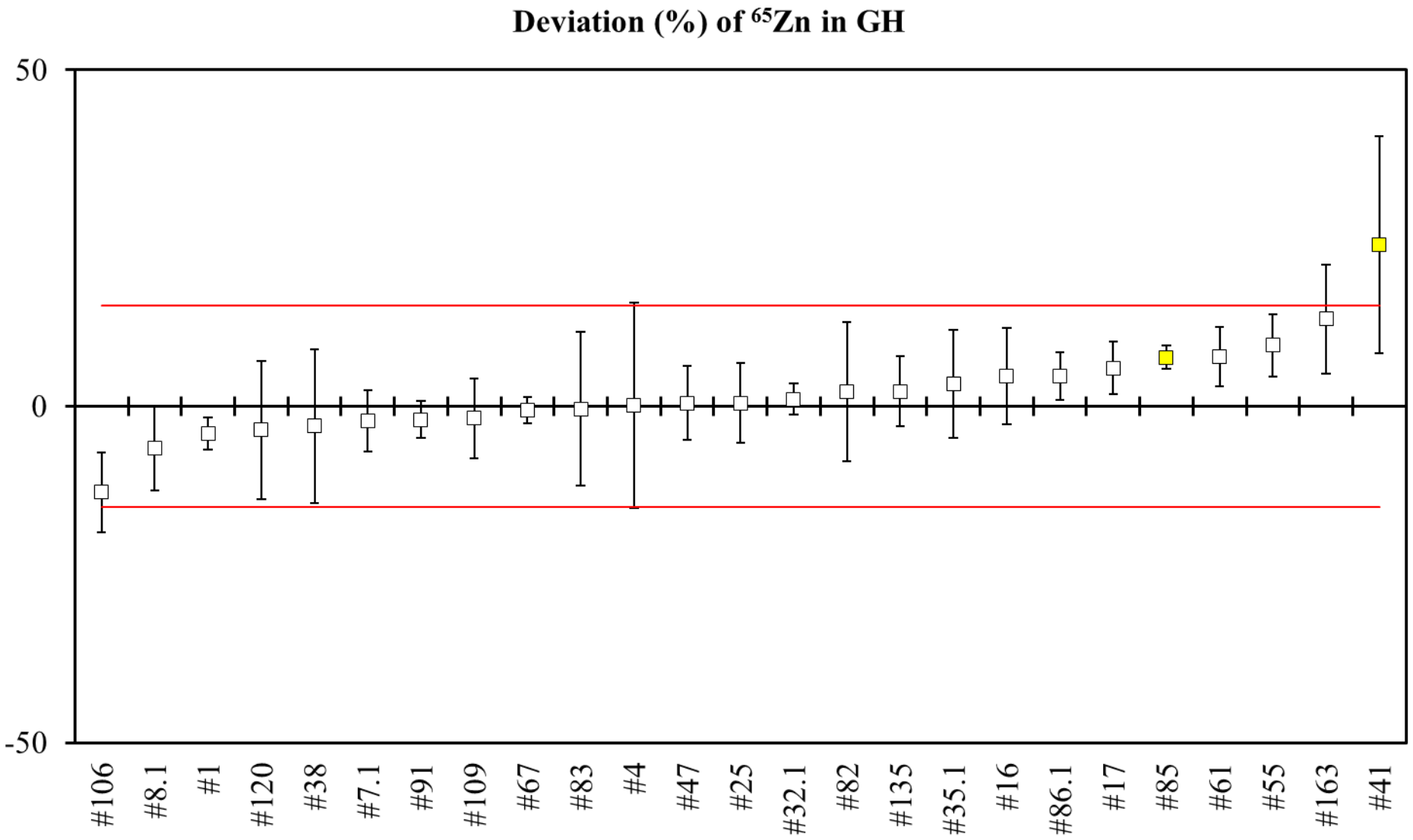
#109

7. Gamma High (GH) Deviation Plots


Deviation (%) of 65Zn in GH
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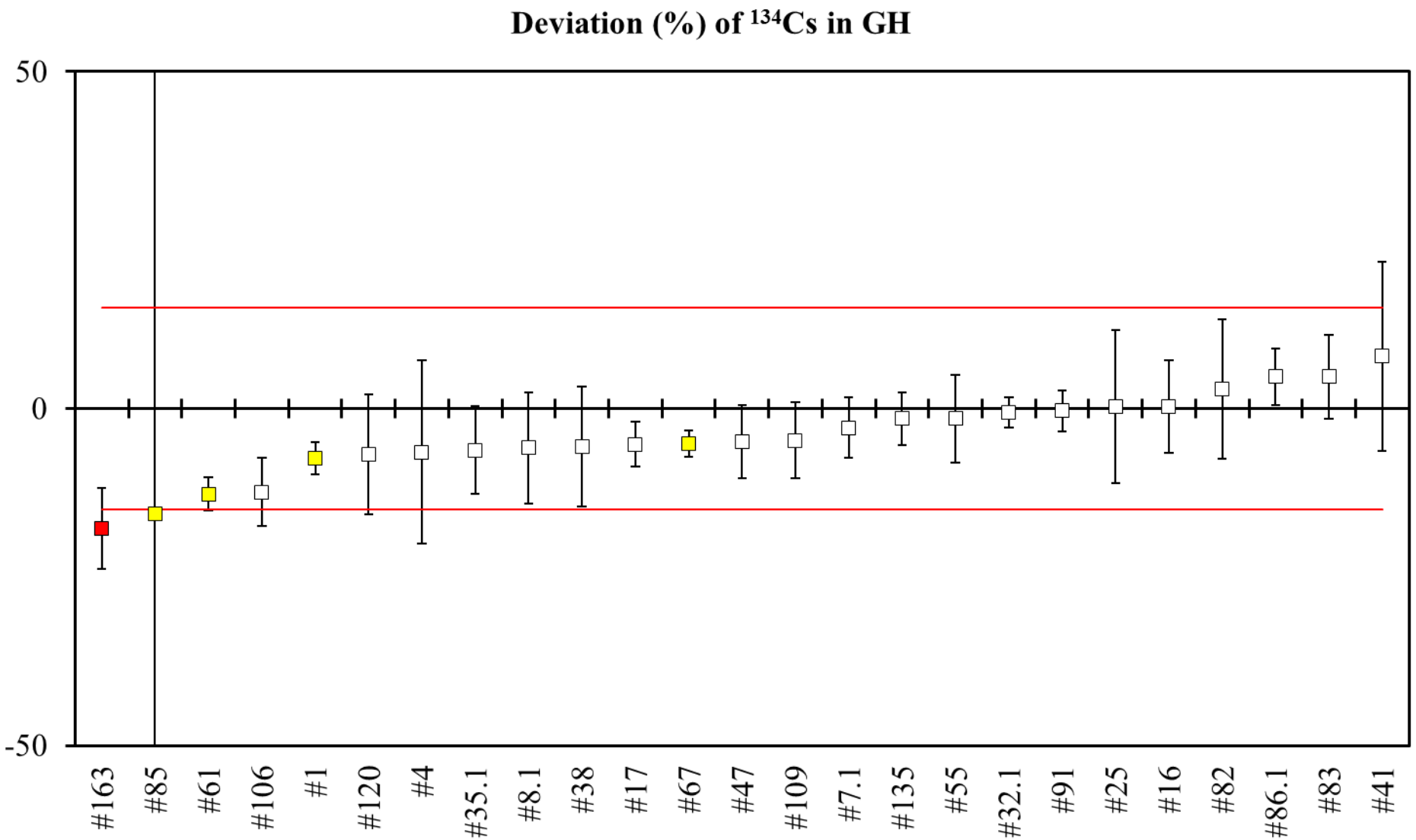
#41


Deviation (%) of 134Cs in GH
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0
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#85
#61
#106
#1
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#35.1
#8.1
#38
#17
#67
#47
#109
#7.1
#135
#55
#32.1
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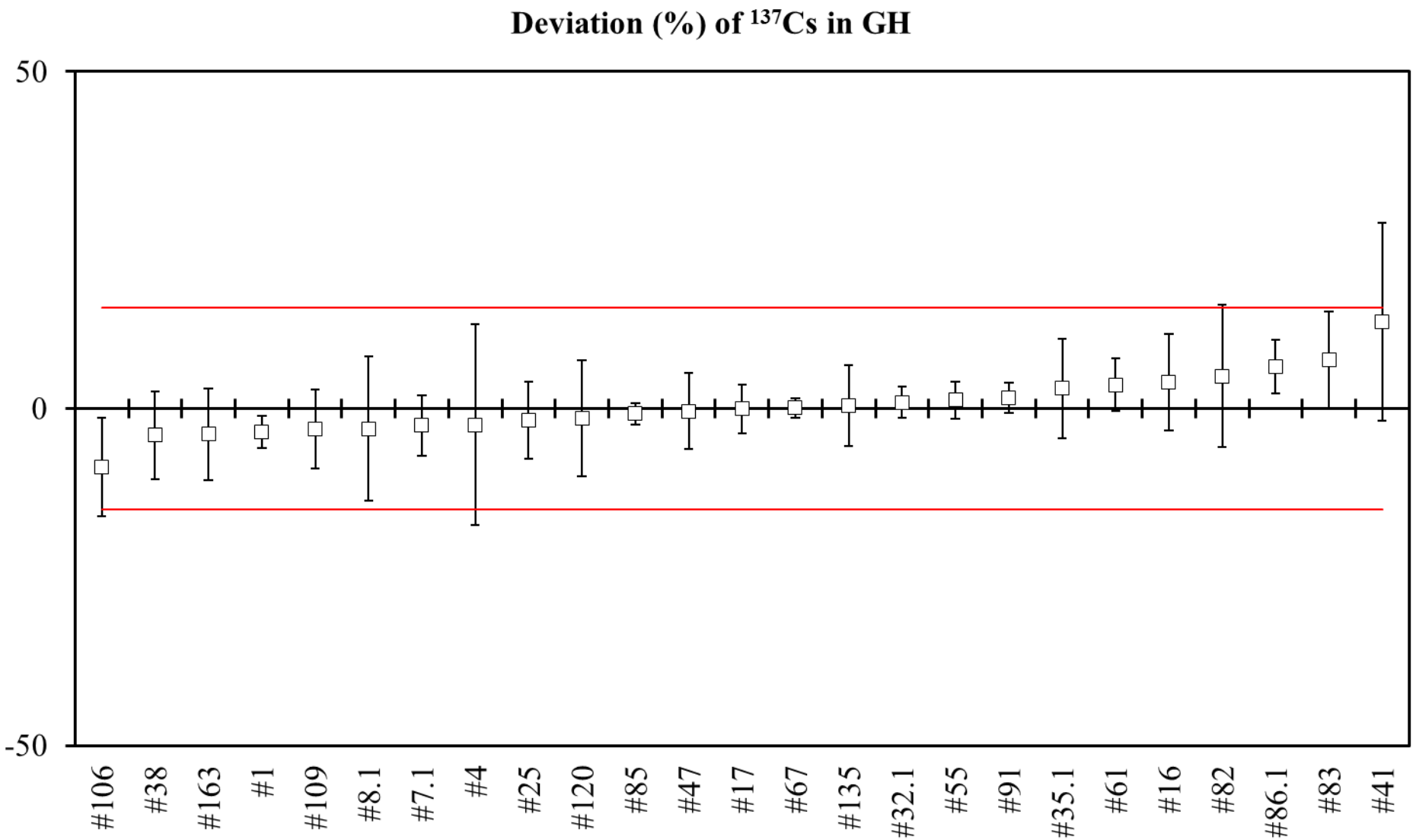
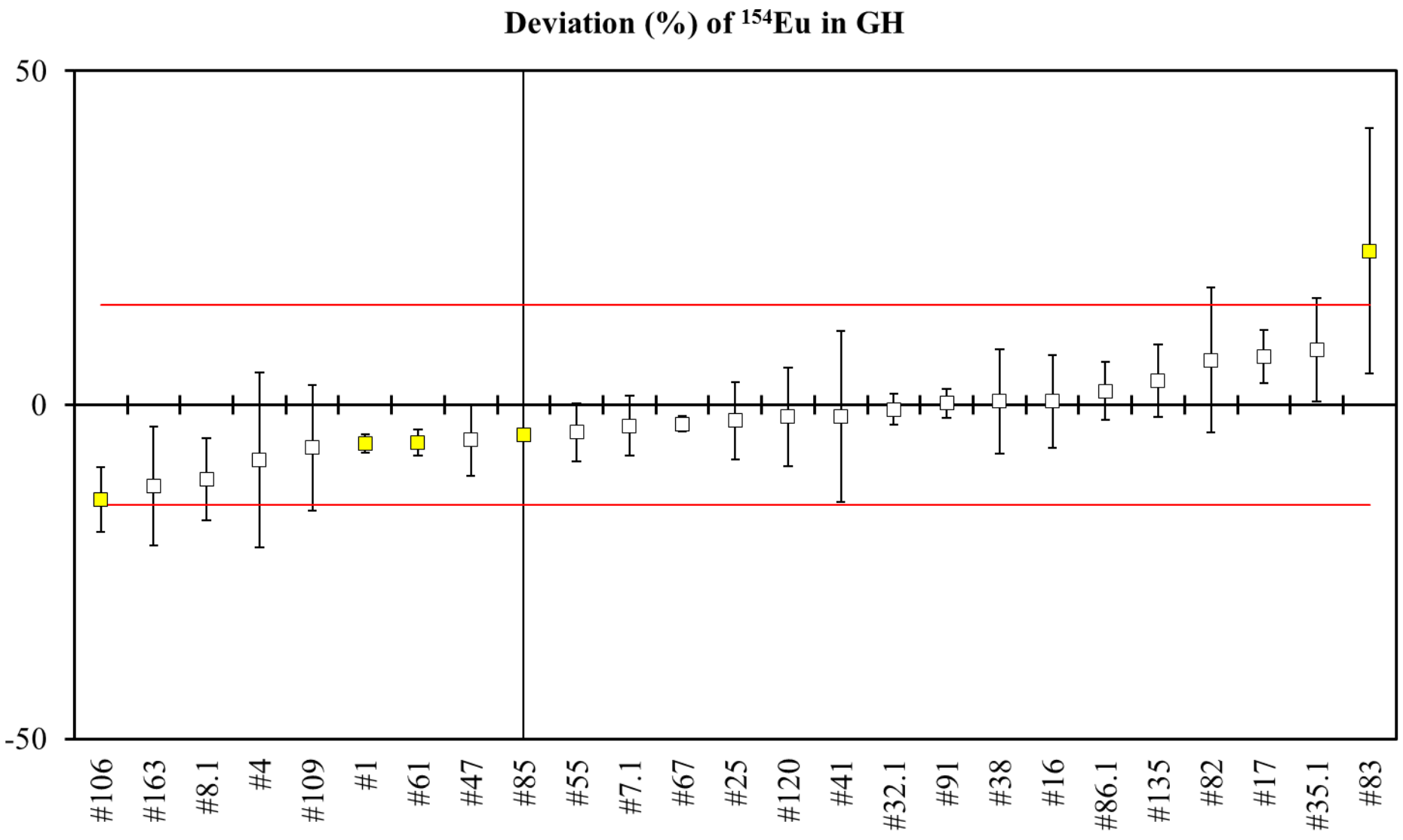
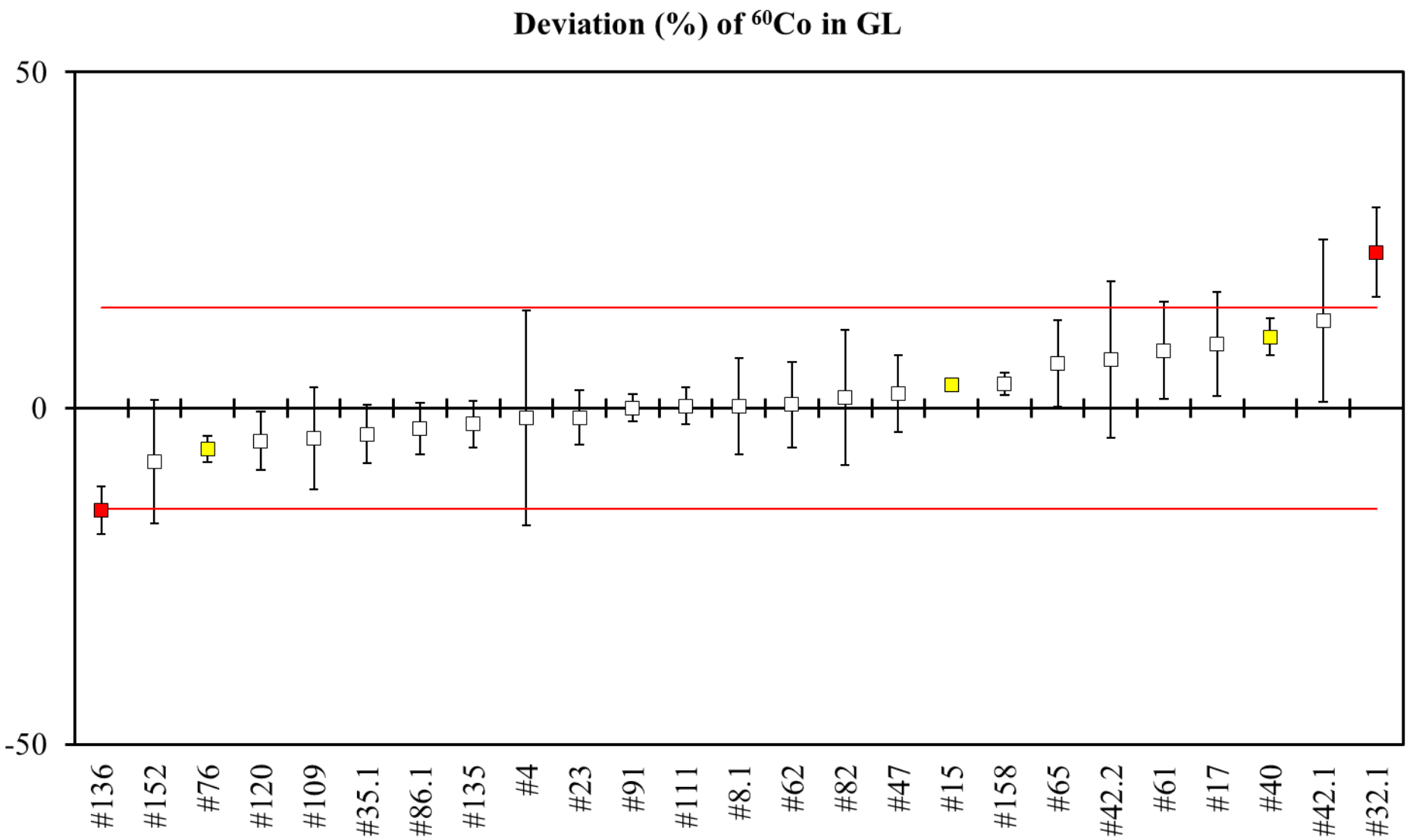
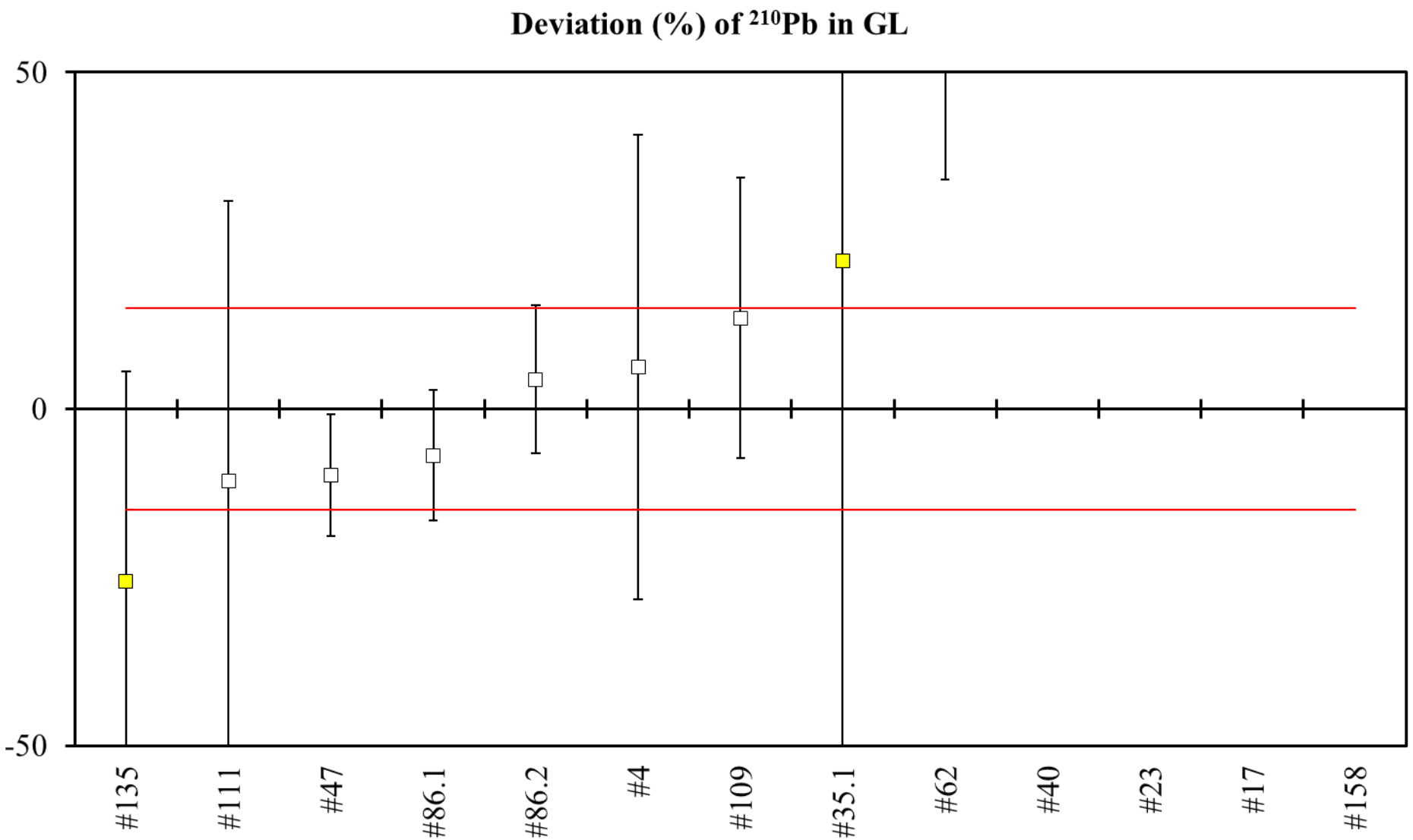
#25
#16
#82
#86.1
#83
#41

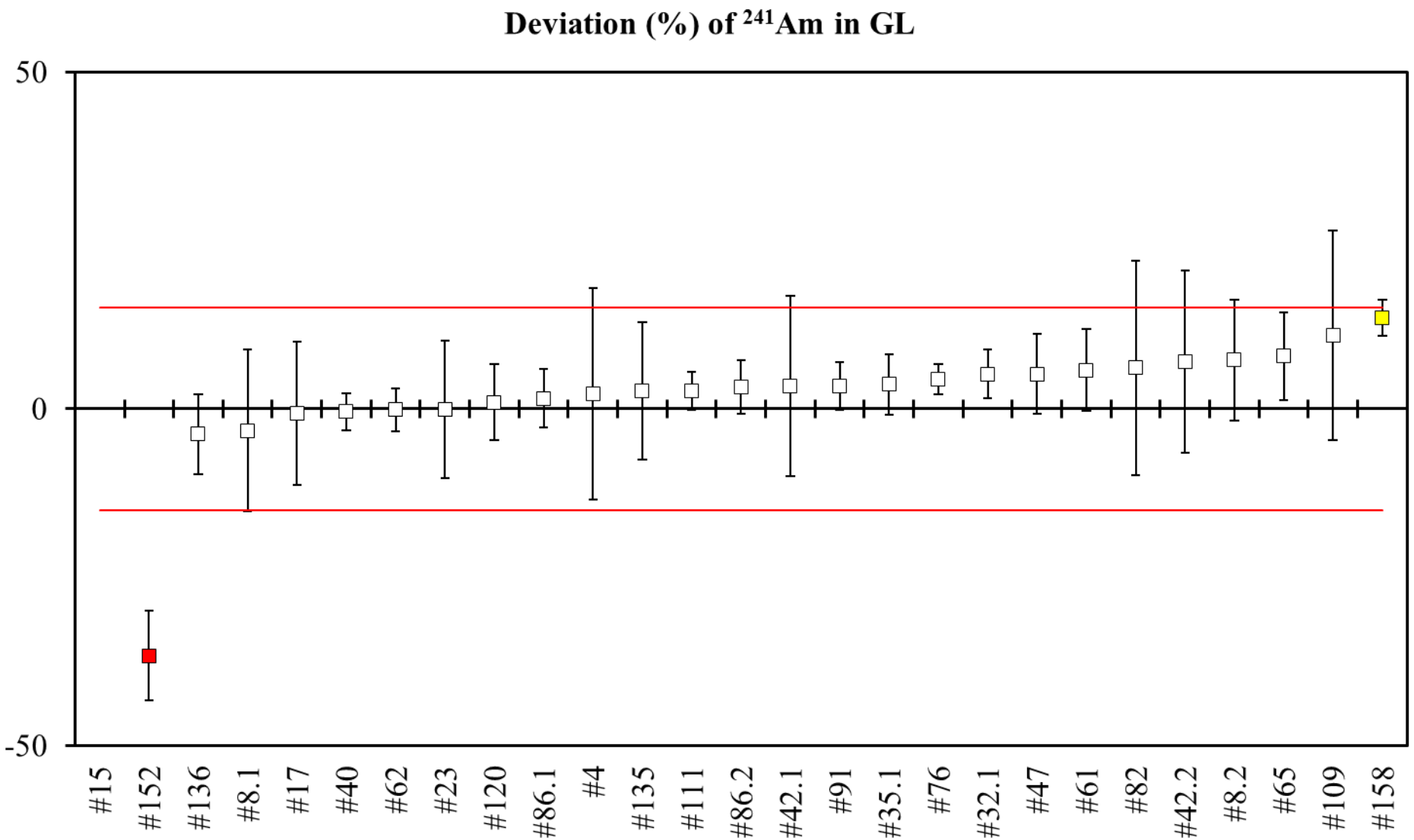

Deviation (%) of 137Cs in GH
50
0
-50
#106
#38
#163
#1
#109
#8.1
#7.1
#4
#25
#120
#85
#47
#17
#67
#135
#32.1
#55
#91
#35.1
#61
#16
#82
#86.1
#83
#41


Deviation (%) of 154Eu in GH
50
0
-50
#106
#163
#8.1
#4
#109
#1
#61
#47
#85
#55
#7.1
#67
#25
#120
#41
#32.1
#91
#38
#16
#86.1
#135
#82
#17
#35.1
#83

8. Gamma Low (GL) Deviation Plots


Deviation (%) of 60Co in GL
50
0
-50
#136
#152
#76
#120
#109
#35.1
#86.1
#135
#4
#23
#91
#111
#8.1
#62
#82
#47
#15
#158
#65
#42.2
#61
#17
#40
#42.1
#32.1

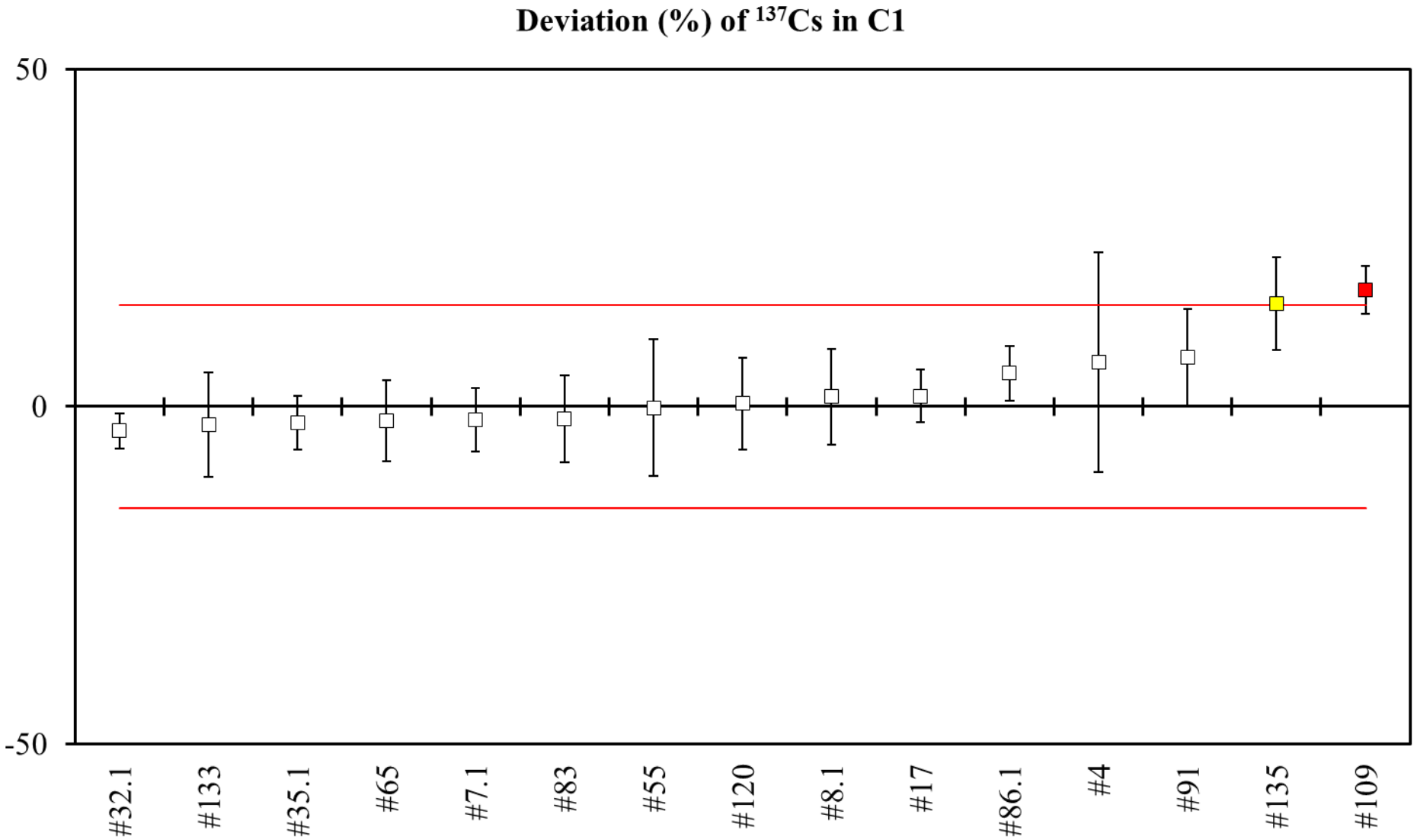

Deviation (%) of 210Pb in GL
50
0
-50
#135
#111
#47
#86.1
#86.2
#4
#109
#35.1
#62
#40
#23
#17
#158


Deviation (%) of 241Am in GL
50
0
-50
#15
#152
#136
#8.1
#17
#40
#62
#23
#120
#86.1
#4
#135
#111
#86.2
#42.1
#91
#35.1
#76
#32.1
#47
#61
#82
#42.2
#8.2
#65
#109
#158

9. Cement (C1) Deviation Plot

NOTE:

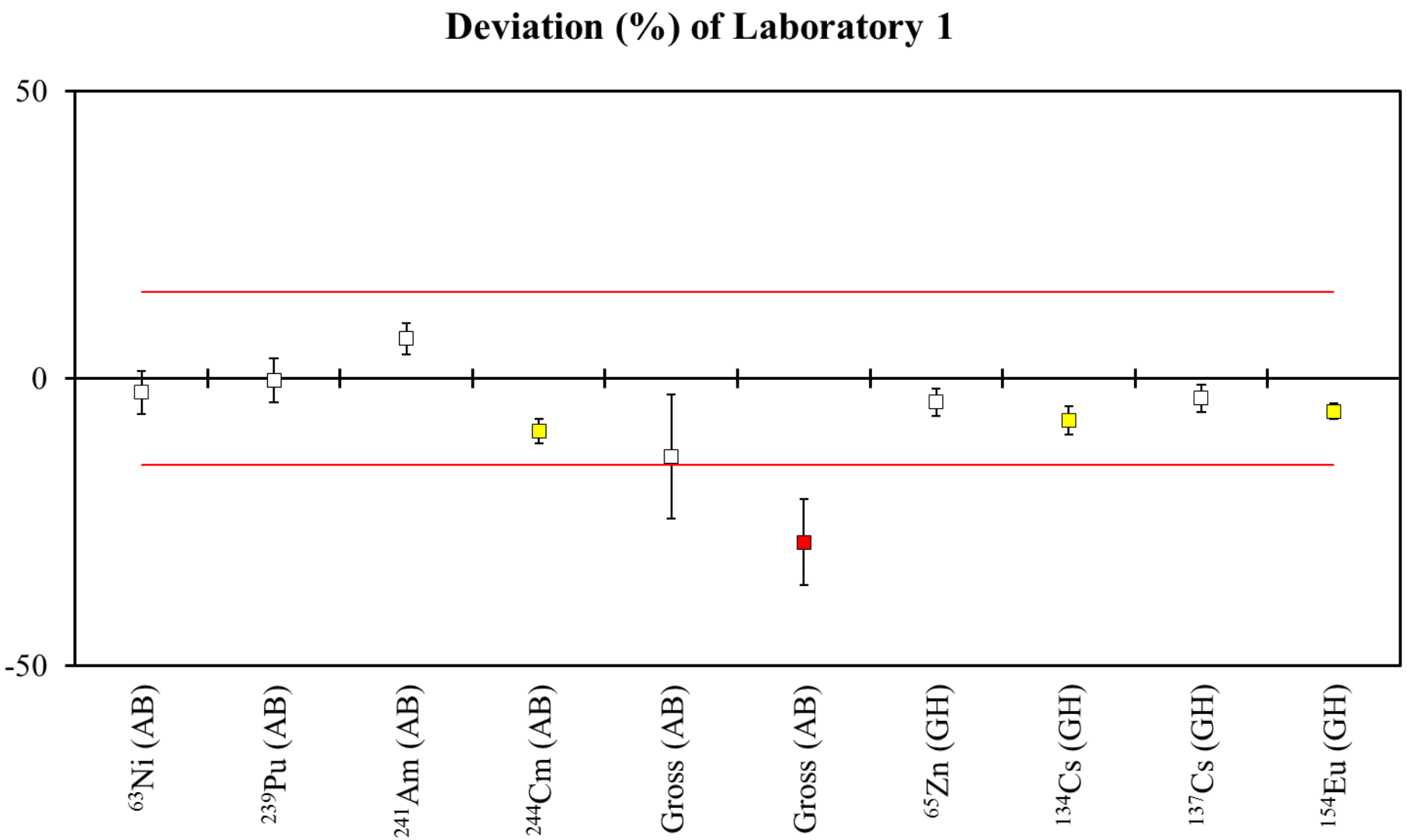
Analysis of data for other radionuclides / radionuclide types in this Sample Type does not fall under NPL's current accreditation to ISO17043 for solid samples types; these data are plotted in Appendix 1.


Deviation (%) of 137Cs in C1
50
0
-50
#32.1
#133
#35.1
#65
#7.1
#83
#55
#120
#8.1
#17
#86.1
#4
#91
#135
#109

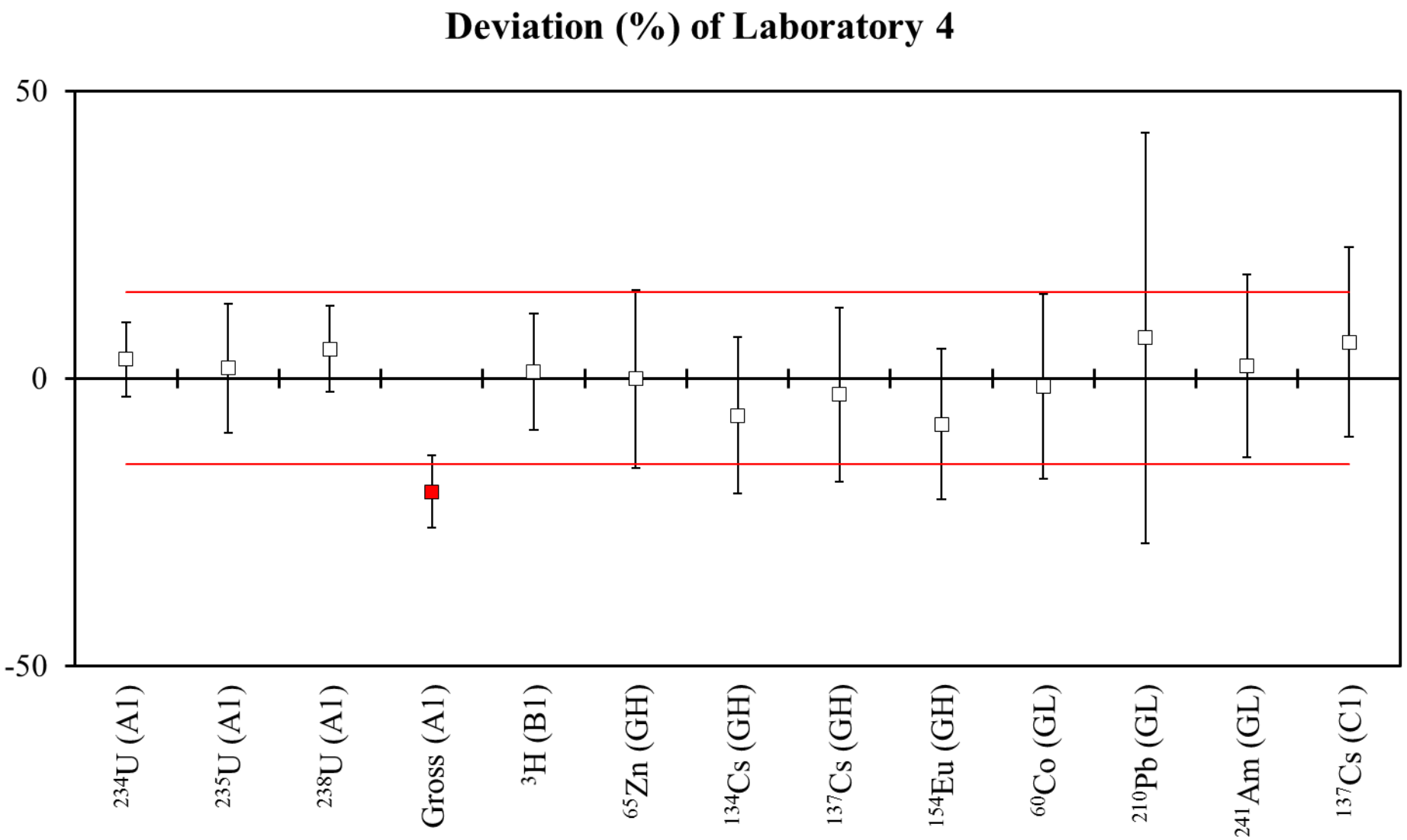
10. Deviation Plots and Tabulated Results Arranged by Lab Number

NOTES:

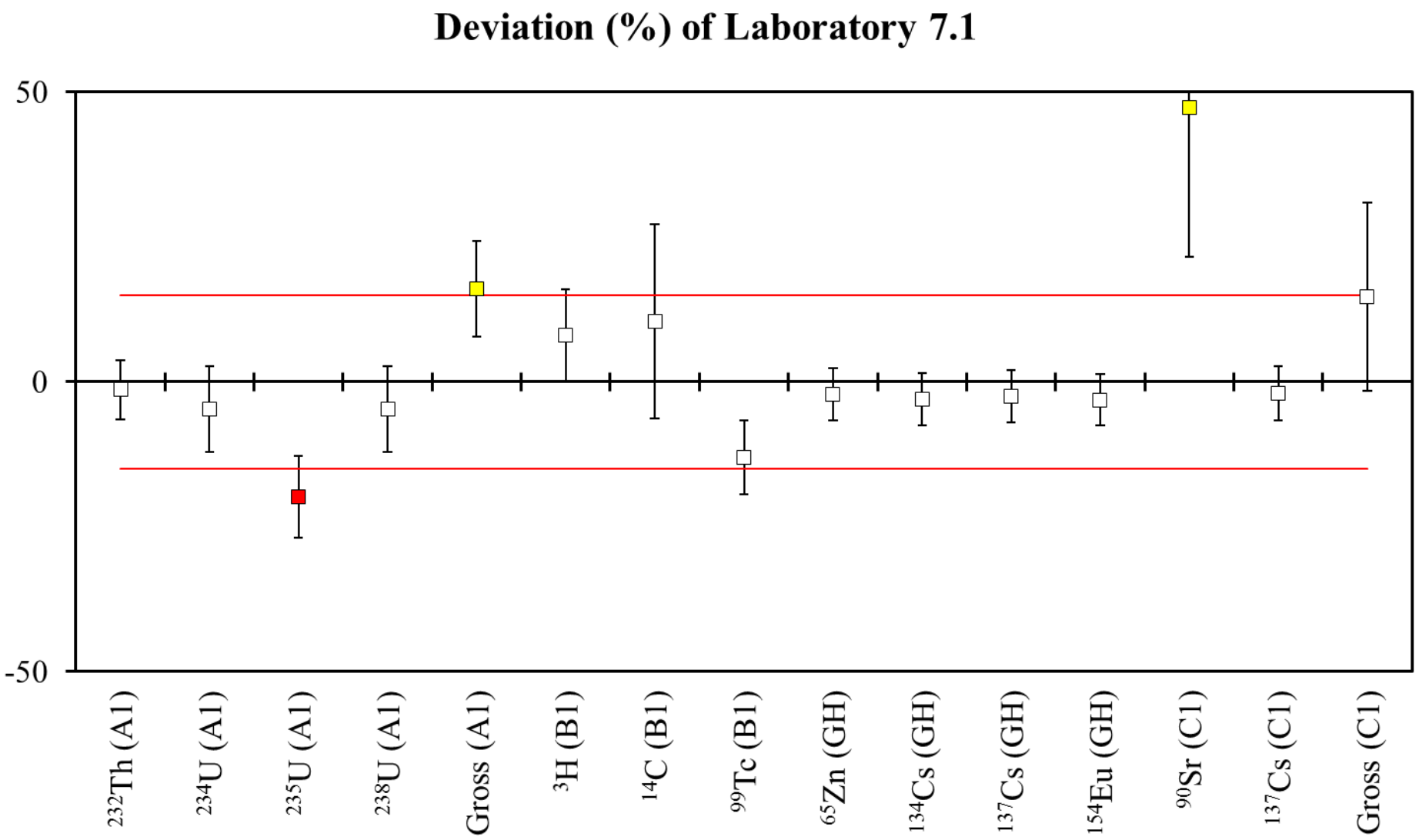
1. Data are quoted rounded, at *k*=1 (standard uncertainty). Data analysis was carried out on data as reported (i.e. before rounding). Uncertainties have been rounded such that the significant figures of the standard uncertainty lie between 3 and 25. The standard rules of rounding have been applied, except in cases where rounding down would have reduced the uncertainty by more than 5 %, in which cases the uncertainty was rounded up.
2. For convenience, the tables include all submitted data (including data for radionuclides / radionuclide types not analysed in Sections 4 to 9 above). Note that there are no Assigned Values for some radionuclides / radionuclide types – this is explained in Section 11 – and in such cases the data are not included in the deviation plot. Again, note that analysis of data from 'non-gamma' measurements of Sample Type C1 does not fall under NPL's current accreditation to ISO17043 for solid sample types.


Deviation (%) of Laboratory 1
50
0
-50
63Ni (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
Gross (AB)
Gross (AB)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)

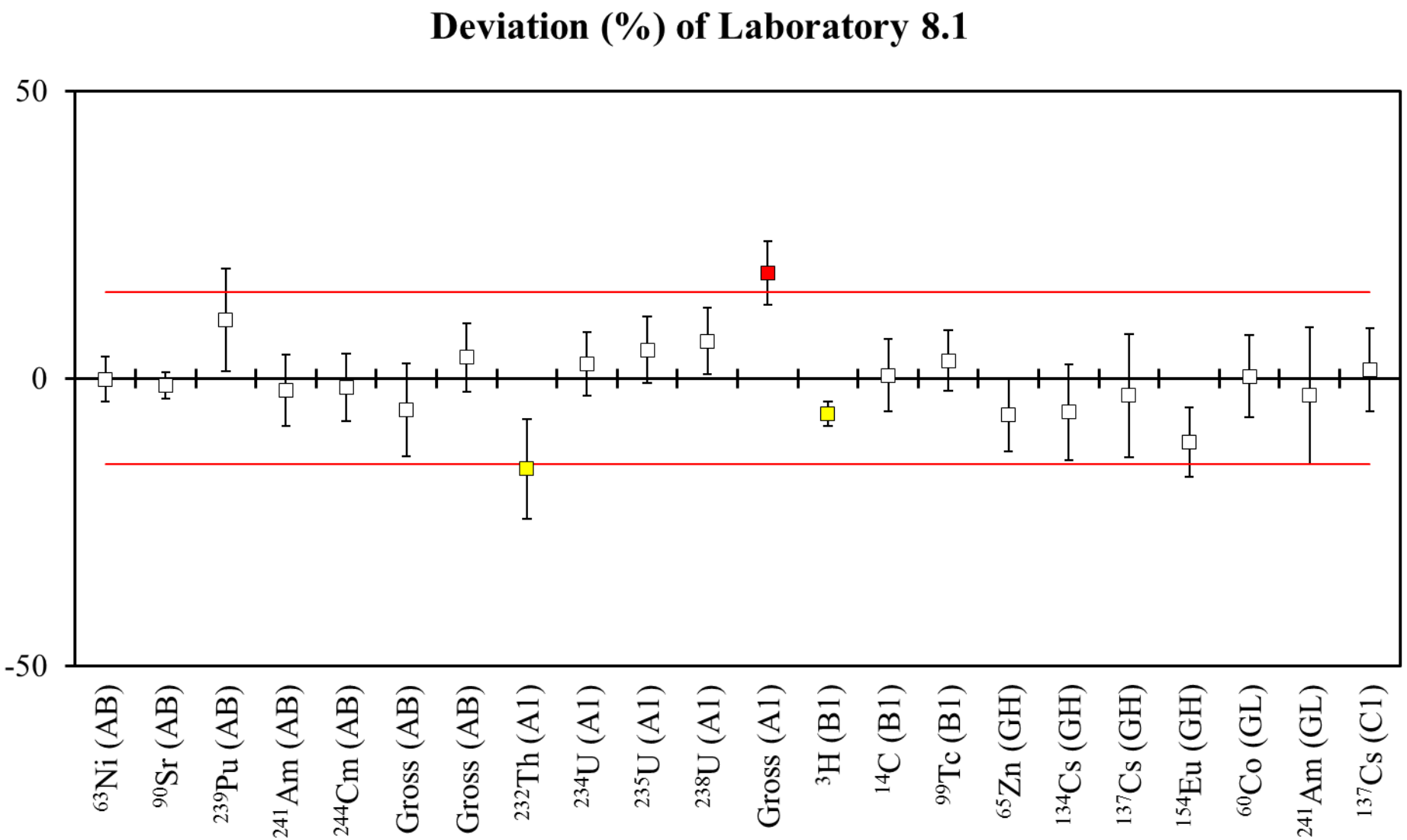
Radionuclide	Laboratory 1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	5.17 ± 0.19	5.298 ± 0.058	-2.4	-0.64	-0.41
^{239}Pu (AB)	1.330 ± 0.050	1.3347 ± 0.0029	-0.4	-0.09	-0.06
^{241}Am (AB)	5.38 ± 0.14	5.034 ± 0.011	6.9	2.46	1.18
^{244}Cm (AB)	9.79 ± 0.23	10.778 ± 0.039	-9.2	-4.24	-1.57
Gross alpha (AB)	15.8 ± 1.5	18.3 ± 1.5	-13.7	-1.18	-2.35
Gross beta (AB)	13.8 ± 1.2	19.3 ± 1.1	-28.5	-3.38	-4.89
^{65}Zn (GH)	16.80 ± 0.40	17.52 ± 0.13	-4.1	-1.71	-0.71
^{134}Cs (GH)	3.140 ± 0.080	3.390 ± 0.024	-7.4	-2.99	-1.27
^{137}Cs (GH)	8.94 ± 0.21	9.264 ± 0.066	-3.5	-1.47	-0.60
^{154}Eu (GH)	12.19 ± 0.15	12.93 ± 0.10	-5.7	-4.10	-0.98


Deviation (%) of Laboratory 4
50
0
-50
234U (A1)
235U (A1)
238U (A1)
Gross (A1)
3H (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
210Pb (GL)
241Am (GL)
137Cs (C1)

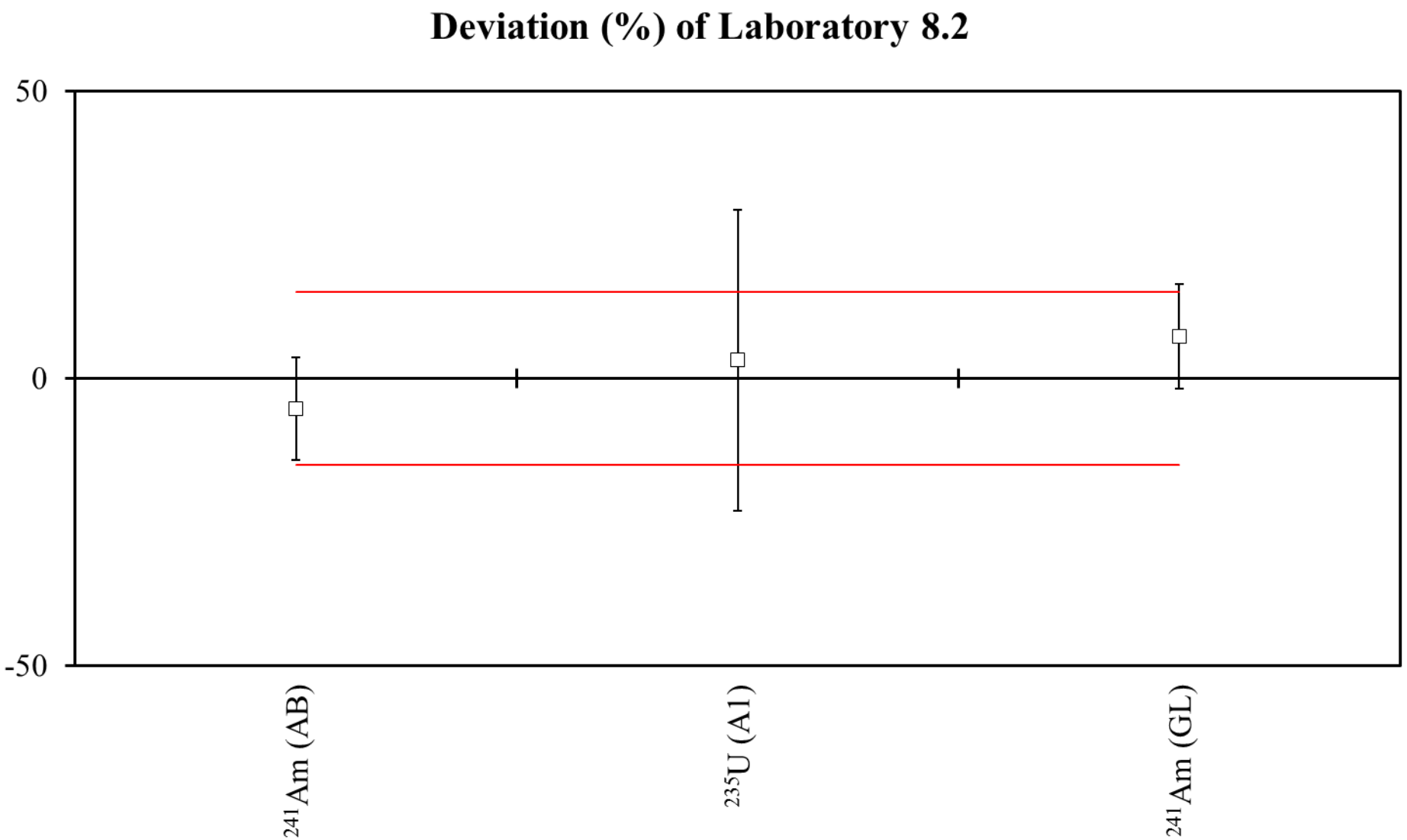
Radionuclide	Laboratory 4	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{234}U (A1)	15.72 ± 0.95	15.22 ± 0.26	3.3	0.51	0.56
^{235}U (A1)	0.740 ± 0.080	0.727 ± 0.015	1.8	0.16	0.31
^{238}U (A1)	16.0 ± 1.1	15.22 ± 0.26	5.1	0.69	0.88
Gross alpha (A1)	32.5 ± 2.1	40.5 ± 1.8	-19.8	-2.89	-3.39
^{3}H (B1)	1.92 ± 0.19	1.898 ± 0.024	1.2	0.11	0.20
^{65}Zn (GH)	17.5 ± 2.7	17.52 ± 0.13	-0.1	-0.01	-0.02
^{134}Cs (GH)	3.17 ± 0.46	3.390 ± 0.024	-6.5	-0.48	-1.11
^{137}Cs (GH)	9.0 ± 1.4	9.264 ± 0.066	-2.8	-0.19	-0.49
^{154}Eu (GH)	11.9 ± 1.7	12.93 ± 0.10	-8.0	-0.60	-1.37
^{60}Co (GL)	9.8 ± 1.6	9.937 ± 0.026	-1.4	-0.09	-0.24
^{210}Pb (GL)	3.6 ± 1.2	3.362 ± 0.035	7.1	0.20	1.22
^{241}Am (GL)	18.0 ± 2.8	17.623 ± 0.039	2.1	0.13	0.37
^{137}Cs (C1)	71 ± 11	66.81 ± 0.87	6.3	0.38	1.08


Deviation (%) of Laboratory 7.1
50
0
-50
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
Gross (A1)
3H (B1)
14C (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
90Sr (C1)
137Cs (C1)
Gross (C1)

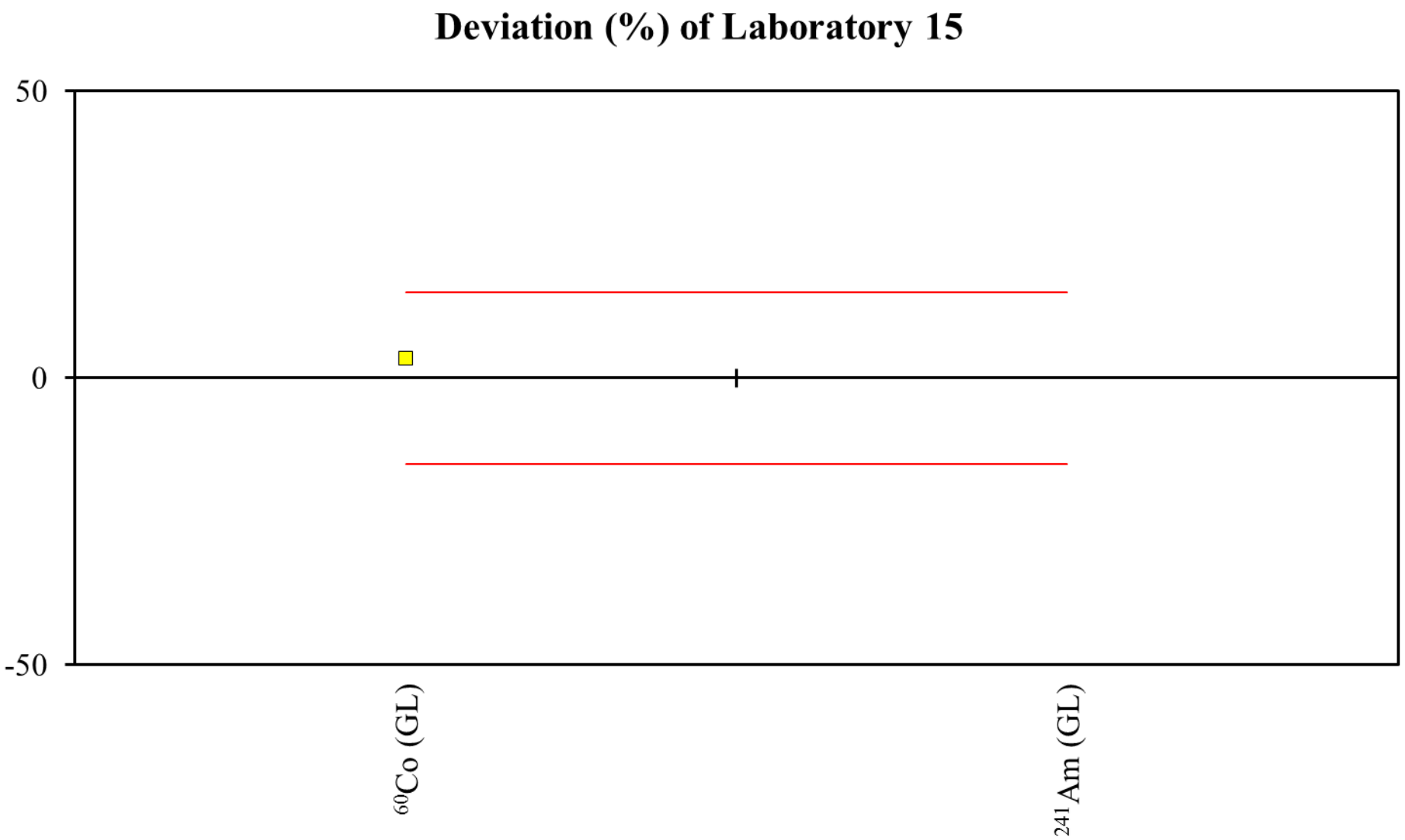
Radionuclide	Laboratory 7.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{232}Th (A1)	3.97 ± 0.20	4.025 ± 0.038	-1.4	-0.27	-0.23
^{234}U (A1)	14.5 ± 1.1	15.22 ± 0.26	-4.7	-0.64	-0.81
^{235}U (A1)	0.583 ± 0.050	0.727 ± 0.015	-19.8	-2.76	-3.40
^{238}U (A1)	14.5 ± 1.1	15.22 ± 0.26	-4.7	-0.64	-0.81
Gross alpha (A1)	47.0 ± 2.6	40.5 ± 1.8	16.0	2.06	2.76
^{3}H (B1)	2.05 ± 0.15	1.898 ± 0.024	8.0	1.00	1.38
^{14}C (B1)	1.12 ± 0.17	1.0146 ± 0.0066	10.4	0.62	1.78
^{99}Tc (B1)	0.468 ± 0.034	0.5377 ± 0.0048	-13.0	-2.03	-2.23
Gross beta (B1)	3.15 ± 0.24	-	-	-	-
^{65}Zn (GH)	17.14 ± 0.78	17.52 ± 0.13	-2.2	-0.48	-0.37
^{134}Cs (GH)	3.29 ± 0.15	3.390 ± 0.024	-2.9	-0.66	-0.51
^{137}Cs (GH)	9.03 ± 0.41	9.264 ± 0.066	-2.5	-0.56	-0.43
^{154}Eu (GH)	12.53 ± 0.57	12.93 ± 0.10	-3.1	-0.69	-0.53
^{90}Sr (C1)	91.4 ± 8.8	62.0 ± 9.1	47.4	2.32	8.14
^{137}Cs (C1)	65.5 ± 3.0	66.81 ± 0.87	-2.0	-0.42	-0.34
^{239,240}Pu (C1)	0.129 ± 0.018	-	-	-	-
Gross alpha (C1)	0.67 ± 0.12	-	-	-	-
Gross beta (C1)	213 ± 29	185.7 ± 7.2	14.7	0.91	2.52


Deviation (%) of Laboratory 8.1
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
Gross (AB)
Gross (AB)
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
Gross (A1)
3H (B1)
14C (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
241Am (GL)
137Cs (C1)

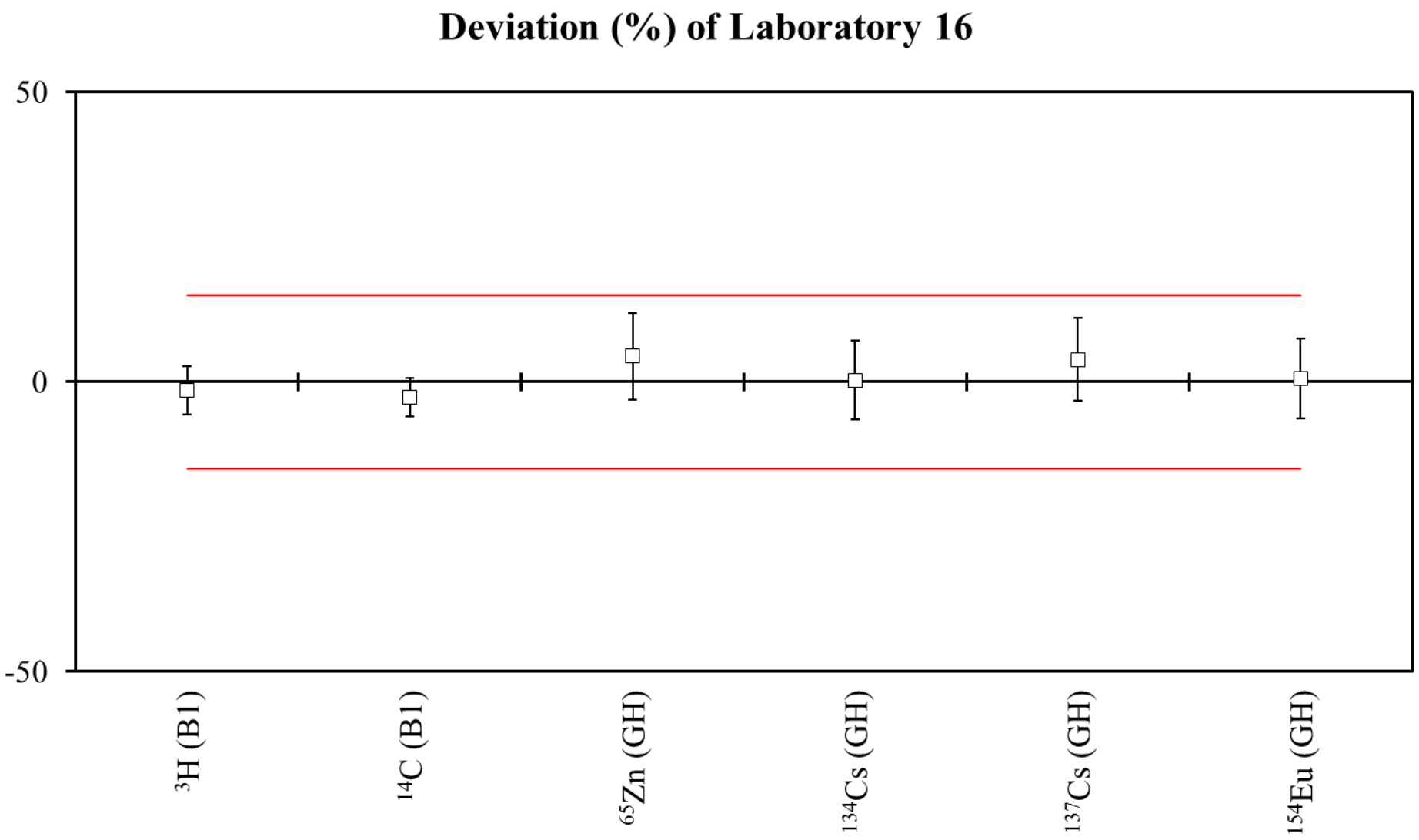
Radionuclide	Laboratory 8.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	5.29 ± 0.20	5.298 ± 0.058	-0.2	-0.04	-0.03
^{90}Sr (AB)	9.43 ± 0.22	9.546 ± 0.042	-1.2	-0.52	-0.21
^{239}Pu (AB)	1.47 ± 0.12	1.3347 ± 0.0029	10.1	1.13	1.74
^{241}Am (AB)	4.93 ± 0.31	5.034 ± 0.011	-2.1	-0.34	-0.35
^{244}Cm (AB)	10.60 ± 0.63	10.778 ± 0.039	-1.7	-0.28	-0.28
Gross alpha (AB)	17.30 ± 0.40	18.3 ± 1.5	-5.5	-0.64	-0.94
Gross beta (AB)	20.00 ± 0.16	19.3 ± 1.1	3.6	0.63	0.62
^{232}Th (A1)	3.39 ± 0.35	4.025 ± 0.038	-15.8	-1.80	-2.71
^{234}U (A1)	15.60 ± 0.80	15.22 ± 0.26	2.5	0.45	0.43
^{235}U (A1)	0.763 ± 0.039	0.727 ± 0.015	5.0	0.86	0.85
^{238}U (A1)	16.20 ± 0.83	15.22 ± 0.26	6.4	1.13	1.11
Gross alpha (A1)	47.9 ± 0.7	40.5 ± 1.8	18.3	3.83	3.14
^{3}H (B1)	1.780 ± 0.034	1.898 ± 0.024	-6.2	-2.84	-1.07
^{14}C (B1)	1.020 ± 0.063	1.0146 ± 0.0066	0.5	0.09	0.09
^{99}Tc (B1)	0.554 ± 0.028	0.5377 ± 0.0048	3.0	0.57	0.52
^{65}Zn (GH)	16.4 ± 1.1	17.52 ± 0.13	-6.4	-1.01	-1.10
^{134}Cs (GH)	3.19 ± 0.28	3.390 ± 0.024	-5.9	-0.71	-1.01
^{137}Cs (GH)	8.99 ± 0.99	9.264 ± 0.066	-3.0	-0.28	-0.51
^{154}Eu (GH)	11.49 ± 0.78	12.93 ± 0.10	-11.1	-1.83	-1.91
^{60}Co (GL)	9.97 ± 0.71	9.937 ± 0.026	0.3	0.05	0.06
^{241}Am (GL)	17.1 ± 2.1	17.623 ± 0.039	-3.0	-0.25	-0.51
^{137}Cs (C1)	67.8 ± 4.7	66.81 ± 0.87	1.5	0.21	0.25
^{239,240}Pu (C1)	0.0380 ± 0.0021	-	-	-	-


Deviation (%) of Laboratory 8.2
50
0
-50
241Am (AB)
235U (A1)
241Am (GL)

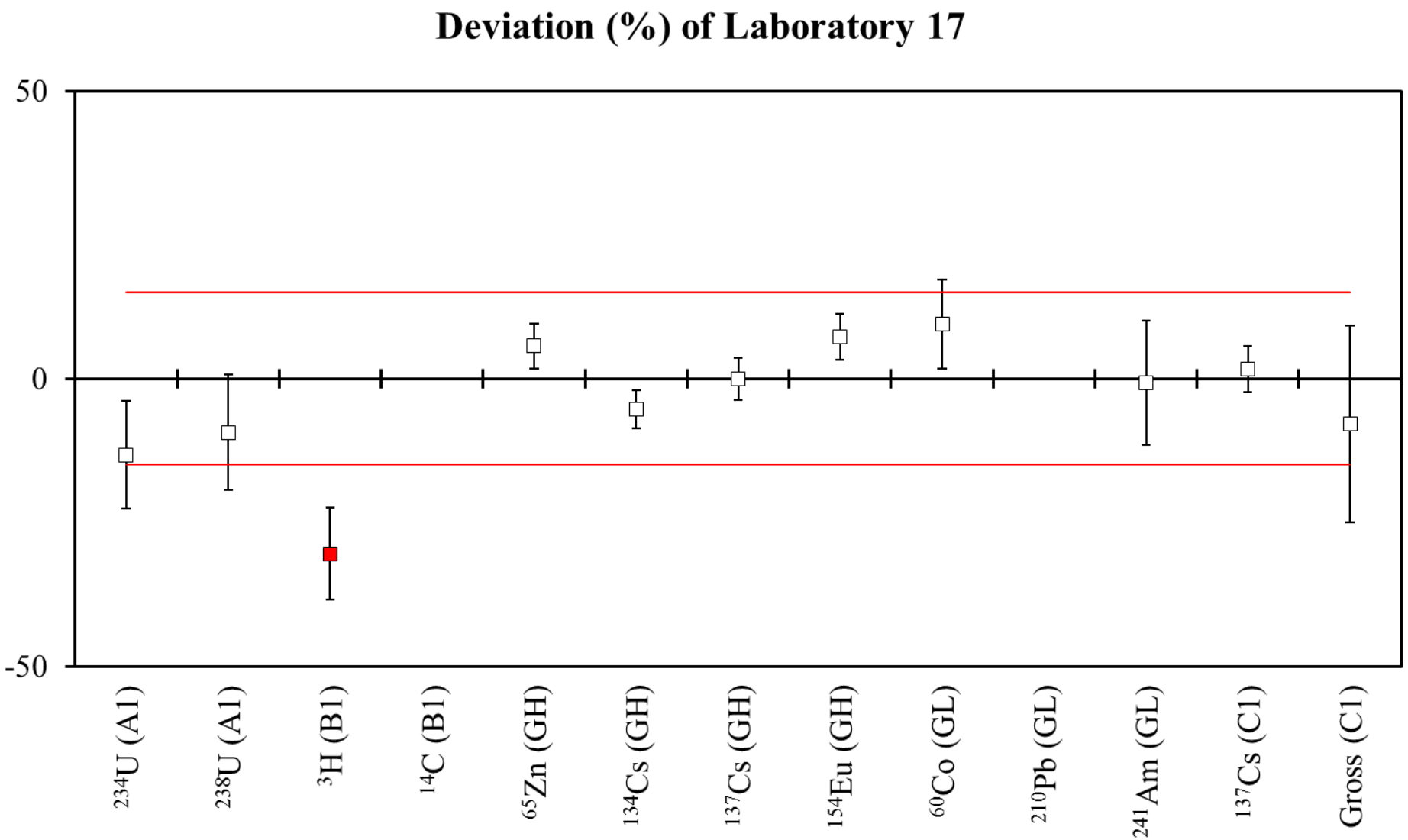
Radionuclide	Laboratory 8.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{241}Am (AB)	4.77 ± 0.45	5.034 ± 0.011	-5.2	-0.59	-0.90
^{235}U (A1)	0.75 ± 0.19	0.727 ± 0.015	3.2	0.12	0.54
^{241}Am (GL)	18.9 ± 1.6	17.623 ± 0.039	7.2	0.80	1.24


Deviation (%) of Laboratory 15
50
0
-50
60Co (GL)
241Am (GL)

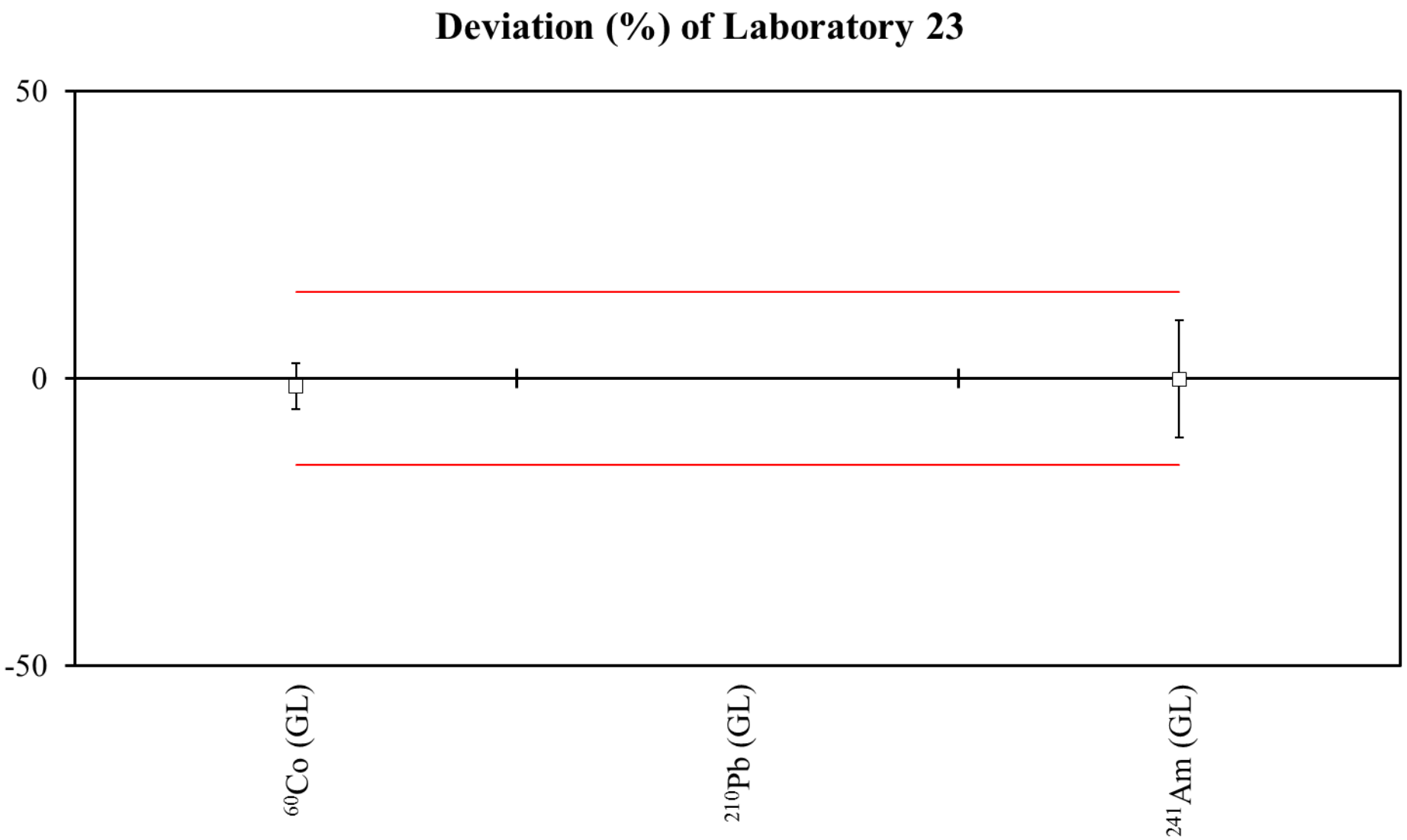
Radionuclide	Laboratory 15	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{60}Co (GL)	10.2797 ± 0.6121	9.937 ± 0.026	3.4	13.18	0.59
^{241}Am (GL)	6.9249 ± 1.1842	17.623 ± 0.039	-60.7	-274.31	-10.43


Deviation (%) of Laboratory 16
50
0
-50
^{3}H (B1)
^{14}C (B1)
^{65}Zn (GH)
^{134}Cs (GH)
^{137}Cs (GH)
^{154}Eu (GH)

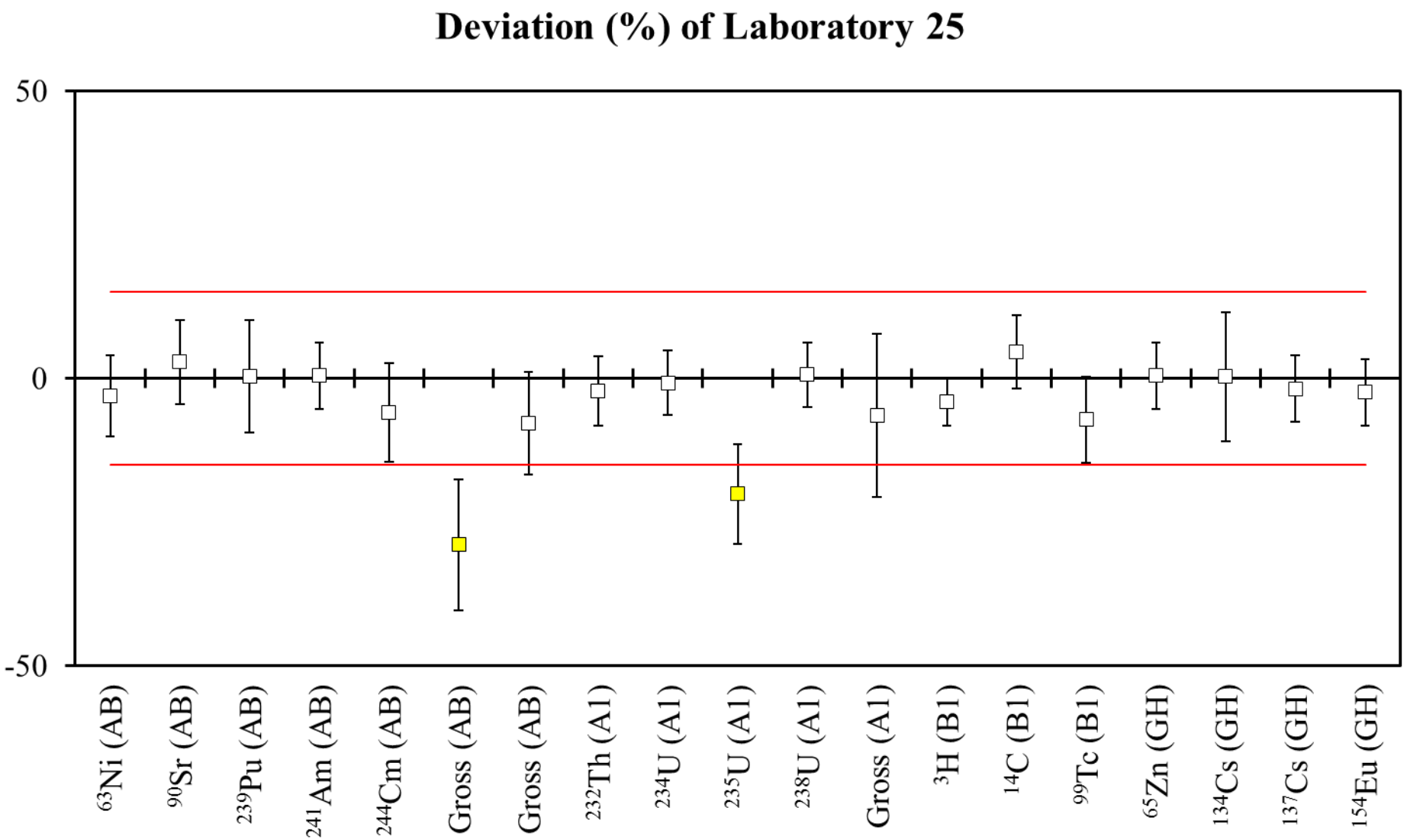
Radionuclide	Laboratory 16	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{3}H (B1)	1.870 ± 0.075	1.898 ± 0.024	-1.5	-0.36	-0.25
^{14}C (B1)	0.988 ± 0.033	1.0146 ± 0.0066	-2.6	-0.79	-0.45
^{65}Zn (GH)	18.3 ± 1.3	17.52 ± 0.13	4.5	0.60	0.76
^{134}Cs (GH)	3.40 ± 0.23	3.390 ± 0.024	0.3	0.04	0.05
^{137}Cs (GH)	9.62 ± 0.66	9.264 ± 0.066	3.8	0.54	0.66
^{154}Eu (GH)	13.00 ± 0.89	12.93 ± 0.10	0.5	0.08	0.09


Deviation (%) of Laboratory 17
50
0
-50
234U (A1)
238U (A1)
3H (B1)
14C (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
210Pb (GL)
241Am (GL)
137Cs (C1)
Gross (C1)

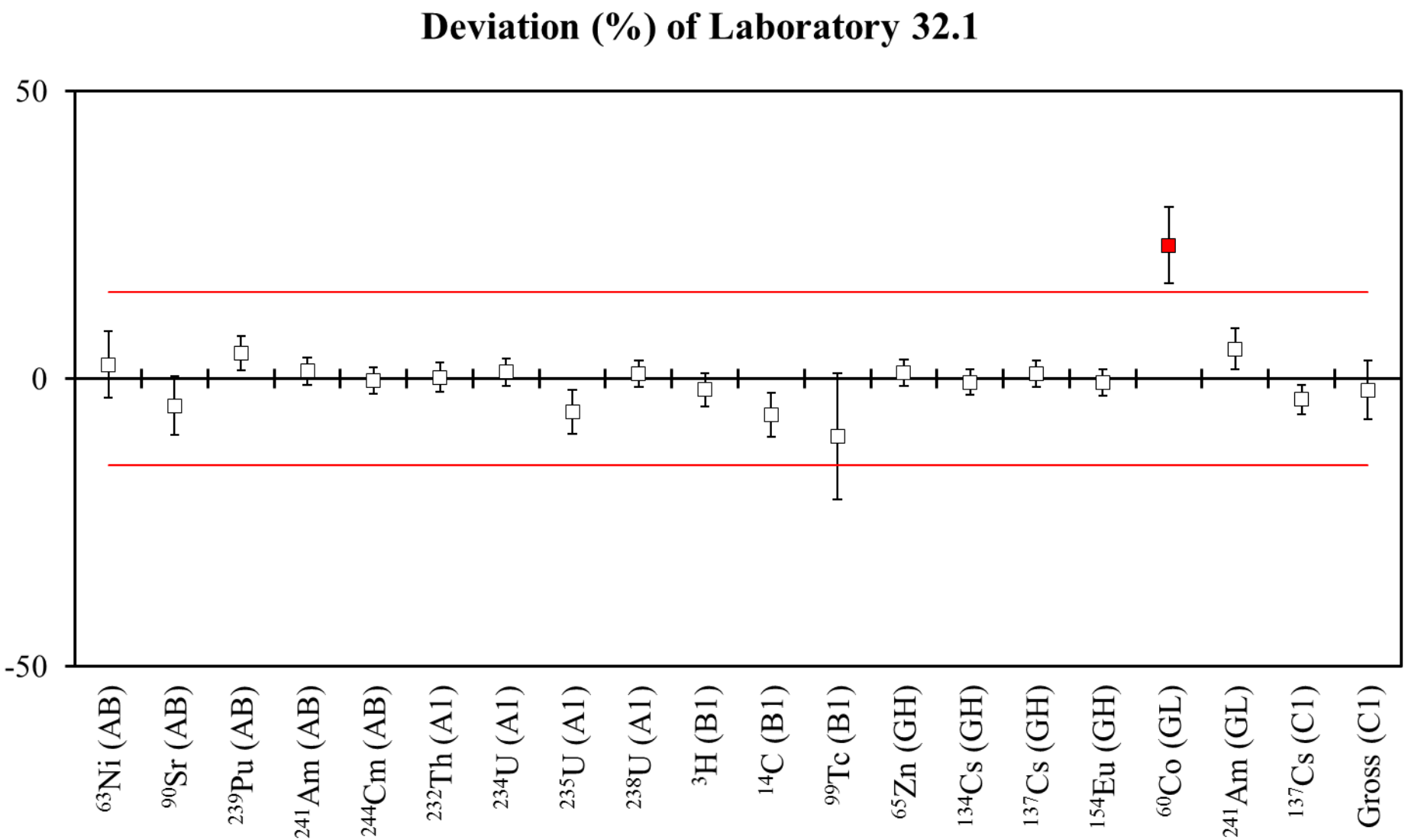
Radionuclide	Laboratory 17	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{234}U (A1)	13.2 ± 1.4	15.22 ± 0.26	-13.3	-1.42	-2.28
^{238}U (A1)	13.8 ± 1.5	15.22 ± 0.26	-9.3	-0.93	-1.60
^{3}H (B1)	1.32 ± 0.15	1.898 ± 0.024	-30.5	-3.80	-5.23
^{14}C (B1)	0.180 ± 0.020	1.0146 ± 0.0066	-82.3	-39.63	-14.13
^{65}Zn (GH)	18.51 ± 0.67	17.52 ± 0.13	5.7	1.45	0.97
^{134}Cs (GH)	3.21 ± 0.11	3.390 ± 0.024	-5.3	-1.60	-0.91
^{137}Cs (GH)	9.26 ± 0.33	9.264 ± 0.066	0.0	-0.01	-0.01
^{154}Eu (GH)	13.87 ± 0.50	12.93 ± 0.10	7.3	1.84	1.25
^{60}Co (GL)	10.88 ± 0.77	9.937 ± 0.026	9.5	1.22	1.63
^{210}Pb (GL)	45 ± 17	3.362 ± 0.035	1238.5	2.45	212.69
^{241}Am (GL)	17.5 ± 1.9	17.623 ± 0.039	-0.7	-0.06	-0.12
^{137}Cs (C1)	67.9 ± 2.5	66.81 ± 0.87	1.6	0.41	0.28
Gross alpha (C1)	17.5 ± 3.2	-	-	-	-
Gross beta (C1)	171 ± 31	185.7 ± 7.2	-7.9	-0.46	-1.36


Deviation (%) of Laboratory 23
50
0
-50
^{60}Co (GL)
^{210}Pb (GL)
^{241}Am (GL)

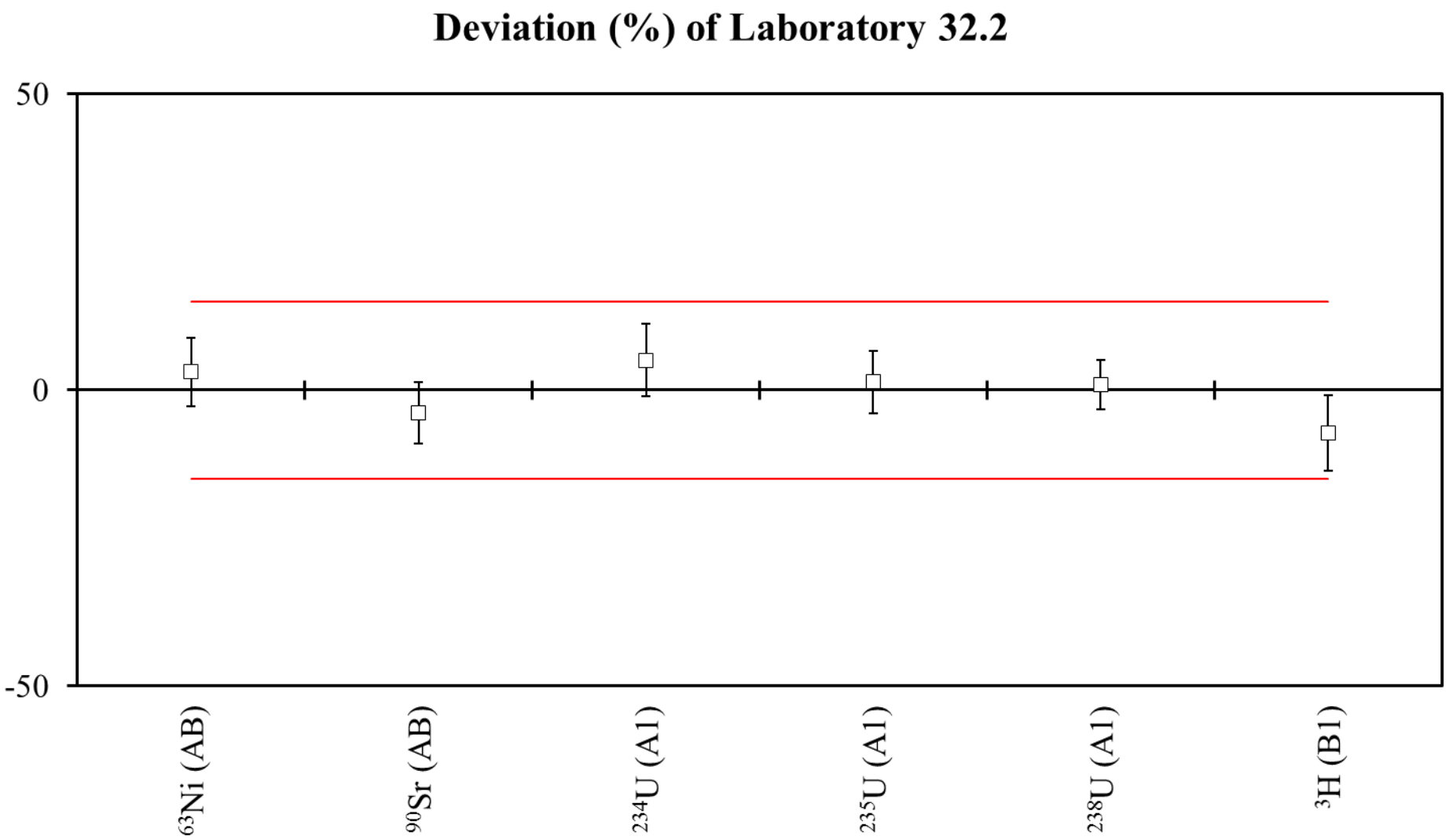
Radionuclide	Laboratory 23	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{60}Co (GL)	9.80 ± 0.40	9.937 ± 0.026	-1.4	-0.34	-0.24
^{210}Pb (GL)	13.0 ± 4.0	3.362 ± 0.035	286.7	2.41	49.23
^{241}Am (GL)	17.6 ± 1.8	17.623 ± 0.039	-0.1	-0.01	-0.02


Deviation (%) of Laboratory 25
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
Gross (AB)
Gross (AB)
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
Gross (A1)
3H (B1)
14C (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)

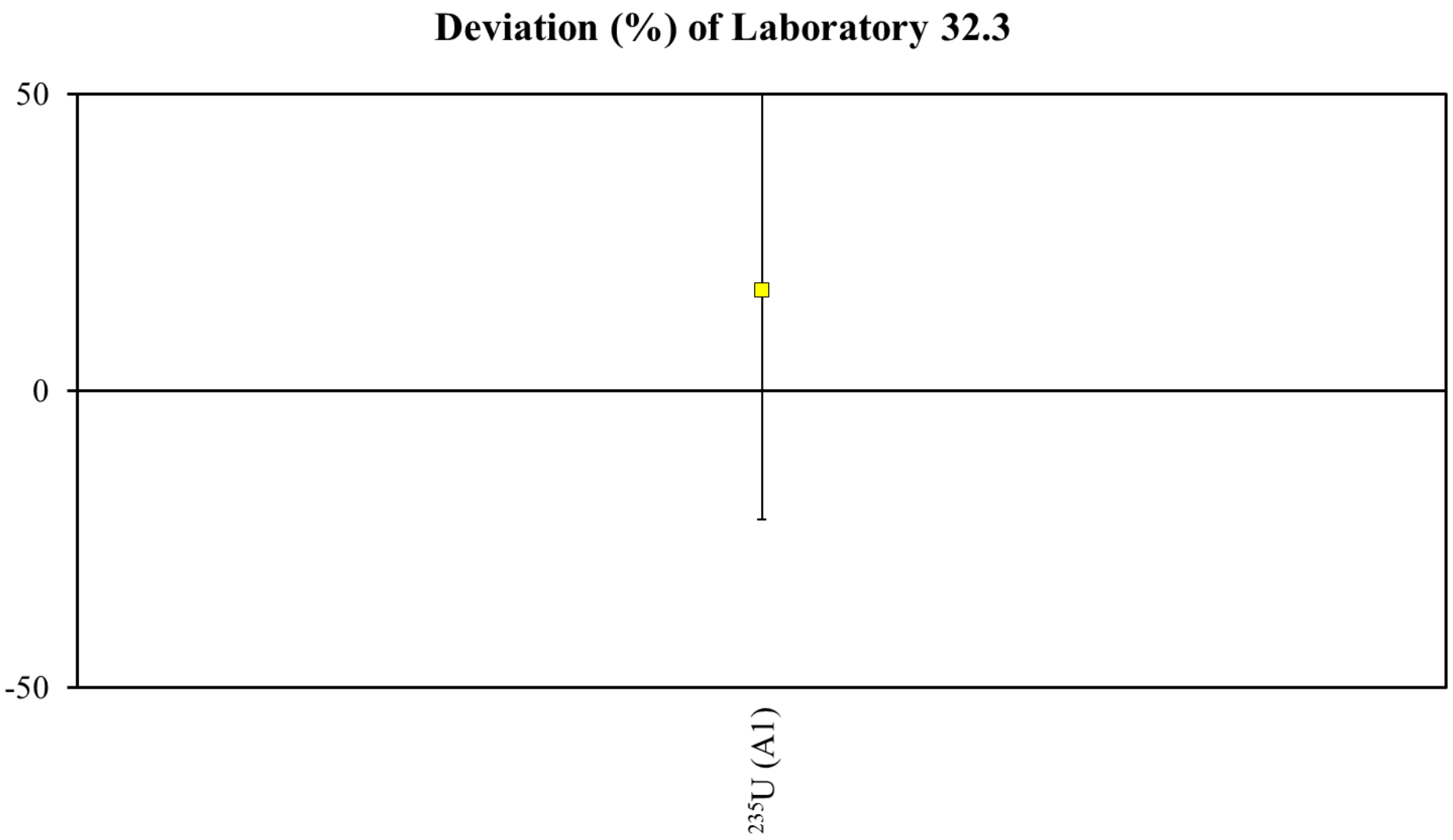
Radionuclide	Laboratory 25	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	5.14 ± 0.37	5.298 ± 0.058	-3.0	-0.42	-0.51
^{90}Sr (AB)	9.820 ± 0.7	9.546 ± 0.042	2.9	0.39	0.49
^{239}Pu (AB)	1.34 ± 0.13	1.3347 ± 0.0029	0.4	0.04	0.07
^{241}Am (AB)	5.06 ± 0.29	5.034 ± 0.011	0.5	0.09	0.09
^{244}Cm (AB)	10.14 ± 0.93	10.778 ± 0.039	-5.9	-0.69	-1.02
Gross alpha (AB)	13.0 ± 1.8	18.3 ± 1.5	-29.0	-2.26	-4.97
Gross beta (AB)	17.8 ± 1.4	19.3 ± 1.1	-7.8	-0.84	-1.33
^{232}Th (A1)	3.94 ± 0.24	4.025 ± 0.038	-2.1	-0.35	-0.36
^{234}U (A1)	15.10 ± 0.81	15.22 ± 0.26	-0.8	-0.14	-0.14
^{235}U (A1)	0.581 ± 0.062	0.727 ± 0.015	-20.1	-2.29	-3.45
^{238}U (A1)	15.32 ± 0.82	15.22 ± 0.26	0.7	0.12	0.11
Gross alpha (A1)	37.9 ± 5.5	40.5 ± 1.8	-6.4	-0.45	-1.10
^{3}H (B1)	1.821 ± 0.076	1.898 ± 0.024	-4.1	-0.97	-0.70
^{14}C (B1)	1.061 ± 0.064	1.0146 ± 0.0066	4.6	0.72	0.79
^{99}Tc (B1)	0.499 ± 0.040	0.5377 ± 0.0048	-7.2	-0.96	-1.24
^{65}Zn (GH)	17.6 ± 1.0	17.52 ± 0.13	0.5	0.08	0.08
^{134}Cs (GH)	3.40 ± 0.38	3.390 ± 0.024	0.3	0.03	0.05
^{137}Cs (GH)	9.10 ± 0.53	9.264 ± 0.066	-1.8	-0.31	-0.30
^{154}Eu (GH)	12.62 ± 0.74	12.93 ± 0.10	-2.4	-0.42	-0.41


Deviation (%) of Laboratory 32.1
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
3H (B1)
14C (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
241Am (GL)
137Cs (C1)
Gross (C1)

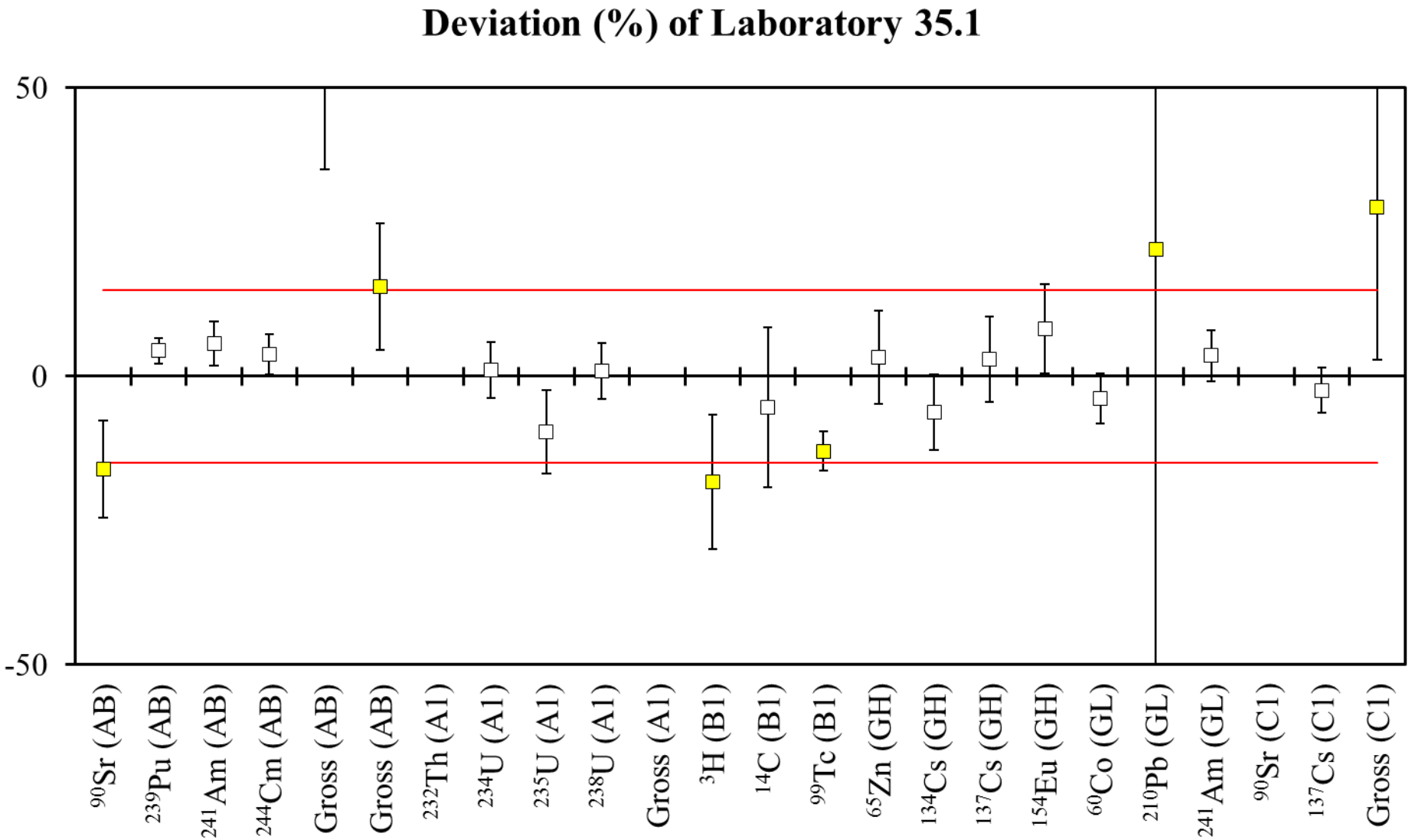
Radionuclide	Laboratory 32.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	5.430 ± 0.3	5.298 ± 0.058	2.5	0.43	0.43
^{90}Sr (AB)	9.10 ± 0.48	9.546 ± 0.042	-4.7	-0.93	-0.80
^{239}Pu (AB)	1.394 ± 0.040	1.3347 ± 0.0029	4.4	1.48	0.76
^{241}Am (AB)	5.10 ± 0.12	5.034 ± 0.011	1.3	0.55	0.23
^{244}Cm (AB)	10.74 ± 0.24	10.778 ± 0.039	-0.4	-0.16	-0.06
^{232}Th (A1)	4.034 ± 0.095	4.025 ± 0.038	0.2	0.09	0.04
^{234}U (A1)	15.40 ± 0.25	15.22 ± 0.26	1.2	0.50	0.20
^{235}U (A1)	0.685 ± 0.024	0.727 ± 0.015	-5.8	-1.48	-0.99
^{238}U (A1)	15.36 ± 0.24	15.22 ± 0.26	0.9	0.40	0.16
^{3}H (B1)	1.862 ± 0.049	1.898 ± 0.024	-1.9	-0.66	-0.33
^{14}C (B1)	0.951 ± 0.039	1.0146 ± 0.0066	-6.3	-1.61	-1.08
^{99}Tc (B1)	0.484 ± 0.059	0.5377 ± 0.0048	-10.0	-0.91	-1.72
^{65}Zn (GH)	17.70 ± 0.38	17.52 ± 0.13	1.0	0.45	0.18
^{134}Cs (GH)	3.370 ± 0.073	3.390 ± 0.024	-0.6	-0.26	-0.10
^{137}Cs (GH)	9.35 ± 0.20	9.264 ± 0.066	0.9	0.41	0.16
^{154}Eu (GH)	12.84 ± 0.28	12.93 ± 0.10	-0.7	-0.30	-0.12
^{60}Co (GL)	12.24 ± 0.66	9.937 ± 0.026	23.2	3.49	3.98
^{241}Am (GL)	18.54 ± 0.64	17.623 ± 0.039	5.2	1.43	0.89
^{137}Cs (C1)	64.4 ± 1.5	66.81 ± 0.87	-3.6	-1.39	-0.62
Gross alpha (C1)	1.329 ± 0.094	-	-	-	-
Gross beta (C1)	182.1 ± 6.4	185.7 ± 7.2	-1.9	-0.37	-0.33


Deviation (%) of Laboratory 32.2
50
0
-50
63Ni (AB)
90Sr (AB)
234U (A1)
235U (A1)
238U (A1)
3H (B1)

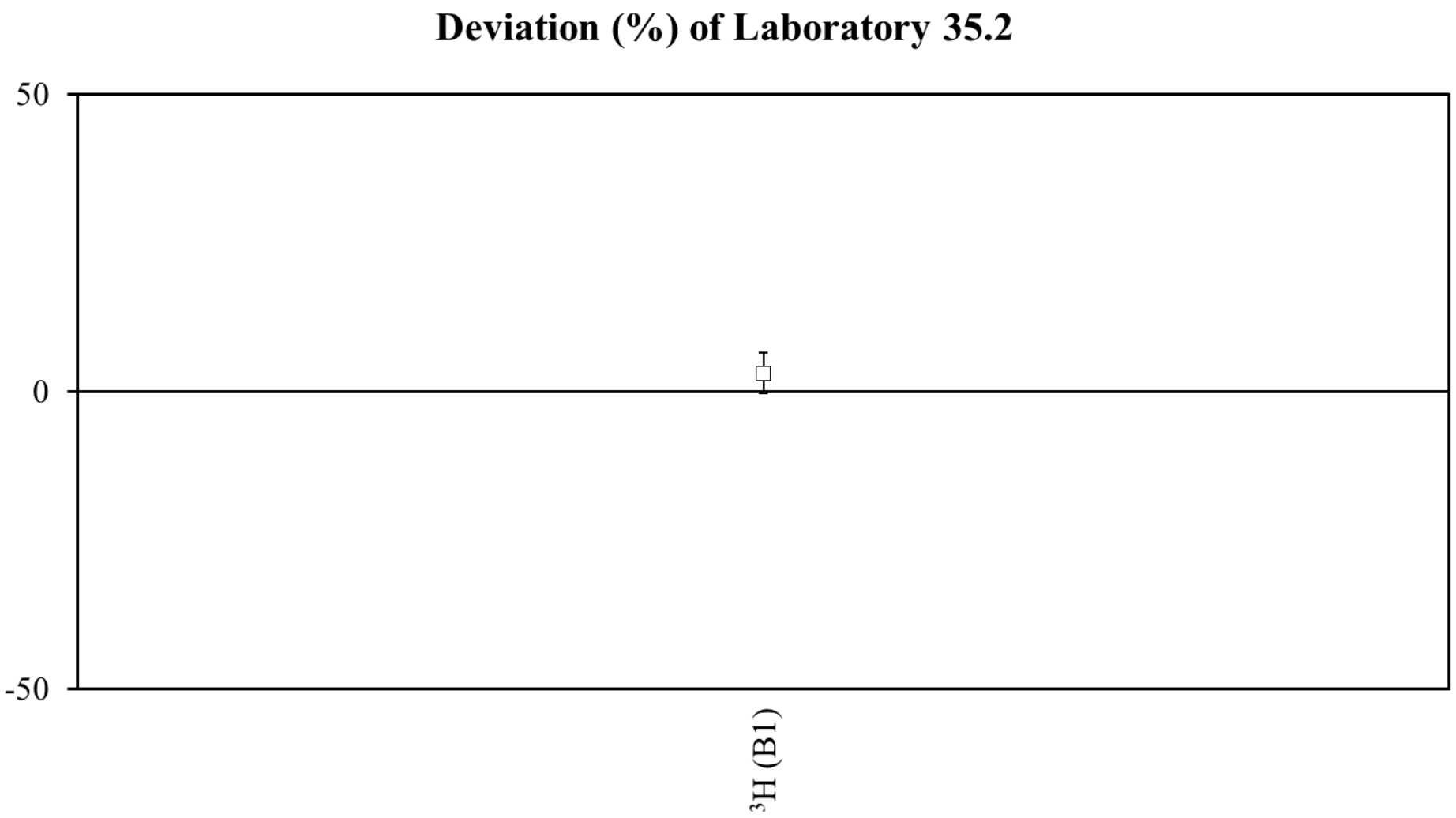
Radionuclide	Laboratory 32.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	5.460 ± 0.3	5.298 ± 0.058	3.1	0.53	0.53
^{90}Sr (AB)	9.18 ± 0.49	9.546 ± 0.042	-3.8	-0.74	-0.66
^{234}U (A1)	15.99 ± 0.89	15.22 ± 0.26	5.1	0.83	0.87
^{235}U (A1)	0.737 ± 0.035	0.727 ± 0.015	1.4	0.26	0.24
^{238}U (A1)	15.36 ± 0.59	15.22 ± 0.26	0.9	0.22	0.16
^{3}H (B1)	1.76 ± 0.12	1.898 ± 0.024	-7.3	-1.13	-1.25


Deviation (%) of Laboratory 32.3
50
0
-50
235U (A1)

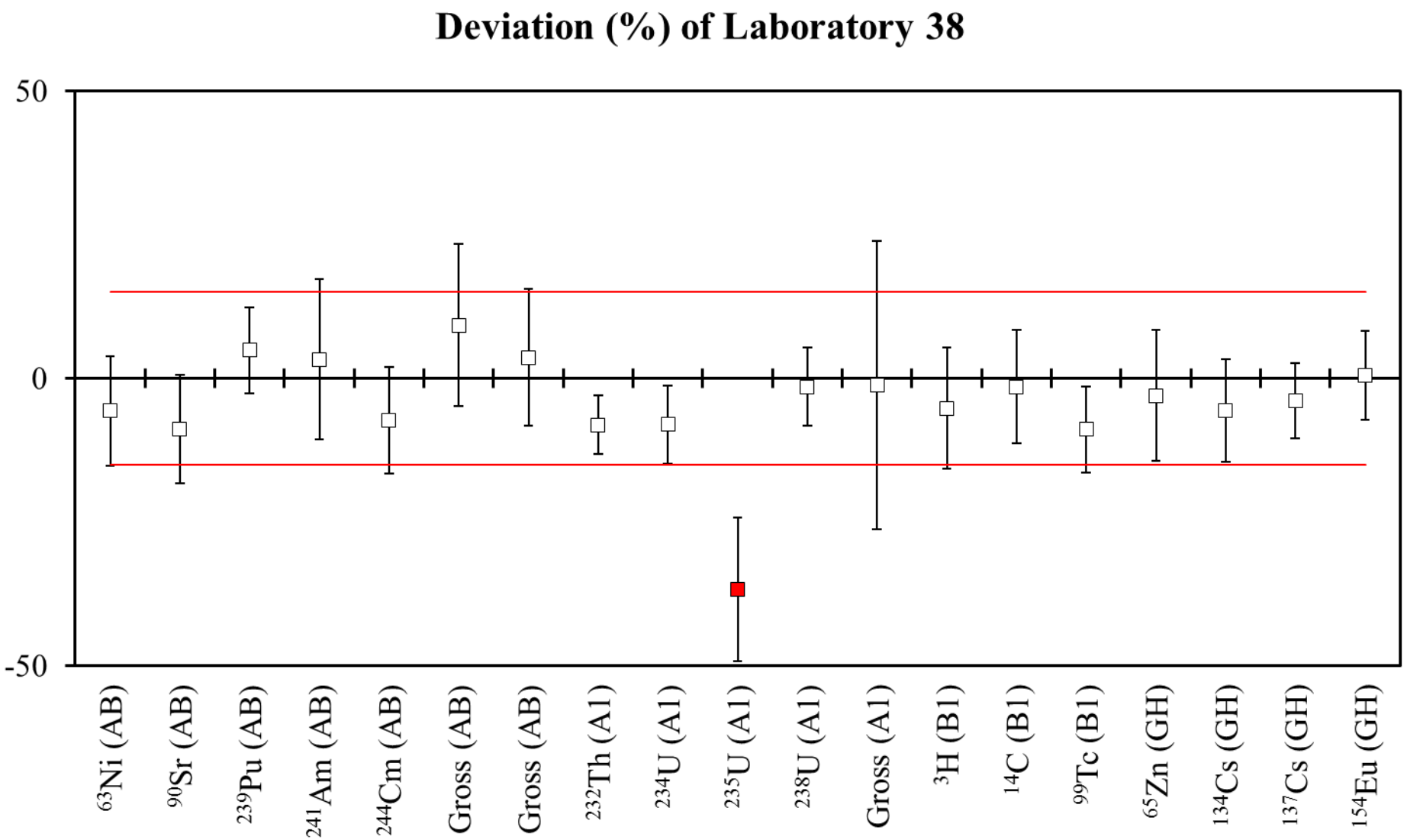
Radionuclide	Laboratory 32.3	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{235}U (A1)	0.85 ± 0.28	0.727 ± 0.015	16.9	0.44	2.91


Deviation (%) of Laboratory 35.1
50
0
-50
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
Gross (AB)
Gross (AB)
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
Gross (A1)
3H (B1)
14C (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
210Pb (GL)
241Am (GL)
90Sr (C1)
137Cs (C1)
Gross (C1)

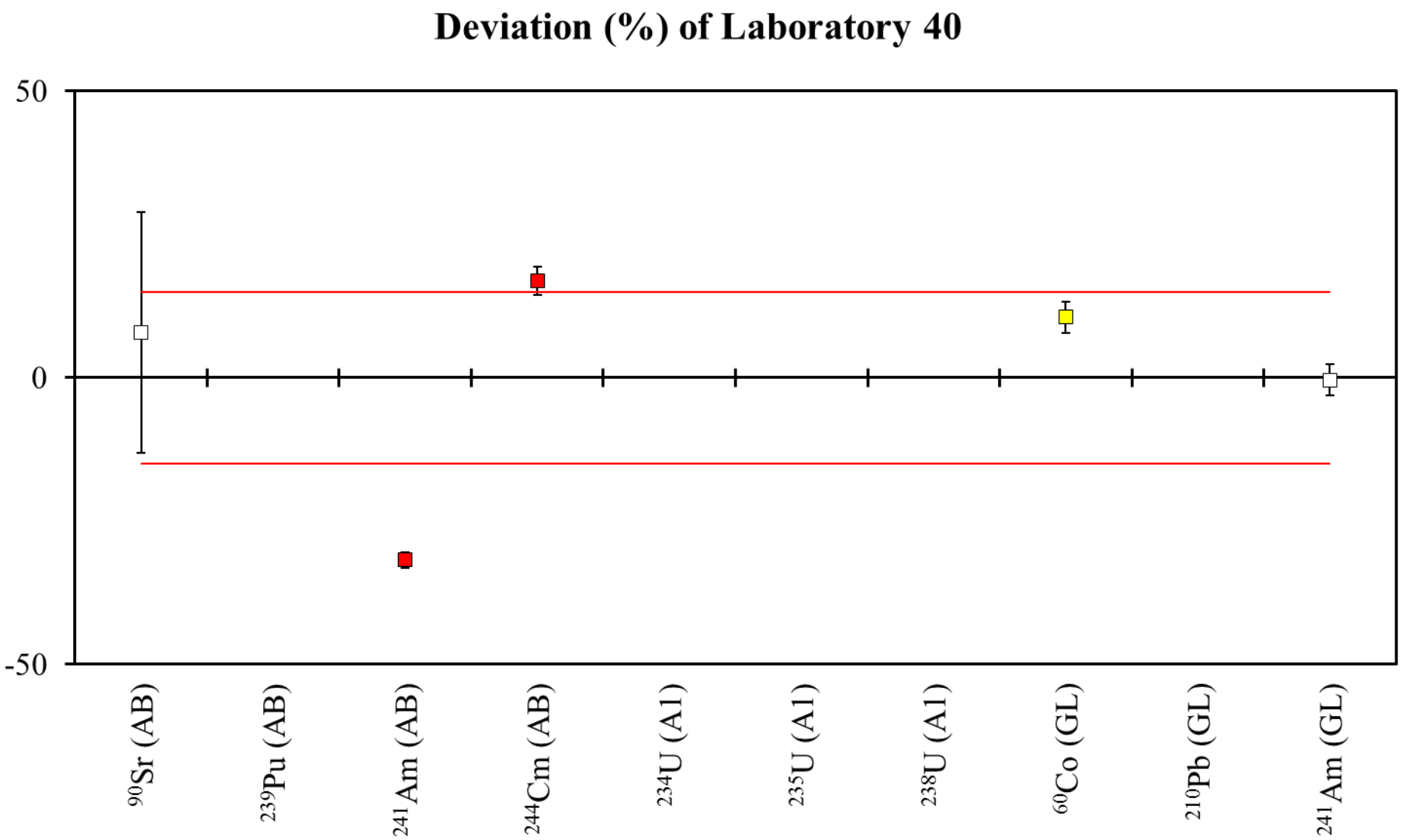
Radionuclide	Laboratory 35.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{90}Sr (AB)	8.01 ± 0.81	9.546 ± 0.042	-16.1	-1.89	-2.76
^{239}Pu (AB)	1.394 ± 0.029	1.3347 ± 0.0029	4.4	2.03	0.76
^{241}Am (AB)	5.32 ± 0.19	5.034 ± 0.011	5.7	1.50	0.98
^{244}Cm (AB)	11.19 ± 0.37	10.778 ± 0.039	3.8	1.11	0.66
Gross alpha (AB)	28.2 ± 2.4	18.3 ± 1.5	54.1	3.50	9.29
Gross beta (AB)	22.3 ± 1.7	19.3 ± 1.1	15.5	1.48	2.67
^{232}Th (A1)	1.562 ± 0.058	4.025 ± 0.038	-61.2	-35.52	-10.51
^{234}U (A1)	15.38 ± 0.69	15.22 ± 0.26	1.1	0.22	0.18
^{235}U (A1)	0.657 ± 0.051	0.727 ± 0.015	-9.6	-1.32	-1.65
^{238}U (A1)	15.360 ± 0.7	15.22 ± 0.26	0.9	0.19	0.16
Gross alpha (A1)	72.7 ± 6.2	40.5 ± 1.8	79.5	4.99	13.65
^{3}H (B1)	1.55 ± 0.22	1.898 ± 0.024	-18.3	-1.57	-3.15
^{14}C (B1)	0.96 ± 0.14	1.0146 ± 0.0066	-5.4	-0.39	-0.92
^{99}Tc (B1)	0.468 ± 0.018	0.5377 ± 0.0048	-13.0	-3.74	-2.23
^{65}Zn (GH)	18.1 ± 1.4	17.52 ± 0.13	3.3	0.41	0.57
^{134}Cs (GH)	3.18 ± 0.22	3.390 ± 0.024	-6.2	-0.95	-1.06
^{137}Cs (GH)	9.54 ± 0.68	9.264 ± 0.066	3.0	0.40	0.51
^{154}Eu (GH)	14.0 ± 1.0	12.93 ± 0.10	8.3	1.06	1.42
^{60}Co (GL)	9.55 ± 0.43	9.937 ± 0.026	-3.9	-0.90	-0.67
^{210}Pb (GL)	4.1 ± 2.5	3.362 ± 0.035	22.0	0.30	3.77
^{241}Am (GL)	18.26 ± 0.78	17.623 ± 0.039	3.6	0.82	0.62
^{90}Sr (C1)	20.34 ± 0.33	62.0 ± 9.1	-67.2	-4.58	-11.54
^{137}Cs (C1)	65.2 ± 2.5	66.81 ± 0.87	-2.4	-0.61	-0.41
^{239,240}Pu (C1)	36.0 ± 1.8	-	-	-	-
Gross alpha (C1)	0.62 ± 0.13	-	-	-	-
Gross beta (C1)	240 ± 48	185.7 ± 7.2	29.2	1.12	5.02


Deviation (%) of Laboratory 35.2
50
0
-50
^{3}H (B1)

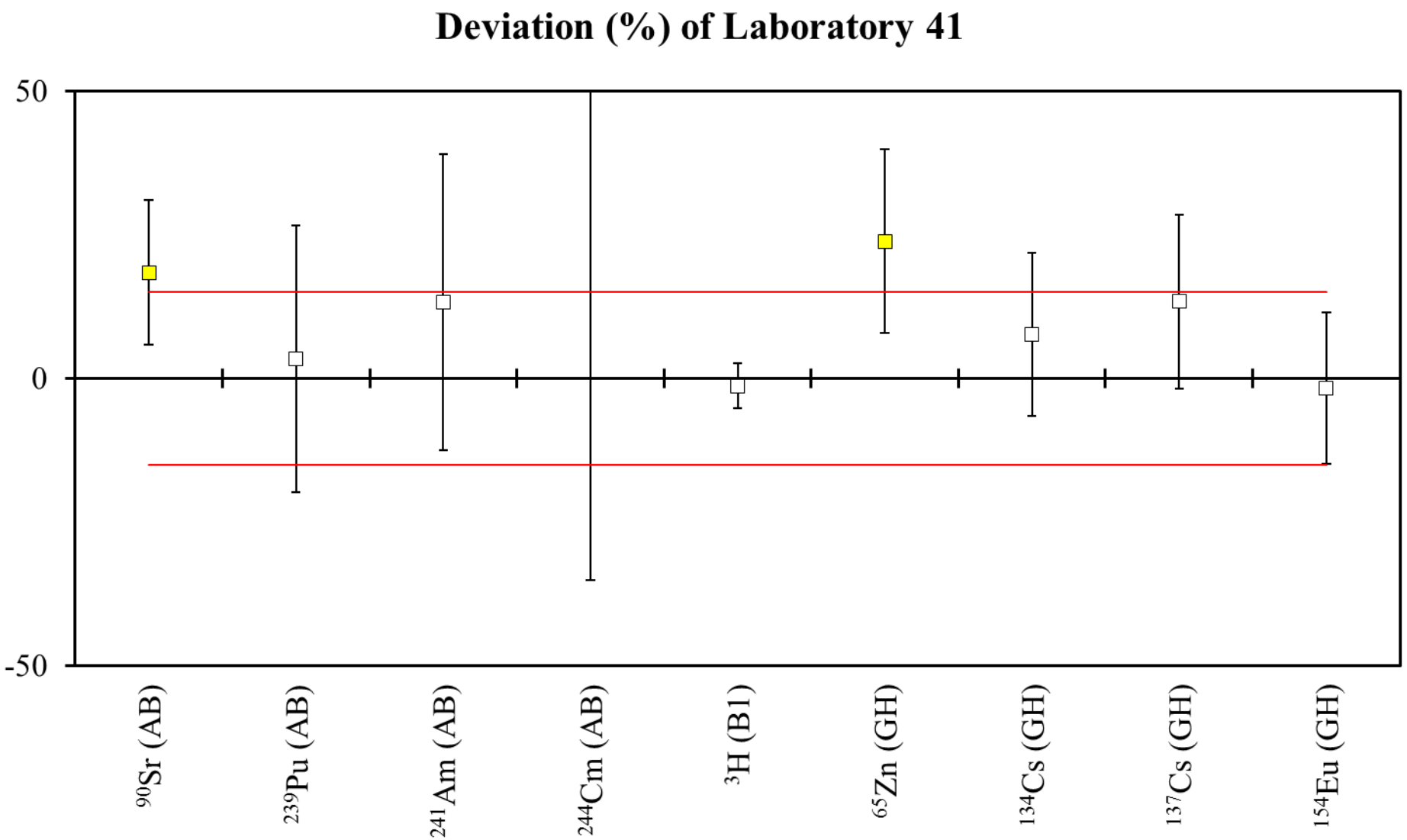
Radionuclide	Laboratory 35.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{3}H (B1)	1.957 ± 0.059	1.898 ± 0.024	3.1	0.93	0.53


Deviation (%) of Laboratory 38
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
Gross (AB)
Gross (AB)
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
Gross (A1)
3H (B1)
14C (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)

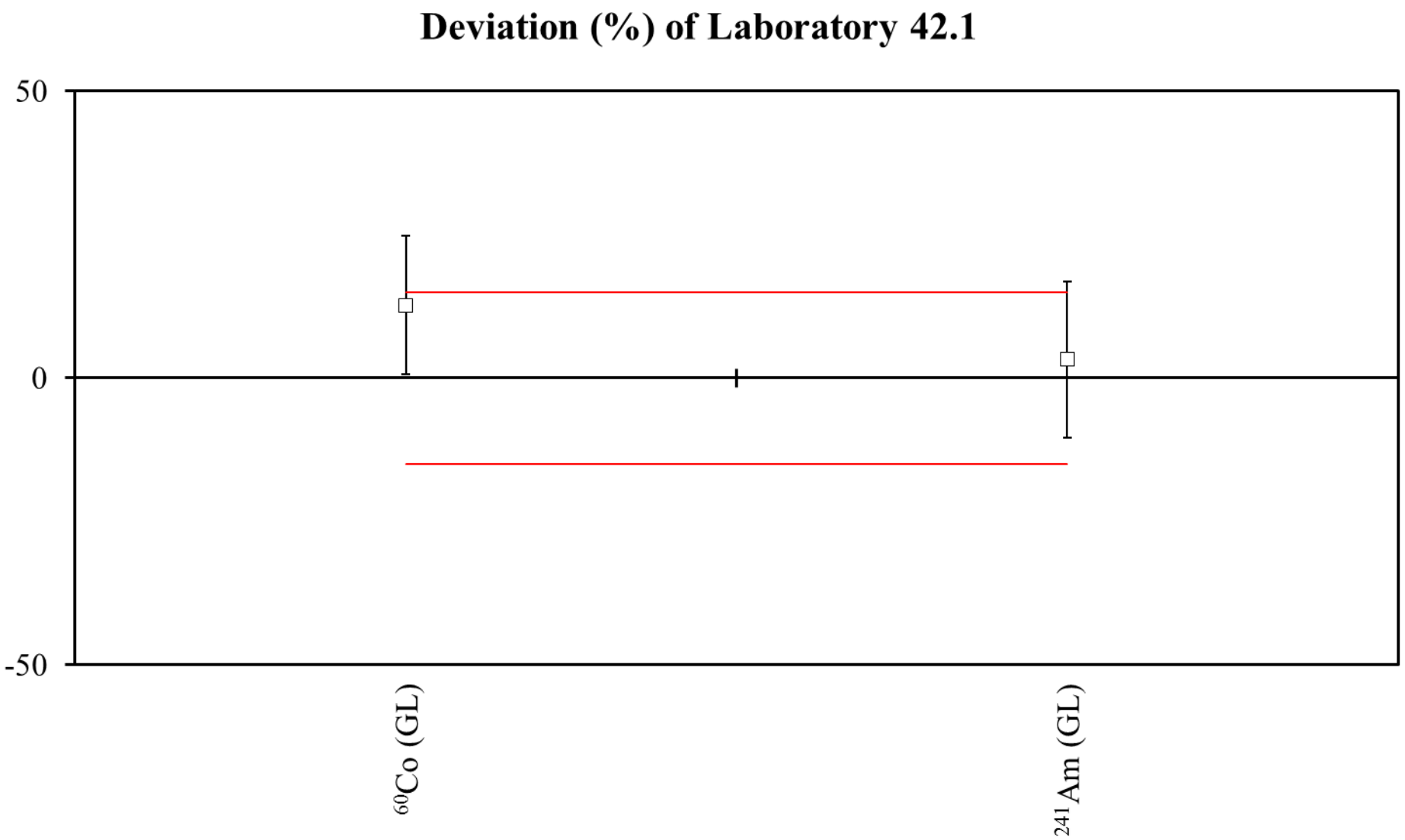
Radionuclide	Laboratory 38	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	5.00 ± 0.50	5.298 ± 0.058	-5.6	-0.59	-0.97
^{90}Sr (AB)	8.70 ± 0.90	9.546 ± 0.042	-8.9	-0.94	-1.52
^{239}Pu (AB)	1.40 ± 0.10	1.3347 ± 0.0029	4.9	0.65	0.84
^{241}Am (AB)	5.2 ± 0.7	5.034 ± 0.011	3.3	0.24	0.57
^{244}Cm (AB)	10.0 ± 1.0	10.778 ± 0.039	-7.2	-0.78	-1.24
Gross alpha (AB)	20.0 ± 2.0	18.3 ± 1.5	9.3	0.68	1.60
Gross beta (AB)	20.0 ± 2.0	19.3 ± 1.1	3.6	0.31	0.62
^{232}Th (A1)	3.70 ± 0.20	4.025 ± 0.038	-8.1	-1.60	-1.39
^{234}U (A1)	14.0 ± 1.0	15.22 ± 0.26	-8.0	-1.18	-1.38
^{235}U (A1)	0.46 ± 0.09	0.727 ± 0.015	-36.7	-2.93	-6.31
^{238}U (A1)	15.0 ± 1.0	15.22 ± 0.26	-1.4	-0.21	-0.25
Gross alpha (A1)	40 ± 10	40.5 ± 1.8	-1.2	-0.05	-0.21
^{3}H (B1)	1.80 ± 0.20	1.898 ± 0.024	-5.2	-0.49	-0.89
^{14}C (B1)	1.00 ± 0.10	1.0146 ± 0.0066	-1.4	-0.15	-0.25
^{99}Tc (B1)	0.490 ± 0.040	0.5377 ± 0.0048	-8.9	-1.18	-1.52
^{65}Zn (GH)	17.0 ± 2.0	17.52 ± 0.13	-3.0	-0.26	-0.51
^{134}Cs (GH)	3.2 ± 0.3	3.390 ± 0.024	-5.6	-0.63	-0.96
^{137}Cs (GH)	8.9 ± 0.6	9.264 ± 0.066	-3.9	-0.60	-0.67
^{154}Eu (GH)	13.0 ± 1.0	12.93 ± 0.10	0.5	0.07	0.09


Deviation (%) of Laboratory 40
50
0
-50
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
234U (A1)
235U (A1)
238U (A1)
60Co (GL)
210Pb (GL)
241Am (GL)

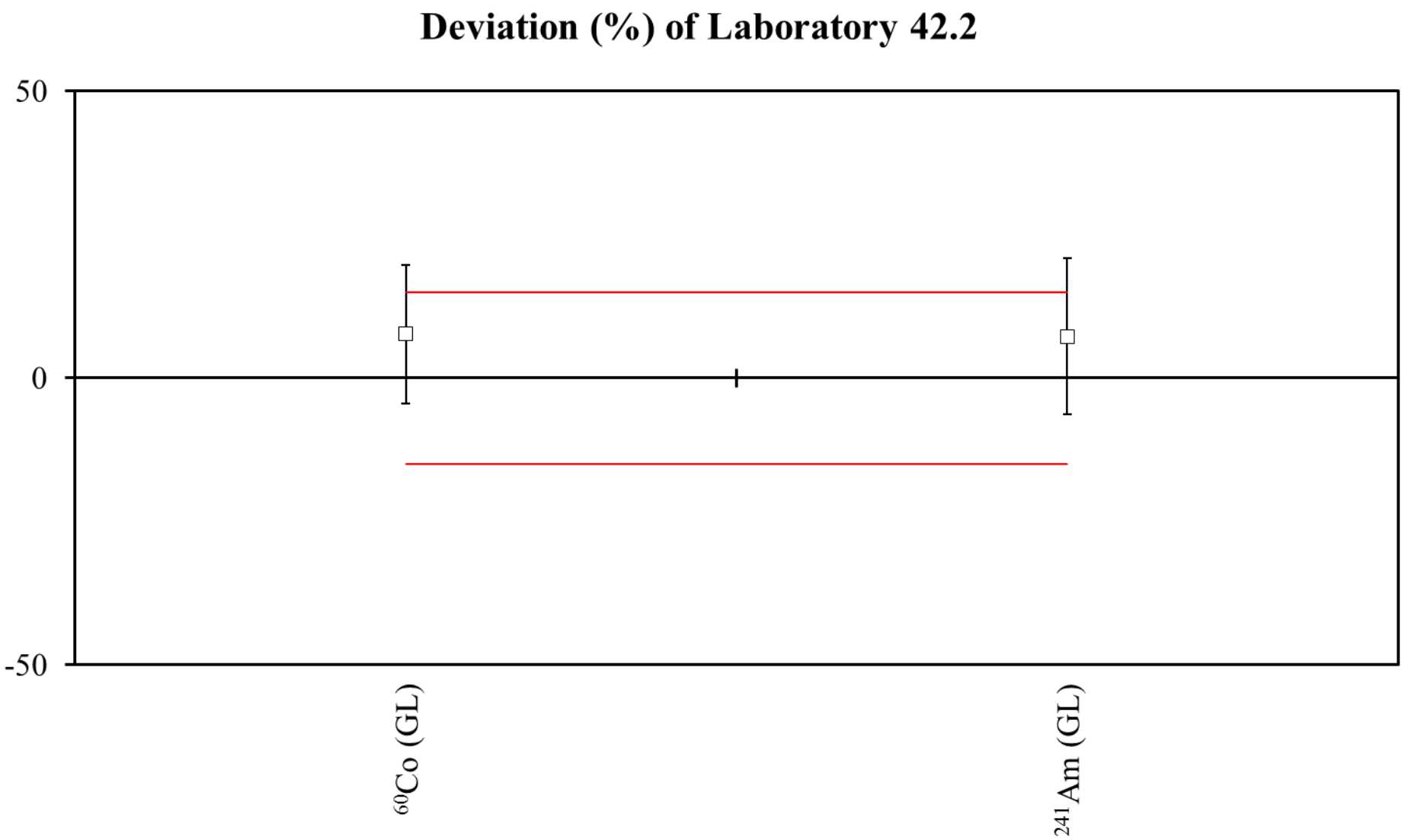
Radionuclide	Laboratory 40	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{90}Sr (AB)	10.3 ± 2.0	9.546 ± 0.042	7.9	0.38	1.36
^{239}Pu (AB)	0.4968 ± 0.0080	1.3347 ± 0.0029	-62.8	-98.47	-10.78
^{241}Am (AB)	3.4330 ± 0.07	5.034 ± 0.011	-31.8	-22.59	-5.46
^{244}Cm (AB)	12.60 ± 0.26	10.778 ± 0.039	16.9	6.93	2.90
^{234}U (A1)	5.28 ± 0.12	15.22 ± 0.26	-65.3	-34.71	-11.22
^{235}U (A1)	0.2475 ± 0.0062	0.727 ± 0.015	-66.0	-29.54	-11.33
^{238}U (A1)	5.28 ± 0.12	15.22 ± 0.26	-65.3	-34.71	-11.22
^{60}Co (GL)	10.99 ± 0.27	9.937 ± 0.026	10.6	3.88	1.82
^{210}Pb (GL)	11.4 ± 2.7	3.362 ± 0.035	239.1	2.98	41.06
^{241}Am (GL)	17.55 ± 0.48	17.623 ± 0.039	-0.4	-0.15	-0.07


Deviation (%) of Laboratory 41
50
0
-50
^{90}Sr (AB)
^{239}Pu (AB)
^{241}Am (AB)
^{244}Cm (AB)
^{3}H (B1)
^{65}Zn (GH)
^{134}Cs (GH)
^{137}Cs (GH)
^{154}Eu (GH)

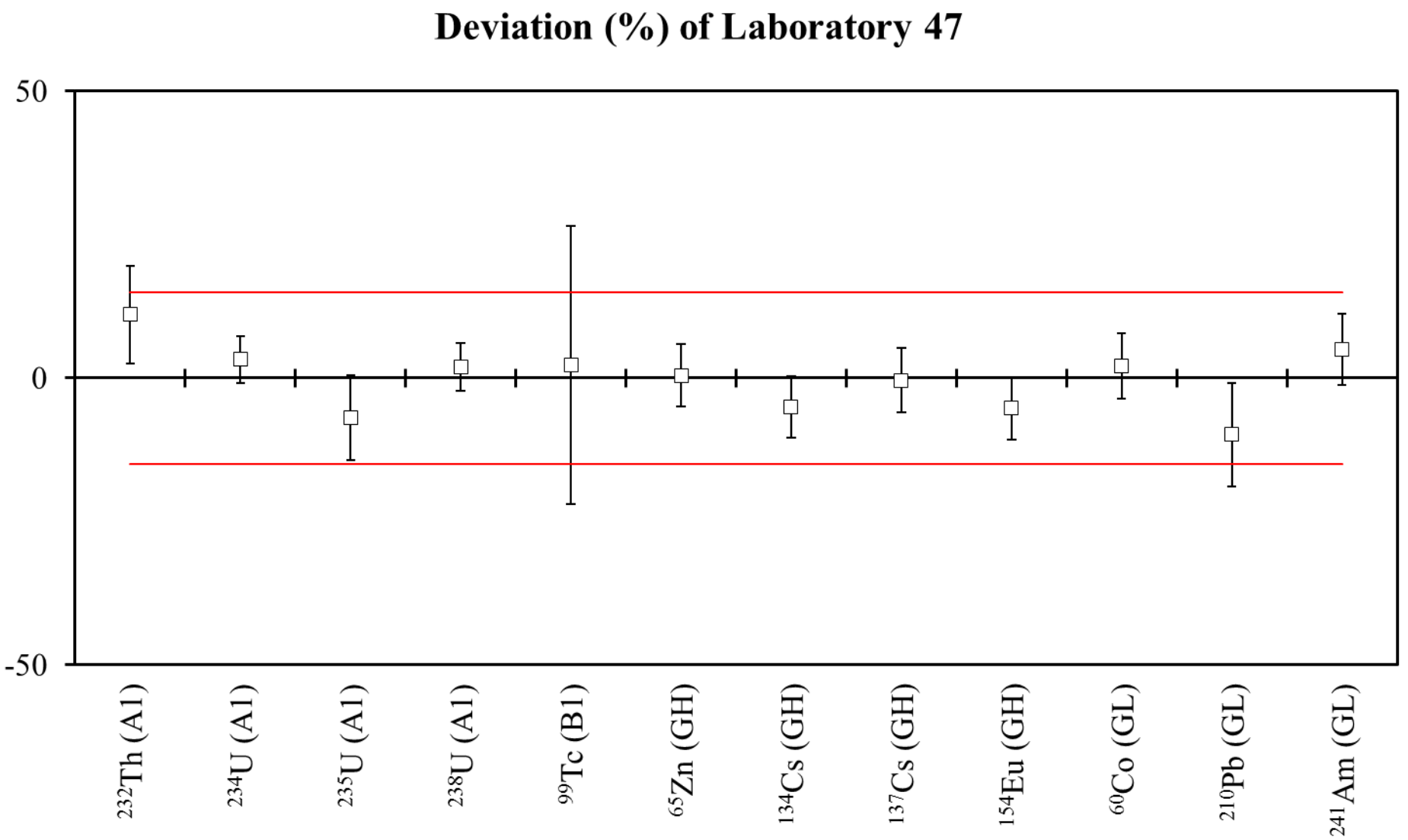
Radionuclide	Laboratory 41	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{90}Sr (AB)	11.3 ± 1.2	9.546 ± 0.042	18.4	1.46	3.16
^{239}Pu (AB)	1.38 ± 0.31	1.3347 ± 0.0029	3.4	0.15	0.58
^{241}Am (AB)	5.7 ± 1.3	5.034 ± 0.011	13.2	0.51	2.27
^{244}Cm (AB)	21 ± 14	10.778 ± 0.039	94.8	0.73	16.29
^{3}H (B1)	1.873 ± 0.071	1.898 ± 0.024	-1.3	-0.33	-0.23
^{65}Zn (GH)	21.7 ± 2.8	17.52 ± 0.13	23.9	1.49	4.10
^{134}Cs (GH)	3.65 ± 0.48	3.390 ± 0.024	7.7	0.54	1.32
^{137}Cs (GH)	10.5 ± 1.4	9.264 ± 0.066	13.3	0.88	2.29
^{154}Eu (GH)	12.7 ± 1.7	12.93 ± 0.10	-1.8	-0.14	-0.31


Deviation (%) of Laboratory 42.1
50
0
-50
60Co (GL)
241Am (GL)

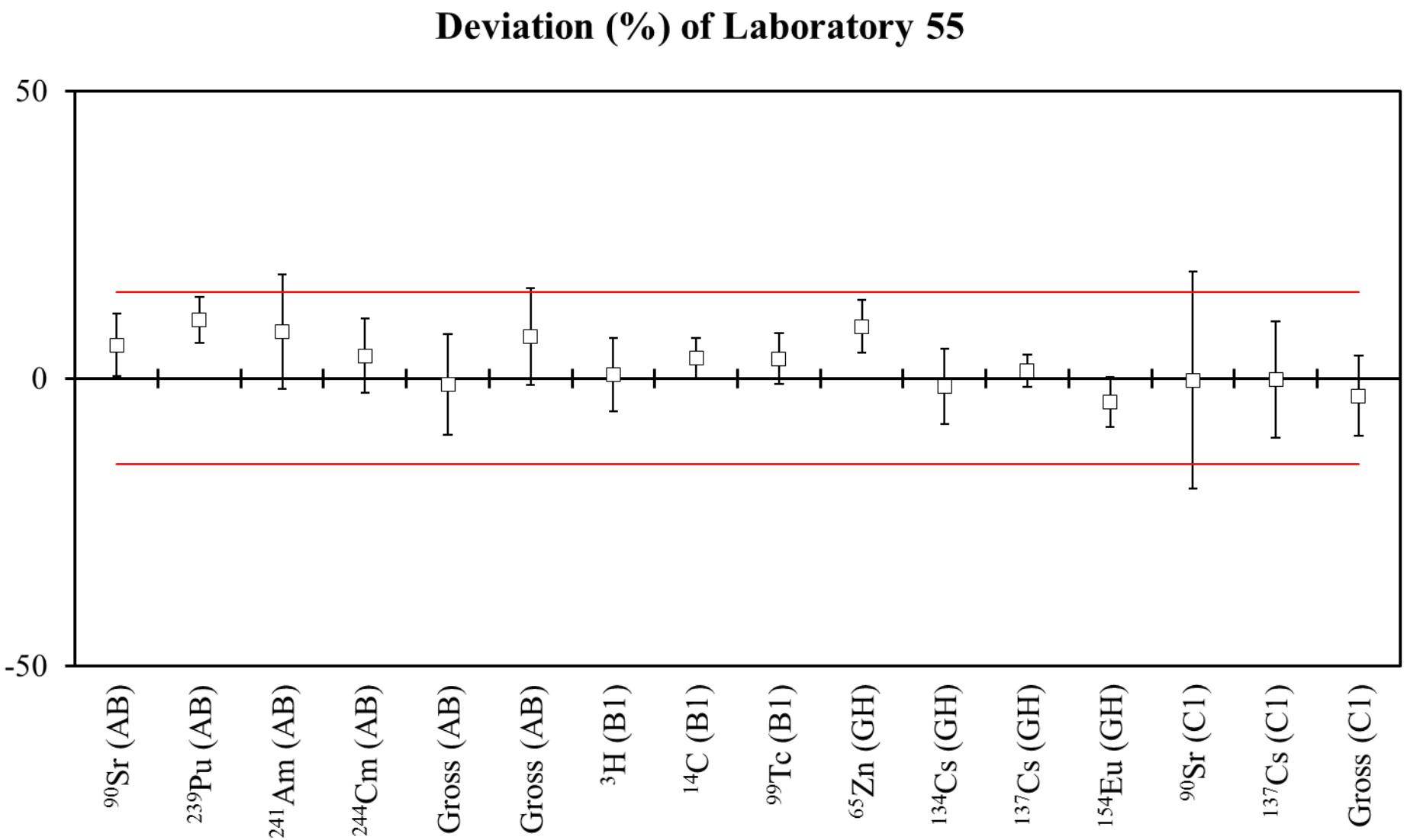
Radionuclide	Laboratory 42.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{60}Co (GL)	11.2 ± 1.2	9.937 ± 0.026	12.7	1.05	2.18
^{241}Am (GL)	18.2 ± 2.4	17.623 ± 0.039	3.3	0.24	0.56


Deviation (%) of Laboratory 42.2
50
0
-50
60Co (GL)
241Am (GL)

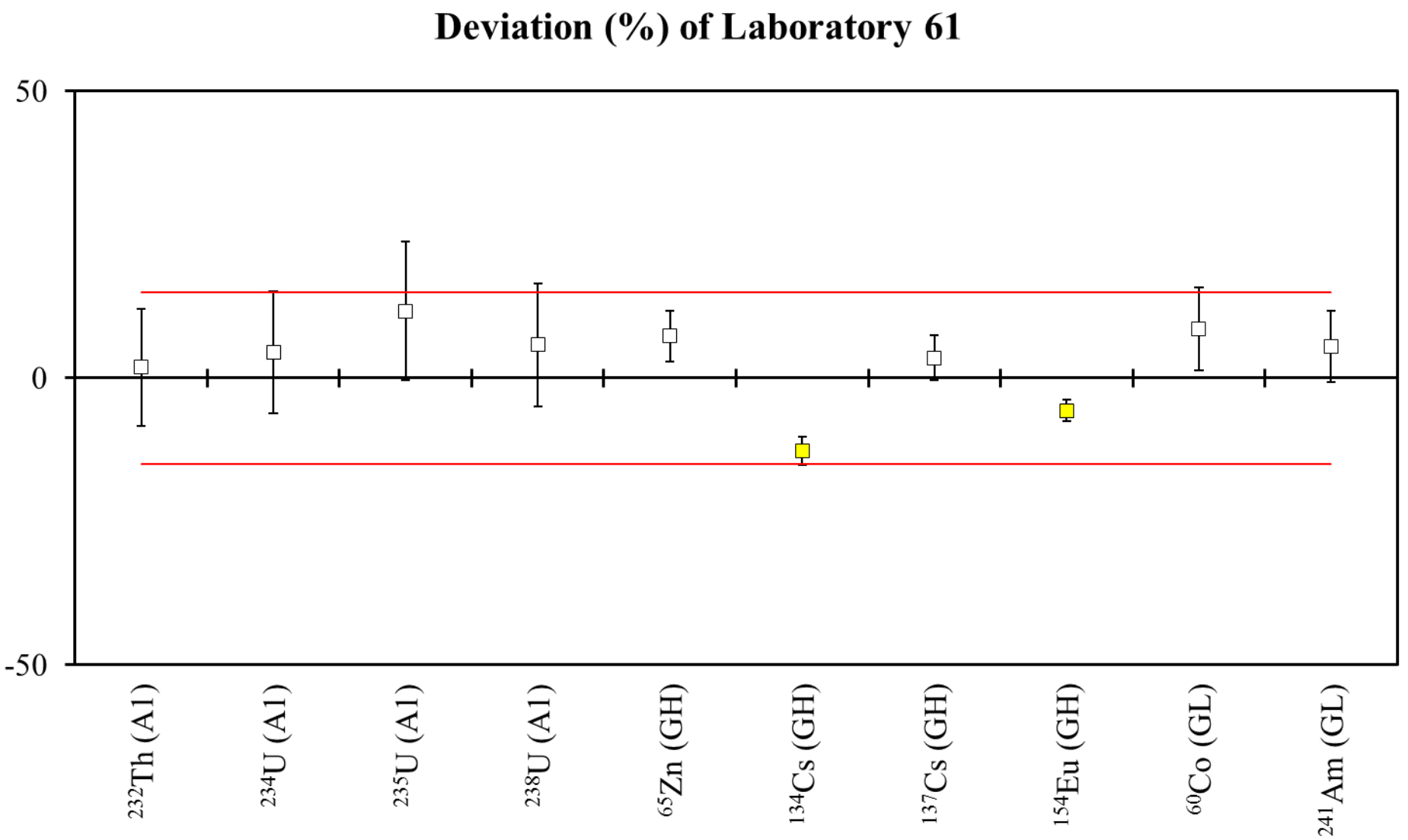
Radionuclide	Laboratory 42.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{60}Co (GL)	10.7 ± 1.2	9.937 ± 0.026	7.7	0.64	1.32
^{241}Am (GL)	18.9 ± 2.4	17.623 ± 0.039	7.2	0.53	1.24


Deviation (%) of Laboratory 47
50
0
-50
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
210Pb (GL)
241Am (GL)

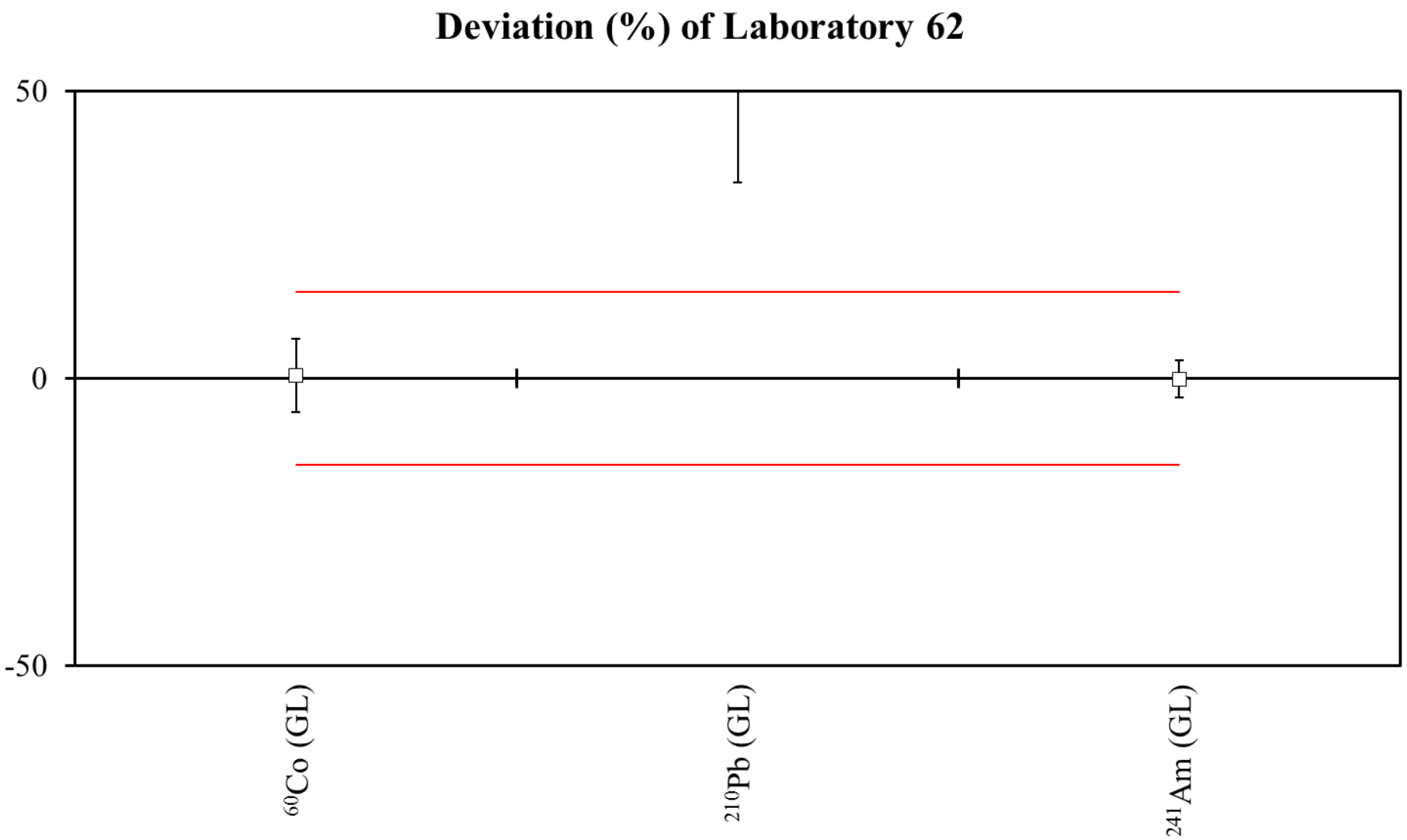
Radionuclide	Laboratory 47	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{232}Th (A1)	4.47 ± 0.34	4.025 ± 0.038	11.1	1.30	1.90
^{234}U (A1)	15.72 ± 0.56	15.22 ± 0.26	3.3	0.81	0.56
^{235}U (A1)	0.677 ± 0.052	0.727 ± 0.015	-6.9	-0.92	-1.18
^{238}U (A1)	15.52 ± 0.58	15.22 ± 0.26	2.0	0.47	0.34
^{99}Tc (B1)	0.55 ± 0.13	0.5377 ± 0.0048	2.3	0.09	0.39
^{65}Zn (GH)	17.60 ± 0.94	17.52 ± 0.13	0.5	0.08	0.08
^{134}Cs (GH)	3.22 ± 0.18	3.390 ± 0.024	-5.0	-0.94	-0.86
^{137}Cs (GH)	9.23 ± 0.52	9.264 ± 0.066	-0.4	-0.06	-0.06
^{154}Eu (GH)	12.25 ± 0.69	12.93 ± 0.10	-5.3	-0.98	-0.90
^{60}Co (GL)	10.15 ± 0.57	9.937 ± 0.026	2.1	0.37	0.37
^{210}Pb (GL)	3.030 ± 0.3	3.362 ± 0.035	-9.9	-1.10	-1.70
^{241}Am (GL)	18.5 ± 1.1	17.623 ± 0.039	5.0	0.80	0.85


Deviation (%) of Laboratory 55
50
0
-50
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
Gross (AB)
Gross (AB)
3H (B1)
14C (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
90Sr (C1)
137Cs (C1)
Gross (C1)

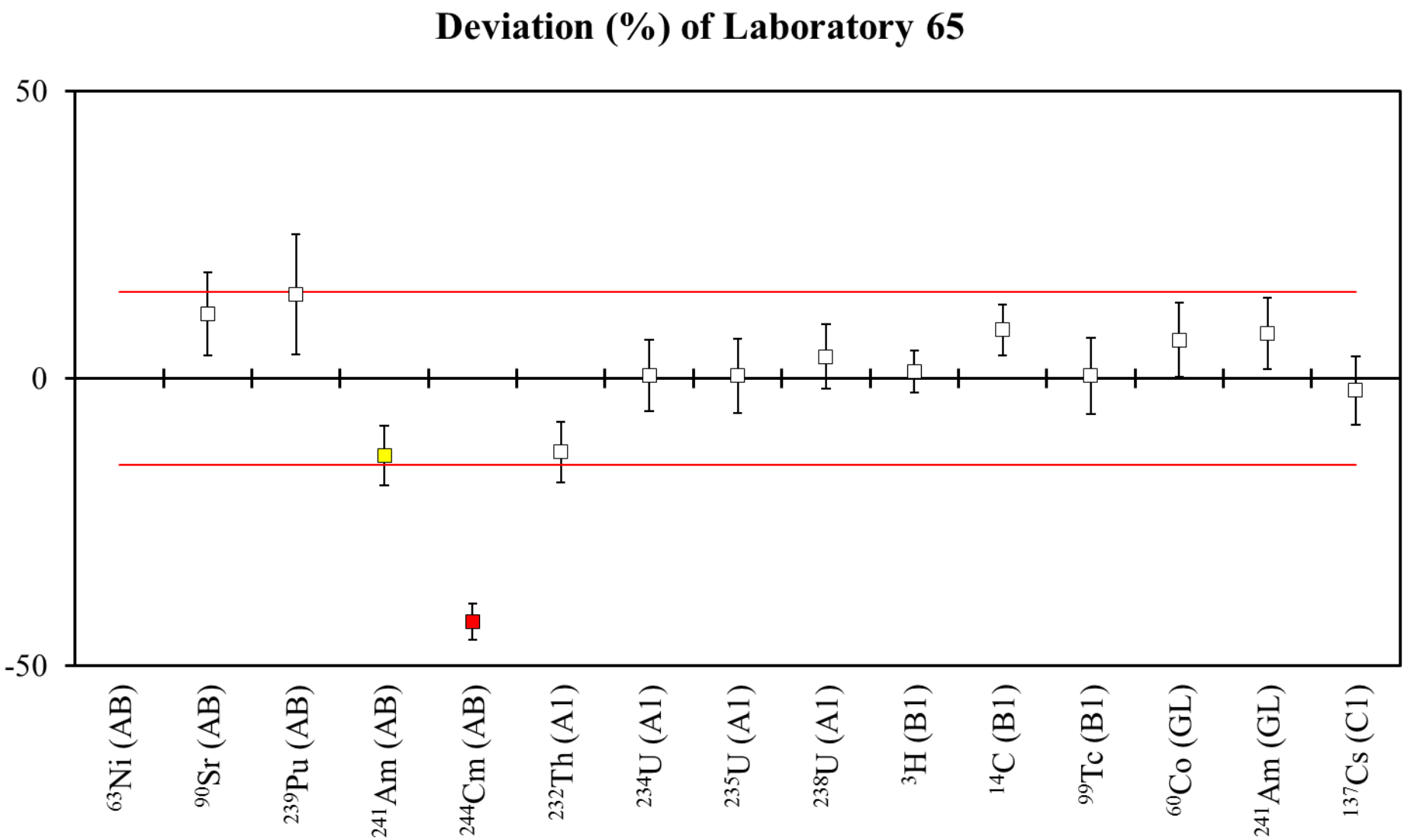
Radionuclide	Laboratory 55	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{90}Sr (AB)	10.10 ± 0.51	9.546 ± 0.042	5.8	1.08	1.00
^{239}Pu (AB)	1.470 ± 0.053	1.3347 ± 0.0029	10.1	2.55	1.74
^{241}Am (AB)	5.44 ± 0.50	5.034 ± 0.011	8.1	0.81	1.39
^{244}Cm (AB)	11.20 ± 0.69	10.778 ± 0.039	3.9	0.61	0.67
Gross alpha (AB)	18.10 ± 0.62	18.3 ± 1.5	-1.1	-0.12	-0.19
Gross beta (AB)	20.7 ± 1.1	19.3 ± 1.1	7.3	0.90	1.25
^{3}H (B1)	1.91 ± 0.12	1.898 ± 0.024	0.6	0.10	0.11
^{14}C (B1)	1.050 ± 0.035	1.0146 ± 0.0066	3.5	0.99	0.60
^{99}Tc (B1)	0.556 ± 0.023	0.5377 ± 0.0048	3.4	0.78	0.58
^{65}Zn (GH)	19.10 ± 0.79	17.52 ± 0.13	9.0	1.97	1.55
^{134}Cs (GH)	3.34 ± 0.22	3.390 ± 0.024	-1.5	-0.23	-0.25
^{137}Cs (GH)	9.38 ± 0.25	9.264 ± 0.066	1.3	0.45	0.22
^{154}Eu (GH)	12.40 ± 0.55	12.93 ± 0.10	-4.1	-0.95	-0.70
^{90}Sr (C1)	61.8 ± 7.4	62.0 ± 9.1	-0.3	-0.02	-0.06
^{137}Cs (C1)	66.7 ± 6.7	66.81 ± 0.87	-0.2	-0.02	-0.03
Gross alpha (C1)	0.68 ± 0.16	-	-	-	-
Gross beta (C1)	180 ± 11	185.7 ± 7.2	-3.1	-0.43	-0.53


Deviation (%) of Laboratory 61
50
0
-50
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
241Am (GL)

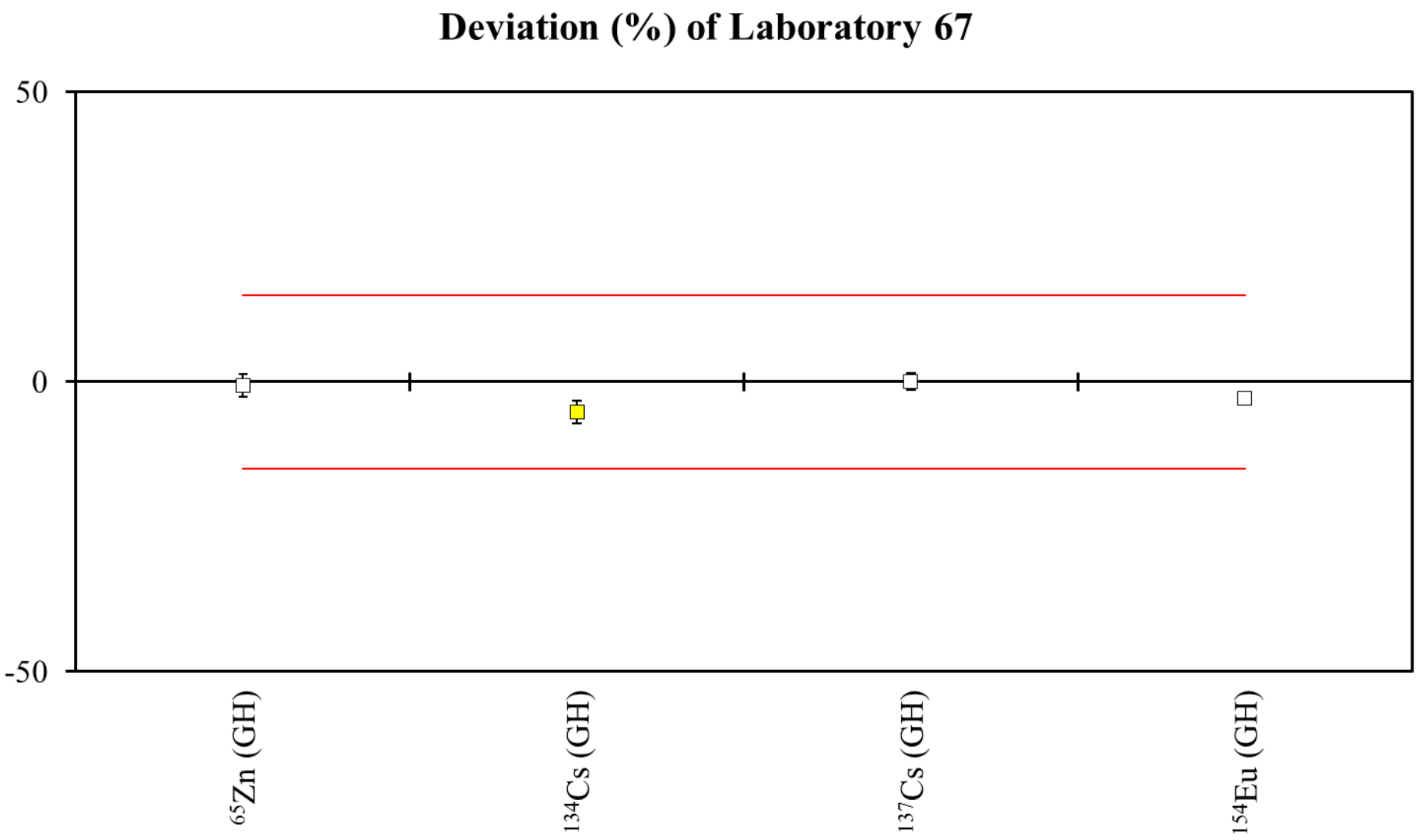
Radionuclide	Laboratory 61	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{232}Th (A1)	4.10 ± 0.41	4.025 ± 0.038	1.9	0.18	0.32
^{234}U (A1)	15.9 ± 1.6	15.22 ± 0.26	4.5	0.42	0.77
^{235}U (A1)	0.812 ± 0.086	0.727 ± 0.015	11.7	0.97	2.01
^{238}U (A1)	16.1 ± 1.6	15.22 ± 0.26	5.8	0.54	0.99
^{65}Zn (GH)	18.80 ± 0.76	17.52 ± 0.13	7.3	1.66	1.25
^{134}Cs (GH)	2.960 ± 0.080	3.390 ± 0.024	-12.7	-5.15	-2.18
^{137}Cs (GH)	9.59 ± 0.36	9.264 ± 0.066	3.5	0.89	0.60
^{154}Eu (GH)	12.20 ± 0.23	12.93 ± 0.10	-5.6	-2.91	-0.97
^{60}Co (GL)	10.79 ± 0.72	9.937 ± 0.026	8.6	1.18	1.47
^{241}Am (GL)	18.6 ± 1.1	17.623 ± 0.039	5.5	0.89	0.95


Deviation (%) of Laboratory 62
50
0
-50
^{60}Co (GL)
^{210}Pb (GL)
^{241}Am (GL)

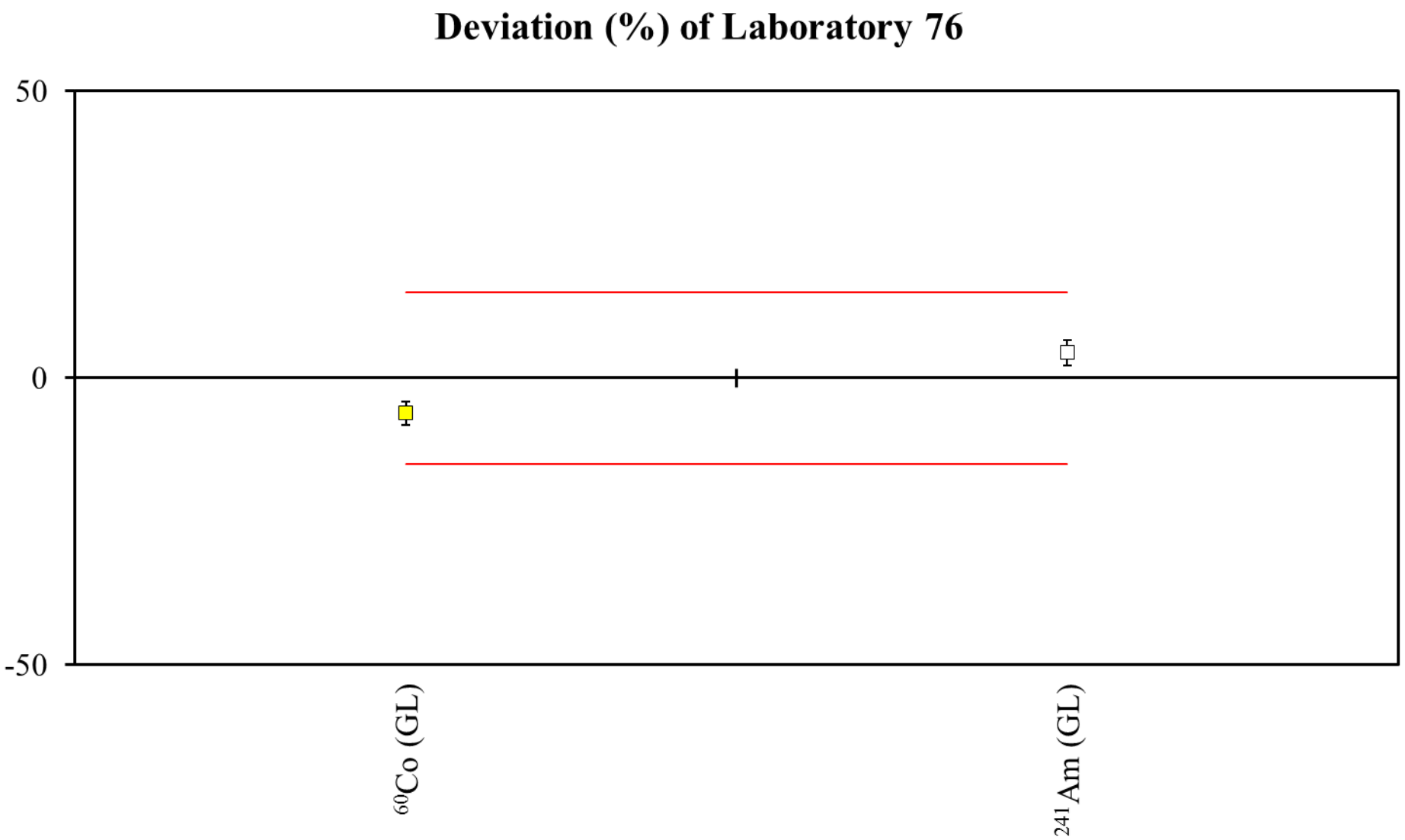
Radionuclide	Laboratory 62	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{60}Co (GL)	9.99 ± 0.63	9.937 ± 0.026	0.5	0.08	0.09
^{210}Pb (GL)	5.19 ± 0.68	3.362 ± 0.035	54.4	2.68	9.34
^{241}Am (GL)	17.60 ± 0.56	17.623 ± 0.039	-0.1	-0.04	-0.02


Deviation (%) of Laboratory 65
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
3H (B1)
14C (B1)
99Tc (B1)
60Co (GL)
241Am (GL)
137Cs (C1)

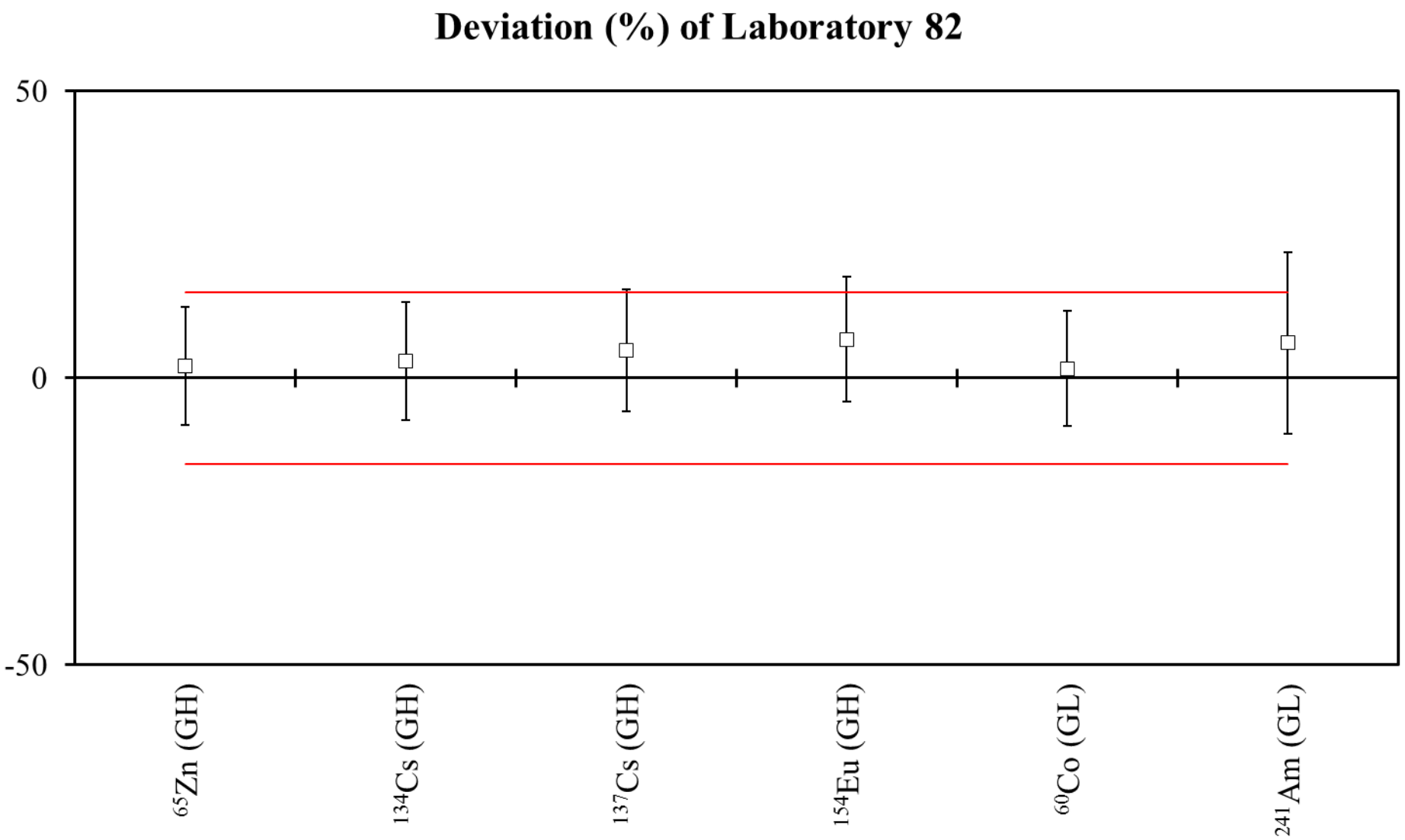
Radionuclide	Laboratory 65	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	0.0604 ± 0.0030	5.298 ± 0.058	-98.9	-90.18	-16.98
^{90}Sr (AB)	10.62 ± 0.69	9.546 ± 0.042	11.3	1.55	1.93
^{239}Pu (AB)	1.53 ± 0.14	1.3347 ± 0.0029	14.6	1.39	2.51
^{241}Am (AB)	4.36 ± 0.26	5.034 ± 0.011	-13.4	-2.59	-2.30
^{244}Cm (AB)	6.21 ± 0.34	10.778 ± 0.039	-42.4	-13.35	-7.28
^{232}Th (A1)	3.51 ± 0.21	4.025 ± 0.038	-12.8	-2.41	-2.20
^{234}U (A1)	15.30 ± 0.90	15.22 ± 0.26	0.5	0.09	0.09
^{235}U (A1)	0.730 ± 0.045	0.727 ± 0.015	0.4	0.06	0.07
^{238}U (A1)	15.80 ± 0.80	15.22 ± 0.26	3.8	0.69	0.65
^{3}H (B1)	1.920 ± 0.065	1.898 ± 0.024	1.2	0.32	0.20
^{14}C (B1)	1.100 ± 0.045	1.0146 ± 0.0066	8.4	1.88	1.45
^{99}Tc (B1)	0.540 ± 0.035	0.5377 ± 0.0048	0.4	0.07	0.07
^{60}Co (GL)	10.60 ± 0.64	9.937 ± 0.026	6.7	1.04	1.15
^{241}Am (GL)	19.0 ± 1.1	17.623 ± 0.039	7.8	1.25	1.34
^{137}Cs (C1)	65.4 ± 3.9	66.81 ± 0.87	-2.1	-0.35	-0.36


Deviation (%) of Laboratory 67
50
0
-50
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)

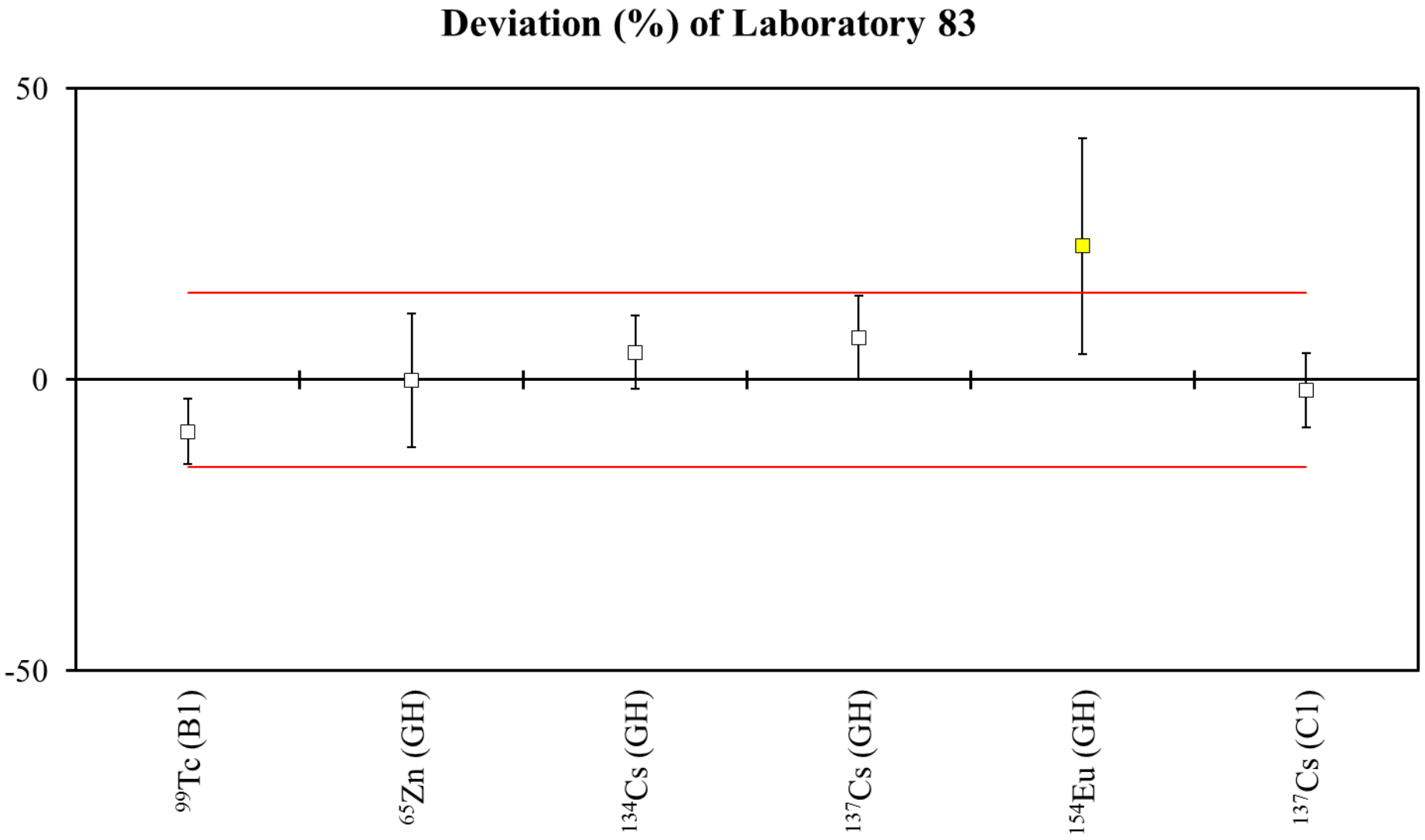
Radionuclide	Laboratory 67	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{65}Zn (GH)	17.42 ± 0.31	17.52 ± 0.13	-0.6	-0.30	-0.10
^{134}Cs (GH)	3.215 ± 0.063	3.390 ± 0.024	-5.2	-2.60	-0.89
^{137}Cs (GH)	9.27 ± 0.12	9.264 ± 0.066	0.1	0.04	0.01
^{154}Eu (GH)	12.56 ± 0.11	12.93 ± 0.10	-2.9	-2.49	-0.49


Deviation (%) of Laboratory 76
50
0
-50
60Co (GL)
241Am (GL)

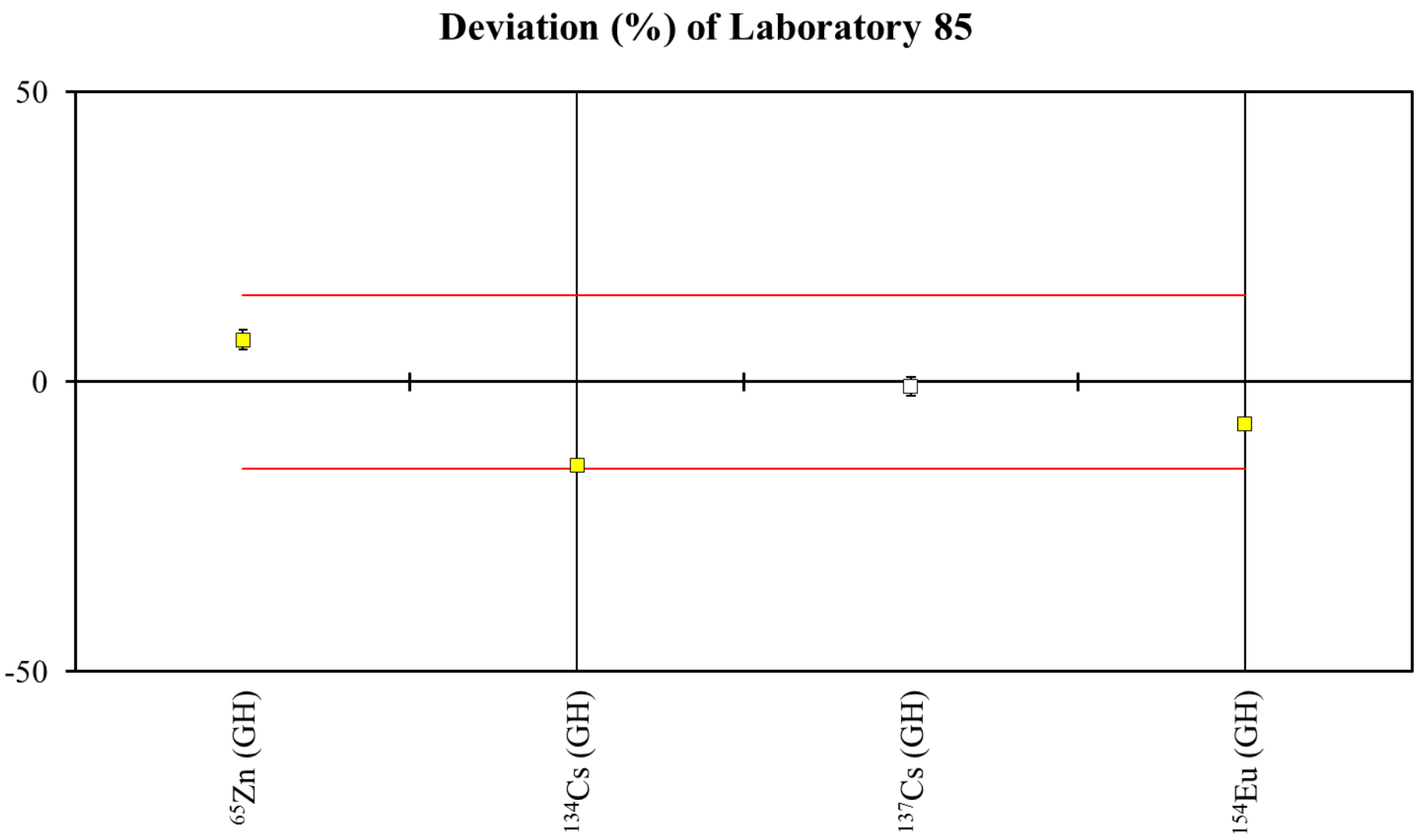
Radionuclide	Laboratory 76	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{60}Co (GL)	9.33 ± 0.20	9.937 ± 0.026	-6.1	-3.01	-1.05
^{241}Am (GL)	18.40 ± 0.39	17.623 ± 0.039	4.4	1.98	0.76


Deviation (%) of Laboratory 82
50
0
-50
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
241Am (GL)

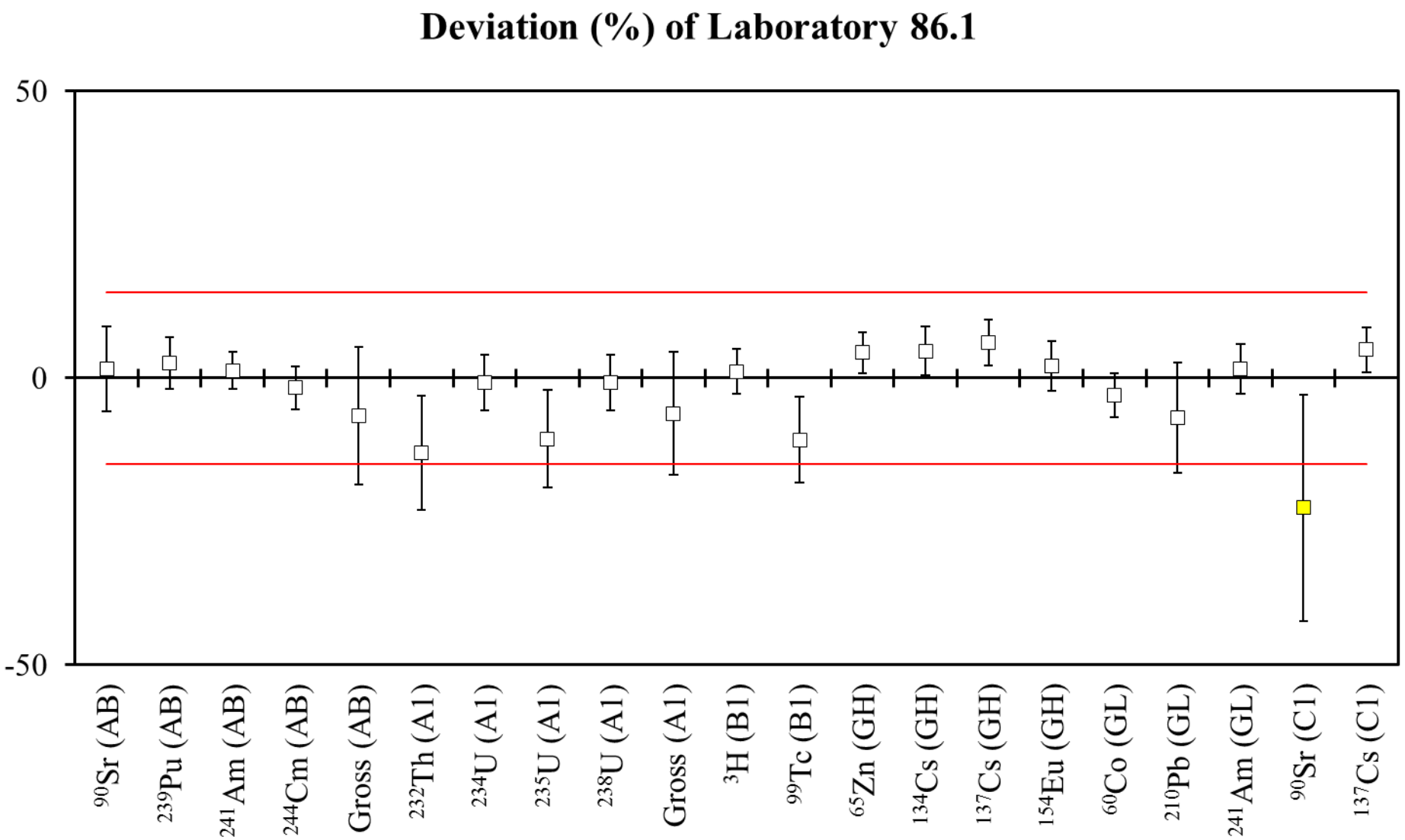
Radionuclide	Laboratory 82	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{65}Zn (GH)	17.9 ± 1.8	17.52 ± 0.13	2.2	0.21	0.37
^{134}Cs (GH)	3.49 ± 0.35	3.390 ± 0.024	2.9	0.29	0.51
^{137}Cs (GH)	9.71 ± 0.98	9.264 ± 0.066	4.8	0.45	0.83
^{154}Eu (GH)	13.8 ± 1.4	12.93 ± 0.10	6.7	0.62	1.16
^{60}Co (GL)	10.1 ± 1.0	9.937 ± 0.026	1.6	0.16	0.28
^{241}Am (GL)	18.7 ± 2.8	17.623 ± 0.039	6.1	0.38	1.05


Deviation (%) of Laboratory 83
50
0
-50
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
137Cs (C1)

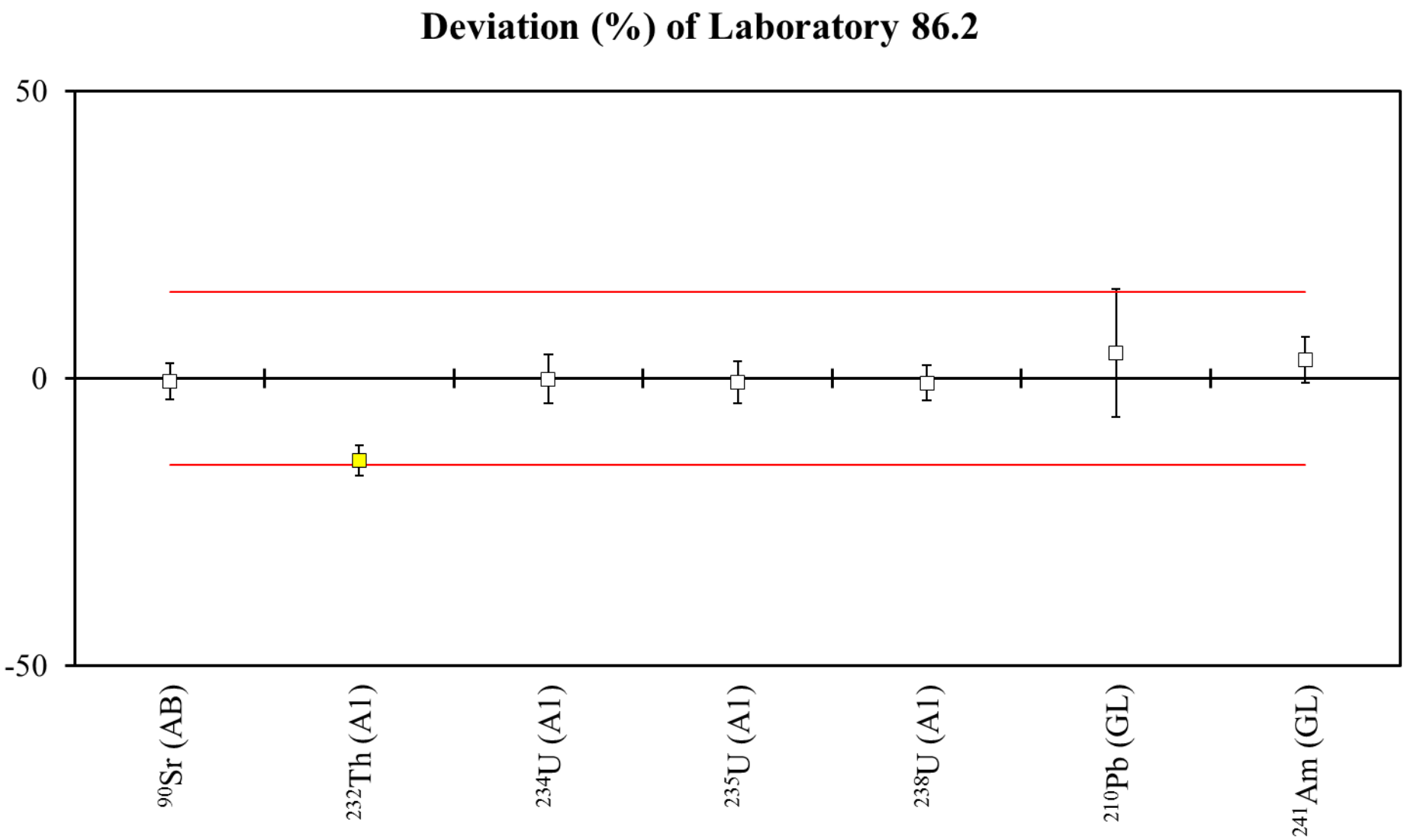
Radionuclide	Laboratory 83	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{99}Tc (B1)	0.49 ± 0.03	0.5377 ± 0.0048	-8.9	-1.57	-1.52
^{65}Zn (GH)	17.5 ± 2.0	17.52 ± 0.13	-0.1	-0.01	-0.02
^{134}Cs (GH)	3.55 ± 0.21	3.390 ± 0.024	4.7	0.76	0.81
^{137}Cs (GH)	9.94 ± 0.66	9.264 ± 0.066	7.3	1.02	1.25
^{154}Eu (GH)	15.9 ± 2.4	12.93 ± 0.10	23.0	1.24	3.94
^{137}Cs (C1)	65.6 ± 4.2	66.81 ± 0.87	-1.8	-0.28	-0.31


Deviation (%) of Laboratory 85
50
0
-50
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)

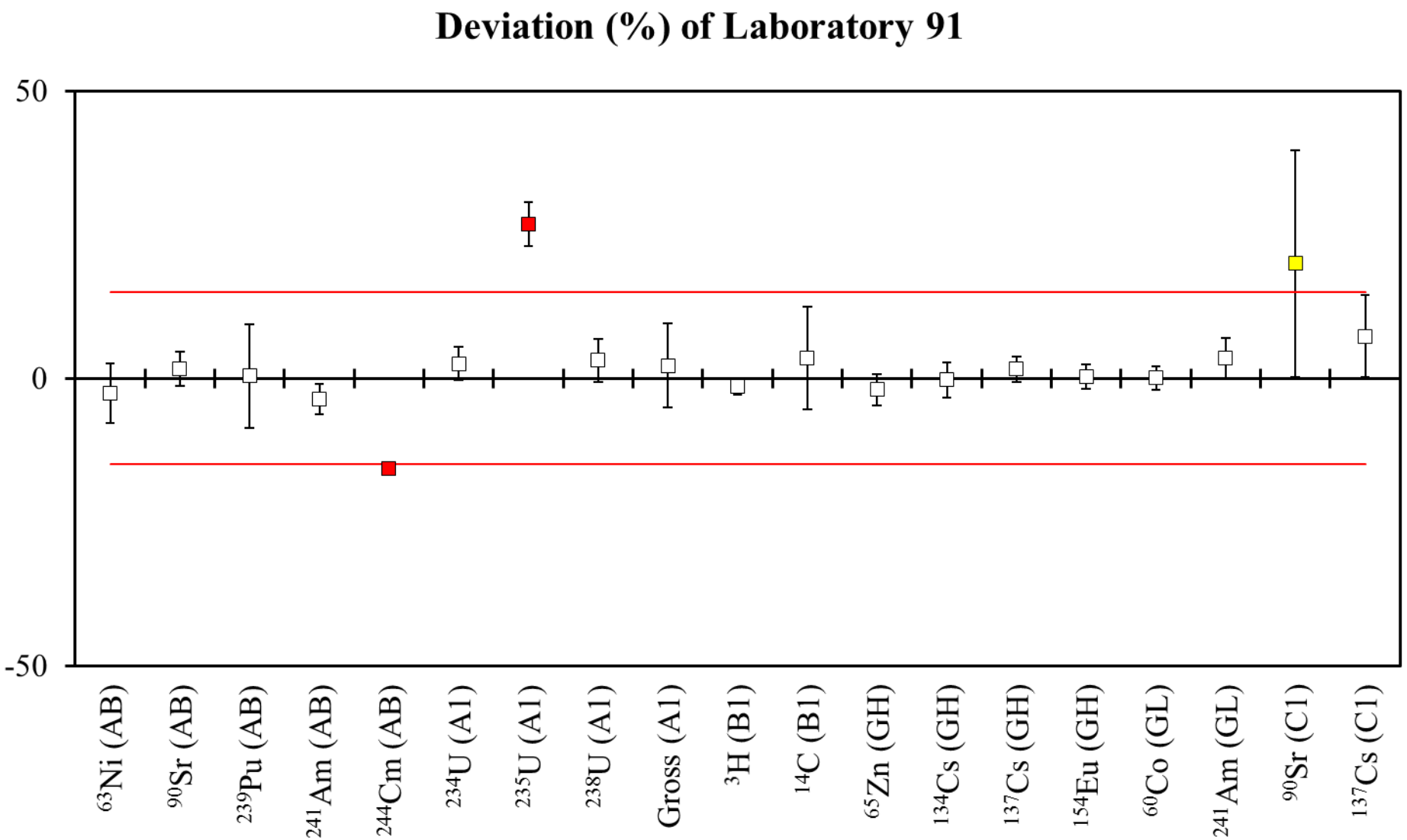
Radionuclide	Laboratory 85	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{65}Zn (GH)	18.79 ± 0.27	17.52 ± 0.13	7.2	4.24	1.24
^{134}Cs (GH)	2.9 ± 4.2	3.390 ± 0.024	-14.5	-0.12	-2.48
^{137}Cs (GH)	9.19 ± 0.13	9.264 ± 0.066	-0.8	-0.51	-0.14
^{154}Eu (GH)	12 ± 32	12.93 ± 0.10	-7.2	-0.03	-1.24


Deviation (%) of Laboratory 86.1
50
0
-50
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
Gross (AB)
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
Gross (A1)
3H (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
210Pb (GL)
241Am (GL)
90Sr (C1)
137Cs (C1)

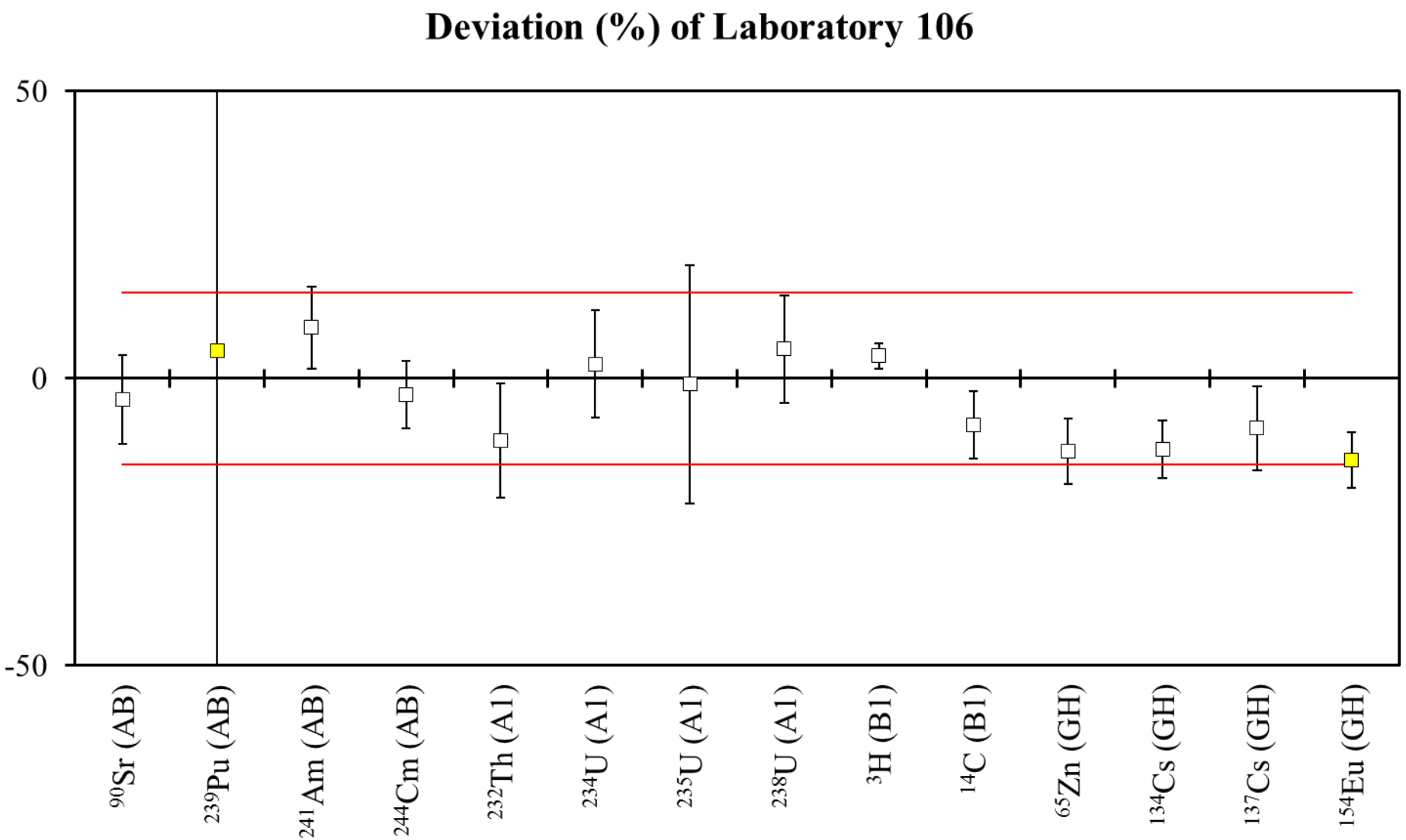
Radionuclide	Laboratory 86.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{90}Sr (AB)	9.7 ± 0.7	9.546 ± 0.042	1.6	0.22	0.28
^{239}Pu (AB)	1.37 ± 0.06	1.3347 ± 0.0029	2.6	0.59	0.45
^{241}Am (AB)	5.10 ± 0.16	5.034 ± 0.011	1.3	0.41	0.23
^{244}Cm (AB)	10.60 ± 0.40	10.778 ± 0.039	-1.7	-0.44	-0.28
Gross alpha (AB)	17.1 ± 1.7	18.3 ± 1.5	-6.6	-0.53	-1.13
^{232}Th (A1)	3.50 ± 0.40	4.025 ± 0.038	-13.0	-1.31	-2.24
^{234}U (A1)	15.1 ± 0.7	15.22 ± 0.26	-0.8	-0.16	-0.14
^{235}U (A1)	0.65 ± 0.06	0.727 ± 0.015	-10.6	-1.25	-1.82
^{238}U (A1)	15.1 ± 0.7	15.22 ± 0.26	-0.8	-0.16	-0.14
Gross alpha (A1)	38.0 ± 4.0	40.5 ± 1.8	-6.2	-0.57	-1.06
^{3}H (B1)	1.92 ± 0.07	1.898 ± 0.024	1.2	0.30	0.20
^{99}Tc (B1)	0.480 ± 0.040	0.5377 ± 0.0048	-10.7	-1.43	-1.84
^{65}Zn (GH)	18.30 ± 0.61	17.52 ± 0.13	4.5	1.25	0.76
^{134}Cs (GH)	3.55 ± 0.14	3.390 ± 0.024	4.7	1.13	0.81
^{137}Cs (GH)	9.84 ± 0.36	9.264 ± 0.066	6.2	1.57	1.07
^{154}Eu (GH)	13.20 ± 0.55	12.93 ± 0.10	2.1	0.48	0.36
^{60}Co (GL)	9.64 ± 0.38	9.937 ± 0.026	-3.0	-0.78	-0.51
^{210}Pb (GL)	3.13 ± 0.32	3.362 ± 0.035	-6.9	-0.72	-1.19
^{241}Am (GL)	17.90 ± 0.76	17.623 ± 0.039	1.6	0.36	0.27
^{90}Sr (C1)	48 ± 10	62.0 ± 9.1	-22.6	-1.04	-3.88
^{137}Cs (C1)	70.1 ± 2.5	66.81 ± 0.87	4.9	1.24	0.85
^{239,240}Pu (C1)	0.0335 ± 0.0040	-	-	-	-


Deviation (%) of Laboratory 86.2
50
0
-50
^{90}Sr (AB)
^{232}Th (A1)
^{234}U (A1)
^{235}U (A1)
^{238}U (A1)
^{210}Pb (GL)
^{241}Am (GL)

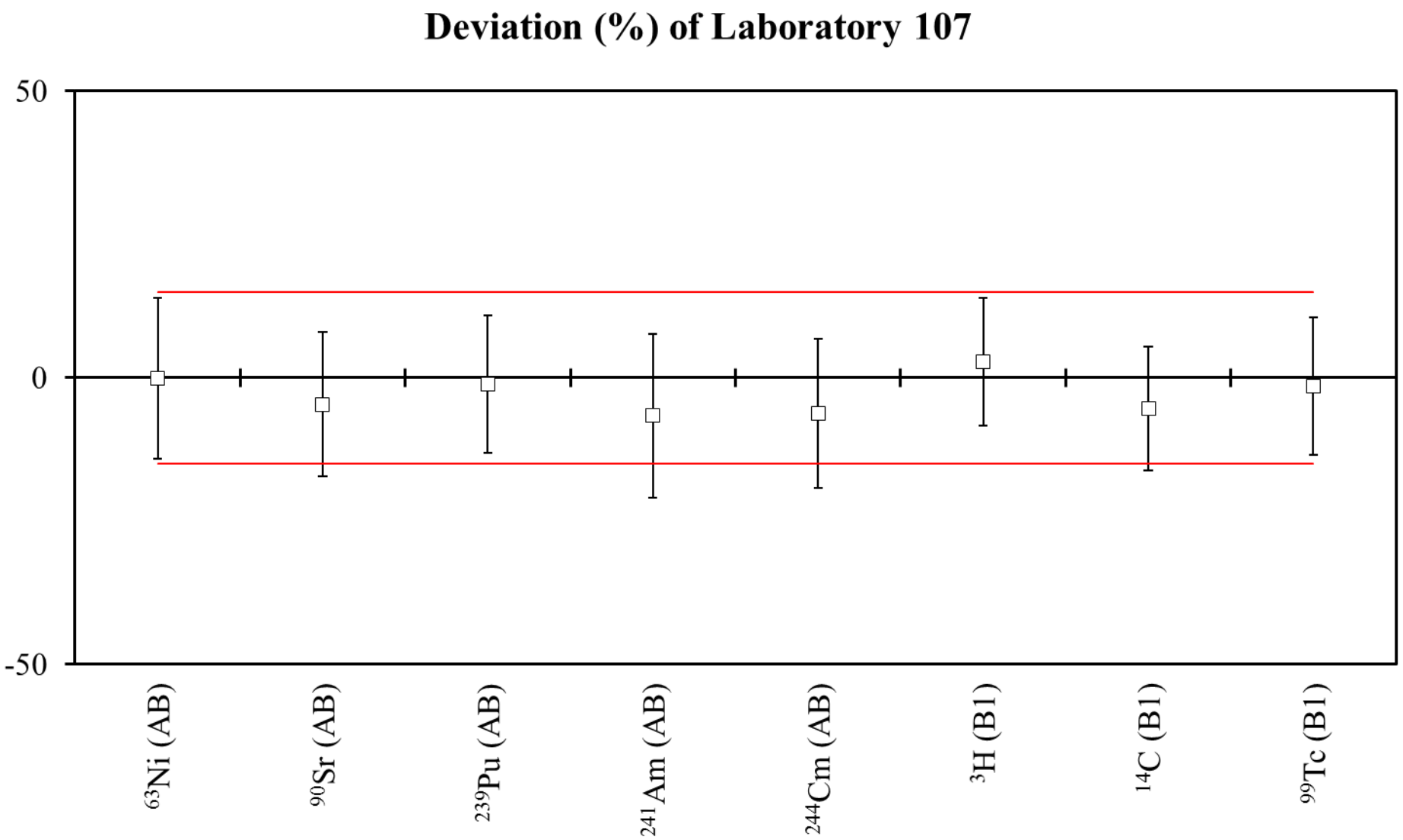
Radionuclide	Laboratory 86.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{90}Sr (AB)	9.5 ± 0.3	9.546 ± 0.042	-0.5	-0.15	-0.08
^{232}Th (A1)	3.45 ± 0.10	4.025 ± 0.038	-14.3	-5.38	-2.45
^{234}U (A1)	15.2 ± 0.6	15.22 ± 0.26	-0.1	-0.03	-0.02
^{235}U (A1)	0.722 ± 0.022	0.727 ± 0.015	-0.7	-0.19	-0.12
^{238}U (A1)	15.10 ± 0.40	15.22 ± 0.26	-0.8	-0.25	-0.14
^{210}Pb (GL)	3.51 ± 0.37	3.362 ± 0.035	4.4	0.40	0.76
^{241}Am (GL)	18.2 ± 0.7	17.623 ± 0.039	3.3	0.82	0.56


Deviation (%) of Laboratory 91
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
234U (A1)
235U (A1)
238U (A1)
Gross (A1)
3H (B1)
14C (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
241Am (GL)
90Sr (C1)
137Cs (C1)

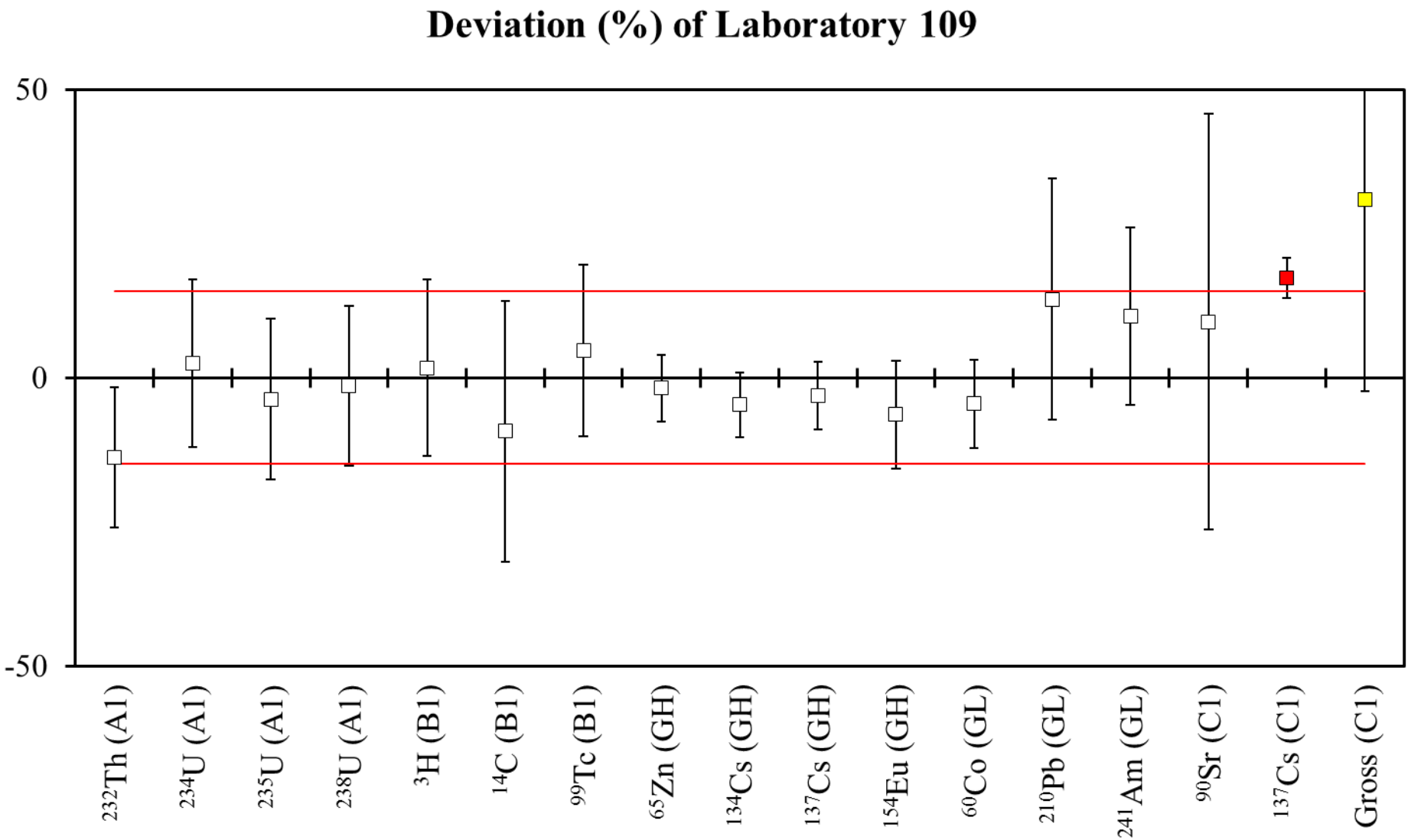
Radionuclide	Laboratory 91	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	5.16 ± 0.27	5.298 ± 0.058	-2.6	-0.50	-0.45
^{90}Sr (AB)	9.71 ± 0.28	9.546 ± 0.042	1.7	0.58	0.30
^{239}Pu (AB)	1.34 ± 0.12	1.3347 ± 0.0029	0.4	0.04	0.07
^{241}Am (AB)	4.85 ± 0.13	5.034 ± 0.011	-3.7	-1.41	-0.63
^{244}Cm (AB)	9.09 ± 0.09	10.778 ± 0.039	-15.7	-17.21	-2.69
^{234}U (A1)	15.61 ± 0.36	15.22 ± 0.26	2.6	0.88	0.44
^{235}U (A1)	0.922 ± 0.020	0.727 ± 0.015	26.8	7.80	4.61
^{238}U (A1)	15.70 ± 0.50	15.22 ± 0.26	3.2	0.85	0.54
Gross alpha (A1)	41.4 ± 2.3	40.5 ± 1.8	2.2	0.31	0.38
^{3}H (B1)	1.870 ± 0.013	1.898 ± 0.024	-1.5	-1.03	-0.25
^{14}C (B1)	1.05 ± 0.09	1.0146 ± 0.0066	3.5	0.39	0.60
^{65}Zn (GH)	17.17 ± 0.47	17.52 ± 0.13	-2.0	-0.72	-0.34
^{134}Cs (GH)	3.38 ± 0.10	3.390 ± 0.024	-0.3	-0.10	-0.05
^{137}Cs (GH)	9.41 ± 0.20	9.264 ± 0.066	1.6	0.69	0.27
^{154}Eu (GH)	12.96 ± 0.26	12.93 ± 0.10	0.2	0.11	0.04
^{60}Co (GL)	9.94 ± 0.20	9.937 ± 0.026	0.0	0.01	0.01
^{241}Am (GL)	18.23 ± 0.62	17.623 ± 0.039	3.4	0.98	0.59
^{90}Sr (C1)	74.4 ± 5.5	62.0 ± 9.1	20.0	1.17	3.43
^{137}Cs (C1)	71.7 ± 4.7	66.81 ± 0.87	7.3	1.02	1.26
^{239,240}Pu (C1)	0.102 ± 0.011	-	-	-	-
Gross alpha (C1)	1.64 ± 0.22	-	-	-	-


Deviation (%) of Laboratory 106
50
0
-50
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
3H (B1)
14C (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)

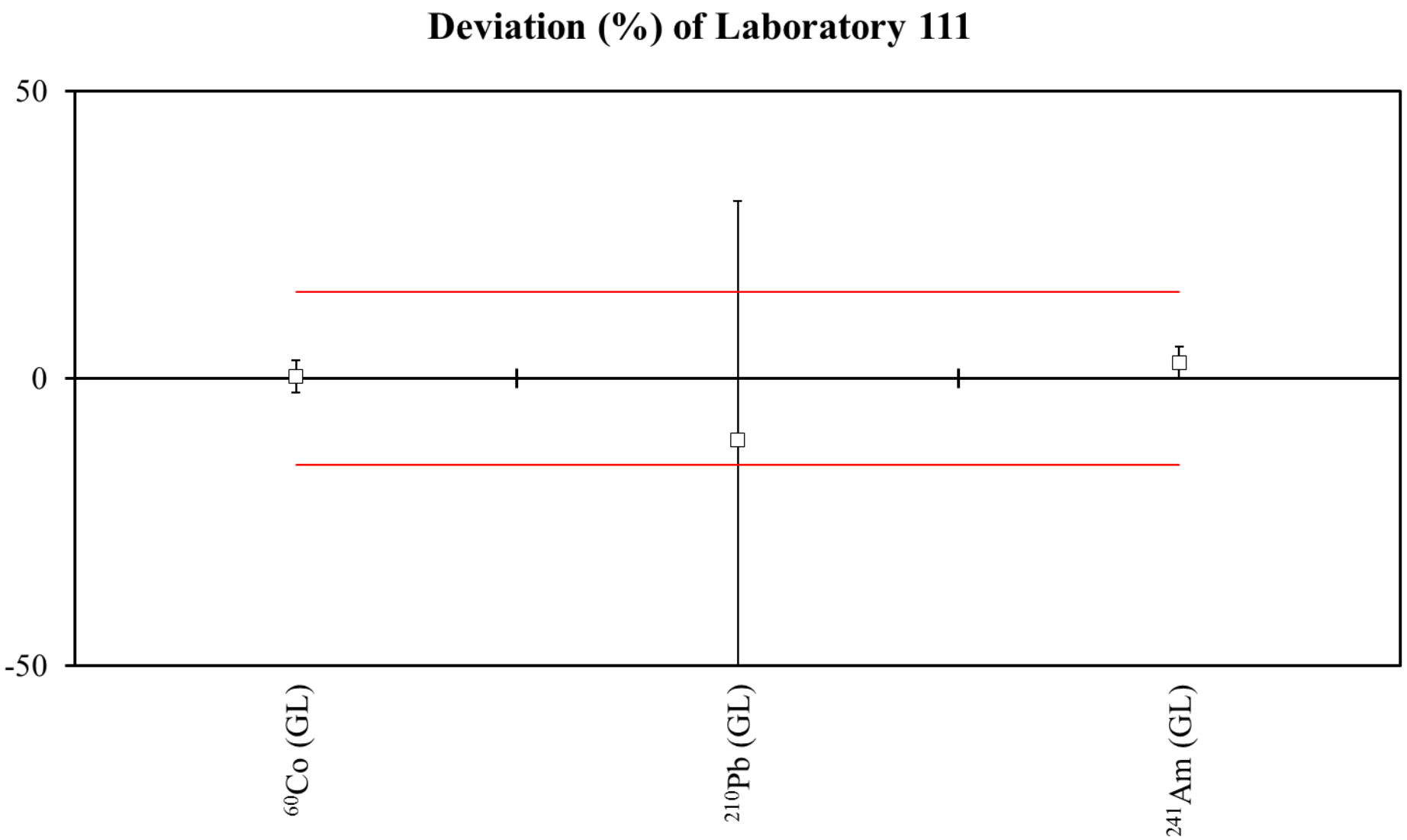
Radionuclide	Laboratory 106	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{90}Sr (AB)	9.20 ± 0.74	9.546 ± 0.042	-3.6	-0.47	-0.62
^{239}Pu (AB)	1.40 ± 0.93	1.3347 ± 0.0029	4.9	0.07	0.84
^{241}Am (AB)	5.48 ± 0.36	5.034 ± 0.011	8.9	1.24	1.52
^{244}Cm (AB)	10.47 ± 0.63	10.778 ± 0.039	-2.9	-0.49	-0.49
^{232}Th (A1)	3.59 ± 0.40	4.025 ± 0.038	-10.8	-1.08	-1.86
^{234}U (A1)	15.6 ± 1.4	15.22 ± 0.26	2.5	0.27	0.43
^{235}U (A1)	0.72 ± 0.15	0.727 ± 0.015	-1.0	-0.05	-0.17
^{238}U (A1)	16.0 ± 1.4	15.22 ± 0.26	5.1	0.55	0.88
^{3}H (B1)	1.973 ± 0.034	1.898 ± 0.024	4.0	1.80	0.68
^{14}C (B1)	0.932 ± 0.059	1.0146 ± 0.0066	-8.1	-1.39	-1.40
^{65}Zn (GH)	15.3 ± 1.0	17.52 ± 0.13	-12.7	-2.20	-2.18
^{134}Cs (GH)	2.97 ± 0.17	3.390 ± 0.024	-12.4	-2.45	-2.13
^{137}Cs (GH)	8.46 ± 0.67	9.264 ± 0.066	-8.7	-1.19	-1.49
^{154}Eu (GH)	11.10 ± 0.62	12.93 ± 0.10	-14.2	-2.91	-2.43


Deviation (%) of Laboratory 107
50
0
-50
^{63}Ni (AB)
^{90}Sr (AB)
^{239}Pu (AB)
^{241}Am (AB)
^{244}Cm (AB)
^{3}H (B1)
^{14}C (B1)
^{99}Tc (B1)

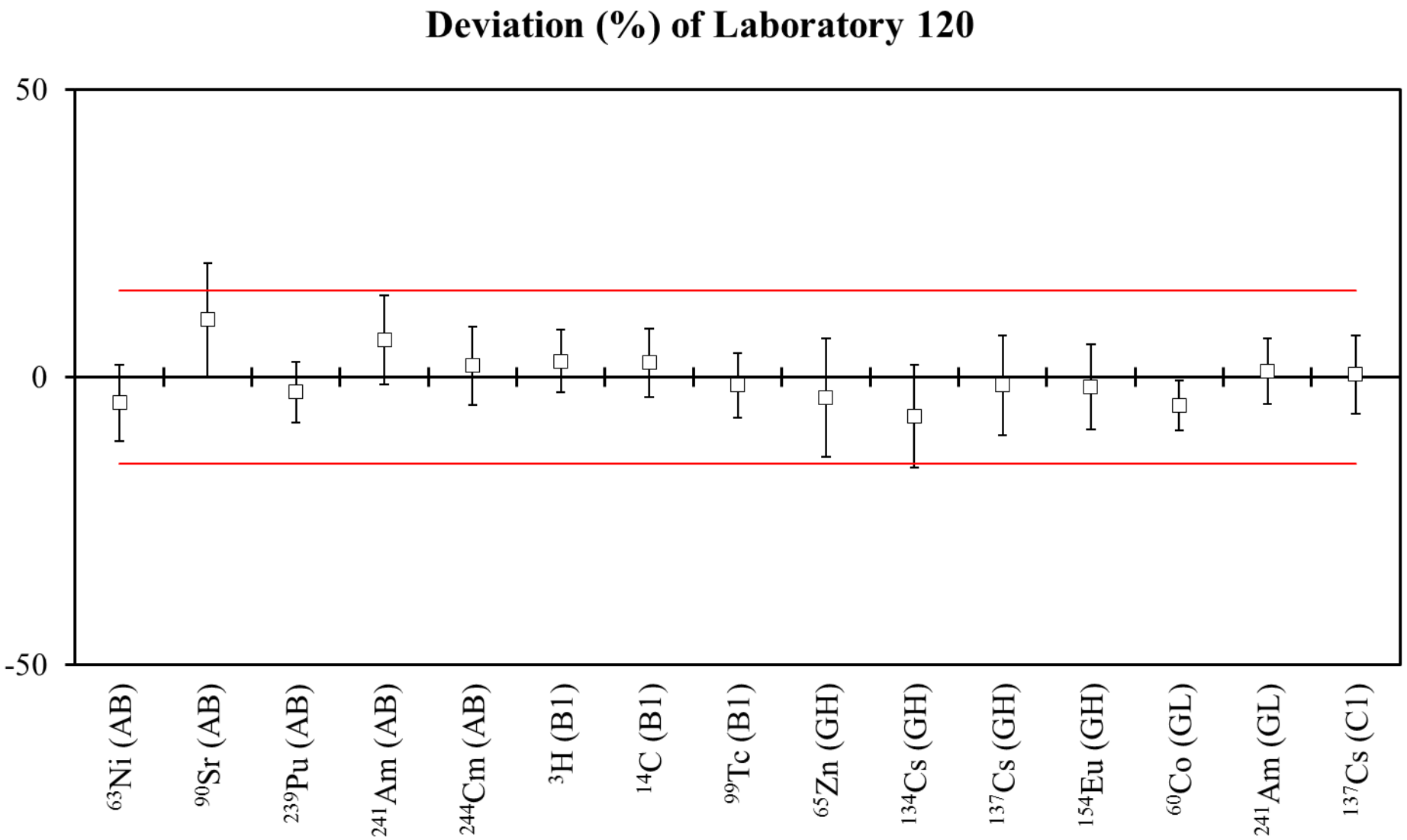
Radionuclide	Laboratory 107	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	5.29 ± 0.74	5.298 ± 0.058	-0.2	-0.01	-0.03
^{90}Sr (AB)	9.1 ± 1.2	9.546 ± 0.042	-4.7	-0.37	-0.80
^{239}Pu (AB)	1.32 ± 0.16	1.3347 ± 0.0029	-1.1	-0.09	-0.19
^{241}Am (AB)	4.70 ± 0.72	5.034 ± 0.011	-6.6	-0.46	-1.14
^{244}Cm (AB)	10.1 ± 1.4	10.778 ± 0.039	-6.3	-0.48	-1.08
^{3}H (B1)	1.95 ± 0.21	1.898 ± 0.024	2.7	0.25	0.47
^{14}C (B1)	0.96 ± 0.11	1.0146 ± 0.0066	-5.4	-0.50	-0.92
^{99}Tc (B1)	0.530 ± 0.064	0.5377 ± 0.0048	-1.4	-0.12	-0.25


Deviation (%) of Laboratory 109
50
0
-50
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
3H (B1)
14C (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
210Pb (GL)
241Am (GL)
90Sr (C1)
137Cs (C1)
Gross (C1)

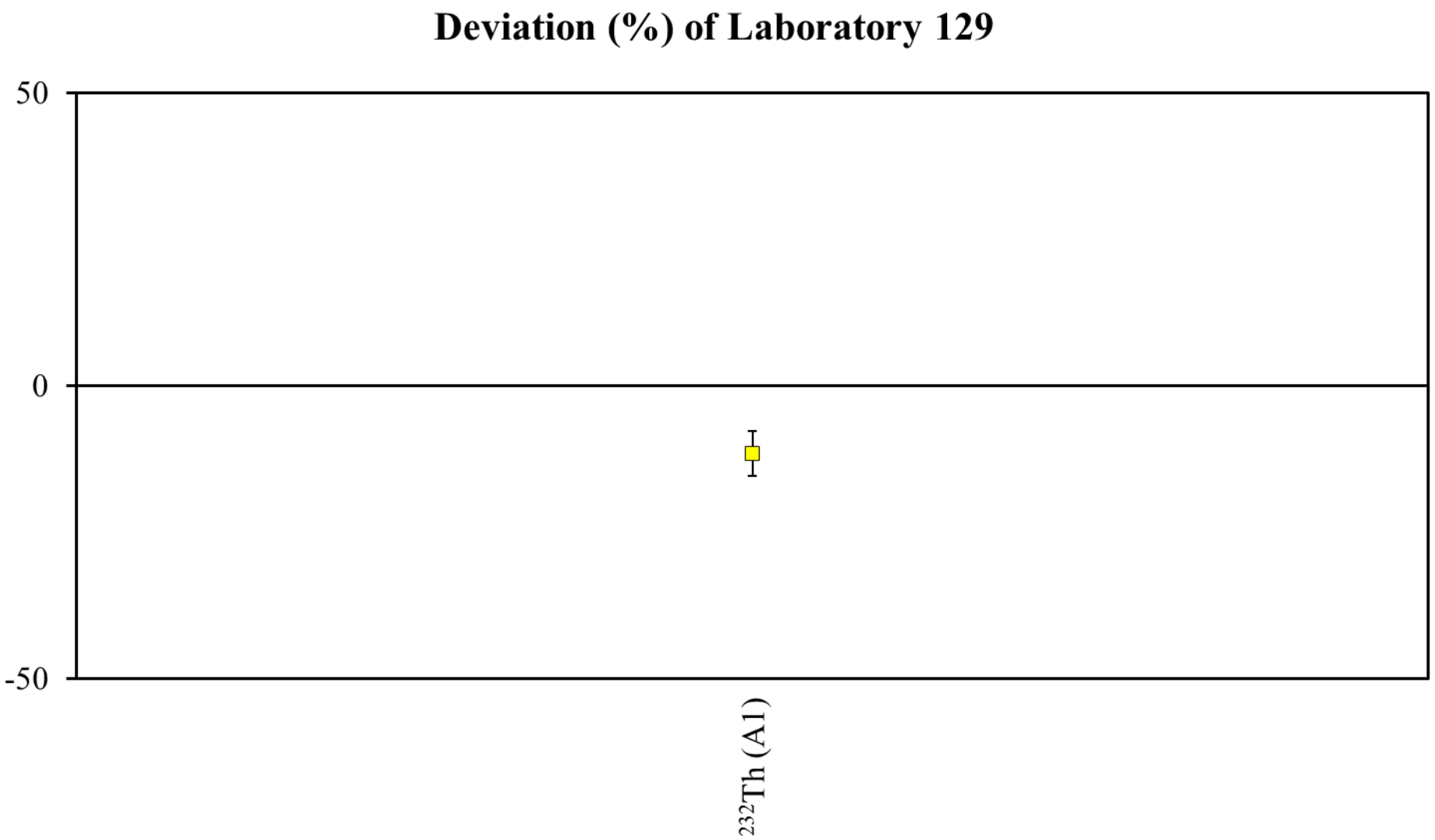
Radionuclide	Laboratory 109	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{232}Th (A1)	3.47 ± 0.49	4.025 ± 0.038	-13.8	-1.13	-2.37
^{234}U (A1)	15.6 ± 2.2	15.22 ± 0.26	2.5	0.17	0.43
^{235}U (A1)	0.70 ± 0.10	0.727 ± 0.015	-3.7	-0.27	-0.64
^{238}U (A1)	15.0 ± 2.1	15.22 ± 0.26	-1.4	-0.10	-0.25
^{3}H (B1)	1.93 ± 0.29	1.898 ± 0.024	1.7	0.11	0.29
^{14}C (B1)	0.92 ± 0.23	1.0146 ± 0.0066	-9.3	-0.41	-1.60
^{99}Tc (B1)	0.563 ± 0.080	0.5377 ± 0.0048	4.7	0.32	0.81
Gross beta (B1)	1.36 ± 0.34	-	-	-	-
^{65}Zn (GH)	17.2 ± 1.0	17.52 ± 0.13	-1.8	-0.32	-0.31
^{134}Cs (GH)	3.23 ± 0.19	3.390 ± 0.024	-4.7	-0.84	-0.81
^{137}Cs (GH)	8.98 ± 0.54	9.264 ± 0.066	-3.1	-0.52	-0.53
^{154}Eu (GH)	12.1 ± 1.2	12.93 ± 0.10	-6.4	-0.69	-1.10
^{60}Co (GL)	9.49 ± 0.76	9.937 ± 0.026	-4.5	-0.59	-0.77
^{210}Pb (GL)	3.820 ± 0.7	3.362 ± 0.035	13.6	0.65	2.34
^{241}Am (GL)	19.5 ± 2.7	17.623 ± 0.039	10.7	0.70	1.83
^{90}Sr (C1)	68 ± 20	62.0 ± 9.1	9.7	0.27	1.66
^{137}Cs (C1)	78.4 ± 2.1	66.81 ± 0.87	17.3	5.10	2.98
Gross alpha (C1)	0.95 ± 0.48	-	-	-	-
Gross beta (C1)	243 ± 61	185.7 ± 7.2	30.9	0.93	5.30


Deviation (%) of Laboratory 111
50
0
-50
^{60}Co (GL)
^{210}Pb (GL)
^{241}Am (GL)

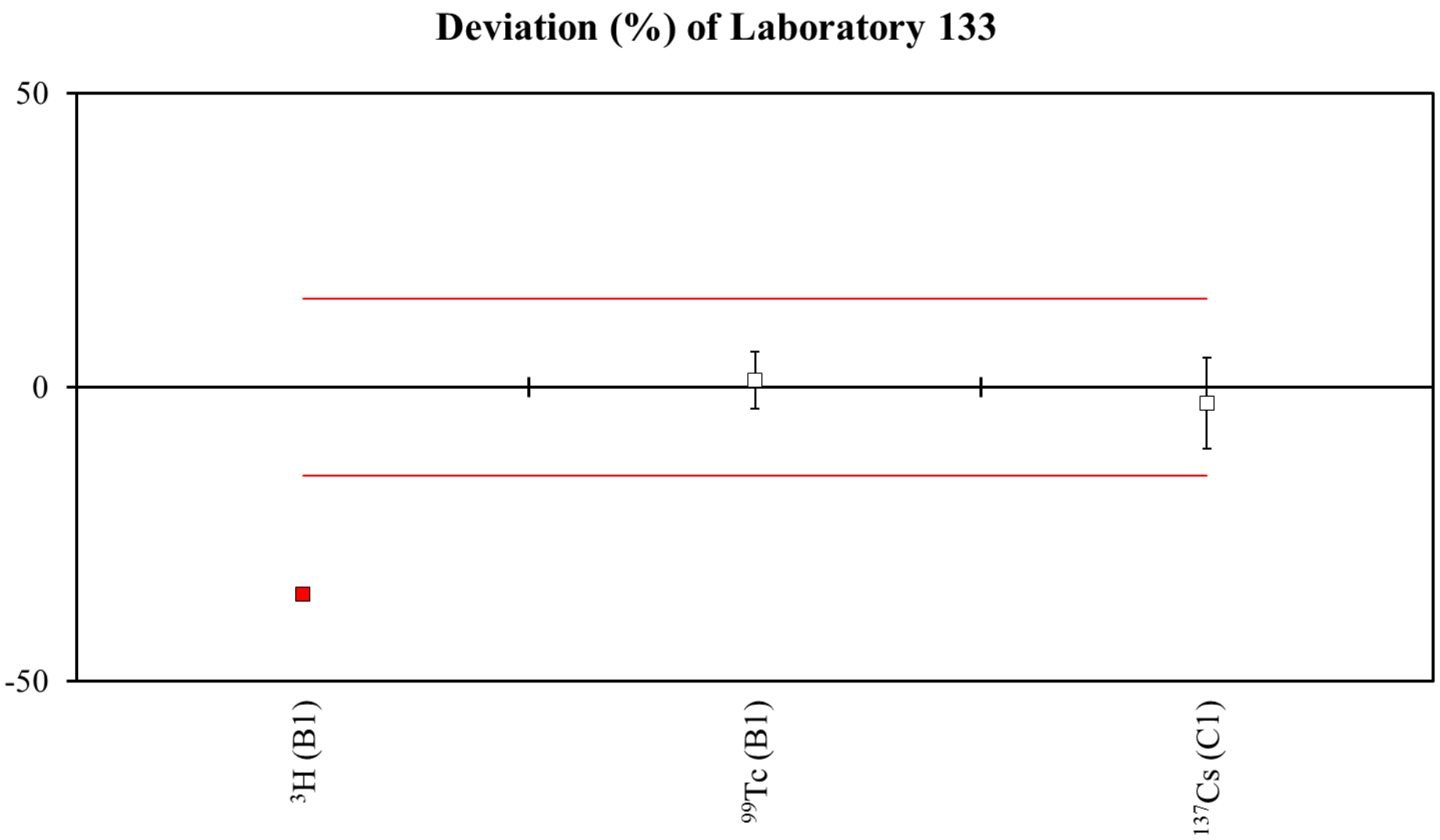
Radionuclide	Laboratory 111	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{60}Co (GL)	9.97 ± 0.27	9.937 ± 0.026	0.3	0.12	0.06
^{210}Pb (GL)	3.0 ± 1.4	3.362 ± 0.035	-10.8	-0.26	-1.85
^{241}Am (GL)	18.10 ± 0.50	17.623 ± 0.039	2.7	0.95	0.46


Deviation (%) of Laboratory 120
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
3H (B1)
14C (B1)
99Tc (B1)
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
241Am (GL)
137Cs (C1)

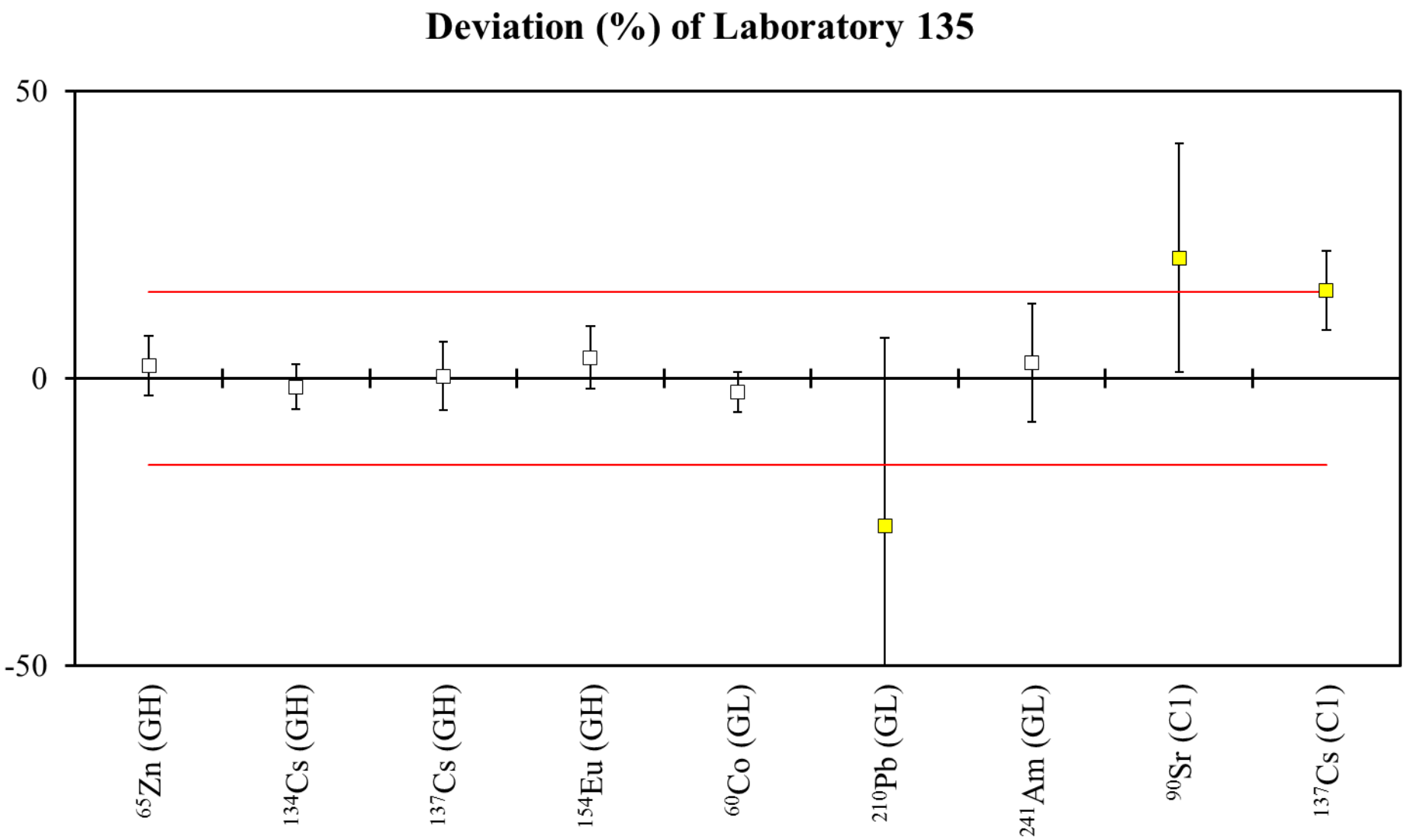
Radionuclide	Laboratory 120	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	5.06 ± 0.35	5.298 ± 0.058	-4.5	-0.67	-0.77
^{90}Sr (AB)	10.50 ± 0.94	9.546 ± 0.042	10.0	1.01	1.72
^{239}Pu (AB)	1.30 ± 0.07	1.3347 ± 0.0029	-2.6	-0.50	-0.45
^{241}Am (AB)	5.36 ± 0.39	5.034 ± 0.011	6.5	0.84	1.11
^{244}Cm (AB)	10.99 ± 0.73	10.778 ± 0.039	2.0	0.29	0.34
^{3}H (B1)	1.95 ± 0.10	1.898 ± 0.024	2.7	0.51	0.47
^{14}C (B1)	1.04 ± 0.06	1.0146 ± 0.0066	2.5	0.42	0.43
^{99}Tc (B1)	0.53 ± 0.03	0.5377 ± 0.0048	-1.4	-0.25	-0.25
^{65}Zn (GH)	16.9 ± 1.8	17.52 ± 0.13	-3.5	-0.34	-0.61
^{134}Cs (GH)	3.160 ± 0.3	3.390 ± 0.024	-6.8	-0.76	-1.17
^{137}Cs (GH)	9.13 ± 0.80	9.264 ± 0.066	-1.4	-0.17	-0.25
^{154}Eu (GH)	12.70 ± 0.95	12.93 ± 0.10	-1.8	-0.24	-0.31
^{60}Co (GL)	9.45 ± 0.43	9.937 ± 0.026	-4.9	-1.13	-0.84
^{241}Am (GL)	17.80 ± 0.99	17.623 ± 0.039	1.0	0.18	0.17
^{137}Cs (C1)	67.1 ± 4.5	66.81 ± 0.87	0.4	0.06	0.07
^{239,240}Pu (C1)	0.0370 ± 0.0030	-	-	-	-


Deviation (%) of Laboratory 129
50
0
-50
232Th (A1)

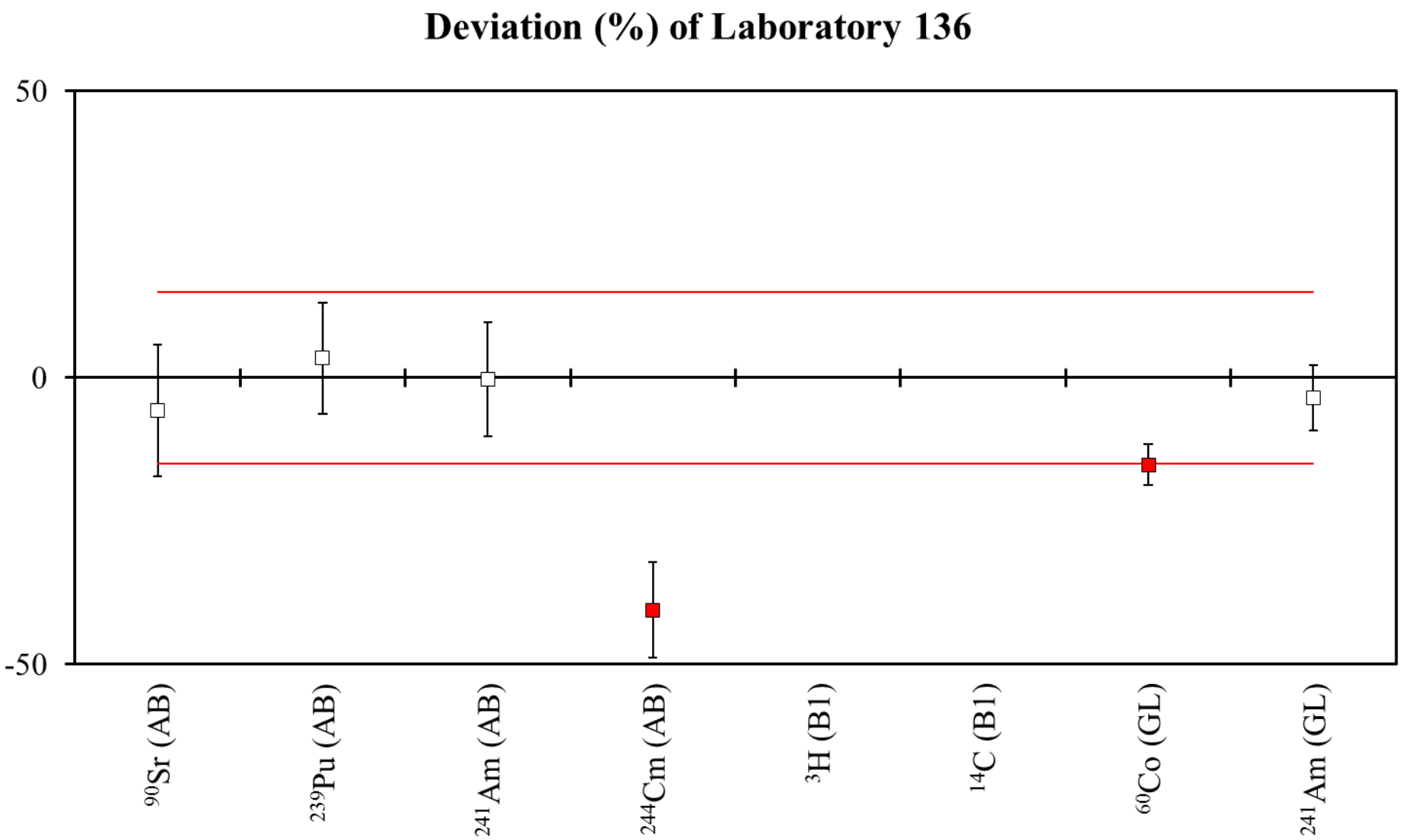
Radionuclide	Laboratory 129	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{232}Th (A1)	3.56 ± 0.15	4.025 ± 0.038	-11.6	-3.01	-1.98


Deviation (%) of Laboratory 133
50
0
-50
3H (B1)
99Tc (B1)
137Cs (C1)

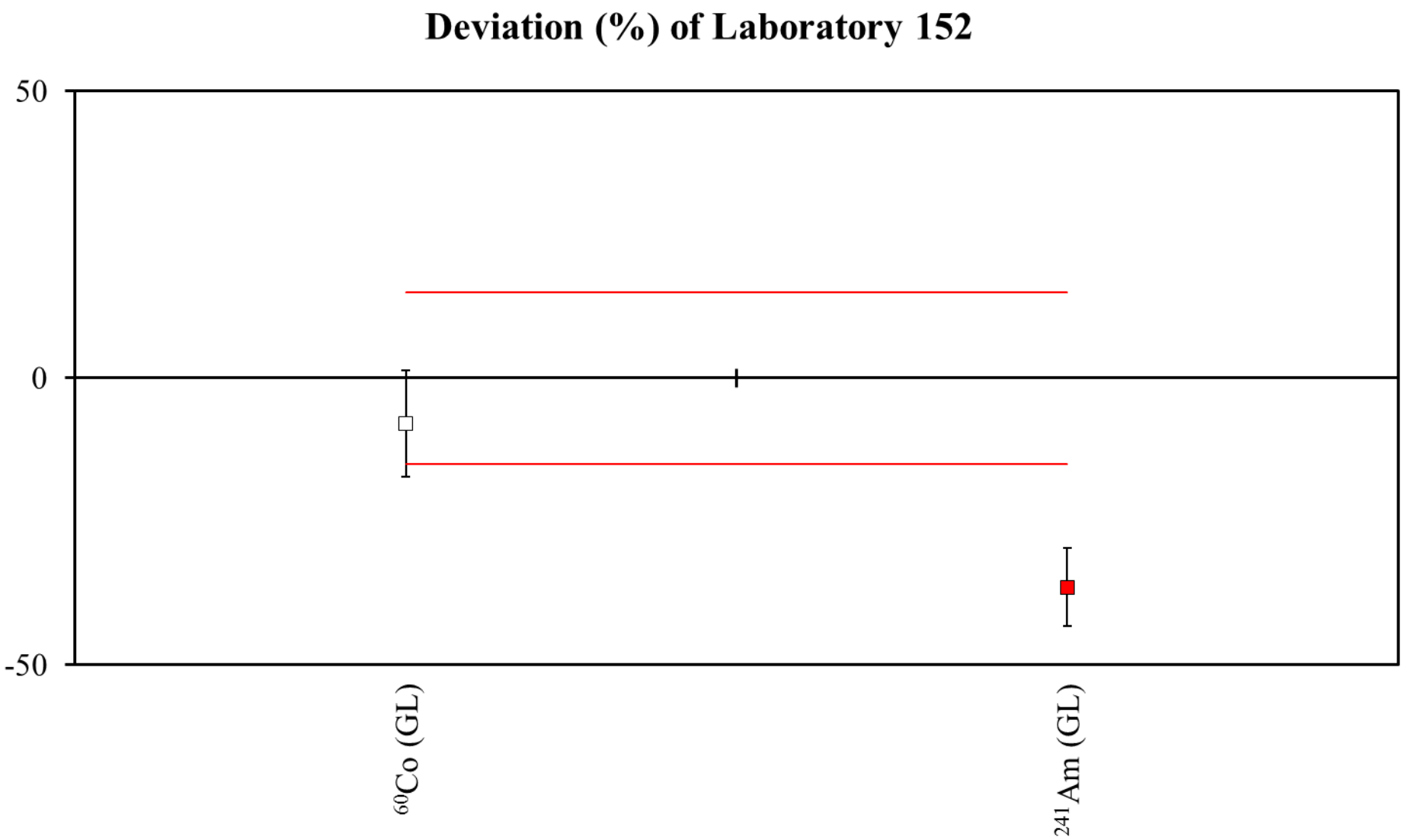
Radionuclide	Laboratory 133	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{3}H (B1)	1.2300 ± 0.0055	1.898 ± 0.024	-35.2	-27.13	-6.04
^{99}Tc (B1)	0.544 ± 0.026	0.5377 ± 0.0048	1.2	0.24	0.20
^{137}Cs (C1)	65.0 ± 5.1	66.81 ± 0.87	-2.7	-0.35	-0.47


Deviation (%) of Laboratory 135
50
0
-50
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)
60Co (GL)
210Pb (GL)
241Am (GL)
90Sr (C1)
137Cs (C1)

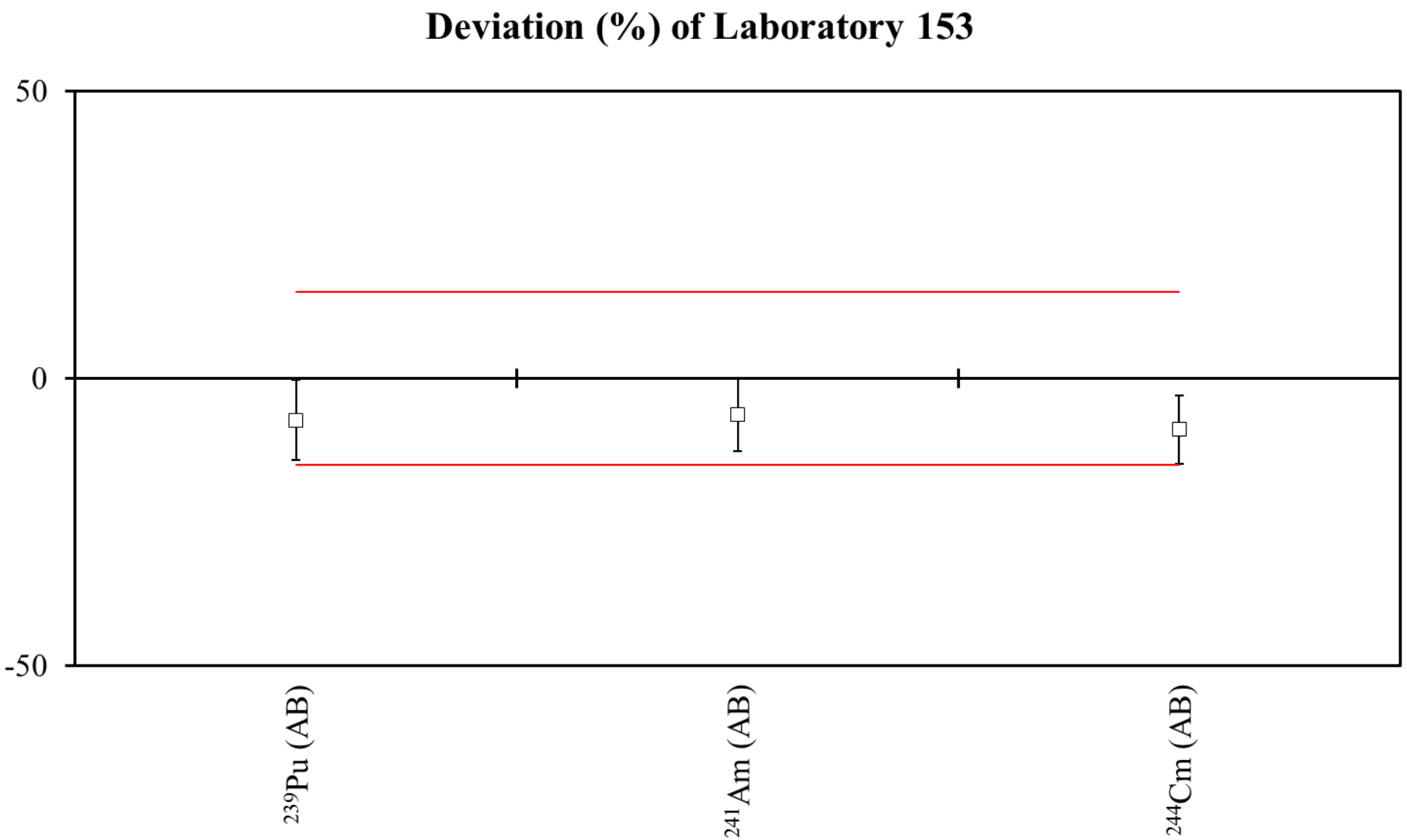
Radionuclide	Laboratory 135	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{65}Zn (GH)	17.90 ± 0.90	17.52 ± 0.13	2.2	0.42	0.37
^{134}Cs (GH)	3.34 ± 0.13	3.390 ± 0.024	-1.5	-0.38	-0.25
^{137}Cs (GH)	9.30 ± 0.55	9.264 ± 0.066	0.4	0.06	0.07
^{154}Eu (GH)	13.4 ± 0.7	12.93 ± 0.10	3.6	0.66	0.62
^{60}Co (GL)	9.70 ± 0.35	9.937 ± 0.026	-2.4	-0.68	-0.41
^{210}Pb (GL)	2.5 ± 1.1	3.362 ± 0.035	-25.6	-0.78	-4.40
^{241}Am (GL)	18.1 ± 1.8	17.623 ± 0.039	2.7	0.26	0.46
^{90}Sr (C1)	75.0 ± 5.5	62.0 ± 9.1	21.0	1.22	3.60
^{137}Cs (C1)	77.0 ± 4.5	66.81 ± 0.87	15.3	2.22	2.62
^{239,240}Pu (C1)	0.0360 ± 0.0035	-	-	-	-


Deviation (%) of Laboratory 136
50
0
-50
^{90}Sr (AB)
^{239}Pu (AB)
^{241}Am (AB)
^{244}Cm (AB)
^{3}H (B1)
^{14}C (B1)
^{60}Co (GL)
^{241}Am (GL)

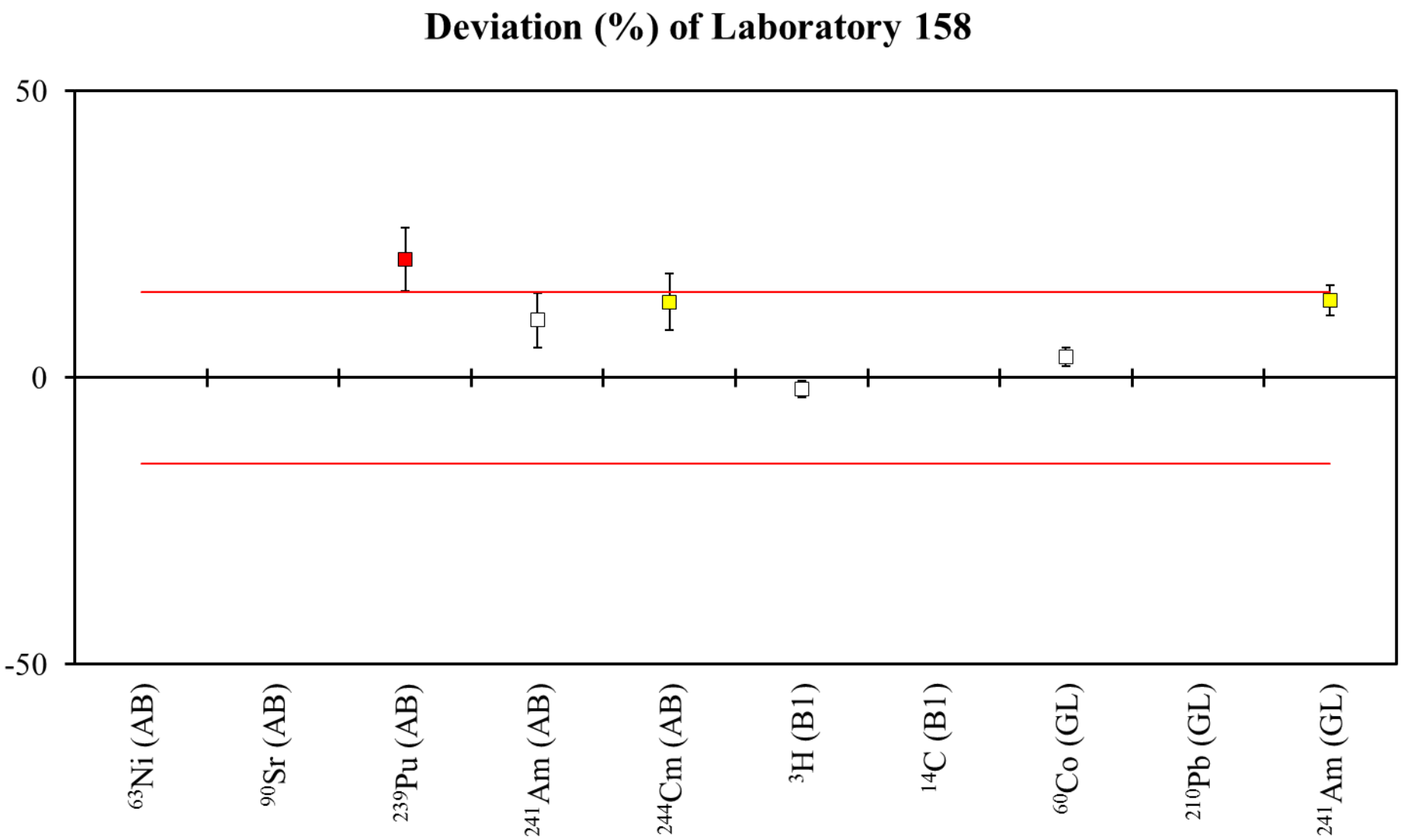
Radionuclide	Laboratory 136	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{90}Sr (AB)	9.0 ± 1.1	9.546 ± 0.042	-5.7	-0.50	-0.98
^{239}Pu (AB)	1.38 ± 0.13	1.3347 ± 0.0029	3.4	0.35	0.58
^{241}Am (AB)	5.02 ± 0.50	5.034 ± 0.011	-0.3	-0.03	-0.05
^{244}Cm (AB)	6.41 ± 0.90	10.778 ± 0.039	-40.5	-4.85	-6.96
^{3}H (B1)	1860 ± 99	1.898 ± 0.024	97897.9	18.77	16812.28
^{14}C (B1)	1098 ± 88	1.0146 ± 0.0066	108120.0	12.47	18567.75
^{60}Co (GL)	8.43 ± 0.35	9.937 ± 0.026	-15.2	-4.29	-2.60
^{241}Am (GL)	17.0 ± 1.0	17.623 ± 0.039	-3.5	-0.62	-0.61


Deviation (%) of Laboratory 152
50
0
-50
60Co (GL)
241Am (GL)

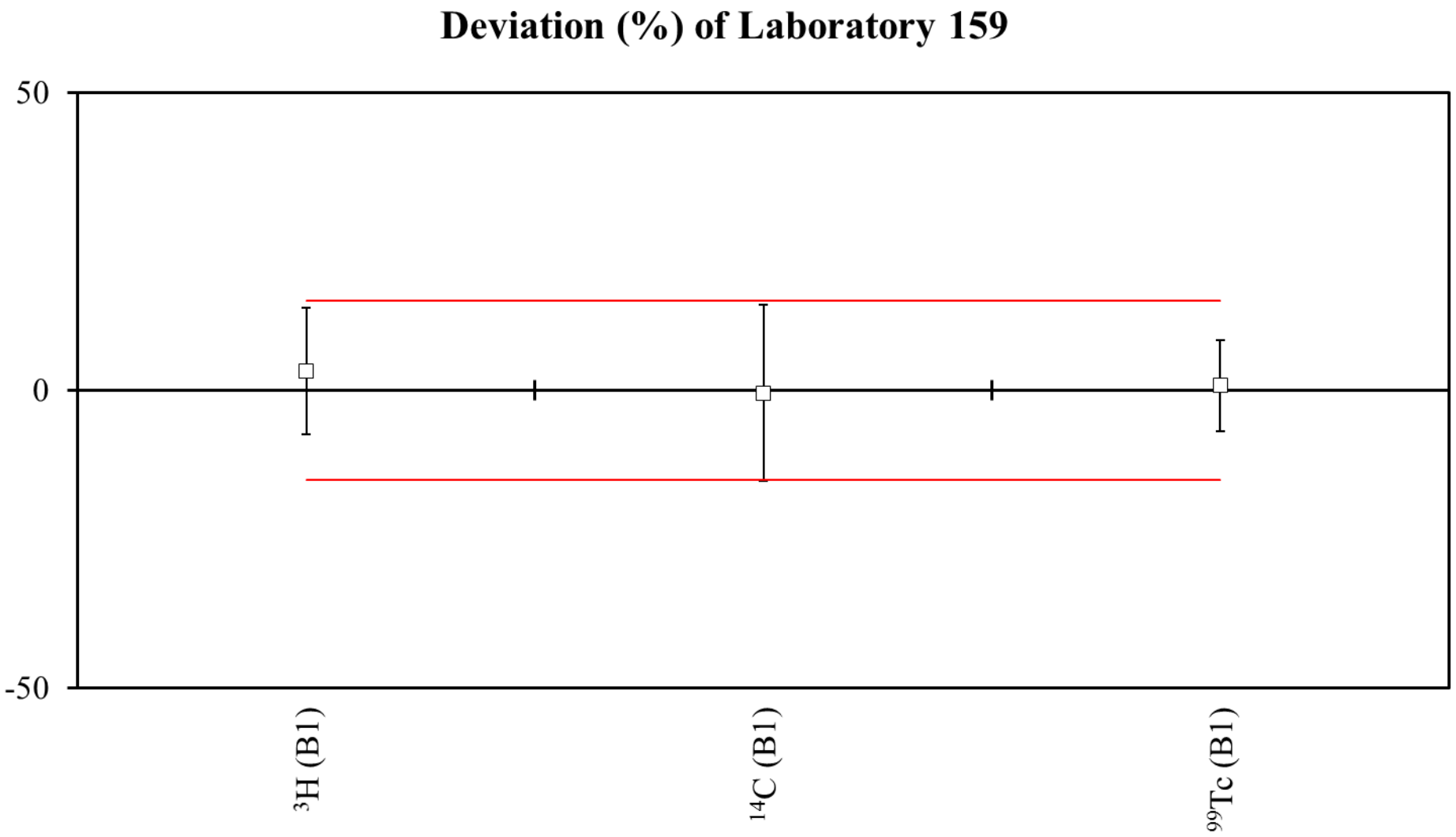
Radionuclide	Laboratory 152	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{60}Co (GL)	9.15 ± 0.92	9.937 ± 0.026	-7.9	-0.86	-1.36
^{241}Am (GL)	11.2 ± 1.2	17.623 ± 0.039	-36.4	-5.35	-6.26


Deviation (%) of Laboratory 153
50
0
-50
239Pu (AB)
241Am (AB)
244Cm (AB)

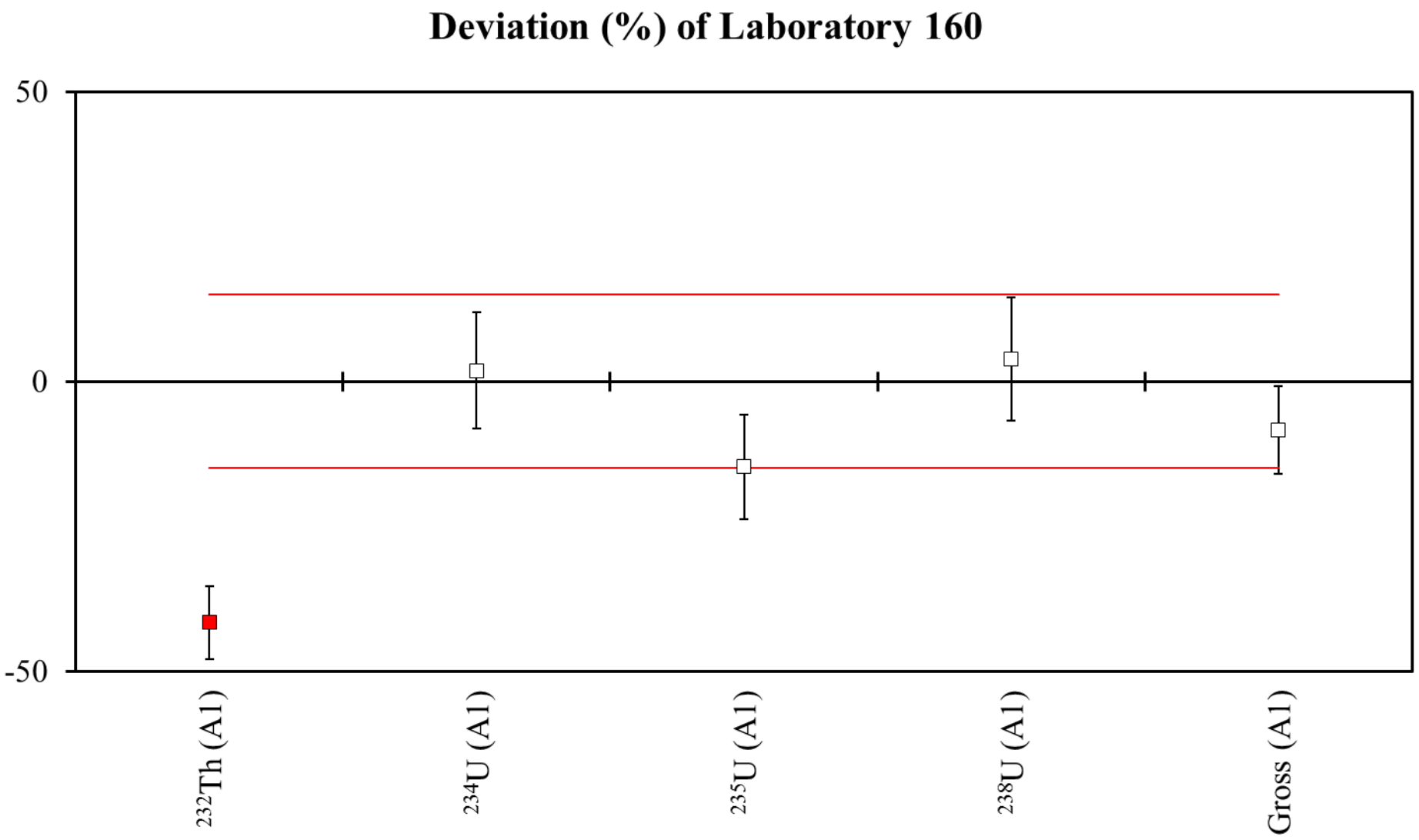
Radionuclide	Laboratory 153	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{239}Pu (AB)	1.238 ± 0.093	1.3347 ± 0.0029	-7.2	-1.04	-1.24
^{241}Am (AB)	4.72 ± 0.32	5.034 ± 0.011	-6.2	-0.98	-1.07
^{244}Cm (AB)	9.82 ± 0.64	10.778 ± 0.039	-8.9	-1.49	-1.53


Deviation (%) of Laboratory 158
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
3H (B1)
14C (B1)
60Co (GL)
210Pb (GL)
241Am (GL)

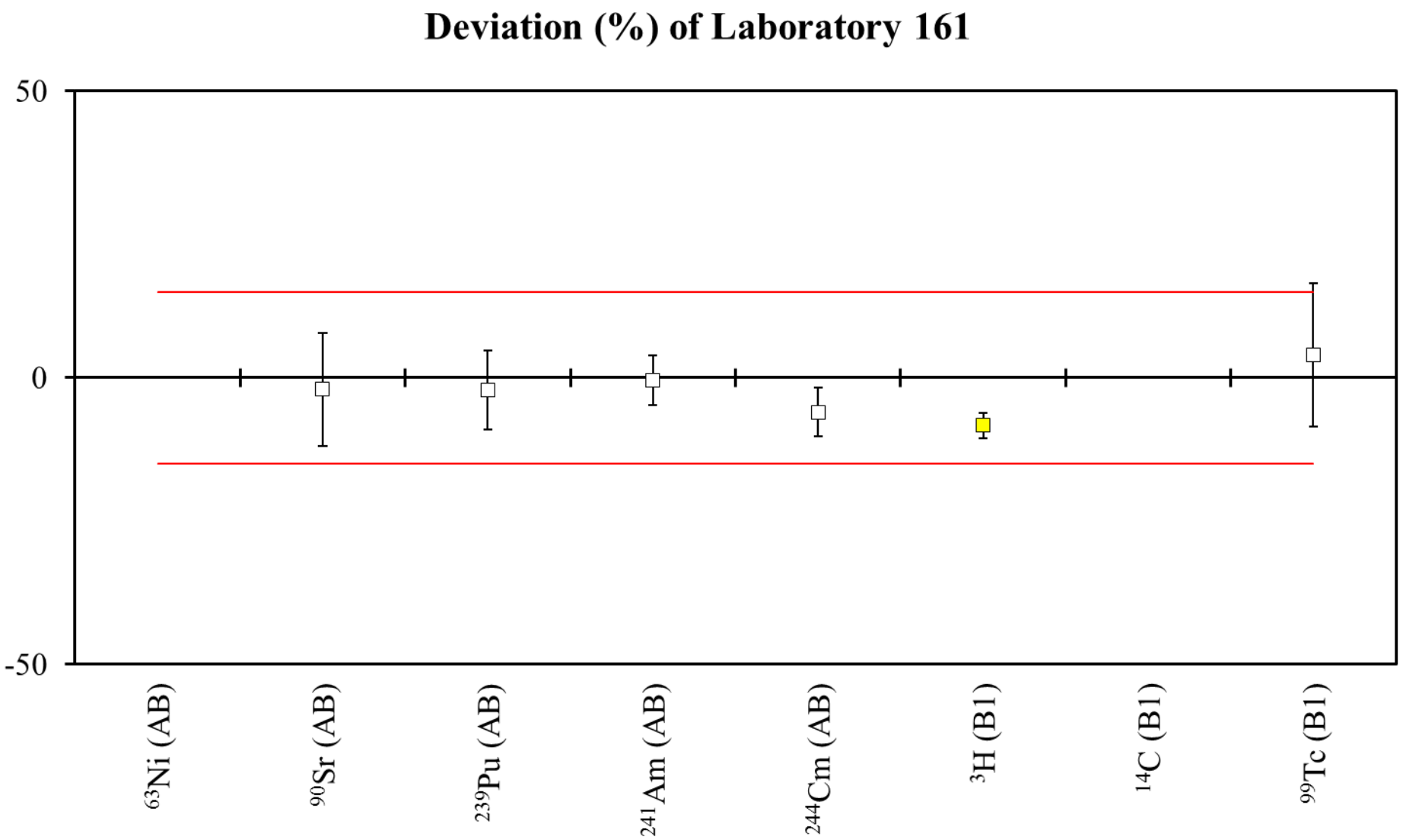
Radionuclide	Laboratory 158	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	0.600 (no uncertainty quoted)	5.298 ± 0.058	-88.7	-81.00	-15.23
^{90}Sr (AB)	1.050 ± 0.065	9.546 ± 0.042	-89.0	-109.78	-15.28
^{239}Pu (AB)	1.610 ± 0.073	1.3347 ± 0.0029	20.6	3.77	3.54
^{241}Am (AB)	5.54 ± 0.24	5.034 ± 0.011	10.1	2.11	1.73
^{244}Cm (AB)	12.20 ± 0.53	10.778 ± 0.039	13.2	2.68	2.27
^{3}H (B1)	1.860 ± 0.015	1.898 ± 0.024	-2.0	-1.34	-0.34
^{14}C (B1)	1.810 ± 0.022	1.0146 ± 0.0066	78.4	34.63	13.46
^{60}Co (GL)	10.30 ± 0.16	9.937 ± 0.026	3.7	2.24	0.63
^{210}Pb (GL)	47 ± 11	3.362 ± 0.035	1298.0	3.97	222.91
^{241}Am (GL)	20.00 ± 0.47	17.623 ± 0.039	13.5	5.04	2.32


Deviation (%) of Laboratory 159
50
0
-50
^{3}H (B1)
^{14}C (B1)
^{99}Tc (B1)

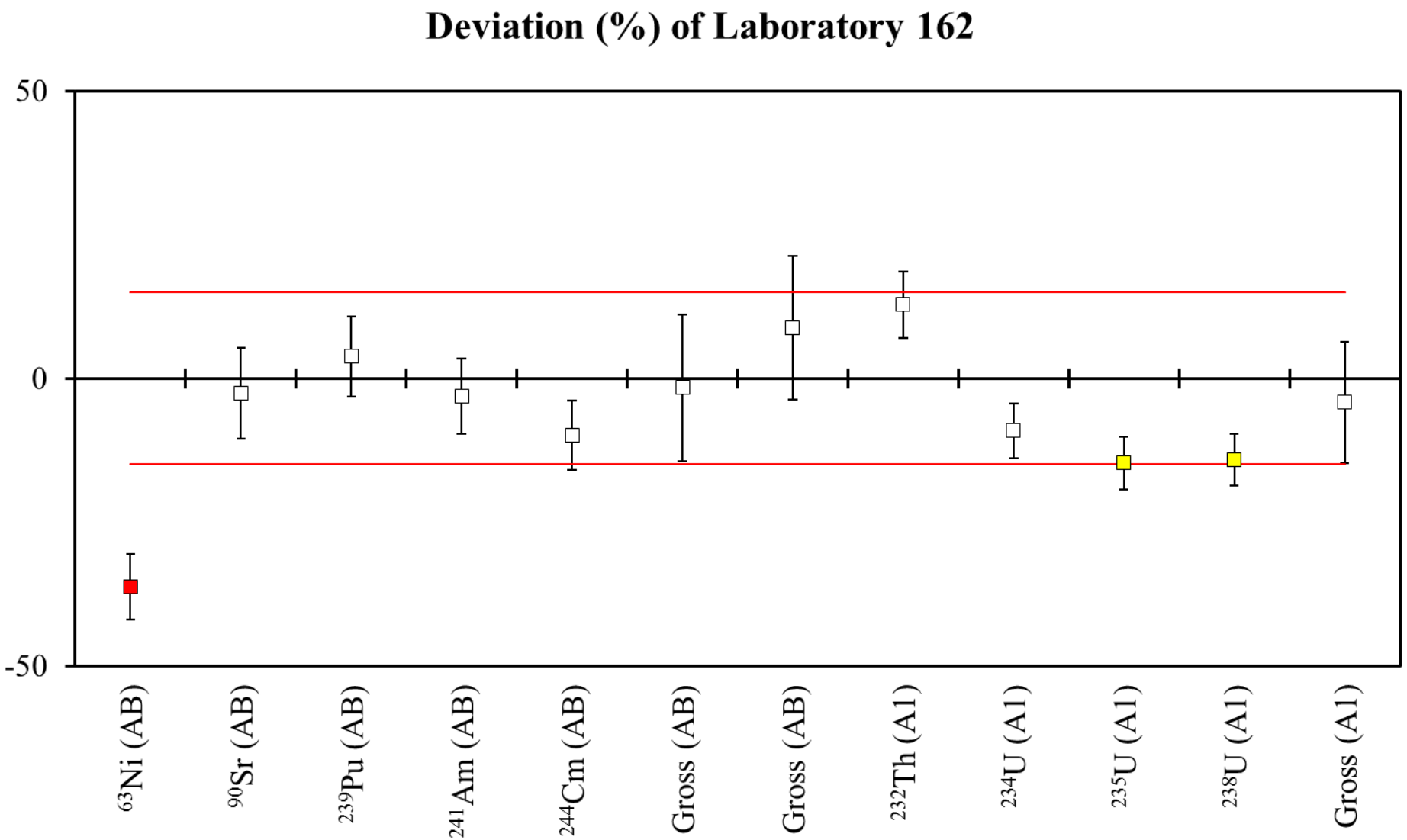
Radionuclide	Laboratory 159	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{3}H (B1)	1.96 ± 0.20	1.898 ± 0.024	3.3	0.31	0.56
^{14}C (B1)	1.01 ± 0.15	1.0146 ± 0.0066	-0.5	-0.03	-0.08
^{99}Tc (B1)	0.542 ± 0.041	0.5377 ± 0.0048	0.8	0.10	0.14
Gross beta (B1)	1.02 ± 0.12	-	-	-	-


Deviation (%) of Laboratory 160
50
0
-50
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
Gross (A1)

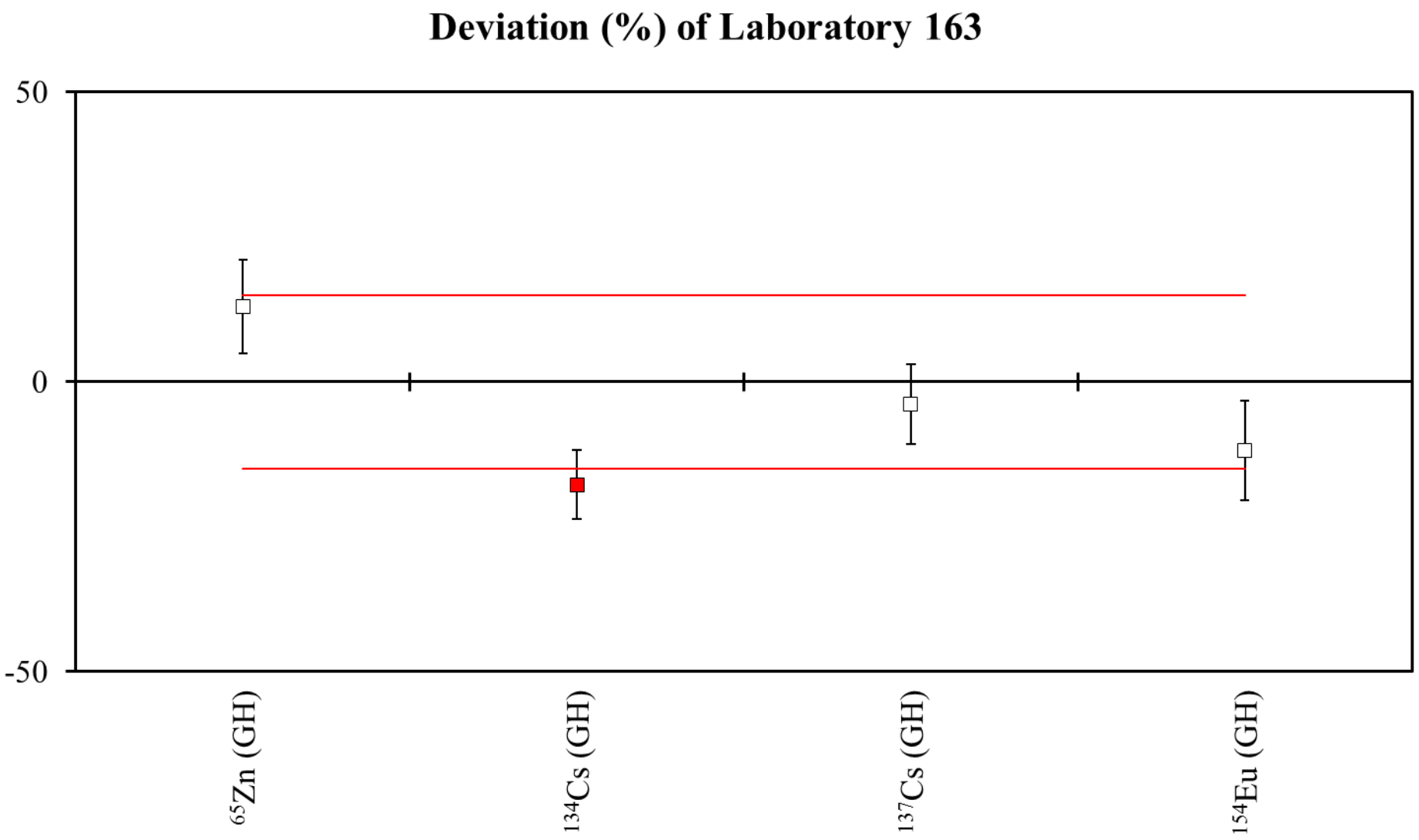
Radionuclide	Laboratory 160	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{232}Th (A1)	2.35 ± 0.25	4.025 ± 0.038	-41.6	-6.62	-7.15
^{234}U (A1)	15.5 ± 1.5	15.22 ± 0.26	1.8	0.18	0.32
^{235}U (A1)	0.620 ± 0.064	0.727 ± 0.015	-14.7	-1.63	-2.53
^{238}U (A1)	15.8 ± 1.6	15.22 ± 0.26	3.8	0.36	0.65
Gross alpha (A1)	37.1 ± 2.6	40.5 ± 1.8	-8.4	-1.08	-1.44


Deviation (%) of Laboratory 161
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
3H (B1)
14C (B1)
99Tc (B1)

Radionuclide	Laboratory 161	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	9.68 ± 0.23	5.298 ± 0.058	82.7	18.47	14.20
^{90}Sr (AB)	9.35 ± 0.94	9.546 ± 0.042	-2.1	-0.21	-0.35
^{239}Pu (AB)	1.306 ± 0.092	1.3347 ± 0.0029	-2.2	-0.31	-0.37
^{241}Am (AB)	5.01 ± 0.22	5.034 ± 0.011	-0.5	-0.11	-0.08
^{244}Cm (AB)	10.13 ± 0.46	10.778 ± 0.039	-6.0	-1.40	-1.03
^{3}H (B1)	1.740 ± 0.037	1.898 ± 0.024	-8.3	-3.58	-1.43
^{14}C (B1)	0.235 ± 0.035	1.0146 ± 0.0066	-76.8	-21.89	-13.20
^{99}Tc (B1)	0.559 ± 0.067	0.5377 ± 0.0048	4.0	0.32	0.68


Deviation (%) of Laboratory 162
50
0
-50
63Ni (AB)
90Sr (AB)
239Pu (AB)
241Am (AB)
244Cm (AB)
Gross (AB)
Gross (AB)
232Th (A1)
234U (A1)
235U (A1)
238U (A1)
Gross (A1)

Radionuclide	Laboratory 162	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	3.380 ± 0.3	5.298 ± 0.058	-36.2	-6.28	-6.22
^{90}Sr (AB)	9.30 ± 0.75	9.546 ± 0.042	-2.6	-0.33	-0.44
^{239}Pu (AB)	1.386 ± 0.093	1.3347 ± 0.0029	3.8	0.55	0.66
^{241}Am (AB)	4.88 ± 0.33	5.034 ± 0.011	-3.1	-0.47	-0.53
^{244}Cm (AB)	9.71 ± 0.65	10.778 ± 0.039	-9.9	-1.64	-1.70
Gross alpha (AB)	18.0 ± 1.8	18.3 ± 1.5	-1.6	-0.13	-0.28
Gross beta (AB)	21.0 ± 2.1	19.3 ± 1.1	8.8	0.72	1.51
^{232}Th (A1)	4.54 ± 0.23	4.025 ± 0.038	12.8	2.21	2.20
^{234}U (A1)	13.83 ± 0.69	15.22 ± 0.26	-9.1	-1.89	-1.57
^{235}U (A1)	0.620 ± 0.031	0.727 ± 0.015	-14.7	-3.11	-2.53
^{238}U (A1)	13.07 ± 0.65	15.22 ± 0.26	-14.1	-3.07	-2.43
Gross alpha (A1)	38.8 ± 3.9	40.5 ± 1.8	-4.2	-0.40	-0.72


Deviation (%) of Laboratory 163
50
0
-50
65Zn (GH)
134Cs (GH)
137Cs (GH)
154Eu (GH)

Radionuclide	Laboratory 163	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{65}Zn (GH)	19.8 ± 1.4	17.52 ± 0.13	13.0	1.62	2.23
^{134}Cs (GH)	2.79 ± 0.20	3.390 ± 0.024	-17.7	-2.98	-3.04
^{137}Cs (GH)	8.91 ± 0.63	9.264 ± 0.066	-3.8	-0.56	-0.66
^{154}Eu (GH)	11.4 ± 1.1	12.93 ± 0.10	-11.8	-1.39	-2.03

11. DISCUSSION

11.1 Gross beta data (in B1), ^{239,240}Pu data (in C1) and gross alpha data (in C1)

The Assigned Values for these radionuclides / radionuclide types were to have been determined as the PMWM of the participants' data, in each case. However, the uncertainty on the PMWM exceeded 15% in each case, so NPL will not declare Assigned Values for these radionuclides / radionuclide types.

11.2 ^{63}Ni in AB

A total of 13 results were submitted for ^{63}Ni with 9 results being in agreement with the Assigned Value. A variety of methods were used to separate the nuclide from the mixture, including ion exchange chromatography, extraction chromatography and solvent extraction. All participants who reported a counting method cited liquid scintillation counting but very few reported the source of the ^{63}Ni standard used. Insufficient information was provided to explain the discrepant results.

11.3 ^{90}Sr in AB

In all, 20 results were submitted for this nuclide with 17 results being in agreement with the Assigned Value, an improvement on the 2014 PTE performance level. Again, various separation methods were used, including precipitation, ion exchange chromatography, extraction chromatography and solvent extraction. The nuclide was measured mostly by LSC, although gas-flow proportional counting and Cerenkov counting were also used. Again, few participants cited the source of the standards used. Yield tracers were used by some laboratories, such as ^{85}Sr and stable strontium.

11.4 ^{239}Pu in AB

A total of 20 results were submitted, with 17 results in agreement with the Assigned Value, similar to the 2014 PTE performance level. Most laboratories who reported a separation method used either ion exchange chromatography or extraction chromatography. Most laboratories used alpha spectrometry to measure the separated radionuclide and the use of ^{242}Pu standards was widely cited.

11.5 ^{241}Am in AB

In all, 21 results were submitted for ^{241}Am and all but one agreed with the Assigned Value. One participant reported using gamma spectrometry to measure this radionuclide but all other laboratories who reported a method used alpha spectrometry.

11.6 ^{244}Cm in AB

Performance levels were less good for ^{244}Cm with 13 of the 20 reported results being in agreement with the Assigned Value. Most of the participants who reported methods used alpha spectrometry and an ^{243}Am tracer and again there was no clear reason for the discrepant results.

11.7 ^{232}Th in A1

A total of 11 out of the 16 reported results agreed with the Assigned Value. Most participants used alpha spectrometry although four used ICPMS; there was no obvious difference between

the two methods from a visual inspection of the data. Most participants who reported their tracer had used ^{229}Th.

11.8 ^{234}U, ^{235}U and ^{238}U in A1

The numbers of results submitted for these nuclides were 20, 21 and 20 respectively. The level of performance for all the nuclides combined was similar to that seen in the 2014 PTE (and, as in 2014, the majority of discrepant results were for ^{235}U). A range of extraction procedures were cited, including ion exchange and extraction chromatography. Alpha spectrometry was again the main measurement technique although again four laboratories used ICPMS and again there was no obvious difference between the results sets from the two techniques. The nuclide ^{232}U was used as the standard in most cases.

11.9 ^{3}H in B1

A total of 25 results were submitted for tritium with 19 results being in agreement with the Assigned Value – lower than the 92% observed in 2014 for tritium in Sample Type B1.

In most cases, the nuclide was separated from the mixture by distillation and subsequently assayed using liquid scintillation counting; some participants used pyrolysis or combustion of the sample. In most cases, LSC efficiencies were based on internal standards although very few source laboratories were cited.

11.10 ^{14}C in B1

In total, 19 results were submitted, with 15 agreeing with NPL. Pyrolysis and combustion were the most cited separation methods. All participants who cited a method used LSC.

11.11 ^{99}Tc in B1

A total of 17 results were submitted for this nuclide, much more than in the previous PTE. All but one result agreed with the Assigned Value. Again, a variety of extraction techniques were cited, mostly ion exchange or extraction chromatography.

11.12 Sample Types GH, GL and C1 (only ^{137}Cs in C1)

The numbers of sets of results submitted for these sample types were 25, 26 and 15 respectively. Almost all measurements were carried out using high-resolution gamma spectrometry (alpha spectrometry was used in a very few cases for ^{210}Pb and ^{241}Am in GL) without pre-treatment of the sample. Most laboratories used mixed radionuclide standards from Analytics, Eckert and Ziegler or NPL or used ISOCS or LABSOCS.

Most of results submitted for the nuclides in these sample types were in agreement with the Assigned Values. Many laboratories did not submit data for ^{210}Pb; the results that were submitted exhibited a very high bias and a large spread. However, this nuclide was present at a very low concentration and also the shape of the gamma calibration curve at low energies may have been an issue for some analysts. There was some evidence of true coincidence summing issues for ^{134}Cs and ^{154}Eu and the results for ^{241}Am exhibited a slightly high bias.

12. REFERENCES

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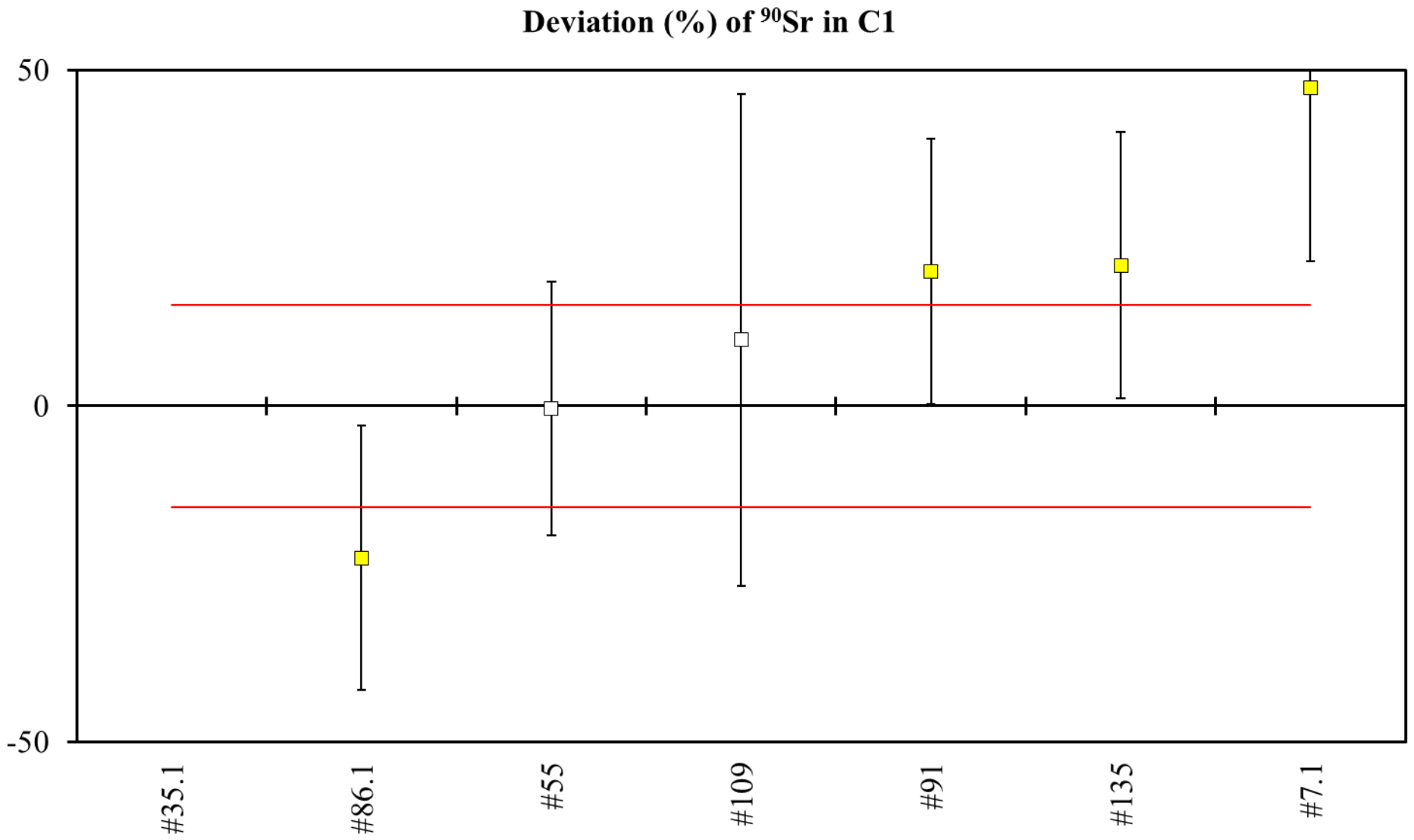
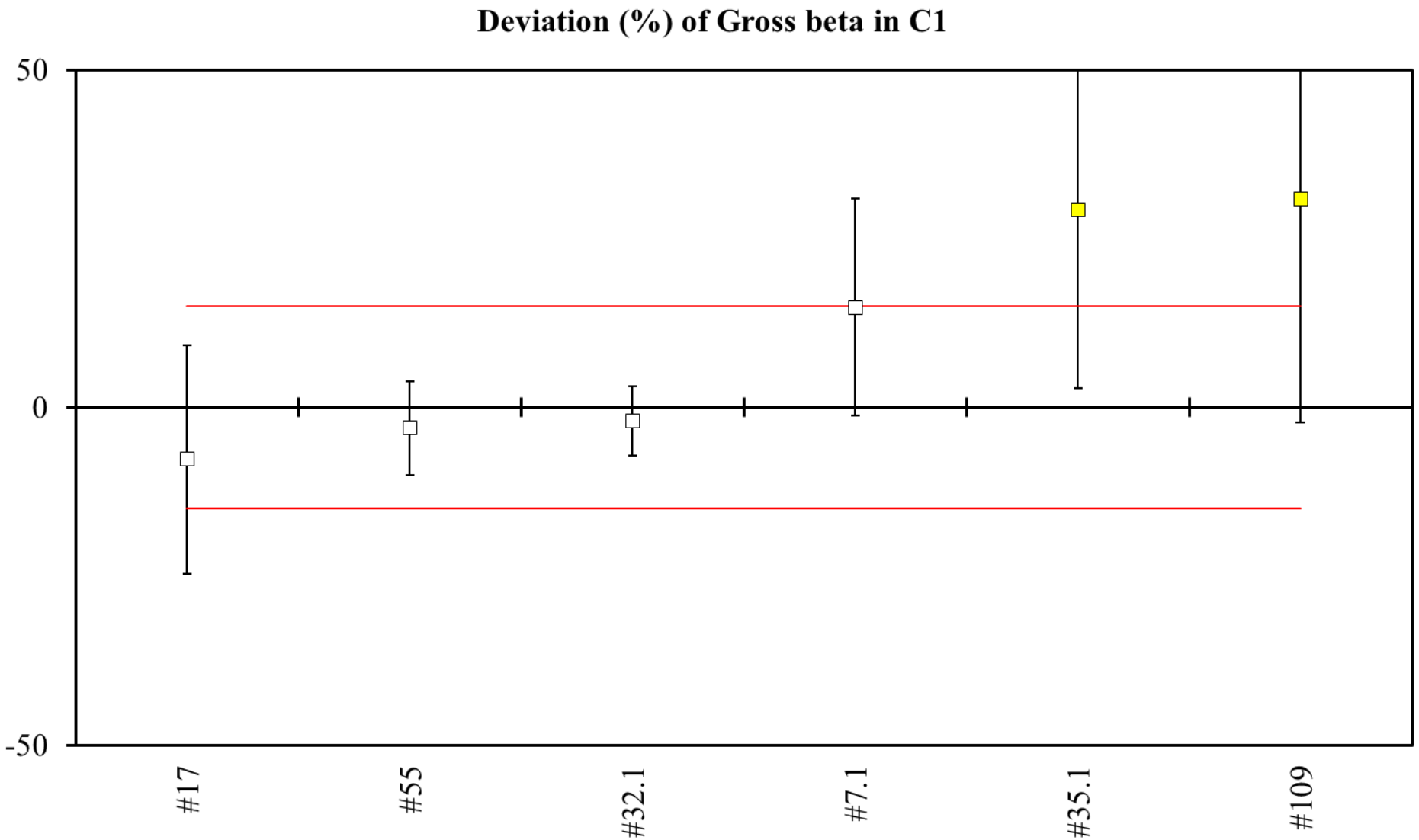
APPENDIX 1 – DATA FOR RADIONUCLIDE / RADIONUCLIDE TYPES IN C1 (OTHER THAN ^{137}Cs)

Table 10 C1 nuclides summary (other than ^{137}Cs)

Nuclides	PMWM (Bq g^{-1})
^{90}Sr	62 ± 9.1
$^{239,240}Pu$	Value not used (see Section 11)
Gross alpha	Value not used (see Section 11)
Gross beta	185.7 ± 7.2

The data for ^{90}Sr and gross beta are plotted below.


Deviation (%) of 90Sr in C1
50
0
-50
#35.1
#86.1
#55
#109
#91
#135
#7.1


Deviation (%) of Gross beta in C1
50
0
-50
#17
#55
#32.1
#7.1
#35.1
#109