



NATIONAL PHYSICAL LABORATORY

Teddington Middlesex UK TW11 0LW Telephone +44 20 8977 3222

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Proficiency Testing Report



0016

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Environmental Radioactivity Proficiency Test Exercise 2024-25

van Es, E M and Pearce, A K

September 2025

Reference: RR10 PTE 24-25 Final Report Version 1.0

Page 1 of 151

Signed:

(Authorised Signatory)

Checked by: *Wanes*

OPearce

Neil Roberts
30 September 2025

on behalf of NPLML

Environmental Radioactivity Proficiency Test Exercise 2024-25

van Es, E M[†] and Pearce, A K

Medical, Marine and Nuclear Department

ABSTRACT

The results of NPL's thirtieth Environmental Radioactivity Proficiency Test Exercise are reported. There were five different sample types offered: an aqueous mixture of one alpha-emitting radionuclide and three beta-emitting radionuclides (designated 'AB'), an aqueous mixture of three alpha-emitting radionuclides ('A1'), an aqueous mixture of three beta-emitting radionuclides ('B1'), an aqueous mixture of five gamma-emitting radionuclides ('GH'), and a second aqueous mixture of four gamma-emitting radionuclides ('GL'). In total, over 350 results were submitted (excluding gross measurements).

[†]PTE coordinator Elsje van Es, elsje.van.es@npl.co.uk, telephone number: +44 (0) 208 943 8596

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FINAL REPORT

Issued September 2025

National Physical Laboratory

Hampton Road, Teddington, Middlesex, TW11 0LW

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Continuation Sheet

Assigned Values (reference time 2024-06-01 12:00 UTC)

Radionuclide (AB)	Assigned Value (Bq g ⁻¹)
³ H	12.55 ± 0.36
⁶³ Ni	4.618 ± 0.052
⁹⁰ Sr	2.607 ± 0.018
²³⁸ U	3.601 ± 0.094
Radionuclide (A1)	Assigned Value (Bq kg ⁻¹)
²³⁷ Np	25.43 ± 0.15
²³⁸ U	55.1 ± 1.4
²⁴¹ Am	89.66 ± 0.70
Radionuclide (B1)	Assigned Value (Bq g ⁻¹)
³ H	0.517 ± 0.016
¹⁴ C	0.1557 ± 0.0024
⁹⁹ Tc	0.1870 ± 0.0036
Radionuclide (GH)	Assigned Value (Bq g ⁻¹)
⁵⁴ Mn	3.89 ± 0.20
⁵⁷ Co	12.35 ± 0.66
⁶⁵ Zn	10.68 ± 0.52
¹³³ Ba	34.4 ± 2.7
¹³⁷ Cs	6.99 ± 0.21

Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide (GL)	Assigned Value (Bq kg ⁻¹)
⁸⁸ Y	36.22 ± 0.46
¹³⁹ Ce	47.7 ± 1.8
²¹⁰ Pb	16.44 ± 0.35
²⁴¹ Am	45.08 ± 0.55

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.

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

CONTENTS

1. SUMMARY	7
2. TREATMENT OF DATA	10
3. SUMMARY OF PARTICIPANTS RESULTS	13
10. DISCUSSION	134
11. REFERENCES	134
12. ACKNOWLEDGEMENTS	144
13. APPENDICES	144

1. SUMMARY

This Environmental Radioactivity Proficiency Test Exercise (PTE) was the thirtieth in a series of annual exercises run by NPL over the last 40 years. These exercises help analysts to identify metrology challenges and support UKAS accreditations in the quantification of radionuclides. A range of sample types were made available during previous exercises. These have been mostly aqueous but have on occasion included solid materials, which have been introduced subject to availability. This exercise consisted of aqueous solutions only with five sample types made available to the participants, summarised in Table 1.

Table 1 Summary of samples available to the participants for this proficiency test exercise.

Sample Type	Sample Type Code	Radionuclides	Activity per Unit Mass Range
Alpha Beta	AB	One alpha- and three beta-emitting radionuclides in dilute nitric acid	1 – 20 Bq g ⁻¹
Alpha One	A1	Three alpha-emitting radionuclides in dilute nitric acid	5 – 100 Bq kg ⁻¹
Beta One	B1	Three beta-emitting radionuclides in 0.01 M NaOH solution	0.1 – 1 Bq g ⁻¹
Gamma High	GH	Five gamma-ray emitting radionuclides in dilute nitric acid	1 – 50 Bq g ⁻¹
Gamma Low	GL	Four gamma-ray emitting radionuclides in dilute nitric acid	1 – 50 Bq kg ⁻¹

The main objective of this exercise remains consistent with previous exercises and was to assess the performance of the participating laboratories. NPL acted as the exercise coordinator, preparing and distributing the samples to participants who identified and quantified the activity per unit mass of the radionuclides present in the samples. NPL then collected, analysed and interpreted the results which were compiled and are presented in this report.

NPL allocated each participant with a unique laboratory code number (if not already allocated in a previous exercise in this series). The allocation of laboratory numbers is done in confidence so that no third parties may identify the participants by their allocated 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 report.

Each sample type was prepared in bulk by combining weighed aliquots of radioactive standards 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 validated using radiometric counting techniques; liquid scintillation counting or high-purity germanium (HPGe) gamma spectrometry. The Assigned Value for each radionuclide was calculated from the division of the standardised activity per unit mass of the original standard solution by the dilution factor(s). 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.

The standard uncertainty of the Assigned Values for each radionuclide was derived from the uncertainty components attributed to the activity of the standardised parent solution, the gravimetric dilution and the decay correction to the reference time. These uncertainties have been evaluated and validated in accordance with the requirements of UKAS.

Throughout this report, unless otherwise stated, all uncertainties quoted in this report are combined standard uncertainties with no coverage factor applied.

The bulk solution was subdivided into (typically) 50 bottles and where applicable the homogeneity was checked by gamma spectrometry. The stability of solution was checked by counting one or more bottles of each sample type at NPL at regular intervals throughout the course of the exercise; all solutions were found to be stable.

Participants' data were analysed to provide the deviation, and the associated standard uncertainty, from the assigned value. The participants' performance was then assessed using the method described in section 2.

After receipt of the results from the participants, the Power-Moderated Mean (PMM, Pommé, 2012) was calculated for each radionuclide. 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 PMM was also calculated for the following quantities:

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

There were no cases where the PMM was used as the Assigned Value. Note that consensus values based on the PMM are not traceable to national standards of radioactivity. The PMM of the gross measurements is provided as an indicator and has not been used for performance assessment. It is for this reason results for gross measurements do not appear in the main body of the report. The gross measurements are given in APPENDIX I.

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, UK

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

2. TREATMENT OF DATA

The data were analysed using the same methods as in the 2023 exercise (van Es et al., 2024).

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 13528:2022 paragraph 8.2). 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 13528:2022 rather than the commonly understood z-score and is used to reject results on based 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 seven.

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 the deviation is less than 15 % from the Assigned Value but the standard uncertainty is insufficient result in agreement with the Assigned Value), 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 .

A result was only classified as 'in agreement' when the three tests (the zeta test, the relative uncertainty outlier test and the z-test) were passed. A failure to pass one of these tests resulted in a classification 'questionable'. Failure of both the zeta test and the z-test resulted in a classification 'discrepant'. The classification criteria used to assess the performance of participants are summarised in Table 2.

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Table 2 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 summary of classification results for each radionuclide in each sample type is provided in Table 3. The number of samples dispatched is assumed to be the number of samples ordered by participants. Please note when interpreting this table that participants may have ordered multiple samples and/or chosen to not submit results. In the instance that a laboratory has submitted multiple results for a given radionuclide all results will appear as a count in the table.

Table 2 Summary of classifications for each radionuclide in each sample type.

Radionuclide	No. of samples dispatched	Pass	Questionable	Fail
AB				
³ H	26	15	1	4
⁶³ Ni		10	5	1
⁹⁰ Sr		17	2	2
²³⁸ U		18	1	1
A1				
²³⁷ Np	19	7	1	4
²³⁸ U		17	0	1
²⁴¹ Am		15	0	3
B1				
³ H	27	21	0	2
¹⁴ C		11	5	2
⁹⁹ Tc		11	1	1
GH				
⁵⁴ Mn	30	28	0	2
⁵⁷ Co		28	0	2
⁶⁵ Zn		26	1	3
¹³³ Ba		29	0	1
¹³⁷ Cs		29	0	1
GL				
⁸⁸ Y	24	19	1	2
¹³⁹ Ce		18	1	3
²¹⁰ Pb		9	8	1
²⁴¹ Am		19	0	2

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

The reference time is 2024-06-01 12:00 UTC.

Table 4 AB summary

Radionuclide	NPL Assigned Values (Bq g ⁻¹)	PMM (Bq g ⁻¹)	Deviation %	Zeta	Critical Value
³ H	12.55 ± 0.18	13.00 ± 0.20	3.6	1.67	2.70
⁶³ Ni	4.618 ± 0.026	4.47 ± 0.15	-3.2	-0.96	2.95
⁹⁰ Sr	2.6067 ± 0.0091	2.481 ± 0.036	-4.8	-3.42	2.88
²³⁸ U	3.601 ± 0.047	3.583 ± 0.028	-0.5	-0.34	2.58

Table 5 A1 summary

Radionuclide	NPL Assigned Values (Bq kg ⁻¹)	PMM (Bq kg ⁻¹)	Deviation %	Zeta	Critical Value
²³⁷ Np	25.433 ± 0.077	22.9 ± 1.4	-10.1	-1.83	3.25
²³⁸ U	55.14 ± 0.72	53.68 ± 0.71	-2.7	-1.45	2.65
²⁴¹ Am	89.66 ± 0.35	86.9 ± 1.5	-3.0	-1.76	2.92

Table 6 B1 summary

Radionuclide	NPL Assigned Values (Bq g ⁻¹)	PMM (Bq g ⁻¹)	Deviation %	Zeta	Critical Value
³ H	0.5175 ± 0.0078	0.5123 ± 0.0046	-1.0	-0.57	2.58
¹⁴ C	0.1557 ± 0.0012	0.1487 ± 0.0038	-4.5	-1.77	2.86
⁹⁹ Tc	0.1870 ± 0.0018	0.1819 ± 0.0038	-2.7	-1.21	2.95

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Table 7 GH summary

Radionuclide	NPL Assigned Values (Bq g ⁻¹)	PMM (Bq g ⁻¹)	Deviation %	Zeta	Critical Value
⁵⁴ Mn	3.89 ± 0.10	3.899 ± 0.024	0.2	0.09	2.58
⁵⁷ Co	12.35 ± 0.33	12.178 ± 0.071	-1.4	-0.51	2.58
⁶⁵ Zn	10.68 ± 0.26	10.617 ± 0.066	-0.6	-0.24	2.58
¹³³ Ba	34.4 ± 1.4	34.20 ± 0.22	-0.6	-0.14	2.58
¹³⁷ Cs	6.99 ± 0.10	6.961 ± 0.037	-0.4	-0.27	2.58

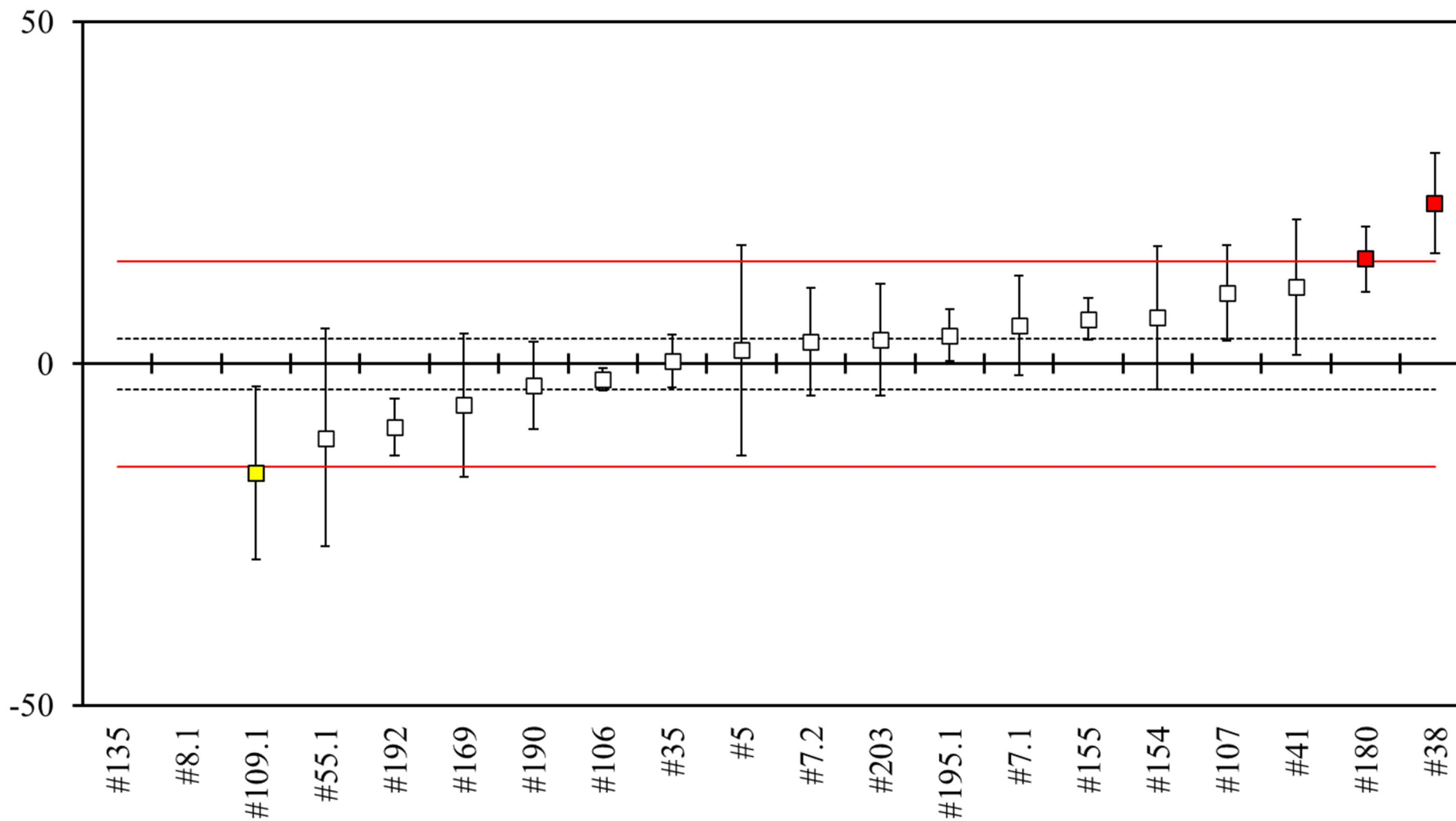
Table 8 GL summary

Radionuclide	NPL Assigned Values (Bq kg ⁻¹)	PMM (Bq kg ⁻¹)	Deviation %	Zeta	Critical Value
⁸⁸ Y	36.22 ± 0.23	36.32 ± 0.46	0.3	0.20	2.75
¹³⁹ Ce	47.65 ± 0.88	48.31 ± 0.59	1.4	0.62	2.58
²¹⁰ Pb	16.44 ± 0.18	15.51 ± 0.38	-5.7	-2.20	2.82
²⁴¹ Am	45.08 ± 0.28	45.38 ± 0.33	0.7	0.68	2.67

4. ALPHA BETA (AB) DEVIATION PLOTS

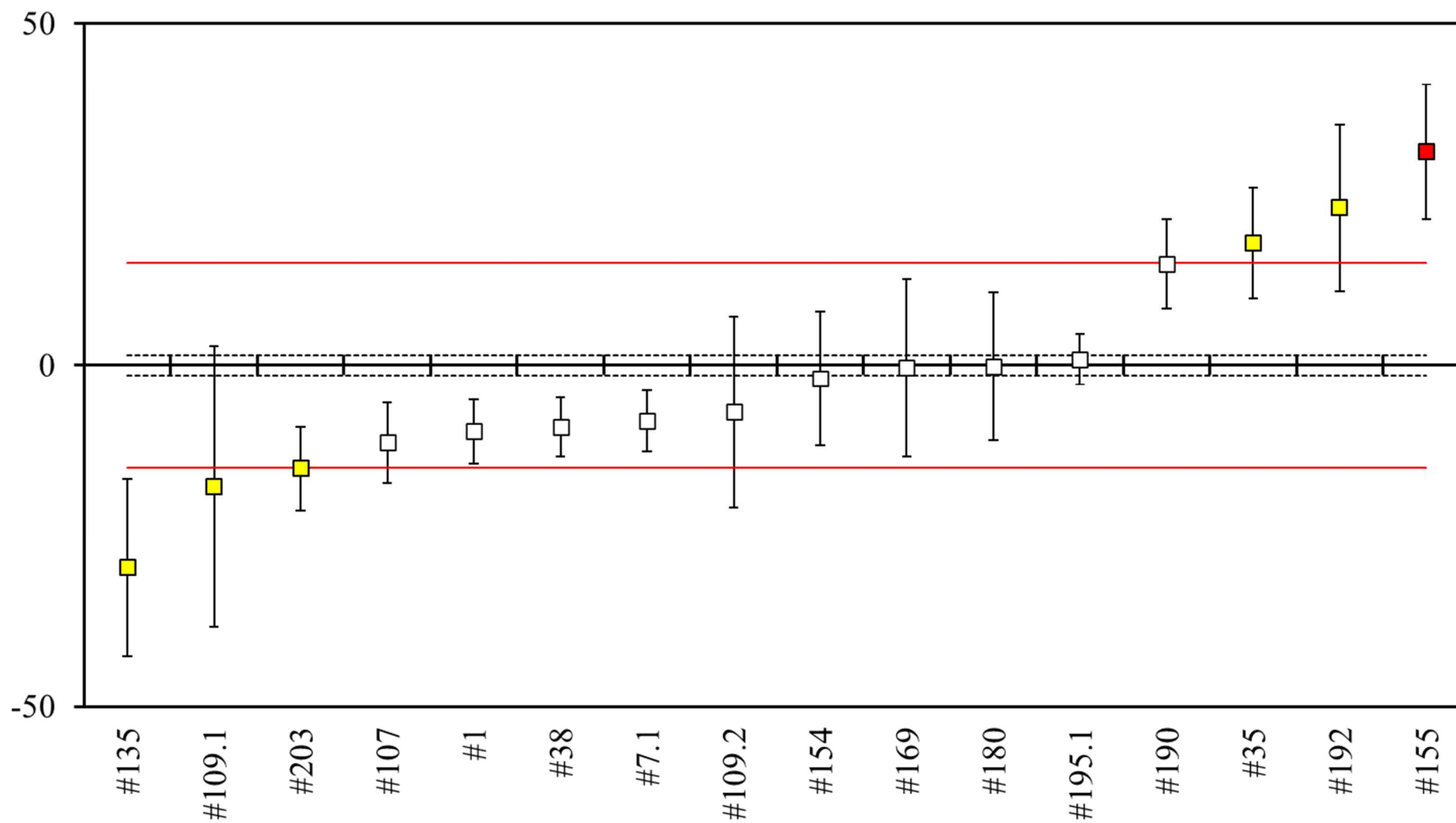
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Continuation Sheet

Deviation (%) of ^3H in AB

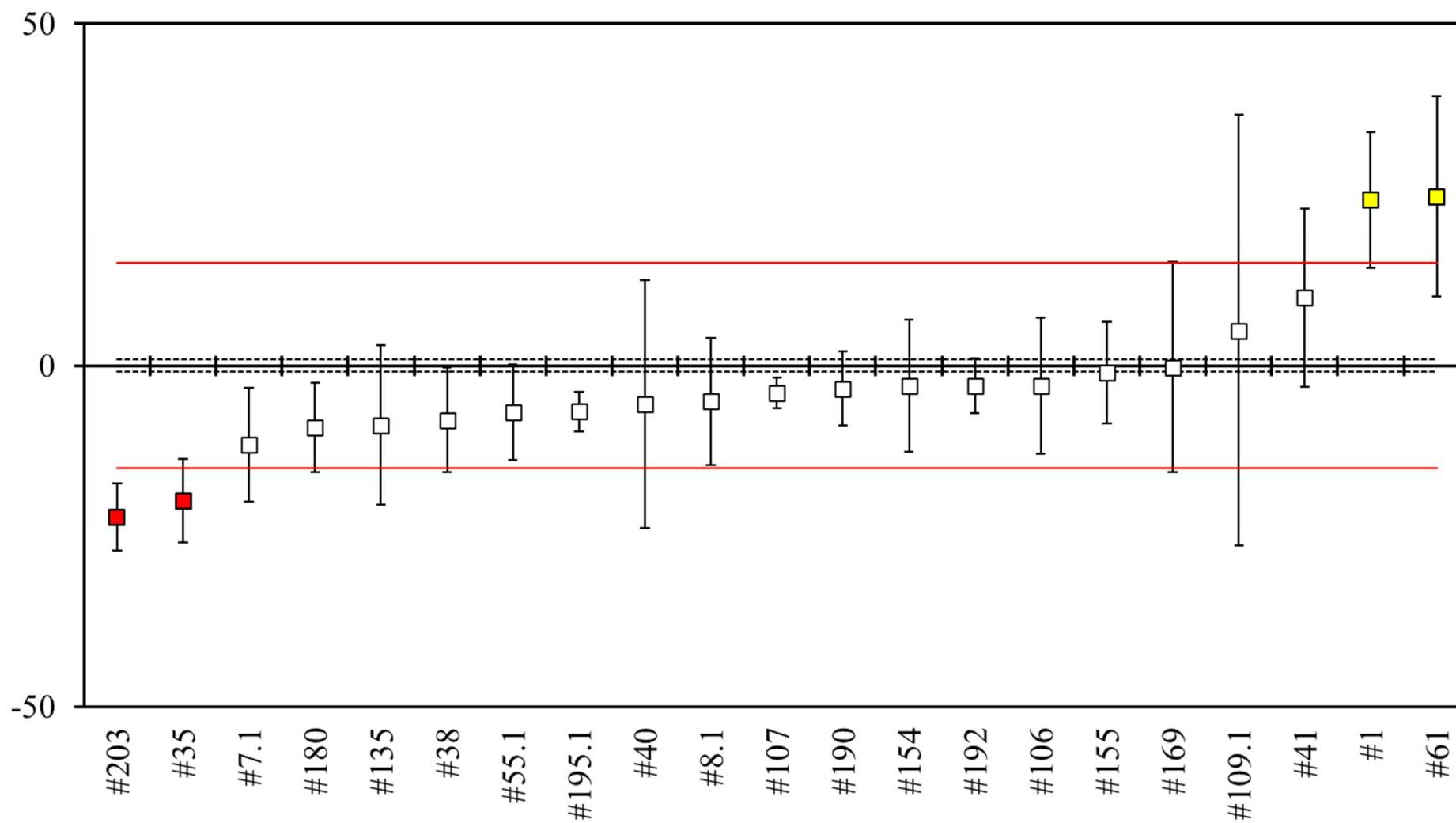
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Continuation Sheet

Deviation (%) of ^{63}Ni in AB

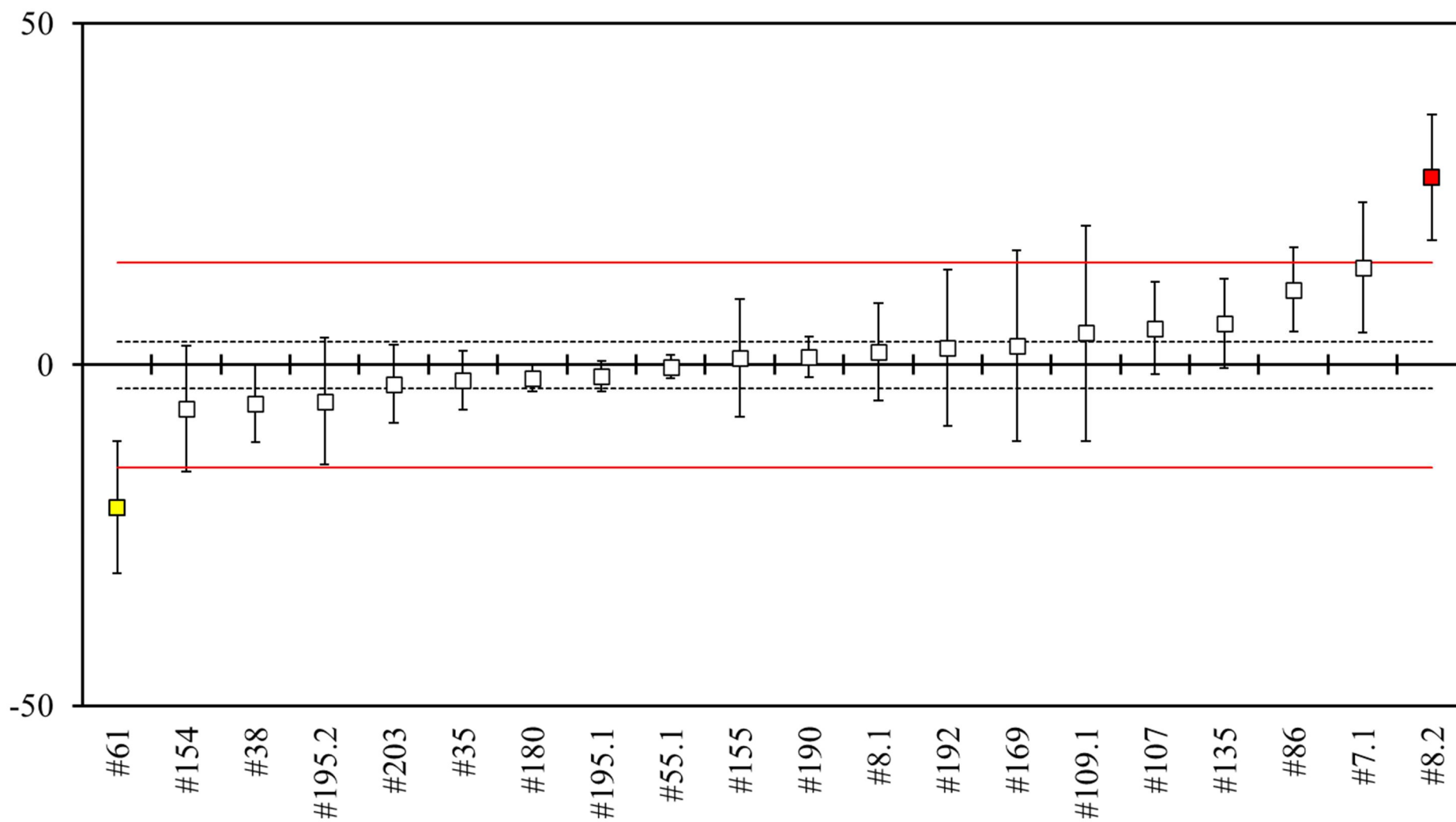
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Continuation Sheet

Deviation (%) of ^{90}Sr in AB

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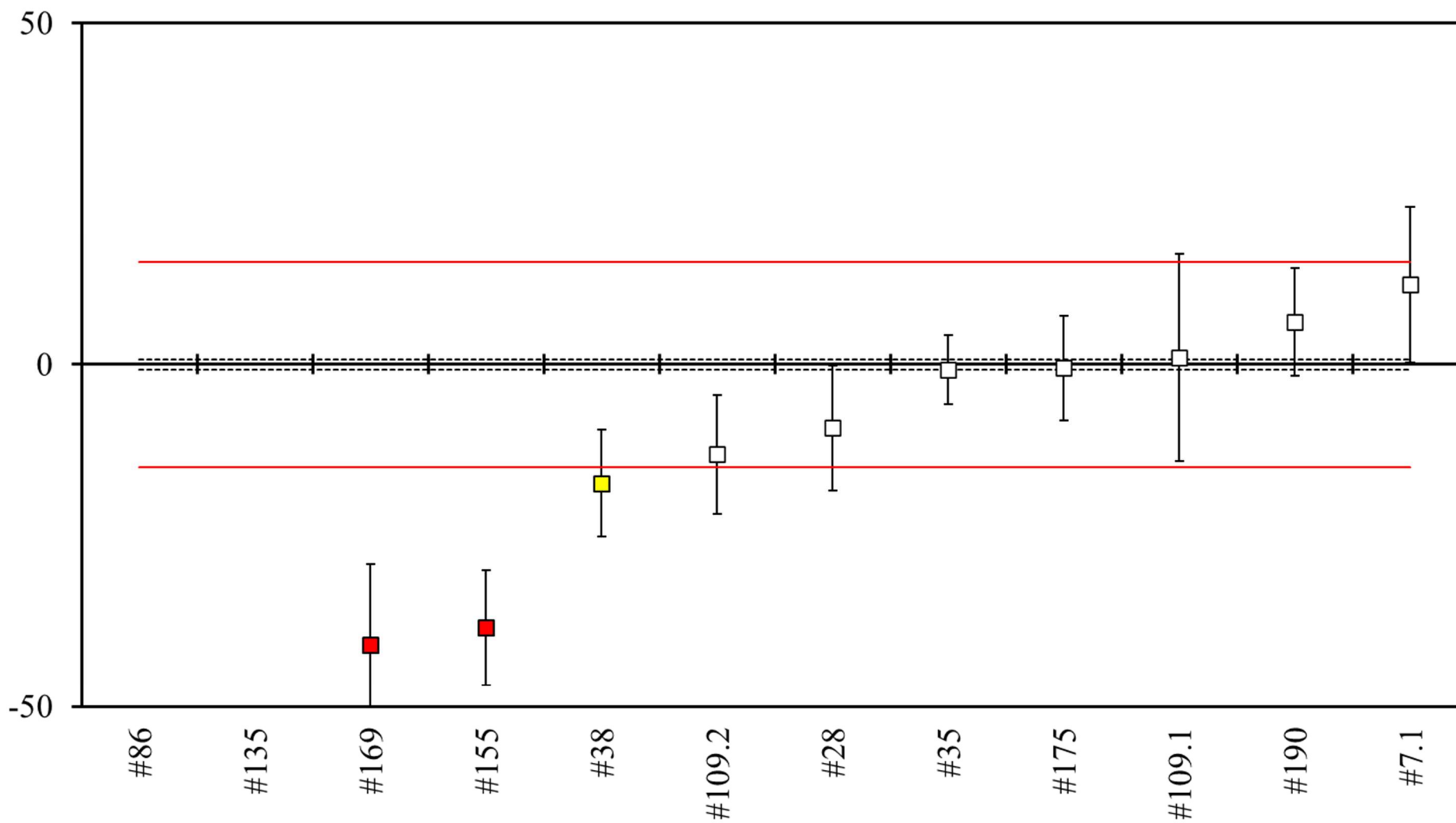
Continuation Sheet

Deviation (%) of ^{238}U in AB

5. ALPHA ONE (A1) DEVIATION PLOTS

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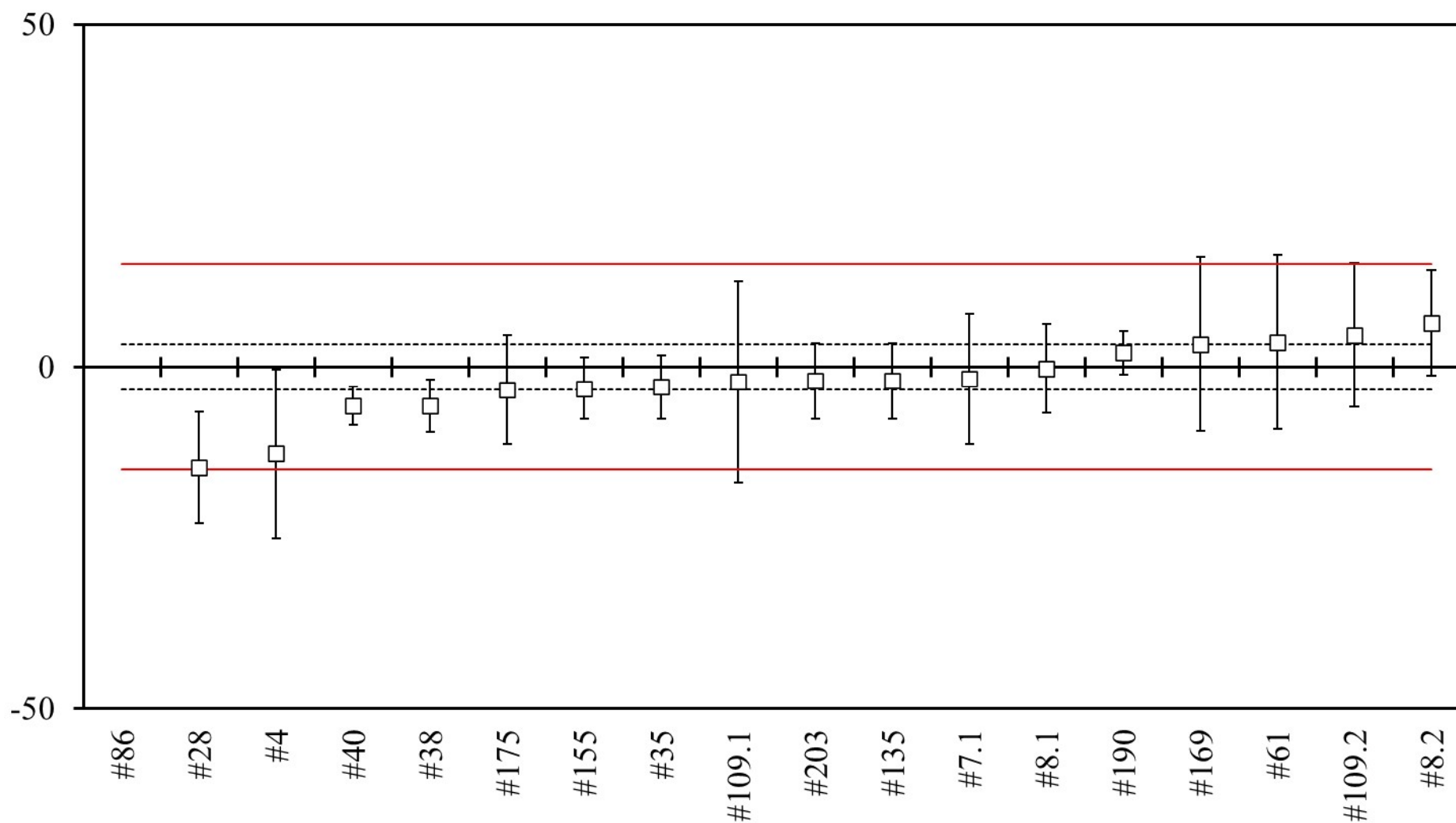
Continuation Sheet

Deviation (%) of ^{237}Np in A1

Reference: RR10 PTE 24-25 Final Report Version 1.0

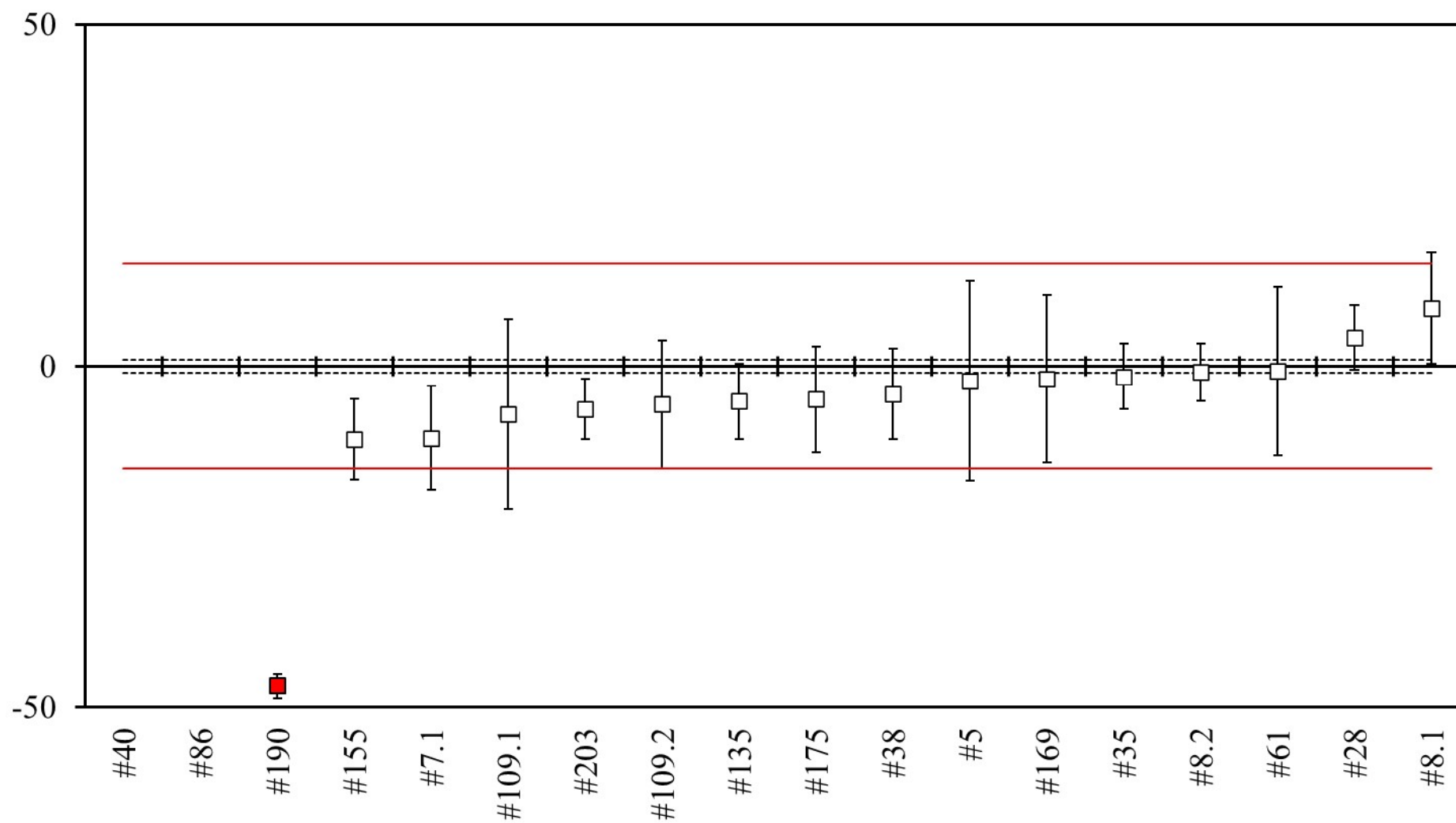
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Continuation Sheet

Deviation (%) of ^{238}U in A1

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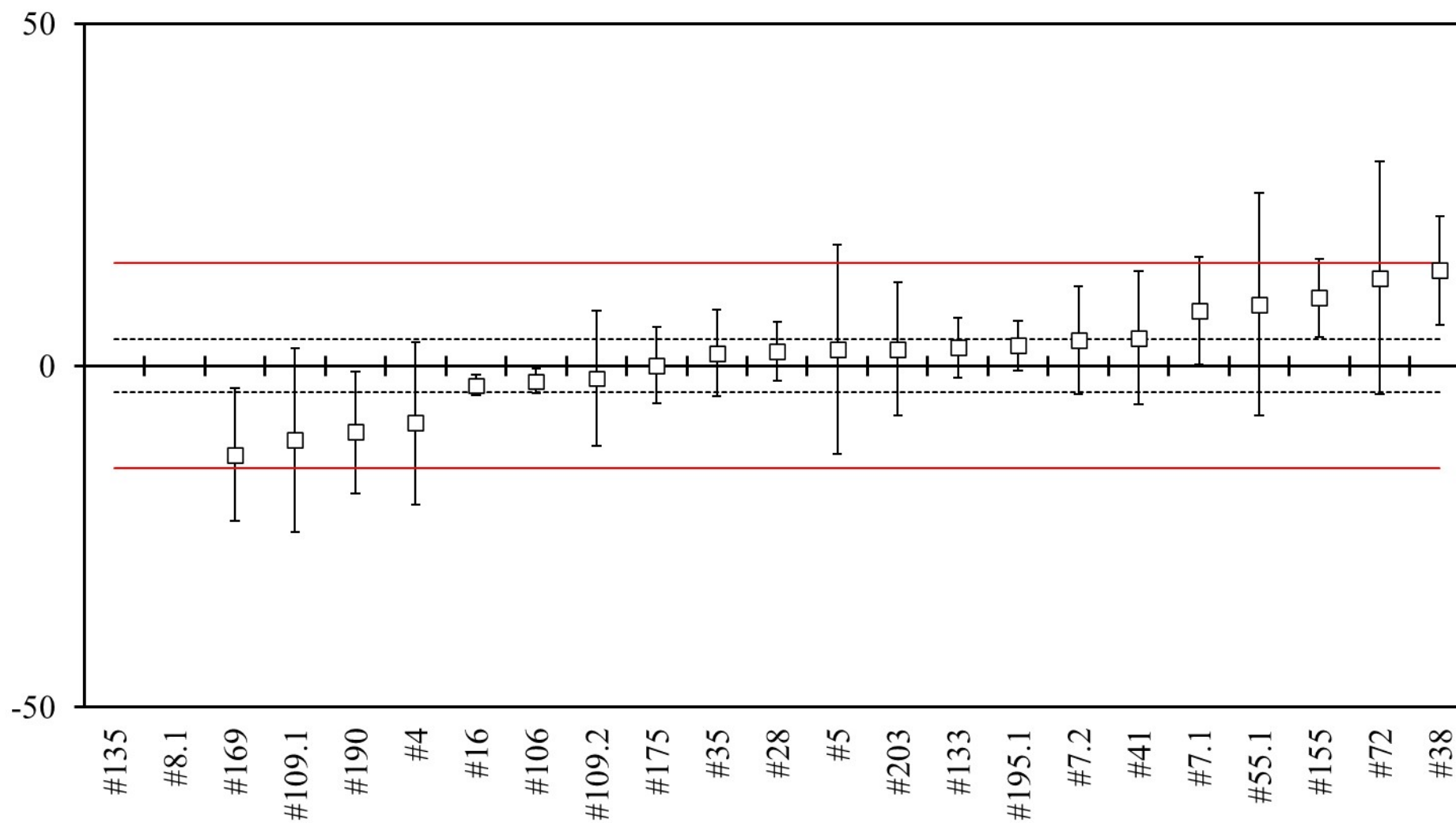
Continuation Sheet

Deviation (%) of ^{241}Am in A1

6. BETA ONE (B1) DEVIATION PLOTS

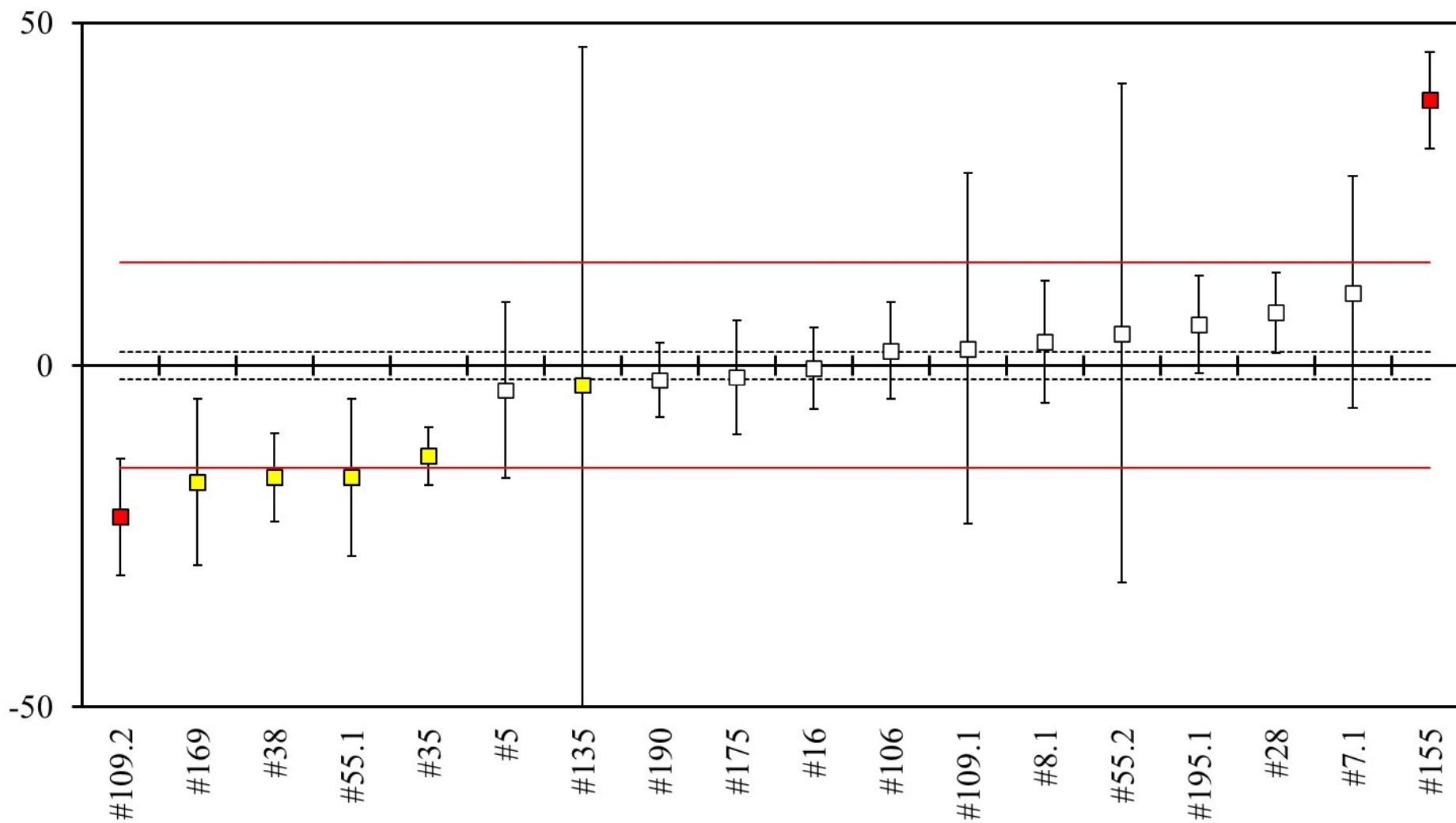
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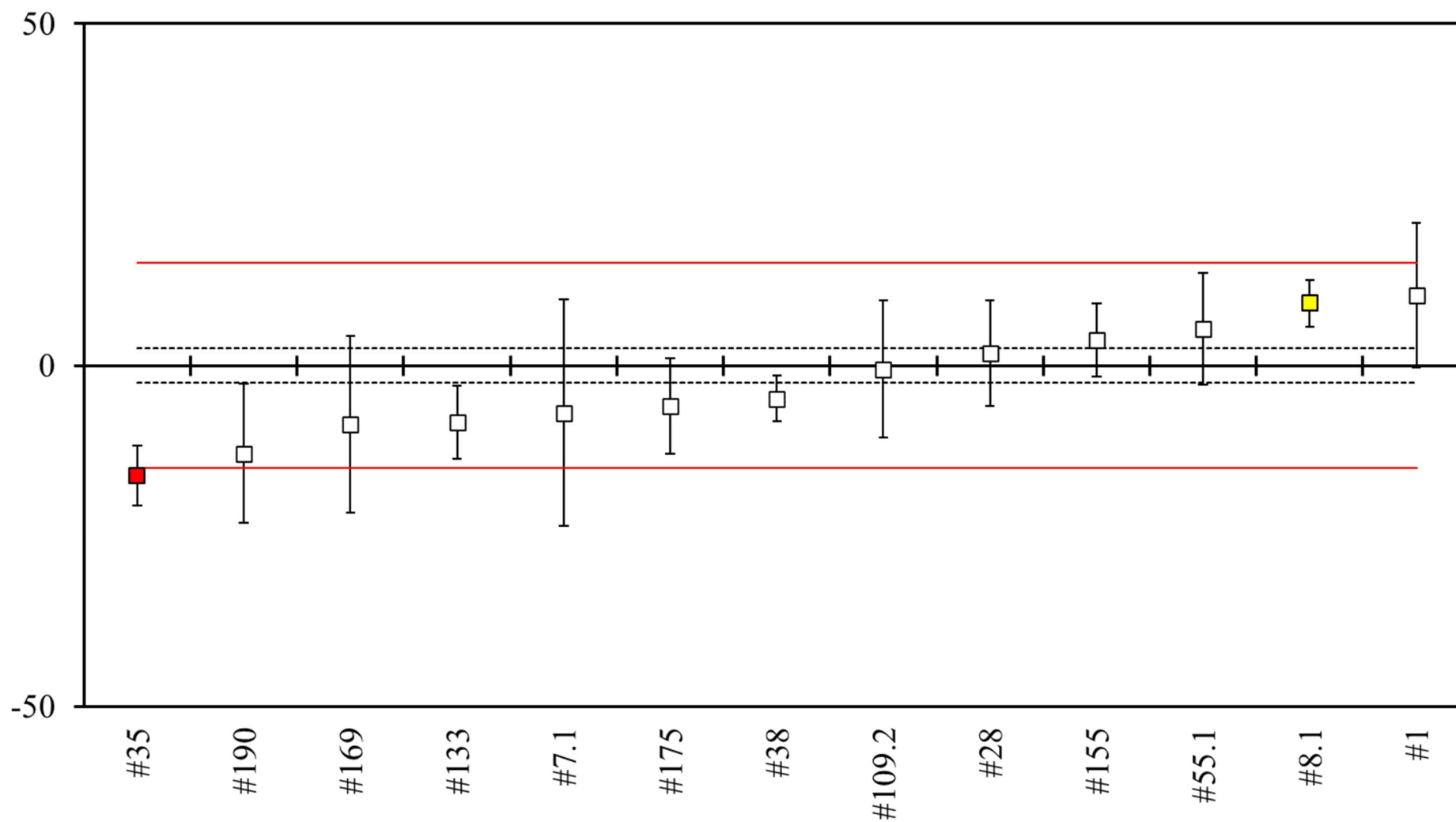
Continuation Sheet

Deviation (%) of ^3H in B1

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Continuation Sheet

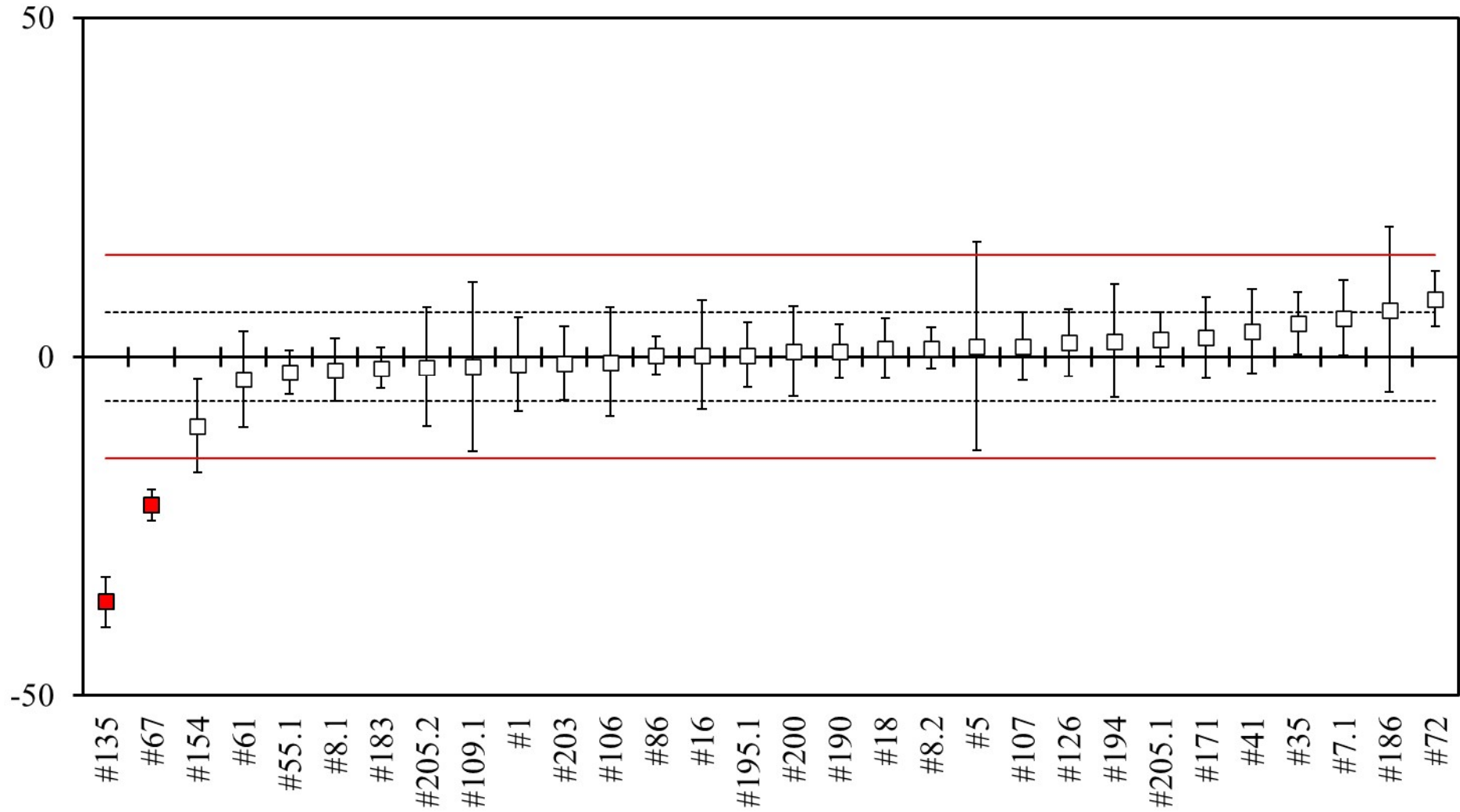
Deviation (%) of ^{14}C in B1

Deviation (%) of ^{99}Tc in B1

7. GAMMA HIGH (GH) DEVIATION PLOTS

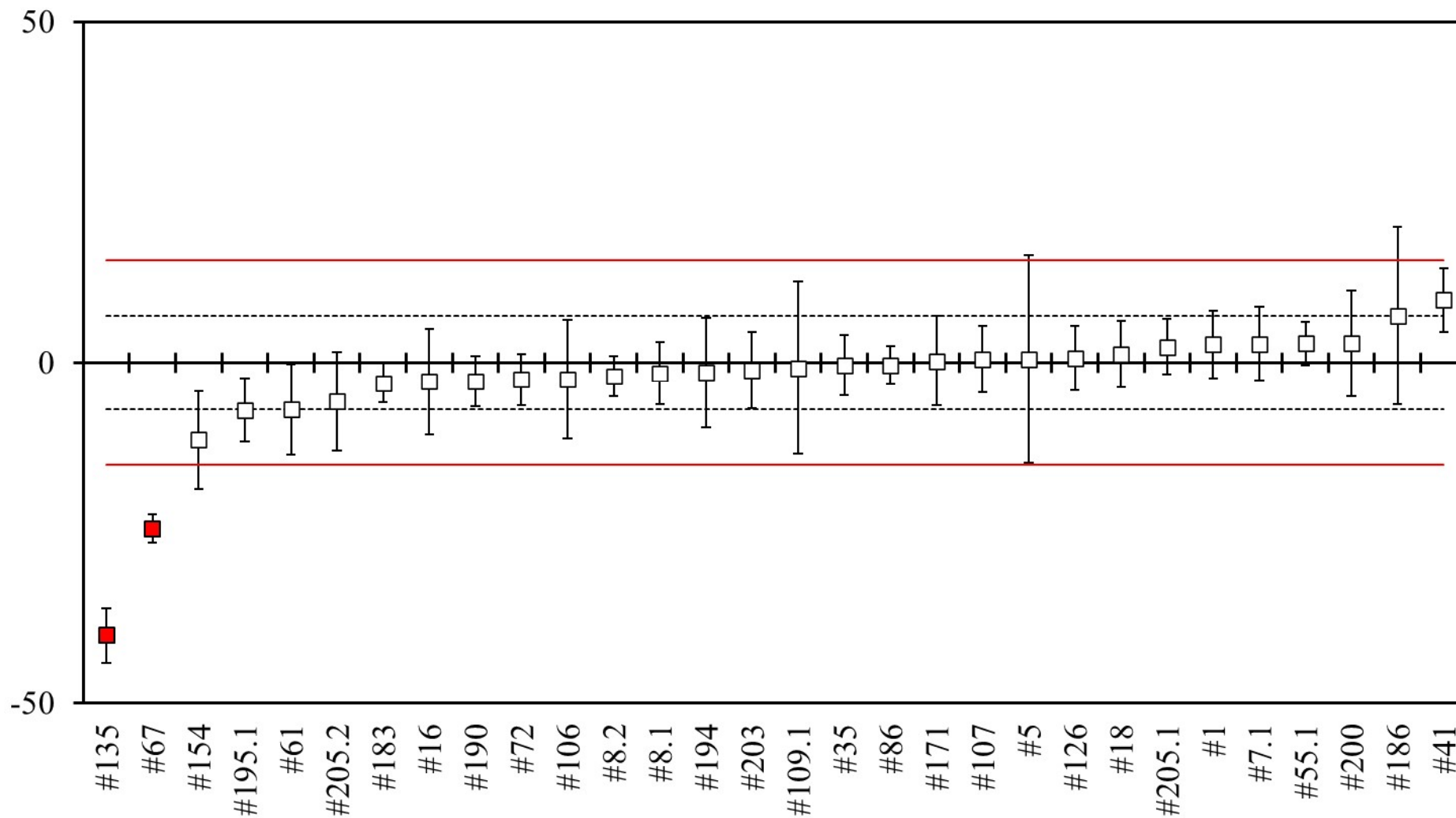
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Continuation Sheet

Deviation (%) of ^{54}Mn in GH

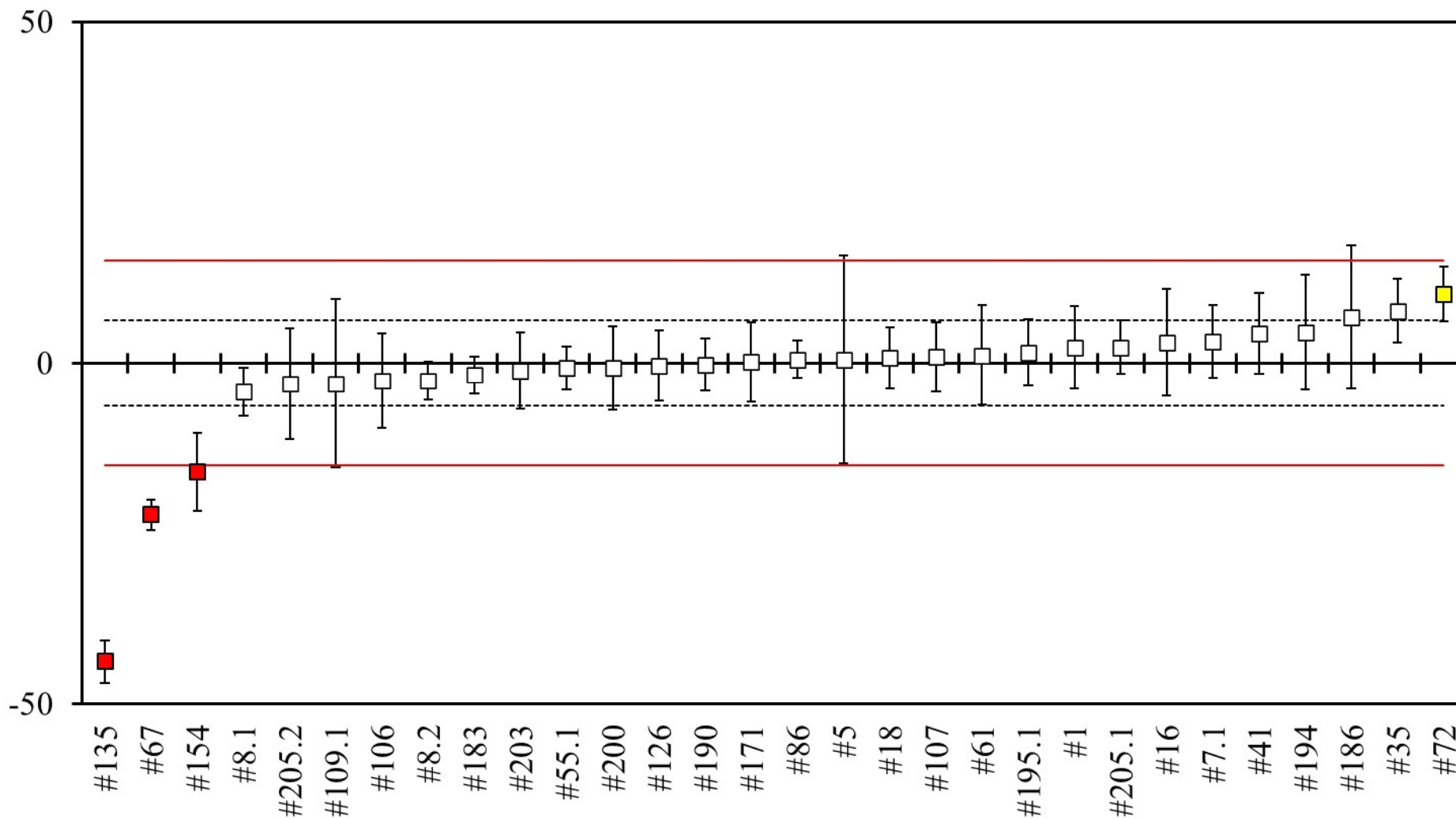
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Continuation Sheet

Deviation (%) of ^{57}Co in GH

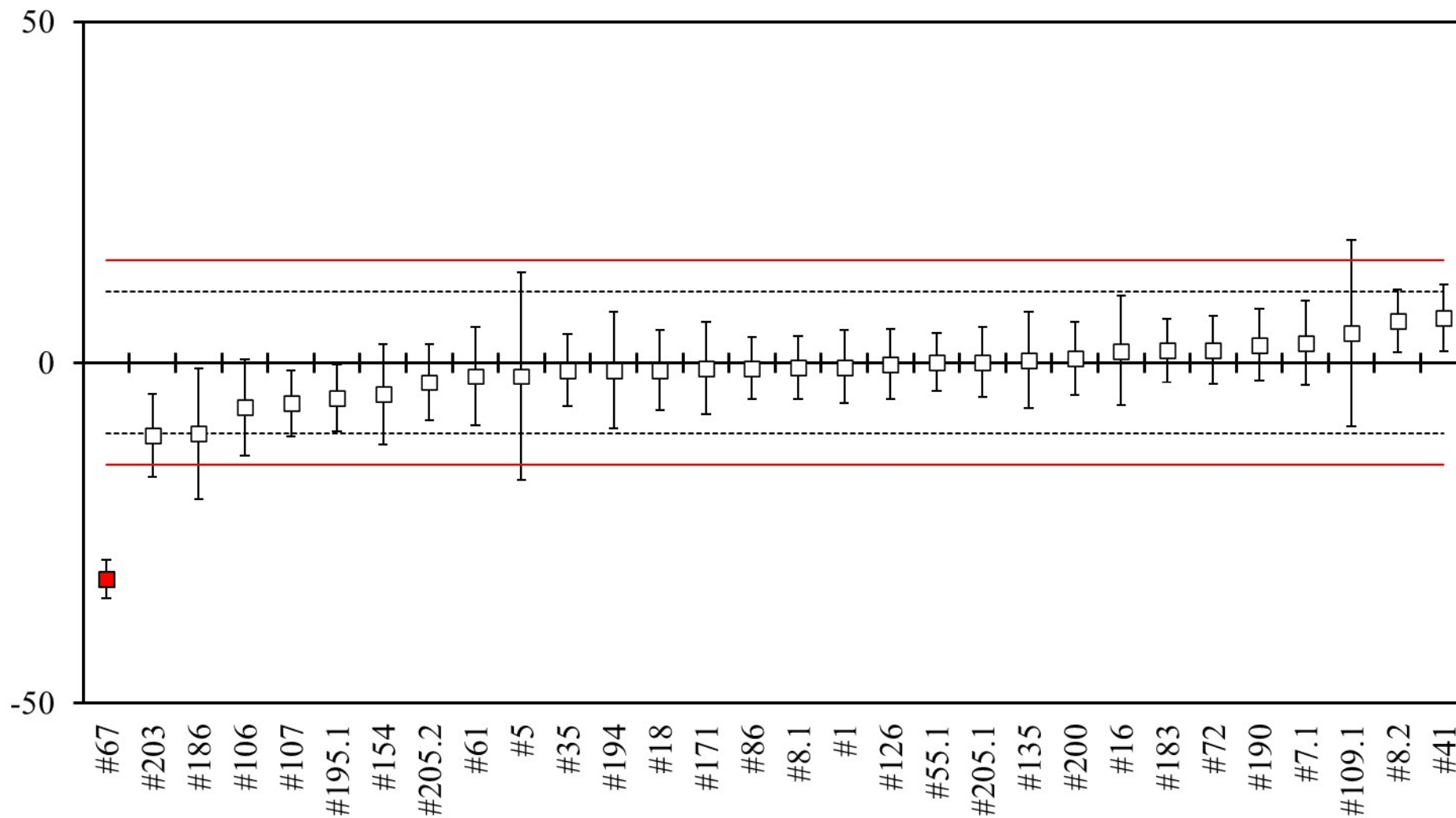
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Continuation Sheet

Deviation (%) of ^{65}Zn in GH

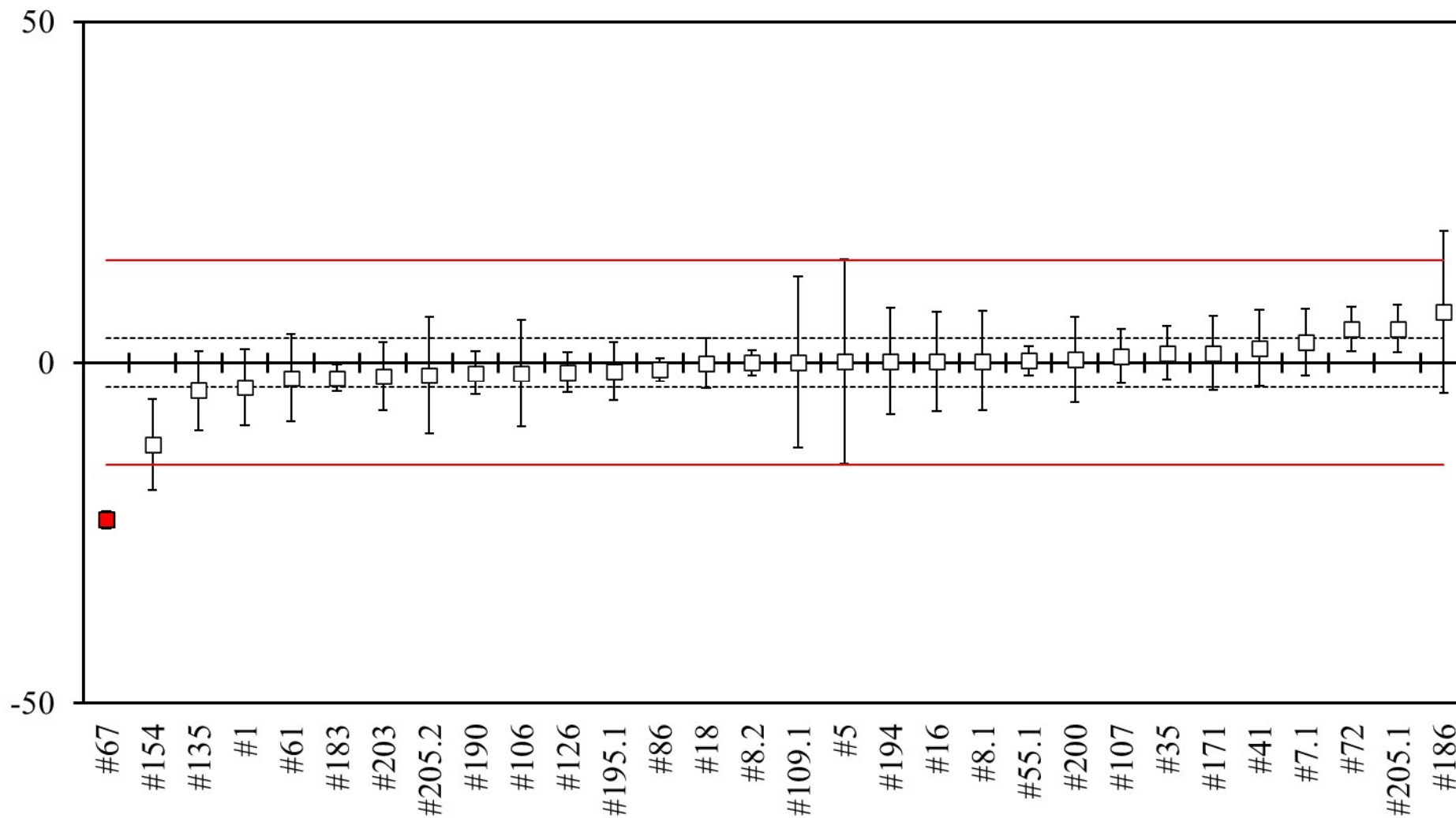
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Continuation Sheet

Deviation (%) of ^{133}Ba in GH

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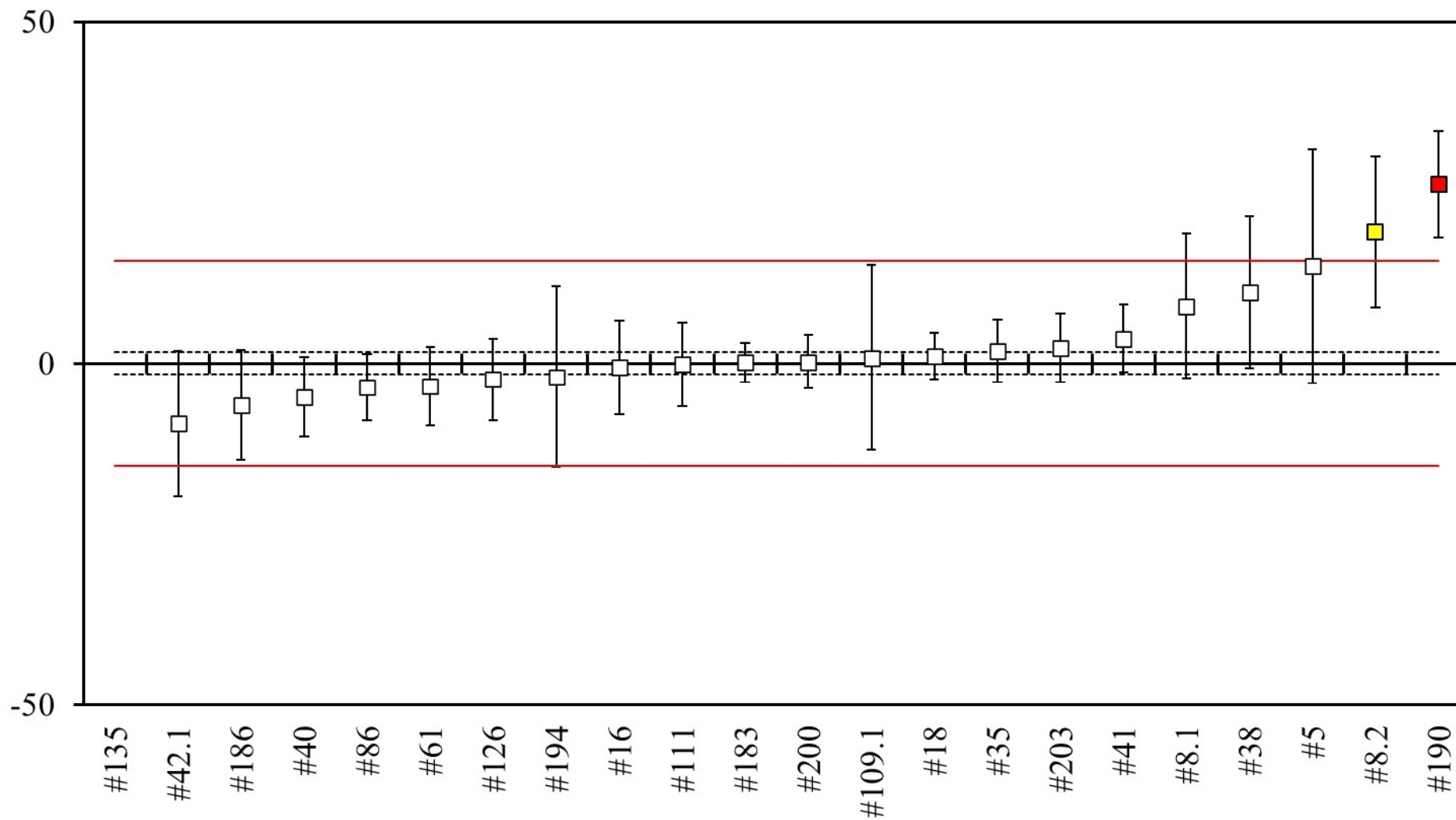
Continuation Sheet

Deviation (%) of ^{137}Cs in GH

8. GAMMA LOW (GL) DEVIATION PLOTS

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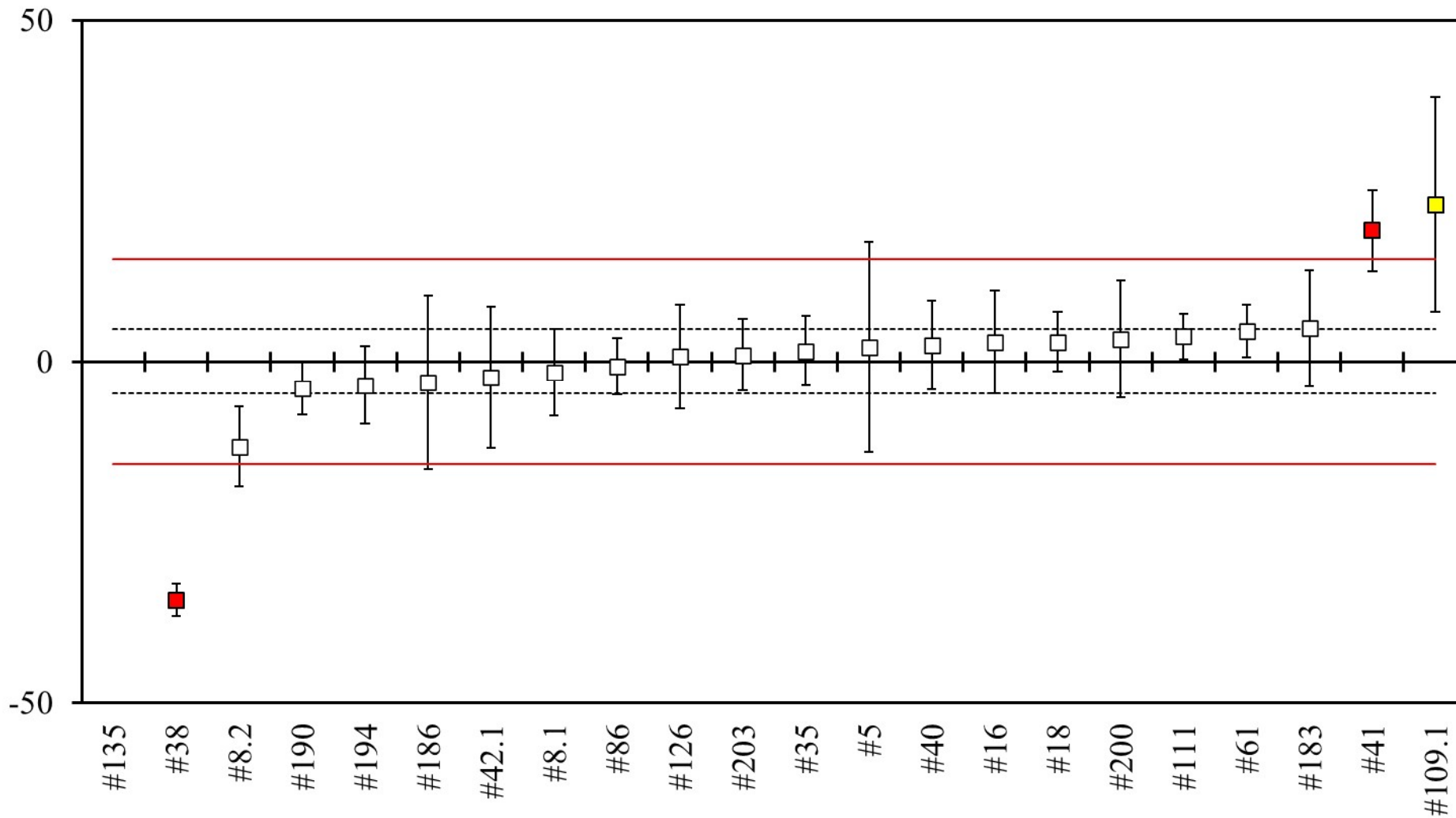
Continuation Sheet

Deviation (%) of ^{88}Y in GL

Reference: RR10 PTE 24-25 Final Report Version 1.0

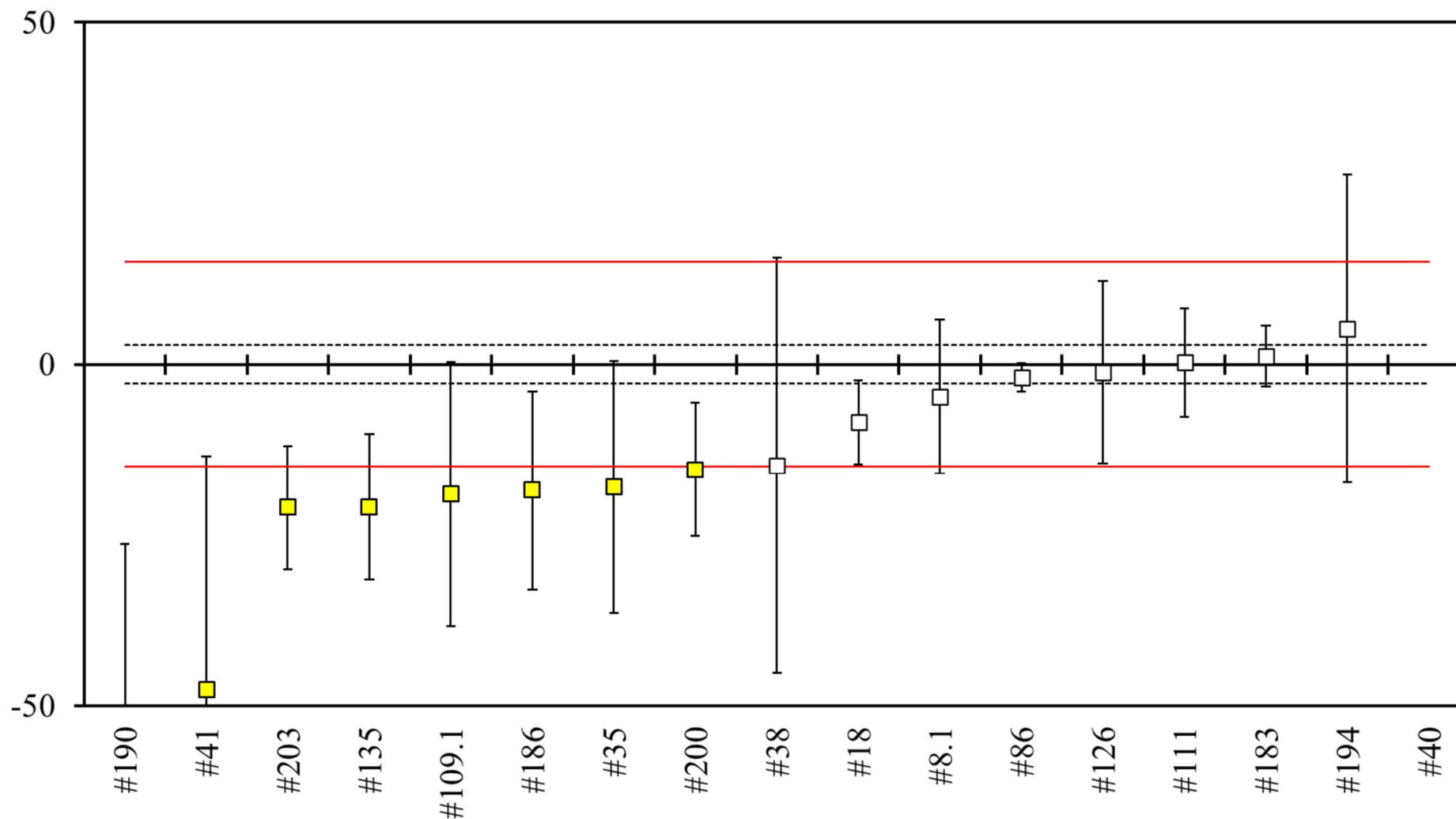
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Continuation Sheet

Deviation (%) of ^{139}Ce in GL

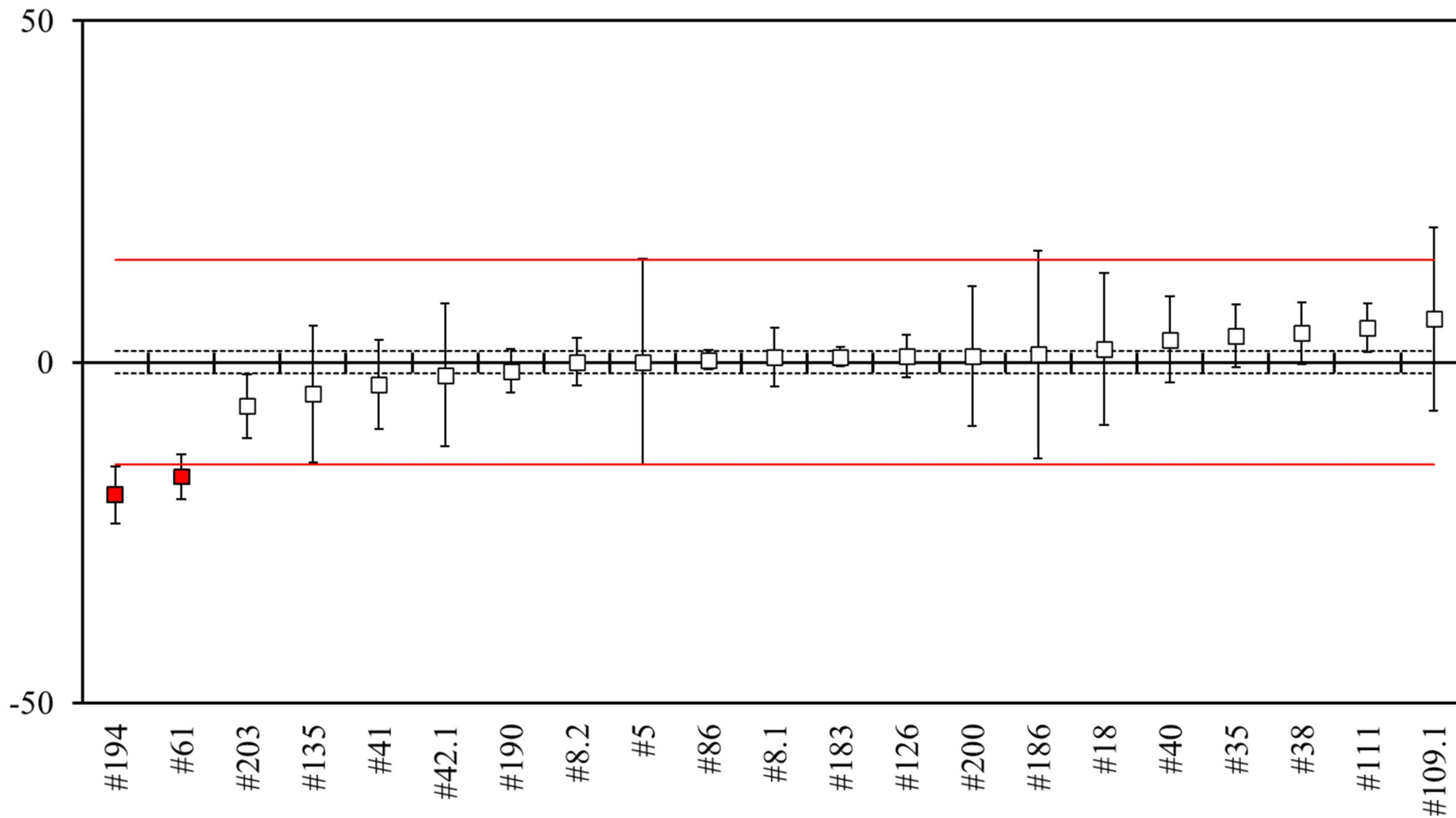
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Continuation Sheet

Deviation (%) of ^{210}Pb in GL

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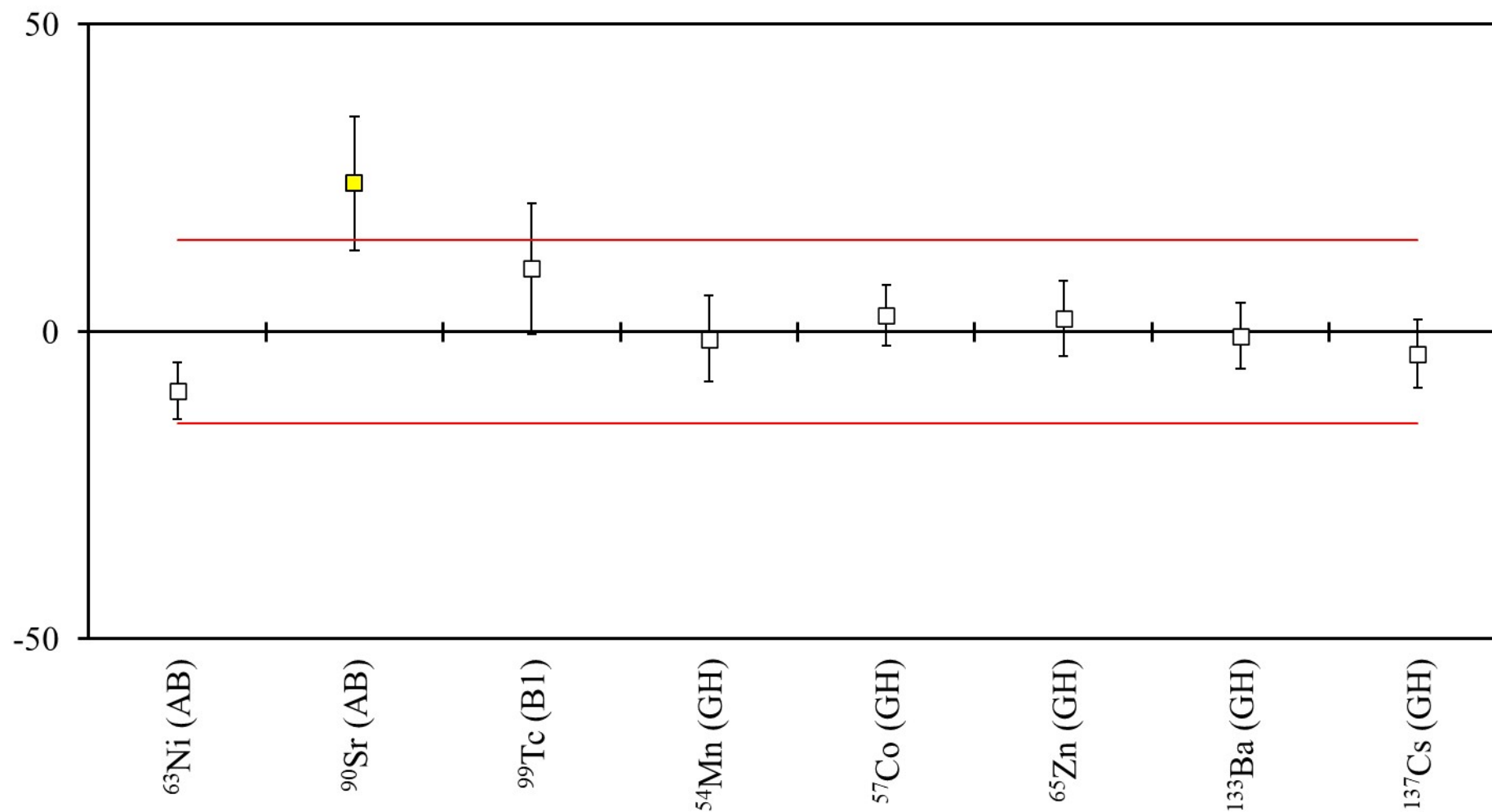
Continuation Sheet

Deviation (%) of ^{241}Am in GL

9. DEVIATION PLOTS AND TABULATED RESULTS ARRANGED BY LAB NUMBER

NOTE:

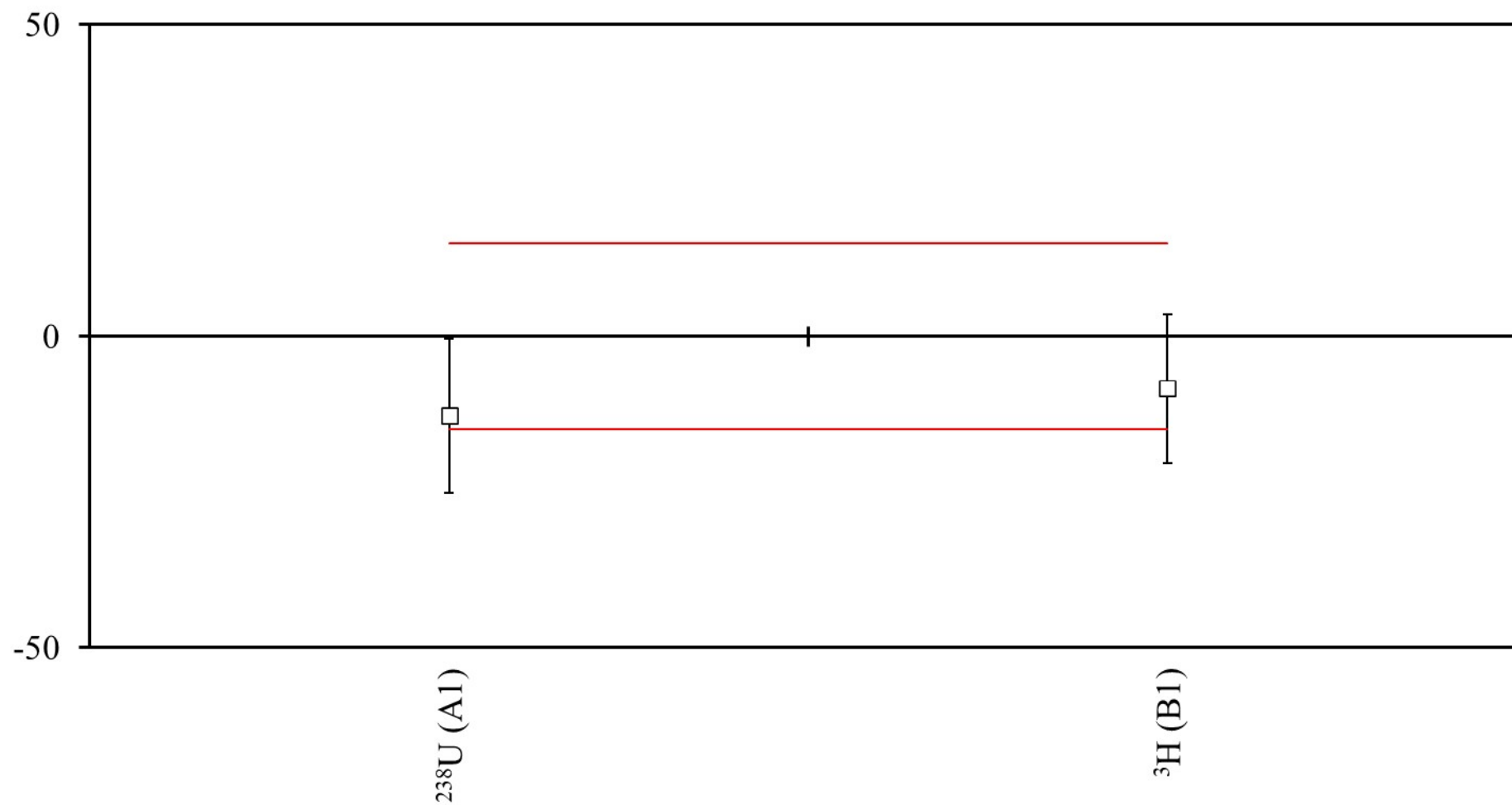
1. The following section contains participants results in the form of deviation plots followed by a corresponding data table. The deviation plots show the percentage deviation for each radionuclide in relation to the NPL assigned value.
2. Data are quoted rounded, at $k = 1$ (standard uncertainty). Data analysis was carried out on data as reported (i.e. before rounding). Uncertainties have been rounded to two significant figures.
3. Units of the Assigned Values and the reported results are as follows:
 - a. AB – Bq g⁻¹
 - b. A1 – Bq kg⁻¹
 - c. B1 – Bq g⁻¹
 - d. GH – Bq g⁻¹
 - e. GL – Bq kg⁻¹

Deviation (%) of Laboratory 1

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Continuation Sheet

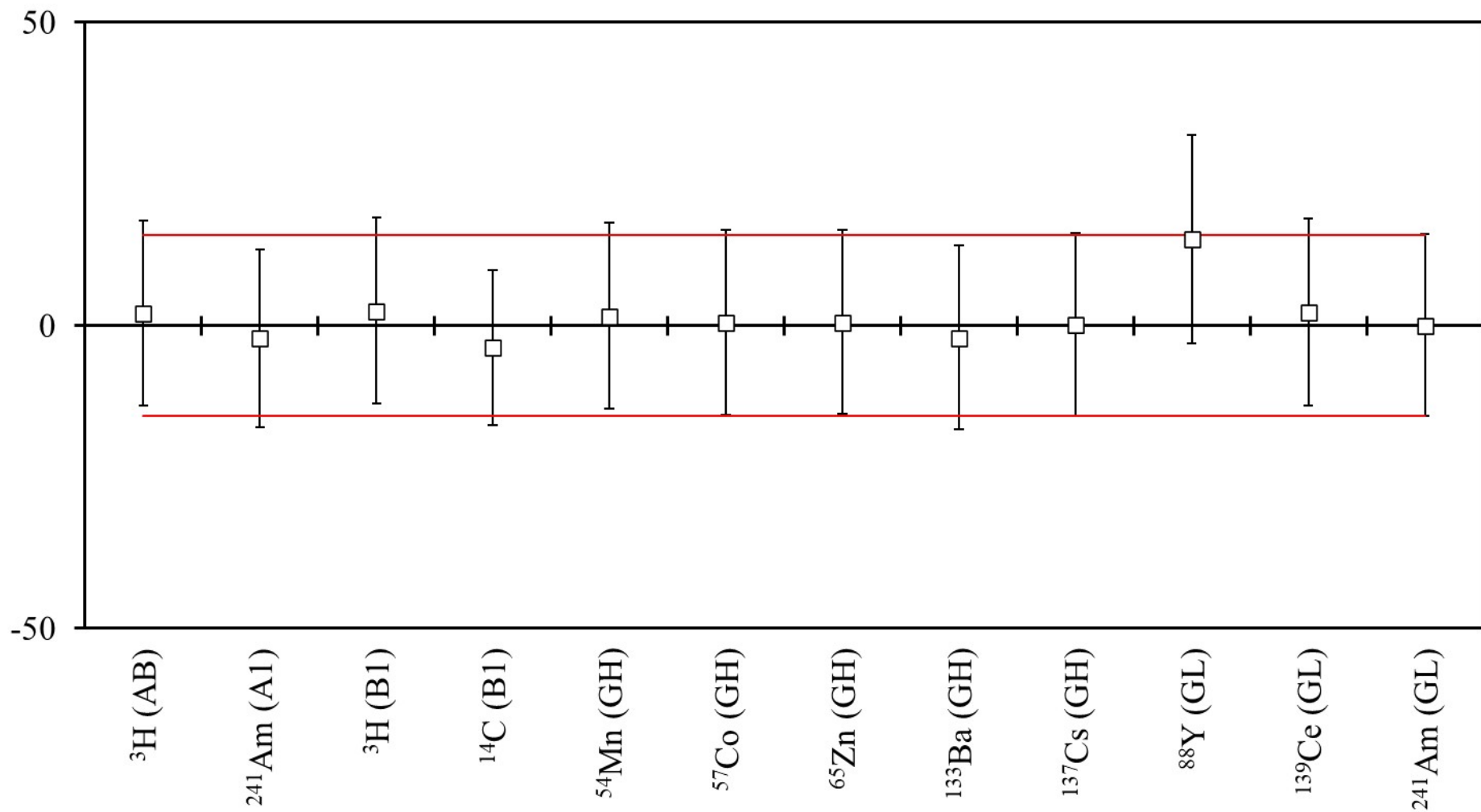
Radionuclide	Laboratory 1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	4.17 ± 0.22	4.618 ± 0.026	-9.7	-2.06	-1.66
^{90}Sr (AB)	3.24 ± 0.26	2.6067 ± 0.0091	24.2	2.43	4.15
^{99}Tc (B1)	0.206 ± 0.020	0.1870 ± 0.0018	10.3	0.97	1.77
^{54}Mn (GH)	3.85 ± 0.25	3.89 ± 0.10	-1.1	-0.16	-0.19
^{57}Co (GH)	12.68 ± 0.50	12.35 ± 0.33	2.7	0.55	0.46
^{65}Zn (GH)	10.92 ± 0.59	10.68 ± 0.26	2.2	0.37	0.38
^{133}Ba (GH)	34.2 ± 1.2	34.4 ± 1.4	-0.6	-0.11	-0.11
^{137}Cs (GH)	6.74 ± 0.38	6.99 ± 0.10	-3.6	-0.65	-0.63

Deviation (%) of Laboratory 4

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 4	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{238}U (A1)	48.1 ± 6.8	55.14 ± 0.72	-12.7	-1.03	-2.18
^3H (B1)	0.474 ± 0.061	0.5175 ± 0.0078	-8.4	-0.70	-1.44

Deviation (%) of Laboratory 5

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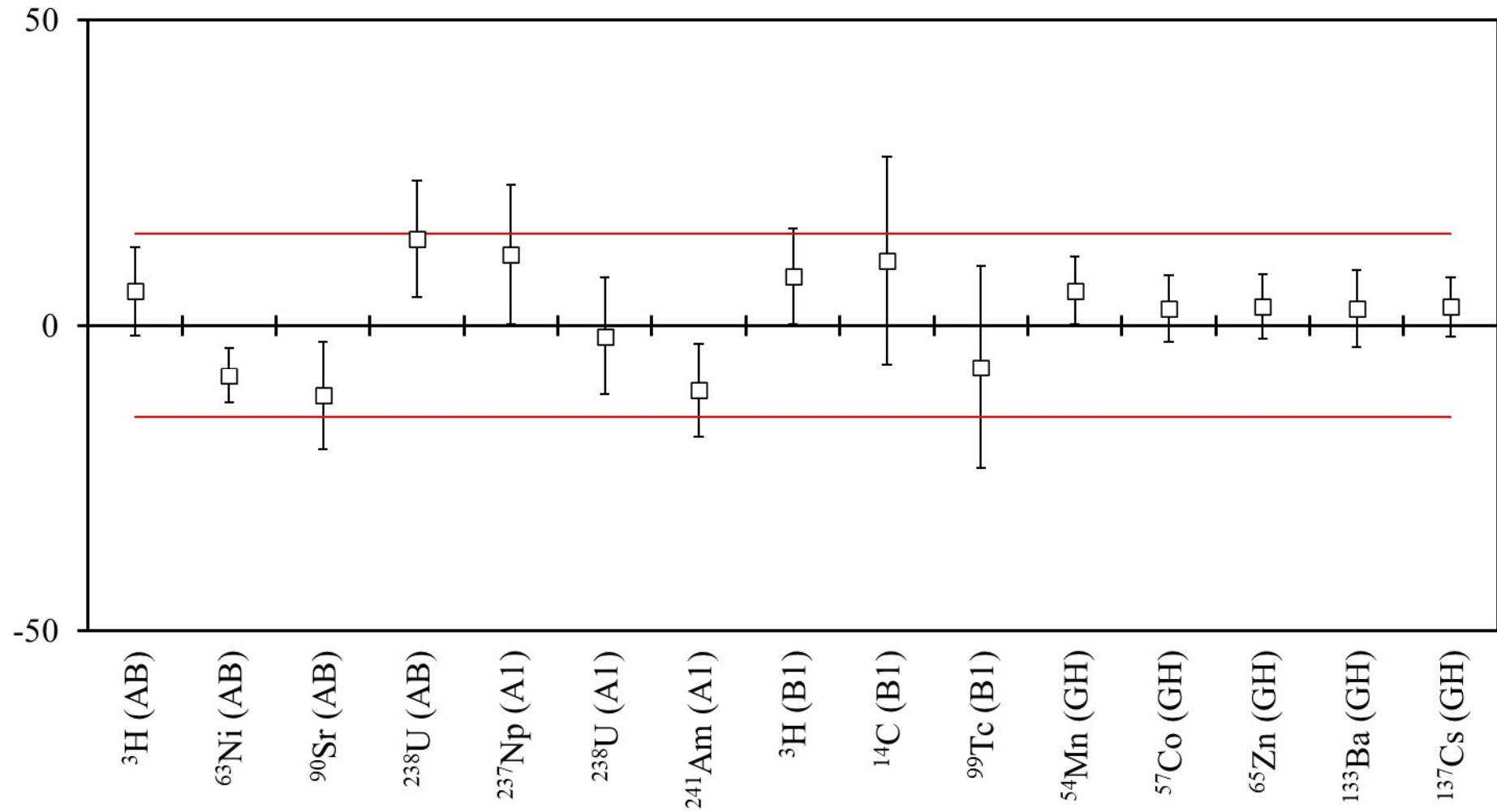
Continuation Sheet

Radionuclide	Laboratory 5	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	12.8 ± 1.9	12.55 ± 0.18	2.1	0.13	0.36
^{241}Am (A1)	88 ± 13	89.66 ± 0.35	-2.1	-0.14	-0.36
^3H (B1)	0.530 ± 0.079	0.5175 ± 0.0078	2.4	0.16	0.41
^{14}C (B1)	0.150 ± 0.020	0.1557 ± 0.0012	-3.7	-0.28	-0.63
^{54}Mn (GH)	3.95 ± 0.59	3.89 ± 0.10	1.5	0.10	0.26
^{57}Co (GH)	12.4 ± 1.9	12.35 ± 0.33	0.5	0.03	0.08
^{65}Zn (GH)	10.7 ± 1.6	10.68 ± 0.26	0.6	0.04	0.10
^{133}Ba (GH)	33.7 ± 5.1	34.4 ± 1.4	-2.0	-0.13	-0.34
^{137}Cs (GH)	7.0 ± 1.0	6.99 ± 0.10	0.1	0.01	0.02
^{88}Y (GL)	41.4 ± 6.2	36.22 ± 0.23	14.2	0.83	2.45
^{139}Ce (GL)	48.7 ± 7.3	47.65 ± 0.88	2.2	0.14	0.37
^{241}Am (GL)	45.1 ± 6.8	45.08 ± 0.28	0.1	0.00	0.01

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

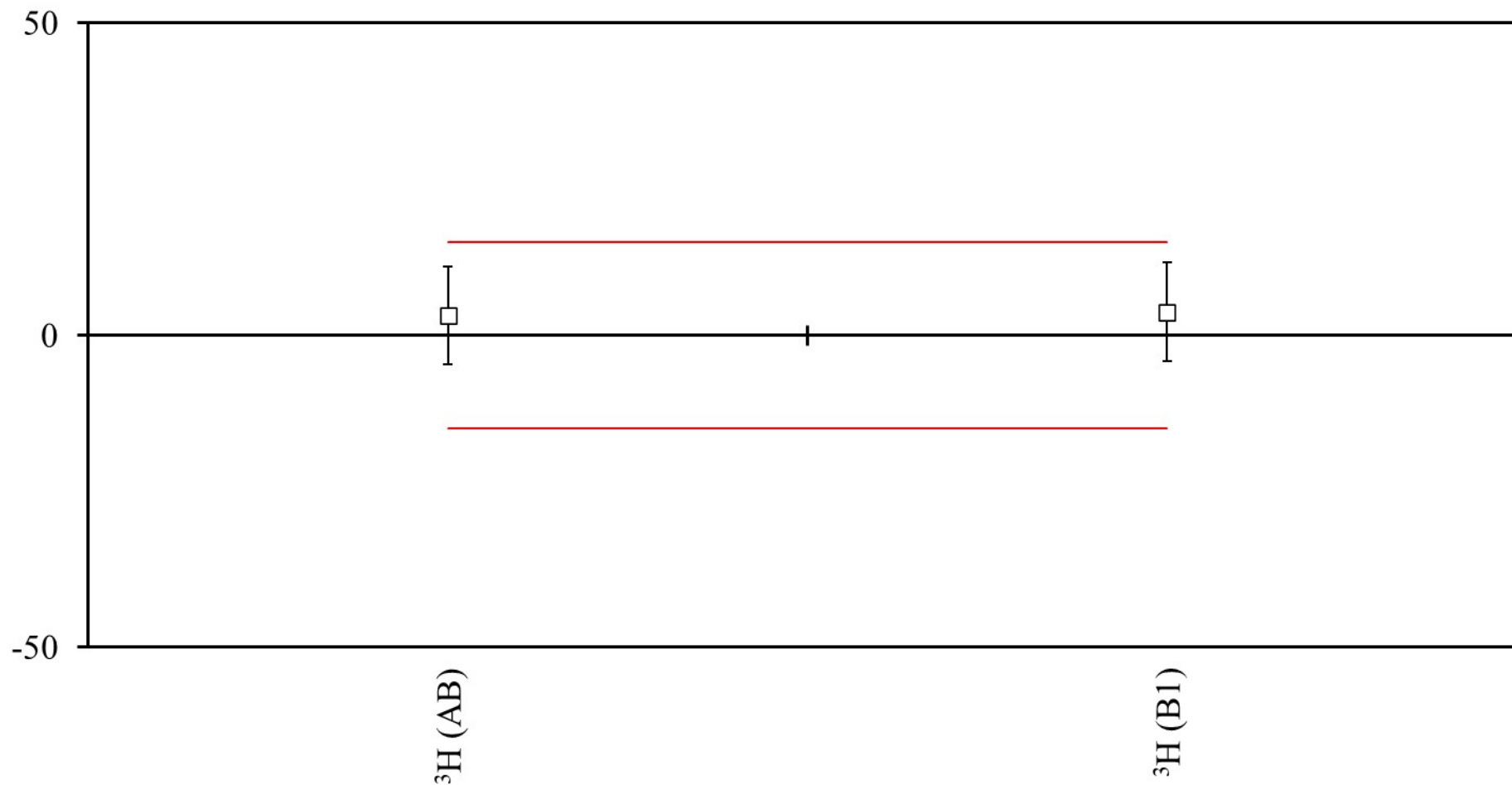
Deviation (%) of Laboratory 7.1



NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 7.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	13.26 ± 0.89	12.55 ± 0.18	5.7	0.78	0.97
^{63}Ni (AB)	4.24 ± 0.21	4.618 ± 0.026	-8.2	-1.82	-1.41
^{90}Sr (AB)	2.31 ± 0.22	2.6067 ± 0.0091	-11.5	-1.39	-1.98
^{238}U (AB)	4.11 ± 0.34	3.601 ± 0.047	14.2	1.50	2.45
^{237}Np (A1)	28.4 ± 2.9	25.433 ± 0.077	11.7	1.03	2.01
^{238}U (A1)	54.2 ± 5.3	55.14 ± 0.72	-1.8	-0.19	-0.31
^{241}Am (A1)	80.2 ± 6.9	89.66 ± 0.35	-10.6	-1.38	-1.82
^3H (B1)	0.559 ± 0.040	0.5175 ± 0.0078	8.1	1.03	1.39
^{14}C (B1)	0.172 ± 0.026	0.1557 ± 0.0012	10.6	0.63	1.82
^{99}Tc (B1)	0.174 ± 0.031	0.1870 ± 0.0018	-6.9	-0.42	-1.18
^{54}Mn (GH)	4.11 ± 0.19	3.89 ± 0.10	5.8	1.06	0.99
^{57}Co (GH)	12.69 ± 0.58	12.35 ± 0.33	2.7	0.51	0.47
^{65}Zn (GH)	11.01 ± 0.50	10.68 ± 0.26	3.1	0.59	0.53
^{133}Ba (GH)	35.4 ± 1.6	34.4 ± 1.4	2.9	0.46	0.49
^{137}Cs (GH)	7.20 ± 0.33	6.99 ± 0.10	3.1	0.62	0.52

Deviation (%) of Laboratory 7.2

NATIONAL PHYSICAL LABORATORY

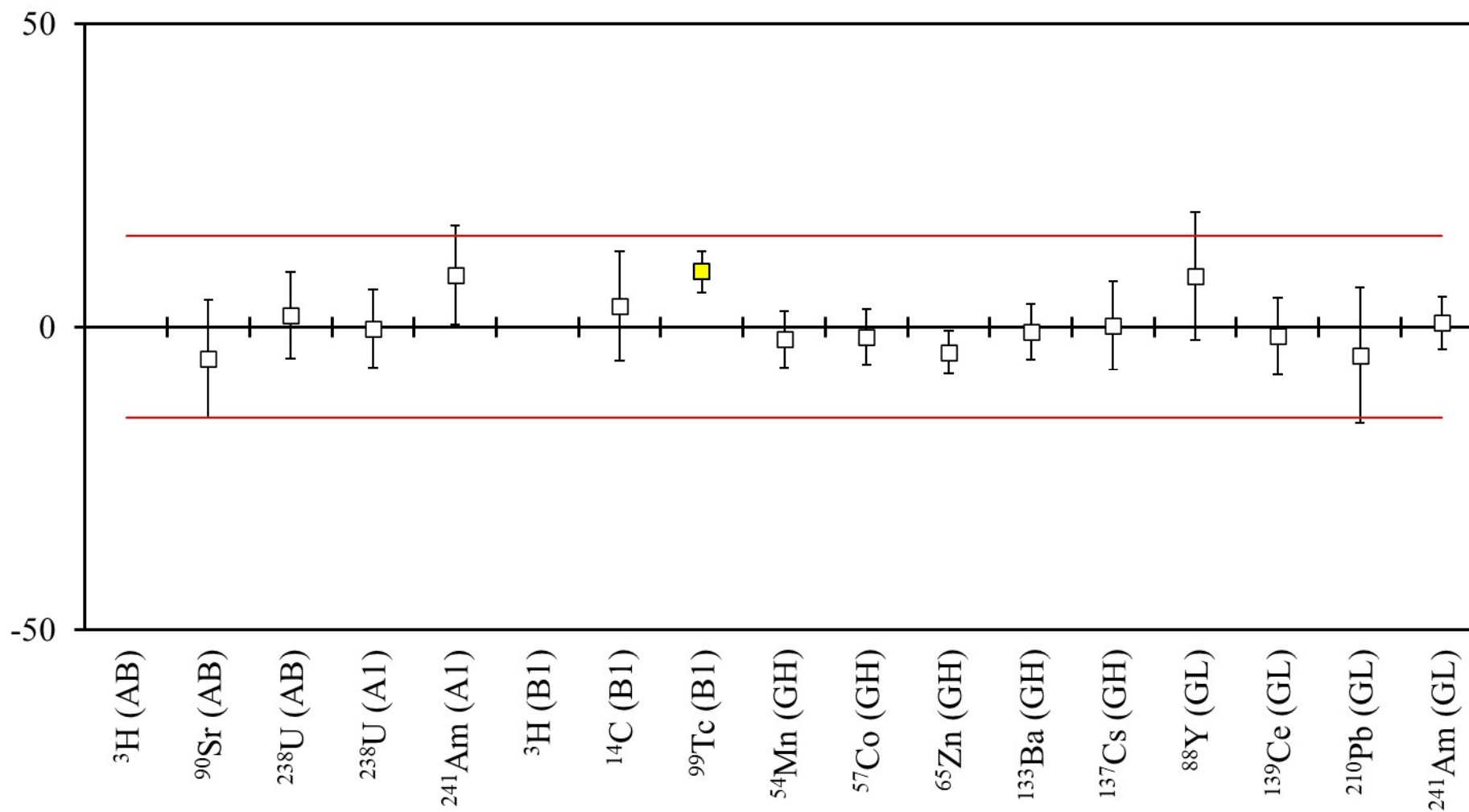
Continuation Sheet

Radionuclide	Laboratory 7.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	12.96 ± 0.97	12.55 ± 0.18	3.3	0.42	0.56
^3H (B1)	0.537 ± 0.040	0.5175 ± 0.0078	3.7	0.47	0.64

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 8.1

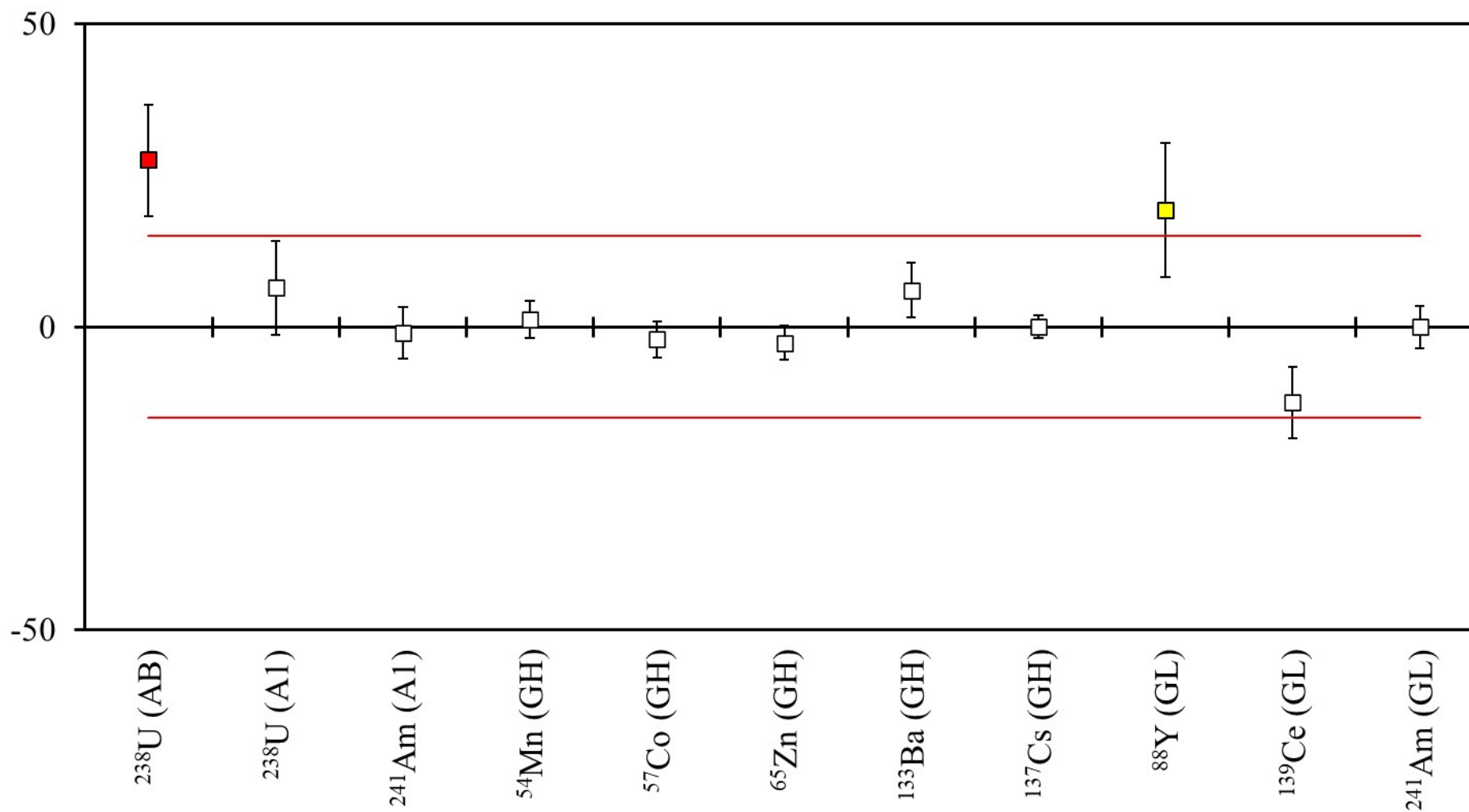


Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

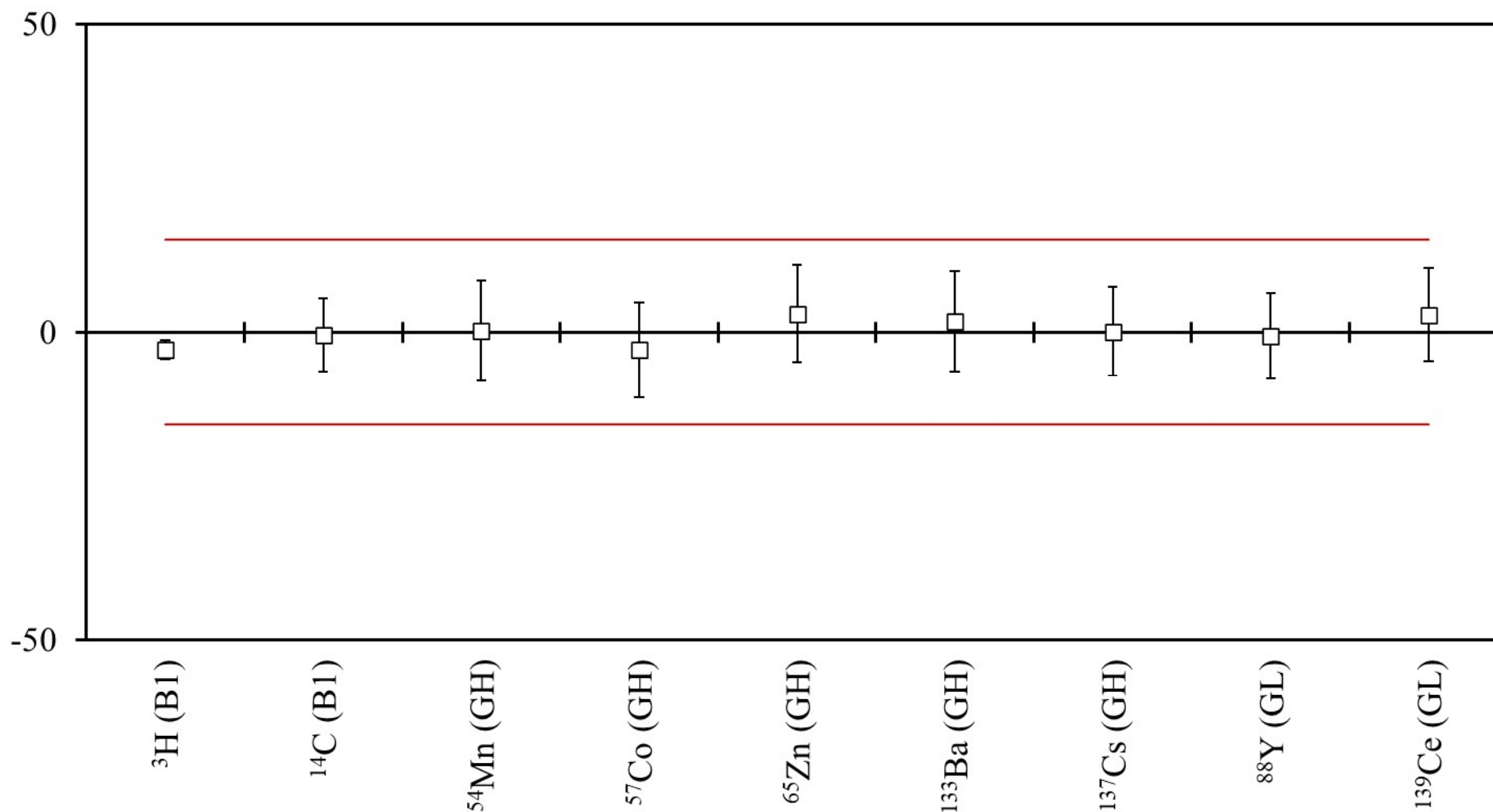
Radionuclide	Laboratory 8.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	2.940 ± 0.058	12.55 ± 0.18	-76.6	-50.82	-13.15
⁹⁰ Sr (AB)	2.47 ± 0.24	2.6067 ± 0.0091	-5.2	-0.57	-0.90
²³⁸ U (AB)	3.67 ± 0.25	3.601 ± 0.047	1.9	0.27	0.33
²³⁸ U (A1)	55.0 ± 3.5	55.14 ± 0.72	-0.3	-0.04	-0.04
²⁴¹ Am (A1)	97.3 ± 7.3	89.66 ± 0.35	8.5	1.05	1.46
³ H (B1)	0.1251 ± 0.0048	0.5175 ± 0.0078	-75.8	-42.84	-13.02
¹⁴ C (B1)	0.161 ± 0.014	0.1557 ± 0.0012	3.4	0.38	0.58
⁹⁹ Tc (B1)	0.2040 ± 0.0061	0.1870 ± 0.0018	9.1	2.67	1.56
⁵⁴ Mn (GH)	3.81 ± 0.15	3.89 ± 0.10	-2.0	-0.43	-0.34
⁵⁷ Co (GH)	12.15 ± 0.47	12.35 ± 0.33	-1.6	-0.35	-0.28
⁶⁵ Zn (GH)	10.23 ± 0.29	10.68 ± 0.26	-4.2	-1.16	-0.72
¹³³ Ba (GH)	34.14 ± 0.77	34.4 ± 1.4	-0.8	-0.16	-0.13
¹³⁷ Cs (GH)	7.01 ± 0.50	6.99 ± 0.10	0.2	0.03	0.04
⁸⁸ Y (GL)	39.3 ± 3.8	36.22 ± 0.23	8.4	0.79	1.44
¹³⁹ Ce (GL)	46.9 ± 2.9	47.65 ± 0.88	-1.5	-0.24	-0.26
²¹⁰ Pb (GL)	15.7 ± 1.8	16.44 ± 0.18	-4.7	-0.42	-0.80
²⁴¹ Am (GL)	45.4 ± 1.9	45.08 ± 0.28	0.7	0.17	0.13

Deviation (%) of Laboratory 8.2

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 8.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³⁸ U (AB)	4.59 ± 0.33	3.601 ± 0.047	27.5	3.01	4.72
²³⁸ U (A1)	58.7 ± 4.2	55.14 ± 0.72	6.5	0.84	1.11
²⁴¹ Am (A1)	88.9 ± 3.8	89.66 ± 0.35	-0.9	-0.21	-0.15
⁵⁴ Mn (GH)	3.940 ± 0.058	3.89 ± 0.10	1.3	0.43	0.22
⁵⁷ Co (GH)	12.10 ± 0.16	12.35 ± 0.33	-2.0	-0.68	-0.35
⁶⁵ Zn (GH)	10.40 ± 0.16	10.68 ± 0.26	-2.6	-0.91	-0.45
¹³³ Ba (GH)	36.50 ± 0.51	34.4 ± 1.4	6.1	1.41	1.05
¹³⁷ Cs (GH)	6.990 ± 0.084	6.99 ± 0.10	0.0	0.00	0.00
⁸⁸ Y (GL)	43.2 ± 4.0	36.22 ± 0.23	19.3	1.75	3.31
¹³⁹ Ce (GL)	41.7 ± 2.7	47.65 ± 0.88	-12.5	-2.10	-2.14
²⁴¹ Am (GL)	45.1 ± 1.5	45.08 ± 0.28	0.0	0.01	0.01

Deviation (%) of Laboratory 16

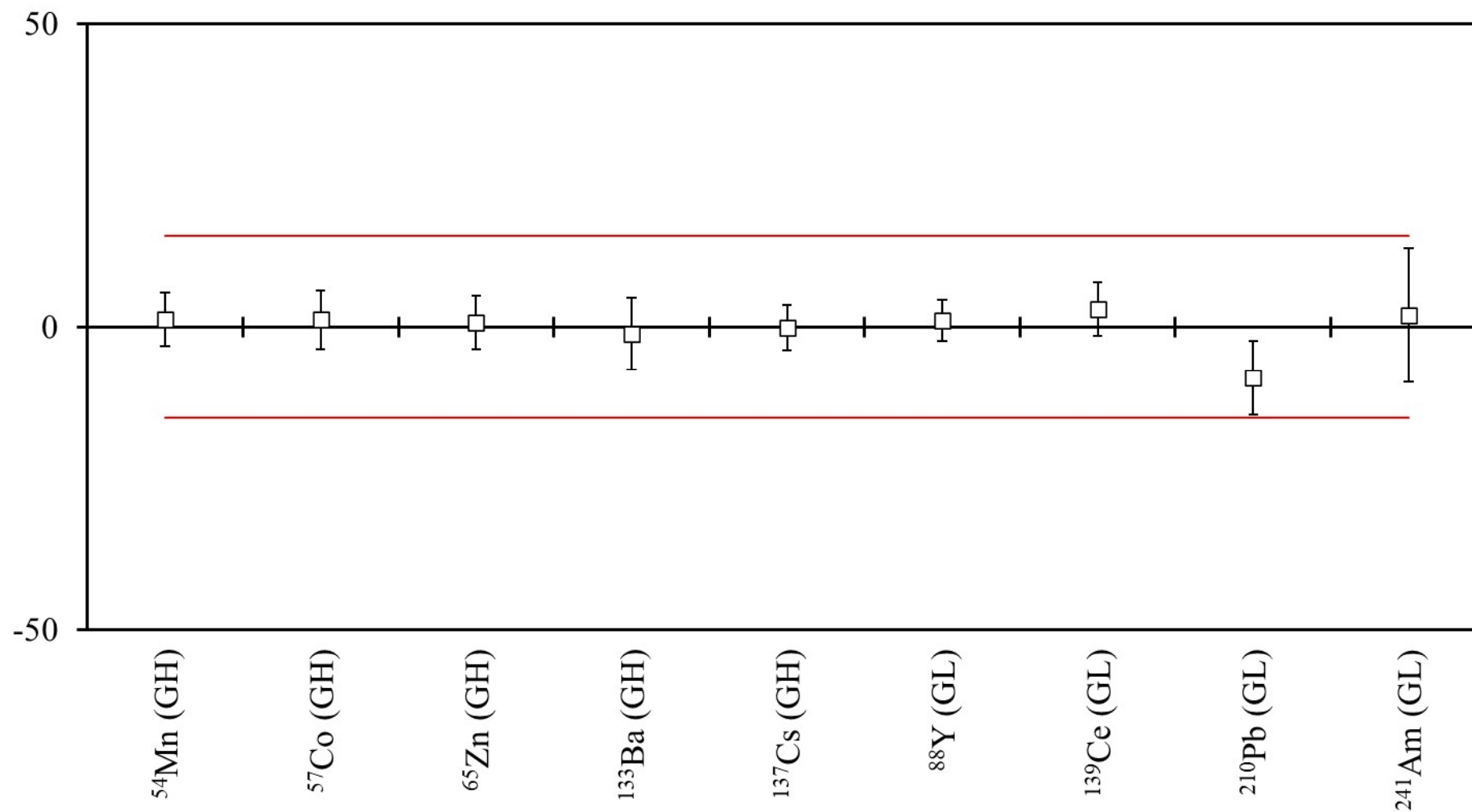
NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 16	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (B1)	0.5030 ± 0.0020	0.5175 ± 0.0078	-2.8	-1.80	-0.48
^{14}C (B1)	0.1550 ± 0.0093	0.1557 ± 0.0012	-0.4	-0.07	-0.08
^{54}Mn (GH)	3.90 ± 0.30	3.89 ± 0.10	0.3	0.03	0.04
^{57}Co (GH)	12.00 ± 0.90	12.35 ± 0.33	-2.8	-0.37	-0.49
^{65}Zn (GH)	11.00 ± 0.80	10.68 ± 0.26	3.0	0.38	0.51
^{133}Ba (GH)	35.0 ± 2.4	34.4 ± 1.4	1.7	0.22	0.30
^{137}Cs (GH)	7.00 ± 0.50	6.99 ± 0.10	0.1	0.02	0.02
^{88}Y (GL)	36.0 ± 2.5	36.22 ± 0.23	-0.6	-0.09	-0.10
^{139}Ce (GL)	49.0 ± 3.5	47.65 ± 0.88	2.8	0.37	0.49

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

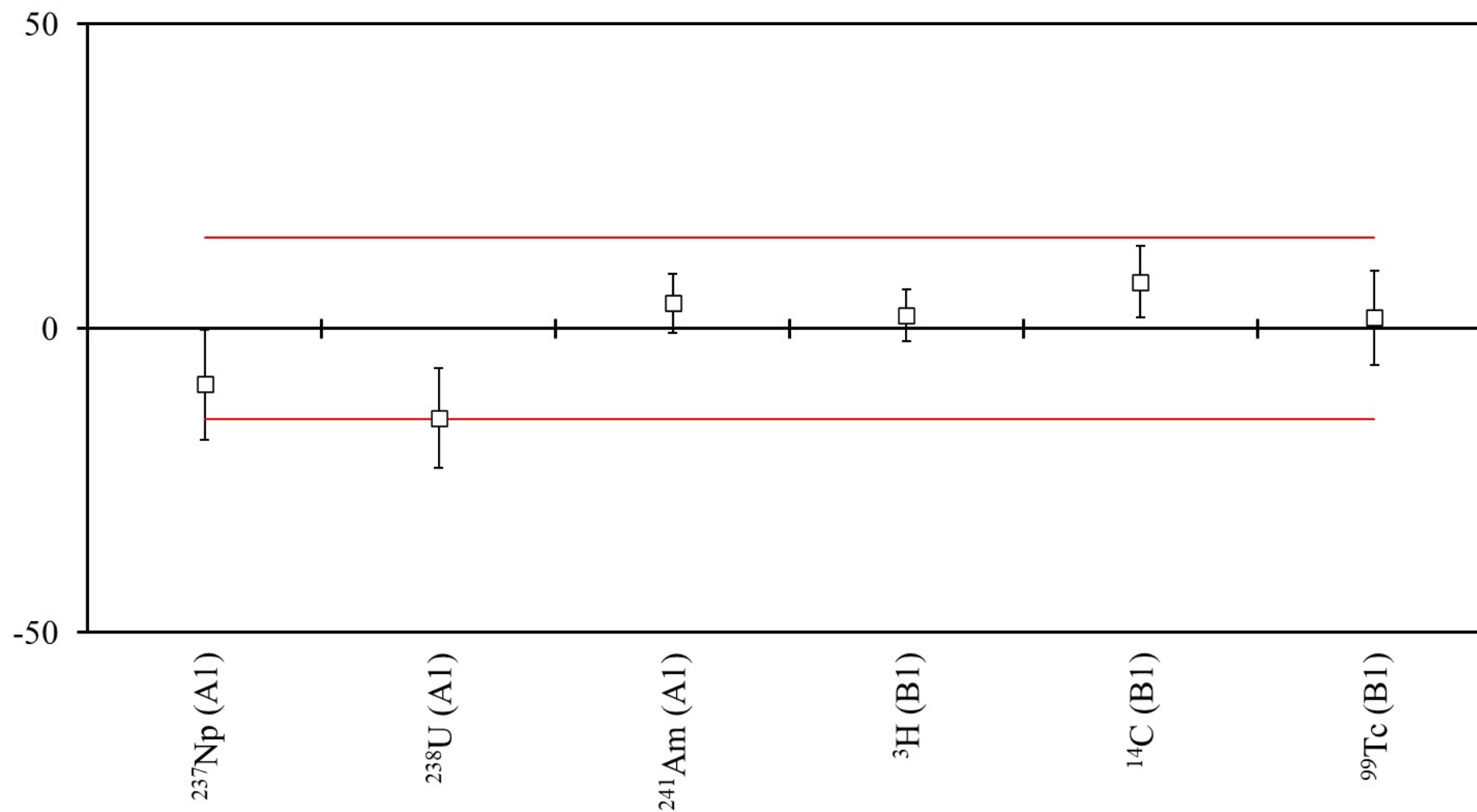
Deviation (%) of Laboratory 18

Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 18	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	3.94 ± 0.14	3.89 ± 0.10	1.3	0.29	0.22
⁵⁷ Co (GH)	12.50 ± 0.50	12.35 ± 0.33	1.2	0.25	0.21
⁶⁵ Zn (GH)	10.76 ± 0.40	10.68 ± 0.26	0.7	0.17	0.13
¹³³ Ba (GH)	34.0 ± 1.5	34.4 ± 1.4	-1.1	-0.19	-0.19
¹³⁷ Cs (GH)	6.98 ± 0.24	6.99 ± 0.10	-0.1	-0.04	-0.02
⁸⁸ Y (GL)	36.6 ± 1.2	36.22 ± 0.23	1.1	0.32	0.18
¹³⁹ Ce (GL)	49.0 ± 1.9	47.65 ± 0.88	2.9	0.66	0.50
²¹⁰ Pb (GL)	15.1 ± 1.0	16.44 ± 0.18	-8.5	-1.37	-1.45
²⁴¹ Am (GL)	46.0 ± 5.0	45.08 ± 0.28	1.9	0.17	0.33

Deviation (%) of Laboratory 28

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

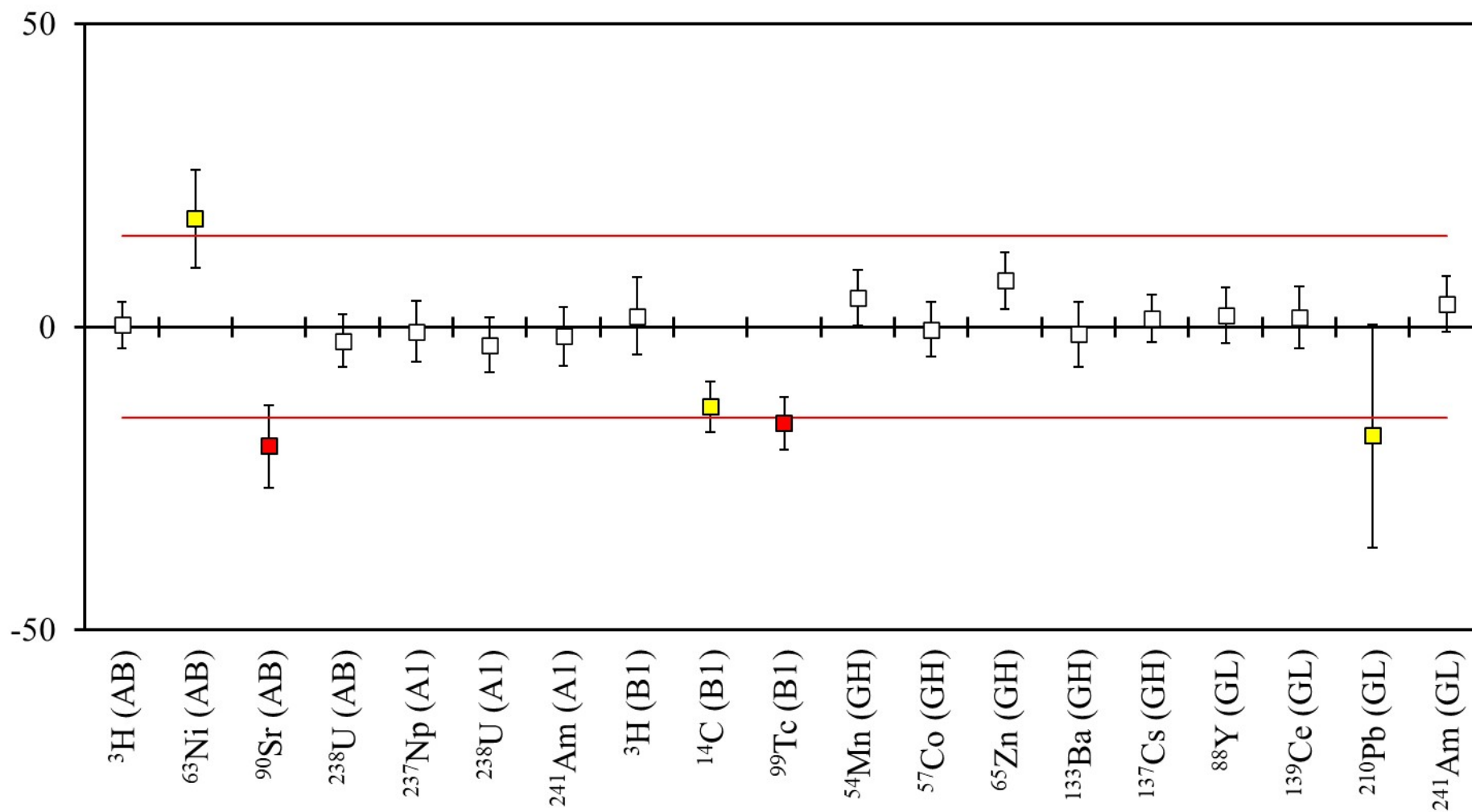
Radionuclide	Laboratory 28	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³⁷ Np (A1)	23.1 ± 2.3	25.433 ± 0.077	-9.3	-1.02	-1.59
²³⁸ U (A1)	47.0 ± 4.5	55.14 ± 0.72	-14.7	-1.79	-2.53
²⁴¹ Am (A1)	93.4 ± 4.3	89.66 ± 0.35	4.2	0.87	0.71
³ H (B1)	0.529 ± 0.021	0.5175 ± 0.0078	2.1	0.50	0.37
¹⁴ C (B1)	0.1677 ± 0.0090	0.1557 ± 0.0012	7.7	1.32	1.32
⁹⁹ Tc (B1)	0.190 ± 0.014	0.1870 ± 0.0018	1.8	0.24	0.31

Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 35



Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

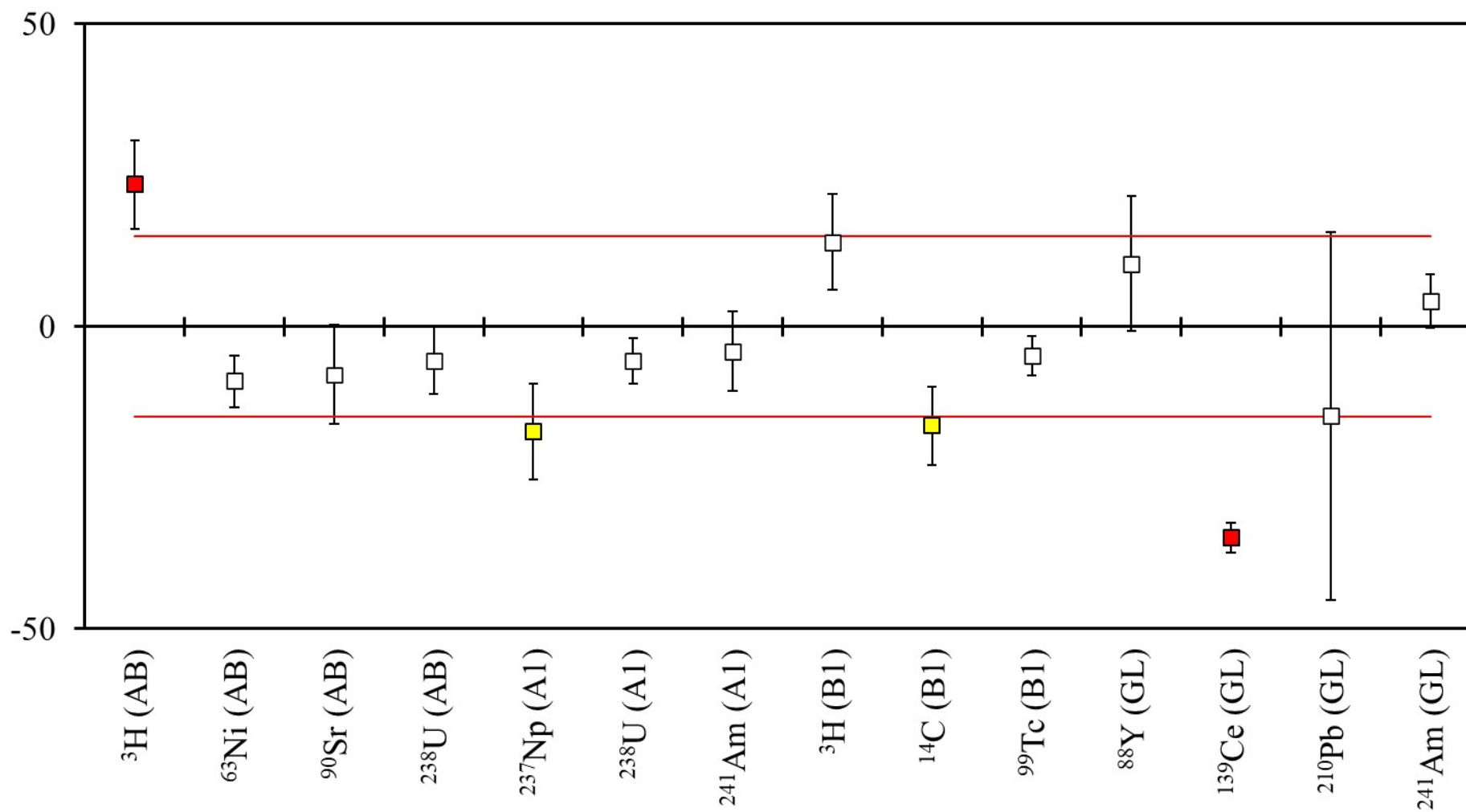
Radionuclide	Laboratory 35	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	12.60 ± 0.45	12.55 ± 0.18	0.4	0.10	0.07
^{63}Ni (AB)	5.44 ± 0.37	4.618 ± 0.026	17.8	2.23	3.06
^{90}Sr (AB)	2.09 ± 0.16	2.6067 ± 0.0091	-19.8	-3.22	-3.40
^{238}U (AB)	3.52 ± 0.15	3.601 ± 0.047	-2.2	-0.52	-0.39
^{237}Np (A1)	25.2 ± 1.3	25.433 ± 0.077	-0.7	-0.15	-0.13
^{238}U (A1)	53.5 ± 2.5	55.14 ± 0.72	-3.0	-0.64	-0.51
^{241}Am (A1)	88.3 ± 4.3	89.66 ± 0.35	-1.5	-0.32	-0.26
^3H (B1)	0.527 ± 0.032	0.5175 ± 0.0078	1.8	0.29	0.32
^{14}C (B1)	0.1350 ± 0.0065	0.1557 ± 0.0012	-13.3	-3.13	-2.28
^{99}Tc (B1)	0.1570 ± 0.0080	0.1870 ± 0.0018	-16.0	-3.66	-2.76
^{54}Mn (GH)	4.08 ± 0.15	3.89 ± 0.10	4.9	1.08	0.84
^{57}Co (GH)	12.30 ± 0.45	12.35 ± 0.33	-0.4	-0.09	-0.07
^{65}Zn (GH)	11.50 ± 0.42	10.68 ± 0.26	7.7	1.67	1.32
^{133}Ba (GH)	34.0 ± 1.2	34.4 ± 1.4	-1.2	-0.22	-0.20
^{137}Cs (GH)	7.09 ± 0.26	6.99 ± 0.10	1.4	0.37	0.25
^{88}Y (GL)	36.9 ± 1.7	36.22 ± 0.23	1.9	0.41	0.32
^{139}Ce (GL)	48.4 ± 2.3	47.65 ± 0.88	1.6	0.31	0.27
^{210}Pb (GL)	13.5 ± 3.0	16.44 ± 0.18	-18.0	-0.97	-3.09
^{241}Am (GL)	46.8 ± 2.1	45.08 ± 0.28	3.8	0.83	0.66

Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 38



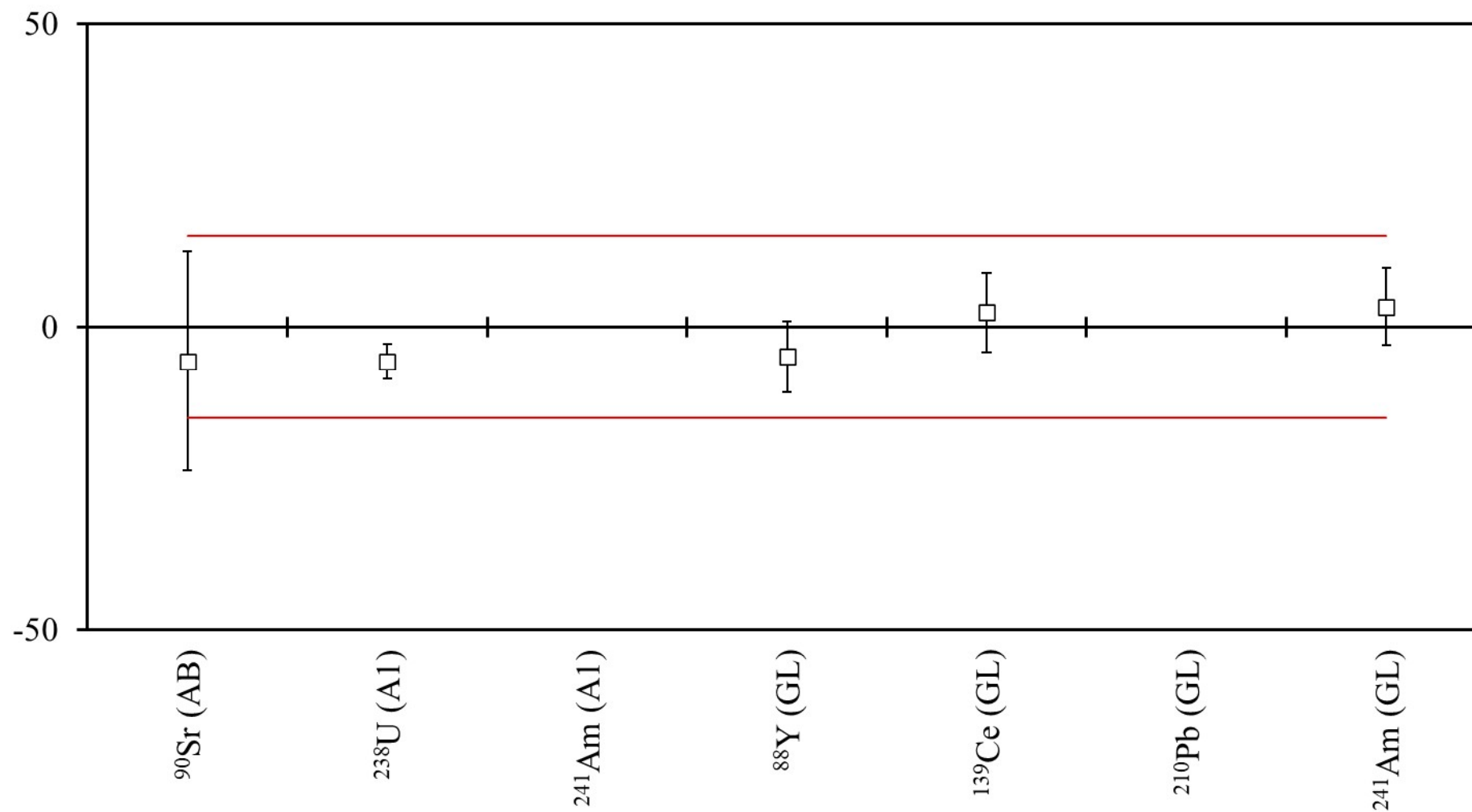
Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 38	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	15.50 ± 0.90	12.55 ± 0.18	23.5	3.21	4.04
⁶³ Ni (AB)	4.20 ± 0.20	4.618 ± 0.026	-9.1	-2.07	-1.55
⁹⁰ Sr (AB)	2.40 ± 0.20	2.6067 ± 0.0091	-7.9	-1.03	-1.36
²³⁸ U (AB)	3.40 ± 0.20	3.601 ± 0.047	-5.6	-0.98	-0.96
²³⁷ Np (A1)	21.0 ± 2.0	25.433 ± 0.077	-17.4	-2.21	-2.99
²³⁸ U (A1)	52.0 ± 2.0	55.14 ± 0.72	-5.7	-1.48	-0.98
²⁴¹ Am (A1)	86.0 ± 6.0	89.66 ± 0.35	-4.1	-0.61	-0.70
³ H (B1)	0.590 ± 0.040	0.5175 ± 0.0078	14.0	1.78	2.41
¹⁴ C (B1)	0.130 ± 0.010	0.1557 ± 0.0012	-16.5	-2.55	-2.83
⁹⁹ Tc (B1)	0.1780 ± 0.0060	0.1870 ± 0.0018	-4.8	-1.44	-0.83
⁸⁸ Y (GL)	40.0 ± 4.0	36.22 ± 0.23	10.4	0.94	1.79
¹³⁹ Ce (GL)	31.0 ± 1.0	47.65 ± 0.88	-34.9	-12.50	-6.00
²¹⁰ Pb (GL)	14.0 ± 5.0	16.44 ± 0.18	-14.8	-0.49	-2.55
²⁴¹ Am (GL)	47.0 ± 2.0	45.08 ± 0.28	4.3	0.95	0.73

Reference: RR10 PTE 24-25 Final Report Version 1.0

Deviation (%) of Laboratory 40

NATIONAL PHYSICAL LABORATORY

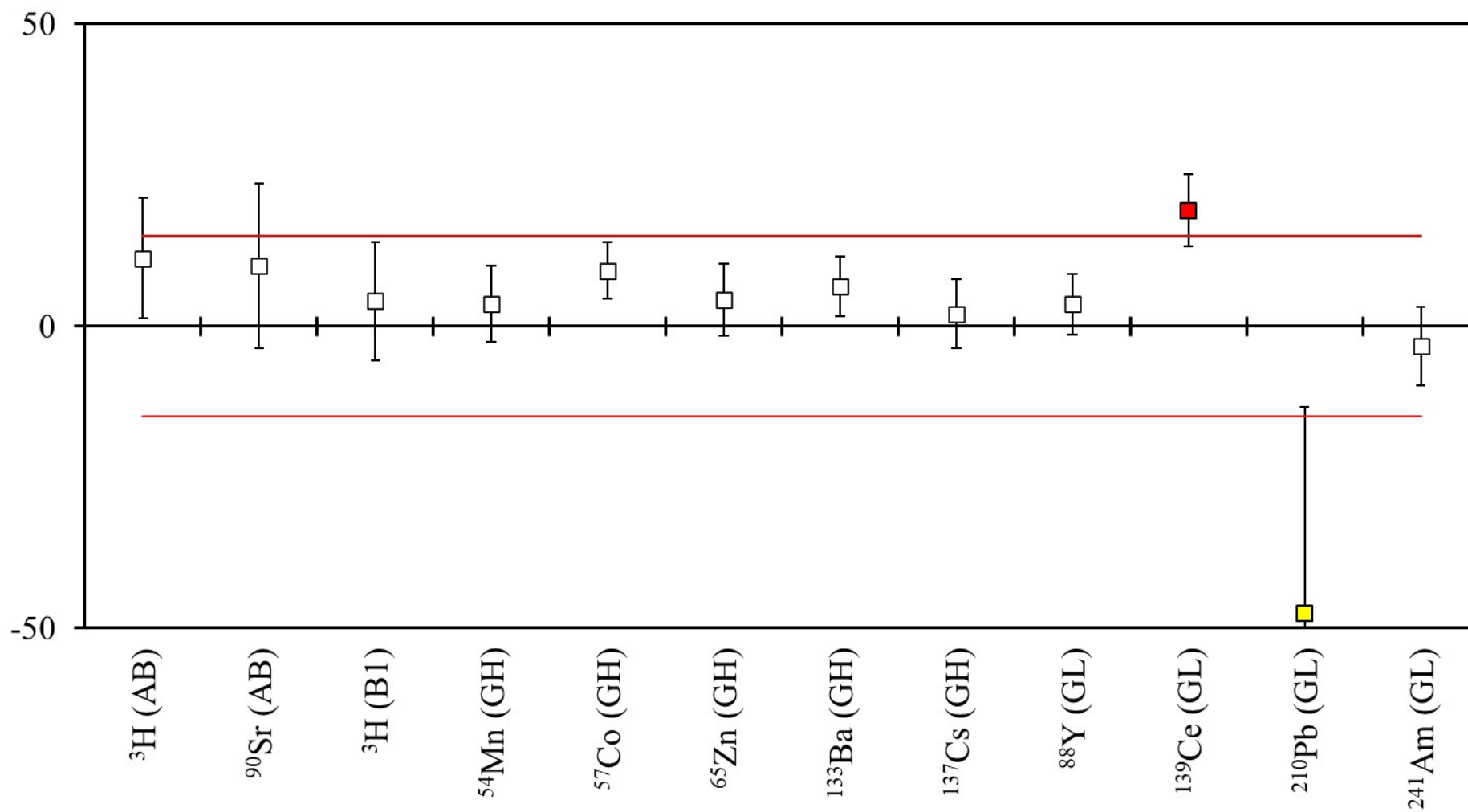
Continuation Sheet

Radionuclide	Laboratory 40	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁹⁰ Sr (AB)	2.46 ± 0.47	2.6067 ± 0.0091	-5.6	-0.31	-0.97
²³⁸ U (A1)	52.0 ± 1.4	55.14 ± 0.72	-5.7	-1.99	-0.98
²⁴¹ Am (A1)	8.67 ± 0.20	89.66 ± 0.35	-90.3	-200.84	-15.51
⁸⁸ Y (GL)	34.4 ± 2.1	36.22 ± 0.23	-4.9	-0.85	-0.85
¹³⁹ Ce (GL)	48.8 ± 3.0	47.65 ± 0.88	2.4	0.37	0.41
²¹⁰ Pb (GL)	56.4 ± 3.4	16.44 ± 0.18	243.3	11.60	41.78
²⁴¹ Am (GL)	46.6 ± 2.8	45.08 ± 0.28	3.3	0.53	0.58

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 41



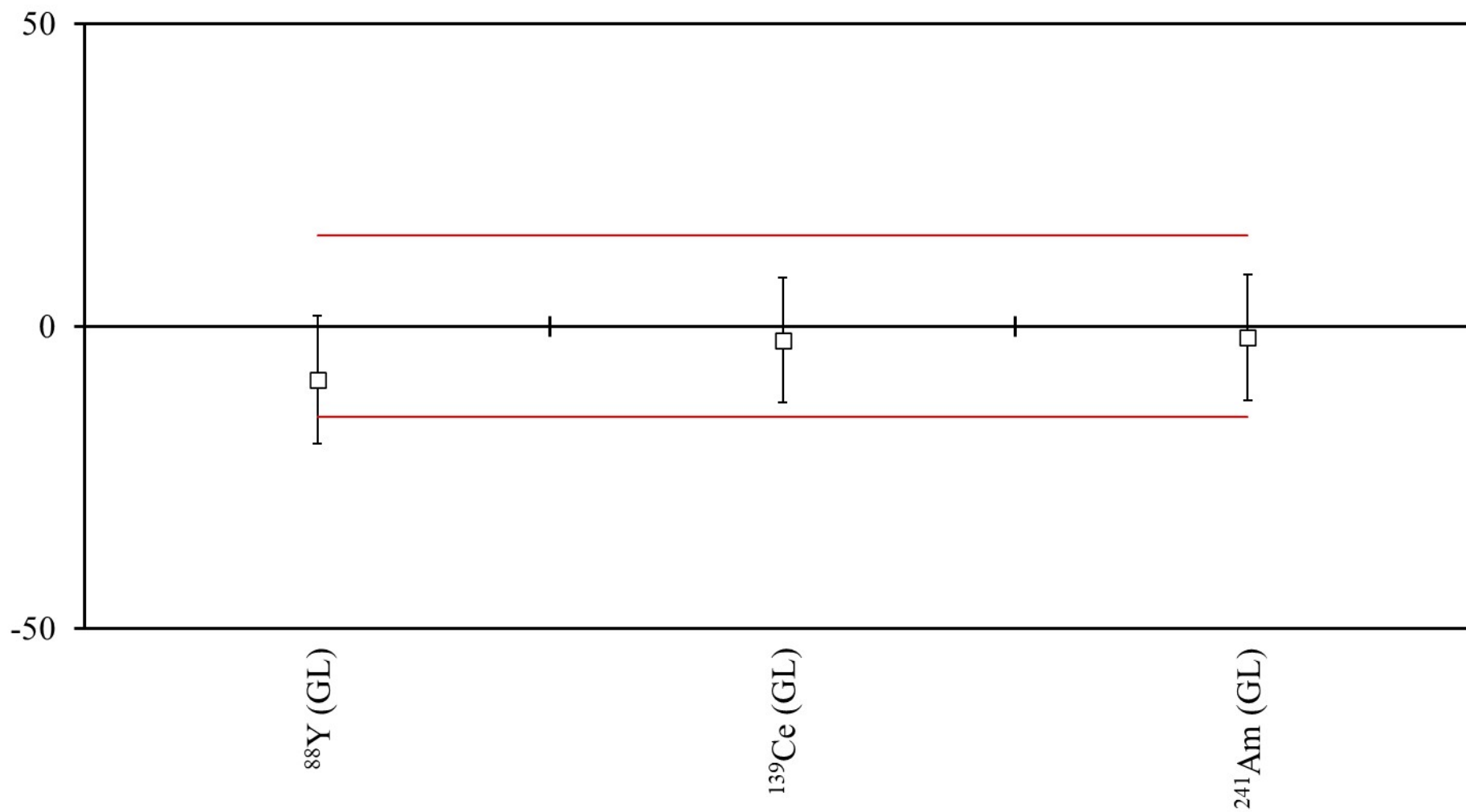
NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 41	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	14.0 ± 1.2	12.55 ± 0.18	11.3	1.14	1.94
^{90}Sr (AB)	2.87 ± 0.34	2.6067 ± 0.0091	10.0	0.77	1.72
^3H (B1)	0.539 ± 0.050	0.5175 ± 0.0078	4.2	0.42	0.71
^{54}Mn (GH)	4.04 ± 0.22	3.89 ± 0.10	3.8	0.60	0.64
^{57}Co (GH)	13.49 ± 0.45	12.35 ± 0.33	9.2	2.04	1.59
^{65}Zn (GH)	11.15 ± 0.57	10.68 ± 0.26	4.4	0.75	0.76
^{133}Ba (GH)	36.66 ± 0.80	34.4 ± 1.4	6.6	1.40	1.13
^{137}Cs (GH)	7.14 ± 0.38	6.99 ± 0.10	2.1	0.37	0.36
^{88}Y (GL)	37.5 ± 1.8	36.22 ± 0.23	3.6	0.73	0.63
^{139}Ce (GL)	56.8 ± 2.6	47.65 ± 0.88	19.2	3.31	3.29
^{210}Pb (GL)	8.6 ± 5.6	16.44 ± 0.18	-47.6	-1.40	-8.17
^{241}Am (GL)	43.6 ± 2.9	45.08 ± 0.28	-3.3	-0.50	-0.56

NATIONAL PHYSICAL LABORATORY

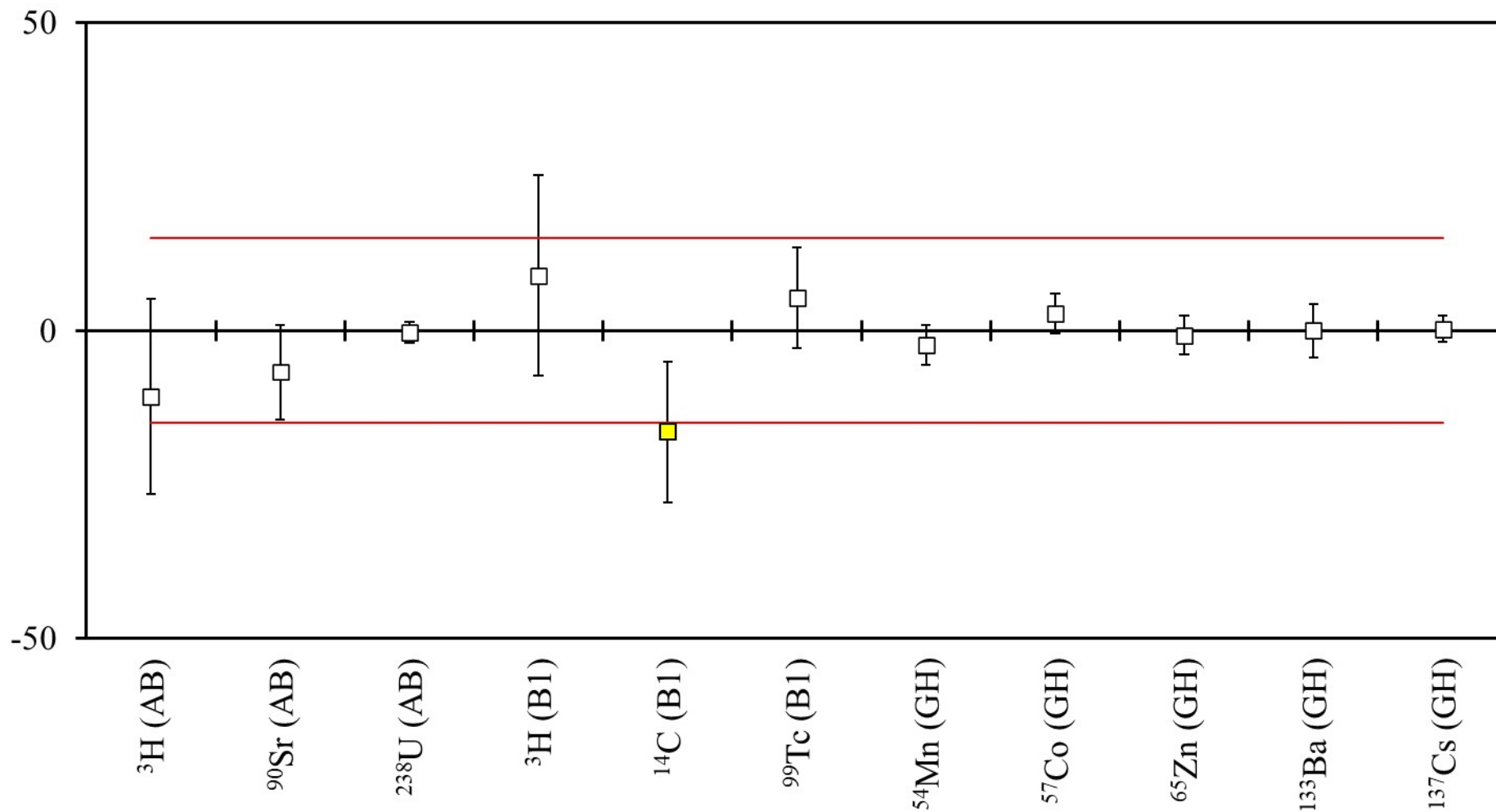
Continuation Sheet

Deviation (%) of Laboratory 42.1

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

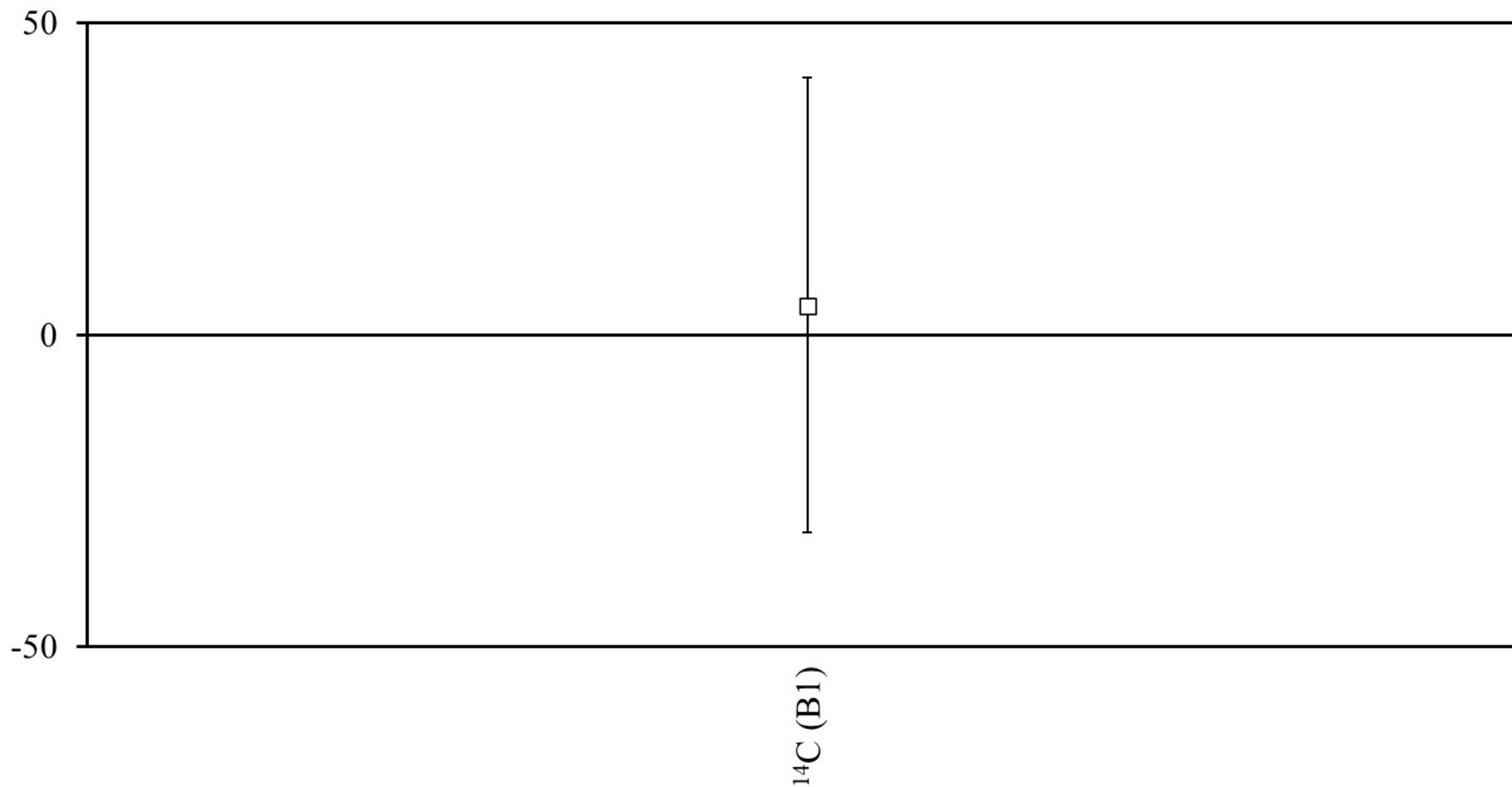
Radionuclide	Laboratory 42.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{88}Y (GL)	33.0 ± 3.9	36.22 ± 0.23	-8.9	-0.83	-1.52
^{139}Ce (GL)	46.6 ± 4.9	47.65 ± 0.88	-2.3	-0.22	-0.40
^{241}Am (GL)	44.2 ± 4.7	45.08 ± 0.28	-1.8	-0.18	-0.32

Deviation (%) of Laboratory 55.1

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 55.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	11.2 ± 2.0	12.55 ± 0.18	-10.8	-0.68	-1.85
^{90}Sr (AB)	2.43 ± 0.18	2.6067 ± 0.0091	-6.8	-0.97	-1.16
^{238}U (AB)	3.590 ± 0.040	3.601 ± 0.047	-0.3	-0.18	-0.05
^3H (B1)	0.564 ± 0.084	0.5175 ± 0.0078	9.0	0.55	1.54
^{14}C (B1)	0.130 ± 0.018	0.1557 ± 0.0012	-16.5	-1.43	-2.83
^{99}Tc (B1)	0.197 ± 0.015	0.1870 ± 0.0018	5.3	0.65	0.92
^{54}Mn (GH)	3.800 ± 0.077	3.89 ± 0.10	-2.3	-0.71	-0.40
^{57}Co (GH)	12.70 ± 0.20	12.35 ± 0.33	2.8	0.91	0.49
^{65}Zn (GH)	10.60 ± 0.22	10.68 ± 0.26	-0.7	-0.24	-0.13
^{133}Ba (GH)	34.40 ± 0.47	34.4 ± 1.4	0.0	0.00	0.00
^{137}Cs (GH)	7.01 ± 0.11	6.99 ± 0.10	0.3	0.14	0.05

Deviation (%) of Laboratory 55.2

NATIONAL PHYSICAL LABORATORY

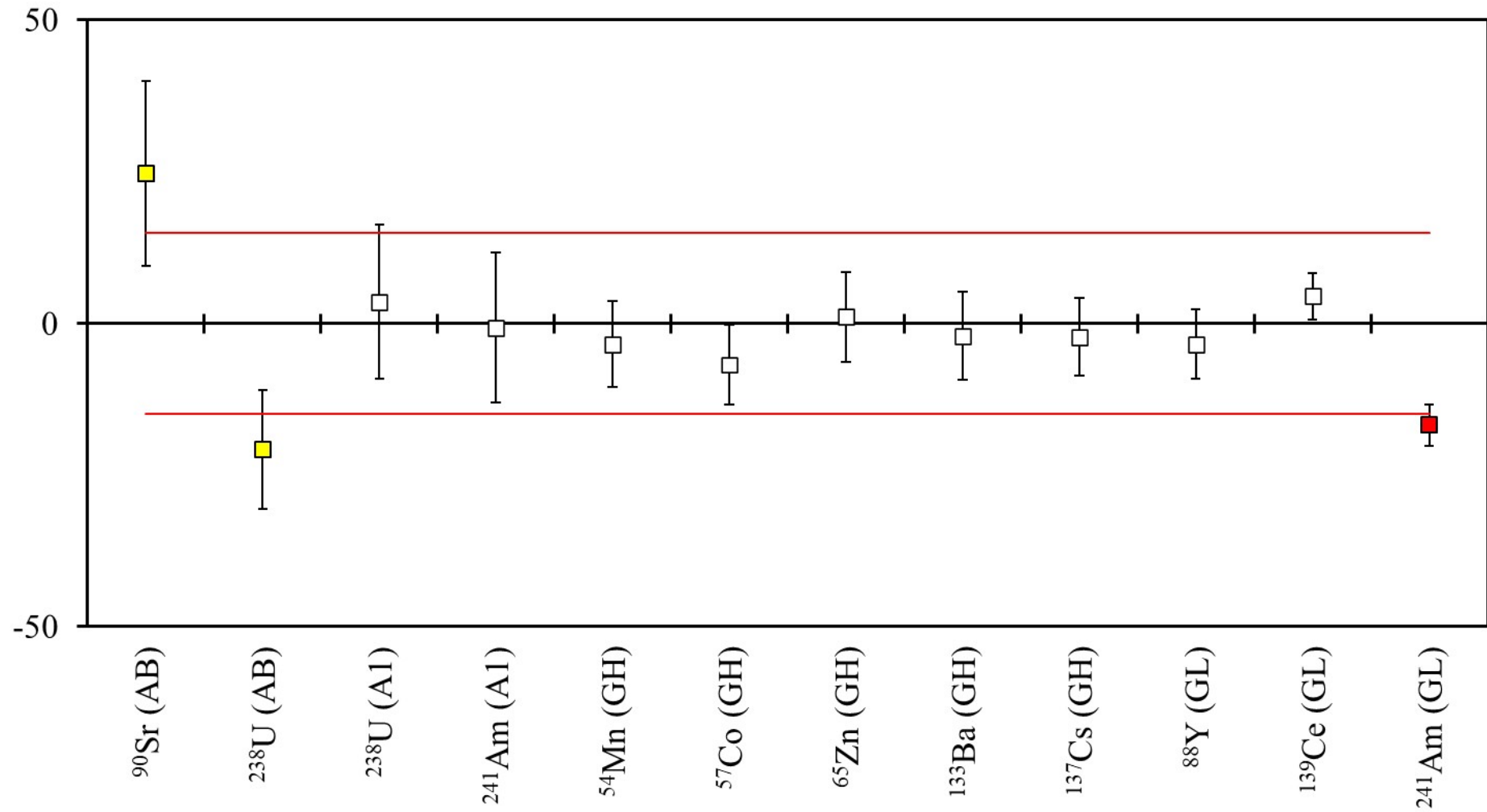
Continuation Sheet

Radionuclide	Laboratory 55.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{14}C (B1)	0.163 ± 0.057	0.1557 ± 0.0012	4.7	0.13	0.81

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

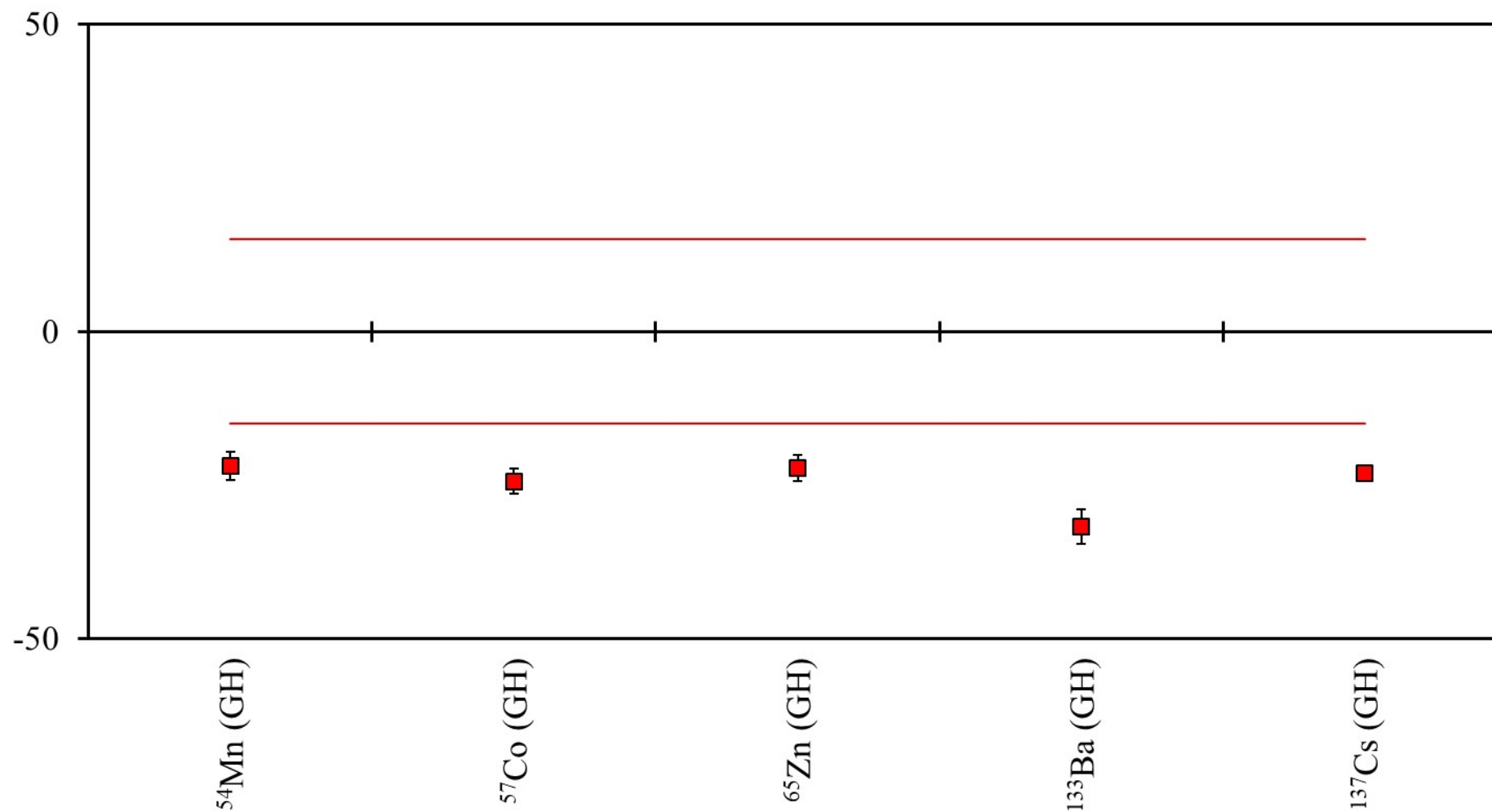
Deviation (%) of Laboratory 61



NATIONAL PHYSICAL LABORATORY

Continuation Sheet

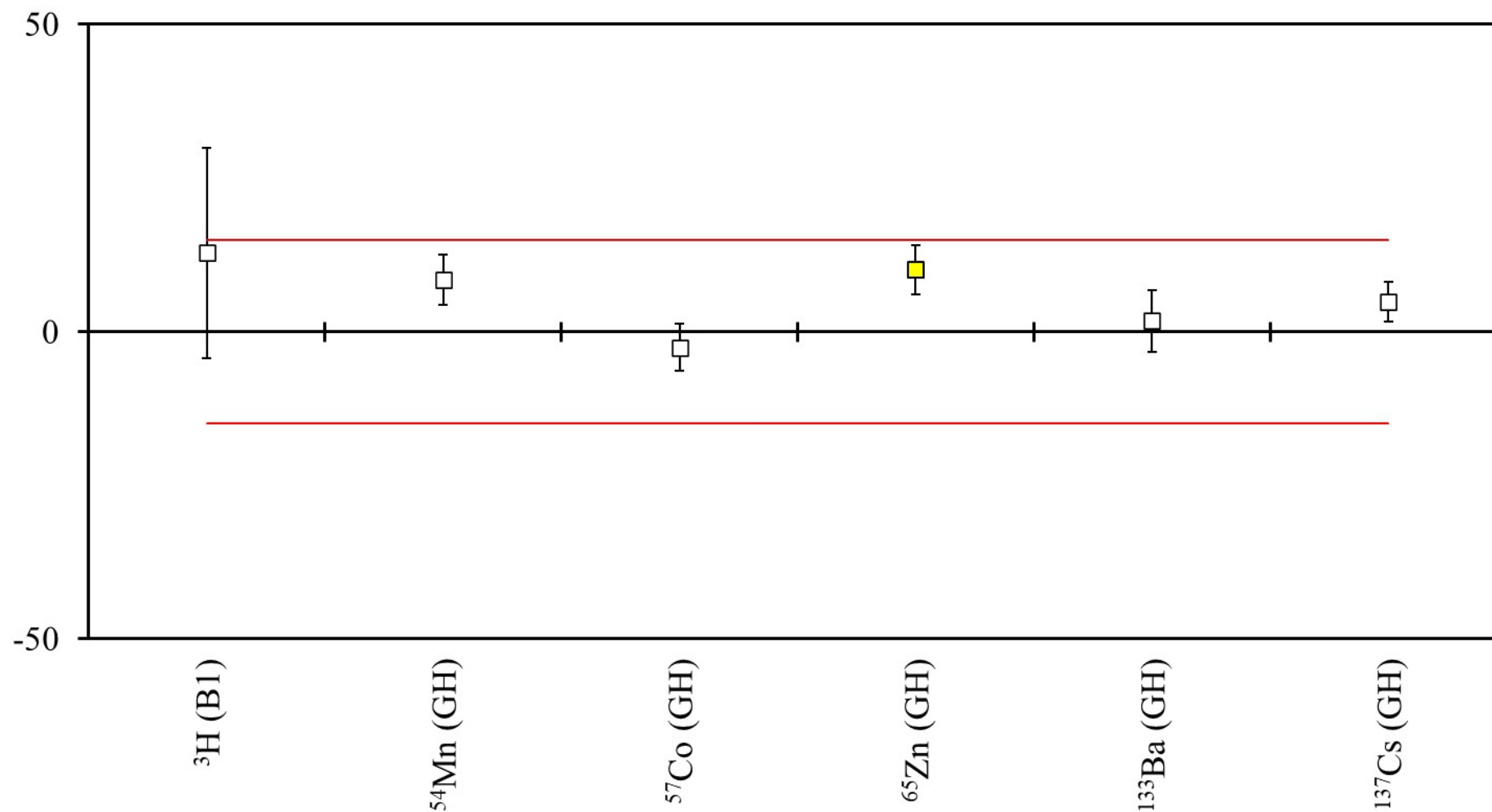
Radionuclide	Laboratory 61	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁹⁰ Sr (AB)	3.25 ± 0.38	2.6067 ± 0.0091	24.7	1.69	4.24
²³⁸ U (AB)	2.85 ± 0.35	3.601 ± 0.047	-20.9	-2.13	-3.58
²³⁸ U (A1)	57.1 ± 7.0	55.14 ± 0.72	3.6	0.28	0.61
²⁴¹ Am (A1)	89 ± 11	89.66 ± 0.35	-0.7	-0.06	-0.13
⁵⁴ Mn (GH)	3.76 ± 0.26	3.89 ± 0.10	-3.3	-0.47	-0.57
⁵⁷ Co (GH)	11.50 ± 0.76	12.35 ± 0.33	-6.9	-1.03	-1.18
⁶⁵ Zn (GH)	10.80 ± 0.74	10.68 ± 0.26	1.1	0.15	0.19
¹³³ Ba (GH)	33.7 ± 2.1	34.4 ± 1.4	-2.0	-0.28	-0.35
¹³⁷ Cs (GH)	6.83 ± 0.44	6.99 ± 0.10	-2.3	-0.35	-0.39
⁸⁸ Y (GL)	35.0 ± 2.1	36.22 ± 0.23	-3.4	-0.58	-0.58
¹³⁹ Ce (GL)	49.8 ± 1.6	47.65 ± 0.88	4.5	1.18	0.77
²⁴¹ Am (GL)	37.5 ± 1.5	45.08 ± 0.28	-16.8	-4.97	-2.89

Deviation (%) of Laboratory 67

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 67	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	3.037 ± 0.044	3.89 ± 0.10	-21.9	-7.80	-3.76
⁵⁷ Co (GH)	9.331 ± 0.045	12.35 ± 0.33	-24.4	-9.06	-4.20
⁶⁵ Zn (GH)	8.30 ± 0.12	10.68 ± 0.26	-22.3	-8.32	-3.83
¹³³ Ba (GH)	23.450 ± 0.062	34.4 ± 1.4	-31.8	-7.81	-5.47
¹³⁷ Cs (GH)	5.372 ± 0.035	6.99 ± 0.10	-23.1	-15.27	-3.97

Deviation (%) of Laboratory 72

NATIONAL PHYSICAL LABORATORY

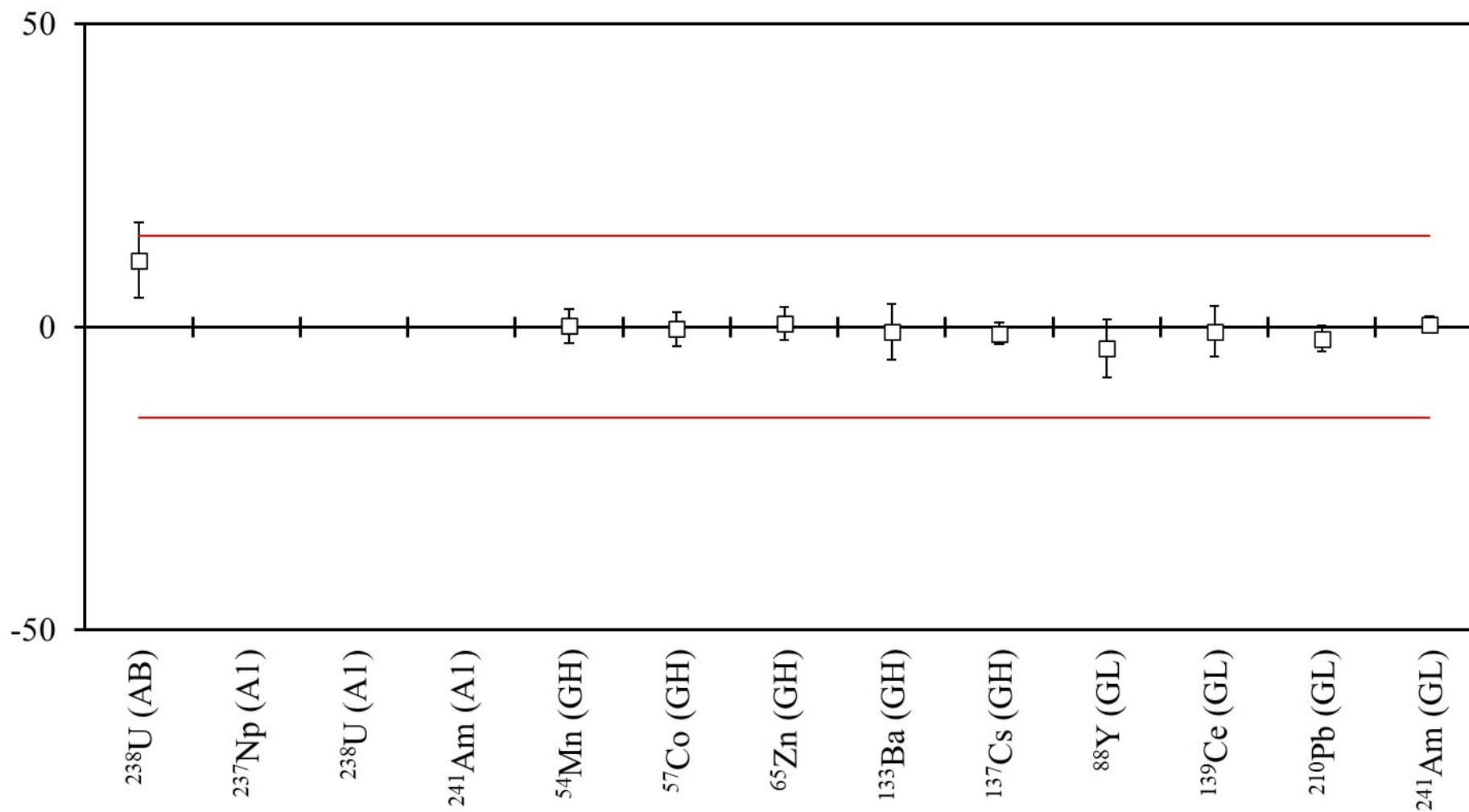
Continuation Sheet

Radionuclide	Laboratory 72	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (B1)	0.584 ± 0.088	0.5175 ± 0.0078	12.9	0.75	2.21
^{54}Mn (GH)	4.22 ± 0.12	3.89 ± 0.10	8.5	2.17	1.47
^{57}Co (GH)	12.04 ± 0.34	12.35 ± 0.33	-2.5	-0.65	-0.43
^{65}Zn (GH)	11.76 ± 0.32	10.68 ± 0.26	10.1	2.60	1.73
^{133}Ba (GH)	35.02 ± 0.96	34.4 ± 1.4	1.8	0.37	0.31
^{137}Cs (GH)	7.34 ± 0.20	6.99 ± 0.10	5.0	1.56	0.85

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 86



Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

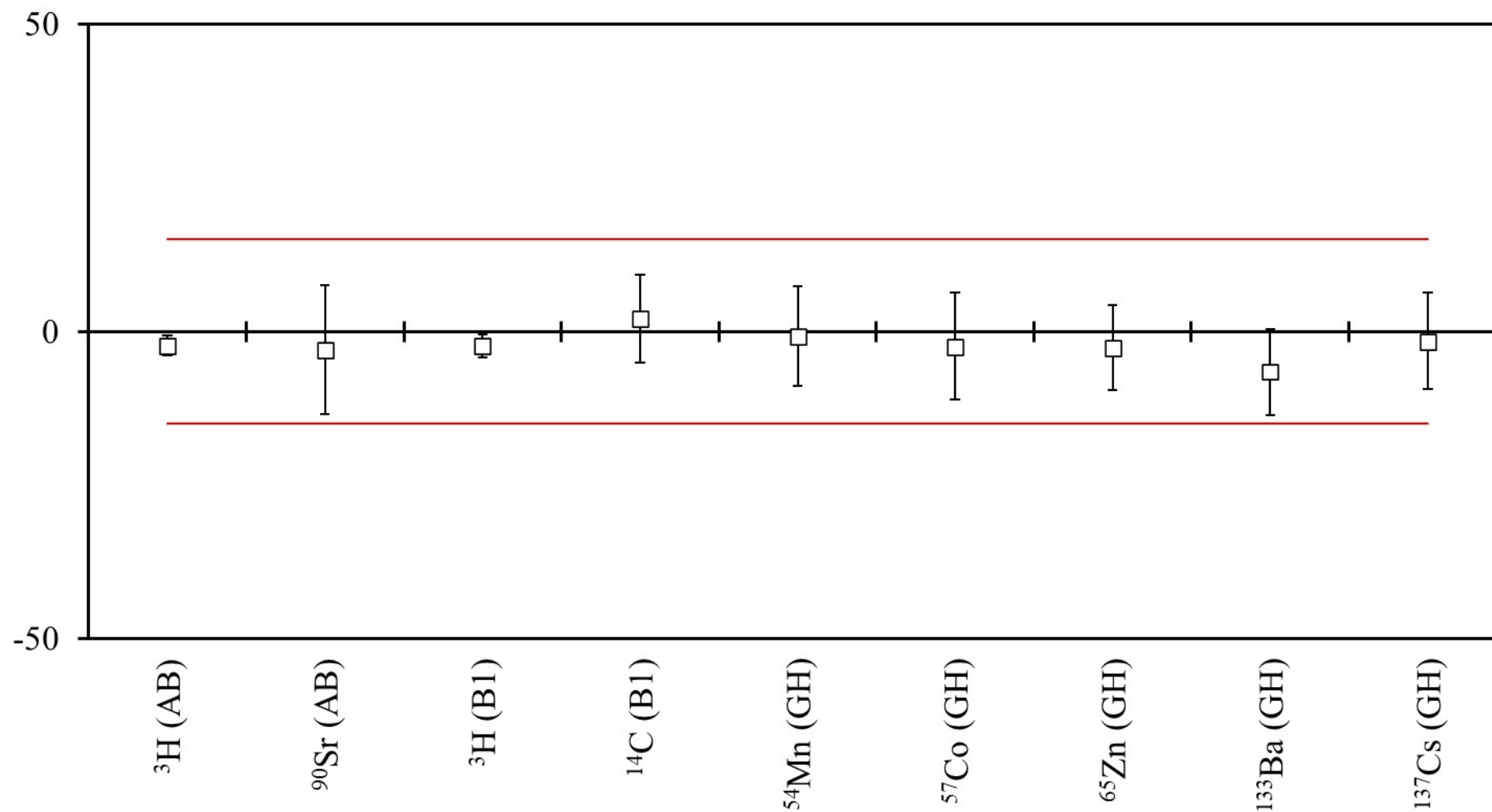
Radionuclide	Laboratory 86	NPL Assigned Value	Deviation /%	Zeta	Z Score
²³⁸ U (AB)	4.00 ± 0.22	3.601 ± 0.047	11.0	1.78	1.89
²³⁷ Np (A1)	2.691 ± 0.061	25.433 ± 0.077	-89.4	-231.95	-15.36
²³⁸ U (A1)	6.39 ± 0.45	55.14 ± 0.72	-88.4	-57.45	-15.18
²⁴¹ Am (A1)	8.84 ± 0.13	89.66 ± 0.35	-90.1	-216.29	-15.48
⁵⁴ Mn (GH)	3.897 ± 0.041	3.89 ± 0.10	0.2	0.06	0.03
⁵⁷ Co (GH)	12.31 ± 0.12	12.35 ± 0.33	-0.4	-0.12	-0.06
⁶⁵ Zn (GH)	10.74 ± 0.14	10.68 ± 0.26	0.6	0.20	0.10
¹³³ Ba (GH)	34.12 ± 0.74	34.4 ± 1.4	-0.8	-0.17	-0.14
¹³⁷ Cs (GH)	6.917 ± 0.069	6.99 ± 0.10	-1.0	-0.60	-0.18
⁸⁸ Y (GL)	34.9 ± 1.8	36.22 ± 0.23	-3.6	-0.73	-0.61
¹³⁹ Ce (GL)	47.3 ± 1.8	47.65 ± 0.88	-0.7	-0.17	-0.12
²¹⁰ Pb (GL)	16.13 ± 0.30	16.44 ± 0.18	-1.9	-0.89	-0.33
²⁴¹ Am (GL)	45.24 ± 0.56	45.08 ± 0.28	0.3	0.25	0.06

Note: Laboratory confirmed error in conversion of units for A1 sample type.

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 106

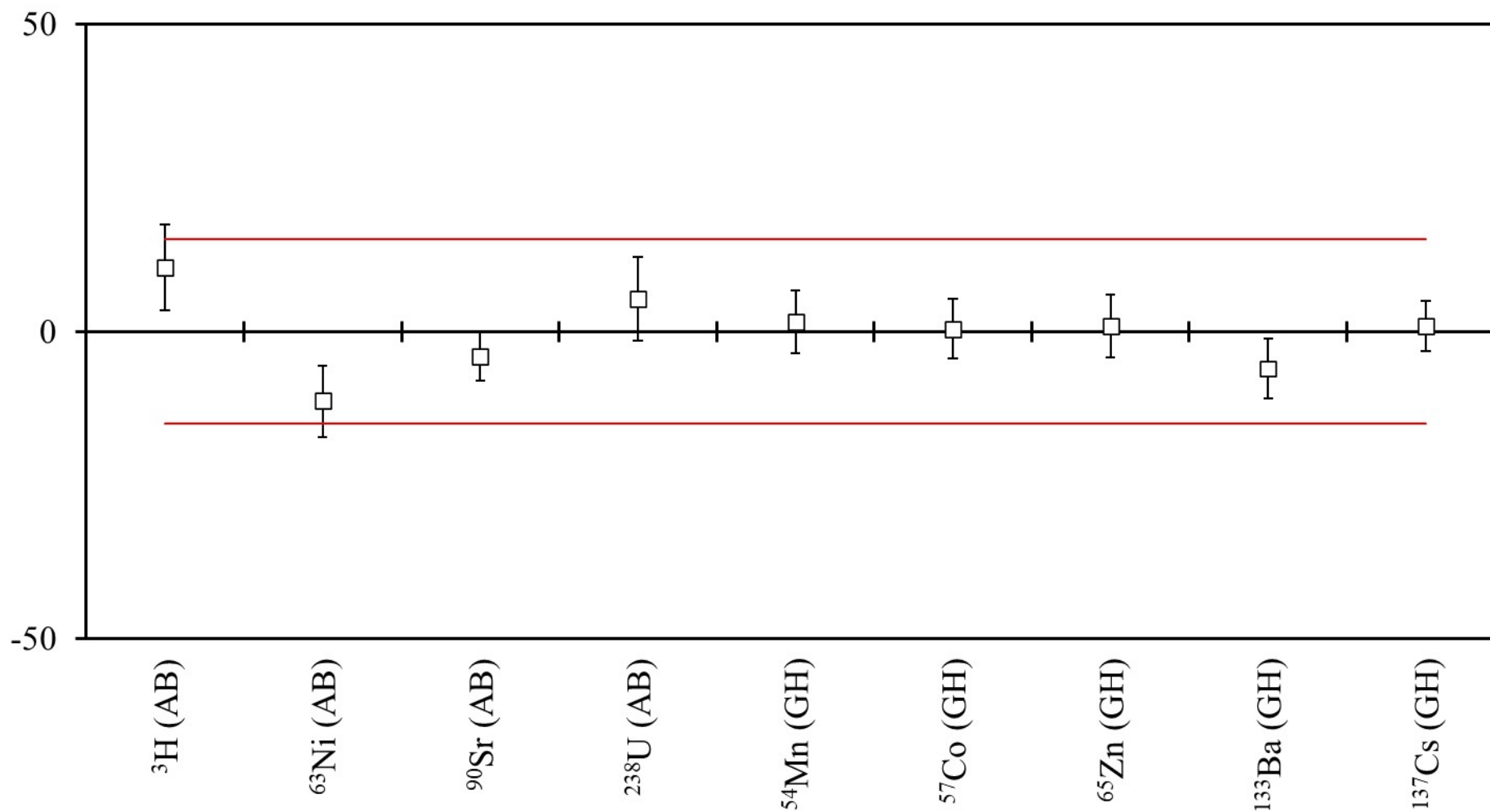


Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 106	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	12.27 ± 0.11	12.55 ± 0.18	-2.2	-1.33	-0.38
^{90}Sr (AB)	2.53 ± 0.26	2.6067 ± 0.0091	-2.9	-0.29	-0.51
^3H (B1)	0.5059 ± 0.0060	0.5175 ± 0.0078	-2.2	-1.18	-0.38
^{14}C (B1)	0.159 ± 0.011	0.1557 ± 0.0012	2.1	0.30	0.36
^{54}Mn (GH)	3.86 ± 0.30	3.89 ± 0.10	-0.8	-0.09	-0.13
^{57}Co (GH)	12.1 ± 1.0	12.35 ± 0.33	-2.4	-0.28	-0.42
^{65}Zn (GH)	10.40 ± 0.70	10.68 ± 0.26	-2.6	-0.37	-0.45
^{133}Ba (GH)	32.1 ± 2.1	34.4 ± 1.4	-6.6	-0.91	-1.14
^{137}Cs (GH)	6.88 ± 0.54	6.99 ± 0.10	-1.6	-0.20	-0.27

Deviation (%) of Laboratory 107

NATIONAL PHYSICAL LABORATORY

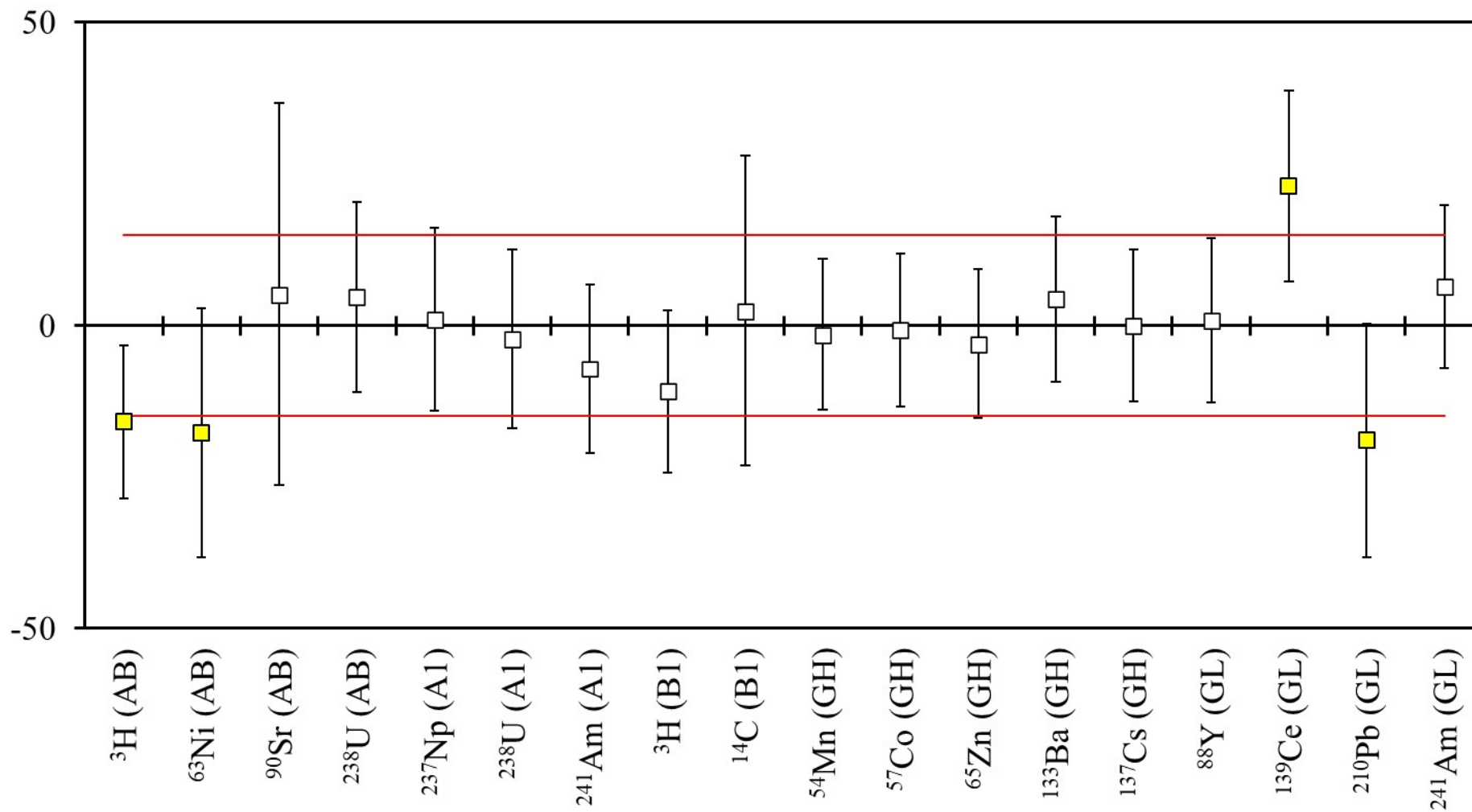
Continuation Sheet

Radionuclide	Laboratory 107	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	13.86 ± 0.85	12.55 ± 0.18	10.5	1.51	1.80
^{63}Ni (AB)	4.10 ± 0.27	4.618 ± 0.026	-11.3	-1.93	-1.94
^{90}Sr (AB)	2.501 ± 0.057	2.6067 ± 0.0091	-4.1	-1.82	-0.70
^{238}U (AB)	3.79 ± 0.24	3.601 ± 0.047	5.4	0.80	0.92
^{54}Mn (GH)	3.95 ± 0.17	3.89 ± 0.10	1.6	0.32	0.27
^{57}Co (GH)	12.41 ± 0.51	12.35 ± 0.33	0.5	0.10	0.08
^{65}Zn (GH)	10.78 ± 0.48	10.68 ± 0.26	0.9	0.17	0.15
^{133}Ba (GH)	32.3 ± 1.1	34.4 ± 1.4	-6.1	-1.20	-1.05
^{137}Cs (GH)	7.06 ± 0.27	6.99 ± 0.10	1.0	0.24	0.16

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 109.1

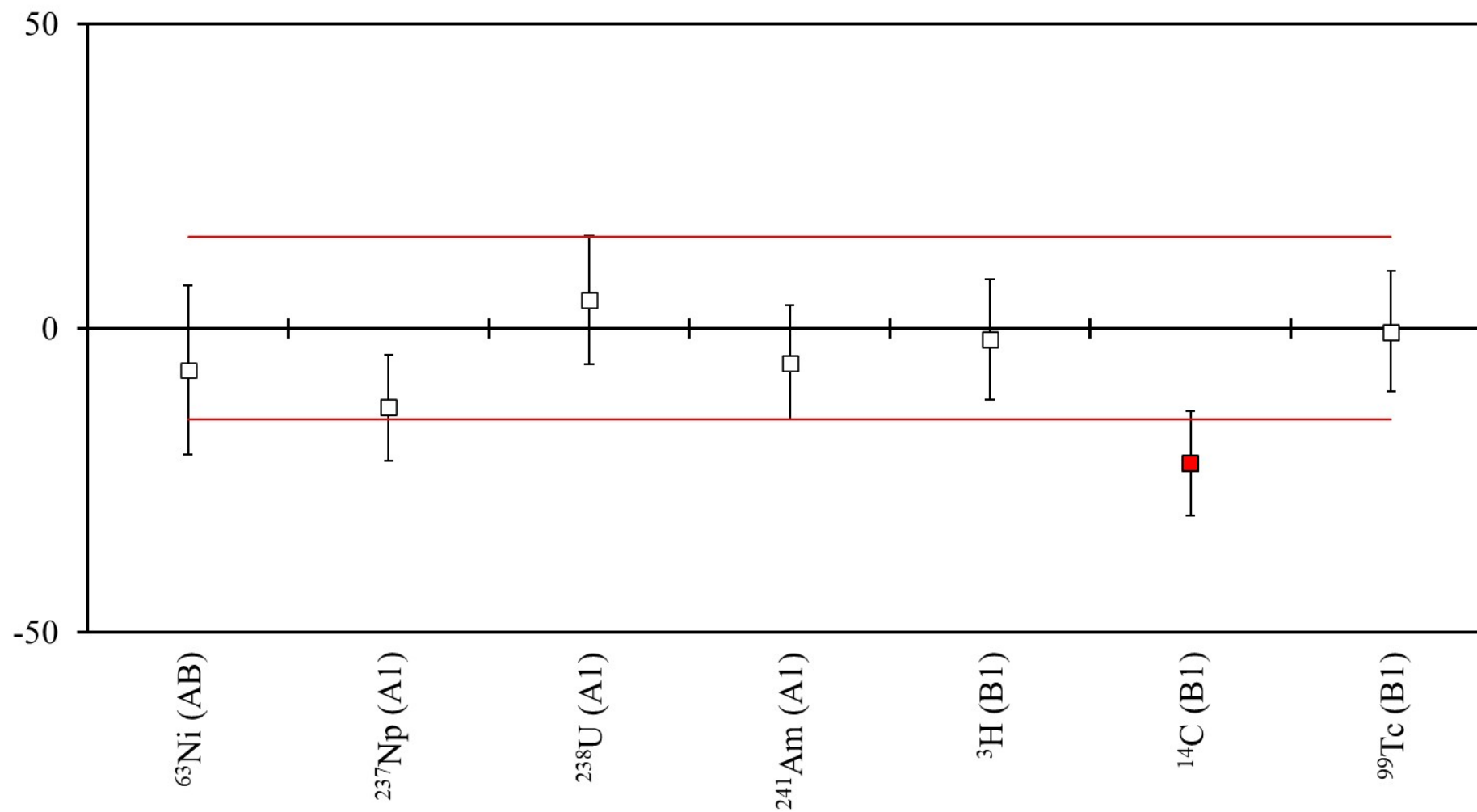


NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 109.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	10.6 ± 1.6	12.55 ± 0.18	-15.9	-1.25	-2.73
⁶³ Ni (AB)	3.80 ± 0.95	4.618 ± 0.026	-17.7	-0.86	-3.04
⁹⁰ Sr (AB)	2.74 ± 0.82	2.6067 ± 0.0091	5.1	0.16	0.88
²³⁸ U (AB)	3.77 ± 0.57	3.601 ± 0.047	4.7	0.30	0.81
²³⁷ Np (A1)	25.7 ± 3.9	25.433 ± 0.077	1.0	0.07	0.17
²³⁸ U (A1)	53.9 ± 8.1	55.14 ± 0.72	-2.2	-0.15	-0.38
²⁴¹ Am (A1)	83 ± 12	89.66 ± 0.35	-7.1	-0.51	-1.22
³ H (B1)	0.461 ± 0.069	0.5175 ± 0.0078	-10.9	-0.81	-1.87
¹⁴ C (B1)	0.159 ± 0.040	0.1557 ± 0.0012	2.4	0.09	0.42
⁵⁴ Mn (GH)	3.83 ± 0.48	3.89 ± 0.10	-1.5	-0.12	-0.26
⁵⁷ Co (GH)	12.3 ± 1.5	12.35 ± 0.33	-0.8	-0.06	-0.13
⁶⁵ Zn (GH)	10.4 ± 1.3	10.68 ± 0.26	-3.0	-0.24	-0.51
¹³³ Ba (GH)	35.9 ± 4.5	34.4 ± 1.4	4.3	0.32	0.74
¹³⁷ Cs (GH)	6.99 ± 0.87	6.99 ± 0.10	0.0	0.00	0.01
⁸⁸ Y (GL)	36.5 ± 4.9	36.22 ± 0.23	0.8	0.06	0.14
¹³⁹ Ce (GL)	58.6 ± 7.4	47.65 ± 0.88	23.0	1.47	3.95
²¹⁰ Pb (GL)	13.3 ± 3.2	16.44 ± 0.18	-19.0	-0.99	-3.27
²⁴¹ Am (GL)	48.0 ± 6.0	45.08 ± 0.28	6.4	0.48	1.10

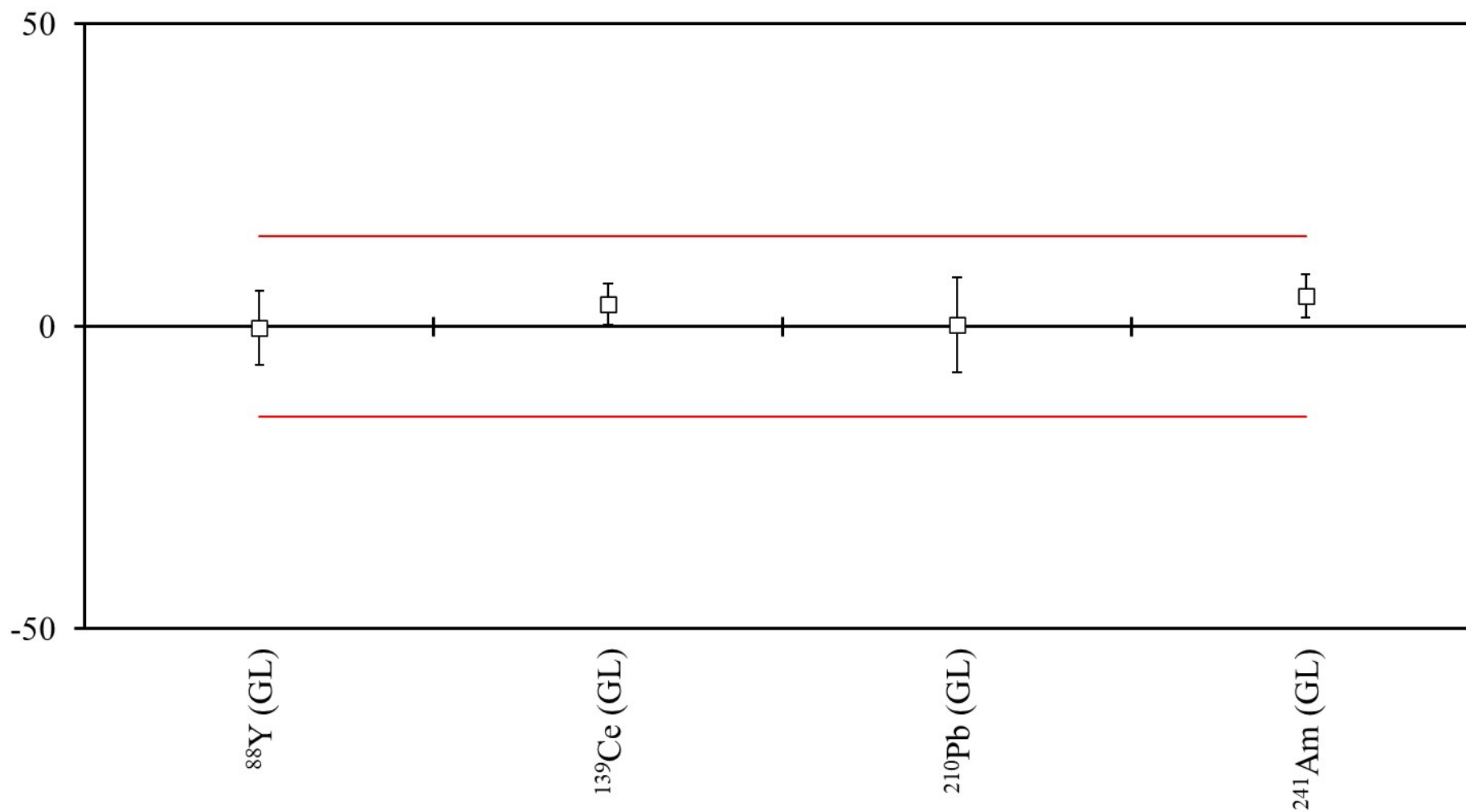
Reference: RR10 PTE 24-25 Final Report Version 1.0

Deviation (%) of Laboratory 109.2

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 109.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{63}Ni (AB)	4.30 ± 0.64	4.618 ± 0.026	-6.9	-0.49	-1.18
^{237}Np (A1)	22.1 ± 2.2	25.433 ± 0.077	-13.1	-1.51	-2.25
^{238}U (A1)	57.7 ± 5.8	55.14 ± 0.72	4.6	0.44	0.80
^{241}Am (A1)	84.6 ± 8.5	89.66 ± 0.35	-5.6	-0.60	-0.97
^3H (B1)	0.508 ± 0.051	0.5175 ± 0.0078	-1.8	-0.18	-0.32
^{14}C (B1)	0.121 ± 0.013	0.1557 ± 0.0012	-22.3	-2.60	-3.83
^{99}Tc (B1)	0.186 ± 0.019	0.1870 ± 0.0018	-0.5	-0.05	-0.09

Deviation (%) of Laboratory 111

NATIONAL PHYSICAL LABORATORY

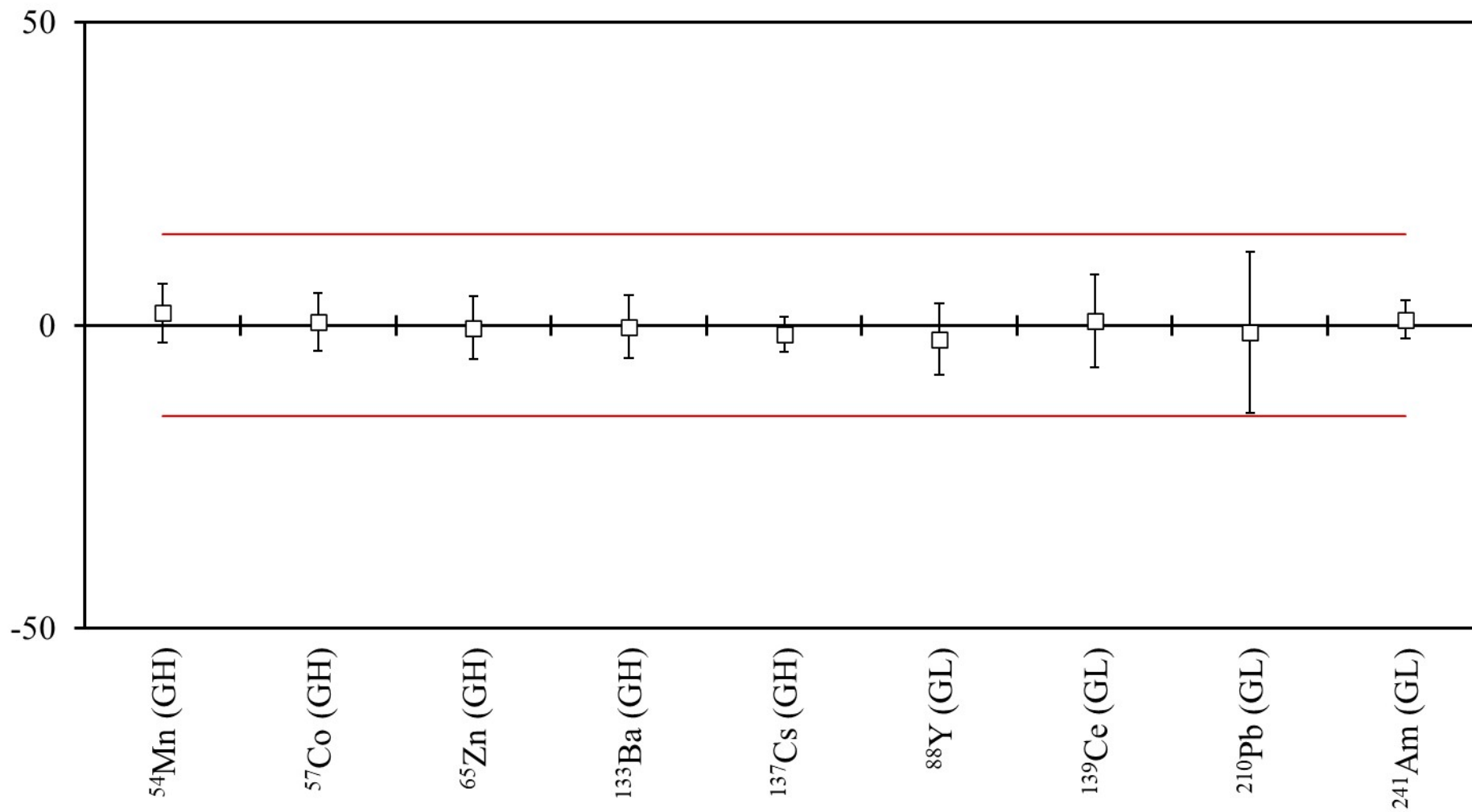
Continuation Sheet

Radionuclide	Laboratory 111	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{88}Y (GL)	36.2 ± 2.2	36.22 ± 0.23	-0.1	-0.02	-0.02
^{139}Ce (GL)	49.4 ± 1.3	47.65 ± 0.88	3.7	1.10	0.63
^{210}Pb (GL)	16.5 ± 1.3	16.44 ± 0.18	0.2	0.03	0.04
^{241}Am (GL)	47.4 ± 1.6	45.08 ± 0.28	5.1	1.43	0.88

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 126

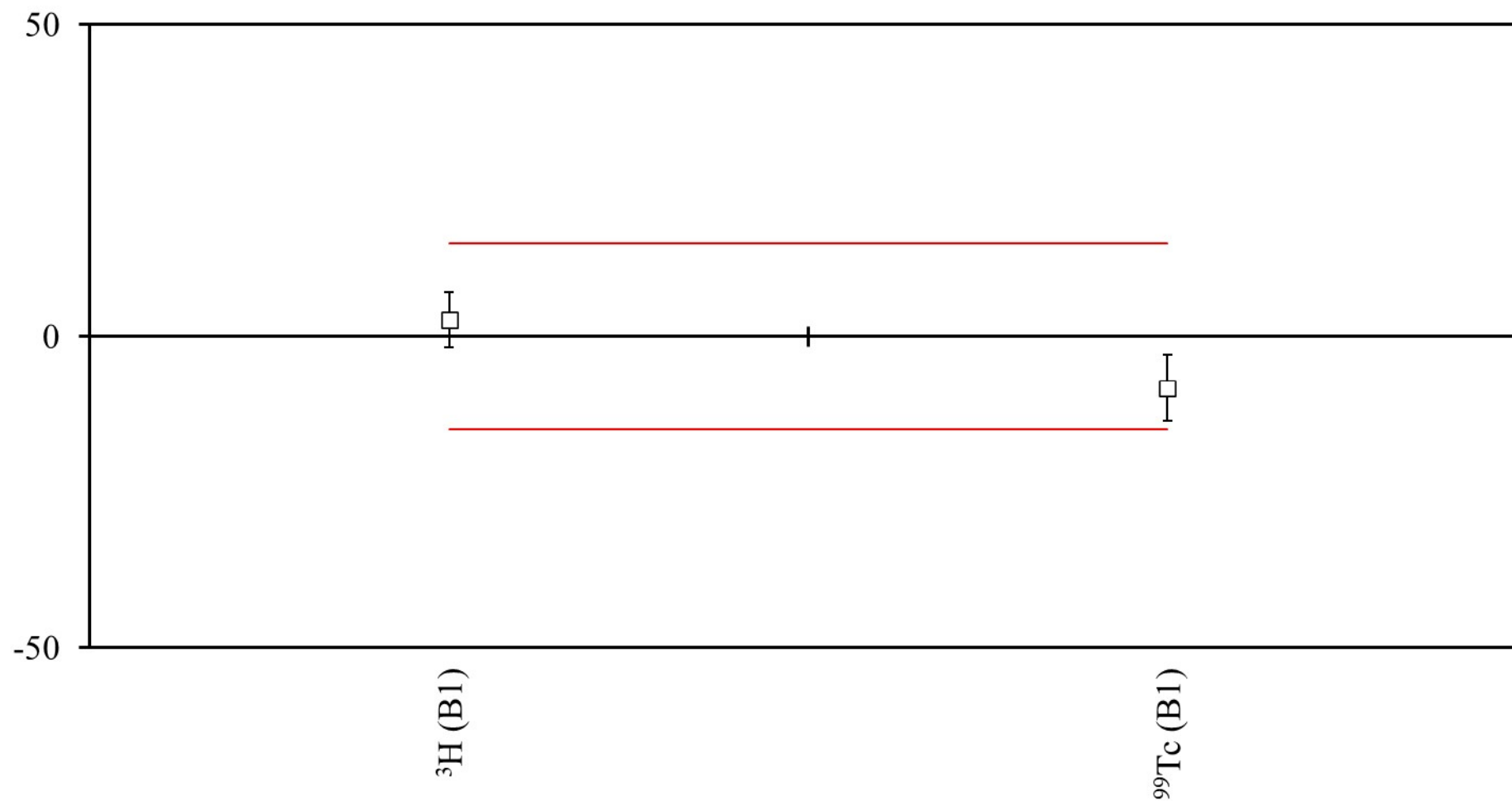


Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 126	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	3.97 ± 0.16	3.89 ± 0.10	2.1	0.42	0.35
⁵⁷ Co (GH)	12.43 ± 0.49	12.35 ± 0.33	0.6	0.14	0.11
⁶⁵ Zn (GH)	10.64 ± 0.50	10.68 ± 0.26	-0.4	-0.07	-0.06
¹³³ Ba (GH)	34.3 ± 1.1	34.4 ± 1.4	-0.2	-0.04	-0.04
¹³⁷ Cs (GH)	6.89 ± 0.18	6.99 ± 0.10	-1.4	-0.49	-0.25
⁸⁸ Y (GL)	35.4 ± 2.2	36.22 ± 0.23	-2.3	-0.39	-0.40
¹³⁹ Ce (GL)	48.0 ± 3.5	47.65 ± 0.88	0.8	0.10	0.13
²¹⁰ Pb (GL)	16.3 ± 2.2	16.44 ± 0.18	-1.2	-0.09	-0.20
²⁴¹ Am (GL)	45.5 ± 1.4	45.08 ± 0.28	0.9	0.30	0.16

Deviation (%) of Laboratory 133

NATIONAL PHYSICAL LABORATORY

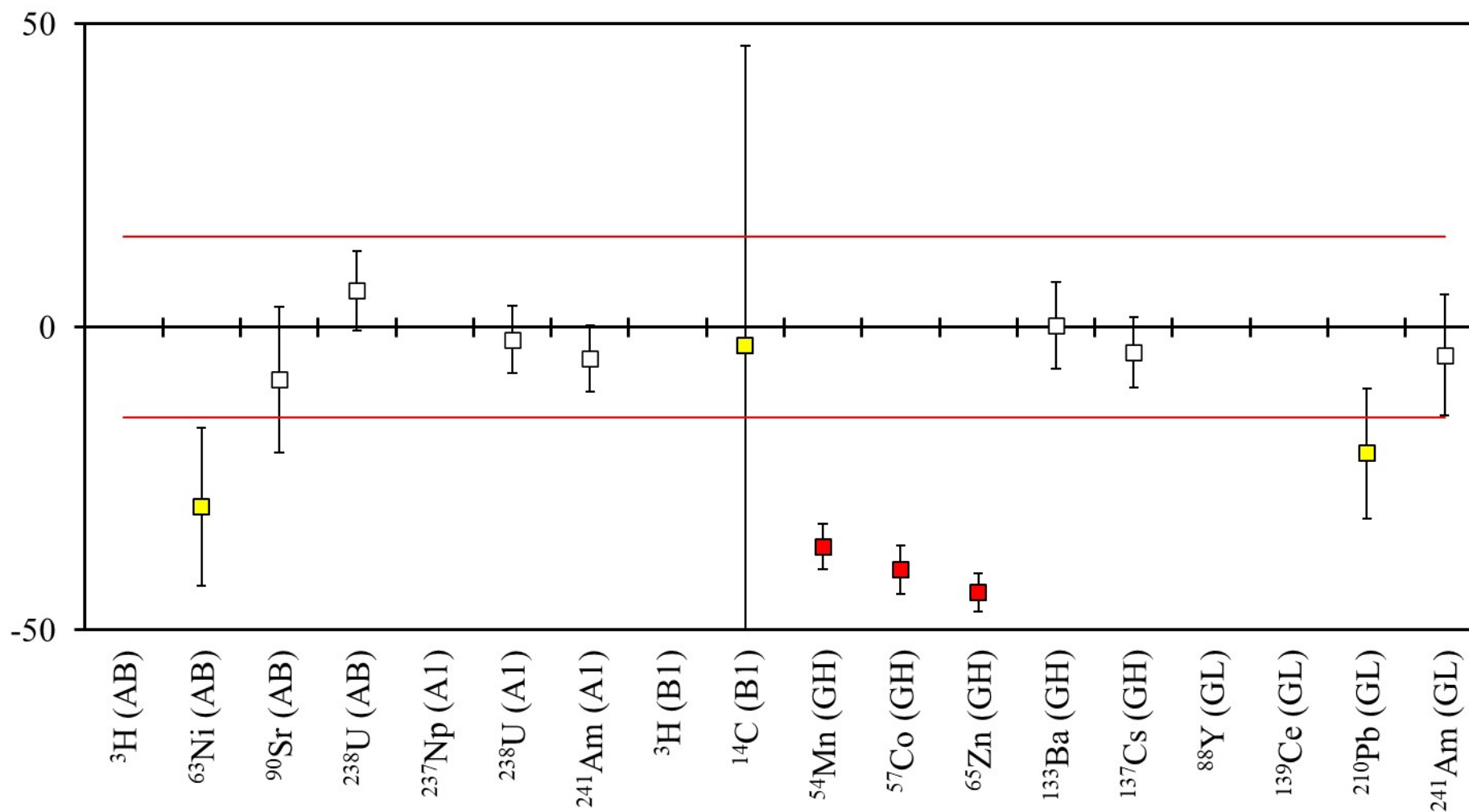
Continuation Sheet

Radionuclide	Laboratory 133	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (B1)	0.532 ± 0.021	0.5175 ± 0.0078	2.7	0.62	0.47
^{99}Tc (B1)	0.17150 ± 0.010	0.1870 ± 0.0018	-8.3	-1.53	-1.42

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 135

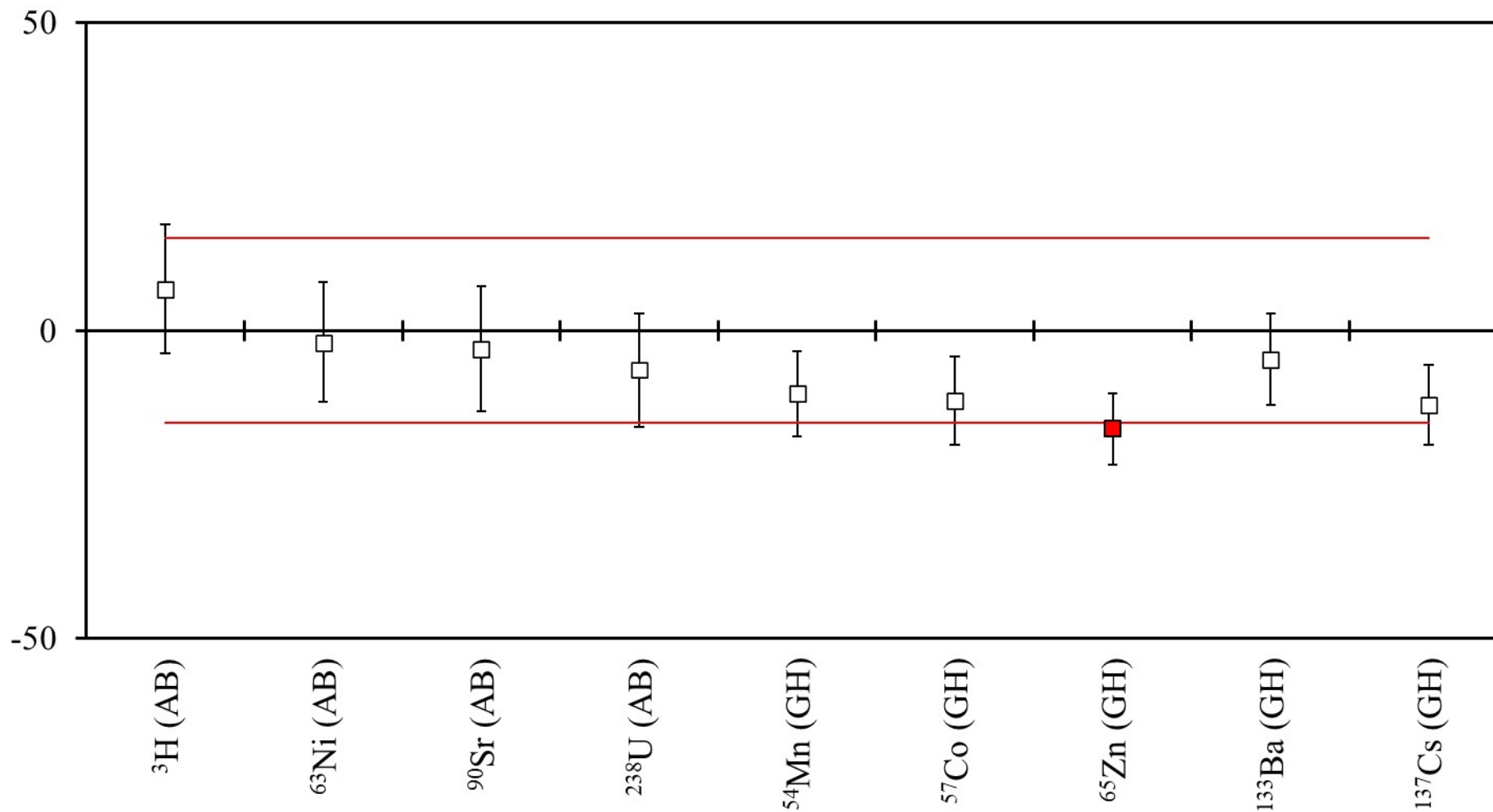


Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

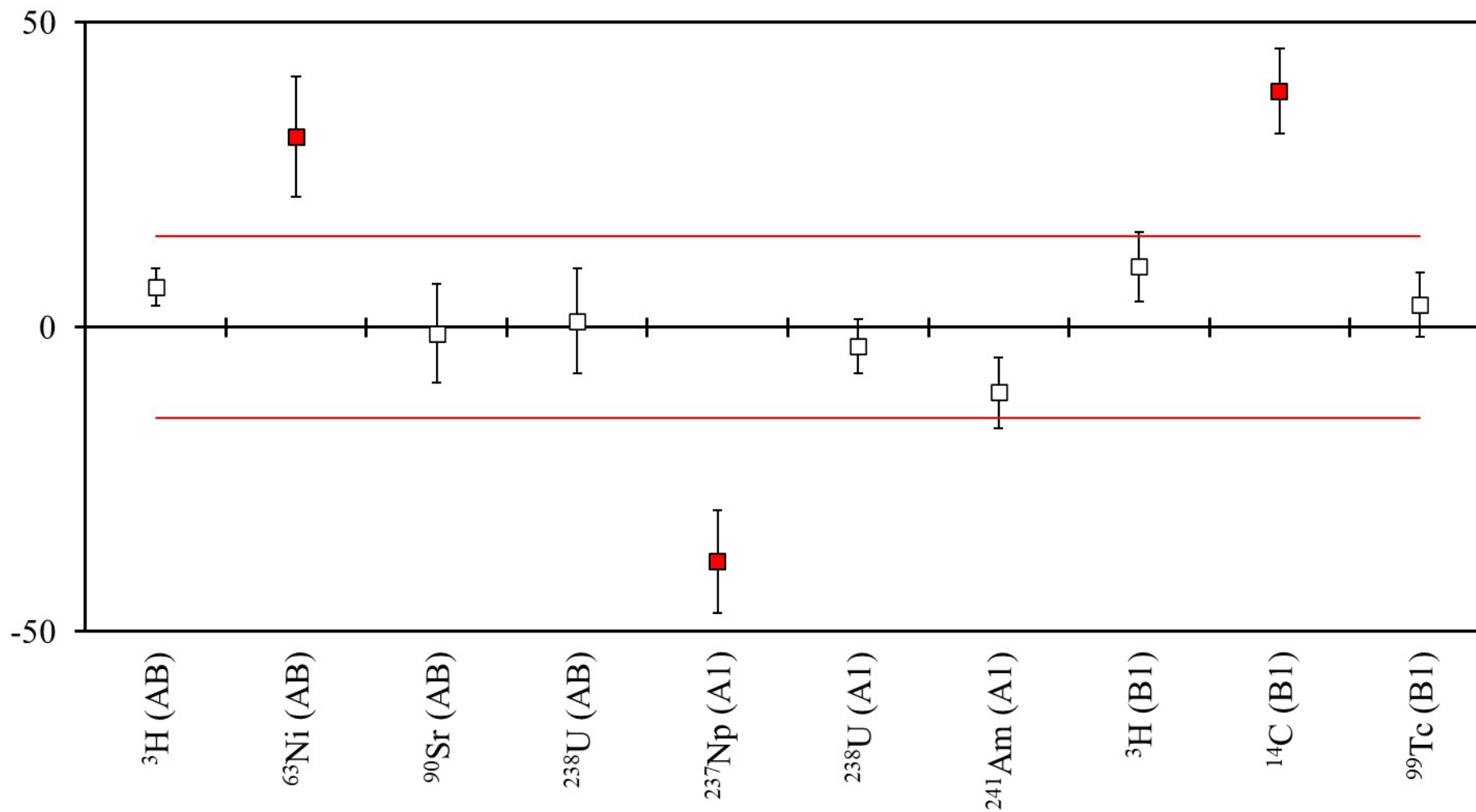
Radionuclide	Laboratory 135	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	0.247 ± 0.020	12.55 ± 0.18	-98.0	-67.93	-16.84
⁶³ Ni (AB)	3.25 ± 0.60	4.618 ± 0.026	-29.6	-2.28	-5.09
⁹⁰ Sr (AB)	2.38 ± 0.30	2.6067 ± 0.0091	-8.7	-0.74	-1.49
²³⁸ U (AB)	3.82 ± 0.23	3.601 ± 0.047	6.1	0.93	1.04
²³⁷ Np (A1)	10.90 ± 0.60	25.433 ± 0.077	-57.1	-24.02	-9.81
²³⁸ U (A1)	54.0 ± 3.0	55.14 ± 0.72	-2.1	-0.37	-0.36
²⁴¹ Am (A1)	85.0 ± 5.0	89.66 ± 0.35	-5.2	-0.93	-0.89
³ H (B1)	0.100 ± 0.013	0.5175 ± 0.0078	-80.7	-27.54	-13.85
¹⁴ C (B1)	0.151 ± 0.077	0.1557 ± 0.0012	-3.0	-0.06	-0.52
⁵⁴ Mn (GH)	2.48 ± 0.13	3.89 ± 0.10	-36.2	-8.60	-6.22
⁵⁷ Co (GH)	7.40 ± 0.45	12.35 ± 0.33	-40.1	-8.87	-6.88
⁶⁵ Zn (GH)	6.00 ± 0.30	10.68 ± 0.26	-43.8	-11.79	-7.53
¹³³ Ba (GH)	34.5 ± 2.0	34.4 ± 1.4	0.3	0.04	0.05
¹³⁷ Cs (GH)	6.70 ± 0.40	6.99 ± 0.10	-4.1	-0.70	-0.71
⁸⁸ Y (GL)	9.60 ± 0.50	36.22 ± 0.23	-73.5	-48.37	-12.62
¹³⁹ Ce (GL)	17.4 ± 1.4	47.65 ± 0.88	-63.5	-18.77	-10.90
²¹⁰ Pb (GL)	13.0 ± 1.8	16.44 ± 0.18	-20.9	-1.96	-3.59
²⁴¹ Am (GL)	43.0 ± 4.5	45.08 ± 0.28	-4.6	-0.46	-0.79

Deviation (%) of Laboratory 154

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

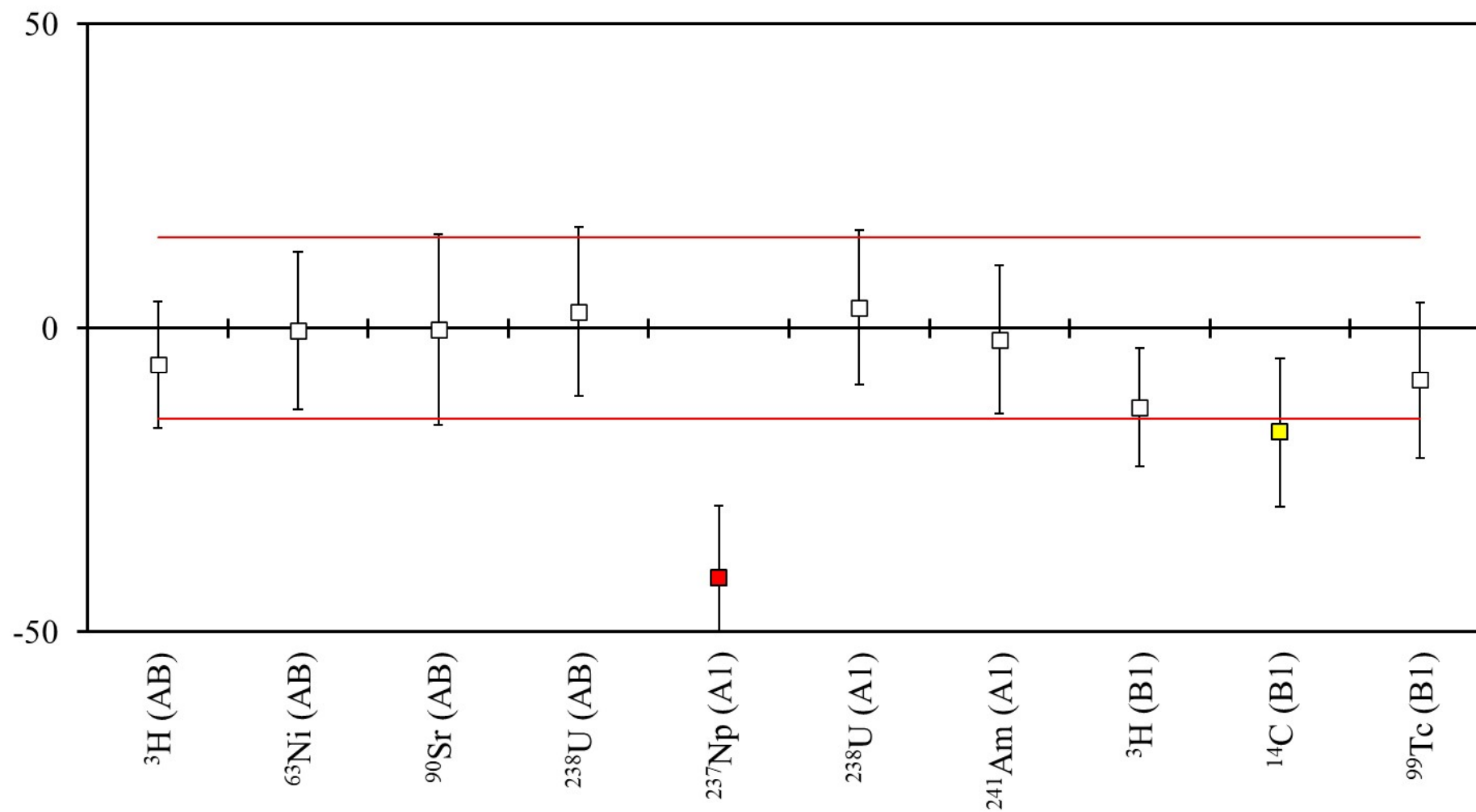
Radionuclide	Laboratory 154	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	13.4 ± 1.3	12.55 ± 0.18	6.8	0.65	1.16
^{63}Ni (AB)	4.53 ± 0.45	4.618 ± 0.026	-1.9	-0.20	-0.33
^{90}Sr (AB)	2.53 ± 0.25	2.6067 ± 0.0091	-2.9	-0.31	-0.51
^{238}U (AB)	3.37 ± 0.33	3.601 ± 0.047	-6.4	-0.69	-1.10
^{54}Mn (GH)	3.49 ± 0.25	3.89 ± 0.10	-10.3	-1.46	-1.76
^{57}Co (GH)	10.94 ± 0.84	12.35 ± 0.33	-11.4	-1.57	-1.96
^{65}Zn (GH)	8.97 ± 0.57	10.68 ± 0.26	-16.0	-2.72	-2.75
^{133}Ba (GH)	32.8 ± 2.2	34.4 ± 1.4	-4.7	-0.62	-0.80
^{137}Cs (GH)	6.14 ± 0.45	6.99 ± 0.10	-12.1	-1.82	-2.08

Deviation (%) of Laboratory 155

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

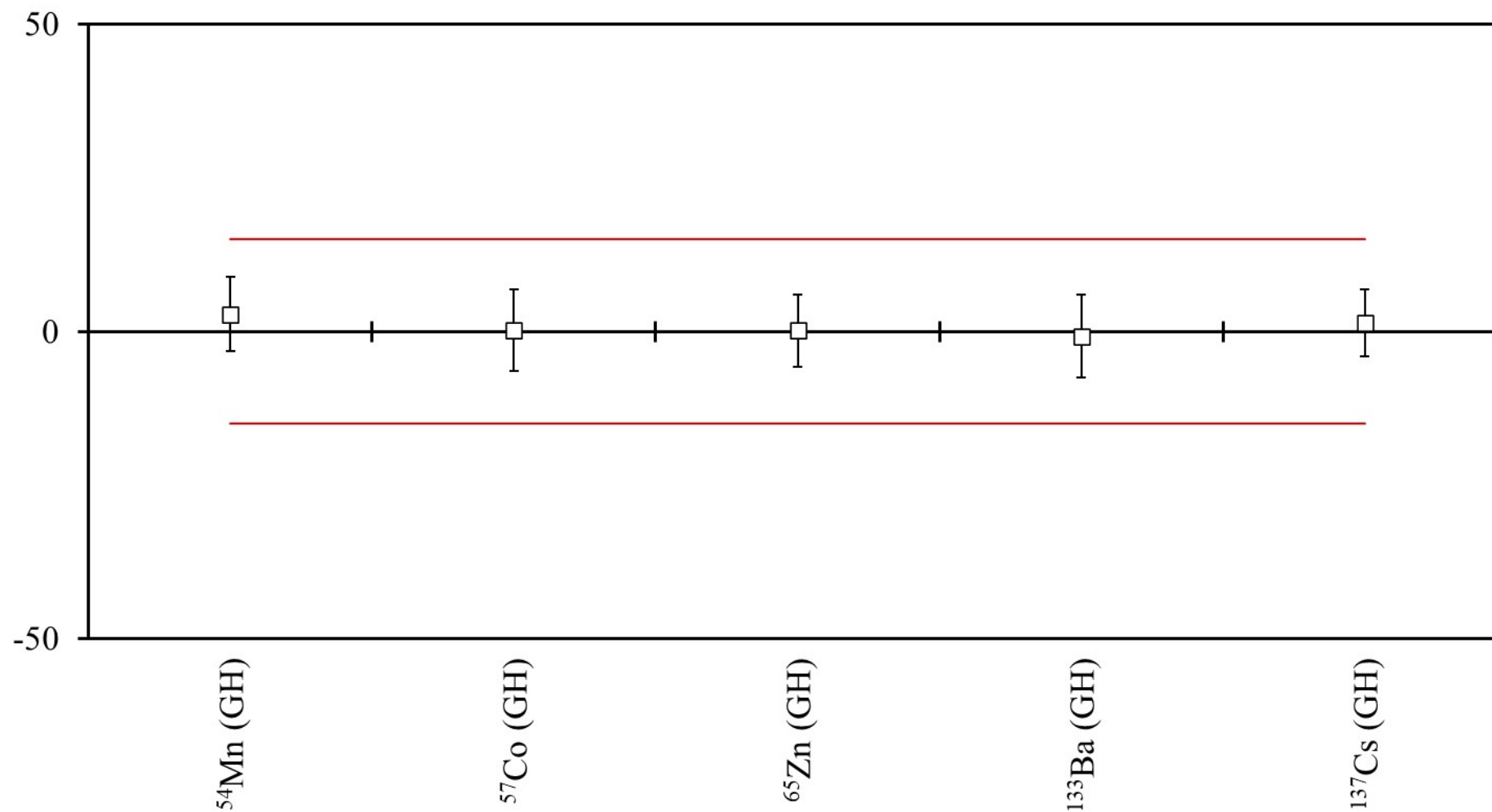
Radionuclide	Laboratory 155	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	13.38 ± 0.34	12.55 ± 0.18	6.6	2.18	1.14
^{63}Ni (AB)	6.06 ± 0.46	4.618 ± 0.026	31.2	3.16	5.36
^{90}Sr (AB)	2.58 ± 0.19	2.6067 ± 0.0091	-1.0	-0.14	-0.18
^{238}U (AB)	3.64 ± 0.31	3.601 ± 0.047	1.0	0.12	0.17
^{237}Np (A1)	15.6 ± 2.1	25.433 ± 0.077	-38.5	-4.57	-6.61
^{238}U (A1)	53.4 ± 2.4	55.14 ± 0.72	-3.2	-0.70	-0.54
^{241}Am (A1)	80.0 ± 5.3	89.66 ± 0.35	-10.8	-1.84	-1.85
^3H (B1)	0.569 ± 0.029	0.5175 ± 0.0078	10.0	1.74	1.71
^{14}C (B1)	0.216 ± 0.011	0.1557 ± 0.0012	38.7	5.55	6.65
^{99}Tc (B1)	0.1940 ± 0.0098	0.1870 ± 0.0018	3.7	0.71	0.64

Deviation (%) of Laboratory 169

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

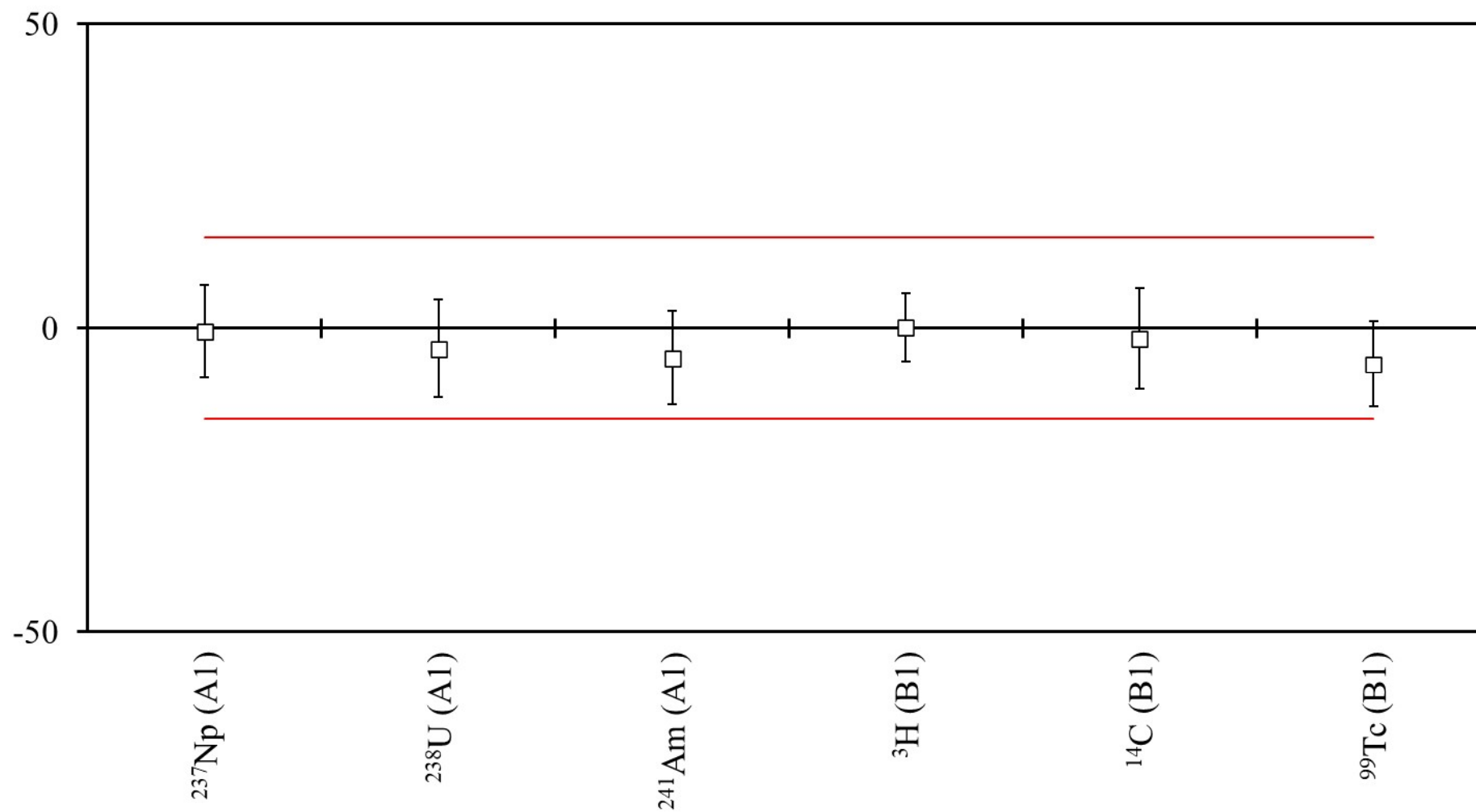
Radionuclide	Laboratory 169	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	11.8 ± 1.3	12.55 ± 0.18	-6.0	-0.57	-1.03
^{63}Ni (AB)	4.60 ± 0.60	4.618 ± 0.026	-0.4	-0.03	-0.07
^{90}Sr (AB)	2.60 ± 0.40	2.6067 ± 0.0091	-0.3	-0.02	-0.04
^{238}U (AB)	3.70 ± 0.50	3.601 ± 0.047	2.7	0.20	0.47
^{237}Np (A1)	15.0 ± 3.0	25.433 ± 0.077	-41.0	-3.48	-7.04
^{238}U (A1)	57.0 ± 7.0	55.14 ± 0.72	3.4	0.26	0.58
^{241}Am (A1)	88 ± 11	89.66 ± 0.35	-1.9	-0.15	-0.32
^3H (B1)	0.450 ± 0.050	0.5175 ± 0.0078	-13.0	-1.33	-2.24
^{14}C (B1)	0.129 ± 0.019	0.1557 ± 0.0012	-17.1	-1.40	-2.94
^{99}Tc (B1)	0.171 ± 0.024	0.1870 ± 0.0018	-8.6	-0.66	-1.47

Deviation (%) of Laboratory 171

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

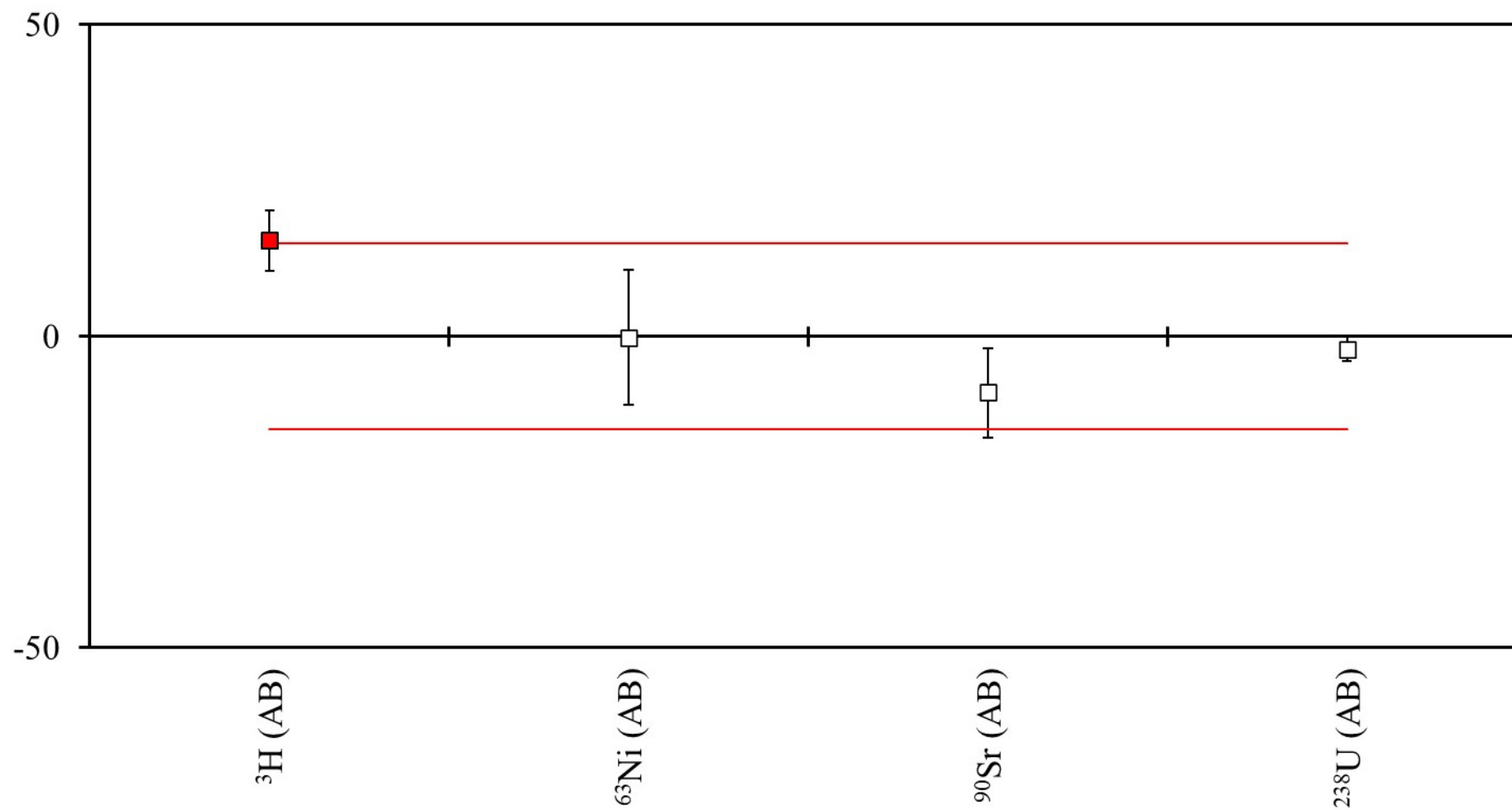
Radionuclide	Laboratory 171	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	4.00 ± 0.21	3.89 ± 0.10	2.8	0.47	0.49
⁵⁷ Co (GH)	12.38 ± 0.75	12.35 ± 0.33	0.2	0.04	0.04
⁶⁵ Zn (GH)	10.70 ± 0.57	10.68 ± 0.26	0.2	0.03	0.03
¹³³ Ba (GH)	34.1 ± 1.9	34.4 ± 1.4	-0.8	-0.12	-0.14
¹³⁷ Cs (GH)	7.09 ± 0.37	6.99 ± 0.10	1.4	0.26	0.25

Deviation (%) of Laboratory 175

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

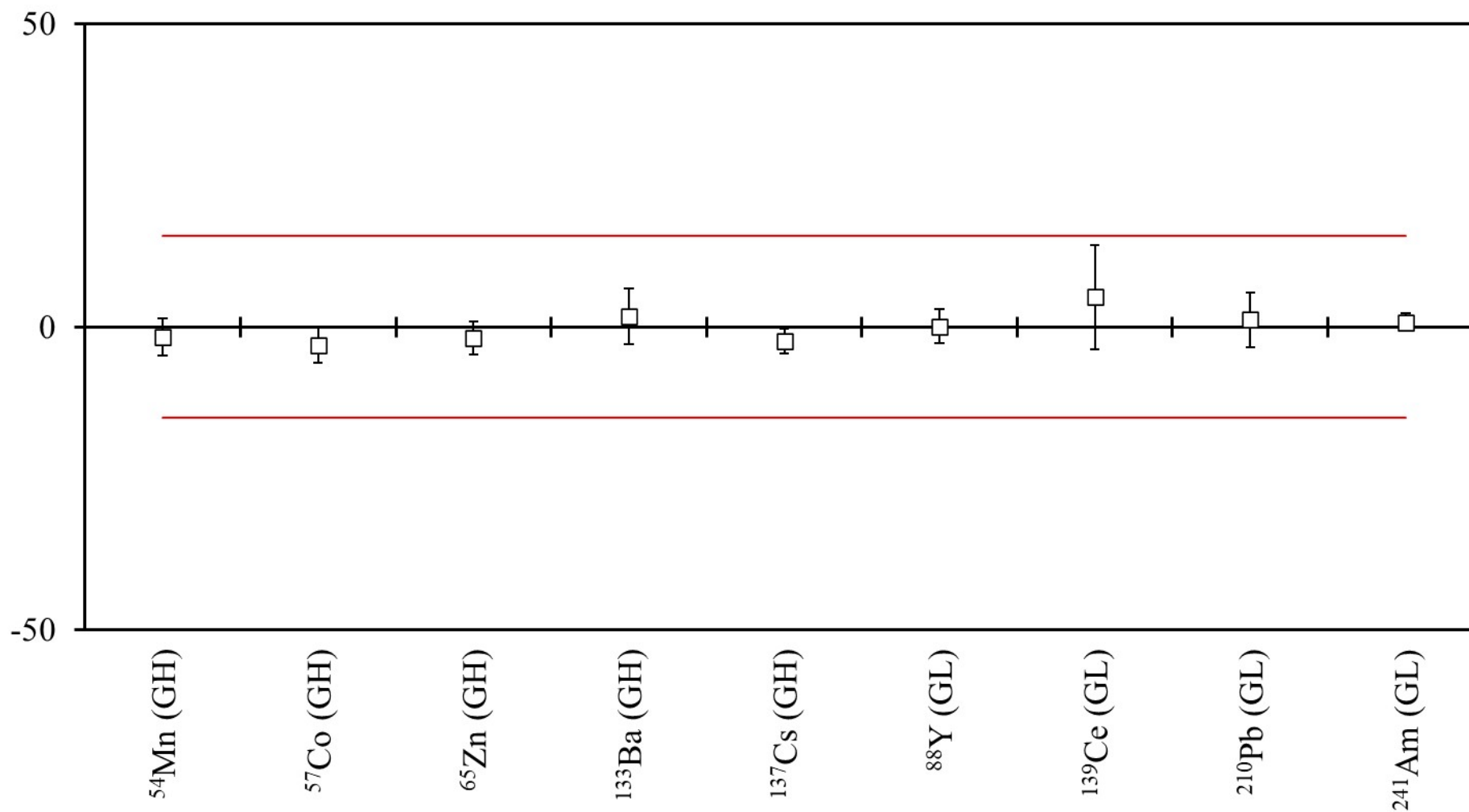
Radionuclide	Laboratory 175	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{237}Np (A1)	25.3 ± 1.9	25.433 ± 0.077	-0.5	-0.07	-0.09
^{238}U (A1)	53.3 ± 4.4	55.14 ± 0.72	-3.3	-0.42	-0.57
^{241}Am (A1)	85.3 ± 7.0	89.66 ± 0.35	-4.9	-0.63	-0.84
^3H (B1)	0.518 ± 0.028	0.5175 ± 0.0078	0.1	0.02	0.02
^{14}C (B1)	0.153 ± 0.013	0.1557 ± 0.0012	-1.7	-0.21	-0.30
^{99}Tc (B1)	0.176 ± 0.013	0.1870 ± 0.0018	-5.9	-0.84	-1.01

Deviation (%) of Laboratory 180

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

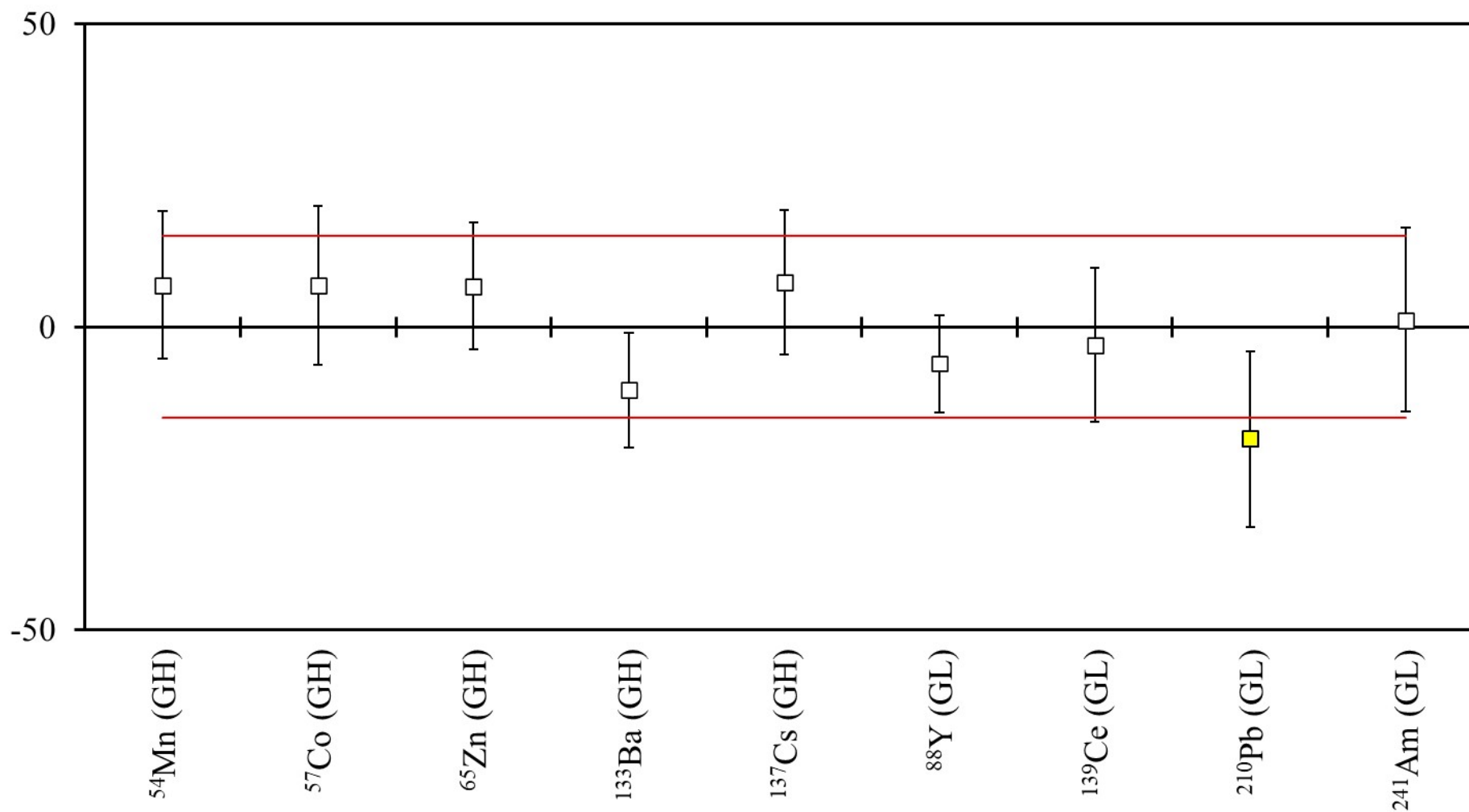
Radionuclide	Laboratory 180	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	14.48 ± 0.57	12.55 ± 0.18	15.4	3.23	2.64
⁶³ Ni (AB)	4.61 ± 0.50	4.618 ± 0.026	-0.2	-0.02	-0.03
⁹⁰ Sr (AB)	2.37 ± 0.17	2.6067 ± 0.0091	-9.1	-1.39	-1.56
²³⁸ U (AB)	3.530 ± 0.054	3.601 ± 0.047	-2.0	-0.99	-0.34

Deviation (%) of Laboratory 183

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 183	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	3.825 ± 0.066	3.89 ± 0.10	-1.7	-0.54	-0.29
⁵⁷ Co (GH)	11.98 ± 0.16	12.35 ± 0.33	-3.0	-1.01	-0.51
⁶⁵ Zn (GH)	10.49 ± 0.15	10.68 ± 0.26	-1.8	-0.64	-0.31
¹³³ Ba (GH)	35.01 ± 0.72	34.4 ± 1.4	1.8	0.39	0.31
¹³⁷ Cs (GH)	6.83 ± 0.10	6.99 ± 0.10	-2.3	-1.12	-0.39
⁸⁸ Y (GL)	36.3 ± 1.0	36.22 ± 0.23	0.2	0.05	0.03
¹³⁹ Ce (GL)	50.0 ± 4.0	47.65 ± 0.88	4.9	0.58	0.85
²¹⁰ Pb (GL)	16.64 ± 0.71	16.44 ± 0.18	1.2	0.27	0.21
²⁴¹ Am (GL)	45.45 ± 0.55	45.08 ± 0.28	0.8	0.59	0.14

Deviation (%) of Laboratory 186

NATIONAL PHYSICAL LABORATORY

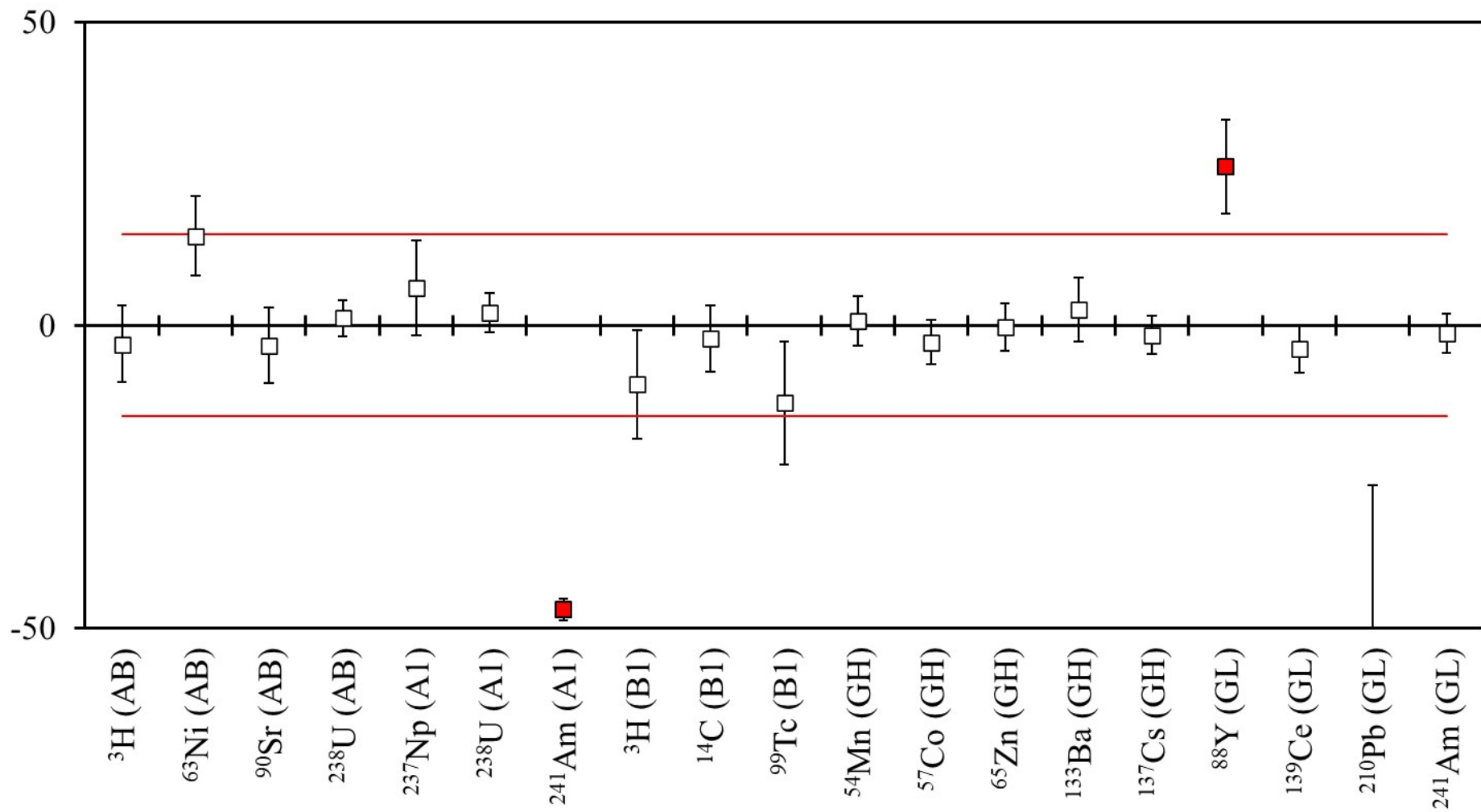
Continuation Sheet

Radionuclide	Laboratory 186	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	4.16 ± 0.46	3.89 ± 0.10	6.9	0.57	1.19
⁵⁷ Co (GH)	13.2 ± 1.6	12.35 ± 0.33	6.9	0.53	1.18
⁶⁵ Zn (GH)	11.4 ± 1.1	10.68 ± 0.26	6.7	0.65	1.16
¹³³ Ba (GH)	30.8 ± 3.0	34.4 ± 1.4	-10.5	-1.07	-1.80
¹³⁷ Cs (GH)	7.51 ± 0.83	6.99 ± 0.10	7.4	0.62	1.28
⁸⁸ Y (GL)	34.0 ± 2.9	36.22 ± 0.23	-6.1	-0.76	-1.05
¹³⁹ Ce (GL)	46.2 ± 6.0	47.65 ± 0.88	-3.0	-0.24	-0.52
²¹⁰ Pb (GL)	13.4 ± 2.4	16.44 ± 0.18	-18.5	-1.27	-3.18
²⁴¹ Am (GL)	45.6 ± 6.8	45.08 ± 0.28	1.2	0.08	0.20

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 190



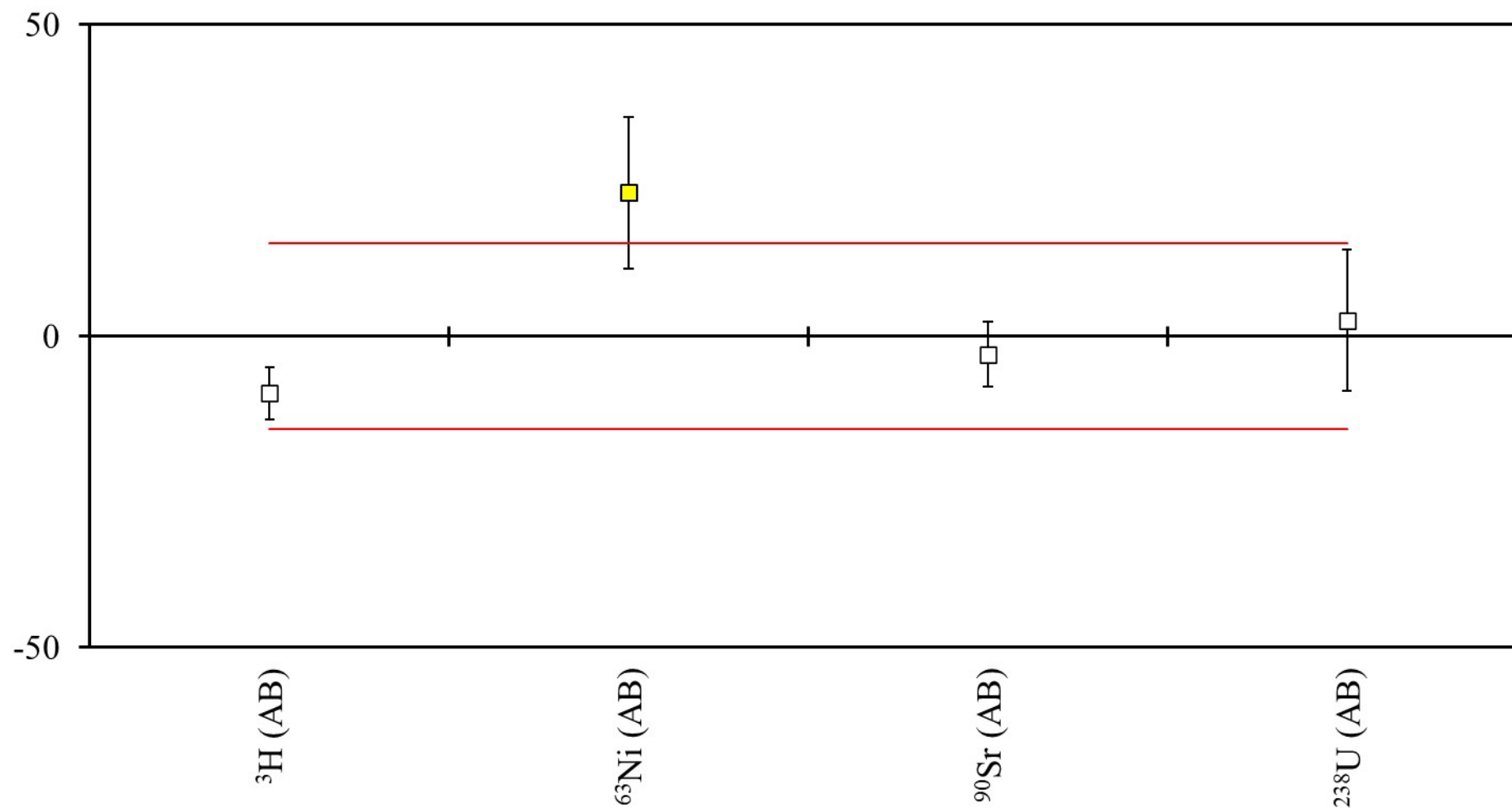
Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 190	NPL Assigned Value	Deviation /%	Zeta	Z Score
³ H (AB)	12.16 ± 0.78	12.55 ± 0.18	-3.1	-0.49	-0.53
⁶³ Ni (AB)	5.30 ± 0.30	4.618 ± 0.026	14.8	2.26	2.54
⁹⁰ Sr (AB)	2.52 ± 0.14	2.6067 ± 0.0091	-3.3	-0.62	-0.57
²³⁸ U (AB)	3.644 ± 0.094	3.601 ± 0.047	1.2	0.41	0.21
²³⁷ Np (A1)	27.0 ± 2.0	25.433 ± 0.077	6.2	0.78	1.06
²³⁸ U (A1)	56.3 ± 1.6	55.14 ± 0.72	2.1	0.66	0.36
²⁴¹ Am (A1)	47.6 ± 1.6	89.66 ± 0.35	-46.9	-25.68	-8.06
³ H (B1)	0.467 ± 0.046	0.5175 ± 0.0078	-9.8	-1.08	-1.68
¹⁴ C (B1)	0.1523 ± 0.0085	0.1557 ± 0.0012	-2.2	-0.40	-0.38
⁹⁹ Tc (B1)	0.163 ± 0.019	0.1870 ± 0.0018	-12.8	-1.26	-2.20
⁵⁴ Mn (GH)	3.92 ± 0.12	3.89 ± 0.10	0.8	0.19	0.13
⁵⁷ Co (GH)	12.01 ± 0.32	12.35 ± 0.33	-2.8	-0.74	-0.47
⁶⁵ Zn (GH)	10.65 ± 0.32	10.68 ± 0.26	-0.3	-0.07	-0.05
¹³³ Ba (GH)	35.3 ± 1.1	34.4 ± 1.4	2.6	0.51	0.45
¹³⁷ Cs (GH)	6.88 ± 0.20	6.99 ± 0.10	-1.6	-0.49	-0.27
⁸⁸ Y (GL)	45.7 ± 2.8	36.22 ± 0.23	26.2	3.37	4.49
¹³⁹ Ce (GL)	45.8 ± 1.7	47.65 ± 0.88	-3.9	-0.97	-0.67
²¹⁰ Pb (GL)	2.7 ± 9.4	16.44 ± 0.18	-83.6	-1.46	-14.35
²⁴¹ Am (GL)	44.5 ± 1.4	45.08 ± 0.28	-1.3	-0.41	-0.22

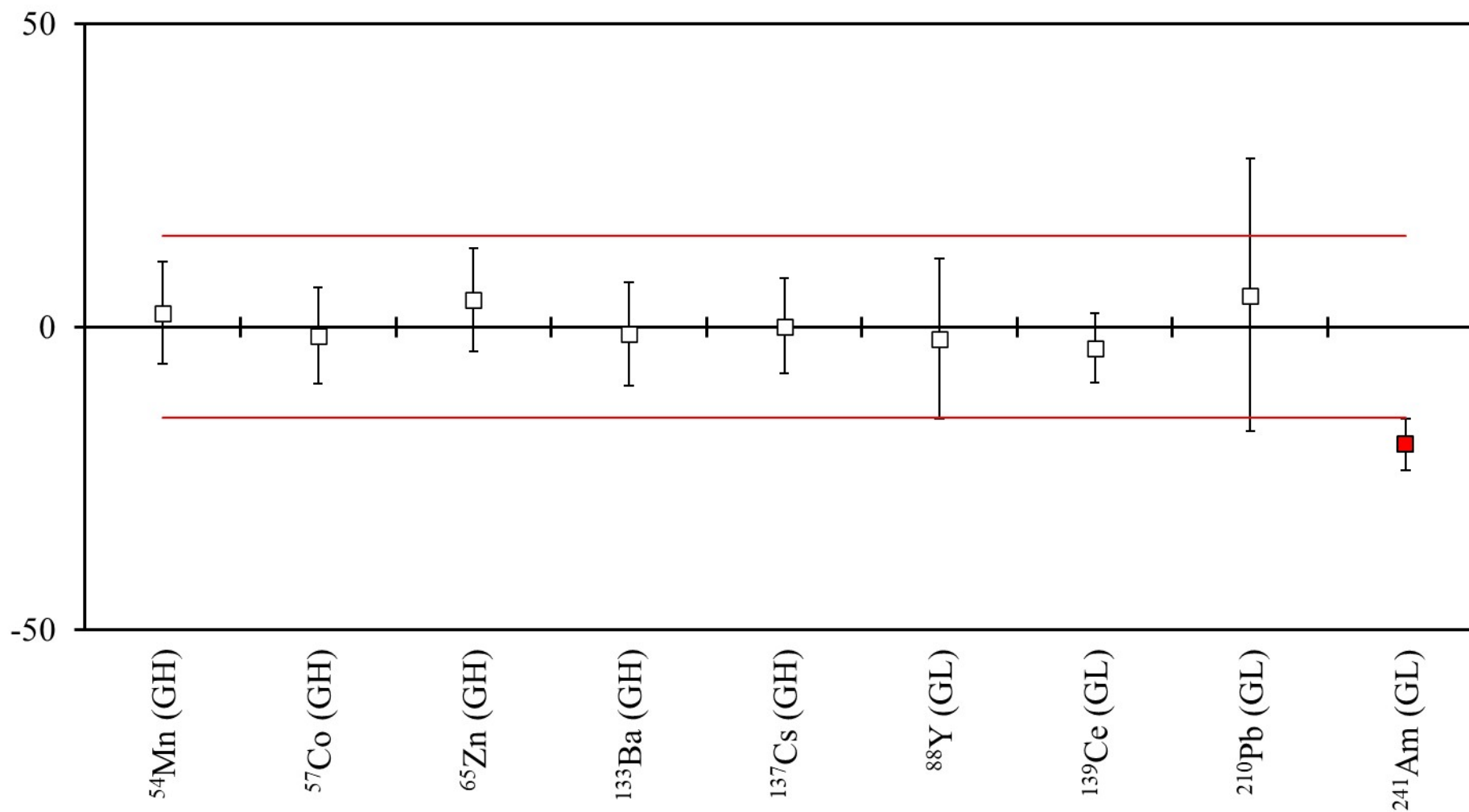
Reference: RR10 PTE 24-25 Final Report Version 1.0

Deviation (%) of Laboratory 192

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

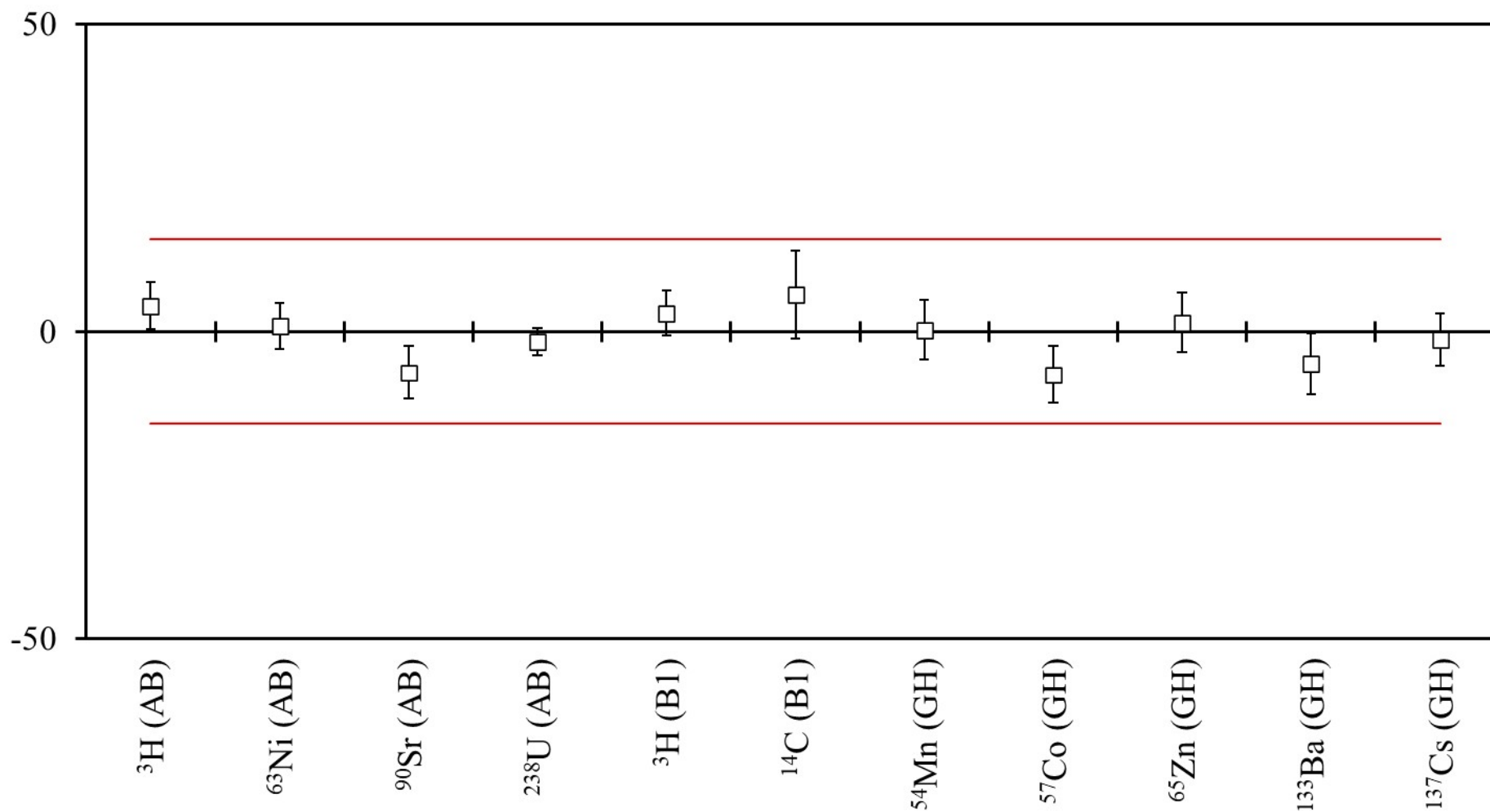
Radionuclide	Laboratory 192	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	11.40 ± 0.50	12.55 ± 0.18	-9.2	-2.16	-1.57
^{63}Ni (AB)	5.68 ± 0.56	4.618 ± 0.026	23.0	1.89	3.95
^{90}Sr (AB)	2.53 ± 0.11	2.6067 ± 0.0091	-2.9	-0.73	-0.51
^{238}U (AB)	3.69 ± 0.41	3.601 ± 0.047	2.5	0.22	0.42

Deviation (%) of Laboratory 194

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

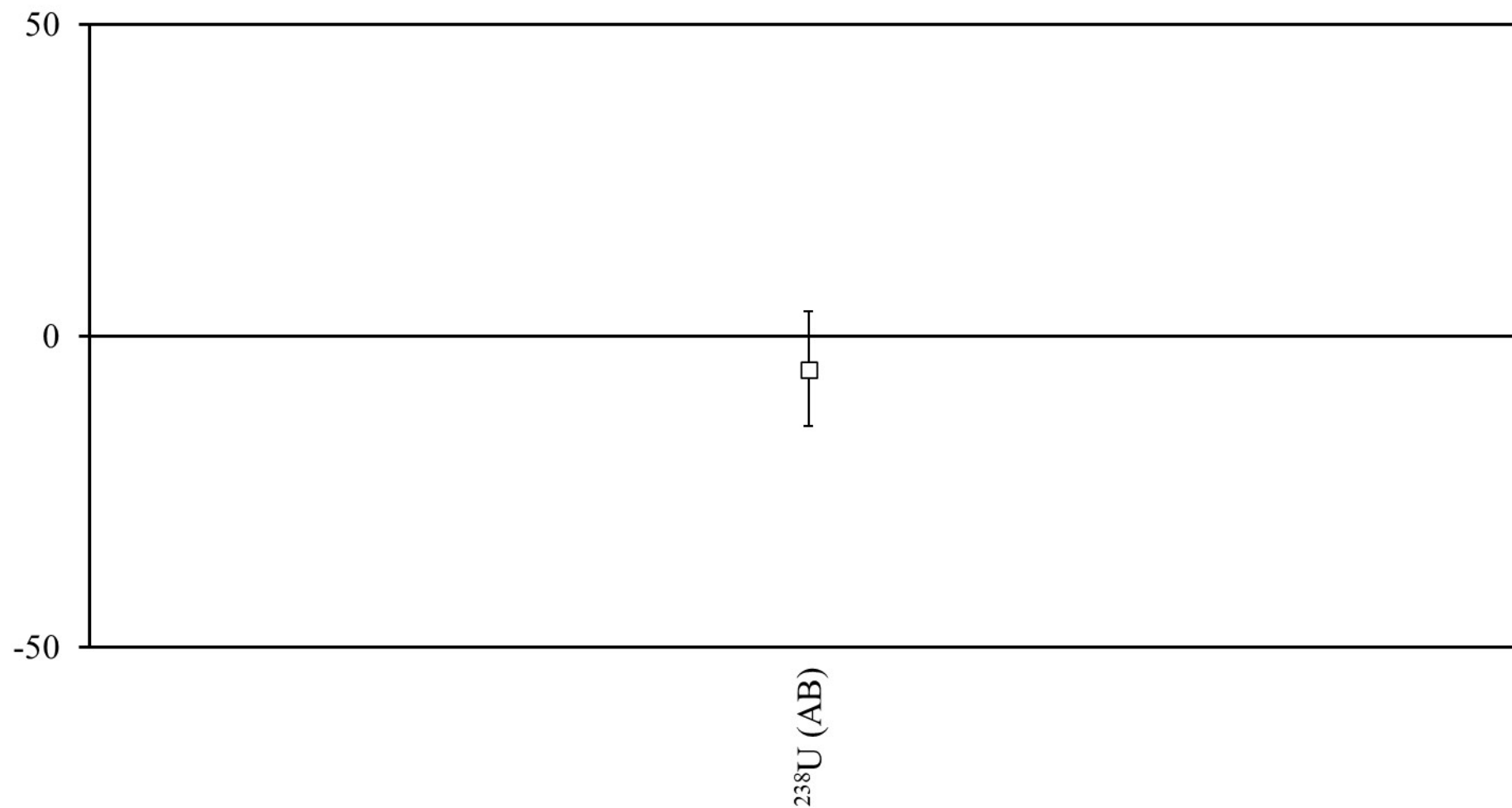
Radionuclide	Laboratory 194	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	3.98 ± 0.31	3.89 ± 0.10	2.3	0.28	0.40
⁵⁷ Co (GH)	12.17 ± 0.94	12.35 ± 0.33	-1.5	-0.18	-0.25
⁶⁵ Zn (GH)	11.16 ± 0.86	10.68 ± 0.26	4.5	0.53	0.77
¹³³ Ba (GH)	34.0 ± 2.6	34.4 ± 1.4	-1.2	-0.14	-0.20
¹³⁷ Cs (GH)	7.00 ± 0.54	6.99 ± 0.10	0.1	0.02	0.02
⁸⁸ Y (GL)	35.5 ± 4.8	36.22 ± 0.23	-2.0	-0.15	-0.34
¹³⁹ Ce (GL)	46.0 ± 2.6	47.65 ± 0.88	-3.5	-0.60	-0.59
²¹⁰ Pb (GL)	17.3 ± 3.7	16.44 ± 0.18	5.2	0.23	0.90
²⁴¹ Am (GL)	36.3 ± 1.9	45.08 ± 0.28	-19.5	-4.57	-3.34

Deviation (%) of Laboratory 195.1

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 195.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	13.08 ± 0.44	12.55 ± 0.18	4.2	1.11	0.73
^{63}Ni (AB)	4.66 ± 0.17	4.618 ± 0.026	0.9	0.24	0.16
^{90}Sr (AB)	2.433 ± 0.075	2.6067 ± 0.0091	-6.7	-2.30	-1.14
^{238}U (AB)	3.542 ± 0.063	3.601 ± 0.047	-1.6	-0.75	-0.28
^3H (B1)	0.533 ± 0.017	0.5175 ± 0.0078	3.0	0.83	0.51
^{14}C (B1)	0.165 ± 0.011	0.1557 ± 0.0012	6.0	0.84	1.03
^{54}Mn (GH)	3.90 ± 0.16	3.89 ± 0.10	0.3	0.05	0.04
^{57}Co (GH)	11.48 ± 0.49	12.35 ± 0.33	-7.0	-1.47	-1.21
^{65}Zn (GH)	10.84 ± 0.45	10.68 ± 0.26	1.5	0.31	0.26
^{133}Ba (GH)	32.6 ± 1.1	34.4 ± 1.4	-5.2	-1.01	-0.90
^{137}Cs (GH)	6.90 ± 0.28	6.99 ± 0.10	-1.3	-0.30	-0.22

Deviation (%) of Laboratory 195.2

NATIONAL PHYSICAL LABORATORY

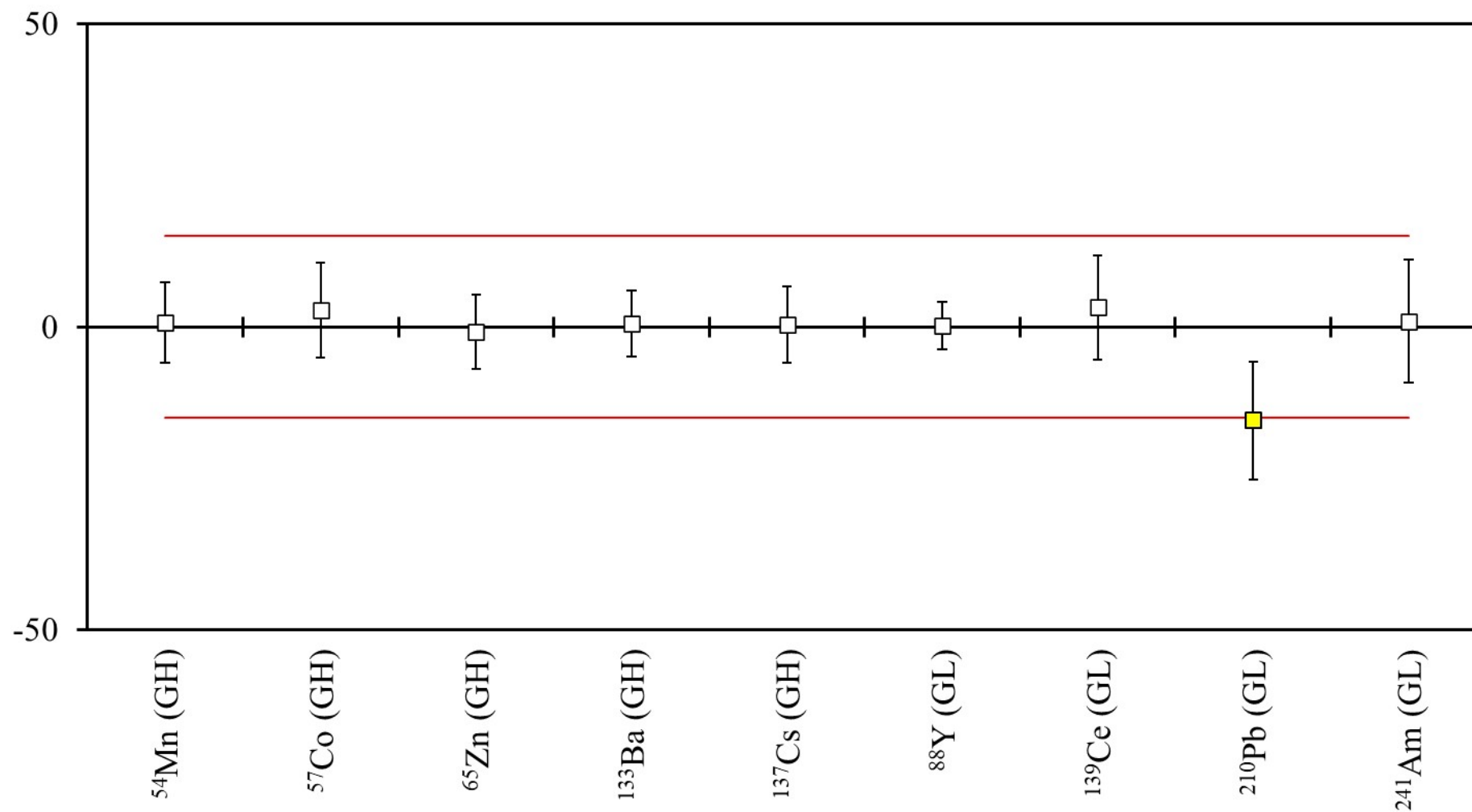
Continuation Sheet

Radionuclide	Laboratory 195.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
^{238}U (AB)	3.41 ± 0.33	3.601 ± 0.047	-5.3	-0.57	-0.91

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Laboratory 200

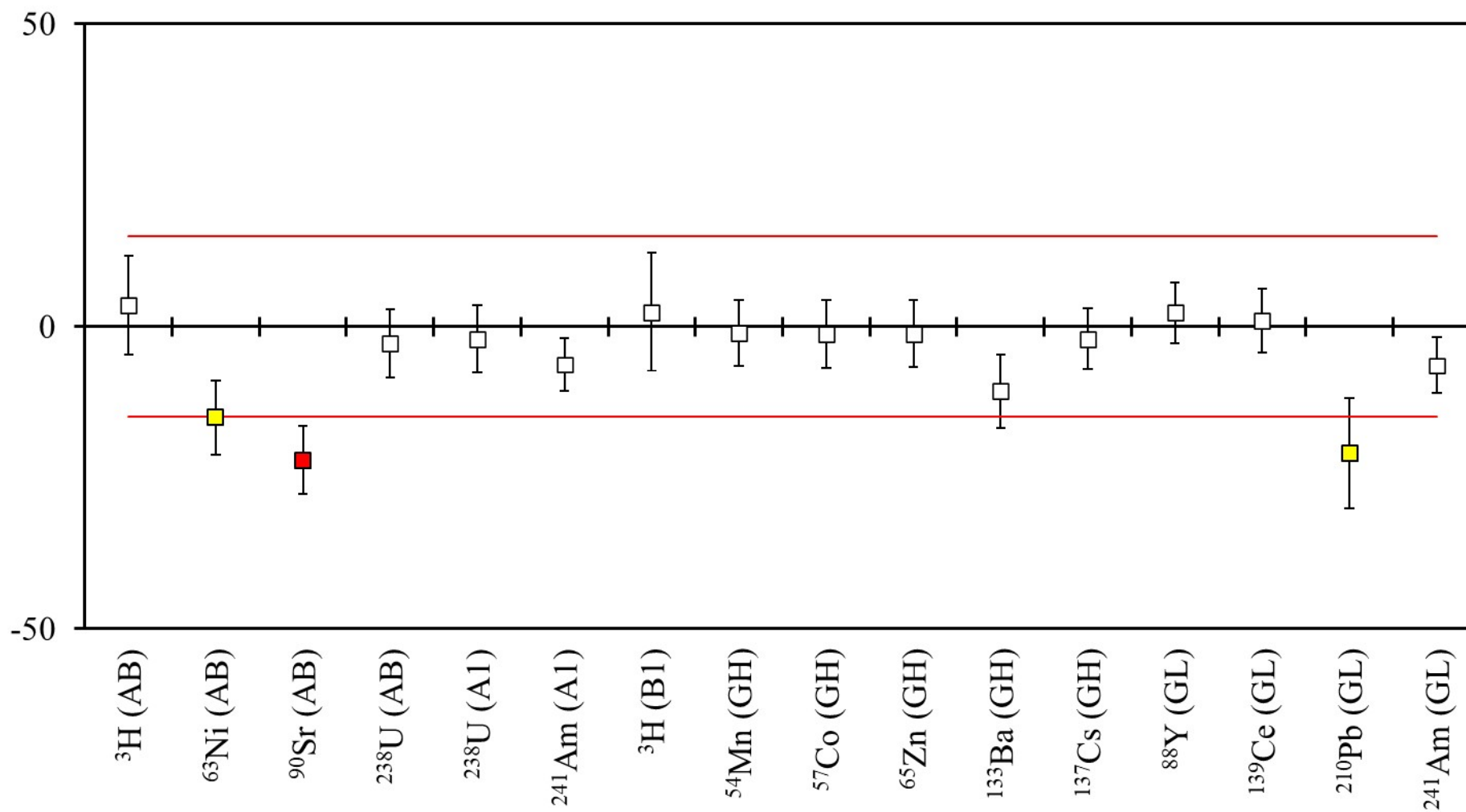


Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

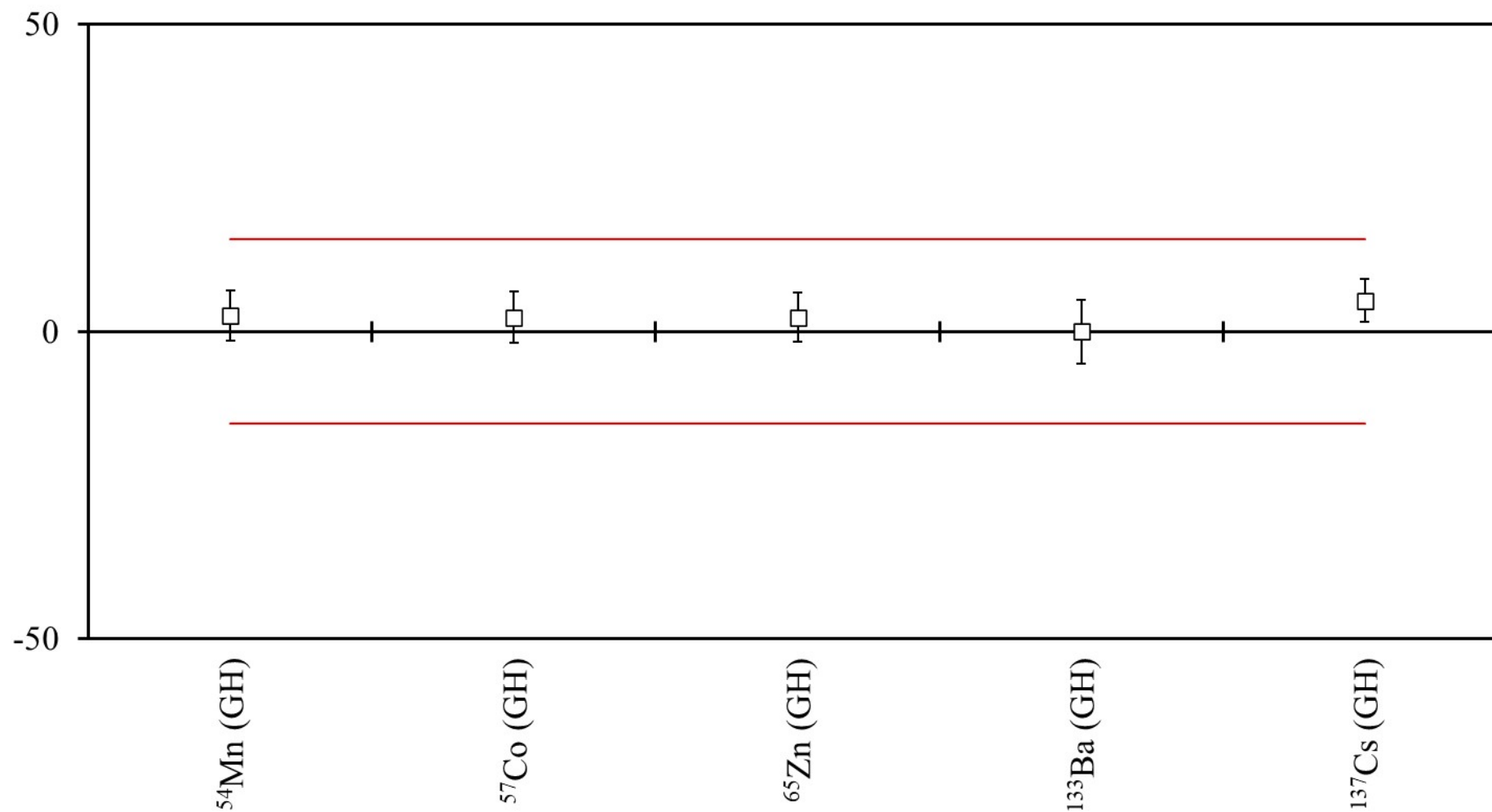
Radionuclide	Laboratory 200	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	3.92 ± 0.24	3.89 ± 0.10	0.8	0.12	0.13
⁵⁷ Co (GH)	12.70 ± 0.90	12.35 ± 0.33	2.8	0.37	0.49
⁶⁵ Zn (GH)	10.60 ± 0.60	10.68 ± 0.26	-0.7	-0.12	-0.13
¹³³ Ba (GH)	34.6 ± 1.2	34.4 ± 1.4	0.6	0.11	0.10
¹³⁷ Cs (GH)	7.02 ± 0.43	6.99 ± 0.10	0.4	0.07	0.07
⁸⁸ Y (GL)	36.3 ± 1.4	36.22 ± 0.23	0.2	0.06	0.04
¹³⁹ Ce (GL)	49.2 ± 4.0	47.65 ± 0.88	3.3	0.38	0.56
²¹⁰ Pb (GL)	13.9 ± 1.6	16.44 ± 0.18	-15.5	-1.58	-2.65
²⁴¹ Am (GL)	45.5 ± 4.6	45.08 ± 0.28	0.9	0.09	0.16

Deviation (%) of Laboratory 203

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 203	NPL Assigned Value	Deviation /%	Zeta	Z Score
^3H (AB)	13.0 ± 1.0	12.55 ± 0.18	3.6	0.44	0.62
^{63}Ni (AB)	3.92 ± 0.28	4.618 ± 0.026	-15.1	-2.48	-2.60
^{90}Sr (AB)	2.03 ± 0.13	2.6067 ± 0.0091	-22.1	-4.43	-3.80
^{238}U (AB)	3.50 ± 0.20	3.601 ± 0.047	-2.8	-0.49	-0.48
^{238}U (A1)	54.0 ± 3.0	55.14 ± 0.72	-2.1	-0.37	-0.36
^{241}Am (A1)	84.0 ± 4.0	89.66 ± 0.35	-6.3	-1.41	-1.08
^3H (B1)	0.530 ± 0.050	0.5175 ± 0.0078	2.4	0.25	0.41
^{54}Mn (GH)	3.85 ± 0.19	3.89 ± 0.10	-1.0	-0.19	-0.18
^{57}Co (GH)	12.21 ± 0.61	12.35 ± 0.33	-1.1	-0.20	-0.19
^{65}Zn (GH)	10.56 ± 0.54	10.68 ± 0.26	-1.1	-0.20	-0.19
^{133}Ba (GH)	30.7 ± 1.7	34.4 ± 1.4	-10.8	-1.69	-1.85
^{137}Cs (GH)	6.85 ± 0.34	6.99 ± 0.10	-2.0	-0.40	-0.34
^{88}Y (GL)	37.1 ± 1.8	36.22 ± 0.23	2.3	0.45	0.39
^{139}Ce (GL)	48.1 ± 2.3	47.65 ± 0.88	1.0	0.18	0.17
^{210}Pb (GL)	13.0 ± 1.5	16.44 ± 0.18	-21.0	-2.31	-3.60
^{241}Am (GL)	42.2 ± 2.1	45.08 ± 0.28	-6.4	-1.38	-1.10

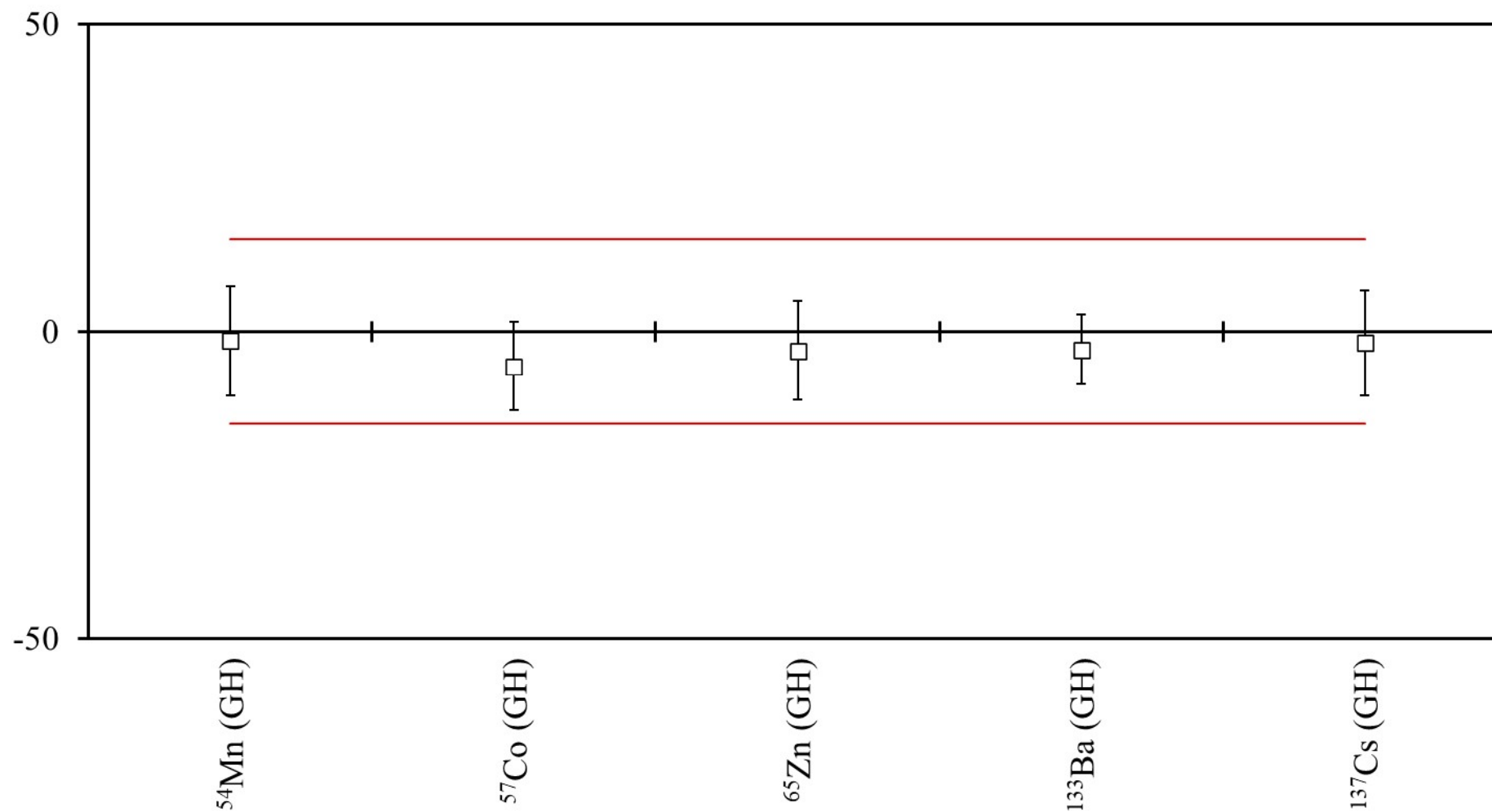
Deviation (%) of Laboratory 205.1

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 205.1	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	3.99 ± 0.12	3.89 ± 0.10	2.6	0.64	0.44
⁵⁷ Co (GH)	12.64 ± 0.38	12.35 ± 0.33	2.3	0.58	0.40
⁶⁵ Zn (GH)	10.93 ± 0.33	10.68 ± 0.26	2.3	0.60	0.40
¹³³ Ba (GH)	34.4 ± 1.1	34.4 ± 1.4	0.0	0.00	0.00
¹³⁷ Cs (GH)	7.34 ± 0.22	6.99 ± 0.10	5.0	1.45	0.86

Reference: RR10 PTE 24-25 Final Report Version 1.0

Deviation (%) of Laboratory 205.2

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Radionuclide	Laboratory 205.2	NPL Assigned Value	Deviation /%	Zeta	Z Score
⁵⁴ Mn (GH)	3.83 ± 0.33	3.89 ± 0.10	-1.5	-0.17	-0.26
⁵⁷ Co (GH)	11.65 ± 0.84	12.35 ± 0.33	-5.7	-0.78	-0.97
⁶⁵ Zn (GH)	10.35 ± 0.83	10.68 ± 0.26	-3.1	-0.38	-0.53
¹³³ Ba (GH)	33.4 ± 1.4	34.4 ± 1.4	-2.9	-0.51	-0.50
¹³⁷ Cs (GH)	6.86 ± 0.59	6.99 ± 0.10	-1.9	-0.22	-0.32

10. DISCUSSION

Accurate and precise measurement of the activity per unit mass of radionuclides in the environment is critical for the assessment of the radiological impact and risk to the public and environment for both routine analysis and in the instance of a nuclear or radiological emergency. It is for this reason that some radionuclides appear routinely in the exercise such as ^3H , ^{14}C , ^{90}Sr , ^{210}Pb and ^{241}Am . The following section of this report discusses the results for the 2024/25 Environmental Radioactivity Proficiency Test Exercise.

As part of the reporting process laboratories are required to submit a reporting form which contains their measurement results and corresponding uncertainties. Laboratories were also invited to submit a techniques form. In some instances, participating laboratories did not submit a techniques form accompanying their results. The information provided below relating to methods/techniques therefore refers to a subset of participants who did report such information. For NPL to provide performance-related feedback, it is encouraged that participants detail the methods and techniques used.

Firstly, it should be mentioned that any standards used during instrument calibration or for yield/recovery calculations should be traceable back to the International System of Units. Such standards can be acquired from a variety of commercial suppliers (including National Metrology Institutes). In particular, activity standards should be traceable to the Becquerel and mass standards to the kilogram. It should be noted that standards purchasable through NPL are frequently those used in the production of the proficiency test items.

This exercise included results for numerous measurands using a wide spread of methodologies. The measurement uncertainties resulting from for each method will consist of different components and should be assessed in accordance with the 'Guide to the expression of uncertainty in measurement' (JCGM 100:2008). Participants are encouraged to review their uncertainty budgets to ensure that they are comprehensive and provide a reasonable estimation of the overall uncertainty. There are instances throughout the report where results are marked as questionable due to failing the relative uncertainty test. It is suggested in these instances that participants review their uncertainty budgets. Following review, if the uncertainty budget is believed to be comprehensive it might be that the R_L test failed because of differences in the applied method as compared with other participating laboratories. This may be that a laboratory chose a direct measurement method, which would generally have a lower uncertainty budget, compared to other participating laboratories who measured following extensive radiochemistry.

Please note that the half-lives stated below are taken from the internationally recognised Decay Data Evaluation Project (DDEP), where a year is defined as 365.24219878 days (BIPM, 2004).

10.1 TRITIUM IN AB

Tritium (^3H) is produced by neutron activation of deuterium and neutron induced fission and spallation. It occurs widely in the environment as a result of cosmic ray interactions, releases from nuclear weapon tests and discharges from the nuclear industry. Tritium is a low-energy beta emitter ($E_{\text{max}} = 18.564 \text{ keV}$) with a half-life of 12.312 (25) years (BIPM, 2004) decaying down to ^3He . Despite its mass difference from protium (^1H), tritium (^3H) shares the same physicochemical behaviour, most commonly occurring as tritiated water (HTO) in the environment. It can also be found in gaseous form in the atmosphere and as organically bound tritium (OBT) in biological systems.

In the AB sample, the primary analytical challenge was the accurate quantification of ^3H in the presence of other beta-emitting radionuclides (^{63}Ni and ^{90}Sr). Complete separation of ^3H is essential for accurate determination and can be achieved either through chemical separation or by defining appropriate regions of interest during liquid scintillation counting (LSC).

All 17 laboratories that reported their detection technique used LSC for ^3H analysis, reflecting its suitability for low-energy beta emitters. However, LSC performance is highly sensitive to quenching, which may vary between samples, and affects counting efficiency. Accurate quantification requires sample-specific quench correction, typically achieved through the use of quench curves. These curves must be tailored to the specific instrument, scintillation cocktail, and sample-to-cocktail ratio. Routine instrument checks to monitor instrument response over time using known activity sources (e.g., ^3H and ^{14}C) are also recommended, with results monitored using Shewhart control charts in accordance with ISO 7870-2:2023.

Of the 16 laboratories that provided details on sample preparation and radiochemistry, the majority (10) used distillation to isolate ^3H . Two laboratories employed chromatographic techniques, including mixed-bed ion exchange and Eichrom resin-based separation.

The majority of results (75 %) were classified as in agreement, indicating satisfactory performance across most laboratories. A small proportion (5 %) were questionable, suggesting minor deviations that may be attributed to quenching effects, calibration drift, incomplete separation or errors in recovery calculations. On average, participant results showed a slight positive bias of approximately 3.6 %, with a zeta-score of 1.67, which remained well within the acceptable critical value.

Reference: RR10 PTE 24-25 Final Report Version 1.0

10.2 NICKEL-63 IN AB

Nickel-63 is a low-energy beta emitter ($E_{\text{max}} = 66.9$ keV) with a half-life of 98.7 (24) years that decays to ^{63}Cu (BIPM, 2004). Nickel-63 is generated by neutron capture of the stable isotope ^{62}Ni and is commonly found in nuclear waste and activation products. In aqueous matrices such as the AB sample type, ^{63}Ni presents analytical challenges due to its low energy emissions and potential interference from other beta emitters.

Of the 16 laboratories that submitted results for ^{63}Ni , 14 reported their detection technique, all of which used liquid scintillation counting (LSC). One laboratory additionally reported using ICP-OES to determine chemical recovery through the measurement of stable Ni. The presence of stable Ni in the AB matrix, used as a carrier for ^{63}Ni , may have contributed to overestimation of recovery in cases where it was not properly accounted for, potentially impacting final activity calculations.

Reported chemical separation techniques varied, with a preference for extraction chromatography. Other methods included solvent extraction, ion exchange, and solid-phase extraction. One laboratory described a multi-stage radiochemical process involving precipitation, purification, and ion exchange.

Participant performance for ^{63}Ni showed the lowest agreement rate among the AB sample radionuclides. Only 63 % of results were classified as in agreement, while 31 % were questionable and 6 % were discrepant. On average, participant results showed a negative bias of approximately 3.2 %, with a zeta-score of -0.96 .

10.3 STRONTIUM-90 IN AB

Strontium-90 is a beta-emitting radionuclide with a half-life of 28.80 (7) years (BIPM, 2004), making it environmentally significant due to its persistence and radiotoxicity. It is a high-yield fission product released into the environment through nuclear weapons testing, reactor accidents, and nuclear fuel reprocessing. In contrast, ^{89}Sr , with a much shorter half-life of 50.57 (3) days, is more relevant in emergency response scenarios but less so in long-term environmental monitoring.

Strontium-90 emits beta particles with a maximum energy of 586.1 (22) keV and decays to ^{90}Y which emits beta particles with a maximum energy of 2278.7 (16) keV. Accurate measurement of ^{90}Sr activity per unit mass requires effective radiochemical separation from other radionuclides. Although ^{90}Y was in secular equilibrium with the ^{90}Sr at time of dispatch, radiochemical separation will usually disrupt this equilibrium and it may be necessary to correct for this effect in any subsequent measurements. ISO 13160:2021 outlines robust

methods for measuring ^{89}Sr and ^{90}Sr in water using LSC and proportional counting, which were reflected in participant methodologies.

A range of separation techniques were reported, including precipitation, purification, extraction chromatography, liquid extraction, solid-phase extraction, evaporation, and ion exchange. Extraction chromatography was the most used method. For detection, laboratories employed LSC (13), Cerenkov counting (4), and proportional counting (1). Tracers such as ^{85}Sr , stable strontium, and yttrium were used to monitor recovery and separation efficiency. Of the results submitted, 81 % were classified as in agreement, while 10 % were discrepant. On average, participant results showed a negative bias of approximately 4.8 %, with a zeta-score of -3.42 .

10.4 URANIUM-238 IN AB

Uranium-238 is a naturally occurring primordial nuclide which decays mainly by emission of alpha particles to relatively short-lived ^{234}Th . Uranium-238 is a terrestrial radionuclide, widely present in soils, rocks, minerals, and water. In addition to its natural abundance, ^{238}U can also originate from anthropogenic sources such as phosphate fertilisers, mining and milling residues, fly ash from coal-fired power plants, and defence-related activities. Its long half-life of $4.468(5) \times 10^9$ years (BIPM, 2004) makes it a persistent contributor to environmental radioactivity.

Uranium-238 can be measured using a variety of techniques, including alpha spectrometry, mass spectrometry, and gamma spectrometry (typically via its short-lived daughter ^{234}Th). The primary analytical challenge in quantifying ^{238}U by alpha spectrometry lies in achieving effective radiochemical separation from other radionuclides present in the sample matrix.

This year's exercise saw 20 laboratories report results for ^{238}U in the AB sample type. Of these, 90 % were classified as in agreement. No significant systematic bias was observed between participant results and the NPL-assigned value.

Of the 20 reporting laboratories, 18 submitted technique forms detailing their methodologies. A wide range of radiochemical separation methods were employed, including cation and anion exchange chromatography, and liquid extraction. The most commonly used detection technique was alpha spectrometry (11), followed by mass spectrometry (2), and gamma spectrometry (2), the latter measuring ^{238}U indirectly via its daughter ^{234}Th . Three laboratories used combined techniques, with two using both alpha and gamma spectrometry, and one using alpha and mass spectrometry. Seventeen laboratories reported using ^{232}U as a tracer, whilst one laboratory used ^{233}U as a tracer in conjunction with thermal ionisation mass spectrometry (TIMS).

10.5 NEPTUNIUM-237 IN A1

This nuclide is produced by the decay of short-lived ^{237}U , which is formed by a ^{238}U (n,2n) reaction. It decays mainly by emission of alpha particles to relatively short-lived ^{233}Pa which subsequently undergoes beta minus decay to ^{233}U . Neptunium-237 is an artificial alpha-emitting radionuclide with a half-life of $2.144(7) \times 10^6$ years. It is primarily produced as a by-product in nuclear reactors and is relevant in waste characterisation and nuclear safeguards. Its chemical behaviour is analogous to uranium and plutonium, making separation challenging.

Neptunium-237 can be measured by three independent techniques: alpha spectrometry, gamma spectrometry and mass spectrometry. The main challenge in measuring the ^{237}Np activity per unit mass with alpha spectrometry and mass spectrometry is the need for a radiochemical separation from the other radionuclides present in the sample.

This year's exercise saw 12 laboratories report results for ^{237}Np , of which 58 % were in agreement and 33 % were discrepant — the highest discrepancy rate among the A1 radionuclides. Technique forms were submitted by 11 laboratories, providing insight into their analytical approaches. Detection methods varied: four laboratories used alpha spectrometry, four used gamma spectrometry, and three used mass spectrometry.

Three laboratories reported using ^{239}Np ($t_{1/2} = 2.39$ days) as a tracer to monitor chemical recovery. Given its short half-life, careful timing and decay correction are essential to ensure accurate yield estimation. Five laboratories measured the sample directly without radiochemistry, and all these results were in agreement with the assigned value.

Neptunium-237 showed the largest deviation among the A1 radionuclides, with a participant mean 10.1 % below the assigned value and a zeta-score of -1.83 . Although this score remained within the critical value of 3.25, the deviation suggests potential issues with chemical recovery, tracer correction, or incomplete separation from chemically similar actinides.

The PMM of mass spectrometry and liquid scintillation counting results were as follows:

Alpha Spectrometry: $(19.0 \pm 3.8) \text{ Bq kg}^{-1}$

Gamma Spectrometry: $(18.3 \pm 6.0) \text{ Bq kg}^{-1}$

Mass Spectrometry: $(22.0 \pm 1.2) \text{ Bq kg}^{-1}$

The ^{237}Np alpha spectrometry results saw four results submitted, two within 1 % deviation and two > -40 % deviation. The gamma spectrometry results were even more spread with two > 6 % deviation and the other two results > -39 %. The three mass spectrometry results all had a low deviation. Due to the size of the dataset and the varied methods leading up to

the final analysis, it is not possible to conclude whether the results obtained with these techniques are equivalent.

10.6 URANIUM-238 IN A1

As described in section 10.4, uranium-238 is a naturally occurring terrestrial radionuclide. Uranium-238 can be measured by alpha spectrometry, gamma spectrometry and mass spectrometry. The main difficulty in measuring the ^{238}U activity concentration with alpha spectrometry is the need for a radiochemical separation from the other radionuclides present in the sample.

This year's exercise saw 18 results reported for ^{238}U in the A1 sample type. Of these results, 94 % were in agreement with the assigned value. There was no significant systematic bias (deviation, -2.7%) between participants' results and the NPL value.

Of the 18 reporting laboratories, 17 provided a techniques form. Many different methodologies for radiochemical separation were reported including cation and anion exchange chromatography, and liquid extraction. The most common detection technique for ^{238}U was alpha spectrometry (12) with three laboratories opting to measure ^{238}U by mass spectrometry. One laboratory reported using gamma spectrometry and another reported using a combination of mass spectrometry and alpha spectrometry.

The PMM of mass spectrometry and alpha spectrometry results were as follows:

Mass Spectrometry: $(53.1 \pm 3.1) \text{ Bq kg}^{-1}$

Alpha Spectrometry: $(53.72 \pm 0.78) \text{ Bq kg}^{-1}$

No significant bias is observed between results obtained by the various detection techniques. Due to the size of the dataset and the varied methods leading up to the final analysis, it is not possible to conclude whether the results obtained with these techniques are equivalent.

10.7 AM-241 IN A1

Americium-241 has a half-life of 432.6 (6) years and is a beta decay product from ^{241}Pu produced in nuclear reactors. It is an alpha emitter, with the most probable emissions being 5.485 MeV (84.45 %) and 5.443 MeV (13.23 %) (BIPM 2004). Americium-241 is the most important radioisotope of americium for environmental measurements due to the other long-lived isotope ^{243}Am being produced in nuclear reactors in smaller activities compared to ^{241}Am . It occurs widely in the environment as a result of weapon tests as well as discharges from the nuclear industry.

Americium-241 can be measured by three independent techniques: alpha spectrometry, gamma spectrometry and mass spectrometry. The main difficulty in measuring the ^{241}Am activity concentration with alpha spectrometry is the need for a radiochemical separation from the other radionuclides present in the sample.

Of the reporting laboratories (18), 16 provided techniques forms which detailed the most popular detection technique as alpha spectrometry with 12 laboratories reporting to use this. Out of the remaining three laboratories, two reported to have used gamma spectrometry and the other one using mass spectrometry.

Out of those who listed their separation and radiochemistry methods extraction chromatography was used the most followed by ion exchange and precipitation, and solid phase extraction. Five laboratories reported using electrodeposition as a source preparation technique for alpha spectrometry. Of all the results submitted for ^{241}Am in the A1 sample type, 83 % were in agreement and 17 % were discrepant.

10.8 TRITIUM IN B1

With a half-life of 12.312 (25) years, tritium decays via beta minus emission to the ^3He with a E_{max} of 18.564 (3) keV (BIPM, 2004). More details relating to the radionuclide provided in section 10.1. The main challenge in measuring the tritiated water activity per unit mass is the need for a radiochemical separation from other beta-emitters i.e. ^{14}C in the B1 sample type. Differing from the AB sample the B1 sample is an alkaline solution.

Out of the 23 who submitted results, 21 also provided a techniques form where all 21 used LSC as their detection technique. Of the 16 that listed separation methods, 13 used distillation, one used pyrolysis and one used combustion. The other one laboratory reported using extraction of ^3H using an Eichrom resin giving a result in agreement with the NPL value. Out of these results 91 % were in agreement and 9 % were discrepant. This is an improvement compared to the previous exercise where 77 % were in agreement, 8 % were questionable and 15 % were discrepant.

10.9 CARBON-14 IN B1

This nuclide is formed by interaction of ^{14}N with neutrons produced in the upper atmosphere by cosmic-ray interactions. It occurs widely in the environment as a result of the natural process mentioned above and as a result of releases from nuclear weapon tests and discharges from the nuclear industry. Carbon-14 has a half-life of 5700 (30) years, and decays via beta minus emission to stable nitrogen (^{14}N) with a E_{max} of 156.476 (4) keV (BIPM, 2004). The primary issue in measuring the activity per unit mass of ^{14}C in B1 is the requirement for a radiochemical separation from ^3H .

Out of those who reported a detection technique, all (16) stated that they used LSC. A number of separation methods were reported with the most used being combustion and oxidation followed by precipitation, pyrolysis, absorption and evaporation. From the results submitted 61 % were in agreement and 11 % were discrepant. This is slightly down from the last exercise which saw 71 % of results in agreement, 10 % questionable and 19 % discrepant.

10.10 TECHNETIUM-99 IN B1

This long-lived nuclide is produced by neutron-induced fission of ^{235}U and ^{239}Pu . It undergoes beta-decay ($E_{\text{max}} = 294 \text{ keV}$) to ^{99}Ru . It occurs widely in the marine environment as a result of discharges from the nuclear industry. The main difficulty in measuring the ^{99}Tc activity per unit mass is the need for a radiochemical separation from ^3H , and ^{14}C in the B1 sample type.

Technetium-99 had the lowest number of reported values for the B1 sample type with 13 reported results. Of the results submitted 85 % were in agreement, 8 % were questionable.

Radiochemical separation of ^{99}Tc from the other beta-emitters was achieved using a wide variety of techniques including, solvent extractions (2), ion-exchange chromatography and extraction chromatography (4) using extraction-based chromatography resins including TEVA (TrisKem International).

Technetium-99 may be measured by multiple detection techniques including mass spectrometry, liquid scintillation counting, gas-flow proportional counting or low-level beta counting. Participants reported using both mass spectrometry (7) and LSC (5). The chemical yield was traced by $^{99\text{m}}\text{Tc}$ (3), stable Re (2) or parallel standards of ^{99}Tc (3).

The PMM of mass spectrometry and liquid scintillation counting results were as follows:

Mass Spectrometry: $(0.1849 \pm 0.0063) \text{ Bq g}^{-1}$

Liquid Scintillation Counting: $(0.1862 \pm 0.0052) \text{ Bq g}^{-1}$

No significant bias is observed between results obtained by the two detection techniques.

10.11 SAMPLE TYPES GH AND GL

Both the GH and GL sample type contained radionuclides covering a broad range of emission energies. The GH sample type contained ^{54}Mn , ^{57}Co , ^{65}Zn , ^{133}Ba , ^{137}Cs and the GL sample type contained ^{88}Y , ^{139}Ce , ^{210}Pb , ^{241}Am . All reported detection techniques for GH and GL samples were done via gamma spectrometry and with 22 laboratories reported using a mix standard as a reference solution for energy/efficiency calibrations (either from NPL or Eckert & Zeigler).

As with previous exercises, the GH sample type saw comparatively few discrepant and questionable results when compared to other sample types. For the GH sample type the radionuclide with the lowest percentage agreement was ^{65}Zn with 87 %. This is the first time ^{65}Zn has appeared in the GH sample type since the 2021. There were three low discrepant results and one high questionable result. Of the low discrepant results, it is thought that one laboratory may have made an error in decay correcting their results (as their ^{133}Ba and ^{137}Cs results are in agreement) and another had a large systematic low bias across all radionuclides measured. There were multiple laboratories who had a consistent high or low bias for their GH/GL results. This is likely due to systematic error(s) and the methodology should be reviewed.

From the results submitted GL had high percentage agreements (> 80 %) in all the nuclides apart from ^{210}Pb with only 50 % of the results “in agreement”. The single gamma-ray emission of ^{210}Pb is of 46.59 keV ($I_\gamma = 4.252(4)$ per 100 decays). The low energy and low intensity of this emission can present a significant measurement challenge. For example, the energy can be outside the range of the measured efficiency calibration of laboratory’s gamma-ray detectors. The shielding of gamma spectrometers usually contains ^{210}Pb to some extent depending on the age of the lead used in the construction. As with previous years the GL sample type had low activity per unit mass for ^{210}Pb , comparable to that of environmental samples (i.e. Bq kg^{-1} levels), coupled with the low intensity of the emission meaning that accurate subtraction of the background is critical for accurate measurement. If the background radiation level is high, variable, or not properly accounted for, it may result in a higher net count rate for the ^{210}Pb peak, thus causing an overestimation.

Of the radionuclides in the GH sample type ^{133}Ba has the highest chance of summing. The deviation of participants’ results was – 0.6 % suggesting that cascade summing of ^{133}Ba had been generally well accounted for.

As with previous exercises there was a large range of uncertainties for the radionuclides measured by gamma spectrometry. More guidance and information on measurement of gamma emitting radionuclides in aqueous sample types are defined in ISO 10703:2021. Participants are advised to review their uncertainty budgets. Information on the uncertainty components (Type A and Type B) that contribute to an uncertainty budget relating to gamma spectrometry may be found in BS EN ISO 20042:2019.

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ISO 10703:2021. Water quality — Gamma-ray emitting radionuclides — Test method using high resolution gamma-ray spectrometry

BS EN ISO 20042:2019. Measurement of radioactivity — Gamma-ray emitting radionuclides — Generic test method using gamma-ray spectrometry

12. ACKNOWLEDGEMENTS

The authors wish to thank the participating organisations for the time and effort they have put into analysing the samples. They also thank colleagues Saskia Burke, Anu Bhaisare, Svetlana Kolmogorova, Heather Thompkins, Robert Shearman, Seán Collins, Steph Perry and Daniel Ainsworth for their help with preparing the samples, checking the dilution factors, dispatching the samples, and reviewing and approving this report. The authors also wish to thank Justin Oliver for assisting with the communications with participants and Arzu Arinc for her role as senior quality lead for the group.

13. APPENDICES

NPL has not used the PMM as the Assigned Value for the gross measurements due to the limited number of results submitted, the spread of those results and the variation in measurement techniques used. The laboratory results provided in the table below are listed as transcribed into the reporting form.

The values provided in the following tables are the PMM of the submitted results and are not traceable to national standards of radioactivity. The PMM of the gross measurements is provided as an indicator and has not been used for performance assessment. It is for this reason results for gross measurements do not appear in the main body of the report.

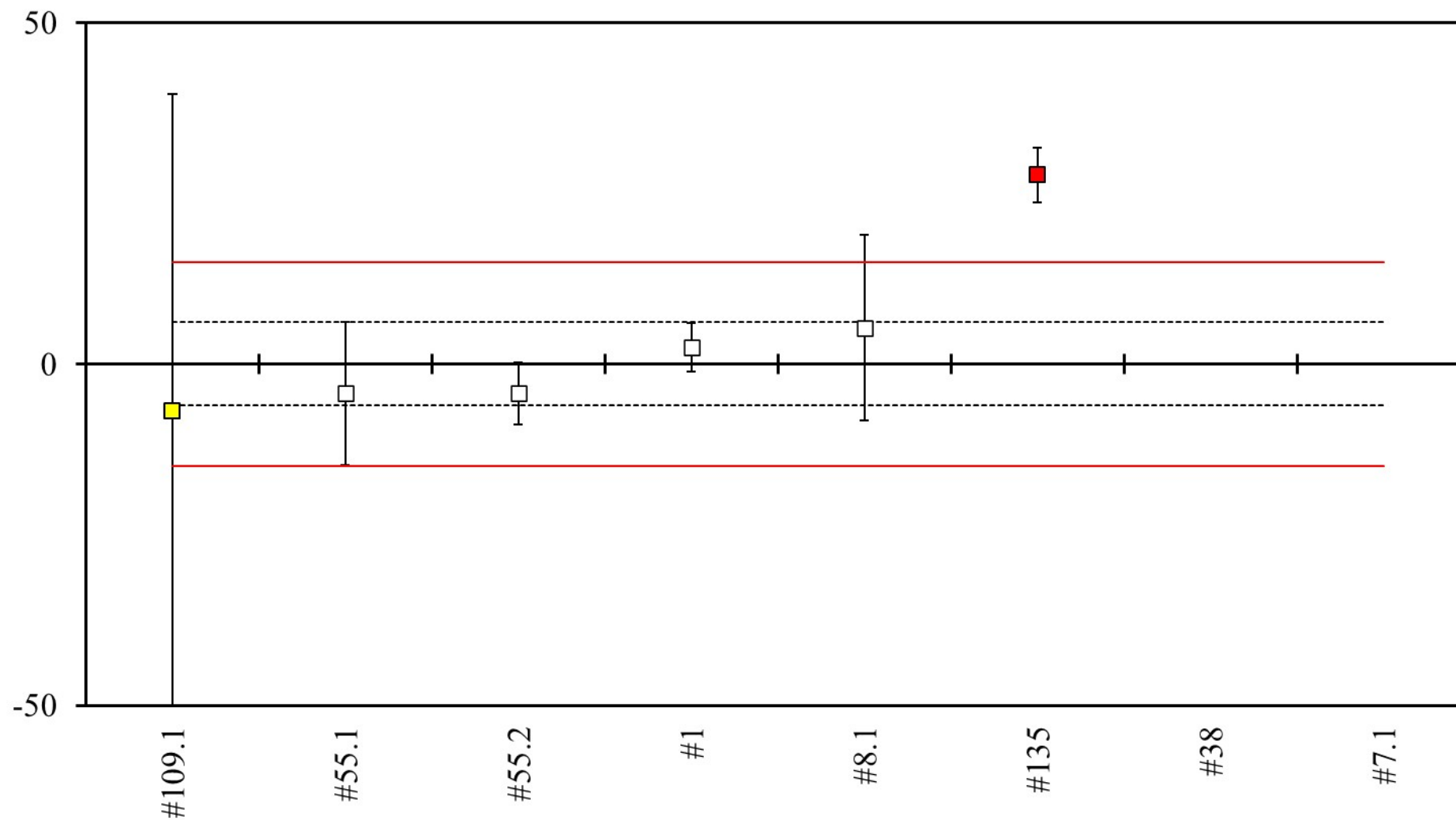
A1 Gross radionuclide measurements summary

Measurement	PMM
Gross beta (AB)	$10.45 \pm 0.25 \text{ Bq g}^{-1}$
Gross alpha (A1)	$217 \pm 11 \text{ Bq kg}^{-1}$
Gross beta (B1)	$0.41 \pm 0.14 \text{ Bq g}^{-1}$

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Grossbeta in AB



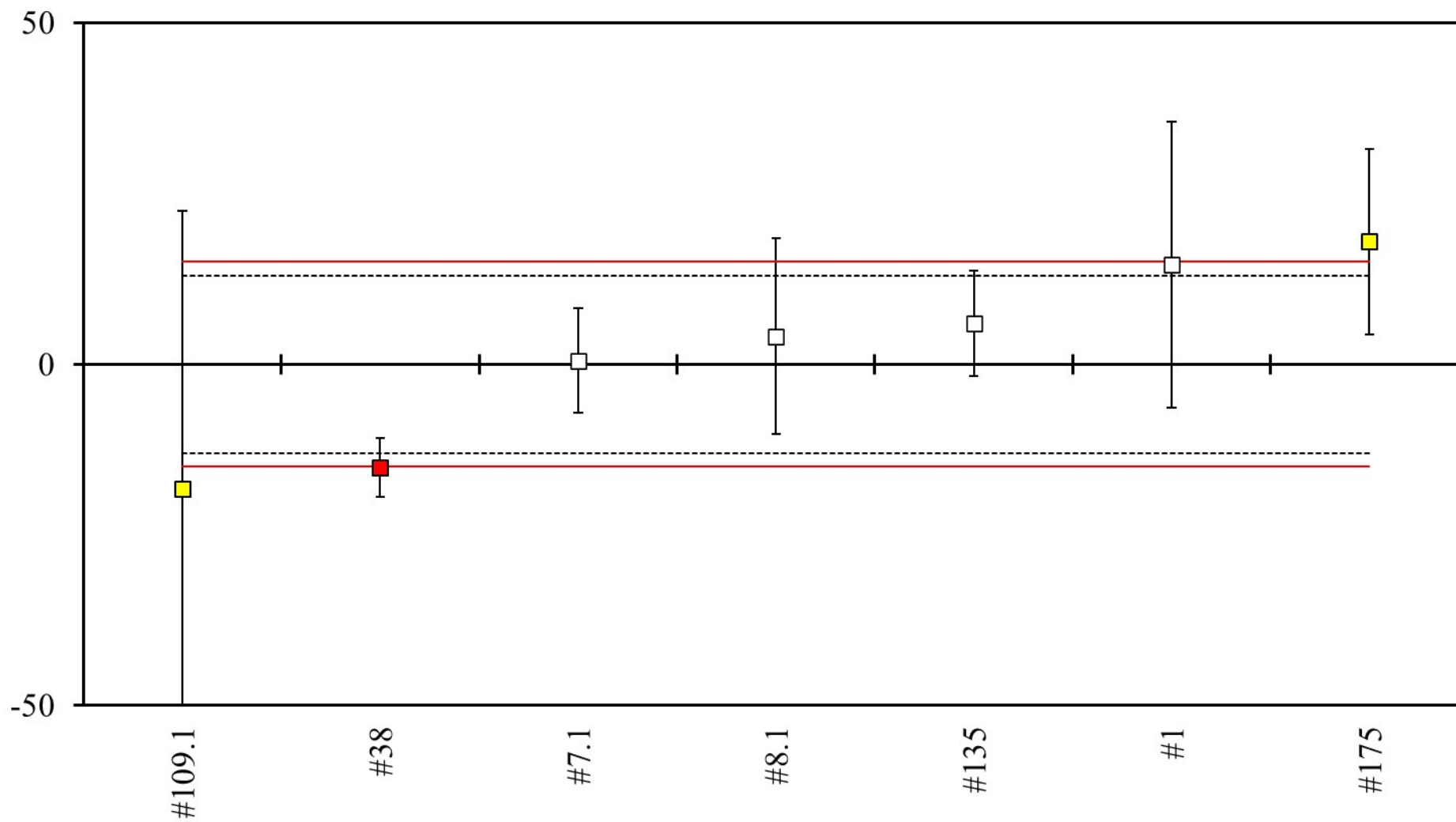
Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Lab Code	Lab Activity	Zeta	Z Score	Deviation
1	10.7129 ± 0.2674	0.72	0.43	3
7.1	35.1 ± 2.7	9.09	40.51	236
8.1	11 ± 1.4	0.39	0.90	5
38	23.8 ± 0.8	15.93	21.94	128
55.1	10 ± 1.07	-0.41	-0.74	-4
55.2	10 ± 0.418	-0.92	-0.74	-4
109.1	9.7245 ± 4.8622	-0.15	-1.19	-7
135	13.347 ± 0.268	7.90	4.76	28

Reference: RR10 PTE 24-25 Final Report Version 1.0

Deviation (%) of Grossalpha in A1

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

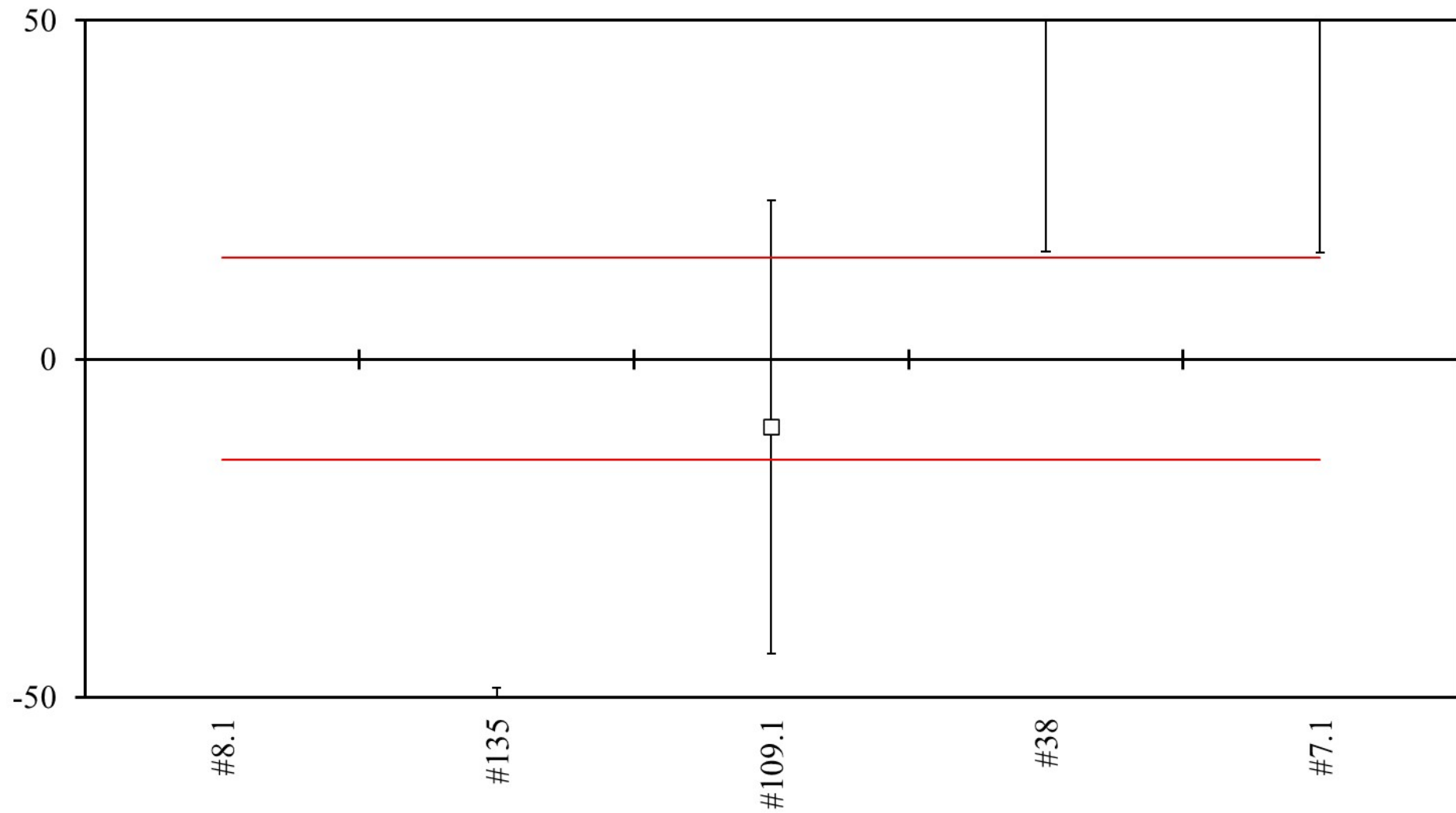
Lab Code	Lab Activity	Zeta	Rel. Unc.	Z Score
1	249 ± 44	0.70	0.18	2.50
7.1	218.23 ± 12.62	0.07	0.06	0.10
8.1	226 ± 29	0.29	0.13	0.71
38	184.0 ± 0.2	-3.00	0.00	-2.61
109.1	177± 88	-0.45	0.50	-3.17
135	230 ± 12	0.80	0.05	1.03
175	256.0 ± 26.3	1.37	0.10	3.09

Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Deviation (%) of Grossbeta in B1



Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

Lab Code	Lab Activity	Zeta	Rel. Unc.	Z Score
7.1	0.731 ± 0.06	2.11	0.08	13.45
8.1	0.0896 ± 0.0017	-2.29	0.02	-13.42
38	0.722 ± 0.005	2.23	0.01	13.07
109.1	0.3686 ± 0.0553	-0.28	0.15	-1.73
135	0.157 ± 0.003	-1.81	0.02	-10.60

Reference: RR10 PTE 24-25 Final Report Version 1.0

NATIONAL PHYSICAL LABORATORY

Continuation Sheet

[END OF REPORT]