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International Centre for Theoretical Physics**



1833-7

**Workshop on Understanding and Evaluating Radioanalytical
Measurement Uncertainty**

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**Analysis of Sr-89, Sr-90, Pu-238 and Pu-239 results in the NPL Environmental
Radioactivity Proficiency Test**

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^{89}Sr , ^{90}Sr , ^{238}Pu and ^{239}Pu results in NPL Environmental Radioactivity Proficiency Test Exercises (1989-2007)

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NPL Environmental Radioactivity Proficiency Test Exercises (I)

Since 1989, NPL has organised 13 environmental radioactivity proficiency test exercises (ER PTEs)

ER PTE 2007 is complete (7 aqueous samples and 1 solid sample)

AL and AH	^{226}Ra , ^{237}Np , ^{238}U , ^{238}Pu , ^{239}Pu , ^{241}Am and ^{244}Cm
BL and BH	^3H , ^{55}Fe , ^{63}Ni , ^{89}Sr , ^{90}Sr and ^{99}Tc
B2	^3H (both HTO and OBT), ^{14}C , ^{36}Cl and ^{129}I
GL and GH	^{60}Co , ^{95}Zr , ^{95}Nb , ^{125}Sb , ^{133}Ba , ^{134}Cs , ^{137}Cs , ^{144}Ce , ^{152}Eu and ^{155}Eu
C (concrete)	^3H , ^{60}Co , ^{133}Ba , ^{152}Eu and ^{154}Eu (and other activation products: ^{14}C , ^{41}Ca , ^{55}Fe and ^{63}Ni)

Treatment of data (I)

- (i) Zeta test
pass if $\text{Abs}(\text{zeta}) \leq 2.58$

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

- (ii) R_L outlier test
pass if not an outlier

$$R_L = \frac{u_L}{L}$$

- (iii) z test
pass if $\text{Abs}(\text{z test}) \leq 2.58$

$$z = \frac{L - N}{R_{\text{med}} N}$$

R_{med} = median of participants relative uncertainties R_L (generally between 5% and 10%)

Treatment of data (II)

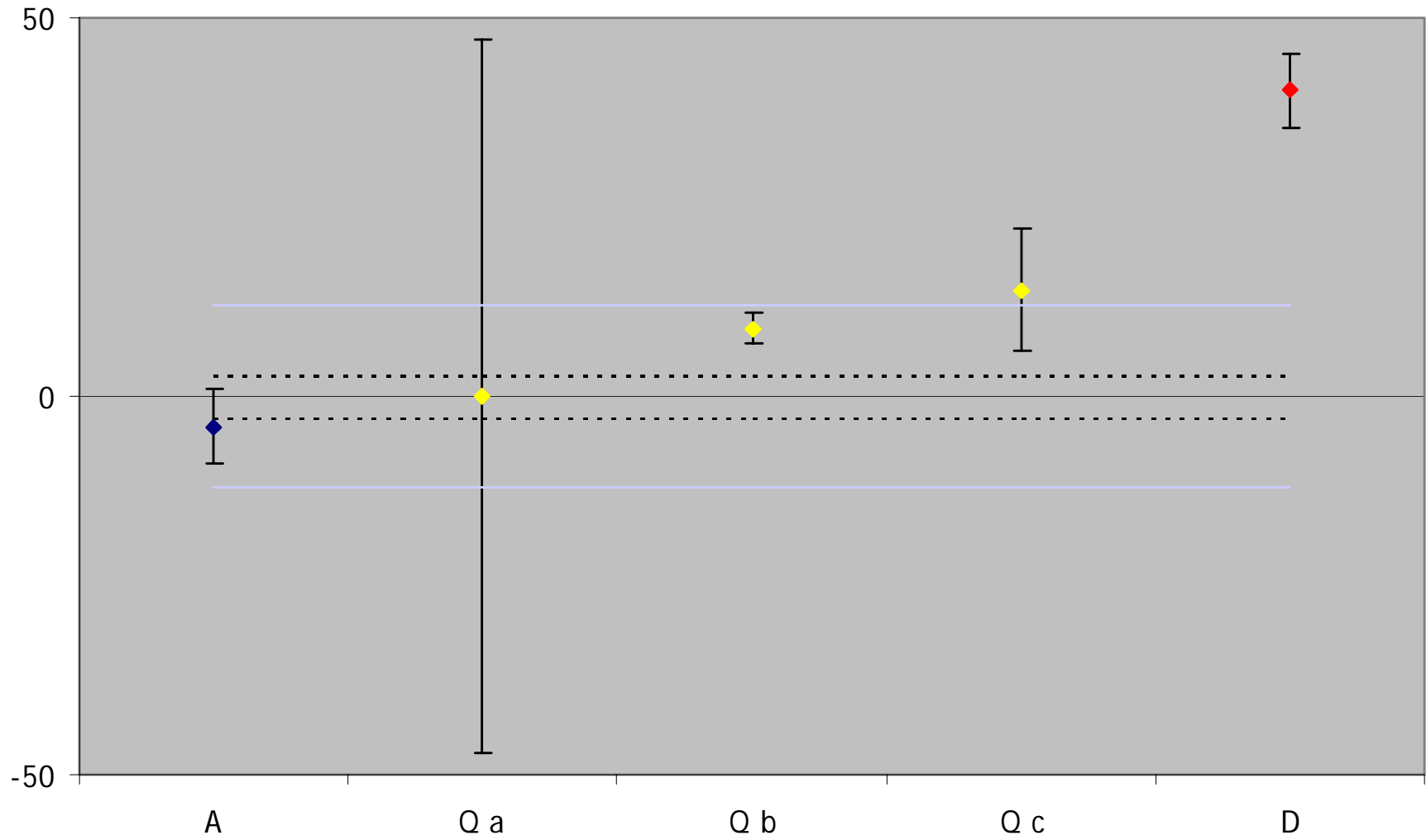
Zeta test	R_L test	z test	
pass	pass	pass	'In agreement'
pass	fail	pass	'Questionable' (a)
fail	pass/fail	pass	'Questionable' (b)
pass	pass/fail	fail	'Questionable' (c)
fail	pass/fail	fail	'Discrepant'

(a) Result close to NPL but unacceptable large uncertainty

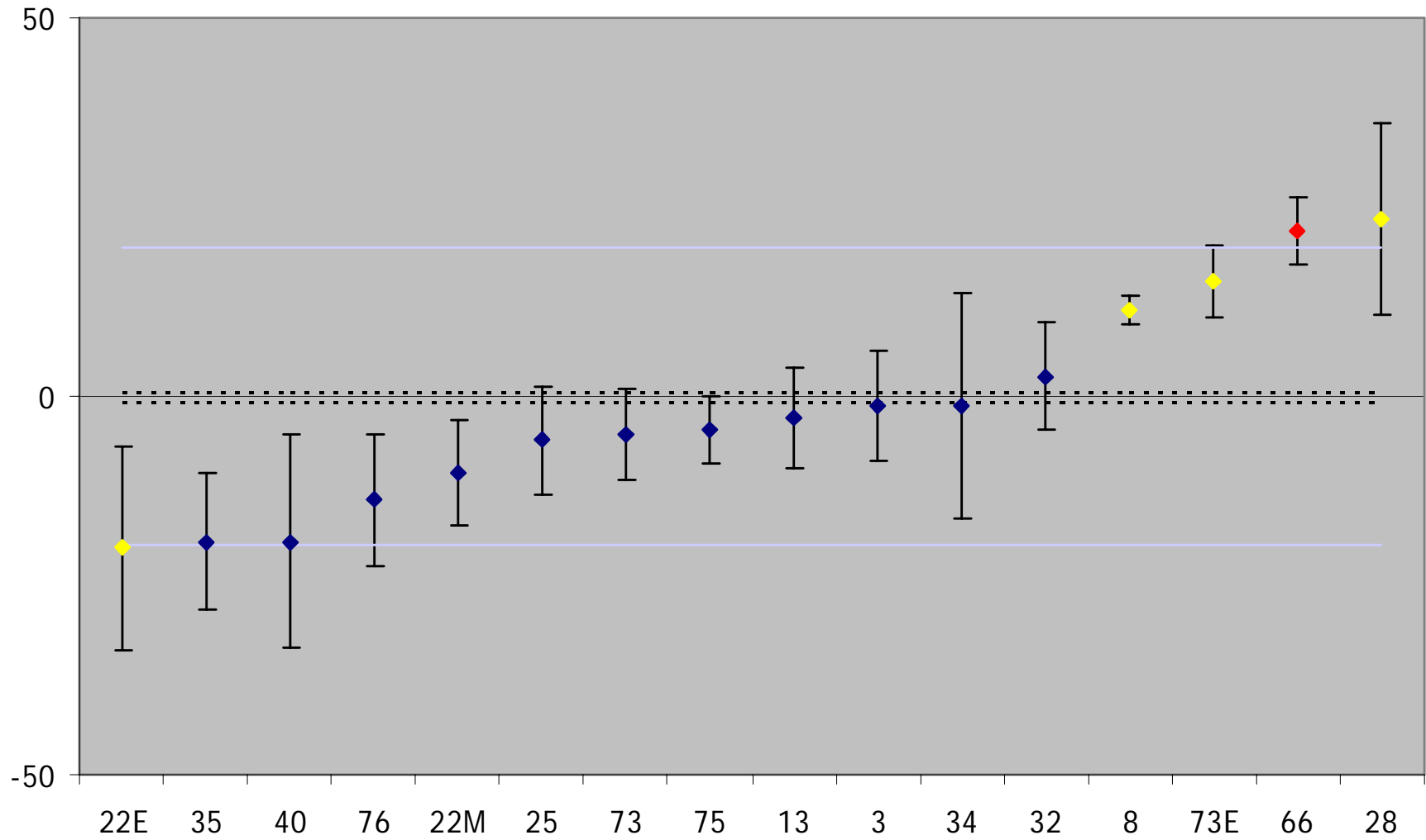
(b) Result close to NPL but uncertainty is too small to pass zeta test

(c) Result not close to NPL but large uncertainty results in passing the zeta test

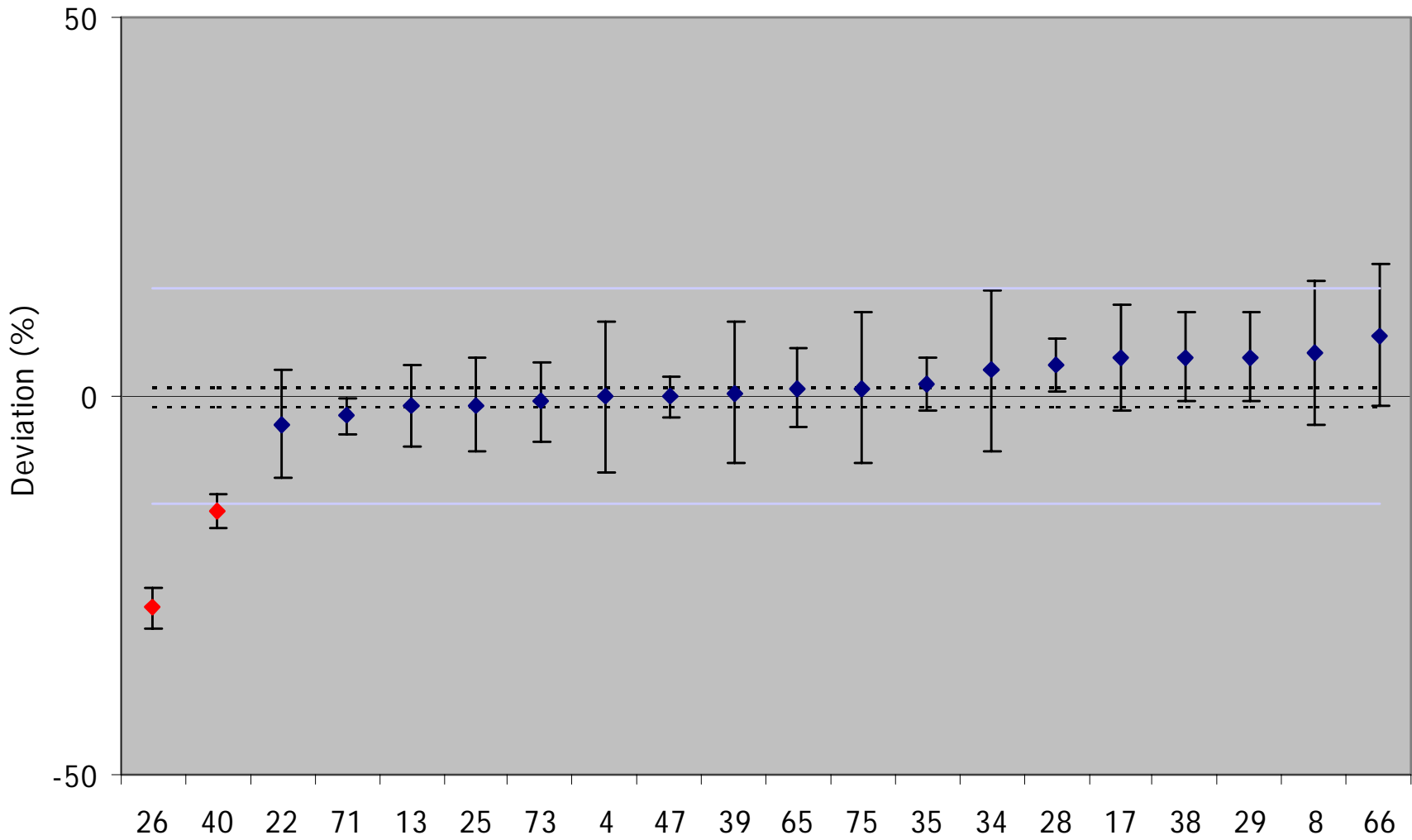
Deviation (%)



Deviation Sr-90 BL (%)



Deviation Pu-238 AL



NPL Environmental Radioactivity Proficiency Test Exercises (II)

Early exercises: almost exclusively UK participants (~20 labs)

ER PTE 2007: 64 participants (31 UK); 1295 results in total

Strontium and plutonium (activity range: 2 to 20,000 Bq kg⁻¹) in aqueous mixed nuclides samples requiring radiochemistry

In general, three months to analyse samples and submit results

Over the years, a variety of other radionuclides were also present in the samples containing Sr and Pu:

³H, ³⁵S, ⁵⁵Fe, ⁶⁰Co, ⁶³Ni, ⁹⁹Tc, ⁹⁵Zr, ⁹⁵Nb, ¹⁰⁶Ru, ¹³⁴Cs, ¹³⁷Cs, ¹⁴⁴Ce, ¹⁵⁴Eu, ²¹⁰Pb, ²²⁶Ra, ²³⁷Np, ²³⁸U, ²⁴¹Am and ²⁴⁴Cm

Data treatment combined exercises

Returned data was received as an activity concentration with a standard uncertainty

Median of the combined results calculated

The interquartile range (IQR) method was used to identify possible outliers. A value is considered as an outlier if it is:

$< (Q_L - 3 \text{ IQR})$ **or** $> (Q_U + 3 \text{ IQR})$ (with $\text{IQR} = Q_U - Q_L$)

Accepted range = 7 IQR

Unw. mean of the combined results (excluding outliers) calculated

NPL Environmental Radioactivity Proficiency Test Exercises (IV)

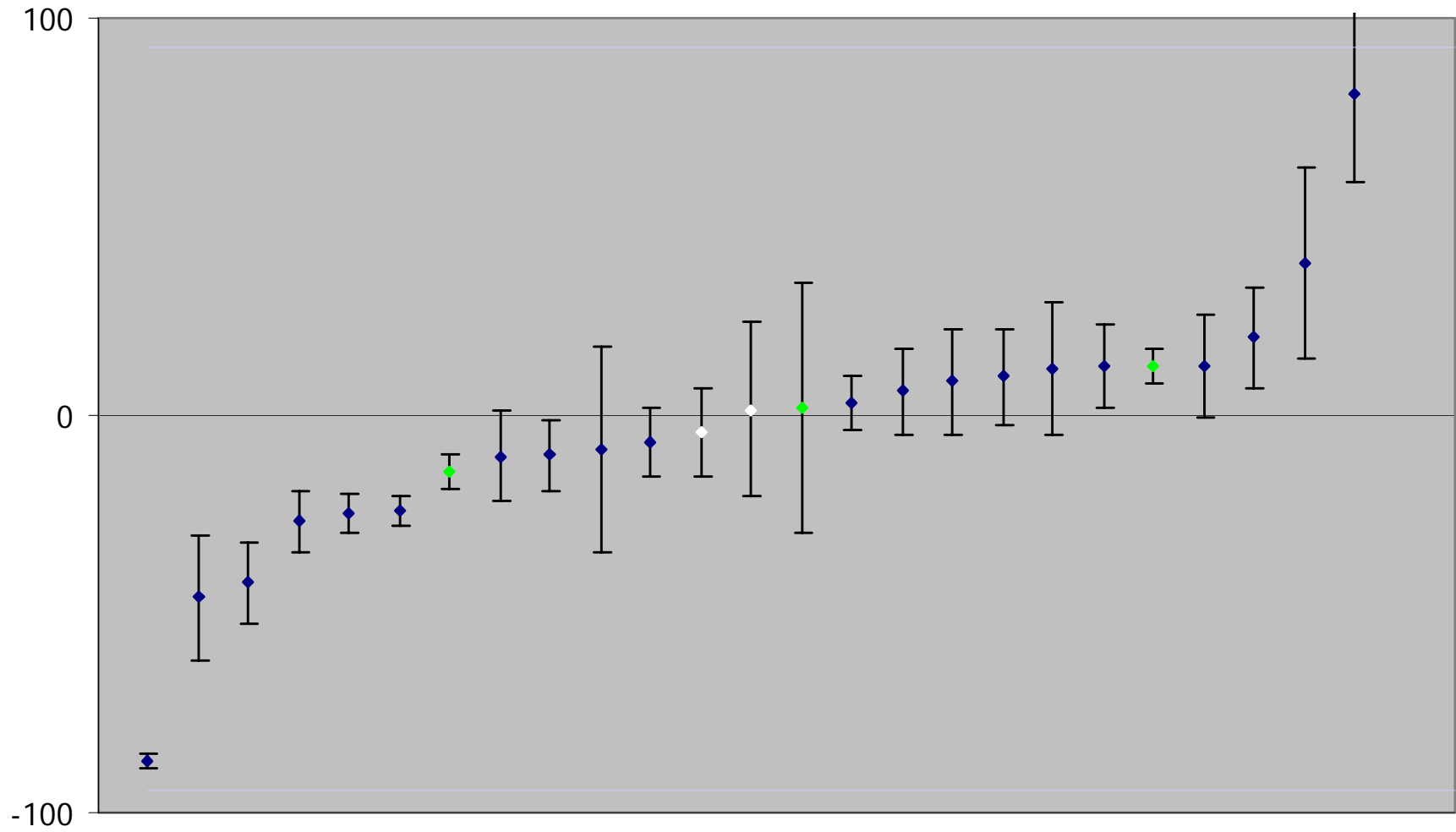
	^{89}Sr	^{90}Sr	^{238}Pu	^{239}Pu
1989		X		
1990		X		
1992		X		X
1993		X	(X)	(X)
1995		X	X	X
1996		X	X	X
1998	X	X	X	X
2000		X	X	X
2001		X	X	X
2002		X	X	X
2003		X	X	X
2005	X	X	X	X
2007	X	X	X	X

Results

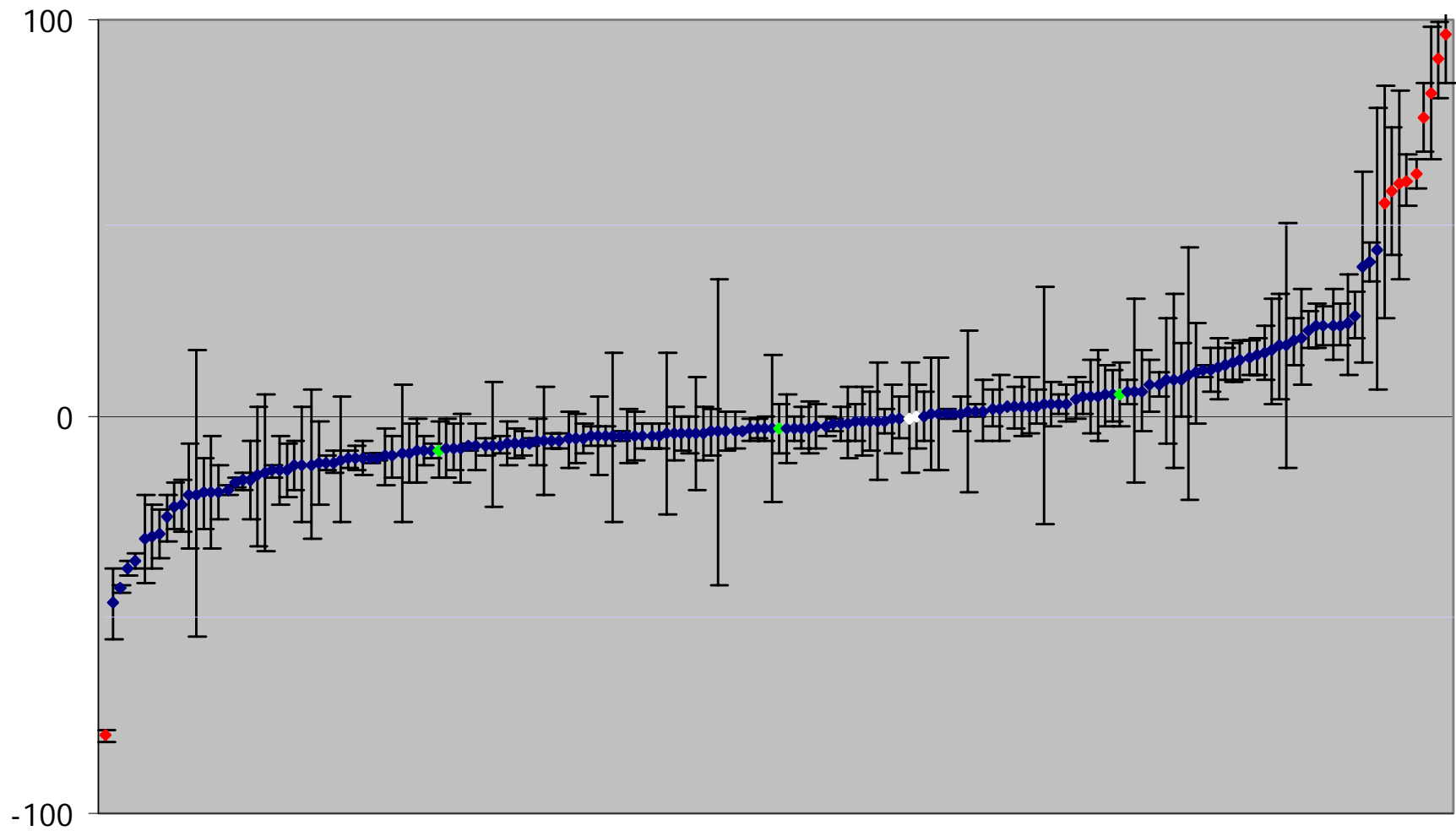
Deviation ($100 \cdot [L/N - 1]\%$) from the assigned (NPL) values

	⁸⁹ Sr	⁹⁰ Sr	²³⁸ Pu	²³⁹ Pu
# of exercises	3	13	9	10
# of results	27	179	192	207
Median (%)	2(5)	-3.0(10)	-3.4(6)	-1.8(5)
Acc. range (%)	187	98	57	51
# of outliers	2	11	8	14
Unw. mean (%)	-3(6)	-2.3(10)	-4.1(6)	-1.4(5)
Std. dev. (%)	31	14	7.8	6.9

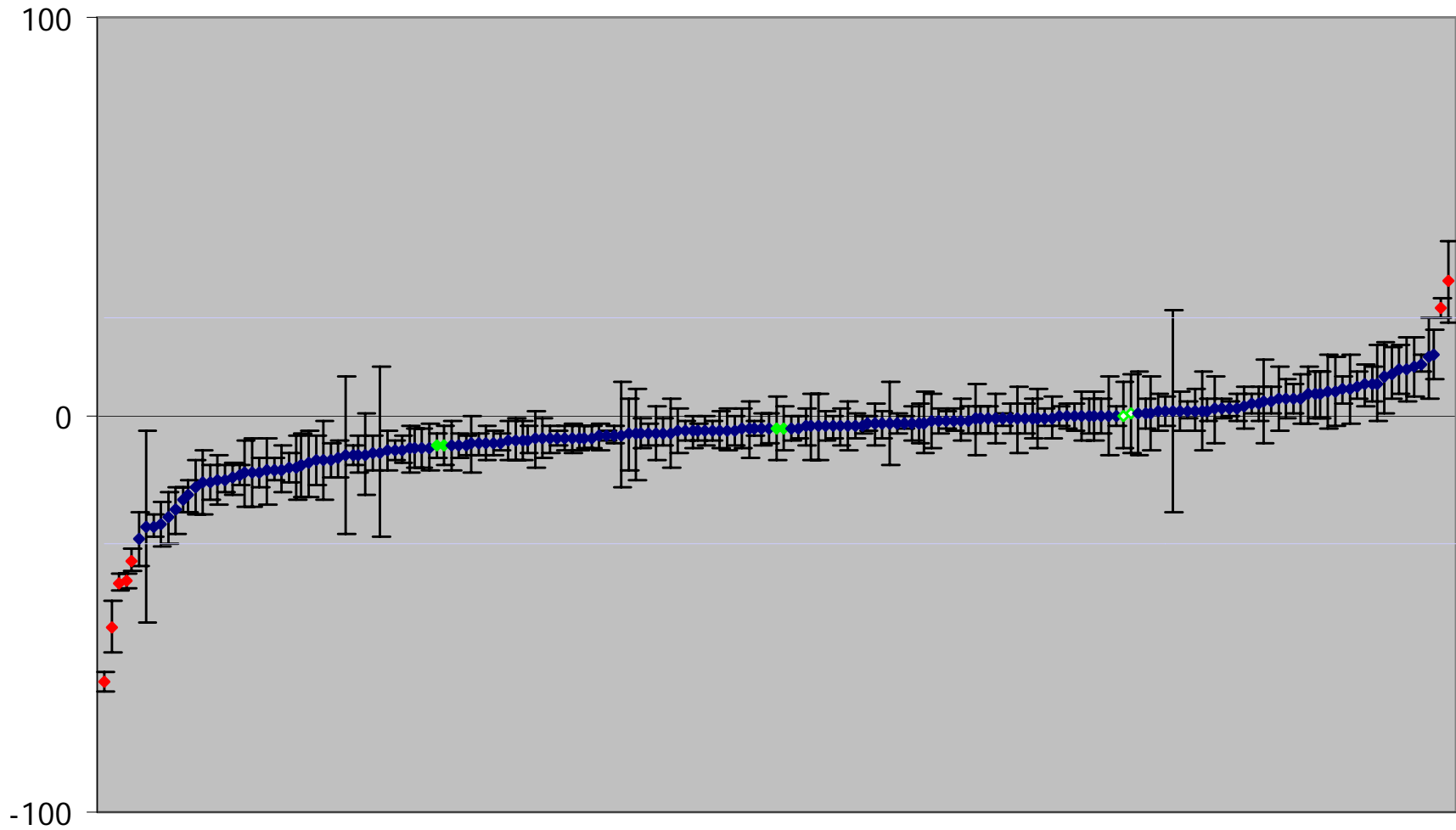
Sr-89 deviation (%)



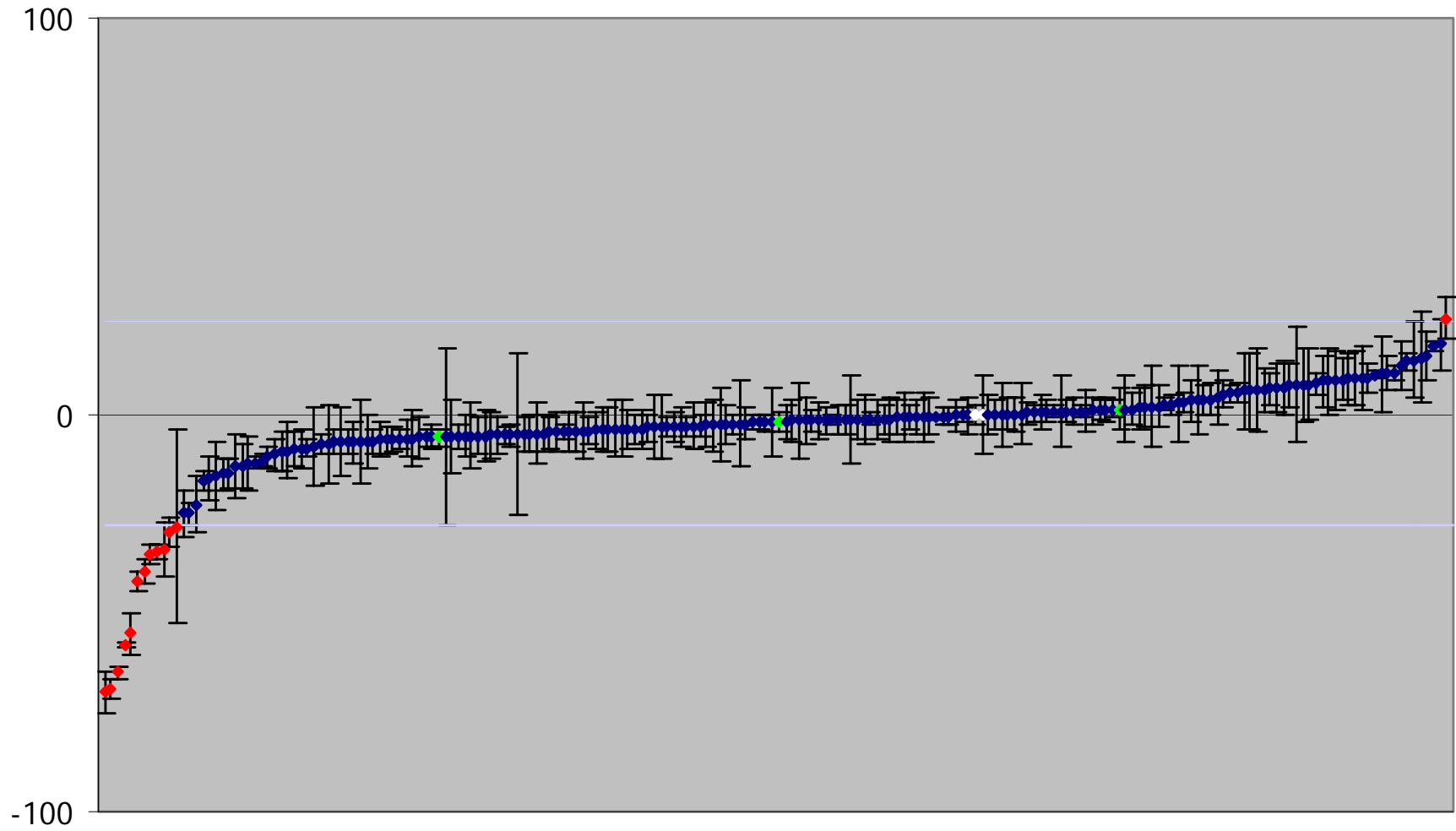
Sr-90 deviation (%)



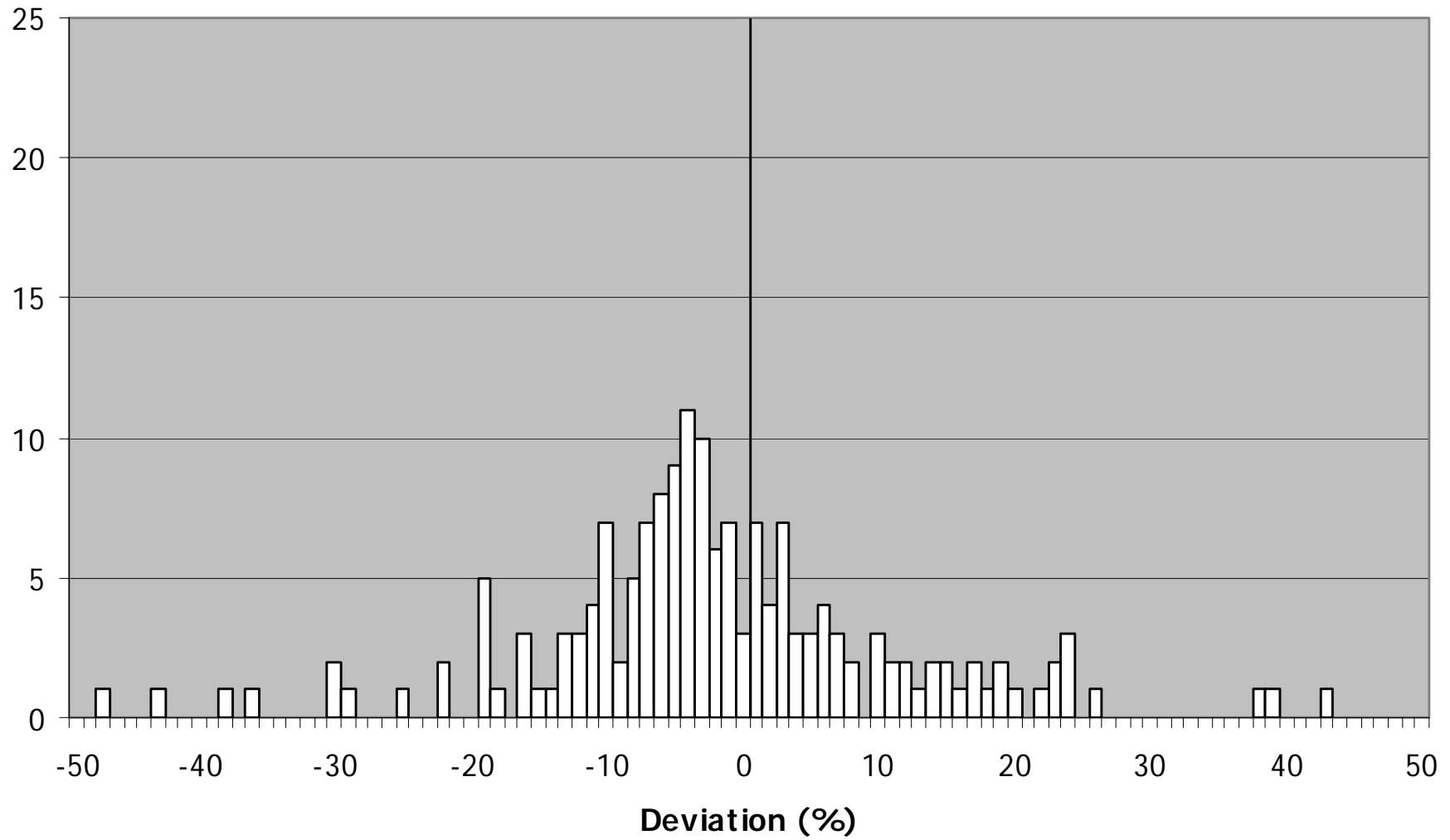
Pu-238 deviation (%)



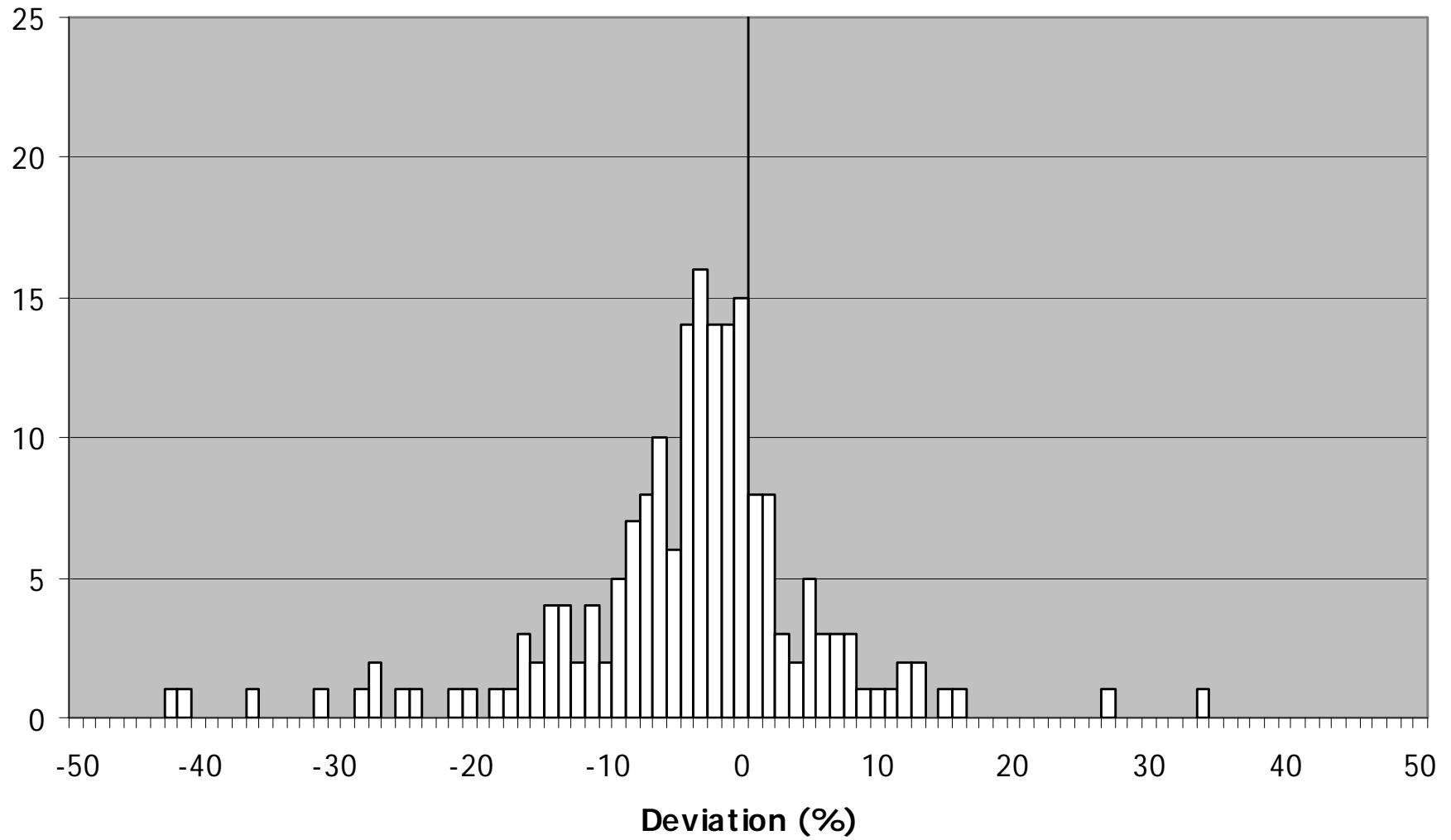
Pu-239 deviation (%)



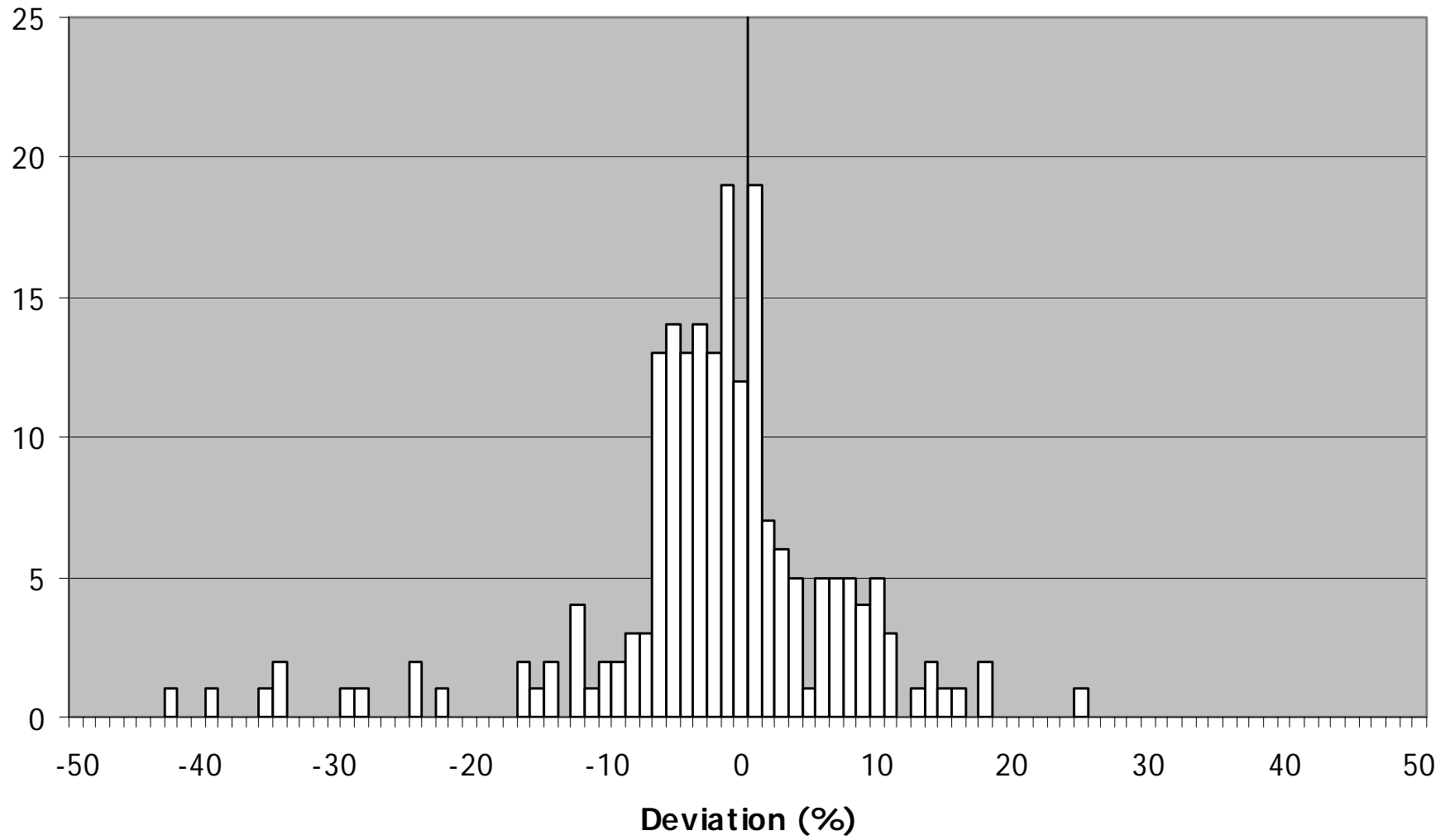
Sr-90 histogram



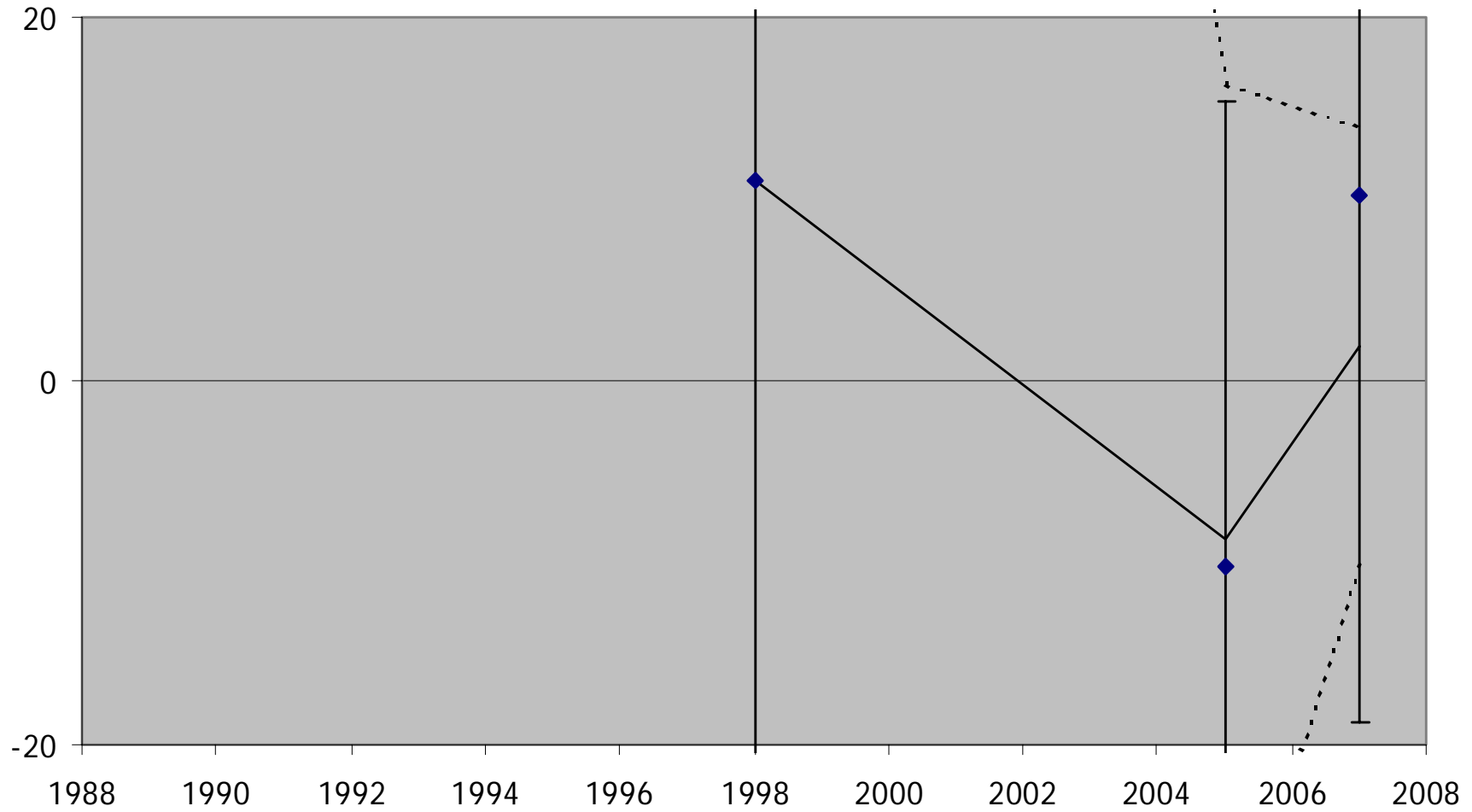
Pu-238 histogram



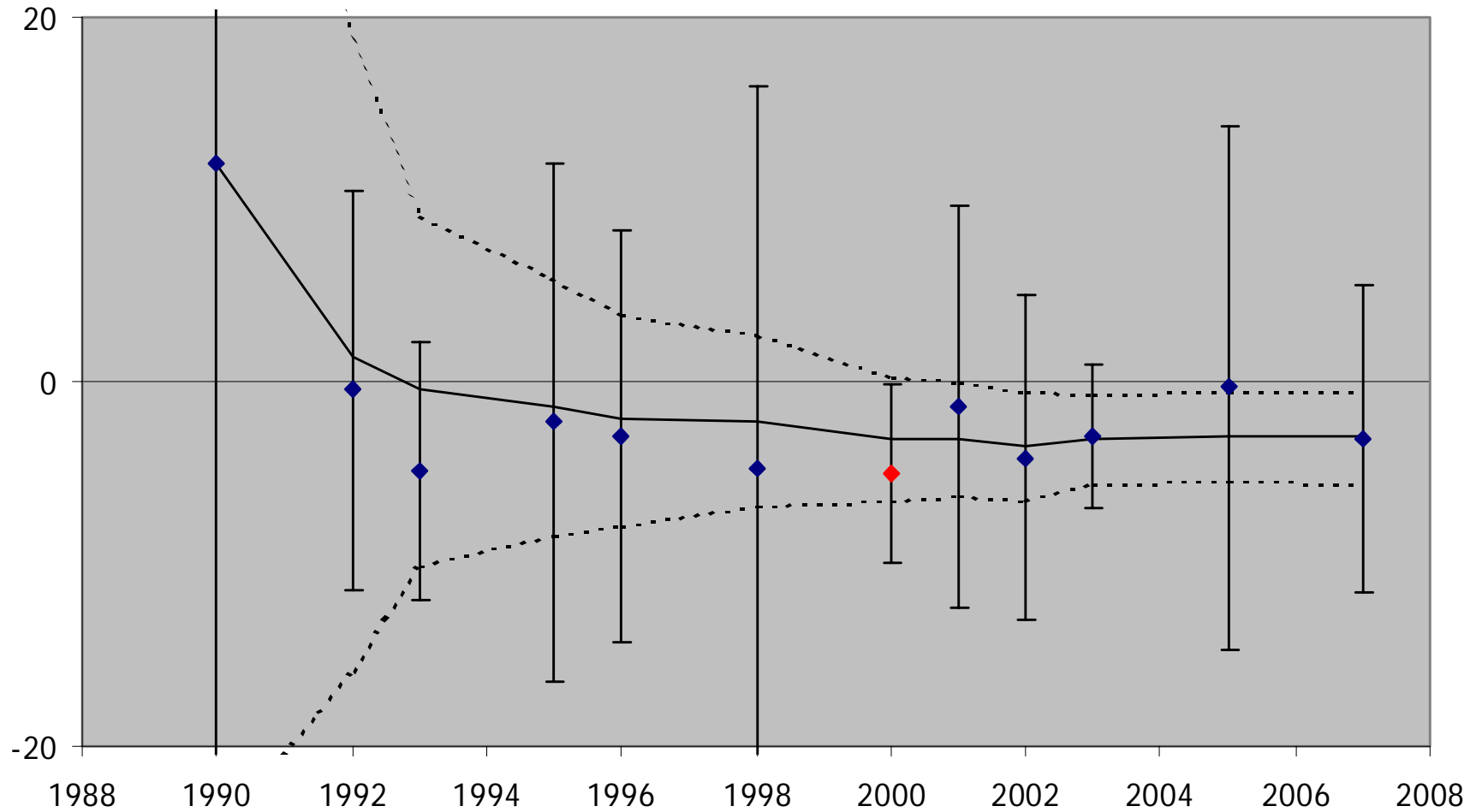
Pu-239 histogram



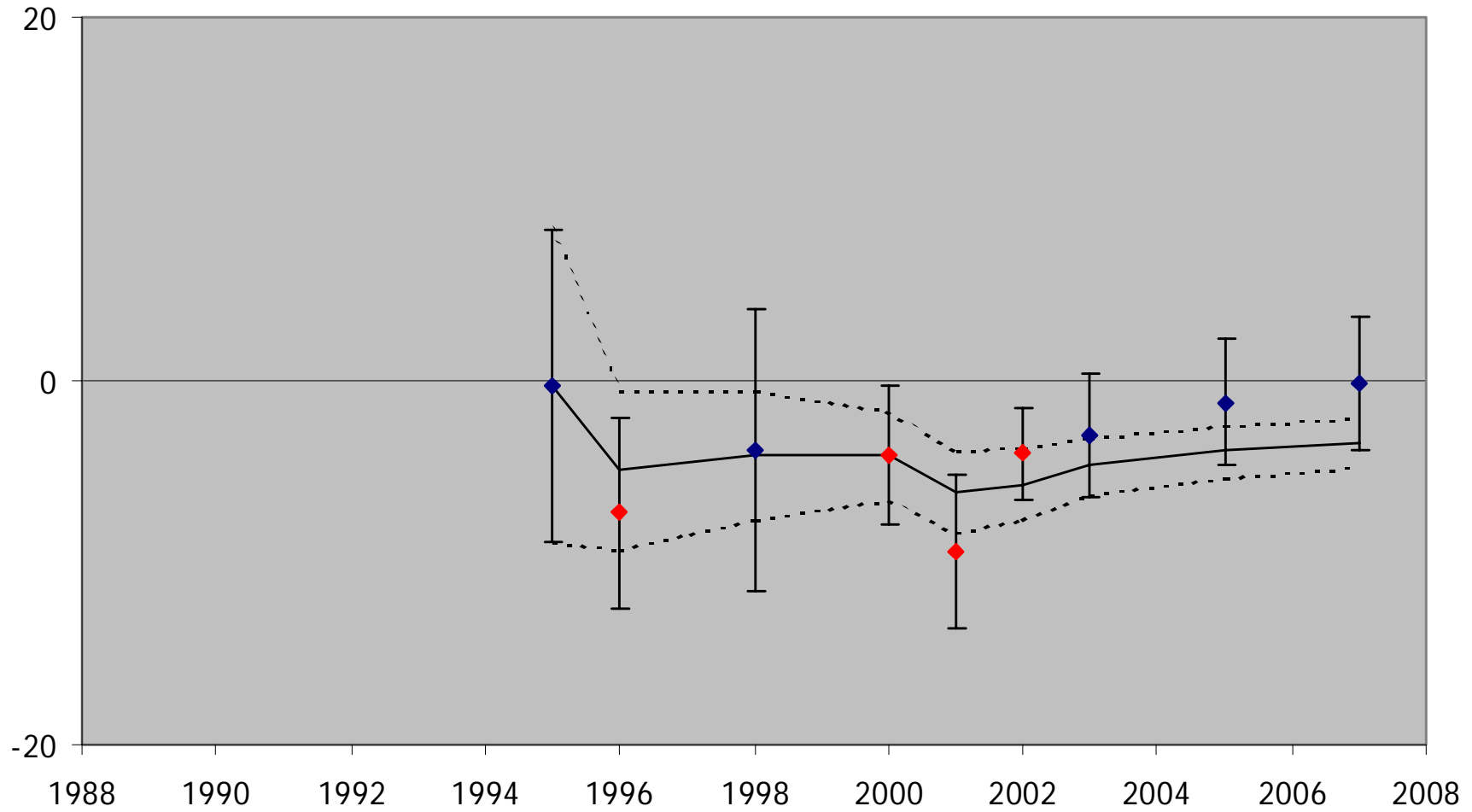
Individual and cumulative Sr-89 deviation medians (%) with 99% c.i.



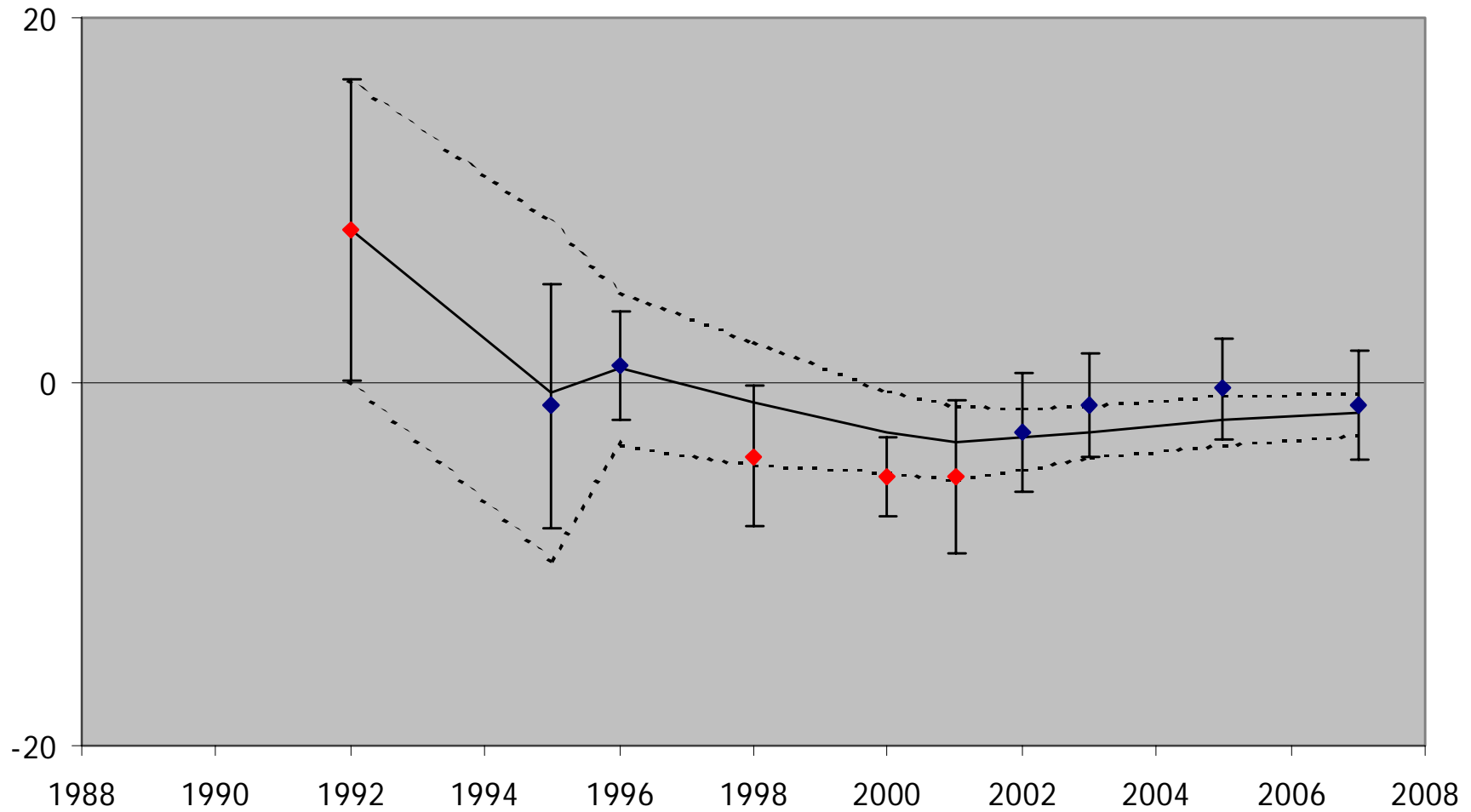
Individual and cumulative Sr-90 deviation medians (%) with 99% c.i.



Individual and cumulative Pu-238 deviation medians (%) with 99% c.i.



Individual and cumulative Pu-239 deviation medians (%) with 99% c.i.



Conclusion

For ^{90}Sr , ^{238}Pu and ^{239}Pu , the combined deviation medians are **significantly lower** than the assigned NPL values (most individual exercise results show a negative bias as well)

Limited data (2003-2007) on:

separation: ion-exchange or extraction chromatography

yield tracer: stable Sr, ^{85}Sr , ^{236}Pu or ^{242}Pu)

measurement: LSC, Čerenkov or PGC

show no significant differences between methods

Not enough data for ^{89}Sr . Larger spread in the ^{90}Sr results when ^{89}Sr was included in the sample (in 1998, 2005 and 2007)