

NPL REPORT DQL-RN 016

**THIRD IRMF COMPARISON OF SURFACE
CONTAMINATION MONITOR
CALIBRATIONS 2004 - 2005**

SEAN COLLINS and CLARE LEE

NOT RESTRICTED

MAY 2006



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Third IRMF Comparison of Surface Contamination Monitor Calibrations 2004 - 2005

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ABSTRACT

The Ionising Radiations Metrology Forum (IRMF) organised a third comparison of surface contamination monitor calibrations in which thirteen establishments in the UK participated. The exercise involved the circulation of two surface contamination monitors for calibration using large area reference sources available in the participants' laboratories.

The instruments used were a Thermo Mini 900 ratemeter with EP15 probe and a Thermo Mini 900 ratemeter with 44B probe. The instrument responses were calculated by the individual participants and submitted to the authors for analysis along with details of the reference sources used. Details of the estimated uncertainties were also reported.

The results are compared and demonstrate, in most cases, reasonable agreement between the participating establishments, though no overall improvement in the results over the previous comparison exercises.

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Approved on behalf of Managing Director, NPL, by
Pete Burgess, Knowledge Leader, Radioactivity and Neutrons

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1 INTRODUCTION

The calibration of surface contamination monitors is performed on an at least annual basis as part of the regulatory requirements¹ governing any organisation undertaking work with unsealed sources of ionising radiation. The quality of these calibrations was examined in comparison exercises organised by the Ionising Radiations Metrology Forum (IRMF) in 1993² and 2000³. The 1993 exercise concluded that review of the current guidance on the calibration of surface contamination monitors was needed, as the main two sources of guidance available were contradictory and confusing.

In the years since the comparison exercise in 1993, much work has been undertaken in the field of monitor calibrations. This work has included a study of the use of the Contiguous Portions method⁴ and the production of a measurement Good Practice Guide⁵ on the calibration of portable instruments. Several NPL surface contamination monitoring workshops have also been run since 1997. All of this work bears directly on the ability of the measurement and user communities to perform accurate calibrations of surface contamination monitors.

A second comparison exercise of contamination monitor calibrations was run in 2000. The results for the EP15 showed a larger spread than in 1993 and concerns were raised about some uncertainty budgets. Since this exercise, a Good Practice Guide on the assessment of uncertainties in radiological calibration and testing⁶ has been published.

In 2004 the IRMF embarked on a third comparison exercise of contamination monitor calibrations; the findings of this exercise are presented in this report. Amongst the aims of this repeat exercise was the desire to ascertain whether there had been an improvement in the calibrations of surface contamination monitors since the 1993 and 2000 exercises and since the publication of new guidance. Members of the working party that organised this comparison exercise are listed in Appendix 1.

2 PARTICIPANTS

In accordance with IRMF policy⁷, participants were allowed to choose whether to take part on an open or anonymous basis. Decisions on disclosure of results were made before an organisation performed measurements for the comparison and could not be reversed later. Anyone wishing to revise their data, once submitted, was allowed to do so but on the understanding that the nature of the changes made would be published in this report.

Appendix 2 contains a list of the participants and the codes that have been used in this report to represent each organisation.

3 INSTRUMENTATION

Instruments for the exercise were selected to incorporate some of the types most widely used and to afford an overlap with the 2000 exercise. The Mini EP15 (a Geiger-Müller detector generally used for beta contamination measurement) and a Mini 44B (a sodium iodide

scintillation detector generally used for low energy X and gamma contamination measurement) were chosen.

These required no setting up and, after an initial inspection, could be calibrated immediately.

All of the equipment for the exercise was circulated in a hard backed suitcase to protect it during transport. Participants were asked to inspect the instruments upon arrival at their organisation and report any breakages to the comparison organiser.

4 MEASUREMENT PROTOCOL

The protocol for this exercise was written by the IRMF working party, paying particular attention to the 1993 and 2000 exercises and the difficulties that were experienced in analysing the results due to variations and ambiguities in the reporting of data. Reporting sheets were designed to encourage the participants to provide as much relevant information as possible that could be useful in identifying sources of error when the results were analysed later.

This exercise covered only the calibration of surface contamination monitors and did not include the calibration of wide area reference sources. Reference sources for the calibration of the monitors were not provided; the participants were asked to use sources available in their establishments to cover as many radionuclides as possible, but to attempt at least ^{14}C , ^{36}Cl or $^{90}\text{Sr} + ^{90}\text{Y}$ and ^{238}U or ^{241}Am for the Mini EP15.

Participants were asked to report the instrument response (in terms of emissions) and the relevant uncertainty of the instruments to a range of reference sources, where:

$$\text{Instrument Response (Emissions)} = \frac{\sum_{i=1}^n (R_i - B)}{SER}$$

where R_i is the observed reading at source position i (s^{-1})
 B is the background count rate (s^{-1})
 SER is the surface emission rate per unit area of the source ($\text{s}^{-1} \text{ cm}^{-2}$)
 n is the number of source positions

Note that this equation assumes that the contiguous portions method was employed. Most of the participants used only one position and, hence, n equal to 1.

Conversion of the instrument response to an activity response and the P-factor used were also requested (see GPG14⁵ for an explanation of P-factors).

$$\text{Instrument Response (Activity)} = \frac{\sum_{i=1}^n (R_i - B)}{SER \cdot P}$$

where P is the appropriate P-factor.

Spaces for reporting the results of background measurements were included on the reporting sheet.

Overall uncertainties, in instrument response (emissions) for each instrument for each radionuclide, were included on the main reporting sheet. In addition to these, a full breakdown of the uncertainty budget was requested for the EP15 with ^{14}C . A table containing some of the possible sources of uncertainty was provided; extra rows were included for additional uncertainty contributions identified by the participants.

Each participant was asked to tabulate details of the reference sources used for their measurements; source type, dimensions, emission rate and the date the source was last calibrated were requested.

The protocol was issued to each of the participating organisations and a copy was circulated in the case with the instruments. The complete measurement protocol is reproduced in Appendix 3.

5 RESULTS

The results presented in this section indicate the final submissions made by each organisation. A significant effort was made by both the participants and the working party to explain, recalculate and/or eliminate anomalous results before these final data sets were achieved. Summaries of the amendments made to the data can be found in Appendix 4.

5.1 Mini EP15

Figures 1 to 7 show the results reported for ^{14}C , ^{36}Cl , ^{60}Co , $^{90}\text{Sr} + ^{90}\text{Y}$, ^{137}Cs , ^{147}Pm and ^{241}Am . Appendix 5, table 1, shows the spread of results obtained for each of these radionuclides and, where possible, compares these values with the outcome of the 1993 and 2000 exercises.

Additional data were reported by some organisations for ^{99}Tc , ^{238}Pu and ^{238}U ; these are presented in Appendix 5, Table 2, but as there were insufficient data points no further analysis of these data was made.

The ^{14}C data (13 participants) has a large spread of 52 %, which is an increase on the previous two exercises, especially the 1993 exercise. The large uncertainties ($> 18\%$ at $k = 2$) reported by a number of laboratories (MPA, BER and NPL) are dominated by the low gross count rate observed using their ^{14}C sources. The large uncertainty quoted by AWE is totally dominated by the uncertainty of the reading from the EP15's display, emphasised by the low gross count rate. The large uncertainty reported by HMS is dominated by both the homogeneity of the source and the low gross count rate. The discrepancy between the two RWE Nukem sites, which use the same calibration procedure and sources produced in the same manufacturing batch, was due to each using a different probe face area. RNH used the area of the visible face of the probe, which gave an active area of 19.6 cm^2 , while RNW used 15.5 cm^2 which the instrument manual states is the area of the mica window.

The ^{36}Cl reported data (11 participants) has a spread of 29 % which is a significant improvement on the spread seen in the 2000 exercise and getting closer to the smaller spread seen in the 1993 exercise. The small uncertainties reported by RNH and RNW are due to omitting the instrument reading uncertainty from the uncertainty budget; the same approach was used for all their reported uncertainties.

The ^{60}Co data (6 participants) has a small spread of only 16 %, the lowest of all the radionuclides used in the comparison. There are no obvious failings with the results reported for ^{60}Co and all the reported values are within 30 % of the mean.

The $^{90}\text{Sr} + ^{90}\text{Y}$ (12 participants) showed a spread of 20 %, down from the 2000 exercise to almost the level observed in the 1993 exercise. The uncertainty shown by AWE is dominated by the method of determining their uncertainty on the instrument reading.

The ^{137}Cs reported data (4 participants only) shows an observed spread of 33 %; there was a large difference between RNH and RNW that was due to the two laboratories using different probe areas, as described for ^{14}C above.

The ^{147}Pm data (5 participants only) shows a spread of 26 %, which is a marked improvement over the results of the 1993 exercise (43 % spread). All the reported values are within 30 % of the mean.

The ^{241}Am reported data (12 participants) shows an increase in the spread from the 2000 exercise to 37 %, though all of the reported results are within 30 % of the mean.

5.2 Mini 44B

Figures 8 to 15 show the results for filtered sources of ^{57}Co , ^{129}I , ^{238}Pu and ^{241}Am and unfiltered sources of ^{55}Fe , ^{36}Cl , ^{137}Cs and ^{241}Am . These are summarised in Appendix 5, table 3. Additional data were reported by some organisations for filtered sources of ^{60}Co and ^{137}Cs and unfiltered sources of ^{60}Co , $^{90}\text{Sr} + ^{90}\text{Y}$, ^{125}I and ^{129}I ; these are presented in Appendix 5, table 4, but, as there were too few data points, no further analysis of this data was made. No comparison with previous exercises was possible, as this instrument had not been used before.

A number of the participants (Appendix 5, table 5) used filtered photon reference sources while others (Appendix 5, table 6) used unfiltered sources, some of which were primarily intended for alpha or beta calibration. Where both filtered and unfiltered sources of a particular nuclide were reported, the effect of the different constructions could be clearly observed as two groups of results. Unlike the filtered sources, the unfiltered sources (other than ^{55}Fe) also emit particles. These are generally measured to establish the emission rate from the source and the photon emission is ignored. This gives a different instrument response. To allow for this, the results have been divided into two groups and analysed separately for those nuclides.

5.2.1 Filtered Sources

The spreads of ^{57}Co , ^{238}Pu and ^{241}Am results (3 participants only) are very small, though the uncertainties on the results from some of the participants are very large (greater than 30 %).

The ^{129}I reported results (6 participants) showed a spread of 29 %. This wide range is due to the instrument response reported by NPL, without which the spread would be 11 %. Investigation into the NPL result showed that even though the homogeneity of the source met the ISO8769-2 specification⁸, some areas of the source gave a markedly different SER from the certificated SER of the source. When the areas of the source with a small variance from the certificated SER were used then the resulting instrument response was brought into line with the other participants' results.

5.2.2 Un-Filtered Sources

The spread of the results for ^{55}Fe was 22 %, though the results from two participants had very large uncertainties (greater than 40 % at $k = 2$).

The spreads of ^{36}Cl , ^{137}Cs and ^{241}Am are all within the required 30 %, though the small number of participants (3) for each of the nuclides makes it difficult to make any considered judgement on the results.

6 DISCUSSION

6.1 Use of Contiguous Portions Technique

The contiguous portions technique was used only once, for ^{57}Co and the 44B; the method adopted was a variant of that described in GPG14. A correction factor of 1.13 was estimated to convert between a single source position and a semi-infinite plane geometry.

The exercise carried out in 2000 showed that the contiguous portions technique is complex to implement for routine use; this was highlighted by the discrepancies in its application.

6.2 Uncertainties

Participants were required to submit a full uncertainty budget for the Mini EP15 with ^{14}C . GPG49 was recommended for guidance.

Components of the standard uncertainty and their values varied greatly between the organisations that submitted uncertainty budgets. Appendix 5, Table 7 contains examples of the uncertainty budgets reported by the participants.

GPG14 recommends that instruments are tested against a pass/ fail criterion of 30 % in terms of the difference of the measured response when compared to the type test value. Large uncertainties produce a risk of instruments type tested by one calibration laboratory failing

the same test at a different laboratory, despite there being no change in instrument response. Note that some laboratories quoted uncertainties in excess of 30 % for some radionuclides.

6.3 Homogeneity of calibration sources

Despite an example homogeneity determination being provided in the protocol there was a paucity of data on the homogeneity of the calibration sources used. In some cases, a limited number of measurements was taken to test homogeneity; in other cases, manufacturer's data were used, or results were used from previous calibrations at NPL. Some participants assumed a rectangular distribution for the homogeneity, others used a normal distribution and there were further differences in whether the standard deviation or the standard error of the mean was used.

The effects of source inhomogeneity may be significant (possibly of the order of 30 %) if the detector window is significantly smaller in area than the area of the reference source, as is the case for the instruments and sources employed in this intercomparison. It should be noted that most reference sources are constructed to comply with ISO8769-2⁸, in which the definition of homogeneity is open to some interpretation.

7 CONCLUSIONS

The spreads of the EP15 instrument response were comparable to the exercises in 2000 and worse than those from 1993.

The contiguous portions technique has not been adopted widely, with only one participant reporting its use. This issue should be considered for future revisions of GPG14.

The sparsely marked log scale on both monitors resulted in some large uncertainty contributions from the instrument readings, although the scaling is satisfactory for operational use.

The uniformity of the sources is, in most cases, not measured and is assumed to be in accordance with ISO8769-2⁸, with participants taking the standard deviation of 10 % or taking the manufacturer's specification. This may be one of the major sources of variation in reported instrument responses.

In general, the comparison exercise was reasonably successful with almost all of the calibrations performed agreeing with the mean value to within $\pm 30\%$.

8 ACKNOWLEDGEMENTS

The Ionising Radiations Metrology Forum is supported under the Ionising Radiation Metrology Programme of the National Measurement System, funded by the Department of Trade and Industry.

9 REFERENCES

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- 2 Woods M J and Hedley R P. *IRMF Intercomparison of Calibration of Large Area Reference Sources and Portable Alpha and Beta Surface Contamination Monitors 1993/4 – Part 1*, NPL Report CIRA(EXT)002, 1996.
- 3 Scott C J., Second IRMF Comparison of Surface Contamination Monitor Calibrations 2000-2001. NPL Report CIRM 54, November 2002.
- 4 Scott C J and Woods M J. *The Use of Relatively Small Sources for the Calibration of Area Survey Meters*, NPL Report CIRM 6, 1997.
- 5 Scott C J, Burgess P H and Woods M J. *The Examination, Testing and Calibration of Portable Radiation Protection Instruments*, Measurement Good Practice Guide 14, NPL 1999.
- 6 Lewis V., Woods M J., Burgess P., Green S., Simpson J., Wardle J. The Assessment of Uncertainty in Radiological Calibration and Testing, Measurement Good Practice Guide 49, NPL 2003.
- 7 Lewis V E. *Minutes of Fifteenth IRMF Meeting*, NPL, April 1998.
- 8 Reference sources for the calibration of surface contamination monitors – Part 2: Electrons of energy less than 0,15 MeV and photons of energy less than 1,5 MeV, p 5, section 5.2.3, ISO 8769-2:1996(E).

APPENDICES

Appendix 1 Members of the IRMF Working Party

Clare Lee	NPL
John Bennett	DSTL
Jan McClure	HPA
John Simpson	RWE Nukem
Peter Burgess	then UKAEA, now NPL
Sean Collins	NPL

Appendix 2 Participants

Organisation	Organisation Code	Contact Person	UKAS Accredited for contamination monitor calibration
RRPPS, Queen Elizabeth's Hospital	QEH	Denise Delahunty	No
DSTL, DERA	DRP	John Bennett	Yes
RWE Nukem, Winfrith	RNW	John Simpson	Yes
HPA*, Chilton	NRC	Jan McClure	No
HMS Sultan, NDCF	HMS	Paola Hayes	Yes
DRMS	AWE	Jon Wardle	Yes
RWE Nukem, Harwell	RNH	Reg Bosley	No
RPS, Velindre Hospital	VH	Wyn Thomas	No
NIRMPA, Forster Green Hospital	MPA	Roy Mooney	No
Johnson Controls Ltd	JCL	Andrew Main	Yes
BIL, Berkeley	BER	Max Pottinger	No
HPA*, Leeds	NRL	Joanne Shaw	No
Health Physics, NPL	NPL	Caroline Felgate	No

* Formerly known as NRPB

Appendix 3 Measurement Protocol

Measurement Protocol

Introduction

This comparison exercise has been organised by the Ionising Radiation Metrology Forum (IRMF) and the National Physical Laboratory (NPL) to assess the standard of calibrations of surface contamination monitors performed in the UK. Two instruments will be circulated to twelve organisations for routine calibration. The results of these calibrations will be collated and reported by NPL.

Participants in the comparison have decided in advance whether they will take part anonymously or whether their results will be disclosed; registration forms have been completed indicating the level of disclosure required prior to the start of the comparison. It is not possible for organisations to change their decision on disclosure once the exercise has commenced. This policy is in accordance with the disclosure scheme agreed by the IRMF in April 1998.

A similar comparison exercise conducted in 1993¹ concluded that 'significant problems exist' in this field and there was a need to update the HSE guidance and practical advice to the user community in general. Since that time, a measurement good practice guide² (GPG 14) on the calibration of radiation protection instruments has been published which provides detailed guidance on techniques that can be employed to calibrate surface contamination monitors.

The report of a further exercise³, beginning in 2000, concluded that 'almost all of the calibrations performed agreed with the mean value to within $\pm 30\%$ ' and some improvements had been seen since the 1993 exercise. The report made recommendations about the quality of reference sources that were in use, some were completely unsuitable and others had not been calibrated in more than fifteen years. Other conclusions related to more care being needed in the use of the contiguous portions technique and the inappropriate or insufficient uncertainty budgets prepared by some laboratories.

The purpose of this comparison exercise is to establish the current standard of surface contamination monitor calibrations and verify whether any improvements have been made.

¹ Woods M J and Hedley R P. IRMF comparison of calibration of large area reference sources and portable alpha and beta surface contamination monitors 1993/4 - Part 1. NPL Report CIRA (EXT)002, January 1996.

² Scott C J, Burgess P H and Woods M J. The examination, testing and calibration of portable radiation protection instruments. Measurement Good Practice Guide 14, NPL, March 1999.

³ Scott C J. Second IRMF Comparison of Surface Contamination Monitor Calibrations 2000 – 2001. NPL Report CIRM 54, November 2002.

Schedule

Laboratories will be given a period of one week in which to perform the required measurements and to forward the instruments to the next participant. After every third participant, one week will be allowed for any necessary maintenance and to absorb any slippage of the schedule that may have occurred. A proposed timetable will be distributed at the start of the exercise; every effort should be made to adhere to this timetable in the interests of completing the comparison within a reasonable time (approx. six months).

It may be possible to rearrange the timetable if sufficient notice is given - please contact Sean Collins to arrange this (contact details are given at the end of the protocol). If a laboratory completes their work before their deadline, they are encouraged to transport the instruments to the next participant early (with the agreement of the next participant).

Participation in the comparison is free of charge, however, participants are responsible for arranging, and meeting the cost of, transporting the equipment to the next laboratory. Since a check source is not being circulated for this exercise, any courier can be used.

Instruments

Mini EP15: a halogen quenched Geiger-Müller tube with thin mica window, suitable for alpha and soft beta-emitters. Manual provided.

Mini 44B: a beryllium windowed scintillation detector suitable for X-rays. Manual provided.

The instruments will be circulated in a single hard-faced suitcase; a list of contents will be enclosed. The suitcase should be transported locked and the key attached to the outside.

Calibration Procedure

The instruments should be calibrated according to the procedures routinely used in the participating organisations. All measurements should be made with a source to detector separation of 3 mm.

Sufficient measurements should be made to determine the instrument response in terms of source emissions and activity. The equations defined below (from GPG14) can be used to calculate the instrument response; these equations apply for calibrations performed using a single source position (where $n = 1$) as well as contiguous portions calibrations where a number of source positions are used ($n > 1$).

$$\text{Instrument Response (Emissions)} = \frac{\sum_{i=1}^n (R_i - B)}{SER}$$

$$\text{Instrument Response (Activity)} = \frac{\sum_{i=1}^n (R_i - B)}{SER \cdot P}$$

where	R_i	is the observed reading at source position i (s^{-1})
	B	is the background count rate (s^{-1})
	SER	is the surface emission rate per unit area of the source ($s^{-1} cm^{-2}$)
	n	is the number of source positions
	P	is the appropriate P-factor.

Please note that n does not correspond to a number of repeated measurements with the reference source in the same measurement position. If repeated measurements are made, R_i should be the mean observed reading for a particular source position.

The results of these calibrations, their associated uncertainties and the value of the P-factor used should be recorded in Table 1.

It is recommended that the monitors are calibrated for as many nuclides as possible but as a minimum, the following should be used:

Mini EP15 Low energy β - emitter (e.g. C-14)
 High energy β - emitter (e.g. Sr-90+Y-90 or Cl-36)
 α - emitter (e.g. Am-241).

Mini 44B Photon reference sources⁴ (see Appendix A for a list of these)

If calibrations are made using photon reference sources, additional information regarding the materials and furniture of the laboratory should be submitted with the results. A contiguous portions type of calibration should be performed if necessary; full details of the measurements made and the calculations to derive the instrument response should be reported on separate sheets.

Details of the uncertainty budget for the calibration of the EP15 with ^{14}C should be entered into Table 2; if this instrument/source combination is not possible, please submit an uncertainty budget for an alternative combination. The method usually employed to quantify uncertainties should be used; guidance is available in GPG49 if needed.

Details of each of the reference sources used during the calibrations should be given in Table 3. It is important to provide as much of this information as possible even if the table cannot be fully completed. It would be useful if measurements could also be made to determine the homogeneity of the sources used, Appendix B outlines a method that can be used for this. Please submit all data and calculations for homogeneity determination.

If one of the instruments provided is not appropriate for the nature of the work carried out in a particular organisation or reference sources of suitable radionuclides are not available, it is not essential to perform the calibration.

⁴ ISO 8769-2 Reference sources for the calibration of surface contamination monitors – electrons of energy less than 0.15 MeV and photons of energy less than 1.5 MeV, 1996.

Reporting of Results

To encourage consistency in the data reported and to ensure that sufficient information is provided, tables have been supplied for recording the results. These tables should be copied as many times as necessary for the number of calibrations performed. Additional sheets can be used for any further comments or information to be reported.

Completed results tables should be sent to Sean Collins at NPL as soon as possible after the calibrations are performed or within two weeks at the latest.

An IRMF working group will consider the results submitted and draw recommendations and conclusions from them. Progress of the comparison will be presented and discussed at IRMF meetings. The results will be published in an NPL report once the analysis is complete.

Useful Contacts

Sean Collins
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All enquires should be addressed to Sean Collins in the first instance.

References

GPG14 The Examination, Testing and Calibration of Portable Radiation Protection Instruments.

GPG49 The Assessment of Uncertainty in Radiological Calibration and Testing

Both guides are available to download, free of charge, from the IRMF website:
<http://www.npl.co.uk/irmf/publications.html>

Appendix A

Photon Reference Sources

Approx. mean photon energy (keV)	Radionuclide and filter
5.9	⁵⁵ Fe, no filter
16	²³⁸ Pu with 32.5 mgcm ⁻² zirconium filter
32	¹²⁹ I with 81 mgcm ⁻² aluminium filter
60	²⁴¹ Am with 200 mgcm ⁻² stainless steel filter
124	⁵⁷ Co with 200 mgcm ⁻² stainless steel filter
600	¹³⁷ Cs with 800 mgcm ⁻² stainless steel filter
1200	⁶⁰ Co with 81 mgcm ⁻² aluminium filter

Reproduced from ISO 8769-2.

Appendix B

Determination of Homogeneity of Wide Area Reference Sources

The homogeneity (uniformity) of a source is defined by ISO as ‘the estimated standard deviation of measurements of individual portions [of a source] about the mean value for the whole surface [of the source] expressed as a percentage of the mean’.

Homogeneity can be measured by inserting a masking plate between the source and a detector. The masking plate should be thick enough to absorb particles and photons of the maximum energy emitted from that particular source. The aperture in the masking plate should be 10 cm² or less. Care should be taken to ensure the same area of the detector is used each time to minimise any effect due to its non-uniformity.

The example below can be used as a template to record and analyse results for homogeneity determination.

Example Homogeneity Determination

1 283 cps + 4.0 %	2 280 cps + 2.9 %	3 289 cps + 6.3 %
4 259 cps - 4.8 %	5 266 cps - 2.2 %	6 276 cps + 1.5 %
7 258 cps - 5.1 %	8 259 cps - 4.8 %	9 277 cps + 1.8 %

Record the count rate observed when the detector is exposed to each area of the source sequentially.

Calculate the mean observed count rate (272 cps for the above example).

Calculate the deviation of the individual count rates from the mean value (for indication only).

Calculate the standard deviation of the individual count rates (11.6 cps).

Convert the standard deviation to a percentage of the mean; this is the homogeneity (4.3%).

IRMF Comparison of Surface Contamination Monitor Calibrations

Table 1

Calibration Results

Laboratory:

Contact Person:

Operator Name:

Instrument Type:

Serial No.:

Calibration Date:

Background Reading

Before:

After:

NUCLIDE / PHOTON ENERGY	SOURCE IDENTIFIER	GROSS READING Cps	NET READING cps	INSTRUMENT RESPONSE (Emissions) cps/(s ⁻¹ cm ⁻²)	UNCERTAINTY IN INSTRUMENT RESPONSE (Emissions) (% at k=1)	INSTRUMENT RESPONSE (Activity) cps/(Bqcm ⁻²)	P - FACTOR APPLIED

Signed..... Print Name Date

IRMF Comparison of Surface Contamination Monitor Calibrations**Table 2****Uncertainty Budget**

Laboratory:

Contact Person:

Operator Name:

Detector:
ID:

Serial Number:

Reference Source

SOURCE OF UNCERTAINTY	METHOD OF ESTIMATION	MAGNITUDE OF UNCERTAINTY ($k=1$)
Detector Window Area		
H T Setting		
Dead Time (if applicable)		
Background Count rate		
Source - Detector Separation		
Surface Emission Rate of Reference Source		
Non - Uniformity of Reference Source		
Backscatter		
Standard Uncertainty ($k=1$)		

Please provide details of your uncertainty budget for one source - detector combination.

Please use additional sheets if necessary to provide as much information as possible.

Signed.....

Print Name

Date

IRMF Comparison of Surface Contamination Monitor Calibrations**Table 3****Reference Source Details**

Laboratory:

Contact Person:

Source identifier	
Nuclide	
Surface emission rate (s^{-1}) and reference date	
Uncertainty in surface emission rate (2σ)	
Half - life used if decay calculated	
Calibration date and laboratory	
Nominal activity	
Active dimensions (mm)	
Outer dimensions (mm)	
Source construction e.g. anodised aluminium	
Substrate material and thickness (mm)	
Source manufacturer	
Date of purchase	
Manufacturers drawing number	

Signed.....

Print Name

Date

Please photocopy this form as required to provide details of all the reference sources that have been used in this exercise.

Appendix 4 Amendments To Submitted Data

Participants were given the opportunity to amend their submitted data even after the relative results of the comparison were available. This allowed any obvious errors to be corrected. Approximately one third of participants elected to amend their results. Details of the amendments made by each organisation are detailed in the remainder of this Appendix.

Health Physics, NPL (NPL)

The measured sources SER cm^{-2} was inserted incorrectly for the ^{241}Am instrument response.

RWE Nukem, Winfrith (RNW)

Results changed for the EP15 (^{14}C , ^{36}Cl and ^{241}Am) after using the nominal window diameter initially rather than the open area of the GM tube window.

Johnson Controls Limited (JCL)

Rectified a data transposition error in the originally submitted results.

BNFL, Berkeley (BER)

Stated uncertainties as absolute instead of percentage.

RRPPS (QEH)

Incorrectly quoted the calibration factor instead of instrument response for ^{241}Am for the EP15.

No revisions were made by: DSTL (DRP); HPA, Chilton (NRC); HMS Sultan (HMS); AWE; RWE Nukem Harwell (RNH); Velindre Hospital (VH) and NIRMPA (MPA).

Appendix 5. Results**Table 1. Summary of Results for EP15 Calibrations**

Nuclide	Mean Instrument Response (Emissions) 2005	Spread in 2005	Spread in 2000	Spread in 1993
¹⁴ C	2.9	52 %	46 %	40 %
³⁶ Cl	8.2	29 %	42 %	19 %
⁶⁰ Co	5.6	16 %	-	-
⁹⁰ Sr + ⁹⁰ Y	8.7	20 %	31 %	16 %
¹³⁷ Cs	7.5	33 %	-	-
¹⁴⁷ Pm	4.0	26 %	-	43 %
²⁴¹ Am	5.2	37 %	28 %	15 %

Table 2. Additional Data Submitted for EP15

Nuclide	Organisation	Instrument Response (Emissions)	Uncertainty (% at $k=2$)	Mean Value
⁹⁹ Tc	BER	6.11	16.7	-
²³⁸ Pu	DRP	5.025	12.6	-
²³⁸ U	DRP	12.071	19.2	-

Table 3. Summary of Results for 44B

Nuclide	Filter	Mean Instrument Response (Emissions) 2005	Spread in 2005
⁵⁷ Co	Yes	6.58	5 %
¹²⁹ I	Yes	7.38	29 %
²³⁸ Pu	Yes	7.74	12 %
²⁴¹ Am	Yes	8.55	11 %
⁵⁵ Fe	No	2.35	22 %
³⁶ Cl	No	1.75	6 %
¹³⁷ Cs	No	2.90	24 %
²⁴¹ Am	No	4.77	13 %

Table 4. Additional Data Submitted for 44B

Nuclide	Filter	Organisation	Instrument Response (Emissions)	Uncertainty (% at $k=2$)	Mean Value
^{60}Co	Yes	DRP	1.06	16	1.16
		AWE	1.26	-	
^{137}Cs	Yes	DRP	1.54	17	1.65
		AWE	1.75	40	
^{60}Co	No	RNW	2.4	5	2.63
		RNH	2.9	5	
^{125}I	No	MPA	6.8	16	-
^{129}I	No	RNW	5.8	5	5.85
		RNH	5.9	5	
$^{90}\text{Sr} + ^{90}\text{Y}$	No	HMS	2.56	33	2.65
		VH	2.69	11	

Table 5. Participants using Filtered Sources

Organisation	Code
DRPS, DERA	DRP
HPA*, Chilton	NRC
DRMS, AWE	AWE
HPA*, Leeds	NRL
Health Physics, NPL	NPL

Table 6. Participants using Un-Filtered Sources

Organisation	Code
RWE Nukem, Winfrith	RNW
HPA*, Chilton	NRC
RWE Nukem, Harwell	RNH
RPS, Velindre Hospital	VH
NIRMPA, Forster Green Hospital	MPA
Johnson Controls Ltd	JCL

* formerly known as NRPB.

Table 7. Uncertainty Contributions Reported

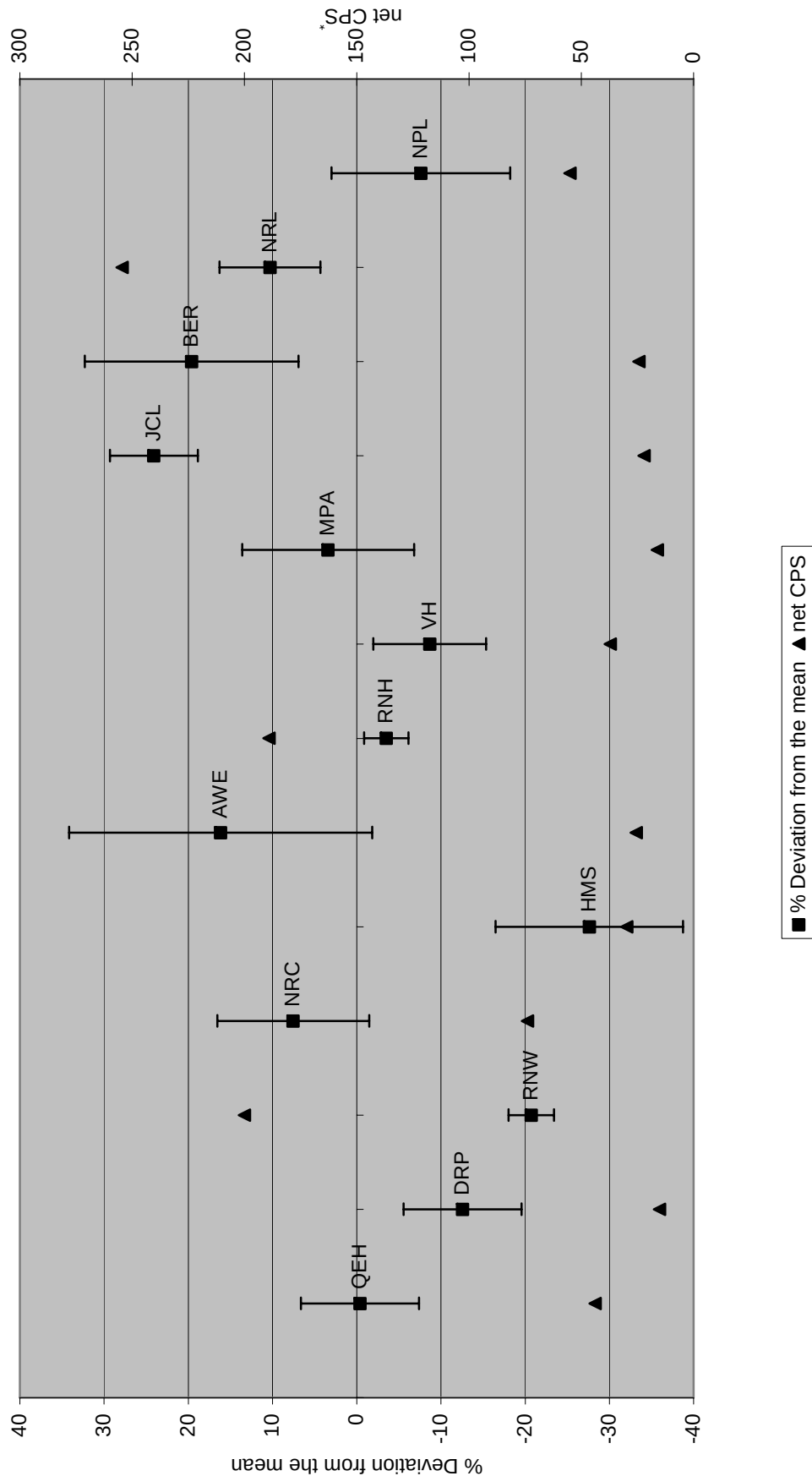
Abbreviations used in the table:

a	semi-width	B	background
c_i	sensitivity co-efficient	cps	counts per second
d_i	divisor	HT	HT setting used for DP6
R	observed instrument reading	SD	standard deviation
SDOM	standard deviation of the mean	SER	surface emission rate per unit area
SQRT	Square Root		

Source of uncertainty	Values reported ($k=1$)	Method of estimation
Background countrate	0.73 %	SDOM of 6 readings
	Included in readings	Uncertainty in net count rate incorporates background uncertainty.
	1.1 %	(SD of 6 reading x 100/Mean count of B)x(Mean B Count/Mean response-B)
	0.32 %	SDOM*sensitivity coeff/SQRT(3)
Backscatter	Negligible	^{14}C is low energy.
Dead time	N/A	Counting loss correction allowed for in meter scaling.
Detector window area	0 %	No data available
	0.27 %	Assumed ± 0.1 mm on manufacturers stated window diameter, using a rectangular distribution.
HT setting	N/A	Preset
Instrument reading	4.8 %	SDOM of 6 sample measurements
	8.6 %	SD of 6 readings
	6.24 %	SDOM*sensitivity coeff/SQRT(3)
Non-uniformity of source	2.31 %	Homogeneity checks
	10 %	Manufacturers specifications
Source – detector separation	1.5 %	As per GPG14
	1.05 %	Estimation of movement between probe and source.
Surface emission rate of reference source	4 %	Calibration data
	3.33 %	Manufacturers specifications
	1.5 %	Calibration data

Not everybody stated how an uncertainty figure was deduced.

Figure 1. Mini EP15 - ^{14}C



* Note that not all participants supplied a reported net cps for each nuclide.

Figure 2. Mini EP15 - ^{36}Cl

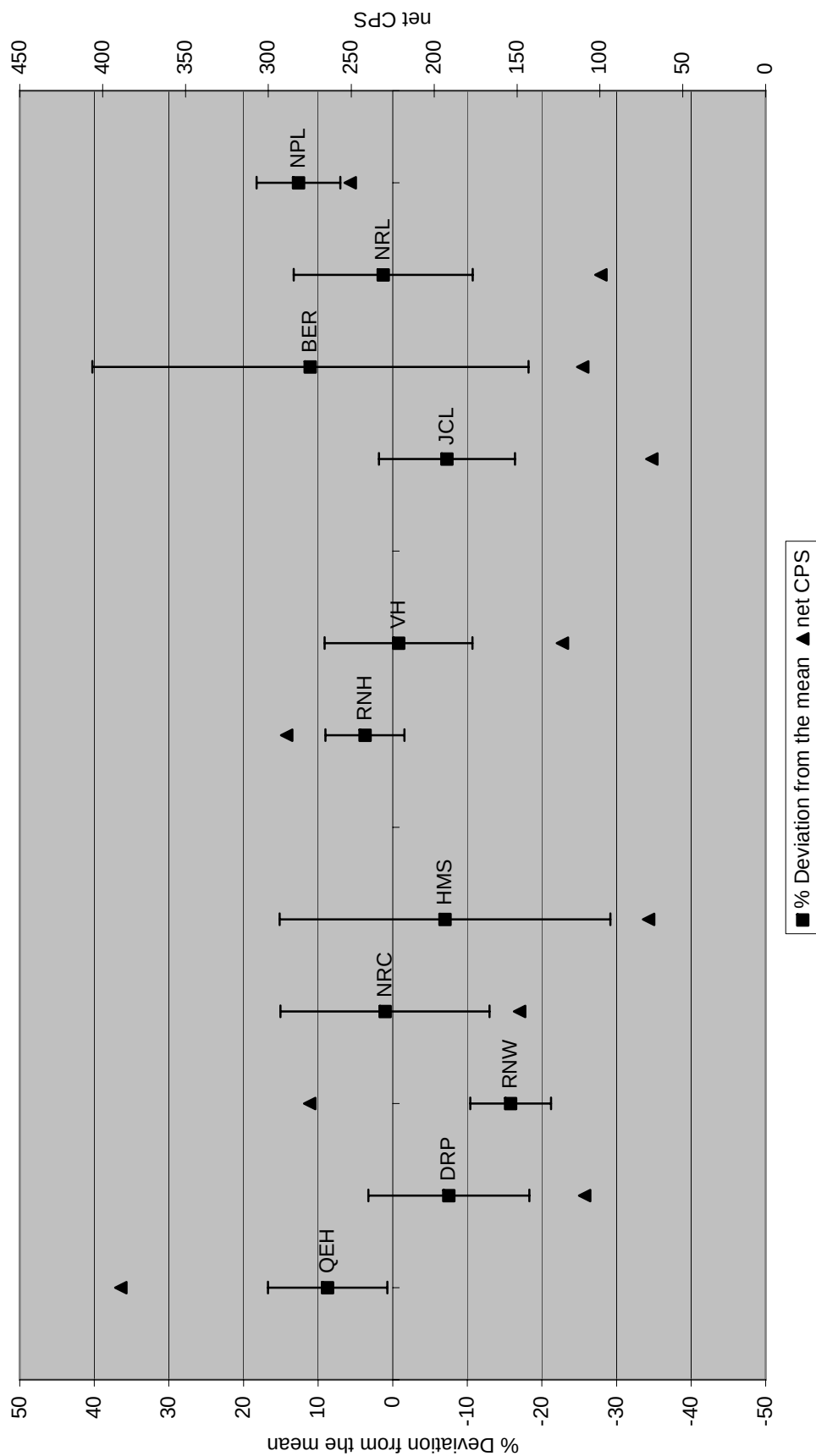


Figure 3. Mini EP15 - ^{60}Co

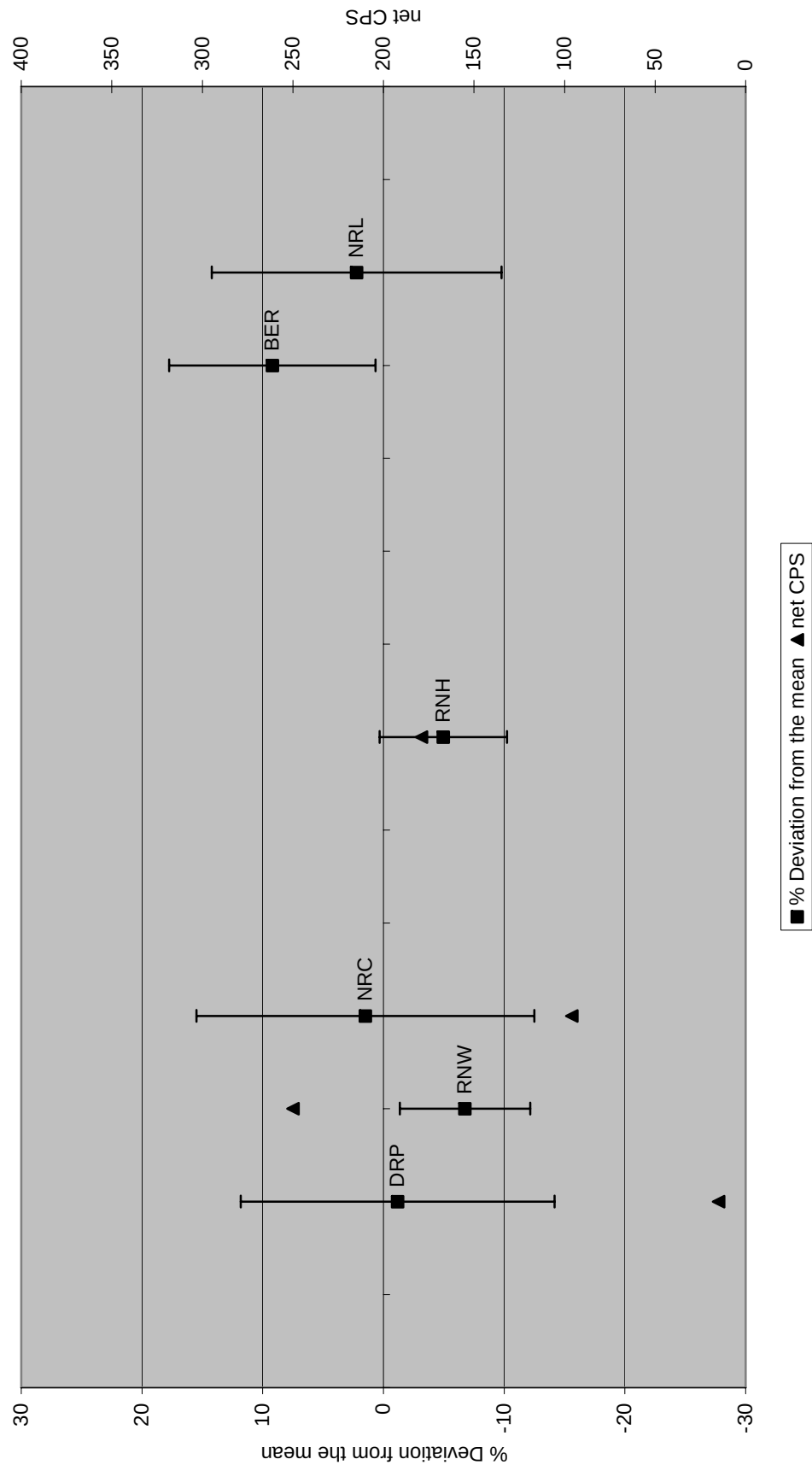


Figure 4. Mini EP15 - $^{90}\text{Sr} + ^{90}\text{Y}$

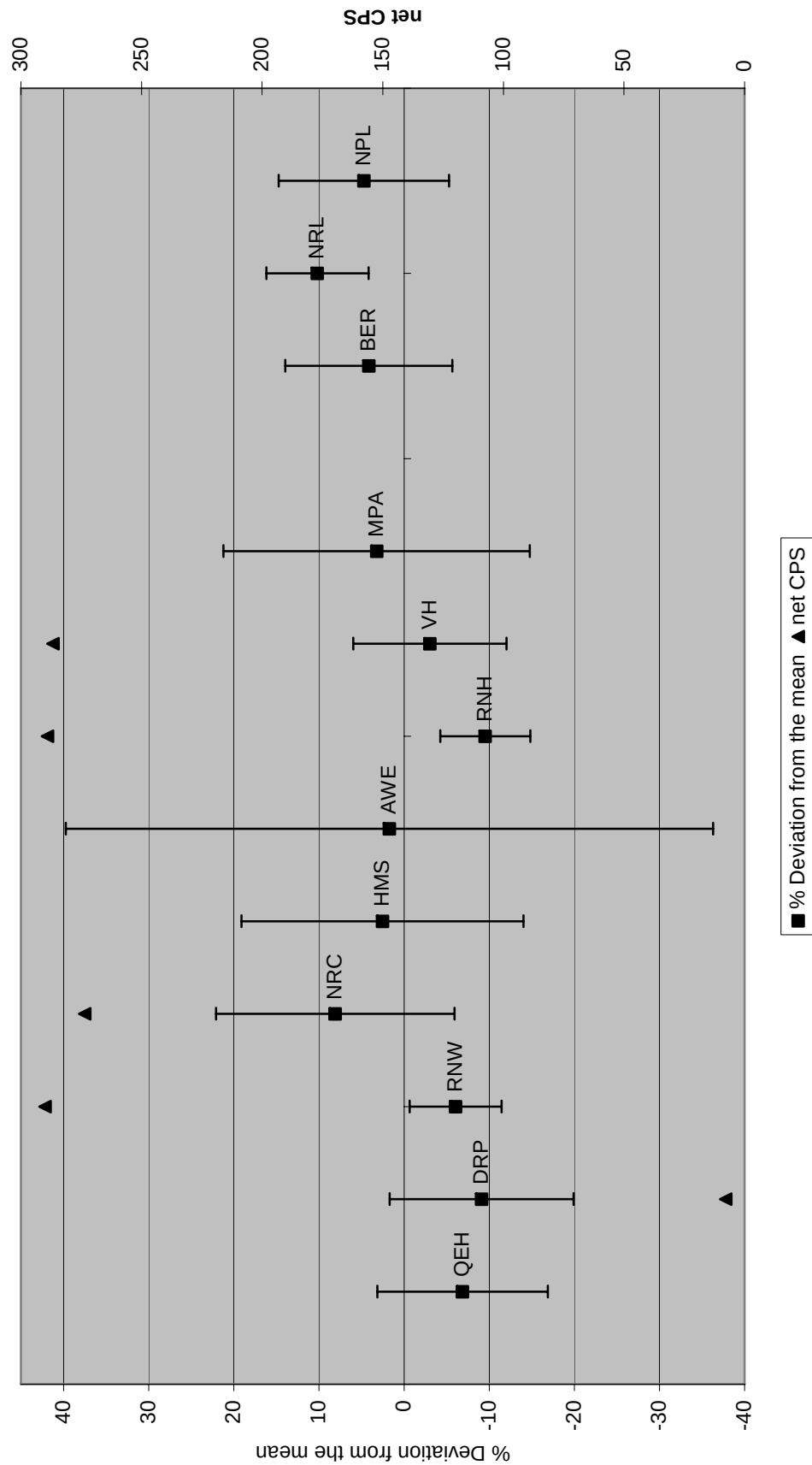


Figure 5. Mini EP15 - ^{137}Cs

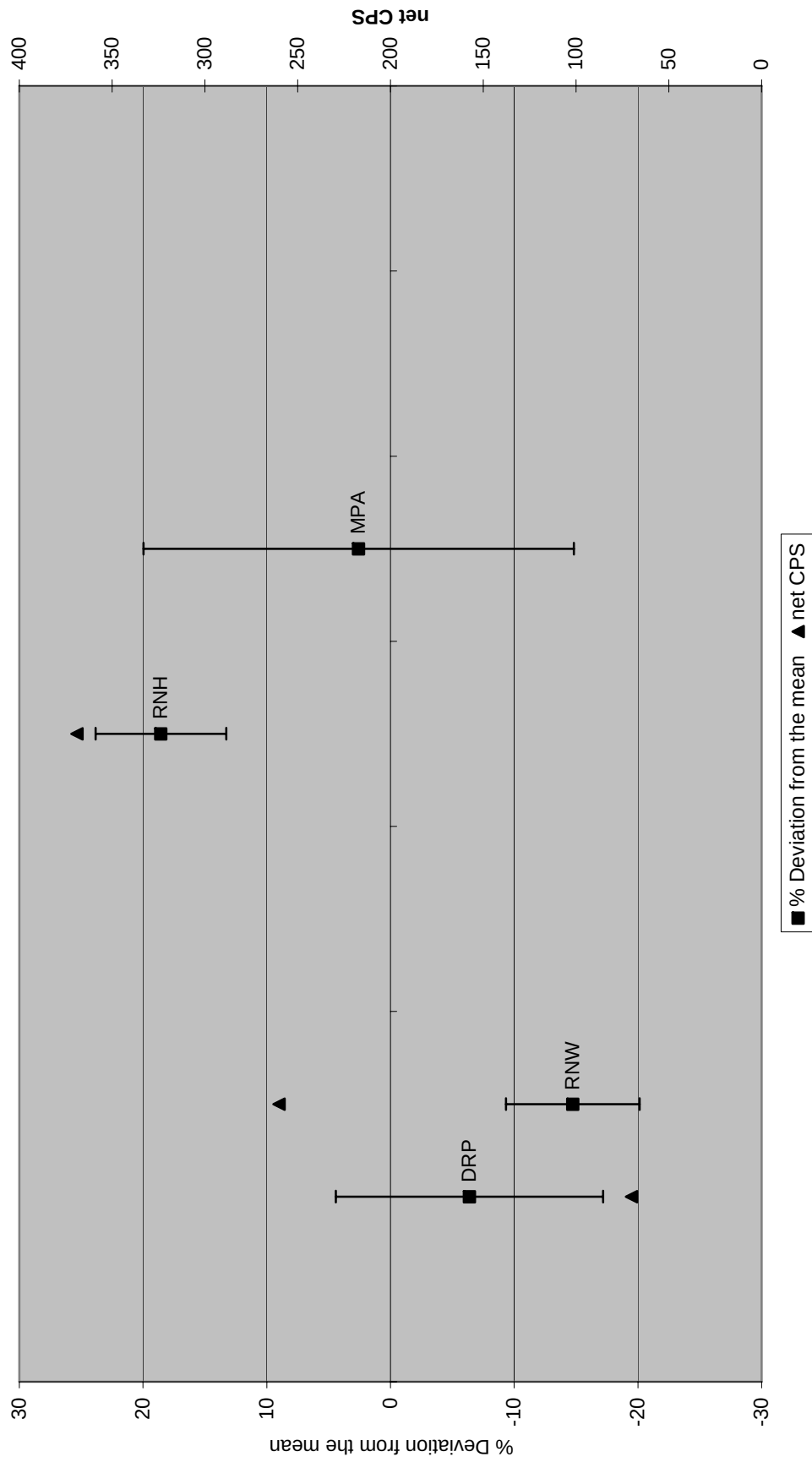


Figure 6. Mini EP15 - ^{147}Pm

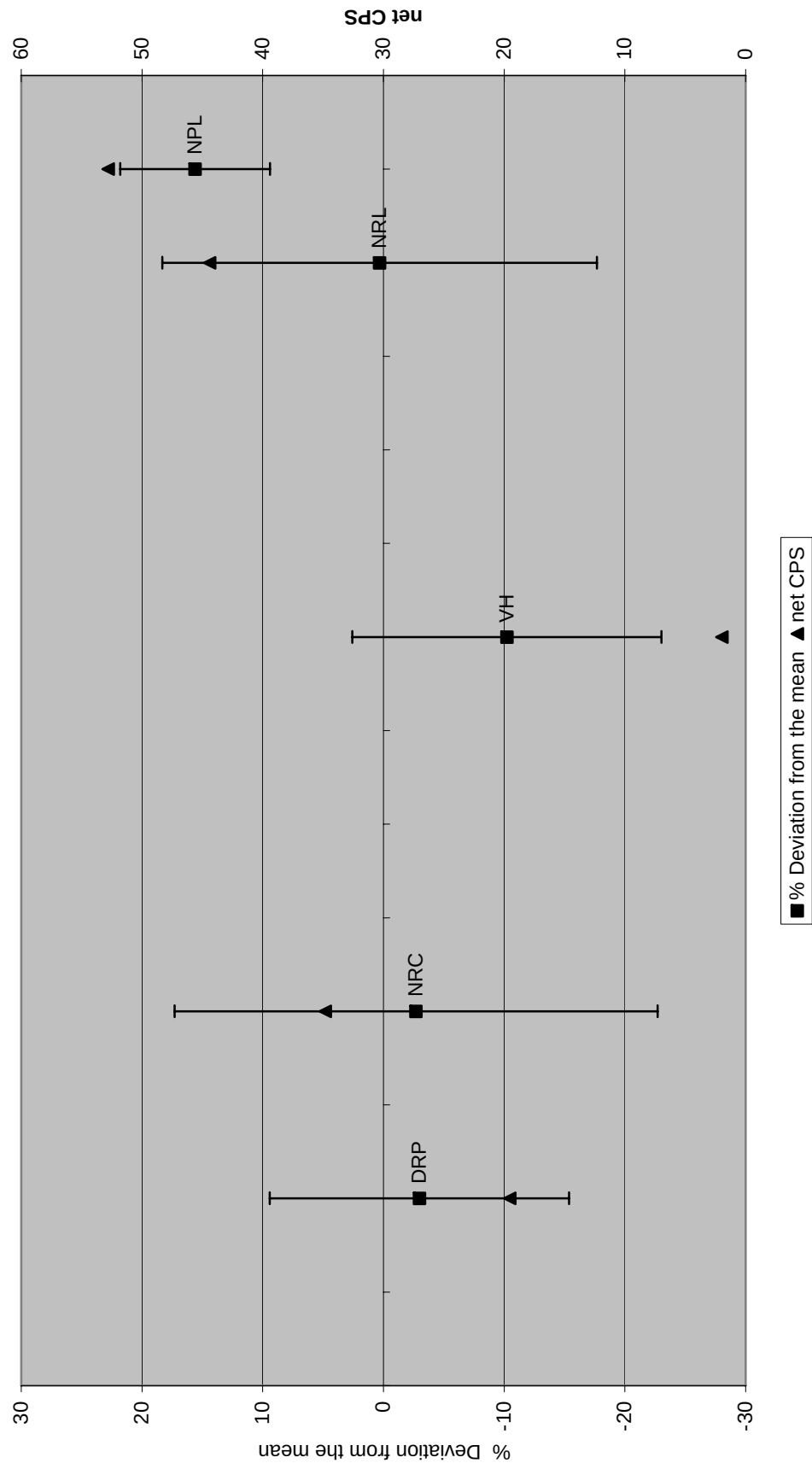


Figure 7. Mini EP15 - ^{241}Am

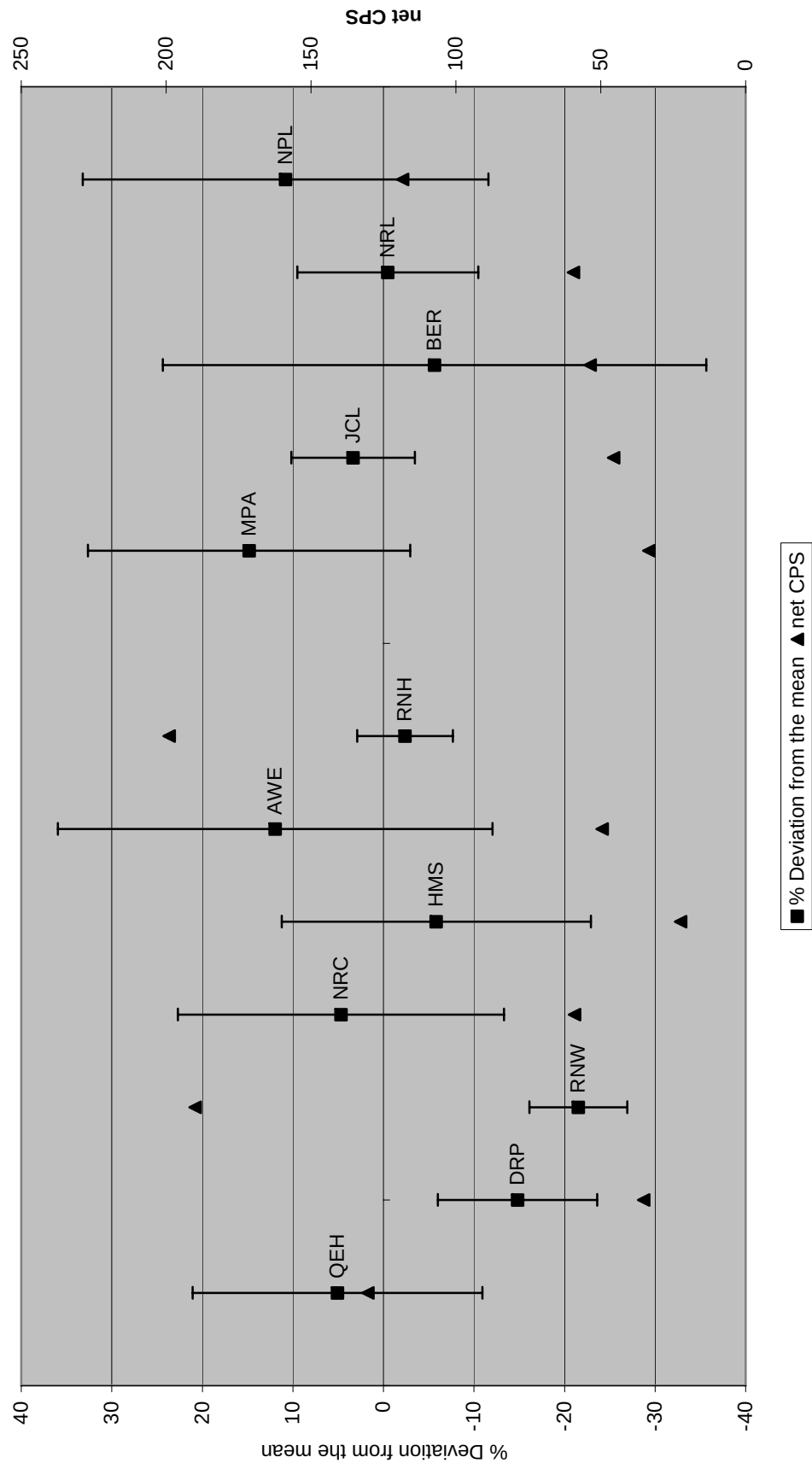


Figure 8. Mini 44B - ⁵⁷Co Filtered Sources

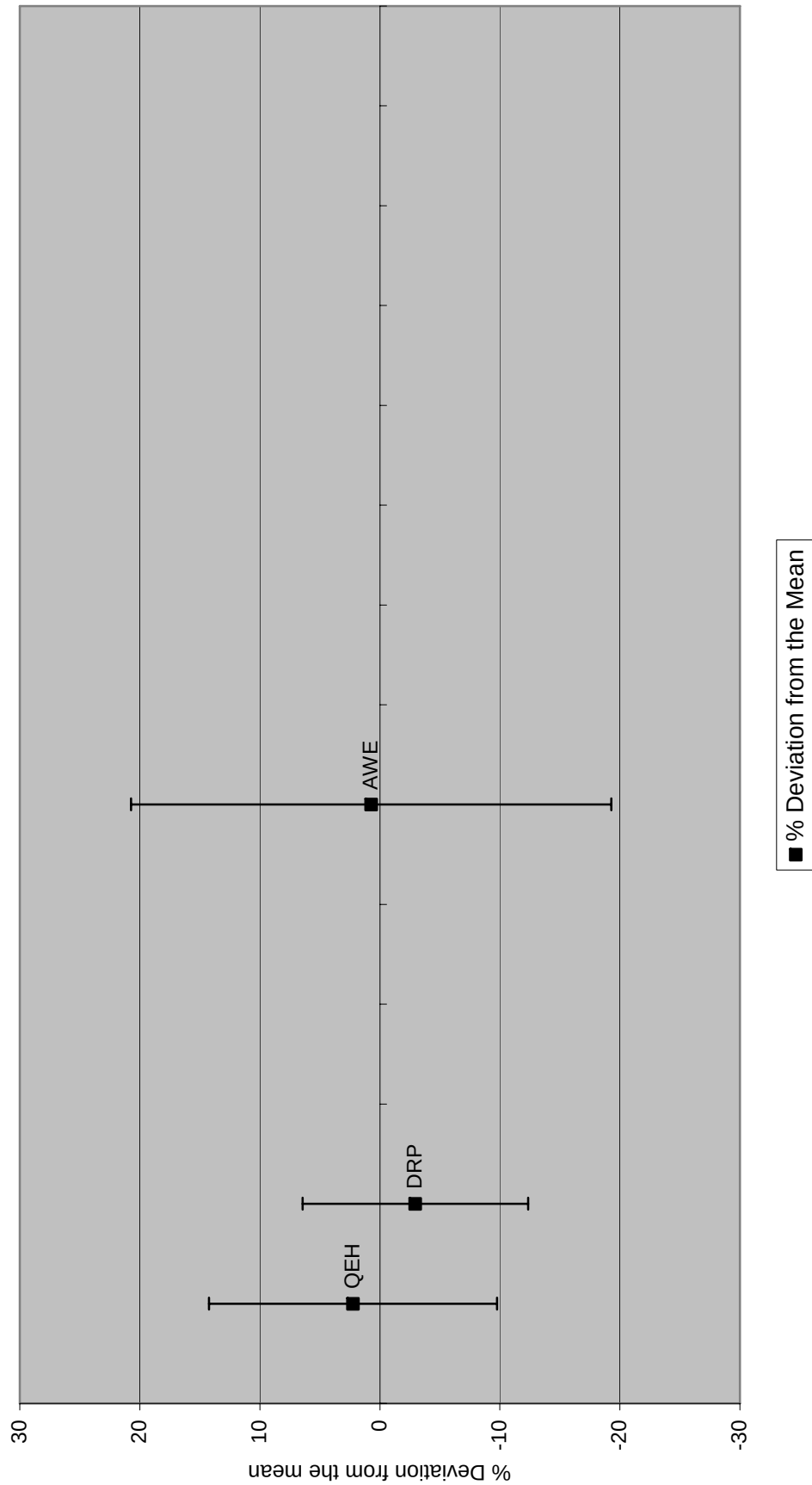


Figure 9. Mini 44B - ^{129}I Filtered Sources

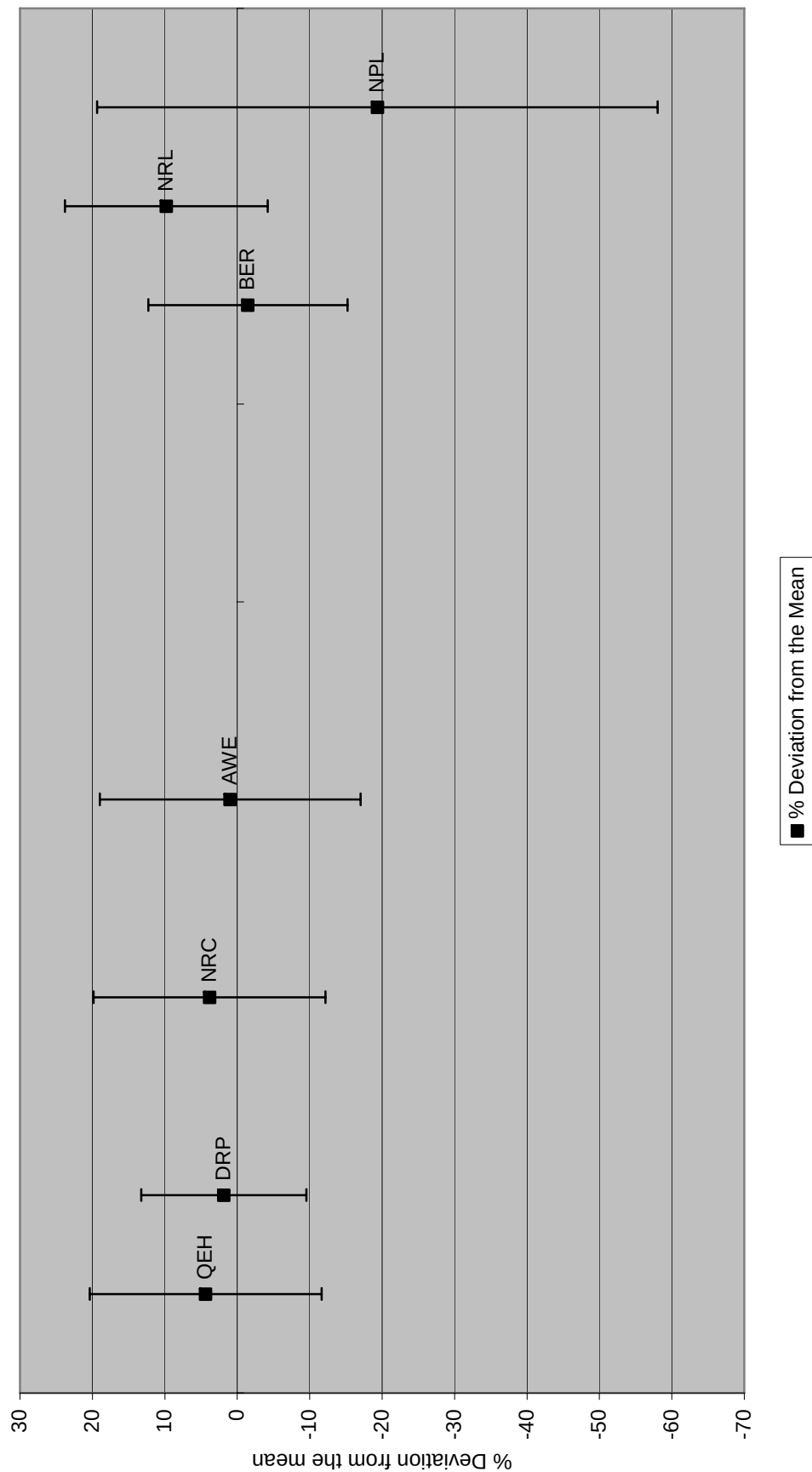


Figure 10. Mini 44B - ²³⁸Pu Filtered Sources

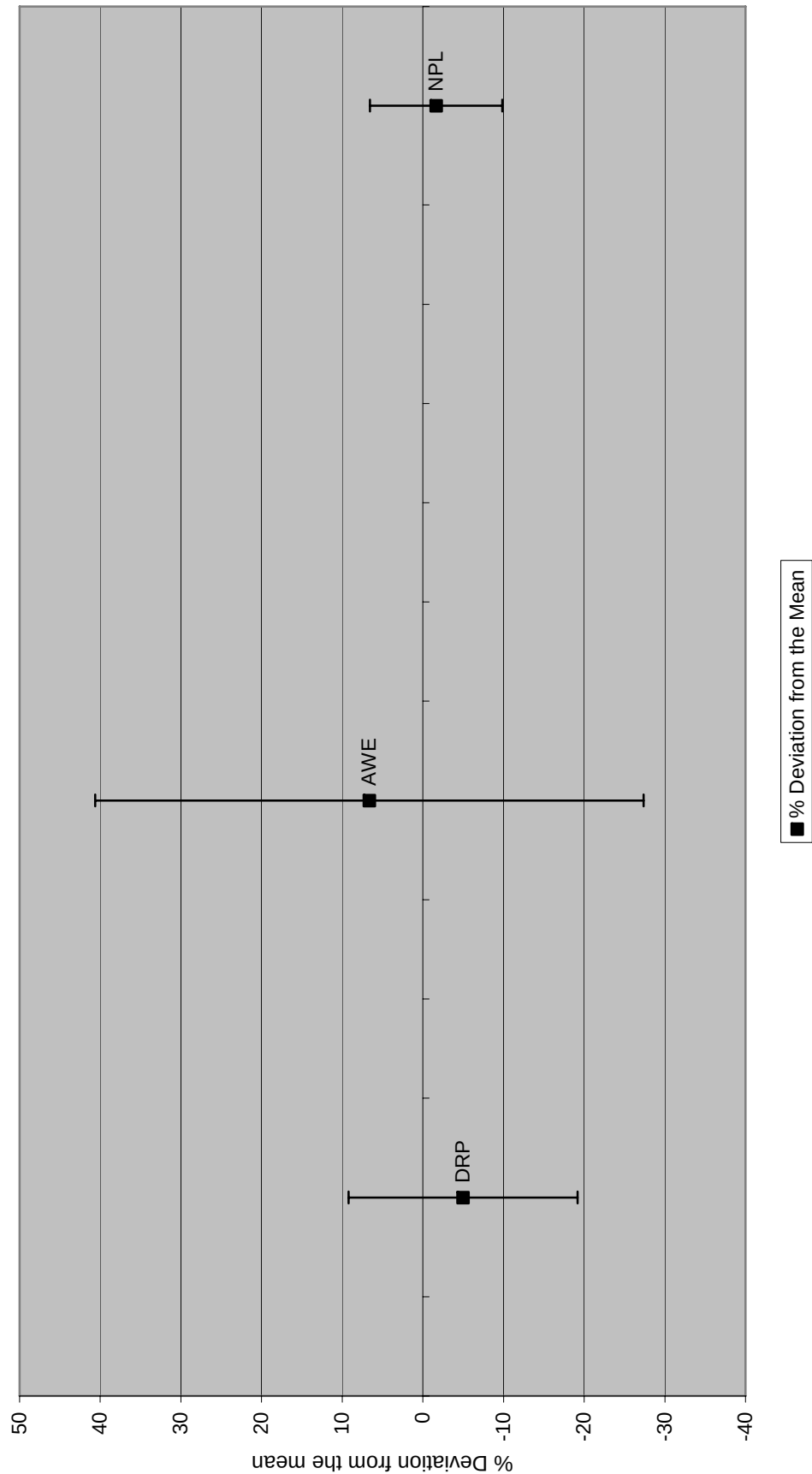


Figure 11. Mini 44B - ²⁴¹Am Filtered Sources

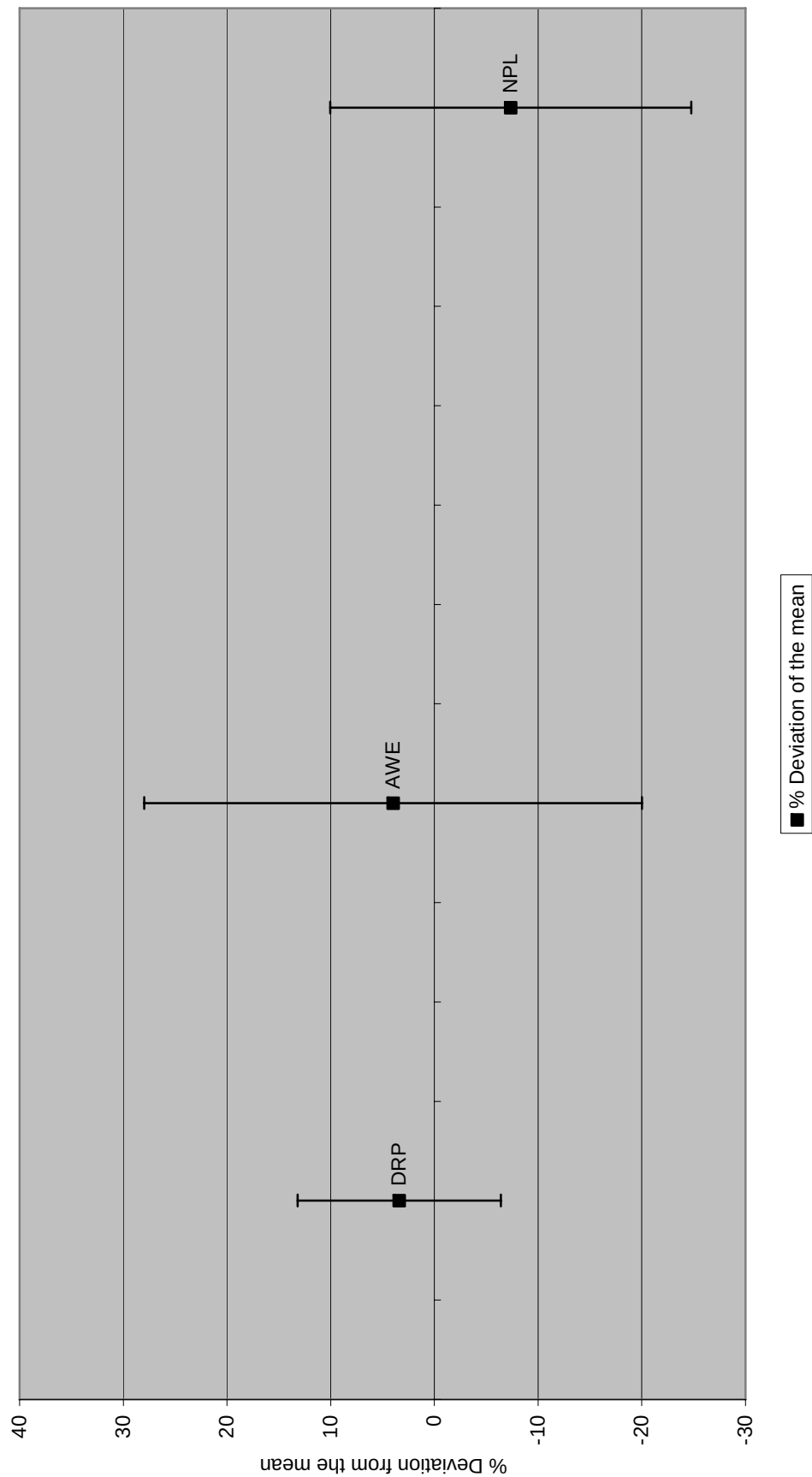


Figure 12. Mini 44B - ^{55}Fe sources

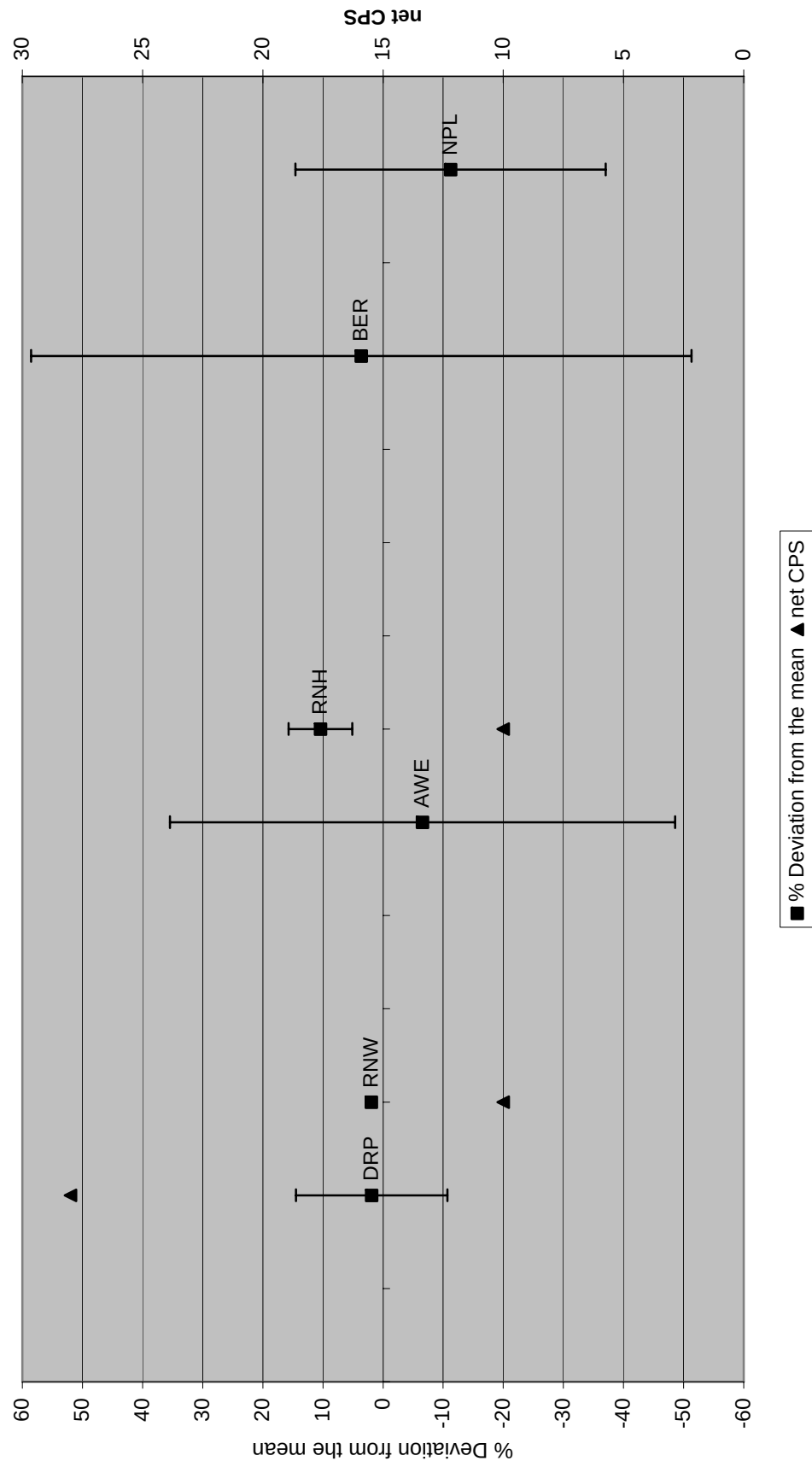


Figure 13. Mini 44B - ^{36}Cl Un-filtered (beta only) Sources

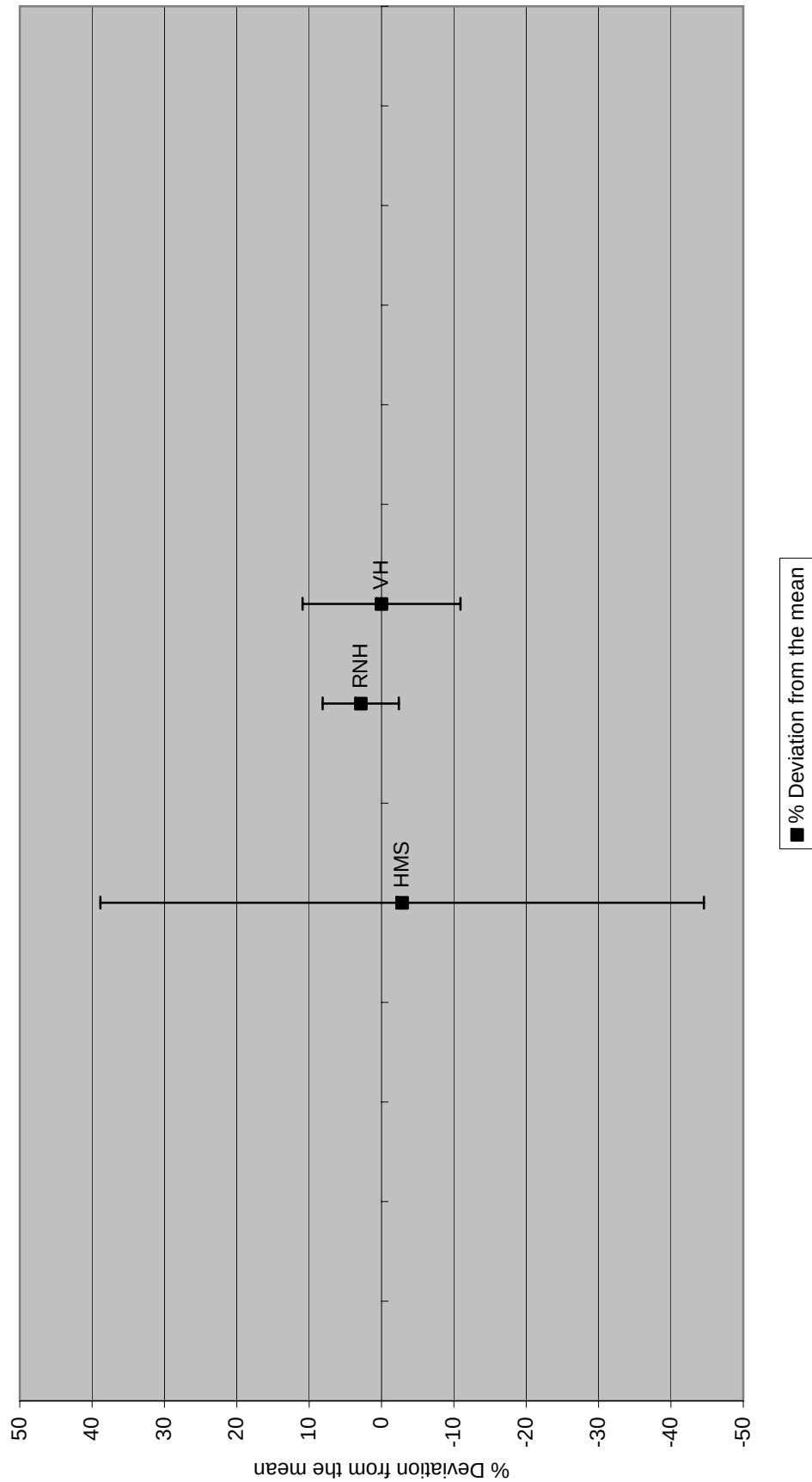


Figure 14. Mini 44B - ^{137}Cs Un-filtered Sources

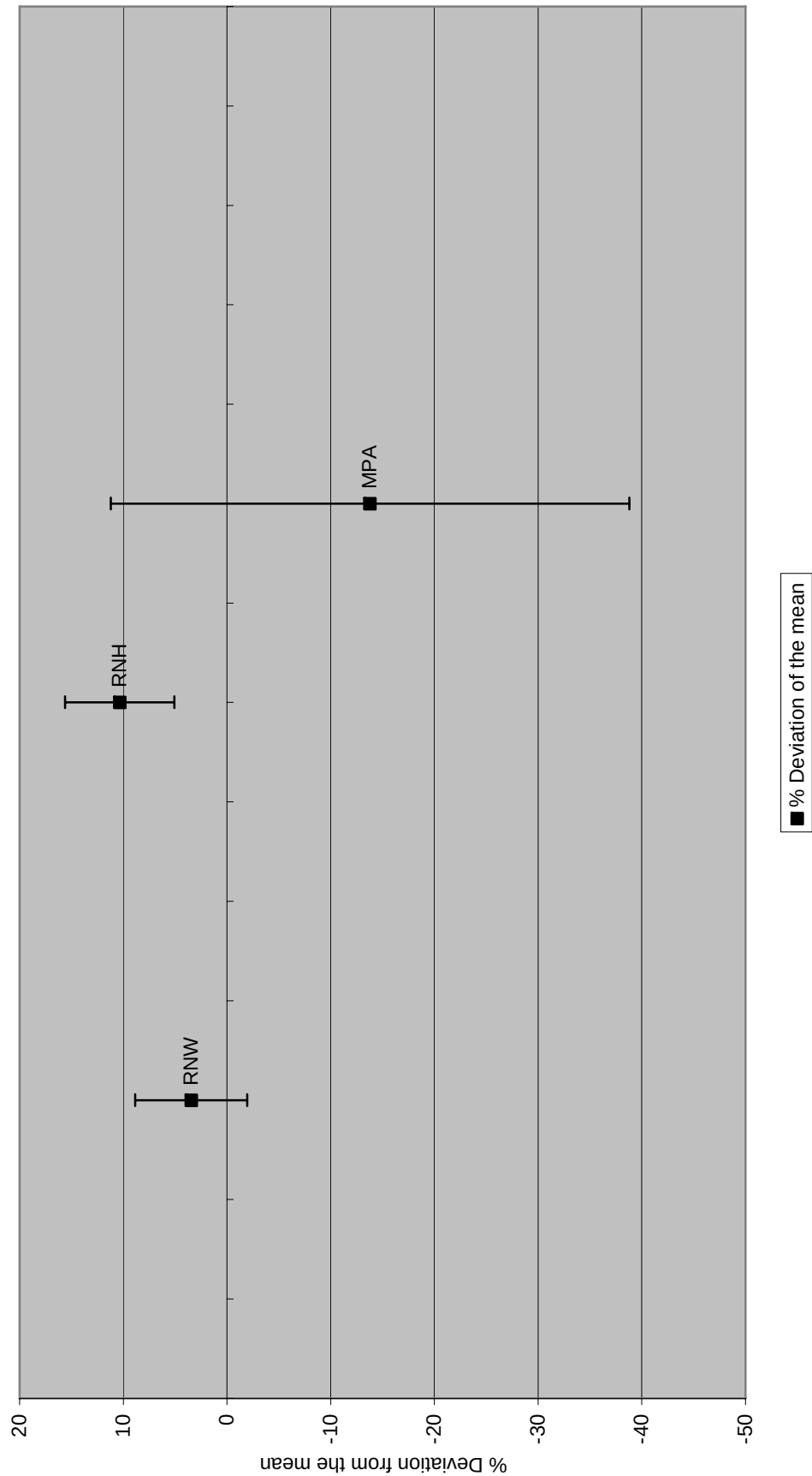


Figure 15. Mini 44B - ²⁴¹Am Un-filtered Sources

