

SPI LOW RANGE ENERGY CALIBRATION DURING FLIGHT

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- TABLE OF CONTENTS -

1. INTRODUCTION.....	4
2. SETUP AND METHODS OF FITTING	5
2.1. CHARACTERISTICS OF REVOLUTION 22.....	5
2.2. CALIBRATION GAMMA RAY LINES USED.....	5
2.3. METHODS OF FITTING	7
2.3.1. <i>Linearity fitting</i>	7
2.3.2. <i>Calibration fitting</i>	7
3. RESULTS	8
3.1. LINEARITY FOR CAMERA ACQUISITION CHAINS	8
3.2. ENERGY CALIBRATION	10

1. INTRODUCTION

This document presents the study of AFEE linearity for the revolution 22.
From these results the energy calibration functions for SPI low range are given.

2. SETUP AND METHODS OF FITTING

2.1. Characteristics of Revolution 22

Why revolution 22 has been chosen to study the acquisition chains linearity and calculate the energy calibration functions?.

To be able to study AFEE linearity, it should be considered that during the studied sequence centroid values of spectral gamma-ray lines do not vary.

For that we need :

- a) a great stability in the cold plate temperature ($\Delta T \approx 0,06$ K),
- b) SPI in a stable nominal configuration,
- c). stability in the AFEE saturation flow.

The Revolution 22 is compliant with these three points.

Another significant data is the manageable duration in the revolution studied ; the manageable duration of the revolution 22 is 2.14 days.

2.2. Calibration gamma ray lines used

On the SPI low range, we can identify more than 50 useful lines, but only 24 had enough statistics to be studied during a revolution. These lines are presented in table 2.2-a.

It should be noted that 23,43 keV and 174,90 keV gamma-ray lines are mono-energetic only in the ME spectra.

For reasons of statistics and mono-energetic status, only the following lines had been retained: 23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV.

It should be noticed that the 1778.9 keV line is not a mono-energetic, it is blended with a line above. But after 1 MeV no line is usable, the 1778.9 keV line has been retained for the calibration because it had enough statistic and it is also quite mono-energetic.

Energy (keV)	Status
23,43	$^{70}\text{Ge}(n,\gamma)^{71*}\text{Ge}$ - In ME spectra
139,68	$^{74}\text{Ge}(n,\gamma)^{75*}\text{Ge}$ - Always measured at 139.8796 keV
174,90	$^{70}\text{Ge}(n,\gamma)^{71*}\text{Ge}$ - In ME spectra
185,72	^{235}U - Two lines mixed
194,06	^{67}Ga - One line
198,34	$^{70}\text{Ge}(n,\gamma)^{71*}\text{Ge}$ - One line
271,24	$^{44*}\text{Sc}$ - One line
309,86	^{67}Ga - One line
438,6	$^{69*}\text{Zn}$ - One line
511,004	e^+/e^- - One line
574,11	$^{75*}\text{Ge}(n,\gamma)^{69}\text{Ge}$ - Two lines mixed
584,48	^{69}Ge - Two lines mixed
810,75	^{58}Co - Two lines mixed
817,86	^{58}Co - One line
825,2	^{203}Pb - One line
882,35	^{69}Ge - One line
1014,4	$^{27*}\text{Al}$ - Two lines
1117,1	^{69}Ge - One line blended with above
1124,5	^{65}Zn - Problem with statistics
1336,6	^{69}Ge - Two lines mixed
1368,53	^{24}Na - 4 lines mixed
1764,3	^{214}Bi - Two lines mixed
1778,9	^{28}Al - One line blended with above

Table 2.2-a. Useful gamma ray lines for SPI low range calibration
(ref. for status of gamma-ray lines : G.Weidenspointner)

2.3. Methods of fitting

2.3.1. Linearity fitting

Instead of used a linear fit as:

$$E = A_0 + A_1 C, \text{ E is the energy and C the channel number.}$$

This function had been preferred:

$$\frac{C}{E} = A_0 + \frac{A_1}{E}, \text{ equation 1}$$

This function allows realizing a very good fitted convergence better than a standard linear fit.

It also makes possible to use the measured channel errors. It is easy then to pass to linear fit by multiply the results by E.

2.3.2. Calibration fitting.

The function used to fit data is a 3 rd order polynomial.

This function is:

$$\frac{C}{E} = A_0 + \frac{A_1}{E} + \frac{A_2}{E^2} + \frac{A_3}{E^3}, \text{ equation 2}$$

To obtain the channel fitted value it must multiply the finding value by E. But, we want know the coefficients (A_0, A_1, A_2, A_3) for the following function: $\frac{E}{C} = f\left(\frac{1}{C}\right)$.

The only solution is to inverse numerically the equation 2. The inversion error is less than 0.0001 keV.

3. RESULTS

3.1. Linearity for camera acquisition chains

Gamma ray used for fitting data are: 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV.

The method used is explained in the 2.3.1.

Figure 3.1-a shows residuals in channel between the values measured and fitted for the detector 0. We can say that the (cf. annex one, for the other detectors) are linear into one channel between 200 keV and 2 MeV.

Figure 3.1-b shows the results obtained for the detector 0 (cf. annex 2 for the other) when the previously function is applied on 20 peaks. We observe a none-linearity (-2.5 channel for the 23.3 keV gamma ray) below 200 keV. On the same figure is superimposed the linearity residuals that we obtained during BRUYERES LE CHATEL SPI calibration campaign. The shape of the residuals measured in flight and SPI on ground is the same one.

So, Which parts of the acquisition chain induced its none linearity?

Figure 3.1-c shows the mean residuals to linearity measured with ground electronics. It is clear, in this case that the answer Energy - channel is linear.

Thus, the none-linearity measured in flight and on the ground on the spectrometer comes from the AFEE and not from the preamplifiers.

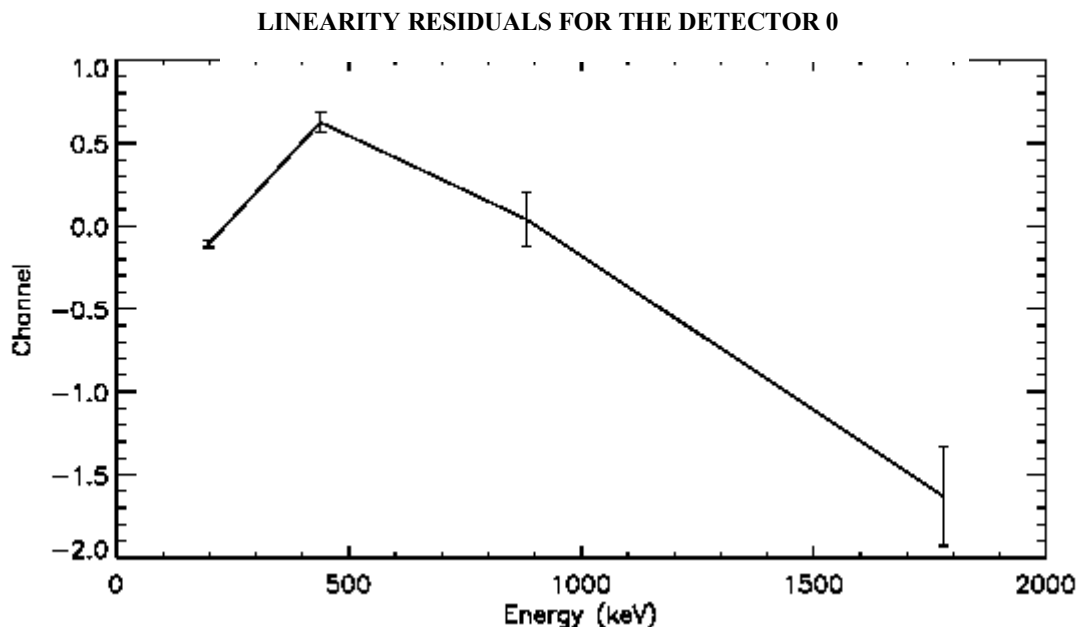


Figure 3.1-a: Linearity residuals for the detector 0 (1st order polynomial), only for calibration lines (198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV). Revolution 22.

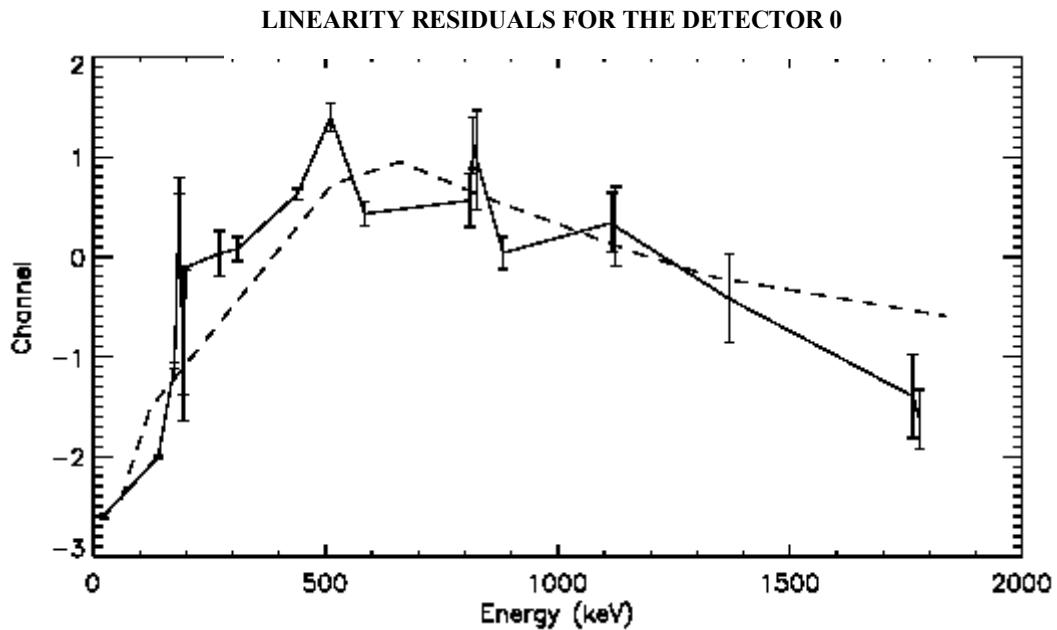


Figure 3.1-b: Linearity residuals for the detector 0 (1st order polynomial).

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used, 4 calibration lines to compute linearity response (198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV), revolution 22.

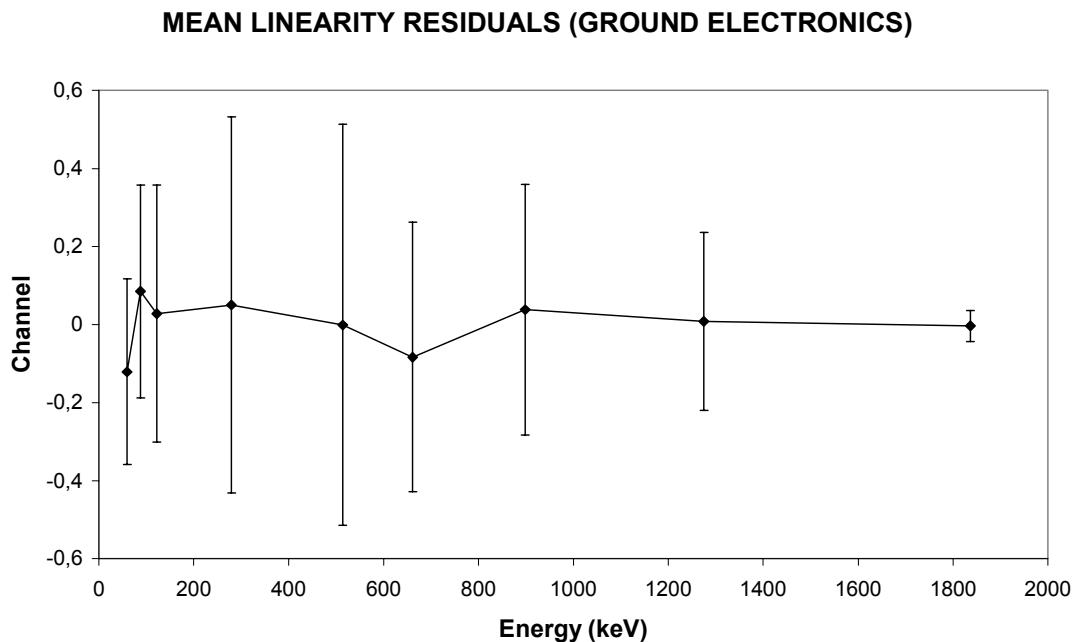


Figure 3.1-c: Camera means linearity residuals for ground electronics (Banc de Test).

These measurements had been performed during the SPI camera calibration.

3.2. Energy calibration

Peaks used: 23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV.

The method of fitting used is explained in the 1.3.2 section.

Figures 3.2-a and 3.2-b show the residuals between measured data and calibrate one for the detector 0. These results are obtained for line whose centroids are well-known (fig 2.2.1 and annex 3) and for all lines studied (fig 3.2.b and Annex 4). We can conclude that it is possible to calibrate the SPI low range at worst ± 1 channel.

To finish, table 3.2-a shown us coefficients calibration ($\frac{E}{C} = A_0 + \frac{A_1}{C} + \frac{A_2}{C^2} + \frac{A_3}{C^3}$) found for the revolution studied (revolution 22).

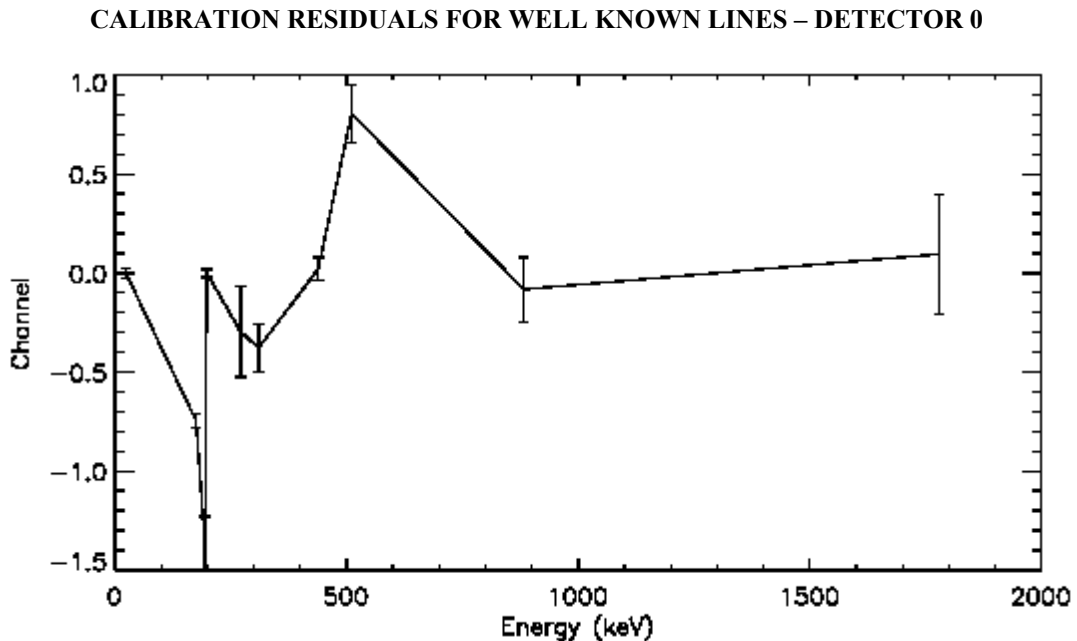


Figure 3.2-a: Calibration residuals for the detector 0 (3rd order polynomial).

**Calibration lines: 23,43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV.
 Revolution 22.**

CALIBRATION RESIDUALS FOR ALL LINES – DETECTOR 0

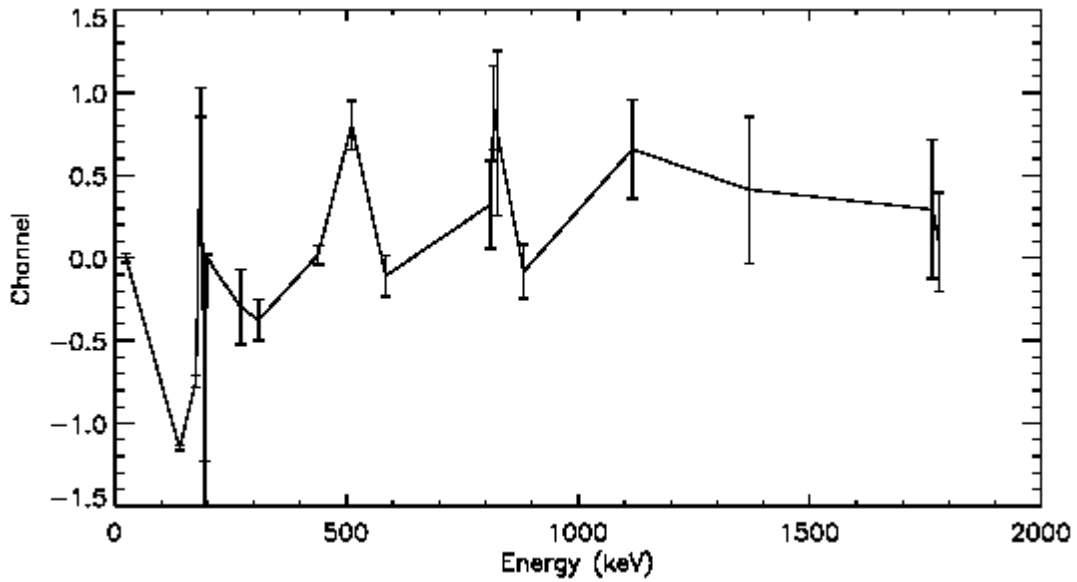


Figure 3.2-b: Calibration residuals for the detector 0 (3rd order polynomial).

*Calibration lines: 23,43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV.
 Revolution 22.*

DETECTOR NUMBER	A ₀	A ₁	A ₂	A ₃
0	0.13566896	1.3739970	-495.23071	63274.922
1	0.13443124	1.4707540	-249.88390	27782.260
2	0.13474136	1.3910645	-428.46790	53293.707
3	0.13365280	2.3179549	-417.54598	50942.319
4	0.13482355	1.4315543	-241.37004	25575.008
5	0.13486428	2.1354298	-427.29725	51991.261
6	0.13442708	1.6446645	-470.73924	58936.306
7	0.13531811	1.4635816	-539.14773	69300.732
8	0.13460487	1.2385193	-425.73204	53775.164
9	0.13461748	1.2595966	-221.96732	22705.352
10	0.13426203	1.5536902	-294.45521	33773.823
11	0.13501858	2.4523628	-349.60258	39990.235
12	0.13531203	1.3453406	-412.49028	50641.204
13	0.13446560	1.2774160	-152.61615	13860.076
14	0.13486408	1.2745028	-372.11223	45596.909
15	0.13470172	1.4552985	-355.34094	42383.997
16	0.13493273	1.0701387	-288.49200	33155.565
17	0.13357310	1.8820558	-273.97205	31331.479
18	0.13488035	1.2443022	-338.93848	41224.183

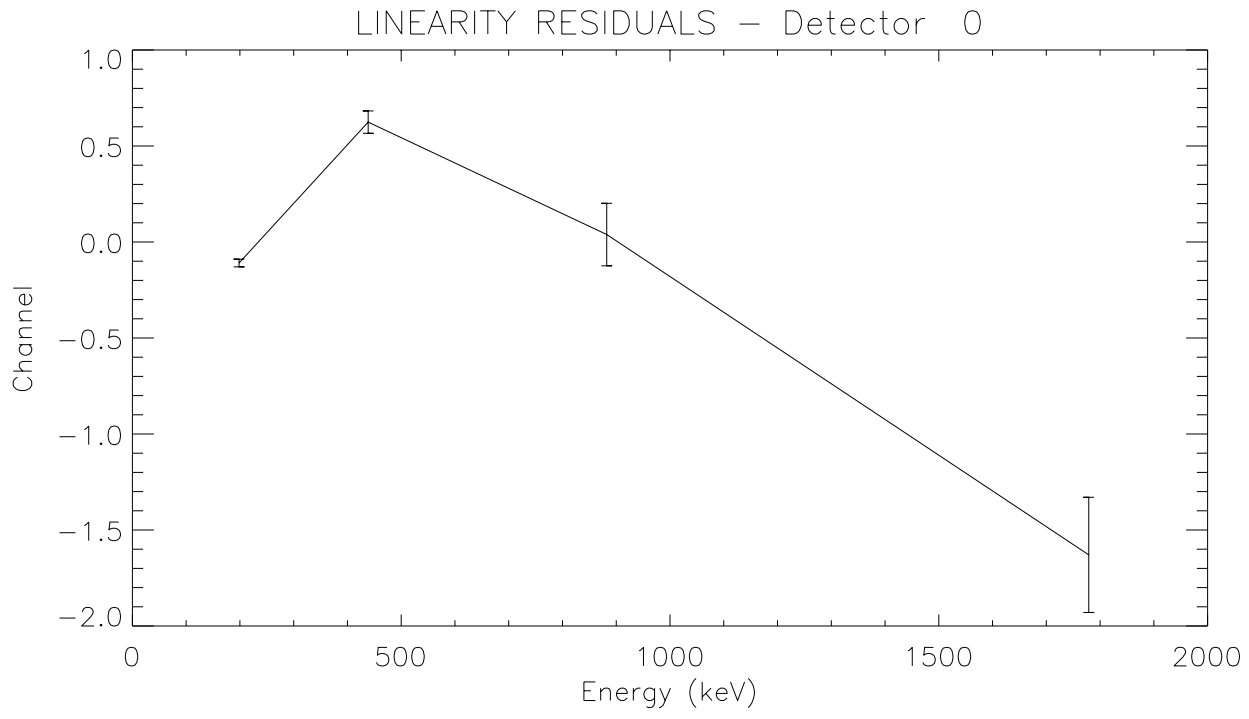
Table 3.2-a: Calibration coefficient for SPI (revolution 22).

$$\text{Calibration function: } \frac{E}{C} = A_0 + \frac{A_1}{C} + \frac{A_2}{C^2} + \frac{A_3}{C^3}$$

ANNEX 1

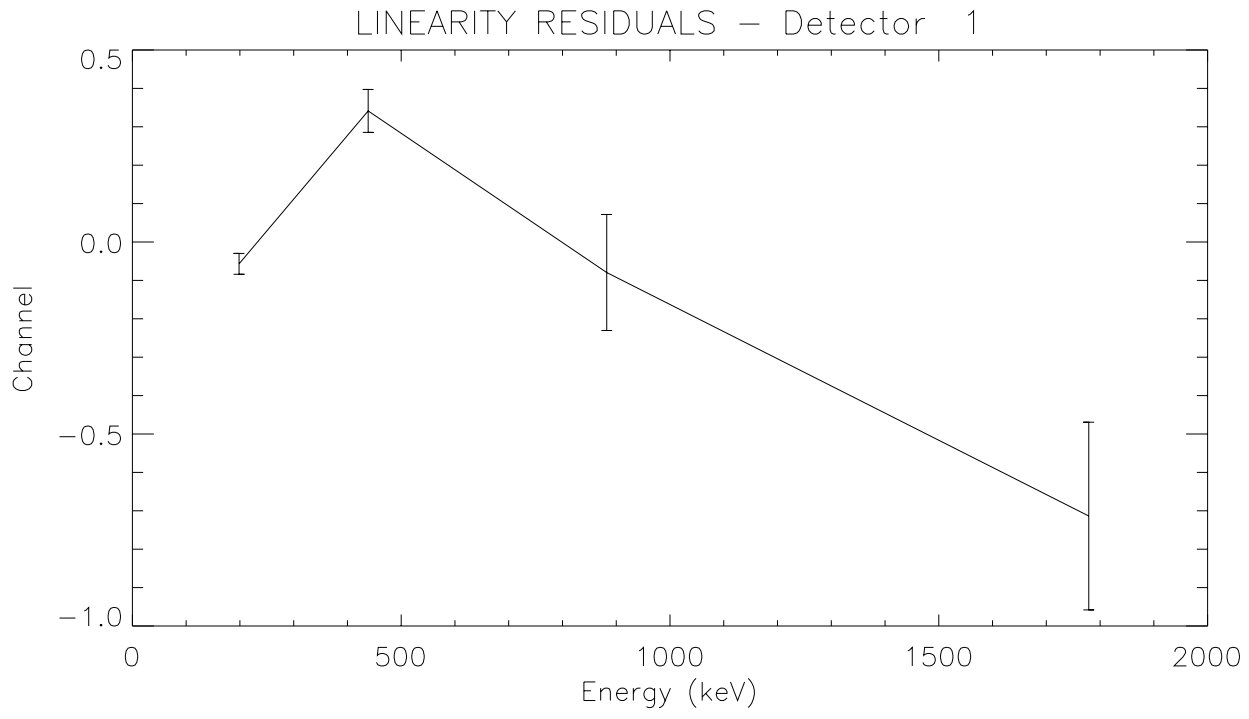
**Linearity residuals (1st order polynomial), only for calibration lines
(198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV).**

Revolution 22.



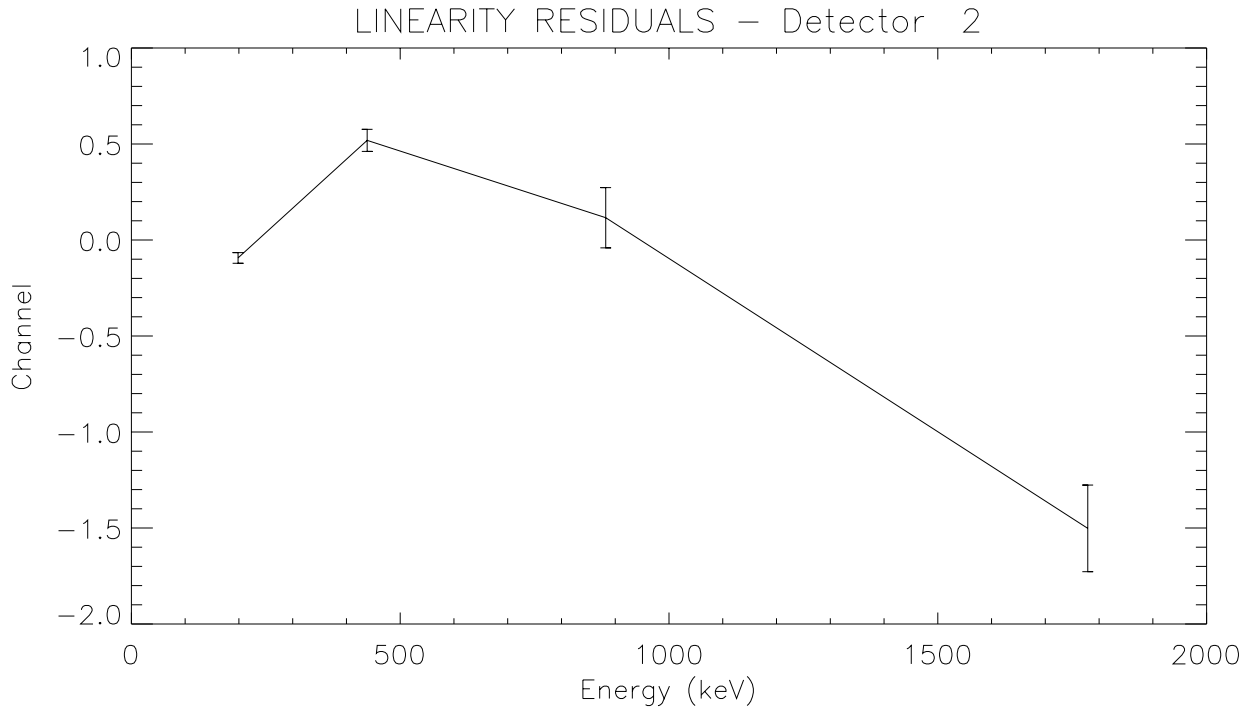
Linearity residuals for the detector 0 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



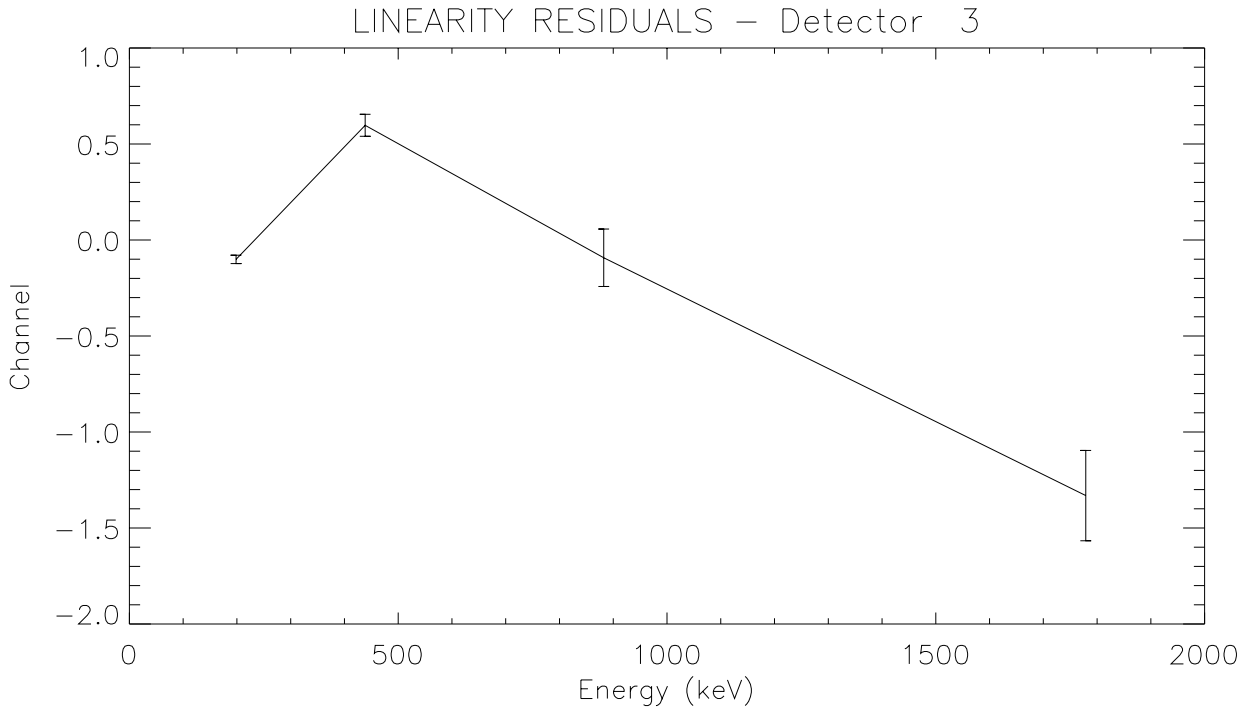
Linearity residuals for the detector 1 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



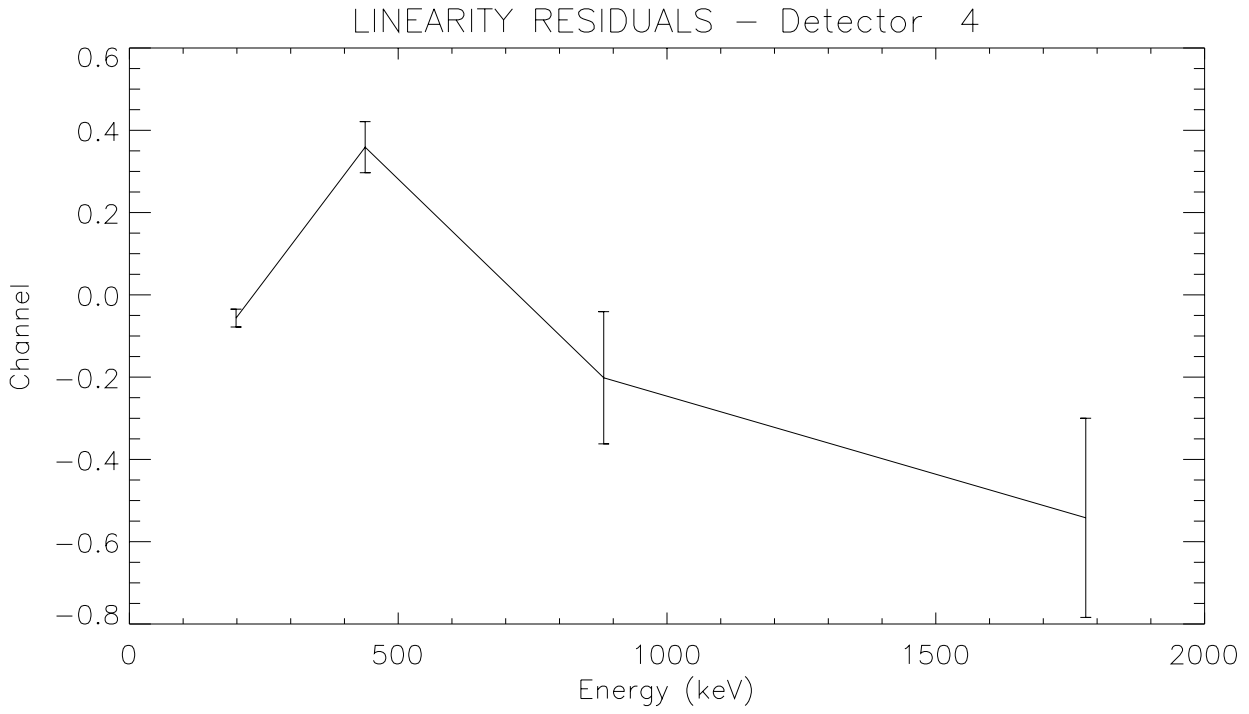
Linearity residuals for the detector 2 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



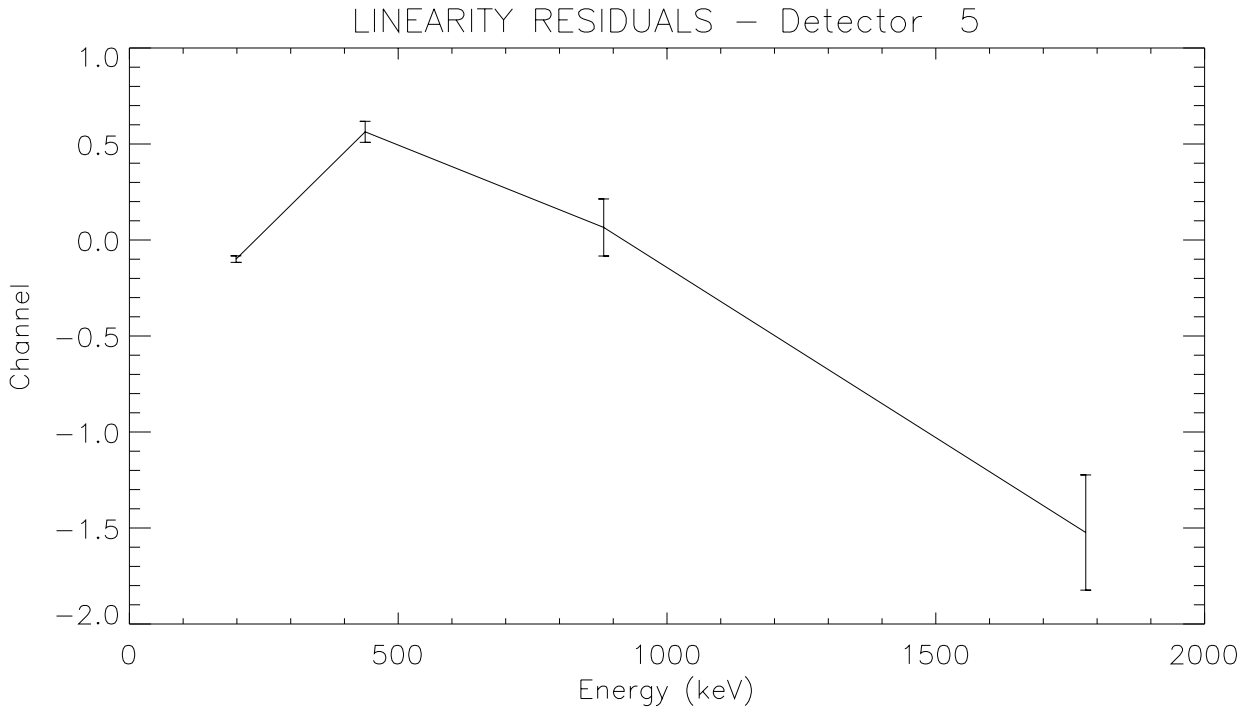
Linearity residuals for the detector 3 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



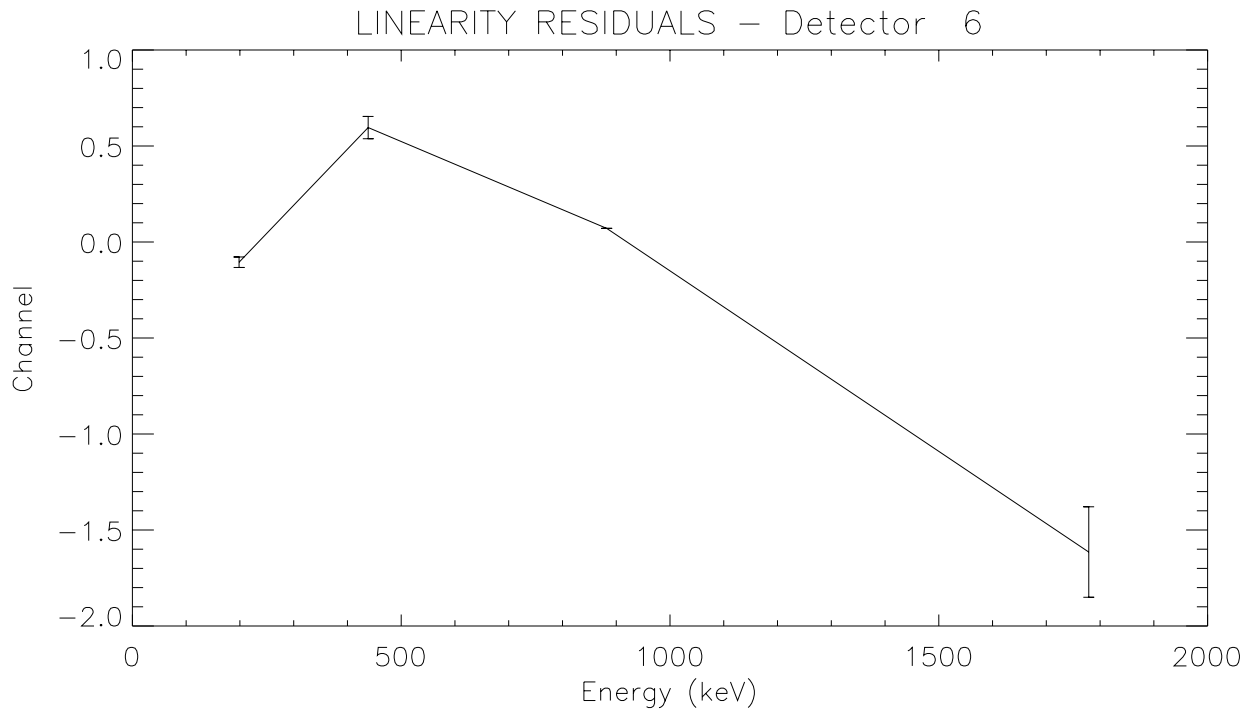
Linearity residuals for the detector 4 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



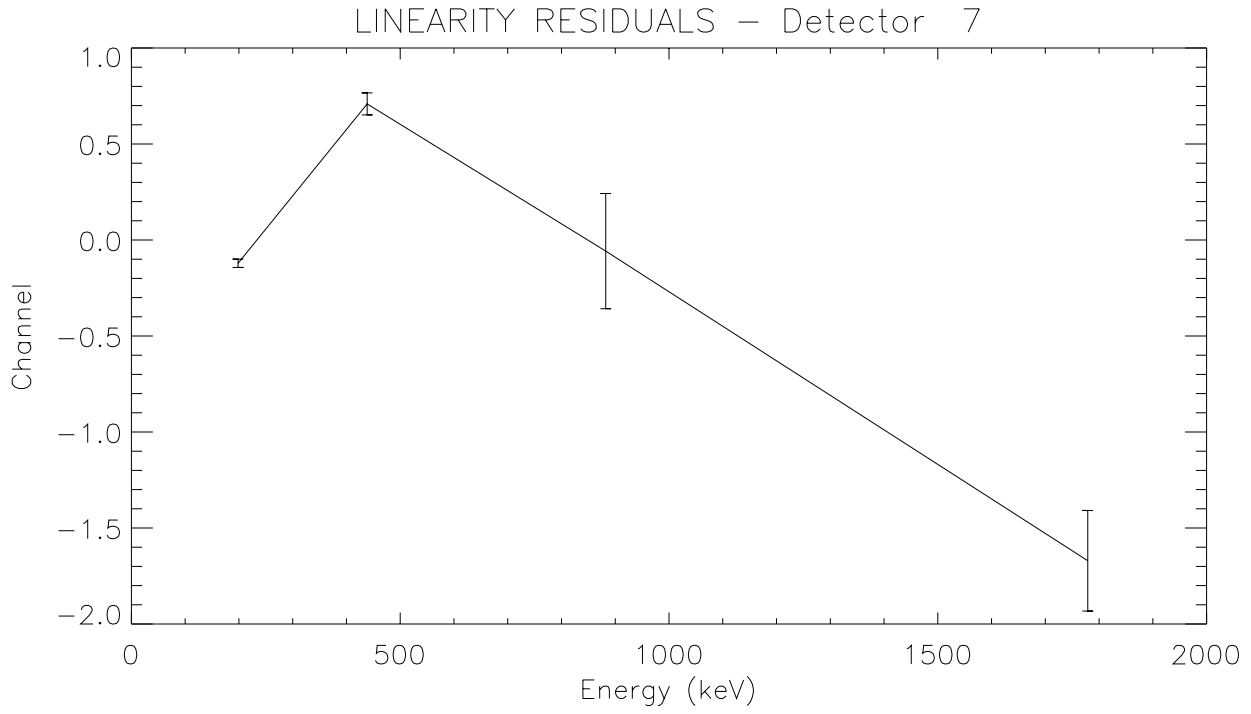
Linearity residuals for the detector 5 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



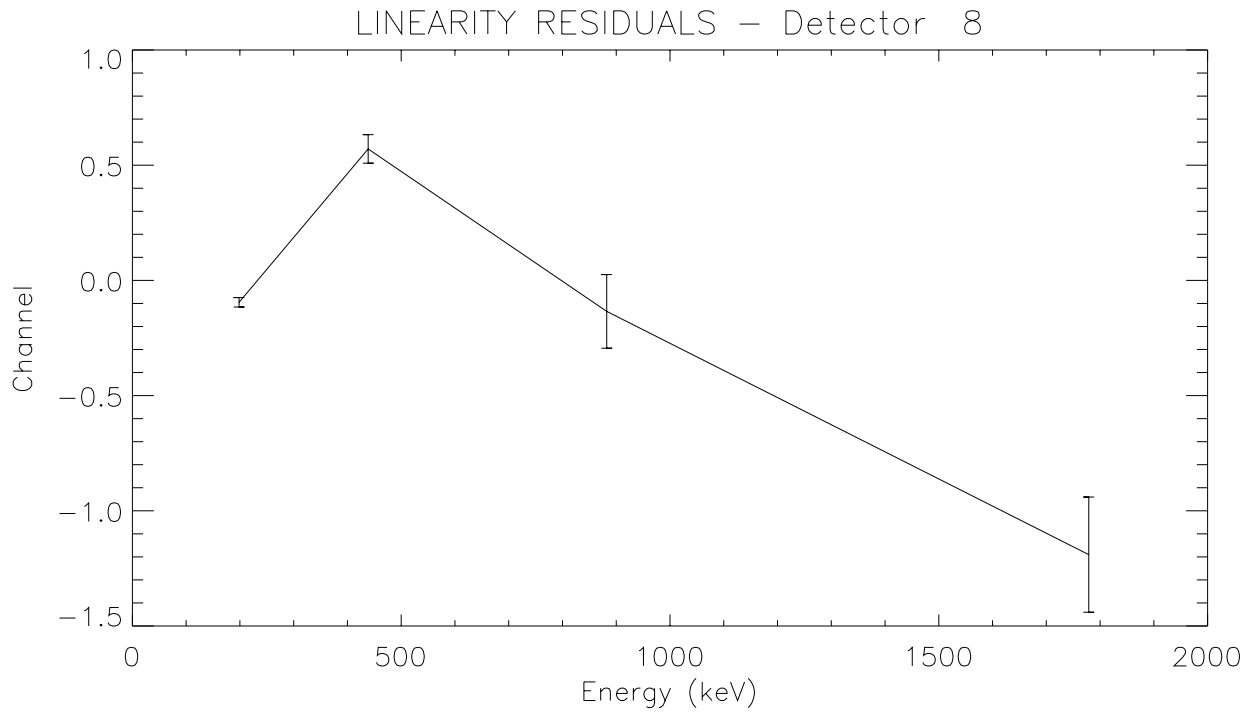
Linearity residuals for the detector 6 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



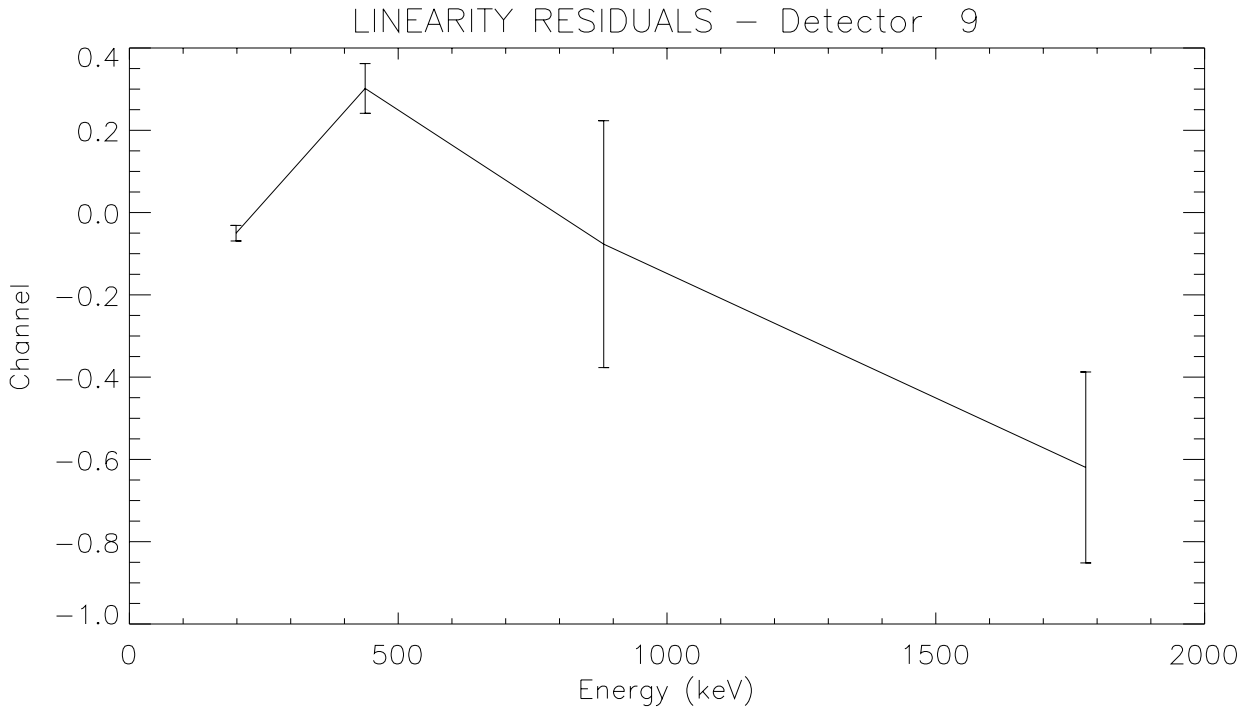
Linearity residuals for the detector 7 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



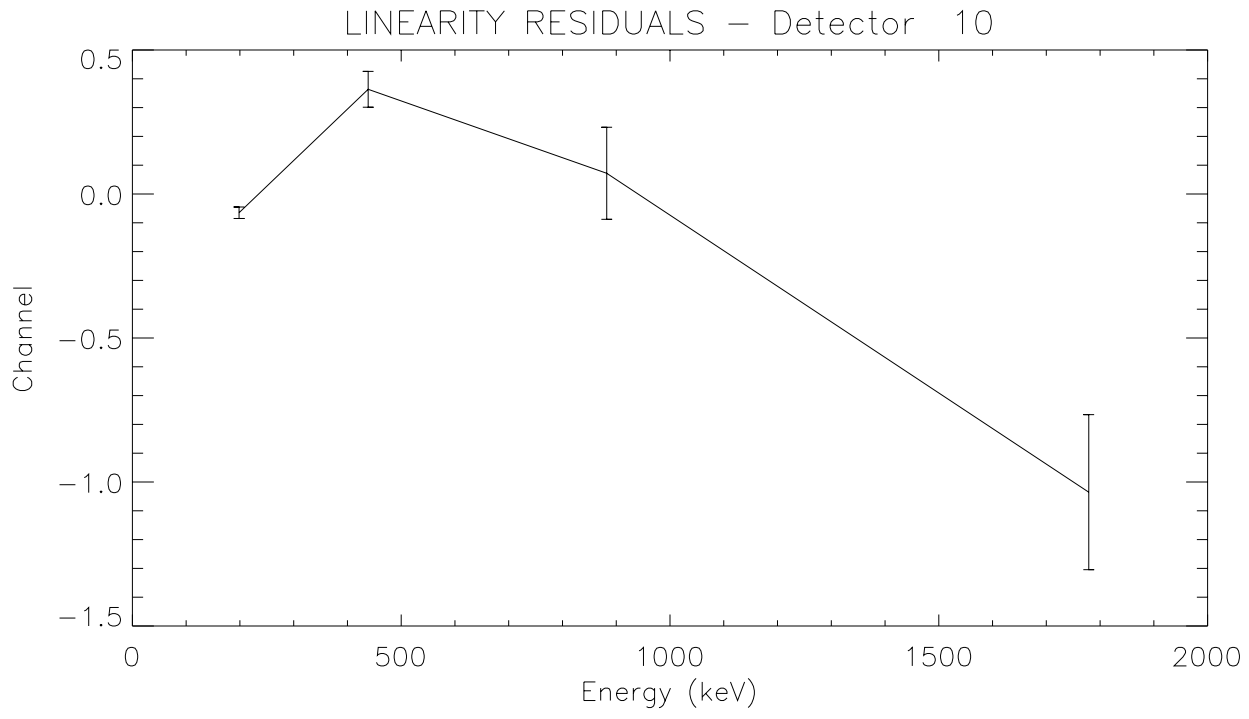
Linearity residuals for the detector 8 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



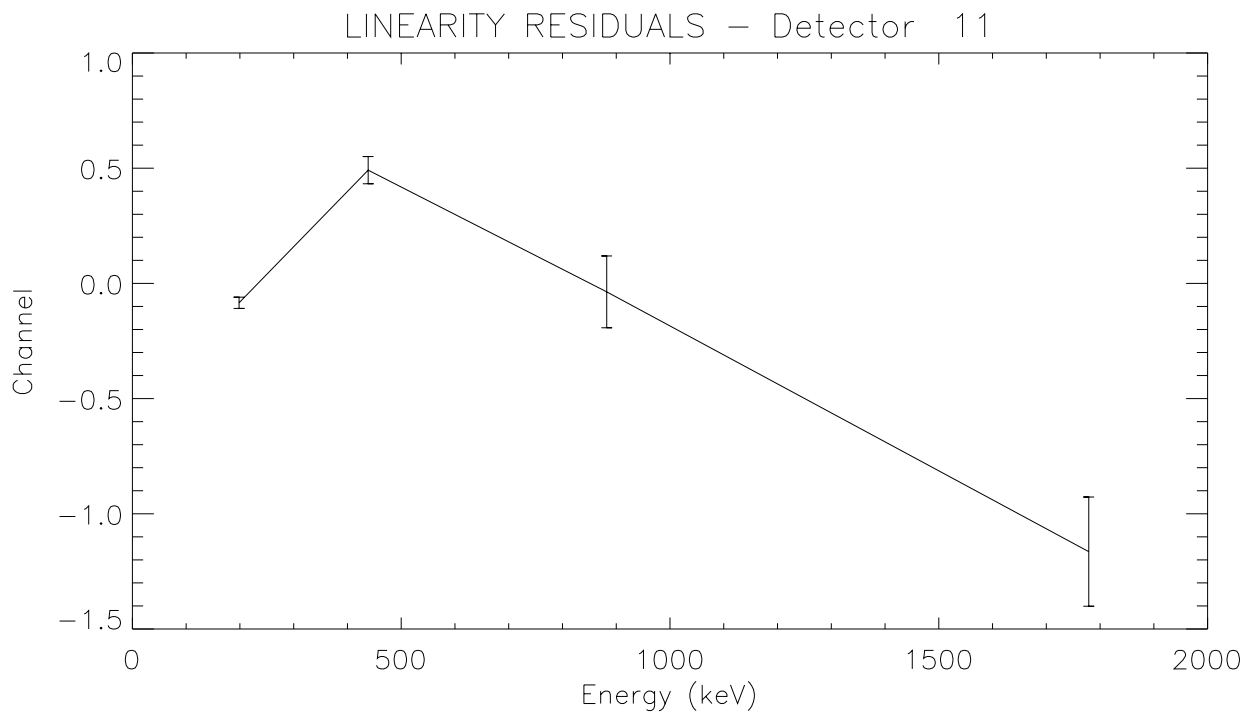
Linearity residuals for the detector 9 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



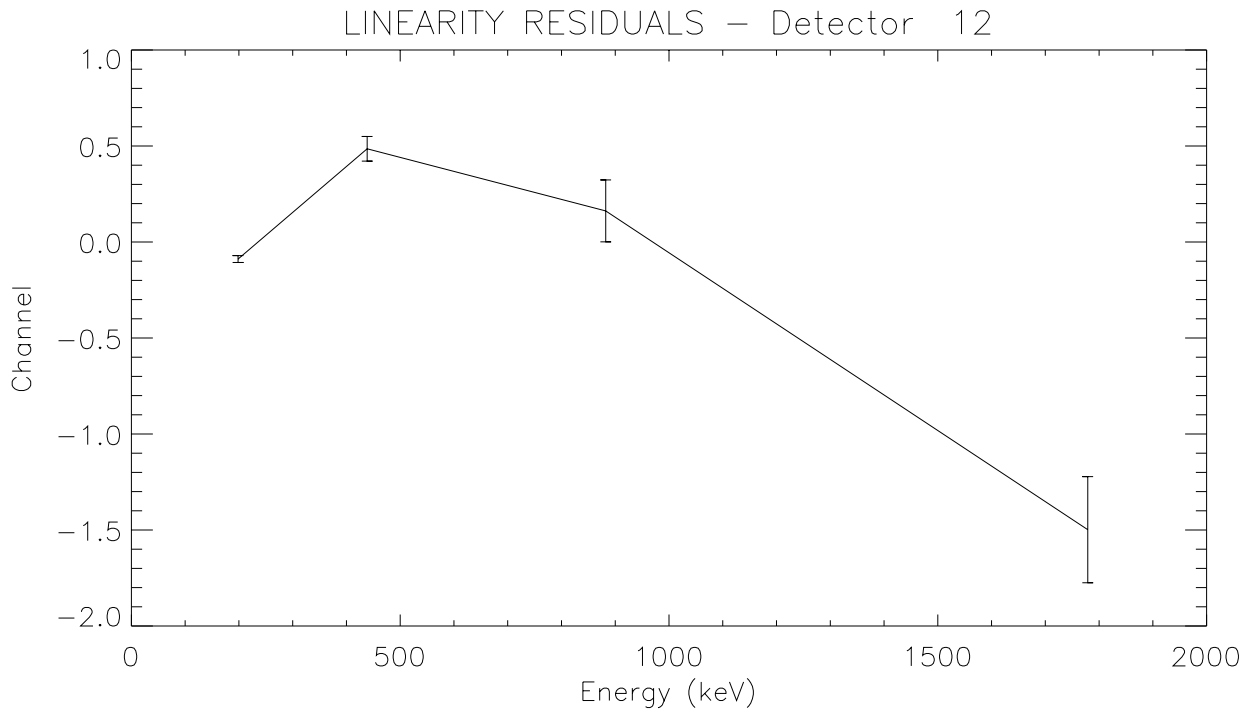
Linearity residuals for the detector 10 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



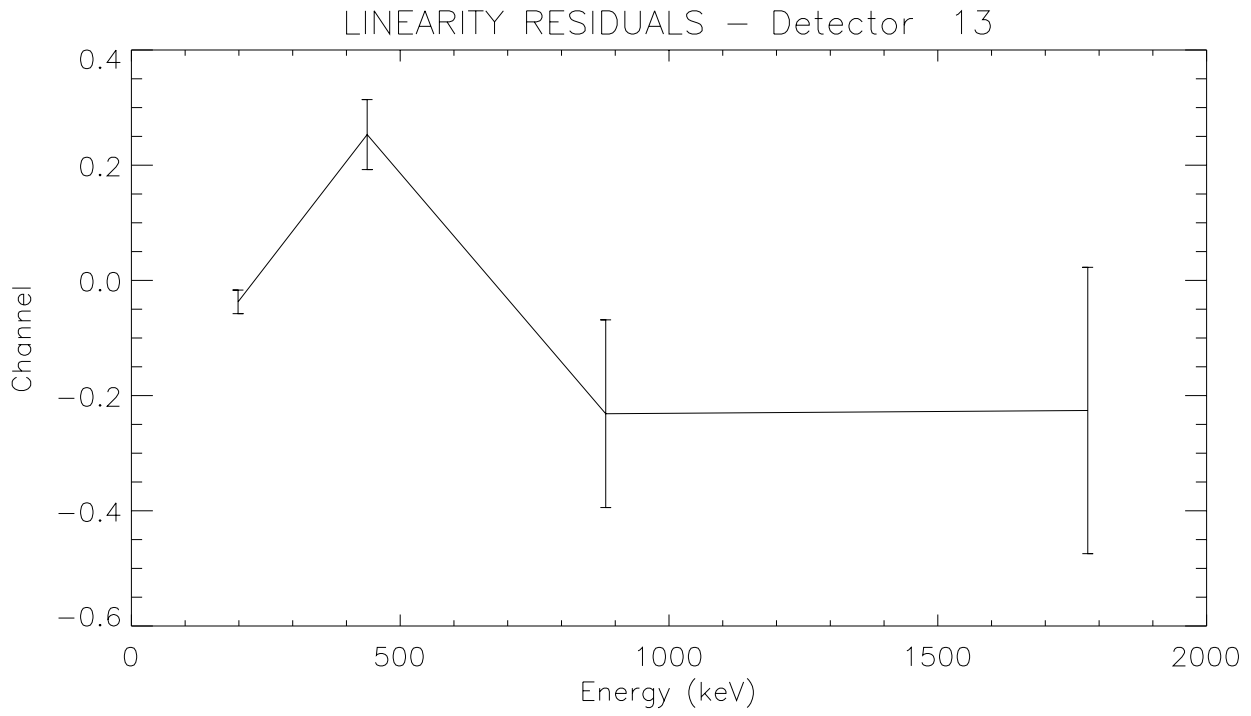
Linearity residuals for the detector 11 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



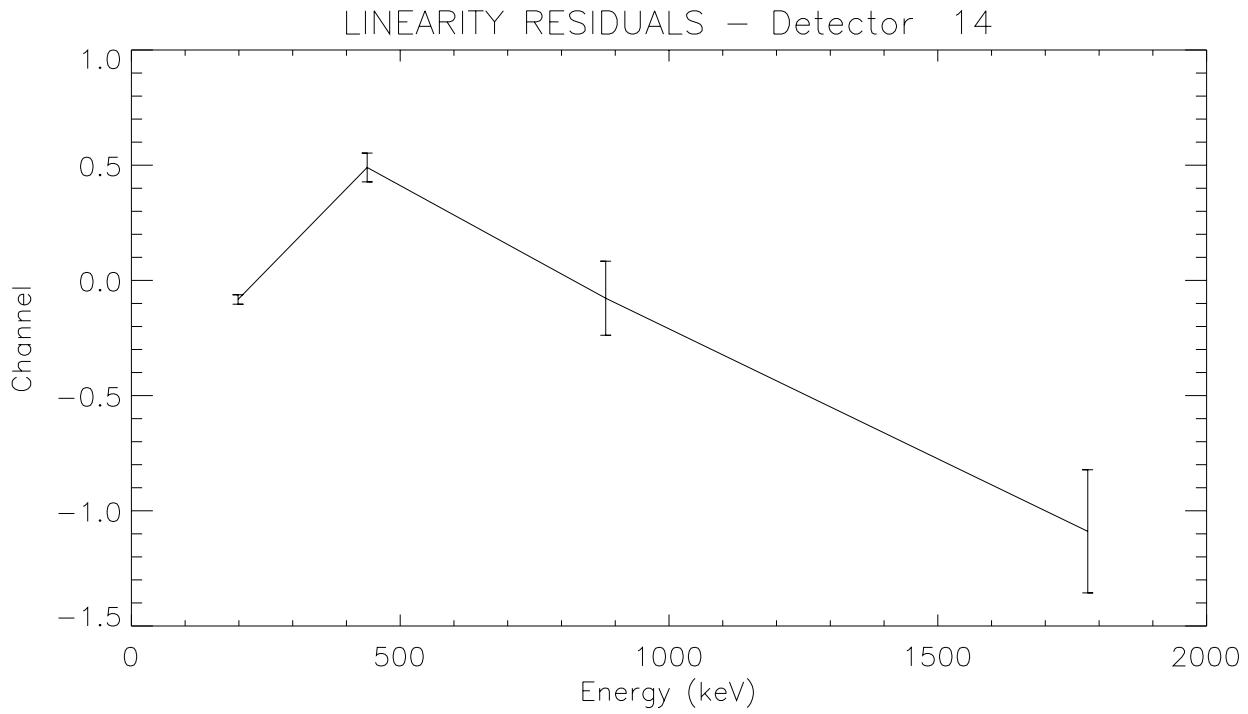
Linearity residuals for the detector 12 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



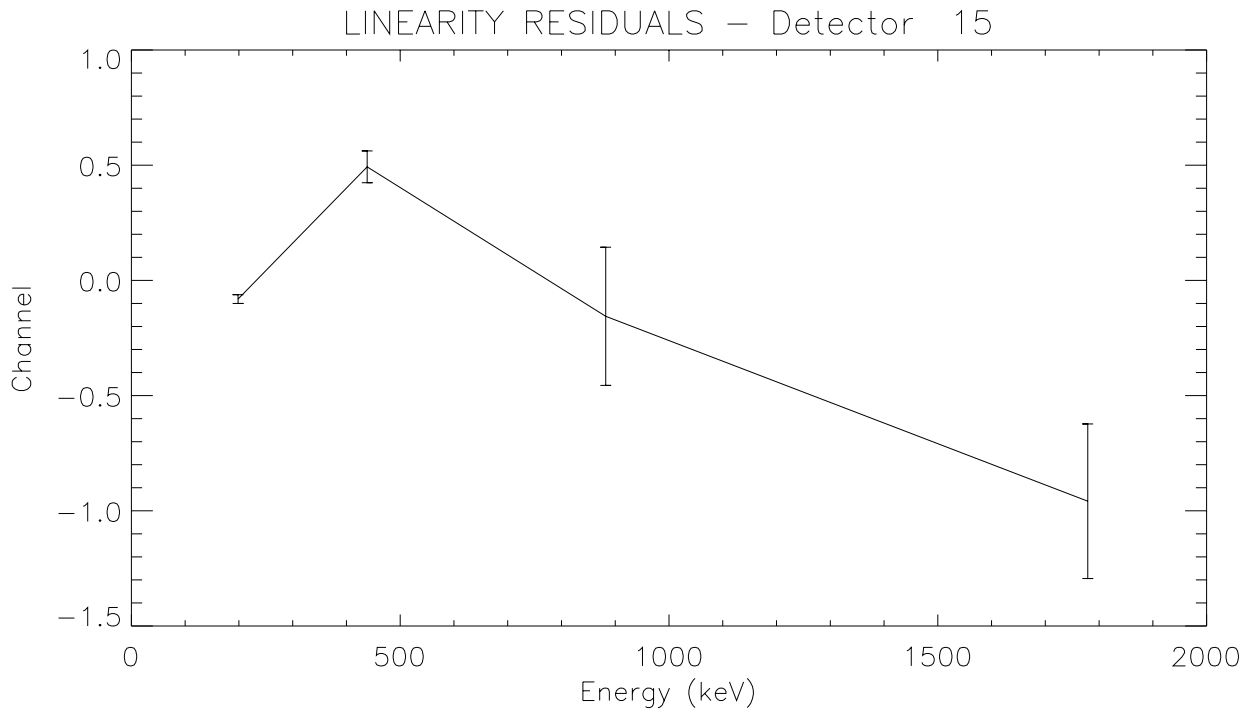
Linearity residuals for the detector 13 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



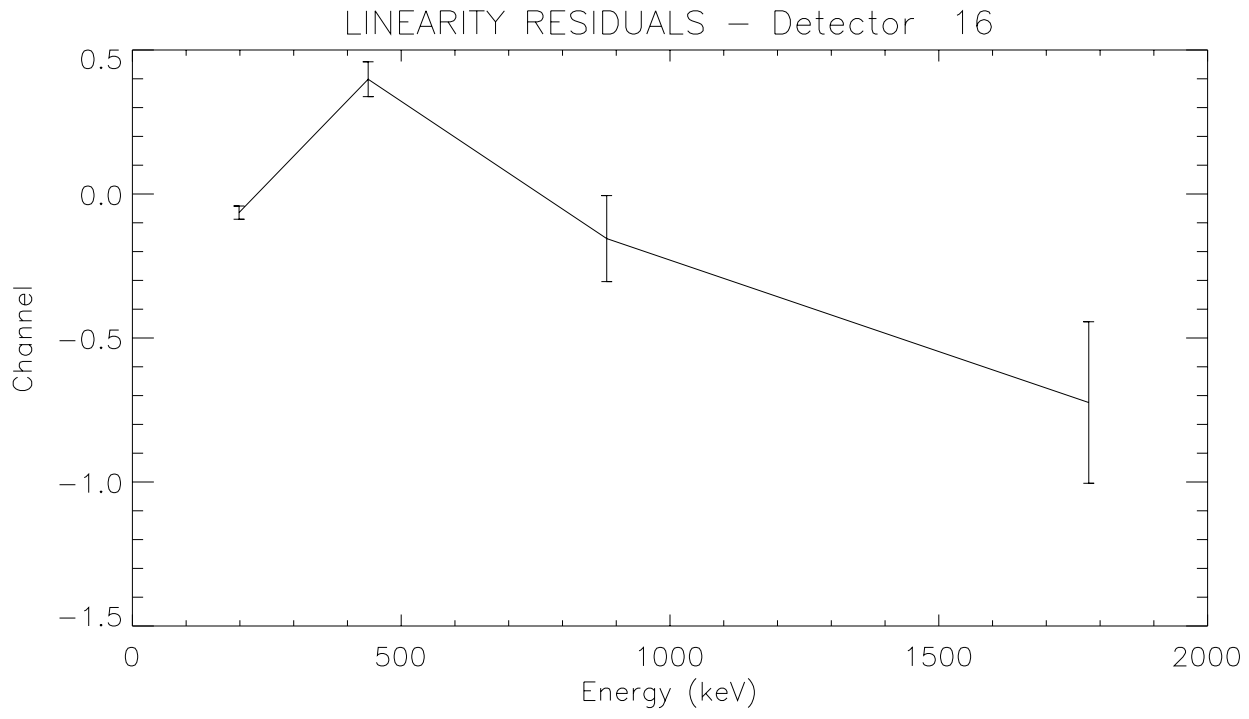
Linearity residuals for the detector 14 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



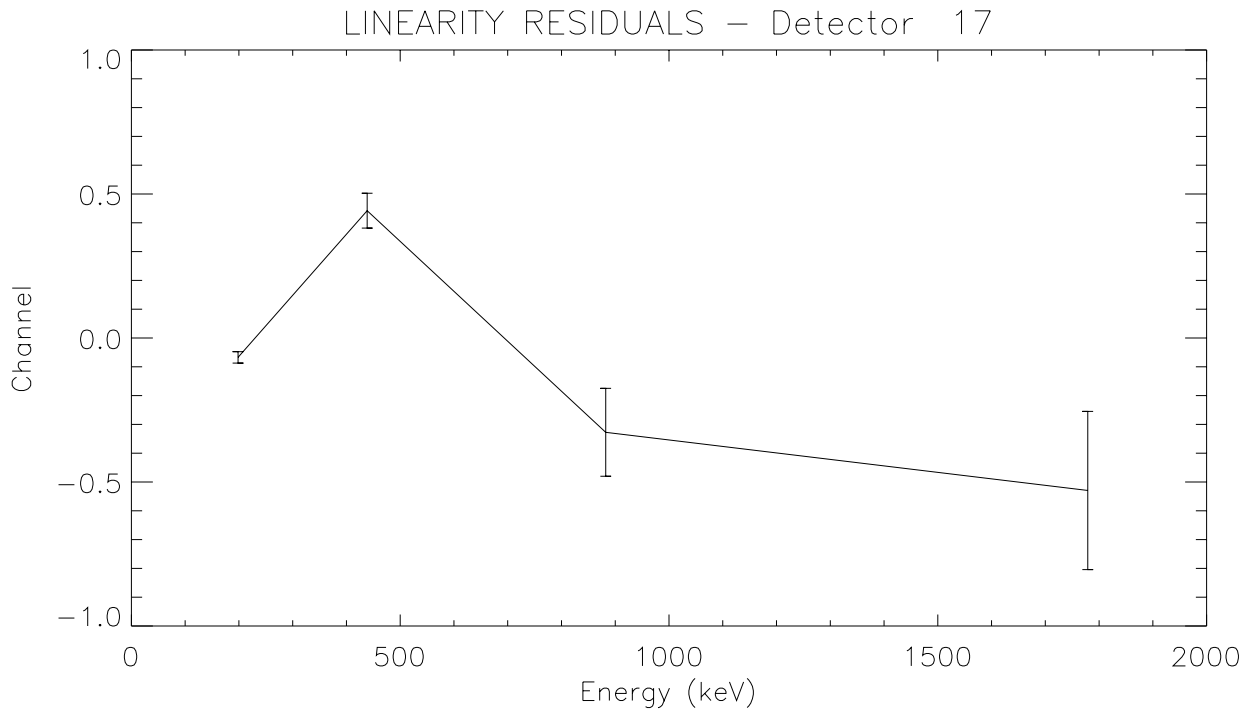
Linearity residuals for the detector 15 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



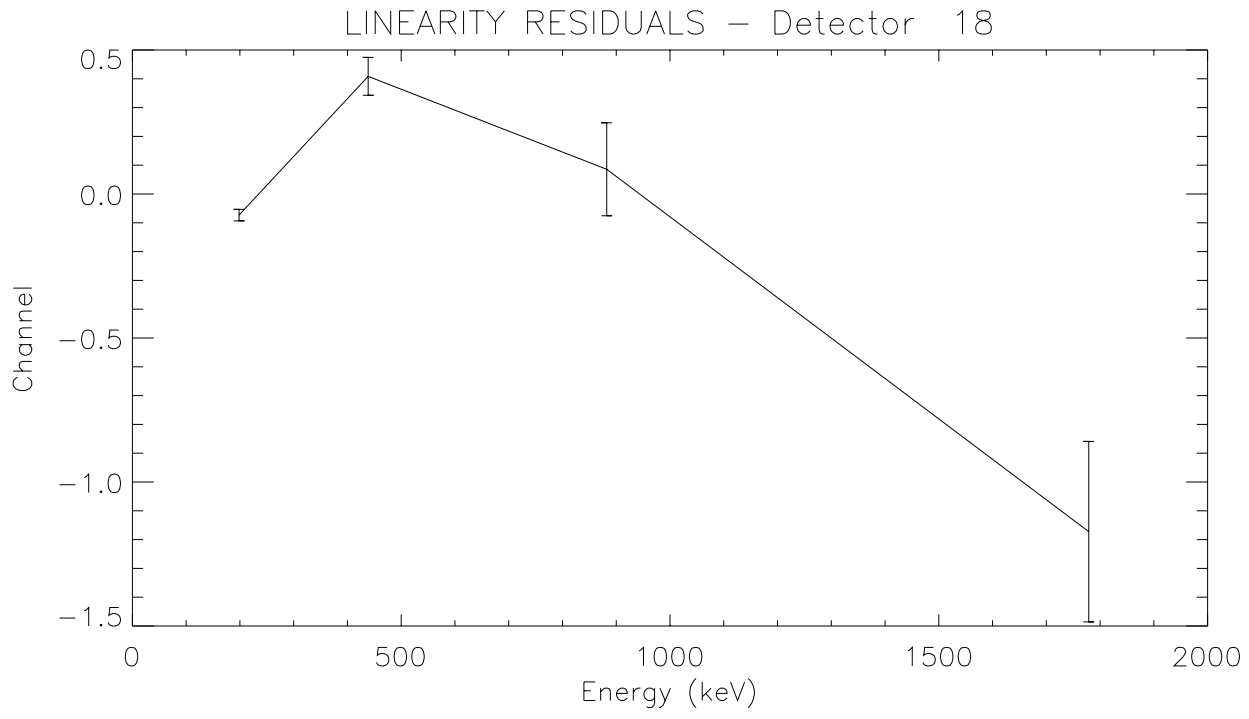
Linearity residuals for the detector 16 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Linearity residuals for the detector 17 (1st order polynomial)

4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Linearity residuals for the detector 18 (1st order polynomial)

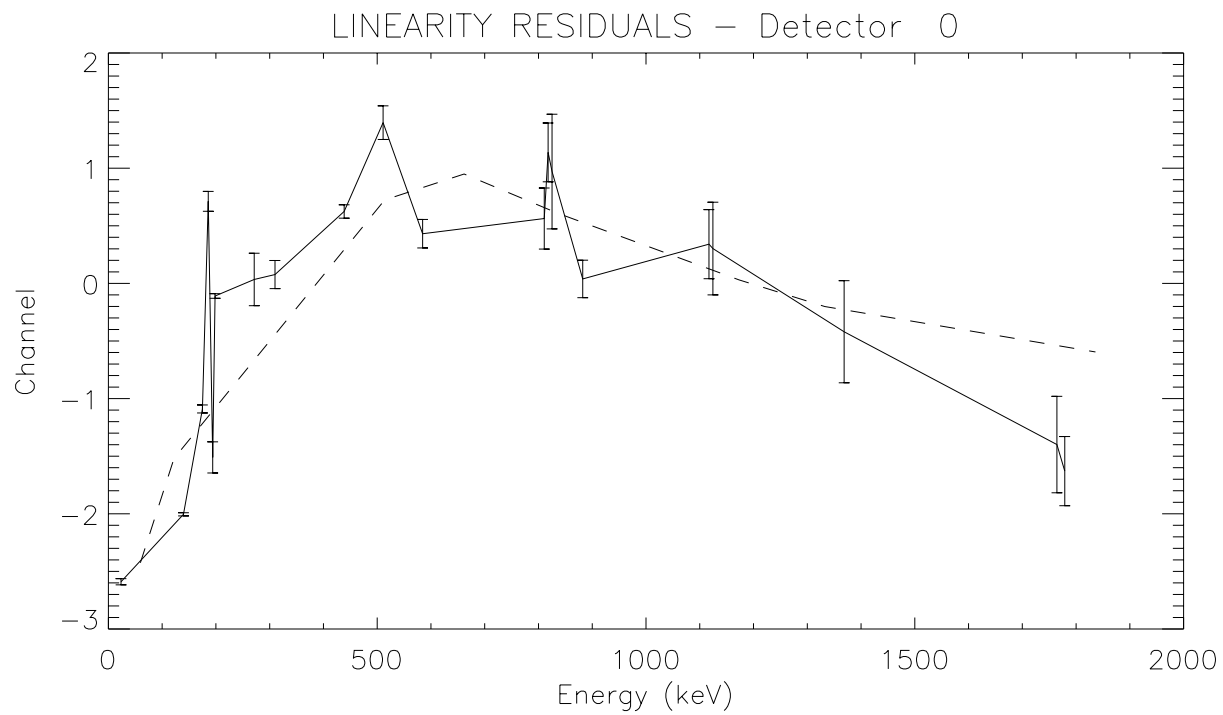
4 calibration lines to compute linearity response (revolution 22):
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

ANNEX 2

Linearity residuals (1st order polynomial)

Data from BLC calibration campaign.

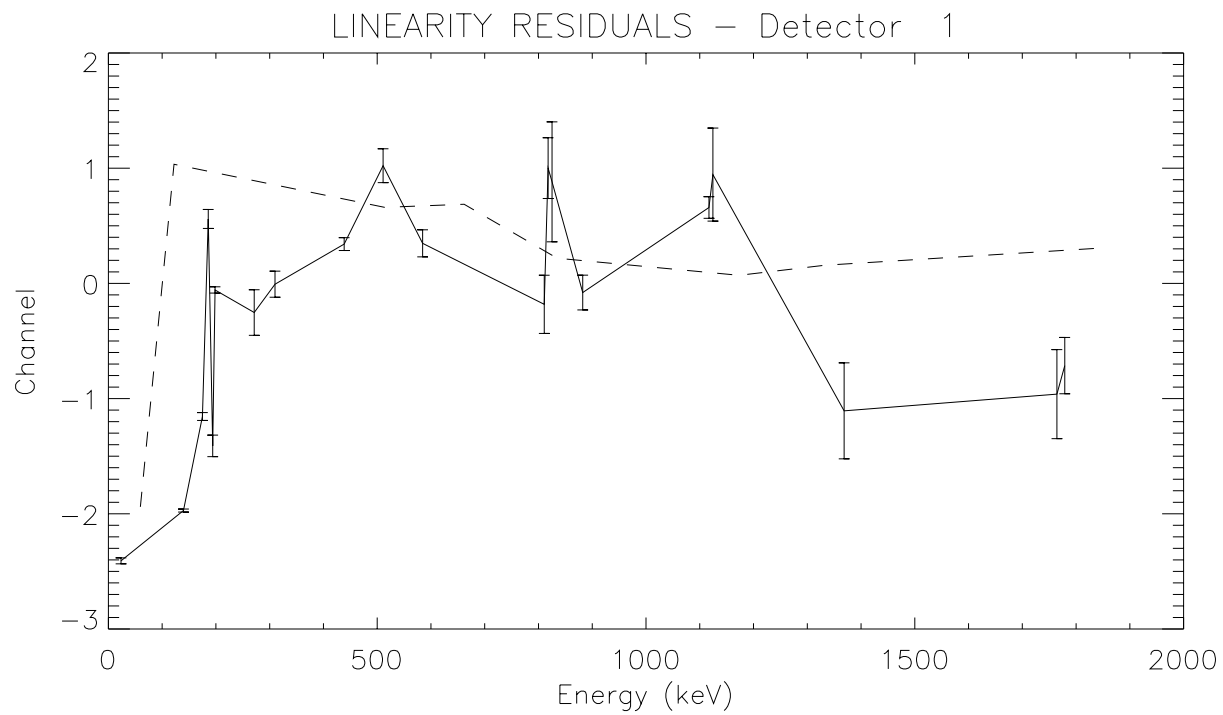
**Revolution 22: 20 gamma ray lines used, 4 calibration lines to compute linearity response
(198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV).**



Linearity residuals for the detector 0 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)
4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

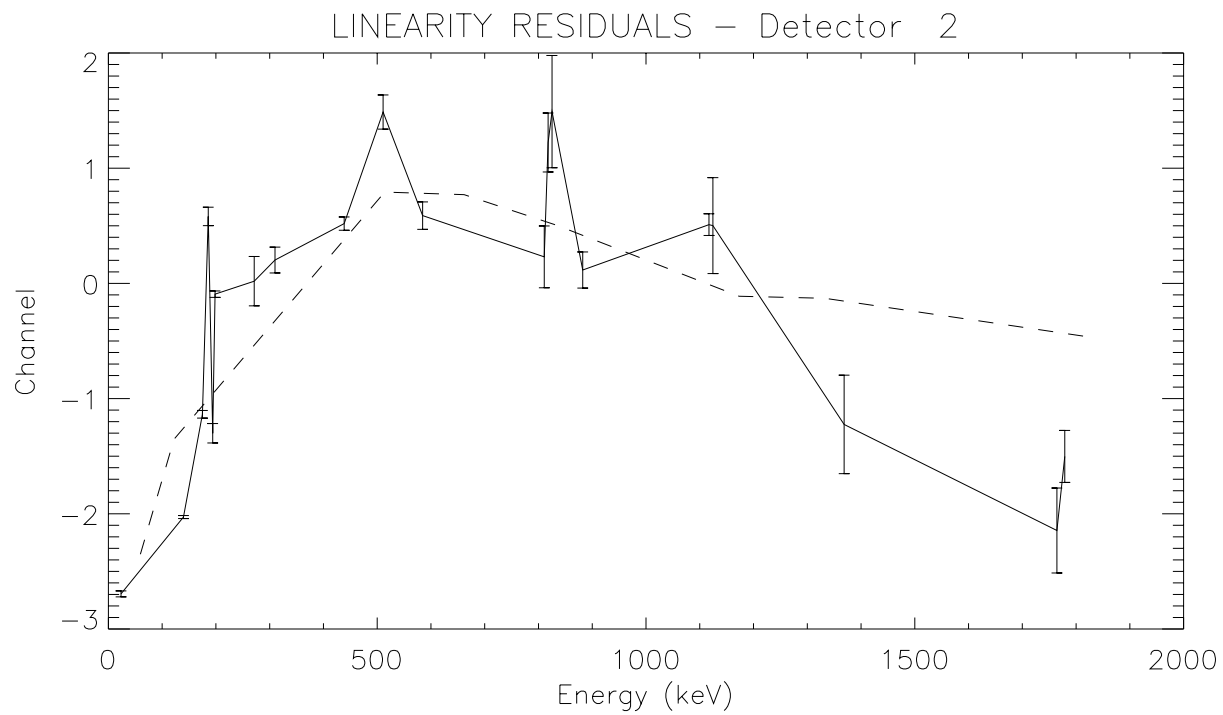


Linearity residuals for the detector 1 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

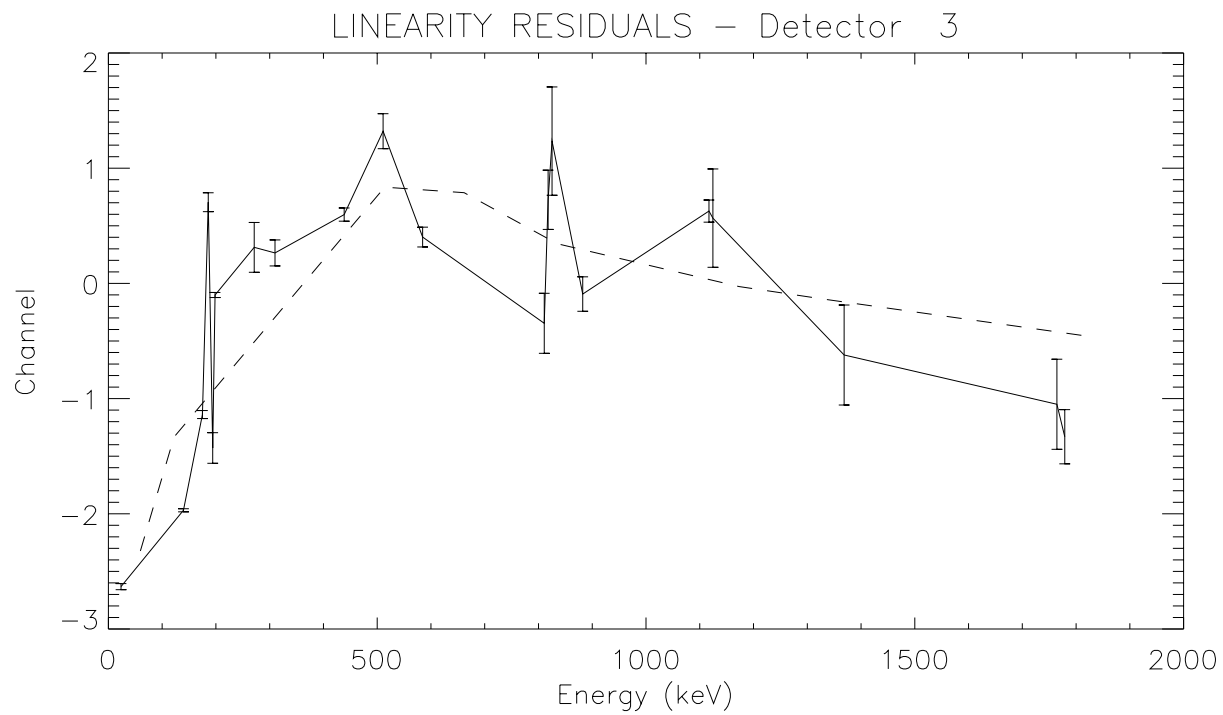
4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Linearity residuals for the detector 2 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)
4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

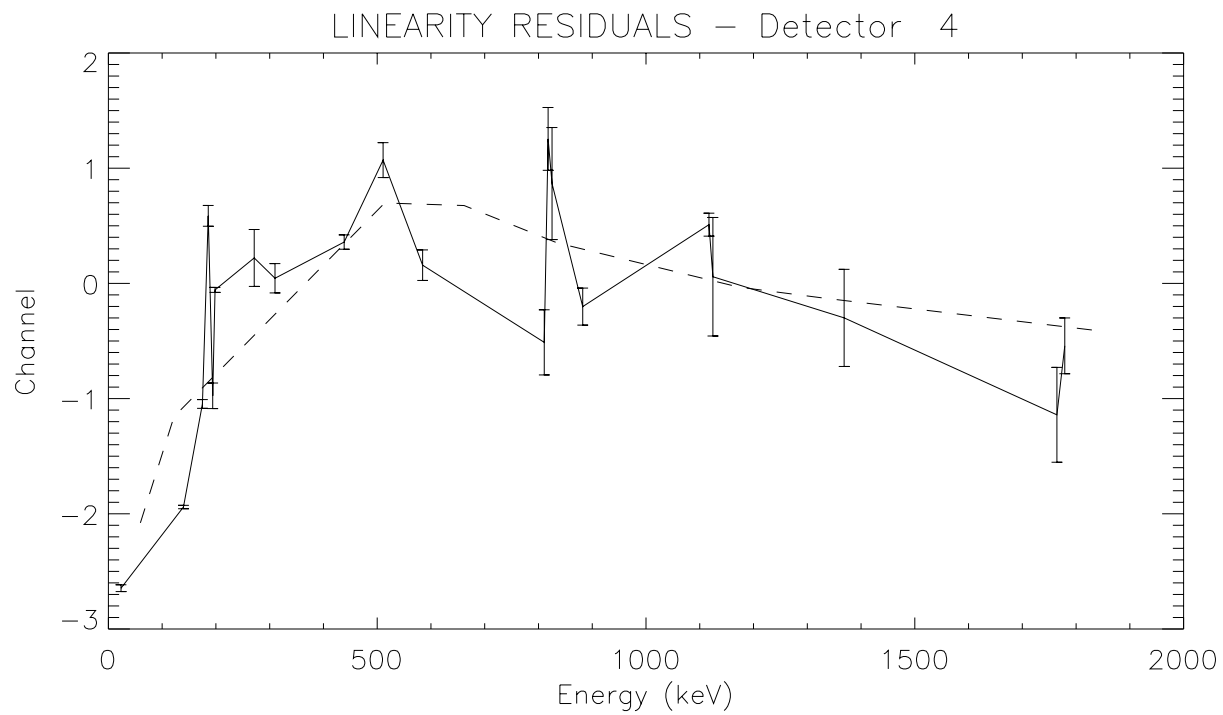


Linearity residuals for the detector 3 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

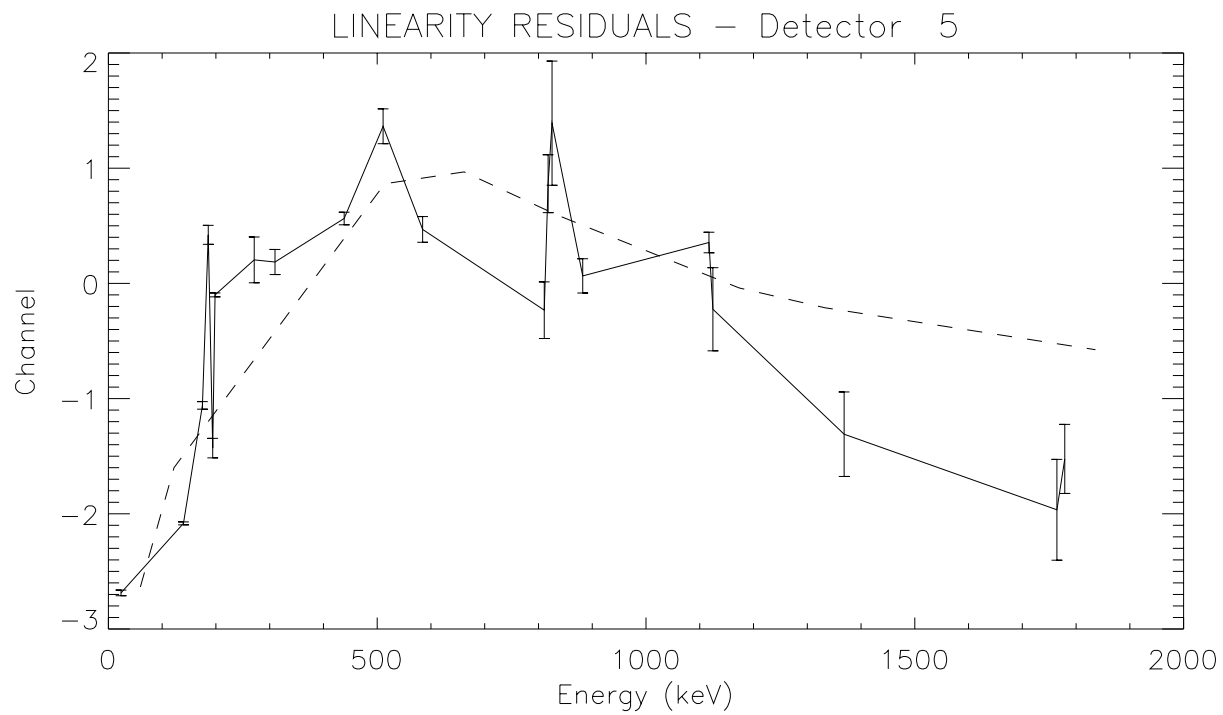
4 calibration lines to compute linearity response :
 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Linearity residuals for the detector 4 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)
4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

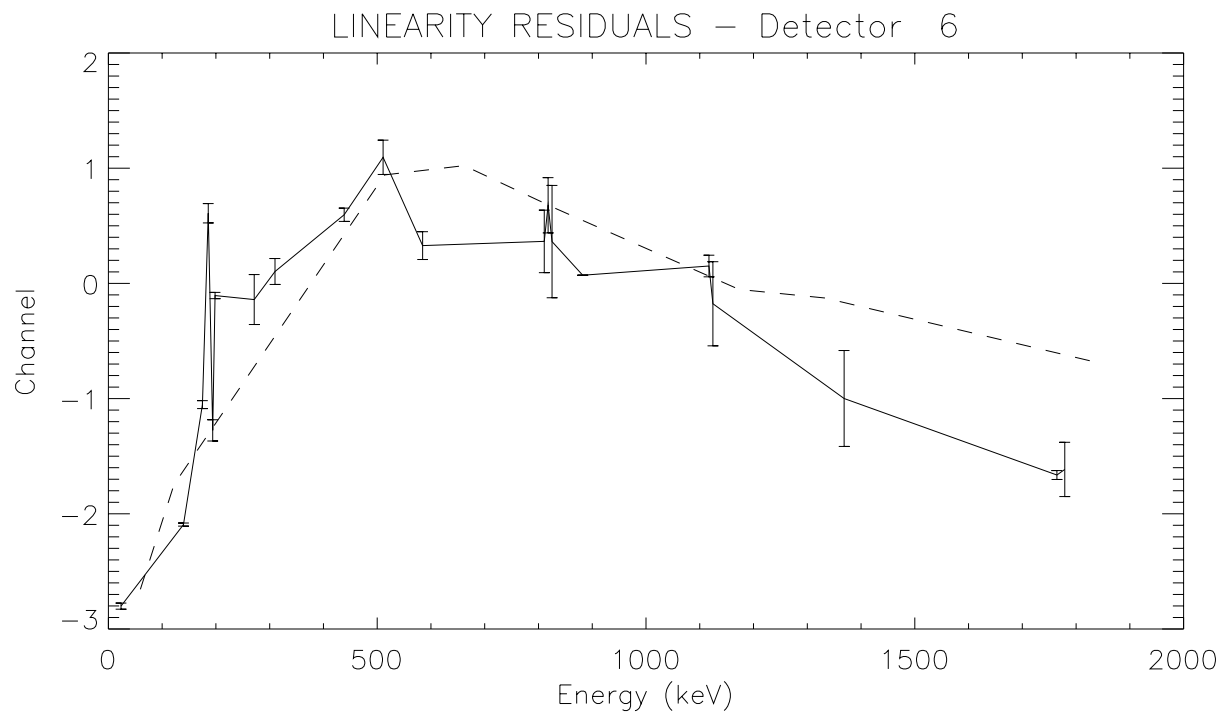


Linearity residuals for the detector 5 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

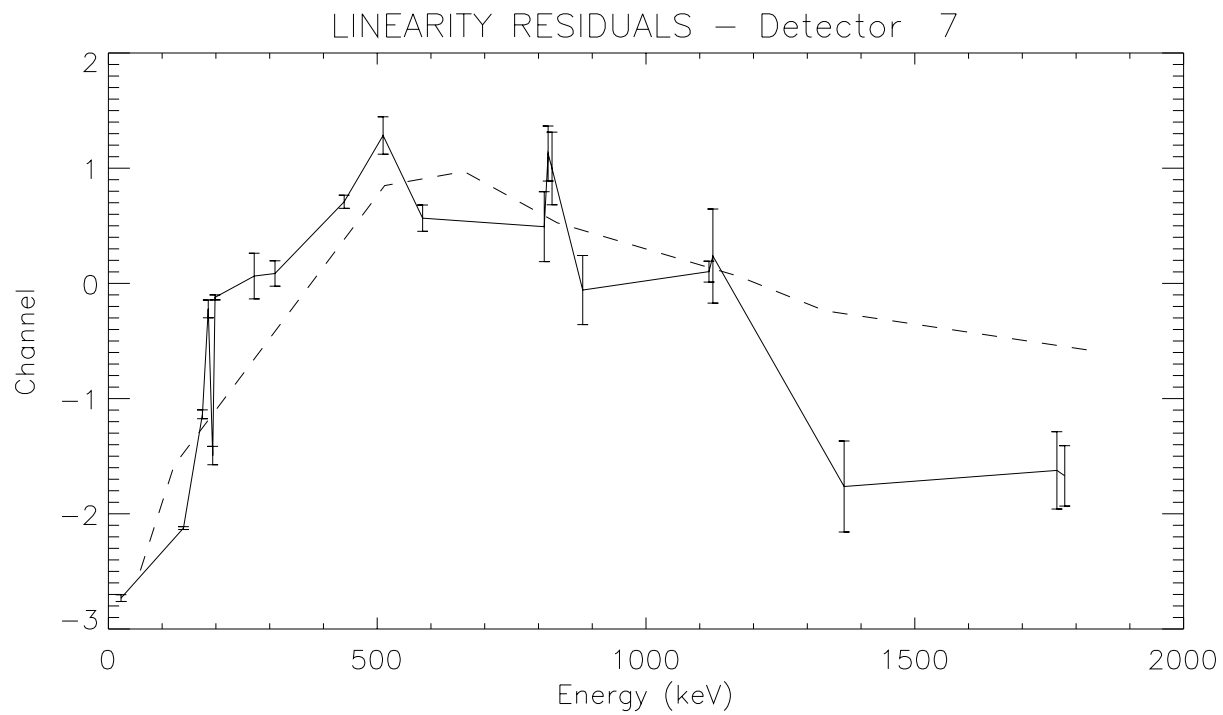


Linearity residuals for the detector 6 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

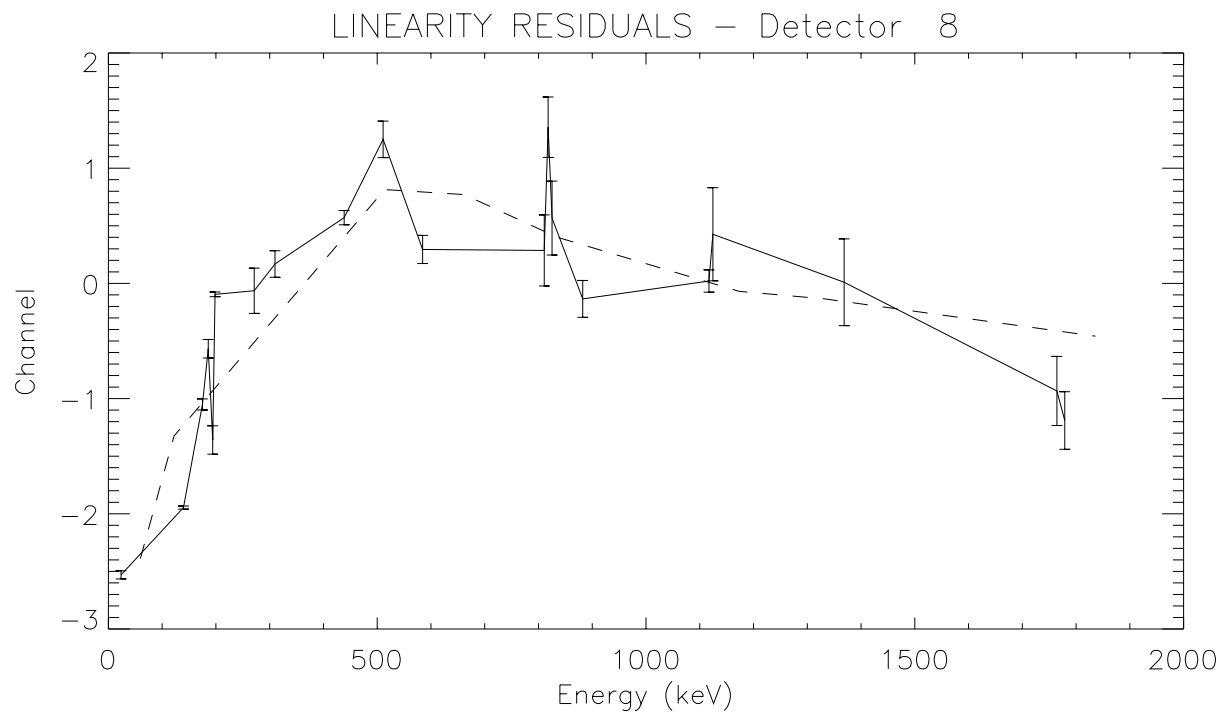


Linearity residuals for the detector 7 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

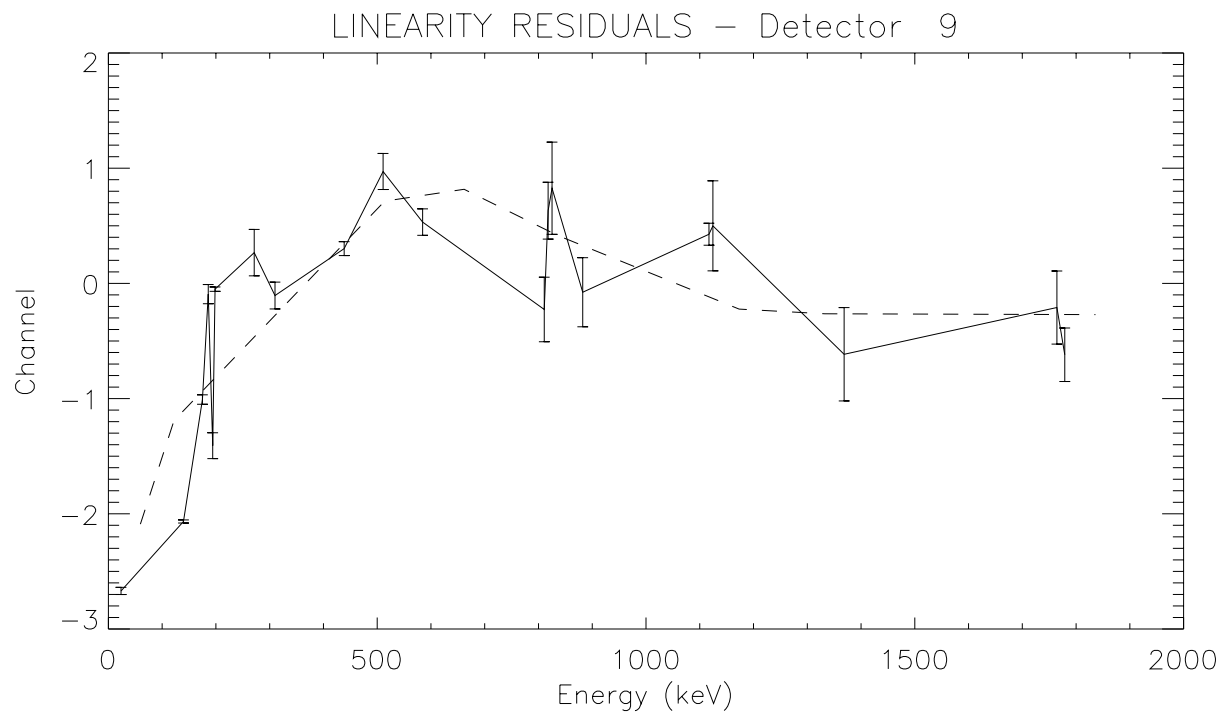
4 calibration lines to compute linearity response :
 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Linearity residuals for the detector 8 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

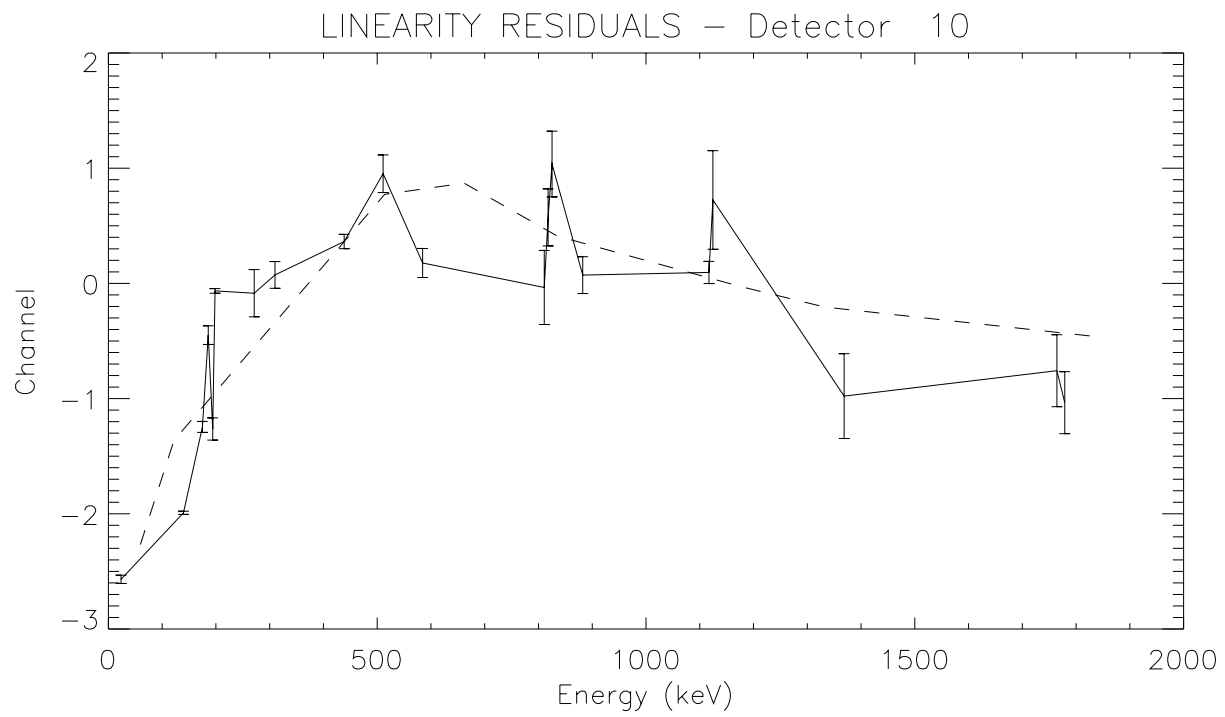
Continuous line: 20 gamma ray lines used (revolution 22)
4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Linearity residuals for the detector 9 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)
4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

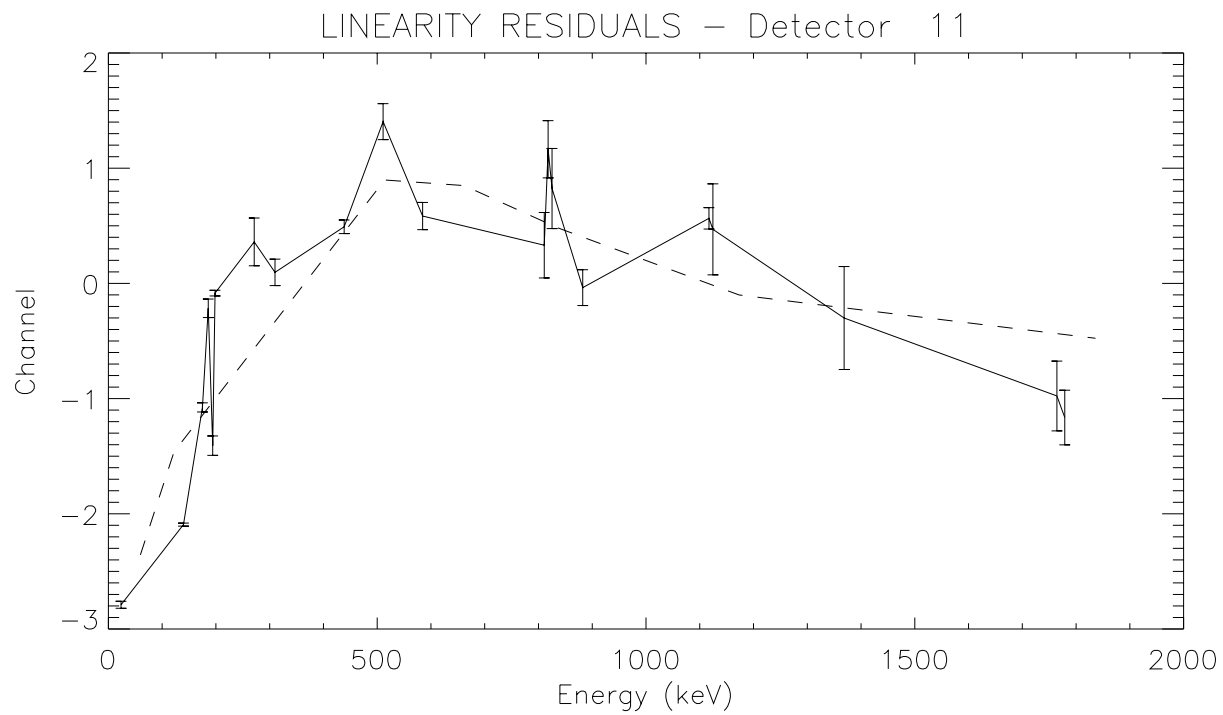


Linearity residuals for the detector 10 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

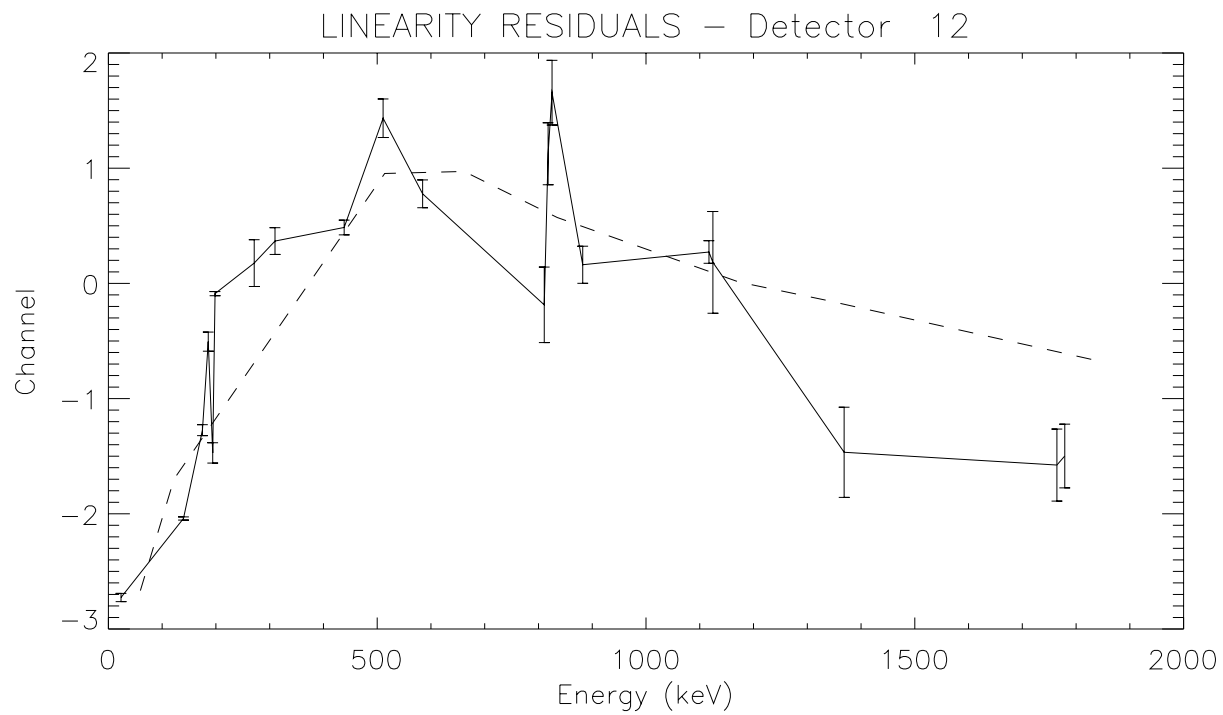


Linearity residuals for the detector 11 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

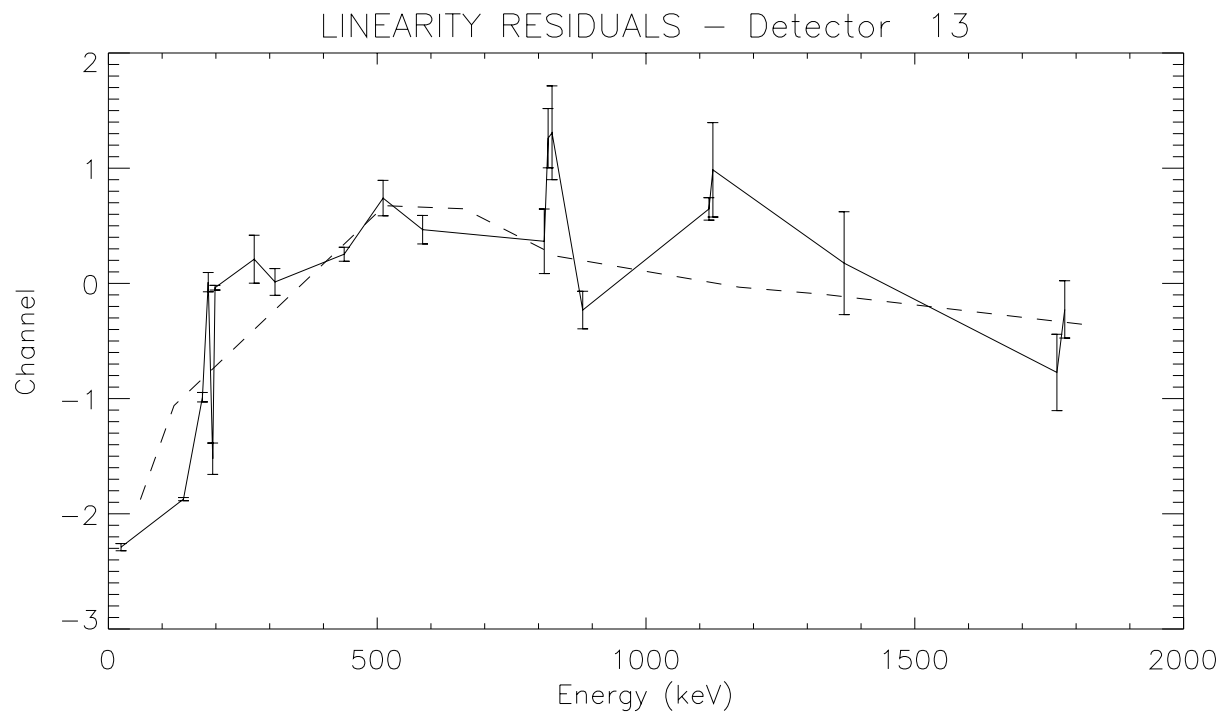


Linearity residuals for the detector 12 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

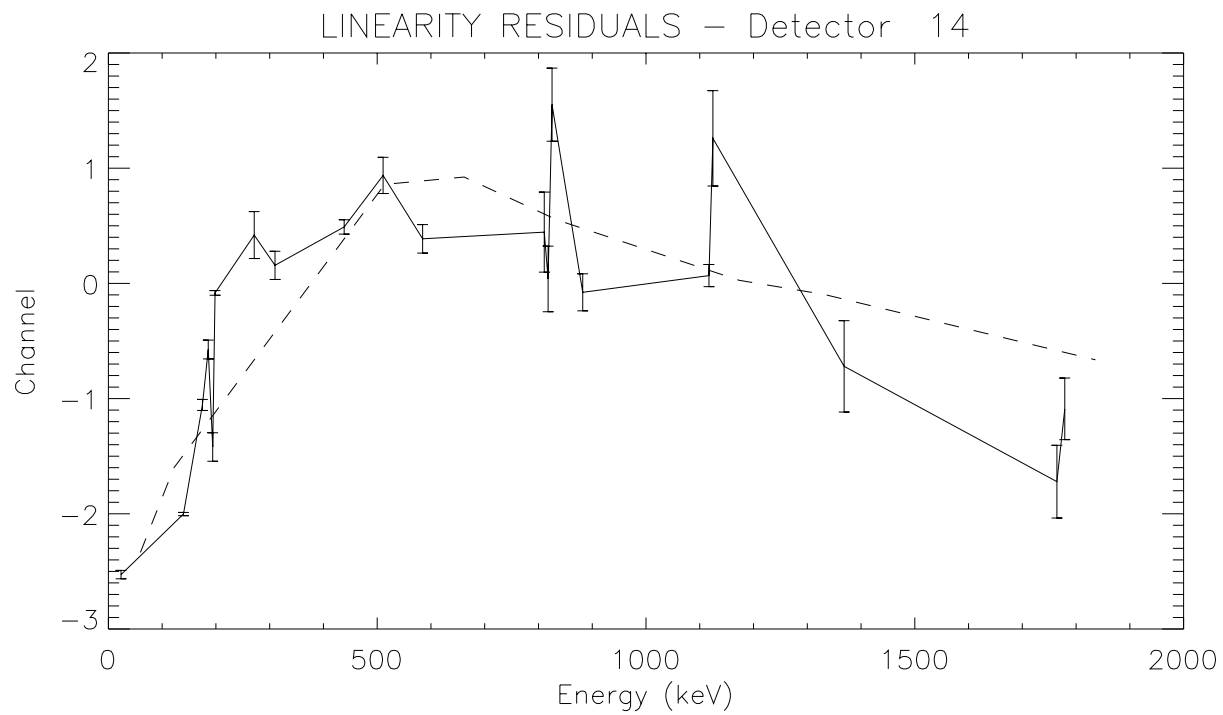


Linearity residuals for the detector 13 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

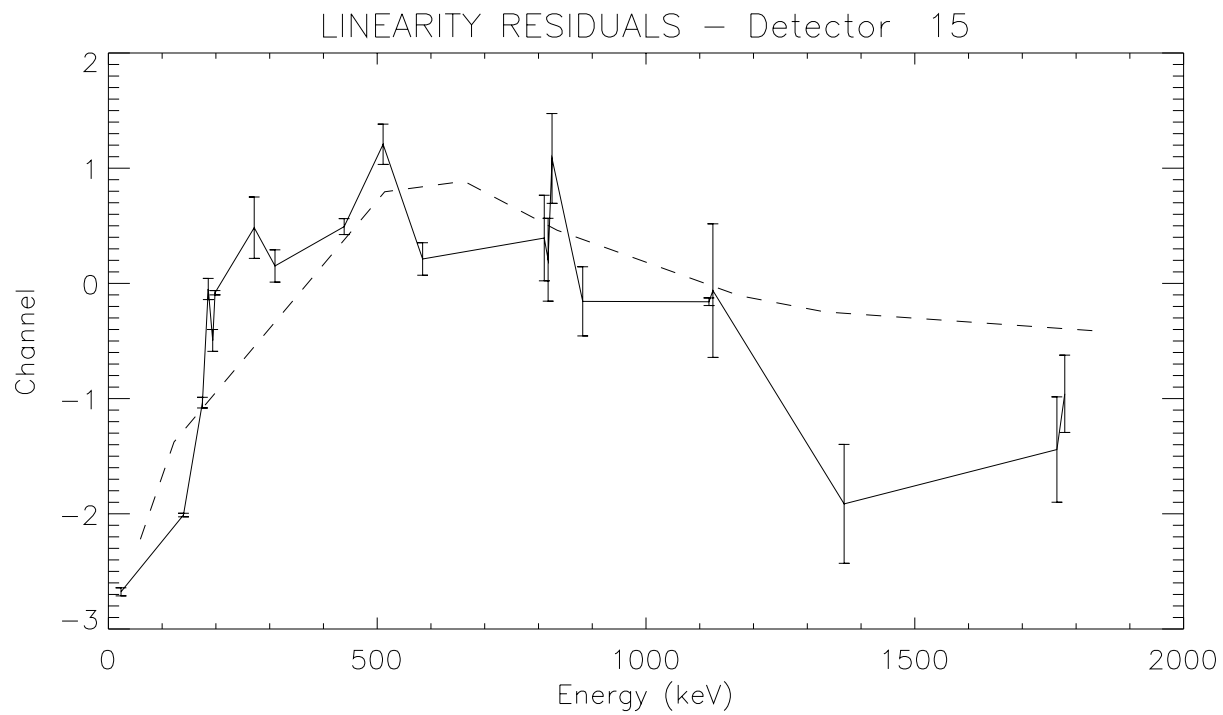


Linearity residuals for the detector 14 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

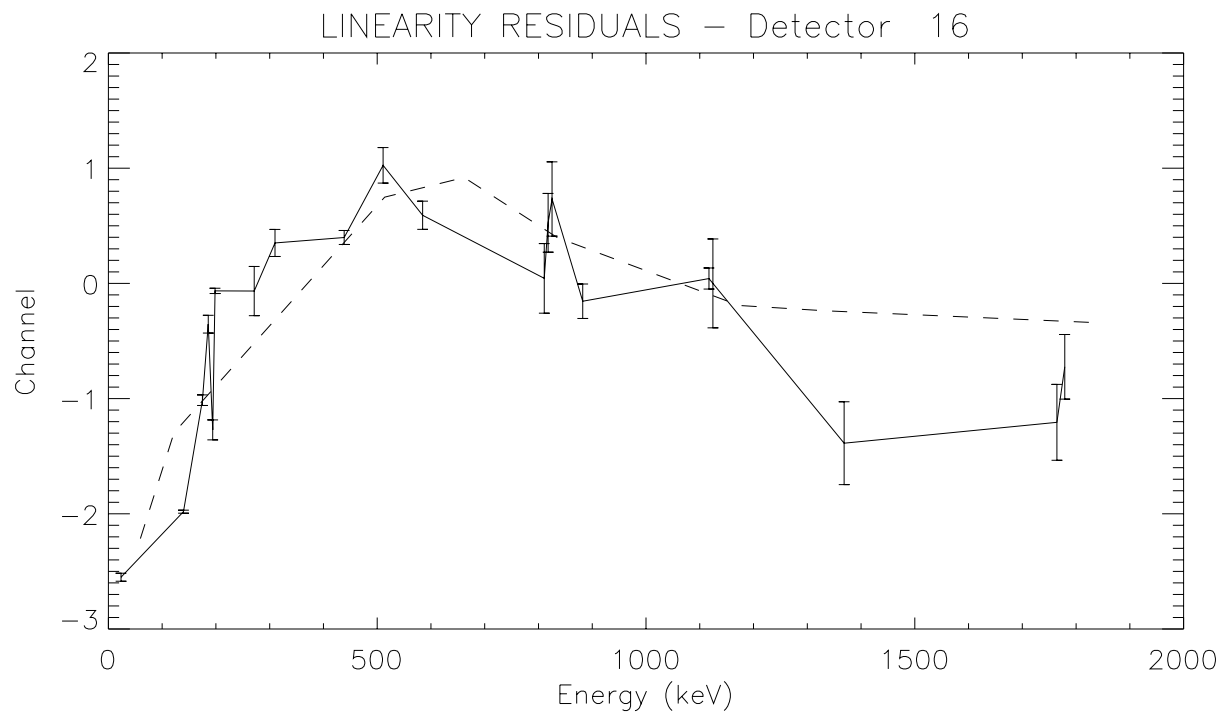


Linearity residuals for the detector 15 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

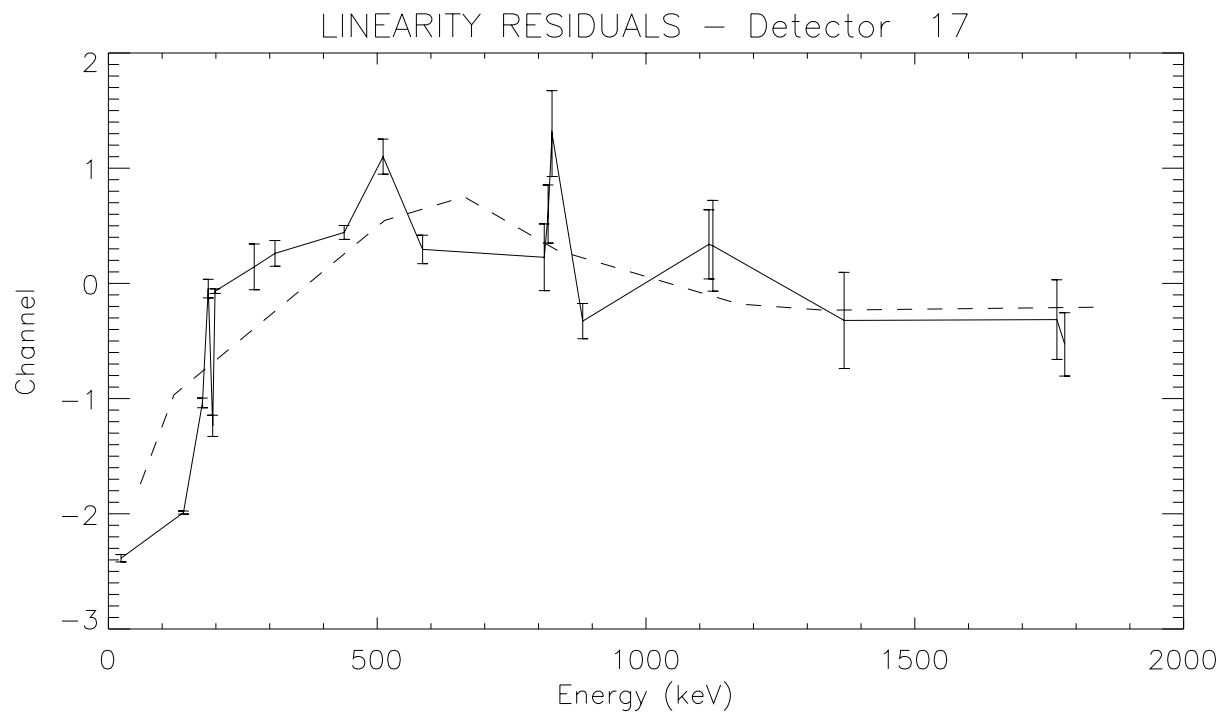


Linearity residuals for the detector 16 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

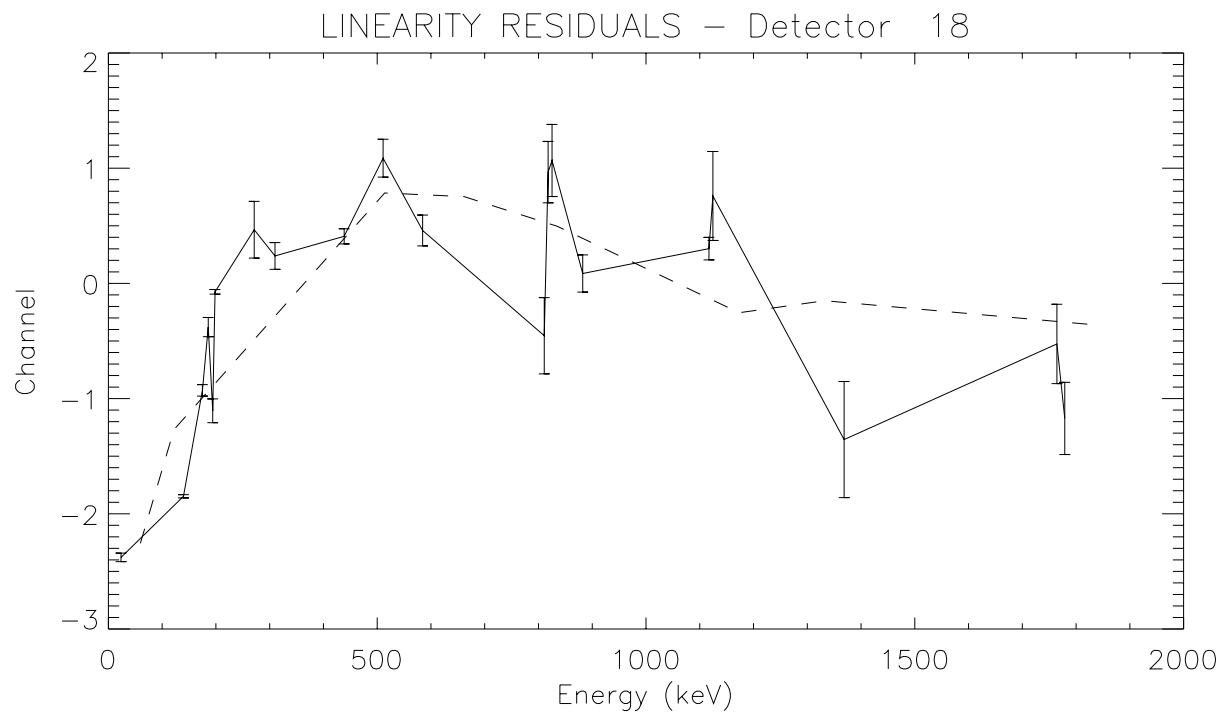


Linearity residuals for the detector 17 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

4 calibration lines to compute linearity response :
 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Linearity residuals for the detector 18 (1st order polynomial)

Line dashed: data from BLC calibration campaign.

Continuous line: 20 gamma ray lines used (revolution 22)

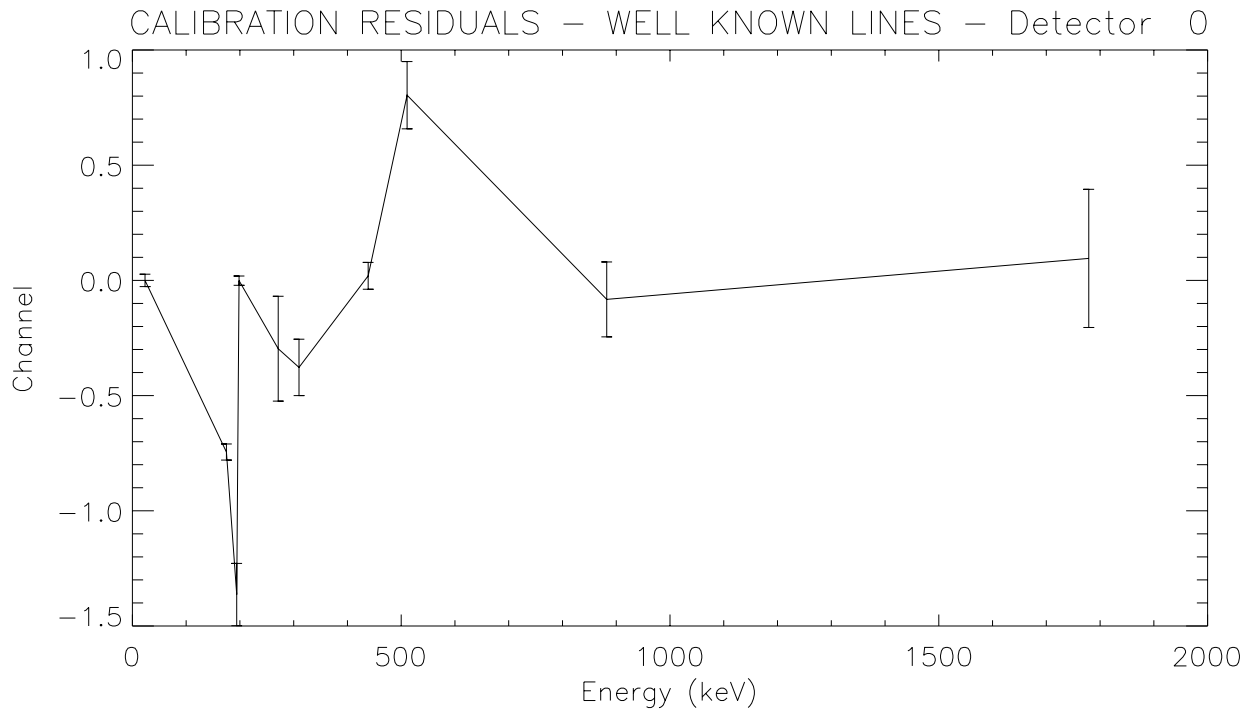
4 calibration lines to compute linearity response :
 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

ANNEX 3

Calibration residuals (3rd order polynomial).

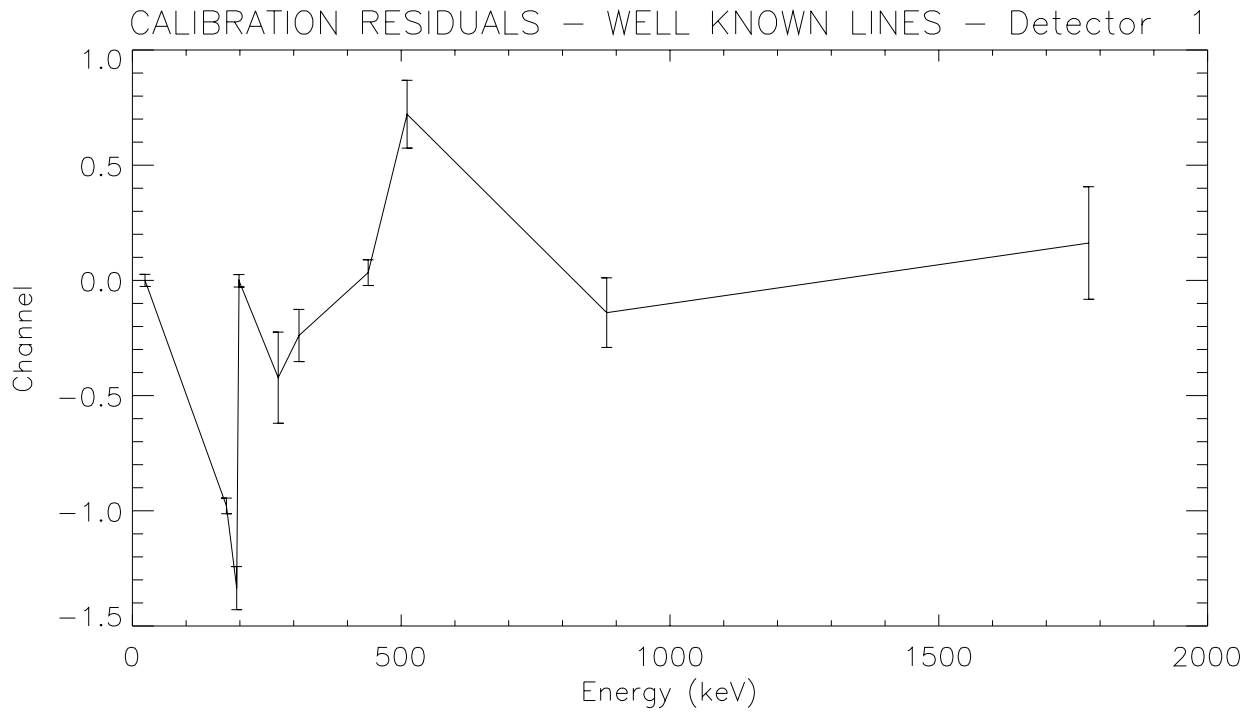
Calibration lines: 23,43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV.

Well known gamma ray lines, revolution 22.



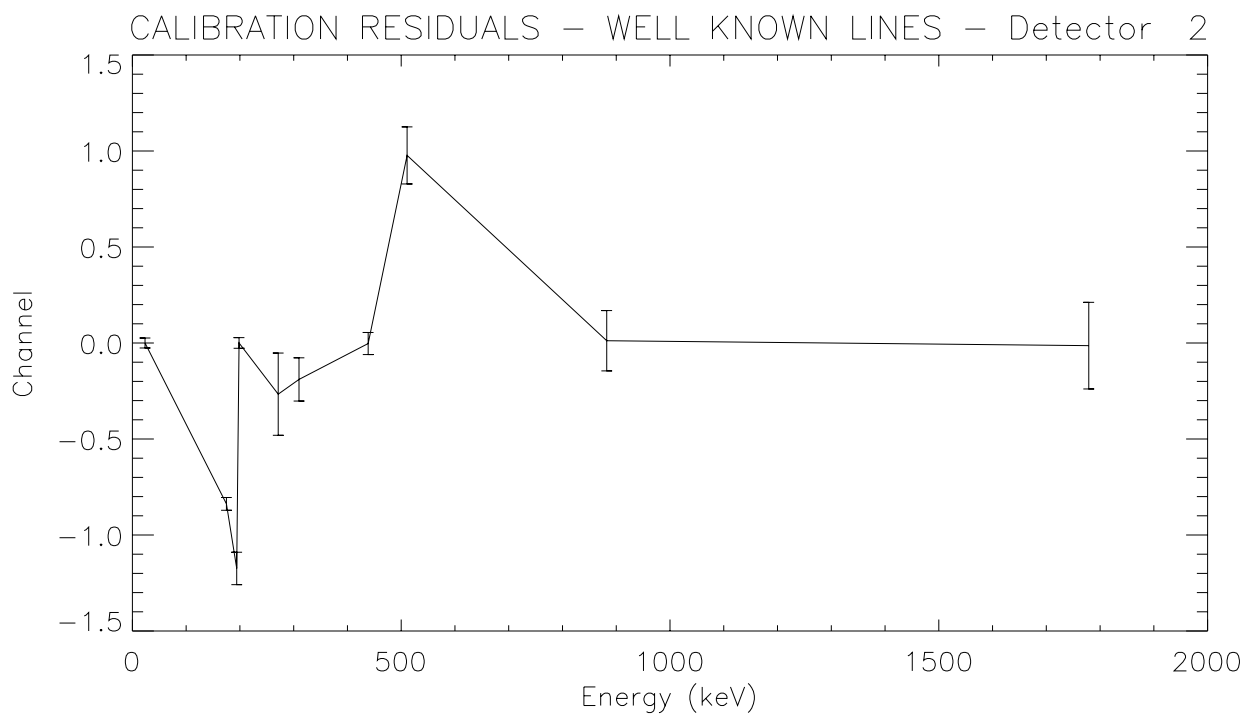
Calibration residuals for the detector 0 (3rd order polynomial)

5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



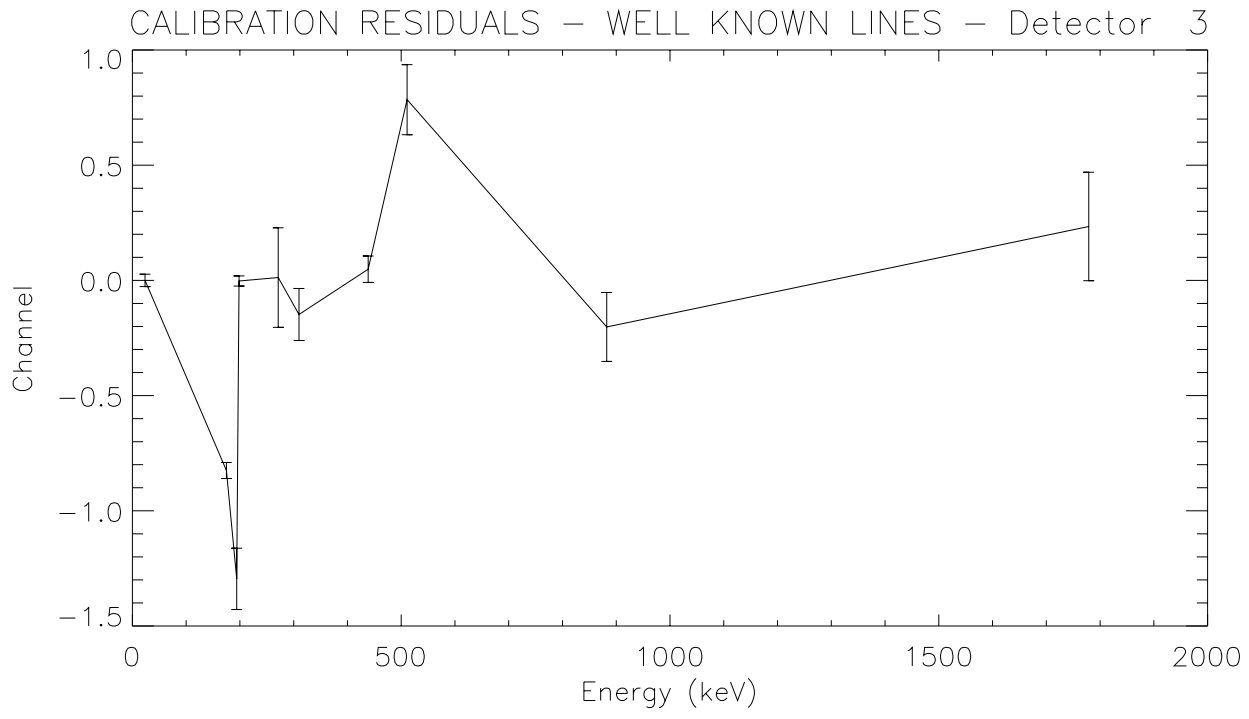
Calibration residuals for the detector 1 (3rd order polynomial)

5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



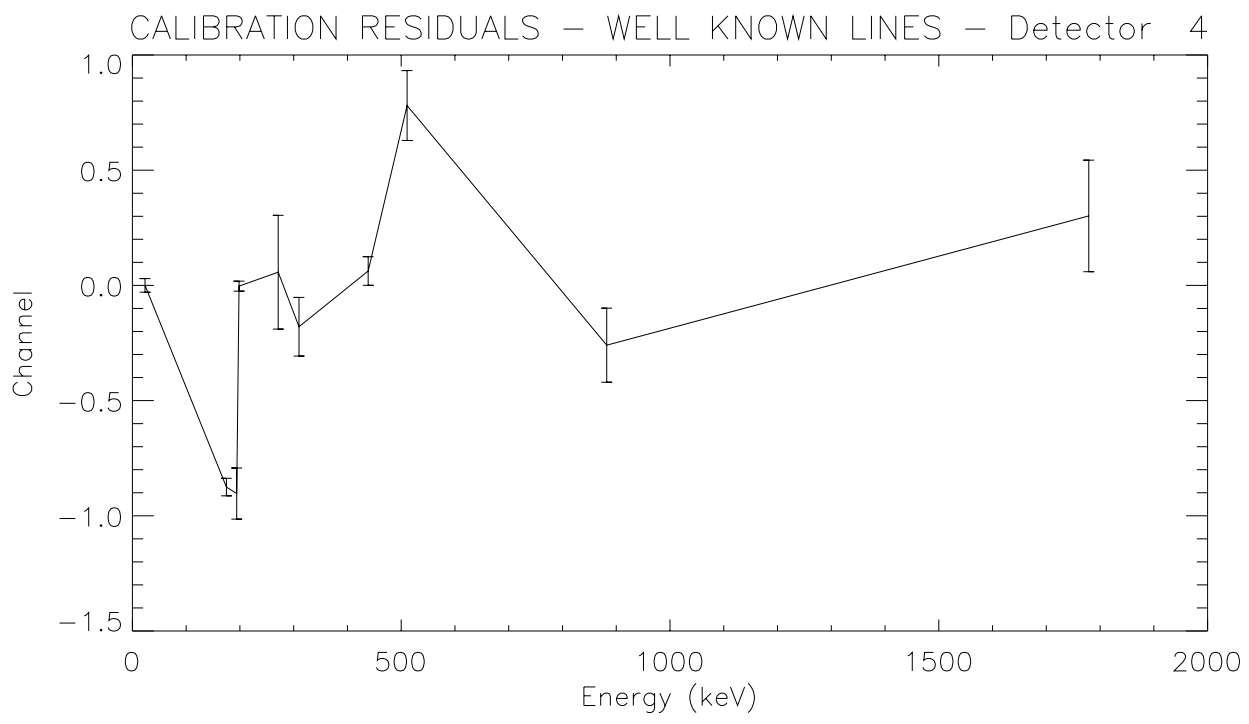
Calibration residuals for the detector 2 (3rd order polynomial)

5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



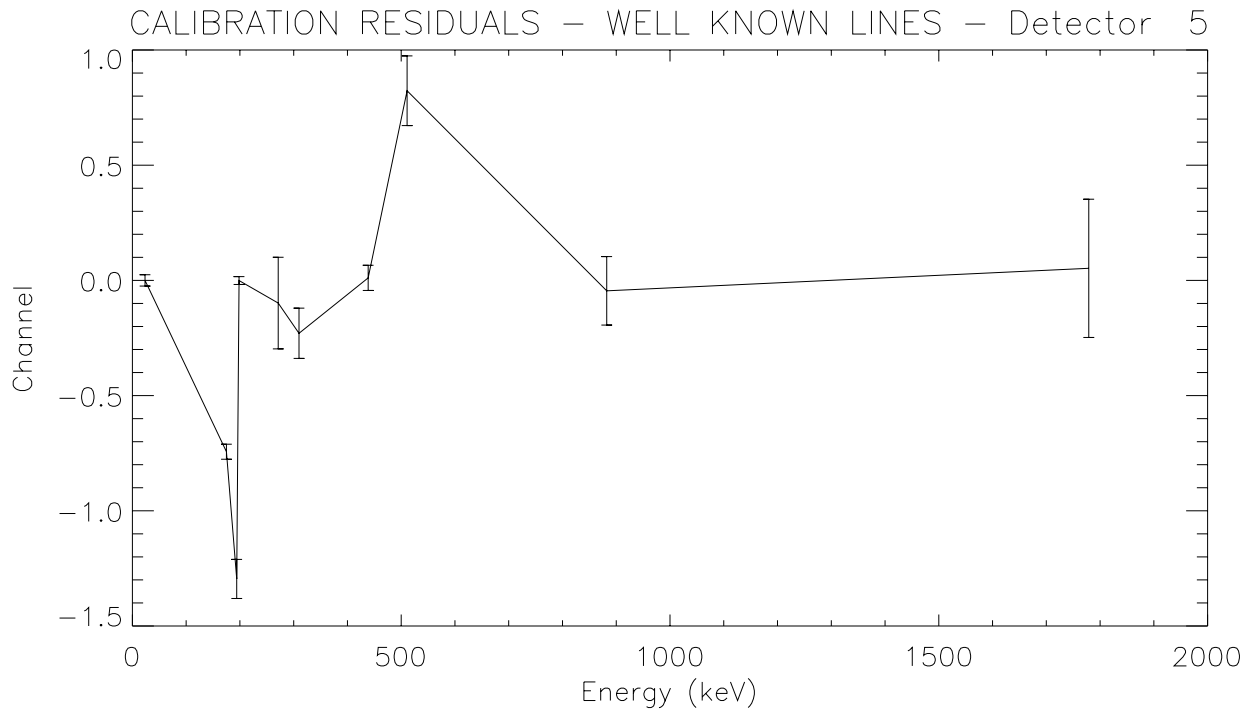
Calibration residuals for the detector 3 (3rd order polynomial)

5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



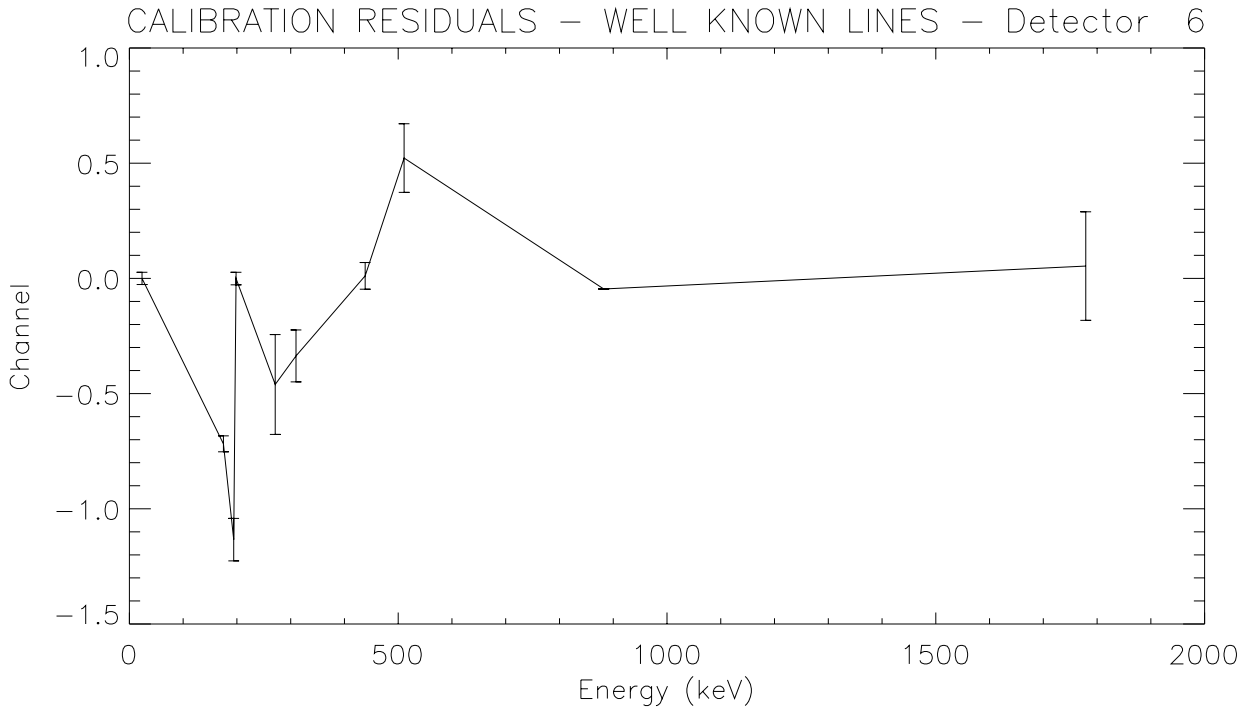
Calibration residuals for the detector 4 (3rd order polynomial)

5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



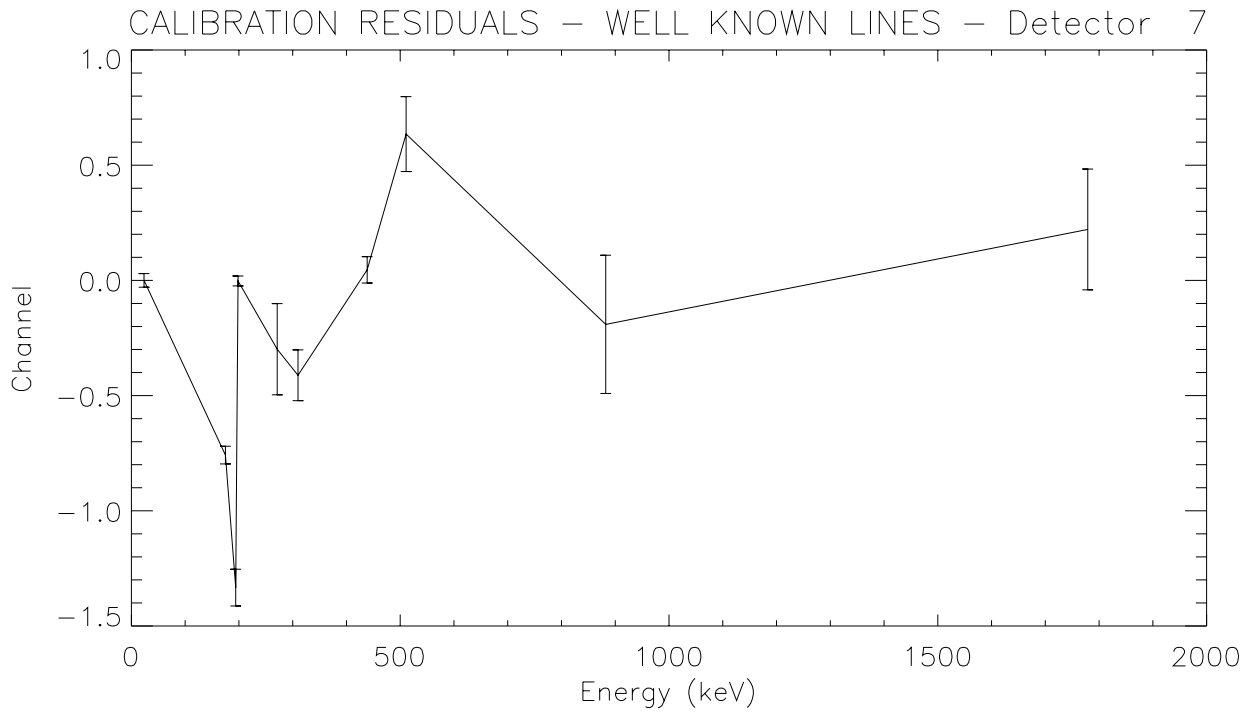
Calibration residuals for the detector 5 (3rd order polynomial)

5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 6 (3rd order polynomial)

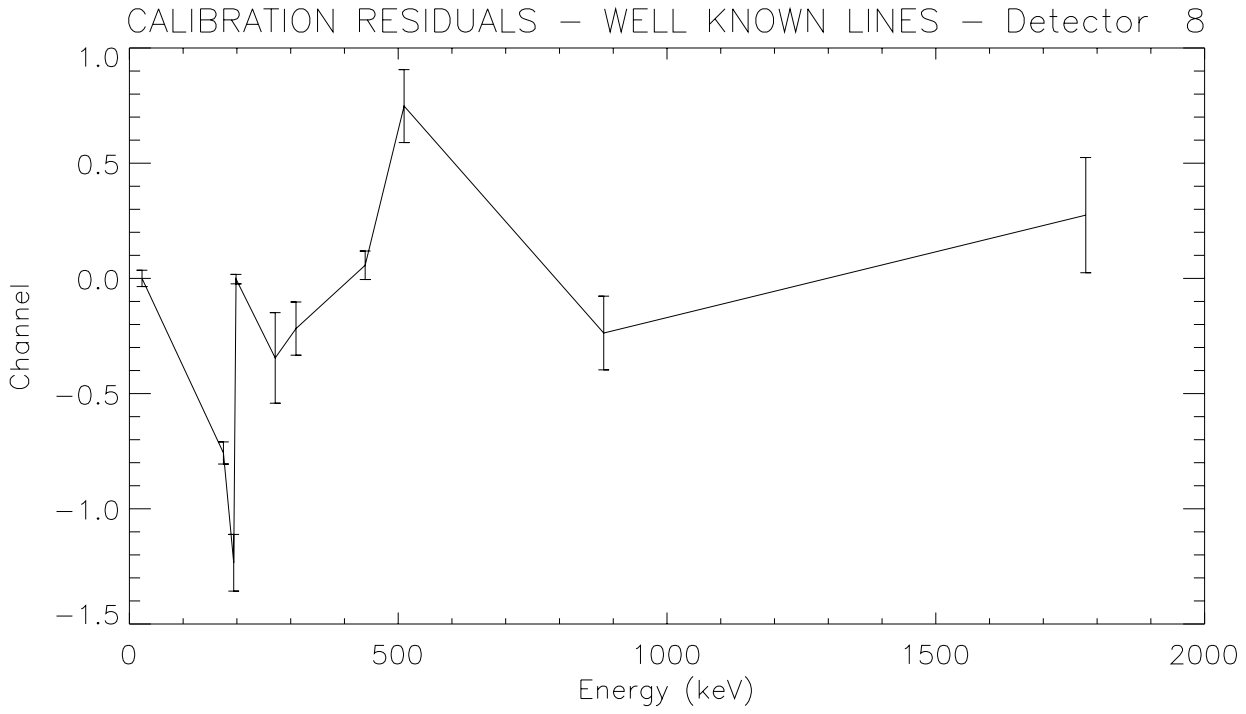
5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 7 (3rd order polynomial)

5 calibration lines (revolution 22):

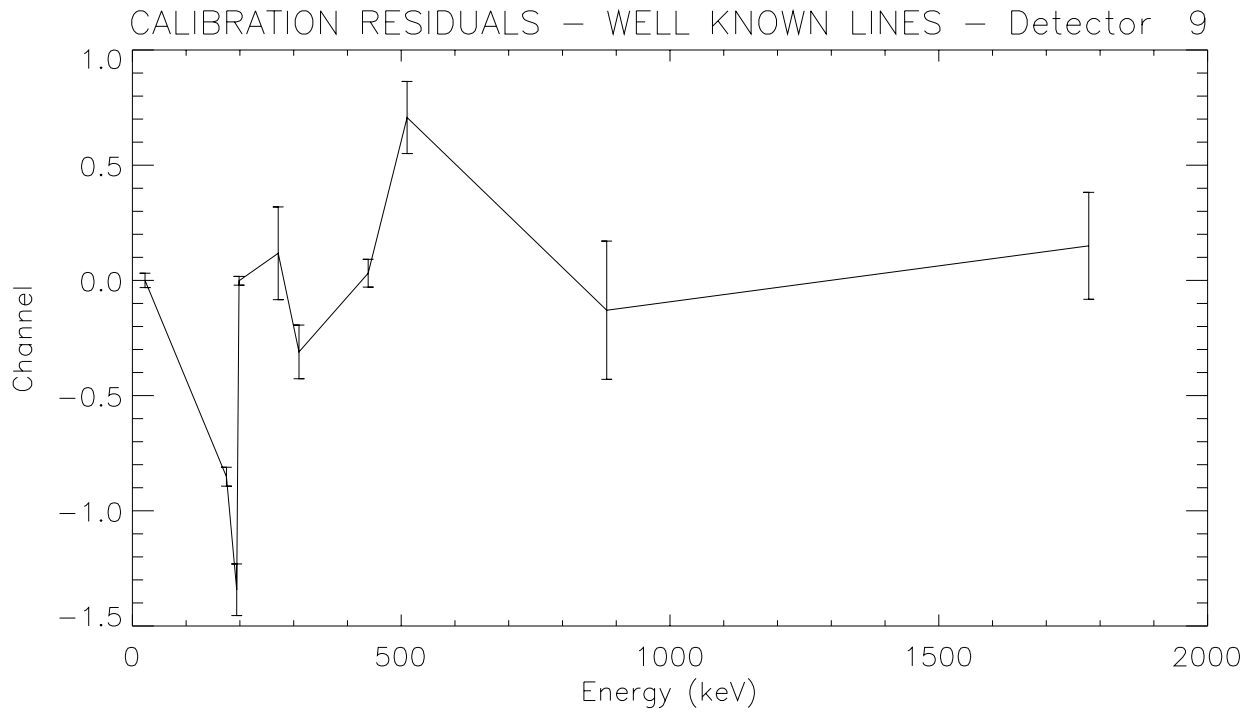
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 8 (3rd order polynomial)

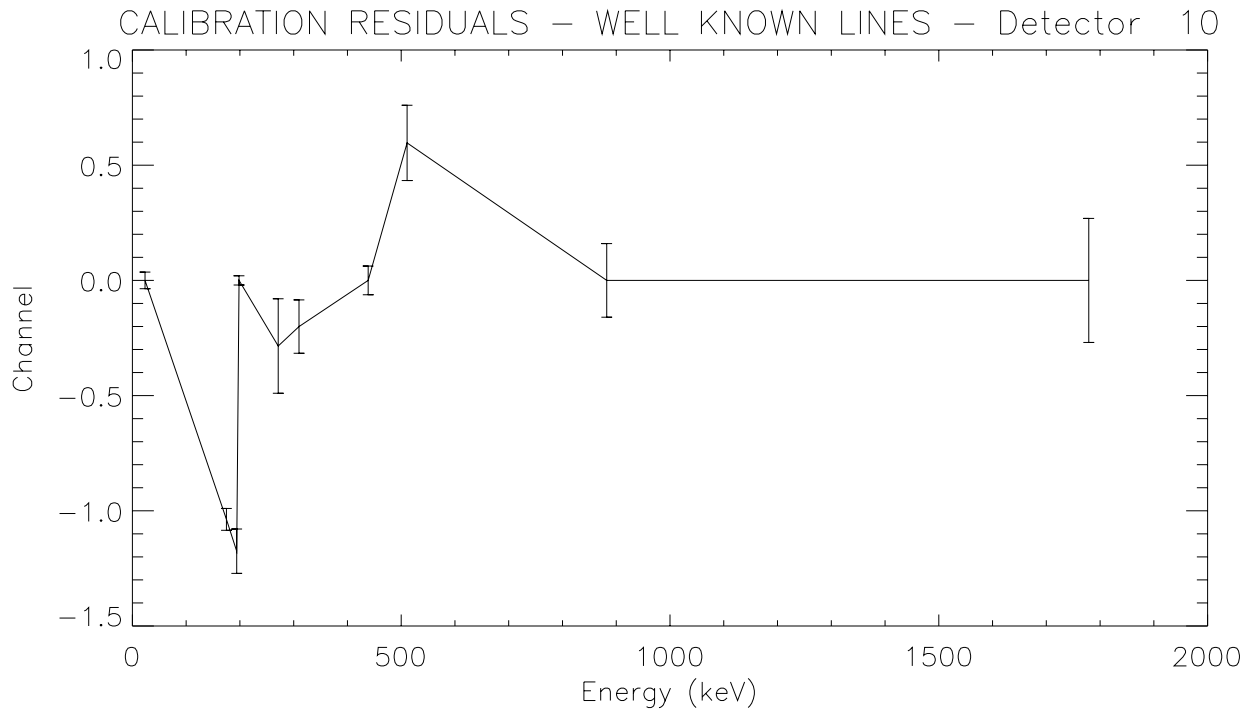
5 calibration lines (revolution 22):

23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



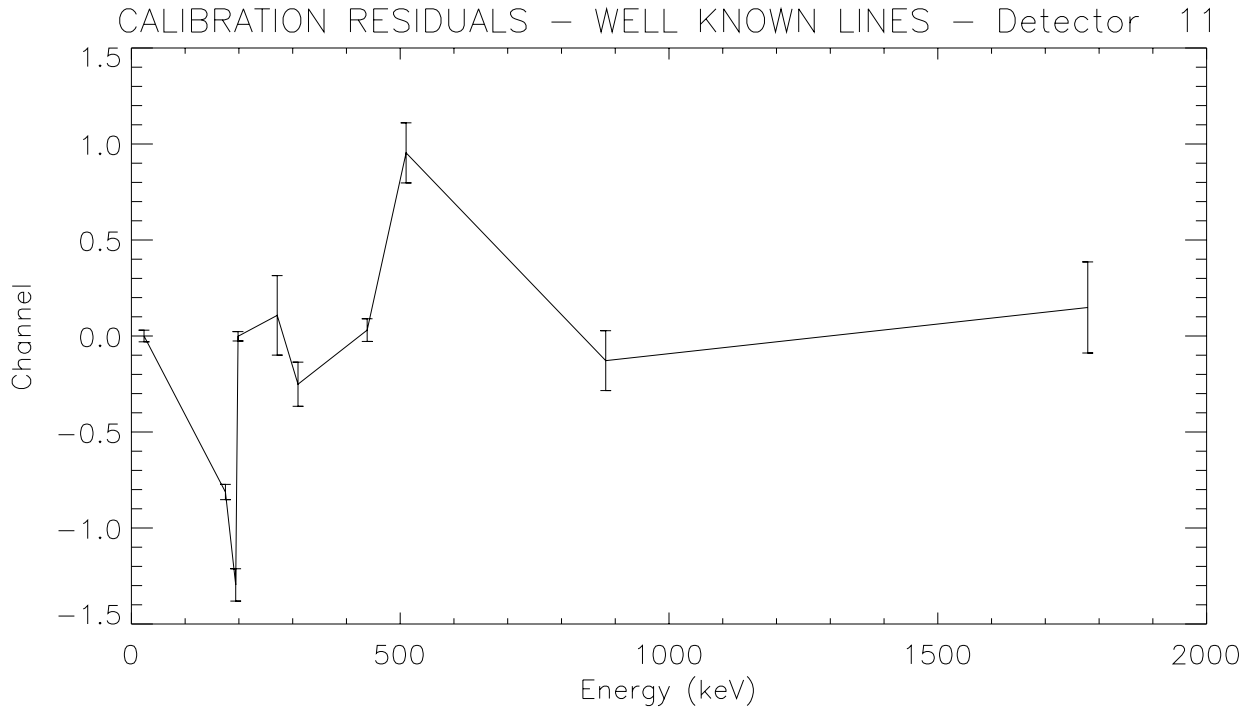
Calibration residuals for the detector 9 (3rd order polynomial)

5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 10 (3rd order polynomial)

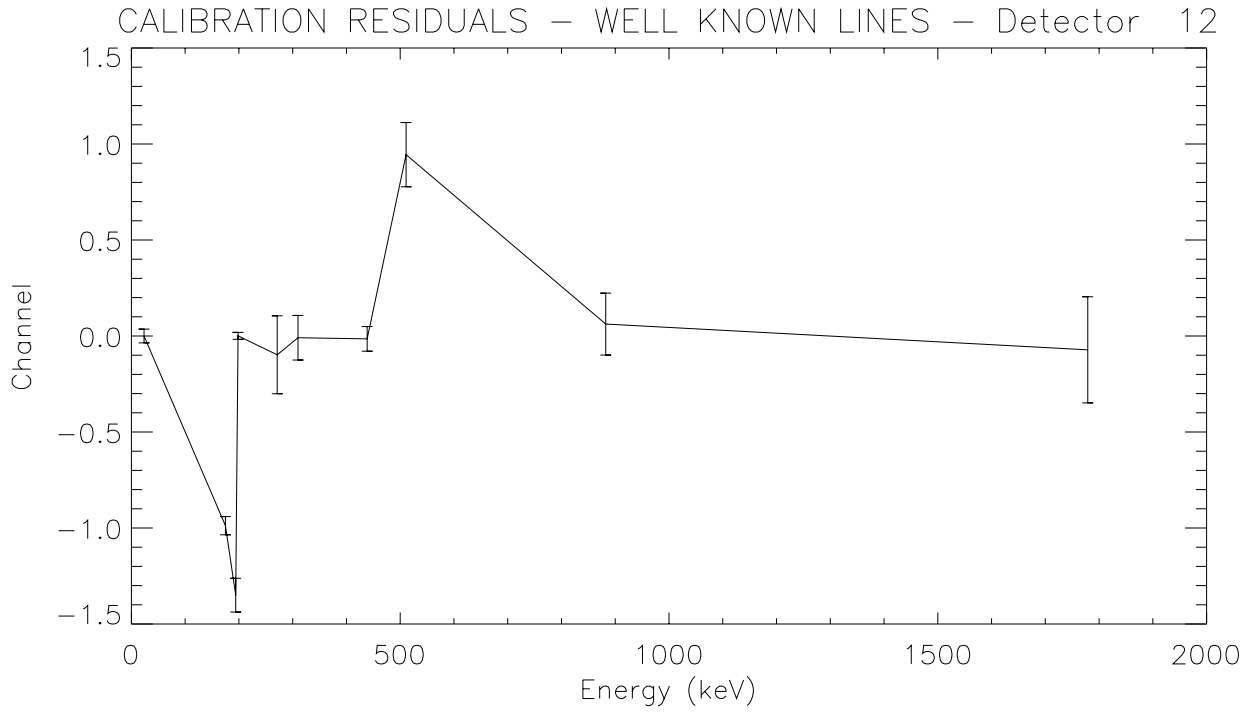
5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 11 (3rd order polynomial)

5 calibration lines (revolution 22):

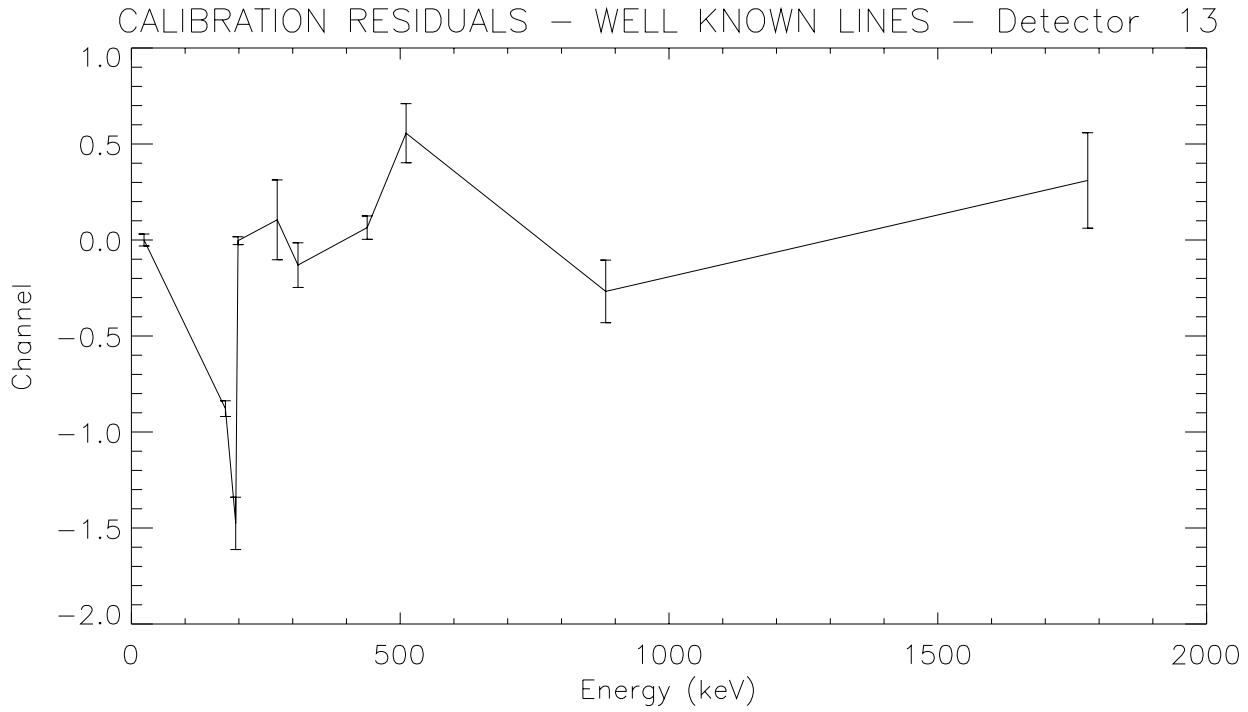
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 12 (3rd order polynomial)

5 calibration lines (revolution 22):

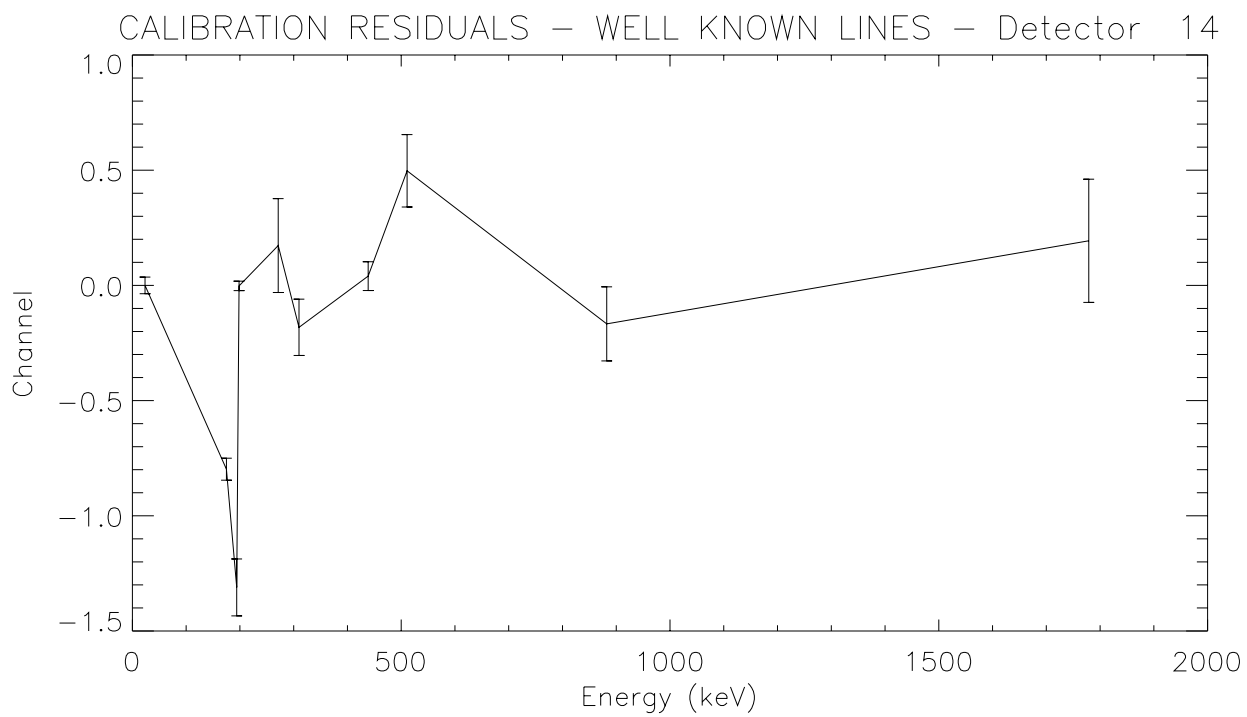
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 13 (3rd order polynomial)

5 calibration lines (revolution 22):

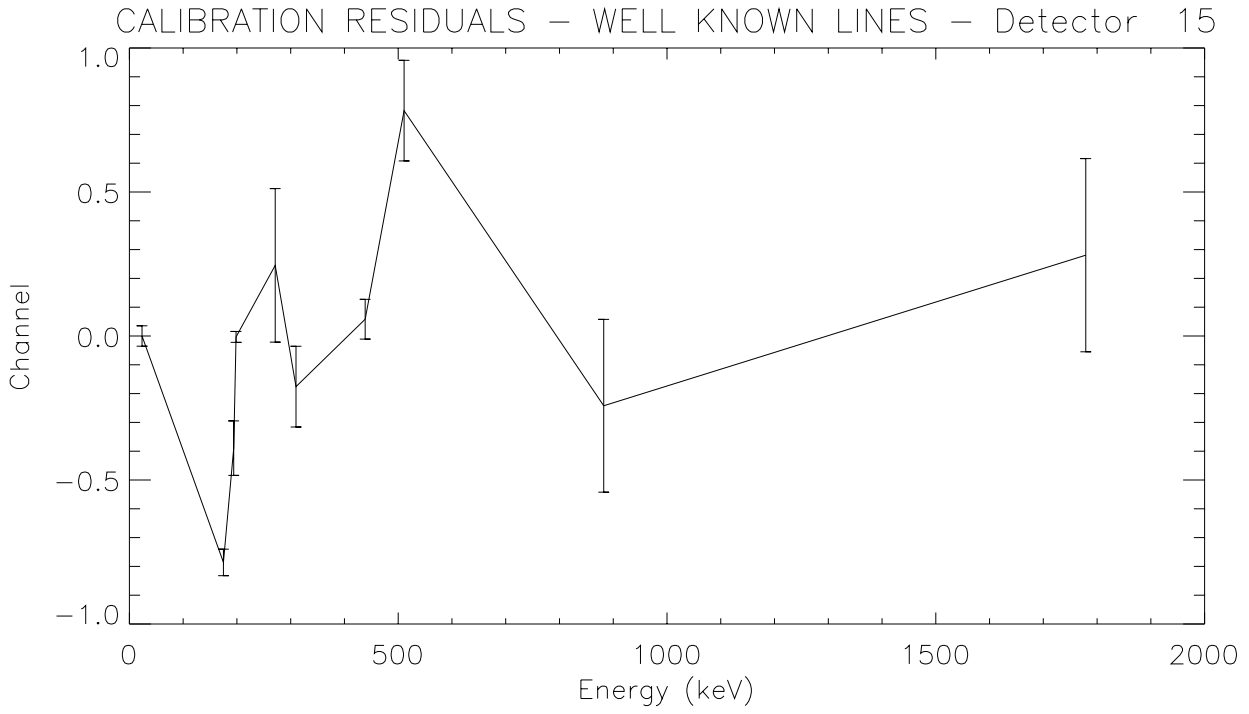
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 14 (3rd order polynomial)

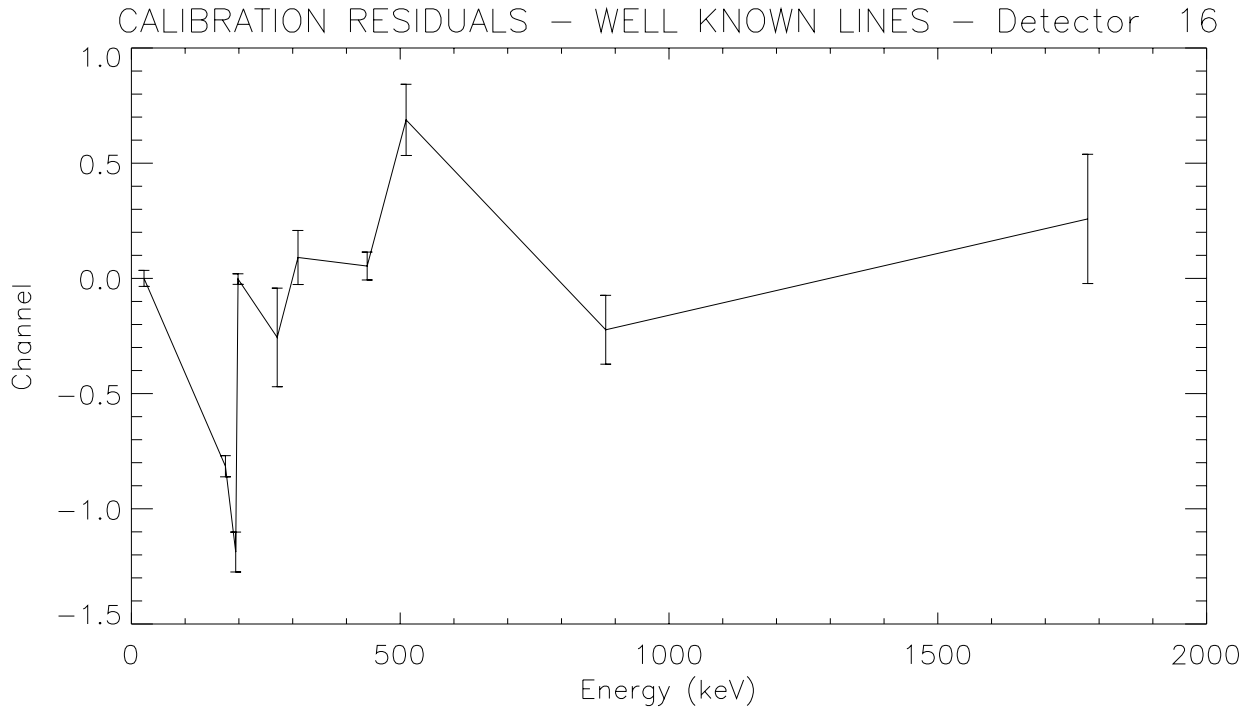
5 calibration lines (revolution 22):

23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 15 (3rd order polynomial)

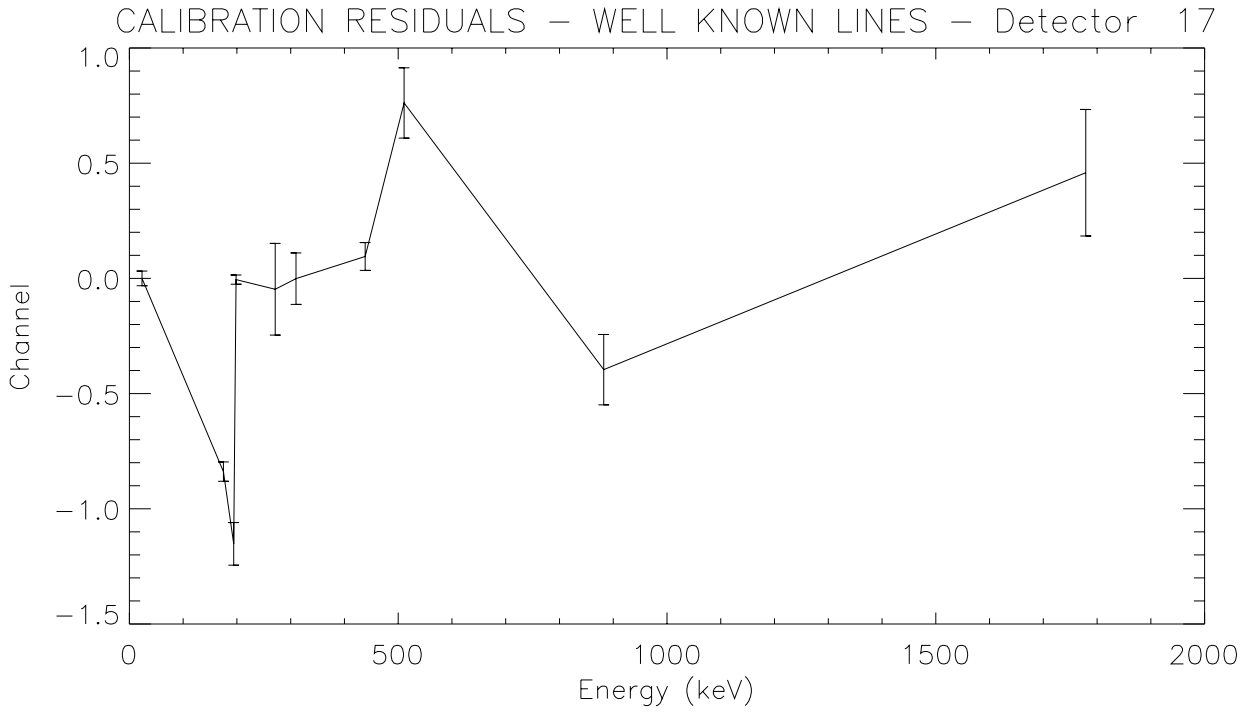
5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 16 (3rd order polynomial)

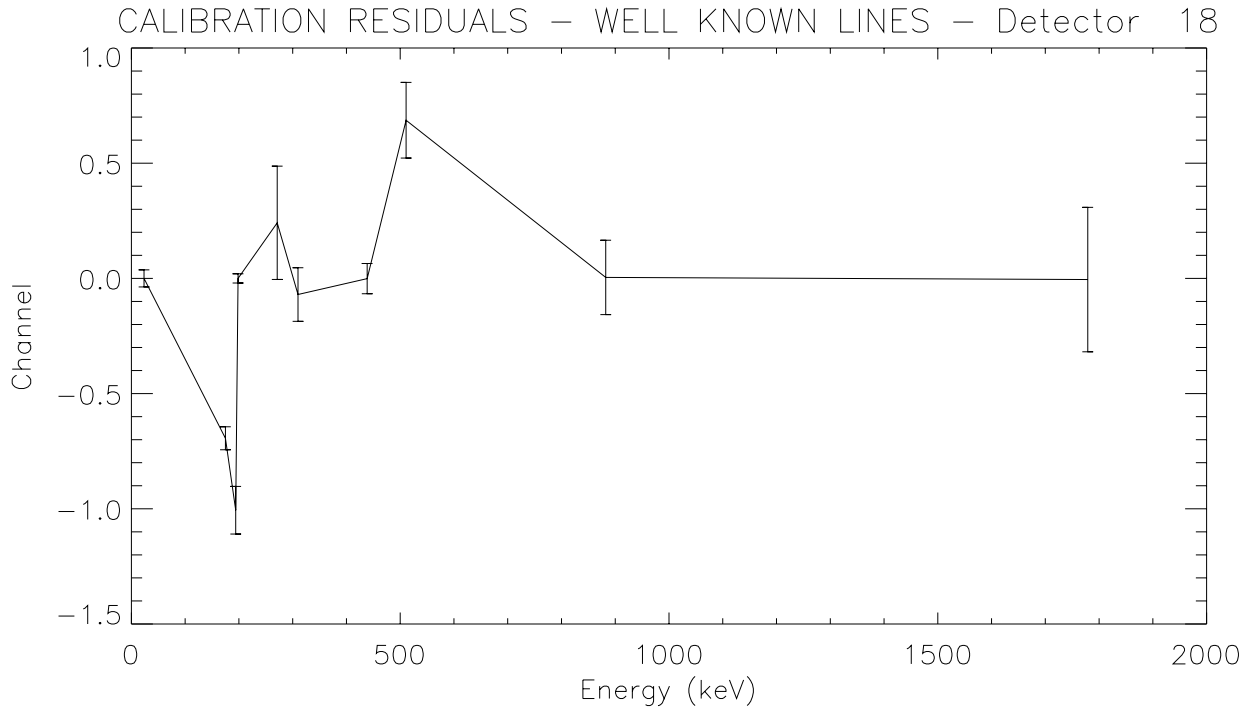
5 calibration lines (revolution 22):

23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 17 (3rd order polynomial)

5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 18 (3rd order polynomial)

5 calibration lines (revolution 22):

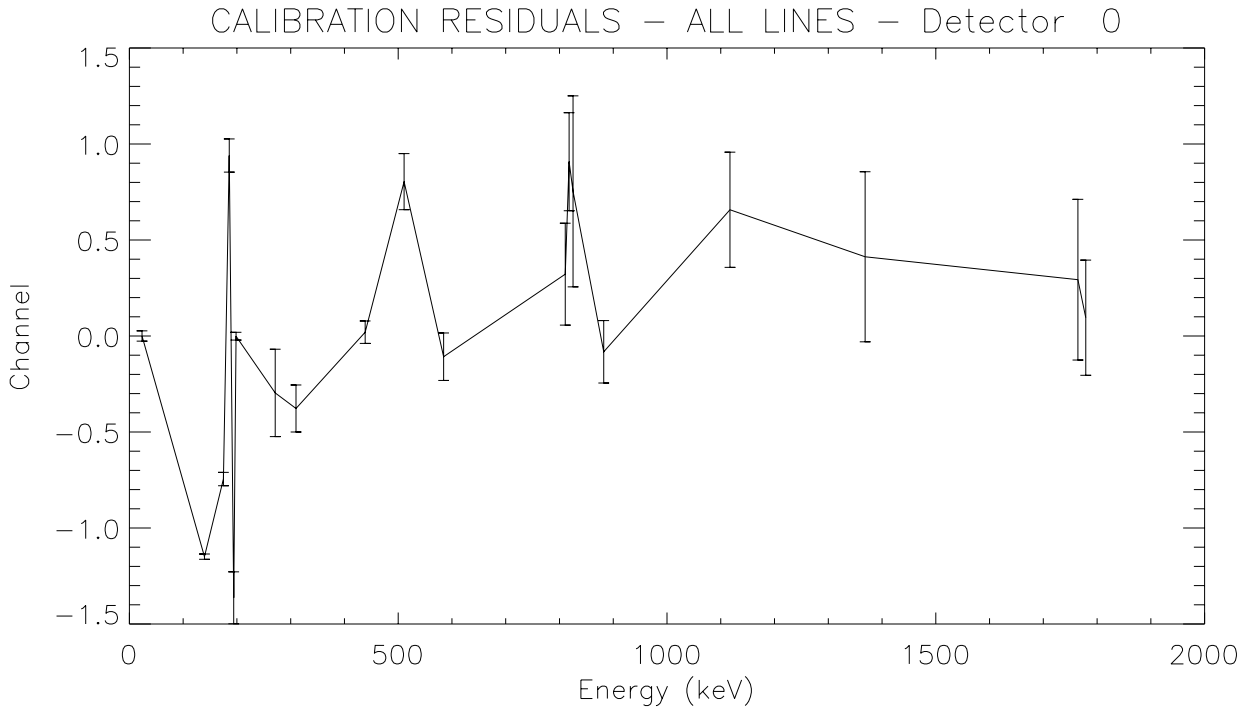
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV

ANNEX 4

Calibration residuals (3rd order polynomial).

Calibration lines: 23,43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV.

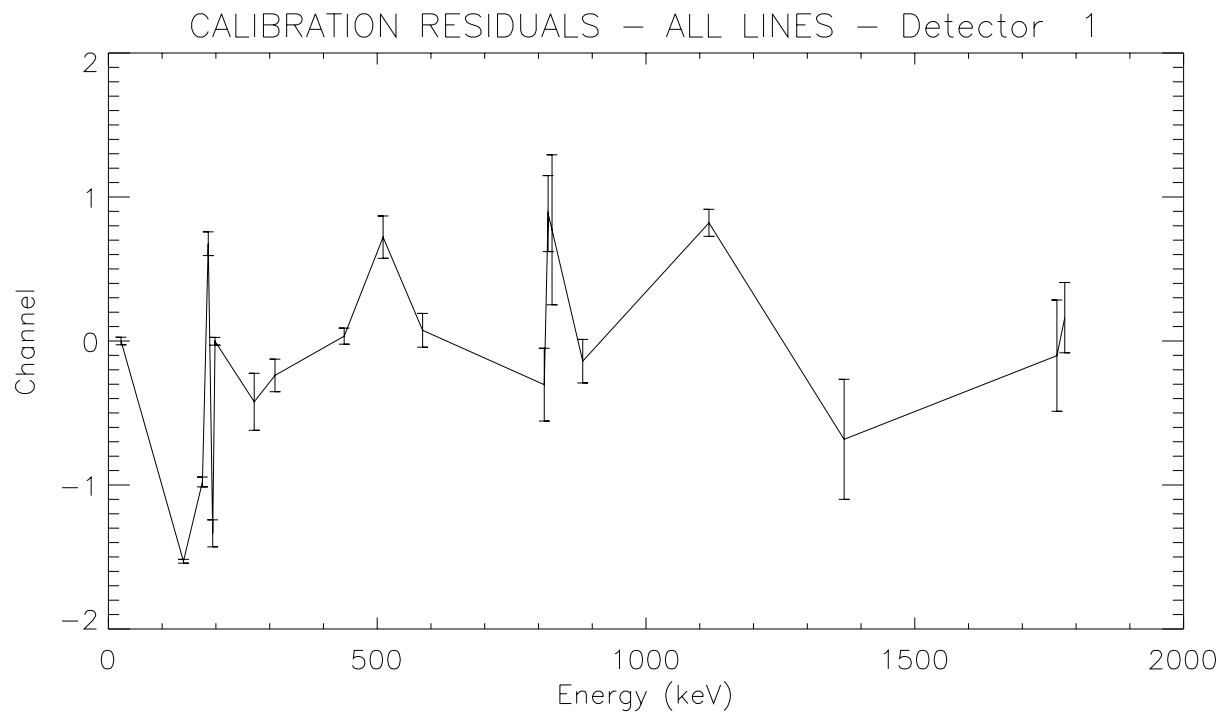
ALL gamma ray lines, revolution 22.



Calibration residuals for the detector 0 (3rd order polynomial)

5 calibration lines (revolution 22):

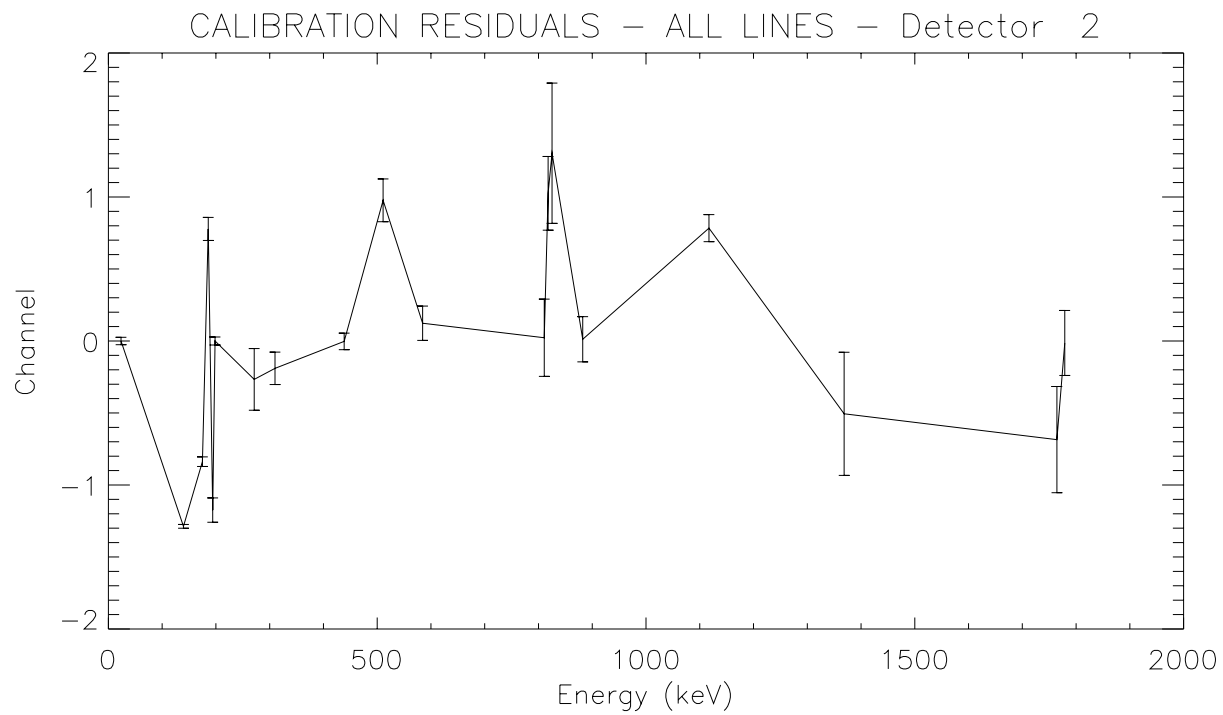
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 1 (3rd order polynomial)

5 calibration lines (revolution 22):

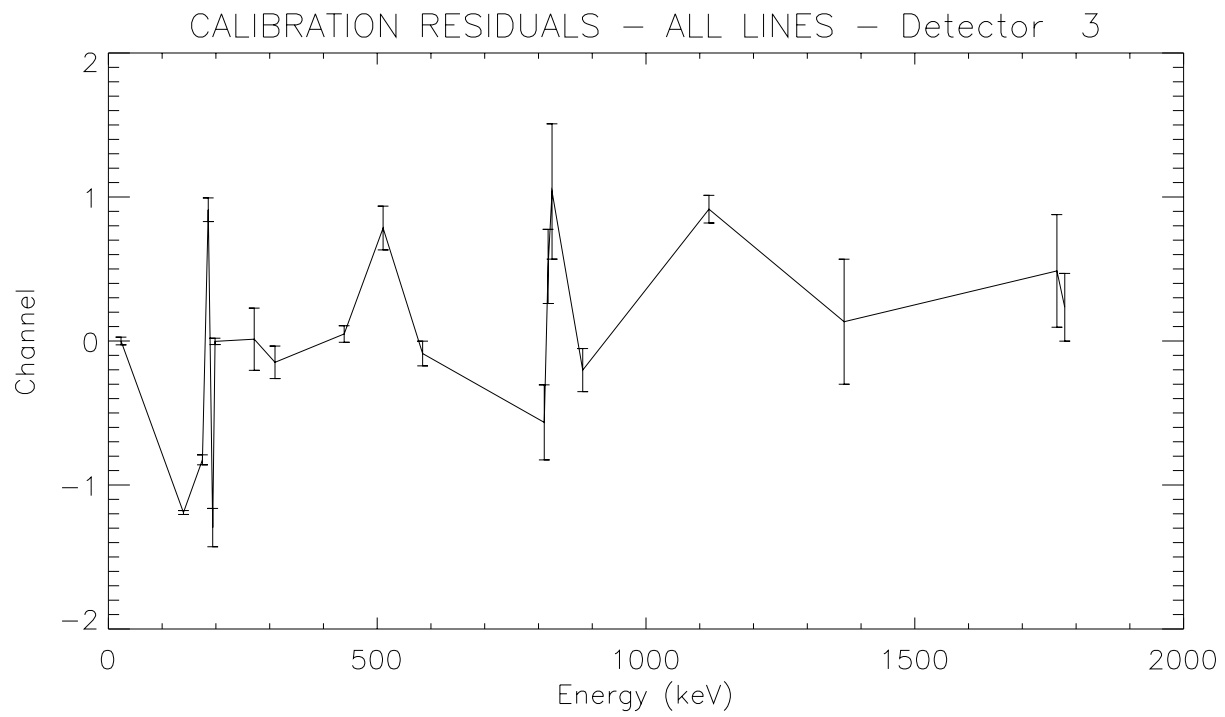
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 2 (3rd order polynomial)

5 calibration lines (revolution 22):

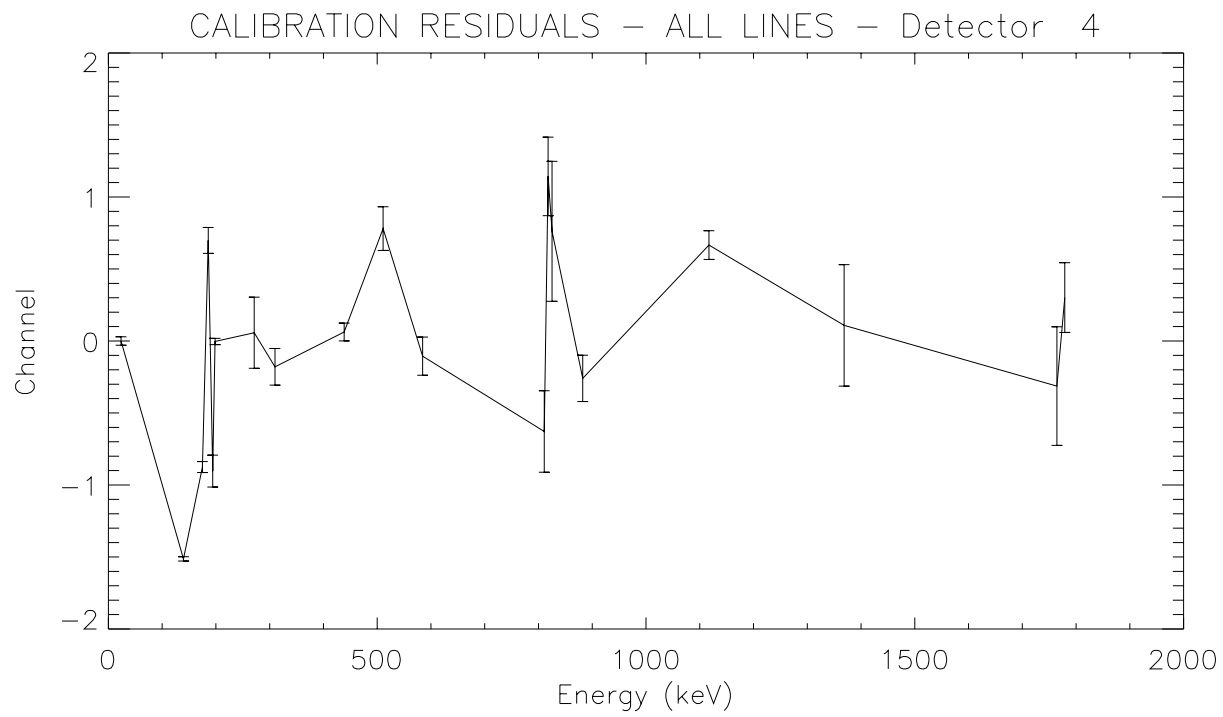
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 3 (3rd order polynomial)

5 calibration lines (revolution 22):

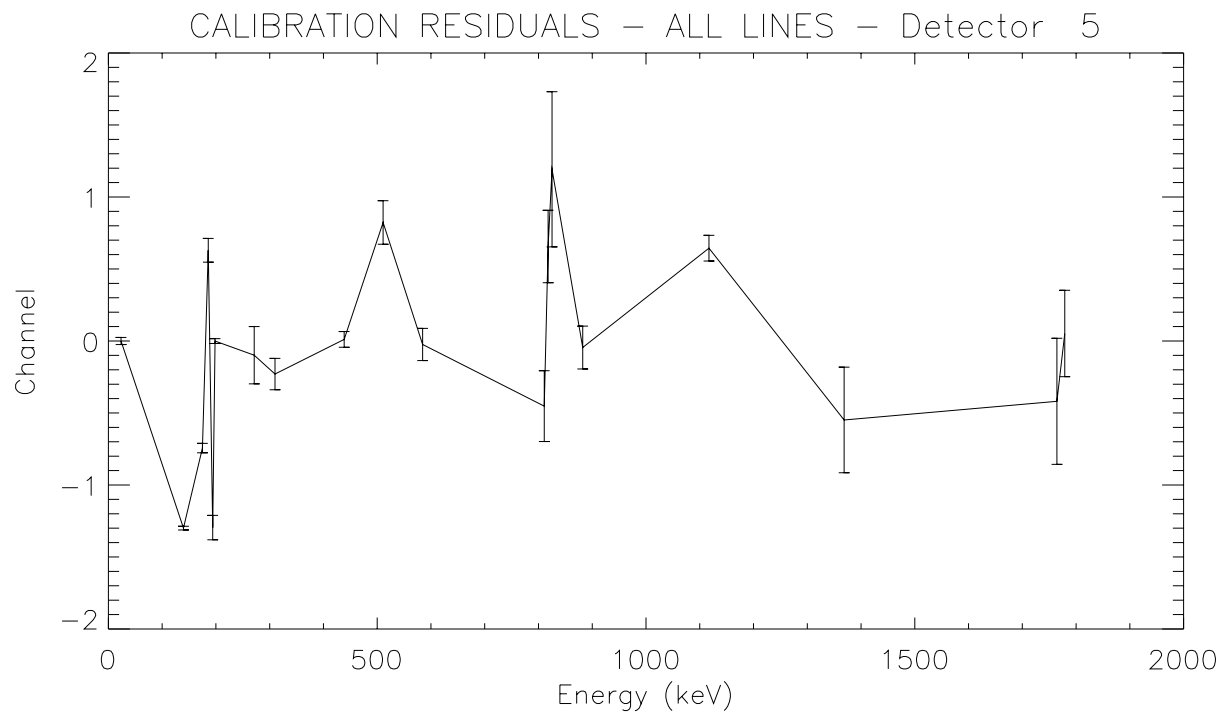
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 4 (3rd order polynomial)

5 calibration lines (revolution 22):

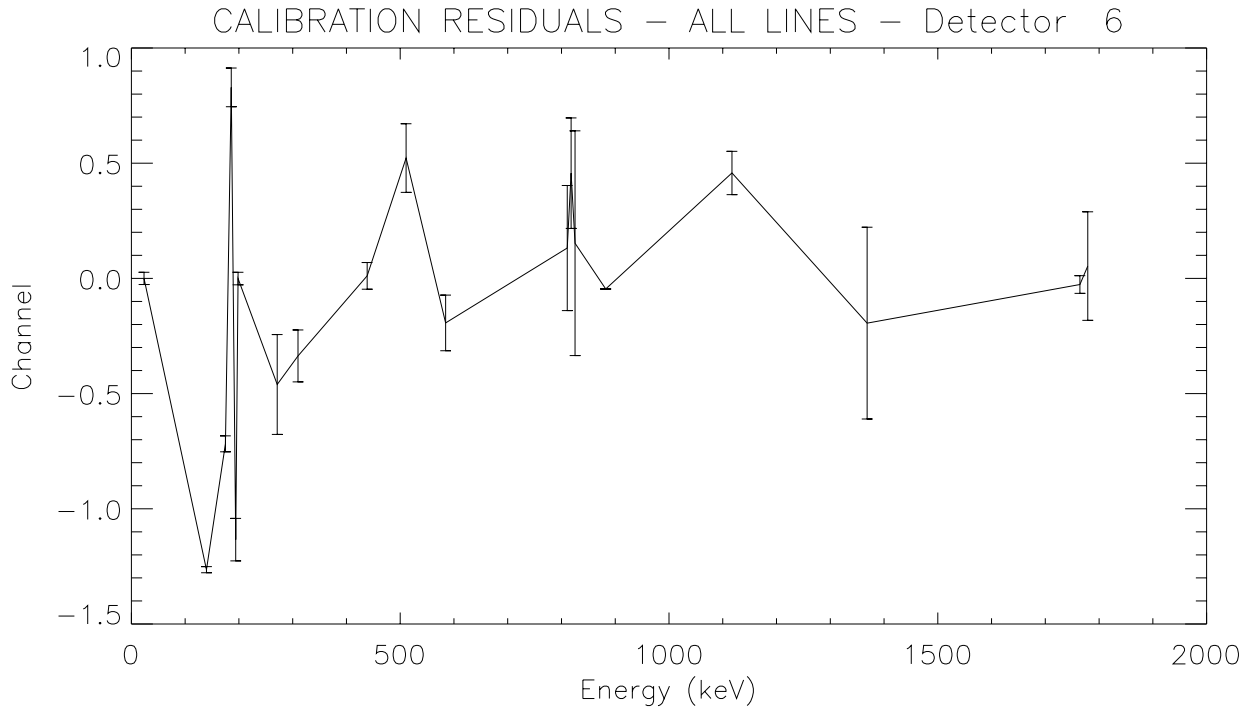
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 5 (3rd order polynomial)

5 calibration lines (revolution 22):

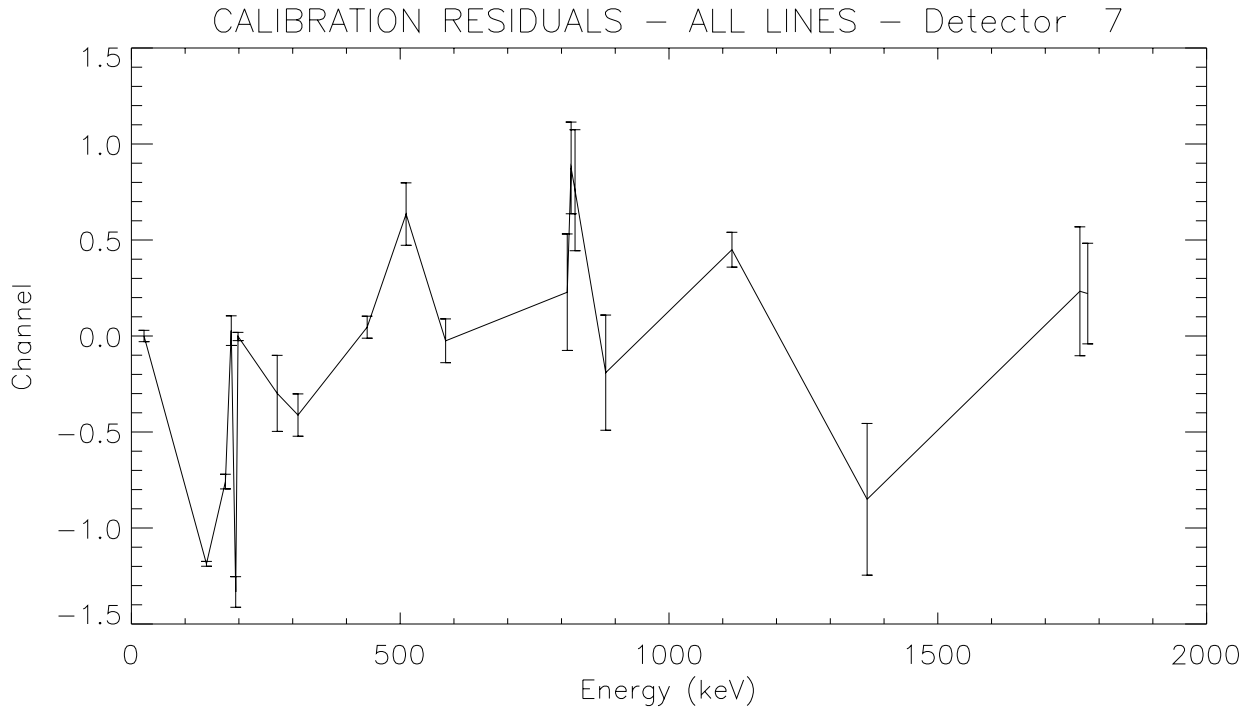
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 6 (3rd order polynomial)

5 calibration lines (revolution 22):

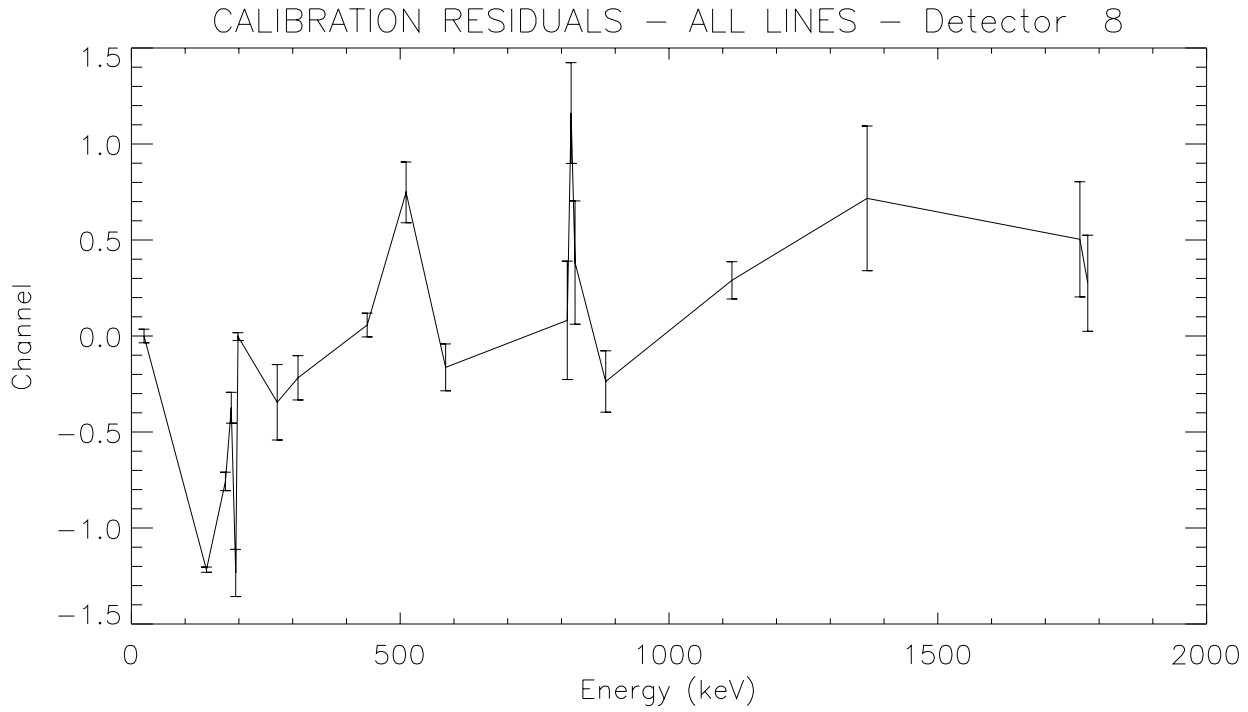
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 7 (3rd order polynomial)

5 calibration lines (revolution 22):

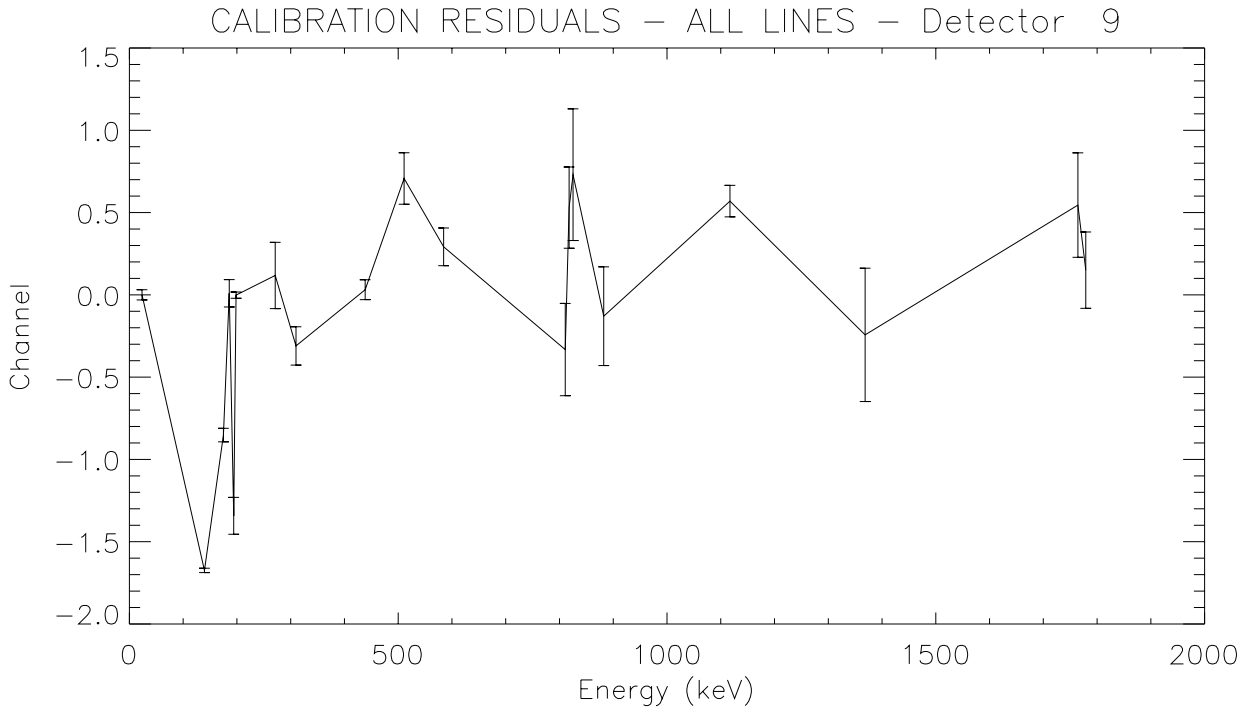
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 8 (3rd order polynomial)

5 calibration lines (revolution 22):

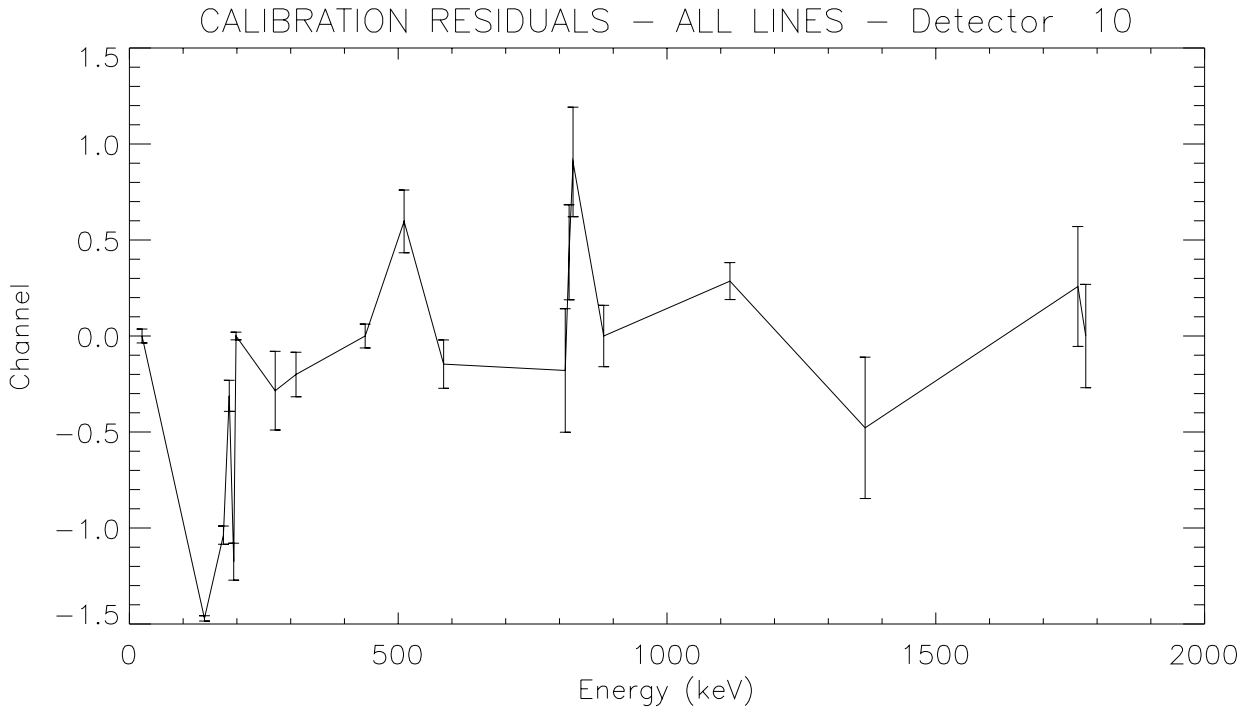
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 9 (3rd order polynomial)

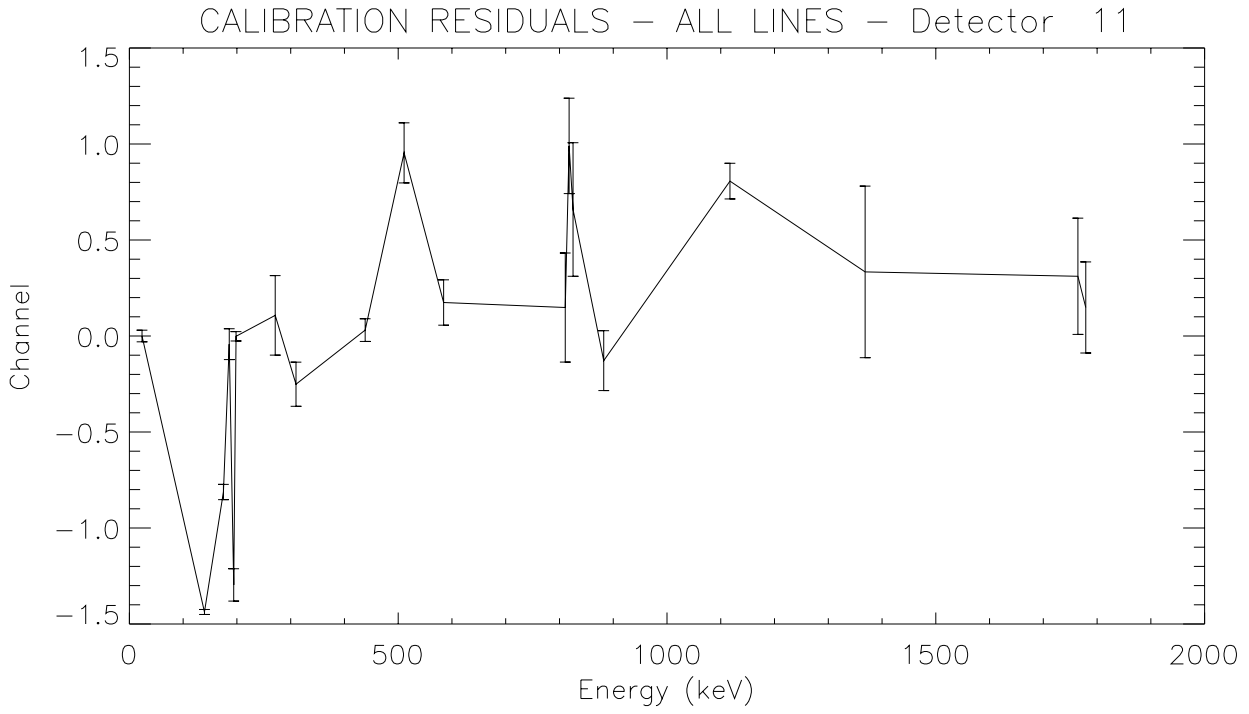
5 calibration lines (revolution 22):

23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 10 (3rd order polynomial)

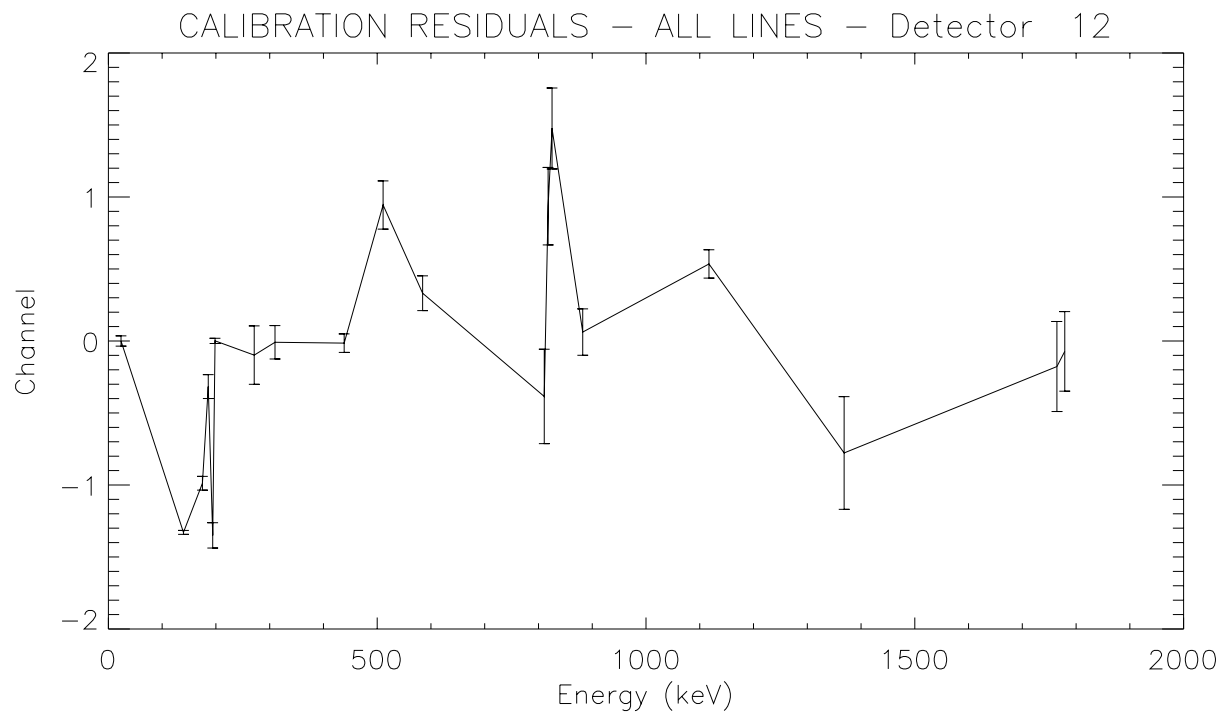
5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 11 (3rd order polynomial)

5 calibration lines (revolution 22):

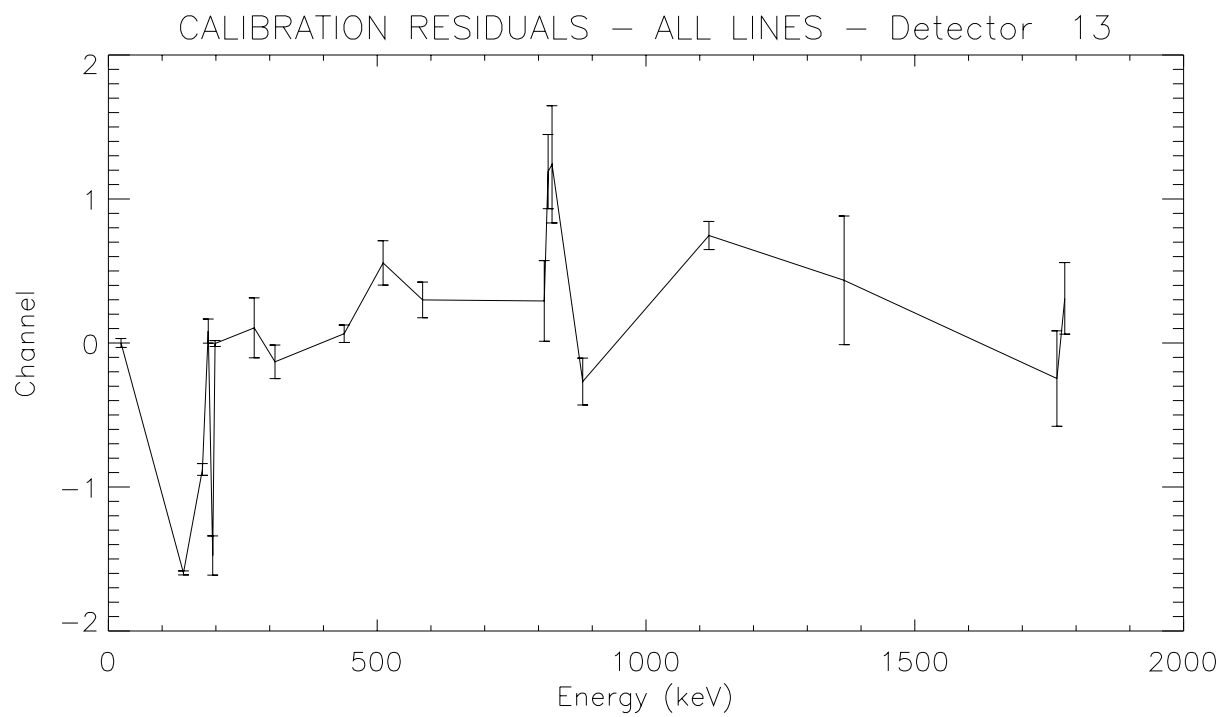
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 12 (3rd order polynomial)

5 calibration lines (revolution 22):

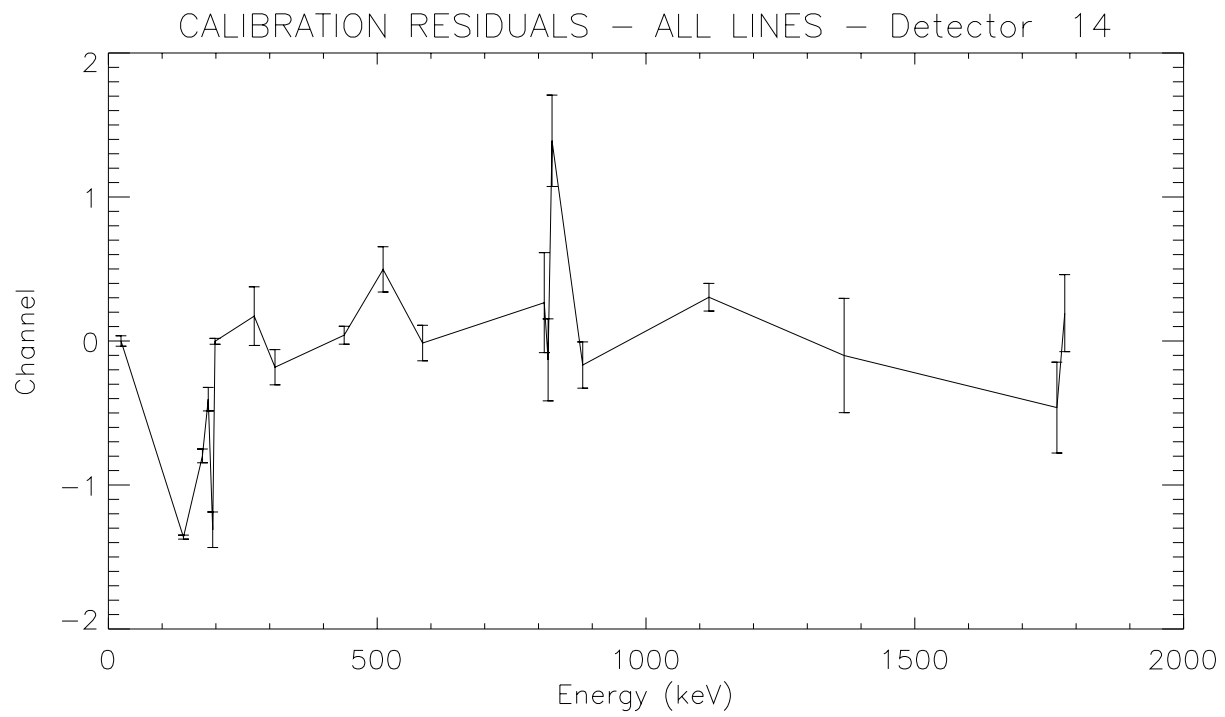
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 13 (3rd order polynomial)

5 calibration lines (revolution 22):

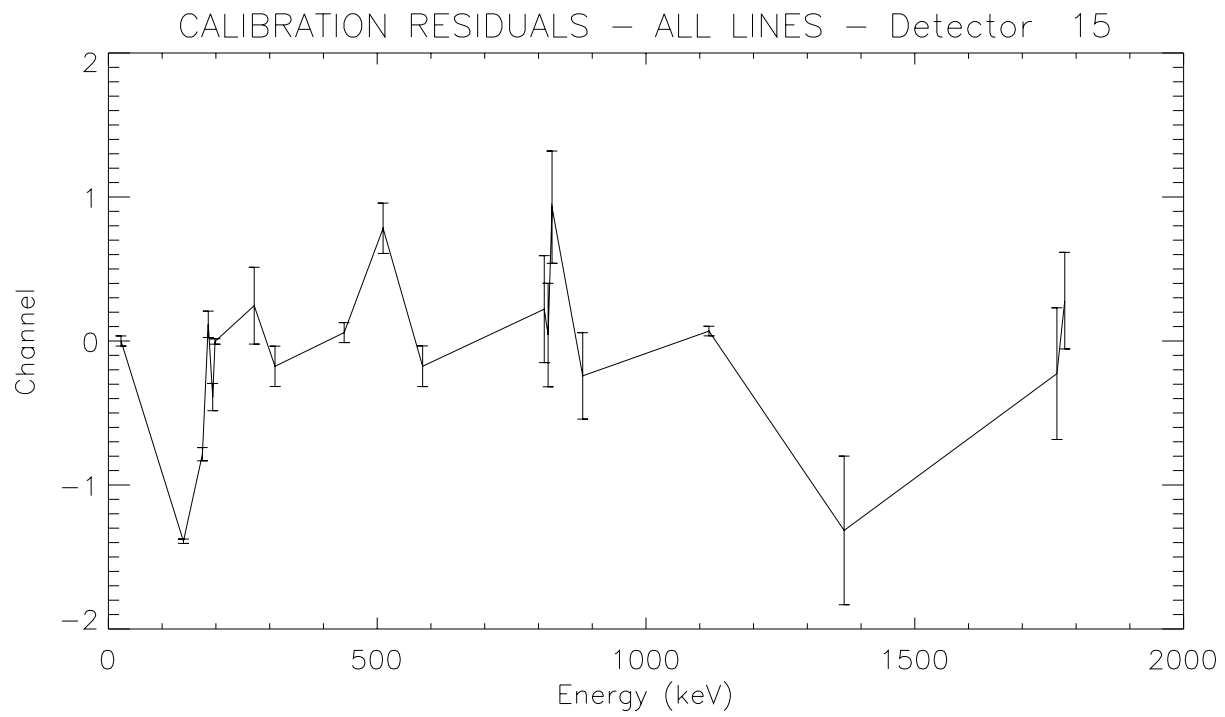
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 14 (3rd order polynomial)

5 calibration lines (revolution 22):

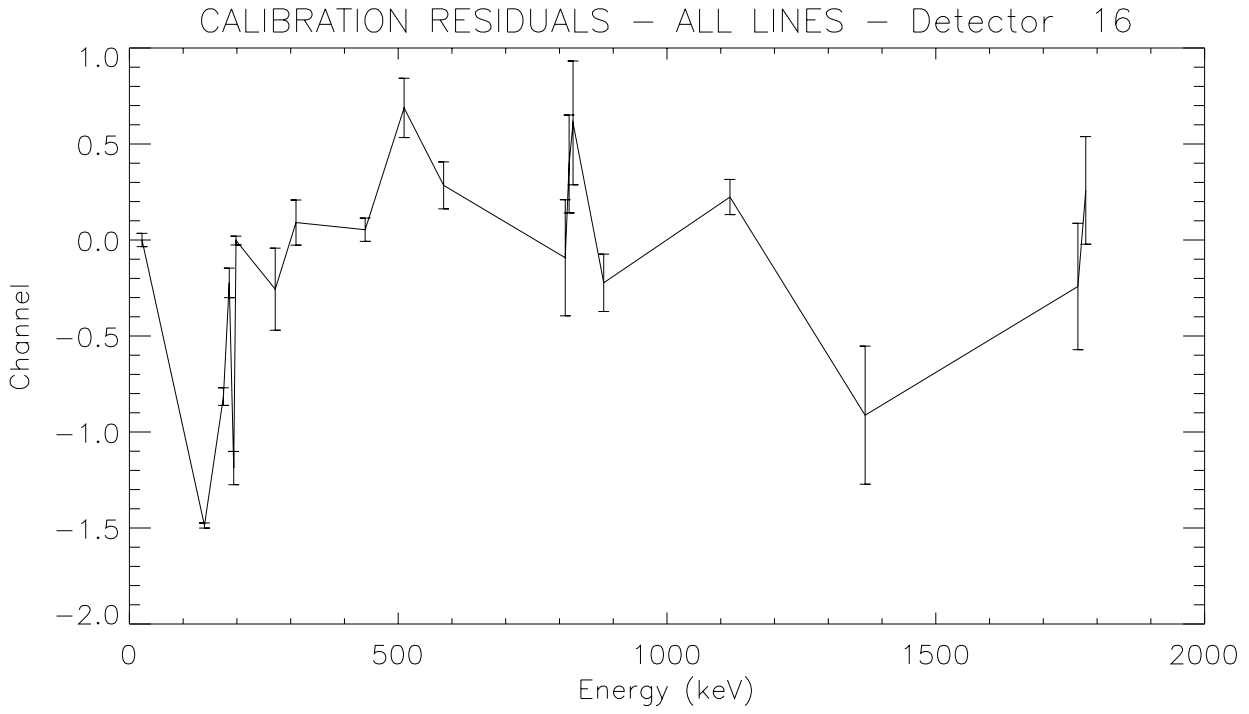
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 15 (3rd order polynomial)

5 calibration lines (revolution 22):

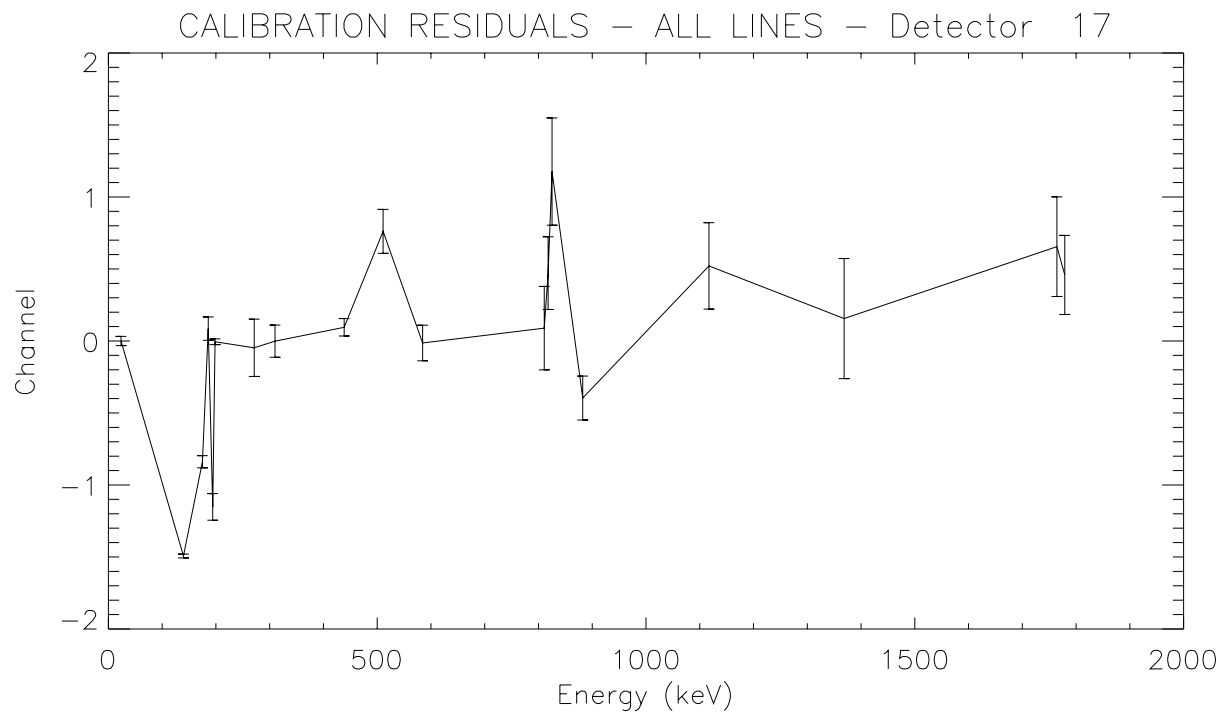
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 16 (3rd order polynomial)

5 calibration lines (revolution 22):

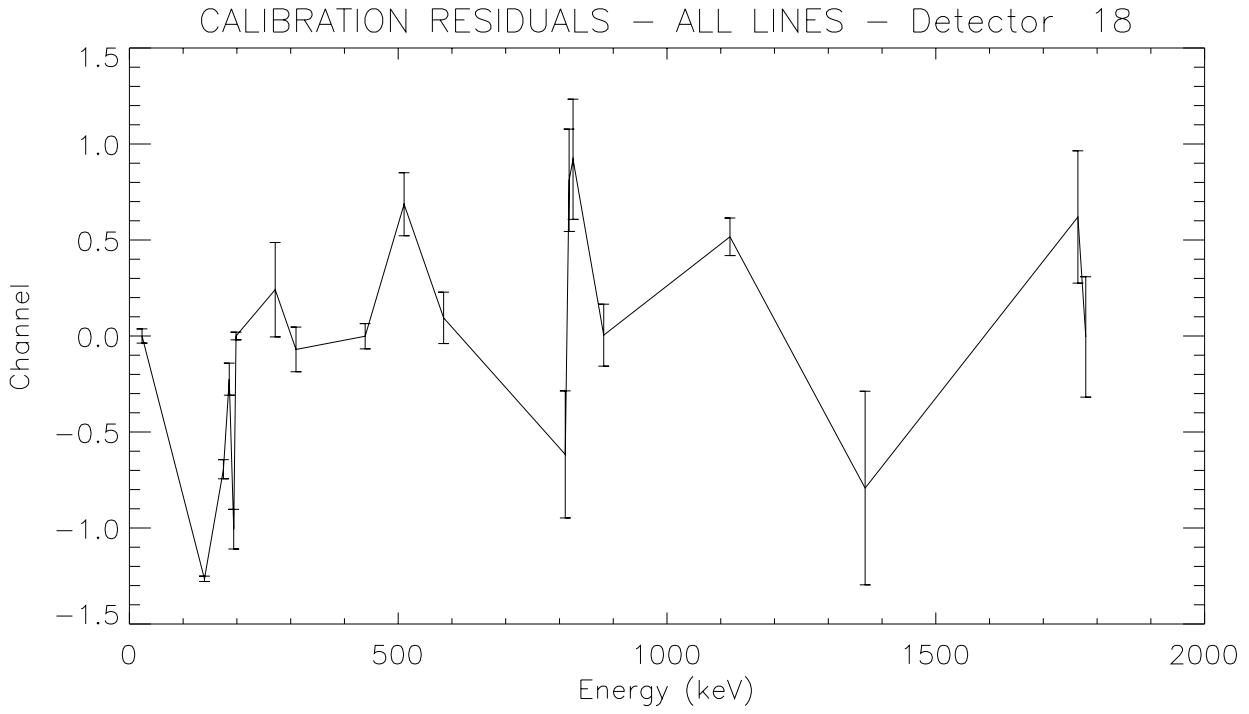
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 17 (3rd order polynomial)

5 calibration lines (revolution 22):

23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV



Calibration residuals for the detector 18 (3rd order polynomial)

5 calibration lines (revolution 22):
23.43 keV, 198.34 keV, 438.6 keV, 882.35 keV, 1778.9 keV