Pulse-shape analysis with a Broad-energy Ge-detector

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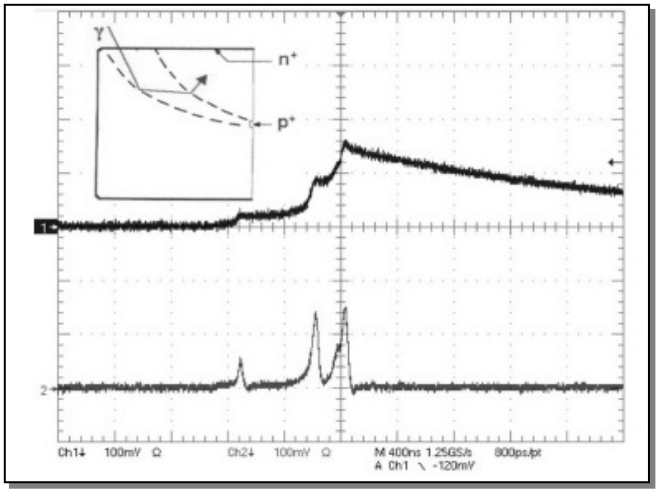
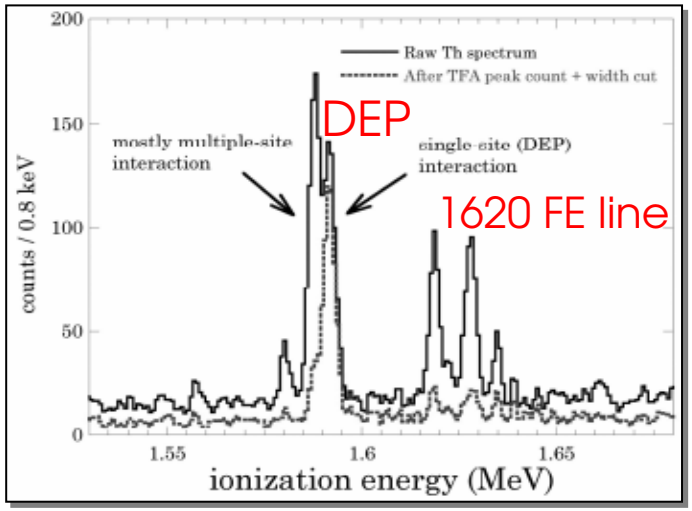
Outline

Max-Planck-Institut für Kernphysik

1. Motivation and goals
2. BEGe detector and set-up description
3. Detector performance
4. Pulse-shape analysis first results
5. Comparison BEGe and 18-segment coax
6. Outlook

Novel p-type point contact HP-Ge detector for DBD search





P.S. Barbeau, J.I. Collar and O. Tench
JCAP 0709:009,2007
(Crystal mass: 475 g)

- **J. Collar/Majorana collab.** recognized potential of p-type point contact (**ppc**) HP-Ge for PSA
- Performance in terms of **MSE suppression** / SSE acceptance **comparable or even better** than **segmented detectors**
- **Number** of electr. **contacts** same as standard p-type coax. detect (1 HV + 1 signal cable per detector), **less** than for **segmented** detectors
- As signal cables & contacts are potential source of backgrounds, achievable **background level of ppc-detector** potentially **superior** to **high-segmented** detectors
- Discussions Stefan Schönert / Canberra Olen ⇒ standard **BEGe** detectors could have **similar pulse shape** performance as the ppc
- **BEGe** ordered by MPIK through DFG/TR27 special funds end of December `07, detector **delivered end of March'08**

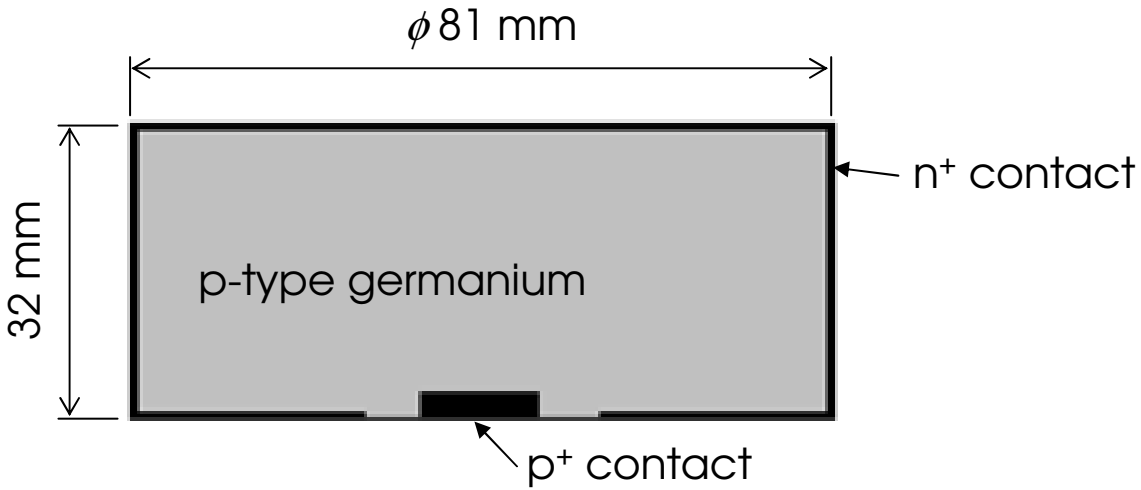
Broad-energy Ge-detector

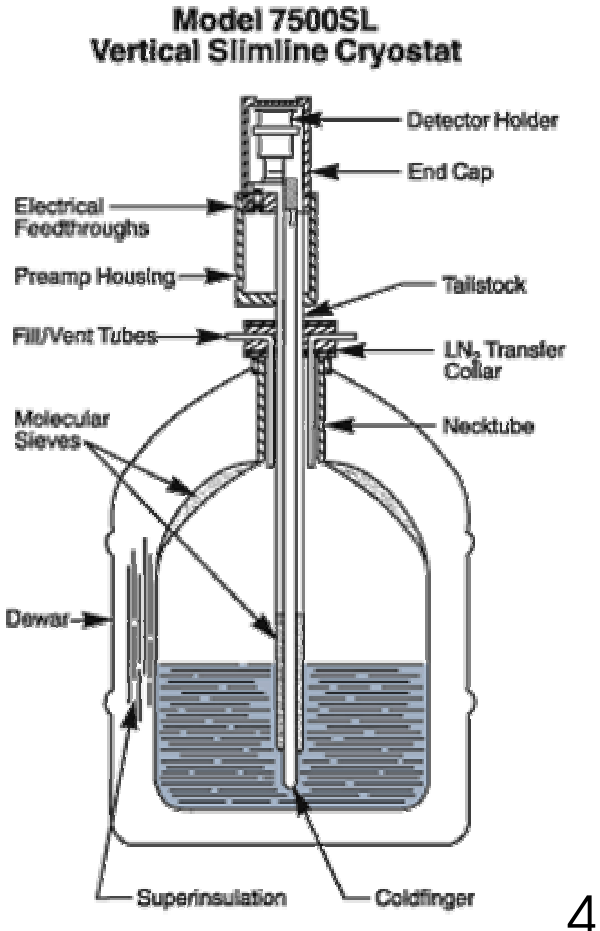
- covers energy range 3 keV - 3 MeV
- enhanced efficiency for low-energy gammas
- low capacitance (⇒ low noise)

CANBERRA

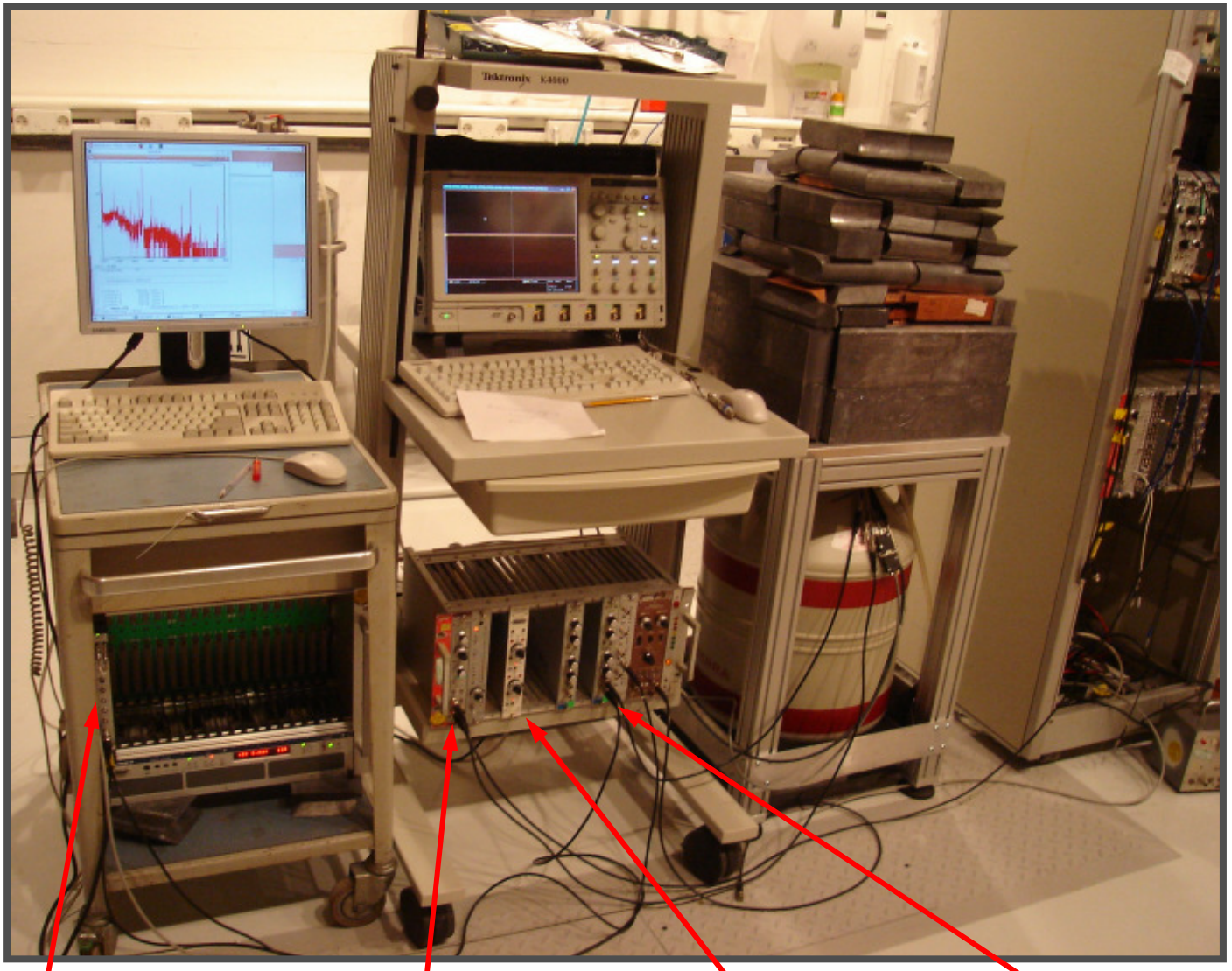
Specifications:

depletion voltage	4000 V
FWHM @ 122 keV	0.63 keV
FWHM @ 1.33 MeV	1.8 keV
mass	870 g



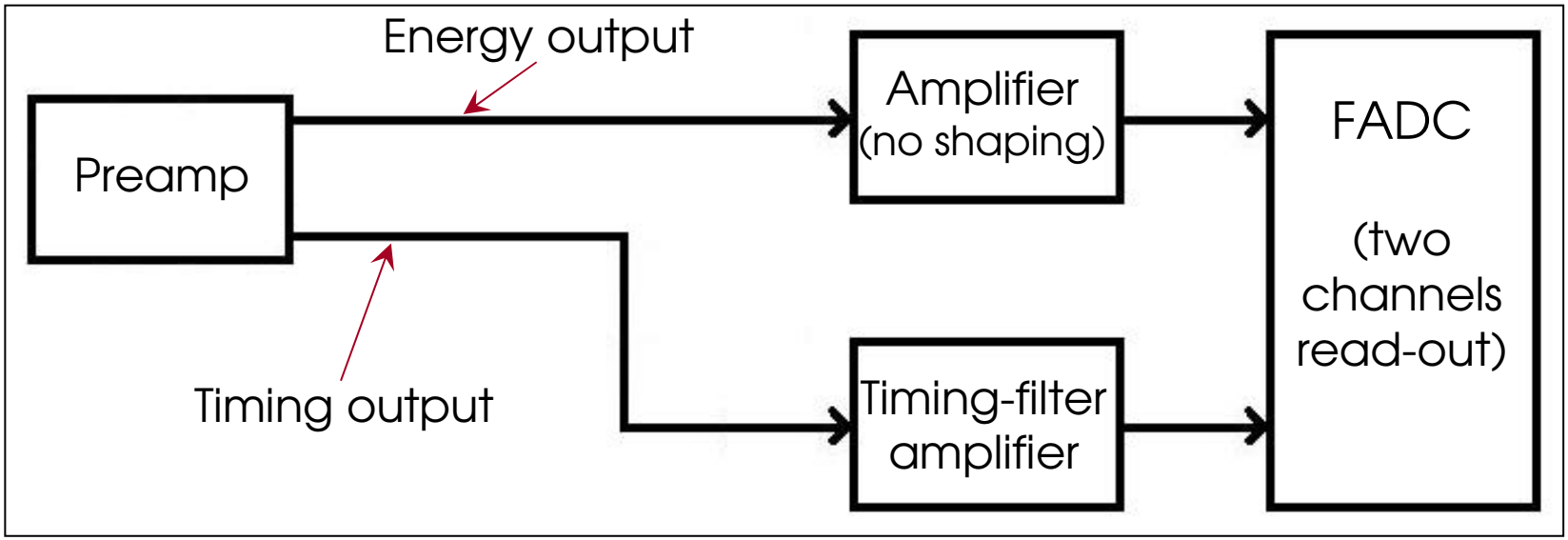


The set-up



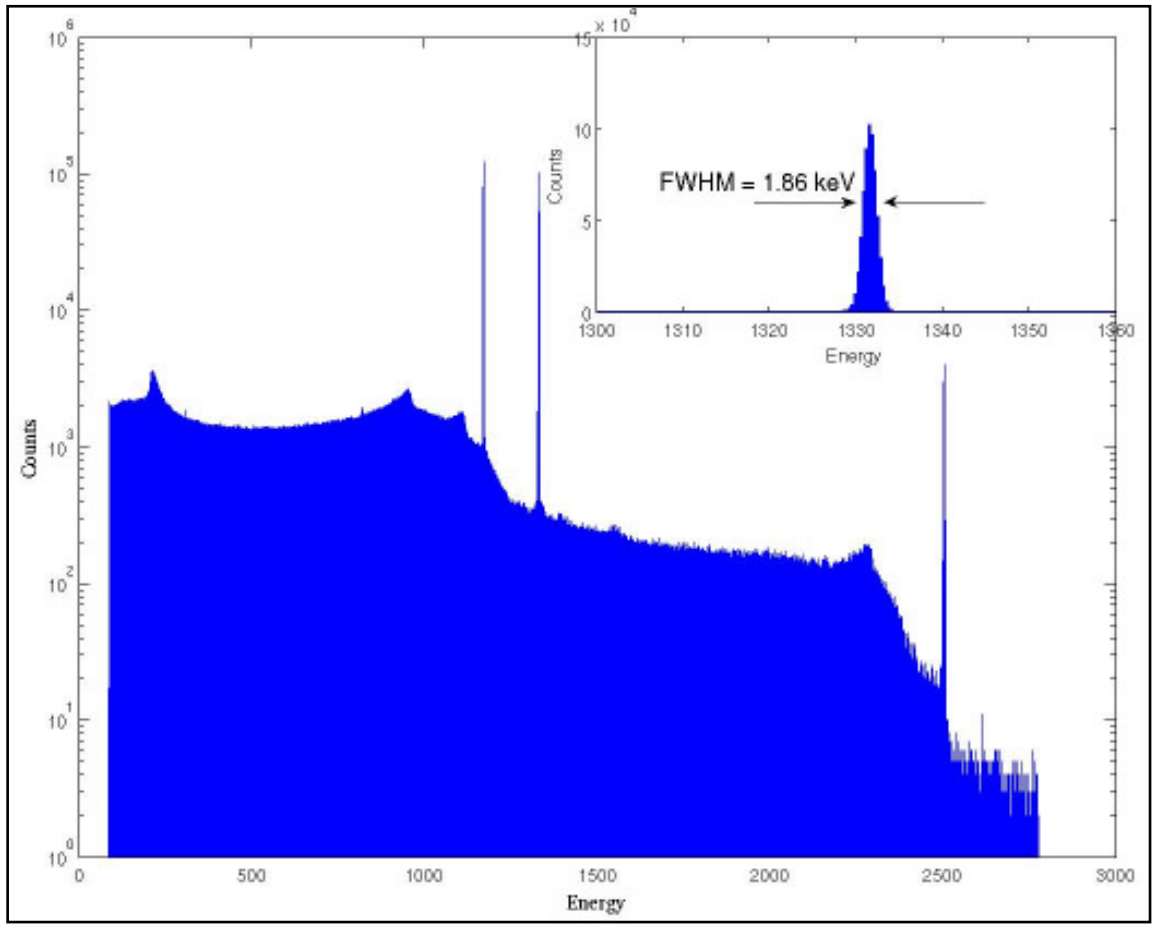
Data acquisition layout

- RC-feedback preamplifier 2002CSL with cooled FET
  noise: (with 0 pF input C) FWHM = 570 eV
  risetime: (with 30 pF input C) < 20 ns
- Analog spectroscopy amplifier with an ADC system
- Struck SIS 3301 flash-ADC with 14-bit resolution,
  100 MHz sampling rate, digital shaping
- Analog timing-filter amplifier Canberra model 2111

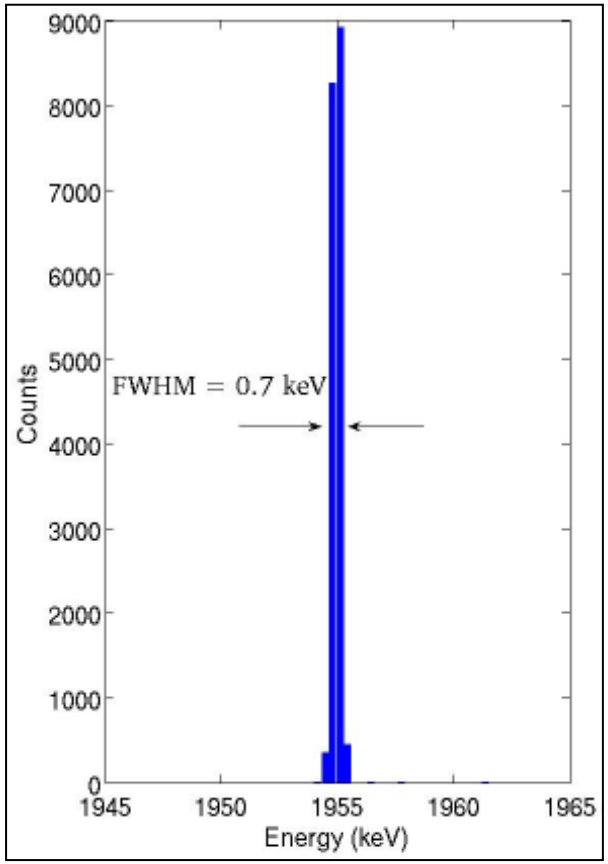


Detector performance

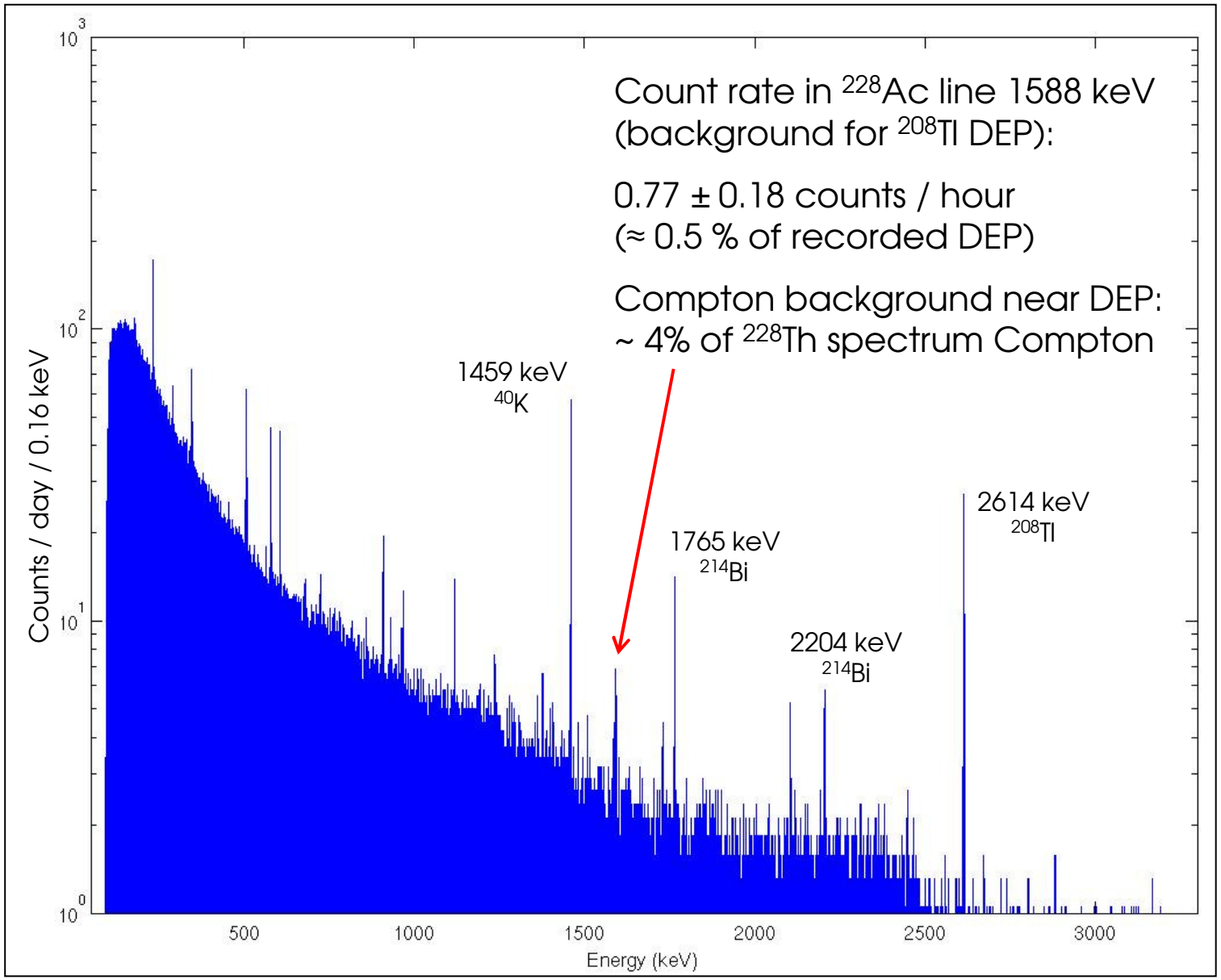
- ^{60}Co spectrum recorded by an ADC with analog spectroscopy amplifier, shaping time = 12 μs
- bias voltage: 3800 V



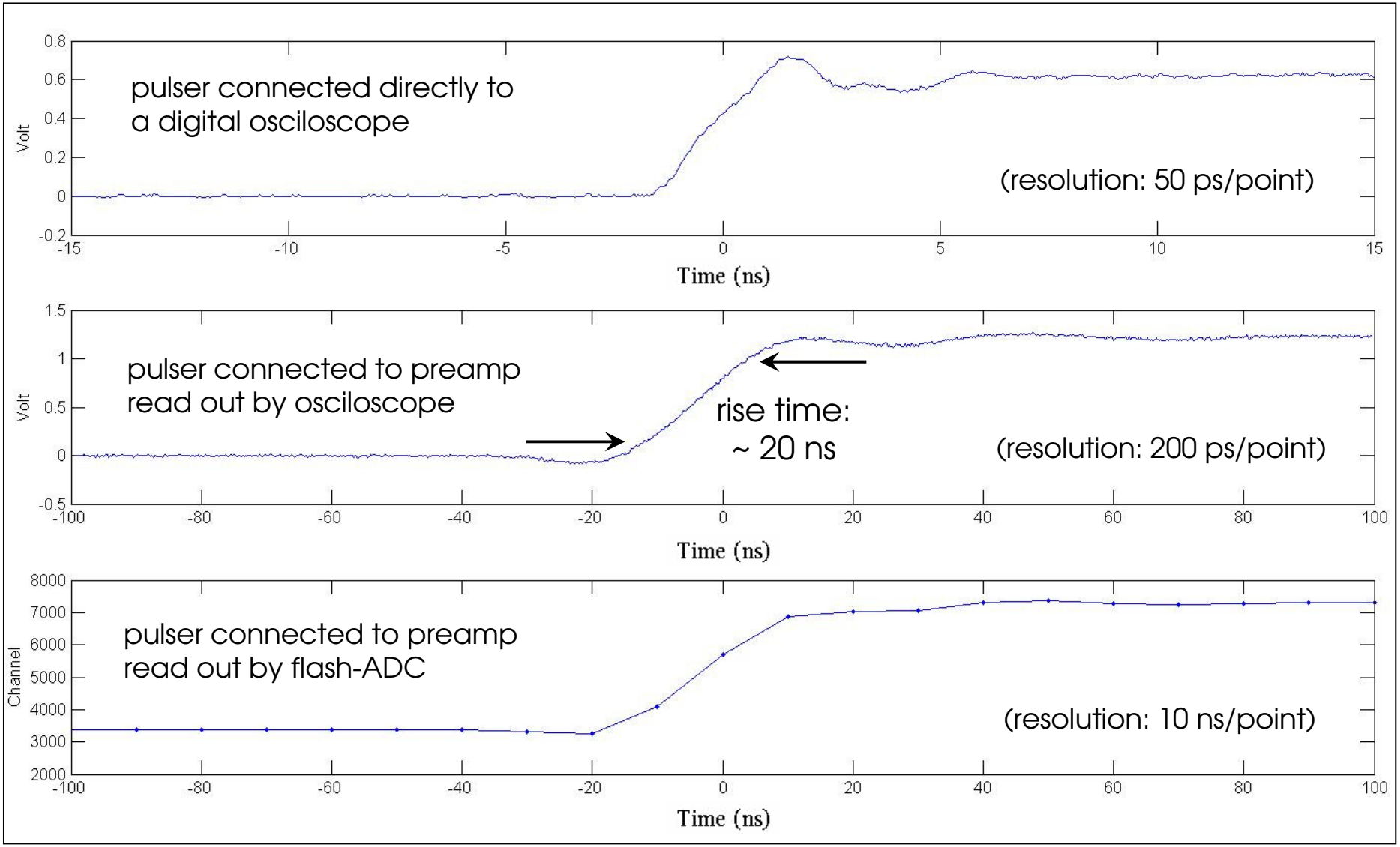
Pulser resolution:



Background spectrum

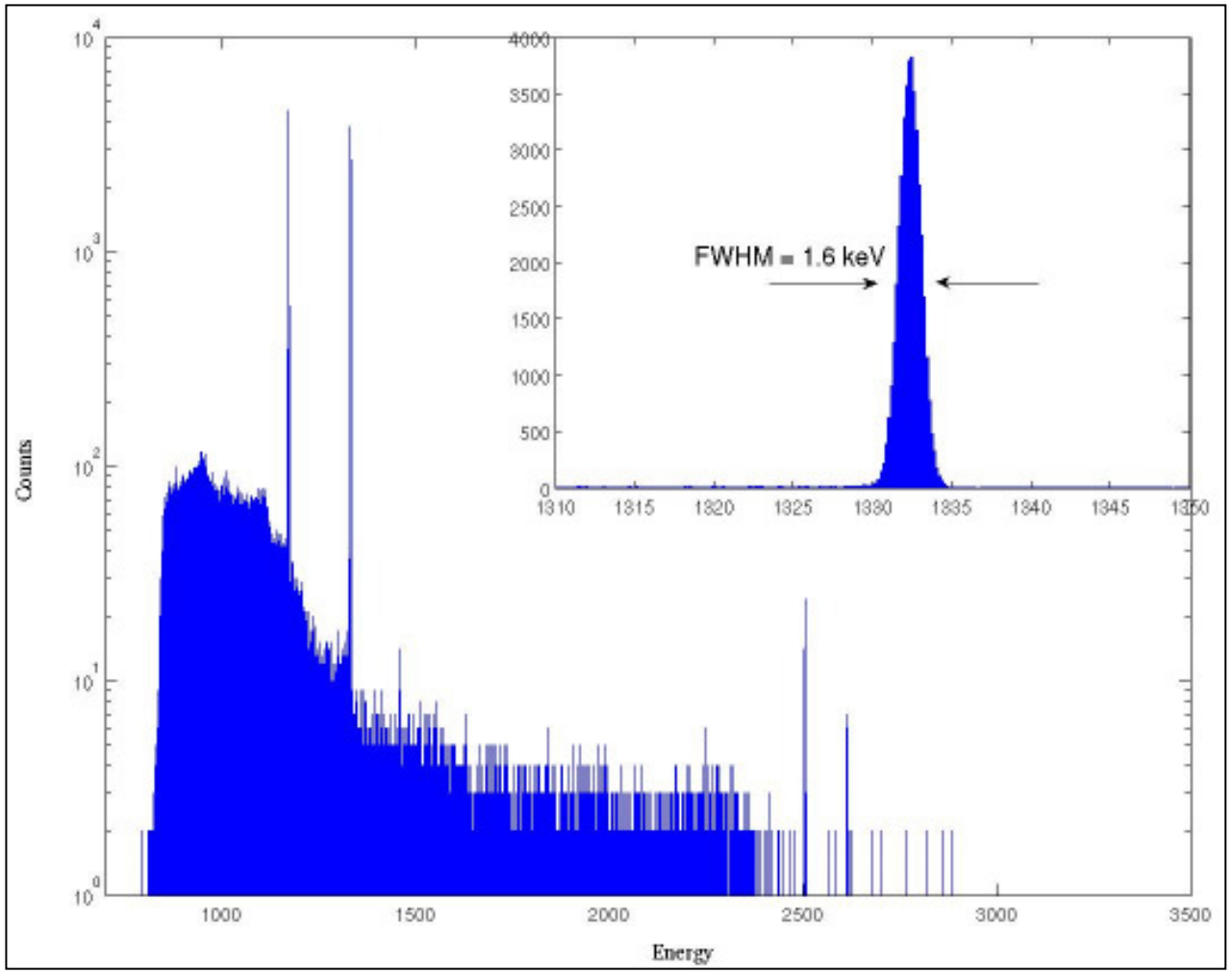


Preamplifier performance

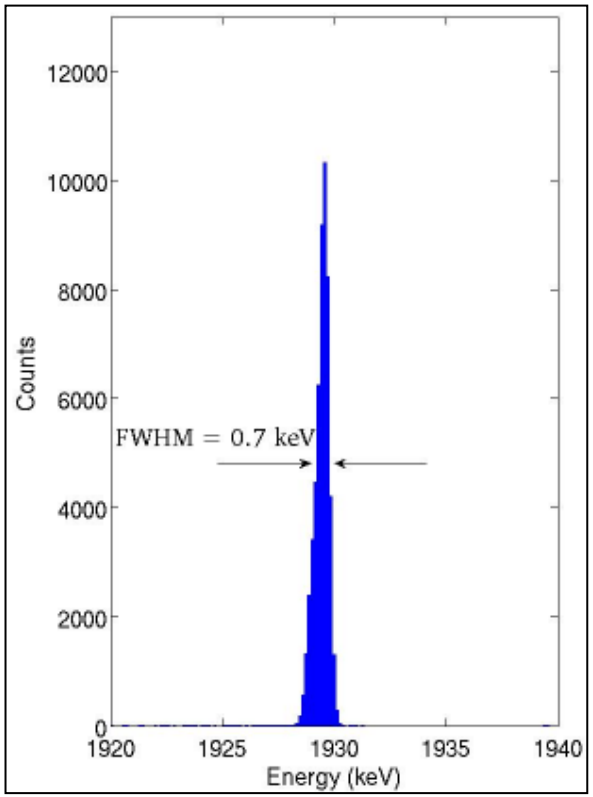


Performance with FADC

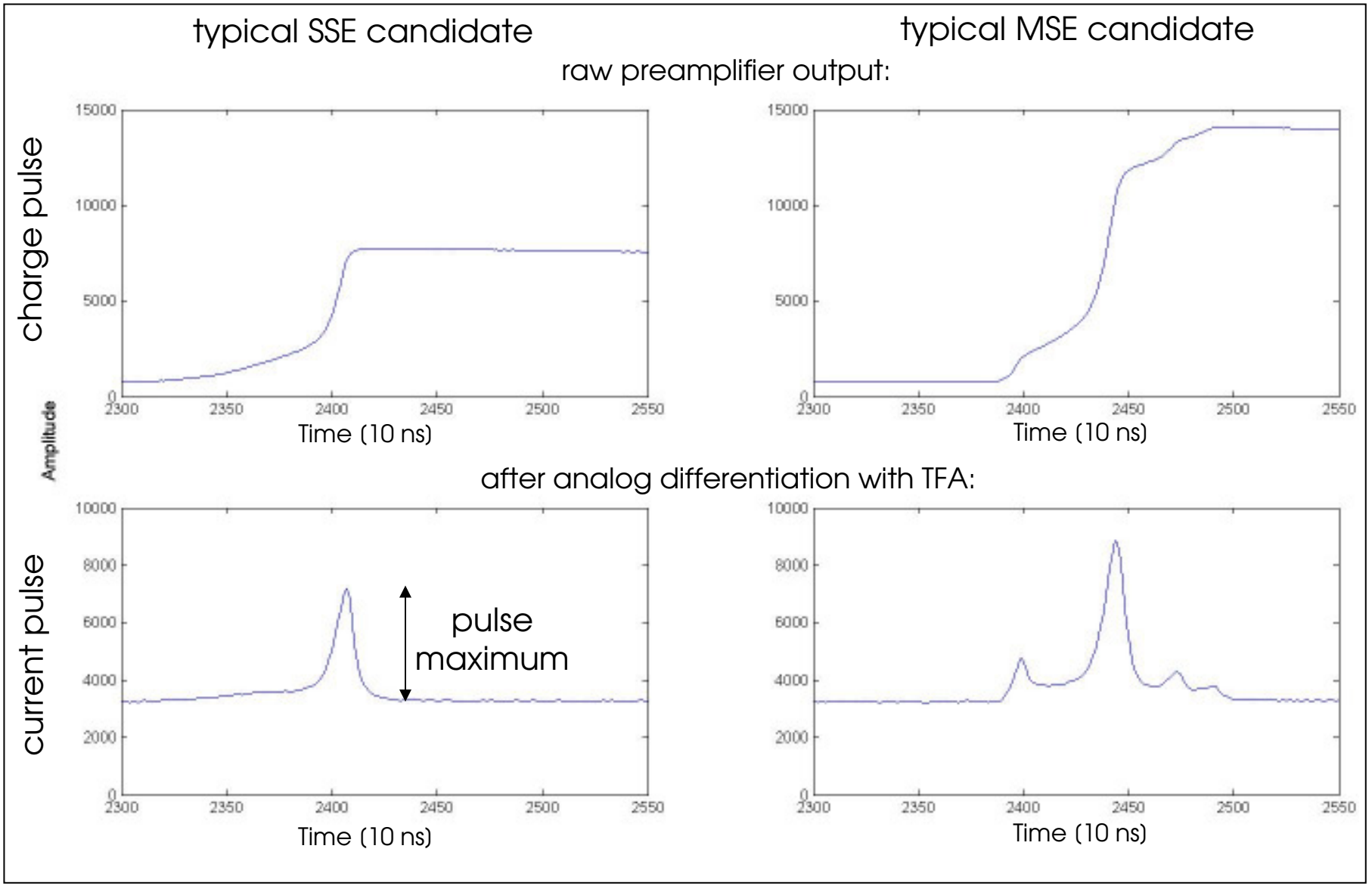
- Co-60 spectrum, shaping time = 10 μs (digital shaping)



Pulser resolution:



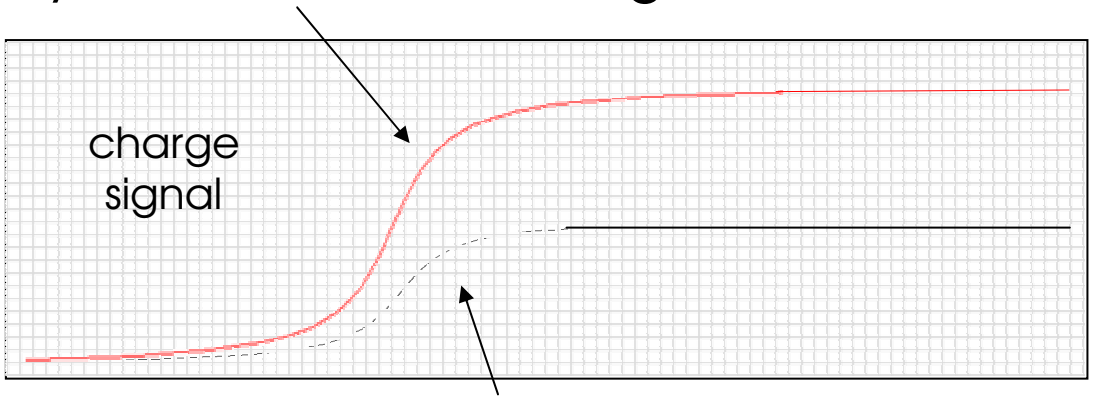
Pulse-shape analysis

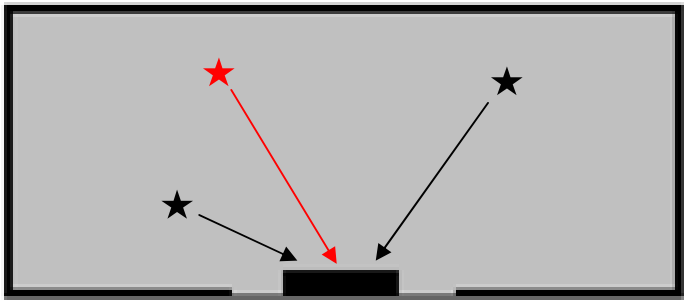


TFA parameters: 10 ns integration, 10 ns differentiation

Pulse-shape analysis

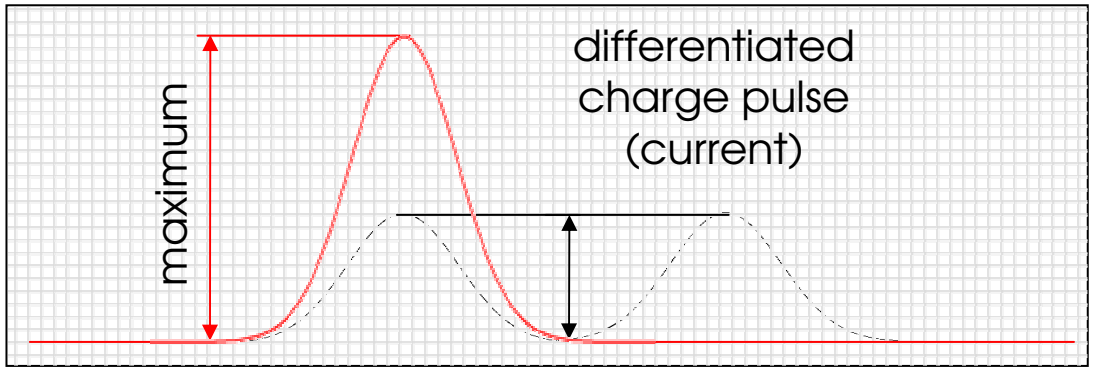
Single site event: signal generated by one cluster of charge carriers



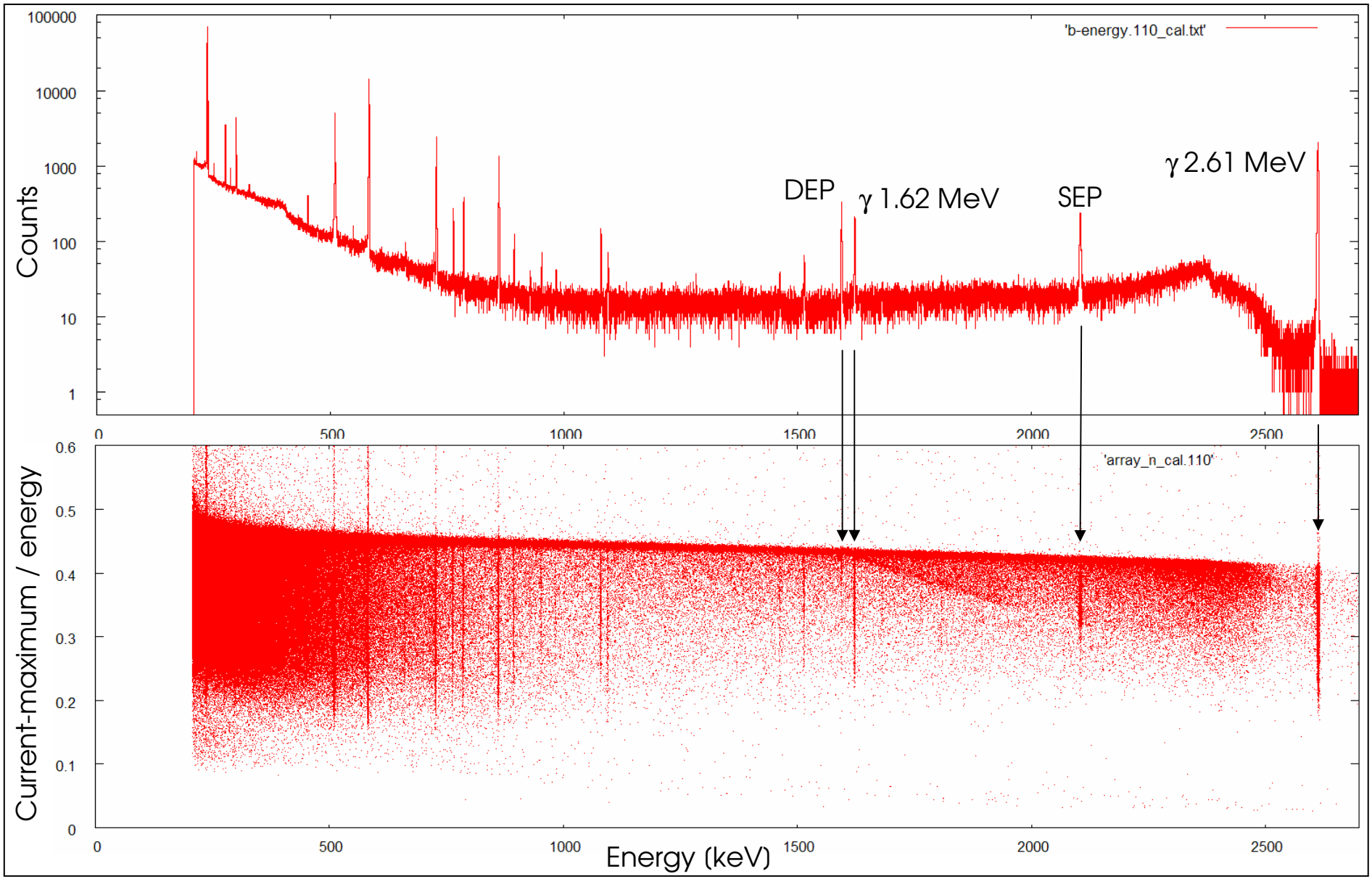


Smaller energy ⇒ less steep pulse (if risetime is constant)

Multiple site event = superposition of more smaller pulses

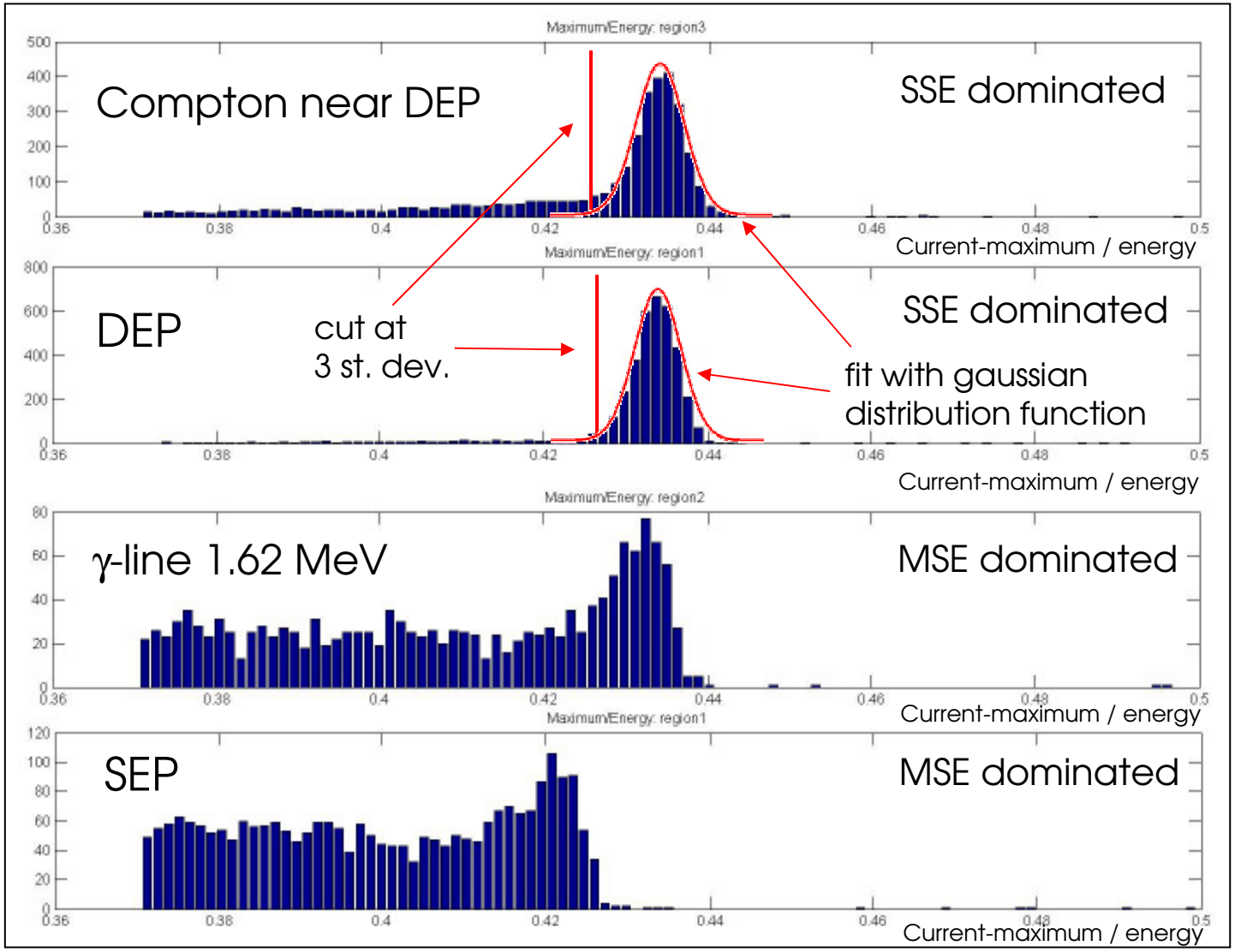


Current-maximum distribution

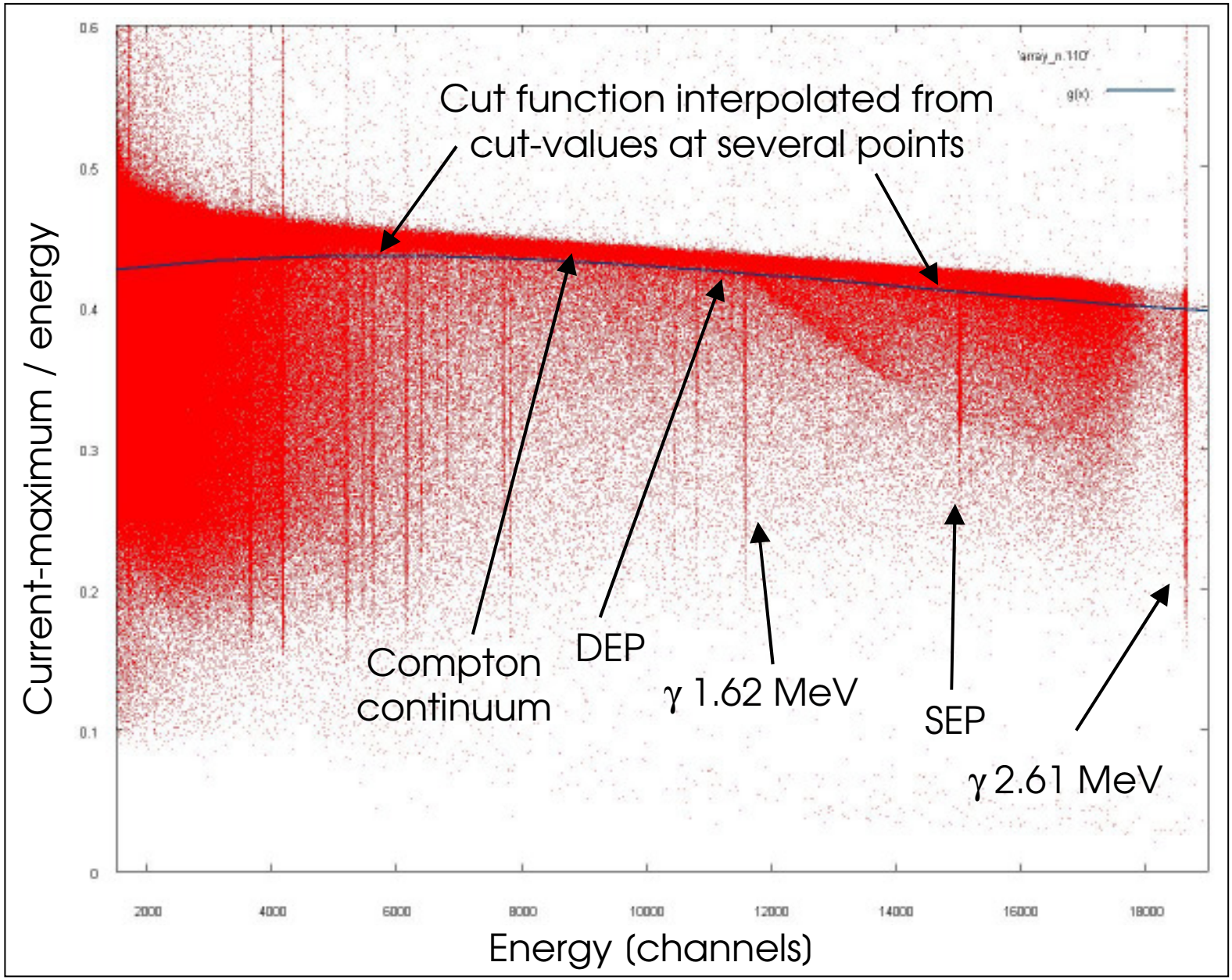


Current-maximum discrimination

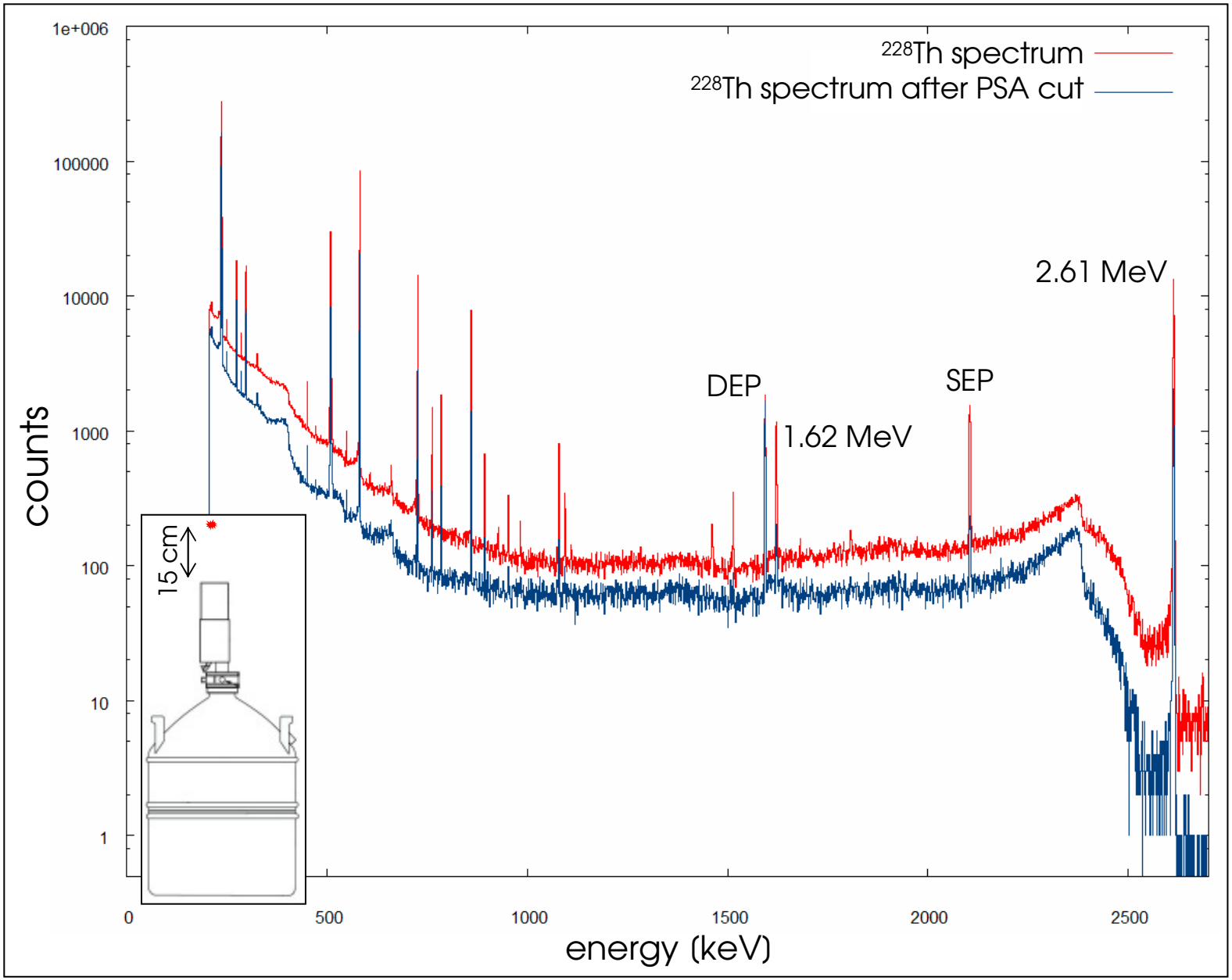
- cut-profile determination from SSE dominated regions:



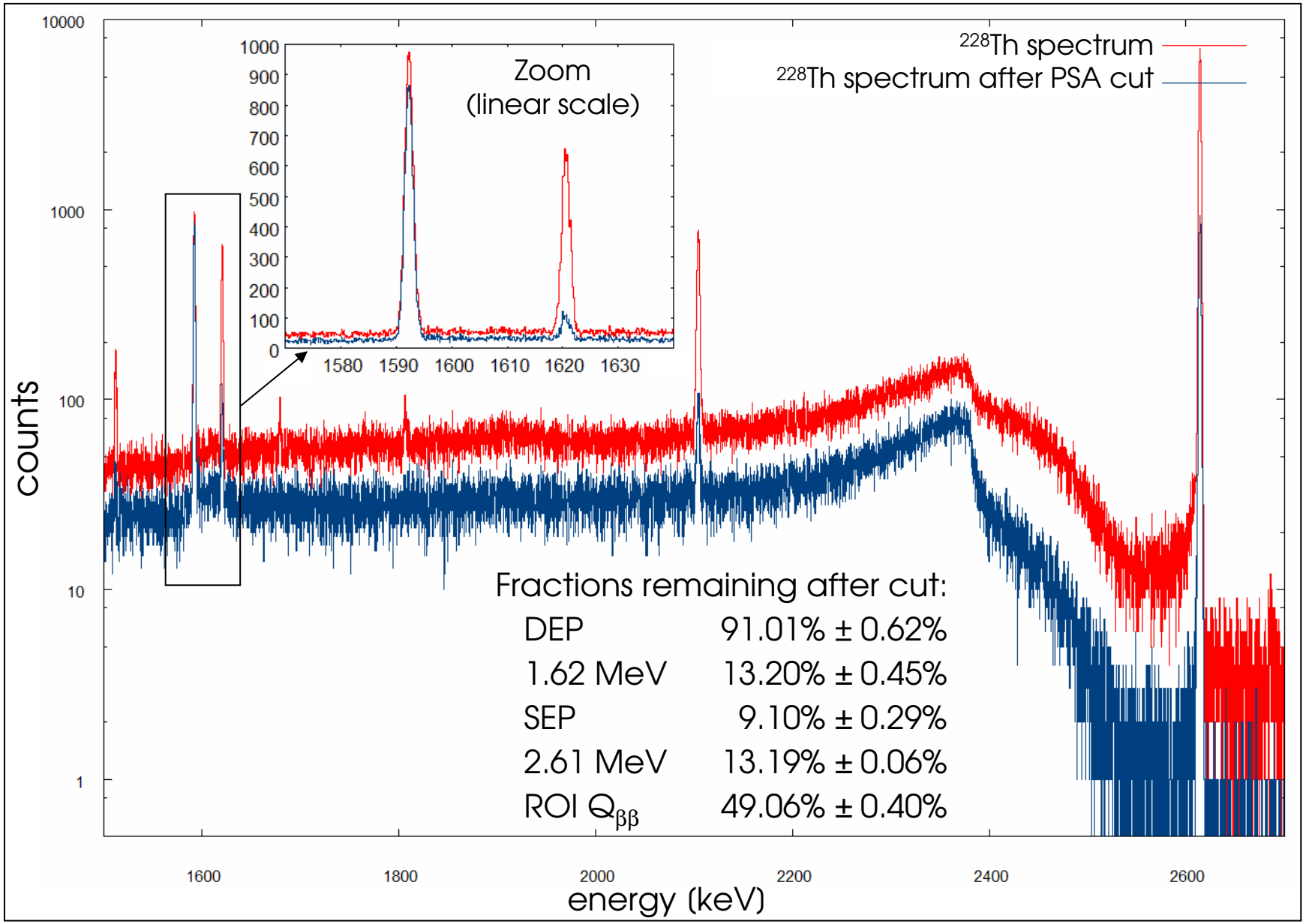
Current-maximum discrimination



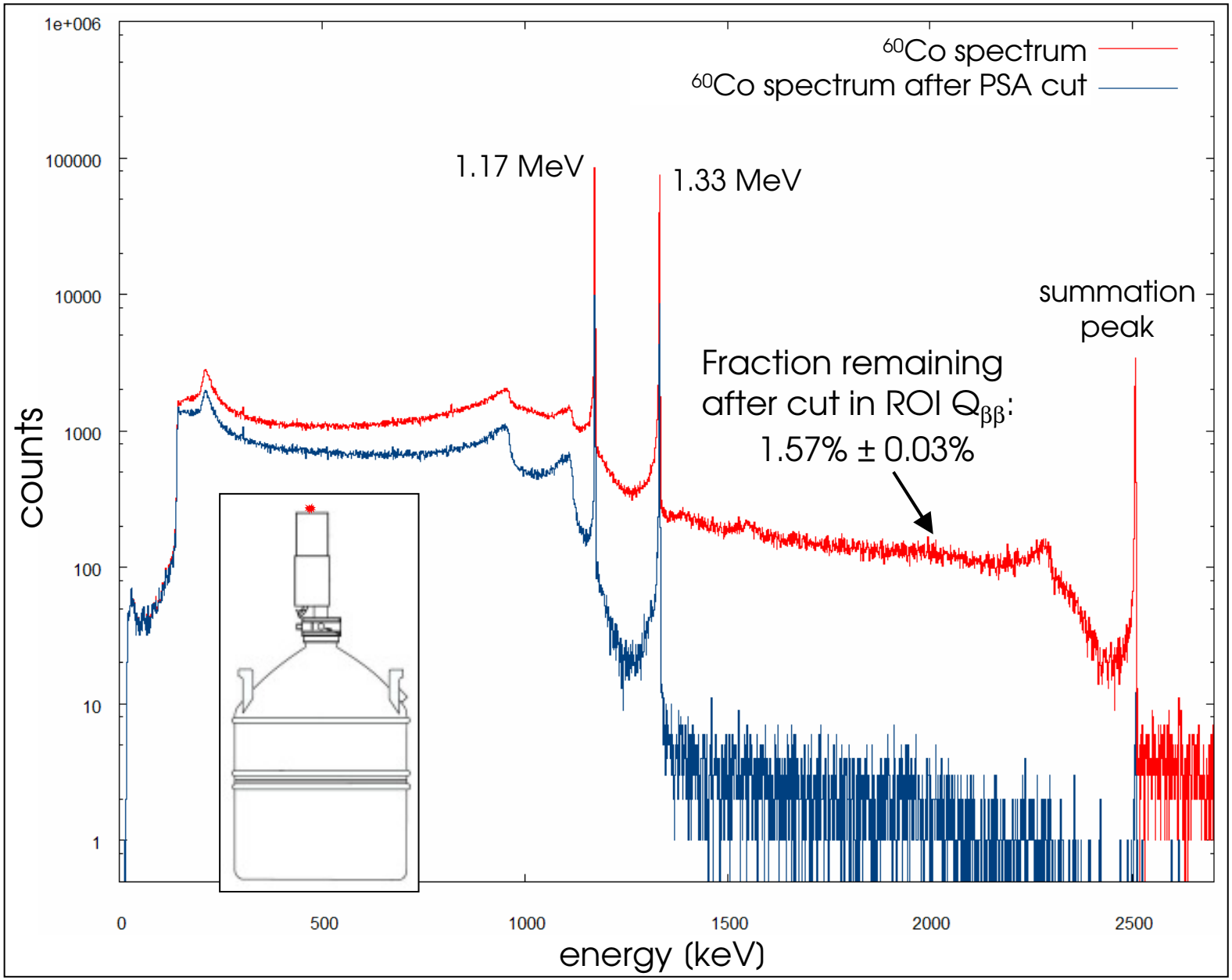
PSA discrimination results



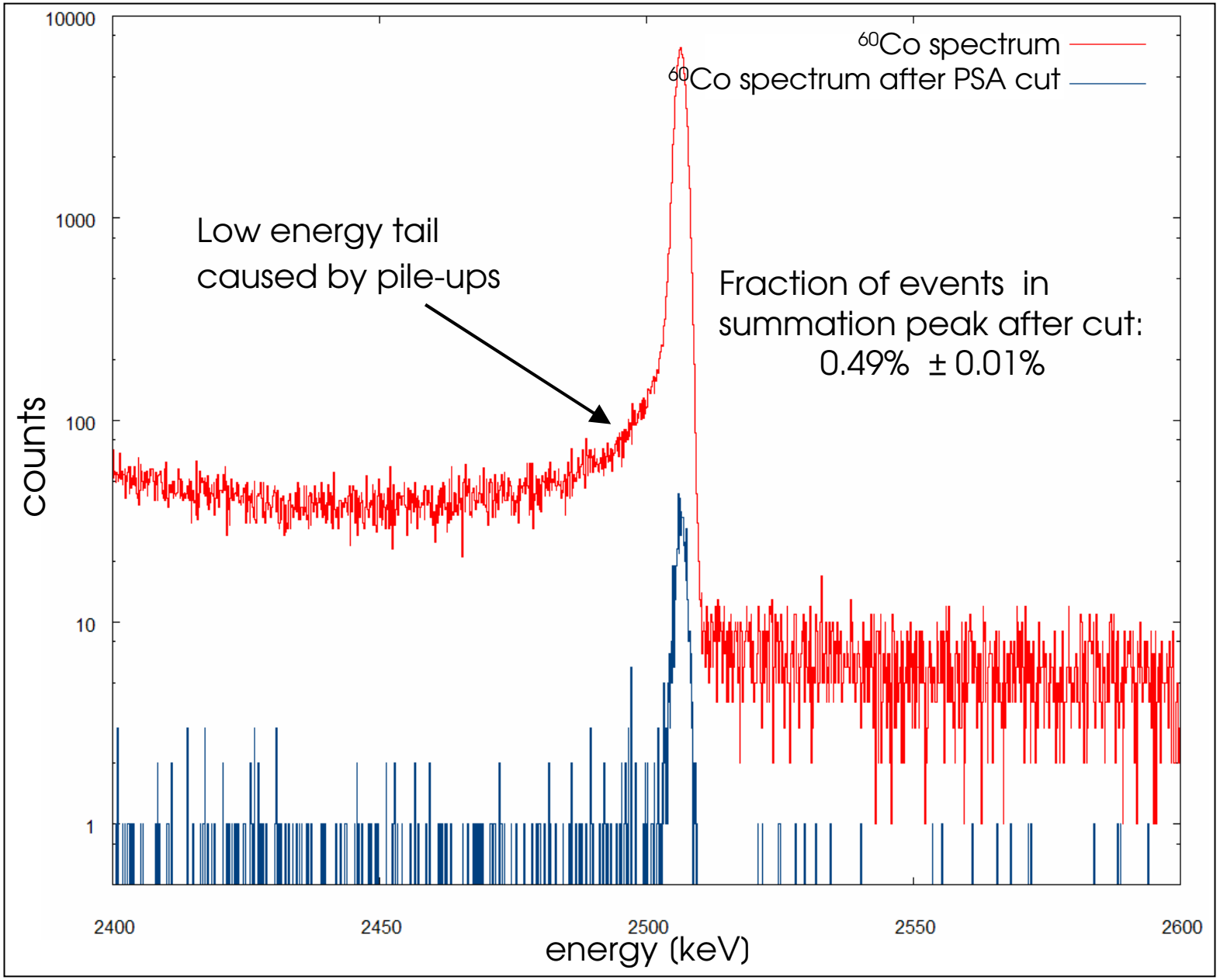
PSA discrimination results



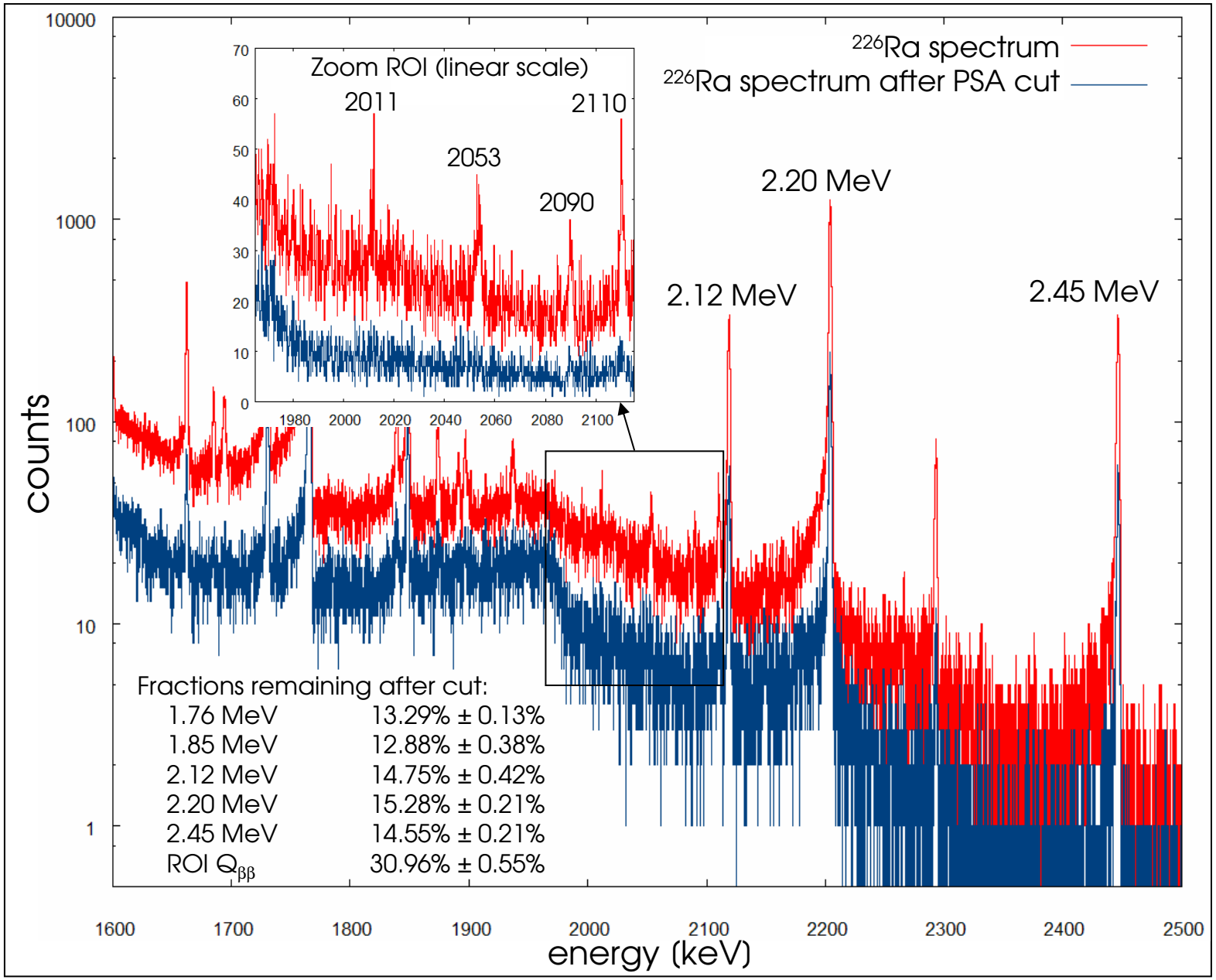
PSA discrimination results



PSA discrimination results



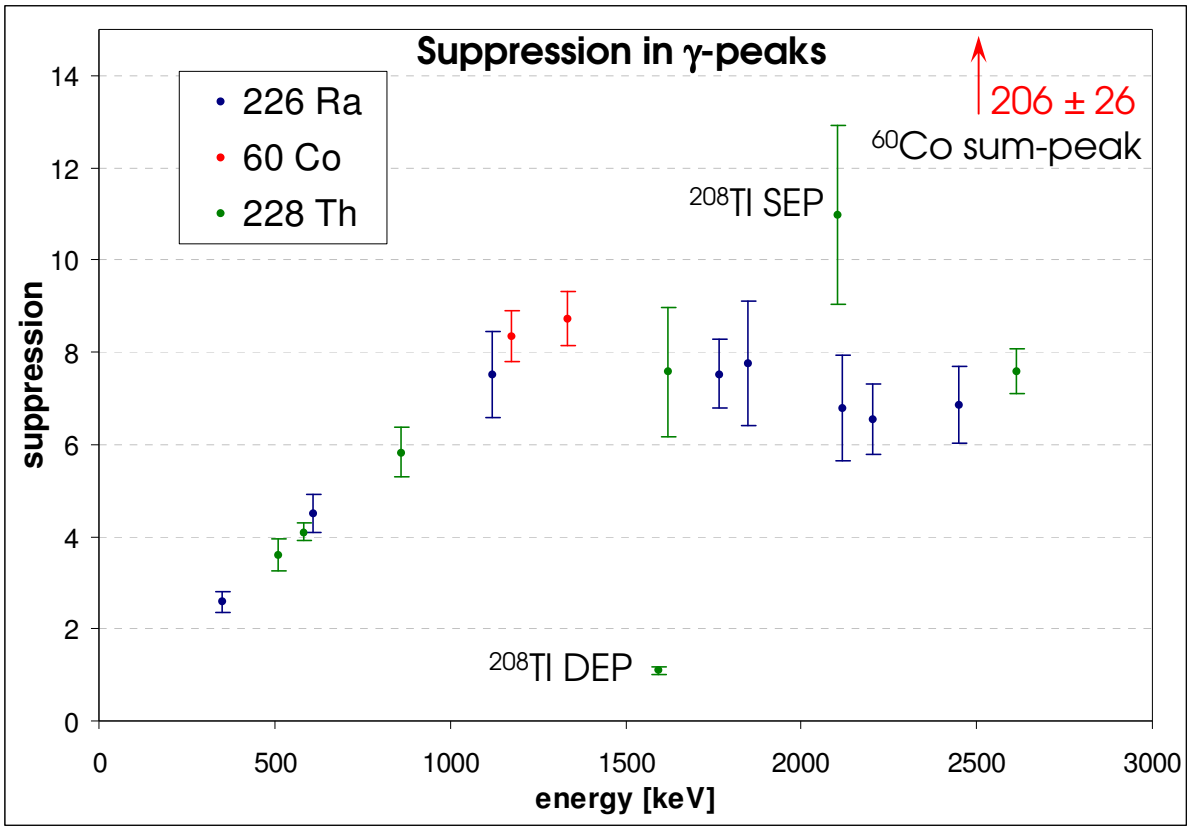
PSA discrimination results



PSA discrimination results

- results summary: suppression factors

$$\text{Suppression factor} = \frac{\text{counts before cut}}{\text{counts after cut}}$$

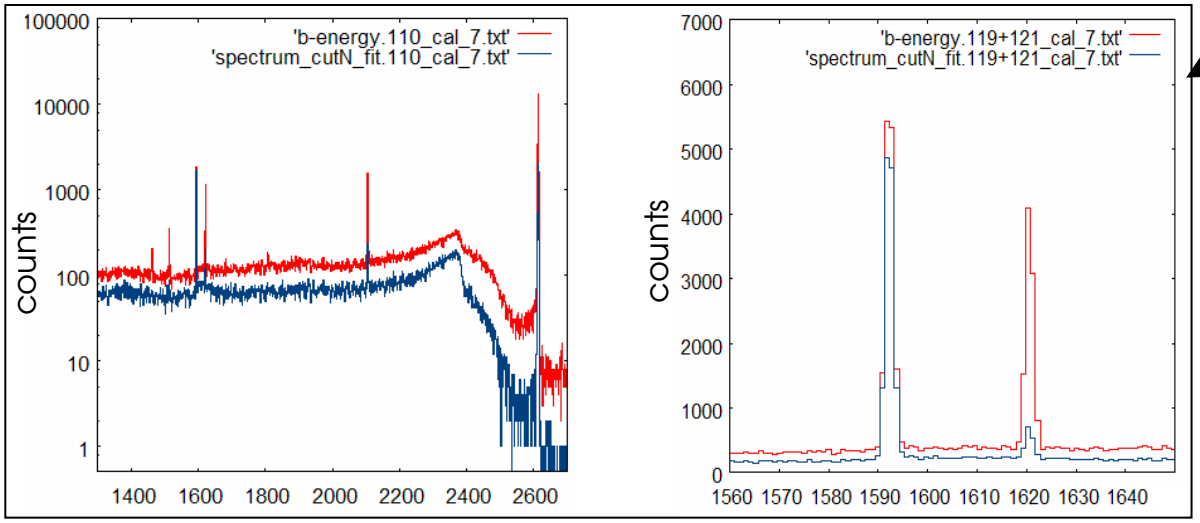


Suppression in ROI
2039 keV ± 56 keV:

^{228}Th	2.04 ± 0.18
^{226}Ra	3.23 ± 0.43
^{60}Co	63.6 ± 8.8

BEGe vs. 18-fold segmented coax

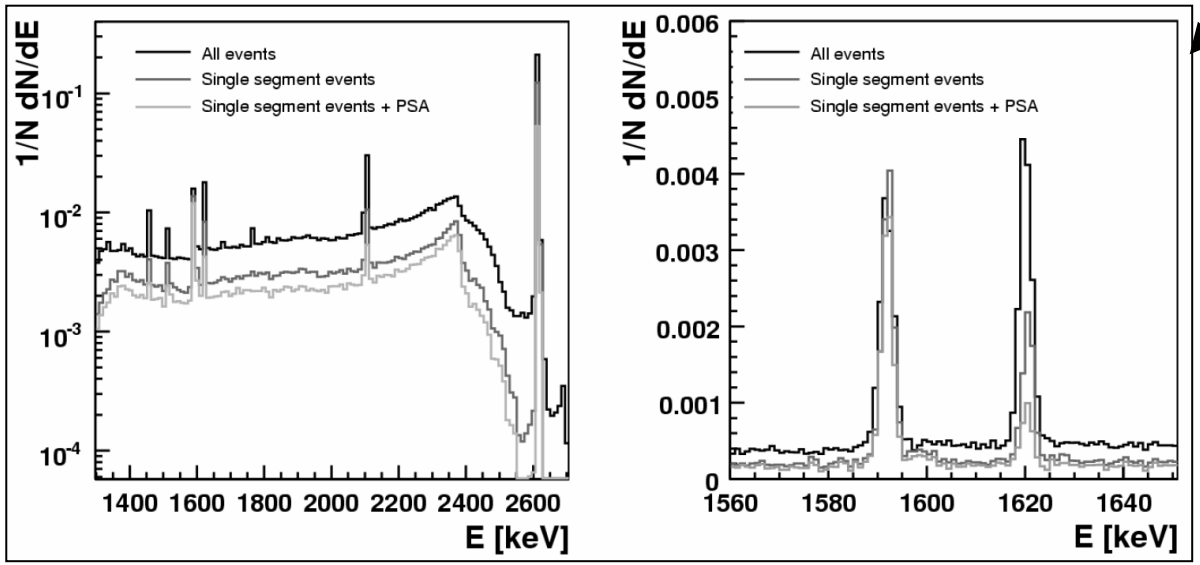
- comparison of discrimination power for ^{228}Th spectrum



BEGe point-contact

Fractions remaining after PSA cut:

DEP	91.01% ± 0.62%
1.62 MeV	13.20% ± 0.45%
2.61 MeV	13.19% ± 0.06%
ROI $Q_{\beta\beta}$	49.06% ± 0.40%



18-fold segmented coax

Fractions remaining after combined single-segment and PSA cut:

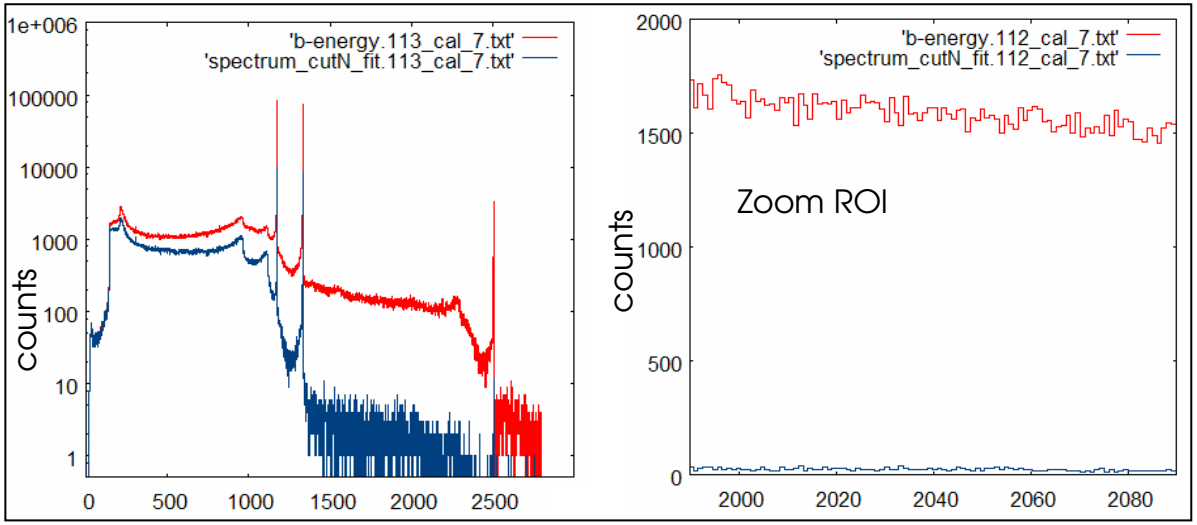
DEP	81.93% ± 2.22%
1.62 MeV	18.98% ± 0.39%
2.61 MeV	14.57% ± 0.31%
ROI $Q_{\beta\beta}$	48.10% ± 1.12%

(PSA data without Compton background subtraction)

I. Abt, A. Caldwell, K. Kroeninger, J. Liu, X. Liu, and B. Majorovits: Nucl. Instr. Methods A 583 (2007), Eur. J. Phys. C 52 (2007) 19-27,

BEGe vs. 18-fold segmented coax

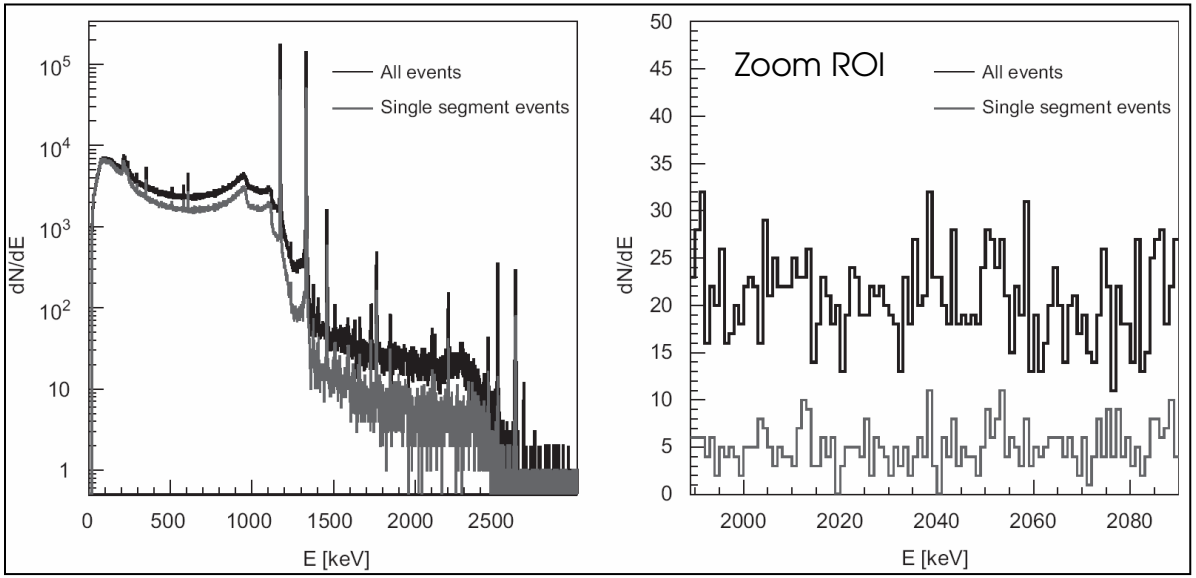
- comparison of discrimination power for ^{60}Co spectrum



← **BEGe point-contact**

Fractions remaining after PSA cut:

1.17 MeV	11.96% ± 0.05%
1.33 MeV	11.45% ± 0.05%
2.51 MeV	0.49% ± 0.01%
ROI $Q_{\beta\beta}$	1.57% ± 0.03%



← **18-fold segmented coax**

Fractions remaining after single-segment cut:

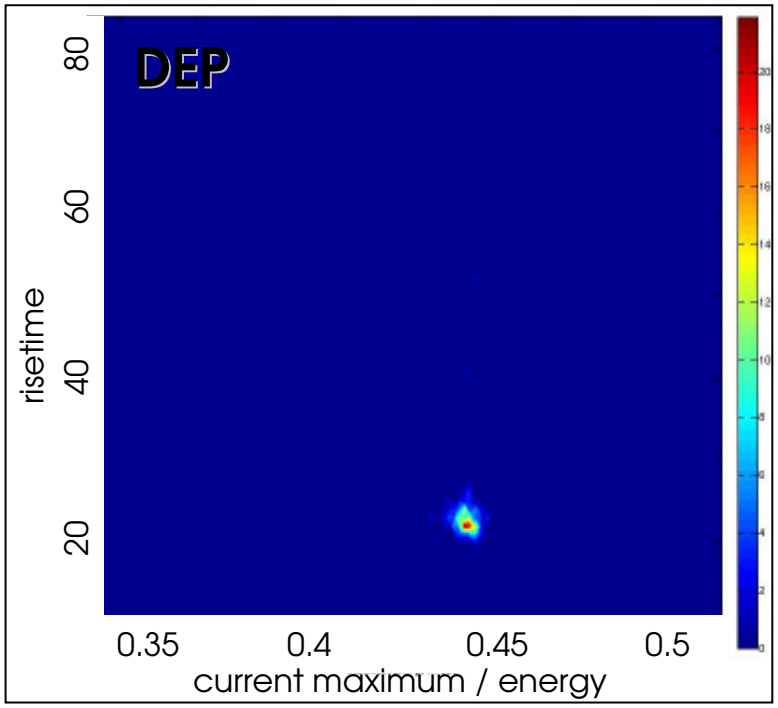
1.17 MeV	39.06% ± 0.15%
1.33 MeV	38.02% ± 0.14%
2.51 MeV	2.89% ± 0.48%
ROI $Q_{\beta\beta}$	7.04% ± 1.04%

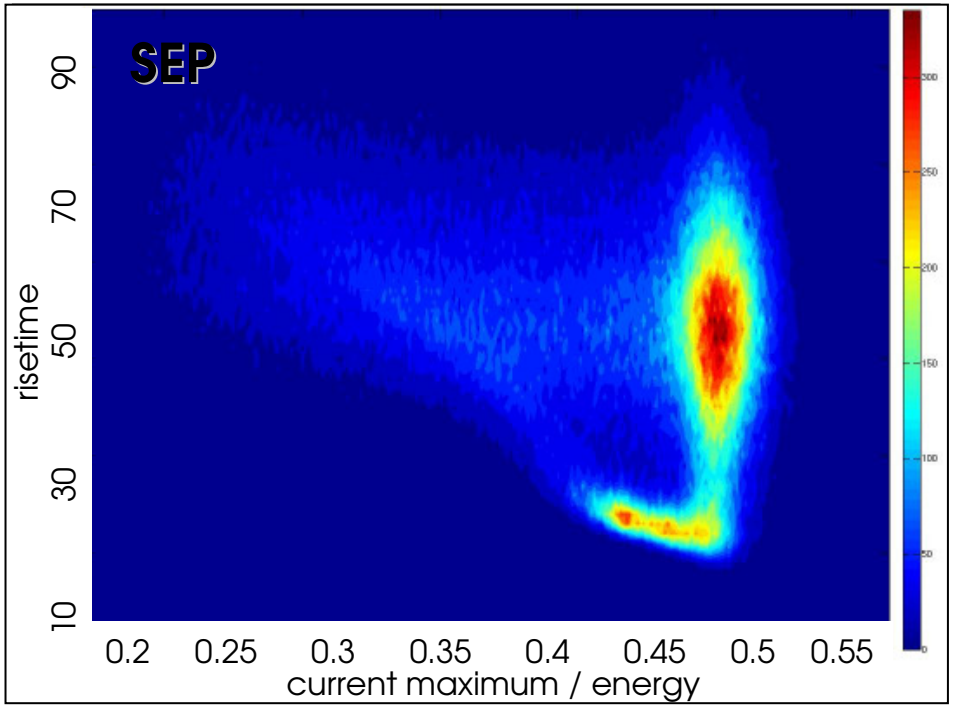
Note: no PSA cut applied!

I. Abt, A. Caldwell, K. Kroeninger, J. Liu, X. Liu, and B. Majorovits: Nucl. Instr. Methods A 583 (2007)

Summary / Outlook

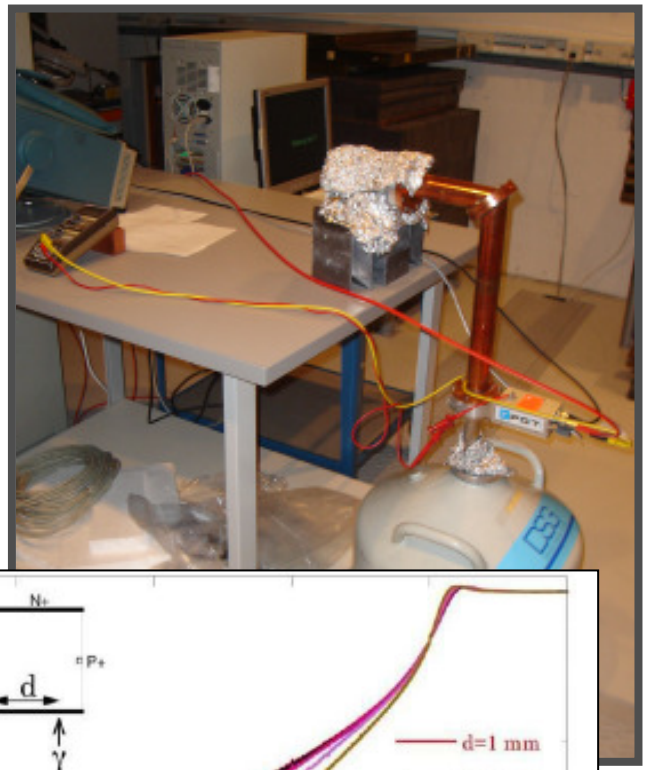
- SSE/MSE discrimination with BEGe comparable to 18-fold segmented detector
- only first PS analysis performed based on a simple cut parameter, other PS parameters under study
  ⇒ room for improvement!

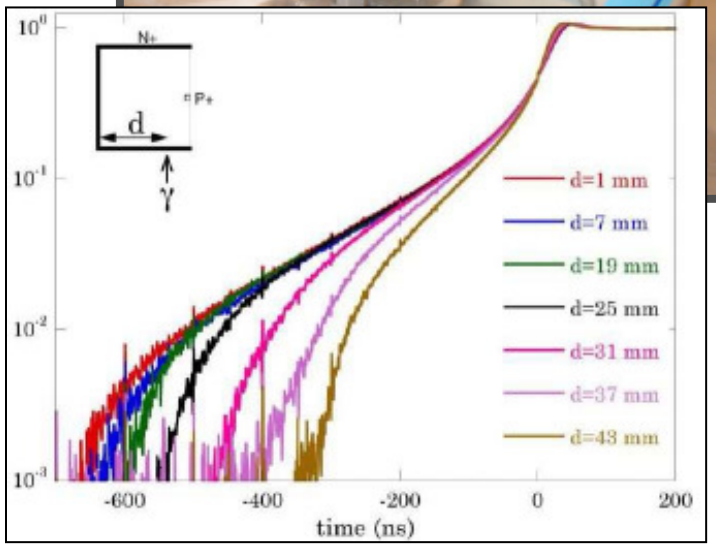




Outlook (continued)

- Single compton-scattering measurements using coincidence with another HPGe detector (Dario)
- Collimator-scan of the Ge crystal to investigate pulse-shape dependance on interaction-position
- PSA efficiency dependance on HV (influence on charge-carrier mobility)

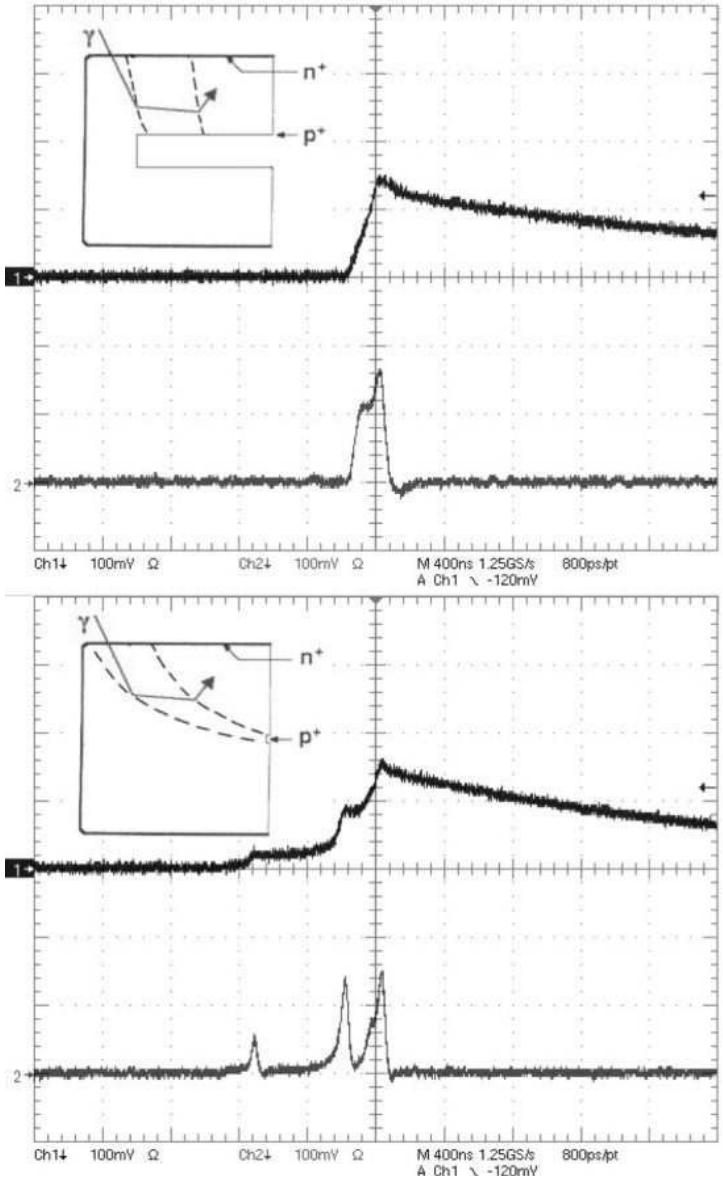


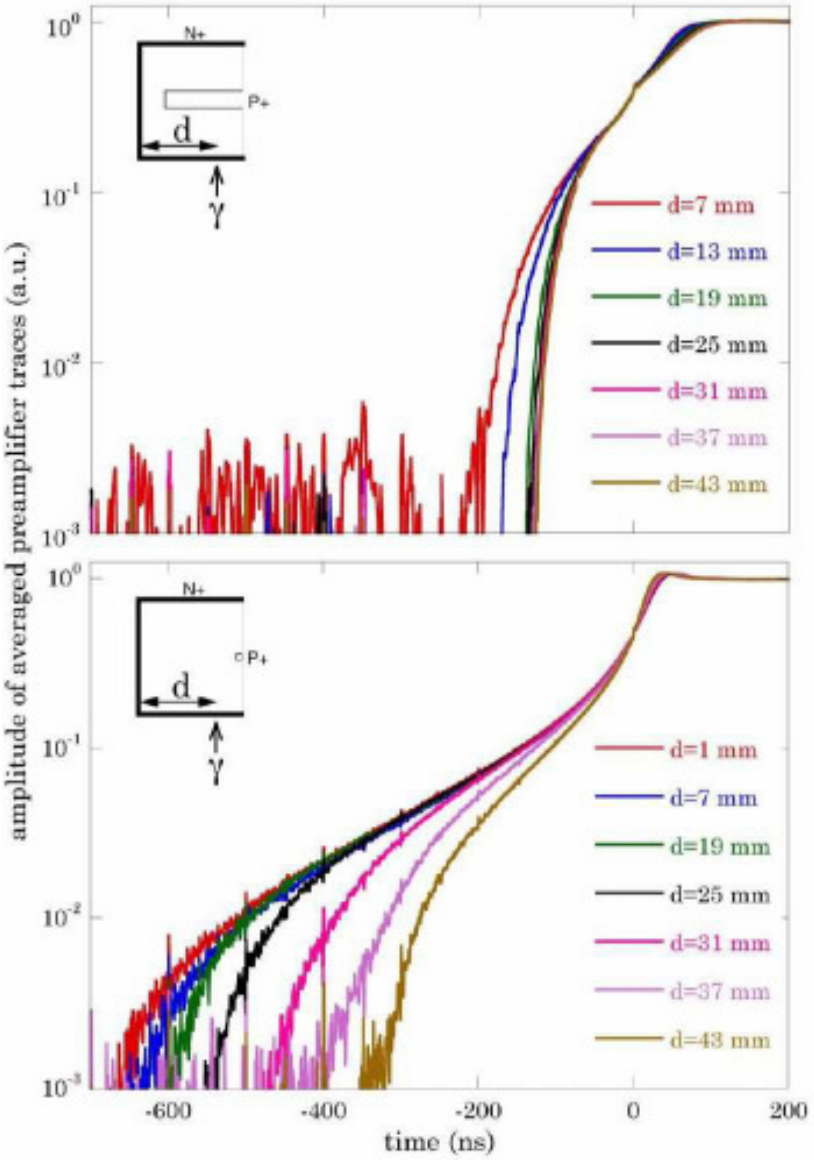


P. S. Barbeau, J. I. Collar, O. Tench arXiv:nucl-ex/0701012v1

Backup slides

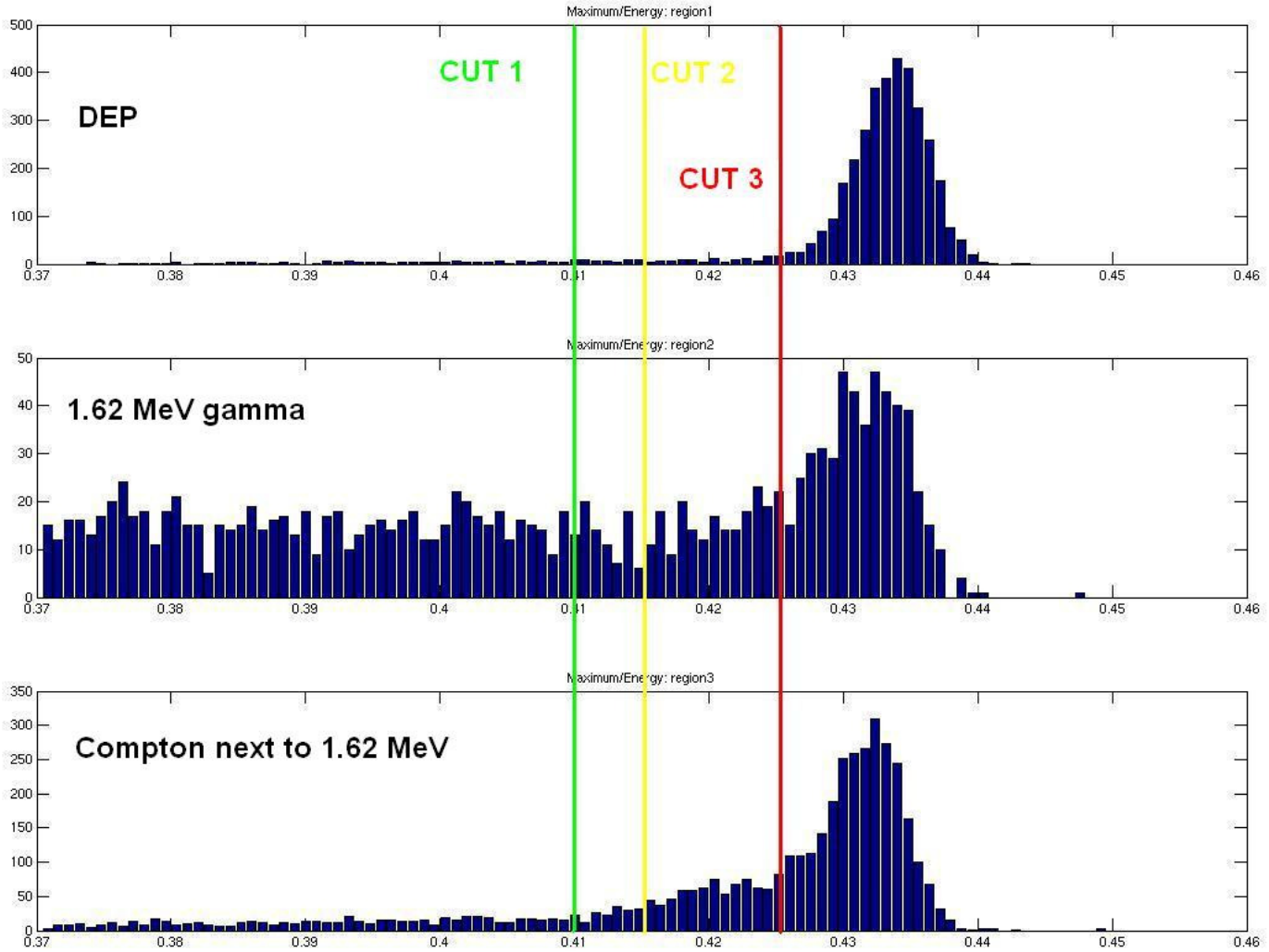
Coax vs. ppc pulse-shapes



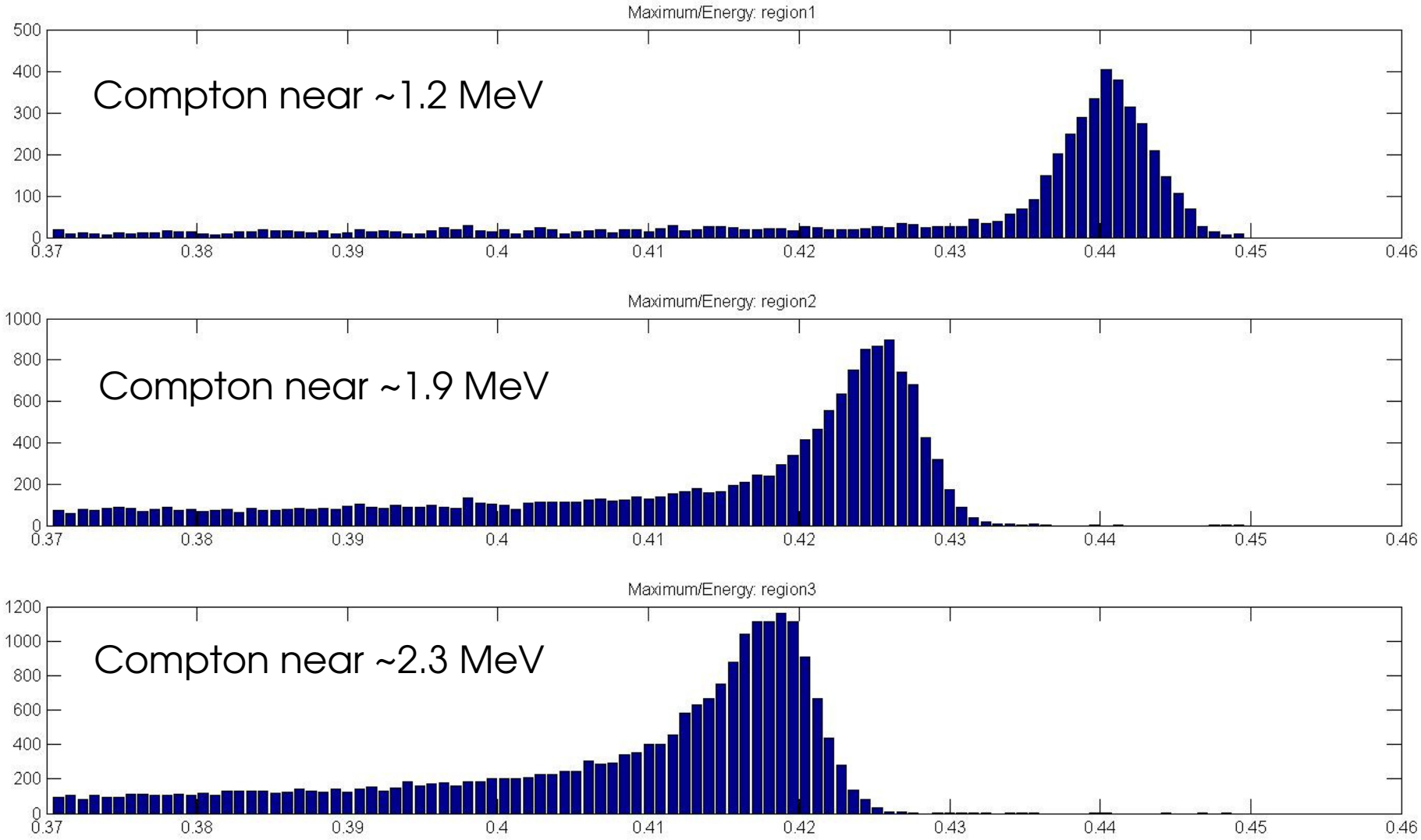


P. S. Barbeau, J. I. Collar, O. Tench arXiv:nucl-ex/0701012v1

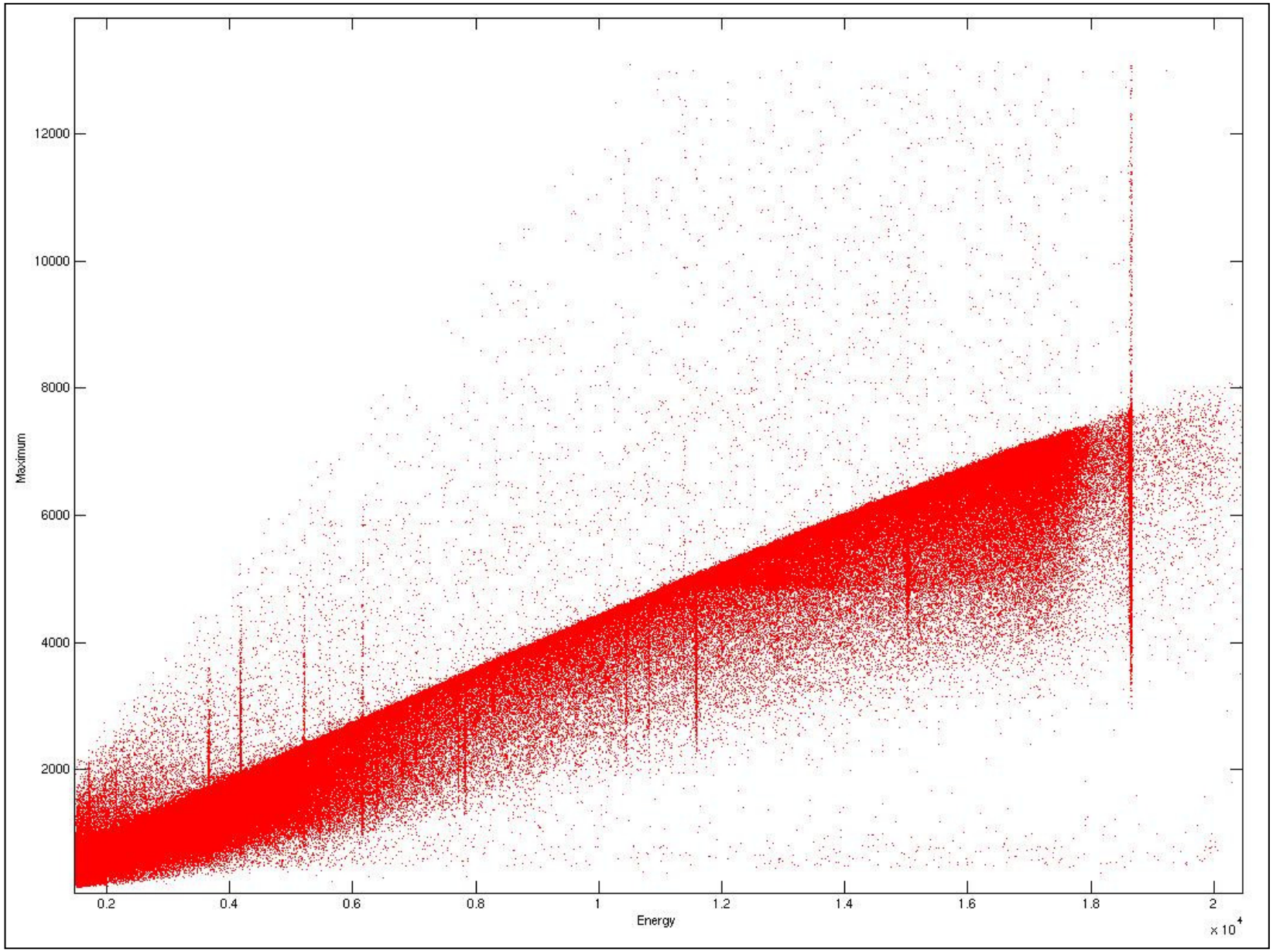
^{228}Th current-maximum distribution histograms



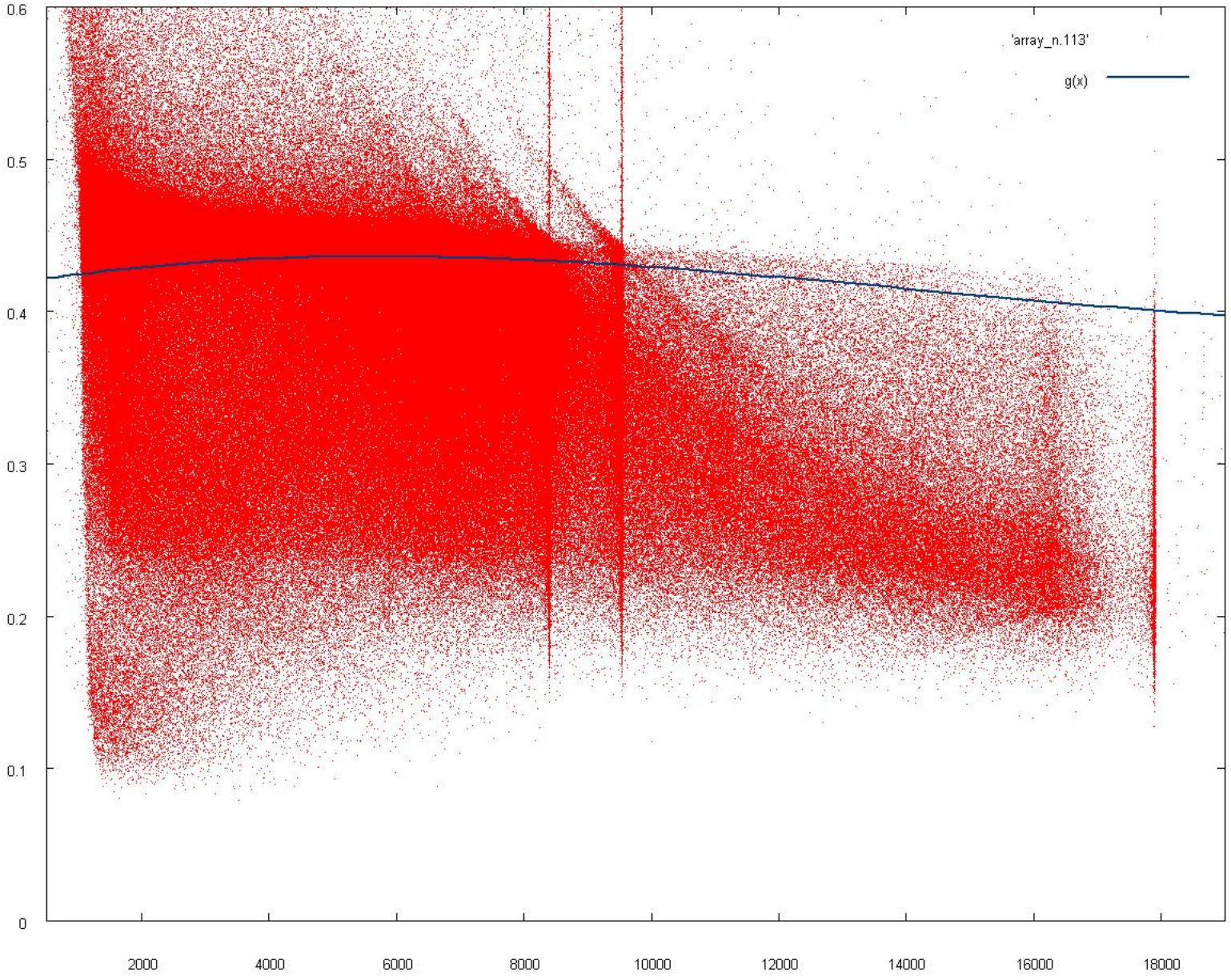
^{228}Th current-maximum distribution histograms



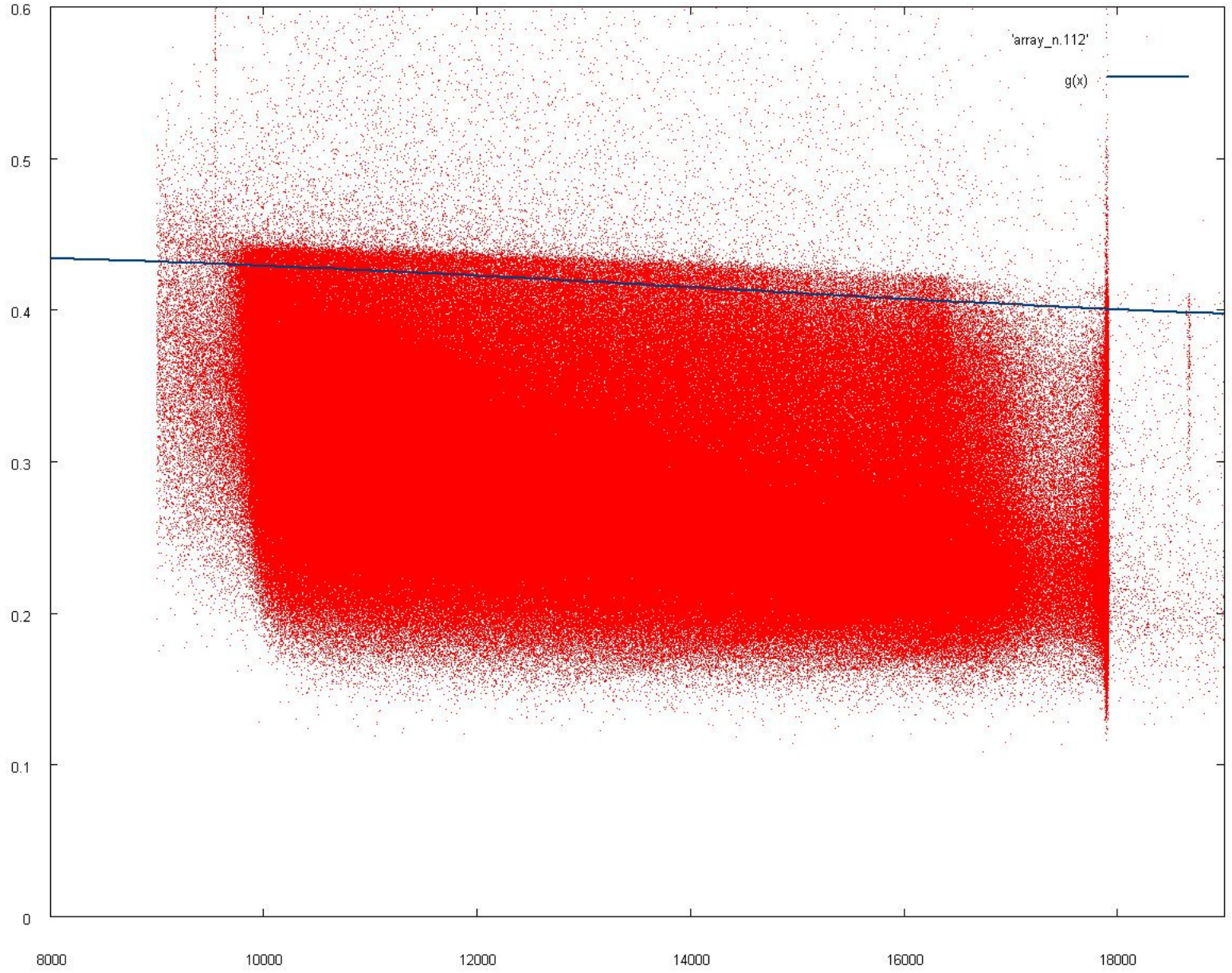
^{228}Th current-maximum distribution (unnormalised)



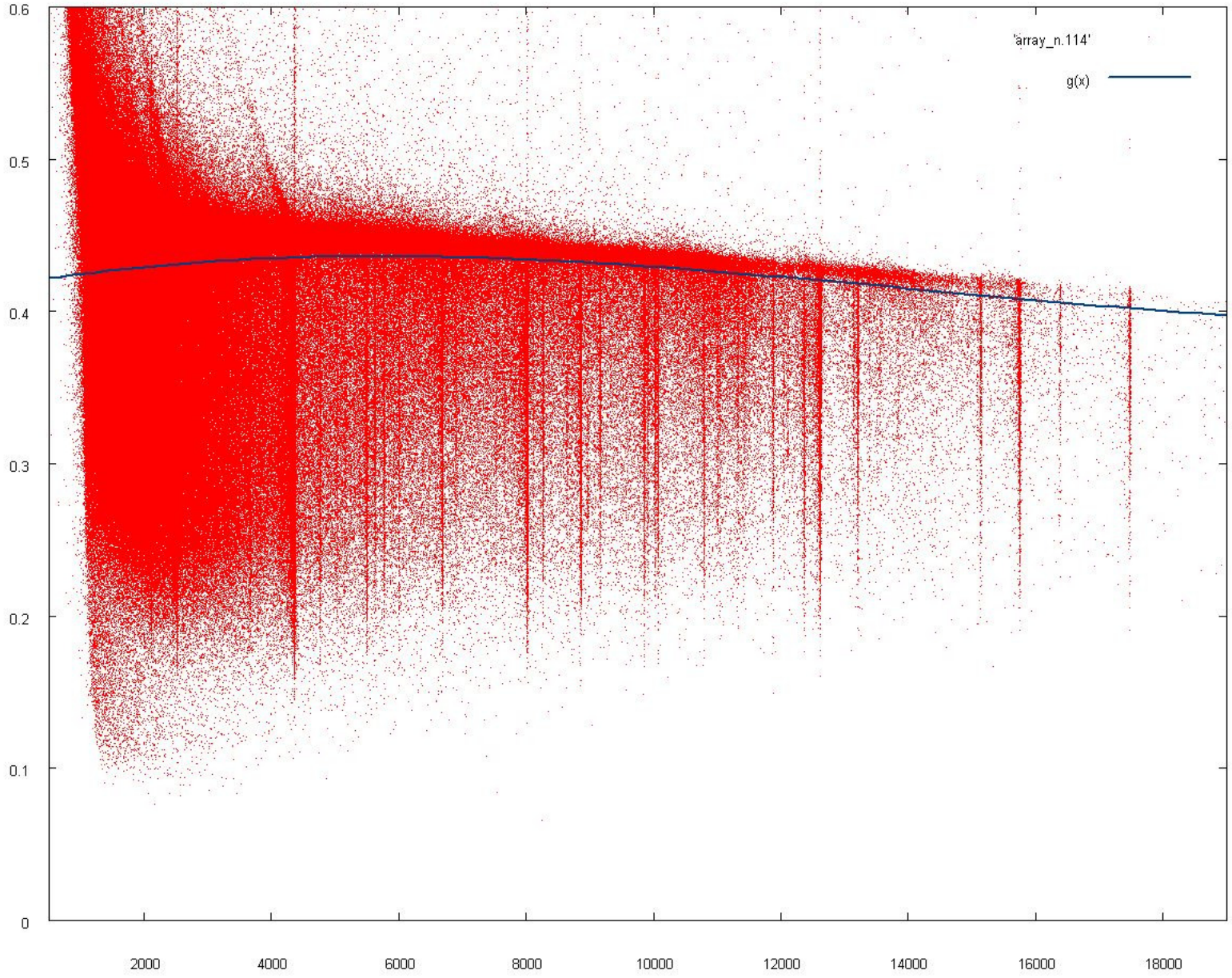
^{60}Co current-maximum distribution with cut



^{60}Co current-maximum distribution with cut (zoom)



^{226}Ra current-maximum distribution with cut



^{226}Ra spectrum with cut

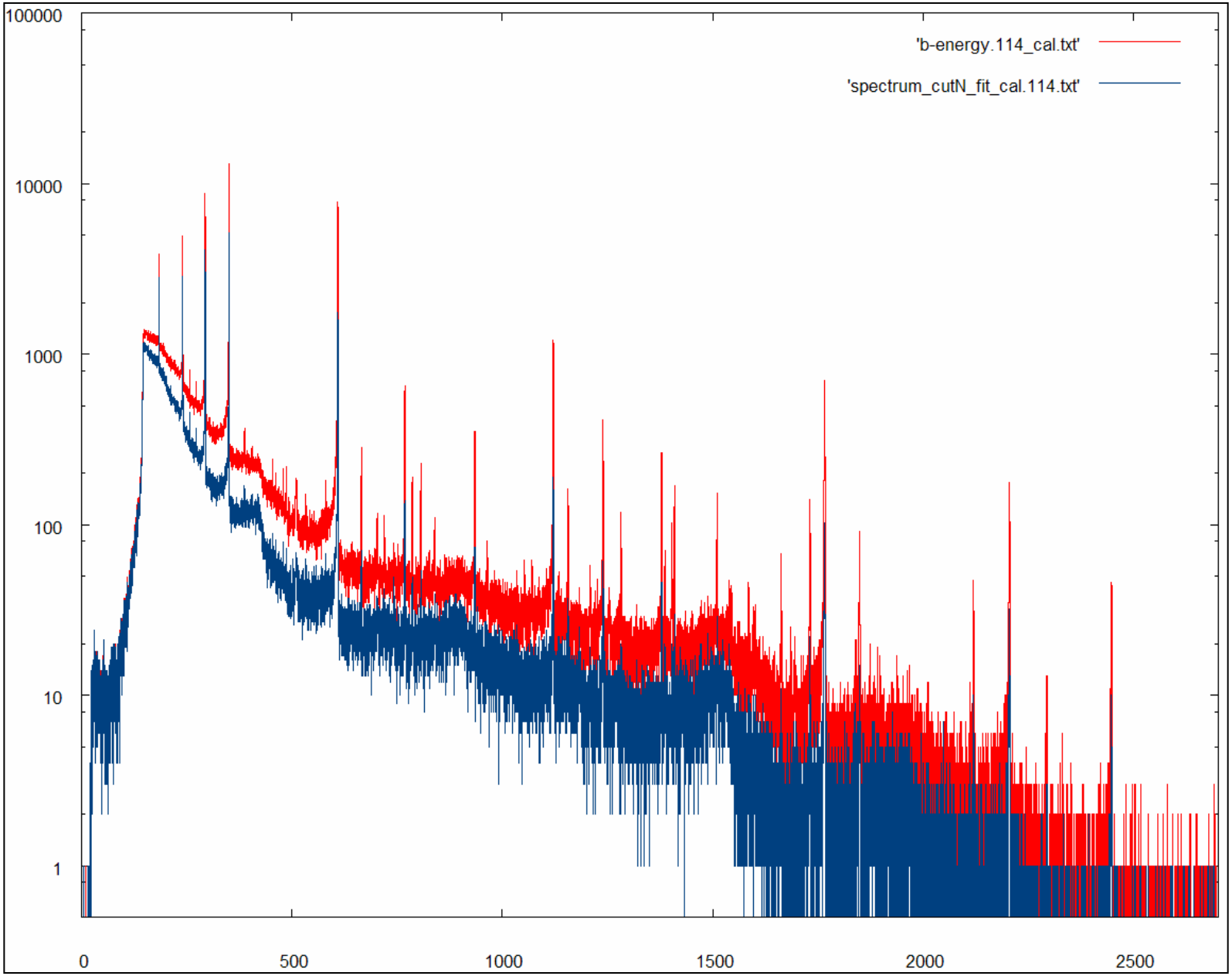


Table of results

	E (keV)	reduction	±	bck. red.	±	suppresion	±
^{226}Ra	351.9	38.74%	0.33%	46.68%	1.29%	2.58	0.24
	609.3	22.20%	0.18%	35.80%	1.81%	4.51	0.41
	1120.3	13.29%	0.20%	35.91%	1.23%	7.52	0.93
	1764.5	13.29%	0.13%	25.91%	1.51%	7.52	0.74
	1847.4	12.88%	0.39%	43.92%	1.65%	7.76	1.35
	2118.6	14.75%	0.42%	33.27%	1.51%	6.78	1.14
	2204.2	15.28%	0.21%	28.86%	1.99%	6.54	0.77
	2447.9	14.55%	0.21%	18.25%	2.27%	6.87	0.83
^{60}Co	1173.2	11.96%	0.05%	12.97%	0.59%	8.36	0.55
	1332.5	11.45%	0.05%	7.76%	0.80%	8.74	0.58
	2505.7	0.49%	0.01%	0.57%	0.15%	205.74	26.48
^{228}Th	510.77	27.64%	0.25%	41.84%	1.23%	3.62	0.34
	583.19	24.41%	0.06%	39.43%	1.63%	4.10	0.20
	860.56	17.14%	0.15%	50.19%	1.14%	5.84	0.54
	1592.5	91.01%	0.62%	58.30%	1.34%	1.10	0.09
	1620.5	13.20%	0.45%	56.42%	0.90%	7.57	1.40
	2103.5	9.10%	0.29%	46.86%	0.61%	10.99	1.94
	2614.5	13.19%	0.06%	8.97%	3.51%	7.58	0.49