New measurements with the BEGe detector

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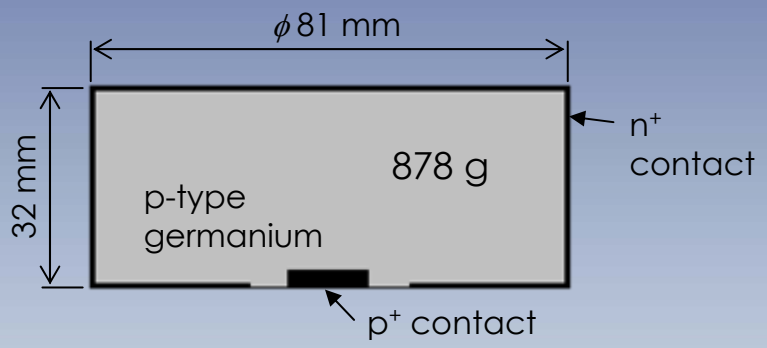
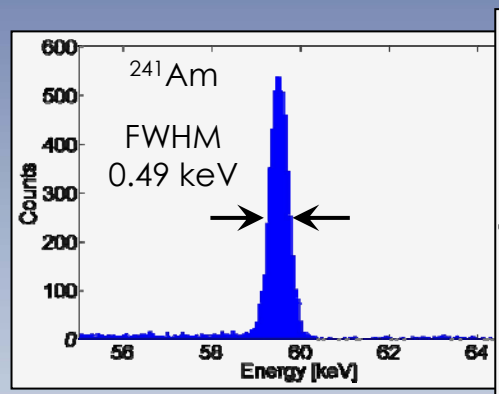
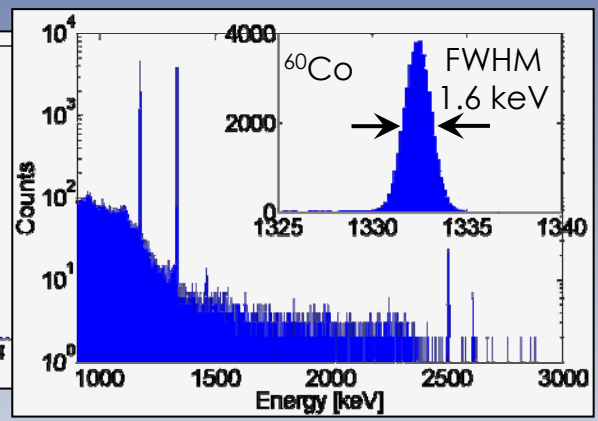
*** also: ITEP • Moscow**

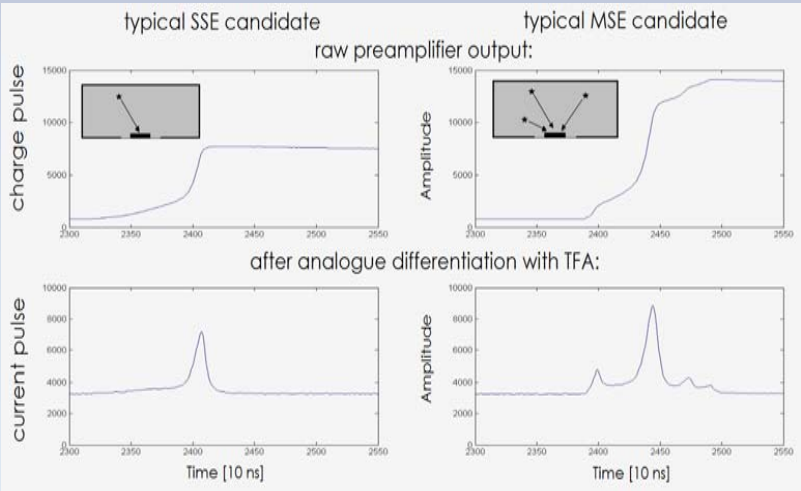
BEGe: promising new detector for 0νββ search

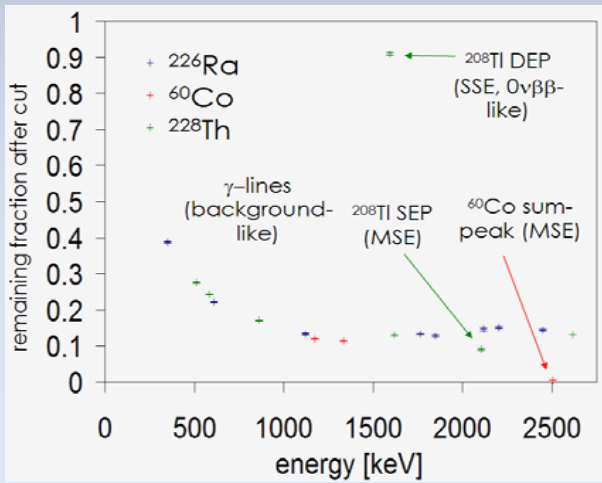
- studied at MPIK since April, motivaded by **Majorana p-pc**
- very good PSA perfomance, minimal amount of signal contacts (potential background), excelent energy resolution, o(kg) mass
  ⇒ ideal for ultra-low background experiments

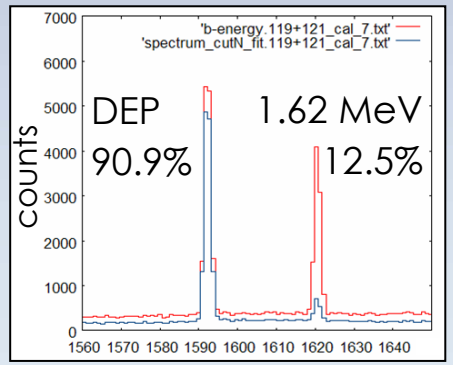












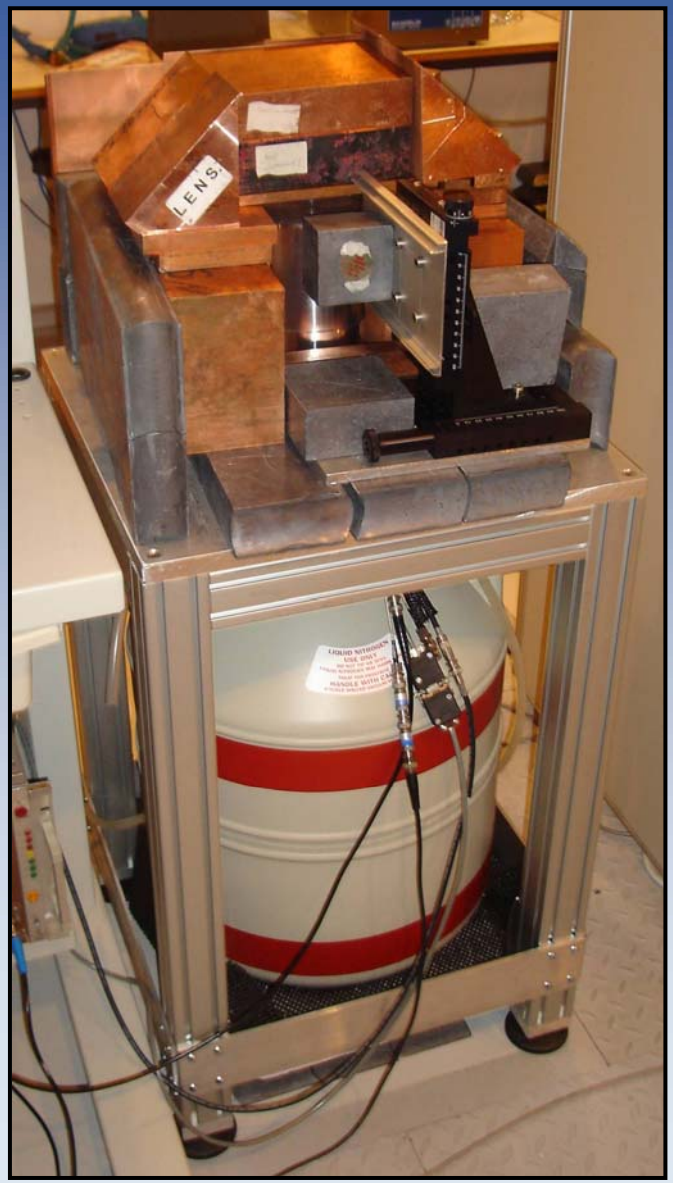
Questions remaining after June GERDA meeting:

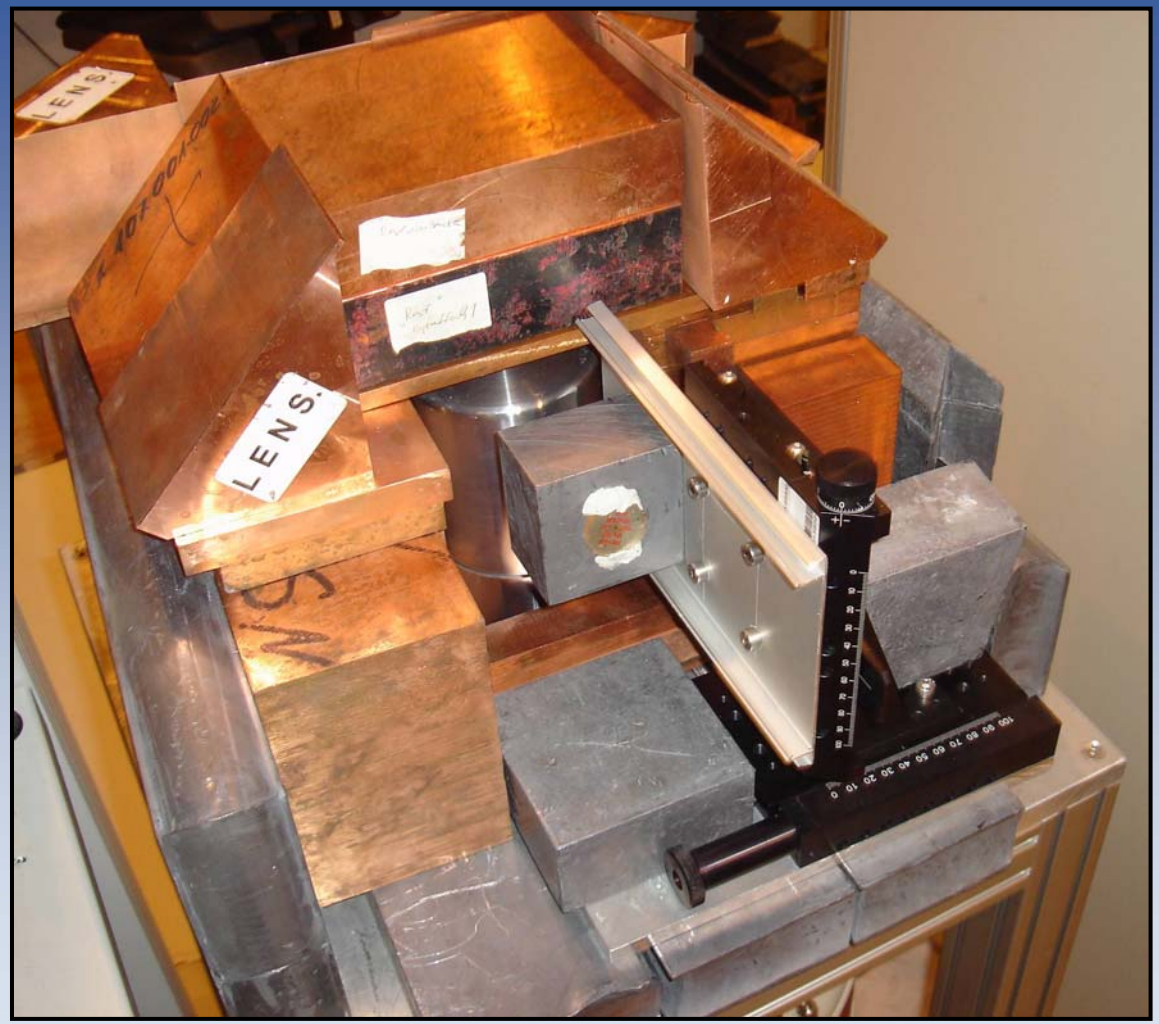
- do we have signal losses due to "inconventional" field distribution in the BEGe crystal?
- how reliable is our pulse-shape analysis?
- does DEP represent the $0\nu\beta\beta$ events well enough?

Work performed since then:

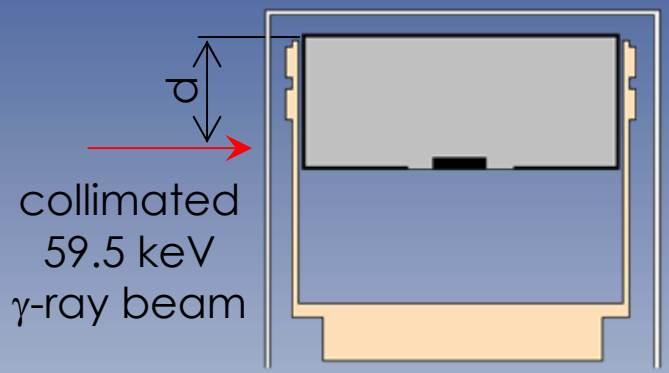
- characterisation of charge collection losses
- single Compton-scattering measurements to obtain pure samples of electron-induced events
- comparison of SCS events at DEP and $Q_{\beta\beta}$ energies

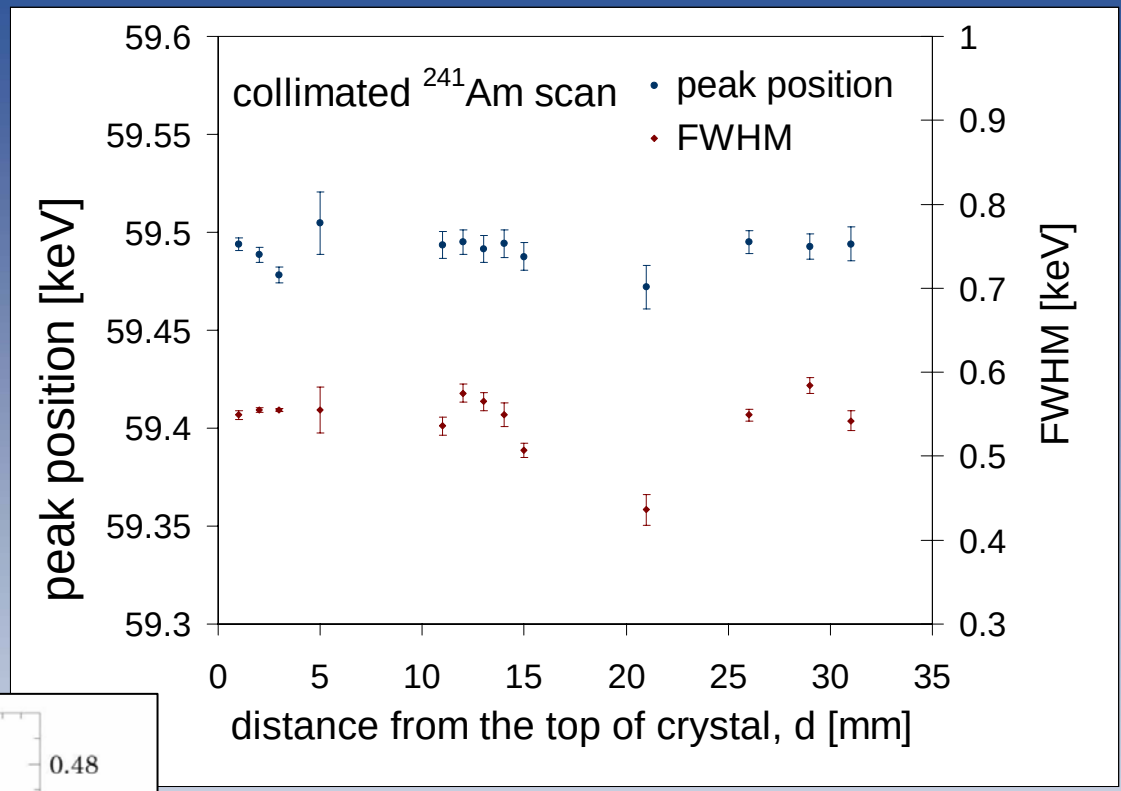
Collimator scanning

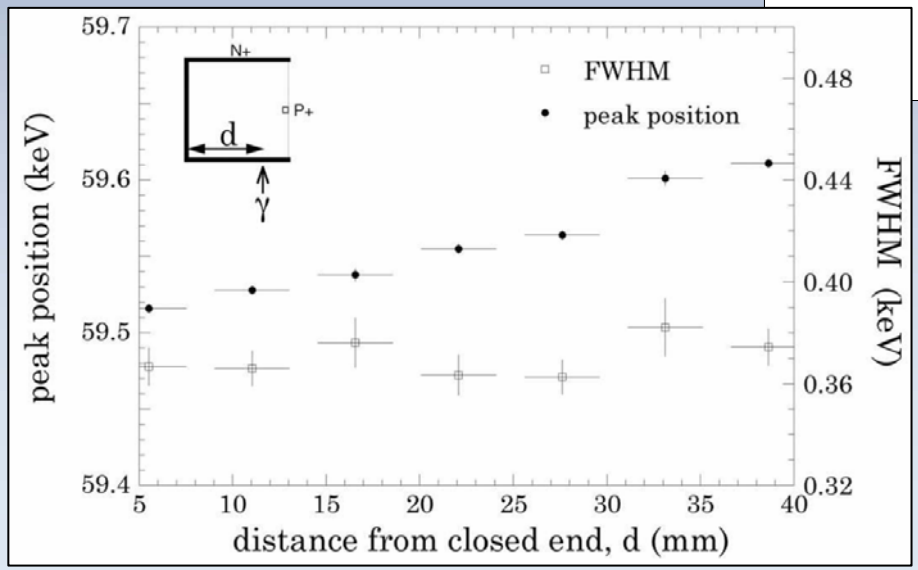




Collimator scanning: side scan





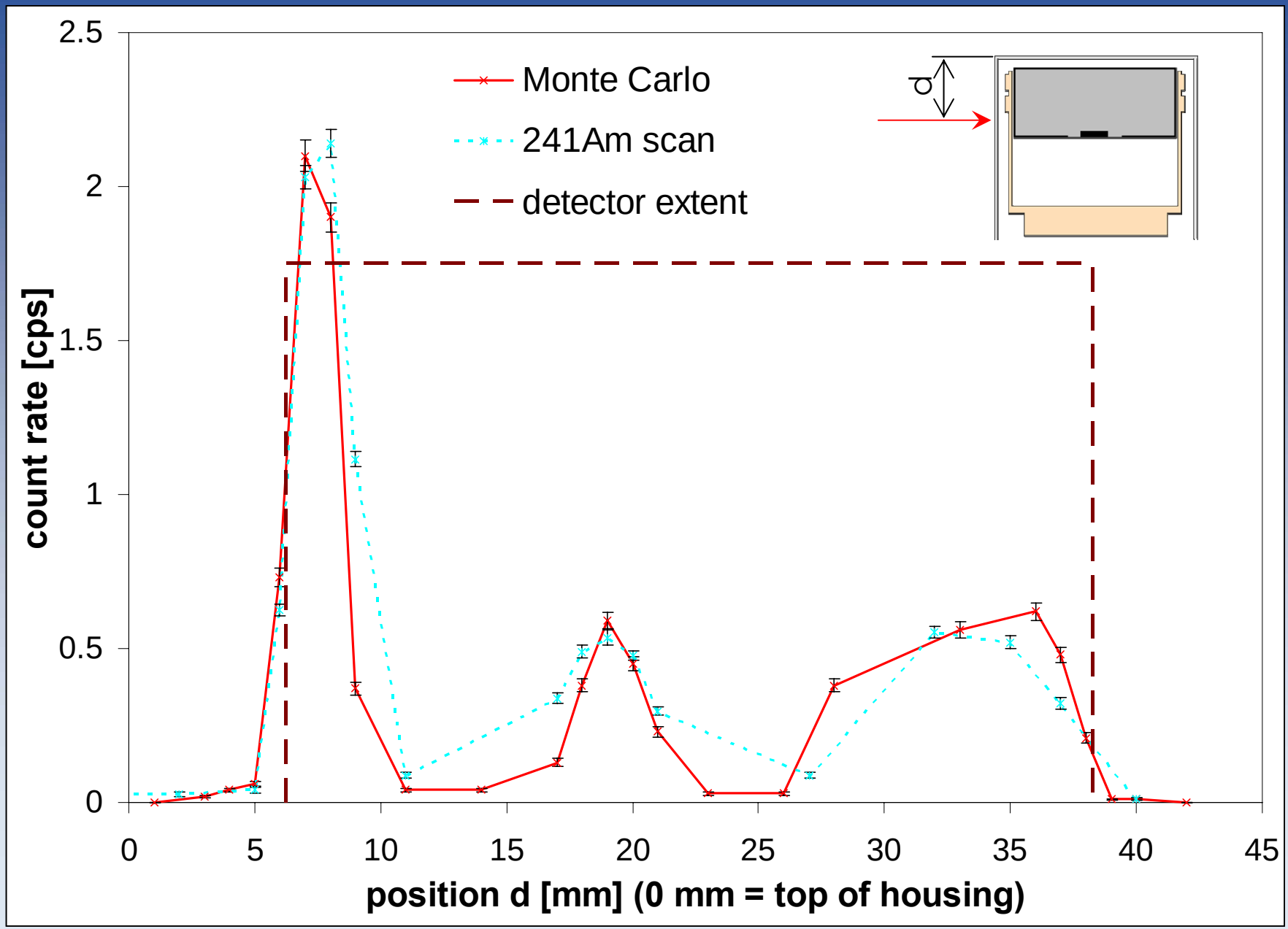


Gain variation: ≤ 0.055%

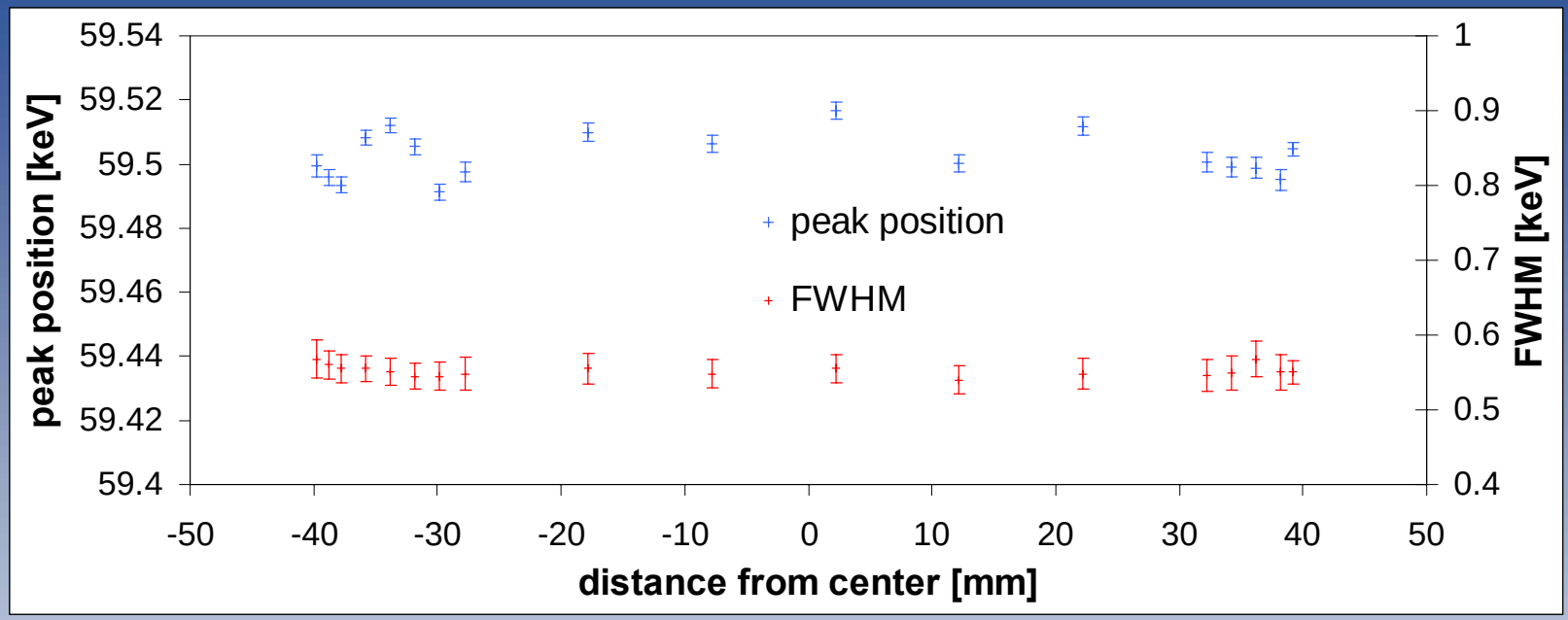
Majorana PPC detector:
Gain variation: ≤ 0.15%

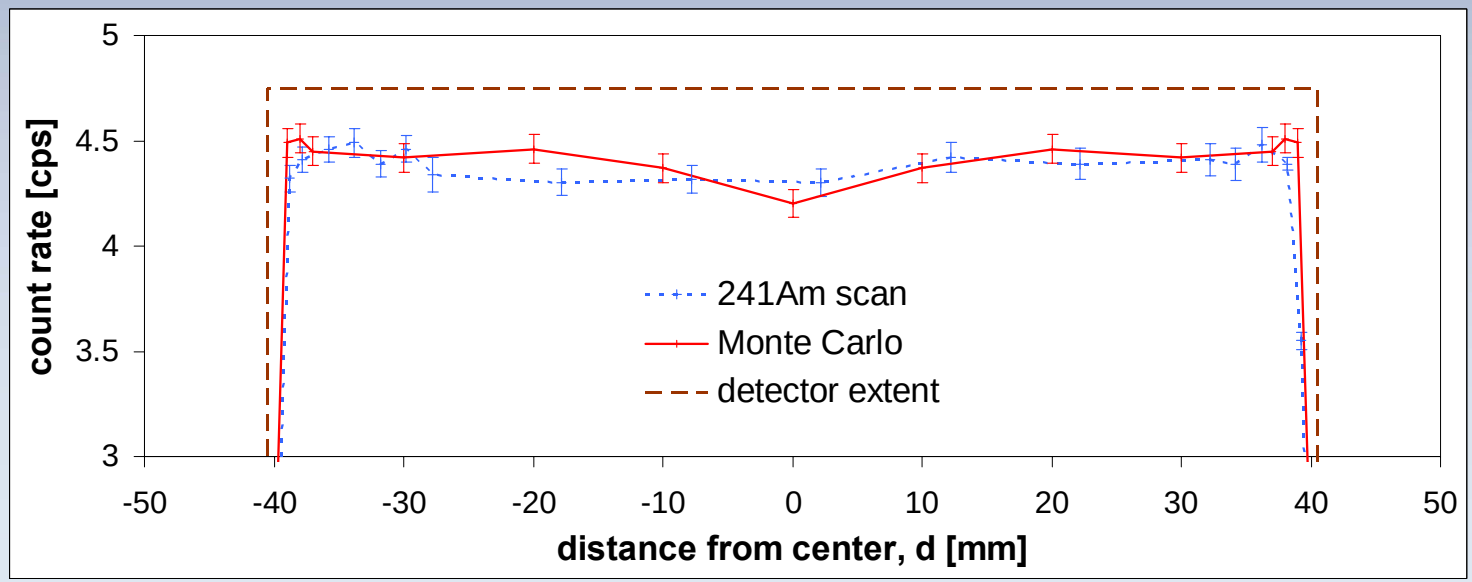
P.S. Barbeau, J.I. Collar and O. Tench
JCAP 0709:009,2007

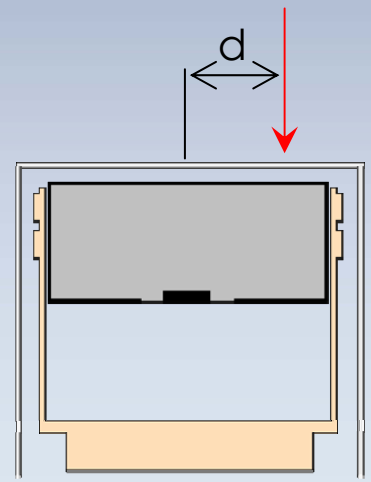
Collimator scanning : side scan



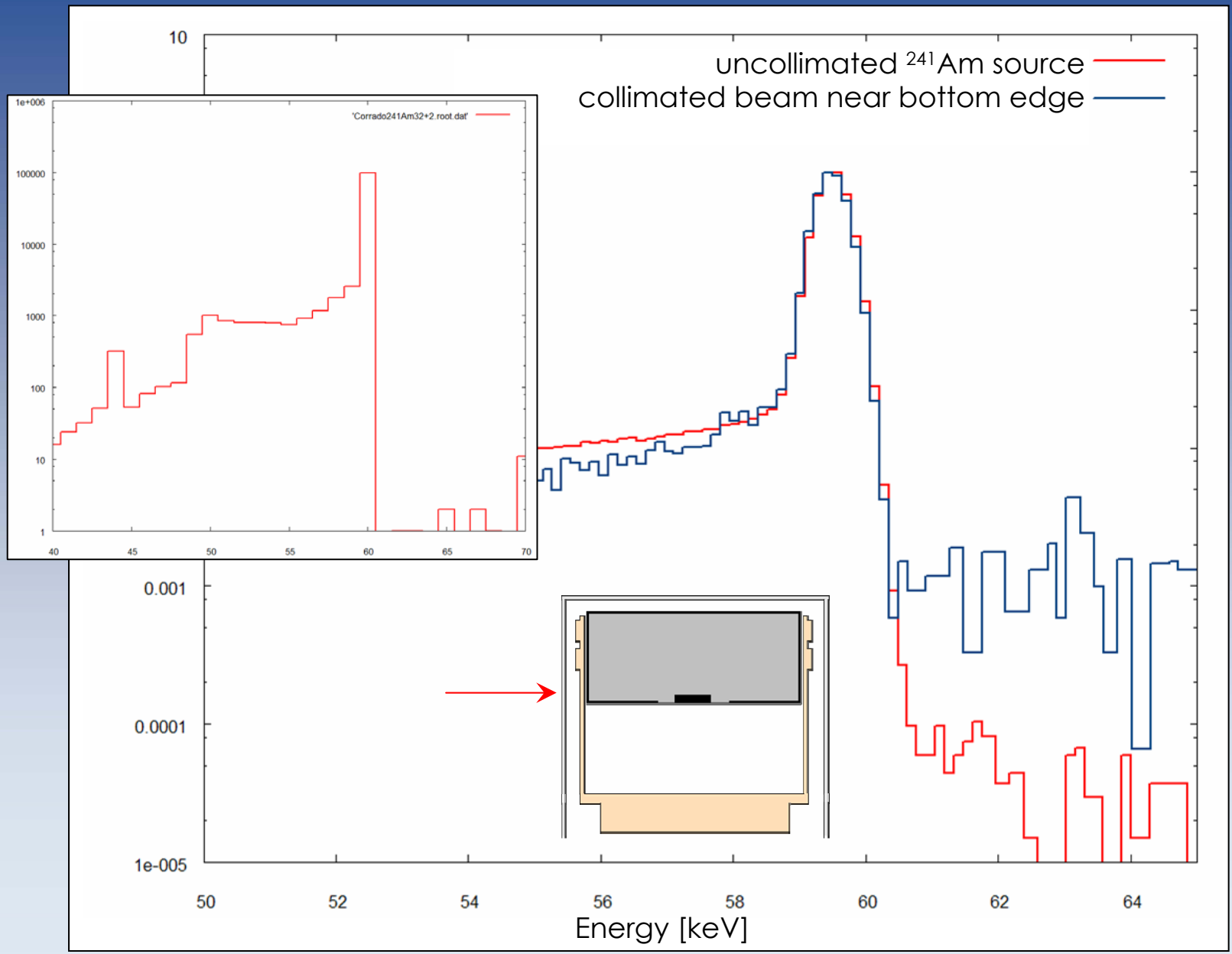
Collimator scanning: top scan



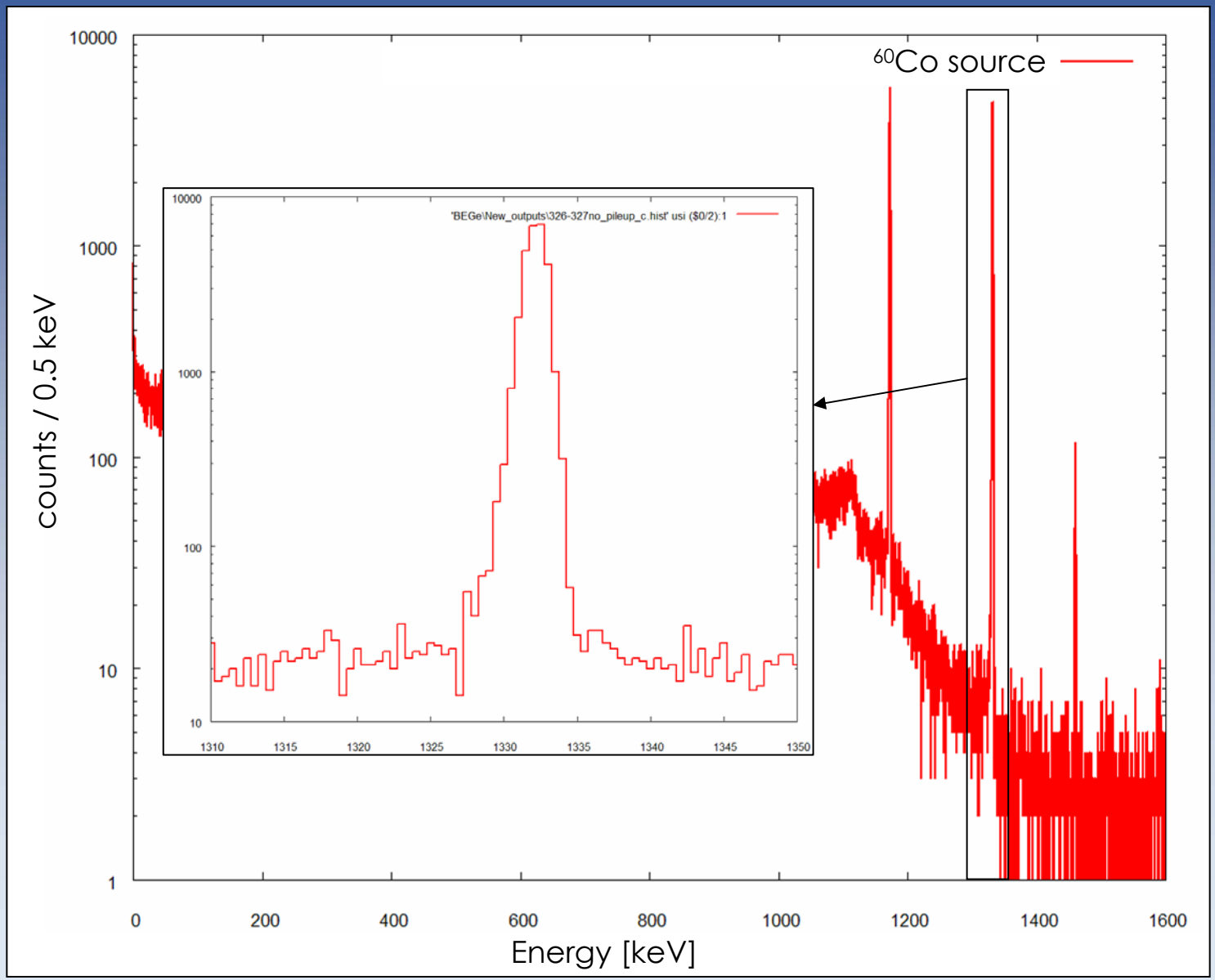




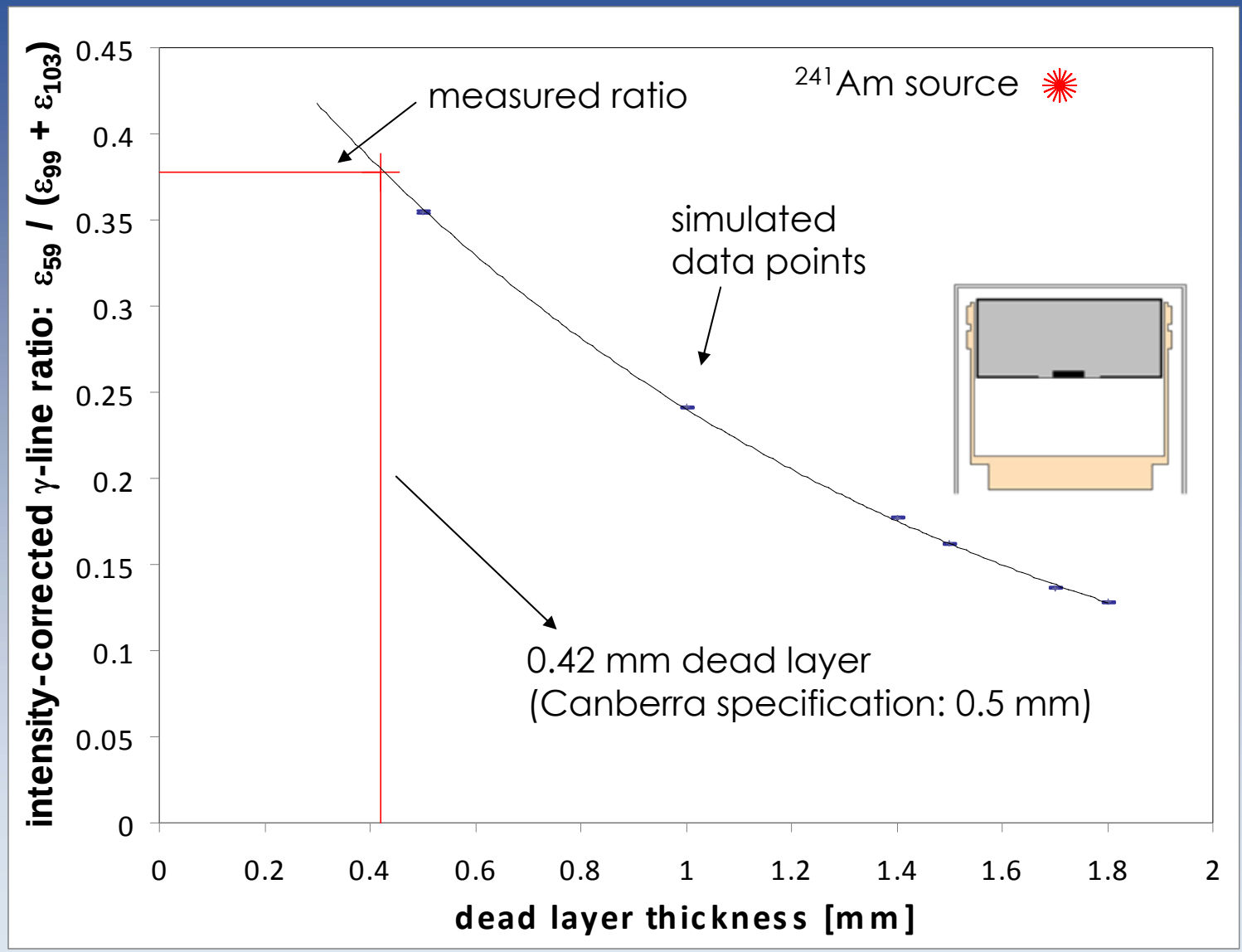
Charge collection losses: peak tails



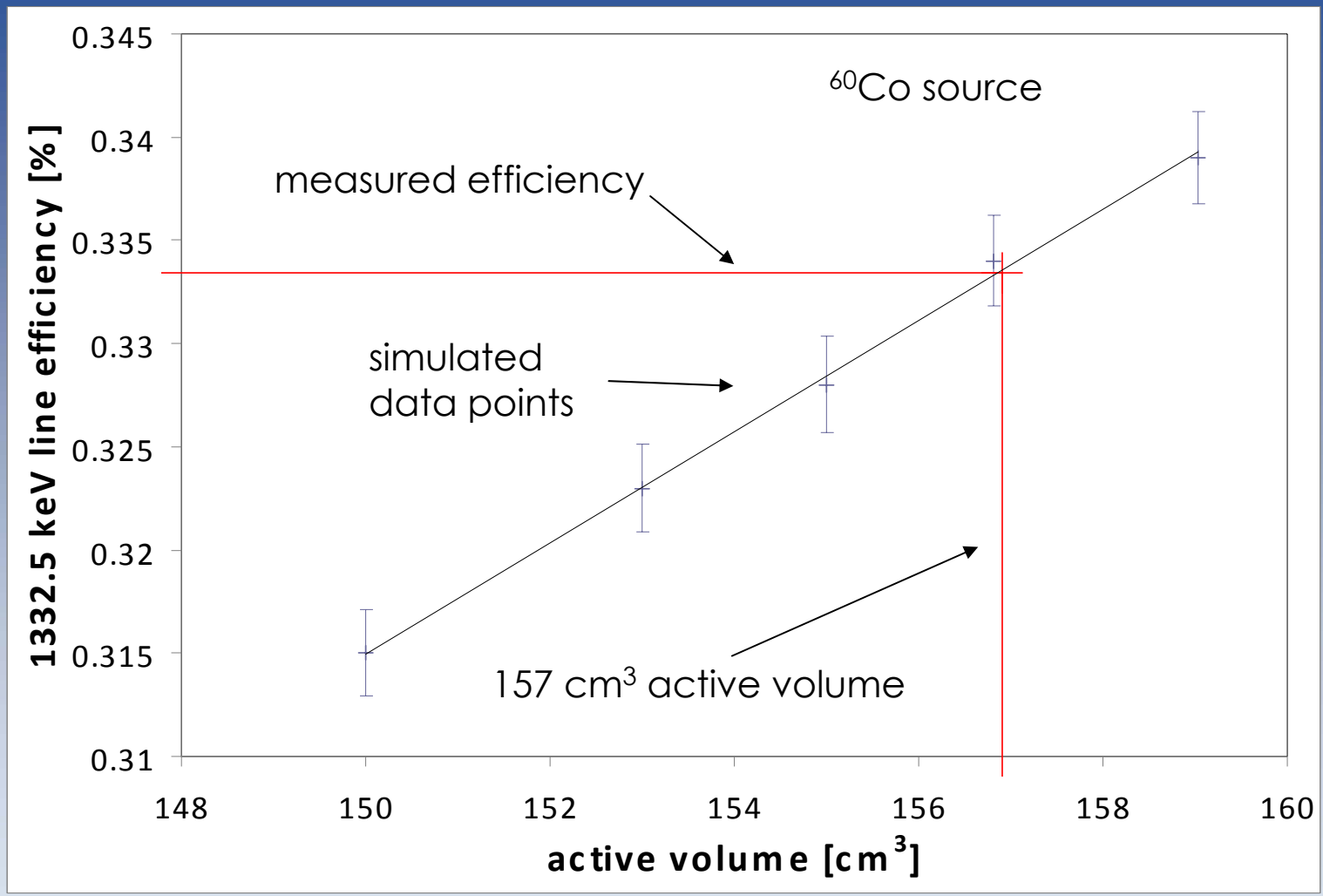
Charge collection losses: peak tails



Charge collection losses: dead layer



Charge collection losses: active volume

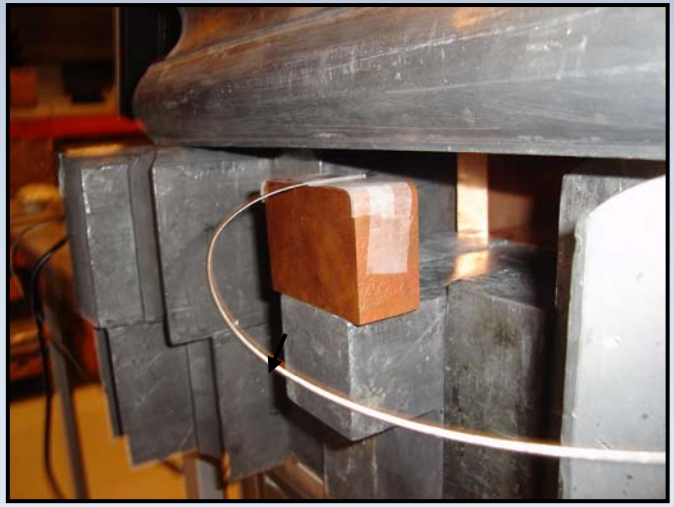


- active mass: **836 g** (95 % of total mass of 878 g)
- corresponds to 0.44 mm dead layer
  (assuming uniform around the crystal)

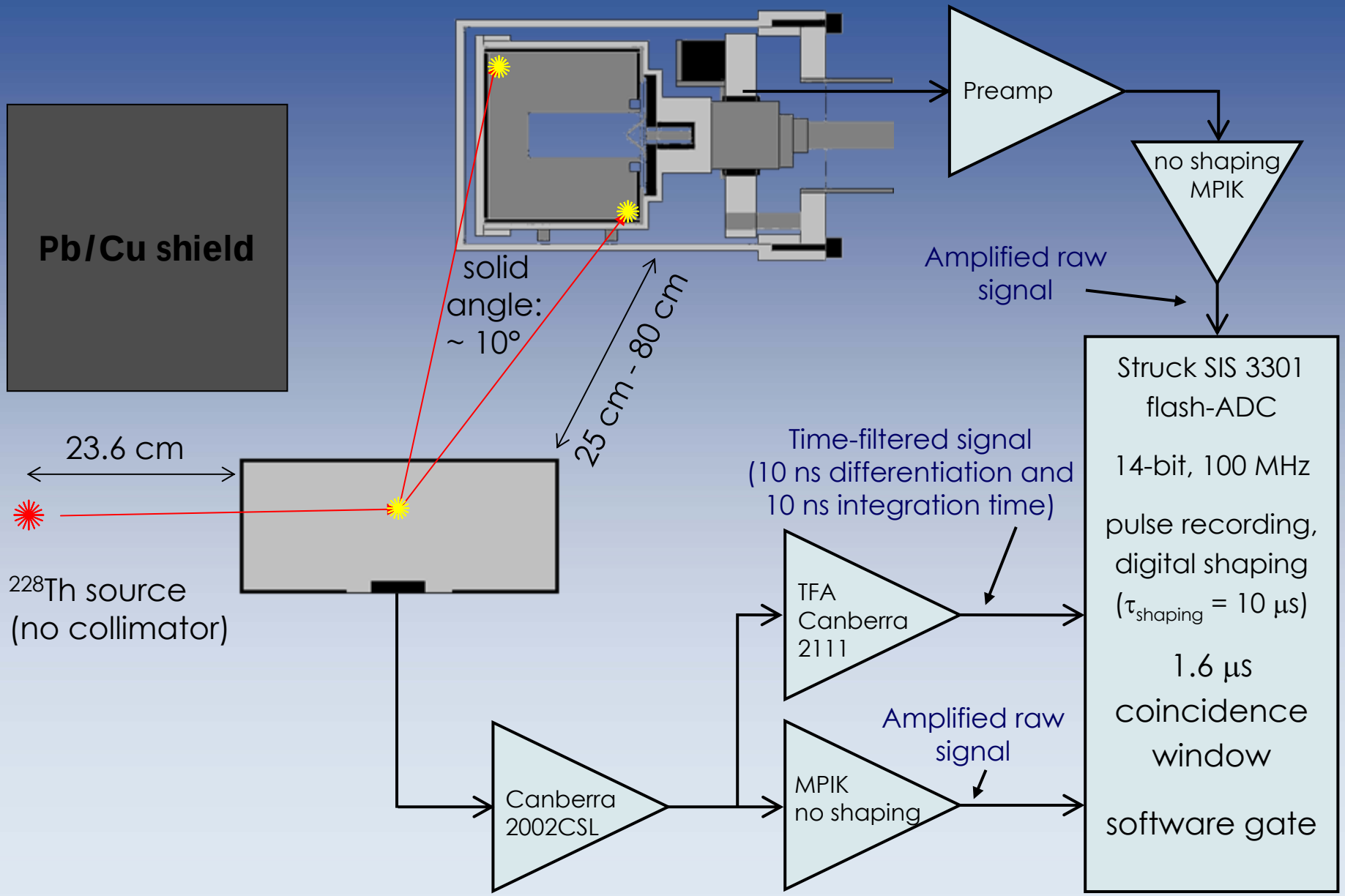
Summary of charge collection

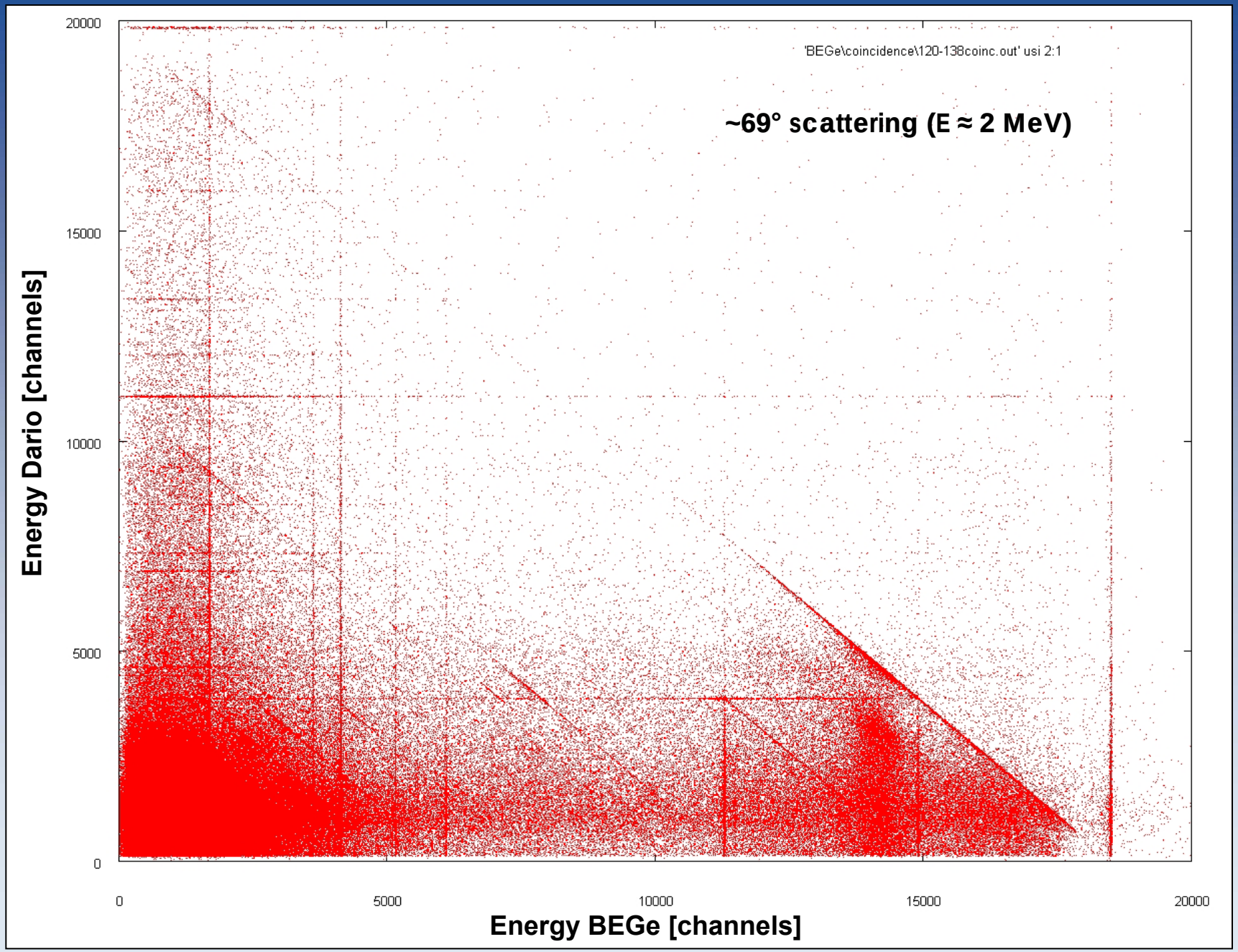
- no inhomogeneity of charge collection
- no incomplete charge collection at all
- BEGe dead layer as thin as in any good quality p-type detector
- active mass is 95 % of the total mass
  $\Rightarrow$ only the Li-drifted n^+ contact inactive

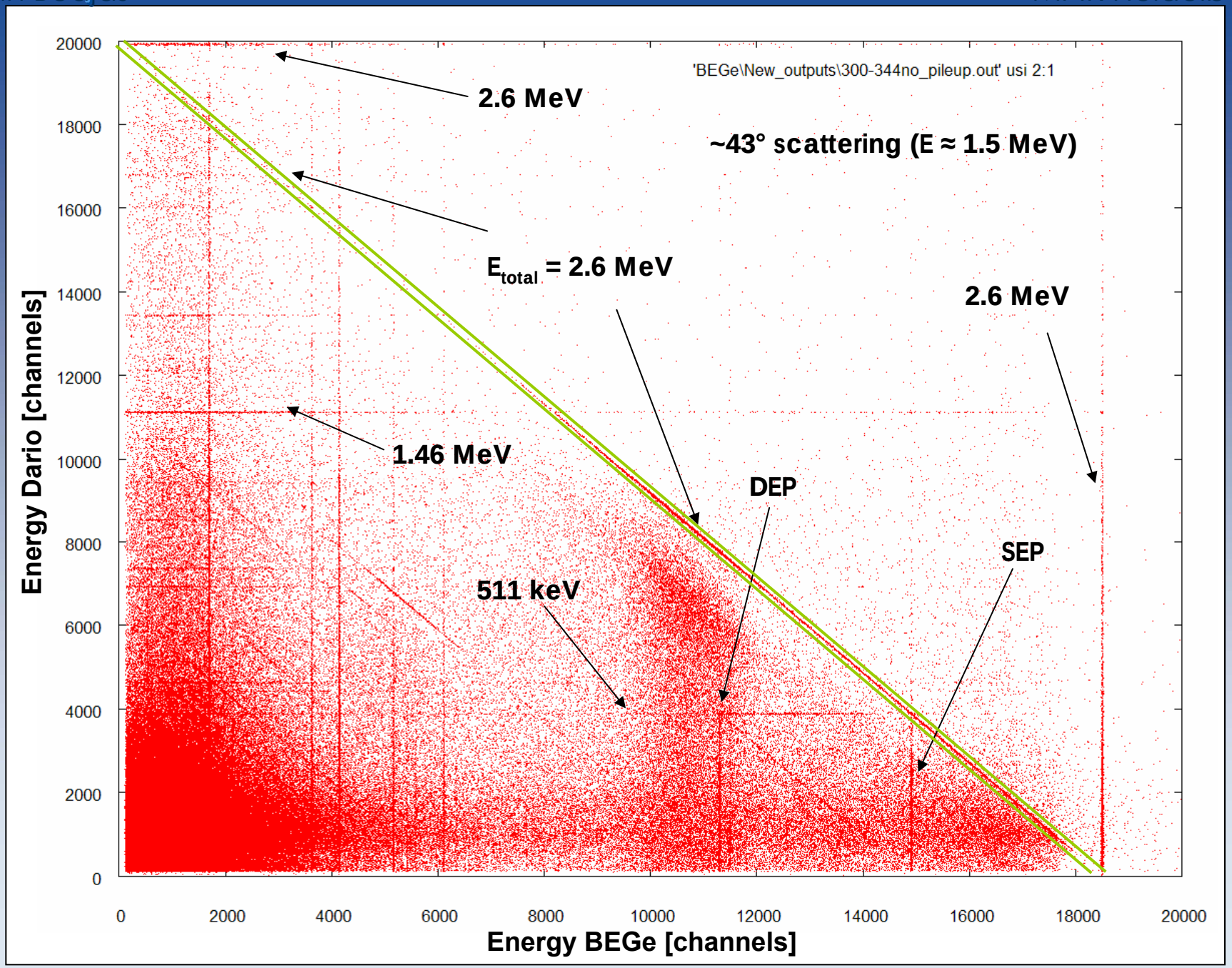
Compton-scattering coincidence measurements



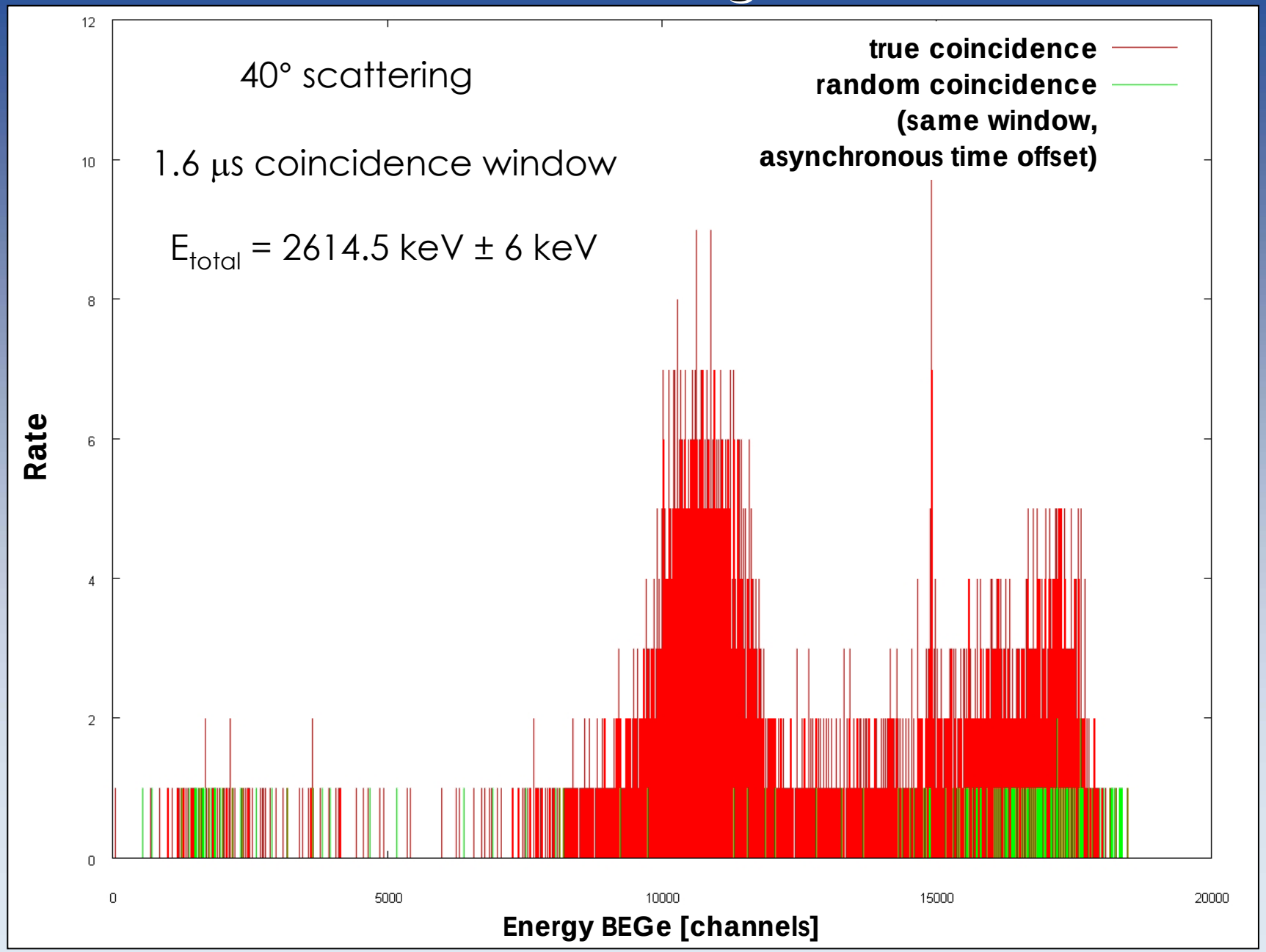
Coincident recording



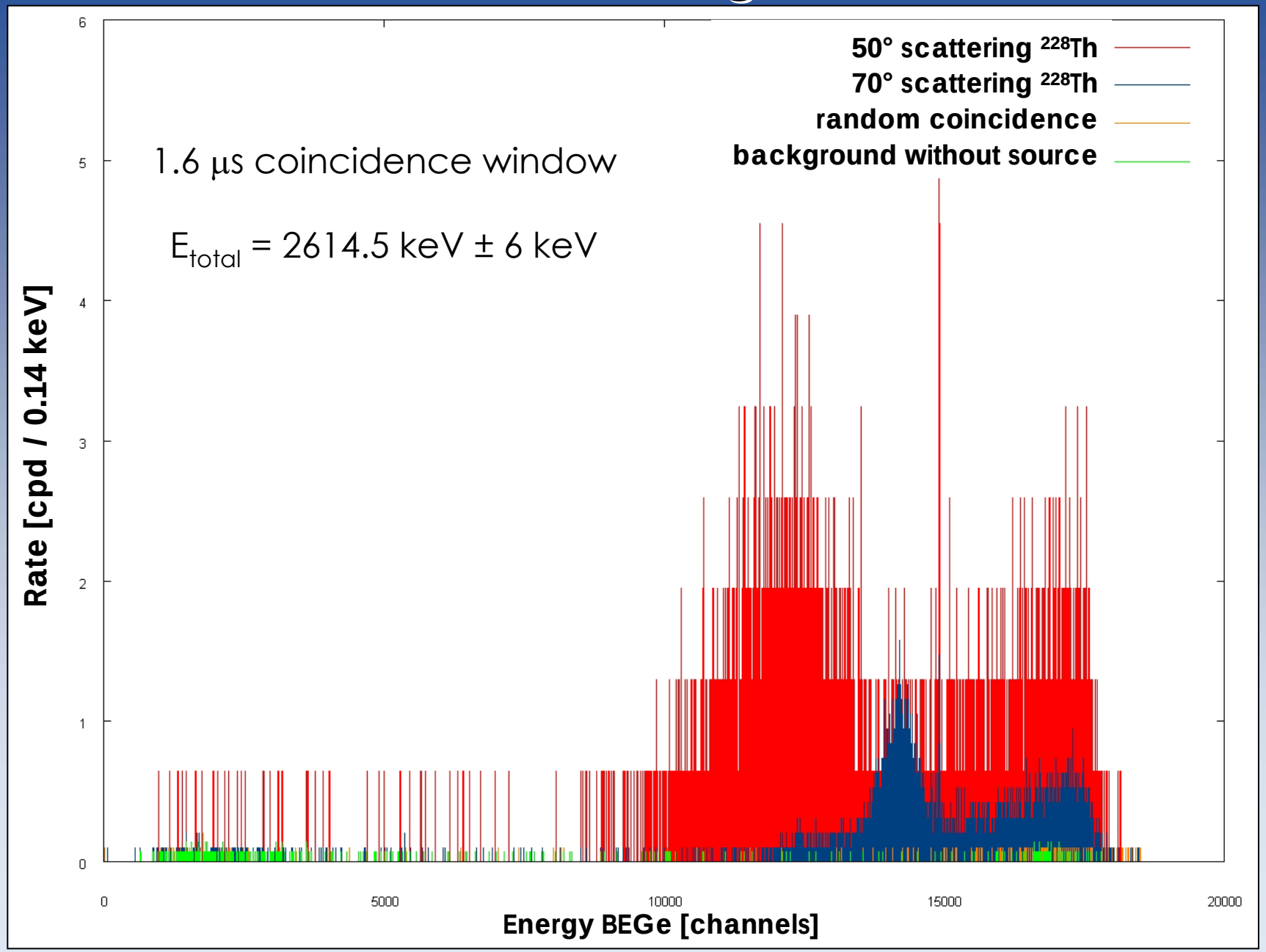

'BEGe\coincidence\120-138coinc.out' usi 2:1
~69° scattering (E ≈ 2 MeV)
Energy Dario [channels]
Energy BEGe [channels]
0
5000
10000
15000
20000

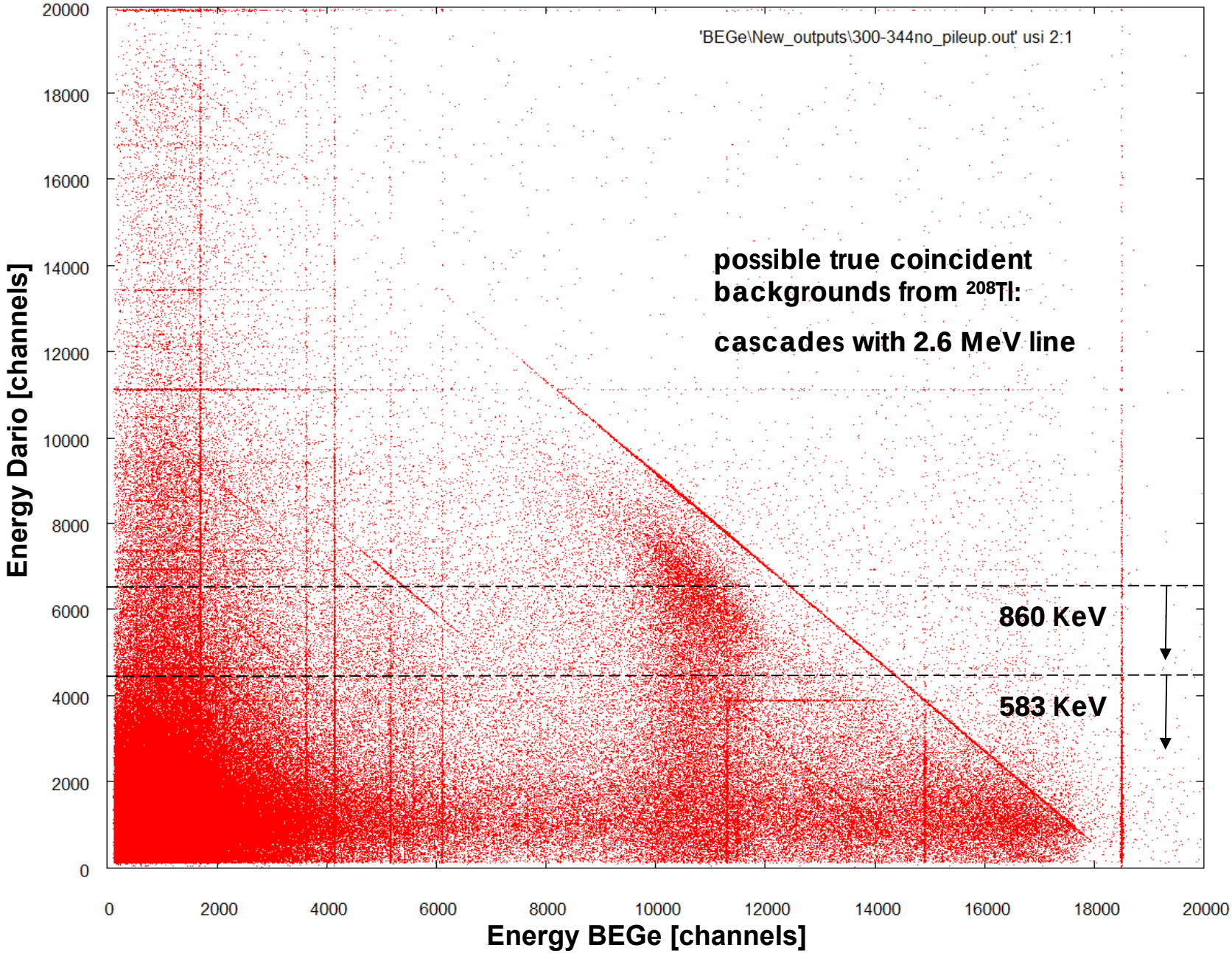

'BEGe\New_outputs\300-344no_pileup.out' usi 2:1
2.6 MeV
~43° scattering (E ≈ 1.5 MeV)
E_total = 2.6 MeV
2.6 MeV
1.46 MeV
DEP
SEP
511 keV
Energy Dario [channels]
Energy BEGe [channels]
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000

Coincident backgrounds

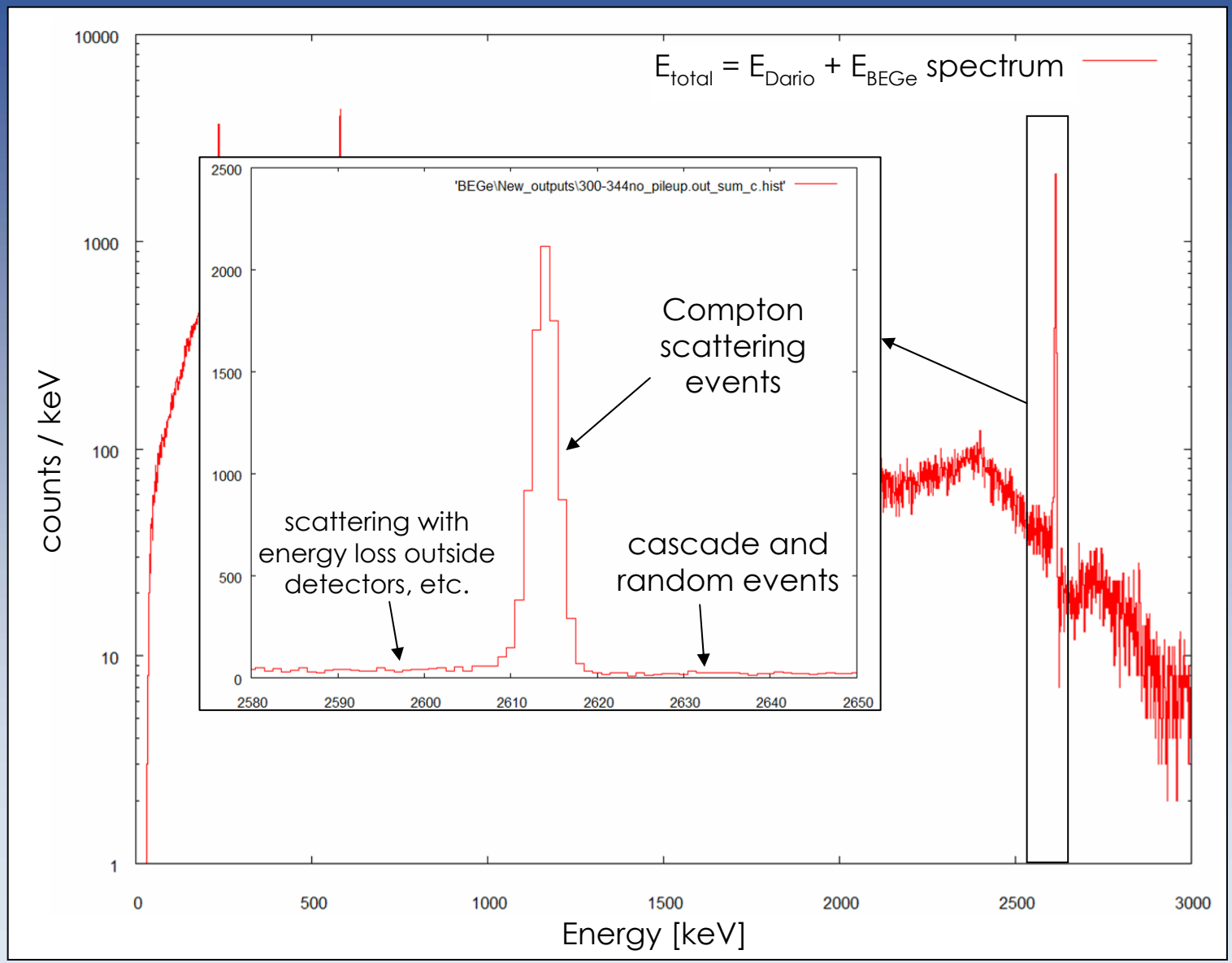


Coincident backgrounds

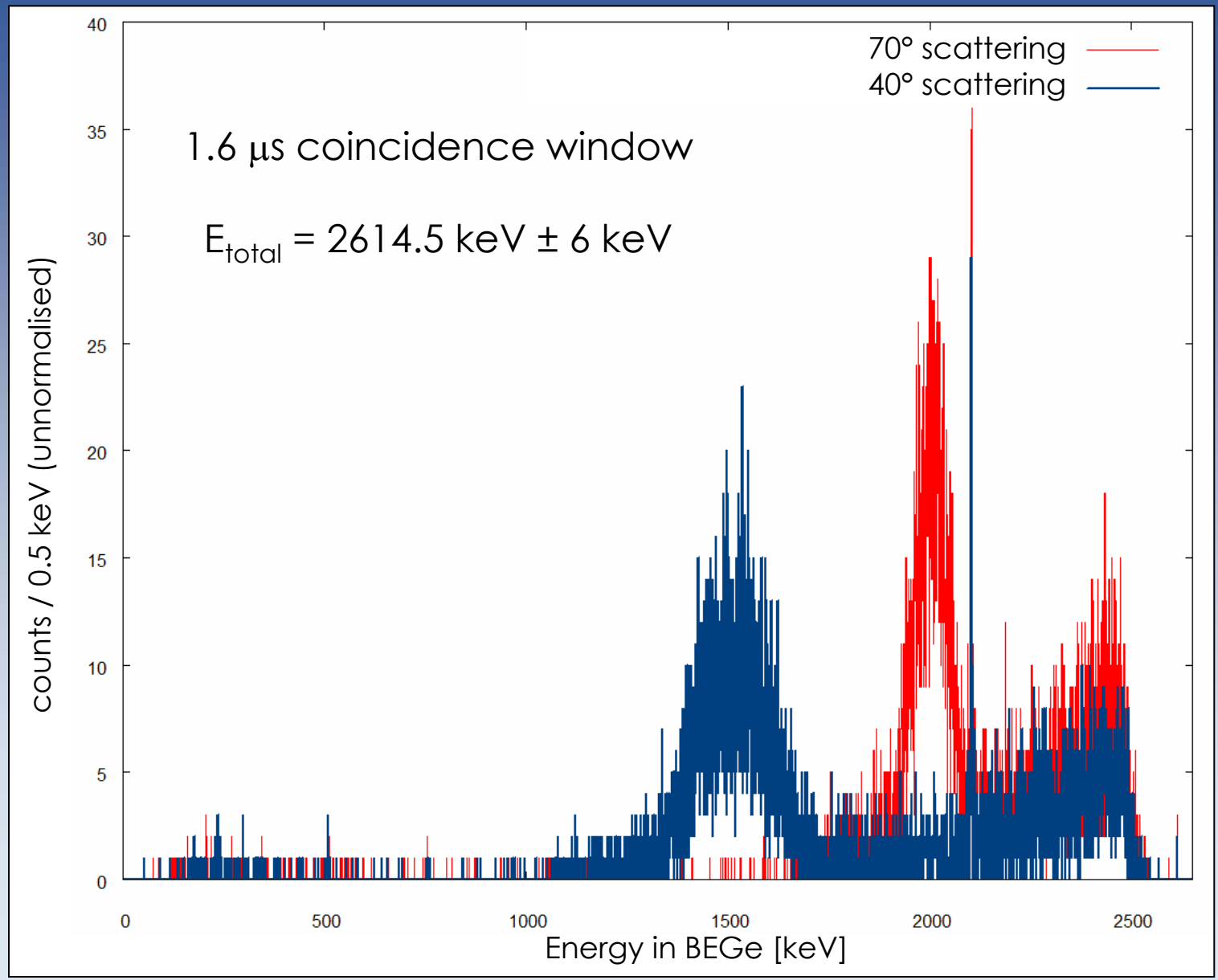



'BEGe\New_outputs\300-344no_pileup.out' usi 2:1
possible true coincident backgrounds from ^{208}Tl:
cascades with 2.6 MeV line
860 KeV
583 KeV
Energy Dario [channels]
Energy BEGe [channels]
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000

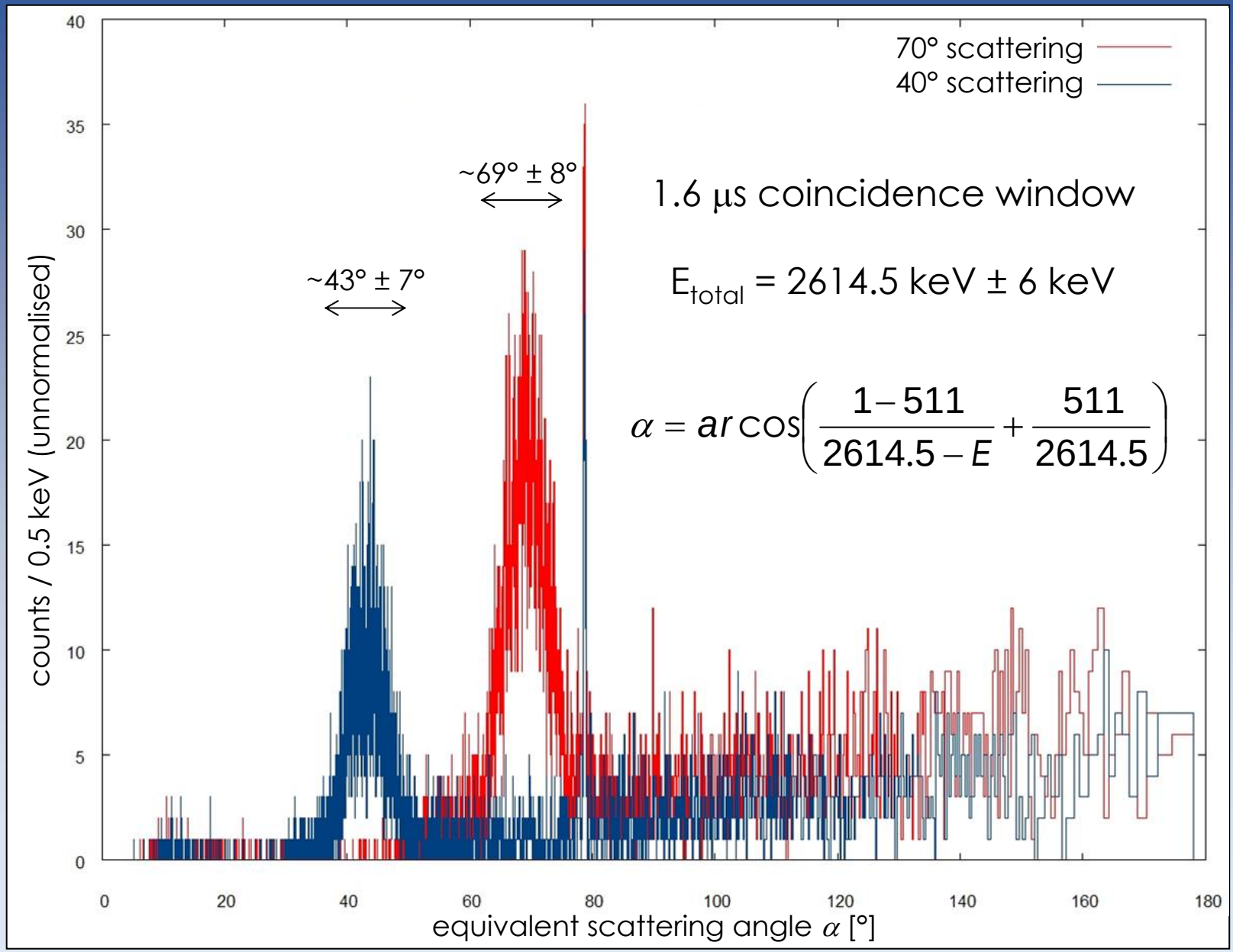
Coincident backgrounds



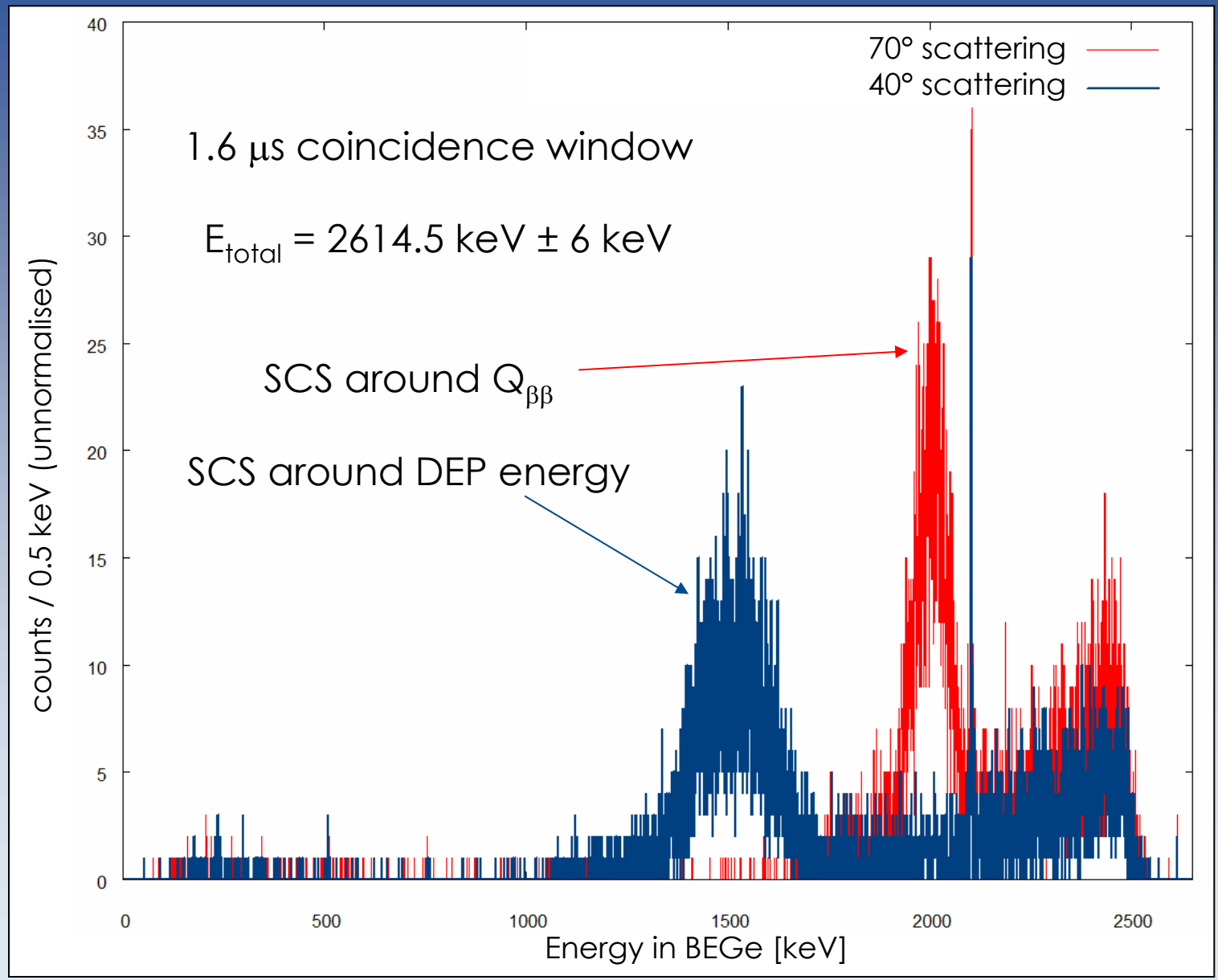
Compton scattering events



Compton scattering events



Compton scattering events

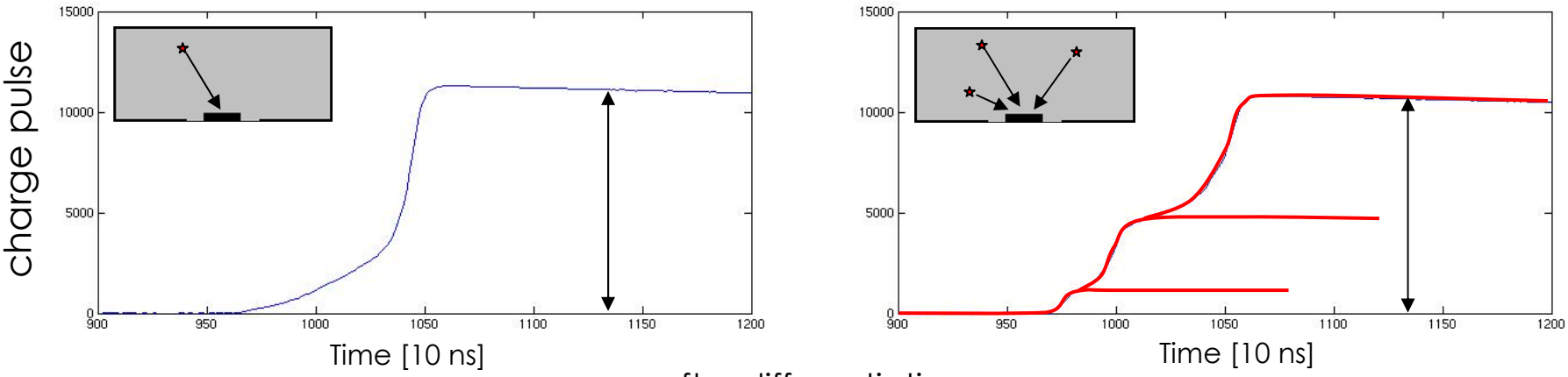


Pulse shape analysis

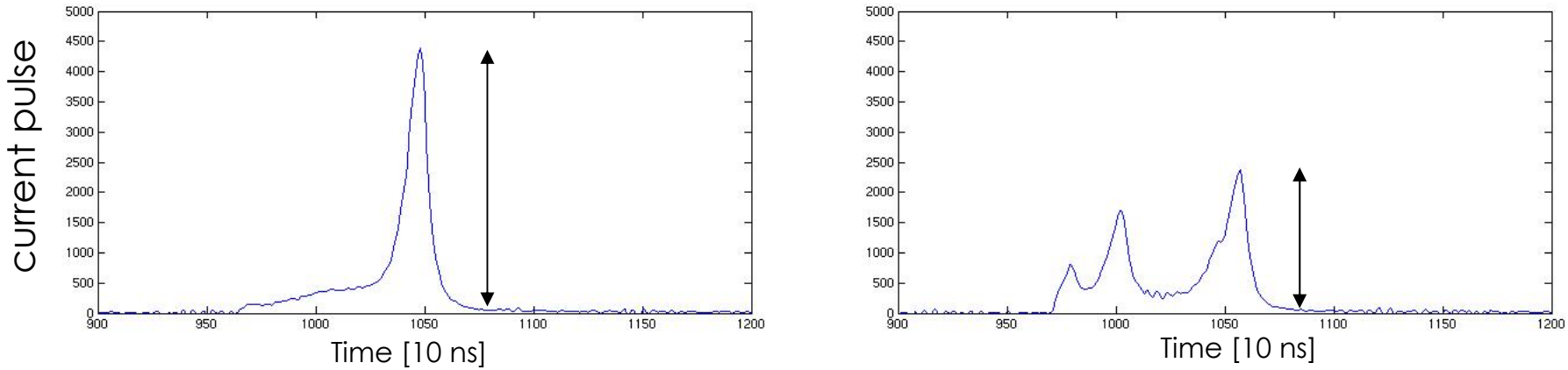
typical electron event

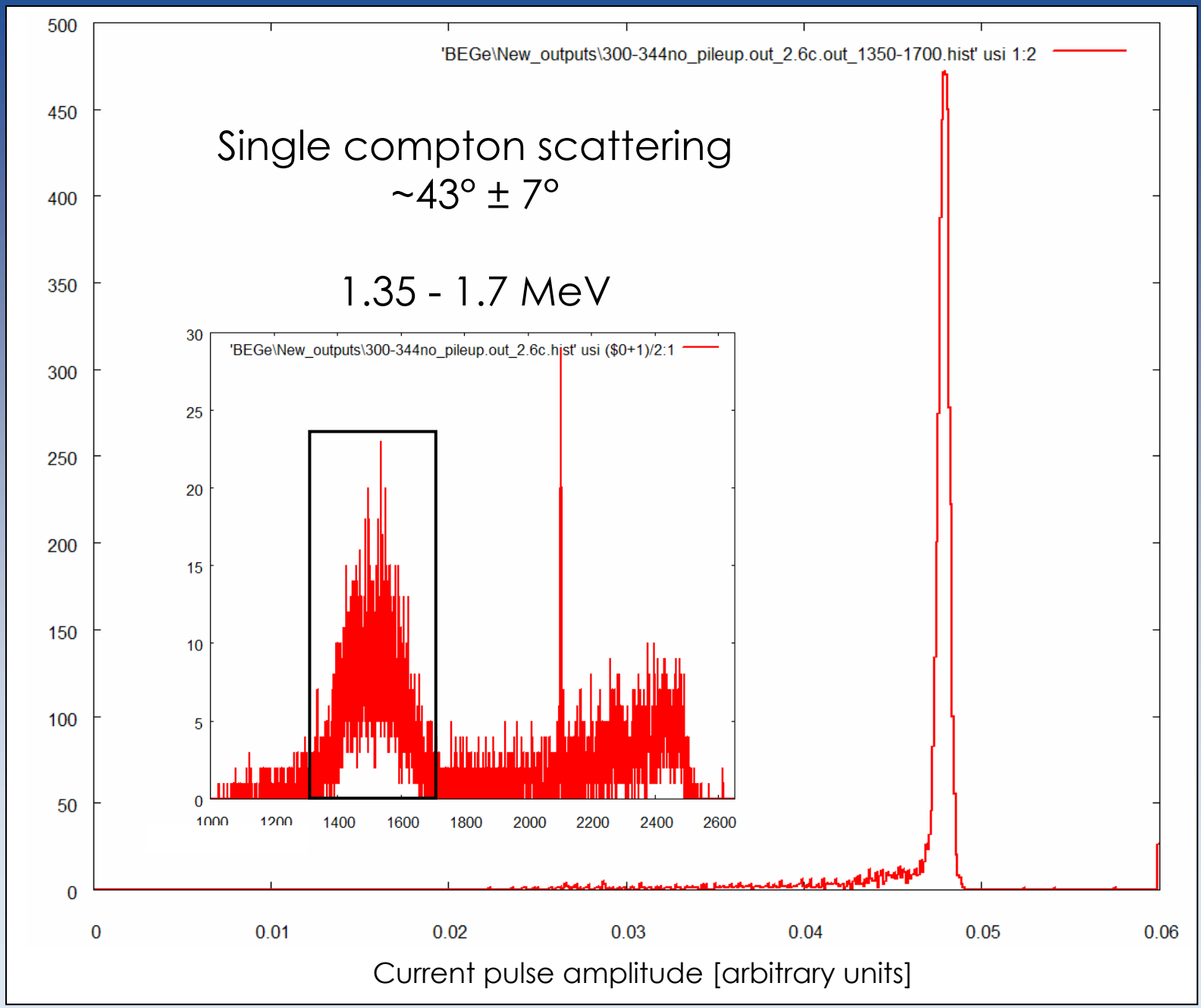
typical gamma-ray event

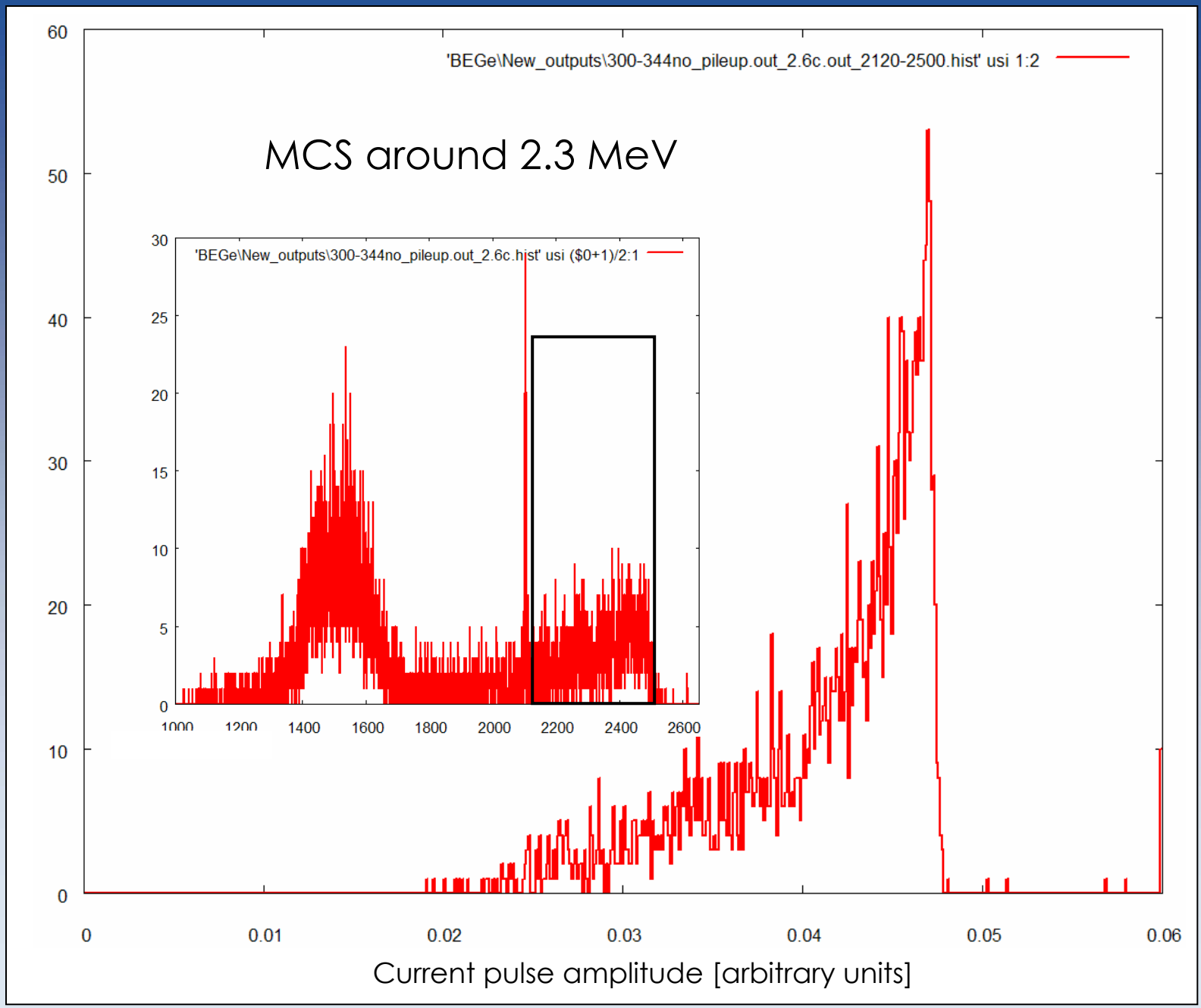
raw preamplifier output:

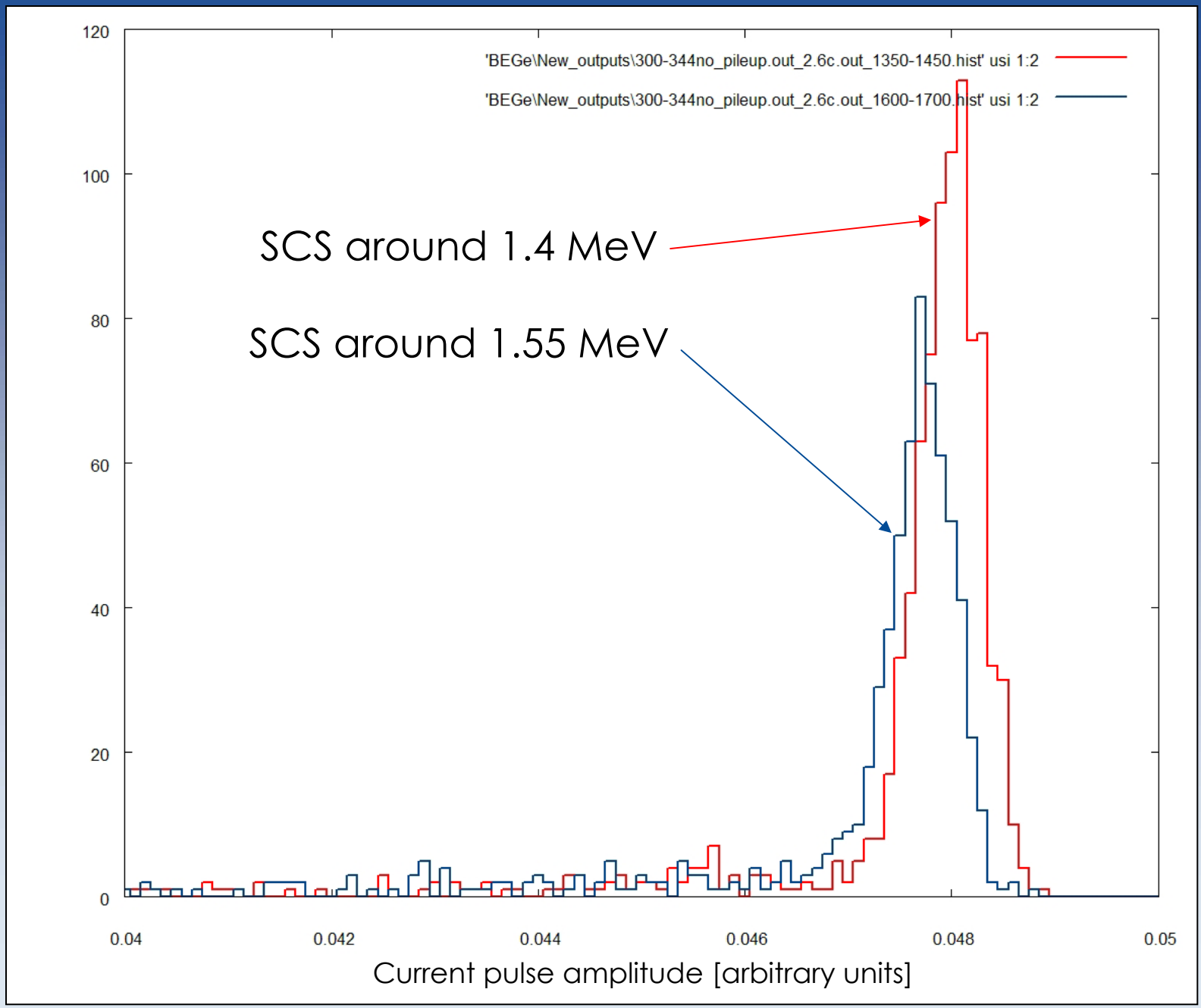


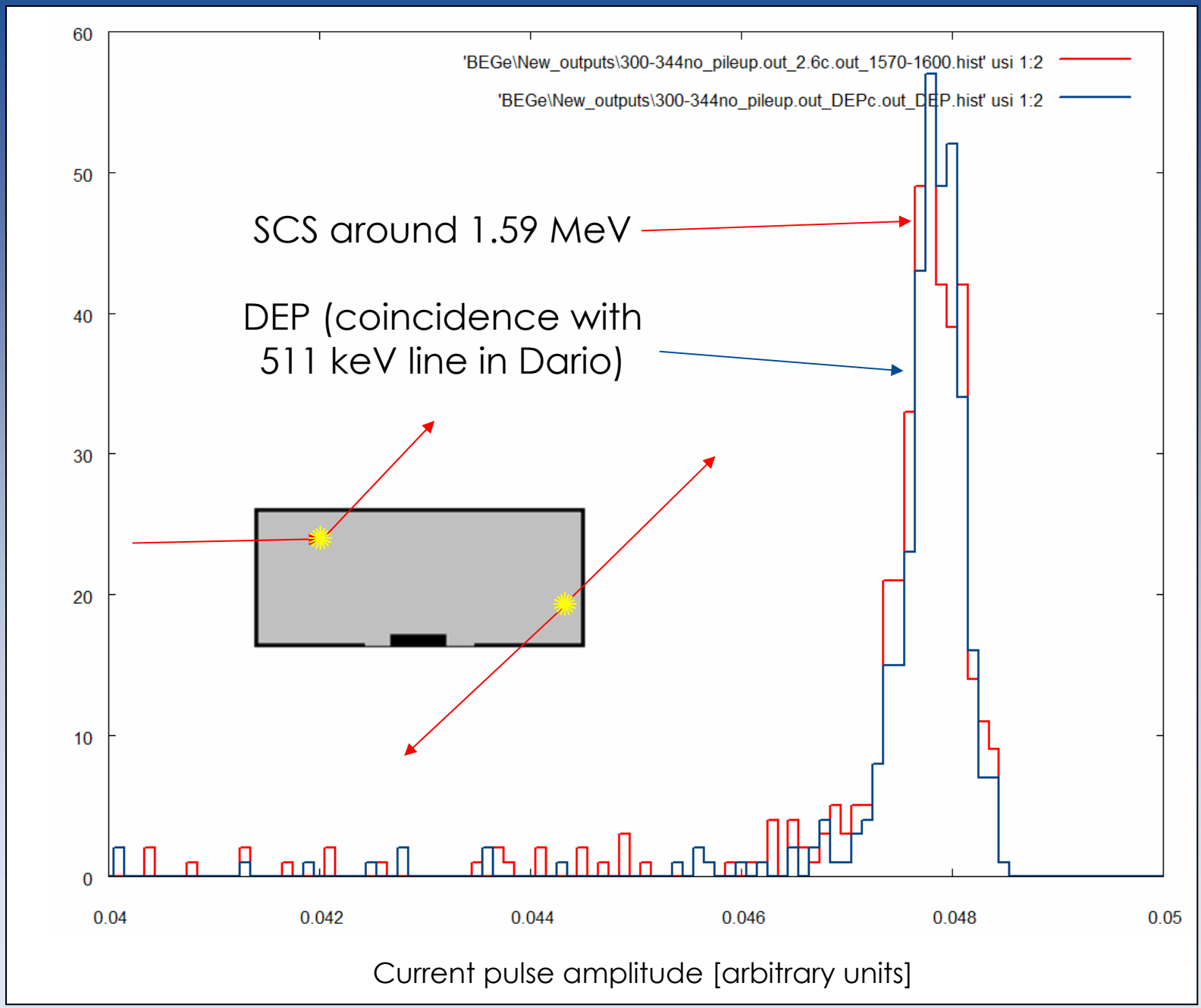
after differentiation:




'BEGe\New_outputs\300-344no_pileup.out_2.6c.out_1350-1700.hist' usi 1:2
Single compton scattering
~43° ± 7°
1.35 - 1.7 MeV
'BEGe\New_outputs\300-344no_pileup.out_2.6c.hist' usi ($0+1)/2:1
Current pulse amplitude [arbitrary units]

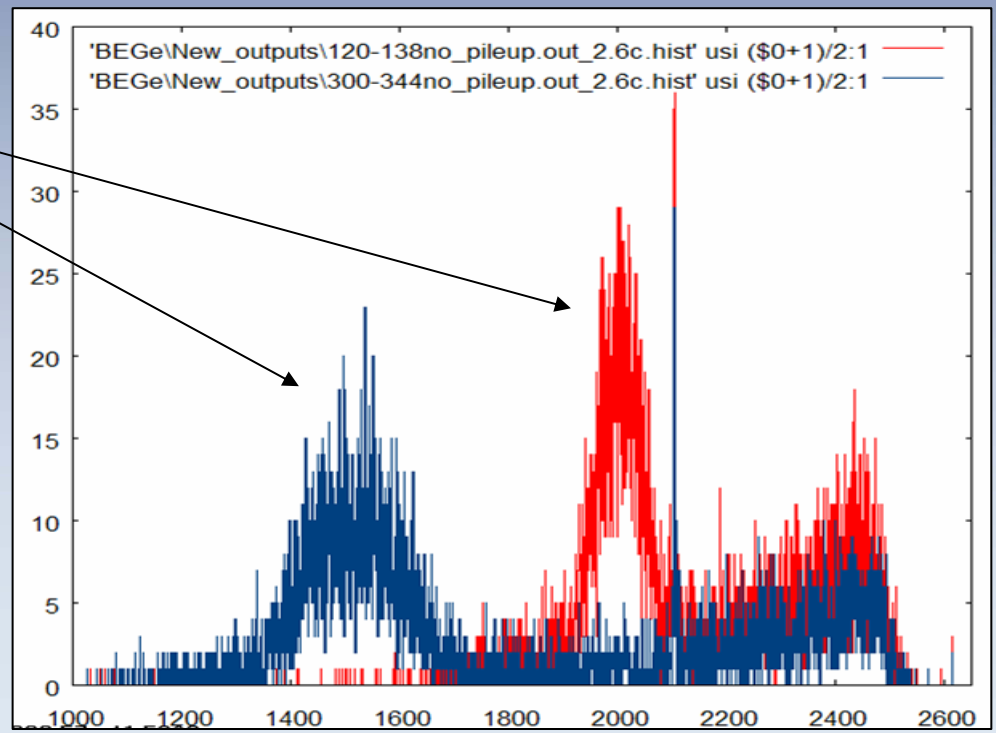

'BEGe\New_outputs\300-344no_pileup.out_2.6c.out_2120-2500.hist' usi 1:2
MCS around 2.3 MeV
'BEGe\New_outputs\300-344no_pileup.out_2.6c.hist' usi ($0+1)/2:1
Current pulse amplitude [arbitrary units]


'BEGe\New_outputs\300-344no_pileup.out_2.6c.out_1350-1450.hist' usi 1:2
'BEGe\New_outputs\300-344no_pileup.out_2.6c.out_1600-1700.hist' usi 1:2
SCS around 1.4 MeV
SCS around 1.55 MeV
120
100
80
60
40
20
0
0.04
0.042
0.044
0.046
0.048
0.05
Current pulse amplitude [arbitrary units]


'BEGe\New_outputs\300-344no_pileup.out_2.6c.out_1570-1600.hist' usi 1:2
'BEGe\New_outputs\300-344no_pileup.out_DEPc.out_DEP.hist' usi 1:2
SCS around 1.59 MeV
DEP (coincidence with 511 keV line in Dario)
60
50
40
30
20
10
0
0.04
0.042
0.044
0.046
0.048
0.05
Current pulse amplitude [arbitrary units]

Summary of PSA

- electron and gamma-induced events can be distinguished with the help of current-pulse amplitude
- DEP and SCS data with different volume distribution have similar distribution of the current-pulse amplitude
- SCS measurements can be used to calibrate cut parameters at different energies
- cut function stability needs to be investigated



Outlook

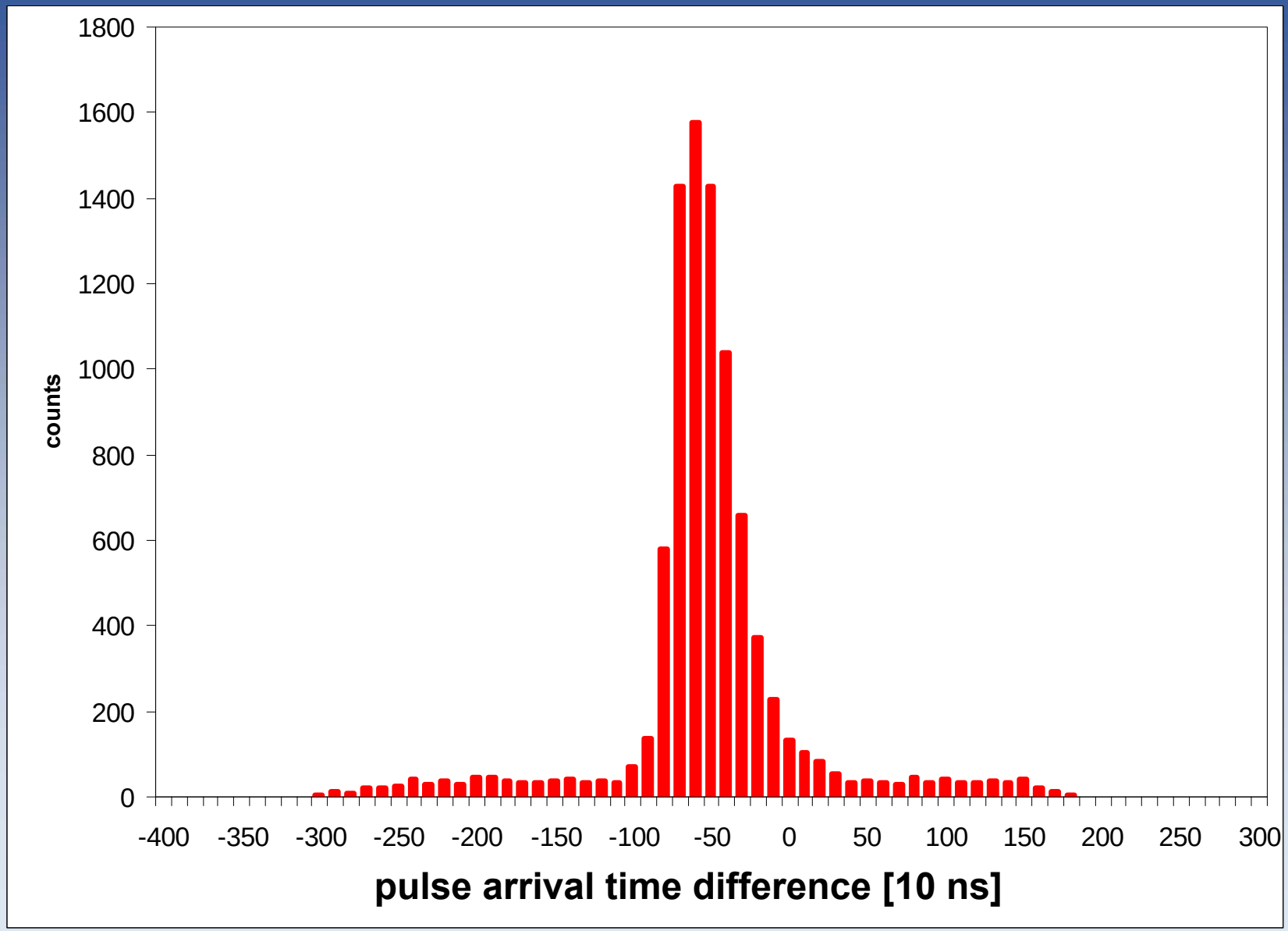
Understand how to generalise our pulse shape discrimination to $0\nu\beta\beta$ events and expected background events:

- measurements with different spatial distributions of electron events to experimentally check how the efficiency of pulse-shape discrimination varies?

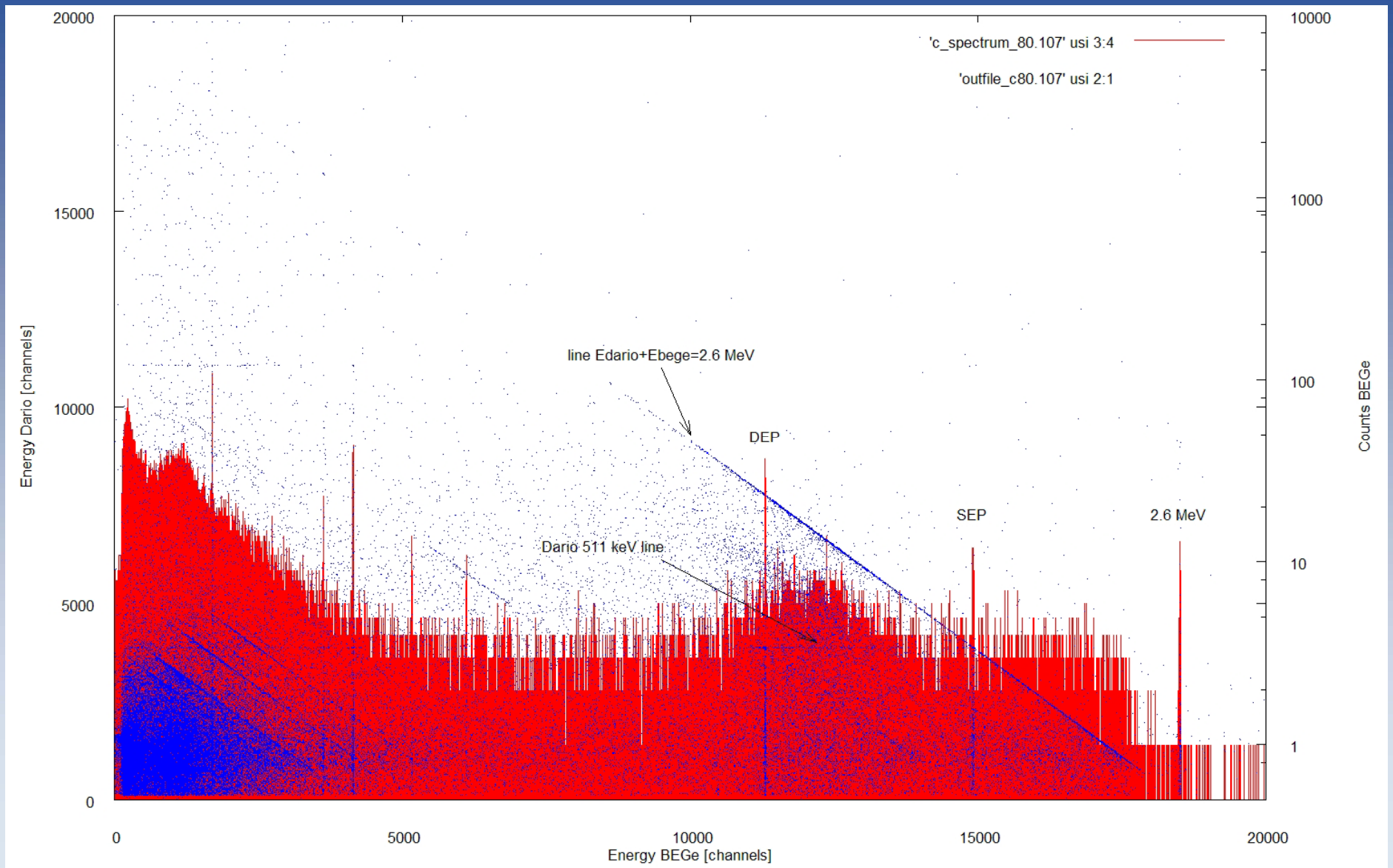
- pulse-shape simulation of the BEGe detector?

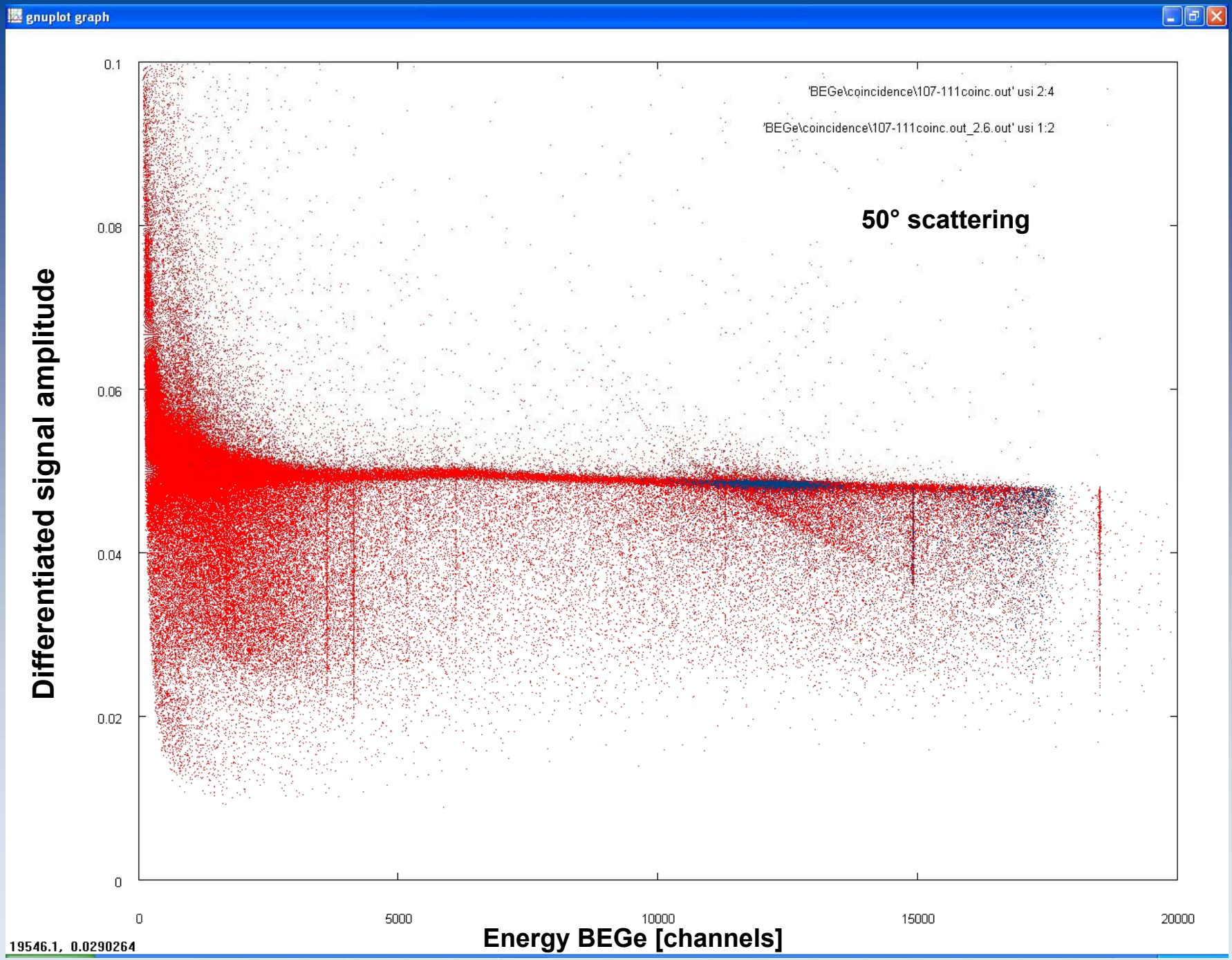
Backup slides

Coincident recording

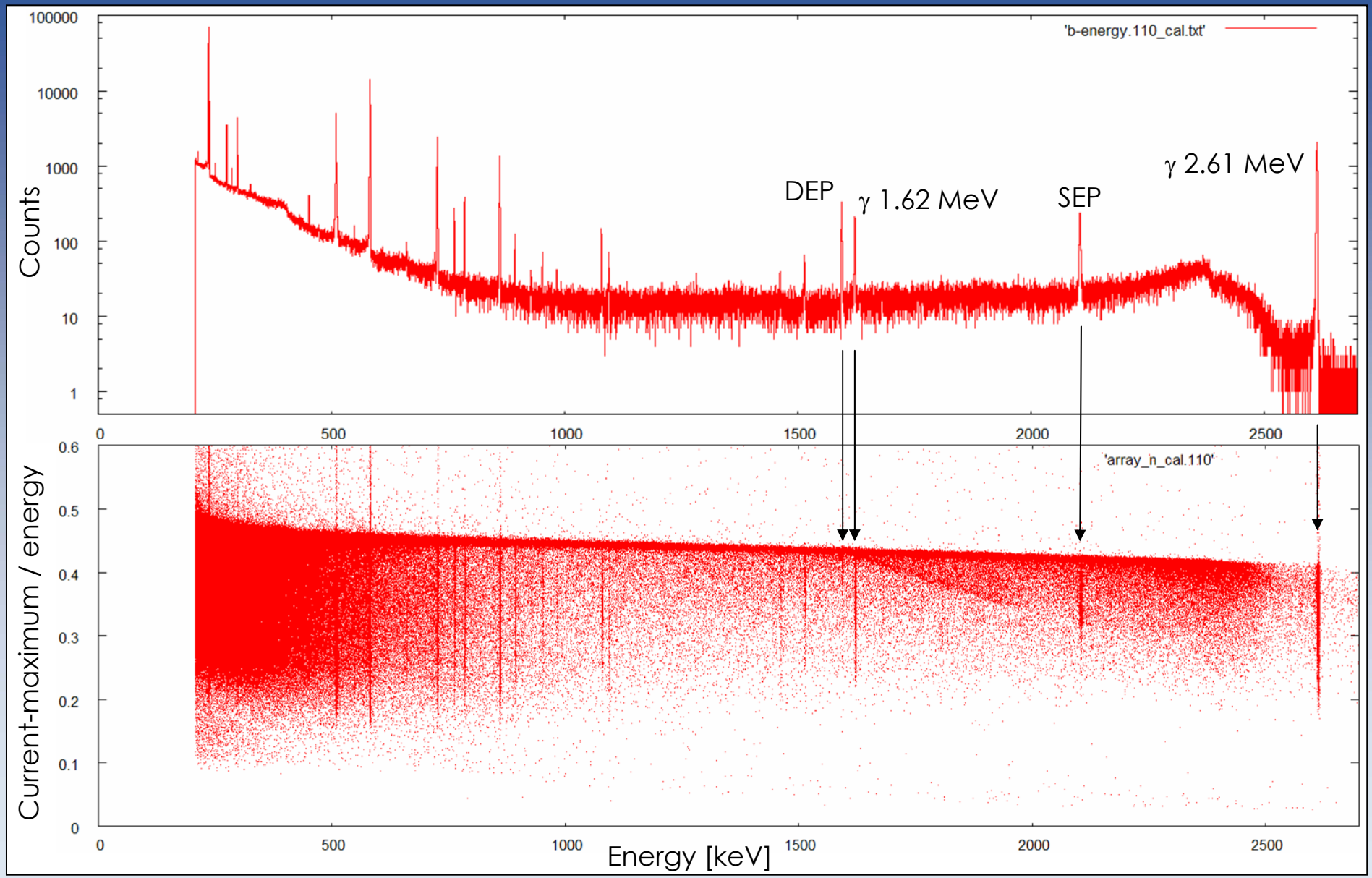


Coincident data



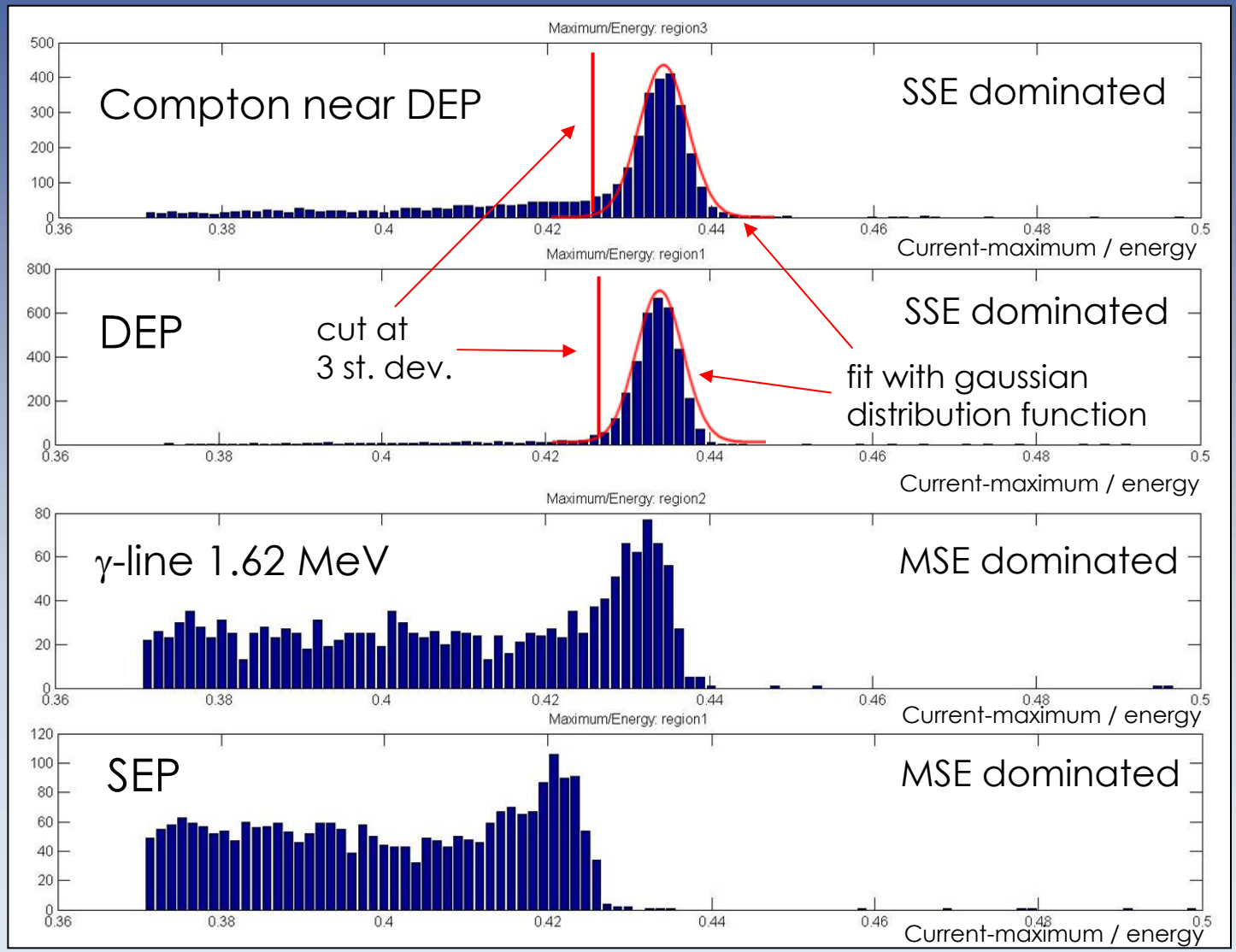

gnuplot graph
'BEGe\coincidence\107-111coinc.out' usi 2:4
'BEGe\coincidence\107-111coinc.out_2.6.out' usi 1:2
50° scattering
Differentiated signal amplitude
0.1
0.08
0.06
0.04
0.02
0
0
5000
10000
15000
20000
Energy BEGe [channels]
19546.1, 0.0290264

Current-maximum distribution



Current-maximum discrimination

- cut-profile determination from SSE dominated regions:



Current-maximum discrimination

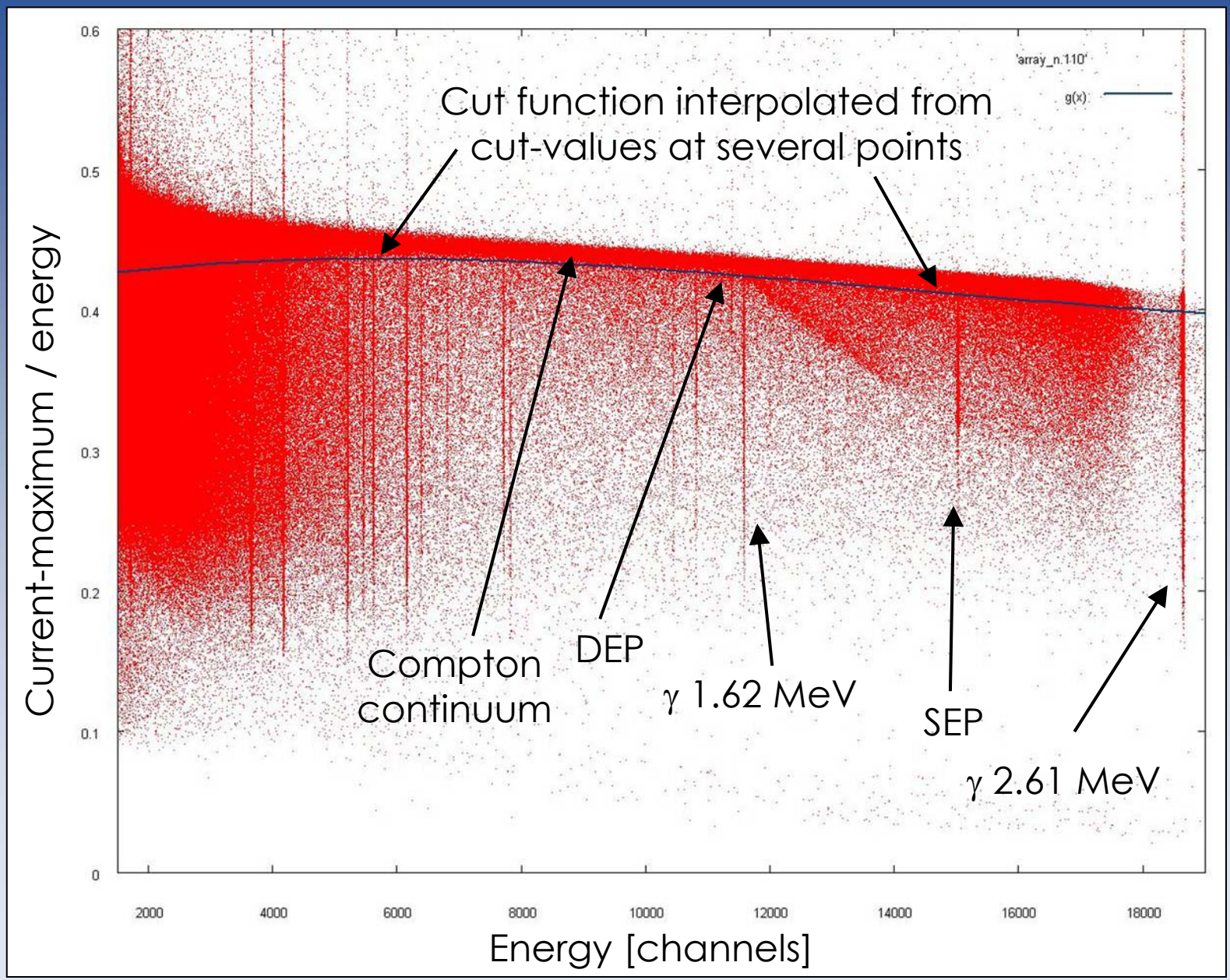
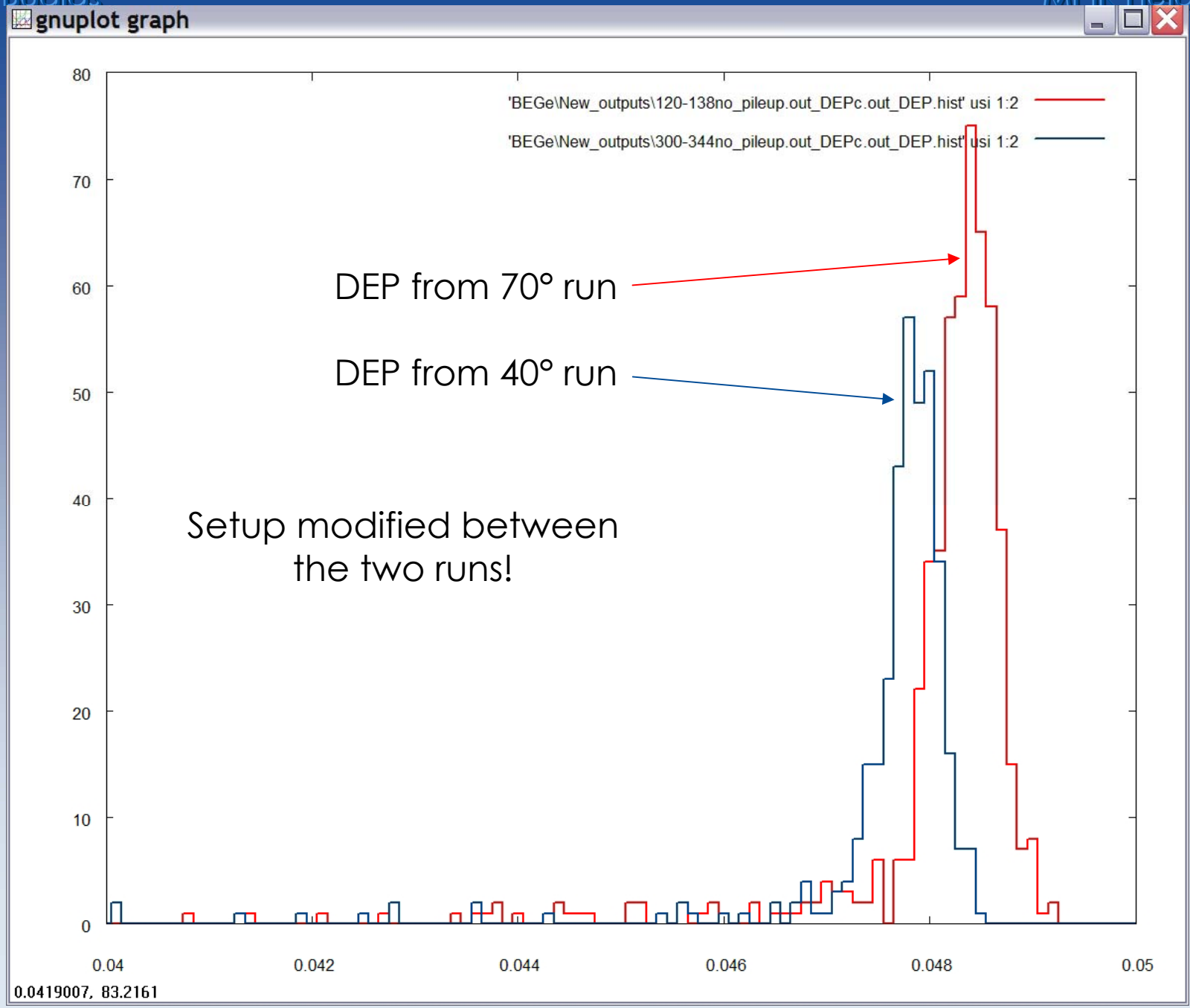
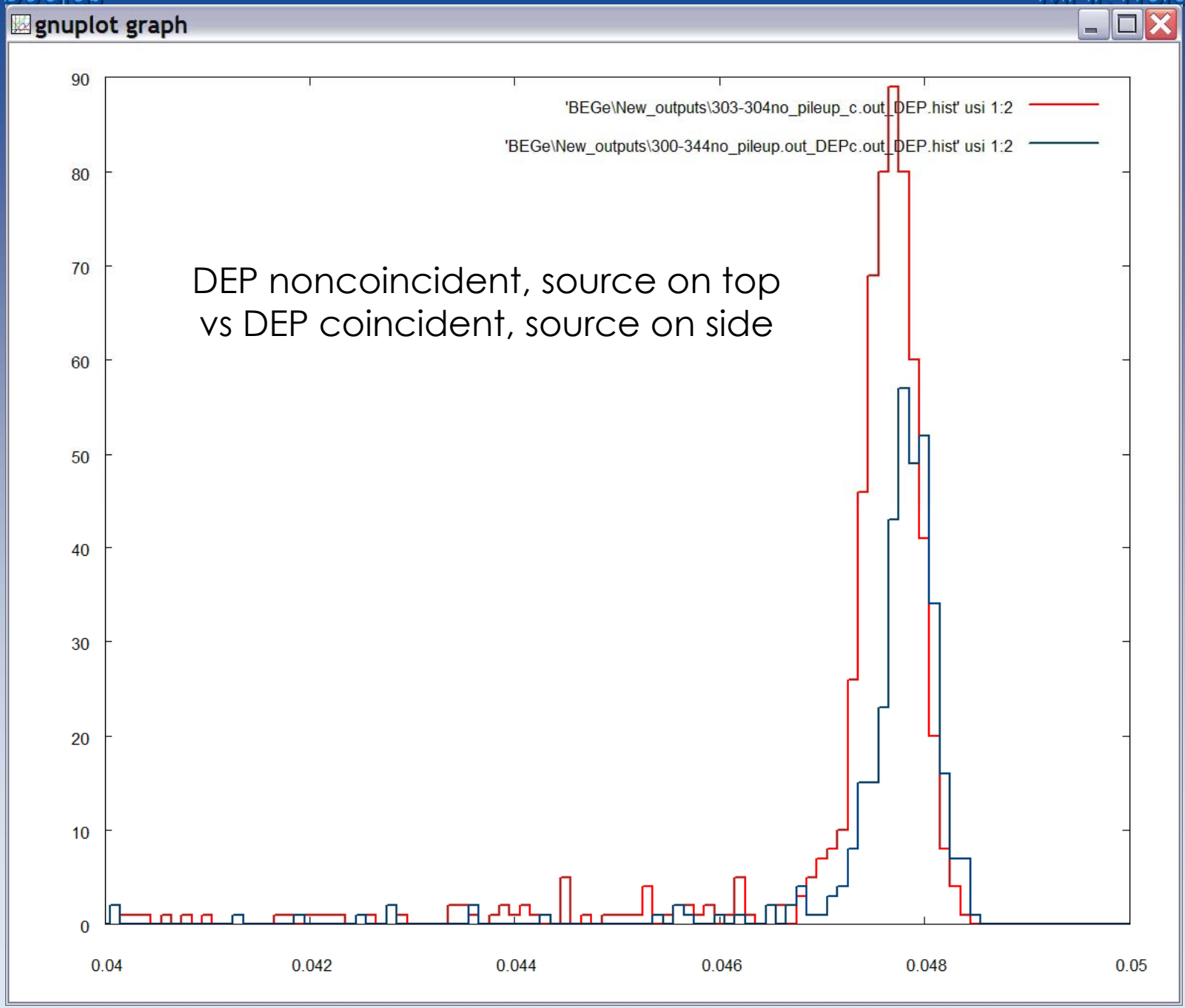
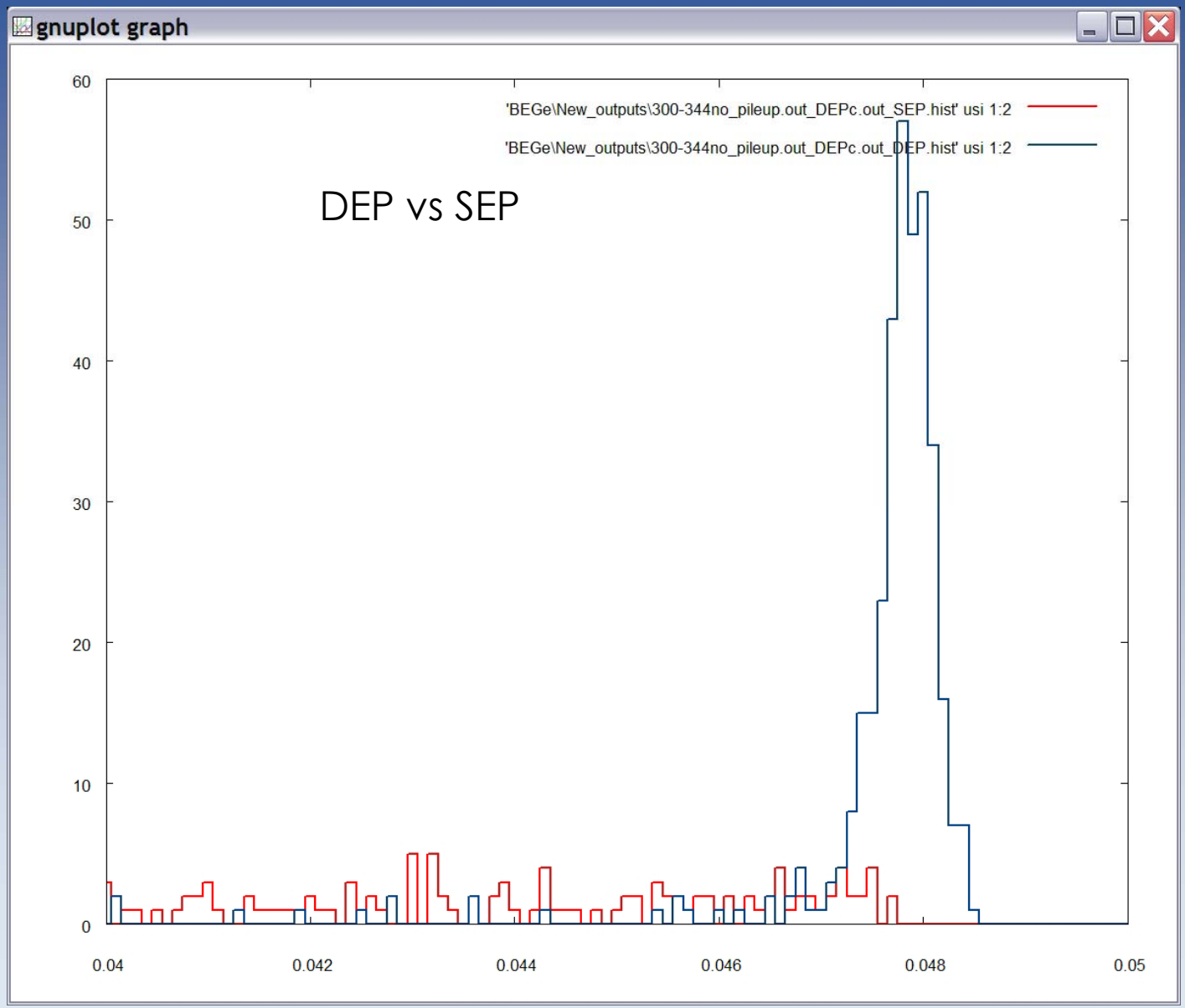


Table of results (June 08)

	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


gnuplot graph
'BEGe\New_outputs\120-138no_pileup.out_DEPc.out_DEP.hist' usi 1:2
'BEGe\New_outputs\300-344no_pileup.out_DEPc.out_DEP.hist' usi 1:2
DEP from 70° run
DEP from 40° run
Setup modified between the two runs!
80
70
60
50
40
30
20
10
0
0.04
0.042
0.044
0.046
0.048
0.05
0.0419007, 83.2161

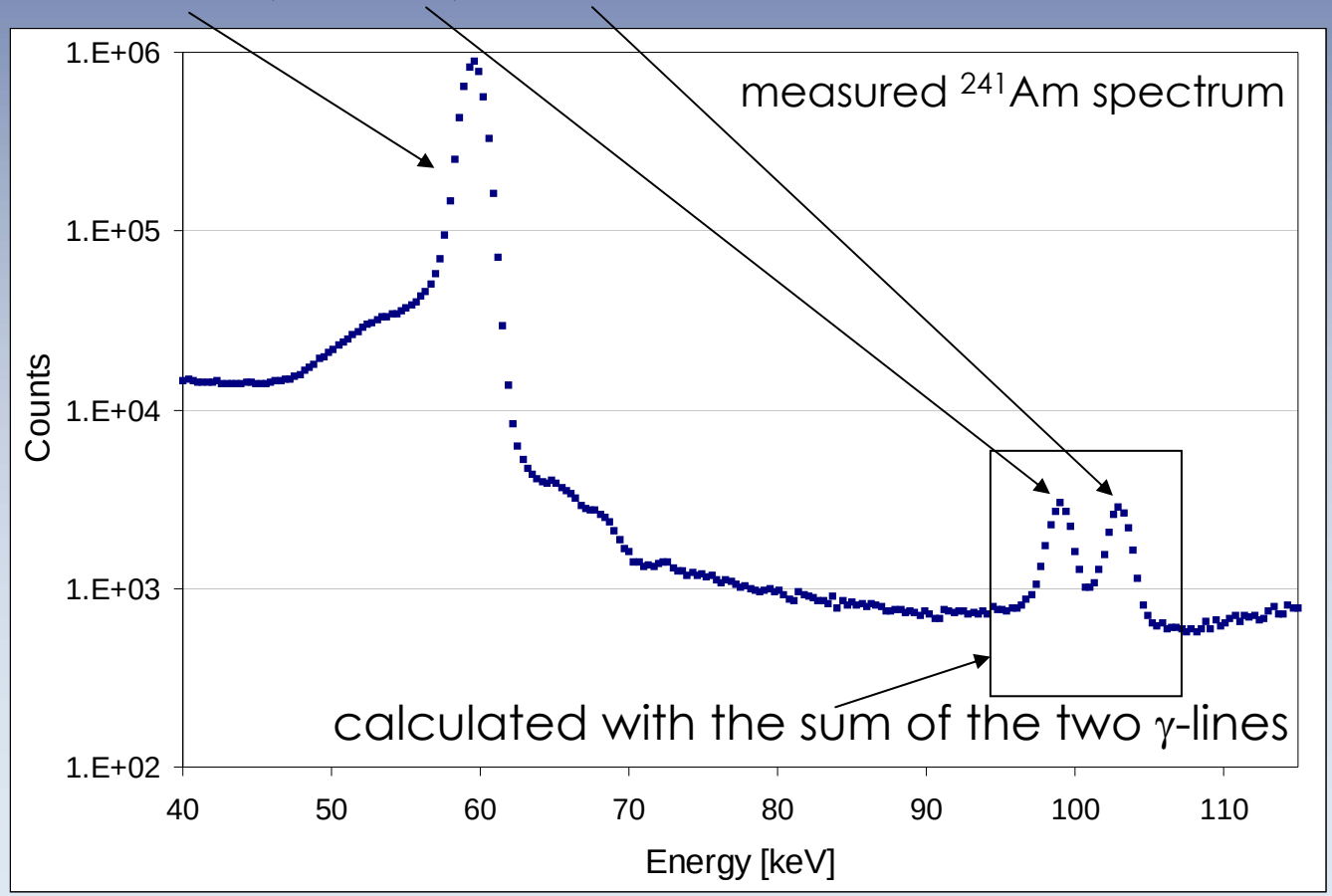

gnuplot graph
'BEGe\New_outputs\303-304no_pileup_c.out_DEP.hist' usi 1:2
'BEGe\New_outputs\300-344no_pileup.out_DEPc.out_DEP.hist' usi 1:2
DEP noncoincident, source on top
vs DEP coincident, source on side
90
80
70
60
50
40
30
20
10
0
0.04
0.042
0.044
0.046
0.048
0.05


gnuplot graph
'BEGe\New_outputs\300-344no_pileup.out_DEPc.out_SEP.hist' usi 1:2
'BEGe\New_outputs\300-344no_pileup.out_DEPc.out_DEP.hist' usi 1:2
DEP vs SEP
60
50
40
30
20
10
0
0.04
0.042
0.044
0.046
0.048
0.05

Dead layer determination

Two methods considered:

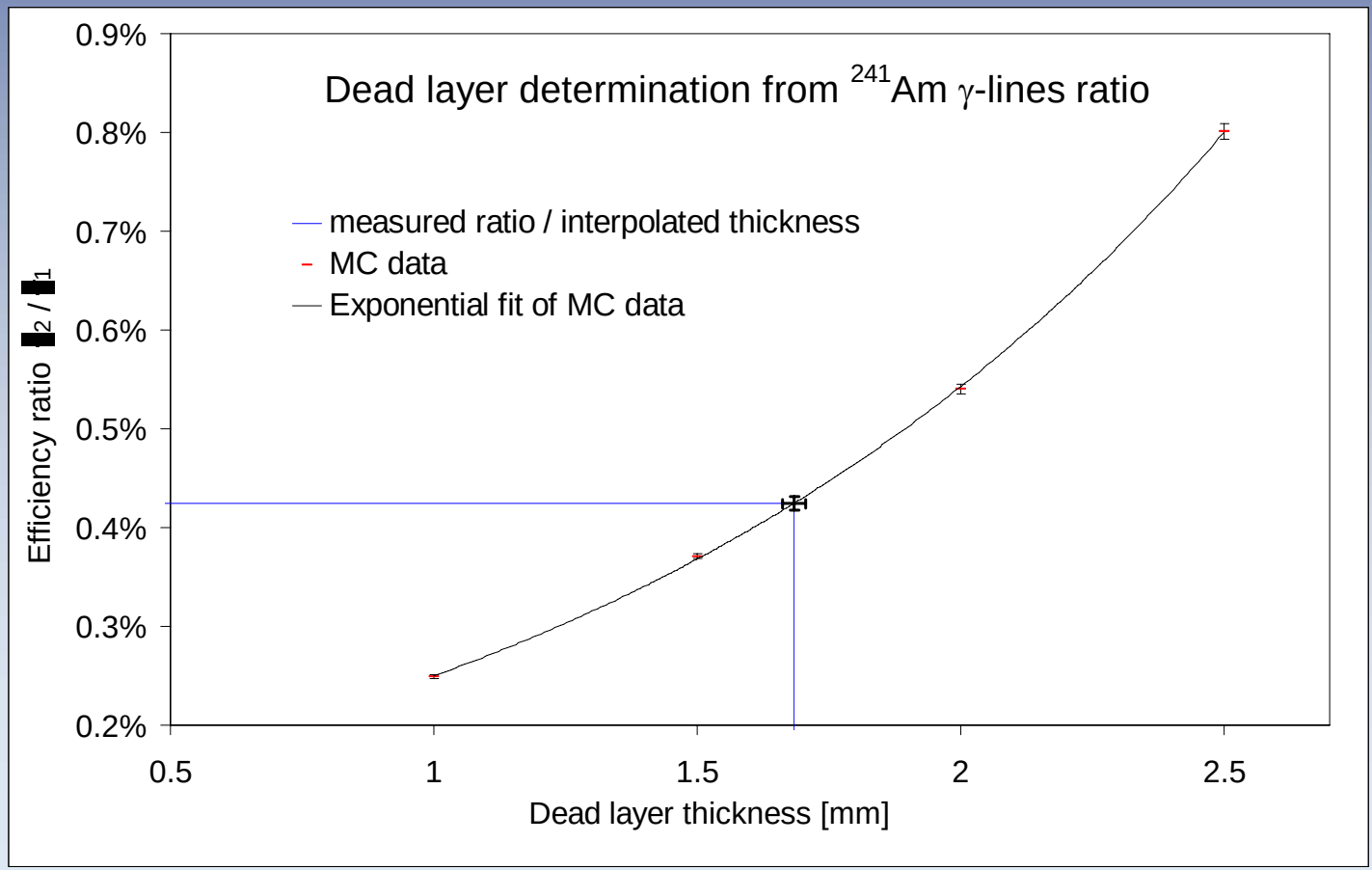
1. using **absolute countrate** in low-energy γ-lines (^{133}Ba: 81 keV, ^{241}Am: 59.5 keV)
2. using **ratio** of γ-line countrates → must use γ-lines with low energy because the size of inner borehole was not known beforehand
   ⇒ ^{241}Am: 59.5 keV, 99 keV, 103 keV



Dead layer determination

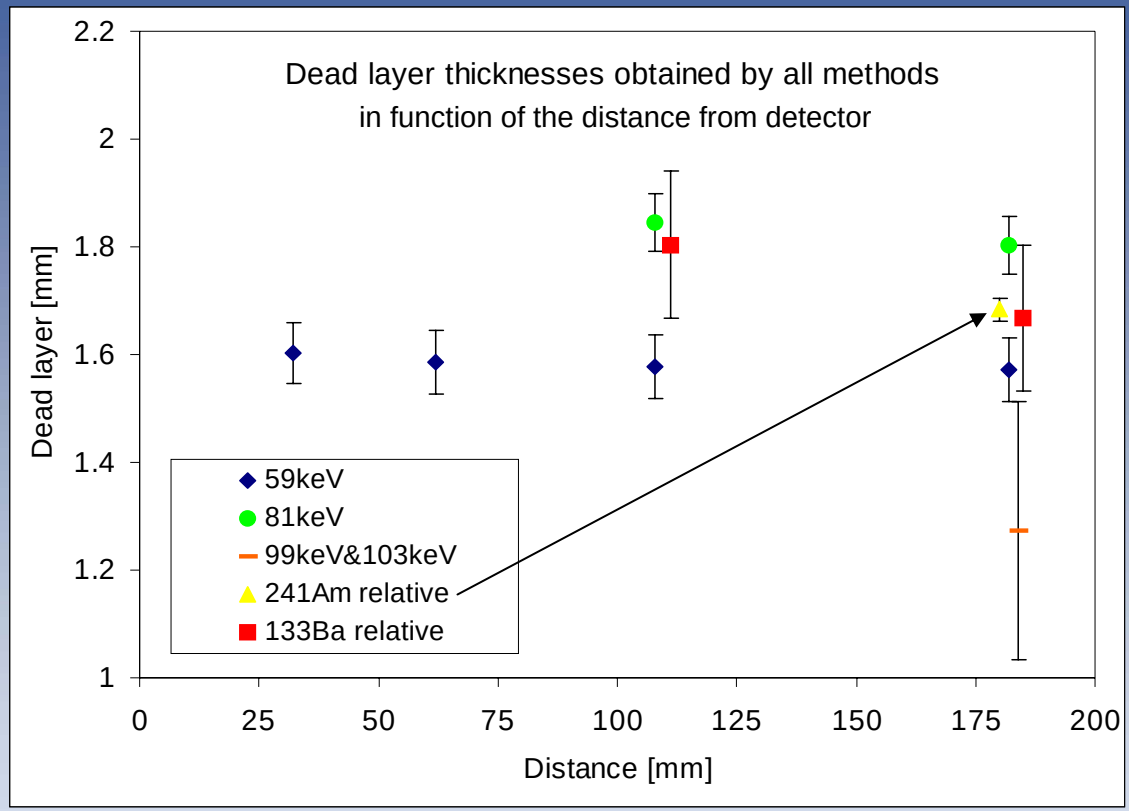
Example of front dead-layer determination using ratio of ^{241}Am γ-lines:

- **MC simulations** performed with different dead-layer thickness values
- **exponential dependancy** of line ratio derived from MC data
- interpolated the dependancy to the **measured γ-line ratio**



Dead layer determination

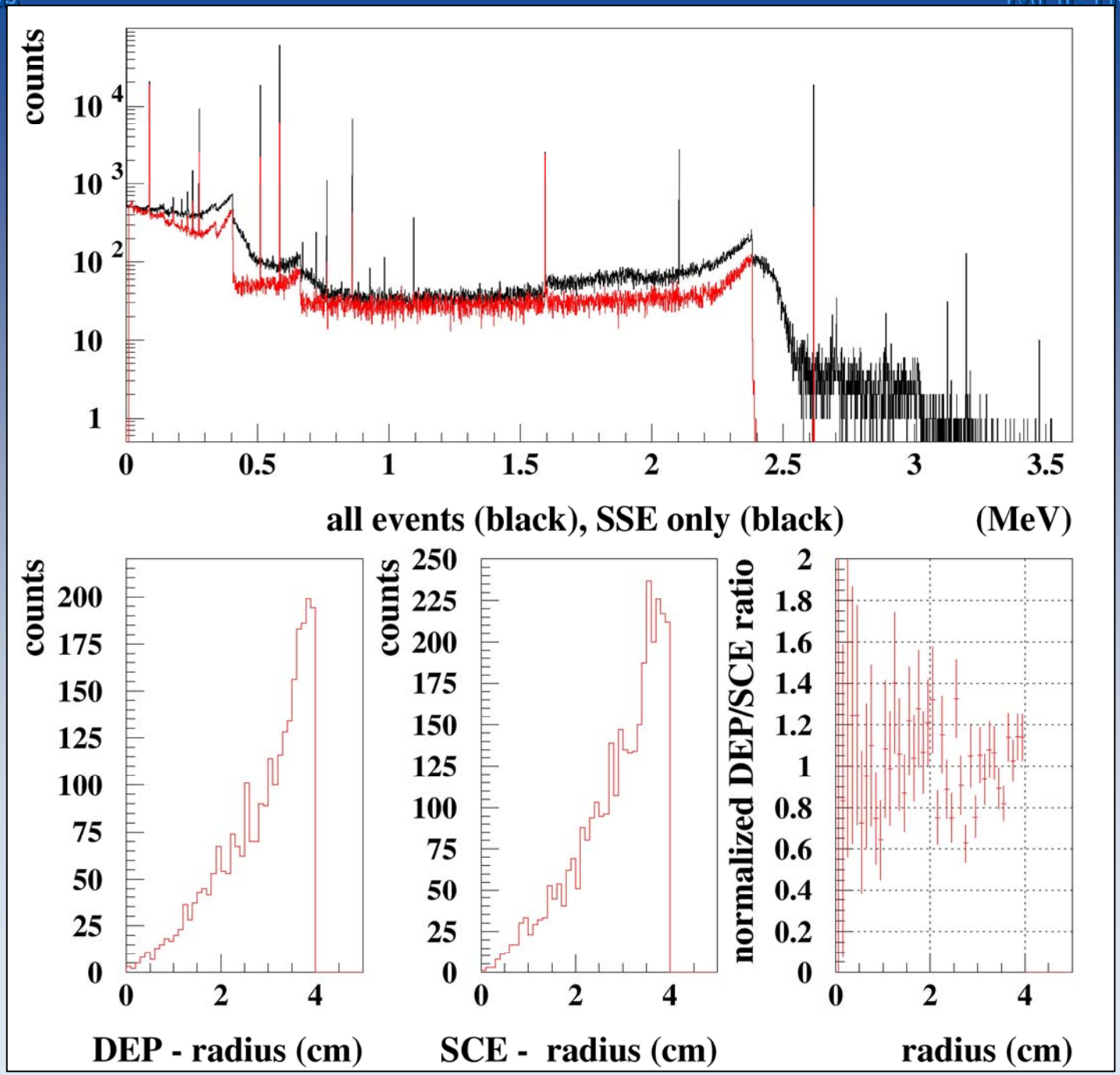
Similar interpolation also with single-line / absolute-countrate method.



Only the result obtained from ^{241}Am with the **ratio** method was used:

- does not depend on **activity** of the source
- does depend only little on source **distance** and other factors (dead time...)
- does not depend on the unknown **borehole-dimensions**

⇒ fewer **uncertainties**


counts
all events (black), SSE only (black)
(MeV)
counts
DEP - radius (cm)
counts
SCE - radius (cm)
normalized DEP/SCE ratio
radius (cm)