Results of the 70x30 Broad Energy Germanium detector under test at LNGS

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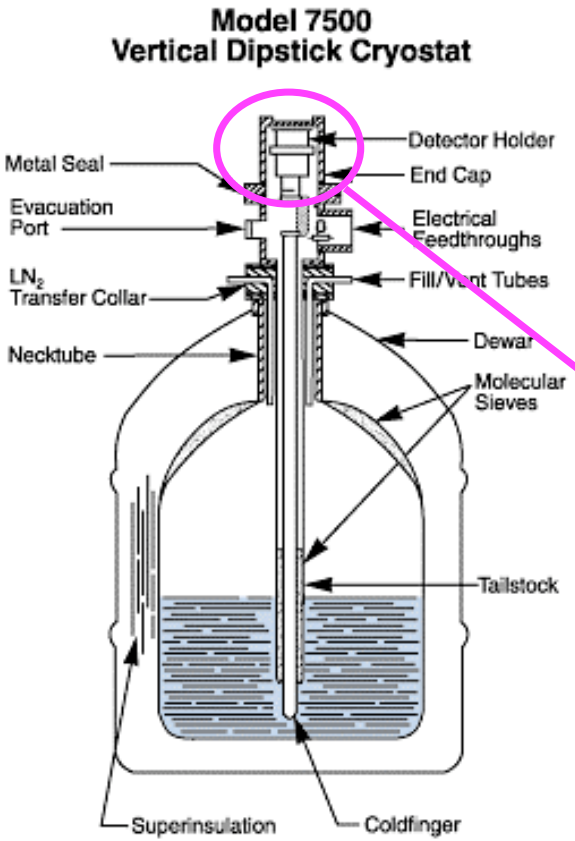
Broad Energy Germanium detector: specifications from Canberra

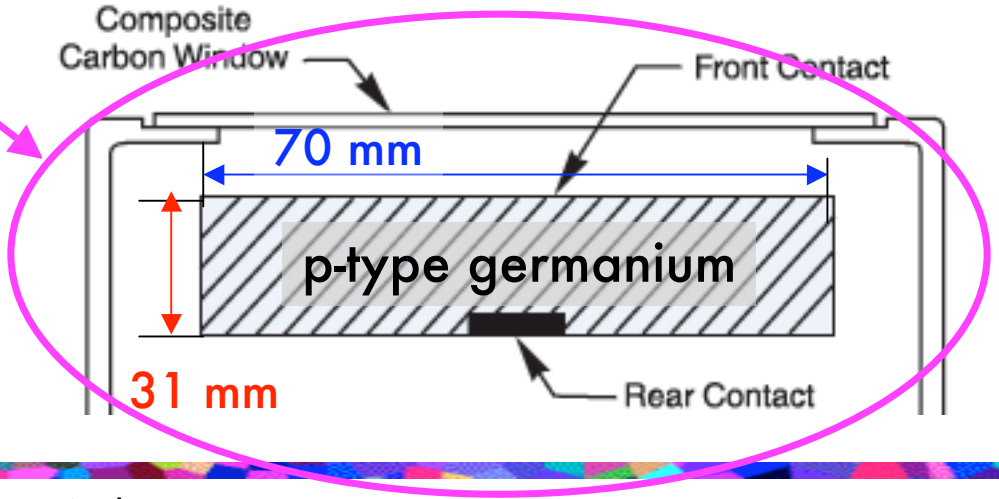
Detector model BE3830/s
Preamplifier model 2002CSL
Depletion voltage +3000 V
Recommended bias voltage +3500 V

Resolution and Efficiency:

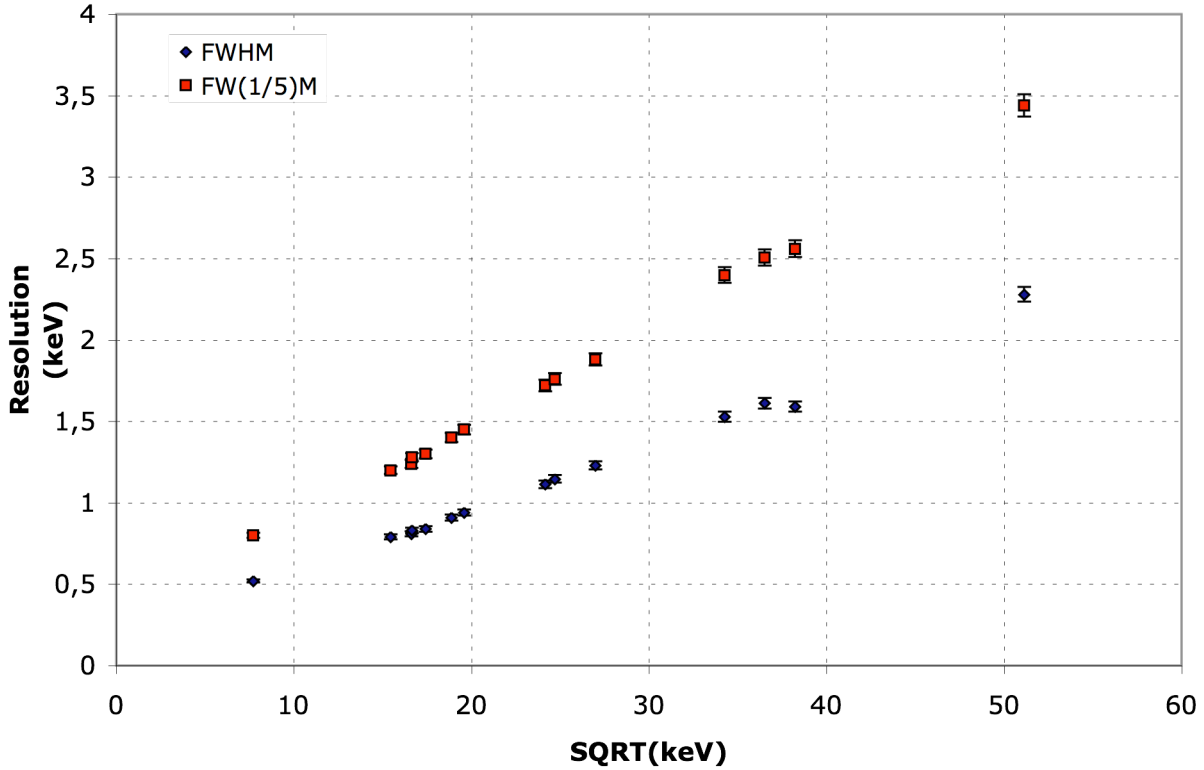
Energy [keV]	Resolution [keV]
122	0.639
1332.5	1.752

Typical relative efficiency ≥ 34%





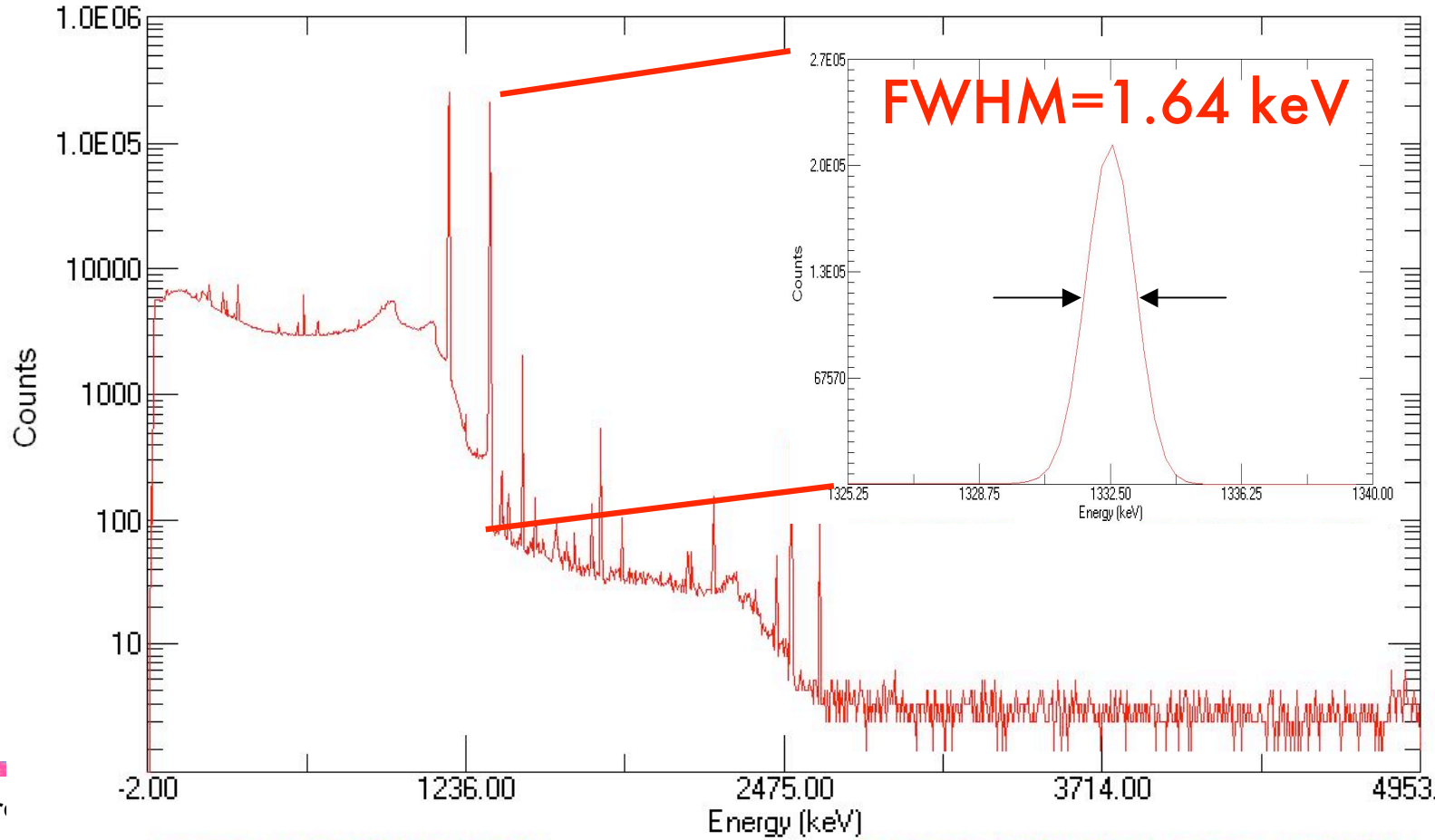
Detector performance: energy resolution



source	Energy (keV)	FWHM (keV)	FW(1/5)M (keV)
^{241}Am	59.5	0.50	0.92
^{137}Cs	661.15	1.19	1.89
^{60}Co	1173.4	1.529 ± 0.011	2.398
^{22}Na	1274.6	1.62	2.59
^{60}Co	1332.8	1.612 ± 0.022	2.507

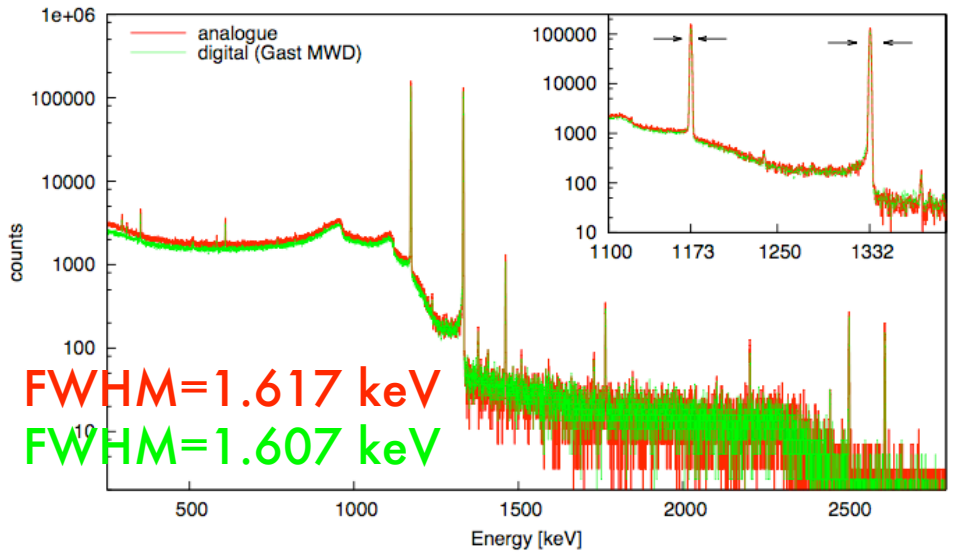
^{60}Co spectrum with analog electronics

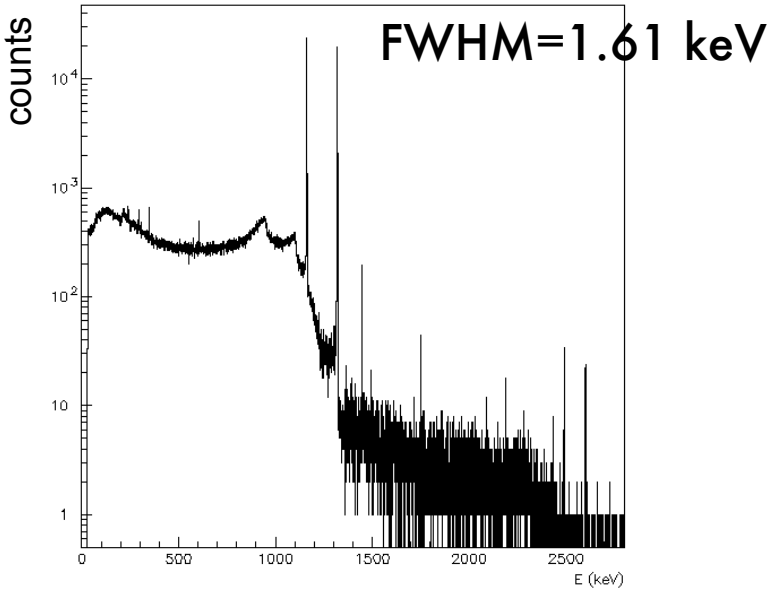
Spectrum obtained by irradiation of the BEGe with a ^{60}Co source (≈15 kBq) for 11 h. It is recorded with the traditional analog electronics (spectroscopy amplifier+ADC).



^{60}Co spectrum with digital electronics

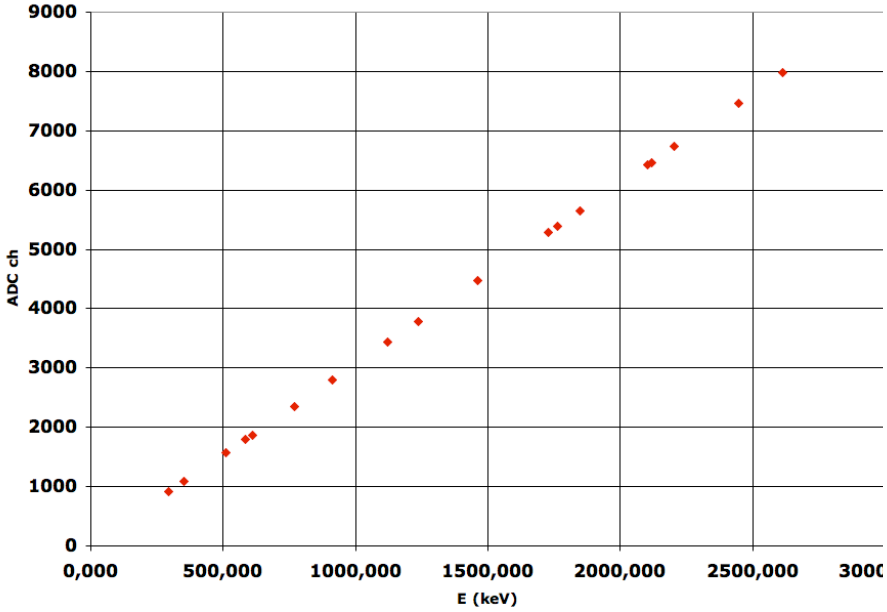
- CAEN N1728B NIM FADC, 4ch, 14 bit resolution, 100 MHz sampling rate.
- Energy reconstruction both by Moving Window Deconvolution Gast algorithm and by Jordanov algorithm.

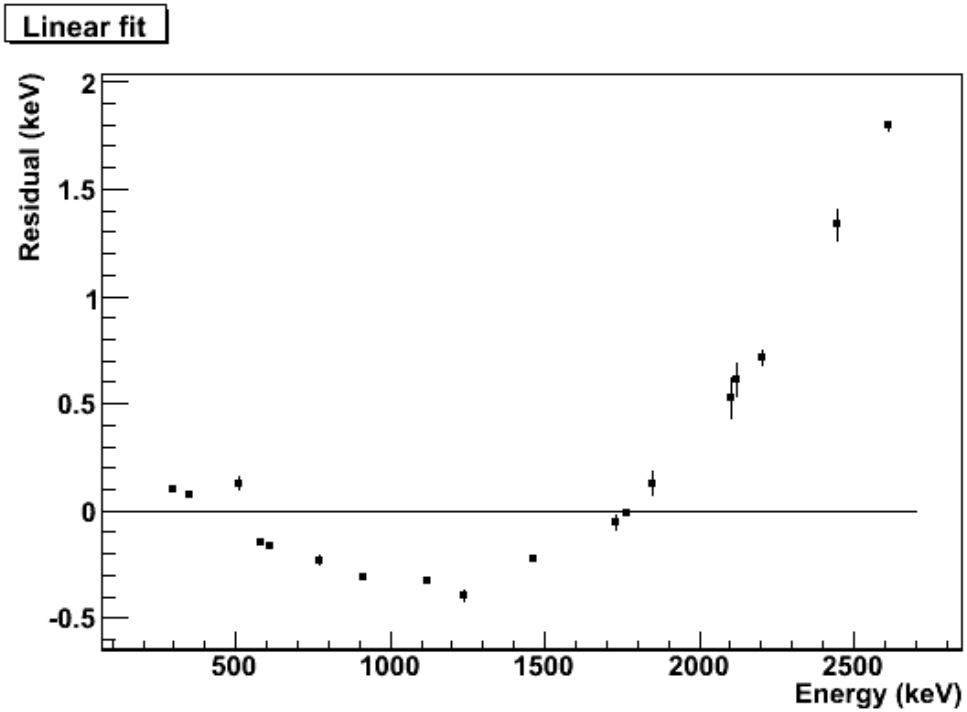




Both methods provide the same energy resolution as traditional analog electronics.

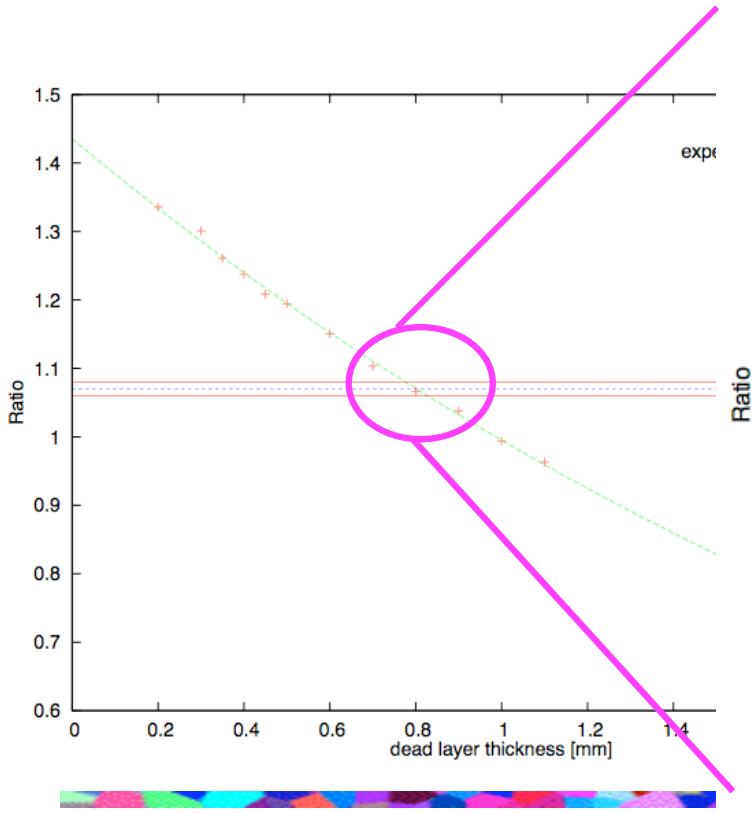
Linearity

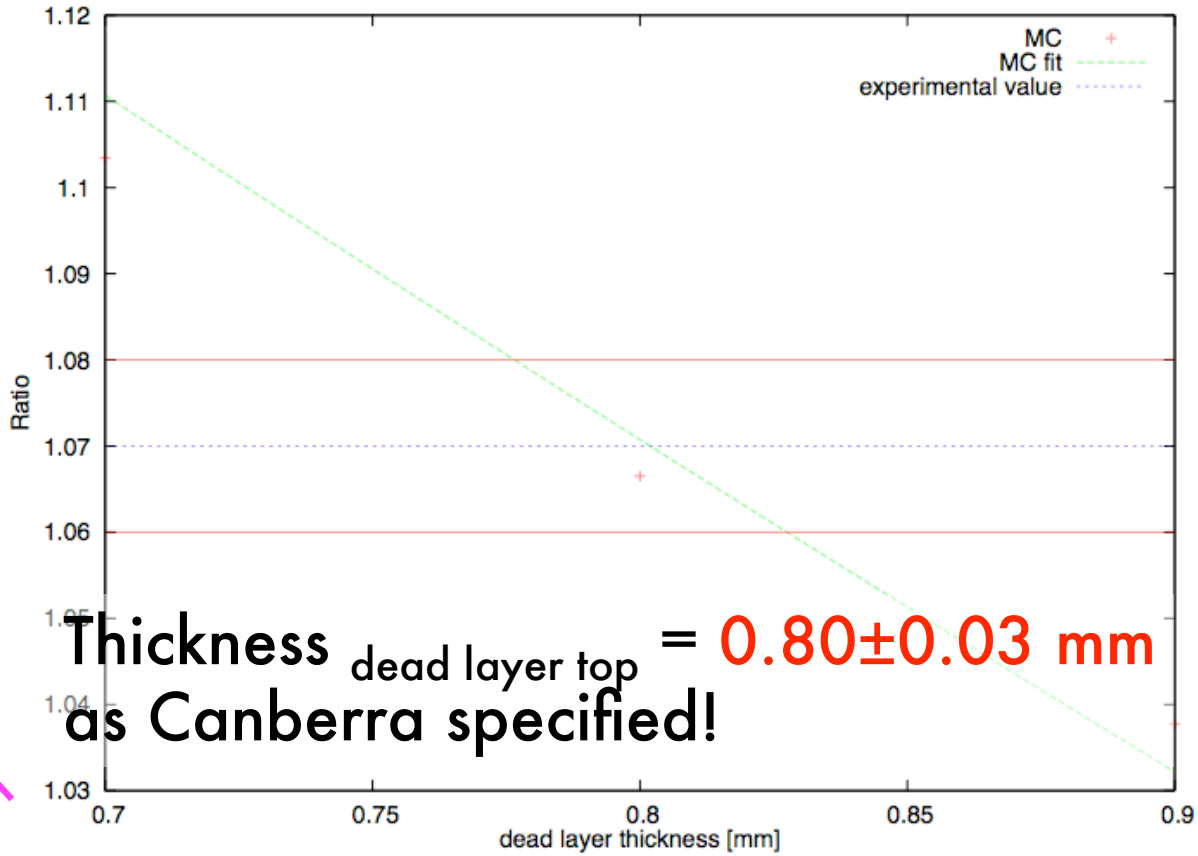

9000
8000
7000
6000
5000
4000
3000
2000
1000
0
ADC ch
0,000
500,000
1000,000
1500,000
2000,000
2500,000
E (keV)


Linear fit
Residual (keV)
2
1.5
1
0.5
0
-0.5
500
1000
1500
2000
2500
Energy (keV)

Dead layer thickness estimation: top face

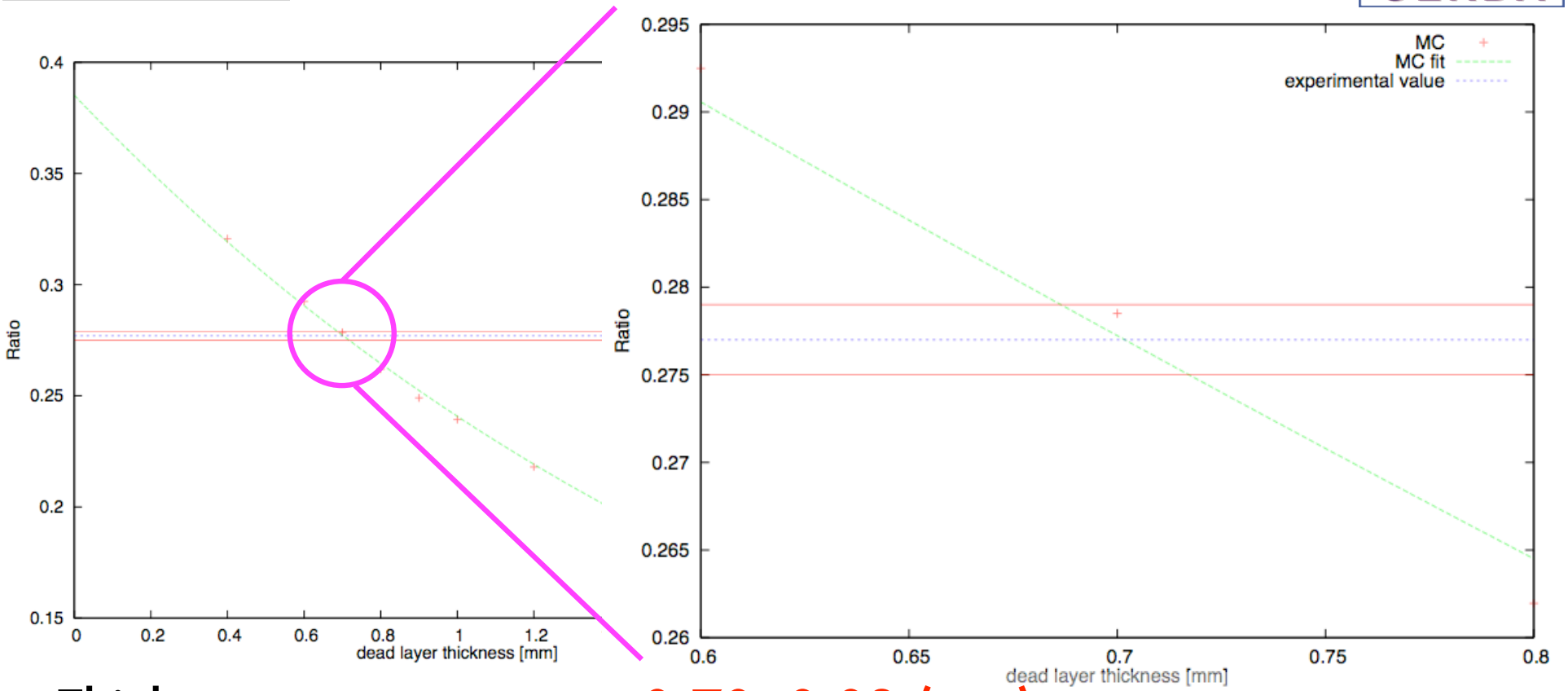
Dead layer thickness is estimated irradiating the detector (top and lateral surface) with a ^{133}Ba source and comparing the ratio of the counting rate of the two lines, E_1=81 keV and E_2=356 keV, to the Monte Carlo Simulation.





Thickness $_{\text{dead layer top}}$ = 0.80±0.03 mm as Canberra specified!

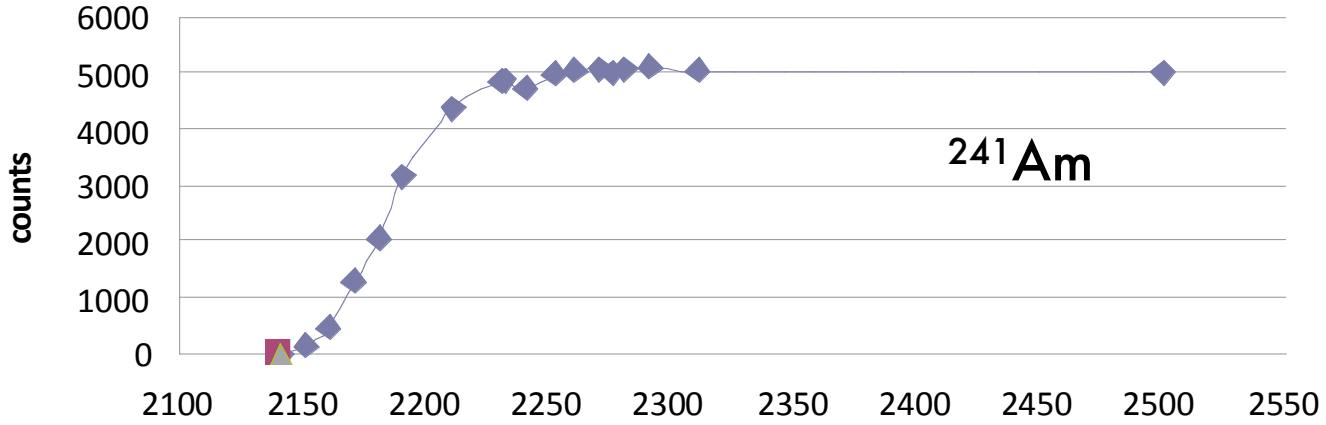
Dead layer thickness estimation: lateral surface

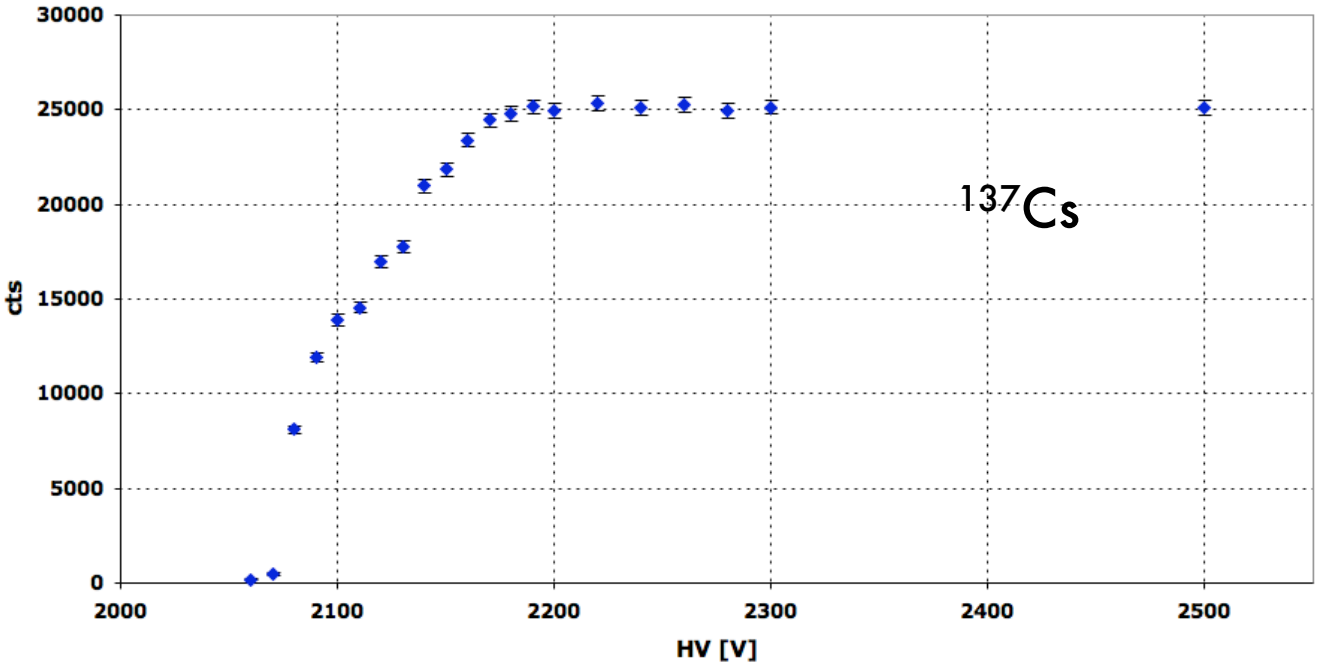


Thickness $_{\text{dead layer lateral}}$ = 0.70±0.03 (stat) mm

Larger systematic uncertainty due to the non precise knowledge of the simulated geometry (thickness of Cu holder)

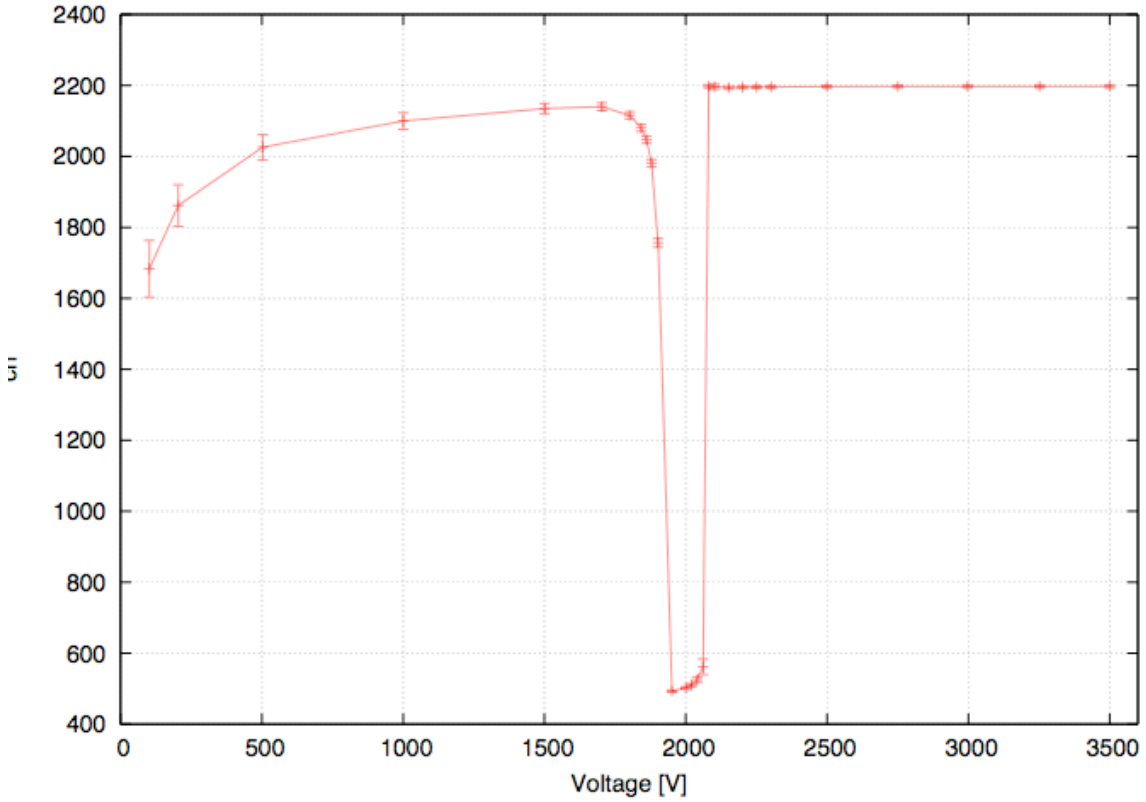
Counting rate versus HV (1)





- Counting Rate (CR) is constant for HV>2250 V, the depletion voltage specified by Canberra is 3000 V;
- energy resolution is constant down to 2250 V

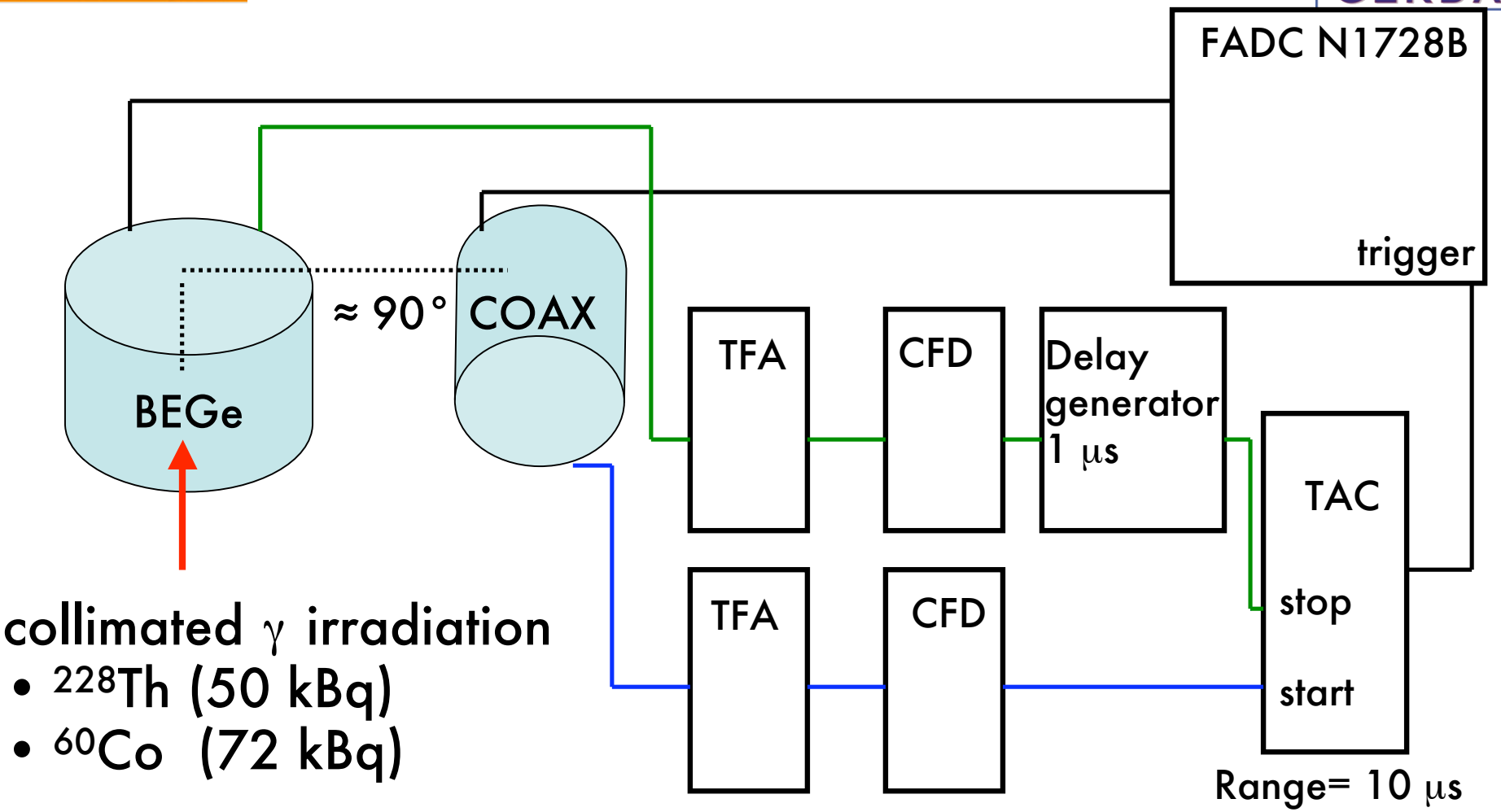
Counting rate versus HV (2)



Irradiation by ^{137}Cs source (100 kBq) at 10 cm from the end cap

An anomaly is observed in the range 1900V-2100V where also the shape of the signals is considerably different respect to other HV bias values.
This is most probably due to the electric field configuration inside the detector.

Coincidence measurement

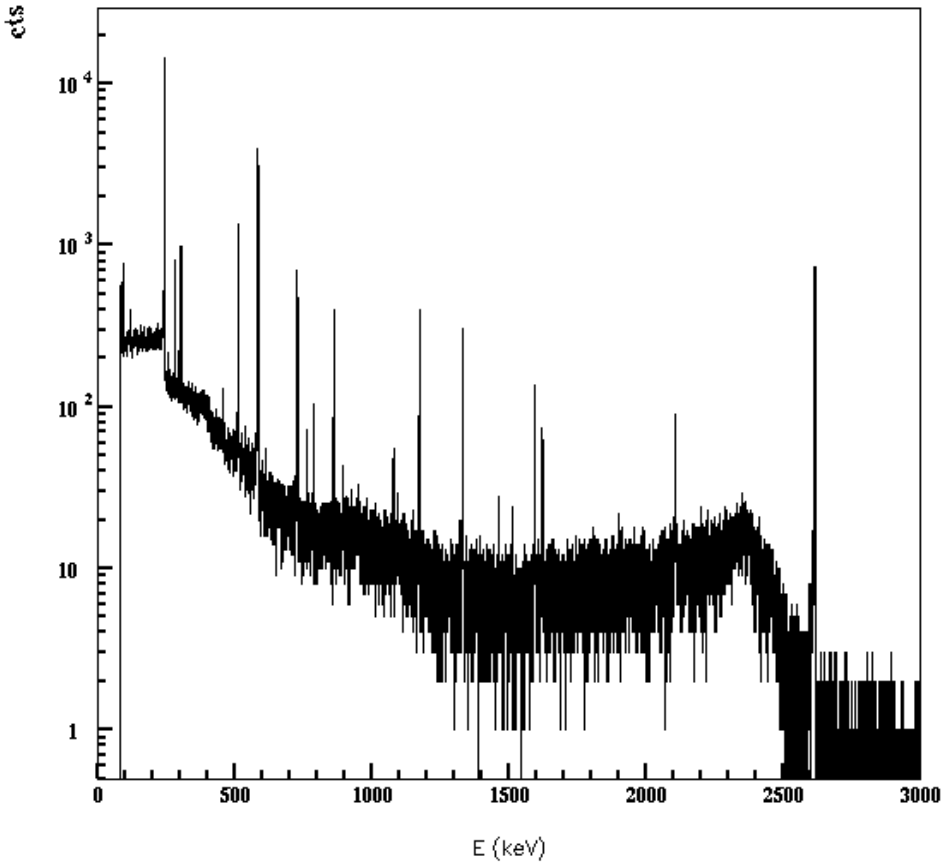


collimated γ irradiation

- ^{228}Th (50 kBq)
- ^{60}Co (72 kBq)

First step: pulse shape analysis of ^{228}Th + ^{60}Co spectrum for calibration

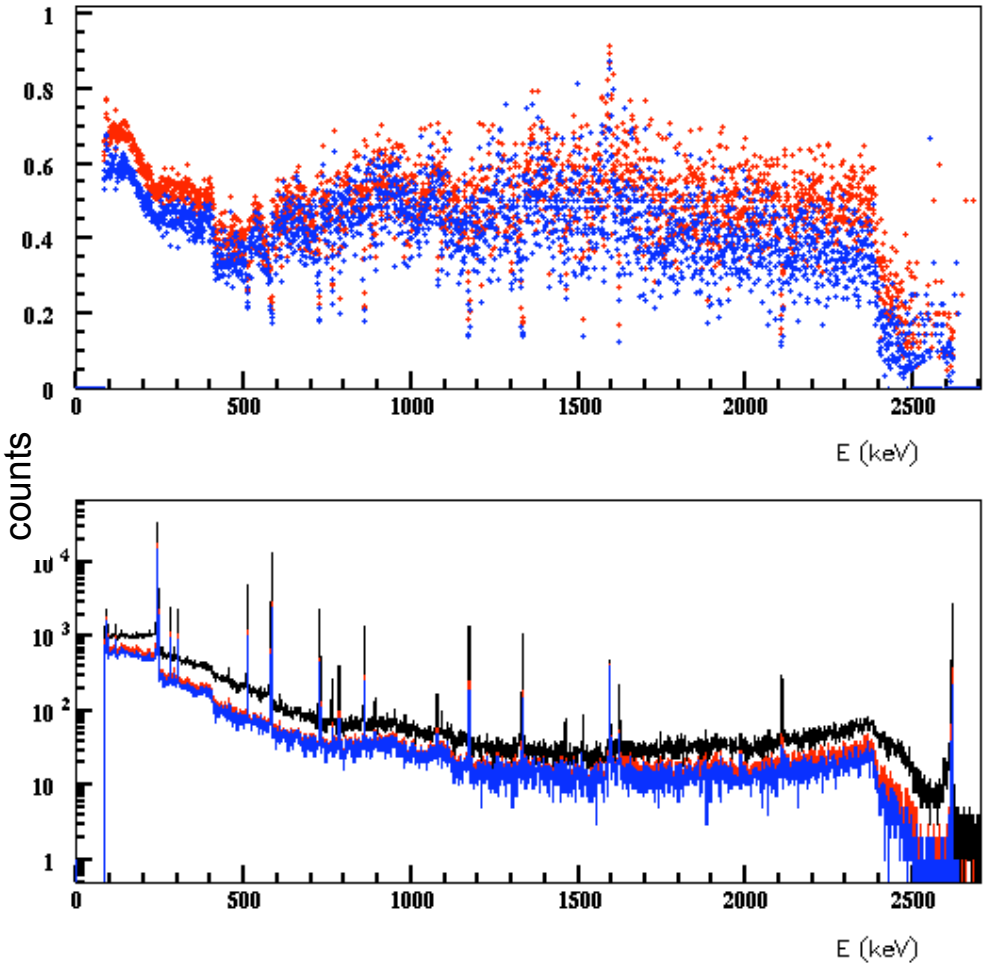
BEGe spectrum acquired for the calibration with digital electronics irradiating the BEGe simultaneously with both a ^{228}Th source (50 kBq) and a ^{60}Co source (low intensity). Trigger given by OR of the signals. Acquisition time ≈ 1 h, Number of events ≈ $1.6 \cdot 10^6$

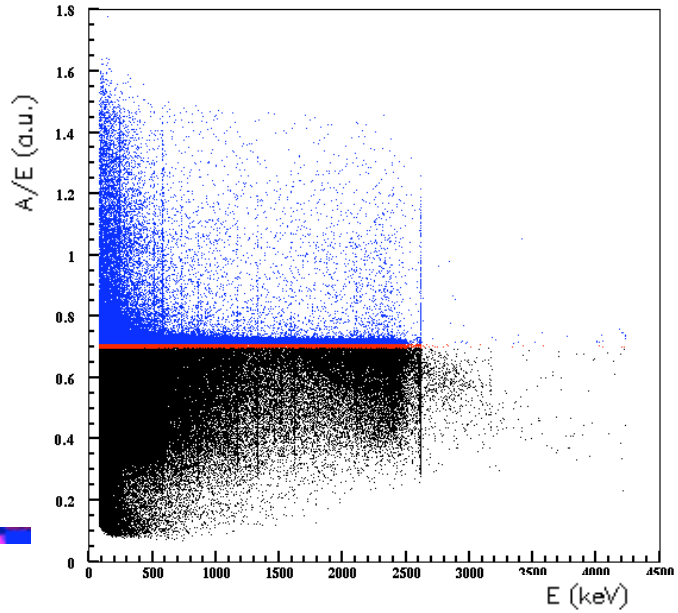


SSE acceptance: a global view

- BEGe spectrum without any cut
- CUT1: A/E threshold for acceptance is determined fitting the A/E ratio taking into account all the events (A/E thrshold =mean value(A/E)-3σ)
- CUT2: A/E threshold only from the DEP

→ mean value (A/E) constant but σ smaller

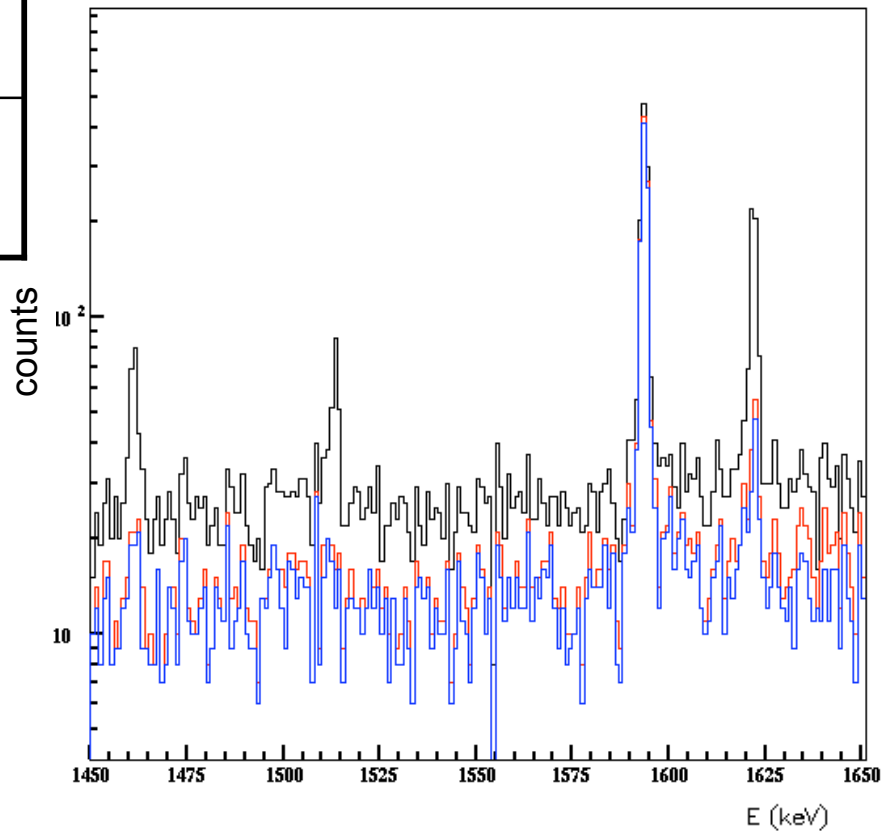




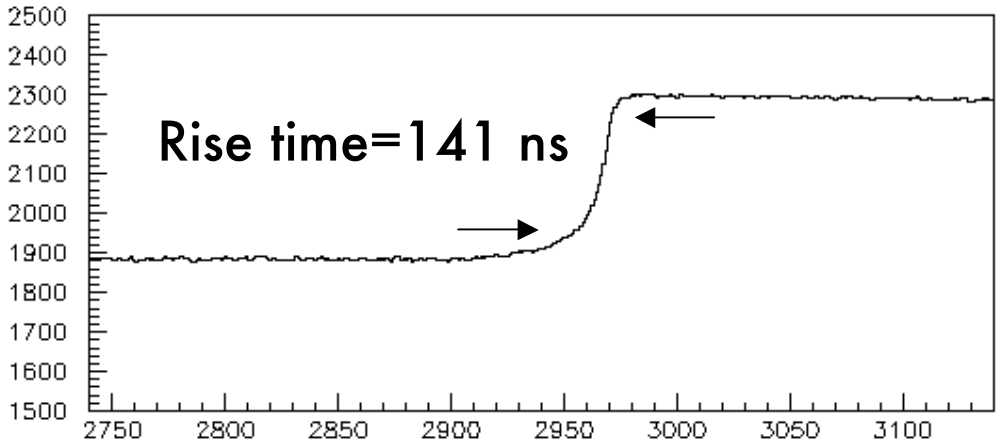
SSE acceptance at DEP and at the 1620 keV γ line

	DEP	1620 keV
CUT 1 A/E on all events	89% 98%	26% 18 %
CUT 2 A/E on DEP	86% 94%	22% 13%

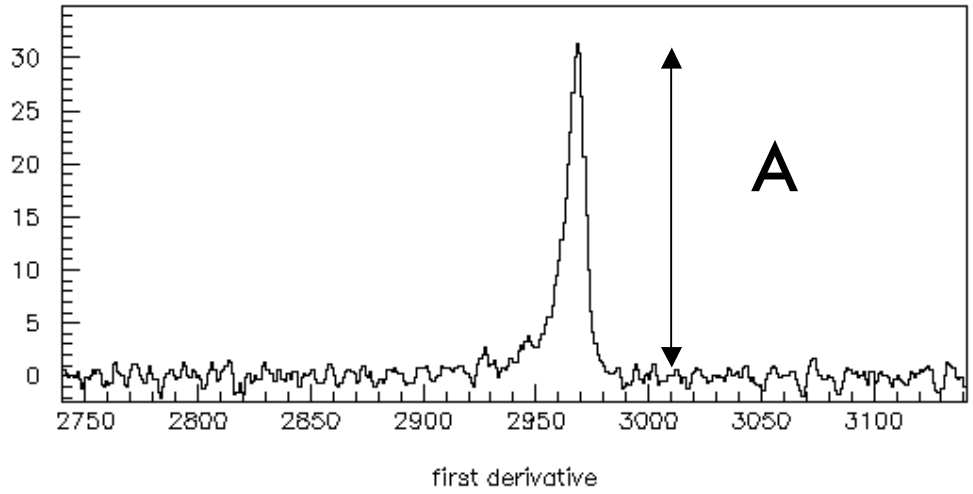
with background subtraction (more refined analysis in progress)



Some pulses and corresponding differentiated pulses: single site event

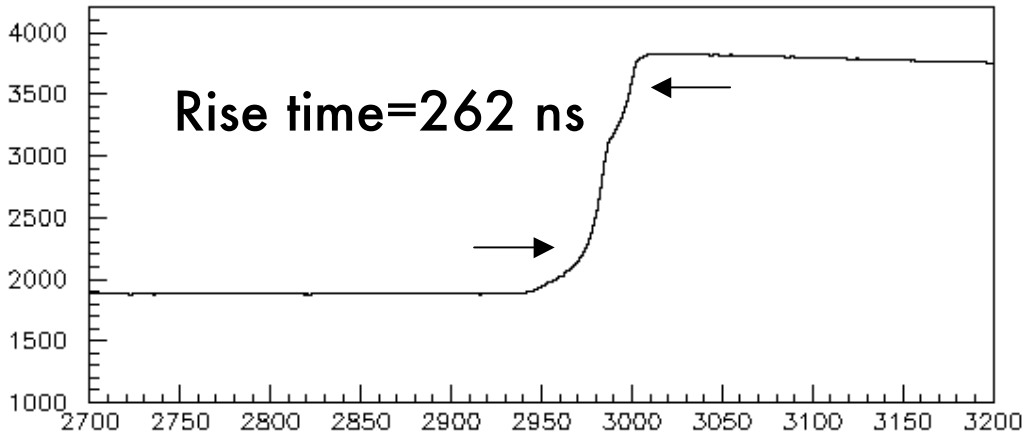


E=846 keV

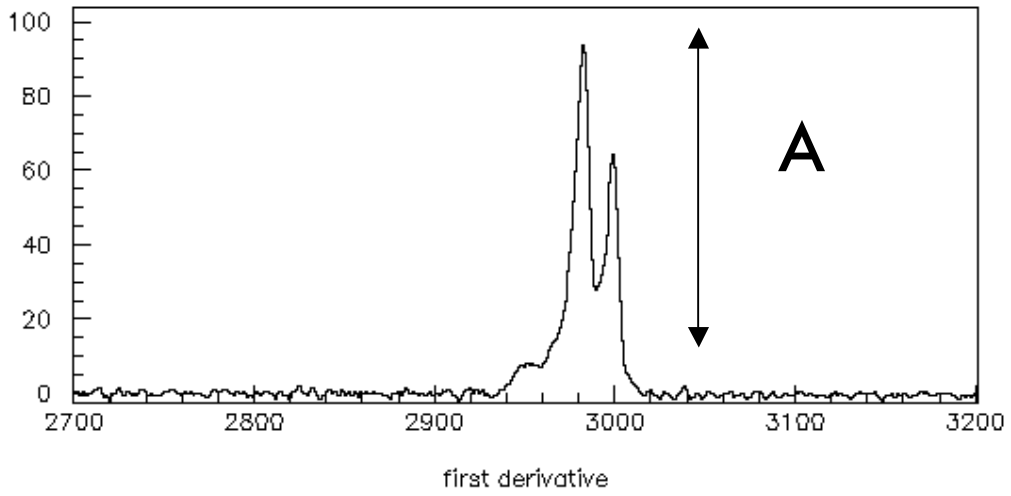


A/E=0.723 a.u.
–> single site event

Some pulses and corresponding differentiated pulses: multi site event



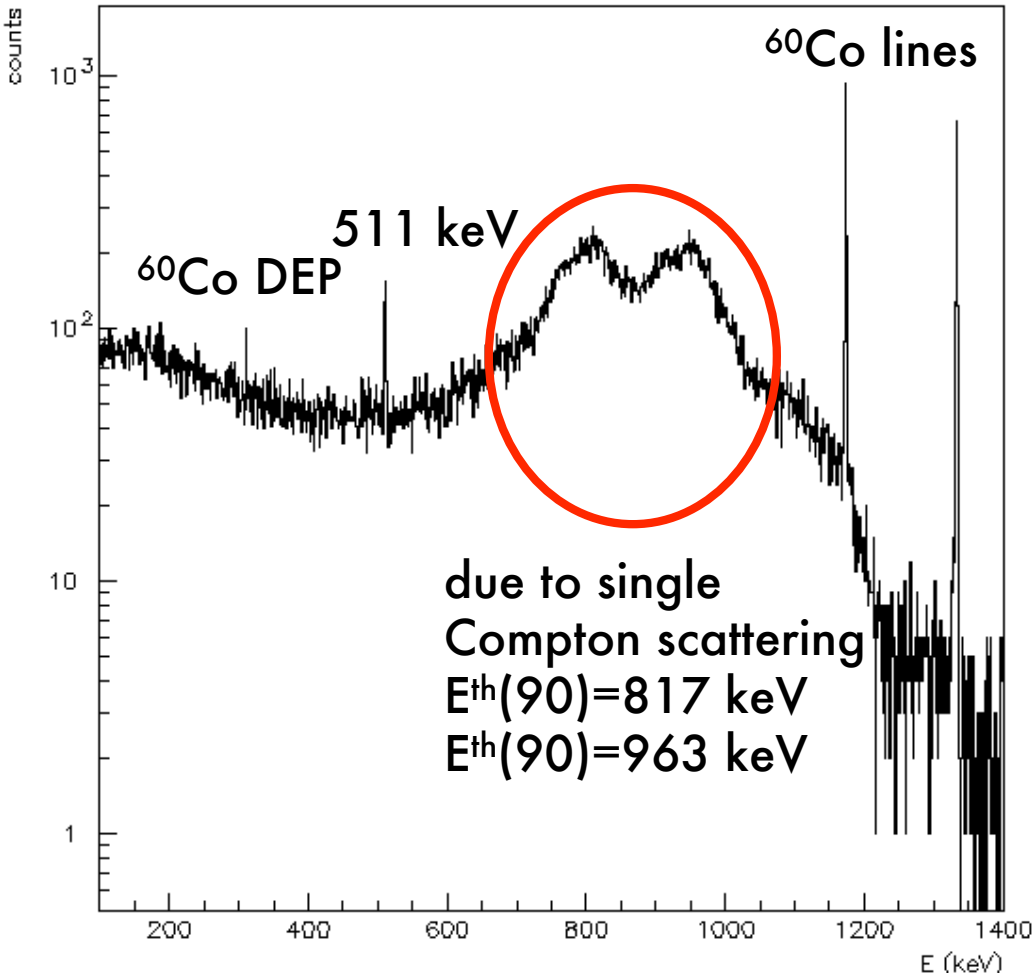
E=726 keV



A/E=0.448 a.u.
–> multi site event

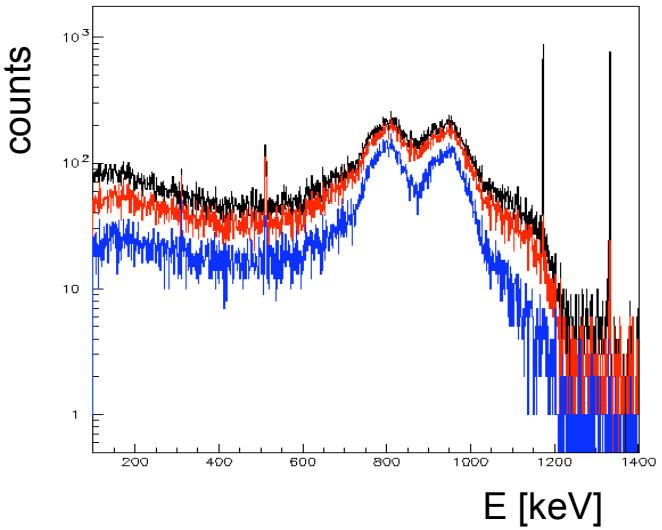
Second step: coincidence with ^{60}Co irradiation

Purpose: to have a population enriched in Single-Site events selecting mainly those events in which a ^{60}Co γ undergoes a unique Compton scattering before escaping.

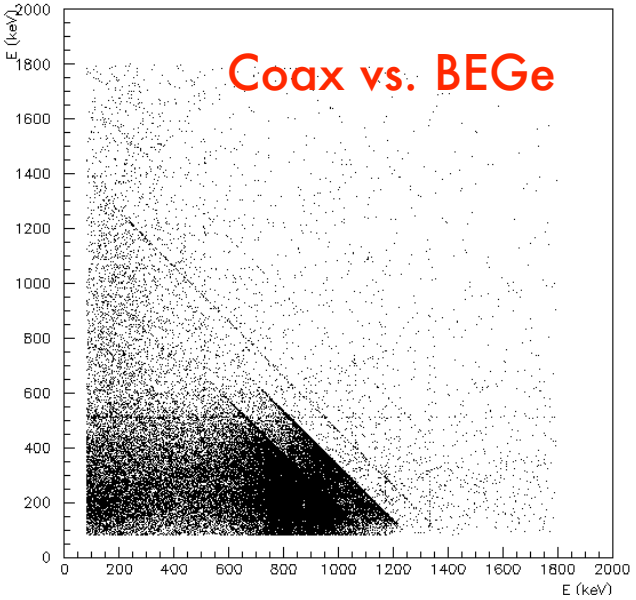


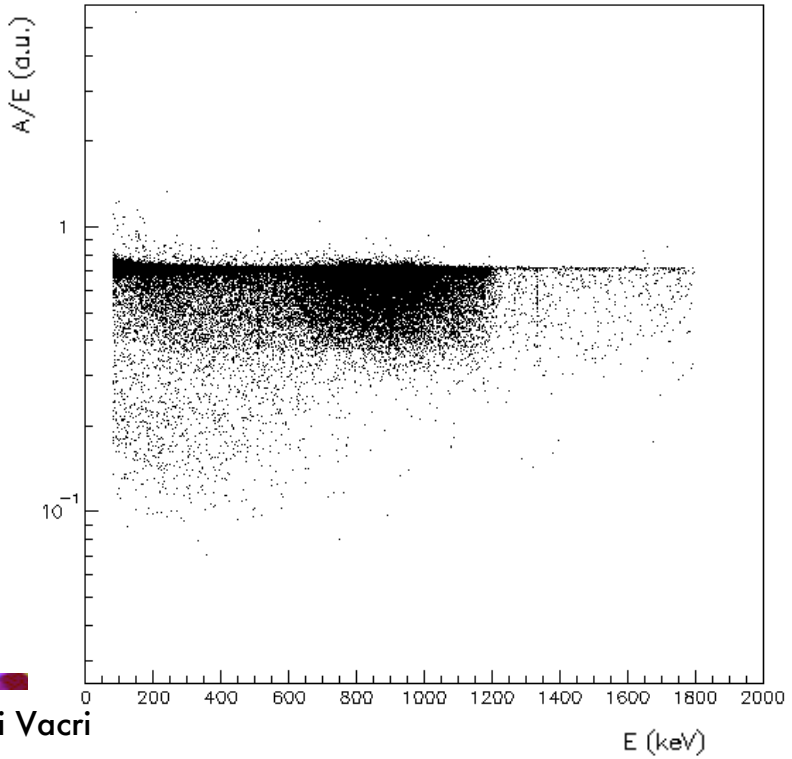
- BEGe coincidence spectrum obtained irradiating the BEGe by a 72 kBq collimated source. The coaxial detectors does not "see" directly the source.
- Acquisition time ≈ 69 h
- Total numbers of events before every possible cut: 111997 events

Pulse shape analysis and SSE acceptance



- BEGe spectrum without any cut
- selecting events in coincidence on the basis of distribution of Δt=t(BEGe)-t(Coax) to reject accidentals
- in coincidence + cut on the ratio A/E.

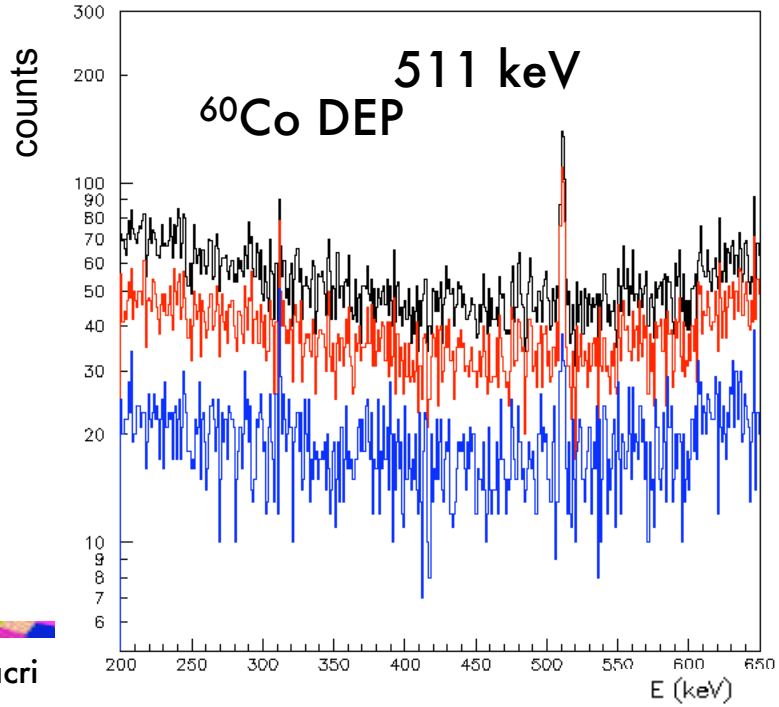




SSE acceptance

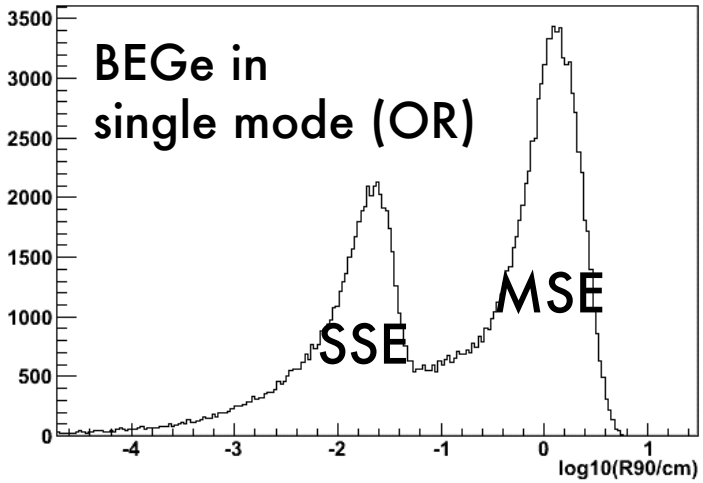
	200-600 keV	656-1077 keV	1162-1346 keV	DEP	511 keV
Coincidence RUN Trigger=AND	49%	61%	26%	42% 94%	23% 21%
RUN in single mode Trigger=OR	53%	54%	29%	–	–

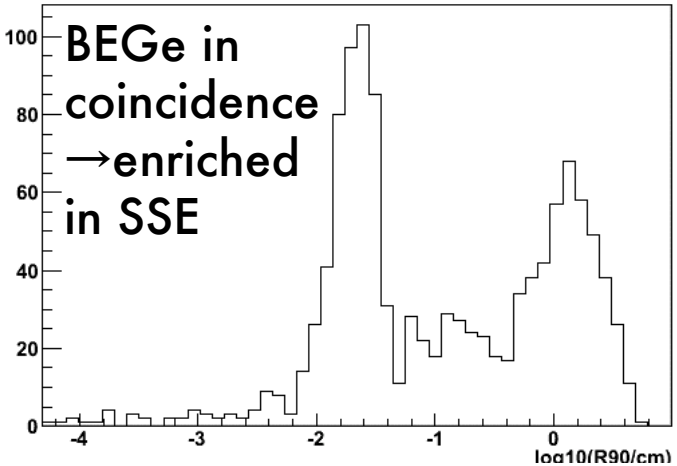
with background subtraction (a more refined analysis in progress)

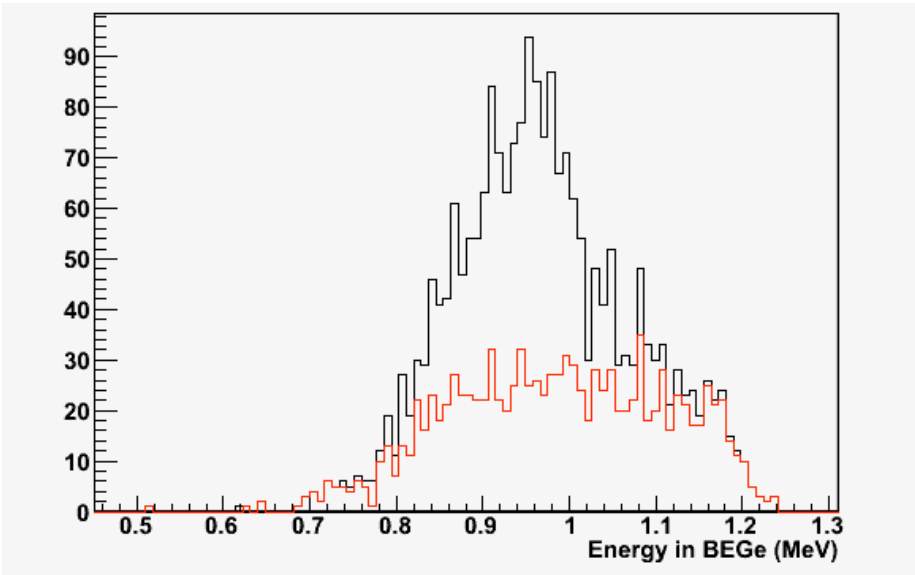


Comparison with MC simulation

R90: radius within 90% of the energy is released.
SSE → R90 ≈ mm or less / MSE→ R90 is few mm.







BEGe simulated energy spectrum requiring the condition:

1) $E_{BEGe}+E_{coax}=1332$ keV

2) Selecting only MSE (R90>1 mm)

⇒ ≈ 1/3 of the events in the single Compton scattering blob are MSE. Compatible with the experimental result (61% acceptance in the corresponding E range)

Conclusions and perspectives (I)

- A 70 mm diameter BEGe detector from Canberra was delivered at LNGS in March 2009.
- It has been completely characterized:

  energy resolution → FWHM = 1.6 keV @ ^{60}Co both with analog and digital electronics;

  linearity → it presents a non-linearity;

  depletion voltage → it is already depleted at 2.3 kV, nominal value is 3 kV and operation voltage 3.5 kV;

  estimation on the dead layer → 0.8 mm on the top and 0.7 mm on the lateral surface in agreement with the Canberra specification.
- Preliminary results on the pulse shape analysis based on the cut on the ratio A/E are the following (without background):
  - >86% SSE acceptance @ DEP
  - >78% MSE rejection @ 1620 keV γ line

Conclusions and perspectives (II)

- There would be room for pulse shape analysis improvements looking for other parameters to be associated to the ratio A/E (rise time, shape of the differential pulses, numbers of peaks of the differentiated pulse like IGEX analysis…)
- Pulse shape analysis on an enriched in SSE population, obtained acquiring the single Compton scattering in coincidence with a coaxial HPGe detector, results in good agreement with the MC simulation which is able to distinguish SSE out from MSE on the basis of the R90 parameter.
- Protocol for testing of the forthcoming new depleted BEGe has to be defined on the basis of the results.