

Efficiency Calibration of an extended-range Ge detector by Monte Carlo Simulation

Virginia Peyres. E. García-Toraño

Laboratorio de Metrología de Radiaciones Ionizantes

CIEMAT. Madrid. Spain

Gamma Spectrometry ICRM WG
LNE. Paris 2009

Extended-range coaxial Ge detector from
CANBERRA

Carbon-epoxy window

Diameter and height 61 x 61 mm

Very thin contact in the front surface (300
nm nominal)

Distance from Ge crystal to Carbon-
epoxy window 5 mm



Monte Carlo simulation is an useful tool in efficiency calculations :

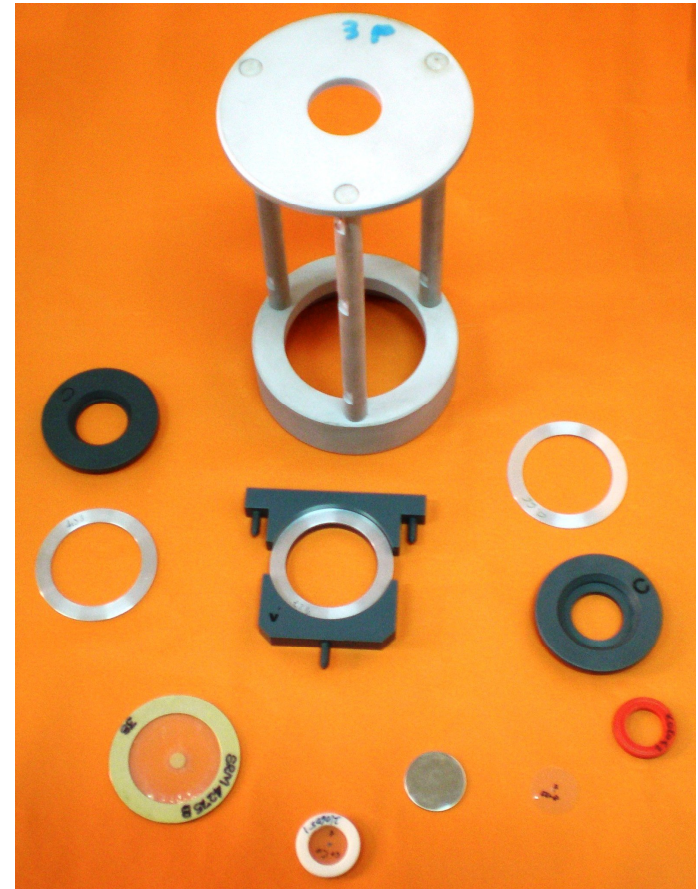
- Helps to extend the existing efficiency curve to other geometries
(eg. From point to disk or volume sources)
- Allows a good efficiency transfer between similar geometries
(e.g. for various source-to-detector distances)
- It is a good method to predict efficiencies for energy values not measured in the calibration curve, because is based in a physical model that includes the interaction of radiation with matter and describes the geometry of the whole measurement system

The procedure followed at CIEMAT includes:

1. Experimental determination of efficiency values for a number of energy points, using point sources previously standardized by absolute methods (if possible!).
2. Elaboration of a detailed numerical model of the detector starting from manufacturer nominal specifications and data from radiographs.
3. Optimization of the model by comparing experimental data and MC calculations, using several energy ranges to find optimal parameters in specific parts of the detector.

Full-absorption peak efficiencies were obtained by measuring a set of 16 sources at 15 cm from the detector window.

- A set of source holders allowed maintaining the measurement position of sources regardless of their shape.
- Their activities were determined, in most cases, by absolute methods at CIEMAT: $4\pi\gamma$ based on NaI(Tl) well detector. $4\pi\beta-\gamma$ coincidence counting. LSC.
- A few sources were provided by external laboratories, as NIST and LEA.
- In all cases uncertainties were below 1 %.



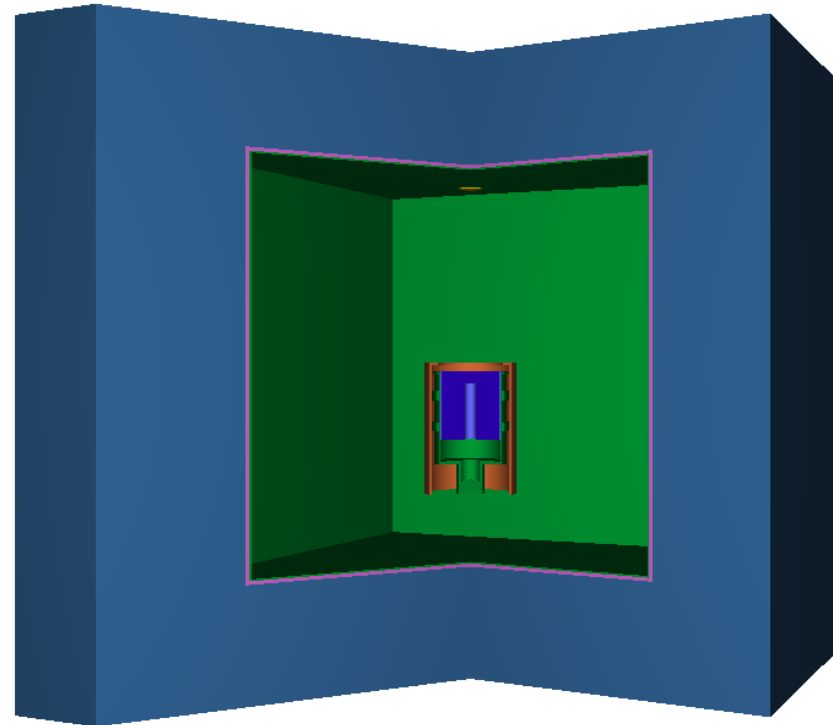
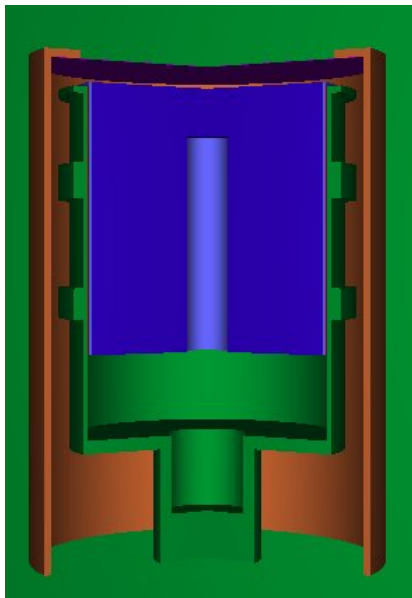
We used PENELOPE package for all simulations because:

- The simulation scheme of PENELOPE for electron transport handles interface crossing of electron and positron appropriately when the particle moves near an interface, *i.e.*, a surface separating two media of different compositions.
- PENELOPE also simulates the emission of characteristic X-rays and Auger electrons that result from vacancies produced in K, L and M shells by photoelectric absorption and Compton scattering of photons and by electron/positron impact.
- This is of particular importance in the study of photons that interact in regions close to the detector surface, as the X-rays generated in the interaction could escape from the detector active area, thus modifying the counting efficiency.

Monte Carlo calculations

The simulation includes :

- Detector: Ge crystal, dead layer, reflector, carbon epoxy window, Cu holder, Al .
- Polyethylene Sources.
- Pb, Cu, Cd shielding.



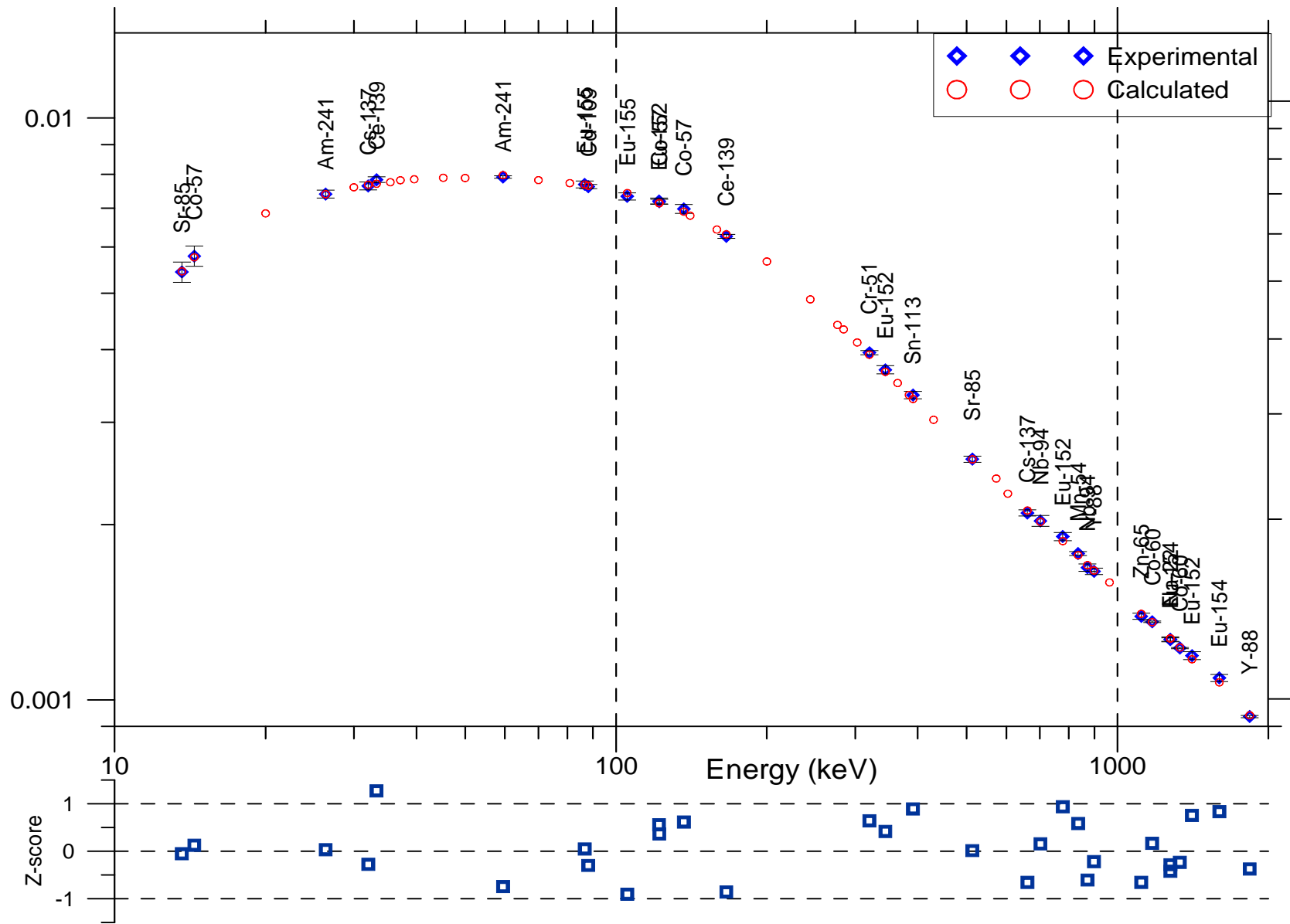
Sources used to optimize the detector dimensions:

- Window to crystal distance: ^{57}Co at two positions.
- Dead layer optimization: ^{57}Co (14.41 keV) and K X-rays from ^{137}Cs .
- Crystal diameter optimization: ^{57}Co , ^{85}Sr , ^{51}Cr .
- Crystal thickness optimization: ^{60}Co

Calculations:

- The relative statistical uncertainties of all results were below 1%.
- Simulated primary particles: 10^7 - 10^8
- Simulation time: 10000-50000 s

Monte Carlo calculations : results



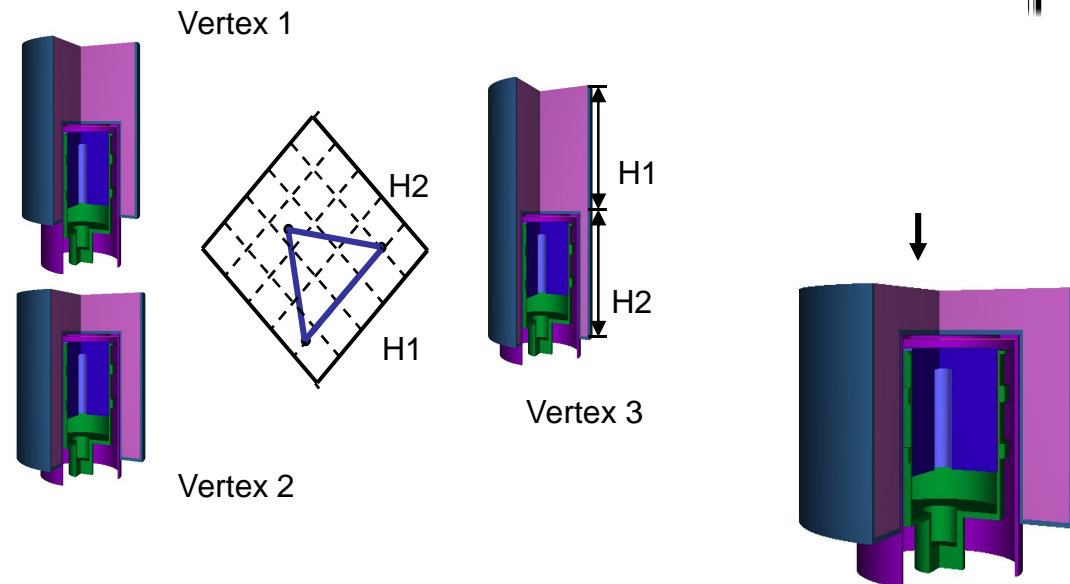
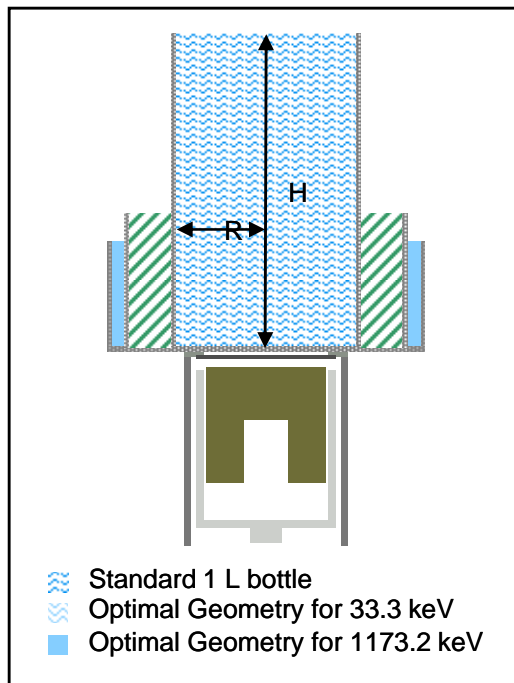
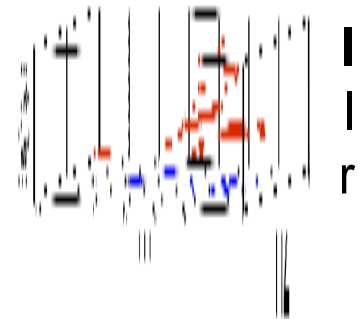
Monte Carlo calculations : results



	Energy (keV)	Experimental Full Energy Peak (x 10 ³)	Calculated Full Energy Peak (x 10 ³)	(Exp-Cal)/Exp %
²⁴¹ Am	26.34	7.400 (111)	7.396 (49)	0.05
	59.54	7.917 (35)	7.975 (69)	-0.73
¹⁰⁹ Cd	88.03	7.623 (66)	7,648 (51)	-0,33
	33.3	7.808 (90)	7.706 (47)	1.30
¹³⁹ Ce	165.86	6.257 (50)	6.311 (36)	-0.86
	14.41	5.792 (232)	5.763 (27)	0.50
⁵⁷ Co	122.06	7.159 (72)	7.140 (71)	0.25
	136.47	6.977 (119)	6.903 (28)	1.06
⁶⁰ Co	1173.23	1.362 (4)	1.360 (12)	0.15
	1332.49	1.227 (2)	1.230 (11)	-0.22
⁵¹ Cr	320.10	3.903 (33)	3.918 (39)	-0.38
	32.06	7.641 (122)	7.677 (46)	-0.48
¹³⁷ Cs	661.66	2.095 (25)	2.115 (16)	-0.93
	121,78	7,202 (81)	7,14 (71)	0.85
¹⁵² Eu	344.30	3.689 (59)	3.662 (36)	0.72
	778.00	1.898 (30)	1.874 (19)	1.26
¹⁵⁴ Eu	1408,01	1,191 (18)	1,174 (13)	1.44
	1274.40	1.269 (8)	1.275 (12)	-0.47
¹⁵⁹⁶ .50	1596.50	1.097 (15)	1.071 (26)	1.71
	86.60	7.689 (108)	7.684 (23)	0.07
¹⁵⁵ Eu	105.30	7.333 (103)	7.430 (31)	1.32
	834.84	1.784 (12)	1.772 (15)	0.67
⁵⁴ Mn	1274.54	1.265 (11)	1.275 (12)	-0.79
	702.60	2.030 (43)	2.023 (13)	0.34
⁹⁴ Nb	871.09	1.687 (25)	1.704 (12)	-1.01
	13.62	5.437 (217)	5.449 (38)	-0.21
⁸⁵ Sr	514.00	2.591 (31)	2.591 (16)	0.02
	898.00	1.669 (20)	1.668 (10)	0.09
⁸⁸ Y	1836.00	9.399 (44)	0.940 (10)	-0.04
	1115.50	1.393 (11)	1.406 (12)	-1.00

Optimization of a Gamma Spectrometry System

Methods: We propose an optimization method that algorithms to find the maximum efficiency for measurement setup.



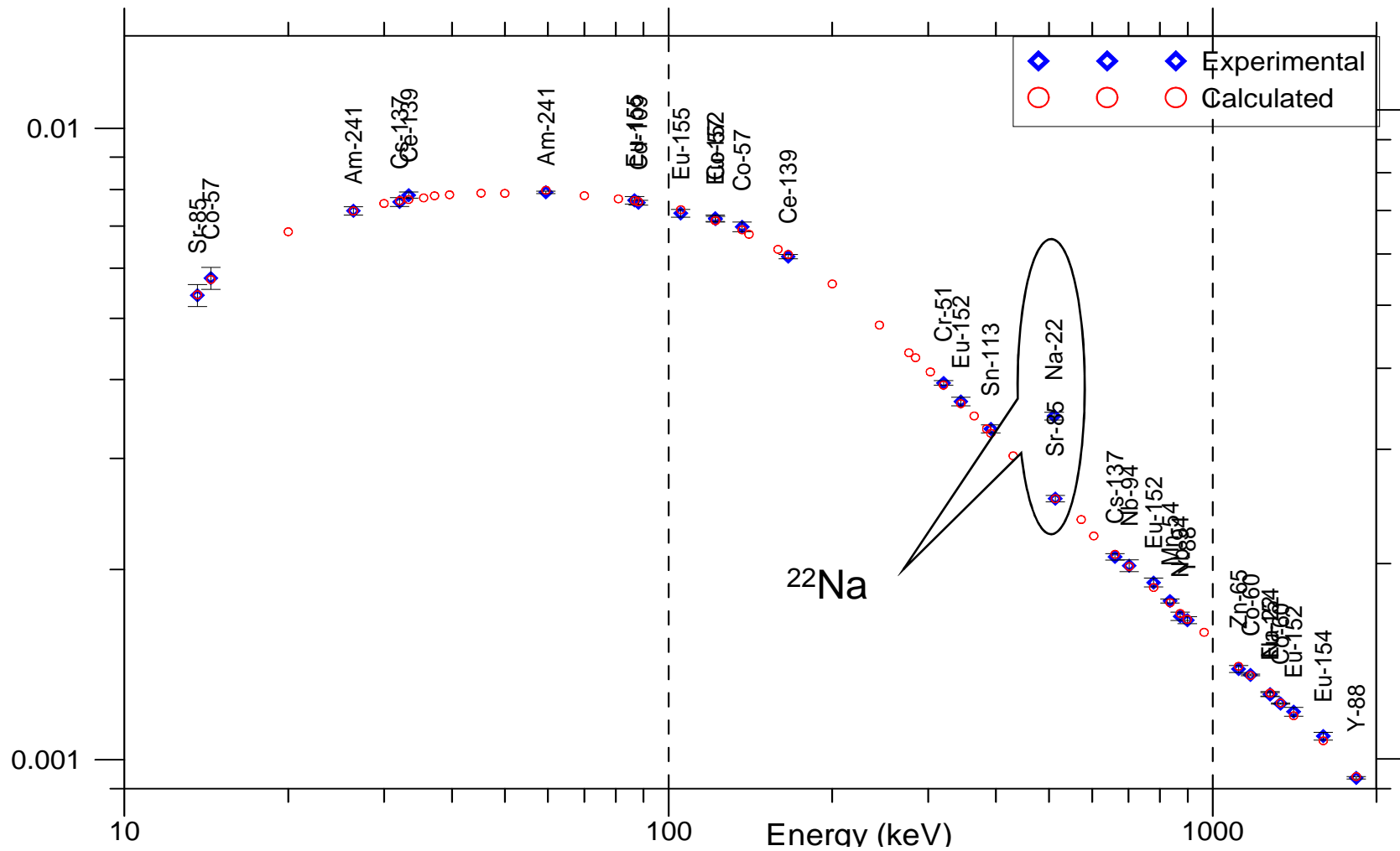
Numerical method: Bisection

One-dimensional problem.
Measurement of an aqueous solution (1 L) in a polypropylene bottle

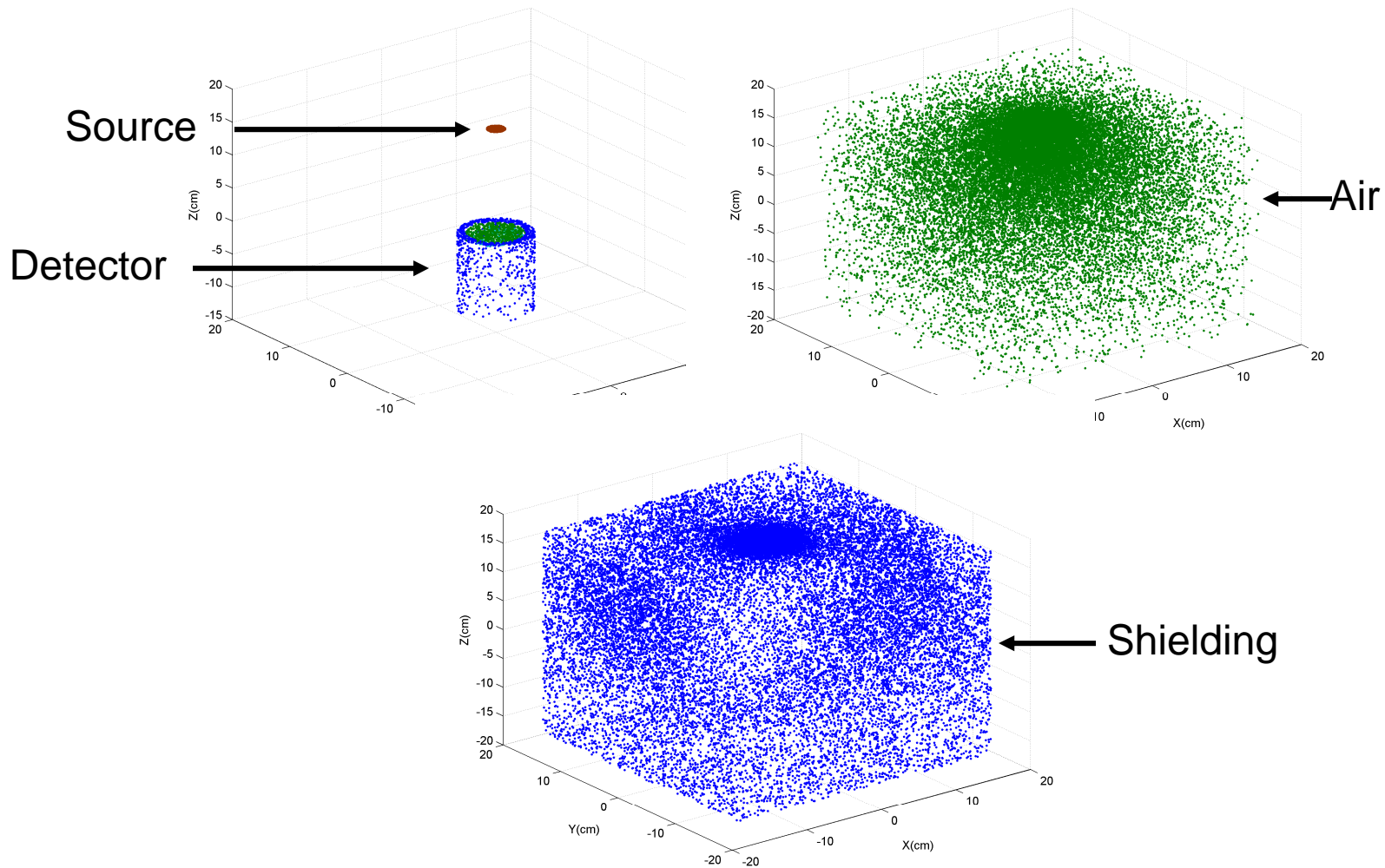
Numerical method: Simplex

Bi-dimensional problem. Measurement of an aqueous solution (1 L) in a Marinelli beaker

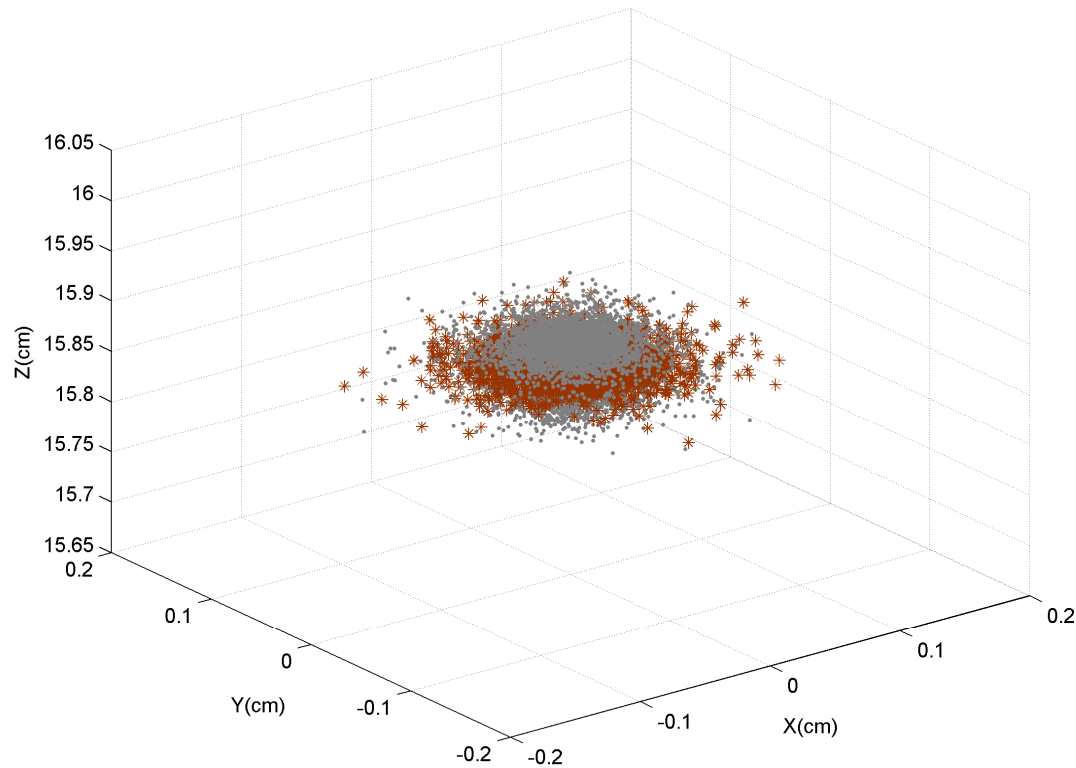
Monte Carlo calculations : Positron emitters



Monte Carlo calculations : Positron emitters

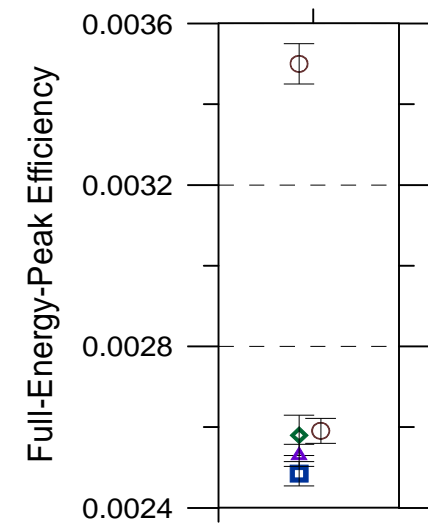
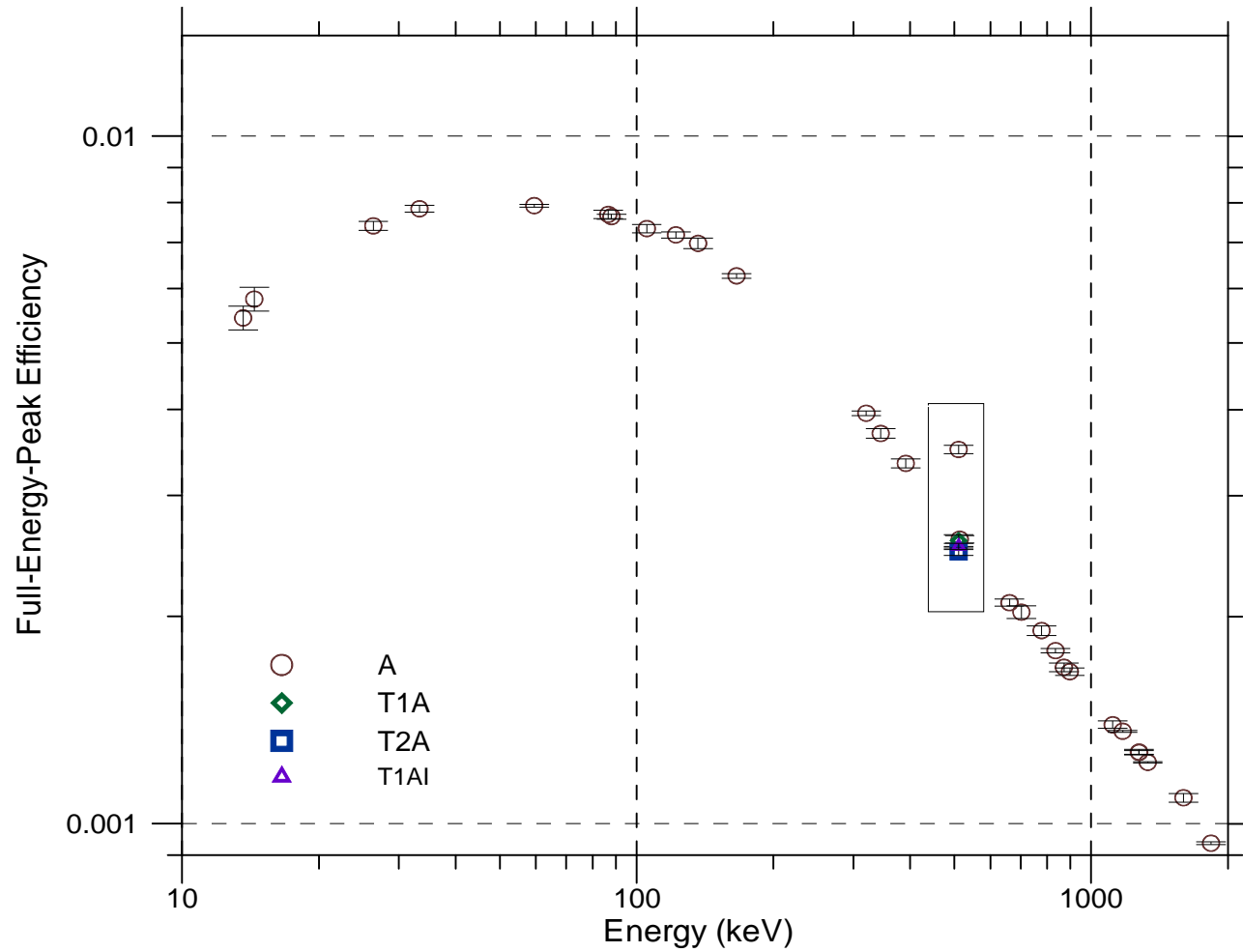


Annihilation positions of positrons in detector, air and shielding.



Annihilation positions of positrons after adding absorbers in both sides.

Monte Carlo calculations : Positron emitters



- Simulation of complete decay schemes (and therefore the coincidence summing corrections) by Monte Carlo simulation with PENELOPE and NUCLEIDE.
- Enhance our efficiency calibration curves in the 90-140 keV energy range.
- Application of efficiency calibration of Ge detector by Monte Carlo simulation to positron emitters (paper to be sent to NIM shortly, concerning the optimization of absorber sizes)