Coincidence Summing Corrections and Peak Fit Functions for γ- Spectra

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Coincidence summing is a process in which the emission of γ-rays in cascade from the decay of a single radionuclide occurs within the resolving time of the detector and ends up being recorded together as a single event. This causes counts to be lost from the full-energy peaks and calls for a correction of the peak areas. The magnitude of the corrections depends on the sample-to-detector geometry and the decay scheme of the nuclides.

For a complex decay scheme when more than two photons are emitted in cascade, like the ones with ^{133}Ba, the effect of absorbers becomes significant. With the insertion of Cadmium absorbers between the source and the detector which effectively blocks the X-rays summing with the γ-rays, considerable modification in the spectra is observed (see Fig. 1). In our measurements the sample is put directly on top of high purity germanium (HPGe) capsule to maximise the absolute efficiency of the detector.

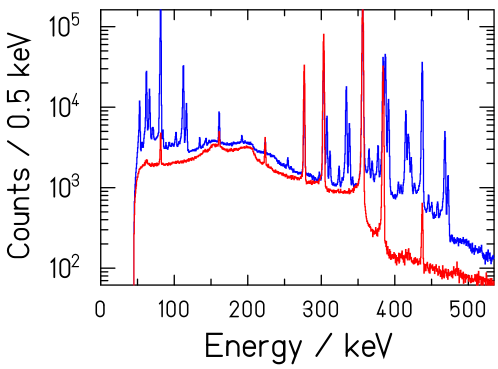

Fig. 1 *HPGe spectrum of ^{133}Ba - upper spectrum is without absorber and lower one is with a 2.1 mm thick Cd absorber.*

While analysing γ-ray lines from the spectra, precision is generally limited by the ability to define and compute consistent peak areas [1]. Simple methods with Gaussian functions are adequate for single, well-resolved peaks. But for a complex peak shape with considerable spectral background and low-energy tailing, an adapted fit routine is necessary.

The extraction of relevant peak parameters from the measured spectrum is done with a fit routine similar to the one in Radware package, see [2] also. Components in their functional form reads

1) a Gaussian

$$y_g = \frac{h \cdot R}{100} \exp\left(-\frac{(x-x_0)^2}{2\sigma^2}\right)$$

2) a skewed Gaussian,

$$y_s = h \cdot \left(1 - \frac{R}{100}\right) \exp\left(\frac{x-x_0}{\beta}\right) \mathrm{erfc}\left(\frac{x-x_0}{\sqrt{2}\sigma} + \frac{\sigma}{\sqrt{2}\beta}\right)$$

3) and a smoothed step function to increase the background on the low-energy side of the peak.

$$y_b = \frac{h \cdot S}{100} \mathrm{erfc}\left(\frac{x-x_0}{\sqrt{2}\sigma}\right) + A + B(x-x_0)$$

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Components (2) or (3) can easily be set to zero if not required.

The Gaussian is the main component of the peak which arises from the complete charge collection of an event inside the detector. The skewed Gaussian represents incomplete charge collection due to impurities inside the detector material resulting in an exponential tail on the low-energy side with β as the decay constant. The different constant background below and above the full efficiency peak stems from multiple interactions (multi-compton scattering, cf.) of one γ-ray inside the crystal where the full energy is not deposited. Fig. 2 illustrates how the components go together to make up the total peak shape.

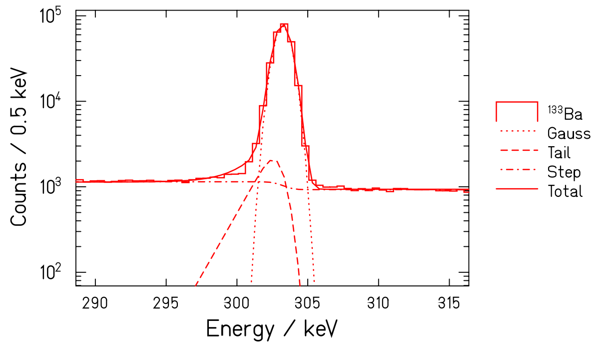

Fig. 2 *Peak fit for one of the strongest decay lines of ^{133}Ba - Fit parameters chosen for display are R = 97.3, β = 3 chs and with a step S = 0.24.*

To study the effect of crystal geometry on the distance dependence of absolute efficiency we simulated the detector setup using GEANT3 [3]. From the simulations we see that we can account for this geometrical effect reasonably well.

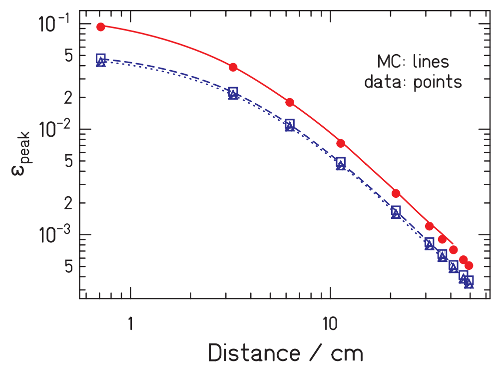

Fig. 3 *GEANT simulations showing the effect of crystal geometry on photopeak efficiencies - upper line is for ^{137}Cs and lower ones are for ^{60}Co.*

[1] T. Kishikawa, C. Yonezawa et al., Nucl. Instrum. Meth. A 369 (1996) 689

[2] K. Debertin, R.G. Helmer, γ and X-ray Spectrometry with Semiconductor Detectors, Elsevier Science Publ. (2001)

[3] CERN program Library Long Writeup Q121, CERN, Geneva (CH), 1994