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Applications of Pulse Shape Analysis to HPGe γ-ray detectors

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We are engaged in a program of applying digital pulse shape analysis to High Purity Ge (HPGe) γ-ray detectors for applications in Compton suppression and γ-ray imaging. Past progress on this effort is detailed in [1,2]. Here we present our most recent results in Compton suppression, and also outline our current work in γ-ray imaging.

Compton suppression and γ-ray imaging are both useful techniques for improving the quality of γ-ray spectra. Compton suppression does this by removing those events which do not deposit their full energy in the detector. Gamma-ray imaging does this by allowing one to discriminate against γ-rays which emanate from directions other than the desired direction. More generally, γ-ray imaging allows one to generate a picture which correlates direction, intensity and energy of all γ radiation incident on the detector. This can also be useful in locating hidden radiation sources.

In [1], we discussed a technique for performing pulse-shape based Compton suppression using a standard 5cm x 5cm HPGe detector (closed-ended co-axial). The technique was to decompose the recorded digital pulse shape for each event into a series of single-site pulse shapes indexed as a function of radius. This yielded, in principle, the radial distribution of the energy deposition. We then made use of an algorithm to either accept or reject the event based on this information. While the algorithm was designed to reject both single-site and multiple site escape events, we have since determined that the best results are obtained if the background is composed primarily of single site Compton scatters (i.e. the peak in question lies near a very strong Compton edge).

In Figure 1 we have plotted experimental counting time improvement factors (i.e. how much longer one would have to count to get the same degree of spectral enhancement) for various 152Eu lines in a very strong (i.e. orders of magnitude stronger) 60Co background. The addition of 60Co background, as opposed to the lone 152Eu source of [1], ensures that several peaks will lie near large Compton edges. In particular, the 1112 keV line from 152Eu lies on top of the Compton edge from the 1332 keV line in 60Co, and thus it has the best suppression. The 964 keV line from 152Eu lies very near the Compton edge from the 1173 keV line in 60Co, and thus it has the next best suppression. The 778 keV line in 152Eu does not lie near a Compton edge, and thus it has the worst suppression shown (but still better than [1] because of the stronger Compton background).

Since the 152Eu source was collimated to a 2mm beam, the results in Figure 1 show the depth dependence of the algorithm. The poor performance in the front region is due to the closed-ended "quasi-planar" electric field (the calculated single-site pulse shapes used in the interaction were based on a pure coaxial field). There is also a slight effect at the back of the crystal, perhaps due to "edge-field" effects. Another scan that was done, but not plotted here, was an azimuthal scan of the 152Eu source around the front face (at r=15mm). The performance of the algorithm showed a 10% peak-to-peak variation. This fluctuation was reasonably in phase with the known 5% azimuthal variation in electron mobilities (due to the orientation of the Ge crystal axes).

Current work is focusing on applying HPGe pulse shape analysis techniques to γ-ray imaging. The idea is to obtain the r,ϕ,z coordinates of each γ-ray interaction for a given event. This would be done using the technique of [1] to get radial information, while using a segmented outer contact to get azimuthal and depth information. By using interpolation, a position resolution better than the segment size could be achieved. Once the location of each of the interaction points is known for a given event, and the points are time ordered (using γ-ray tracking, [3]), standard Compton camera imaging techniques can be used to create (over many events) an image. Experimental work is now proceeding to measure 3-D position resolution with the 36-fold segmented GRETA prototype at Lawrence Berkeley Lab.

References:

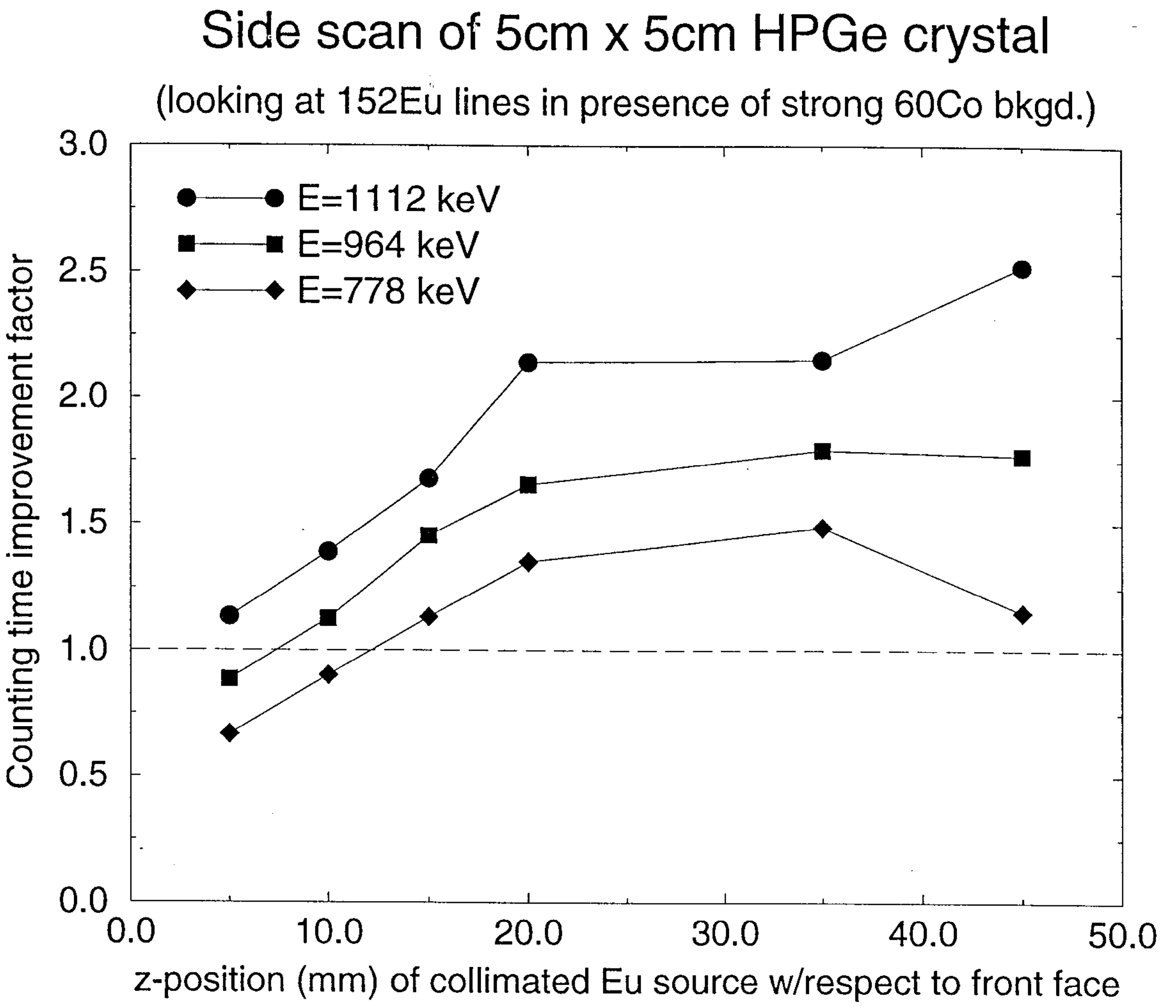
[1] G.J. Schmid, D. Beckedahl, J.J. Blair, A. Friensehner, J.E. Kammeraad, NIM A422, 368 (1999)

[2] J. Blair, D. Beckedahl, J. Kammeraad, G. Schmid, NIM A422, 331 (1999)

[3] G.J. Schmid, M.A. Deleplanque, I.Y. Lee, et al., NIM A430, 69 (1999)

Figure Caption:

Figure 1: Compton suppression results as a function of depth. The "counting time improvement factor" is equivalent to the square of the "effectiveness" presented in [1].


Side scan of 5cm x 5cm HPGe crystal

(looking at 152Eu lines in presence of strong 60Co bkgd.)

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