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Pulse shape analysis of individual gamma events - correlation to resolution and the possibility of its improvement

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The recent measurement of non-proportionality of each of the decay components in CsI:Tl (fast, slow, and tail) [1] found opposite slopes of the fast and tail proportionality curves above about 10 keV. This suggests that combining both components could improve resolution by more than just the statistics of the additional photons. Indeed, Moszynski et al had shown this in studies of peaking-time and resolution in CsI:Tl several years earlier [2]. While modeling the results from [1], we considered that the relative amounts of the three decay components in the as-measured scintillation pulse probably do not represent the optimum linear combination to produce best total proportionality [3]. We presented an optimization analysis showing that a linear combination of the form "fast + 3.4 tail"produced a significantly flatter proportionality curve than the natural scintillation pulse "fast + slow + tail"[3]. However, to determine if an optimized linear combination could result in improvement of resolution requires applying a similar algorithm to each gamma event.

In this work we measured pulse shapes of individual gamma events in CsI:Tl and other scintillators using an eMorpho multichannel analyzer as a digital oscilloscope. Decomposition of every scintillation pulse into three exponential decay components following [1] allowed to extract the weight of each component. It was found that the nominal energy resolution evaluated as FWHM over the position of the photopeak maximum in a reconstructed PH spectrum can be altered by scaling the weight of each decay component. The coefficients in the linear combination can be optimized to achieve an energy resolution which is better than the similarly reconstructed "natural"PH spectrum where the scaling factors are all unity, i.e. when the decay components preserve their as-measured amplitudes. The results are presently mixed due to a factor we believe is separate from the effect of an optimized linear combination of pulse shape components. Specifically, we measured the normal PH spectrum of CsI:Tl without reconstruction in terms of decay components and found 5.8% resolution at 662 keV. Reconstruction in terms of three decay components lost resolution to 8.6%, which we believe is due to neglect of the rising part of the pulse in the present analysis scheme, losing both significant total counts and the proportionality information represented in that component. The important result of this study is that optimization of the weights of the three decay components improved the resolution of the reconstructed data from 8.6% to 6.6%. Thus while 6.6% is not a net improvement over 5.8%, it is a distinct improvement over 8.6% in the comparison of equivalent things, i.e. PH spectra represented as two different weighted sums of the decay components. If this direction continues to seem promising, such processing can be implemented in real time with available technology such as field-programmable gate arrays.

Some of the CsI:Tl crystals we investigated exhibit a secondary peak in the PH spectrum. In the course of this study we used scanning absorption spectroscopy and spectrally resolved TSL measurements to understand the origin of the secondary peaks.

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References

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