3D Position and Energy Estimation of Gamma Rays in Columnar CsI(Tl) Using Maximum-Likelihod Estimation

Recent advances have been made in a new class of CCD-based, single-photon-counting gamma-ray detectors which offer sub-100μm intrinsic resolutions. These detectors show great promise in small-animal SPECT and molecular imaging and exist in a variety of configurations. In such detectors gamma-ray interactions in columnar CsI(Tl) scintillators are imaged onto a CCD as clusters of signal. These detectors operate in photon-counting mode when individual interactions are seen as spatially separable events. Due to the low-light-level nature of the scintillation process, gain processes have been used to amplify the signal for single-photon detection. For example, the use of an electron-multiplying CCDs (EMCCDs) amplifies the optical signal prior to the charge-to-voltage conversion process. Another system, our CGRI Bazooka SPECT, employs a second generation image intensifier where gain is applied prior to a lens-coupling system.

Crystallites in columnar CsI(Tl) act somewhat like optical fibers in that they direct light towards an exit surface which is imaged onto the CCD. However, the crystallites are not perfect optical fibers and emerging light is blurred by an amount related to the depth-of-interaction (DOI) of the gamma-ray. Depth-of-interaction effects result in a degradation of both spatial resolution and energy resolution.

Depth-of-interactions effects can be corrected for and energy resolution can be improved through maximum-likelihood (ML) 3D position and energy estimation. For ML estimation, a calibration is performed to obtain the functional forms of the depth-dependence of the light output and its spatial variance. With the functional forms of light output and spatial variances verses depth, we can then obtain the 3D (x,y,z) position and energy (E) estimates for individual gamma-ray interactions.

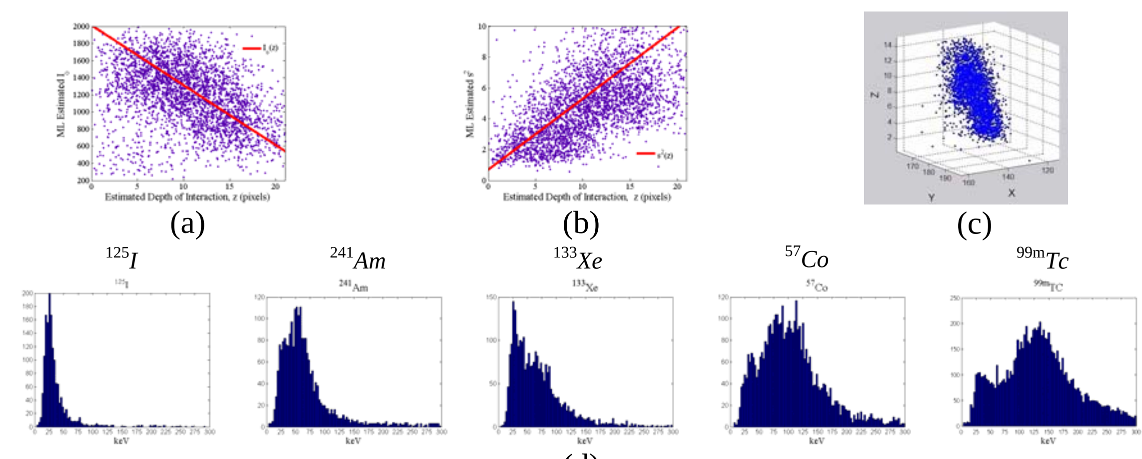

Figure 1. (a) Functional form of light output verses depth, (b) functional form of spatial variance verses depth, (c) maximum-likelihood 3D position estimation of individual gamma-ray interactions in an angled collimated beam, and (d) maximum-likelihood estimation of various isotopes.

1. "Single-photon spatial and energy resolution enhancement of a columnar CsI (Tl)/EMCCD gamma-camera using maximum-likelihood estimation," B. W. Miller, H. Barber, H. Barrett, I. Shestakova, B. Singh, and V. Nagarkar, *Proc. SPIE* 6142, p. 61421T, 2006.