Three-dimensional position sensitivity in two-dimensionally segmented HP-Ge detectors

K. Vetter[a], A. Kuhn[a], M.A. Deleplanque,[a] I.Y. Lee[a], F.S. Stephens[a], G.J. Schmid[b], D. Beckedahl[b], J.J. Blair[c], R.M. Clark[a], M. Cromaz[a], R.M. Diamond[a], P. Fallon[a], G.J. Lane[a], J.E. Kammeraad[b], A.O. Macchiavelli[a], C.E. Svensson[a],
[a] Lawrence Berkeley National Laboratory, Berkeley CA 94720, U.S.A.
[b] Lawrence Livermore National Laboratory, Livermore CA 94550, U.S.A.
[c] Bechtel Nevada, North Las Vegas, NV 89130-4134, U.S.A.

Currently, a new technique for tracking of γ radiation is being developed which will allow the determination of the time sequence of interactions of γ rays and their respective positions in a detector as well as their energies [1]. An implementation of this concept, the gamma-ray energy tracking array, known as GRETA, is currently being developed at LBNL and focuses on improving the performance of γ-ray spectrometers primarily in the field of nuclear structure physics.

One crucial element in the concept of γ-ray tracking is the ability to determine the energy and position of individual interactions with a three-dimensional position resolution on the order of a few millimeters. In the approach we are pursuing, the determination of the position is achieved by employing pulse-shape analysis in a two-dimensionally segmented coaxial HP-Ge detector. With sufficiently small segments, charge is not only induced on the charge-collecting segment but also transiently on the neighboring segments. Since the segmentation is perpendicular to the electric field lines (radial direction), from the induced signal, a position sensitivity in the orthogonal two dimensions (the depth and azimuthal angle) can be obtained. The measurements to determine the three-dimensional position sensitivity in segmented coaxial Ge detectors have been performed with a GRETA prototype detector manufactured by Eurysis Measures. We used this 36-fold segmented detector in a coincidence set-up which allowed us to localize single interactions in the crystal. Pulse-shape calculations in combination with Monte-Carlo simulations of γ-ray interactions have been performed which yield good agreement with the measured signals. From the variation of the signals as a function of distance and the level of noise, a position sensitivity between 0.2 mm and 0.5 mm (rms) has been obtained for most positions at an energy of 374 keV, dependent on the position and the direction [2]. The sensitivity in the radial direction is higher than that in the two other directions. By comparing signals with noise, we found that even for a γ-ray energy of as low as 100 keV a sensitivity of about 1 mm can be achieved. This excellent position sensitivity indicates that it is not the limiting factor for the localization of individual interactions. Other effects such as the range of the Compton electrons for higher γ-ray energies and the uncertainty in the energy-angle relation in the Compton scattering formula due to momentum distribution of the electrons (Compton profile) for lower γ-ray energies will be the dominant factors in the limitation for γ-ray tracking. However, even with these effects we expect a three-dimensional position resolution of about 1 mm which still satisfies the requirement for efficient tracking.

References

[1] M.A. Deleplanque, et al., Nucl. Instr. and Meth. A 430 (1999) 292

[2] K. Vetter, et al., submitted to Nucl. Instr. and Meth. A