Signal Decomposition for GRETA

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To track γ rays in GRETA, energies and three-dimensional positions of their interactions have to be measured. Recently, a position sensitivity of 0.2-0.5 mm was demonstrated for γ-ray interactions in a 36-fold segmented Ge detector. However, this sensitivity only reflects the accuracy of locating single interactions. In order to determine locations and energies of multiple interactions in multiple segments, we are developing algorithms to decompose signals into their individual components. The goal of these algorithms is not only to optimize the position resolution, but also to perform the decomposition in real time. While an adaptive grid method has achieved a position resolution of about 1 mm for multiple interactions, it is far too slow for on-line processing.

Currently, we are exploring a method of solving systems of equations using generalized matrix-inverse methods, which is closely related to least-square fitting techniques. This approach is potentially very fast since the inverse can be calculated a priori and the decomposition is reduced to a multiplication of a matrix with a vector. The matrix is composed of base signals for interaction points on a three-dimensional grid. However, this matrix is usually singular and its inverse can not be obtained. A mathematical technique known as the singular value decomposition (SVD) is used to separate the matrix into a product of a diagonal and two orthogonal matrices. By taking the inverse of each matrix, we arrive at the Moore-Penrose generalized inverse. When a measured signal is multiplied by the generalized inverse, the optimal positions of the interactions points are obtained. Fig. 1 shows results obtained in a two-dimensionally segmented true-coaxial Ge detector. Basis signals were calculated on a Cartesian grid with a spacing of 1 mm in each direction resulting in about 5000 grid points. For each point, 9 signals were used, one from the segment containing the interaction and 8 from its neighbors. Two interactions were placed in one of the middle segments, indicated by the open red squares with amplitudes of 1 and 0.5, respectively With the total set of basis signals it appears only possible to determine the radius and the depth of the interactions accurately. The azimuthal position can be obtained in a second step by limiting the radius and the depth. Generally, the key of the SVD is to implement constraints in the number and the sign of amplitudes.

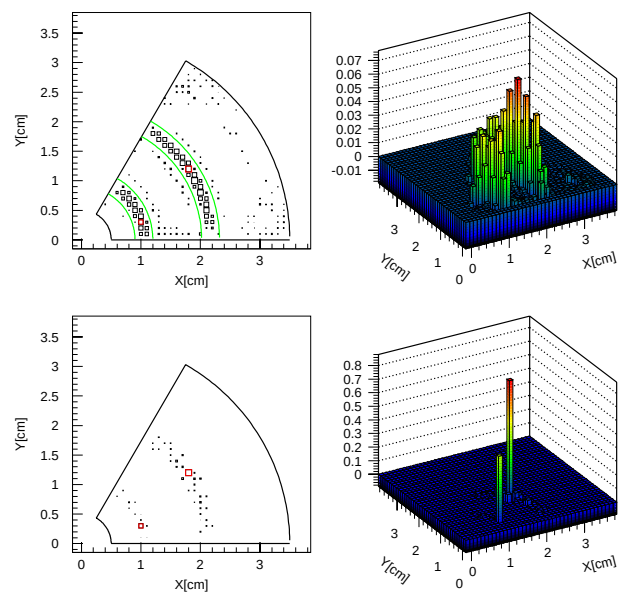

Figure 1: Results of SVD in three dimensions for two interactions indicated by red squares. The upper row shows obtained probability distributions taking all possible positions into account. The bottom row shows the results after limiting the radius to the regions between the green lines. The final result agrees well with the input positions.