

Pulse Shape Analysis for MINIBALL

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One of the most important tools to investigate the structure of nuclei is the spectroscopy of γ -rays. Large-volume high-purity germanium detectors (HPGe) provide an excellent energy resolution and a good efficiency and are therefore especially adapted for γ -ray spectroscopy in the energy regime up to 5 MeV.

Experiments using very exotic secondary beams produced by projectile fragmentation in most cases are performed in inverse kinematics. The high velocity of the reaction products imparts large Doppler shifts and the finite angle of the detector leads to a Doppler broadening.

The MINIBALL detectors [1] used for the described measurement consist of three coaxial germanium crystals which are six-fold segmented on the outer contact. Together with a digital readout the interaction point of the photons can be reconstructed much more precisely by analysing the signal pulse shapes of each contact (DGF-4C moduls [2]).

First of all the signal shape of the hit segment depends on the drift path and therefore on the drift times for electrons and holes respectively. Beside the net charge signal in the hit segment also transient signals in the neighbouring segments are induced while the charge carriers are drifting. Their ratio strongly depends on the azimuthal position of the interaction point.

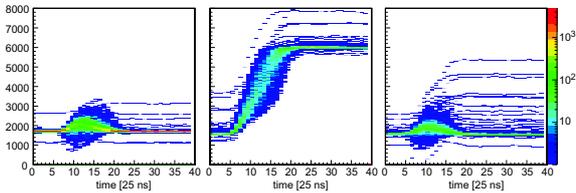


Fig. 1: Superimposed pulse shapes of the hit segment (center) and transient signals of the left and right neighbouring segment respectively chosen for an interaction near the inner contact only.

In figure 1 the net signal (center) and the two neighbouring signals are shown. Though it is much larger and less sensitive to noise, the net signal mostly contains redundant information. Therefore in the described method for pulse shape analysis only the transient signals were studied.

To deal with these transient signals we have applied a square shaped digital filter. The filter consists of three parts: part I and III are each 150 ns long and weighted negatively, the central part II is 300 ns long, accordingly to the time performance of the induced signals (see figure 1), and weighted positively. The output is on the one hand sensitive to the time evolution and on the other hand to the amplitude of these signals.

The right hand side of figure 2 shows the strong correlation of the filter output for the left and right transient induced signal, named I_L and I_R respectively. A detailed simulation based on numerical field calculations and charge carrier mobilities (MGS, [3]) shows a clear assignment of interaction points and I_L - I_R -combinations (figure 2 left).

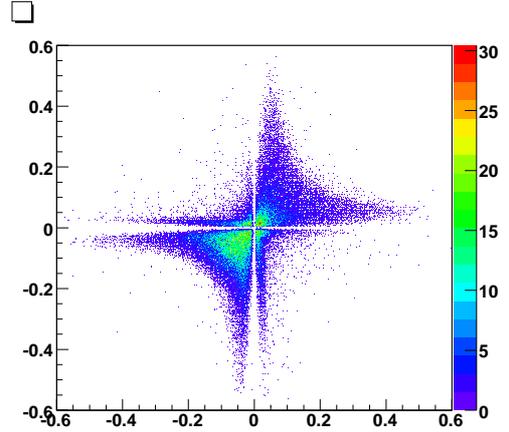


Fig. 2: Left: Classification of the combination of the induced signals within a MINIBALL segment (simulation). Right: Correlation of the filter output for left and right induced signals.

Based on these simulation results a transformation algorithm was developed to project the results from the I_L - I_R -space to the crystal coordinates r (distance from the core contact) and φ (azimuthal angle). Using a heuristic approach, based on cylindrical field geometry originating from the edges of the electrodes, two simple formulas were derived and adopted to the geometrical constraints of the detector using only four parameters each [4]: $\varphi \propto f(\ln |I_L/I_R|)$ and $r \propto g(\ln |I_L \cdot I_R|)$.

To check this new method of pulse shape analysis a laboratory experiment with ^{137}Cs source (662 keV) collimated to 4 mm FWHM was performed. Exemplary, the result of two scanned points is shown in figure 3.

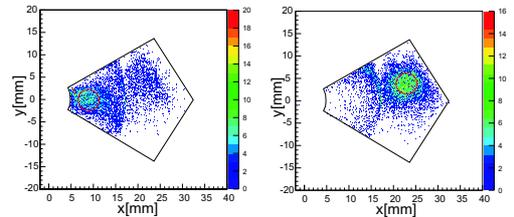


Fig. 3: By pulse shape analysis reproduced positions of collimated points for small (left) and large (right) radii. The expected beam positions are marked with circles.

This pulse shape analysis works successfully near the inner as well as near the outer contact. A relative position resolution of about 5 mm (FWHM) was achieved which is close to the diameter of the collimated beam. However, there are still systematic ambiguities in the absolute position measurement related to crystal orientation and signal crosstalk which are not yet included in the model.

The advantage of this pulse shape analysis is that it is based on a simple filter and a small number of parameters which will also allow its implementation into hardware. However, the complexity of the electrical field in the front part of the crystal will always limit the resolution of MINIBALL for certain applications.

References

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- [3] <http://iphc.in2p3.fr/~MGS-.html>
- [4] K. Eppinger, diploma thesis, TU München, 2006