A novel technique for the characterization of a HPGe detector response based on pulse shape comparison.

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Abstract

In the next generation HPGe segmented detectors it will be possible to fully reconstruct the path of the incident γ ray inside the active volume of the detectors. This feature will permit to identify the incident direction of the measured gamma. Consequently, it will be possible to correct for the energy shift caused by Doppler effect, recovering the intrinsic HPGe energy resolution and to reject the background events which do not deposit their full energy inside the array or do not originate from the target position. These features are especially critical for the next-generation HPGe arrays for γ spectroscopy like AGATA or GRETA .
In order to reconstruct the γ-ray trajectory inside the array it is necessary to determine the 3D coordinates of the γ-ray interaction points inside the HPGe detectors and the related energy release. The position sensitivity of the detectors is achieved by a segmentation of the outer contact and by analyzing the current pulse shapes given by the different segments. We present a novel technique for measuring a HPGe detector pulse shape as a function of the γ-ray interaction position inside the detector volume. This technique is based on a specific pulse shape comparison procedure and its main feature is that it allows to characterise the 3D positional response of a HPGe segmented γ detector with much less time consumption compared to standard coincidence based techniques. The method has been first validated using a GEANT simulation of a 36-fold HPGe AGATA detector realized taking into account the effects of the electronic chain response and electrical noise on the calculated signal shape. The same procedure has been applied to experimentally extract the positional response of a non-segmented coaxial HPGe detector along the radial direction, using a 438 MBq 137Cs collimated γ source. The results of this measurement show a dependence of the pulse shape as a function of γ-ray interaction radial coordinate consistent with that obtained with calculations. The signal acquisition rate reached using this characterization technique allows to realize a full scan of a large volume highly segmented HPGe detector in less than a week.

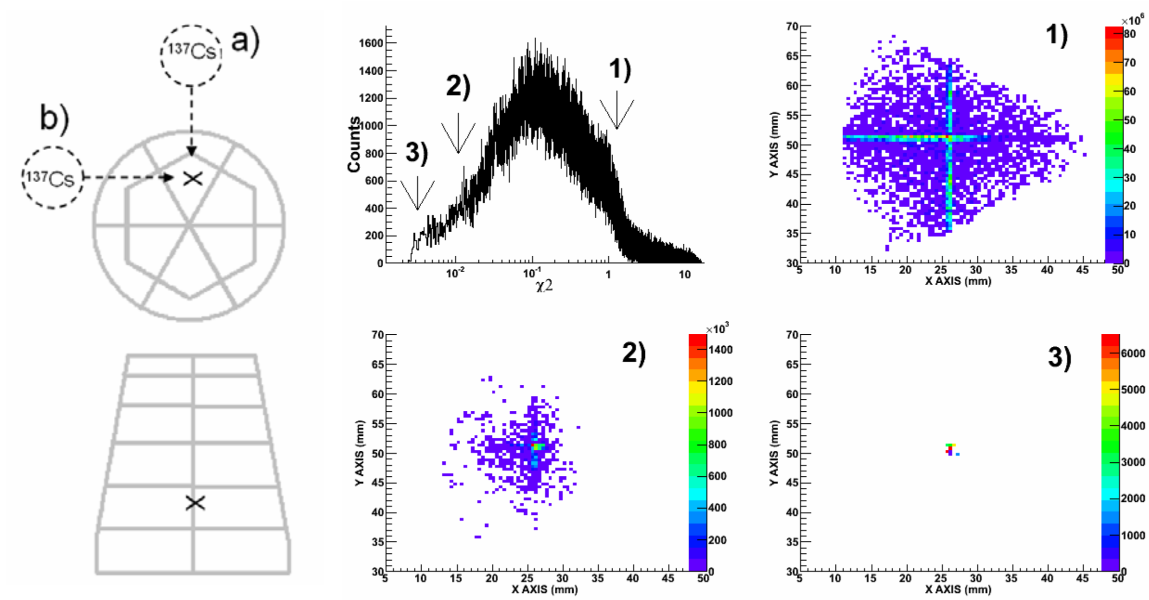
Summary

The geometrical segmentation in HPGe detectors will allow in the next generation arrays to fully reconstruct the path of the incident γ ray inside the active volume of the detectors. This will allow to correct for the energy shift caused by Doppler effect, recovering the intrinsic HPGe energy resolution, even with sources moving at relativistic velocity, and to reject the background events which do not deposit their full energy inside the array or which do not originate from the target position [1].

Basic information needed to reconstruct the γ-ray trajectory inside the array is the 3D localization of the γ-ray interaction points (IPs) inside the HPGe detectors and the related energy release. The position sensitivity of the detectors is achieved by a segmentation of the outer contact and by analyzing the current pulse shapes given by the different segments. Most of the Pulse Shape Analysis (PSA) algorithms developed for highly segmented HPGe detectors [2,3,4,5] make use of a signal data base which contains the detector pulse shapes for all the possible interaction positions inside the detector volume. Such kind of information is usually extracted calculating the induced current pulses by solving the appropriate electrostatic equations [6,7]. In principle it is also possible to extract the detector position response experimentally but the standard techniques [8,9,10] based on coincidence measurements require an extremely long time for a full volume detector scan. Nevertheless measurements for the characterization of segmented HPGe detectors are presently performed in many laboratories [8,9,11,12] since experimental data are strictly needed to validate the calculated signals.

We present a novel technique for measuring a HPGe detector position response based on a specific pulse shape comparison procedure (therefore we named it Pulse Shape Comparison Scan, PSCS). Its main feature is that it does not require any 'coincidence' between events or γ rays: this approach allows to increase by orders of magnitude the acquisition rate of signals associated to single interaction points with a determined position and does not require additional detectors in the experimental set up.

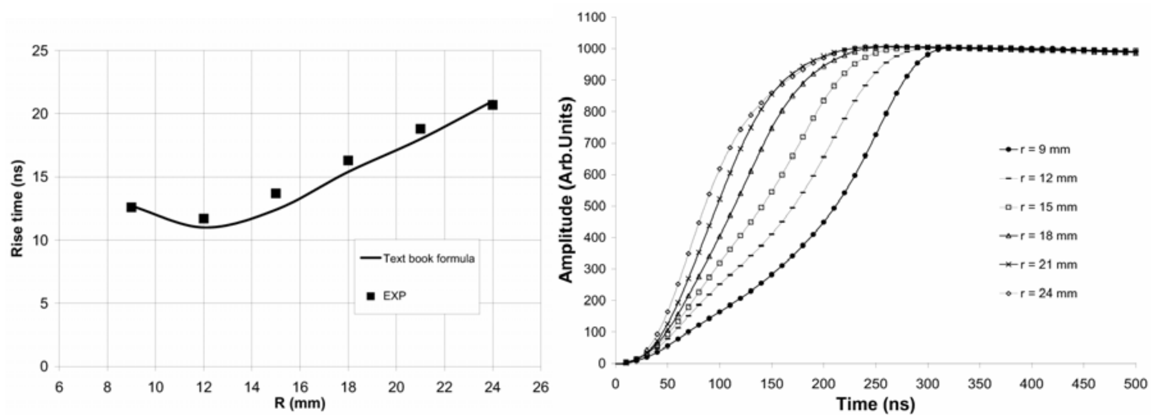
In order to test the PSCS method we have first performed two simulations in which a collimated 662 keV γ-ray beam hits a 36 fold segmented HPGe detector used in the AGATA demonstrator array [13]. The collimation lines [denoted as a) and b) in the bottom left panel of figure 1] are perpendicular one in respect to the other. The calculated pulses are produced using the GEANT4 libraries [14] and the MGS [7] signal basis. The effect of the noise and of the preamplifier response was taken into account [15]. The upper left plot in figure 1 shows the distribution of the χ^2 values obtained comparing the shape of all the signals associated one to an event of the simulation "a)" and the other to an event of simulation "b)". The other three plots in figure 1 represent the distribution of the energy release for different gates on χ^2 value (each one associated with the arrows in the upper left plot). As can be clearly seen the smaller is the χ^2 threshold value the more localized is the deposition of energy.



<u>Figure 1:</u> Left Panel: *Sketch of an AGATA detector, the detector segment on which the measure is focused is labelled with a cross. The perpendicular collimation directions [a) and b) respectively] of the γ-ray source used in the simulation are indicated.* **Right Panel:** Upper left panel: *distribution of the χ^2 values for the comparison of any combination of 2 signals.* Other panels: *distributions of the energy release with different threshold on χ^2 (each one associated with values denoted by the arrows in the upper left panel)* .

We have experimentally validated the PSCS method by applying it to a non segmented coaxial P-Type HPGe detector, using a 438 MBq ^{137}Cs collimated γ-source and extracting the detector signal shape variation as a function of the interaction radial coordinate. The detector signals were digitised at the output of the preamplifier at 100 MSample/s (16-bit) by means of a SIS3302 board [16].

The rise time of the experimentally extracted signals was compared with the one expected from calculations based on a text book formula [17], obtaining a good agreement as can be see from the plot in the left panel of figure 2. The signal line-shapes experimentally extracted using the PSCS χ^2 procedure are shown in the right panel of figure 2.



<u>Figure 2:</u> Left Panel: *Rise time values of the pulses obtained averaging all the signals associated with the same interaction position (black squares), compared with the values expected from simple calculations [17] (full black line). Error bars for the experimental data are not plotted since they are smaller than the size of the symbols.* **Right Panel:** *Signal line-shape of the pulses obtained after averaging the signals associated with the same interaction position, extracted using the PSCS χ^2 procedure described in the text.*

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