In-beam measurements of silicon detector homogeneity via Pulse Shape Analysis

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One of the main research topics of the recently established FAZIA collaboration [1] is an R&D project, aiming at studying the pulse shape properties of the output of silicon detectors. The use of digital sampling and processing methods is under investigation for obtaining the isotopic identification of charged particles stopped in a silicon detector.

It is well known in the literature (see for example [2]) that the doping homogeneity of the detector play an important role in defining the final particle identification capabilities, i.e. good uniformity detectors are needed in order to obtain a pulse-shape-based (isotopic) particle identification over wide charge and energy ranges.

The main aim of this test was the evaluation of the detector response as a function of the impact point in a typical experimental configuration.

EXPERIMENTAL SETUP

As shown in Fig. 1, in the experiment a fixed collimator and a motorized detector support have been used. The setup thus allows to scan the detector surface and to measure the detector response as a function of the position. A collimation of 1.5 mm diameter has been used. The detector scan has been performed with a 2 mm step size, collecting ~1000 elastic events for each position. The test has been performed using a ^{58}Ni @ 703 MeV beam, scattered by a gold target.

The detector was connected to the PACI preamplifier [3], that provides both charge and current outputs. The two signals have been digitized and acquired using two different digitizers, namely the 12 bit 125 MS/s card described in [4] and a commercial digital oscilloscope (9 bit, 5 GS/s). Finally the waveforms have been stored on disk together with the corresponding x and y coordinates for offline analysis.

Two detectors have been tested – namely a circular one (385 μm, 450 mm^2, referred to as "E" in the following) and a square one (300 μm, 200 mm^2, referred to as "D" in the following). The detectors present full depletion in the 120-130 V range. They all operated at a voltage about 50% higher. Both detectors were produced by Canberra.

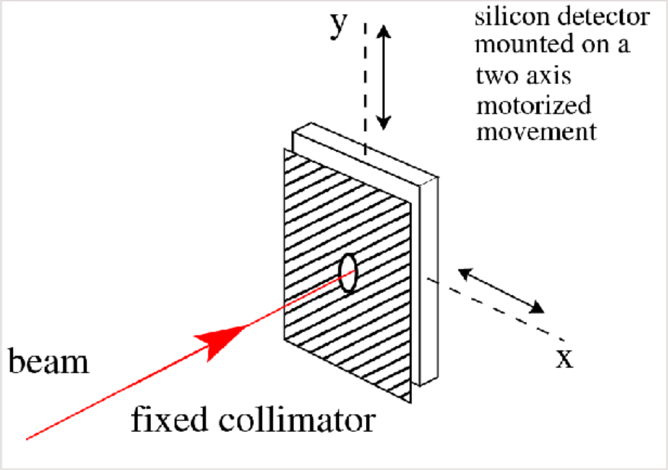


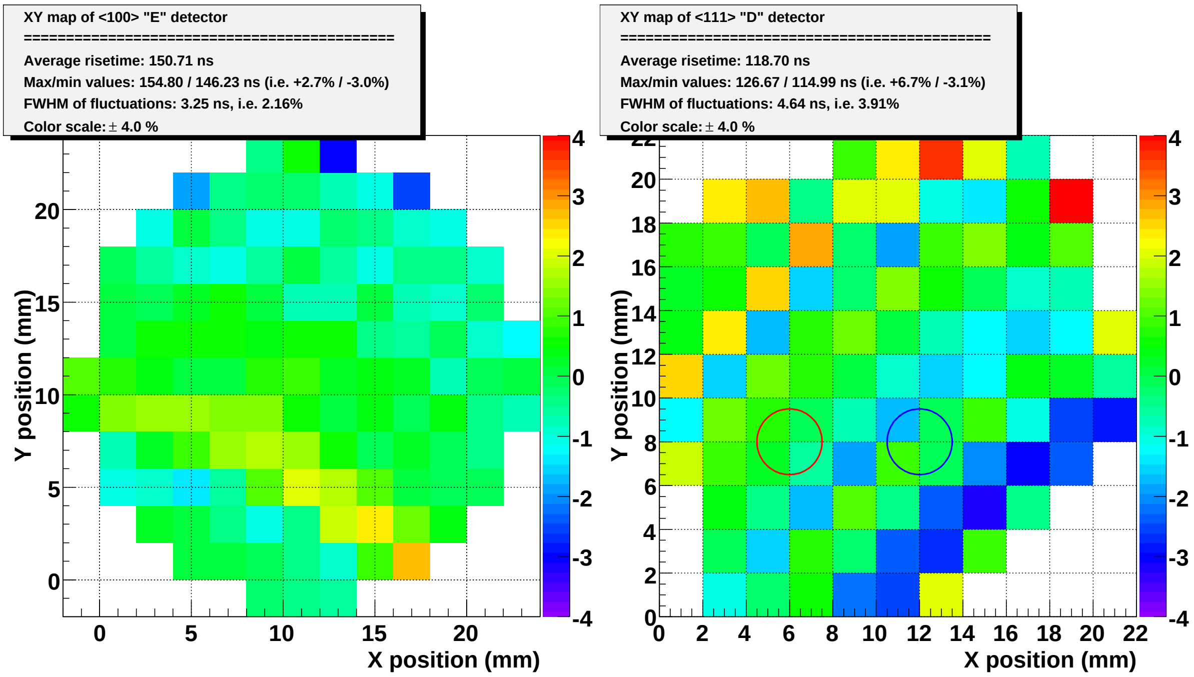
FIG. 1: Sketch of the used experimental apparatus. A remotely controlled support can move the detector along two perpendicular directions, thus allowing for an xy detector scan.

The setup is very similar to the one used in [5, 6].

RESULTS

The following analysis has been performed on the collected waveforms – for each waveform the measured energy is extracted with digital filtering [7] and the signal rise-time with digital CFD algorithms [8]. By gating on the measured energy, the events corresponding to elastic scattering are selected, discarding the others.

For each scanned detector point (x,y coordinates), the local average risetime is computed and compared with the overall detector average risetime – the results are reported in Fig. 2 (all data refer to the 125 MS/s digitizer). In the figure, the color codes refer to percent variation with respect to the overall detector average risetime, while in the labels some relevant parameters are reported, both in absolute units (ns) and in relative ones (%). The


XY map of <100> "E" detector
==
Average risetime: 150.71 ns
Max/min values: 154.80 / 146.23 ns (i.e. +2.7% / -3.0%)
FWHM of fluctuations: 3.25 ns, i.e. 2.16%
Color scale: ± 4.0 %

XY map of <111> "D" detector
==
Average risetime: 118.70 ns
Max/min values: 126.67 / 114.99 ns (i.e. +6.7% / -3.1%)
FWHM of fluctuations: 4.64 ns, i.e. 3.91%
Color scale: ± 4.0 %

FIG. 2: Results of the XY scan of the two tested detectors. Colors refer to percent variation of the signal risetime with respect to the mean value. Left: results for detector "E". Right: results for detector "D" (two selection cuts are shown, see text).

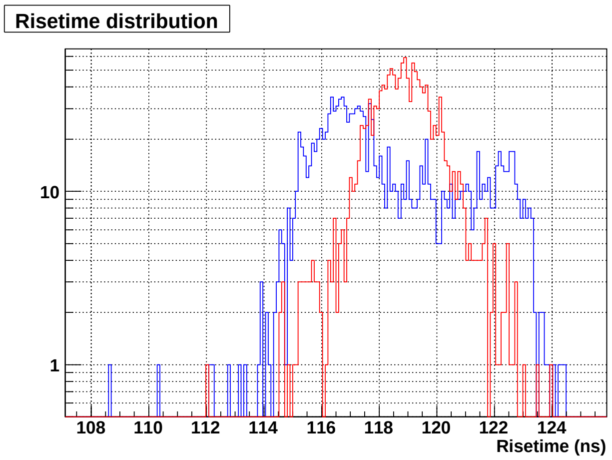


FIG. 3: Selected risetime distributions for the "D" detector. The red (blue) distribution corresponds to the red (blue) selection shown in Fig. 2 (right).

measured fluctuations thus provide an estimate of the "risetime-homogeneity" of the detector over its surface. Both detectors have fluctuations over the few % scale – the max variation is 5.7 % for the "E" detector and 9.8 % for the "D" one. The most striking feature of these plots is the geometrical arrangement of the non-homogeneities – it is clear from the pictures that the non-homogeneities of the "D" detector evolve on a very short scale (of the order of 2-3 mm) whereas the "E" detector has a much "smoother" behavior.

From the experimental point of view this means that the resolution-worsening effects due to the detector non-homogeneities cannot – for detector "D" – be reduced by a simple collimation. An example is shown in Fig. 3. In the figure two experimental risetime distributions are presented, corresponding to the two selections shown in Fig. 2 (right). It is clear from the figures that when the xy selection is placed in a relatively flat area (the "red" one) it is possible to achieve a narrow and gaussian risetime distribution. On the contrary, when the xy selection is placed in an area containing abrupt jumps (the "blue" one) a wider and strongly not-gaussian risetime distribution is obtained.

These tests show that, depending on the geometrical structure of the non-homogeneities, a simple collimation of the detector may not suffice to reduce the apparent non-homogeneity and to improve the achieved pulse-shape identification performances. Studies aimed at improving and controlling the overall detector homogeneity are in progress.

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