High precision mapping of single-pixel Silicon Drift Detector for application in astrophysics and advanced light source

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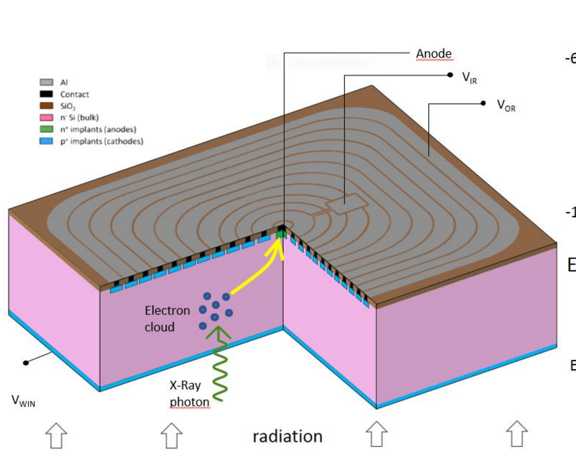
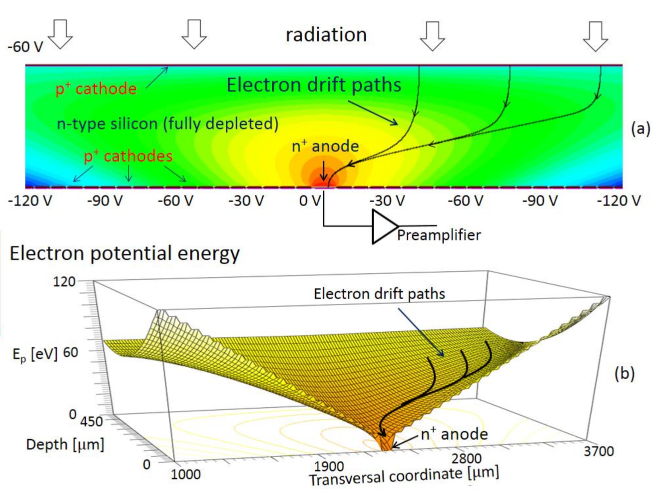
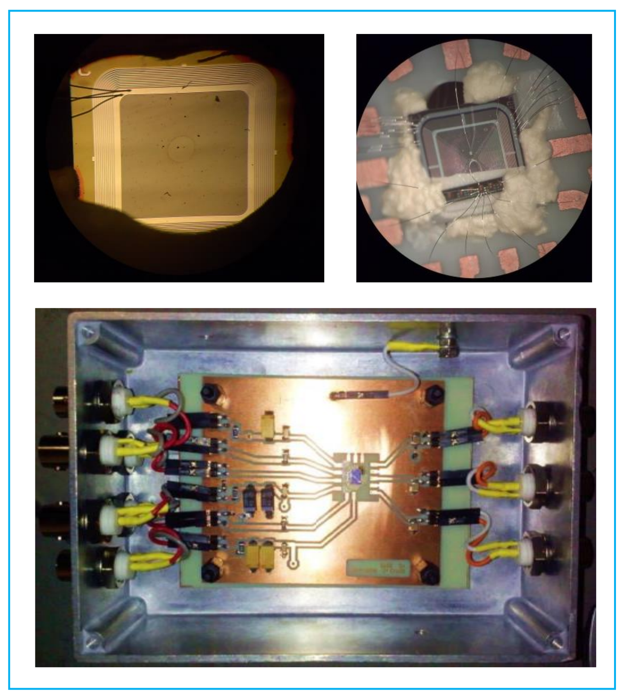
Abstract

A Silicon Drift Detector with 3x3 mm² sensitive area was designed by INFN of Trieste and built by FBK-Trento.
It represents a single-pixel precursor of a monolithic matrix of multipixel Silicon Drift Detectors and, at the same time, a model of one cell Fluorescence Detector System (XAFS) for SESAME.
The point-by-point mapping tests of the detector were carried out in the X-ray facilities at INAF-IAPS in Rome, equipped with a motorized two-axis micrometric positioning system.
High precision characterization of this detector was done with a radioactive ^{55}Fe source and a collimated Ti X-ray tube equipped with a Bragg crystal monocromator.
The mapping in different positions and bias condition was specifically-aimed to the detailed analysis of the charge collection efficiencies at the edge of the detector.
The result is important to understand and verify the aspects related to the collection of the signal with respect to the position of interaction of the photons, especially in consideration of the new design and development of monolithic multipixel detectors.

Introduction: the detector

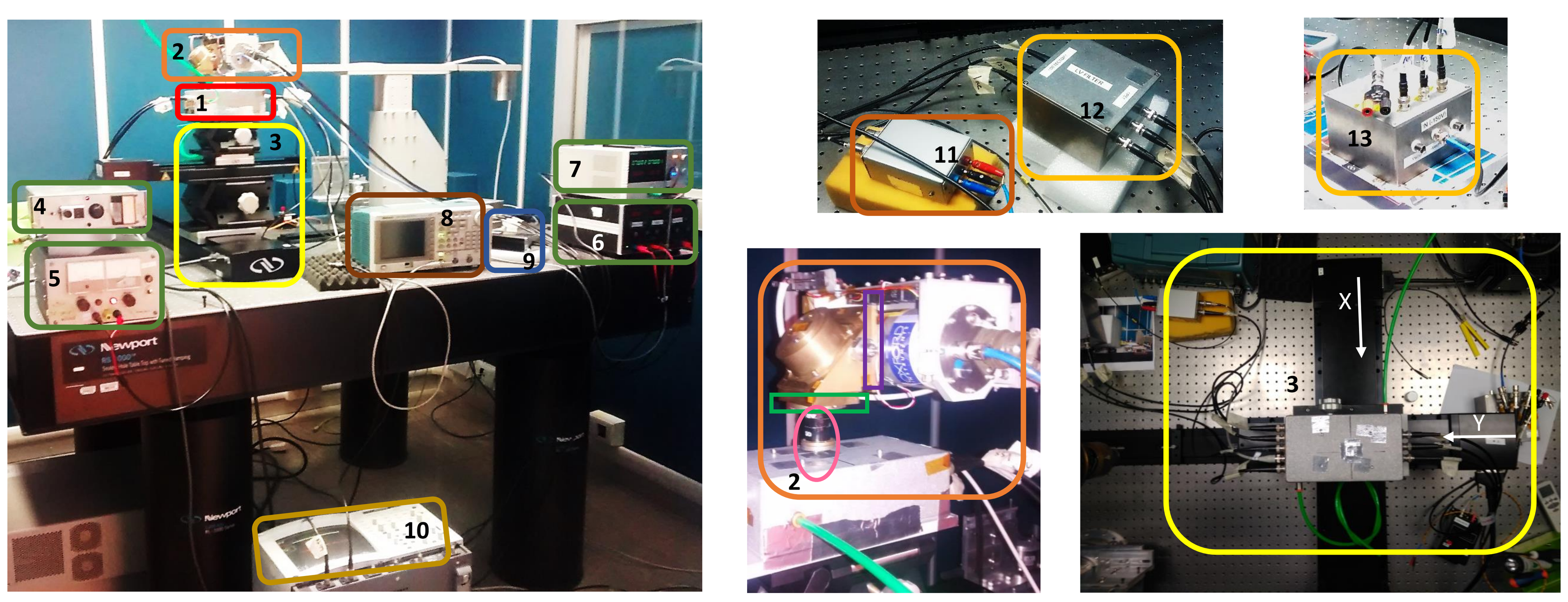






On the left - Working principle and structure of the detector
In the center - Section of SDD sensor (a) and potential energy of the electrons (b)
On the right (in clockwise direction) - Picture of the detector from the side of the window, from the side of the readout and picture of the detector circuit

Experimental setup



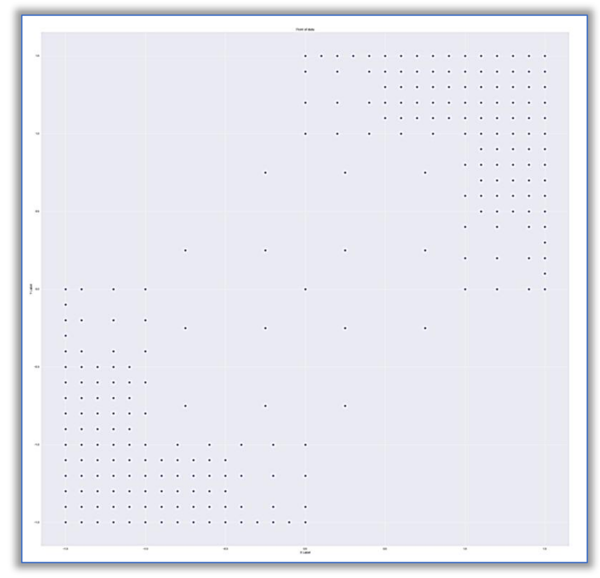
1. Detector and SIRIO amplifiers
2. Ti anode X-ray tube equipped with a Bragg diffractor to select the Ti K_α line (4.5 keV), crystal: Fluorite CaF_2 (220), The X-ray tube was configured at 35 kV and 0.6 mA. A 1/40-ratio diaphragm (purple box in 2) is between the tube and the diffractor, the diaphragm between the diffractor and the detector is composed of: a second 1/40-ratio diaphragm (green box in 2), a 34 mm length diaphragm and a diaphragm with 100 µm hole size (pink box in 2)
3. Two motorized micrometric rails for two-dimensional positioning
4. Supply voltage needed for depletion voltage (window, V_{WIN}) and the anode (inner ring, V_{IR}) for the detector
5. Supply voltage needed for the cathode (outer ring, V_{OR}) for the detector
6. Supply voltage needed for the SIRIO preamplifier
7. Supply voltage needed for the amplifier
8. Reset pulser
9. DP5 digital pulse processor
10. Oscilloscope
11. Amplifier
12. Low voltage filter for the SIRIO preamplifier supply voltage
13. High voltage filter for the detector
14. Nitrogen

Measurements

Foregoing measurement (in an air-conditioned room with an ambient temperature of 18 °C):
- searched dimension of gaussian shape beam: for the X axis the FWHM of the beam is 165.48 µm and for the Y axis is 128.83 µm;
- aligned the detector with the X-Ray tube, searched for the center position;
- calibration with radioactive ^{55}Fe source and Ti X-ray tube.

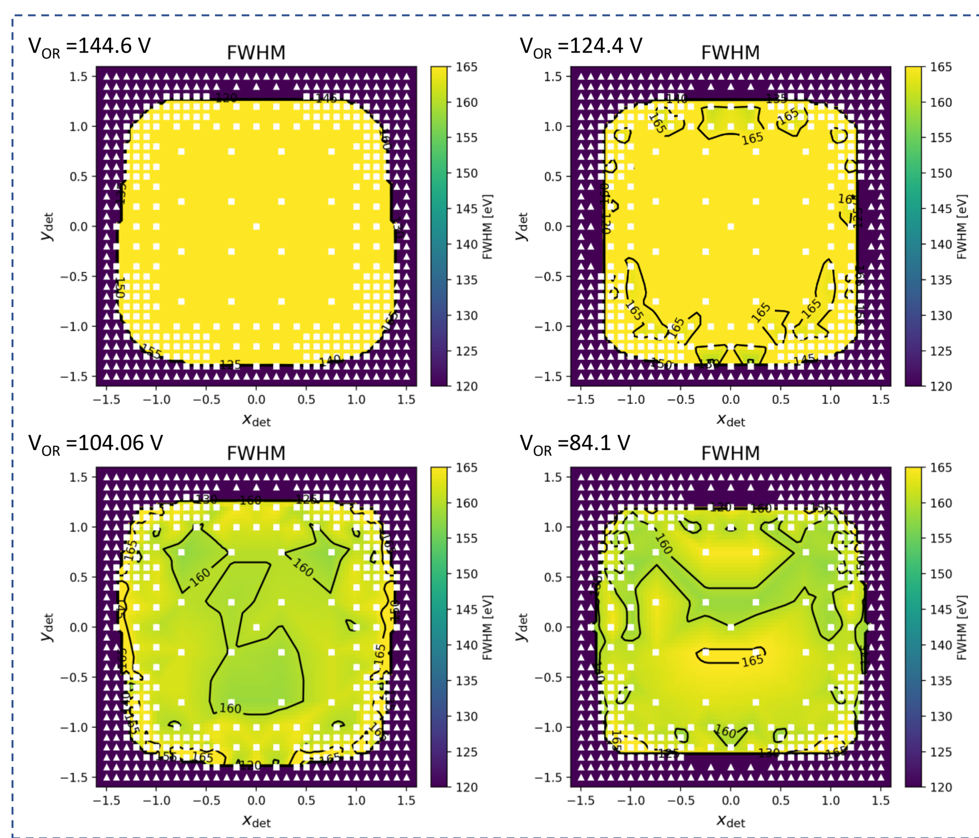
For the point-by-point mapping, we have used a different step between the points for the central zone (500 µm) and a thinner step (100 µm) for the edges of the detector.
The measurements have been made for different 4 outer ring voltages.

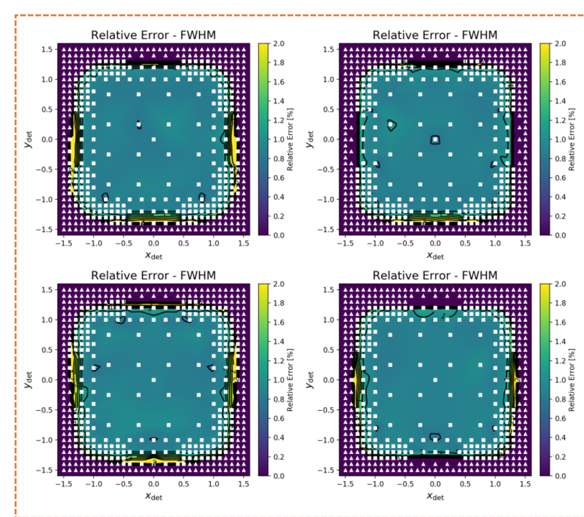
Outer ring voltage (V_{OR})	Windows voltage (V_{WIN})	Inner ring voltage (V_{IR})
-144,6 V	-85,10 V	-23,8 V
-124,4 V	-80,66 V	-21,13 V
-104,06 V	-80,85 V	-19,81 V
-84,1 V	-80,97 V	-18,59 V



On the left – The 4 different voltages used for 4 mapping measurements
On the right – Scheme of the map used for acquisition with different step for the inner and the edge of the detector

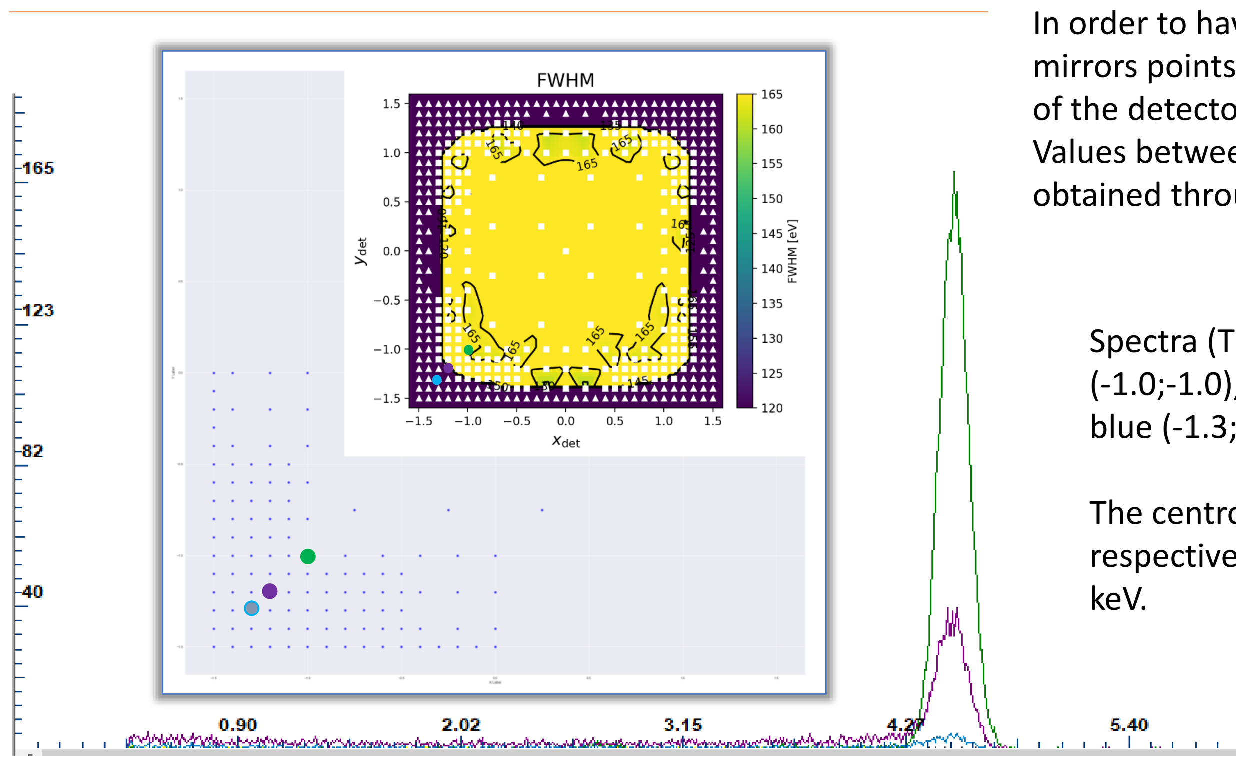
Results





Figures show the results of the mapping of FWHM (on the left - blue dashed box) and the relative error (on top - orange dashed box).

The squares are the points that have much than 25 counts for the Ti K_α line, and were processed. Instead the triangles have less than 25 counts for the Ti Kα line and were discarded.
In order to have a better view of the results, we mirrors points to obtain a square representative of the detector.
Values between the experimental points were obtained through linear interpolation.



Spectra (Ti K_α line) at points: green (-1.0;-1.0), purple (-1.2;-1.2) and blue (-1.3;-1.3) with V_{OR} = 124.4 V.

The centroid of the peak is, respectively, at 4.51, 4.50 and 4.47 keV.

The outer ring voltage changes the efficient area of the detector. This detector has a larger effective area (2.7x2.7 mm²) than the previous designed one tested in 2016 (2.5x2.5 mm²), but still less than the nominal 3.0x3.0 mm² area.

Conclusions/Future work

The mapping is useful for analysis of the detector behaviour. In particular, it allows to verify aspects related to the charge collection to the detector's edge. Furthermore, the mapping increases progress in the design and development of new monolithic matrix of multipixel Silicon Drift Detectors for application in astrophysics and advanced light source.

References

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Poster

Speaker

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Acknowledgments

ReDSoX Collaboration
https://web.infn.it/redsox2