# R&D Status of SOI Sensors*

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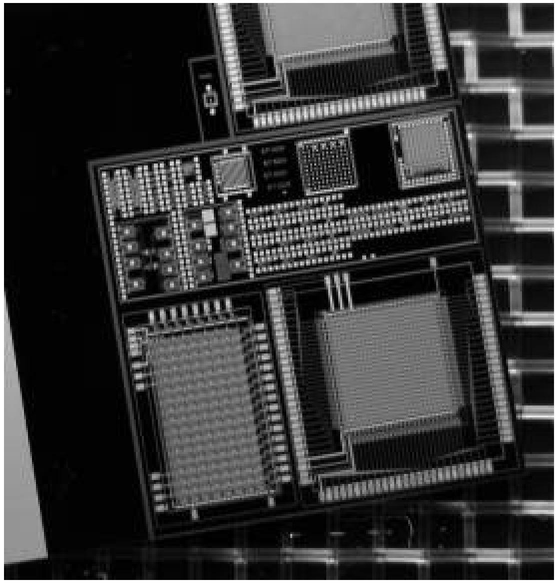
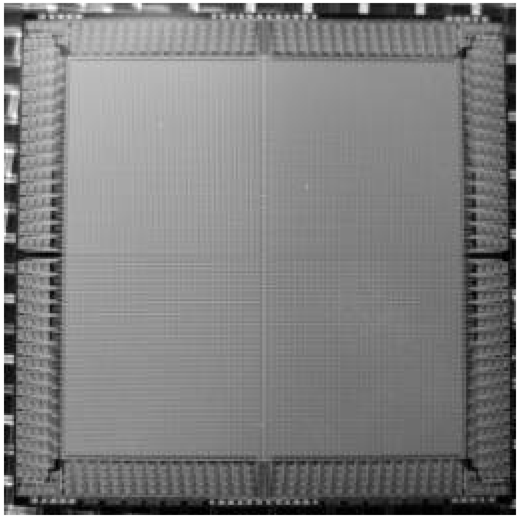
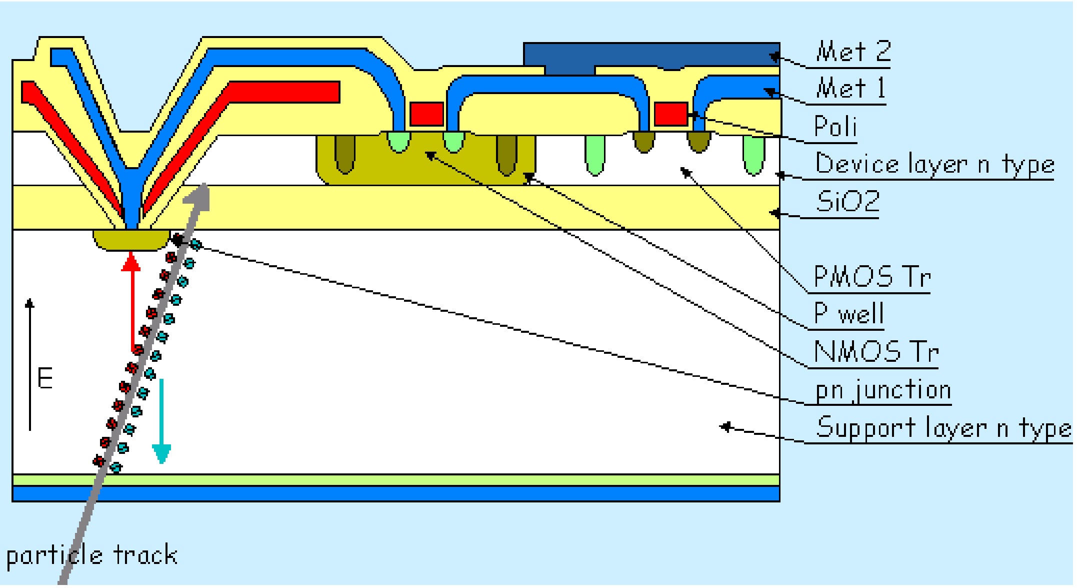
# Outline

- Principle of the SOI sensor
- Summary of results obtained with SOI sensor test structures
- Present R&D status - first large-scale SOI sensors
- Plans of further development

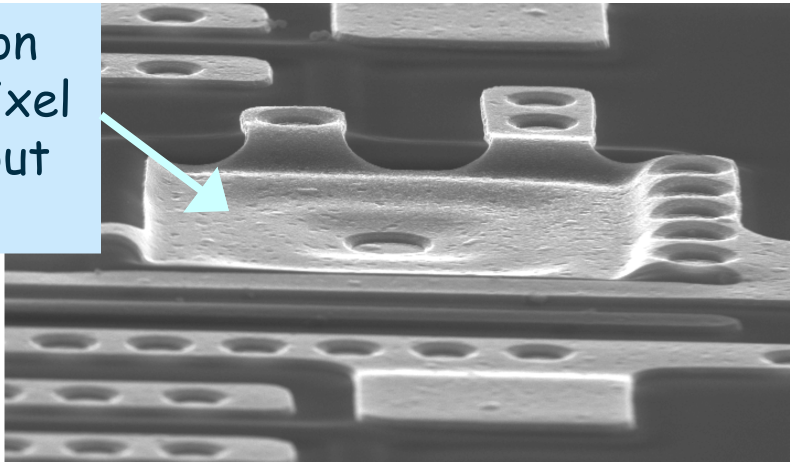




# Principle of SOI monolithic detector




Connection between pixel and readout channel



Integration of the pixel detector and readout electronics in a wafer-bonded SOI substrate

Detector → handle wafer

- High resistive (> 4 kΩcm,FZ)
- 400 μm thick
- Conventional $p^+$-n

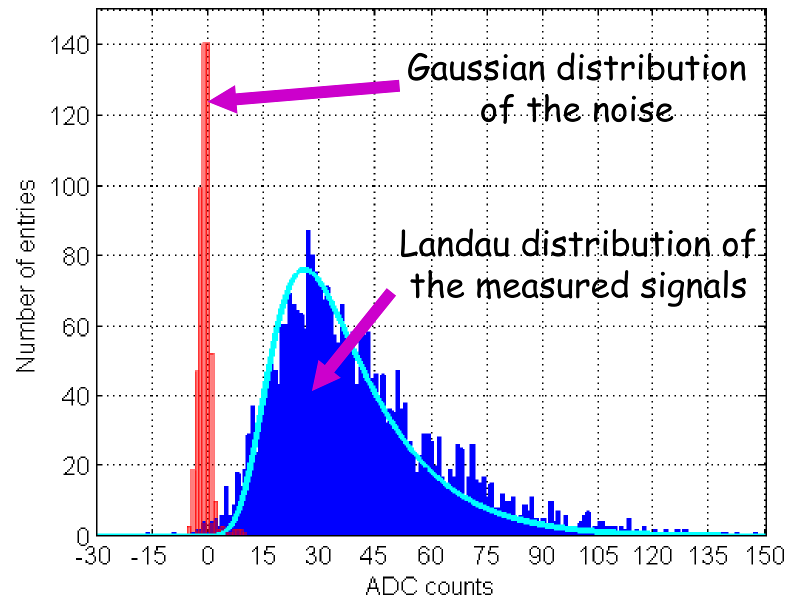
Electronics → active layer

- Low resistive (9-13 Ωcm, CZ)
- 1.5 μm thick
- Standard CMOS technology

# First step of Development - SOI Detector Test Structures

- The possibility of the SOI detector realization has been studied during last several years. The concept of the device was first validated in several iterations of productions and tests of simple detector test structures:
  - matrices of 8x8 sensor cells
  - Cell dimensions 140x122 $\mu m^2$
  - Readout channel similar to 3T cell
  - No digital control blocks
- Performed tests (some results presented during LCWS04):
  - Linearity tests with infrared laser light and alpha source Am241
  - Gain calibration with gamma source Am241 and beta source Sr90
  - Sensor sensitivity tests for particles with limited range in Silicon with alpha source

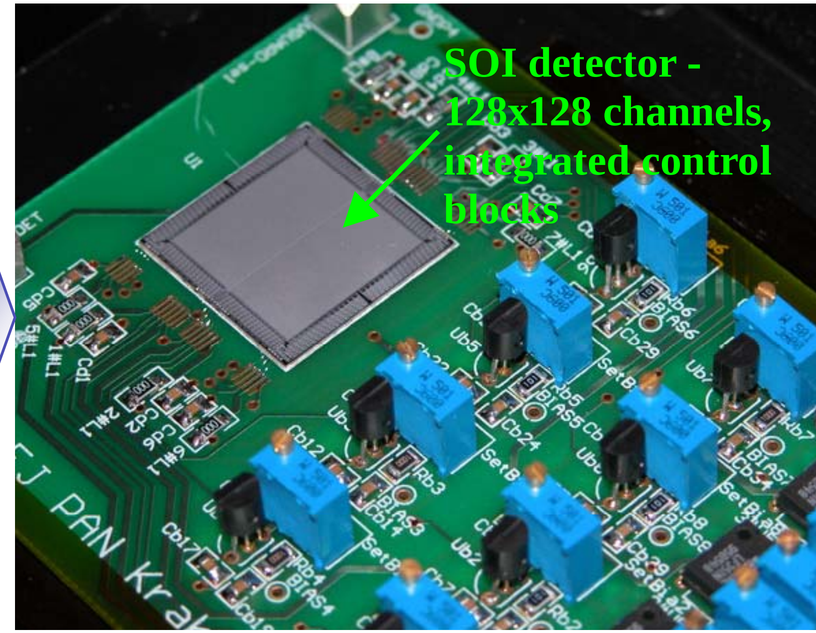
Measured energy spectra of $\beta$ particles from Sr90

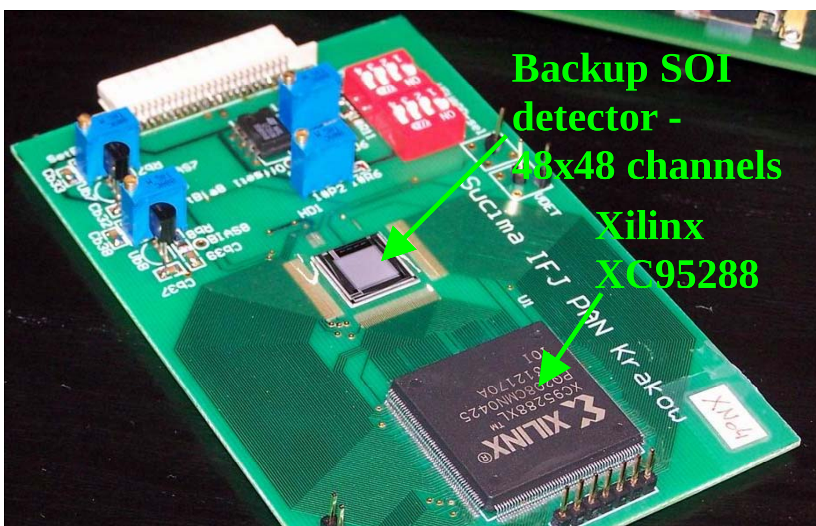



- Charge to voltage gain: 3.6 mV/fC
- Input dynamic range: 0.5 to 40 MIP

# First large-scale SOI Detectors

- Fully functional detectors with implemented readout blocks on chip
  - 128 x 128 readout channels
  - area 2.4 cm x 2.4 cm
  - 4 independent sub-matrices
  - Operation in charge integration mode
  - Dead time below 1% with respect to integration time
- Optimised for medical applications



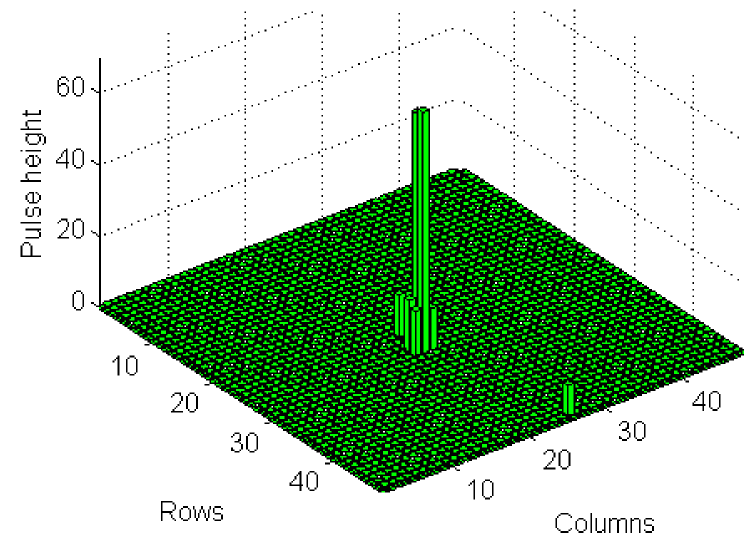

- „Baby Detector” – 48 x 48 readout channels, area 1.2 cm x 1.2 cm, no digital control blocks
- Column, row and reset signals generated by Xilinx CPLD (XC95288XL)

# First large-scale SOI Detectors (cont.)

- Parameters according to design:
  - Pitch: 150 μm x 150 μm
  - Dynamic range: up to 500 fC (~ 100 MIP)
  - Charge to voltage gain: 3.6 mV/fC
- Very preliminary test results:
  - Sensor sensitivity observed with laser pointer and α particles
  - Problems with the production yield – for the best large sensor proper readout operation observed for 3 quarters
  - Readout frequency up to 4 MHz

<u>Recorded α particle</u>

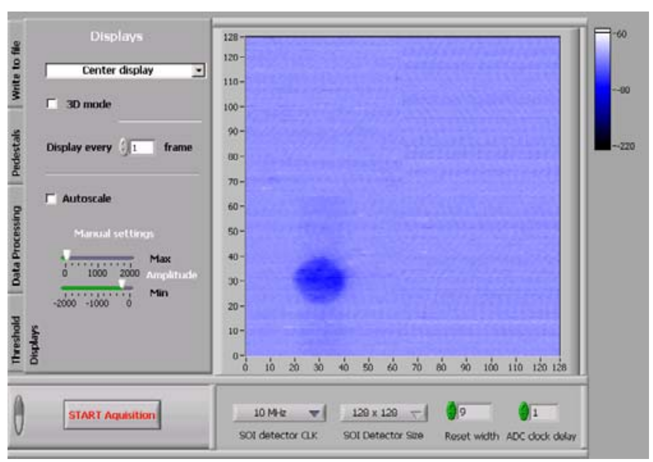
Detector: 48x48 cells

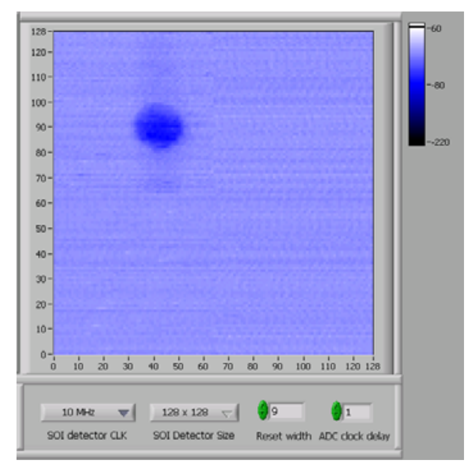



<u>Visualization of the readout results</u>

Detector: 128x128 cells

Laser pointer light shined on two different quarters of the detector



# Summary

- SOI sensor development status:
  - The technology of the sensor manufacturing was developed.
  - Tests of the first small test structures were performed. The results proven the feasibility of the SOI sensor.
  - Larger and fully functional SOI sensors (128x128 readout channels) have been designed and produced. Although preliminary tests showed some problems with production yield, proper readout operation and sensitivity to ionising radiation was observed for the good structures.
- Nearest future – works on the SOI sensors produced at IET will be carried on:
  - The tests of the large-scale sensors and next production runs are in progress. The design and process were improved to achieve better reliability and yield.
  - Works on the SOI sensor for digital radiology are foreseen.

# The future – SOI for HEP experiments?

## Might be the SOI solution suitable for future HEP experiments?

- Yes, because:
  - SOI sensors as monolithic devices can be thin.
  - Fully depleted p-n junctions
  - SOI sensors are flexible – both transistor types can be used in readout channel, which allows implementation of signal pre-processing in the sensor cell.
  - They are expected to be inherently more radiation hard for SEE.
- No, because:
  - The presented SOI sensors are produced in 3 μm technology, which makes them too slow, too radiation soft and not granular enough for HEP experiments. Present SOI sensor can be used only in less demanding applications.

Moving the sensor production to sub-micron process should open the way to development of detectors suitable for future HEP experiments.

We are looking for partners from silicon foundries for production future SOI sensors and... we received some preliminary interests...