Towards a New Generation of Monolithic Active Pixel Sensors

15th Pisa Meeting on Advanced Detectors

The TANGERINE project – MAPS in a 65 nm Process

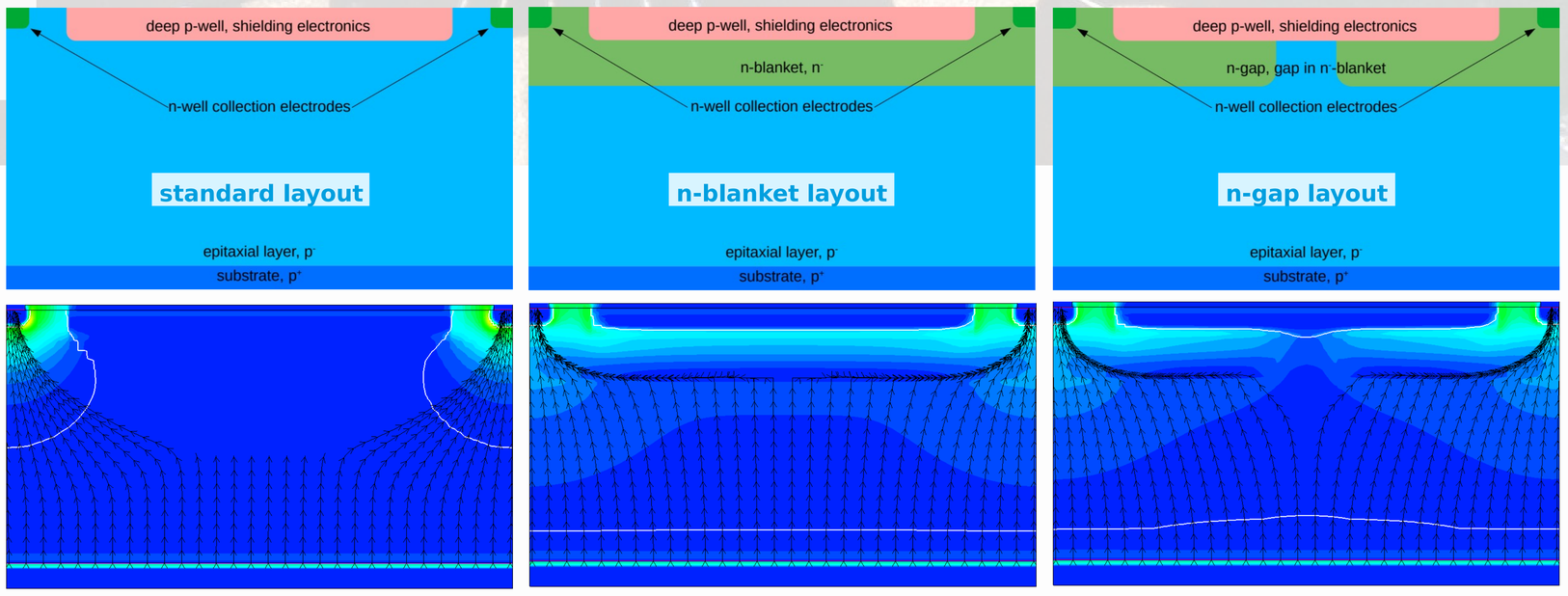
MAPS – Advantages over Hybrid Sensors
- Monolithic Active Pixel Sensors (MAPS)
- Readout circuitry in deep p-well on top of sensitive volume
  - ➔ Only one device to produce, no flip chipping needed
  - ➔ Reduces yield issues and production cost
  - ➔ Thinner devices, less multiple Coulomb scattering

Sensors Produced in 65 nm – Getting Smaller
- A 65 nm process for CMOS Image Sensors (CIS), now explored for HEP applications
- Higher densities of in-pixel logic
  - ➔ Smaller pixels AND/OR
  - ➔ Smarter pixels

Project Goals
- Spatial resolution: 3 um
- Temporal resolution: 10 ns
- Thickness: < 50 um
- In-pixel charge measurement (time-over-threshold)
- Exploit/ explore capabilities for in-pixel logic

Application
- Short term: Beam-line instrumentation at DESY (reference for detector research and development)
- Long term: Future lepton collider/ Higgs factory

Approach
- Small collection electrode
  - ➔ Maximize signal-to-noise ratio
  - ➔ Minimize power consumption



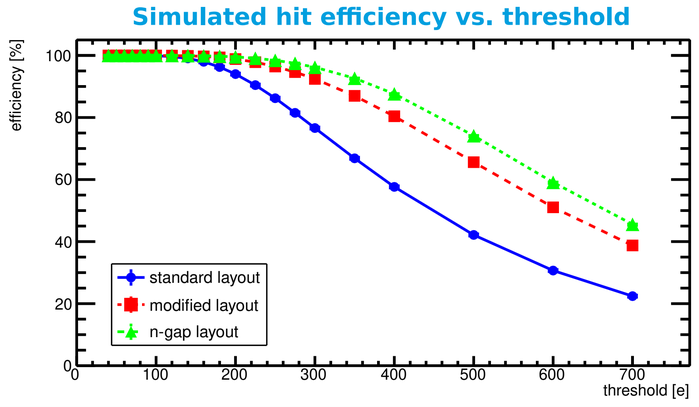
Simulation Studies

TCAD – Electric Field Simulation
- Synopsys Technology Computer Aided Design (TCAD)
- Starting from generic doping profiles
- Derive detailed electric fields by numerically solving Poisson equations

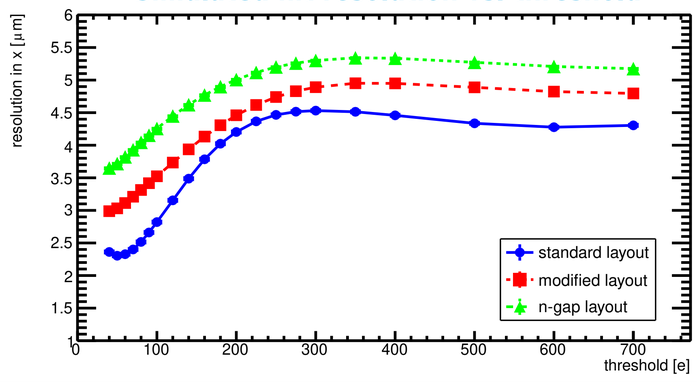
Allpix² – Monte Carlo Simulations
- High-statistics time-resolved MC simulation of signal evolution in sensor
- Charge deposition via GEANT4
- Import electric fields from TCAD for charge transport simulation
- Make predictions of sensor performance

➔Compare to measurement and other simulations
➔Investigated layouts: Standard, n-blanket, n-gap
➔Study impact of design parameters and operation conditions
- Width of p-well opening and gap in n-blanket
- Pixel-pitch (here 20 x 20 um²)
- Biasing conditions

Simulated hit efficiency vs. threshold

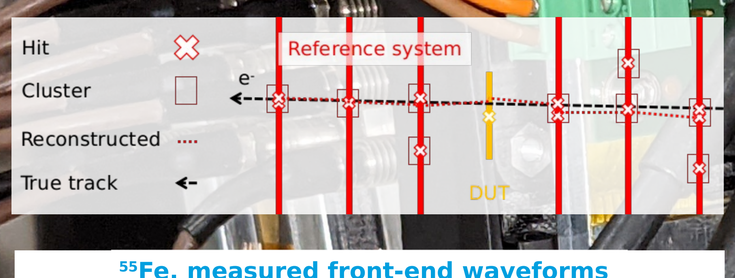


Simulated hit resolution vs. threshold

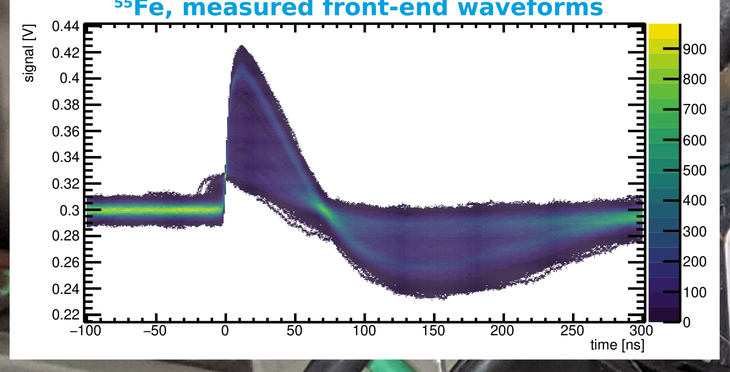


Sensor Characterization

Test Beam Measurements
- Using test chip with 2 x 2 pixels
- Challenging due to small active area (32.6 x 32.6 um²)
- Oscilloscope based readout in self-triggered mode
- DESY II
  - 2 to 5 GeV electrons, recorded ~ 1 event per hour
- CERN SPS
  - 120 GeV pions, recorded few events per hour
- MAMI Microtron
  - 855 MeV electrons, achieved few Hz of events



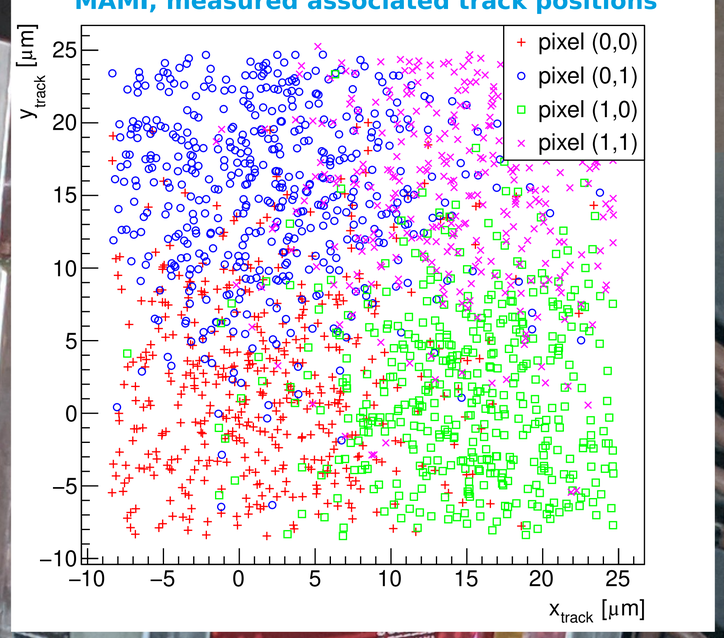
^{55}Fe, measured front-end waveforms



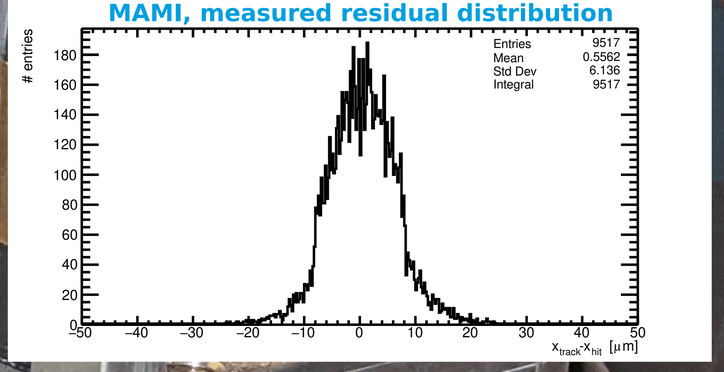
Preliminary Results
- First successful operation of a 65 nm CMOS sensor developed at DESY
- Resolution measurement dominated by reference measurement due to multiple Coulomb scattering
- Small hit detection efficiency revealed design issue
  - ➔ Fixed for next submission
- Rise time (20-80%) ranges 4 – 9 ns
  - ➔ O(ns) time resolution achievable
- Characterized Charge Sensitive Amplifier (CSA)
  - ➔ Reduce time-over-threshold non-linearity

Next Steps
- Characterize Analogue Pixel Test Structures (APTS)
  - ➔ Use results to validate simulation procedure
- Submission of second prototype generation
  - ➔ Characterization starting end of 2022

MAMI, measured associated track positions



MAMI, measured residual distribution



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