Simulation of ILC type DEPFET Sensors

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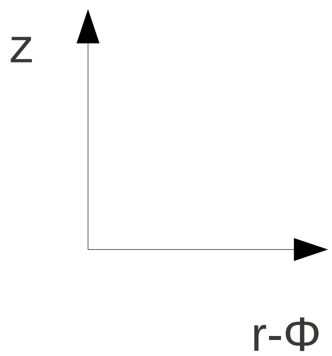
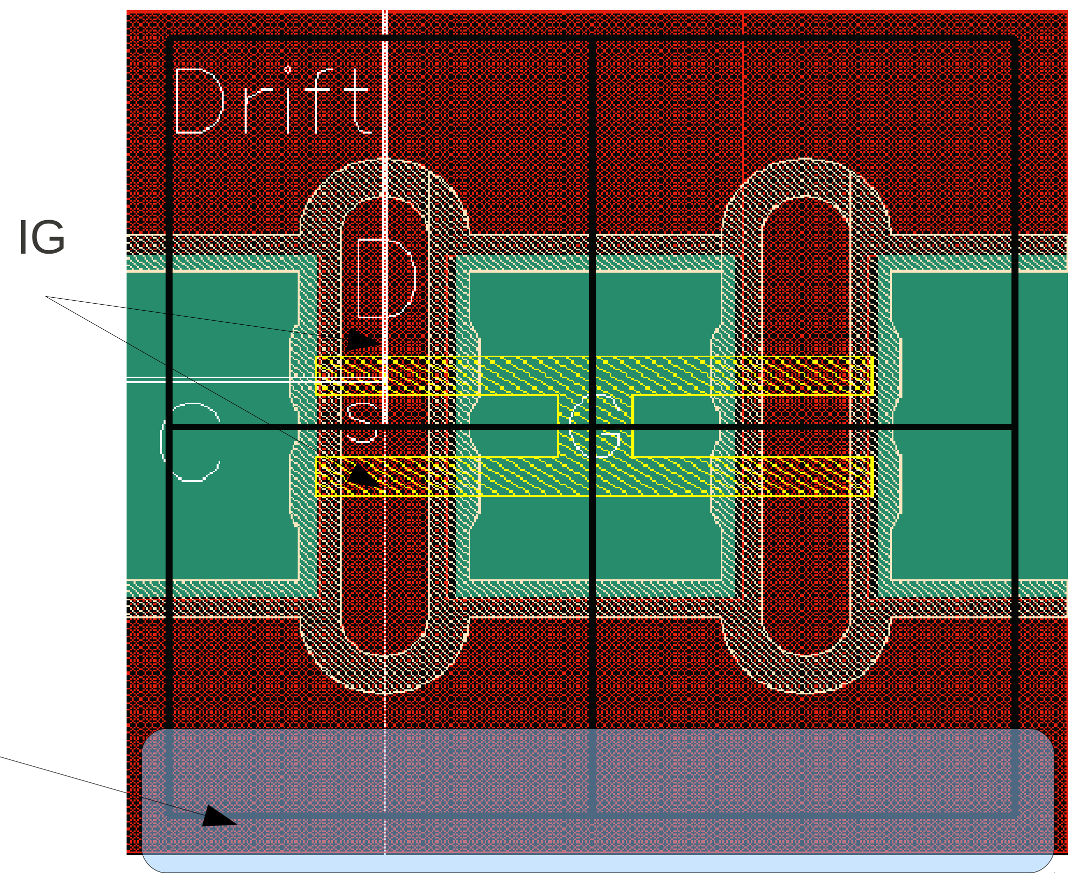
Outline

- “Fast” Simulation of DEPFET Senors
  - To be used in detector optimization
  - Overview simulation model
- Validation using test beam data
  - Different sensot layouts tested
    - 450µm thick with 20x20μm^2 pitch
    - 50µm thick with 50x75μm^2 pitch
- Spatial resolution of ILC type sensors

DEPFET Pixel Cell

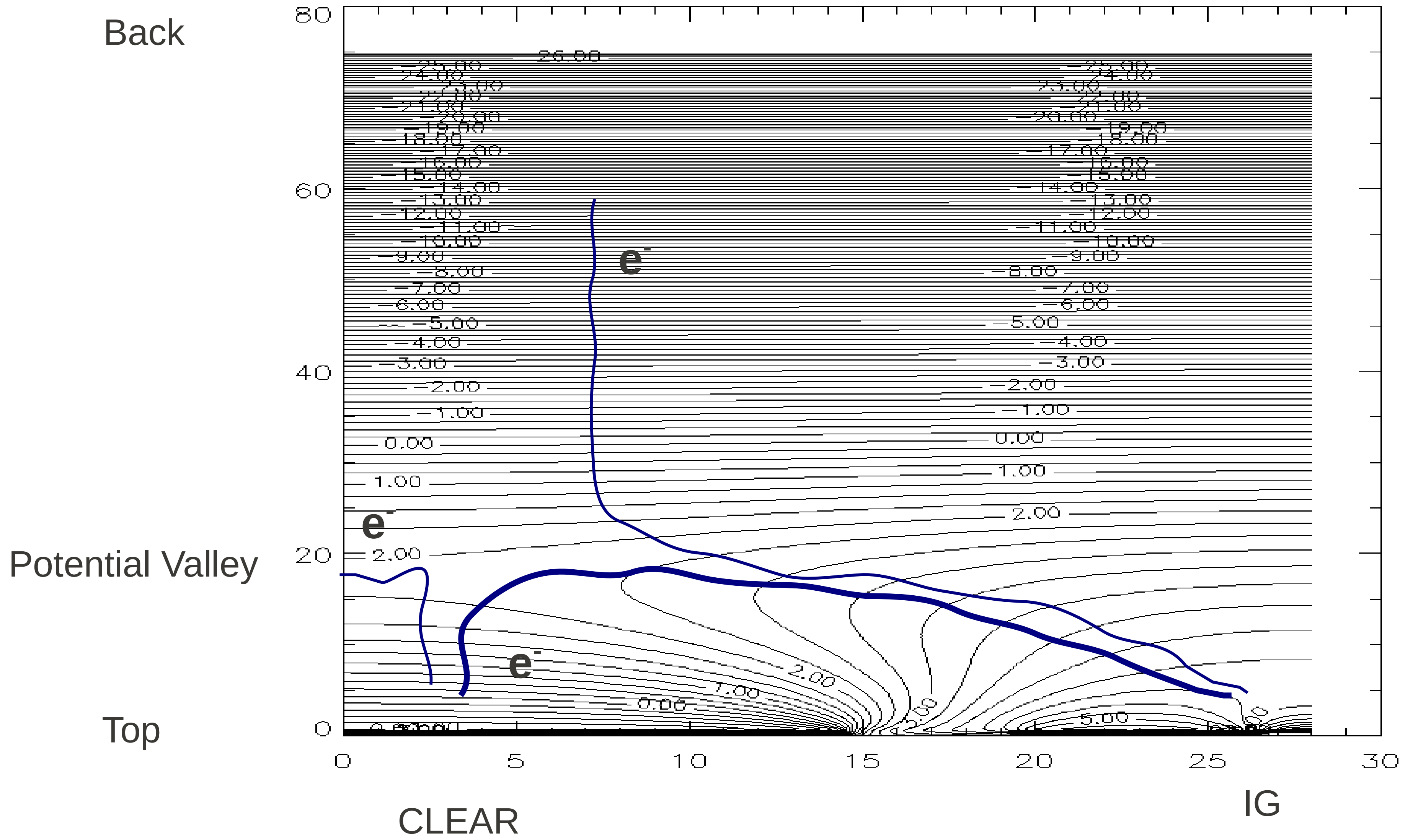
Prototype layout for 50x50x75 DEPFET pixel cell



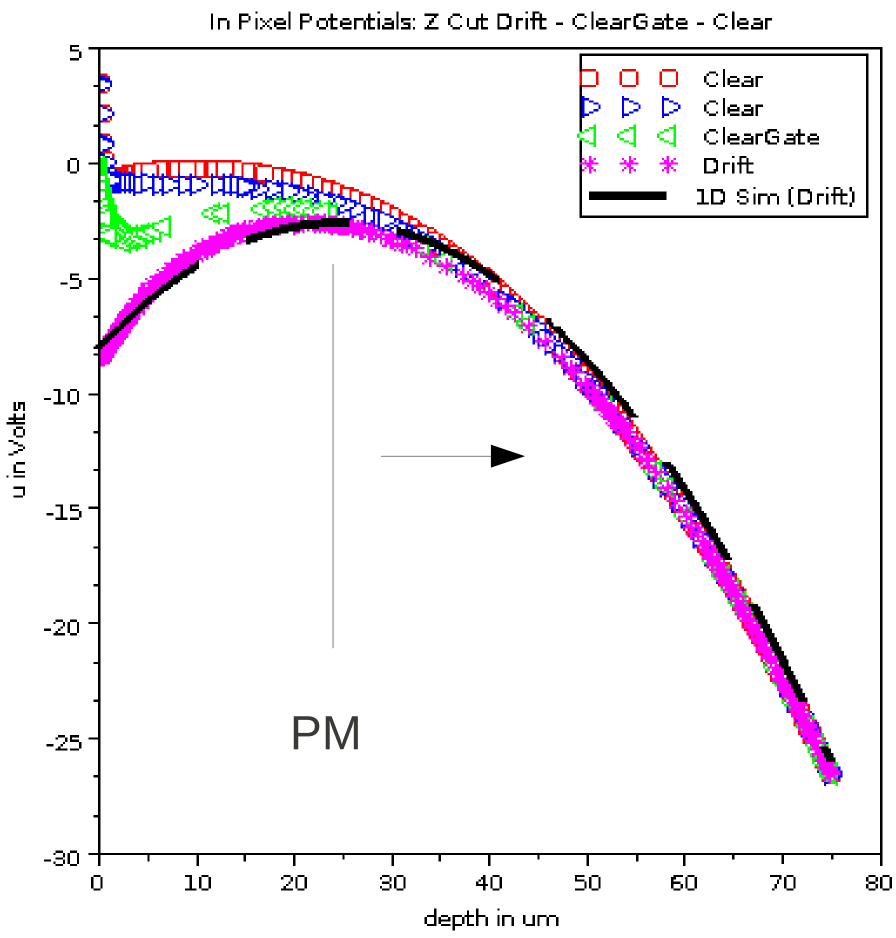


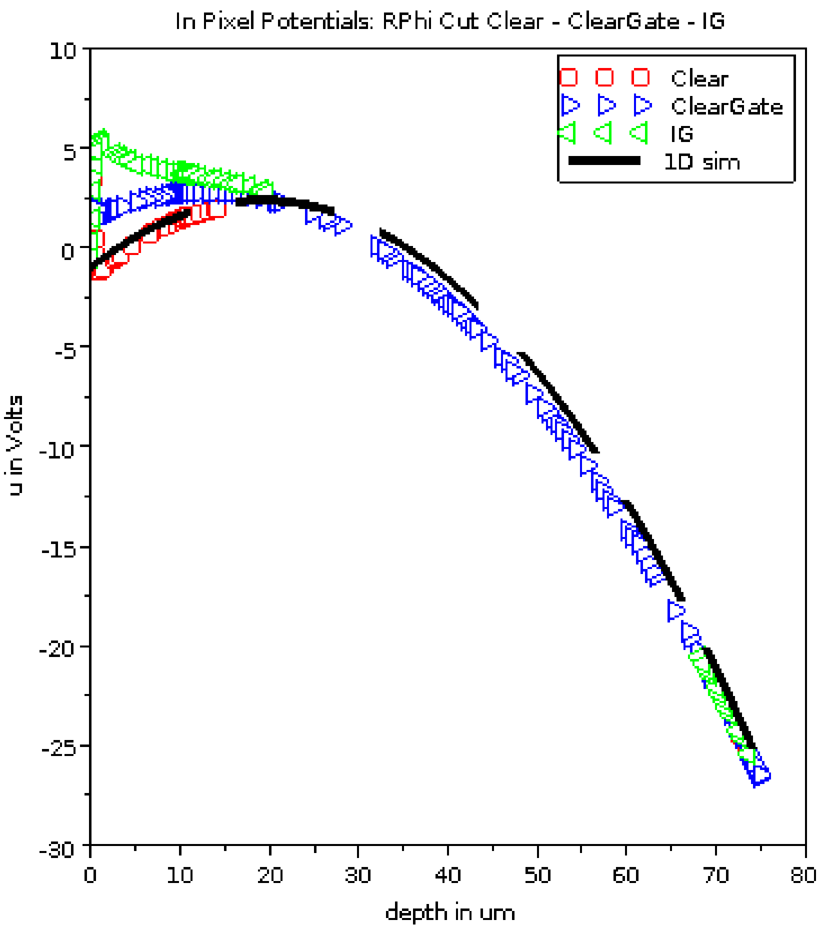
Pixel Border: Weak lateral drift fields
and pixel charge sharing.

2D Potential Map in R-Φ Cut: Clear – Clear Gate – IG



Vertical Charge Transport

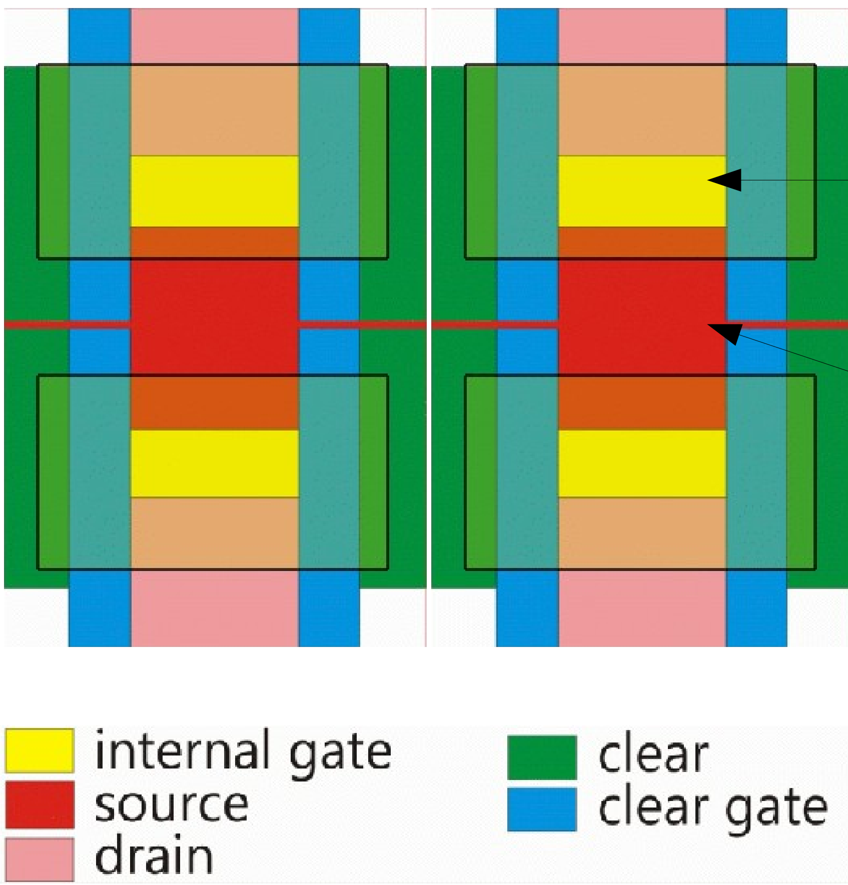




Simple parabolic potential model works below the potential maximum and in Drift/Clear pixel borders.

Charge Collection in Readout Plane

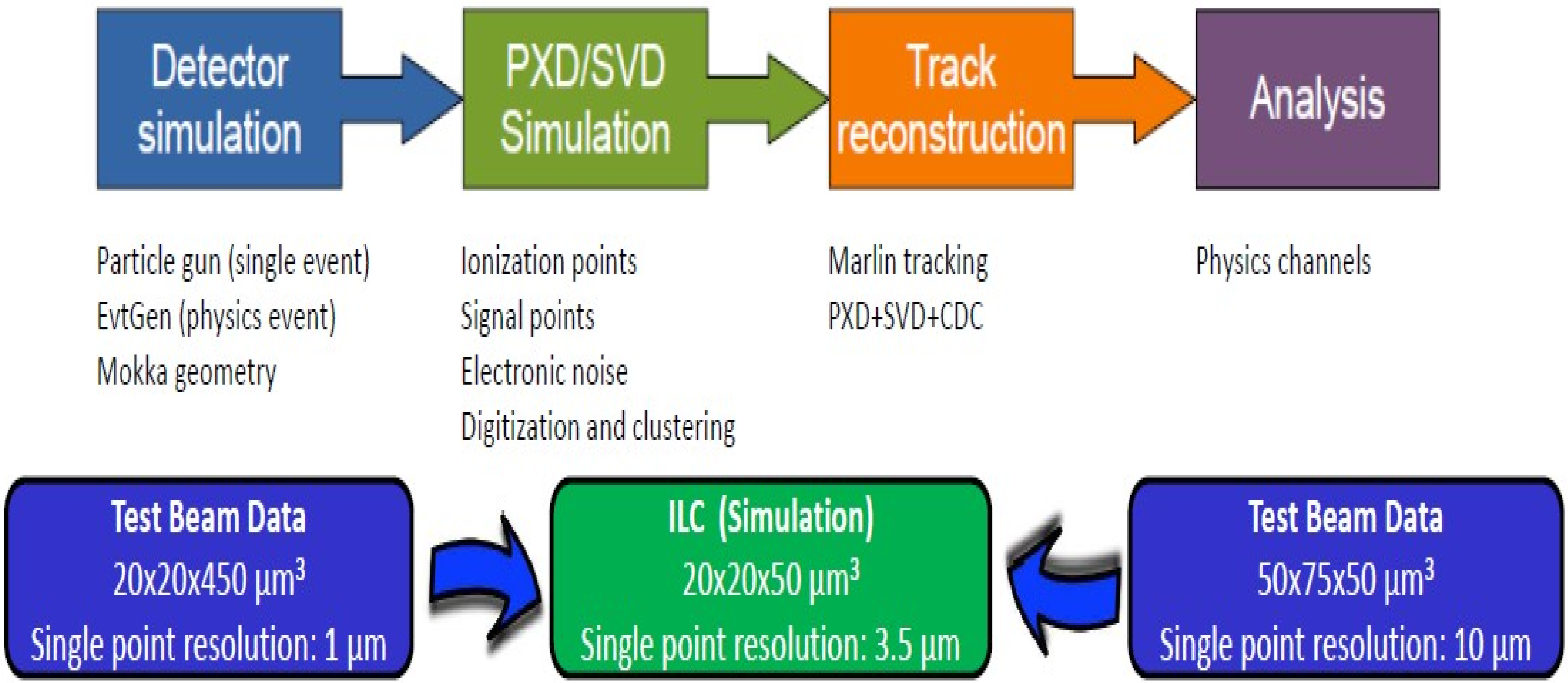
PXD5 32x24um^2



Drift fields move all charge into internal gate; Diffusion is small.

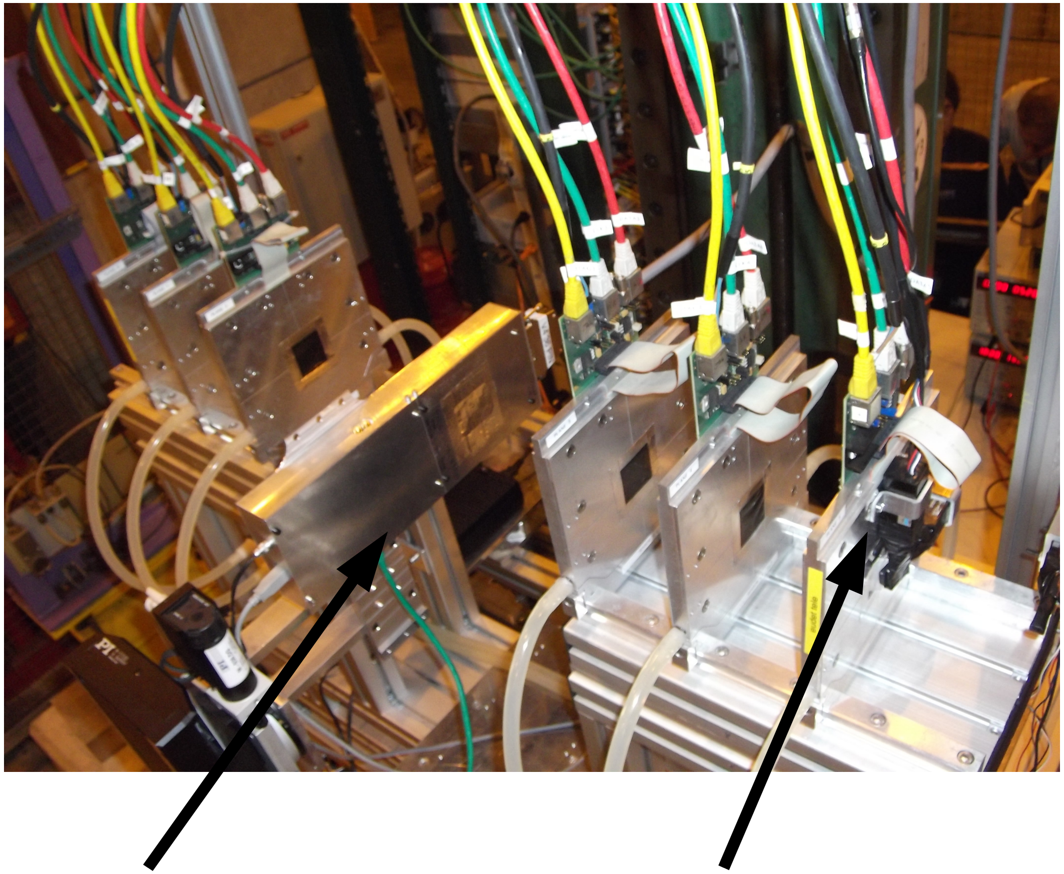
Drift fields are small. Only diffusion of e- towards internal some gate.

Length of drain border region



- Geant4 models energy loss in Si
  - Low range cut ~1um → Landau fluctuations and delta electrons
- Digitization implemented as Marlin Processor
  - Inputs are Geant4 steps (all) and Mokka Geometry
  - Charge drift/diffusion, Lorentz effect, 8bit ADC
- Test beam analysis using Eutelescope

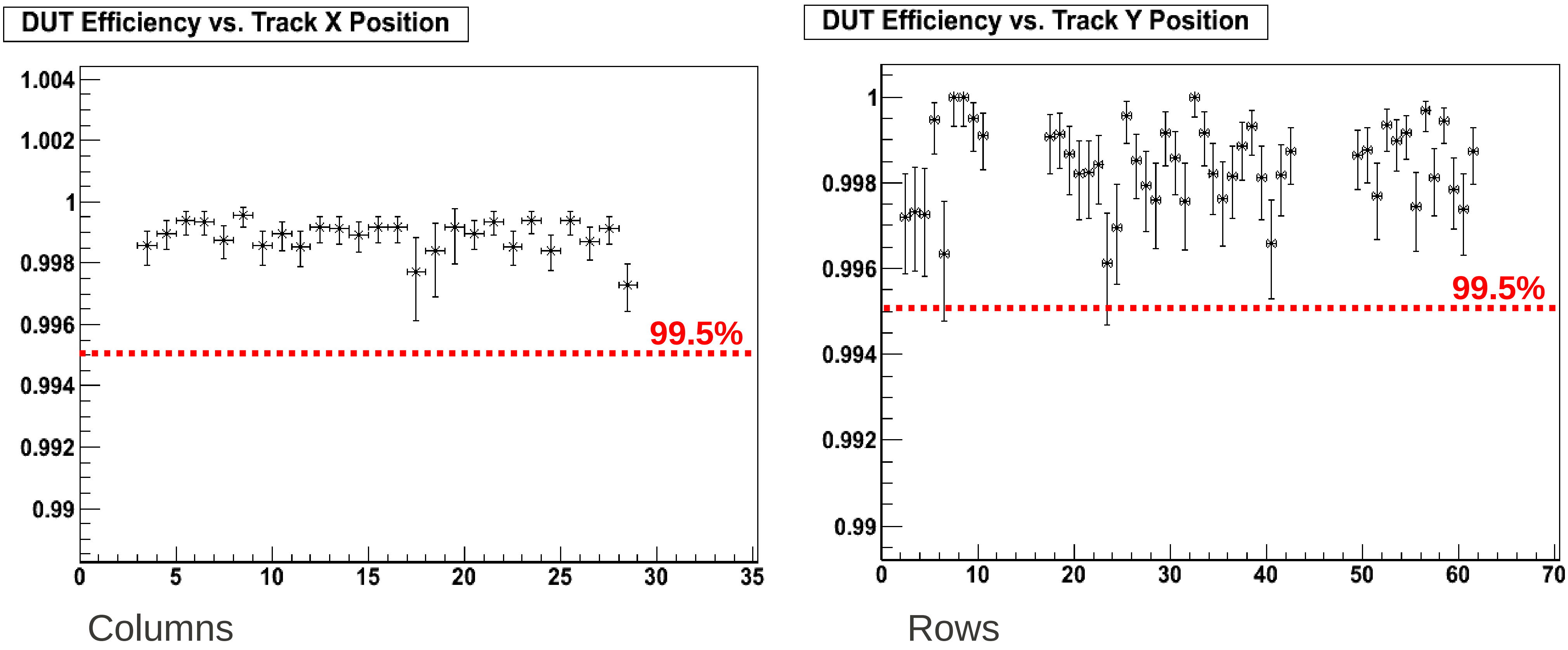
Test beam 2011-2013 @ CERN SPS and DESY



DEPFET Module   Mimosa26 Pixel Module

- Take fully tested DEPFET module to
  - CERN SPS: 120GeV pions
  - DESY: 1-6GeV e-/e+
- Record ~millions of precisely reconstructed tracks
- Measurement goals:
  - Spatial resolution
  - hit efficiency
  - Uniformity of gains/noise
  - In-pixel: uniformity of charge collection
  - Tilt scans / voltage scans

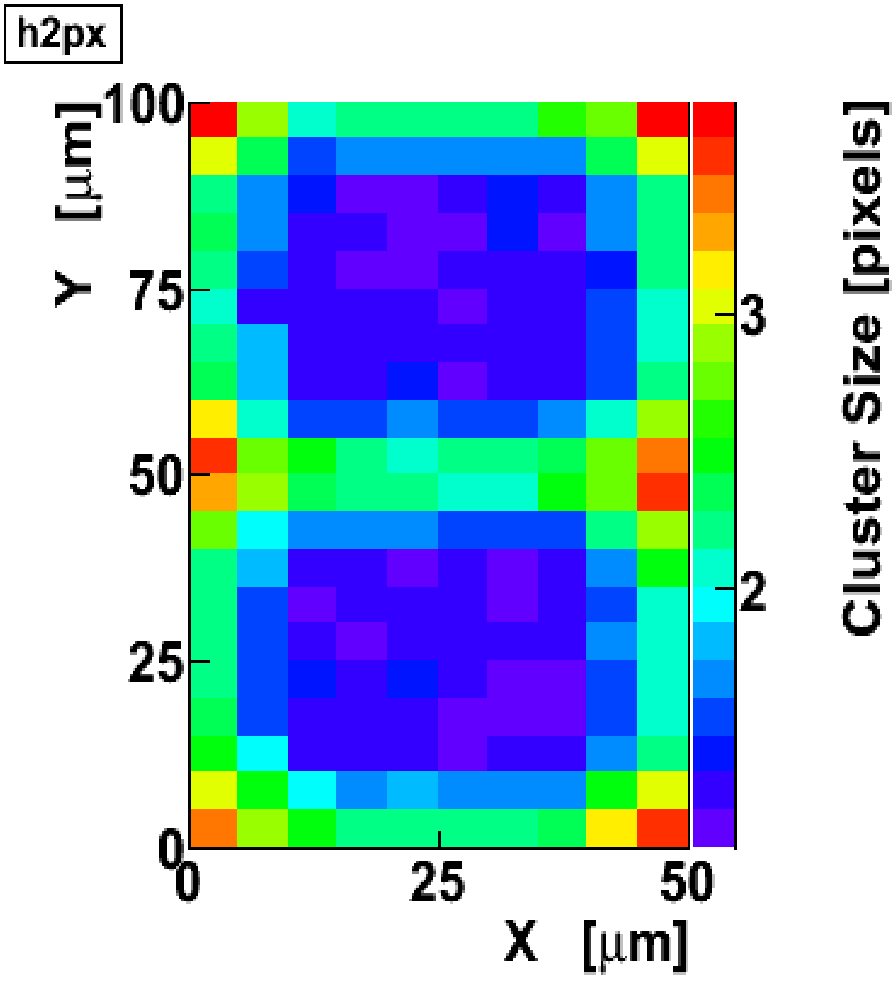
Efficiency



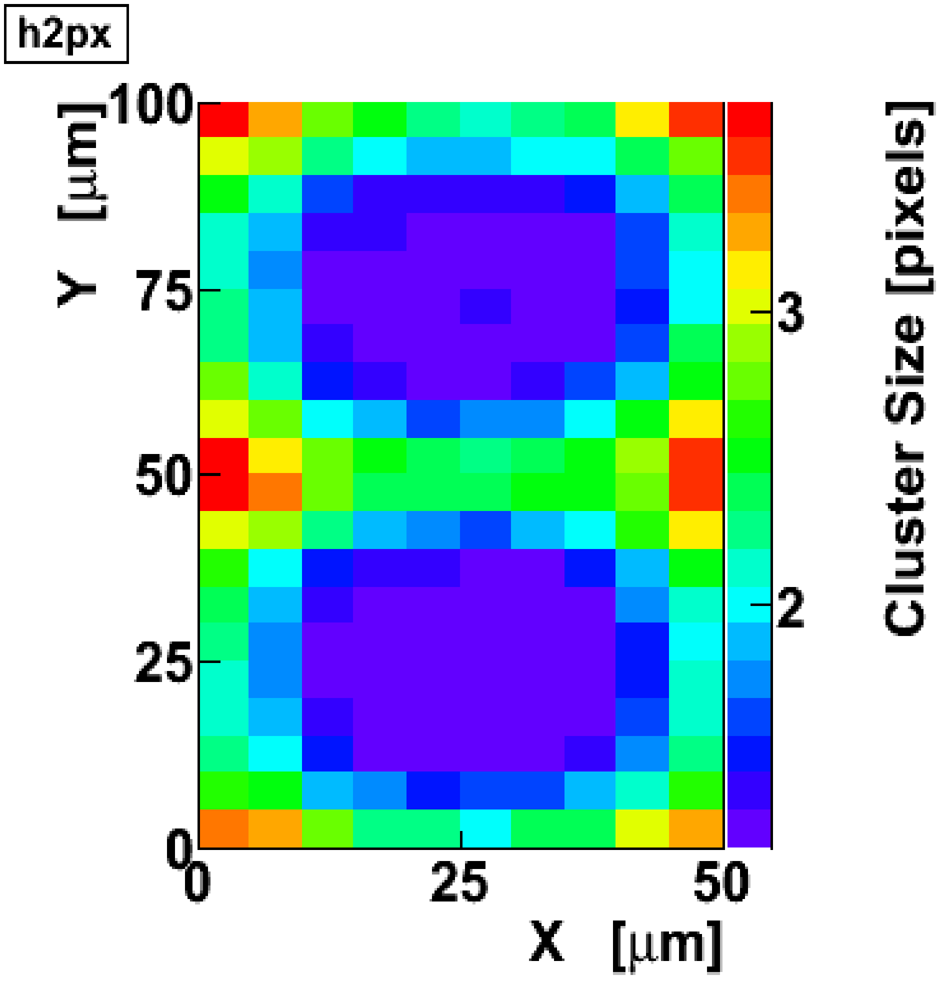
→ The efficiency is higher, both column and row wise, than 99.5%

Mean Cluster Size vs. In-pixel Hit

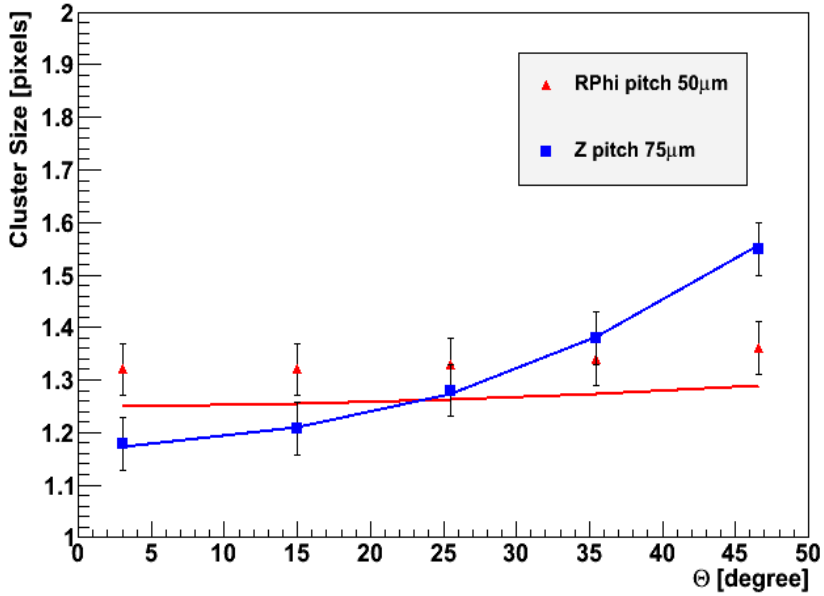
Digitizer

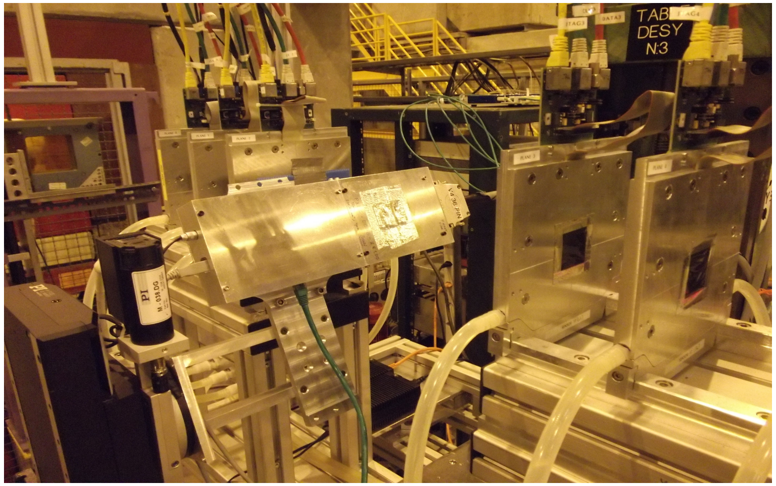


TB

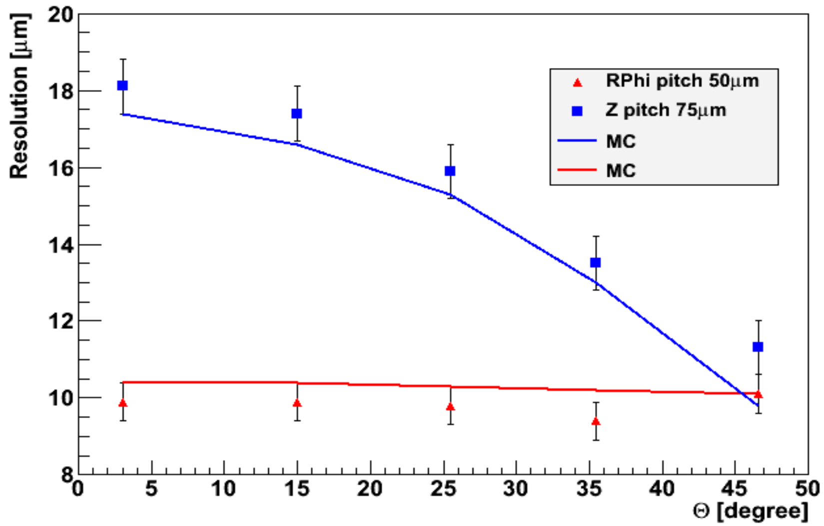


Resolution vs. Track Incidence

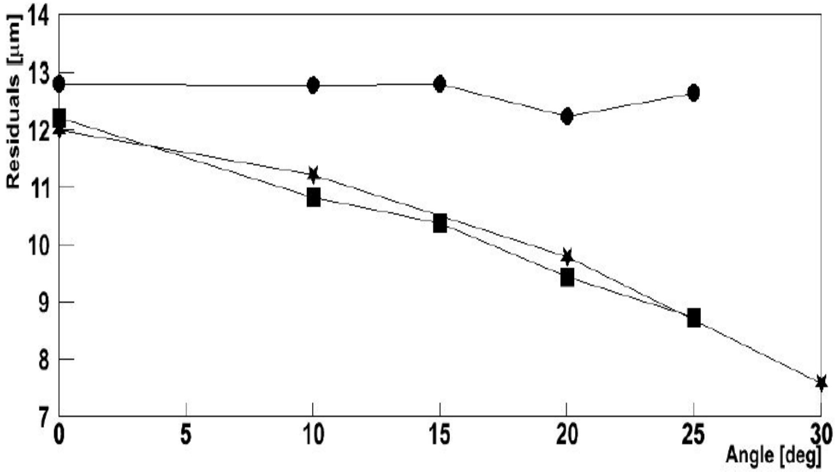




Z pitch 75µm



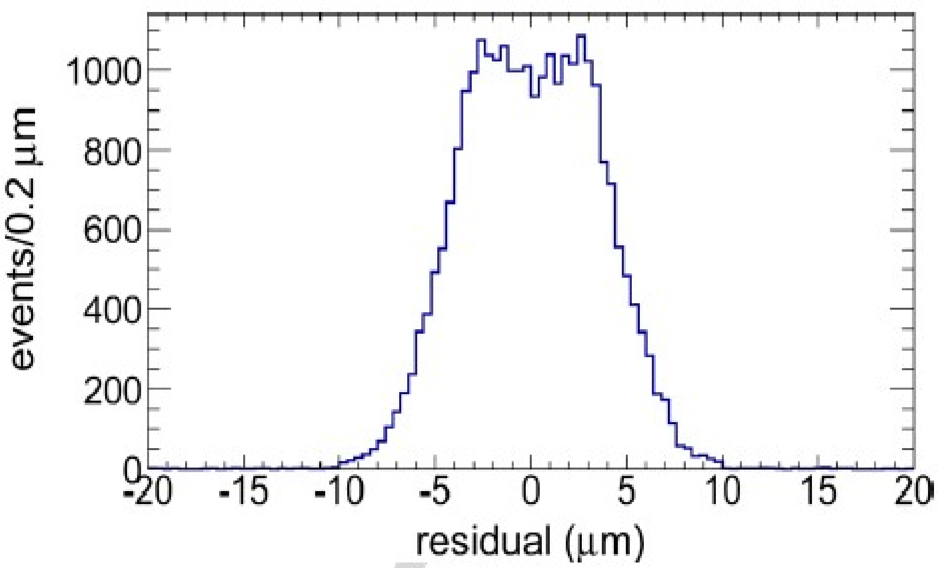
Z pitch 50µm



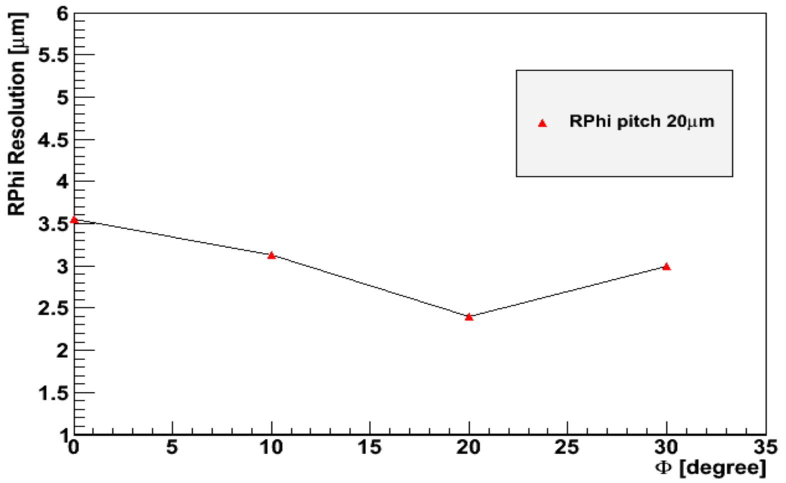
ILC type DEPFET designs

- 50µm thick, rphi pitch 20µm, z pitch 20-75µm
- Pixel noise 100e-, 8bit ADC, Hit threshold 500e-
- Resolution defined as RMS95 of position measurement errors
  - Measurement errors typically non Gaussian

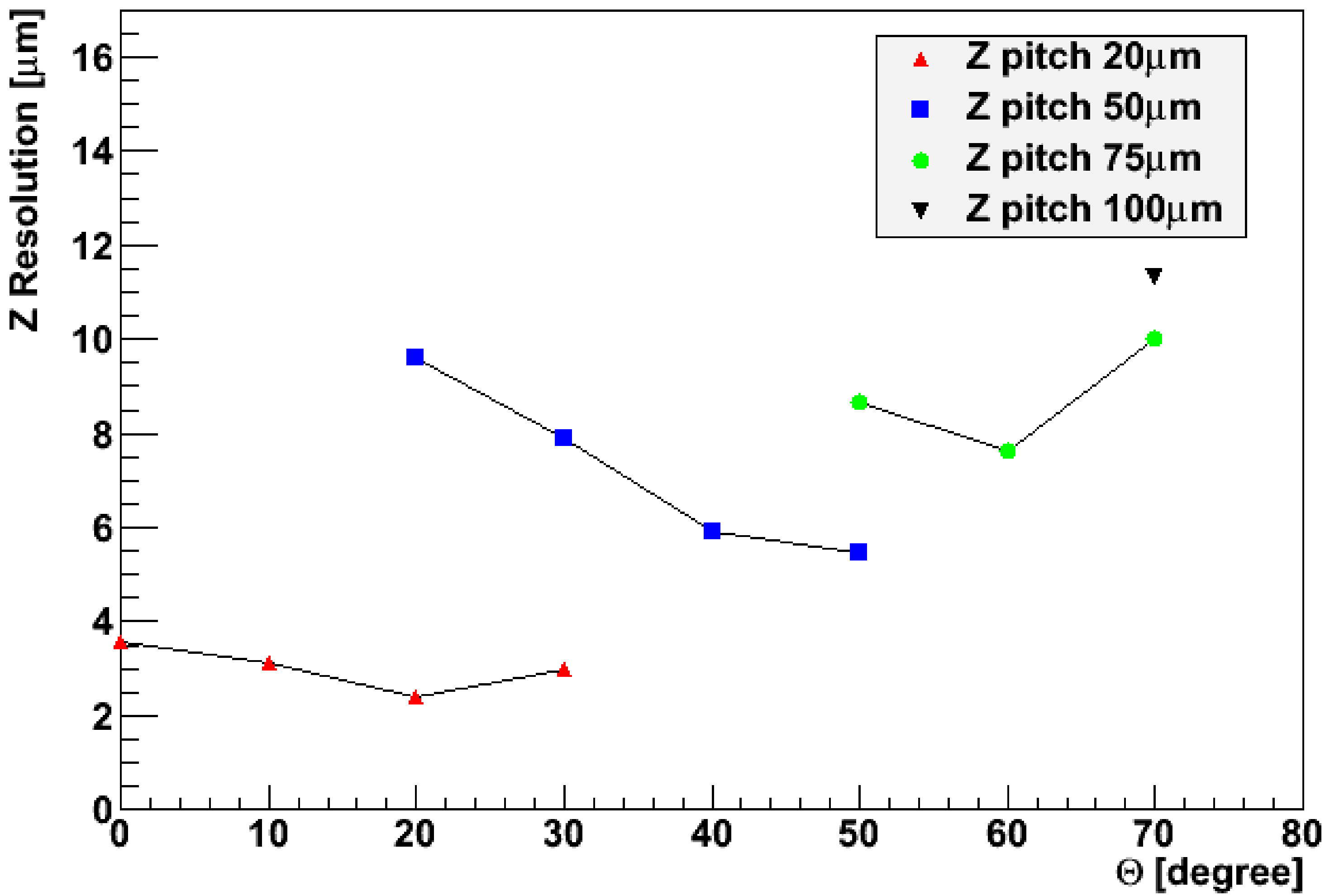
Position Error at normal incidence



Rphi resolution vs. incidence angle



Position Resolution vs. Track Incidence in rz-view



Summary

- “Fast” simulation of DEPFET sensors available in ILC framework.
- Extensive validation of code against test beam (and lab) measurements.
  - Small 20x20µm pixels and 450µm thick
  - Thin 50µm sensor and large pixels 50x75µm
- Simulation of spatial resolution for ILC type sensors vs. track incidence angle
  - Cover barrel acceptance $\theta = 0\text{-}75°$
  - Increase pixel pitch from 50µm (z=0) to 75µm
  - Z resolution ranges from 2.4µm (best) to 8µm (worst)

THANK YOU

450um thick, 20x20 pitch