Digitizer Validation

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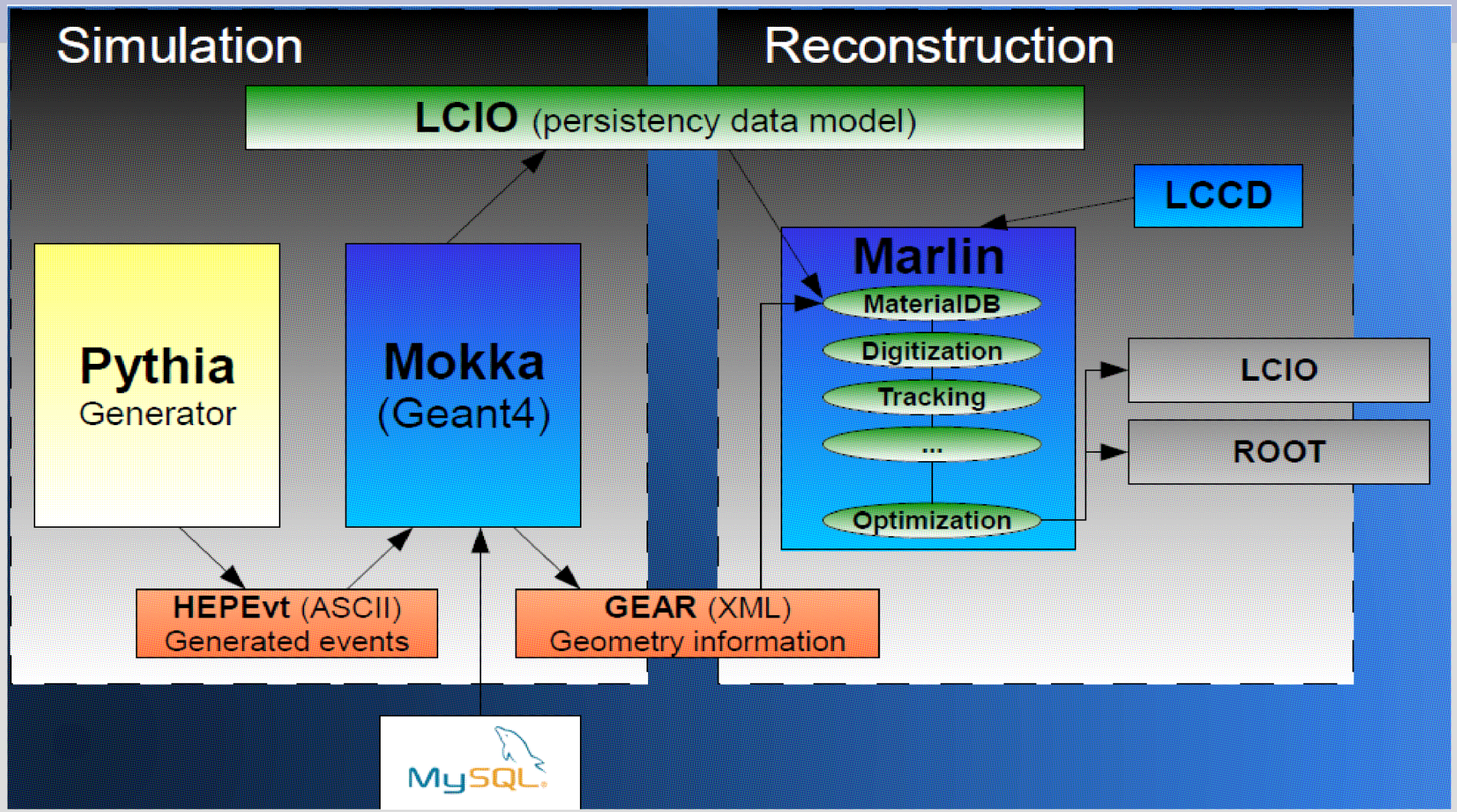
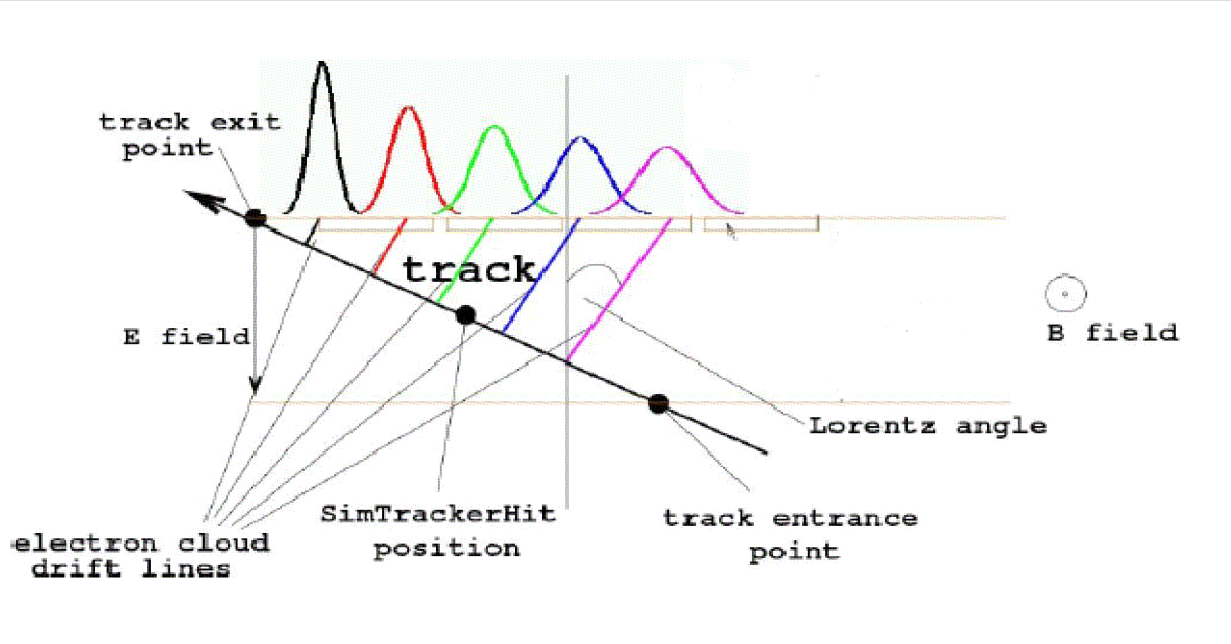
Outline

- Overview of current status of Depfet Pixel Digitizer (SiPxlDigi)
- Validation of simulation algorithm with data from Depfet Testbeams 2008/2009
- Outlook and discussion:
  - Geant4/Mokka simulation (energy deposition in thin Si sensors)
  - Clustering and hit reconstruction
  - Digitizer parameters: bias voltage, ...

Tool Chain - Scheme



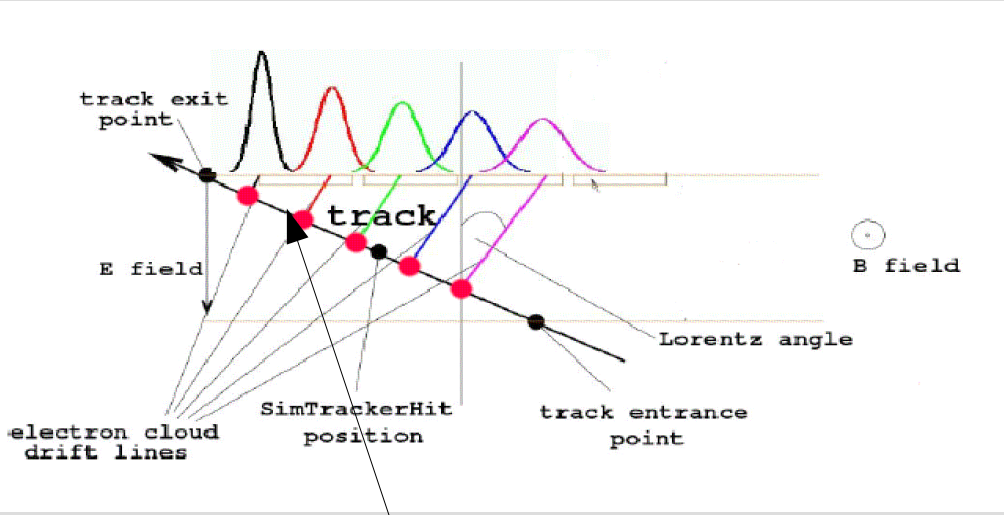
Digitization algorithm



Digitization is implemented taking into account:

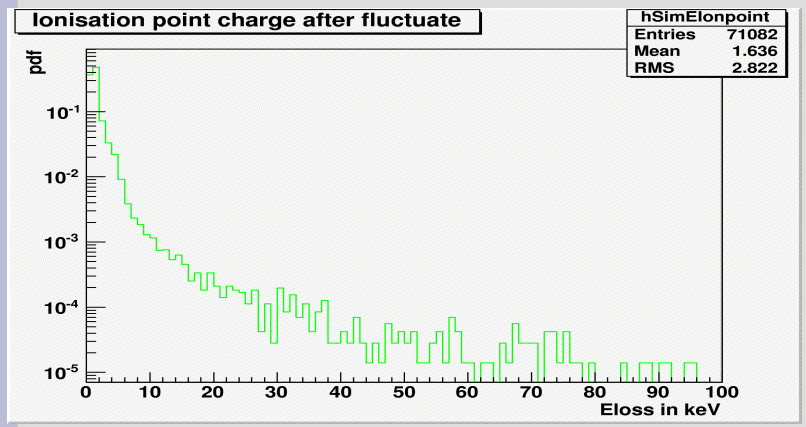
- Landau fluctuations of energy loss along the track path
- Drift and diffusion of signal charge to sensor surface
- Lorentz shift in magnetic field
- Electronic noise effects (read out electronic)

Digitization Details – Energy Loss

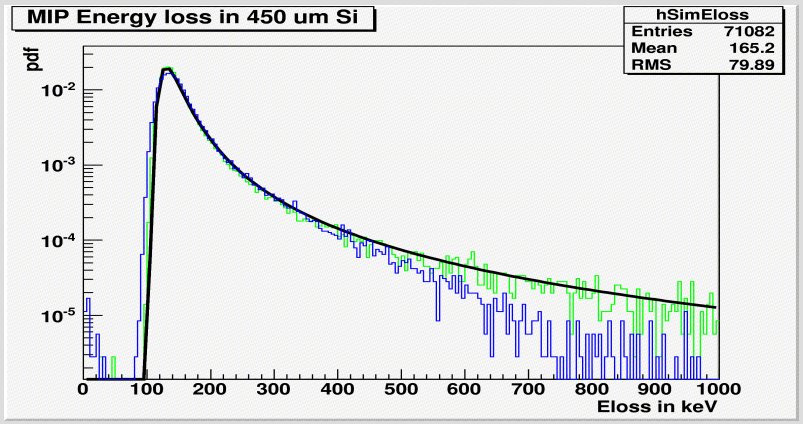


Input: LCIO SimTrackerHit
(x, p, L_{length} , dE)
Output: LCIO TrackerHit
(CoG estimator)

Energy deposition in Ionisation points is 'fluctuated':



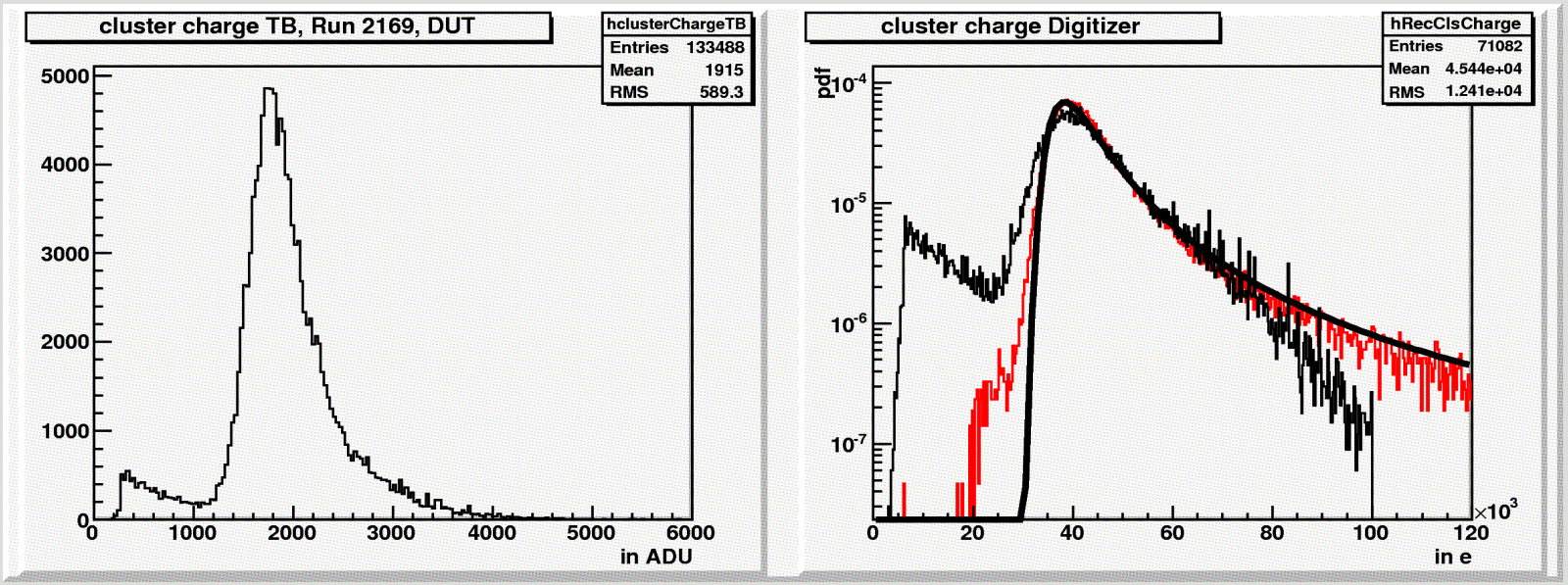
Total energy deposition in 450 um Si sensor:



Digitizer Parameters

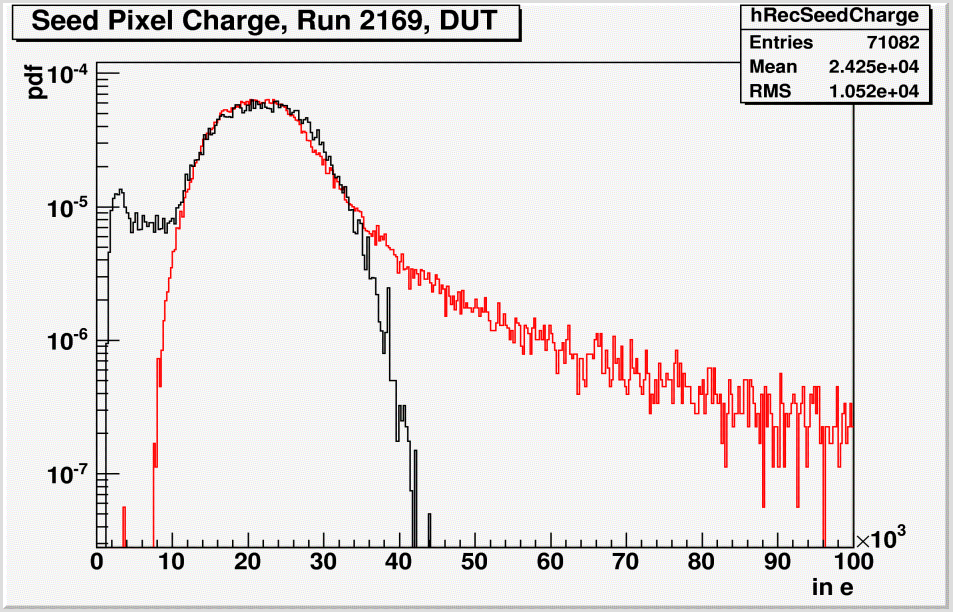
- Digits:
  - Cut on charge cloud tail, 4 sigma of Gaussian charge density: not all pixel are digitized (zero suppresion).
  - No additional background clusters added to digitized frame (for simplification).
  - Gaussian noise of 400 ENC is added to signal of every digitized pixel; noise level matched to TB conditions.
  - Diffusion of signal charge: Ionisation point at bottom of sensor extends to Gaussian profile with rms of ~12 um after drift to pixel.
- Particle Gun:
  - Simple Geant4 particle gun with 120 GeV pi- shot along z-axis
  - Gaussian smearing of gun vertex position

Cluster Charge



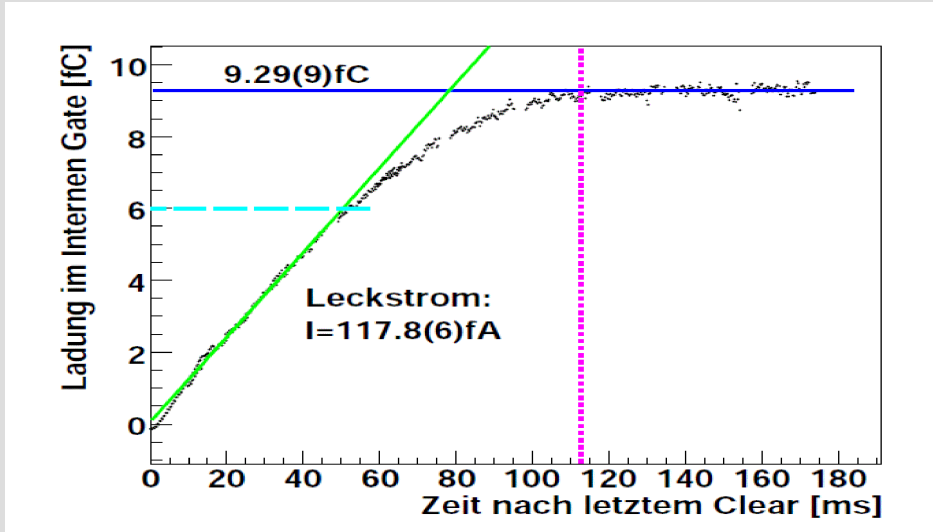
- Conversion of ADU to signal charge by matching MPV to TB 2009 data (24x24 DUT module, Run 2169) for normal incidence.
- TB 2009 average pixel noise of 15 ADU matches to a total pixel noise of ~400 ENC (mostly from current readout chain).
- Tail of TB cluster charge distribution decays too rapidly compared with simulations -> saturation of internal gate ?

Seed Pixel Charge



- Digitizer seed pixel signal matched to TB 2009 data.
- Indication for missing signal charge in Landau tail.

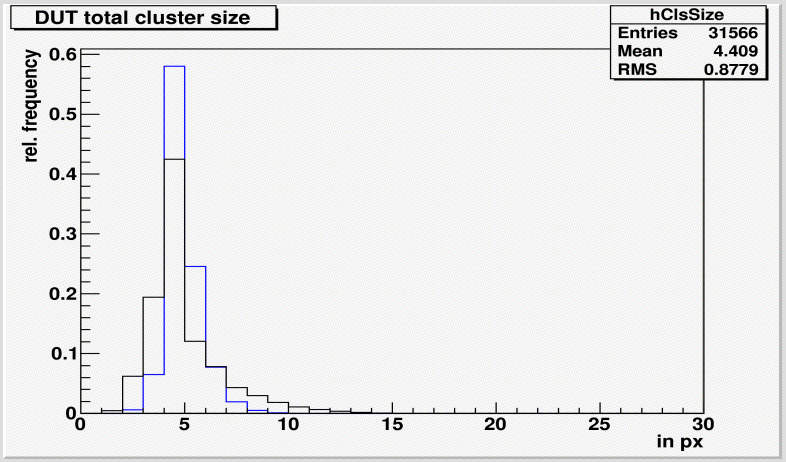
- Lab measurment of internal gate saturation by K. Schmieden
- Module type: PXD 5 COCG LB (telescope modules TB 2009)
- Saturation at a signal charge of ~58.000 e-.



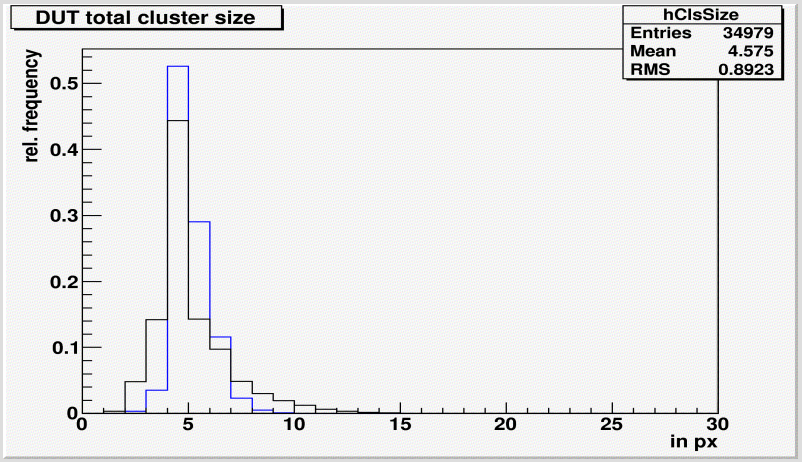
K. Schmieden, Thesis

Cluster Size Distributions

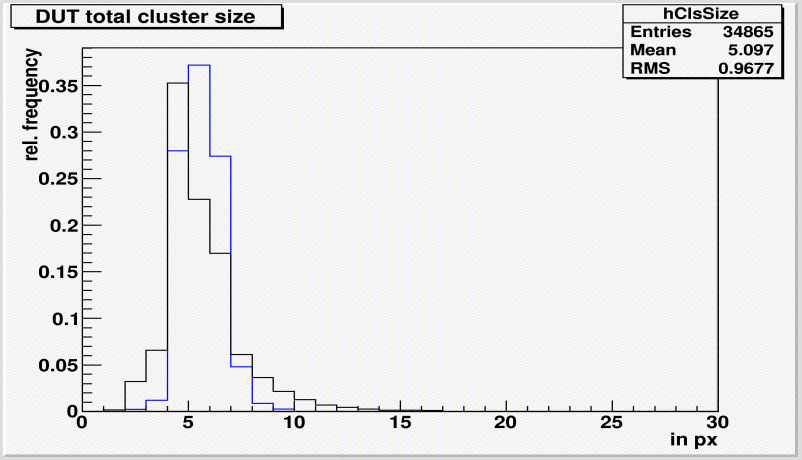
0 ° rotation, Run 1308



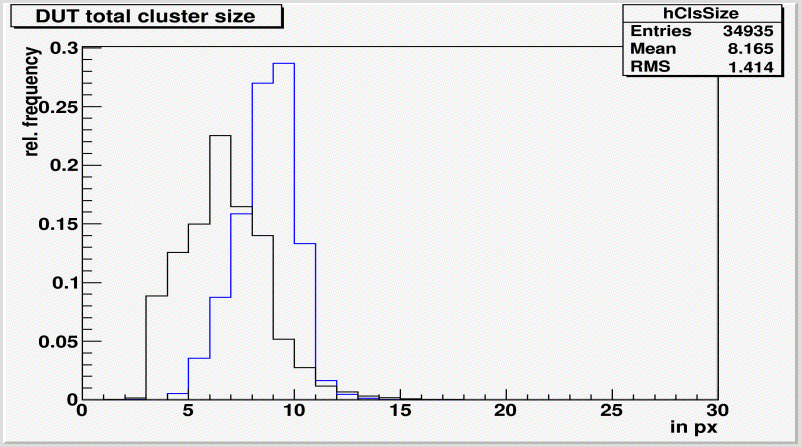
2 ° rotation, Run 1307



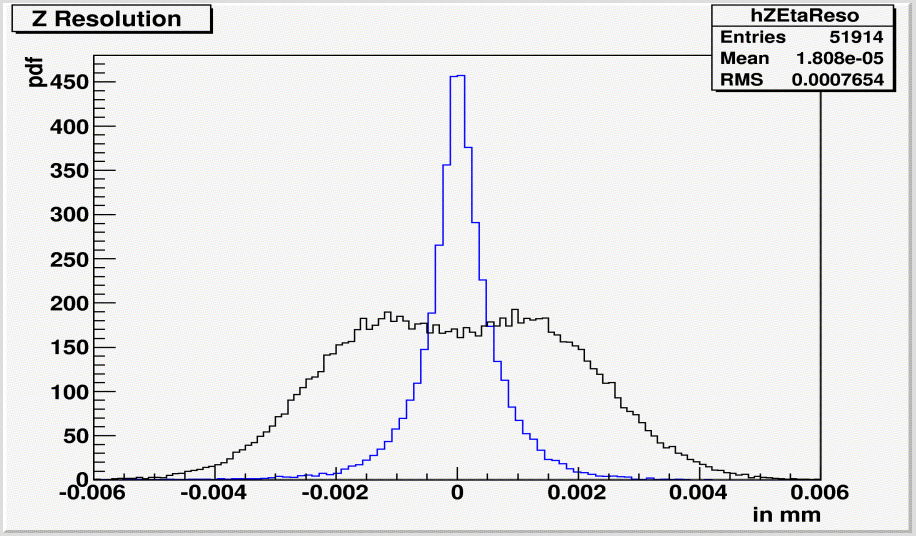
4 ° rotation, Run 1300



12 ° rotation, Run 1314



Simulated Point Resolution

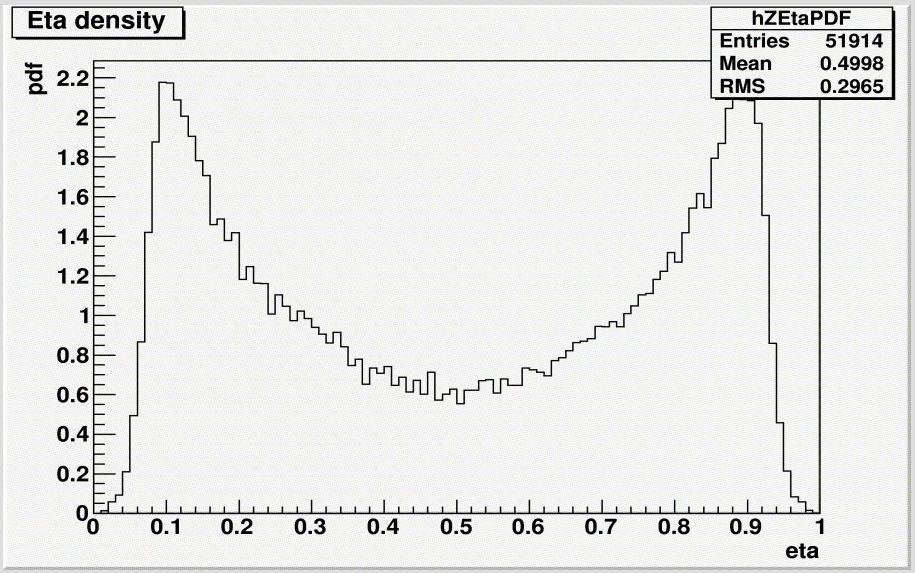


- Sensor is uniformly illuminated by pi- beam of 120 GeV.
- Resolution is calculated from MC hit and reconstructed hit.
- Compare CoG estimator and Eta estimator for hit position.

Simple version of Eta algorithm uses only two signal pixel:

$$\eta = \frac{S_{left}}{S_{rigth} + S_{left}}$$

$$Z(\eta) = Z_{left} + pitch \star \int_0^{\eta} \rho(\eta')d\eta'$$



Outlook and Discussion

- To Do:
  - Study signal to noise ratio for 50 um Si sensors with improved physics model.
  - Study relation between cluster size vs. bias voltage.
  - Match TB residuals on each module for complete Depfet telescope.
  - Point resolution and cluster size @ Belle II and ILC (50 µm Si, correct px pitch).
- Software Development:
  - Energy deposition: smaller G4 step size vs 'fluctuate'.

Outlook and Discussion II

- Clustering: accumulate SimTrackerHits for primary MIP, secondary delta rays, ...
- Option: digitizer should produce LCIO Clusters (-> 'realistic' hit reconstruction)
- Reparametrize digitizer: use bias voltage to parametrize size of charge density.

Thanks for your attention!