Update of DEPFET Digitizer

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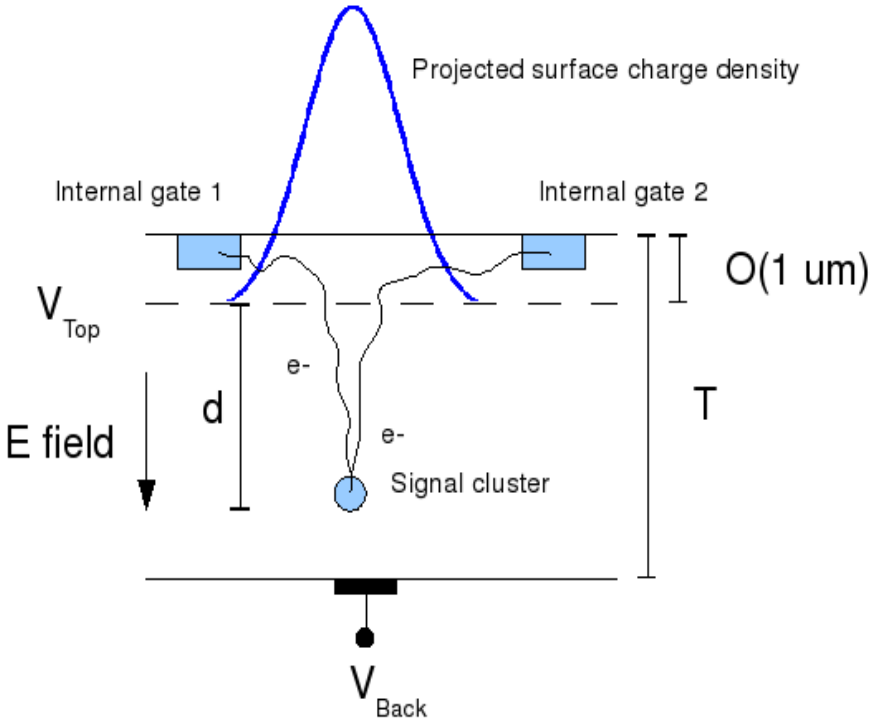
Outline

- Improved model for charge collection in DEPFET sensors based on device simulations from Rainer Richter:
  - More realistic parametrization of in pixel potentials.
  - Expected to work for ILC and Belle II type sensors.
- Listing of DEPFET Digitizer parameters and recommended values for ILC/Belle II designs.
- Validation of DEPFET Digitizer with test beam data (new results):
  - Ionization in 450um Si.
  - Cluster size spectra.
  - In pixel residuals.

DEPFET Digitizer Charge Collection



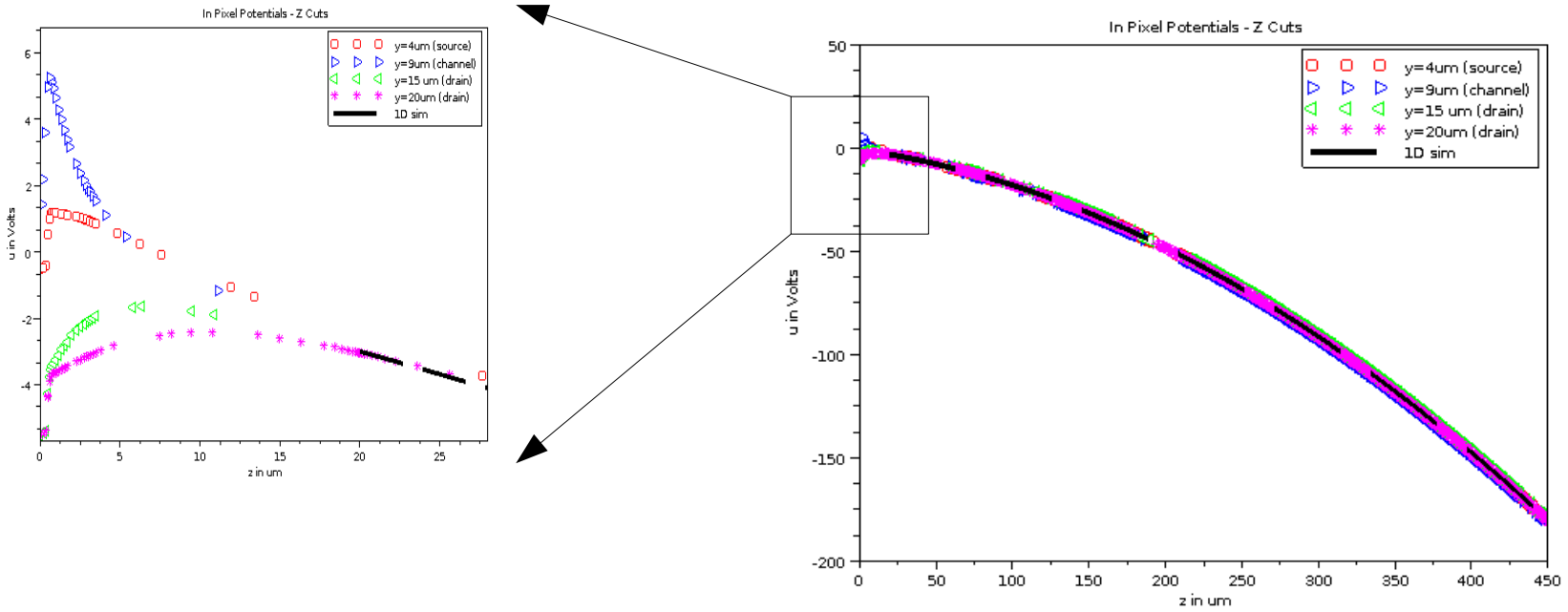
Trajectory of e- is split in a vertical and lateral part:

1) Vertical Part: (in Bulk)
- Upward drift of charge cloud(s) to readout plane.
- Diffusive spread in xy directions. Spread is calculated from drift time.

2) Lateral Part: (in Readout Plane)
- Split signal cluster (~500e-) in smaller groups (~50e-).
- Charge groups drift and diffuse in readout plane into internal gate.
- Note: very weak drift fields in Drain, Source and Clear regions.

Vertical Charge Transport

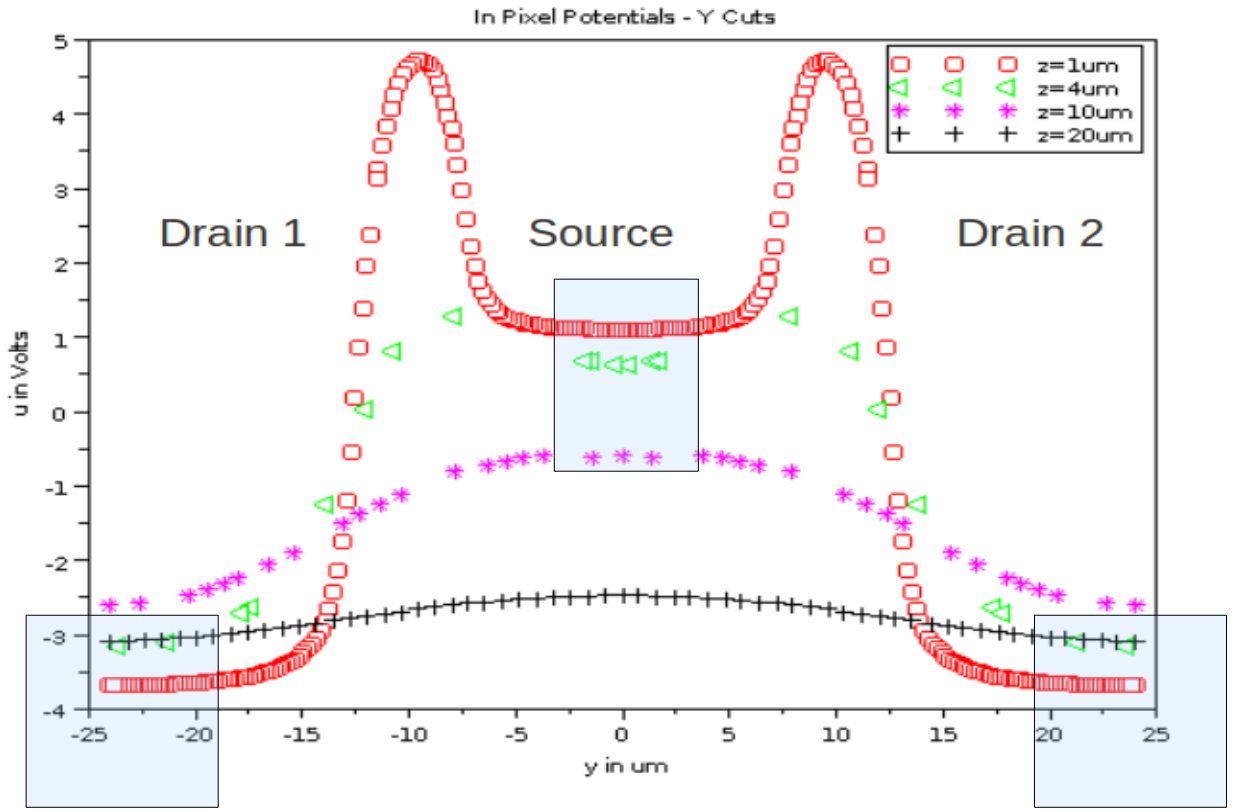
In pixel potentials along z-axis: [Device simulations from Rainer for PXD5 Sensors]



Conclusions: a) potential has simple parabolic shape from backplane to readout plane.
→ used to calculate vertical drift time.
b) no lateral (xy) gradients in sensor bulk.

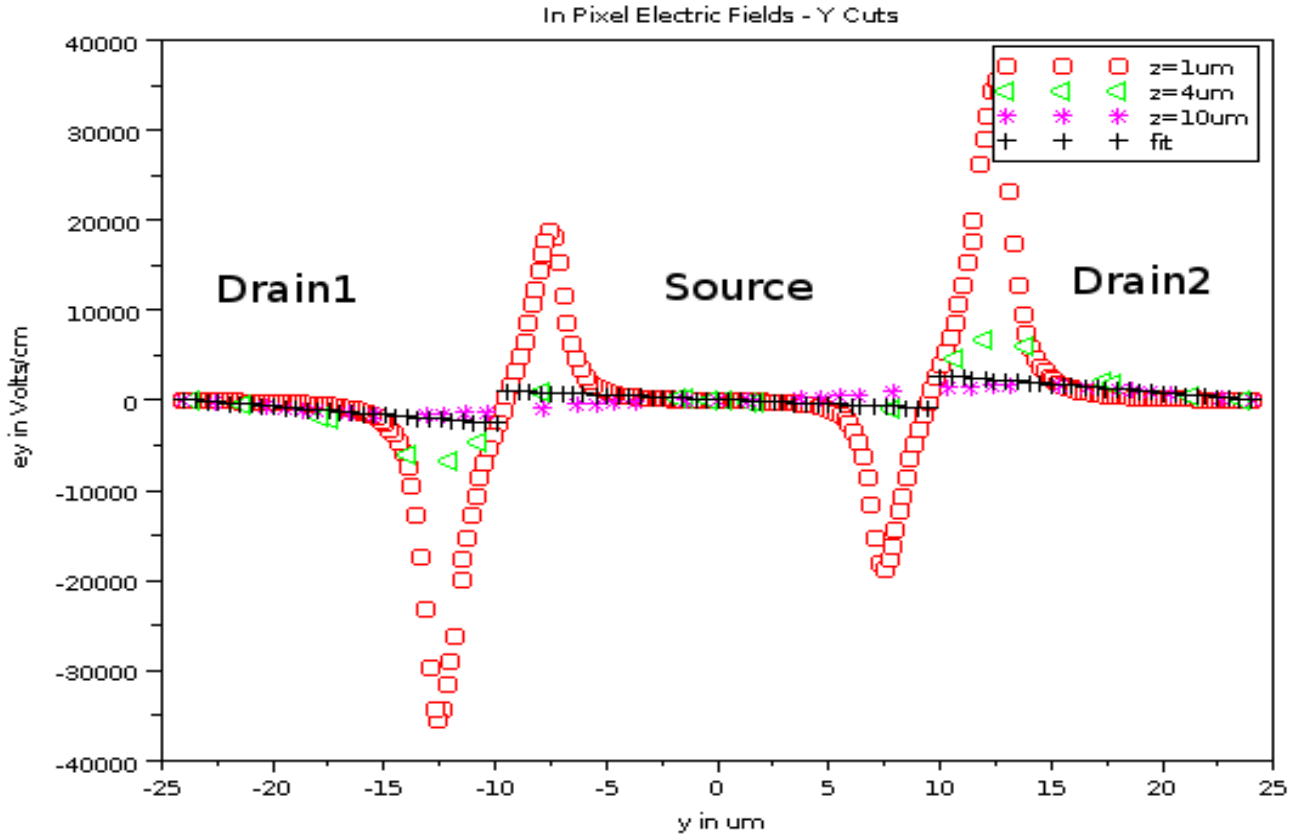
Lateral Charge Transport

In pixel potentials along channel for PXD5 double pixel:



Regions with very small potential gradients. Charge transport is dominated by diffusion.

Electric Fields in Readout Plane



Conclusions: a) Electric field is zero at center of Source and Drain.
b) Electric field rises (slowly) linearly towards internal gate.
c) Field slope is smallest in source region; hard to see :)

1D Toy Model

Question: Estimate size of diffusion dominated region ???

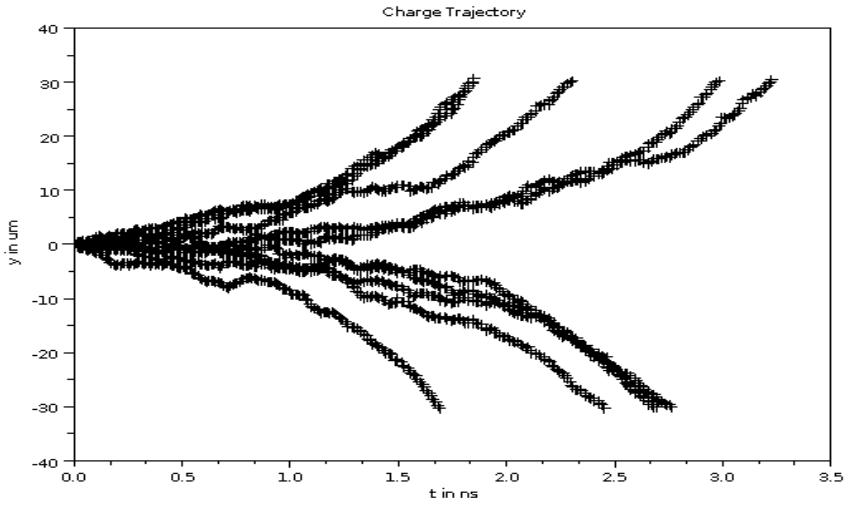
Simulate charge transport in readout plane:
[Diffusion and drift]

$$dy = -\mu E dt + \sqrt{2\mu U_{th}} dW(t)$$

$$E(y) = -\alpha y$$

Field slope α can be read off from device simulations. For PXD5 sensors values are:
a) Source: 100 V/cm per um
b) Drain: 200 V/cm per um
c) Belle II Source: ~10 V/cm per um

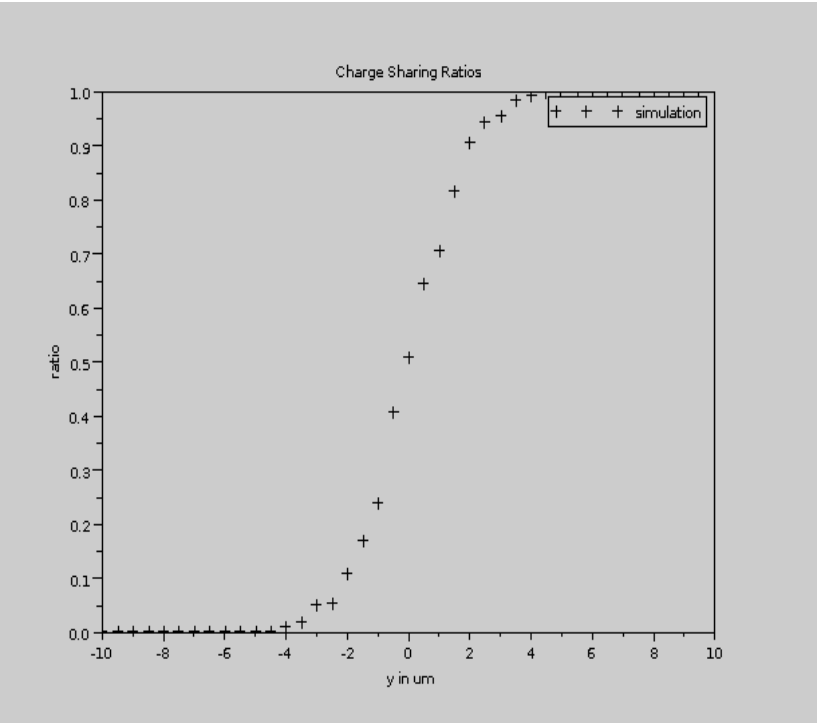
[Realizations starting from source at y = 0 with α = 100 V/cm/um]



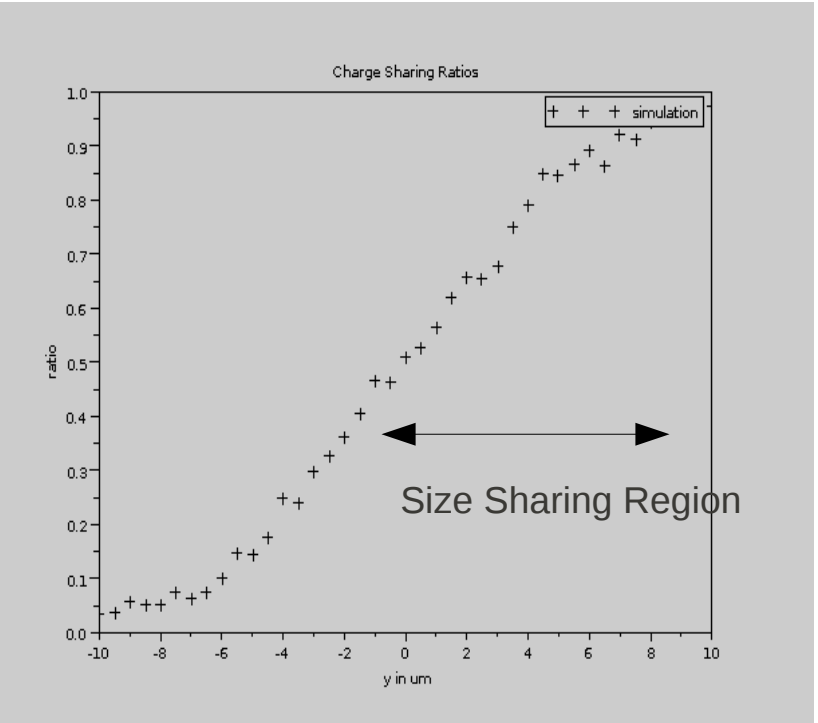
Pixel Charge Sharing

Consider e- with distance y from center of source region. Simulate the probability to end up in rigth hand internal gate:

PXD5 Source:



BelleII Source:

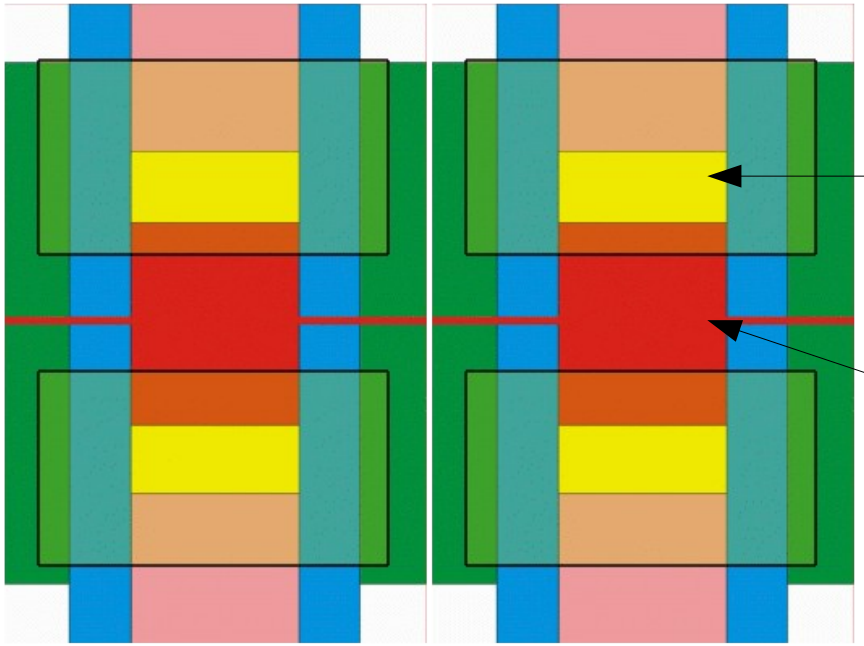


Toy Model: Conclusions

- Observation of charge sharing between adjacent pixels in readout plane:
  - Due to weak drift fields in border regions of a single pixel (Drain+Source+Clear).
  - Extra diffusion step of signal charge needs to be added to the Digitizer simulation → new model.
  - Fields **near** internal gate need no explicit modeling. Charge groups are always drifted to correct internal gate.
- Size of charge sharing region depends on slope of electric field (→ design of DEPFTE sensor). Estimated values are:
  - PXD 5 (source/drain/clear): ~3um
  - BelleII (source/drain/clear): ~10um
- The charge sharing ratio has S shape. Approximating a linear charge sharing function is equivalent to pure diffusion.

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

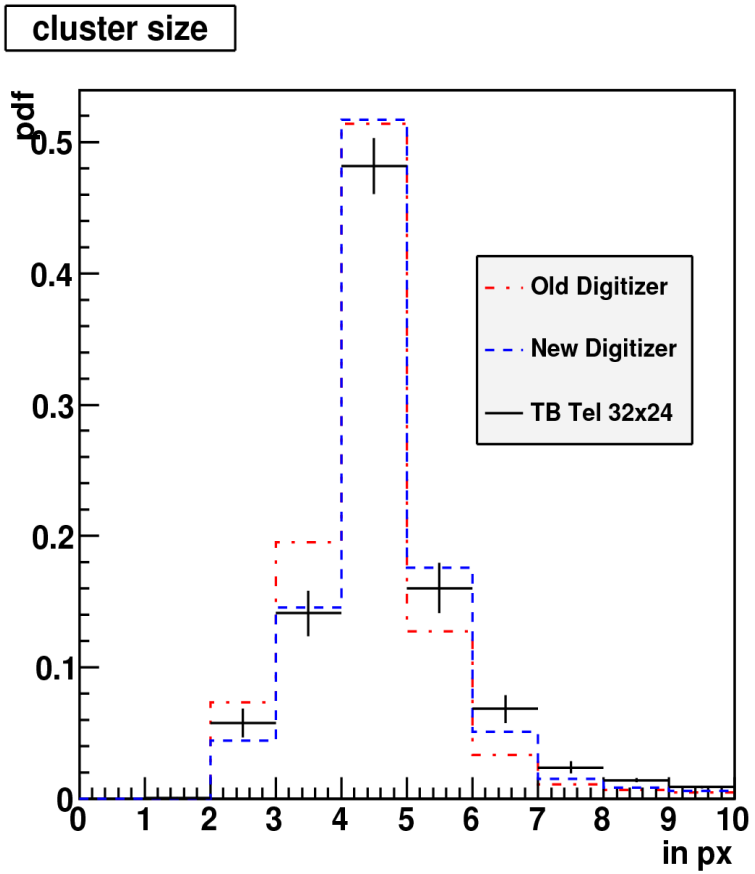
internal gate
source
drain
clear
clear gate

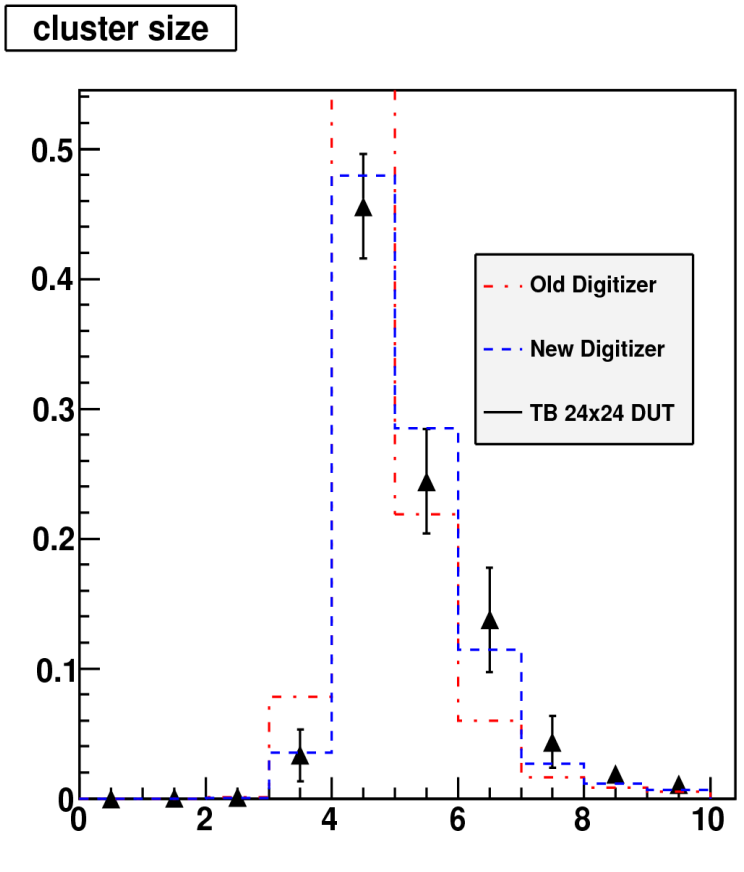
List of Digitizer Parameter Values

	PXD 5 (TB2009)	PXD 6 (BelleII PXD)
Noise (in ENC)	~290	~100
Bulk Doping (in $10^{12}\mathrm{cm}^{-3}$)	0.85	10
Backplane Voltage (in V)	-180	-20
Drain Border Length (in μm)	3	~10
Clear Border Length (in μm)	3	~10
Source Border Length (in μm)	3	~10

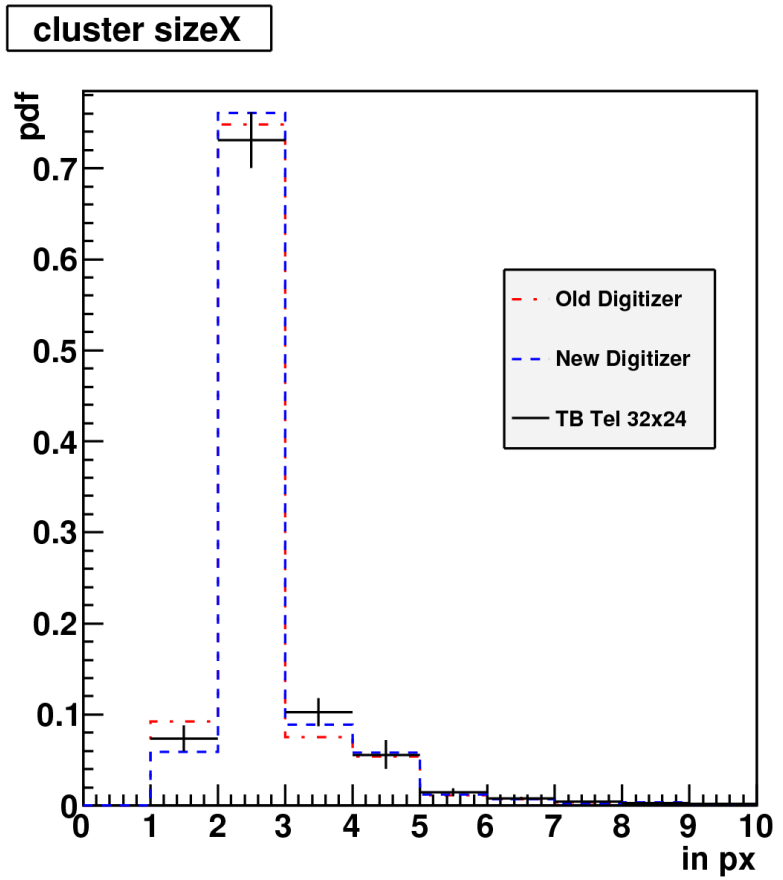
Table 1: Preliminary listing of DEPFET digitizer parameters for TB and Belle II.

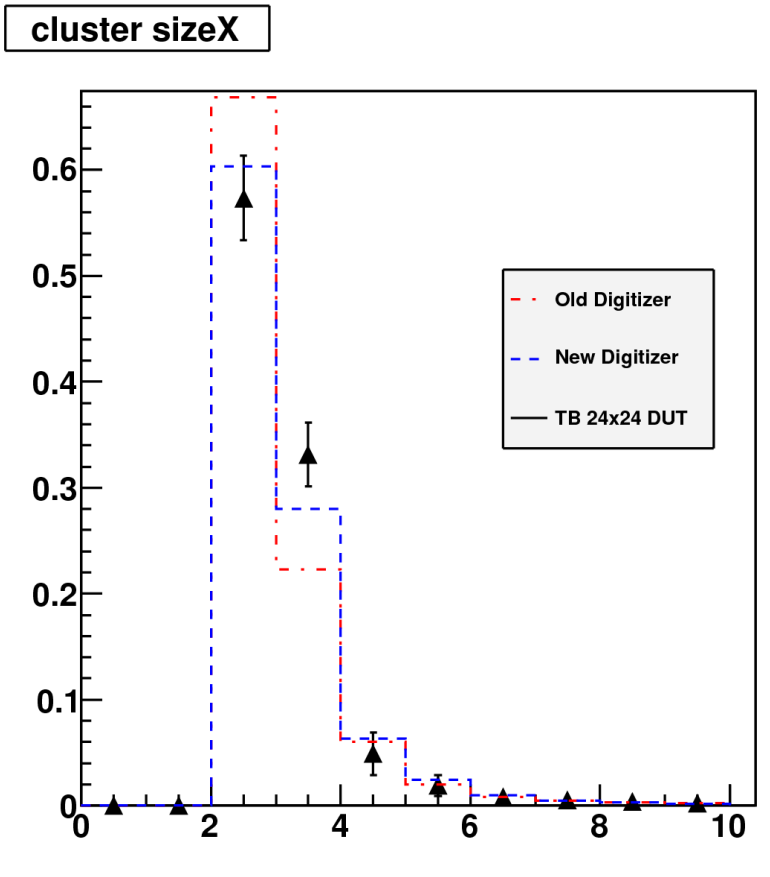
Cluster Size TB 2009





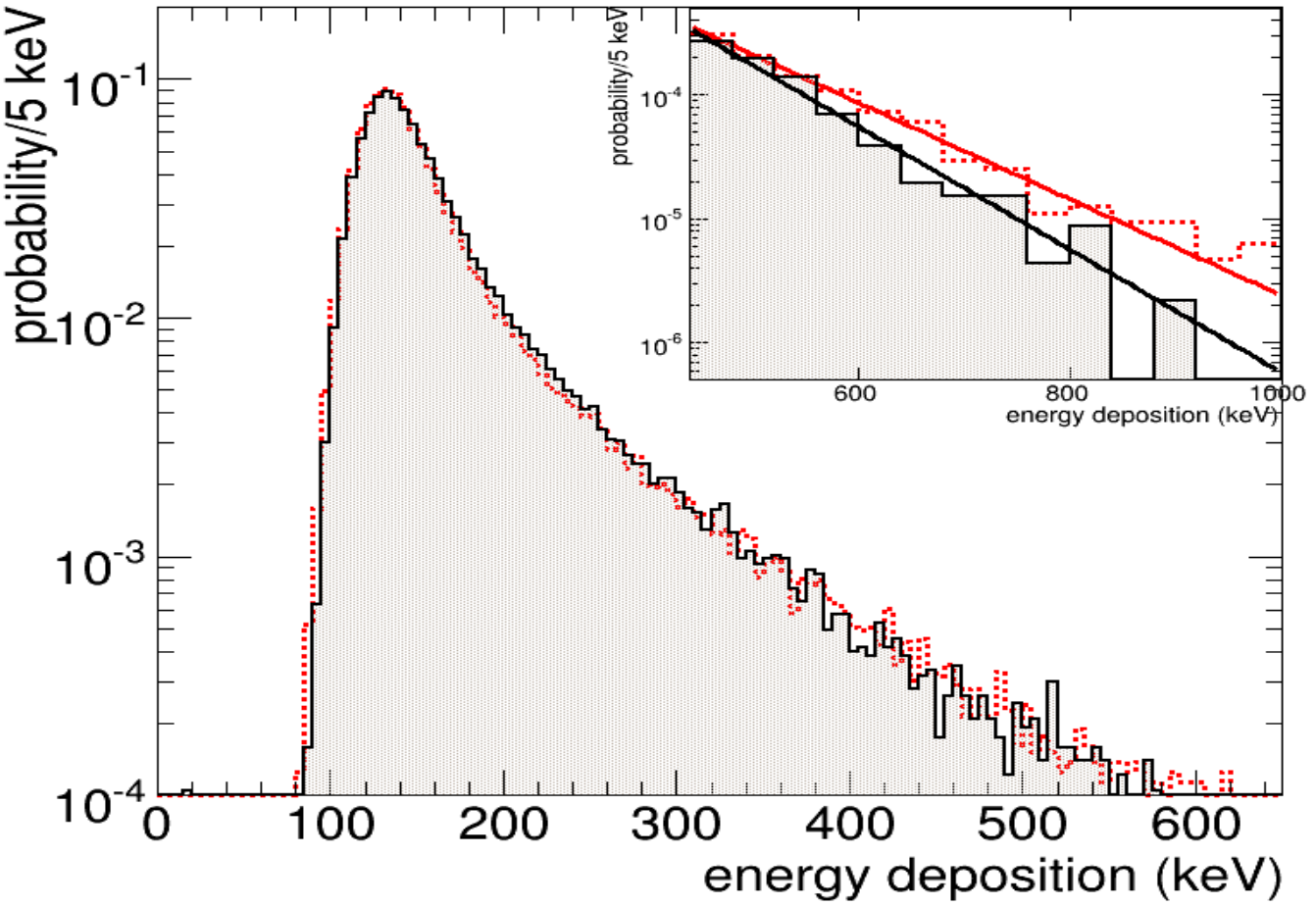
Cluster Size X



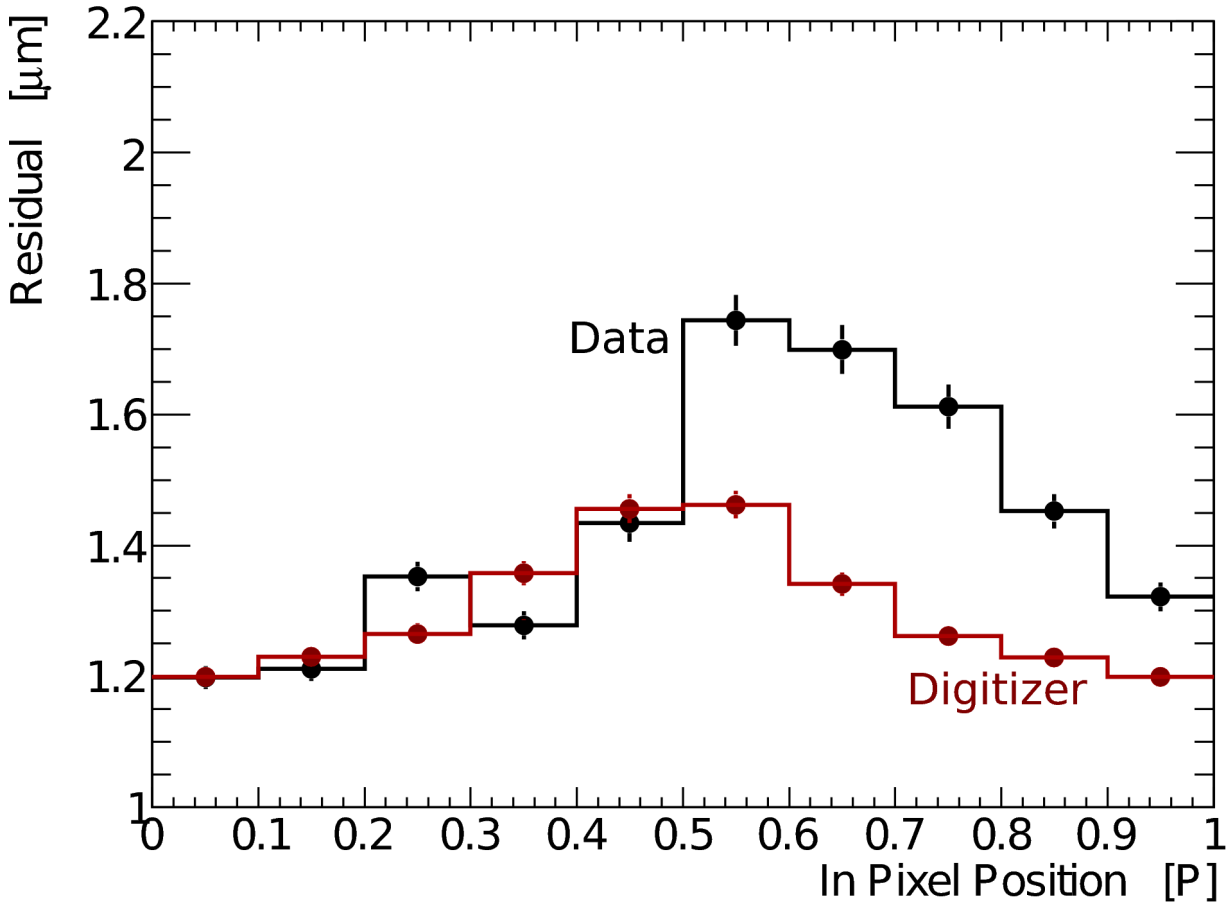


Ionization in 450um Si

Digitizer (red) vs. TB 2009 data (grey)



In Pixel Residuals



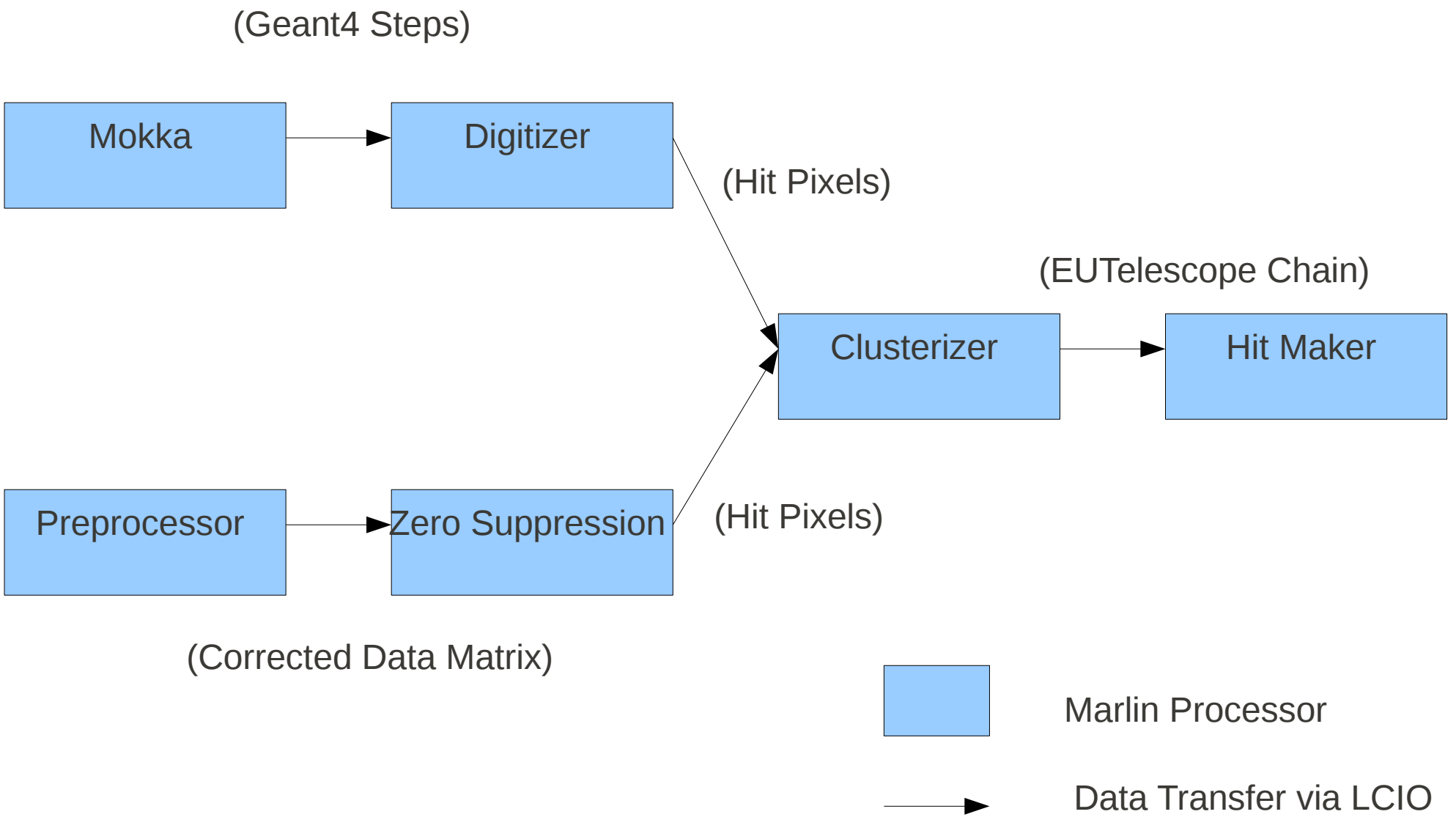
[24x24 DUT in TB2009]

Summary

- Implementation of improved charge transport model in DEPFET sensors → Learning from TB data and device simulations.
- Pixel borders (drain/source/clear) have weak drift fields and give rise to 'extra' charge sharing → Larger clusters ...
- Final analysis of test beam data 2008/2009 completed; See also talk of C. Geisler in TB session.
- Next steps:
  - Integration of improved model into Belle II framework.
  - Quantification of effect on Belle II vertex resolution ...
  - Repeat validation process for planned PXD6 test beam.

Back Up Slides

Analysis Flow



Cluster with long Delta