The CBM sensor digitizer

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Outline

- Motivation
- Model requirements
- Description of the model
  - Important definitions (1)
  - charge generation
  - charge sharing
- Evaluation
  - Important definitions (2)
  - Comparison with experimental data
- Outlook

Motivation

- Digitizer model developed in order to allow simulating the CBM-MVD.
- In collaboration with the *IPHC-PICSEL* group in Strasbourg and the *IKF-MVD* group in Frankfurt.
- It was inspired by a detector response model developed for the ILC vertex tracker
  - M. Battaglia, “Response simulation of CMOS pixel sensors for the ILC vertex tracker” , Nuclear Instruments and Methods in Physics Research A 572 (2007) 274–276

CBM-MVD response model requirements

- Realistic simulations allowing to simulate:
  - Cluster properties: size, shape
  - pixel size
  - vary number of ADC channels of the readout
  - particles impinging with high incident angles
  - noise, fake hits

- Rapid simulation features
  - simulate collision pile up
  - delta electrons (of concern in CBM)
  - fast, allowing high statistics simulations

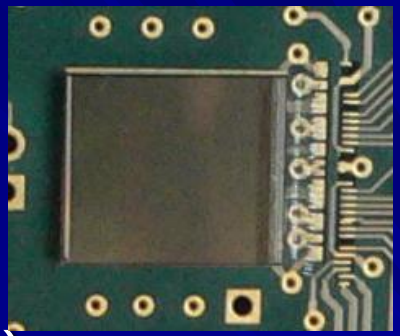
Spirit of the model

- Challenge:
  - Charge carrier transport process too complex and slow for simulation
- Solution:
  - Parameterization of the sensor response
  - Use experimental data
  - GEANT provides only entry and exit coordinates of the particle in the volume
  - no dE/dx from GEANT

Reference data

- Data acquired at CERN/SPS with pions 120 GeV/c

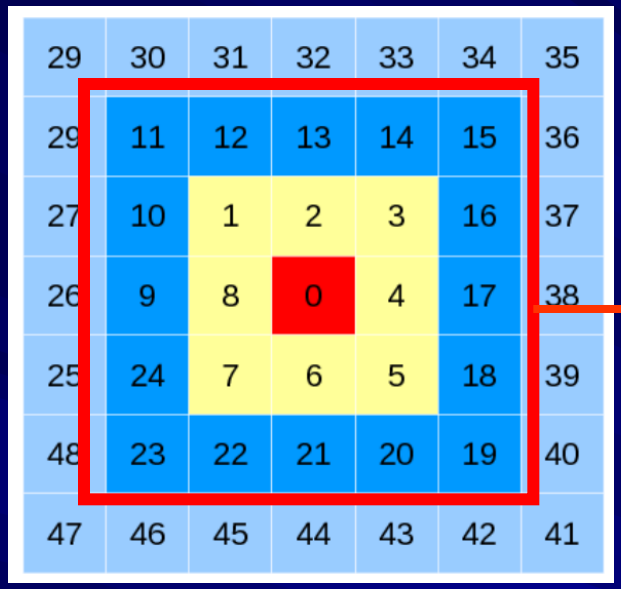
- Sensor under test: MIMOSA17
  - AMS 0.35
  - standard low resistivity epitaxial layer
  - analogue output (12 bit charge resolution)
  - 30 μm pixel pitch



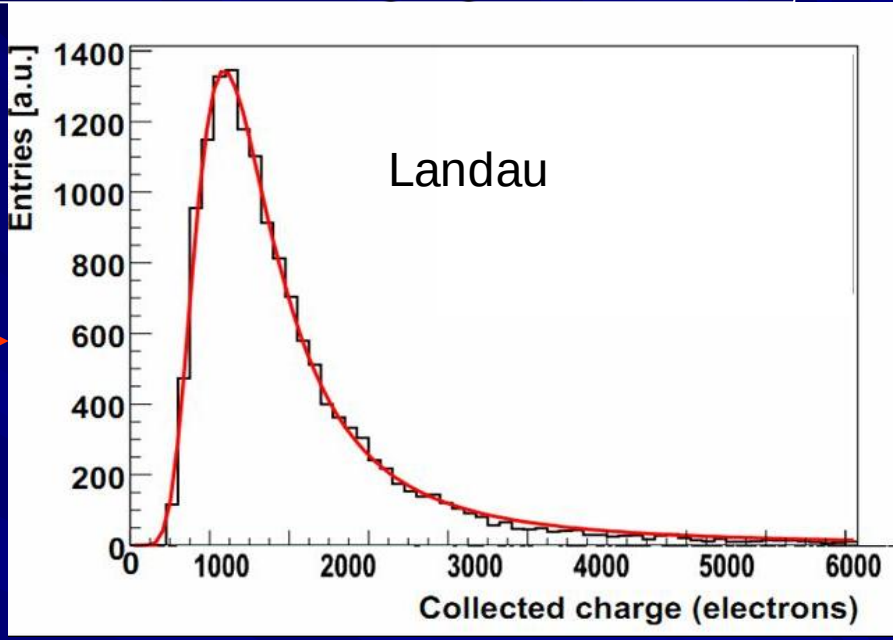
- Particle incident angles 0-75 degrees
  (90 degrees is parallel to the sensor plane)

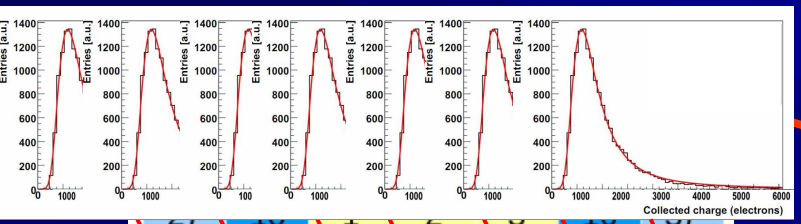
The digitizer

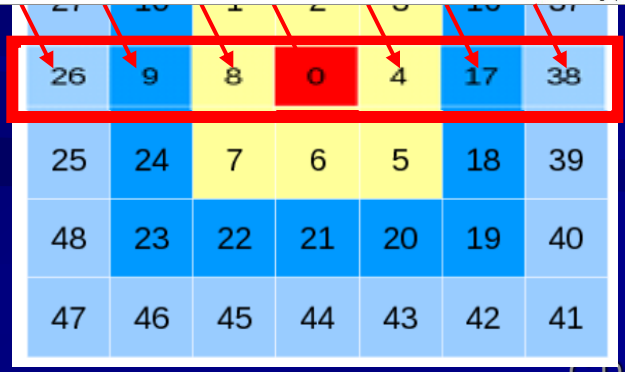
Important definitions (1)

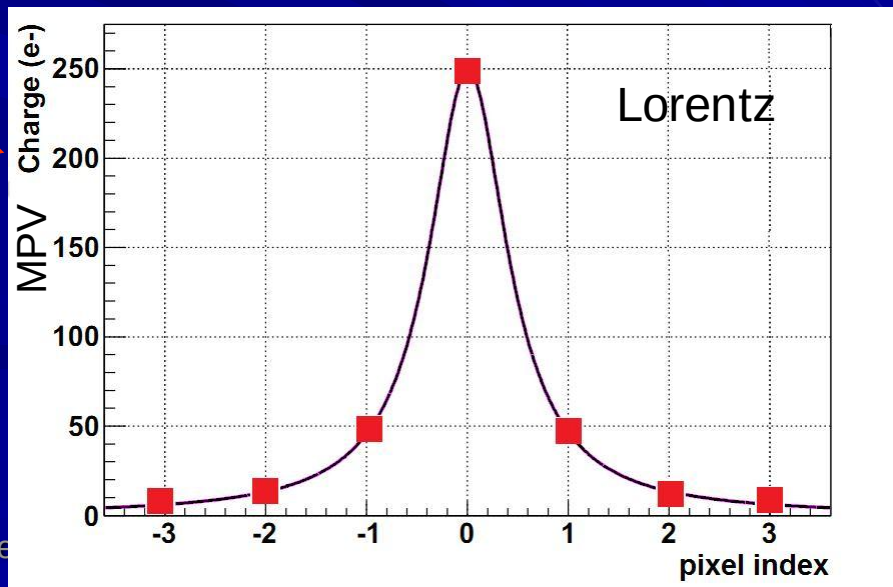


$$Q_{25} = \sum_{i=0}^{24} Q_i$$





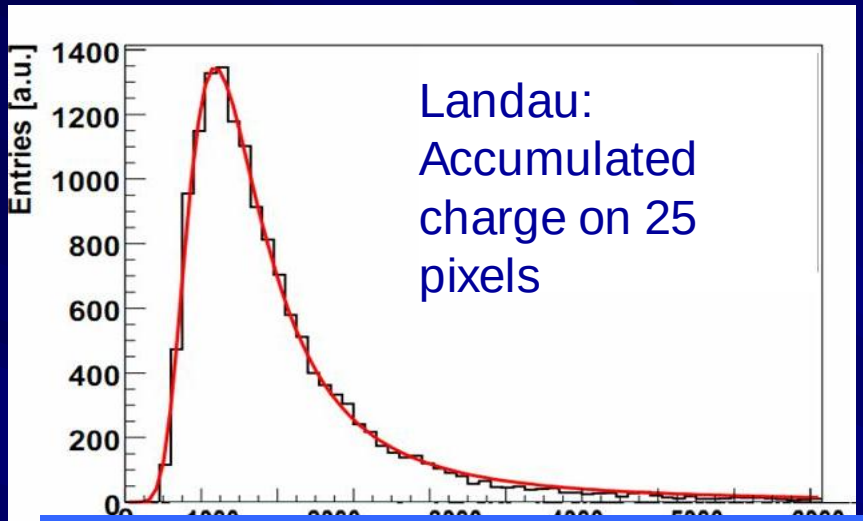




Other features

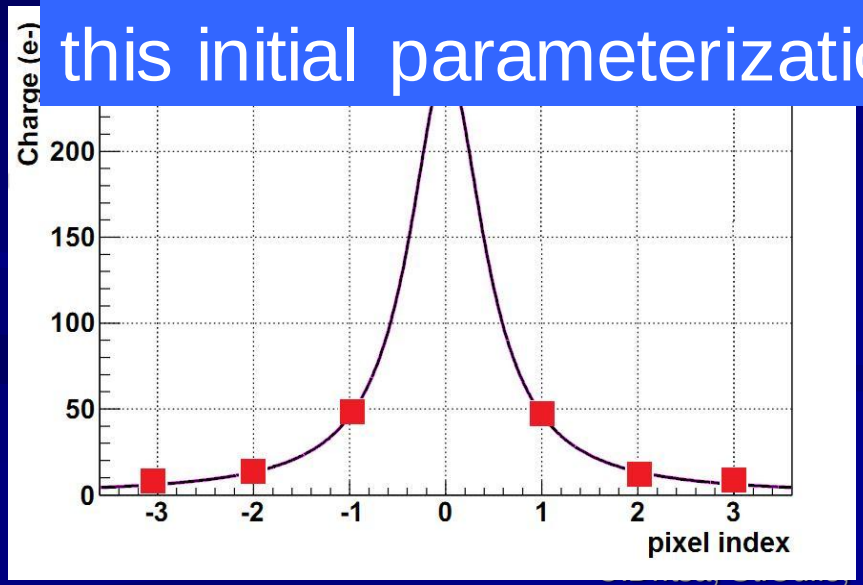
- Simulated by random sampling of a distribution following a Gauss law with adjustable μ, σ
  - mean=0
  - σ =15 electrons
- Number of ADC bits adjustable
  - 12 bits
- Pixel pitch adjustable
  - 30 μm

The model: Input



- The charge of the cluster is taken by random sampling of the experimental distribution for 25 pixels
- 0 degrees incident angle

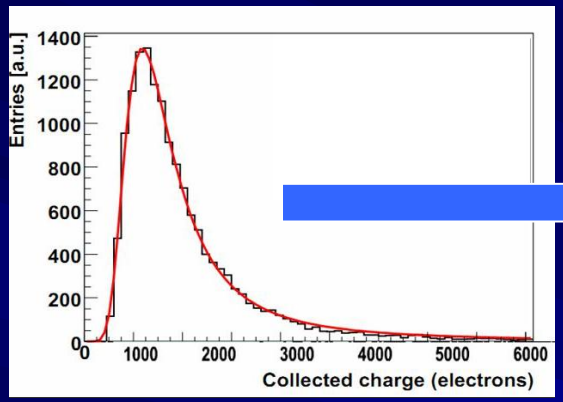
The simulation of inclined particles is derived by this initial parameterization.

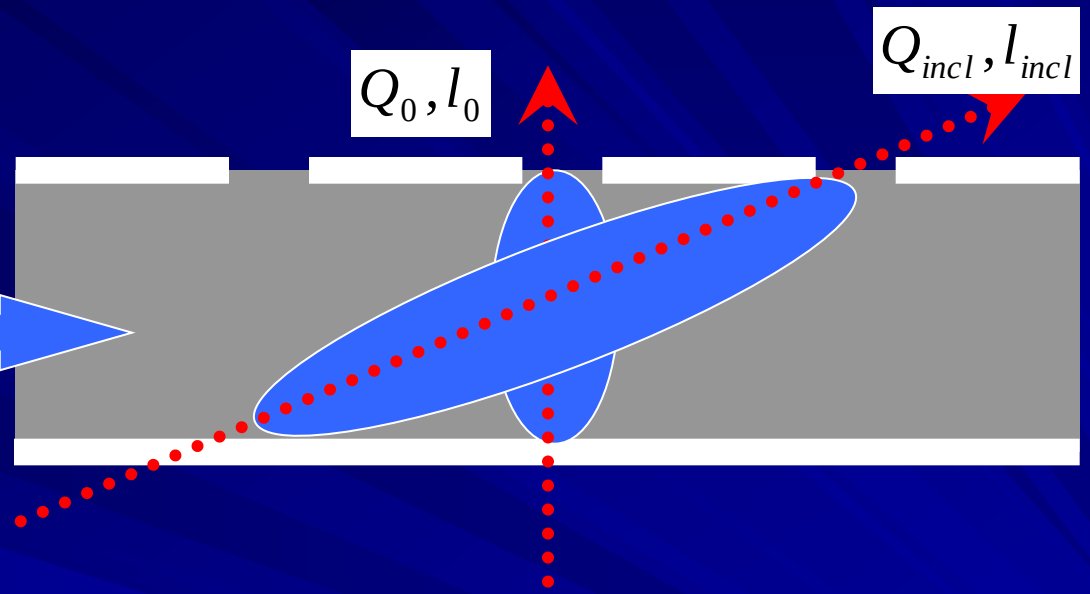


among the pixels in the cluster is based on a 2D Lorentz distribution (derived from the 1D)

- 0 degrees incident angle

The model: charge generation



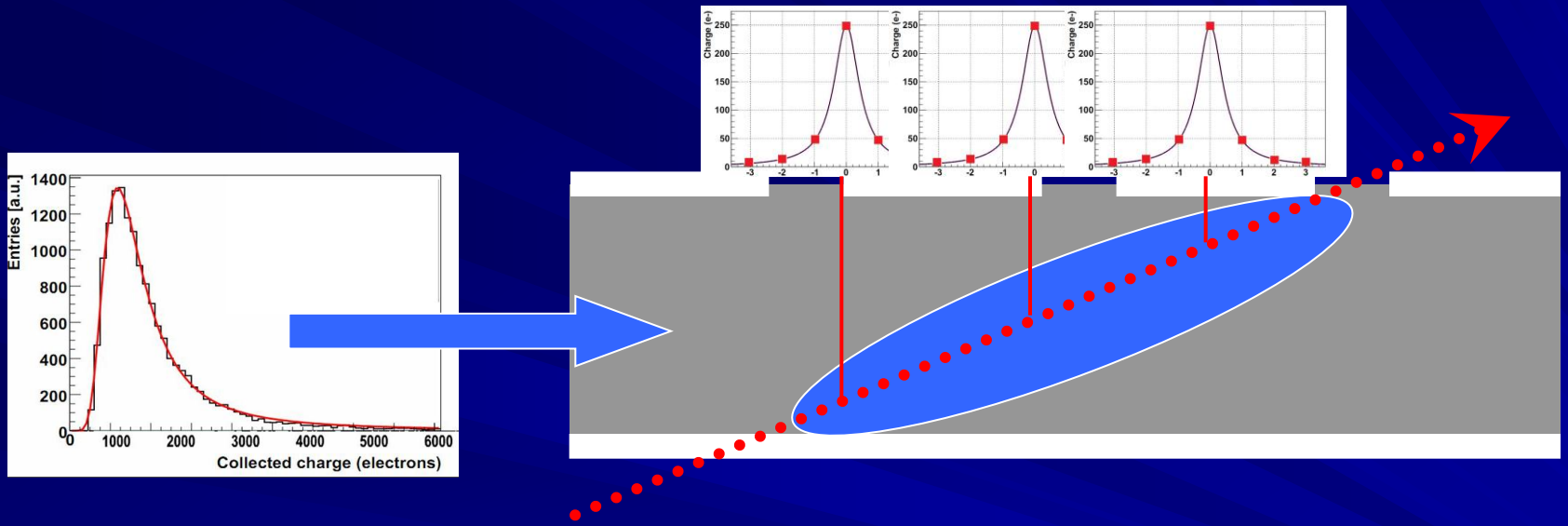


$$Q_{incl} = Q_0 \times \frac{l_{incl}}{l_0}$$

- Q_0, l_0 : known
- l_{incl}: provided by GEANT

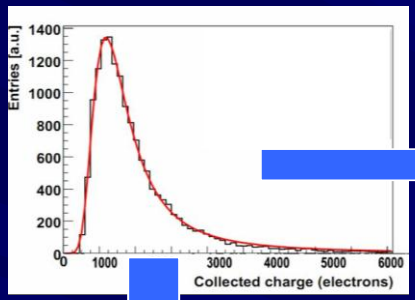
The model: charge distribution

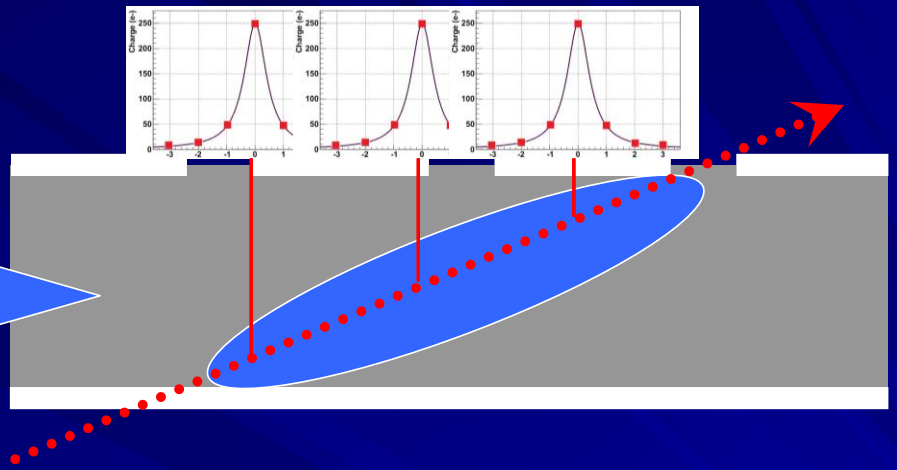
Illustration for inclined track



- Charge provided by Landau (25 pixels)
- The trajectory is divided in segments
- A Lorentz function corresponds to each segment

The model





Charge on pixel i

x,y-coordinates of segment k

Lorentz Amplitude

Lorentz width

$$Q_i = \frac{1}{n} \times Q_{Landau} \times \sum_{k=1}^{n} \mathcal{L}(x_{k,i}, y_{k,i}) \cdot \frac{A \times \frac{G}{2\pi}}{(y_k - y_i)^2 / P^2 + G^2/4}$$

Sum over segments (k)

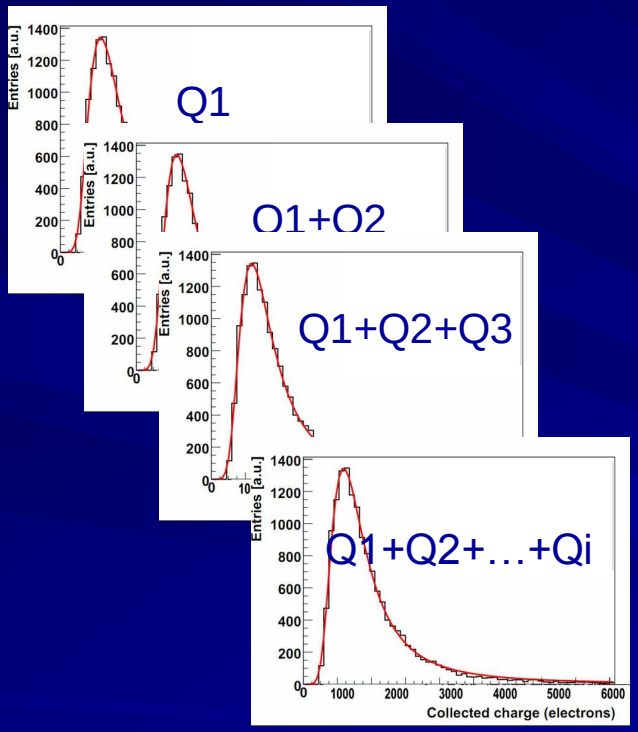
x,y-coordinates of pixel i

Pixel pitch

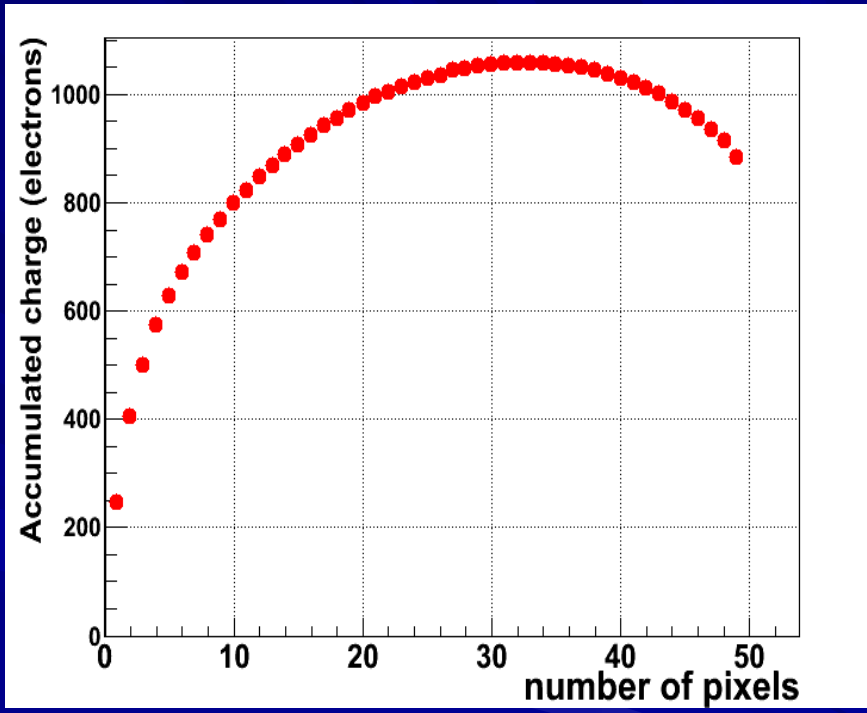
Evaluation

Important definitions (2)

Q1>Q2>Q3…

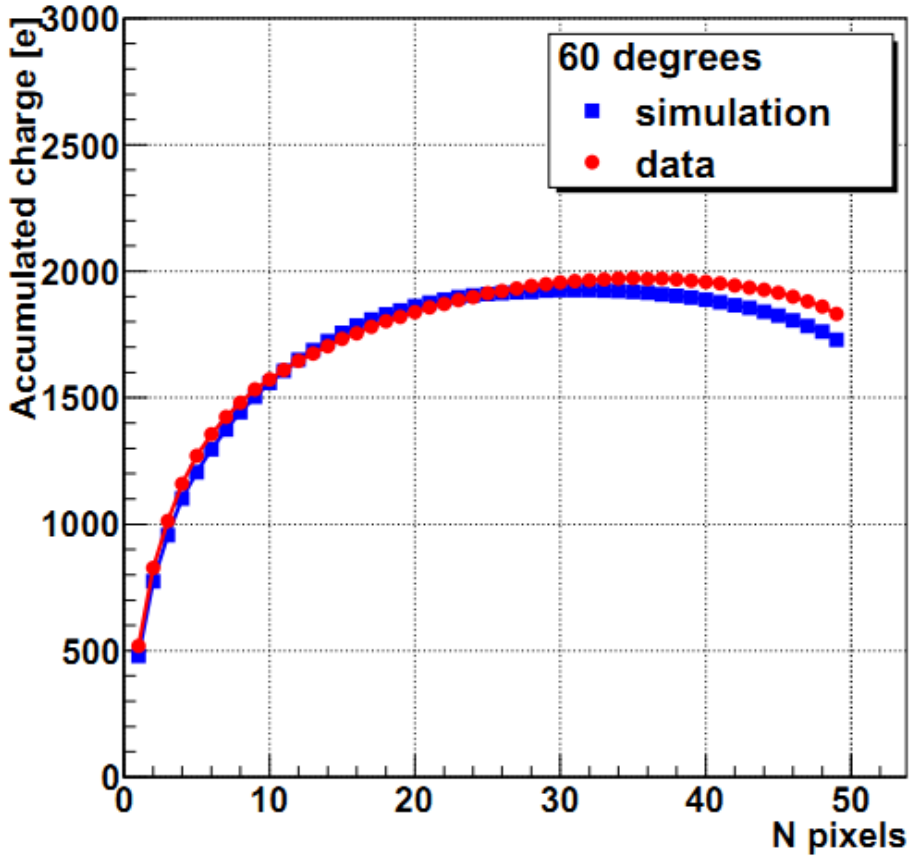


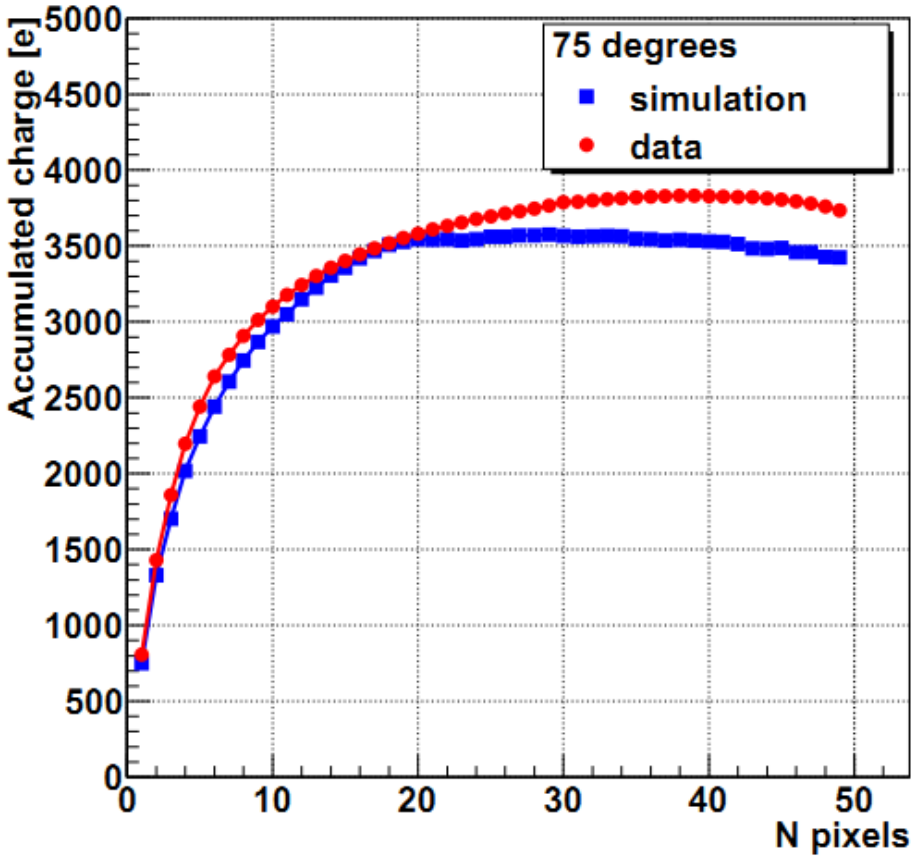
Accumulated charge plot



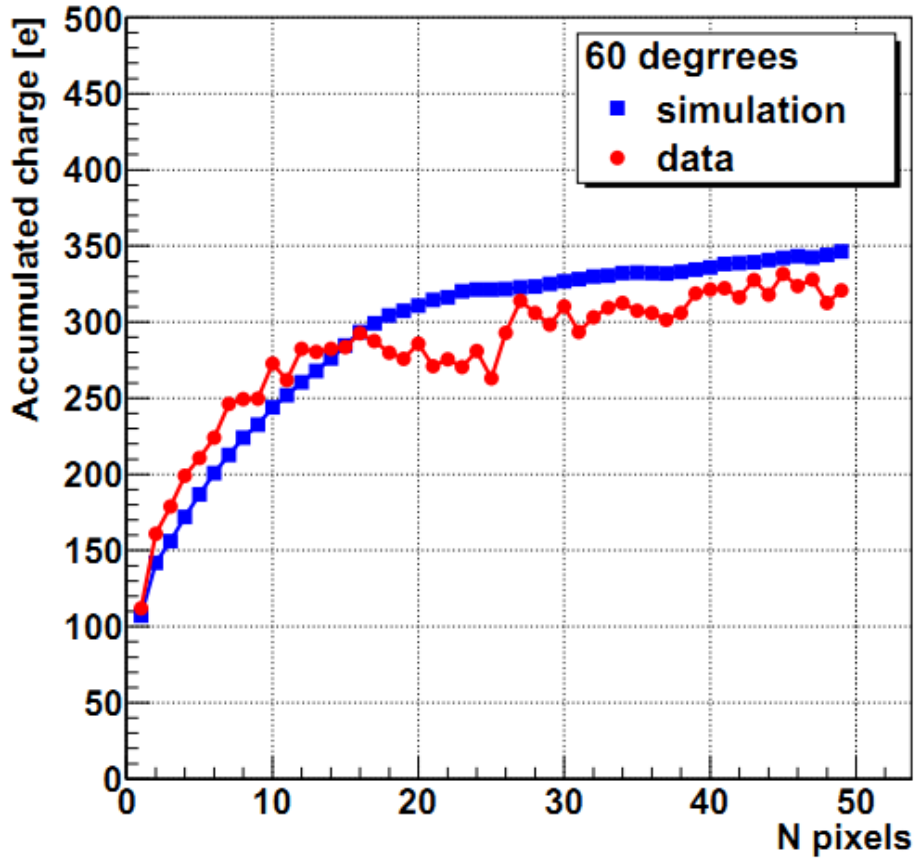
The accumulated charge plot describes the charge sharing among the pixels of the cluster:
e.g. the seed pixel collects ~30% of the total cluster charge.

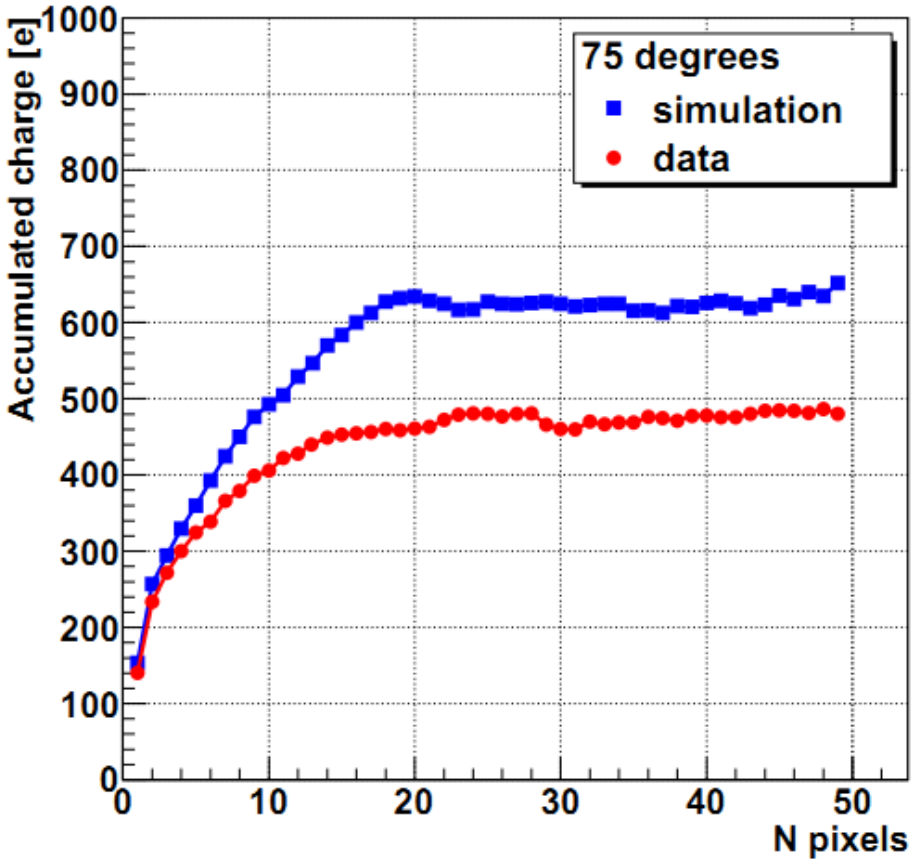
Evaluation: MPV of Landau





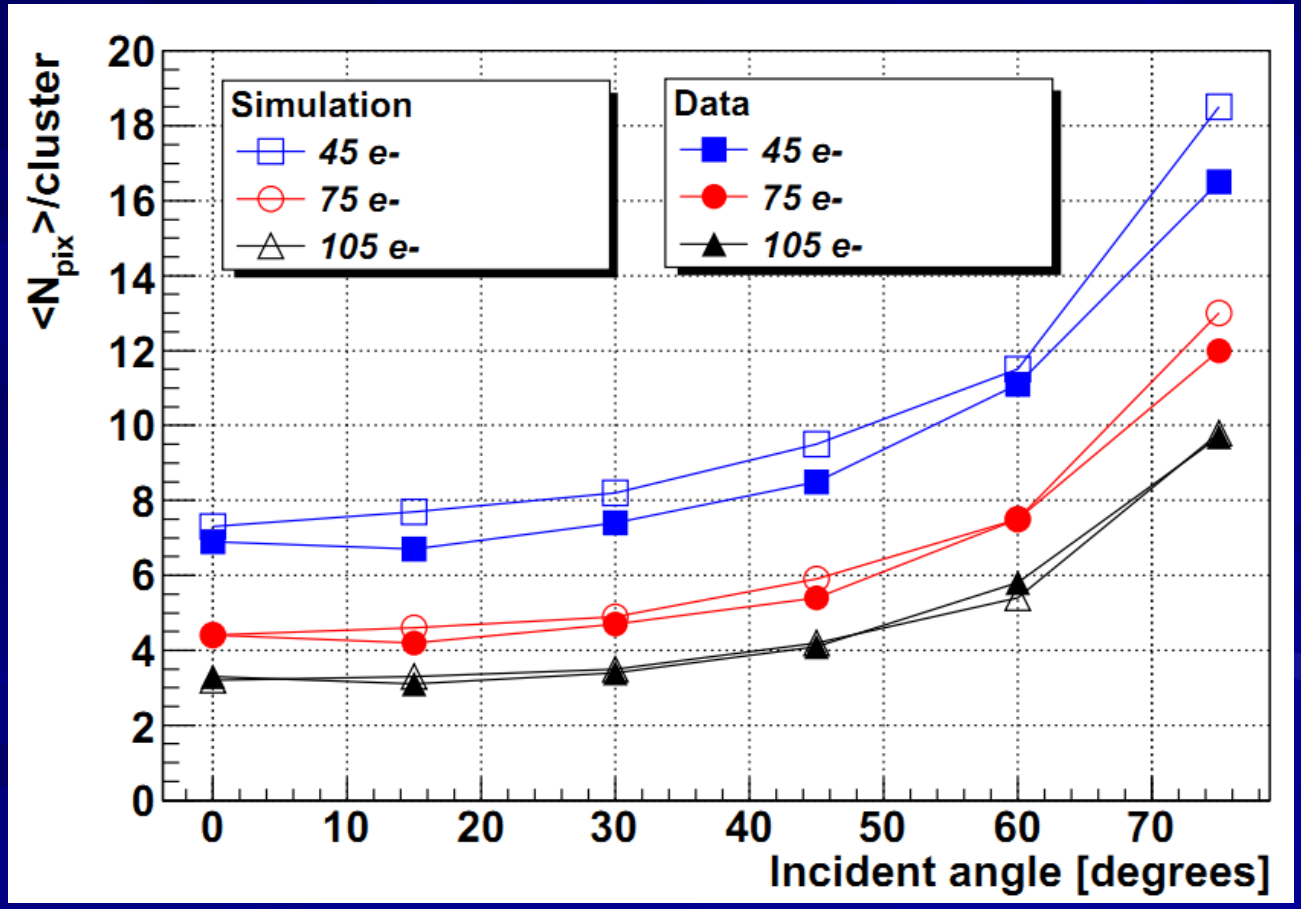
Evaluation: sigma of Landau



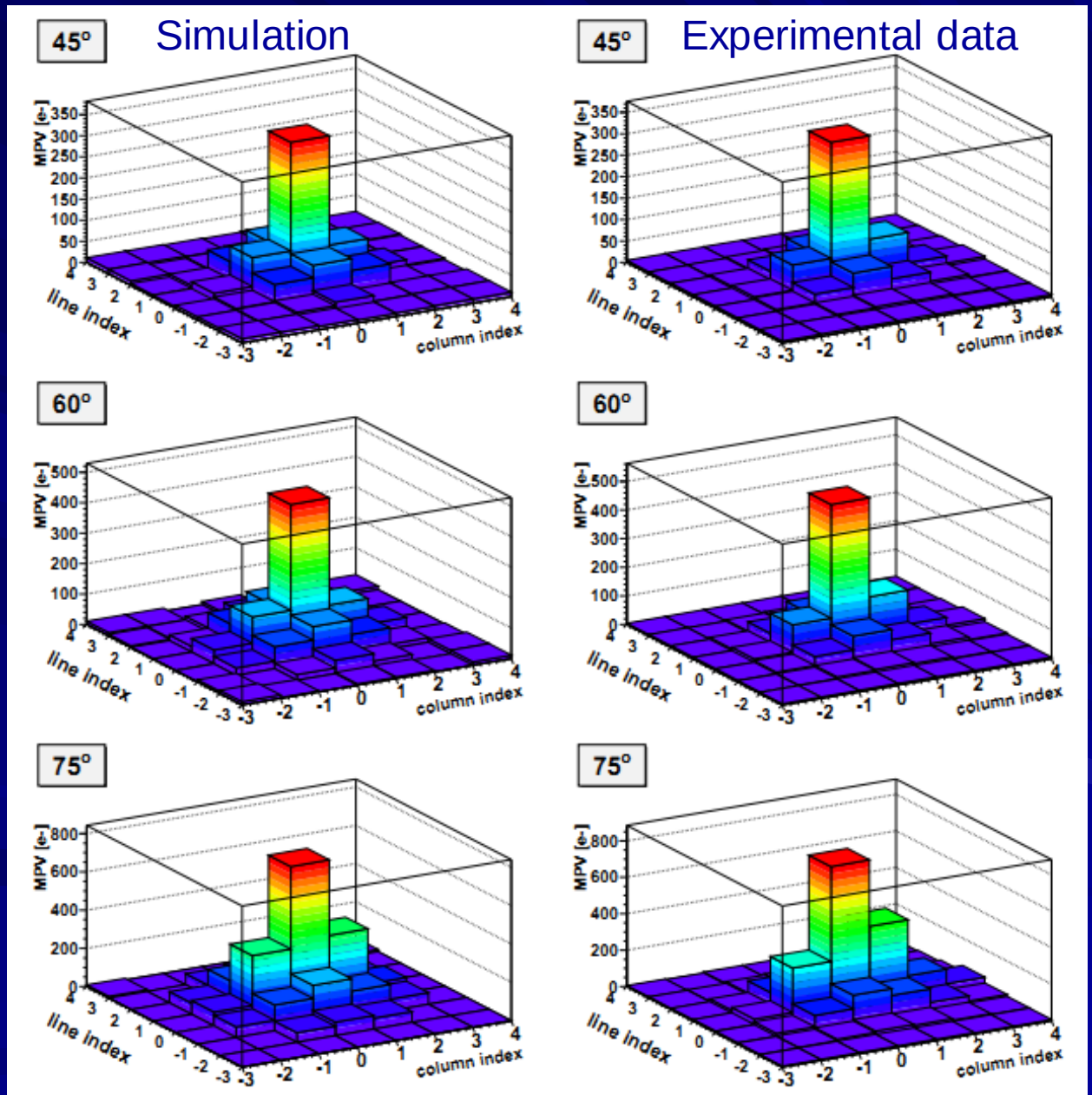


Evaluation

Average number of pixels/cluster



Evaluation: shape



Summary and outlook

- Digitizer model developed for the CBM-MVD and successfully tested with experimental data.
- Model was successfully tested on High-Resistivity sensors (M.Domachowski)
- Successfully tested on neutron irradiated sensors (M.Domachowski)
- Simulation of MIMOSA-26 data sparcification in process (Q.Li)

Acknowledgments

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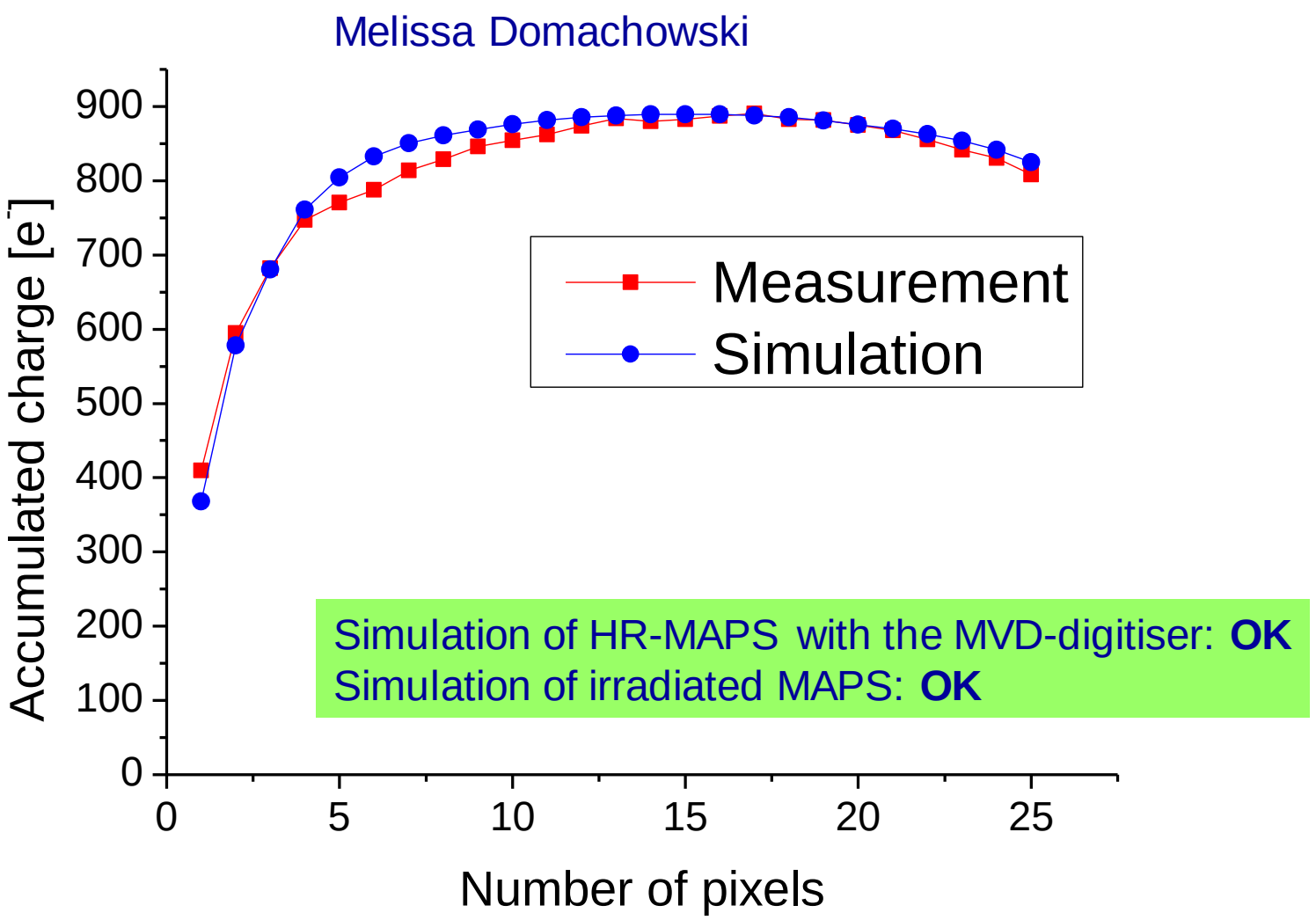
In particular:

IPHC: J.Baudot, M.Goffe, R.DeMasi, M.Winter

IKF: M.Deveaux, M.Domachowski, Q.Li, J.Stroth

Backup

High-Res MAPS: Measurement vs. simulation



Particle yields