EUDET JRA1 meeting
Strasbourg, 4 March 2009

Monte Carlo simulations of the MAPS response

- Motivation
- Simple model of the charge diffusion
- Validation of the proposed model
- ILC Software implementation

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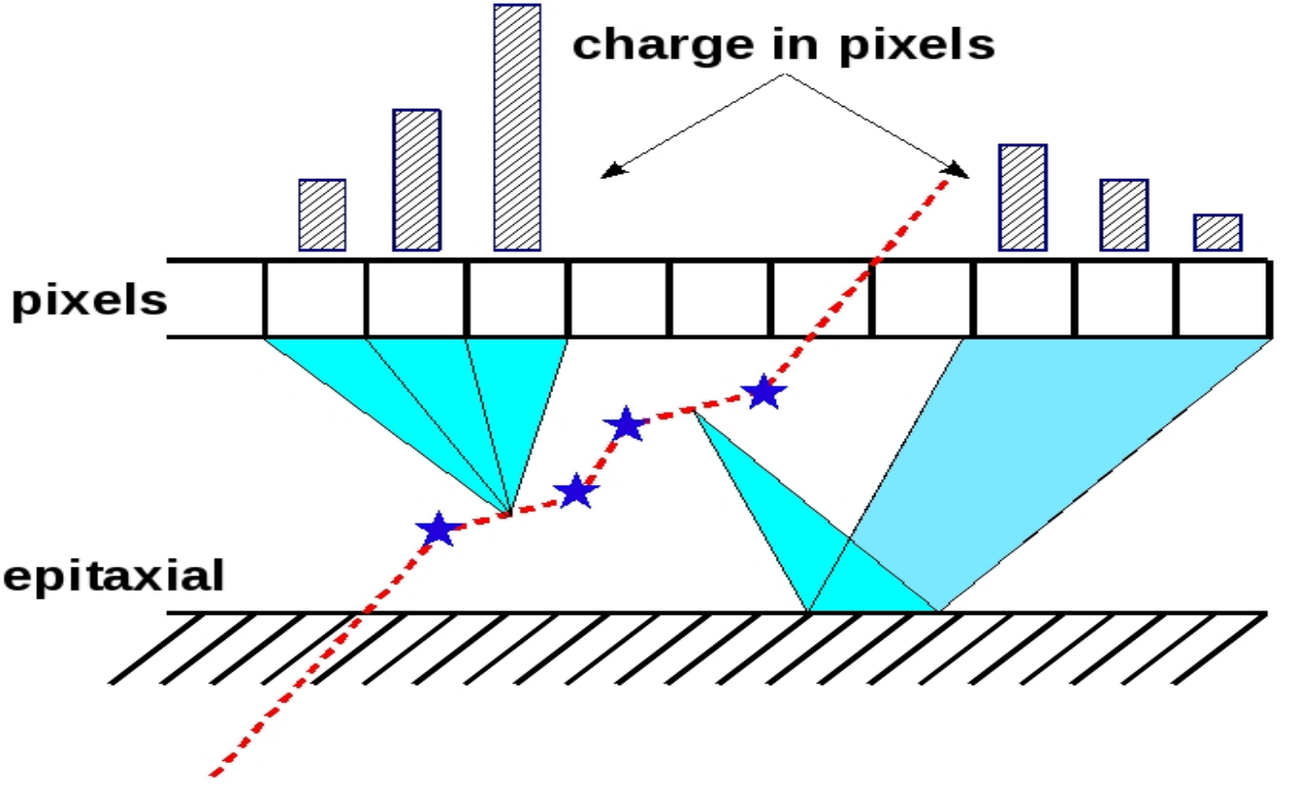
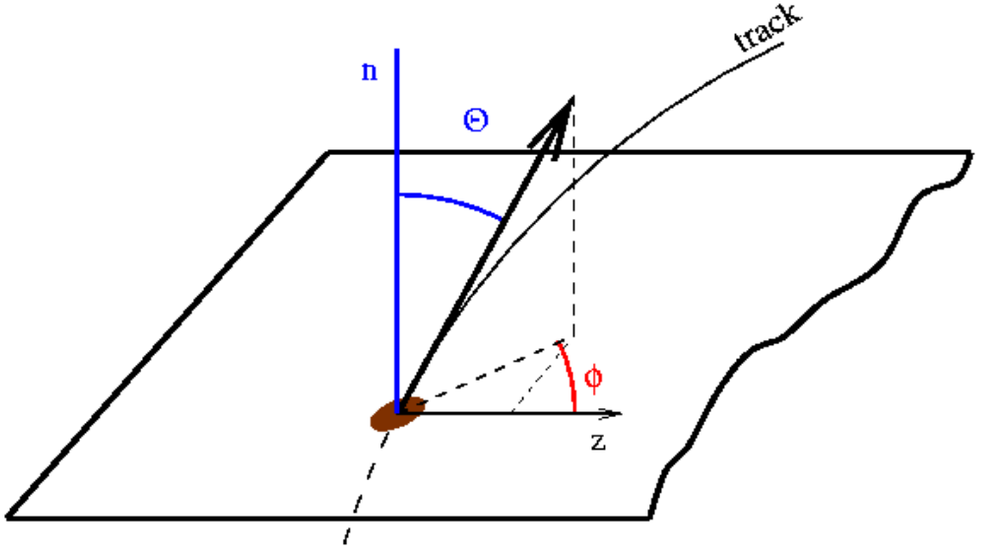
Motivation

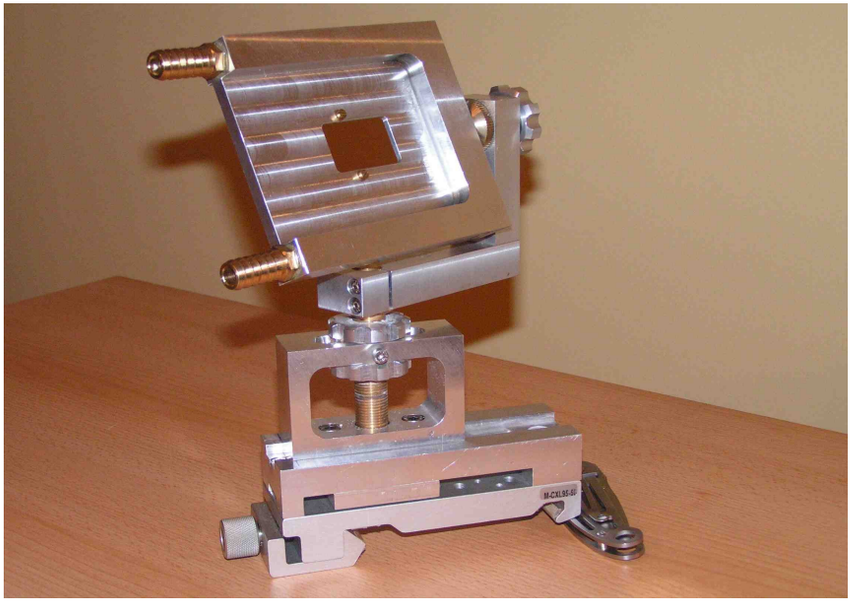


- The detector MC simulations do not supply detector response
  - Studies of the single point resolution (pixel pitch size, noise level)
  - Studies of the pixel detector occupancy (pixel pitch size, B field)
  - Improvement of the cluster selection and position reconstruction

Performed measurements

- Measurements with 6 GeV and 0.3 GeV electrons for different particles incident angles $\theta \in (0°,80°)$ (DESY and Frascati test beam facilities)
- Tested detectors (MAPS):
  - MIMOSA-5 – 17 µm pixel pitch
  - MIMOSA-18 – 10 µm pixel pitch
- Studies of cluster shapes
  - Single point resolution
  - Occupancy

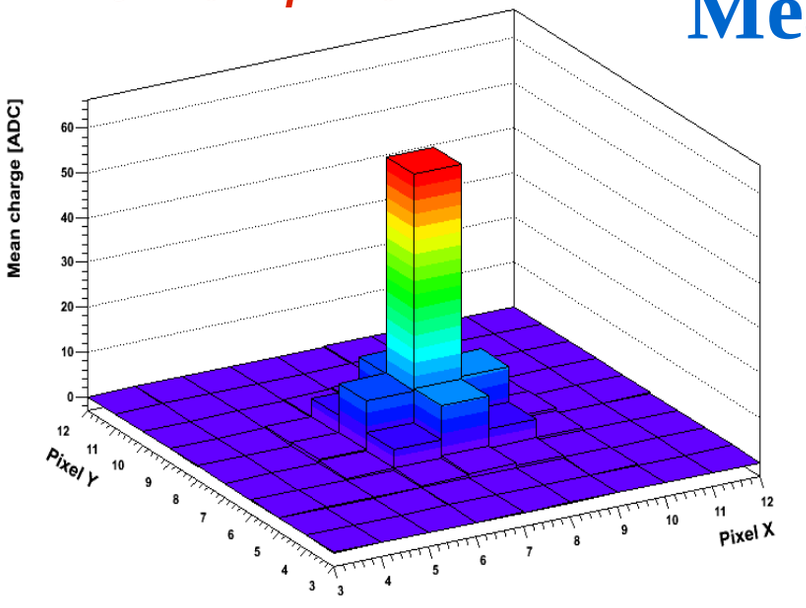




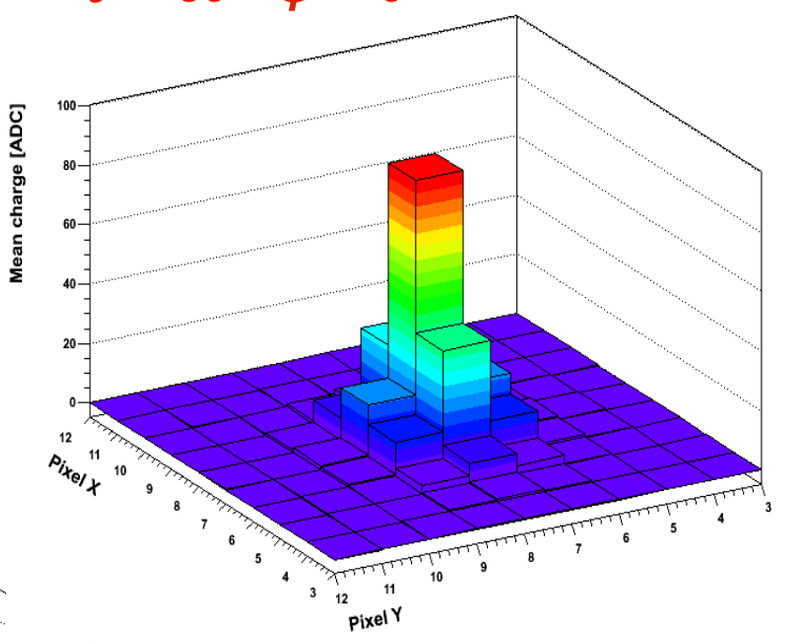
Mean cluster shapes - measurements

Mean clusters

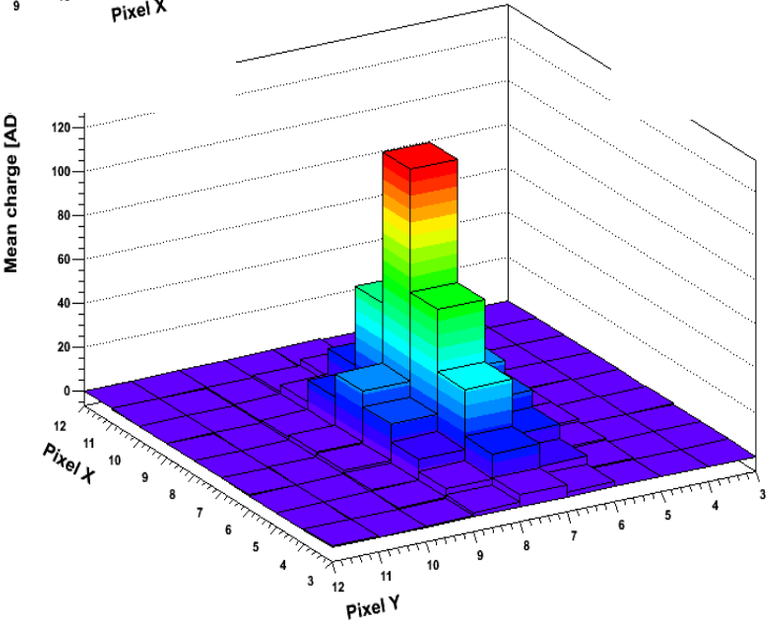
$\theta = 0^\circ \quad \varphi = 0^\circ$



$\theta = 60^\circ \quad \varphi = 0^\circ$



$\theta = 75^\circ \quad \varphi = 0^\circ$

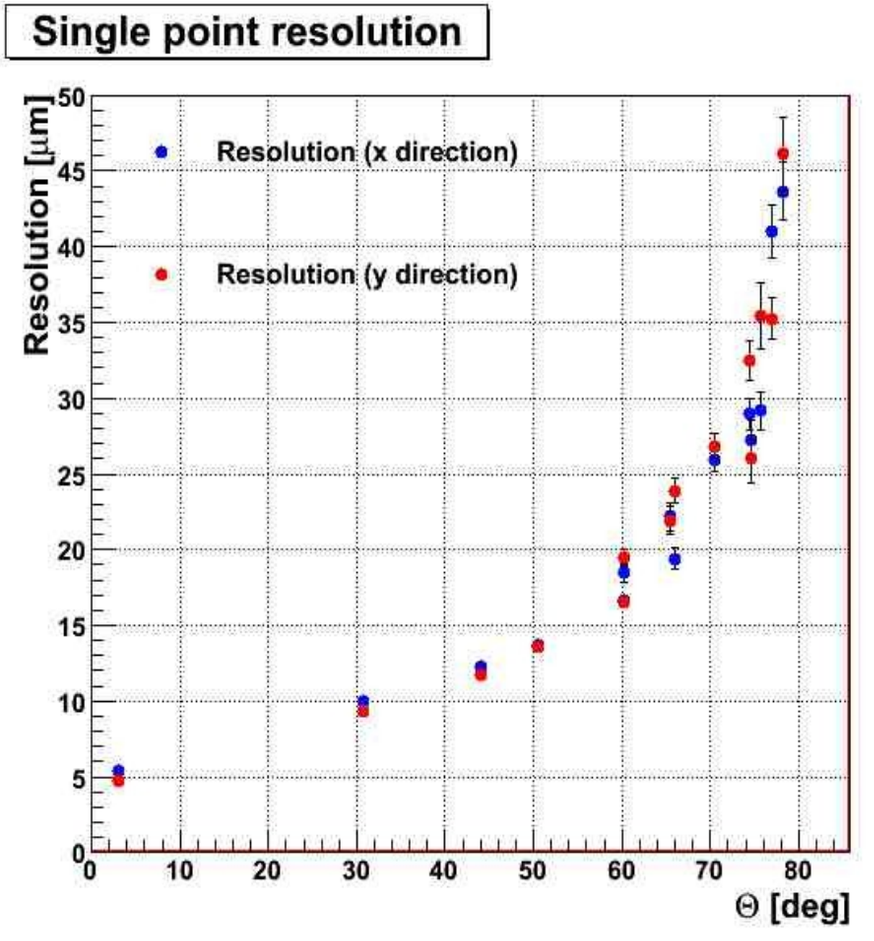


Cluster elongation depends on θ !!!

Deterioration of the single point resolution

- With our setup at DESY the 6 GeV electron beam it was very difficult to determine the single point resolution
- Obtained results are dominated by the MVD silicon strip telescope
  - $\sigma_{MIMOSA-5} \sim 1.5$ µm (CERN)
  - $\sigma_{MVD} \sim 9.0$ µm
- Single point resolution deteriorates with the increasing θ – need to be taken into account in simulations

MIMOSA-5

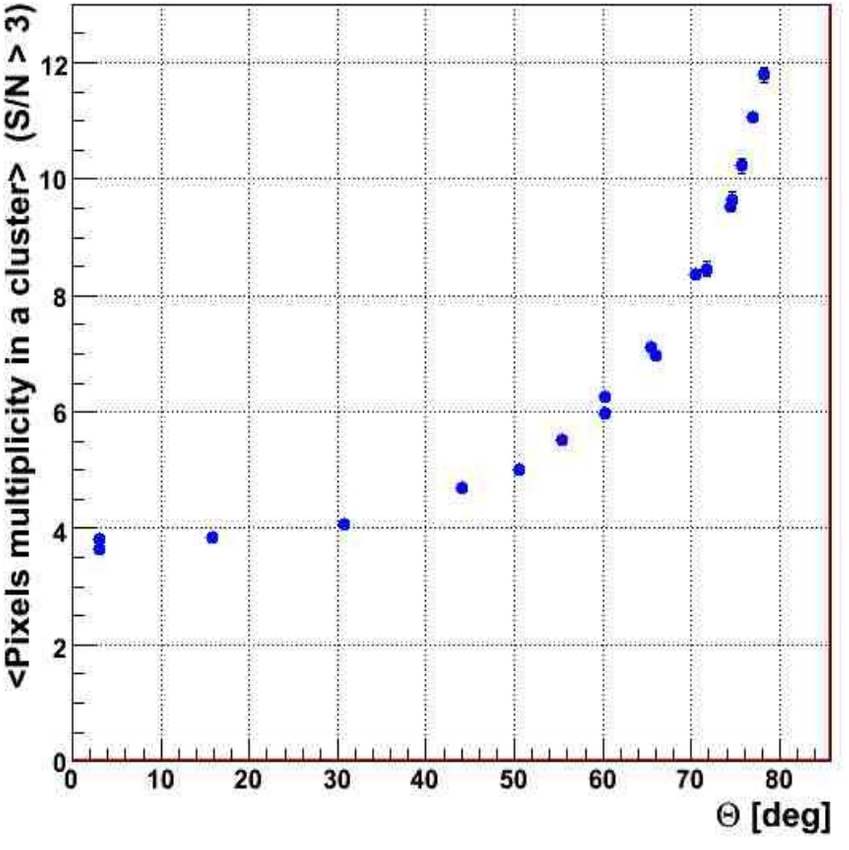


Position reconstructed for 3x3 cluster using the centre of gravity al.

Number of pixels involved in the charge collection

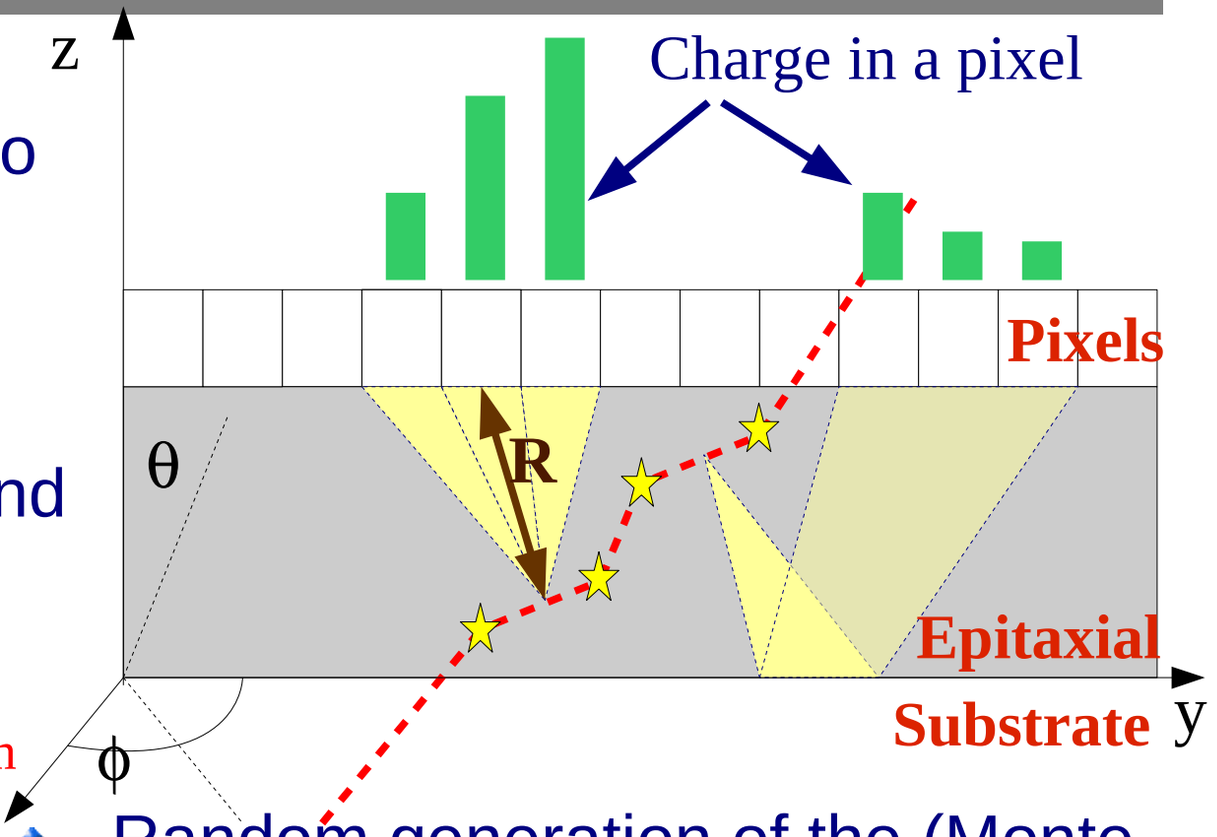
- The number of signal pixels (S/N > 3) increases with the incident angle θ
- This has to be taken into account in clustering to preserve resolution
- Also important for estimates of the detector occupancy
- Detailed modelling of the pixel detector response is crucial for the VXD performances studies

MIMOSA-5



A simple model of charge diffusion

- Isotropic thermal diffusion leads to charge spread into adjacent pixels – cluster formation
- Deposited energy is converted to charge (Q) and redistributed into pixels according to the formula:



Isotropic diffusion Attenuation term

$$\mathbf{q}(\mathbf{R}) = \mathbf{Q}\frac{\mathbf{d}\,\Omega}{(\mathbf{4}\,\pi)}\exp\left(\frac{-\mathbf{R}}{\lambda}\right)$$

λ to be determined

- Random generation of the (Monte Carlo approach)
  - Direction of the charge carrier emission
  - Attenuation
  - Reflection

Determining λ

- Also include:
  - Noise
  - Conversion to ADC

Determined from measurements

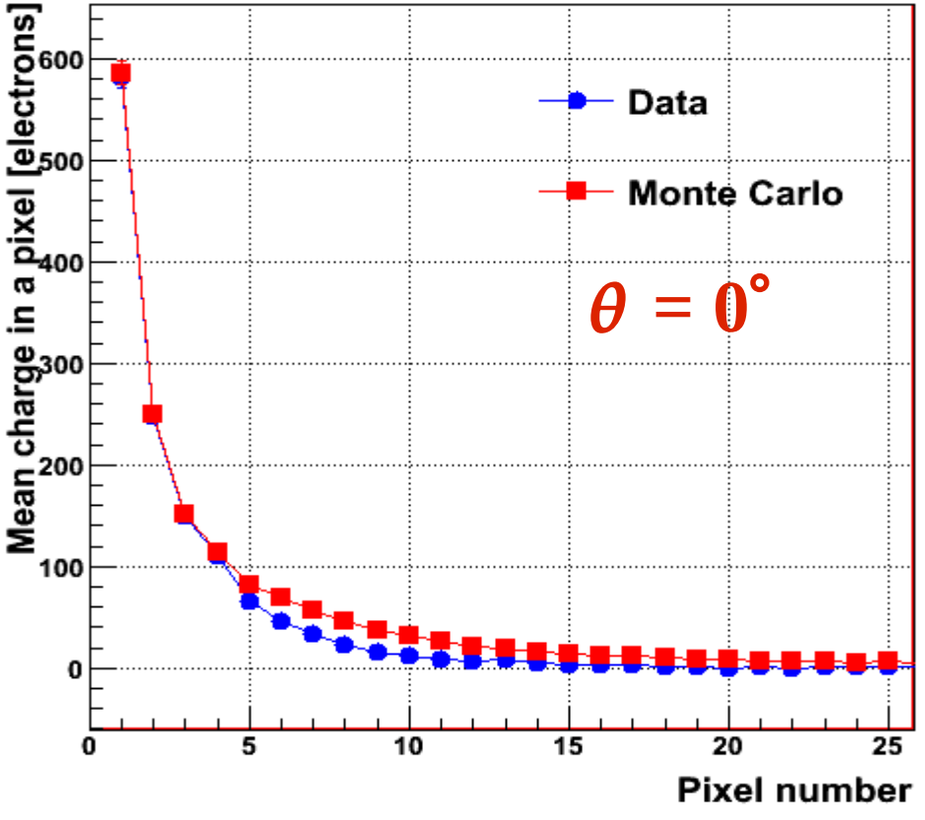
Monte Carlo

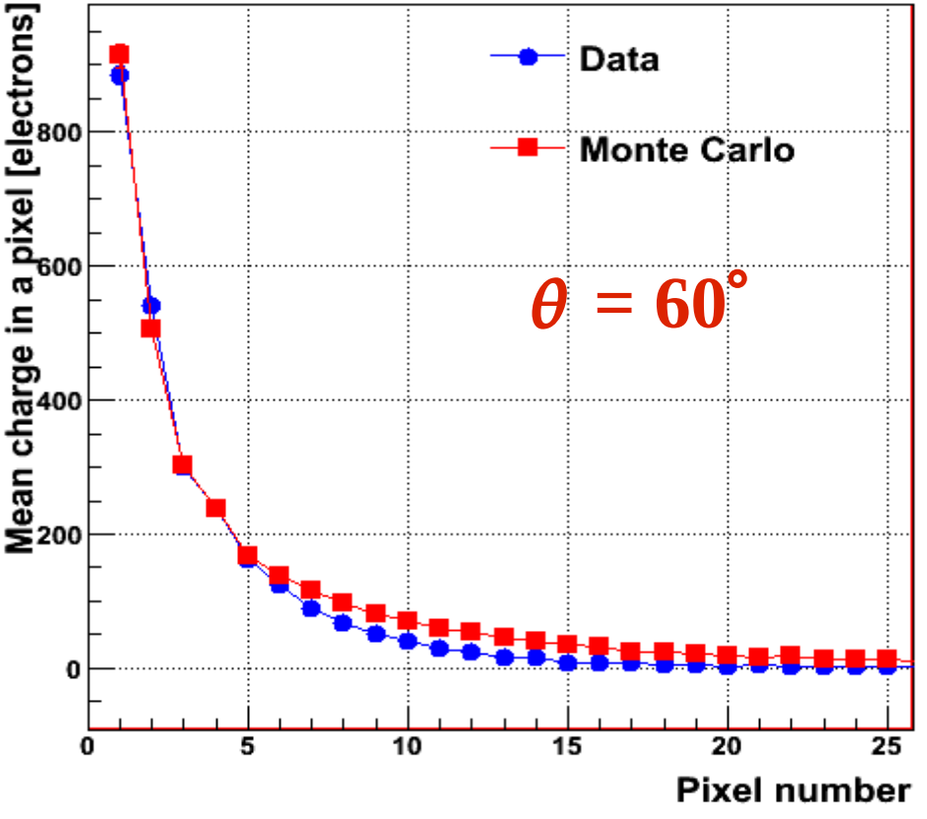
$$\mathrm{Signal}_{\mathrm{pixel}} = \mathrm{int}\left(\alpha \cdot \mathrm{Charge}_{\mathrm{MC}}(\lambda) + \mathrm{Noise}\right)$$

- α and λ to be determined from comparison Monte Carlo to data

Fitting λ for the MIMOSA-5

λ = 50 μm and α=1.94

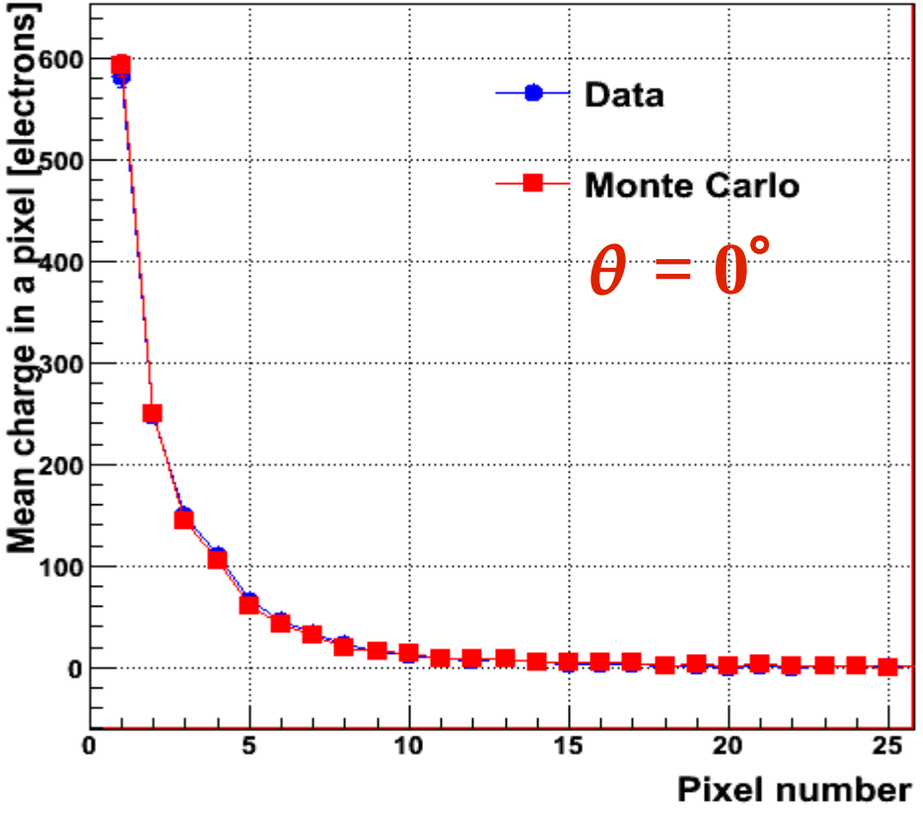


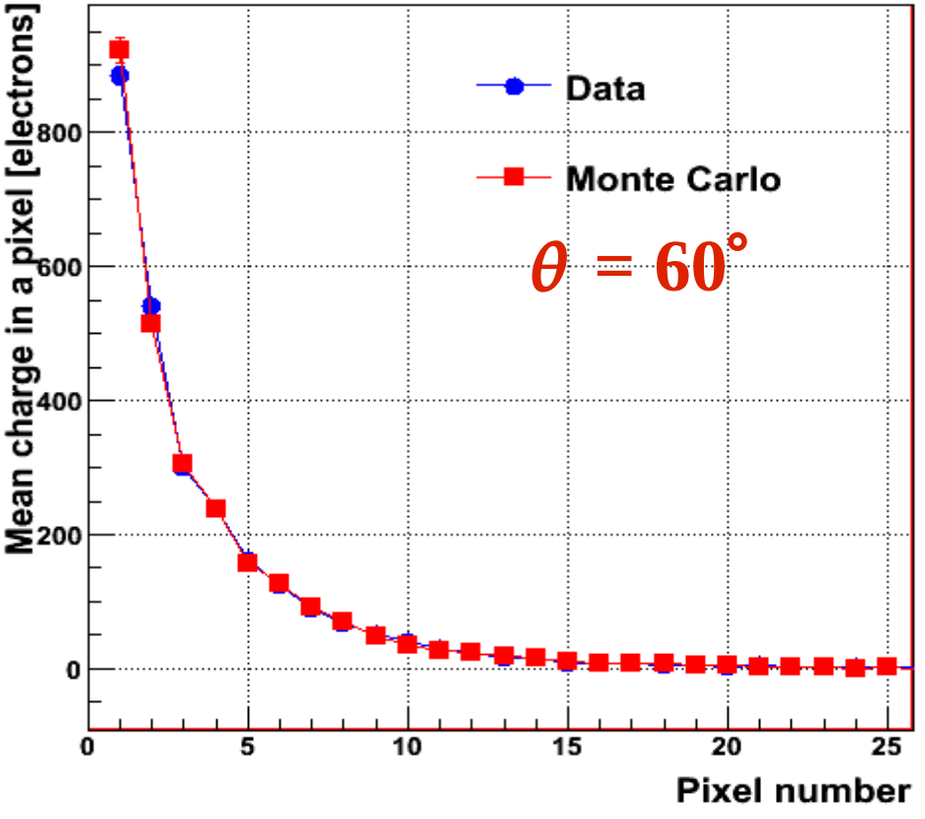


- Pixels with the highest signal are well described by the simple model
- In case of pixels in the tail of the distribution the signal seems to be overestimated

Fitting λ for the MIMOSA-5

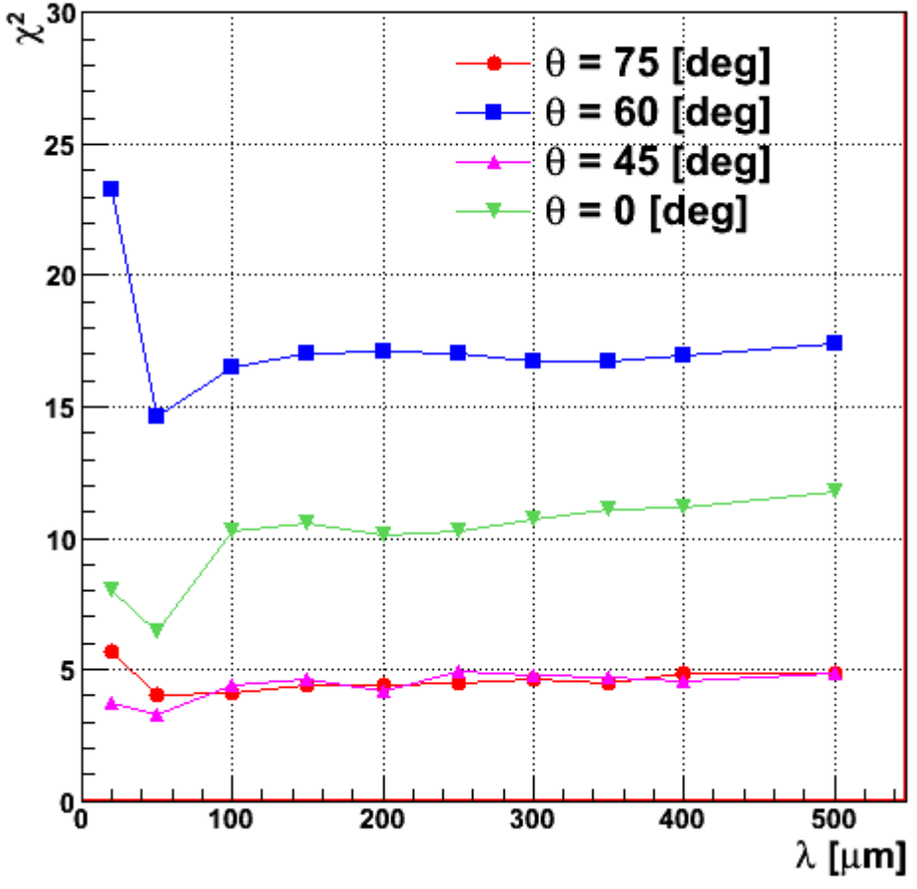
λ = 50 μm and α=2.05

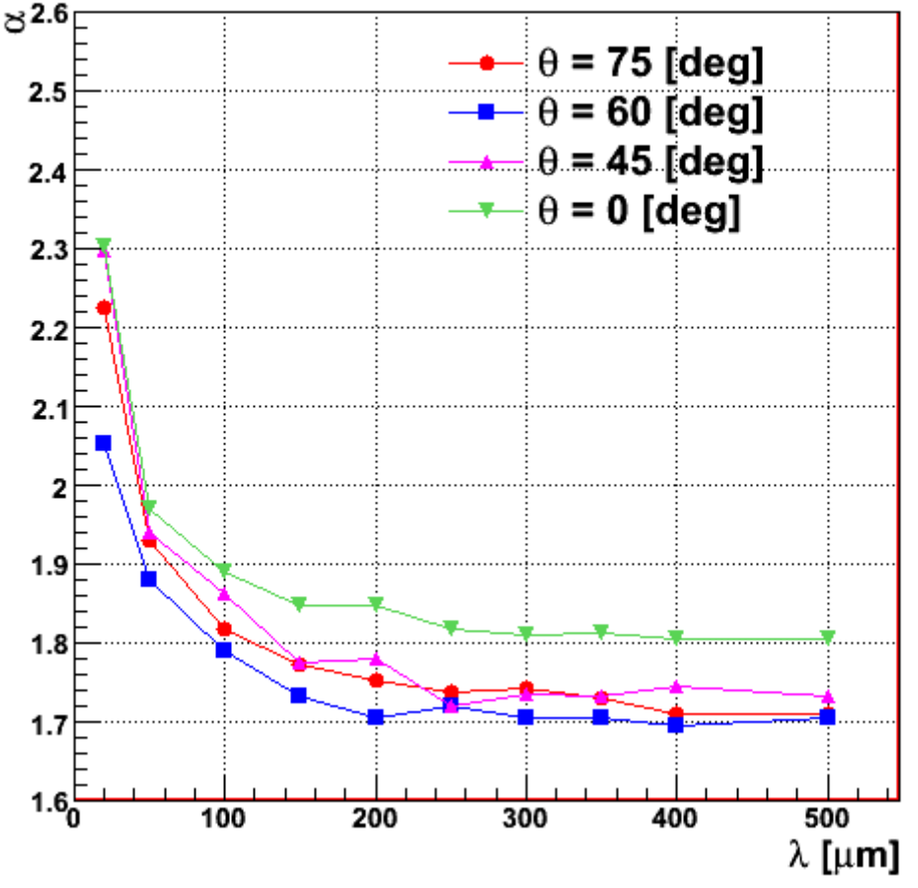




- The fit becomes much better if the signals which are lower than noise are removed from the analysis – S/N < 1.0

Fitting λ for the MIMOSA-5

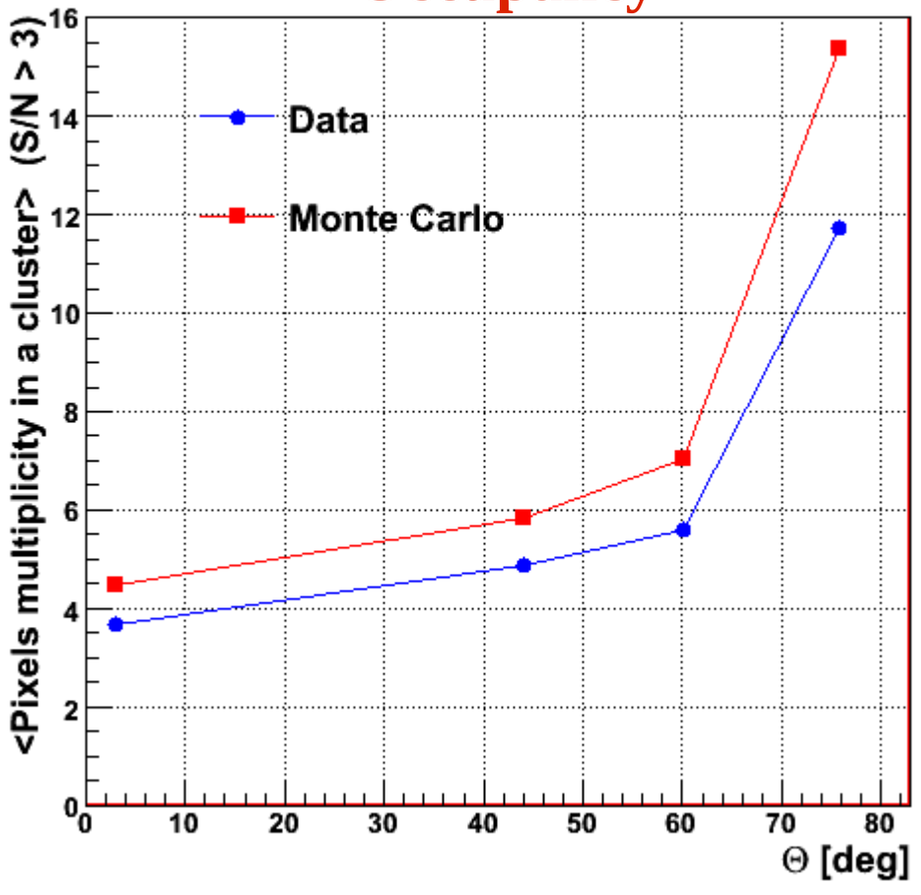




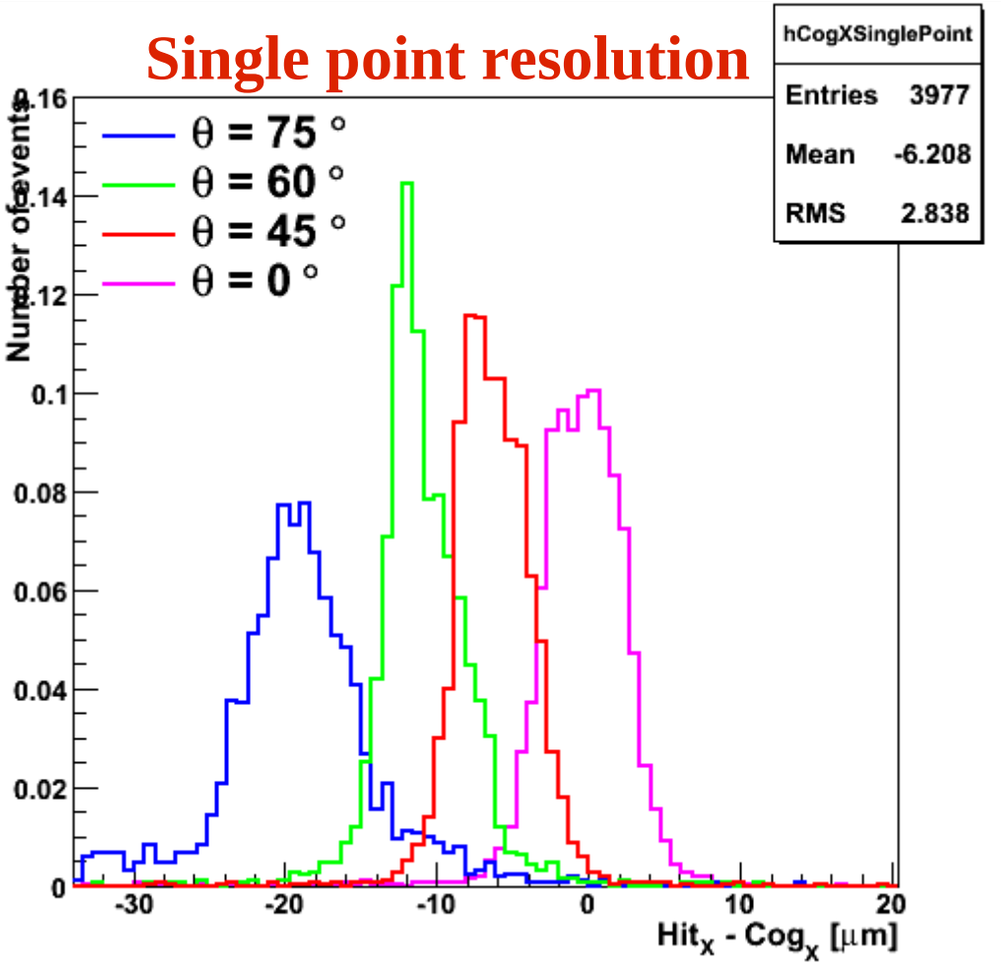
The best fit obtained for λ = 50 μm and α=1.94

Occupancy and single point resolution

Occupancy



Single point resolution



- The pixel multiplicity in case of the MC is overestimated
- The shift of the reconstructed track position at pixel surface increases with the track inclination (effective deposit depth has to be taken into account)

Implementation in the ILC software

- A new Mokka option has been implemented in order to store all Geant steps: /Mokka/init/detailedHitsStoring VXD
- The approach exploiting probability density function has been implemented to the Marlin framework – the numerical integration of charge diffusion formula (TDS)
  - The results of the integration are stored in the grid – simulation is very fast
- The Monte Carlo approach has been implemented to the Marlin framework
- Data can be stored in the root and in the lcio format
- The parametrisation of the MPAS detector response is being used in the EUTelescope software – results are going to be presented in the next talk given by A. F. Żarnecki

Summary

- Measurements at different incident angles show cluster elongation. In order to study VXD performances detailed description of the pixel detectors is required
- New Mokka option for detailed track storing has been delivered
- Parametrisation of MAPS detector presents a good agreement with a data
- Parametrisation of the MAPS detector response has been implemented in the ILC Software framework
- The comparison of MC simulations to the data for the MIMOSA-18 are ongoing