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DESY - Hamburg

Parametrisation of the Monolithic Active Pixel Sensors response – a Geant4 study

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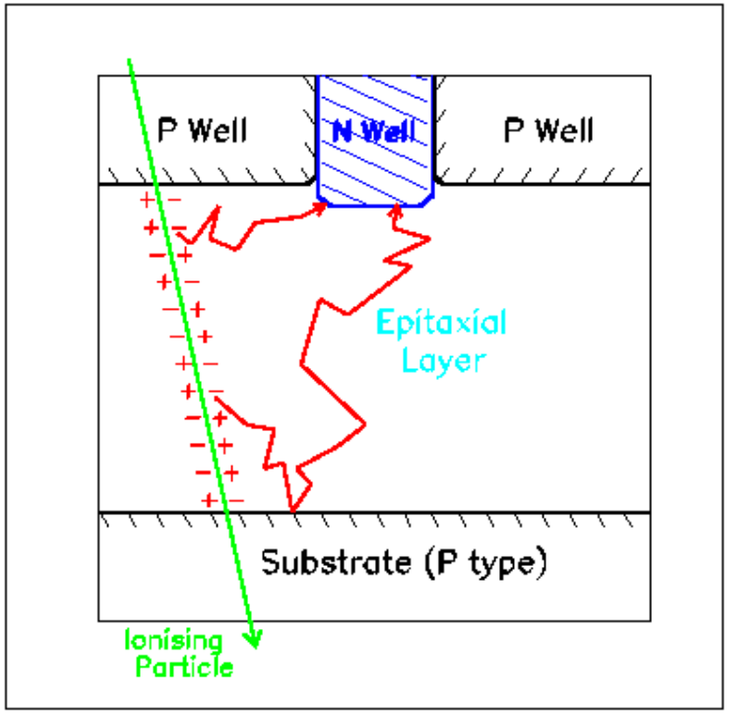
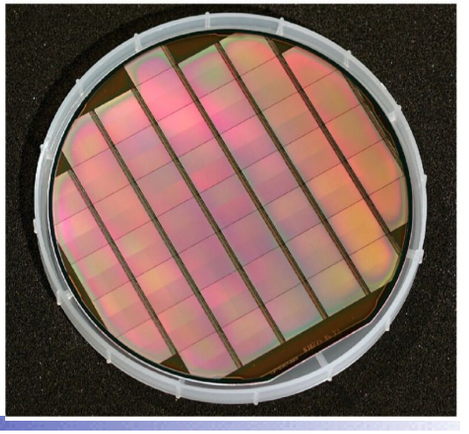
MAPS – Monolithic Active Pixel Sensor

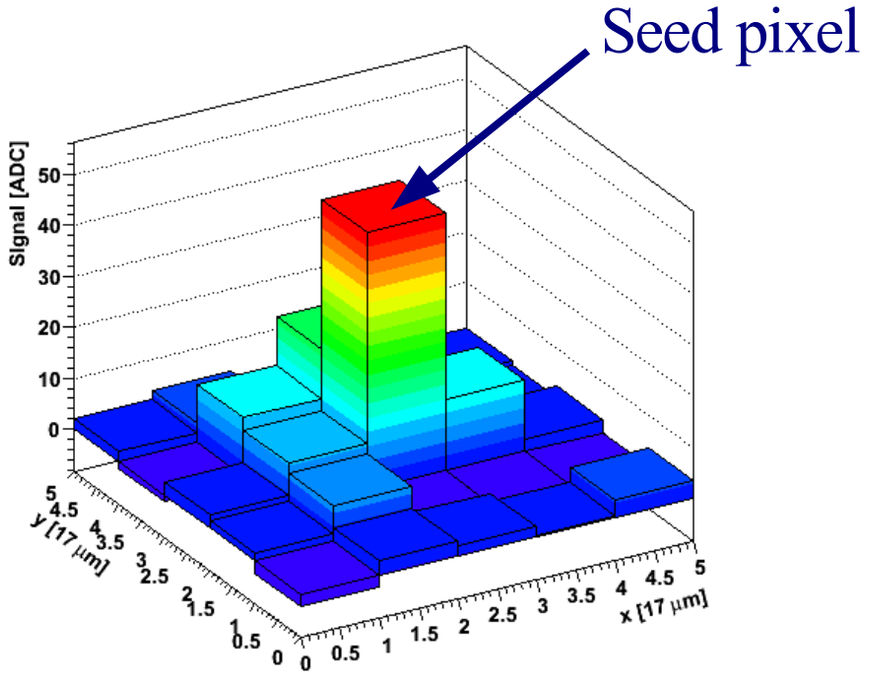
- Generated charge in a sensitive epitaxial layer transported by thermal diffusion to the n-well/p-well diode
- Readout electronics on the top of the sensitive volume → fill factor 100%.
- MIMOSA5 – first real-scale MAPS prototype (3.5 cm²)
  - Pixel size: 17μm × 17μm
  - Epitaxial layer: 14μm
  - Thickness: 120μm
  - Beam tests with 6 GeV electrons at θ = 0°



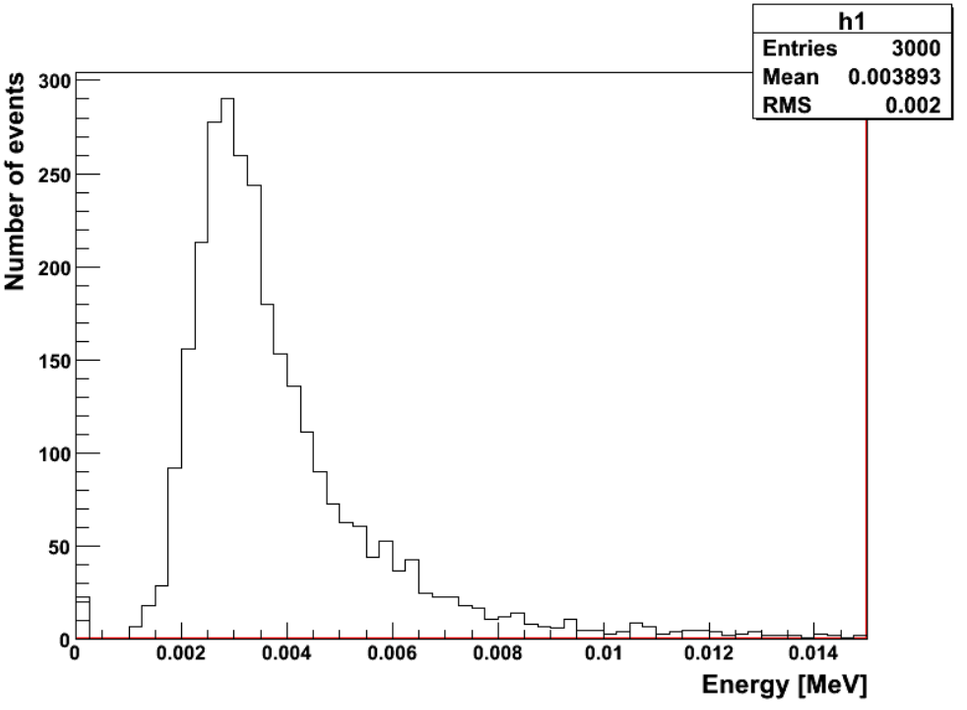


Energy deposition by 6 GeV electrons

Beam test data – cluster



Geant4 – distribution of energy deposition

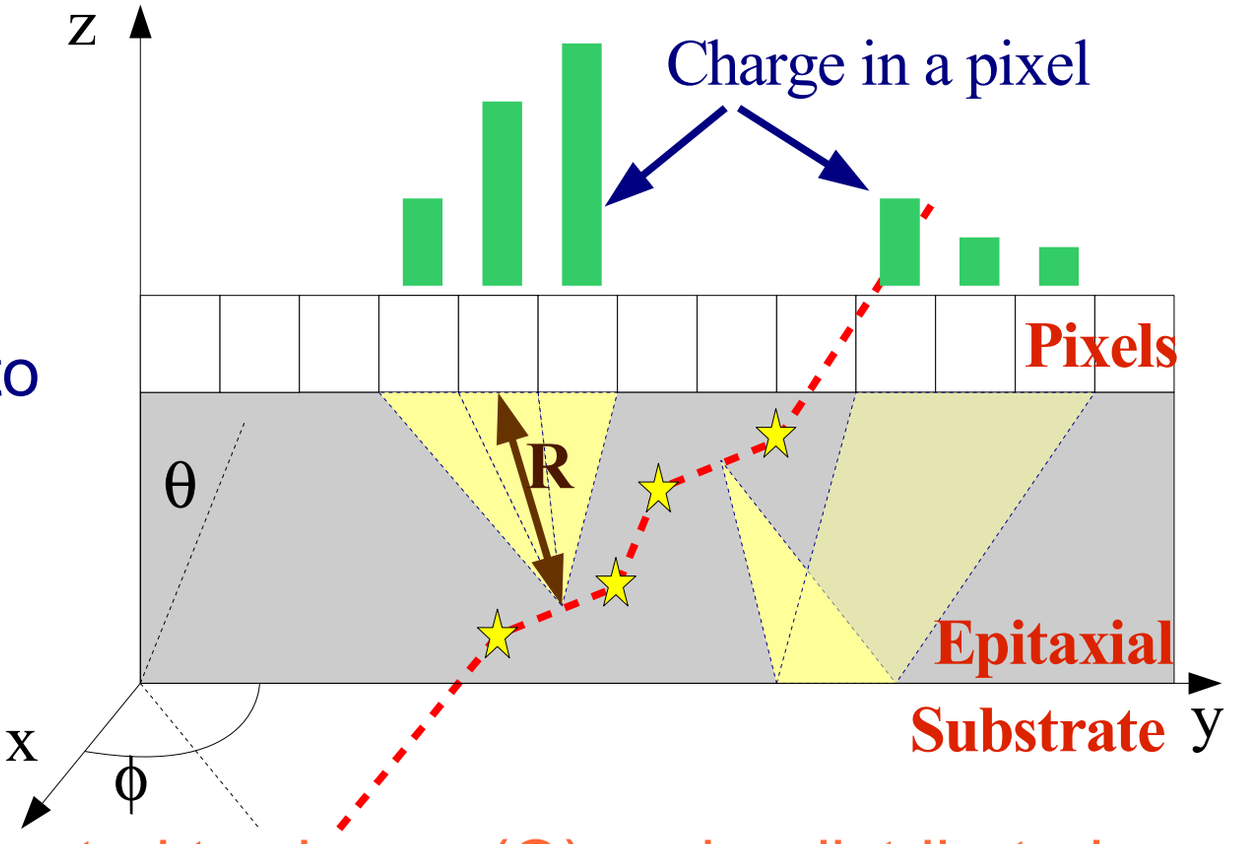


- Data – a cluster (charge distributed into several pixels)
- MC – distribution of energy deposition
- To simulate a cluster, parametrisation of the detector response needed

Not to forget about electronic effects: noise, ADC conversion

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:

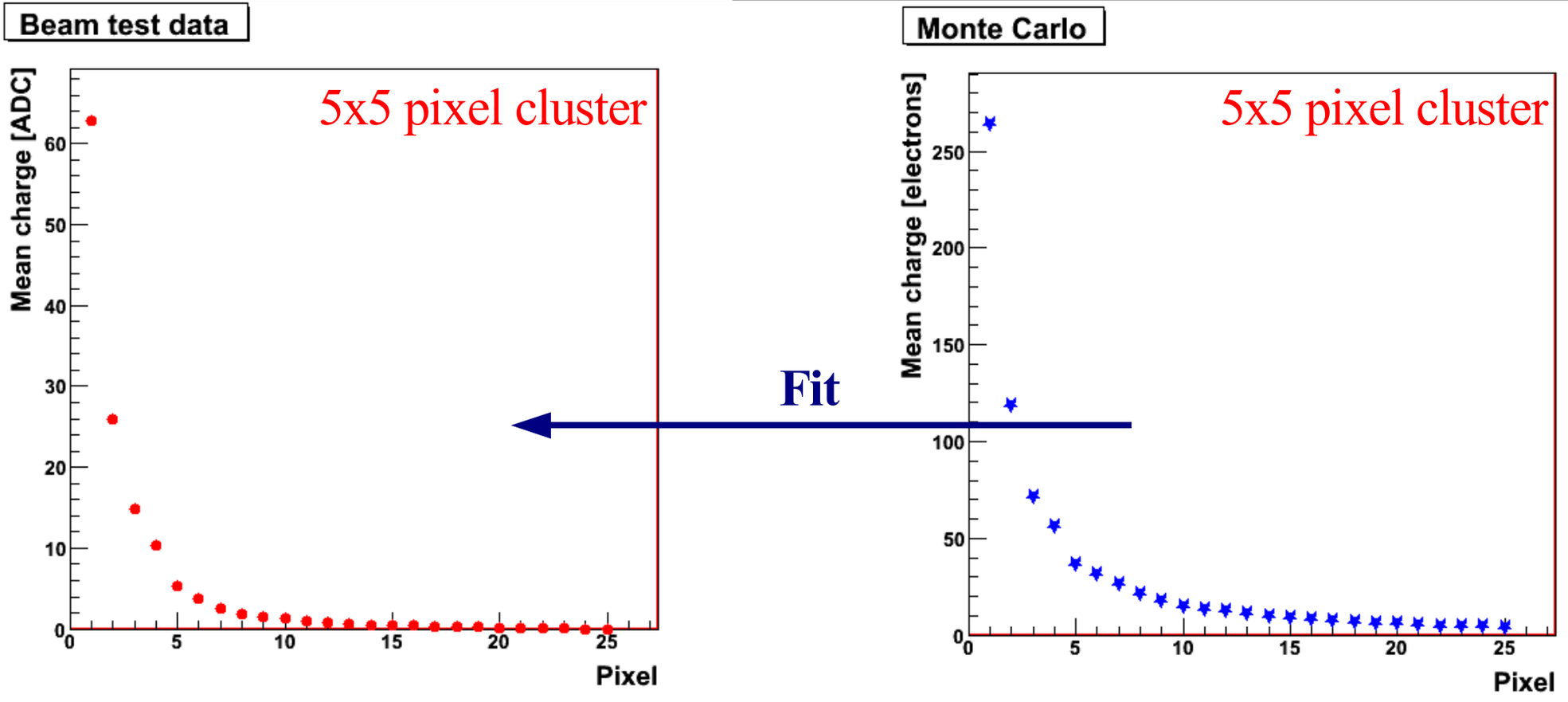
Isotropic diffusion

Attenuation term

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

λ to be determined

Determining λ



- Output of the Geant4 simulation contains only information on physical signals left by electrons

Determining λ

- Also include:
  - Noise
  - Conversion to ADC

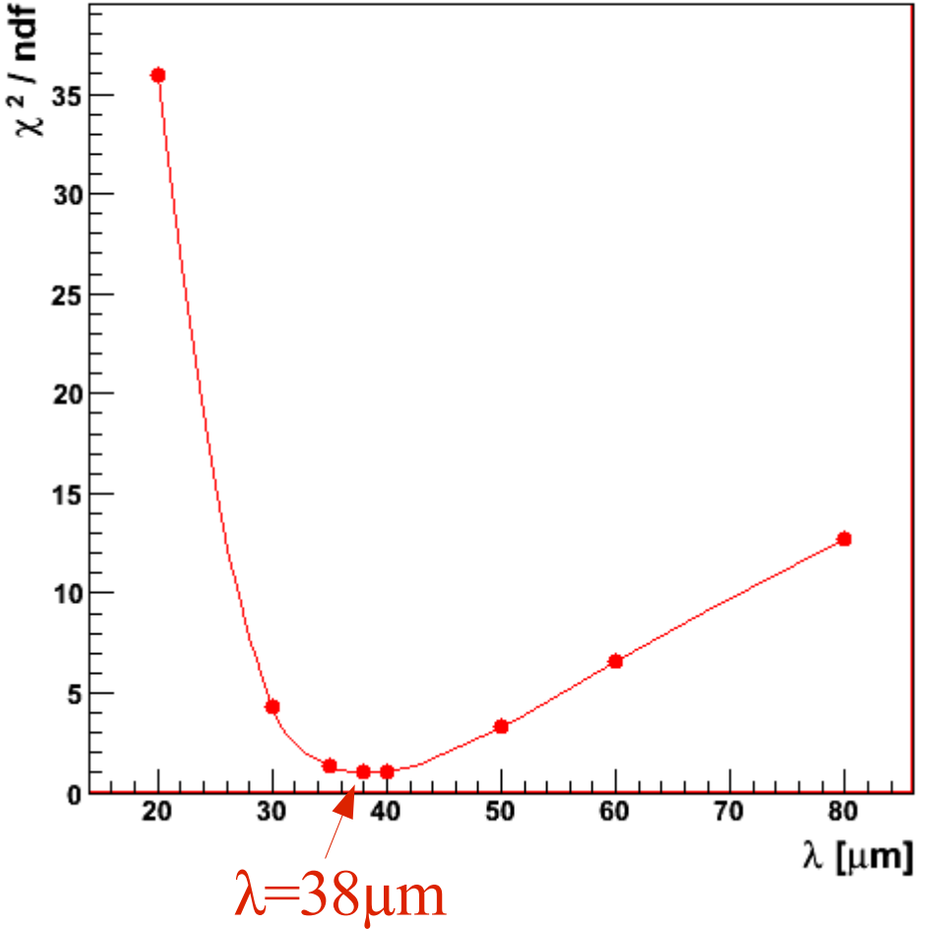
Determined from measurements

Monte Carlo

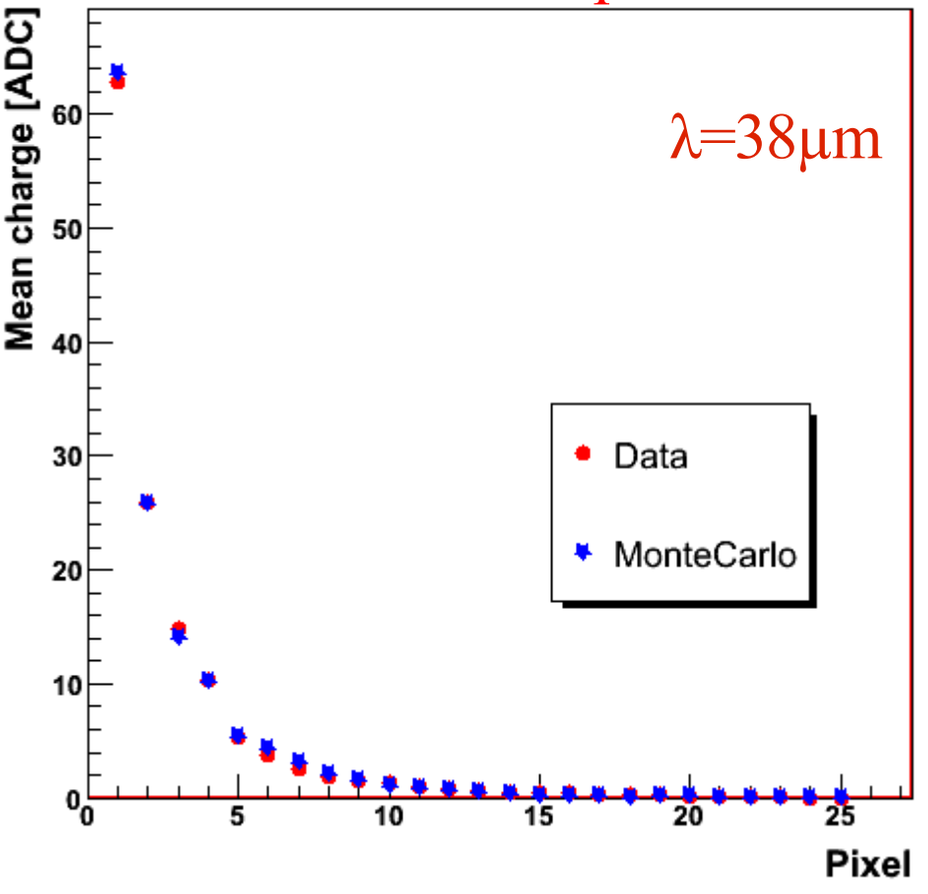
$$\mathrm{Signal}_{\mathrm{pixel}} = \mathrm{int}\left(\alpha \cdot \mathrm{Charge}_{\mathrm{MC}}(\lambda) + \mathrm{Noise}\right)$$

- α and λ to be determined by fitting

Fitting λ

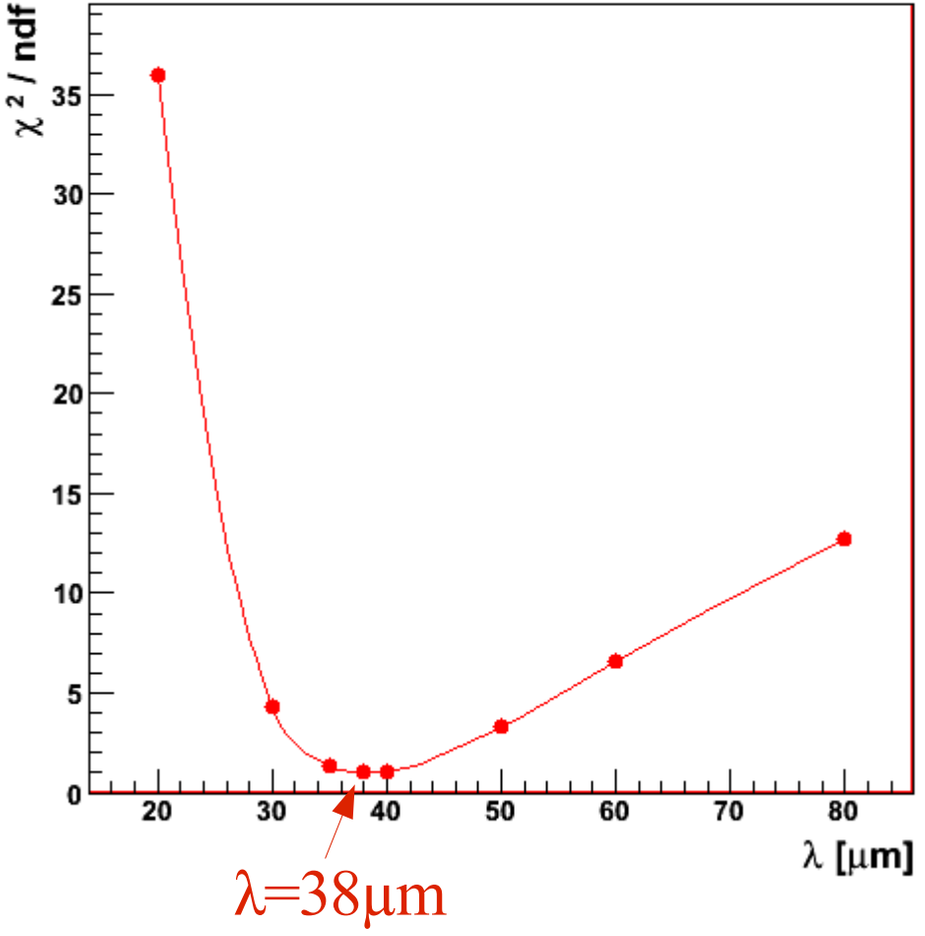


5x5 pixel cluster



- The best fit for λ=38μm

Fitting λ



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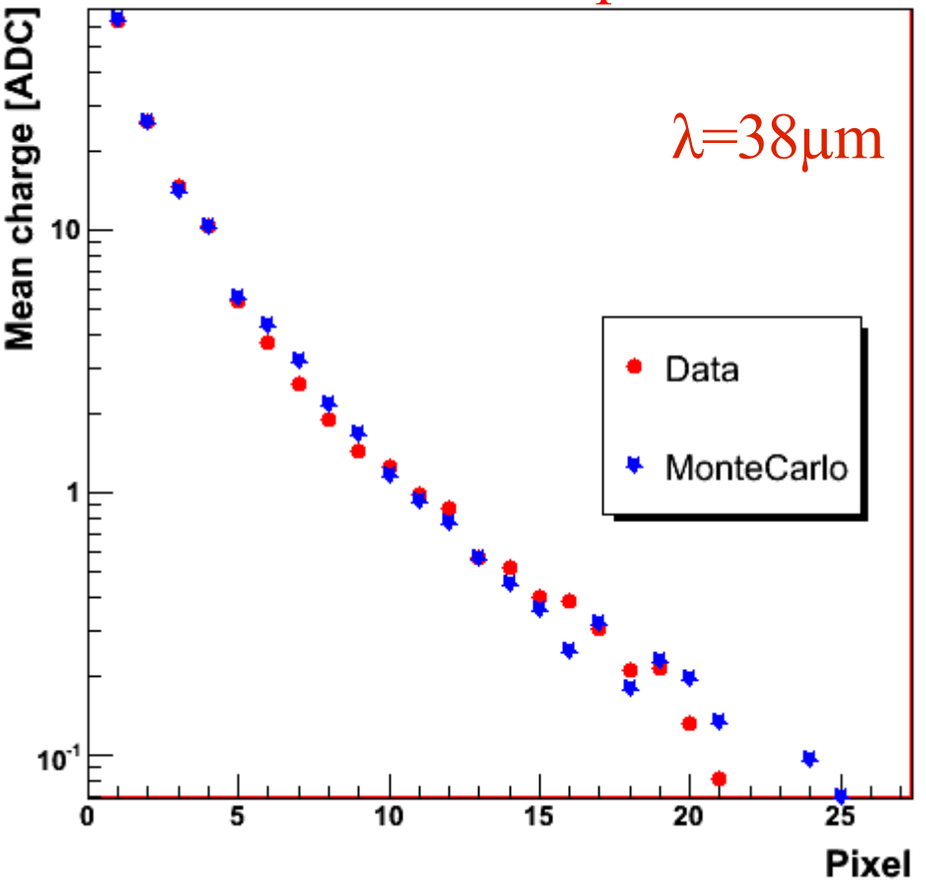
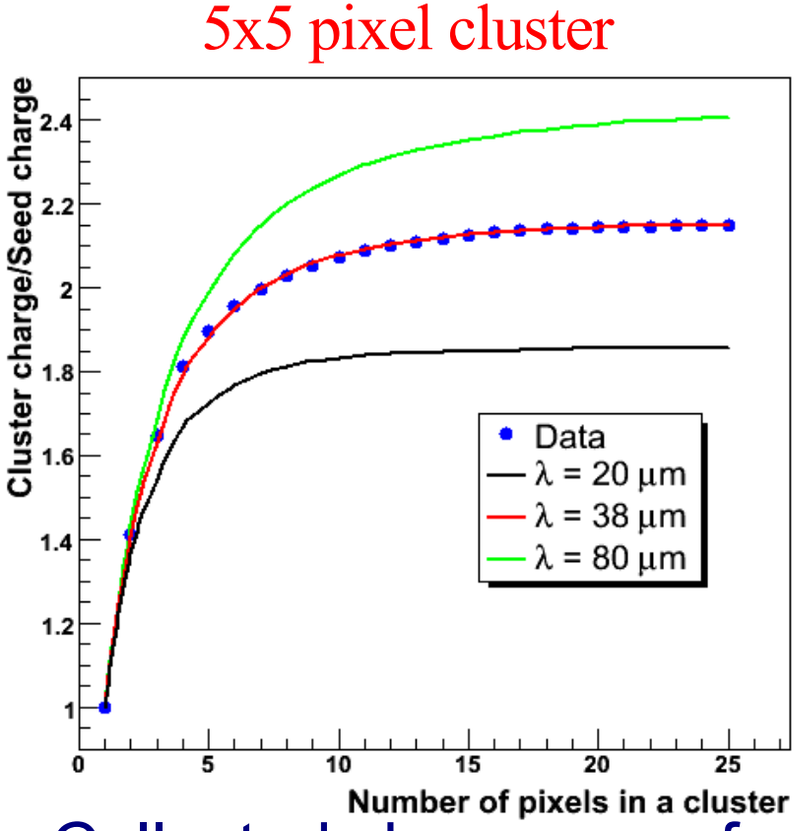
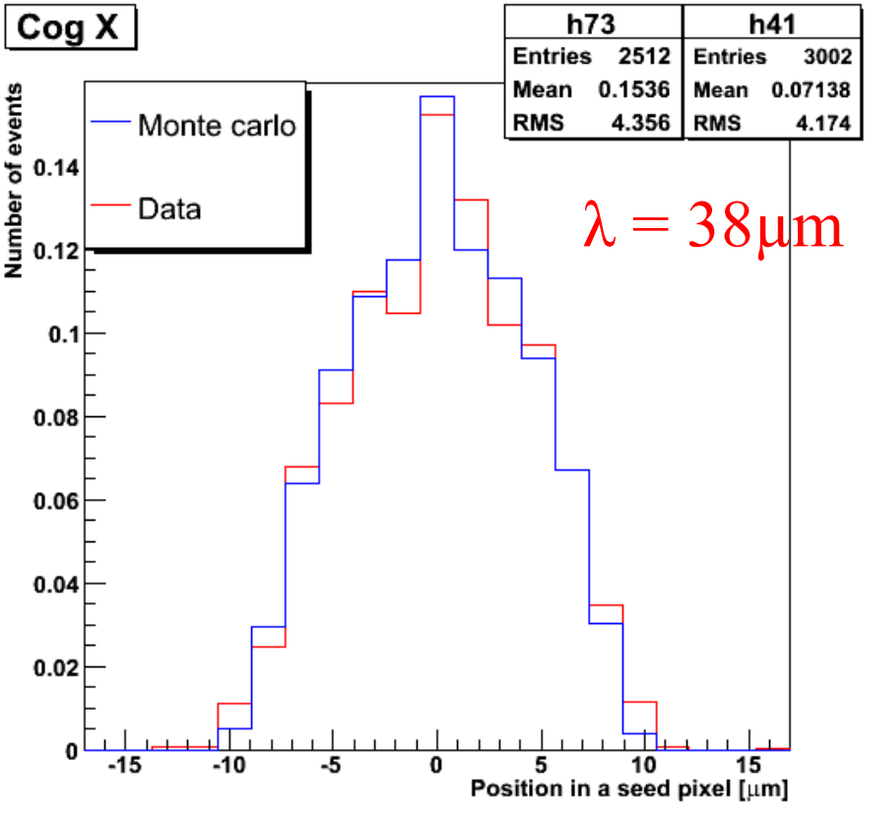


- The best fit for λ=38μm

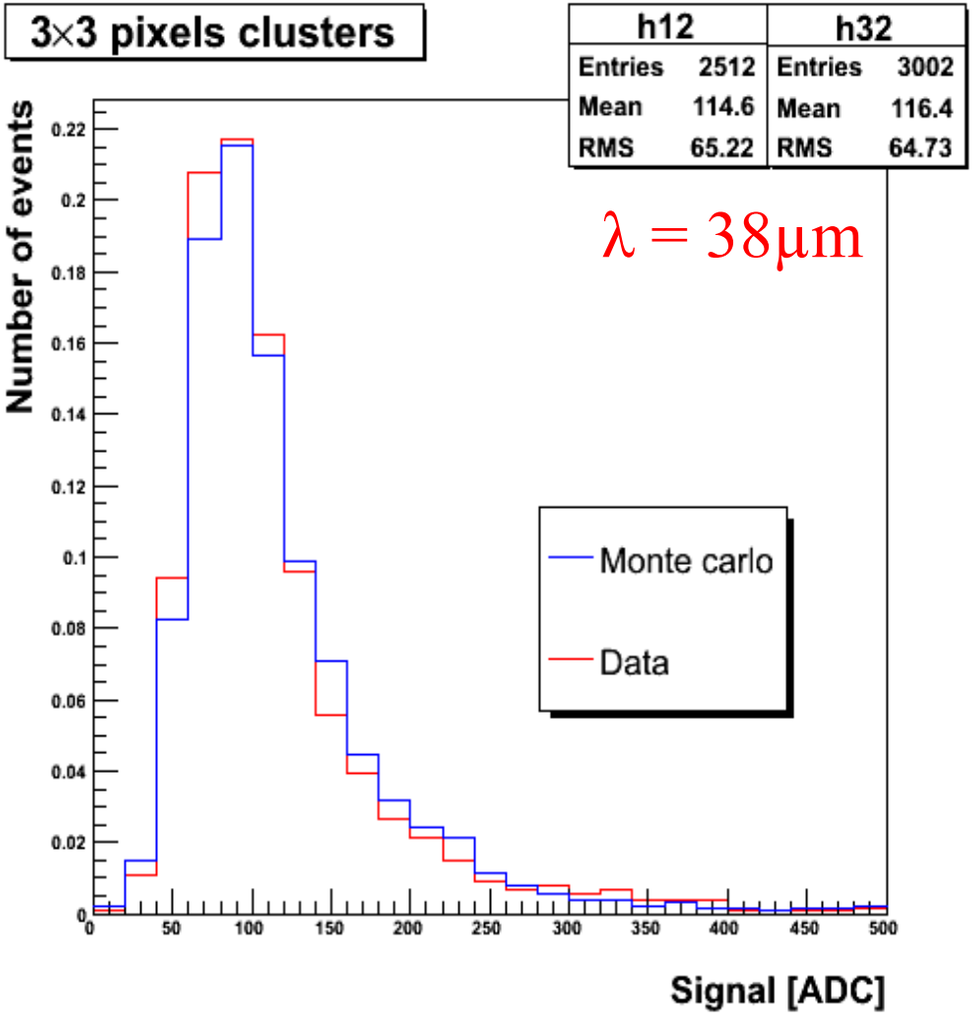
Comparison of Geant4 clusters with data clusters

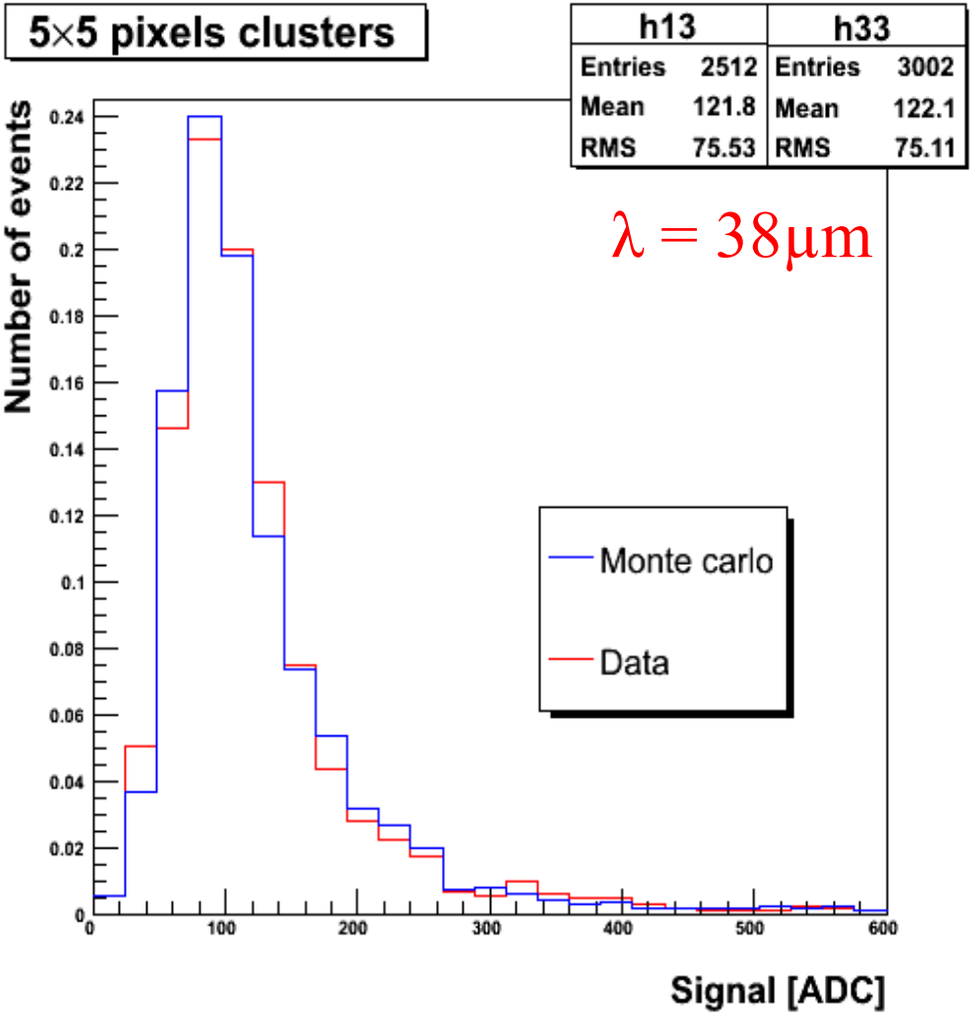




- Collected charge as a function of the cluster size (normalised to one pixel cluster – seed pixel) – good agreement with data for λ = 38μm
- Position of the particle (Cog algorithm) in respect to the centre of a seed pixel (λ = 38μm)

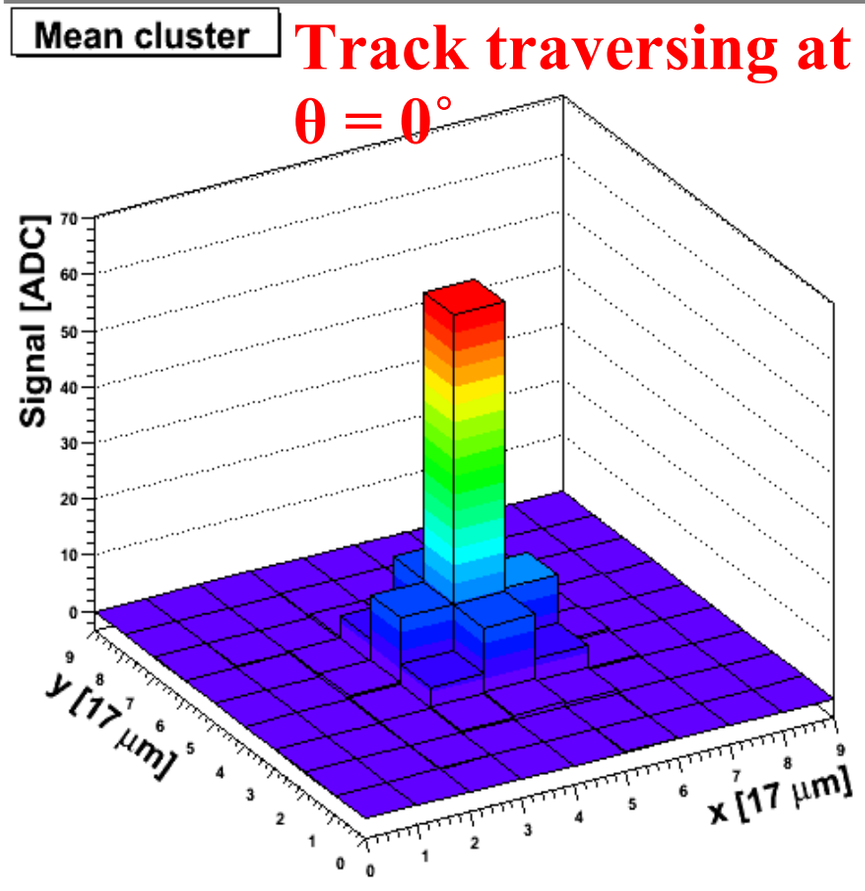
Comparison of Geant4 clusters with data clusters

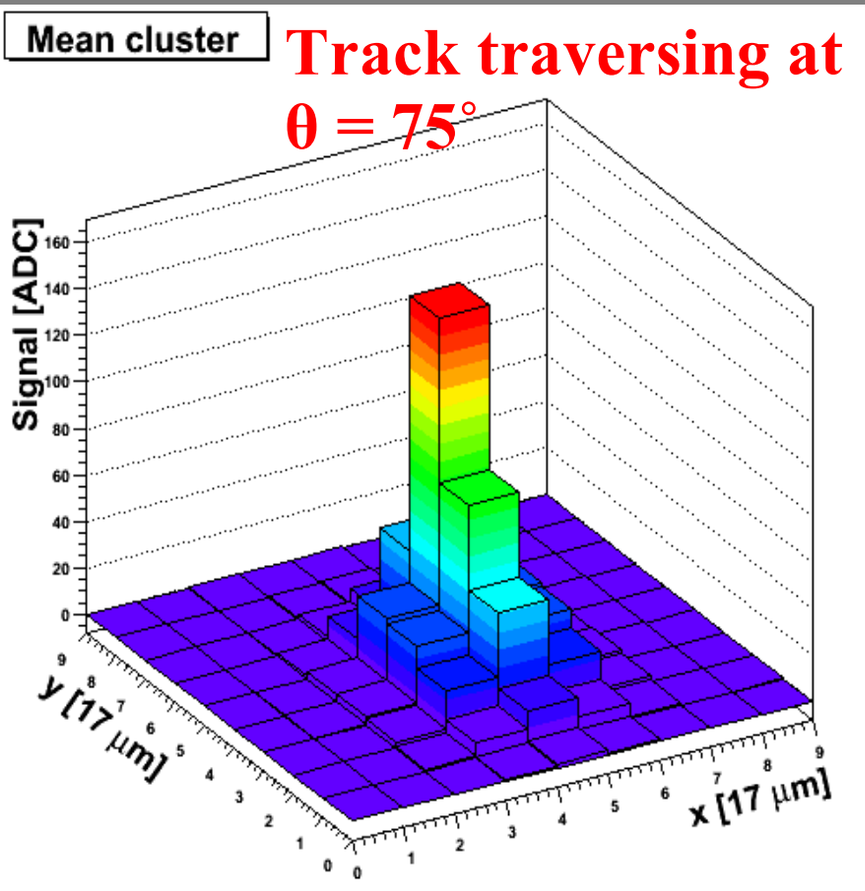




- Charge collected in symmetrical clusters formed around a seed pixel (3x3 and 5x5 pixel clusters)

Cluster shape





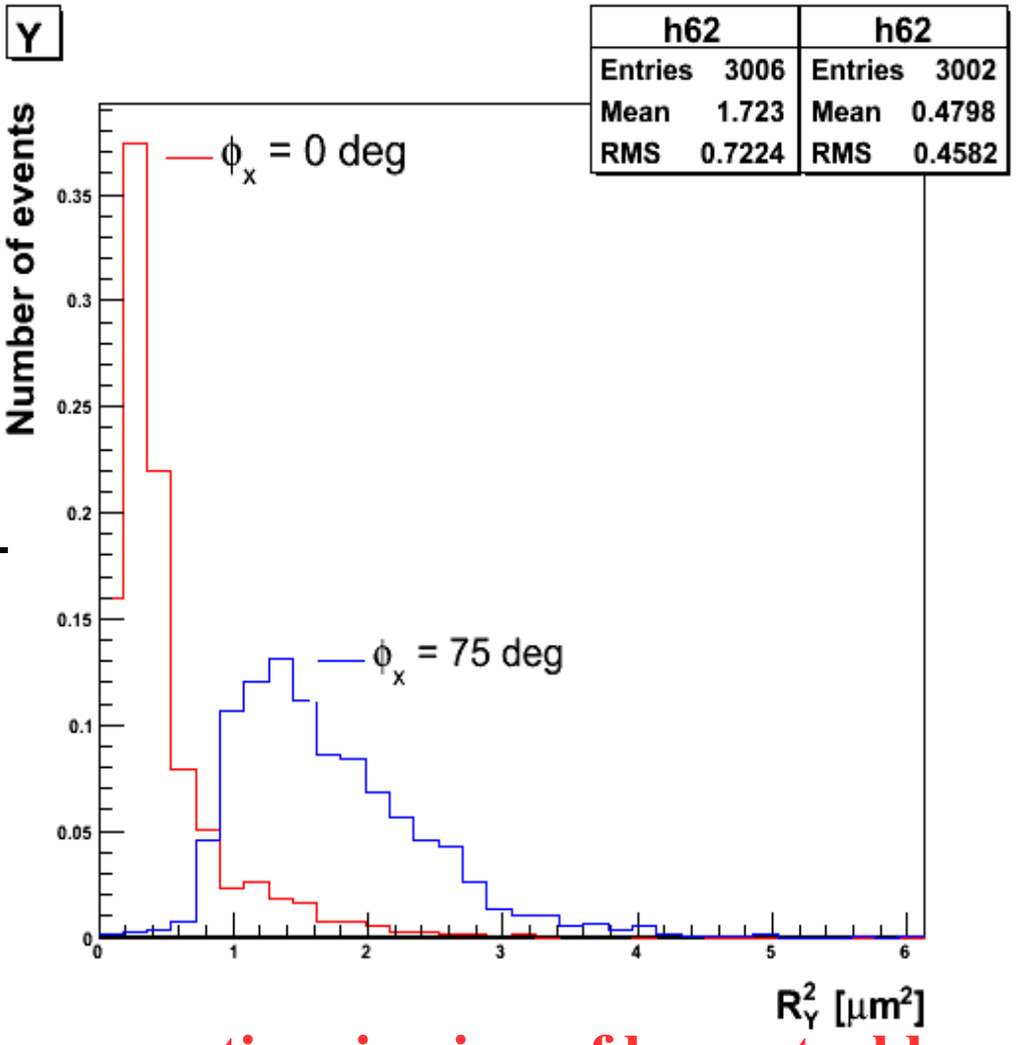
- MC predicts that cluster shape depends on θ - asymmetry
- Is it possible to distinguish clusters originating from particles passing detector at different angles θ ??

Background rejection based on cluster shape?

- In order to distinguish clusters from particles incident at different angles one can exploit cluster asymmetry
  - Define R_Y^2:

$$R_Y^2 = \sum_i \left(Y_{seed} - Y_i\right)^2 \frac{Charge_i}{Charge_{cluster}}$$

  - Distributions of R_Y^2 are distinctly different for $\theta = 0°$ and $\theta = 75°$



This preliminary result gives promising perspectives in view of beamstrahlung rejection (see talk of Paweł Łużniak)

Summary and prospects

- Proposed parametrisation of MAPS response describes test data for particles passing detector at $\theta = 0^{\circ}$
  - Needed measurements with rotated array in order to check how our parametrisation works for $\theta \neq 0^{\circ}$
- The model presented here can be used to implement detailed detector response description in a Geant4 simulation
- Check possibility to reject beamstrahlung background exploiting cluster shape.