Digitalisation for the Geant4 simulation of the MAPS pixel detectors

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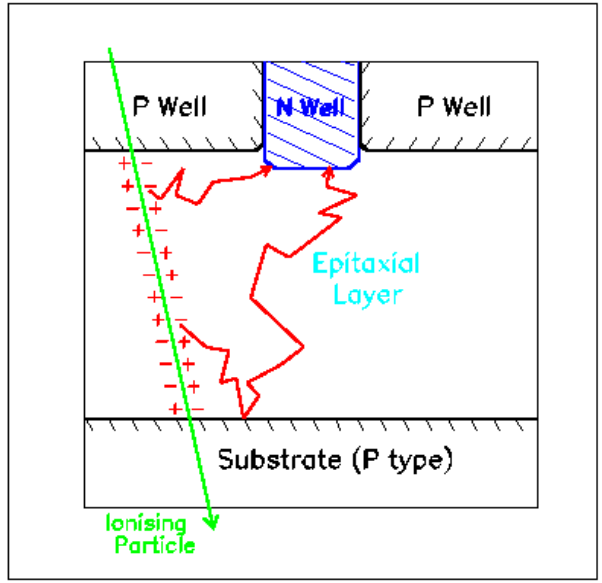
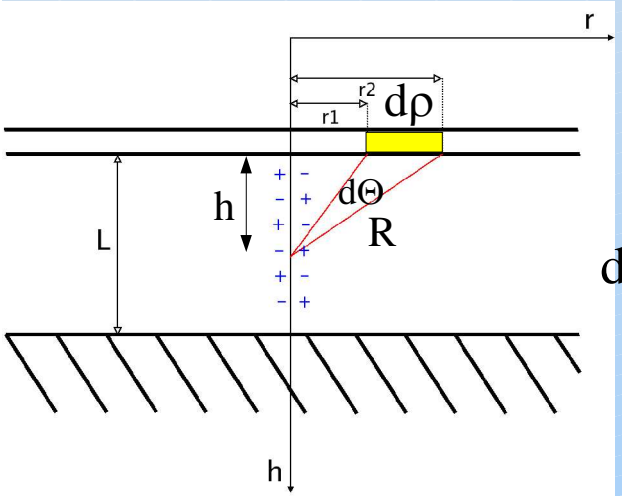
Outline

- MAPS pixel detectors – operation principles
- Charge diffusion in sensor – idea of the simple model for describing charge sharing between adjacent pixels
- Comparison of the Geant4 simulation (using described model) with MIMOSA5 test data (Nov. 2006 tests at DESY, 6 GeV electrons)
- Future prospects
- Summary

MAPS detectors

- MAPS – Monolithic Active Pixel Sensor Charged particle passing through the detector produces charge in a sensitive epitaxial layer. Generated charge is transported (thermal diffusion) to n-well/p-well diode where it is collected. In MAPS detectors read out electronics is under sensitive what makes fill factor to be 100%.





$$d\rho(\theta, \varphi, h) = \frac{1}{(4\pi)} d(-\cos\theta) \exp\left(\frac{-R}{\lambda}\right) d\varphi \frac{dh}{L}$$

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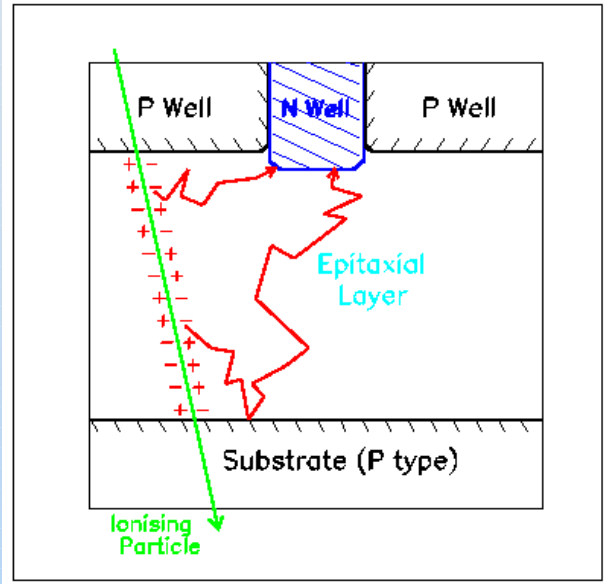

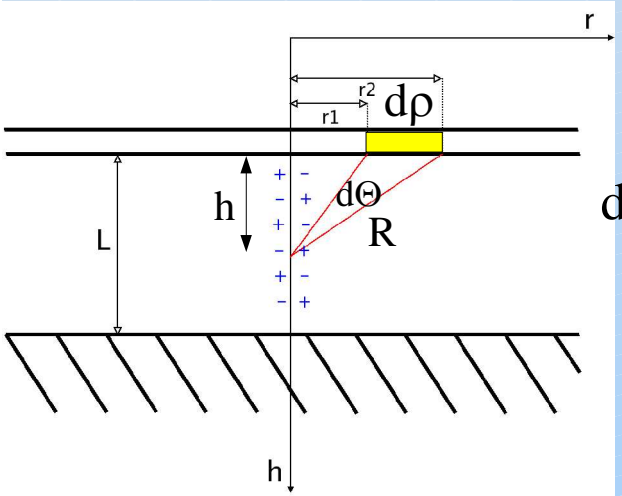

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Charge trapping term λ has to be find

L = 14 μm – epitaxial layer

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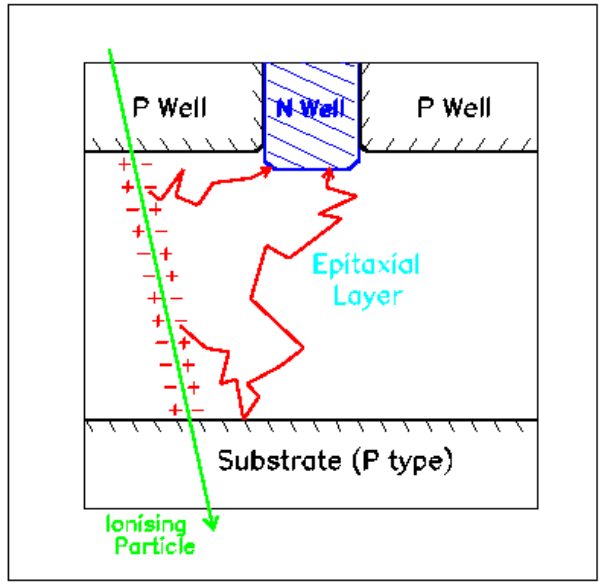
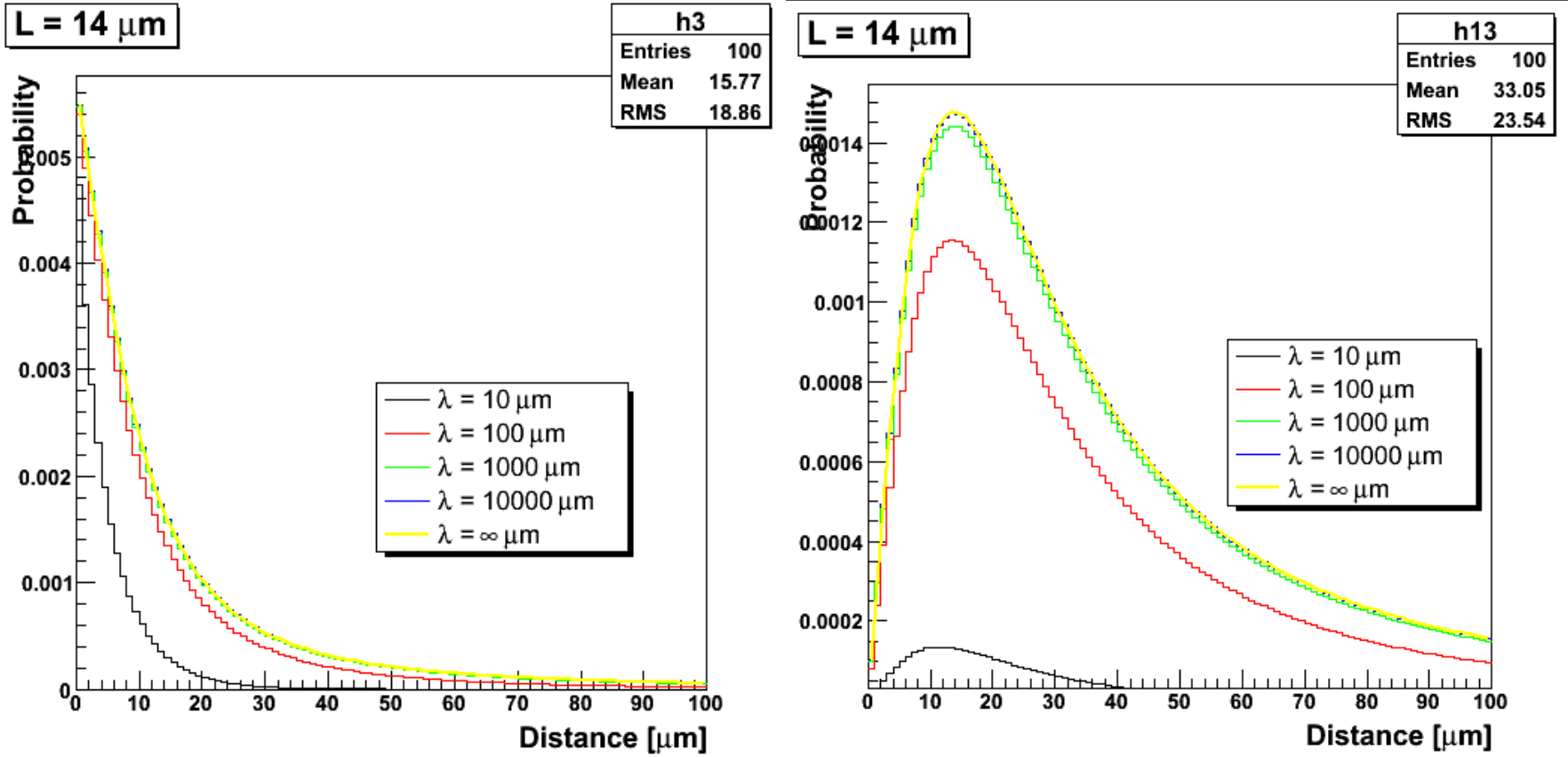


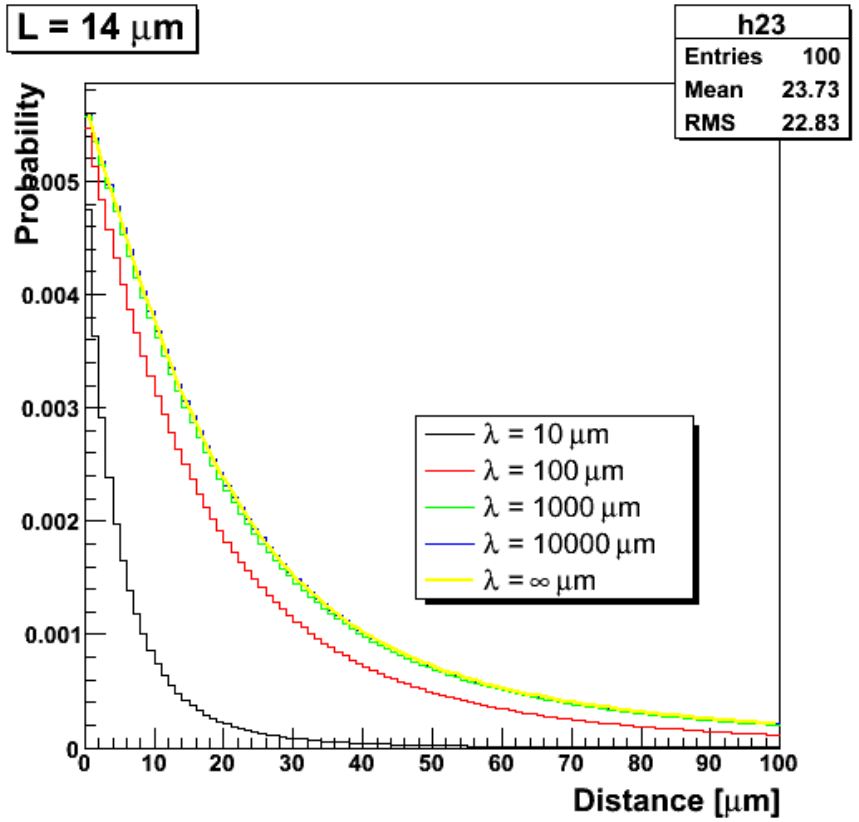
$$d\rho(r,\varphi,h) = \frac{1}{(4\pi L)} \frac{hr}{(h^2+r^2)^{3/2}} \exp\left(\frac{-\sqrt{h^2+r^2}}{\lambda}\right) dr\, d\varphi\, dh$$

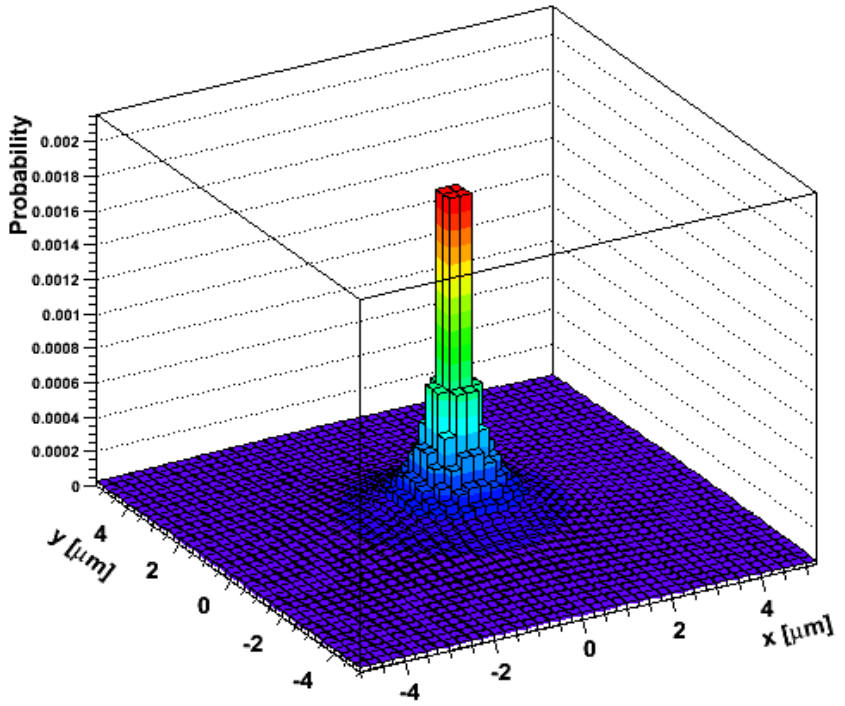
Probability distribution



- Left plot - charge directly reaching the collecting diodes
- Right plot - charge reaching collecting diodes after reflection off the potential barier note scale difference !!!

Probability distribution

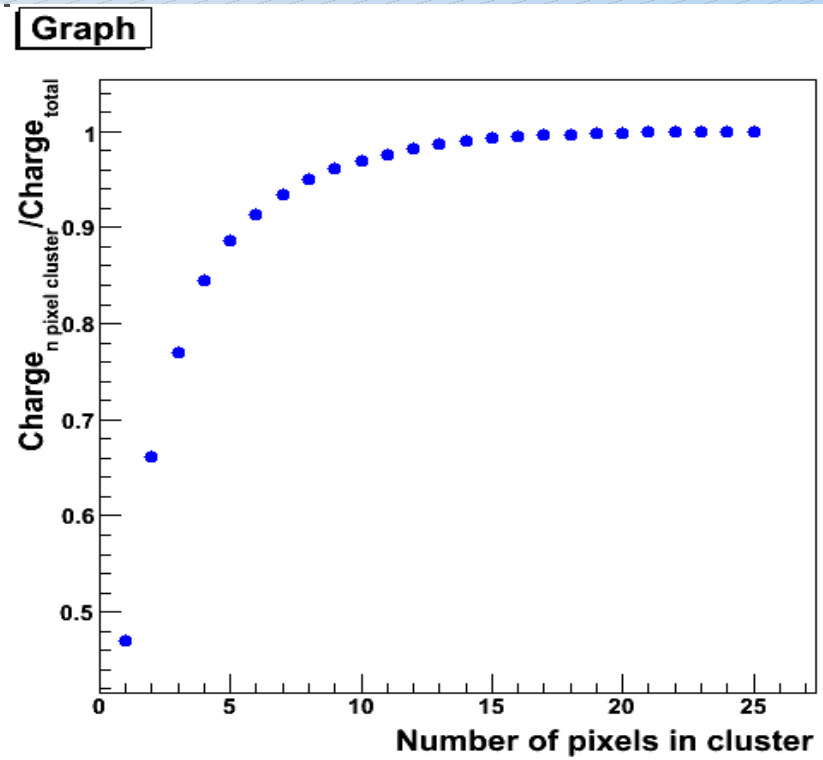


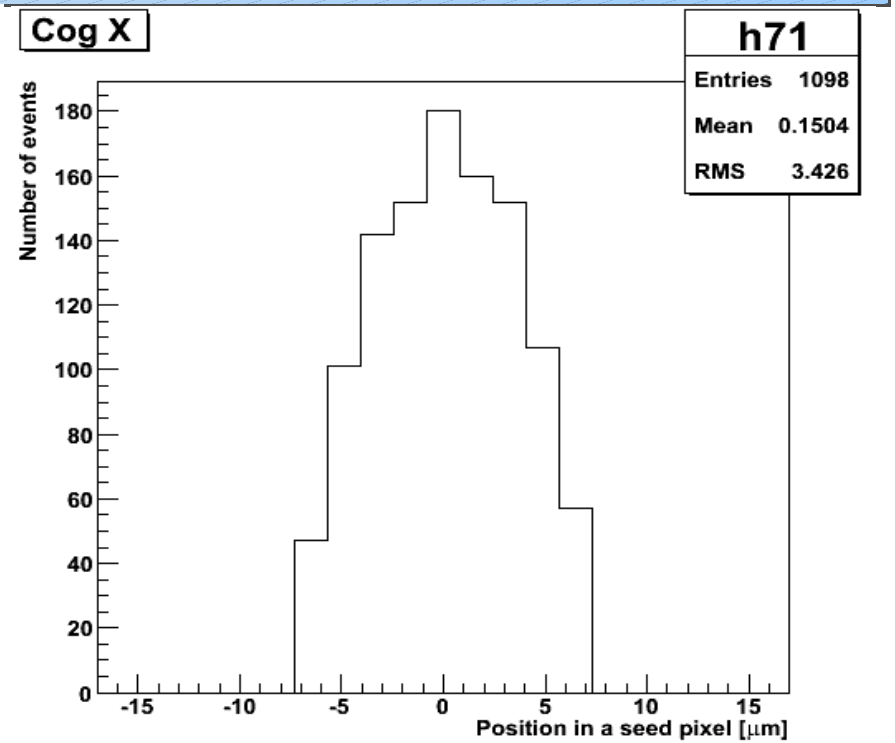


- In order to distribute charge between neighboring pixels, two-dimensional distribution of the probability was calculated

  In the MIMOSA5 detector pixel size is 17μm x 17μm

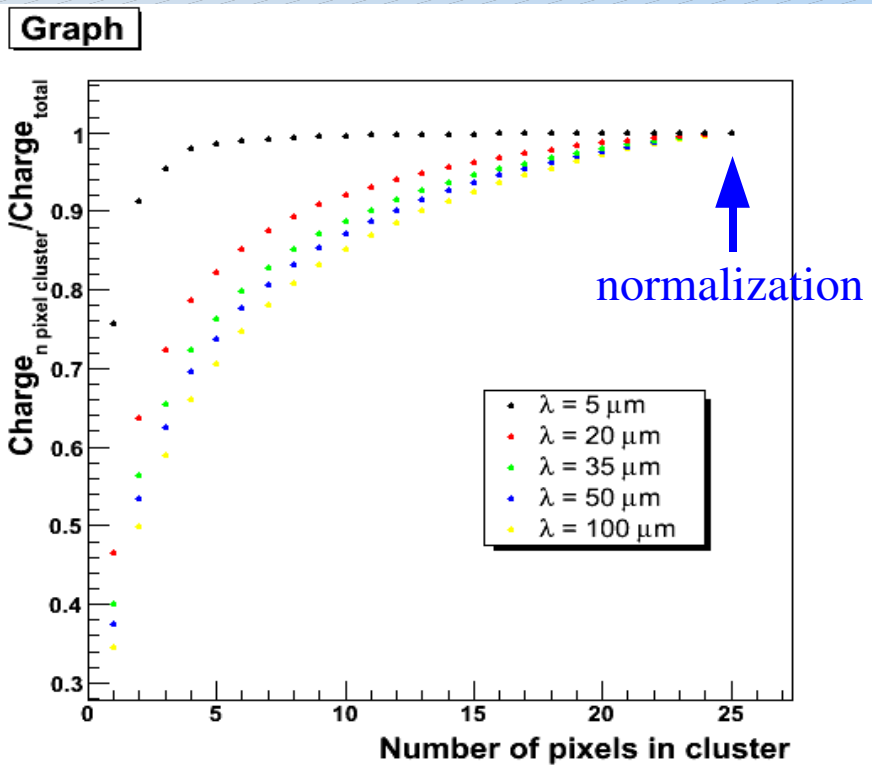
Looking for λ parameter

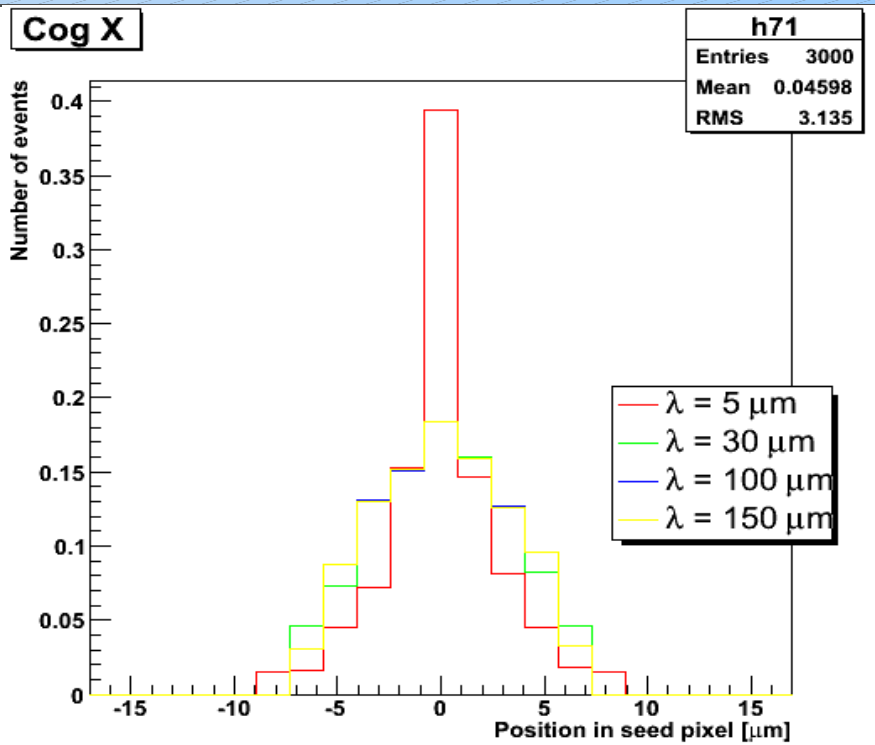




- In order to find λ, comparison of experimental data with Geant4 data was done. Two λ - sensitive distributions were considered:
  - Cluster charge dependence on a cluster size
  - Position of a hit CoG relative to the seed pixel

Dependance on the λ parameter – Geant4 events





- For small λ (high trapping probability) charge generated by ionizating particles collected in a small cluster of less than 5 pixels.
  Size of cluster grows with increasing λ (decreasing trapping).
- Distribution of CoG position peaked for small λ, broadens with increasing λ.

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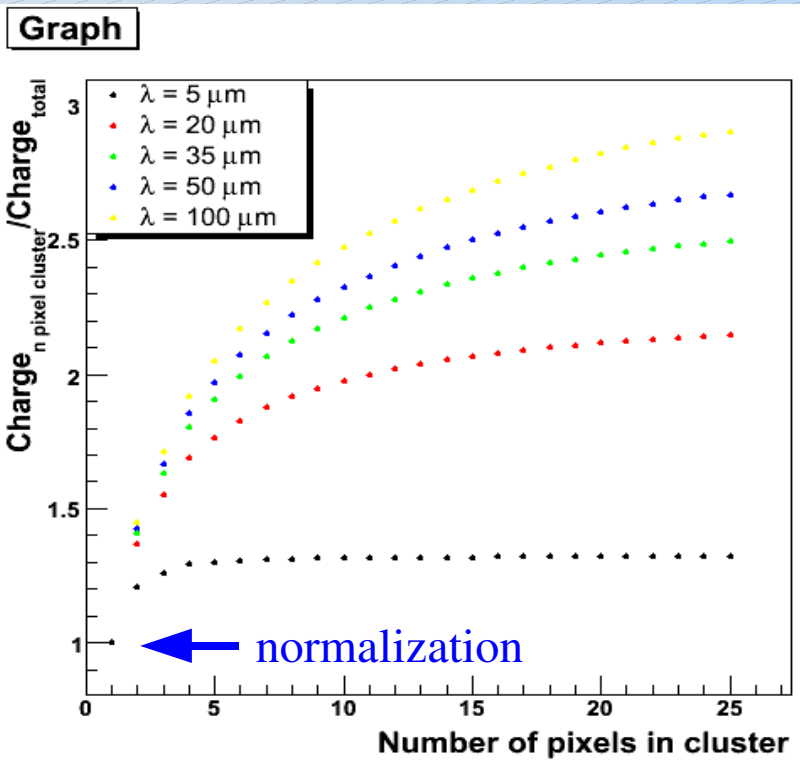

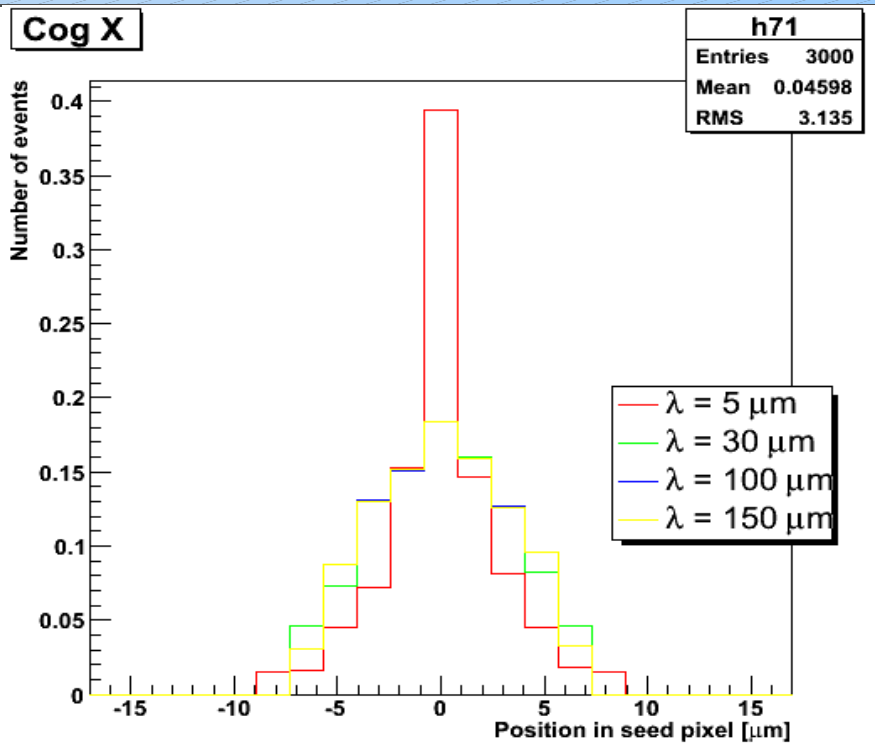

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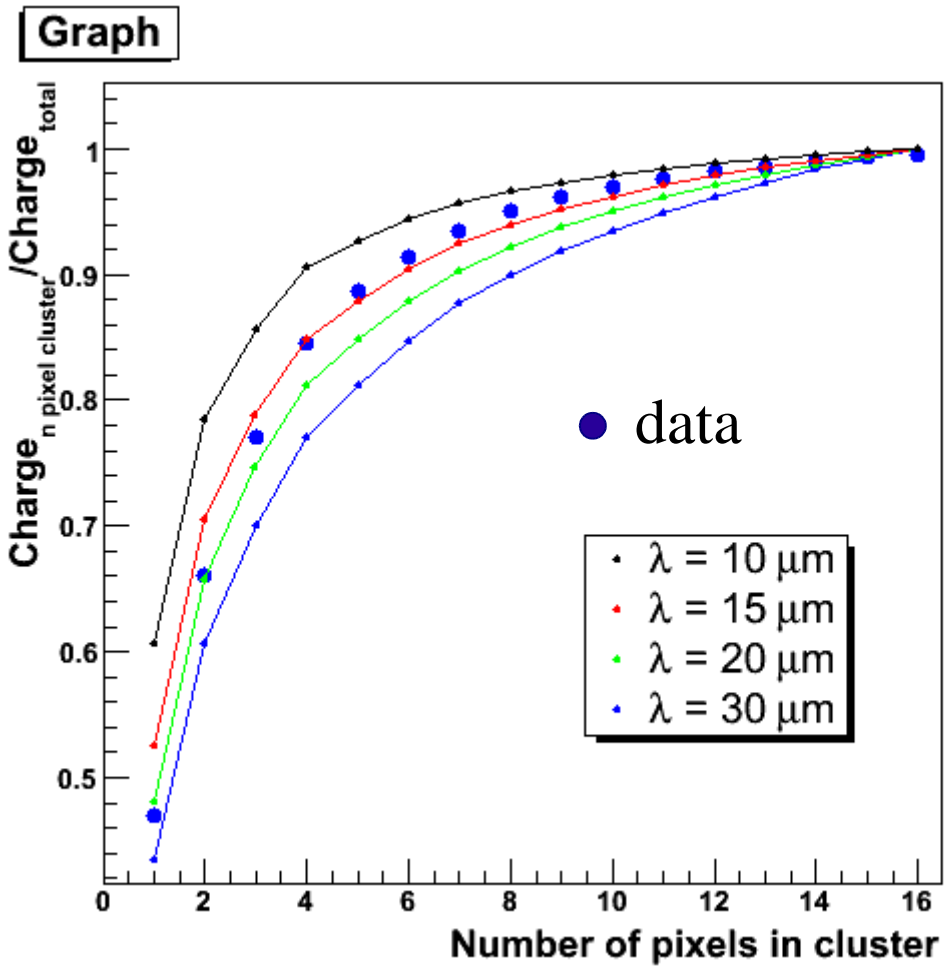
Geant4 events versus test beam data

- Comparison of the experimental data with Geant4 simulation shows that presented approach to charge distribution gives only qualitative description.
- In order to improve parametrisation method, effects related to readout electronics (noise, digitization) should be included.



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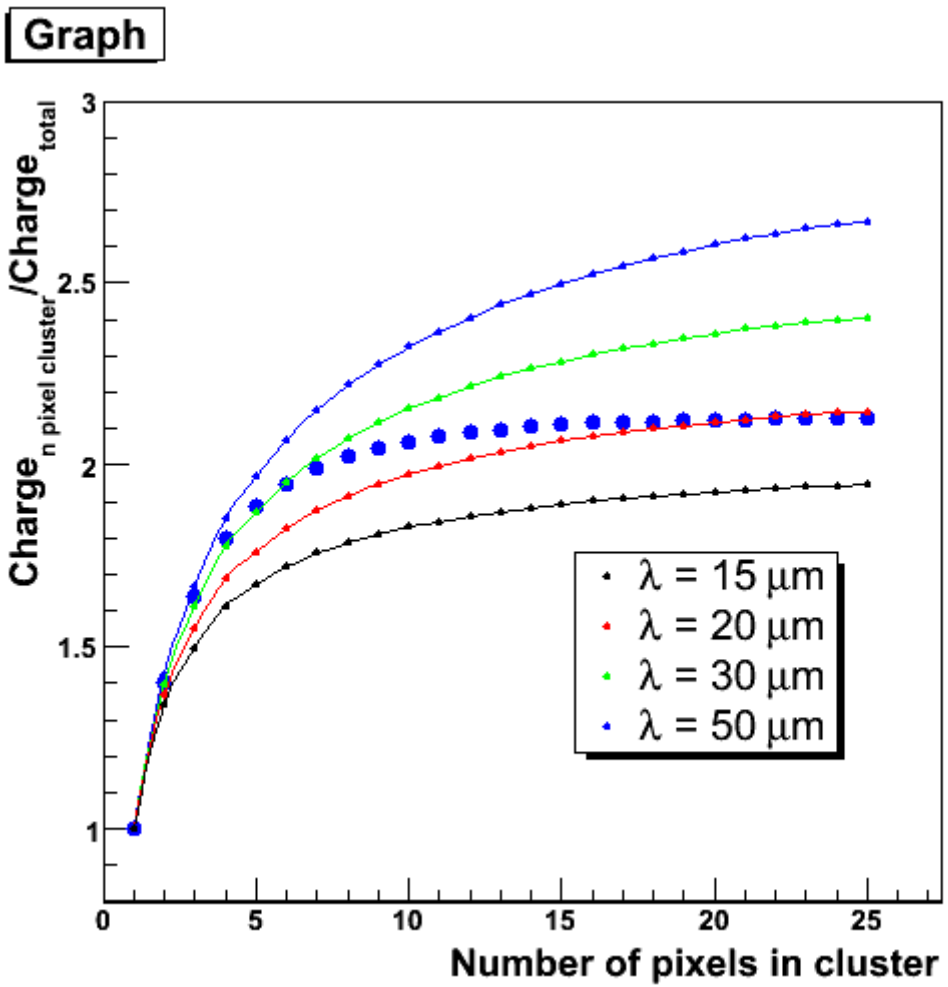
- From this plot one can see that the "core" of cluster is best described for $\lambda \sim 30\mu m$



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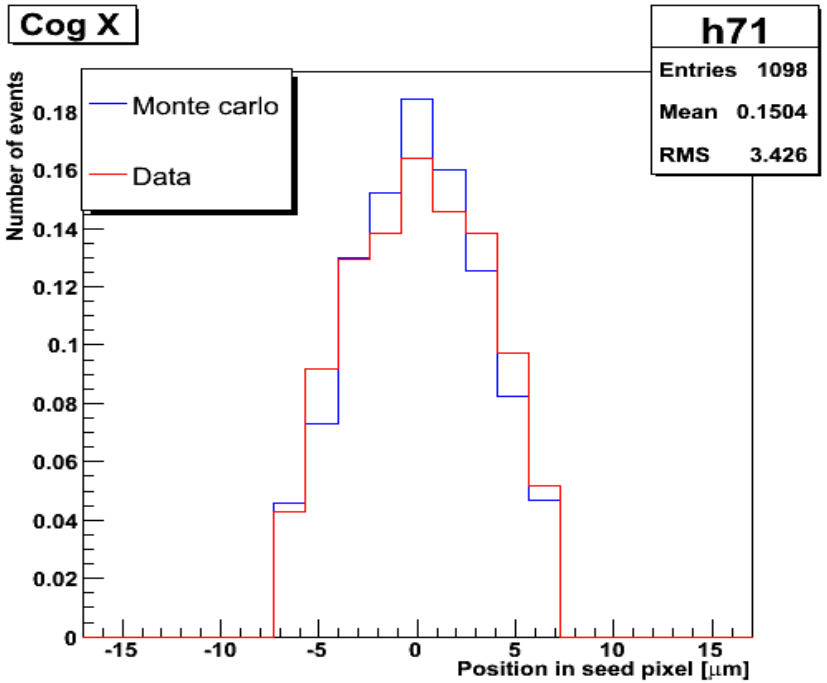
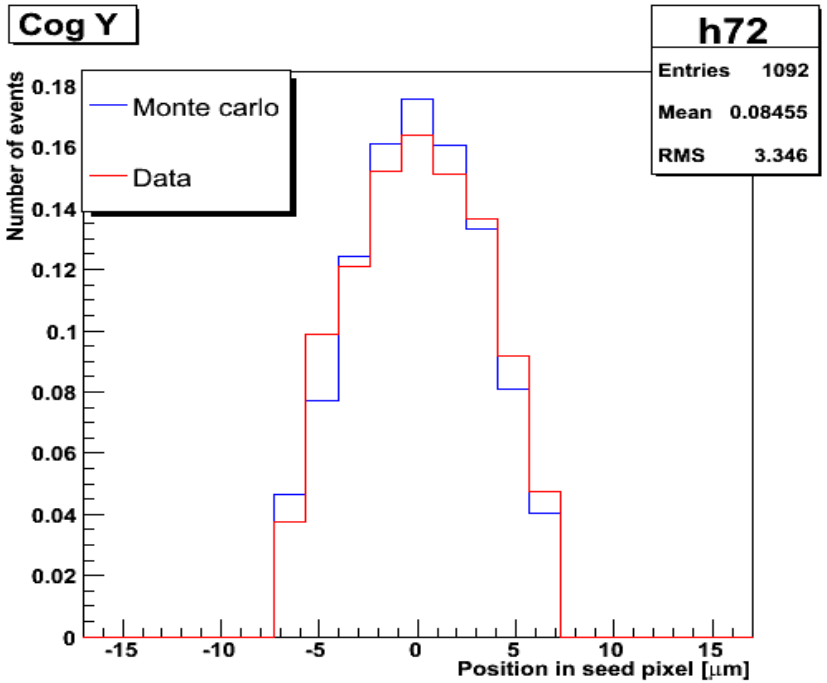
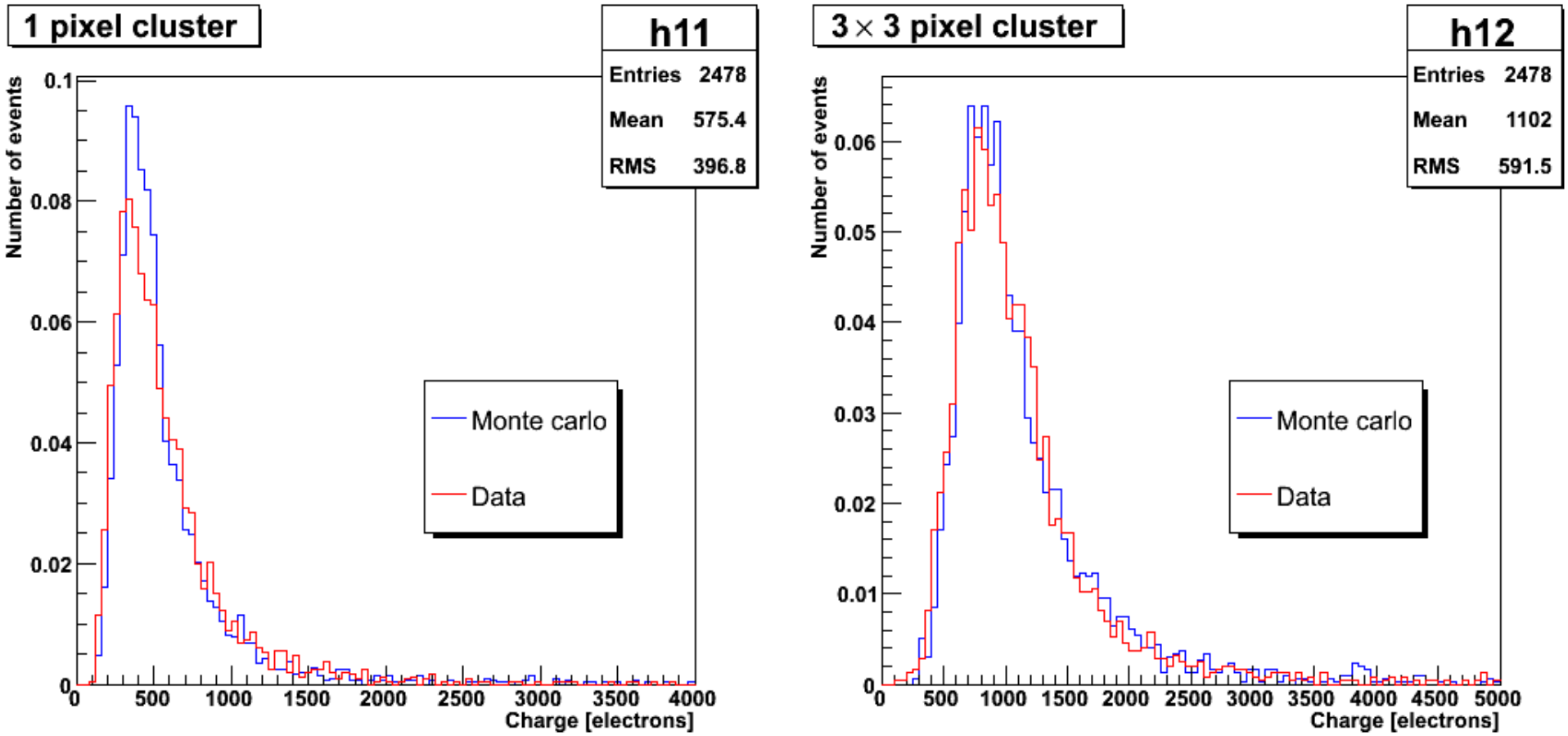




- CoG position w.r.t. Seed pixel - results obtained for $\lambda = 30\mu m$
- Data description by simple model is not perfect.
  However the approach can be used as an approximation of the detector response.

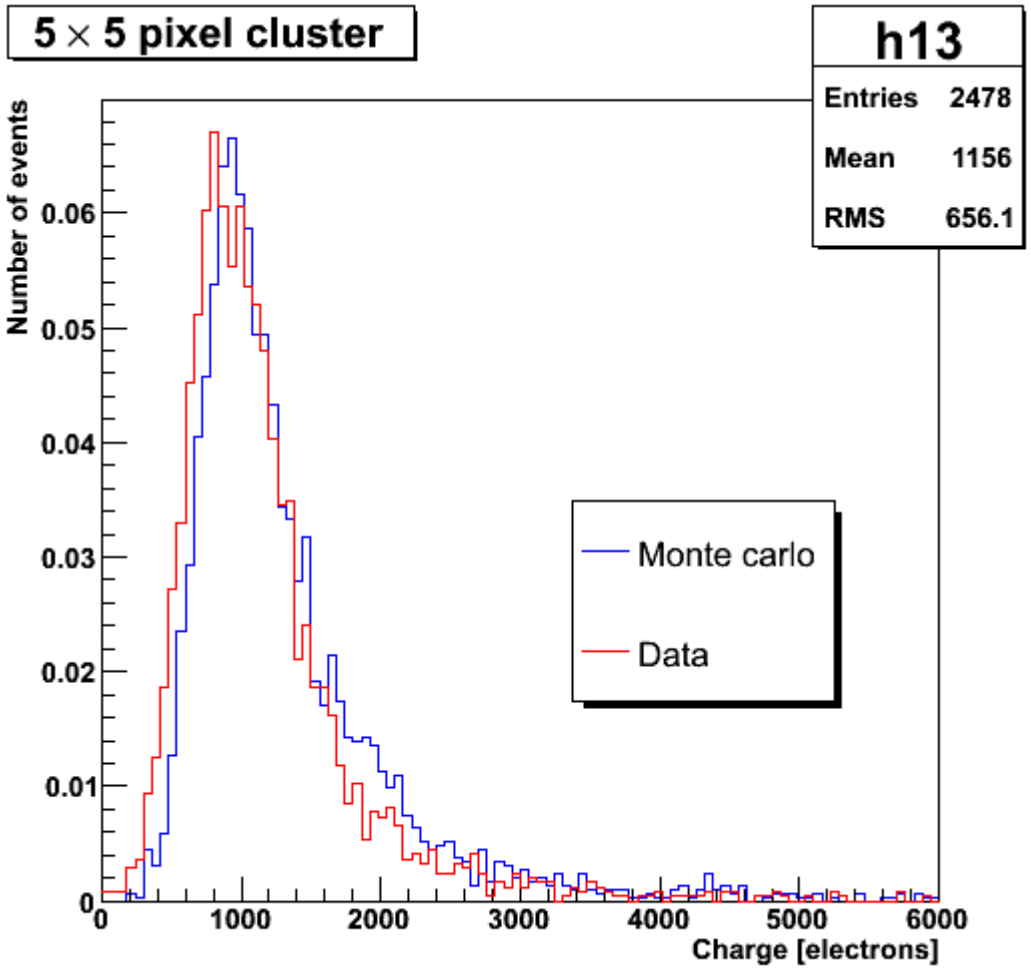
Geant4 events versus test beam data



After applying charge normalization correction !

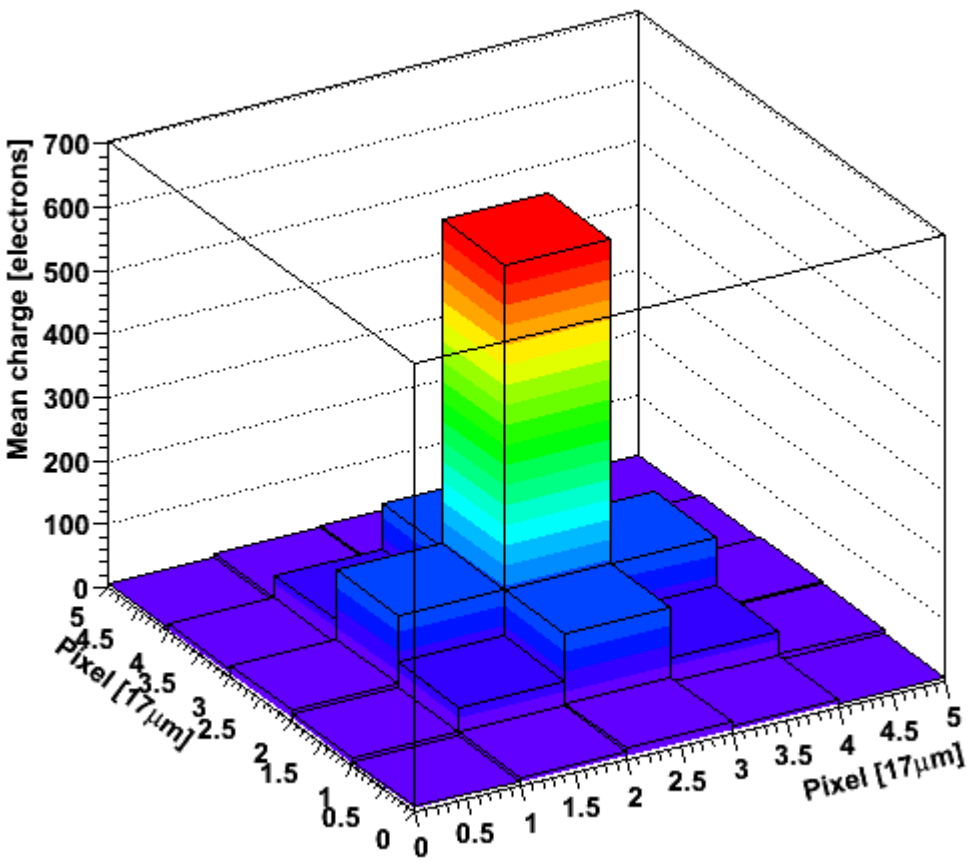
Geant4 events versus test beam data

- Using proposed model it is possible to reconstruct charge distributions got from experiment.
- Normalization obtained from 1x1 pixel and 3x3 pixel clusters does not describe 5x5 pixel clusters - there is a systematic shift between Monte Carlo and data.
- We hope this can be reduced by taking in to account effects related to readout electronics.

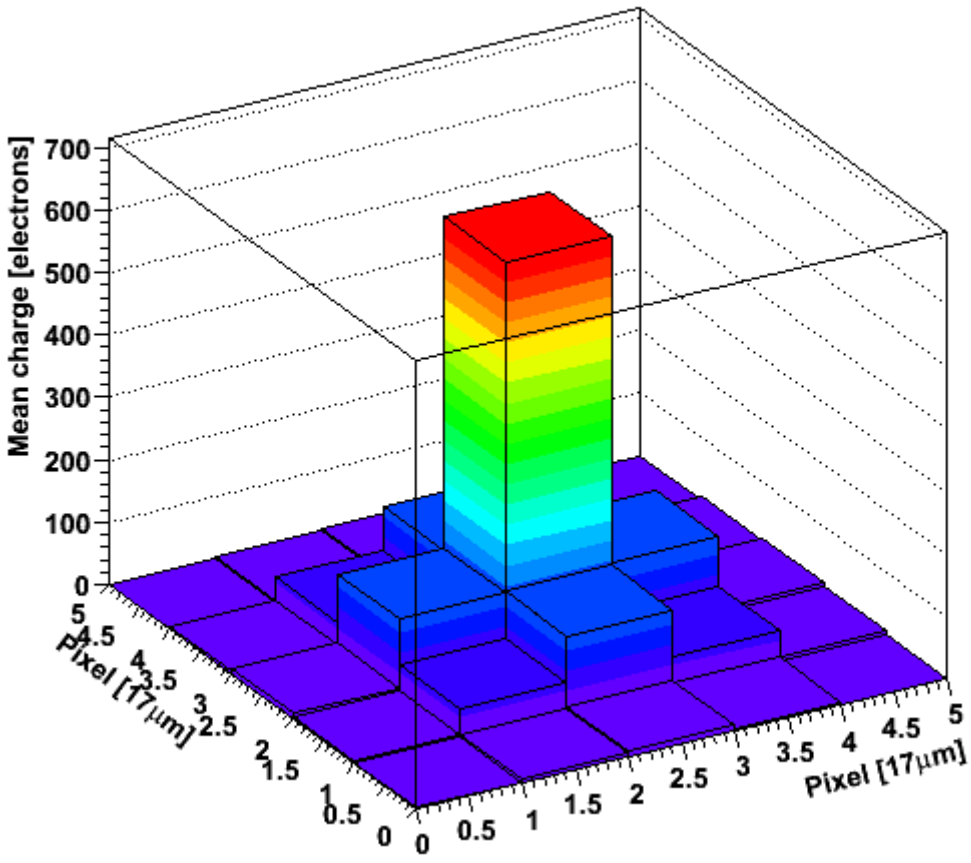


Parametrisation of the detector respons – mean cluster

Monte Carlo



Data



Future prospects

- In order to make the model and simulation results more realistic, effects related to the readout electronics have to be added (noise, digitization, ?)
- It was assumed that electron beam was perpendicular to the detector surface. In general particles can pass the detector at sundry angels. This should be included in the algorithm.
- We would like to perform additional beam measurements, with twisted MIMOSA5 chip to verify our cluster description.
- If the improved model is in good agreement with the data we would consider writing a dedicated code for telescope simulation.
- Impact of the magnetic field on the cluster shape should be checked. If this effect is significant it should be included in the model as well.

Summary

- Presented simple “digitalisation” method can be used to obtain an (approximate) description of the detector response.
- The model still needs a lot of improvements:
  - Effects related to the readout electronics will have to be included
  - Extend the description to particles passing the detector at angels different than 90°
  - Additional measurements (eg. with twisted detector) would be very helpful for cluster shape studies.