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Full Monte Carlo of a TPC equipped with Micromegas

- *Motivation*
- *Simulation content*
- *Comparison with data*

Introduction

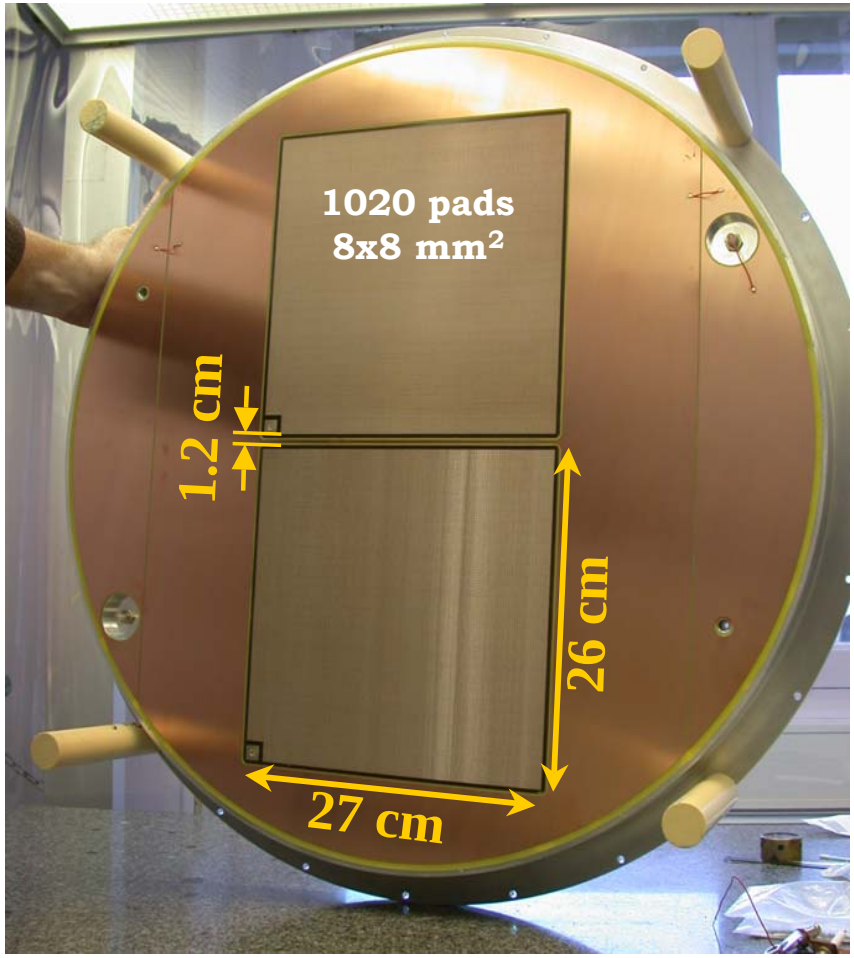
- T2K near detector will have 3 TPCs used for momentum measurement and e/μ separation.
- A TPC equipped with Micromegas detector was tested at CERN in Nov. 2005

⟶ Monte Carlo simulation of these tests

Cosmic Setup

~1.5m drift length

Ex-HARP TPC field cage



Micromegas End-plate

~ 1300 cm² instrumented

Simulation

Simulation Content

- Primary generation
- Tracking
- Electrons creation and transport
- Amplification in Micromegas
- Electronics (ALTRO, Alice TPC Readout)

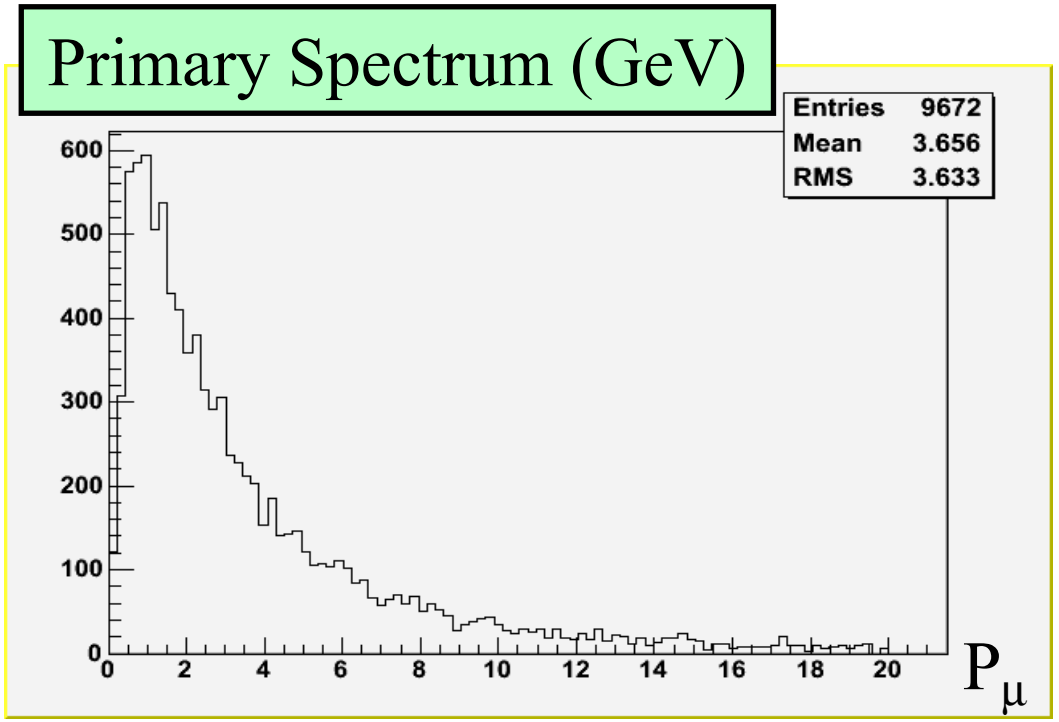
Primary Generator

Cosmic spectrum

or

^{55}Fe source (5.9 keV γ)

This generator was not tuned to reproduce *perfectly* the setup.



It roughly reproduces the characteristics of the trigger planes (above and below the TPC field cage) and the μ angular distribution and spectrum.

Tracking

- GEANT 4 does the tracking and simulates the energy loss in the gas.
- Physics processes:
  - low energy EM processes
  - delta-rays production

Ionization

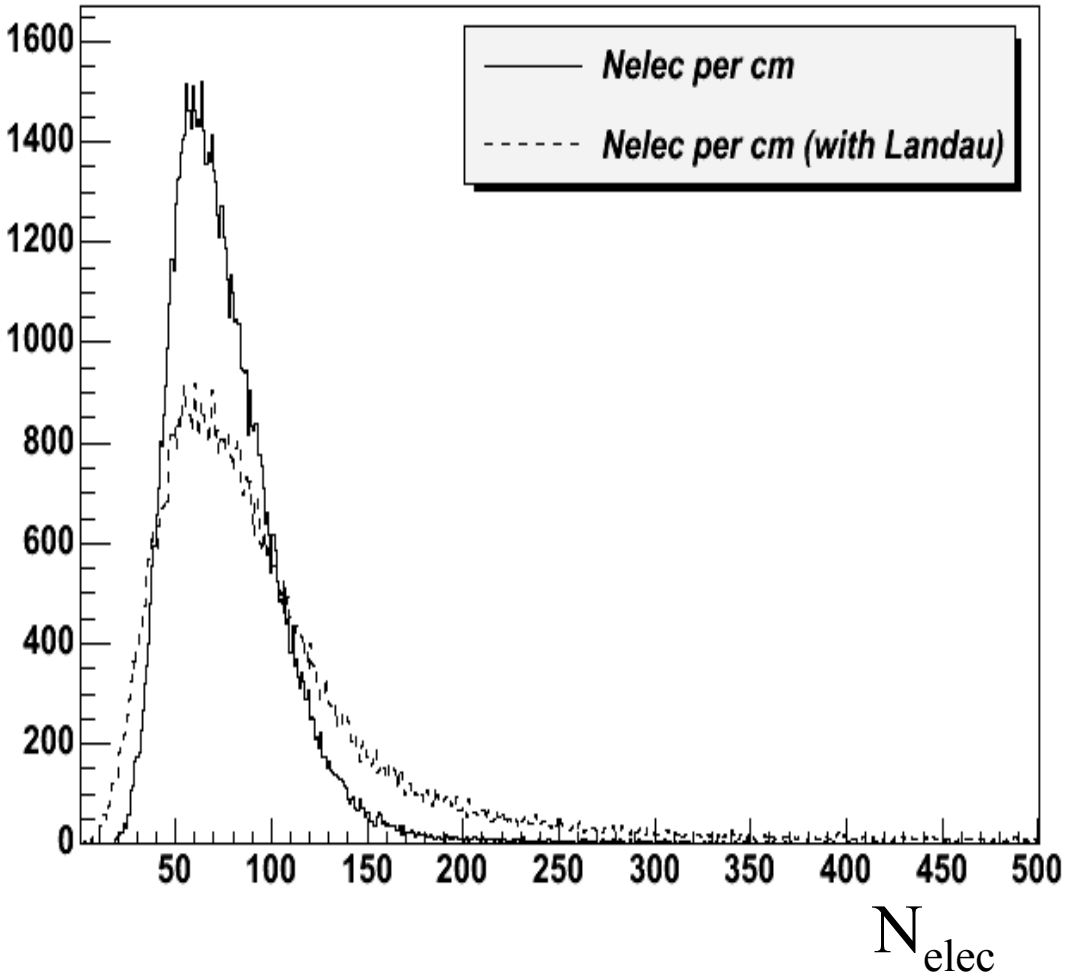
- Number of electrons:

$$N = E_{loss} / W_I$$

with $W_I = 26$ eV (Sauli)

- Step $\leq$ 1mm

$N_{elec} \sim 100$ cm^{-1} (mean)
$N_{elec} \sim 60$ cm^{-1} (peak)



Drift And Diffusion

Magboltz calculation

- **Drift speed**

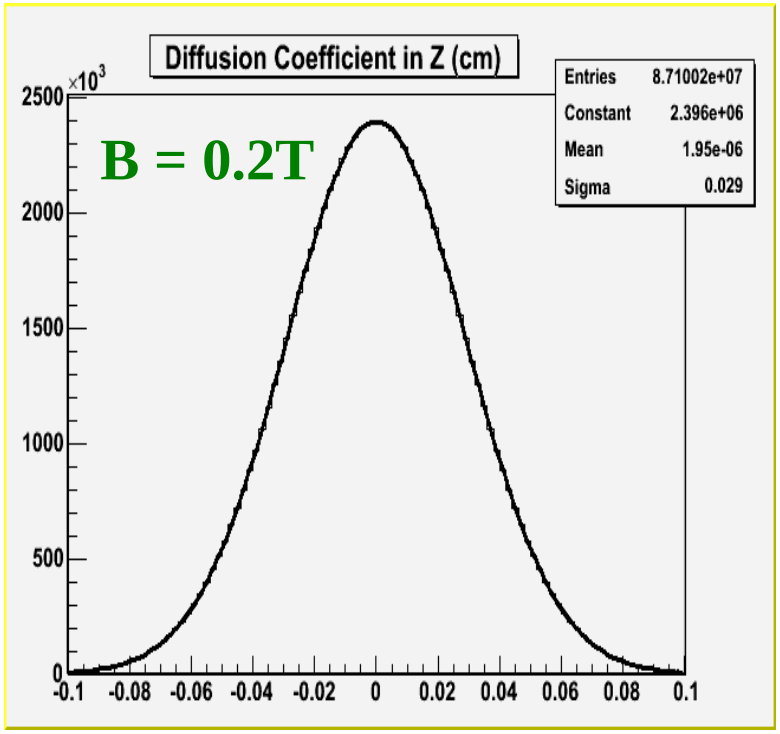
  $V_{drift} = 6.5\ cm.\mu s^{-1}$

- **Diffusion coefficient**

  $\sigma_L = 290\ \mu m.cm^{-1/2}$

  $\sigma_T = 240\ \mu m.cm^{-1/2}$ @ 0.2T

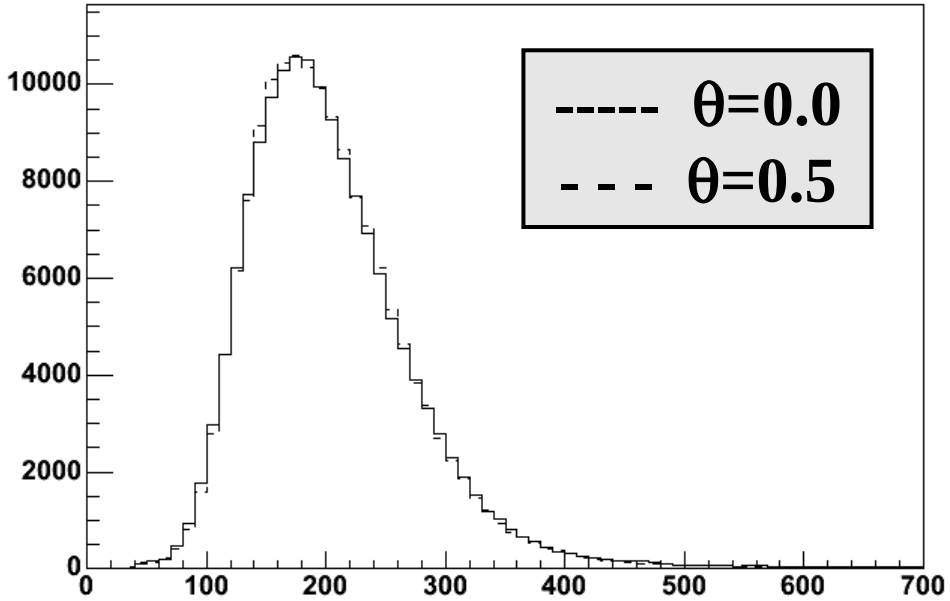
  with Gaussian distributions



Amplification

- Simulate gain distribution with an exponential distribution (Furry).

Polya distribution was also investigated, but it is not needed to reproduce data.



Electronics

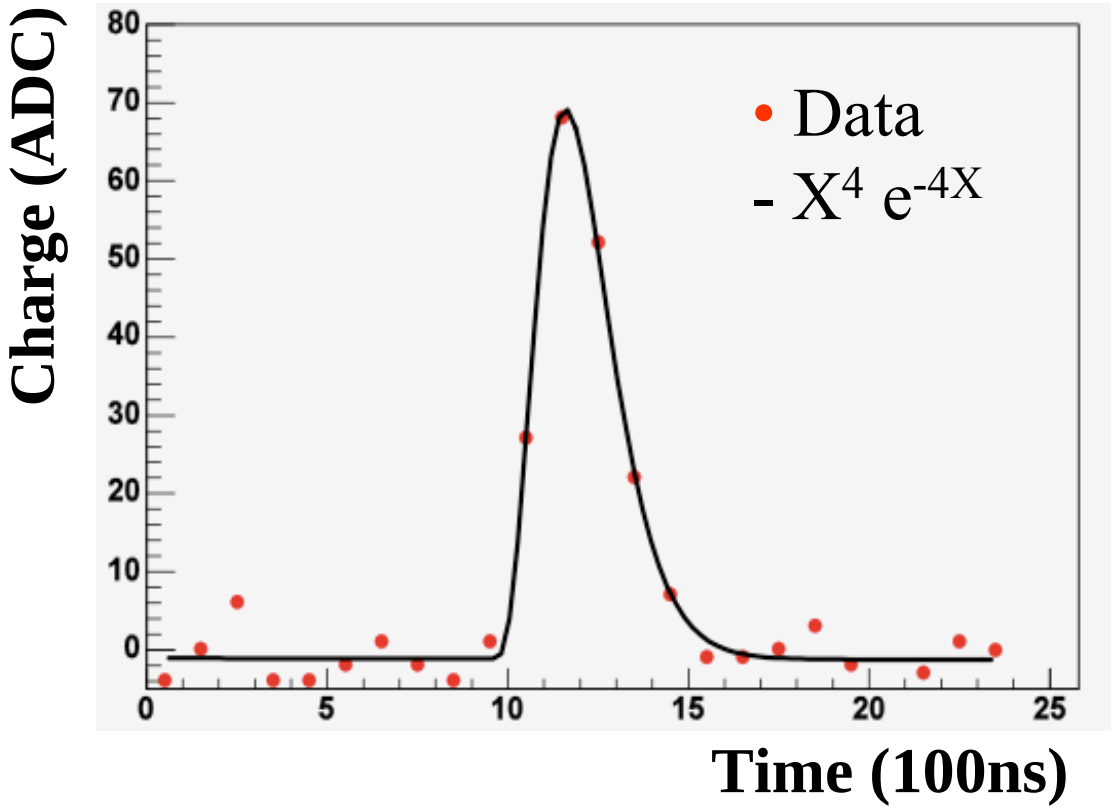
- 4^{th} order semi-gaussian filter

$$(X\ e^{-X})^4$$

with $X = (T - T_0) / \tau$

and $\tau = 190$ ns

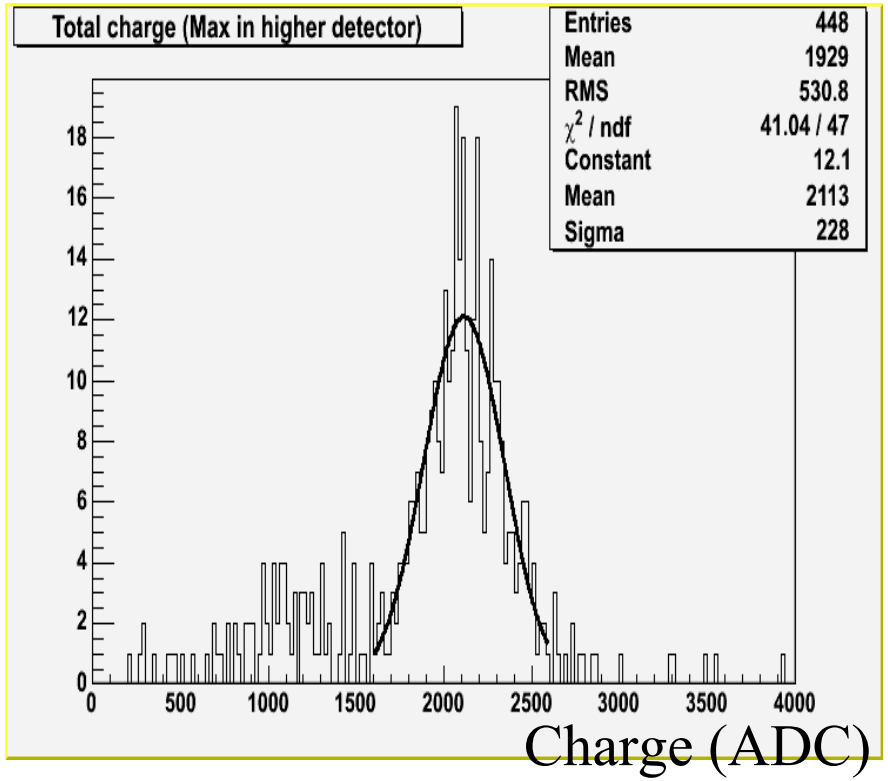
ALTRO electronics
(Alice TPC Readout)



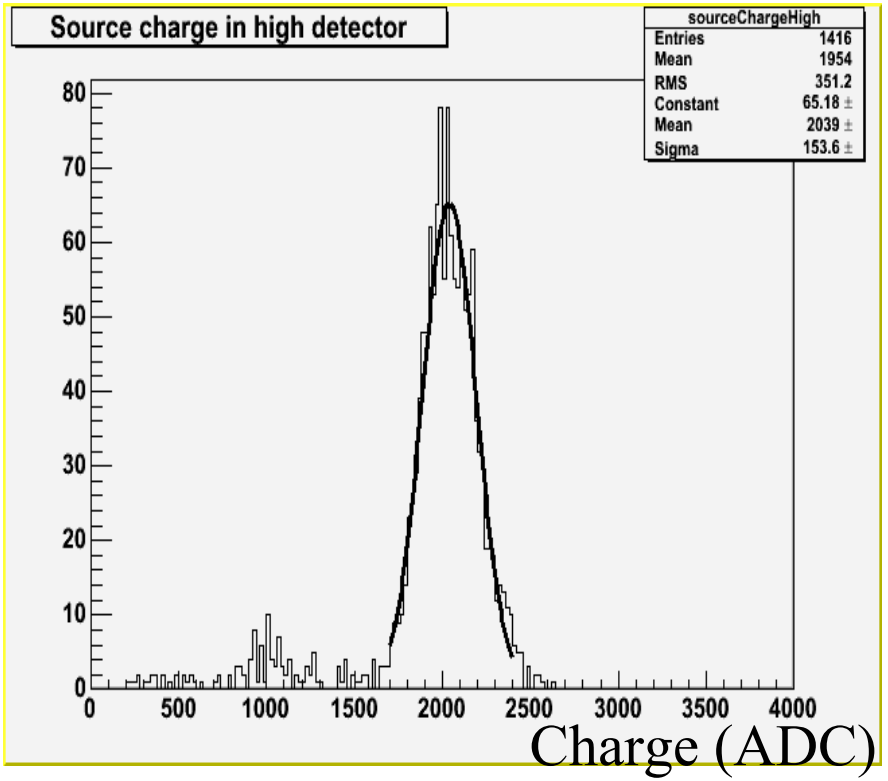
Data / MC Comparison

Gain Tuning

^{55}Fe radioactive source data



Simulation of ^{55}Fe photons



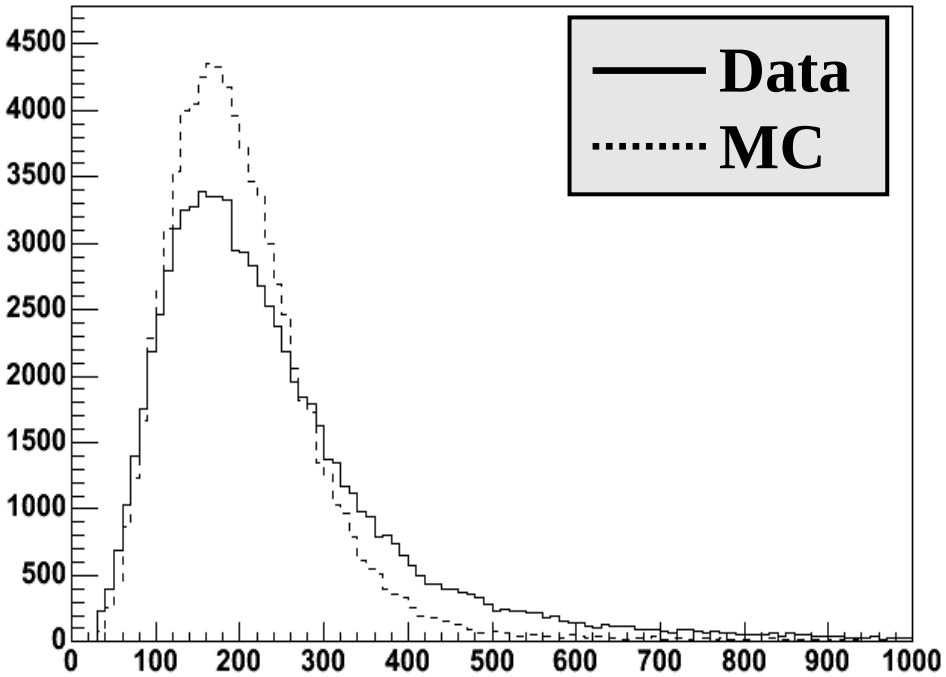
Larger σ in data: the Fano factor is not introduced in the fluctuations

Other possibles sources: - Transparency of the mesh ?

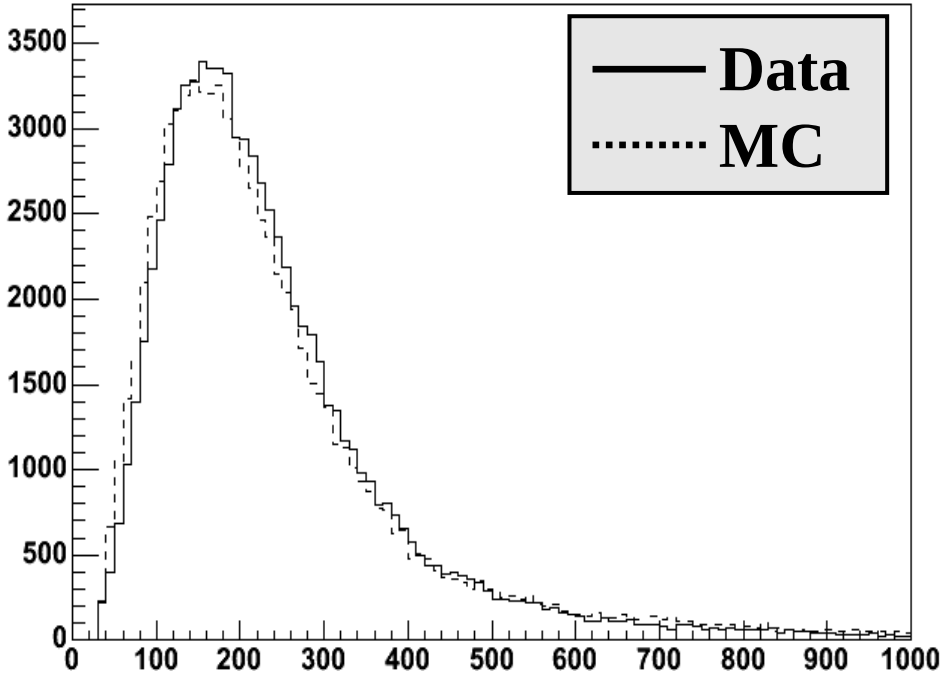
- Channel to channel fluctuations ?

Energy Loss

- Distribution of the charge per row for data/MC



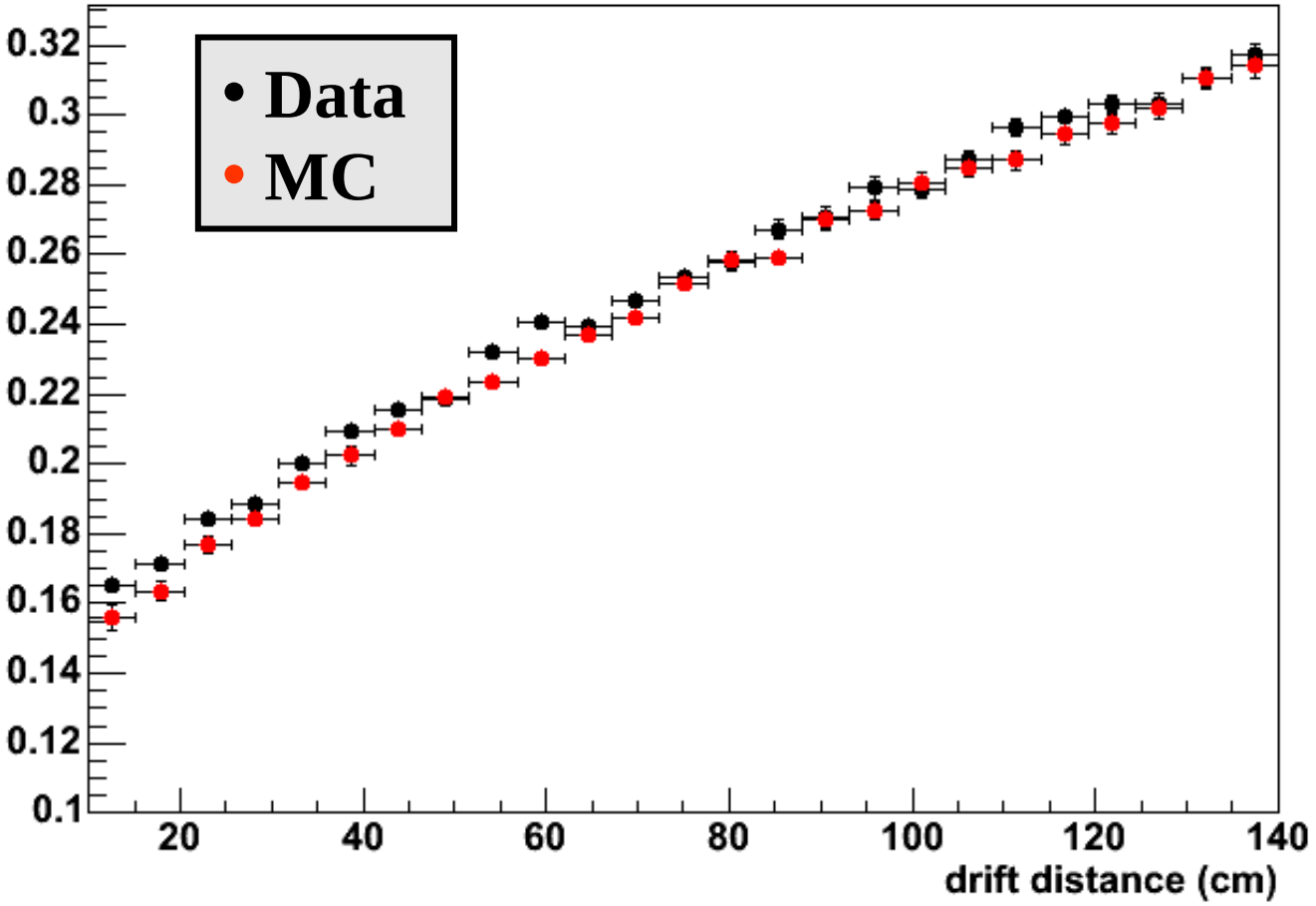
Calculating N_{elec} from Geant E_{loss} ($N_{elec}=E_{loss}/W_I$)



Adding Landau fluctuations to the average number of electrons N_{elec}

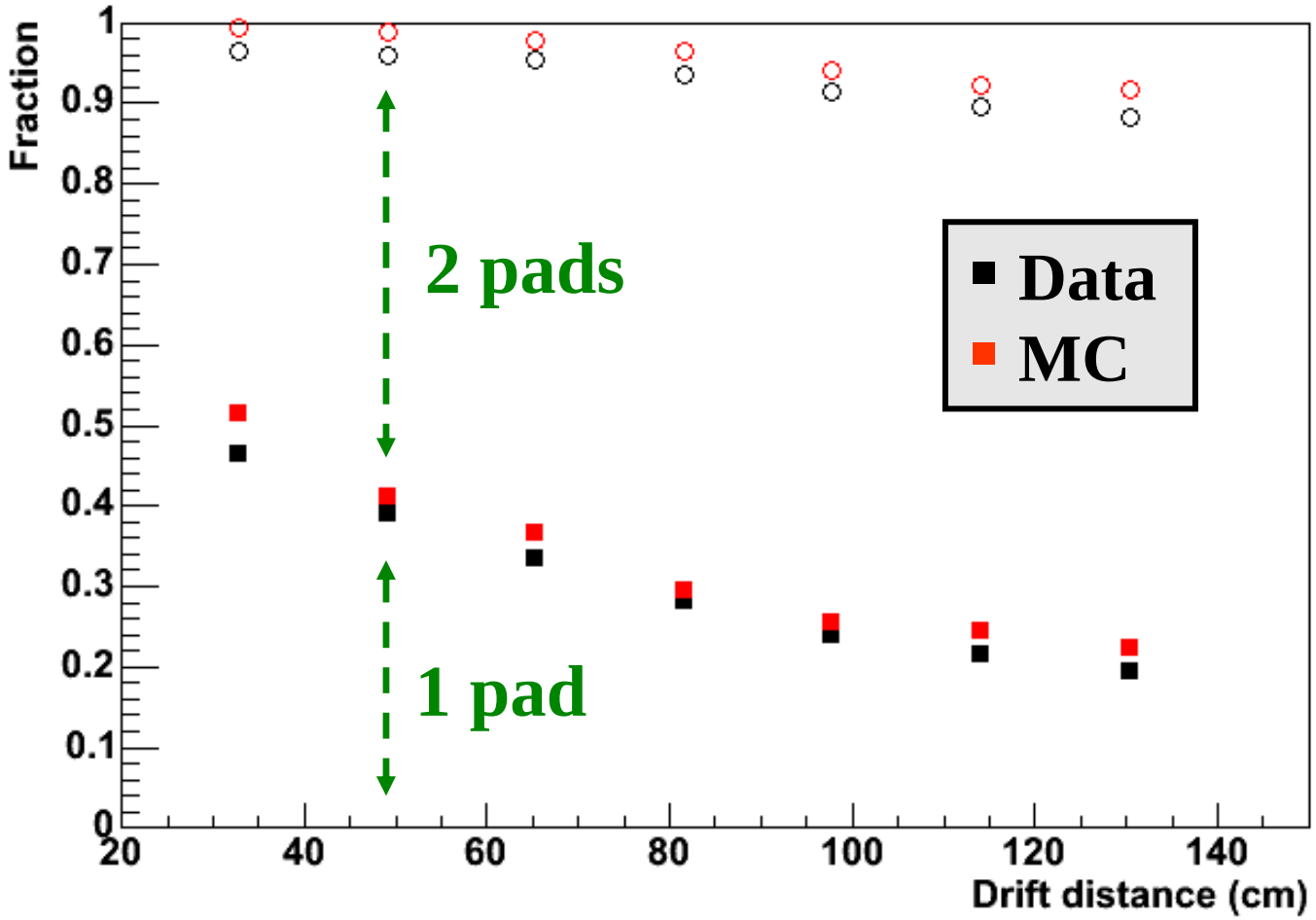
Estimated Track Width

- Estimated track width vs drift distance for data/MC



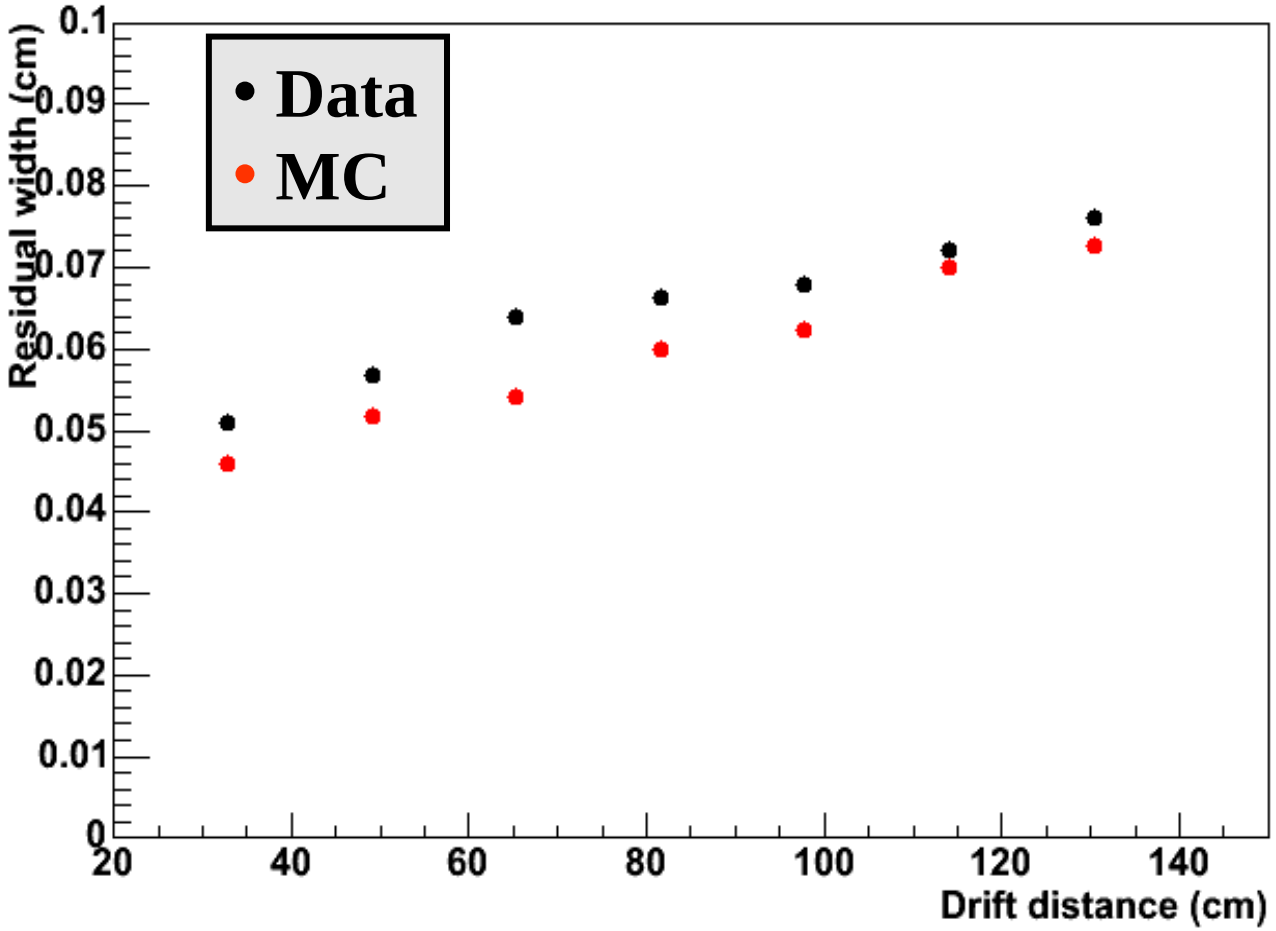
Fraction of Pad Per Cluster

- Cumulative fraction of pad per cluster vs drift distance for data/MC



Resolution

- Residuals Gaussian width of two pads clusters vs drift distance for data/MC



Conclusion

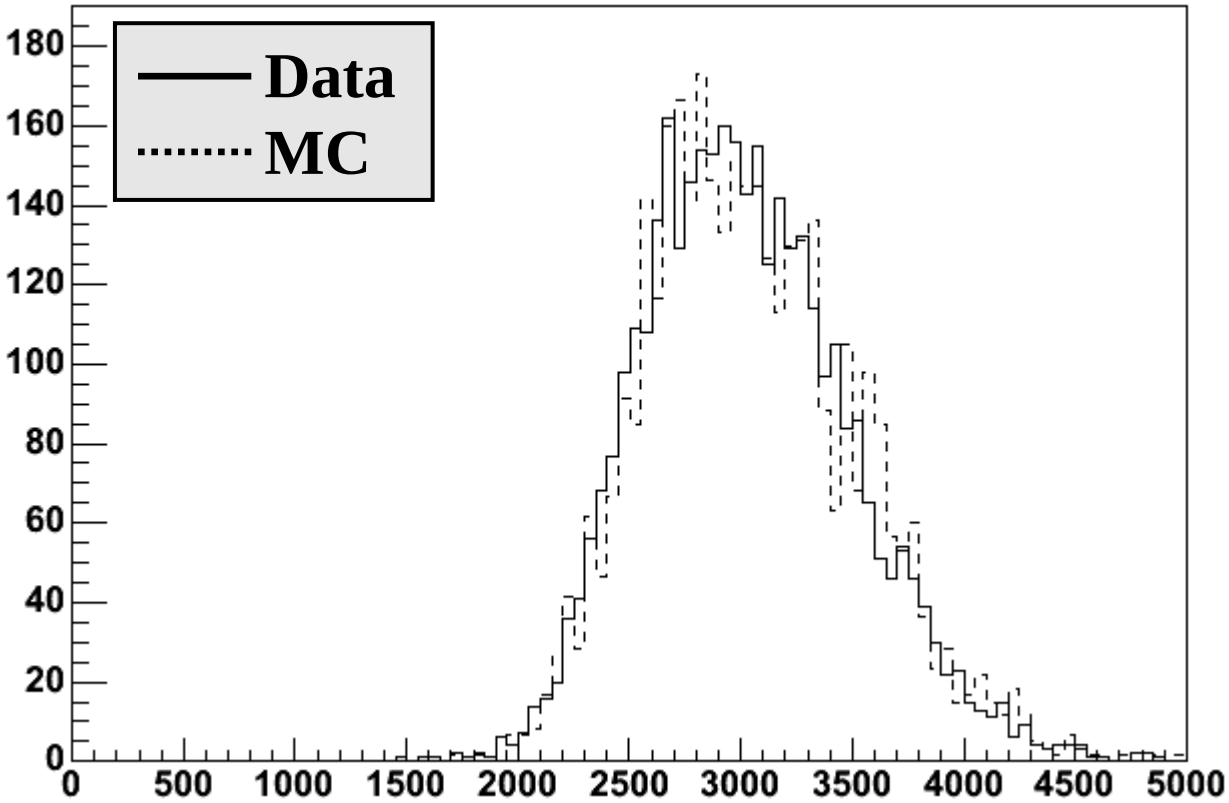
- A full Monte Carlo simulation of a TPC is written for T2K's near detector, using Geant 4.
- Data and MC are in fair agreement
- Energy deposition needs to be better understood

Energy Loss Resolution

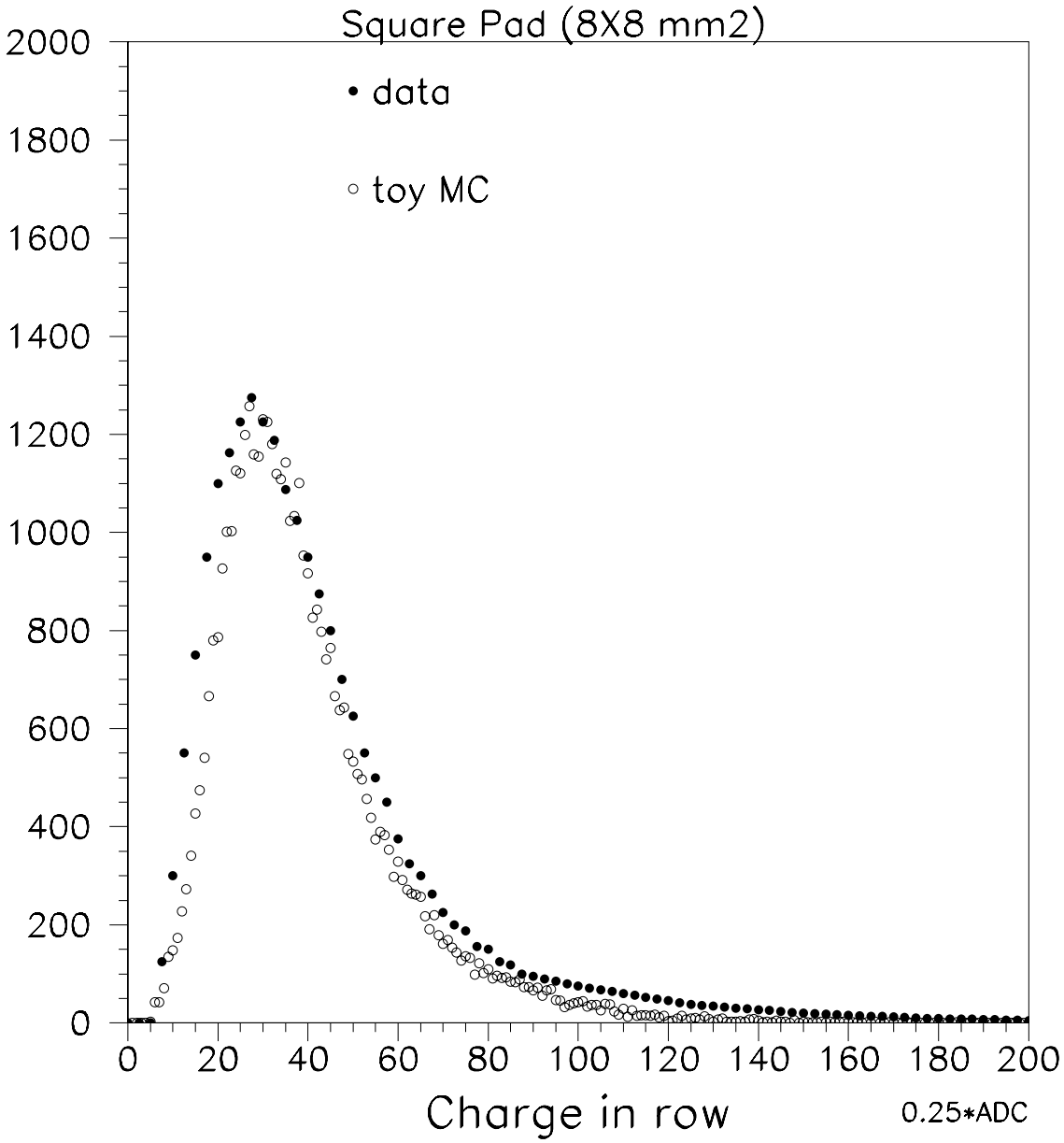
- Energy loss resolution for data and MC.

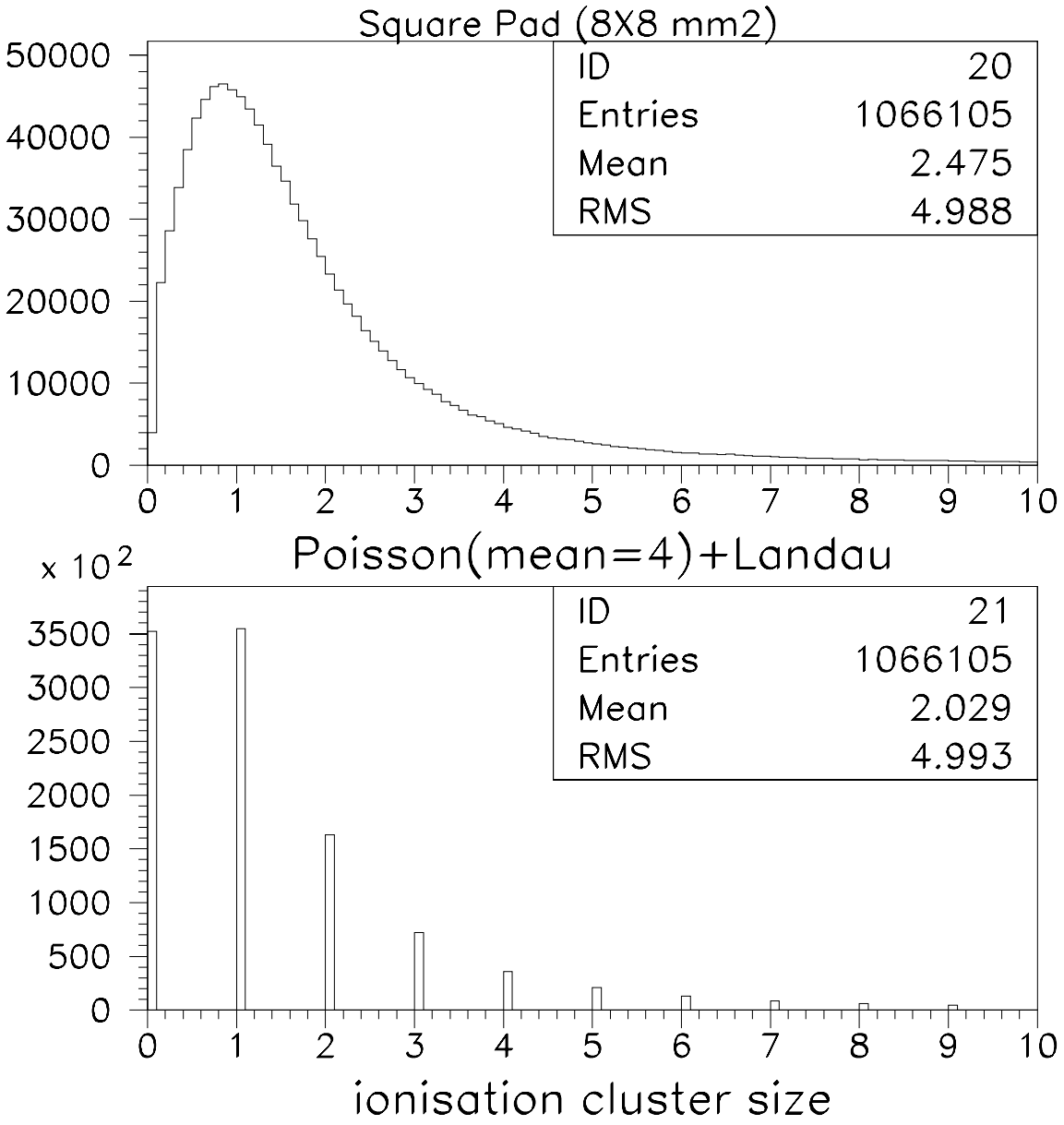
Energy loss calculated from 80% truncated mean of the distribution of the total charge in each row.

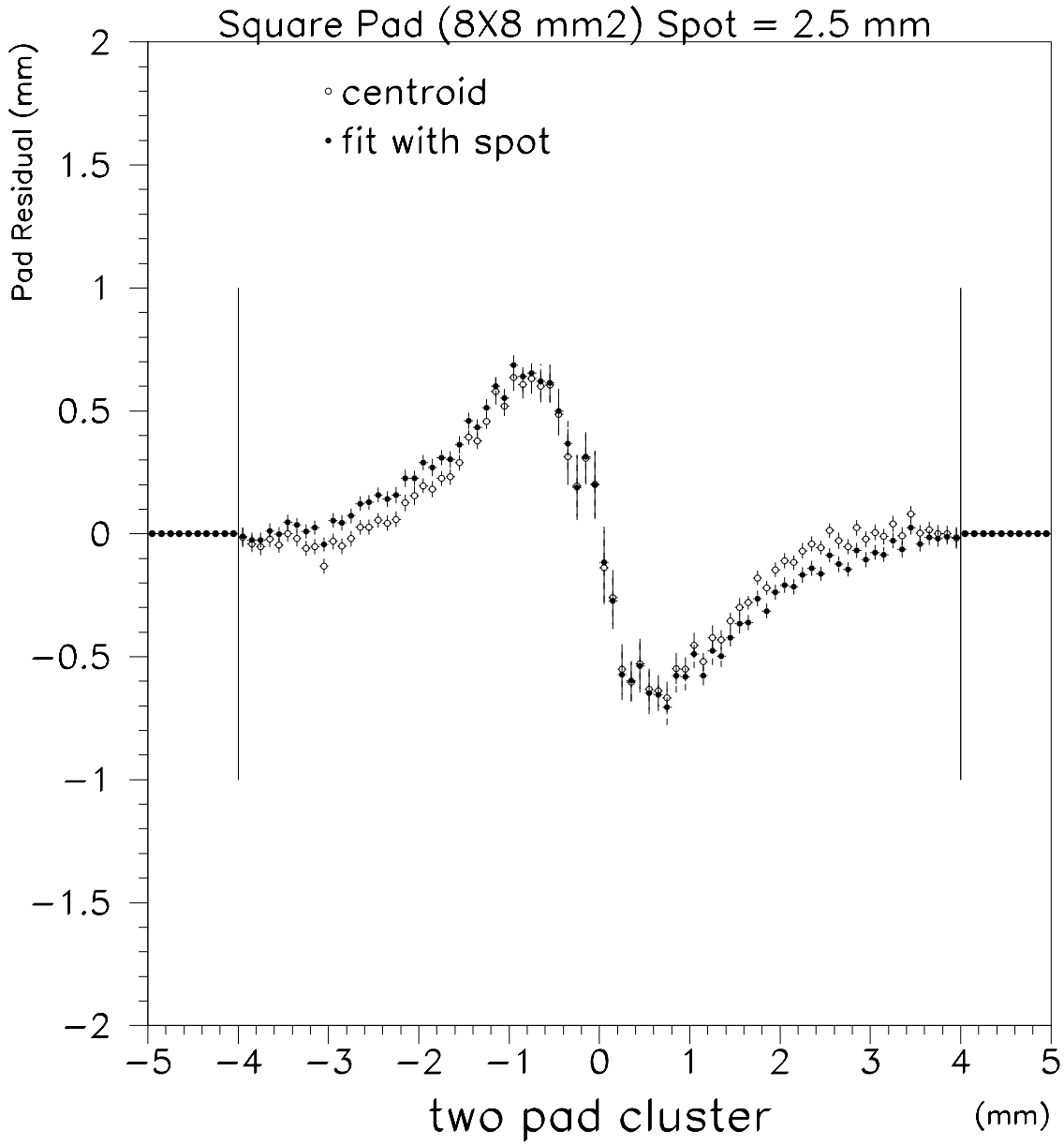
$\sigma \sim 13\%$ for both data and MC

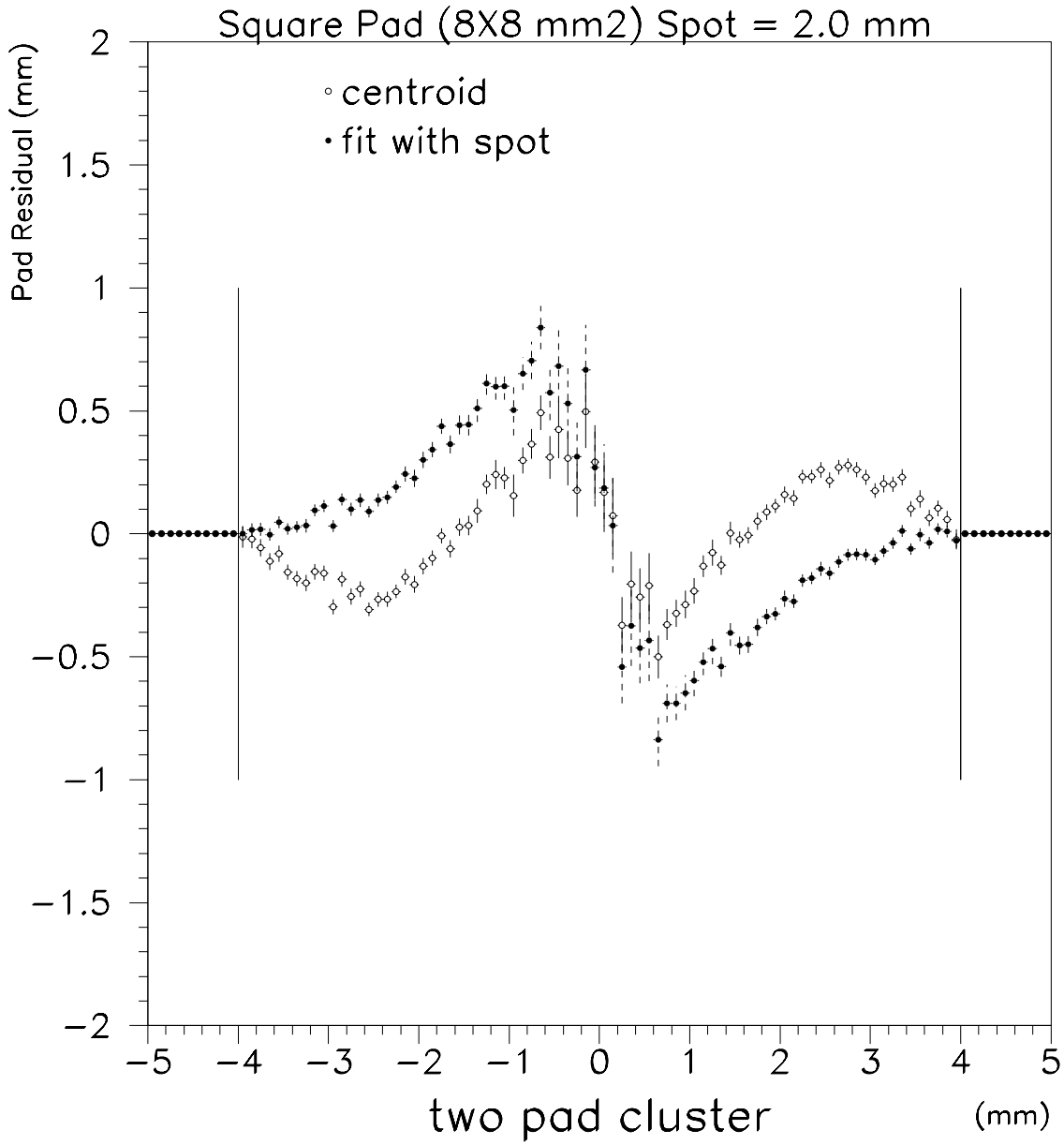


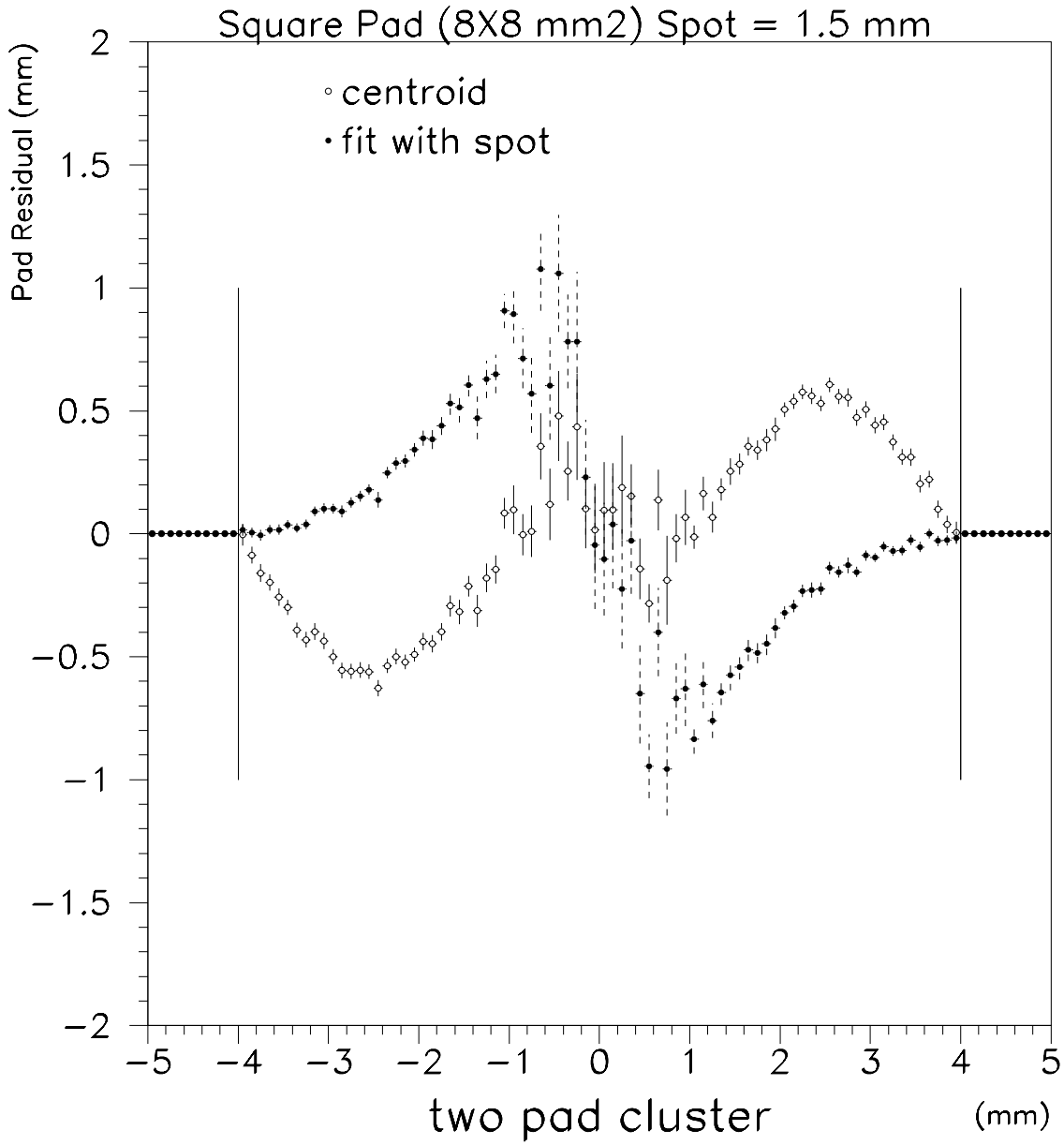
Toy Monte-Carlo

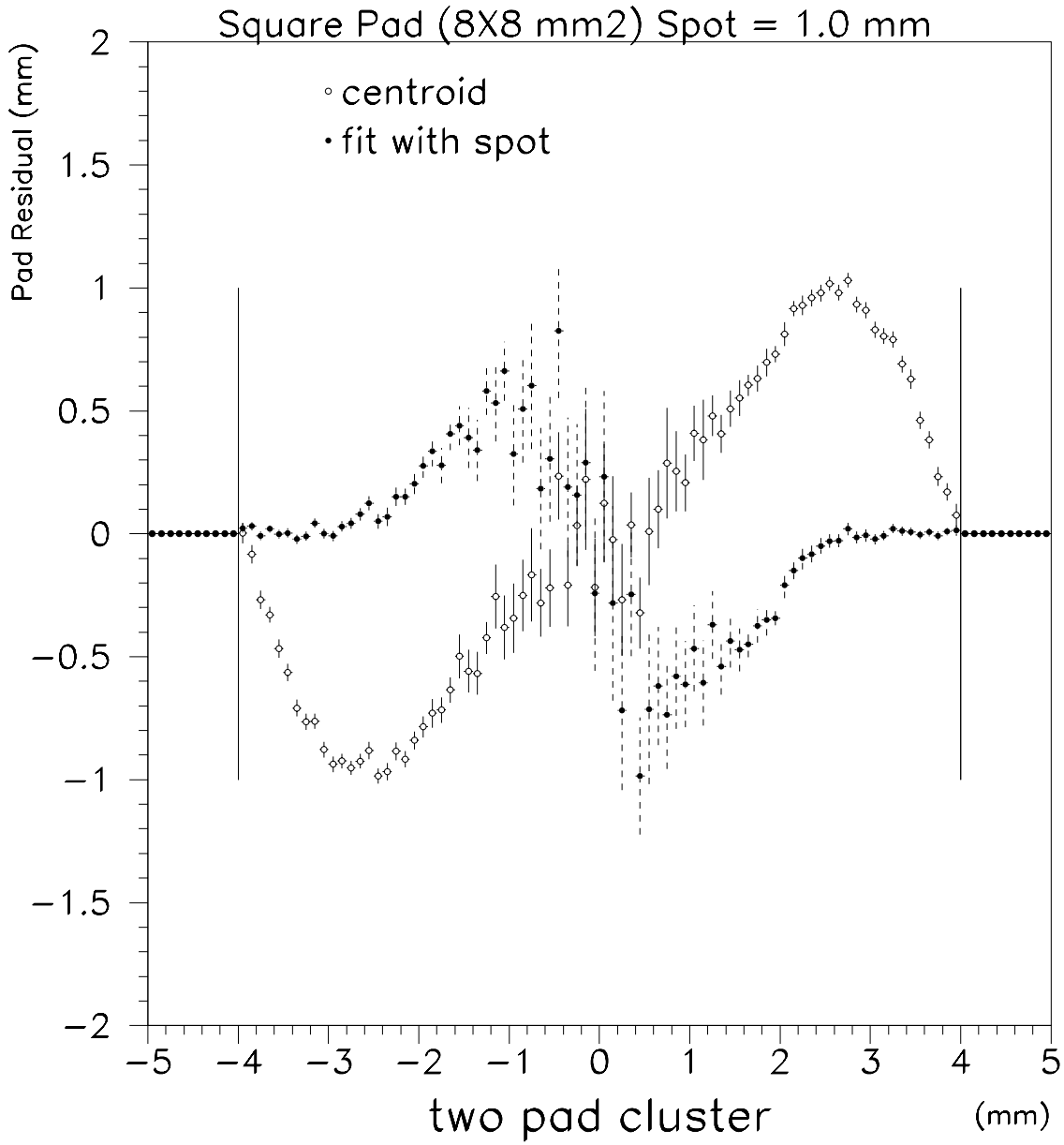

Square Pad (8X8 mm2)
• data
○ toy MC
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
20
40
60
80
100
120
140
160
180
200
Charge in row
0.25*ADC


Square Pad (8X8 mm2)
ID 20
Entries 1066105
Mean 2.475
RMS 4.988
50000
40000
30000
20000
10000
0
0 1 2 3 4 5 6 7 8 9 10
Poisson(mean=4)+Landau
x 10 2
ID 21
Entries 1066105
Mean 2.029
RMS 4.993
3500
3000
2500
2000
1500
1000
500
0
0 1 2 3 4 5 6 7 8 9 10
ionisation cluster size


Square Pad (8X8 mm2) Spot = 2.5 mm
centroid
fit with spot
Pad Residual (mm)
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−5
−4
−3
−2
−1
0
1
2
3
4
5
two pad cluster
(mm)


Square Pad (8X8 mm2) Spot = 2.0 mm
centroid
fit with spot
Pad Residual (mm)
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−5
−4
−3
−2
−1
0
1
2
3
4
5
two pad cluster
(mm)


Square Pad (8X8 mm2) Spot = 1.5 mm
centroid
fit with spot
Pad Residual (mm)
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−5
−4
−3
−2
−1
0
1
2
3
4
5
two pad cluster
(mm)


Square Pad (8X8 mm2) Spot = 1.0 mm
centroid
fit with spot
Pad Residual (mm)
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−5
−4
−3
−2
−1
0
1
2
3
4
5
two pad cluster
(mm)