Performances of the Calocube prototype using 2016 SPS electron beam

Calocube Data Analysis

Eugenio Berti, 8 May 2017

Outline

Purpose

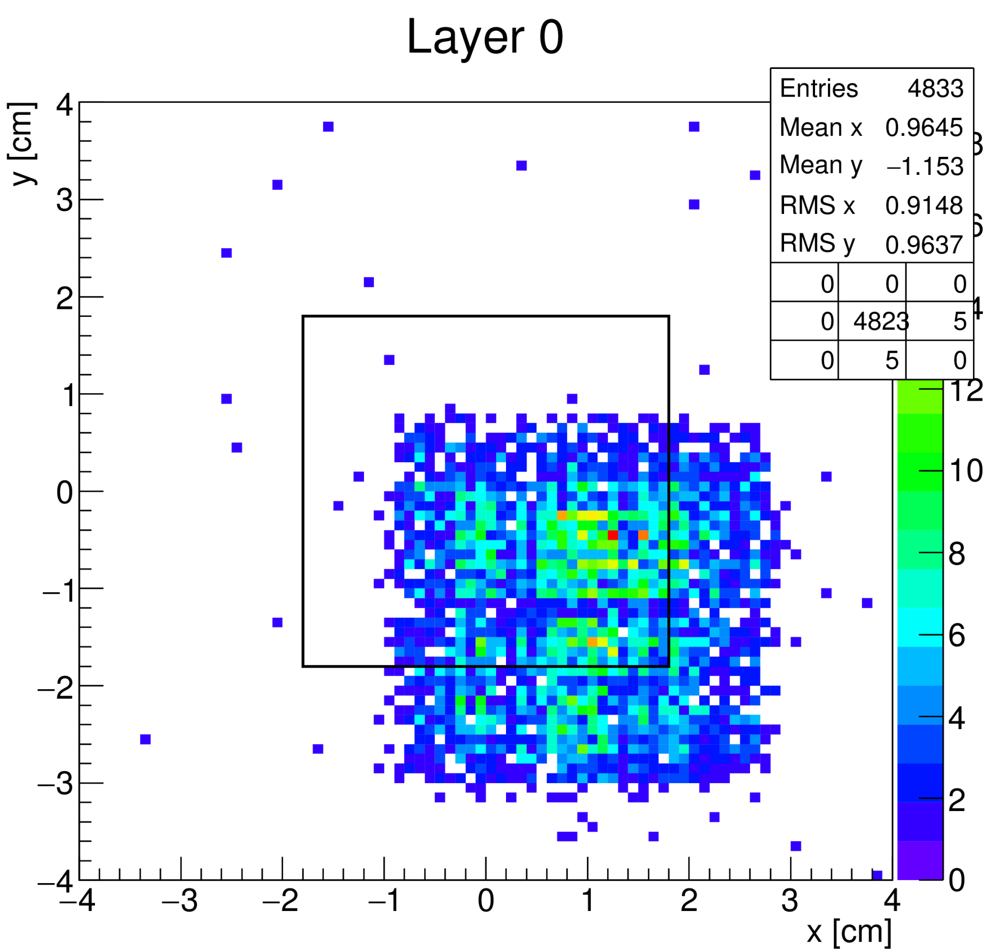
Measure the linearity and the resolution of the Calocube prototype for electron beam

Analysis steps

- Extract Tracker information
- Relative Gain Calibration
- Leakage correction
- Performances

Extract Tracker information

Tracker-Calocube offset
Muon beam



Event selection

<u>Main selection</u>
fBTfitflag = 3
fBTtracksX(Y) = 0, 1

<u>... not strict condition</u>
fChi2X(Y)/NdofX(Y) < 1

<u>... always true if fBTfitflag = 3</u>
fNpointX(Y) = 5
fNdofX(Y) = 3

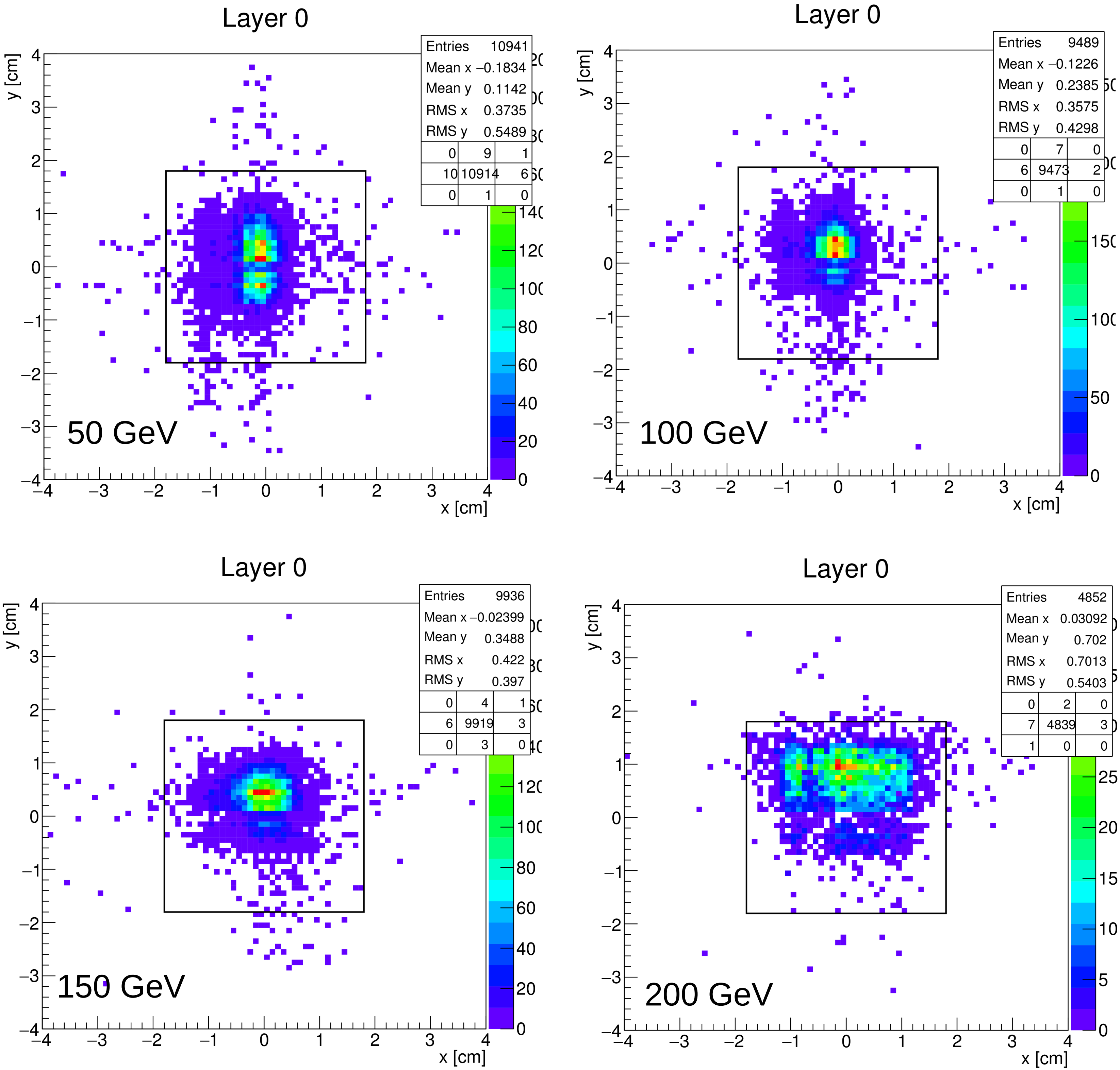
<u>.. always true with e, m or p beam</u>
finteraction = 0, 1

cube > 1 MIP

The displacement between tracker RS and Calocube RS is

x = +0.95
y = -1.2

Electron Beam Profile



Relative Gain Calibration

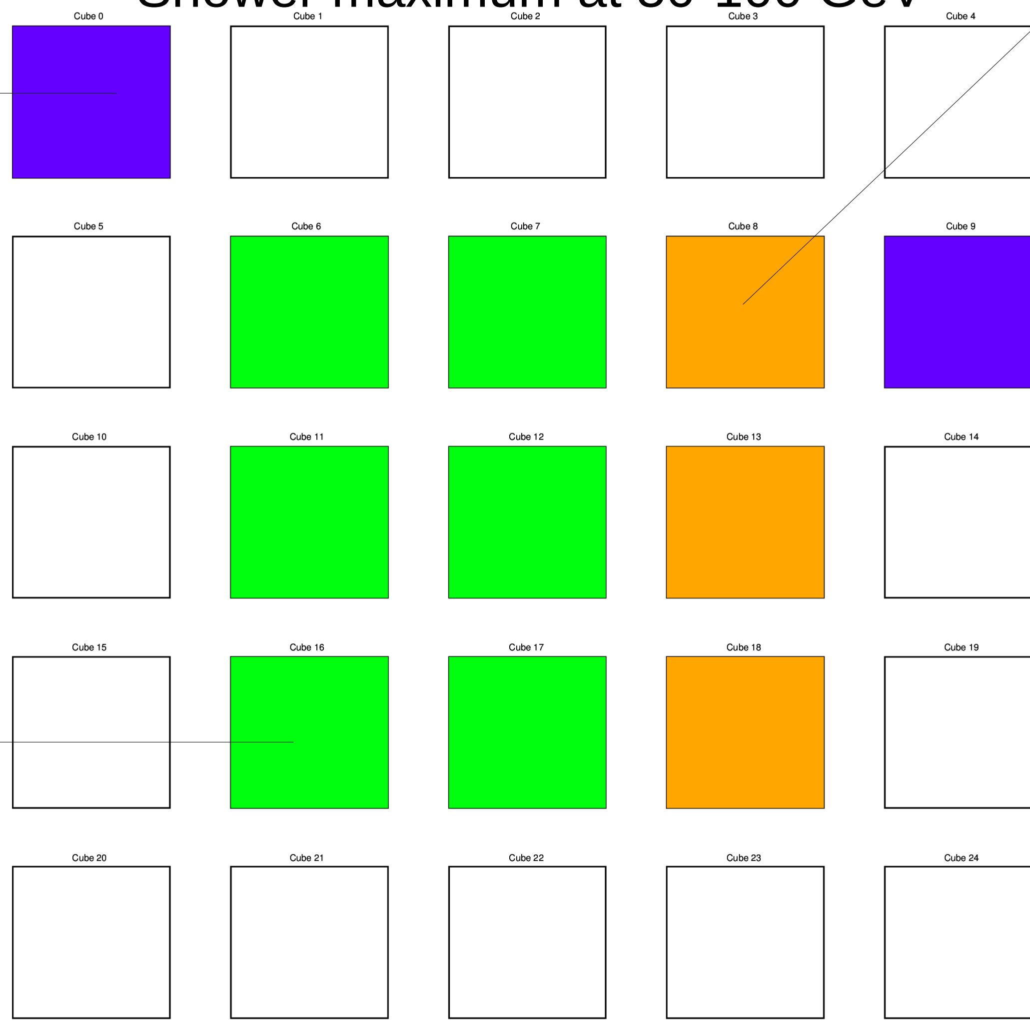
Calibration Map

Only Small PD calibrated (Elena using electron shower)

Layer 3

Shower maximum at 50-100 GeV

Dead or noisy channels

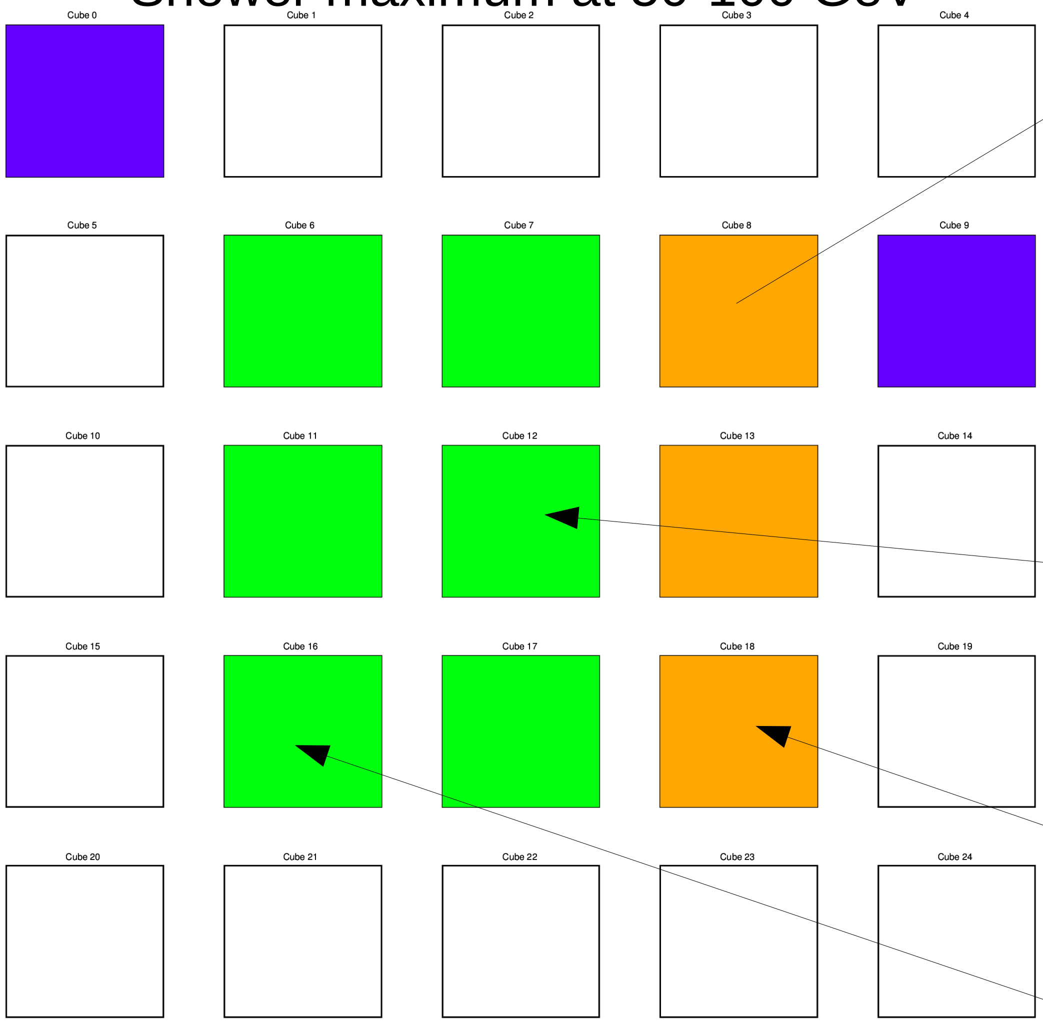


Both Small (Elena using electron shower) and Large (Elena using muon MIP) PD calibrated

Calibration Map

Layer 3

Shower maximum at 50-100 GeV

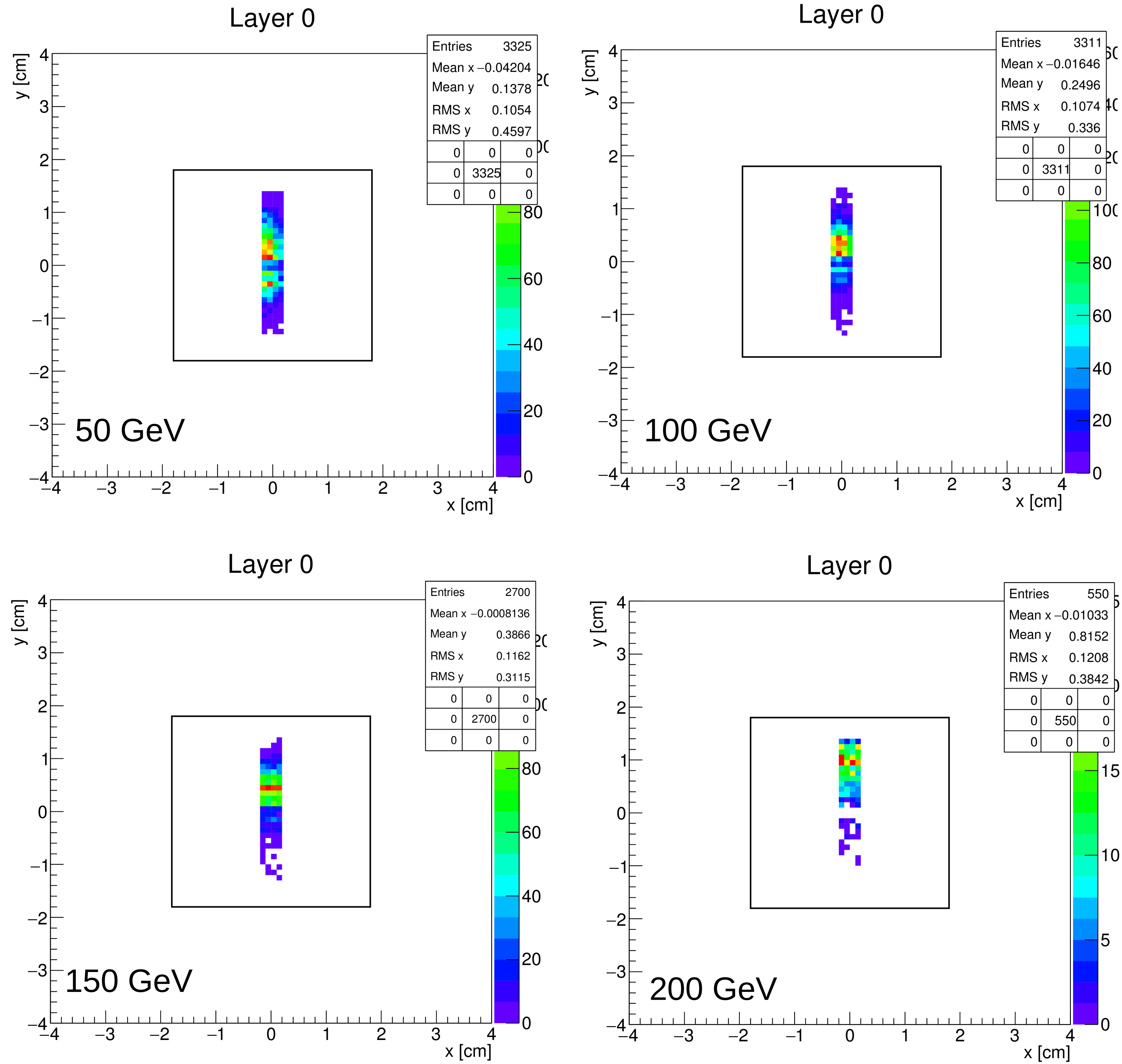


<u>Purpose</u>

Calibrate the gain of Large PD of these three crystals for layers 1-10

<u>Idea</u>

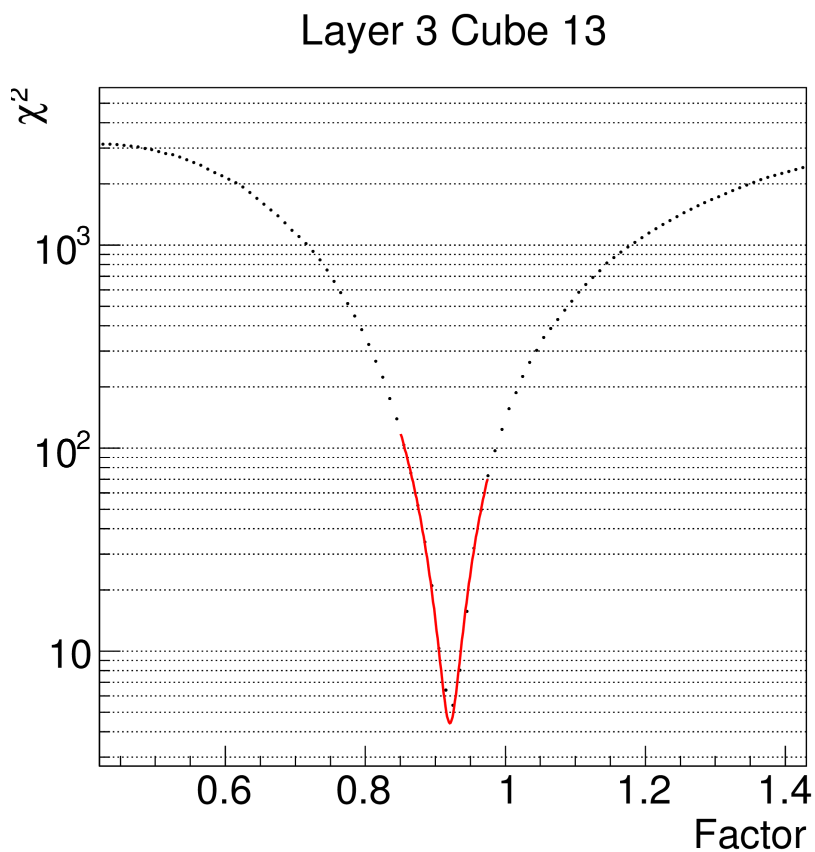
- Use tracker to select electron hitting the <u>*central cube*</u> of calorimeter at center
- Perform relative calibration between <u>*cube on column 3*</u> and the relative <u>*cube on column 1*</u>

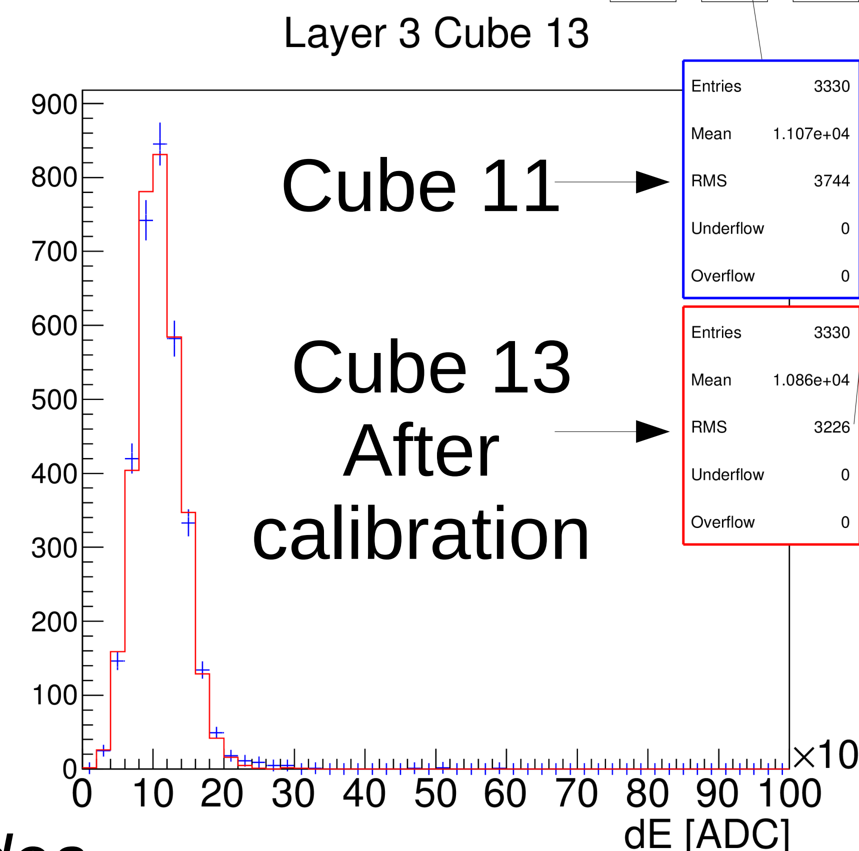


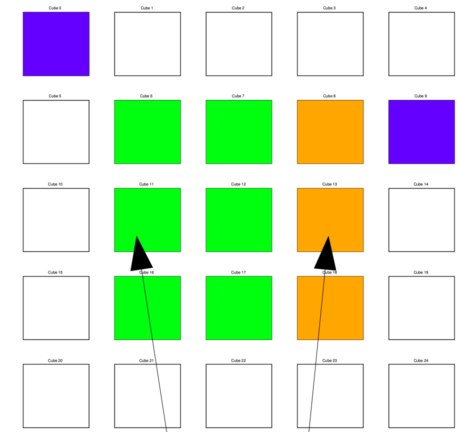
Electron Beam Profile

An example

100 GeV electron beam







Idea

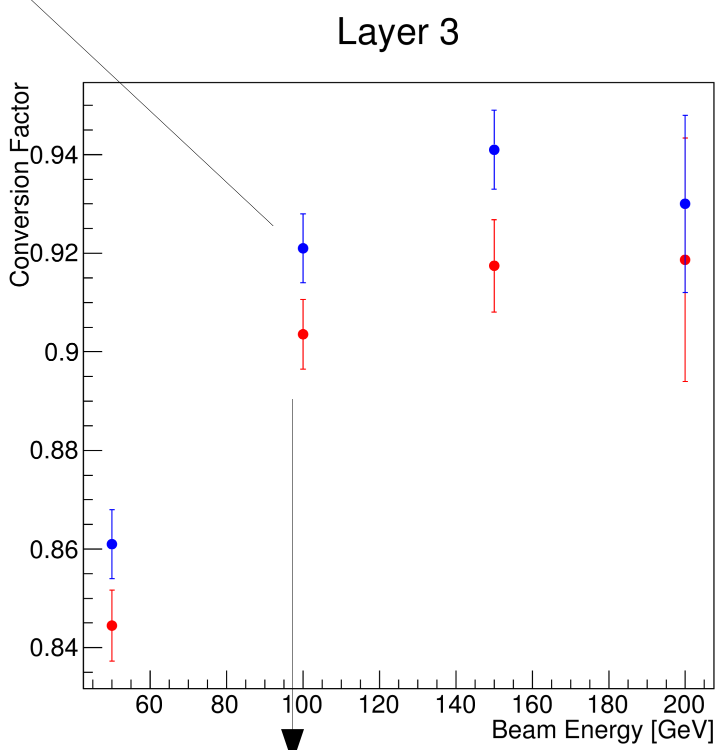
- Try different values of **Factor= Gain[13] / Gain[11]** from 0 to 3
- Build χ^2 distribution using all these points
- Fit χ^2 distribution in order to extract best value of Factor

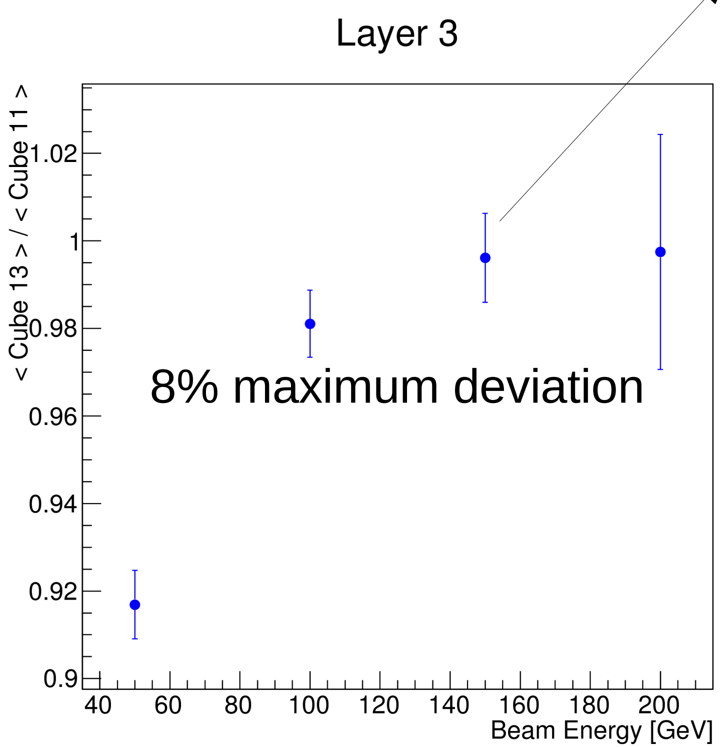
Layer 3 Cube 13

Energy dependence
An example

Factor from χ^2 method

Mean ratio after calibration

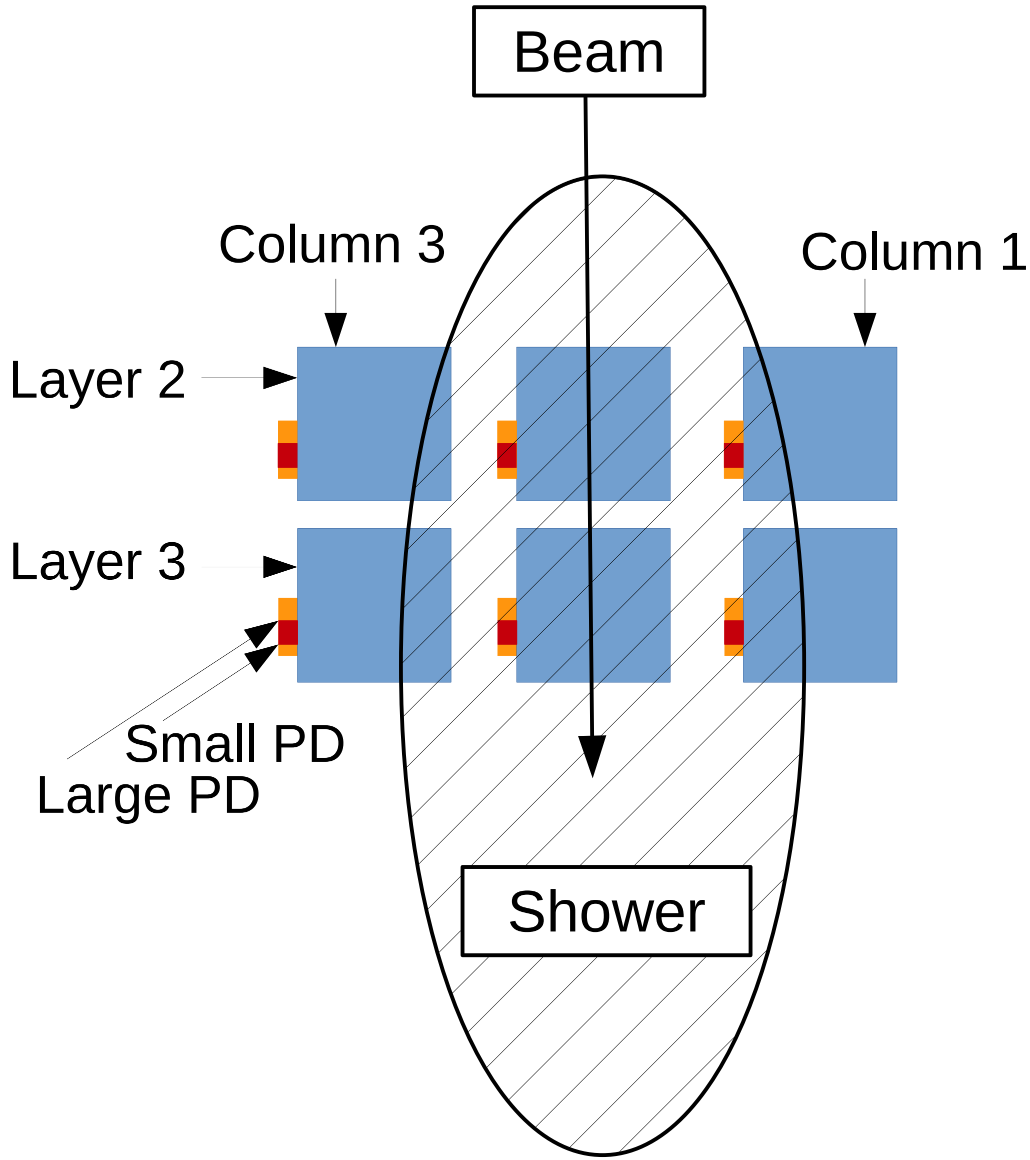




Factor from simple mean ratio

In most cases an energy dependence value of the factor was found with a similar trend to the one shown

Possible explanation of the energy trend of the relative gain factor



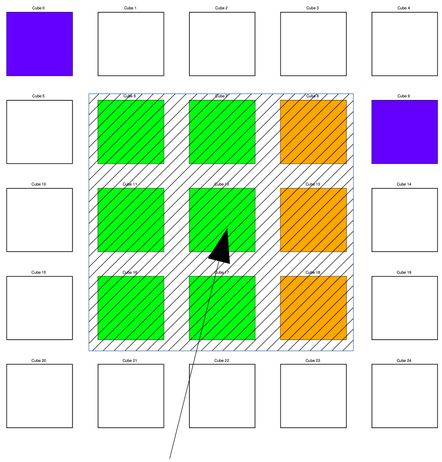
In our approach we neglected the different position of PDs between Column 1 and Coloumn 3, but the signal due to *direct ionization* is different among these columns.

In addition *this difference depends on the beam energy*, because of different maximum depth (and different energy flow?)

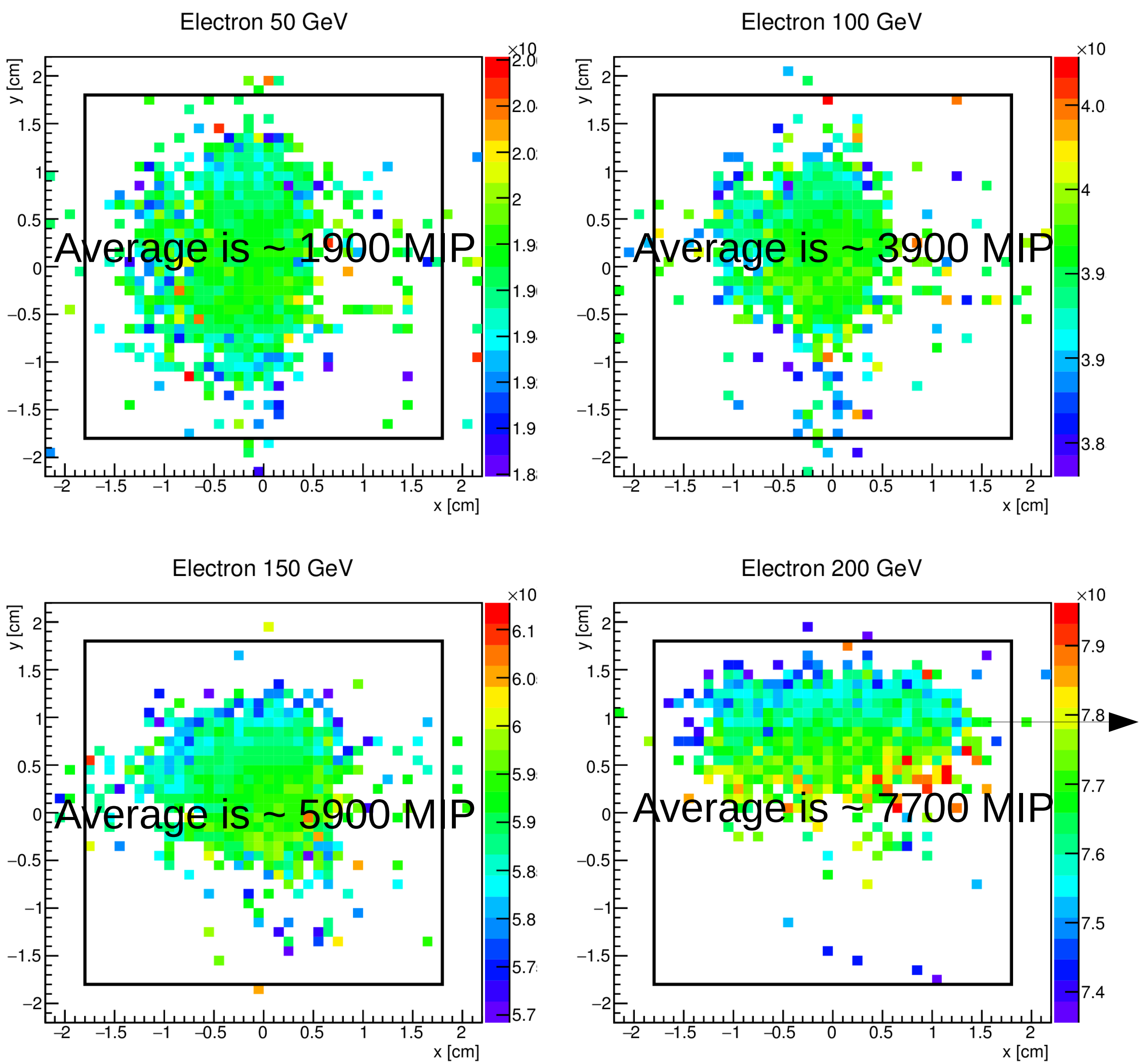
We need simulations to study this point in detail.

Leakage correction

Energy Flux



Energy deposit is reconstructed using 3x3 cubes for the first 15 layers



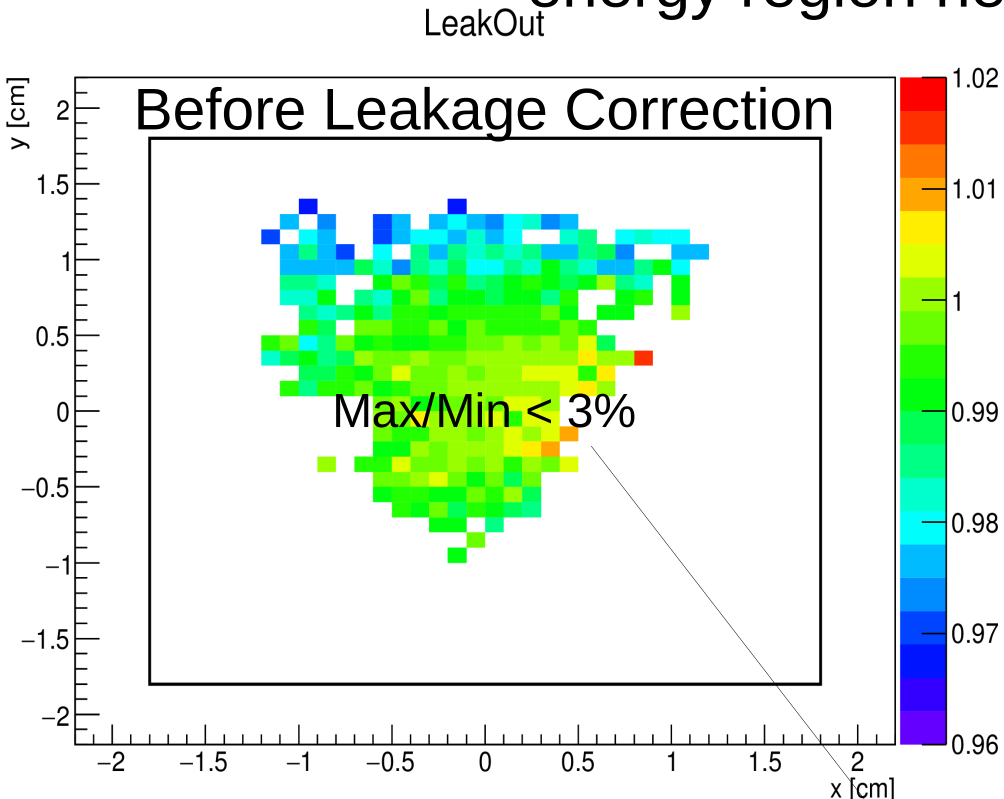
The 200 GeV electron beam is problematic:

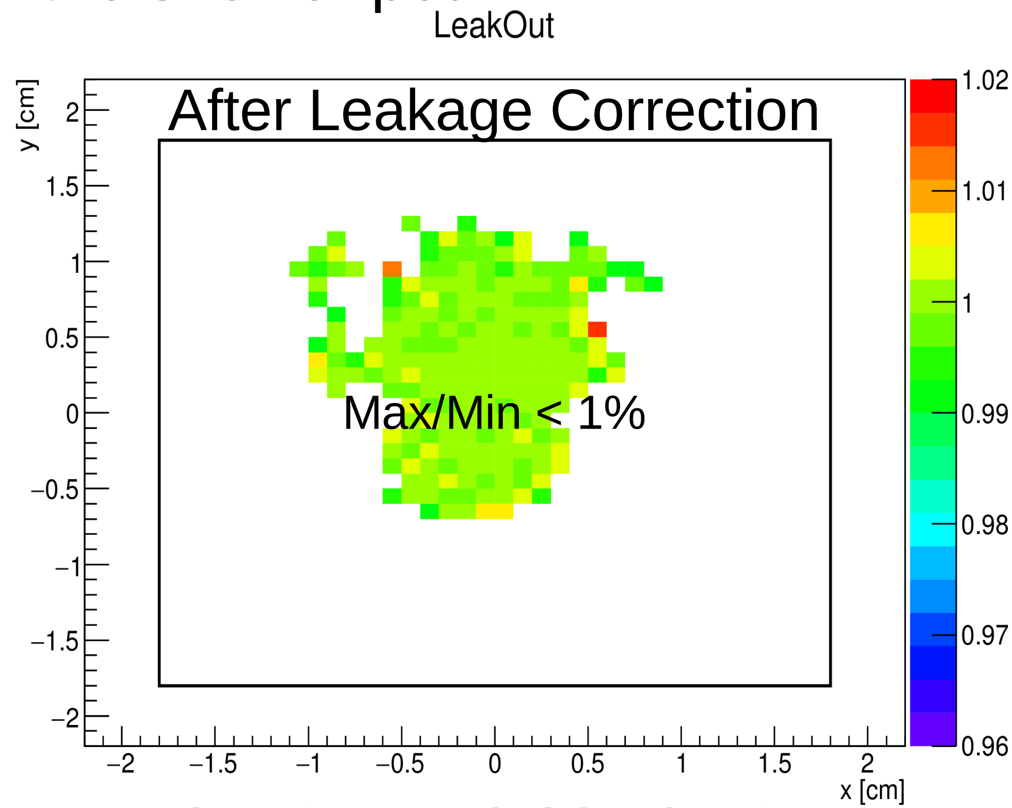
- it is outside the center of the cube
- it is spread on a large surface

LeakOut (x, y) = <Energy(x, y)> / <Energy(center)>

LeakOut Map

Selecting only bins for which we have at least 5 entries in an energy region near the shower peak



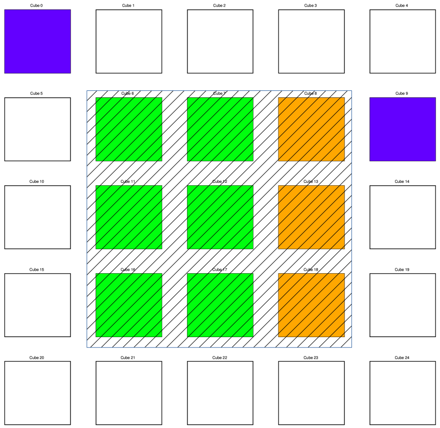


The final LeakOut map is made selecting for each bin the factor estimated from the sample (50, 100, 150 or 200 GeV) having the highest statistics in that bin

Energy deposit is higher in the right direction (where PDs are), probably because of *direct ionization*

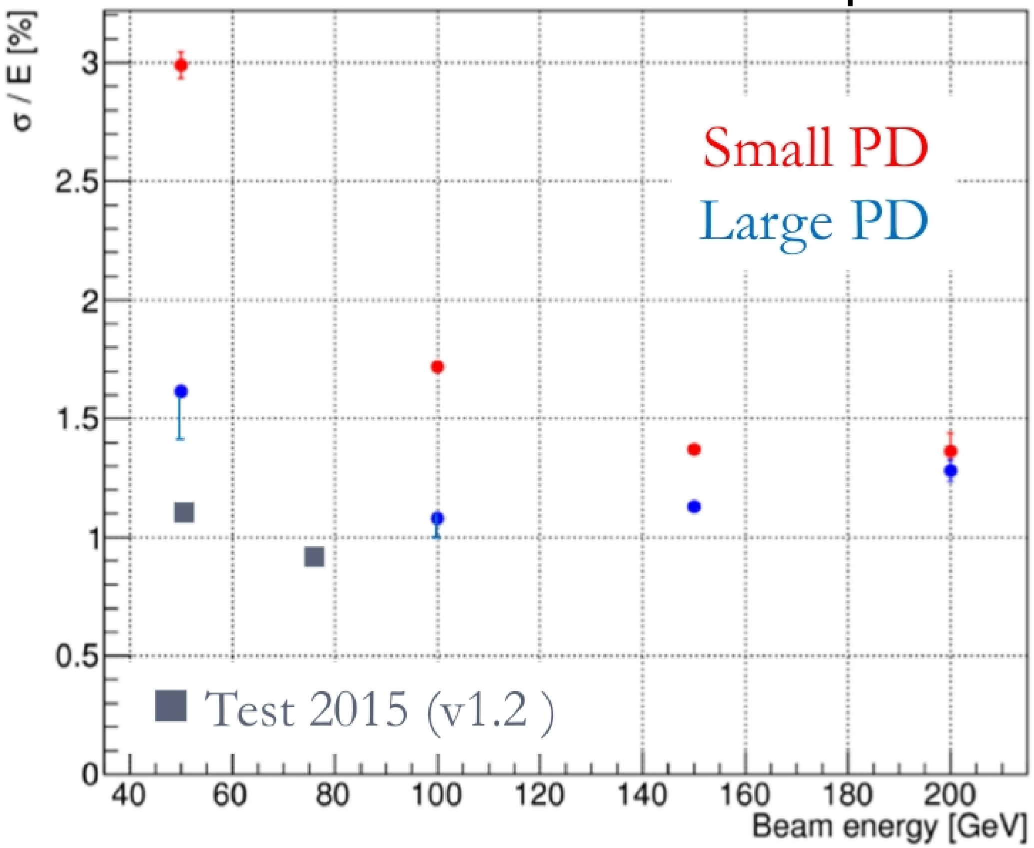
Performances

We use 3x3 cubes
of the first 15 layers



Starting point

Slide presented by Elena
at the 4th HERD Workshop



Resolution better than 1.5% with Large PD
and comparable with Small PD at 200 GeV

<u>Status of calibration</u>
Large PD: column 1 and 2 (muons)
Small PD: column 1, 2 and 3 (electrons)

<u>Reconstruction</u>
The energy deposit in a crystal is take into account (***Hit***) if:

- Large PD>0.6 MIP in case of Large PD
- Small PD>0.6 MIP in case of **Large PD**

Position is reconstructed using Calocube center of gravity
Energy is reconstructed from the total energy deposit [MIP]

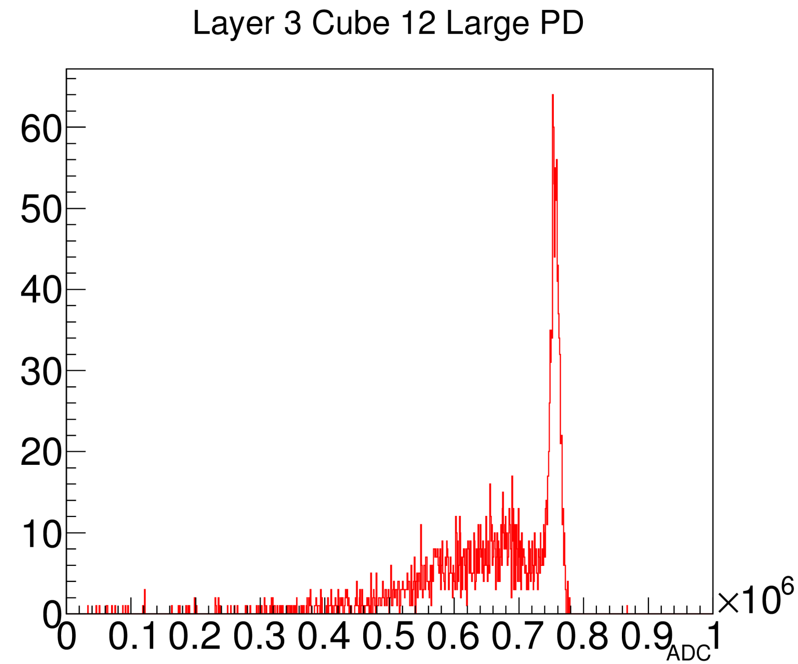
<u>Event selection</u>

- Select only events having an energy deposit more than 15 MIP in Layer 0
- Select an energy dependent area of 1-4 mm where response is uniform

About saturation

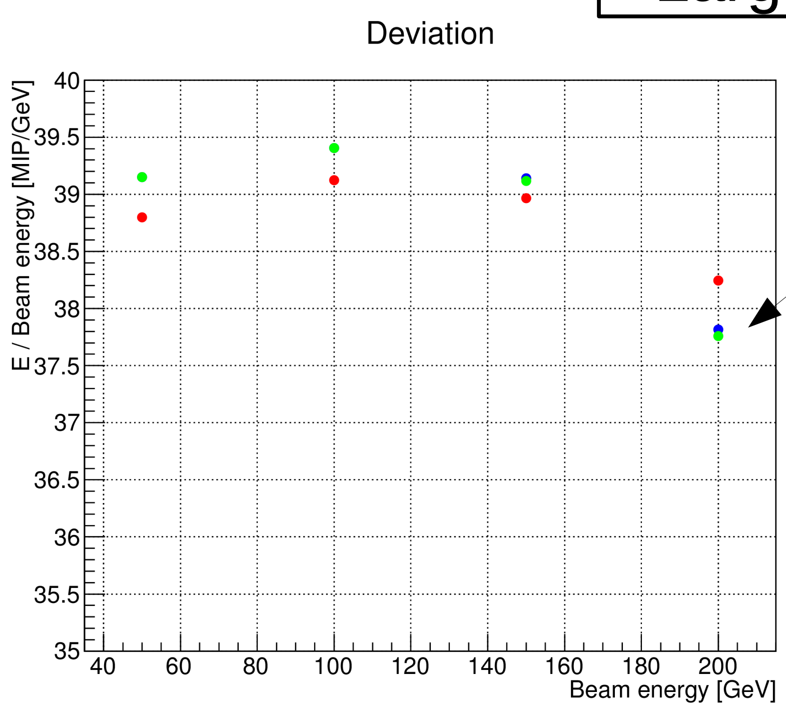
<u>Definition of saturated event</u>

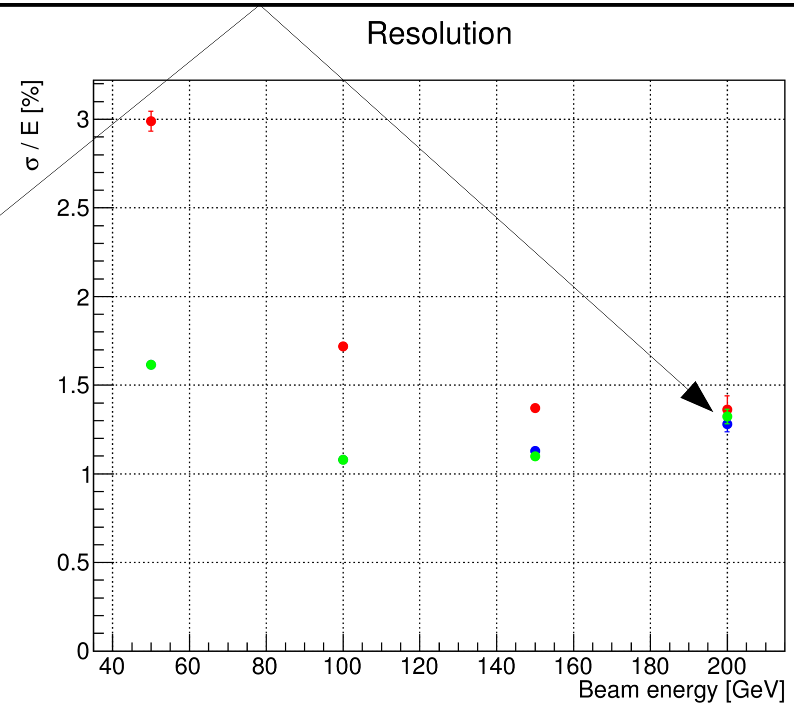
Event in which the energy deposit in the cube with maximum signal (layer 3 cube 12) is greater than 710000 ADC



- Large - No Saturation
- Large - All
- Small

Saturation is not significant for the Large PD even with 200 GeV beam





Update

<u>What can be improved</u>

<u>Reconstruction</u>

Position is reconstructed using **tracker** information

Energy should benefits of the **calibration** of Large PDs gains in column 3

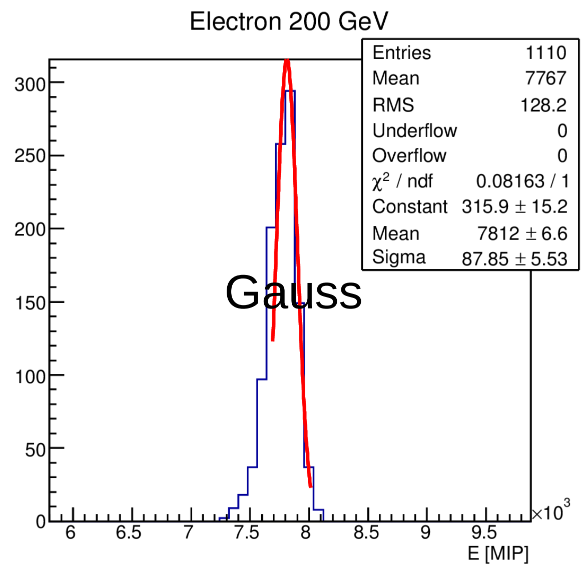
<u>Event selection</u>

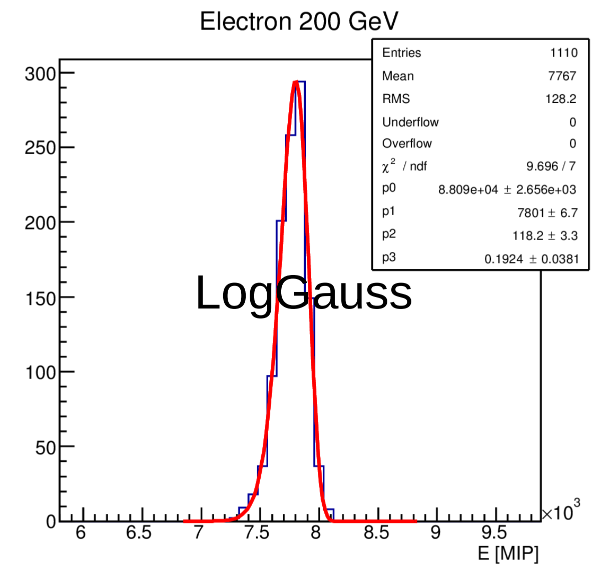
- Select only events having an energy deposit more than 15 MIP in Layer 0
- Use all events and correct for position dependence using **LeakOut** table

<u>Determination of mean and resolution</u>

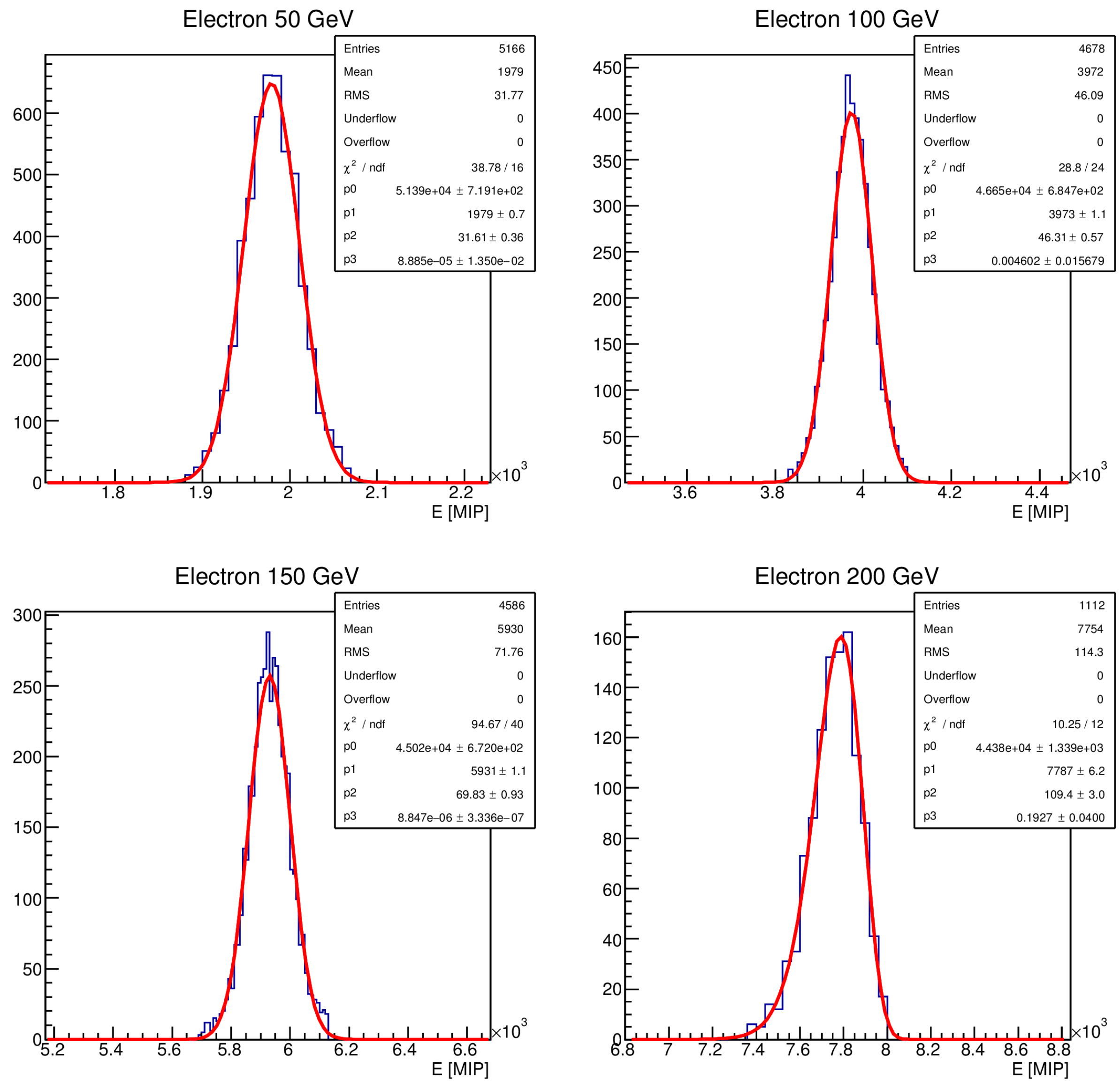
In the past analysis the energy distribution were fitted using a Gaussian

Because in some cases we found a low energy tail this time we used **LogGaussian** function



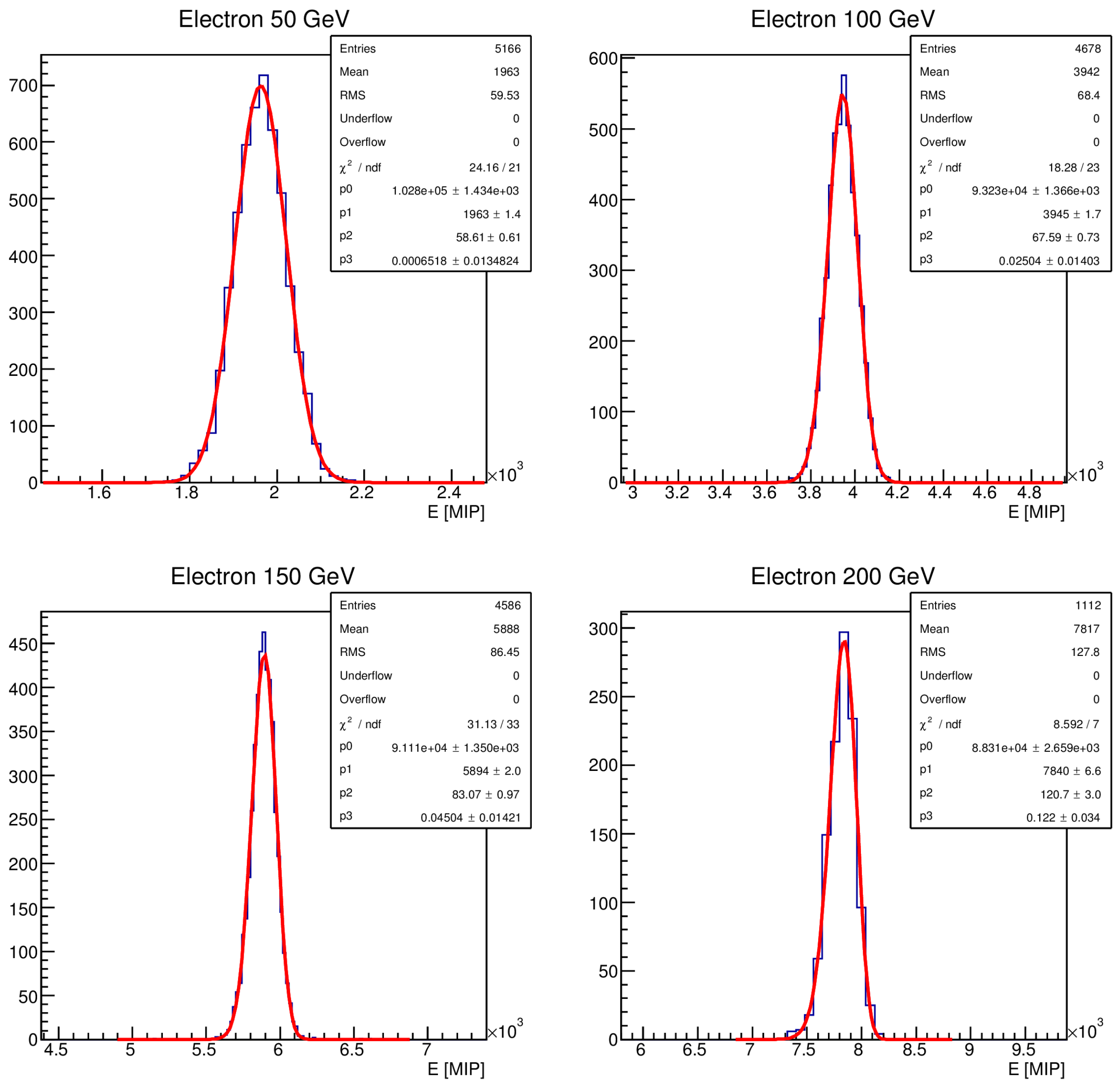


Large PD



Electron 50 GeV
Entries 5166
Mean 1979
RMS 31.77
Underflow 0
Overflow 0
χ² / ndf 38.78 / 16
p0 5.139e+04 ± 7.191e+02
p1 1979 ± 0.7
p2 31.61 ± 0.36
p3 8.885e−05 ± 1.350e−02
E [MIP]
×10³
Electron 100 GeV
Entries 4678
Mean 3972
RMS 46.09
Underflow 0
Overflow 0
χ² / ndf 28.8 / 24
p0 4.665e+04 ± 6.847e+02
p1 3973 ± 1.1
p2 46.31 ± 0.57
p3 0.004602 ± 0.015679
E [MIP]
×10³
Electron 150 GeV
Entries 4586
Mean 5930
RMS 71.76
Underflow 0
Overflow 0
χ² / ndf 94.67 / 40
p0 4.502e+04 ± 6.720e+02
p1 5931 ± 1.1
p2 69.83 ± 0.93
p3 8.847e−06 ± 3.336e−07
E [MIP]
×10³
Electron 200 GeV
Entries 1112
Mean 7754
RMS 114.3
Underflow 0
Overflow 0
χ² / ndf 10.25 / 12
p0 4.438e+04 ± 1.339e+03
p1 7787 ± 6.2
p2 109.4 ± 3.0
p3 0.1927 ± 0.0400
E [MIP]
×10³

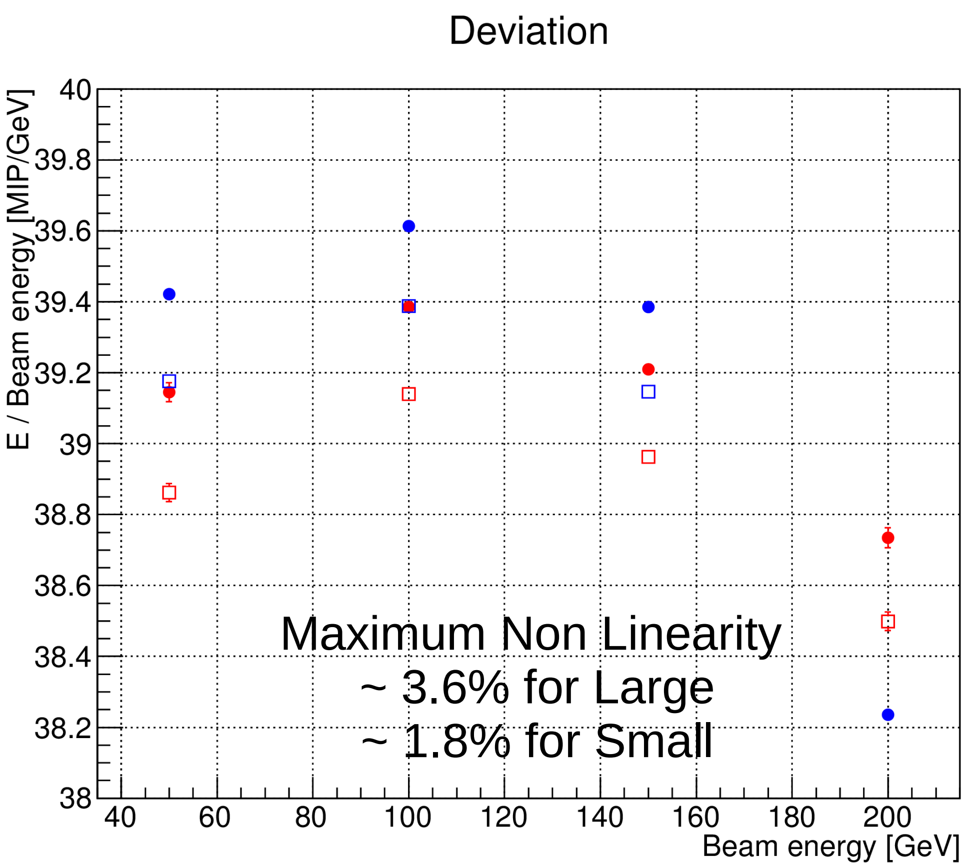
Small PD

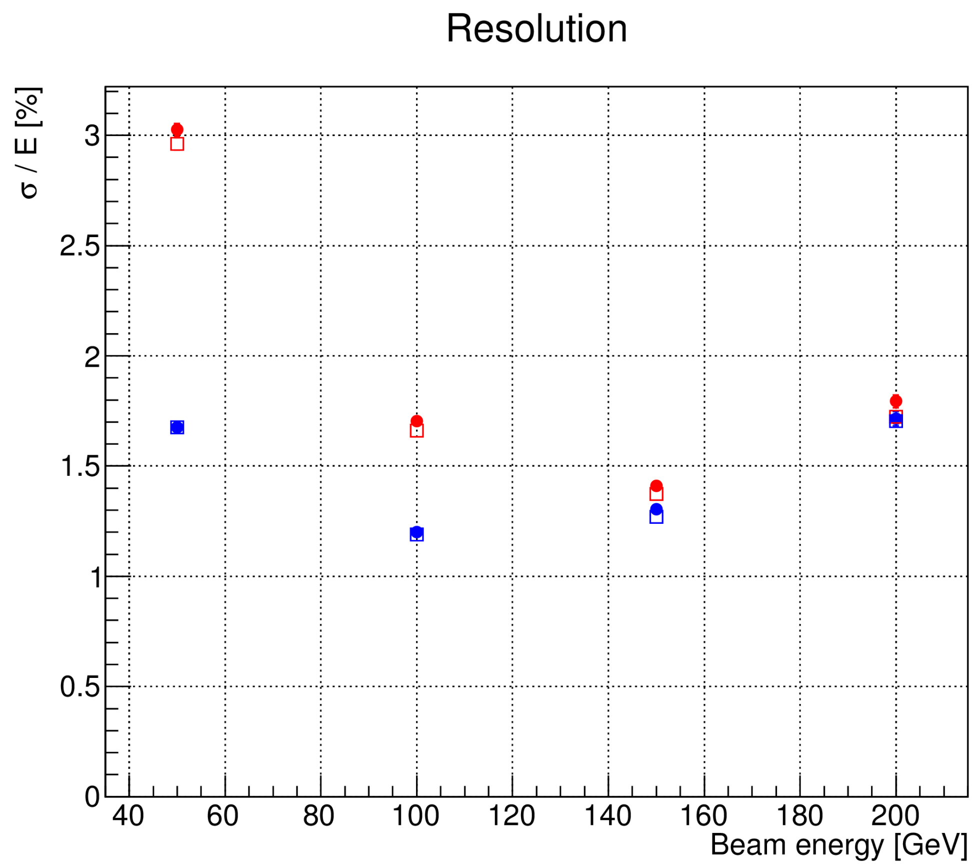

Electron 50 GeV
Entries 5166
Mean 1963
RMS 59.53
Underflow 0
Overflow 0
χ^2 / ndf 24.16 / 21
p0 1.028e+05 ± 1.434e+03
p1 1963 ± 1.4
p2 58.61 ± 0.61
p3 0.0006518 ± 0.0134824
E [MIP]
×10³
Electron 100 GeV
Entries 4678
Mean 3942
RMS 68.4
Underflow 0
Overflow 0
χ^2 / ndf 18.28 / 23
p0 9.323e+04 ± 1.366e+03
p1 3945 ± 1.7
p2 67.59 ± 0.73
p3 0.02504 ± 0.01403
E [MIP]
×10³
Electron 150 GeV
Entries 4586
Mean 5888
RMS 86.45
Underflow 0
Overflow 0
χ^2 / ndf 31.13 / 33
p0 9.111e+04 ± 1.350e+03
p1 5894 ± 2.0
p2 83.07 ± 0.97
p3 0.04504 ± 0.01421
E [MIP]
×10³
Electron 200 GeV
Entries 1112
Mean 7817
RMS 127.8
Underflow 0
Overflow 0
χ^2 / ndf 8.592 / 7
p0 8.831e+04 ± 2.659e+03
p1 7840 ± 6.6
p2 120.7 ± 3.0
p3 0.122 ± 0.034
E [MIP]
×10³

Performances

No Leakage correction applied

Large after Rel.Gain.Cal.
Small after Rel.Gain.Cal.
Large before Rel.Gain.Cal.
Small before Rel.Gain.Cal.



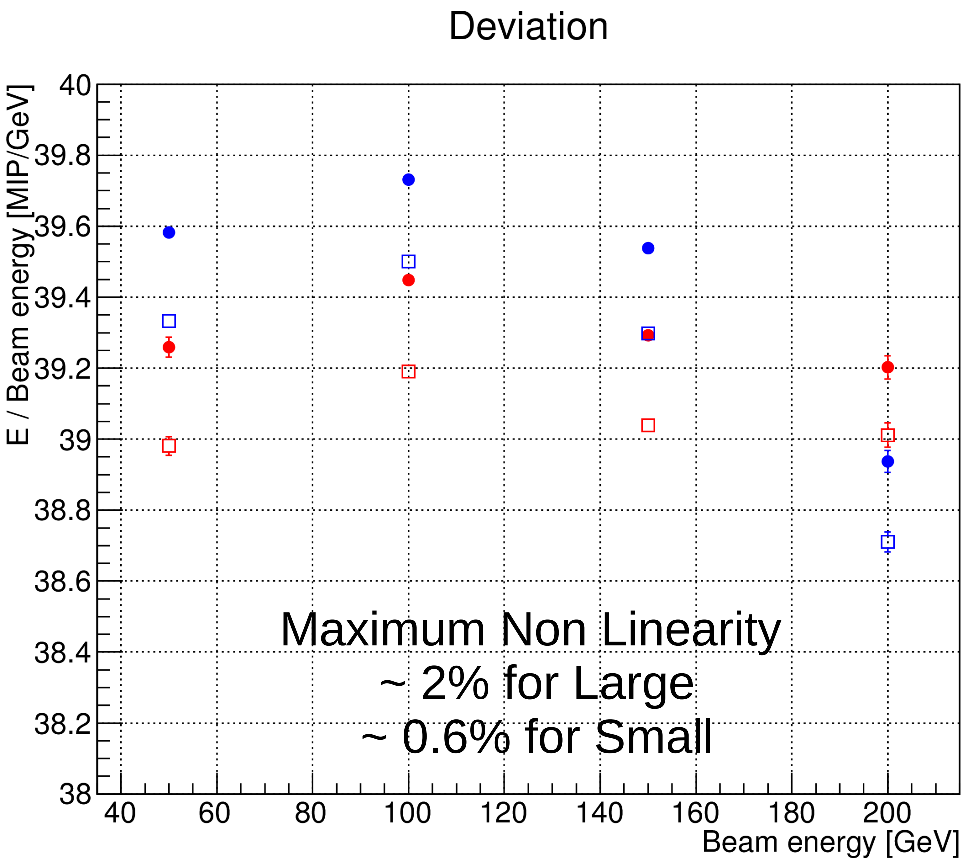


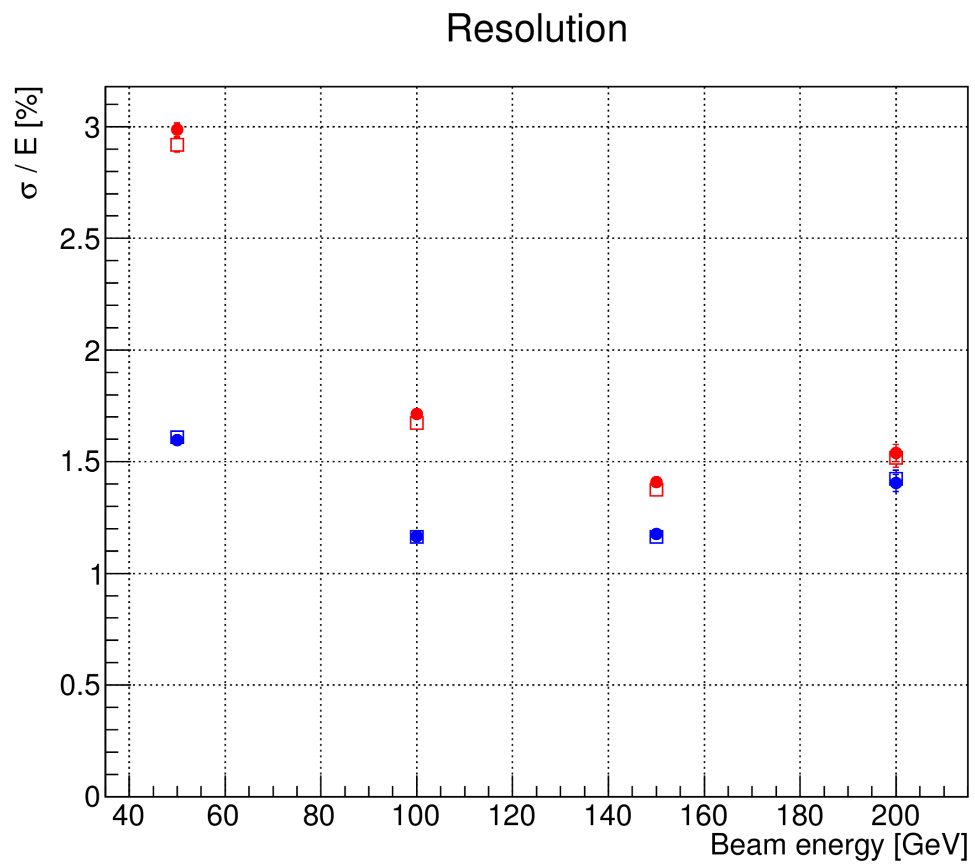
There is no improvement after Relative Gain Calibration because of the basic assumption to neglect differences in the direct ionization in PDs
With available data, we can not calibrate column 3 better than this, unless we make use of full detector simulations

Performances

Leakage corrections applied

Large after Rel.Gain.Cal.
Small after Rel.Gain.Cal.
Large before Rel.Gain.Cal.
Small before Rel.Gain.Cal.





<u>Leakage correction</u> improves both linearity and resolution in case of <u>200 GeV beam</u>.
This is reasonable because, as observed, the beam is outside the center of the cube (linearity) and is spread on a large surface (resolution)

Summary

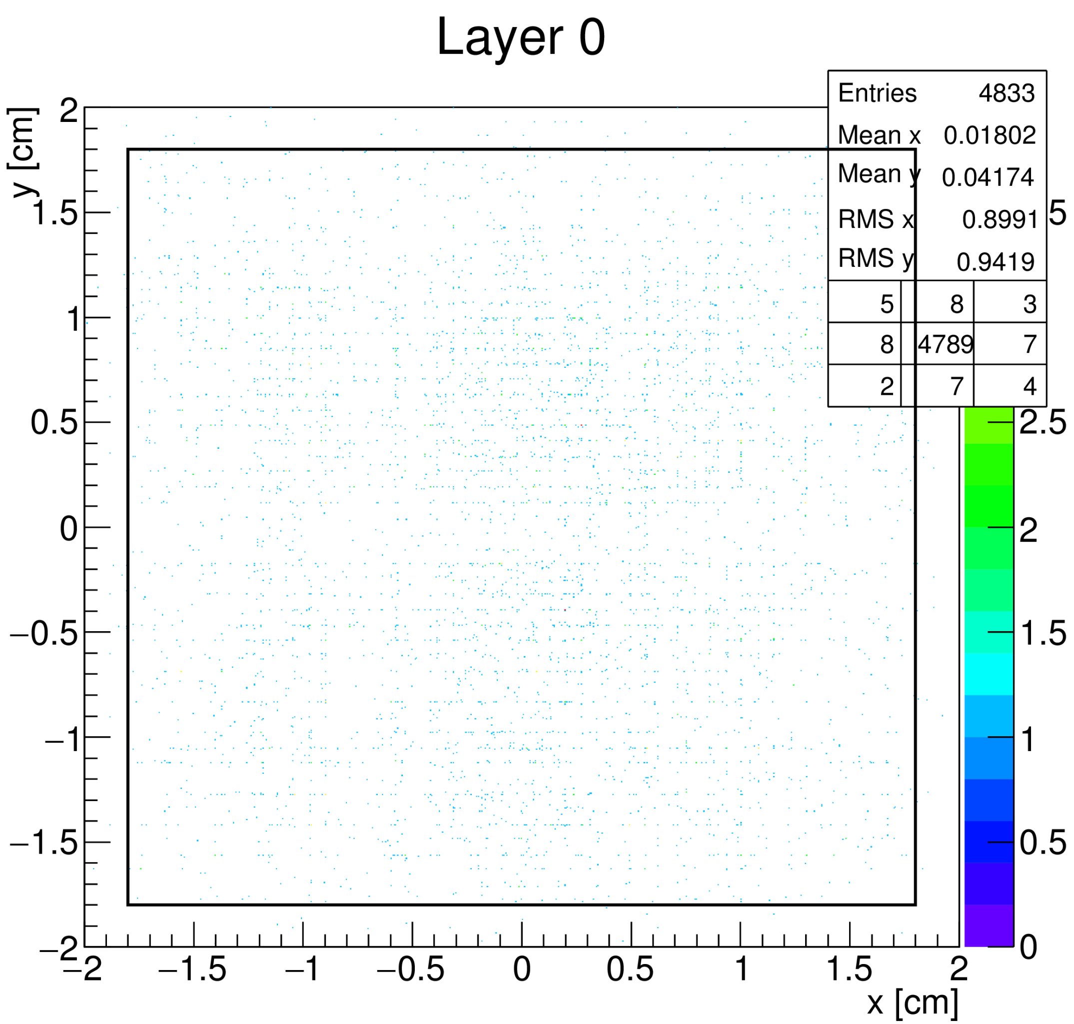
- Tracker information is very useful to compute the calibration factors and study the performances of the prototype
- It is not possible to calibrate all cubes relevant for electromagnetic shower without simulations
  - Next beam test is very important to acquire enough statistics with muons in order to calibrate all prototype
- Shower leakage is less than 3% for the electron beams configuration acquired in last beam test
- Performances at 200 GeV benefit by the application of leakage correction

<u>What to do next</u>

- Study the variation of the performances in very small position bins
- Study the performances for hadronic showers using 50-300 GeV hadrons beam acquired in last beam Test

Back Up

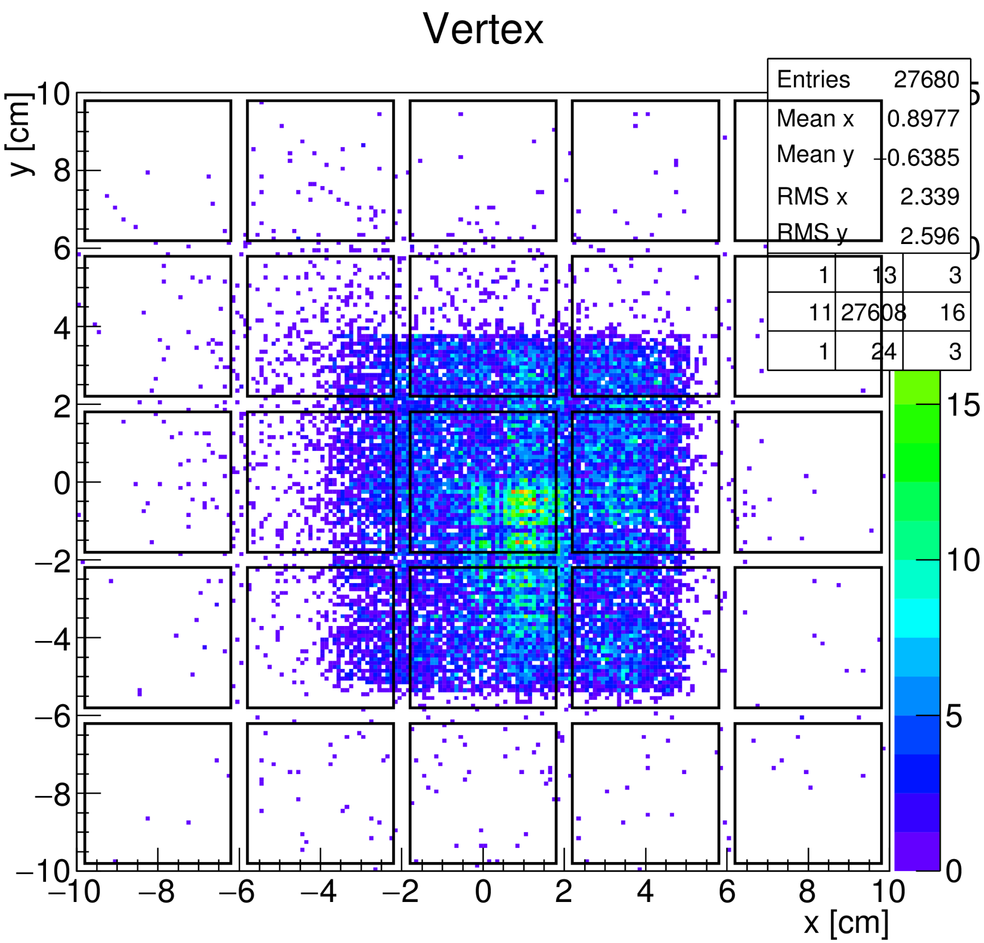
Tracker resolution



The distance between tracks shows discrete steps of almost 1 mm

This distance seems consistence with tracker pitch (0.75 mm)

Using Tracker information
Muon beam



Event selection

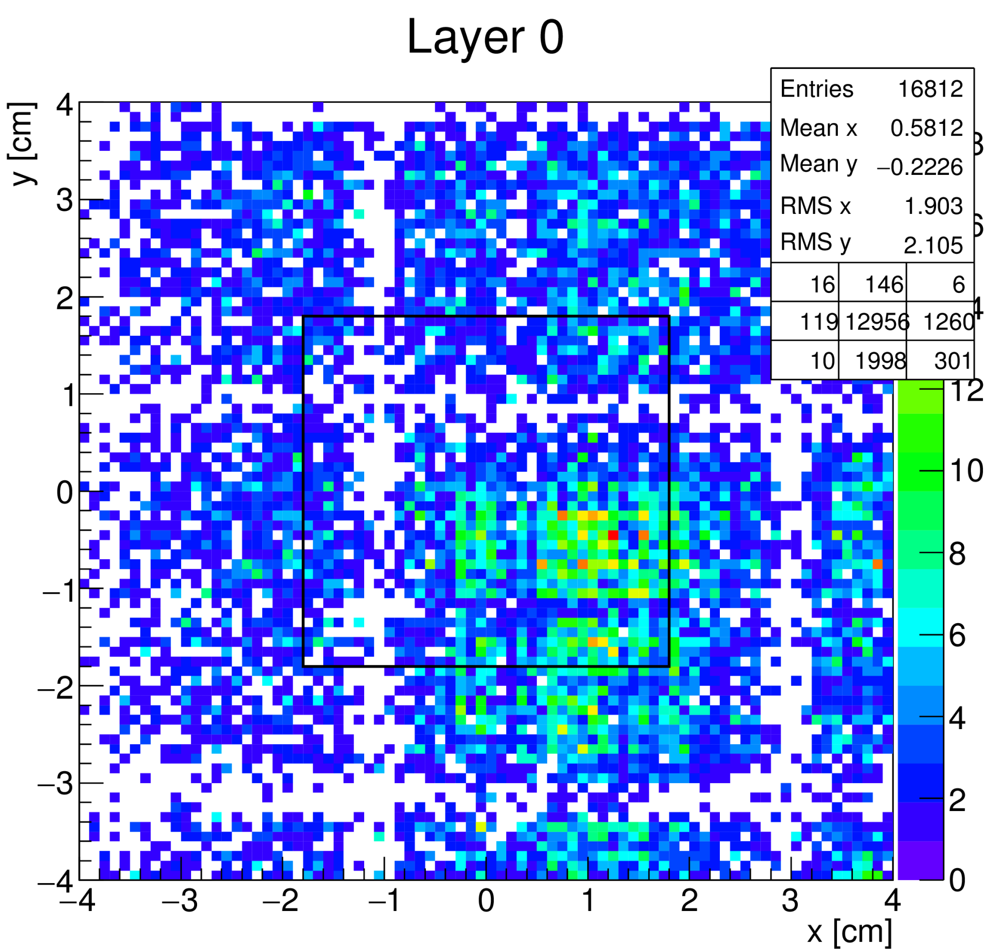
<u>Main selection</u>
fBTfitflag = 3
fBTtracksX(Y) = 0, 1

<u>... not strict condition</u>
fChi2X(Y)/NdofX(Y) < 1

<u>... always true if fBTfitflag = 3</u>
fNpointX(Y) = 5
fNdofX(Y) = 3

<u>.. always true with e, m or p beam</u>
finteraction = 0, 1

Calocube position
Muon beam



Event selection

Main selection
fBTfitflag = 3
fBTtracksX(Y) = 0, 1

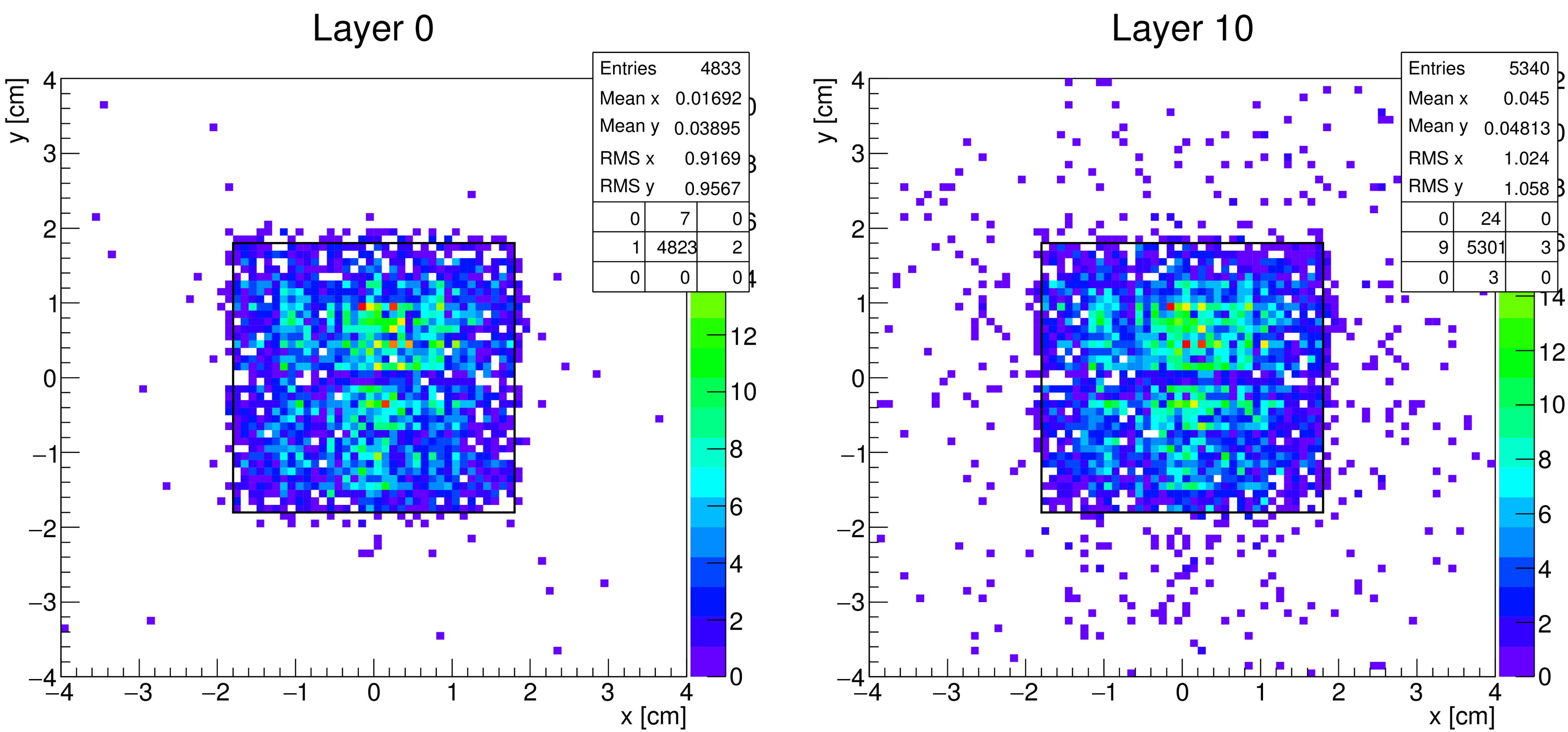
... not strict condition
fChi2X(Y)/NdofX(Y) < 1

... always true if fBTfitflag = 3
fNpointX(Y) = 5
fNdofX(Y) = 3

.. always true with e, m or p beam
finteraction = 0, 1

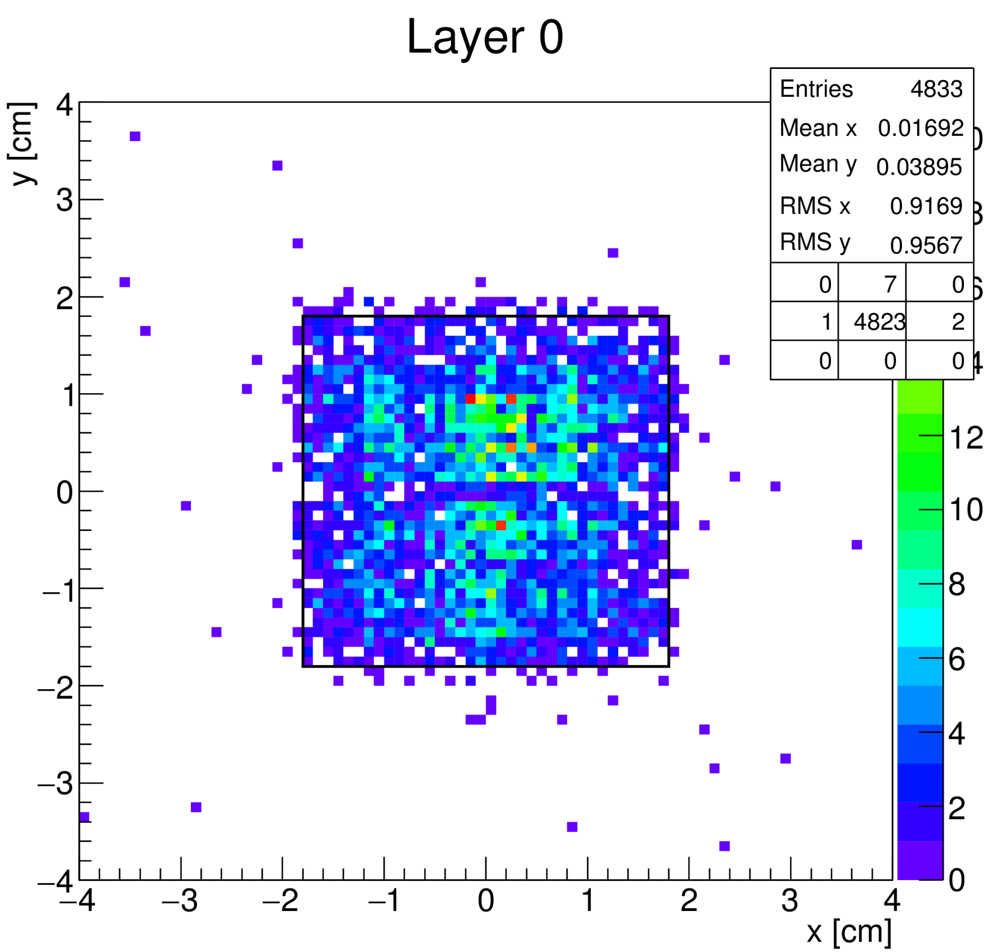
cube > 1 MIP

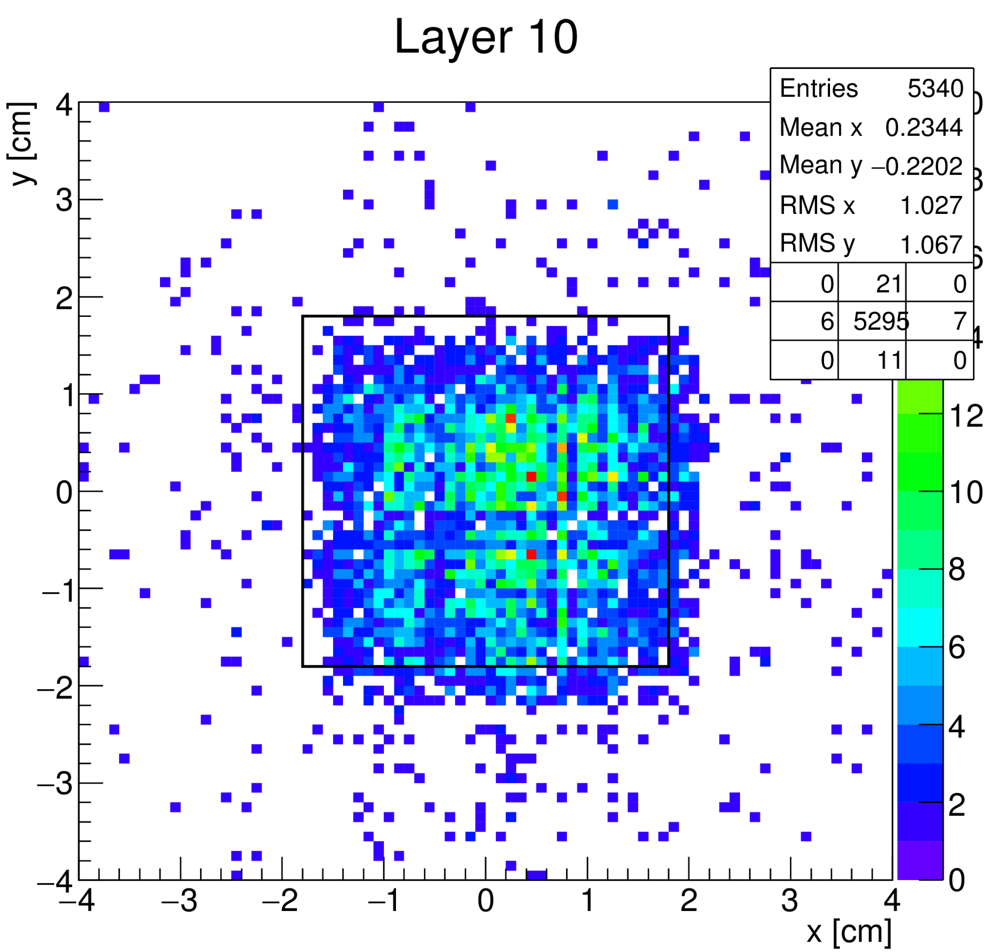
Using the projected position on Calocube first layer for all layers



No apparent tilt of the detector if we use for all layers the projected position on the first Calocube layer

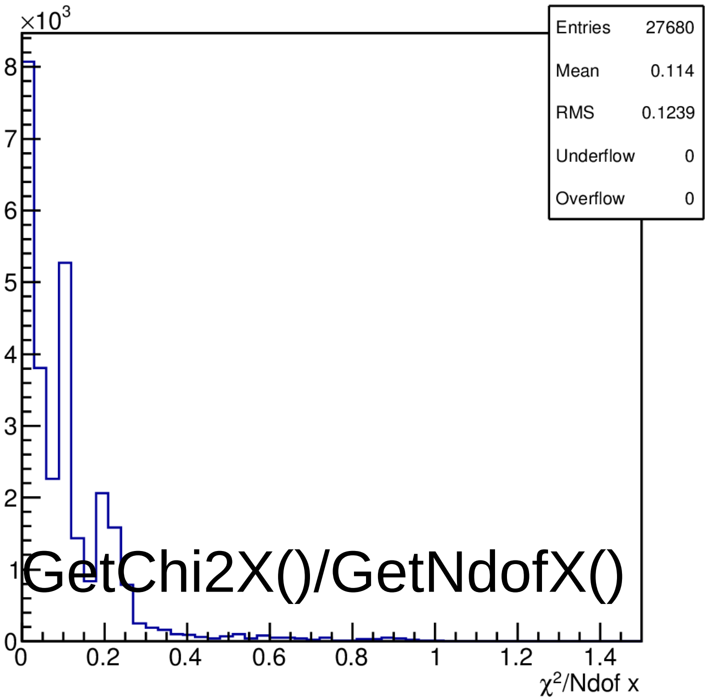
Using for each Calocube layer the projected position on each layer itself

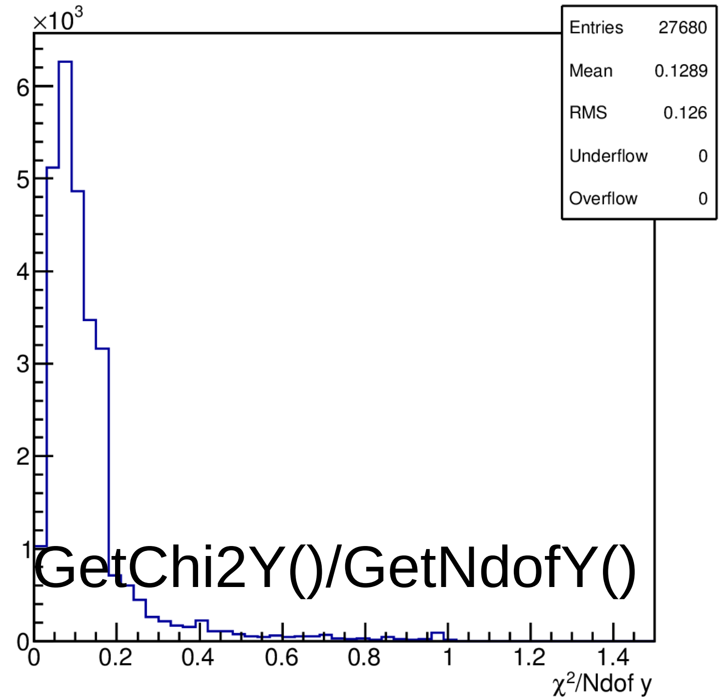


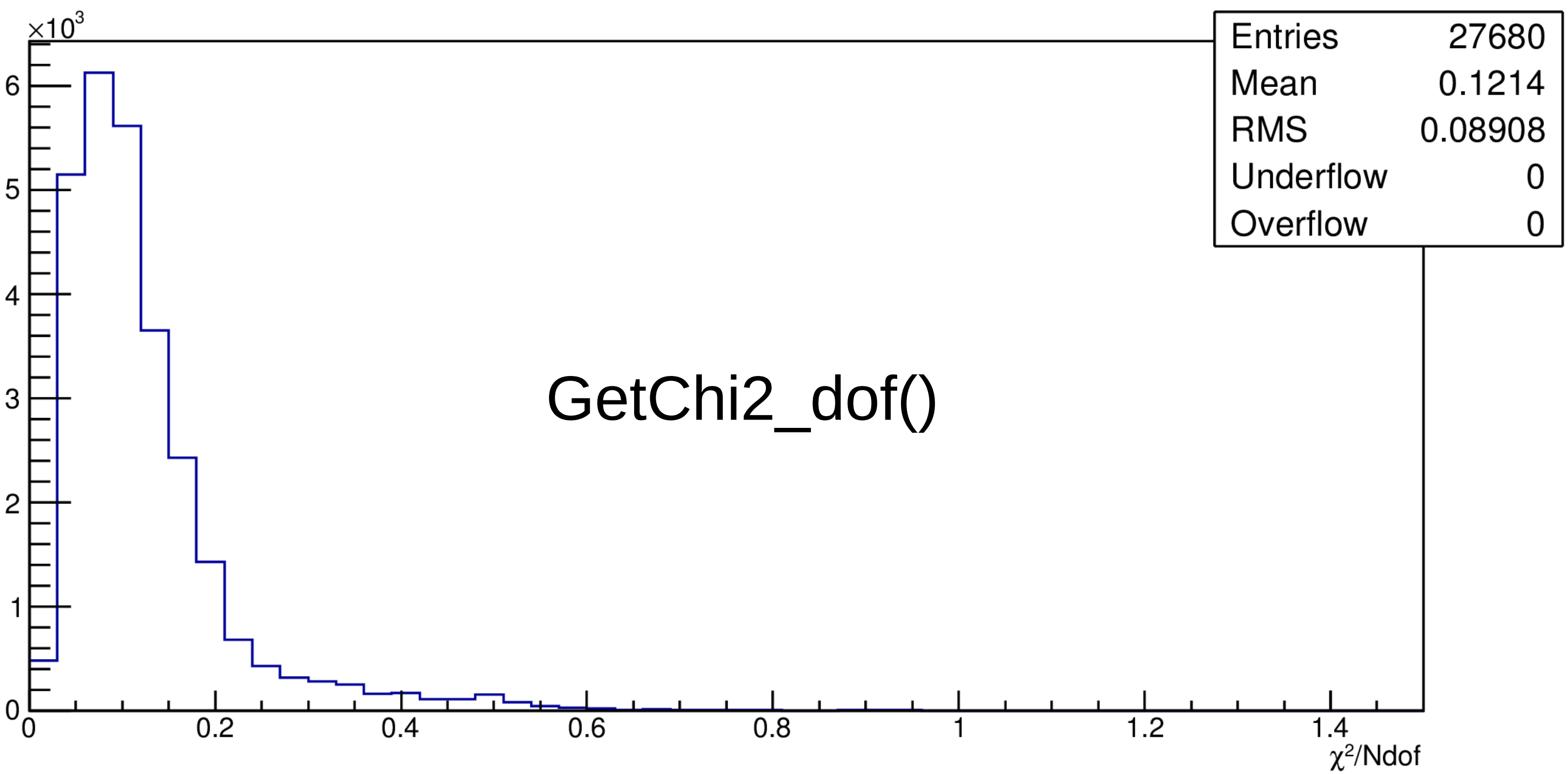


A **tilt** of the detector is found if we for each layer we use the projected position on the layer itself

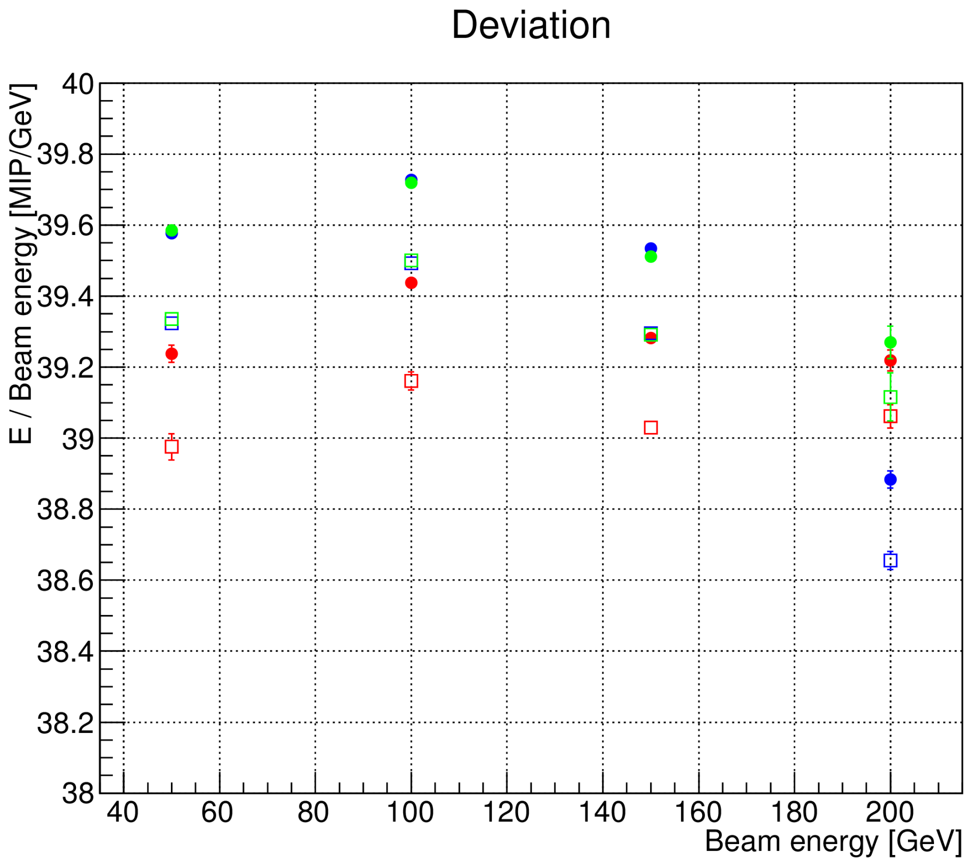
Reduced χ^2 from DirFit

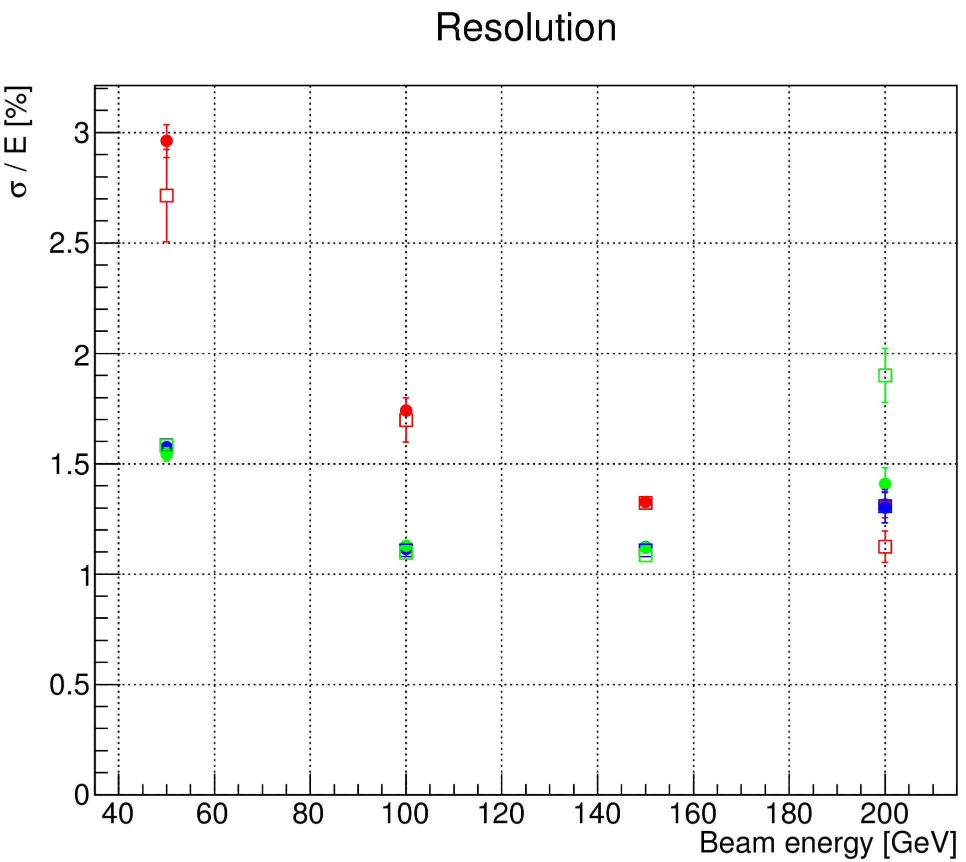




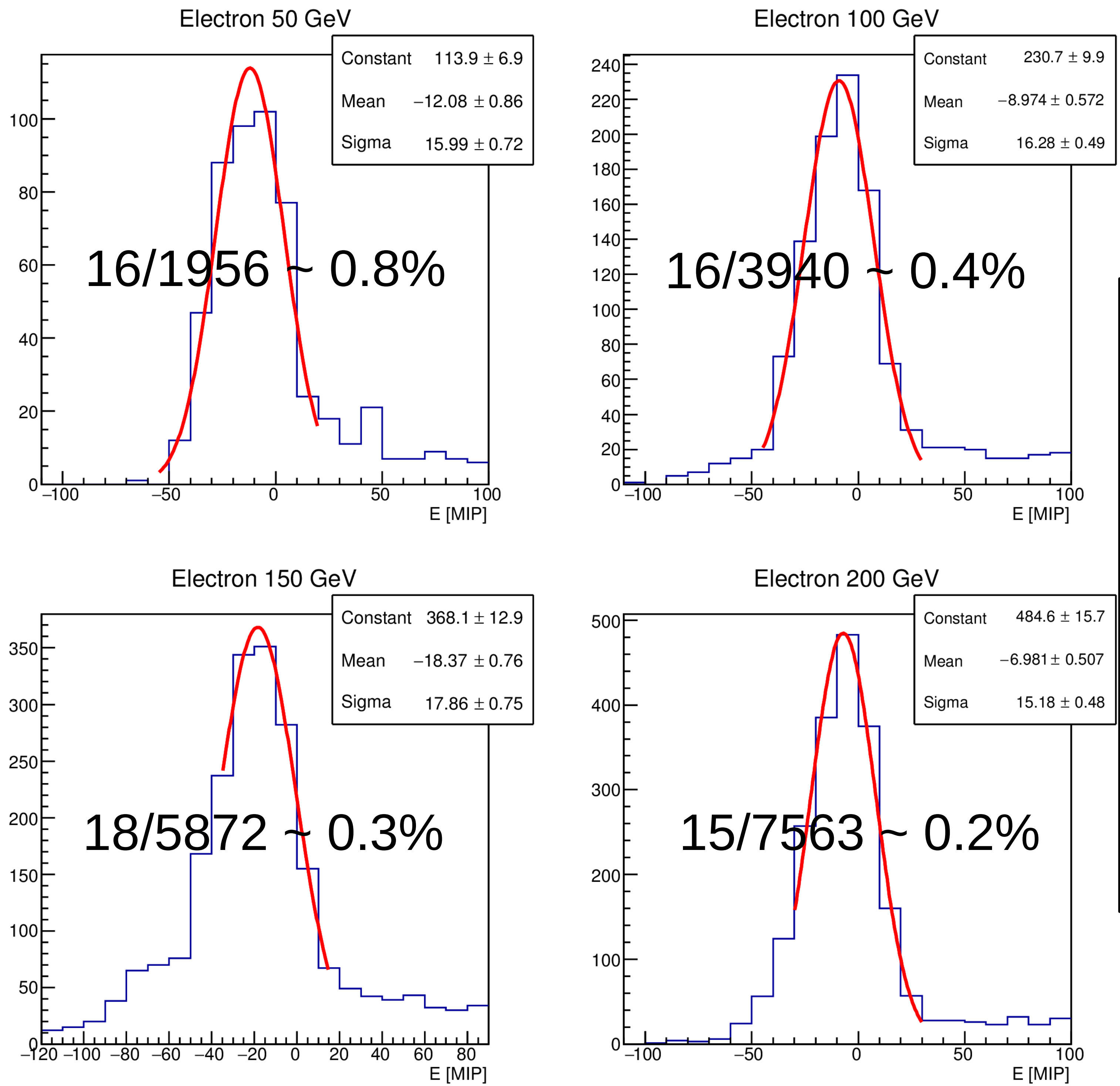


Performances with Gauss fit



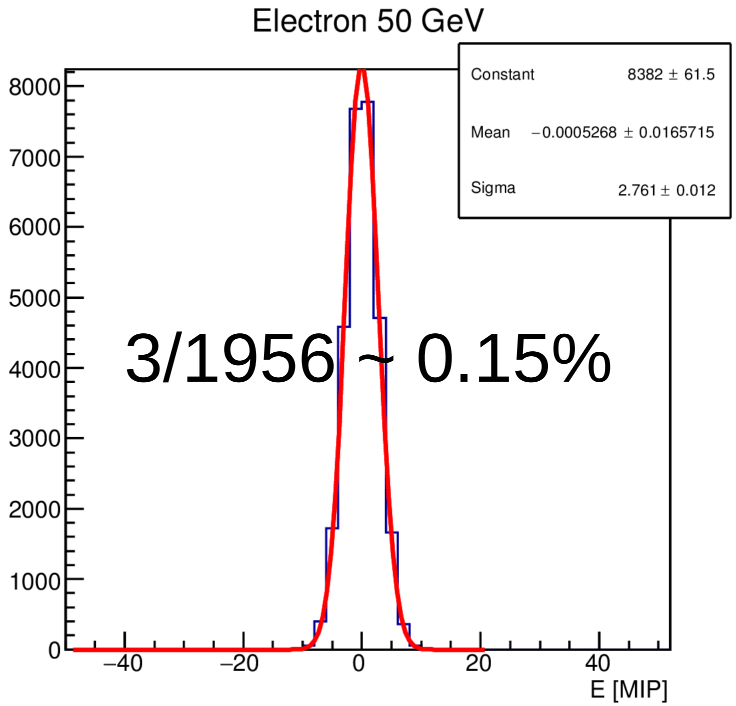


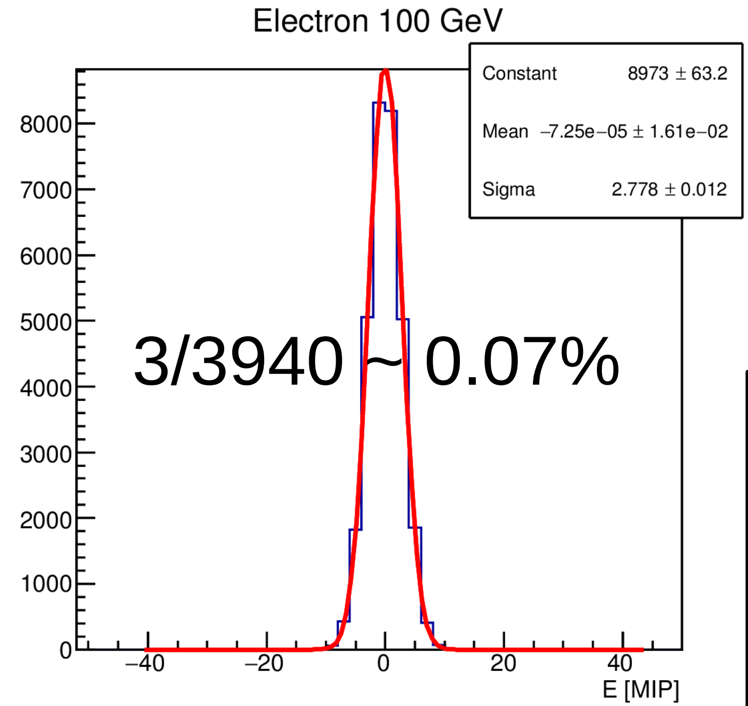
Pileup Large PD

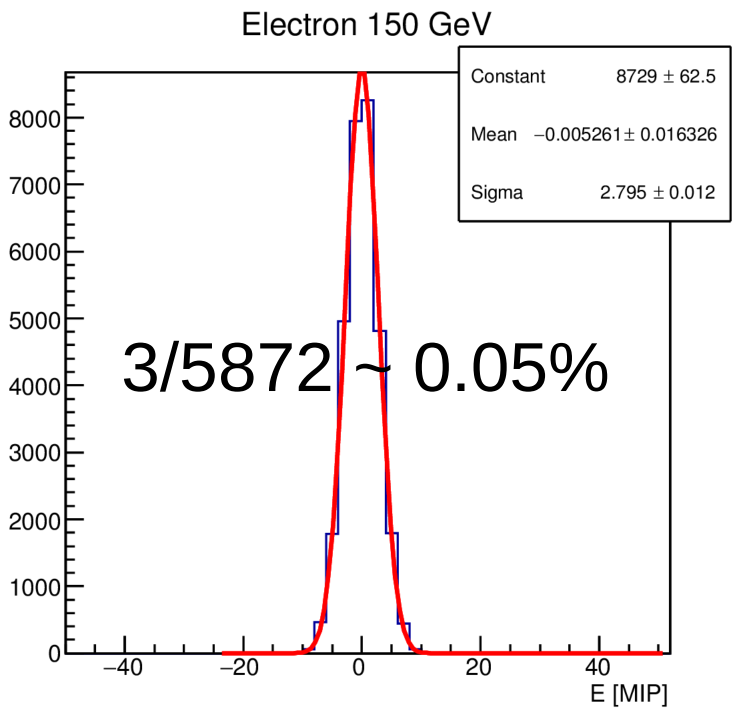


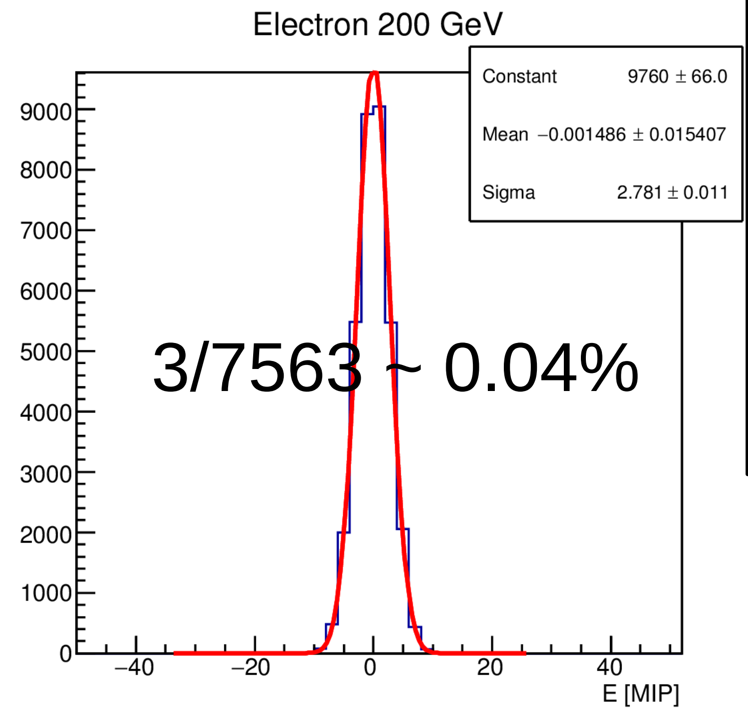
sumdE of Large sensors for **beam events** having a signal in crystal with maximum energy deposit (layer 3 cube 12) less than 250 ADC

Pileup Large PD



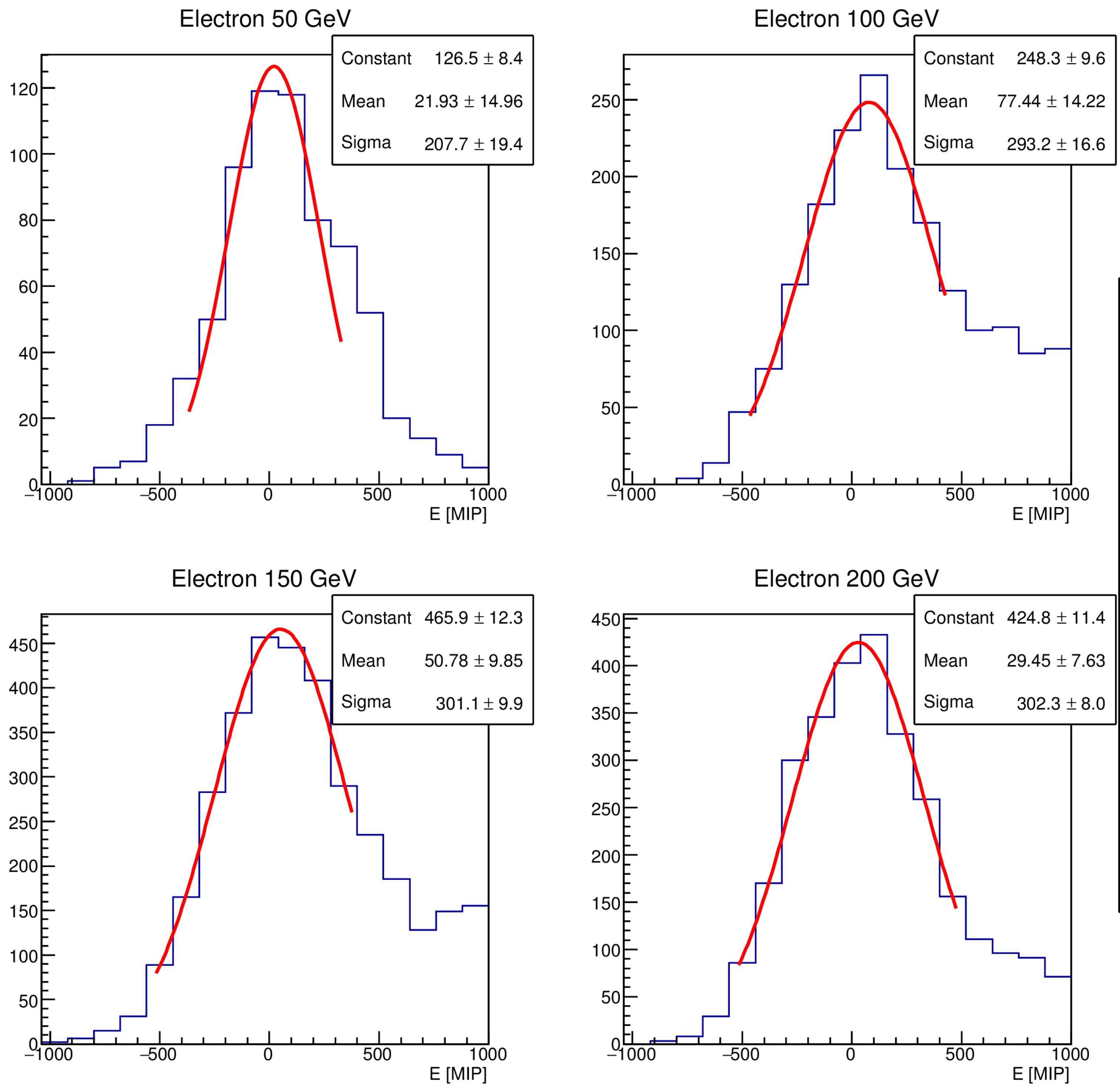




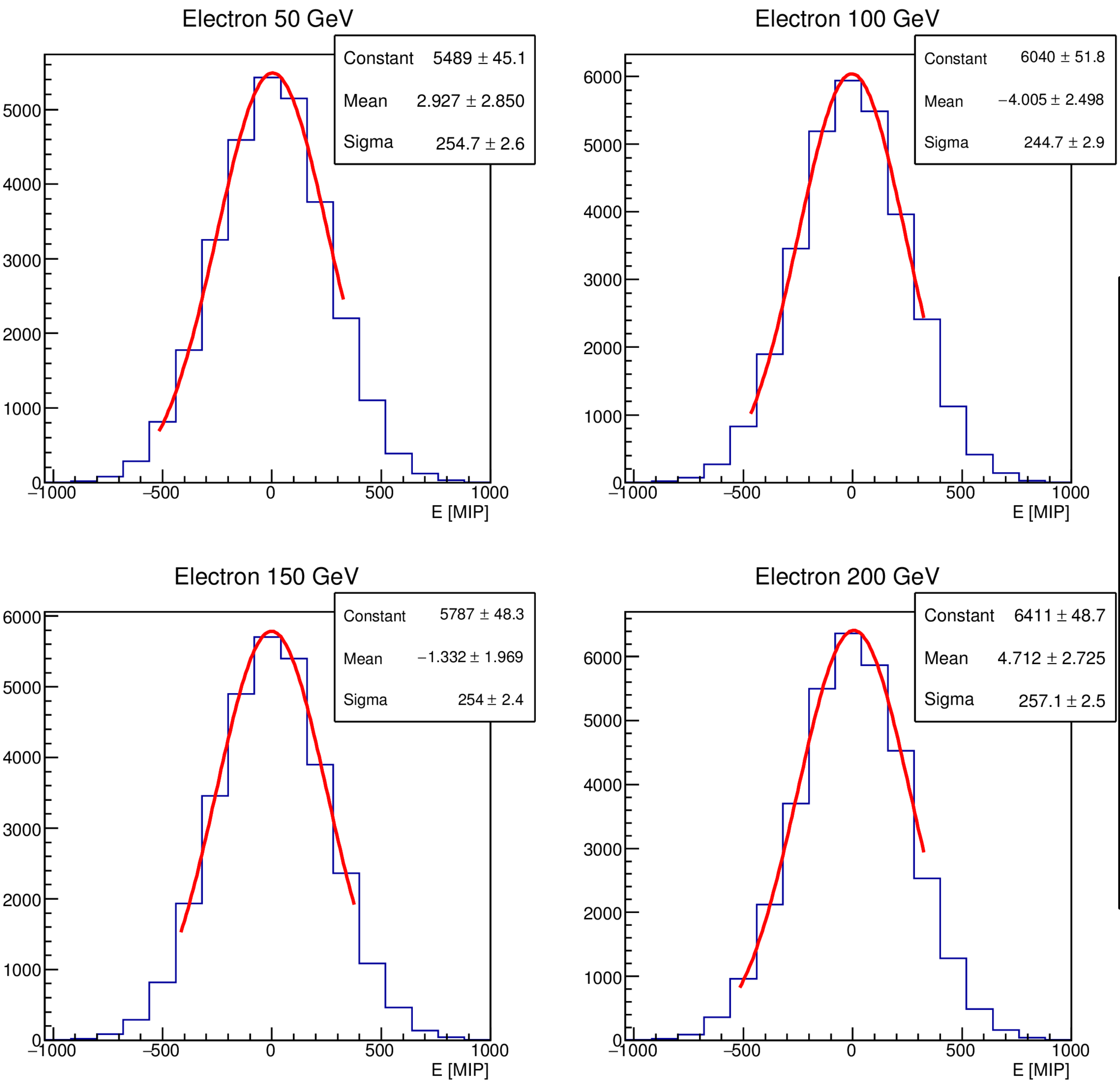


sumdE of Large sensors for **pedestal events** having a signal in crystal with maximum energy deposit (layer 3 cube 12) less than 250 ADC

Pileup Small PD



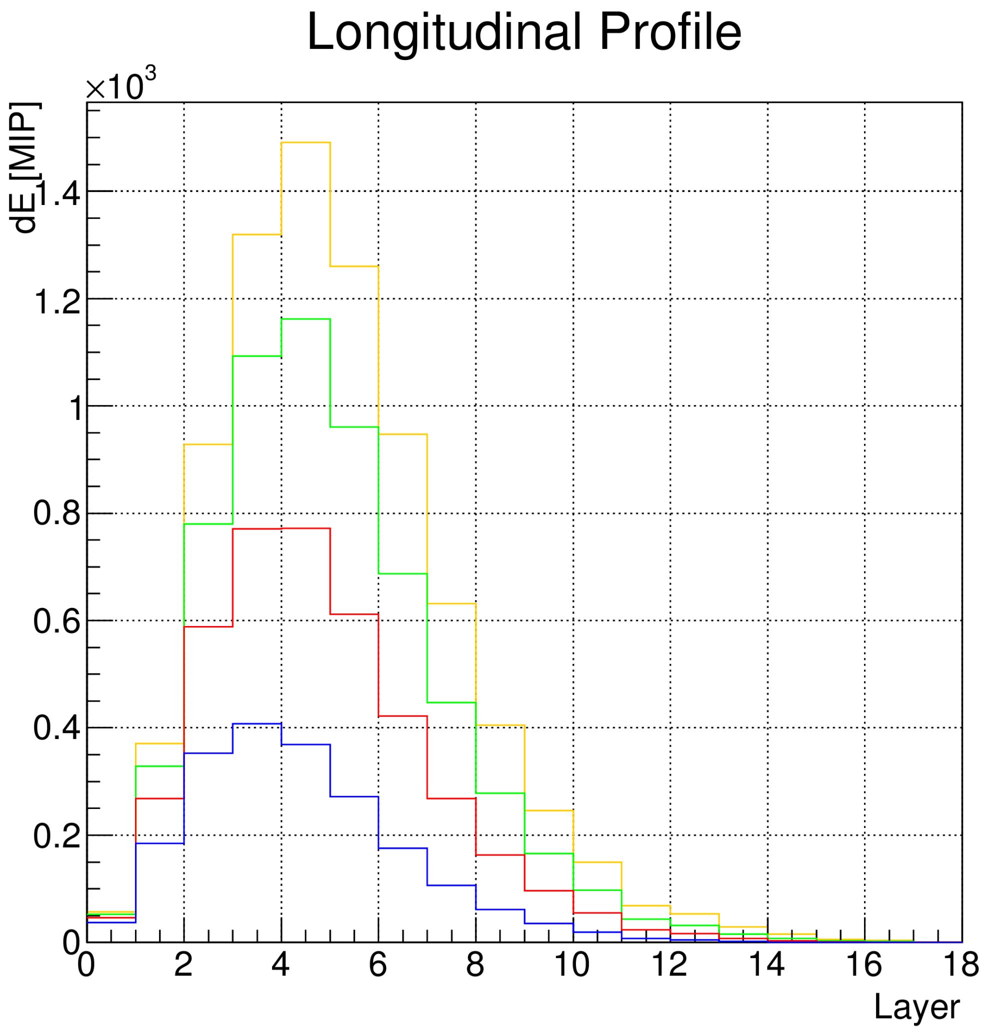
sumdE of Large sensors for **beam events** having a signal in crystal with maximum energy deposit (layer 3 cube 12) less than 250 ADC



Pileup Small PD

sumdE of Large sensors for **pedestal events** having a signal in crystal with maximum energy deposit (layer 3 cube 12) less than 250 ADC

Longitudinal Profile



Maximum signal is on layer:
- 3 for E = 50,100 GeV
- 4 for E = 150, 200 GeV