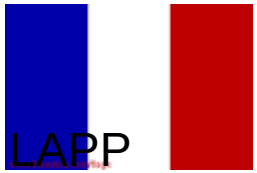

IHEP


LAPP


INFN Pisa

A 3D imaging calorimeter for AMS

Resolution, Linearity, X0 With Test Beam Data

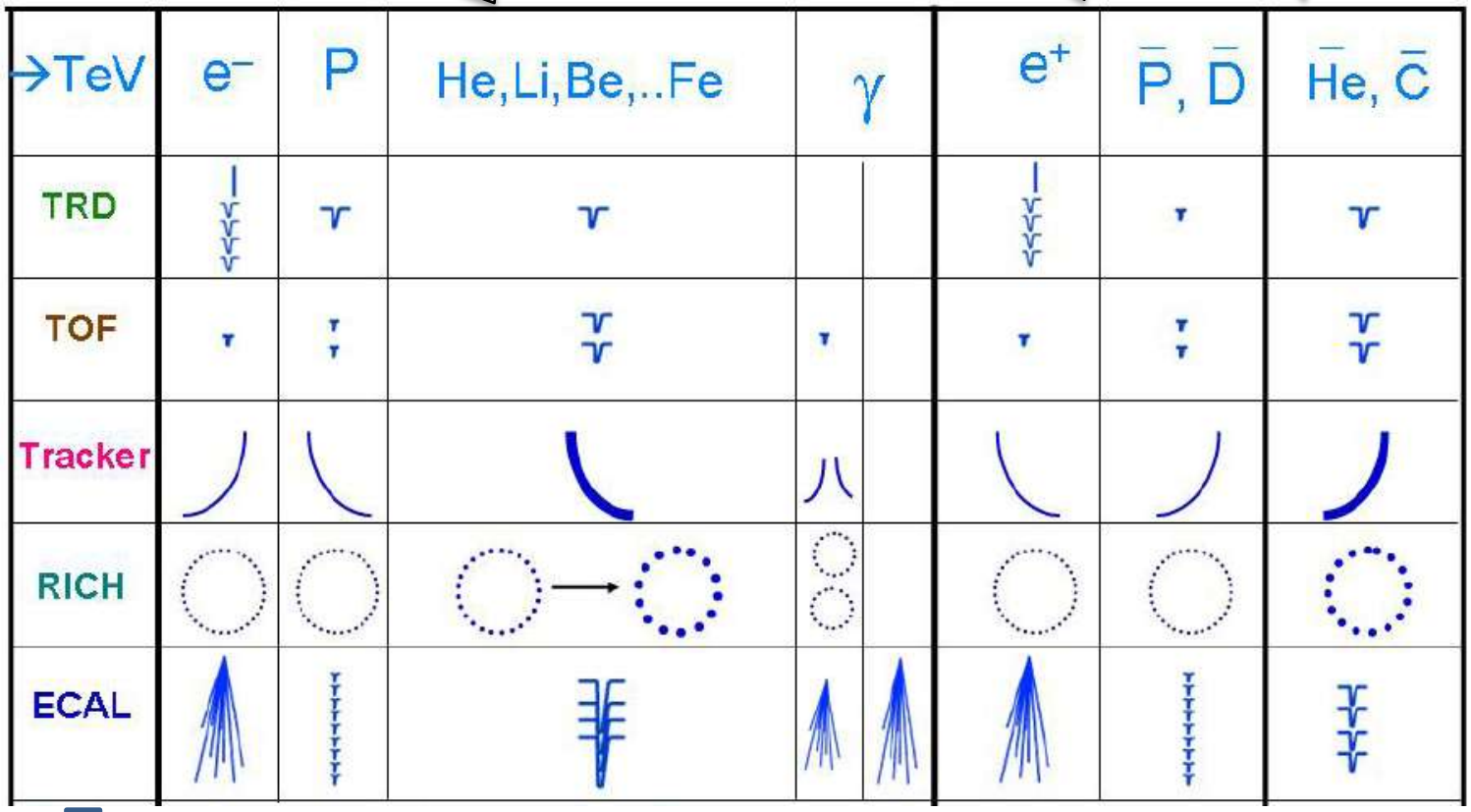
Corinne Goy on behalf of the Ecal Group
LAPP/IN2P3/CNRS/UdS

Physics of AMS on ISS

Cosmic Ray Physics
Gev – TeV range

Annihilation products
of Dark Matter

Primordial
AntiMatter ?



e/h

Trigger/
Direction

P, Nuclei

Nuclei

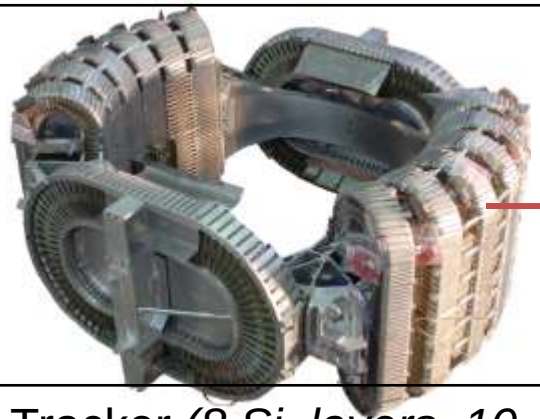
E, e/h,
γTrigger

A Particle Physics_like Detector

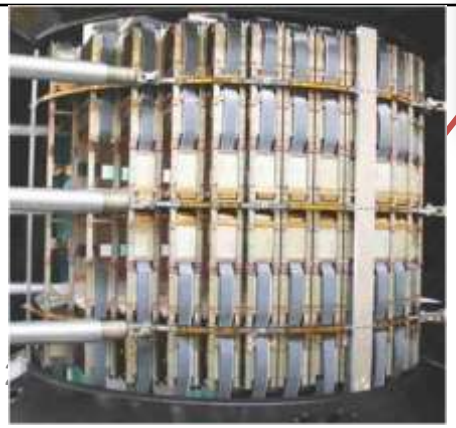
The Completed AMS Detector

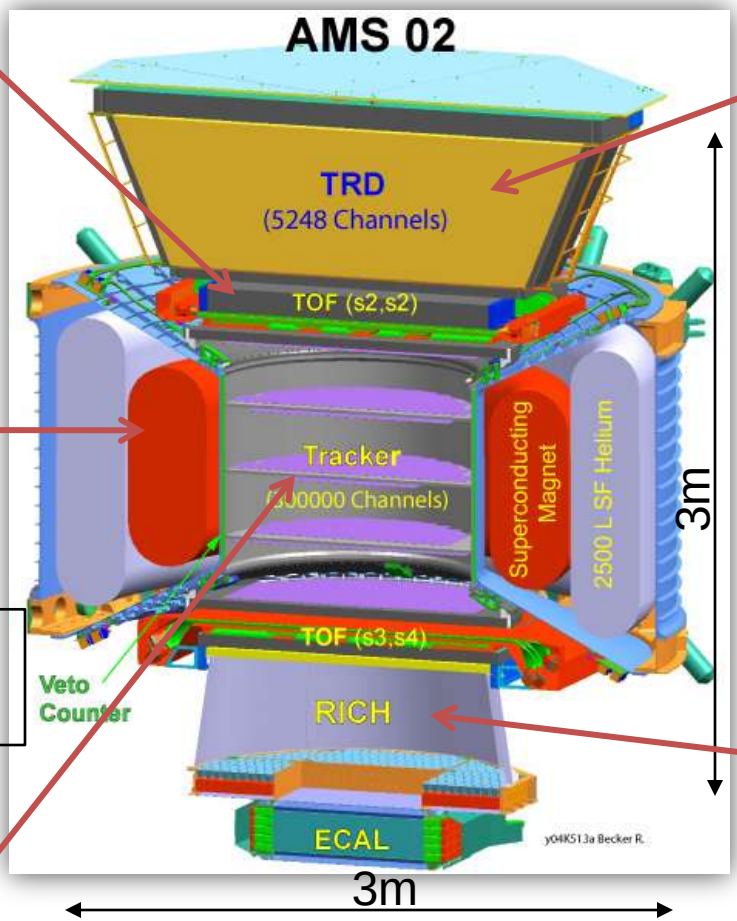
TOF *(plastic scintillators; 130 ps)*

Magnet *(superconducting; 0.86 T)*



Tracker *(8 Si layers, 10 μm)*

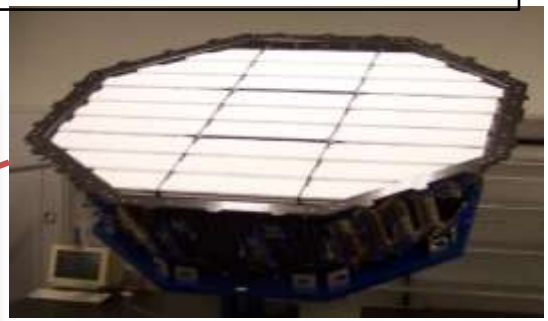




7 tons

Geometrical Acceptance : 0.5 m^2.sr

TRD *(foam + Xe/Co2)*



e/h : 10^{-2} – 10^{-3}

Rich *(NaF 1.33, aerogel 1.05) : $d\beta/\beta = 0.001$*

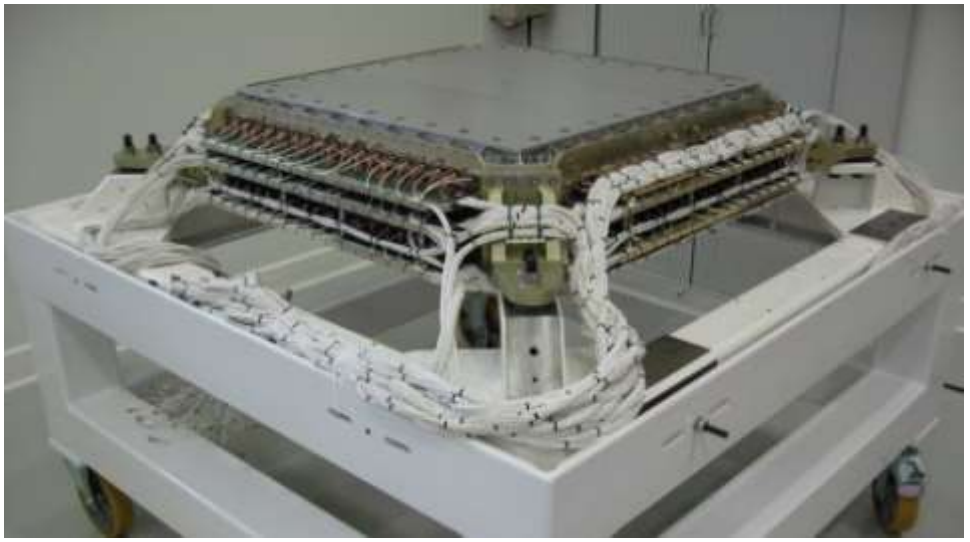
nuclei : Z = 25 (Fe)

isotopes (+tracker): A = 26 (Al)

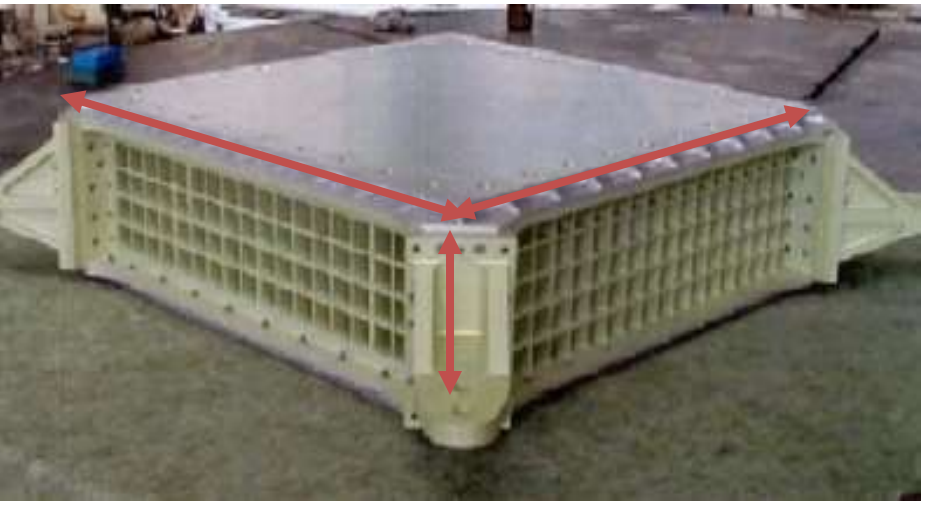
Aims Of ECAL

- Energy measurement :
  - GeV to TeV
  - e+ /e- / γ
- e/h separation (+ tracker) :
  - $10^3 - 10^4$
- Stand Alone γ trigger
- γ identification

The Flight Model equipped with FE electronics

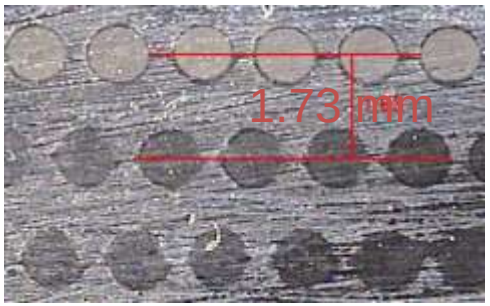


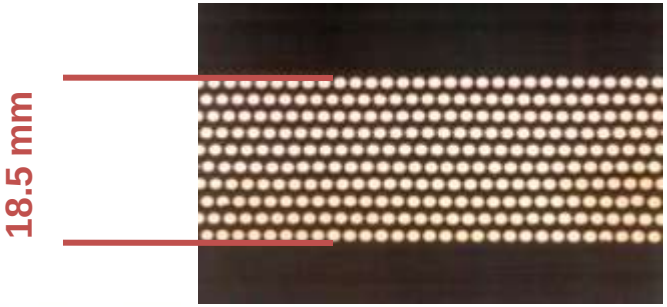
ECAL Structure

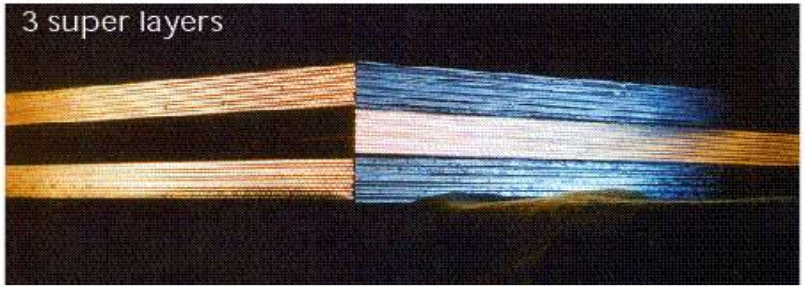


65 * 65 * 18 cm (sensitive volume)

Lead
+Scintillating
Fibers

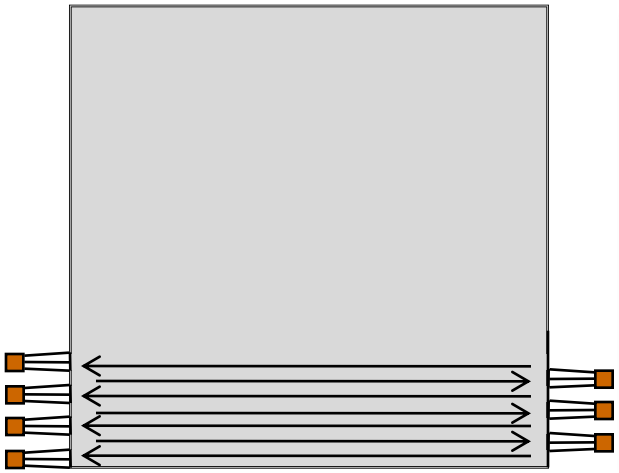


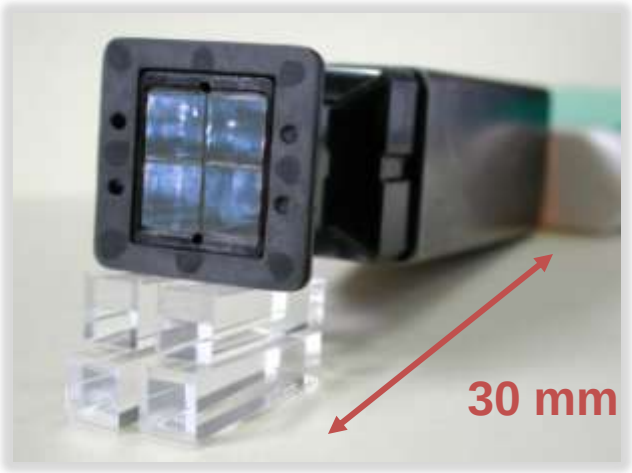




9 super layers in total

ECAL Readout

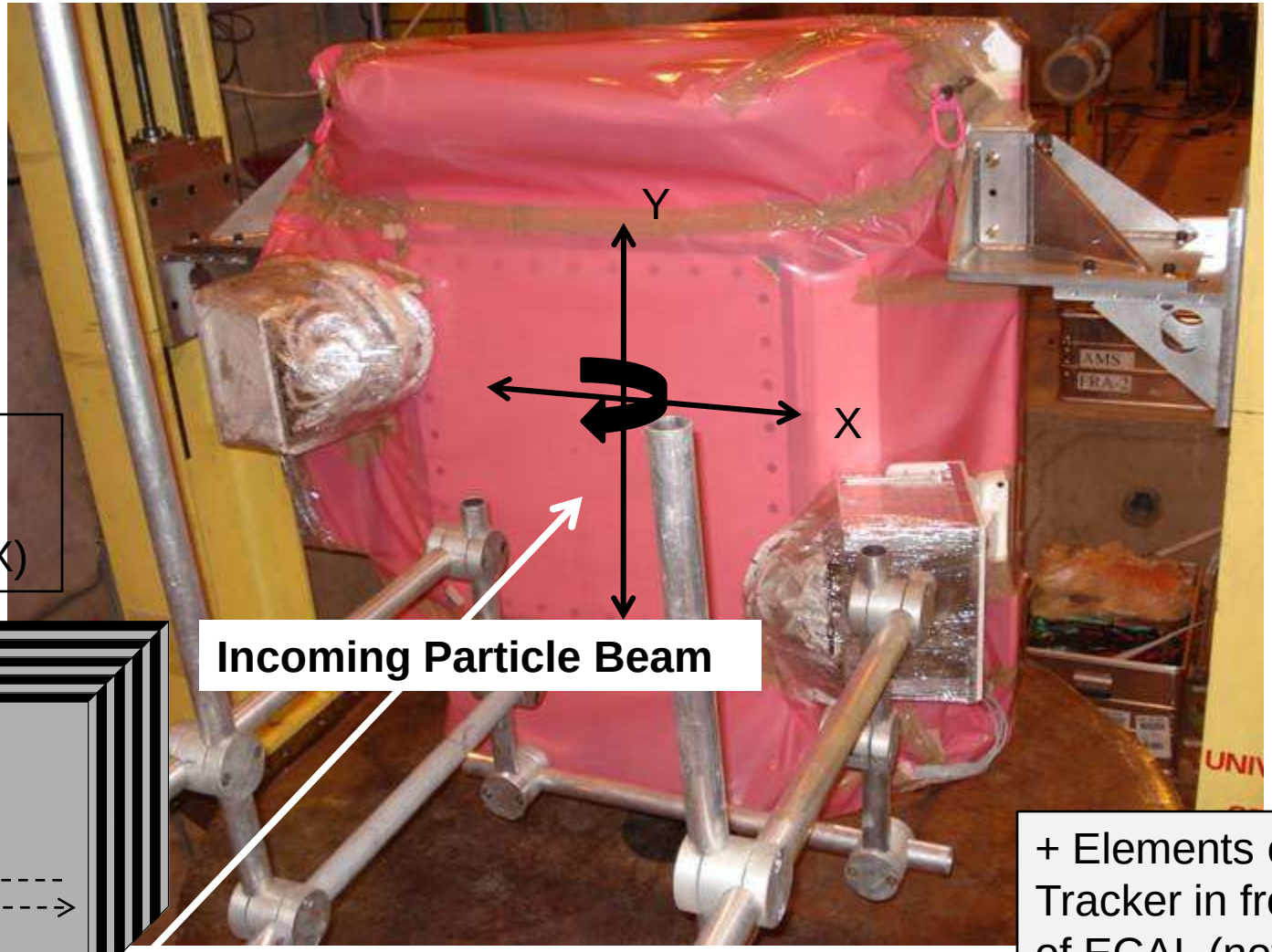




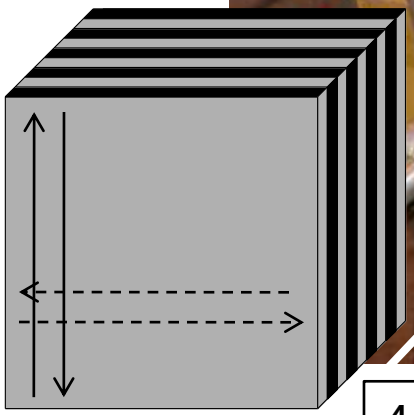
Anodes → Energy
Dynode →Trigger

- Granularity:
  - 324 PMts / 1296 anodes
  - 18 points long. (18 layers)
  - 72 cells (0.5 R_M)
- Dynamics :
  - MIP to TeV
  - 2 gains
- -30°C/ + 50°C

Test Beam Setup (2006-07)



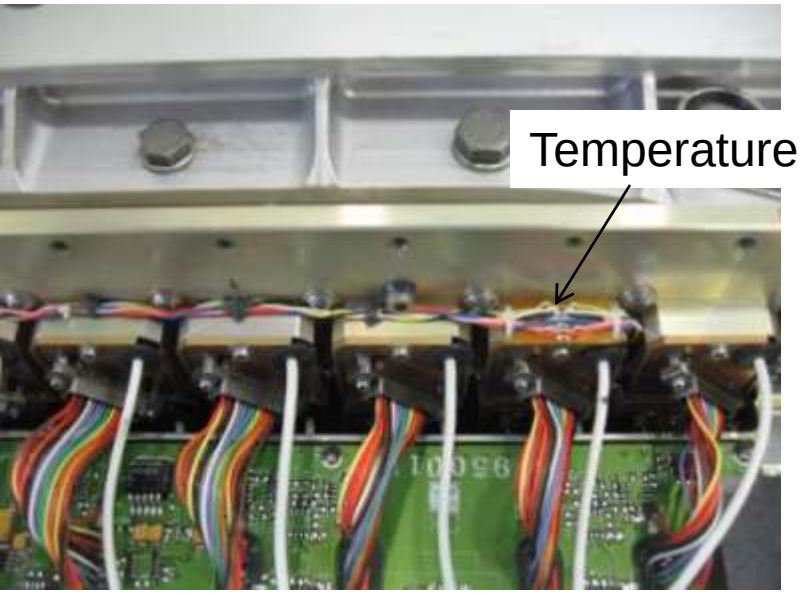
5 layers measure X (energy in X)



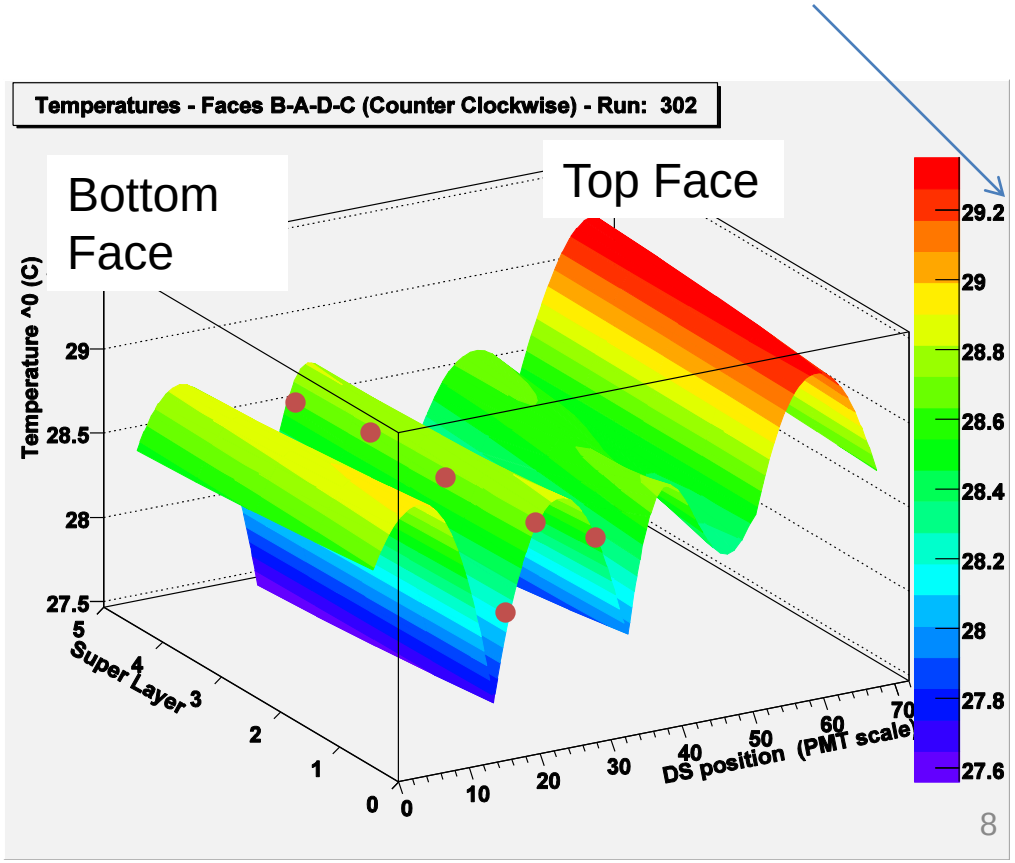
4 layers measure Y (energy in Y)

+ Elements of Tracker in front of ECAL (not shown here)

Slow Control : Temperature

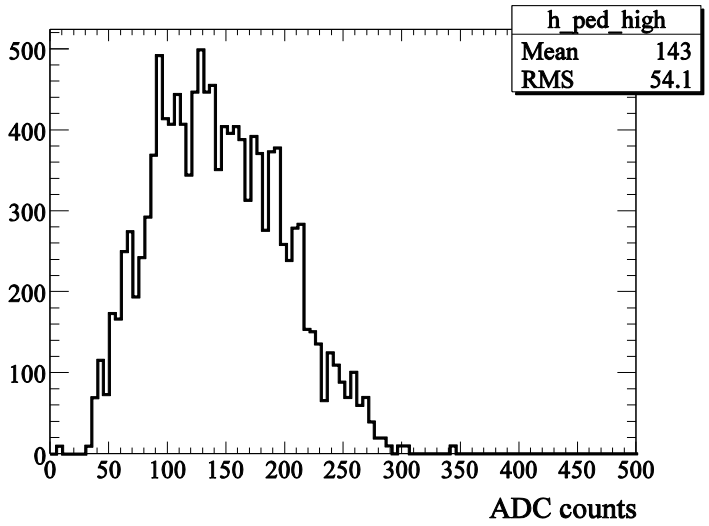


A Signal dependence per channel <0.1% /C can be eventually taken into account.

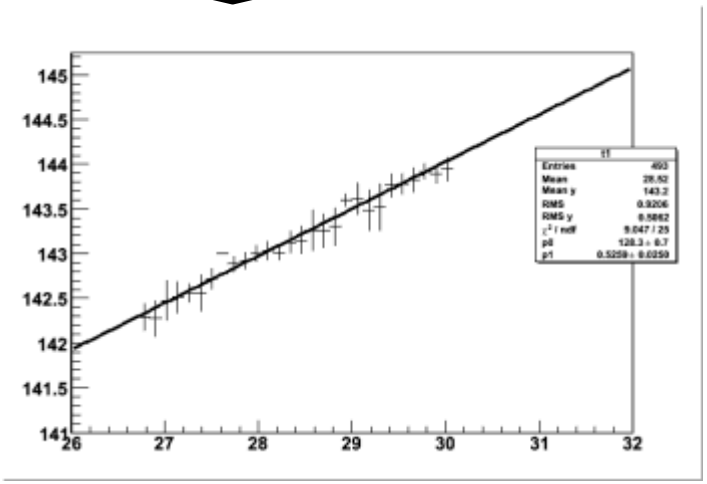


Slow Control : Pedestals

Pedestals' distribution at 25 °C



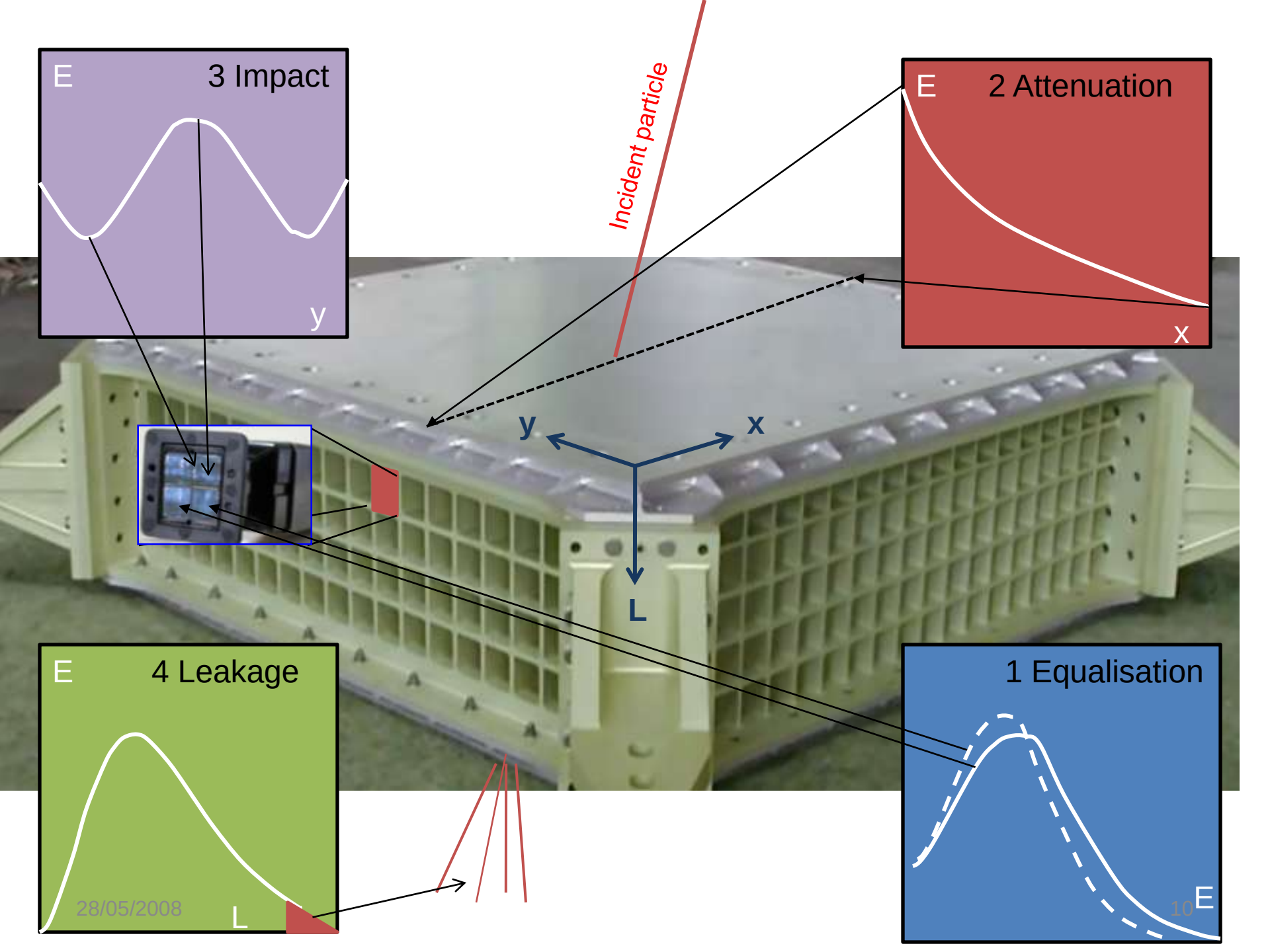
Typical pedestal's dependence with T



T (°C)

0.44 ADC counts/ degrees

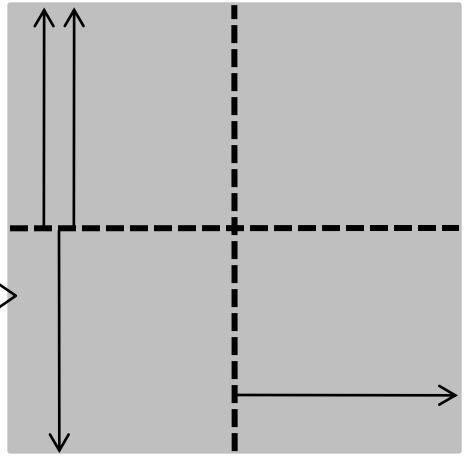
Only 3 Channels (High/Low) with a pedestal at 0 at a temperature of -20 °C.

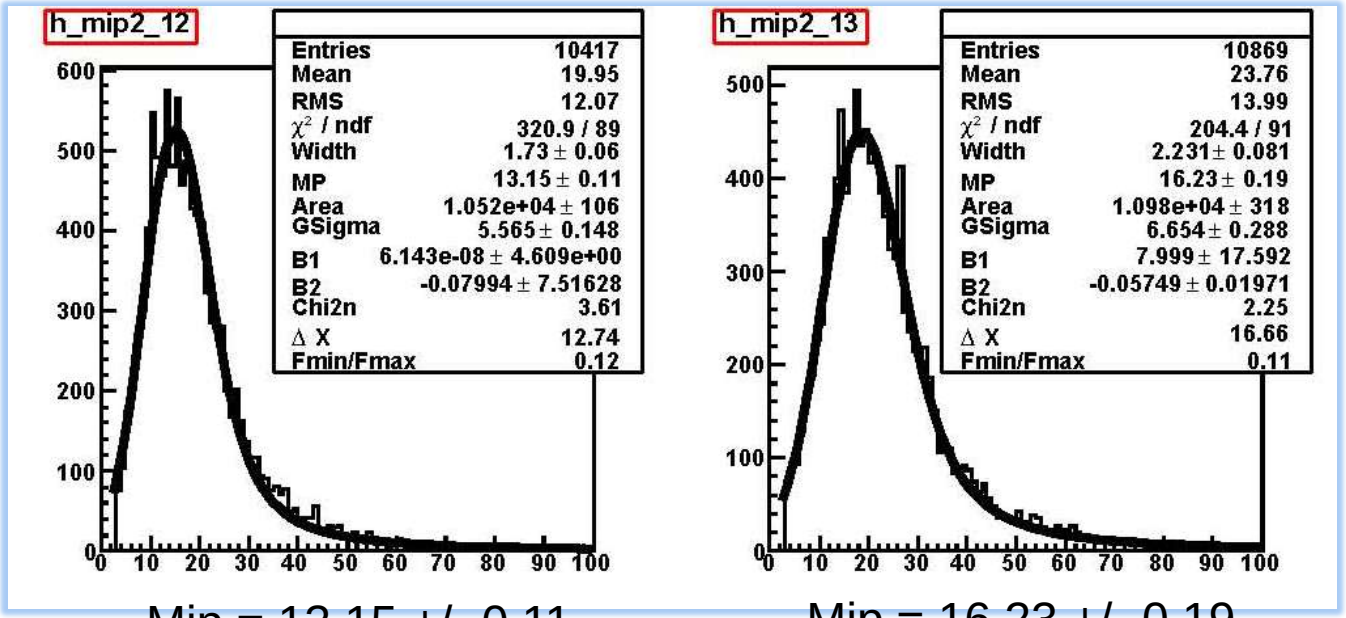

E
3 Impact
y
Incident particle
E
2 Attenuation
x
y
x
L
E
4 Leakage
L
1 Equalisation
E

Equalization

- 100 GeV hadron beam
- MIP signal in each cell
- Landau ⊗ Gauss

Scan along X et Y with a 100 GeV proton beam centered in the middle of the calorimeter.





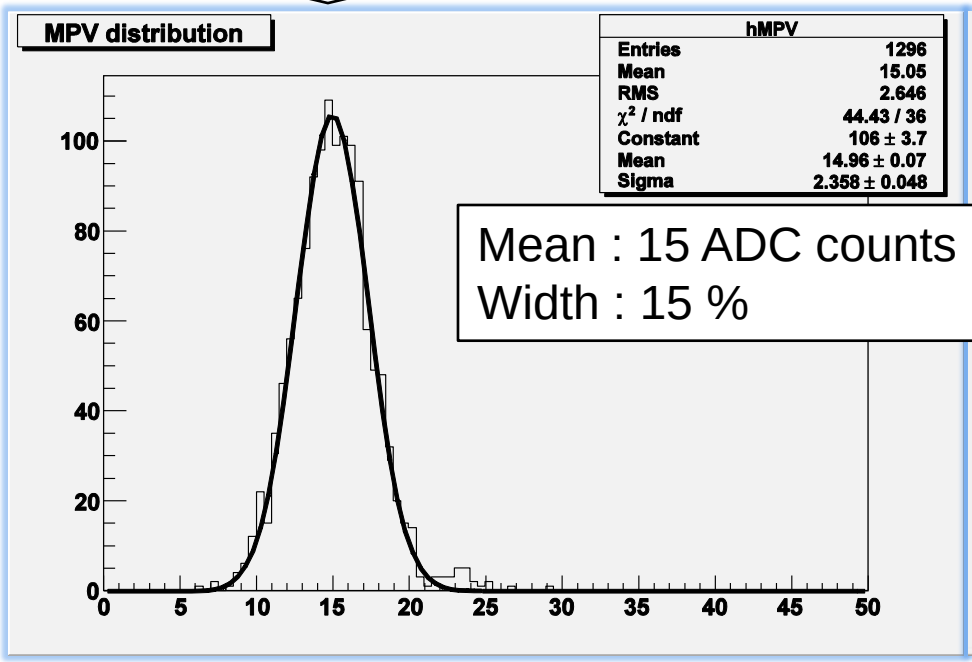
Mip = 13.15 +/- 0.11

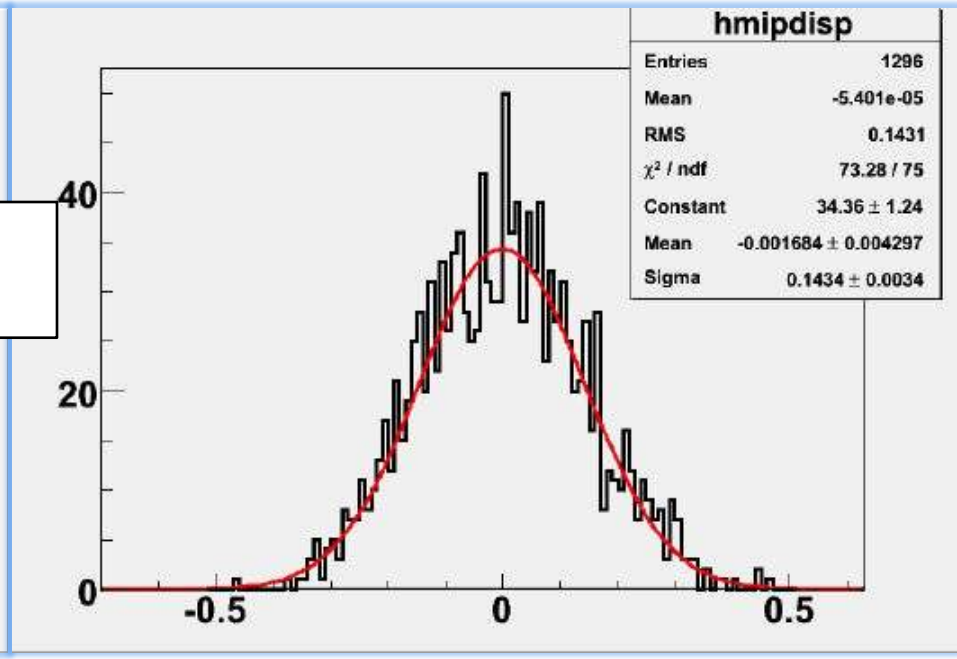
Mip = 16.23 +/- 0.19

Equalization

Distribution of MIP Values during Test Beam (after pre-equalization with cosmic-rays)

Dispersion inside a PMt = 15% consistent with specifications





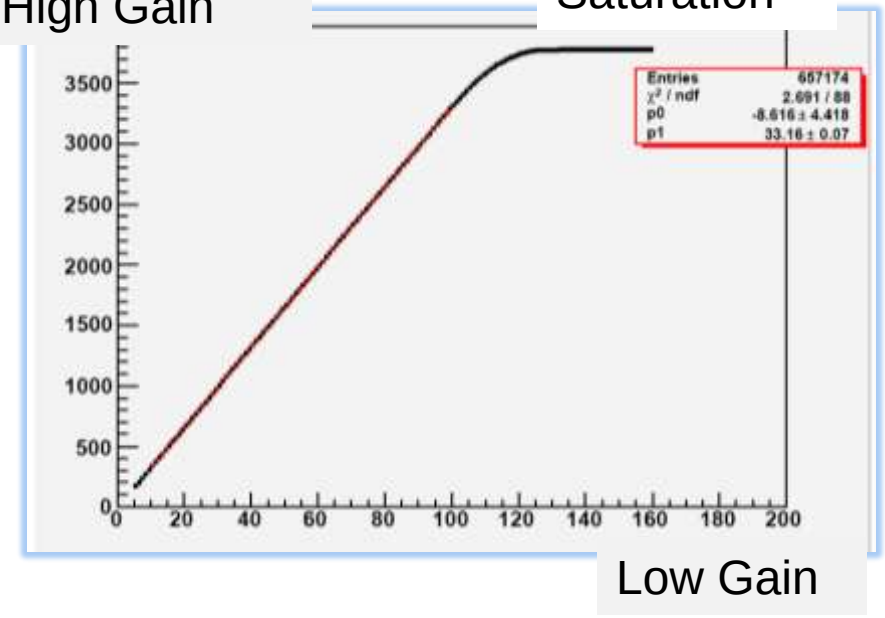
Equalization

High Gain Vs Low Gain

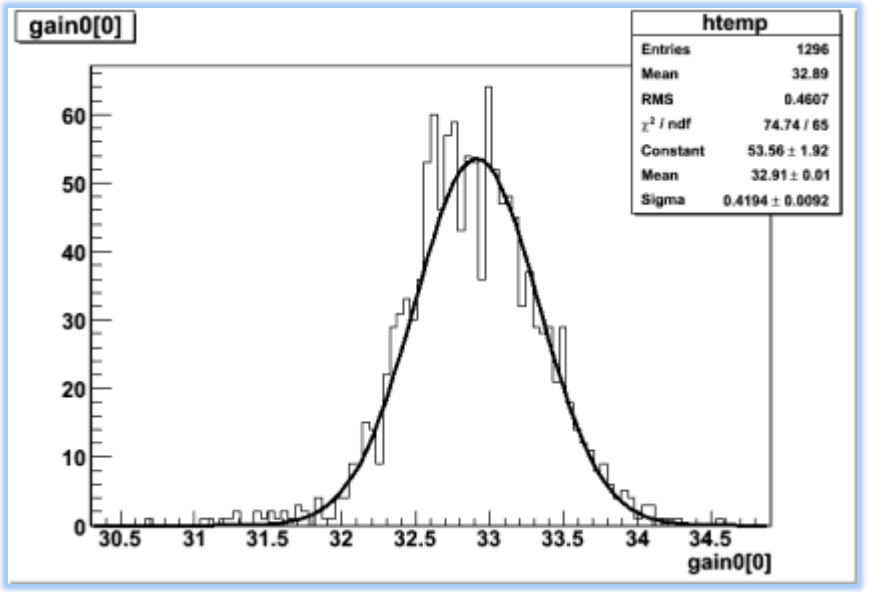
Distribution of Gains

High Gain

Saturation



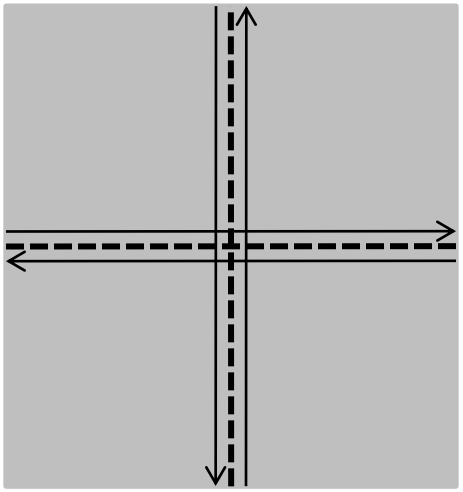
Low Gain



Mean : 33 Sigma: 0.4

Attenuation

- Can be measured on central cells :
  - Mip : all layers
  - Electrons : central layers
    - 10 and 30 GeV



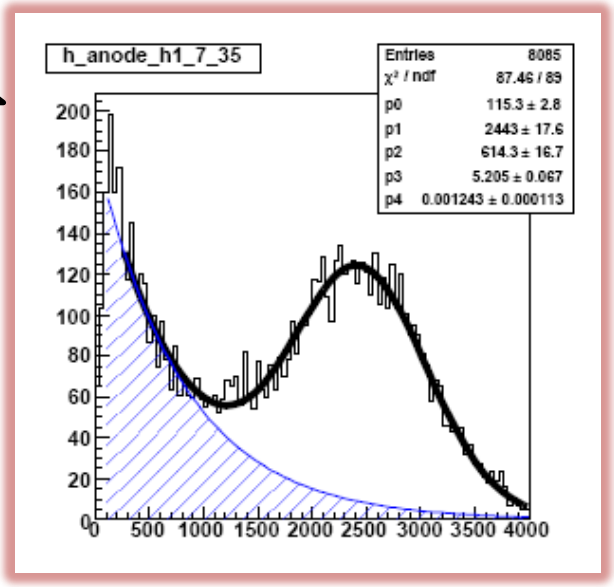
Scan along X and Y (protons and electrons)

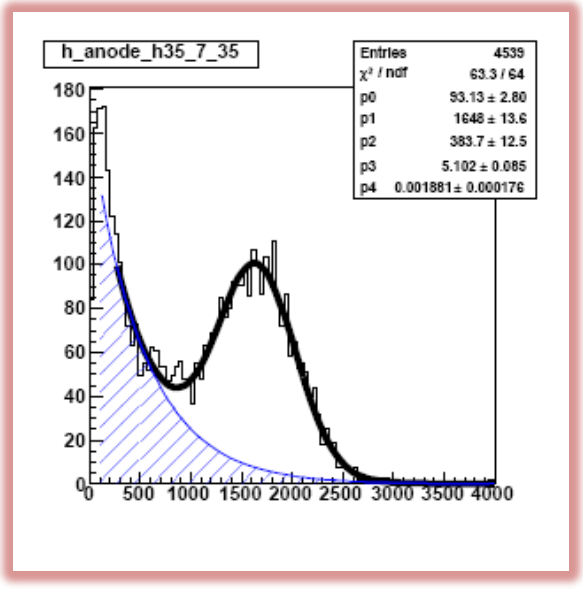
- Hypothesis
  - attenuation identical for all cells
  - combined fit

$$f \times \exp(-x/\lambda_{fast}) + (1-f) \times \exp(-x/\lambda_{slow})$$

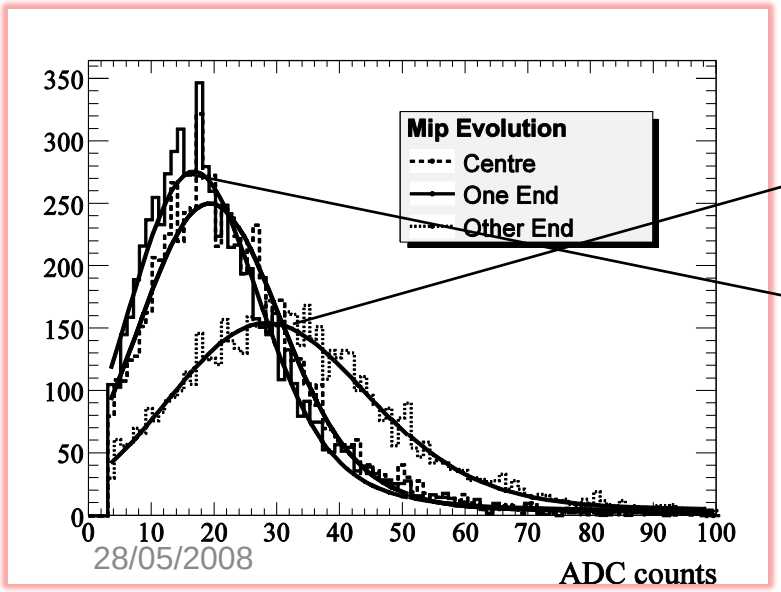
Attenuation With Electrons & MIP

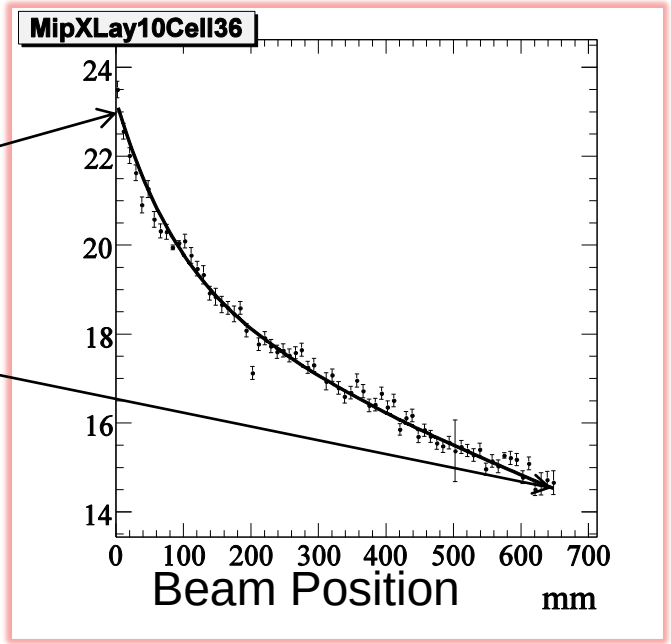
Electrons





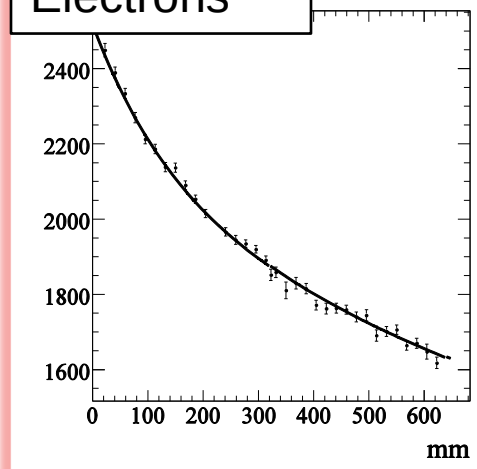
MIP



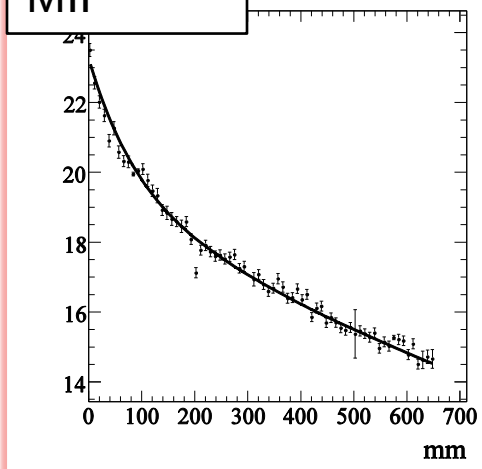


Attenuation Correction

Electrons

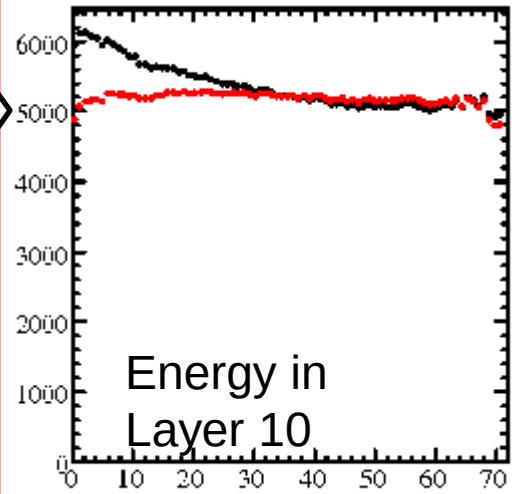


MIP



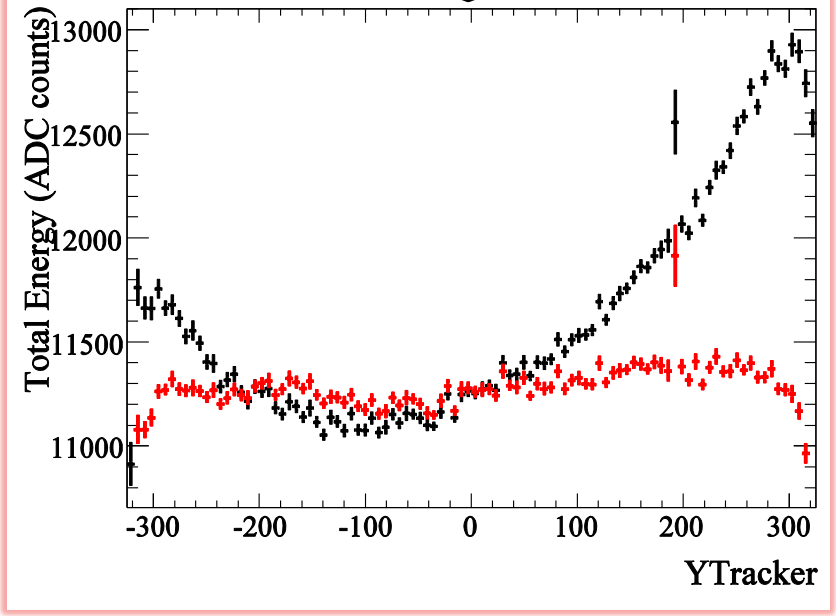
41 such sets of points fitted simultaneously

Scan Along X – 30 GeV Electrons

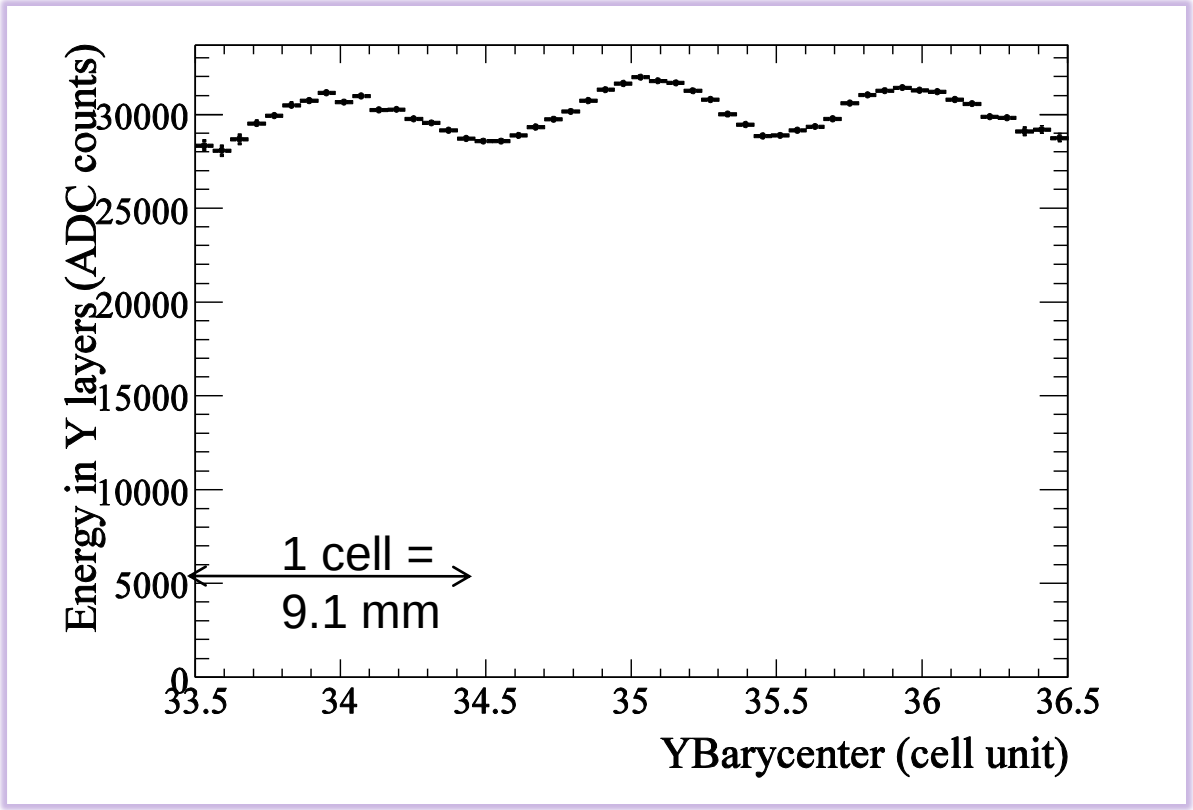


Energy in Layer 10

Scan Along Y – 10 GeV Electrons



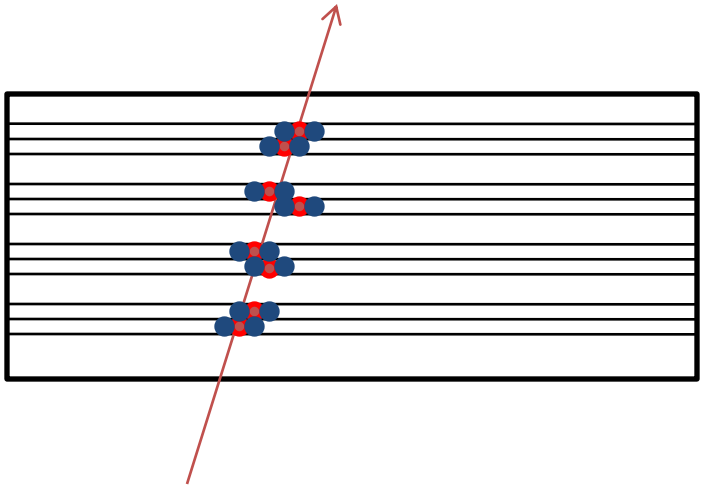
Impact Correction

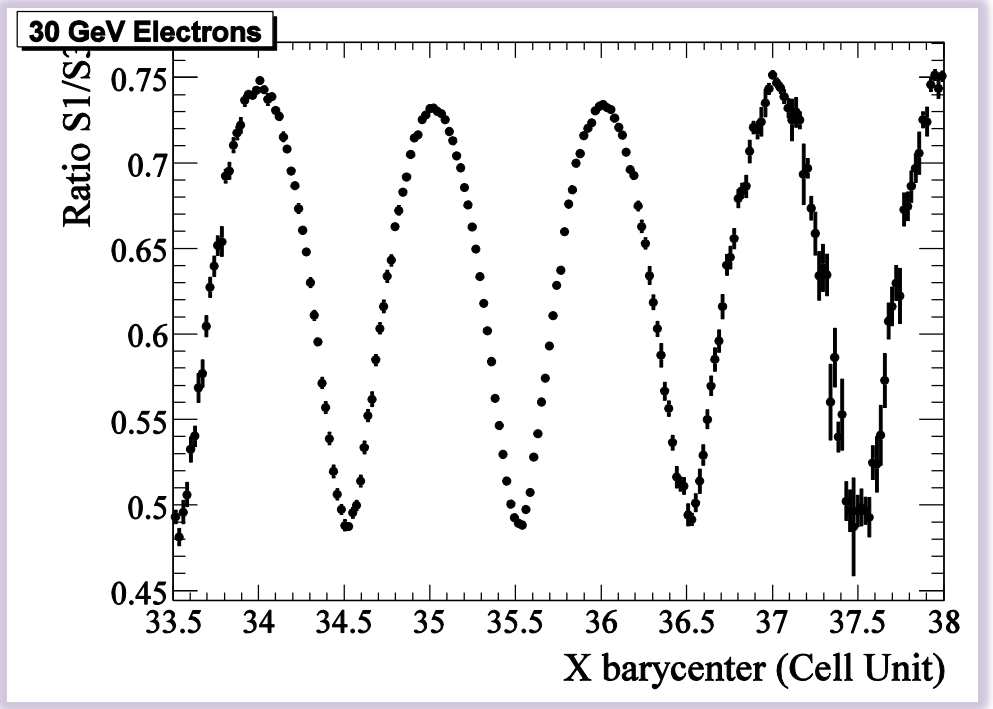


The energy measurement is sensitive to the impact point given here by the barycenter

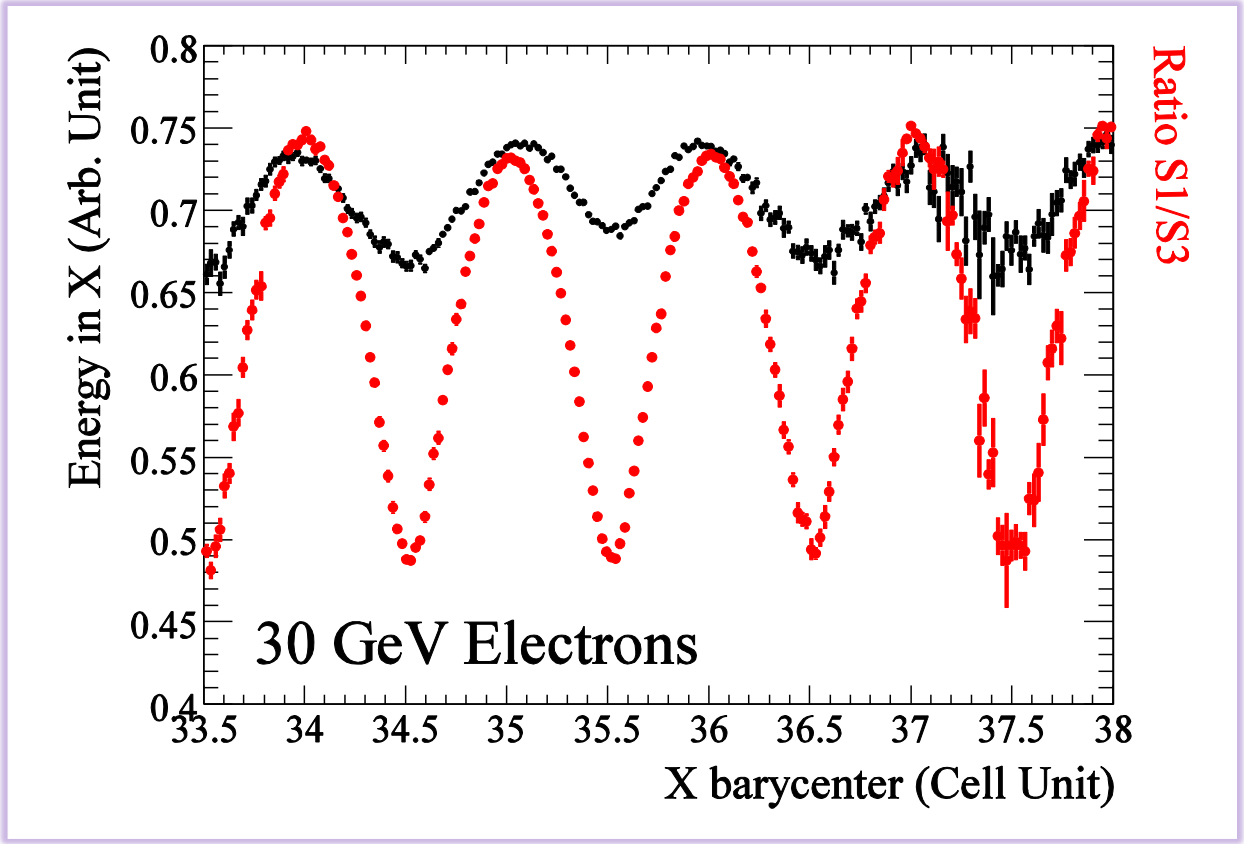
Method

- Adapted from a method used by the L3 experiment.
- Compute S1/S3 :
  - S1 : signal of the cell with maximum signal
  - S3 : signal over [cell+1;cell-1]



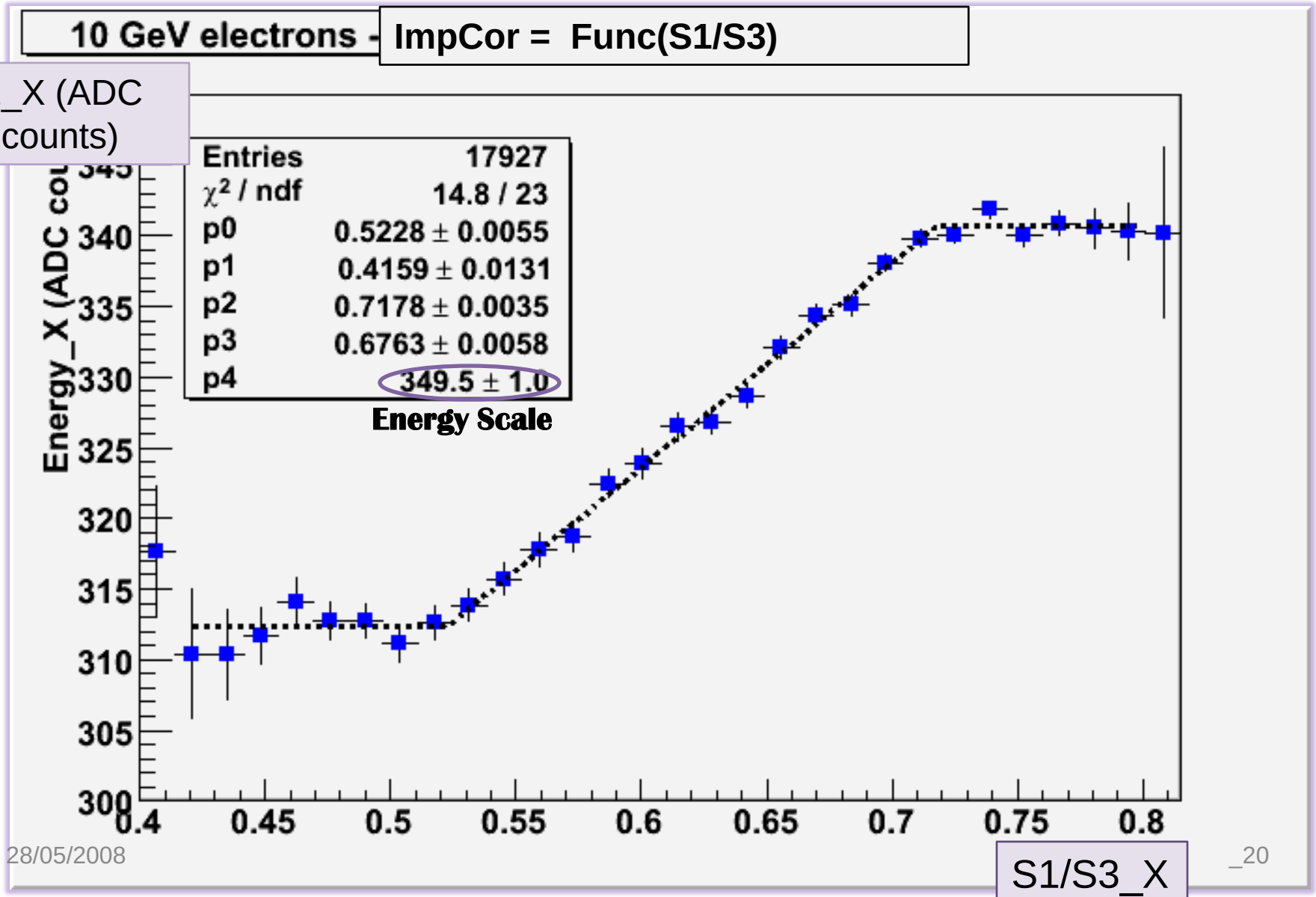


S1/S3 sentivity



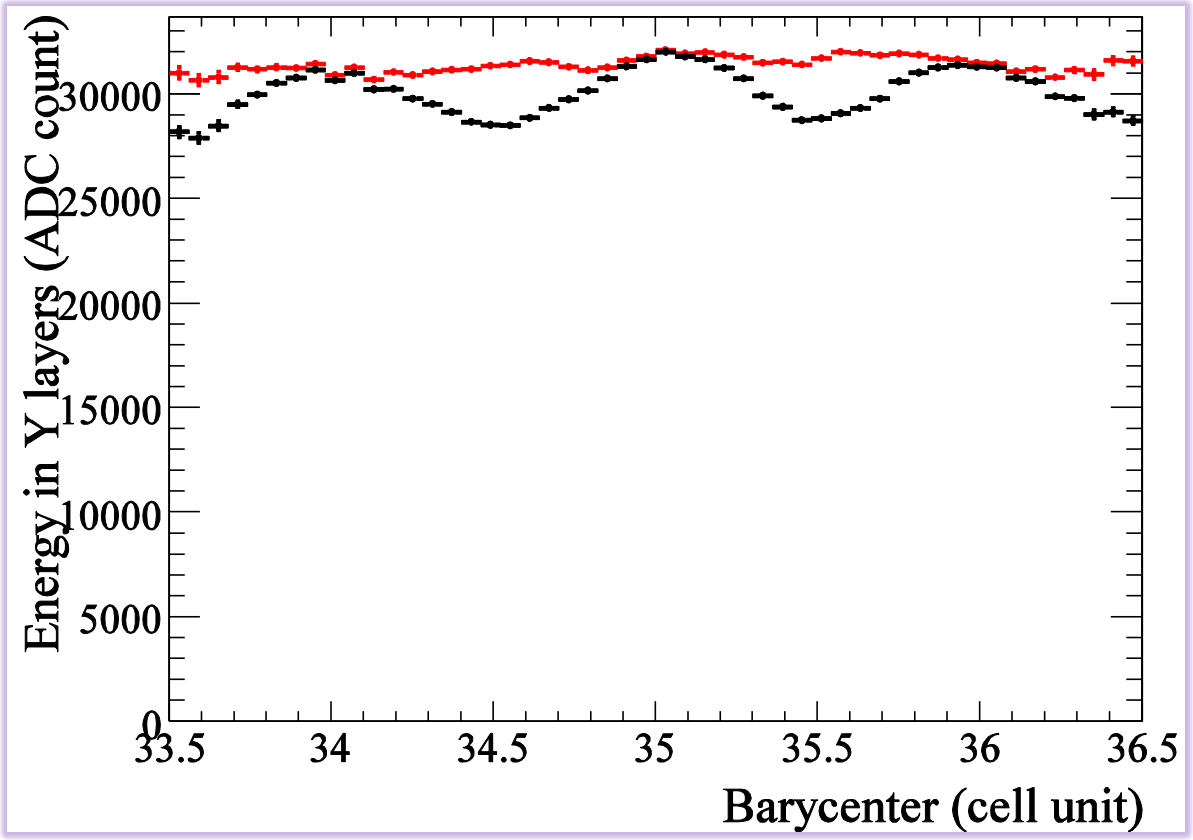
S1/S3 ratio has a better sensitivity to the barycenter than the total energy.

Impact Correction



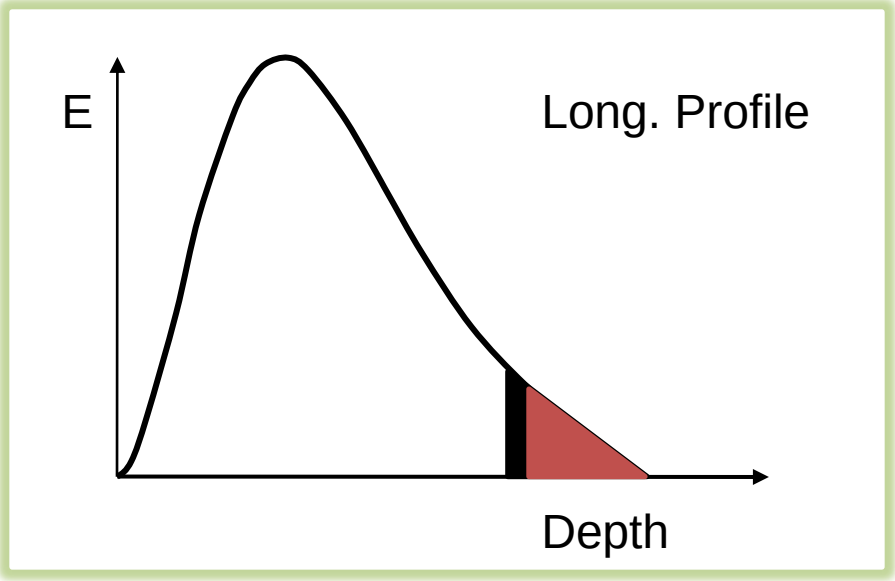
After Impact Correction

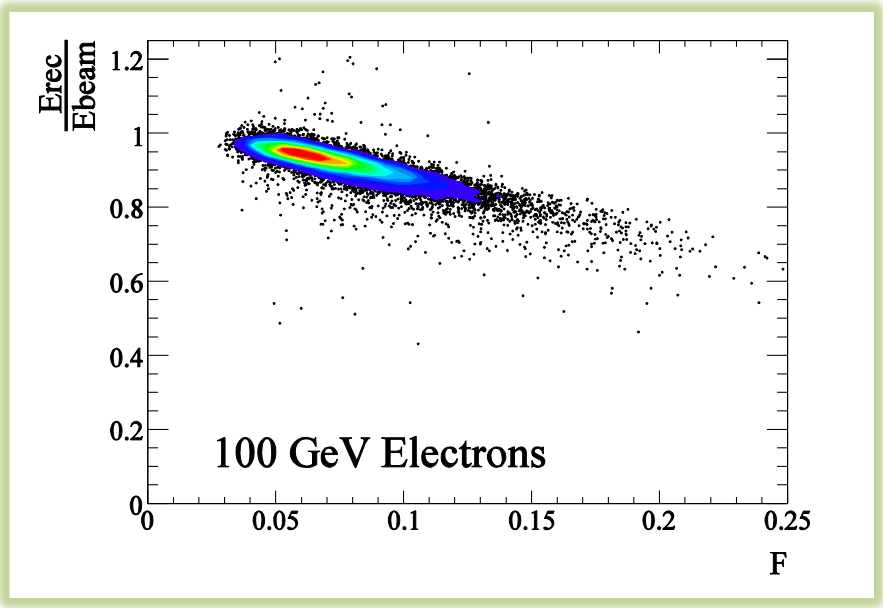
Energy measurement before and after Impact Correction



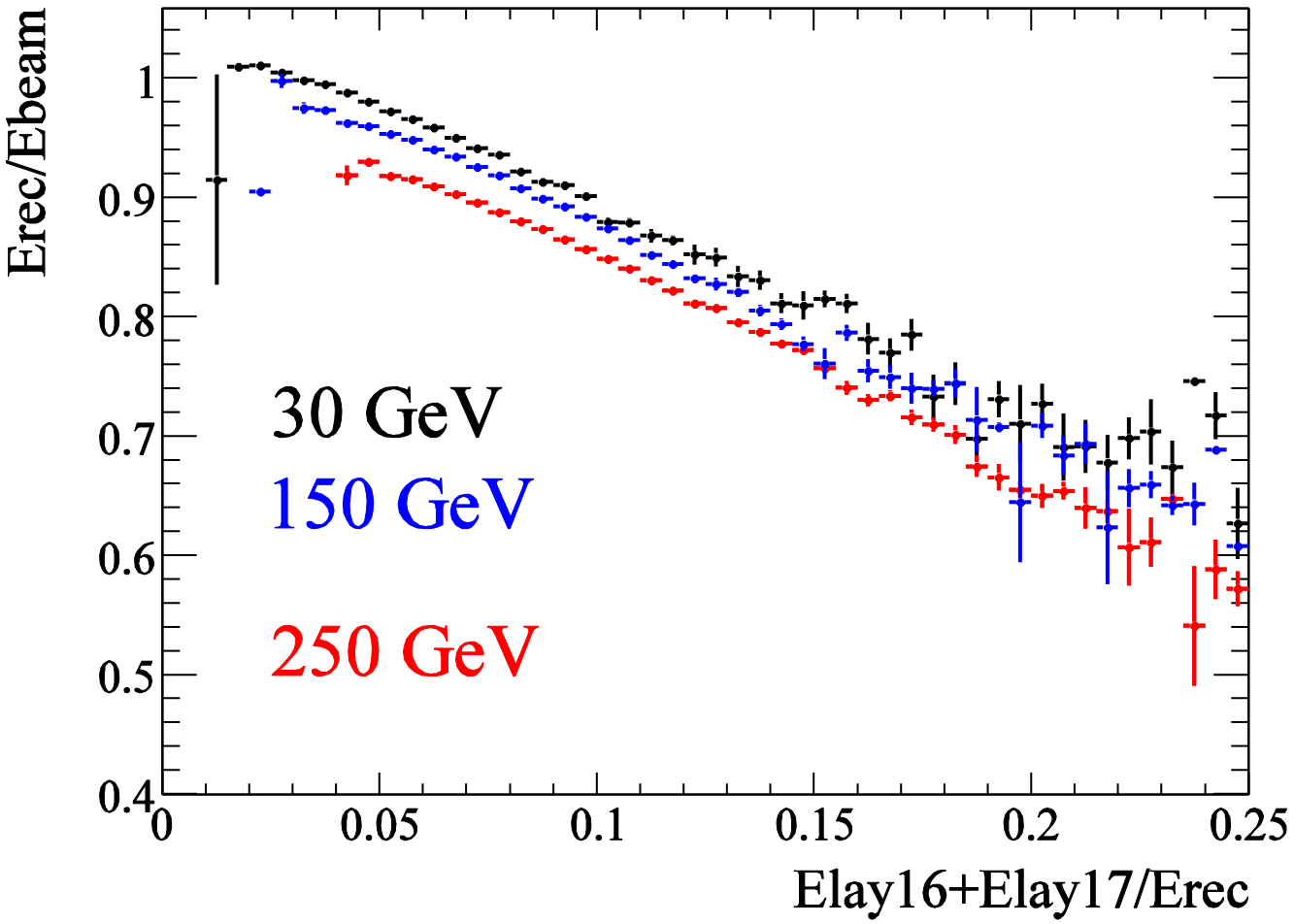
Rear Leakage Correction

- Benefit from the longitudinal segmentation :
  - Approximation of the energy leakage by a triangle
- Erec : Energy after equalization + attenuation + impact corrections
- F : Fraction of energy in the last 2 layers
  - Erec/Ebeam = A + Slope * F



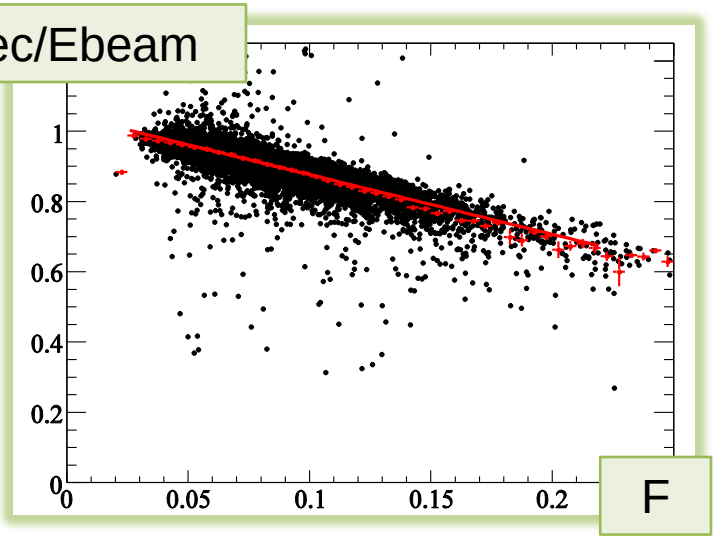


Energy Dependence



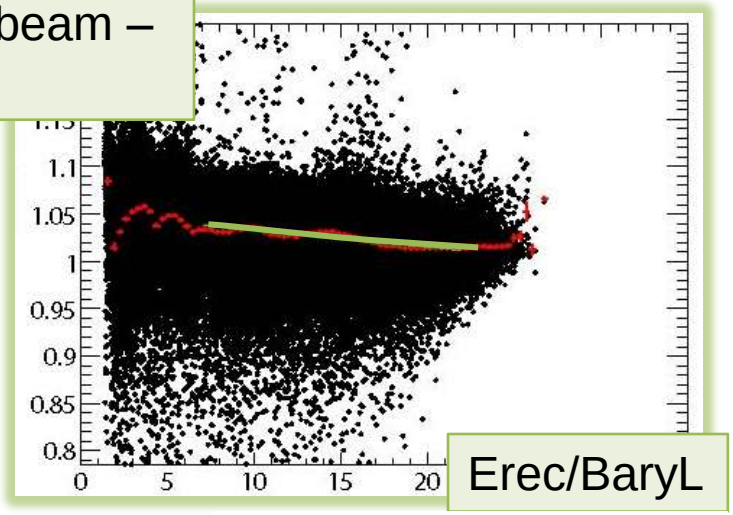
Leakage Correction

Erec/Ebeam

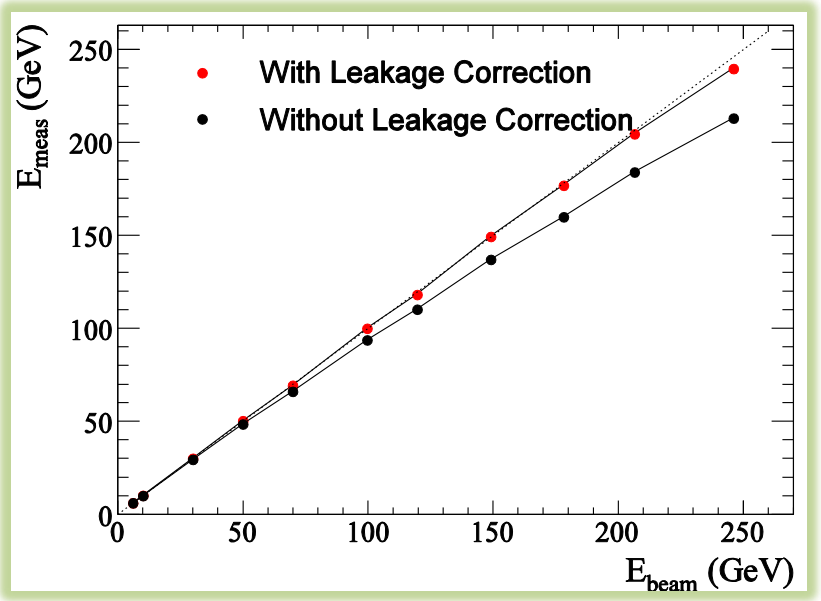


Find a mean slope

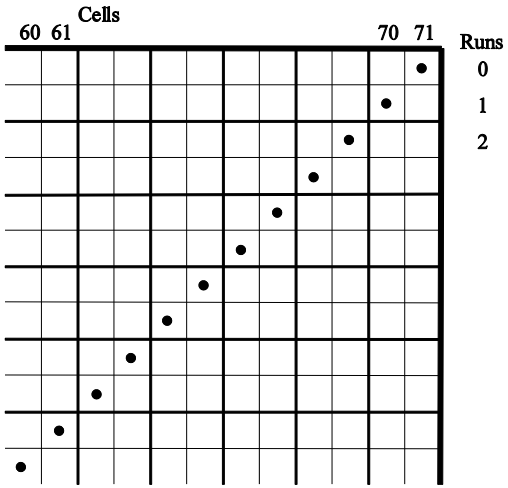
A = Erec/Ebeam – Slope * F



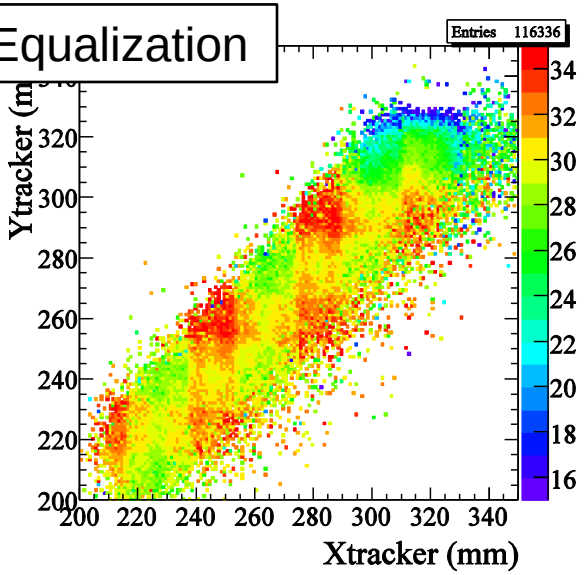
Find the Energy dependence of A



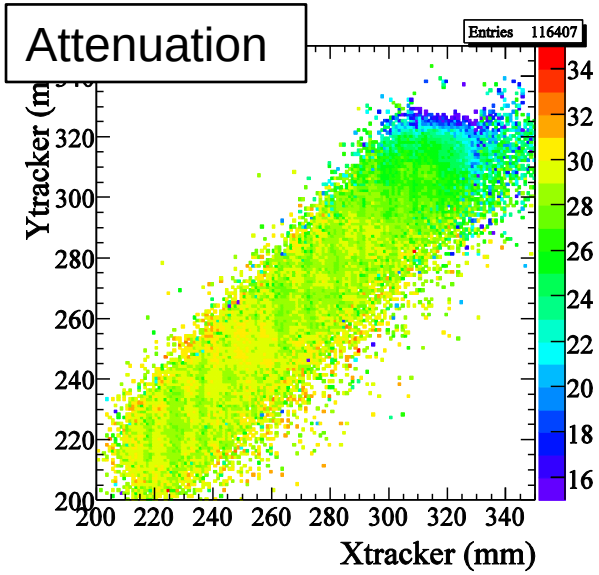
Off Center – 30 GeV



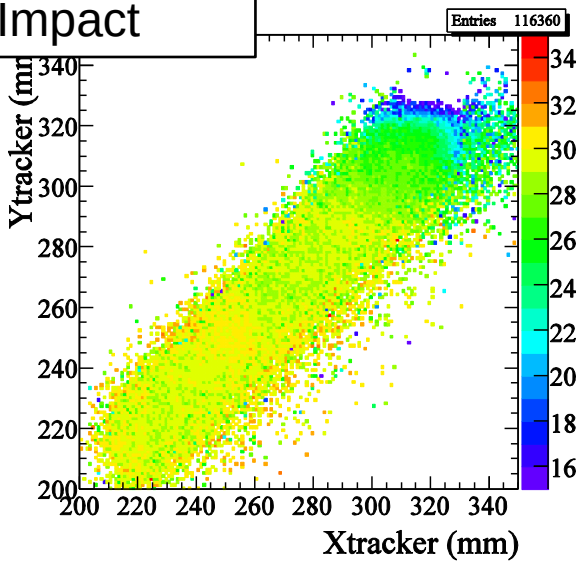
Equalization



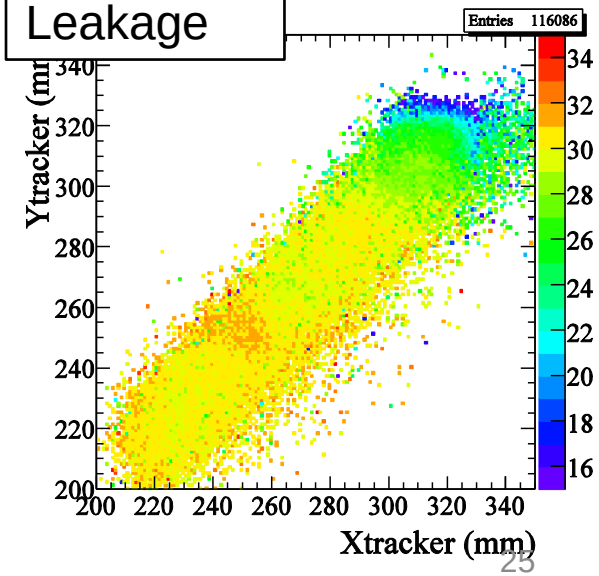
Attenuation



Impact

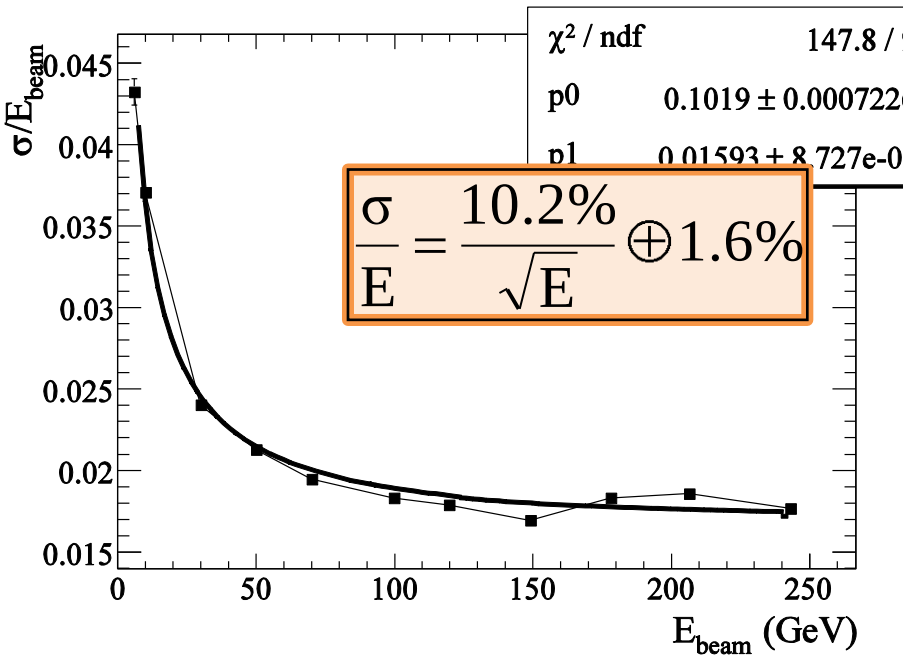


Leakage



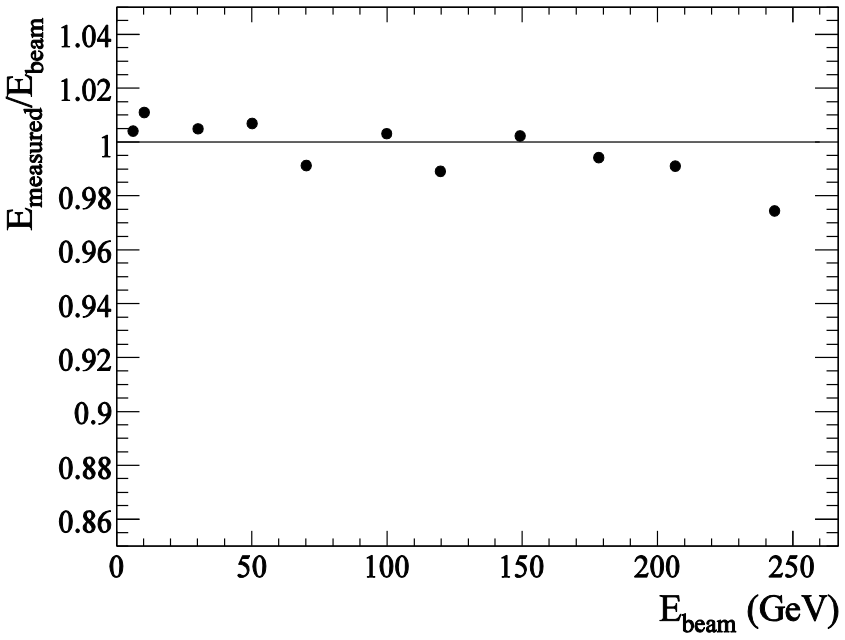
All Corrections Included

Resolution



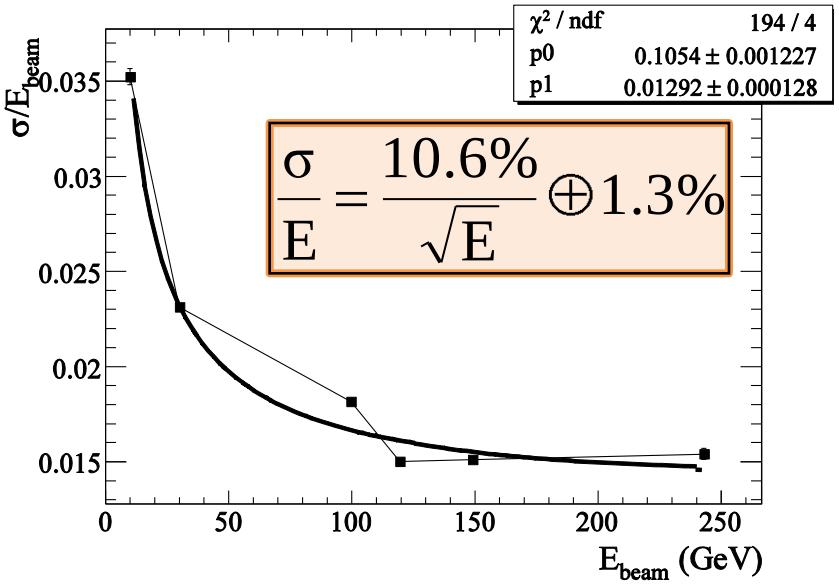
$$\frac{\sigma}{E} = \frac{10.2\%}{\sqrt{E}} \oplus 1.6\%$$

Linearity

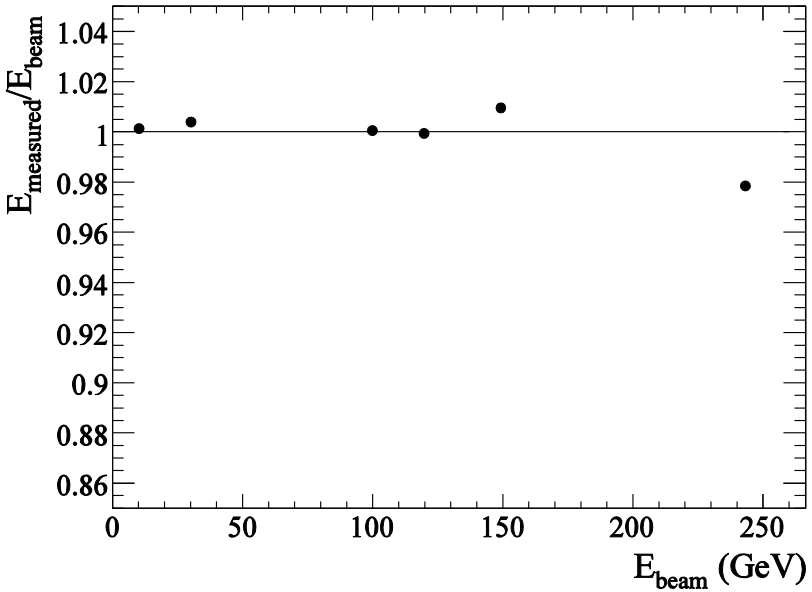


Preliminary Results

15° Incidence Angle



$$\frac{\sigma}{E} = \frac{10.6\%}{\sqrt{E}} \oplus 1.3\%$$

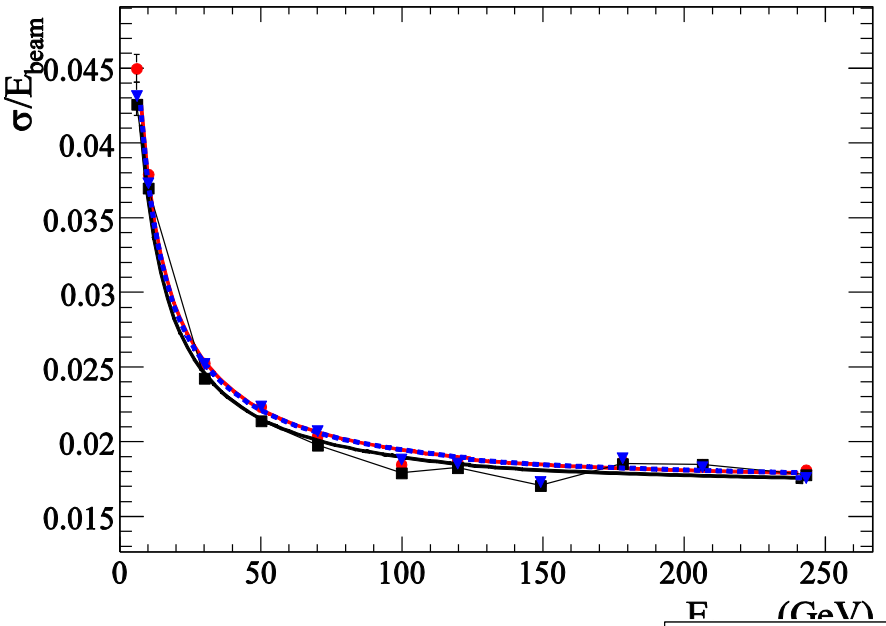


Preliminary Results

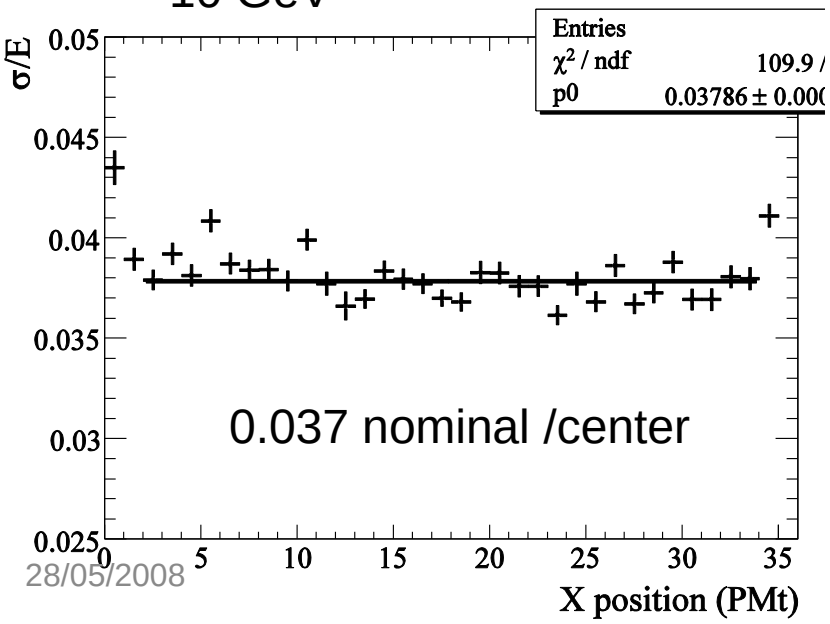
Stability/Homogeneity

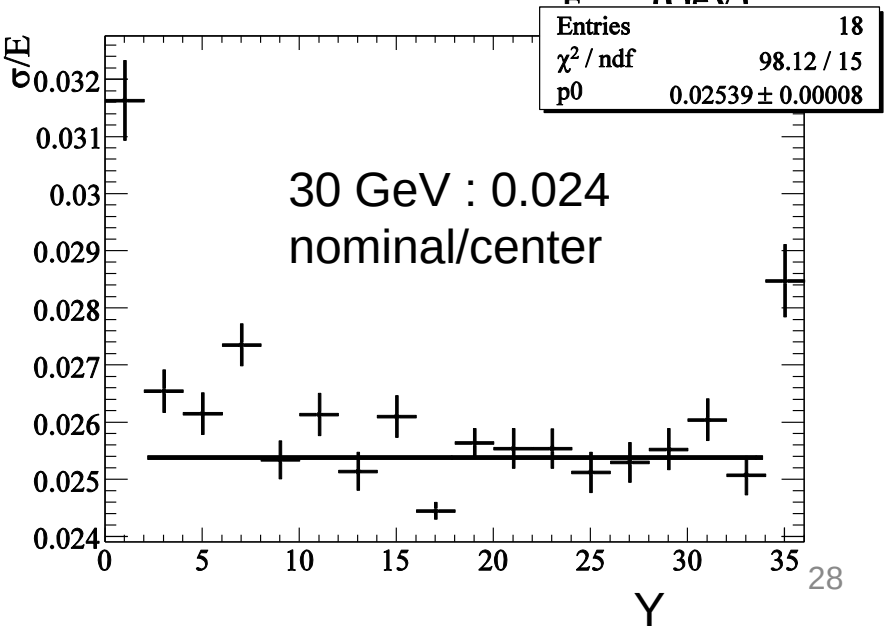
Fraction of energy in :

- Last layer
- Last 4 layers
- Last 2 layers



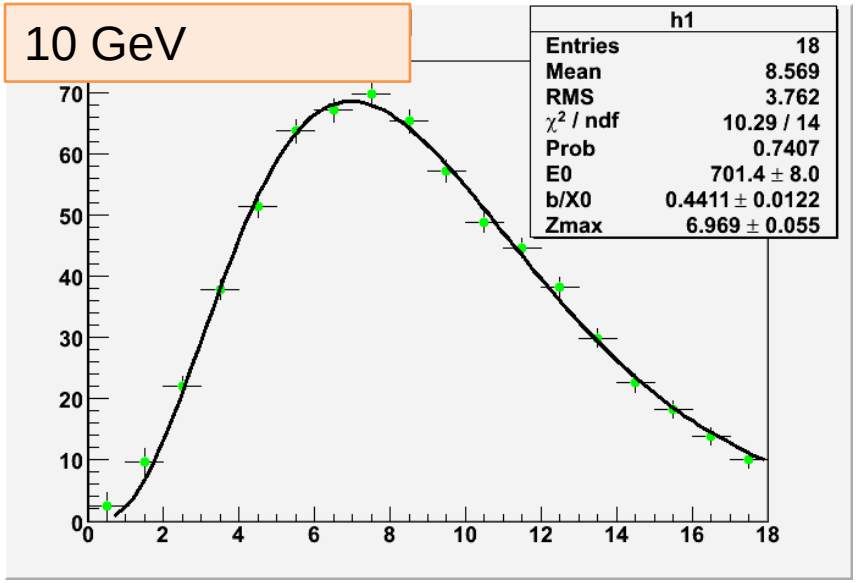
10 GeV



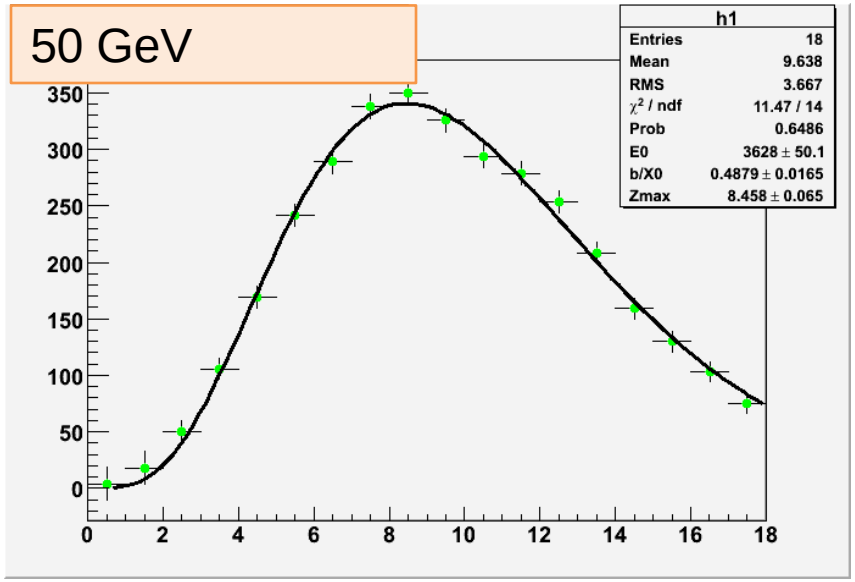


Longitudinal Profile

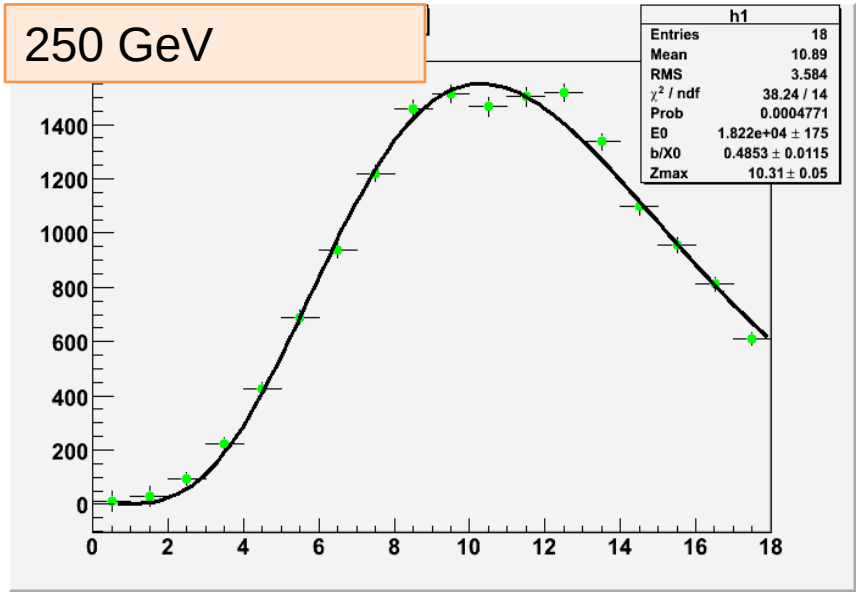
10 GeV



50 GeV

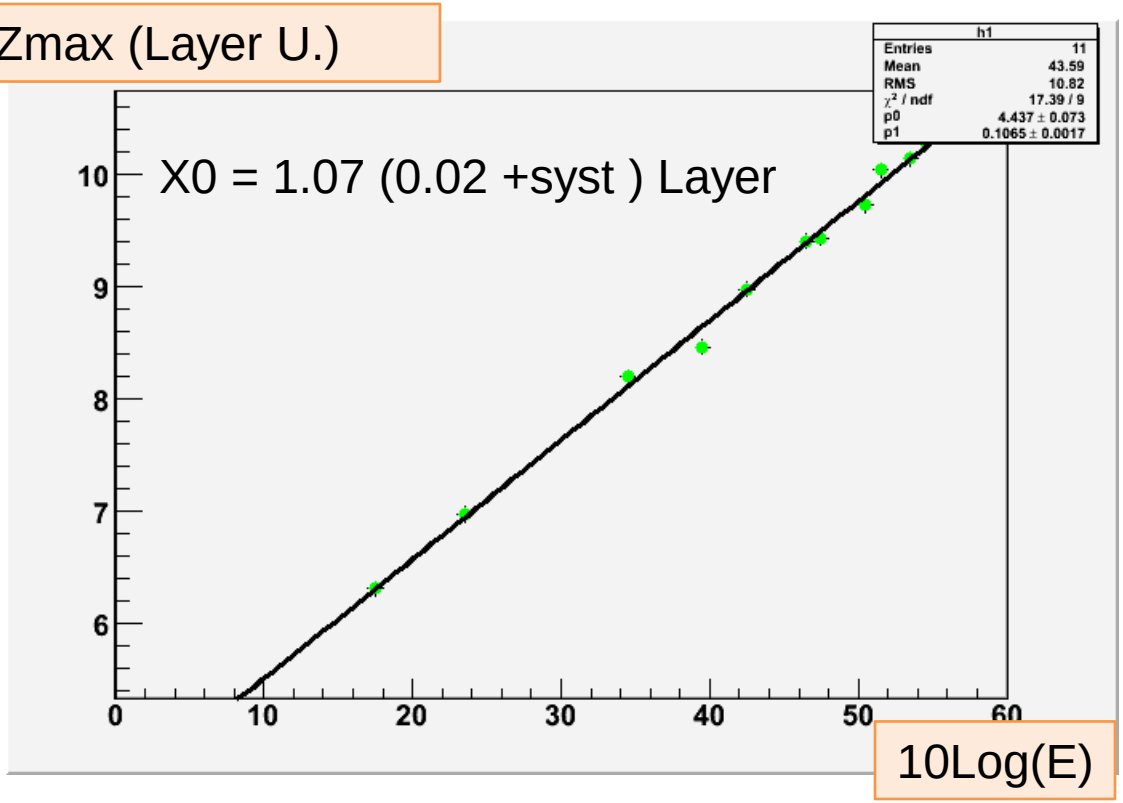


250 GeV



X 0

Zmax (Layer U.)

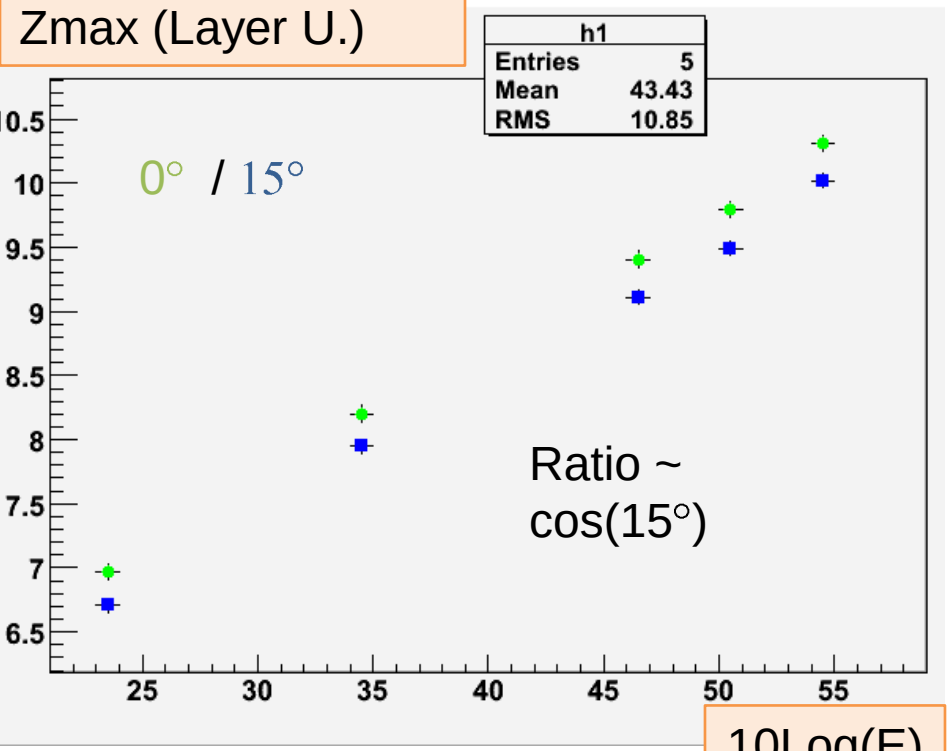


Calorimeter : ~16.9 X0

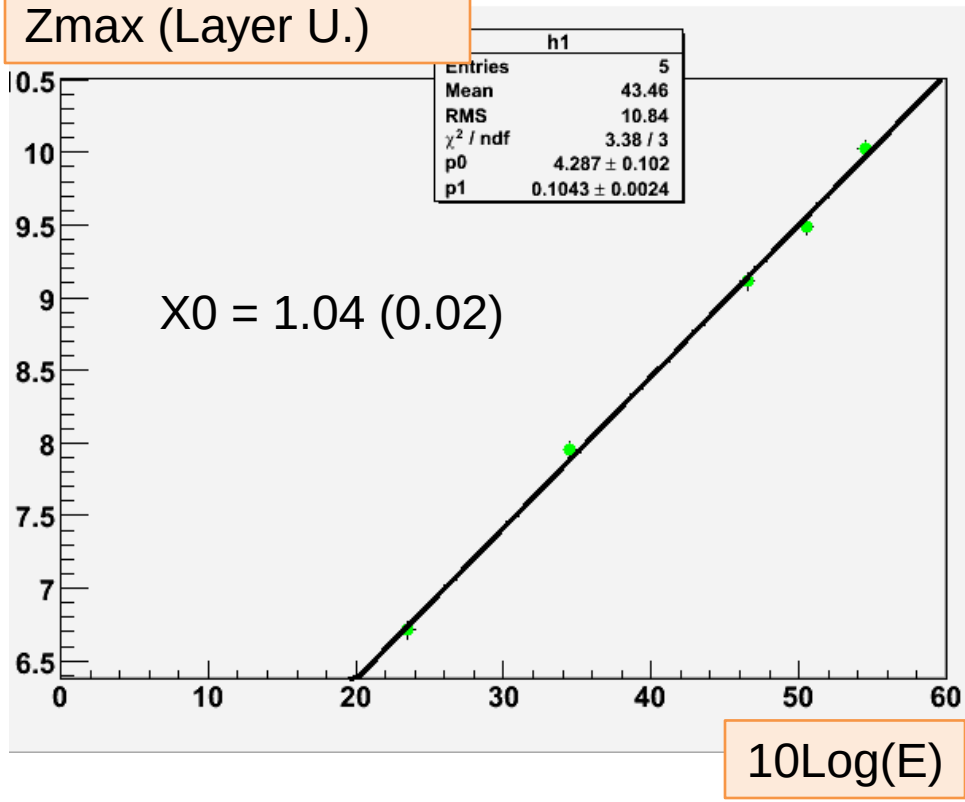
Preliminary Results

X0 : 15° Incidence Angle

Zmax (Layer U.)



Zmax (Layer U.)



Preliminary Results

Conclusion

- Flight Model of the calorimeter tested in Test Beam :
  - No Dead or Noisy channels observed (FE ready since 2004)
- Resolution :

$$\frac{\sigma}{E} = \frac{10.2\%}{\sqrt{E}} \oplus 1.6\%$$

  - Same Results with an alternative method (different impact and leakage corrections)
  - Possible Improvements (Equalizations, Temperature, Fit, …)
    - Constant Term of 1.4 % achievable

- Linearity within 2% in the range [6- 250] GeV

- ~17 Radiation Lengths

- Angular Resolution (not presented here)
  - 100 GeV e- :$\Delta\Theta$ = 11 mrad

Conclusion

AMS currently being integrated at CERN
ECAL fixed at the bottom

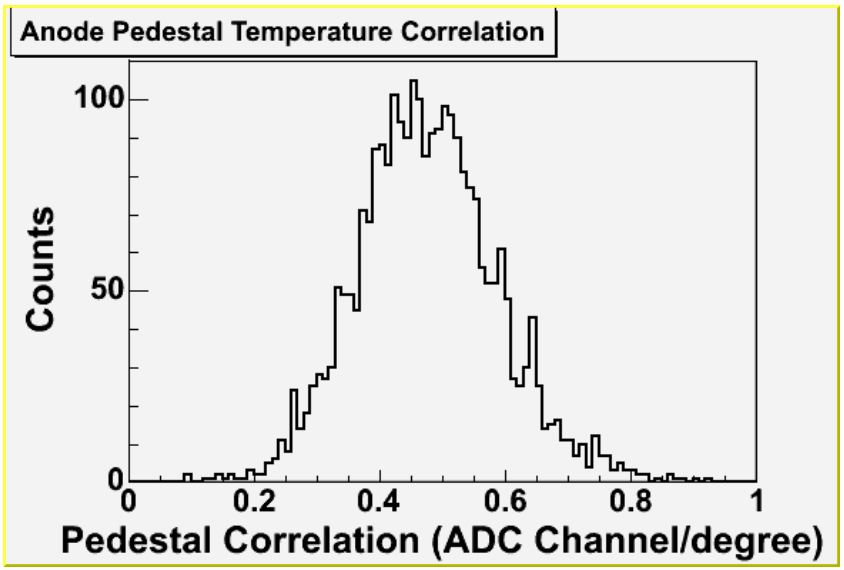
1. PMt Response Equalization:
   - Individual Gain correction
   - Individual correction applied per cell

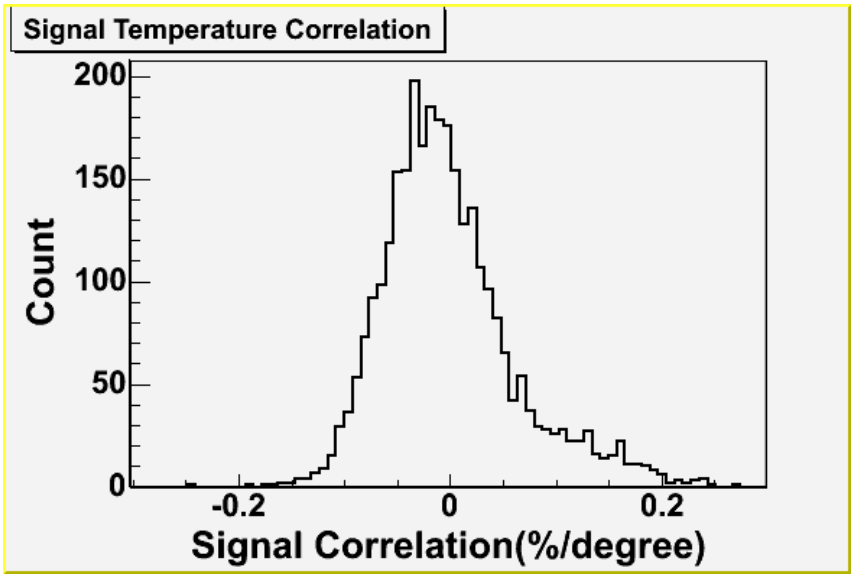
2. Signal Attenuation Correction:
   - Global correction applied per cell

3. Impact Correction:
   - Global factor applied per event

4. Rear Leakage Correction:
   - Global factor applied per event

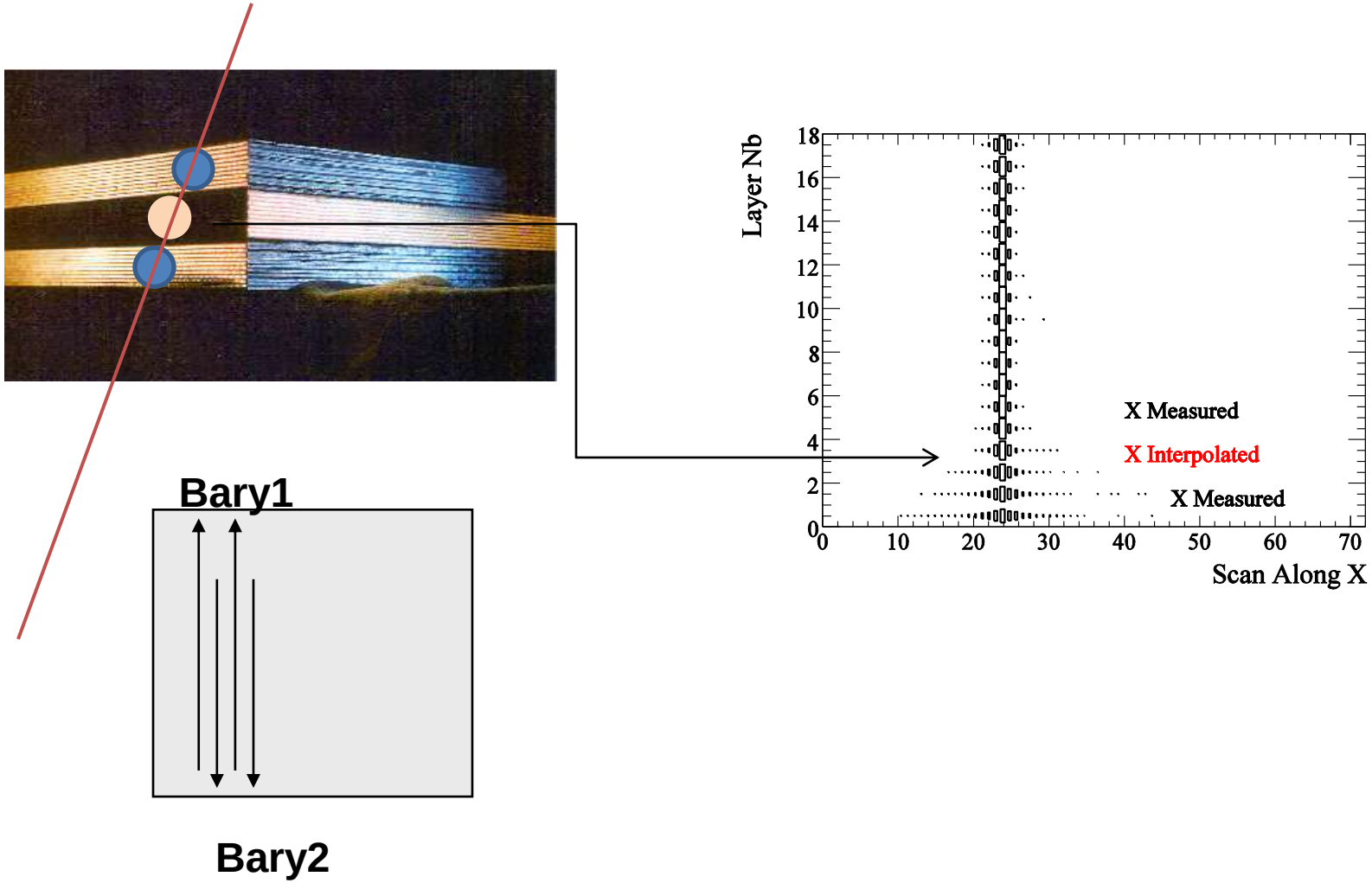
Variation / Temperature



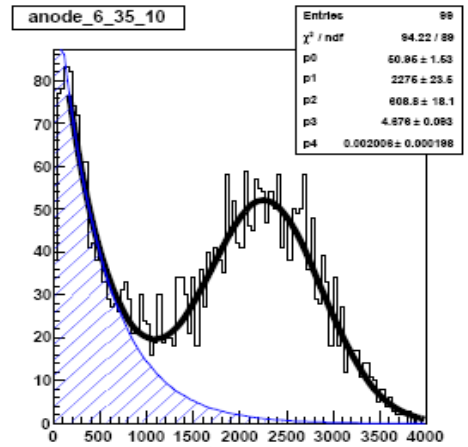


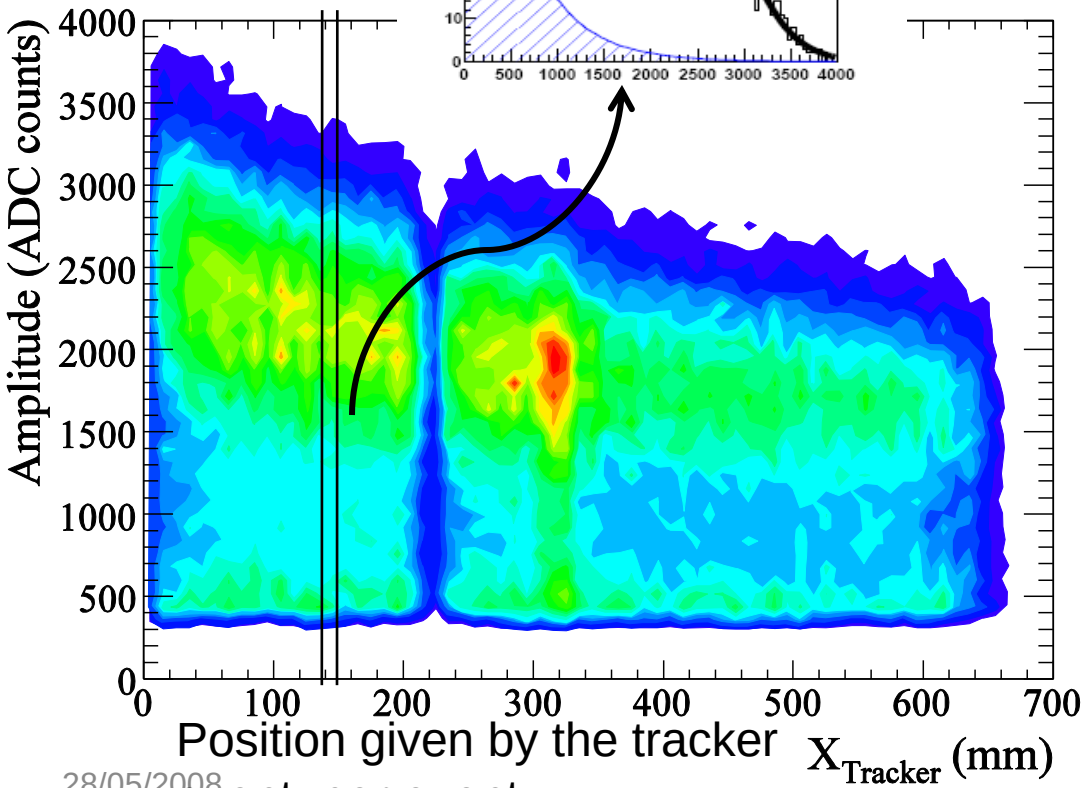
0.5 ADC counts/Degree
Pedestal ~ 150 ADC Channels

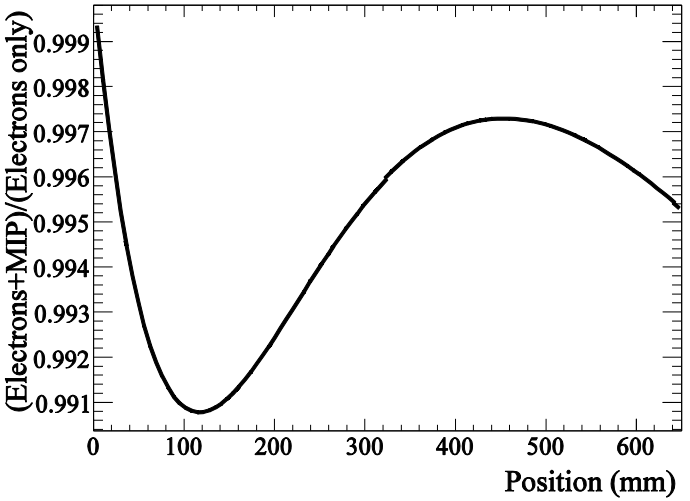
Attenuation Correction



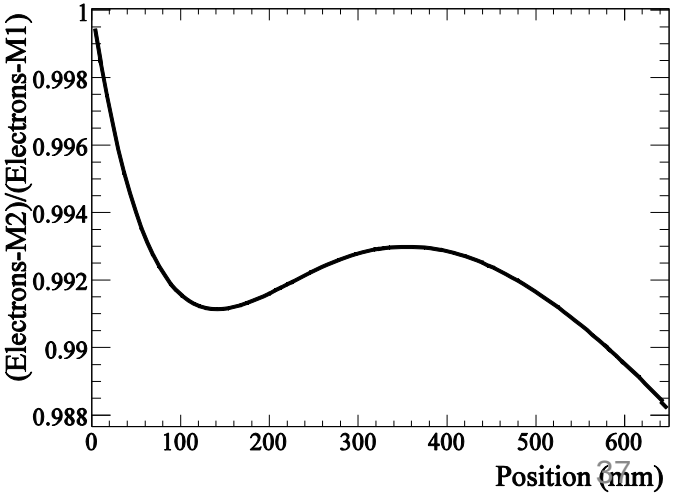
Attenuation Systematics







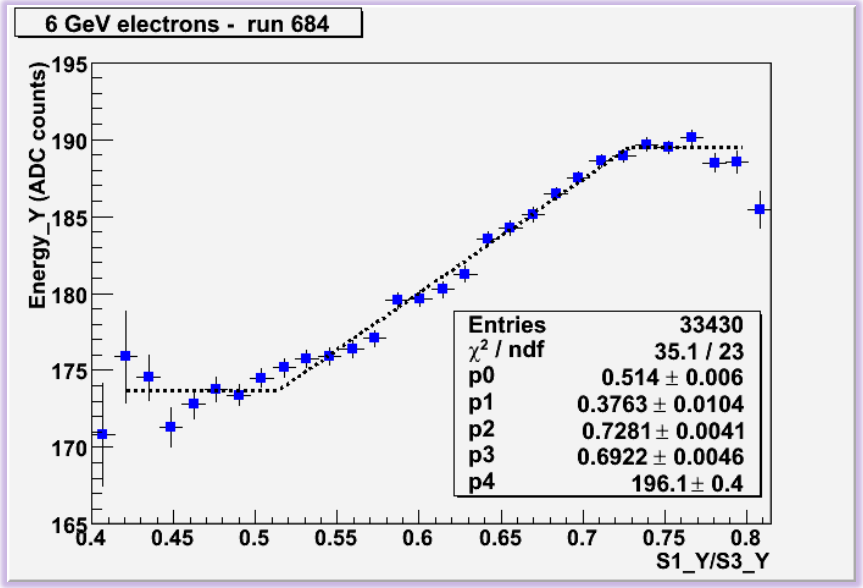
Maximum : 1%

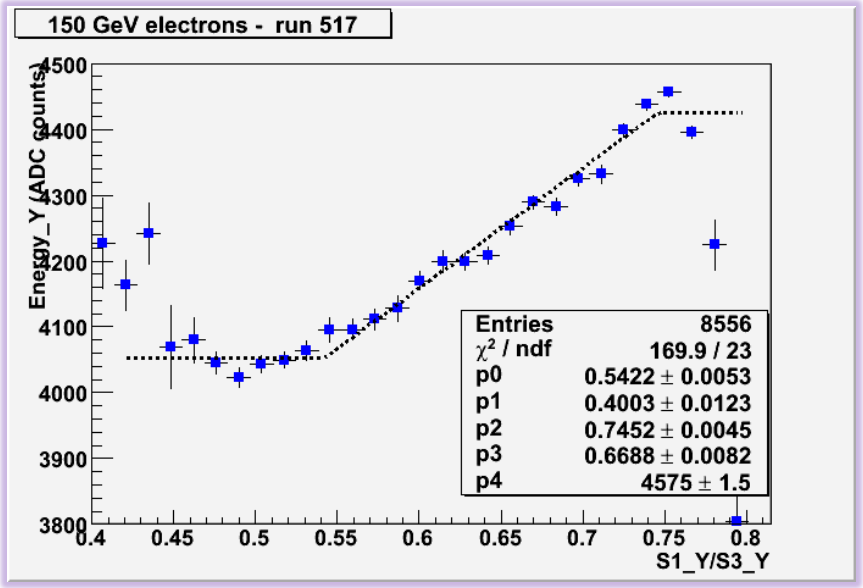


Energy Dependence

6 Gev Electrons (High Statistics Run)

150 GeV Electrons

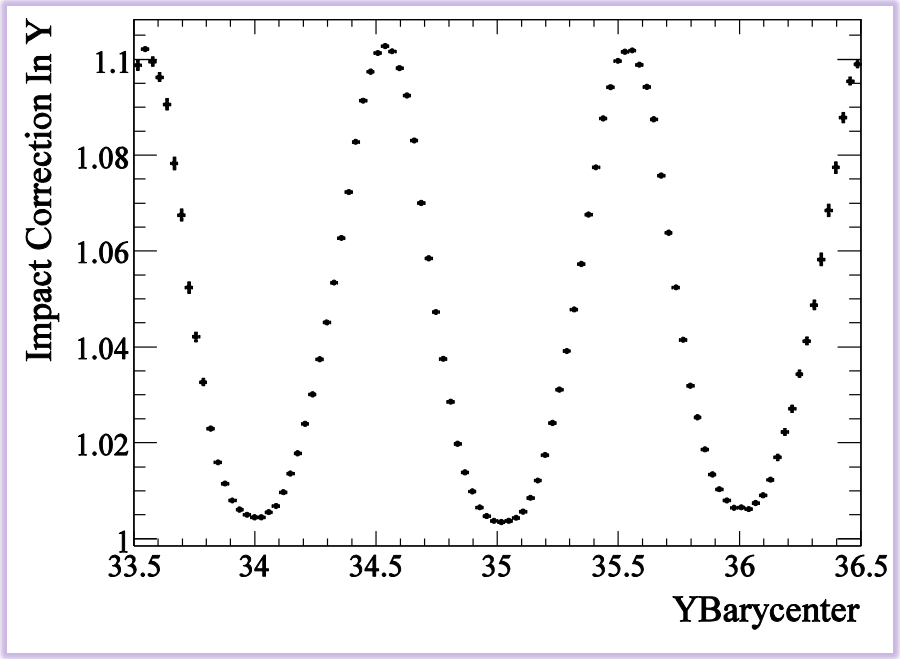




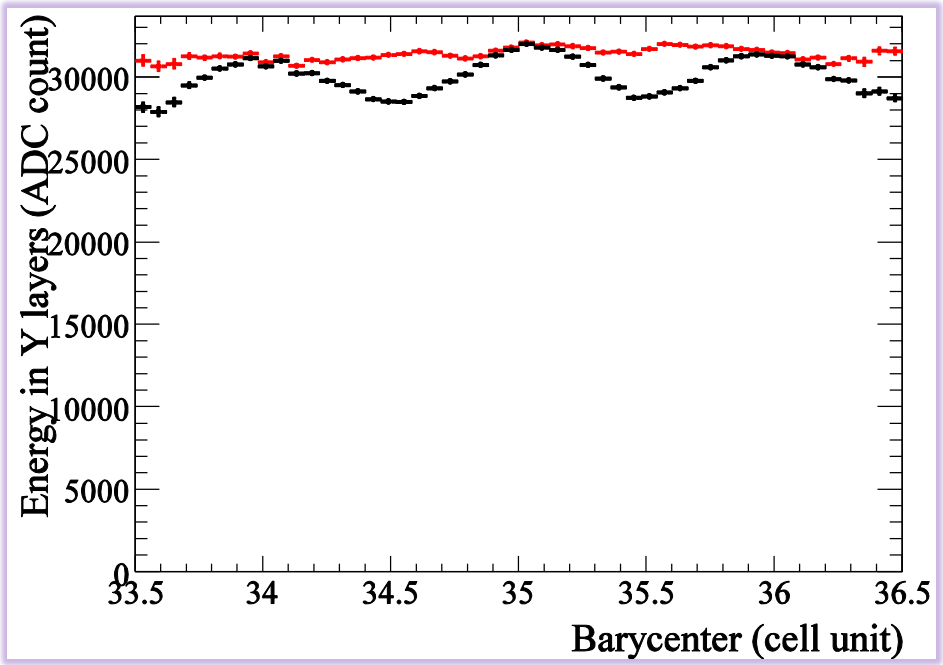
- The other parameters are fairly independent of energy
- Computed with high statistics 30 GeV electrons and apply to all energies

After Impact Correction

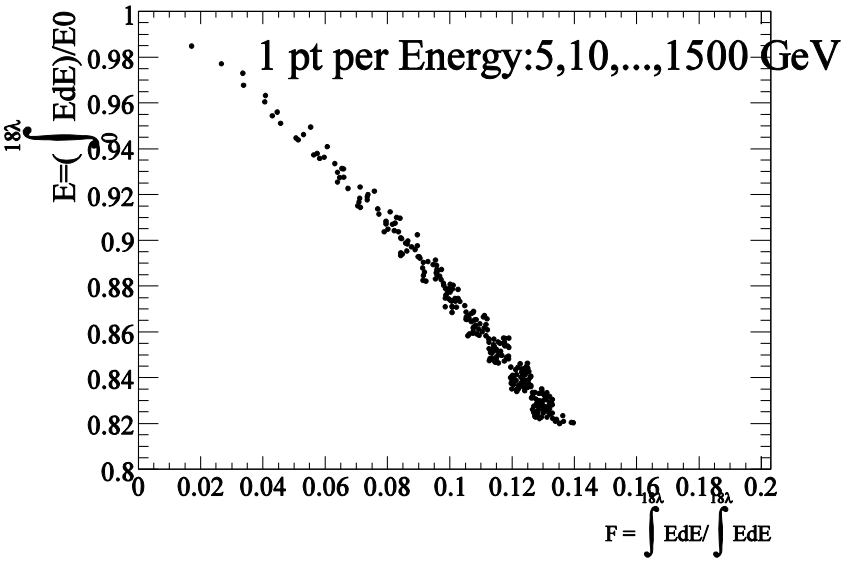
Average Correction as a function of the Barycenter for a normal incidence

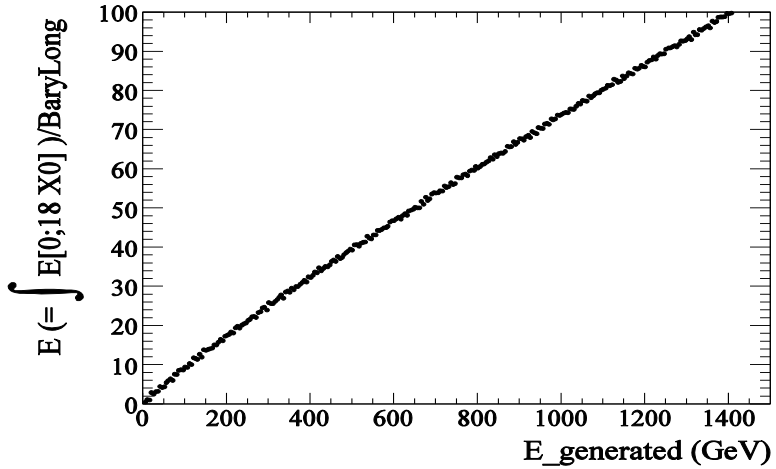


Energy measurement Before and After Impact correction



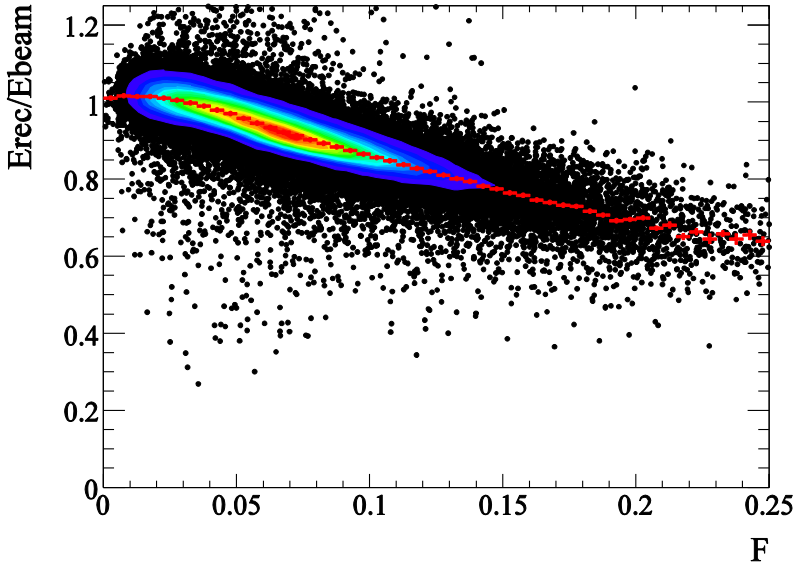
Analytical formula

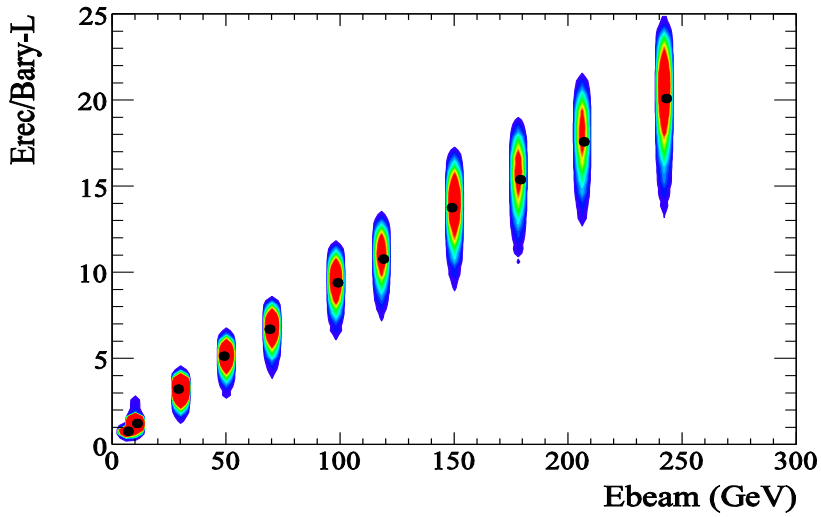




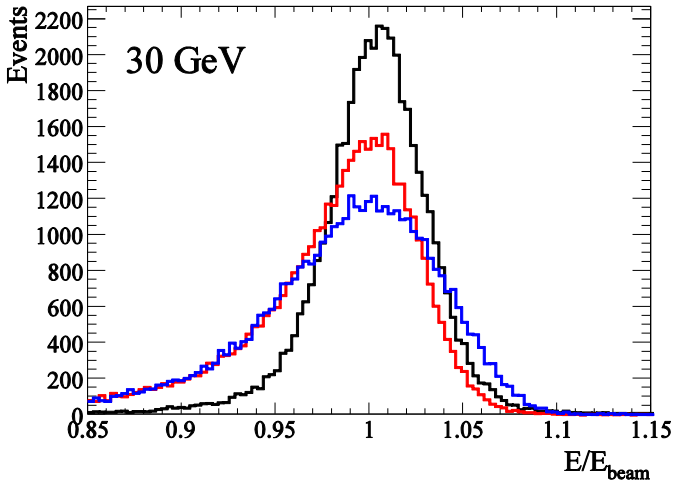
Erec = ⌡ E[0;18 X0]

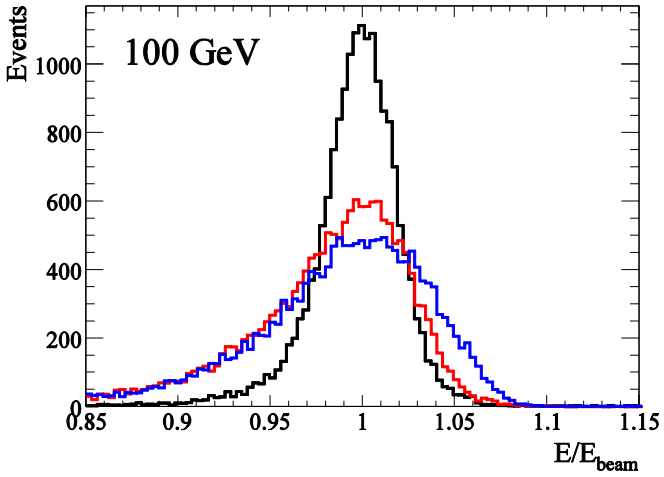
Data





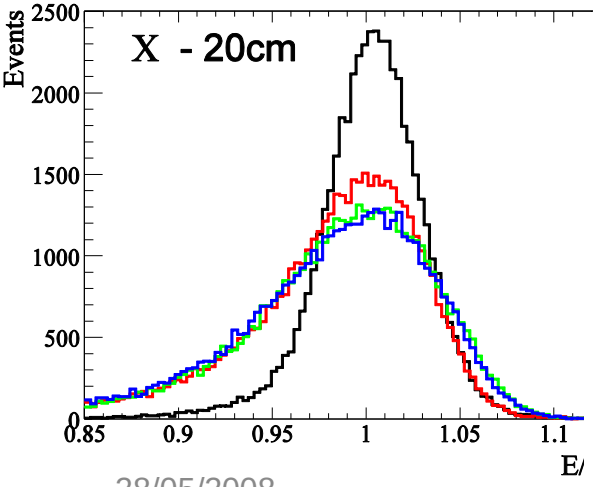
Effects on the resolution

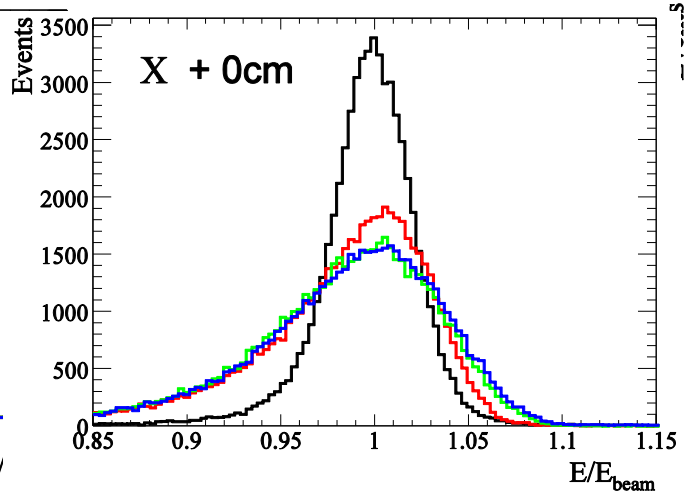


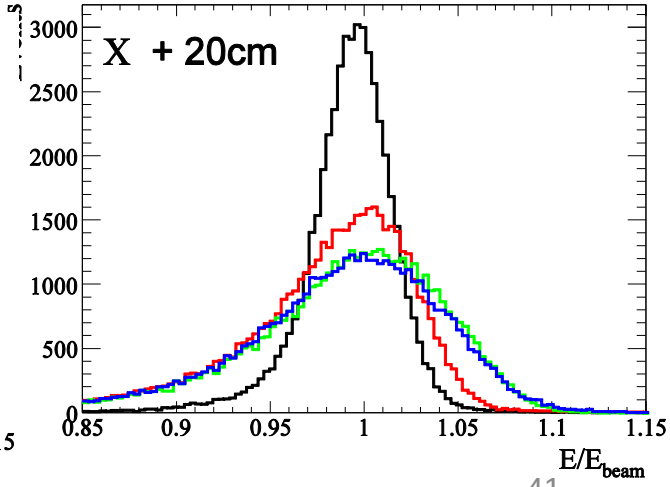


Equalization
Attenuation
Impact Correction
Rear Leakage

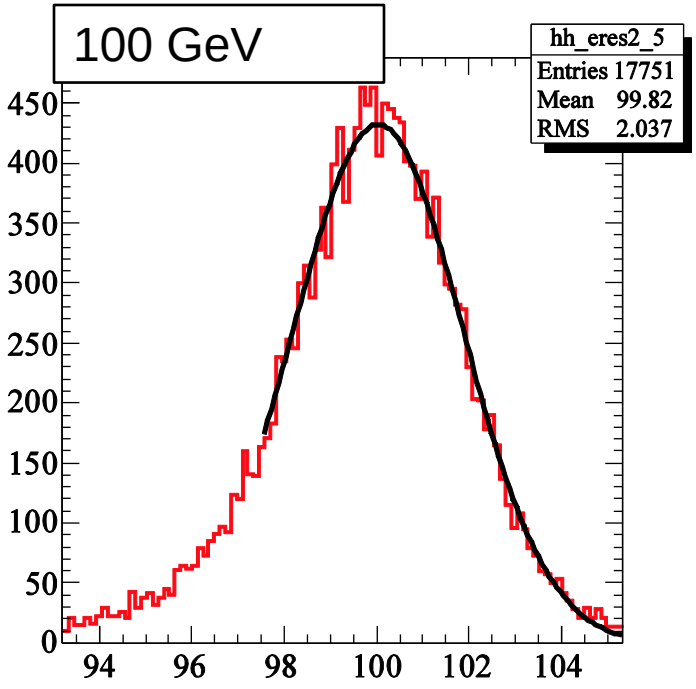
150 GeV

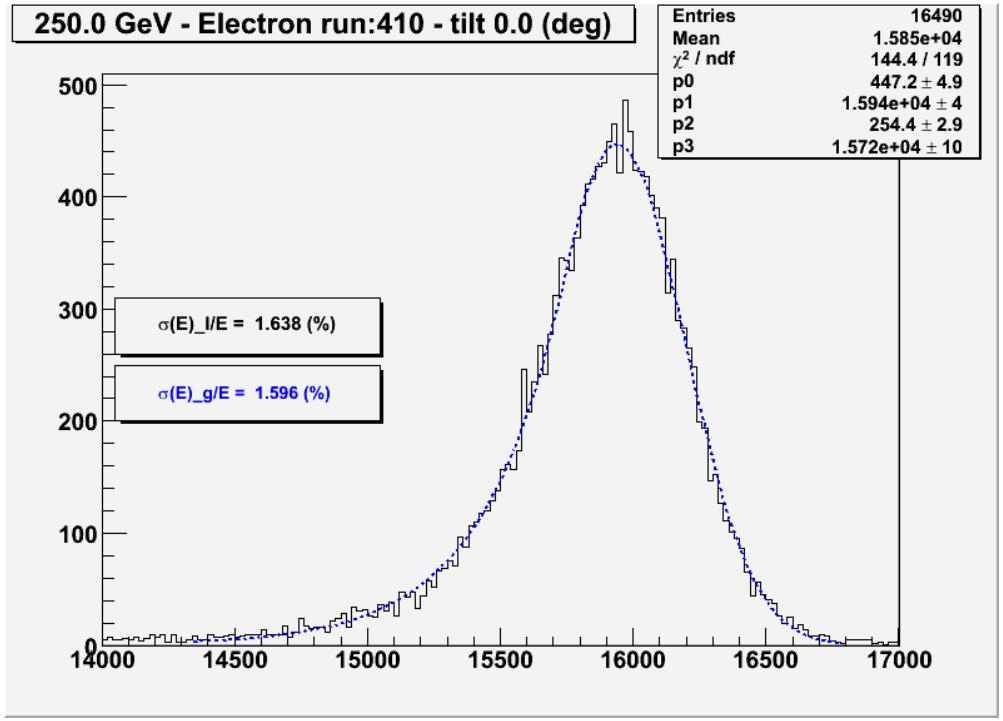






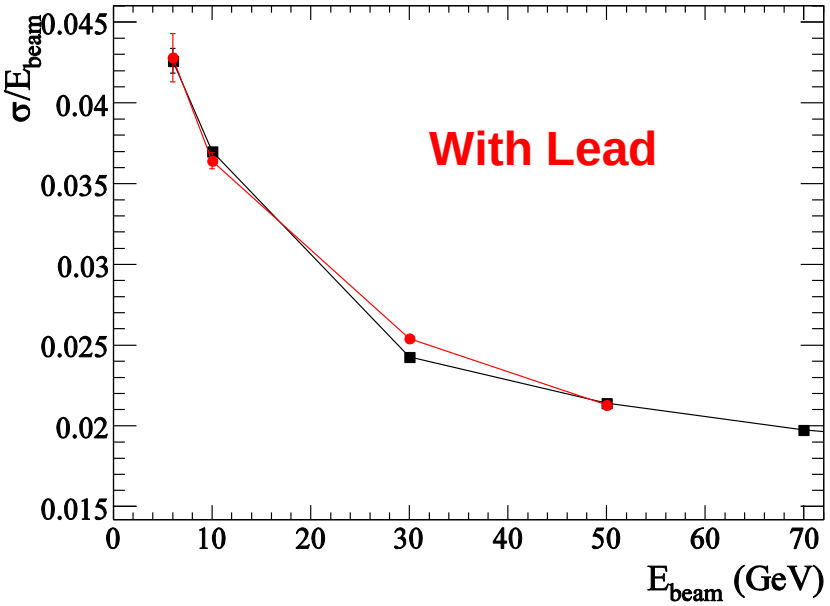
Resolution Function

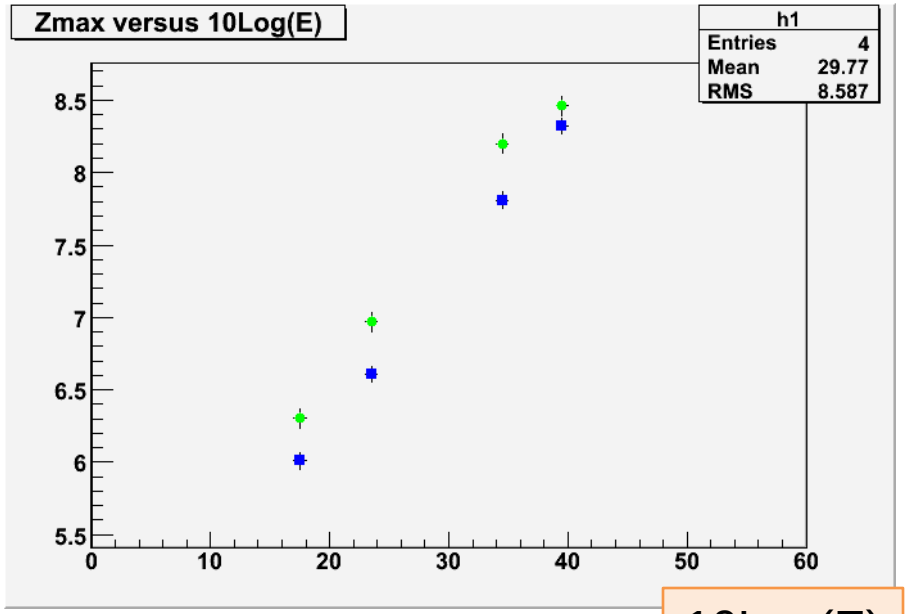




A better description of the energy distribution is given by a “Cristal Ball Function “ (Gaussian + Exponential)

Resolution with 2mm of Lead





10Log(E)

Angular Resolution