Response of CMS Hadron Calorimeter to Electron Beams

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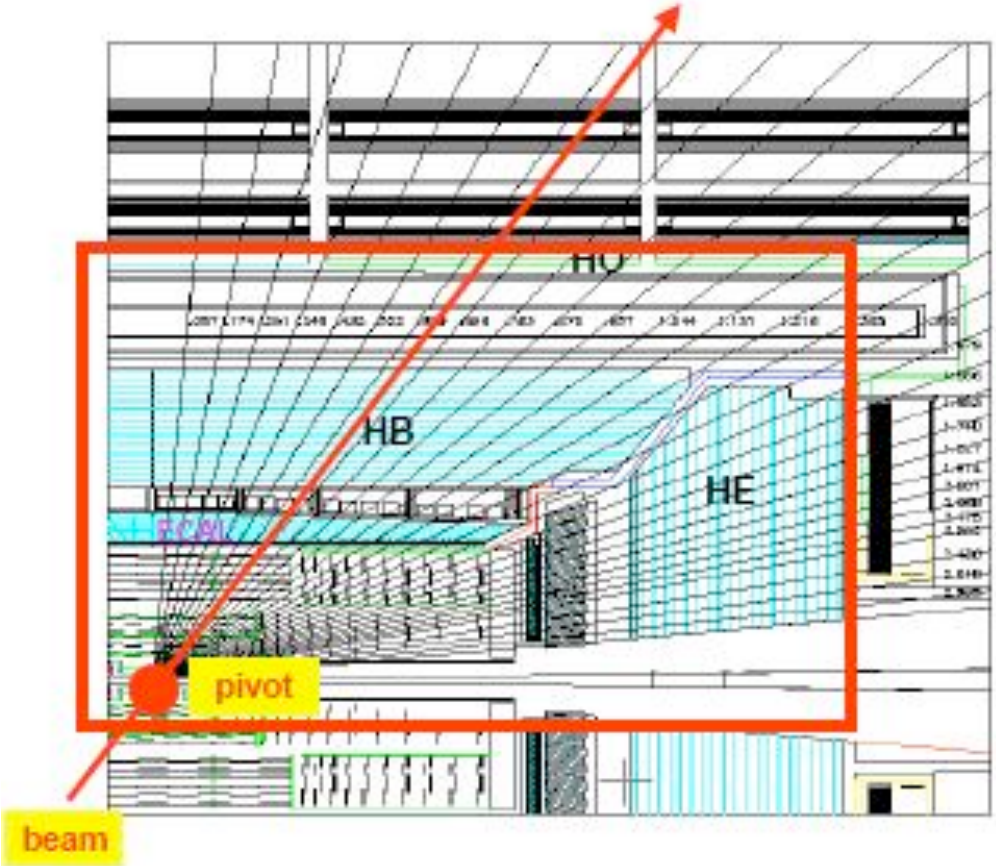
Outline:

- Experimental setup
- Calibration of hadron barrel with electrons
- Longitudinal shower profile study with electrons and comparing them with pions
- Conclusion and outlook

The experimental setup of Test Beam (TB)

- **A slice of of the CMS calorimeter was tested at the H2 test beam area of CERN with different beams with energies ranging from 1 GeV to 300 GeV.**
- **The HCal in test beam includes the barrel (HB), endcap (HE) and the outer hadron (HO).**
- **Data is taken for the hadron calorimeter prototype where every individual layers were readout independently.**
- **Tower structure (η, φ).**
- **Grouping of towers :**

  HB1 (φ = 1 – 4); HB2 (φ = 4 – 8)

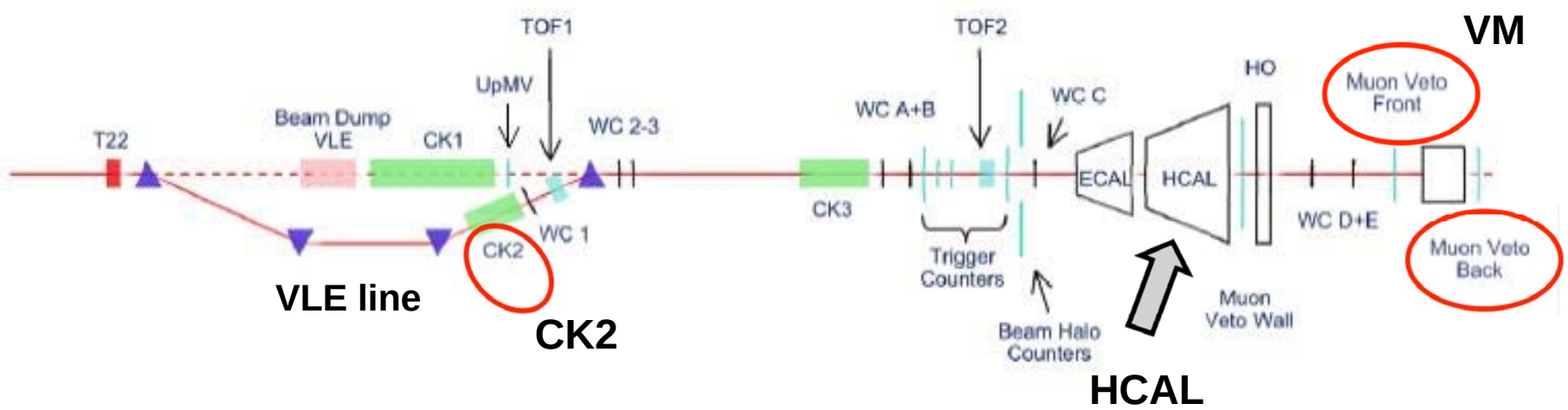


$$\Delta\eta \times \Delta\phi = 0.087 \times 0.087$$

For HB: ***η*** runs from 0 to 1.3

The beam line for TB 2006

- **Very Low Energy (VLE) line provides 1 to 9 GeV π^-, π^+, e^- and e^+ with good rate, a few hundred/spill using a tertiary target (T22).**
- **At lower end of the range, particles are mostly electrons.**
- **There is a significant muon contamination as well. Particle ID is accomplished by *time of flight counters* (TOF), *Cerenkov counters* (CK) and *muon veto counters* (VM).**
- **High energy (HE) line covered a momentum range from 10 to 300 GeV for hadrons through secondary particle production. For electrons/ positrons, the range was 10 to 150 GeV.**



The data used for longitudinal shower profile study ..

- **Beam is shot at the tower $\eta = 7^*$, $\varphi = 6$ (HB2, for longitudinal shower study)**
- **Very Low Energy (VLE) runs: 2, 3, 5, 7, 9 GeV**
- **High Energy (HE) runs: 9, 15, 20, 30, 50, 100, 150 GeV**

- **For VLE, electron runs are not available. So VLE pion runs have upto 90% electron contamination. Putting appropriate selection criteria pions are freed from the beam and the electrons are used.**

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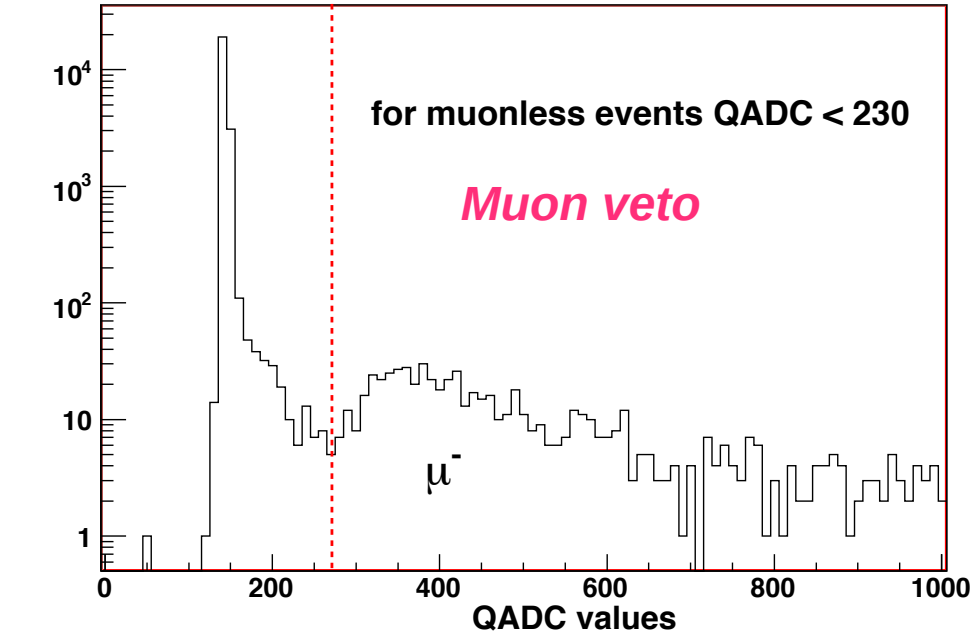
* This η index in a tower is not the physical η.
In a hadron barrel η runs from 0 to 1.3
$\eta = -\ln(\tan(\theta/2))$; $\eta = (\eta_{tower} - 0.5) \times \Delta\eta$

Selection criteria

Putting selection criterion on muon veto counter

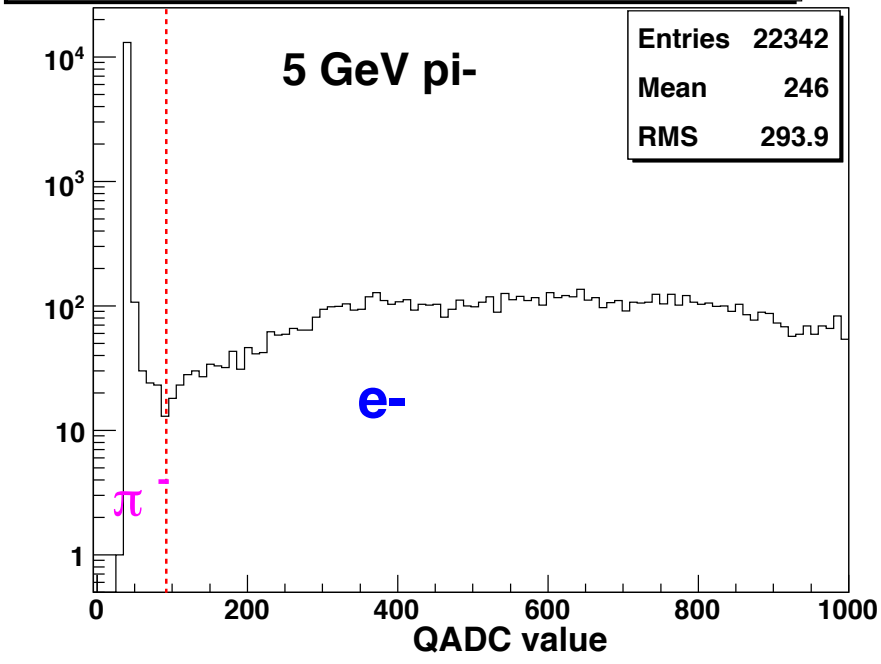


Selecting out muons

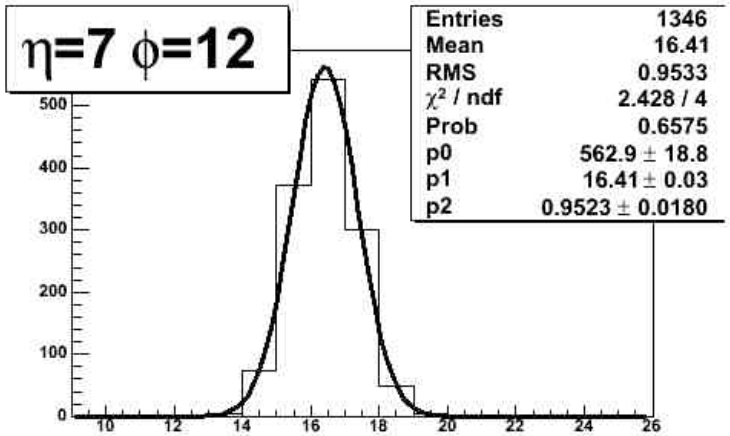
Cerenkov counter (VLE) (π / e)

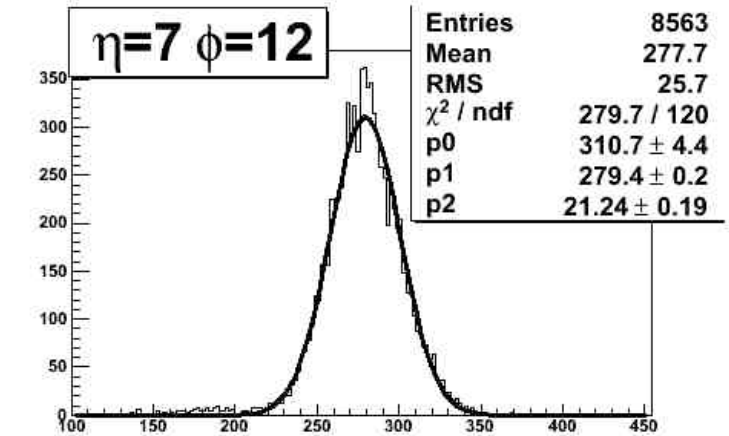
Separating out pions from electrons

Putting selection criterion on Cerenkov counter



Calibration of Hadron Barrel (HB1) with electron beam





❑ Pedestal and pedestal-subtracted-signal distribution in HB1 for 50 GeV e^-

Pedestal events: Random trigger events

Signal events: Beam trigger events with the selection criteria for selecting out muons and pions using beam counters

The procedure:

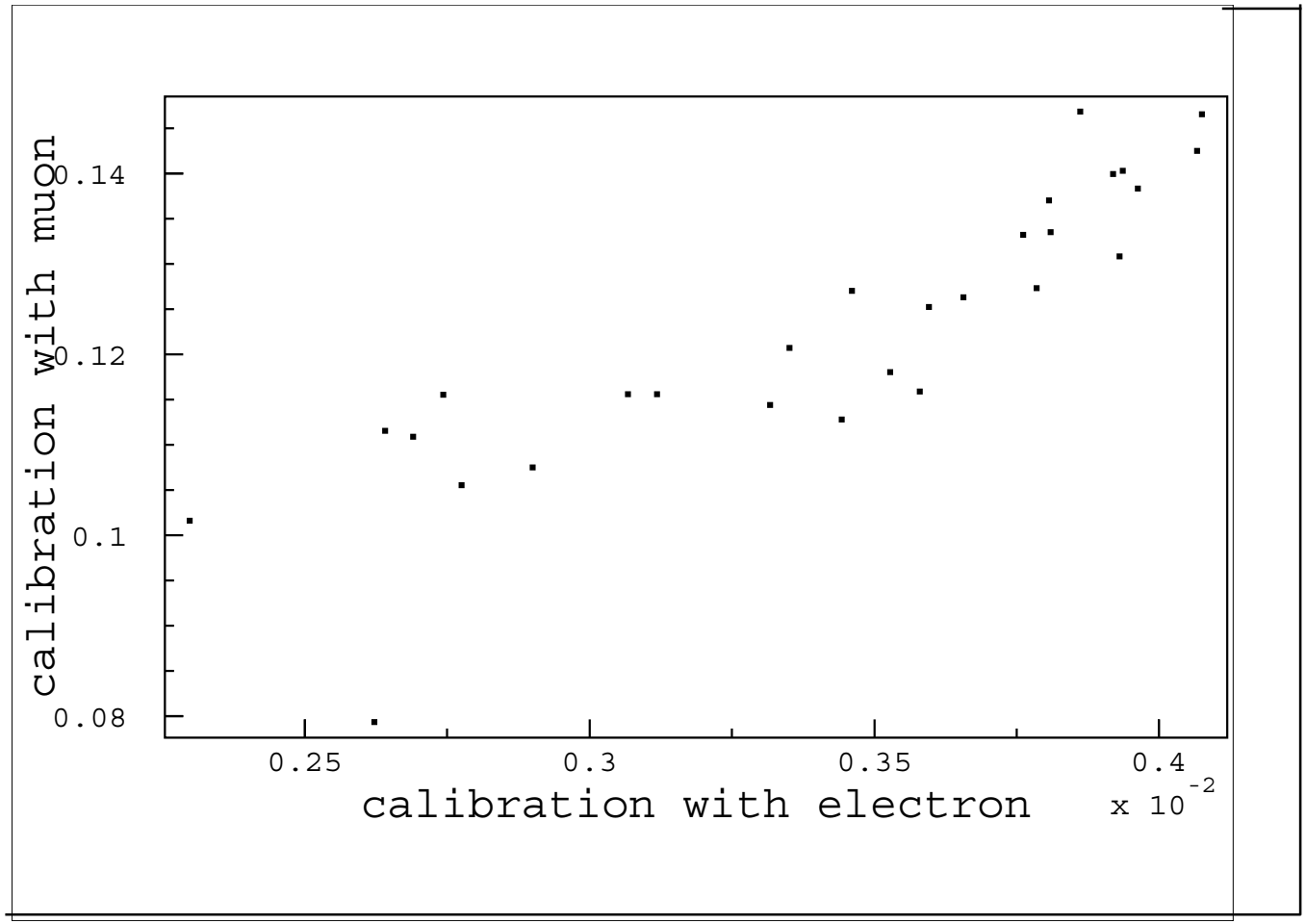
i. First the pedestal and signal events plotted separately.

ii. The pedestal was fitted with a Gaussian function.

iii. The signal function was fitted with a sum of Gaussian (with its width and peak fixed from pedestal data) and a Gaussian convoluted with Landau.

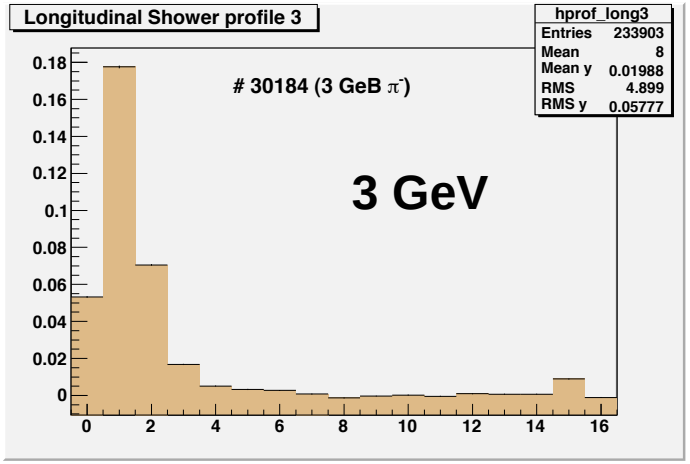
iv. The calibration constant was found out by taking the inverse of the mean of the fitted function on the signal.

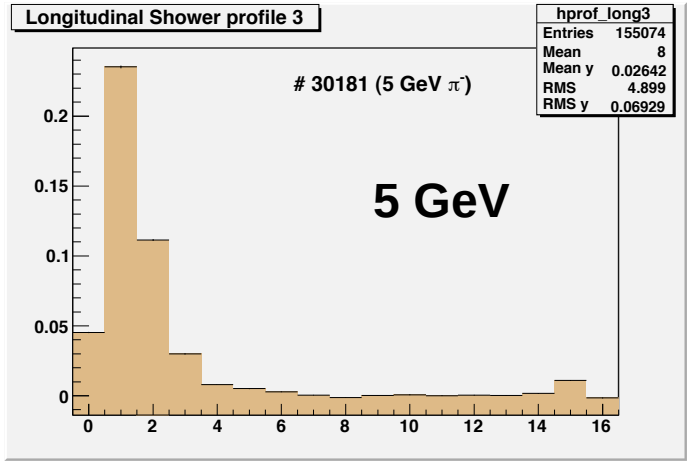
- The scatter plot showing the correlation between the calibration constants as obtained with muon runs and electron runs

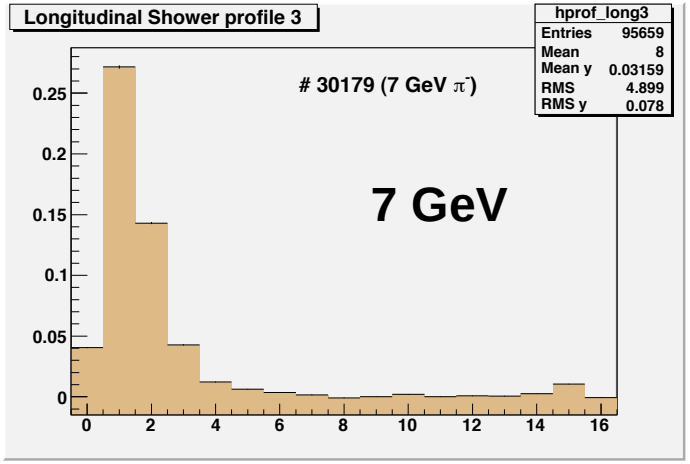


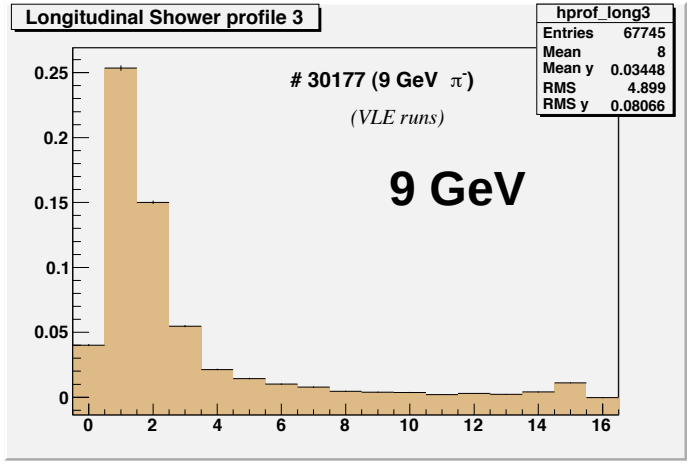
Longitudinal shower profiles for VLE Electron runs (2 – 9 GeV)

Longitudinal shower profiles – VLE electrons

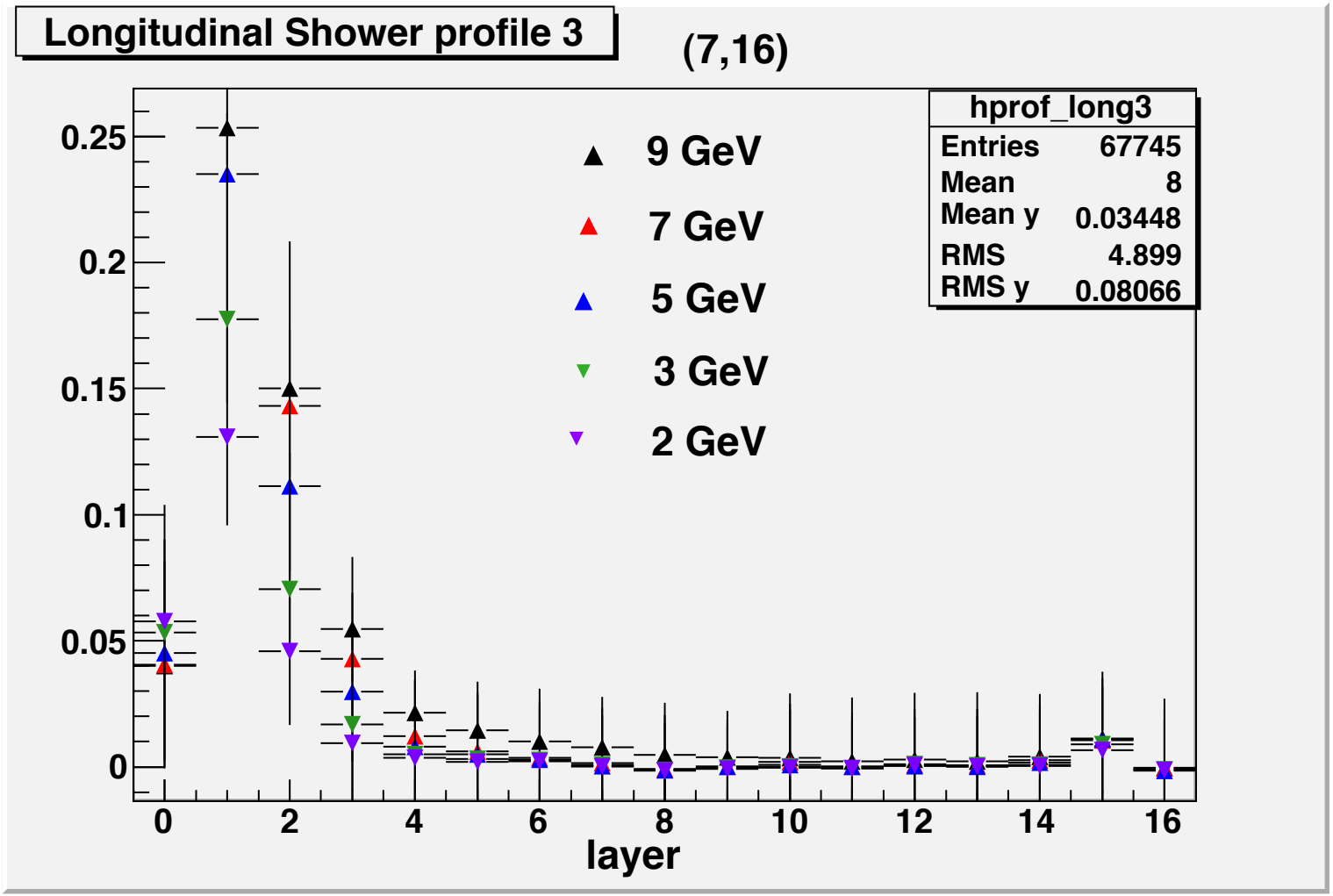






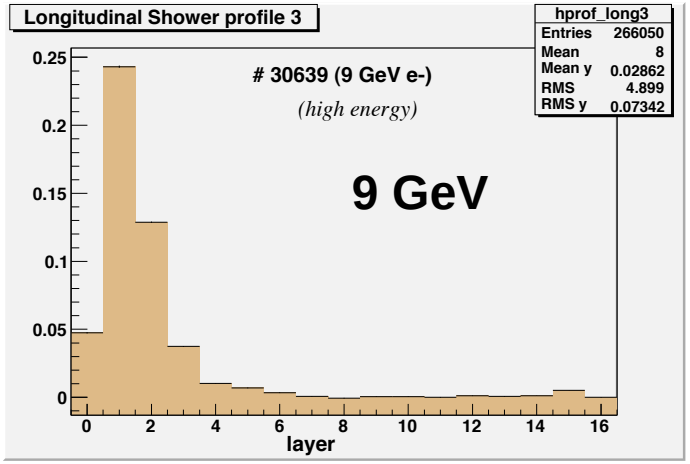


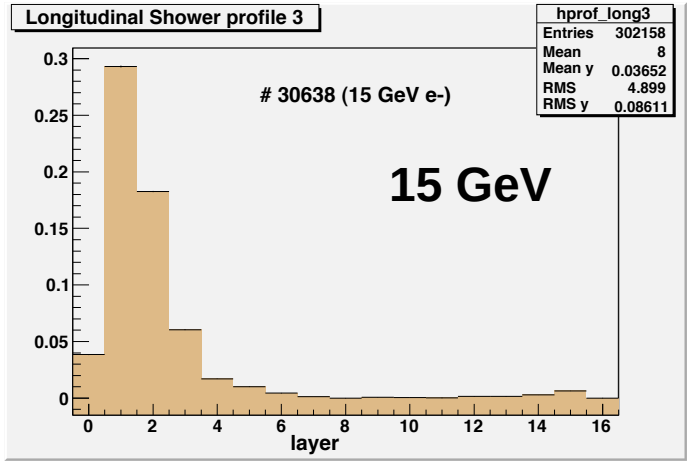
Longitudinal shower profiles – VLE electrons

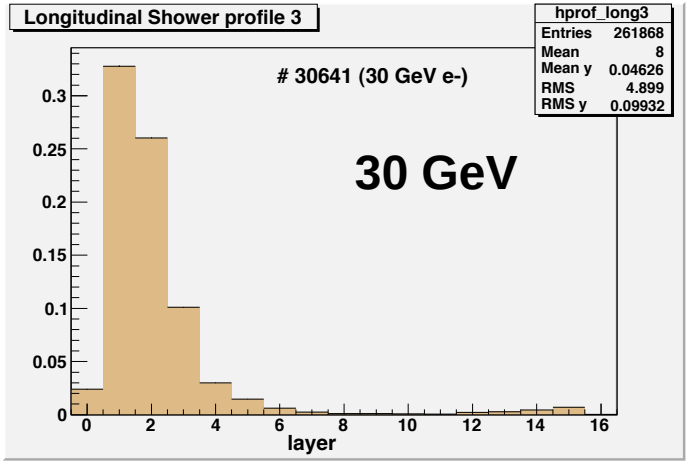


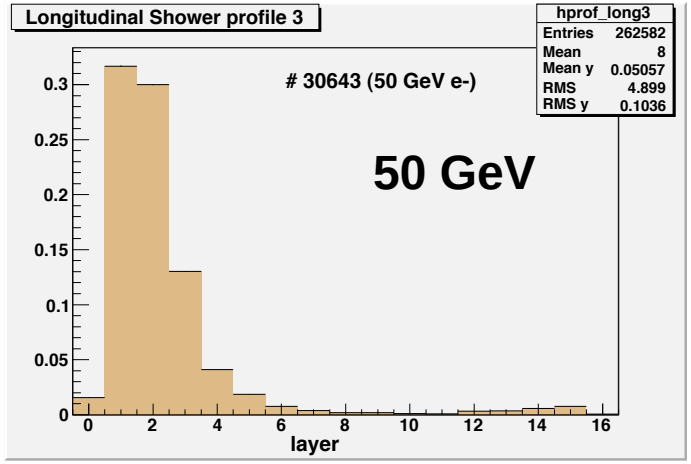
Longitudinal shower profiles for High Energy Electron Runs (9 – 150 GeV)

Longitudinal shower profiles – HE electrons



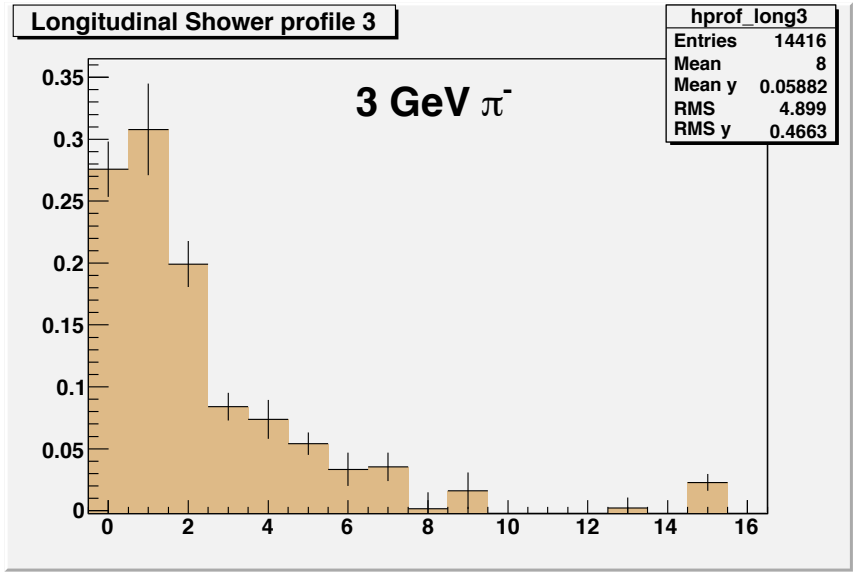


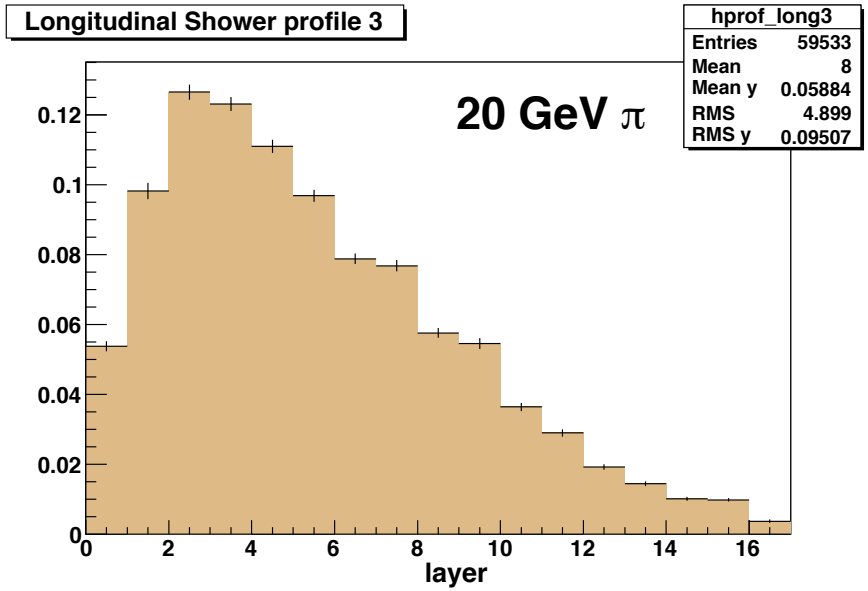


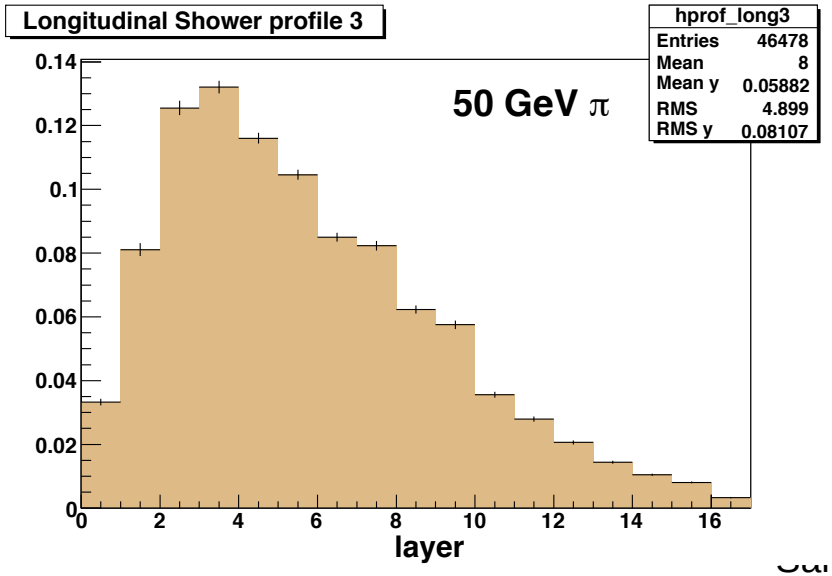


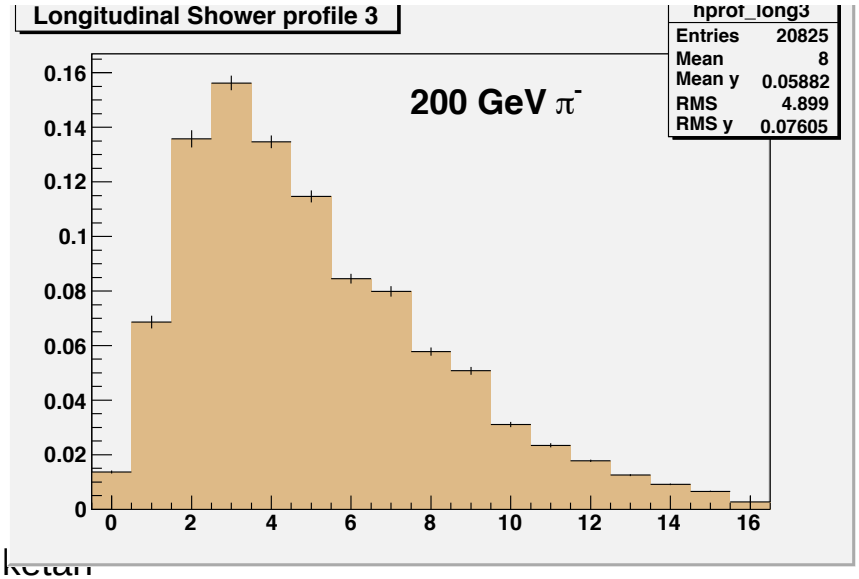
Longitudinal Shower profile for Pion Runs (3 – 200 GeV)

Longitudinal shower profiles – Pion

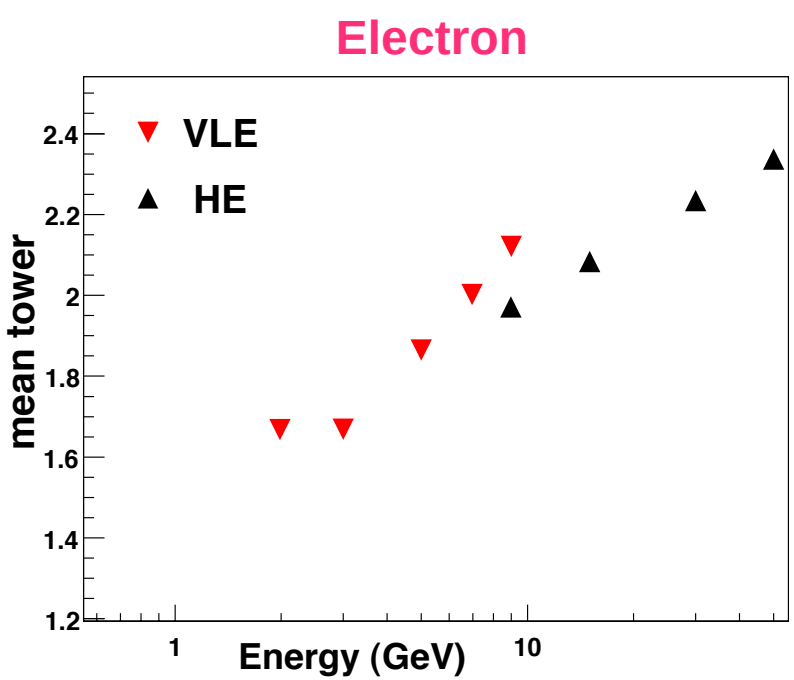


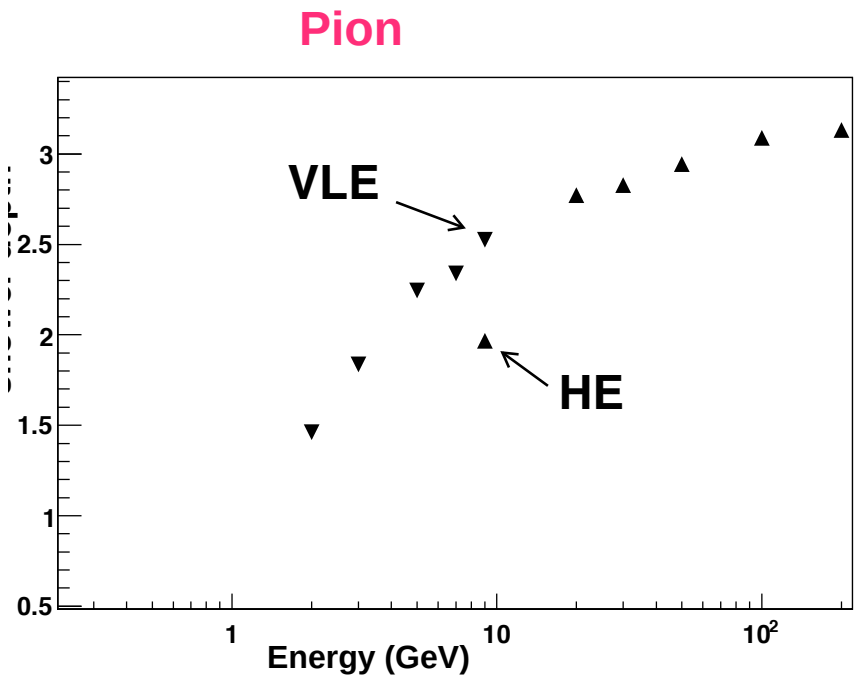






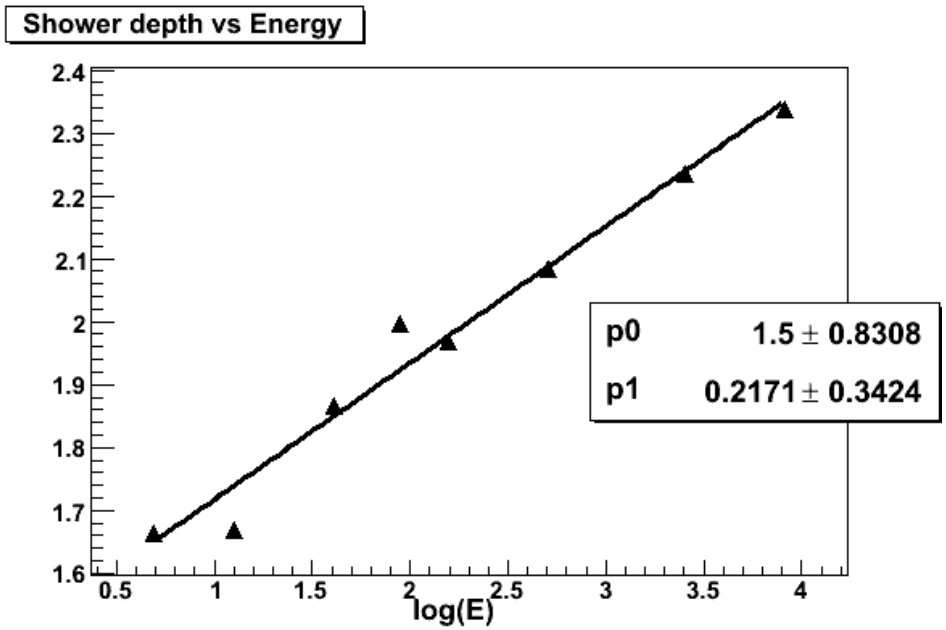
Shower depth as a function of beam energy

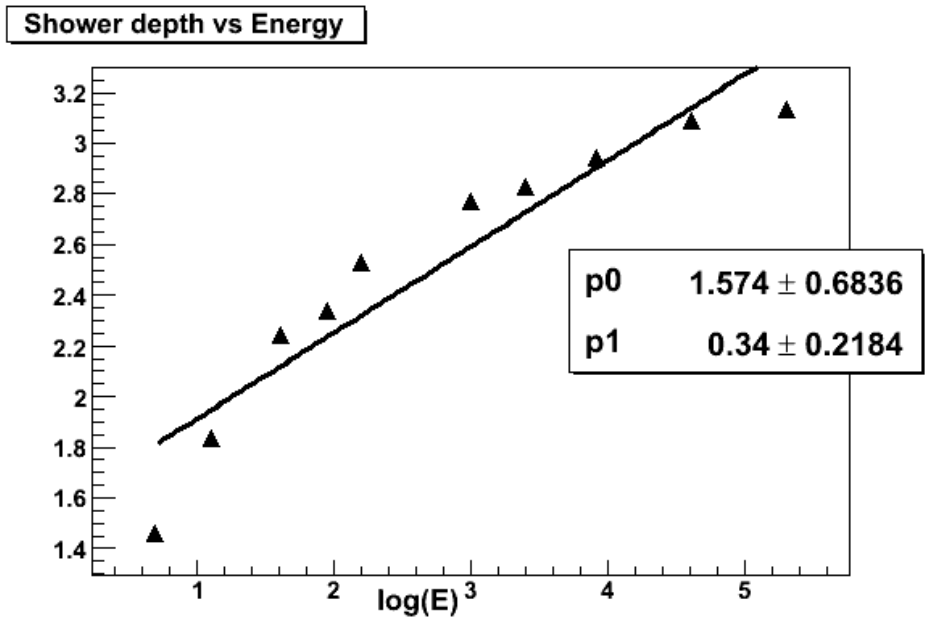




Shower depth as a function of beam energy (contd)..

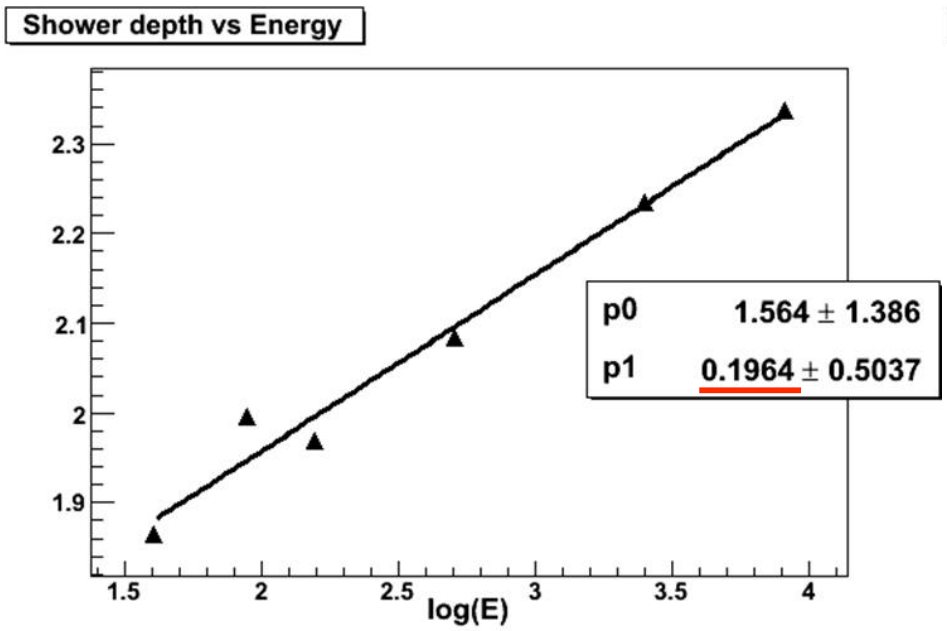
- The shower depth in a calorimeter varies logarithmically with the beam energy.

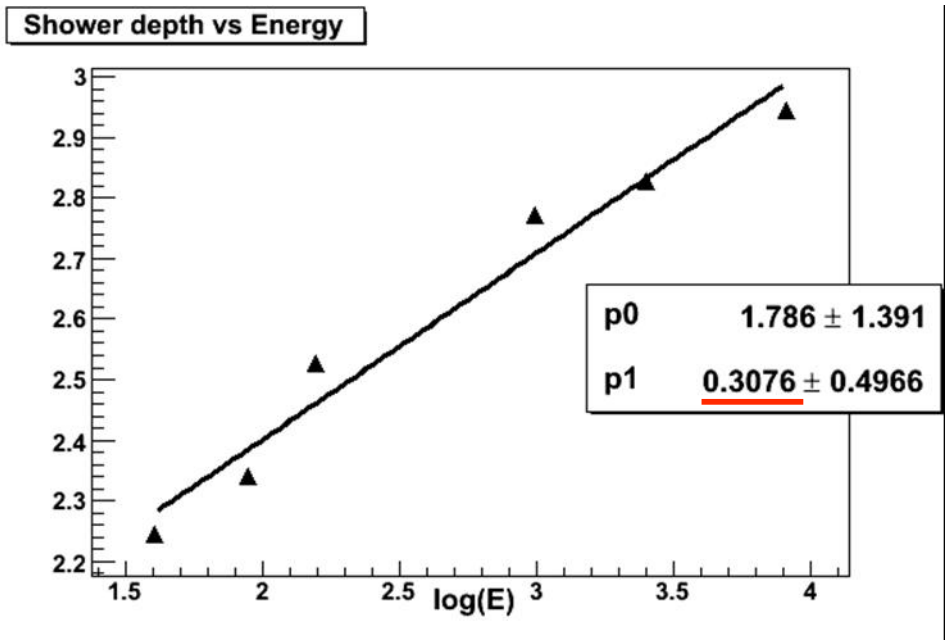




Shower depth as a function of beam energy (contd)..

the very low energy plots have more contamination (specially for the pion runs) so if we ignore them and take the difference in the intercept becomes more distinct, as seen in the plots.





The shower depth is seen to be more in the case of pions, as expected !

Conclusion and outlook

- The hadron calorimeter is calibrated using the electrons.
- The relative calibration constants obtained from the electrons are plotted against those obtained from the muons and they are shown to have a correlation.
- Longitudinal shower profiles for electron as well as pion are studied as a function of beam energy. The average shower depth increases logarithmically with energy for both electrons and pions.
- The shower depth is seen to be more in the case of pions.
- We are yet to look at the shower profiles coming from monte carlo calculations. We have to validate the Geant4 simulation models with the test beam data.

Thank you

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