UTA GEM-DHCal Study

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- Single Pion Study
  - GEM Analog study
  - GEM Digital study
- Study of $e^{+}e^{-} \rightarrow t\bar{t} \rightarrow 6\,jets$ Pythia events
- Energy Flow Algorithm – Preliminary study
  - Hits weighted method
  - Energy weighted method
  - Density weighted method
- Conclusion

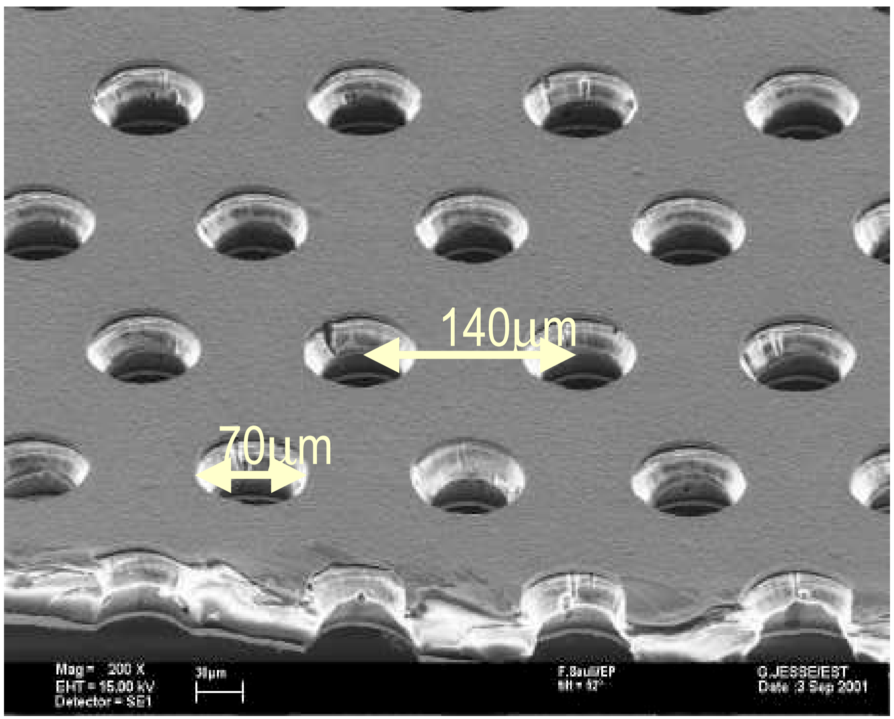
*On behalf of the HEP group at UTA.

Introduction

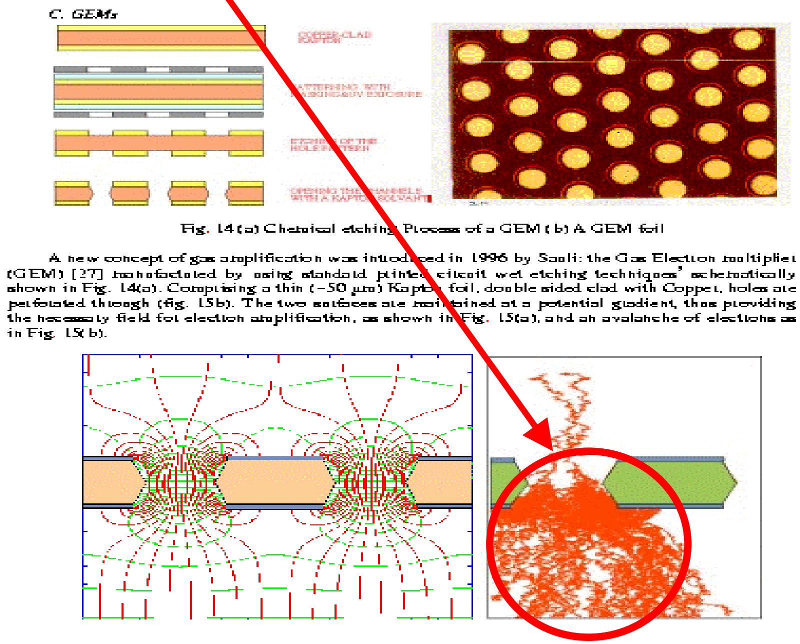
- DHCAL a solution for keeping the cost manageable for EFA
- Finer cell sizes are needed for effective calorimeter cluster association with tracks and subsequent energy substraction
- UTA Has been working on DHCAL using GEM for
  - Flexible geometrical design, using printed circuit readout
  - Cell sizes can be as fine a readout as GEM tracking chamber!!
  - High gains, above $10^{3\sim4}$,with spark probabilities per incident π less than 10^{-10}
  - Fast response
    - 40ns drift time for 3mm gap with $ArCO_2$
  - Relatively low HV
    - A few 100V per each GEM gap
  - Reasonable cost
    - Foils are basically copper-clad kapton
    - ~$200 for a specially prepared and framed 10cmx10cm foil
    - Now there is a mass production facility at 3M in Texas!!!

Gas Electron Multiplier (GEM)

Large Amplification



CERN-open-2000-344, A. Sharma



C. GEMs

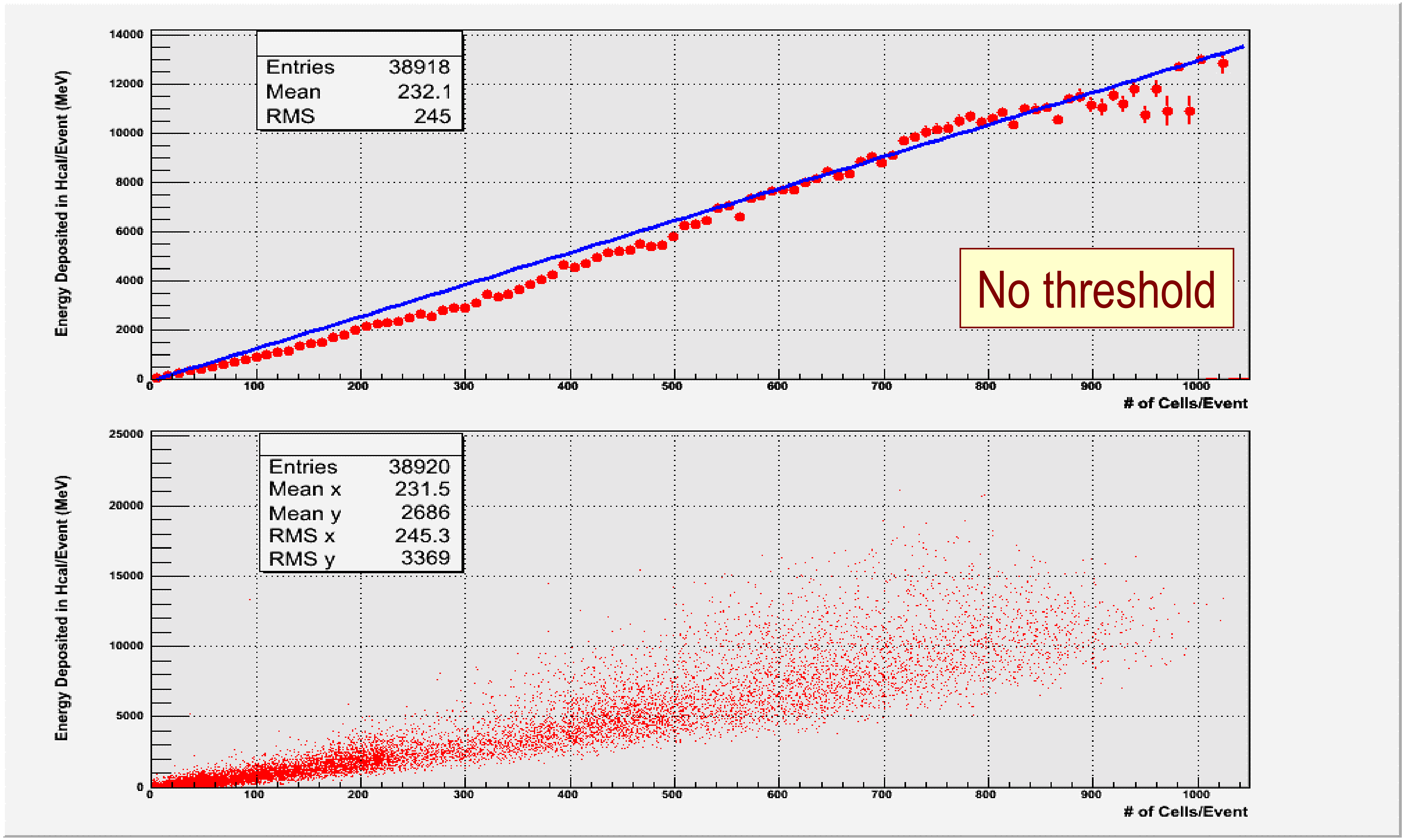
Fig. 14(a) Chemical etching Process of a GEM (b) A GEM foil

A new concept of gas amplification was introduced in 1996 by Sauli: the Gas Electron multiplier (GEM) [27] manufactured by using standard printed circuit wet etching techniques' schematically shown in Fig. 14(a). Comprising a thin (~50 μm) Kapton foil, double sided clad with Copper, holes are perforated through (fig. 15b). The two surfaces are maintained at a potential gradient, thus providing the necessary field for electron amplification, as shown in Fig. 15(a), and an avalanche of electrons as in Fig. 15(b).

Fig. 15(a) Electric Field and (b) an avalanche across a GEM channel

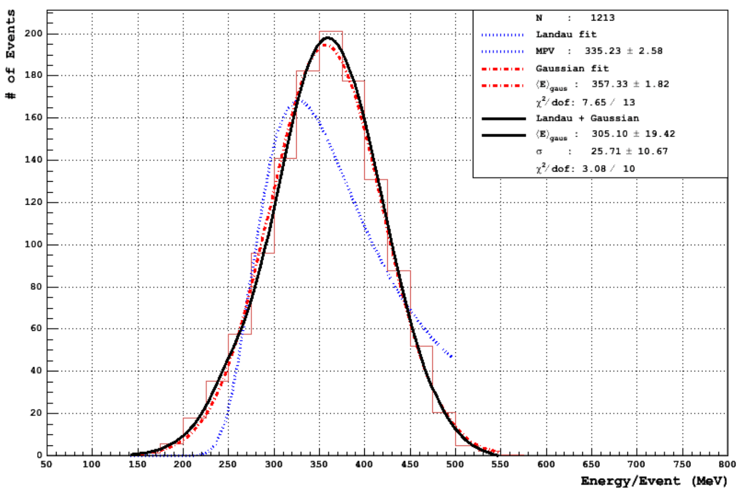
Coupled with a drift electrode above and a readout electrode below, it acts as a highly performing micropattern detector. The essential and advantageous feature of this detector is that amplification and detection are decoupled, and the readout is at zero potential. Permitting charge transfer to a second amplification device, this opens up the possibility of using a GEM in tandem with an MSGC or a second GEM.

GEM-Digital: E_{live} vs # of hits for π^-

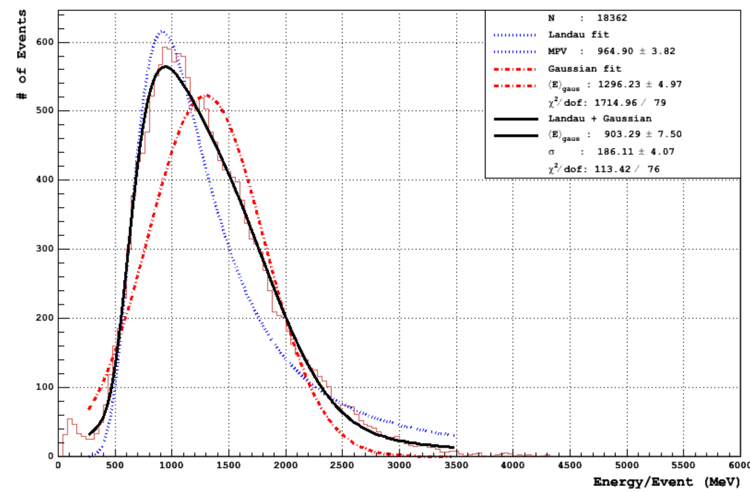


Ecal and Hcal: 15 and 50 GeV π^-

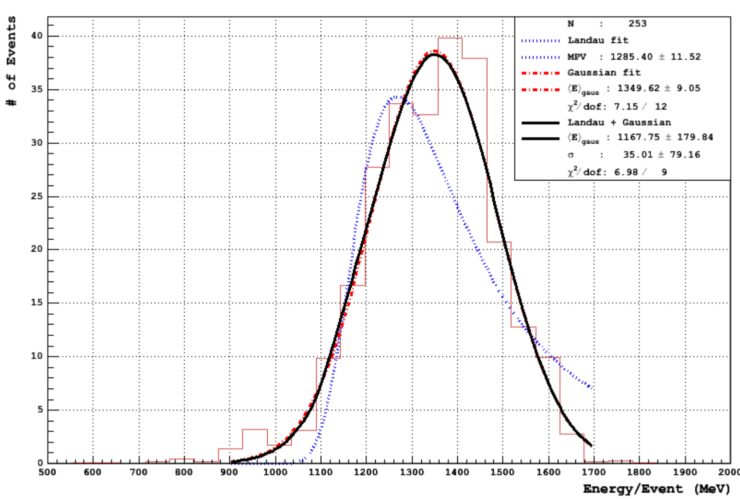
15GeV /ecal distribution



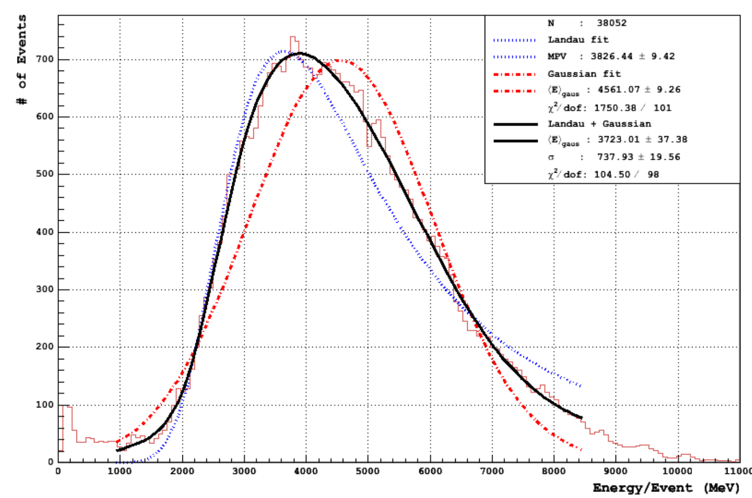
15GeV /hcal distribution



50GeV /ecal distribution



50GeV /hcal distribution

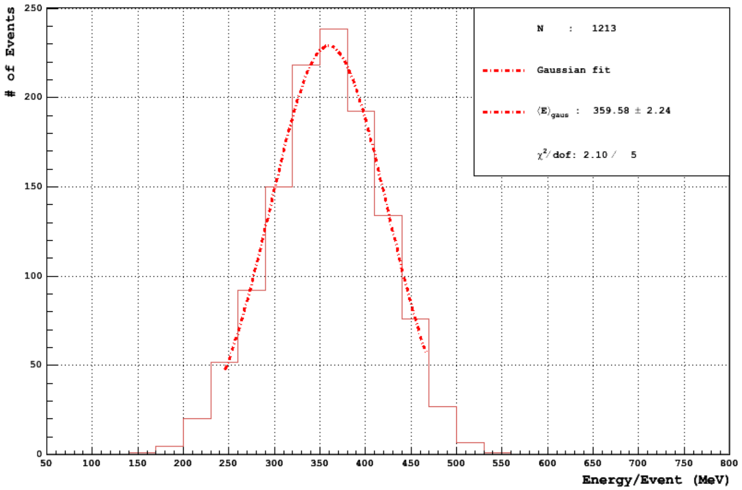


EM-HCAL Weighting Factor

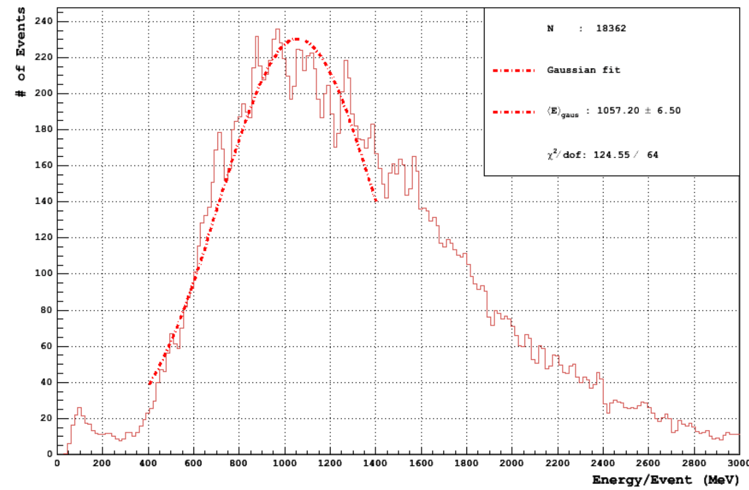
- $E_{Live} = \Sigma E_{EM} + W\, \Sigma G E_{HCAL}$
- Landau + Gaussian is used to determine the mean values as a function of incident pion energy for EM and HAD
- Define the range for single Gaussian fit using the mean
- Take the mean of the Gaussian fit as central value
- Obtained the relative weight W using these mean values for EM only v/s HCAL only events
- Perform linear fit to Mean values as a function of incident pion energy
- Extract ratio of the slopes ➔ Weight factor *W*
- $E = C^* E_{Live}$

Ecal and Hcal: 15 and 50 GeV π^-

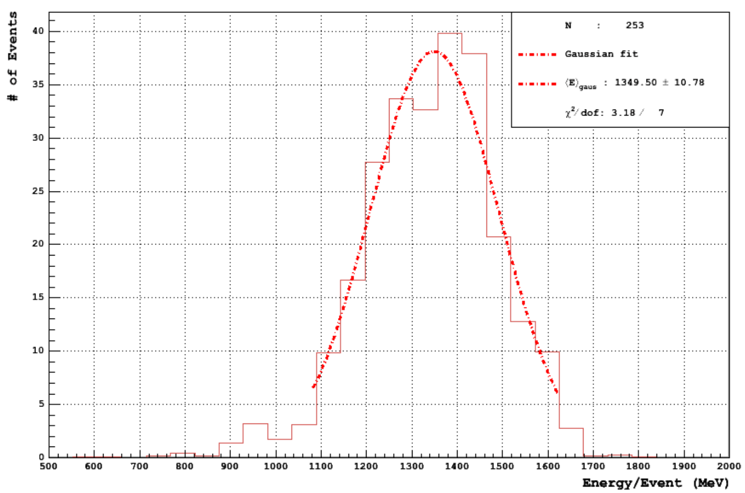
15GeV /ecal distribution



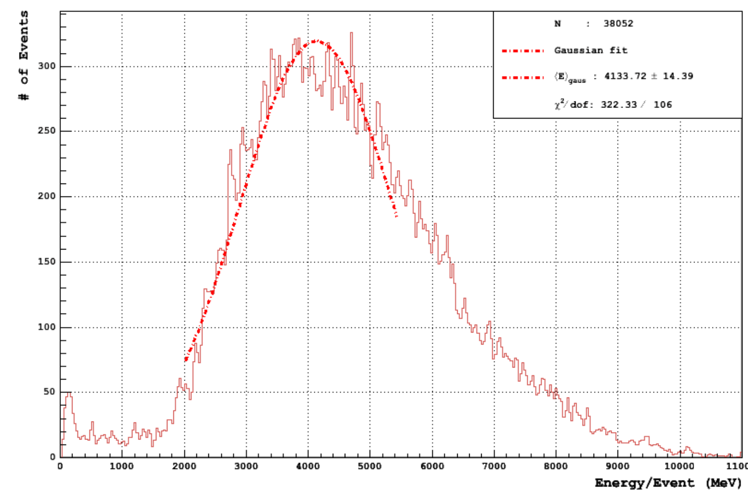
15GeV /hcal distribution



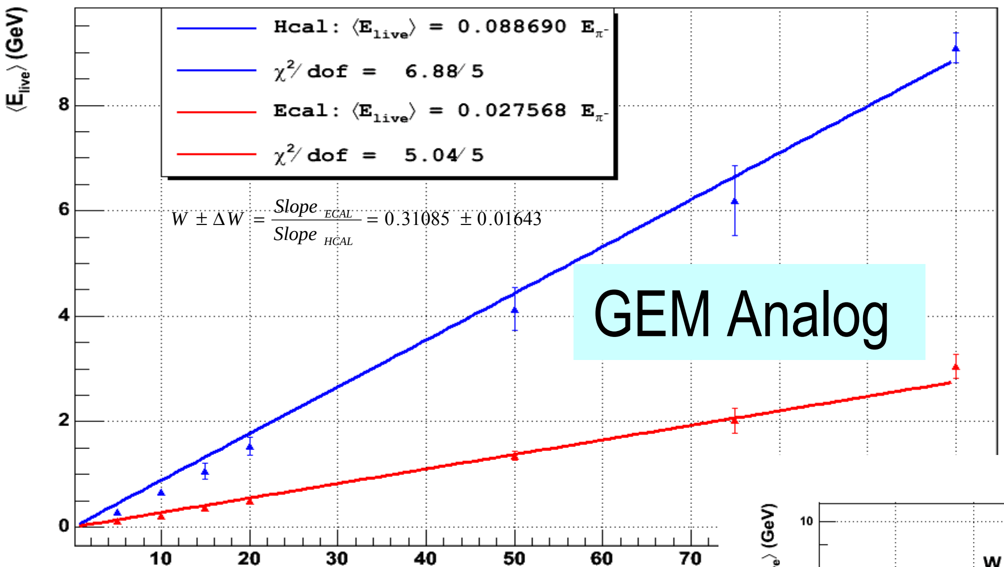
50GeV /ecal distribution

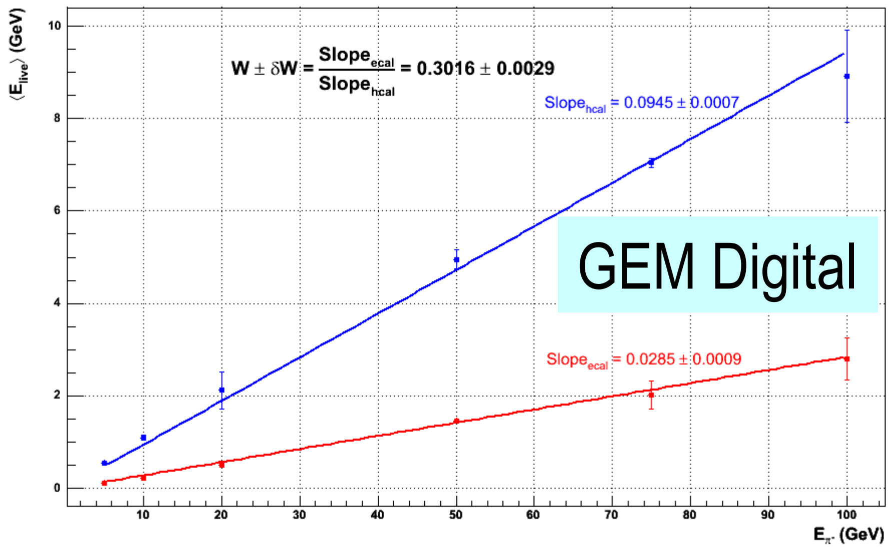


50GeV /hcal distribution

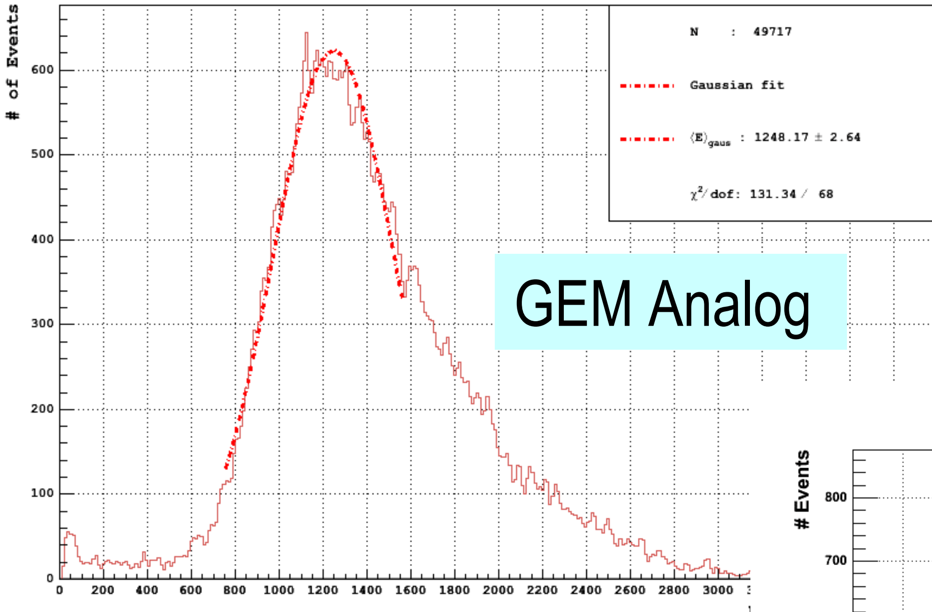


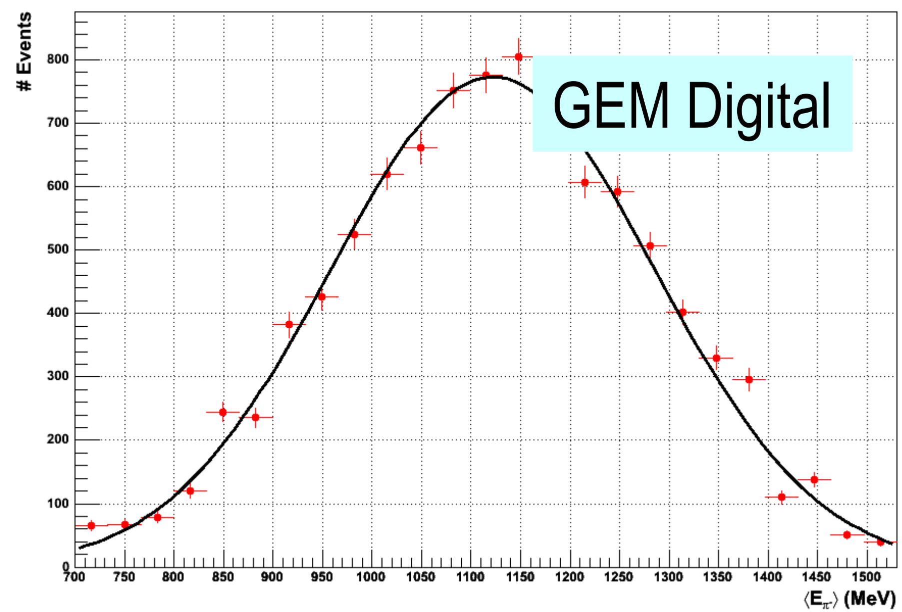
GEM Analog – Relative Weights



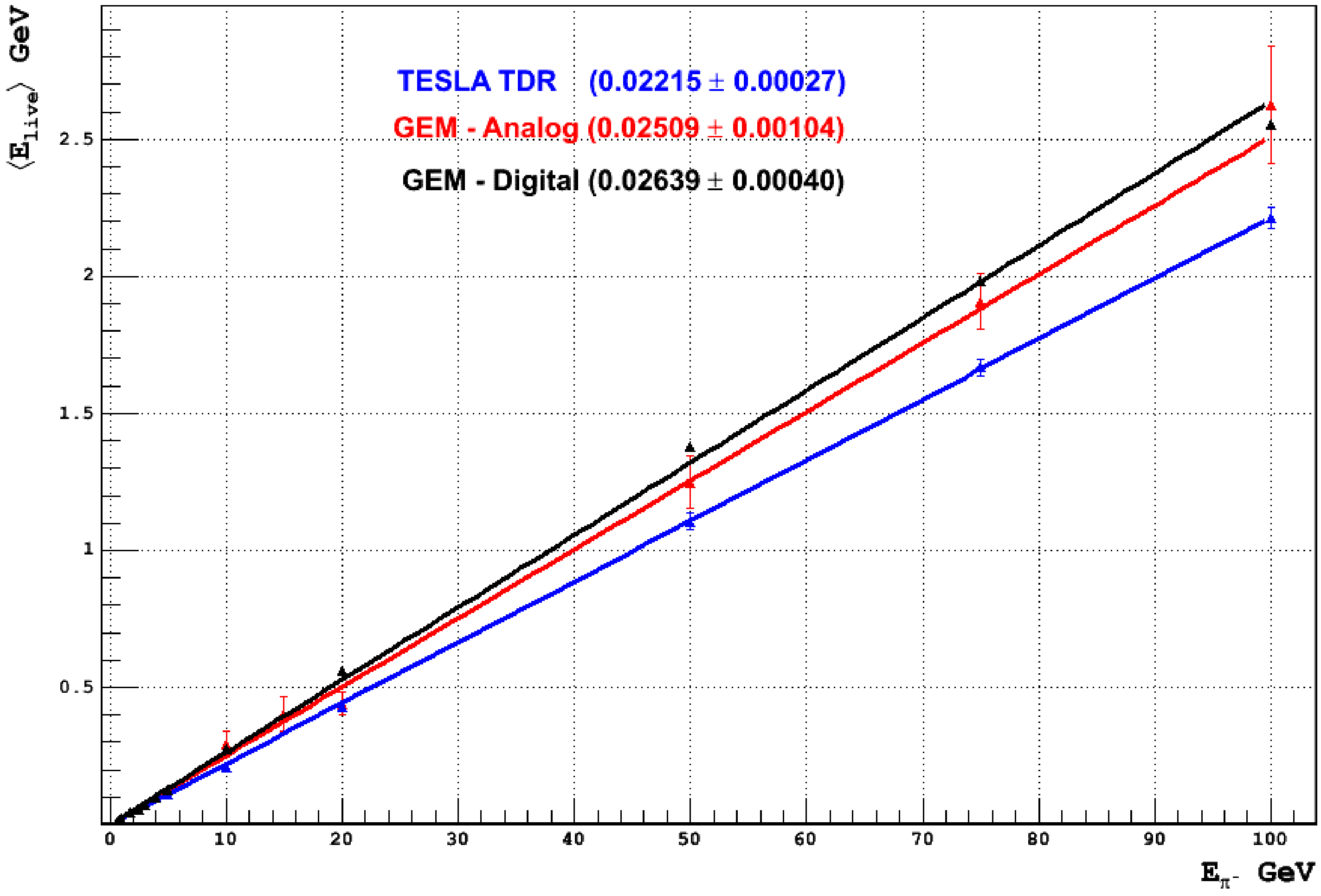


Live Energy 50 GeV π^-

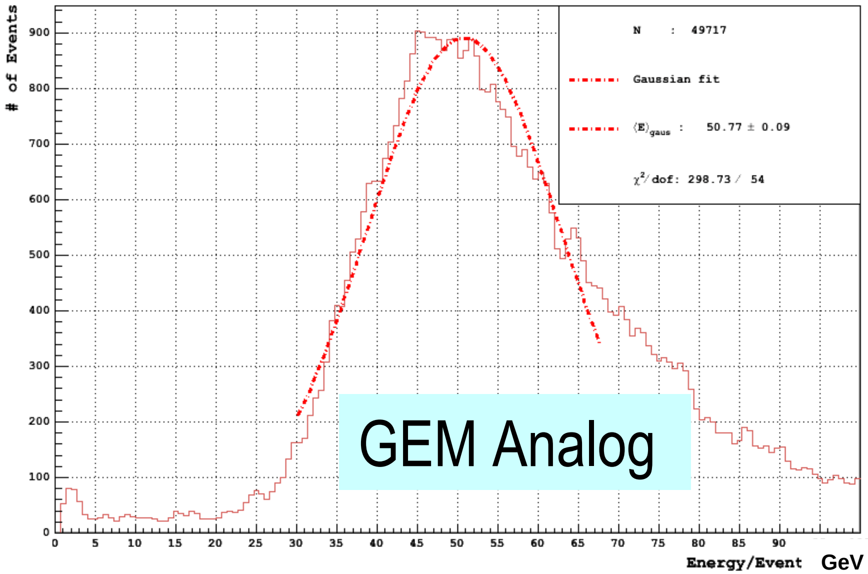


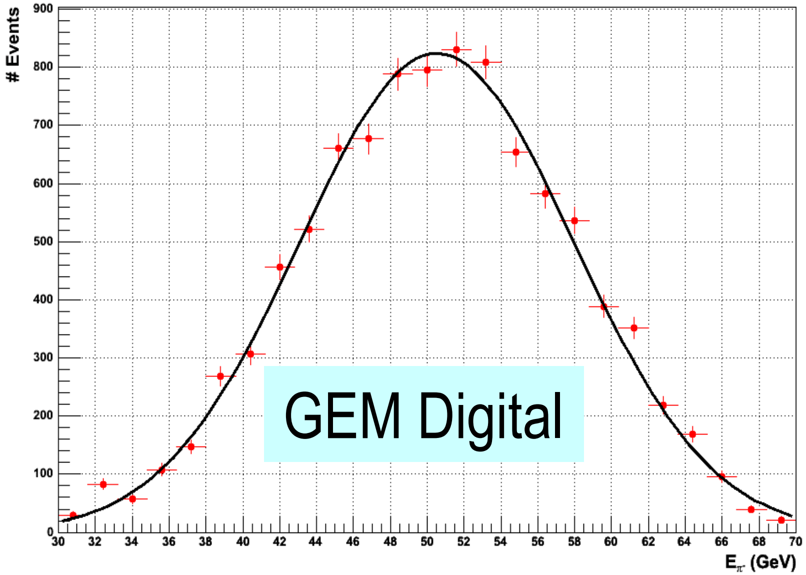


Response - Comparison

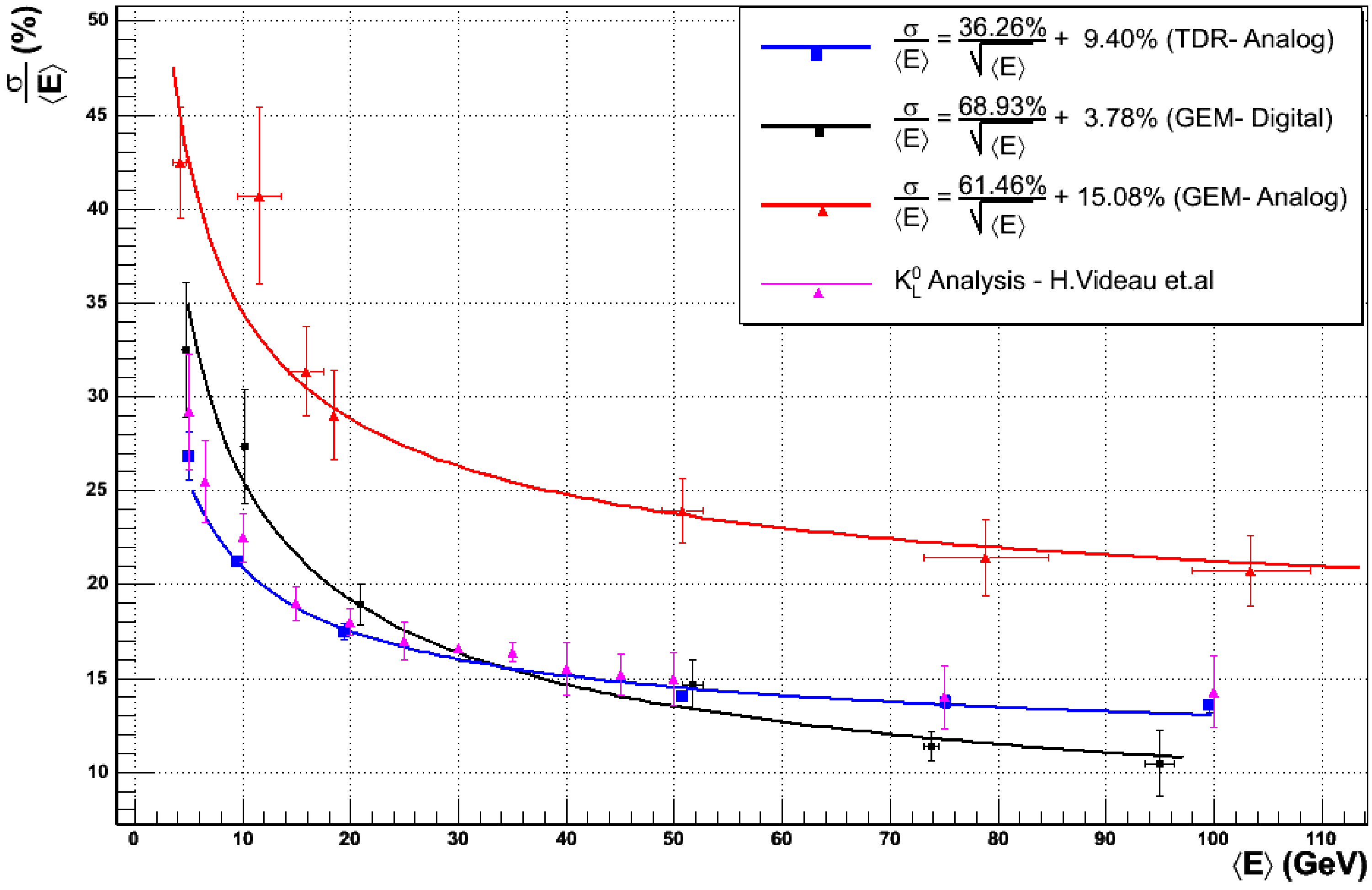


Converted energy: 50 GeV π^-





Resolution - Comparison



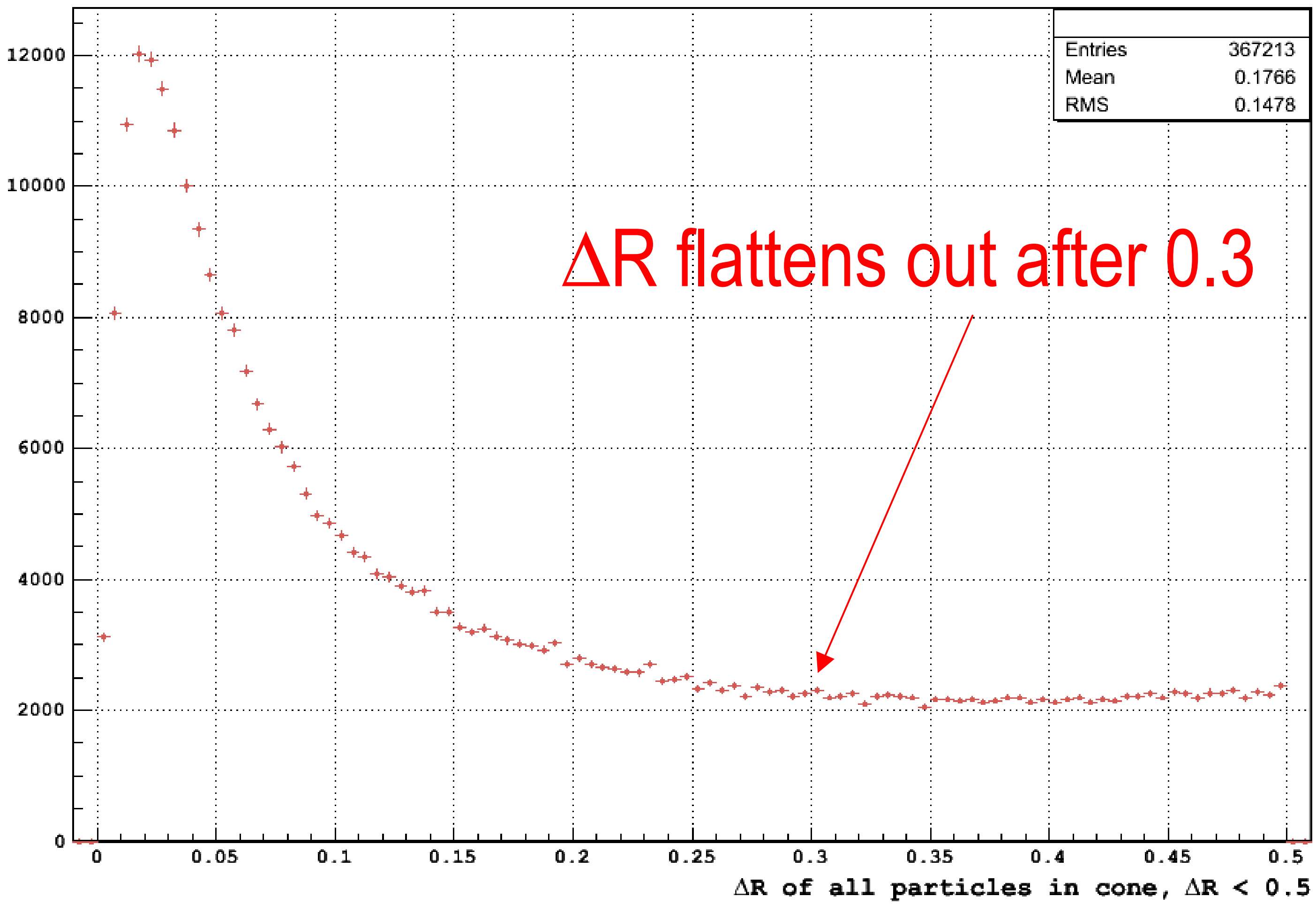
GEM Performance Study Summary

- GEM digital and analog responses comparable
  - Large remaining Landau fluctuation in analog mode observed
  - Digital method removes large fluctuation
- GEM Energy resolutions
  - Digital comparable to TDR
  - Analog resolution worse than GEM digital or TDR
- GEM is as good a detector as others for DHCAL

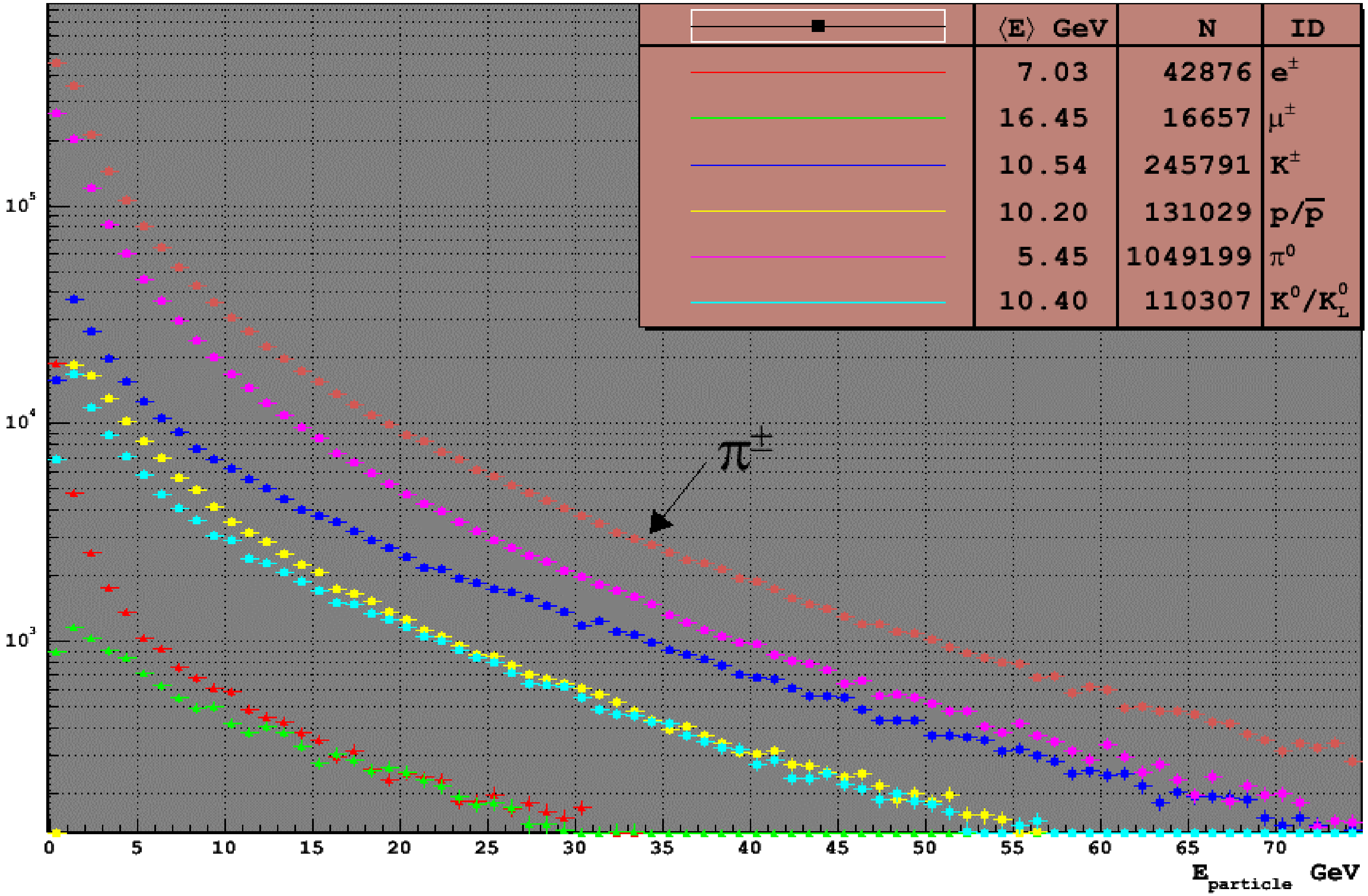
Analysis of $e^+e^- \rightarrow t\bar{t} \rightarrow 6\ jets$

- Energy distribution of final state particles in jets
- Choose a ΔR = 0.5 cone around a quark to define a jet
- Determine energy fraction of jets carried by EM, Neutral and Hadrons
- Determine the relative distances between all pairs of charged, neutral particles in the cone
- Use two pions to study effective charged hadron energy subtraction
- Study of centroid finding algorithm

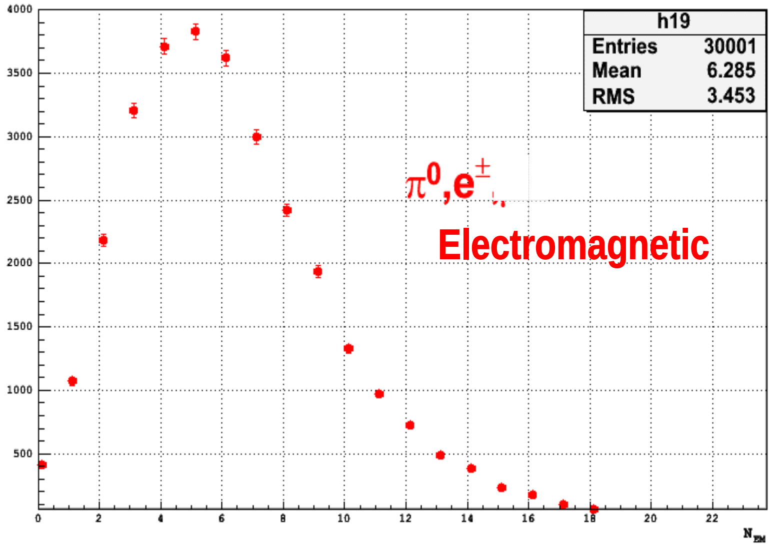
ΔR of all the particles relative to quark

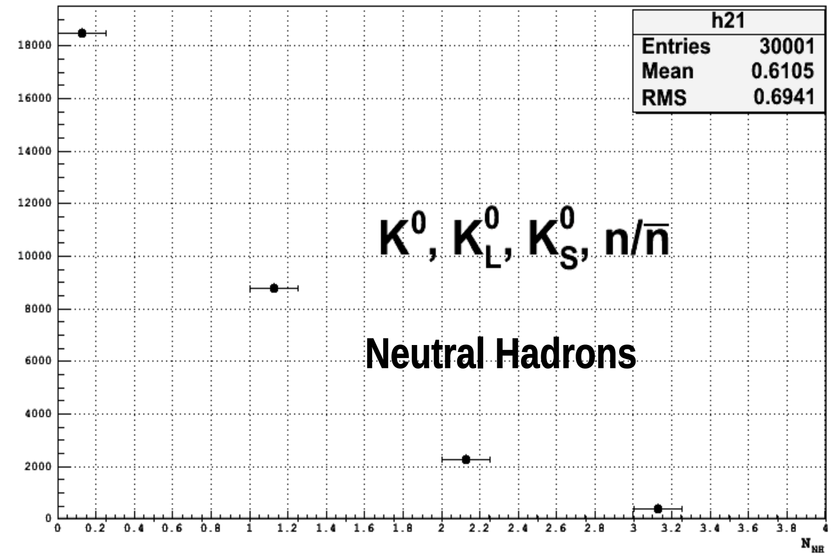


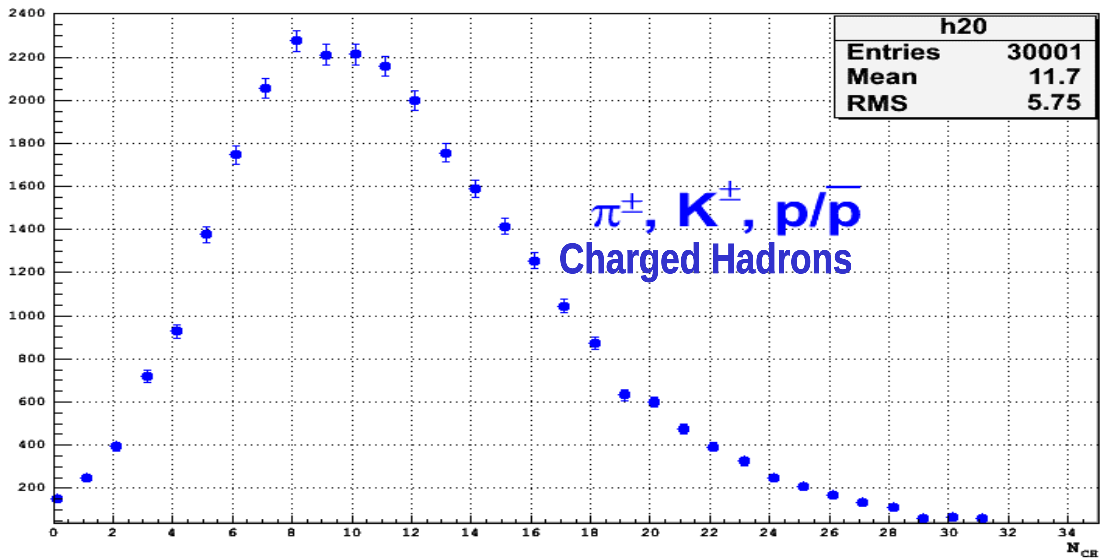
Energy distribution in a jet



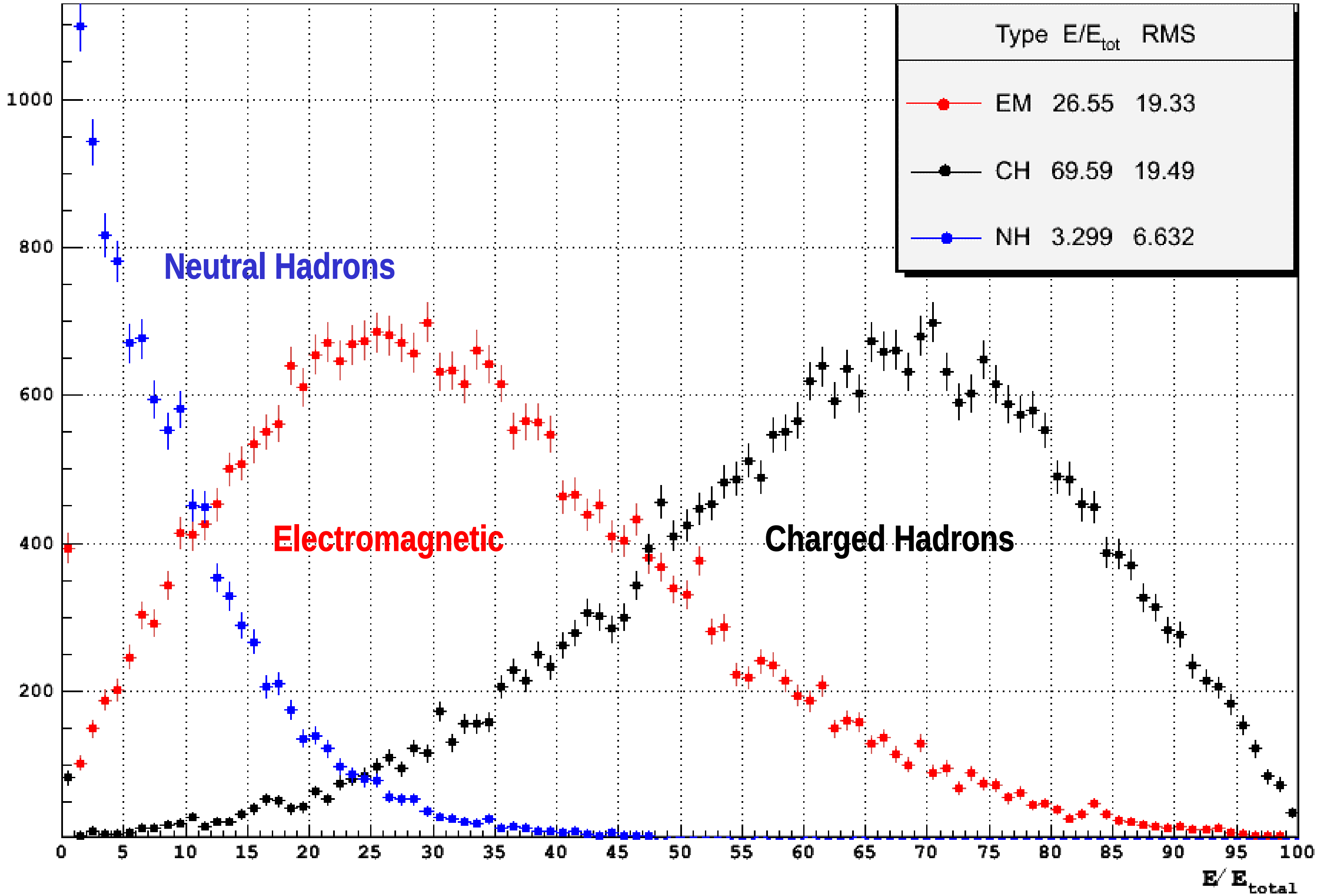
Fraction of Particles in Jets



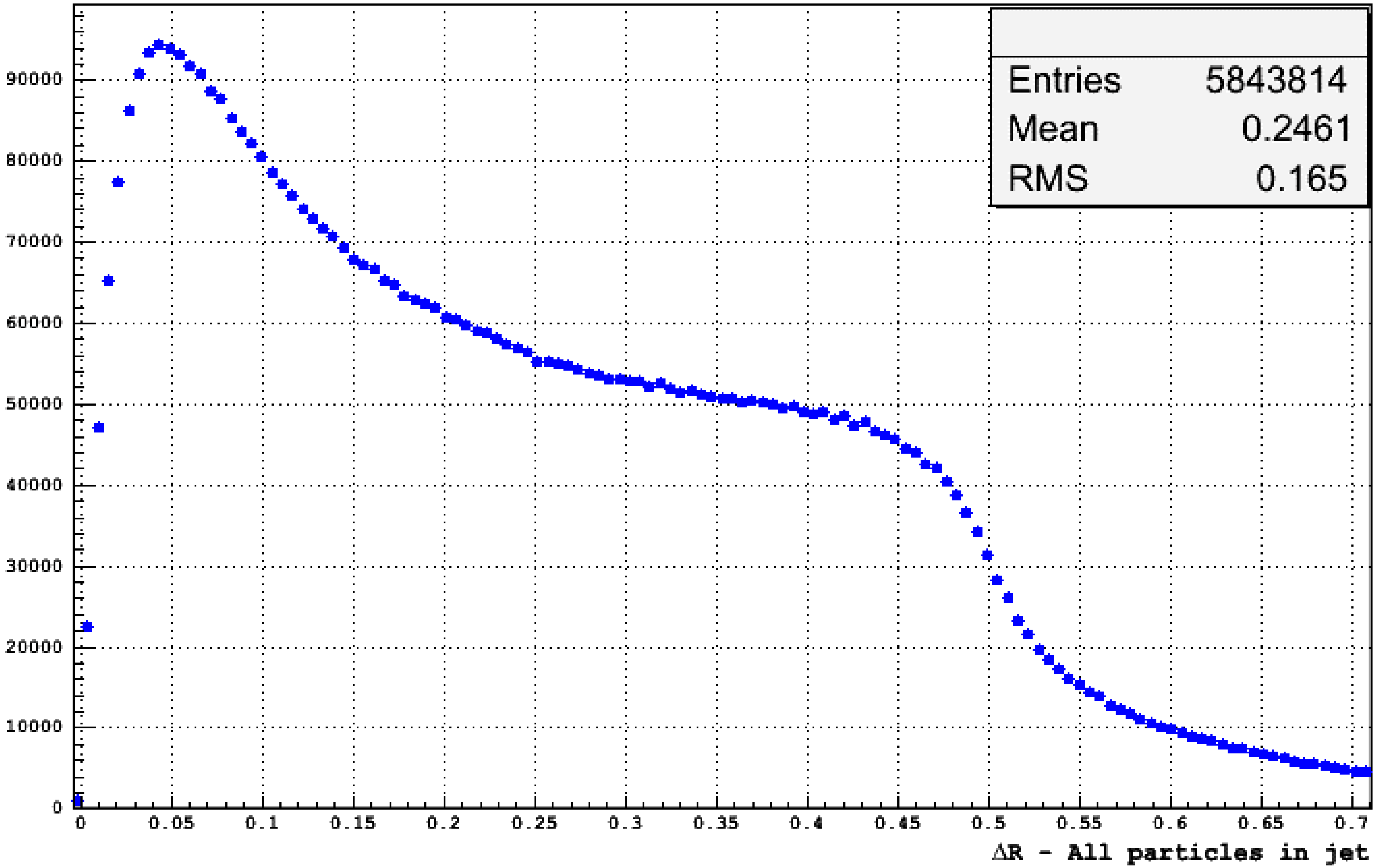




Fraction Energy of Particles in Jets



ΔR Between All Particles in Jets



Energy Flow Studies for π^-

- Pions $\langle E_{\pi^-} \rangle = 7.5$ GeV chosen for study
- Studied the energy distribution of pions in jet events

$$e^+e^- \rightarrow t\bar{t} \rightarrow 6\,jets \quad \sqrt{s} = 1.0TeV$$

- Find the centroid of the shower (HCAL) using
  - Energy weighted method
  - Hits weighted method
  - Density weighted method
- Matched the extrapolated centroid with TPC last layer hit to get $\Delta\theta$ and $\Delta\varphi$ distribution

Determination of Calorimeter Centroid

- Identify layers with hits (at least 3 hits required)
- Fit a line through all layers (at least 2 layers with 3 or more hits required)
- Extrapolate the line to TPC last layer
- Compare θ_{tpc} with θ_{hcal} and ϕ_{tpc} with ϕ_{hcal}

Methods for determination of centroid

Hits Weighted Method

$$\overline{\theta_i} = \frac{\sum_{j=1}^{n} \theta_{ij}}{n} \qquad \overline{\phi_i} = \frac{\sum_{j=1}^{n} \phi_{ij}}{n}$$

Energy Weighted Method

$$\overline{\theta_i} = \frac{\sum_{j=1}^{n} E_{ij}\theta_{ij}}{\sum_{j=1}^{n} E_{ij}} \qquad \overline{\phi_i} = \frac{\sum_{j=1}^{n} E_{ij}\phi_{ij}}{\sum_{j=1}^{n} E_{ij}}$$

Density Weighted Method

$$d_i = \sum_{j=1, j\neq i}^{n} \frac{1}{R_{ij}} \qquad \overline{\theta_i} = \frac{\sum_{j=1}^{n} d_{ij}\theta_{ij}}{\sum_{j=1}^{n} d_{ij}} \qquad \overline{\phi_i} = \frac{\sum_{j=1}^{n} d_{ij}\phi_{ij}}{\sum_{j=1}^{n} d_{ij}}$$

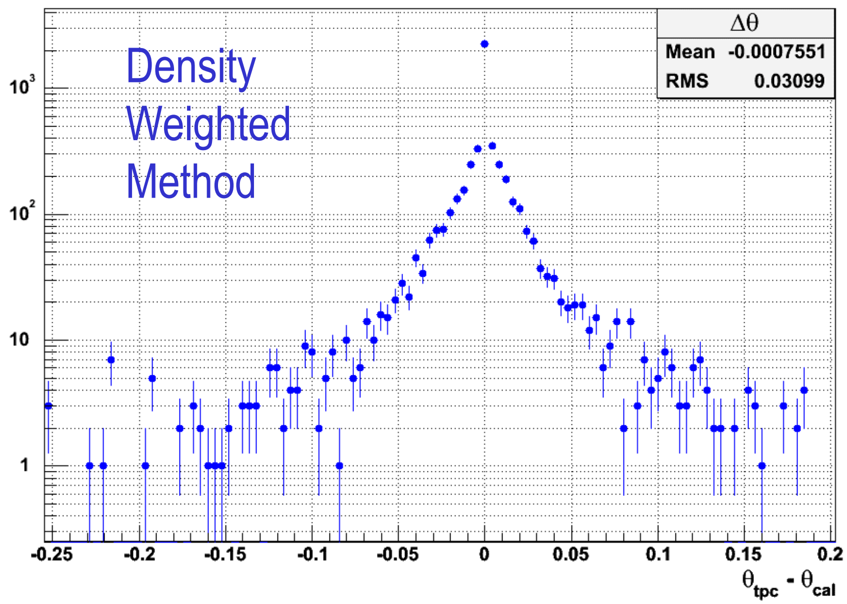
For all three methods:

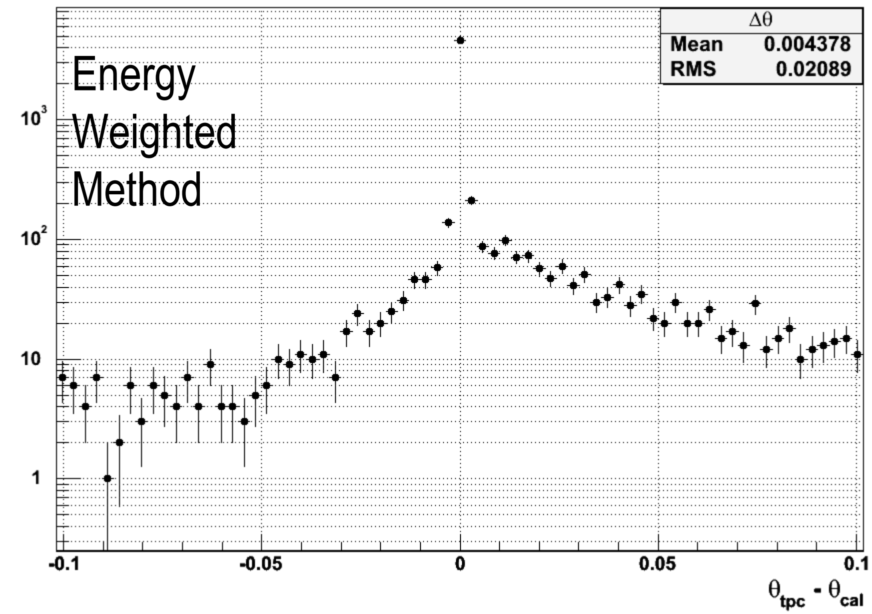
$j : 1 \rightarrow n$

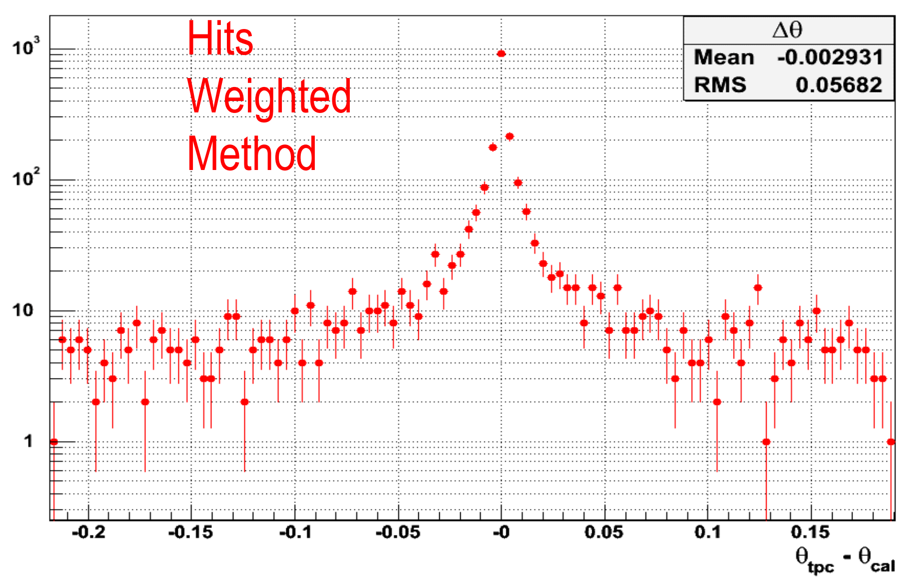
$n : Number\ of\ hits\ in\ layer\ i$

$i : 1 \rightarrow 40$

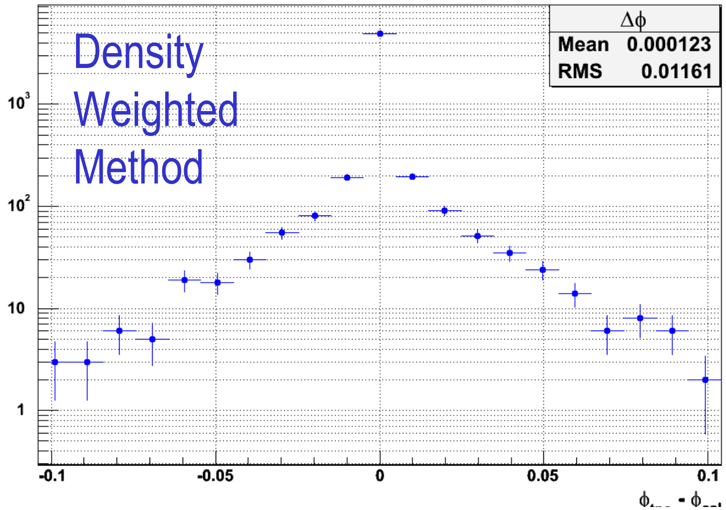
Δθ - 7.5 GeV π^-

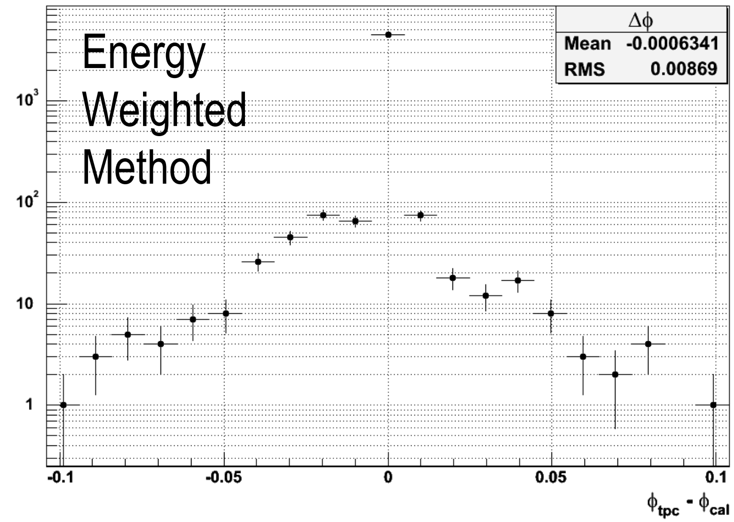

Density
Weighted
Method
Δθ
Mean -0.0007551
RMS 0.03099
10^3
10^2
10
1
-0.25 -0.2 -0.15 -0.1 -0.05 0 0.05 0.1 0.15 0.2
$\theta_{tpc} - \theta_{cal}$

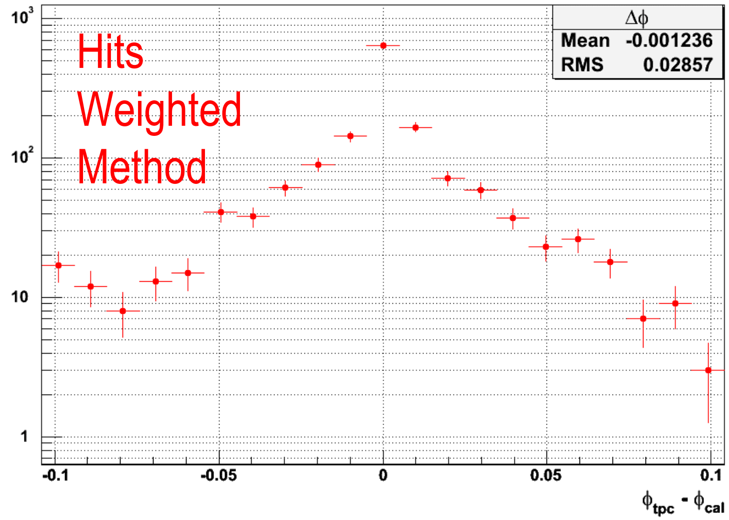

Energy
Weighted
Method
Δθ
Mean 0.004378
RMS 0.02089
10^3
10^2
10
1
-0.1 -0.05 0 0.05 0.1
$\theta_{tpc} - \theta_{cal}$


Hits
Weighted
Method
Δθ
Mean -0.002931
RMS 0.05682
10^3
10^2
10
1
-0.2 -0.15 -0.1 -0.05 -0 0.05 0.1 0.15
$\theta_{tpc} - \theta_{cal}$

$\Delta\phi$ - 7.5 GeV π^-







Conclusions

- Mokka – GEM Analog and digital performance studies completed
  - GEM Analog resolution comparable with TDR and other studies
  - GEM Digital resolution comparable with TDR and other studies
- A basic understanding of energy flow method applied to single pions
  - ΔR of single particles in typical jets
  - $\Delta\theta$ and $\Delta\phi$ using 3 different methods
  - Compare the three methods
- Resolving 2 pions as function of ΔR comes next