GEM-DHCal Performance and Energy Flow Algorithm Studies

LCWS 2004, SLAC
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- Single Pion Performance Study
- Study of $e^+e^- \rightarrow t\bar{t} \rightarrow 6\,jets$ Pythia events
- Energy Flow Algorithm
  - Two pion cluster matching and energy subtraction
- Conclusions

*On behalf of the HEP group at UTA.

Introduction

- DHCAL: a solution for keeping the cost manageable for EFA
- Fine cell sizes are needed for efficient calorimeter cluster association with tracks and subsequent energy subtraction
- UTA focused on DHCAL using GEM for
  - Flexible geometrical design, using printed circuit pads
  - Cell sizes can be as fine a readout as in a GEM tracking chamber!
  - 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 foil
  - Possibility for reasonable cost
    - Foils are basically etched, copper-clad kapton
    - 3M produces foils in large quantities (12”x500ft rolls)

UTA GEM Simulation

- Use Mokka as the primary tool
  - Kept the same detector dimensions as TESLA TDR
  - Replaced the HCAL scintillation counters with GEM (18mm SS + 6.5mm GEM, 1cmx1cm cells)
- Single Pions used for performance studies
  - 5 – 100 GeV single pions
  - Analyzed them using ROOT
  - Compared the results to TDR analog as the benchmark
    - GEM Analog and Digital (w/ and w/o threshold)
    - ECal is always analog
- Two pion studies for EFA development

UTA Double GEM Geometry

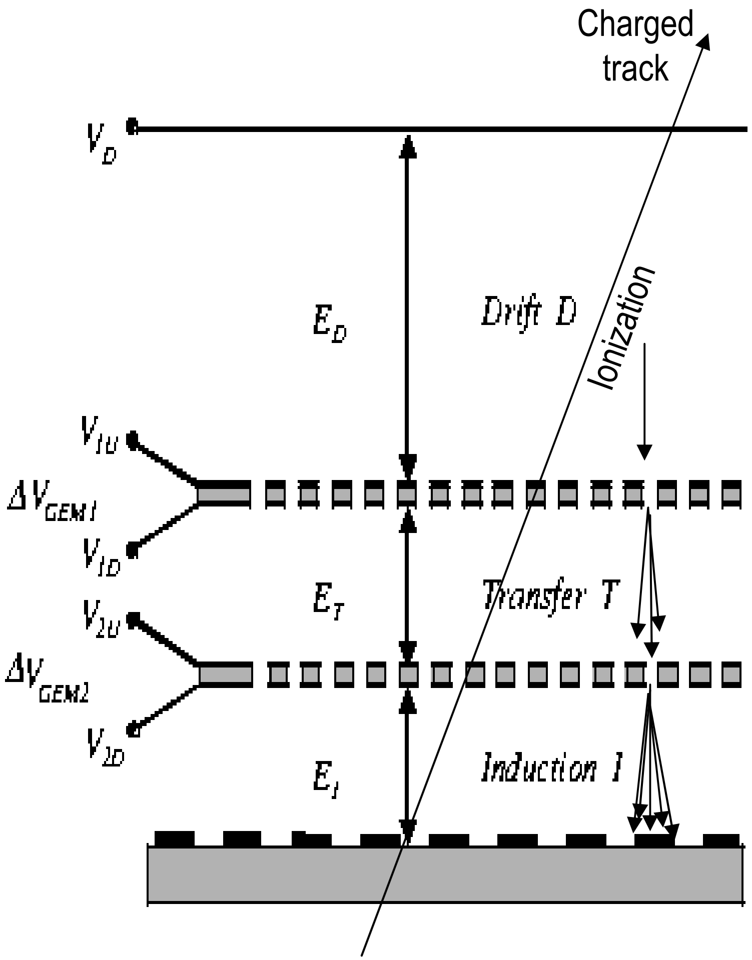
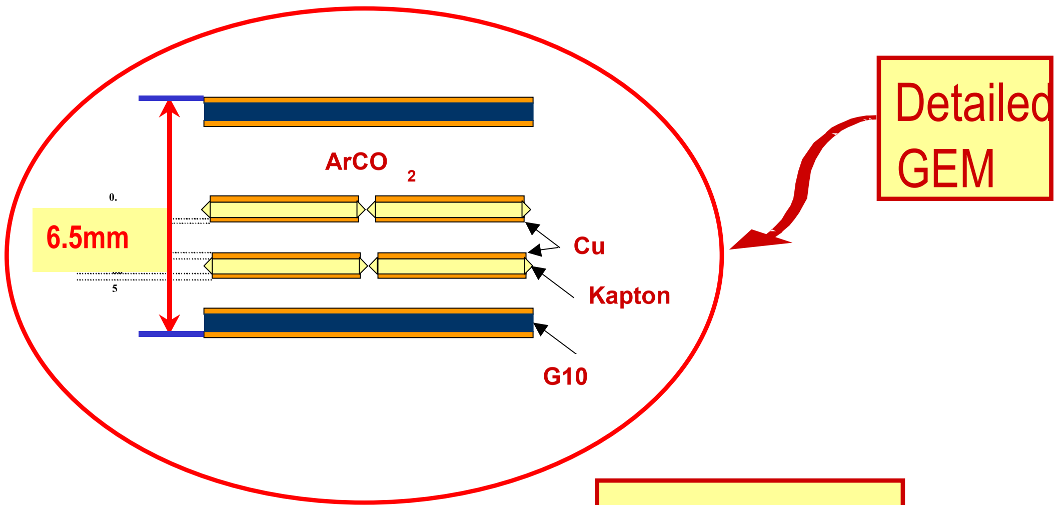
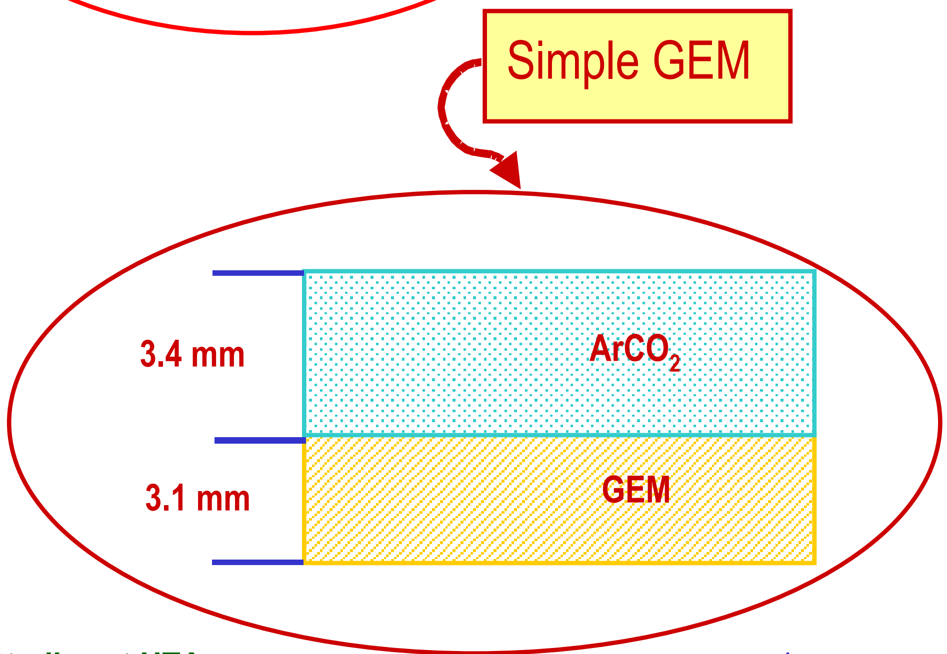
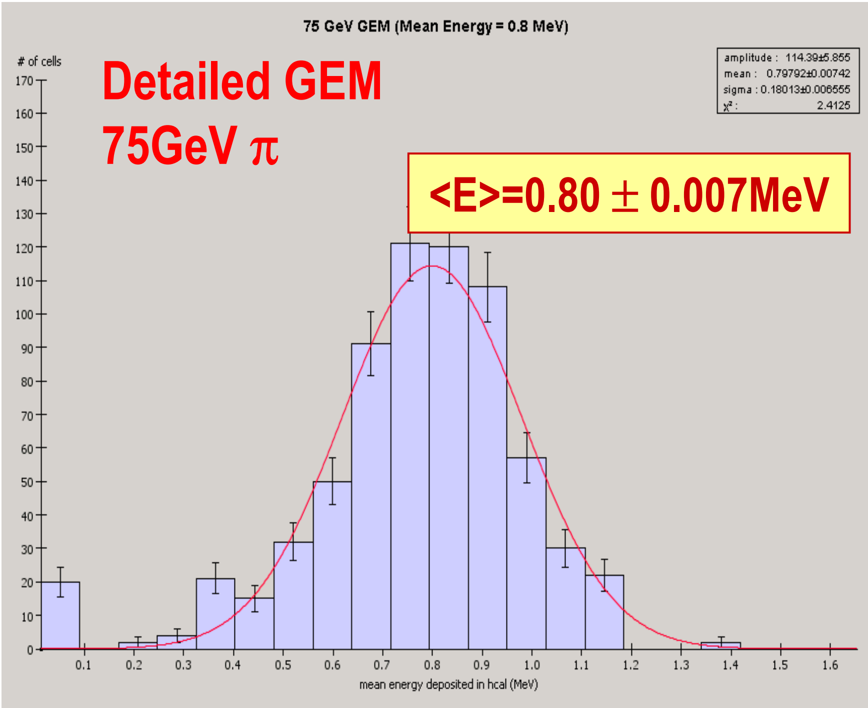


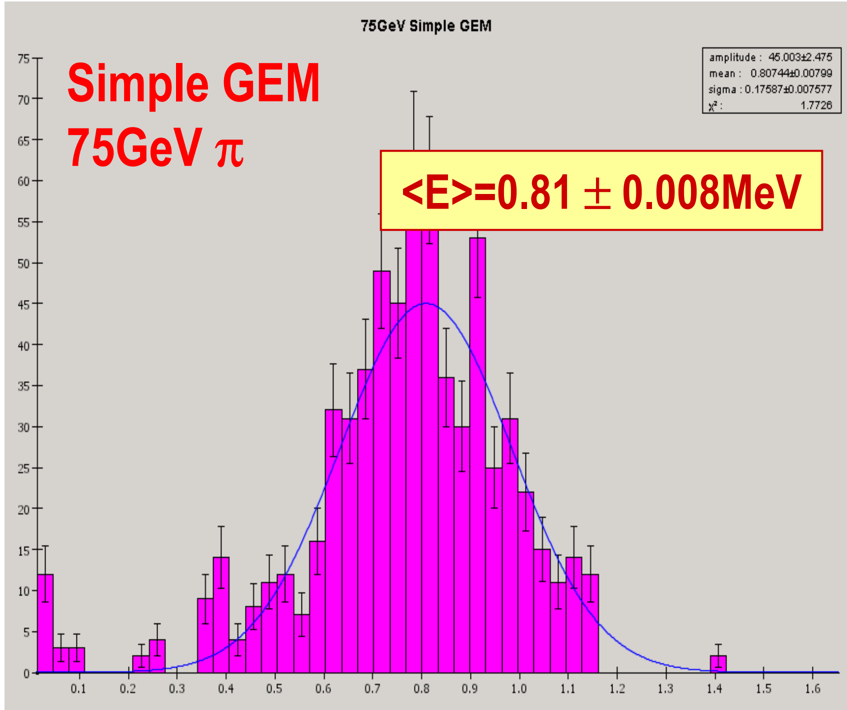
Fig. 1: Schematics of a double-GEM detector.





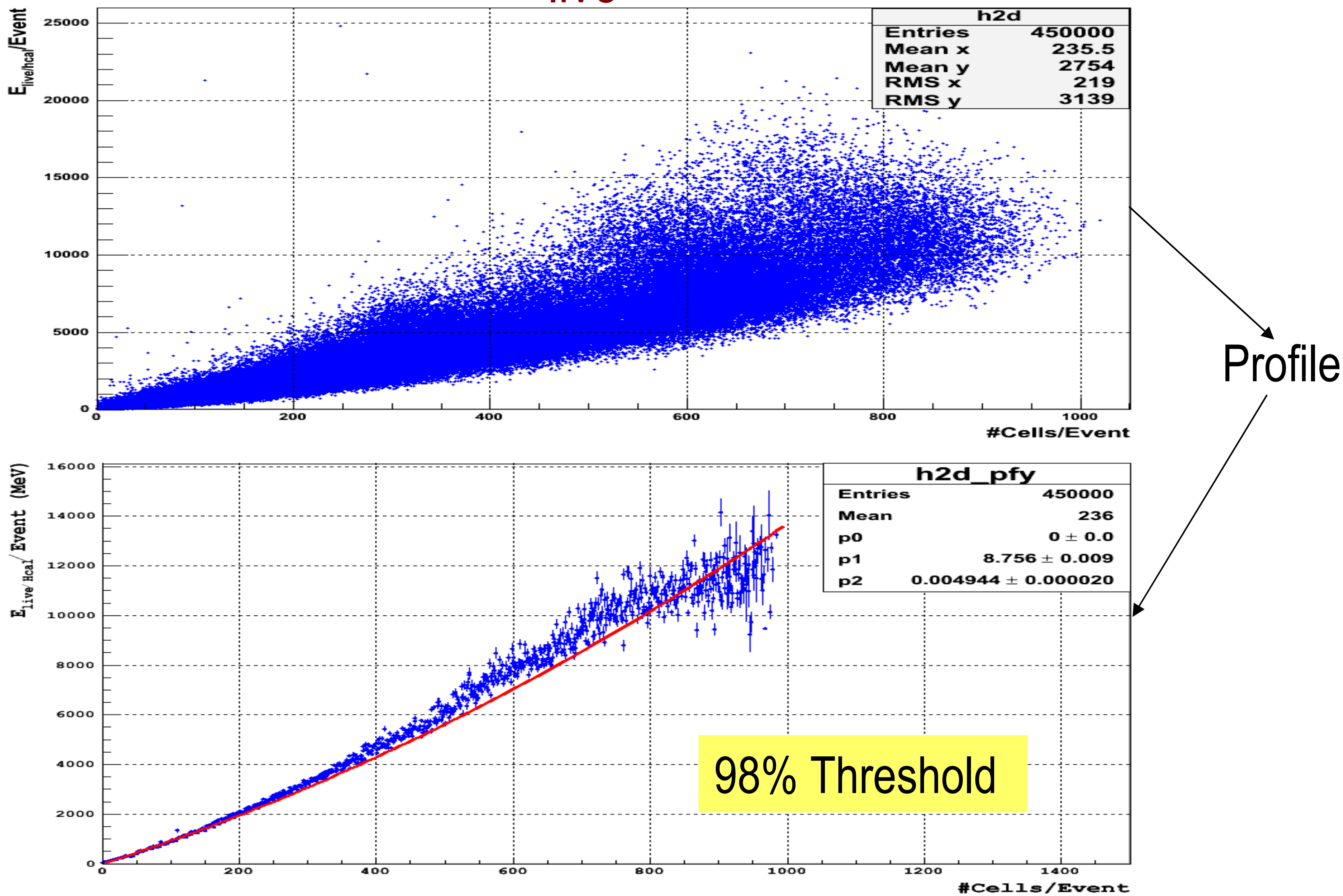
Performance Comparisons of Detailed and Simple GEM Geometries





- 25 sec/event for Simple GEM v/s 44 sec/event for Detailed GEM
- Responses look similar for detailed and simple GEM geometry
- Simple GEM sufficient

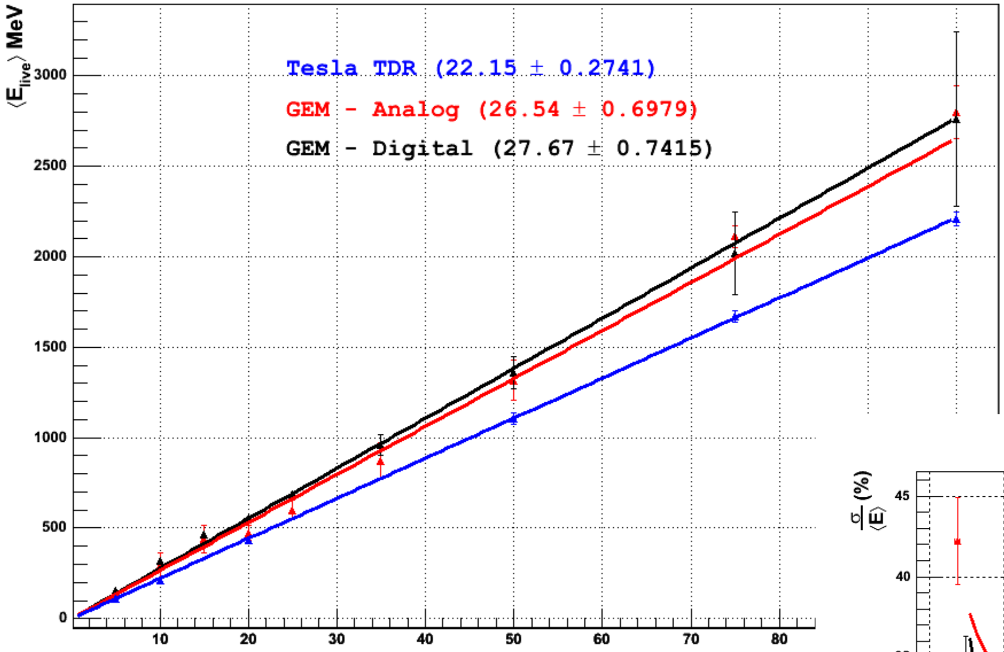
GEM-Digital: E_{live} vs # of hits for π^-



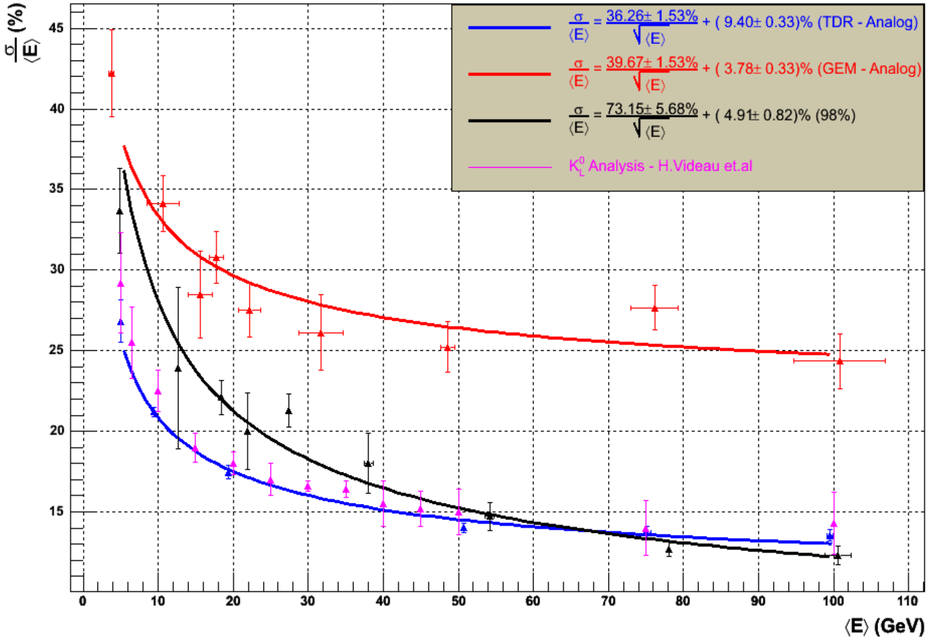
EM-HCAL Weighting Factor

- $E_{Live}=\Sigma E_{EM}+ \mathcal{W}\Sigma \mathbf{G} E_{HCAL}$
- For analog:
  - Landau + Gaussian (L+G) fit is used to determine the mean values as a function of incident pion energy for EM and HAD
  - Define the range for single Gaussian (G) fit using the mean
  - Take the mean of the G-fit as central value
  - Choose the difference between G and L+G fit means as the systematic uncertainty
- For digital:
  - Gaussian for entire energy range is used to determine the mean
  - Fit in the range that corresponds to 15% of the peak
  - Choose the 15% G fit mean as the central value
  - Difference between the two G as the systematic uncertainty
- Obtained the relative weight $\mathcal{W}$ 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 $\mathcal{W}$
- $E = C^* E_{Live}$

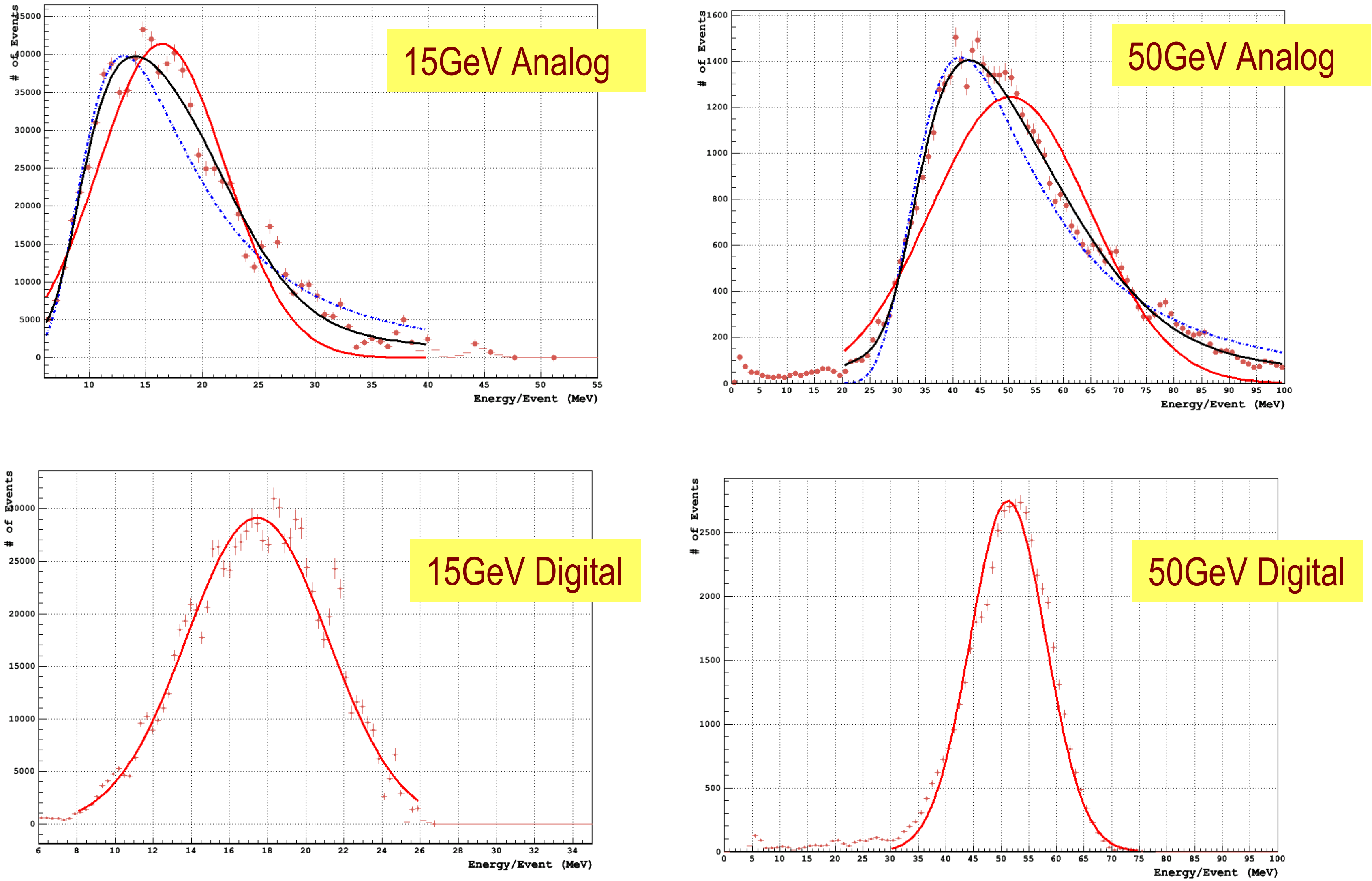
GEM HCAL Responses and Resolutions



DHCAL w/ 98% Threshold



GEM Analog & Digital Converted: 15 and 50 GeV π^-



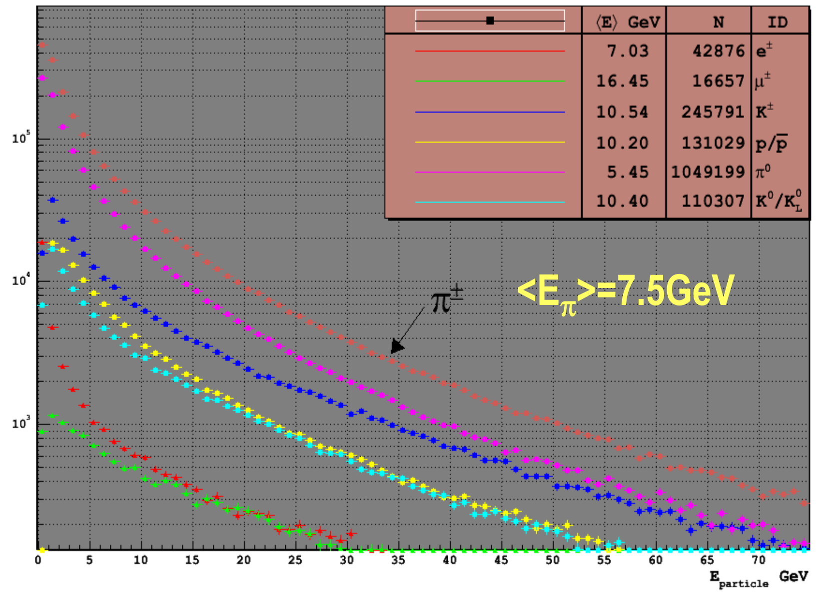
GEM Performance Study Summary

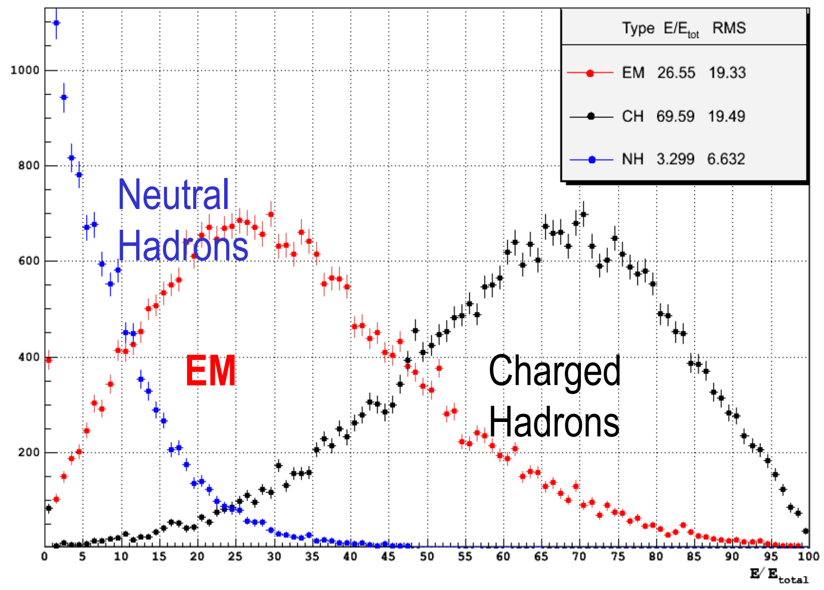
- GEM digital and analog responses comparable
  - Large remaining Landau fluctuation in analog mode observed
  - Digital method removes large fluctuation → Becomes more Gaussian
- GEM Energy resolutions
  - Digital comparable to TDR
  - Analog resolution worse than GEM digital or TDR
- GEM is as good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

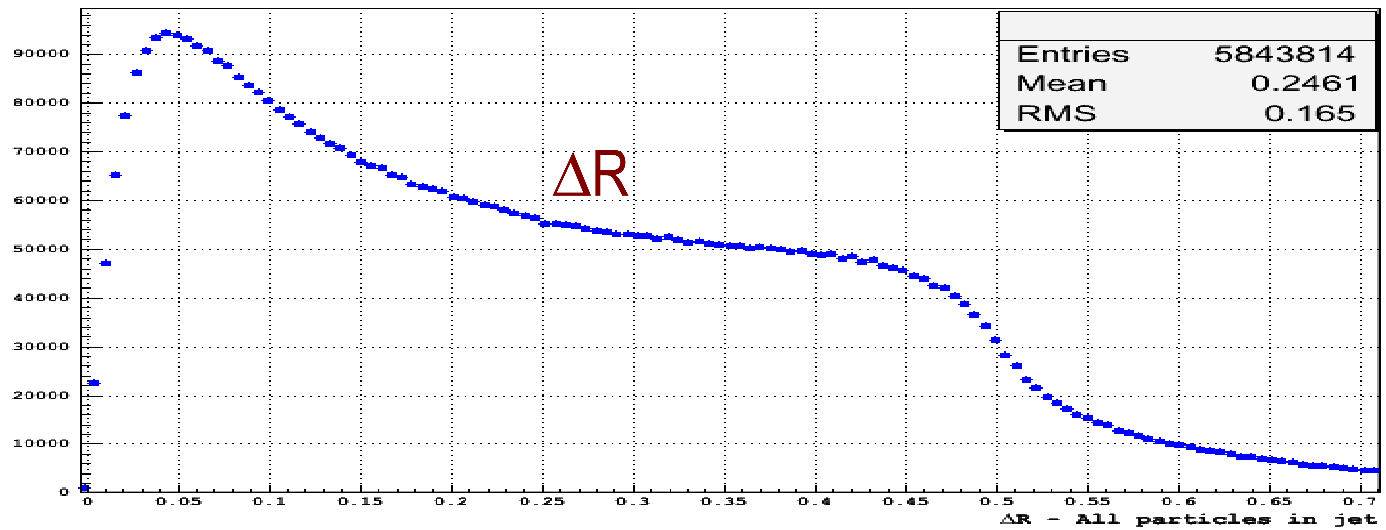
Analysis of $e^+e^- \rightarrow t\bar{t} \rightarrow 6\, jets$

- Energy distribution of final state particles in jets
- Choose a $\Delta R = 0.5$ 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

Particle Properties in a jet







Energy Flow Studies with two π^-

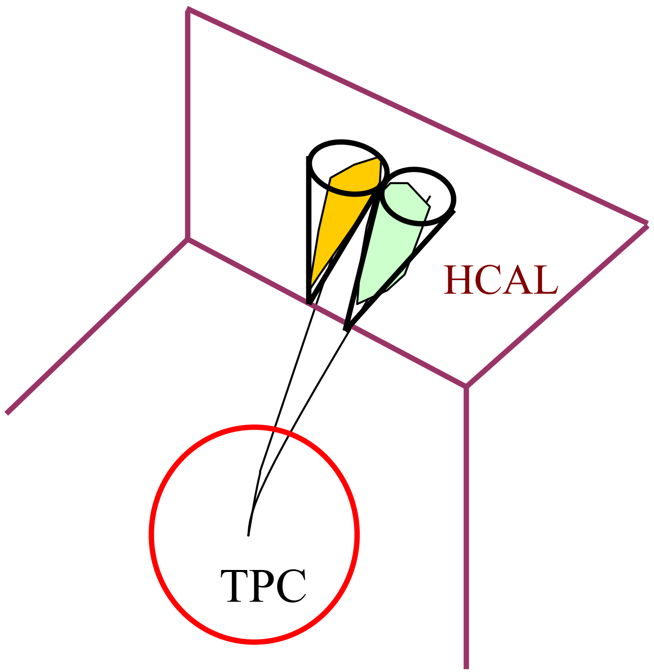
- Based on the studies of particles in jet events

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

- Pions $\langle E_{\pi-} \rangle = 7.5$ GeV chosen for study
- Chose the distance between two pions $\Delta R=0.12$ (Half mean separation)
- Develop an algorithm to subtract charged pion energies
- Use the density weighted method

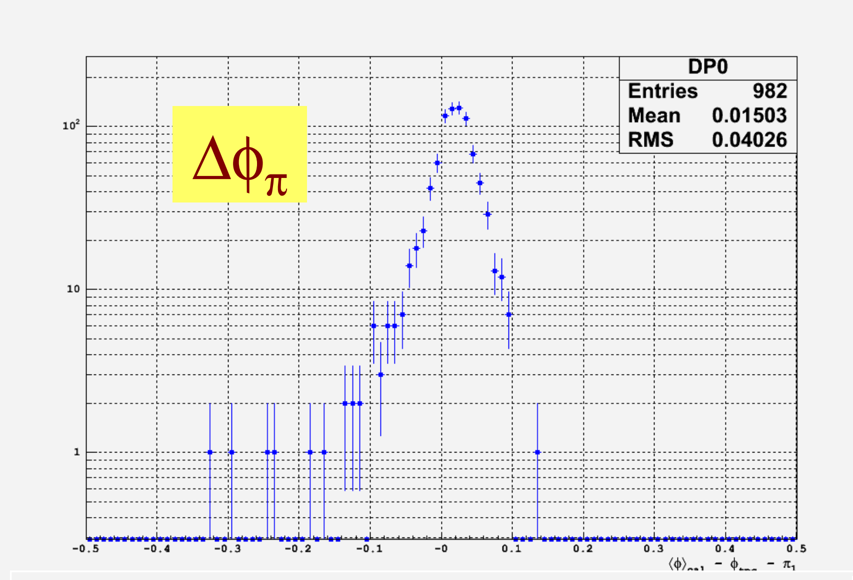
$$d_i = \sum_{j=1, j\neq i}^{n} \frac{1}{R_{ij}} \quad \bar{\theta}_i = \frac{\sum_{j=1}^{n} d_{ij}\theta_{ij}}{\sum_{j=1}^{n} d_{ij}} \quad \bar{\phi}_i = \frac{\sum_{j=1}^{n} d_{ij}\phi_{ij}}{\sum_{j=1}^{n} d_{ij}}$$

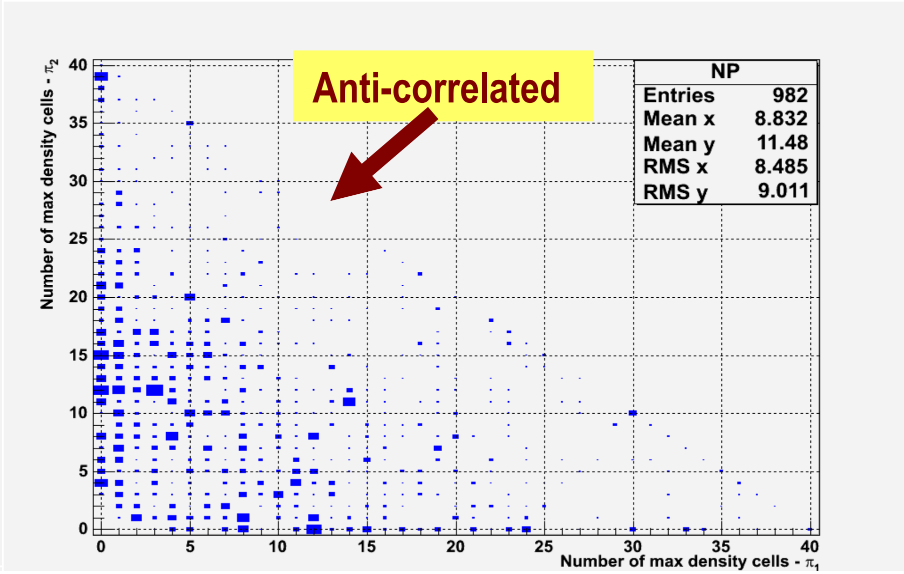
Two π Energy Flow Algorithm

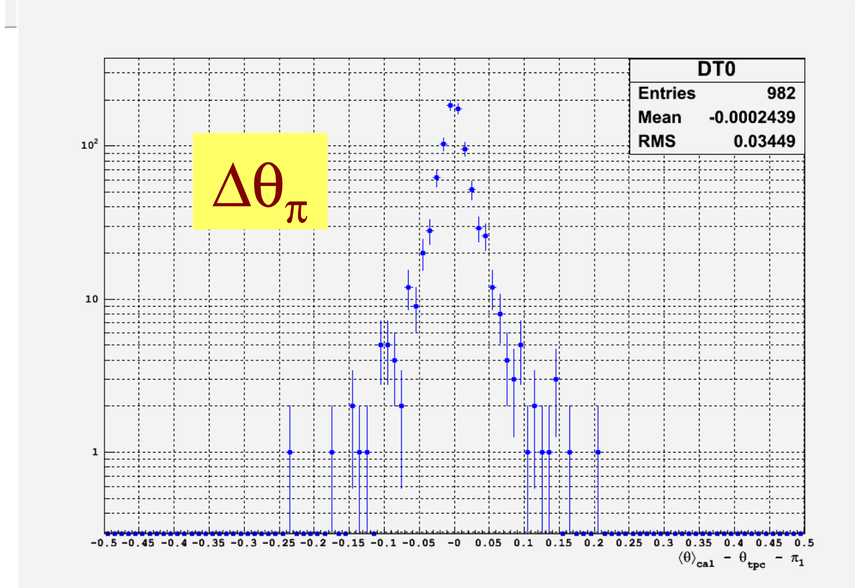


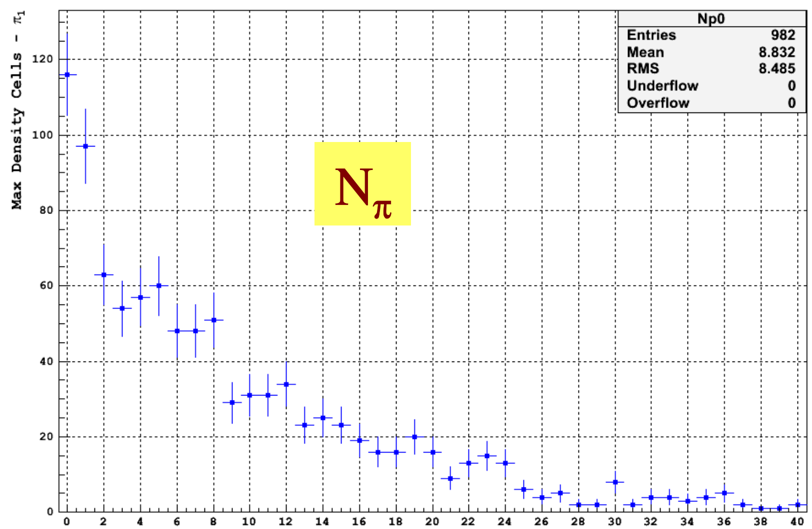
1. Fit the tracks in TPC and extrapolate to Hadronic Calorimeter
2. Find the maximum density cell/layer in HCAL
3. Associate the cell with each π based on distance to the extrapolated track position
4. Compute cal-centroid using the max cells
5. Draw fixed size cones w/ radius half the distance between the two π cal-centroids
6. Compute the density weighted center of each π shower in each layer
7. Re-determine the cal-centroid using the density weighted center
8. Use the new centroid to add energy in the cone of half the distance of the two π

TPC and Cal-Centroid Match: First Pass



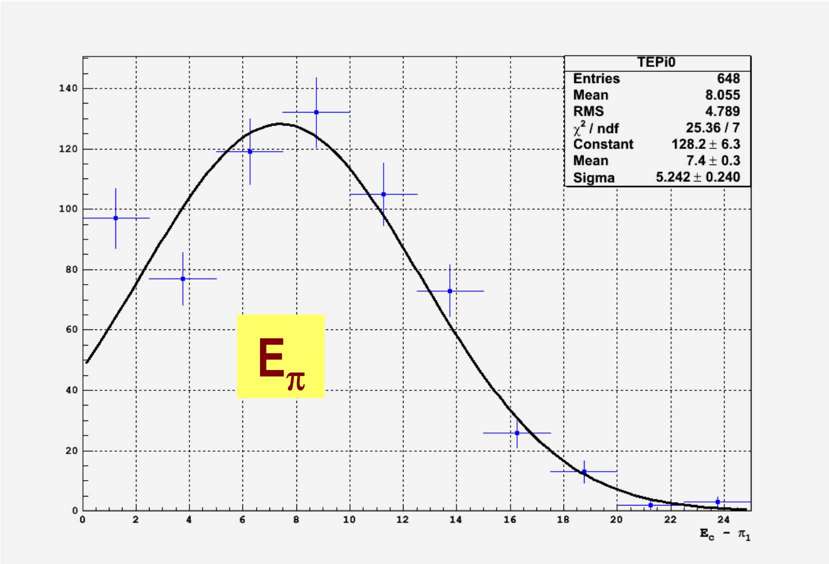


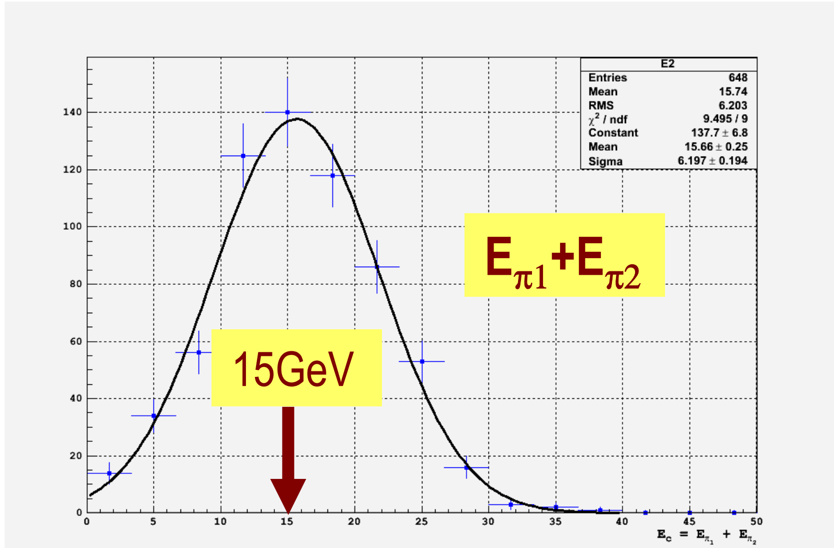


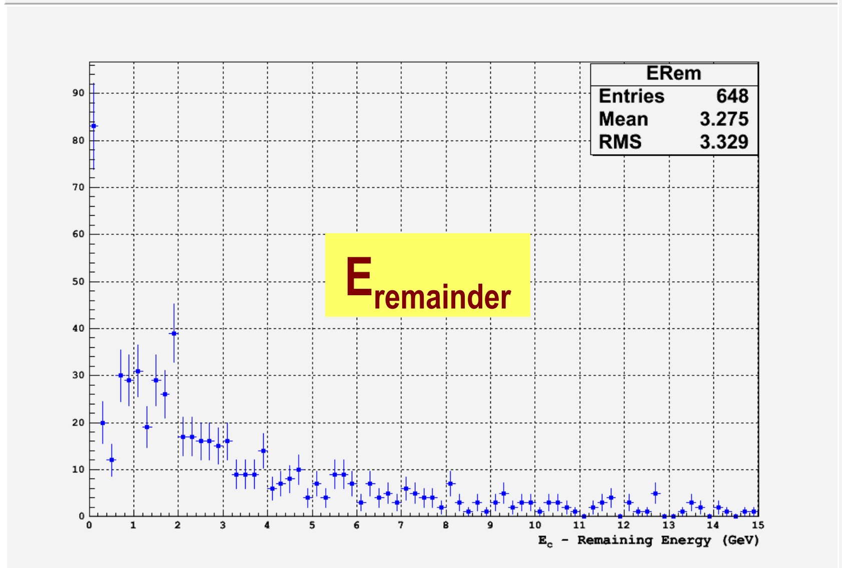


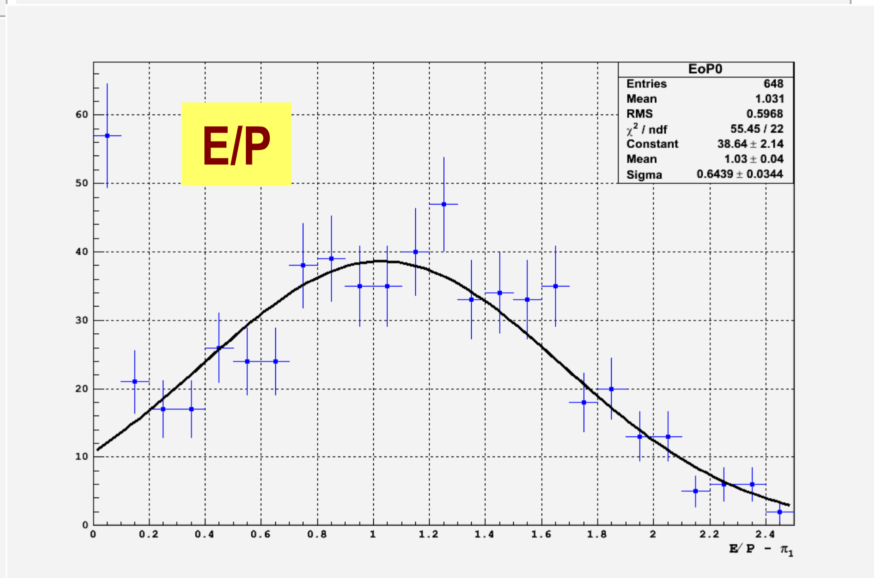
Nmax

Energy in the cluster

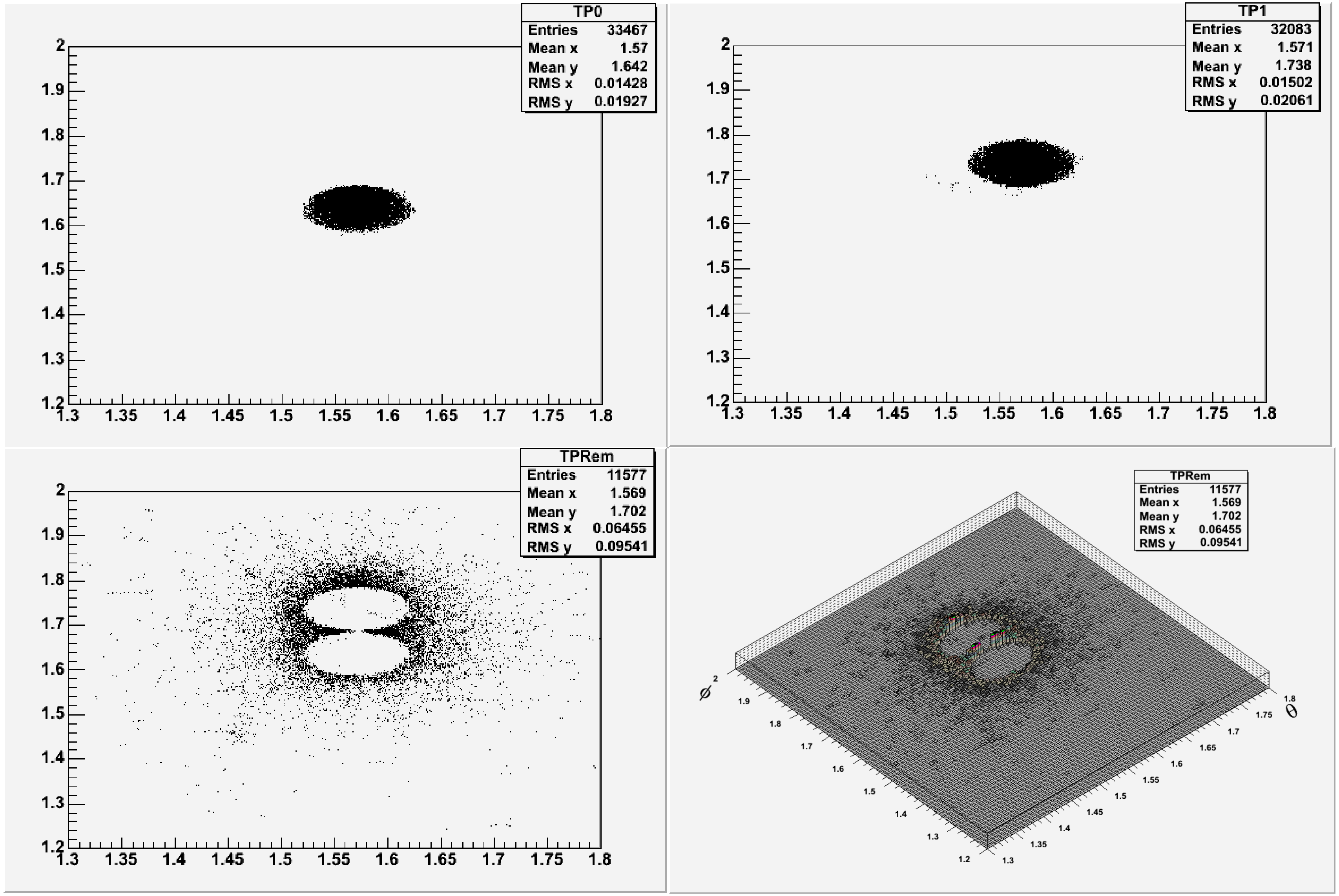








Energy Subtraction Performance



Conclusions

- GEM Analog and digital performance studies completed
  - Completed DHCAL performance study with a reasonable threshold
  - GEM Analog resolution found a bit worse than TDR and other studies due to large Landau like fluctuation
  - GEM Digital resolution w/ and w/o threshold comparable with TDR and other studies
- Initial results of energy flow algorithm study using two-single pion events look encouraging
  - Resolving 2 pions as function of ΔR using Mokka
  - $\Delta\theta$ and $\Delta\phi$ using the density weighted method
  - The energy subtraction seems reasonable
  - Will need to make the algorithm more sophisticated
- Kaushik is almost done with his thesis
- A visiting professor and an undergraduate student started working with the group
  - Start developing two-pion Mokka input generator