Simulation Studies of GEM-DHCal

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Jae Yu
University of Texas at Arlington

- GEM Analog and Digital Performance Studies
- "Jet" Energy Resolution Study
- Initial Development of Particle Flow Algorithm
- Moving on ….
- Magnetic Field Impact Study
- 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
    - 3M produces foils in large quantities (12"x500ft rolls)

Mokka-based UTA GEM Simulation

- Use old version of Mokka as the primary simulation 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
- "Jet" Energy Resolution
- Two pion studies for PFA development

UTA Double GEM Geometry

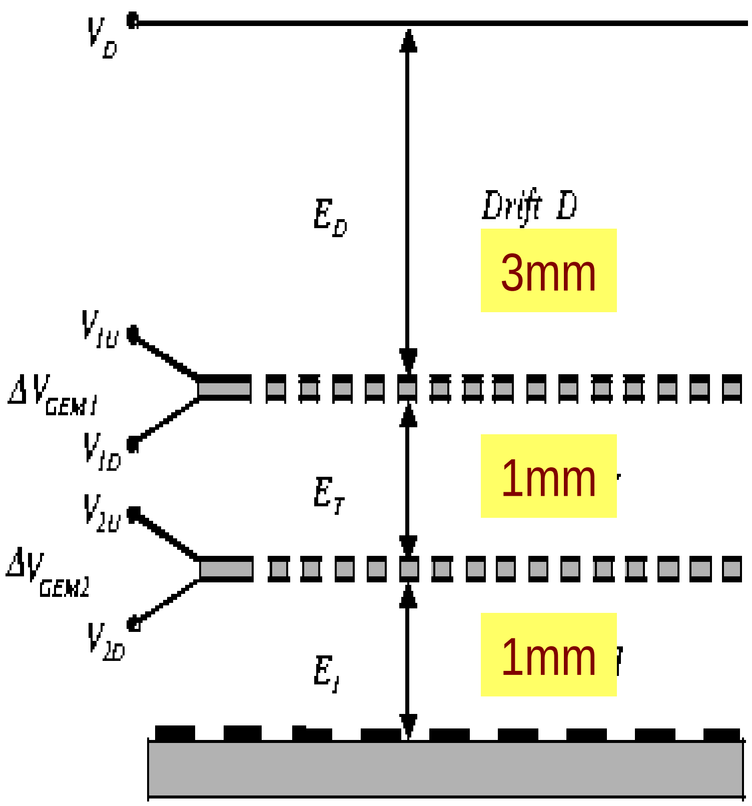
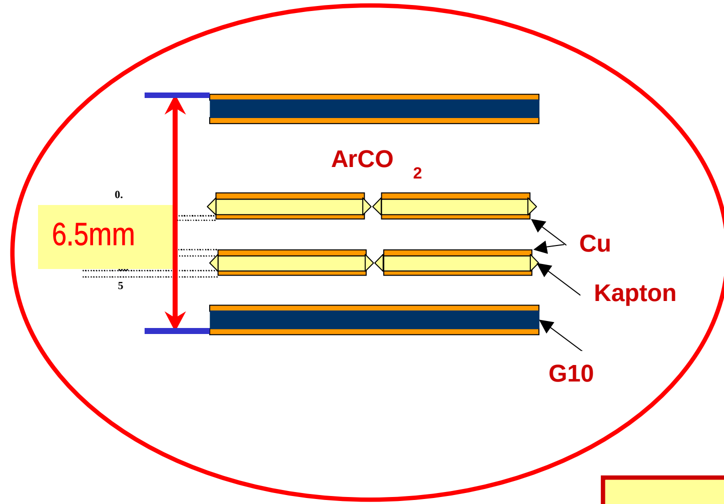
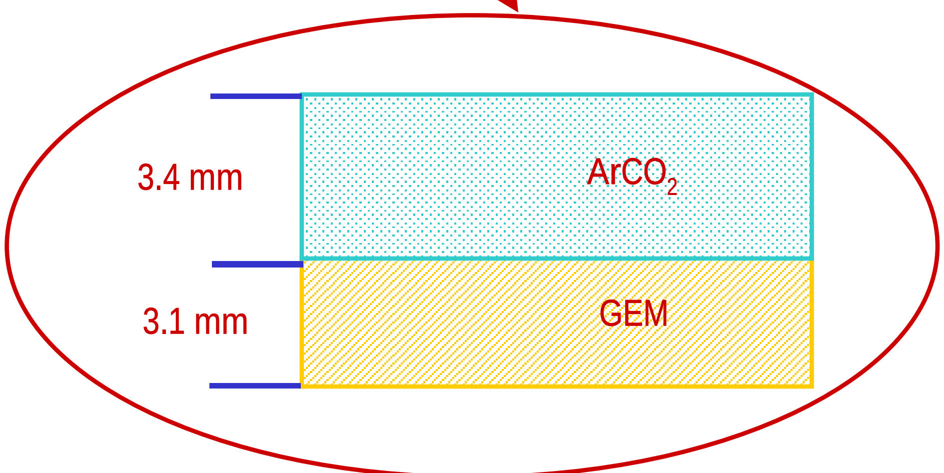


Fig. 1: Schematics of a double-GEM detector.

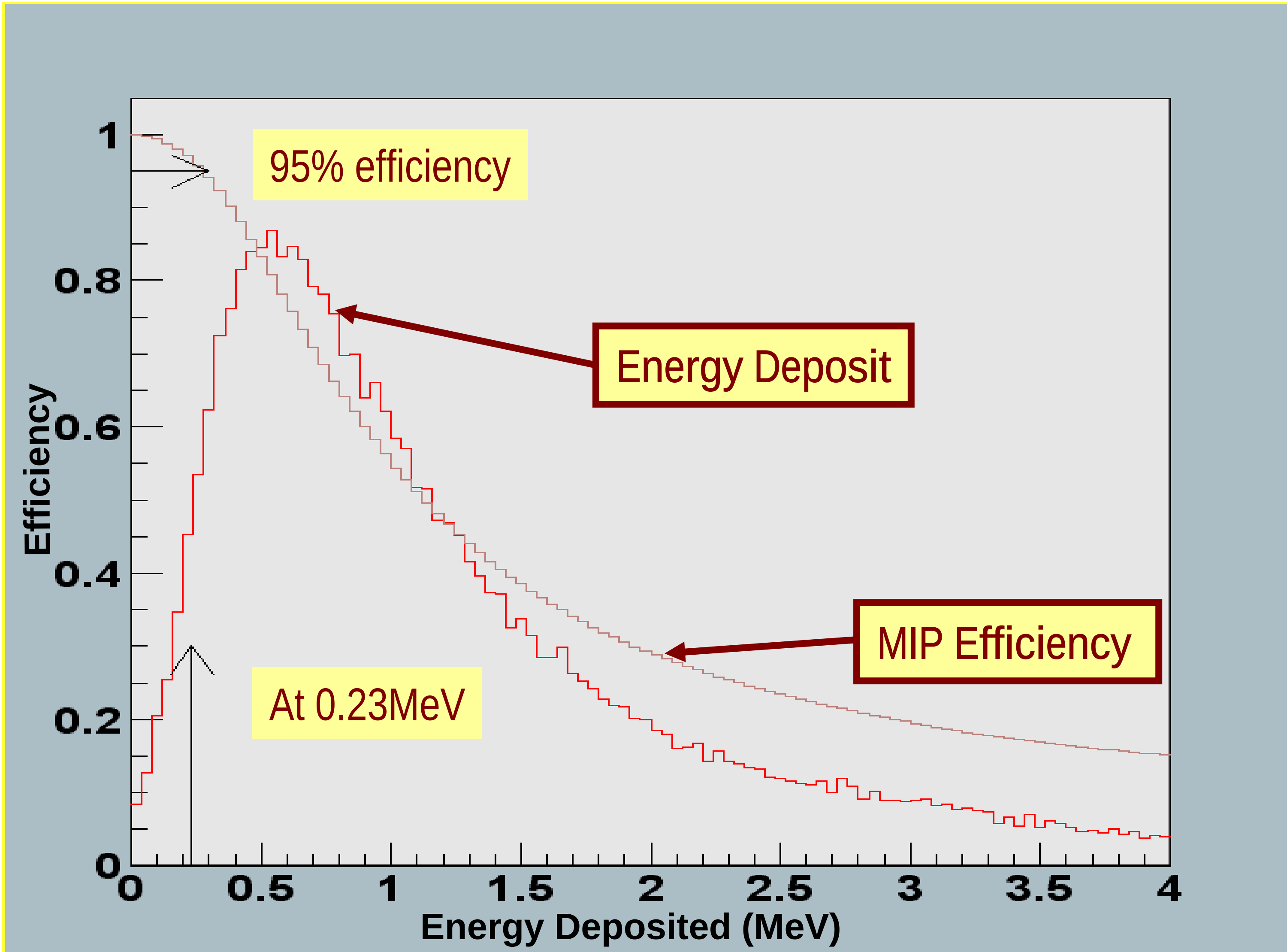


Detailed GEM

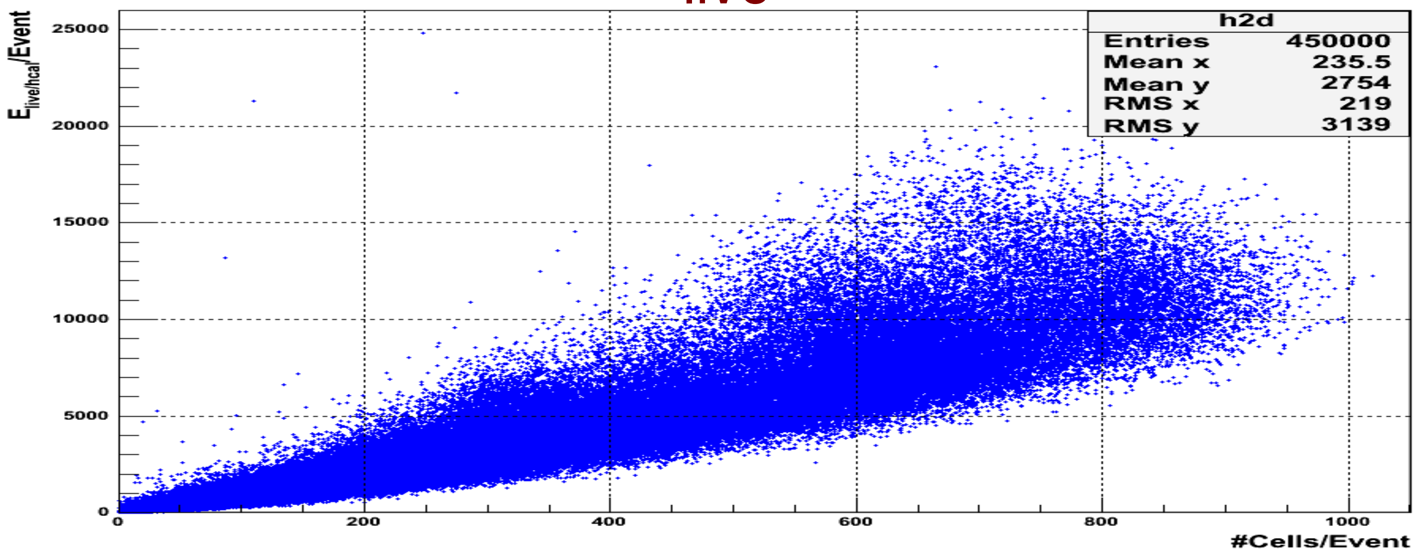
Simple GEM

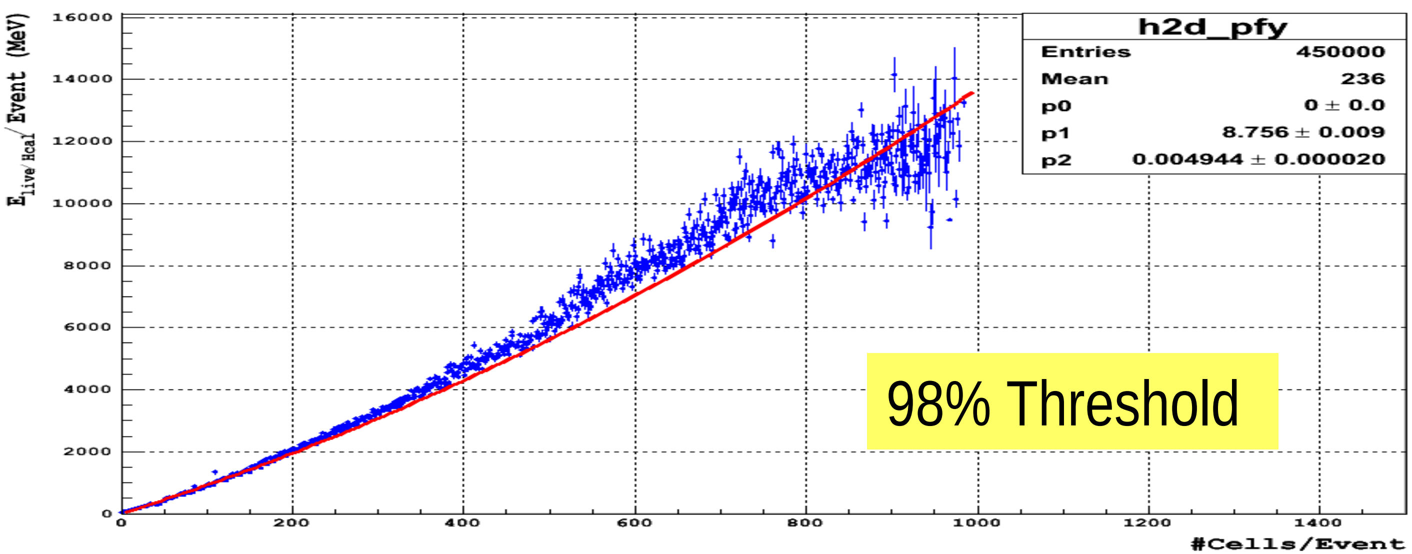


GEM MIP Digital Threshold Efficiency



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

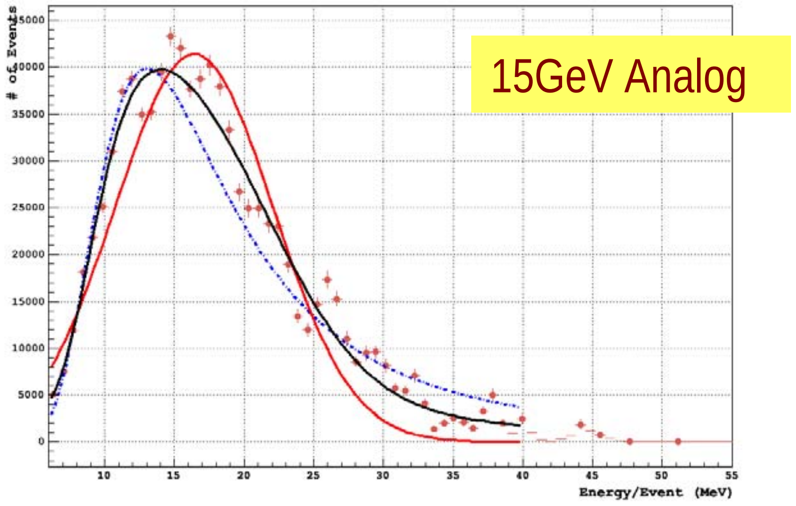


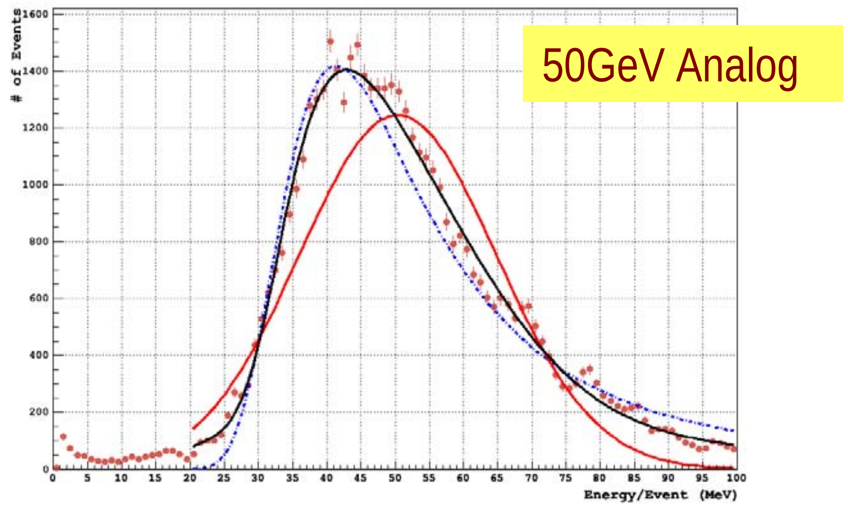


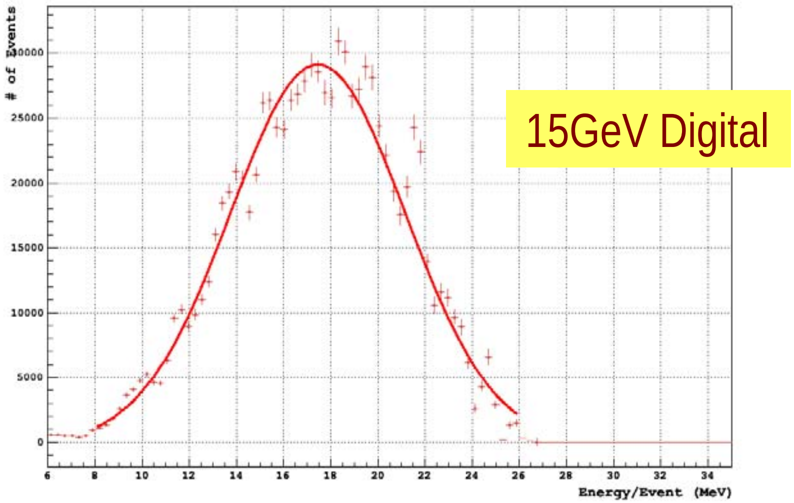
EM-HCAL Weighting Factor

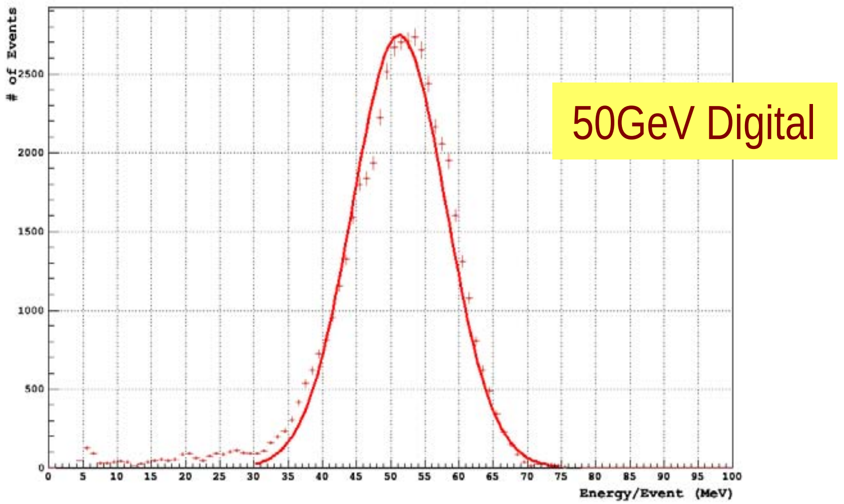
- $E_{Live} = \Sigma E_{EM} + \mathcal{W} \Sigma G E_{HCAL}$
- For analog:
  - Landau + Gaussian (L+G) fit is used to determine the mean values as a function of incident pion energy for EM and HAD
  - Define the range for single Gaussian (G) fit using the mean
  - Take the mean of the G-fit as central 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 Analog & Digital Converted: 15 and 50 GeV π^-

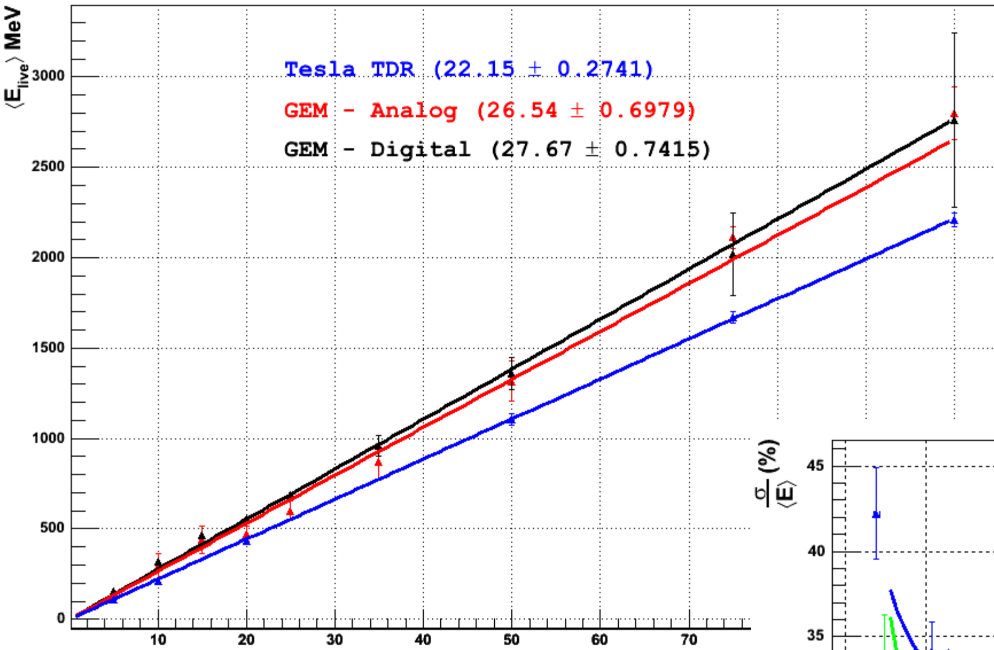




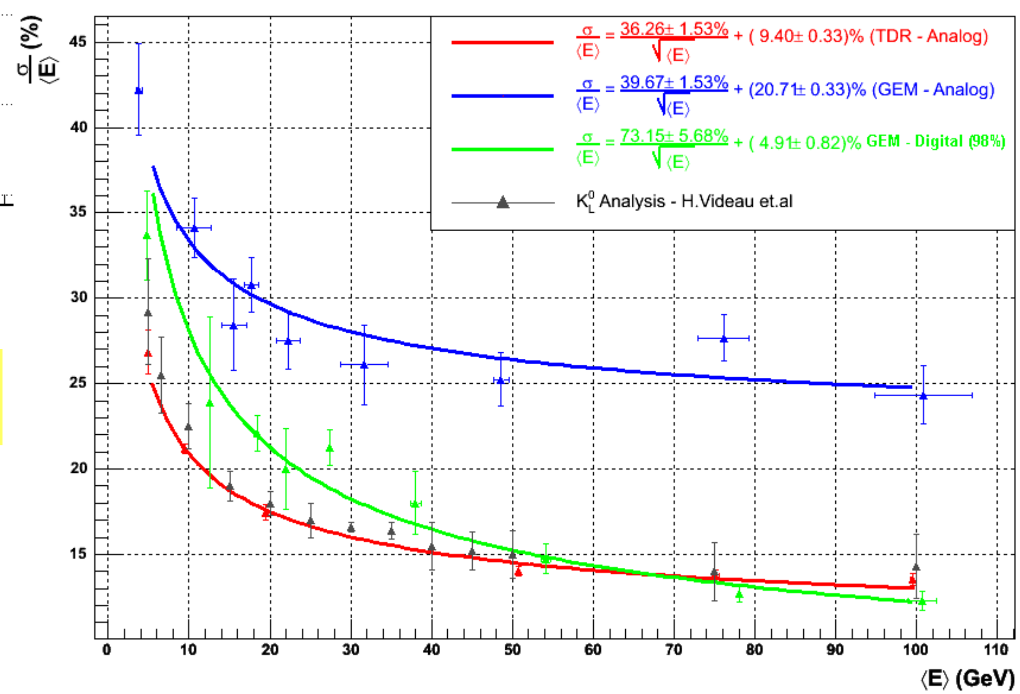




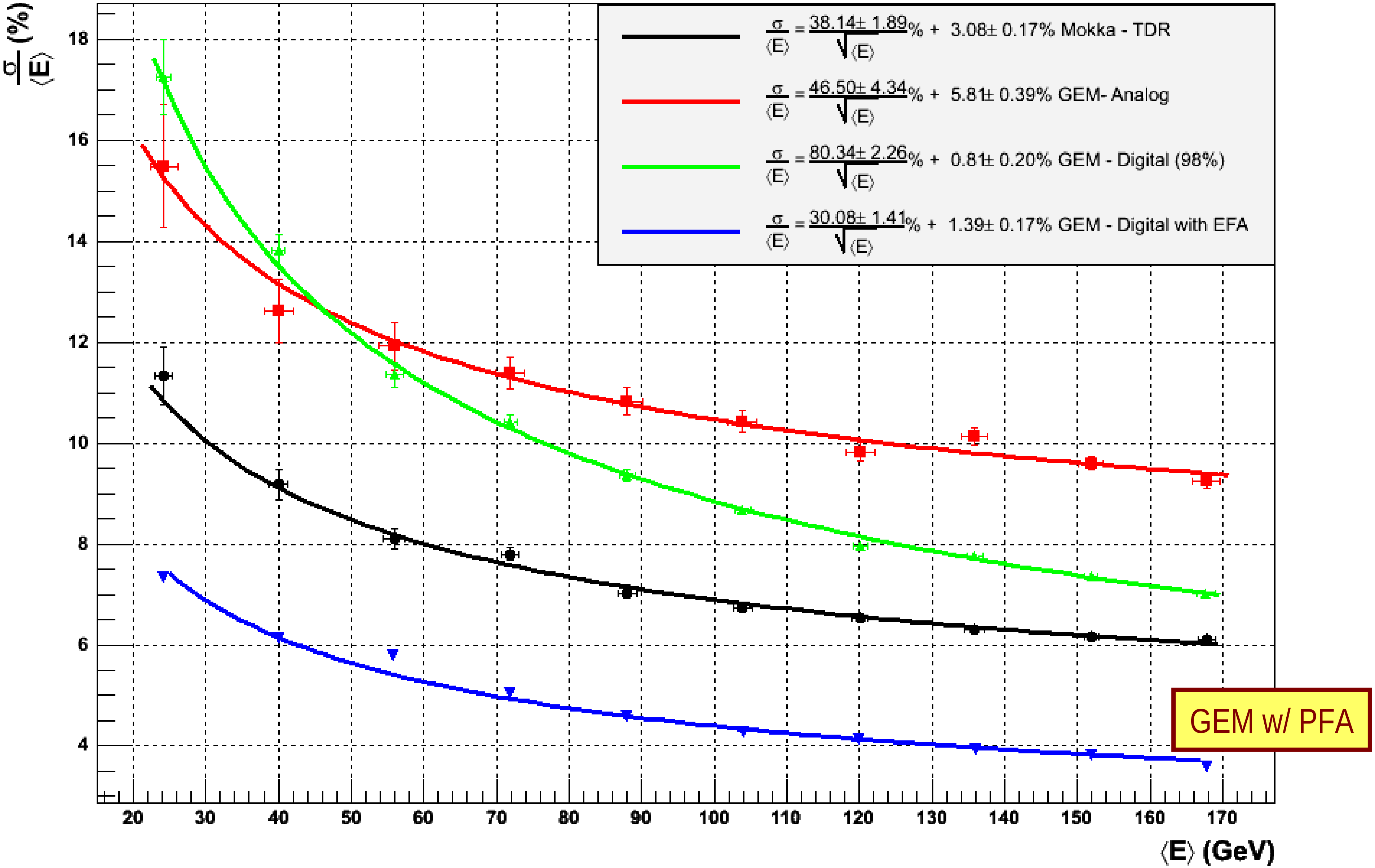
GEM HCAL Responses and Resolutions



DHCAL w/ 98% Threshold



Jet Energy Resolution



Energy Flow Studies with two π^-

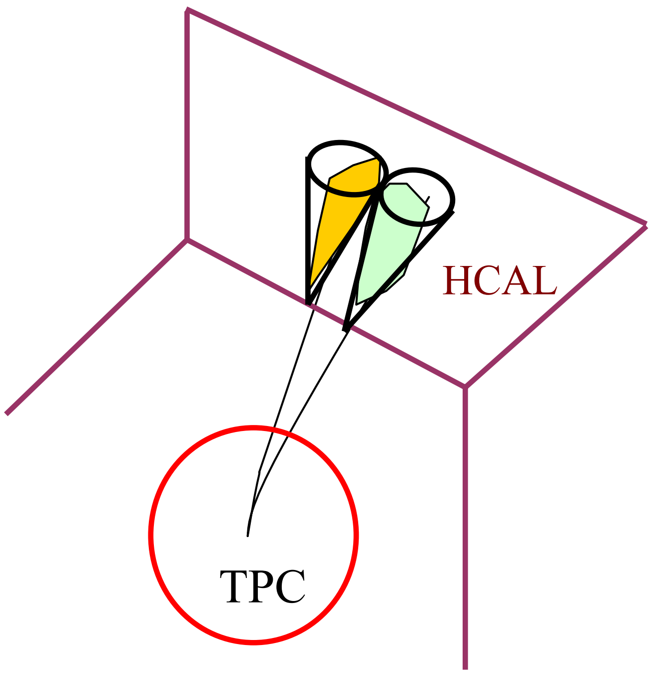
- Based on the studies of particles in jet events

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

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

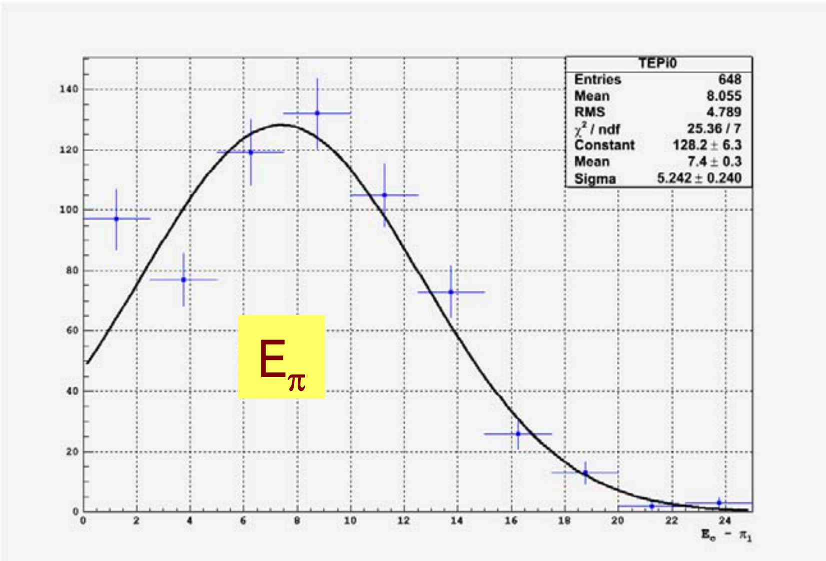
$$d_i = \sum_{j=1, j\neq i}^{n} \frac{1}{R_{ij}} \quad \bar{\theta}_i = \frac{\sum_{j=1}^{n} d_{ij}\theta_{ij}}{\sum_{j=1}^{n} d_{ij}} \quad \bar{\phi}_i = \frac{\sum_{j=1}^{n} d_{ij}\phi_{ij}}{\sum_{j=1}^{n} d_{ij}}$$

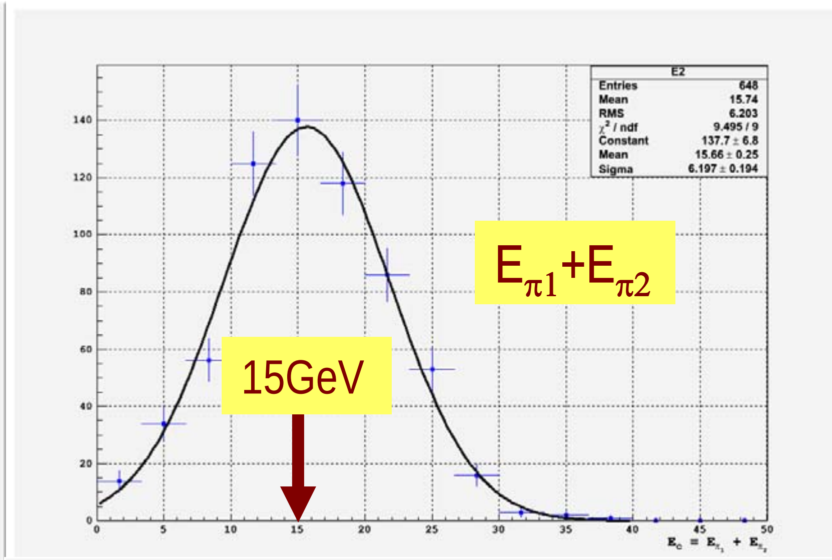
Two π Energy Flow Algorithm

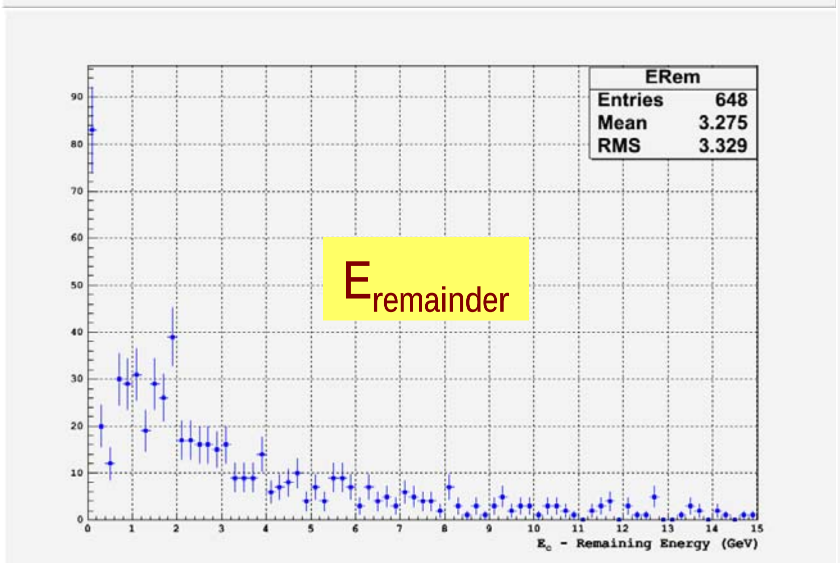


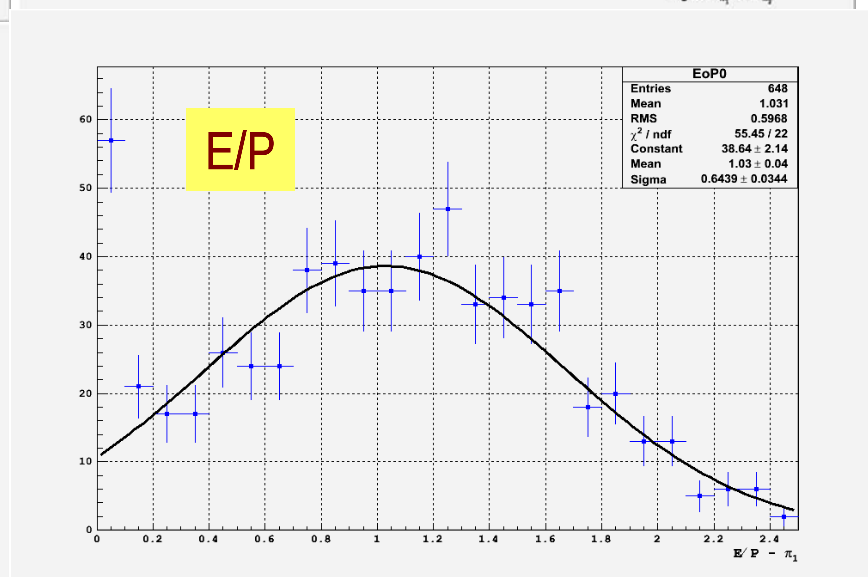
1. Fit the tracks in TPC and extrapolate to Hadronic Calorimeter
2. Find the maximum density cell in each HCAL layer
3. Associate cells with each π based on distance to the extrapolated track position
4. Compute cal-centroid using the max cells
5. Draw fixed size cones w/ radius half the distance between 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

Energy in the cluster

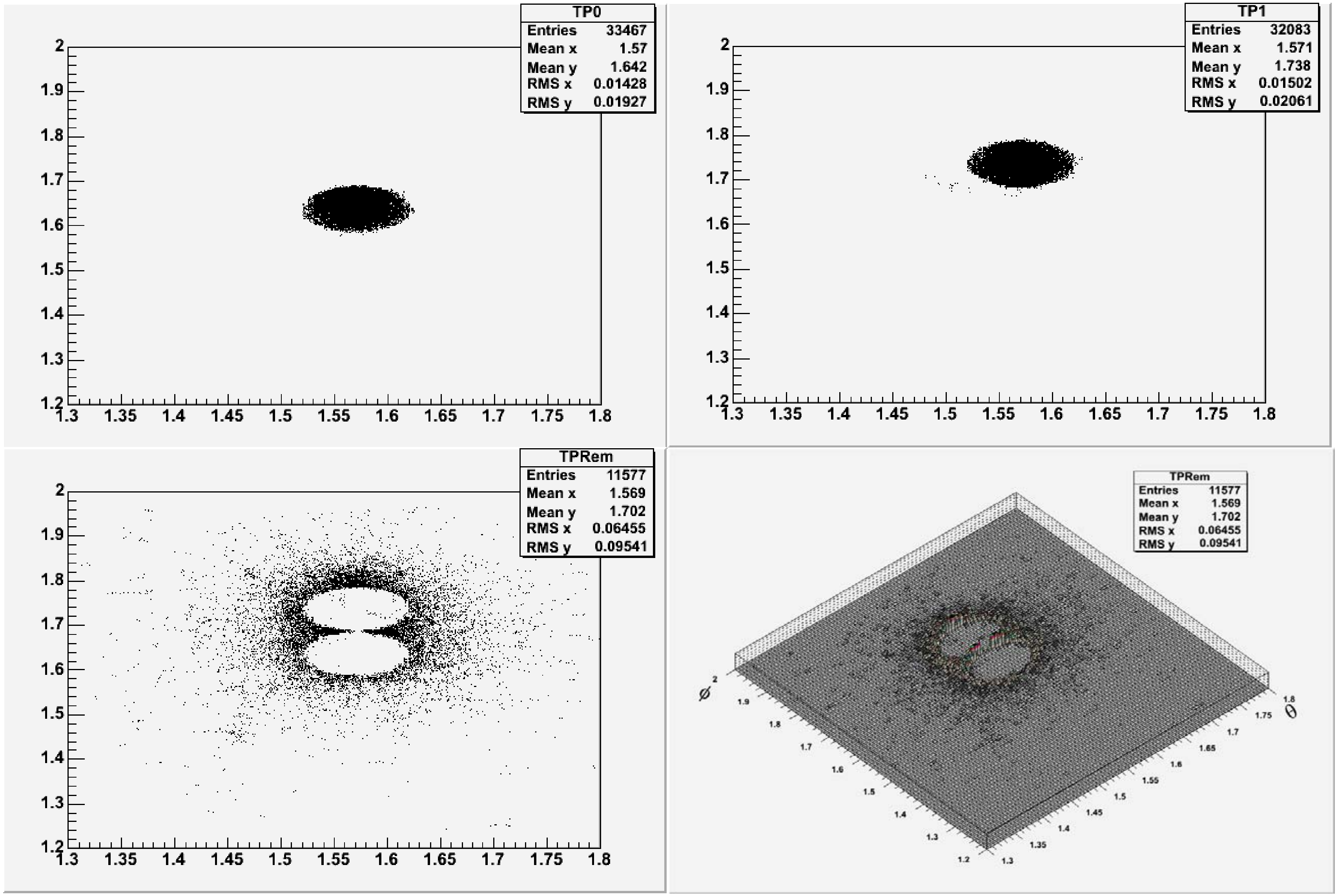








Energy Subtraction Performance



Moving On – LCIO Version of Mokka

- Conversion to LCIO incorporated version of Mokka 04.00 completed
  - Reproduction of previous results for verification w/ the GEM geometry
    - Will commit GEM geometry driver to the central DB for inclusion to the new Mokka releases and to the LCD concept studies
  - Develop analysis framework using LCIO
  - Continue onto developing universally usable PFA
  - Prepare for test beam geometry and data analysis

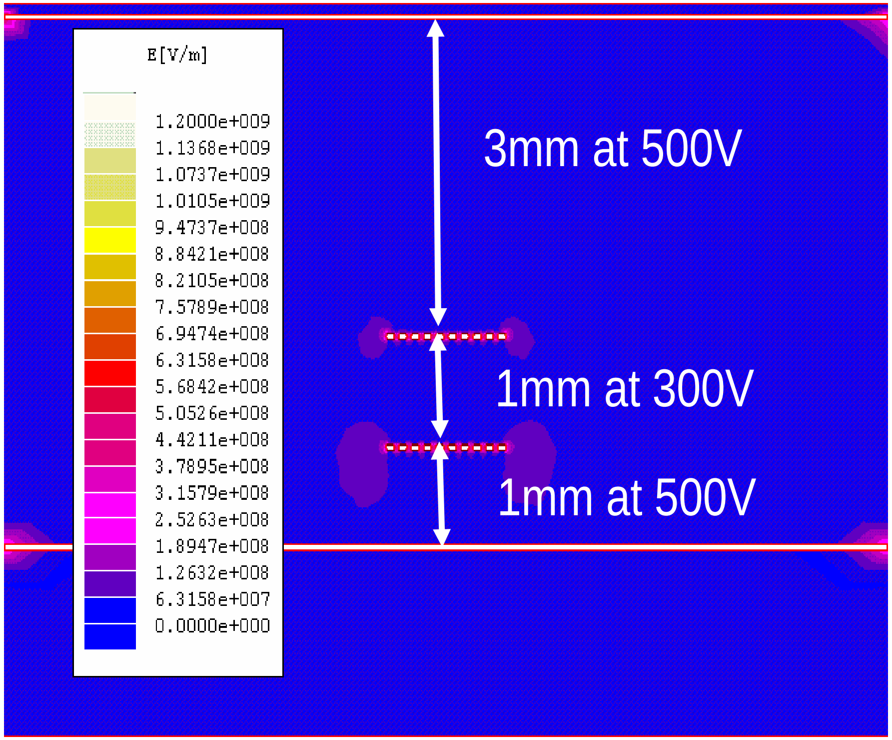
Moving On – SiD Simulation

- Inclusion of GEM into SiD simulation package
  - Both the detailed and mixture version of the GEM Geometry given to Norman for the inclusion
- Large number of SiD simulated events with GEM requested
  - 50k each of single pions in energy ranges of 5 – 150 GeV
  - 50k each of single electrons in ranges of 5 – 150 GeV
  - Two 7.5 GeV pions separated by ΔR=0.12
  - For performance studies with SiD geometry

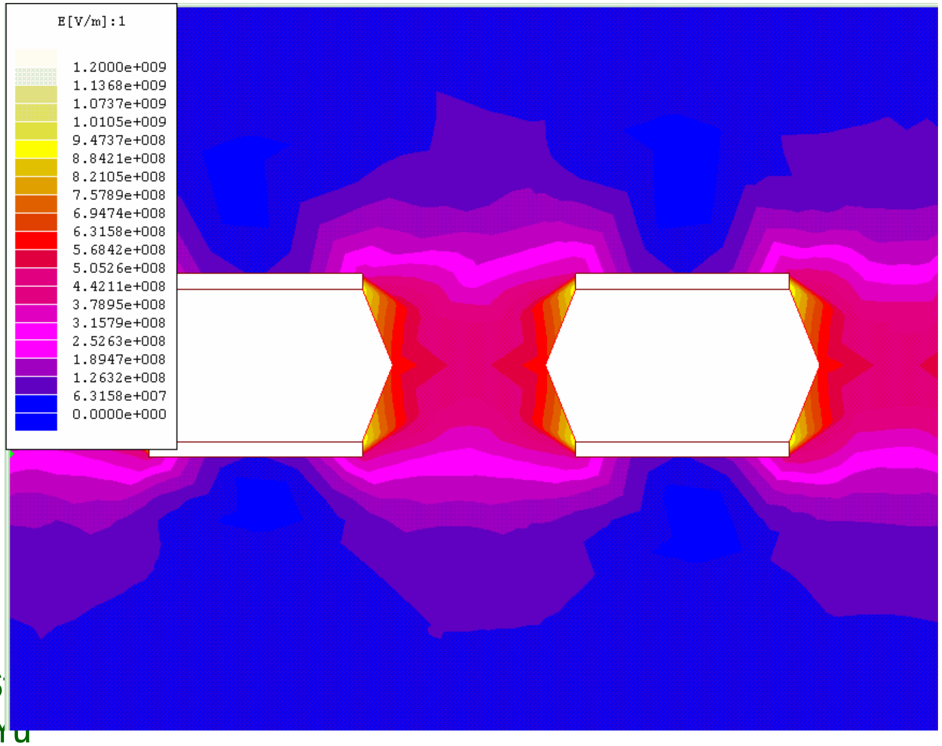
Magnetic Field Impact Study

- Concerns on possibly spiral of ionization electrons, causing unwanted signal spread and amplification due to the perpendicular E and B
- Have two UG students working on this subject
- Use Maxwell to generate field lines
  - Completed an initial implementation of prototype chamber structure implementation
    - 11 holes suffice for our purpose
  - First run on double GEM for E field completed
    - Some interesting features are being investigated
- Feed the output field map from Maxwell into Garfield

Maxwell Geometry and E field



Top and bottom of a GEM foil (60μm) at 400V



Conclusions

- GEM-based DHCAL performance studies completed
- PFA-based jet energy resolution seems to be right on target
- Initial results of PFA study using two-single pion completed
  - Will need to make the algorithm more sophisticated
- Graduated two MS students (see http://www-hep.uta.edu/ for theses)
  - Two undergraduate student currently working on this project
  - One MS student candidate in line..
- Conversion to LCIO-based Mokka completed
  - GEM based test beam geometry implementation to occur soon
- Inclusion of GEM into SiD simulation package
- Impact of magnetic field to ionization electrons under study