Usage of Tracking for Jet Measurements

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Includes important contributions from J.Lu, D.Gingrich, N.Davidson, D.Tovey,R.Duxfield,M.Hodgkinson

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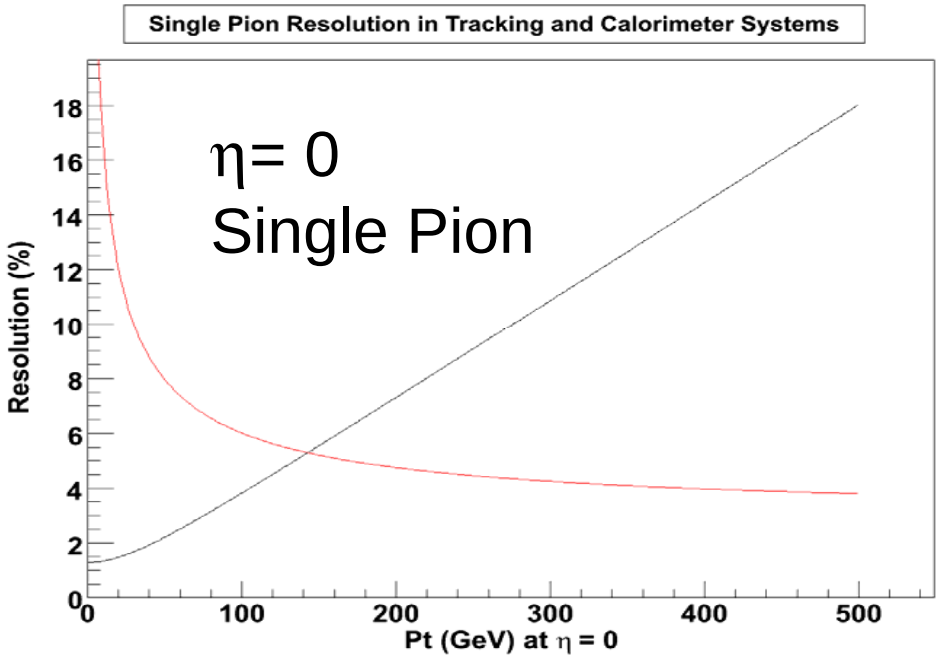
- Introduction
- Jet Fragmentation Studies
- Measurement of e/p using hadronic tau decays
- Measurement of e/p using hadrons in minimum bias events
- Energy Flow (Tracks + Clusters) based jets
- Magnetic Field corrections for use in jet reconstruction

Introduction

- At low energy tracking has better resolution



Tracking: $\sigma p_T/p_T \approx 0.036\% p_T \oplus 1.3\%$

Calo: $\sigma E/E \approx 50\%/\sqrt{E} \oplus 3\%$

(numbers from Atlas TDR for single pions in central region)

- E/P can be used as cross-check on calorimeter calibration
- Tracking can be used in principle to improve jet resolution (already is used to complement calorimeter for taus in e.g. TauP13P package)
- Can also be used to estimate energy lost from reconstructed jet cone due to Magnetic field

Jet Fragmentation (M.Hodgkinson - Univ. of Sheffield)

- Gives energy range of particles in jets
- Indicates the energy range to study for the use of e/p for jet calibration
- Currently have looked at Rome Jx samples in 11.0.41
- Divided in 3 eta bins:
  - 0->1.5 (Central)
  - 1.5->3.2 (EndCap)
  - >3.2 (Forward)

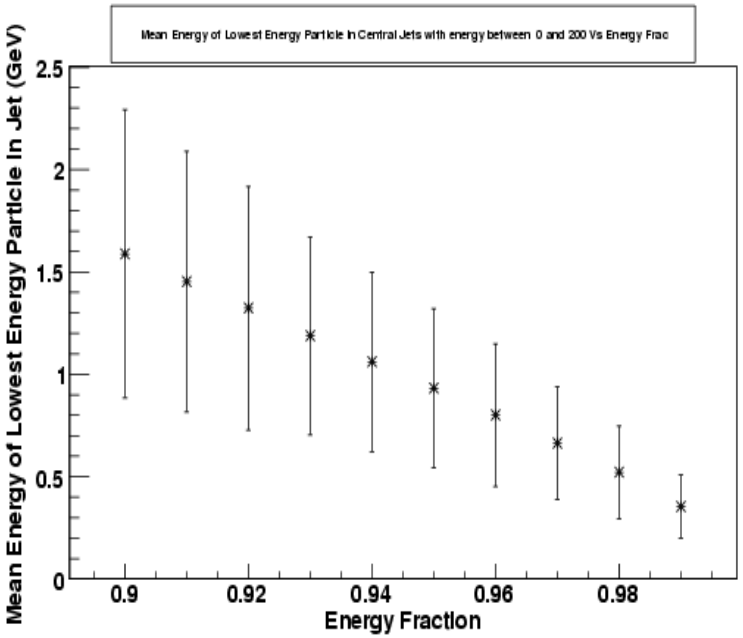
• Also divide into 20 energy bins in 200 GeV steps from 0 to 4 TeV

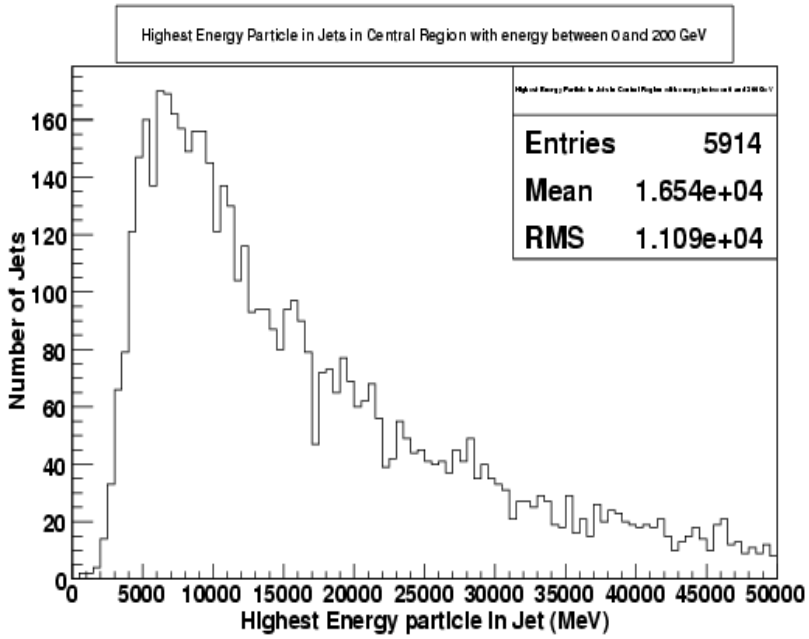
• The truth particles list is defined as all stable generator level particles (defined in JetsFromTruthTool.cxx) that interact

Lowest Energy Particles (LEJPS)

- Order truth particles in highest pt jet in energy order (highest to lowest)
- Sum up the particle energies from highest to lowest
- Each time particle added to sum check ratio of summed_true_energy/total_true_energy
- When this hits some value, x, put the particle that pushed the fraction over this threshold in histogram
- Do for x = 0.9->0.99 in 0.1 steps

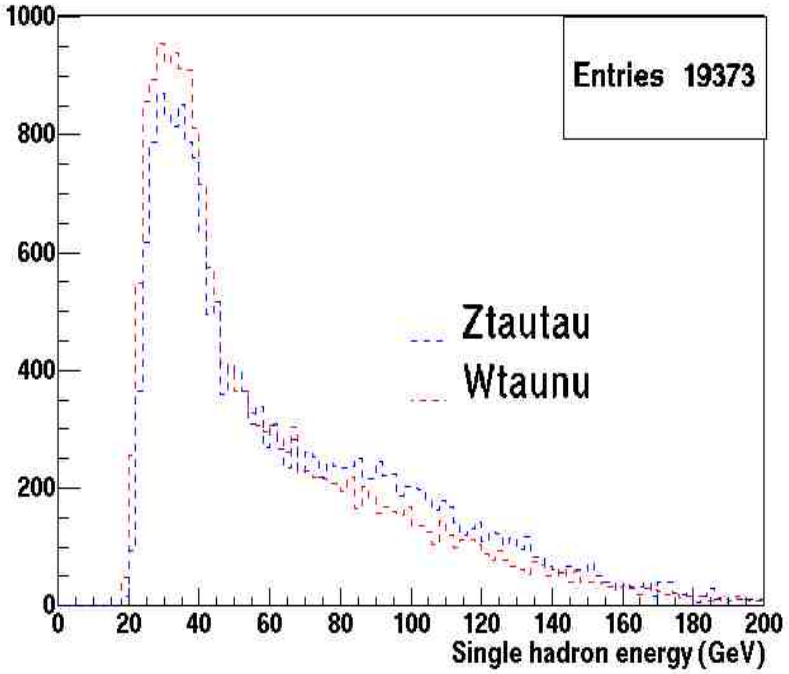
Jets with 0 - 200 GeV Energy and eta < 1.5

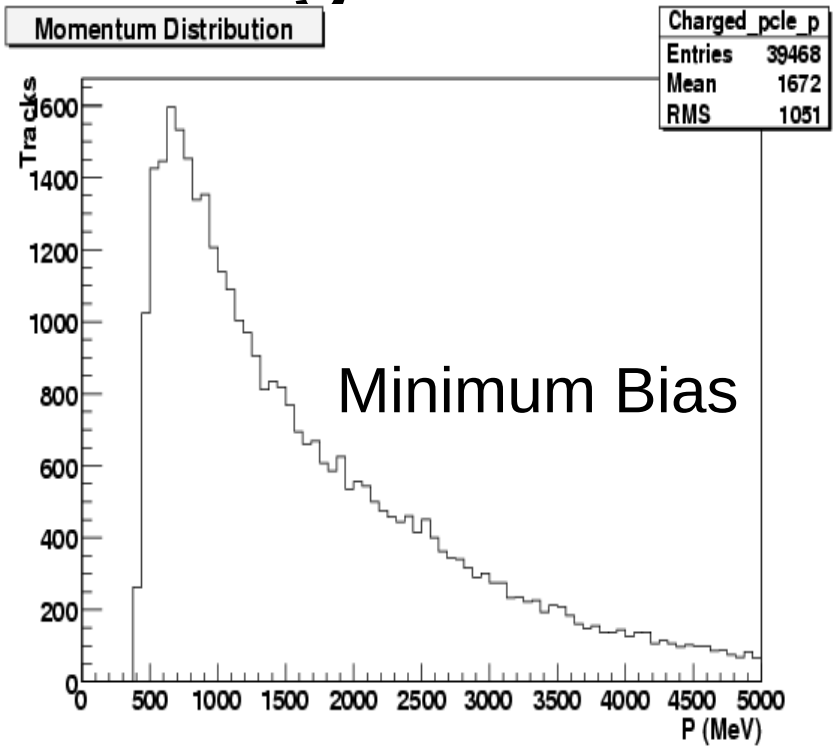




- Length of error bars corresponds to RMS of energy spectra - e.g. to reconstruct 92% of jet energy must reconstruct particles down to 1.4 GeV
- Can see particle energies span large range (400 MeV to 45 GeV)
- Not time to show plots for all the bins in this talk, please wait for a document to appear (or ask me for specific sets of plots if needed) - 6 month old version of document available on Jets wiki page using J2,4,5 samples only

Momentum Coverage E/P





- Could use hadrons from MB from few 400 MeV to 5 - 10 GeV, taus from 20 GeV (depends on trigger) to few hundred GeV
- Of course depends on final event selections used and amount of data (large MB cross-section can give many tracks in the tail) collected

E/P Using Hadronic τ Decays (J.Lu,D.Gingrich - U Alberta)

- 11% of τ decay to $\pi\upsilon$
- Can use these to measure E/P
- Main background is QCD jets and other τ decay modes (in particular $\tau\rightarrow\rho\upsilon$, $\rho\rightarrow\pi\pi^0$ - τ branching fraction is 24%)
- Challenge is therefore to reject QCD events and separate hadronic from electromagnetic showers
- Use CSC $Z\rightarrow\tau\tau$, $W\rightarrow\tau\upsilon$, QCD J1 + J2 samples

Event Selection

- Trigger aware AODS for relevant samples not yet made
- Use “Trigger-Like” cuts for now (tau + etmiss30)

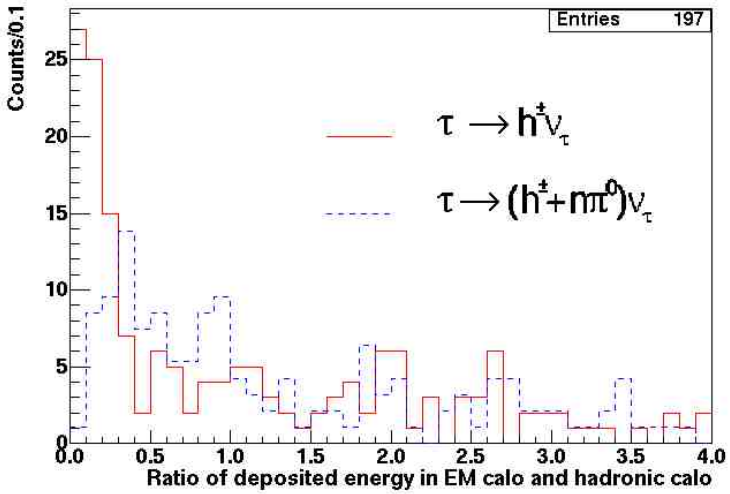
Cut A

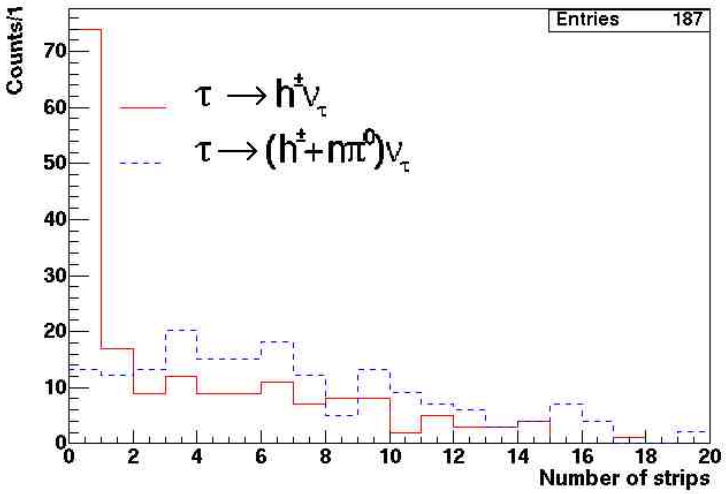
- Require 1 Tau Jet (with 1 track only - P_T > 20 GeV and $|\eta|$ < 2.5)
- EtMiss > 30 GeV
- Tau Likelihood > 4
- ΔR between tau jet and nearest electron > 0.4
- ΔR between tau jet and nearest photon > 0.4

- Ratio of energy deposited in EM and Hadronic calorimeter < 0.3
- Number of strip hits in EM layer < 3

Cut B

$\pi^0/\pi^{\pm}$ Separation

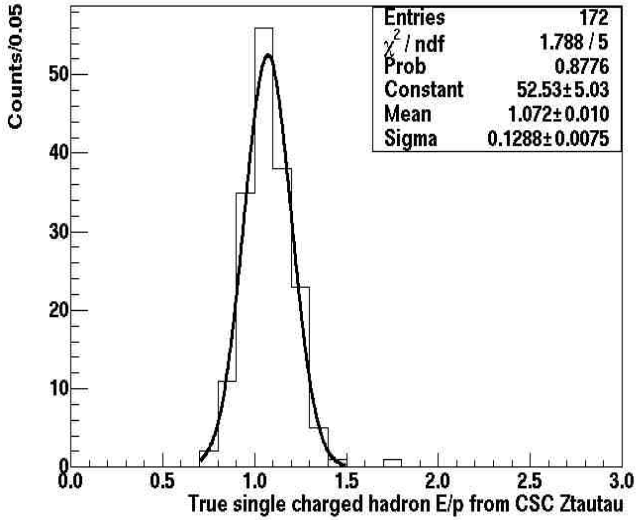




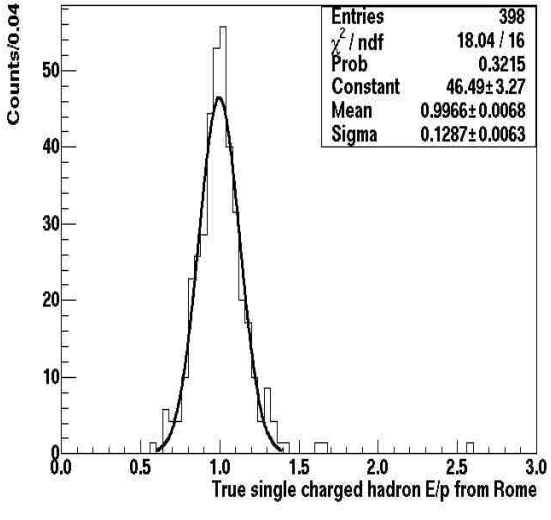
- Left plow shows ratio of energy in EM calo to hadronic calo
- Right plot shows number of strips in strip layer of EM calo with energy deposit
- Both variables give good separation in MC

E/P from True Tau Decays

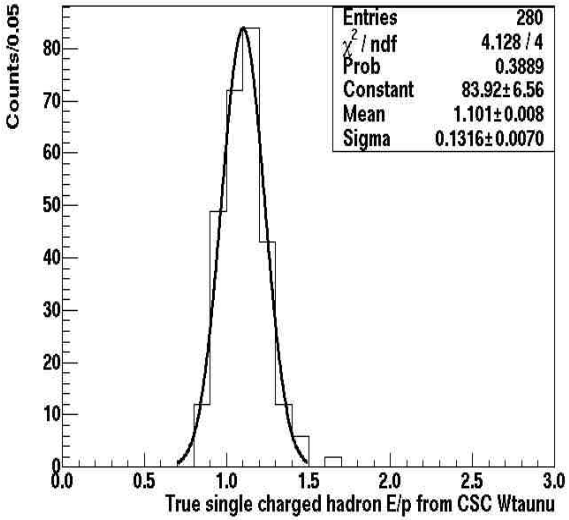
E/P is defined as ratio of calorimeter energy (H1WeightToolG4) in tauRec cone to energy of track in tauRec cone



CSC $Z \rightarrow \tau\tau$



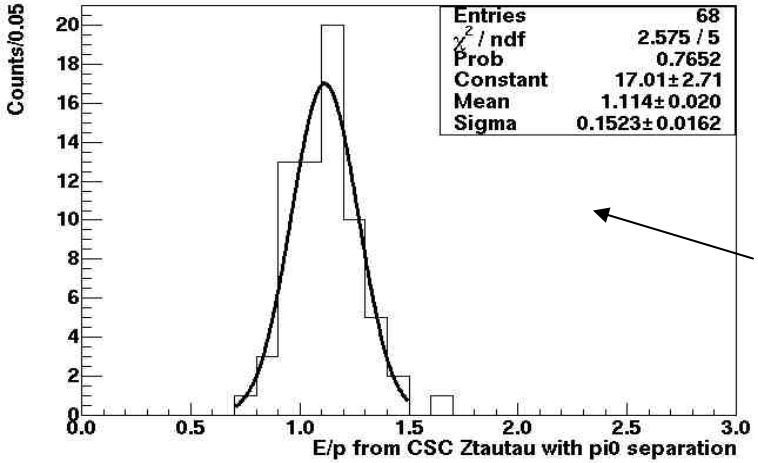
Rome $Z \rightarrow \tau\tau$



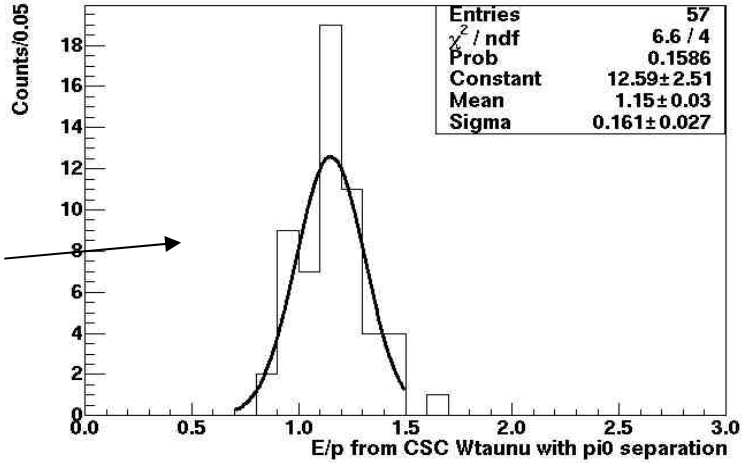
CSC $W \rightarrow \tau\nu$

- Apply Cut A and require match between reconstructed pion and truth pion (which should not be from $\tau \rightarrow \rho$ decay)
- CSC Mean NOT consistent with E/P = 1 - tau experts found bug in usage of calibration factors and have fixed problem for 12.0.1 release

E/P from Reco Tau Decays

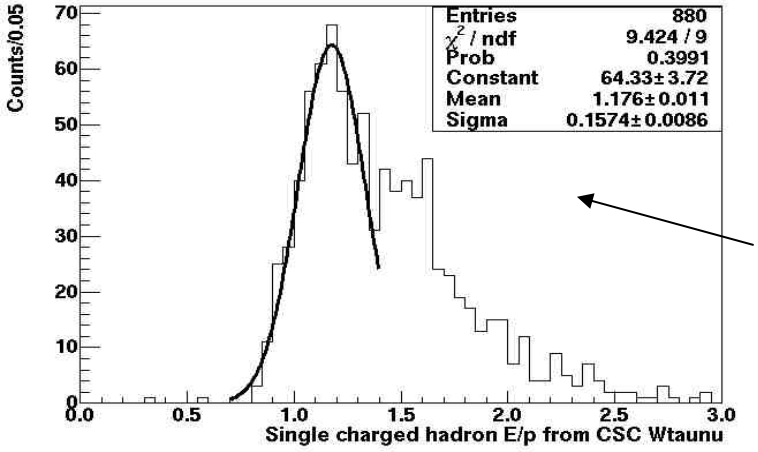


Cut A
+
Cut B



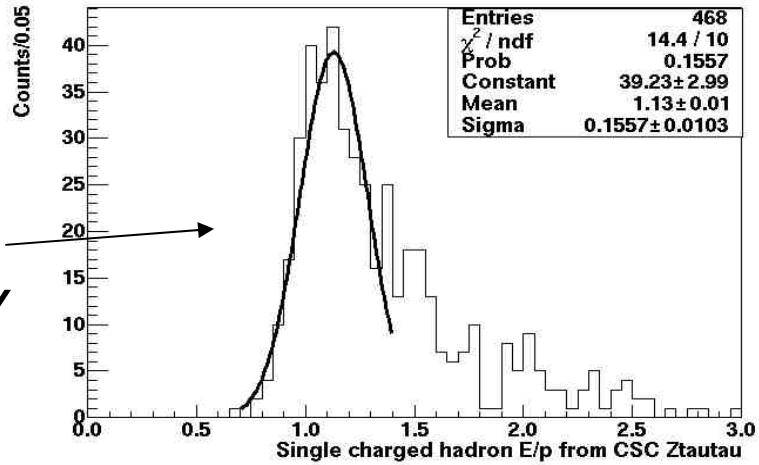
CSC $Z \rightarrow \tau\tau$

CSC $W \rightarrow \tau\nu$



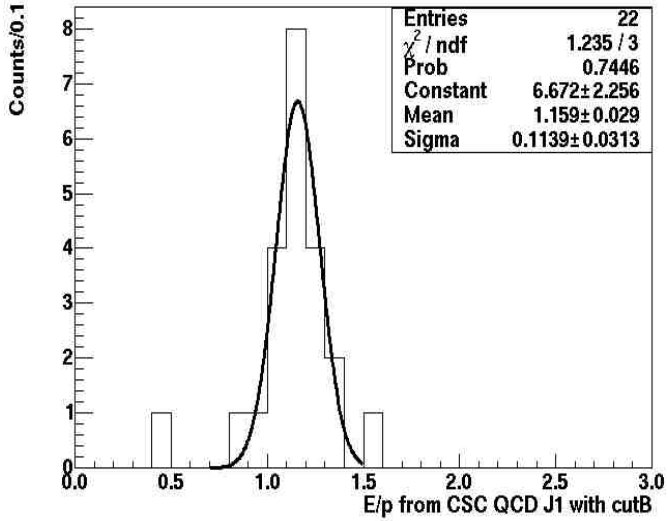
Cut A

ONLY

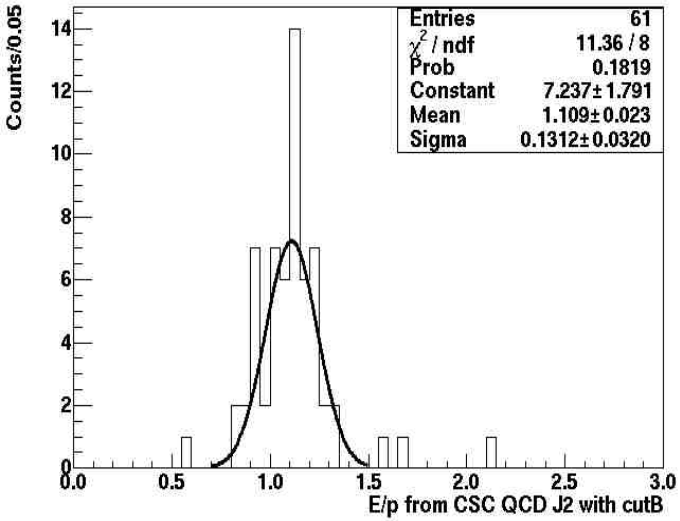


E/P from QCD Events

- QCD dominates over tau samples, but do get candidate events (but are not true taus, however these pions give reasonable e/p) using Cut B + Cut A (minus etmiss cut)



CSC J1



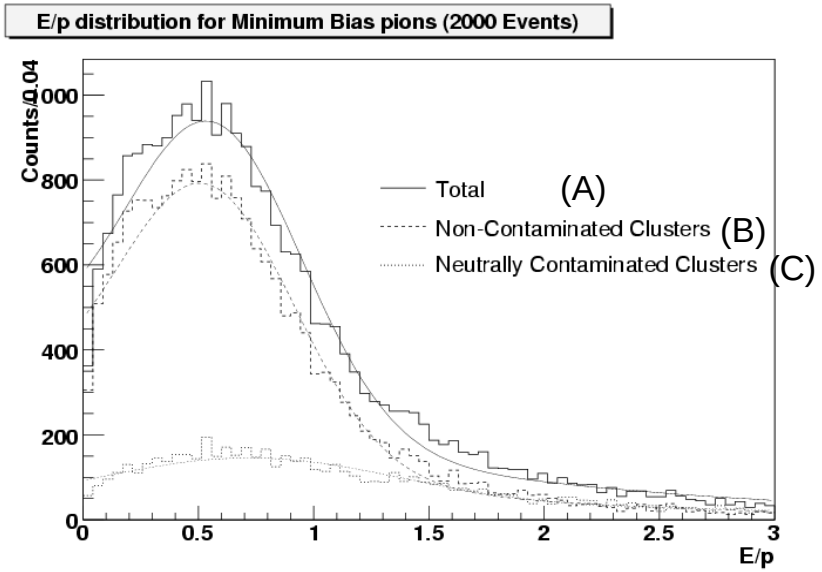
CSC J2

- Result consistent with $W \rightarrow \tau\upsilon$
- Find 2/3 of these pions are isolated
- Could be ok to use them for measurement of e/p

E/P Using Minimum Bias Events (N.Davidson - U.Melbourne)

- New study using CSC 5001 minimum bias samples in 11.0.42
- Start with all tracks (that have a match to a truth pion) and using TrackToCalo match to topoclusters with deltaR match
- Calorimeter energy is sum of topocluster (uncalibrated) energies in cone of ΔR (size 0.2 and 0.05 tried) around track
- Define “Contaminated” clusters as track with matched neutral truth particle within $\Delta R = 0.2$

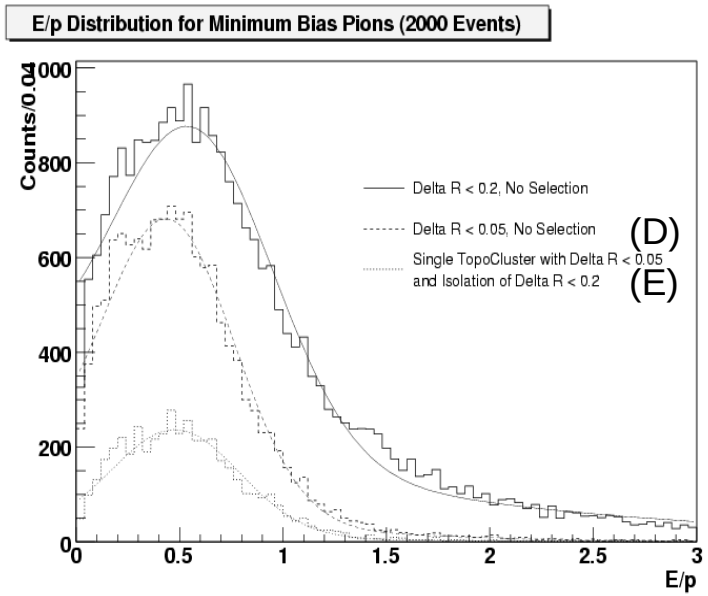
Results with $\Delta R = 0.2$ Cone



Sample	Mean	Sigma
A	0.568 ± 0.008	0.389 ± 0.074
B	0.532 ± 0.008	0.389 ± 0.009
C	0.721 ± 0.24	0.666 ± 0.036

- Fit with Gaussian + decaying exponential
- Table shows Gaussian fit parameters for 3 scenarios
- Contaminated clusters have large shift in mean,sigma but overall shift is not as large

Results with ΔR = 0.05 Cone



Sample	Mean	Sigma
D	0.479 ± 0.007	0.312 ± 0.007
E	0.447 ± 0.006	0.319 ± 0.006

- E/p smaller with smaller cone size
- E/p smaller with isolation requirement on topocluster

Conclusions/Plans for E/P

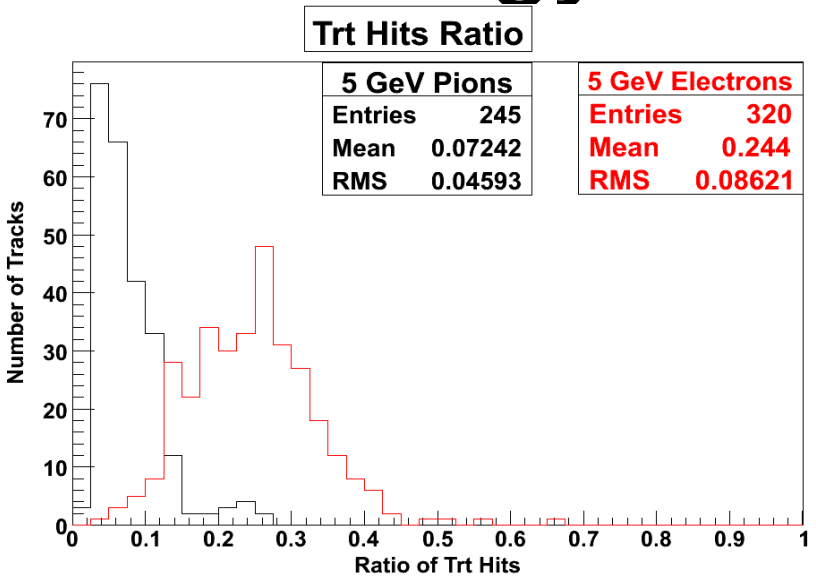
- Effects from neutral/charged hadron showers overlapping in MB events appear smaller than for the higher energy particles in the tau decays studied
- Potentially useful if both MB and tau study used same definition of measured E/P
- Also look at 900 GeV data sets (MB,J1 QCD)
- Find affect of relevant triggers on efficiencies of event selection etc
- Compare different models for MB studies
- Study E/p for different calorimeter calibration methods

Energy Flow Based Jets
(M.Hodgkinson,R.Duxfield,D.Tovey - Sheffield)

- Main concept is to measure energy deposits from charged hadrons using the tracker, not the calorimeter
- Therefore need to match tracks to topoclusters and remove the hadronic shower
- Build eflow objects (tracks, topoclusters, and pairs of tracks-topoclusters)
- Run JetRec on eflow objects instead of clusters
- Current performance evaluated using eflowRec-00-01-60 + eflowEvent-00-01-31 in 12.0.1 (with postRome Jx ESDs made with 12.0.1)

Energy Flow Methodology

- Use uncalibrated topoclusters and tracks (should pass pion particle identification criteria and have more than 1 pixel hit - in the end more cuts may have to be used)



- If there is a match between a track and cluster the expected energy deposit (calculated from single particle MC) is subtracted
- E/P is binned in energy, eta and calorimeter layer in which pion first interacts
- If the remaining energy in cluster is < 1.28* (expected_energy_deposit) do not use cluster
- 1.28 is best guess…can and will study the effect of altering this criteria on performance in near future

Subtracting Energy Deposits

- Have explored two methods currently
- First method is to simply recompute cluster kinematics (fine for isolated showers). But ratio of particles/topoclusters in jets is > 1
- Second method is to remove cells according to an ordered cell subtraction (harder to do this, but allows cell based calibration of left over cells in cluster in case of overlapping showers)

Calibration of Neutral Particles

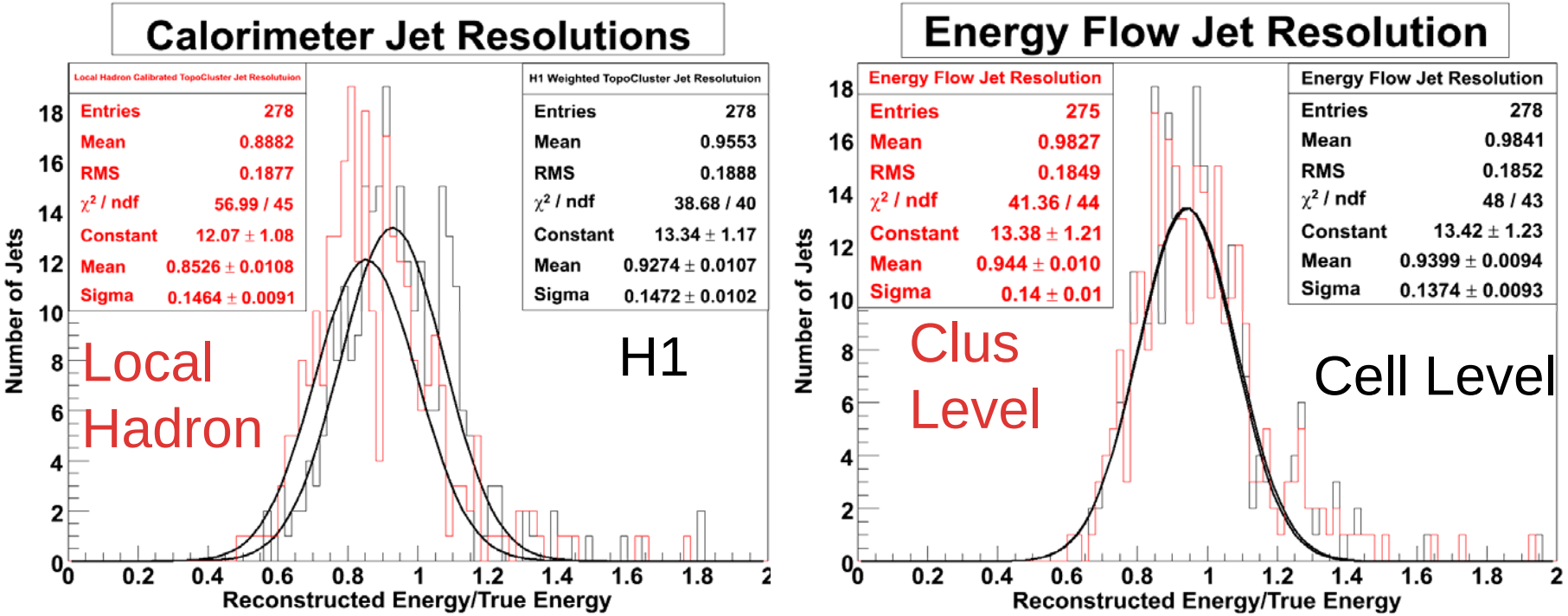
• Today show performance where all clusters/cells remain uncalibrated, but tracking effectively calibrates most charged hadron showers to correct energy scale

• Could calibrate at cell level (cell subtraction, cluster subtraction of isolated clusters only)

• Could calibrate at cluster level (cluster subtraction of all tracks)

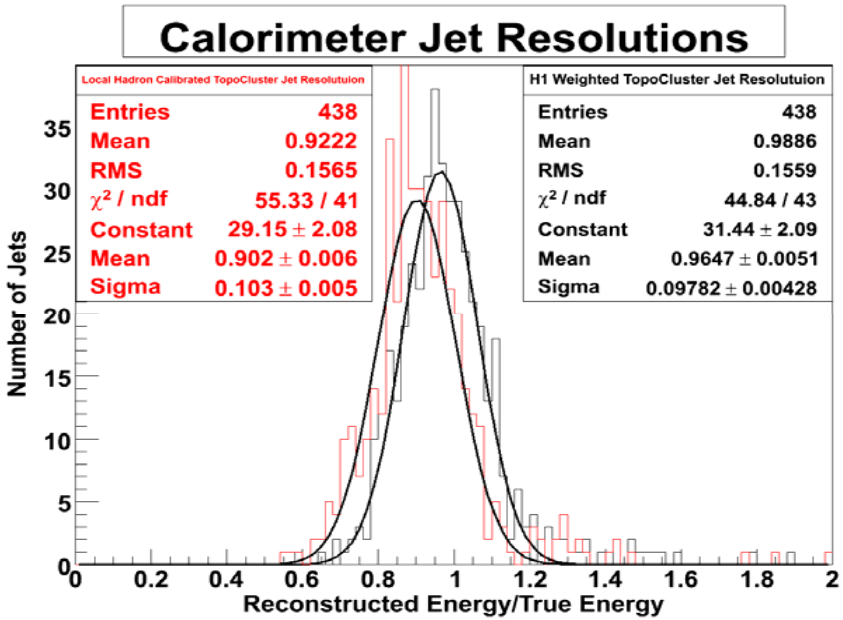
• We don’t know the best thing to do yet (main emphasis of work in near future)

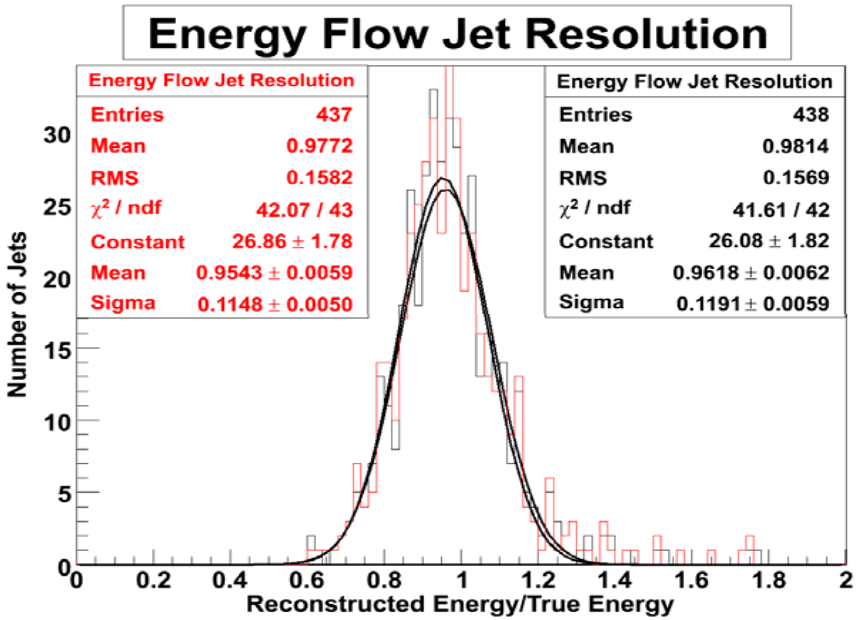
Performance in J1 Sample (Jet |η|< 1.8)



- Find highest pt H1 cluster jet and ensure ΔR between jets < 0.1
- Eflow gives a better linearity for 17 -35 GeV pt jets
- Local Hadron (i.e. jet find on CaloCalTopoCluster collection) jets have much worse linearity - due to charged particles swept out of cone (discussed in next section of talk)

Performance in J2 Sample (Jet |h|< 1.8)



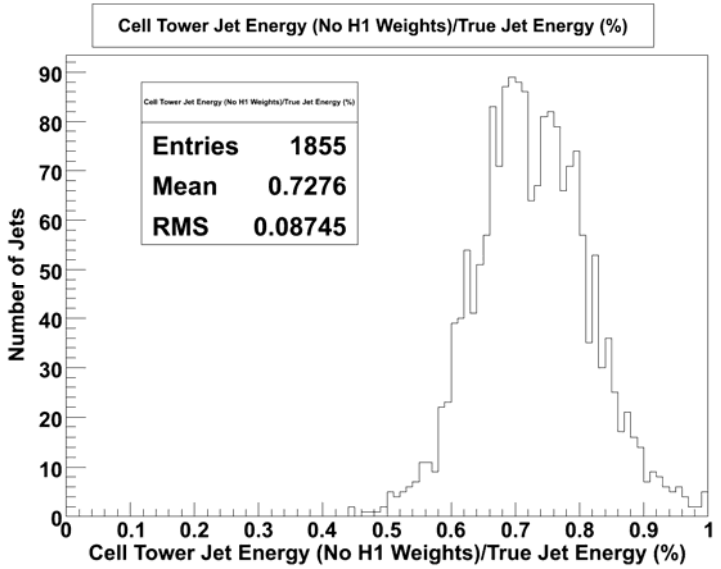


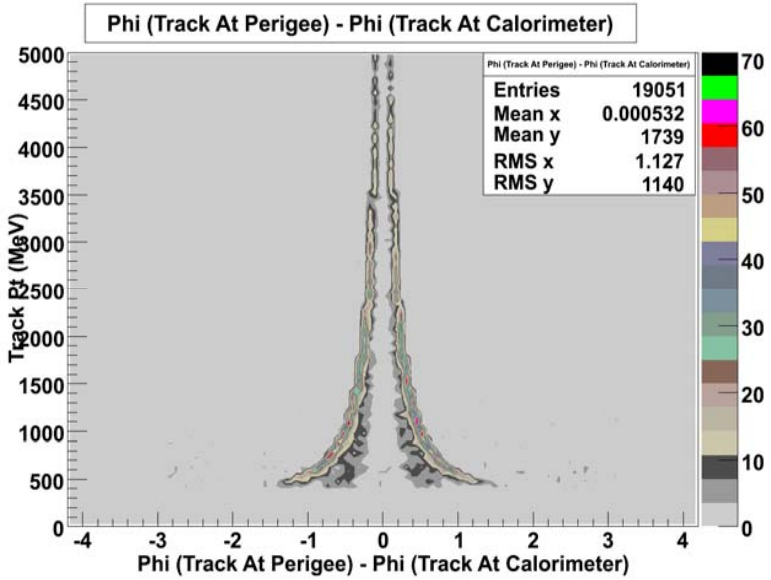
- In this regime eflow does not improve linearity,sigma (should use larger samples and plot linearity, sigma vs E for J1,2 to see where the crossover is and then push that point as high as is possible)
- Cell and Cluster eflow give similar result in absence of any calibration of remaining cells/clusters

EnergyFlow Plans

- Work with CSC data to find optimal parameters for jet finding on energyflow objects
- Have seen gives better linearity for J1 but not for J2 (without calibrating remaining topoclusters/calocells)
- Parameters to study include:
- Which scheme (Clus level, Cell Level, Clus level using only isolated clusters etc) gives best performance when calibrating remaining calorimeter energy deposits?
- What is the best way to decide if energy left in clusters is another shower (varying sigma cut, cell level might allow use of topological inputs to this decision)?

Effect of Magnetic Field on Jets (M.Hodgkinson - Sheffield)



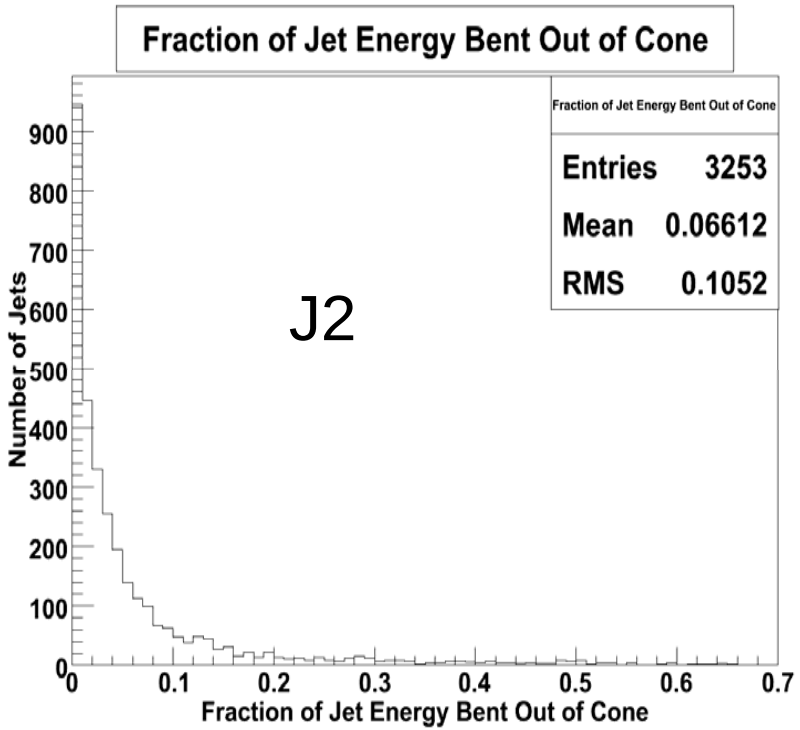


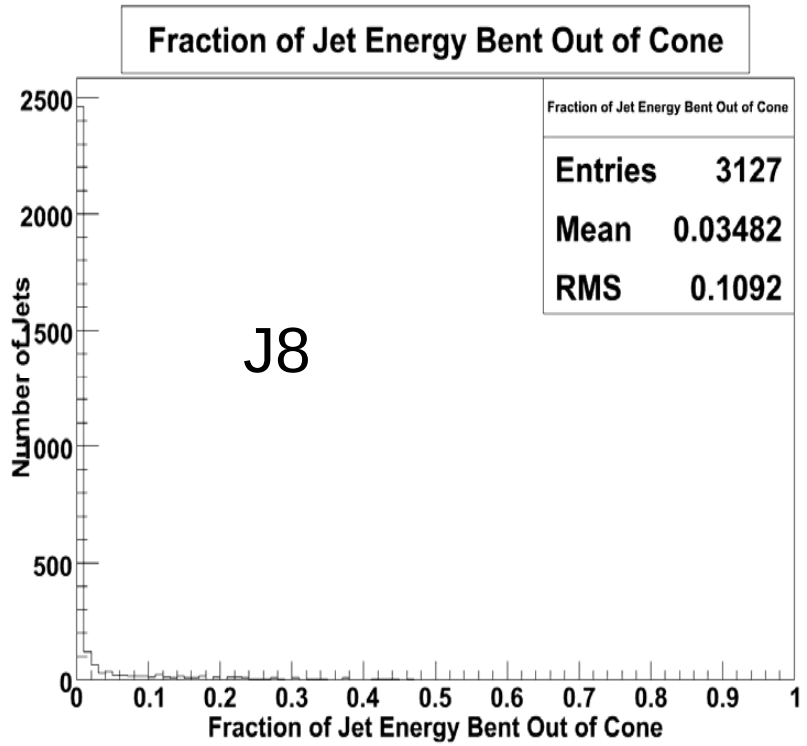
- Low pt particles in jet deflected by up to deltaPhi = pi/2
- Jet Energy scale 30% too low for J2 - how much of this is due to affect of B-Field?

Method

- Took highest pt reconstructed jet (cell based jets in 11.0.41)
- Find tracks (no cuts applied) in 0.7 cone
- Match track to topocluster using TrackToCalo - if cluster outside cone add this tracks energy to energy flagged as lost (E_lost)
- Plot:
  - E_lost/(E_true)

Results





- Loss due to magnetic field is smaller for high pt jets vs low pt jets
- To develop correction for jets should also account for tracks swept into cone

Conclusions

- CSC Jet note “Single Hadron Energy Scale in Atlas: E/p Performance for Pions” will include the work on jet fragmentation, e/p in tau decays and minimum bias events
- The samples mentioned in this talk will be used and the corresponding trigger aware AODS must be studied in 11.0.5 when they are made available (in fact for taus need > 12.0.1 for correct energy calibration?)
- If there are other contributions for this note please contact myself or Elisabetta Barberio ASAP
- Intend to produce set of out of cone magnetic field corrections to be applied to local hadron topocluster jets in 12.0.x - should help with non-linearity effects

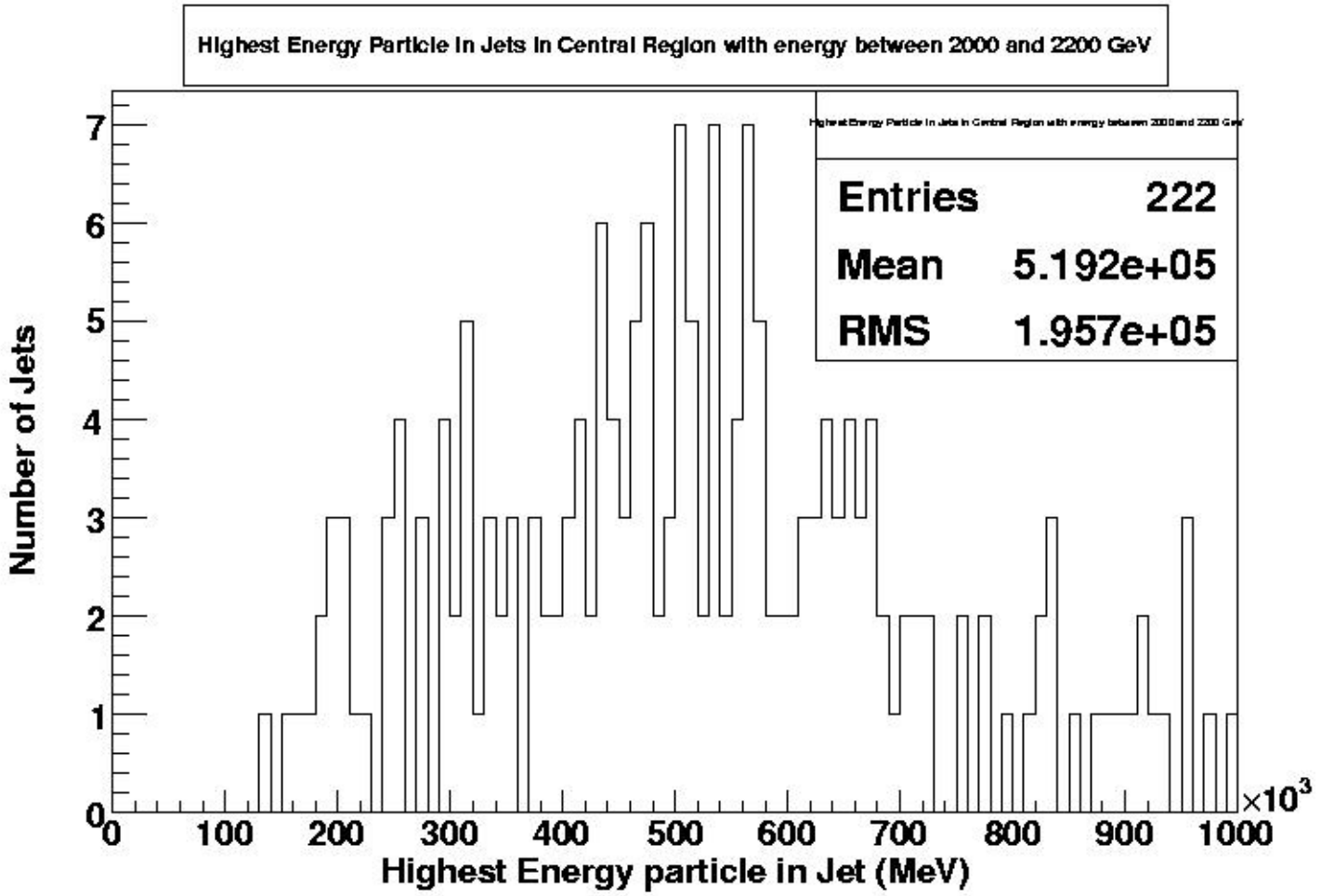
Conclusions (2)

- Intend to explore different calibration schemes for energy flow jets + tuning of parameters in algorithm to find optimal performance on the CSC jets samples with 12.0.x
- Document performance in ATLAS note
- Most of the needed functionality for these studies is in eflowRec athena package now

BACKUP SLIDES

Jet Frag

2 -> 2.2 TeV

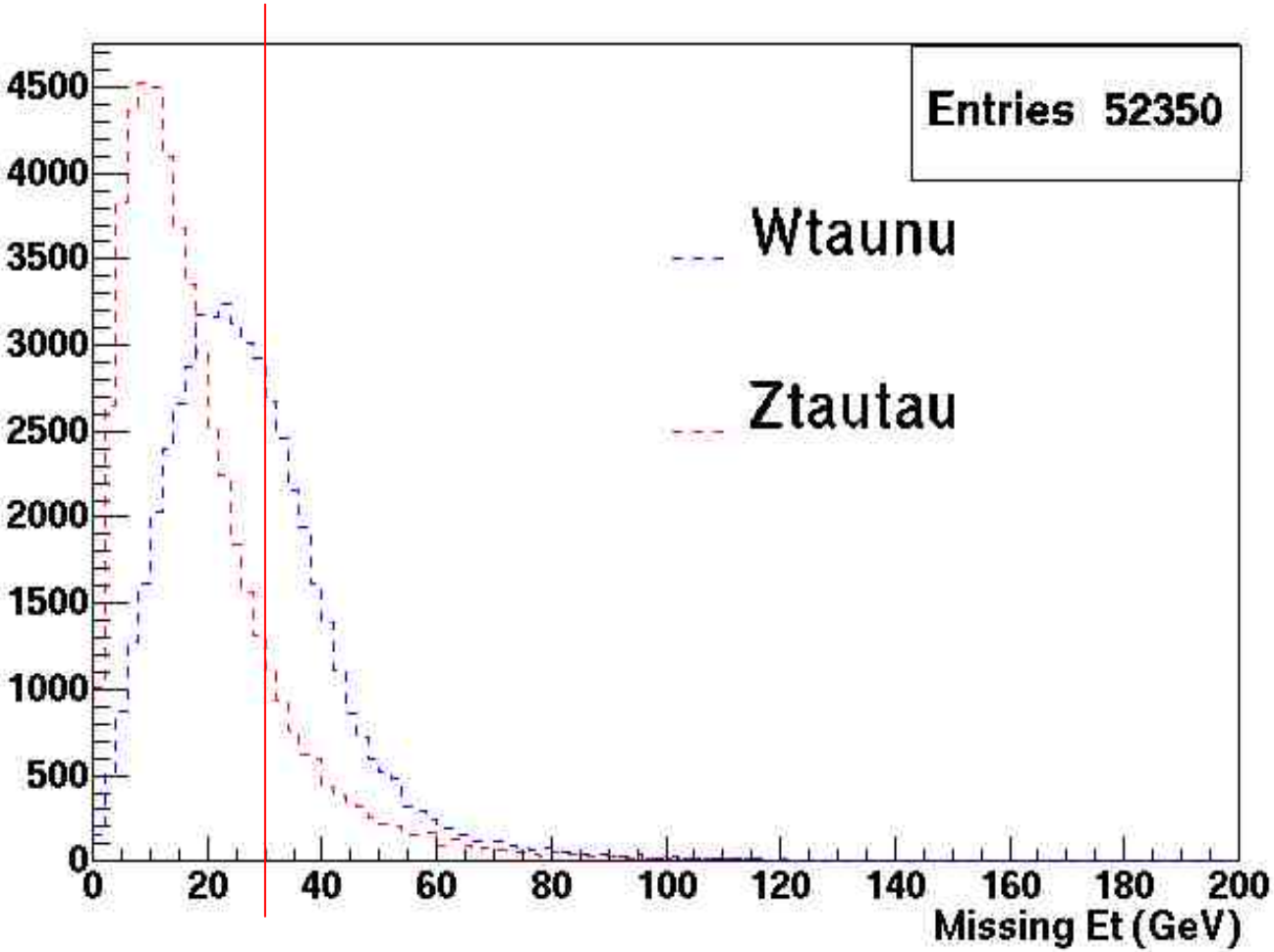

Highest Energy Particle In Jets In Central Region with energy between 2000 and 2200 GeV
Entries 222
Mean 5.192e+05
RMS 1.957e+05
Number of Jets
0
1
2
3
4
5
6
7
0
100
200
300
400
500
600
700
800
900
1000
×10^3
Highest Energy particle in Jet (MeV)

E/P

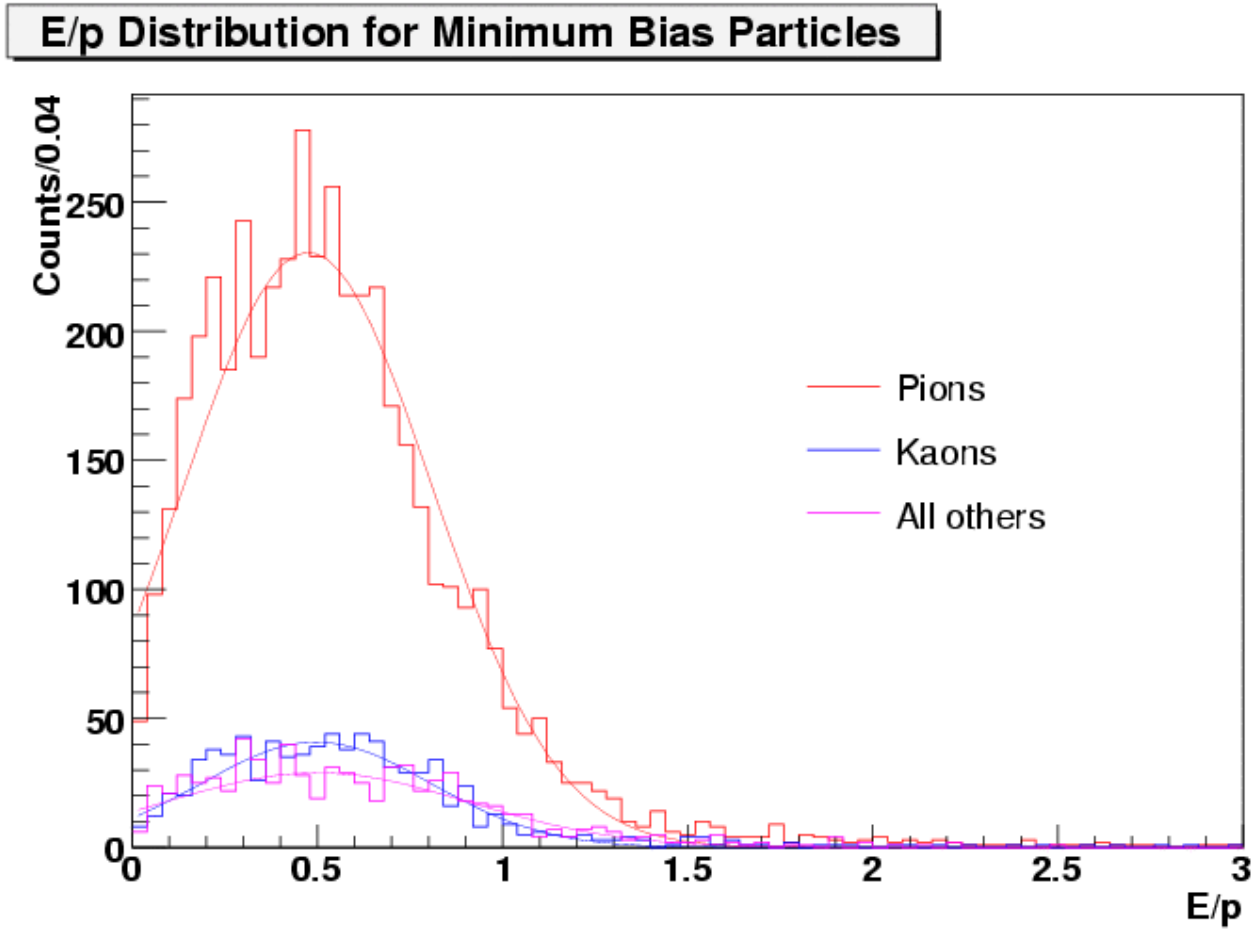
CSC Samples Used

Process	X-section (pb)	X-section*filter efficiency (pb)	Events	Luminosity pb-1
DC3.005010.J1_pythia_jetjet.py CSC plan, Herwig	1.37E+009 1.38E+009	1.37E+009, eff=1 1.38E+009	298950 500000	2.18E-04 3.62E-04
DC3.005011.J2_pythia_jetjet.py CSC plan Herwig	9.33E+007 9.49E+007	9.33E+007,eff=1 (9.49E+007)	304000 500000	3.26E-03 5.36E-03
DC3.005188.A3_Ztautau_filter.py CSC plan	1640 1640	180 (eff=0.11) 246 (eff=0.15)	36250 150000	201 610
DC3.005189.A3_Ztautau_filterA.py CSC plan	1640 1579	344 (eff=0.21) 458(eff=0.29)	16100 100000	46.8 218
DC3.005107.pythia_Wtauhad.py CSC plan	17280 17313	5011 (eff=0.29) 5540 (eff=0.32)	47850 250000	9.55 45.1

EtMiss in Tau Samples

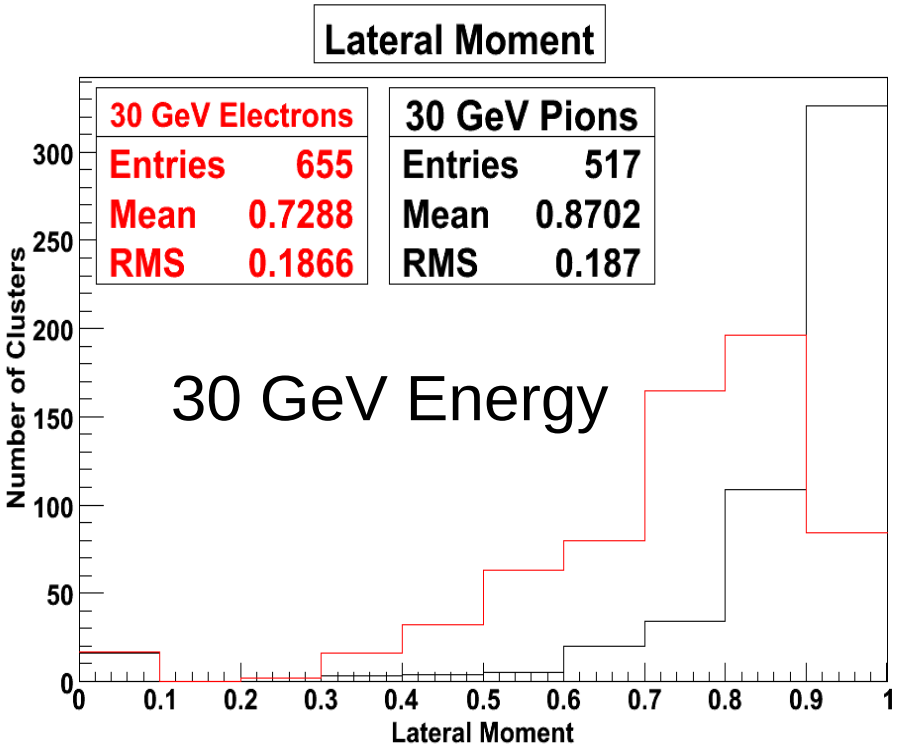


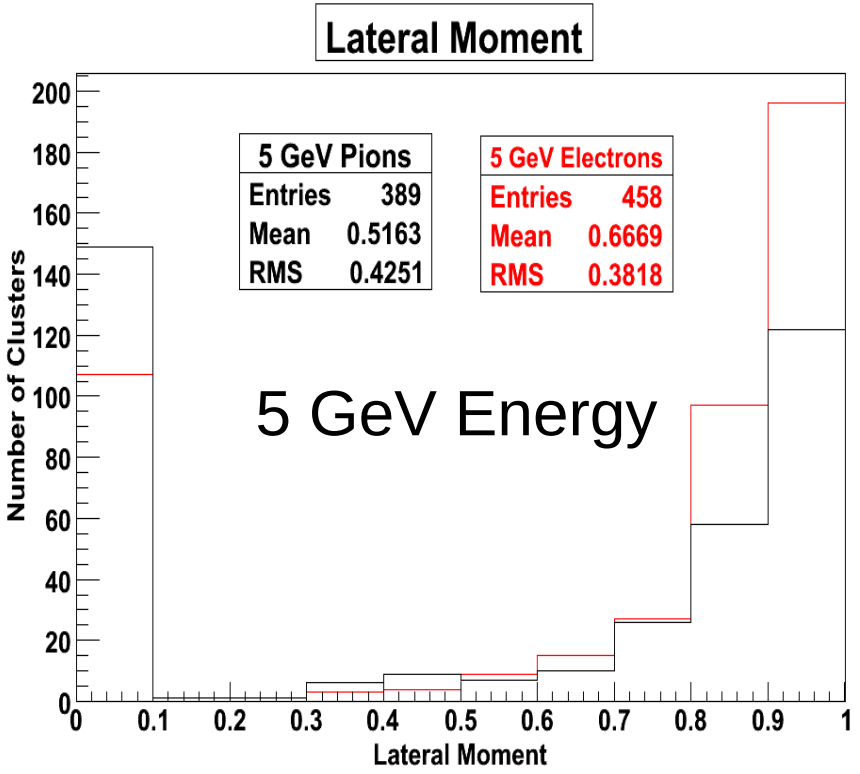
E/P for Particle Types



Energy Flow

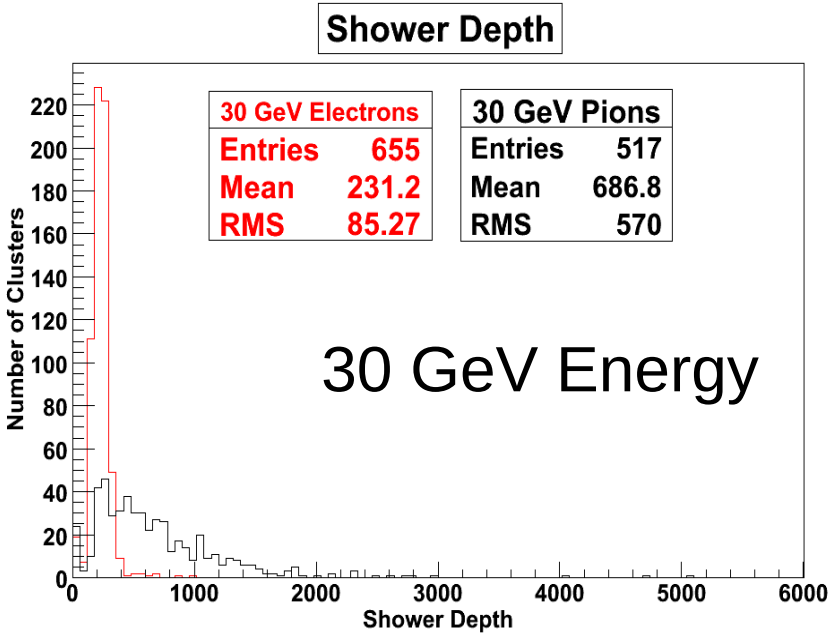
Cluster Moments: Lateral Moment

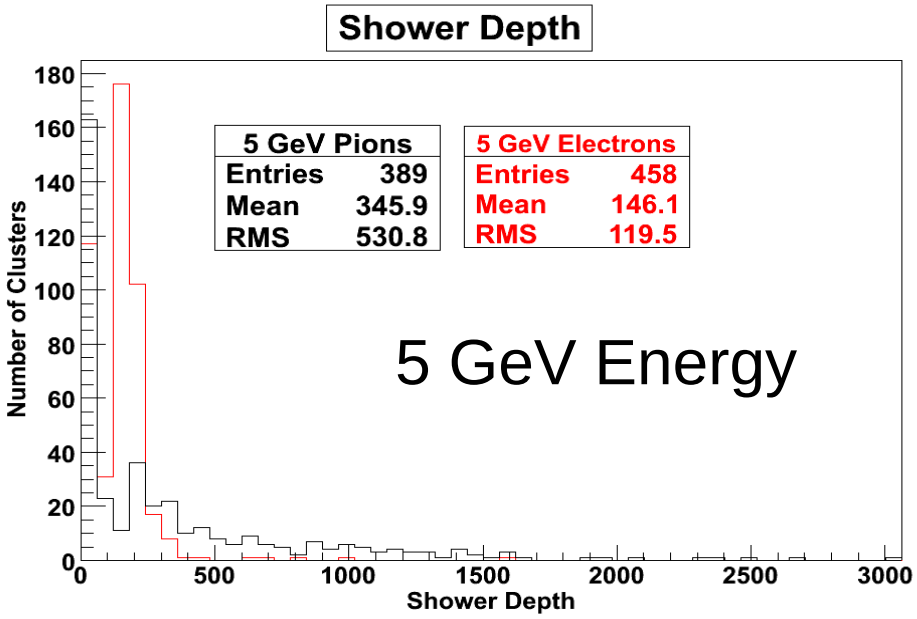




- Study topoClusters matched to tracks
- Define distance from shower axis to cell as r
- Calculate sum of energy_cell * r *r for all cells in cluster except two highest energy cells
- Calculate sum of energy_cell * r *r for all cells in cluster
- Take ratio of two

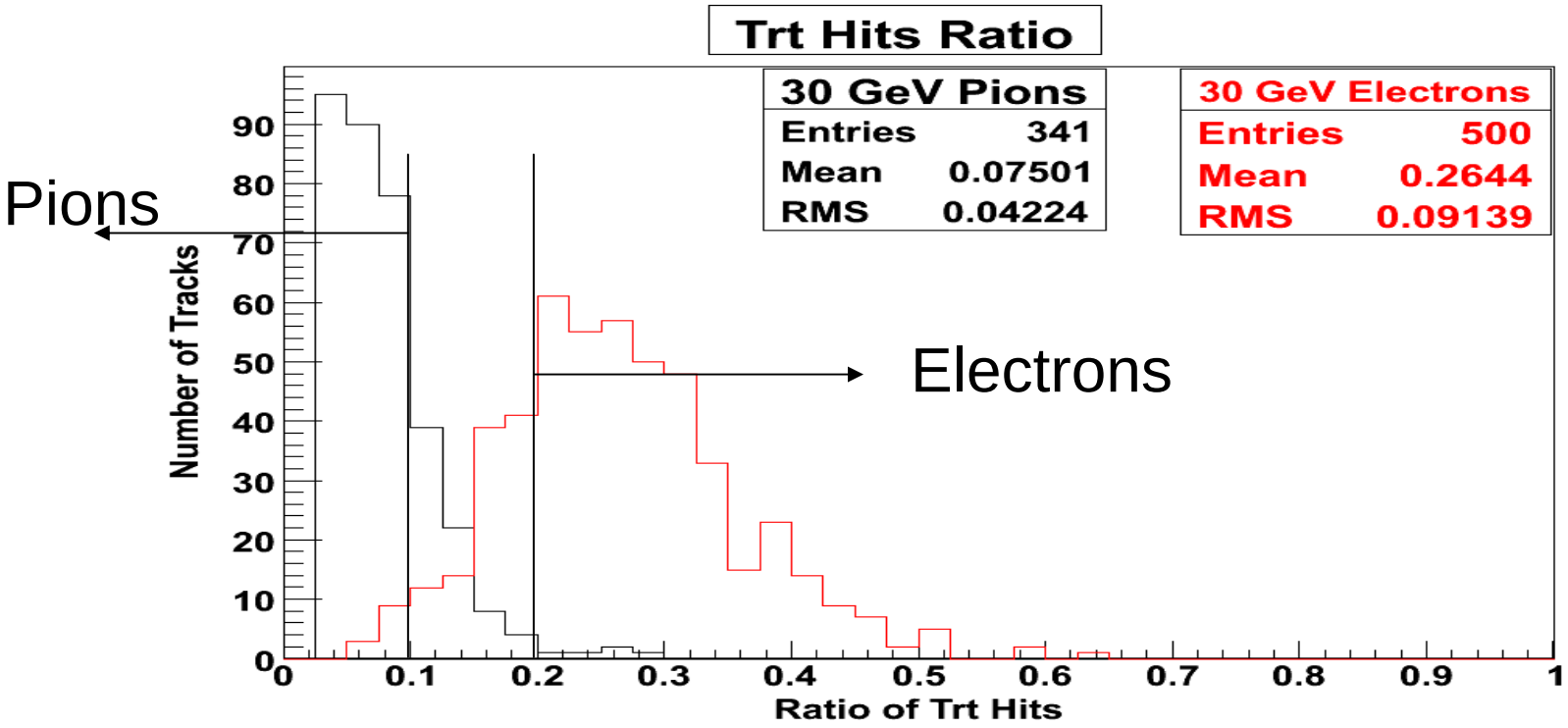
Cluster Moments: Center Lambda





- Longitudinal distance along the shower axis of the shower center from the calorimeter start
- Discrimination not as good at 5 GeV compared to 30 GeV for both moments

Trt-Cluster Particle ID



- If ratio < 0.1 it is a pion
- If ratio > 0.2 it is an electron
- Else use cluster quantities : electron should have lateral moment < 0.9 and shower depth < 400

Layer of First Interaction

- Extrapolate track to calorimeter
- Define track trajectory in calorimeter as charged pion shower axis and build 2-d gaussian around this of width Moliere radius
- Plot the longitudinal energy density profile along shower axis (as function of interaction lengths)
- Largest gradient difference between layers used to define layer of first interaction

Short Guide to Cell Subtraction

- For each calo layer bin in ΔR relative to track h,f (each bin in a layer is a “ring” of cells)
- Order all rings in all layers in order of energy density
- Remove rings of cells in descending energy density order (I.e. should start from first em interaction and go from there)
- This ordering is binned in energy,eta and layer of first interaction (just like e/p) - remove as much variance in shape as possible (other variables to reduce this further?)
- Tested in single particle gun (firing up two particles in close proximity)
- Once start to use cell calibration in eflow jets (in fact have tried H1 standard jet weights but not really good solution for eflow) should get better idea how well it works for jets
- Please look at Paris s/w week (Dec 05) talk in jets session for further details