Progress on E/p for low energy pions

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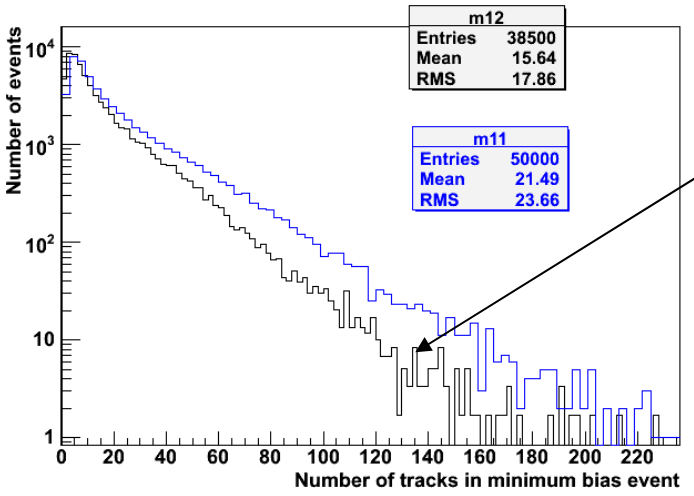
E/p method

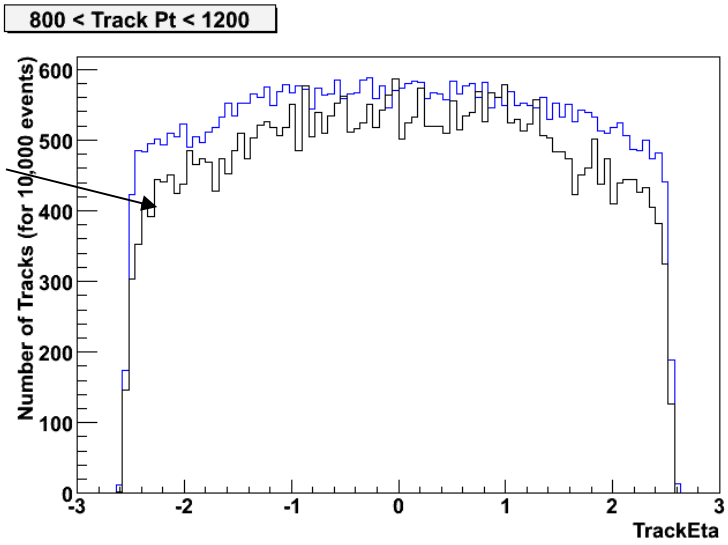
- Recall: E/p is a method to check the energy scale calibration.
- Minimum bias events have been studied to find isolated pions and check the low energy (Pt < 15GeV) range of the single hadron calibration.
- P – taken from track momentum (precise)
- E – taken as the sum of caloTopoClusters energies within a cone of ΔR=0.4 centered on the track position when extrapolated to the 2nd layer of the EM calorimeter.
  - Only tracks with matching cluster within ΔR<0.05 are considered
  - Only clusters with |eta| < 2.5 are used.
- Previous work was done with csc datasets reconstructed with Athena 11.0.4
- Now looking at 12.0.6 MC
- 400k minbias events:
  - trig1_misal1_csc11.005001.pythia_minbias.recon.v12000601
- 25k single pions with et=1GeV
  - trig1_misal1_mc12.007421.singlepart_singlepi_et1.recon.v12000601
- 15k single pions with et=10GeV
  - trig1_misal1_mc12.007422.singlepart_singlepi_et10.recon.v12000601
- Many sample have 1mm problem and will be compared to 30 micron datasets when available.

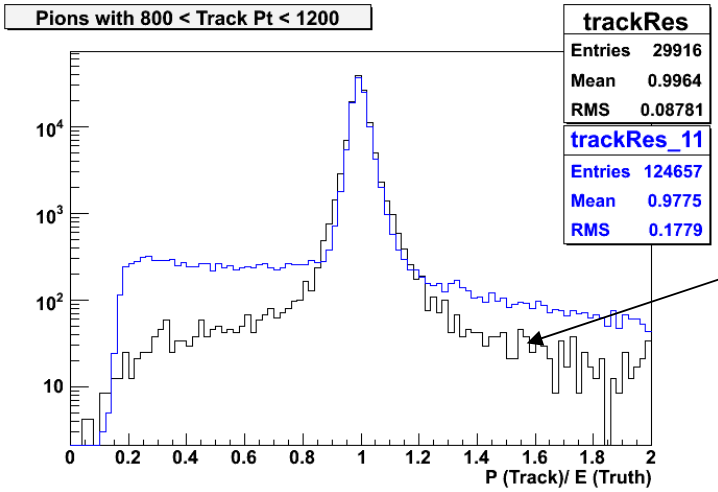
Tracks in minimum bias for 11 vs 12

- Different default track rec. in Athena 12



less tracks in 12



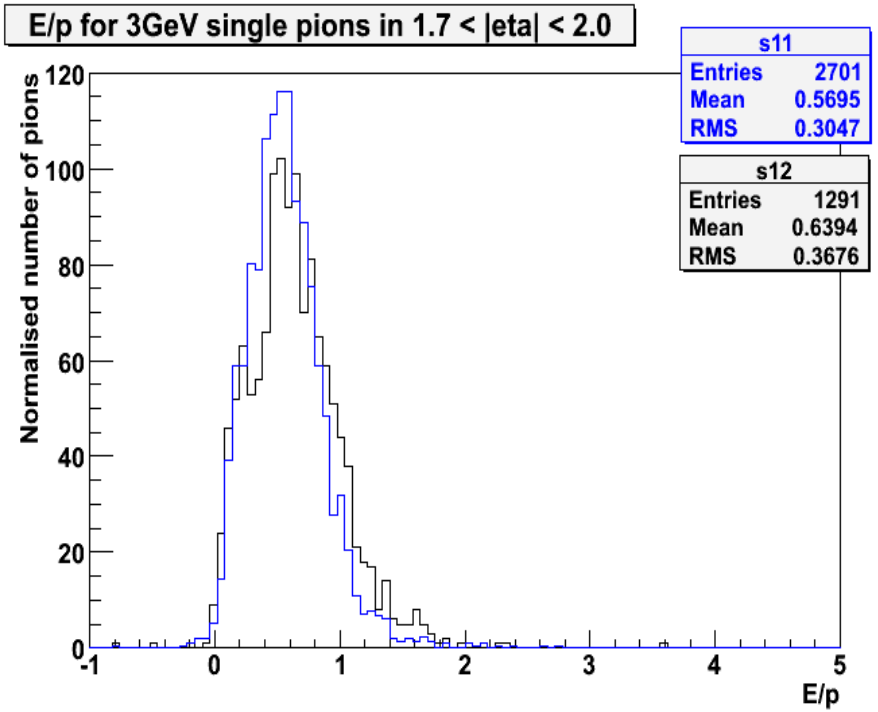


tracks of better quality when matched to a truth pion

(less fake tracks?)

Clusters: 11 vs 12

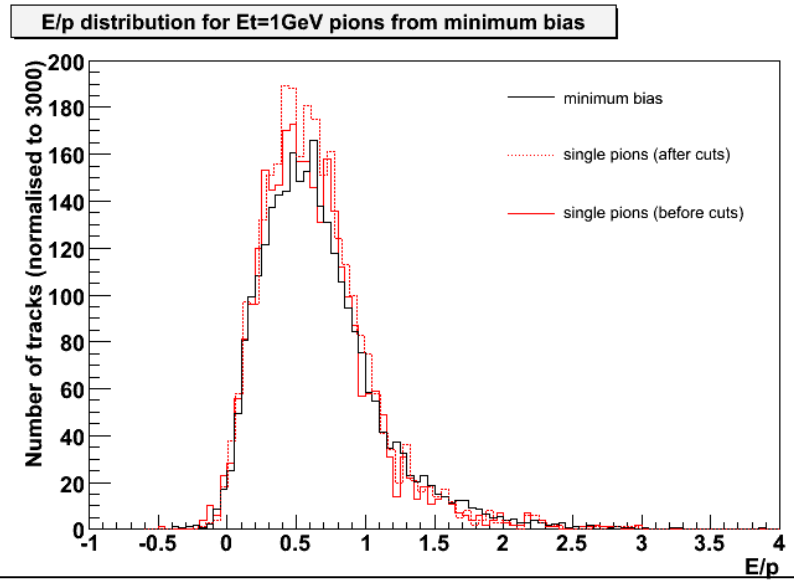
- CaloCalTopoClusters calibrated to local hadronic scale (but no dead material or out of cluster corrections). Previous calibration was to EM scale only
- Result: Larger E/p. but not centred on 1 yet. Increase in RMS



Selection of isolated pions (et=1GeV)

- Cuts made to find isolated pions in athena 11 data:
  - Based on tracks:
    - Number of tracks in event < 15
    - $\Delta R_{\text{track isolation}} > 0.8$
    - >=1 B Layer Hit (to remove electron tracks from conversions)
  - Based on clusters
    - Cluster Multiplicity < 4
    - Energy difference in cones ΔR=1.0 and Δ R=0.4 < 200MeV
    - Energy fraction in cone ΔR=0.2 > 0.7xEnergy in cone ΔR=0.4
  - Approx. 1 track in 200 survive. (or 1 per 10 events)
- **For version 12:** Can make harder cuts since there are x10 more statistics
  - Changes:
    - Removed cut on number of tracks as this was ineffectual
    - $\Delta R_{\text{track isolation}} > 1.0$
    - magnitude of energy difference in cones ΔR=1.0 and Δ R=0.4 < 100MeV
  - Approx. same order of tracks survive

Results for et=1GeV pions



Sample	E/p mean	RMS
-minimum bias	0.668	0.441
-single pion (after cuts)	0.645	0.401
-single pion (before cuts)	0.631	0.409

Error: ±0.007

- An improvement to the E/p bias can be made by requiring all the energy to be within R< 0.2
- This is equivalent to an isolated 0.2 cone
- E/p mean within 0.01 but RMS still larger

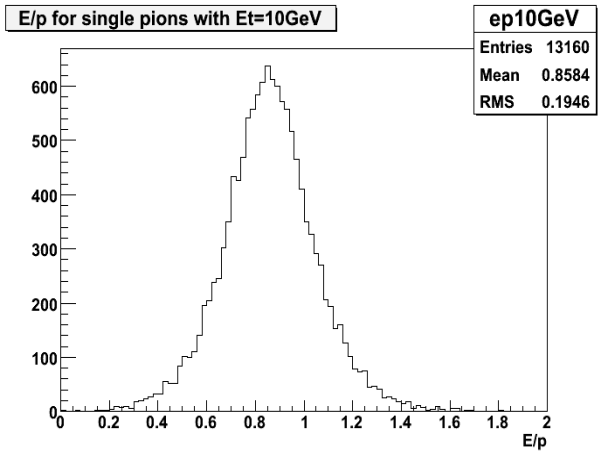
For Cone 0.2:

Sample	E/p mean	RMS
-minimum bias (0.2)	0.647	0.441
-single pion cone 0.4	0.645	0.401
-single pion cone 0.2	0.639	0.401

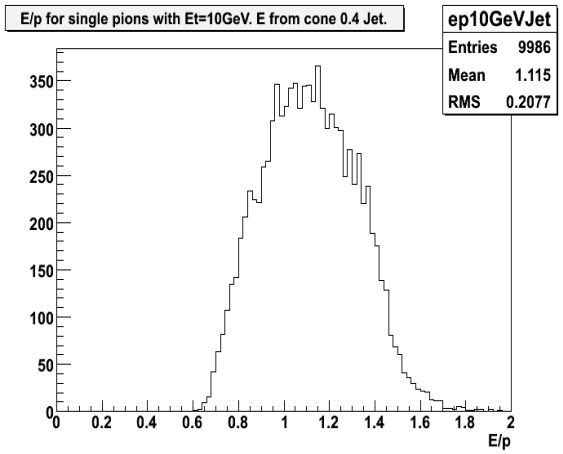
Error: ±0.007

Pions with et=10GeV

Single Pion sample with pt=10GeV



Sum of topoClusters within R<0.4

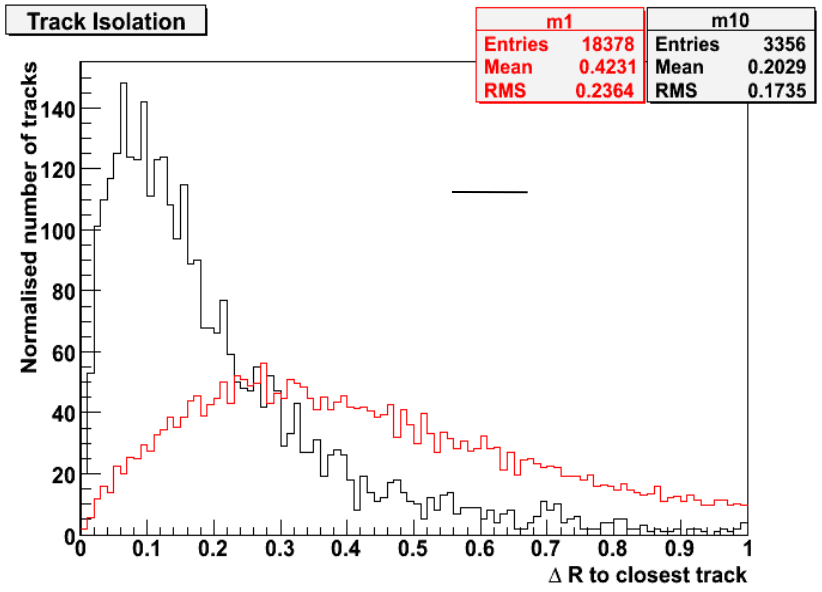


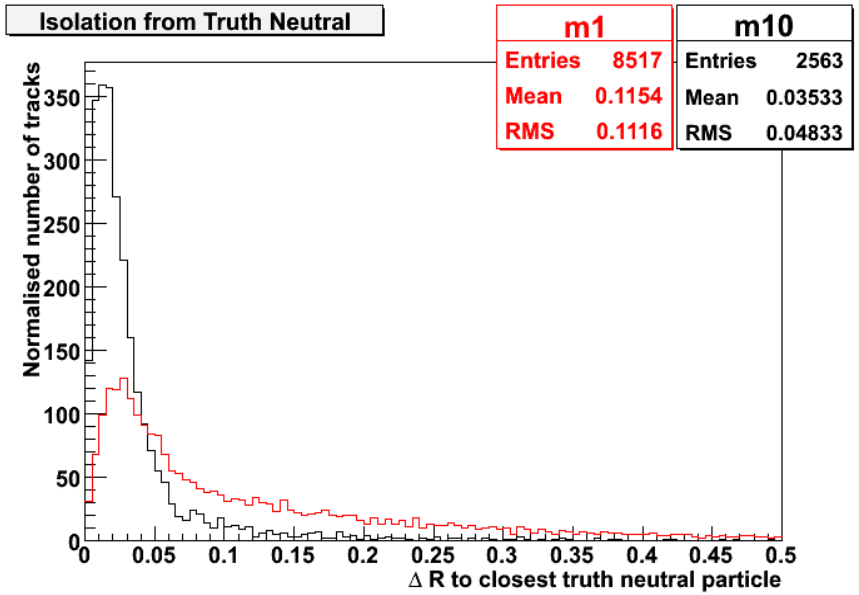
Cone0.4TowerJet

- First look at higher energy tail of minimum bias events.
- Pt=8-12 GeV pions in minimum bias were compared to Pt=10 GeV single pion sample
- For minimum bias approx 1/100 events have a track with 8GeV<pt<12GeV
- ¾ have matching topoCluster within R < 0.05
- ¾ with matching 0.4 Cone Jet within R < 0.2

Pt=10GeV pions in minimum bias

- However higher Pt tracks have large correlated contamination when compared with the 1GeV case:
  - out of 400k events:
    - 450 tracks remain with track isolation > 0.4
    - 50 tracks with no truth neutral or track within 0.4

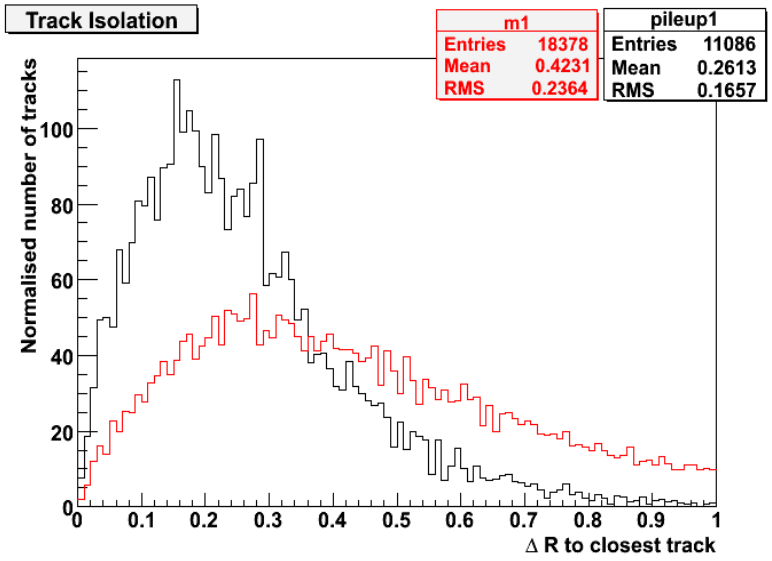


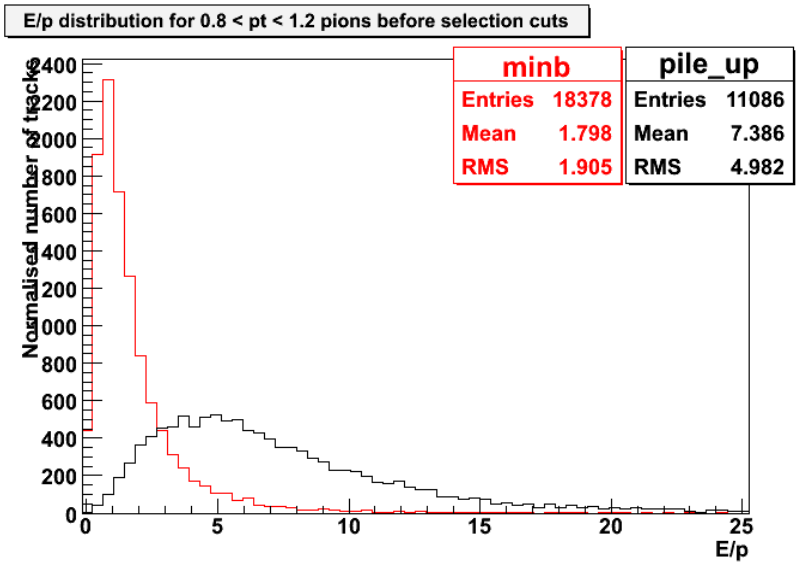


- Conclusion: Not many isolated pions in minimum bias for this energy
  - A method to measure the neutral contamination is required. see later.

Pile-up

- First look at pile-up sample
  - 5.6 minimum bias events piled up.
  - sample of 1000 studied.
  - Contamination much larger – Not suprising.

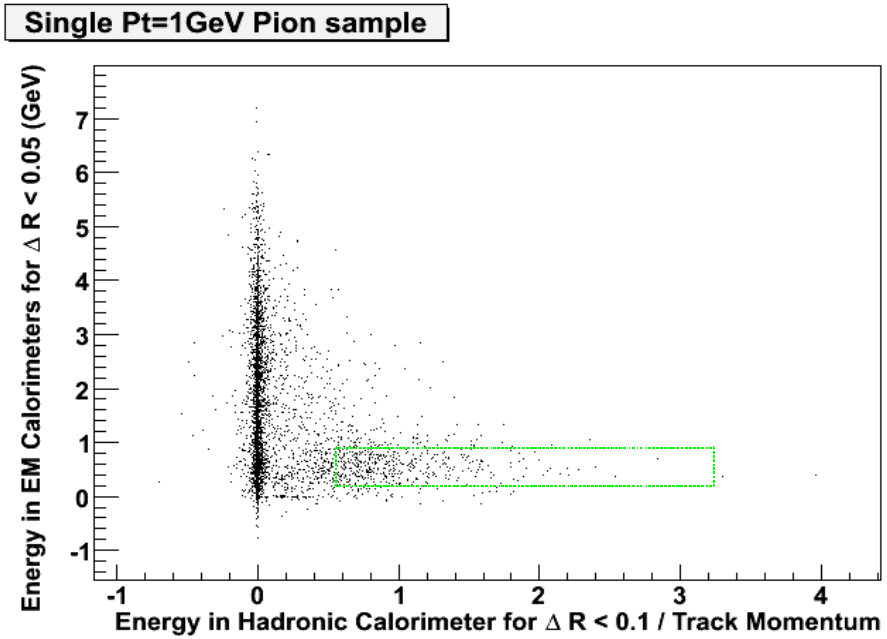


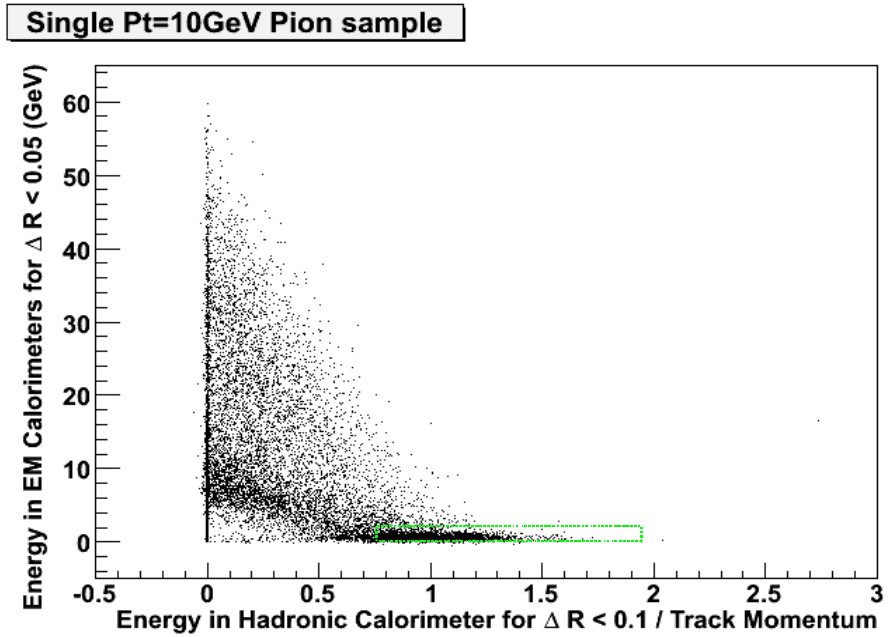


  - No tracks (out of 1000 events) pass cuts defined previously.
    - Method of cuts to find isolated pion probably not possible. Especially for pile-up with 20 events!
  - Will need to use some kind of background subtraction.

First look at contamination subtraction

- Method to estimate background energy in the EM calorimeter:
  - Identify pions which shower late depositing minimal energy in the EM Calorimeter.
    - EM calo energy in R<0.05 around track is between 200-800MeV
    - Energy in cone 0.1 in Hadronic Calorimeter > 0.6 x Track P

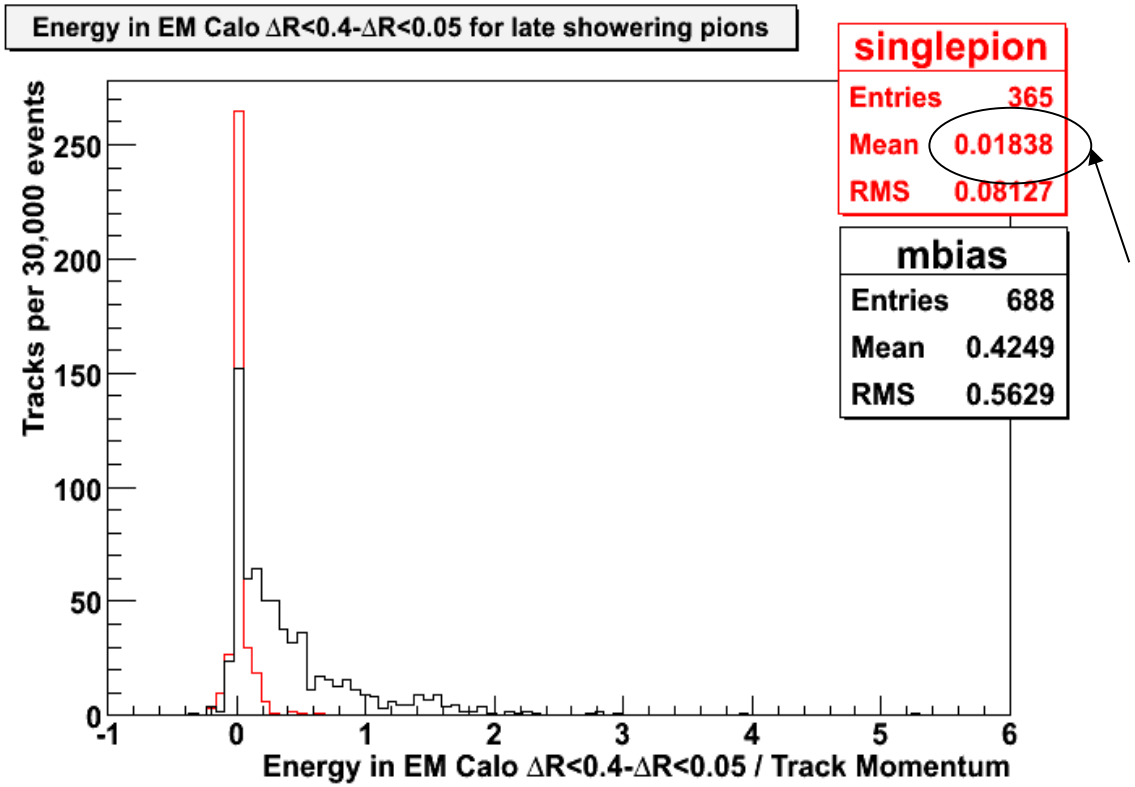




Estimate of contaminating energy

- Take the EM energy contamination as the energy difference between a cone of 0.4 and 0.05.

Plot shows such an estimate for pt=1GeV.
Late showering pions in minimum bias selected as described on the pervious slide. Plus cuts on Track Isolation > 0.4 and at least one hit in the B layer



For 1GeV pions there will be an overestimate of the contam. due to pion EM energy outside R<0.05

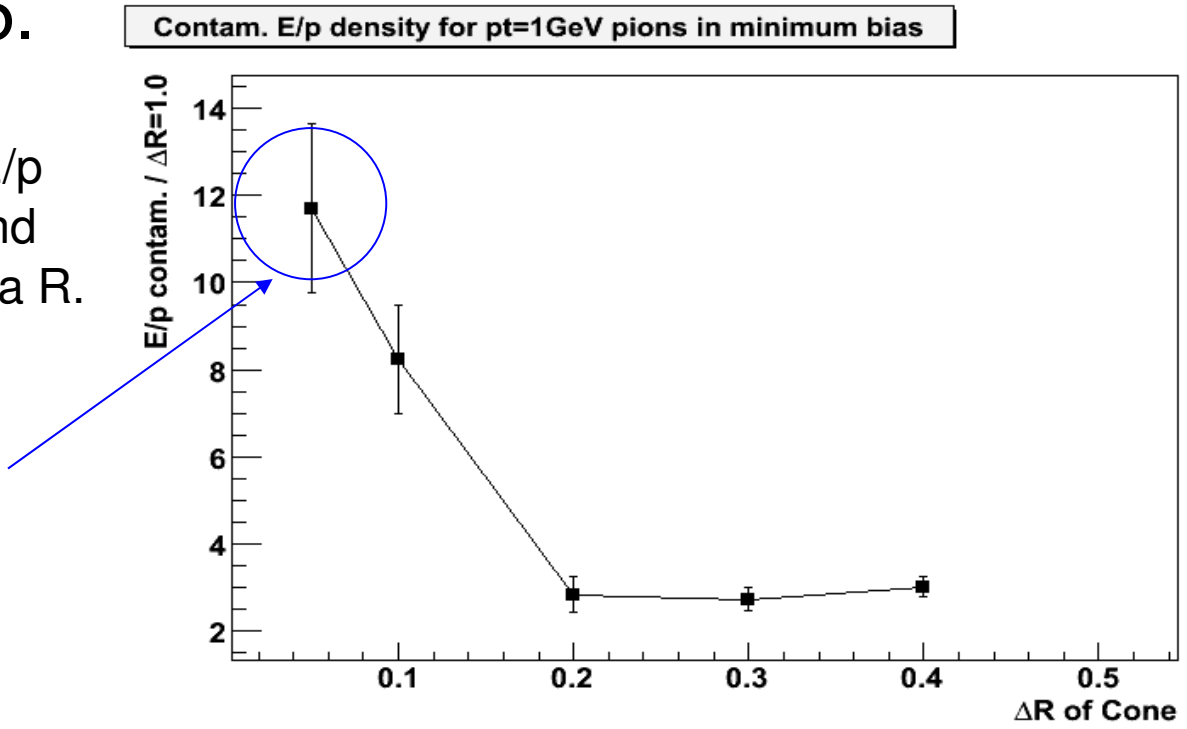
For 10GeV pions this appears to be less than 0.005

Estimate of contaminating energy (cont.)

- Estimate the contaminating energy density in the 0.05 cone as the same density as that is R<0.1 - R<0.05.

plot shows the difference in E/p between the single sample and minimum bias per unit of Delta R.

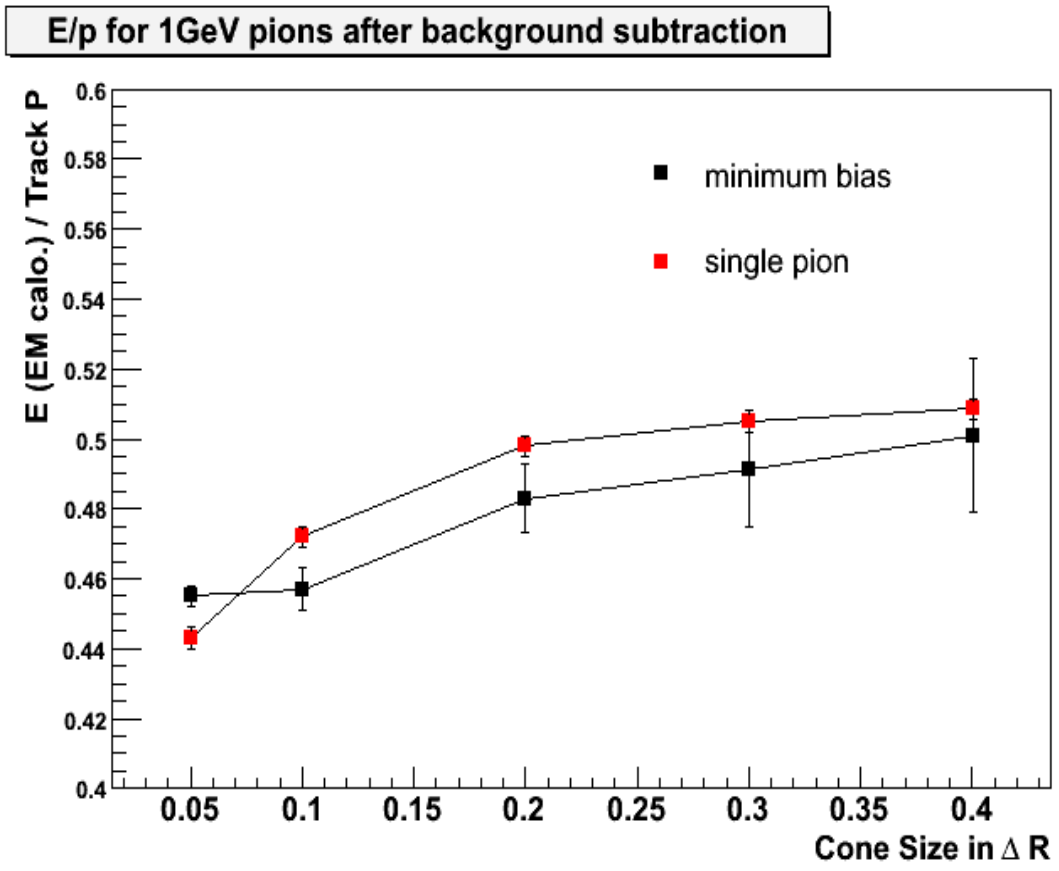
In this example an estimate for the 0.05 cone would be incorrect by approx.
$(12-8)*0.05^2 = 0.01$



- More cuts may be needed to reduce the background until this approximation is valid.

EM Calo. energy subtraction results

- Result of subtracting the measured background energies:



For 30k minimum bias events

Only statistical error shown here.

Differences may be explained by the reasons outlined before:

- Overestimate of contam outside 0.05 cone due to pion energy
- Underestimate of contam inside 0.05

More study required but looks interesting for very peliminary work.

Background in hadronic calorimeter

- Also need to estimate the contamination in the hadronic calorimeter:
  - This can be measured in the area between R<0.4 and R<0.2 from the track as very little of the pions energy is deposited here on average.
  - Below R< 0.2 contam. should be small (approx 0.02, but still needs to be accounted for.
  - More investigation is required into this.
- In general more work will be done to see if this method can be used for pions where the cuts method can not be used.

Conclusions

- We can get a resonable measurement of the E/p for Et=1GeV pions based on cuts to find isolated pions in minimum bias events.
- This method will be difficult to use for pile-up and pions of more than a few GeV where isolated pions can not be found.
- Background estimation and subtraction is being examined to find the E/p in these cases.
- Should be studied in more detail with a range of datasets including pile-up and various jet reconstruction algorithms.
- Plan to also look at dijet samples as these contain a lot of tracks in the low energy range (pt<15GeV).