ATLAS NOTE

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E/p check of the single hadron energy scale using pions from minimum bias

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Abstract

In this note we ...

1 Introduction

Things to cover:

- Motivation
- Description of E/p
- Previous work
- Summary of note contents

This note is based on simulated Monte-Carlo data from the ATLAS CSC production. All datasets were reconstruction with Athena version 12.0.6. The dataset name, number of events and simulated cross-section of are shown in Appendix **??**.

Also need to describe:

- geometry
- no of event, simulated cross-section
- something about the trigger?
- basis for minimum bias prediction

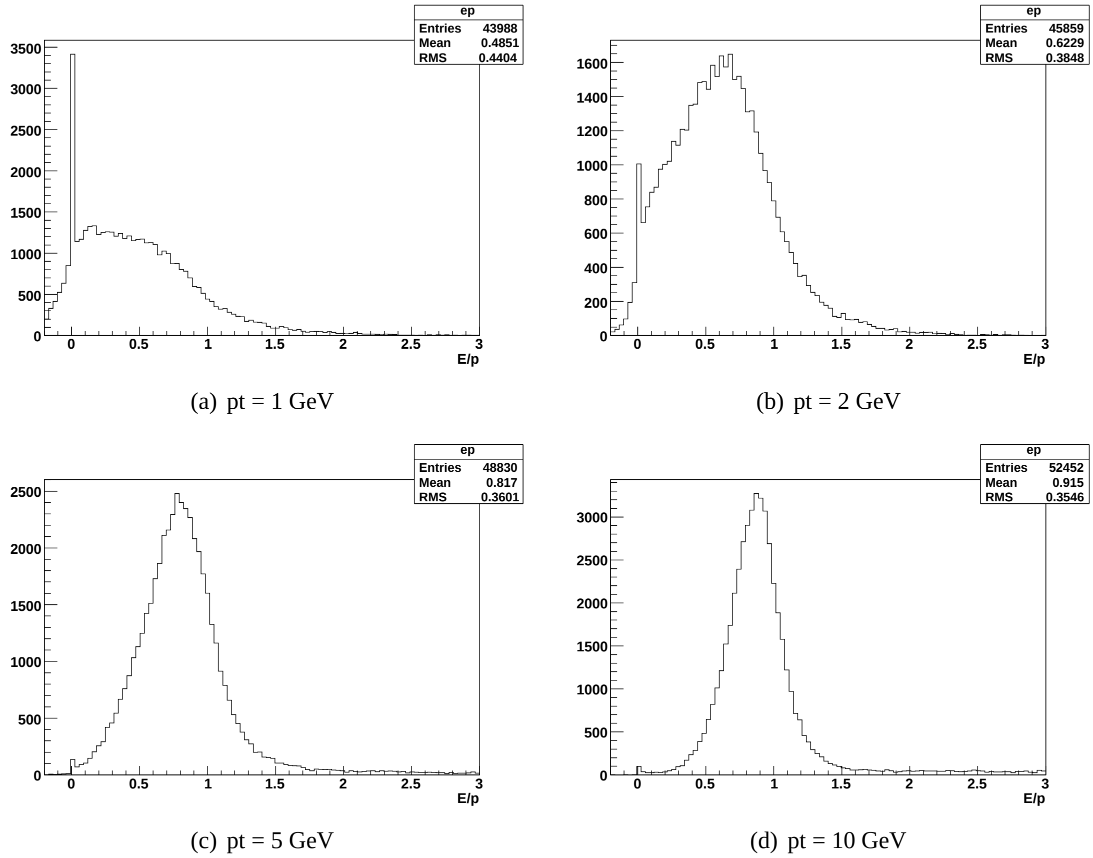
Minimum bias events can provide a source of pions with energies up to and above the lower limit of 15GeV from tau studies. Figure **??** shows the momentum reach of tracks. Trigger efficiency has not been included here, but the very large cross-section of events mean that adequate statistic should be collectable for the tail of the distribution The lower cut-off of 500MeV is due to particles being captured by the magnetic field in the inner detector. The η range is defined by the coverage of the inner detector, $|\eta| < 2.5$. Figure **??** shows the distribution for pions of pt= 1GeV (800MeV-1.2GeV), 2GeV (1.6GeV-2.4GeV), 5GeV (4GeV-6GeV) and 10GeV (8GeV-12GeV). In all cases, the tracking resolution, shown in figure **??** is well within the required value to obtain an E/p known to within 1%.

2 Energy of very low pt pions

Due to the extremely low pion energies in this study, it differs in two respects to the E/p studies for pions from tau decay.

Previously, the energy (E) was based on taus reconstructed from calorimeter towers. For minimum bias events, however, this can not be done and no tower based jets are reconstructed due to the default energy thresholds not being met. Instead, CaloTopoClusters, clusters based on topological clustering were used. The pion energy was calculated as the sum of such clusters around a radius $\Delta R_{cone} = \sqrt{\Delta\phi^2 + \Delta\eta^2}$ from the track when extrapolated to the 2nd layer of the EM calorimeter. The TrackToCalo tool was used for track extrapolation. CaloTopoClusters outside $|\eta| < 2.5$ were not included because in this region the background contribution to energy is too large. This is discussed further in section **??**.

The reconstructed CaloTopoClusters stored in the data samples were calibrated to the local hadronic scale, but did not include corrections for energy losses in dead material or outside the cluster. These losses are significant for very low energy pions and resulted in an E/p well below 1. In previous studies, biases due to backgrounds were determined by the shift of the E/p from 1, where this value was checked against Truth information. As this could not be done here it was necessary to instead assess the background biases by comparing the distribution to that of pions from single particle samples. Hence, single particle events were examined to determine the expected distribution.



(a) pt = 1 GeV

(b) pt = 2 GeV

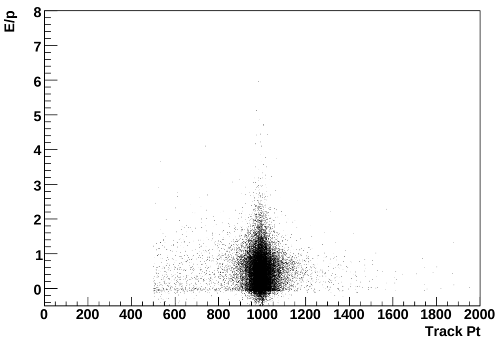
(c) pt = 5 GeV

(d) pt = 10 GeV

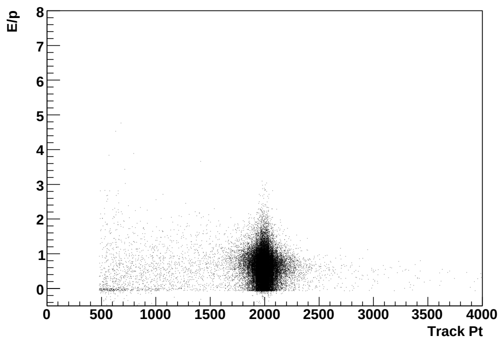
Figure 1: E/p distributions for pions from single particle Monte Carlo

Figure **??** shows the pion E/p distributions for energies of pt=1,2,5 and 10GeV. The entries in the lower end of the distribution including E/p=0 are due to cell thresholds used for noise suppression in the CaloTopoCluster reconstruction as well as energy losses in dead material in front of the calorimeter. For 1GeV and 2GeV pions this accounts for a substantial number of candidate tracks. A study of pions in this case, with no associated clusters, could be useful to optimize the noise suppression for reconstruction of very low energy particles and/or to gain an understanding of the upstream material. However, this study was focused on only those tracks with an associated cluster. Because clusters are present from electronic noise in the calorimeters, some 'fake' matching between track and cluster occurred. This caused the E/p to shift lower. The procedure to correct for this was: Assume all entries with an E/p below 0 are due to noise. The energy distribution of clusters due to noise is centered on zero and symmetric, so there must be an equal number above zero. This was then subtracted from the E/p distribution. A matching criteria was used of $\Delta R_{match} <?$ between the closest cluster and extrapolated track. However, as arbitrary choice of ΔR_{match} can bias the E/p due to higher energy clusters being closer to the track position. Several values of ΔR_{match} were examined and the lowest which biased the E/p by less that 1% was used.

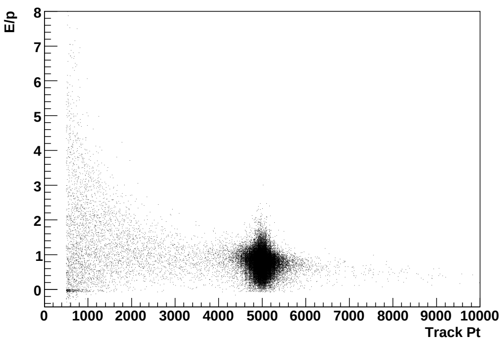
The high E/p tail in Figure **??** is due to early interactions in the inner detector which result in the production of charged particles below the generated energy. The cone that CaloTopoClusters are searched within may contain the energy of all daughter particles and will therefore still have approximately the energy of the original pion. This effect is shown more clearly in Figure **??** where tracks below the generated energy cause an over estimate in the E/p. For this reason, the ideal pion E/p distribution is taken as that for events where only one truth particle is stored in the McEventCollection container. These distributions are shown in Figure 3 and their mean E/p across pseudorapidity in Figure **??**. In minimum bias, backgrounds of this type can be treated like any other background from closely spaces particles. This is described more in section3.



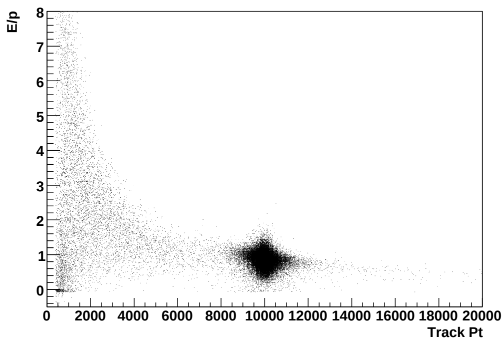
(a) pt=1GeV



(b) pt=2GeV



(c) pt=5GeV



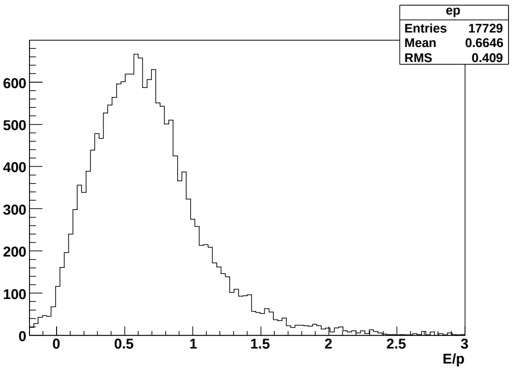
(d) pt=10GeV

Figure 2: Distribution of track momentum in single particle samples showing the effect on the E/p from secondary particles.

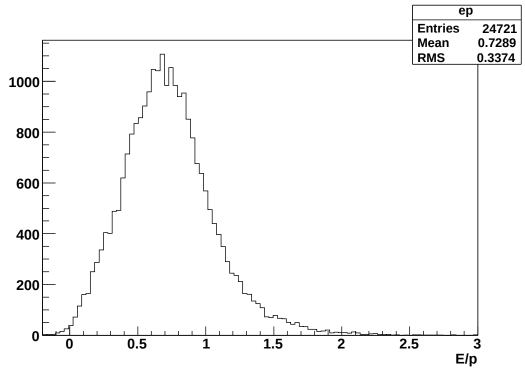
Single pions were also used to determine an appropriate value for ΔR_{cone}, the cone radius. The choice of ΔR_{cone} was based on the amount of energy deposited within various cones as shown in Figure 4. Only events from the ideal case described above were used and the size was chosen to be as small as possible but have an average E/p within 1% of a cone of $\Delta R_{cone} = 1.0$. For pions at pt = 1,2,5 and 10 GeV the optimal sizes were found to be ΔR_{cone} = 0.8, 0.5, 0.5 and 0.4 respectively.

3 Measuring pion E/p with minimum bias events

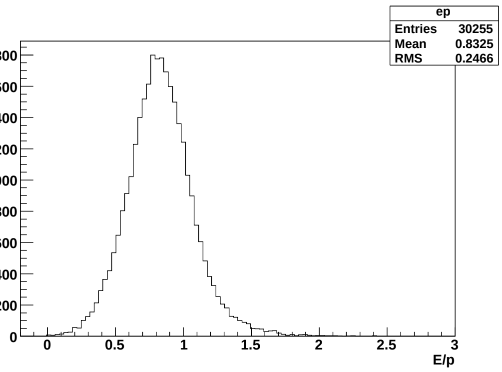
Selection of pions in minimum bias events need to account for two potential biases to the E/p. One is caused by non-isolated pions as additional particles closely spaced in ΔR cause a bias to the measured E. Attempts to identify isolated pions through selection cuts are described in detail in section 3.0.1. For



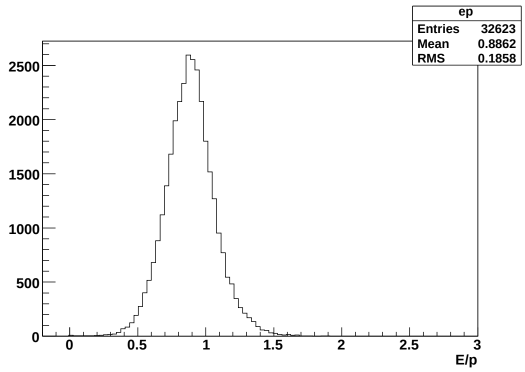
(a) pt = 1 GeV



(b) pt = 2 GeV

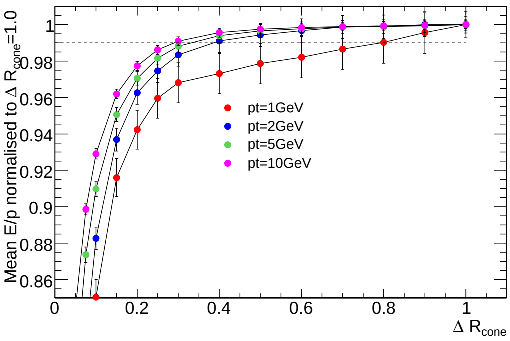


(c) pt = 5 GeV

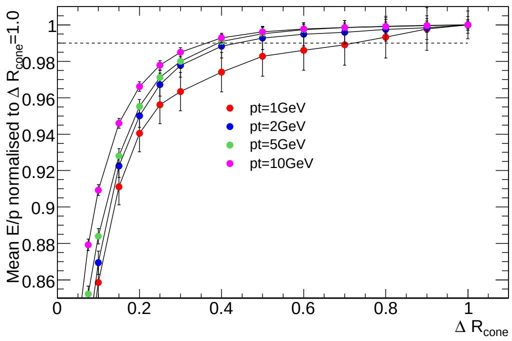


(d) pt = 10 GeV

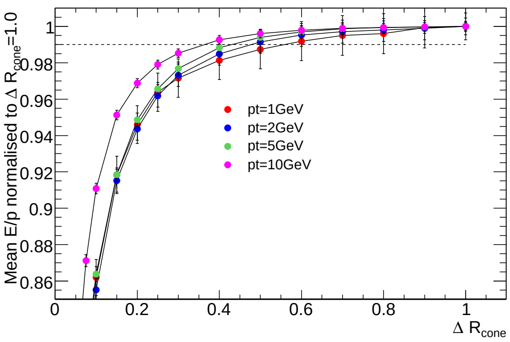
Figure 3: E/p distributions for ideal pions from single particle Monte Carlo



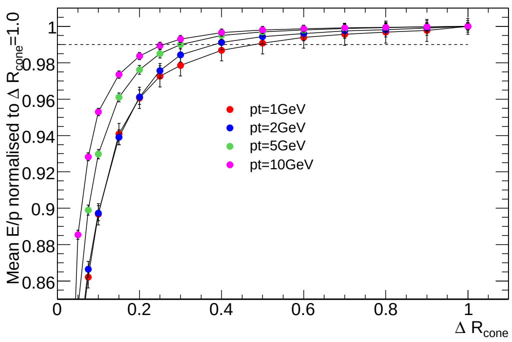
(a) $|\eta| < 0.625$



(b) $0.625 < |\eta| < 1.25$



(c) $1.25 < |\eta| < 1.875$



(d) $1.875 < |\eta| < 2.5$

Figure 4: Proportion of energy in various cone sizes for pions at pt=1,2,5 and 10GeV

tracks in the tail of the minimum bias pt distribution, i.e. above 2GeV, the energy contamination is proportionally larger than for pions around 1 GeV. This, combined with lower statistics, made it difficult to define cuts to select isolated pions. For this reason, a method to subtract the background due to additional particles inside the cone is proposed in section 3.0.2. This was also shown to be (or not be?) useful for pile-up events, where the background is very large, but uncorrelated. The other concern in a measurement of the E/p is the shift caused by tracks which belong to other particles types such as kaons, protons or electron. This is discussed in section.3.0.3

3.0.1 Selection of isolated pions

- Some plots showing the E/p before cuts
- Distance from neutrals
- Distance from other tracks

A number of selection criteria were used to separate isolated pions in minimum bias. Only tracks matched to a pion in the TrackTruthCollection were used.

Tracks were required to be isolated from other tracks. $\Delta R_{trackisolation}$ was calculated using the position of the tracks when extrapolated to the 2nd layer of the EM calorimeter. This criteria eliminated much of the E/p bias caused by extra charged particles, however as track reconstruction is only ??? efficient, some contamination due to charged particles must be removed through the same cuts as for neutral particles. The coverage of the inner detector also limits the usefulness of this requirement. As contributes from charged particles can not be accounted for easily outside $|\eta| > 2.5$, clusters in this range were not included in the cone. This results in an underestimate of the E/p in the region $|\eta| > 2.1$. However, a background subtraction method could potentially resolve this problem.

Describe other cuts with plot and table of efficiencies.

- Hit in B-layer
- track quality,
- number of Holes, used to eliminate decays
- cone isolation
- core fraction
- number of clusters

3.0.2 Subtraction of contaminating energy

stuff from latest talks?

3.0.3 Effect of non-pion tracks

Minimum bias events produce many charged particles with associated tracks. The majority, between 58%-73% are pions followed by kaons, protons and other heavier hadrons. A few percent are due to electrons and muons which are present from conversion of photons in the inner detector and the decay of pions or kaons(??).

Table **??** lists the proportion of each particle type based on information in the TrackTruthCollection after applying the cuts described in **??**. The mean E/p in given for each case and the potential shift in the pion E/p measurement is also shown.

- Some conclusion about this.
- Mention the hit in the B-Layer for removing secondary particles

4 Effect of pile-up on E/p measurement

Still to come.

5 Effect of trigger on E/p distribution

Still to come.

6 Conclusion and prospects

References

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Appendices