

# Response of single isolated hadrons in the first ATLAS data at $\sqrt{s} = 900$ GeV

*Pier-Olivier DeViveiros* for the ATLAS Collaboration

University of Toronto, Department of Physics, 60 Saint George Street, Toronto M5S 1A7, Canada

**DOI:** will be assigned

The response of single isolated hadrons in the ATLAS calorimeters has been studied in 360 thousand collision events at 900 GeV collected during the December 2009 LHC commissioning run. Good agreement is found between the data collected and the Monte Carlo predictions. The results will be used as an input to the estimation of the Jet Energy Scale at ATLAS.

## 1 Introduction

The ATLAS calorimeters span a large coverage in pseudo-rapidity ( $\eta < 4.9$ ) and are built using sampling technology [1]. The calorimeters are made from 2 sections; the electromagnetic calorimeter provides measurement of the energy of electromagnetic particles and most of the energy from hadrons while the hadronic calorimeter completes the measurement of the energy of hadronic particles. Both sections have further longitudinal segmentation to improve the resolution of the energy measurement. The calorimeters are non-compensating; the energy response of hadrons is smaller than that of electromagnetic particles.

The ATLAS tracking system is composed of pixel detectors, silicon microstrip detectors and transition radiation trackers. The system is immersed in a solenoidal magnetic field of 2 Tesla, and offers coverage up to  $\eta < 2.5$ . The measured curvature of the tracks can be used to measure the momentum of charged particles with an excellent resolution. The overall momentum scale of charged particles measured in the tracking system is known to better than 1%.

By combining the precise momentum measurement ( $p$ ) in the tracking with the energy deposited in the calorimeters ( $E$ ), the response of charged hadrons can be measured ( $E/p$ ) [2]. The knowledge of this response is an important component in the estimation of the uncertainty on the Jet Energy Scale.

## 2 Event selection

Collision events were chosen by requiring at least one hit in either of the Minimum Bias Trigger Scintillators (MBTS), and a well-reconstructed vertex with at least 2 associated tracks. This results in a data sample of approximately 360 thousand events.

### 3 The observable

Energy depositions in the calorimeter cells are grouped into 3 dimensional ‘topoclusters’ using a noise suppression scheme [3]. The resulting topoclusters are meant to represent the energy deposits of single particles.

High quality tracks, requiring at least 1 hit in the pixel detectors, 6 hits in the silicon strips and  $p_T > 500$  MeV, are selected. The tracks are further required to be matched to the event vertex, and isolated, such that no nearby track-like objects are found within a cone of  $\Delta R < 0.4$ , defined as:

$$\Delta R = \sqrt{(\eta_1 - \eta_2)^2 + (\phi_1 - \phi_2)^2} \quad (1)$$

The tracks are then associated to energy depositions in the calorimeter. The energy in the topoclusters is split into the different longitudinal layers of the calorimeter. The separate layers are matched with the isolated track using a cone of size  $R_{coll}$ , using the centroid of the energy deposit in each given layer. The value of  $R_{coll}$  is chosen to optimize shower containment while minimizing the contamination from the energy deposits of nearby neutral particles. Figure 1 shows the results of a Monte Carlo study of single particles versus minimum bias events. From this study, a value of 0.2 was chosen for  $R_{coll}$ , which corresponds to a shower containment of 90% and a background contamination in the order of 2%.

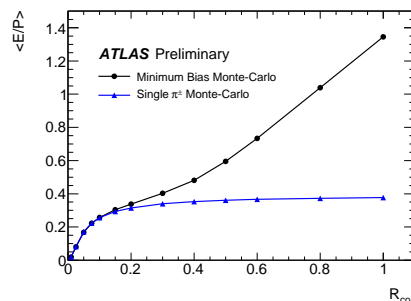


Figure 1: Monte Carlo simulation of the mean  $E/p$  value for single particles and minimum bias events in function of the matching cone size  $R_{coll}$ . The difference between the two lines is attributed to the background contamination from neutral hadrons.

### 4 The measurement

Figure 2 shows the distribution of  $E/p$  for two different fiducial and kinematic regions in data and Monte Carlo. The ATLAS Monte Carlo simulation consists of a combination of the PYTHIA [4] event generator and a GEANT4 [5] full detector simulation. The Monte Carlo simulations are in good agreement with the data.

#### 4.1 Tracks not associated to any energy deposits

One of the features of the distributions is the peak at  $E/p$  values of zero. This peak corresponds to events where tracks are not associated to any energy deposits in the calorimeter. This can be due to two different effects:

1. The algorithm used to create topoclusters requires a seed cell with a ratio of signal over expected noise larger than 4. This requirement is not always fulfilled by showers from hadrons with low momentum.

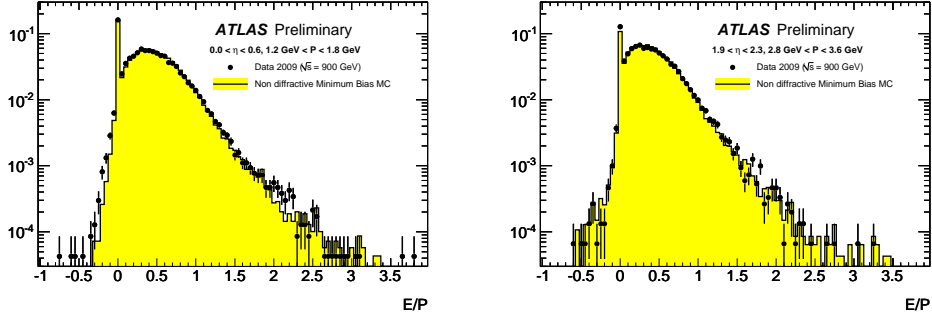


Figure 2: Distribution of  $E/p$  for data and Monte Carlo.

- There is a probability that the particles will undergo hadronic interactions in the material in front of the calorimeter. In this case, the showers may not reach the calorimeter.

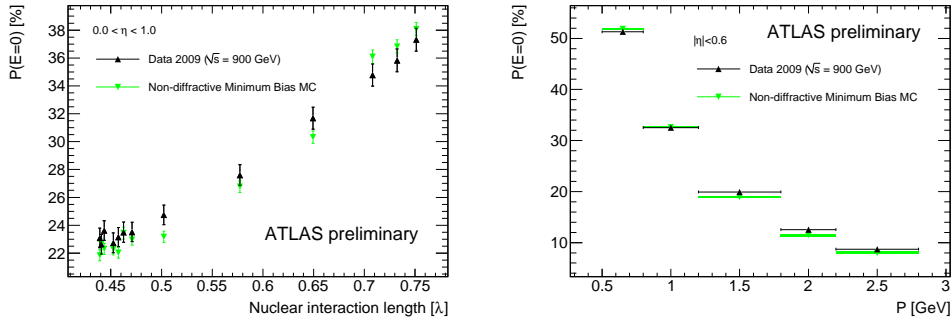


Figure 3: Probability of not having any calorimeter energy deposit associated to a isolated track as a function of the density of the dead material in front of the calorimeter and of the track  $p$ .

To study such effects, the figure of merit  $P(E/p = 0)$  is used.  $P(E/p = 0)$  is an estimator of the probability that a particle deposits no energy in the calorimeter, and is defined as:

$$P(E/p = 0) = \frac{N(E/p < \sigma)}{N_{total}} \quad (2)$$

where  $\sigma$  is the noise width of the  $E/p$  distribution, approximated by taking the width of the negative tail of the distribution in data.

Figure 3 shows the distribution of  $P(E/p = 0)$  for both data and Monte Carlo as a function of both the amount of dead material in front of the calorimeter, and the particle momentum. The Monte Carlo simulations predict the behaviour of the probability well.

## 4.2 $E/p$ as a function of $P$ and $\eta$

Comparisons between the Monte Carlo and the data are shown using different bins of track momentum and track pseudo-rapidity. The results are shown in Figure 4. General agreement is found at the 5% level, with the exception of the region around  $\eta = 1.7$ , where the agreement is at the 10% level.

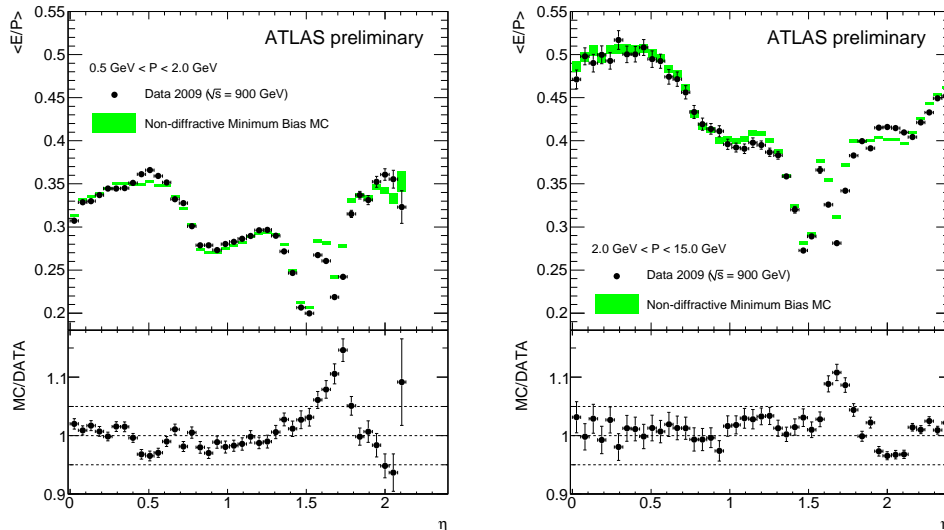


Figure 4: Mean  $E/p$  as a function of track  $\eta$  for two different track momentum ranges.

## 5 Conclusion

The mean response of single isolated hadrons in the ATLAS calorimeters has been measured using data from the December 2009 LHC commissioning run at  $\sqrt{s} = 900$  GeV. General agreement has been found with the Monte Carlo predictions at the 5% level for  $0.5 < p < 10$  GeV and  $|\eta| < 2.3$ .

## References

- [1] ATLAS Collaboration, “*The ATLAS Experiment at the CERN Large Hadron Collider*”, JINST **3** S08003 (2008).
- [2] ATLAS Collaboration, “*Response of the ATLAS calorimeters to single isolated hadrons produced in proton-proton collisions at a center-of-mass energy of  $\sqrt{s} = 900$  GeV*”, ATLAS-CONF-2010-017
- [3] W. Lampl *et al.*, *Calorimeter clustering algorithms: Description and performance*, ATL-LARG-PUB-2008-002.
- [4] T. Sjostrand, S. Mrenna and P. Skands, *PYTHIA 6.4 Physics and Manual*, JHEP **05** (2006) 026.
- [5] S. Agostinelli *et al.*, *GEANT4: A simulation toolkit*, NIM **A 506** (2003) 250.