

Underlying event studies in inelastic pp collision events with the ATLAS detector

Markus Warsinsky for the ATLAS Collaboration

Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

DOI: <http://dx.doi.org/10.3204/DESY-PROC-2010-01/272>

The first measurement of the charged particle flow in inelastic pp collision events with the ATLAS detector is described. The analysis is based on minimum-bias events collected at centre of mass energies of 900 GeV and 7 TeV. The density of charged particles and their transverse momentum sum is measured in different regions of azimuthal angle defined with respect to the leading charged particle in the event. The data show a higher underlying event activity than predicted by different Monte Carlo models and tunes.

1 Introduction

Main goals of the LHC are the search for new physics phenomena and precision measurements. In order to perform these, it is important to not only have a good description of the hard scattering process, but also of soft-QCD effects which influence the accompanying beam-beam remnants, initial and final state QCD radiation and multiple parton interactions. These effects are collectively called the underlying event (UE).

These soft physics processes cannot be derived from first principles, but instead are predicted from different phenomenological models implemented in Monte Carlo (MC) event generators. The free model parameters are adjusted to describe the available data, among these measurements of the UE activity, as well as possible. Previous measurements of the UE by the CDF experiment [1, 2] have been made at a significantly lower centre of mass energy than the LHC. It is thus important to measure the UE at LHC energies, as the extrapolation to higher centre of mass energies results in large uncertainties.

For a measurement of the UE activity, it is necessary to investigate activity in a region of the event that receives only little contribution from the hard scattering process. In the following, this is accomplished by dividing the event into regions of azimuthal angle relative to the charged particle with the highest transverse momentum (called *leading* charged particle in the following), as shown in Figure 1. The transverse region is expected to receive the largest fraction from the UE and only minimal contribution from the hard

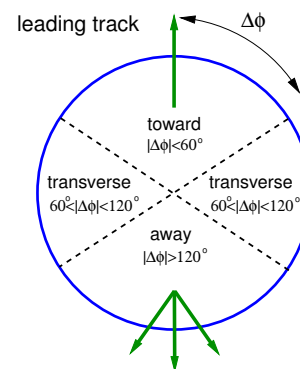


Figure 1: Azimuthal regions with respect to the leading charged particle.

scattering process. The toward and away regions are influenced more by the dijet structure of an assumed $2 \rightarrow 2$ scattering.

2 Analysis Procedure

The ATLAS detector is described in [3]. Of relevance for the presented analysis are the minimum bias trigger scintillators (MBTS) and the inner detector (ID). The MBTS consist of scintillators mounted at $|z| = \pm 3.56$ m and covering a pseudorapidity range of $2.09 < |\eta| < 3.84$. The ID consists of a three-layer pixel detector, a silicon strip detector and a transition radiation tracker. It covers $|\eta| < 2.5$ and is immersed in a 2 T solenoidal magnetic field. Details of the analysis can be found in [4]. The data were collected in the 900 GeV run of the LHC from December 6th to 14th 2009 and in the first run at 7 TeV on March 30th 2010. Events were triggered by requiring a signal on any side of the MBTS. The event selection in addition requires at least one reconstructed track with a transverse momentum p_T of at least 1 GeV within $|\eta| < 2.5$ and requiring transverse and longitudinal impact parameters of less than 1.5 mm. In addition a reconstructed primary vertex [5] with at least two tracks ($p_T > 100$ MeV) was required. Tracks used for the analysis were required to have $p_T > 0.5$ GeV and the same cuts as used for the tracks to select the event. The number of events, the number of tracks and the integrated luminosity of the datasets are shown in Table 1. Beam- and cosmic-muon induced background were estimated to be negligible after this event selection.

\sqrt{s} [GeV]	selected		
	events	tracks	$L_{\text{int}}[\mu\text{b}^{-1}]$
900	202285	1540373	9
7000	265622	3474551	6.8

Table 1: Selected events, tracks and integrated luminosity.

The data were corrected to the level of primary¹ charged particles satisfying the event-level requirement of at least one primary charged particle with $p_T > 1$ GeV and $|\eta| < 2.5$ and the selection of primary charged particles with $p_T > 500$ MeV and $|\eta| < 2.5$. The correction procedure is described in more detail in [4, 6, 7]. To account for events lost due to the event selection, the trigger efficiency was estimated from an orthogonal trigger setup from data, the vertexing efficiency is measured in data, and lastly a correction factor to account for not reconstructing all charged primary particles with $p_T > 1$ GeV was applied [4]. Tracks lost due to tracking inefficiency were corrected for by the track-reconstruction efficiency as estimated from the detector simulation. In addition remaining secondary particles and the fraction of primary particles corresponding to reconstructed tracks being outside the specified kinematic range were subtracted. As a final step, a bin-by-bin unfolding method is applied to account for bin-to-bin migrations and effects not covered by the other corrections. The ATLAS MC09 tune [8] of the PYTHIA6 [9] MC generator was used for this unfolding. The systematic uncertainty was estimated by using the PHOJET [10] generator as an alternative model and was found to be at most 2%, which is small compared to the systematic uncertainty of the tracking efficiency of about 5%. More detail on the systematic uncertainties can be found in [4].

¹Primary particles are defined as having a mean lifetime $\tau > 3 \cdot 10^{-11}$ s.

3 Results

The charged particle density and the scalar p_T sum density of charged particles are shown in Figure 2 for the transverse region. The data are compared to the PYTHIA6 [9] generator using the ATLAS MC09 [8], DW [11] and the Perugia0 [12] tunes, and to the PHOJET [10] generator. While the MC models describe the basic behaviour, all predictions are lower than the data, especially at $\sqrt{s} = 7$ TeV. The DW tune is closest to the data, while the PHOJET description is furthest off. The recently derived ATLAS AMBT1 tune [13] of the PYTHIA6 event generator, which improves the description of charged particle multiplicities in a diffraction-limited phase space gives a comparable description of the data as the ATLAS MC09 tune [13].

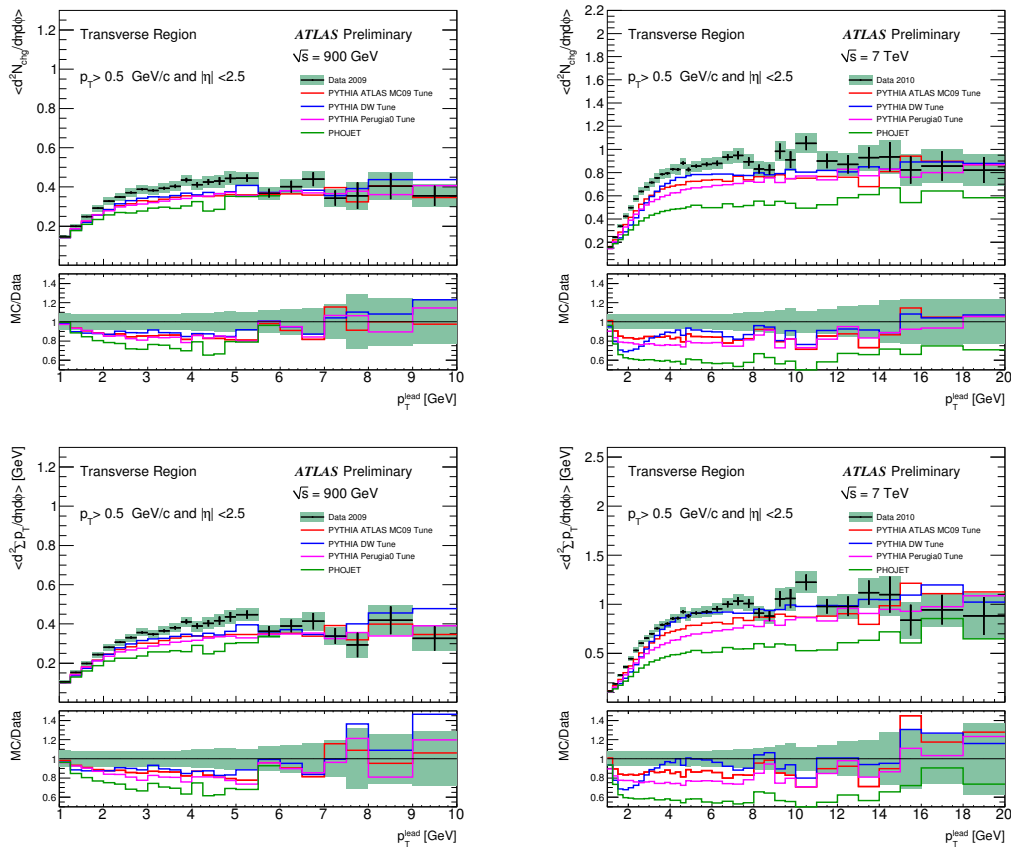


Figure 2: Observables in the transverse region. Charged particle (top row) and scalar p_T sum density (bottom row) vs. the p_T of the leading charged particle. Left column: $\sqrt{s} = 900$ GeV, right column: $\sqrt{s} = 7$ TeV. Black data-points: ATLAS data (shaded area total, error-bars only statistical uncertainty). Solid lines: predictions of the PYTHIA6 [9] and the PHOJET [10] MC generators.

Figure 3 shows the difference in azimuthal angle between charged particles and the leading charged particle for different cuts on the p_T of the leading charged particle. Clearly a larger

density towards and away from the leading charged particle as predicted by the MC generators is observed. This becomes more visible for higher cuts on the p_T of the leading charged particle, pointing to the emergence of a jet-like structure. The prediction of the ATLAS MC09 tune differs both in shape and normalization from the data.

Further measurements can be found in [4].

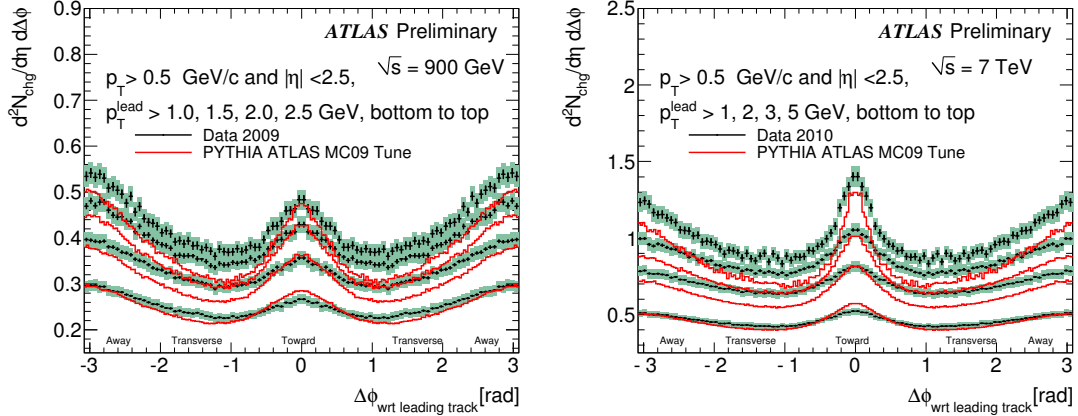


Figure 3: Azimuthal angle difference to the leading charged particle at $\sqrt{s} = 900$ GeV (left) and 7 TeV (right) for different transverse momentum requirements for the leading charged particle. Black data-points: ATLAS data (shaded area total, error-bars only statistical uncertainty), solid line: prediction of the PYTHIA6 MC generator with the ATLAS MC09 tune.

4 Conclusions

A first measurement of the underlying event activity at LHC energies has been presented [4]. Despite the large step in centre-of-mass, the Monte Carlo models describe the basic features of the underlying event activity, but predict slightly less activity than observed. These data will be important for constraining these models and will be used for tuning of MC event generators in the near future.

5 Acknowledgments

M. Warsinsky acknowledges the support of the Initiative and Networking Fund of the Helmholtz Association, contract HA-101 (“Physics at the Terascale”).

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