Charged particle multiplicities in inelastic pp interactions with ATLAS and the ATLAS Minimum Bias Tune 1

Gerhard Brandt for the ATLAS Collaboration

DESY, Notkestraße 85, 22607 Hamburg, Germany

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Measurements of the charged particle multiplicity produced in proton-proton collisions at the LHC at centre-of-mass energies $\sqrt{s} = 0.9$ TeV and 7 TeV recorded with the ATLAS detector are presented. Distributions are presented for events with at least one charged particle $n_{ch} \geq 1$ in the kinematic range $|\eta| < 2.5$ and $p_T > 500$ MeV. Measurements have also been made in a diffraction-limited region of phase-space $n_{\rm ch} \geq 6$ and used for the production of the first PYTHIA6 tune to LHC data, the ATLAS Minimum Bias Tune 1 (AMBT1).

We present the first measurement of the properties of charged particle production in pp collisions produced at the LHC at centre-of-mass energies of $\sqrt{s} = 0.9$ TeV (corresponding to about $12\mu\text{b}^{-1}$ of integrated luminosity) [1] and $\sqrt{s} = 7$ TeV ($6.8\mu\text{b}^{-1}$) [2]. Such measurements can be used to constrain phenomenological models of soft-hadronic interactions and for predictions at higher centre-of-mass energies. Events with at least one primary charged particle with transverse momentum $p_{\rm T} > 500$ MeV and in the pseudo-rapidity[1] range $|\eta| < 2.5$ are studied. Primary charged particles are defined as charged particles with a mean lifetime $\tau > 0.3 \times 10^{-10}$ s, directly produced in pp interactions or from subsequent decays of particles with a shorter lifetime. The distributions of tracks reconstructed in the ATLAS inner detector were corrected to obtain the particle-level distributions:

$$\frac{1}{N_{\rm ev}} \cdot \frac{{\rm d}N_{\rm ch}}{{\rm d}\eta}, \quad \frac{1}{N_{\rm ev}} \cdot \frac{1}{2\pi p_{\rm T}} \cdot \frac{{\rm d}^2 N_{\rm ch}}{{\rm d}\eta {\rm d}p_{\rm T}}, \quad \frac{1}{N_{\rm ev}} \cdot \frac{{\rm d}N_{\rm ev}}{{\rm d}n_{\rm ch}} \quad \text{and} \quad \langle p_{\rm T} \rangle \text{ vs. } n_{\rm ch},$$

where $N_{\rm ev}$ is the number of events with at least one charged particle inside the selected kinematic range, $N_{\rm ch}$ is the total number of charged particles, $n_{\rm ch}$ is the number of charged particles in an event and $\langle p_{\rm T} \rangle$ is the average $p_{\rm T}$ for a given number of charged particles.

The two most important components of the ATLAS detector [4] for this analysis are the Inner Detector (ID) to reconstruct tracks and the Minimum Bias Trigger Scintillators (MBTS) to trigger events. The 32 MBTS counters are mounted on the inner face of the endcap calorimeter cryostats, covering $2.09 < |\eta| < 3.84$. A hit in at least one of the MBTS is required to trigger an event. Coincidence in both MBTS is not required to avoid having to derive the trigger efficiency using Monte Carlo and therefore introducing a dependence on the modeling of diffraction.The

[1] The ATLAS reference system is a Cartesian right-handed co-ordinate system, with the nominal collision point at the origin. The anti-clockwise beam direction defines the positive z-axis. The polar angle θ is measured with respect to the z-axis. The pseudo-rapidity is defined as $\eta = -\ln\tan(\theta/2)$.

ID consists of a silicon pixel detector, a silicon microstrip detector (SCT) and a transition radiation tracker (TRT). Its coverage corresponds to the pseudo-rapidity range $|\eta| < 2.5$ used in this analysis. Tracks were reconstructed beginning with track seeds in the silicon detectors. Events were required to contain a primary vertex with at least two tracks having $p_T > 150$ MeV. Where available the beam-spot position was used as a constraint in the vertex reconstruction. Tracks used to measure the charged particle multiplity were selected requiring at least one pixel and at least six SCT hits as well as longitudinal and transverse impact parameters with respect to the primary vertex of $\sin\theta \cdot |z_0| < 1.5$ mm and $|d_0| < 1.5$ mm, respectively. Only events with at least one selected track were considered to avoid uncertainties stemming from the Monte Carlo description of events with no charged particles inside the kinematic region.

The track distributions were corrected back to the particle-level by using the inverse of the trigger-, vertex- and track-efficiencies as weights, where the first two were determined in data and the latter from a GEANT4-based full simulation of the ATLAS detector. The charged particle multiplicity was corrected event-by-event using iterative Bayesian unfolding and an additional analytic correction applied to correct for events lost due to trackfinding inefficiency.

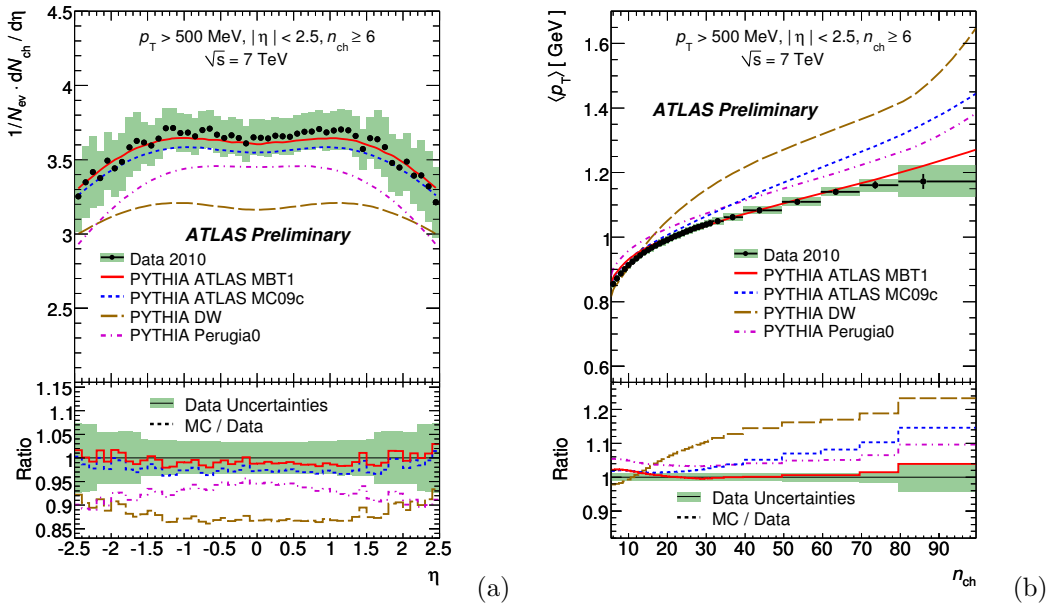

Figure 1: Charged-particle multiplicities for events with $n_{\rm ch} \geq 6$ within the kinematic range $p_T \geq 500$ MeV and $|\eta| < 2.5$. Shown is the charged-particle multiplicity as a function of pseudo-rapidity (a) and the average transverse momentum as a function of the number of charged particles in the event (b). The dots represent the data. The vertical bars represent the statistical uncertainties, while the shaded areas show statistical and systematic uncertainties added in quadrature.

In order to reduce uncertainties stemming from diffractive components in the selected sample, the measurement is further restricted to $n_{ch} \geq 6$. The charged particle multiplicity as function of pseudo-rapidity measured at $\sqrt{s} = 7$ TeV is shown in figure 1 (a) and the average transverse momentum $\langle p_T \rangle$ as function of multiplicity n_{ch} is shown in figure 1 (b). The data are

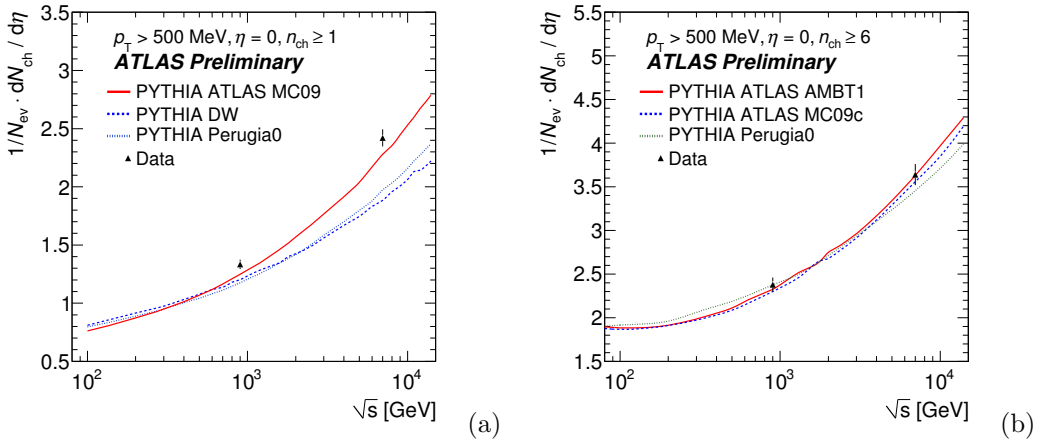

Figure 2: The average charged particle multiplicity per unit of rapidity for $\eta = 0$ for events with $n_{\rm ch} \geq 1$ (a) [2] and in a diffraction-limited phase-space $n_{\rm ch} \geq 6$ (b) [3] within the kinematic range $p_T \geq 500$ MeV and $|\eta| < 2.5$ as a function of the centre of mass energy. In (b) the new ATLAS Minimum Bias Tune 1 is already shown.

compared to predictions from Monte Carlo models, in particular the new AMBT1. This new PYTHIA6 [5] tune is based on the MC09c [6] tune. The data presented here and a measurement of the charged particle flow in different event regions relative to the leading particle [7] are used as input and the PROFESSOR [8] tool is used for the tuning. The tuned parameters are connected to multi-parton interactions and color reconnection of the hadronic final state. The dependence of the average multiplicity at central rapidity on the centre-of-mass energy is shown in figure 2 (a) for $n_{ch} \geq 1$. The measured values are observed to be higher than the predictions from Monte Carlo models. Figure 2 (b) shows the dependence in the diffraction-limited phase-space $n_{ch} \geq 6$. The agreement of data and all Monte Carlo predictions, in particular the AMBT1 tune, is much better here.

References

[1] G. Aad *et al.* [ATLAS Collaboration], "Charged-particle multiplicities in pp interactions at $\sqrt{s} = 900$ GeV measured with the ATLAS detector at the LHC," Phys. Lett. B **688**, 21 (2010) [arXiv:1003.3124 [hep-ex]].

[2] ATLAS Collaboration, "Charged-particle multiplicities in pp interactions at $\sqrt{s} = 7$ TeV measured with the ATLAS detector at the LHC", ATLAS-CONF-2010-024.

[3] ATLAS Collaboration, "Charged particle multiplicities in *pp* interactions at $\sqrt{s} = 0.9$ and 7 TeV in a diffractive limited phase space measured with the ATLAS detector at the LHC and a new PYTHIA6 tune", ATLAS-CONF-2010-031.

[4] G. Aad *et al.* [ATLAS Collaboration], "The ATLAS Experiment at the CERN Large Hadron Collider", JINST 3 (2008) S08003.

[5] T. Sjostrand, S. Mrenna and P. Z. Skands, JHEP **0605**, 026 (2006) [arXiv:hep-ph/0603175].

[6] ATLAS Collaboration, "ATLAS Monte Carlo Tunes for MC09", ATL-PHYS-PUB-2010-002.

[7] [ATLAS Collaboration], "Track-based underlying event measurements in pp collisions at $\sqrt{s} = 900$ GeV and 7 TeV with the ATLAS Detector at the LHC", ATLAS-CONF-2010-029.

[8] A. Buckley, H. Hoeth, H. Lacker, H. Schulz and J. E. von Seggern, Eur. Phys. J. C **65**, 331 (2010) [arXiv:0907.2973 [hep-ph]].