## ATLAS first results
## Charged-particle multiplicities in $pp$ interactions at $\sqrt{s} = 900$ GeV

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The first physics results from $pp$ collisions measured with the ATLAS detector [1] at the Large Hadron Collider (LHC) [2] are presented. The analysis within the kinematic range $p_T > 500$ MeV, $|\eta| < 2.5$, and at least one charged-particle in this range, is summarised. The charged-particle multiplicity per event and unit of pseudorapidity at $\eta = 0$ is measured to be 1.333±0.003(stat.)±0.040(syst.), which is 5–15% higher than the Monte Carlo model predictions.

# 1 Introduction

The charged-particle spectra produced in inelastic $pp$ and $p\bar{p}$ collisions have previously been studied over a wide range of centre-of-mass energies [3–10]. These experimental results have been used to tune phenomenological models of soft QCD interactions. Measurements of charged-particle multiplicities have been presented as inelastic, non-diffractive and non-single-diffractive results, with and without trigger and primary vertex reconstruction corrections. Results are most commonly presented as non-single-diffractive measurements. The selection of these events typically involves a double-arm coincidence trigger, where the remaining single-diffractive events are removed either with measurements from a single-arm trigger or by using a Monte Carlo model. In the cases where the trigger or vertex-reconstruction efficiencies have not been corrected for, it is difficult to determine the effects of these requirements at the particle-level. In general, previous measurements have included events with no charged particles within the acceptance of the tracking volume. These events may be accepted due to beam-induced-background, electronic noise, or inelastic interactions with no reconstructed tracks. Therefore, a Monte Carlo is used to determine the trigger efficiency, which introduces model dependence into these measurements.

These proceedings discuss the first ATLAS measurements of charged-particle multiplicities at 900 GeV [3], within the kinematic range $p_T > 500$ MeV and $|\eta| < 2.5$ and the requirement of at least one charged-particle within this range. Primary charged particles were 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:

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

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

## 2 Event Selection

A total of 455,593 events were selected with a single-arm scintillator trigger covering the region of $(2.09 < |\eta| < 3.84)$ at $z = \pm 3.56$ m from the centre of the detector. Tracks were reconstructed within the inner detector volume $|\eta| < 2.5$ from measurements within the silicon pixel detector (Pixel), silicon microstrip detector (SCT) and transition radiation tracker. Events were required to contain a reconstructed primary vertex fit from three or more $p_{\mathrm{T}} > 150$ MeV tracks with transverse impact parameter with respect to the beam-spot position $d_0^{\mathrm{BS}} < 4$ mm. Tracks were selected for the multiplicity measurements by requiring $p_{\mathrm{T}} > 500$ MeV, a minimum of one Pixel and six SCT hits, and transverse and longitudinal impact parameters calculated with respect to the primary vertex $d_0 < 1.5$ mm and $z_0 \cdot \sin\theta < 1.5$ mm respectively. The multiplicity of these selected tracks is denoted by $n_{\mathrm{Sel}}$. Events were required to have one or more selected tracks.

## 3 Analysis and Results

The selected-track distributions were corrected back to the particle-level. The vertex-reconstruction efficiency was parameterized in terms of selected tracks with a requirement of $d_0^{\mathrm{BS}} < 4$ mm, matching the primary vertex fit preselection, and without requirements on the impact parameters with respect to the primary vertex. The multiplicity of these tracks within an event is denoted as $n_{\mathrm{Sel}}^{\mathrm{BS}}$. The trigger efficiency was defined in a similar manner, but from a sample selected with a control trigger. The trigger and vertex efficiency were derived from data and are illustrated in Fig. 1(a) and 1(b). The $n_{\mathrm{Sel}}^{\mathrm{BS}}$ value for a given event was used to select the trigger and vertex-reconstruction efficiency values. The selected tracks in the given event were then weighted by the reciprocal of the product of these two values. The trigger requirement was found to introduce no dependency on $p_{\mathrm{T}}$ or $\eta$. The small dependency introduced through the primary vertex requirement on the selected-track $\eta$ for events with one selected-track was also corrected for.

The track-reconstruction efficiency was determined from a Geant4 simulation as a function of $p_{\mathrm{T}}$ and $\eta$ and is illustrated in profile form in Fig. 1(c) and 1(d). The effects of this efficiency on the $p_{\mathrm{T}}$ and $\eta$ distributions were corrected for on a track-wise basis by weighting each track with the reciprocal of the binned efficiency function. The track-weight also included a term for the fraction of secondary tracks as a function of $p_{\mathrm{T}}$ and tracks migrating into the selected kinematic range due to reconstruction resolution.

The charged-particle multiplicity ($n_{\mathrm{ch}}$) was determined from the track multiplicity ($n_{\mathrm{Sel}}$) on an event-by-event basis via Bayesian unfolding [11]. The $n_{\mathrm{ch}}$ spectrum was also corrected for the migration of events with $n_{\mathrm{ch}} \geq 1$ to $n_{\mathrm{Sel}} = 0$ by using a correction factor of the form $1/(1-(1-\epsilon(n_{\mathrm{ch}}))^{n_{\mathrm{ch}}})$, where $\epsilon(n_{\mathrm{ch}})$ is the mean track-reconstruction efficiency. Final results and the comparison with different Monte Carlo models and tunes are shown in Fig. 2.

## 4 Conclusions

The first ATLAS charged-particle multiplicity measurements from $pp$ collisions at $\sqrt{s} = 900$ GeV have been discussed. Particle-level inclusive-inelastic distributions are presented within the kinematic range $p_{\mathrm{T}} > 500$ MeV and $|\eta| < 2.5$ and the requirement of at least one charged-particle within this range. The charged-particle multiplicity per event and unit of pseudorapidity at $\eta = 0$ is measured to be 1.333±0.003(stat.)±0.040(syst.), which is 5–15% higher than the Monte Carlo model predictions. The selected kinematic range, precision of this analysis, and the absence of additional model dependent corrections, highlights clear differences between Monte Carlo models and the measured distributions.

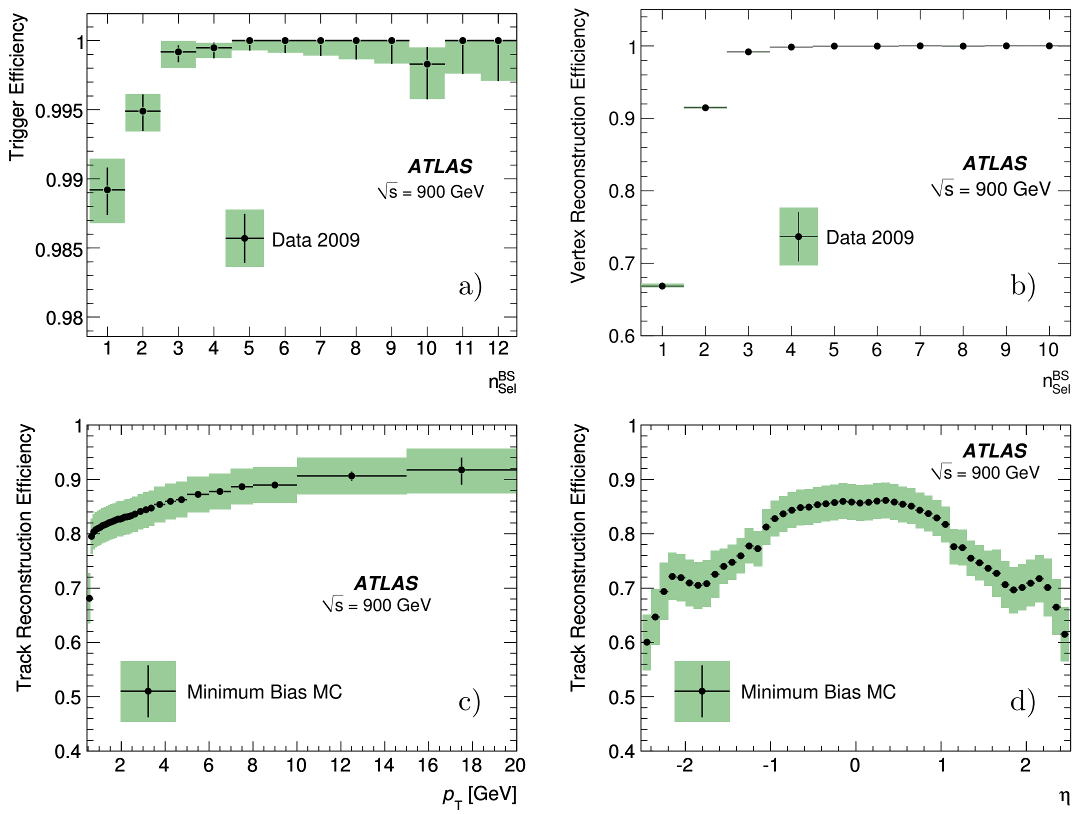


Figure 1: Trigger (a) and vertex-reconstruction (b) efficiencies as a function of $n_{\mathrm{Sel}}^{\mathrm{BS}}$ reconstructed tracks; track-reconstruction efficiency as a function of $p_{\mathrm{T}}$ (c) and of $\eta$ (d). The vertical bars represent the statistical uncertainty, while the shaded areas represent the statistical and systematic uncertainties added in quadrature. The two bottom panels were derived from the PYTHIA ATLAS MC09 sample.

## Acknowledgments

The work was undertaken within the framework of the ATLAS Collaboration. This paper presents results that were obtained from LHC *pp* collisions, using the ATLAS collaboration reconstruction and Geant4 simulation software. The author therefore thanks all of those involved in these areas of research, together with colleagues who contributed directly to the analysis presented.

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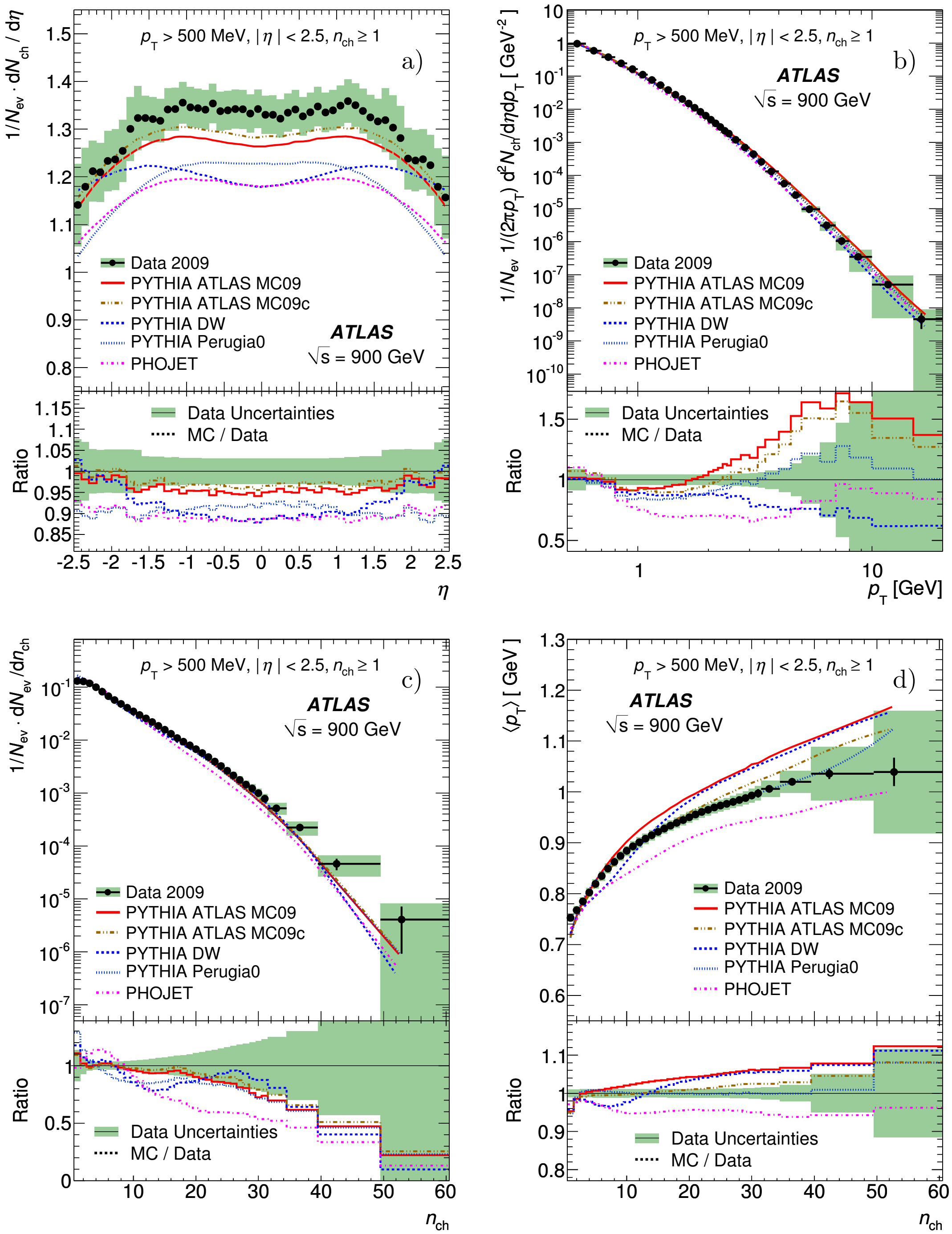


Figure 2: Charged-particle multiplicities for events with $n_{ch} \geq 1$ within the kinematic range $p_T > 500$ MeV and $|\eta| < 2.5$. The panels show the charged-particle multiplicity as a function of pseudorapidity (a) and of the transverse momentum (b), the charged-particle multiplicity (c), and the average transverse momentum as a function of the number of charged particles in the event (d). The dots represent the data and the curves the predictions from different MC models. The vertical bars represent the statistical uncertainties, while the shaded areas show statistical and systematic uncertainties added in quadrature. The values of the ratio histograms refer to the bin centroids.

# 2.
# Heavy Flavours