PROCEEDINGS OF SCIENCE

ATLAS Studies of Soft QCD Processes at 7 TeV

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Using Minimum Bias data recorded in 2010, ATLAS has carried out several studies of the global properties of pp collisions at 7 TeV. A precise measurement of the total inelastic cross-section is presented in a well-defined fiducial volume, taking advantage of the precise knowledge of the luminosity available from van der Meer scans. First detailed studies of diffraction cross-sections are also reported, based on pseudo-rapidity gap distributions. The fraction of the inelastic cross-section arising from diffractive processes is studied, and the differential cross-section is measured as a function of gap size.

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1. Introduction: Soft QCD

The processes of interest at hadron colliders are mostly the hard scattering events. However, soft [1] QCD processes are an unavoidable background to all the collider observables and they are generally not well understood since non-perturbative physics is involved. Soft QCD distributions are used to test the predictions from the phenomenological models implemented in various Monte-Carlo (MC) generators. Exploring the different aspects of QCD in a new high energy and high multiplicity regime is interesting in itself, since high Q^2 and low x phenomena, such as the effect of high parton densities and the interplay between perturbative and non perturbative regimes are also not well understood. Several soft QCD measurements made using ATLAS proton-proton collision data at center of mass energy of $\sqrt{s} = 7$ TeV are discussed here.

2. Minimum Bias and Underlying Event

Minimum bias (MB) is dominated by purely soft QCD scattering with minimal event selection criteria, whereas underlying event (UE) is the soft QCD component which forms an irreducible background in events with an identified hard scattering. ATLAS performed minimum bias [1] and underlying event [2] measurements with 2010 low pileup data. For the MB distributions, pre-LHC models show significant disagreement, especially in the low p_{T} and low multiplicity region where one expects to have the largest contribution from diffractive events, as shown in Fig. 1 (a). All the pre-LHC MC tunes considered show lower activity than the data in the transverse region UE distributions, as shown in Fig. 1 (b). The cluster p_{T} sum from UE, sensitive to both charged and neutral components was also measured for the first time [3], shown in Fig. 1 (c). The new ATLAS tunes [4] of shower MC, obtained by using these data, resulted in a significant improvement in describing the soft QCD distributions.

3. Two Particle Correlation

Correlations in the pattern of radiation emitted in proton-proton collisions can give an insight into the underlying particle production mechanism. The correlation is defined as:

$$R(\Delta\eta, \Delta\phi) = \frac{\langle (N_{ch} - 1) F(N_{ch}, \Delta\eta, \Delta\phi) \rangle_{ch}}{B(\Delta\eta, \Delta\phi)} - \langle N_{ch} - 1 \rangle_{ch} \tag{3.1}$$

where $<>_{ch}$ indicates an average over contributions from all particle multiplicities.

The two-particle correlation function shows the probability that given a single particle emission in (η, ϕ), there will be a second particle emitted at a distance $(\Delta\eta, \Delta\phi)$. The strength of the correlation seen in data is not reproduced by available MC tunes, as seen in Fig. 2.

4. Diffractive Measurements

Diffractive events are characterized by the fact that the one or both of the incoming protons emerge from the interaction intact, or are excited into a low mass state with only a small energy loss.

[1] By soft we mean low transverse momenta transfer from initial to final state and very few or no particles produced with significant p_T.

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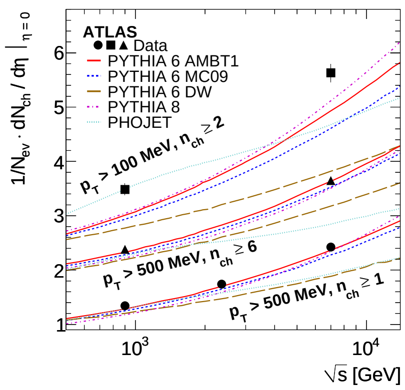

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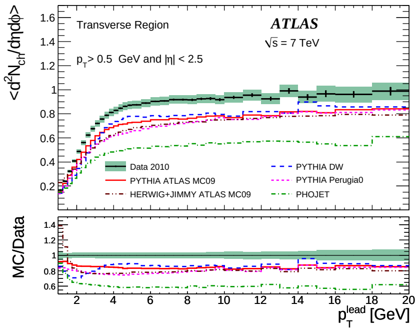

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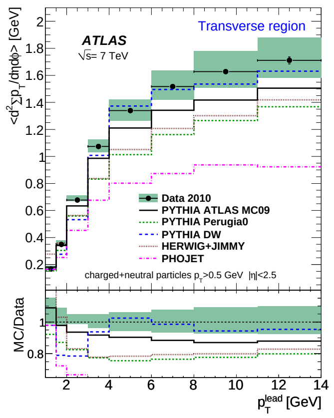

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Figure 1: In (a) the average charged particle multiplicity per unit of rapidity for $\eta = 0$ is plotted as a function of the center of mass energy and compared to various particle level MC predictions [1]. In (b) and (c), the density of the charged particles and average scalar p_{T} sum for stable particles per unit area in $\eta - \phi$ in the transverse region as a function of p_{T} of the leading track [2] or cluster [3] is shown.

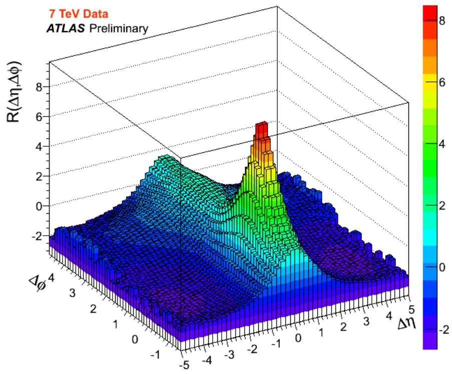
The topology of diffractive events is characterized by an empty region in the rapidity distribution of final-state hadrons, known as a rapidity gap.

4.1 Full Inelastic Cross-section

Events are selected by requiring hits on scintillation counters mounted in the forward region of the detector. We define $\xi = M_X^2/s$, calculated from the invariant mass, M_X, of hadrons selected using the largest rapidity gap in the event. Experimentally the cross-section is calculated using:

$$\sigma_{inel}(\xi > 5\times 10^{-6}) = \frac{(N - N_{BG})}{\varepsilon_{trig} \times Ldt} \times \frac{1 - f_{\xi < 5\times 10^{-6}}}{\varepsilon_{sel}} \tag{4.1}$$

where N is the number of selected events, N_{BG} is the number of background events, $f_{\xi<10^{-6}}$ is the fraction of events with $\xi < 10^{-6}$ that pass the selection, $\int Ldt$ is the integrated luminosity, and ε_{trig} and ε_{sel} are the trigger and offline event selection efficiencies in the selected ξ range. Data values



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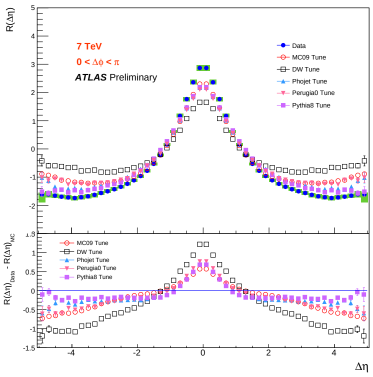

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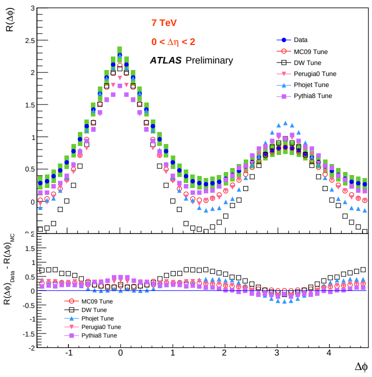

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Figure 2: (a) Two-particle correlation distribution in $\Delta\eta$ and $\Delta\phi$. To explore the structure of the correlation in more detail, the (b) pseudorapidity and (c) azimuthal two-particle correlation distributions are compared with different MC predictions [5].

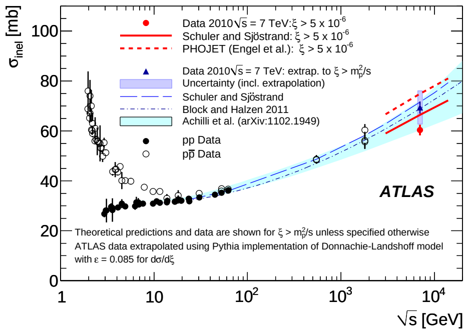
are found to be lower than MC predictions, but the extrapolated value agrees with most analytic models, as shown in Fig. 3 (a).

4.2 Rapidity Gap

Inelastic cross section is also measured as a function of forward rapidity gap size $\Delta\eta^F$, defined as the the largest empty eta region extending to the edge of the calorimeter acceptance, as shown in Fig. 3 (b). The size of the rapidity gap is related to the invariant mass of the dissociated diffractive system(s). The non-diffractive contribution dominates for $|\Delta\eta| < 3$, as seen in in Fig. 3 (c).

5. Summary

In the first year of LHC running, ATLAS successfully performed a number of different soft QCD measurements, with the aim of 'rediscovering' the Standard Model. Finding New Physics at the LHC requires an excellent understanding of Standard Model and QCD, to which all of these studies are essential ingredients.



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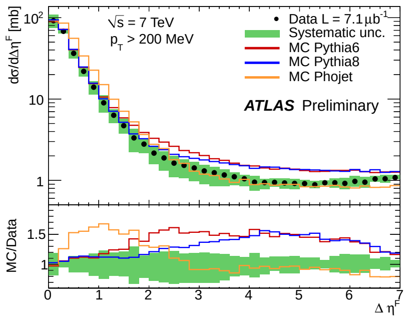

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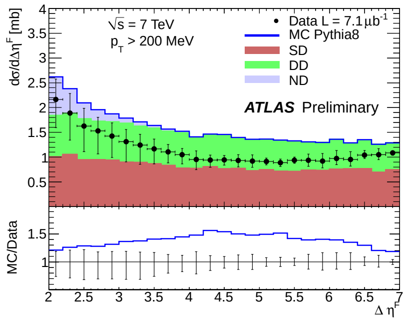

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Figure 3: In (a), the measured inelastic cross section is compared with various theoretical predictions [6]. In (b), the inelastic cross section as a function of gap size is compared between data and different MC predictions, while in (c) the contributions of the PYTHIA 8 single-, double- and non-diffractive components are shown separately for $\Delta\eta > 2$ [7].

References

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[2] The ATLAS Collaboration, *Measurement of underlying event characteristics using charged particles in pp collisions at $\sqrt{s} = 900$ GeV and 7 TeV with the ATLAS detector*, Phys. Rev. D **83** (2011) 112001, `arXiv:1012.0791 [hep-ex]`.

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