Particle Production and Diffraction in ATLAS

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1 Introduction

The study of soft QCD provides insight into the physics of hadronic cross-sections and hadron formation, while also enabling the validation and tuning of models of particle production and helping to describe and correct for pile-up or soft backgrounds to other processes. Soft QCD measurements in ATLAS [1] at the LHC mainly use the inner tracking detectors, sensitive to charged particles with $p_{\mathrm{T}} > 100$ MeV and $|\eta| < 2.5$, and the electromagnetic and hadronic calorimeters, sensitive to electrons, photons and hadrons that have E_{T} greater than a few hundred MeV and $|\eta| < 4.9$. Most such measurements utilise Minimum Bias events: inclusive collisions which have been triggered by scintillators located in the region $2.1 < |\eta| < 3.8$.

2 Inclusive Two Particle Angular Correlations

Correlations in $\Delta\eta$ and $\Delta\phi$ were examined through a variable which takes into account both inter-event and intra-event correlations. Results, corrected using the HBOM unfolding technique [2] (repeatedly applying detector folding n times and extrapolating to the hypothetical $n = -1$ case), were compared to several Pythia 6 tunes [3], Pythia 8 and Herwig++ [4], with the data not satisfactorily described by any of these. A large difference between Pythia and Herwig++ is visible, reflecting the string/cluster hadronisation modelling difference [5].

3 Forward-backward Correlations

Correlations between the forward and backward regions were measured as a function of the multiplicity and $\sum p_{\mathrm{T}}$ of charged particles in bins of $|\eta|$. The data were corrected for detector effects using multiple regression. This was the first measurement of $\sum p_{\mathrm{T}}$ correlations, with the latest Monte Carlo tunes accurately reproducing the data [6].

4 Azimuthal ordering of charged hadrons

A spectral analysis of correlations between angular, energy and p_{T} orderings was performed. After correcting for detector effects, the comparison with Monte Carlo simulation showed too much correlation for high-p_{T} charged particles, but too little correlation at low-p_{T} (see Figure 1).

Increasing the level of underlying event in the Monte Carlo could improve the agreement at high p_{T}, while increasing the levels of initial state radiation could improve the agreement at low p_{T}. The net result is a problem for Monte Carlo tuning - simply changing the typical settings will not find a tune that can fit all of the data.

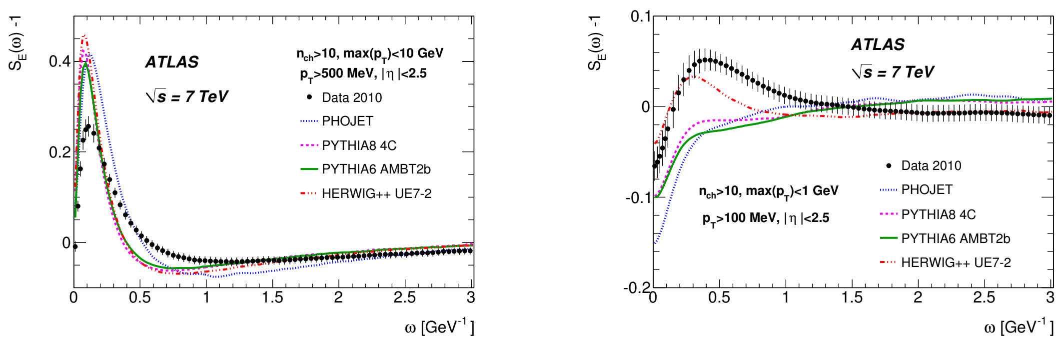

Figure 1: Angular/energy correlations at high p_{T} (left) and low p_{T} (right) [7].

The measured spectra show features consistent with helix-ordered gluon chain models [8], which impose correlations between angular and p_{T} orderings; including such effects could improve soft particle production and hadronisation models [7].

5 Inelastic cross-section as a function of forward rapidity gap size

Cross-sections, corrected to the hadron-level, were measured as a function of $\Delta\eta_F$, the largest η-region containing no particles with p_{T} above p_{T}^{cut}, counting inwards from the edge of the detector acceptance, at $|\eta| = 4.9$.

At low values of $\Delta\eta_F$, this measurement tests the reliability of hadronisation models in describing rapidity fluctuations in final-state particle production; at higher values it probes the diffractive cross-section. Figure 2 shows that the rise of the cross-section at the largest $\Delta\eta_F$ values is not reproduced in Monte Carlo (left) and also indicates that the data contain a higher proportion of low mass single-diffractive events than any of the theoretical models (right): this is shown by the steepness of the transition between ATLAS and TOTEM data [9].

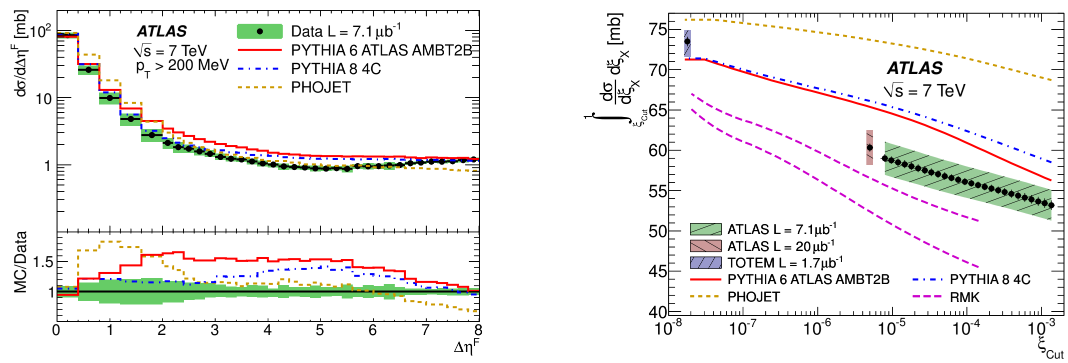

Figure 2: Rapidity gap cross sections in Pythia 6, Pythia 8, Phojet and data, with $p_{\mathrm{T}}^{cut} = 200$ MeV (left). The total cross-section as a function of $\xi_X = M_X^2/s$, where ξ_{cut} is a minimum (right), comparing data against various theoretical predictions [9].

6 K_S^0 and Λ production

K_S^0 and Λ candidates were identified by fitting pairs of opposite-sign tracks to a common vertex and cutting on the transverse flight distance between primary and secondary vertices and on the angle between this vector and the particle momentum.

The observed distributions of p_{T}, y and multiplicity for K_S^0 and Λ hadrons were corrected to the hadron level and compared to Monte Carlo simulations. While the K_S^0 distributions agreed to within 15%, the Λ p_{T} distribution showed substantial discrepancies visible in both the Herwig and Pythia predictions and across multiple generator tunes [10].

7 Underlying event in charged-particle jet events

Underlying event (UE) is used to describe any hadronic activity not associated with the hard scattering process. In typical measurements, the highest p_{T} jet in the event used to define a "transverse region", the area satisfying $\pi/3 < |\phi^{particle} - \phi^{jet}| \leq 2\pi/3$, where ϕ is the azimuthal angle. The multiplicity and $\sum p_{\mathrm{T}}$ of charged particles are used to characterise the UE.

Several Monte Carlo simulations are compared to the unfolded data, with Pythia 6 (AUET2B tune) showing the best agreement. The analysis is performed using a range of different anti-k_t R-parameters to identify the jets [11]. Figure 3 shows the ratio at different R-parameters of number of charged tracks identified in the transverse region as a function of the p_{T} of the jet. The number of tracks identified has a strong dependence on the R-parameter, both in data and Monte Carlo, indicating that the choice of hard scatter has a crucial effect on UE distributions [12].

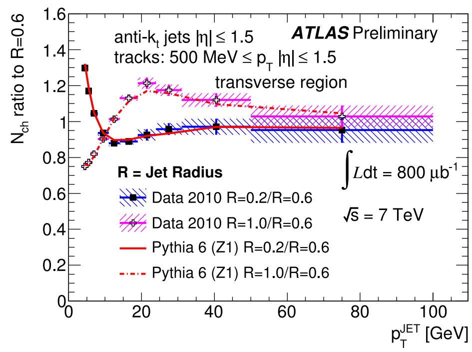

Figure 3: Ratio of number of charged tracks for different anti-k_t R-parameters [12].

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