Forward Physics Results from ATLAS

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The measurements of rapidity gap cross sections and dijet production with a veto on additional central jet activity, performed at the ATLAS experiment at the LHC, are discussed. The rapidity gap cross section analysis measures the differential cross section as a function of the forward rapidity gap size. The data are compared to PYTHIA 8, PYTHIA 6 and PHOJET. The measured cross section is approximately 1mb per forward rapidity gap size for a gap size greater than 3. The measurement of dijet production with a veto on additional central jet activity studies the fraction of dijet events that remain after the application of a jet veto of 20 GeV in the rapidity interval bounded by the dijet system. This fraction is presented against the rapidity separation of the boundary dijets (in the range $0 < \Delta y < 6$) and the average transverse momentum of the boundary jets (in the range $50 < p_T < 500$ GeV). The data are compared to a next-to-leading order plus parton shower prediction from the POWHEG-BOX and an all-order resummation using the HEJ calculation.

§1. Introduction

Two measurements from the ATLAS experiment at the LHC will be reported in these proceedings. The first study is the first ATLAS measurement of the inelastic cross-section as a function of the forward pseudorapidity gap size. The pseudorapidity gaps are destroyed by pile-up so data from low luminosity runs were used (giving an integrated luminosity of 7.1 μ b⁻¹). The second study is a measurement of the jet activity in the rapidity interval between the jets in a dijet system.

§2. Rapidity gap cross sections in pp interactions at $\sqrt{s} = 7$ TeV

This section is based on the ATLAS conference note "Rapidity Gap Cross Section in pp Interactions at $\sqrt{s} = 7$ TeV".¹⁾ In this analysis the differential cross section is measured as a function of the forward pseudorapidity gap size, which extends to the forward acceptance of the detector. A comparison of the data to different Monte Carlo (MC) generators' single diffractive dissociation (SD), double diffractive dissociation (DD) and non-diffractive (ND) contributions is shown.

The data used in this analysis were from the first LHC run in 2010. Only events for which the calorimeters and inner detectors were fully functional were considered. The MBTS trigger was used to collect events, and the integrated luminosity of the data used was 7.1 μ b⁻¹. The run had a very low probability of pile-up (which could destroy the pseudorapidity gap) and suspected pile-up events were removed.

Both the ATLAS²⁾ calorimeter and inner detector were used in this analysis. The ATLAS inner detector reconstructs charged particles with pseudorapidity, $|\eta| < 2.5$. In this analysis only tracks with a transverse momentum, p_T , above 200 MeV



Fig. 1. (color online) Pseudorapidity gap distribution is shown as a function of $\Delta \eta$ and η_{start} for both data (left) and PYTHIA 8 with the nominal mix of SD, DD and ND events (right).¹⁾

are considered. The ATLAS calorimeter measures both electromagnetic (EM) and hadronic energy deposits out to $|\eta| < 4.9$. Calorimeter cell energy is determined to be significant by comparing the energy to the root-mean-squared electronic noise.

To help define the gap, the detector is split into 49 rings across the range $-4.9 < \eta < 4.9$. If there is neither a track with $p_T > 200$ MeV nor a significant cell energy, then the ring is classed as empty. A pseudorapidity gap is formed by consecutive empty pseudorapidity rings. A forward pseudorapidity gap is the largest rapidity gap which extends to the forward acceptance of the detector. The MC generators, have the same pseudorapidity rings, but they are defined as empty if there is no stable particle with $p_T > 200$ MeV in the ring. An additional floating gap (no requirement to be on edge of detector acceptance) is defined to optimise the ND, SD, and DD contributions of the MC generators. The floating gap has both a gap size, $\Delta \eta$, and a gap starting position, η_{start} . Figure 1 shows the fraction of events in $\Delta \eta$ and η_{start} for both the data and one of the MC generators (PYTHIA 8³). The PYTHIA 8 (using tune 2C) distribution has the nominal mix of SD, DD and ND events, this is then optimised using a template to get better agreement to the data. Similarly, a template is created for the other MCs used for comparison, PYTHIA 6 (using tune ATLAS MC09)⁴) and PHOJET.⁵</sup>

Figure 2 shows the differential cross section as a function of the forward pseudorapidity gap size, $\Delta \eta^F$ comparing the data to both PYTHIA 8 and PHOJET. In these plots, only $\Delta \eta^F > 2$ is shown, this cuts out the low $\Delta \eta^F$ which is dominated by the ND component. After $\Delta \eta^F = 3$ there is a plateau in the data. On the plateau, the diffractive cross section is ~ 1mb ± 0.2mb per pseudorapidity gap size. At the plateau, the PHOJET curve agrees better with the data, while PYTHIA 8 has too high a differential cross section. While both PYTHIA 8 and PHOJET agree on the SD contribution, PYTHIA 8 has a significantly larger DD contribution.



Fig. 2. (color online) Inelastic cross section as a function of the forward gap size for particles with $p_T > 200$ MeV and $\Delta \eta > 2$. The black points are the data with error bars which include both the systematic and statistical uncertainty. (Left) shows the data compared to PYTHIA 8 and (right) shows the data compared to PHOJET. Both show the breakdown of the different contributions to the differential cross section from SD, DD, and ND components from both generators.¹⁾

$\S3.$ Dijet production with a jet veto

This section is based on the ATLAS paper "Measurement of dijet production with a veto on additional central jet activity in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector".⁶⁾ A veto on additional central jet activity was used to measure the fraction of dijet events without an additional jet with transverse momentum, p_T , greater than the jet veto scale, Q_0 (default value 20 GeV) in the rapidity interval bounded by the dijet system. This fraction is referred to as the "gap fraction". Two boundary jets were defined as the two highest p_T jets in the event. They have average transverse momentum, $\bar{p_T}$, and rapidity separation, Δy . The boundary jets were required to have a $\bar{p_T} > 50$ GeV to be on the trigger plateau. The gap fraction is measured as a function of either Δy , or $\bar{p_T}$.

The jet algorithm used was the anti- k_t algorithm⁷⁾ with a distance parameter R = 0.6 and with an input of calorimeter clusters. Only jets with $p_T > 20$ GeV and |y| < 4.4 were considered.

Only events where the detector was fully functioning and where there were stable beam conditions were used, and events were rejected if there were either badly measured jets, or jets arising from detector noise.

At large values of Δy or $\frac{p_T}{Q_0}$, fixed-order calculations are expected to fail and an all-order resummation will be necessary. The data is compared to HEJ⁸) and the POWHEG-BOX.⁹) HEJ is a parton level event generator, which is a BFKLlike resummation in Δy and therefore supplies an all-order description of hard wide angle emissions. POWHEG-BOX supplies a NLO dijet calculation interfaced to the parton showering, hadronisation and underlying event in PYTHIA⁴) or HER-WIG.¹⁰) The parton shower approach provides an all-order resummation of soft and collinear emissions, to leading logarithmic accuracy, and is therefore important as



Fig. 3. (color online) Gap fraction as a function of the Δy for different \bar{p}_T slices. (Left) Comparison of the data to both the HEJ and POWHEG predictions. (Right) The ratio of the HEJ and POWHEG predictions to the data.⁶)

 $\frac{p_T}{Q_0}$ increases.

The main systematic uncertainties come from the jet energy scale $(JES)^{11}$ and the unfolding of the data. Both are weakly dependent on p_T , but they both rise at large Δy . The JES increases with Δy as the jets occur in regions that have different JES uncertainties. The unfolding uncertainty rises as there are lower statistics in the large Δy region.

Figure 3 (left) shows the gap fraction as a function of Δy for various $\bar{p_T}$ ranges. Fig. 3 (right) shows the ratio of the theory predictions to the data. HEJ agrees well with the data as a function of Δy for the low $\bar{p_T}$ slices, but gives too high a gap fraction at large $\bar{p_T}$. It is expected that HEJ would do well as a function of Δy , because the event generator's resumation is in Δy . POWHEG (with PYTHIA parton showering) agrees well at low Δy for all $\bar{p_T}$ ranges, but gives too low a gap fraction for large Δy .

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