Jet Production Measurements with the ATLAS Experiment

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Introduction In 2010, the LHC delivered an integrated luminosity of $46.4\,\mathrm{pb}^{-1}$ at a center-of-mass energy of $\sqrt{s} = 7\,\mathrm{TeV}$. The focus of this contribution is the measurement of jet production, performed with the ATLAS detector [1], which is extended to new kinematic regions in this data set, allowing a probe of next-to-leading order (*NLO*) perturbative QCD (*pQCD*) with a transverse momentum of the jets of up to $\mathrm{p_T} = 1.5\,\mathrm{TeV}$ and an invariant mass of the dijet system of $\mathrm{m}_{1,2} = 4.1\,\mathrm{TeV}$.

Jet Reconstruction, Calibration Jets are reconstructed and calibrated using the so-called *EM+JES scheme*. The reconstruction is based on energy depositions at cell level, measured at the electromagnetic scale and combined to 3-dimensional topological clusters. These serve as input to the reconstruction algorithm. The anti-kt algorithm [2] with distance parameter $\mathrm{R} = 0.6$ is used. The calibration of the jet energy scale (*JES*) [3] is derived from the kinematics of MC truth information and accounts for the non-compensating nature of the calorimeter, dead material in the detector and shower leakage. The resulting correction factor is a function of η and $\mathrm{p_T}$, given by the ratio $\mathrm{R} = \mathrm{E_{truth}}/\mathrm{E^{em}_{reco}}$.

Due to the steeply falling $\mathrm{p_T}$ spectrum of the jets, the JES uncertainty dominates the uncertainty on jet cross section measurements [3]. In the central region ($|y| < 0.8$), the JES uncertainty amounts to 2.3% at $\mathrm{p_T^{jet}} = 200\,\mathrm{GeV}$, and 4.3% at $\mathrm{p_T^{jet}} = 20\,\mathrm{GeV}$. In the forward region ($3.6 < |y| < 4.4$), it reaches 2.9% at $\mathrm{p_T^{jet}} = 200\,\mathrm{GeV}$, and 12.6% at $\mathrm{p_T^{jet}} = 20\,\mathrm{GeV}$. The MC-derived JES uncertainty was validated by direct in-situ measurements.

Data Set Good operation status of the relevant detector components is required for the measurements, resulting in a data set with an integrated luminosity of $37.3\,\mathrm{pb}^{-1}$. For jets with $\mathrm{p_T} < 60\,\mathrm{GeV}$, only data in the low-luminosity phase was considered in order to ensure the absence of pile-up. In the region $|y| > 2.8$, only data after commissioning of the forward trigger was used. Minimum bias trigger scintillators were employed for $20\,\mathrm{GeV} < \mathrm{p_T} < 60\,\mathrm{GeV}$, while single jet triggers with the smallest possible trigger prescales were used for $\mathrm{p_T} > 60\,\mathrm{GeV}$, requiring the trigger efficiency to be $> 99\%$. This strategy maximises the accumulated luminosity in each bin, and the statistical error only dominates in the high $\mathrm{p_T}$ range. Events are required to have

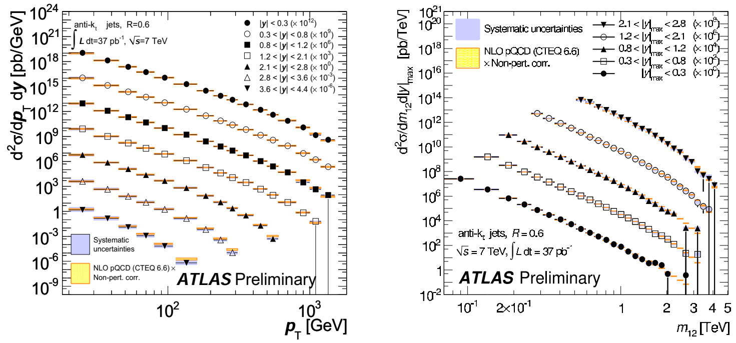

Figure 1: Inclusive jet (left) and dijet (right) double-differential cross section [4].

at least one primary vertex, which is defined by having at least five associated tracks. Furthermore, jet quality selection criteria are applied to reject reconstructed jets that do not originate from p-p collisions.

Inclusive Jet and Dijet Cross Sections The measurement of the inclusive jet and dijet cross sections [4] is an important test of pQCD. Data are corrected to particle level using a single-step bin-by-bin unfolding method based on MC and compared to NLO pQCD predictions from NLOJET++ [5] (CTEQ6.6 PDF [6]) with non-perturbative corrections from PYTHIA (AMBTS1 tune) [7].

The p_T spectrum of the inclusive jet cross section (see Fig. 1) covers $20\,\mathrm{GeV} < p_T < 1.5\,\mathrm{TeV}$, $|y| < 4.4$. It shows very good agreement over nine orders of magnitude within the systematic uncertainty of 20%. Discrepancies are only seen in the high-p_T forward region, which can be attributed to the fact that it was never probed before. Hence, the measurement allows NLO pQCD predictions of several PDF sets in this region [8] to be constrained. Also, the parton shower models of PYTHIA (AMBT1 tune) and HERWIG (AUET1 tune) [9] were compared to the measurement. A difference of 20% between the two models and a trend to overestimate (underestimate) the cross section at low (high) p_T by 20 - 40 % was observed.

Figure 1 also shows the double-differential dijet cross section, measured as a function of the dijet invariant mass $m_{1,2}$ for bins of the maximum rapidity of the two leading jets $|y|_{\mathrm{max}}$. The kinematic requirements on the two leading jets are $p_T^1 > 30\,\mathrm{GeV}$, $p_T^2 > 20\,\mathrm{GeV}$, and $|y| < 2.8$. Predictions from NLO pQCD with non-perturbative corrections are in good agreement with the data.

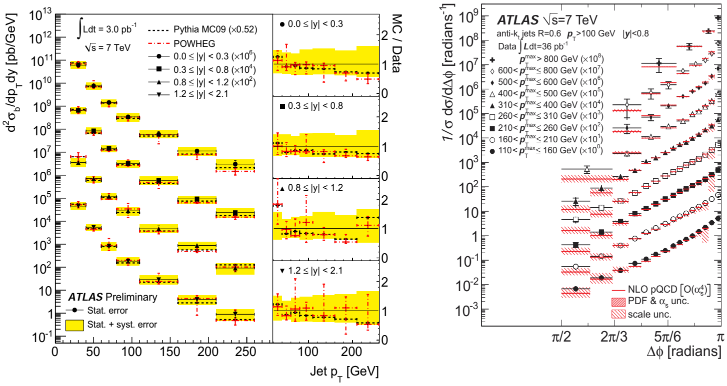

Figure 2: Inclusive double-differential cross section of b-tagged jets [10] (left) and azimuthal decorrelation of the dijet system [11] (right).

Inclusive Jet Cross Section of b-tagged Jets The measurement of the inclusive jet cross section of b-tagged jets in Fig. 2 uses a subset of the data, corresponding to an integrated luminosity of $3\,\mathrm{pb}^{-1}$ [10]. It covers the kinematic region of $20\,\mathrm{GeV} < \mathrm{p_T} < 260\,\mathrm{GeV}$ and $0 < |y| < 2.1$, where jets with a distance parameter of $\mathrm{R} = 0.4$ are fully contained in the tracking system. Jets from b-quarks are identified with a secondary vertex algorithm. Additional systematic uncertainties in comparison to the previous measurement from the b-jet energy scale and b-tagging efficiency add up to a total uncertainty of about 50%. Predictions from PYTHIA with the MC09 tune, normalised to the cross section in data, and POWHEG are in agreement with data within the uncertainty, but show a softer spectrum.

Azimuthal Decorrelation in Dijets QCD predicts the azimuthal decorrelation $\Delta\phi$ of the two leading jets as a function of the number of partons[1]. A perfectly balanced dijet event is expected to have $\Delta\phi = \pi$, while a hard third jet causes $\Delta\phi \ll \pi$. The measurement of $\Delta\phi$ of the two leading jets therefore is a sensitive test of additional radiation in the dijet system, without actually measuring these additional jets [11]. Jets in the barrel $|y| < 0.8$ are considered and binned in nine regions in $\mathrm{p_T}$ of the leading jet, starting from 110 GeV. The subleading jet is required to have $p_T > 100$ GeV. The experimental uncertainties are the JES $(2 - 17\%)$, unfolding

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[1] Here $\Delta\phi$ denotes the angle between two objects in the plane perpendicular to the beam axis.

$(1 - 19\%)$, and jet energy and position resolution $(0.5 - 5\%)$. The uncertainties on NLO pQCD predictions are scale uncertainties $(5 - 60\%)$, uncertainties on the PDF, and α_s (3%). Theory predictions describe the data well (see Fig. 2).

Jet-Veto Analysis The jet-veto analysis probes dijet events that do not contain additional jets in the rapidity region spanned by the jets, to test the pQCD predictions in the limit of large Δy and high $\mathrm{p_T}$ [12]. The observable is the gap fraction, which is the fraction of events that do not contain additional jets in the rapidity gap with a transverse momentum above a veto scale $Q_0 = 20\,\mathrm{GeV}$. The event is required to have exactly one primary vertex and the average jet momentum $\overline{p}_T > 50\,\mathrm{GeV}$, with $\mathrm{p_T} > 20\,\mathrm{GeV}$, and $|y| < 4.5$. Data is compared to predictions from several event generators. PYTHIA6 gives a good description, while HERWIG++ and ALPGEN overestimate the gap radiation.

Conclusions An overview of measurements of jet production with the ATLAS detector was presented. The measured cross sections show good agreement with NLO pQCD calculations and state-of-the-art Monte Carlo generators over up to nine orders of magnitude, covering a significantly larger phase space than previous measurements. By means of the refined jet energy scale uncertainty, the experimental and theoretical errors are of similar size. Hence, the measurements are sensitive to parton distributions in the proton in the extended energy regime and larger rapidities.

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