PROCEEDINGS OF SCIENCE

First Measurement of Inclusive Jet Production Cross Sections in Proton Proton Collisions at a Centre-of-Mass Energy of 7 TeV with the ATLAS Detector

PoS(ICHEP 2010)101

Tancredi Carli[*]
On behalf of the ATLAS collaborations
CERN
tancredi.carli@cern.ch

Jet production cross sections have been measured for the first time in proton-proton collisions at a centre–of–mass energy of 7 TeV with the ATLAS detector. The measurement uses the first data recorded at the Large Hadron Collider (LHC) corresponding to an integrated luminosity of 17 nb^{-1}. The anti-k_t algorithm with two jet resolution parameters, $R = 0.4$ and 0.6, is used to identify jets.

Inclusive single differential jet cross sections are presented as functions of jet transverse momentum and rapidity. Jets up to transverse momenta of 600 GeV and with rapidities of $|y| < 2.8$ are measured. Dijet cross sections are presented as functions of di–jet mass and the rapidity difference of the two leading jets. The total uncertainty on the cross section measurement is dominated by the jet energy scale, which is determined to below 7% for central jets above 60 GeV transverse momentum. The measurement agrees well with the NLO QCD predictions, providing a validation of the theory in a new kinematic regime.

35th International Conference of High Energy Physics,
July 22-28, 2010,
Paris, France

[*]Speaker.

1. Introduction

Jets are collimated bundles of hadrons produced by short–distance interactions in high–energy particle collisions. In hadron–hadron collisions first evidence for jet production was reported at the 21st ICHEP conference in Paris in the year 1982 shortly after the comissioning of the proton anti–proton collider at CERN [1]. It started operation near the end of 1981 at low energy and intensity and by summer 1982 it had increased the centre–of–mass (cms) energy to $\sqrt{s} = 540$ GeV. Events with a dominant two-jet structure and a di-jet invariant mass above 50 GeV were measured. The highest di–jet invariant mass observed was 140 GeV.

In December 2009 the Large Hadron Collider (LHC) at CERN collided for the first time protons on protons at $\sqrt{s} = 0.9$ TeV and $\sqrt{s} = 2.1$ TeV. Since March 2010 collisions at $\sqrt{s} = 7$ TeV have been available for physics analyses. The first observation of jets at high transverse momentum (p_{T}) by ATLAS were reported at the winter and spring conferences [2]. In this conference, the first preliminary measurements of jet production cross sections at $\sqrt{s} = 7$ TeV are reported in a data sample corresponding to an integrated luminosity of 17 nb^{-1} recorded in March–July 2010. This measurement has meanwhile been published in ref. [3].

2. Cross Section Definition

Jets are identified using the anti-k_t jet algorithm [4] with resolution parameters of $R = 0.4$ and of $R = 0.6$. The anti-k_t algorithm is an infrared and collinear safe jet clustering algorithm and produces geometrically well-defined ("cone-like") jets.

Inclusive single–jet double–differential cross sections are measured as a function of p_{T} and y for all jets in the kinematic region $p_{\mathrm{T}} > 60$ GeV, $|y| < 2.8$. The di–jet double-differential cross section is measured as a function of the invariant mass of the di–jet system, m_{12}, binned in the maximum rapidity of the two leading (i.e. highest p_{T}) jets, $|y|_{\max} = \max(|y_1|, |y_2|)$. It is also measured as a function of the angular variable

$$\chi = \exp(|y_1 - y_2|) \approx \frac{1 + \cos\theta^*}{1 - \cos\theta^*} \tag{2.1}$$

binned in the di–jet mass m_{12}. Here the subscripts 1, 2 label the highest and second highest p_{T} jet in the event within $|y| < 2.8$, respectively, and θ^* is the polar scattering angle of the outgoing jets in the dijet cms frame.

3. NLO QCD Calculation and Non-perturbative Corrections

The NLO QCD prediction are calculated using NLOJET++ 4.1.2 [5]. The renormalisation (μ_R) and factorisation (μ_F) scales are defined to be equal to the p_{T} of the leading jet in the event. To estimate the scale uncertainty μ_R and μ_F are varied independently between $1/2$ and 2 of the chosen scale.

In addition, the effect of the uncertainty in the strong coupling constant, $\alpha_s(M_Z)$, was estimated by calculating the cross section using $\alpha_s(M_Z)$ values within the uncertainty range, and using proton parton density functions (PDFs) fitted using these values [6]. The CTEQ 6.6 [7] NLO parton densities were used for the central value and uncertainties, and the MSTW 2008 [8], NNPDF 2.0 [9] and HERAPDF 1.0 [10] parton density sets were used as cross–checks. The theory uncertainties are calculated using the APPLGRID package [11, 12]. They amount to 5–10% in the kinematic range of this analysis [13].

The soft, non–perturbative corrections due to hadronisation and the so–called "underlying event" are calculated using leading–logarithmic parton shower Monte Carlo programs with the help of the RIVET [14] package, by evaluating the ratio of the cross section before and after hadronisation and underlying event simulation. The central value is calculated with the PYTHIA 6 MC09 sample [15–20], and the uncertainty is estimated as the maximum spread of the other models investigated. The size of these effects, and their dependence on jet size, increases with decreasing p_{T}. The corrections are within 5% over most of the kinematic region, but drop to -10% for the lowest p_{T} jets with $R = 0.4$, and rise to about 15% for the lowest p_{T} jets with $R = 0.6$.

4. Jet Reconstruction and Calibration

Jets are formed from energy deposition in the calorimeter that are calibrated to the electromagnetic scale[1]. Topologically connected calorimeter energy depositions are merged to clusters. The final jet energy is corrected for the lower response of the ATLAS calorimeter to hadrons with respect to electrons or photons and for energy losses in the dead material in front of and in between the calorimeter by an overall scale factor that is derived from Monte Carlo simulations shown to give an adequate description of the data [21]. Test-beam data [22] and in-situ measurements [23] show that the detector simulation models the calorimeter response to single hadrons to within 5% for hadron momenta between 0.5 and 350 GeV.

The jet energy scale uncertainty is derived from test–beam data and in–situ measurements of the single hadron response, central to forward di–jet balance and from systematic variations of Monte Carlo simulation within the known uncertainties. The overall uncertainty is below 7% for central jets with $p_{\mathrm{T}} > 60$ GeV (see [24].).

5. Results

The differential single inclusive jet cross section as a function of the jet p_{T} is shown in Fig. 1a for jets with $R = 0.6$. The cross section extends from $p_{\mathrm{T}} = 60$ GeV up to around $p_{\mathrm{T}} = 600$ GeV, and falls by more than four orders of magnitude over this range. The data are compared to NLO QCD calculations corrected for non-perturbative effects. Fig. 1b shows data to theory comparisons in five rapidity regions. The measurement is consistent with the theory prediction. The experimental uncertainty (light blue band) is presently larger than the one from theory (red band). This uncertainty can be significantly reduced with the full statistics collected in 2010.

Fig. 2a shows the double–differential di–jet cross section as function of the di–jet mass in rapidity in bins of the most forward jet. In the most central rapidity bin di–jet masses up to 700 GeV are measured. For the most forward rapidities di–jet masses of about 2 TeV are observed. The highest observed di–jet masses exceed the cms energies available at previous colliders.

[1] "Electromagnetic scale" is the calibrated scale for energy deposited by electrons and photons in the calorimeter.

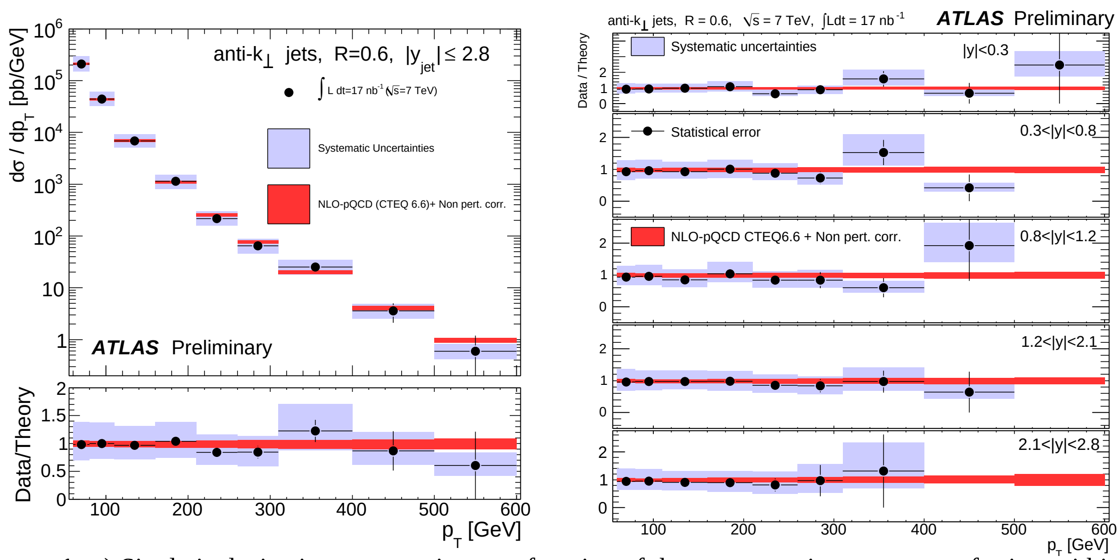

Figure 1: a) Single inclusive jet cross section as a function of the transverse jet momentum for jets within $|y| < 2.8$. b) Ratio of the calculated to the measured single inclusive jet cross section for five rapidity region between $0 < |y| < 2.8$.

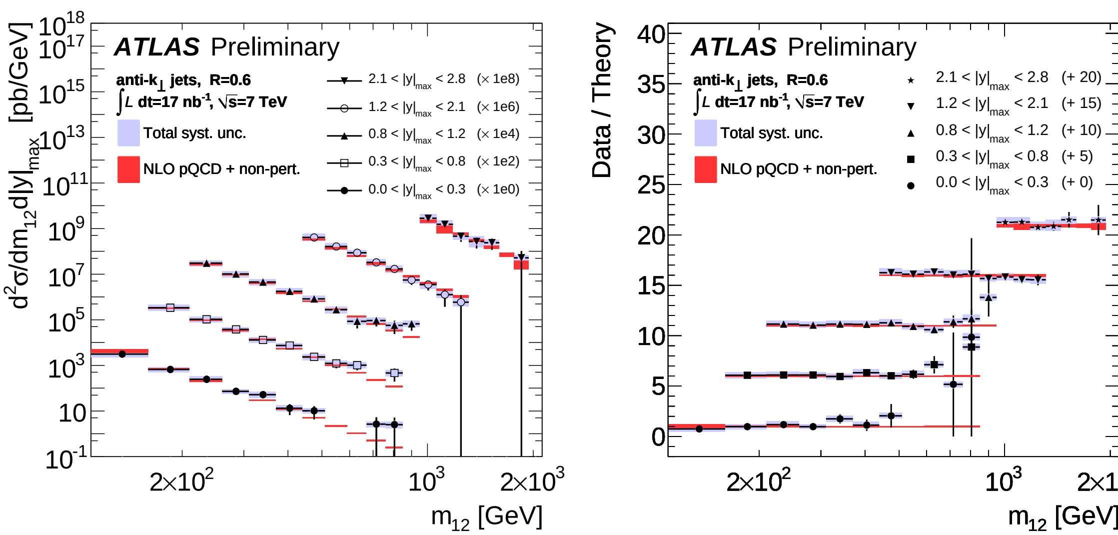

Figure 2: a) Di–jet cross section as a function of the invariant mass of the two leading jets in bins of rapidity of the leading jet between $0 < |y_{max}| < 2.8$. b) Ratio of the calculated to the measured di–jet cross section.

The data are in good agreement with theory predictions (see Fig. 2b). Similar good agreeement is found for the angular observable.

6. Conclusion

Jet production cross sections at a centre–of–mass energy of 7 TeV have been measured for the first time with the ATLAS detector and are compared to NLO QCD predictions. Good agreement between data and theory is found. The dominant uncertainty on the cross section is due to the jet energy scale that has been determined to be below 7% for central jets with $p_{\mathrm{T}} > 60$ GeV. The cross sections extend into previously unmeasured kinematic regimes. The leading jet p_T distribution extends up to 600 GeV and di–jet masses up to nearly 2 TeV are observed. The measurements use only 17 nb^{-1} of integrated luminosity. Data already recorded by ATLAS will extend the reach of subsequent measurements and their precision at high transverse momenta. This will allow for stringent tests of short distance physics and space-time structure at very small distances.

References

[1] G. Wolf, Journal de Physique, 21st ICHEP **Colloque C3** (1982) 525.

[2] ATLAS Collaboration, ATLAS-CONF-2010-001, Geneva 2010; ATLAS Collaboration, ATLAS-CONF-2010-043, Geneva 2010.

[3] ATLAS Collaboration, arXiv:1009.5908, accepted by Eur. Phys..

[4] M. Cacciari, G. Salam, and G. Soyez, HEP **0804** (2008) 063.

[5] Z. Nagy, Phys. Rev. **D68** (2003) 094002,

[6] H. L. Lai et al., Phys. Rev. D 82 (2010) 054021.

[7] P. M. Nadolsky et al., Rev. **D78** (2008) 013004.

[8] A. D. Martin, W. J. Stirling, R. S. Thorne, and G. Watt, Eur. Phys. J. **C63** (2009) 189–285,

[9] NNPDF Collaboration, R. D. Ball et al., Nucl. Phys. **B809** (2009) 1–63,

[10] The H1 and ZEUS Collaborations, JHEP 1001 (2010) 109.

[11] T. Carli, G. P. Salam and F. Siegert, `arXiv:0510.0324 [hep-ph]`.

[12] T. Carli et al., Eur. Phys. J. **C 66** (2010) 503–524.

[13] P. Starovoitov, `arXiv:1010.1569 [hep-ph]`.

[14] A. Buckley et al., `arXiv:1003.0694 [hep-ph]`.

[15] T. Sjöstrand, S. Mrenna, and P. Skands, JHEP 05 (2006) 026.

[16] G. Corcella et al., JHEP 01 (2001) 010.

[17] M. Bahr et al., Eur. Phys. J. C58 (2008) 639–707

[18] M. L. Mangano, M. Moretti, F. Piccinini, R. Pittau, and A. D. Polosa, JHEP 07 (2003) 001.

[19] T. Gleisberg et al., JHEP 02 (2009) 007.

[20] ATLAS Collaboration, ATL-PHYS-PUB-2010-002, Geneva, 2010.

[21] ATLAS Collaboration, ATLAS-CONF-2010-053, Geneva 2010;

[22] M. Aharrouche et al., Nucl. Instrum. Meth., A 614 (2010) 400-432; E. Abat et al., ATL-CAL-PUB-2010-001, Geneva 2010; P. Adragna et al., Nucl. Instrum. Meth., A 615 (2010) 158-181; E. Khramov et al., ATL-TILECAL-PUB-2009-007, Geneva 2010; E. Abat et al., Nucl. Instrum. Meth. A 607 (2009) 372. C. Cojocaru, Nucl. Instrum. Meth. A 531 (2004) 481-514.

[23] ATLAS Collaboration, ATLAS-CONF-2010-017, Geneva 2010; ATLAS Collaboration, ATLAS-CONF-2010-052, Geneva 2010;

[24] ATLAS Collaboration, ATLAS-CONF-2010-056, Geneva 2010.