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Inclusive jet production measured with ATLAS, and constraints on PDFs

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Inclusive jet and dijet double-differential cross sections have been measured in proton-proton collisions at a centre-of-mass energy of 2.76 and 7 TeV using the ATLAS detector at the LHC. The cross sections were measured using jets clustered with the anti-k_t algorithm. The data are compared to expectations based on next-to-leading order QCD calculations corrected for non-perturbative effects, as well as to next-to-leading order matrix-element + parton shower Monte Carlo predictions. The ratio of cross section measurements at 2.76 and 7 TeV gives a substantial reduction in experimental and/or theoretical uncertainties. An NLO QCD analysis of the data indicates some constraining power for the gluon density.

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1. Introduction

Collimated jets of hadrons are a dominant feature of high-energy particle interactions. In Quantum Chromodynamics (QCD) they can be interpreted in terms of the fragmentation of quarks and gluons produced in a scattering process. The inclusive jet production cross section provides information on the strong coupling and the structure of the proton, and tests the validity of perturbative QCD (pQCD) down to the shortest accessible distances.

At the start of the 2011 data taking period of the Large Hadron Collider (LHC), the ATLAS experiment [1] collected pp collision data at $\sqrt{s} = 2.76$ TeV corresponding to an integrated luminosity of 0.20 pb^{-1}. Having a centre-of-mass energy close to the highest energies reached in $p\overline{p}$ collisions, the dataset provides a connection from LHC measurements to previous measurements at the Tevatron. Moreover, measurements with the same detector at different centre-of-mass energies provide stringent tests of the theory, since the dominant systematic uncertainties are correlated. These correlations can be explored in a common fit to the measurements at different $\sqrt{s}$, or in ratios of the inclusive jet double-differential cross sections, leading to a reduction of systematic uncertainties.

2. Results

In this note the inclusive jet double-differential cross section $d^2\sigma/dp_{\mathrm{T}}dy$ is measured for $20 \leq p_{\mathrm{T}} < 430$ GeV and rapidities of $|y| < 4.4$ at $\sqrt{s} = 2.76$ TeV [2]. Moreover, the ratio to the previously measured cross section at $\sqrt{s} = 7$ TeV [3] is determined as a function of p_{T} and as a function of $x_{\mathrm{T}} = 2p_{\mathrm{T}}/\sqrt{s}$

$$\rho(y, p_{\mathrm{T}}) = \frac{\sigma(y, p_{\mathrm{T}}, 2.76\ \ \mathrm{TeV})}{\sigma(y, p_{\mathrm{T}}, 7\ \ \mathrm{TeV})} \text{ and } \rho(y, x_{\mathrm{T}}) = \left(\frac{2.76\ \ \mathrm{TeV}}{7\ \ \mathrm{TeV}}\right)^3 \cdot \frac{\sigma(y, x_{\mathrm{T}}, 2.76\ \ \mathrm{TeV})}{\sigma(y, x_{\mathrm{T}}, 7\ \ \mathrm{TeV})},$$

where $\sigma(y, x_{\mathrm{T}}, \sqrt{s})$ corresponds to the measured averaged cross section $d^2\sigma/dp_{\mathrm{T}}dy$ in a bin $(y, p_{\mathrm{T}} = \sqrt{s} \cdot x_{\mathrm{T}}/2)$, and x_{T} is chosen to be at the bin centre. For the ratio measured as a function of p_{T}, many experimental systematic uncertainties cancel, while for the ratio measured as a function of x_{T}, theoretical uncertainties are reduced. This allows a precise test of NLO pQCD calculations.

The reconstruction procedure and the calibration factors for the jet cross section measurement at $\sqrt{s} = 2.76$ TeV are nearly identical to those used for the measurement at $\sqrt{s} = 7$ TeV with 2010 data [3]. Jets are reconstructed with the anti-k_t algorithm using as input objects, topological clusters [3] of energy deposits in the calorimeter, calibrated at the electromagnetic scale. A jet energy scale (JES) correction is then applied to correct for detector effects such as energy loss in dead material in front of the calorimeter or between calorimeter segments, and to compensate for the lower calorimeter response to hadrons than to electrons or photons [3]. Due to the low number of interactions per bunch crossing at $\sqrt{s} = 2.76$ TeV, an offset correction accounting for additional energy depositions from multiple interactions in the same bunch crossing, pile-up, is not applied in this measurement.

The estimation of the uncertainty in the jet energy measurement uses single-hadron calorimeter response measurements [3] and systematic Monte Carlo simulation variations. An uncertainty of

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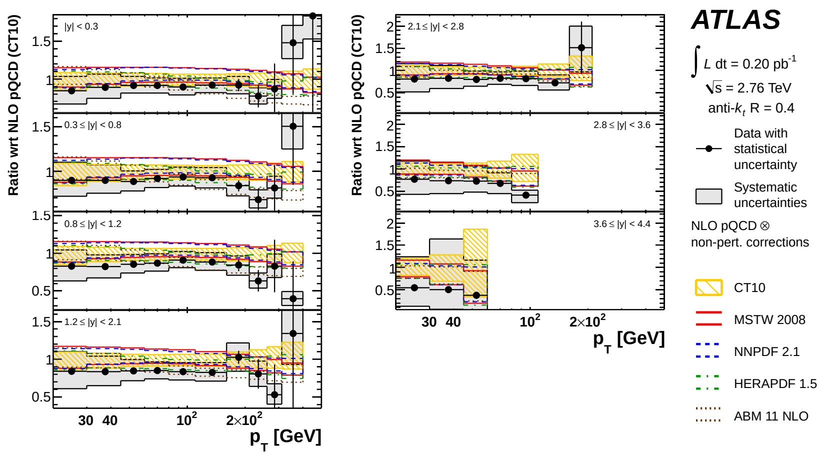


Figure 1: Ratio of the measured inclusive jet double-differential cross section to the NLO pQCD prediction The shaded area indicates the experimental systematic uncertainties. The 2.7% uncertainty from the luminosity measurements is not shown.

about 2.5% in the central calorimeter region over a wide momentum range of $60 \leq p_{\rm T} < 800$ GeV is obtained [3]. For jets with lower $p_{\rm T}$ and for forward jets the uncertainties are larger.

Corrections for the detector inefficiencies and resolutions are performed to extract the particle-level cross section, based on a transfer matrix that relates the $p_{\rm T}$ of the jet at particle-level and the reconstruction-level.

The following sources of systematic uncertainty are considered in this measurement: the trigger efficiency, jet reconstruction and calibration, the unfolding procedure and the luminosity measurement.

The uncertainty due to the jet energy calibration is evaluated using the same uncertainties on the sources as in the previous measurement at $\sqrt{s} = 7$ TeV [3]. The uncertainty on the jet energy resolution (JER) is assigned by considering the difference between data and Monte Carlo simulation in the estimated JER using *in situ* techniques. The jet angular resolution is estimated in Monte Carlo simulation from the polar angle between the reconstructed jet and its matched jet at particle level.

The NLO pQCD predictions are calculated using the NLOJET++ 4.1.2 [5] program. For fast and flexible calculations with various PDFs and factorisation and renormalisation scales, the APPLGRID software [6] is interfaced with NLOJET++.

The fixed-order NLO pQCD calculations predict the parton-level cross section, which should be corrected for non-perturbative effects before comparison with the measurement at particle level. The corrections are derived using leading order matrix element + leading logarithm parton shower Monte Carlo generators by evaluating the bin-wise ratio of the cross section with and without hadronisation and the underlying event. Each bin of the NLO pQCD cross section is then multiplied by the corresponding correction for non-perturbative effects. The baseline correction factors are obtained from PYTHIA 6.425 with the AUET2B CTEQ6L1 tune [4].

The ratio of the measured cross sections to the NLO pQCD predictions using the CT10 PDF

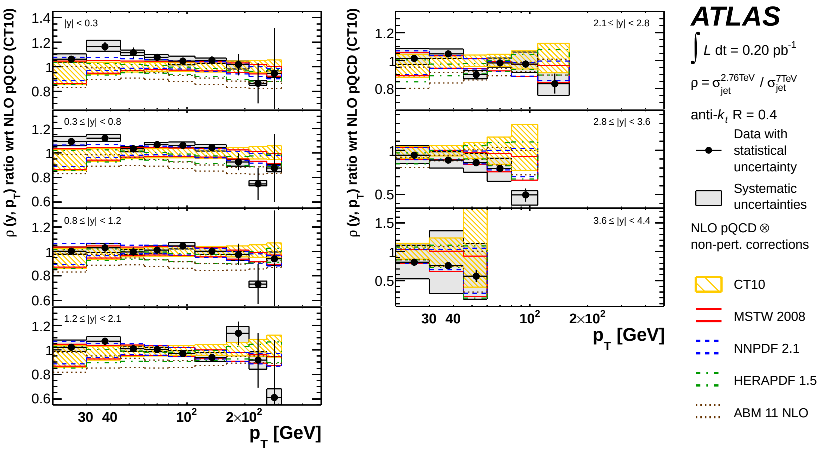


Figure 2: Ratio of the inclusive jet cross section at $\sqrt{s} = 2.76$ TeV to the one at $\sqrt{s} = 7$ TeV as a function of p_T in bins of jet rapidity, for anti-k_t jets with $R = 0.4$. The theoretical prediction is calculated at next-to-leading order with the CT10 PDF set and corrected for non-perturbative effects. Statistically insignificant data points at large x_T are omitted. The 4.3% uncertainty from the luminosity measurements is not shown.

set is presented in Figs. 1 for jets with $R = 0.4$. The results are also compared to the predictions obtained using the PDF sets MSTW 2008 (NLO), NNPDF 2.1, HERAPDF 1.5 (NLO) and ABM 11 (NLO). The value for α_S is taken from the corresponding PDF set. The measurement is consistent with all the theoretical predictions using different PDF sets within their systematic uncertainties.

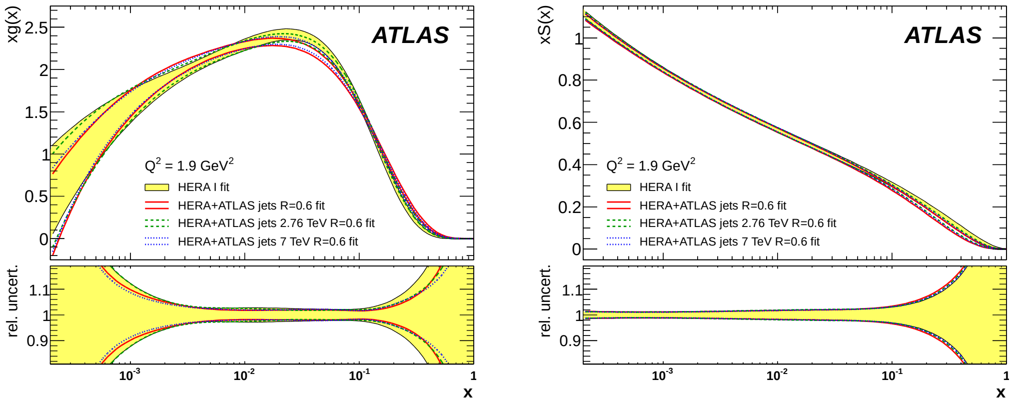
Figure 2 shows the cross section ratio as a function of the jet p_T, plotted as the double ratio with respect to the NLO pQCD prediction using the CT10 PDF set with non-perturbative corrections applied, for anti-k_t jets with $R = 0.4$. The ratio is extracted using the coherent treatment of the systematic uncertainties in the two measurements at the two different beam energies, by shifting the measured cross section at $\sqrt{s} = 7$ TeV from the published result within its uncertainty.

A combined NLO pQCD analysis of the inclusive jet cross section measured with ATLAS in pp collisions at $\sqrt{s} = 2.76$ TeV and $\sqrt{s} = 7$ TeV [3] and HERA-I data [7] is presented. The analysis is performed using the HERAFitter package [7], which uses the light-quark coefficient functions calculated to NLO as implemented in QCDNUM and the heavy-quark coefficient functions from the variable-flavour number scheme (VFNS) for the PDF evolution, as well as MINUIT for minimisation of the χ^2. The data are compared to the theory using the χ^2 function defined in Refs [7]. The result of the fit is shown in the Figure 3. A harder gluon distribution and a softer sea-quark distribution in the high Bjorken-x region are obtained with respect to the fit of HERA data only.

3. Conclusions

The inclusive jet cross section in pp collisions at $\sqrt{s} = 2.76$ TeV has been measured and the ratio of the inclusive jet cross sections at $\sqrt{s} = 2.76$ TeV and $\sqrt{s} = 7$ TeV is discussed.

The measurements are compared to fixed-order NLO perturbative QCD calculations, to which corrections for non-perturbative effects are applied. The predictions are in good agreement with



(a) xg (b) xS

Figure 3: Momentum distributions of the (a) gluon $xg(x)$ and (b) sea quarks $xS(x)$ together with their relative experimental uncertainty as a function of x for $Q^2 = 1.9$ GeV^2. The filled area indicates a fit to HERA data only. The bands show fits to HERA data in combination with both ATLAS jet datasets, and with the individual ATLAS jet datasets separately, each for jets with $R = 0.6$.

the data in general, in both the jet cross section and the cross section ratio. This confirms that perturbative QCD can describe jet production at high jet transverse momentum. The very small systematic uncertainty in the $\rho(y, p_{\mathrm{T}})$ measurement suggests that the measured jet cross section at $\sqrt{s} = 2.76$ TeV may contribute to constrain the PDF uncertainties in a global PDF fit in the pQCD framework by correctly taking the correlation of systematic uncertainties to the previous $\sqrt{s} = 7$ TeV measurement into account. Indeed, an NLO pQCD analysis in the DGLAP formalism has been performed using the ATLAS inclusive jet cross section data at $\sqrt{s} = 2.76$ TeV and $\sqrt{s} =$ 7 TeV, together with HERA I data. By including the ATLAS jet data, a harder gluon distribution and a softer sea-quark distribution in the high Bjorken-x region are obtained with respect to the fit of HERA data only.

References

[1] ATLAS Collaboration, JINST **3** S08003 (2008)

[2] ATLAS Collaboration, arXiv:1304.4739 [hep-ex].

[3] ATLAS Collaboration, Phys. Rev. D **86**, 014022 (2012); ATLAS Collaboration, Eur. Phys. J. C **73**, 2304 (2013); ATLAS Collaboration, Eur. Phys. J. C **73**, 2305 (2013)

[4] ATLAS Collaboration, ATL-PHYS-PUB-2011-009, (2011)

[5] Z. Nagy, Phys. Rev. D **68**, 094002 (2003)

[6] T. Carli, D. Clements, A. Cooper-Sarkar, C. Gwenlan, G. P. Salam, F. Siegert, P. Starovoitov and M. Sutton, Eur. Phys. J. C **66**, 503 (2010); M. Sutton, T. Carli, D. Clements, A. Cooper-Sarkar, C. Gwenlan, G. P. Salam, F. Siegert and P. Starovoitov, PoS DIS **2010**, 051 (2010).

[7] H1 Collaboration, Eur. Phys. J. C **64**, 561 (2009); H1 Collaboration, Eur. Phys. J. C **30**, 1 (2003); ZEUS Collaboration, Phys. Rev. D **67**, 012007 (2003); H1 and ZEUS Collaboration, JHEP **1001**, 109 (2010); H1 Collaboration, Eur. Phys. J. C **63**, 625 (2009)