



Low p_T Jet Cross Section Measurement in pp Collisions at $\sqrt{s} = 8$ TeV

Salim Cerci (for the CMS Collaboration)

Adiyaman University, Science and Letters Faculty, Physics Department, 02040 Adiyaman, TURKEY

Abstract

Recent measurement of inclusive jet cross sections at low jet transverse momenta $21 < p_T < 74$ GeV/c in the rapidity region of $|y| < 4.7$ is presented. Jets are reconstructed with the anti- k_T clustering algorithm for a jet size parameter $R = 0.7$. The data is collected with the CMS detector using pp collisions at $\sqrt{s} = 8$ TeV, exploiting special low-pileup runs of the LHC. The measured jet cross section is corrected for detector effects. The results are compared to theoretical predictions of next-to-leading order (NLO) QCD calculations.

Keywords: Inclusive Jets, PDFs, QCD, CMS

1. Introduction

The inclusive jet cross section measurement can be used to test the theory of the strong interaction, QCD, constrain parton distribution functions (PDFs) of the proton, differentiate among PDF sets, and look for possible deviations from the Standard Model. The hadronization, parton shower models and also the parameters of PDFs can be optimized by using the jet variables. The jets in pp collisions are described by QCD in terms of parton-parton scattering, where the outgoing scattered partons manifest themselves as hadronic jets. In this frame the partonic cross section is convoluted with PDFs, which give the probability to find a parton with a momentum fraction x of the proton momentum. The jet cross section as a function of the rapidity y and the transverse momentum p_T of the jet is a sensitive probe for the calculation of the hard partonic cross section as well as for the parton densities.

2. Experimental Setup

A detailed description of the CMS experiment can be found in Ref. [1]. CMS uses a right-handed coordinate system, with the origin at the nominal interaction point, the x axis pointing to the centre of the LHC, the y axis

pointing up (perpendicular to the LHC plane), and the z axis along the anticlockwise-beam direction. The polar angle θ is measured from the positive z axis and the azimuthal angle ϕ is measured in the $x-y$ plane. The rapidity y is defined as $y = 1/2 \ln((E+p_z)/(E-p_z))$ and the pseudorapidity as $\eta = -\ln \tan(\theta/2)$. The central feature of the CMS detector is a superconducting solenoid of 6 m internal diameter providing an axial magnetic field with the nominal strength of 3.8 T. The pixel tracker, the silicon-strip tracker, the lead tungstate electromagnetic calorimeter, the brass/scintillator hadron calorimeter and the muon detection system are immersed in the magnetic field. In addition to the barrel and endcap calorimeters, the steel/quartz-fibre forward calorimeter covers the pseudorapidity region $3.0 < |\eta| < 5.2$.

3. Analysis Technique

The data, recorded with the CMS detector in 2012 at the center-of-mass energy $\sqrt{s} = 8$ TeV have been used and correspond to an integrated luminosity of 5.61 pb^{-1} with low pileup runs with an average of 4 interactions per bunch crossing [2]. The dataset contains all events, which were triggered by the CMS zero-bias trigger. The zero-bias trigger accepts events if at least two charged tracks in the pixel detector, in coincidence with the cor-

rect bunch crossing. In order to obtain good quality jets, certain identification criteria are applied. The collinear and infrared safe anti- k_T clustering algorithm of size parameter $R = 0.7$ in the ranges $0 < |y| < 4.7$ and $p_T = 21 - 74$ GeV/c is used for the jet reconstruction. The clustering is performed by four-momentum summation, where the chosen size parameter allows for the capture of most of the parton shower. The four-momentum vectors of particle-flow (PF) objects are utilized as inputs for the jet clustering algorithm. The particle-flow technique [3], combining the information from several sub-detectors (tracker, electromagnetic calorimeter, hadronic calorimeter and muon detector), is used for the reconstruction of individual particles like leptons, photons, charged and neutral hadrons. The reconstructed jet four momenta are corrected for various experimental effects such as the additional energy reconstruction, the non-uniform detector response, which depends on jet η and jet p_T .

4. Jet Cross Section Measurements

The differential cross section is measured using the formula

$$\frac{d^2\sigma}{dp_T dy} = \frac{1}{L_{eff}} \frac{N}{\Delta p_T \cdot \Delta y} \times C_{unfold}, \quad (1)$$

where L_{eff} is the effective integrated luminosity, N is the number of jets in the bin, Δp_T and Δy are the bin widths in jet p_T and jet rapidity, respectively. C_{unfold} is the unsmearing correction factor. In order to remove the detector smearing effects the measured spectra are unfolded by using the Bayesian unfolding (d'Agostini) [4] technique, as implemented in the RooUnfold package.

The Jet Energy Scale (JES), p_T and η dependent, is the dominant source of systematic uncertainty. The JES uncertainty is estimated to be 2 – 6% at $|y| < 4.7$ and it gives rise to 5% to 48% uncertainty on the final jet cross section. The uncertainty on the integrated luminosity is estimated to be 4.4%, which propagates directly to the measurement of cross section. The unfolding uncertainty and Jet Energy Resolution introduce 5% to 30% and 3% to 17% uncertainty on the cross section measurement, respectively. The total experimental uncertainty, which is obtained by adding the individual uncertainties in quadrature, can reach 60% especially in the low p_T region.

The theoretical predictions for the jet cross sections consist of NLO QCD calculation and a non-perturbative correction (NP) to account for the hadronization and multi-parton interaction (MPI) effects. The next to

leading (NLO) theory calculations are performed by using NLOJet++ package within the framework of fastNLO program with five different PDF sets: ABM11 [5], CT10 [6], HERAPDF1.5 [7], MSTW2008NLO [8], NNPDF2.1 [9]. The renormalization and factorization scales (μ_R and μ_F) for the inclusive measurement, are equal to the jet p_T . The variation of $\alpha_S(M_Z)$ by 0.001 introduces 12% uncertainty on the theoretical prediction. The renormalization and factorization scale uncertainty is estimated as the maximum deviation at the six points $(\mu_F/\mu, \mu_R/\mu) = (0.5, 0.5), (2, 2), (1, 0.5), (1, 2), (0.5, 1), (2, 1)$, where $\mu = p_T$ (inclusive). An additional uncertainty up to 17.5% is caused by the non-perturbative correction. Hence, the total theoretical uncertainty reach up to 19%.

The measured cross-section is compared to NLO theory predictions corrected by the NP correction factor. Figure 1 shows the comparison of differential inclusive jet cross sections measured at low and high transverse momenta to NLO predictions using the NNPDF2.1 PDF set times the NP correction factor. The low p_T jets measurement is obtained with the integrated luminosity of 5.61 pb^{-1} of minimum bias data for low pile-up conditions whereas the high p_T jets are obtained with integrated luminosity of 10.71 fb^{-1} of jet trigger data for high pileup.

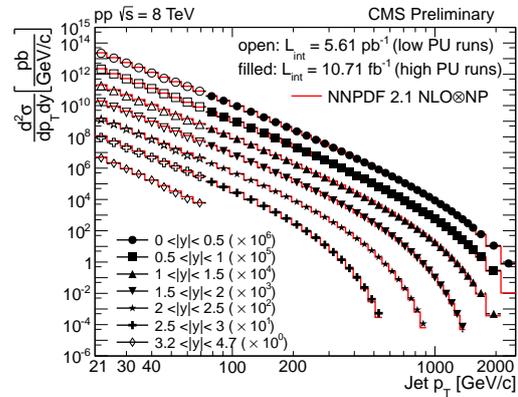


Figure 1: The differential inclusive jet cross sections in comparison to the prediction of the NNPDF2.1 PDF times the NP correction factor.

5. Results

The ratio of the measurement to the theoretical prediction of NNPDF2.1 is shown for $0 < |y| < 0.5$ and $3.2 < |y| < 4.7$. The experimental and theoretical systematic uncertainties are also shown. Within the uncertainties, the measurements

are found to have reasonable agreement with the prediction.

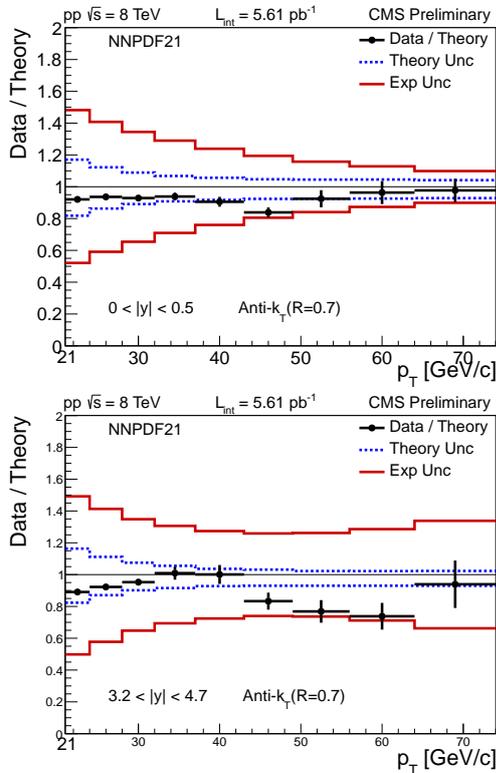


Figure 2: Inclusive jet cross sections for data over the theoretical prediction of the NNPDF2.1 PDF set for $0 < |y| < 0.5$ and $3.2 < |y| < 4.7$. The experimental and theoretical systematic uncertainties are represented by the continuous and dashed lines, respectively.

A similar comparison but instead of the theoretical uncertainty for each PDF set the ratios of the predictions with alternative PDF sets is shown in Fig. 3 for rapidity bins of $0 < |y| < 0.5$ and $3.2 < |y| < 4.7$. In addition, the ratio of the prediction by POWHEG+PYTHIA6 tune Z2* [10] at particle level is shown. As seen in Fig. 3, for the central region, data is within 5% agreement to NNPDF2.1 theory prediction, whereas it deviates up to 25% for the outer most bin and different p_T bins.

Within the current experimental and theoretical uncertainties, perturbative QCD calculations are found to be in agreement with the measured inclusive jet cross sections.

6. Acknowledgement

The author would like to acknowledge to the Organizing Committee of ICHEP14 and the Adiyaman Uni-

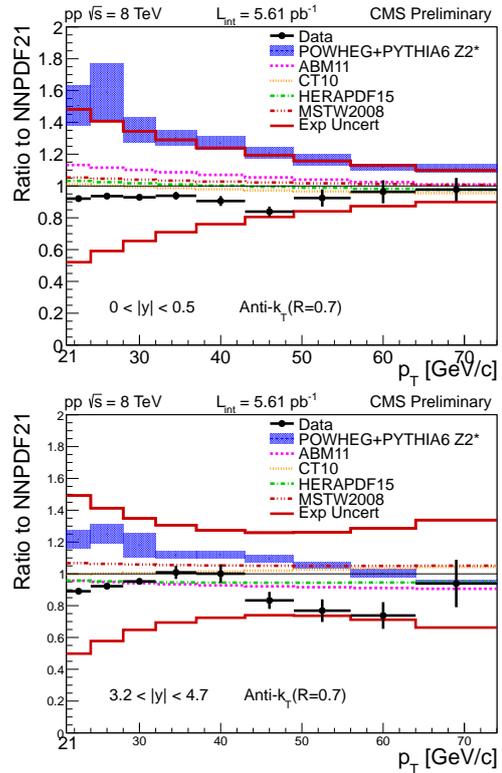


Figure 3: Ratio of inclusive jet cross sections to the theoretical prediction using the central value of the NNPDF2.1 PDF set for $0 < |y| < 0.5$ and $3.2 < |y| < 4.7$. The ratio of the cross sections calculated with the other PDF sets to that calculated with NNPDF2.1 is shown with dash lines. The continuous line represent the experimental uncertainty. The ratio of the prediction by POWHEG+PYTHIA6 tune Z2* at particle level is shown with boxes indicating the statistical uncertainty.

versity Scientific Activity Foundation for the financial support.

References

- [1] S. Chatrchyan et al. [CMS Collaboration], *JINST* **3**, S08004 (2008).
- [2] CMS Collaboration, *CMS PAS FSQ-12-031* (2013).
- [3] CMS Collaboration, *CMS PAS PFT-09-001* (2009).
- [4] T. Auye, *Proc. of the PHYSTAT 2011 Workshop*, CERN, Geneva, Switzerland, CERN-2011-006, arXiv:1105.1160 (2011).
- [5] M. S. Alekhin and J. Blumlein, arXiv:hep-ph/1202.2281v2 (2012).
- [6] H.L. Lai et al., *Phys. Rev.* **D82** 074024 (2010).
- [7] H1 and ZEUS Collaboration, *JHEP* **01** 109 (2010).
- [8] A. D. Martin et al., *Eur. Phys. J.* **C63** 189 (2009).
- [9] R. D. Ball et al., *Nucl. Phys.* **B838** 136 (2010).
- [10] S. Alioli et al., arXiv:hep-ph/1012.3380 (2010).