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Measurement of the jet production cross section at 7 TeV

Gagik VARDANYAN[*†]
Yerevan Physics Institute
E-mail: gagik.vardanyan@cern.ch

Measurements of jet production are sensitive to the strong coupling constant, next-to-leading order perturbative calculations and parton distribution functions. The measurements are obtained using data corresponding to an integrated luminosity of 4.5 fb^{-1}, recorded by the ATLAS detector in 2011. Cross sections are measured up to 5 TeV dijet mass using jets reconstructed with the anti-k_t algorithm for values of the jet radius parameter of 0.4 and 0.6. The quantitative comparison of data and theoretical predictions obtained using various parameterizations of the parton distribution functions is performed using a frequentist method.

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[*]Speaker.
[†]On behalf of the ATLAS Collaboration.

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1. Introduction

Differential dijet cross-sections are useful tools for probing perturbative regime of Quantum Chromo-Dynamics (QCD). They are sensitive to Parton Distribution Functions (PDF) and the strong coupling constant α_S. In addition, dijet invariant mass is sensitive to resonances or new interactions beyond the Standard Model (SM). Double differential dijet cross-section has been measured in proton-proton collisions at $\sqrt{s} = 7$ TeV [1] for anti-k_t jets [2] with radius parameter of 0.4 and 0.6. The data was collected in 2011 by the ATLAS detector [3] at LHC [4], corresponding to a total integrated luminosity of 4.5 fb^{-1}. Cross-sections are measured in bins of half of the absolute rapidity separation between the leading two jets (y^*) as a function of invariant mass (m_{12}) of those. The amount of statistics and better understanding of jet energy scale (JES) and it's systematic uncertainties [5] with respect to the previous ATLAS measurement of the same observable [6] allowed measuring this quantity up to 5 TeV in dijet mass with experimental uncertainty comparable to the theoretical uncertainty in magnitude. Results are quantitatively analysed within the context of next-to-leading order (NLO) perturbative QCD (pQCD) predictions with various PDF sets. Non-perturbative (NP) effects (i.e. hadronisation, underlying event (UE)) and higher-order electro-weak (EW) effects have been taken into account.

The present note is designed as follows: Section 2 summarises the theoretical predictions, the experimental measurement is described in Section 3, the results are discussed in Section 4, conclusions follow after.

2. Theoretical Predictions

The NLOJet++ package [7, 8] is used to calculate the fixed order $O(\alpha_S^3)$ pQCD predictions. The software is interfaced with APPLGRID [9] for fast convolution with different PDF sets. The PDF sets considered are CT10 [10], HERAPDF1.5 [11], epATLJet13 [12], MSTW2008 [13], NNPDF2.1 [14, 15], NNPDF2.3 [16] and ABM11 [17]. For consistency with the previous ATLAS measurement [6], the renormalisation (μ_R) and factorisation (μ_F) scales have been chosen as:

$$\mu = \mu_R = \mu_F = p_T^{max} e^{0.3y^*},$$

where p_T^{max} is the transverse momentum of the leading jet. To estimate systematic uncertainties in the fixed order calculation, these scales have been varied independently up and down by a factor of two, and the calculation was performed with all possible combinations of these variations, except the case, when they are varied in opposite directions. The maximum deviation of the results with modified scale choices with respect to the nominal one is considered as a systematic uncertainty attributed to missing higher order terms. Besides, uncertainties rising from that on α_S are considered, and the uncorrelated uncertainty components of each PDF set are also propagated through the fixed order calculation.

Although being negligible for integral cross-sections, electro-weak effects can be significant for differential cross-sections (up to 9% for $m_{12} > 3$ TeV in the range $y^* < 0.5$). Thus, they have been taken into account in the final comparisons with the data. These effects are assessed as NLO EW tree-level corrections of $O(\alpha\alpha_S, \alpha^2)$ and weak loop level corrections of $O(\alpha\alpha_S^2)$ on top of leading order (LO) QCD [18].

Finally, non-perturbative effects are also taken into account to bring the parton-level cross-section predictions to the jet level. These corrections have been derived using leading logarithmic parton shower Monte Carlo generators (MC) as binwise ratio of cross-sections with UE and hadronisation on over the cross-section with those effects off. The nominal NP correction was derived using PYTHIA6.425 [19] with AUET2B tune [20] derived for MRST LO** PDF set [21]. To assess the systematic uncertainty on NP effects, the same generator with the AUET2B tune derived for CTEQ6L1 PDF set [22], as well as HERWIG++ generator [23, 24, 25] with UEEE3 tune [26] derived for CTEQ6L1 and MRST LO** PDF sets are used.

3. Measurement

Dijet cross-section is measured using ATLAS 2011 data of proton-proton collisions at centre-of-mass energy of 7 TeV. Jets are reconstructed from topological 3-dimensional clusters of energy depositions in ATLAS calorimeters using the anti-k_t algorithm with jet radius parameter of R=0.4 and R=0.6. Jet energy and direction are calibrated using a sequence of methods described in details in [5]. A suite of fully efficient high level jet triggers is used to pre-select events. Events are required to have at least one reconstructed primary vertex with two or more tracks each with $p_T > 400$ MeV. The jet acceptance is restricted to $|y| < 3.0$. Events with two or more jets are considered, imposing $p_T > 100$ GeV cut on the leading jet and $p_T > 50$ GeV cut on the subleading jet. To reject cosmic and other non-collision background, these jets are furthermore required to fulfill the "medium" quality selection criteria described in [27].

Events passing all these requirements described above are used to fill the reconstruction level dijet mass spectra in data. These spectra are then unfolded to particle level using Iterative, Dynamically Stabilised method [28]. The response matrices are built from PYTHIA6.425 generator with AUET2B tune using GEANT4 toolkit [29] for detector simulation.

The dominant experimental systematic uncertainty for this measurement is the JES uncertainty. It is assessed by shifting the JES with one σ up and down for each of the independent component of JES uncertainties, thus propagating these to the cross-section level, and then adding them in quadrature. The uncertainties rising from Jet Energy Resolution (JER) and Jet Angular Resolution (JAR) are also propagated through the cross-section level randomly smearing the JES according to the resolutions. Unfolding non-closure and jet cleaning efficiency are also considered as systematic uncertainties, however they are fairly small with respect to the JES uncertainty across all the y^* and dijet mass bins. The statistical uncertainty is assessed via pseudo-experiments exploiting 10000 replicas of data spectra and MC response matrices with Poisson distributed random event weights centered at one.

4. Results and Discussion

The measured cross-section is presented in Fig. 1 overlaid with the theoretical prediction with the CT10 PDF set. A general agreement is observed between the data and the theoretical prediction covering almost 8 orders of magnitude in the measured cross-section values. To express the level of agreement quantitatively, a frequentist method is used exploiting a generalised definition of χ^2 to account for correlations and the asymmetries in the systematic uncertainties. The resulting observed *P values* for several PDF sets are shown in the Fig. 2, where the ratio of the theoretical prediction over the measured cross-section is illustrated.

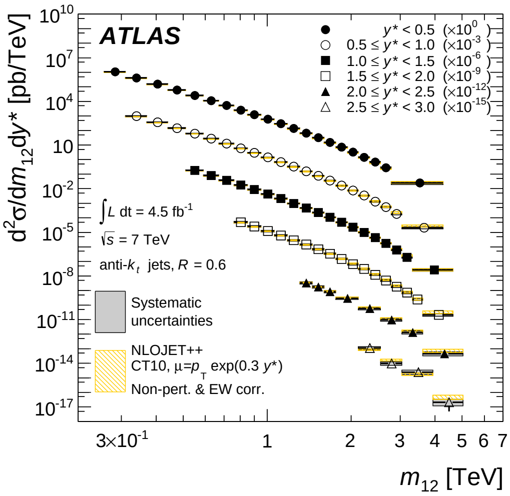

Figure 1: Dijet double differential cross-sections as a function of dijet invariant mass in different y^* bins in data and theoretical prediction for anti-k_t jets with R=0.6 [1].

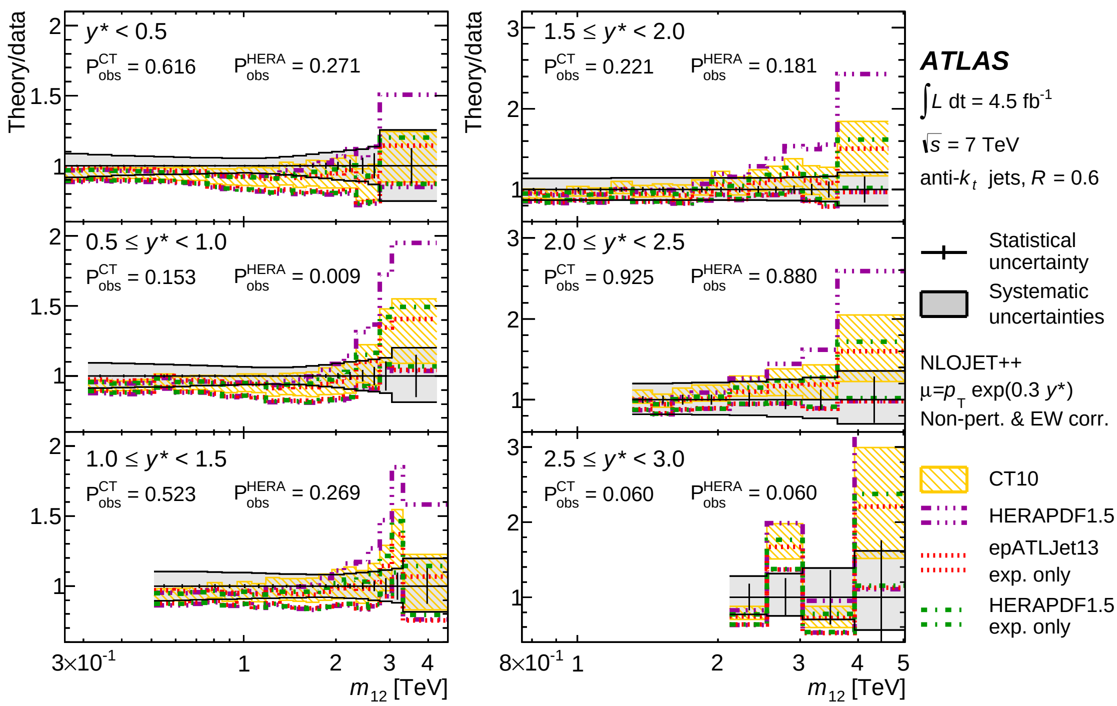

Figure 2: The ratios of the cross-sections predicted by theory with several PDF sets over the measured ones as a function of dijet invariant mass in different y^* bins [1].

No major deviation of data from theory prediction is observed for CT10, MSTW2008, NNPDF2.3 PDF sets. The agreement is somewhat worse for HERAPDF1.5 PDF set in the high mass range of the spectra and for ABM11 PDF set almost across all the spectra in the first y^* bins.

5. Conclusions

Dijet double differential cross-section is measured with 4.5 fb^{-1} of proton-proton collision data at $\sqrt{s} = 7$ TeV with the ATLAS detector [1]. These results extend the kinematic reach and experimental precision with respect to the previous ATLAS publication [6] due to more statistics and improved understanding of JES. The measured cross-sections are quantitatively compared with NLO pQCD predictions with various PDF sets corrected for higher order electro-weak and non-perturbative effects. In general, predictions agree with the measurement except for some PDF sets in specific kinematic regions. These results can be exploited to further constrain the PDFs at high momentum fraction, as well as to confront different theoretical models beyond the Standard Model with the data, as shown in the example given in [1]. The used method for the assessment of the statistical uncertainties via pseudo-experiments also allows taking automatically into account the statistical correlations when combining this measurement with any other one, that is based on the same data sample and uses the same method.

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