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Differential jet cross sections at the CMS experiment

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We present measurements of differential jet cross sections over a wide range in transverse momenta from inclusive jets to multi-jet final states. Studies on the impact that these measurements have on the determination of the strong coupling α_s as well as on parton density functions are reported.

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1. Introduction

Collimated bunches of particles, conventionally called jets, are produced in proton-proton (pp) collisions at the LHC. The measurement of the cross sections for inclusive jet production in pp collisions can test predictions of perturbative QCD (pQCD) and is sensitive to the value of the strong coupling α_s, which is a fundamental parameter of QCD. In addition, this provides important constraints on the description of the structure of proton, expressed by the parton distribution functions (PDFs).

Analyses performed using the LHC data by the CMS experiment [1] generally employ the anti-k$_T$ jet algorithm [2] with different jet values of the size parameter R ranging between 0.4 and 0.7. In this note, results of inclusive jet measurements at center-of-mass energies $\sqrt{s}$ =7 [3], 8 [4], and 13 [5] TeV are presented. The phase space in rapidity is subdivided into six ranges, from |y| = 0 to |y| = 3 with $|\delta y|$ = 0.5. For the measurement at 13 TeV, one bin from $3.2 \leq |y| \leq 4.7$ is also added which is normally referred to as 'forward rapidity region'. In the analysis performed at $\sqrt{s} = 7$ TeV, the ratio R(0.5,0.7), between the cross sections measured for jets reconstructed with jet sizes R = 0.5 and 0.7, is also shown.

2. Jet measurements and double-differential inclusive jet cross section

The data samples used for the measurements is collected with single-jet high level triggers (HLT). In each region, the HLT triggers are chosen to have an efficiency $> 99\%$ to detect a jet in the full rapidity coverage of the CMS experiment. The double-differential inclusive jet cross section is defined as:

$$\frac{d^2\sigma}{dp_{\mathrm{T}}dy} = \frac{1}{\varepsilon\mathscr{L}}\frac{N_j}{\Delta p_T \Delta y}$$

where $\mathscr{L}$ is the integrated luminosity, N_j is the number of jets in a bin of width Δp_{T} in the transverse momentum of the jet with respect to the beam axis and Δy in rapidity, and ε is the product of the trigger and jet selection efficiencies, which is $> 99\%$.

In order to compare the measured cross section with pQCD predictions at the particle level, the double-differential inclusive jet cross section is corrected using the unfolding technique. The unfolding procedure corrects the measured spectra for detector effects and is based on the iterative d'Agostini method [7]. The dominant contribution to the experimental systematic uncertainty on the measured cross sections is due to the jet energy scale (JES) [8]. Other sources of systematic uncertainty to the inclusive jet cross section measurements are the uncertainty on the determination of the integrated luminosity, dependence on the simulated event sample used for unfolding and the uncertainty on the jet energy resolution (JER).

NLOJET++ uses fixed-order NLO calculations for predicting the spectrum and uses different PDFs. Its predictions are corrected for electroweak (EW) and non-perturbative (NP) effects and uses PYTHIA8 for the complete event description. The predictions at the leading-order (LO) are obtained using PYTHIA6, PYTHIA8 and HERWIG++. POWHEG uses NLO matrix elemet calculations and is interfaced with PYTHIA6 and PYTHIA8 for a complete event description.

The unfolded inclusive jet cross sections for R = 0.5 and 0.7 as functions of p_{T} for different ranges of $|y|$ are compared to theoretical predictions of NLOJet++ based on the CT10 PDF set

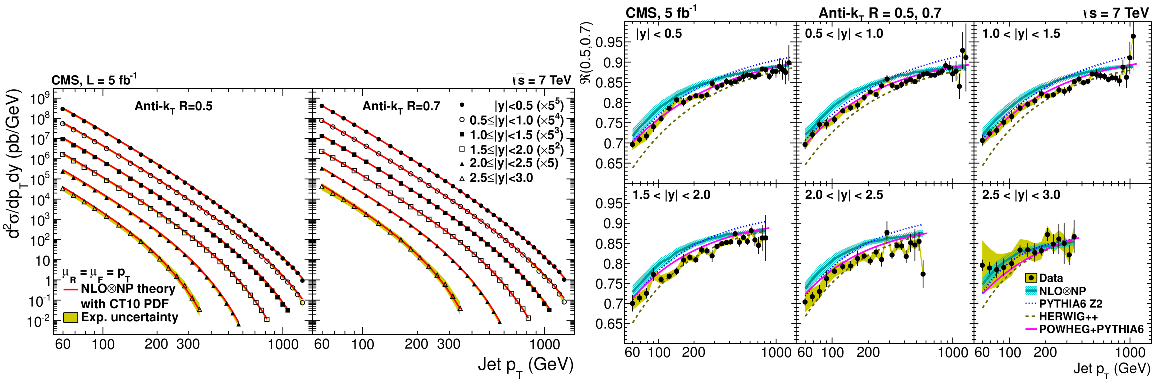

Figure 1: Double-differential cross sections for two choices of R, compared to NLO×NP predictions (left). Jet radius ratio R(0.5, 0.7) in six rapidity bins up to |y| = 3.0 are compared to various MC predictions (right) [3]

figure 1. Figure 1 also shows the ratios of cross-sections for R = 0.5 and 0.7. POWHEG, interfaced with PYTHIA6 gives the best overall agreement with the data. NP effects dominate in the low p_T region, where predictions of the Z2 tune of Pythia6 agree well with data. The HERWIG++ predictions, on the other hand, are in disagreement with the low p_T data, which is expected, primarily due to the limitations of the underlying event tune in HERWIG++.

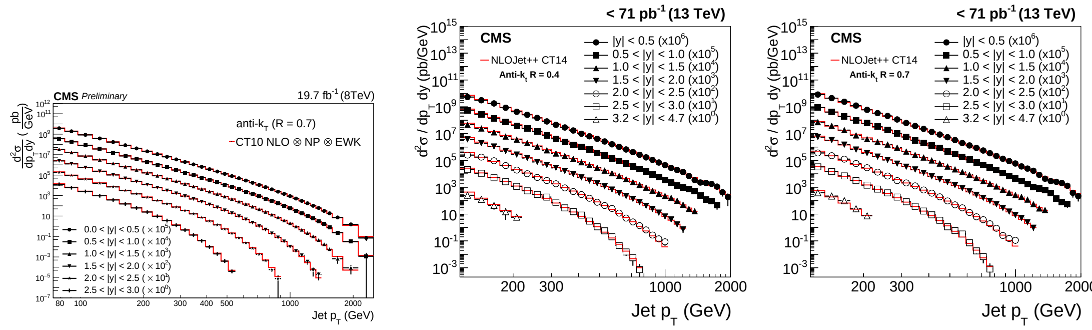

Figure 2: Double-differential inclusive jet cross sections as function of jet p_T measured at $\sqrt{s} = 8$ TeV(left) [4], $\sqrt{s} = 13$ TeV(middle and right) [5]. Data (points) and NLO predictions based on CT10 and CT14 PDFs set corrected for the NP factor and electroweak correction factor (line).

The left plot of figure 2 shows the measurement of the double-differential inclusive jet cross section at $\sqrt{s}$=8 TeV, presented as a function of p_{T} for different |y| ranges. The measurements are compared to the NLO theory predictions which use the CT10 PDF set. The data are consistent with the theoretical predictions for a wide range of jet p_{T} from 74 GeV up to 2.5 TeV.

The double-differential inclusive jet cross section measurements at $\sqrt{s}$=13 TeV are presented as functions of p_T for seven |y| ranges for R=0.4 and 0.7 are shown, respectively in the middle and right plots of figure 2. Ratio plots are shown in figure 3. Good agreement between data and NLOJET++ with CT14 PDF is observed for a wide range of jet p_T, from 114 GeV to 2 TeV. For R = 0.4, the NLOJET++ systematically overestimates by 5-10%, while provides a better description jets reconstructed with R = 0.7. The relatively poor agreement for R = 0.4 is due to PS and soft gluon resummation contributions, missing in fixed-order calculations, which is more relevant for

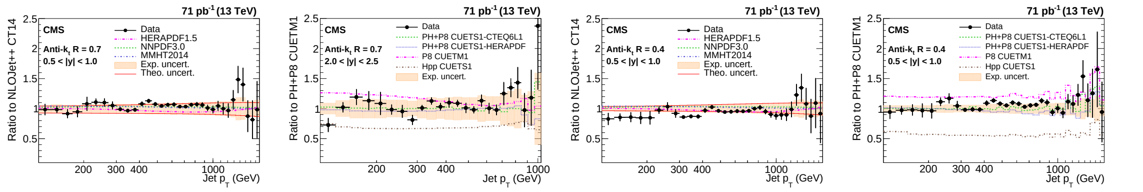

Figure 3: Ratios of measured values and predictions from NLOJET++ using the CT14 PDF set and corrected for the NP and EW for R = 0.7 (first) and 0.4 (third). Ratios of measured values and predictions from POWHEG(PH) + PYTHIA8(P8) with tune CUETM1 for R = 0.7(second) and 0.4(fourth) [5].

smaller jet cone sizes because of out-of-cone effects.

3. Summary and conclusions

Measurement of the double-differential cross section using data of proton-proton collisions collected by the CMS detector at centre-of-mass energies 7, 8, 13 TeV are presented as functions of jet transverse momentum, rapidity and jet sizes. Good agreement is observed between measurements and theoretical predictions based on perturbative quantum chromodynamics. In general, it is observed that jet cross sections for larger jet sizes are better described by fixed-order predictions complemented by corrections for nonperturbative and electroweak effects. For smaller jet sizes, theory overestimates the cross section by 5-10% almost globally. On the other hand for both jet sizes, NLO predictions matched to parton showers perform well. This collection of jet measurements is a crucial baseline for more exclusive analyses and shows that production of qurks and gluons in proton-proton collisions is well understood over a wide range of centre-of-mass energies at the TeV scale accessible at the LHC.

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