Measurements of jet production properties in CMS

Patrick Connor for the CMS Collaboration

Abstract

We present measurements of the inclusive jet production at centre-of-mass energies of 8 and 13 TeV, and of multijets at 8 TeV. These measurements allow to constrain PDFs and the strong coupling constant. Two measurements of the azimuthal correlations at 8 and 13 TeV are also presented, testing higher order QCD calculations.

Presented at LHCP2017 5th Large Hadron Collider Physics Conference 2017
Measurement of jet properties in CMS

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ABSTRACT

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PRESENTED AT

The Fifth Annual Conference
on Large Hadron Collider Physics
Shanghai Jiao Tong University, Shanghai, China
May 15-20, 2017

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Figure 1: Left: comparison to fixed-order parton-level calculations of the inclusive jet production at 8 TeV. Right: gluon PDF before and after inclusion of inclusive jet data [2].

1 Introduction

We summarise the six most recent jet measurements in CMS [1] at 8 and 13 TeV. Analog measurements at 8 and 13 TeV are presented together.

2 Inclusive jet analyses at 8 and 13 TeV

The double differential cross section as a function of the transverse momentum and the rapidity is given by

$$\frac{d^2\sigma}{dp_T^2dy} = \frac{1}{\epsilon L_{\text{eff}} \Delta p_T \Delta |y|} N_{\text{jets}}$$

(1)

At 8 TeV [2], the luminosity for the high $p_T$ region is 19.7 fb$^{-1}$, while for the low $p_T$ region with dedicated low-pile-up runs, it is 5.6 fb$^{-1}$. The measurement is performed for large cone size jets only with the anti-$k_T$ algorithm [8]. The rapidity coverage is $0 < |y| < 4.7$.

A similar measurement was performed with the first data at 13 TeV [3]. The luminosity is 71 pb$^{-1}$ in the central region ($|y| < 3.0$) and 44 pb$^{-1}$ in the forward region ($3.2 < |y| < 4.7$). The rapidity coverage and binning are kept the same as for the analysis at 8 TeV. The measurement at 13 TeV is performed for two cone size radii: $R = 0.4$ and $R = 0.7$.

The measurements are compared to predictions from MC event generators and from fixed-order parton-level calculations. In general, the uncertainty related to the correction of the jet energy scale is of the order of a percent.

The fixed-order calculation includes the electroweak and non-perturbative QCD corrections. We observe a very good agreement over the two orders of magnitude. The gluon PDF can be constrained with the inclusive jet data, and $\alpha_S$ can be extracted together with the fit of the PDF, as an additional parameter, with a value of $0.1164^{+0.0093}_{-0.0073}$. The measurement and the PDF fit are illustrated in Fig. 1.

The comparison to fixed-order parton-level calculations (not shown here) agrees better for a large cone size radius than for a small cone size radius. This is understood as being related to missing higher order calculations.

The comparison of the measurement with predictions from PowHEG + P8 (NLO + PS) shows very good agreement for both cone sizes at 13 TeV.
3 Multijet analysis at 8 TeV

The measurement of the multijet production was performed as a function of \( H_{T,n} = \sum_{i=1}^{n} p_{T,i} \) with all the jets of an event in the considered phase space [4]:

\[
\frac{d\sigma}{d(H_{T,2}/2)} = \frac{1}{\epsilon L_{\text{int}}^{\text{eff}} \Delta(H_{T,2}/2)} \frac{N_{\text{events}}}{N_{\text{events}}} \tag{2}
\]

Since \( R_{nn} = \frac{\sigma_{\text{out}}}{\sigma_{\text{jet}}} \propto \alpha_S \), \( \alpha_S \) can be extracted from the ratio of 3 and 2-jet measurements. Some uncertainties cancel in the ratio. The selection consists of jets of \( p_T > 150 \text{ GeV} \) in \( |y| < 2.5 \), clustered with the anti-\( k_T \) algorithm with \( R = 0.7 \). Events where the leading jet would be in the forward region are vetoed. The measurement is shown in Fig. 2 and \( \alpha_S = 0.1150^{+0.0088}_{-0.0038} \) is extracted.

4 Dijet triple differential cross section at 8 TeV

The triple differential cross section of the di-jet production at 8 TeV consists in the following measurement [5]:

\[
\frac{d^3\sigma}{dp_{T,\text{avg}}dy^*dy_b} = \frac{1}{\epsilon L_{\text{int}}^{\text{eff}} \Delta p_{T,\text{avg}} \Delta y^* \Delta y_b} \frac{N_{\text{di-jet events}}}{N_{\text{di-jet events}}} \tag{3}
\]

where

- \( p_{T,\text{avg}} = \frac{1}{2} (p_{T,1} + p_{T,2}) \) is the average transverse momentum of the di-jet system;
- \( y_b = \frac{1}{2} |y_1 + y_2| \) is the rapidity boost of the di-jet system;
- \( y^* = \frac{1}{2} |y_1 - y_2| \) is the rapidity separation of the di-jet system.

Anti-\( k_T \) jets with \( R = 0.7 \) are selected with \( p_{T,\text{jet}} > 50 \text{ GeV}, |y_{\text{jet}}| < 3.0 \) and \( p_{T,\text{avg}} > 133 \text{ GeV} \).

The different regions of the phase space are then exploited to extract the strong coupling and to constrain PDFs: the central region (small \( y_b \) and small \( y^* \)) is most suited for \( \alpha_S \) extraction at high energy scales; in the boosted region (higher \( y_b \) but small \( y^* \)), the high-\( x \) region of PDFs can be better constrained; finally, in the region of large rapidity separation (small \( y_b \) but higher \( y^* \)), PDF and detector effects can be better disentangled.

The measurement is compared first to NLO parton-level calculations as well as predictions from MC event generators (HERWIG 7 and PYTHIA 8). In general, predictions are slightly overestimated at high transverse momentum in the boosted region. Eventually, the di-jet data may be used to extract gluon PDFs. This is illustrated in Fig. 3.
5 Azimuthal correlations at 8 and 13 TeV

The azimuthal correlations allow to investigate higher-order QCD corrections: the more extra radiations, the less correlated the two leading jets.

CMS has published two measurements:

1. the measurement of the azimuthal correlations between the two leading jets at 8 TeV with a jet reconstructed with the anti-$k_T$ algorithm of $R = 0.7$ [6];

2. the analog measurement at 13 TeV for a radius of 0.4 [7]; in addition, the same measurement is also performed with minimum jet multiplicities of 3 and 4 jets in order to be more sensitive to higher order effects; finally, correlations between the subleading and the closest third- or fourth-leading jet are measured, also in order to increase the sensitivity to parton showers.

Here, given the large amount of results reported in these analyses, we only show corresponding measurements at 8 and 13 TeV in Fig. 4.

6 Conclusions

In general, the QCD predictions describe well the measurements. With jet data, gluon PDFs can be significantly improved at high $x$. The value of $\alpha_S$ is also extracted. The azimuthal correlations in multijet events illustrate the importance of higher-order QCD corrections.

References


Figure 4: Analog measurements at 8 and 13 TeV (with respective cone size radii) for the azimuthal correlations [7].

[4] CMS Collaboration, Determination of the strong coupling constant from the measurement of inclusive multijet event cross sections in pp collisions at $\sqrt{s} = 8$ TeV, CMS-PAS-SMP-16-008 (CDS 2253091)


[7] CMS Collaboration, Measurements of inclusive 2-jet, 3-jet and 4-jet azimuthal correlations in pp collisions at $\sqrt{s} = 13$ TeV, CMS-PAS-SMP-16-014 (CDS 2257685)