PROCEEDINGS OF SCIENCE

Inclusive jet, multijet and photon measurements

Deniz Sunar Cerci[a,b,*]

[a] *Adiyaman University,*
Faculty of Arts and Sciences, Department of Physics, 02040 Adiyaman, Turkey
[b] *On behalf of the ATLAS and CMS Collaborations*

E-mail: Deniz.Sunar.Cerci@cern.ch

The large amount of data at the LHC allows the study of QCD with unprecedented precision. In this document, recent measurements performed by the ATLAS and CMS Collaborations are presented, based on samples of inclusive jet, multijet and photon events. The data are compared to higher-order calculations and various Monte Carlo generator predictions.

The Tenth Annual Conference on Large Hadron Collider Physics-LHCP2022
16-20 May, 2022
online

*Speaker

PoS(LHCP2022)121

1. Introduction

During the Run 2 period, a large amount of data has been accumulated by the Large Hadron Collider (LHC) providing rich jet data in a previously unexplored region. Jets are the fundamental probes to test the higher order pertubative quantum chromodynamics (QCD) predictions as well as to extract the strong coupling constant α_S. The final states with high jet multiplicities can be used to tune Monte Carlo generators and to study hadronization effects. In the following, recent jet and photon related measurements performed with the data collected by the ATLAS [1] and CMS [2] experiments are presented.

2. Jet reconstruction

Jets are collimated sprays of charged and neutral hadrons. In the ATLAS and CMS experiments, jet reconstruction is performed by using a particle-flow (PF) algorithm which identifies and reconstructs the individual particles in the event by combining the information from all subdetectors. The anti-k_T clustering algorithm [3] is widely used in both experiments. The main experimental difficulties for jet-based measurements are the jet energy calibration, the estimation of the jet energy resolution and the subtraction of pileup effects. The reconstructed jet energy must be corrected for several effects including pile-up interactions, the jet flavor composition and the absolute and relative jet energy scale. The effect of the hadron content on the detector response of hadronic jets has been investigated by the ATLAS Collaboration using several Monte Carlo simulation models [4]. The ratio of the jet response between the default Pythia8 sample and the various Monte Carlo samples is shown in Fig. 1 (left). Significant variations are observed between the baseline Pythia8 model and the other generator configurations. A study on jet energy scale and resolution using 13 TeV legacy data collected from 2016-2018 has been performed by the CMS Collaboration [5]. Absolute transverse momentum p_T dependent residual correction is shown in Fig. 1 (right). The great agreement between different methods is observed.

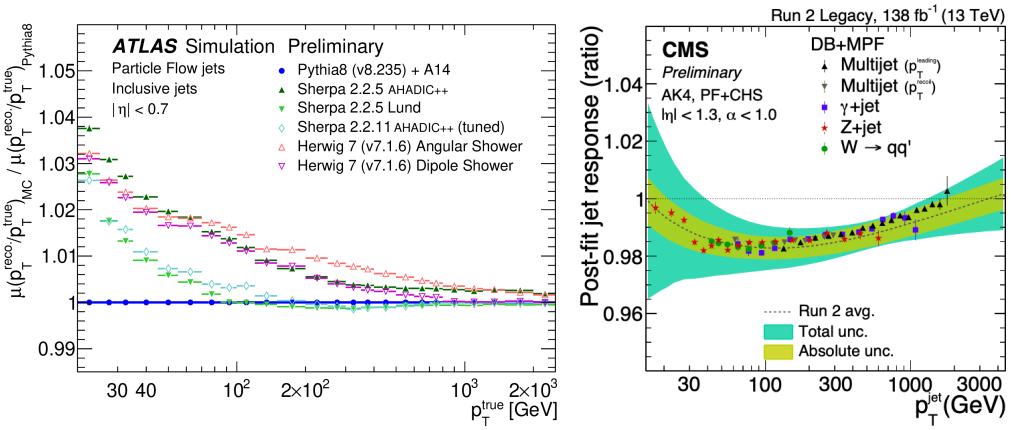

Figure 1: Left: Response to inclusive jets for different MC simulations normalized to that for Pythia8 [4]. Right: Residual jet energy corrections [5].

3. Inclusive and multiple jets measurements

A first measurement of the differential inclusive jet production cross section in proton-proton collisions at $\sqrt{s} = 5$ TeV has been performed by the CMS experiment [6]. In Fig. 2 (left), results are compared with the NLO theoretical prediction, using the CT14NLO PDF set. Such a measurement can complement data from other collision energies in offering new constraints to proton PDFs.

Inclusive jet cross sections are measured in proton-proton collisions at a centre-of- mass energy of 13 TeV in CMS [7] and ATLAS [8], with an integrated luminosity of 33.5 fb^{-1} and 3.2 fb^{-1}, respectively. The CMS measurement relies on reconstructed anti-k_T jets within a cone parameter of 0.4 and 0.7. The inclusive jet cross sections as functions of the jet p_T and $|y|$ for $R = 0.7$ is shown in Fig. 2 (right). A comprehensive QCD analysis is performed to investigate the sensitivity of the presented measurement to the proton PDFs and α_S and the top quark mass is determined as $m_t^{pole} = 170.2 \pm 0.6\,(\text{fit}) \pm 0.1\,(\text{model})$ GeV. The understanding of characteristics of the events with multijets play an important role in precision measurements, as well as in searches for new physics.

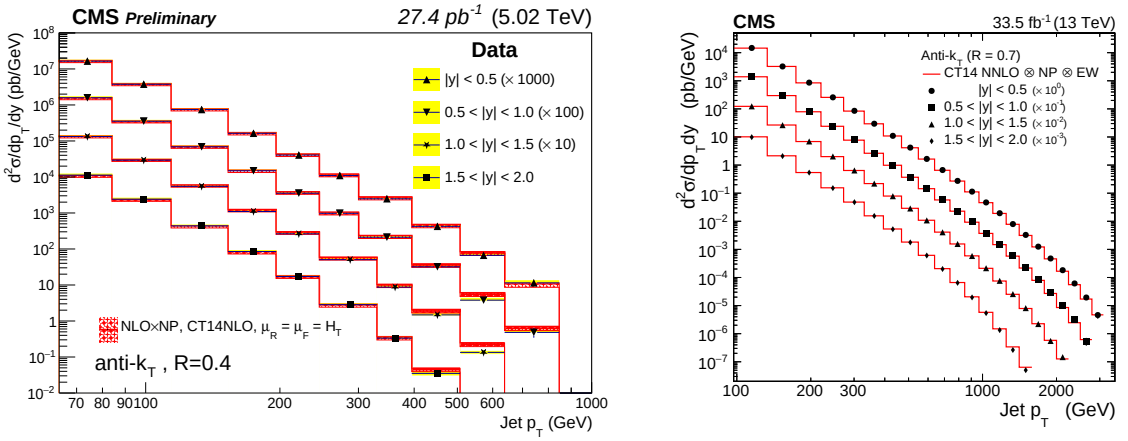

Figure 2: Inclusive jet cross sections as a function of p_T and y, for anti-k_T jets with (left) $R = 0.4$ at $\sqrt{s} = 5$ TeV [6] and (right) with jet $R = 0.7$ at $\sqrt{s} = 13$ TeV [7].

A recent CMS analysis investigates the properties of multijet events, measuring their multiplicity, p_T distributions and their azimuthal correlations [9]. The same analysis strategy as the inclusive jet measurement at 13 TeV is followed except the jets clustered with $R = 0.4$ are used. The events which have at least two jets with the leading jet of $p_{T1} > 200$ GeV and subleading jet of $p_{T2} > 100$ GeV are considered. All jets must satisfy the range of $|y| < 2.5$. The multiplicity of additional jets with $p_T > 50$ GeV is measured in bins of the azimuthal separation between leading and subleading jets ($\Delta\phi_{1,2}$) and transverse momenta of the leading jet (p_{T1}). Results are compared to NLO dijet and three-jet predictions as well as with Parton Branching (PB) Transverse Momentum Dependent (TMD) parton densities and PB-TMD initial state parton shower as shown in Fig. 3. Reasonable agreement is observed with the normalization of MG5 AMC+PY8 (jj) NLO calculation even for three jets. The measurement is larger than the predictions particularly in the low p_{T1} region.

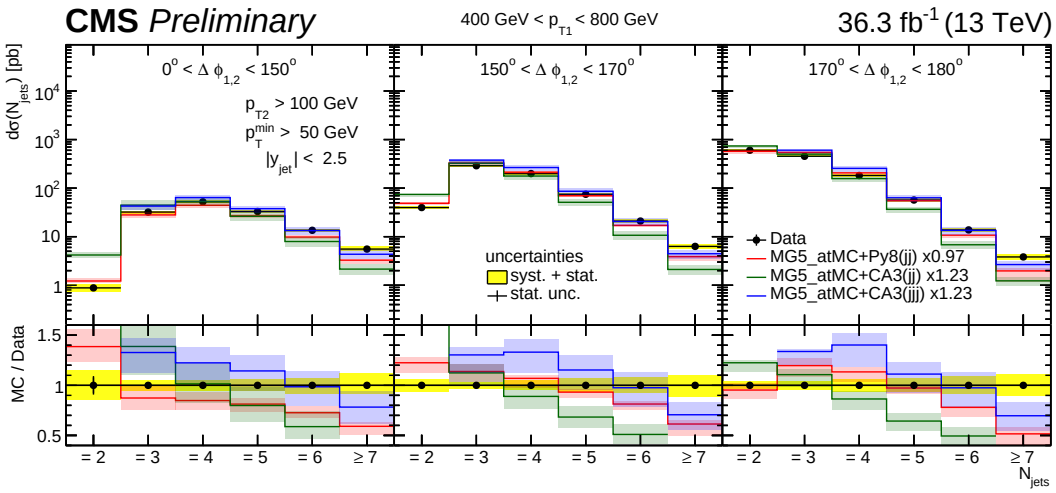

Figure 3: Comparison of the differential cross section of two leading jets as a function of the exclusive jet multiplicity (inclusive for 7 jets) in bins of p_{T1} and $\Delta\phi_{1,2}$ [9]. NLO QCD matrix-element calculations MG5_atMC + CA3(jj) and MG5_atMC + CA3(jjj) are combined with Parton Branching (PB) Transverse Momentum Dependent (TMD) parton densities and PB-TMD initial state parton shower.

4. Z/γ+jets measurements

The production of Z bosons in association with jets in proton-proton collisions at a centre-of-mass energy of 13 TeV has been measured by CMS [10]. In the analysis, single- and double-differential observables are unfolded to particle level and compared with predictions from LO and NLO calculations as well as various Monte Carlo event generators. Another recent ATLAS analysis explores the properties of events with a Z boson and at least one high-p_T jet in proton collisions at 13 TeV [11]. Furthermore, ATLAS has extensively studied the events with two photons including fiducial and differential cross sections [12].

5. Summary

Jet physics providing several tests of the perturbative QCD, is an essential part of the scientific program of the ATLAS and CMS experiments. Extensive jet measurements in proton-proton collisions at different centre-of-mass energies performed by the ATLAS and CMS Collaborations are impressive both in terms of quantity and relevance. Existing Run 2 data together with the new Run 3 may help further explorations the results and verifications of Standard Model predictions.

References

[1] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, JINST **3** (2008) S08003, doi:10.1088/1748-0221/3/08/S08003.

[2] CMS Collaboration, *The CMS Experiment at the CERN LHC*, JINST **3** (2008) S08004, doi:10.1088/1748-0221/3/08/S08004.

[3] M. Cacciari, G.P. Salam and G. Soyez, *The Anti-k(t) jet clustering algorithm*, JHEP **0804** (2008) 063, doi:10.1088/1126-6708/2008/04/063.

[4] ATLAS Collaboration, *Dependence of the jet energy scale on the particle content of hadronic jets in the ATLAS detector simulation*, ATL-PHYS-PUB-2022-021, https://cds.cern.ch/record/2810864.

[5] CMS Collaboration, *Jet energy scale and resolution measurement with Run 2 legacy data collected by CMS at 13 TeV*, CMS-DP-2021-033, https://cds.cern.ch/record/2792322.

[6] CMS Collaboration, *Measurement of the double-differential inclusive jet cross section in proton-proton collisions at* $\sqrt{s}$ = 5.02 *TeV*, CMS-PAS-SMP-21-009, https://cds.cern.ch/record/2777126.

[7] CMS Collaboration, *Measurement and QCD analysis of double-differential inclusive jet cross sections in proton-proton collisions at* $\sqrt{s}$ = 13 *TeV*, JHEP **2022** (2022) 142, doi:10.1007/JHEP02(2022)142.

[8] ATLAS Collaboration, *Measurement of inclusive jet and dijet cross-sections in proton-proton collisions at* $\sqrt{s}$ = 13 *TeV with the ATLAS detector*, JHEP **1805** (2018) 195, doi:10.1007/JHEP05(2018)195.

[9] CMS Collaboration, *Cross section measurements of jet multiplicity and jet transverse momenta in multijet events at* $\sqrt{s}$ = 13 *TeV*, CMS-PAS-SMP-21-006, https://cds.cern.ch/record/2776772.

[10] CMS Collaboration, *Measurement of multi-differential cross sections for the production of a Z boson in association with jets in proton-proton collisions at* $\sqrt{s}$ = 13 *TeV*, CMS-PAS-SMP-19-009, https://cds.cern.ch/record/2767703.

[11] ATLAS Collaboration, *Measurements of the production cross section of a Z boson in association with high transverse momentum jets in pp collisions at detector*, ATLAS-CONF-2021-033, https://cds.cern.ch/record/2777239.

[12] ATLAS Collaboration, *Measurement of the production cross section of pairs of isolated photons in pp collisions at 13 TeV with the ATLAS detector*, JHEP **169** (2021), doi:10.1007/JHEP11(2021)169.