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Electroweak and QCD aspects in vector boson plus jets associated production with CMS

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The study of the associated production of vector bosons and jets constitutes an excellent testbench to check numerous QCD predictions. Measurements of the total and differential cross sections of vector bosons produced in association with jets have been performed at 13 TeV center-of-mass energies with the CMS experiment at the LHC. Differential distributions as function of a broad range of kinematical observables are measured and compared with theoretical predictions. Final states with a vector boson and jets can be also used to study electroweak initiated processes, such as the vector boson fusion production of a Z boson that is accompanied by a pair of energetic jets having large invariant mass.

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1. Introduction

Measurements of total and differential production cross sections of vector bosons produced in association with jets are instrumental for fundamental tests of perturbative quantum chromodynamics (pQCD) and help to better understand strong interactions. The high center-of-mass energy of collisions at the CERN LHC facilitates the production of these events, reaching out to high jet p_T and high-multiplicity multijet final states. The production of vector bosons in association with jets is also an important background for many Standard Model (SM) processes as well as for searches for physics beyond the SM. In this contribution, recent differential cross section measurements of W [1], Z [2], and γ [3] in association with jets in proton-proton collisions at $\sqrt{s} = 13$ TeV with the CMS experiment [4] are discussed.

The pure electroweak production of the $Z(\to \ell\ell)jj$ final state has been studied in detail in [5]. This EWK Zjj process exhibits the typical signature of a Vector Boson Fusion (VBF) process: two jets with large energy and pseudorapidity separation produced in association with a dilepton pair from the Z boson decay. The study is important for a more general investigation of VBF and scattering processes in both SM and physics beyond the SM. The properties of the EWK Zjj production are compared to the SM predictions and the final state is also used to perform a search for anomalous trilinear gauge couplings.

2. Measurements of differential cross sections of vector boson plus jets production

2.1 W+jets

The differential W+jets cross section measurement [1] is based on 13 TeV proton-proton collision data corresponding to an integrated luminosity of $2.2\,\text{fb}^{-1}$, recorded by the CMS detector at the LHC in 2015. The cross sections are measured in the muon decay channel of the W boson as a function of various kinematic quantities: the jet multiplicity, jet transverse momentum p_T, jet rapidity, the scalar p_T sum of the jets, and angular correlations between the muon and each jet for different jet multiplicities. The measured cross sections are compared to the predictions from Monte Carlo (MC) event generators that use a leading-order (LO), or a next-to-LO (NLO) matrix element (ME) calculation interfaced with parton showering, and with a fixed-order calculation of a W boson and one jet (W+1-jet) at next-to-NLO (NNLO). The results for the exclusive jet multiplicity is shown in Figure 1 (left). The predictions describe the data well within uncertainties as functions of the exclusive and inclusive jet multiplicities and are in good agreement with data for the jet p_T spectra, with the exception of the LO MG_aMC prediction, which underestimates the data at low to moderate jet p_T.

2.2 Z+jets

The differential Z+jets cross section measurement [2], with a leptonically decaying Z boson, is performed on data from proton-proton collisions at a centre-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 2.2 fb^{-1}. The cross section is measured as a function of the jet multiplicity and its dependence on the transverse momentum of the Z boson, the jet kinematic variables (transverse momentum and rapidity), the scalar sum of the jet momenta, which quantifies the hadronic activity, and the balance in transverse momentum between the reconstructed jet recoil

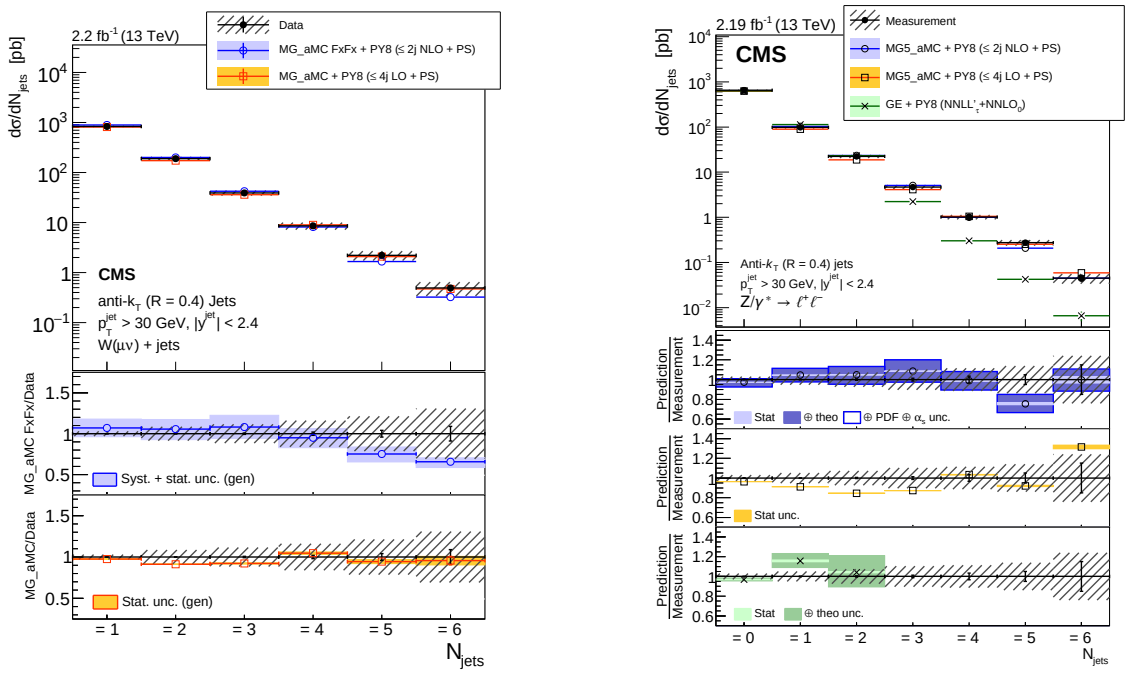

Figure 1: Differential W+jet cross section measurement for the exclusive jet multiplicity [1] (left), and differential Z+jet cross section measurement for the exclusive jet multiplicity [2] (right), compared to the predictions of NLO MG_aMC FxFx and LO MG_aMC (W/Z+jet) and a combination of NNLO calculation with NNLL resummation, based on GENEVA, and parton showering with PYTHIA8 (Z+jet).

and the Z boson. In addition to the equivalent predictions discussed in Section 2.1, a combination of NNLO calculation with NNLL resummation, based on GENEVA, and parton showering with PYTHIA8 is available for some observables. The results for the exclusive jet multiplicity are shown in Figure 1 (right). The measured cross sections are in good agreement with the results of the NLO multiparton calculation. The multiparton LO prediction exhibits significant discrepancies with data in jet multiplicity as well as transverse momentum and rapidity distributions of the leading jet.

2.3 γ+jets

Measurements of the photon+jet production in data from proton-proton collisions at $\sqrt{s} = 13\,\text{TeV}$, corresponding to an integrated luminosity of $2.3\,\text{fb}^{-1}$, are presented in detail in [3]. The cross section for photon+jet production is measured as a function of the photon transverse energy, binned in two photon rapidity and two jet rapidity bins, see Figure 2 (left). Measured cross sections are in agreement with NLO perturbative QCD calculations from the JETPHOX 1.3.1 generator within statistical and systematic uncertainties.

3. Electroweak production of Z+jets

The pure electroweak production of the $(Z \to ll)\,jj$ final state has been studied in detail in [5], analysing data corresponding to an integrated luminosity of $35.9\,\text{fb}^{-1}$. The measured cross section in the kinematic region $m_{\ell\ell} > 50\,\text{GeV}$, $m_{\text{jj}} > 120\,\text{GeV}$, and transverse momenta $p_{\text{Tj}} > 25\,\text{GeV}$ is

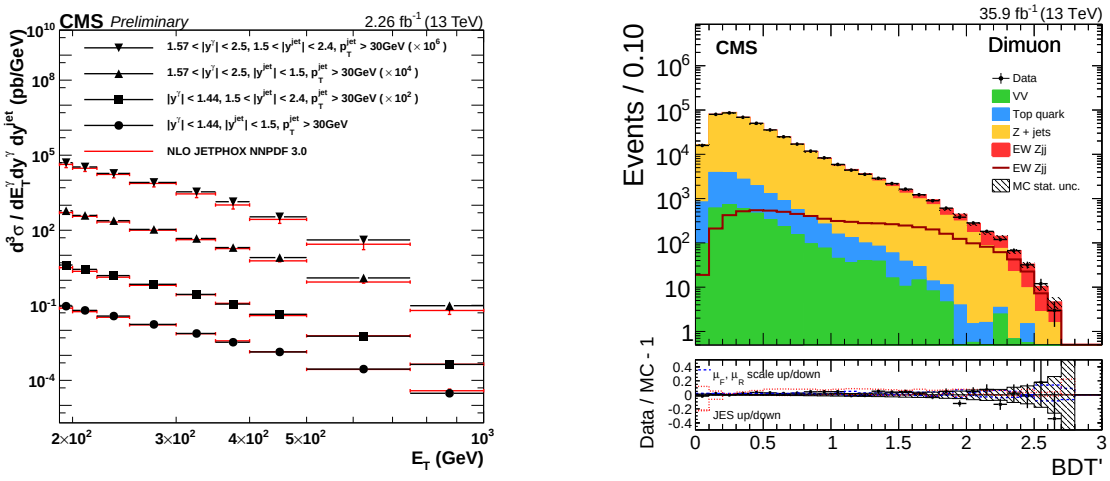

Figure 2: Measurement of γ+jet triple differential cross section in photon E_{T}, y^{photon}, and y^{jet} of highest p_{T} jet, compared to NLO QCD calculations [3] (left). Distribution of the BDT discriminant for separation of EWK $(Z \to ll)jj$ from background in dimuon events. The contributions from the different background sources and the signal are shown stacked, with data points superimposed. The expected signal-only contribution is also shown as an unfilled histogram [5] (right).

extracted using a BDT discriminant shown in Figure 2 (right) and measured as $\sigma_{\mathrm{EW}}(\ell\ell\mathrm{jj}) = 534 \pm 20\,(\mathrm{stat}) \pm 57\,(\mathrm{syst})$ fb, in agreement with leading-order standard model predictions.

4. Conclusion

The latest CMS measurements of the associated production of $\mathrm{W}^{\pm}/\mathrm{Z}/\gamma$ and jets, as well as the study of electroweak initiated vector boson fusion production of a Z boson accompanied by a pair of energetic jets have been summarized. SM predictions are in general in good agreement with these measurements.

References

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