PRAMANA — journal of physics
© Indian Academy of Sciences
Vol. 86, No. 2
February 2016
pp. 487–491

Z^0/γ^*+Jet via electron decay mode at $\sqrt{s} = 7$ TeV in CMS@LHC

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DOI: 10.1007/s12043-015-1170-x; ***e*Publication:** 23 January 2016

Abstract. The area-normalized angular distributions in events containing a Z^0 boson and a jet, using the electron decay mode, are presented. The data samples correspond to 5 fb^{-1} of proton–proton collisions at $\sqrt{s} = 7$ TeV, collected by the CMS detector. Events in which there is a Z boson and at least one jet, with a jet transverse momentum threshold of 30 GeV/c and absolute jet rapidity less than 2.4, are selected for this analysis. We compare our measurements with a next-to-leading order perturbative QCD calculation and two generators that combine tree-level matrix element calculations with parton showers.

Keywords. CMS; angular; electron; reconstruction.

PACS Nos 29.85.Fj; 29.90.+r

1. Introduction

The measurement of the angular distributions has been a tool for understanding the structure and interactions of matter from the time of Rutherford first scattering experiments. At the Large Hadron Collider (LHC), copious amounts of prompt photons and Z bosons (collectively called V) in association with jets are produced. The measurement of the rapidity distributions of Z+jet events is necessary for characterizing Higgs boson properties, and for providing an important test of the modelling of these properties in theory calculations. For Z boson decays to electron and muon pairs, the signal is nearly background-free, and triggering is very efficient. From a theoretical point of view, the presence of the electroweak vertex makes the perturbative calculation of dynamical quantities more stable, and next-to-leading order (NLO), perturbative quantum chromodynamics (pQCD) calculations exist for Z+up to 4 jets [1] and photon+jet production [2,3].

The rapidity of a particle is defined as $Y = 1/2 \log((E + pz)/(E - pz))$, where E is the energy and p_z is the momentum component along the direction of one of the proton beams. If the V and the jet are the only objects in the event, the polar scattering angle (θ^*)

is defined with respect to the incident proton direction in the two-object centre of momentum (COM) reference frame, and can be written in terms of the measured quantities Y_V and Y_{jet} as $\cos\theta^* = \tanh(Y_{\text{dif}})/\beta^*$,where β^* is the speed of V and $Y_{\text{dif}} = |Y_V - Y_{\text{jet}}|/2$. The quantity $Y_{\text{sum}} = |Y_V + Y_{\text{jet}}|/2$ approximates the rapidity boost from laboratory to the COM reference frame. In the laboratory frame, Y_V and Y_{jet} are highly correlated because there is usually a relatively high momentum quark interacting with a low momentum gluon or antiquark. The transformed rapidity relations ($Y_{\text{sum}}, Y_{\text{dif}}$) are effectively a rotation in phase-space of the system (Y_V, Y_{jet}), resulting in two approximately uncorrelated quantities. At leading order (LO), matrix element calculations of V+jet events have asymptotic small-angle $\cos\theta^*$ distributions which vary in proportion to $1/(1 - |\cos\theta^*|)$, while the dijet spectrum is proportional to $1/(1 - |\cos\theta^*|)^2$. The difference is due to the spin of their respective propagators. Theory predictions of all the four Y distributions, Y_V, Y_{jet} , Y_{sum} and Y_{dif}, are compared with data taken by the compact muon solenoid (CMS) detector.

This paper is organized as follows: In §2, we briefly discuss some relevant details of the detector. Section 3 lists the data and simulated samples used in this analysis and describes our selection criteria. Results for data and MC comparison are discussed in §4. We conclude in §5.

2. CMS detector

A counterclockwise coordinate system is used in CMS, with the origin at the nominal interaction point, the x-axis pointing to the centre of the LHC ring, the y-axis pointing up (perpendicular to the LHC plane) and the z-axis along the anticlockwise beam direction. The polar angle θ is measured from the positive z-axis and the azimuthal angle ϕ is measured in the $x-y$ plane. Pseudorapidity, which is given by $\eta = \ln[\tan(\theta/2)]$, is used for acceptance requirements. The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, providing a magnetic field of 3.8 T. Within the field volume are a silicon pixel and a strip tracker, an electromagnetic calorimeter and a brass/scintillator hadron calorimeter. Muons are detected in gas ionization detectors embedded in the steel return yoke. In addition to the barrel and end cap detectors, CMS has extensive forward calorimetry. A more detailed description of CMS is given in [4].

3. Event selection

The proton–proton collision data recorded for this analysis by CMS during 2011 at $\sqrt{s} =$ 7 TeV correspond to an integrated luminosity of (4.9 ± 0.1) fb^{-1}. The dielectron events are triggered using two electron candidates with transverse momentum p_{T} thresholds of 17 and 8 GeV as well as loose shower shape and isolation cuts. All fully reconstructed Monte Carlo (MC) samples used in this analysis were produced during the 'Summer 2011' official production. For this analysis, exclusive $Z + 1$ jet events are used to isolate the differences between the data and the theory. If another jet with $p_{\text{T}} > 30$ GeV and $|\eta| < 2.4$ exists, the event is rejected. To reconstruct jets and leptons, the particle flow (PF) algorithm [5] is used, which attempts to identify all the stable particles in an event by using the full ensemble and redundancy of the CMS detector. Offline event analysis requires at least one reconstructed vertex in the centre of CMS ($|z_{\text{vertex}}| < 15$ cm) and inside the beam pipe (< 2 cm).

Jets are reconstructed using the anti-kT algorithm [6] with a distance parameter of $R = 0.5$ and are required to have $|\eta| < 2.4$ to benefit from the tracker coverage. The energy of particles arising from the additional overlapping pp interactions in the same bunch crossing, but not associated with hard scattering, is referred to as pile-up. This energy is subtracted using vertex information. The neutral energy from pile-up events adds 0.5 GeV per additional interaction to the jet energy, which is subtracted on an event-by-event basis. Dielectron events are required to have at least two oppositely charged reconstructed electrons with $p_{\mathrm{T}} > 20$ GeV, $|\eta| < 2.1$ and an invariant mass (M_{ee}) in the range of 76–106 GeV around the Z boson mass. We apply a minimum p_{T} threshold on the Z^0 boson at 40 GeV/c. Although the $p_{\mathrm{T}}(Z^0) > 40$ GeV/c selection reduces the amount of events available at large Y_{dif} and Y_{sum}, it allows a fair comparison with the photon channel [7]. Detailed explanation of electron reconstruction in CMS can be found in [8]. The combined relative isolation of a lepton is defined as the sum of electromagnetic and hadronic calorimeter energies, plus charged track momentum in a $\eta - \phi$ cone of radius 0.4, divided by the lepton momentum. Electrons and jets are required to be separated $[R(e, \text{jet}) > 0.5]$ in η–ϕ space. After this selection, the sample is 99% pure in $Z + 1$ jet events. Small contributions from the processes $t\bar{t}$, diboson production and from QCD processes are neglected.

4. Results

We compare the rapidity distributions for events with a Z boson in association with one jet between MC and data at Large Hadron Collider using the CMS detector. The proton–proton collision data used in this analysis correspond to an integrated luminosity of

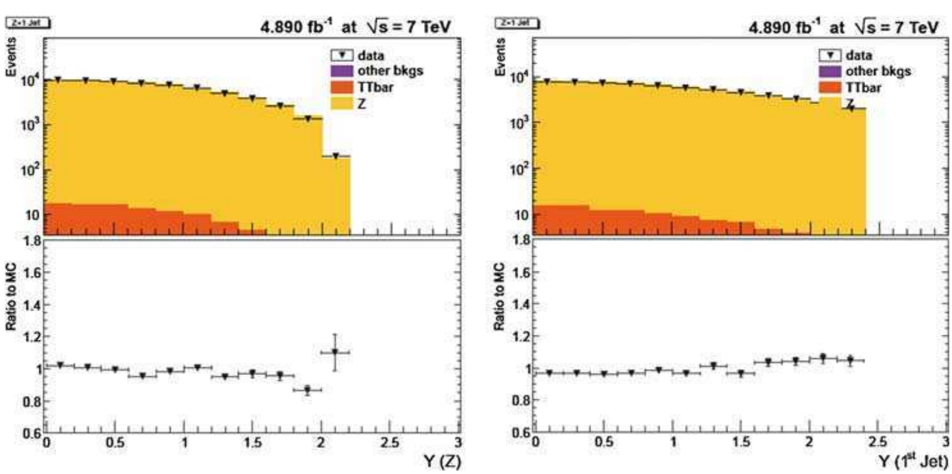

Figure 1. Distributions from the data and from the sum of simulated MADGRAPH Z^0/γ^*, $t\bar{t}$ + jets and PYTHIA QCD events, for $|Y_z|$ and $|Y_{\text{jet}}|$.

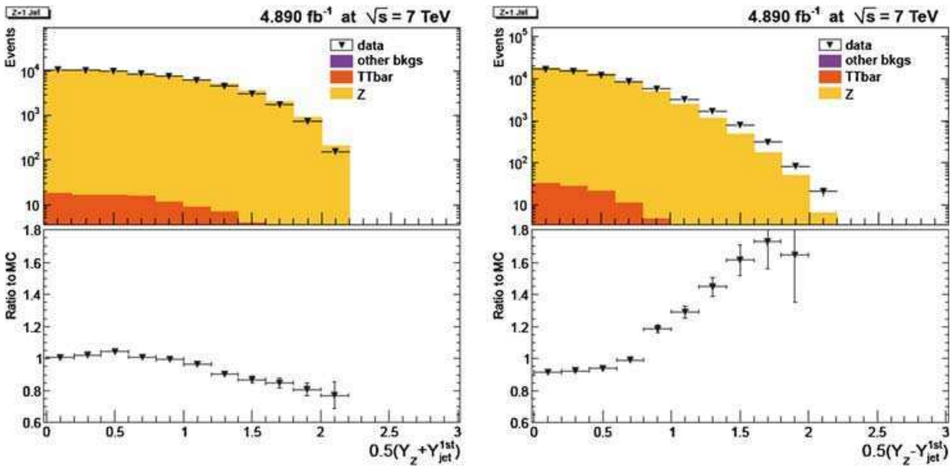

Figure 2. Distributions from the data and from the sum of simulated MADGRAPH Z^0/γ^*, $t\bar{t}$ + jets and PYTHIA QCD events, for $|Y_{\rm sum}| = 0.5(Y_Z + Y^{\rm 1st}_{\rm jet})$ and $|Y_{\rm dif}| = 0.5(Y_Z - Y^{\rm 1st}_{\rm jet})$.

4.9 fb^{-1} at $\sqrt{s}$ = 7 TeV. Rapidity distributions that are compared between the data and MC are: Y_V, $Y_{\rm jet}$, $Y_{\rm sum}$ and $Y_{\rm dif}$. Figure 1 shows the distributions from the data and sum of simulated MADGRAPH [9] Z^0/γ^*, $t\bar{t}$ + jets and PYTHIA [10] QCD events, for $|Y_Z|$ and $|Y_{\rm jet}|$. $|Y_{\rm sum}|$ and $|Y_{\rm dif}|$ distributions from the data and MC are shown in figure 2. The agreement between the data and MC is good as seen in figures 1 and 2. These measurements will be compared with a next-to-leading order perturbative QCD calculation and two generator programs that combine tree-level matrix element calculations with parton showers.

5. Conclusions

We present the area-normalized distributions of the angular correlation in events containing $Z^0(\rightarrow ee)$ + Jet, using 4.9 fb^{-1} of proton–proton collisions at $\sqrt{s}$ = 7 TeV collected by CMS in the year of 2011. Good agreement is found between the data and MC [11].

Acknowledgements

This work is done in collaboration with A P Singh, S S Yu, D Mekterovic, Y H Chang, W Lin and L K Saini from National Central University, Chung-Li, Taiwan. The authors thank CMS Collaboration for their help and support. The authors acknowledge UGC/DAE/DST (Govt. of India) for financial support.

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