PRAMANA — journal of physics

Vol. 79, No. 5
November 2012
pp. 1285–1288

W/Z+jet(s) production in pp collisions at $\sqrt{s} = 7$ TeV

S B BERI, L K SAINI and A P SINGH*, on behalf of the CMS Collaboration
Department of Physics, Panjab University, Chandigarh 160 014, India
*Corresponding author. E-mail: singh.ap79@gmail.com

Abstract. The measurements of the cross-sections are presented for the production of jets in association with W and Z bosons reconstructed in their decays to electrons and muons. The results are based on 36 pb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV collected by the CMS Collaboration. Jets are reconstructed with the CMS particle flow algorithm and must pass a transverse momentum threshold of 30 GeV. The study presents the ratios $\sigma(V+ \geq n\text{-jet})/\sigma(V)$ and $\sigma(V+ \geq n\text{-jet})/\sigma(V+ \geq (n-1)\text{-jet})$. The comparison between the data and the Monte Carlo prediction is also showed.

Keywords. Large Hadron Collider; CMS; Z boson; jets.

PACS No. 14.70.Hp

1. Introduction

The production of jets in association with vector bosons provides a stringent test of perturbative quantum chromodynamics (QCD). Moreover, these processes are a major background for most of the new physics searches and for the studies of top quark. So a precise measurement of cross-section and an understanding of the jet and lepton kinematics is essential. We used 35.9 ± 1.4 pb^{-1} of integrated luminosity from proton–proton collisions at $\sqrt{s} = 7$ TeV in the current analysis. Comparison to the theoretical predictions has been done using Monte Carlo (MC) samples, which were generated using Madgrapgh [1] and PYTHIA [2], followed by the full detector simulation based on GEANT4, detailed trigger emulation and the CMS event reconstruction.

2. CMS experiment

CMS is a general-purpose detector built for studying many aspects of proton collisions at 14 TeV, the centre-of-mass energy of the LHC particle accelerator. The detector has many subsystems, where the innermost layer is a silicon-based tracker, surrounded by a scintillating crystal electromagnetic calorimeter, which is itself surrounded by a sampling calorimeter for hadrons. The central feature of the CMS detector is a 6-m diameter superconducting solenoid, which provides a 3.8 T axial field. Outside the magnet are the large

DOI: 10.1007/s12043-012-0441-z; *e*Publication: 16 November 2012

muon detectors, which are inside the return yoke of the magnet. A detailed description of the detector and its performance can be found in ref. [3].

3. Event selection

For the muon channel, we use those events which pass the high-level trigger (HLT) system of the CMS detector having at least one muon with $p_T > (9–15)$ GeV. We require presence of one muon well-fitted from hits in the tracker and in the muon chambers and consistent with identification requirements (ID) designed to reject punch-through and decay in flight. This muon must have $p_T > 20$ GeV, $|\eta| < 2.1$, and must be isolated. If there is a second muon with $p_T > 10$ GeV, $|\eta| < 2.4$ and 50 GeV $< M_{\mu\mu} <$ 120 GeV, the event is put in the Z sample; otherwise, if $M_T(\mu\nu) > 20$ GeV, it is put in the W sample.

Similarly, in the electron channel we select only the events with one electron with $p_T > (10–17)$ GeV at the HLT. We require the presence of one electron satisfying tight (80% efficient) isolation, electron identification, and conversion rejection criteria. This electron must have $p_T > 20$ GeV, $|\eta| < 2.5$ $(1.44 < |\eta| < 1.57$ excluded), and must match the trigger primitive. Events were assigned to the W or to the Z sample using the same criteria described for the muon channel, with the only difference that the second electron was required to pass a loose (95% efficient) ID, and that the η cut was identical for the two electrons.

We use particle flow jets reconstructed using anti-k_T algorithm [4] with del $R = 0.5$. We require that jets should have $p_T > 30$ GeV and $|\eta| < 2.4$. Jets are required to pass loose identification conditions based on various detector-level variables. Leptons from vector boson decay should not be counted as jets. So isolated muons are removed from the list of particles before PF jets are clustered, and jets which have $\delta R < 0.3$ from the selected electron are also not considered.

4. Signal extraction and unfolding

The signal yields are estimated using an extended likelihood fit to M_{ll} for the Z+jets sample and to M_T for the W+jets sample. For Z events, the fit uses two functions, one for signal and the other for all backgrounds. For W events, the background contribution is divided into two components, one with peaking structure in M_T, dominated by $t\bar{t}$ and the other which does not, dominated by QCD multijet events. We perform the two-dimensional fit to the M_T distribution and number of b-jets. The M_T distribution allows the statistical separation of signal from non-peaking backgrounds and the number of b-jets distinguishes the signal and background from $t\bar{t}$. Fits are done for exclusive jet bins, for $N \leq 3$ jets, and an inclusive $N \leq 4$ jet bin. Muon events are efficiency-corrected by p_T and η before the fit, using the tag and probe method and the electron events for each n-jet are adjusted for selection efficiency after fitting. The exclusive cross-sections, within the acceptance, are then unfolded using the SVD-unfolding algorithm [5]. The unfolding procedure removes the effects of imperfect jet energy resolution and reconstruction efficiency and yields a result closer to the true, particle level, distribution of jets.

5. Results and systematics

The ratios of $V+ \geq N$-jet cross-section to the inclusive cross-section and the ratios of $V+ \geq N$-jet cross-section to the $V+ \geq (N-1)$-jet are measured. Dealing with ratios is easier since the luminosity uncertainty is cancelled, jet energy scale (JES) uncertainty is

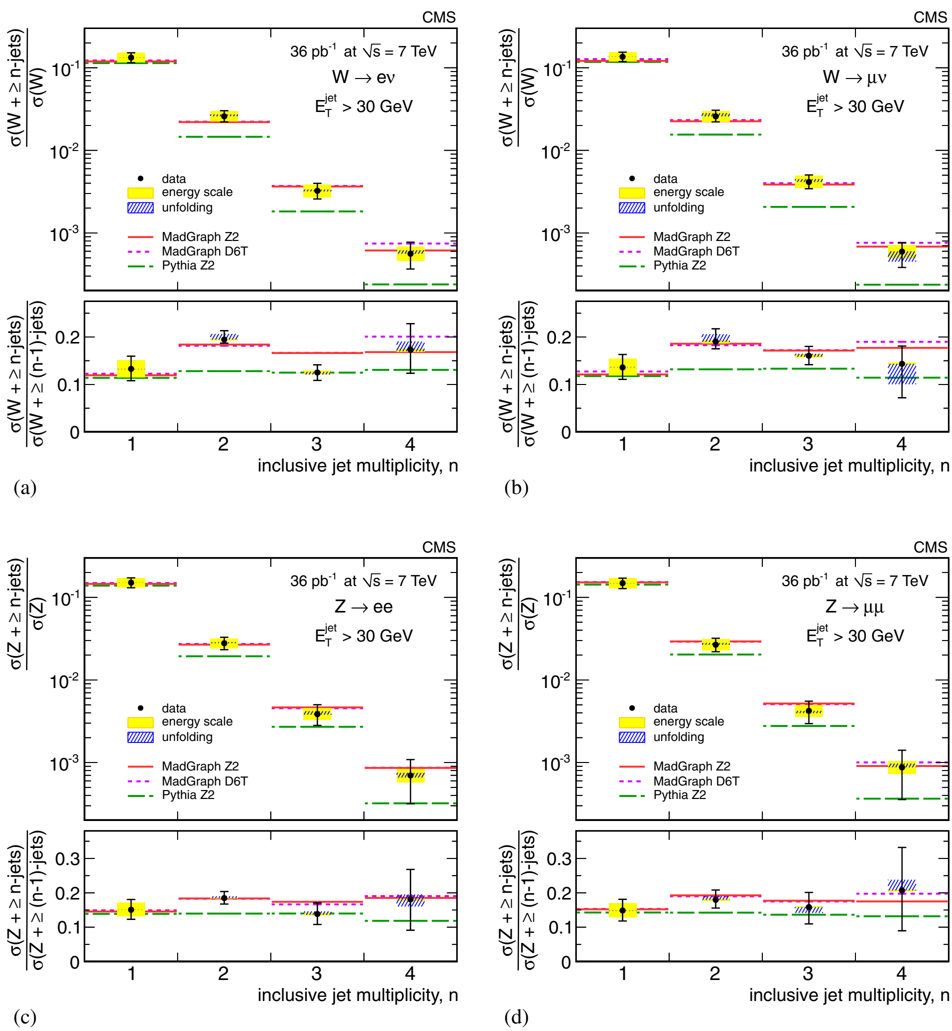

Figure 1. The ratios $\sigma(V+ \geq n\text{-jets})/\sigma(V)$ (top) and $\sigma(V+ \geq n\text{-jets})/\sigma(V+ \geq (n-1)\text{-jets})$ (bottom) for W+jets in the electron channel (**a**), for W+jets in muon channel (**b**), for Z+jets in electron channel (**c**) and for Z+jets in muon channel (**d**). Data have been compared with the expectations from two MADGRAPH tunes and PYTHIA. Points with error bars correspond to the data. The uncertainties due to the energy scale and unfolding procedure are shown as yellow and hatched bands, respectively. The error bars represent the total uncertainty.

reduced, and efficiency-correction uncertainties are reduced. Final results were obtained after subtracting pile-up effects, correction for efficiency and unfolding of detector effects. The measured ratios are in excellent agreement with MC predictions from ME+PS (MadGraph), while PYTHIA alone starts to fail for n-jets$\geq$2 in W+jet events. In Z+jet events, both calculations are compatible with data because of limited statistics and hence larger errors [6] (figure 1).

Acknowledgement

Financial support of DST is duly acknowledged.

References

[1] F Maltoni and T Stelzer, *J. High Energy Phys.* **02**, 027 (2003), arXiv:hep-ph/0208156
[2] T Sjostrand, S Mrenna and P Z Skands, *J. High Energy Phys.* **05**, 026 (2006), arXiv:hep-ph/0603175
[3] CMS Collaboration, *J. Instrum.* **3**, S08004 (2008)
[4] M Cacciari, G P Salam and G Soyez, *J. High Energy Phys.* **0804**, 063 (2008)
[5] A Hocker and V Kartvelishvili, *Nucl. Instrum. Methods* **A372**, 469481 (1996), arXiv:hep-ph/9509307
[6] CMS Collaboration, arXiv:1110.3226v1 [hep-ex] 14 October 2011