Jet production in association with vector bosons in ATLAS

Maria Fiascaris, on behalf of the ATLAS Collaboration
Enrico Fermi Institute, University of Chicago,
Chicago, IL 60637, USA

1 Introduction

The study of vector boson V (V = W, Z) production in association with jets is of great importance at the Large Hadron Collider (LHC). These processes can be used to validate the strong-interaction dynamics at the LHC energies and are also important backgrounds to both Standard Model and Beyond the Standard Model physics.

This article presents the measurement of the cross-sections for W and Z bosons produced in association with jets performed with approximately 33 pb^{-1} of data collected by the ATLAS detector [1] in 2010 at a centre of mass energy of 7 TeV. The cross-sections are determined for both electron and muon decay modes. The results are quoted in a limited and well-defined region of jet and lepton kinematics and are corrected for all detector effects. The measurements are compared to theoretical predictions at leading order (LO) and next-to-leading order (NLO) in perturbative QCD. More details on the measurements presented here can be found in [2, 3, 4].

2 Event Selection and Backgrounds

W and Z bosons events are selected on-line using a single, high transverse momentum (p_{T}) lepton trigger. The offline selection for W boson candidates requires exactly one lepton with p_{T}> 20 GeV, large missing transverse energy, $E_{\mathrm{T}}^{\mathrm{miss}} > 25$ GeV, and a cut on the W transverse mass, $M_{\mathrm{T}} = \sqrt{2p_{\mathrm{T}}^{l}p_{\mathrm{T}}^{\nu}(1 - cos(\phi^{l} - \phi^{\nu}))} > 40$ GeV. The Z boson selection requires exactly two leptons with opposite charge and p_{T}> 20 GeVand the invariant mass of the two leptons 66 GeV< Z_{ll} < 116 GeV. The kinematic cut on the lepton η is determined by the detector acceptance and varies slighlty between electron and muon channels: $|\eta_e| < 2.47$ excluding $1.37 < |\eta_e| < 1.52$, $|\eta_\mu| < 2.4$.

To improve the background rejection, identification and isolation criteria are applied to electrons and muons. Electrons are reconstructed from an electromagnetic energy deposit in the calorimeter with a matching track in the inner detector. In the Z + jets analysis, electrons must satisfy the standard ‘medium‘ identification cuts [5].

The W analysis, which suffers from larger background, uses more stringent requirements. The candidate electron from W boson decay is required to pass the 'tight' criteria and, in addition, a relative calorimeter isolation. Muons are reconstructed combining information from both the muon spectrometer and the inner detector. Identification criteria for muons include requirements on the impact parameter, track quality and track isolation.

Jets are reconstructed from calorimeter clusters using the anti-k_t algorithm with distance parameter R=0.4. The kinematic selections on jets are $|y| < 2.8$ and $p_{\mathrm{T}} > 20$ (30) GeV in the W (Z) analysis. Furthermore, jets within a cone of $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.5$ around the leptons from V boson decay are rejected.

Backgrounds to W and Z bosons can arise from electroweak processes or from QCD multi-jet events. The first category includes $Z \to \ell\ell$ (background to $W \to \ell\nu$) and $W \to \ell\nu$ (background to $Z \to \ell\ell$), diboson (WW, ZZ, WZ), single top and top pair production. These backgrounds are estimated from Monte Carlo (MC) using the most precise predictions available (NLO or NNLO) for the normalization. Background from QCD multi-jets is estimated from data by a template fit to the missing transverse energy distribution (for $W \to \ell\nu$) or to the invariant mass (for $Z \to ee$). In $Z \to \mu\mu+$ jets, the QCD multi-jet background is estimated from simulation and is cross-checked with data.

3 Unfolding and Systematic Uncertainties

The measurements are unfolded from detector back to particle level using a bin-by-bin unfolding procedure. The unfolding corrections account for all known detector effects and are computed using ALPGEN MC samples.

The following systematic uncertainties are considered: lepton trigger and reconstruction efficiencies, energy scale and resolution on lepton, jets and missing transverse energy, background estimation, pile-up jet removal and unfolding. The measurements are dominated by systematic uncertainties, which increase with jet multiplicity and with jet p_{T}. The uncertainty on the jet energy scale has the largest impact, accounting for about 10% uncertainty in the 1-jet bin and about 26% for $N_{jets} \geq 4$. In addition, an uncertainty on the total integrated luminosity of 3.4% is taken into account.

4 Results

The cross sections for Z boson production as a function of inclusive jet multiplicity $\sigma(Z+ \geq N_{jets})$ and the ratio of cross sections $\sigma(Z+ \geq N_{jets})/\sigma(Z+ \geq (N-1)_{jets})$ are measured for $N_{jets} = 0-3$ and jet $p_{\mathrm{T}} > 30$ GeV. Differential cross sections $d\sigma/dp_{\mathrm{T}}$ as a function of p_{T} of the leading jet in events with at least one jet and of the second leading jet for events with at least two jets are also presented. Measurements are compared to predictions from ALPGEN and SHERPA, Monte Carlo generators which implement the LO matrix elements supplemented by parton showers. Comparison is also made with predictions from the MC generator MCFM. These are at NLO in QCD for up to two jets and at LO for higher multiplicities. Figure 1 shows the cross section ratio and the differential cross section as a function of leading jet p_{T}, in the electron and muon decay channel respectively. Data are well described by the ALPGEN, SHERPA and NLO predictions.

The W + jets analysis presents similar measurements using a jet p_{T} threshold of 20 GeV. Thanks to the higher statistics, however, the cross section as a function jet multiplicity can be measured up to five jets. This is shown in Fig. 2 (left). In addition to SHERPA, ALPGEN and MCFM, predictions are shown also for PYTHIA and BLACKHAT-SHERPA. The latter are calculations at NLO for up to $N_{jets} = 3$. All predictions agree well with the data, with the exception of PYTHIA which does not properly model final states with high number of jets. In addition to the differential distributions in jet p_{T}, cross sections are also measured as a function of the variable H_{T}, where H_{T} is the scalar sum of the p_{T} of all jets passing the selection, the lepton p_{T} and the $E_{\mathrm{T}}^{\mathrm{miss}}$. Figure 2 (right) shows $d\sigma/dH_{\mathrm{T}}$ for events with $N_{jets} \geq 1-4$. Once again there is good agreement between data and predictions.

5 Conclusions

In summary, results for inclusive jet production in Z and W events were presented. The studies were performed with approximately 33 pb^{-1} of data collected with the ATLAS detector in 2010 at a centre of mass energy of 7 TeV. Measurements as a function of jet multiplicities and ratios of multiplicities were presented. In addition, differential cross sections as a function of jet p_{T} and (for W + jets) of H_{T} were also shown. The data agrees well with predictions from ALPGEN and SHERPA MC generators and with NLO calculations in perturbative QCD.

References

[1] ATLAS Collaboration, J. Instrum. 3, S08003 (2008).

[2] ATLAS Collaboration, ATLAS-CONF-2011-042, http://cdsweb.cern.ch/record/1338571.

[3] ATLAS Collaboration, ATLAS-CONF-2011-060, http://cdsweb.cern.ch/record/1344778.

[4] ATLAS Collaboration, Phys. Lett. B 698, 325 (2011).

[5] ATLAS Collaboration, J. High Energy Phys. 1012, 060 (2010).

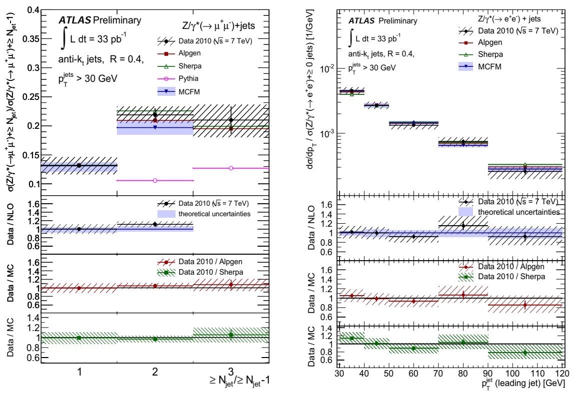

Figure 1: Cross sections for jet production in association with Z bosons. Left: ratio of cross sections $\sigma(Z+\geq N_{jets})/\sigma(Z+\geq (N-1)_{jets})$ for the muon decay channel. Right: cross section as a function of leading jet p_{T} in events with at least one jet, for the electron decay channel.

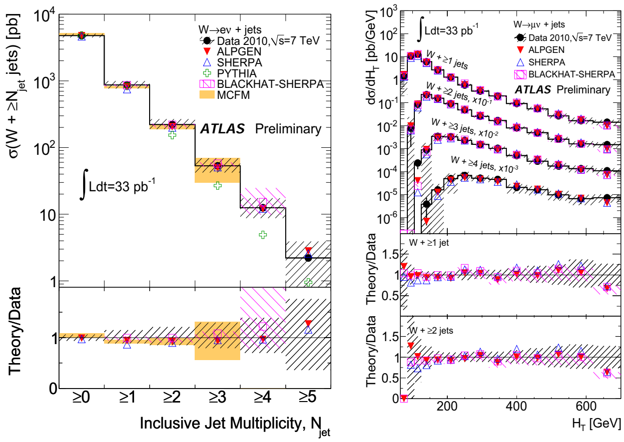

Figure 2: (Left) Cross section for $W \to e\nu$ +jets as a function of inclusive jet multiplicity. (Right) Differential cross section for $W \to \mu\nu$ +jets as a function of H_{T}, scalar sum of p_{T} of all jets which satisfy the selection, p_{T} of the lepton and $E_{\mathrm{T}}^{\mathrm{miss}}$.