

Measurement of the production cross section for W^- and Z -bosons in association with jets in ATLAS

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Abstract. We report on the measurements of inclusive W +jets and Z +jets cross sections in proton–proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector. Cross sections, in both the electron and muon decay modes of the bosons, are presented as a function of jet multiplicity, the transverse momentum of the jets and the quantity H_T which is the scalar sum of the p_T in the event. Measurements are also presented of the ratios of cross sections. The measured cross sections are compared to different particle–level predictions, based on perturbative QCD, where the measured W +3jet cross section is for the first time compared with next–to–leading order calculations.

Keywords: LHC, ATLAS, QCD, W , Z , jets

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INTRODUCTION

The experimentally clean signatures of W^- and Z -bosons make the measurement of these processes in association with jets well suited to test perturbative QCD at the LHC. The processes allow for comparisons of multi–jet production with predictions either from the parton shower approach or from exact multi–parton matrix elements (ME) matched with parton showers. In addition, full next–to–leading order (NLO) calculations are also available for comparison with many of the results. The W/Z processes also differ from pure QCD multi–jet processes with respect to the scale of the hard interaction, due to the large mass of the electroweak gauge bosons.

Measurements of W/Z +jets are also important to control backgrounds to other measurements at the LHC. In the Standard Model context, one example is the top quark cross section measurements, where W +jet is often the dominant background. Also several beyond the standard model searches, such as the zero lepton SUSY search, suffer from irreducible background from either W +jets or Z +jets, or both.

Here we report on the ATLAS Z +jets and W +jets cross section measurements [1, 2] based on data recorded during 2010. The analyses include the electron and muon decay channels and are based on an integrated luminosity of 33 pb^{-1} .

ATLAS ANALYSIS

The ATLAS detector systems were all fully operational during this data taking period and the detector acceptance considered was approximately determined by the follow-

ing constraints. Electrons were used within the inner detector acceptance ($|\eta| < 2.5$), whereas reconstructed muons were considered inside the acceptance of the trigger chambers ($|\eta| < 2.4$). The electron (muon) E_T (p_T) was required to be larger than 20 GeV, in order to be well inside the highly efficient plateau of the triggers. Jets were reconstructed inside the main calorimeters ($|\eta| < 3.2$) and missing transverse energy was based on the full calorimeter acceptance ($|\eta| < 4.5$). The cross section measurements were made within the kinematic region defined by the event selection, which was well covered by the ATLAS detector acceptance,

- *Electrons* : $E_T > 20$ GeV; $|\eta| < 2.47$; *excluding* $1.37 < |\eta| < 1.52$.
- *Muons* : $p_T > 20$ GeV; $|\eta| < 2.4$.
- *Jets (anti - k_T , $R = 0.4$)* : $p_T > 20$ or 30 GeV; $|y$ or $|\eta| < 2.8$; $\Delta R(\ell, jet) > 0.5$.
- *W selection* : $N_\ell = 1$; $E_T^{miss} > 25$ GeV; $m_T > 40$ GeV.
- *Z selection* : $N_\ell = 2$; $66 < m_{\ell\ell} < 116$ GeV.

Note that here the jet p_T requirement, as well as the rapidity variable, differs between the W (20 GeV) and Z analysis (30 GeV). The $\Delta R(\ell, jet)$ ¹ criteria refers to the leptons and all selected jets and the Z selection also require the two leptons to be of opposite charge. The results were then corrected for detector effects, using a bin-by-bin unfolding method, and compared with theory (MC) predictions inside the same kinematic region. For the theory results, jets were reconstructed using the same algorithm based on all final state particles with a lifetime larger than 10 ps, except the leptons from the W/Z decays. Lepton momenta also included any photons radiated within $\Delta R < 0.1$.

A good agreement was generally found between the selected data candidates and predictions from MC, for both Z and W events in both the electron and muon channels. Regarding the background for these measurements, the background coming from QCD was estimated based on a data-driven method whereas the electroweak and top backgrounds were estimated from MC. The background contamination of the selected Z +jets samples was of the order of 1% for the muon channel, as well as 5% for the electron channel. In the W +jets samples, the background was in the order of 10%. The main source of uncertainty in these measurements comes from the jet energy scale, which contributes with approximately 10%, followed by pile-up corrections ($\sim 5\%$) and luminosity ($\sim 4\%$). More details about the analysis are found in [1, 2].

CROSS SECTION MEASUREMENTS

The obtained number of events were then used to measure the differential cross section times branching ratio with respect to a number of different quantities. All the results correspond to inclusive measurements, corrected for detector effects, within the kinematic region defined by the event selection above.

The differential cross section with respect of the number of selected jets was measured both using W and Z events. The absolute cross section and the ratio of cross sections

¹ The following definition was used, $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$.

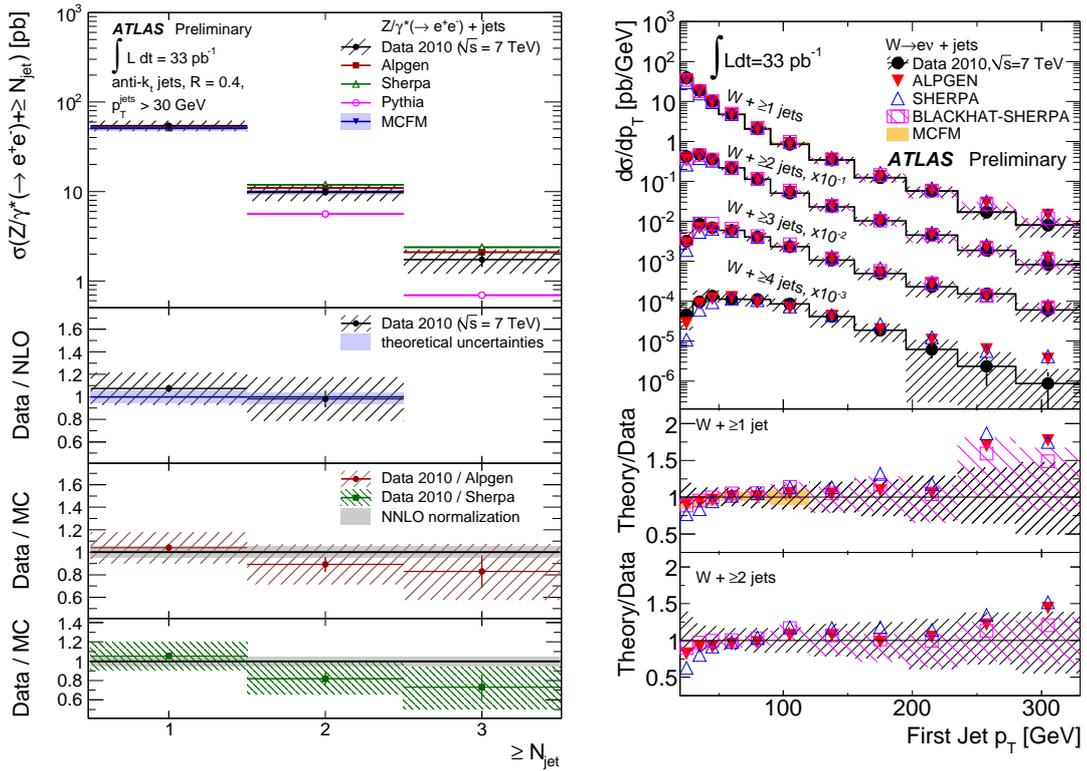


FIGURE 1. Cross section for $Z \rightarrow ee$ as function of the number of jets (left). Cross section for $W \rightarrow e\nu$ as function of p_T of the leading jet (right).

from events with N jets over $N - 1$ jets were measured. Some of the uncertainties are reduced in the ratios. Figure 1 (left) shows the $Z \rightarrow ee$ cross section as a function of number of selected jets. The measured values show a good agreement with the NLO predictions, here represented by results obtained by MCFM. The results are also in good agreement with expectations from the multi-parton ME programs (ALPGEN and SHERPA), which have been normalized to the inclusive NNLO cross sections obtained by the FEWZ program. The results do on the other hand show poor agreement with the LO plus parton shower results (PYTHIA) for events with more than one jet. This is due to the combination of a not-properly-covered phase space (Z s are not produced by the parton shower) together with using the parton shower approach for the hard jets. The results are shown together with the corresponding ratios between the results obtained from data over predictions from the MC programs MCFM, ALPGEN and SHERPA.

Figure 1 (right) shows the differential cross section with respect to the leading jet p_T for $W \rightarrow e\nu$. The measurement is performed separately for events with 1 to 4 jets. The results from the W +jets measurements are also compared against NLO predictions from BLACKHAT-SHERPA, where W +3jets predictions at NLO is compared with LHC data for the first time. The results are shown together with the corresponding ratios between results from MC over data, for events with 1 and 2 selected jets. Again a good agreement was found between the measurement and the MC predictions. The differential cross sections were also measured with respect to the p_T of the other selected jets in the

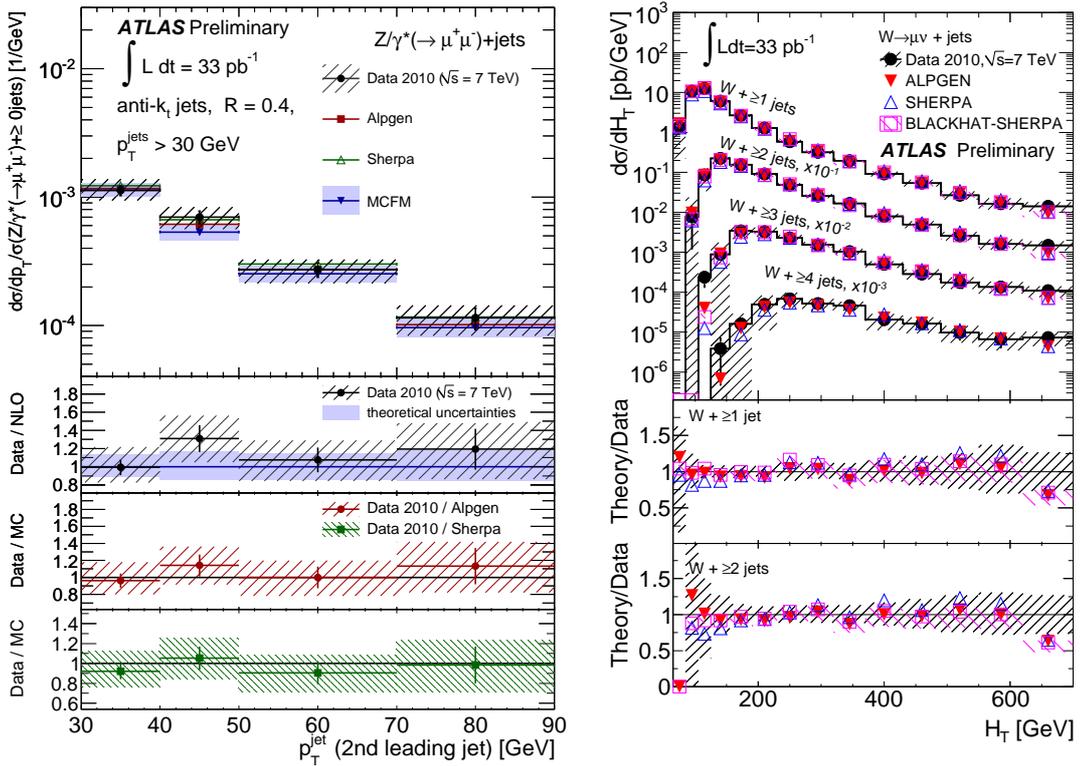


FIGURE 2. Cross section for $Z \rightarrow \mu\mu$ as function of p_T of the second leading jet (left). Cross section for $W \rightarrow \mu\nu$ as function of H_T (right).

event, using the 2 leading jets in Z events and up to 4 leading jets in the W analysis. The cross section with respect to the p_T of the second leading jet is shown in figure 2 (left) for $Z \rightarrow \mu\mu$. A good agreement is shown and similar agreements were also found with respect to the other jets, both in the W and Z results.

In the W analysis the cross section was also measured with respect to H_T . This quantity corresponds to the scalar sum of the p_T from the jets as well as leptons, i.e. muon, electron and neutrinos, in the event, and this is the quantity which was used to characterize the scale of the hard process in the MC simulations. The results from $W \rightarrow \mu\nu$ are shown in figure 2 (right), which are produced separately for event with 1 to 4 jets. The ratios between the results from MC over data are shown and a generally good agreement was found in both the electron as well as the muon channel.

REFERENCES

1. ATLAS Collaboration, ATLAS-CONF-2011-042 (<https://twiki.cern.ch/twiki/bin/view/AtlasPublic>).
2. ATLAS Collaboration, ATLAS-CONF-2011-060 (<https://twiki.cern.ch/twiki/bin/view/AtlasPublic>).