PoS PROCEEDINGS OF SCIENCE

First Results from ATLAS on W and Z Boson Production in proton-proton Collisions at $\sqrt{s} = 7\,$TeV

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First measurements by the ATLAS experiment are presented of the $W \to \ell\nu$ and $Z \to \ell\ell$ production cross section, where $\ell = e, \mu$. The observed 118 $W \to \ell\nu$ and 125 $Z \to \ell\ell$ candidates were produced in pp collisions at $\sqrt{s} = 7\,$TeV at the LHC. The total integrated luminosities correspond to approximately $17\,\text{nb}^{-1}$ for the W and $225\,\text{nb}^{-1}$ for the Z. The total inclusive W-boson production cross section times the leptonic branching ratio is measured to be $[8.5 \pm 1.3(\text{stat}) \pm 0.7(\text{syst}) \pm 0.9(\text{lumi})]\,$nb for the $W \to e\nu$ channel, and $[10.3 \pm 1.3(\text{stat}) \pm 0.8(\text{syst}) \pm 1.1(\text{lumi})]\,$nb for the $W \to \mu\nu$ channel. The total inclusive Z-boson production cross section times leptonic branching ratio within the invariant mass window $66 < m_{\ell\ell} < 116$ GeV was measured to be $[0.72 \pm 0.11(\text{stat}) \pm 0.10(\text{syst}) \pm 0.08(\text{lumi})]\,$nb for the $Z \to ee$ channel and $[0.89 \pm 0.10(\text{stat}) \pm 0.07(\text{syst}) \pm 0.10(\text{lumi})]\,$nb for the $Z \to \mu\mu$ channel. Both cross section values are in good agreement with theoretical calculations at NNLO in QCD. In addition, the expected charge asymmetry between the cross sections for W^+ and W^- production is experimentally confirmed.

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1. Introduction

The inclusive production of W and Z bosons with subsequent decay in the electron or muon channels, $\ell = e, \mu$, are processes with large cross sections at the Large Hadron Collider (LHC) with about 10 nb and 1 nb, respectively. Their measurement is therefore feasible already using the initial data. A precision measurement serves a two-fold purpose. Firstly, it constitutes an important test of the Standard Model. The theoretical calculations are available up to NNLO in QCD [1].The main uncertainty stems from the knowledge of the proton parton distribution functions (PDFs), which were measured in most of the relevant range with high precision by the HERA collider experiments [2], albeit at a lower energy scale and involving mostly different couplings to the partons. Therefore a measurement can be a precision test of QCD and help to constrain the PDFs. Secondly, the clean signature and the well known Z properties measured at LEP and SLC [3], makes these channels important for the detector calibration and the lepton efficiency measurements.

The ATLAS detector is described elsewhere in more detail [4]. The coordinate system is defined in the conventional way with the beam direction defining the z-axis, θ measuring the polar angle w.r.t. the beam axis and the pseudorapidity defined as $\eta = -\ln\tan(\theta/2)$. The distance ΔR in the $\eta - \phi$ space is defined as $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$. The detector consists of a inner tracker system immersed in a 2 T solenoidal field to provide tracking information for charged particles in the range $|\eta| < 2.5$. The calorimeter system covers the range $|\eta| < 4.9$, using a variety of detector technologies with electromagnetic and hadronic sections. The electromagnetic calorimeter in the range $|\eta| < 2.5$ is of prime importance for the electron channel measurements. It is divided into a barrel and endcap parts with the transition region $1.37 < |\eta| < 1.52$ excluded for the early measurements. The muon spectrometer, covering the range of $|\eta| < 2.7$, is instrumented with separate trigger ($|\eta| < 2.4$) and high-precision tracking chambers inside large superconducting air-core toroid magnets. While ATLAS employs a sophisticated three level trigger system, the data covered in this presentation was taken only using the first level trigger based on information of the calorimeter and the muon chambers, respectively.

The results presented here [5] are compared to expectations based on Monte Carlo simulations (MC). The samples were generated mostly with Pythia [6], then simulated with GEANT4 [7], and reconstructed and treated as the data. For the measurement of the cross sections the MC samples are an indispensable tool. Total cross sections are determined from the observed events $N^{\rm obs}$ using two correction factors A and C as

$$\sigma^{\rm tot}_{W/Z} \times {\rm BR}(W \to l\nu / Z \to \ell\ell) = \frac{N^{\rm obs} - N^{\rm bkg}}{CA\mathscr{L}_{\rm int}}\,. \tag{1.1}$$

Here the factor $C = N_{\rm rec}/N_{\rm gen,fid}$ corrects for experimental effects, like efficiencies, within the fiducial acceptance defined by the selection requirements. C may also contain corrections of the MC efficiencies to values determined from data. The factor $A = N_{\rm gen,fid}/N_{\rm gen,all}$ is a pure MC quantity extrapolating the result to the full phase space outside the kinematic acceptance of the detector. The backgrounds $N^{\rm bkg}$ are determined using data driven techniques for the QCD sources, while MC samples are used for the backgrounds involving electro-weak processes. The integrated luminosity $\mathscr{L}_{\rm int}$ is known to 11%.

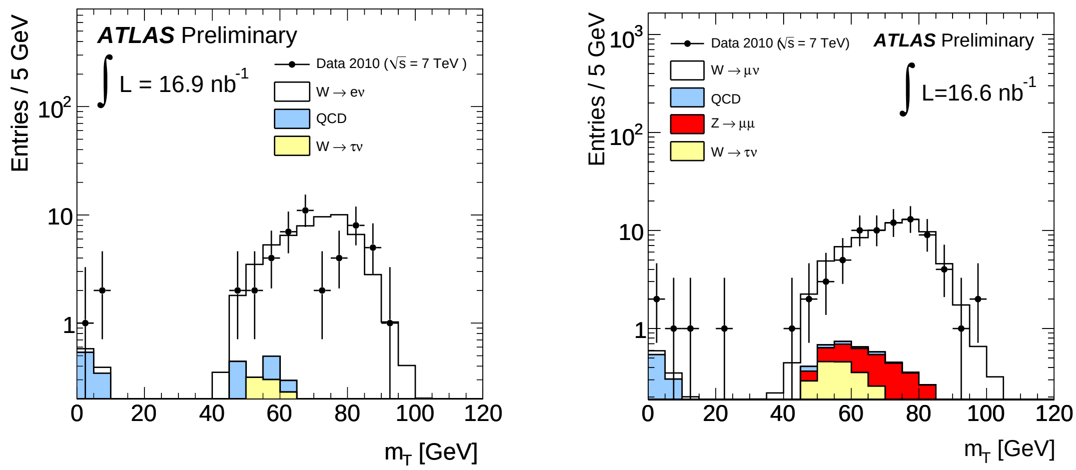

Figure 1: Transverse mass spectra after full event selection excluding the m_T requirement for the electron and muon channels in the left and right panel, respectively. The signal region is chosen as $m_T > 40$ GeV.

2. Measurement of the $W \to \ell\nu$ Cross Section

The selection of $W \to \ell\nu$ candidates is relatively straight-forward. One component is the selection of a well identified high transverse momentum $p_{T,\ell} > 20$ GeV lepton candidate within the acceptance of the detector, i.e. $|\eta| < 1.37$ or $1.52 < |\eta| < 2.47$ for the electron and $|\eta| < 2.4$ for the muon. "Tight" quality criteria are required for the electron taking into account various shower shapes of the calorimeter cluster, track properties and track-cluster matching. The muon is primarily defined by the tracks in the ID and the muon spectrometer and fakes are reduced by requiring good matching between the two and minimum p_T requirements. In addition the track activity in a $\Delta R < 0.4$ cone around the muon candidate is required to be small.

The second important component in selecting W candidates is requiring a large missing transverse energy, $E_T^{miss} > 25$ GeV. This is computed primarily as vectorial sum over all calorimeter clusters, calibrated for the different response of the calorimeters for electromagnetic and hadronic showers. In the muon analysis, the muon is added for the E_T^{miss} reconstruction. The signal is extracted requiring the transverse mass of the lepton-E_T^{miss} system to be large, $m_T > 40$ GeV.

Figure 1 shows the transverse mass distribution of the W candidates, where in $\mathscr{L}_{\text{int}} = 17\,\text{nb}^{-1}$ there are 46 and 72 observed candidates in electron and muon channel, respectively, over a small $\sim 5\%$ background. A good agreement with the MC prediction is observed. In the electron channel the main background contributions are $W \to \tau\nu$ events and fake electrons+E_T^{miss} from QCD jets. In the muon channel $W \to \tau\nu$ events as well as $Z \to \mu\mu$ events with one muon escaping the detection are important.

The experimental correction factors C_W have sizable systematic uncertainties for the small data set. There are contributions from the trigger efficiency (especially in the muon channel), the lepton reconstruction and identification (especially in the electron channel) and effects from the lepton and E_T^{miss} scale and resolutions. The total systematic uncertainties amount to 8% and 7% in the electron and muon channels, respectively. The extrapolation factors A_W are of the order $0.45 - 0.50$ depending on channel and W charge with about 3% systematic uncertainty. The total

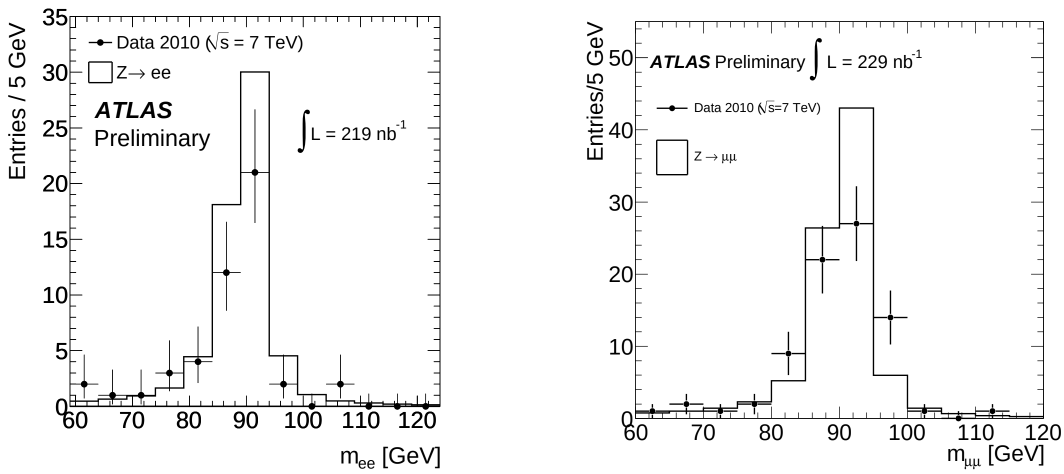

Figure 2: Dilepton invariant mass spectra excluding the $m_{\ell\ell}$ requirement for the electron and muon channels in the left and right panel, respectively. The signal region is chosen as $66 < m_{\ell\ell} < 116\,\text{GeV}$.

W-boson production cross section is measured as $[8.5 \pm 1.3(\text{stat}) \pm 0.7(\text{syst}) \pm 0.9(\text{lumi})]\,\text{nb}$ and and $[10.3 \pm 1.3(\text{stat}) \pm 0.8(\text{syst}) \pm 1.1(\text{lumi})]\,\text{nb}$ for the $W \to e\nu$ and $W \to \mu\nu$ channels, in good agreement with the NNLO QCD prediction of $(10.5 \pm 0.4)\,\text{nb}$. Also the predicted ratio of W^+ to W^- cross sections is confirmed within large statistical uncertainties. Figure 3, left panel, shows the new ATLAS measurements in context of other W cross section measurements at hadron colliders.

3. Measurement of the $Z \to \ell\ell$ Cross Section

The selection of $Z \to \ell\ell$ candidates is even simpler than the W selection and requires essentially only two well identified high p_T leptons. The quality criteria are similar to the ones applied for the corresponding $W \to \ell\nu$ measurement, but slightly relaxed in the electron case to give higher efficiency at still small background levels. Figure 2 shows the invariant mass distributions for the selected lepton pairs. The signal region is defined as $66 < m_{\ell\ell} < 116\,\text{GeV}$. In $\mathscr{L}_{\text{int}} = 220 - 230\,\text{nb}^{-1}$ there are 46 and 79 observed candidates in electron and muon channel, respectively, in good agreement with the MC prediction. The backgrounds are very small $\lesssim 1\%$ and dominated by fake electrons from QCD jets and muons from electro-weak backgrounds, respectively.

The systematic uncertainty on the experimental correction factors C_Z is dominated by the lepton efficiencies, which equals to 14% and 7% in the electron and muon case, respectively. The total Z-boson production cross section within the invariant mass window is measured to be $[0.72 \pm 0.11(\text{stat}) \pm 0.10(\text{syst}) \pm 0.08(\text{lumi})]\,\text{nb}$ and $[0.89 \pm 0.10(\text{stat}) \pm 0.07(\text{syst}) \pm 0.10(\text{lumi})]\,\text{nb}$ for the electron and muon channels, in good agreement with the NNLO QCD prediction of $(0.96 \pm 0.04)\,\text{nb}$. Figure 3, right panel, shows the new ATLAS measurements in context of other Z cross sections at hadron colliders.

4. Summary

The first measurements of the $W \to \ell\nu$ and $Z \to \ell\ell$ production cross sections were performed

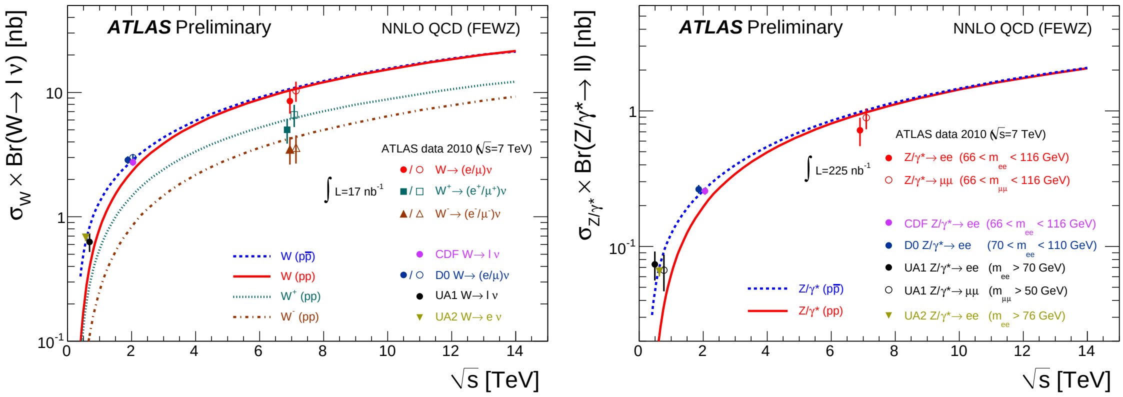

Figure 3: Summary of total inclusive W and Z cross section measurements at hadron colliders.

with the ATLAS detector. Clear signals with 118 $W \to \ell\nu$ and 125 $Z \to \ell\ell$ candidates are observed in good agreement with MC simulations. The total integrated luminosities correspond to approximately $17\,\mathrm{nb}^{-1}$ for the W and $225\,\mathrm{nb}^{-1}$ for the Z. The total inclusive W- and Z-boson production cross section times the leptonic branching ratio are measured to be in good agreement with theoretical calculations at NNLO in QCD. In addition the expected charge asymmetry between the cross sections for W^+ and W^- production is experimentally confirmed. The results are so far clearly limited by the available statistics. Measurements on a slightly larger ATLAS data set of $315\,\mathrm{nb}^{-1}$ have meanwhile be published [8].

Future measurements can be expected to yield much more precise results, in both statistical and systematical uncertainties. They will include as well differential cross section measurements in terms of interesting observables like the boson or lepton rapidities.

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