Studies of EW Boson Production in the Forward Region with LHCb

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1 Introduction

The LHCb detector is a single arm spectrometer fully instrumented in the pseudorapidity region $1.9 \leq \eta \leq 4.9$. It has been designed to study heavy flavour physics in the forward region where B mesons are predominantly produced in proton proton collisions. While it shares some of its pseudorapidity range with the ATLAS and CMS general purpose detectors ($|\eta| > 2.5$), the rest is unique to LHCb. Further information about the detector can be found in [1].

Measurements of W and Z production cross-sections at the LHC consitute an important test of the Standard Model. While the partonic cross-sections are well understood and known to the percent level, additional theoretical uncertainties arise due to the knowledge of the Parton Density Functions (PDFs) which parameterise the behaviour of the colliding protons. This results in an overall uncertainty of between 3 and 10% [2]. LHCb's pseudorapidity range allows it to probe these PDFs in a distinct region of (x, Q^2) space. Thus measurements of the W and Z cross-sections at LHCb can provide important constraints to these PDFs in a unique kinematic region.

The measurements presented here are performed using 16.5 pb^{-1} of data taken by LHCb in 2010.

2 $Z \to \mu\mu$ Selection

Z candidates are selected by requiring two well reconstructed muons with a transverse momentum, $p_T > 20$ GeV/c and in the pseudorapidity range $2 < \eta < 4.5$. The dimuon invariant mass spectrum is shown in Figure 1. To further identify Z candidates, the invariant mass of the candidates is required to be in the range $81 < M_{\mu\mu} < 101$ GeV/c^2. Background sources considered are $Z \to \tau\tau$ where both tau leptons decay to muons within the LHCb acceptance, semi-leptonic heavy flavour decays and generic

[1]On behalf of the LHCb Collaboration

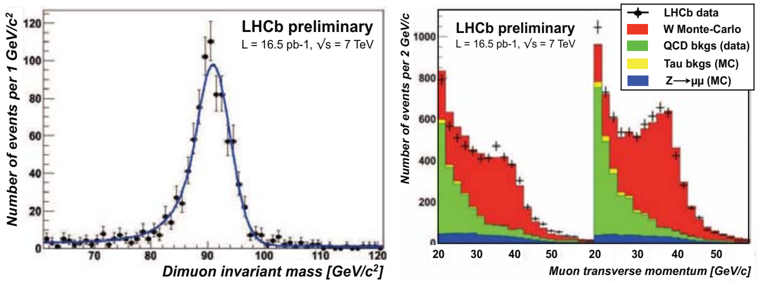

Figure 1: (left) DiMuon invariant mass spectrum of selected Z candidates, (right) p_T spectrum for negatively (left) and positively (right) charged muons passing the W selection

QCD events with misidentified pions or kaons. The $Z \to \tau\tau$ background is estimated from MC while the others are estimated using data driven methods. We select 833 events with an estimated background of 1.2±1.2.

3 $W \to \mu\nu$ Selection

W events are characterised by a single isolated high p_T muon and minimal activity in the event. The higher background contamination compared to the Z analysis means that further constraints must be applied in addition to requiring $p_T > 20$ GeV/c and $2 < \eta < 4.5$. Isolated muons are selected by by requiring that the vector p_T sum of the tracks in a cone of radius $R \equiv \sqrt{\eta^2 + \phi^2} < 0.5$ be less than 2 GeV/c. Heavy flavour decays are also suppressed by requiring that the muon is consistent with the primary vertex, having an impact parameter significance less than 2. Finally, we require minimal additional activity in the event by imposing restrictions on the mass and p_T of the rest of the event. We require that the invariant mass of the other tracks in the event is less than 20 GeV/c^2 and their summed p_T is less than 10GeV/c. We select 7624 W^+ candidates and 5732 W^- candidates.

The backgrounds considered are $Z \to \mu\mu$ where one of the muons goes outside of LHCb's acceptance, $W \to \tau\nu$ where the τ decays to a muon, $Z \to \tau\tau$ where the final state contains a single muon in LHCb's acceptance, semi-leptonic B and D meson decays involving muons, and generic QCD events. The background and signal shapes are estimated from a combination of data and simulation and are fitted to the muon p_T spectrum in 5 bins of pseudorapidity. The fit result is shown in Figure 1.

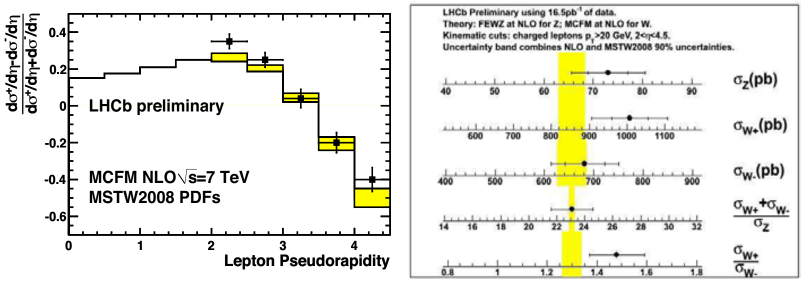

Figure 2: (left) $W^{\pm}$ differential cross-section asymmetry as a function of lepton pseudorapidity. (right) Summary of the results obtained, compared to the NLO Predictions using FEWZ and MCFM with the MSTW PDF Set. The shaded areas represent the theoretical uncertainty

4 Results

The cross-section is defined as

$$\sigma_{Z,W} = \frac{N_{tot}^{Z,W} - N_{bkg}^{Z,W}}{\epsilon^{Z,W} \int \mathcal{L}}$$

where N_{tot} is the total number of observed candidates and N_{bkg} is the estimated background. The luminosity, $\int \mathcal{L}$ is determined using both a Van Der Meer Scan [3] and a Beam Gas Method [4] and is known to a precision of 10%. The efficiency, ϵ, is the product of the trigger, track finding, muon identification and selection efficiencies and is estimated using data driven methods, more details can be found in [5].The W and Z production cross-sections are measured with the kinematic requirements that the signal muons have $p_T > 20$ GeV and pseudorapidity in the range $2.0 < \eta < 4.5$. The results obtained are

$$\sigma(Z \to \mu^+\mu^-, p_T > 20GeV, 2.0 \leq \eta \leq 4.5) = 73 \pm 4 \pm 7\,\text{pb}$$
$$\sigma(W^+ \to \mu^+\nu_\mu, p_T > 20GeV, 2.0 \leq \eta \leq 4.5) = 1007 \pm 48 \pm 101\,\text{pb}$$
$$\sigma(W^- \to \mu^-\overline{\nu_\mu}, p_T > 20GeV, 2.0 \leq \eta \leq 4.5) = 680 \pm 40 \pm 68\,\text{pb}$$

where the first error is statistical and systematic combined, and the second error is due to the luminosity determination. The systematic errors on the efficiencies are estimated from the statistical uncertainty of the determination, while those on the backgrounds are statistical for the Z selection, and estimated from the template fit to the muon p_T spectrum for the W selection. The $W^\pm$ cross-section asymmetry is also measured in bins of lepton pseudorapidity and is shown in Figure 2.

Cross-section ratios are independent of luminosity, providing a more precise measurement, and so are calculated within the kinematic acceptance of the leptons

$$\sigma(W^+ \to \mu^+\nu_\mu)/\sigma(W^- \to \mu^-\overline{\nu_\mu}) = 1.48 \pm 0.11$$
$$\sigma(W \to \mu\nu)/\sigma(Z \to \mu\mu) = 23.1 \pm 1.5$$

where the error is systematic and statistical combined. All of the results are compared to the NLO predictions calculated using FEWZ[6] and MCFM[7] with the MSTW08[2] PDF set in Figure 2.

5 Conclusion

The cross sections and ratios of W and Z boson production have been measured using $\int \mathcal{L} = 16.5$ pb^{-1} of data collected at LHCb in 2010. The luminosity uncertainty of 10% dominates the precision of the cross-section measurements while the ratios are independent of this and thus provide a more precise test of the Standard Model. All the results obtained are consistent with the NLO predictions.

References

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