Measurement of W and Z production in the forward region with LHCb

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DOI: http://dx.doi.org/10.3204/DESY-PROC-2012-02/147

We report on measurements of W and Z production in the forward region, using data collected at the LHCb experiment with a centre of mass energy of $\sqrt{s} = 7$ TeV with an integrated luminosity of up to 1 fb^{-1}. W and Z bosons are reconstructed in leptonic decay channels, and their cross-sections determined using data-driven techniques. Results are presented inclusively (within the fiducial region considered), and differentially as a function of boson rapidity (Z) and lepton pseudorapidity (W). The ratio of W to Z production, W^+/W^- production and the W charge asymmetry (for three lepton p_T thresholds) is also given. All results are compared to NNLO predictions.

1 Introduction

The LHCb detector is a single arm spectrometer fully instrumented in the pseudorapidity region $2.0 \leq \eta \leq 5.0$. 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 remaining coverage 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 constitute 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, where x is the fractional momentum carried by the struck quark, and Q^2 is the energy transfer of the interaction. Thus measurements of the W and Z cross-sections at LHCb can provide important constraints to these PDFs in a unique kinematic region.

2 Event Selection

2.1 $Z \to \mu\mu$

The $Z \to \mu\mu$ analysis is performed on the full dataset collected by LHCb in 2010, corresponding to a luminosity of 37.1 pb^{-1}. Events are triggered on a single high momentum muon trigger requiring a transverse momentum, $p_T > 10$ GeV. Events are then selected which contain two well reconstructed muons with $p_T > 20$ GeV with a pseudorapidity in the range $2.0 < \eta^\mu < 4.5$ and with a di-muon invariant mass in the range $60 < M_{\mu\mu} < 120$ GeV. The backgrounds considered are from $Z \to \tau\tau$ events where both tau leptons decay to muons, heavy flavor decays with two semi-leptonic muonic decays and generic QCD events, where pions or kaons either decay in flight to muons, or punch through the detector and are falsely identified. The total number of selected events is 1966 with an estimated purity of 99.7%.

2.2 $Z \to ee$

For the $Z \to ee$ analysis, the 2011 dataset is used, with a luminosity of 945 pb^{-1} . Events are triggered on a high momentum electron trigger which passes events containing electrons with $p_T > 15$ GeV. Events are then selected containing two identified electrons with a transverse momentum greater than 20 GeV and lying within the pseudorapidity region $2 < \eta^e < 4.5$. Due to saturation of the electromagnetic calorimeter and incomplete Bremsstrahlung recovery, the $Z \to ee$ mass peak is spread to lower values, and so the mass window is chosen to be $M_{ee} > 40$ GeV. The backgrounds considered are $Z \to \tau\tau$ where both tau leptons decay to electrons, and generic QCD events. In total, 21535 events are selected with an estimated purity of 97.8%.

2.3 $Z \to \tau\tau$

Two different final states are considered to measure the $Z \to \tau\tau$ cross-section, which is performed on both the the 2010 and 2011 datasets, with a combined luminosity of up to 247 pb^{-1}. Both final states contain a high momentum muon with a transverse momentum greater than 20 GeV that is required to pass the trigger, while the second candidate can be either a muon ($\mu\mu$) or an electron (μe) with a transverse momentum exceeding 5 GeV. In all cases the tracks are required to have a pseudorapidity in the range $2 < \eta < 4.5$, with a visible mass greater than 20 GeV, where the visible mass is the mass of the combined momentum of the visible decay products. Due to large backgrounds a number of different requirements are placed on the events. In both cases, the tracks are required to be isolated and have a separation of greater than 2.7 radians in the transverse plane. In addition, due to a large background from Drell-Yan produced di-muon pairs in the ($\mu\mu$) final state, the tracks are required to have a large summed impact parameter, and a p_T asymmetry between the two candidates of greater than 0.2. A total of 81 events are selected in the (μe) channel with a purity of 85% while 33 events are selected in the ($\mu\mu$) channel with a purity of 78%.

2.4 $W \to \mu\nu$

In the $W \to \mu\nu$ analysis, performed with the full 2010 dataset of 37.1 pb^{-1}, events are selected which trigger on a high momentum single muon trigger and possess a well reconstructed muon with $p_T >$20 GeV in the pseudorapidity region $2.0 < \eta^\mu < 4.5$. Further restrictions are placed on the event to reject backgrounds. The muons are isolated and prompt, have a small impact parameter, and deposit less than 4% of their momentum in the calorimetry system. In addition the events contain no other muons with a $p_T >$5 GeV. The backgrounds considered are from the decay-in-flight and punch-through of kaons and pions, $Z \to \mu\mu$ events where one of the muons is not reconstructed in the LHCb acceptance, the decay of W and Z bosons through tau decay modes producing a single muon in the final state, and the decay of heavy quarks. The signal

Source	$\Delta\sigma^Z(\%)$				$\Delta\sigma^W(\%)$	
	$\mu\mu$	ee	$\tau\tau(\mu e)$	$\tau\tau(\mu\mu)$	W^+	W^-
Systematic	4.3	3.1	16	10	3.2	2.9
Luminosity	3.5	3.5	5.1	5.1	3.5	3.5
Statistical	2.2	0.7	17	12	1.1	1.2
Luminosity(pb^{-1})	37.1	945	247	246	37.1	37.1

Table 1: Summary of the uncertainties on the measurements made by LHCb.

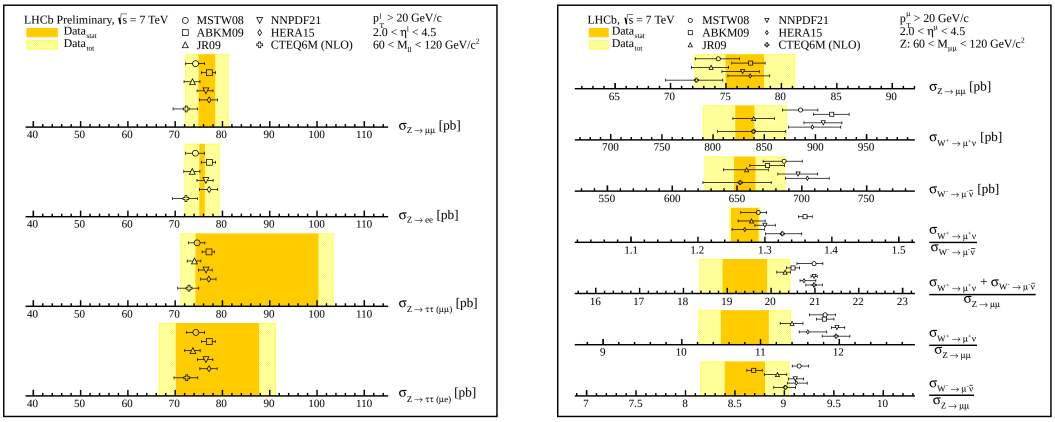

Figure 1: Summary and comparison to theory for the Z cross-section measurements (left) and W and Z cross-section and ratio measurements (right)

purity is obtained by fitting signal and background templates to the p_T spectrum of the muon in data, where templates are obtained from a combination of data and simulation. A total of 14660 (11618) $W^+(W^-)$ events are selected with a purity of 78.8%(78.4%).

3 Cross-Section Determination

The cross section is determined from the number of events selected, N, through the formula

$$\sigma = \frac{\rho \cdot N}{A \cdot \varepsilon \cdot \int \mathcal{L}} \cdot f_{FSR} \tag{1}$$

where ρ represents the purity of the selected events. The integrated 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 3.5%. The efficiency, ε, is the product of the trigger, track finding, muon identification and selection efficiencies and is estimated primarily using data driven methods; more details can be found in [5, 6, 7]. All cross-sections are quoted in the kinematic regions defined by the selection of the $Z \to \mu\mu$ and $W \to \mu\nu$ selections, where the leptonic product of the W or Z are required to have transverse momenta exceeding 20 GeV and pseudorapidites between 2

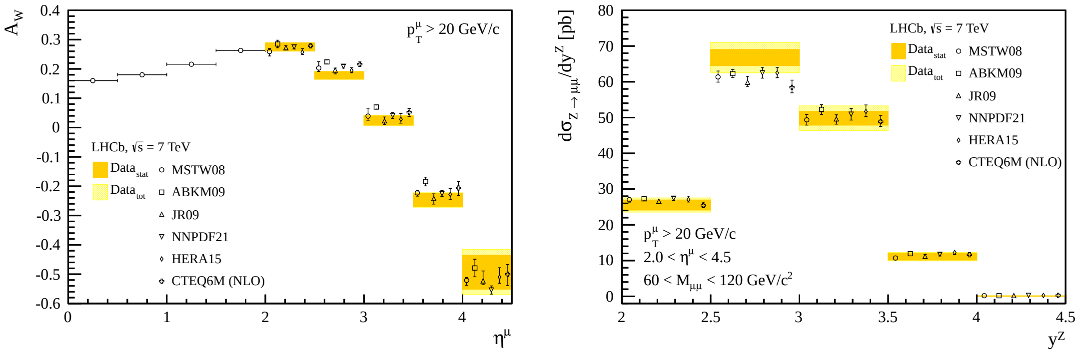

Figure 2: Summary and comparison to theory for the W asymmetry differential cross-section as a function of lepton pseudorapidity (left) and Z differential cross-section as a function of boson rapidity (right).

and 4.5, and in the case of the Z the di-lepton mass is between 60 and 120 GeV. The acceptance factor, A, is used when necessary to correct to this kinematic region, while the factor f_{fsr}, is used to correct the measurements for final state radiation. Both of these factors are calculated from simulation.

3.1 Results

The results are presented both as overall cross-section in Fig. 1 and as differential cross-sections in Fig. 2 as a function of boson rapidity, in the case of the Z measurements, and lepton pseudorapidity, in the case of the W. All results are consistent with the theoretical predictions calculated using DYNNLO[8] at NNLO and a number of different PDF sets. A summary of the uncertainties is given in Table 1. The $Z \to \mu\mu$ measurement is limited by the statistical determination of the efficiencies in 2010 data, with $Z \to \tau\tau$ limited by statistics, and the $W \to \mu$ and $Z \to ee$ measurements are limited by the luminosity determination.

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