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EWK physics: Measurements and prospects from LHCb

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LHCb experiment offers a complementary phase-space to study electroweak processes, compared to the ATLAS and CMS experiments, which benefits from the forward detector acceptance and large bandwidth of the triggers allowing low energy thresholds. The LHCb electroweak results provide sensitivity to PDF at high x values and at low x values, which is unexplored by other experiments. In this proceeding, electroweak measurements and prospects from the LHCb, using data collected in the LHC Run I and Run II, are presented.

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1. Introduction

The LHCb detector is a forward spectrometer, designed for b and c hadrons physics [1]. Among the four LHC experiments, the LHCb detector provides precision coverage in the forward region, $2 < \eta < 5$. In both Run I and Run II period, the LHCb collaboration demonstrated its capability in electroweak physics and jet physics, which becomes a general purpose forward detector. Precision measurements involving W and Z bosons are important tests of perturbative QCD and electroweak theory, within the Standard Model (SM). Moreover, they can be used to probe Parton Distribution Functions (PDFs).

2. Measurement of the W and Z bosons production in association with a jet at $\sqrt{s}$ = 8 TeV

The cross-section measurement of the W and Z boson production in association with a jet has been performed by the LHCb using 2 fb^{-1} of integrated luminosity of pp collisions at a centre-of-mass energy of 8 TeV [2]. The W and Z bosons are reconstructed in the $W^{\pm} \to \mu^{\pm}\nu^{-}$ and $Z \to \mu^{+}\mu^{-}$ decays. The associated jet is reconstructed using the anti-k_t algorithm with a distance parameter of 0.5 and is required to have $p_T > 20$ GeV/c and must be in the range $2.0 < \eta < 4.2$. The cross-sections have been measured as a function of the jet and muons kinematic: Z + jet cross-section as a function of the jet p_T, and the W^{+} (W^{-}) + jet cross-section as a function of the jet η, as shown in Fig. 1. The dominated systematic uncertainties are from purity determination and jet energy scale. As shown in the figure data are compatible with different theoretical predictions.

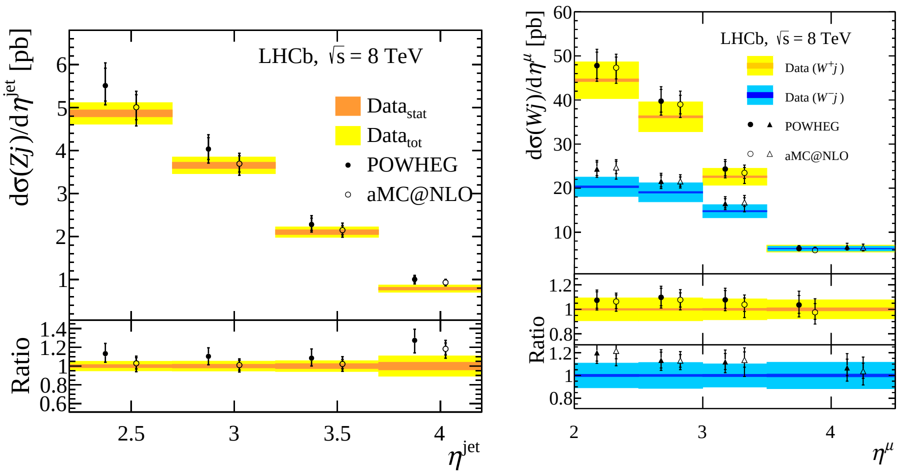

Figure 1: Z + jet cross-section as a fuction of the jet p_T (left), and W + jet cross-section as a function of the jet η (right). Theoretical predictions are also shown.

3. Measurement of forward Z production at $\sqrt{s}$ = 13 TeV

The LHCb collaboration performed a measurement of the Z boson production cross-section, reconstructing the $Z \to \mu^+\mu^-$ and $Z \to e^+e^-$ decays in pp collisions at $\sqrt{s}$ = 13 TeV [3] using 294 pb^{-1} data. The leptons are required with pseudo-rapidity in the range $2 < \eta < 4.5$, and transverse momentum $p_T > 20$ GeV/c. In addition, the di-lepton invariant mass must be in the $60 < m_{ll} < 120$ GeV/c^2 range. The measurements are compatible with the prediction, and the measured $Z \to \mu^+\mu^-$ and $Z \to e^+e^-$ cross sections are consistent with each other, which can also be considered as a test of Lepton Flavour Universality.

4. Measurement of the $W \to e\nu$ production at $\sqrt{s}$ = 8 TeV

For the W boson production, the LHCb collaboration performed a measurement of the cross-section for $W \to e\nu$ using pp collision data corresponding to an integrated luminosity of 2 fb^{-1} at 8 TeV [4]. The electrons are required to have more than 20 GeV/c of transverse momentum and to lie between 2.00 and 4.25 in pseudorapidity. The signal yields are determined by fitting to the electron p_T distribution. The cross section has been measured as a function of electron pseudorapidity, the results are shown in Fig. 2. They are compatible with the theoretical predictions calculated with different PDFs sets.

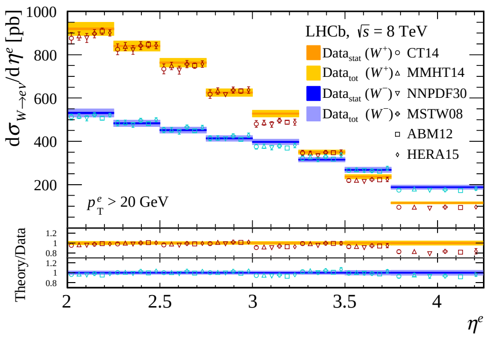

Figure 2: Measured $W \to e\nu$ cross-section as a function of electron pseudorapidity compared with theoretical predictions.

5. Forward $Z \to \tau^-\tau^+$ production at $\sqrt{s}$ = 8 TeV

This is the latest electroweak physics result from the LHCb collaboration, which is the forward $Z \to \tau^+\tau^-$ production measurement at 8 TeV, corresponding to an integrated luminosity of 2 fb^{-1} [5]. The reconstruction of tau-pair candidates is performed in both leptonic and hadronic decay modes of the tau lepton, requiring at least one leptonic mode for the tau-pair combination. The backgrounds are mainly from QCD and W/Z +jets, which are estimated with a data driven method. The measured result is shown in Fig. 3. The combined cross-section is about $95.8 \pm 2.1 \pm 4.6 \pm 0.2 \pm 1.1$pb, with uncertainties from statistical, systematic, the LHC beam energy uncertainty, and the integrated luminosity uncertainty, respectively. This result is compatible with NNLO SM predictions. The ratio of the cross-sections for $Z \to \tau^+\tau^-$ to $Z \to \mu^+\mu^-$ ($Z \to e^+e^-$) is determined to be close to 1, which is consistent with the lepton-universality hypothesis in Z decays.

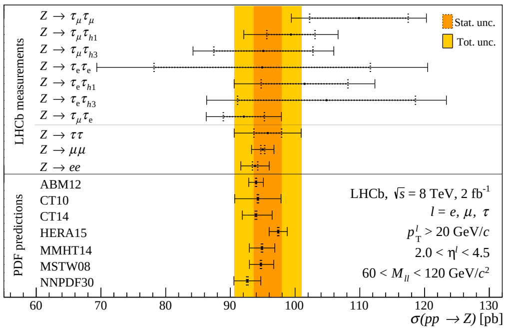

Figure 3: Summary of the measurements of $Z \to l^+l^-$ production cross-section inside the LHCb acceptance region from pp collisions at 8 TeV.

6. Weak mixing angular measurement

The LHCb can make a competitive measurement of weak mixing angle in the HL-LHC era. The forward-backward asymmetry increases as rapidity of Z boson increase, and dilution effect is expect to be small. The dilution is a possibility of wrong direction determination, which could be decreased in high η region. The LHCb result in Run I agrees well with the world average and is one of the most precise measurements from hadron colliders [6–12]. Run II analysis is in process. The weak mixing angle is measured by using full angular distribution of Z boson decays, because it contains more information than forward-backward asymmetry. Also, the Z angular coefficient measurement is ongoing.

7. W mass measurement

The electroweak fit predicts W mass with 7 MeV uncertainty, but the best individual measurements (CDF, D0, ATLAS) [13–15] have uncertainties of ~20 MeV. The W mass measurement in the LHCb is onging [16–18]. For this measurement, LHCb has some advantages. At first, the LHCb permit about 10 MeV statistical precision using Run II data. Secondly, the parton distribution function uncertainty would partially cancel in an average of LHCb with ATLAS and CMS. Our PDF uncertainties can be tightly constrained with a fit to the double differential distribution in p_T and η and it is possible to simultaneously constrain the W p_T shape and fit the W mass, to mitigate the QCD uncertainties.

8. Conclusion

The LHCb performed measurements of electroweak in the forward region of pp collisions, which are unexplored by other experiments. With unique acceptance, the LHCb data can provide unique tests of the SM and constrains on the PDFs. Many EWK measurements are in progress, let's wait for new exciting measurements from the LHCb.

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