PROCEEDINGS OF SCIENCE

W and Z studies at CMS

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The production of W and Z bosons has been observed in pp collisions at a center-of-mass energy of 7 and 8 TeV using data collected in the CMS experiment. W events were selected containing an isolated, energetic electron or muon. Z events were selected containing a pair of isolated, energetic electrons or muons. Data-driven methods are used to estimate reconstruction and triggering efficiencies, and well as the main backgrounds. We present the W and Z signal yields and the extracted cross-sections at $\sqrt{s} = 8$ TeV. We discuss the measurements of the lepton charge asymmetry in the reconstructed W events decaying to a lepton and a neutrino, obtained in the electron and muon decay channels at $\sqrt{s} = 7$ TeV. We also report on the measurements of the differential cross section, forward-backward asymmetry and electroweak couplings of events coming from the Drell-Yan process at $\sqrt{s} = 7$ TeV.

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1. Introduction

The Large Hadron Collider (LHC) was running at $\sqrt{s} = 7$ TeV and 8 TeV at 2010 – 2011 and 2012 correspondingly. The main LHC goal in study of W and Z bosons production is explore physics at the TeV energy scale via proton-proton collision. W and Z production is well established, so it provides tests of perturbative quantum chromodynamics. In addition, W and Z production is a major source of background for various physics analyses, such as $t\bar{t}$, diboson measurements and Standard Model (SM) Higgs production, as well as for searches for new physics beyond the SM, such as the production of high-mass dilepton resonances.

All measurements, presented here, are based on the data from CMS detector. The CMS experiment is described in more detail elsewhere [1]. The central features is at 3.8 T superconducting solenoid with a 6 m bore. Inside the magnet are the silicon pixel and strip tracker, the crystal electromagnetic calorimeter, and the brass scintillator hadron calorimeter. Muons are detected in gas-ionization detectors embedded in the steel return yoke.

2. Inclusive W and Z boson cross section at $\sqrt{s} = 8$ TeV

In order to perform a precision measurement of the inclusive W and Z boson cross sections at $\sqrt{s} = 8$ TeV at CMS [2], a dedicated LHC configuration was deployed to accumulate a dataset with low pileup and low transverse momentum trigger thresholds. During such special LHC runs were selected proton-proton data with integrated luminosity of 18.8 pb^{-1}. Theoretical predictions of the inclusive W and Z cross sections are available at next-to-next-to-leading order (NNLO) in perturbative QCD. The calculations are limited by uncertainties on parton distribution functions (PDFs), higher-order QCD, and EWK radiative corrections, which are available at next-to-leading order (NLO).

At Figure 1, the measured and predicted W versus Z and W^+ versus W^- cross sections are presented. The measurements are consistent between the electron and muon channels, and in agreement with next-to-next-to-leading order cross section calculations.

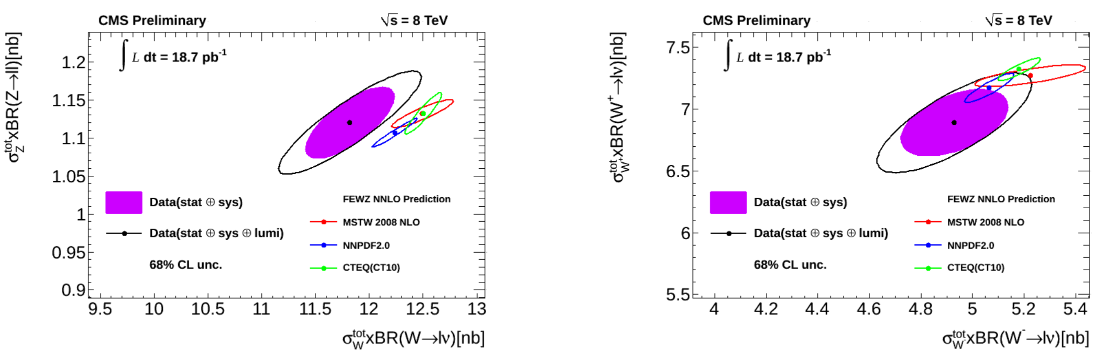

Figure 1: Measured and predicted W versus Z (left) production and W^+ versus W^- (right) cross sections. The ellipses illustrate the 68% coverage for total uncertainties (open black) and excluding the luminosity uncertainty (purple filled). The uncertainties of the theoretical predictions correspond to the PDF uncertainties only.

3. Measurement of the charge asymmetry in inclusive W at $\sqrt{s} = 7$ TeV

In proton-proton collisions, W bosons are produced primarily via the processes $u\bar{d} \to W^+$ and $d\bar{u} \to W^-$. The first quark is a valence quark from one of the protons, and the second one is a sea anti-quark from the other proton. Due to the presence of two valence u quarks in the proton, there is an overall excess of W^+ over W^- bosons. Measurement of this production asymmetry between W^+ and W^- bosons as a function of boson rapidity can provide better constraints on the u/d ratio and the sea antiquark densities in the ranges of the Björken parameter x. However, due to the presence of neutrinos in leptonic W decays the boson rapidity is not directly accessible. That is why the lepton charge asymmetry is defined to be

$$A(\eta) = \frac{d\sigma/d\eta(W^+) - d\sigma/d\eta(W^-)}{d\sigma/d\eta(W^+) + d\sigma/d\eta(W^-)},$$

where η is the charged lepton (μ or e) pseudorapidity from decay of W boson.

At Figure 2, the comparison of the measured muon (left) [3] and electron (right) [4] charge asymmetry at CMS to different PDF models are presented. This high precision measurement of the W lepton charge asymmetry at the LHC provides new inputs to the PDF global fits.

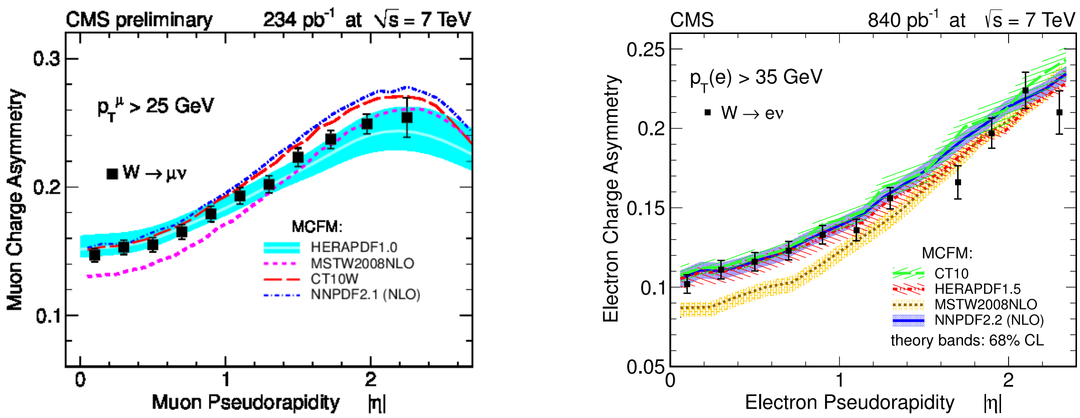

Figure 2: Left: Comparison of the measured muon charge asymmetry to different PDF models. The theoretical predictions are obtained using MCFM MC tool and the muon $p_T > 25$ GeV is imposed. Right: Comparison of the measured electron asymmetry to the predictions of different PDF models for electron $p_T > 35$ GeV. For both plots: The error bars include both statistical and systematic uncertainties. The data points are placed in the center of the $|\eta|$ bins. The PDF uncertainty bands are estimated using the PDF reweighting technique and correspond to 68% confidence level.

4. Drell-Yan at $\sqrt{s} = 7$ TeV

Drell-Yan lepton-pair production in hadron-hadron collisions is described in the SM by s-channel γ^*/Z exchange. Theoretical calculations of the differential cross section $d\sigma/dM$ and the double-differential cross section $d^2\sigma/dMdY$, where M is the dilepton invariant mass and Y is the absolute value of the dilepton rapidity, are well established up to the NNLO. Comparisons between theoretical calculations and experimental measurements, provide tests of perturbative QCD and constraints on the PDFs.

At CMS the Drell-Yan [5] differential cross section in dilepton mass and double differential cross section in dimuon mass and rapidity are studied in the mass range from 15 to 1500 GeV and 20 to 1500 GeV with absolute rapidity less than 2.4 using 4.5 fb^{-1} data. At Figure 3, the measurements are presented. Good agreement with NNLO prediction and PDF functions is observed.

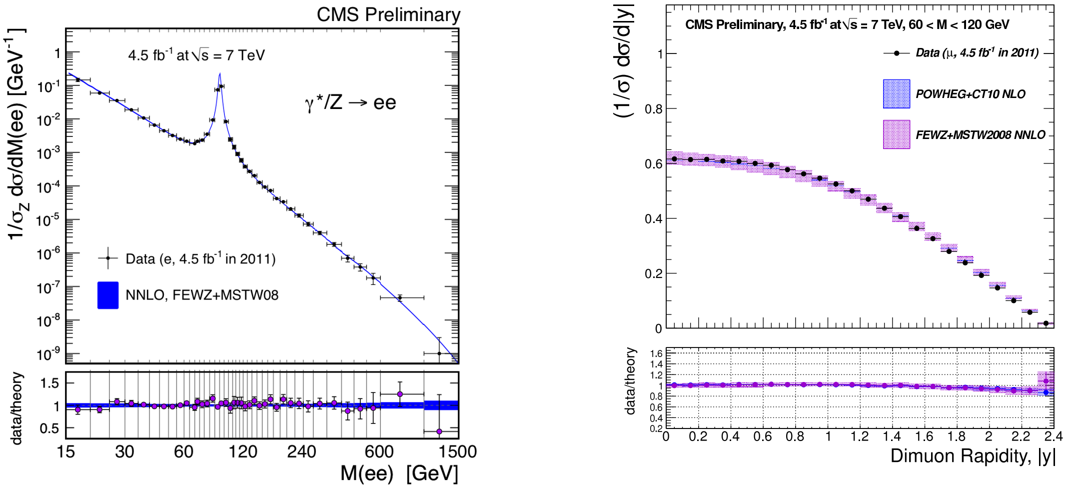

Figure 3: Left: Drell-Yan invariant mass spectrum in the dielectron channel, normalized to the Z resonance region, as measured and as predicted by NNLO calculation, for the full phase space. Right: Drell-Yan rapidity-invariant mass spectrum in detector acceptance in the dimuon channel ($60 < M < 120$ GeV), normalized to the Z resonance region, as measured and as predicted by NLO POWHEG+CT10 PDF and NNLO FEWZ+MSTW2008 PDF calculations.

In the SM process $q\bar{q} \to \gamma^*/Z \to l^- l^+$, both the vector and axial-vector couplings of electroweak bosons to fermions are present. This results in a forward-back ward asymmetry, A_{FB} in the Drell-Yan pairs. The asymmetry parameter, A_{FB}, is calculate by following formula:

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}.$$

At Figure 4, the unfolded forward-backward asymmetry measured at CMS [6] is presented. It is calculated for combined $\mu^+\mu^-$ and e^+e^- events at the Born level in four Y bins with the acceptance cuts of $p_T(l) > 20$ GeV and $|\eta(l)| < 2.4$. This measurement is very sensitive to the test of the SM. The final results show consistence with the SM predictions within the estimated uncertainties.

The measurement of the weak mixing angle with different initial and final states in the fermion-antifermion process $f_1\overline{f_1} \to \gamma^*/Z \to f_2\overline{f_2}$ tests the universality of the fermion-gauge-boson interactions and predictions of the SM.

At CMS [7] we present a multivariate analysis that uses full information about the Drell-Yan process $q\bar{q} \to \gamma^*/Z \to \mu^-\mu^+$ parametrized as a function of the dimuon rapidity, Y, dimuon invariant mass, M, and dimuon decay angle, θ^*. To calculated weak mixing angle, we use an unbinned extended maximum-likelihood fit that simultaneously describes the signal and background yields

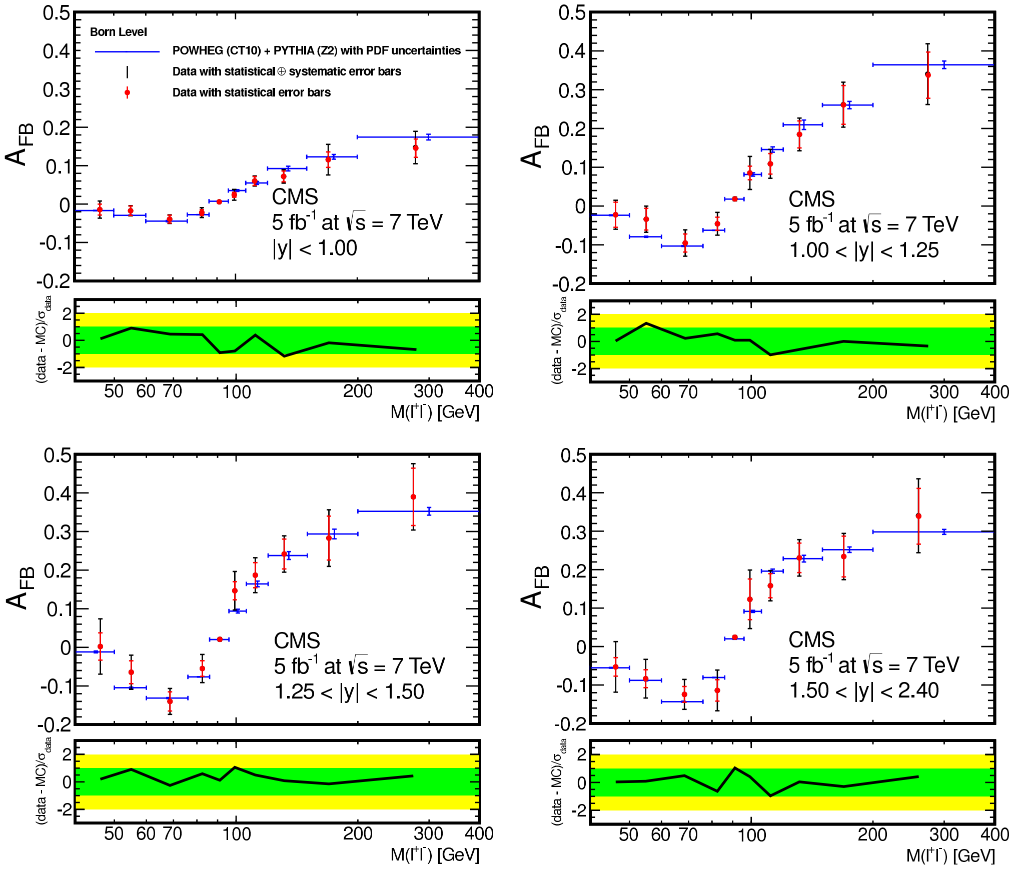

Figure 4: The unfolded and combined ($\mu^+\mu^-$ and e^+e^-) measurement of AFB at the Born level in four abs(y) bins for $p_T > 20$ GeV and $|\eta| < 2.4$. The data points are shown with both statistical error bars and combined statistical and systematic error bars. The error bars on the MC points are the PDF uncertainties. The MC statistical errors are of the same order of magnitude as the PDF uncertainties. The horizontal extent of the error bars indicates the bin width (except for the last bin, which is truncated at 400 GeV). Beneath each plot is shown the difference between data and MC, normalized by the combined statistical and systematic uncertainty. The green and yellow bands indicate the 1σ and 2σ differences of data from theory predictions.

and the parameters of the Y, M, $\cos\theta^*$ distributions and it equals to:

$$\sin^2\theta_W = 0.2287 \pm 0.0020(stat.) \pm 0.0025(syst.)\,.$$

The measurement of the weak mixing angle is predominantly in the $u\bar{u}$ and $d\bar{d} \to \gamma^*/Z \to \mu^-\mu^+$ processes in proton-proton collisions, as expected within the SM. The weak mixing angle is measured at $\sqrt{s} = 7$ TeV with 1% precision like at all hadronic experiments: CDF and D0 (Tevatron), H1 (HERA).

5. Conclusion

Study of W and Z production at CMS experiment are presented. They are very important for test of the SM, contribution to PDFs and better understanding of background for Higgs and new physics searches.

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