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W/Z PHYSICS WITH THE CMS DETECTOR AT THE LHC*

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In this paper, I present Standard Model electroweak results obtained by the CMS Collaboration after nearly 3 years of data taking. Selected measurements are discussed concerning single- and di-boson W/Z production in proton–proton collisions at the center-of-mass of 7 and 8 TeV. Results for data are compared to predictions of various Monte Carlo models.

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1. Introduction

Observation of the electroweak gauge bosons (EWK) via their decays to electrons and muons provides an important test of the Standard Model (SM) of particle physics. Inclusive W and Z boson cross section measurement provides a test of Next-to-Next-to-Leading-Order (NNLO) perturbative QCD calculations, electron charge asymmetry provides constraints for parton distribution functions (PDF) and differential and double-differential Drell–Yan cross section provide both test of QCD and PDF constraints.

2. Experimental setup

A detailed description of the CMS detector can be found in [1]. The main part of the CMS detector is superconducting solenoid of 6 m internal diameter, providing 3.8 T magnetic field for charged particle transverse momentum measurement. Within the field volume, there are a silicon strip tracker, an electromagnetic calorimeter (ECAL), and a hadron calorimeter

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(HCAL). Muons are detected in a gas-ionization detectors embedded in the iron return yoke. For measurement of particles with high rapidity, extensive forward calorimeters are installed.

The CMS has the origin of the coordinate system at the interaction point, the x-axis pointing to the center of the LHC ring, the y-axis pointing up (perpendicular to the LHC plane), and the z-axis along the anticlockwise-beam direction. The polar angle θ is measured from the positive z-axis and azimuthal angle ϕ is measured in the xy-plane. The pseudorapidity is given by $\eta = -\ln(\tan\theta/2)$.

3. Selected electroweak results

3.1. Inclusive W and Z boson cross sections in pp collisions at $\sqrt{s} = 8$ TeV

The study presented here was carried using an integrated luminosity of 18.7 ± 0.9 pb^{-1} of CMS data collected in pp collisions at the center-of-mass energy of 8 TeV (2012). A detailed description of this analysis can be found in [2].

In order to perform a precise measurement of the inclusive W and Z boson cross section, a dedicated LHC configuration was deployed to accumulate dataset with low pileup and low transverse momentum trigger thresholds. Two final states are analyzed: electron and muon channels. On-line selection of W and Z boson events requires single electron and muon triggers. For electrons, the transverse momentum p_{T} threshold were 12 GeV for the Level 1 trigger and 22 GeV for the high level trigger (HLT). For muons, the thresholds are 7 and 15 GeV, respectively.

3.1.1. Event selection criteria

Electrons are identified as an ECAL energy deposits matched to tracks measured with the silicon tracker. Pseudorapidites are in range of $|\eta| < 1.4442$ (in barrel) and $1.566 < |\eta| < 2.5$ (in endcaps). Region between the barrel and endcaps is excluded because this part of detector is shadowed by cables and services exiting. Electrons are required to have transverse energy $E_{\mathrm{T}} > 25$ GeV and to be isolated in a cone of $\Delta R = 0.3$, where $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$.

Muons are reconstructed from a seed track in the muon detector, using a global fit, with silicon strip and pixel information. Muons are required to have transverse momentum $p_{\mathrm{T}} > 25$ GeV, pseudorapidity $|\eta| < 2.1$ and to be isolated in a cone of $\Delta R = 0.4$.

3.1.2. *W* and *Z* boson signal extraction

An accurate missing transverse energy $E_{\mathrm{T}}^{\mathrm{miss}}$ measurement is essential for distinguishing a W signal from QCD multijet backgrounds. The shape of the $E_{\mathrm{T}}^{\mathrm{miss}}$ is modeled by a parametric function (modified Rayleight distribution),

$$f_{\mathrm{QCD}}\left(E_{\mathrm{T}}^{\mathrm{miss}}\right) = E_{\mathrm{T}}^{\mathrm{miss}} \exp\left(-\frac{E_{\mathrm{T}}^{\mathrm{miss}2}}{2\left(\sigma_0 + \sigma_1 E_{\mathrm{T}}^{\mathrm{miss}}\right)^2}\right), \tag{1}$$

where σ_0 and σ_1 are the background shape parameters. The $W \to e\nu$ and $W \to \mu\nu$ signals are extracted using a binned maximum likelihood fit to $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution. The results of extraction are shown in Fig. 1.

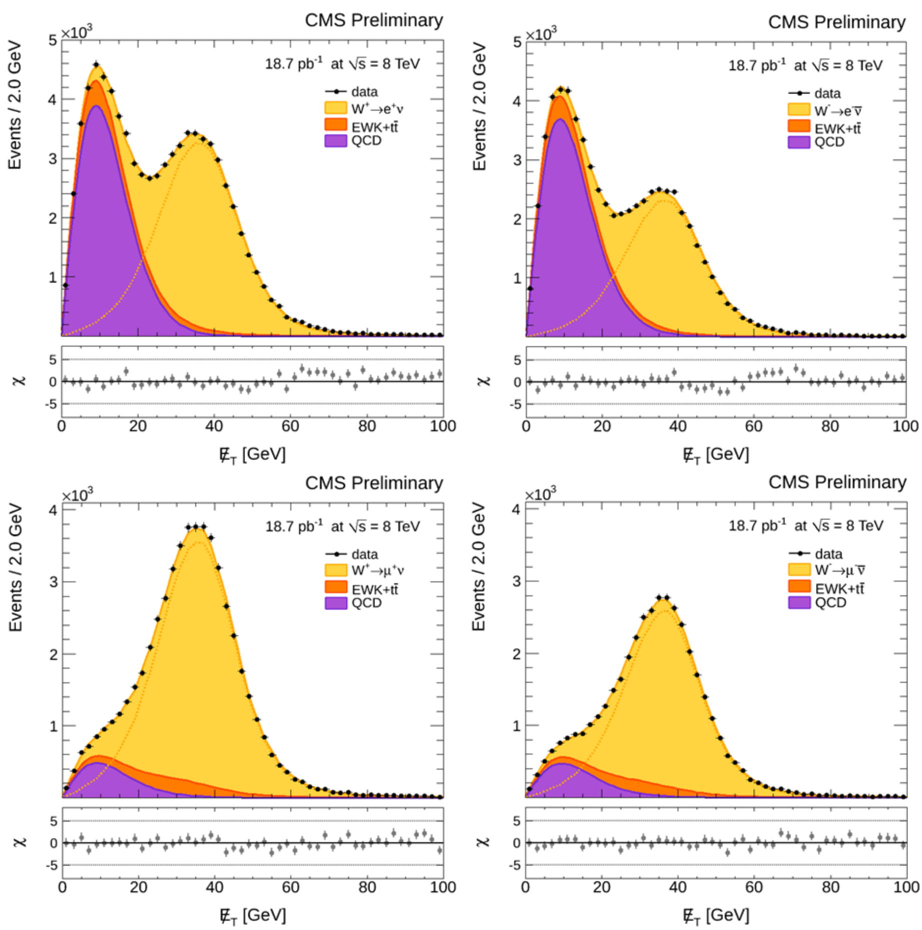

Fig. 1. The missing transverse energy distributions for the selected W^+ (left) and W^- (right) candidates in the electron (top) and muon (bottom) channels.

To extract the Z boson yield, the events in the Z mass peak are counted.

Results for the electron and muon channels are presented separately in Fig. 2 compared to the theoretical predictions (gray/yellow band) computed at the NNLO in QCD with FEWZ generator and the MSTW2008 PDF set. Good agreement of data and predictions is observed.

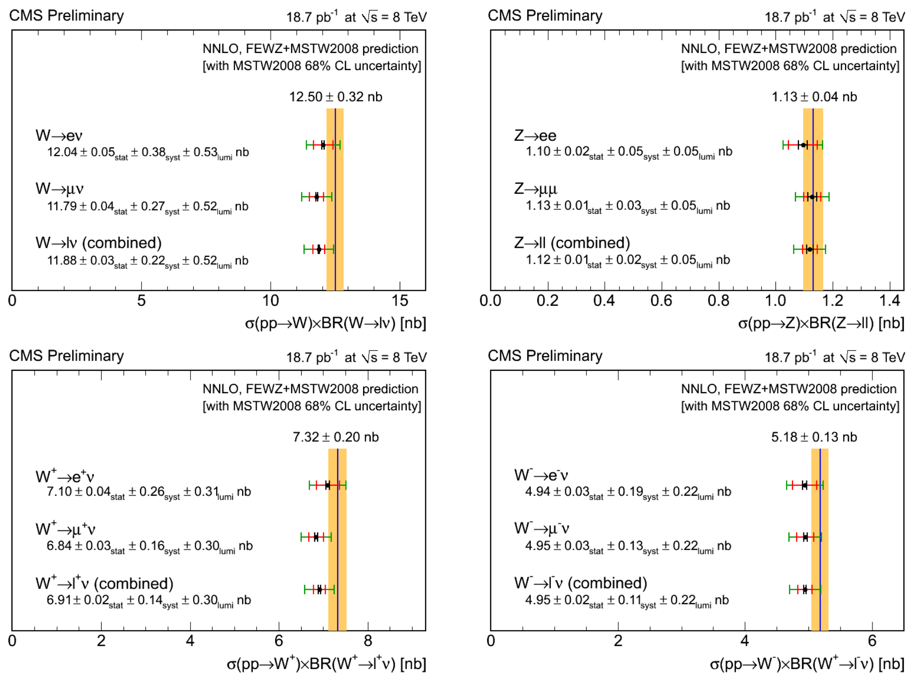

Fig. 2. Summary of the W (top left), Z (top right), W^+ (bottom left) and W^- (bottom right) production cross section times branching ratio measurements. Measurements are compared to the theoretical predictions (gray/yellow band) computed at the NNLO in QCD with FEWZ and the MSTW2008 PDF set. Statistical uncertainties are represented as black error bars, while the middle/red error bars also include systematic uncertainties, and the outer/green error bars also include luminosity uncertainties.

3.2. Electron charge asymmetry in inclusive W production in pp collisions at $\sqrt{s} = 7$ TeV

Electron charge asymmetry measurement presented here was carried using an integrated luminosity of 840 pb^{-1} of CMS data collected in pp collisions at the center-of-mass energy of 7 TeV (2011). A detailed description of this analysis can be found in [3].

Because the proton contains two valence u quarks and one valence d quark, W^+ bosons are produced more frequently then W^- bosons. Electron charge asymmetry is defined as

$$A(\eta) = \frac{d\sigma/d\eta(W^+ \to e^+\nu) - d\sigma/d\eta(W^- \to e^-\bar{\nu})}{d\sigma/d\eta(W^+ \to e^+\nu) + d\sigma/d\eta(W^- \to e^-\bar{\nu})}\,, \tag{2}$$

where η is pseudorapidity in lab frame, and $d\sigma/d\eta$ is the differential cross section for electrons from W boson decays. Measurements of asymmetry provide constrains on the $u, d, \bar{u}$, and $\bar{d}$ PDF's in the range of $10^{-3} < x < 10^{-1}$, where x is the proton momentum fraction carried by parton.

The experimental results are compared in Fig. 3 to theoretical predictions obtained with the Next-to-Leading-Order MCFM generator interfaced with CT10, HERAPDF, NNPDF and MSTW2008NLO PDF models. The experimental data are in agreement with the predictions from CT10, NNPDF, and HERAPDF, while predictions from MSTW are systematically lower then the observed asymmetry in the region $|\eta| < 1.4$.

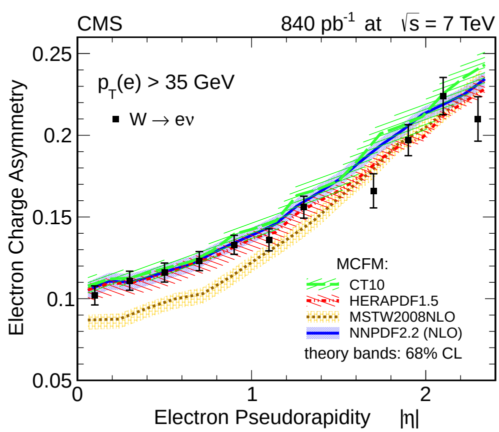

Fig. 3. Comparison of measured electron charge asymmetry to the prediction of different PDF models for the electron $p_{\mathrm{T}} > 35$ GeV. The error bars include both statistical and systematic uncertainties.

3.3. Differential and double-differential Drell–Yan cross section in pp collisions at $\sqrt{s} = 7$ TeV

Differential $d\sigma/dM$ and double-differential $d^2\sigma/dMdY$ the Drell–Yan cross section (M is the dilepton invariant mass, Y is the absolute value of the dilepton rapidity) measurements presented here were based on 4.5 fb^{-1} of

2011 full dataset from proton–proton collisions at $\sqrt{s} = 7$ TeV. Analysis was performed in the dielectron and dimuon channels for $d\sigma/dM$ and in the dimuon channel for $d^2\sigma/dMdY$ measurement.

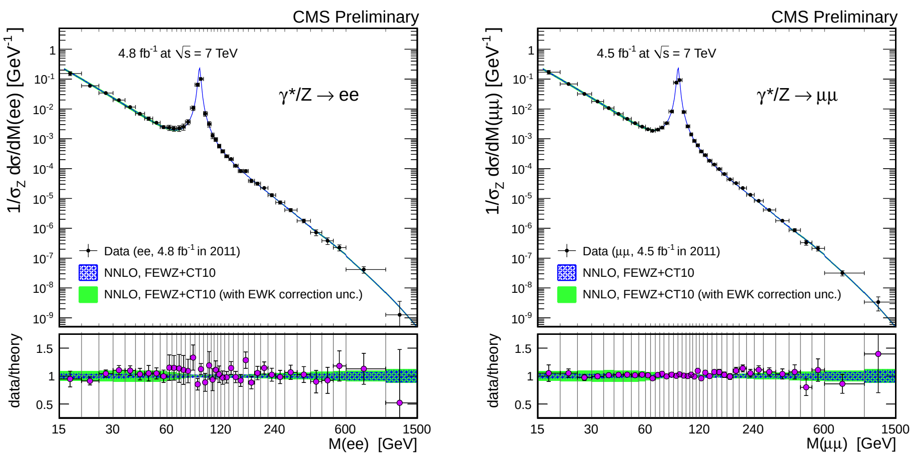

Fig. 4. The Drell–Yan invariant mass spectrum in the dielectron (left) and dimuon (right) channels, normalized to the Z resonance region.

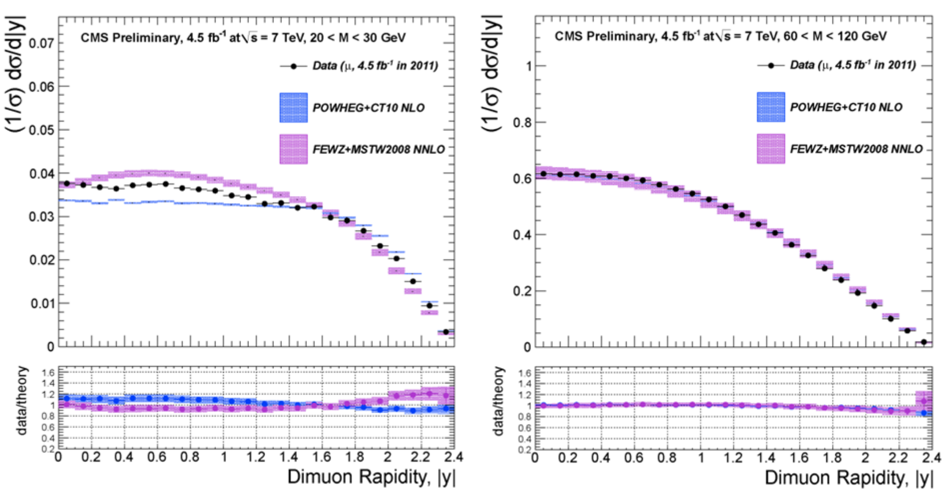

Fig. 5. The Drell–Yan rapidity-invariant mass spectrum in detector acceptance, normalized to the Z resonance region, as measured and as predicted by NLO FEWZ+CT10 PDF and NNLO FEWZ+MSTW2008PDF calculations. The error bands in the ratio plot combine the statistical calculation error and the PDF error.

The Drell–Yan lepton-pair production in hadron–hadron collisions is described in the Standard Model by s-channel γ^*/Z exchange. Comparison between theoretical calculations and experimental measurements provides a test of perturbative quantum chromodynamics (QCD) and constraints on the parton distribution functions.

Results of differential cross section measurement are shown in Fig. 4. Good agreement is observed with NNLO theoretical predictions with FEWZ generator with MSTW08 PDFs.

Results of double differential cross section measurements are shown in Fig. 5. Theoretical calculations with NLO POWHEG+CT10 PDF and NNLO FEWZ+MSTW2008 PDF are not in good agreement with data for region $20 < M < 30$ GeV. It shows sensitivity of this measurement to PDFs and shows its potential for PDFs improvement.

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