Electroweak results from CMS

This content has been downloaded from IOPscience. Please scroll down to see the full text.
2013 J. Phys.: Conf. Ser. 455 012025
(http://iopscience.iop.org/1742-6596/455/1/012025)

View the table of contents for this issue, or go to the journal homepage for more

Download details:

IP Address: 110.168.127.141
This content was downloaded on 25/06/2016 at 07:59

Please note that terms and conditions apply.
Electroweak results from CMS

V Ciulli on behalf of the CMS Collaboration

1 Dipartimento di Fisica, Università di Firenze, via G. Sansone 1, 50019 Sesto F. (FI), Italy

E-mail: vitaliano.ciulli@fi.infn.it

Abstract. The latest electroweak results from CMS, based on pp collision data taken at 7 and 8 TeV, are presented. In particular precise measurements of the inclusive and differential cross sections for W and Z boson production, and for multi-boson production are reviewed and compared with theory predictions. Results agree with Standard Model and limits are set on anomalous triple gauge couplings.

1. Introduction

The dominant mechanism for W and Z boson production in pp collisions at the Large Hadron Collider (LHC) is the annihilation of a valence quark from one proton with a sea antiquark from the other. The contribution from sea quark-antiquark scattering is also relevant, as a value of \( Q^2 \sim M^2_Z \) is reached in the interactions between partons carrying a proton momentum fraction \( 10^{-3} < x < 10^{-1} \). Furthermore, the process where a vector boson is produced in association with a jet, depends primarily on the gluon content of the proton. Therefore, the W and Z production allows probing both the electroweak couplings to the quarks and constraining the PDFs.

Similarly the measurement of the diboson production is a direct test of triple gauge couplings (TGC). In the Standard Model only the charged triple gauge couplings, WWZ and WW\( \gamma \), are allowed, while the neutral, ZZZ, ZZ\( \gamma \) and Z\( \gamma \gamma \), are forbidden. Any deviation of the latter from a null value would be therefore an evidence of new physics beyond the Standard Model.

Theory calculations and Monte Carlo generators are now available at next-to-leading order (NLO), and even next-to-next-to-leading order (NNLO) predictions for single W and Z cross-section.

In the following the latest measurements of single and diboson cross-section measurements done by the Compact Muon Solenoid experiment at the LHC are reviewed and compared with expectations from the theory.

2. The CMS detector

The central feature of the Compact Muon Solenoid (CMS) apparatus is a superconducting solenoid of 6 m internal diameter, providing a magnetic field of 3.8 T. Within the superconducting solenoid volume are a silicon pixel and strip tracker, a lead tungstate crystal electromagnetic calorimeter (ECAL), and a brass/scintillator hadron calorimeter (HCAL). Muons are measured in gas-ionization detectors embedded in the steel return yoke outside the solenoid. Extensive forward calorimetry complements the coverage provided by the barrel and endcap detectors. The ECAL energy resolution for electrons with \( E_\perp \approx 45 \) GeV from Z\( \rightarrow ee \) decays is better than 2%.
in the central region of the ECAL barrel ($|\eta| < 0.8$), and is between 2% and 5% elsewhere. The electron energies are measured by the ECAL and their directions are measured by the tracker. The energy resolution for photons with $E_\perp \approx 60 \text{ GeV}$ varies between 1.1% and 2.5% over the solid angle of the ECAL barrel, and from 2.2% to 5% in the endcaps. Muons are measured in the pseudorapidity range $|\eta| < 2.4$, with detection planes made using three technologies: drift tubes, cathode strip chambers, and resistive plate chambers. Matching muons to tracks measured in the silicon tracker results in a transverse momentum resolution between 1 and 5%, for $p_\perp$ values up to 1 TeV. A more detailed description can be found in Ref. [1].

3. Single W and Z cross-section measurements

A precision measurement of the inclusive W and Z boson cross sections at $\sqrt{s} = 8 \text{ TeV}$ [2] has been performed with the same method used at 7 TeV [3]. The instantaneous luminosity was reduced to accumulate a dataset with an average low number of proton-proton interactions (pileup) and low transverse momentum trigger thresholds. The beam separation was periodically adjusted to compensate the loss of instantaneous luminosity, which therefore was maintained in the range $3 \times 10^{32}$ to $6 \times 10^{32} \text{ cm}^{-2} \text{s}^{-1}$ (“luminosity leveling”). A data sample corresponding to an integrated luminosity of $18.7 \pm 0.9 \text{ pb}^{-1}$ was collected, where both electron and muon final states were analyzed. The measured values are shown in Fig. 1 and agree with NNLO cross section calculations obtained with FEWZ [4] and the MSTW2008 PDF set.

In addition to the analysis of 8 TeV data, several analyses have been updated with the full dataset at 7 TeV. A measurement of the Drell-Yan differential cross section $d\sigma/dM$ in the dielectron and dimuon channels and the first measurement of the double-differential cross section $d^2\sigma/dM dY$ in the dimuon channel, have been been performed with an integrated luminosity of 4.5 $\text{fb}^{-1}$ [5]. Distributions are unfolded for the effects of resolution and final state QED radiation using POWHEG Monte Carlo [6], and an additional acceptance correction is applied to take the NNLO effects into account. The $d\sigma/dM$ results are overall in very good agreement with the NNLO theoretical predictions, as computed with FEWZ using the MSTW2008 PDFs. A small deviation is observed for $d^2\sigma/dMdY$ measurement for dimuon mass $M < 45 \text{ GeV}$.

The forward-backward asymmetry ($A_{FB}$) of Drell-Yan lepton pairs has been also measured as a function of dilepton mass and rapidity in the dielectron and dimuon channels [7]. The $A_{FB}$ measurement in the dimuon channel and the combination of the two channels are the first such results obtained at a hadron collider. The measured asymmetries are consistent with the Standard Model predictions.

Lepton charge asymmetry have been measured in the $W \rightarrow e$ [8] and $W \rightarrow \mu$ [9] channels. Electrons (muons) are selected with $p_\perp > 35 (25) \text{ GeV}$ in a sample of proton-proton collisions at 7 TeV corresponding to an integrated luminosity of 840 (234) $\text{pb}^{-1}$. The measured distributions are shown in Fig. 2. In the muon channel the distribution is flatter than expected, while in the electron channel it is difficult to draw any conclusion as the uncertainty increases at high values of the pseudorapidity because of the larger background. Overall the experimental data are in good agreement with the predictions from CT10, NNPDF, and HERAPDF, while the predictions from MSTW are systematically lower than the observed asymmetry in the region $|\eta| < 1.4$.

Using the dataset collected at $\sqrt{s} = 7 \text{ TeV}$, the Z boson decaying to four leptons (electrons and/or muons) has been observed for the first time in proton-proton collisions [10]. A pronounced resonance peak, with a statistical significance of 9.7 $\sigma$, is present in the distribution of the invariant mass of four leptons with mass and width consistent with expectations for Z boson decays. The measured branching fraction is $\mathcal{B}(Z \rightarrow 4l) = (4.2^{+0.9}_{-0.8} \text{ (stat.)} \pm 0.2 \text{ (syst.)}) \times 10^{-6}$, in agreement with the Standard Model prediction of $4.45 \times 10^{-6}$. The measured cross section times branching fraction is $\sigma(pp \rightarrow Z) \mathcal{B}(Z \rightarrow 4l) = 112^{+23}_{-20} \text{ (stat.)}^{+7}_{-5} \text{ (syst.)}^{+3}_{-3} \text{ (lumi.)} \text{ fb}^{-1}$, also consistent with the Standard Model prediction of 120 fb. The four-lepton mass peak arising
Figure 1. Summary of the W (top) and Z (bottom) production cross section times branching ratio measurements. Measurements in the electron and muon channels, and combined, are compared to the theoretical predictions (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 red error bars also include systematic uncertainties, and the green error bars also include luminosity uncertainties from $Z \rightarrow 4l$ decays provides a very important calibration channel for the Higgs boson search in the $H \rightarrow ZZ \rightarrow 4l$ decay mode.

4. Diboson production and limits on TGC couplings

The WW and ZZ production cross sections are measured in proton-proton collisions at $\sqrt{s} = 8$ TeV in data samples corresponding to an integrated luminosity of up to 5.3 fb$^{-1}$ [11]. The measurements are performed in the leptonic decay modes $WW \rightarrow l\nu l'\nu'$ and $ZZ \rightarrow 2l2l'$, where $l = e, \mu$ and $l' = e, \mu, \tau$. The measured cross sections $\sigma(pp \rightarrow WW) = 69.9 \pm 2.8$ (stat.) $\pm 5.6$ (syst.) $\pm 3.1$ (lum.) pb and $\sigma(pp \rightarrow ZZ) = 8.4 \pm 1.0$ (stat.) $\pm 0.7$ (syst.) $\pm 0.4$ (lum.) pb, for both $Z$ bosons produced in the mass region $60 < M_Z < 120$ GeV are consistent with Standard Model predictions. Figure 3 shows the dilepton transverse momentum of the WW candidate events.
Figure 2. Comparison of the measured electron (top) and muon (bottom) asymmetry to the predictions of different PDF models. 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.
Figure 3. Distributions for WW candidate events of the dilepton transverse momentum. Points represent the data, and shaded histograms represent the WW signal and the background processes. The last bin includes the overflow. The WW signal is scaled to the measured cross section, and the background processes are normalized to the corresponding estimated values.

These are the first measurements of the diboson production cross sections at $\sqrt{s} = 8$ TeV.

The full data sample recorded at $\sqrt{s} = 7$ TeV, corresponding to an integrated luminosity of 5 pb$^{-1}$, has been used to measure $W\gamma$ and $Z\gamma$ production cross sections and set limits on anomalous triple $WW\gamma$, $ZZ\gamma$, and $Z\gamma\gamma$ gauge couplings.

The total cross sections for $W\gamma \rightarrow l\nu\gamma$ and $Z\gamma \rightarrow ll\gamma$, where $l = e$ or $\mu$, are measured for photon transverse energy $E_\perp > 15$ GeV and angular separation from charged leptons $\Delta R(l, \gamma) > 0.7$. For the $Z\gamma$ final state an additional dilepton invariant mass requirement of $M(ll) > 50$ GeV is imposed. Preliminary results shows no deviation from the Standard Model values.

The first measurement of the $Z\gamma \rightarrow \nu\nu\gamma$ cross section in pp collisions at $\sqrt{s} = 7$ TeV has been also done. The measurement is performed normalizing to photons with transverse energy of 145 GeV in the pseudorapidity region $|\eta| < 1.4$. Figure 4 shows the photon $p_\perp$ distribution for the candidates on a data sample corresponding to an integrated luminosity of 5 fb$^{-1}$. The measured cross is $21.3 \pm 4.2$ (stat.) $\pm 4.3$ (syst.) $\pm 0.5$ (lumi.) fb, which is in good agreement with the theoretical prediction of $21.9 \pm 1.1$ fb, obtained at NLO accuracy using the WGRAD generator [12]. Combining this measurement with the one of $Z\gamma \rightarrow ll\gamma$, the most stringent limits to date have been set on anomalous $ZZ\gamma$ and $Z\gamma\gamma$ couplings.

The sum of WW and WZ diboson production cross section has been also measured at $\sqrt{s} = 7$ TeV, using events containing a leptonically decaying W boson and exactly two jets [13]. The measured value of the total cross section is $68.89 \pm 8.71$ (stat) $\pm 9.70$ (syst) $\pm 1.52$ (lumi) pb, consistent with the Standard Model NLO prediction of $65.6 \pm 2.2$ pb [14] and no evidence for
anomalous triple gauge couplings is found.

In addition, the invariant mass spectrum of the two jets with highest transverse momentum in W+2-jets and W+3-jets events has been studied [15]. The relative contribution of the known Standard Model processes to the observed dijet invariant mass spectrum has been determined using an unbinned maximum likelihood fit in the range between 40 GeV and 400 GeV. The fit is performed separately for the electron and muon channels and for the 2 jets and 3 jets samples since relative background contributions and composition differ. Figure 5 shows the distribution of the invariant mass spectrum of the leading two jets observed in data, after subtraction of all SM components except the electroweak diboson WW/WZ. No evidence is found for the anomalous structure reported by the CDF Collaboration, and an upper limit of 5.0 pb is established at 95 % confidence level on the production cross section for a generic Gaussian signal with mass near 150 GeV.

5. Conclusions
The CMS experiment at the LHC accomplished a large program of electroweak measurements that allows testing the Standard Model with a precision comparable or even better than available (N)NLO predictions. The results are in agreement with expectations for production cross sections that span over several order of magnitude. The measurements of inclusive and differential cross sections of W and Z bosons provides significant constraints on PDFs. The measurements of diboson production set stringent limits on the triple gauge couplings. No significant deviation from the Standard Model is observed.

[1] S. Chatrchyan et al. The CMS experiment at the CERN LHC. JINST, 03:S08004, 2008.
[2] CMS Collaboration. Inclusive W/Z cross section at 8 TeV. CMS Physics Analysis Summary CMS-PAS-SMP-12-011, 2012.
[3] S. Chatrchyan et al. Measurement of the inclusive W and Z production cross sections in pp collisions at $\sqrt{s} = 7$ TeV with the CMS experiment. Journal of High Energy Physics, 2011:1–76, 2011.
[4] Ryan Gavin, Ye Li, Frank Petriello, and Seth Quackenbush. FEWZ 2.0: A code for hadronic Z production at next-to-next-to-leading order. Comput.Phys. Commun., 182:2388–2403, 2011.
[5] CMS Collaboration. Measurement of the differential and double-differential Drell-Yan cross section in proton-proton collisions at 7 TeV. CMS Physics Analysis Summary CMS-PAS-EWK-11-007, 2012.
Figure 5. Distribution of the invariant mass spectrum of the leading two jets observed in data, after subtraction of all SM components except the electroweak diboson WW/WZ. The region between the vertical dotted lines is excluded in the fit. Error bars correspond to the statistical uncertainty. The band represents the systematic uncertainty in the sum of the SM components.

[6] Simone Alioli, Paolo Nason, Carlo Oleari, and Emanuele Re. NLO vector-boson production matched with shower in POWHEG. JHEP, 07:060, 2008, 0805.4802.
[7] S. Chatrchyan et al. Forward-backward asymmetry of Drell-Yan lepton pairs in pp collisions at \( \sqrt{s} = 7 \) TeV. Physics Letters B, 718(3):752 – 772, 2013.
[8] S. Chatrchyan et al. Measurement of the Electron Charge Asymmetry in Inclusive W Production in pp Collisions at \( \sqrt{s} = 7 \) TeV. Phys. Rev. Lett., 109:111806, Sep 2012.
[9] CMS Collaboration. Measurement of the muon charge asymmetry in inclusive W production in pp collisions at \( \sqrt{s} = 7 \) TeV. CMS Physics Analysis Summary CMS-PAS-EWK-11-005, 2012.
[10] S. Chatrchyan et al. Observation of Z decays to four leptons with the CMS detector at the LHC. Journal of High Energy Physics, 2012:1–28, 2012.
[11] Serguei Chatrchyan et al. Measurement of W+W− and ZZ production cross sections in pp collisions at \( \sqrt{s}=8 \) TeV. CERN-PH-EP-2012-376, arXiv:1301.4698 [hep-ex], 2013.
[12] U. Baur and Edmond L. Berger. Probing the weak boson sector in Z\gamma production at hadron colliders. Phys.Rev., D47:4889–4904, 1993.
[13] S. Chatrchyan et al. Measurement of the sum of WW and WZ production with W+dijet events in pp collisions at \( \sqrt{s} = 7 \) TeV. The European Physical Journal C, 73:1–18, 2013.
[14] John M. Campbell, R. Keith Ellis, and Ciaran Williams. Vector boson pair production at the LHC. JHEP, 1107:018, 2011, 1105.0020.
[15] S. Chatrchyan et al. Study of the Dijet Mass Spectrum in \( pp \rightarrow W + \text{jets} \) Events at \( \sqrt{s} = 7 \) TeV. Phys. Rev. Lett., 109:251801, Dec 2012.