PROCEEDINGS OF SCIENCE

Electroweak precision measurements in CMS

Ilya Gorbunov on behalf of the CMS Collaboration[a,*]

[a] *International Intergovernmental Organization Joint Institute for Nuclear Research, 6 Joliot-Curie St, Dubna, Moscow Region, Russia, 141980*

E-mail: Ilya.Gorbunov@cern.ch

In this note, recent CMS electroweak results are discussed. W rapidity helicity and differential cross section measurements are discussed in details along with results on 13 TeV Drell-Yan differential invariant mass study and Drell-Yan angular coefficients measurements at 8 TeV. CMS projections to measure $sin^2\theta_W$ at the High Luminosity LHC are discussed as well.

The Eighth Annual Conference on Large Hadron Collider Physics-LHCP2020
25-30 May, 2020
online

*Speaker

PoS(LHCP2020)019

1. Introduction

Electroweak (EWK) precision measurements are important for a number of reasons: they allow tests of Standard Model (SM) predictions, they can provide constraints on parton distribution functions (PDFs), precision EWK measurements can be used to extract parameters of interest (for example $sin^2\theta_W$), EWK SM processes can be an important source of background for many Beyond the Standard Model searches, for example the Drell-Yan lepton pair production is an important source of background for many Z' searches. Another motivation for the precision EWK measurements is to test different Monte Carlo models, evaluate production mechanism dynamics by studying parameters such as the Drell-Yan Angular Coefficients. The CMS experiment [1] has a large program of precision measurements as a hadron-collider experiment. Fig. 1(left) shows the summary of the cross section measurements of SM processes carried out by the CMS Collaboration.

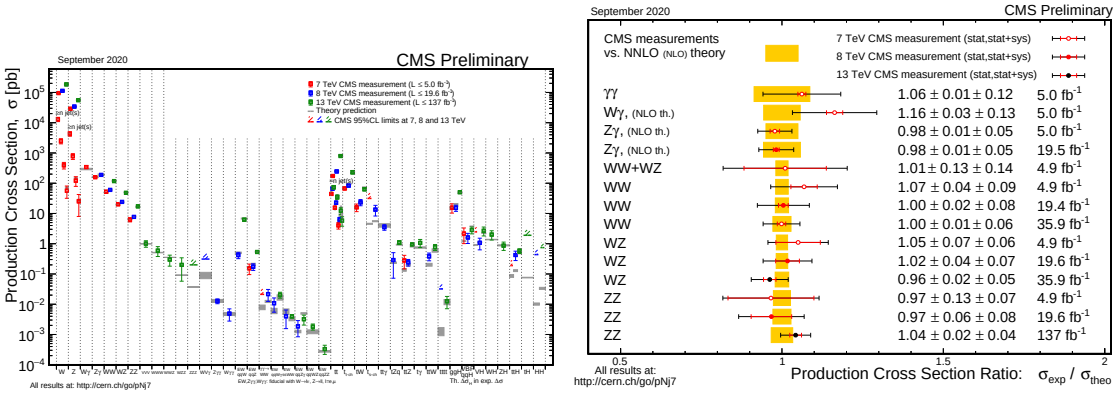

Figure 1: (left)Summary of the cross section measurements of Standard Model processes. (right) Di-boson cross section ratio comparison to theory: Theory predictions updated to latest NNLO calculations where available compared to predictions in the CMS papers and preliminary physics analysis summaries [2].

Fig. 1(right) shows the summary of the CMS Collaboration di-boson cross section ratio comparison to theory. There are new 13 TeV di-boson cross section measurements available.

More CMS summary plots can be found at [2].

2. Measurements of the W boson rapidity, helicity, double-differential cross sections, and charge asymmetry in pp collisions at 13 TeV

The differential cross section and charge asymmetry for inclusive W boson production at $\sqrt{s}$ = 13 TeV are measured [3] for the two transverse polarization states as a function of the W boson absolute rapidity. The measurement uses events in which a W boson decays to a neutrino and either a muon or an electron. The measurement is carried out using proton-proton collision data recorded with the CMS detector at the LHC in 2016 corresponding to an integrated luminosity of 35.9 fb^{-1}. The absolute differential W production cross section is measured over the rapidity range $|y_W| < 2.5$ along with its value normalized to the total inclusive W boson production. In addition, measurements of the charge asymmetry as functions of the charged lepton transverse momentum and pseudorapidity are presented. The double-differential W cross section, $d^2\sigma/dp_T^l d|\eta^l|$ has also

been measured. The precision of these measurements is used to constrain the parton distribution functions of the proton using the next-to-leading order NNPDF3.0 set.

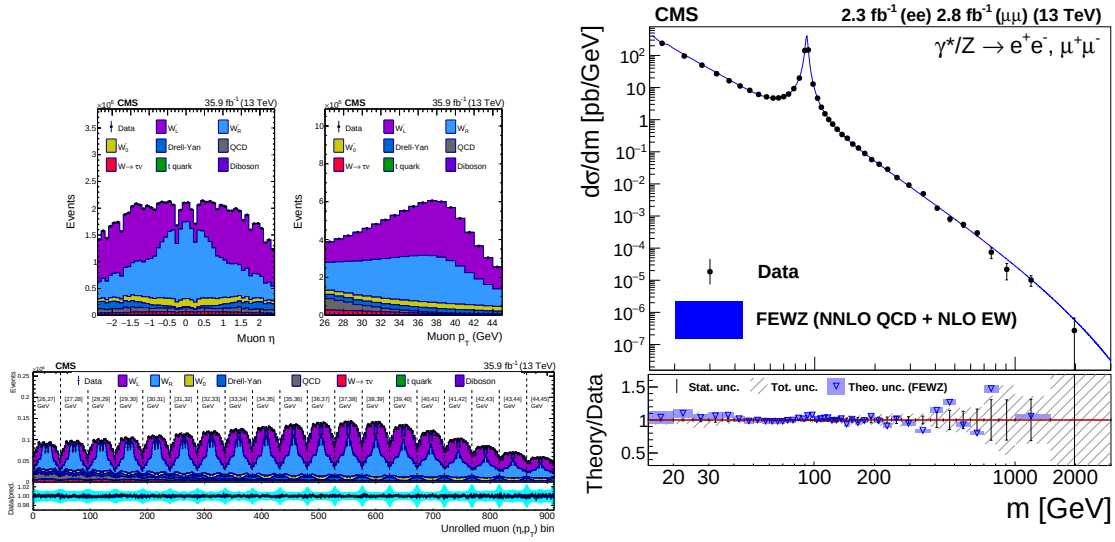

Figure 2: (left)Distributions of η^{μ} (upper left), p_T^{μ} (upper right) and unrolled muon (η, p_T) bin (lower) for $W^- \to \mu^-\nu^-$ events for observed data superimposed on signal plus background events. The signal and background processes are normalized to the result of the template fit. The cyan band over the data-to-prediction ratio represents the uncertainty in the total yield in each bin after the profiling process. (right) The differential DY cross section measured for the combination of the two channels and as predicted by the NNLO theoretical calculation of FEWZ in the full phase space. The ratio between the data and the theoretical prediction is presented in the bottom panel. The coloured boxes represent the theoretical uncertainties.

Fig. 2 (left) shows distributions of η^{μ} (upper left), p_T^{μ} (upper right) and unrolled muon (η, p_T) bin (lower) for $W^- \to \mu^-\nu^-$ events for observed data superimposed on signal plus background events. Contributions of different helicities are shown separately. Similar plots are available for $\mu^+\nu^+$ and electron final states. No deviation from SM predictions is observed.

3. Drell-Yan measurements

The CMS Collaboration published 13 TeV results on differential Drell-Yan cross section measurement [4], using data corresponding to an integrated luminosity of 2.8 (2.3) fb^{-1} in the dimuon (dielectron) channel. The total and fiducial cross section measurements are presented as a function of dilepton invariant mass in the range 15 to 3000 GeV, and compared with the perturbative predictions of SM. Fig. 2 (right) shows the differential DY cross section measured for the combination of the two channels. The measured differential cross sections are in good agreement with the theoretical calculations.

CMS also carried out measurements of differential cross sections measurements for Z bosons produced in proton-proton collisions at $\sqrt{s} = 13$ TeV decaying to muons and electrons [5]. The data analyzed were collected in 2016 with the CMS detector at the LHC and correspond to an integrated luminosity of 35.9 fb^{-1}. The measured fiducial inclusive product of cross section and branching fraction agrees with next-to-next-to-leading order QCD calculations.

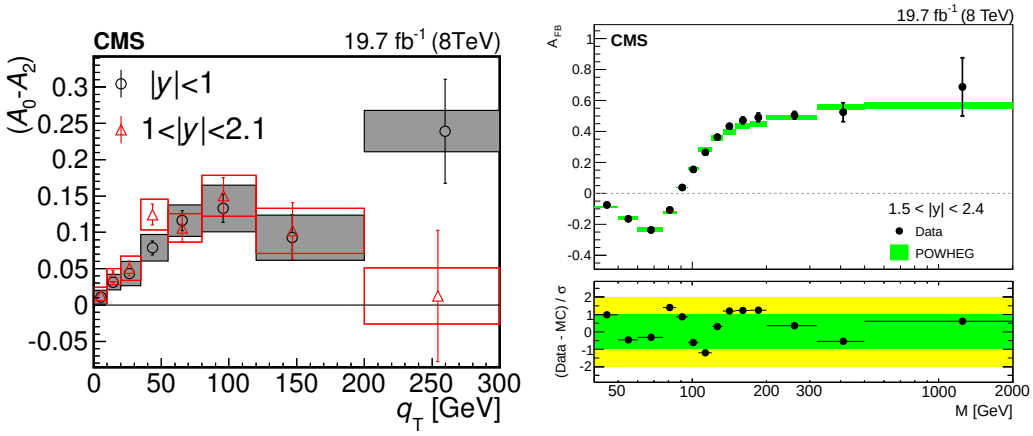

Figure 3: (left)Comparison of the $A_0 - A_2$ measured in the Collins–Soper frame in bins of transverse momentum q_T between $|y| < 1$ (circles) and $1 < q_T < 2.1$ (triangles). The vertical bars represent the statistical uncertainties and the boxes the systematic uncertainties of the measurement. (right) The combined ($\mu^+\mu^-$ and e^-e^+) unfolded A_{FB} distributions in the 1.5 to 2.4 rapidity region. The statistical (thick vertical bar) and statistical plus systematic (thin vertical bar) uncertainties are presented. The measurements are compared with the prediction of POWHEG. The total uncertainties (considering the statistical, PDF, and scale uncertainties) in the POWHEG prediction are shown as shaded bands.

The CMS Collaboration carried out Drell-Yan angular coefficients measurement at 8 TeV [6]. Fig. 3(left) shows the comparison of $A_0 - A_2$ measured in the Collins–Soper frame in bins of q_T between $|y| < 1$ (circles) and $1 < q_T < 2.1$ (triangles). The Lam-Tung relation was found to be violated at high transverse momentum and a significant rapidity dependence of the coefficients was observed.

The CMS Collaboration measured Forward-Backward Asymmetry at 8 TeV [7]. The measurement has been done in bins of rapidity and dilepton invariant mass as shown in Fig. 3(right). Measurements were corrected to take into account effects of the Final State Radiation, misalignment, reconstruction efficiency, etc.. No deviation from SM predictions is observed.

Using Forward-Backward Asymmetry the CMS Collaboration published one of the most precise measurements of the $sin^2\theta_W$ [8]. Also, it has been shown that at the High Luminosity LHC era it will be possible to carry out the most precise measurement of the $sin^2\theta_W$ [9].

4. Conclusion

CMS has a huge program of high precision measurements, covering various SM processes in many different final states and at different centre of mass energies. The measurements, as summarized in this note provide stringent tests of the SM predictions, some of which are also used to constrain parton distribution functions. Also, it has been shown that at the High Luminosity LHC era CMS will be able to improve the precision of its measurements.

References

[1] Chatrchyan, S. and others, *The CMS experiment at the CERN LHC*, *JINST* **3** 2008 S08004

[2] https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsCombined

[3] CMS Collaboration, *Measurements of the W boson rapidity, helicity, double-differential cross sections, and charge asymmetry in pp collisions at 13 TeV*, *Submitted to Phys. Rev. D, CMS-SMP-18-012 ; CERN-EP-2020-116*, [hep-ex/2008.04174]

[4] CMS Collaboration, *Measurement of the differential Drell-Yan cross section in proton-proton collisions at* $\sqrt{s}$ = 13 *TeV*, *JHEP* **12** (2019) 059, [hep-ex/1812.10529]

[5] CMS Collaboration, *Measurements of differential Z boson production cross sections in proton-proton collisions at* $\sqrt{s}$ = 13 *TeV*, *JHEP* **12** (2019) 061, [hep-ex/1909.04133]

[6] CMS Collaboration, *Angular coefficients of Z bosons produced in pp collisions at* $\sqrt{s}$ = 8 *TeV and decaying to* $\mu^+\mu^-$ *as a function of transverse momentum and rapidity*, *Phys. Lett. B* **750** (2015) 154, [hep-ex/1504.03512]

[7] CMS Collaboration, Forward-backward asymmetry of Drell-Yan lepton pairs in pp collisions at $\sqrt{s}$ = 8 TeV, *Eur. Phys. J.* **C 76** (2016) 325, [hep-ex/1601.04768]

[8] CMS Collaboration, *Measurement of the weak mixing angle using the forward-backward asymmetry of Drell-Yan events in pp collisions at 8 TeV*, *Eur. Phys. J.* **C 78** (2018) 701, [hep-ex/arXiv:1806.00863]

[9] CMS Collaboration, A proposal for the measurement of the weak mixing angle at the HL-LHC, CMS-PAS-FTR-17-001, http://cds.cern.ch/record/2294888