PROCEEDINGS OF SCIENCE

PoS(LHCP2021)262

Measurements of weak diboson production cross sections in leptonic decays at 5.02 TeV with the CMS experiment

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A new center-of-mass energy at 5 TeV is explored to study diboson production in proton-proton collisions using data collected with the CMS detector. The WW, WZ, and ZZ cross sections are measured analyzing events with two, three, or four charged leptons in the final state. These measurements are compared with the best available theoretical predictions and across other experiments.

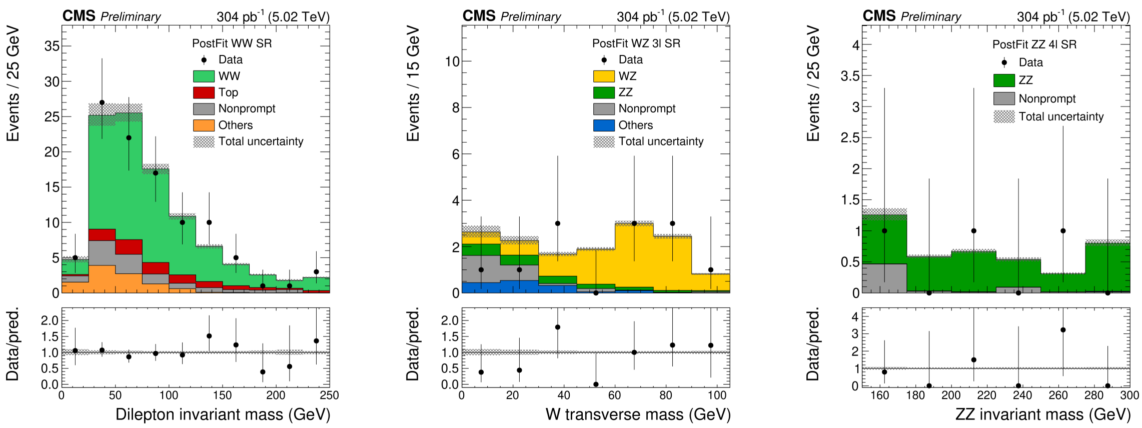
The Ninth Annual Conference on Large Hadron Collider Physics - LHCP2021
7-12 June 2021
Online

1. Motivation

Measurements of diboson production at the LHC are a crucial test of the standard model (SM) of particle physics, due to their sensitivity to the self-interactions between the gauge bosons via trilinear or quartic gauge coupling. Furthermore, its importance extends to other kinds of studies such as Higgs boson measurements and other beyond-the-SM searches, where these diboson processes represent an irreducible background contribution. Both the CMS and ATLAS collaborations have performed measurements of the cross section of diboson processes in proton-proton (pp) collisions at center-of-mass energies of 7, 8, and 13 TeV. In these studies, a new energy regime of 5 TeV is explored, and the cross section of different diboson processes is measured. The 5 TeV run of the CMS experiment took place in 2017, with an instantaneous luminosity of $\mathcal{L}$=1.38×10^{33}cm^{-2}s^{-1}, and the mean number of pp interactions per bunch crossing was around two.

2. Analysis strategy

Several Monte Carlo (MC) generators such as `Madgraph_5aMC@NLO` [1] and `Powheg` (v2) [2] have been used for the simulation of signal and background processes, whereas the effects of parton showering as well as underlying event are simulated using `Pythia 8` [3]. Finally, particle candidates are reconstructed using the particle-flow algorithm [4].



(a) (b) (c)

Figure 1: Kinematic distributions for some of the SRs defined for this analysis. Dilepton invariant mass in the WW channel, in final states with a pair of two leptons with opossite electric charge and different flavor (left). W transverse mass in WZ events with three leptons (center). Invariant mass of the ZZ pair in ZZ events with four leptons in the final state (right). The lower panels at each plot show the ratio between the number of observed events in data, and the total number of events expected from the MC prediction. The total uncertainty band (shaded band in the plot) accounts for both the statistical and systematic uncertainties, which are propagated in the plots [7].

Interesting events are selected using the CMS trigger system [5], and only events that fired at least one single-lepton trigger are considered. Since this analysis is based on leptonic selections, candidate events need to have at least two leptons passing loose identification criteria with a minimal invariant mass of any lepton pair greater than 12 GeV. Considering this baseline selection, the multiplicity and flavour of the leptons involved in the final state is used as a main figure of merit to define different signal regions (SRs) for WW, WZ and ZZ final states. Due to the lepton identification being of great importance in these measurements, a multivariate discriminant based on a gradient boosted decission tree [6] is trained to separate between leptons that have originated from a W or Z boson decay (known as prompt) and those who do not. The purity of signal over background in the final selection is further enhanced by establishing minimal requirements on the transverse momentum of the leptons, the minimum amount of missing energy, the number of jets in the final state and consistency between the invariant mass of a lepton pair, originated after a Z boson decay, and the mass of the Z boson. A more detailed description on this matter can be found in [7]. The modelling and agreement between data and prediction for some kinematic distributions is shown in Fig. 1 for WW (1a), WZ (1b) and ZZ (1c) events with two, three and four leptons; respectively.

3. Results

Cross sections are computed in inclusive regions, which are built by including additional requirements to each of the different SRs. The underlying hypothesis is that one can find a sector of the total phase space in which the measurement has no dependencies with the detector acceptance. The total cross section is then computed as shown in equation 1, where ϵ is the efficiency of the lepton reconstruction in the inclusive regions, $\mathcal{L}$ is the integrated luminosity, N^{SR}_{signal} is the number of signal events in a given SR, and $\mathcal{BR}$ is the branching ratio, which is used to extract the total cross section using only leptonic final states.

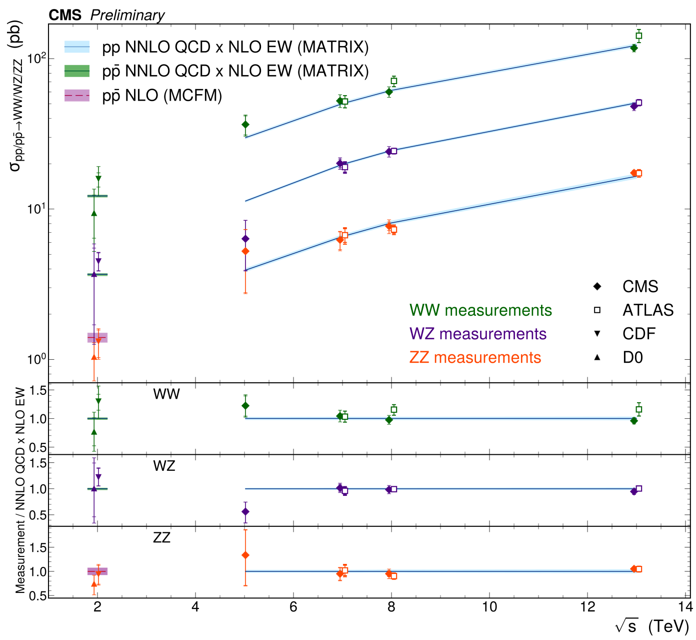


Figure 2: Results obtained in this analysis along with other diboson production cross section measurements at different center-of-mass energies for the CMS, ATLAS, CDF, and D0 collaborations, compared to `Matrix` NNLO QCD×NLO EWK predictions [7].

$$\sigma = \frac{N^{SR}_{\text{signal}}}{\mathcal{BR}(\mathrm{V} \to \mathrm{XX})\mathcal{BR}(\mathrm{V} \to \mathrm{XX})\epsilon\mathcal{L}} \tag{1}$$

The measured cross sections for WW, WZ and ZZ production are: $\sigma_{\mathrm{WW}} = 36.5^{+5.5}_{-5.1}(\mathrm{stat})^{+2.6}_{-2.5}(\mathrm{syst})$ pb, $\sigma_{\mathrm{WZ}}= 6.4^{+2.4}_{-2.1}(\mathrm{stat})^{+0.5}_{-0.3}(\mathrm{syst})$ pb, $\sigma_{\mathrm{ZZ}} = 5.3^{+2.5}_{-2.0}(\mathrm{stat})^{+0.5}_{-0.4}(\mathrm{syst})$ pb, which are found to be consistent with `Matrix` [8] predictions at next-to-next-to-leading-order QCD times next-to-leading order electroweak cross sections (NNLO QCD×NLO EWK), as shown in Fig. 2, which summarises different diboson production cross section measurements at different collaborations and energy regimes.

4. Conclusions

A measurement of the diboson production cross sections at a new center-of-mass energy of 5.02 TeV has been presented, using 304 pb^{-1} of data collected with the CMS detector during 2017 and only considering leptonic decays for the W and Z bosons. All in all, the measured total cross sections for the production of WW, WZ and ZZ in proton-proton collisions are found to be consistent with NNLO QCD×EWK predictions.

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