Measurements of WV Boson Production and Limits on Charged aTGCs at CMS

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We present a summary of the latest measurements of the WV production cross-sections, where V is either W or Z. The data sample(s) correspond to proton-proton collision events collected with the CMS detector at $\sqrt{s} = 7$ and 8 TeV. Subsequent searches for Anomalous Triple Gauge Couplings, which allow us to probe the non-Abelian structure in the Electroweak Sector, are described. We present exclusion limits on the corresponding couplings.

1 Introduction

Triple gauge boson couplings, which determine the self-interactions of W and Z bosons, are fixed by the gauge symmetry of the standard model (SM). Consequently, pair production of vector gauge bosons allows a direct test of the electroweak sector of the SM [1]. Observation of anomalous triple gauge boson couplings (aTGCs) would correspond to the presence of physics beyond the SM.

In this paper we summarize the measurements in the diboson final states $WZ \to \ell\nu\ell\ell$ [2], $WW \to \ell\nu\ell\nu$ [3] and $WV \to \ell\nu jj$ [4] in pp collisions in the Compact Muon Solenoid (CMS) detector at the Large Hadron Collider (LHC) [5]. Understanding of these processes is essential, as they serve as backgrounds for new physics searches and other measurements (*e.g.* Higgs production). Furthermore, for each channel we verify the Standard Model (SM) predictions by comparing the measured cross-section to the theory expectation. An additional enhancement of the spectrum in the high transverse momentum (p_T) region would correspond to nonzero aTGC values.

2 $WZ \to \ell\nu\ell\ell$

We present measurements of the $WZ \to \ell\nu\ell\ell$ production corresponding to the luminosities of 4.9 fb^{-1} collected at $\sqrt{s} = 7$ TeV and 19.6 fb^{-1} collected at $\sqrt{s} = 8$ TeV. In order to select the Z candidate the presence of two leptons of the same flavor (muons or electrons) and opposite charge with the transverse momentum $p_T > 20, 10$ GeV and mass near the Z resonance ($71 < m_{ll} < 111$ GeV) is required. In case of multiple pairs of candidates the one with the mass closest to the Z is selected. Likewise, in order to reconstruct the W, a lepton with $p_T > 20$ GeV, $MET > 30$ GeV are required. The remaining backgrounds can be separated into the non-peaking (*e.g.* $t\bar{t}$) and prompt lepton (real Z plus a lepton-like object) types, which are taken from the Monte Carlo; as well as the real Z plus a jet faking a lepton, which is estimated from the sideband region in the data. Overall, we predict at total of 211 background out of the 1480 ($\sqrt{s} = 8$ TeV) events in the data after all of the cuts have been applied.

Upon subtracting the backgrounds a high purity signal is extracted. After accounting for the systematics, with the largest sources originating from the MET resolution as well as the data driven background estimates, cross section for each lepton combination is evaluated Fig. 1. The combined values are $20.8 \pm 1.3(stat.) \pm 1.1(syst.) \pm 0.5(lumi.)$, $24.6 \pm 0.8(stat.) \pm 1.1(syst.) \pm 1.1(lumi.)$ pb at $\sqrt{s} = 7{,}8$ TeV, while the $\sigma_{W^+Z}/\sigma_{W^-Z} = 1.94 \pm 0.25(stat.) \pm 0.04(syst.)$,$1.81 \pm 0.12(stat.) \pm 0.03(syst.)$. The measurements are consistent with the theory predictions of 17.8, 21.9 pb.

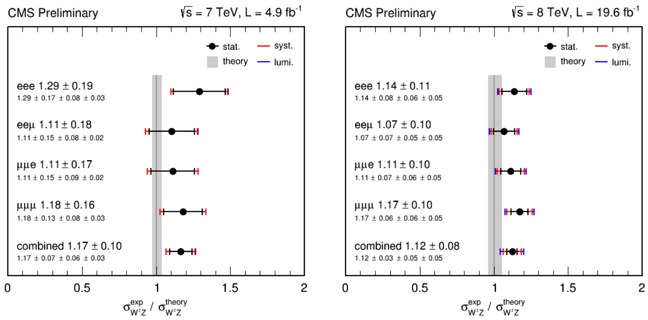

Figure 1: Ratio of measured inclusive cross-section to the theoretical prediction in the $WZ \to \ell\nu\ell\ell$ channel at $\sqrt{s} = 7$ TeV(left) and $\sqrt{s} = 8$ TeV(right).

3 $WW \to \ell\nu\ell\nu$

The $WW \to \ell\nu\ell\nu$ signal measurements correspond to the luminosities of 4.9 fb^{-1} collected at $\sqrt{s} = 7$ TeV and 4.92 fb^{-1} collected at $\sqrt{s} = 8$ TeV. We reconstruct W^+W^- signal by requiring two oppositely charged central leptons ($|\eta| < 2.4$,2.5 for muons, electrons) with $p_T > 20$ GeV. In order to further reduce background contamination the following cuts are implemented: remove events with jet $p_T > 30$ GeV and apply top-quark tagging techniques, require $MET > 45$ GeV (> 20 GeV in the μe channel), remove events with third lepton $p_T > 10$ GeV, reject photon-conversion electrons. The Top, Drell Yan and Diboson yields are determined from the data sideband region with the overall background contribution $\sim 30\%$ of the total event count.

We evaluate the cross section after subtracting the expected background contributions from the data. The main systematics are due to the jet veto uncertainty as well as the error in estimating the background yields. The measured cross sections are $52.4 \pm 2.0(stat.) \pm 4.5(syst.) \pm 1.2(lumi.)$, $69.9 \pm 2.8(stat.) \pm 5.6(syst.) \pm 3.1(lumi.)$ pb at $\sqrt{s} = 7{,}8$ TeV. Similarly to the WZ case, the results show a small ($\sim 1\sigma$) excess over the SM expectation, but overall are consistent with the theory predictions of 47.0, 57.3 pb.

In addition, we perform a search for the aTGCs based on the leading lepton p_T spectrum. The presence of anomalous signal would enhance the yield at high p_T values with an overall quartic dependence of the cross-section on the aTGCs. The systematic uncertainties are incorporated into the likelihood function by introducing nuisance parameters with Gaussian constraints. We see no evidence for the anomalous signal and obtain 1-Dimensional limits of $-0.048 < \lambda < 0.048$, $-0.095 < \Delta g_1^Z < 0.095$, $-0.22 < \Delta\kappa_\gamma < 0.22$ at 95% C.L., with 2-D limits shown in Fig. 2.

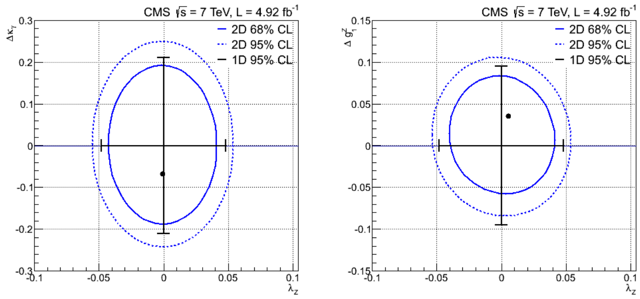

Figure 2: The 68% (solid line) and 95% C.L. (dashed line) aTGC limit contours, as well as the central value (point) for $\Delta g_1^Z = 0$ (left) and $\Delta\kappa_\gamma = 0$ (right). The corresponding 1-D 95% C.L. limits are shown along the axes.

4 $WV \to \ell\nu jj$

The first semileptonic channel measurement is performed for the 5.0 fb^{-1} CMS dataset collected at $\sqrt{s} = 7$ TeV. The analysis is particularly challenging due to the fact that vast majority of events in this final state originate from the $W + Jets$ irreducible background, but has a higher expected event count due to the larger branching fraction of W and Z bosons to quarks. We select events with on-shell W bosons by requiring lepton $p_T > 25$ GeV (35 GeV), $\eta < 2.1$ (2.4), W transverse mass > 30 GeV (50 GeV), $MET > 25$ GeV (30 GeV) and secondary lepton veto in the muon (electron) channel. Exactly two AK5 jets are reconstructed subject to PileUp corrections, isolation from leptons > 0.3, $p_T > 35$ GeV, $\eta < 2.6$ and jet b-tag veto on the secondary vertex. Additional requirements of dijet $p_{Tjj} > 20$ GeV, $|\Delta\eta_{jj}| < 1.5$ are placed in order to reduce the dominant $W + Jets$ background. A reasonable agreement between data and MC is observed.

In order to extract the cross section we perform an unbinned maximum likelihood for the dijet mass $40 < m_{jj} < 150$ GeV. The shape templates are taken from Monte Carlo (and multijet sideband), while the background yield contributions are free to float subject to Gaussian constraints. An empirical combination of default, alternate ME-PS and alternate QCD scale samples is used to describe the $W + Jets$ shape. The biases in the fit procedure and systematics are accounted for. A total of 2682 ± 482 $WW + WZ$ events is extracted out of 1.15×10^5 with a significance is 8.8σ using a simple likelihood ratio and 4.3σ using the profile likelihood ratio. The corresponding $WW + WZ$ cross section is $68.9 \pm 8.7(stat.) \pm 9.7(syst.) \pm 1.5(lumi.)$ pb, consistent with the SM prediction of 65.6 ± 2.2 pb.

Subsequently, limits on the aTGC parameters are set based on the hadronic $V \to jj$ p_T spectrum. We place an additional $75 < m_{jj} < 95$ GeV cut to enhance signal purity, normalize the backgrounds based on fit results and take $\Delta g_1^Z = 0$, since it is expected to be small. The

1-D limits of $-0.038 < \lambda < 0.030$, $-0.111 < \Delta\kappa_\gamma < 0.142$ at 95% C.L. are set, with 2-D limits shown in Fig. 3.

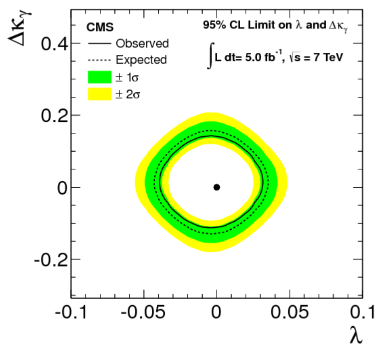

Figure 3: Observed (solid) and expected (dashed) exclusion limits at 95% CL for anomalous triple gauge couplings set based on the semileptonic WV final state $V \to jj$ p_T spectrum. The dark green(inner) and light yellow(outer) bands correspond to the one and two sigma intervals, respectively, in the expected limit distribution. The SM expectation is shown by the solid dot.

5 Summary

We implement the selections and measure the WV diboson productions for $WZ \to \ell\nu\ell\ell$, $WW \to \ell\nu\ell\nu$ and $WW + WZ \to \ell\nu jj$ final states at CMS. Excesses are observed for several channels, but no evidence for physics beyond SM is found. Furthermore, the presence of Anomalous Triple Gauge Couplings is expected to modify the spectrum at high values of p_T. We do not find evidence for such anomalous interactions between the charged vector bosons and set either competitive or the strongest limits to date.

References

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