Diboson cross section measurement at ATLAS and limits on anomalous gauge couplings

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1 Introduction

The diboson measurements using ATLAS pp collisions at $\sqrt{s} = 7\,\text{TeV}$ offer a good opportunity to study the high energy behavior of electroweak interactions in the Standard Model (SM). The measurements not only verify the SM theory but also aim for new physics search by probing the triple gauge-boson vertices through the search for anomalous couplings. Besides, the SM W^+W^- and ZZ productions are the irreducible backgrounds of dibosons produced by the Higgs decay.

2 Diboson measurement

We present measurements of diboson production in ATLAS [1] involving five different electroweak diboson channels (ZZ, WZ, WW, $W\gamma$ and $Z\gamma$). Cross sections are measured with full leptonic decay channels including neutrinos wherever relevant. $ZZ \to \ell^+\ell^-\nu\overline{\nu}$ and $WW \to \ell\nu\ell'\nu$ are measured for exclusive production, namely without the presence of jets, whereas the other channels are measured for inclusive production, with any number of accompanying jets (Throughout this document, ℓ and ℓ' denote either electron or muon). For each channel, a total cross section is measured. Furthermore, in order to be less sensitive to theoretical uncertainties related to the extension of our measurement to the complete phase space volume, a fiducial cross section is measured within a phase space volume defined on the Monte Carlo generated particles which corresponds to the same kinematic cuts applied by the event selection. Limits on anomalous triple-gauge couplings (aTGCs) are set. Part of the results presented below are based on the full data sample taken in 2011, and correspond to an integrated luminosity of 4.7 fb^{-1}. The other results are based on a partial data set taken in the first part of 2011 and correspond to 1.02 fb^{-1}.

The ZZ cross section is measured [2] using the leptonic $\ell^+\ell^-\ell'^+\ell'^-$ channels with the full 2011 data set. To extract the ZZ signal, four isolated leptons are considered with a transverse momentum $p_T > 7\,\text{GeV}$ while the leading lepton must have

$p_T > 25/20\,\text{GeV}$ (e/μ) to ensure a high single-lepton trigger efficiency. The two Z candidates are selected by requiring $|m_{\ell^+\ell^-} - m_Z| < 25\,\text{GeV}$ and 62 observed candidates are left. The measured total cross section is $7.2^{+1.1}_{-0.9}$ (stat)$^{+0.4}_{-0.3}$ (syst)$\pm$0.3 (lumi) pb, consistent with the SM prediction calculated at the Next-to-Leading Order (NLO), $\sigma_{ZZ} = 6.5^{+0.3}_{-0.2}\,\text{pb}$. The measured fiducial cross section is $21.2^{+3.2}_{-2.7}$ (stat)$^{+1.0}_{-0.9}$ (syst)$\pm$0.8 (lumi) fb. Limits on the neutral triple-gauge couplings [3] shown in Figure 1 are determined using the total number of observed events with the partial 2011 data set.

The ZZ cross section is also measured [4] using the $\ell^+\ell^-\nu\overline{\nu}$ channels with the full 2011 data set. Neutrinos are detected by the presence of the missing transverse energy E_T^{miss}. Candidate events are preselected after requiring exactly two same-flavor opposite-sign (SFOS) leptons with $p_T > 20\,\text{GeV}$ within the Z mass window ($|m_{\ell^+\ell^-} - m_Z| < 15\,\text{GeV}$). The largest $Z+jets$ background is suppressed by requiring axial-$E_T^{miss} > 80\,\text{GeV}$, where axial-$E_T^{miss}$ is the projection of the E_T^{miss} vector along the direction opposite to the reconstructed Z transverse momentum. The remaining $Z+jets$ and top backgrounds are further reduced by retaining only the events without any reconstructed jets with $p_T > 25\,\text{GeV}$ and $|\eta| < 4.5$. Finally, the signal event candidates are required to satisfy $|E_T^{miss} - p_T^Z|/p_T^Z < 0.6$. The measured total cross section is $5.4^{+1.3}_{-1.2}$ (stat)$^{+1.4}_{-1.0}$ (syst)$\pm$0.2 (lumi) pb, consistent with the SM prediction, σ_{ZZ} (NLO) $= 6.5^{+0.3}_{-0.2}\,\text{pb}$. The measured fiducial cross section is $12.2^{+3.0}_{-2.8}$ (stat)$\pm$1.9 (syst)$\pm$0.5 (lumi) fb.

The cross section results of the $W^{\pm}Z$ leptonic decay channel [5] are extracted using the partial 2011 data set. Events with at least three isolated leptons with $p_T > 15\,\text{GeV}$ are considered. Z bosons are selected by requiring an SFOS lepton pair with invariant mass within 10 GeV of m_Z. The third lepton, assigned to the W, is required to have $p_T > 20\,\text{GeV}$. The events must also have $E_T^{miss} > 25\,\text{GeV}$, and the transverse mass reconstructed from E_T^{miss} and the third lepton p_T is required to exceed 20 GeV. The measured total cross section is $20.5^{+3.1}_{-2.8}$ (stat)$^{+1.4}_{-1.3}$ (syst)$^{+0.9}_{-0.8}$ (lumi) pb, consistent with the SM prediction, σ_{WZ} (NLO) $= 17.3^{+1.3}_{-0.8}\,\text{pb}$. The measured fiducial cross section is 102^{+15}_{-14} (stat)$^{+7}_{-6}$ (syst)$\pm$4 (lumi) fb. Limits on aTGCs, which are shown in Figure 1, are calculated using the total number of observed signal candidates.

$WW \to \ell\nu\ell'\nu$ cross section results [6] are based on the full 2011 dataset. Candidate events are required to have exactly two opposite-sign isolated leptons with the leading (subleading) lepton p_T above 25 (20) GeV. The most dominant background of $Z + jets$ is reduced by requiring $m_{\ell\ell'} > 15\,\text{GeV}$ and $|m_{\ell\ell'} - m_Z| > 15\,\text{GeV}$ for $\ell\ell' = ee$ or $\mu\mu$. Besides, the relative E_T^{miss} which is the E_T^{miss} projected onto the direction orthogonal to the closest lepton or jet (if the angle is below $\pi/2$, otherwise, it is simply the E_T^{miss}) is required to exceed 50, 55 or 25 GeV for $\ell\ell' = ee$, $\mu\mu$ or $e\mu$ respectively. The remaining dominant background is from top production, which can be reduced by requiring an exclusive final state, rejecting events with jet(s) having $p_T > 25\,\text{GeV}$ and $|\eta| < 4.5$ or jets with $p_T > 20\,\text{GeV}$ containing a b-hadron. The measured total cross section is 53.4 ± 2.1 (stat)$\pm$4.5 (syst)$\pm$2.1 (lumi) pb, consistent

with the SM prediction, σ_{ZZ} (NLO) $= 45.1 \pm 2.8$ pb. The fiducial cross sections vary between different channels, which have different kinematic cuts, and they are listed in [6]. Limits on aTGCs with the partial 2011 data set [7] are obtained using the p_T distribution of the leading lepton. They are shown in Figure 1 and compared with other measurements.

$W\gamma$ and $Z\gamma$ cross section results [8] are based on the partial 2011 data set. W bosons are required to have one isolated lepton with $p_T > 25\,\text{GeV}$, $E_T^{miss} > 25\,\text{GeV}$ and transverse mass, $m_T > 40\,\text{GeV}$. Z bosons are required to have two isolated SFOS leptons with $p_T > 25\,\text{GeV}$ and invariant mass $m_{\ell\ell} > 40\,\text{GeV}$. Isolated photons are required to have transverse energy $E_T > 15\,\text{GeV}$. The remaining major backgrounds are from $W/Z + jets$. Both inclusive and exclusive cross section results are measured and compared with theoretical NLO predictions as shown in Figure 2. Measurements of the exclusive fiducial cross sections for $W\gamma$ with $E_T^\gamma > 100\,\text{GeV}$ and $Z\gamma$ with $E_T^\gamma > 60\,\text{GeV}$ are used in aTGCs limit extraction. Results are summarized in Figure 1 and compared with other measurements.

3 Summary

Diboson measurements using the 2011 7 TeV pp collisions at ATLAS are presented. Both total and fiducial cross sections are measured. Limits on aTGCs are determined for the measured diboson productions. The results are competitive with those of LEP and Tevatron, and some are more restrictive than those of the Tevatron.

References

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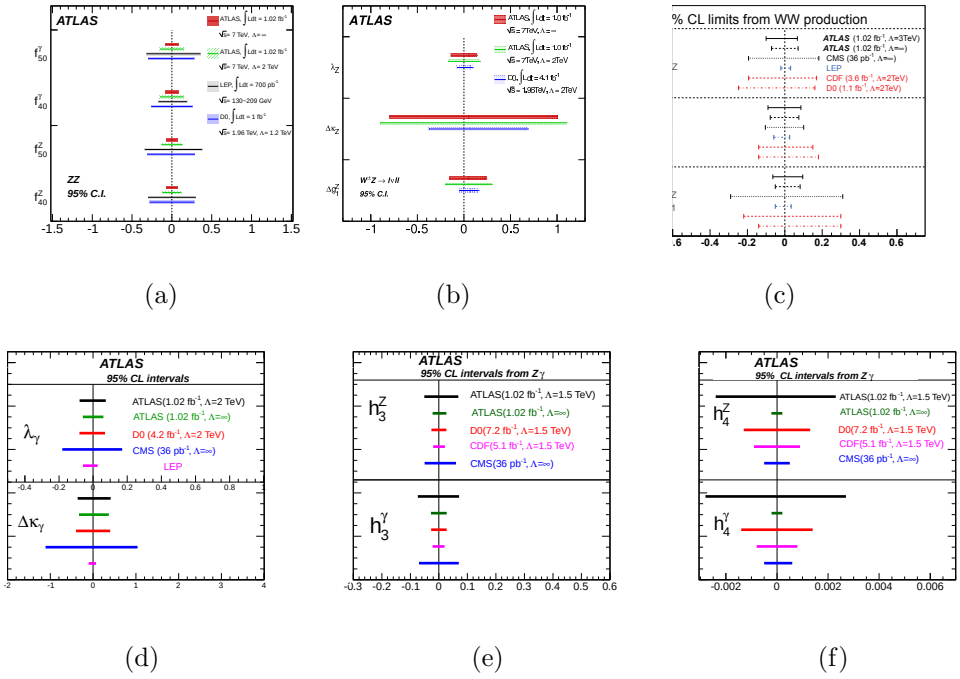
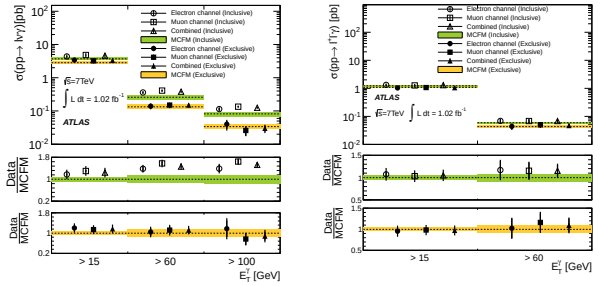


(a) (b) (c)

(d) (e) (f)

Figure 1: The 95% Confidence Intervals for anomalous couplings from ATLAS, D0, CDF, CMS and LEP for the aTGCs in ZZ(a), WZ(b), WW(c), $W\gamma$(d) and $Z\gamma$(e,f). The luminosities and the values assumed for the cut-off parameter Λ, which corresponds to a dipole form factor $f(\hat{s}) = 1/(1+\hat{s}/\Lambda^2)^2$ needed for unitarity, are indicated.



(a) (b)

Figure 2: The measured cross section for $W\gamma$(a) and $Z\gamma$(b) production together with the SM prediction in the fiducial region. The measurements are performed in different E_T^γ and jet multiplicity regions. For a better comparison to SM predictions, the events are analyzed both inclusively, with no requirements on the recoil system, and exclusively, requiring there be no hard jet. The lower plots show the ratio between the data and the NLO prediction of the MCFM generator [9].