DIBOSON PRODUCTION CROSS SECTION AT LHC

VINCENZO P. LOMBARDO
(on behalf of the ATLAS and CMS Collaborations)
Laboratoire d'Annecy-le-Vieux de Physique des Particules
9 Chemin de Bellevue, Annecy-le-Vieux, France

This paper presents an overview of the diboson production cross-section measurements and constraints on anomalous triple-gauge boson couplings performed by the ATLAS and CMS collaborations using proton-proton collisions produced at a centre-of-mass energy of $\sqrt{s} = 7$ and 8 TeV at LHC. Results for all combinations of W, Z and γ gauge bosons (excluding $\gamma\gamma$) are presented with emphasis on the new WZ and ZZ production cross sections measured by ATLAS at $\sqrt{s} = 8$ TeV and on the new constraints on anomalous triple-gauge couplings set by CMS in the WW and $Z\gamma$ modes.

1 Introduction

In the Standard Model (SM) of particle physics, measurements of diboson final states at the TeV scale provide excellent tests of the electroweak sector. Any deviation of the diboson production cross sections or kinematic distributions from the SM predictions may be an indication of anomalous triple-gauge boson couplings (aTGC) and of the existence of new particles such as those predicted by technicolor models, little Higgs and Randall-Sundrum graviton models, to mention only a few examples. It is therefore very important to have precise diboson measurements as well as reliable and accurate theoretical predictions for these processes. In addition non-resonant diboson production processes must be understood in detail as they represent a significant background to the measurements of the Higgs boson. The diboson results presented in this note are based on the proton-proton collision data collected by the ATLAS [1] and CMS [2] detectors at the LHC [3] in 2011 and 2012.

2 Diboson production cross-section measurements

The measurements of the total production cross sections of $pp \to W\gamma + X$ and $pp \to Z\gamma + X$ have been performed in the decay channels $W\gamma \to \ell\nu\gamma$ and $Z\gamma \to \ell\ell\gamma$ [4,5] by requiring a W or a Z boson candidate in association with an isolated photon. The photon is required to be separated by the lepton to suppress QED Final State Radiation. The dominant background includes $W/Z + jets$ and $\gamma + jets$ where jet-induced photons or jet-faking leptons are selected. In addition to the total cross section both the ATLAS and CMS Collaborations have unfolded the E_T^{γ} spectrum observing a reasonable agreement with theoretical predictions. The $Z\gamma \to \nu\nu\gamma$ mode has also been measured by the two Collaborations [4,6] by requiring a tighter selection on the photon and on the missing transverse energy (E_T^{miss}) in order to suppress the backgrounds. A fair agreement with theoretical predictions is observed.

The $pp \to WZ + X$ production cross section has been measured in the $WZ \to \ell\nu\ell\ell$ channel by both ATLAS and CMS at a centre-of-mass energy $\sqrt{s} = 7$ TeV with 4.6 and 1.1 fb^{-1}, respectively [7,8]. The signal region is selected by requiring three isolated high-p_T leptons and E_T^{miss}. A tighter identification requirement on the lepton coming from the W decay reduces the Z+jet background where jet-faking leptons are selected. In addition to the the total cross section ATLAS has measured the inclusive WZ cross section as function of the transverse momentum of the Z boson and of the invariant mass of the WZ system. Recently, ATLAS has also released the first measurement [9] of the $pp \to WZ + X$ production cross section at 8 TeV with an integrated luminosity of 13 fb^{-1}. The measured cross section is $20.3^{+0.8}_{-0.7}(stat)^{+1.2}_{-1.1}(syst)^{+0.7}_{-0.6}(lumi)$ pb, in excellent agreement with the next-to-leading order (NLO) QCD predictions provided by MCFM + CT10 parton distribution functions [10,11].

The $pp \to WW + X$ production cross section has been measured by ATLAS and CMS at 7 TeV with 4.6 and 4.9 fb^{-1}, respectively [12,13]. The selection of the $WW \to \ell\nu\ell\nu$ channel requires two opposite charged isolated leptons. The Drell-Yan background in the ee and $\mu\mu$ channels is suppressed by means of a Z veto and a requirement on a E_T^{miss}-related variable. In addition a jet veto is applied to reduce the top-quark background. The cross section measured by ATLAS is $51.9 \pm 2.0(stat) \pm 3.9(syst) \pm 2.0(lumi)$ pb and the one measured by CMS is $52.4 \pm 2.0(stat) \pm 4.5(syst) \pm 1.2(lumi)$ pb. They agree to each other but they are higher than the NLO calculations provided by MCFM+CT10 which predicts $44.7^{+2.1}_{-1.9}$ pb. The CMS collaboration has also measured the WW cross section at 8 TeV with a dataset corresponding to an integrated luminosity of 3.5 fb^{-1} [14]. The measured cross section is $69.9 \pm 2.8(stat) \pm 5.6(syst) \pm 3.1(lumi)$ pb confirming a higher cross section with respect to the NLO predictions calculated by MCFM+CT10 which gives $57.3^{+2.4}_{-1.6}$ pb.

Both ATLAS and CMS have also measured the total cross section of $WW + WZ \to \ell\nu jj$ at 7 TeV with 4.7 and 5.0 fb^{-1}, respectively [15,16]. The request of exactly two high-p_T jets in addition to an isolated lepton and E_T^{miss} is used to select the signal region. After these selection requirements the $W/Z + jets$ background is still huge compared to signal and a binned maximum-likelihood fit to the dijet invariant mass has been used to extract the signal yield and measure the cross section. Both ATLAS and CMS report results which are in good agreement with the SM predictions.

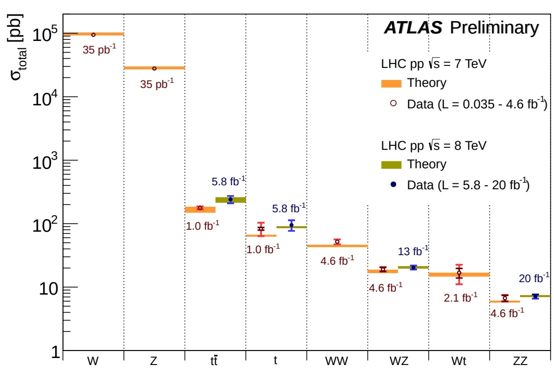

Figure 1: Summary plot of ATLAS cross-section measurements [22].

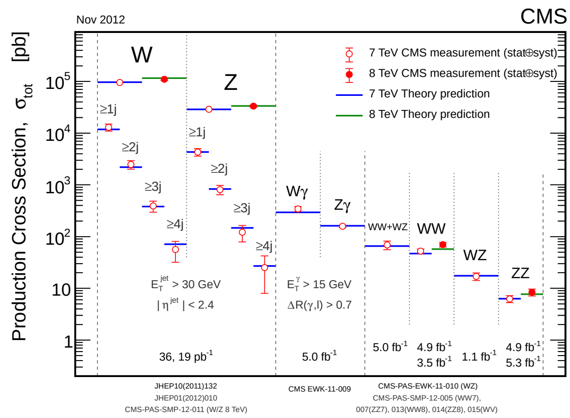

Figure 2: Summary plot of CMS cross-section measurements [23].

The $pp \to ZZ + X$ production cross section has been measured by ATLAS and CMS at the centre-of-mass energy of $\sqrt{s} = 7$ and 8 TeV [17,18,14]. The $ZZ \to 4\ell$ final state requires two pairs of isolated charged leptons (e or μ) which are compatible with two on-shell Z bosons. The ATLAS Collaboration has also measured the ZZ cross section at $\sqrt{s} = 7$ TeV in the $ZZ \to \ell\ell\nu\nu$ channel [17] by applying a tight cut on a E_T^{miss}-related variable in order to suppress the dominant $Z + jets$ background. On the other hand, the CMS measurement at 8 TeV includes the $ZZ \to 2\ell 2\tau$ mode. The ATLAS Collaboration has recently released an updated measurement of the $ZZ \to 4\ell$ cross section with 20 fb^{-1} at $\sqrt{s} = 8$ TeV [19]. The measured cross section is $7.1^{+0.5}_{-0.4}(stat) \pm 0.3(syst) \pm 0.2(lumi)$ pb which agrees very well with the NLO calculation provided by MCFM with CT10 predicting $7.2^{+0.3}_{-0.2}$ pb.

A summary of the up-to-date diboson production cross-section measurements performed by ATLAS and CMS are shown in Figure 1 and 2. The diboson cross sections, as well as several other SM production cross sections, are compared to their theoretical predictions.

3 Anomalous triple-gauge boson couplings

In the SM, triple-gauge boson couplings (TGC) are completely fixed by the gauge structure of the electroweak theory and any deviation from the SM couplings indicates new physics beyond the SM. An effective lagrangian featuring such anomalous triple-gauge boson couplings (aTGCs) can be constructed and then compared to the experimental data. Under some general assumptions, aTGCs can be parameterized using the set of parameters shown in Table 1 [20,21]. All these parameters are equal to zero in the SM. Anomalous couplings are expected to modify the total production cross section as well as the kinematic distributions of the diboson processes, in particular in high momentum or high mass regions. The ATLAS and CMS Collaborations have searched for anomalous triple-gauge boson couplings and found no deviation from the SM values. Figure 3, 4, 5 and 6 show the limits at 95% confidence level on the aTGCs set by ATLAS and CMS as well as those set by LEP and Tevatron.

coupling	parameters	channel
$WW\gamma$	$\lambda_\gamma, \Delta k_\gamma$	$WW, W\gamma$
WWZ	$\lambda_Z, \Delta k_Z, \Delta g_1^Z$	WW, WZ
$ZZ\gamma$	h_3^Z, h_4^Z	$Z\gamma$
$Z\gamma\gamma$	h_3^γ, h_4^γ	$Z\gamma$
$Z\gamma Z$	f_{40}^Z, f_{50}^Z	ZZ
ZZZ	$f_{40}^\gamma, f_{50}^\gamma$	ZZ

Table 1: List of TGC parameters commonly used in ATLAS and CMS [20,21].

The CMS Collaboration has recently released new limits on aTGCs in the $WW \to \ell\nu\ell\nu$ channel analyzing 4.9 fb^{-1} of data collected at a centre-of-mass energy of $\sqrt{s} = 7$ TeV [13]. These limits are shown in Figure 3 and 4, together with previous results. In addition CMS has extracted limits on aTGCs in the $Z\gamma \to \nu\nu\gamma$ channel [6] setting tighter constraints on aTGCs with respect to those extracted in the $Z\gamma \to \ell\ell\gamma$ analyses [5,4].

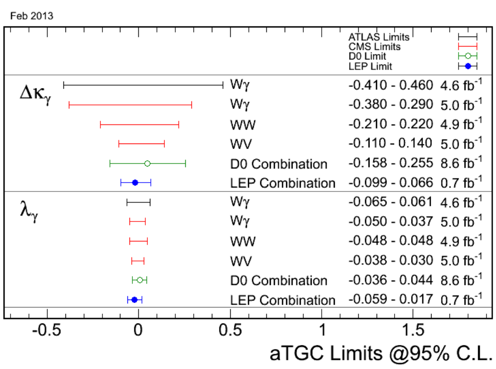

Figure 3: Limits on $WW\gamma$ anomalous triple-gauge couplings [24].

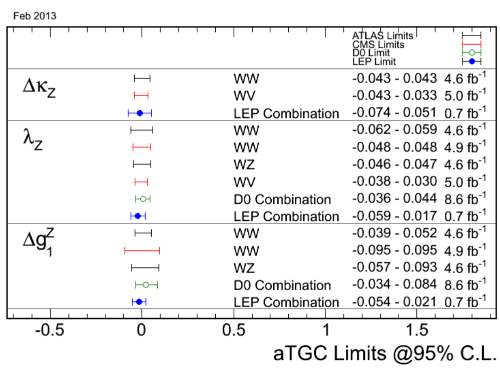

Figure 4: Limits on WWZ anomalous triple-gauge couplings [24].

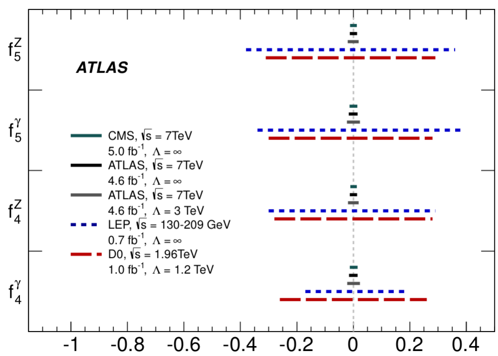

Figure 5: Limits on $Z\gamma Z$ and ZZZ anomalous triple-gauge couplings [17].

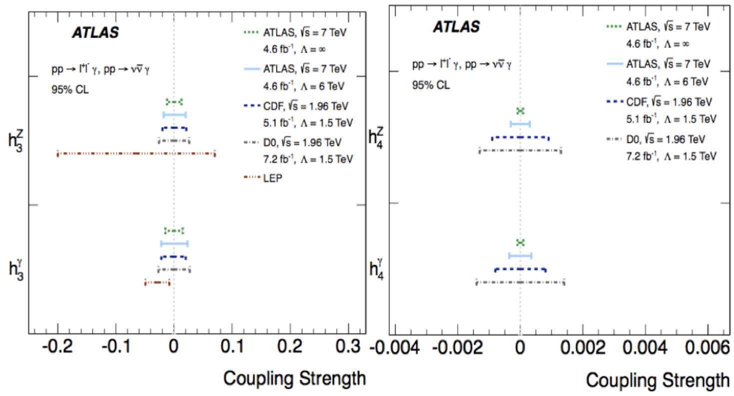

Figure 6: Limits on $ZZ\gamma$ and $Z\gamma\gamma$ anomalous triple-gauge couplings [4].

4 Summary

Measurements of the production cross sections of diboson final states performed by the ATLAS and CMS Collaborations at a centre-of-mass energy of $\sqrt{s} = 7$ and 8 TeV have been presented. The total production diboson cross sections are in reasonable agreement with the SM predictions within the uncertainties. Several distributions have also been unfolded and directly compared with the available theoretical distributions. A search for anomalous triple-gauge couplings have been performed by both ATLAS and CMS with almost 5 fb^{-1} of data collected at 7 TeV at LHC. Limits on aTGGs are set in all channels showing no deviation from the SM couplings.

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