PROCEEDINGS OF SCIENCE

Measurement of the ZZ production cross section in Proton-Proton collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector

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This work presents a measurement of the ZZ production cross section in proton-proton collisions at $\sqrt{s}$ = 7 TeV using $\sim$ 1 fb^{-1} of data collected by the ATLAS experiment at the LHC. Limits on the anomalous triple gauge couplings (aTGCs) are also presented. The systematic uncertainties of the cross section measurement as well as the data driven estimation technique for the background are discussed in detail.

The 2011 Europhysics Conference on High Energy Physics-HEP 2011,
July 21-27, 2011
Grenoble, Rhône-Alpes France

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PoS(EPS-HEP2011)467

1. Introduction

The dominant ZZ production mechanism at the LHC comes from quark-antiquark initial states which proceed through the t-channel and u-channel. The s-channel process is forbidden in the Standard Model (SM) and corresponds to a vertex with an aTGC. The $ZZ \to 4l$ cross section measurement is of great interest since it constitues the irreducible background in the discovery of the Higgs boson via the "golden" decay channel $H \to ZZ \to 4l$. It is also an indirect probe of new physics through aTGCs as well as a direct probe to new physics through massive resonances (e.g. $Graviton \to ZZ$). In this work the fiducial and the total cross section (equation 1.1) have been measured. The fiducial volume corresponds closely to the experimental acceptance and is defined by the leptons' $p_T > 15$ GeV, $|\eta| < 2.5$ as well as the invariant mass of the candidate pair of leptons, which must be within 25 GeV from the Z pole mass. The total ZZ cross section is obtained from the fiducial cross section, by correcting for the known branching fraction (BR) of Zs decaying leptonically and the kinematic and geometrical acceptance ($A_{ZZ\to ll l' l'}$). $C_{ZZ\to ll l' l'}$ is the reconstruction efficiency.

$$\sigma_{ZZ}^{tot} = \frac{N_{ll l' l'}^{obs} - N_{ll l' l'}^{bkg}}{L \times BR(ZZ \to ll l' l') \times A_{ZZ\to ll l' l'} \times C_{ZZ\to ll l' l'}} \tag{1.1}$$

2. Event Selection - Background Estimation

The signatures studied in this work [1] [2] correspond to the leptonically decaying channels of ZZ ($4e$, 4μ, $2e2\mu$ and $2\mu 2e$). Selected events must have a vertex with at least three tracks and be triggered by a lepton (electron or muon) with high transverse momentum (p_T). Candidate electrons and muons should satisfy quality and identification requirements based on the shower shape of the cluster in the electromagnetic calorimeter (only for electrons), the track from the Inner Detector (both) and the track from the muon spectrometer (only for muons). Both electrons and muons must fulfill various kinematic and track parameter requirements and be isolated from track activity around them. In total 12 candidates have been detected (2 $4e$, 8 4μ and 2 $2e2\mu$). Figure 1 shows the invariant mass (left) and the p_T (right) of the ZZ system.

The main sources of background in the $ZZ \to 4l$ channel are $W/Z + X$ and $t\bar{t}$ processes where some of the decay objects fake a lepton from Z decays. For muons the fake lepton sources are π/K decay in flight and heavy flavor decays. Fake electrons result from photons, hadrons and heavy flavor decays. Due to the fact that Monte Carlo (MC) simulations may not model well the lepton isolation from activity around them, a data-driven technique is used for the background estimation based on equation 2.1 below:

$$N_{background} = N_{LLLJ} \times FR - N_{LLJJ} \times FR^2 - N_{ZZ\to 4l} \tag{2.1}$$

Where $N_{background}$ is the number of background events, N_{LLLJ} and N_{LLJJ} are the number of events in our sample with one or two lepton-like objects failing the full set of selection criteria, and FR is the ratio of fake leptons which fail some (and get denoted by J) over those which pass all the lepton selection criteria (and get denoted by L). The last term $N_{ZZ\to 4l}$ corrects for the case that one or two

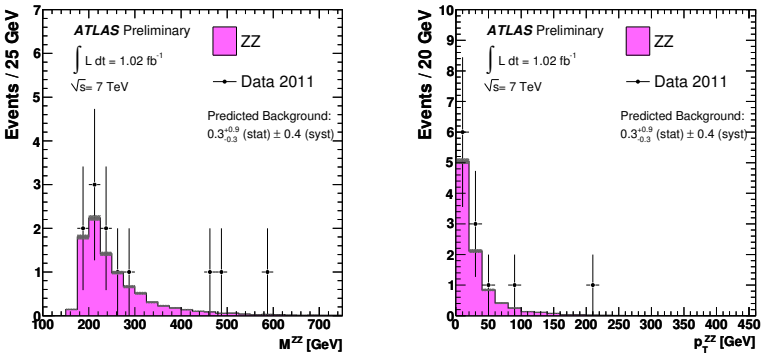

Figure 1: Kinematic distributions of four-lepton system for the selected ZZ candidates. The left plot shows the invariant mass distribution and the right plot represents the transverse momentum of the system. The shaded band indicates the systematic uncertainty. The predicted number of background events from the data-driven background estimate is indicated on the plot.

of the signal ZZ leptons fail the full selection criteria. The estimated background for the combined channels is $0.3^{+0.9}_{-0.3}(stat)^{+0.4}_{-0.3}(syst)$ [1].

3. Systematic Uncertainties

The main systematic uncertainties (SU) in the cross section calculation result from the background estimation technique due to the discrepancy between data and MC in the FR distributions. The error for both the electron and muon reconstruction efficiencies is 1.2% while the error for the electron identification is 2.4%. The SU due to the parton distribution functions (PDF) is 1.5%. Luminosity error is 3.7%. All other sources of SU like E_T/p_T smearing, energy rescaling, track isolation and track parameters are approximately $\sim$0.1%.

4. Cross section measurement - aTGCs Results

The fiducial and total cross section measurement were determined using a maximum likelihood fitting method to combine the four four-lepton channels. The SU were included in the fitting procedure as nuisance parameters. The fiducial cross section is $19^{+6}_{-5}(stat)\ ^{+1}_{-2}(syst)\ \pm 1(lumi)$ fb and the total cross section is $8.4^{+2.7}_{-2.3}(stat)\ ^{+0.4}_{-0.7}(syst)\ \pm 0.3(lumi)$ pb, comparing well with the NLO SM total cross section of $6.5^{+0.3}_{-0.2}$ pb.

The ZZV (where V=(Z,γ)) couplings of Lorentz invariant gauge interactions are parametrized by two CP violating f_4^V and two CP conserving f_5^V complex parameters. The limits in table 1 have been extracted using the ZZ cross section alone, without the use of any kinematic information of the ZZ candidates.

[1] The results presented here reflect the status of the work at the time of the EPS conference. Improvements since then are incorporated in the draft submited for publication to the PRL (hep-ex, arXiV:1110.5016v1, 23-Oct-2011).

Coupling 95% CI	f_4^γ	f_4^Z	f_5^γ	f_5^Z
$\Lambda = 2\ TeV$	[-0.15, 0.15]	[-0.12, 0.12]	[-0.15, 0.15]	[-0.13, 0.13]
$\Lambda = \infty$	[-0.08, 0.08]	[-0.07, 0.07]	[-0.08, 0.08]	[-0.07, 0.07]

Table 1: One dimensional 95% CL limits on anomalous neutral gauge boson couplings, where the limit for each coupling assumes the other couplings fixed at their SM value. Limits were derived using both statistical and systematic uncertainties.

References

[1] ATLAS Collaboration, G. Aad at al., *The ATLAS Experiment at the CERN Large Hadron Collider*, JINST 3 (2008) S08003

[2] ATLAS Collaboration, G. Aad at al., *Measurement of the ZZ Production Cross section in Proton-Proton Collisions at $\sqrt{s}$ = 7 TeV with the ATLAS Detector*, ATLAS Conf Note **http://cdsweb.cern.ch/record/1372920/files/ATLAS-CONF-2011-107.pdf** (2011).