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Measurement of total ZZ production cross section and limits on anomalous triple gauge couplings with the ATLAS detector

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Summary. — This report presents a measurement of the $ZZ \to llll$ production cross section performed by the ATLAS detector in LHC proton-proton collisions at $\sqrt{s} = 7\,\text{TeV}$. Three ZZ decay channels are considered: $eeee$, $ee\mu\mu$ or $\mu\mu\mu\mu$, including also leptons produced in the τ decay of the Z's. The results are based on an integrated luminosity of $4.7\,\text{fb}^{-1}$ collected by ATLAS in 2011 with a fully operational detector and stable beam conditions. Limits on ZZ anomalous triple gauge couplings derived using the cross section alone obtained with an integrated luminosity of $\sim 1\,\text{fb}^{-1}$ are also presented.

PACS 13.38.-b – Decays of intermediate bosons.
PACS 13.38.Dg – Decays of Z bosons.

1. – Introduction

The production of pairs of Z bosons [1] at the Large Hadron Collider (LHC) is of great interest since it provides a unique opportunity to test the predictions of the electroweak sector of the Standard Model at the TeV energy scale. In addition, it is the irreducible background to the search for the Higgs boson in the $H \to ZZ$ decay channel. In the Standard Model, ZZ production proceeds via quark-antiquark t-channel annihilation, with a small (6%) contribution from gluon fusion. The ZZZ and $ZZ\gamma$ neutral triple gauge boson couplings (nTGCs) are zero in the Standard Model, hence there is no contribution from s-channel qq annihilation at tree level. The signature of non-zero nTGCs is an increase of the ZZ cross section at high ZZ invariant mass and high transverse momentum.

2. – Events selection

Muons are selected in the region $2.5 < |\eta| < 2.7$ and are required to have a full muon spectrometer track and $p_T > 10\,\text{GeV}$. Electron candidates are required to have a transverse energy of at least $7\,\text{GeV}$ and a pseudorapidity $|\eta| < 2.47$.

TABLE I. – *Summary of observed events and expected signal and background contributions in each of the four-lepton channels and combined for the ZZ selection.*

Final state	$eeee$	$ee\mu\mu$	$\mu\mu\mu\mu$	combined
Observed	15	21	26	62
Signal(MC)	$9.9 \pm 0.5 \pm 0.8$	$16.6 \pm 0.6 \pm 0.3$	$26.8 \pm 0.8 \pm 1.0$	$53.2 \pm 1.1 \pm 1.9$
Bkg(d.d.)	$0.6^{+0.7+0.8}_{-0.6-0.6}$	$< 0.3^{+0.5}_{-0.2}$	$0.3^{+0.9+0.8}_{-0.3-0.3}$	$0.7^{+1.3+1.3}_{-0.7-0.7}$
Bkg(MC)	0.3 ± 0.3	< 0.8	0.6 ± 0.6	1.0 ± 0.6

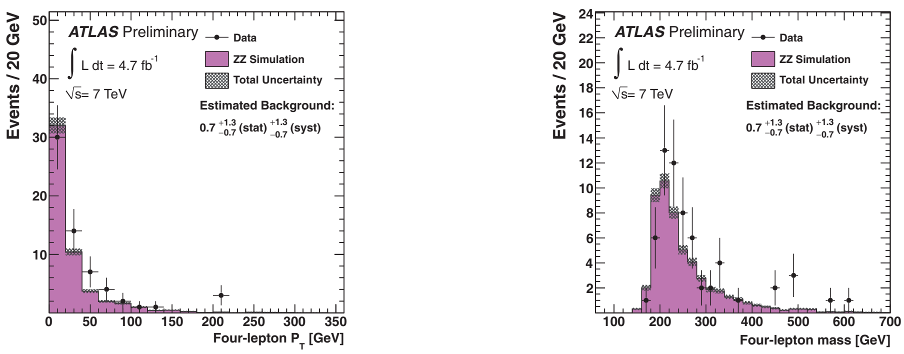

Fig. 1. – Transverse momentum (left) and mass distributions (right) of the ZZ candidates.

Events are required to have exactly four leptons selected as above, and to have passed a single-muon or single-electron trigger. To ensure high trigger efficiency, at least one of these leptons must have $p_T > 20\,\text{GeV}$ ($25\,\text{GeV}$) for a muon (electron) and match to a muon (electron) trigger object within $\Delta R < 0.1(0.15)$. The trigger efficiencies are found to be $(99.4 \pm 0.2)\%$. Same-flavour, oppositely-charged lepton pairs are combined to form Z candidates. An event must contain two such pairs. In the $eeee$ and $\mu\mu\mu\mu$ final states there is an ambiguity in pairing the leptons into Z bosons. It is resolved by choosing the pairing which results in the smaller value of the sum of the two $|m_{l^+l^-} - m_Z|$ values, where $m_{l^+l^-}$ is the invariant mass of a lepton pair and m_Z is the mass of the Z boson. The numbers of expected and observed events after applying all selection criteria and background expectation from MC and data-driven (d.d.) estimates are shown in table I. Both statistical and systematic uncertainties are given.

Figure 1 reportsthe transverse momentum and mass distributions of the ZZ candidates.

3. – Results

The fiducial and total ZZ production cross sections were determined to be [1]

$$\sigma^{\text{fid}}_{ZZ\to ll'l'} = 21.2^{+3.2}_{-2.7}(\text{stat.})^{+1.0}_{-0.9}(\text{syst.})^{+0.8}_{-0.8}(\text{lumi.})(\text{fb}),$$

$$\sigma^{\text{tot}}_{ZZ\to ll'l'} = 7.2^{+1.1}_{-0.9}(\text{stat.})^{+0.4}_{-0.3}(\text{syst.})^{+0.3}_{-0.3}(\text{lumi.})(\text{pb}).$$

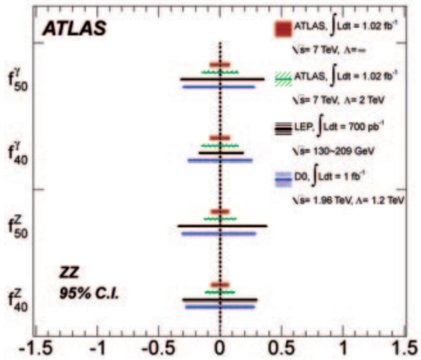

Fig. 2. – Anomalous nTGC 95% confidence intervals from ATLAS, LEP [hep-ex/0612034] and Tevatron (*Phys. Rev. Lett.*, **100** (2008) 131801) experiments. Luminosities, centre-of-mass energy and cut-off Λ for each experiment are shown.

The total ZZ production cross section confirms the previous measurement in [2] of $8.5^{+2.7}_{-2.3}(\text{stat.})^{+0.4}_{-0.3}(\text{syst.})^{+0.3}_{-0.3}(\text{lumi.})(\text{pb})$ performed with the first $1\,\text{fb}^{-1}$. The result is also consistent with the NLO Standard Model total cross section for this process of $6.5^{+0.3}_{-0.2}$ pb calculated with MCFM [3] and PDF set MSTW2008 [4].

Limits on anomalous nTGCs are determined using the total number of observed events only, obtained with $1\,\text{fb}^{-1}$. The ZZ production yield dependency on couplings is parametrized using fully simulated events generated with SHERPA [5], subsequently reweighted using the leading-order matrix element within the framework of [6]. The reweighting procedure uses simulated samples with standard model as well as non-standard-model coupling values to ensure adequate coverage of all kinematic regions. One dimensional 95% confidence intervals for the anomalous nTGCs are determined using a maximum profile likelihood fit to the observed number of events. The systematic errors are included as nuisance parameters. The resulting limits for each coupling, determined assuming real couplings and with the other couplings fixed at their standard model value, are shown in fig. 2.

REFERENCES

[1] ATLAS Collaboration, ATLAS-CONF-2012-026 2012 `https://cdsweb.cern.ch/record/1430735`.
[2] ATLAS Collaboration, *Phys. Rev. Lett.*, **108** (2012) 041804, arXiv:hep-ex/1110.5016.
[3] Campbell J., Ellis K. and Williams C., *JHEP*, **07** (2011) 018, DOI:10.1007/JHEP07(2011)018.
[4] Martin A. D., Stirling W. J., Thorne R. S. and Watt G., *Eur. Phys. J. C*, **63** (2009) 189, arXiv:hep-ph/0901.0002.
[5] Gleisberg T., Hoche S., Krauss F., Schonherr M., Schumann S., Siegert F. and Winter J., *JHEP*, **02** (2009) 007.
[6] Bella G., arXiv:0803.3307, 2008.