W[±]Z PRODUCTION IN PP COLLISIONS AT 7 TEV WITH ATLAS

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ABSTRACT

The measurement of the W[±]Z diboson production cross section in proton-proton interactions at E_{CM} = 7 TeV is reported from the ATLAS experiment using 1.02 fb⁻¹ of data. The measurement is derived from events with purely leptonically decaying bosons with electrons, muons, and missing energy in the final state. Limits on anomalous triple gauge boson couplings (TGC) are derived.

LEPTON ID AND MISSING E_T

- Electron** identification is based on calorimeter clusters and tracks in the Inner Detector (ID)
- Require p_T > 15 GeV, |η| < 2.5 removing crack region of (1.37, 1.52)
 - Medium identification*: Track quality, track matching, shower shape, impact parameter cuts
 - Tight identification*: E/p matching, e/π discrimination, conversion rejection
 - Isolation*: Sum of calorimeter energy in cone of ΔR<0.3 around electron less than 4 GeV
- Muon** identification is based on tracking information in the Muon Spectrometer (MS) and ID
- Require p_T > 15 GeV, |η| < 2.5
 - Use MS+ID combined tracks and ID tracks matched to segments in MS (Tag tracks)
 - Apply track quality requirements to reject decays in flight and improve track matching
 - Ensure muon is from primary vertex with |z₀|<10mm requirement
 - Isolation*: Scalar sum of pT of tracks in cone ΔR<0.2 around muon less than 10% of muon pT
- Missing E_T** calculated with reconstructed electrons with |η| < 2.5, muons with |η| < 2.7, and jets and calorimeter energy clusters outside of other reconstructed objects within |η| < 4.5. Clusters are calibrated as electromagnetic or hadronic energy according to cluster topology.
- Trigger** with single electron and muon triggers.

EVENT SELECTION

- Z Cut**
- Two same flavor opposite charge leptons
 - |M_{ll}-M_Z^{Pole}| < 10 GeV
 - Muons*: Combined tracks or Tag tracks
 - Electrons*: Medium identification requirement
- Third Lepton** (W candidate lepton)
- p_T > 20 GeV
 - Muons*: Combined tracks
 - Electrons*: Tight identification requirement
- Missing transverse energy**
- E_T^{Miss} > 25 GeV
- Transverse mass**
- E_T^{Miss} and W candidate lepton, m_T > 20 GeV
- Trigger Match**
- Muon (p_T > 20 GeV) or Electron (p_T > 25 GeV)

W[±]Z EVENT PROPERTIES

MOTIVATION

The W[±]Z production cross section can now be measured at the new energy scale of 7 TeV. Triple gauge boson interactions, which are fixed in the Standard Model by the electroweak gauge structure, play an important role in W[±]Z production. Thus a precise measurement of this process is essential to test the high energy behavior of electroweak interactions and to probe for possible new physics in the bosonic sector.

OBSERVED AND PREDICTED YIELDS

W[±]Z Signal simulated with MC@NLO 4.0

Electroweak Background mainly ZZ and W/Z+γ, taken from Monte Carlo

Top Background taken from Monte Carlo

Z/W+jets Background data-driven methods

- Isolation and object quality used to distinguish between “fake-able” and good leptons
- Lepton fake rate derived from Z+jets data with low E_T^{Miss}, extrapolated to high E_T^{Miss}
- Lepton fake rate applied to Z+ “fake-able” lepton sample after all cuts

Final State	eee+E _T ^{Miss}	eeμ+E _T ^{Miss}	eμμ+E _T ^{Miss}	μμμ+E _T ^{Miss}	Combined
Observed	11	9	22	29	71
Expected W [±] Z Signal	7.55±0.17	11.27±0.20	12.12±0.22	18.16±0.27	49.1±0.4±3.02
ZZ	0.34±0.07	1.03±0.13	0.82±0.12	1.40±0.15	3.55±0.24±0.17
Z/W+Jets	2.03±0.38	0.64±0.18	2.03±0.38	0.44±0.15	5.14±0.59 ^{+2.97} _{-2.08}
Top	0.26±0.10	0.31±0.09	0.41±0.12	0.60±0.15	1.58±0.23±0.10
Z/W+γ	0.49±0.28	-	0.56±0.39	-	1.05±0.48±0.08
Total Background	3.08±0.49	1.98±0.24	3.82±0.56	2.44±0.21	10.5±0.8 ^{+2.9} _{-2.1}

PRODUCTION CROSS SECTION

Minimize negative log likelihood (LL) to determine cross section, and errors defined by ΔLL=0.5.

$$-\log L(\sigma, \{x_k\}) = -\log \left(\prod_{i=1}^4 \frac{e^{-(N_s^i(\sigma, \{x_k\}) + N_b^i(\{x_k\}))} \times (N_s^i(\sigma, \{x_k\}) + N_b^i(\{x_k\}))^{N_{obs}^i}}{(N_{obs}^i)!} \right) + \sum_{k=1}^n \frac{x_k^2}{2}$$

- Fit to all four decay channels simultaneously
- N_{obs}ⁱ = Number of observed events in decay mode i
- N_sⁱ = Number of expected signal events in decay mode i
- N_bⁱ = Number of expected background event in decay mode i
- X_k = Gaussian constrained nuisance parameter, one for each systematic
- σ = W[±]Z cross section

Result $\sigma_{W^{\pm}Z} = 21.1^{+3.1}_{-2.8} (stat) {}^{+1.2}_{-1.2} (syst) {}^{+0.9}_{-0.8} (lumi) pb$

Theoretical cross section from MC@NLO 17.2^{+1.2}_{-0.8} pb

ANOMALOUS TGC LIMITS

New physics at high energy may appear at low energy as anomalous triple gauge couplings (TGC)

- Model with most general C and P invariant effective Lagrangian. In SM, g₁^Z=κ^Z=1 and λ=0.

$$\frac{\mathcal{L}_{WWZ}}{g_{WWZ}} = i \left[g_1^Z (W_{\mu\nu}^\dagger W^\mu Z^\nu - W_{\mu\nu} W^{\dagger\mu} Z^\nu) + \kappa^Z W_\mu^\dagger W_\nu Z^{\mu\nu} + \frac{\lambda}{m_W^2} W_{\rho\mu}^\dagger W_\nu^\mu Z^{\nu\rho} \right], \text{ and } \alpha(\hat{s}) = \frac{\alpha_0}{(1 + \hat{s}/\Lambda^2)^2}$$

- Avoid violating unitarity by adding a cut-off Λ=3 TeV
- Where α stands for Δg₁^Z, Δκ^Z, or λ, the deviations of the anomalous coupling from the SM
- Use frequentist limit setting approach
- Determine all cross section consistent with the observed data at the 95% confident level
 - Values of anomalous coupling which predict an anomalous cross section inside the 95% confidence interval (C.I.) of the measured cross section determine the 95% C.I. of the coupling
 - Confidence interval for each coupling determined separately, with others set to SM value of 0

Anomalous Coupling	Expected Limit of the 95% C.I.	Observed Limit of the 95% C.I.
Δg ₁ ^Z	[-0.16 ^{+0.05} _{-0.05} , 0.24 ^{-0.05} _{+0.05}]	[-0.21, 0.30]
Δκ ^Z	[-0.7 ^{+0.2} _{-0.2} , 0.9 ^{-0.2} _{+0.2}]	[-0.9, 1.2]
λ	[-0.14 ^{+0.04} _{-0.03} , 0.14 ^{-0.04} _{+0.03}]	[-0.18, 0.18]

SUMMARY

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Using 1.02 fb⁻¹, the measured W[±]Z production cross section is in good agreement with the Standard Model. Using the measured cross section, limits on anomalous triple gauge couplings have been derived and compared to the Tevatron.