PROCEEDINGS OF SCIENCE

ttW and ttZ production cross-sections in leptonic final states at 8 TeV with ATLAS

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A measurement of the production cross-section of top quark pairs in association with a W or Z boson is presented, using $20.3\,\mathrm{fb}^{-1}$ of pp collision data collected by the ATLAS detector at the LHC, at $\sqrt{s} = 8\,\mathrm{TeV}$. The measurement combines four separate analyses which consider final states with two oppositely-charged, two like-charged, three and four leptons. A simultaneous fit to data of the $t\bar{t}W$ and $t\bar{t}Z$ signals measures their cross-sections to be $\sigma_{t\bar{t}Z} = 176^{+58}_{-52}$ fb and $\sigma_{t\bar{t}W} = 369^{+100}_{-91}$ fb, consistent with next-to-leading order theoretical calculations. Tested against the background-only hypothesis, these correspond to an observed (expected) significance of 4.2σ (4.5σ) for $t\bar{t}Z$ and 5.0σ (3.2σ) for $t\bar{t}W$.

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1. Introduction

With the integrated luminosity collected at the Large Hadron Collider (LHC) in its first run, rare processes producing top quark pairs in association with electroweak Standard Model (SM) bosons have become experimentally accessible. The $t\bar{t}Z$ production cross-section directly probes the top-Z coupling and, as with $t\bar{t}W$ production, is a background to $t\bar{t}H$ measurements and searches for new physics. These proceedings present measurements [1] of the $t\bar{t}W$ and $t\bar{t}Z$ production cross-sections using 20.3 fb^{-1} of 8 TeV pp collision data collected by the ATLAS detector [2].

2. Analysis channels and regions

The leptonic final states are divided into four channels based on the charge and multiplicity of prompt leptons (e or μ) present. Channels are divided into signal and control regions as in Fig. 1.

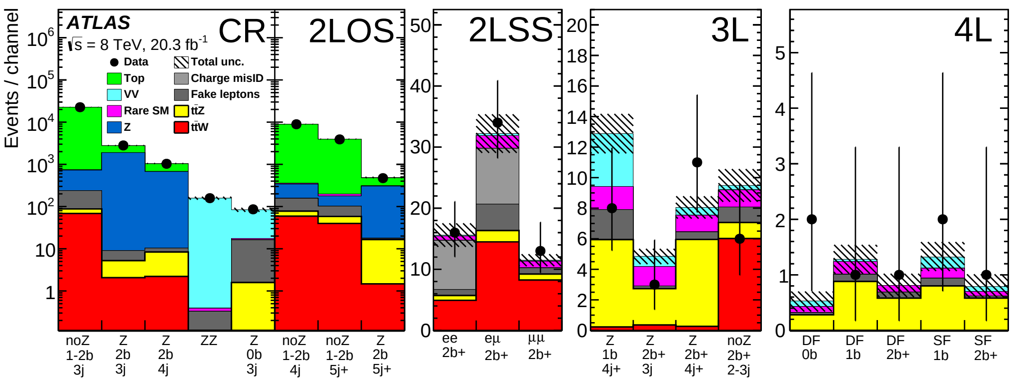

Figure 1: Expected yields after the fit compared to data in the five control regions (CR), and fifteen signal regions. In the two dilepton channels the fit also includes shape information. Taken from Ref. [1].

The opposite-sign dilepton (2LOS) channel selects events with a pair of oppositely-charged leptons with $p_T > 15$ GeV and at least three jets of which at least one is tagged as originating from a b quark. Two sub-selections are made: (a) a Z-enriched sample requiring the dilepton invariant mass $m_{\ell\ell}$ to be inside the Z mass window ($|m_{\ell\ell} - m_Z| < 10$ GeV), and (b) a fully-hadronic sample requiring events with either (i) different-flavour leptons and the scalar p_T sum of leptons and jets $H_T > 130$ GeV, or (ii) same-flavour leptons with $m_{\ell\ell} > 15$ GeV and outside the Z mass window, and missing transverse momentum $E_T^{\text{miss}} > 40$ GeV. 5-jet events from (a) and 4- and 5-jet events from (b) are treated as signal regions, with the remaining events used as control regions to constrain the Z and $t\bar{t}$ normalisation. SM backgrounds are modelled in Monte Carlo simulation, as is the contribution from non-prompt and misidentified leptons, and leptons with misidentified charge. A neural network is trained in each signal and control region using an optimised list of input variables particular to that region, and its response is used to separate the small signal from the backgrounds.

The same-sign dilepton (2LSS) channel selects events with a pair of like-charged leptons with $p_T > 15$ GeV, at least two b-tagged jets, $E_T^{\text{miss}} > 40$ GeV and $H_T > 240$ GeV. The sample is divided based on lepton flavour due to their differing background compositions, and for the ee sample events with the dielectron invariant mass consistent with the Z mass are excluded. The $e\mu$ and $\mu\mu$

samples are subdivided into four bins according to $E_{\mathrm{T}}^{\mathrm{miss}}$ (< 80 or ≥ 80 GeV) and jet multiplicity (2-3 or ≥ 4). Lepton charge misidentification, which dominates the *ee* sample, is measured in a sample of *ee* events inside the Z mass window by maximising a likelihood function. The background from misidentified and non-prompt leptons is estimated in a sample with an inverted H_{T} cut using a fake factor method. Overlap between these two data-driven estimates is taken into account.

The trilepton (3L) channel selects events containing three prompt leptons with $p_{\mathrm{T}} > 15$ GeV. The events are divided into (*a*) a sample targeting $t\bar{t}Z$ requiring the presence of a e^+e^- or $\mu^+\mu^-$ pair inside the Z mass window, and (*b*) a sample targeting $t\bar{t}W$ consisting of the remaining 3-lepton events in which the leptons do not all have the same charge sign. These samples are subdivided into bins of b-jet multiplicity chosen to optimise significance. The WZ (diboson) background is constrained in a control region inside the Z mass window with exactly three jets of which none are b-tagged. The contribution from non-prompt leptons is estimated from data in a dilepton sample.

The tetralepton (4L) channel selects events containing four prompt leptons with $p_{\mathrm{T}} > 15$ GeV which are not contained in the trilepton channel. One pair of leptons is required to be same-flavour and inside the Z mass window, and the other pair either (*a*) same-flavour but with a mass not consistent with a second Z boson, and accompanied by at least one b-jet, or (*b*) different-flavour and satisfying a more stringent set of p_{T} requirements. The ZZ (diboson) background normalisation is constrained in a control region consisting of events where both lepton pairs are inside the Z mass window and $E_{\mathrm{T}}^{\mathrm{miss}} < 50$ GeV. The contribution from non-prompt leptons is simulated and corrected by a constant factor derived from data. The selected data contain seven signal events.

3. Results

A binned maximum likelihood fit is performed over all twenty signal and control regions to simultaneously measure the production cross-sections $\sigma_{t\bar{t}W}$ and $\sigma_{t\bar{t}Z}$. Systematic uncertainties are treated as nuisance parameters with prior uncertainties, and are constrained by the fit procedure. Sources of uncertainty related to reconstruction are treated as correlated between all regions. The expected yields after the fit are compared with data in Fig. 1. The systematic uncertainties obtained by fitting one signal at a time with the other fixed to its SM value are summarised in Tab. 1. The dominant sources of uncertainty for both signals are statistical. The production cross-sections are

Uncertainty	$\sigma_{t\bar{t}W}$	$\sigma_{t\bar{t}Z}$
Luminosity	3.2%	4.6%
Reconstructed objects	3.7%	7.4%
Background from simulation	5.8%	8.0%
Fake leptons and charge misID	7.5%	3.0%
Signal modelling	1.8%	4.5%
Total systematics	12%	13%
Statistics	+24% / − 22%	+30% / − 27%
Total	+27% / − 24%	+33% / − 29%

Table 1: Breakdown of uncertainties on the measured cross-section of $t\bar{t}Z$ and $t\bar{t}W$ processes from one-dimensional fits. Systematic uncertainties are symmetrised. Taken from Ref. [1].

Channel	$t\bar{t}W$ significance		$t\bar{t}Z$ significance	
	Expected	Observed	Expected	Observed
2ℓOS	0.4	0.1	1.4	1.1
2ℓSS	2.8	5.0	-	-
3ℓ	1.4	1.0	3.7	3.3
4ℓ	-	-	2.0	2.4
Combined	3.2	5.0	4.5	4.2

Table 2: Signal significances for $t\bar{t}Z$ and $t\bar{t}W$ determined from the fit to individual channels and the combined fit where the null hypothesis is assumed for the process under consideration. Taken from Ref. [1].

extracted from the yields resulting from the combined simultaneous fit are:

$$\sigma_{t\bar{t}W} = 369^{+86}_{-79}(\text{stat.}) \pm 44(\text{syst.})\,\text{fb} = 369^{+100}_{-91}\,\text{fb}$$
$$\sigma_{t\bar{t}Z} = 176^{+52}_{-48}(\text{stat.}) \pm 24(\text{syst.})\,\text{fb} = 176^{+58}_{-52}\,\text{fb}$$

and are shown with theoretical predictions in Fig. 2. Expected signal significances are calculated using the asymptotic formula of Ref. [3] and presented in Tab. 2 with the observed significances.

All measurements are consistent with next-to-leading order (NLO) theoretical calculations.

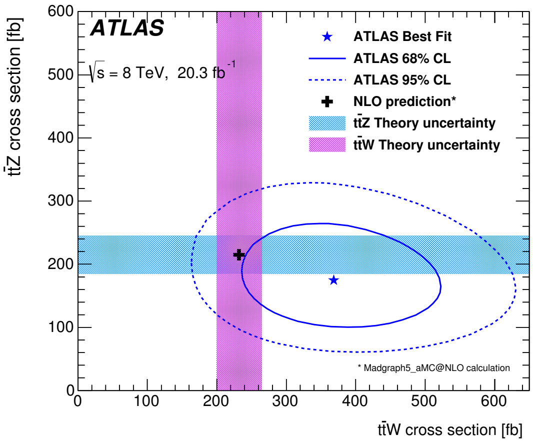

Figure 2: The combined two-dimensional simultaneous fit to the $t\bar{t}W$ and $t\bar{t}Z$ cross-sections along with the 68% and 95% CL uncertainty contours. The shaded areas correspond to 14% theory uncertainty, which includes renormalisation, PDF and factorisation scale uncertainties [4, 5]. Taken from Ref. [1].

References

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