PROCEEDINGS OF SCIENCE

Measurement of the $t\bar{t}Z$ cross section in the four lepton channel at 13 TeV with the ATLAS experiment

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The measurement of a Z boson together with a top quark pair in the four lepton channel is presented. The analysis uses the first data at $\sqrt{s}$ =13 TeV collected by the ATLAS detector at the Large Hadron Collider in the year 2015. The data sample corresponds to 3.2 fb^{-1} of integrated luminosity. The inclusive $t\bar{t}Z$ cross section is extracted using a likelihood fit to signal and control regions in the three and four lepton channel, resulting in $\sigma_{t\bar{t}Z} = 0.92 \pm 0.30(\text{stat.}) \pm 0.11(\text{syst.})$pb.

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1. Introduction

The measurement of a Z boson together with a top quark pair provides an important test of the standard model. The current measurement using data collected at an integrated luminosity of 3.2 fb^{-1} and at an energy of $\sqrt{s}$ =13 TeV reaches about the same sensitivity as that at 8 TeV as the $t\bar{t}Z$ cross section increases of about a factor four.
The $t\bar{t}Z$ cross section is extracted from a combined fit to signal regions selecting 3 or 4 leptons final states and dedicated control regions. In the following the analysis of the 4 lepton channel is presented [1].

2. 4 Lepton Analysis

The selection of 4 leptons final states provides a good signal to background ratio but a small number of events in the signal regions. In fact about one event only is expected in each signal region. This is mainly due to the low branching ratio of less than 1%. Therefore one of the main challenges in this analysis is the correct statistical treatment of distributions with a very small number of events.

2.1 Signal and Backgrounds

Figure 1 shows a possible Feynman-diagram of the $t\bar{t}Z$ production. The main background is the ZZ production, followed by the Higgs ($t\bar{t}$H, WH, ZH), the Triboson and the WtZ production.

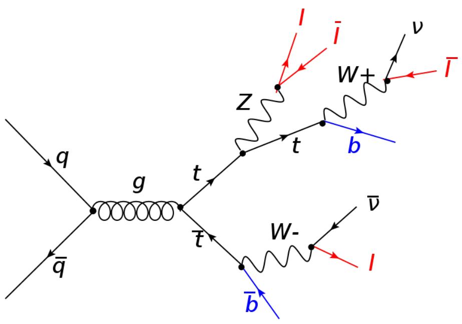


Figure 1: A possible Feynman-diagram of the $t\bar{t}Z$ signal.

2.2 Signal Regions

In all signal regions four leptons and one or two b-tagged jets are required. The lepton pair coming from the Z boson has opposite charge and same flavour, see Fig. 2. The remaining pair can have leptons with same or different flavour.

The signal regions are defined according to the flavour of the second lepton pair and the number of b-tagged jets, namely one (1b) or two b-tagged jets (2b) in the signal regions. This second lepton pair coming from the two top quarks can have either same flavour (SF) or different flavour (DF). Based on that the final signal regions are labeled 1bDF, 2bDF, 1bSF and 2bSF. In the 1bDF and 2bDF signal regions the very dominant ZZ background is dramatically suppressed by the requirement that the second lepton pair has different flavour. In the signal region events with a second pair

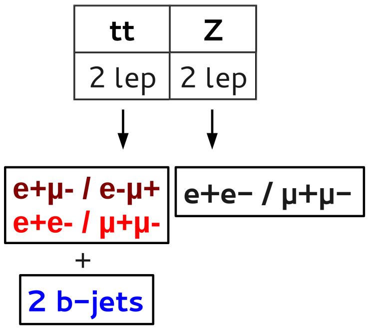
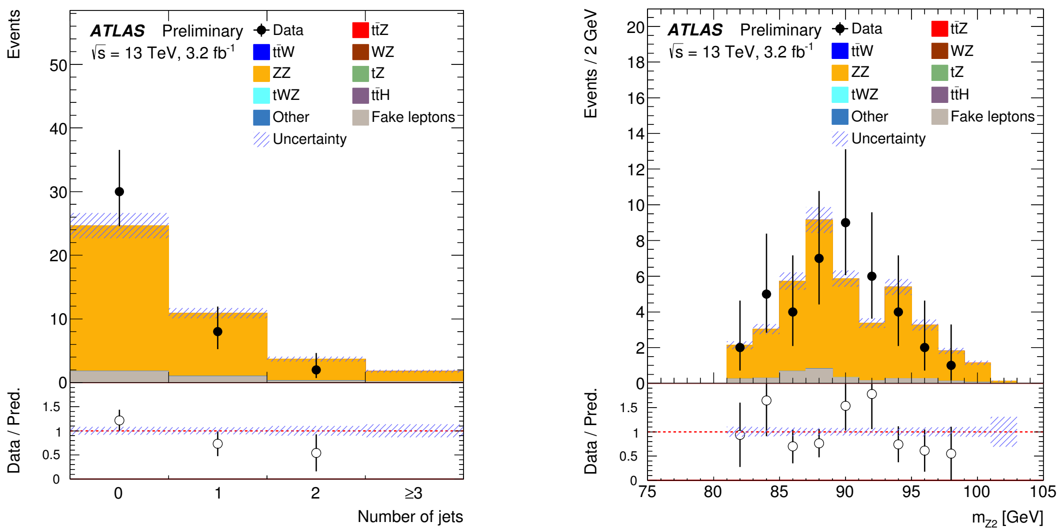


Figure 2: Decay modes in the 4 lepton channel.

made of leptons with same flavour are rejected if their invariant mass is within a window around the Z mass.

2.3 ZZ Control Regoin

In the ZZ control region two lepton pairs with the same flavour and opposite sign are required. The invariant mass of the lepton pairs is required to be in a window around the Z boson mass. Fig. 3 shows the jet multiplicity distribution a), and the invariant mass distribution b) in the ZZ control region.



(a) (b)

Figure 3: Number of jets and the invariant mass of the second lepton pair in the ZZ control region.

2.4 Fake Factor Method

One of the main backgrounds comes from processes which have less than four true leptons. For these processes the Monte Carlo expectation is corrected by a data-driven "Fake Factor Method". The main idea is to correct the Monte Carlo predictions for various sources of fake leptons. In order to do so, correction factors describing the potential discrepancy in the fake efficiencies between data and the Monte Carlo simulation are extracted in dedicated control regions, which are enriched with processes that contain at least one fake lepton. The fake efficiencies "fake factors" are derived separately for fake electrons and muons in $t\bar{t}$ and Z control regions. For the $t\bar{t}$ control regions, it is assumed that the fake lepton originates from the same sources as in all processes with true top quarks ($t\bar{t}$H,ttt,tttt), called top-like. For all other processes without true top quarks it is assumed that the origin of fakes is the same as in Z events, called Z-like. The top-like fake factors (derived in $t\bar{t}$+e or $t\bar{t}$+μ control region) are applied for processes with real top quarks ($t\bar{t}$Z, $t\bar{t}$H, ...), the Z-like fake factors (derived in Z+e or Z+μ control regions) for the others (WZ, Triboson, ...).

3. Results

In the four lepton channel five events are observed with an expectation of ∼2.4 signal and ∼1.4 background events. The $t\bar{t}$Z cross section is extracted from a combined fit of the distributions of events obtained with the three and four lepton analyses. A comparison between the observed events and the ones predicted by the simulation, obtained after the fit, in various regions of the analysis, is shown Fig. 4. The contribution from the three lepton channel is labeled with "3L", the one from the four lepton channel with "4L". In the profile likelihood fit the systematic uncertainties are treated as nuisance parameters, which are constrained by the fit. The sensitivity of the 13 TeV analysis despite the lower luminosity, is similar to that measured at 8 TeV, thanks to the higher $t\bar{t}$Z cross section [1] [2]. The $t\bar{t}$Z cross section at 13 TeV is extracted by a fit in 10 regions:

$$\sigma_{t\bar{t}Z} = 0.92 \pm 0.30(\text{stat.}) \pm 0.11(\text{syst.})\text{pb} \tag{3.1}$$

The measurements is consistent with the NLO QCD theoretical calculations, $\sigma_{t\bar{t}Z} = 0.84 \pm 0.09$ pb [3] [4].

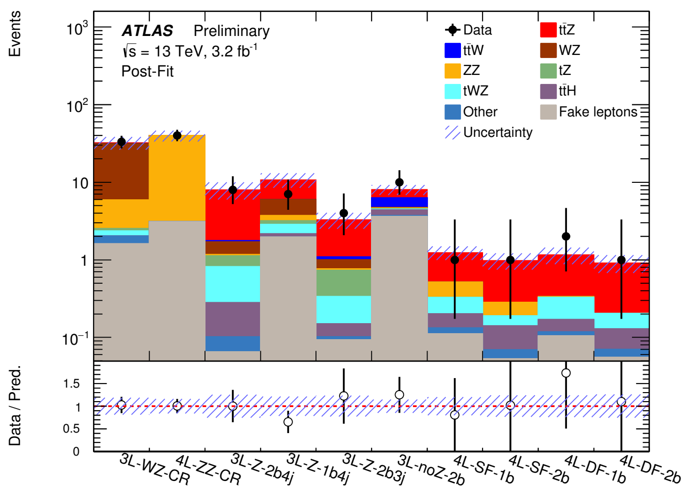


Figure 4: Comparison between the observed events and the ones predicted by the simulation, obtained after the fit, in signal and control regions of the analysis. The regions with 4 leptons are labeled with:“ 4L-”.

References

[1] ATLAS Collaboration, Measurement of the $t\bar{t}Z$ and $t\bar{t}W$ production cross sections in multilepton final states using 3.2 fb^{-1} of pp collisions at 13 TeV at the LHC, ATLAS-CONF-2016-003, 2016, https://cds.cern.ch/record/2138947

[2] ATLAS Collaboration, Measurement of the $t\bar{t}W$ and $t\bar{t}Z$ production cross sections in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector, JHEP11(2015)172, [arXiv:1509.05276 [hep-ex]].

[3] S. Frixione, V. Hirschi, D. Pagani, H.-S. Shao and M. Zaro, Electroweak and QCD corrections to top-pair hadroproduction in association with heavy bosons, JHEP 1506(2015)184 [arXiv:1504.03446 [hep-ph]].

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