Single top-quark production with the ATLAS detector in pp collisions at $\sqrt{s} = 7$ TeV

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Abstract

The ATLAS experiment at the LHC at CERN has analyzed 2010 and 2011 data looking for electroweak production of single top quarks in the lepton+jets and di-lepton final states. The production cross section for the t-channel process is measured to be 76^{+41}_{-21} pb using 156 pb^{-1} of 2011 data. A first limit is set on the Wt associated production process using lepton+jets and di-lepton events. The 95% CL upper limit on the Wt production cross section is 158 pb using 35 pb^{-1} of 2010 data.

1 Introduction

Single top quark production in the SM is the electroweak production of a single top quark at a hadron collider. A measurement of the single top quark production cross section provides a direct measurement of the the quark mixing matrix element $|V_{tb}|$ [1]. It also serves as a probe of the Wtb coupling [2, 3] and is sensitive to several models of new physics [4]. Single top quark production at the LHC proceeds via three separate modes shown in Fig. 1, each resulting in a unique final state: the t-channel exchange of a virtual W boson between a light quark line and a heavy quark line, the Wt associated production of a top quark and a W boson, and the s-channel production and decay of a virtual W boson. The predicted cross sections for single top production at NLO are 66.2 pb for the t-channel, 14.6 pb for Wt associated production and 4.3 pb for the s-channel [5].

Single top quark production was observed in 2009 at the Tevatron [6, 7, 8], and the t-channel mode was also observed by the D0 collaboration [9].

This note presents a measurement of the t-channel cross section using 156 pb^{-1} of 2011 7 TeV ATLAS lepton+jets data [10] and a search for Wt associated production using 35 pb^{-1} of 2010 7 TeV ATLAS data in the lepton+jets and di-lepton channels [11].

[1] For the ATLAS collaboration

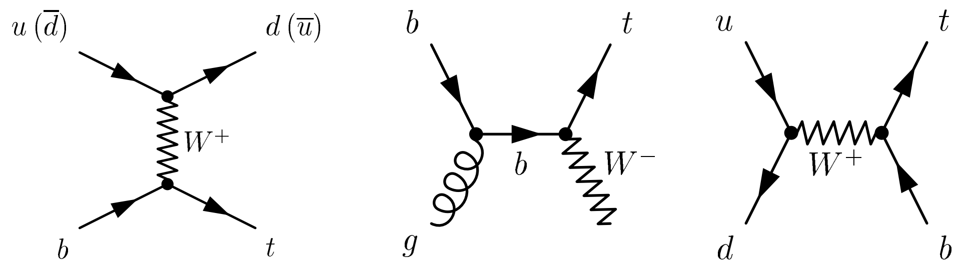

Figure 1: Feynman diagrams for single top quark production in the t-channel, Wt associated production and s-channel mode.

2 T-channel analysis

Single top-quark events are selected in the final state containing one isolated lepton (electron or muon with $p_T > 25$ GeV), missing transverse energy ($E_T^{miss} > 25$ GeV) and two jets ($p_T > 25$ GeV), exactly one of which is required to be b-tagged.

The main backgrounds to this signature are from W+jets production, QCD multijet events, and top quark pairs. Smaller backgrounds are due to Z+jets and diboson production.

The t-channel analysis is done both using a cut-based approach and a multivariate approach employing a Neural Network (NN). The cut-based approach requires the light quark jet (non b-tagged jet) to be forward in pseudo-rapidity ($\eta > 2.0$), the reconstructed top quark mass to be between 140 GeV and 190 GeV, the sum of the transverse energies of all objects to be larger than 180 GeV, the pseudo-rapidity difference between the two jets to be large ($\Delta\eta > 2.0$), and the b-tagged jet to be central ($\eta_b < 2.0$). The distribution of the selected events as a function of lepton flavour and charge is shown in Fig. 2(a).

The NN analysis of t-channel events uses 22 discriminating variables. The most important variable is the reconstructed top-quark mass, followed by the invariant mass of the two jets and the pseudo-rapidity of the light quark jet. The resulting NN output distribution is shown in Fig. 2(b). For the final statistical analysis a cut is made at a NN value of 0.86.

The cross section measurement is extracted using a frequentist approach with profiling of systematic uncertainties. Systematic uncertainties are larger than statistical uncertainties, with the largest contributions to the systematic uncertainty due to the signal modeling, jet energy calibration, b-tag modeling and background normalization. The t-channel cross section is measured to be 97^{+54}_{-30} pb by the cut-based analysis and 76^{+41}_{-21} pb by the neural network analysis. Both are consistent with the SM expectation. The observed significances are 6.1 standard deviations for the cut-based analysis and 6.2 standard deviations

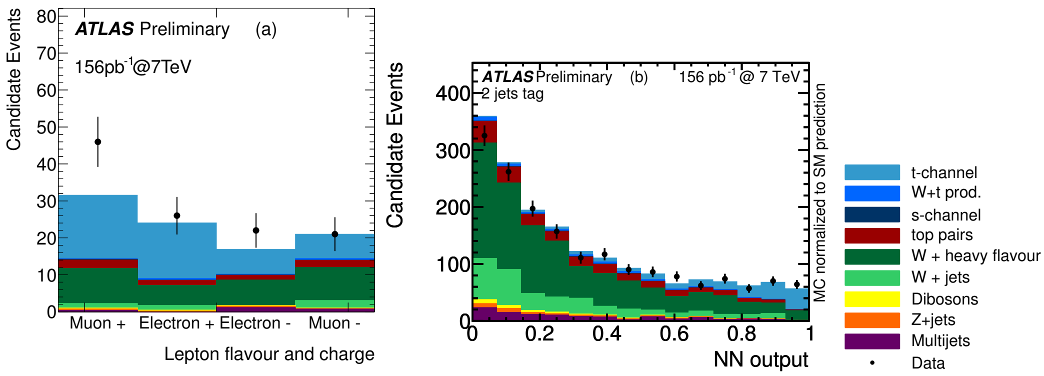

Figure 2: (a) Single top t-channel cut-based events separated by lepton flavour and charge and (b) neural network output distribution.

for the neural network analysis.

3 Wt analysis

Single top-quark Wt events are selected in two final states, one containing two isolated leptons and one jet and the other containing one lepton and two to four jets. The lepton+jets analysis has similar backgrounds as the t-channel analysis and uses the same object selection and background estimation methods. It requires the b-tagged jet to have $p_T > 35$ GeV and the angular separation between the two leading jets to be less than 2.5.

The dilepton analysis requires two opposite-charge leptons with $p_T > 20$ GeV, one jet with $E_T > 20$ GeV and $E_T^{miss} > 50$ GeV. The main backgrounds to this event signature are from top quark pair di-lepton events and Drell-Yan production of Z/γ+jets. Smaller contributions come from $Z \to \tau\tau$ events, dibosons, W+jets and multijet events. The jet-multiplicity distribution for dilepton events is shown in Fig. 3.

The observed data are consistent with the background-only expectation in both the dilepton and the lepton+jets channels for the Wt analysis. An upper limit is set on the Wt production cross section using a frequentist approach with profiling of systematic uncertainties. The dominant sources of systematic uncertainty are the top quark pair production modeling and the background normalization. The combined limit on the Wt production cross section at the 95% confidence level (CL) is 158 pb.

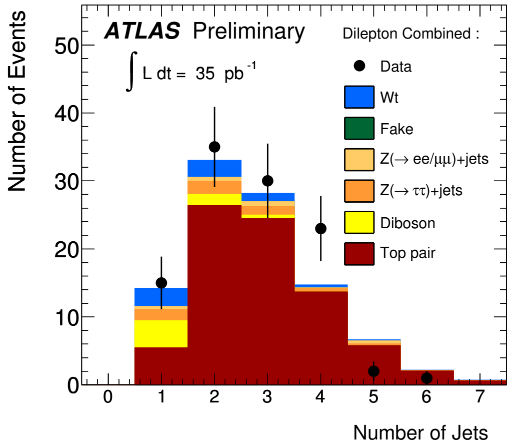

Figure 3: Jet-multiplicity for the single top Wt dilepton analysis.

4 Summary

The ATLAS experiment has observed single top quark production in the t-channel at the LHC. This is the first observation of single top at the LHC and complements Tevatron results. ATLAS has also set a first upper limit on Wt associated production.

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