Measurements of single top-quark production with the ATLAS detector

W. H. Bell[1] *on behalf of the ATLAS Collaboration*

[1]Université de Genève, Section de Physique, 24 rue Ernest Ansermet, CH-1211 Genève 4

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These proceedings summarise the single top-quark production cross-section results obtained with the ATLAS [1] detector at a centre-of-mass energy of 7 TeV. Cross-section results for the t, Wt and s-channels are presented. These results are interpreted in terms of the CKM matrix element $|V_{\mathrm{tb}}|$ assuming $|V_{\mathrm{tb}}| \gg |V_{\mathrm{ts}}|$ and $|V_{\mathrm{td}}|$. Searches for flavour changing neutral-currents and right-handed W' in single top-quark events are also presented.

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1 Introduction

Top-quark production in proton-proton collisions at the LHC [2] is dominated by top anti-top production processes. In contrast to the dominant production via flavour-conserving strong interactions, single top quarks are produced through the electroweak interaction. In the Standard Model (SM) three processes are responsible for single top-quark production: the exchange of a virtual W-boson in the t and s channels, and the associate production of a top quark and a real W-boson (Wt).

Experimental measurements of the single top-quark production cross-section directly probe the W-t-b vertex, constraining possible sources of beyond the SM physics processes [3]. Cross-section measurements set constraints on the absolute value of V_{tb}, without an assumption on the number of quark generations. The same results can alternatively be used to constrain the b-quark parton density function (PDF) using the t-channel measurements. Within the SM, production of a single top-quark via flavour changing neutral currents (FCNC) is forbidden at the tree-level and suppressed at higher orders [4]. However, beyond the standard model theories, which include exotic quarks [5], new scalars [6], supersymmetry [7] and technicolour [8] predict higher FCNC rates.

2 Event selection

Data were selected using a high transverse momentum (p_{T}) inclusive single lepton trigger. Electrons were then required to have cluster E_{T} greater than 25 GeV and an absolute pseudorapidity ($|\eta|$) less than 2.47. Electron clusters within the barrel-endcap transition region $1.37 < |\eta| < 1.52$ were excluded. Muons candidates were required to be within $p_{\mathrm{T}} > 25$ GeV and $|\eta| < 2.5$. Tight isolation requirements around the lepton candidate were made using the inner detector tracker and calorimeter, to reduce the QCD-multijet background contribution.

Jets were reconstructed using the anti-k$_t$ algorithm [9] and a radius parameter of 0.4. A tagging algorithm based on the combination of secondary vertex and combined lifetime information was used to tag jets from b-quark decays. The missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$) was then calculated from the reconstructed objects and unclustered calorimeter cells.

The event sample for the t-channel analysis [10] was defined by requiring exactly two or three jets $p_{\mathrm{T}} > 25$ GeV and $|\eta| < 4.5$. Exactly one jet $p_{\mathrm{T}} > 25$ GeV and $|\eta| < 2.5$ was required to be b-tagged, with an efficiency of 57% and a light jet rejection factor of 520 (reciprocal of light jet tagging efficiency). Events with more than one selected lepton were rejected. The QCD-multijet background was reduced by requiring $E_{\mathrm{T}}^{\mathrm{miss}} > 25$ GeV and the sum of the $E_{\mathrm{T}}^{\mathrm{miss}}$ and transverse W mass $m_{\mathrm{T}}(W)$ [1] to be greater than 60 GeV. Events were selected for the FCNC [11] and right-handed W' [12] searches using the same lepton, b-tagging, jet p_{T} $E_{\mathrm{T}}^{\mathrm{miss}}$ and $E_{\mathrm{T}}^{\mathrm{miss}} + m_{\mathrm{T}}(W)$ requirements. For both searches, jets were required to be within $|\eta| < 2.5$. In the case of the FCNC analysis, events with exactly one b-jets were selected, whereas the W' analysis required two jets and exactly one b-tag. The s-channel analysis [13] used a b-tagging efficiency of 50% with a corresponding light jet rejection rate of 270. Exactly two jets ($|\eta| < 2.5$) and one or two b-tagged jets $|\eta| < 2.5$ were required.

Dilepton events were selected for the Wt analysis [14] by requiring exactly two selected leptons with opposite charge. The backgrounds from Z boson processes were reduced by rejecting events with a dilepton mass $81 < m_{\mathrm{ll}} < 101$ GeV and by requiring an azimuthal separation $\Delta\phi(l_1, E_{\mathrm{T}}^{\mathrm{miss}}) + \Delta\phi(l_2, E_{\mathrm{T}}^{\mathrm{miss}}) > 2.5$. The QCD-multijet background was reduced by requiring $E_{\mathrm{T}}^{\mathrm{miss}} > 50$ GeV.

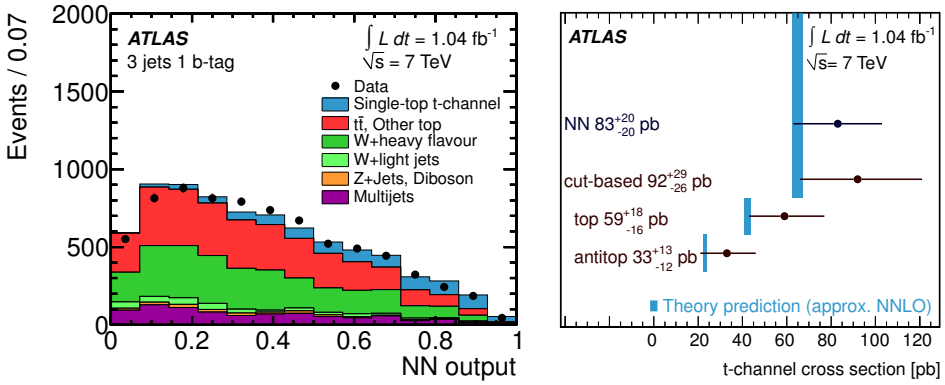
3 Analyses and results

The t-channel analysis was performed using multivariate and cut-based signal discrimination techniques. The dominant systematic uncertainties were found to be the initial and final state radiation (14%) and the b-tagging efficiency (13%). In comparison, the statistical uncertainty was found to be 5%. The t-channel cross-section was determined to be $\sigma_t = 83 \pm 4(\mathrm{stat.})\ ^{+20}_{-19}(\mathrm{syst.})$ pb from the simultaneous measurement in the two and three jet channels. A value of $|V_{\mathrm{tb}}|^2$ was extracted by assuming $|V_{\mathrm{tb}}| \gg |V_{\mathrm{td}}|$, $|V_{\mathrm{ts}}|$ and that the W-t-b interaction is a SM-like left-handed weak coupling. The cross-section measurement from the neural network analysis was divided by the SM expectation to determine $|V_{\mathrm{tb}}|^2$. Using the constraint $0 < |V_{\mathrm{tb}}| < 1$, $|V_{\mathrm{tb}}|$ was found to be greater than 0.75 at the 95% confidence level (CL). The separation between signal and background contributions for the output of the neural network is shown in Fig. 1(a). The results of the multivariate and cut based analyses are summarised in Fig. 1(b), and are found to be consistent with SM predictions.

The Wt analysis was performed using an integrated luminosity of 0.70 fb^{-1}. The dominant systematic uncertainties were found to be the jet energy scale (35%), jet reconstruction efficiency (33%), jet energy resolution (32%) and the top anti-top background (24%). The statistical uncertainty was found to be 37%. The 95% CL observed (expected) cross-section limit was found to be $\sigma(pp \to Wt + X) < 39(41)$ pb.

The s-channel analysis was carried out for an integrated luminosity of 0.70 fb^{-1}. The dominant uncertainties were found to be statistical (100%), MC generator modelling (60%) and

[1] $m_{\mathrm{T}}(W)$ is defined as $\sqrt{2p_{\mathrm{T}}^{l}p_{\mathrm{T}}^{\nu}(1-\cos(\phi^{l}-\phi^{\nu}))}$, where l and ν refer to the lepton and neutrino terms respectively. In the event selection the neutrino terms were replaced with the $E_{\mathrm{T}}^{\mathrm{miss}}$ and its azimuthal angle.



(a) (b)

Figure 1: (a) Neural network output distribution in the 3-jet b-tagged sample [10]. All component distributions are normalised to the result of the maximum-likelihood fit. (b) Summary of the ATLAS single top-quark t-channel cross-section results [15]. Theoretical predictions obtained from N. Kidonakis, Phys. Rev. D 83 (2011) 091503 (approximate NNLO) are shown by the vertical bands.

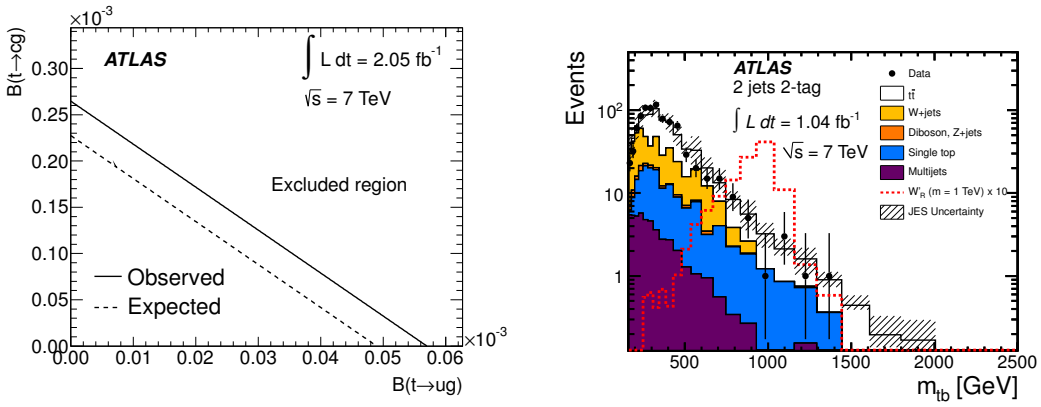
luminosity (50%). A cross-section limit was extracted using a likelihood function, including the statistical uncertainties, nuisance parameters for the systematic uncertainties, and a Gaussian constraint on the luminosity. The observed (expected) cross-section limit was found to be $\sigma(pp \to Wt + X) < 26.5(20.5)$ pb.

The FCNC search was carried out in the framework of the t-channel analysis using an integrated luminosity of 2.05 fb^{-1}. The largest systematic uncertainties were the jet p_{T} and η-dependent scale factors (23–45%). A binned likelihood method was applied to the neutral network output distributions, including the systematic and statistical uncertainties. Since no significant rate of FCNC is observed, an upper limit on the production cross-section was determined to be 3.9 pb at 95% CL. The resulting limit on the branching fractions $t \to ug$ and $t \to cg$ is shown in Fig. 2(a).

A right-handed W' search was performed within the framework of the s-channel analysis, and an integrated luminosity of 1.04 fb^{-1}. Following the event selection, the m_{tb} mass shown in Fig 2(b) was used to discriminate between signal and background events. The dominant systematic uncertainties were found to be the jet energy scale and the b-tagging scale factors (8-20%). No statistically significant excess was observed in the selected data. Upper limits on the cross-section times branching ratio were found to be 6.1–1.0pb at the 95% CL for W' masses of 0.5–2.0 TeV. The limits were translated into a lower bound on the allowed right-handed W'mass of greater than 1.13 TeV at the 95% CL.

4 Conclusion

The ATLAS collaboration has performed a complete set of single top-quark analyses, using data collected from pp collisions at a centre-of-mass energy of 7 TeV. The measurements and limits on each of the components of the single-top production cross-section have been performed and



(a) (b)

Figure 2: (a) Upper limit on the branching fractions $t \to ug$ and $t \to cg$ [11]. (b) The distribution of m_{tb} for double-tagged two-jet events compared to Standard Model expectations [12]. The expected W'signal was normalised to the theoretical cross-section and then scaled by a factor of 10.

found to be in agreement with standard model predictions. Limits on the production of single top quarks via FCNC and right-handed W' have been established.

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