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Search for single b^*-quark production with the ATLAS detector at $\sqrt{s} = 7$ TeV ☆

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ABSTRACT

The results of a search for an excited bottom-quark b^* in pp collisions at $\sqrt{s} = 7$ TeV, using 4.7 fb^{-1} of data collected by the ATLAS detector at the LHC are presented. In the model studied, a single b^*-quark is produced through a chromomagnetic interaction and subsequently decays to a W boson and a top quark. The search is performed in the dilepton and lepton+jets final states, which are combined to set limits on b^*-quark couplings for a range of b^*-quark masses. For a benchmark with unit size chromomagnetic and Standard Model-like electroweak b^* couplings, b^* quarks with masses less than 870 GeV are excluded at the 95% credibility level.

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1. Introduction

The single top-quark signature is sensitive to many models of new physics [1]. Single top-quark production in the Standard Model (SM) has been measured at the LHC in the t-channel [2,3] and in association with a W boson (Wt-channel) [4,5]. Searches for resonant production of a new particle which decays with a single top-quark have been carried out in the s-channel production of a top quark together with a b quark [6,7]. This Letter presents the first search for a resonance decaying to a single top-quark and a W boson [8]. Here we consider the production of an excited quark b^* which decays to a single top-quark and a W boson. This is the first search for excited-quarks coupling to the third generation of fermions.

Previous searches for excited quarks have focused on their strong interactions [9,10], as well as their electromagnetic interactions [11,12] with SM quarks. These searches exploit the coupling between the excited quark and up or down quarks in the proton. Here the production of excited-quarks coupling primarily to the third generation of SM quarks is investigated. This coupling occurs for example in Randall–Sundrum models that address the strong interaction sector [13,14] or in models with a heavy gluon partner, such as composite Higgs models [15–17]. The b^* quark is produced singly through its coupling to a b quark and a gluon, as shown in Fig. 1.

The Lagrangian describing this interaction is given by [18,19]

$$\mathcal{L} = \frac{g_s}{2\Lambda} G_{\mu\nu} \bar{b} \sigma^{\mu\nu} \left(\kappa_L^b P_L + \kappa_R^b P_R\right) b^* + \text{h.c.}, \tag{1}$$

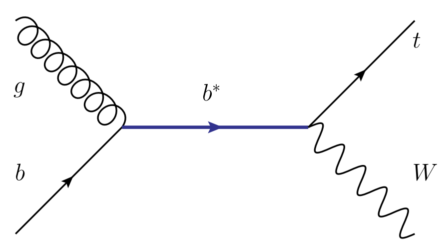

Fig. 1. Leading-order Feynman diagram for single-b^*-quark production and decay to Wt.

where g_s is the strong coupling, $G_{\mu\nu}$ the gauge field tensor of the gluon and $\Lambda = m_{b^*}$ the scale of the new physics. P_L and P_R are the left- and right-handed projection operators and κ_L^b and κ_R^b are the respective coupling strengths. This analysis is thus complementary to excited-quark searches focusing on the coupling to the first generation [9,20,21]. Single b^*-quark production can also reveal the chiral nature of the excited bottom-quark [8].

In addition to the chromomagnetic coupling, the b^* quark investigated here also has weak couplings, as in a general class of new physics models where new heavy particles stabilise the Higgs-boson mass at the electroweak scale [22–26]. In such models, the heavy quarks can have left-handed or right-handed couplings to the W boson or can be vector-like with equal strength for both couplings. The Lagrangian describing the electroweak decay of the b^* quark, shown in Fig. 1, is

$$\mathcal{L} = \frac{g_2}{\sqrt{2}} W_\mu^+ \bar{t} \gamma^\mu \left(g_L P_L + g_R P_R\right) b^* + \text{h.c.}, \tag{2}$$

where g_2 is the $\mathrm{SU}(2)_L$ weak coupling and g_L and g_R are the coupling strengths for left-handed and right-handed couplings, respectively.

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While the search is general and considers any resonance decaying into the Wt signature, three specific b^*-quark coupling scenarios are considered in order to extract b^*-quark coupling and mass limits: left-handed (κ_L^b, g_L non-zero and $\kappa_R^b = g_R = 0$), right-handed ($\kappa_L^b = g_L = 0$ and κ_R^b, g_R non-zero) and vector-like ($\kappa_L^b = \kappa_R^b = \kappa_{L/R}^b$ and $g_L = g_R = g_{L/R}$ non-zero) production and decay. Limits are derived as a function of the b^*-quark mass as well as the couplings $\kappa_{L,R}^b$ and $g_{L,R}$. These limits take into account both the change of the production cross-section and the $b^* \to Wt$ decay branching ratio, which depend on the couplings and the b^*-quark mass. The branching ratio to Wt varies between 20% at $m_{b^*} = 300$ GeV and 40% at higher values, with decays to bg, bZ and bH also allowed. Contributions from non-Wt decay modes that may increase the b^*-quark acceptance of this analysis are not considered, resulting in conservative limits. Signal event yields presented in the following tables are calculated with $\kappa_L^b = g_L = 1$ and $\kappa_R^b = g_R = 0$.

For a left-handed b^* at $\sqrt{s} = 7$ TeV with $\kappa_L^b = g_L = 1$ and $\kappa_R^b = g_R = 0$, the leading-order cross-section times branching ratio to Wt is 0.80 pb for $m_{b^*} = 900$ GeV [8]. The uncertainties due to the choice of factorisation and renormalisation scales are evaluated by varying the scales between $m_{b^*}/2$ and $2 \times m_{b^*}$, and those due to the choice of PDF by comparing results obtained using the CT10 [27], MRST [28] and NNPDF [29] sets. These uncertainties are added in quadrature to yield cross-section uncertainties ranging from 12% at $m_{b^*} = 300$ GeV to 25% at $m_{b^*} = 1200$ GeV.

This channel proceeds via two W bosons from b^*-quark and top-quark decays. At least one W boson is required to decay to a lepton (electron or muon). The analysis is performed separately in the dilepton and lepton + jets final states. The lepton + jets channel has the advantage that the invariant mass of the b^* quark can be reconstructed, whereas the dilepton channel benefits from smaller backgrounds. A discriminant that separates the b^*-quark signal from the backgrounds is defined in each final state. Limits on b^*-quark production are obtained from a combined Bayesian analysis of both discriminant distributions.

2. The ATLAS detector

The ATLAS detector [30] is a general purpose detector with a precise tracking system, calorimeters and an outer muon spectrometer. The inner tracking system consists of a silicon pixel detector, a silicon microstrip tracker, and a straw-tube transition radiation tracker. This system is immersed in a 2 T axial magnetic field produced by a solenoid and provides charged particle tracking and identification in the pseudorapidity[1] region $|\eta| < 2.5$. The central calorimeter system consists of a liquid-argon electromagnetic sampling calorimeter with high granularity and an iron/scintillator tile calorimeter providing hadronic energy measurements in the central pseudorapidity range ($|\eta| < 1.7$). The endcap and forward regions are instrumented with liquid-argon calorimeters for both electromagnetic and hadronic energy measurements up to $|\eta| = 4.9$. The muon spectrometer is operated in a toroidal magnetic field provided by air-core superconducting magnets and includes tracking chambers for precise muon momentum measurements up to $|\eta| = 2.7$ and trigger chambers covering the range $|\eta| < 2.4$.

[1] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z-axis along the beam pipe. The x-axis points from the IP to the centre of the LHC ring, and the y-axis points upwards. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ is the azimuthal angle around the beam pipe. The pseudorapidity η is defined in terms of the polar angle θ as $\eta = -\ln(\tan\theta/2)$.

3. Data and simulated samples

This analysis uses data collected with the ATLAS detector in 2011, corresponding to an integrated luminosity of $4.7 \pm 0.2\ \text{fb}^{-1}$ [31,32] of 7 TeV proton–proton (pp) collisions delivered by the LHC. The data are selected using single-electron or single-muon triggers whose efficiencies reach their plateau at 25 GeV and 20 GeV, respectively [33,34]. The data must also pass stringent quality requirements [35]. Events are selected if they contain at least one primary vertex candidate with at least five associated tracks.

The signal is modelled using MadGraph5 [36] and the CTEQ6L1 parton distribution functions (PDFs) [37]. Events with single top-quarks in the t-channel are generated with the AcerMC [38] generator, using the MRST LO** PDF set [39]. MadGraph5 and AcerMC are interfaced to Pythia [40] for parton showering and modelling of the underlying event. Other processes producing single top-quarks and top-quark pairs ($t\bar{t}$) are modelled with the next-to-leading-order (NLO) generator MC@NLO [41] using the CT10 PDF set [27], interfaced to Herwig [42] for parton showering and Jimmy [43] for the underlying event. Alpgen [44] is used to model vector boson (W and Z) production in association with jets as well as diboson processes (WW, WZ and ZZ) using the CTEQ6L1 PDF set. It is interfaced to Herwig for parton shower modelling. In the lepton + jets analysis the diboson processes are modelled with Herwig only. Decays of τ leptons are handled by Tauola [45]. A top-quark mass of 172.5 GeV [46] is assumed. Approximate next-to-next-to-leading-order (NNLO) cross-section calculations are used to normalise the $t\bar{t}$ [47] (Hathor) and single top-quark samples [48–50], while the vector boson and diboson samples are normalised using calculations with MCFM [51] at NNLO and NLO, respectively.

A variable number of additional pp interactions (pile-up) are overlaid on simulated events, which are then weighted to reproduce the distribution of the number of collisions per bunch crossing observed in data. All samples are passed through a GEANT4-based simulation [52] of the ATLAS detector [53] and are then reconstructed using the same procedure as for collision data.

4. Physics object selection

Electron candidates are reconstructed from clusters of energy deposits in the calorimeter [54]. The transverse energy E_T of electron candidates is required to be larger than 25 GeV and their pseudorapidity is required to be $|\eta| < 2.47$. Electrons in the barrel–endcap transition region of the calorimeter, corresponding to $1.37 < |\eta| < 1.52$, are not considered. Selected electrons must pass a set of "tight" quality criteria [54] and the electrons must be matched to a track reconstructed in the inner tracking system. Electrons must also be isolated from close-by tracks in a cone of $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} < 0.3$ and from calorimeter energy deposits not belonging to the electron candidate in a cone of $\Delta R < 0.2$. The isolation requirements on the sum of transverse momenta of tracks in the cone and on the sum of energy deposits in the calorimeter in the cone are chosen as a function of p_T and η such that an efficiency of 90% for electrons in the simulation is achieved.

Muon candidates are reconstructed from matching tracks in the muon spectrometer and inner tracking system. Muons are required to have transverse momentum $p_T > 25$ GeV and $|\eta| < 2.5$ and fulfil tight quality criteria [55]. Muons must be isolated from close-by tracks in a cone of $\Delta R < 0.3$ and from energy deposits in the calorimeter in a cone of $\Delta R < 0.2$. The sum of transverse momenta of tracks in the cone must not exceed 2.5 GeV and the sum of energy deposits in the calorimeter in the cone must be below 4 GeV.

In order to reject events in which a muon emitting a hard photon is also reconstructed as an electron, events are vetoed if a selected electron–muon pair shares the same track.

Jets are reconstructed from clusters of energy deposits in the calorimeter [56] using the anti-k_t algorithm [57] with a radius parameter $R = 0.4$. These jets are calibrated to the hadronic energy scale through p_T- and η-dependent scale factors, which are derived from simulation. An additional uncertainty due to residual differences between simulation and data is applied in the analysis [58]. Jets are required to have $p_T > 30$ (25) GeV and $|\eta| < 2.5$ in the dilepton (lepton + jets) channel. The ratio of the scalar sum of the p_T of tracks associated with the jet and the primary vertex to the scalar sum of the p_T of all tracks associated with the jet must be at least 0.75 to reject jets from pile-up interactions. Muons overlapping with jets within $\Delta R < 0.4$ are removed and the jet is kept. The closest jet overlapping with electrons within $\Delta R < 0.2$ is removed and the electron is kept. If electrons subsequently still overlap with any remaining jet within $\Delta R < 0.4$, they are removed. Information about jets containing b quarks [59] is also used in the lepton + jets channel. A neural network combines lifetime-related information reconstructed from the tracks associated with each jet. At the chosen working point, the b-tagging algorithm has an efficiency of 70% (20%/0.7%) for jets containing b quarks (c quarks/light quarks or gluons) in a simulated $t\bar{t}$ sample.

The missing transverse momentum E_T^{miss} is calculated using topological clusters of energy deposits in the calorimeter and corrected for the presence of muons [60].

5. Event selection in the dilepton channel

The event selection and background modelling in the dilepton channel is the same as in the ATLAS measurement of the single top-quark production in the Wt-channel [4]. Candidate events must contain exactly two leptons (ee, $\mu\mu$ or $e\mu$) with opposite electric charge and exactly one jet. At least one of the leptons in each event must match the corresponding trigger-level object. No b-tagging requirement is made since the dominant background from $t\bar{t}$ production also contains b quarks. The E_T^{miss} is required to be greater than 50 GeV. In the ee and $\mu\mu$ channels, the invariant mass of the lepton pair, $m_{\ell\ell}$, is required to be outside the Z boson mass window: $m_{\ell\ell} < 81$ GeV or $m_{\ell\ell} > 101$ GeV. In all three channels, the $Z \to \tau\tau$ background is reduced by a dedicated veto, which requires the sum of the azimuthal angle differences between each lepton and the E_T^{miss} vector to be greater than 2.5 rad. After all cuts, the acceptance for signal events with $m_{b^*} = 800$ GeV in which both W bosons decay leptonically (to either e or μ) is 26%.

The main background, accounting for 63% of the total, comes from $t\bar{t}$ events in which one of the two jets originating from b quarks is not detected. The second largest background is from SM Wt production, which has the same final state as the b^*-quark signal, and accounts for 13% of the total background. Diboson events produced in association with jets account for 12% of the total background. With the exception of single- and diboson samples, these backgrounds are taken from NLO simulation and are normalised to their NNLO theoretical predictions. Drell–Yan (DY) events contribute a small background of 7.3% to the sum of ee and $\mu\mu$ channel events. The events are taken from the simulation and normalised to data using a two-dimensional sideband region with low E_T^{miss} and/or $m_{\ell\ell}$ outside of the Z boson mass window [4]. The contribution from $\tau\tau$ final states, where both τ leptons decay leptonically, is estimated from simulated samples, with the normalisation checked in an orthogonal data sample obtained by reversing the $Z \to \tau^+\tau^-$ veto cut described above. $Z \to \tau^+\tau^-$ events account for 0.7% of the total background. The small background from jets that are misidentified as primary leptons and from non-prompt leptons (fake dileptons) is modelled and normalised using data [61]. It accounts for 4% of the background.

Table 1
Observed and predicted event yields in the dilepton channel. Only normalisation uncertainties are given. The signal yields are calculated with $\kappa_L^b = g_L = 1$ and $\kappa_R^b = g_R = 0$.

Process	Event yield
b^* (400 GeV)	1250 ± 170
b^* (600 GeV)	211 ± 32
b^* (800 GeV)	41 ± 8
b^* (1000 GeV)	8.9 ± 1.9
b^* (1200 GeV)	2.1 ± 0.5
Wt	293 ± 21
$t\bar{t}$	1380 ± 140
Diboson	255 ± 63
$Z \to e^+e^-$	41 ± 4
$Z \to \mu^+\mu^-$	118 ± 12
$Z \to \tau^+\tau^-$	14 ± 9
Fake dileptons	90 ± 90
Total expected bkg.	2190 ± 180
Total observed	2259

The predicted event yields for the backgrounds and signal at a few mass points are compared to data in Table 1. The p_T distributions of the two leptons and the jet are shown in Fig. 2.

A discriminating variable that separates the signal from the backgrounds is H_T, the scalar sum of the transverse momenta of the leptons, jet and E_T^{miss}. The H_T distribution is shown in Fig. 3.

6. Event selection in the lepton + jets channel

The analysis in the lepton + jets channel follows the same background modelling strategy as the cross-section measurement for single top-quark production in the t-channel [2]. Events are required to have either exactly one muon and $E_T^{miss} > 25$ GeV or exactly one electron and $E_T^{miss} > 30$ GeV, as well as exactly three jets with $p_T > 25$ GeV. Exactly one of the jets is required to be b-tagged to reduce backgrounds. The lepton must also match the corresponding trigger object. Additional requirements are made to reject multijet events, which tend to have low E_T^{miss} and a low transverse mass[2] of the lepton–E_T^{miss} system, m_T^W. In the muon channel events are required to have $m_T^W + E_T^{miss} > 60$ GeV, while in the electron channel a requirement of $m_T^W > 30$ GeV is made. The acceptance for signal events with $m_{b^*} = 800$ GeV in which one of the W bosons decays leptonically (e or μ) and the other hadronically is 9%.

In this channel, one of the largest backgrounds is W + jets production for which the normalisation and flavour composition (the heavy-flavour fraction, HF, includes b quarks and c quarks) are derived from data [62]. The overall normalisation is determined from the charge asymmetry between W^+ and W^- production in three-jet events without the b-tag requirement. The flavour composition is determined in two-jet events by comparing the predicted W + jets yields to data with and without a b-tag requirement. The resulting normalisation and flavour scale factors are then applied to b-tagged W + 3-jets events. About 37% of the total background comes from W + jets events, including 28% from events with heavy flavour.

[2] The transverse mass, m_T^W, is calculated from the lepton transverse momentum p_T^{lep} and the difference of the azimuthal angle, $\Delta\phi$, between the E_T^{miss} and p_T^{lep} vector as $m_T^W = \sqrt{2E_T^{miss} p_T^{lep}(1 - \cos(\Delta\phi(E_T^{miss}, p_T^{lep})))}$.

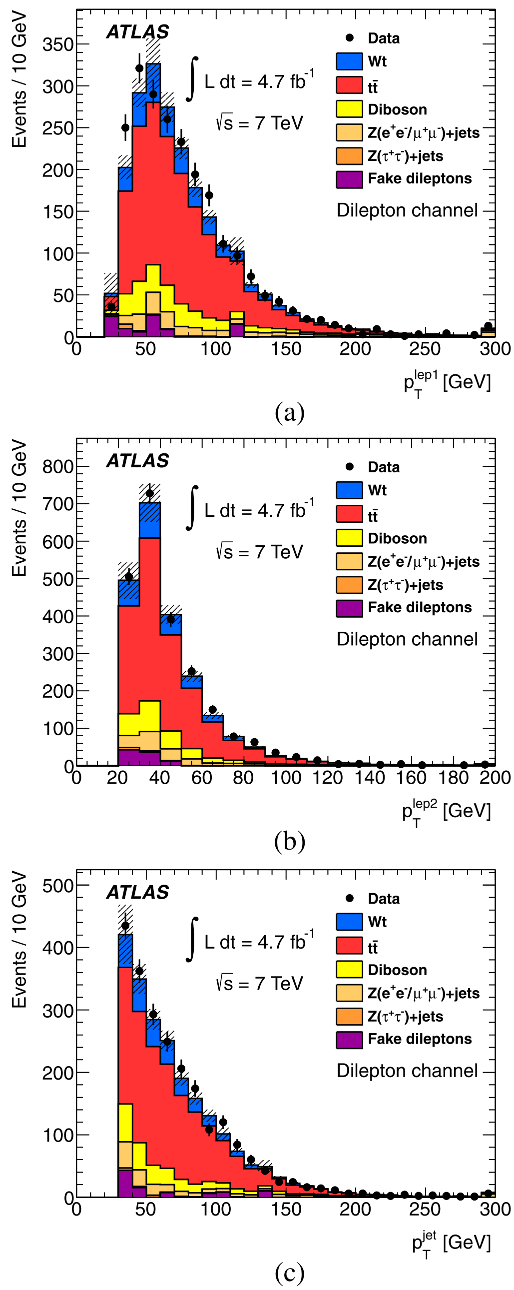


Fig. 2. Kinematic distributions comparing data to predictions in the dilepton channel for (a) the leading lepton $p_{\mathrm{T}}^{\mathrm{lep1}}$, (b) the sub-leading lepton $p_{\mathrm{T}}^{\mathrm{lep2}}$ and (c) the jet $p_{\mathrm{T}}^{\mathrm{jet}}$. The hatched band shows the uncertainty due to the background normalisation. The last bin includes overflows.

Backgrounds from $t\bar{t}$ yield 41% of the total background and single top-quark production in the t-, s- and Wt-channel 9%. The multijet background is obtained using a data-based approach by comparing the numbers of events passing loose and tight lepton identification criteria [63]. It accounts for 9% of the total background. Smaller backgrounds from $Z+$jets and diboson processes are normalised to their theoretical predictions and contribute 4%.

The predicted event yields are compared to data in Table 2. The distributions of the p_{T} of the highest-p_{T} jet and $E_{\mathrm{T}}^{\mathrm{miss}}$ are shown in Fig. 4.

In the lepton + jets channel it is possible to reconstruct the candidate b^*-quark mass from the decay products. The only missing information is the neutrino longitudinal momentum, which is set to zero. The resulting reconstructed mass provides good discrimination between background and signal, as shown in Fig. 5.

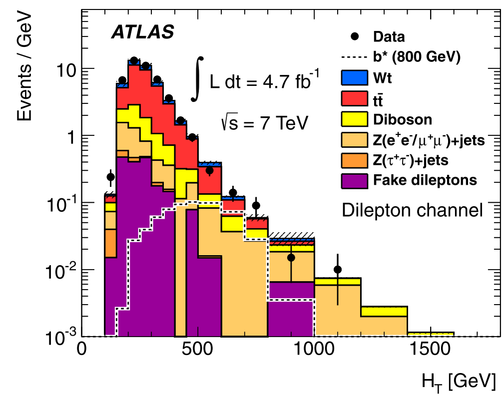


Fig. 3. H_{T} distribution for data and background expectation for the dilepton channel. The hatched band shows the uncertainty due to the background normalisation. The signal for a b^*-quark mass of 800 GeV is also shown.

Table 2
Observed and expected event yields in the lepton + jets channel. Only normalisation uncertainties are given. The signal yields are calculated with $\kappa_L^b = g_L = 1$ and $\kappa_R^b = g_R = 0$.

Process	Event yield
b^* (400 GeV)	$12\,100 \pm 1600$
b^* (600 GeV)	1950 ± 300
b^* (800 GeV)	370 ± 70
b^* (1000 GeV)	79 ± 17
b^* (1200 GeV)	20 ± 5
Wt	1660 ± 120
single top s, t-channel	1960 ± 140
$t\bar{t}$	$15\,700 \pm 1600$
$W+$light jets	3200 ± 400
$W+$jets HF	$10\,900 \pm 1400$
Diboson	327 ± 16
$Z+$jets	1300 ± 800
Multijet	3500 ± 1700
Total expected bkg.	$38\,500 \pm 2900$
Total observed	38 175

7. Systematic uncertainties

Systematic uncertainties affecting the signal acceptance and the background normalisation are considered, together with uncertainties affecting the shape of the discriminant distributions. The main experimental source of systematic uncertainty comes from the limited knowledge of the jet energy scale [58], which carries an uncertainty of 2–7% per jet, parameterised as a function of jet p_{T} and η. The presence of a b quark in the jet adds an additional uncertainty of 2–5% to the jet energy scale uncertainty, depending on the jet p_{T}. The jet energy scale uncertainty has the largest impact on the limit setting, because a variation of the jet energies shifts and broadens both the H_{T} and mass distributions. Other jet-related uncertainty sources are the jet energy resolution, jet reconstruction efficiency and b-tagging efficiency [59]. Lepton-related uncertainties come from trigger and identification efficiencies as well as the lepton energy scale and resolution. Event-related uncertainties are due to the modelling of multiple proton–proton interactions and the underlying event as well as $E_{\mathrm{T}}^{\mathrm{miss}}$ [60]. The uncertainty on the integrated luminosity is 3.9% [31,32].

Simulation uncertainties include modelling of the hard process, parton shower and hadronisation, and initial- and final-state radiation. These have been assessed for the $t\bar{t}$ background events by

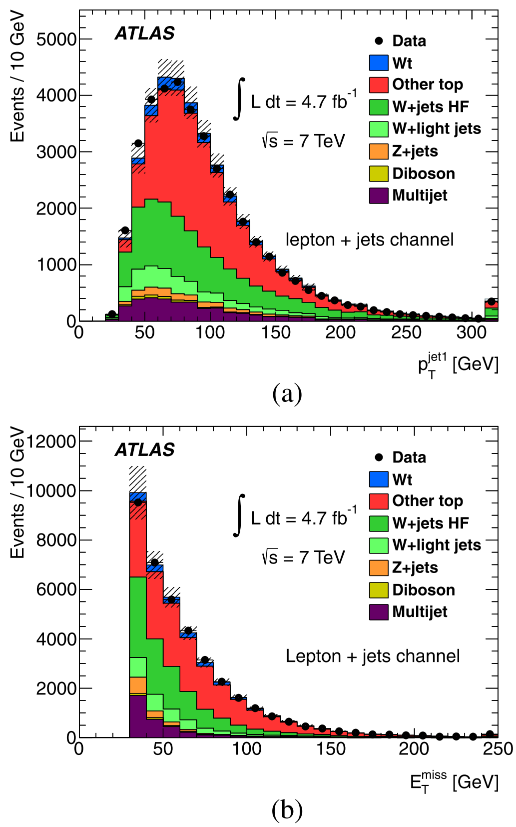


Fig. 4. Kinematic distributions comparing data to predictions in the lepton + jets channel for (a) the p_T^{jet1} of the highest-p_T jet and (b) E_T^{miss}. "Other top" includes $t\bar{t}$, *s*- and *t*-channel single top-quark production. The hatched band shows the uncertainty due to the background normalisation. The last bin includes overflows.

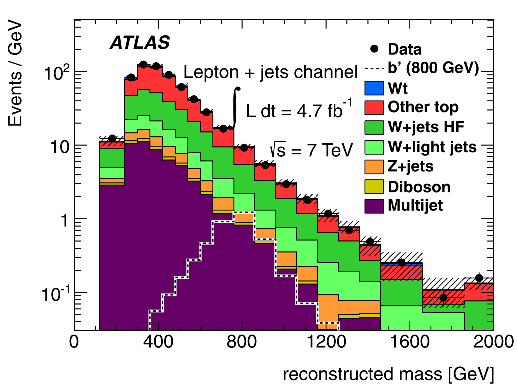


Fig. 5. Reconstructed mass distribution for data and background expectation for the lepton + jets channel. "Other top" includes $t\bar{t}$, *s*- and *t*-channel single top-quark production. The hatched band shows the uncertainty due to the background normalisation. The signal for a mass of 800 GeV is also shown. The last bin includes overflows.

comparing different generators (Powheg and MC@NLO), different shower models (Pythia and Herwig), and for $t\bar{t}$ and signal events different settings for the amount of additional radiation [64]. Other sources of theoretical uncertainty include the normalisation for $t\bar{t}$ ($^{+7\%}_{-10\%}$) [47,65–67], single top-quark ($\pm 7\%$) [48–50] and diboson ($\pm 5\%$ with an additional 24% per extra jet) production [61], as well as the choice of PDF. The latter was assessed using the CT10 [27], MRST [28] and NNPDF [29] sets.

The rate and shape variations of the data-driven background templates are modelled using the experimental systematic uncer-

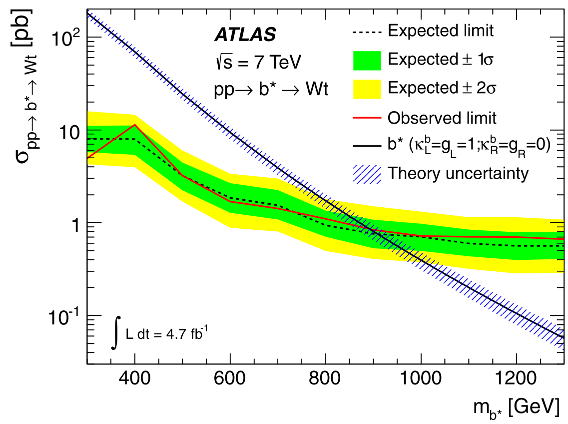


Fig. 6. Expected and observed limits at the 95% CL as a function of the b^*-quark mass. Also shown is the theory prediction for b^*-quark production with couplings $\kappa_L^b = g_L = 1$ and $\kappa_R^b = g_R = 0$, including PDF and scale uncertainties.

tainties together with the following rate uncertainties: The uncertainty on the DY background normalisation in the dilepton channel is 10% for ee and $\mu\mu$ final states and 60% for $\tau\tau$ final states. The uncertainty on the fake-dileptons normalisation in the dilepton channel is 100%. The uncertainty on the W + jets normalisation in the lepton + jets channel is 13%. The W + jets flavour composition has two additional uncertainties: the HF contribution has a relative uncertainty of 6%, and the W_{bb}/W_{HF} ratio has an uncertainty of 17%. The multijet background normalisation in the lepton + jets channel has an uncertainty of 50%. The uncertainties on the multijet background normalisation are determined from the comparison of alternative background models and agreement with data in control samples. Since the shape of the multijet background is distinct from the signal shape, the impact of the multijet uncertainties on the limit is moderate.

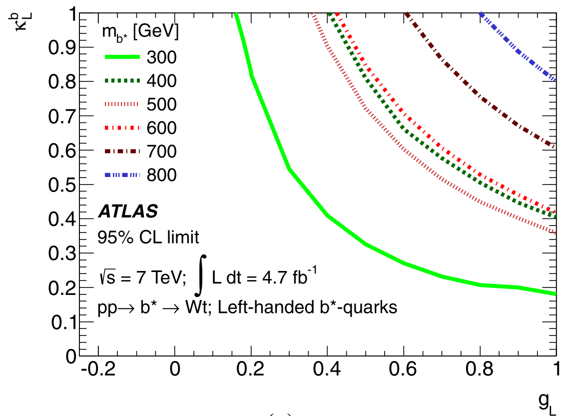
8. Statistical analysis

Both the H_T distribution in the dilepton channel and the reconstructed mass distribution in the lepton + jets channel show good agreement between the data and the background model. These two discriminants are used to set limits on the b^*-quark signal using a Bayesian analysis technique [68]. The likelihood function is defined as

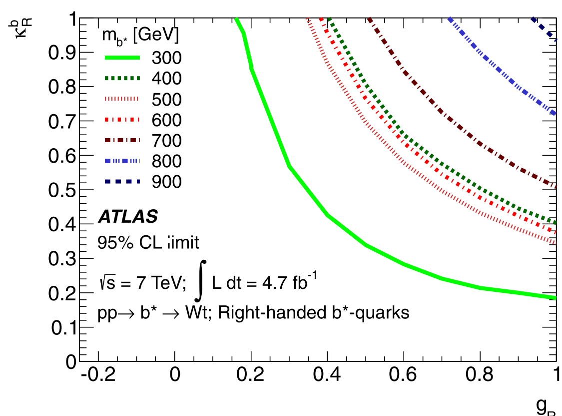
$$\mathcal{L}(\text{data}|\sigma_{b^*}) = \prod_k \frac{\mu_k^{n_k} e^{-\mu_k}}{n_k!} \prod_i G_i, \tag{3}$$

where k is the index of the discriminant template bin, running over both analysis channels; $\mu_k = s_k + b_k$ is the sum of predicted signal and background yields; n_k is the observed yield and G_i is a Gaussian prior for the ith systematic uncertainty. A flat prior is assumed for the signal cross-section. Upper limits on the b^*-quark production cross-section times branching ratio to Wt are set at the 95% credibility level (CL) for a series of b^* masses at 100 GeV intervals.

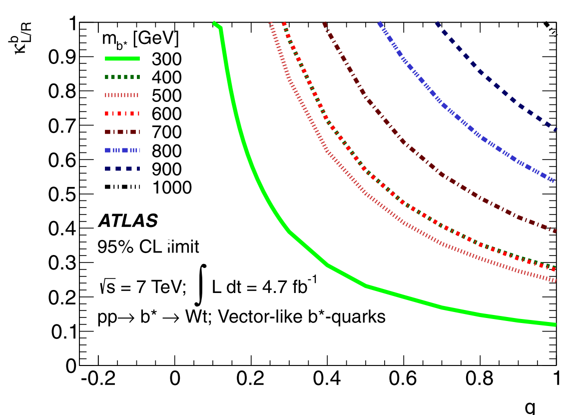
The observed and expected cross-section limits as a function of the b^*-quark mass for the left-handed coupling scenario ($\kappa_L^b = g_L = 1$ and $\kappa_R^b = g_R = 0$) are shown in Fig. 6, where the expected limit and its uncertainty are derived from ensembles of background-only pseudo-datasets. The intersection of the theoretical cross-section and the observed (expected) cross-section limit defines the observed (expected) b^*-quark mass limit. The observed lower limit on the b^*-quark mass for this left-handed coupling scenario is 870 GeV with an expectation of 910 GeV. When considering only the dilepton channel, the observed (expected) limit



(a)



(b)



(c)

Fig. 7. Limit contours at the 95% CL as a function of the coupling parameters for several different b^*-quark masses, for (a) left-handed b^* quarks, (b) right-handed b^* quarks and (c) vector-like b^* quarks.

on the b^*-quark mass is 800 GeV (820 GeV); for the lepton + jets channel, the limits are 800 GeV (830 GeV).

Limits are also computed for models with right-handed and vector-like couplings of the b^* quark. Setting $\kappa^b_L = g_L = 0$ and $\kappa^b_R = g_R = 1$, the observed lower mass limit is 920 GeV with an expected limit of 950 GeV. Setting $\kappa^b_L = \kappa^b_R = g_L = g_R = 1$, the observed lower mass limit is 1030 GeV with an expected limit of 1030 GeV.

At each mass point, the corresponding cross-section is parameterised as a function of the couplings $\kappa^b_{L,R}$ and $g_{L,R}$ in order to extract coupling limits in each of the three b^*-quark coupling scenarios. The resulting limit contours are shown in Fig. 7. The coupling limits increase as the theoretical cross-section decreases with b^* mass, except for the region between 400 GeV and 500 GeV where the backgrounds decrease rapidly with increasing mass (see Figs. 3 and 5).

9. Summary

A search for a singly produced excited b^*-quark in 4.7 fb^{-1} of data collected with the ATLAS detector in pp collisions at $\sqrt{s} = 7$ TeV has been presented. This is the first search for excited-quarks coupling to the third generation. It considers the dilepton and lepton + jets final states. Limits are computed as a function of the b^*gb and b^*Wt couplings in three different scenarios. For purely left-handed couplings and unit strength chromomagnetic coupling, b^* quarks with mass below 870 GeV are excluded at the 95% credibility level.

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