Letter

Search for top and bottom squarks from gluino pair production in final states with missing transverse energy and at least three *b*-jets with the ATLAS detector

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Abstract This letter reports the results of a search for top and bottom squarks from gluino pair production in 4.7 fb^{-1} of *pp* collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector at the LHC. The search is performed in events with large missing transverse momentum and at least three jets identified as originating from a *b*-quark. Exclusion limits are presented for a variety of gluino-mediated models with gluino masses up to 1 TeV excluded.

Supersymmetry (SUSY) [1–9] provides an extension of the Standard Model (SM) which resolves the hierarchy problem [10–13] by introducing supersymmetric partners of the known bosons and fermions. In the framework of the *R*-parity conserving minimal supersymmetric extension of the SM (MSSM) [14–18], SUSY particles are produced in pairs and the lightest supersymmetric particle (LSP) is stable, providing a possible candidate for dark matter. In a large variety of models, the LSP is the lightest neutralino ($\tilde{\chi}_1^0$). The colored superpartners of quarks and gluons, the squarks ($\tilde{q}$) and gluinos ($\tilde{g}$), if not too heavy, would be produced in strong interaction processes at the Large Hadron Collider (LHC) and decay via cascades ending with the LSP. The undetected LSP results in missing transverse momentum—whose magnitude is referred to as E_T^{miss}—while the rest of the cascade yields final states with multiple jets and possibly leptons. In the MSSM, the right-handed and left-handed squarks, $\tilde{q}_R$ and $\tilde{q}_L$, can mix to form two mass eigenstates $\tilde{q}_1$ and $\tilde{q}_2$. The mixing effect is proportional to the masses of the SM fermion partners and can therefore be large for the third generation. This may lead to the lightest sbottom ($\tilde{b}_1$) and stop ($\tilde{t}_1$) mass eigenstates being much lighter than the other squarks. As a consequence, $\tilde{b}_1$ and $\tilde{t}_1$ could be produced with relatively large cross sections at the LHC, ei-

ther directly in pairs, or through $\tilde{g}\tilde{g}$ production followed by $\tilde{g} \to \tilde{b}_1 b$ or $\tilde{g} \to \tilde{t}_1 t$ decays.

This letter extends the search for gluino-mediated $\tilde{b}_1$ and $\tilde{t}_1$ production at ATLAS reported earlier [19], which used 2.05 fb^{-1} of data collected in the first half of 2011 at a center-of-mass energy of 7 TeV. The present analysis comprises the full 2011 dataset of 4.7 fb^{-1} and adopts an improved selection that requires large E_T^{miss}, no electron or muon and at least three jets identified as originating from *b*-quarks (*b*-jets) in the final state. Results are interpreted in four simplified models where sbottoms or stops are the only squarks produced in the gluino decays, leading to final states with four *b*-quarks. Searches in similar scenarios have also been reported by the CMS Collaboration [20].

The ATLAS detector [21] consists of inner tracking devices surrounded by a superconducting solenoid, electromagnetic and hadronic calorimeters and a muon spectrometer with a toroidal magnetic field. The inner detector provides precision tracking of charged particles for $|\eta| < 2.5$.[1] It is immersed in a 2 T magnetic field from the solenoid and consists of a silicon pixel detector, a silicon strip detector and a straw tube tracker that also provides transition radiation measurements for electron identification. The calorimeter system covers the pseudorapidity range $|\eta| < 4.9$. It is composed of sampling calorimeters with either liquid argon (LAr) or scintillating tiles as the active medium. The muon spectrometer has separate trigger and high-precision tracking chambers which provide muon identification and momentum measurement for $|\eta| < 2.7$.

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[1]ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the *z*-axis along the beam pipe. The *x*-axis points from the IP to the center of the LHC ring, and the *y* axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln\tan(\theta/2)$. The distance ΔR in the $\eta - \phi$ space is defined as $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$.

Samples of simulated events are used for the description of the background and to model the SUSY signal. The dominant sources of background come from events with b-quarks in the final state. Monte Carlo (MC) samples of $t\bar{t}$, W/Z and diboson events produced in association with light- and heavy-flavor jets are generated with ALPGEN [22] and the parton distribution function (PDF) set CTEQ6L1 [23]. These samples are generated with different maximum numbers of additional partons at the matrix-element level. Diboson samples are generated with up to three additional partons, $t\bar{t}$ + jet and $Z(\to \ell^{+}\ell^{-})$ + jets ($\ell = e, \mu, \tau$) samples with up to five additional partons, and $W(\to \ell\nu)$ + jets and $Z(\to \bar{\nu}\nu)$ + jet samples with up to six additional partons. Single top quark production is simulated with MC@NLO [24] using the next-to-leading-order (NLO) PDF set CTEQ6.6 [25]. The fragmentation and hadronization for the ALPGEN and MC@NLO samples are performed with HERWIG [26, 27], using JIMMY [28] for the underlying event. Samples of $t\bar{t}+W$, $t\bar{t}+Z$ and $t\bar{t}+WW$ events are generated with MADGRAPH [29] interfaced to PYTHIA [30]. The signal samples are generated using Herwig++ [31]. The MC samples are processed through the ATLAS detector simulation [32] based on GEANT4 [33] taking into account the effect of multiple pp interactions per bunch crossing. For the comparison with data, all SM background cross sections are normalized to the results of higher-order calculations when available, using the same values as in Ref. [19].

Jets are reconstructed from three-dimensional calorimeter energy clusters using the anti-k_t jet algorithm [34, 35] with a radius parameter of 0.4. The measured jet energy is corrected for inhomogeneities and for the non-compensating nature of the calorimeter by using p_T- and η-dependent correction factors, and additional corrections for pile-up are applied [36]. Jets are required to have $p_T > 20$ GeV, and are reconstructed in the range $|\eta| < 4.9$. Events are rejected if they include jets failing the quality criteria described in Ref. [36], or if there is any selected jet with $|\eta| < 2$ for which the scalar sum of the transverse momenta of its associated tracks is less than 5 % of the jet p_T. A neural-network-based algorithm [37] is used to identify jets containing a b-hadron decay. This uses as input the output weights of different algorithms exploiting the impact parameter of the inner detector tracks, the secondary vertex reconstruction and the topology of b- and c-hadron decays inside the jet. Three operating points are used, corresponding to efficiencies of 60 %, 70 % and 75 % for tagging b-jets in a MC sample of $t\bar{t}$ events. In all cases the tagging rate is less than 2 % for light-quark and gluon jets, 10 % for τ leptons decaying hadronically and 25 % for c-quark jets. The b-jets are identified within the nominal acceptance of the inner detector ($|\eta| < 2.5$) and are required to have $p_T > 30$ GeV. To compensate for the differences between the b-tagging efficiency and the mistag rates in data and MC simulation, b-tagging

Table 1 Definition of the five signal regions based on the number of jets (N_J), the E_T^{miss}, m_{eff} requirements and the b-tagging operating point (OP)

SR	N_J	E_T^{miss}	m_{eff}	b-tag OP
SR4-L	≥ 4j	> 160 GeV	> 500 GeV	60 %
SR4-M	≥ 4j	> 160 GeV	> 700 GeV	60 %
SR4-T	≥ 4j	> 160 GeV	> 900 GeV	70 %
SR6-L	≥ 6j	> 160 GeV	> 700 GeV	70 %
SR6-T	≥ 6j	> 200 GeV	> 900 GeV	75 %

Common criteria: lepton veto, $p_T^{j_1} > 130$ GeV, ≥ 3 b-jets, $E_T^{\mathrm{miss}}/m_{\mathrm{eff}} > 0.2$, $\Delta\phi_{\mathrm{min}} > 0.4$

Table 2 Definition of the four control regions used to estimate the $t\bar{t}$ + jets background

CR	N_J	b-tag OP	corresponding SR
CR4-60	≥ 4j	60 %	SR4-L, SR4-M
CR4-70	≥ 4j	70 %	SR4-T
CR6-70	≥ 6j	70 %	SR6-L
CR6-75	≥ 6j	75 %	SR6-T

Common criteria: lepton veto, $p_T^{j_1} > 130$ GeV, $= 2$ b-jets, $E_T^{\mathrm{miss}}/m_{\mathrm{eff}} > 0.2$, $\Delta\phi_{\mathrm{min}} > 0.4$, $E_T^{\mathrm{miss}} > 160$ GeV, $m_{\mathrm{eff}} > 500$ GeV

scale factors are applied to each jet in the simulations, as described in Refs. [37–39].

Electrons are reconstructed from energy clusters in the electromagnetic calorimeter matched to a track in the inner detector. Electron candidates are required to have $p_T > 20$ GeV and $|\eta| < 2.47$ and must satisfy the "medium" selection criteria described in Ref. [40]. Muons candidates are identified using a match between an extrapolated inner detector track and one or more track segments in the muon spectrometer, and are required to have $p_T > 10$ GeV and $|\eta| < 2.4$.

Since electrons are also reconstructed as jets, jets within a distance of $\Delta R = 0.2$ of an electron candidate are rejected. Furthermore, any lepton candidate with a distance $\Delta R < 0.4$ to the closest remaining jet is discarded. Events containing any remaining electrons and muons are vetoed in the control and signal regions defined in Tables 1 and 2.

The measurement of the missing transverse momentum two-dimensional vector (and its magnitude E_T^{miss}) is based on the transverse momenta of all remaining jets with $|\eta| < 4.9$, all electron and muon candidates and all calorimeter clusters not associated to such objects.

Events are selected using triggers requiring one high $_T$ jet and E_T^{miss}. Different trigger thresholds were used to cope with the increasing luminosity. These triggers are fully efficient for this analysis, which requires one jet with $p_T > 130$ GeV and $E_T^{\mathrm{miss}} > 160$ GeV at the offline reconstruction

stage. Events must pass basic quality criteria to reject detector noise and non-collision backgrounds. They are also required to have a reconstructed primary vertex associated with five or more tracks with $_T > 0.4$ GeV; when more than one such vertex is found, the vertex with the largest summed $_T^2$ of the associated tracks is chosen as the hard interaction vertex. Events are required to have at least three b-tagged jets, and two jet-multiplicity regions ($N_J \geq 4$ and $N_J \geq 6$) are considered by selecting jets with $|\eta| < 2.8$ and $_T > 50$ GeV.

Two variables are calculated from the reconstructed objects to further select the events: m_{eff} and $\Delta\phi_{\min}$. The effective mass m_{eff} is defined as the scalar sum of the E_T^{miss} and the p_T of all selected jets in a given jet-multiplicity region. The $\Delta\phi_{\min}$ is defined as the minimum azimuthal separation between the selected jets and the missing transverse momentum direction. Placing the requirements $\Delta\phi_{\min} > 0.4$ and $E_T^{\text{miss}}/m_{\text{eff}} > 0.2$ reduces the amount of multi-jet background, where E_T^{miss} results from mis-reconstructed jets or from neutrinos emitted close to the direction of the jet axis.

Two sets of signal regions are defined which yield good signal sensitivity for the various models and parameter values studied here. They are characterized by having at least four (SR4) or six (SR6) jet candidates, no electron or muon, and are further classified as loose (L), medium (M) or tight (T) depending on the E_T^{miss} and m_{eff} thresholds and on the b-tagging operating point. The requirements that characterize each signal region are summarized in Table 1.

The main source of reducible background is the production of $t\bar{t}$ events in association with additional jets followed by the leptonic decay of one W boson, where the lepton is not reconstructed or is misidentified as a jet (mainly through the hadronic decays of a τ lepton). This background is estimated by normalizing the MC event yield in the signal region to the extrapolated event yield observed in a $t\bar{t}$-dominated control region. Systematic uncertainties that are correlated between the control and the signal regions largely cancel out in this procedure. Additional sources of reducible background are single top, $t\bar{t} + W/Z$ and W/Z + heavy-flavor jets. Their contributions are taken from MC simulation and account for 10 % to 20 % of the total background depending on the signal region. The irreducible background $t\bar{t} + b\bar{b}$ is also estimated from MC simulation and accounts for about 10 % of the total background in all signal regions. The reducible contribution from multi-jet events is estimated with a data-driven method, based on a jet response smearing technique [41], and is found to account for less than 5 % of the total background in all signal regions.

Four control regions where the $t\bar{t}$ + jets background accounts for more than 80 % of the total yield are defined by applying the same jet requirements and lepton veto as in the signal regions, but requiring exactly two b-jets instead of three or more. The requirements $m_{\text{eff}} > 500$ GeV

Table 3 Expected numbers of SM events and observed data events in the four $t\bar{t}$ control regions. The contribution from $t\bar{t}$ + jets events is taken directly from MC simulation. The column "others" includes the contributions from single top, $t\bar{t} + b\bar{b}$, $t\bar{t} + W/Z$ and W/Z + jets processes, also estimated from MC simulation, and the contribution from multi-jet events which is estimated with the jet smearing technique and accounts for less than 5 % of the total background. The column "SM" shows the total expected background and is the sum of the columns "$t\bar{t}$ + jets" and "others". The uncertainties include all detector-related systematic uncertainties

CR	$t\bar{t}$ + jets	others	SM	data
CR4-60	330 ± 90	65 ± 25	395 ± 115	402
CR4-70	490 ± 125	100 ± 35	590 ± 160	515
CR6-70	38 ± 11	7 ± 3	45 ± 13	46
CR6-75	40 ± 12	10 ± 4	50 ± 15	52

and $E_T^{\text{miss}} > 160$ GeV are applied to all control regions to make them kinematically similar to the signal regions, while reducing the contamination from possible SUSY signal events. The definition of the control regions is summarized in Table 2. The numbers of expected SM events in the four control regions, as predicted by the jet smearing technique for multi-jet events and by MC simulation for other processes, are compared to those observed in data in Table 3. The results agree within experimental errors.

The dominant detector-related systematic effects are due to the jet energy scale (JES) and resolution (JER) uncertainties, and the uncertainty on the b-tagging efficiency and mistag rates. The JES uncertainty is derived from a combination of simulations, test beam data and in-situ measurements [36], and includes additional uncertainties due to the jet flavor and nearby jets. Uncertainties on the JER are obtained with an in-situ measurement of the jet response asymmetry in di-jet events. These uncertainties on jets are propagated to the E_T^{miss} measurement, and additional uncertainties on E_T^{miss} arising from energy deposits not associated with any reconstructed objects are also included. The b-tagging uncertainty is evaluated by varying the η-, $_T$- and flavor-dependent scale factors applied to each jet in the simulation within a range that reflects the systematic uncertainty on the measured tagging efficiency and mistag rates.

The systematic uncertainties in the modeling of the $t\bar{t}$ + jets background are assessed as follows: the uncertainty due to the choice of the MC generator is estimated by comparing the leading-order ALPGEN generator to the MC@NLO generator; the uncertainty due to the factorization and matching scale ambiguities in ALPGEN are estimated by independently varying their nominal settings by factors of one half and two; the uncertainty due to the finite number of additional partons at the matrix-element level is assessed by comparing inclusive ALPGEN samples generated with up to three and up to five extra partons. Finally the PDF uncertainties are estimated using the MSTW2008NNLO PDF set.

Table 4 Comparison between the results of the fits and the numbers of observed events in the five signal regions. The $t\bar{t}+$ jets event yield predicted by the MC simulation is quoted in parentheses. The column "others" includes the contributions from single top, $t\bar{t}+b\bar{b}$, $t\bar{t}+W/Z$, $W/Z+$ jets and multi-jet processes. Multi-jet events contribute less than 5 % of the total background. The column "SM" shows the total expected background and is the sum of the columns "$t\bar{t}+$ jets" and "others". The uncertainties include the statistical and systematic uncertainties

SR	$t\bar{t}+$ jets (MC)	others	SM	data
SR4-L	33.3 ± 7.9 (32.6 ± 15.4)	11.1 ± 4.9	44.4 ± 10.0	45
SR4-M	16.4 ± 4.1 (16.1 ± 8.4)	6.6 ± 2.9	23.0 ± 5.4	14
SR4-T	9.6 ± 2.1 (11.4 ± 5.4)	3.7 ± 1.6	13.3 ± 2.6	10
SR6-L	10.3 ± 3.3 (10.0 ± 6.2)	2.4 ± 1.4	12.7 ± 3.6	12
SR6-T	8.3 ± 2.4 (7.9 ± 5.3)	1.6 ± 1.1	9.9 ± 2.6	8

Table 5 Observed (expected) 95 % CL upper limits on the non-SM contributions to all signal regions. Limits are given on numbers of events and in terms of visible cross sections defined by cross section times kinematic acceptance times experimental efficiency. Systematic uncertainties on the SM background estimation are included in the limits

SR	Obs (exp) 95 % CL upper limit	
	N events	σ_{vis}(fb)
SR4-L	23.8 (23.4)	5.1 (5.0)
SR4-M	8.6 (12.8)	1.8 (2.7)
SR4-T	7.1 (9.2)	1.5 (2.0)
SR6-L	9.6 (10.1)	2.0 (2.1)
SR6-T	7.1 (8.3)	1.5 (1.8)

Uncertainties of 100 % are assumed for the multi-jet prediction and for the cross section of $t\bar{t}$ and W/Z production in association with a $b\bar{b}$ pair. For $t\bar{t}+W/Z$ production, an uncertainty of approximatively 70 % has been derived from the variations of the factorization and renormalization scales and from the PDF uncertainties [42].

The $t\bar{t}+$ jets yield in each signal region is extrapolated from the measured number of events in the corresponding control region (as per Table 2) using a fit based on the profile likelihood method [43]. Each pair of control and signal regions is fitted separately, assuming no signal events. The free parameter in each fit is the $t\bar{t}+$ jets overall normalization scale, while the contributions from subdominant background processes are fixed at the expected value. Systematic uncertainties are treated as nuisance parameters constrained with a Gaussian function and correlations are taken into account where appropriate. The results of the fits and the numbers of observed events for each signal region are summarized in Table 4. The fitted values of the normalization factors for $t\bar{t}+$ jets are compatible with one and the main impact of the data-driven estimate is a reduction in the uncertainty by approximately a factor of two. Figure 1 shows the measured m_{eff} distributions and the MC predictions for the SM backgrounds in each signal region. Also shown are the prediction of two benchmark signal models described below.

The reliability of the MC extrapolation of the $t\bar{t}$ background to larger b-jet multiplicities has been checked in validation regions defined with kinematic cuts similar to those used in the control and signal regions, except that exactly one isolated electron or muon is required. The transverse mass of the lepton and the $E_{\mathrm{T}}^{\mathrm{miss}}$ is required to be less than

100 GeV in all validation regions to minimize the possible contamination from stop production. The extrapolated event yield in the validation regions with at least three b-jets from the validation regions with exactly two b-jets is found to be consistent with the number of observed events for all b-tagging operating points.

The background predictions have been further validated using a data-driven method that simultaneously estimates all SM background contributions with at least one misidentified b-jet. This method consists of predicting the number of jets originating from b-quarks in each event by solving a system of equations based on the number of b-tagged and non b-tagged jets in the event, along with the b-tagging efficiency and mistag rates. Consistent background predictions with respect to the fit results have been found in all signal regions.

Limits for non-SM signal at 95 % confidence level (CL) are derived by testing the signal plus background hypothesis in each signal region with the CL_s prescription [43]. These limits are obtained with fits similar to those used to estimate the background in each signal region, except that the number of observed events in the signal region is added as an input to the fit and a second free parameter for the non-SM signal strength, constrained to be non-negative, is adjusted in the likelihood maximization. This additional free parameter ensures a proper treatment of the expected signal contamination in the control regions when the results are interpreted in the framework of specific SUSY scenarios. Model-independent upper limits at 95 % CL on the number of signal events and on the visible cross section (defined as the cross section times kinematic acceptance times experimental efficiency) for non-SM contributions derived for each signal region are given in Table 5.

These data have been used to derive limits in the parameter space of the following SUSY models.

Gluino–sbottom model MSSM scenarios where the $\tilde{b}_1$ is the lightest squark, all other squarks are heavier than the gluino, and $m_{\tilde{g}} > m_{\tilde{b}_1} > m_{\tilde{\chi}_1^0}$, so the branching ratio for
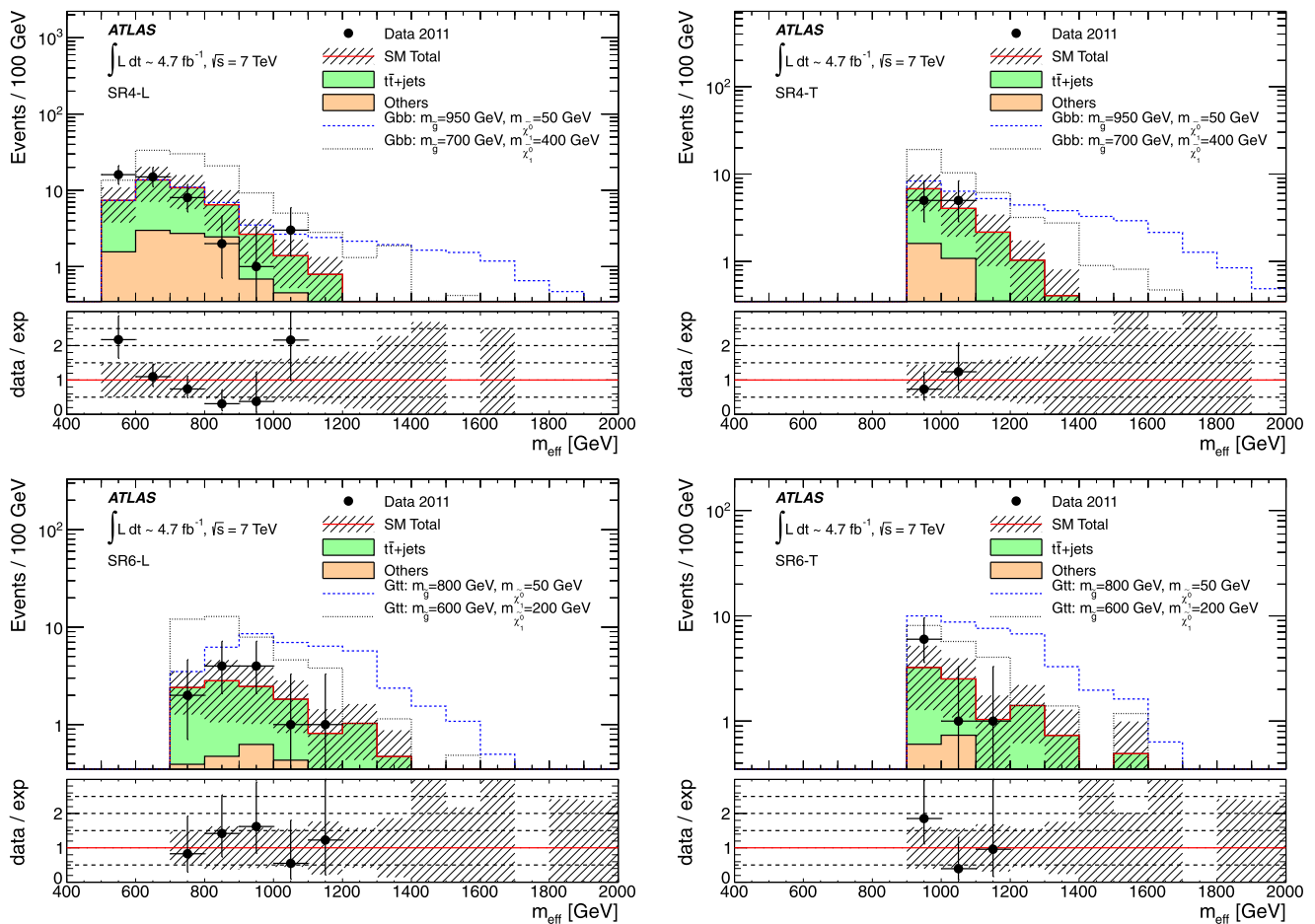
Fig. 1 Distribution of m_{eff} for SR4-L and SR4-T (*top*) and SR6-L and SR6-T (*bottom*). The hatched band shows the systematic uncertainty on the MC prediction, which includes both experimental uncertainties (among which JES and b-tagging uncertainties are dominant) and theoretical uncertainties on the background normalization and shape. The label "others" includes the contributions from single top, $t\bar{t} + b\bar{b}$,

$t\bar{t} + W/Z$, $W/Z +$ jets and multi-jet processes. The *lower plot in each figure shows* the ratio of the observed distribution to that expected for the SM background. Two signal points (with small and large mass splitting between the gluino and the LSP) for the *Gbb* and *Gtt* models described in the text are overlaid

$\tilde{g} \rightarrow \tilde{b}_1 b$ decays is 100 %. Sbottoms are produced via $\tilde{g}\tilde{g}$ or by $\tilde{b}_1\tilde{b}_1$ direct pair production and are assumed to decay exclusively via $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$, where $m_{\tilde{\chi}_1^0}$ is set to 60 GeV. Exclusion limits are presented in the $(m_{\tilde{g}}, m_{\tilde{b}_1})$ plane.

Gbb model Simplified scenarios, where $\tilde{b}_1$ is the lightest squark but $m_{\tilde{g}} < m_{\tilde{b}_1}$. Pair production of gluinos is the only process taken into account since the masses of all other sparticles apart from the $\tilde{\chi}_1^0$ are set above the TeV scale. A three-body decay via an off-shell sbottom is assumed for the gluino, yielding a 100 % BR for the decay $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$. The sbottom mass has no impact on the kinematics of the decay and the exclusion limits are presented in the $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$ plane.

Gluino–stop model MSSM scenarios where the $\tilde{t}_1$ is the lightest squark, all other squarks are heavier than the gluino,

and $m_{\tilde{g}} > m_{\tilde{t}_1} + m_t$, so the branching ratio for $\tilde{g} \rightarrow \tilde{t}_1 t$ decays is 100 %. Stops are produced via $\tilde{g}\tilde{g}$ and $\tilde{t}_1\tilde{t}_1$ and are assumed to decay exclusively via $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$. The neutralino mass is set to 60 GeV, the chargino mass to 120 GeV and the latter is assumed to decay through a virtual W boson. Exclusion limits are presented in the $(m_{\tilde{g}}, m_{\tilde{t}_1})$ plane.

Gtt model Simplified scenarios, where $\tilde{t}_1$ is the lightest squark but $m_{\tilde{g}} < m_{\tilde{t}_1}$. Pair production of gluinos is the only process taken into account since the mass of all other sparticles apart from the $\tilde{\chi}_1^0$ are above the TeV scale. A three-body decay via off-shell stop is assumed for the gluino, yielding a 100 % BR for the decay $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$. The stop mass has no impact on the kinematics of the decay and the exclusion limits are presented in the $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$ plane.

The SR4 regions are mostly sensitive to the SUSY models where sbottom production dominates, whilst the SR6
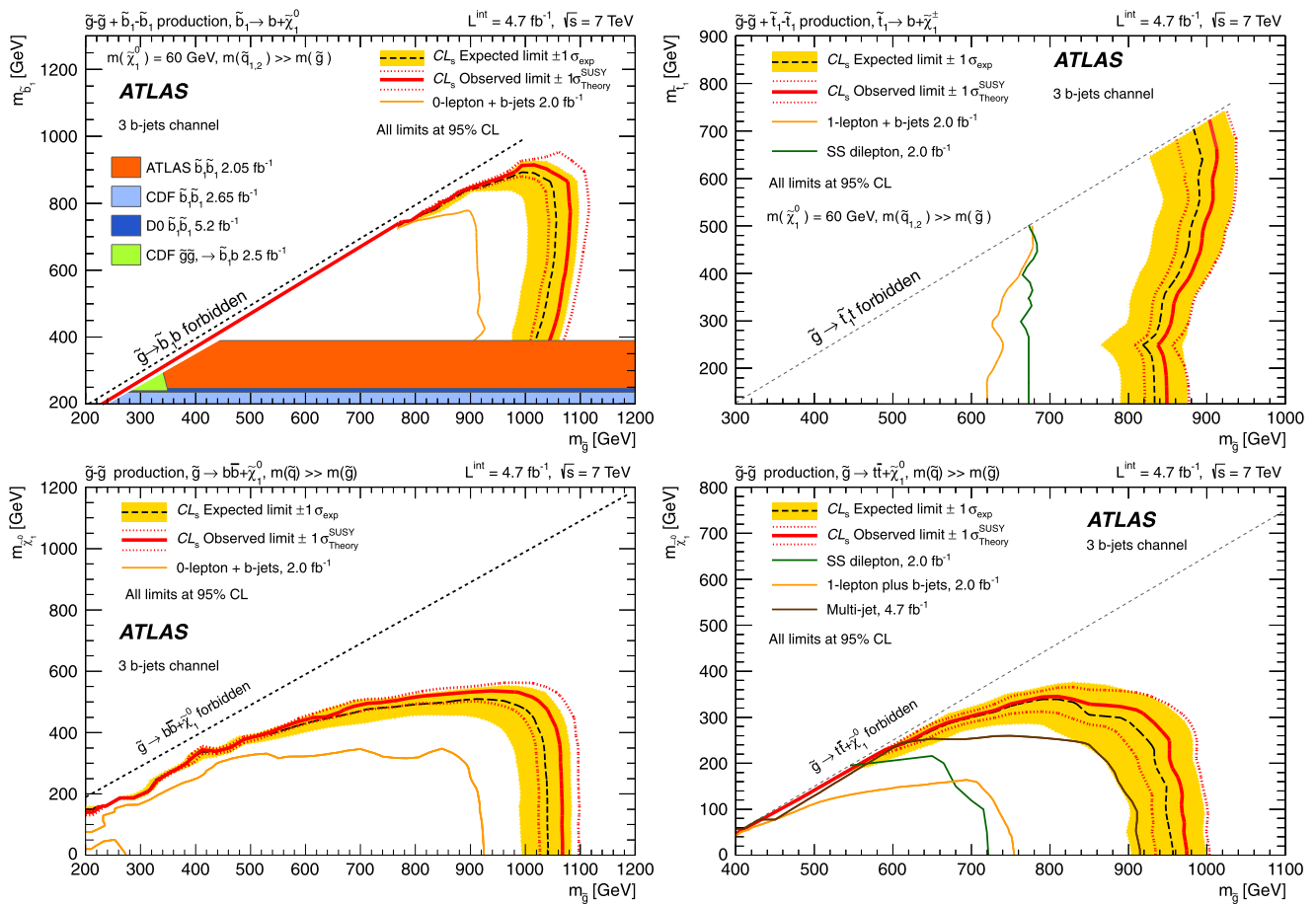
Fig. 2 Exclusion limits in the $(m_{\tilde{g}}, m_{\tilde{b}_1})$ plane for the gluino–sbottom model (*top left*), in the $(m_{\tilde{g}}, m_{\tilde{t}_1})$ plane for the gluino–stop model (*top right*) and in the $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$ plane for the *Gbb* (*bottom left*) and *Gtt* (*bottom right*) models. The *dashed black* and *solid bold red lines* show the 95 % CL expected and observed limits, respectively, including all uncertainties except the theoretical signal cross-section uncertainty. The *shaded* (*yellow*) *bands* around the expected limits show the impact of the experimental uncertainties while the *dotted red lines* show the impact on the observed limit of the variation of the nominal signal cross section by 1σ theoretical uncertainty. Also shown for reference are the previous CDF [44, 45], D0 [46] and ATLAS [19, 42, 47, 48] analyses (Color figure online)

regions are used to set exclusion limits in models characterized by on-shell or off-shell stop production, where top-enriched final states are expected. The signal region with the best expected sensitivity at each point in the parameter space is used to derive the limits at 95 % CL. Signal cross sections are calculated to next-to-leading order in the strong coupling constant, including the resummation of soft gluon emission at next-to-leading-logarithmic accuracy (NLO + NLL) [49–53]. The nominal cross section and the uncertainty $\sigma_{\text{Theory}}^{\text{SUSY}}$ are taken from an envelope of cross-section predictions using different PDF sets and factorization and renormalization scales, as described in Ref. [54]. All detector-related systematic uncertainties are treated as fully correlated between signal and backgrounds. In the *Gbb* scenario, the impact of initial-state radiation (ISR) is expected to be large in the region with low $m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$ due to the small signal acceptance. Therefore, an uncertainty on the modeling of ISR is assessed by comparing the signal accep-

tance obtained with the Herwig++ samples to the one obtained with dedicated MADGRAPH samples generated with additional jets. This uncertainty varies from 4 % to 35 % as a function of $m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$ and is included in the $\pm 1\sigma_{\text{Theory}}^{\text{SUSY}}$ band.

The expected and observed 95 % CL exclusion limits in the four models considered above are shown in Fig. 2. In the gluino–sbottom model, gluino masses below 1000 GeV are excluded for sbottom masses up to about 870 GeV using the most conservative $-1\sigma_{\text{Theory}}^{\text{SUSY}}$ hypothesis. This extends by approximatively 100 GeV the limits derived in the same scenario by the previous ATLAS analysis performed with 2 fb^{-1} [19] and is complementary to the ATLAS search for direct sbottom pair production, also carried out with 2 fb^{-1} [47]. The exclusion is less stringent in the region with low $m_{\tilde{g}} - m_{\tilde{b}_1}$, where softer jets are expected. Because of the kinematic cuts applied, the limits depend on the neutralino mass assumption for low mass splitting between the

sbottom and the neutralino as shown for the *Gbb* model where gluino masses below 1020 GeV are excluded for neutralino masses up to about 400 GeV, improving the previous ATLAS limits [19] by approximatively 100 GeV. In the gluino–stop model, gluino masses below 820 GeV are excluded for stop masses up to 640 GeV, extending the previous ATLAS limits [19, 42] by approximatively 150 GeV. In the *Gtt* model, gluino masses below 940 GeV are excluded for $m_{\tilde{\chi}_1^0} < 50$ GeV while neutralino masses below 320 GeV are excluded for $m_{\tilde{g}} = 800$ GeV. This search extends the exclusion limits on the gluino mass from the ATLAS multi-jet analysis carried out with the same data set [48] and from the CMS same-sign dilepton analysis performed with 5 fb^{-1} [20] by approximatively 60 GeV and 130 GeV, respectively, for neutralino masses below 100 GeV. In the region with low $m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$, the limits obtained with the CMS analysis are most stringent due to the softer kinematic cuts.

In summary, this letter presents results from a search for top and bottom squarks in the decay of gluino pairs produced in *pp* collisions at $\sqrt{s} = 7$ TeV, based on 4.7 fb^{-1} of ATLAS data. The events are selected with large E_T^{miss}, four or six jets and at least three jets originating from *b*-quarks in the final state. The results are in agreement with the SM background prediction and translate into 95 % CL upper limits on excluded masses for a variety of SUSY benchmark scenarios. Gluino masses up to 1 TeV are excluded, depending on the model, which significantly extends the previous results.

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