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Searches for gluino-mediated production of third generation squarks with the ATLAS detector

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Naturalness arguments for weak-scale supersymmetry favour supersymmetric partners of the third generation quarks with masses not too far from those of their Standard Model counterparts. Real and virtual production of third generation squarks via decay of a gluino can be significant if the mass of the gluino does not exceed the TeV scale. The talk presents recent ATLAS results from searches for gluino mediated stop and sbottom pair production.

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1. Introduction

Supersymmetry (SUSY) [1] provides an extension of the Standard Model (SM) which resolves the hierarchy problem [2] by introducing supersymmetric partners for Standard Model bosons and fermions. In the framework of the *R*-parity conserving minimal supersymmetric extension of the SM (MSSM) [3], SUSY particles are produced in pairs and the lightest supersymmetric particle (LSP) is stable. In a large variety of models, the LSP is the lightest neutralino ($\tilde{\chi}_1^0$), which only interacts weakly. SUSY can naturally resolve the hierarchy problem provided that the scalar top quark ($\tilde{t}$) has a mass at around the TeV scale. The SUSY partners of the right-handed and left-handed quarks mix to form two mass eigenstates $\tilde{q}_1$ and $\tilde{q}_2$, with a mixing effect proportional to the masses of the SM fermion partners, which could be large for the third generation, leading to the lightest sbottom ($\tilde{b}_1$) or stop ($\tilde{t}_1$) mass eigenstates being much lighter than those of the other squarks. As a consequence, $\tilde{b}_1$ and $\tilde{t}_1$ could be produced with relatively large cross-sections at the LHC, either directly in pairs, or through $\tilde{g}\tilde{g}$ production followed by $\tilde{g} \rightarrow b\tilde{b}_1$ or $\tilde{g} \rightarrow t\tilde{t}_1$ decays when when the $\tilde{t}$ and $\tilde{b}$ are the only light squarks, and all other squarks have masses larger than the mass of the gluinos.

In these proceedings, a summary of searches for gluino-mediated production of third generation squarks with data collected by the ATLAS detector [4] at $\sqrt{s} = 8$ TeV is presented, with emphasis on new results from two analyses: a search in final states with no leptons, large missing transverse momentum (E_T^{miss}), three jets tagged as originating from *b*-quarks, and large jet multiplicity (0-lepton + 3 *b*-jets) [5], and a search in final states with two leptons with the same electric charge (same-sign leptons), moderate to large E_T^{miss} and jets (SS + jets) [6]. The analyses are interpreted in a number of different simplified SUSY scenarios with different assumptions made regarding the mass spectrum of the SUSY particles involved. Models for stop production are used for interpretation in both analyses, while only final states with no leptons present sensitivity to sbottom production models. Both analyses are interpreted in the context of a *Gtt* model where $\tilde{g} \rightarrow tt + \tilde{\chi}_1^0$ via off-shell stops. The SS + jets analysis has several additional interpretations: *Gluino-stop* models with $\tilde{g} \rightarrow tt + \tilde{\chi}_1^0$ or $\tilde{g} \rightarrow t\tilde{t}_1$ with $\tilde{t}_1 \rightarrow b + \tilde{\chi}_1^{\pm}$ where the chargino and the neutralino masses are almost degenerate, both via on-shell stops; the *Gtb* model, where $\tilde{g} \rightarrow tb + \tilde{\chi}_1^{\pm}$ via off-shell stops and sbottoms; and a *Gluino-stop RPV* model, where $\tilde{g} \rightarrow t\tilde{t}_1$ with $\tilde{t}_1 \rightarrow bs$. The 0-lepton + 3 *b*-jets analysis results are also interpreted in the context of a *Gbb* model where $\tilde{g} \rightarrow bb + \tilde{\chi}_1^0$ via off-shell sbottoms.

2. 0-lepton + 3 b-jets Analysis

Final states arising from 3rd generation gluino-mediated production are very rich in the number of jets and *b*-tagged jets. Signatures with no identified leptons in particular constitute one of the most powerful ways to search for such signals, especially in high mass splitting regimes, where hard kinematic constraints can be placed on variables such as E_T^{miss}, m_{eff} (the scalar sum of the transverse momenta p_T of the final objects in the event), and the p_T of the jets or related observables. The 0-lepton + 3 *b*-jets analysis, described in detail in Ref. [5], is performed using 12.8 fb^{-1} of $\sqrt{s} = 8$ TeV data collected with the ATLAS detector at the LHC. The analysis targets the gluino mediated production of both bottom and top squarks, and has dedicated signal regions (SR) for each scenario. SR aiming at sbottom production require at least four jets in the final state, with $p_T > 50$ GeV and $|\eta| < 2.8$ and with at least three of them identified as a b-jet. Additional requirements are placed in the m_{eff} variable, reconstructed using the four leading jets in the event m_{eff}^{4j} to define three signal regions SR4L, SR4M and SR4T: $m_{eff}^{4j} > 900, 1100$ and 1300 GeV, respectively. SR targeting stop production are defined with events with at least six jets with $p_T > 30$ GeV and $|\eta| < 2.8$ of which at least three must be b-tagged. Additional requirements placed on m_{eff}^{incl}, defined with all the jets in the event, are used to define three signal regions SR6L, SR6M and SR6T: $m_{eff}^{incl} > 1100, 1300$ and 1500 GeV.

The dominant background contribution arises from $t\bar{t}$ production in association with jets, which is estimated differently depending on whether three or more jets originate from b-quarks at generator level. The $t\bar{t}$+ light flavour jets component ($t\bar{t}$+LF) is estimated by fitting its normalisation in a number of control regions (CR) defined by requiring the same jet selection criteria as in the various SR, but relaxed m_{eff} requirements and exactly two b-tagged jets. Other backgrounds including production of $t\bar{t}+b/b\bar{b}$, $V(=W,Z)+jets$, $t\bar{t}+V/VV/Vj$, single-top quarks, and diboson are estimated using simulated events. Validation regions (VR) are defined to cross-check the extrapolation from CR to SR for the $t\bar{t}$+LF background fit.

SR		L	M	T
4	Exp.	46 ± 10	10.7 ± 2.9	2.9 ± 1.0
	Obs.	38	8	4
6	Exp.	18.1 ± 6.2	6.3 ± 2.4	2.2 ± 1.3
	Obs.	20	4	2

Table 1: The number of expected and observed events in each of the six signal regions in the 0-lepton + 3 b-jets analysis. The uncertainties on the expected number of events include all systematic and statistical uncertainties.

Table 1 summarises the results in the six signal regions of the analysis. Good agreement between data and SM background expectations is observed, and the results are used to place constraints in both *Gtt* and *Gbb* models. Figure 1 shows the 95% CL [7, 8] exclusion contour for the *Gbb* (left) and the *Gtt* (right) models. Since signal regions are not exclusive, the region giving the best expected exclusion is chosen for each signal point. Taking the central cross-section prediction for SUSY signals, gluino masses below 1250(1300) GeV are excluded for $m_{LSP} < 200(300)$ GeV, while LSP masses below 500(600) GeV are excluded for $m_{\tilde{g}} < 1150(1200)$ GeV for the *Gtt* (*Gbb*) model.

3. Same-sign lepton + jets Analysis

Gluino-mediated stop production may result in signatures with many leptons, in addition to moderate to large E_T^{miss} and jet multiplicities. Given that gluinos are Majorana fermions, final states with two same-sign leptons present a very powerful way to look for such signals, especially in low mass splitting regimes where requiring two same-sign leptons reduces the contribution from SM backgrounds by a large amount. This analysis [6] uses the full 20.7 fb^{-1} data set at $\sqrt{s} =$ 8 TeV, collected by the ATLAS detector during 2012. It defines two sets of SR, each of them

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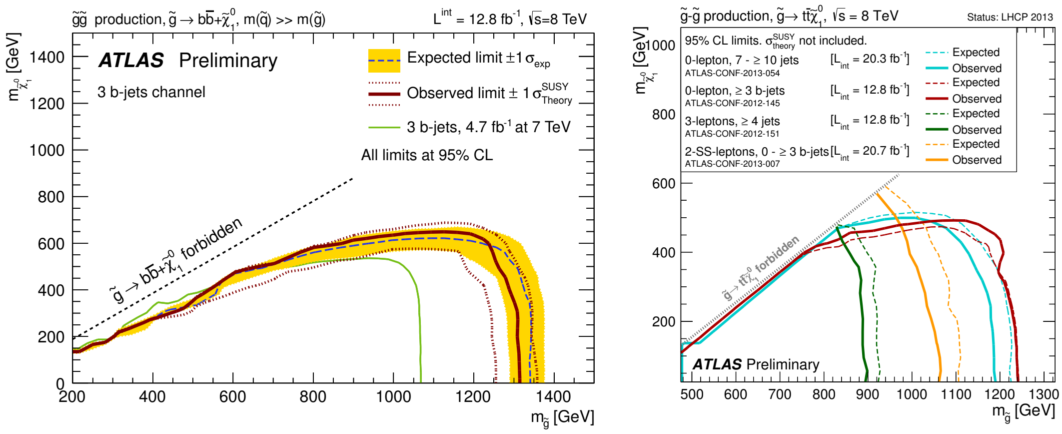

Figure 1: Exclusion limits in the $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$ plane for the *Gbb* (left) model. The dashed blue and solid bold red lines show the 95% CL expected and observed limits respectively, including all uncertainties except the theoretical signal cross-section uncertainty. The shaded (yellow) bands around the expected limits show the impact of the experimental and background theoretical uncertainties while the dotted red lines show the impact on the observed limit of the variation of the nominal signal cross-section by 1σ of its theoretical uncertainty [5]. The 95% CL exclusion contours are shown in the right for the *Gtt* model for 8 TeV analyses.

targeting discovery and exclusion. SR aiming discovery are inclusive, while SR targeting exclusion are exclusive and limits are derived by fitting the m_{eff} variable, which has a looser requirement compared to that in the discovery SR. In addition to the m_{eff} variable, SR are defined by selecting events with 0, ≥ 1 and ≥ 3 b-tagged jets (SR0b, SR1b and SR3b, respectively), and by placing requirements on the number of jets in the event, the E_T^{miss} and the transverse mass of the lepton and the E_T^{miss}, defined as $m_T = \sqrt{2p_T E_T^{miss}(1-\cos(\Delta\phi(\ell, E_T^{miss})))}$. For 3rd generation searches, only SR with ≥ 1 and ≥ 3 b-tagged jets play a significant role.

The main backgrounds to this search can be divided into different categories: prompt same-sign lepton pairs, charge mis-measurement and fake leptons. Background events with prompt same-sign lepton pairs arise from diboson production (WZ, ZZ) in association with jets, and from $t\bar{t}$ production in association with a Z or a W, followed by a leptonic $t\bar{t}$ decay. These backgrounds are estimated from MC. Background events arising from charge mis-measurement are only important for channels with electrons in the final state, and are estimated by measuring the charge mis-measurement probability in $Z \to ee$ events in data. Fake lepton backgrounds are estimated in channels involving both muons and electrons in the final state from data using a "loose - tight" matrix-mehod, as described in [6]. All background estimates are validated in dedicated VR.

Table 2 details the results in the four signal regions targeting 3rd generation searches, good agreement between data and expected SM backgrounds is observed, and exclusion limits are set for several models predicting top quarks in the final state. The results obtained for the *Gtt* model are shown in the left plot of Fig. 1, together with results from searches in other complementary channels. The constraints from SS + jets events are more powerful in regions closer to the kinematic bound of the decay, and LSP masses below 600 GeV are excluded for $m_{\tilde{g}}$=950 GeV. The 95% CL exclusion contours for the *Gluino-stop RPV* model are shown in Fig. 2. These are nearly independent of the $\tilde{t}_1$ mass, and gluinos below 900 GeV are excluded for all masses considered.

Exclusions for the other models considered can be found in Ref. [6].

SR		1b	3b
Discovery	Exp.	3.7 ± 1.6	3.1 ± 1.6
	Obs.	8	4
Exclusion	Exp.	10.1 ± 3.9	1.8 ± 1.8
	Obs.	11	1

Table 2: The number of expected and observed events in each of the signal regions with b-tagged jets in the SS + jets analysis. The uncertainties on the expected number of events include all systematic and statistical uncertainties.

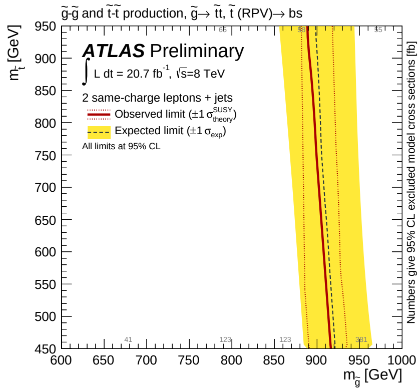

Figure 2: Expected and observed limits for the *Gluino-stop RPV* model obtained with 20.7 fb^{-1} at $\sqrt{s}$=8 TeV. The numbers give the limits on the excluded model cross sections. All limits are computed at 95% CL [6].

4. Conclusions

ATLAS has a broad program of dedicated searches for gluino-mediated 3rd generation production. These proceedings focus on the newest results from two complementary searches, in final states with zero leptons, large E_T^{miss} and multiple b-jets, and in events with two same-sign leptons and jets. In both cases, no excess above the SM predictions is observed, and constraints are set in the masses gluinos and stop quarks for the various tested models.

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