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Searches for third generation squarks with the ATLAS detector

Martin White*
On behalf of the ATLAS Collaboration
ARC Centre of Excellence for Particle Physics at the Terascale, University of Melbourne, Australia
E-mail: mwhi@unimelb.edu.au

The ATLAS experiment has recently searched for evidence of third generation squark production in a variety of final states, using proton–proton collision data from the Large Hadron Collider (LHC) operating at $\sqrt{s} = 7$ TeV. We briefly review the design and result of each analysis, and interpret the results in a series of simplified model scenarios.

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*Speaker.

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1. Introduction

Supersymmetry (SUSY) remains a popular solution to the problems of the Standard Model (SM) (for a pedagogical introduction, see [1]). By introducing TeV-scale partners for the fermions and bosons of the SM (called "sparticles"), one can cancel the quadratic divergences of the Higgs mass, obtain precise gauge unification and, in the case of *R*-parity conserving models, provide an ideal candidate for WIMP dark matter.

No evidence for supersymmetric particle production has yet been obtained at the LHC, and, if SUSY exists at all, it must be a broken symmetry. Although our ignorance of the correct mechanism for SUSY breaking permits a wide range of phenomenology, *R*-parity conserving models are heavily constrained in the case that all coloured sparticle masses are of the order of ≈ 1 TeV. If one continues to assume that all of the squark masses are similar (as might typically occur in a model with unified scalar masses at the GUT scale), the only solution is to raise masses further at the cost of introducing a large degree of fine tuning, removing much of the motivation for SUSY in the first place.

Another option is to permit the possibility that SUSY breaking is flavour dependent, in which case the third generation sparticles can be much lighter than those of the first and second generations. Furthermore, the left- and right-handed superpartners of a given quark mix to form mass eigenstates, and large mixing effects in the stop sector can lead to one of the stop mass eigenstates being significantly lighter than the other. The limits on models with the $\tilde{t}_1$ being the only light coloured sparticle are considerably weaker than those on models with similar squark masses. The limits on models with additional light third generation squarks and a light gluino are stronger, but still weaker than those on models in which all of the coloured sparticles are light.

These proceedings review the results of six recent ATLAS [2] searches for third generation squark production, using 4.7 fb^{-}1 of the ATLAS data recorded in 2011. Five analyses target $\tilde{t}_1$ pair production, focussing on two possible options for the stop decay:

1. $m_{\tilde{t}} < 200$ GeV with the stop decaying with 100% branching ratio via $\tilde{t} \to b\tilde{\chi}_1^{\pm}$, and the chargino subsequently decaying via $\tilde{\chi}_1^{\pm} \to W^*\tilde{\chi}_1^0$. In this case, one expects events with 2 *b* jets, missing energy and either leptons or additional jets from the *W* decays.

2. $m_{\tilde{t}} > 200$ GeV with the stop decaying via $\tilde{t} \to t\tilde{\chi}_1^0$. In this case, one expects events with two top quarks and missing energy.

We here provide a brief synopsis of each analysis in order to increasing stop mass sensitivity. Full details may be found in the relevant papers. We then present results of an updated search for gluino-mediated stop and sbottom production, using the 4.7 fb^{-1} 2011 dataset [3].

2. Searches for $\tilde{t} \to b\tilde{\chi}_1^{\pm}$

Two searches have been performed for top squarks decaying to a *b* quark and a chargino, each optimised for a different range of stop masses. Both searches use 4.7 fb^{-1} of the ATLAS data collected in 2011.

The first search targets very light top squarks [4], with $m_{\tilde{t}} < 140$ GeV. Assuming that both (off shell) *W* bosons decay leptonically, the small mass difference $m_{\tilde{\chi}_1^{\pm}} - m_{\tilde{\chi}_1^0}$ gives rise to soft leptons, whilst the small mass difference $m_{\tilde{t}} - m_{\tilde{\chi}_1^\pm}$ means that the b jets from the stop decay might not be tagged efficiently. The search looks for events with two leptons, vetoing events that contain leptons with $p_T > 30$ GeV. Further requirements include cuts on the missing energy and missing energy significance to reduce the multijet background ($E_T^{miss} > 20$ GeV and $E_T^{miss}/\sqrt{H_T} > 7.5$ GeV$^{1/2}$, where H_T is the scalar sum of the lepton and jet transverse momenta), cuts on the dilepton invariant mass to reduce the impact of low mass resonances and the Z background, and a jet requirement. No evidence for physics beyond the SM is found, and the results were interpreted in a simplified model with $m_{\tilde{\chi}_1^\pm} = 106$ GeV, but free stop and neutralino masses. The search extends the limit previously set by the CDF experiment [5].

The second search [6] was performed in both the one and two lepton final state, for the case where $m_{\tilde{t}} \approx m_t$. Requiring b-tagged jets reduces the non-top background in both final states, and a generalised transverse mass variable $\sqrt{s}_{min}^{(sub)}$ [7] is used to separate the hypothesised stop signal from the dominant top background. In the one lepton case, further discrimination between stop and top events can be obtained by attempting the kinematic reconstruction of a top quark from its hadronic decay products. This should be successful in the case of top background events, but would yield a different answer in the case of stop signal events. Further selections include a missing energy requirement (E_T^{miss}>40 GeV) for both final states, a cut on the transverse mass formed from the lepton and missing energy for the one lepton final state, and a cut on the dilepton invariant mass in the two lepton final state. No evidence for physics beyond the SM is obtained, and the results are interpreted using the same simplified model as that considered in the very light stop analysis, and in an additional model with $m_{\tilde{\chi}_1^\pm} = 2m_{\tilde{\chi}_1^0}$, but free neutralino and stop masses. Light top squarks with masses between 123-167 GeV are excluded for neutralino masses around 55 GeV.

A summary of the 95% exclusion limits obtained with both analyses is given in Figure 1.

3. Searches for $\tilde{t} \to t\tilde{\chi}_1^0$

If the top squark is heavier than the top quark, one might expect to observe stop decays to top quarks and neutralinos. Three searches for this scenario have been performed, covering the cases where no, one or both top quarks in each event decay leptonically.

In the case of stop events with purely hadronic top decays, one would expect two b jets, 4 additional light jets and a large amount of missing energy resulting from the missing neutralinos in the event. Furthermore, one should be able to kinematically reconstruct both top quarks. The dominant hadronic $t\bar{t}$ background, meanwhile, will have two top quarks but a much lower amount of missing energy. The zero lepton search [9] therefore requires six jets with large transverse momentum (including at least one b jet), performs kinematic top reconstruction and uses a large cut on the missing energy, optimised for stop masses well above the top mass. Two signal regions are defined with different requirements on the missing energy in the event. No evidence for stop production is obtained in either region, and the results are interpreted in a simplied model featuring a top squark decaying 100% of the time to a top quark and a neutralino, with free stop and neutralino masses. Top squark masses between 370 GeV and 465 GeV are excluded for $m_{\tilde{\chi}_1^0} \approx 0$ GeV, while $m_{\tilde{t}} = 445$ GeV is excluded for $m_{\tilde{\chi}_1^0} \leq 50$ GeV.

A one lepton analysis has also been performed [10], targetting the case of one leptonic top decay and one hadronic top decay. Here, one can perform kinematic reconstruction of one of the

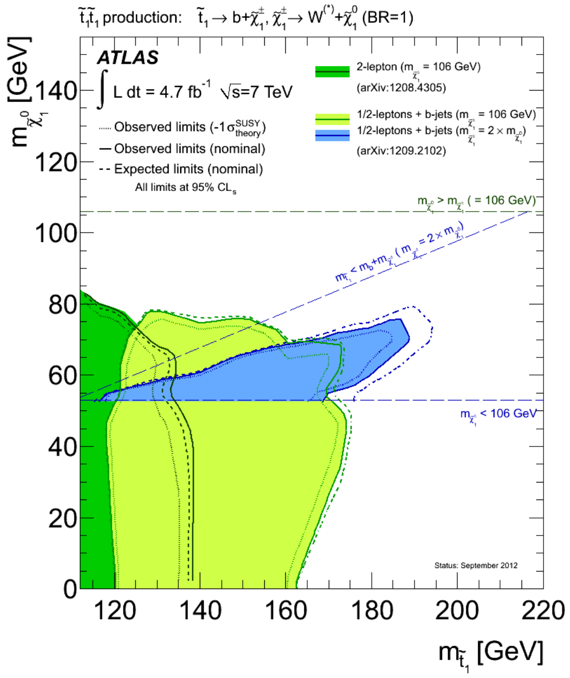

Figure 1: 95% exclusion limits in the $m_{\tilde{t}_1}$–$m_{\tilde{\chi}_1^0}$ mass plane, assuming that the stop decays to a b quark and a chargino. Taken from [8].

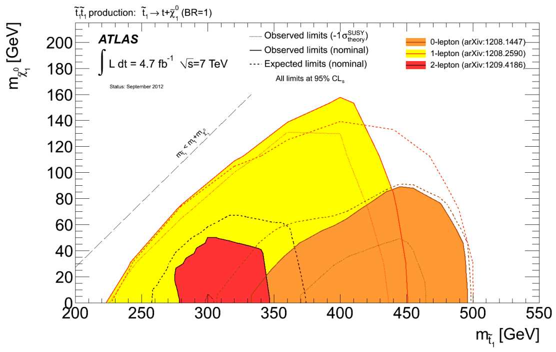

Figure 2: 95% exclusion limits in the $m_{\tilde{t}_1}$–$m_{\tilde{\chi}_1^0}$ mass plane, assuming that the stop decays to a top quark and a neutralino. Taken from [8].

top quarks in the event, and the analysis uses cuts on the transverse mass formed from the lepton and missing energy, along with cuts on the missing energy and missing energy significance to further separate the stop signal and top background. Five different regions are defined to optimise the reach in the stop-neutralino mass plane, and no region shows any evidence for physics beyond the SM. The results are interpreted in the same simplified model scenario as that considered by the zero lepton analysis. Top squark masses between 230 GeV and 440 GeV are excluded with 95% confidence for massless neutralinos, and top squark masses around 400 GeV are excluded for neutralino masses up to 125 GeV.

Finally, a search has been performed in the two lepton final state [11], assuming that both tops in the event decay leptonically. At least one b jet is required, along with exactly two leptons. A cut

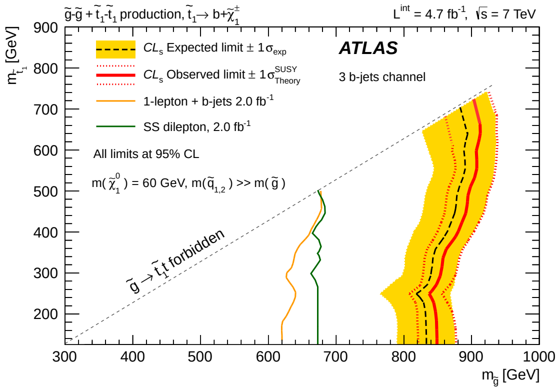

Figure 3: 95% exclusion limit in a simplified model with gluino-mediated stop production [3].

on the dilepton invariant mass is used to reduce the impact of low mass resonances and Z events, and the top background is rejected using a cut on the generalised transverse mass variable M_{T2} [12]. No evidence for new physics is observed, and the results are interpreted using the same model as that described above.

A summary of the 95% exclusion limits derived from all of the analyses considered in this section is shown in Figure 2.

4. A search for gluino-mediated stop and sbottom production

In addition to performing new searches for direct stop production, the ATLAS experiment has recently updated a previous search for gluino-mediated stop and sbottom production [3]. This proceeds under the assumption that one has both a light gluino and light stop and bottom squarks, and uses 4.7 fb^{-1} of $\sqrt{s} = 7$ TeV data collected in 2011.

The basic strategy is to select events enriched in b jets, with at least 3 b jets required in all signal regions. Further requirements are placed on the total number of jets, the missing energy, the effective mass (the scalar sum of the jet transverse momenta in the event and the missing transverse energy), and the ratio of the missing energy to the effective mass. Three signal regions with at least four jets are optimised for SUSY events with bottom squarks in the decay chains, and two further regions with at least six jets are optimised for SUSY events with top squarks in the decay chain. No region reveals evidence for new physics, and the results are interpreted in a variety of simplified models featuring different combinations of gluino pair, stop pair and sbottom pair production. An example of a 95% exclusion contour, obtained for a model in which one assumes that both gluino pair and stop pair production can occur, is shown in Figure 3.

5. Conclusions

The ATLAS experiment has performed 5 searches for direct stop pair production at the LHC, targetting models that are well motivated from a theoretical perspective, but would have evaded detection in the analyses performed so far. One set of searches covers the case of a stop lighter than the top quark, with a decay via a chargino to a W boson and a neutralino. The other set targets the case of heavier top squarks decaying directly to a neutralino and a top quark. In all cases, the results obtained are consistent with the SM prediction, and the results provide the worlds best limits on third generation squark production. An updated search for gluino-mediated third generation squark production further extends the limits on this scenario set by the ATLAS experiment. The large amount of data collected at the LHC at $\sqrt{s} = 8$ TeV in 2012 promises to significantly extend the reach of these results.

References

[1] Stephen P. Martin. A Supersymmetry primer. 1997.

[2] The ATLAS Collaboration. The ATLAS Experiment at the CERN Large Hadron Collider. *JINST*, 3:S08003, 2008.

[3] The ATLAS Collaboration. 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. *arXiv:1207.4686*, 2012.

[4] The ATLAS Collaboration. Search for light scalar top quark pair production in final states with two leptons with the ATLAS detector in sqrt(s) = 7 TeV proton-proton collisions. *arXiv:1208.4305*, 2012.

[5] Search for Pair Production of Supersymmetric Top Quarks in Dilepton Events from $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.96 TeV. *Phys. Rev. Lett.*, 104:251801, 2010.

[6] The ATLAS Collaboration. Search for light top squark pair production in final states with leptons and b-jets with the ATLAS detector in sqrt(s) = 7 TeV proton-proton collisions. *arXiv:1209.2102*, 2012.

[7] Partha Konar, Kyoungchul Kong, Konstantin T. Matchev, and Myeonghun Park. RECO level $\sqrt{s}_{min}$ and subsystem $\sqrt{s}_{min}$: Improved global inclusive variables for measuring the new physics mass scale in E_T events at hadron colliders. *JHEP*, 1106:041, 2011.

[8] ATLAS Collaboration, https://twiki.cern.ch/twiki/bin/view/AtlasPublic/CombinedSummaryPlots#SusyDirectStopSummary (2012).

[9] The ATLAS Collaboration. Search for a supersymmetric partner to the top quark in final states with jets and missing transverse momentum at sqrt(s) = 7 TeV with the ATLAS detector. *arXiv:1208.1447*, 2012.

[10] The ATLAS Collaboration. Search for direct top squark pair production in final states with one isolated lepton, jets, and missing transverse momentum in sqrt(s) = 7 TeV pp collisions using 4.7 fb-1 of ATLAS data. *arXiv:1208.2590*, 2012.

[11] The ATLAS Collaboration. Search for a heavy top-quark partner in final states with two leptons with the ATLAS detector at the LHC. *arXiv:1209.4186*, 2012.

[12] Alan Barr, Christopher Lester, and P. Stephens. m(T2): The Truth behind the glamour. *J.Phys.*, G29:2343–2363, 2003.