PROCEEDINGS OF SCIENCE

Searches for 3rd generation partners at the LHC

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The search for direct production of third generation squarks is a main part of the new physics programme of the LHC experiments. Unfortunately, no evidence of supersymmetry has been observed after the first data taking period (Run1). A non-exhaustive review of the latest results from the ATLAS and CMS experiments is presented here.

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Introduction

Supersymmetry (SUSY) [1] is one of the most popular and well motivated extensions of the Standard Model (SM) which naturally resolves the hierarchy problem by introducing supersymmetric partners to all known fermions and bosons. In generic R-parity conserving models, SUSY particles are produced in pairs and the lightest supersymmetric particle (LSP), typically the lightest neutralino ($\tilde{\chi}_1^0$), is stable and regarded as a good dark matter candidate.

The scalar partners of right-handed and left-handed quarks (squarks) can mix to form two mass eigenstates ($\tilde{q}_1$, $\tilde{q}_2$). Third generation squarks (stop $\tilde{t}$ and sbottom $\tilde{b}$) can be lighter than other squarks due to their R-L mixing and large Yukawa couplings. They can be directly produced with relatively high cross sections at the LHC if their masses lie below the TeV scale.

Both ATLAS [2] and CMS [3] Collaborations have deployed a comprehensive programme to search for the direct production of third generation sparticles since the beginning of the LHC. Unfortunately, no significant sign of new physics was found so far in any of the scenarios explored. The main results have been reviewed in recent publications by the two experiments [4, 5, 6]. The exclusion limits imposed by several searches is summarized in Fig. 1, for the direct production of a top superpartner decaying to a neutralino LSP. A rich variety of models was considered, e.g. with stop decaying via intermediate charginos and different mass hierarchies.

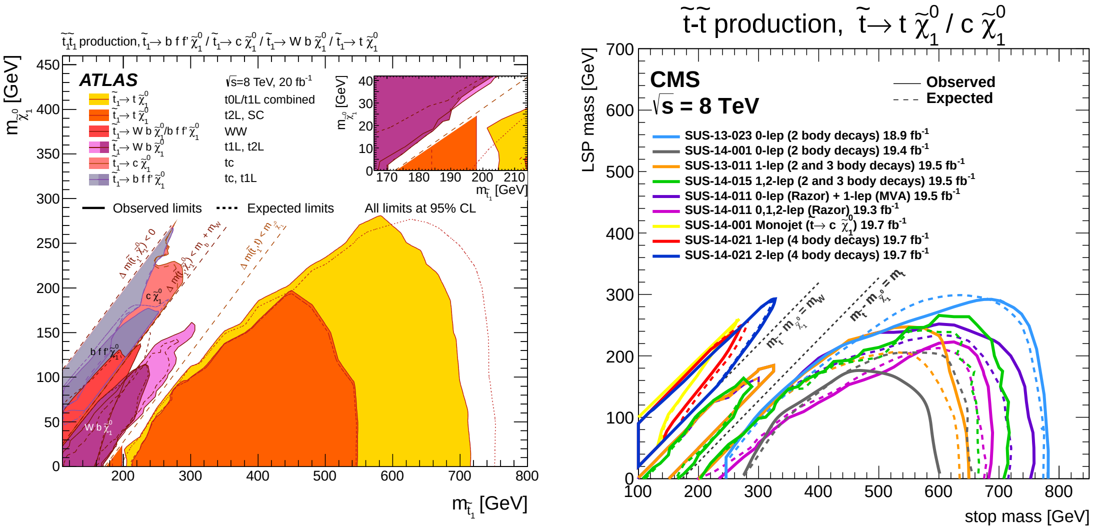

Figure 1: Summary of the searches for direct stop pair production by ATLAS [4] (left) and CMS [7] (right) during Run1 of the LHC.

Recent results

The lack of evidence for SUSY has motivated some of the most recent analyses, in a last effort to fully exploit the Run1 dataset. These include new channels introduced to improve the sensitivity in specific regions of the parameter space, most complex analysis techniques (MVA, shape fits, etc), as well as the combination of several searches to maximize the exclusion power.

Among the first, ATLAS has recently published a search for a direct stop decaying via a scalar tau to a nearly massless gravitino [8], which is the first result on this channel at hadron colliders. Three independent channels were considered, to fully exploit the distinct features of a fully hadronic, semi-leptonic or fully leptonic decay of the stop pair [1]. Depending on the scalar tau mass, ranging from the 87 GeV LEP limit to the scalar top mass, lower limits between 490 GeV and 650 GeV were placed on the scalar top mass within the model considered.

The measurement of the production cross section of nonresonant WW pairs in the two-lepton channel at the LHC [10, 11, 12] has given rise to theoretical speculations [13, 14, 15] which interpret the possible excess as due to the production of a light stop. This has motivated a dedicated search carried by ATLAS for a WW-like final state, produced by a light stop (with mass ~ 200 GeV) decaying via a degenerated chargino to the neutralino LSP, few tens of GeV away in mass from it. The signal selection exploits the higher longitudinal boost of the system and the larger missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$) expected for the signal, with respect to the background dominated by SM WW production. In absence of any significant excess, stop masses up to about 250 GeV were excluded, almost independently of the neutralino mass. This limit filled nicely the gap between the exclusion of previous searches in the region $\Delta(\tilde{t}_1, \tilde{\chi}_1^0) \sim m_W$.

The traditional searches for $\tilde{t}_1$ become very challenging in some regions of the parameters space, particularly close to the diagonal $\Delta(\tilde{t}_1, \tilde{\chi}_1^0) \sim m_t$ where the separation of $\tilde{t}_1$ pair production from SM top quark pair production is difficult. It is convenient in this case to search for a $\tilde{t}_2$ instead, even if its production cross section is smaller. Dedicated analyses were designed by the two experiments to detect $\tilde{t}_2$ pair production followed by the decays $\tilde{t}_2 \to \tilde{t}_1 h$ and $\tilde{t}_2 \to \tilde{t}_1 Z$. In both cases, here referred as t2t1h and t2t1Z analyses respectively, a limit on $m(\tilde{t}_2)$ is set at about 600 GeV for a massless neutralino in the case of exclusive decays. The assumption on the branching ratio of the $\tilde{t}_2$ has also been relaxed, and limits have been derived assuming three possible decays $\tilde{t}_2 \to \tilde{t}_1 h$, $\tilde{t}_2 \to \tilde{t}_1 Z$ and $\tilde{t}_2 \to t\tilde{\chi}_1^0$ (Fig. 2). It can be observed the nice complementarity of the different analyses (including also the combination of the 0- and 1-lepton searches), and how little space remains unexcluded in the three mass scenarios explored.

Contrary to the popular saying, the latest Run1 efforts aimed to *combine and conquer*. Several analyses were reinterpreted in different models, compiled in a common parameter space or statistically combined to improve the final exclusion. For instance, Fig. 3 shows CMS combination of the searches for stop and sbottom pairs in fully hadronic final states. Three complementary searches are included, optimized for different decay topologies: 1) a multijet search requiring a fully reconstructed top candidate, which is sensitive to scenarios with a large $\Delta(\tilde{t}_1, \tilde{\chi}_1^0)$; 2) a dijet search requiring one or two b-tagged jets, which is sensitive to scenarios with large or intermediate $\Delta(\tilde{b}, \tilde{\chi}_1^0)$ and a monojet search, which is sensitive to scenarios with highly compressed spectra. Stop (sbottom) masses below ~ 600 (700) GeV are excluded, for a light neutralino LSP. In the compressed region, the exclusion goes up to $m_{\tilde{t}/\tilde{b}} \sim 250$ GeV. Limits were derived also for different assumptions on the relative branching ratios for $\tilde{t} \to t\tilde{\chi}_1^0$ and $\tilde{t} \to b\tilde{\chi}_1^{\pm}$ ($\Delta(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0) = 5$ GeV), as denoted by the dashed red lines in Fig. 3(left). A similar approach was followed by ATLAS in these channels. As mentioned above, a statistical combination of the stop searches in 0- and 1-lepton final states was performed in ATLAS, by fitting simultaneously the signal and background-dominated regions of

[1]The fully leptonic channel is a reinterpretation of [9] to this model.

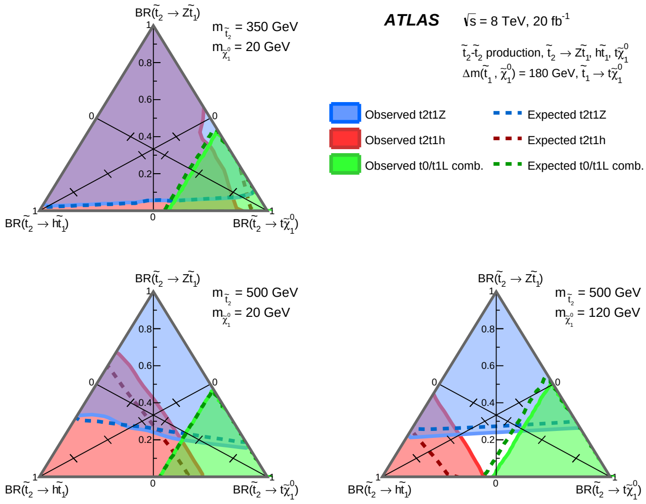

Figure 2: ATLAS exclusion limits as a function of the $\tilde{t}_2$ branching ratio for $\tilde{t}_2 \to \tilde{t}_1 h$, $\tilde{t}_2 \to \tilde{t}_1 Z$ and $\tilde{t}_2 \to \tilde{\chi}_1^0$ [4]. The blue, red and green limit refers to the t2t1Z, t2t1h and combination of t0L and t1L analyses respectively. The limits are given for three different values of the $\tilde{t}_2$ and $\tilde{\chi}_1^0$ masses.

the two analyses. The combined exclusion limit ($\sim$ 700 GeV) is about 50 GeV better than in the individual analyses.

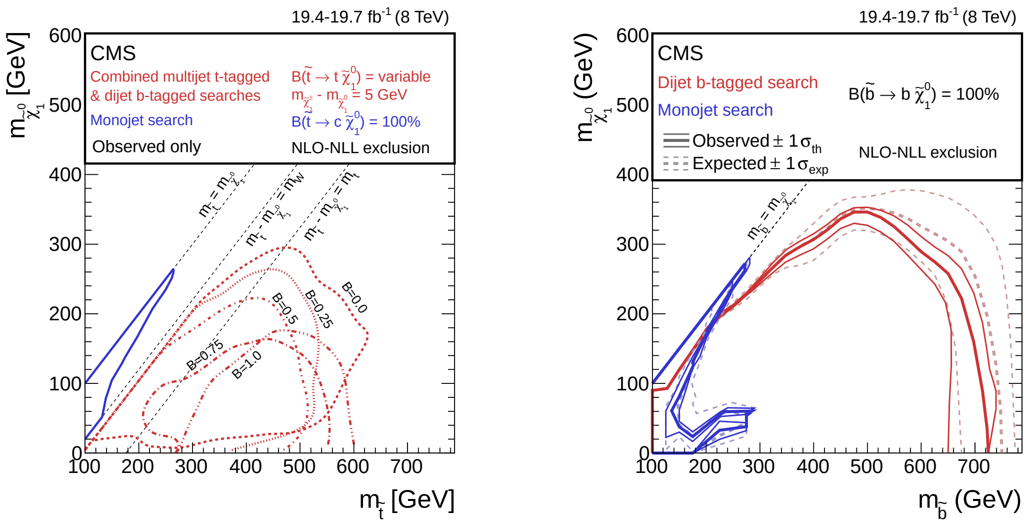

Figure 3: Best-expected combination of CMS exclusion limits for stop (left) and sbottom (right) pair production [5]. The (b-tagged) dijet (red line) drives the exclusion in the bulk of the parameter space while the monojet analysis (blue line) gives the best sensitivity in the more compressed region.

Conclusions

Despite the yet elusive nature of SUSY, the Run1 searches helped to significantly reduce the allowed phase space and a lot of experience and knowledge was gained in the process. The promising unexplored window offered by the new center of mass energy the LHC is operating at since its restart has renovated the expectations of the two Collaborations, which are in full blow preparing the Run2 sequel of the new physics' hunting.

References

[1] S. P. Martin, *A Supersymmetry primer*, arXiv:hep-ph/9709356 [hep-ph]. [Adv. Ser. Direct. High Energy Phys.18,1(1998)].

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

[3] CMS Collaboration, *The CMS experiment at the CERN LHC*, JINST **3** (2008) S08004.

[4] ATLAS Collaboration, *ATLAS Run 1 searches for direct pair production of third-generation squarks at the Large Hadron Collider*, arXiv:1506.08616 [hep-ex].

[5] CMS Collaboration, *Searches for third-generation squark production in fully hadronic final states in proton-proton collisions at* $\sqrt{s} = 8$ *TeV*, JHEP (2015) 116, arXiv:1503.08037 [hep-ex].

[6] CMS Collaboration, *Searches for supersymmetry using the MT2 variable in hadronic events produced in pp collisions at 8 TeV*, Journal of High Energy Physics **2015:78** (2015).

[7] https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS/.

[8] ATLAS Collaboration, *Search for direct scalar top pair production in final states with two tau leptons in pp collisions at* $\sqrt{s} = 8$ *TeV with the ATLAS detector*, arXiv:1509.04976 [hep-ex].

[9] CMS Collaboration, *Search for direct top-squark pair production in final states with two leptons in pp collisions at* $\sqrt{s} = 8$ *TeV with the ATLAS detector*, Journal of High Energy Physics **2014:124** (2014).

[10] ATLAS Collaboration, *Measurement of the WW cross section in pp collisions with the ATLAS detector and limits on anomalous gauge couplings*, Physics Letters B **712** (2012) 289 – 308.

[11] CMS Collaboration, *Measurement of the* W^+W *cross section in pp collisions at* $\sqrt{s}$ *=7 TeV and limits on anomalous* $WW\gamma$ *and WWZ couplings*, The European Physical Journal C **73** (2013).

[12] CMS Collaboration, *Measurement of the WW and ZZ production cross sections in pp collisions at* $sqrts = 8$ *TeV*, Physics Letters B **721** (2013) 190 – 211.

[13] J. Kim, K. Rolbiecki, K. Sakurai, and J. Tattersall, *Stop that ambulance! New physics at the LHC?*, Journal of High Energy Physics **2014:10** (2014).

[14] K. Rolbiecki and K. Sakurai, *Light stops emerging in WW cross section measurements?*, Journal of High Energy Physics **2013:4** (2013).

[15] D. Curtin, P. Meade, and P.-J. Tien, *Natural SUSY in plain sight*, Phys. Rev. D **90** (2014) 115012.