Searches for direct pair 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. Top or bottom squarks with masses less than a few hundred GeV can also give rise to direct pair production rates at the LHC that can be observed in the data sample recorded by the ATLAS detector. This note presents recent ATLAS results from searches for direct stop and sbottom pair production.

1 Introduction

Supersymmetry (SUSY) [1, 9] is an extension of the Standard Model (SM) which can resolve the hierarchy problem by introducing supersymmetric partners to the known fermions and bosons. The dominant contributions for the radiative corrections to the Higgs mass are loop diagrams with top quarks. These can be canceled (naturally) if the supersymmetric partner of the top quark (stop) has a mass below the TeV range. A light bottom squark is also likely because the partners of the left-handed top and bottom squarks share the same mass term in the SUSY-breaking Lagrangian. In R-parity conserving supersymmetric models, the SUSY particles are produced in pairs and the lightest supersymmetric particle (LSP) is stable. In many models the LSP is the lightest neutralino, $\tilde{\chi}_1^0$, which is only weakly interacting and provides a candidate particle to address the dark matter problem.

In these proceedings, a summary of ATLAS searches for third generation squarks is presented. All the searches are based on the 2012 dataset of p p collisions at $\sqrt{s} = 8$ TeV representing about 20 fb^{-1} of integrated luminosity.

2 The ATLAS detector

The ATLAS detector [10] consists of an inner detector (ID) operating in a 2 T superconducting solenoid, a calorimeter system and a muon spectrometer with a toroidal magnetic field. The ID tracking system includes a silicon pixel detector, a silicon microstrip detector (SCT), and a transition radiation tracker (TRT). It provides tracking information for charged particles in a pseudo-rapidity range $|\eta| < 2.5$ and allows identification of jets originating from b-hadron decays. The ID is surrounded by high-granularity liquid-argon (LAr) sampling electromagnetic calorimeters. An iron/scintillator tile calorimeter provides hadronic energy measurements in the central pseudo-rapidity range ($|\eta| < 1.7$). In the forward regions ($1.5 < |\eta| < 4.9$), it is complemented by two end-cap calorimeters using LAr as the active material and copper or tungsten as an absorber. The muon spectrometer (MS) surrounds the calorimeters and consists of three large superconducting eight-coil toroids, a system of tracking chambers, and detectors for triggering.

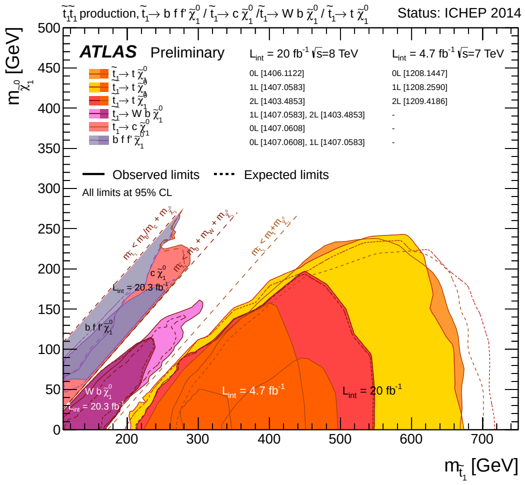

Figure 1: Summary of top squark pair production searches. Exclusion limits at 95% CL are shown in the stop-neutralino mass plane.

3 Top squark searches

The decay of the top squark depends on the mass splitting between the stop and its possible decay products, leading to very different topologies depending on the mass spectrum. For a heavy stop, the dominant decays would be $\tilde{t_1} \rightarrow t\tilde{\chi}_1^0$ (kinematically allowed if $\mathrm{m}(\tilde{t_1}) > \mathrm{m(t)} + \mathrm{m}(\tilde{\chi}_1^0)$) and $\tilde{t_1} \rightarrow b\tilde{\chi}_1^{\pm}$ which is allowed if $\mathrm{m}(\ \tilde{t_1}) > \mathrm{m(b)} + \mathrm{m}(\ \tilde{\chi}_1^{\pm})$.

If the $\tilde{t_1} \rightarrow t\tilde{\chi}_1^0$ decay is kinematically forbidden, the stop could have a three-body decay $\tilde{t_1} \rightarrow bW\tilde{\chi}_1^0$ via an off-shell top and if the mass difference between the stop and the lightest neutralino is smaller than the sum of the W boson and b-quark masses, eventually the decay can proceed with an off-shell W or with a loop decay to a charm quark and the lightest neutralino $\tilde{t_1} \rightarrow c\tilde{\chi}_1^0$.

The searches for a heavy stop decay are designed based on the decay of the W boson in the top or chargino decay modes, leading to topologies with zero, one or two leptons.

Searches for stop decay in the fully hadronic channel [11] require up to six jets (two of which b-tagged) and show a very good sensitivity at high stop masses. This is reached using large radius ($\Delta R = 1.2$) re-clustering techniques that become very efficient in boosted topologies.

The semi-leptonic analyses [12] make use of shape fits in the E_T^{miss} and m_T variables to distinguish a potential stop signal from the $t\bar{t}$ background showing good sensitivity for high and medium stop masses. The shape-fit techniques push the sensitivity toward the kinematic limit for the stop decay though top. Here the kinematic properties of the signal closely resemble the

$t\bar{t}$ pairs production making this region very challenging. (Stop pairs production cross-section is typically a few percent of the top pairs production and LSPs are very soft).

The fully leptonic final state analyses [13] target both $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm}$ and $\tilde{t}_1 \to t\tilde{\chi}_1^0$ decays, making use of a generalization of the transverse mass variable (m_{T2}) as a discriminator between signal and background.

Two other analyses target the very small Δm values, using charm-tagging jets techniques and the monojet selections [14]. These analyses show good sensitivity in this very challenging region up to the kinematic limit. Both these approaches use ISR or FSR to select boosted stops and explore the very compressed decay spectra.

4 Bottom squark searches

The direct production of bottom squarks is targeted by complementary analyses, which are sensitive to different decay modes. A fully hadronic final state search [15] selects events with two b-jets and large E_T^{miss}, and is sensitive to the $\tilde{b}_1 \to b\tilde{\chi}_1^0$ decay mode. Selection with large values of invariant and cotransverse mass of the two b-jets is sensitive to large values of $\Delta m(\tilde{b}_1, \tilde{\chi}_1^0)$, while the sensitivity to small values of the mass difference is achieved by looking for events with a hard jet produced by initial or final state radiation. We require an untagged leading jet. The observed number of events is in agreement with the SM expectations for both selections. The resulting limits in the sbottom, neutralino mass plane are shown in Fig. 2.

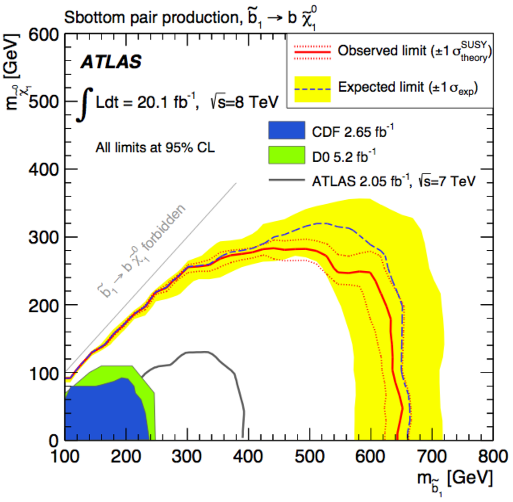

Figure 2: Expected and observed exclusion limits at 95% CL in the $\tilde{b}_1$ $\tilde{\chi}_1^0$ mass plane for the sbottom pair production scenario considered.

A search in events with two same-sign leptons [16] is sensitive to the $\tilde{b}_1 \to t\tilde{\chi}_1^{\pm} \to tW\tilde{\chi}_1^0$ decay mode and places exclusion limits on the $\tilde{b}_1$ $\tilde{\chi}_1^{\pm}$ mass plane for fixed neutralino mass values. A search with three b-jets [17] in the final state places limits on models with $\tilde{b}_1 \to b\tilde{\chi}_2^0 \to bh\tilde{\chi}_1^0$ where h is the CP-even Higgs boson.

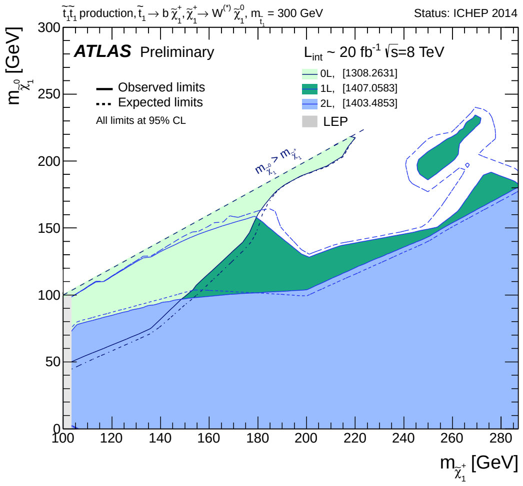

Figure 3: Summary of top squark pair production searches. Exclusion limits at 95% CL are shown in the chargino-neutralino mass plane for stop of 300 GeV.

5 Summary

ATLAS has a number of dedicated searches sensitive to direct production of third-generation squarks. These proceedings give a short reference to these searches, with emphasis on new results.

No significant excesses over the SM expectations are observed, and exclusion limits are set on squark masses. Figure 1 summarizes the exclusion limits obtained by ATLAS as a function of the stop and neutralino masses for simplified models with different stop decays. Under the many assumptions used on these models, stop masses up to about 700 GeV are excluded for a massless neutralino, while for massive neutralinos of 250-300 GeV, stop sensitivity falls to 450-500 GeV. Many important holes are still present close to the various kinematic limits, as illustrated in Figure 3 in the chargino-neutralino mass plane.

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