Search for top squark pair production in final states with one isolated lepton, jets and missing transverse momentum in $\sqrt{s}$ = 8 TeV pp collisions using 21 fb^{-1} of ATLAS data

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The ATLAS Collaboration has performed a search for natural weak scale Supersymmetry (SUSY) in the form of light top quark partners (top squarks). Signal regions are optimized separately for the $\tilde{t} \mapsto t + \tilde{\chi}_1^0$ and $\tilde{t} \mapsto b + \tilde{\chi}_1^\pm$ decays. To increase the sensitivity of the search near the compressed scenario in which $m_{\text{top squark}}$ is only slightly more massive than $m_t + m_{\tilde{\chi}_1^0}$, a two-dimensional shape fit is performed in the missing momentum and transverse mass plane. No excess over the background is observed and limits are set on top squark pair production. For example, assuming the top squark decays only into a top quark and the lightest neutralino, top squark masses between 200 and 610 GeV are excluded at the 95% confidence level for a massless neutralino.

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1. Introduction

The quantum corrections to the Higgs-boson mass are small in weak-scale SUSY, providing a natural solution to the technical hierarchy problem. Since no particles beyond the Standard Model (SM) have been discovered, the SUSY breaking scale must be above the electroweak scale. A minimal requirement for naturalness is that the top squark (stop) be relatively light. The search [1] presented here considers two simplified models of direct production and decay of the lighter top squark ($\tilde{t}_1$): $\tilde{t} \mapsto t + \tilde{\chi}_1^0$ (tN) and $\tilde{t} \mapsto b + \tilde{\chi}_1^\pm$ (bC). Each decay possibility is assumed to have a 100% branching ratio; thus both cannot happen at the same time.

2. Methods

In order to focus on a relatively clean signature while mantaing an appreciable cross section, the search presented here is conducted in final states with one lepton. Thus, all signal regions require exactly one electron or muon, at least four resolved jets (≥ 1 b-tagged), and large missing transverse momentum, E_T^{miss}. Requiring large W transverse mass, M_T, removes most $t\bar{t}$ lepton + jets events. The dominant residual background is dileptonic $t\bar{t}$ where the second charged lepton is either lost, misidentified (as a jet), or is a hadronically decaying τ. Several variables have been designed to isolate such scenarios. For example, a hadronic m_{top} variable is useful as the dileptonic background does not have a hadronic top. To directly target a second lepton, M_{T2} variables are built such that kinematic maxima exist for dileptonic backgrounds, but not for the signal. In particular, M_{T2} variables are designed to target topologies in which a second lepton is part of the E_T^{miss} (aM_{T2}) and in which there is a hadronic τ among the list of jets (M_{T2}^τ). In addition to kinematic variables, a veto is constructed to reject isolated tracks characteristic of one prong τ decays and of electrons or muons that fail the lepton particle identification, thus failing the second lepton veto.

Three signal regions are constructed each for the tN and bC decays. The selections are categorized by successively tighter kinematic selections for larger splittings between m_{stop} and the neutralino/chargino masses. Of these six regions, five of them – the three bC signal regions and the two tightest tN regions – are each defined by a single set of cuts. Each of these signal regions has associated control and validation regions. The $t\bar{t}$ and W+jets normalizations are determined from fits in the corresponding dedicated control regions. See [1] for a complete description of the selections.

The final signal region is designed for the experimentally challenging *compressed* spectra in tN for which m_{stop} is only slightly more massive than $m_t + m_{\tilde{\chi}_1^0}$. Here, a two-dimensional *shape fit* is performed in the M_T, E_T^{miss} plane to take advantage of slight shape differences in kinematic distributions between the background and the signal. Figure 1 shows a pictorial representation of the SM predictions and observed counts in the two-dimensional shape fit plane. The shape is binned in three values of E_T^{miss} and four values of M_T. The region with a b-jet veto in the left plot of Fig. 1 is naturally enriched in W+jets and so acts as the W control region in the simultaneous fit. Likewise, the lowest M_T bin without the b-jet veto is dominated by $t\bar{t}$. The intermediate $90 < M_T/\text{GeV} < 120$ regime still has a low signal/background and has less weight in determining the $t\bar{t}$ and W + jets normalizations so can serve as a 'validation' region. This pattern is seen most clearly in the right plot of Fig. 1, which shows the predicted background composition in the bin of highest E_T^{miss}.
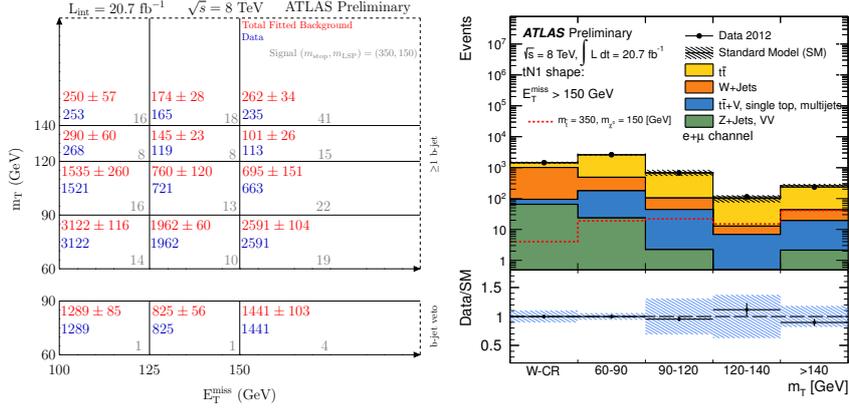
Figure 1: Schematic setup of the shape fit (left) and the post-fit composition in the highest E_T^{miss} bin (right).
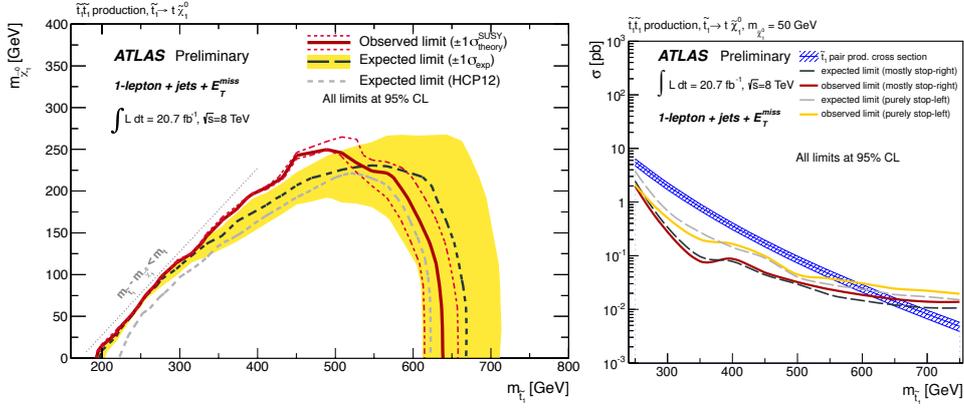

Figure 2: 95% CL exclusion for tN (left) and 95% excluded cross section at fixed $m_{\tilde{\chi}_1^0}$ (right).

3. Results and Conclusions

No evidence has been found for weak-scale top squarks. Figure 2 shows a selected set of exclusion results. The left plot of Fig. 2 contains the exclusion limits for the tN scenario; the increase in luminosity with respect to the previous 13 fb^{-1} limits allowed for slightly tighter kinematic cuts leading to a stronger limit at high $m_{\tilde{t}}$ and the shape fit pushed the limit at lower $m_{\tilde{t}}$ toward the compressed region. The right plot in Fig. 2 shows the effect of the $\tilde{t}_L - \tilde{t}_R$ mixing on the exclusion. A mostly ($\sim$70%) $\tilde{t}_R$ mixing is the baseline. The field content determines the top polarization, affecting lepton and neutrino momenta, resulting in a 75 GeV difference in limits. Regardless of mixing, the bounds for stops have been pushed to 600 GeV, within the context of simplified models, provided that the mass spectra are not too compressed. Probing TeV-scale stop masses is almost within reach as the parameter space for natural SUSY continues to shrink.

References

[1] ATLAS Collaboration, *Search for direct top squark pair production in final states with one isolated lepton, jets, and missing transverse momentum in $\sqrt{s} = 8$ TeV pp collisions using 21 fb^{-1} of ATLAS data*, ATLAS-CONF-2013-037, https://cds.cern.ch/record/1532431