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Search for supersymmetric partners of third-generation quarks in 139 fb^{-1} of *pp* collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

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This poster presents the latest results on searches for pair production of supersymmetric partners of the top and bottom quarks using the LHC proton-proton collision data, recorded by the ATLAS detector at a centre of mass energy of $\sqrt{s} = 13$ TeV from 2015 to 2018, corresponding to an integrated luminosity of 139 fb^{-1}. Three main analyses are presented; a search for top squark pair production in events with Z bosons, a search for bottom squark pair production in events with two Higgs bosons and a search for top squark pair production in events with a three body decay. The ATLAS Collaboration has also published new results which offer interpretations with third generation squarks and extend the current exclusion limits.

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Searches for third generation supersymmetric particles using LHC data recorded by the ATLAS detector [1], are presented. New results which offer interpretations with third generation squarks [2], [3] and extend the current exclusion limits have also been published by the ATLAS collaboration.

1. Search for top squarks pair production in events with Z bosons

A search for top squark pair production in events with large missing transverse momentum and a same-flavour opposite-sign lepton pair consistent with originating form the decay of a Z boson [4] is presented. Two different simplified models represented by the Feynman diagrams of Figure 1 are used to interpret the results.

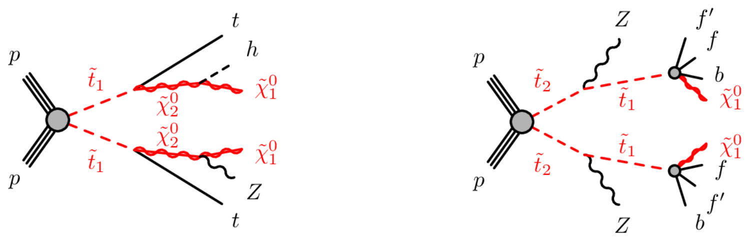

Figure 1: Feynman diagrams for the simplified models one (left) and two (right) targeted by the search for top squark pair production in events with Z bosons.

Model one (Figure 1 left) features pair production of the lighter of the two top squark mass eigenstates ($\tilde{t}_1$). In this model the $\tilde{t}_1$ decays to a top quark (t) and the second lightest neutralino ($\tilde{\chi}_2^0$), and the $\tilde{\chi}_2^0$ decays either to a Z or Higgs boson and the lightest neutralino ($\tilde{\chi}_1^0$) with 50% branching ratio each. Model two (Figure 1 right) features pair production of the heavier of the two top squark mass eigenstates ($\tilde{t}_2$). In this model the $\tilde{t}_2$ decays to a $\tilde{t}_1$ and a Z boson, with the $\tilde{t}_1$ subsequently decaying to an off-shell top quark (t^*) and a $\tilde{\chi}_1^0$ with a 100% branching ratio. The mass difference between the $\tilde{t}_1$ and the $\tilde{\chi}_1^0$ is set to 40 GeV and the top quark is assumed to undergo a 4-body decay to a b quark and two fermions from the decay of the off-shell W boson (W^*).

Two signal regions (SRs) are defined for each model (1 and 2), optimised for small (A) and large (B) mass splittings between the $\tilde{\chi}_2^0$ and the $\tilde{\chi}_1^0$ in model one and between the $\tilde{t}_1$ and the $\tilde{\chi}_1^0$ for model two, resulting in the four (binned) SRs (SR1A, SR1B, SR2A and SR2B) shown in Figure 2. The SR1A which targets model one at small mass splitting is divided in 4 bins by $E_{\mathrm{T}}^{\mathrm{miss}}$, the SR1B and the SR2B are divided by $E_{\mathrm{T}}^{\mathrm{miss}}$ and dilepton p_{T} also in 4 bins while SR2A is defined by a single bin. The final state is characterised by having at least 3 leptons, large $E_{\mathrm{T}}^{\mathrm{miss}}$ and at least 3 to 5 jets depending on the SR. Pair production of a top quark in association with a Z boson (ttZ) is the main background with some minor contributions from multi-boson (mainly WZ) events and $t\bar{t}$ events with "fake" (misidentified jets) or non-prompt (FNP) leptons. Control regions are defined to normalise the ttZ and multi-boson backgrounds, while a data-driven method is used to estimate the number of events with FNP leptons. No excess of events above the expectation from the SM prediction is observed and exclusion limits are placed on the masses of the $\tilde{t}_1$, $\tilde{t}_2$, $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$, as shown in Figure 3.

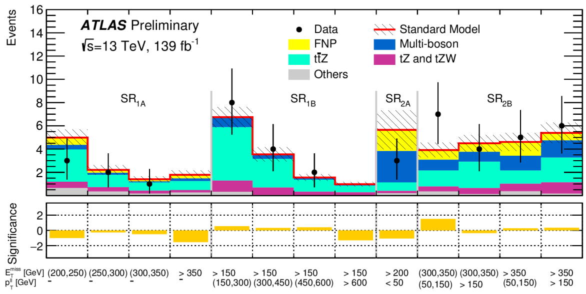

Figure 2: Comparison of the observed and expected event yields in the different (binned) SRs [4].

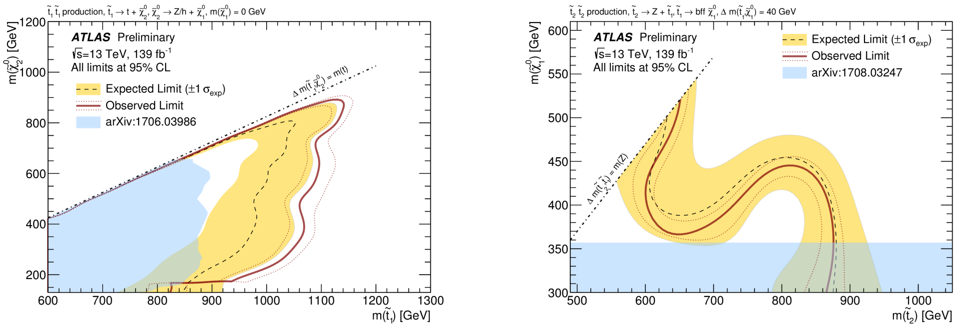

Figure 3: Exclusion limits for the simplified model one (left) and two (right) in the search for top squark pair production in events with Z bosons [4].

2. Search for bottom squark pair production in events with Higgs bosons

This analysis presents a search for bottom squark ($\tilde{b}$) pair production [5] where each $\tilde{b}$ is assumed to decay to a bottom quark (b) and a $\tilde{\chi}_2^0$. Subsequently, each $\tilde{\chi}_2^0$ is assumed to decay to a $\tilde{\chi}_1^0$ and a Higgs boson (Figure 4) . Two classes of models are targeted, one where the $\tilde{\chi}_2^0$ mass is varied and the $\tilde{\chi}_1^0$ has a fixed mass of 60 GeV and the other where the mass difference between the $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^0$ is $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = 130$ GeV, following an on-shell decay of the Higgs boson. The analysis requires at least 3 b-jets, large missing transverse energy and zero leptons.

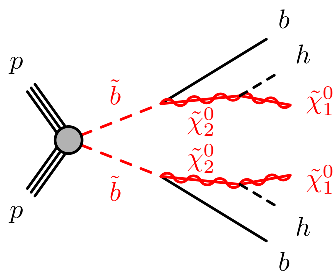

Figure 4: Feynman diagram for bottom squark pair production in events with Higgs bosons.

Three (binned) SRs are defined to target different kinematic regions. SR A requires high p_{T}

b-jets from the $\tilde{b}$ decay and is divided in three bins using the effective mass (m_{eff}). The other two SRs target compressed scenarios with soft b-jets from the $\tilde{b}$ decay, where SR B is sensitive to an on-shell Higgs model while SR C is sensitive to the off-shell model and therefore also requires soft b-jets from the Higgs bosons. The main background contamination for SRs A and B is top quark pair production ($t\bar{t}$), while SR C has Z+jets as main background with some contribution of top-related processes ($t\bar{t}$ and single top). Control regions are defined to normalise these backgrounds in each SR. No excess above the SM expectation is observed and bottom squarks with masses up to 1.45 TeV are excluded, as shown in Figure 5.

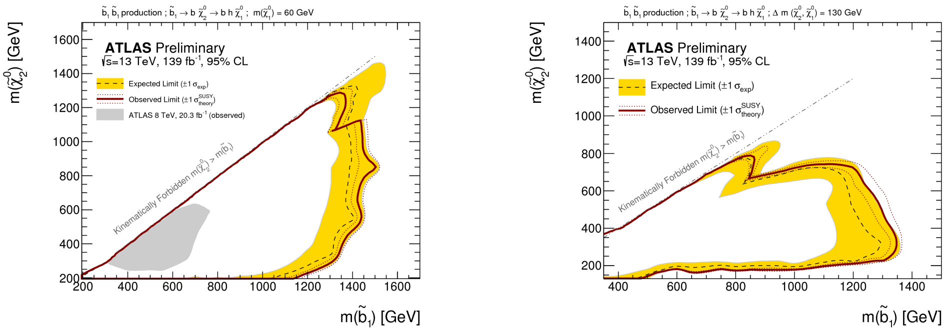

Figure 5: Exclusion limits for bottom squark pair production with a fixed LSP mass of 60 GeV (left) or on-shell Higgs (right) [5].

3. Search for top squark pair production in events with one lepton

A search for top squark pair production in events with one lepton is presented [6]. The models targeted are those where the top squark undergoes a 3-body decay to a b-quark, a W boson and a $\tilde{\chi}_1^0$ as shown in Figure 6. The final state is characterised by having at least 4 jets, large $E_{\text{T}}^{\text{miss}}$ and one lepton.

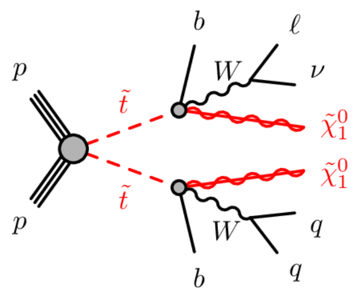

Figure 6: Feynman diagrams for top squark pair production in three body decay.

Two different analysis techniques are employed to define a single (binned) SR. Events are first selected by applying a set of cuts which ensures that they possess similar characteristics to the signal sample. To further discriminate between signal and background, a machine learning classifier consisting of a recurrent neural network combined with a shallow neural network (NN) is used. The output of the NN, shown in Figure 7(left) is used to define a CR, a validation region (VR) and a SR divided in ten bins. The main background contamination in the SR is produced by di-leptonic $t\bar{t}$ events. No excess above the SM background prediction is observed and top squarks with masses up to 720 GeV are excluded for neutralino masses up to 580 GeV, as shown in Figure 7(right).

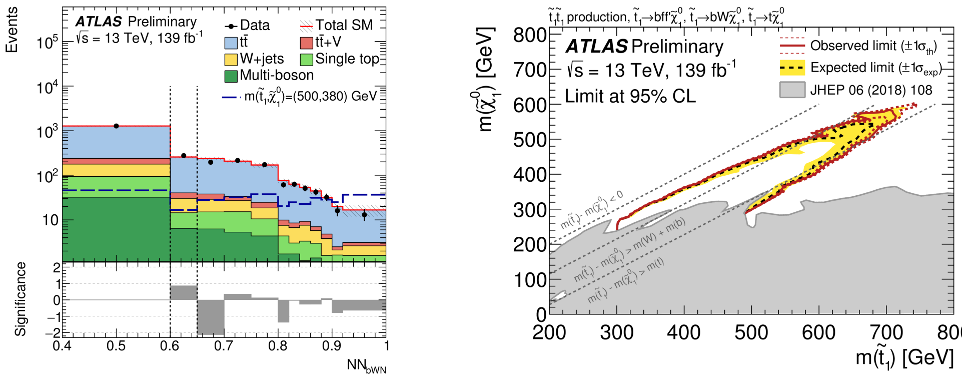

Figure 7: CR, VR, and binned SR (left) and exclusion limits for top squark pair production in events with one lepton and a three body top-quark decay [6].

References

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

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[6] ATLAS collaboration, *Search for direct top squark pair production in the 3-body decay mode with a final state containing one lepton, jets, and missing transverse momentum in $\sqrt{s} = 13$ TeV pp collision data with the ATLAS detector*, ATLAS-CONF-2019-017, CERN, Geneva, https://cds.cern.ch/record/2676594.