PROCEEDINGS OF SCIENCE

Searches for direct pair production of third generation squarks in final states with no leptons with the ATLAS detector

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Naturalness arguments favour supersymmetric partners of the third generation quarks with masses not too far from those of their Standard Model counterparts. Two ATLAS searches for direct top and bottom squark pair production in final states containing no leptons are reported. In 36 fb^{-1} of *pp* collisions data collected during the LHC Run 2, no evidence of a signal is found and limits are placed on the mass of supersymmetric particles.

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1. Introduction

Supersymmetry [1] is an extension of the Standard Model (SM) which introduces for each known particle a partner with the same quantum numbers except spin and mass. It is well motivated as it can potentially solve the hierarchy problem, provide a candidate particle for Dark Matter, and allow gauge coupling unification at high energy. However, no experimental evidence of the supersymmetric partners has been found yet.

Naturalness considerations suggest that the mass of the partners of third generation quarks, the bottom and top squarks, be of the same order of magnitude of the scale of electroweak symmetry breaking. The second run of the Large Hadron Collider (LHC), with its increased center of mass collision energy of 13 TeV and luminosity, potentially allows to probe the existence of these particles over a large fraction of the theoretically motivated mass range. Here the results of two analyses of the LHC data performed by the ATLAS collaboration [2] are presented, one targeting the production of top squarks and the other the production of bottom squarks. Both searches are based on the data collected in 2015 and 2016, for a total integrated luminosity of 36.1 fb^{-1}.

2. Search for a top squark

In the framework of R-parity conserving Supersymmetry, the top squark $\tilde{t}$ is produced in pairs, and decays to the lightest supersymmetric particle, which is stable and it is assumed here to be the lightest neutralino $\tilde{\chi}_1^0$. The direct decay $\tilde{t} \to t\tilde{\chi}_1^0$ and the decay through the lightest chargino $\tilde{t} \to \tilde{\chi}^{\pm}b \to Wb\tilde{\chi}_1^0$ are considered in the ATLAS search reported here [3]. The final state includes the undetected weakly interacting neutralinos, two b-quarks, and two W bosons. The event selections target the case where both W bosons decay into quarks.

Candidate signal events must have a missing transverse momemtum $E_{\mathrm{T}}^{\mathrm{miss}}$larger than 250 GeV, and four jets. Further alternative selections are then required, each targeting different signal masses and decays. The so-called SRA and SRB selections target the direct decay with a large mass difference $\Delta m = m(\tilde{t}) - m(\tilde{\chi}_1^0)$. Tight kinematic cuts are applied, including the requirement that the mass of the two leading large-radius reconstructed jets be consistent with them being produced by the hadronic decay of a boosted W boson or top quark. SRC targets events with Δm just above the top quark mass, and use the recursive Jigsaw reconstruction techniques [4] to select the kinematics expected for events produced by a pair of two top squarks recoiling against initial state radiation. SRD targets the decay through charginos. A fifth selection SRE targets gluino pair production which decays to a top quark, a neutralino, and low momemtum particles, yielding a final state similar to that of top squark production.

The contribution of SM background processes to the selected event sample is estimated using a mixture of data control samples and Monte Carlo simulated samples. Top pair production, single top, and W+jets are normalized in a control selection (CR) requiring one electron or muon and requirements on jets and $E_{\mathrm{T}}^{\mathrm{miss}}$mimicking those of the signal selection, but loosened to have a large enough sample of background events. The $Z(\nu\nu)$+jets process, which is the main contributor in SRA and SRB, is normalized in a sample with two electrons or muons consistent with a Z boson decay, while $tt\gamma$ candidate events are used to constrain the normalization of the related ttW and ttZ processes.

A good agreement between the data and the estimated background is found in all the signal selections (Figure 1). As a results, limits are placed on the masses of supersymmetric particles. These are displayed [1] in Figure 2 as a function of the top squark and neutralino masses, under the assumption that the direct decay is the only decay mode of the top squark. Limits considerably stronger than those placed in Run 1 searches are set. The lower limit on the top squark mass is 1000 GeV for a light neutralino, while for $\Delta m \simeq m_t$ the range 235 GeV $< m(\tilde{t}) <$ 590 GeV is excluded.

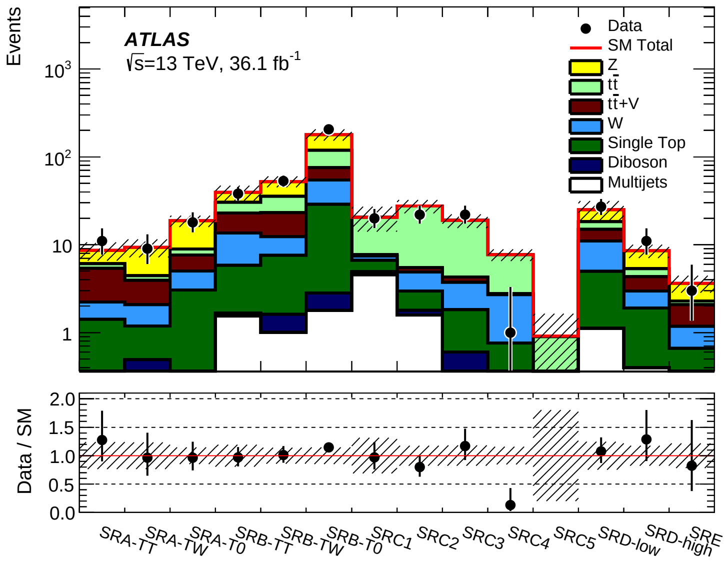

Figure 1: Yield for the signal region of the top squark search. The stacked histogram shows the SM prediction, with the hatched band being the total uncertainty on that [3].

3. Search for a bottom squark

The ATLAS search reported here [5] targets a bottom squark which decays directly into the lightest neutralino and a b quark. The search for this scenario requires two b-tagged jets, large transverse missing momentum, and no electrons or muons. Three alternative selections are optimized for different ranges of the mass of the supersymmetric particles. The large $\Delta m = m(\tilde{b}) - m(\tilde{\chi}_1^0)$ case selects events with large values of the cotransverse mass [6]. The intermediate Δm selections drops this requirement in favour of a selection on the minimum transverse mass between the four leading jets and the missing transverse momentum. The low Δm selection targets events with a bottom squark pair recoiling against an high-p_{T} ISR jet : it requires both the transverse missing momentum and the p_{T} of the leading jet to be larger than 500 GeV, and also the invariant mass of the two b-jets to be larger than 200 GeV.

The main backgrounds are estimated with MonteCarlo and the use of normalization factors derived from the data event count in appropriate control selections. The $Z(\nu\nu)$+jets background is dominant and it is normalized using a $Z(\ell\ell)$+jets control sample.

[1] All limits are quoted at 95% confidence level.

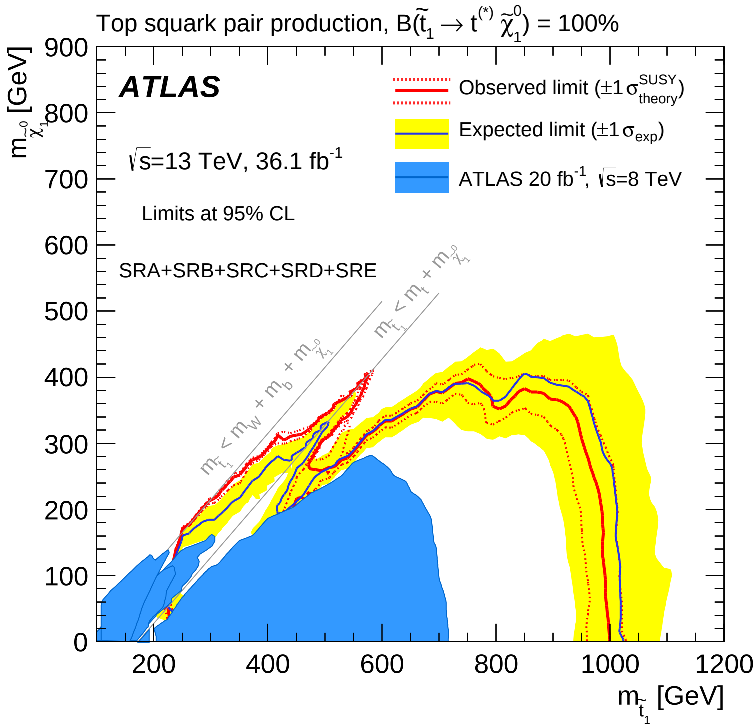

Figure 2: Observed (red solid line) and expected (blue dashed line) exclusion limits as a function of the top squark and lightest neutralino masses in the scenario where both top squarks decay via $\tilde{t} \to t\tilde{\chi}_1^0$ [3]. Observed limits from all the ATLAS third generation squark searches performed with Run 1 data are shown as the blue filled area.

Data are found to be in agreement with the background prediction in all signal selections. The limits derived on the bottom squark direct decay model are shown in Figure 3.

4. Conclusions

Two analyses searching for the direct production of third generation squarks in the data collected by ATLAS during the LHC Run2 have been presented. No excess over the Standard Model background expectation has been found. Limits have been placed on the mass of the supersymmetric particles, which are considerably more stringent than those available after the analysis of Run 1 data.

References

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[3] ATLAS Collaboration, *Search for a scalar partner of the top quark in the jets+E_T^{miss} final state at $\sqrt{s} = 13$ TeV with the ATLAS detector*, submitted to *JHEP*, arXiv:1709.04183.

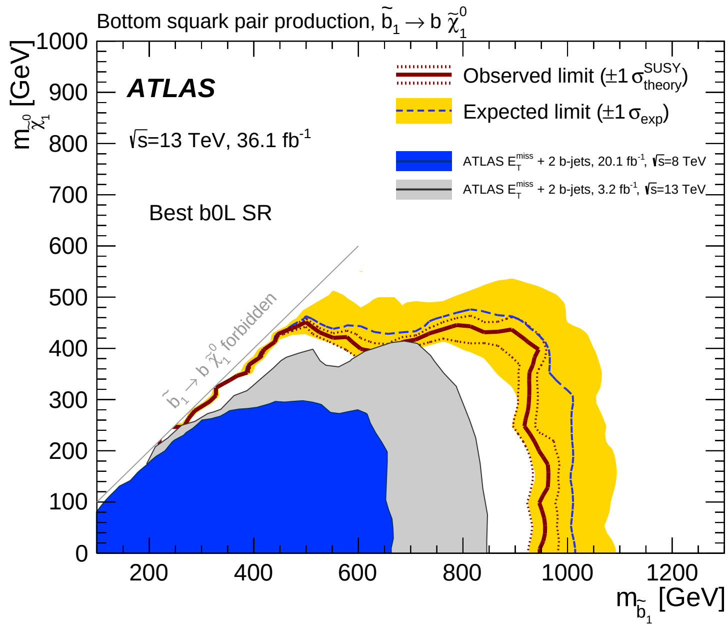

Figure 3: Observed (red solid line) and expected (blue dashed line) exclusion limits as a function of the bottom squark and lightest neutralino masses in the scenario where both bottom squarks decay via $\tilde{b} \rightarrow b\tilde{\chi}_1^0$ [5]. Observed limits from the searches performed by ATLAS with the Run 1 data and the Run 2 dataset collected in 2015 are shown as blue and grey filled areas, respectively.

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