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Search for squarks and gluinos in final states with leptons or no leptons, with the ATLAS detector

PoS(DIS2017)265

Danijela Bogavac on behalf of the ATLAS Collaboration
Ludwig-Maximilians-University Munich
E-mail: danijela.bogavac@cern.ch

Weak scale supersymmetry is one of the best motivated and studied extensions of the Standard Model. This talk summarises recent ATLAS results on searches for supersymmetric squarks and gluinos, including third generation squarks produced via the decay of gluinos. The searches involved final states containing jets (possibly identified as coming from b-quarks), missing transverse momentum and leptons. Results using collision data from the LHC Run 2 will be shown.

XXV International Workshop on Deep-Inelastic Scattering and Related Subjects
3-7 April 2017
University of Birmingham, UK

1. Introduction

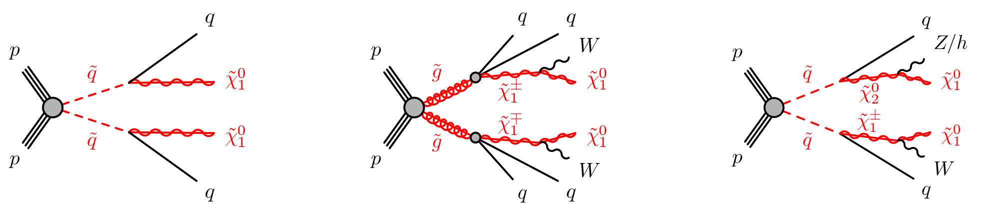
Supersymmetry [1, 2] (SUSY) is one of the best motivated extensions of the Standard Model (SM) and predicts for each SM particle the existence of supersymmetric partner particles (sparticle) differing by half a unit of spin. The partner particles of SM fermions (quarks and leptons) are the scalar squarks ($\tilde{q}$) and sleptons ($\tilde{l}$). In the boson sector, the supersymmetric partner of the gluino is the fermionic gluino ($\tilde{g}$). If strongly interacting supersymmetric particles are present at TeV-scale, then such particles could be produced in the 13TeV collisions by the Large Hadron Collider (LHC).

ATLAS [3] developed a broad and systematic search program for supersymmetric particles during LHC Run I. Unfortunately no significant evidence for beyond Standard Model (BSM) physics was found. In LHC Run II the higher centre-of-mass of 13 TeV offers a large increase in the production cross-section of squarks and gluinos, thus the first searches to take advantage of this new dataset are those focusing on squark and gluino production. The searches presented here use 36.1 fb^{-1} of proton-proton collision data, recorded in 2015 and 2016.

Although the SUSY search program targets a wide range of final states and signal scenarios, the general analysis strategy follows a similar structure for all analyses considered. Signal regions (SR) are defined based on properties of the signal kinematics. Usually several SRs are designed to cover as much phase-space as possible. Control regions (CR) are constructed to be dominated by the background process of interest. In these CRs the relevant background processes are normalised to data. Minor backgrounds are directly taken from MC simulation. The background estimates are cross-checked in dedicated validation regions (VRs).

2. Inclusive 0-lepton analysis

This analysis [4] considers final states with jets and large missing transverse momentum (E_T^{miss}), but without leptons. Examples of SUSY signal topologies probed by such a search can be seen in Figure 1, with squarks or gluinos being pair-produced and subsequently undergoing either direct (a) or cascade (b, c) decays to the stable lightest supersymmetric particle (LSP). In



(a) (b) (c)

Figure 1: The decay topologies of squark-pair production and gluino-pair production with (a) direct or (b, c) one-step decays of squarks or gluinos as considered in the search in Ref. [4].

order to cover as much phase-space as possible, the analysis uses two complementary techniques to isolate signal like events. The m_{eff}-based part of the analysis has 24 SRs defined using the effective mass ($m_{eff} = \sum_{i=1}^{n} |\vec{p}_T^{\,i}| + E_T^{miss}$) as a final discriminanting variable. Among those, SRs with >= 2 - 5 jets target events where squarks or gluinos undergo direct decays, whereas SRs with higher jet multiplicity (>= 5 - 6 jets) are used to isolate scenarios with cascade decay chains, such

as shown in Figure 1 (b, c). SRs requiring the same jet multiplicity are distinguished by increasing the threshold on m_{eff} and $E_T^{miss}/m_{eff}(N_j)$ or $E_T^{miss}/\sqrt{H_T}$ where $m_{eff}(N_j)$ is defined to be the scalar sum of the transverse momenta of the leading N_j and E_T^{miss}, while H_T is defined as the scalar sum of the transverse momenta of all jets. Dedicated SRs are designed for one-step decay models to improve the sensitivity in cases where the $\tilde{\chi}_1^{\pm}$ or $\tilde{\chi}_2^0$ are nearly degenerate in mass with the squarks or the gluinos (Figure 1 c). These SRs with additional requirements on the mass of large-radius jets select the candidate decaying to W or Z bosons hadronically. Due to the small mass difference between the parent SUSY particles and intermediate $\tilde{\chi}_1^{\pm}$ or $\tilde{\chi}_2^0$ particle, these events can have a significant transverse momentum and appear as a single high-mass jet. The second part of this analysis uses the so-called recursive jigsaw reconstruction (RJR) techniques to define 19 SRs. For topologies such as those in Figure 1 (a), the recursive jigsaw variables allow to enhance the sensitivity to compressed regions of the kinematic phase-space, where the squark and LSP masses are very close. The largest SM backgrounds in both searches presented here are: Z+jets, W+jets, $t\bar{t}$ and multi-jet production. Each of these primary backgrounds are estimated using dedicated CRs with isolated leptons for $t\bar{t}$ and W+jets and with isolated photons for Z+jets. The $t\bar{t}$ and W+jets CRs are divided by enforcing orthogonality by vetoing events containing b-tagged jets, respectively. In case of multi-jet background, the estimate is based on the data-driven method.
The observed data agree with the SM background expectation in all SRs as shown in Figure 2.

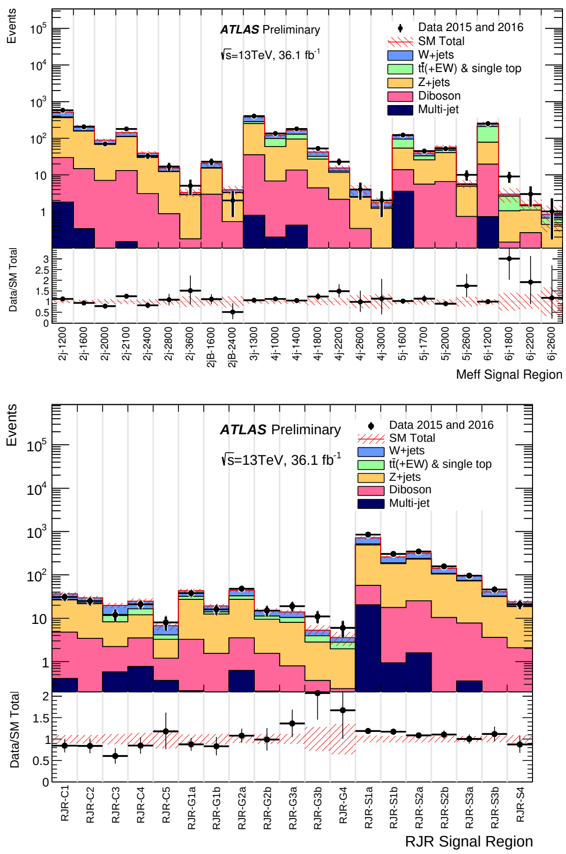
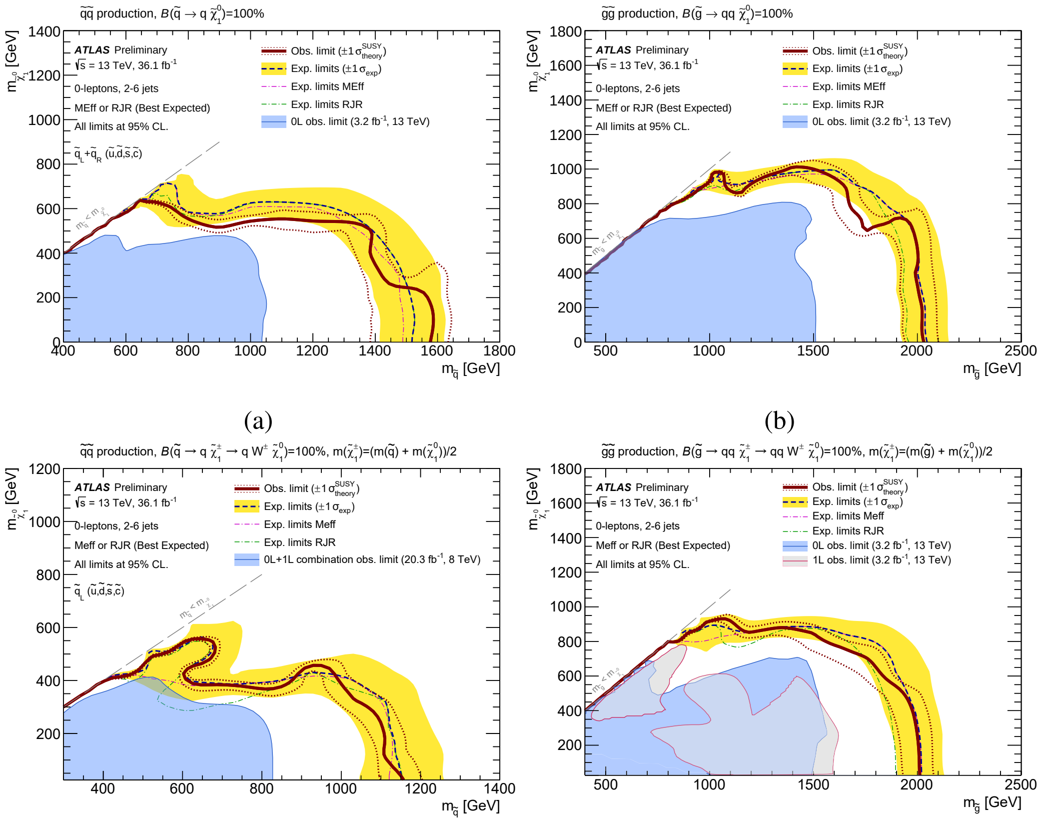


Figure 2: Data and expected background yields in the SRs in the m_{eff}-based (top) and RJR-based (bottom) searches, [4].

This analysis excludes squark masses up to ~ 1.6 TeV and gluino masses up to ~ 2.0 TeV at 95% confidence level (CL) as shown in Figure 3.

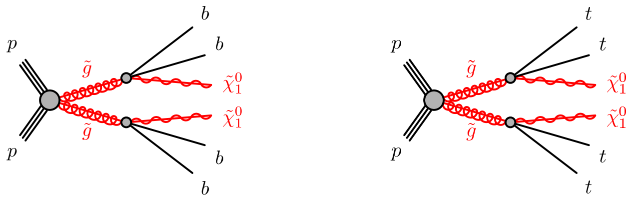


(a) (b) (c) (d)

Figure 3: Exclusion limits at 95% CL for the simplified models with direct (a, b) and cascade (c, d) squark-pair (a, c) and gluino-pair (b, d) production [4].

3. Multi b-jets analysis

Events with jets, one or no lepton and missing transverse momentum are also studied with a b-tag requirement in order to essentially remove the SM multijet background from the SRs. The search [5] presented here targets two different simplified models. In the Gbb (Gtt) model, presented in Figure 4a (4b), each gluino undergoes an effective three-body decay $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ ($\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$) via off-shell sbottom (stop) quarks, with a branching ratio of 100 %. Two different analysis strategies are followed: the cut-and-count and the multi bin approach. In the cut-and-count analysis, 10 partially overlapping single-bin SRs maximise the expected discovery power using requirements on the b-jet multiplicity, $m_{\rm eff}$, $m_{\rm T}$ and large-R jet mass. These SRs target compressed, intermediate and large mass split between the sbottom/stop and LSP. In the multi bin analysis, the non-overlapping SRs are optimized ranging from low to high $m_{\rm eff}$ and $N_{\rm jets}$ to cover a board range of mass spectra. Those SRs are combined to improve the exclusion limits on the signal models targeted.



(a) (b)

Figure 4: The decay topologies in the (a) Gbb and (b) Gtt simplified model, as considered in the search in Ref [5].

The dominant background in all these regions is the associated production of a $t\bar{t}$ pair together with heavy and light flavour jets. While the normalisation of non-$t\bar{t}$ backgrounds is taken from theory prediction, the $t\bar{t}$ normalization for each individual SR is extracted from a data CR that has comparable background composition and kinematics. The observed data in all SRs are in good agreement with the SM background prediction as shown in Figure 5.

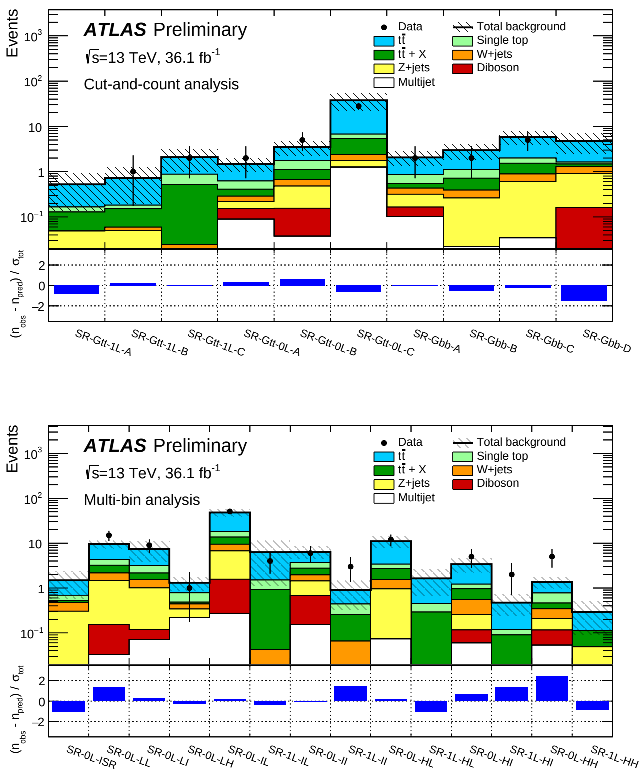
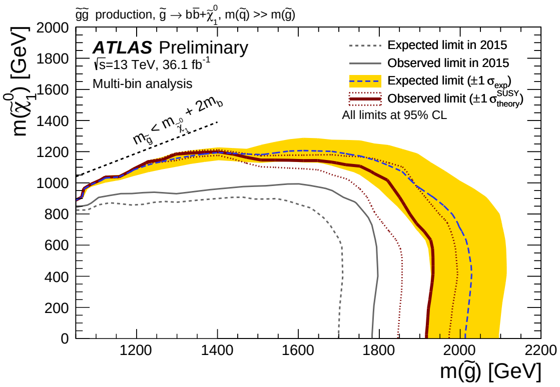
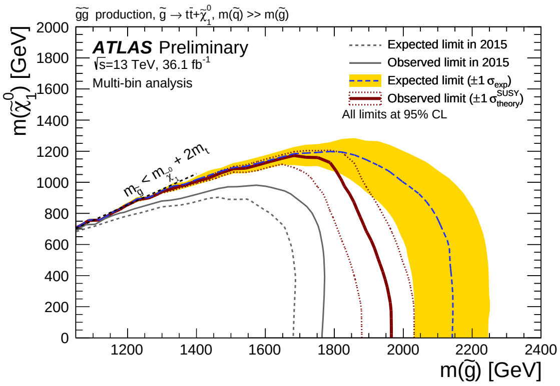


Figure 5: Data and background estimates in the SRs in the cut-and-count (top) and multi-bin (bottom) analyses, [5].

Exclusion limits are set on gluino and LSP masses, as shown in Figure 6. For LSP masses below approximately 300 GeV, gluino masses of less than 1.92 TeV and 1.97 TeV are excluded at 95% CL for the $\tilde{g} \to b\bar{b}\tilde{\chi}_1^0$ and $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$ models, respectively.



(a)



(b)

Figure 6: Exclusion limits at 95% CL for the simplified models $\tilde{g} \to b\bar{b}\tilde{\chi}_1^0$ (a) and $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$ (b), [5].

4. Conclusion

The first SUSY searches with a 36.1 fb^{-1} of proton-proton collision data target strongly produced squarks and gluinos. No significant excess is observed beyond SM expectation in the analyses presented. The ATLAS collaboration is looking forward to analyse the full Run II dataset, as well as to analyse other signatures.

References

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