PROCEEDINGS OF SCIENCE

Search for squark and gluino production in leptonic final states with the ATLAS detector

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Weak scale supersymmetry is one of the best motivated and studied extensions of the Standard Model. The recent increase in the center of mass energy of the Large Hadron Collider proton-proton collisions gives an opportunity to extend the sensitivity to production of supersymmetric particles. This talk summarises recent ATLAS results on searches for supersymmetric squarks and gluinos, including third generation squarks produced directly or via decay of gluinos, with the data collected in 2015 ($3.2\,\mathrm{fb}^{-1}$) from proton-proton collisions at a center of mass energy of 13 TeV. The searches involve final states containing jets (possibly identified as coming from b-quarks), missing transverse momentum and leptons.

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1. Introduction

Supersymmetry is one of the best motivated Beyond Standard Model theories [1]. This theory predicts a supersymmetric partner for each Standard Model particle, potentially discoverable with the data collected by the ATLAS detector [2]. Between 2012 and 2015, the center of mass energy of the proton-proton collisions produced by the LHC has increased from 8 to 13 TeV, raising the production cross section of heavy particles. For example, the gluino pair production cross section for assumed gluino mass of 1.5 TeV increased by a factor 46. It is then possible to discover strongly produced supersymmetry beyond Run-1 $(2010-2012)$ limits already with the 2015 data ($3.2\,\mathrm{fb}^{-1}$). Even though the simplest and kinematically favoured decay modes of squarks and gluinos are $\widetilde{q} \rightarrow q\widetilde{\chi}_1^0$ and $\widetilde{g} \rightarrow qq\widetilde{\chi}_1^0$ [1], decays involving leptons in the final states are also relevant in some supersymmetric models. Such final states benefit from lesser Standard Model backgrounds and are therefore complementary with fully hadronic final states. If R-parity is conserved, supersymmetric processes would produce a large missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$), a large number of ($b$-)jets and generally boosted objects. It is therefore possible to define signal regions enriched in hypothetical supersymmetric processes using $E_{\mathrm{T}}^{\mathrm{miss}}$, the number of ($b$-)jets, variables defined as the scalar sum of the reconstructed objects and transverse masses (depending on the SUSY process). The contribution from irreducible background is generally estimated using Monte Carlo simulations. If the considered background is abundant enough, the estimate is scaled using the ratio between Monte Carlo predictions and data measured in a Control region. The control regions are usually defined reverting two relevant discriminating variables to get a pure background sample with large enough statistics[2]. When the background is too rare, this strategy does not provide any improvement and the Monte Carlo predictions are simply checked in dedicated validation regions. Some backgrounds normally rejected by the definition of the signal regions can still contribute to the signal regions due to mis-measurements. For example $Z+$jets processes, normally rejected with a cut on $E_{\mathrm{T}}^{\mathrm{miss}}$, can contribute to the signal regions if the missing transverse energy is overestimated. Such instrumental backgrounds are estimated using data driven techniques as their modelling is usually not accurate enough. In these proceedings, three inclusive searches for squarks and gluinos and two searches for direct stop production using $3.2\,\mathrm{fb}^{-1}$ of data at $\sqrt{s} = 13$ TeV collected by the ATLAS detector are presented.

2. Inclusive squarks and gluinos searches

2.1 One lepton, jets and missing transverse energy

In this analysis [3], six signal regions have been defined to search for $\widetilde{g} \rightarrow qq\widetilde{\chi}_1^{\pm} \rightarrow qqW\widetilde{\chi}_1^0$ processes (see Figure 1, top left) for all possible mass configurations. Two signal regions consider soft electrons ($6-7$ GeV $< p_{\mathrm{T}} <$ 35 GeV) and the four others hard leptons ($p_{\mathrm{T}} >$ 35 GeV). The main backgrounds, $t\bar{t}$ and $W+$jets, have been estimated using control regions. As no significant excess has been found in the signal regions, exclusion limits on simplified models have been set,

[1] $\widetilde{\chi}_1^0$ being the lightest superpartner of the gauge bosons. This particle is generally stable if R-parity is conserved, being then a good candidate to dark matter.

[2] The two regions defined reverting only one variable are also used to check the modeling of the shapes of the discriminant variable to asses the validity of the extrapolation from the control region to the signal region.

as shown in Figure 2 (left). For example, simplified models with a gluino mass lower than 1.6 TeV and a neutralino mass lower than 200 GeV are excluded, which represents an improvement on the gluino mass limit of $\sim$ 200 GeV with respect to the Run-1 exclusions.

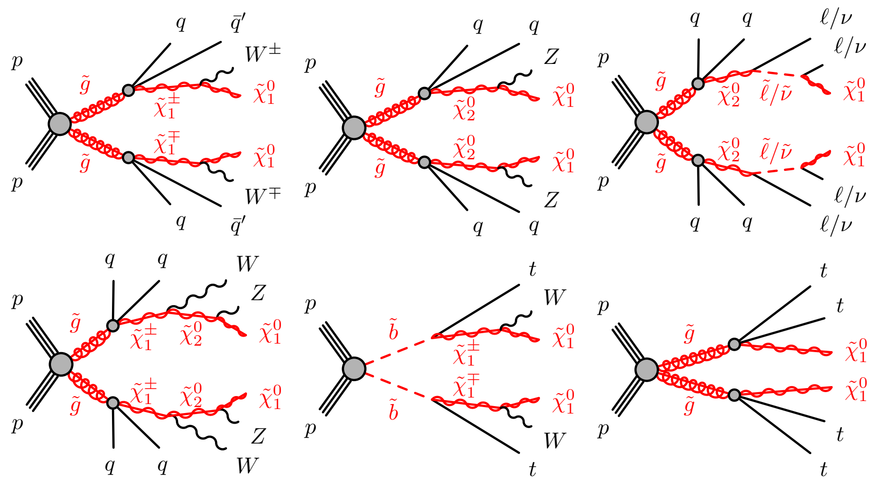

Figure 1: Supersymmetric processes searched for the inclusive squarks and gluinos analyses.

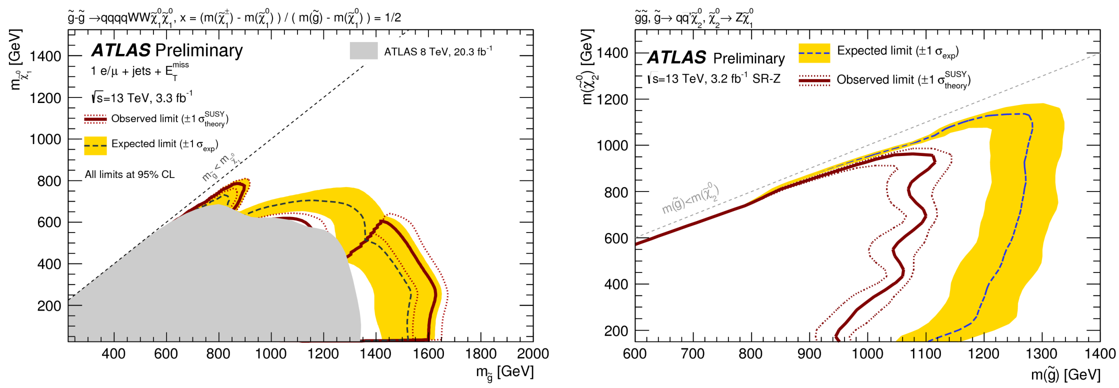

Figure 2: Exclusion limits on simplified models obtained with the one lepton analysis (left) and the $Z \to ll+$jets analysis as a function of the mass of the gluino ($m_{\tilde{g}}$), the mass of the lightest neutralino (left) and the second lightest neutralino (right). The blue dashed lines correspond to the expected exclusions and the yellow bands to a 1σ variation of the background systematics. The red thick lines and the dotted ones correspond to the observed limits and to the 1σ variations of the supersymmetric signal cross sections. The grey area shows the Run-1 combined exclusions limits. Sources [3, 4].

2.2 Leptonically decaying Z boson, jets and missing transverse energy

This analysis [4] searches for $\tilde{g} \to qq\tilde{\chi}_2^0 \to qqZ\tilde{\chi}_1^0$ (see Figure 1, top middle) and uses the signal region defined in Run-1 for which an excess of 3 (1.7) σ was observed in the ee ($\mu\mu$) channel [5][3]. The main background ($\sim 60\%$) arises from processes producing lepton pairs from W

[3] Not observed by CMS Collaboration

boson decays ($t\bar{t}$, WW, etc..) and is estimated using control regions. A Z/γ^* background is also present as $E_{\mathrm{T}}^{\mathrm{miss}}$ can be mis-reconstructed and is estimated using data driven techniques. Only a modest excess of $2.2\,\sigma$ has been observed, used to set limits on simplified models. As shown in Figure 2 (right), scenarios with a gluino mass lower than 1.1 TeV for a second lightest neutralino mass of 950 GeV are excluded.

2.3 Two same-sign leptons or three leptons and jets

This analysis [6] benefits from a low background contribution, allowing to use loose kinematic selections. This provides sensitivity to models with compressed mass spectra and to a wide variety of processes. Four signal regions have been defined depending on their (b-)jet multiplicity, focusing on different kinds of processes (see the top right and the three diagrams at the bottom of Figure 1). The main prompt backgrounds are $t\bar{t}Z$, $t\bar{t}W$ and $WZ+$jets. Processes producing opposite sign leptons such as $t\bar{t}$ can also contribute if the charge of a lepton is mis-measured or if an object is mis-identified as a prompt lepton. This detector background is estimated using data driven techniques. As no excess has been found in the signal regions, limits on simplified models have been set as shown in Figure 3. These limits complement the Run-1 ones for high neutralino masses, improving for example the gluino mass exclusions by 200 GeV for neutralinos masses 450 GeV $< m_{\tilde{\chi}_1^0} <$ 550 GeV in the $\tilde{g} \to qqWZ\tilde{\chi}_1^0$ models.

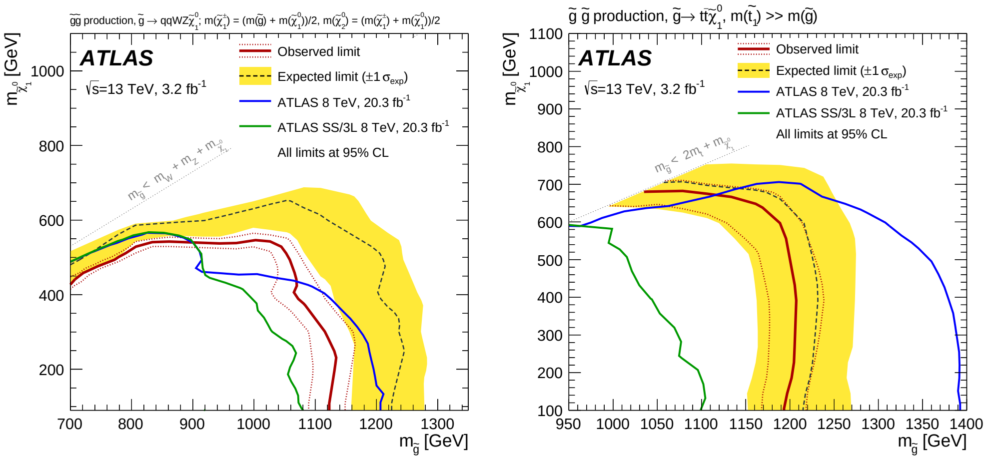

Figure 3: Example of exclusion limits obtained with the same-sign-leptons or three-leptons analysis on simplified models as a function of the mass of the gluino and the mass of the neutralino. The blue dashed lines and the yellow bands correspond to the expected limits, and the red lines to the observed ones. The green and the blue lines correspond to the limits obtained with the Run-1 same-sign-lepton analysis and with the Run-1 combination of all searches for supersymmetry. Source [6].

3. Direct top squark production

If supersymmetry solves the naturalness problem of the Standard Model, the mass of the stop should be at the electroweak scale [1], motivating dedicated searches for this particle. Two analyses are presented. The first one [7] uses final states with one lepton to probe for stop pair production with subsequent decay to top quarks and neutralinos (see Figure 4, left) and for gluino pair production with subsequent decay to top quarks, neutralinos and soft objects (see Figure 4, middle). The second one [8] considers final states with two leptons to probe for stop pair production with subsequent decays to soft b jets, W bosons and neutralinos (see Figure 4, right).

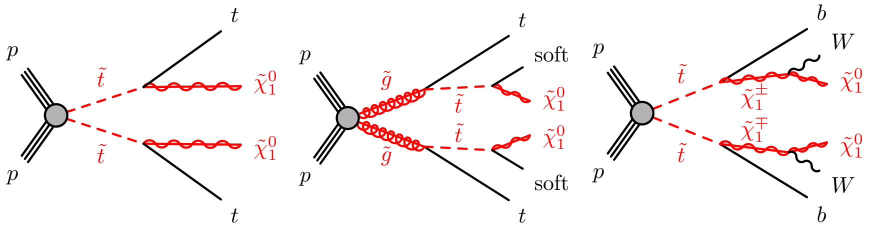

Figure 4: Processes searched by the direct stop analyses.

The most important background for these analyses arises from processes producing leptonically decaying W bosons, such as $t\bar{t}$, reduced by cuts on transverse masses. This background is estimated using Monte Carlo predictions scaled with control regions. Detector background arising from fake $E_{\mathrm{T}}^{\mathrm{miss}}$ and object mis-identified as prompt leptons are estimated using data driven techniques. As no significant excess has been found, exclusions limits have been set beyond Run-1 limits, as shown in Figure 5. For example, the largest gluino mass excluded for $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$ models with $\Delta m(\tilde{t}, \tilde{\chi}_1^0) = 5$ GeV has been increased by ~ 250 GeV.

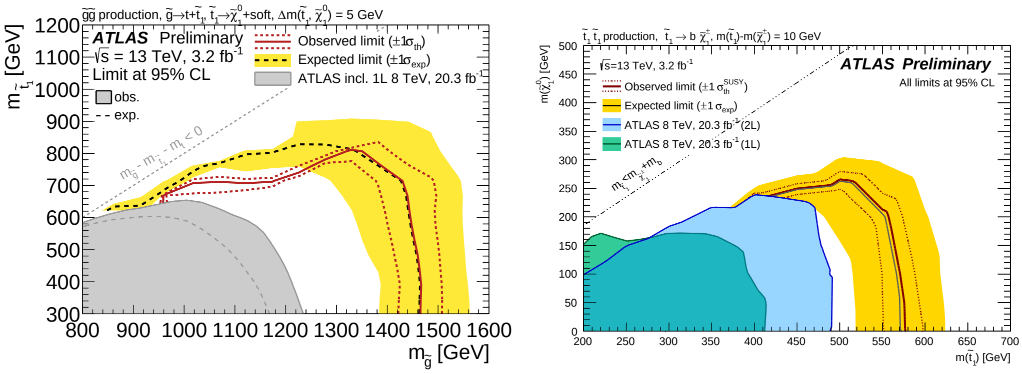

Figure 5: Example of exclusions limits obtained with the direct stop analyses as a function of the mass of the stop, the gluino and the neutralino. The grey area (left) correponds to the phase space excluded by the Run-1 analyses and the green and the blue areas (right) to the exclusion of the Run-1 one-lepton and the two-leptons analyses, respectively. Sources [7, 8].

4. Conclusion

Leptonic final states have been used by a full set of analyses to probe for squarks and gluino production with 2015 data. No excess has been found and exclusions beyond Run-1 limits have already been set by all analyses, complementing the results from the fully hadronic searches and allowing to cover a large spectrum of supersymmetric models.

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