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Inclusive searches for squarks and gluinos with the ATLAS detector

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This contribution summarises recent results on inclusive searches for first- and second-generation squarks and gluinos in events containing jets, missing transverse momentum and light leptons or taus. These searches have been performed using proton-proton collision data at $\sqrt{s}$ = 8 TeV recorded with the ATLAS detector at the Large Hadron Collider. No excess above the Standard Model background expectation has been observed and 95% confidence level visible cross section upper limits for new phenomena are set. Exclusion limits have been derived also for mSUGRA/CMSSM and GMSB models.

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1. Introduction

Supersymmetry (SUSY) is one of the most popular extensions of the Standard Model (SM) that provides solutions to some of its shortcomings, predicting a supersymmetric partner for each SM particle that differs in spin by $1/2$ from its SM counterpart.

Production cross-sections for gluinos or first- and second-generation squarks are large compared to third-generation squark production and to electroweak gaugino production. Therefore, searches for first- and second-generation squarks and gluinos are a critical component of the overall SUSY search strategy.

This contribution is focused on the latest results of inclusive searches for first- and second-generation squarks and gluinos using proton-proton collision data at a centre of mass energy of 8 TeV recorded with the ATLAS detector [1] at the Large Hadron Collider (LHC). The latest results from all analyses can be found on the ATLAS SUSY public results web page [2].

2. SUSY models

A possible scenario providing a mechanism of SUSY breaking is Gauge-Mediated Supersymmetry Breaking (GMSB)[3], where the gravitino ($\widetilde{G}$) is the Lightest Supersymmetric Particle (LSP) and escapes detection, leading to missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$) . The phenomenology of GMSB models is determined by the nature of the next-to-lightest supersymmetric particle (NLSP). At large values of $\tan\beta$, the $\widetilde{\tau}_1$ is the NLSP for most of the parameter space. Since the $\widetilde{\tau}$ decays involve τ leptons, analyses looking for final states rich in τ leptons are optimal to probe these scenarios. On the other hand, for a large part of the GMSB parameter space the NLSP is the lightest neutralino ($\widetilde{\chi}_1^0$). For a higgsino-like $\widetilde{\chi}_1^0$ the decay $\widetilde{\chi}_1^0 \to Z\widetilde{G}$ is enhanced. Therefore, final states with Z bosons are sensitive to other GMSB scenarios.

In recent years, the effort to formulate GMSB in a model-independent way has led to the development of general gauge mediation (GGM) (see Ref. [4] and references therein). Starting from GGM, it is possible to construct a natural gauge mediation (nGM) (see Ref. [5] and references therein) model. The parameters can be chosen so as to have a $\widetilde{\tau}$ NLSP, which again leads to final states with τ leptons.

Another SUSY scenario is the minimal supersymmetry gravity (mSUGRA) [6], which also predicts final states with τ leptons and final states with two leptons with the same electric charge (same-sign leptons) for a specific set of model parameters which takes into account the observation of a Higgs boson with a mass around 126 GeV.

Moreover, there are several simplified models (effective models built with the minimal particle content necessary to produce SUSY-like final states contributing to the channels of interest, parametrized directly in terms of the sparticle masses) leading to the creation of squarks and gluinos decaying to final states with two same-sign leptons:

- Gluino-squark (via W) describes $\widetilde{g}\widetilde{g}$ production with a subsequent gluino decay $\widetilde{g} \to q\widetilde{q} \to qq\widetilde{\chi}_1^{\pm} \to qqW\widetilde{\chi}_1^0$. The chargino mass is related to the LSP mass by $m_{\widetilde{\chi}_1^{\pm}} = 2m_{\widetilde{\chi}_1^0}$. Final states with four light jets, two W bosons, two LSPs and no b-jets are created.
- Gluino-squark (via sleptons) again considers $\widetilde{g}\widetilde{g}$ production. The gluino is assumed to decay with equal probability through $\widetilde{g} \to q\widetilde{q} \to qq\widetilde{\chi}_1^{\pm}$ or $\widetilde{g} \to q\widetilde{q} \to qq\widetilde{\chi}_2^0$. The $\widetilde{\chi}_1^{\pm}$ or the $\widetilde{\chi}_2^0$ decay to combinations of leptons, neutrinos, sleptons and sneutrinos, leading to final states that can

contain four light jets, up to four charged leptons and $E_{\mathrm{T}}^{\mathrm{miss}}$. The masses of the $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ are assumed to be equal to the average of the gluino and the LSP masses, and the slepton and sneutrino masses are assumed to be equal to the average of the $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ and the LSP masses. All three flavours of sleptons are considered and are degenerate in mass. Squark masses are assumed to be much larger than the gluino masses.

- Direct-squark (via sleptons) is similar to the Gluino-squark (via sleptons). However, in this case the first step is the direct pair production of $\tilde{q}$ (first and second generation only). Final states contain two light jets, up to four charged leptons and $E_{\mathrm{T}}^{\mathrm{miss}}$.

3. Analyses

3.1 Final states with at least one tau lepton, jets and large missing transverse momentum

Two mutually exclusive final states with taus and no electrons or muons are considered for this search, based on 21 fb^{-1} of $\sqrt{s}$ = 8 TeV proton-proton collision data. A signal region (SR) is optimised for the mSUGRA/CMSSM and GMSB scenarios requiring the presence of $\geq 1\tau$, while two SRs are defined requiring at least 2 τs: one oriented to the GMSB model and the other one to the nGM [5].

Table 1 summarises the expected number of background events and the number of observed events in data. No significant excess is observed in any of the signal regions, and so an upper limit at 95% Confidence Level (CL) is calculated on the observed event yield and the visible cross section (the product of cross section, branching fraction, acceptance and efficiency) from any scenario of physics beyond the SM .

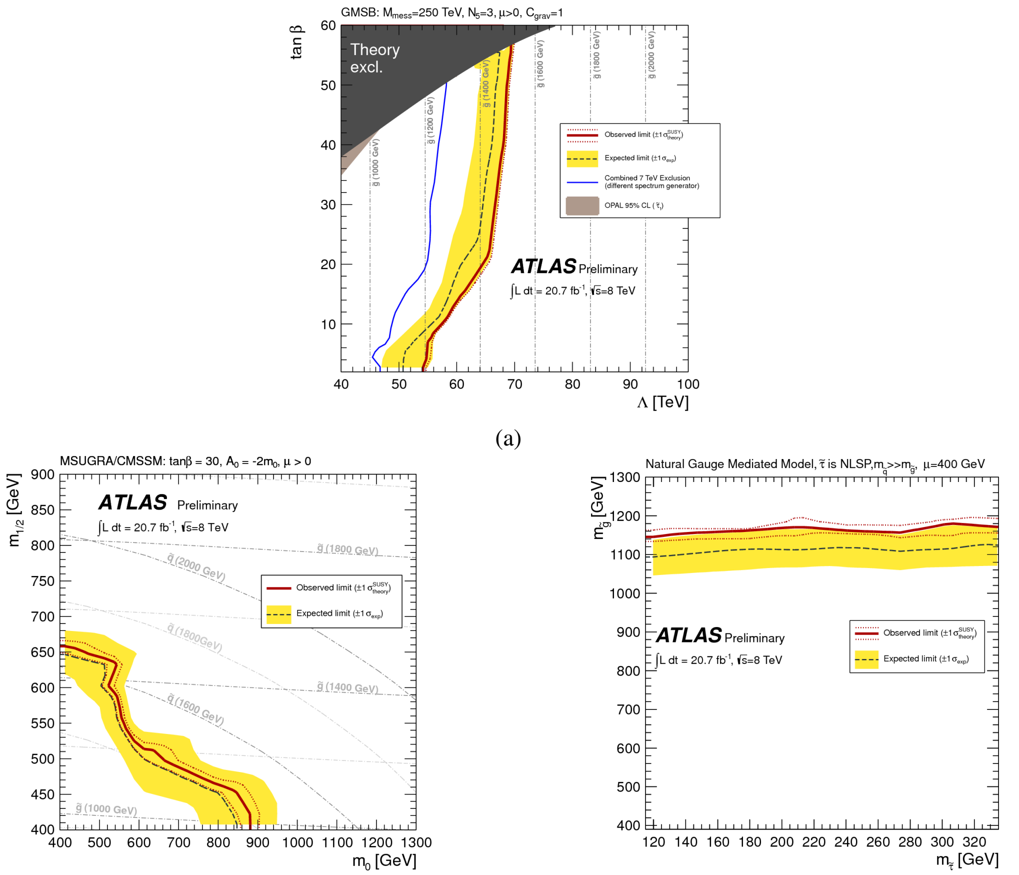
	1τ	2τ GMSB	2τ nGM
Total background	$4.9 \pm 1.5 \pm 1.3$	$7.2 \pm 1.3 \pm 1.6$	$3.5 \pm 1.1 \pm 1.9$
Data	3	5	1
Obs (exp) limit on signal events	$8.2(8.3^{+3.1}_{-2.2})$	$8.4(9.9^{+4.8}_{-3.3})$	$5.4(7.6^{+3.1}_{-2.2})$
Obs limit on Cross Section (fb)	0.40	0.41	0.26

Table 1: Number of expected background events and data yields and the resulting 95% CL limit on the number of observed (expected) signal events and on the visible cross sections from any new physics scenario for each of the final states. Where possible, the uncertainties are separated in statistical (first) and systematic (second). From [5].

The observed and expected limits on the GMSB model parameters Λ and $\tan\beta$ for the combination of the 1τ and 2τ channels are shown in Fig. 1a. The yellow band around the expected exclusion limit represents the 1σ statistical and systematic uncertainty on the expected background. The influence of the theoretical uncertainties on the signal cross section on the limit is indicated by the dashed red lines around the observed limit. Figure 1b shows the limits obtained when interpreting the 1τ analysis results using the mSUGRA/CMSSM model plane, and Fig. 1c shows the limits obtained with the interpretation of the nGM scenarios using the dedicated SR of the 2τ analysis.

3.2 Two same-sign leptons and jets

For this search, final states with two same-sign (SS) leptons (ee, $e\mu$ or $\mu\mu$) are required, using 21 fb^{-1} of proton-proton collisions. They are classified in three different SRs requiring: events with no b-jets (SR0b); events with one or more b-jets (SR1b); or events with three or more b-jets (SR3b) [7]. Table 2 summarizes the total number of expected background events and the observed data events for the three SRs. Since no significant excess is observed, model independent



(a) (b) (c)

Figure 1: Expected and observed 95% CL lower limits on the (a) minimal GMSB, (b) mSUGRA/CMSSM and (c) simplified nGM models. From [5].

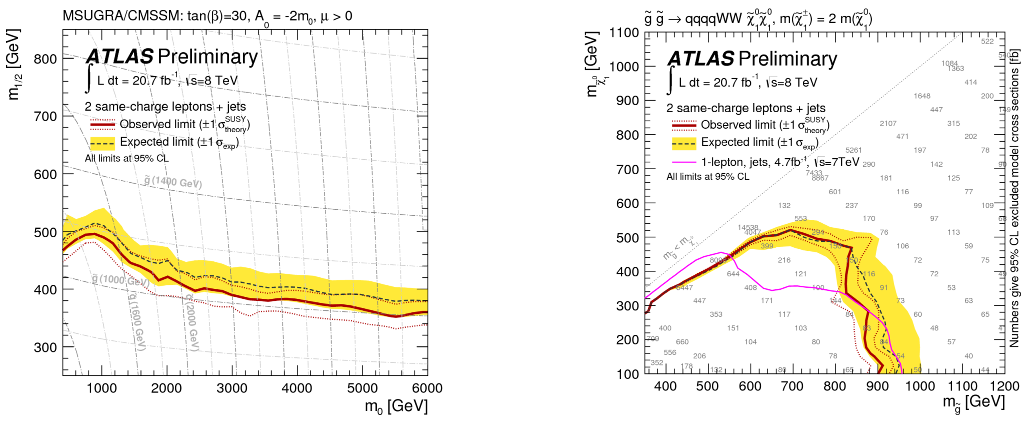
upper limits are set on the number of signal events and on the visible cross section (the product of the cross section, branching ratio, the acceptance and efficiency). The 95% CL limits on these observables are also listed in Table 2. In addition, model dependent exclusion limits are provided in a mSUGRA/CMSSM scenario and in the context of three simplified models: Gluino-squark (via W), (via sleptons), and Direct-squark (via sleptons). These can be seen in Fig. 2 and 3.

	SR0b	SR1b	SR3b
Total background	7.5 ± 3.2	10.1 ± 3.9	1.8 ± 1.3
Data	5	11	1
Obs (exp) limit on signal events	$6.7(7.9^{+2.6}_{-2.0})$	$11.0(6.8^{+2.6}_{-1.5})$	$7.0(5.9^{+2.4}_{-1.3})$
Obs limit on Cross Section (fb)	0.33	0.53	0.34

Table 2: Number of expected background events and data yields and the resulting 95% CL limit on the number of observed (expected) signal events and on the visible cross sections from any new physics scenario for each of the final states. The quoted background errors include statistical and systematic uncertainties. From [7].

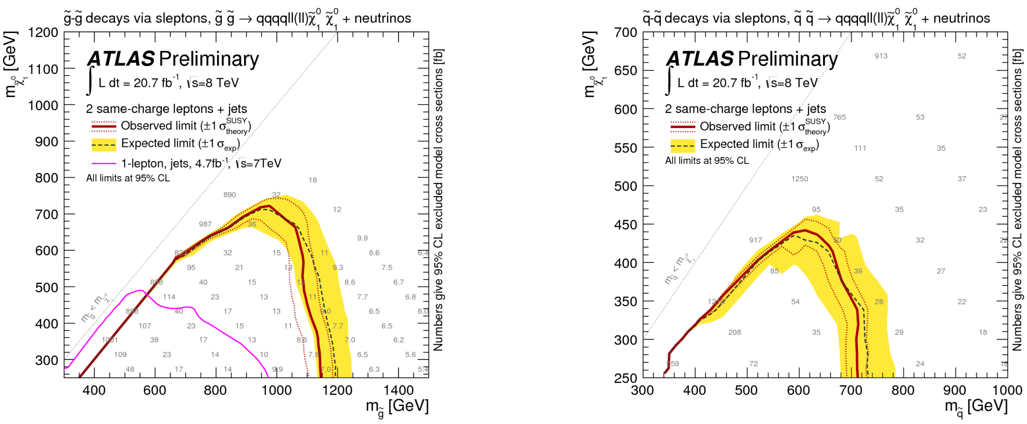
3.3 Z boson and large missing transverse momentum

Events with jets, large missing transverse momentum and a Z boson decaying into two electrons or two muons are considered for this search, using 5.8 fb^{-1} of proton-proton collisions [4]. Table 3 shows the total number of background events and the observed data for the ee and $\mu\mu$ channels. The expectation and observation agree within uncertainties. Given the lack of any significant



(a) (b)

Figure 2: Expected and observed 95% CL limits on the (a) mSUGRA/CMSSM model and (b) Gluino-squark (via W) simplified model, where the numbers give the limits on the excluded model cross sections in fb. From [7].



(a) (b)

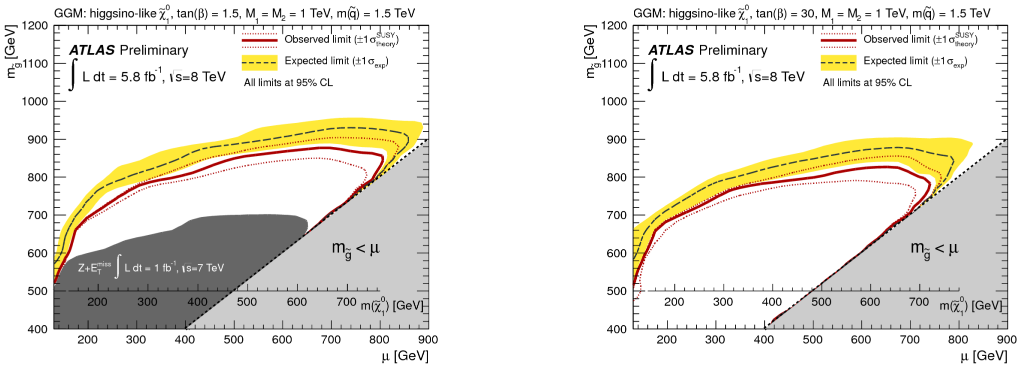
Figure 3: Expected and observed 95% CL limits on the (a) Gluino-squark (via sleptons) and (b) Direct-squark (via sleptons) simplified models. The numbers give the limits on the excluded model cross sections in fb. From [7].

excess in the observed data, the 95% CL upper limits on the visible cross section are computed and shown in Table 3.

	ee	$\mu\mu$
Total background	$3.1 \pm 1.1(stat.) \pm 0.5(syst.)$	$3.2 \pm 1.3(stat.) \pm 0.4(syst.)$
Data	5	5
Obs (exp) limit on Cross Section (fb)	2.0 (1.3)	

Table 3: Number of expected background events and data yields and the resulting 95% CL limit on the observed (expected) visible cross sections from any new physics scenario for each of the ee and $\mu\mu$ channels. The uncertainties are separated in statistical (first) and systematic (second). From [4].

In addition, the results of the analysis are interpreted as 95% CL exclusion limits in the plane of parameters $m(\tilde{g})$ and μ in the higgsino-like NLSP scenario for two GGM models, one with $\tan\beta = 1.5$ and the other with $\tan\beta = 30$. The exclusion limits for these two different models can be seen in Fig. 4a and Fig. 4b respectively.



(a) (b)

Figure 4: Expected and observed 95% exclusion limits on the $m(\tilde{g})$ and μ parameters for GGM models with $M_1 = M_2 = 1$ TeV, $c\tau_{\rm NLSP} < 0.1$mm, $m(\tilde{q}) = 1.5$ TeV and (a) $\tan\beta = 1.5$ (the dark grey area shows the observed exclusion based on the analysis in [8]) and (b) $\tan\beta = 30$. An additional axis corresponding to $m(\tilde{\chi}_1^0)$ is provided. The light grey area indicates the region where the NLSP is the gluino, which was not considered in this analysis. From [4].

4. Summary

Inclusive searches for squarks and gluinos are a very powerful tool to test a large set of SUSY models. Some of the latest results from this kind of search with the ATLAS detector have been presented here with no evidence of physics beyond the SM observed so far. Nevertheless, several searches with the full 8 TeV data set are still ongoing and more results are expected with higher energy runs of the LHC.

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