Search for strongly produced superpartners in final states with 2 same-sign leptons and jets with the ATLAS detector.

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A search for the production of supersymmetric particles decaying into final states with jets (b-tagged or not), missing transverse momentum and two isolated leptons, electron or muon, of the same sign is presented. The analysis uses a data sample collected during 2012, which corresponds to a total integrated luminosity of 21 fb^{-1} of $\sqrt{s} = 8$ TeV proton-proton collisions recorded with the ATLAS detector at the Large Hadron Collider. The absence of any observed excess with respect to the expected Standard Model contribution is interpreted in terms of exclusion limits on several SUSY scenarios.

1 Introduction

The framework of Supersymmetry [2] (SUSY) has been proposed as a natural generalization of the Standard Model (SM), by the introduction of a new symmetry between bosons and fermions doubling the number of fundamental particles. One of the assets of SUSY is its ability to solve the hierarchy problem of the SM, while maintaining a low level of fine tuning (the so-called natural SUSY scenario). In this context, stringent constraints apply on superpartner masses. Mostly, the mass of the lightest scalar top $\tilde{t}_1$ must lie below 1 TeV, while the gluon partner $\tilde{g}$ is not allowed to exceed 2 TeV. The scalar bottom $\tilde{b}_1$ is often light as well. A Higgs boson mass around 125 GeV can also constrain the stop mass from below [3]. It is therefore particularly interesting to search for evidences of third generation squarks, either from their direct production, or through their presence in gluino decays that benefit from a large cross-section.

The search presented here looks for hints of decays of these superpartners in events with two leptons of the same electric charge, in association with several hadronic jets. While extremely rare in the SM, such signatures occur naturally in several decay scenarios of superpartners, depending on the underlying mass spectrum. The typical pattern features pair production of gluino-mediated stop or sbottom $\widetilde{g} \to t\widetilde{t}_1^*$ (or $b\widetilde{b}_1^*$) followed by subsequent decays to the lightest SUSY particle, respectively $\widetilde{t}_1^* \to \bar{t}\widetilde{\chi}_1^0$ or $\widetilde{b}_1^* \to \bar{t}\widetilde{\chi}_1^+ \to \bar{t}W^+\widetilde{\chi}_1^0$. The squarks $\widetilde{t}_1, \widetilde{b}_1$ can possibly be off-shell, if they are too heavy to be produced in gluino decay. The final states are characterized by the presence of 4 W bosons and 4 bottom quarks, which can lead to same-sign lepton pairs. In addition, in the context of R-parity conserving models, the two stable non-interacting neutralinos $\widetilde{\chi}_1^0$ constitute a source of high missing transverse momentum $\not{E}_T$. One can also look for $\widetilde{b}_1\widetilde{b}_1^*$ direct production with $\widetilde{b}_1$ decaying as above, that results in final states with 4 W bosons, 2 bottom quarks, and 2 neutralinos. Several scenarios are also considered for $\widetilde{g}\widetilde{g}$ decays in gauginos through squarks from the two first generations $\widetilde{g} \to q\widetilde{q}$, either directly in $\widetilde{q} \to q\widetilde{\chi}_1^\pm \to qW^\pm\widetilde{\chi}_1^0$, or with sleptons $\widetilde{q} \to q\widetilde{\chi}_1^\pm \to q\,\widetilde{\ell}\nu/\ell\widetilde{\nu}$ (or $\widetilde{q} \to q\widetilde{\chi}_2^0 \to q\,\widetilde{\ell}\ell/\widetilde{\nu}\nu$) followed by $\widetilde{\ell} \to \ell\widetilde{\chi}_1^0$ and $\widetilde{\nu} \to \nu\widetilde{\chi}_1^0$. In these cases, advantage is taken of the Majorana nature of the gluino, which results in equiprobability of obtaining opposite or same-sign pairs lepton pairs when only one lepton is produced in each gluino decay. Search for direct squark production in the aforementioned decays is also possible, although the rate of same-sign leptons is substantially reduced. One may notice the absence of bottom quarks in these final states, third generation being not involved. The large variety of scenarios that can be covered, combined with a very low expected SM background, makes this signature a powerful tool to search for new physics.

In the following, we report on the latest results from an ATLAS search [1,4] using the whole 2012 dataset, corresponding to 20.7 fb^{-1} of proton-proton collisions at $\sqrt{s} = 8$ TeV.

2 Event selection

Leptons, either electrons or muons, are required to have $E_T > 20$ GeV and $|\eta| < 2.5$ (resp. $|\eta| < 2.4$ for muons). Fake candidates are suppressed by tight identification criteria (electrons), combined to cuts on isolation (sum of surrounding tracks E_T or calorimeter energy deposits in a cone of $\Delta R < 0.3$) and impact parameter to reject non-prompt leptons yielded by heavy flavor hadron decays, or photon conversions. Leptons within $\Delta R < 0.4$ of a jet are discarded.

Jets are reconstructed by a standard anti-k_T algorithm with a radius of 0.4, with acceptance cuts of $E_T > 40$ GeV and $|\eta| < 2.8$. Jets containing B-hadrons are identified by a neural network based *b-tagging* algorithm used at a 70% efficiency operating point. In this case, the acceptance cuts are modified to $E_T > 20$ GeV and $|\eta| < 2.5$.

Missing transverse momentum $\not{E}_T$ is reconstructed as the vectorial E_T sum of identified and calibrated objects, as well as remaining non-associated topological clusters up to $|\eta| < 4.9$. Pile-up effects are suppressed by a track-based method, improving the resolution.

Only the pair constituted by the two leading p_T leptons is considered, and its constituents are required to share the same electric charge. An invariant mass cut $m_{\ell\ell} > 12$ GeV is required, to further reject possible contributions from heavy flavor hadronic resonance decays involving leptons. Three signal regions are built to provide sensitivity to the various scenarios listed above. The baseline kinematic selection is the following: presence of at least 3 jets, a missing transverse momentum cut $\not{E}_T > 150$ GeV, and a transverse mass cut (with the leading lepton) $m_T > 100$ GeV. This selection is then split into two signal regions, namely SR1b and SR0b, according to the presence or not of at least one b-jet. In addition, a requirement on the effective mass m_{eff} (scalar sum of $\not{E}_T$ and p_T of the selected leptons and jets) of 700 GeV (resp. 400 GeV in SR0b) is imposed. A third signal region (SR3b) is built to increase acceptance to scenarios with 4 b-quarks in the final state. In this case, the cuts on $\not{E}_T$, m_T, and m_{eff} are dropped, replaced by requiring of at least 4 jets among which at least 3 should be identified as b-jets. Relaxing the $\not{E}_T$-based cuts allows to access more compressed scenarios, in which the small mass splitting between the neutralino and its parent $(\tilde{g}, \tilde{q}, \tilde{\chi}_1^{\pm})$ yields lower $\not{E}_T$.

3 Background estimation

Final states with two same-sign leptons are characterized by very low background, which can be classified in 3 categories combining irreducible and detector-related contributions:

- Standard Model processes with same-sign leptons. These irreducible processes include diboson production (WZ, ZZ, $W^{\pm}W^{\pm}$) which contributes mainly in SR0b, and the associate $t\bar{t}$ + vector boson (W, Z) production, which dominates in SR1b and SR3b.

- Opposite-sign pairs, with the reconstructed charge flipped for one lepton. This process occurs predominately for electrons. In most cases, a Bremsstrahlung photon converts in the material $e^{\pm} \to e^{\pm}\gamma \to e^{\pm}e^{\pm}e^{\mp}$ and the wrong track $(e^{\mp})$ is picked up in the reconstruction. The largest related contribution in the signal regions is provided by dileptonic $t\bar{t}$ events.

- Fake or non-prompt leptons. These include light hadrons mimicking the signature of an electron in the calorimeter, photon conversions, or semi-leptonic decays of heavy flavour

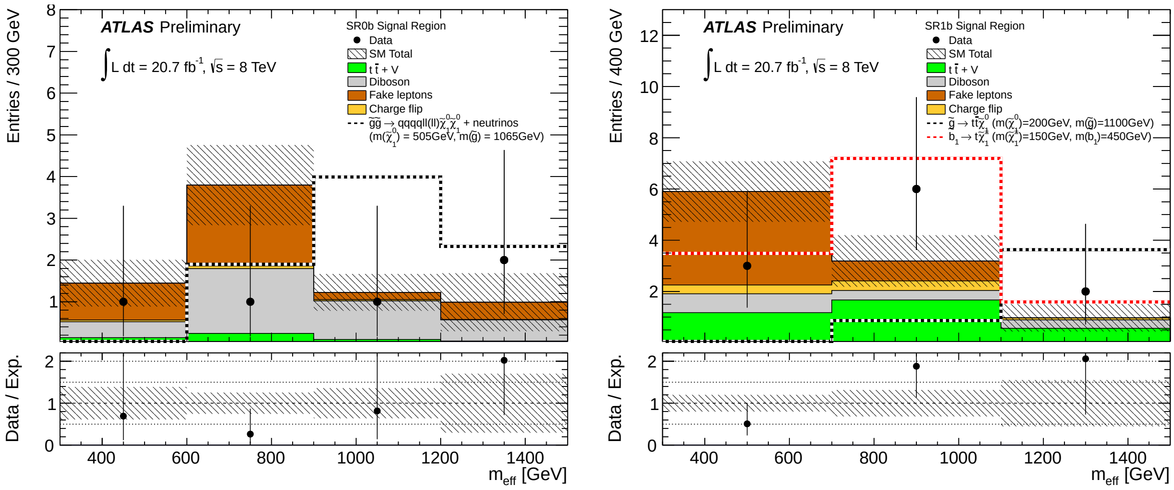

Figure 1: Effective mass distribution in the signal regions with 0 (left) and 1 or more b-jets (right). Ref [4].

hadrons yielding non-isolated leptons. A major contribution in the signal regions originates from $t\bar{t}$ events in which a non-prompt lepton is produced by a B-meson.

Contributions from irreducible processes are estimated by Monte-Carlo. Systematic uncertainties are dominated by jet energy scale, and barely known $t\bar{t}+V$ cross-sections ($\Delta\sigma \geq 30\%$).

A data-driven estimate of the charge flip background is performed. The charge flip rate is measured as a function of η and p_T in a pure electron sample ($Z \to ee$), comparing the yields of opposite/same-sign pairs. This rate, varying from 0.1% up to 2% at large η, is then used to weight data events passing the same selection, but with opposite-sign pairs.

Background with fake leptons is estimated with the so-called matrix method, relying only on data. The application of tight isolation criteria on loosely identified leptons allows to classify events in 4 categories, depending on the lepton passing/failing the tight cut. Given the probabilities for real or fake leptons to satisfy the tight requirement, a system of 4 equations can be built and inverted to retrieve the number of events with at least one fake lepton. The needed probabilities are measured independently in samples enriched in real $Z \to \ell\ell$ or fakes leptons (same-sign lepton pairs with one jet, prompt lepton contribution subtracted from Monte-Carlo).

In both data-driven methods, the main uncertainties come from the measurement of the needed parameters, and their extrapolation to the signal regions. Figure 1 shows the effective mass distribution in the signal regions SR0b and SR1b, that are dominated respectively by diboson or $t\bar{t}+V$ processes, as well as the contribution due to fake leptons.

4 Results with the 2012 dataset

Table 1 presents the number of events observed in the signal regions, together with the total background prediction. No significant excess is found in data compared to SM expectations. This is interpreted in terms of exclusion limits on the various scenarios listed in the introduction.

Table 1: Number of observed/expected events, 95% upper limits (U.L.) on visible cross-section and signal yield.

Signal region	SR0b	SR1b	SR3b
Observed events	5	8	4
Expected background events	7.5 ± 3.3	3.7 ± 1.6	3.1 ± 1.6
U.L. on visible cross-section	0.33 fb	0.53 fb	0.34 fb
U.L. on observed signal (expected)	$6.7\,(7.9^{+2.6}_{-2.0})$	$11.0\,(6.8^{+2.6}_{-1.5})$	$7.0\,(5.9^{+2.4}_{-1.3})$

Expected signal yields are computed in topological models where only the particles involved in

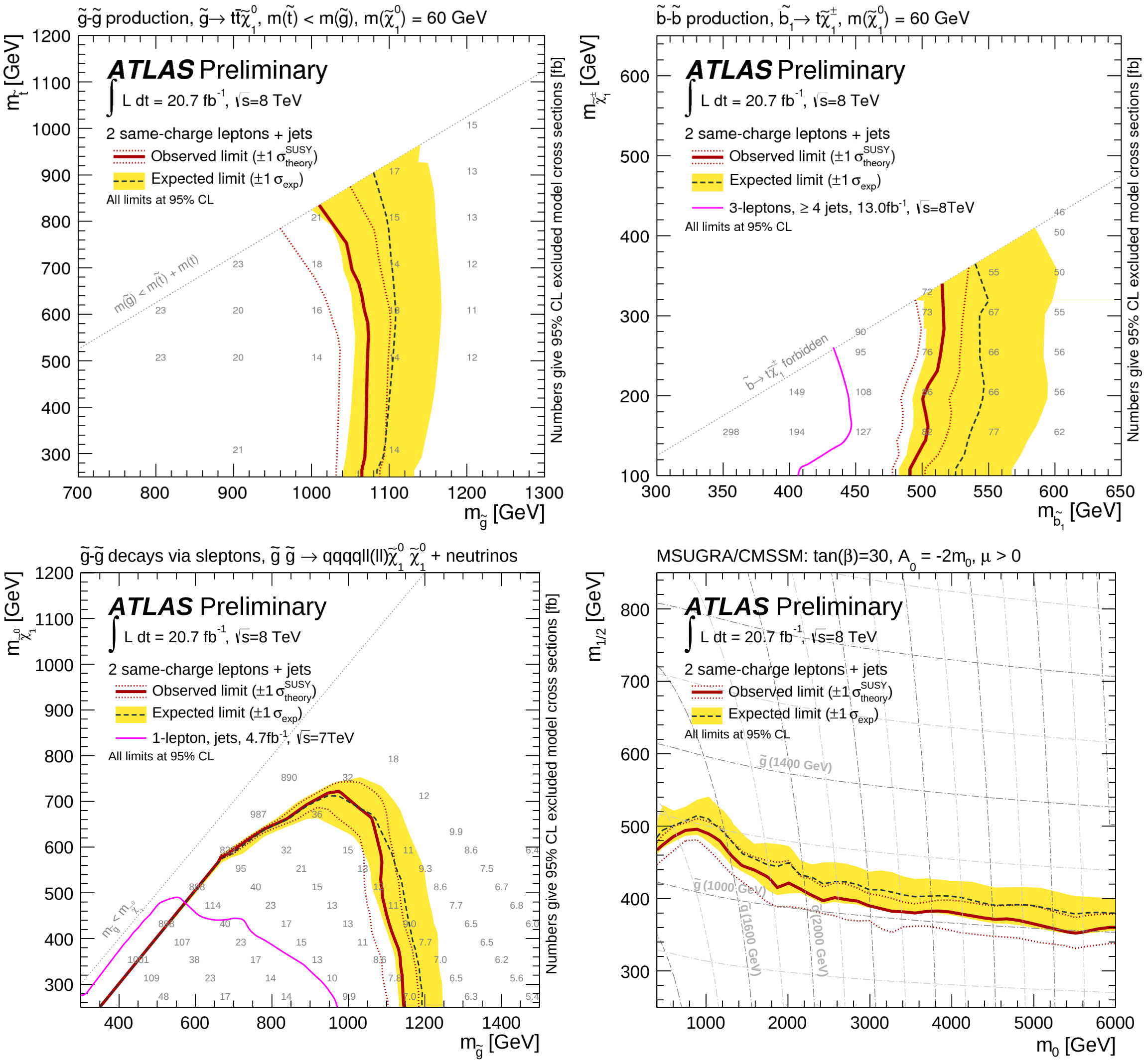

Figure 2: Exclusion limits for different simplified model, as well as mSUGRA/cMSSM (bottom right). The gray numbers indicate upper limits (in fb) on the corresponding process cross-section, for a BR of 100%. Ref [4].

production and decay play a role, the others being decoupled by setting them to large masses (> 2 TeV). Branching ratios of 100% are also assumed on the considered decay chain. Upper limits on the signal strength are obtained by relaxing the m_{eff} cut in SR0b and SR1b, and performing a combined signal+background fit of the m_{eff} shape in the 3 signal regions. The limits are provided as 95% confidence level intervals in the standard CL$_s$ approach.

In conclusion, Fig. 2 displays the obtained limits for gluino-mediated stop, and $\tilde{b}_1\tilde{b}_1^*$ production. Gluino masses up to 1 TeV, and sbottom masses up to 500 GeV, are excluded in these models. Similar limits are set on the gluino mass in the mSUGRA model for $\mu > 0$, $\tan\beta = 30$, and A_0 set to $-2m_0$ so that $m_H \sim 125$ GeV. In the scenarios without genuine b-jets, accessed with SR0b, competitive limits can be obtained as well (Fig. 2 bottom left, gluino decays in sleptons). Limits for other scenarios mentioned in the introduction are provided in Ref [4].

References

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