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Search for strongly produced supersymmetric particles in final states with two same-sign leptons and jets with the ATLAS detector using 21 fb^{-1} of pp collisions at 8 TeV

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A search for the production of supersymmetric (SUSY) particles decaying into final states with jets, b-jets, missing transverse momentum and two isolated leptons, e or μ, with the same electric charge (same-sign leptons) is presented. The analysis uses a data sample collected during 2012, which corresponds to a total integrated luminosity of 20.7 fb^{-1} of $\sqrt{s}$ = 8 TeV proton - proton collisions recorded with the ATLAS detector at the Large Hadron Collider. Three signal regions are defined by number of b-jets in the final state to search for the strong production of SUSY particles. No deviation from the Standard Model expectation is observed. Exclusion limits are derived for a mSUGRA/CMSSM model, for which the parameters are chosen in such a way that the model is compatible with the recently discovered Higgs-like particle, and for a wide variety of simplified SUSY models. The result significantly extends previous exclusion limits for several SUSY models.

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1. Introduction

An excellent description of currently known phenomena at high energy is given by the Standard Model (SM). However, the theory is known to be incomplete and some hints of new physics are expected at the TeV scale. LHC data allows us to probe new models, eg. SUSY models [1], with new particles with masses up to TeV scale.

In the Minimal Supersymmetric Model (MSSM), the scalar partners of right-handed and left-handed quarks, $\tilde{q}_R$ and $\tilde{q}_L$, can mix to form two mass eigenstates, $\tilde{q}_1$ and $\tilde{q}_2$, where $\tilde{q}_1$ denotes the lighter particle. The RL mixing effect is proportional to the corresponding SM fermion masses and therefore becomes important for the third generation. Large mixing can yield a bottom squark, $\tilde{b}_1$, and a top squark, $\tilde{t}_1$, mass eigenstates which are significantly lighter than other squarks. Light $\tilde{t}_1$ and $\tilde{b}_1$ squarks, and gluinos are also favored by natural SUSY. Consequently, $\tilde{b}_1$ and $\tilde{t}_1$ could be produced with large cross sections at the LHC, either directly in pairs, or through $\tilde{g}\tilde{g}$ production with subsequent $\tilde{g} \to b\tilde{b}_1$ or $\tilde{g} \to t\tilde{t}_1$ decays (gluino-mediated production). Several possible decay chains can lead to same-sign (SS) leptons. For instance, the gluino mediated top squark production, followed by the decay $\tilde{t}_1 \to t\tilde{\chi}_1^0$, leads to four top quarks in the final state. Alternatively, the decay via a chargino ($\tilde{\chi}_1^{\pm}$), $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm} \to bW^{\pm}\tilde{\chi}_1^0$ can also lead to SS lepton pairs. Direct pair-production of bottom squarks, $\tilde{b}_1\tilde{b}_1$, with $\tilde{b}_1 \to \tilde{t}\tilde{\chi}_1^{+}$, can give final states with 4 W bosons, 2 bottom quarks and 2 neutralinos. Several scenarios are also considered for $\tilde{g}\tilde{g}$ decays in gauginos through squarks from the two first generations, either in $\tilde{g} \to q\tilde{\chi}_1^{\pm} \to qW^{\pm}\tilde{\chi}_1^0$ either via sleptons $\tilde{g} \to q\tilde{\chi}_1^{\pm} \to q\tilde{l}\nu/l\tilde{\nu}$ (or $\tilde{g} \to q\tilde{\chi}_2^0 \to q\tilde{l}l/\tilde{\nu}\nu$) with $\tilde{l} \to l\tilde{\chi}_1^0$ and $\tilde{\nu} \to \nu\tilde{\chi}_1^0$. 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.

This document describes a search that utilizes final states with SS lepton pairs, multiple jets, and missing transverse momentum ($\not{E}_T$) observed by the ATLAS detector [2] at the LHC (see Ref. [3]). The search is conducted using 20.7 fb^{-1} of proton-proton collisions at $\sqrt{s}$ = 8 TeV recorded in 2012. Production of the SS pairs in association with jets is rare for the SM processes but can have high cross-section for the considered SUSY models.

2. Event selection and signal regions definition

Event selection requirements utilize electrons, muons, jets (including b-tagged jets) and $\not{E}_T$. All jets are required to have p_T > 25 GeV (> 40 GeV in the signal regions) and $|\eta|$ < 2.8. If b-tagging is required, the threshold is lowered to 20 GeV. Leptons are required to have p_T > 20 GeV. Selection requirements for the signal regions are presented in the table below. Selection criteria for the regions used for model-independent limits on cross-sections (discovery case) include additional requirements for m_{eff} or N_{jets}. We performed a fit of distributions in m_{eff} to set model-specific limits using the signal regions for the exclusion case. The signal regions for a given case are made exclusive to each other to allow statistical combination of the limits on cross-sections.

Three signal regions are defined depending on number of b-jets identified in the final state:

Sr	N_{b-jets}	Other variables, exclusion case	Additional cuts for discovery case
Sr0b	==0	$N_{jets} \geq 3$, $\not{E}_T > 150$ GeV, $m_T > 100$ GeV	m_{eff} >400 GeV
Sr1b	$\geq$1	$N_{jets} \geq 3$, $\not{E}_T > 150$ GeV, m_T >100 GeV	m_{eff} >700 GeV
Sr3b	$\geq$3	$N_{jets} \geq 5$, ($\not{E}_T < 150$ GeV or $m_T < 100$ GeV)	$N_{jets} \geq 4$

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Sr3b is considered to increase the sensitivity for compressed models with low $E\!\!\!/_T$, or models with R-parity violation.

3. Background estimation

Evaluation of backgrounds is performed using a combination of MC simulations and data-driven techniques. Sources of real SS leptons arise mainly from the production of a W or Z boson, decaying leptonically, in association with $t\bar{t}$, and from pairs of bosons (WZ, ZZ) produced in association with jets. These backgrounds are estimated with MC simulations. Reducible background from charge mis-measurement consists mostly of events with two opposite-sign electrons for which the charge of an electron is mis-identified.Another reducible background is caused by real non-promt leptons form decays of b-hadrons and light meson and by electron conversions. Also, electron candidates can result from mismeasurements of hadronic jets.

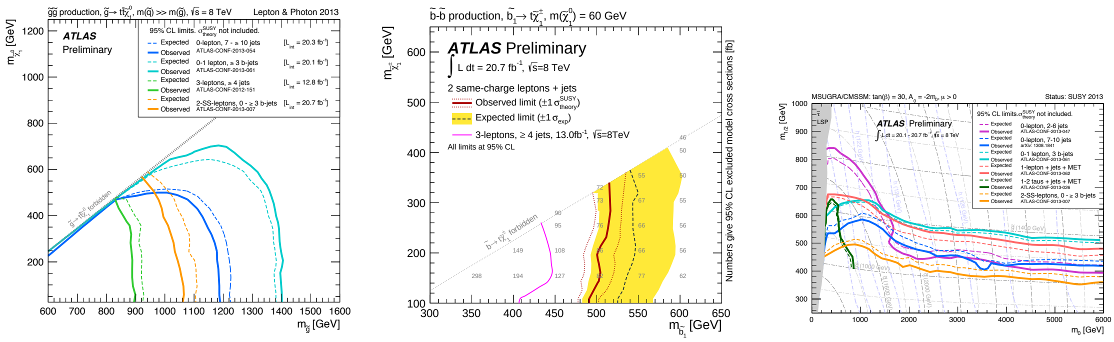

Figure 1: Expected and observed limits for the following models: gluino mediated stop ($t\tilde{\chi}_1^{\pm}$) (left), $\tilde{b}_1\tilde{b}_1$ ($t\tilde{\chi}_1^{\pm}$) (middle) and mSUGRA/CMSSM (right). Limits are computed at 95% CL [3].

4. Results and conclusions

A good agreement between the observed number of events in signal regions and SM expectation is obtained. Number of observed (expected) events, for the exclusion case, are: 5 (7.46 $\pm$ 3.24) in Sr0b, 11 (10.6 $\pm$ 3.93) in Sr1b and 1 (1.79 $\pm$ 1.29) in Sr3b; for the discovery case: 5 (7.5 $\pm$ 3.2) in Sr0b, 11 (10.1 $\pm$ 3.9) in Sr1b and 1 (1.8 $\pm$ 1.3) in Sr3b.

Model dependent exclusion limits are provided in the parameter space of several SUSY models. In Figure 1 three models are considered: gluino mediated stop ($t\tilde{\chi}_1^{\pm}$), $\tilde{b}_1\tilde{b}_1$ ($t\tilde{\chi}_1^{\pm}$) and direct-squark (via slepton). At 95% CL gluinos are excluded up to masses of 900 - 1020 GeV for LSP (lightest supersymmetric particle) masses below 550 GeV. Bottom squarks with masses up to 470 - 480 GeV for chargino masses below 320 GeV are also excluded.

The search improves sensitivity of the ATLAS experiment especially to SUSY processes where the mass difference between the decay products can be small, and, therefore, inaccessible via other decay modes.

References

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