

# Search for Strongly-Produced Supersymmetric Particles in Decays with Two Leptons at $\sqrt{s} = 8$ TeV

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## Abstract

This contribution presents a search for squarks and gluinos in final states containing two isolated electrons or muons using the  $20.3 \text{ fb}^{-1}$  of  $\sqrt{s} = 8$  TeV proton-proton collisions recorded by the ATLAS detector at the LHC during 2012. The search uses a set of variables carrying information on the event kinematics both transverse and parallel to the beam line. No excess above the Standard Model expectation is observed, therefore exclusion limits are set on sparticle masses for various simplified model scenarios and a minimal universal extra dimensions model.

*Keywords:* ATLAS, Supersymmetry, LHC, leptons

## 1. Introduction

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

This contribution summarizes a search for gluinos and first- and second-generation squarks in events with two isolated leptons (in  $20.3 \text{ fb}^{-1}$  of  $\sqrt{s} = 8$  TeV data collected in 2012 by the ATLAS [1] detector at the LHC) making use of the Razor variables [2], a set of kinematic variables that exploit both transverse and longitudinal event information. The full description of the methods and results of this analysis can be found in Ref.[3].

## 2. Signal models

In this contribution, simplified models with SUSY-like topologies are studied. These models contain only a subset of SUSY particles and decay chains possible for a complete SUSY signal model. The simplified models considered in this analysis feature direct pair-production of either gluinos ( $\tilde{g}$ ) or left-handed first- and second-generation squarks ( $\tilde{q}$ ), in the latter case with degenerate first- and second-generation squarks and a decoupled third-generation. Since only first-

and second-generation squarks are included the rate of heavy-flavour jets is not appreciable. The heavy SUSY particles then decay to the LSP (lightest SUSY particle), assumed to be the lightest neutralino ( $\tilde{\chi}_1^0$ ), via either:

- a one-step cascade  $\tilde{q} \rightarrow qW\tilde{\chi}_1^0$   
 $\tilde{g} \rightarrow qqW\tilde{\chi}_1^0$
- or a two-step cascade  $\tilde{q} \rightarrow q(l\ell/l\nu/\nu\nu)\tilde{\chi}_1^0$   
 $\tilde{q} \rightarrow qq(l\ell/l\nu/\nu\nu)\tilde{\chi}_1^0$

In addition, results are interpreted in a minimal universal extra dimensions (mUED) model.

## 3. Razor variable definitions

The Razor variables [2] are a set of kinematic variables that exploit the symmetry in the visible portion of sparticle decays when sparticles are produced in pairs. The final state jets and leptons are grouped into two “mega-jets”, where all visible objects from one side of the di-sparticle decay are collected together to create a single four-vector representing the decay products of a single sparticle. Using this mega-jet configuration a characteristic mass,

$M'_R = \sqrt{(j_{1,E} + j_{2,E})^2 - (j_{1,L} + j_{2,L})^2}$ , is defined in the rest frame of the sparticles (the so-called “R-frame”),

Signal region	SR1 $ee/\mu\mu$	SR1 $e\mu$	SR2 $ee/\mu\mu$	SR2 $e\mu$
Z-veto	yes	no	yes	no
Njets ( $p_T > 50$ GeV)	$\leq 2$	$\leq 2$	$\geq 3$	$\geq 3$
$R$	$> 0.5$	$> 0.5$	$> 0.35$	$> 0.35$
$M'_R$ [GeV]	$> 400$	$> 400$	$> 800$	$> 800$

Table 1: Signal region definitions. From Ref. [3]

where  $j_{i,L}$  denotes the longitudinal momentum, and  $j_{i,E}$  the energy in the  $R$ -frame, of the mega-jet  $i$ . The transverse information of the system is contained in another variable,  $M'_R$ . In the di-sparticle decay there are two mega-jets, each with associated  $E_T^{\text{miss}}$  from the escaping LSPs. Assigning half of the missing transverse momentum per event to each of the LSPs,  $M'_R$  is defined as  $M'_R = \sqrt{\frac{|\vec{E}_T^{\text{miss}}|(|\vec{j}_{1,T}|+|\vec{j}_{2,T}|) - \vec{E}_T^{\text{miss}} \cdot (\vec{j}_{1,T} + \vec{j}_{2,T})}{2}}$ , where  $j_{i,T}$  denotes the transverse momentum of the mega-jet  $i$ .

Finally a Razor variable is defined:  $R = \frac{M'_R}{M'_R}$ . For SM processes  $R$  tends to peak at low values, while it is approximately uniformly distributed between 0 and 1 for SUSY-like signal events. Thus  $R$  is a discriminant between signal and background. A selection using  $R$  is made to reduce background processes before a search for new physics is performed in the distribution of the variable  $M'_R$ .

#### 4. Event selection

Events selected for this analysis are required to contain exactly two signal leptons, these being two electrons, two muons, or one of each, and no other baseline electrons (muons) of  $p_T > 10$  GeV within the range  $|\eta| < 2.47$  (2.4). Di-leptonic events where the invariant mass of the two leptons is less than 20 GeV are discarded in order to reject low-mass resonances.

Signal regions (SR) are defined to target two different regions of kinematic phase space: SR1 targets models at high  $x = \frac{(m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})}{m_{\tilde{q}/\tilde{g}} - m_{\tilde{\chi}_1^0}}$  (which result in fewer high- $p_T$  jets, lower  $M'_R$  and a large  $M'_R$ , so therefore  $R$  tends to take on larger values), whereas SR2 is motivated by lower  $x$  topologies (which give rise to higher  $M'_R$  and  $R$  is generally lower, furthermore higher  $p_T$  and more numerous jets are allowed). Each of these signal regions are further separated into opposite and same lepton flavour channels. Moreover they exclude events containing b-tagged jets and, in order to minimise the background due to leptonically decaying Z-bosons, a Z-veto is introduced in all same-flavour signal regions. Table 1 summarizes SR definition.

#### 5. Background estimation

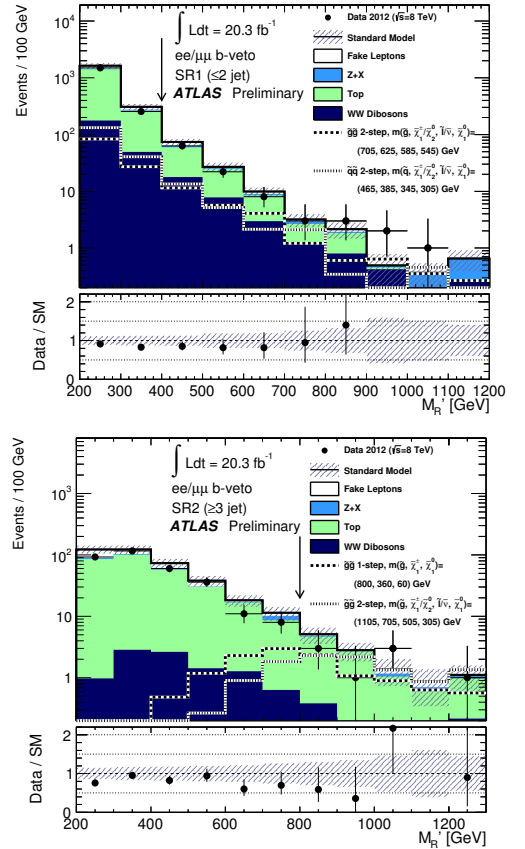
In order to establish an observation of physics beyond the SM in any of the signal regions, a reliable prediction

Channel	SR1 $ee/\mu\mu$	SR1 $e\mu$	SR2 $ee/\mu\mu$	SR2 $e\mu$
Observed events	102	87	8	8
Fitted bkg events	$117 \pm 16$	$103 \pm 15$	$11.0 \pm 2.8$	$10.1 \pm 2.7$

Table 2: Observed number of events and predictions from the fit to the SM backgrounds in the control regions extrapolated to the signal regions, for an integrated luminosity of 20.3 fb<sup>-1</sup>. The errors shown are the statistical plus systematic uncertainties. From Ref. [3]

of the SM backgrounds in these regions is necessary.

The major backgrounds, namely Top [which includes fully-leptonic  $t\bar{t}$ , single top,  $t\bar{t}$  + EW] and Z + X [meaning Z/ $\gamma$  + jets (where Z decays leptonically), WZ and ZZ], are estimated using control regions (CR) where the distribution of the simulated background in  $M'_R$  is adjusted, according to a binned shape fit, to data. The results of this fit are then extrapolated to estimate the background contribution to the signal regions.

Figure 1: The distribution in  $M'_R$  in SR1 (top) and SR2 (bottom), with all requirements except that on the minimum  $M'_R$  applied, in the same-flavour channels. For each distribution data to SM prediction ratios are also shown. Statistical and systematic uncertainties are indicated. Two representative signal distributions are overlaid. The lower signal region bounds in  $M'_R$  are indicated with arrows. From Ref. [3]

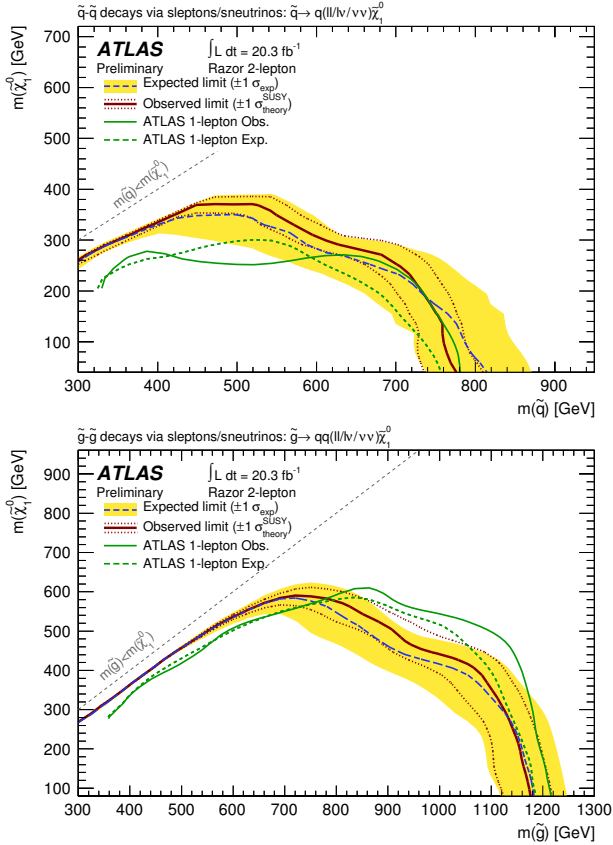


Figure 2: Expected and observed exclusion limits for a simplified model with squark pair production (top) and gluino pair production (bottom), where each squark (gluino) decays to a quark (two quarks) and chargino, and the chargino subsequently decays through a slepton or sneutrino to the LSP. The limits from Ref. [4] are overlaid. From Ref. [3]

The background due to semi-leptonic  $t\bar{t}$  and  $W + jets$  enters into the two-lepton signal regions either due to jets being misidentified as leptons or due to the detection of a real lepton, sufficiently isolated, coming from a heavy-flavour decay. These backgrounds are estimated with the data-driven matrix method [4]. The largest remaining background, the  $WW$  diboson background, is estimated entirely from simulation.

## 6. Results and Interpretation

Table 2 summarises the observed number of events in the signal regions and the predictions from the background fit after extrapolation to the signal regions. No significant deviation from the expected backgrounds is observed in the data. The distributions of  $M'_R$  for SR1  $ee/\mu\mu$  and SR2  $ee/\mu\mu$  are shown in Fig. 1.

As mentioned before, several SUSY-inspired simplified models are used for the interpretation of the fit results. A binned likelihood fit is performed considering

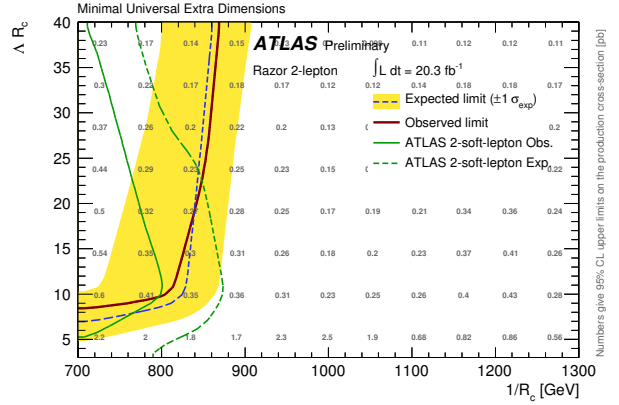


Figure 3: Expected and observed exclusion limits from the minimal universal extra dimensions model. 95% CL upper limits on the production cross section are shown. The limits from Ref. [4] are overlaid. From Ref. [3]

simultaneously both the signal and control regions, using the  $CL_s$  method to determine whether a signal model is excluded at 95% CL.

Limits for the various models are shown in Figs. 2 and 3. In these figures, the yellow band around the expected limit shows the  $\pm 1\sigma$  uncertainty region including all statistical and systematic uncertainties except the theoretical uncertainties on the model production cross section. The dotted theoretical uncertainty lines around the observed limit are obtained by changing the signal production cross section by  $\pm 1\sigma$ .

## 7. Summary

A search for SUSY in final states containing two leptons with  $20.3 \text{ fb}^{-1}$  of  $pp$  collision data at  $\sqrt{s} = 8 \text{ TeV}$  collected with the ATLAS detector at the LHC has been presented. No significant deviation from the SM background expectation is observed. The results are interpreted in terms of limits on SUSY-inspired simplified models and a minimal universal extra dimensions model.

## References

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