Search with the ATLAS detector for new physics with significant missing transverse energy and two isolated leptons

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Abstract. We present results of searches for supersymmetry in events with significant missing transverse energy and two isolated leptons with the ATLAS experiment at the LHC. Three analyses are presented, the first two are analyses with leptons of opposite charge and same charge respectively. The third one is an analysis that searches for an excess of same-flavour opposite-charge lepton pairs over those of different-flavour. We analyse data corresponding to an integrated luminosity of 1 fb^{-1} .

Keywords. ATLAS, SUSY, dilepton, Flavour Subtraction

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1. Introduction

In many extensions of the Standard Model (SM) one predicts the existence of new states that decay into invisible particles. In the case of supersymmetry (SUSY), these new states are typically squarks and gluinos and they could be accessible at the LHC.

In R-parity SUSY scenarios, SUSY particles are produced in pairs. Therefore in each event, two independent decay branches are produced. In each branch, the lightest SUSY particle (LSP) is stable and weakly interacting. These scenarios give rise to events with significant missing transverse energy (E_T^{miss}) and often high transverse momentum (p_T) jets. High transverse momentum leptons can also be produced through the decay of neutralinos and charginos (typical chains are : a) $\tilde{\chi}_i^0 \rightarrow l^\pm \nu \tilde{\chi}_j^\mp$, b) $\tilde{\chi}_0^\pm \rightarrow l^\pm \nu \tilde{\chi}_j^0$, c) $\tilde{\chi}_i^0 \rightarrow l^\pm l^\mp \tilde{\chi}_j^0$, d) $\tilde{\chi}_i^\pm \rightarrow l^\pm l^\mp \tilde{\chi}_j^\pm$).

In the following, excesses of opposite-sign (OS) and same-sign (SS) dilepton events are separately searched for. Also, a search for an excess of OS events with same flavour (SF) over those of opposite flavour (OF) is made.

These analyses use a data sample collected during 2011, that corresponds to a total integrated luminosity of 1 fb^{-1} of $\sqrt{s} = 7 \text{ TeV}$ proton-proton collisions recorded with the ATLAS detector at the LHC [1].

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26 2. Object Reconstruction and Event Selection

27 Detailed information is found in [1] but the main attributes are described here.
 28 Electrons are required be isolated and to have $p_T > 20$ GeV and to be within $|\eta| < 2.47$.
 29 Muons are required to be isolated and to have $p_T > 10$ GeV and $|\eta| < 2.4$. Jets are
 30 reconstructed using the anti- k_t jet clustering algorithm with a distance parameter of 0.4.
 31 Jets are required to have $p_T > 20$ GeV and $|\eta| < 2.8$. An overlap removal is done
 32 between leptons and jets¹. Events with any jet failing quality criteria designed to suppress
 33 noise and non-collision background are rejected. The missing transverse momentum is
 34 defined as the magnitude of the vector sum of the p_T of reconstructed objects in the event.
 35 The event selection is defined as follows: the primary vertex in each event is required to
 36 have at least 5 associated tracks. Events containing a jet or electron with $-0.1 < \eta < 1.5$
 37 and $0.9 < \phi < -0.5$ are rejected due to readout problems in the LAr calorimeter for a
 38 subset of the data. This event rejection is applied in data and simulation. Each selected
 39 event must contain exactly two reconstructed leptons. If the highest p_T lepton in the pair
 40 is an electron it must have $p_T > 25$ GeV. If the highest p_T lepton in the pair is a muon
 41 the p_T requirement is raised to 20 GeV.
 42 Events are triggered using the single electron and single muon triggers which reach full
 43 efficiency for electrons and muons of p_T greater than 25 GeV and 20 GeV respectively.
 44 Typical efficiencies are 96% for electrons and 75% (88%) for muons in the barrel (end-
 45 cap).

46 3. Background Evaluation

47 In a search for OS dilepton events $t\bar{t}$ and $Z/\gamma^* + \text{jets}$ events are dominant background
 48 sources. Smaller contributions arise from single top and diboson events, and events con-
 49 taining "fake" leptons. In a search for SS dilepton events, fake leptons, single top and
 50 diboson events dominate. A small contribution arises from OS events in which the charge
 51 of one of the leptons is misidentified. Single top and diboson backgrounds are estimated
 52 using simulation. The other backgrounds are estimated using a combination of fully and
 53 partially data-driven techniques.
 54 Z/γ^* : A low E_T^{miss} region (< 20 GeV) is defined and events with 2 leptons with invari-
 55 ant mass between 81 and 101 GeV in data are compared with simulation expectations. A
 56 normalization factor is found and the simulation expectations are used to extrapolate from
 57 the control region to the signal.
 58 $t\bar{t}$: Control regions are defined from top-tagged events that have lower E_T^{miss} than the
 59 signal region but otherwise similar kinematics. We use the $m_{CT}[1]$ variable which allows
 60 us to get enriched top samples with high purity.
 61 "Fake" leptons: The probabilities of misidentifying fake electrons and muons respectively
 62 are measured by considering, in control regions dominated by fake leptons, the fractions
 63 of these fake leptons (which satisfy looser identification requirements) passing the tight
 64 lepton identification requirements used to define signal leptons.
 65 Charge misidentification: The contribution from charge misidentification is studied using
 66 $Z \rightarrow e^+e^-$ simulated events. The probability of charge misidentification is ascertained
 67 by comparing the charges of generator level electrons to those of reconstructed electrons.
 68 It is then applied to simulated events to estimate the number of same-sign events in each
 69 signal-region from incorrect charge assignment.

¹If a jet is closer than $\Delta R < 0.2$ from an electron it is removed. If a lepton is closer than $\Delta R < 0.4$ from
 the remaining jets it is removed. $\Delta R(\tilde{a}, \tilde{b}) = \sqrt{(\Delta\phi(\tilde{a}, \tilde{b}))^2 + (\Delta\eta(\tilde{a}, \tilde{b}))^2}$

70 4. Results

In the following we present model independent limits on the effective cross sections for new physics in a variety of signal regions². In the flavour subtraction analysis, the same

Signal Region	Background	Observation	95% CL
OS-SR1	15.5 ± 4.0	13	9.9 fb
OS-SR2	13.0 ± 4.0	17	14.4 fb
OS-SR3	5.7 ± 3.6	2	6.4 fb
SS-SR1	32.6 ± 7.9	25	14.8 fb
SS-SR2	24.9 ± 5.9	28	17.7 fb
FS-SR1	118.7 ± 27.0	131.6 ± 2.5	94
FS-SR2	67.1 ± 28.6	142.2 ± 1.0	158
FS-SR3	0.7 ± 1.6	-3.06 ± 0.04	4.5

Table 1. Expected numbers of background events, numbers of observed events and limits on the effective cross section for each opposite-sign (OS-xx) and same-sign (SS-xx) signal region. For each flavour subtraction (FS-xx) signal region the mean expected value of S from background events is given, with the value of S observed in data and the limit on S from new physics. Full details of the limit setting techniques used are available in [1].

flavour excess is quantified using the variable S defined in the following equation³:

$$S = \frac{N_{ee}}{\beta \times (1 - (1 - \tau_e)^2)} + \frac{N_{\mu\mu} \times \beta}{(1 - (1 - \tau_\mu)^2)} - \frac{N_{e\mu}}{1 - (1 - \tau_e) \times (1 - \tau_\mu)} \quad (1)$$

71 and limits are set on the same flavour excess from new physics. Results are given in table
72 1 with full details of the technique used available in [1].

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76 References

77 [1] The ATLAS Collaboration, arXiv:1110.6189v1 [hep-ex] (submitted to Physics Letters B)

²OS-SR1=FS-SR3 : $E_T^{\text{miss}} > 250$ GeV, OS-SR2 : 3-jets ($p_T > 80, 40, 40$ GeV) and $E_T^{\text{miss}} > 220$ GeV, OS-SR3=4-jets ($p_T > 100, 70, 70, 70$ GeV) and $E_T^{\text{miss}} > 100$ GeV, SS-SR1 : $E_T^{\text{miss}} > 100$ GeV, SS-SR2 : 2-jets ($p_T > 50, 50$ GeV) and $E_T^{\text{miss}} > 80$ GeV, FS-SR1 : $E_T^{\text{miss}} > 80$ GeV and Z peak veto, FS-SR2 : 2-jets ($p_T > 20, 20$ GeV) and $E_T^{\text{miss}} > 80$ GeV.

³ Here τ_e and τ_μ are the electron and muon trigger efficiencies respectively, β the ratio of electron to muon reconstruction efficiencies and acceptances and $N_{ee, e\mu, \mu\mu}$ the numbers of events in each channel.