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

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**Abstract.** Results of searches for supersymmetry in events with significant missing transverse energy and two isolated leptons with the ATLAS experiment at the LHC are presented. Three analyses are presented here, 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. Data corresponding to an integrated luminosity of 1 fb$^{-1}$ are analysed.

**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 can 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 ($E_{\mathrm{T}}^{\mathrm{miss}}$) and often high transverse momentum ($p_{\mathrm{T}}$) 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) $\tilde{\chi}_i^0 \rightarrow l^{\pm}l^{\mp}\tilde{\chi}_j^0$, and (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 $\sqrt{s} = 7$ TeV proton–proton collisions recorded with the ATLAS detector at the LHC [1].

## 2. Object reconstruction and event selection

Detailed information is found in ref. [1] but the main attributes are described here.

Electrons are required to be isolated and to have $p_{\mathrm{T}} > 20$ GeV and to be within $|\eta| < 2.47$. Muons are required to be isolated and to have $p_{\mathrm{T}} > 10$ GeV and $|\eta| < 2.4$. Jets are reconstructed using the anti-$k_{\mathrm{t}}$ jet clustering algorithm with a distance parameter of 0.4. Jets are required to have $p_{\mathrm{T}} > 20$ GeV and $|\eta| < 2.8$. An overlap removal is done between leptons and jets [2]. Events with any jet failing quality criteria designed to suppress noise and non-collision background are rejected. The missing transverse momentum is defined as the magnitude of the vector sum of the $p_{\mathrm{T}}$ of reconstructed objects in the event.

The event selection is defined as follows: the primary vertex in each event is required to have at least five associated tracks. Events containing a jet or electron with $-0.1 < \eta < 1.5$ and $0.9 < \phi < -0.5$ are rejected due to read-out problems in the LAr calorimeter for a subset of the data. This event rejection is applied in data and simulation. Each selected event must contain exactly two reconstructed leptons. If the highest $p_{\mathrm{T}}$ lepton in the pair is an electron, it must have $p_{\mathrm{T}} > 25$ GeV. If the highest $p_{\mathrm{T}}$ lepton in the pair is a muon, the $p_{\mathrm{T}}$ requirement is raised to 20 GeV.

Events are triggered using the single-electron and single-muon triggers, which reach full efficiency for electrons and muons of $p_{\mathrm{T}}$ greater than 25 GeV and 20 GeV, respectively. Typical efficiencies are 96% for electrons and 75% (88%) for muons in the barrel (end-cap).

## 3. Background evaluation

In a search for OS dilepton events, $t\bar{t}$ and $Z/\gamma^{*}$+jets events are dominant background sources. Smaller contributions arise from single-top and diboson events, and events containing 'fake' leptons. In a search for SS dilepton events, fake leptons, single-top and diboson events dominate. A small contribution arises from OS events in which the charge of one of the leptons is misidentified. Single-top and diboson backgrounds are estimated using simulation. The other backgrounds are estimated using a combination of fully and partially data-driven techniques.

$Z/\gamma^{*}$: A low $E_{\mathrm{T}}^{\mathrm{miss}}$ region (<20 GeV) is defined and events with two leptons with invariant mass between 81 and 101 GeV in data are compared with simulation expectations. A normalization factor is found and the simulation expectations are used to extrapolate from the control region to the signal.

$t\bar{t}$: Control regions are defined from top-tagged events that have lower $E_{\mathrm{T}}^{\mathrm{miss}}$ than the signal region but otherwise similar kinematics. We use the $m_{\mathrm{CT}}$ [1] variable which allows us to get enriched top samples with high purity.

'Fake' leptons: The probabilities of misidentifying fake electrons and muons, respectively are measured by considering, in control regions dominated by fake leptons, the fractions of these fake leptons (which satisfy looser identification requirements) passing the tight lepton identification requirements used to define signal leptons.

Charge misidentification: The contribution from charge misidentification is studied using $Z \to e^{+}e^{-}$ simulated events. The probability of charge misidentification is

**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].

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

ascertained by comparing the charges of generator level electrons to those of reconstructed electrons. It is then applied to simulated events to estimate the number of same-sign events in each signal region from incorrect charge assignment.

## 4. Results

In the following, we present model-independent limits on the effective cross-sections for new physics in a variety of signal regions [3]. In the flavour subtraction analysis, the same-flavour excess is quantified using the variable $S$ defined in the following equation [4]:

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

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

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### References

[1] The ATLAS Collaboration, arXiv:1110.6189v1 [hep-ex], submitted to *Phys. Lett. B*
[2] If 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. $\Delta R(\vec{a}, \vec{b}) = \sqrt{(\Delta\phi(\vec{a}, \vec{b}))^2 + (\Delta\eta(\vec{a}, \vec{b}))^2}$.

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

[4] Here $\tau_e$ and $\tau_\mu$ are the electron and muon trigger efficiencies respectively, $\beta$ is the ratio of electron to muon reconstruction efficiencies and acceptances and $N_{ee,e\mu,\mu\mu}$ are the numbers of events in each channel.