Search for electroweak supersymmetric particle production in final states with two leptons and missing transverse momentum with the ATLAS detector

Janet Dietrich\textsuperscript{a,b,1}

\textsuperscript{a}Deutsches Elektronen-Synchrotron, Hamburg, Germany
\textsuperscript{b}Humboldt Universität zu Berlin, Institut für Physik, 12489 Berlin, Germany

Abstract

Searches for the production of electroweak supersymmetric particles decaying into final states with exactly two isolated, oppositely-charged leptons (electrons, muons) and missing transverse momentum are performed using 20.3 fb\(^{-1}\) of 2012 proton-proton collision data at \(\sqrt{s} = 8\) TeV recorded with the general purpose detector ATLAS at the Large Hadron Collider. The negative search results are interpreted in the framework of simplified Supersymmetry models and in various scenarios of the phenomenological Minimal Supersymmetric Standard Model [1].

Keywords: Supersymmetry, electroweak supersymmetric particles, di-lepton final state, ATLAS

1. Introduction

Weak scale Supersymmetry (SUSY) is one of the best motivated extensions of the Standard Model (SM), providing a possible solution to the hierarchy problem and a viable dark matter candidate in the form of the lightest supersymmetric particle (LSP). The dominant SUSY production channels at the LHC depend on the masses of the sparticles. In scenarios where the first and second generation sfermions and gluinos are heavier than few TeVs, direct production of weak gauginos (charginos, \(\tilde{\chi}^\pm\) and neutralinos, \(\tilde{\chi}^0\)) as well as sleptons (\(\tilde{\ell}\) and \(\tilde{\nu}\)) may be the dominant SUSY process. The searches presented here target final states with two leptons and missing energy. They can appear in \(\tilde{\ell}\tilde{\ell}\) production followed by \(\tilde{\ell}^\pm \rightarrow \tilde{\ell}^\pm \tilde{\chi}^0\) decay giving rise to a pair of “same flavour” leptons, or by \(\tilde{\chi}^\pm\tilde{\chi}^\mp\) production followed by \(\tilde{\chi}^\pm \rightarrow (\tilde{\ell}^\pm\nu\) or \(\tilde{\ell}^\pm\tilde{\nu}) \rightarrow \tilde{\ell}^\pm\nu\tilde{\chi}^0\) decay to leptons of same or different flavours and two additional neutrinos contributing to the missing transverse momentum. In scenarios with a lightest chargino \(\tilde{\chi}^+_1\) heavier than the LSP, the chargino decays as \(\tilde{\chi}^+_1 \rightarrow W^\pm \tilde{\chi}^0_1\), producing an on- or off-shell W boson. Only if the \(\tilde{\chi}^+_1\) and \(\tilde{\chi}^0_2\) are mass degenerated and co-NLSP, the direct \(\tilde{\chi}^+_1\tilde{\chi}^0_2\) production is followed by the decays \(\tilde{\chi}^+_1 \rightarrow W^\pm \tilde{\chi}^0_1\) and \(\tilde{\chi}^0_2 \rightarrow Z\tilde{\chi}^0_1\). This final state contains two oppositely charged leptons, two hadronic jets, and missing transverse momentum from the leptonic Z boson and hadronic W boson decay, respectively.

2. Event selection

Seven signal regions (SRs) are designed selecting final states with two isolated leptons (electrons or muons) of opposite charge and missing transverse momentum (for details see [1]). The three SR-\(m_T^2\) signal regions are optimised to provide sensitivity to sleptons either through direct production or in chargino decays, while the three SR-\(WW\) signal regions are targeting chargino- and neutralino-pair production followed by on-shell W decays. For all six signal region a jet-veto (including b-tagged jets) was applied, while SR-Zjets, modelled specifically for chargino and second lightest neutralino associated production followed by hadronic W and leptonic Z decays, required two leading central light jets in the final state. Events containing one or more \(\tau\)-jet candidates are rejected.
3. Background estimation

The main SM backgrounds for SR-$m_{T2}$ and SR-WW are from WW diboson and top-pair production where two leptonically decaying $W$ bosons result in the same final state as the SUSY signal. Another significant source of background in the same-flavour channel is $WZ$ and $ZZ$ production. These events are estimated by defining dedicated control regions (CR) for each background and extracting a normalization factor to be applied to the simulations in the signal regions. Other minor backgrounds such as $Z +$ jets and Higgs production are estimated using the MC predictions. For SR-Zjets, the dominant sources of background are $ZV$ production, where $V = W$ or $Z$, and $Z/\gamma^* +$ jets. The former is estimated from simulation, validated using $ZV$-enriched control samples, and the latter is estimated by a data-driven technique (‘jet smearing’ method). Leptons originating from heavy-flavour decays or photon conversion or mistakenly reconstructed hadronic jets can be misidentified as signal leptons. This “fake” background is obtained in a fully data-driven way (matrix method).

4. Results

Fig. 1 shows the comparison between data and the SM prediction for a key kinematic variable $m_{T2}$ in signal regions. No significant excesses over the SM predictions are observed. Exclusion limits at 95% confidence-level are set on the slepton, chargino and neutralino masses within the specific scenarios considered using a CL$_S$ limit-setting procedure [2].

---

$T2$ is the ‘transverse’ mass $m_{T2}$

$$m_{T2} = \min_{q_T} \max \{ m_{T2}(p_T^{l_1}, q_T), m_{T2}(p_T^{l_2}, p_T^{miss} - q_T) \}.$$
(expected) exclusion contours, including all uncertainties except for the theoretical signal cross-section uncertainty arising from the PDF and the renormalization and factorization scales. The solid band around the expected exclusion contour shows the \( \pm 1 \sigma \) result where all uncertainties, except those on the signal cross-sections, are considered.

In scenarios with direct sleptons decays, a common value for left- and right-handed slepton masses between 90 GeV and 325 GeV is excluded at 95\% confidence level for a massless neutralino (Fig. 2 a). The sensitivity decreases as the \( \tilde{\ell}_R \tilde{\chi}_1^0 \) mass splitting decreases: For \( m_{\tilde{\ell}_R} = 100 \) GeV, common left and right-handed slepton masses between 160 GeV and 310 GeV are excluded. For models with chargino-pair production, with wino-like charginos decaying into the lightest neutralino via an intermediate slepton, chargino masses between 140 GeV and 465 GeV for a massless neutralino (Fig. 2 b). The exclusion for this decay depends on the assumed slepton mass, which is chosen to be halfway between the \( \tilde{\chi}_1^+ \) and \( \tilde{\chi}_1^0 \) masses in this analysis and its choice minimizes (maximizes) the acceptance for small (large) \( \tilde{\chi}_1^- - \tilde{\chi}_1^0 \) mass splitting.

In case of chargino-pair production with \( W \) boson decays, the best sensitivity is obtained for \( m_{\tilde{\chi}_1^0} = 0 \): chargino mass ranges of 100–105 GeV, 120–135 GeV and 145–160 GeV are excluded at 95\% CL. For simplified-model \( \tilde{\chi}_1^+ \tilde{\chi}_2^0 \) production followed by \( W \) and \( Z \) decays, \( \tilde{\chi}_1^+ \) and \( \tilde{\chi}_2^0 \) masses between 180 GeV and 355 GeV are excluded at 95\% CL for a massless \( \tilde{\chi}_1^0 \). Combined with results from the relevant signal regions in the ATLAS search for electroweak SUSY production in the three-lepton final states [5] improves significantly the sensitivity: Degenerate \( \tilde{\chi}_1^+ \) and \( \tilde{\chi}_2^0 \) masses between 100 GeV and 415 GeV are excluded for \( m_{\tilde{\chi}_1^0} = 0 \).

The results can be also interpreted for phenomenological Minimal Supersymmetric Standard Models (pMSSM). Fig. 3 shows some of the 95\% CL exclusion regions in the pMSSM \( \mu - M_2 \) plane for (a) a scenario with right-handed sleptons with \( m_{\tilde{\ell}_R} = (m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_2^0})/2 \) (\( M_1 = 250 \) GeV, \( \tan \beta = 6 \)) and (b) for a scenario with heavy sleptons (\( M_1 = 50 \) GeV, \( \tan \beta = 10 \)). The exclusion regions are obtained by combining the results of this analysis with those from the ATLAS three-lepton search [5].

References

[1] Search for direct production of charginos, neutralinos and sleptons in final states with two leptons and missing transverse momentum in pp collisions at \( \sqrt{s} = 8 \) TeV with the ATLAS detector, JHEP 05 (2014) 071. arXiv:1403.5294 [hep-ex].

[2] A. L. Read, Presentation of search results: The \( C_L \) technique, J. Phys. G28 (2002) 2693.

[3] LEP SUSY Working Group (ALEPH, DELPHI, L3, OPAL), Notes LEPSUSYWG/01-03.1, 04-01.1, http://lepsusy.web.cern.ch/lepsusy/Welcome.html.

[4] Search for direct slepton and gaugino production in final states with two leptons and missing transverse momentum with the ATLAS detector in pp collisions at \( \sqrt{s} = 7 \) TeV, Phys. Lett. B718 (2013) 879. arXiv:1208.2884 [hep-ex].

[5] Search for direct production of charginos and neutralinos in events with three leptons and missing transverse momentum in \( \sqrt{s} = 8 \) TeV pp collisions with the ATLAS detector, JHEP 04 (2014) 169. arXiv:1402.7029 [hep-ex].