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Searches for electroweak production of supersymmetric gauginos and sleptons with the ATLAS detector

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Abstract. Results from the searches for electroweak production of gauginos or sleptons decaying into leptonic final states performed using 20.3 fb^{-1} of proton-proton collision data at $\sqrt{s}$ = 8 TeV recorded with the ATLAS experiment at the Large Hadron Collider are presented. No significant excesses are observed with respect to the prediction from Standard Model processes. Limits are set on a wide range of SUSY models.

1 Introduction

A new symmetry relating bosons and fermions, Supersymmetry (SUSY) is one of the favoured theories for beyond the Standard Model (SM) physics. It states that each SM particle is required to have a super-partner which differs in spin by one half. Amongst the new spectrum of particles are the sleptons ($\tilde{\ell}$), the electroweak gauginos ($\tilde{W}^{0,\pm}$, $\tilde{B}^0$) and the Higgsinos as corresponding super-partners of the leptons (ℓ), electroweak gauge bosons ($W^{\pm}$, Z, γ) and the Higgs bosons, respectively. After electroweak symmetry breaking, the gauginos and Higgsinos will mix resulting in mass eigenstates known as charginos ($\tilde{\chi}^{\pm}_j$, $j = 1, 2$) and neutralinos ($\tilde{\chi}^0_i$, $i = 1, 2, 3, 4$). If R-parity [1] is conserved, SUSY particles will only be produced in pairs and will eventually decay into SM particles, implying that the lightest SUSY particle (LSP) is stable and therefore a good dark matter candidate.

The stringent constraints on the masses of the strongly produced SUSY particles (squarks and gluinos) [2] may imply that electroweak production of SUSY particles is the dominant production mode at the Large Hadron Collider (LHC). Charged sleptons may also be produced directly if they are sufficiently light. A way to search for these SUSY particles is through the detection of charged leptons in the final states.

In this document, the results of the latest SUSY searches are presented using the full 8 TeV data delivered by the LHC in its first run and a total integrated luminosity of 20.3 fb^{-1} recorded by the ATLAS detector [3]. Only R-parity conserving SUSY models are presented, where the lightest neutralino ($\tilde{\chi}^0_1$) is considered as the LSP.

2 Supersymmetric Models

A wide range of supersymmetric models are considered by various multilepton analyses, in particular, phenomenological MSSM and simplified models.

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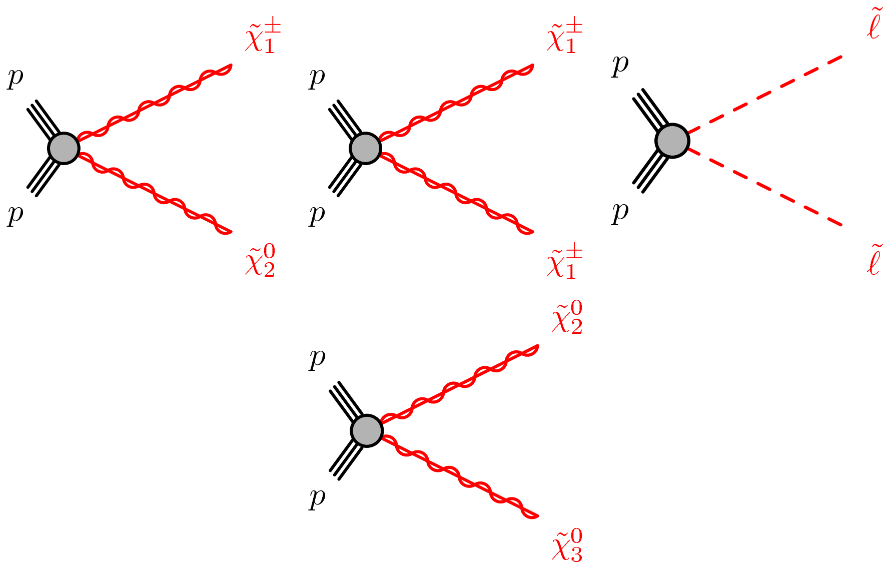

Figure 1. Diagrams illustrating the supersymmetric particle production modes considered by EWK analyses. In the figures, the term $\tilde{\ell}$ refers to $\tilde{e}, \tilde{\mu}, \tilde{\tau}$.

The search strategies for these analyses are based on different lepton multiplicity in the final state, depending on the SUSY scenario. This is achieved by optimisation methods to boost the SUSY signals focused on simplified models, which target the direct production of $\tilde{\chi}_1^{\mp}\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$, $\tilde{\chi}_2^0\tilde{\chi}_3^0$ or $\tilde{\ell}\tilde{\ell}$ (illustrated in Figure 1) with specific cascade decays, either through W and/or Z bosons or $\tilde{\ell}$, into charged leptons and missing transverse momentum. In the case of simplified models, the only free parameters are the masses of the relevant particles in the decay chain. The final results are also re-interpreted in the context of phenomenological MSSM.

3 Signature-based Analyses

There are several analyses searching for electroweak production of SUSY particles, this document summarises the searches performed in the following leptonic modes: one lepton (e, μ) and two b-tagged jets, two leptons (e, μ) with opposite charge, two hadronic taus with opposite charge, three leptons (e, μ, τ) and four leptons (e, μ, τ).

3.1 One lepton analysis

In this analysis events are selected by requiring one lepton (e, μ), two b-tagged jets and E_T^{miss} in the final state to offer sensitivity to $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ decays which are mediated by the W boson and the Higgs boson with SM couplings (h) decaying into two b-tagged jets [4]. This is the first SUSY analysis to include a Higgs with $m_h = 125$ GeV for the optimisation. For a massless $\tilde{\chi}_1^0$, mass ranges of $125 < m_{\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0} < 141$ GeV and $166 < m_{\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0} < 287$ GeV are excluded at 95% confidence level.

3.2 Two lepton analysis

In this analysis [5] events are selected by requiring two opposite charged leptons (e, μ), high E_T^{miss} and in some cases, jets in the final state to offer sensitivity to various simplified models: $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ decays which are mediated by WZ with the W decaying hadronically; $\tilde{\chi}_1^{\mp}\tilde{\chi}_1^{\pm}$ decays which are mediated by $\tilde{\ell}$ or WW; and direct-slepton production. Due to the wide variety of SUSY scenarios, seven signal regions are defined during the optimisation process to offer dedicated sensitivity to each of them. It has been found that kinematic variables such as $E_T^{\text{miss,rel}}$ and m_{T2}, defined as follows

$$m_{\text{T2}} = min_{\mathbf{q}_\text{T}}[max(m_\text{T}(\mathbf{p}_\text{T}^{\ell_1}, \mathbf{q}_\text{T})), m_\text{T}(\mathbf{p}_\text{T}^{\ell_2}, \mathbf{p}_\text{T}^{\text{miss}} - \mathbf{q}_\text{T}))] \tag{1}$$

$$E_T^{\text{miss,rel}} = \begin{cases} E_T^{\text{miss}} & \Delta\phi_{\ell,j} \geq \pi/2 \\ E_T^{\text{miss}} \times sin\Delta\phi_{\ell,j} & \Delta\phi_{\ell,j} < \pi/2, \end{cases} \tag{2}$$

have good discrimination power against SM background processes, in particular, m_{T2} has a kinematic end-point at the mass of the W boson and $E_T^{\text{miss,rel}}$ suppresses events with mis-measured jets or leptons.

3.3 Two tau analysis

This analysis [6] is the first electroweak search including hadronic taus in the final state. Events are selected by requiring two opposite charged hadronic taus and high E_T^{miss} in the final state. By considering hadronic taus in the final state this analysis is able to offer sensitivity to three different simplified models: $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ decays which are mediated by staus instead of WZ; $\tilde{\chi}_1^{\mp}\tilde{\chi}_1^{\pm}$ decays which are mediated by staus; and direct-stau pair production. A good understanding of the fake background, such as, multi-jets and W+jets, is key for this analysis due to fake taus. The fake background is estimated using a data-driven technique known as the "ABCD" method which is discussed in detail in Ref [6]. Optimisation studies show that m_{T2} is an excellent discriminating variable for this analysis.

3.4 Three lepton analysis

In this analysis [7] events are selected by requiring three leptons (e, μ, τ), high E_T^{miss} and veto b-tagged jets in the final state to offer sensitivity to $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ simplified models with different particles mediating the decays: WZ where the W boson decays semi-leptonically; Wh where the h is a Higgs with SM couplings; sleptons and staus. For the cases where there are only light leptons (e, μ) in the final state a same flavour opposite charge veto (targeting decays via Wh) and a binning approach (targeting decays via WZ and sleptons) are defined, where kinematic properties which have been found optimal in previous results [8], i.e. E_T^{miss}, m_T and $m_{\ell\ell}$, are split up in slices (a total of 20 bins) and by doing so maximising the overall significance improving previous results. With the inclusion of up to two hadronic taus in the final states, the decays mediated by staus and Wh are probed.

For scenarios where the intermediate decay of the $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ is mediated by W and Z bosons, a combination of results obtained from the two and three lepton analyses is performed to improve their individual exclusion limit. As a result, degenerate lightest chargino and the second lightest neutralino masses between 100 GeV and 415 GeV are excluded at 95% confidence level for a massless LSP.

3.5 Four lepton analysis

In this analysis [9] events are selected by requiring four leptons (e, μ, τ), high E_T^{miss} which are either enriched in or depleted of production of a Z boson. The SM background processes for this final state is small with respect to the previous analyses mentioned in this document, which makes this a clean signature to look for new physics. The four lepton analysis offers sensitivity to R-parity conserving models: $\tilde{\chi}_2^0\tilde{\chi}_3^0$ simplified models and General Gauge Mediation (GGM) models where the gravitino $\tilde{G}$ is considered to be the LSP. The simplified models considered are $\tilde{\chi}_2^0\tilde{\chi}_3^0$ decays which are mediated by ZZ, $\tilde{\ell}$ or staus which are targeted by a total of nine signal regions. The optimisation process mainly focuses on kinematic variables such as E_T^{miss} and m_{eff}. This signature is also sensitive to R-parity violating scenarios, discussed in detail in Ref [9].

4 Results

The results presented show no significant excess in the number of observed events above the SM expectation in all signal regions within statistic and systematic uncertainties. Exclusion limits are set in many simplified models in all analyses as well as pMSSM by the two lepton, two tau and three lepton analyses. Some of these results are shown in Figure 2 with the expected and observed exclusion limits for each scenario are set at 95% confidence level using the CL_s prescription [11]. For the direct-stau pair production scenario, upper limits on the production cross section are set due to the low cross sections and low sensitivity in the two tau analysis. The best observed upper limit on the signal strength is found for a mass of the stau of 90.6 GeV and a massless LSP. Overall improvements are seen on the exclusion limits with respect to previously published results [8, 10] with 7 TeV centre-of-mass energy.

5 Conclusions

The ATLAS collaboration has presented a thorough search strategy focused on direct production of charginos, neutralinos and sleptons by exploiting multi-leptonic final states with high missing transverse energy. No evidence of physics beyond the SM has been observed in the first run of the LHC. Stringent limits are set on the masses of the SUSY particles explored, Figure 3 shows the summary of the current exclusion limits at 95% confidence level [12] for charginos and neutralinos analysed in a variety of simplified model scenarios, where in the case of a massless LSP the lightest chargino masses up to 720 GeV are excluded at 95% confidence level for large mass differences with the LSP. Masses of the lightest neutralino can be excluded up to 370 GeV at high mass of the $\tilde{\chi}_1^{\pm}$.

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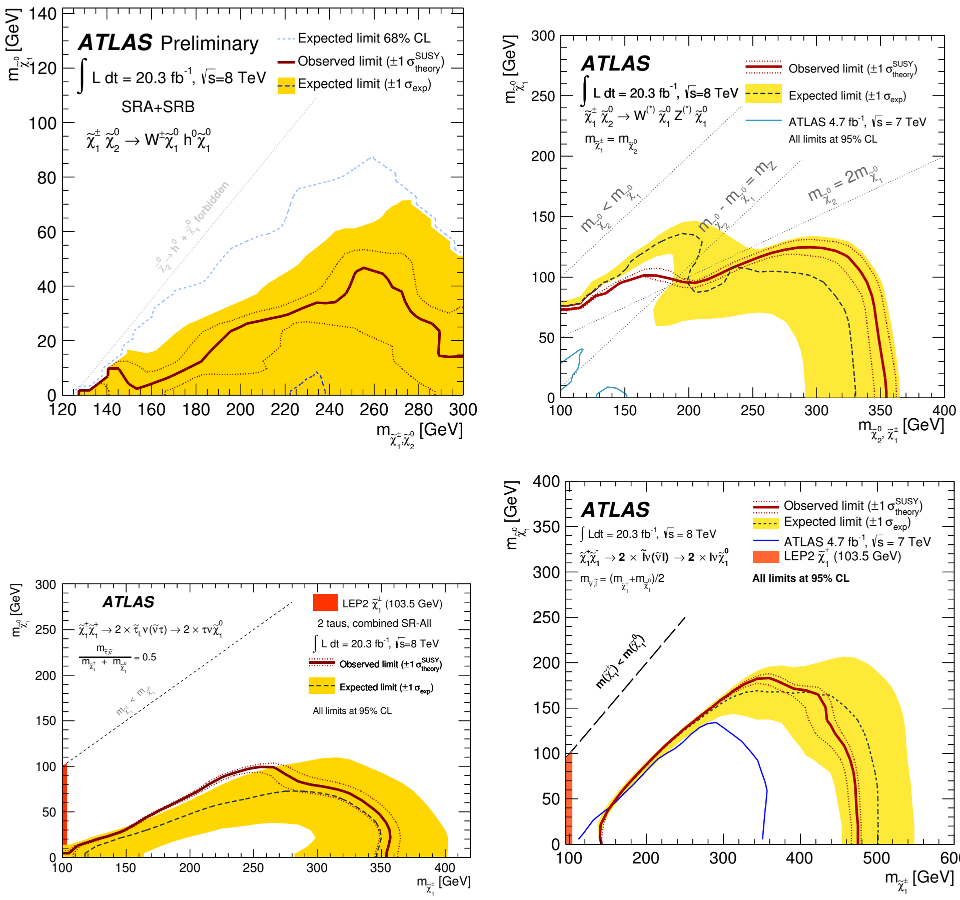

Figure 2. Four exclusion limits at 95% confidence level are shown in the $m_{\tilde{\chi}_1^{\pm}}$, $m_{\tilde{\chi}_1^0}$ plane for direct production of (a) $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ via (a) Wh [4] and (b) WZ [7], and $\tilde{\chi}_1^{\pm}$-pairs via (c) $\tilde{\tau}$ [6] and (d) $\tilde{\ell}$ [5]. The dashed and solid lines correspond to the expected and observed limits, respectively.

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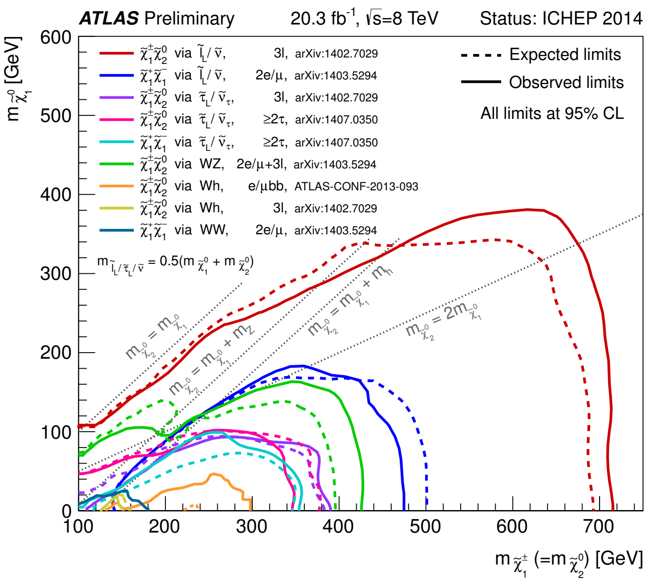

Figure 3. Summary of ATLAS searches for electroweak production of charginos and neutralinos based on 20 fb^{-1} of proton-proton collision data at $\sqrt{s} = 8$ TeV [12].