PROCEEDINGS OF SCIENCE

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

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Results from a search for supersymmetry in events with four or more charged leptons (electrons, muons and taus) are presented. The analysis uses a data sample corresponding to 36.1 fb^{-1} of proton–proton collisions delivered by the Large Hadron Collider at $\sqrt{s} = 13$ TeV and recorded by the ATLAS detector. Four-lepton signal regions with up to two hadronically decaying taus are designed to target different supersymmetric scenarios. Data yields are consistent with Standard Model expectations and results are used to set upper limits on the event yields from processes beyond the Standard Model. Exclusion limits are set at the 95% confidence level in R-parity-violating simplified models with decays of the lightest supersymmetric particle to charged leptons where wino masses are excluded up to ~ 1.5 TeV.

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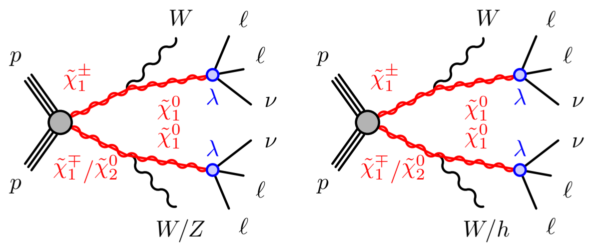
1. Introduction

This proceeding presents a search for supersymmetry (SUSY) in final states with at least four isolated, charged leptons (electrons, muons or taus) where up to two hadronically decaying taus are considered [1]. The analysis exploits the full proton–proton dataset collected by the ATLAS experiment during the 2015 and 2016 data-taking periods, corresponding to an integrated luminosity of 36.1 fb^{-1} at a center-of-mass energy of 13 TeV. The search itself is optimized using several signal models but is generally model-independent using loose requirements on effective mass or missing transverse energy. Results are presented in terms of the number of events from new physics processes with a four charged lepton signature, and in particular in terms of R-parity-violating (RPC) simplified models with decays of the lightest supersymmetric particle to charged leptons.

2. RPV scenarios

Simplified models of RPV scenarios are considered, where the lightest supersymmetric particle (LSP) is a bino-like neutralino ($\tilde{\chi}_1^0$) and decays via an RPV interaction. The LSP decay is described by the $\frac{1}{2}\lambda_{ijk}L_iLj\bar{E}_k$ lepton-number-violating superpotential term, where L_i and E_i indicate the lepton SU(2)-doublet superfield and singlet superfield, respectively. Lepton generations are referred to by the indices i, j and k while λ_{ijk} corresponds to nine Yukawa couplings which allow the decay of the LSP to every possible combination of charged lepton pairs. In this search, two extremes of the λ_{ijk} RPV couplings are considered: $L_1L_2\bar{E}_k\,(k = 1,2)$ where only decays to electrons and muons are considered, and $L_iL_3\bar{E}_3\,(i = 1,2)$ where only decays to taus and either electrons or muons are included.

In this proceeding, one of the three different RPV scenarios is presented for the next-to-lightest-supersymmetric particle (NLSP) in the $L_1L_2\bar{E}_k$ and $L_iL_3\bar{E}_3$: a Wino NLSP, where mass-degenerate wino-like charginos and neutralinos are produced in association. This scenarios, as diagrammatically shown in Figure 1, result in signatures with high lepton multiplicities and substantial missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$). These features of the final state can be used to select signal events while suppressing the SM background significantly.



(a) Wino W/Z NLSP (b) Wino W/h NLSP

Figure 1: Diagrams of the processes in the SUSY RPV models considered in the analysis.

3. Event selection and signal regions

Events are selected using single-lepton or dilepton triggers, where the trigger efficiencies are in the plateau region above the offline p_{T} thresholds. The latter are typically a bit higher than the online ones. Dilepton triggers are used only when the leptons in the event fail p_{T}-threshold requirements for the single-lepton triggers.

Events with four or more signal leptons ($\ell = e, \mu$ and hadronically decaying $\tau_{\mathrm{had-vis}}$) are selected and are classified according to the number of light signal leptons (L = e, μ) and signal taus (T): at least four light leptons and exactly zero taus 4L0T , exactly three light leptons and at least one tau 3L1T , or exactly two light leptons and at least two taus 2L2T .

Events are further classified according to whether they are consistent with a leptonic Z boson decay or not. The Z requirement selects events where any same-flavor LL pair combination with opposite electric charge (SFOS) has an invariant mass close to the Z boson mass, in the range $81.2 - 101.2$ GeV. A second Z candidate may be identified if a second SFOS LL pair is present and satisfies $61.2 < m(LL) < 101.2$ GeV. To suppress radiative Z boson decays into four leptons (where a photon radiated from a $Z \rightarrow \ell\ell$ decay converts to a second SFOS lepton pair) the Z veto also considers combinations of any SFOS LL pair with an additional lepton (SFOS+L), or with a second SFOS LL pair (SFOS+SFOS), and rejects events where either the SFOS+L or SFOS+SFOS invariant mass lies in the range $81.2 - 101.2$ GeV.

In order to separate the SM background from SUSY signal, the $E_{\mathrm{T}}^{\mathrm{miss}}$ and the effective mass of the event, m_{eff}, are both used. The m_{eff} is defined as the scalar sum of the $E_{\mathrm{T}}^{\mathrm{miss}}$, the p_{T} of signal leptons and the p_{T} of all jets above 40 GeV (in order to suppress jets stemming from pileup events and the underlying event).

Two signal regions (SR) are defined with 4L0T and a Z-boson veto: a general, model-independent signal region (SR0A) with $m_{\mathrm{eff}} > 600$ GeV, and a tighter signal region (SR0B) with $m_{\mathrm{eff}} > 1.1$ TeV, optimized for the RPV $LL\bar{E}_{12k}$ scenarios.

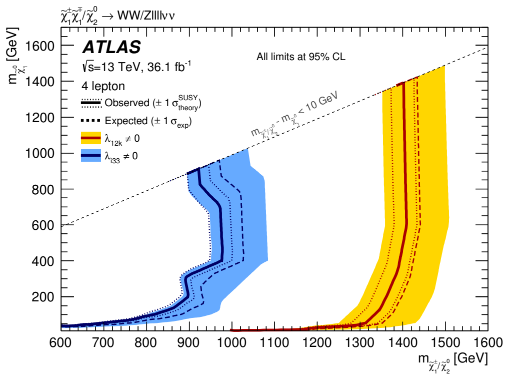
The background processes are classified into two categories: a) irreducible background consisting of hard-scattering processes giving rise to events with four or more real leptons (e.g. ZZ and $t\bar{t}Z$), and b) reducible background consisting of processes leading to events with at least one fake lepton (e.g. $t\bar{t}$, Z+jets and WW). The irreducible backgrounds are estimated from MC simulation, while the reducible backgrounds are derived from data. Finally, the predictions for irreducible and reducible backgrounds are tested in validation regions (VR).

4. Results

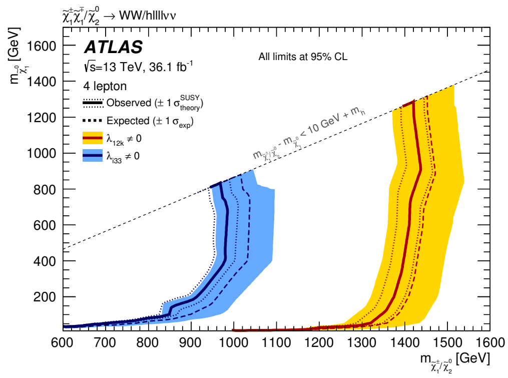
In general, the observed yields in each signal region are consistent with the Standard Model (SM) expectations within a local significance of at most $\sim 1\sigma$.

In order to quantify the probability for the background-only hypothesis to fluctuate to the observed number of events or higher, a one-sided p_0-value is calculated using pseudo-experiments, where the profile likelihood ratio is used as a test statistic to exclude the signal-plus-background hypothesis. A signal model can be excluded at 95% confidence level (CL) if the $\mathrm{CL_s}$ of the signal-plus-background hypothesis is below 0.05. The 95% CL upper limits on the signal cross section times efficiency and the $\mathrm{CL_b}$ value for the background-only hypothesis are also calculated for each signal region.

The number of observed events in each signal region is used to set exclusion limits in the SUSY models, where the statistical combination of all disjoint signal regions is used. Since SR0A and SR0B are overlapping signal regions, the one with the better expected exclusion is used in the



(a) Wino W/Z NLSP



(b) Wino W/h NLSP

Figure 2: Expected (dashed) and observed (solid) 95% CL exclusion limits on the SUSY models considered in the analysis. The limits are set using the statistical combination of disjoint signal regions. Where the signal regions are not mutually exclusive, the observed CL_s value is taken from the signal region with the better expected CL_s value [1].

combination. For the exclusion limits, the observed and expected 95% CL limits are calculated by performing pseudo-experiments for each SUSY model point, taking into account the theoretical and experimental uncertainties in the SM background and the experimental uncertainties in the signal. For all expected and observed exclusion limit contours, the $\pm 1\sigma_{\mathrm{exp}}$ uncertainty band indicates the impact on the expected limit of the systematic and statistical uncertainties included in the fit. The $\pm 1\sigma^{\mathrm{SUSY}}_{\mathrm{theory}}$ uncertainty lines around the observed limit illustrate the change in the observed limit as the nominal signal cross section is scaled up and down by the theoretical cross section uncertainty.

Figure 2 shows the exclusion contours for the RPV models considered in the search. The exclusion limits in the RPV models extend to high masses due to the high lepton multiplicity in these scenarios and the high efficiency of the m_{eff} selections. Wino-like $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ masses are excluded up to 1.46 TeV.

5. Conclusions

Results are reported from a search for new physics in the final state with four or more leptons (electrons, muons or taus), using proton-proton collision data at $\sqrt{s} = 13$ TeV collected by the ATLAS detector at the LHC in 2015 and 2016. Signal regions are defined with up to two hadronically decaying taus, and target lepton-rich RPV SUSY signals with selections requiring large effective mass or missing transverse momentum, and the absence of reconstructed Z-boson candidates. Data yields in the signal regions are consistent with SM expectations. In R-parity-violating simplified models with decays of the lightest supersymmetric particle to charged leptons, a lower limit of 1.46 TeV are placed on wino masses.

References

[1] ATLAS Collaboration, "Search for supersymmetry in events with four or more leptons in $\sqrt{s} = 13$ TeV pp collisions with ATLAS," Phys. Rev. D **98**, no. 3, 032009 (2018) doi:10.1103/PhysRevD.98.032009 [arXiv:1804.03602 [hep-ex]].