The results from a search for chargino-neutralino or chargino pair production via electroweak interactions are summarized. The results are based on a sample of $\sqrt{s} = 13$ TeV proton-proton collisions from the LHC, recorded with the CMS detector and corresponding to an integrated luminosity of 137 fb$^{-1}$. The search considers final states with large missing transverse momentum and pairs of hadronically decaying bosons WW, WZ, and WH, which are identified using novel algorithms. No significant excess of events is observed relative to the expectation from the standard model. Limits at the 95% confidence level are placed on the cross section for production of mass-degenerate wino-like superpartners of SU(2) gauge bosons, $\tilde{\chi}^+_1/\tilde{\chi}^0_2$. In the limit of nearly-massless neutralinos $\tilde{\chi}^0_1$, $\tilde{\chi}^+_1$ and $\tilde{\chi}^0_2$ with masses up to 870 and 960 GeV are excluded for $\tilde{\chi}^0_2 \rightarrow Z\tilde{\chi}^0_1$ and $\tilde{\chi}^0_2 \rightarrow H\tilde{\chi}^0_1$, respectively. Interpretations for other models are also presented.

1 Introduction

Supersymmetry$^2$ (SUSY) proposes the addition of a new symmetry to the standard model (SM) of particle physics and proposes for each boson (fermion) in the SM, there is also a fermionic (bosonic) superpartner (sparticle). The results presented here search for electroweak production of sparticles under the assumption that strongly-coupled sparticles are too massive to be produced at the LHC. Assuming that the superpartners of the SM leptons, the sleptons, are much heavier than the charginos and neutralinos, the decays of charginos and neutralinos proceed through W, Z and Higgs (H) bosons. Using simplified models$^3$ of $\chi^+_1\chi^0_2$ and $\tilde{\chi}^+_1\tilde{\chi}^0_1$ production, where the $\tilde{\chi}^+_1$ always decays to the W boson and the $\tilde{\chi}^0_1$, $\tilde{\chi}^0_2$ decays 100% of the time to either a Z or H plus the $\tilde{\chi}^0_1$. In $\tilde{\chi}^+_1\tilde{\chi}^0_2$ production, the $\tilde{\chi}^+_1$ and $\tilde{\chi}^0_2$ are considered to be the wino-like mass-degenerate next-to-lightest supersymmetric particles (NLSPs), while in $\tilde{\chi}^+_1\tilde{\chi}^0_1$ production, the $\tilde{\chi}^+_1$ is the wino-like NLSP. Assuming that R-parity is conserved and that the $\tilde{\chi}^0_1$ is a bino-like lightest supersymmetric particle (LSP) which escapes the detector unobserved. Targeted final states are WH, WZ, or WW together with a large transverse momentum imbalance. The corresponding simplified models are referred to as TChiWH, TChiWZ, and TChiWW respectively.
2 Event Selection

All events in the four signal regions (SRs) are required to pass a common set of baseline selection criteria. Each event is required to have a primary vertex and no isolated leptons, photons, or isolated tracks. Few other selections include $p_T^{\text{miss}} > 200$ GeV and $H_T > 300$ GeV. Large $p_T^{\text{miss}}$ and $H_T$ are typical of chargino and neutralino production when a high-momentum boson is present. For signal events we require at least two AK8 jets and 2–6 (inclusive) AK4 jets. Within this baseline phase space, four SRs are defined. Three SRs require at least one b-tagged AK4 jet ($n_b \geq 1$), referred to as the b-tag regions. The remaining SR requires zero b-tagged AK4 jets ($n_b = 0$), referred to as the b-veto region. In addition to these SRs, there are several control regions (CRs), which are used to help constrain the background estimates.

2.1 The b-veto search region

The b-veto SR seeks to isolate events that are consistent with the production of WW, WZ pairs of bosons plus large $p_T^{\text{miss}}$. In addition to the baseline event selection described above, the b-veto SR requires that at least two AK8 jets satisfy $65 < m_J < 105$ GeV. At least one AK8 jet must be W tagged, and at least one other AK8 jet must be V tagged.

2.2 The b-tag search region

The main b-tag SR which is most sensitive is the WH signal region. The WH SR requires at least one W boson candidate $\Delta R(b\text{-jet, AK8 jet}) < 0.8$ with the AK8 jet mass $65 < m_J < 105$ GeV and W-tagged and at least one Higgs boson candidate $\Delta R(b\text{-jet, AK8 jet}) > 0.8$ with the AK8 jet mass $75 < m_J < 140$ GeV that is bb tagged.

3 Background Estimation

For the b-veto SR, the background yields in the b-veto SR are estimated using two sets of transfer factors derived from simulation, $R_i$, defined as the ratio of the summed 0- and 1-res event yields in the SR with respect to either the zero-tag or one-tag CR. The values of $R_i$ are computed separately for each $p_T^{\text{miss}}$ bin and typically range between 0.2 and 0.3. The contributions of rare processes to the SRs and CRs are taken from simulation with appropriate data-to-simulation corrections applied. The total background prediction is given by:

$$N_{\text{data}}^{\text{SR}} = R_i (N_{\text{data}}^{\text{CR}_i} - N_{\text{CR}_i,\text{rare}}^{\text{MC}}) + N_{\text{SR},\text{rare}}^{\text{MC}}$$

where $R_i = N_{\text{SR},0&1-res}^{\text{MC}}/N_{\text{CR}_i,0&1-res}^{\text{MC}}$ and CR$_i$ is either the zero-tag or one-tag CR. The final background predictions for the SR are determined by a simultaneous fit of the two CRs.
For the WH SR, the background yield is estimated for top and non-resonant processes separately. A transfer factor, $R_{0l/1l}$, is used to provide an estimate of the number of top background events in either the SR or the $0l$ antitag CR. The values of $R_{0l/1l}$ are computed from simulation, including all corrections to the lepton reconstruction efficiencies, $b$-tagging efficiencies, and AK8 jet tagging efficiencies. The predicted number of top background events in either the SR or the $0l$ antitag CR is given by:

$$N_{i,\text{top}}^{\text{pred},0l} = N_{i,\text{top}}^{\text{MC},0l} N_{i,\text{all}}^{\text{data},1l} = R_{0l/1l} N_{i,\text{all}}^{\text{data},1l}$$

(2)

where $N_{i}^{\text{MC}}$ denotes the number of events expected from simulation, $N_{i}^{\text{data}}$ denotes the number of observed events, and $N_{i}^{\text{pred}}$ denotes the number of events predicted via this method. Additionally, the subscript $i$ denotes the tagging region, tag or antitag. The subscript “all” refers to all of the SM backgrounds, while “top” refers to only the top background.

Using $R_{p/f}$ and the prediction of top backgrounds described above, the predicted 0-res background contribution to the SR is given by:

$$N_{0-\text{res}}^{\text{pred}} = R_{p/f} \left( N_{\text{data},0l}^{\text{antitag}} - N_{\text{pred},0l}^{\text{antitag, top}} - N_{\text{MC},0l}^{\text{antitag, rare}} \right)$$

(3)

where $N_{\text{data},0l}^{\text{antitag}}$ denotes the number of observed events in the $0l$ antitag CR, $N_{\text{pred},0l}^{\text{antitag, top}}$ denotes the predicted number of top background events from Eq. (2), and $N_{\text{MC},0l}^{\text{antitag, rare}}$ denotes the number of rare background events, such as diboson and triboson events, expected from simulation.

4 Results

Fits to the SRs and CRs are performed using a statistical model of our SM background predictions. This fitting procedure further constrains the predictions and the uncertainties in the predictions. The predicted SM backgrounds based on this procedure, the observations, and the predicted signal yields in each of the SRs are shown below. No statistically significant excess of events is observed in the data with respect to the SM background predictions.

Figure 2 – Prediction vs. data in the b-veto SR (left), the WH SR (right). The filled histograms show the SM background predictions, and the open histograms show the expectations for selected signal models, which are denoted in the legend by the name of the model followed by the assumed masses of the NLSP and LSP. The observed event yields are indicated by black markers [4].
5 Summary

Using wino-like pair production cross sections, 95% confidence level (CL) mass exclusions are derived. For signals with WW, WZ, or WH final states, the NLSP mass exclusion limit for low-mass LSPs extends up to 670, 760, and 970 GeV, respectively. When we consider models including both wino-like NLSP $\tilde{\chi}_1^0 + \tilde{\chi}_2^0$ and $\tilde{\chi}_1^+ + \tilde{\chi}_1^- \tilde{\chi}_1^0$ production with either $\tilde{\chi}_2^0 \to Z \tilde{\chi}_1^0$ or $\tilde{\chi}_2^0 \to H \tilde{\chi}_1^0$, the NLSP mass exclusion extends up to 870 and 960 GeV, respectively. These mass exclusions are the most stringent constraints to date set by CMS at high NLSP masses.

Figure 3 – The 95% CL upper limits on the production cross sections for $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ assuming that each $\tilde{\chi}_2^0$ decays to a W boson and $\tilde{\chi}_1^0$ (left) and $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ production assuming that the $\tilde{\chi}_1^+$ decays to a W boson and $\tilde{\chi}_1^0$ and that the $\tilde{\chi}_2^0$ decays to a Z boson and $\tilde{\chi}_1^- \tilde{\chi}_1^0$ (middle) or that the $\tilde{\chi}_2^0$ decays to a H and $\tilde{\chi}_1^+$ (right). The black curves represent the observed exclusion contour and the change in this contour due to variation of these cross sections within their theoretical uncertainties ($\sigma_{\text{theory}}$). The red curves indicate the mean expected exclusion contour and the region containing 68% ($\pm 1 \sigma_{\text{experiment}}$) of the expected exclusion limits under the background-only hypothesis [4].

Results are also shown using the higgsino-like NLSPs $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, and $\tilde{\chi}_3^0$. NLSP masses between 300 and 650 GeV are excluded for low mass LSPs at 95% CL under the standard model hypothesis; however, the observed cross section upper limits lie mostly below the theoretical cross section because of a modest excess in data.

Figure 4 – Expected and observed 95% CL exclusion for mass-degenerate higgsino-like $\tilde{\chi}_1^+ \tilde{\chi}_1^-$, $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, $\tilde{\chi}_1^+ \tilde{\chi}_1^-$, and $\tilde{\chi}_1^- \tilde{\chi}_2^-$ production as functions of the NLSP and LSP masses. The 95% CL upper limits on the production cross sections are also shown. The $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, and $\tilde{\chi}_3^0$ are considered to be mass degenerate [4].

References

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