PROCEEDINGS OF SCIENCE

Search for electroweak production of SUSY at CMS

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Searches for the direct electroweak production of supersymmetric charginos and neutralinos are presented in signatures with one, two or more leptons. Results are based on a sample of proton-proton collision data collected at a center-of-mass energy $\sqrt{s} = 13$ TeV with the CMS detector in 2016, corresponding to an integrated luminosity of 12.9 fb^{-1}. The observed event rates are in agreement with expectations from the standard model. These results probe charginos and neutralinos with masses up to 400-1000 GeV depending on the assumed model parameters.

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1. Introduction

Searches for new physics in the context of supersymmetry (SUSY) constitute a major part of the CERN LHC physics programme. While no evidence of such new particles has been found with the samples of proton-proton (pp) collision data collected at $\sqrt{s}$ = 7 and 8 TeV, stringent constraints were put on the masses of the colored superpartners (squarks and gluinos) ranging from several hundreds of GeV to about 1.8 TeV, depending on the assumptions entering the models for the interpretation of the results.

Using a data sample of 12.9 fb^{-1} of pp collision data, recorded with the CMS detector at the LHC in the first part of 2016 we present various searches targetting electroweak production of supersymmetric particles, see Figure 1. The smaller cross sections motivates the usage of multiple signatures to enhance the sensitivity to the production of such particles. We present searches with one, two or more leptons and lite to no hadronic activity in the final state trying to cover a broad range of possible new physics scenarios. The various searches are described in the following sections.

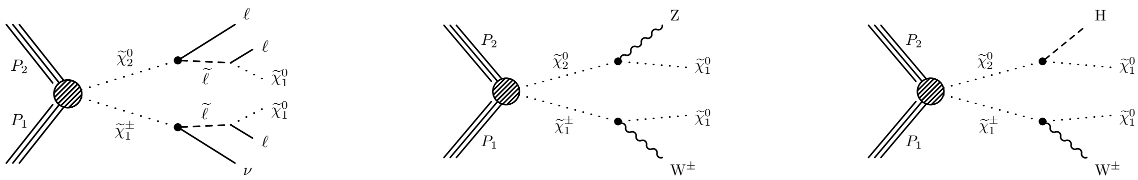

Figure 1: Chargino-neutralino pair production with decays mediated by (a) sleptons. Chargino-neutralino pair production decaying directly to an LSP via a (b) W and Z boson or (c) a Higgs boson.

2. Multilepton search

This search [1] is designed to cover a broad range of possible new physics scenarios which manifest themselves in multilepton or same-sign dilepton signatures with little to no hadronic activity. Assuming that R-parity is converved, we do expect the presence of particles in final states that evade detection, yielding a sizable E_T^{miss}. We expect to get final states with three leptons of different flavor and charge combinations, both resonant (from W and Z boson decay) and non-resonant. The signature with two leptons of the same charge can arise in case one of the leptons is too soft to be detected, as is expected to occur in models with a compressed mass spectrum. With this in mind, the analysis is subdivided into several categories defined by the number of leptons in the event, their flavor and charge. Each of these categories is further subdivided into bins defined by the kinematic variables such as the invariant mass of the two leptons forming an opposite-sign dilepton pair (if any) (M_{ll}), the transverse mass of the third lepton and E_T^{miss} system (M_T), the two-lepton transverse mass (M_{T2}), and E_T^{miss}. These variables are chosen to either suppress background contributions arising from standard model processes or to enhance the sensitivity to possible mass hierarchies of new particles.

The dominant background arises from WZ production, when both W and Z bosons decay leptonically. The WZ background is normalized to data in a control region adjacent to the same-sign dilepton search region. The uncertainty in the normalization is found to be 12–14%. Furthermore, to estimate the potential mismodeling of the W M_T shape in the simulation of the process, the M_T shape prediction of the simulation is verified in a Wγ and W + jet control sample in data. The measured shape was found to agree well with the simulated prediction. Another important source of background is arising from processes with at least one non-prompt e, μ and τ_h, such as $t\bar{t}$, W + jet or DY + jet. It is estimated using the "tight-to-loose" ratio method. The probability for a loosely defined light lepton to pass the full set of selection criteria is measured in a multi-jet sample in data enriched in non-prompt leptons, called the measurement region. Once measured, this probability is applied in a sample of events which pass the full kinematic selection, but where at least one of the leptons fails the nominal selection but passes the loose requirements, in order to predict the amount of events from non-prompt leptons entering each search region. Processes with external or internal conversions contribute as background to our final states when a W or a Z boson radiates an initial- or final-state photon and this photon undergoes an asymmetric internal or external conversion in which one of the leptons has very low p_T. The modeling of the conversion background is verified in a data control region enriched in both external and internal conversions. Finally, irreducible standard model processes that yield to many prompt-leptons include multi-boson production (W, Z, H, or a prompt γ), single boson production in association with a $t\bar{t}$ pair, and double-parton scattering.

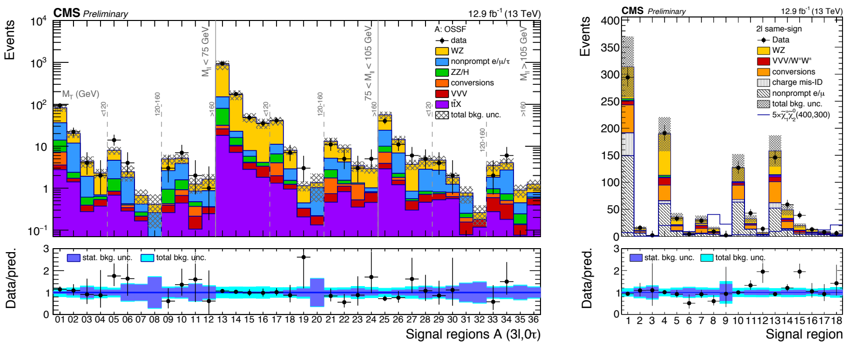

Figure 2: Left shows a comparison of the expected and observed yields in trilepton signal regions: three light leptons with an opposite-sign same-flavour pair. Right shows expected yields and observed counts for the search regions defined in the same-sign dilepton category. The lower panels show the ratio between the observed and expected yields in all signal regions, with the dark blue band indicating the statistical background uncertainty, and the light blue band corresponding to the total background uncertainty propagated to the ratio.

Background estimation methods are applied in each of the search regions, a comparison between the predicted and observed yield is shown in Figure 2 for the same-sign and three-lepton (with an opposite-sign same-flavour pair). Results from other search regions can be found in [1]. Observed yields agree well with the SM prediction, and thus the results are interpreted are interpreted in the context of the simplified models of chargino-neutralino pair production. We compute 95% confidence level (CL) upper limits on the new-physics cross sections using the CLs method, as shwown in Figure3.

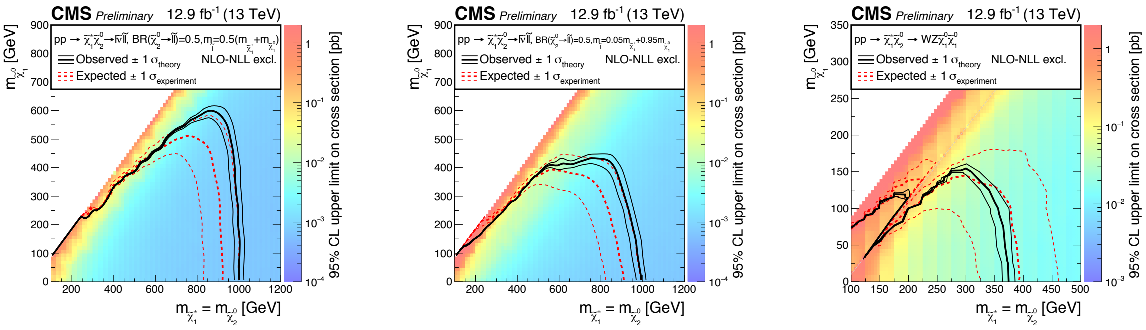

Figure 3: Interpretation of the results of the three-lepton search in the flavor-democratic signal model with slepton large mass splitting, The shading indicates the 95% CL upper limit on the chargino-neutralino production cross section times branching fraction. The contours bound the mass regions excluded at 95% CL assuming the NLO+NLL cross sections for a branching fraction of 50%, as appropriate for the visible decay products in this scenario. The observed and expected bounds are also shown.

3. Soft opposite-sign dilepton search

A search for new physics in events with two low-momentum opposite-sign leptons and missing transverse momentum is also presented [2]. This signature can arise in many new physics scenarios, in particular in those referred to as "compressed", when some of the decay particles are nearly degenerate in mass. The search has been optimised to target signs of electroweakinos in a compressed mass spectrum. In addition to the presence of two opposite-sign leptons and moderate missing transverse energy together with the presence of at least one jet in the event, a complex search strategy is designed to enhance the sensitivity to signal events while reducing SM backgrounds to a minimum. The signal region is then divided in four regions of the invariant mass of the two leptons, that will correspond to the mass difference between the two gauginos.

Backgrounds with two prompt leptons are estimated using control regions that are identified to be similar in phase space to the signal regions, yet remain relatively signal free. Different control regions are employed for each physics process that contributes significantly in the signal region, namely the $t\bar{t}$ dilepton background, the DY+jets background and the diboson background.T he background in the signal region (SR) is estimated independently for each physics process, using the number of events observed in the data in the corresponding control region (CR) and a transfer factor which describes the expected ratio of events in the SR and in the CR region for each physics process. The transfer factor for a specific physics process is determined from Monte Carlo (MC) simulation. Effectively, this estimate assumes that the simulation describes well the kinematic dependence of the physics process, and normalizes the expected yield from the physics process in question to the one observed in the corresponding CR in the data. Deviations from this assumption are accounted for as systematic uncertainties in the value of the transfer factor.

The predicted yields of the SM background processes in the SR are presented compared to data in Figure 4 (the different integrated luminosities is due to the trigger strategy). The predicted yields are determined using data assisted methods. Having found no evidence of new physiscs above the SM backgrounds, results are interpreted in the context of chargino-neutralino production

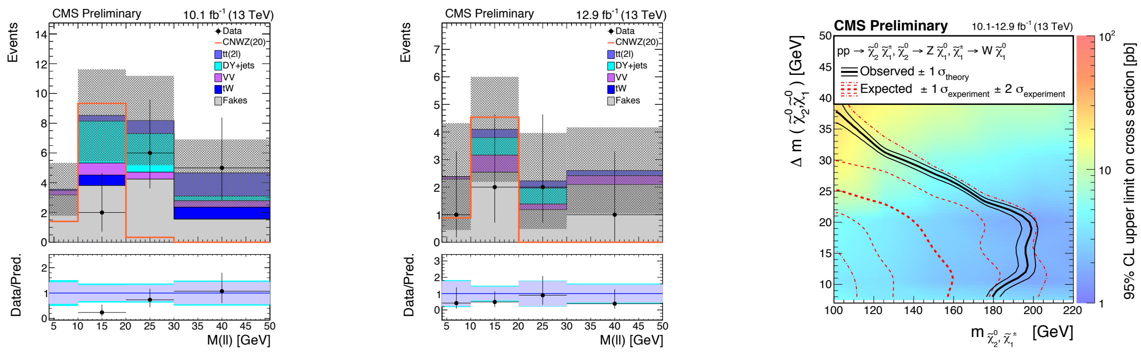

Figure 4: Dilepton mass distributions in data, compared with the SM predictions for two E_T^{miss} ranges: $125 < E_T^{miss} < 100$ GeV ($\mu\mu$ channel) (left) and $E_T^{miss} > 200$ GeV ($\mu\mu$,ee channels) (middle). The shaded grey band in the SM prediction is the total uncertainty (both statistical and systematic) in the background prediction. In the ratio plot the light purple band indicates the statistical uncertainty, while the light cyan band includes both statistical and systematic uncertainties. Right: The observed exclusion contours (black curves) assuming the NLO+NLL cross sections are shown, the dashed (red) curves present the expected limits.

with a compressed mass spectra, see Figure 4 (right). We probe chargino masses up to 175 GeV for a mass difference of 7.5 GeV.

4. WH final state search

This search targets beyond the standard model physics in events with a leptonically-decaying W boson, a Higgs boson decaying to a pair of b-quarks, and missing transverse energy, like the one predicted in supersymmetric models from electroweak production of gauginos. We select events with one lepton, 2 b-jets and $E_T^{miss} > 100$ GeV. To suppress background from semi-leptonic $t\bar{t}$, a requirement on the transverse mass is imposed. Signal region is defined by asking the invariant mass of the two b-jets to be compatible with the higgs mass. Thus look for a resonance in the m_{bb} spectrum.

The backgrounds for this search are classified into six categories, based on the available control regions and strategies to estimate their contributions. The first and most important category is "Dilepton top quark". This category accounts for around 90% of the total background in the signal region. Next three categories include processes with a single leptonically-decaying W boson. The second category is "W + light jets," which here includes all flavours except b-jets. The third category is from a W boson produced in association with b-jets, called W + HF. The fourth category is WZ production, where the W boson decays leptonically and the Z boson decays to bb. The fifth category is the "Single lepton top quark" background, consisting of semi-leptonic $t\bar{t}$ as well as single top quark t- and s-channel production. Finally, other standard model processes contribute a small amount to the expected yield in the signal region and are grouped together in the "Rare" category. All of the background processes are modeled using MC simulation. Three data control regions are defined by inverting signal region selection requirements, to make them orthogonal to the signal region and reduce potential signal contamination. They are used to validate the modeling of the main backgrounds and assign associated systematic uncertainties.

The observed data are in agreement with the standard model prediction. The results are used to set cross section limits on chargino-neutralino production in a simplified model of supersymmetry with the chargino, netrualino decaying to a W and a H boson respectively, shown in Figure 5.

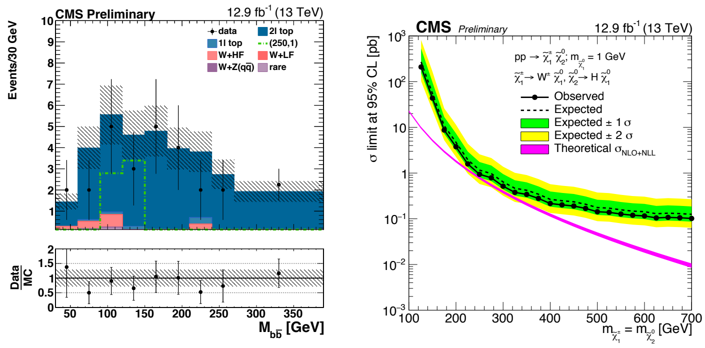

Figure 5: Left: Distribution of $M_{b\bar{b}}$ after all signal region kinematic requirements. The hatched band shows the total uncertainty on the background prediction, including statistical and systematic components. The signal distribution for a reference mass point is overlaid as an open histogram. Right: Expected and observed cross section limits at the 95% CL as a function of the chargino mass, where the LSP is assumed to have a mass of 1 GeV. The NLO theoretical cross section for production of chargino, neutralino is also shown.

5. Conclusions

The first results from CMS at 13 TeV on searches for EWK production of SUSY have been presented. Different final states including one, two or more leptons have been used to search for evidence of new physics. The data are split into categories formed according to the number, sign and flavor of the leptons, and are further subdivided in various kinematic regions to be sensitive to a broad range of electroweakly produced new particles. No significant deviation from the standard model expectations is observed. The results are used to set limits on the various simplified models with a chargino-neutralino pair production. We probe chargino-neutralino masses up to 1 TeV (light sleptons), 375 GeV (heavy sleptons). For very compressed scenarios ($\Delta M < 20$ GeV) we probe chargino-neutralino masses up to 200 GeV.

References

[1] CMS Collaboration, *Search for electroweak SUSY production in multilepton final states in pp collisions at sqrt(s)=13 TeV with 12.9/fb*, CMS-PAS-SUS-16-024 (2016).

[2] CMS Collaboration, *Search for new physics in the compressed mass spectra scenario using events with two soft opposite-sign leptons and missing transverse momentum at 13 TeV*, CMS-PAS-SUS-16-025 (2016).

[3] CMS Collaboration, *Search for electroweak production of charginos and neutralinos in the WH final state at 13 TeV*, CMS-PAS-SUS-16-026 (2016).