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Search for electroweak SUSY production at the CMS experiment

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Abstract. A review of recent results from CMS on searches for the electroweak production of supersymmetry particles is presented. All possible production scenarios including $\chi^{\pm}\chi^{\mp}$, $\chi^0\chi^{\pm}$, $\chi^0\chi^0$, $\tilde{l}\tilde{l}$ and also the vector boson fusion (VBF) production mechanism are investigated. The full 2012 data sample which comprises 19.6 fb^{-1} of proton-proton collisions at $\sqrt{s} = 8$ TeV is used. In all studied decay modes, the observed yields agree well with the expectation of the standard model (SM) predictions and limits are set on the rates of the direct production of charginos, neutralinos and sleptons.

Introduction

Most of the searches for Super Symmetry (SUSY) [1] at the Compact Muon Solenoid (CMS) [2] have focused on the production of gluinos and squarks productions, the SUSY partners of the gluon and quarks, via strong interactions [3, 4, 5]. Observing no evidence of new physics, the strongly-interacting SUSY particles up to a mass scale of ~1 TeV are excluded. If squarks and gluinos are heavy, direct electroweak production of charginos and neutralinos, the SUSY partners of the $W^{\pm}$, Z, and Higgs bosons, may be dominated at the LHC. Although the electroweak SUSY production may suffer from the very low rate, the clean leptonic final state and the QCD-free selection makes this study possible.

Search for $\tilde{\chi}^{\pm}\tilde{\chi}^0_2$ productions

The production of a chargino and a neutralino has the highest rate among electroweak SUSY productions. The masses of $\tilde{\chi}^{\pm}$ and $\tilde{\chi}^0_2$ are assumed to be equal for this study. The results of these studies are documented in [6]. Different decay scenarios for this study are considered.

The first scenario is for the slepton mass between $\tilde{\chi}^{\pm}$ and LSP ($\tilde{\chi}^0_1$) masses. In this case the parent SUSY particle decays to leptons via sleptons. The final state of such decay would be three leptons together with missing transverse energy ($\vec{E}_{\mathrm{T}}^{\mathrm{miss}}$). For selecting signal events, all events with 3 leptons and $\vec{E}_{\mathrm{T}}^{\mathrm{miss}} > 50$ GeV are selected. To suppress $t\bar{t}$ events, events with at least one b-tagged jet are discarded. The WZ contribution is estimated using simulated samples where a data driven fake rate method is exploited to estimate the remaining $t\bar{t}$ background. Events are classified based on lepton flavors, the invariant mass of the leptons and $\vec{E}_{\mathrm{T}}^{\mathrm{miss}}$ [6].

For the compressed spectrum, when the slepton mass is close to the LSP mass, the produced lepton could be so soft that escapes detection. To cover this part of the phase space, a search for events with two same-sign leptons plus missing energy is also performed [6].

Another possible decay scenario which has been considered is the case in which the SUSY parent particles decay to Z and W bosons because their decay to sleptons is forbidden and the neutralino is bino-like (Fig. 1 (left)). The leptonic decay of the Z boson together with leptonic and hadronic decays of the W boson are taken into account for this study. For the leptonic decay of the W boson, the 3 lepton selection which is described in the previous part is used.

Discovering the SM Higgs boson motivates the search for a Higgsino-like neutralino (Fig. 1 (right)). The leptonic decay of the W boson along with different Higgs decays are studied [6]. For the Higgs bosons decaying to $b\bar{b}$, events

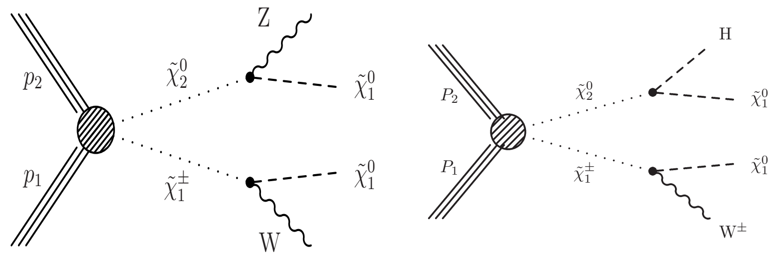

FIGURE 1. When sleptons are heavier than chargino and neutralino, they decay to SM bosons [6].

with one lepton and exactly two b-tagged jets are selected. Moderate cuts on $\vec{E}_{\mathrm{T}}^{\mathrm{miss}}$ and the transverse mass of the lepton are applied. All the backgrounds are estimated using simulation. A peak is searched for in the invariant mass of the $b\bar{b}$ system.

To search for $H \to W(l\nu)W(jj)$, events with two same-sign leptons and two jets are selected. For backgrounds from fake leptons, a data driven method is employed. All backgrounds with two prompt same-sign leptons are taken from MC. In the invariant mass of the lepton and two jets a search is performed to find the Higgs peak. As no evidence of new physics is observed, the results are used to set exclusion limits on the mass of chargino and neutralino (Fig 2 (right))

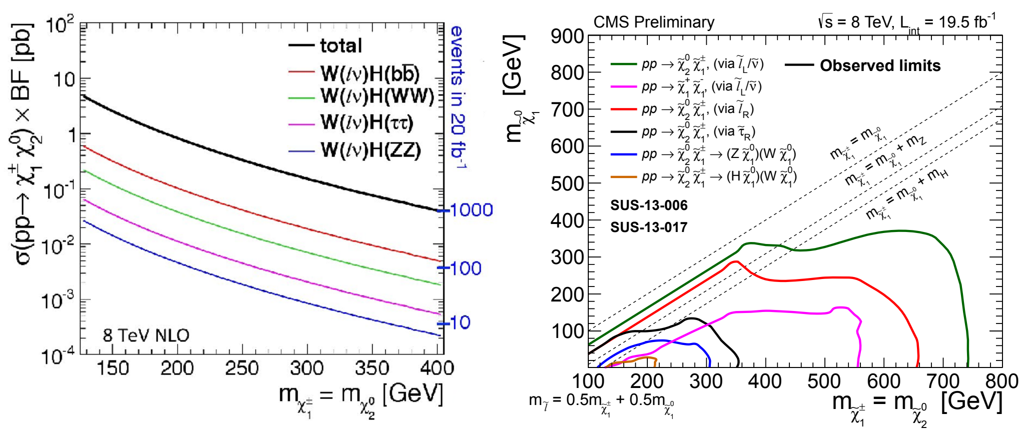

FIGURE 2. Cross section of WH via SUSY electroweak production vs. the $\tilde{\chi}^{\pm}$ mass for different branching fractions (left) and the exclusion limits on the mass of the chargino and neutralino in $\tilde{\chi}^{\pm}\tilde{\chi}_2^0$ searches by the CMS collaboration (right) [6].

Search for $\tilde{\chi}^0\tilde{\chi}^0$ production

When $\tilde{\chi}^0$ and $\tilde{\chi}^{\pm}$ are both wino-like, the production of $\tilde{\chi}^0\tilde{\chi}^0$ is very suppressed. In gauge-mediated-SUSY-breaking (GMSB) models [7, 8, 9] the production rate of this process is enhanced. LSP in this model is an almost massless gravitino. For the case of Higgsino-like $\tilde{\chi}^0$, two produced $\tilde{\chi}^0$s decay to two Higgs bosons and $\vec{E}_{\mathrm{T}}^{\mathrm{miss}}$ according to Fig. 3.

As the Higgs boson decays in 60% of cases into two b-quarks, only the $H \to b\bar{b}$ decay is considered for this search [10]. Events with four or five jets in the final state are selected among which at least three jets must be tagged as b-quark jet. To reconstruct the Higgs bosons, the combination of jets minimizing $|\Delta m_{jj}| \equiv |m_{jj,1} - m_{jj,2}|$ is selected. To select events with $m_{jj,1}$ and $m_{jj,2}$ consistent with the SM Higgs mass, two cuts are applied : $100 < \langle m_{jj} \rangle < 140$ GeV and $|\Delta m_{jj}| < 20$ GeV. To estimate the backgrounds which is mostly $t\bar{t}$, the $\langle m_{jj} \rangle$ and $|\Delta m_{jj}|$ variables are used to define the signal and control regions.

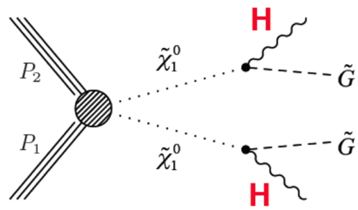

FIGURE 3. The $\tilde{\chi}^0\tilde{\chi}^0$ decay to two Higgs bosons and $\vec{E}_{\mathrm{T}}^{\mathrm{miss}}$

Yields in different $\vec{E}_{\mathrm{T}}^{\mathrm{miss}}$ ranges are compared to the background expectation and no sign of new physics is observed. However, because of a slight excess of data events compared to the background expectation we are unable to exclude the signal hypothesis for any value of Higgsino mass [10]. Figure 4 shows the results in terms of the signal

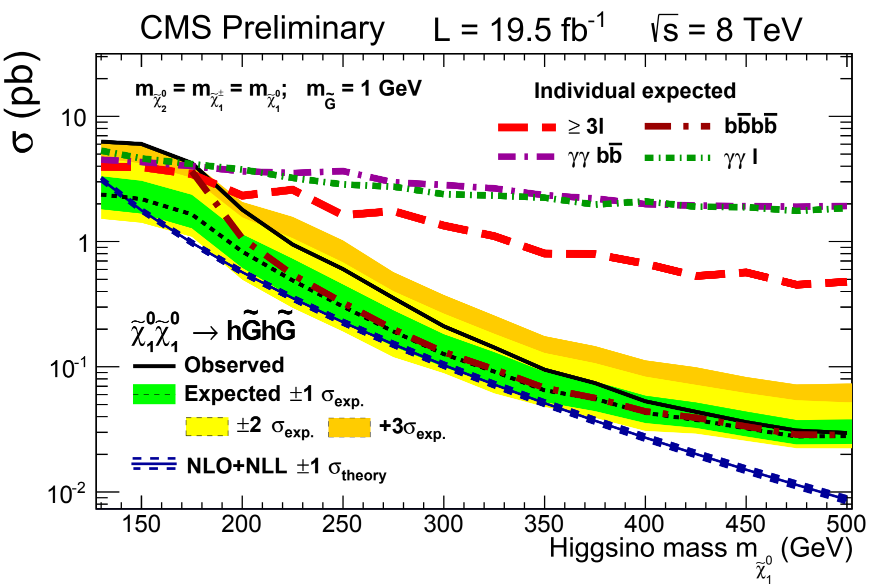

FIGURE 4. The expected and observed upper limits on the cross section of the $\tilde{\chi}^0\tilde{\chi}^0$ production for $HH + \vec{E}_{\mathrm{T}}^{\mathrm{miss}}$ studies [10].

model cross section.

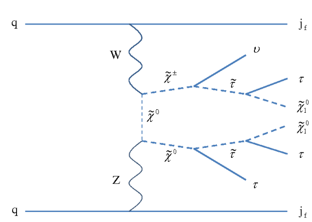

FIGURE 5. Feynman diagram of the SUSY electroweak production via VBF mechanism.

Search for electroweak SUSY with VBF tagging

The most recent result published by the CMS experiment, studies scenarios in which two electroweakino particles are produced via the vector boson fusion mechanism [11]. The Feynman diagram of such process is shown in Fig. 5. The specific signature of this signal is the production of two jets which are produced in the forward region of the detector. Requesting for two jets with $p_T > 30$ GeV in the opposite forward directions ($\eta_1 * \eta_2 < 0$ and $|\Delta\eta| > 4.2$) and applying a tight requirement on their invariant mass ($m(jj) > 250$ GeV) discard considerably the standard model backgrounds. For the central region, events with two isolated leptons are selected. Here in addition to electrons and muons, the

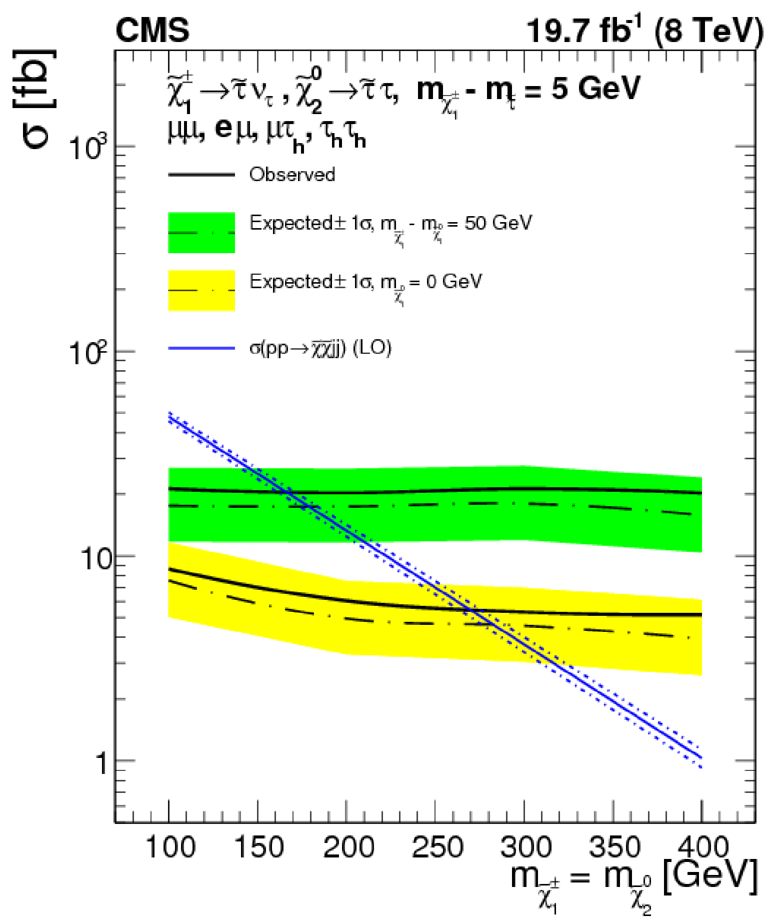

FIGURE 6. The exclusion limit on the cross section of this process vs. the χ^{pm} mass when $m_\chi - m_{\tilde{\tau}} = 5$ GeV [11].

hadronic decay of the τ leptons (τ_h) are also included. In addition, a moderate cut on $\vec{E}_{\mathrm{T}}^{\mathrm{miss}}$ is applied. To reject the $t\bar{t}$ background, events with exactly zero b-tagged jet are selected. Dividing events according to their lepton content (eμ, $\mu\mu$, $\mu\tau_h$ and $\tau_h\tau_h$) and their charges (same sign (SS) and opposite sign (OS)), leads to 8 different categories. Backgrounds in all categories are estimated using data-driven techniques. As no difference between the estimated backgrounds and the observed data is seen, upper limit on the cross section vs. the $\chi^{\pm}$ mass is evaluated. The excluded region for the case where the mass difference of the $\chi^{\pm}$ and $\tilde{\tau}$ is only 5 GeV is shown in the Fig. 6.

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