Search for supersymmetry with Higgs bosons in the final state

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Abstract

The recent observation of a Standard Model (SM) like Higgs boson offers the chance to exploit the measured properties of this particle to perform beyond-the-SM searches. A number of searches for Standard Model like Higgs bosons produced in cascade decays of supersymmetric particles are presented, including both strong and weak production mechanisms. A data sample of pp collisions at a center-of-mass energy $\sqrt{s}$ = 8 TeV corresponding to an integrated luminosity of about 19.5 fb^{-1}, collected by the CMS experiment [1] at the LHC, is used. SM-like branching fractions are considered for the Higgs boson, with a mass $M_{h^0} \simeq 125$ GeV.

Keywords: CMS, supersymmetry, Higgs boson

1. $Wh^0 + E_T^{miss}$

Searches for direct electroweak production of supersymmetric charginos and neutralinos in final states with a Higgs boson are presented [2, 3]. A chargino-neutralino pair is produced, and decays to a W boson, a Higgs boson, and missing transverse energy from escaping lightest supersymmetric particles. Searches explore three channels, depending on the particles detected in the final state: single lepton, same sign dilepton, and multilepton channels. The search performed in the single lepton final state provides sensitivity to events with a Higgs boson decaying as $h^0 \rightarrow b\bar{b}$. The search in the same sign dilepton final state targets events with a Higgs boson decaying as $h^0 \rightarrow W^+W^-$, where one W boson decays semi-leptonically, and the other hadronically. Finally, the search in the multilepton final states is targeting events where the Higgs boson decays as $h^0 \rightarrow W^+W^-$, $h^0 \rightarrow ZZ$, and $h^0 \rightarrow \tau^+\tau^-$. The data are consistent with the Standard Model backgrounds (Fig. 1). Results are used to set constraints on the mass of charginos and neutralinos up to 204 GeV (Fig. 2).
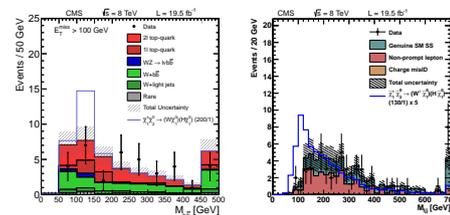

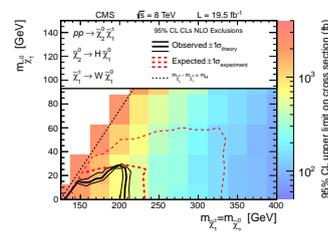Figure 1: Results of searches for $Wh^0 + E_T^{miss}$ final states.

Figure 2: Interpretation of searches for $Wh^0 + E_T^{miss}$ final states.

2. $h^0 h^0 + E_T^{miss}$

A search for electroweak pair production of higgsinos, both of which decay to a Higgs boson and an almost massless lightest supersymmetric particle is presented [4, 5]. Each Higgs boson is reconstructed in its decay to a $b\bar{b}$ pair, and the escaping lightest supersymmetric particles lead to missing transverse energy in the event. Three mutually exclusive samples of events with tagged b jets are defined: 2b sample, 3b sample, and 4b sample. The sample most sensitive to signal events is the 4b sample. The 3b sample is added to improve signal efficiency, while the 2b sample is only used for background evaluation. The data are consistent with the Standard Model predictions within uncertainties (Fig. 3). For higgsino masses between about 270 and 350 GeV, the expected 95% confidence level upper limits on the cross section reach the predicted production cross section. Because of a slight excess in the observed number of events, compared to the estimated background, no exclusion is obtained for any higgsino mass value (Fig. 4).
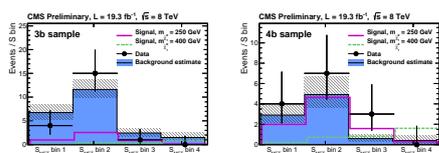

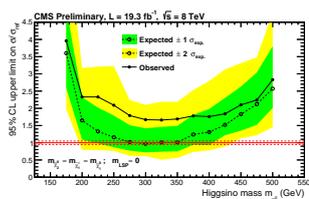Figure 3: Results of search for $h^0 h^0 + E_T^{miss}$ final states.

Figure 4: Interpretation of search for $h^0 h^0 + E_T^{miss}$ final states.

3. M_{T2} Higgs

A search designed for events that contain a Higgs boson in the decay chain of a heavy SUSY particle is described. Assuming Higgs bosons decay primarily to a $b\bar{b}$ pair in accordance with the Standard Model branching fraction, this category of events is investigated to seek an excess at 125 GeV in the invariant mass distribution of the selected b-tagged jet pairs. The h^0 boson can

be produced together with the lightest supersymmetric particle in the decays of neutralinos, such as $\tilde{\chi}_2^0 \rightarrow h^0 \tilde{\chi}_1^0$. The final state chosen to be considered comprises at least two b jets, multiple hard jets, and significant M_{T2} caused by the production of $\tilde{\chi}_1^0$. The data are found to agree with Standard Model prediction (Fig. 5), and results are interpreted for the following model: gluino pair production, with one gluino decaying via $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_2^0$, with $\tilde{\chi}_2^0 \rightarrow h^0 \tilde{\chi}_1^0$, and the other gluino decaying via $\tilde{g} \rightarrow qq'\tilde{\chi}_1^\pm$, with $\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$. The search excludes at the 95% confidence level gluinos with masses $M(\tilde{g})$ up to about 825 GeV, and $M(\tilde{\chi}_1^0)$ up to about 410 GeV (Fig. 6).
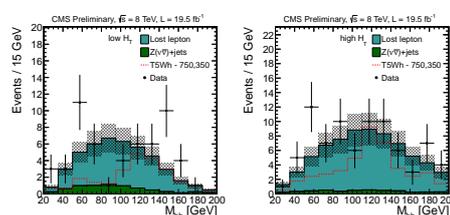

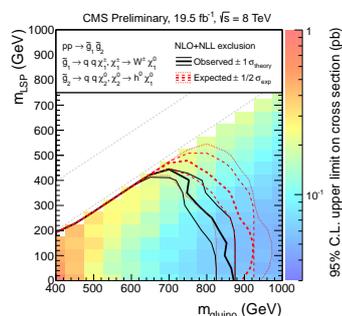Figure 5: Results of search for fully hadronic final states with a Higgs boson, using M_{T2}.

Figure 6: Interpretation of search for fully hadronic final states with a Higgs boson, using M_{T2}.

4. Higgs boson from s-top decay

A search for direct top squarks pair production followed by decays to Higgs bosons is performed using events with one or two electrons or muons and several jets, with at least three jets identified as originating from a b quark [6, 7]. Events are classified according to the lepton multiplicity, and charge requirements on the leptons. Four event categories are considered. The first two include events with one lepton, or two opposite sign

leptons, with at least three b jets. The other two categories are events with exactly two same sign leptons, and events with three or more leptons, with at least one b jet. Signal regions are defined with requirements on the transverse mass M_T, or the invariant $b\bar{b}$ pair mass, $M_{b\bar{b}}$, to be consistent with the Higgs boson mass of 125 GeV. The observed yields in the signal regions agree with the predicted backgrounds within the assessed uncertainties (Fig. 7). The results are interpreted in the context of a simplified model with pair production of a top squarks $\tilde{t}_2$, decaying to a top squarks $\tilde{t}_1$ via a Higgs boson. The search excludes at the 95% confidence level top squarkss with masses $M(\tilde{t}_2)$ up to about 530 GeV, and $M(\tilde{t}_1)$ up to about 350 GeV (Fig. 8).
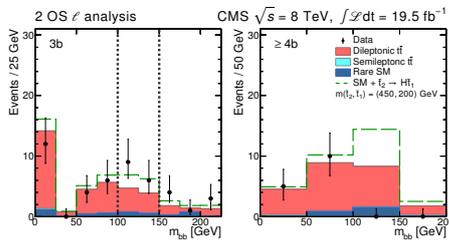

Figure 7: Results of search for direct top squarks pair production followed by decays to Higgs bosons.
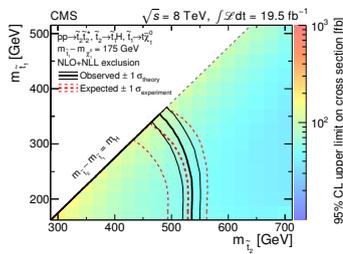

Figure 8: Interpretation of search for direct top squarks pair production followed by decays to Higgs bosons.

5. Higgs boson from s-top and Higgsino decay

A search for a natural supersymmetry scenario with gauge mediated symmetry breaking is presented [8]. Complete Gauge Mediated Supersymmetry Breaking (GMSB) models are considered, with a minimal number of accessible supersymmetric partners to satisfy the naturalness requirements, namely the right-handed top squarks and the higgsino (i.e., the supersymmetric partner of the Higgs boson). The lightest chargino ($\tilde{\chi}_1^\pm$)

and neutralinos ($\tilde{\chi}_1^0$, χ_2^0) are almost pure higgsinos and almost mass-degenerate. Pairs of higgsinos are produced either directly through electroweak production or through $\tilde{t}_R$ pairs (strong production). The $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ higgsinos decay into a very off-shell W or Z boson and a $\tilde{\chi}_1^0$. The lightest neutralino always decays as $\tilde{\chi}_1^0 \to h^0\tilde{G}$, or $\tilde{\chi}_1^0 \to Z\tilde{G}$, where $\tilde{G}$ is the gravitino. Events are selected in which the Higgs boson decays to two photons, and there are at least two b jets. No evidence for signal is found and lower limits at the 95% confidence level are set, excluding the top squarks mass below 360 to 410 GeV, depending on the higgsino mass (Fig. 9).
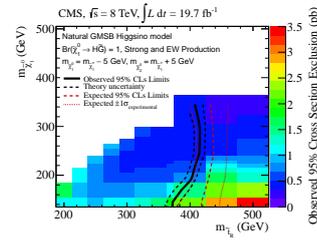

Figure 9: Interpretation of search for GMSB scenarios with a Higgs boson in the final state.

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