PROCEEDINGS OF SCIENCE

Combined searches for the production of supersymmetric top quark partners in proton-proton collisions at $\sqrt{s} = 13$ TeV

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A search for scalar top quark pair production at the LHC with the CMS experiment is presented. This search targets a region of parameter space where the kinematics of top squark pair production and top quark pair production are very similar because of the mass difference between the top squark and the neutralino is close to the top quark mass. The search is performed with the full data set of proton-proton collisions collected by the CMS experiment during the Run 2 of the LHC, at a centre-of-mass energy of 13 TeV. An algorithm based on a deep neural network is used to separate signal from background. Furthermore, searches for scalar top quark searches by CMS are combined.

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1. Introduction

Supersymmetry (SUSY) is a popular extension of the Standard Model (SM) of particle physics that provides a solution for several open questions in the SM such as the hierarchy problem or the absence of a suitable particle candidate for dark matter. Moreover, SUSY provides a natural solution if the values of the mass of the top quark, gluon and Higgs boson SUSY partners are not too large.

In particular, arguments related to naturalness favor a scalar top quark ($\tilde{t}_1$) with a mass close to that of the SM top quark. In this study we consider the production of a pair $\tilde{t}_1\bar{\tilde{t}}_1$, each one decaying into a top quark (t) or antitop quark ($\bar{t}$) and a neutralino ($\tilde{\chi}^0_1$).

Exclusion limits have been set by CMS [1] on the production of scalar top quark pairs using the full Run 2 data set in searches with 0, 1 and 2 leptons [2–4]. However, these searches show limited sensitivity to the presence of top quark partners with masses close to that of the top quark [5]. In particular, the sensitivity of these searches drop in the so-called *top corridor* phase space region, defined by $\Delta m = |m_{\tilde{t}_1} - m_{\tilde{\chi}^0_1}| \simeq m_t$.

In this document, a search for top quark SUSY pair production in the top corridor region is presented, using a luminosity of 137 fb^{-1} recorded by CMS during the LHC Run 2 [6]. A parametric neural network algorithm is trained to discriminate background an signal events for signal models with multiple $m_t$and $m_{\tilde{\chi}^0_1}$. Moreover, a combination of the Run 2 CMS searches for top squarks is presented.

2. Event selection

This search is characterized by an overwhelming background from $t\bar{t}$ events due to the very similar kinematics of $t\bar{t}$ production and signal when $\Delta m \simeq m_t$. Additionally, when $m_{\tilde{t}_1} \simeq m_t$ (so $m_{\tilde{\chi}^0_1} \simeq 0$), $t\bar{t}$ and signal production is really similar and most of the sensitivity to the signal is obtained by the precise determination of the background cross section. Small kinematic differences can be exploited to increase the sensitivity of the search when $m_{\tilde{\chi}^0_1} > 0$ or $|\Delta m - m_t| > 0$.

A baseline selection is defined to first select a final state in which $t\bar{t}$ events are dominant. This selection requires at least two opposite-charge leptons, at least two jets and at least one b-tagged jet. After this selection, around 94% of the SM background correspond to $t\bar{t}$ or tW events.

On top of this selection, the missing transverse momentum (p_T^{miss}) is used to discriminate signal from $t\bar{t}$ background, as neutralinos can contribute to the total $p_T^{miss}$of the event. Furthermore, the $m_{T2}^{\text{miss}}(\ell\ell)$ observable [5] is used, which shows and endpoint for $t\bar{t}$ events at around the mass of the W boson, while this threshold is not present for signal events, especially out of the top corridor region. Cuts on $p_T^{miss} > 50$ GeV and $m_{T2}^{\text{miss}}(\ell\ell) > 80$ GeV are set.

The distributions if $p_T^{miss}$and $m_{T2}^{\text{miss}}(\ell\ell)$are shown in Fig. 1 for data and signal and background prediction.

3. Multivariate categorization

A parametric neural net is trained using events after the baseline selection. Several observables related to the kinematics of the leptons and $p_T^{miss}$are used, such as $p_T$and η of the leptons, p_T^{miss},

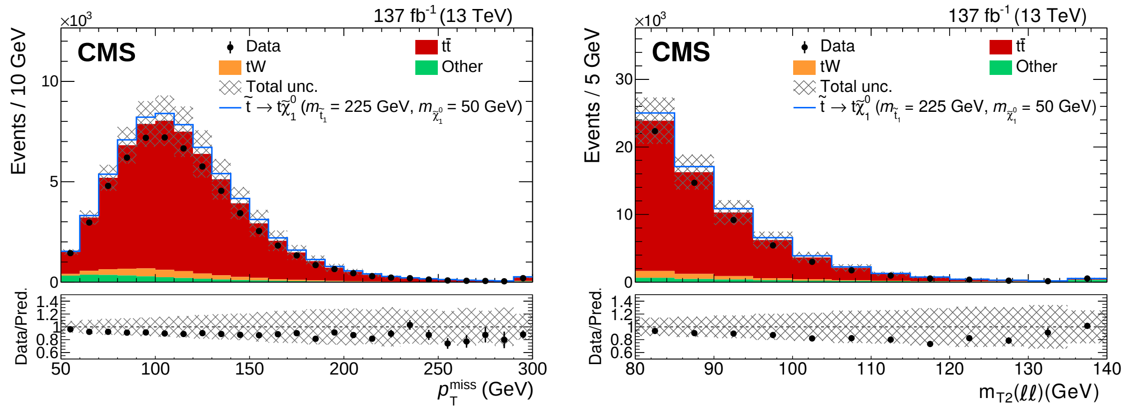

Figure 1: Data and prediction distributions of p_T^{miss}(left) and $m_{T2}^{miss}(\ell\ell)$(right) for events passing the full selection. The signal is stacked on top of the background expectation for a given mass choice of $\tilde{t}_1$ and $\tilde{\chi}_1^0$. [6].

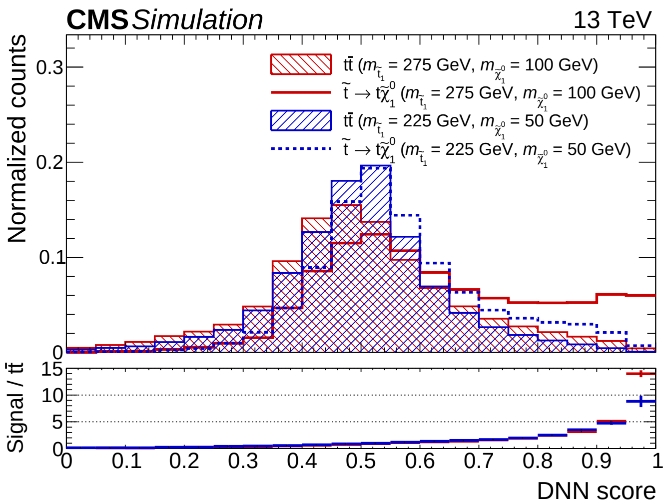

Figure 2: Normalized distributions of the output score of the neural net comparing the signal and $t\bar{t}$ background for two different mass hypotheses [6].

$m_{T2}^{miss}(\ell\ell)$and angular distances between the leptons. Furthermore, $m_{\tilde{t}_1}$and $m_{\tilde{\chi}_1^0}$are used in the training so the neural net can learn to optimally separate signal and $t\bar{t}$ depending on the mass of the SUSY particles.

Fig. 2 show normalized distributions of the neural net output for $t\bar{t}$ and two signal models with different $m_{\tilde{t}_1}$and $m_{\tilde{\chi}_1^0}$. We can observe that, as a consequence of using a parametric neural net, the output distributions for both signal and background depend on the input mass of the SUSY particles.

4. Result

The SM hypothesis is tested against the SUSY hypothesis using a binned profile likelihood fit to the neural net output distributions in categories of flavor of the two selected leptons and period of the data taking. Systematic uncertainties are set as nuisances of the fit and the effect of some of

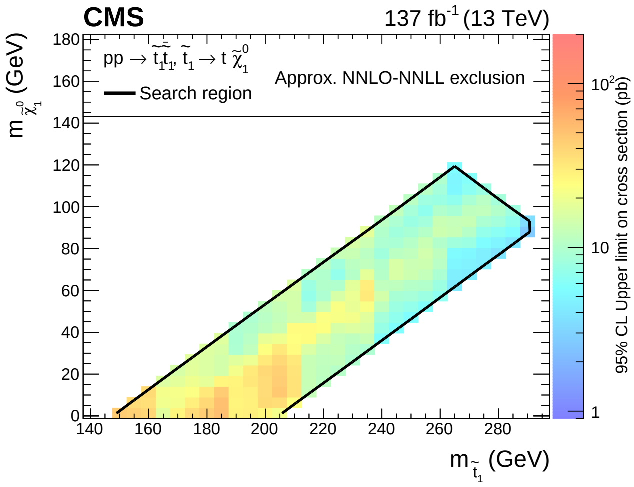

Figure 3: Upper limits at 95% CL on the signal cross section as a function of $m_{\tilde{t}_1}$ and $m_{\tilde{\chi}^0_1}$ in the top corridor. The model is excluded at 95% CL in the full explored region [6].

them is constrained. The total uncertainty is dominated by experimental uncertainties related to the jet energy scale and resolution, which affects the scale and resolution of p_{T}^{miss}.

Upper limits on the production cross section of top squark pairs are calculated at 95% confidence level (CL), shown in Fig. 3. The whole studied region is excluded at 95% CL.

5. Combination

A statistical combination of the results of three searches by CMS is performed, outside the top corridor region. Figure 4 shows exclusion limits for the production of top squarks from this combination. The presence of the SUSY signal is excluded at 95% CL for $m_{\tilde{t}_1}$ = 1325 GeV and a massless $\tilde{\chi}^0_1$ and for a $m_{\tilde{\chi}^0_1}$ up to 700 GeV for $m_{\tilde{t}_1}$ = 1150 GeV.

6. Conclusions

A dedicated search for top squark production in the corridor region has been presented. This search excludes the full studied region, for which previous CMS searches show limited sensitivity.

A combination of three searches of top squark production of 0, 1, and 2 leptons in the final state are combined. Upper limits con the cross section of the signal are set, improving previous results by up to around 100 GeV in the mass of the top squark.

References

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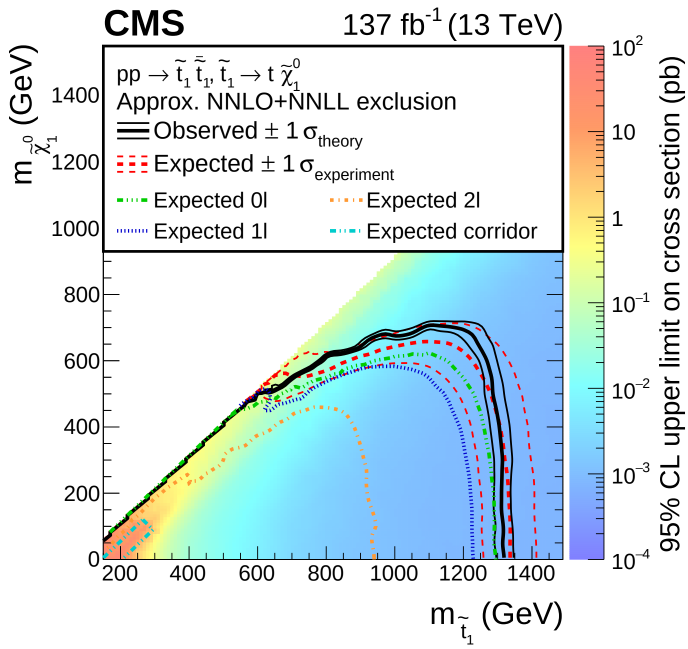

Figure 4: Expected and observed upper limits at 95% CL on the signal cross section as a function of $m_{\tilde{t}_1}$ and $m_{\tilde{\chi}^0_1}$ [6].

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