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Search for scalar top quark pair production in the top corridor region at the CMS experiment

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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 being close to the top quark mass. The search is performed with the full Run 2 data set of proton-proton collisions at a centre-of-mass energy of 13 TeV, collected by the CMS detector, using events containing dilepton pairs with opposite charge. A DNN algorithm is used to separate signal from background.

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1. Introduction

Supersymmetry (SUSY) is a promising extension of the Standard Model (SM) that introduces a relation between bosons and fermions and resolves some problems that the SM cannot explain, for example, the hierarchy problem. It also provides a dark matter candidate.

Different simplified models exist that describe the production of top squark ($\tilde{t}$) pairs, but this poster focuses on the so-called "T2tt" model from the Simplified Model Spectra (SMS) [1], in which a 100% branching ratio is assumed for the top squark to top quark + lightest neutralino ($\tilde{\chi}_1^0$) decay. This poster presents the combination[6] of previously published searches for the pair production of SUSY top quark partners in final states without leptons [3], with one [4], or with two charged leptons [5], in events from proton-proton (pp) collisions at a center-of-mass energy of 13 TeV at the CERN LHC, corresponding to an integrated luminosity of 137fb^{-1} collected by the CMS experiment. It also includes a new analysis [6] targeting a parameter space where the mass difference between the top squark and the neutralino is close to the top quark mass. In this region of the parameter space, the signal has very similar kinematics to the top quark pair production ($t\bar{t}$) background, and it is very difficult to separate them. This region is referred to as “top corridor” and to improve the separation a Deep Neural Network (DNN) is used.

2. Top corridor region search

The top corridor region corresponds to events where the mass difference between $\tilde{t}$ and $\tilde{\chi}_0$ is close to the top mass, in which signal and $t\bar{t}$ background have similar kinematics, especially at low $\tilde{\chi}_0$ masses. Therefore, signal events can only be detected as an excess on the $t\bar{t}$ cross section and it is important to have an accurate estimation of the background to be sensitive to such SUSY signals.

The signal model used was the direct pair production of top squarks, for a sequence of values of the top squark mass in the range 145–295 GeV and a mass difference between $\tilde{t}$ and $\tilde{\chi}_0$ from 0 to 30 GeV.

This analysis uses the full Run 2 data set and events are selected if they contain an opposite-sign lepton pair (electron or muons). Then, to suppress Drell-Yan and other boson backgrounds, also are required at least two jets and at least one b-tagged jet. This set of requirements is referred to as the baseline selection.

After the baseline selection, most of the background events (about 98%) are expected to come from $t\bar{t}$. To suppress this background, the signal region is defined with the requirements $p_T^{miss} > 50$ GeV and $m_{T2}(\ell\ell) > 80$ GeV.

One of the main discriminating variables between signal and $t\bar{t}$ is $m_{T2}(\ell\ell)$ [2], which has an endpoint for $t\bar{t}$ at the W boson mass, while signal events are expected to populate the tails of the distribution. Higher discrepancies between signal and $t\bar{t}$ appear at large values of the $m_{T2}(\ell\ell)$ distribution, and they are larger at high $\tilde{\chi}_0$ mass. The $m_{T2}(\ell\ell)$ observable is computed as:

$$m_{T2}(\ell\ell) = \min_{\vec{p}_{\mathrm{T},1}^{\,\mathrm{miss}} + \vec{p}_{\mathrm{T},2}^{\,\mathrm{miss}} = \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}} \left(\max \left[m_T(\vec{p}_{\mathrm{T}}^{\,\ell 1}, \vec{p}_{\mathrm{T},1}^{\,\mathrm{miss}}), m_T(\vec{p}_{\mathrm{T}}^{\,\ell 2}, \vec{p}_{\mathrm{T},2}^{\,\mathrm{miss}}) \right] \right), \tag{1}$$

where m_T is the transverse mass, and $\vec{p}_{\mathrm{T1}}^{\,\mathrm{miss}}$ and $\vec{p}_{\mathrm{T2}}^{\,\mathrm{miss}}$ correspond to the estimated transverse momenta of two neutrinos that are presumed to determine the total $\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}$ of the event. The transverse mass is calculated for each lepton-neutrino pair, for different assumptions of the neutrino p_T.

In order to maximize the sensitivity and to exploit all the differences between the signal and $t\bar{t}$ background, a multivariate analysis is implemented using a parametric DNN [7]. The training was done using events passing the baseline selection in order to use the separation power of different observables over a large range. A total of 13 variables are selected for the training, including the $\tilde{t}$ and $\tilde{\chi}_0$ masses in order to exploit the kinematic differences to maximize sensitivity. For background events those values are randomly taken, to avoid introducing correlations. In this way, a specific model for each signal point training a single DNN is achieved.

The data and predicted distributions for the DNN response in the signal region are combined in the nine channels (3 data-taking period x 3 lepton flavor combinations of the two leading leptons) in order to maximize the sensitivity to the signal. Each of the distributions is computed for different values of the mass parameters and compared to the prediction for the signal model with the corresponding masses.

The exclusion limits on the production cross section of top squark pairs at 95% confidence level (CL) are calculated and the full top corridor region is excluded for the first time, shown in Figure 1.

3. Summary

This poster focuses on the dedicated search of top squark pair production in the 'top corridor' region, where other analyses do not have enough sensitivity and the full region, ranging top squark masses of 145–295 GeV and a mass difference between $\tilde{t}$ and $\tilde{\chi}_0$ from 0 to 30 GeV, is excluded at 95% CL. It also summarizes the combination of the last exclusion limits achieved by the CMS Collaboration with the full Run 2 data set for top squark pair production on a simplified SUSY model assuming a 100% branching fraction to a top quark and a neutralino, excluding top squarks with masses up to 1.3 TeV.

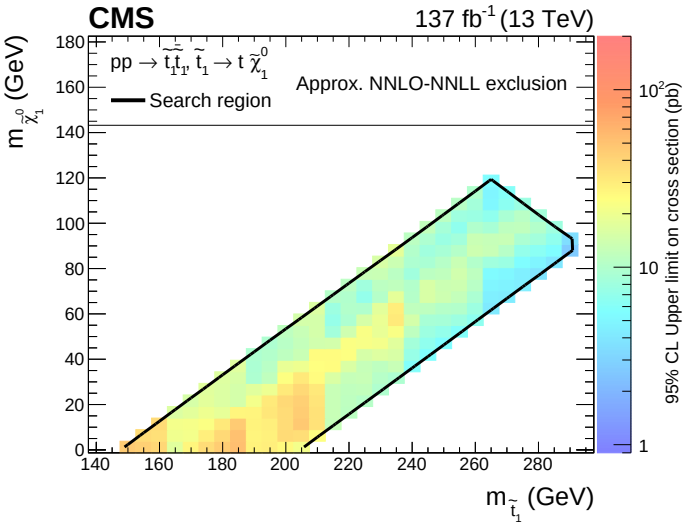

Figure 1: Upper limit at 95% CL on the signal cross section as a function of the top squark and neutralino masses in the top quark corridor region [6]. The model is excluded for all of the colored region inside the black boundary.

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