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Search for the direct production of top squark pairs with the CMS detector

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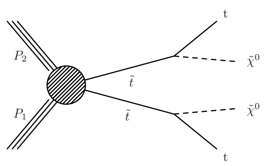
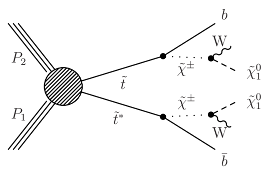
Abstract. Naturalness, especially in light of the recent results of Higgs boson searches, motivates the existence of light third-generation squarks, well within the eventual reach of the LHC. Depending on the specific production (gluino-mediated or direct) and decay (two- or three-body decay, charged or neutral current) scenario, the signal kinematics can differ significantly. Therefore, one needs dedicated analyses targeting these different options. In this poster we present results of searches for the direct production of top squark pairs in proton-proton collisions recorded by the CMS detector at the LHC.

1 Introduction

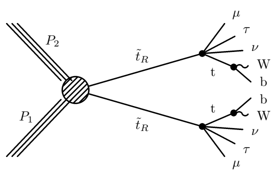
Supersymmetric extensions of the Standard Model (SM) address several issues present in the SM, such as how the Higgs boson can remain light. Many searches for supersymmetry have been conducted over the past years, but no signs of new physics have been observed. First and second generation squarks and gluinos have been excluded up to masses of about 1 TeV for large ranges of parameter space. Constraints on third generation squarks are, however, much weaker. Moreover, naturalness arguments only require these third generation squarks to be relatively light, with a gluino that is not much heavier. Searches dedicated to these third generation squarks are thus strongly motivated.



(a) T2tt simplified model



(b) T2bw simplified model



(c) RPV model

Figure 1: Top squark production diagrams

One can consider several production and decay modes of top and bottom squarks. In this document we will focus solely on top squarks (or *stops*), $\tilde{t}$. As production modes there are the gluino-mediated production $pp \to \tilde{g}\tilde{g} \to t\tilde{t}t\tilde{t}$ and the direct production $pp \to \tilde{t}\bar{\tilde{t}}$. In what follows, three CMS analyses that interpret their results in terms of direct top squark pair production are summarized. As decay modes we will consider the R-parity conserving decays $\tilde{t} \to t\tilde{\chi}_1^0$ (fig. 1a) and $\tilde{t} \to b\tilde{\chi}_1^+$ (fig. 1b), and the R-parity violating decay $\tilde{t}_R \to t\tilde{\chi}_1^{0*} \to tl_i\nu_j l_k$ (fig. 1c). Decay modes such as $\tilde{t} \to c\tilde{\chi}_1^0$ and 3- or 4-body decays will not be discussed here.

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2 CMS search strategy

The CMS search strategy consists of performing searches in various complementary ways, exploiting different analysis techniques and final states.

The experimental signatures of R-parity conserving stop production are typically a large jet multiplicity, including b-jets, large missing momentum ($\not{E}_T$) from the unobserved neutralino $\tilde{\chi}_1^0$ and 0, 1 or 2 isolated leptons.

R-parity violating stop production typically has a more moderate $\not{E}_T$ as the $\tilde{\chi}_1^0$ decays to SM particles. There can be a large number of leptons from the decay of the $\tilde{\chi}_1^0$, as well as several jets, which might also be b-jets.

3 α_T analysis (SUS-12-028)

The α_T analysis [1] is an all-hadronic analysis based on the variable α_T, using 11.5 fb^{-1} of data at $\sqrt{s}$ = 8 TeV.

As baseline selection the following requirements are made: two or more jets should be present, which are then clustered in two pseudo-jets [1]; $H_T = \sum_{jets} E_T > 275$ GeV; a veto on isolated electrons, muons and photons; and finally $\alpha_T > 0.55$. The variable α_T is defined as

$$\alpha_T = \frac{E_T^{j_2}}{M_T}, \quad M_T = \sqrt{\left(\sum_{i=1}^{2} E_T^{j_i}\right)^2 - \left(\sum_{i=1}^{2} p_x^{j_i}\right)^2 - \left(\sum_{i=1}^{2} p_y^{j_i}\right)^2},$$

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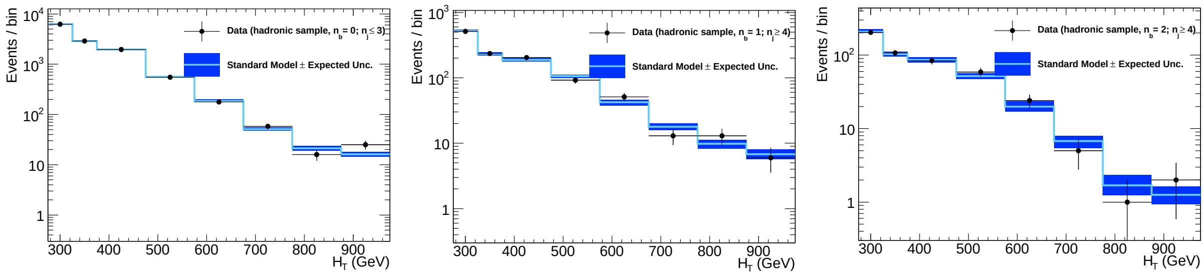


(a) 0 b-jets, ≤ 3 jets (b) 1 b-jet, ≥ 4 jets (c) 2 b-jets, ≥ 4 jets

Figure 2: Observed and predicted number of events for several search bins of the α_T analysis

where $E_T^{j_2}$ is the transverse energy of the least energetic jet of the two pseudo-jets, and M_T is the transverse mass of the dijet system.

On top of this baseline selection several signal regions are defined. They are binned in H_T, jet multiplicity and btagged jet multiplicity. By including the btagged jet multiplicity the sensitivity to third generation squarks is increased. Results for several of these search regions are shown in figure 2.

In this analysis, backgrounds are estimated from three data control regions using translation factors (per bin) from simulation. The $t\bar{t}$ + jets and W + jets backgrounds are estimated from a μ + jets data sample, whereas the $Z \rightarrow \nu\bar{\nu}$ background is estimated from a $Z \rightarrow \mu\bar{\mu}$ + jets and γ + jets data sample.

The final SM background prediction is obtained from a binned likelihood fit using all four data samples. No significant excess in the signal regions is observed and results are interpreted in various simplified model topologies.

4 Direct stop search in single lepton final state (SUS-12-023)

In this section a dedicated search for direct stop production in the single lepton final state will be summarized. The analysis uses 9.7 fb^{-1} of data at $\sqrt{s}$ = 8 TeV and targets the R-parity conserving decay modes of the top squark (see figures 1a and 1b) [2] .

The requirements of the baseline selection are: the presence of four or more jets of which at least one is btagged; exactly one isolated lepton (e or μ); and $\not{E}_T > 50$ GeV.

The main background processes are W + jets and $t\bar{t}$ + jets. Due to the presence of a real W in these processes, the transverse mass of the lepton-neutrino system, M_T, has a kinematic endpoint at the W mass. The signal on the other hand, has additional $\not{E}_T$ from the $\tilde{\chi}_1^0$'s, thus enlarging M_T. This observation is used to define several signal regions by putting additional requirements on $\not{E}_T$ and M_T. Figure 3 shows the $\not{E}_T$ distribution after applying the cut $M_T > 120$ GeV.

The dominant backgrounds are estimated by an extrapolation of the observed number of events in the M_T peak. To obtain the correct normalization, the simulation

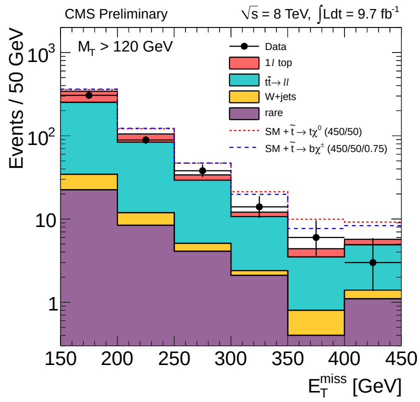


Figure 3: $\not{E}_T$ distribution after $M_T > 120$ GeV cut

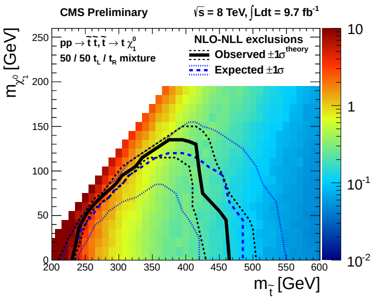
is scaled to the data in the peak region. To estimate the number of background events in the signal region, tail-to-peak ratios are used. These ratios are evaluated from simulation, with Data/MC scale factors obtained from data control regions. Correction factors for the mismodeling of the jet multiplicity in $t\bar{t} \rightarrow l\bar{l}$ events, which form a large portion of the background, are derived and applied. The shapes for the rare backgrounds are taken directly from simulation and are normalized to their NLO cross sections.

A good agreement between data and prediction is found and the results are interpreted in simplified models, for both considered decay modes, as shown in figure 4.

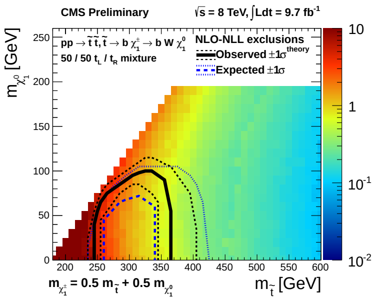
5 RPV search with multileptons and btagged jets (SUS-12-027)

As opposed to the previous two sections, the analysis presented in this section is targeting R-parity violating (RPV) models. It is an inclusive multilepton search using 9.2 fb^{-1} of data at $\sqrt{s}$ = 8 TeV, requiring only the presence of at least three isolated leptons (e, μ or τ), with at most one hadronically decaying τ [3].

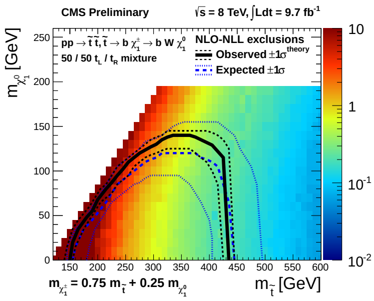
240 exclusive search regions are constructed based on the number, charge and flavour of the leptons, the btagged jet multiplicity, the value of $S_T = \not{E}_T + H_T + \sum_{leptons} p_T$ and whether or not an opposite sign same flavour lepton pair is on the Z-peak.



(a) T2tt SMS



(b) T2bw ($x = 0.5$) SMS

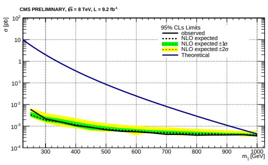


(c) T2bw ($x = 0.75$) SMS

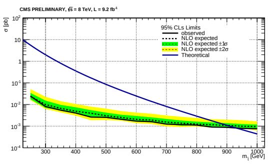
Figure 4: Exclusion limits in various simplified models

The largest background for this analysis are misidentified and non-prompt leptons, mainly $Z \to l\bar{l}$ + jets, with a third lepton stemming from a jet or photon. Their contribution in each signal region is estimated from data [3].

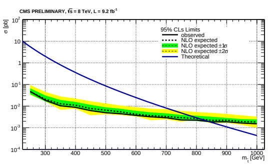
The contribution from jets was estimated using a dilepton data sample, by relating the rate of isolated lepton production to the rate of isolated track production. The contribution from internal photon conversions was determined using a low $\not{E}_T$, low H_T data sample, in which the photon to e/μ conversion factors were measured as a ratio of the number of $l^+l^-l^\pm$ events to the number of $l^+l^-\gamma$ events, both on the Z-peak.



(a) RPV coupling λ_{122}



(b) RPV coupling λ_{123}



(c) RPV coupling λ_{233}

Figure 5: Exclusion limits for three RPV coupling assumptions

Simulations are used to estimate the contribution from $t\bar{t}$ + jets, diboson production and rare processes. Corrections are applied to match the $\not{E}_T$ resolution and lepton efficiency measurements in data.

No significant excess was observed in any of the search channels. Results are interpreted, among others, in a stop RPV model, considering three couplings λ_{ijk} from the RPV superpotential $W = \lambda_{ijk} L_i L_j \bar{e}_k$, as shown in figure 5.

6 Conclusion

We summarized three CMS analyses targeting top squark production. No hints of top squarks have been observed and results have been interpreted in simplified models.

References

[1] CMS Collaboration, Search for supersymmetry in final states with missing transverse energy and 0, 1, 2, 3, or ≥ 4 b-quark jets in 8 TeV pp collisions using the variable α_T. CMS-PAS-SUS-12-028, (2012)

[2] CMS Collaboration, Search for direct top squark pair production in events with a single isolated lepton, jets and missing transverse energy at sqrt(s) = 8 TeV. CMS-PAS-SUS-12-023, (2012)

[3] CMS Collaboration, Search for RPV supersymmetry with three or more leptons and b-tags, CMS-PAS-SUS-12-027, (2012)