PROCEEDINGS OF SCIENCE

Searches for third generation supersymmetric particles with the CMS experiment

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Results from the CMS experiment are presented for searches for supersymmetric partners of the top and bottom quarks and of the tau lepton. A wide range of final state decays are considered in order to maximize the sensitivity to different possible supersymmetric particle spectra. The searches use proton-proton collision data with luminosity up to 138 fb^{-1} recorded by the CMS detector at a center of mass energy of 13 TeV during the LHC Run 2.

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1. Motivations for third generation supersymmetry

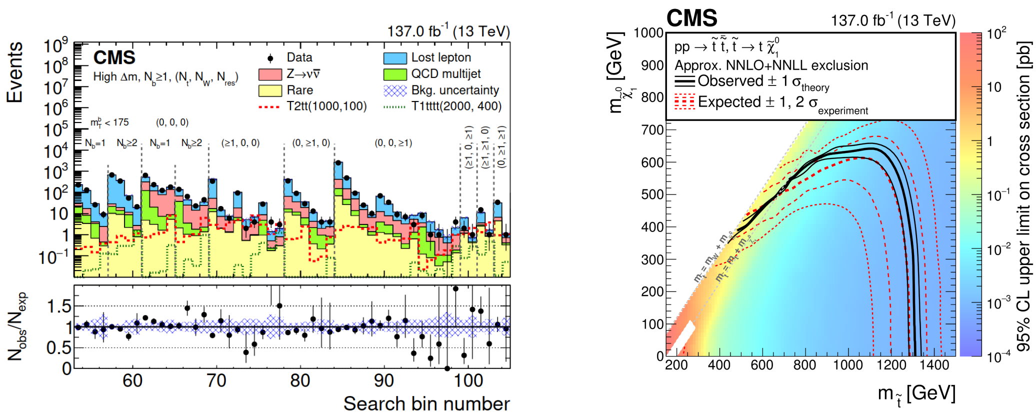
Among many different supersymmetry (SUSY) searches, those involving third generation sfermions are of particular interest since they are favoured by naturalness, with expected masses of the order of 500 GeV [1], and sizable cross sections [2]. In the scenario in which R-parity is conserved, third generation SUSY particles are expected to decay to a third generation quark or lepton, together with a stable lightest neutralino (LSP), which provides for a good dark matter candidate.

Three types of searches will be therefore presented, covering the production of the top squark (stop), bottom squark (sbottom) and tau slepton (stau), respectively. Scenarios with R-parity violating (RPV) decays and long lived particles (LLP) production are also considered.

2. Searches for the top squark

2.1 Search for the top squark in the hadronic final state

The search for top squark ($\tilde{t}$) production in hadronic final states [3] targets events with many jets, high p_T^{miss} and a veto on leptons. Two different object reconstructions are used depending on the mass splitting (Δm) between the top squark and the LSP. For low Δm, a soft b-tagged jet and another jet coming from initial state radiation (ISR) are required, whereas a neural network (NN) is used to reconstruct boosted top quarks or W bosons in the high Δm case. Signal regions are thus defined in terms of several event kinematic variables and multiplicity of dedicated objects (i.e. number of top quarks), giving the yields shown in Fig. 1a. Exclusion limits are derived on the $\tilde{t}$ mass, reaching up to 1300 GeV for low LSP mass, as shown in Fig. 1b.



(a) Yields per search bin number.

(b) Observed (black) and expected (red) exclusion limits.

Figure 1: Results from a $\tilde{t}$ search in the hadronic final state [3].

2.2 Summary of direct top squark searches

Several analyses, probing for direct stop decays in final states with both hadrons and leptons, have been combined in [4]. Stop masses are excluded up to 1300 GeV for low LSP masses (m_{LSP}), and up to 1100 GeV for m_{LSP}=700 GeV . Finally, the $\Delta m \sim m_t$ is also now excluded up until 295 GeV.

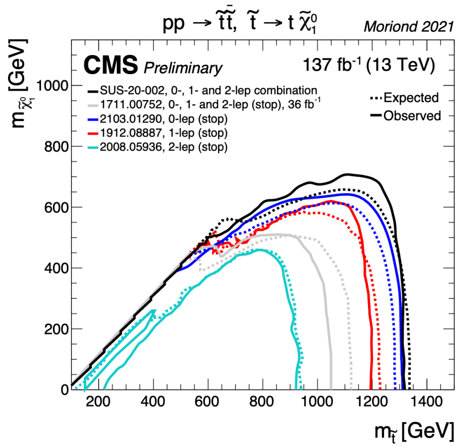


Figure 2: Summary of limits for the $\tilde{t}$ mass with respect to the LSP's mass [4].

2.3 Search for the top squark in four body decays in one lepton final states

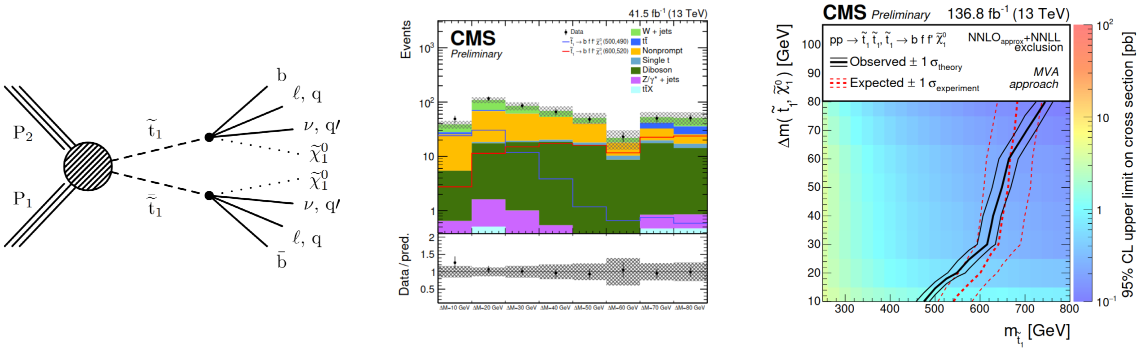
Other top squark searches in addition to the aforementioned can be made. One such example is this analysis [5], which probes for a signal in which the top squark pair is produced, each of them produce a b-jet, two other fermions, and the LSP through a four body decay, providing great sensitivity for the area with a low mass splitting (Δm). A diagram for this process is shown in Fig. 3a. Events with 1 lepton plus jets, high H_T (defined as the scalar p_T sum of the of all of the jets) and p_T^{miss} are thus selected. A boosted decision tree (BDT) is used, with the p_T^{miss} together with other b-tagged-jets variables used as discriminant, being the BDT trained per Δm. Event yields for the 2017 data are shown in Fig. 3b, from where it can be observed that the main backgrounds are the W+jets and the $t\bar{t}$+jets production processes. Expected and observed limits are obtained, as shown in Fig. 3c, reaching exclusions on the stop mass from 480 GeV for Δm=10 GeV to 700 GeV for Δm=80 GeV.

3. Bottom squark searches

Several analyses have been performed with the bottom squark as a target, mainly through the all hadronic channel, taking advantage of the b-tagging techniques. Figure 4 shows the limits set on the bottom squark mass, reaching up to 1200 GeV for low m_{LSP}, and around 800 GeV in the compressed (small mass splitting) region.

4. Direct tau slepton pair production

Tau slepton pair production is probed in events where each stau decays into a tau lepton that decays hadronically (τ_h) and a LSP [6]. Two main discriminant variables are used: the sum of the τ_h's transverse masses ($\sum m_T$), and the $m_{T2}^{\ell\ell}$, defined as a generalisation of the transverse mass [7]. Both prompt and displaced leptons are considered. No statistically significant excesses have been



(a) Targeted signal diagram.

(b) Data and expected signal and background events per Δm bin for the year 2017.

(c) Expected (Black) and observed (red) limits.

Figure 3: A diagram and results from a $\tilde{t}$ search in the four body decay mode in one lepton final states [5].

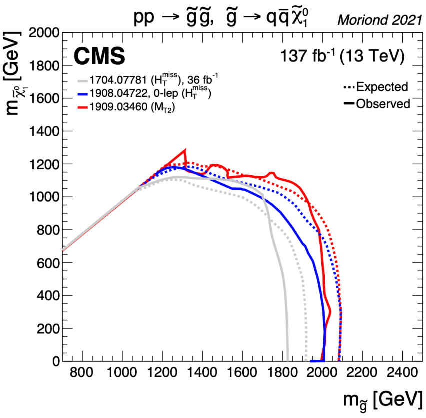
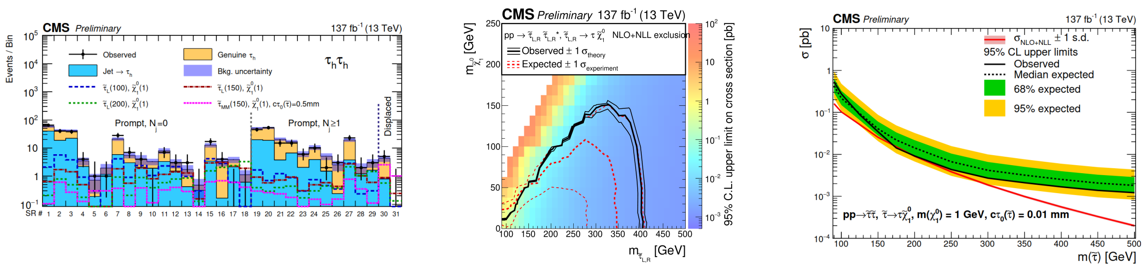


Figure 4: Summary of limits for the bottom squark mass with respect to the LSP's mass.

found, as can be observed in the yields shown in Fig. 5a for the prompt scenario. Exclusion limits on the tau slepton's mass in both cases are obtained, going up to 400 GeV in the prompt case, as shown in Fig. 5b, and excluding stau masses between 150 and 220 GeV in the displaced scenario of $c\tau_0$=0.01 mm case, as shown in Fig. 5c.



(a) Yields per signal region in the prompt scenario.

(b) Expected (red) and observed (black) limits for the slepton prompt search.

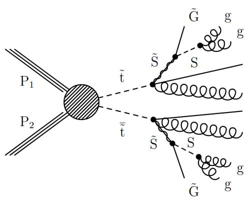
(c) Expected exclusion limits for the LLP stau for m_{LSP}=1 GeV and $c\tau_0$=0.01 mm.

Figure 5: Results from a search for direct tau slepton pair production [6].

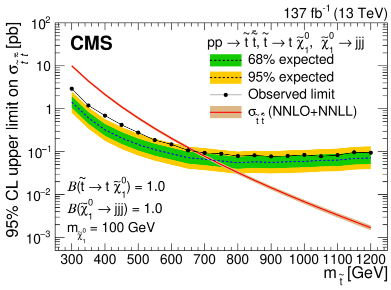
5. Searches for RPV, stealth and LLP SUSY

5.1 Searches for the top squark in RPV decays and stealth SUSY

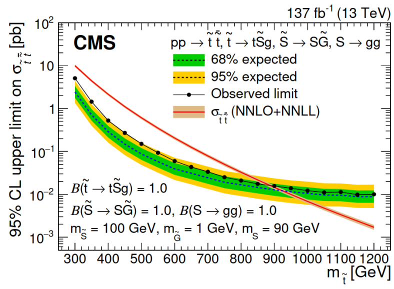
An analysis has been made searching for RPV decays and stealth SUSY models [8], in particular studying the production of two top squarks, each one decaying into a top quark and three light flavour jets, as shown in Fig. 6a for the stealth scenario. A selection is made, with at least 7 jets and 1 b-tagged jet, H_T>300 GeV, and one lepton. A NN is then used with the information on the 7 jets and the lepton as input. This leads to exclusions of the stop mass up to around 670 GeV for the RPV model (Fig. 6b) and 870 GeV for the stealth one (Fig. 6c).



(a) Feynman diagram for the gluino production.



(b) 68 and 95 % expected and observed limits for the RPV model.

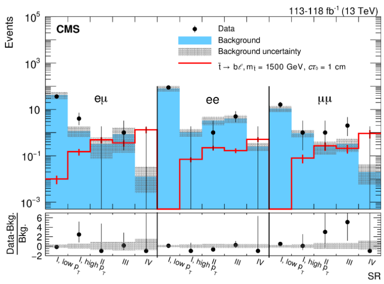


(c) 68 and 95 % expected and observed limits for the stealth model.

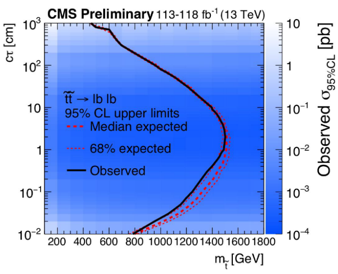
Figure 6: A diagram and results from the RPV and stealth SUSY search [8].

5.2 Long lived particle searches

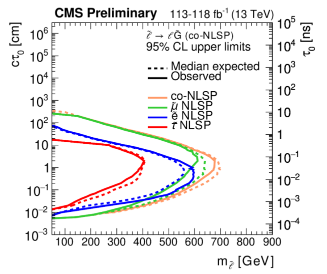
One example of a LLP SUSY search is presented here [9]. This analysis has been designed to be as broad as possible, being sensitive to any model whose signature contains two displaced leptons (ee, $\mu\mu$, eμ), including two SUSY models, $\tilde{t} \rightarrow b\ell$ production, whose yields in the signal regions are presented in Fig.7a, and a $\tilde{\ell} \rightarrow b\ell$ model. The transverse impact parameter (d_0) is used as the discriminant variable, with 10μm<$|d_0|$<10 cm. Limits were set, excluding decay lengths from 0.1 to 30 cm for a stop mass of about 1.3 TeV (Fig. 7b), whereas masses up to 400 GeV were excluded for the tau slepton, for decay lengths of around 1 cm (Fig.7c).



(a) Yields found per signal regions.



(b) Limits on the stop mass in terms of the decay length.



(c) Limits in the slepton mas in terms of the decay length.

Figure 7: Results from long lived particle search [9].

6. Summary and outlook

Plenty of analyses have been published by the CMS Collaboration with Run 2 data targeting third generation SUSY particle production, also in R-parity violating and long lived particle models. So far, many constraints on SUSY particle generations have been set, constraining the third generation squarks over 1300 GeV and the tau slepton at 400 GeV for low m_{LSP}. However, LHC's Run-3 is about to start, with higher luminosity and improved detectors, so that, together with refinements on the analysis techniques, will help us probing for SUSY with even greater sensitivity.

References

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