Third Generation SUSY Searches at CMS

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In this talk, the latest results from CMS on searches for stop and sbottom squarks are presented. Searches for direct squark production and indirect production through gluino cascades in a variety of decay channels are reviewed. The results are based on 20/fb of data collected during the 8 TeV LHC run.

1 Introduction

Supersymmetry (SUSY) is a popular extension of the standard model (SM), offering an additional symmetry of nature between fermions and bosons. A new supersymmetric partener particle (sparticle) is proposed for each SM particle, providing an elegant mechanism to mitigate the hierarchiy problem. The symmetry is not exact, as no sparticles have been observed experimentally; however the stabilising features of SUSY can survive if sparticles are not too much heavier than their SM partners. The third generation in particular offers scope to search for SUSY because of the relatively large mass of the top quark. The mass difference between the stop quark and its SUSY partener the top squark must be small to provide a “natural” solution to the hierarchy problem, and similarly for the bottom quark and the sbottom squark. They may be accessible at the TeV scale, and pair produced at the LHC.

This paper presents the latest results of the searches performed with the CMS detector [1] looking for direct and indirect production of the third generation squarks in a variety of decay channels. The results are based on the data collected during the 2012 8 TeV LHC run.

2 Direct top squark production

Light (stop1) and heavy (stop2) stop squarks can be directly pair produced at the LHC via gluon fusion or quark annihilation and are investigated in CMS by a broad search program.

2.1 Light stop results

Several analyses have been performed in CMS to search for the direct production of a pair of light stop, assuming that the stop decays to a top quark and a neutralino: a fully hadronic search using a top tagger [2], an inclusive analysis based on the razor variables [3], a fully hadronic analysis using the MT2 variable [4] and an analysis looking to the single-lepton final state [5]. The razor and single-lepton results have been combined in a recent publication [6].

If the mass difference between the stop squark and the lighest supersymmetric particle (LSP) is very small, the stop decays to a charm quark and the LSP through loop. In this case the charm jets are expected to be relatively soft and hidden by the low energy QCD background events or too soft for the CMS detector to identify. However these events can be detected if they are accompanied by initial state radiation (ISR). Provided final state particles are invisible, such events contain a high pt jet and missing transverse energy. A monojet analysis have been designed to search for these events [7].

No significant deviations from the standard model predictions have been observed in all these analyses. Results are interpreted as exclusion limits on Simplified Model Spectra and are presented in Figure 1.

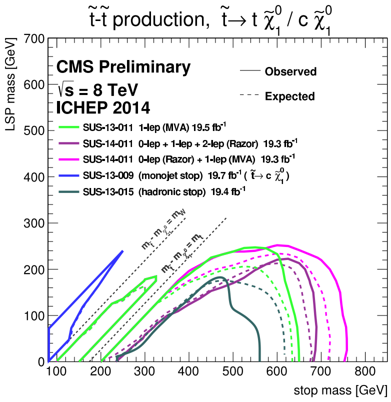

Figure 1: Expected and observed limit curves for stop pair production, assuming 100% branching fraction of the stop decay mode to a top quark and a neutralino or, in case of a highly compressed spectrum, the stop decay mode to a charm quark and a neutralino.

The stop squark can also decay into a chargino and a b-jet, with the chargino decaying into a W boson and a neutralino. This model has been studied in the reference [5] where the limits obtained are shown for different mass relations for the chargino, neutralino and stop squark. The sensitivity is dependent on assumptions made on the chargino polarization and the left/right handedness of the coupling. An other interpretation with chargino is presented in the reference [6], assuming a mass difference of 5 GeV between the chargino and the neutralino, resulting in a decay with a virtual W.

2.2 Heavy stop results

Several analyses are looking to heavy stop pair production. In this case the stop2 decays to stop1 and either a Higgs boson or a Z boson. The resuls of the single-lepton+2 opposite charge leptons analysis [8], the same-sign dileptons analysis [9] and the 3-leptons analysis [10] have been combined and are presented in the reference [11]. The limits obtained for Higgs only and Z only decays are presented in Figure 2, but mixed branching ratio scenario results are also avialable in the reference [11].

2.3 Other direct stop searches

Some R-parity violating models have also been investigated by CMS, with a search for anomalous production of events with three or more isolated leptons and at least one b-jet produced [12].

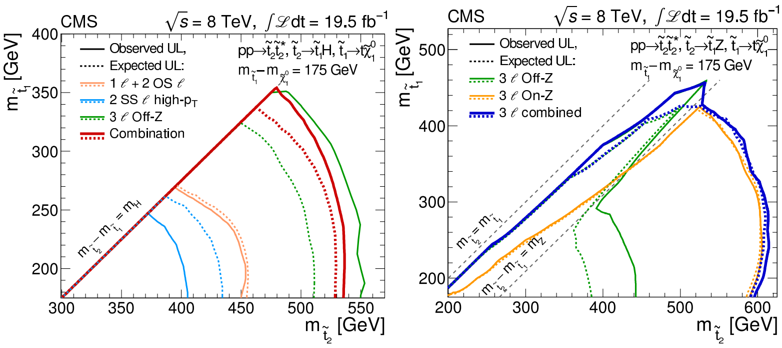

Figure 2: Observed (expected) exclusion contours, which are indicated by the solid (dashed) curves for the contributing channels. The excluded region in the m(stop1) and m(stop2) parameter space is obtained assuming that the stop2 decays to stop1 and a Higgs boson in the left plot and assuming a decay to stop1 and Z boson in the right plot.

There is also a program of gauge mediated susy breaking scenarios using diphoton Higgs decays [13] and three leptons events [10].

3 Direct sbottom production

Instead of a pair of stop squarks, a pair of sbottom squarks can be produced in LHC collisions. Three decays of the sbottom squarks have been investigated:

- b quark and a neutralino;
- top quark and a chargino, with the chargino decaying in a W boson and a neutralino;
- b quark and a neutralino 2, with the neutralino 2 decaying in a Z boson and a neutralino 1.

The first model has been investigated by a dedicated sbottom search [14] and with the inclusive MT2 analysis [4]. A multilepton search [15], the same-sign dilepton search [9] and the three leptons search [10] have been used to search for the second model with a chargino. The third model has been investigated by the three leptons search [10], assuming a mass difference between the neutralinos of 110 GeV. In this case the neutralino 2 is indeed decaying only to a Z boson and the LSP, the decay with a Higgs boson being forbidden.

4 Gluino mediated production

Stop and sbottom are also searched in gluino mediated processes, looking for deviation in specific final states that can be produced if an intermidiate third generation squark has been involved in the process. They have been investigated in models where the stop/sbottom squarks are produced off-shell, in which case the third generation squarks existence is probed indirectly.

The first simplified model considered (T1bbbb) is when the pair produced gluinos decay to two b jets and a neutralino. This leads to a purely hadronic final state and has been investigated by the razor analysis [6], the met+ht analysis [16], the alphaT analysis [17] and the MT2 analysis [4].

The other simplified model considered (T1tttt) is when the gluinos decay to two top quark and a neutralino. All the lepton multiplicities in the final state are investigated by different analyses: 0-lepton analyses [4, 6, 16, 17], 1-lepton analyses [18], 2-leptons analyses [9, 19] and 3-leptons analyses [10, 15].

The results of these two models are presented in Figure 3.

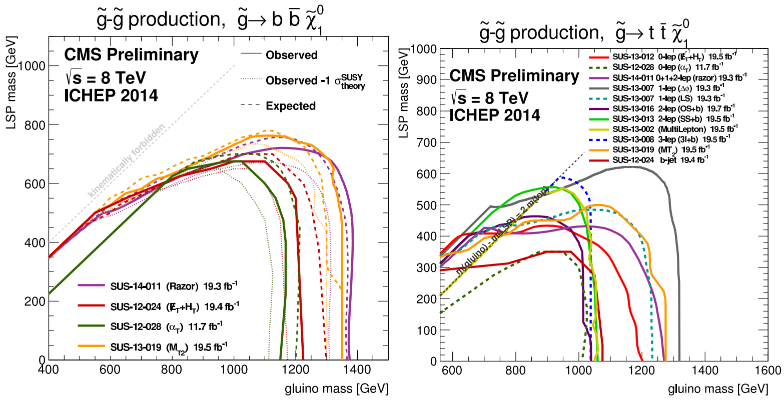

Figure 3: Expected and observed limit curves in the (LSP mass, gluino mass) plane for the T1bbbb (left) and T1tttt (right) simplified models.

The mixed branching ratios scenarios (T1tbbb, T1ttbb and T1tttb) have also been studied with the razor analysis [6]. The limits obtained for mixed branching ratios lie within the T1bbbb and the T1tttt contours. So the limit obtained with the razor analysis for the model where both gluinos decay to top quarks can be considered as a conservative branching ratio independent limit.

The gluino mediated stop and sbottom squarks production has also been investigated when the stop/sbottom are produced on-shell. On-shell stop squark in gluino decay are investigated by the single-lepton search [18], the same-sign dilepton search [20] and the three lepton search [10]. Two analyses interpret their results in term of on-shell sbottom squark: the same-sign dilepton search [20] and the three lepton search [10].

5 Conclusion

The CMS program to discover third generation SUSY is wide and rich, covering many topologies and final states. So far no significant hint of SUSY particle has been observed, putting the naturalness of the SM Higgs under severe pressure. However the missing corners need to be explored, in particular with the future data taken with a higher energy in the centre of mass.

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