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3rd generation squark searches at CMS

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Abstract

Searches for the direct production of third generation supersymmetry at CMS are presented. The analyses use the full 8 $\sqrt{s} = 8\,\text{TeV}$ dataset recorded by the CMS experiment, corresponding to approximately 20fb^{-1}. This paper presents a search for top squark production in the final state with a single lepton. The statistical combination of the single lepton search with an inclusive hadronic search significantly extends the reach. A search utilizing single and double lepton final states is sensitive to the production of the heavier top squark mass eigenstate. Bottom squark production is probed with a fully hadronic search. No statistically significant excesses above the Standard Model background expectation are observed.

Keywords: Supersymmetry, CMS, 3rd generation, top squark, bottom squark

1. Introduction

The newly discovered Higgs boson [1][2] is difficult to be fully interpreted in the context of the standard model (SM). Radiative corrections to the Higgs boson self-energy via SM particles require a high level of parameter fine-tuning, known as the hierarchy problem [3]. Supersymmetry (SUSY) is an appealing extension to the SM that addresses this problem. SUSY predicts the existence of a spectrum of new particles. Due to the fact that the radiative corrections to the Higgs mass depend on the masses of the SM particles, a natural solution to the hierarchy problem requires light third generation squarks, with a mass up to the TeV scale [4]. Therefore, the CMS collaboration [5] has developed a very diverse 3rd generation SUSY search program that is sensitive to a large range of signal topologies. They range in both the type and parameters of produced particles in addition to their decay channels.

A survey of the 8 TeV program is presented here. Only signal topologies with the direct production of third generation squarks are considered and greater focus will be placed on the experimental methods employed by searches dedicated to discovering third generation SUSY. No significant excesses have been observed so all results are presented in the context of limits on produced SUSY particle masses.

2. Light Stop Production

The left and right handed top squarks are allowed to mix, resulting in two possible mass eigenstates. Multiple CMS searches have been designed to be sensitive to the direct production of the lightest mass eigenstate. These include dedicated $\tilde{t}$ searches, ranging in lepton multiplicity [6][7], in addition to inclusive SUSY searches [8][9]. Signals in which the $\tilde{t}$ decays directly into a top quark and a LSP are considered in addition to those where the $\tilde{t}$ decays into a chargino and a b quark. The chargino subsequently decays into a W boson and a LSP. The signal topologies span a wide range of $\tilde{t}$ and LSP masses in addition to multiple polarization scenarios.

Hadronic and leptonic search regions are intrinsically complimentary when searching for top squarks. Hadronic searches are sensitive to high mass top squarks due to the large branching ratio of the fully hadronic decay channel. This is particularly important for high mass signatures due to the rapidly decreasing cross section of the top squark as a function of mass. Conversely, single lepton searches are sensitive to low mass top squarks because the lepton selection significantly reduces hadronic backgrounds in regions with low missing energy. The baseline selection of the single lepton search for direct $\tilde{t}$ production is a single isolated electron or muon, where events with any additional electrons, muons, or taus are vetoed. Events are required to have at least four jets, at least one of which is identified as originating from a b-quark decay (b-tagged), in addition to at least 100 GeV of missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$). The semi-leptonic top and W boson backgrounds are reduced with a 120 GeV cut on the transverse mass. A series of search regions are then defined on top of this selection with boosted decision tree discriminators. These discriminators are each trained to isolate a specific signal topology from the remaining standard model background, which is primarily composed of semi and di-leptonic $t\bar{t}$.

The standard model backgrounds are predicted with MC simulation. Each MC process is normalized to data in low transverse mass control regions, in which all other search region selections have been applied. Subsequently, the simulation of the transverse mass shape is studied by comparing MC to data in process specific control regions defined by lepton and b-tag multiplicity. The dominate uncertainties of the background predictions originate from these studies. The limits on excluded signal production of top squarks which decay into a b-quark and chargino are shown in Figure 1 with two different mass relations between the chargino and the other SUSY particles. The first features signals with a chargino mass closer to the top squark mass while the second presents the case of the chargino mass closer to the LSP mass. This figure also shows the dependence of the search on the assumption of top squark polarization.

The limits on production cross section for signals where the top squark decays into a top quark and LSP are shown in Figure 2. The single lepton result is displayed in conjunction with the fully hadronic result achieved with the inclusive Razor SUSY search [10]. These two searches are weakly correlated because they utilize completely different standard model background predictions. The combined result is shown in the same figure, displaying sensitivity to both high and low mass top squark signals.

An additional interpretation of the combined result from the fully hadronic and single lepton searches is shown in Figure 3. A signal point production is considered excluded only if it is excluded independently of its branching ratio into either the top quark and LSP channel or the b quark and chargino decay channel.

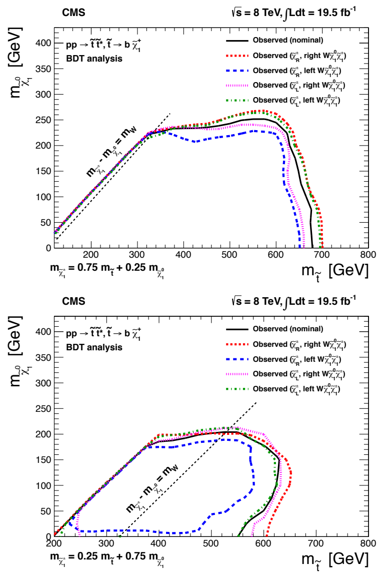

Figure 1: Observed limits on top squark production where the squark decays into a b quark and a chargino [6].

3. Heavy Stop Production

Searches for light $\tilde{t}$ production typically have low sensitivity to signals where the difference between the top squark and LSP mass is near the top quark mass because the event kinematics of these signals are very similar to those of $t\bar{t}$. As a result, this particular piece of signal phase space is relatively unexplored territory. CMS searches have been designed to isolate a subset of this signal topology where the heavier top squark mass eigenstate ($\tilde{t}_2$) is light enough to be produced at LHC energies. Both inclusive multi-leptonic SUSY searches [11][12] and a dedicated heavy top squark search [13] are sensitive to these signals. In these interpretations the heavier top squark decays into a lighter top partner and either a Z or Higgs boson.

The dedicated search for the direct production of heavy top squarks utilizes both single and di-leptonic search regions. The single lepton regions are defined by a high transverse mass cut and at least four jets. These regions are further divided into three and at least four b-tag search regions. The standard model backgrounds to this search are predicted with MC, which is normalized to observed data in a low transverse mass control region. The MC transverse mass shape is then studied in control regions where the jet and b-tag requirements are altered. The di-leptonic search regions also feature high jet and b-jet multiplicities. The b-tagged jet kinematics are required to be consistent with the decay from a Higgs bo-

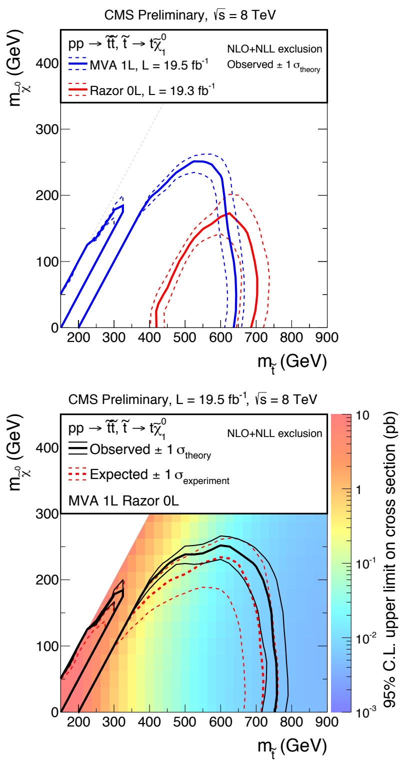

Figure 2: Observed and expected limits on top squark production where the squark decays into a top quark and a LSP [10].

son. The standard model backgrounds in these search regions are also predicted with MC. In these cases the b-tag kinematic cuts are inverted in order to normalize the MC to data. The MC modeling of these kinematics is then compared to data in single lepton control regions.

Figure 4 shows the limit on produced signal as a function of heavy and light top squark masses. The first shows the result when the heavy top squark decays into a lighter top squark and a Higgs boson, while the boson is a Z in the second. The results from the inclusive multi-lepton searches are also shown in addition to their combination with the dedicated search [14].

4. Sbottom Production

The direct production of the supersymmetric partner of the bottom quark ($\tilde{b}$) is also searched for. A dedicated bottom squark search [15] in addition to an inclusive hadronic search utilizing the M_{T2} variable [9] are sensitive to the signal topology where the $\tilde{b}$ decays into a bottom quark and a LSP. The signals topologies where the bottom squark decays into either a top or bottom

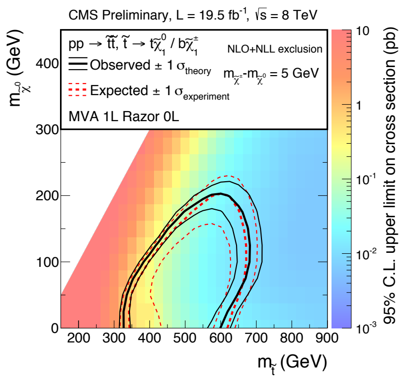

Figure 3: Observed and expected limits on top squark production, independent of decay branching ratio [10].

quark and a chargino are not detailed here. Both two and three lepton inclusive SUSY searches are sensitive to these signals [11][12].

The dedicated direct bottom squark search has eight exclusive search regions defined by contransverse mass and b-tag multiplicity. The common baseline selection is precisely two jets, at least one of which must be b-tagged and no isolated leptons. Furthermore, events must have both high missing energy and transverse mass. This definition of transverse mass is calculated with and the second leading jet in the event.

W and Z bosons in addition to $t\bar{t}$ are the dominate standard model backgrounds of this search. Their contributions are predicted by leptonic control regions with MC corrections. The largest systematic uncertainties of the background predictions originate from these corrections. The $\tilde{b}$ production exclusion limits are shown in Figure 5. This figure also shows the corresponding result for the inclusive search. These results are complimentary, with the inclusive search having greater sensitivity at low mass splitting between the $\tilde{b}$ and LSP.

5. Summary

Results from third generation SUSY searches with the CMS detector have been presented. Multiple decay scenarios of the direct production of both top and bottom squarks were detailed. All results have been found to be consistent with standard model expectations.

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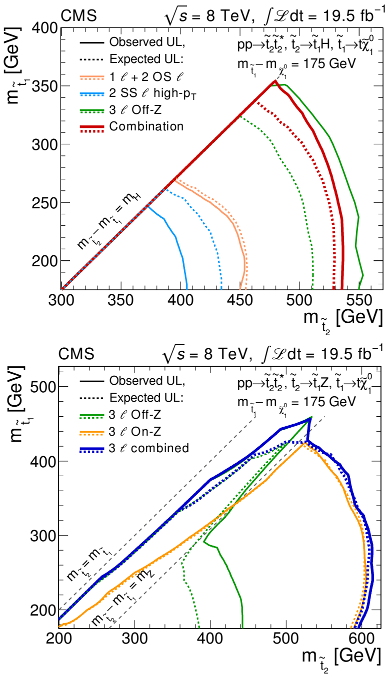

Figure 4: Observed and expected limits on the production of the heavy mass eigenstate of the top squark. Decays into both Higgs and Z bosons are shown [14].

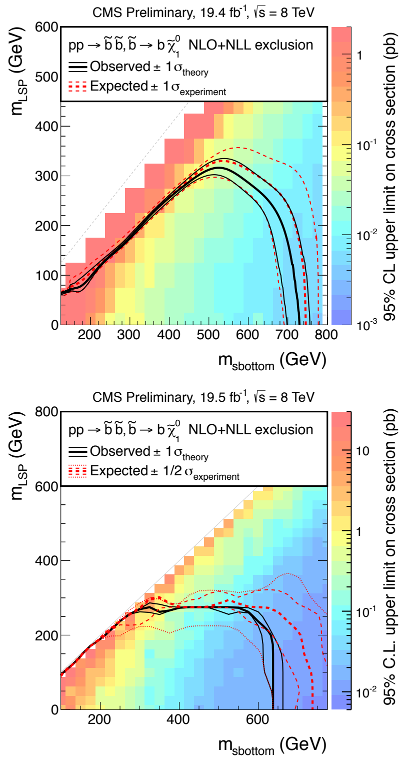

Figure 5: Observed and expected limits on the bottom squark production. Results are shown for both the inclusive $\tilde{b}$ search in addition to the inclusive hadronic search [15][9].

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