Searches for supersymmetry at CMS in leptonic final states with 13 TeV Data

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Abstract

The CMS SUSY program is very active in performing searches with the 13 TeV data including multiple analyses done in regions with leptonic final states. The results of these analyses are used to expand the reach of the searches done by CMS at 8 TeV and additionally to investigate two excesses seen in run I, namely a 2.6 sigma excess seen by CMS and a 3.0 sigma excess seen by ATLAS. These excesses were observed in two separate signal regions both having final states of at least 2 opposite sign same flavor leptons, jets, and E_T^{miss}.

Supersymmetry (SUSY) [1] is an extension to the standard model that can explain some of the open problems in physics such as a solution the hierarchy problem as well as providing potential candidates for dark matter. Searches for SUSY are performed by the CMS collaboration in a variety of final states, including searching for processes with leptons (e or μ) in the final state. Simplified models [2] are used to interpret results of these searches, where two examples are shown in figure 1. On the left is a diagram of a gauge mediated SUSY breaking (GMSB) model with a massless gravitino as the lightest SUSY particle (LSP). In this model, gluinos are pair produced, and each decays to a pair of quarks and a neutralino, which subsequently decays to a Z boson and a gravitino. Another model showing direct stop production with one of the stops eventually decaying to a top that decays leptonically is shown on the right. The results presented in these proceedings focus on direct squark and gluino production. In all of the following results, no significant deviation from the SM was observed, and limits are set on the upper limit of the cross section of simplified models at the 95% level using the CLs method [3, 4].

The SUSY analyses performed by CMS share very similar object definitions for electrons, muons, and jets. They are then grouped by the number of leptons in the final state, and for analyses with at least two leptons, they are categorized according to the charge of the two leptons with the highest p_T in same-sign, or opposite-sign final states. Additionally, a large range of topologies are targeted by varying the following event variables: Visible energy: H_T is the scalar sum of the jet p_T in the event.
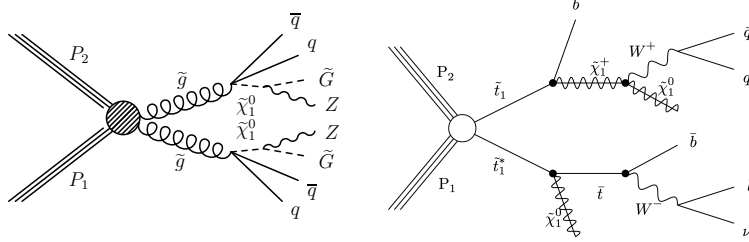
Figure 1: Diagrams showing different SUSY processes which may contain leptons in the final state are shown in this figure. On the left, gravitinos are pair-produced, where each eventually decays to a Z boson, two quarks, and a gravitino. On the right, stops are pair-produced, where one leg eventually decays to a top and a neutralino where the top decays leptonically.

M_J is the sum of reclustered jets; this is explained in more detail in the M_J analysis section. Invisible energy: E_T^{miss} is the magnitude of the vector sum of all the objects in the event, which is corrected to be consistent with the corrections applied to jets. M_T is the transverse mass made using a lepton and the E_T^{miss} vector. M_{T2} is the stransverse mass, which is made from two visible objects and the E_T^{miss} vector; This is explained in more detail in the 1-lepton stop search section. $\Delta\Phi(W, \ell)$ is the difference in ϕ between the lepton and the W-candidate in the 1-lepton inclusive analysis. L_T is defined as the vector sum of the lepton and the E_T^{miss} in the 1-lepton inclusive analysis. Jet multiplicity and flavor content: N_{jets} and N_{b-tags}.

In the analyses with exactly one lepton, three separate searches are performed. In the first search, a search for direct stop pair production [5], the signal region is defined by having exactly 1 lepton, at least 2 jets with at least one of the jets passing the criteria to be tagged as a b-jet, and $E_T^{miss} > 250$ GeV. In order to suppress backgrounds from ttbar, a cut is then made on M_{T2W}, which is an M_{T2}-like variable that uses the b-jets and leptons as visible objects, and has a kinematic cut-off at the top mass. After the cuts are applied, the largest background comes from SM $t\bar{t}$ to dilepton where one of the leptons is lost leading to increased E_T^{miss} in the event. The results of this analysis increase the sensitivity to stop production for signal models with a stop mass of 750 GeV, which is an improvement on the previous result which was sensitive to models with a stop mass up to 650 GeV.

The next analysis is a search targeting final states with exactly one lepton [6], and many jets from hadronic top decay. In this analysis, events with exactly 1 lepton in the final state are selected, and the jets in the event ($R = 0.4$) are reclustered to form large-R jets ($R = 1.2$). The mass of these large-R jets is then summed to form the variable M_J which tends to be large for events where large mass particles decay hadronically, for example in SUSY in final states with many top quarks. The results of this analysis are interpreted in the context of a SUSY model where gluinos are

pair-produced then each decays to a $t\bar{t}$ pair and a stable LSP, and gluinos up to a mass of 1600 GeV are excluded.

The final analysis with exactly one lepton [7] is an inclusive search which uses the $\Delta\Phi(W, \ell)$ and L_T variables to suppress SM backgrounds which mostly consist of $t\bar{t}$ and W+jets. The search is binned in the H_T, N_{jets}, N_{b-tags} in order for the search to be inclusive as possible. The results of the search are interpreted many SUSY scenarios, for example the same model as the M_J analysis, and this analysis is seen to have similar sensitivity when interpreting the results within the context of this simplified model.

The rest of the analyses all require at least 2 leptons in the final state [8]. The first analysis in this category is a search for SUSY in a final state with two same sign leptons. The baseline selection requires at least two same sign leptons with $p_T > 10\text{-}15$ GeV depending on the trigger, $E_T^{miss} > 50$ GeV. The analysis is then binned in H_T, N_{jets} and N_{b-tags}. The largest background in this analysis comes from fake lepton signatures in the detector, and a data-driven method was developed to predict this background which ends up with an uncertainty of about 40%.

The next analysis is a search in events with three or more leptons [9]. This analysis is binned in H_T, N_{jets} and N_{b-tags}, and the largest backgrounds in the signal region comes from either SM WZ associated production, or non-prompt leptons passing all the lepton ID requirements.

The final analysis is a search in final states with at least two opposite-sign same-flavor leptons. Two separate excesses were observed in different $M_{\ell\ell}$ regions in run I [10, 11]. CMS saw an excess in events with $M_{\ell\ell}$ between 20-70 GeV with a significance of 2.6 σ while ATLAS saw no excess. ATLAS observed a 3 σ excess in events with two leptons having $M_{\ell\ell}$ between 81-101, large H_T, and large E_T^{miss}. In the CMS analysis, a similar signal region was explored and showed no significant deviation from the SM prediction.

The analysis done by CMS was repeated in 13 TeV [12], and an additional signal region was added in order to search where ATLAS saw an excess at 8 TeV. No significant excess was seen in either region where an excess was reported in 8 TeV, and the result of this analysis can be seen in figure 2.

References

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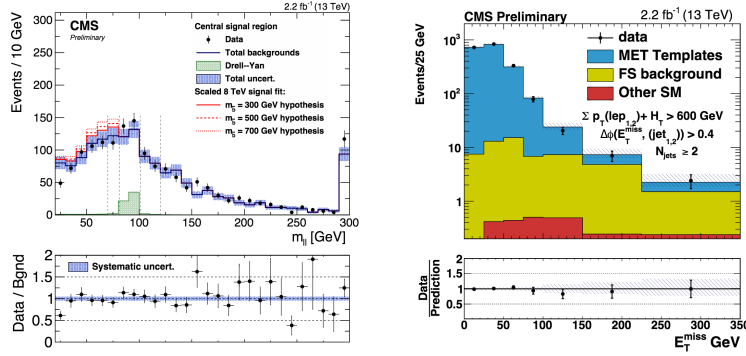[4] A. L. Read, "Presentation of search results: The CL_s technique," *J. Phys. G*, vol. 28, p. 2693, 2002.

Figure 2: Observed yields and background predictions are shown for the "edge" signal regions (left) and ATLAS-like on Z signal region (right).

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