SUSY Searches with Leptons at CMS

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The results of searches for extensions of the Standard Model in the framework of Supersymmetry (SUSY) at the CMS [1] experiment are presented, concentrating on final state signatures containing one or multiple leptons in combination with hadronic activity and missing transverse energy ($E_T^{\text{miss.}}$). All presented analyses are based on the full 2011 LHC dataset of 7 TeV pp collisions, corresponding to an integrated luminosity of 4.98 fb^{-1}. No excesses above expectations are observed and the results are interpreted as constraints on the parameter space of the Constrained Minimal Supersymmetric Standard Model (CMSSM) and of signature specific "simplified model scans" (SMS).

1 Opposite-Sign Dilepton Channels

Selecting events with opposite-sign dileptons, jets, and $E_T^{\text{miss.}}$, yields a sample dominated by the $t\bar{t}$ + jets and Z + jets processes. In SUSY cascade decays, pairs of leptons can be produced in several ways, either independently in the same or in both decay chains, or via production and subsequent decay of Z-bosons, generating different kinematic signatures. In particular the shape of the invariant mass distribution can be used as a tool in the estimation, but also to search for edge features hinting at cascade decays.

In CMS, three separate analyses target the opposite-sign final state, specializing on different model phase-spaces and complementary methods[2, 3, 4]. We present here some of the key estimation methods and results.

Controlling the background from $t\bar{t}$+jets events is straightforward when focussing on same-flavor final states, as it is flavor symmetric in ee, $\mu\mu$, and $e\mu$ channels. Hence the cross-flavor $e\mu$ channel can be used to estimate and subtract $t\bar{t}$ events from the same-flavor yields.

Selecting final states with leptonic Z boson decays probes regions of the SUSY parameter space where the neutralinos have a large Higgsino or neutral Wino component, and where the decay $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 Z$ can enhance the production of Z bosons[2]. After subtraction of the $t\bar{t}$ background, the remaining events are from Z + jets processes, where the $E_T^{\text{miss.}}$ is generated by jet mis-measurements.

The Jet-Z Balance (JZB) method exploits the fact that in a SUSY cascade decay, the Z boson is correlated with $E_T^{\text{miss.}}$, whereas in $Z+$jets events they are independent. The JZB variable is defined as JZB $= |\sum_{\text{jets}} \vec{p_T}| - |\vec{p_T}^{(Z)}|$, and tends to be positive for signal, whereas it is expected to be symmetric for $Z+$jets events. Using the negative arm of the distribution, one can then extrapolate to the positive tail defining the signal region (figure 1 (left)). No excess above predictions is observed, and the results are interpreted as constraints on the two parameters of a simplified model framework in which gluino pair production leads to two Z bosons, two $\tilde{\chi}_1^0$'s (LSP), and several hadronic jets. The resulting exclusion curve in the gluino and LSP mass plane is shown in figure 1, right, for a scenario where the intermediate $\tilde{\chi}_2^0$ mass is fixed to be at 0.75 of the interval between $m_{\tilde{g}}$ and $m_{\tilde{\chi}_1^0}$. Furthermore, signal selection efficiencies in the model space are provided for validation and calibration of results from fast simulation software, to allow the application of these results to arbitrary BMS models.

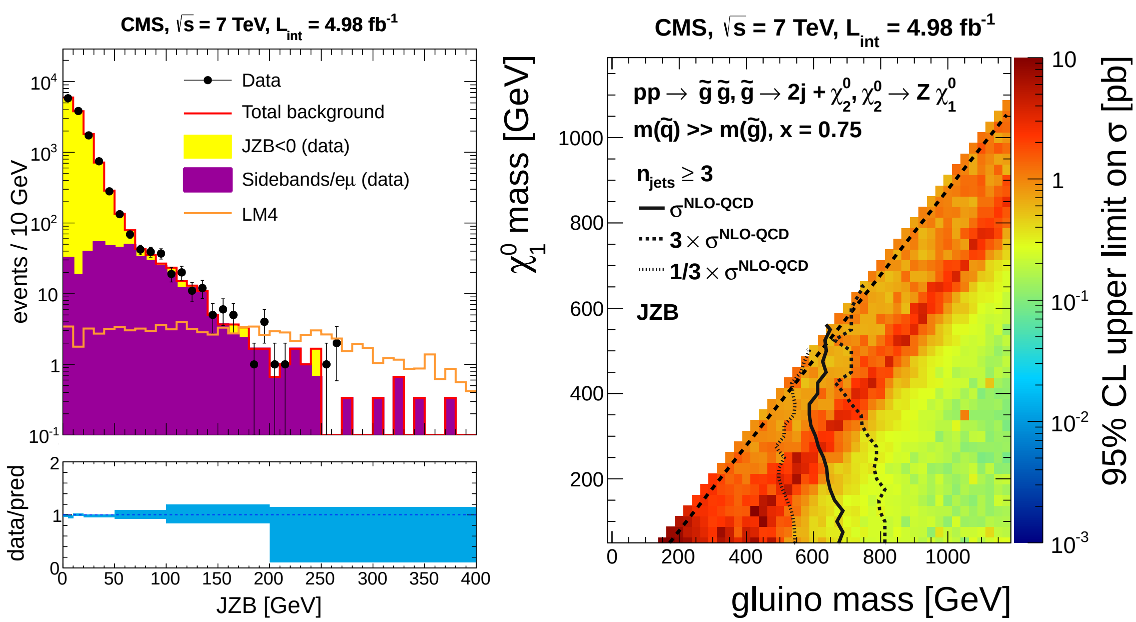

Figure 1: Observed JZB distribution vs. prediction, with a possible MC signal overlaid, from [2] (left). 95 % C.L. upper limits on the cross-section of the inclusive Z boson decay mode in a neutralino LSP scenario, using the JZB method (right).

2 Same-Sign Dilepton Channels

Signatures with two leptons of the same charge, $E_T^{\text{miss.}}$, and hadronic jets have very low Standard-Model backgrounds to contend with. Three categories of backgrounds remain: mis-reconstructed jets and leptons produced in heavy-flavor decays within jets can combine with prompt leptons from W and Z boson decays to form same-sign pairs; opposite-sign lepton pairs from $Z+$jets or $t\bar{t}+$jets with a mis-identified charge; and rare SM processes with genuine same-sign pairs. In CMS, two publications concern the same-sign channel: one with a general, inclusive approach[5], and one focussing on models with enhanced production of third-generation quarks[6]. Both employ similar background estimation techniques, employing purely data-driven methods for backgrounds involving mis-reconstructed leptons.

To estimate contributions from events with non-prompt leptons from heavy-flavor decays and mis-reconstructed jets, a loose-tight extrapolation method is employed. Two sets of lepton isolation and identification cuts are defined (loose and tight), and the ratio of tight to loose leptons is measured in a control region dominated by QCD multijet events. By relaxing the signal selection to include leptons passing loose cuts in sidebands, one can estimate the non-prompt contribution to the tight window by extrapolating with the measured tight-to-loose ratios. Backgrounds involving mis-identified charges are furthermore estimated by measuring the charge mis-identification probability in events with leptonic Z decays, and extrapolating from opposite-sign control regions with cuts identical to the same-sign signal region.

Several search regions are defined using $E_T^{\text{miss.}}$, and H_T (defined as the scalar sum of jet p_Ts), and the observed yields are compared with the result of background predictions. The non-observation of any excess over predictions is interpreted as excluding a region of parameter-space of the CMSSM, and information on signal selection efficiencies and detector response are provided to facilitate re-interpretation of the results in other models.

3 Single and Multilepton Channels

Several analysis efforts within CMS target the single lepton signature, where the main backgrounds arising are from $W+$jets and $t\bar{t}+$jets events, using complementary background estimation methods[7, 8], and focussing on models with enhanced production of third generation superpartners[9].

Final states with three and more leptons can be used to probe parameter spaces of many BSM models, such as the slepton co-NLSP scenario in gauge mediated SUSY breaking frameworks, or direct electro-weak production of SUSY particles. In CMS, one analysis is dedicated to multilepton channels [10], and one combined effort of leptonic channels investigates electroweak production [11].

References

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