Searches for supersymmetry with the CMS detector at the LHC

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Abstract. Results of searches for supersymmetry performed using data collected by the CMS experiment at the LHC in pp collisions at a centre-of-mass energy of 7 TeV are presented. Searches are performed in all-hadronic final states with jets and missing transverse energy and in final states including one or more isolated leptons or photons. Various data-driven techniques used to measure the Standard Model backgrounds are discussed. The results are interpreted in a range of supersymmetric scenarios.

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INTRODUCTION

The Large Hadron Collider (LHC) at CERN is the highest energy particle collider in the world, designed to collide protons at energies of up to 14 TeV. The Compact Muon Solonoid (CMS) experiment [1] is a general purpose detector for studying collisions produced by the LHC. The principal goals of the LHC and CMS are to determine the origin of electroweak symmetry breaking and search for physics beyond the Standard Model. Supersymmetry (SUSY) is one of the best motivated extensions to the Standard Model, and one of the main focusses of the CMS experiment. In this report the results of searches for evidence of SUSY are reported. The results reported in this paper are based on the data collected in 2011 with integrated luminosity of around 5 fb^{-1} at a centre-of-mass energy of 7 TeV.

SEARCH STRATEGY

Searches should be as model independent as possible but the large number of free parameters in many SUSY models makes this a challenging task.

At LHC energies squark and gluino (the SUSY partners of the quarks and gluons) production are expected to dominate SUSY particle production. Since squarks and gluinos are coloured particles they are predicted to be produced via the strong interaction with a cross section similar to that of QCD processes at the same scale. To a good approximation the production cross sections depend only on the masses of the particles and are therefore independent of the SUSY model. In contrast the decays of the SUSY particles depend critically on the details of the SUSY model under consideration, such as mass spectra and branching ratios. However some generic properties can be identified. Assuming R-parity is conserved then the decay chains end with the lightest SUSY particle which escapes undetected, leading to missing transverse momentum (MET). Assuming that the squarks and gluinos are heavy, long decay chains are expected, with several jets or leptons involved.

The search strategy of the CMS collaboration is to focus on simple and robust event signatures, characterised by numbers of jets and leptons or photons, which are common to a wide variety of models and let the Standard Model (SM) backgrounds and the performance of the detectors define the search ranges.

HADRONIC SEARCHES

Searches using events with only hadronic jets and missing transverse momentum are amongst the most sensitive to SUSY, but suffer from large and diverse backgrounds from Standard Model processes, making them especially challenging. The CMS collaboration pursues several complementary approaches based on both detector understanding and event kinematics [2, 3, 4, 5] to estimate and suppress backgrounds.

The search described here [3] is based on the variables H_T and $\not{H}_T$, the scalar and vector sums, respectively, of the hadronic jets in each event. Standard Model backgrounds are from a variety of processes:

- QCD multijet events in which one or more of the hadronic jets are mismeasured, resulting in artificial missing energy;
- Z-boson production with associated hadronic jets, in which the Z boson decays to neutrinos, resulting in missing energy;
- W-boson prodution with associated jets and top-quark pair-production events with semi-leptonic decays to muons or electrons which are not efficiently vetoed, or hadronic decays of tau leptons.

Estimates of each of the SM backgrounds are made based on techniques using data. These are shown in Fig. 1 in bins of H_T and $\not{H}_T$ and compared with the data events in each bin. No deviation from the background predictions is observed and limits may be set by combining the bins statistically. Figure 1 shows the limits placed on SUSY masses in the CMSSM model [6, 7, 8]. Gluino and squark masses can be excluded below 1 TeV in much of the model phase space. Limits are also placed on Simplified Model Spectra [9], which are simple models of the kinematics of new particle production with minimal new particle content and without the theoretical constraints of full theories. Figure 2 shows cross section limits on simplified models of squark and gluino pair-production.

DILEPTON SEARCHES

In comparision with all-hadronic searches adding the requirement that there be two isolated electrons or muons reduces the backgrounds from multijet QCD and W-boson production, leaving Z-boson production and top-quark pair-production as the remaining backgrounds.

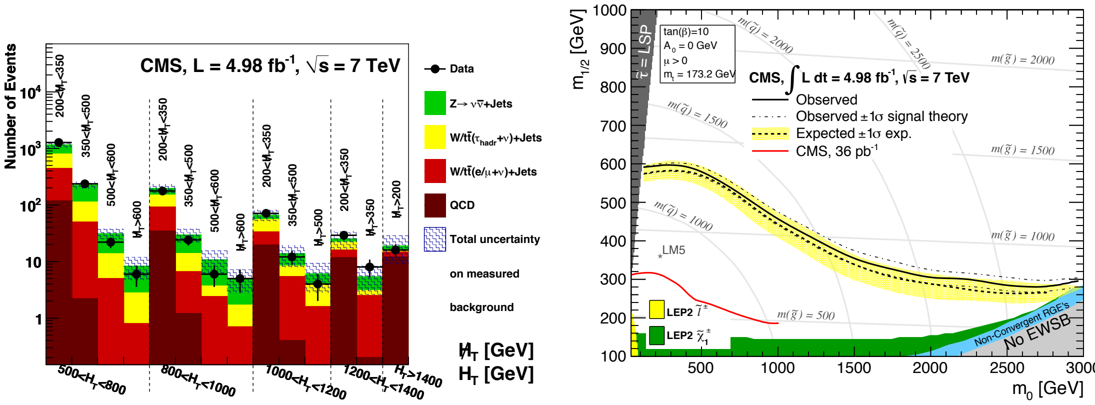

FIGURE 1. Data yields compared to SM background predictions (left) and limits in the CMSSM (right).

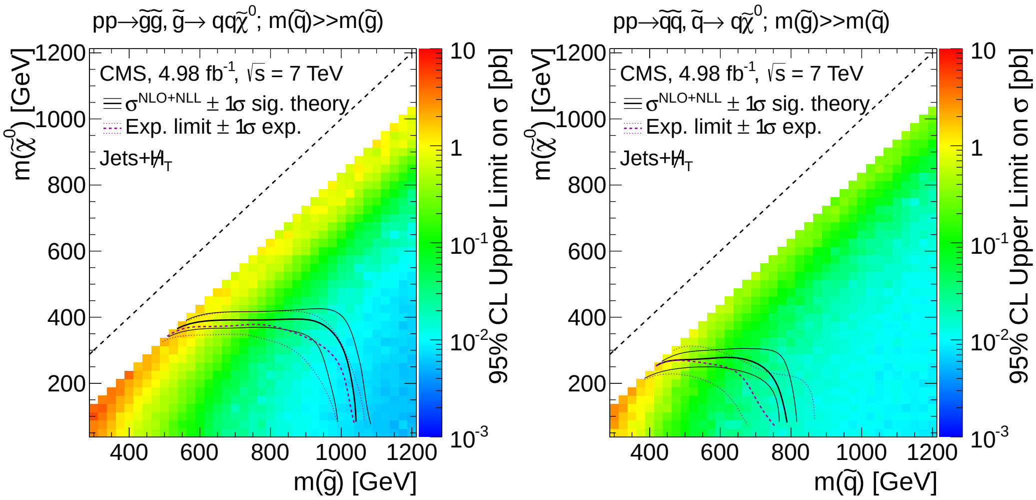

FIGURE 2. Limits placed on Simplified Model Spectra. The lines show expected and observed upper limits assuming QCD production of SUSY particles.

Searches are performed in several event configurations, such as requiring the pair of leptons have the same or opposite electric charge, or are produced in the decay of a Z boson. The latter is described in this paper.

Backgrounds stem from Standard Model events with a Z-boson decay in which the event constituents are poorly measured giving rise to MET, or in $t\bar{t}$ production in which the lepton momenta happen to sum to give the Z-boson mass. Two complementary approaches are pursued to search for such events [10].

The jet-Z balance (JZB) variable probes the balance in transverse momentum between the Z boson reconstructed from the leptons and the hadronic energy in the event. SM background gives an approximately symmetric JZB distribution, while in constrast a SUSY signal would give an excess in the positive side of the JZB distribution. Figure 3 shows the distribution of the JZB variable for data and SM background. No excess of data events over the SM prediction is observed.

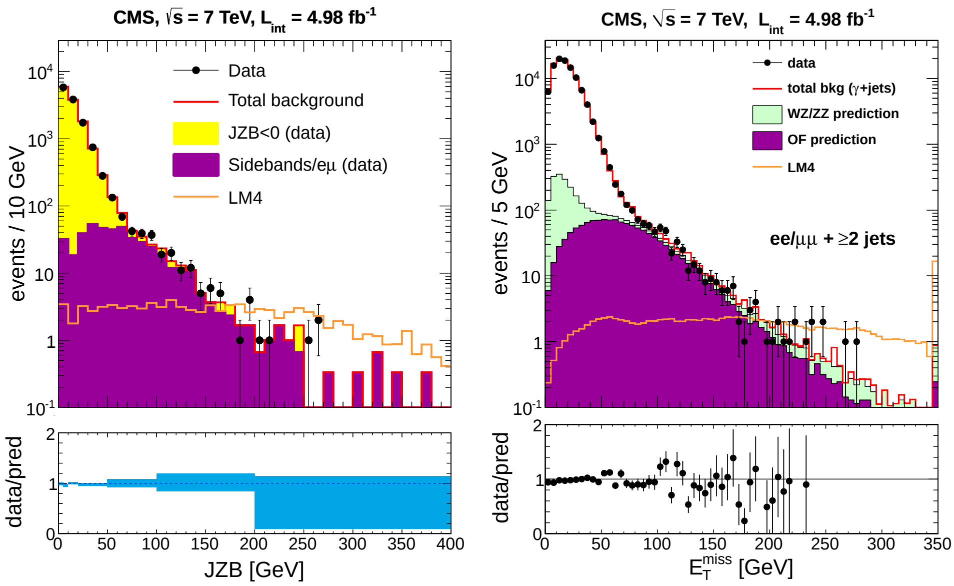

FIGURE 3. Distributions comparing data with the SM background predictions for the JZB variable (left) and the missing transverse energy (right).

The second technique uses independent control samples of QCD multijet events and photon and hadronic jets to predict the MET distribution due to mismeasured hadronic activity in Z events. Figure 3 shows the distribution of the MET for data and SM backgrounds. No excess of data events over the SM prediction is observed.

Both techniques predict the background from $t\bar{t}$ events using an independent sample of dileptonic decays to a muon and electron.

PHOTON SEARCHES

Photons occur naturally in General Gauage Mediated (GGM) SUSY models , through the next-to-lightest SUSY particle decaying to a photon and a Gravitino. CMS performs searches in events with one or two photons, hadronic jets and MET. The two photon search [11] is described in this paper.

The principal backgrounds come from QCD events. In multijet events and QCD photon and jets events, jets may fragment in a way that gives a photon signal. These backgrounds are estimated from two data control samples, Z-boson production events with associated jets and QCD multijet events with less stringent isolation requirements. Electroweak background is expected to be much smaller than the QCD background and is estimated using events with Z-boson decays to electron and positron pairs. Figure 4 shows the MET distribution comparing data and background estimations. No excess of data events over the predicted backgrounds is observed.

Limits are set in a GGM inspired SUSY model. Figure 4 shows lower mass limits for squarks and gluinos of around 1 TeV.

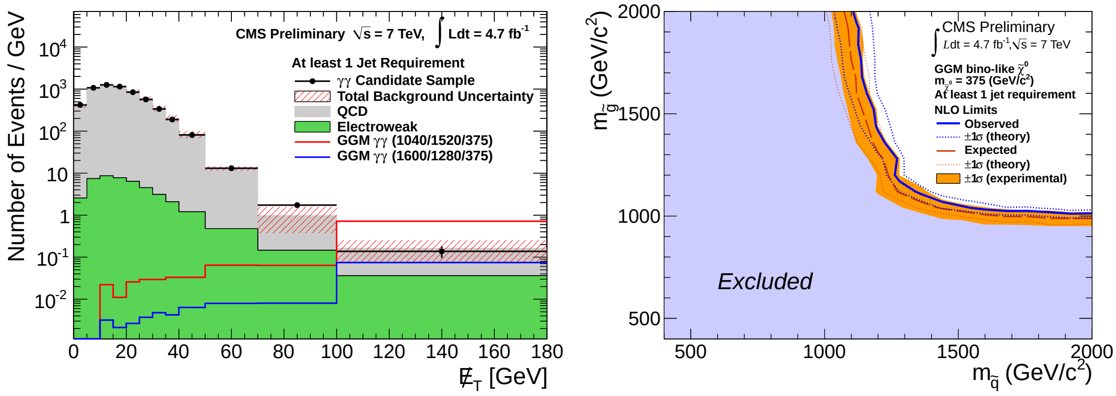

FIGURE 4. Data yields compared to SM background predictions (left) and squark and gluino mass limits in the Bino-like GGM model (right).

CONCLUSION AND OUTLOOK

A wide range of searches for supersymmetry have been performed by the CMS collaboration with the 5 fb^{-1} of data collected in 2011. Searches based on generic topological signatures have focussed on the strong production of SUSY particles with high production cross sections and rich phenomenology. No significant deviations from the Standard Model background predictions have been found.

Looking towards the future the larger data sample being collected in the 2012 LHC run will allow for more thorough searches in electroweak production modes and access to exclusive decay channels, in particular in searches for third generation SUSY particles which are predicted to be accessible by natural SUSY models.

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