The Compact Muon Solenoid Experiment
Conference Report

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Search for Supersymmetry at CMS in lepton or photon final states

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Abstract

We present results of searches for Supersymmetry in signatures involving lepton or photon final states. These searches are performed with data collected by the CMS experiment at the LHC in pp-collisions at a center of mass energy of 7 TeV. Various data driven techniques used to measure the Standard Model background are demonstrated. The results are interpreted within the CMSSM as well as more general, simplified models.

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Keywords: Supersymmetry, CMS, lepton, photon

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INTRODUCTION

Despite the outstanding agreement with the experimental data it is widely believed that the Standard Model (SM) is not the ultimate theory, but only a low-energy effective theory. The Large Hadron Collider (LHC) built at the European Organization for Nuclear Research (CERN) in Geneva, is a machine designed in terms of center of mass energy and luminosity to scan the unknown physics sector in the energy range of TeV. Supersymmetry (SUSY) is one of the best studied theoretical extension of the SM. In SUSY the exact signal topology is unknown, in general we expect strongly produced SUSY particles which will subsequently decay to jets, leptons and the Lightest SUSY Particle (LSP). Searching for an excess of events over the SM background, in a final state with jets, leptons and large missing transverse energy (MET) is a known recipe to discover SUSY with stable weakly interacting LSPs [1].

In most SUSY searches, a counting of events in the signal region is performed and the observed number of events is compared with the expected SM background. The physics analysis challenge is to keep small the overall background event yield and its uncertainty, while retaining high signal event selection efficiency. Both requirements are satisfied by including leptons in the final state which significantly reduces the background at a hadron collider. The remaining background is mostly of electroweak nature and thus accompanied by less theory uncertainty compared to the QCD multijet production. Apart from experimental convenience, the potential of characterizing the new signal by probing its mass spectrum using kinematic endpoints is a strong motivation for leptonic SUSY studies.

The Compact Muon Solenoid (CMS) is a general purpose hermetic detector optimized for reconstructing photons, leptons and MET with excellent performance [2][3]. Understanding the detector performance is essential for new physics searches, where rare signals need to be discriminated over the large SM background. Triggering, reconstruction and MC detector modeling were extensively studied in-situ using SM physics events [4].

$l + \gamma + \text{MET}$ SEARCH

In the framework of General Gauge Mediated (GGM) SUSY new physics signals may populate the final state with a lepton, photon and MET. The most important background in this search is the SM $W\gamma$ production, which is irreducible. This process is estimated by using MADGRAPH MC generator interfaced with PYTHIA. The leading order cross section is scaled to next-to-leading (NLO/LO = 2.3) order using BAUR NLO $W\gamma$ generator and CTEQ66 NLO parton distribution function (PDF) sets. The theoretical cross section estimate is in very good agreement with the $W\gamma$ CMS cross section measurement [5]. Residual backgrounds involving mis-identification of lepton or photon, or mis-measurement of MET are estimated from control regions in the data. The overall background composition is shown in Figure 1. A benchmark GGM point is also used to model signal selection efficiency and an upper limit on the signal cross sections is set [6].

FIGURE 1. The MET distribution in the combined $e\gamma$ and $\mu\gamma$ samples. The black points represent the data and the colored histograms show the individual background components. The expectation from example SUSY benchmark point GMC is shown by the red dashed line. The last bin includes overflows.

FIGURE 2. Comparison of the predicted and observed JZB distributions in an inclusive ≥ 3 jet selected e^-e^+ and $\mu^-\mu^+$ data sample. The background prediction has been fitted to display the $\pm\sigma$ uncertainty band based on Poisson statistics.

$Z^0 + \text{JET} + \text{MET SEARCH}$

The $Z^0 + \text{jet} + \text{MET}$ final state is a clean signature for new physics searches. The SM Z^0 +jets production is an irreducible process that does not contain true missing energy but can have apparent MET due to detector resolution and reconstruction effects. The total expected SM background is exclusively estimated from control regions in the data using a novel analysis approach, the jet- Z -balance (JZB) method [7]. The JZB observable is defined as the p_T difference of the vector sum of all jets (hadronic recoil) minus the transverse momentum of the Z^0 boson. For background events, the JZB is equivalent with a signed MET, where the sign keeps track of whether the MET is due to under (−) or over (+) measurement of the reconstructed jet energy. For new physics signals, where the Z^0 and the particle responsible for the MET (LSP) have a common mother, the JZB distribution tends to be largely positive. For the background, at the other hand, the Z^0 is directly produced in the hard scatter and evenly fluctuates to positive and negative values. This kinematic property is exploited in the Z^0 +jets background estimation. For processes that involve real missing energy due to neutrinos, the lepton universality is exploited and the background is determined in an $e\mu$ triggered data sample. The shape of the total estimated background is compared with the observed event yields and no significant excess is found, as shown in Figure 2. The analysis uses SUSY benchmark points to model signal selection efficiency and puts limits on new physics models [8].

FIGURE 3. Summary of background predictions and observed yields in the search regions for the same sign di-lepton search. Two complementary backgrounds estimates are compared to the observed number of events in the signal regions.

SAME SIGN DI-LEPTON SEARCH

This final state is almost background free. There are only a few rare sources of SM background which result in same sign di-leptons, e.g. $W^\pm W^\pm$ or double parton scattering. These types of backgrounds are estimated from MC simulation and a conservative systematic uncertainty is assigned. Experimentally the dominant background comes from mis-identification of a lepton (fake lepton) or of mis-reconstruction of the charge. The background coming from jets identified as a lepton is estimated with the tight-to-loose ratio method [9]. The probability that a loose lepton (relaxed isolation and id) passes also the tight selection, is estimated in a control region in the data. This probability is then used to re-weight the number of loose leptons in the signal region and get a direct estimate of the background event yield in the signal region. The analysis makes use of all lepton flavors, including τ leptons. Various signal regions have been pre-defined to cover different part of the SUSY parameter space. The total background predictions are comparing very well with the observed event yields, as shown in Figure 3. The analysis finds no significant excess and put limits on the allowed SUSY models [10].

CONCLUSIONS

The CMS detector has been commissioned in-situ with physics events and has well modeled performance. No significant deviation from the SM has been observed so far.

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