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Searches for Gauge Mediated Supersymmetry Breaking scenarios at CMS

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Abstract. In this proceedings, the latest results from the CMS collaboration on searches for Supersymmetry with Gauge Mediated Supersymmetry Breaking (GMSB) in final states with photons and leptons are presented using pp collision data from the 7 and 8 TeV LHC run. The experimental results are interpreted in terms of weak as well as strong production of SUSY particles, followed by cascade decays to a Gravitino as lightest supersymmetric particle.

1 Introduction

The CMS experiment [1] at the Large Hadron Collider (LHC) has accumulated data corresponding to an integrated luminosity of around 5 fb^{-1} in 2011 and around 20 fb^{-1}. The discovery of a Brout-Englert-Higgs (BEH) boson has moved the phase of hunting for the Standard Model (SM) BEH boson to evaluating the consistency of this new particle with the SM expectation. Beyond the SM, it is predicted that there should be super-partner particles corresponding to the SM model particles in order to explain the unification of the forces, the stability of the BEH boson mass and the dark matter candidate. The CMS experiment has pursued the searches for the super-partner particles. The gauge mediated supersymmetry breaking (GMSB) model has been motivated at low energy scale where the required breaking of supersymmetry can occur in hidden sector by a mean of couping to the visible sector through the SM gauge interactions [2]. In GMSB model, the large flavor-changing neutral currents (FCNC) is suppressed so we can avoid the large FCNC. In this model, the lightest super-symmetry (SUSY) particle is gravitino (< around 1 keV) and the lightest neuralino becomes the next-to-lightest-superpartner (NLSP). Therefore, the final signature is determined by the nature of the NLSP. The neutralino (NLSP) is the mixture of binos, winos and higgsinos. The CMS experiment has performed the searches sensitive to the bino- or wino-like neutralino scenario scanning the parameters of squark and gluino mass.

The bino-like neutralino will decay dominantly into a gravitino LSP and photon while decaying into a gravitino and a Z boson is suppressed [3]. If the NLSP is wino-like neutralino, the neutral wino would decay dominantly into a gravitino and a Z boson. Since the splitting the charged and neutral wino becomes small, the charged wino becomes co-NLSP which decays directly to a gravitino LSP and a W boson.

In this proceedings, the results of GMSB searches by the time LHCP2013 conference with the fraction of collected data which is correspond to an integrated luminosity of up to 9.2 fb^{-1} at 8 TeV as well as 5 fb^{-1} at 7 TeV will be presented. The searches with photon final states has been updated with 8 TeV [5]. The review of 7 TeV results will contain the Gamma-Jet Balancing (JGB) method [7], Stealth SUSY searches with low MET [8] and searches for the charged NLSP with tau final states [10]. The interpretation of di-lepton final states analysis in the context of GMSB will be also briefly mentioned [11].

2 Physics objects

The physics objects are reconstructed through a particle-flow reconstruction algorithm which combines information from all sub-detectors and reconstruct all particles [9]. Photons are selected using the ECAL cluster shape to be consistent with that expected from a photon. The energy in HCAL behind the photon shower should not exceed 5 % of the ECAL energy. Photons should be isolated to suppress hadronic jets. Since these selections are similar to electron selection, the candidates are rejected if there are hit patterns in the pixel detector consistent with a track from an electron. Tau is identified with the Hadrons plus strips (HPS) algorithm combining charged hadrons and calorimeter information in strips to take into account π^0 [12]. Particle-flow jets are reconstructed using anti-kt algorithm with R=0.5. E_T^{miss} is the opposite direction of vector sum of reconstructed particles.

3 Photon final states

3.1 single- and di-photon selections

Searches with photons as final states has been already performed at 7 TeV [4]. Two final state topologies has been considered in the searches with photons using data corresponding to an integrated luminosity of 4 fb^{-1} at 8 TeV [5].

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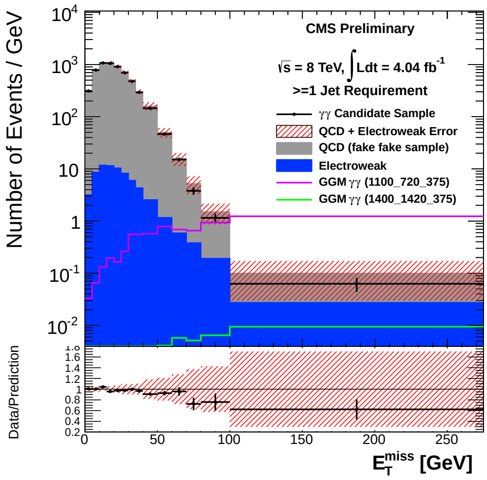
One topology is to select two photons (or more) with 40 (25) GeV, at least one jet and MET > 50 GeV. The other topology is at least one photon with 80 GeV, at least two jets and MET > 100 GeV. Single-photon topology is sensitive to bino-like neutralino scenario while di-photon topology is sensitive to wino-like neutralino scenario. Data-driven method is used to estimate the background contributions which are mainly from the QCD process where jets can fake photons and the electroweak (EWK) process where electrons can fake photons. The QCD process was determined using the control samples that are kinematically similar to the candidate sample. The electroweak process estimation was based on the electron misidentification rate as photon which is estimated using Z candidate decaying to ee or eγ in the mass window around Z peak. Figure 1 shows E_T^{miss} distribution comparing data with QCD and EWK background contributions. The example signal expectations for di-photon and single-photon topologies are also shown. There is no excess observed in this distribution. The limits are calculated in six distinct bins above MET requirement.

The 95 % confidence level cross section upper limits in squark-gluino mass plane are shown in Fig. 2. For bino-like neutralino scenario, mass for squark and gluino below around 1.1 TeV has been excluded in di-photon selection. For wino-like neutralino scenario, mass below 850 GeV has been excluded in single-photon selection. This is a significant improvement with respect to 7 TeV result [4]. As expected, it was observed that bino-like neutralino scenario is less sensitive in single-photon while wino-like neutralino scenario is less sensitive in di-photon selection.



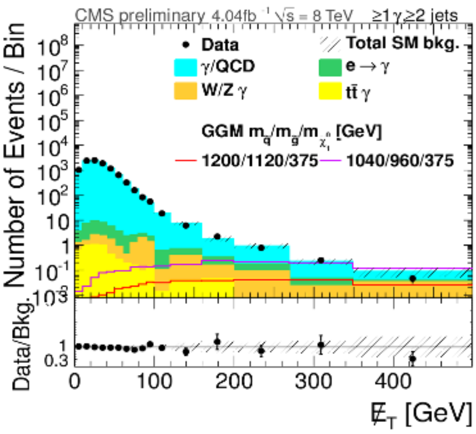


Figure 1. E_T^{miss} distributions comparing data and QCD background estimation together with EWK background estimation for single-photon selection (upper) and di-photon selection (lower). Two GGM benchmark points with masses $(m_{\tilde{q}}/m_{\tilde{q}}/m_{\tilde{\chi}_1^0})$ are shown together as examples.

3.2 Jet-gamma balance method

Jet-Gamma Balancing (JGB) method is a complementary analysis to sideband method described in Section 3.1. The analysis was performed at 7 TeV with 4.7 fb^{-1} data [7]. There is Jet-Z Balancing (JZB) analysis which is based on the balance between Z and jets [6]. In this analysis, Z is replaced with photon. In the JGB method, the requirement of the jet p_T is much harder than the relevant of other method 3. For event selection, at least one photon with p_T > 80 GeV and $|\eta| < 1.442$ is required. There should be also at least 3 jets with p_T > 100 GeV. HT > 460 GeV is also required.

JGB variable is basically the MET information with the sign. In the case of cascade decay like SUSY, JGB tends to go higher. If photons from primary vertex are kinematically balanced like in the SM, JGB will close to 0. Figure 3 shows the simulated JGB distributions for the signal and the SM backgrounds. We do not observe any excess in this distribution so the limit was set for wino-like scenario. JGB method has been shown to be have more sensitivity for wino-like scenario in Fig. 4. Green-dashed line indicates 7 TeV analysis result with sideband method.

3.3 Stealth SUSY

As the parameter space available for high E_T^{miss} SUSY has been reduced by recent LHC results, interest in low E_T^{miss} alternatives has increased. The simplest Stealth SUSY model introduces additional hidden sector SUSY particle (LHSP) at the week scale. The LHSP (singlino) decays to the SM partner (singlet) and LSP (gravitino). Near mass degeneracy requires the LSP to carry out the small momentum which represents low MET. This analysis was performed at 7 TeV with 5 fb^{-1} data [8]. The S_T is defined as a scalar sum of E_T^{miss}, the energy of all photons and the energy of all jets in the event. The background is estimated directly from data by taking the shape of S_T with 2 jets or 3 jets requirement assuming that the shape is similar in the signal region where 4 or >=5 jets are required. The data are in good agreement with the background expectation. The number of events with S_T greater than a threshold is

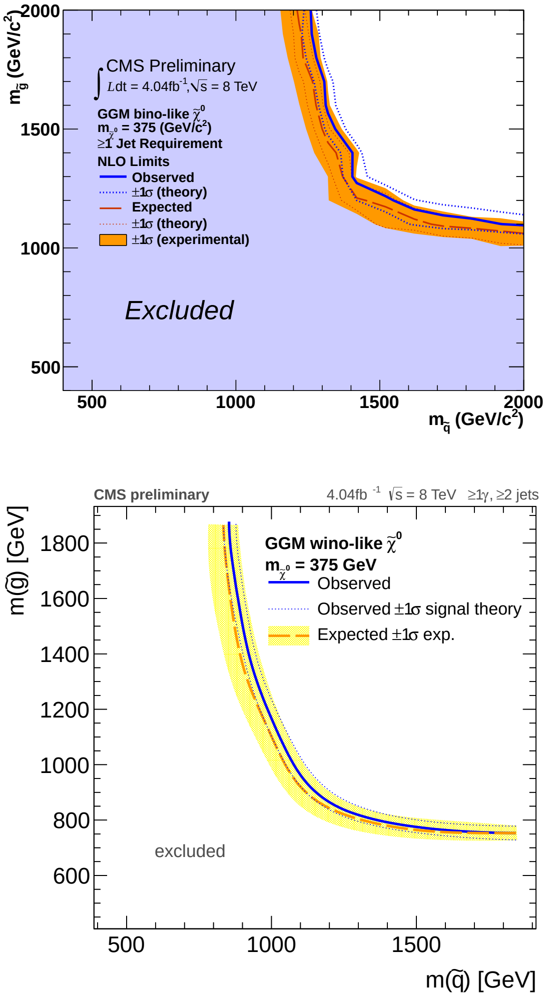


Figure 2. 95 % confidence level upper limit cross section exclusion contours in gluino-squark mass space for bino-like neutralino for di-lepton event topology (upper) and for wino-like neutralino scenario for single-lepton event topology (lower).

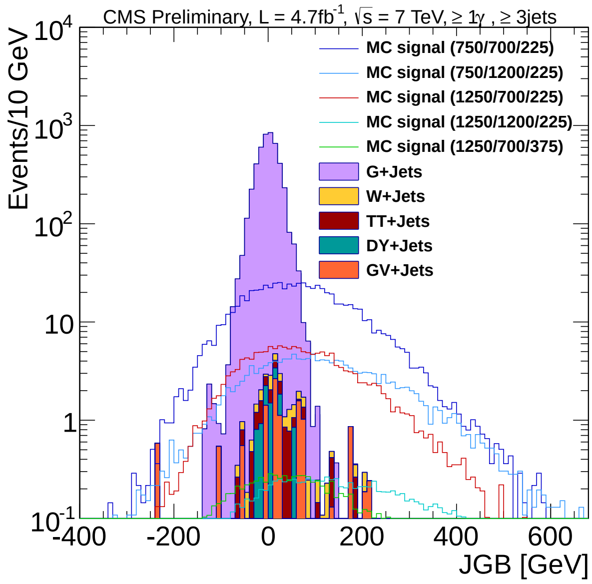


Figure 3. The JGB distribution in MC simulation for five different signals and the most important SM backgrounds with at least one photon and at least 3 jets.

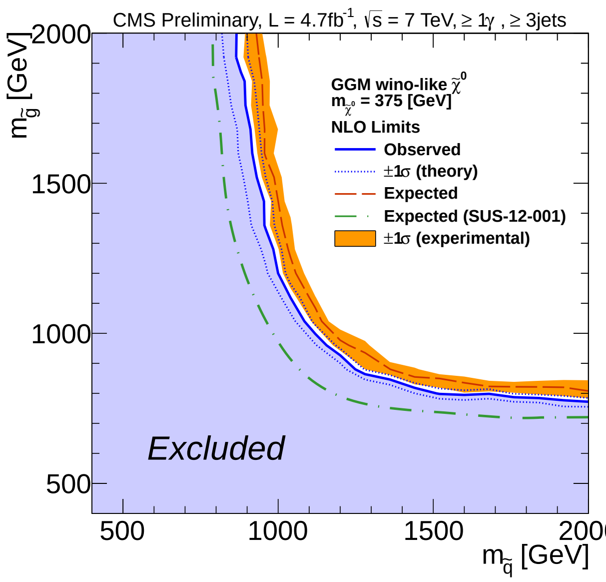


Figure 4. 95 % confidence level exclusion contours for a wino-like neutralino in the squark-gluino mass plane.

counted. The squark mass is excluded below 1430 GeV for bino-like neutralino as shown in Fig. 5.

4 Lepton final states

4.1 tau final state

The $\tilde{\tau}$ is produced via chargino and neutralinos in cascade of decays of colored SUSY particles. In about two third of cases, τ-leptons decay into a hadronic system with one, three or five charged mesons that can be accompanied by neutral pions and a τ-neutrino while one third of cases, τ-leptons decay into lighter leptons plus neutrinos. Therefore, events with τ-leptons in the presence of a high multiplicity of jets is an interesting probe for new physics. The searches with tau final states has been performed at 7 TeV with data corresponding to 5 fb^{-1} [10]. The result is interpreted in the context of GMSB where $\tilde{\tau}$ is the charged NLSP which decays to a τ and a gravitino ($\tilde{\chi}_2^0 \rightarrow \tau\tilde{\tau} \rightarrow \tau\tau\tilde{G}$). It it important to understand the τ mis-identification rate as the main contribution comes from one or more jets being mis-identified as a τ. The mis-identification rate was estimated from data and found to be 1–2 %. Each background contribution estimation is based on a well defined control region in data.

Di-tau final state result is interpreted in the context of GMSB assuming 100% branching ratio to $\tau\tau$. Figure 6

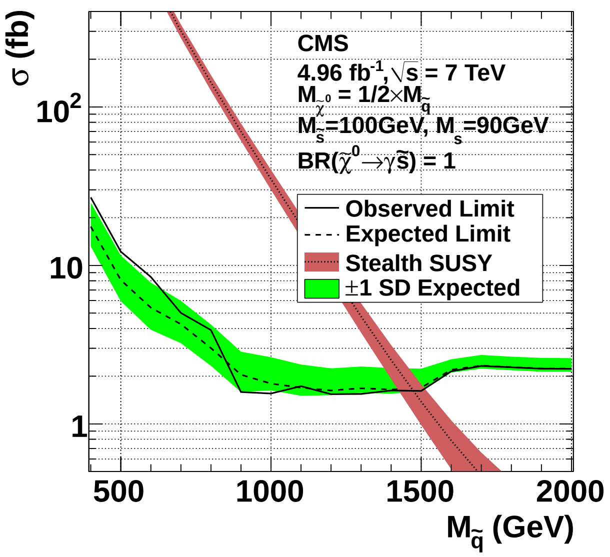


Figure 5. Cross section limit at 95 % confidence level as a function of squark mass. We show the observed limit, median expected limit with ± standard deviation. The predicted cross section from Stealth SUSY for bin-like neutralino scenario is also shown together.

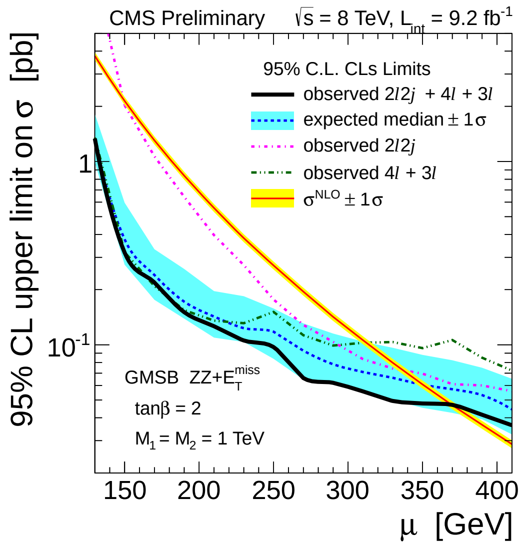


Figure 7. Interpretations of the analyses with di-lepton and four-lepton final states in the context of GMSB model. The observed and expected cross section upper limit at 95 % confidence level are shown as a function of neutralino mass (μ). The mass below 370 GeV is excluded.

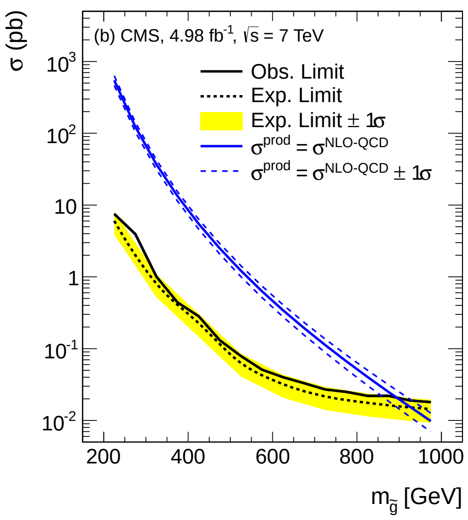


Figure 6. 95 % confidence level cross section upper limit as a function of gluino mass in the GMSB scenario.

shows the exclusion limits for the simplified GMSB scenario as a function of gluino mass. The mass below 860 GeV is excluded at 95 % CL in this analysis.

4.2 multi-lepton final state

Di- and four-lepton and final state analyses are sensitive to SUSY particles in electroweak production and has been performed with 9.2 fb^{-1} data at 8 TeV [11]. The result has been interpreted in the context of GMSB Z-enriched higgsino model as it has a large branching ratio to the $ZZ + E_T^{miss}$ final state with assuming that the ratio of Higgs expectation values $\tan\beta = 2$ and fixed squark and gluino mass equal to 1 TeV. Figure 7 shows the cross section upper limit at 95 % confidence level The neutralino mass below 370 GeV is excluded in this model.

5 Conclusions

The CMS experiment has pursued the searches for the super-partner particles in the context of GMSB model with data collected at 7 TeV in 2011 corresponding to an integrated luminosity of 5 fb^{-1} and up to 9.2 fb^{-1} at 8 TeV in 2012. The results by the time LHCP2013 conference has been presented. The gluino and squark mass are excluded below around 1.1 TeV for bino-like NLSP scenario and around 850 GeV for wino-like NLSP scenario. Searches with low E_T^{miss} or lepton final states have been explored also in the context of GMSB. SUSY in GMSB like other SUSY models at the LHC is excluded more if it is strongly produced. It has yet been explored that much for EWK production. Updating with full data with lepton+photons, sensitive to EWK production, is foreseen in near future. More searches for the higgsino-like neutralino are also expected in the future.

References

[1] CMS Collaboration, “The CMS experiment at the CERN LHC", JINST 3:S08004,2008.

[2] G.F. Giudice and R. Rattazzi, "Theories with Gauge-Mediated Supersymmetry Breaking", Phys.Rep. **322** (1999) 419.

[3] Joshua T.Ruderman and David Shih, "General Neutralino NLSPs at the Early LHC", arXiv:1103.6083.

[4] CMS Collaboration, "Search for new physics in events with photons, jets and missing transverse energy in pp collisions at $\sqrt{s}$ = 7 TeV", JHEP **03** (2013) 111.

[5] CMS Collaboration, "Search for Supersymmetry in Events with Photons and Missing Energy", **PAS SUS-12-018**.

[6] CMS Collaboration, "Supplemental Material for : Search for physics beyond the standard model in events with a Z boson, jets and missing transverse energy in pp collisions at $\sqrt{s}$ = 7 TeV", PLB **716**, 260–284.

[7] CMS Collaboration, "SUSY Search in Photon(s)+jets+E_T^{miss} final state with the Jet-Gamma Balance method", **PAS SUS-12-013**.

[8] CMS Collaboration, "Search for supersymmetry in events with photons and low missing transverse energy in pp collisions at $\sqrt{s}$ = 7 TeV", PLB **719** (2013) 42.

[9] CMS Collaboration, "Particle-Flow Event Reconstruction in CMS and Performance for Jets, Taus, and E_T^{miss}", **PAS PFT-09-001**.

[10] CMS Collaboration, "Search for physics beyond the standard model in events with tau leptons, jets and large transverse momentum imbalance in pp collision at $\sqrt{s}$ = 7 TeV", Submitted to Eur.Phys.J.C, arXiv:1301.3792.

[11] CMS Collaboration, "SUSY searches for EWK production of Gauginos and Sleptons at the LHC", **PAS SUS-12-022**.

[12] CMS Collaboration, “Performance of τ-lepton reconstruction and identification in CMS", JINST **7** (2012) 1001, doi:10.1088/1748-0221/7/01/P01001, arXiv:1109.6034.