PROCEEDINGS OF SCIENCE

Searches for electroweak SUSY in ATLAS and CMS

PoS(EPS-HEP2015)111

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Results for SUSY searches in the electroweak sector are summarized, based on $20\ \mathrm{fb}^{-1}$ of 8 TeV proton-proton collisions collected by the CMS and ATLAS detector. A variety of complementary final state signatures and methods are used to probe gaugino and slepton production, including compressed scenarios. This talk includes the latest CMS results from the first ever search for SUSY production through vector boson fusion processes in a topology of two leptons, two forward jets and missing transverse energy.

The European Physical Society Conference on High Energy Physics
22–29 July 2015
Vienna, Austria

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[*] Speaker.

[†] I would like to thank LHC colleagues for the outstanding performance of the accerlerator, members of ATLAS and CMS Collaborations for their hard work in producing the results presented in this conference, and to the organizers of EPS-HEP 2015 for a fruitful conference.

1. Introduction

The standard model of particle physics (SM) is a theoretical framework predicting the nature of interaction among elementary particles and its properties. The SM has been tested to the greatest precision by various experimental observations which are consistent with its predictions e.g. discovery of the Higgs boson by the CMS [1] and ATLAS [2] collaborations at LHC etc. But still it fails to answer many questions i.e. the hierarchy problem and unification of forces, the nature of dark matter and energy. Supersymmetry (SUSY) [3] is one of extension of the SM which tries to answer these questions. In SUSY, every SM particle has a superpartner which differs from it by spin. SUSY is a broken symmetry. Some R-Parity conserving SUSY models [4] have a stable, weakly interacting lightest supersymmetric particle (LSP) which is a suitable dark matter candidate. Most of the SUSY searches at LHC are focussed on the strong colored sector due to their large cross sections and limits on these particles (i.e. gluinos and 1st/2nd generation squarks) reach up to 1.5 TeV [5] – [6]. However, the constraints on the electroweak sector are less stringent.

CMS and ATLAS have done a variety of SUSY searches covering most of the parametric space. However, in this paper, only some of the latest results on data collected by CMS and ATLAS detectors with pp collisions at 8 TeV have been briefly summarized.

2. Searches for compressed SUSY scenario in Vector Boson Fusion production

CMS has done a search for compressed SUSY scenarios in stau dominated scenarios where electroweak SUSY particles (winos) are produced in pairs with two forward jets [7] with high dijet invariant mass as shown in Figure 1. These jets are generally in opposite hemispheres of the detector with large pseudorapadity gaps. Despite of lower production cross section as compared to the direct processes, VBF topology provides a powerful handle against the SM backgrounds. The chargino/neutralinos (wino-like) decays to a pair of τ leptons through $\tilde{\tau}$s, which can be same-sign or opposite-sign and LSP (bino-like). The VBF jet and E_T^{miss} requirement reduces the background rate by a factor of $10^{-2} - 10^{-4}$. Mostly, background contribution in the signal region is taken from data in their respective control regions. Control regions are selected in such a way that they do not bias the $\mathrm{m_{jj}}$ shape. No significant excess of data over the SM prediction is observed in $\mathrm{m_{jj}}$ distributions and limits have been set combining the results from eight final states $\tau_h\tau_h$, $\mu\tau_h$, $\mu\mu$, eμ with both opposite-sign and same-sign requirement on leptons. Most of the sensitivity is provided by the same-sign final states $e\mu$ and $\mu\mu$ due to better background rejection.

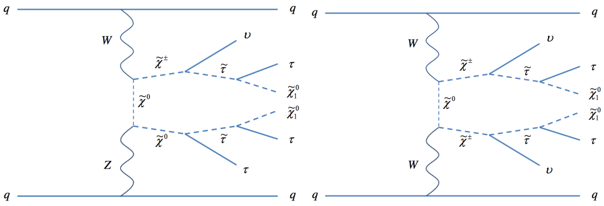

Figure 1: pair production of charginos/neutralinos through vector boson fusion processes.

The results are interpreted in the R-parity conserving MSSM models where chargino and neutralinos are mass degenerate. Four scenarios are considered depending on the mass of $\tilde{\tau}$ and LSP.

This analysis excludes $\chi_1^{\pm}/\chi_1^0$ with masses up to 300 GeV, at 95% CL for the scenarios where stau mass is set to be the average of mass of chargino and LSP i.e. $m_{\tilde{\tau}} = \frac{1}{2}m_{\tilde{\chi}_1^0} + \frac{1}{2}m_{\tilde{\chi}_1^{\pm}}$ and $m_{\tilde{\chi}_1^0} = 0$ GeV (large gap scenario) and masses up to 170 GeV for compressed mass scenarios having mass separation $\Delta m = m_{\tilde{\chi}_1^{\pm}} - m_{\tilde{\chi}_1^0} = 50$ GeV with $\tilde{\tau}$ mass closer to chargino mass i.e. $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\tau}) = 5$ GeV as shown in Figure 2.

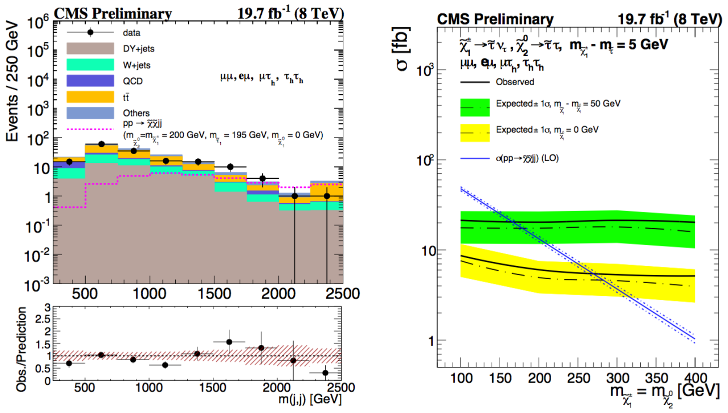

Figure 2: (a) m_{jj} distribution in the signal region obtained by combining all the final states (b) Combined 95% CL upper limits on the cross section for scenario having $\tilde{\tau}$ mass closer to $m_{\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0}$ i.e. $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\tau}) = 5$ GeV for large mass gap scenarios where $m_{\tilde{\chi}_1^0} = 0$ GeV (yellow band) and the compressed mass scenario having a mass difference between chargino and LSP to be 50 GeV (green band).

3. Searches for Exotic Higgs decaying to invisible particle with photon and forward jets

Some gauge-mediated SUSY-breaking (GMSB) models predict the decay of exotic Higgs boson produced through VBF processes to nearly massless gravitino $\tilde{G}$ and a next-to-lightest supersymmetric particle (NLSP) neutralino ($\tilde{\chi}^0$) having mass ($m_h/2 < m_{\tilde{\chi}^0} < m_h$) as shown in Figure 3(a) [8]. This neutralino further decays to a photon and $\tilde{G}$. Next-to-Minimal Supersymmetric Models (NMSSM) also predict such decays of Higgs boson to $\tilde{\chi}_2^0$ as NLSP, and $\tilde{\chi}_1^0$ as LSP. In VBF topologies, Higgs is more boosted in the transverse plane causing the decay products closer to each other. Angular relation between the final state particles i.e. between photon, missing transverse energy and VBF jets is used to reject the SM backgrounds. The major SM backgrounds having the same signatures are γ+jets/multijets the estimation of which is data-driven while other backgrounds (W/Z+γ, W/Z+jets and VV (where V can be W, Z) etc.) are taken from simulation and normalized to data in dedicated control regions.

Number of data events observed in the signal region is larger than the SM background prediction ($\sim 1.1\sigma$ excess) so observed limit on $(\sigma/\sigma_{SM}) \times BF(h \to NLSP + LSP)$ is higher than expected limit for all signal points as can be seen in Figure 3(b). These limits are the first direct limits on the decay of Higgs boson to beyond Standard Model particles.

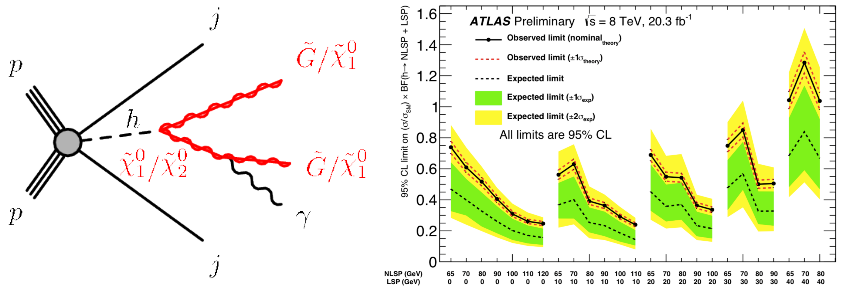

Figure 3: (left) production and decay of the Higgs boson into $\gamma + E_T^{miss}$ + jj final state (b) Observed and expected limits for various NLSP and LSP masses for $\gamma + E_T^{miss}$ + jj final state.

4. Searches through Higgs tagging in hh, hW, hZ topologies

These searches involve the decay of chargino and neutralinos in hh, hZ, hW states with "h" taken as the lightest neutral CP-even state of an extended Higgs sector of mass $\sim$ 125 GeV as shown in Figure 4(a). For hh, hZ, ZZ states, R-parity-conserving GMSB scenarios are considered having $\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_2^0$, $\tilde{\chi}_1^0$ nearly mass degenerate and gravitino ($\tilde{G}$) as LSP. These topologies are studied with the Higgs decaying to a pair of photons, bottom quark-antiquark, and to ZZ, WW, $\tau\tau$ yielding at least one electron or muon [9].

For h($\rightarrow b\bar{b}$) h($\rightarrow b\bar{b}$) search, the Higgs is reconstructed from the pair of b-jets. No isolated track or lepton was required. Missing transverse energy significance cut i.e. $\mathrm{S_{MET}} > 30$ GeV is used against events with "spurious $\mathrm{E_T^{miss}}$". In contrast, for h($\rightarrow \gamma\gamma$) h($\rightarrow b\bar{b}$) search, the other Higgs is reconstructed from a pair of photons. Backgrounds are estimated in the signal region by fitting the $m_{\gamma\gamma}$ distribution excluding the Higgs mass window. Data is found to be consistent with the SM prediction for these analyses within statistical uncertainties as shown in Figure 4(b).

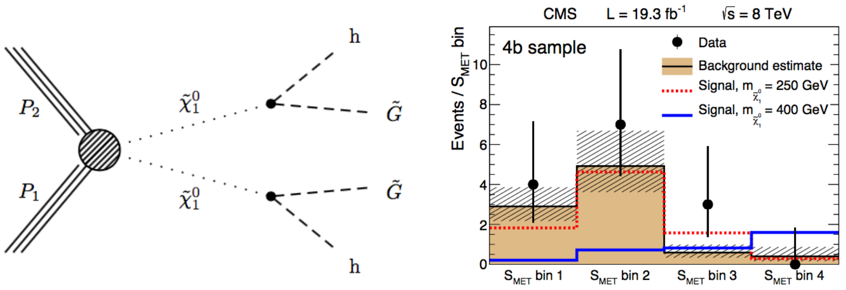

Figure 4: (a) hh production in GMSB SUSY models where $\tilde{\chi}_1^0$ is NLSP, $\tilde{G}$ is LSP and h is the Higgs boson of mass $\sim$ 125 GeV. (b) Observed number of events in comparison to the SM prediction in hh$\rightarrow b\bar{b}b\bar{b}$ final state as a function of $\mathrm{S_{MET}}$ bin.

For hh(WW/ZZ/$\tau\tau$), hZ, hW channels, one of the Higgs decays to a pair of photons and other to at least one detectable electron or muon. Two samples are created with one containing only isolated electron with two photons from Higgs and other with isolated muon only.

For the muon channel, data is found to be consistent but for the electron channel, an excess of 2.1 σ is observed as can be seen in Figure 5(a). Most of these events lie in the low E_T^{miss} region

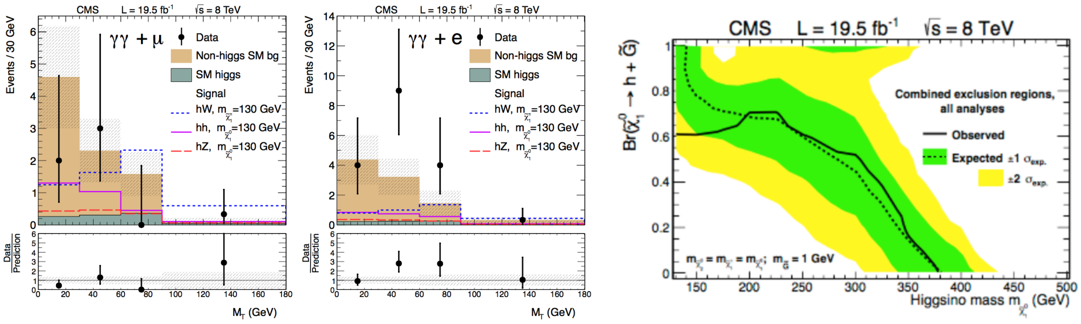

Figure 5: (a) Observed and expected event yield in $\gamma\gamma$+μ and $\gamma\gamma$+e final state as function of transverse mass M_T. (b) Combined observed and expected 95% CL exclusion region in a plane of Br($\tilde{\chi}_1^0 \rightarrow h+\tilde{G}$) vs Higgsino mass.

which are not signal-like. So this excess is considered to be consistent with the SM prediction within statistical uncertainty. Figure 5(b) shows the 95% CL exclusion region for the GMSB higgsino NLSP scenario in the two-dimensional plane of the $\tilde{\chi}_1^0 \rightarrow h^0 + \tilde{G}$ branching fraction versus higgsino mass $m_{\tilde{\chi}_1^0}$. The combination of results explained above exclude a significant fraction of the plane.

For hW topologies as seen in Figure 6(a), those SUSY scenarios are considered where higgsinos are much heavier than winos and binos , $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ being wino-like are nearly mass degenerate and $\tilde{\chi}_1^0$ is bino-like [10]. For the final states having a lepton (e or μ) and 2 b-jets, variables E_T^{miss}, contransverse mass $m_{CT} = \sqrt{(E_T^{b_1}+E_T^{b_2})^2 - |p_T^{b_1} - p_T^{b_2}|^2}$, and m_T^W are used to discriminate the signal events againts W+jets and $t\bar{t}$ backgrounds. The signal region is defined in 5 bins of invariant mass of 2 b-jets $m_{b\bar{b}}$ and no significant excess is observed in data over the SM expectations as shown in Figure 6(b).

For the states with the Higgs decaying to a pair of photons, angular correlation between p_T of W and the Higgs system is taken into consideration. Two signal regions are defined depending upon the transverse mass of W and γ system, i.e. $m_T^{W\gamma_i}$.

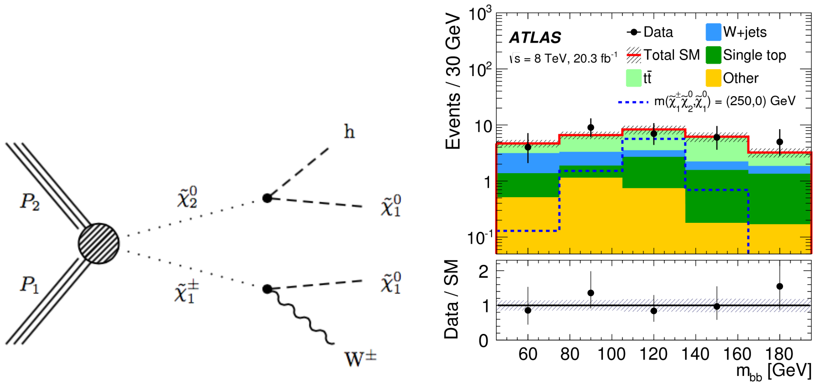

Figure 6: (a) hW production through chargino-neutralino ($\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$) pair with $\tilde{\chi}_1^0$ as LSP. (b) m_{bb} distribution in signal region for hW$\rightarrow b\bar{b} + l + E_T^{miss}$ analysis showing overall consistency between data and the SM prediction.

In contrast, for $\mathrm{h}(\rightarrow \mathrm{WW}/\mathrm{ZZ}/\tau\tau)\mathrm{W} \rightarrow \mathrm{l}^{\pm}\mathrm{l}^{\pm} + $jets analysis, 6 signal regions are defined depending upon the flavor of leptons (e/μ) and the number of jets in the final state. The event yield observed in data are consistent with the SM predictions within uncertainities in all signal regions as shown in Figure 7(a).

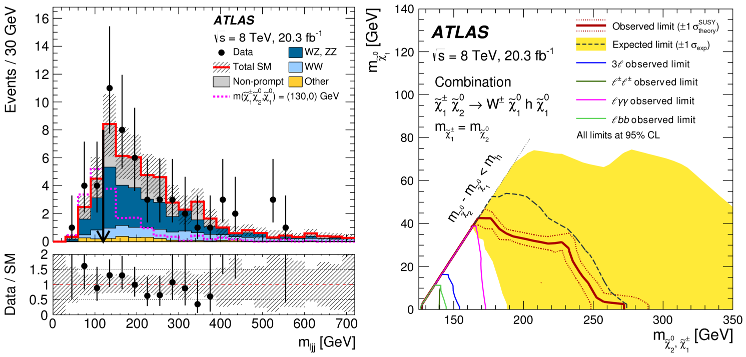

Figure 7: (a) m_{ljj} distribution for same-sign lepton + 2jet analysis without m_{ljj} cut (b) Combined observed and expected 95% CL exclusion region in the plane of $m_{\tilde{\chi}_1^0}$ vs $m_{\tilde{\chi}_2^0,\tilde{\chi}_1^{\pm}}$ for hW topologies.

The results are interpreted in Simplified SUSY Models. Figure 7(b) shows the observed and expected 95% CL exclusion regions in the mass plane of $m_{\tilde{\chi}_1^0}$ vs $m_{\tilde{\chi}_2^0,\tilde{\chi}_1^{\pm}}$ combining the analyses above with the ATLAS three-lepton search [11] to improve the sensitivity. The combination of these independent channels excludes $\tilde{\chi}_1^{\pm}/\ \tilde{\chi}_1^0$ up to masses of 250 GeV for massless LSP i.e. ($m_{\tilde{\chi}_1^0}$ = 0 GeV).

5. Summary

ATLAS and CMS employed various new and specialized analysis techniques covering more of the SUSY parameter space i.e. searches via Higgs and VBF jets tagging *etc*. No evidence of new physics is found yet but stringent limits are put on the production of these sparticles.

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