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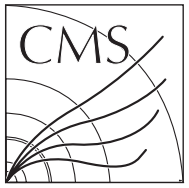

The Compact Muon Solenoid Experiment

Conference Report

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Progress with electroweak-ino searches with 13 TeV data

Matthieu Pierre Marionneau on behalf of the ATLAS and CMS collaborations.

Abstract

Recent results from searches for production of supersymmetric partner of electroweak bosons are presented, using 13 to 36 fb^{-1} 13 TeV data sets collected by the ATLAS and CMS experiments in 2016. The various results are interpreted in simplified SUSY models.No signal of physics beyond the Standard Model has been observed so far.

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Progress with electroweakino searches with 13 TeV data

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Recent results from searches for production of supersymmetric partner of electroweak bosons are presented, using 13 to 36 fb^{-1} 13 TeV data sets collected by the ATLAS and CMS experiments in 2016. The various results are interpreted in simplified SUSY models. No signal of physics beyond the Standard Model has been observed so far.

1 Introduction

The Supersymmetry (SUSY) is a powerful and favored extention of the Standard Model (SM) able to solve several unanswered questions left open by the SM, with the ability to explain the naturalness problem, or the ability to provide a potential candidate for the nature of the dark matter.

In this paper are summarized a selection of electroweakino searches for supersymmetric signatures performed by the ATLAS [1] and CMS [2] collaborations, with proton-proton collision data recorded in 2016 at $\sqrt{s} = 13$ TeV. The production of electroweak boson supersymmetric partners, the "electroweakinos", $\tilde{\chi}_i^{\pm}$ and $\tilde{\chi}_i^0$, $i = 1, 2, 3, 4$, is probed in the frame of simplified SUSY production models [3]. Fig.1 illustrates a subset of the production modes probed. Other searches for SUSY are discussed in other proceedings of the Moriond EW 2017 conference.

In Section 2 are presented the results of searches for $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ or $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production modes with slepton $\tilde{\ell}$, $\tilde{\nu}$, mediated decay, where $\tilde{\chi}_i^{\pm}$, $\tilde{\chi}_i^{\mp}$ denote the charginos and $\tilde{\chi}_i^0$ the neutralinos. In Section 3, the production of $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ pair with a direct decay into a SM electroweak boson Z,W or H and a $\tilde{\chi}_1^0$ are discussed. Searches for a specific Gauge Mediated Supersymmetry Breaking (GMSB) model are presented in Section 4, and finally the probe of $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ production mode with R-parity violating decay is presented in Section 5.

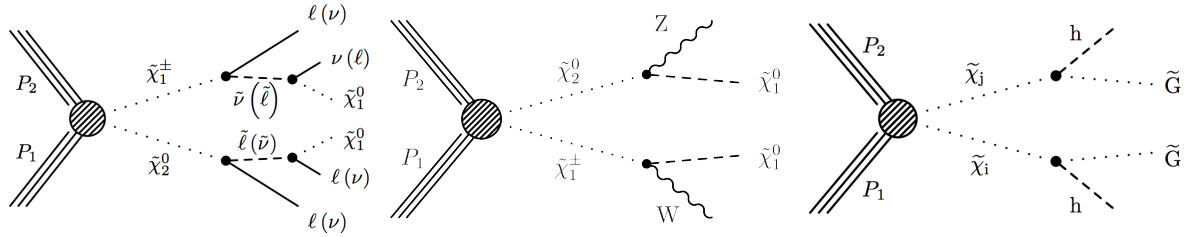


Figure 1 – Non exhaustive list of diagrams illustrating the supersymmetric signatures searches covered in this paper.

2 $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ and $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^{0}$ production with $\tilde{\ell}/\tilde{\nu}$ mediated decays

The electroweakino pair production with slepton mediated decays has been probed in several searches performed by the ATLAS and CMS collaboration.

Two searches, one performed by the ATLAS collaboration [4] with 16 fb^{-1} of 13 TeV data, and one performed by the CMS collaboration [5] with 36 fb^{-1} of 13 TeV data target the general case, with no flavor assumption on the SUSY partner mediating the electroweakino decay. Those searches target final states with two leptons of opposite sign [4] or of same-sign [5], as well as final states with three leptons. Both analyses classify the selected events into so-called signal regions, 5 for [4], and 158 for [5], based on different kinematic variables, such like the invariant mass of a dilepton system, the number of hadronic jets or the missing transverse energy E_T^{miss} or the "s-transverse" mass m_{T2}, useful variable to identify events containing a top-antitop quark pair, and which is defined as

$$m_{T2}^2 = \min_{q_T}[\max(m_T^2(\mathbf{p_T^{\ell 1}}, \mathbf{q_T}), m_T^2(\mathbf{p_T^{\ell 2}}, \vec{E}_T^{miss} - \mathbf{q_T}))] \quad (1)$$

where $\mathbf{p_T^{\ell i}}$, with $i = 1, 2$ are the transverse momentum of the two leading leptons, where $m_T = \sqrt{2p_T^{\ell}\mathrm{E}_T^{miss}(1 - cos(\Delta\phi(\ell, \mathrm{E}_T^{miss})))}$, and where $\mathbf{q_T}$ is the optimized fraction of the E_T^{miss} associated to one of the two W boson produced by the top quarks decays. The dominant backgrounds are controlled with data, by measuring the associated yields in control regions and propagating the estimation to the signal regions using transfer factors, measured independently in collision data. Major uncertainties are related to the theoretical knowledge of rare SM processes (diboson production, top antitop pair production in association to a W or Z boson) and to the knowledge of the hadronic jet energy scale. The observations are in good agreement with the expectations (Fig.2) and limits are set on the SUSY particles mass plane (Fig.3a and Fig.3b. In [5], several models with different slepton masses are considered. Electroweakino $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^{0}$ masses up to 1.15 TeV are excluded, for $\tilde{\chi}_1^{0}$ masses up to 700 GeV.

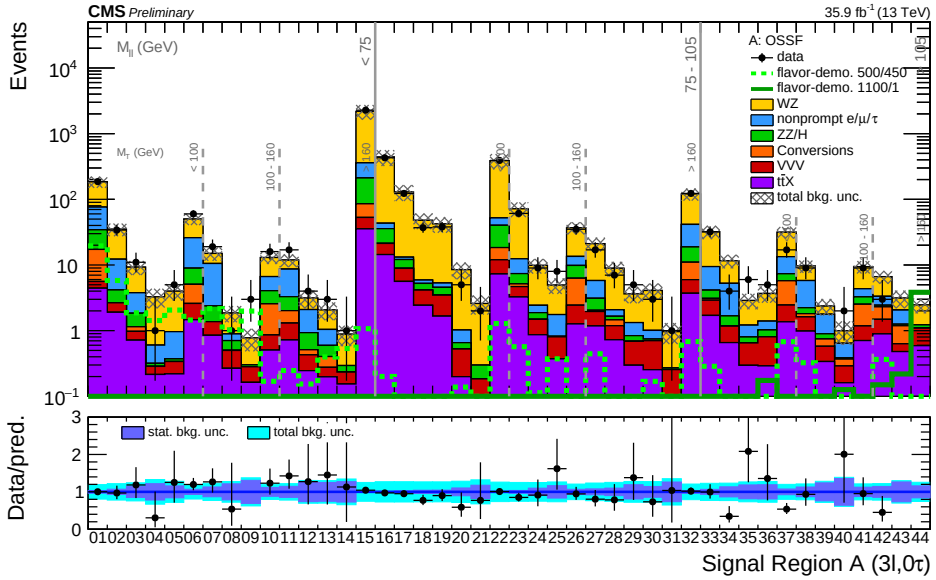


Figure 2 – Subset of the signal regions defined in [5]. Collision data are represented by black points and SM predictions in color.

The search presented in [6] focuses on $\tilde{\tau}$ mediated decay by selecting events with a pair of two hadronic taus with opposite sign in the final state, and looking for an excess of event with large E_T^{miss} or with large m_{T2} values. A data set of 15 fb^{-1} of 13 TeV data has been

used. The dominant backgrounds originating from QCD processes and Drell-Yan processes are estimated or controlled from dedicated regions, defined with relaxed E_T^{miss} and m_{T2} selection and relaxed hadronic tau identification. No evidence of deviation with respect to the Standard Model expectation has been found, and exclusion limits were set in the $(\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0,\tilde{\chi}_0^0)$ mass plane (Fig. 3c). Results obtained in [5] also contribute to the search of $\tilde{\tau}$ mediated decays, with a better exclusion of the compressed part of the mass spectrum where the $\tilde{\chi}_1^0$ mass is close from the $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ masses, but with a lower sensitivity at low $\tilde{\chi}_0^0$ masses.

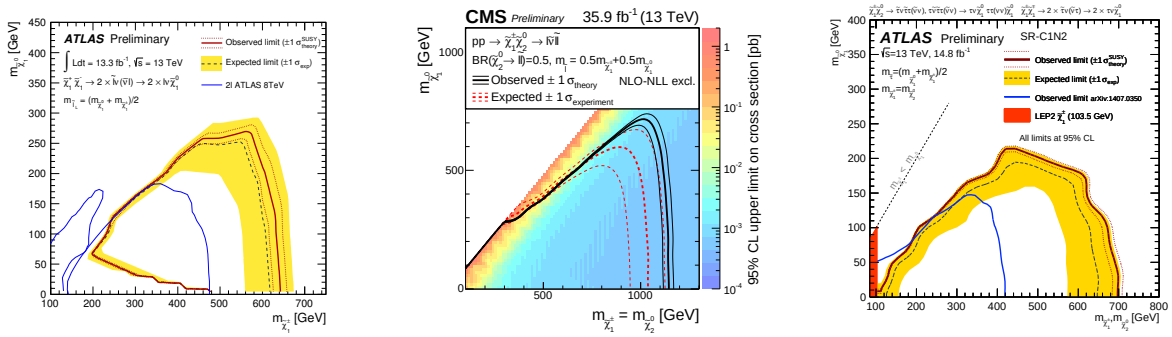


Figure 3 – Most stringent limits on EWK SUSY partner masses for $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ from [4] (a) and $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ from [5] (b) production mode for general slepton mediated decays, and for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production mode with $\tilde{\tau}$ mediated decays from [6] (c).

3 $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production with direct decay in SM electroweak boson

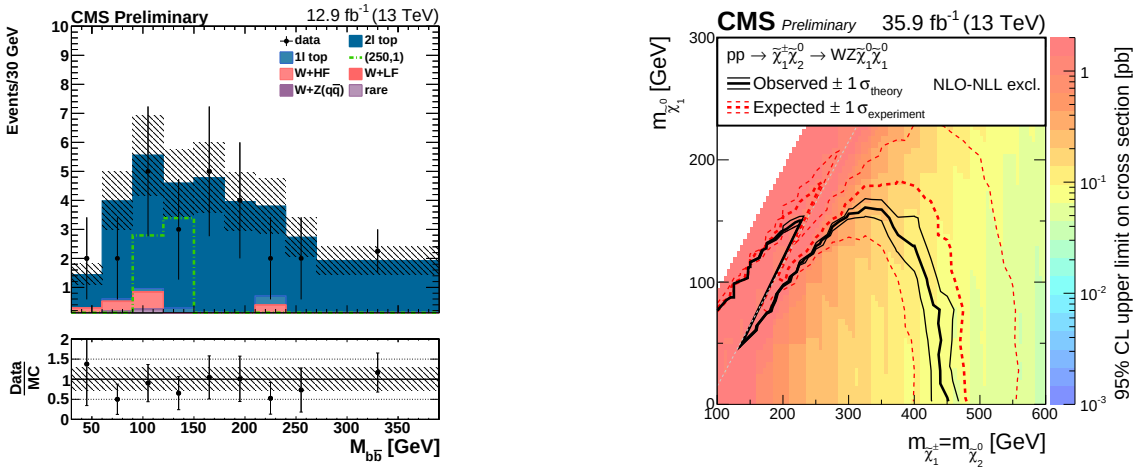
The processes $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow (\tilde{\chi}_1^0 W^{\pm})(\tilde{\chi}_1^0 V)$, with $V = Z$, have been probed by the analysis presented in [5]. Another analysis presented in [7] probed the model where $V = H$, requesting that the produced Higgs boson decays into a b quark pair. Only events containing a well identified and isolated lepton, as well as two jets tagged as originating from b quark decays are selected. A minimal requirement of $E_T^{miss} > 100$ GeV and a minimal 150 GeV selection on both the transverse mass of the lepton-E_T^{miss} system and on the con-transverse mass $m_{CT} = \sqrt{2p_T^{b1}p_T^{b2}(1 + cos\Delta\phi_{bb})}$ are also applied. The final selection requires the invariant mass of the b-tagged jet pair to be consistent with an on-shell Higgs boson decay. As can be seen on Fig.4a, no evidence of any excess above the SM prediction is observed and exclusion limits are set. The sensitivy of the analysis appeared to be limited with 13 fb^{-1}, showing no exclusion of electroweakino masses. With 36 fb^{-1} of 13 TeV pp collision data, a similar search should be able to probe mid-range electroweakino masses, from $\sim$ 200 to 500 GeV. The search performed in [5] is complementary to [7] with an exclusion of low electroweakino masses, up to 200 GeV for low $\tilde{\chi}_1^0$ masses.

The interpretation of [5] results in a $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow (\tilde{\chi}_1^0 W^{\pm})(\tilde{\chi}_1^0 Z)$ context leads to an exclusion of SUSY masses illustrated on Fig.4b.

4 Gauge Mediated Supersymmetry Breaking SUSY model

A specific SUSY model with Gauge Mediated Supersymmetry Breaking has been also probed by the CMS collaboration [8,9] with 36 fb^{-1} of 13 TeV data. In this model, the super-partner of the Higgs boson, the higgsino, is considered as the next-to Lightest Supersymmetric Particle (LSP) and the Goldstino $\tilde{G}$ is considered as the LSP.

The analysis presented in [8] focuses on the production mode $\tilde{\chi}_i\tilde{\chi}_j \rightarrow HH\tilde{G}\tilde{G}$ with each of the two Higgs boson decaying into two b quarks, while in [9] the production mode $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^0 \rightarrow \gamma W^{\pm}\tilde{G}\tilde{G}$ is probed.



(a) (b)

Figure 4 – Left: invariant mass of the $H \to bb$ candidate for the $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to W^{\pm}H\tilde{\chi}_1^0\tilde{\chi}_1^0$ search with a Higgs boson decay into b quarks [5]. Right: Exclusion limits in the electroweakino mass plane for the $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to W^{\pm}Z\tilde{\chi}_1^0\tilde{\chi}_1^0$ production mode [5].

The former uses events with at least four jets, ranked accordingly to their likelihood to originate from a b quark. Events are selected online using triggers requesting a large amount of E_T^{miss}. Advanced kinematic variables are used, such like the maximal angle between two b-tagged jets, the difference of reconstructed Higgs masses, $\Delta m_H < 40$ GeV, or the median of the two reconstructed Higgs masses $\langle m \rangle$ which has to be compatible with an on-shell Higgs boson decay (Fig. 5a). No significant excess above the SM expectation has been seen, and exclusion limits are set on the Higgsino mass (Fig.6), excluding a range between 225 and 770 GeV.

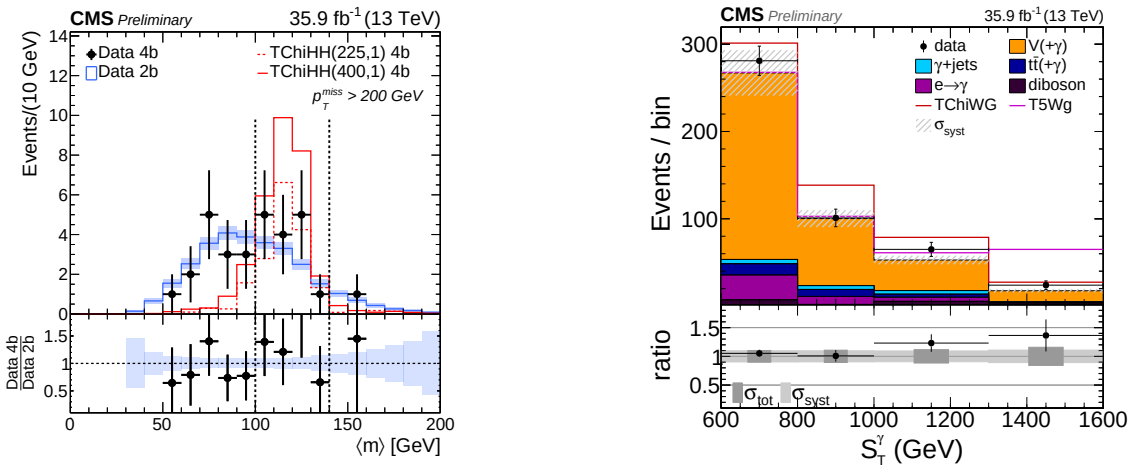
The search introduced in [9] looks for an excess of events containing a high transverse momentum photon as well as a fair amount of missing transverse energy. The minimal photon momentum is 180 GeV. The observable used to quantify the presence of potential signal is defined as

$$S_T^{\gamma} = \mathrm{E}_T^{miss} + \sum_{\gamma} p_T. \tag{2}$$

The SM background is highly dominated by the associated production of an electroweak boson recoiling against a photon with large p_T, and which decays into either a neutrino pair or a neutrino and a charged lepton. The sub-dominant background originates from γ + jets production processes. If the background shapes are taken from the Monte Carlo simulation, the normalization is determined in a control region by a simultaneous fit of the collision data, using Monte Carlo templates of the variable $\Delta\phi(\mathrm{E}_T^{miss}, \text{nearest jet}/\gamma)$. Again, data are observed to be in good agreement with the SM expectation and limits are set on Higgsino masses, with an exclusion of the Higgsino mass up to 750 GeV (Fig. 5b).

5 $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ production mode with RPV decay

Finally, a search [10] performed by the ATLAS collaboration targets $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp} \to (W\tilde{\chi}_1^0)(W\tilde{\chi}_1^0)$ production with R-parity violating decay into charged leptons ℓ and neutrinos: $\tilde{\chi}_1^0 \to \ell_k\ell_{i/j}\nu_{j/i}$, with $i, j, k \in e, \mu$. For such models, a large number of leptons is expected in the final state. Events with at least four leptons are selected. A minimal p_T requirement of 5 (7) GeV is applied on muons (electrons). Those requirements correspond to the p_T selection used at the trigger level. Low masses resonances and Z resonances are vetoed. The main discriminant variable used



(a) (b)

Figure 5 – (a) reconstructed median Higgs mass distribution in events with 4 b-tagged jets [8]. (b) S_T^{γ} distribution in $\gamma + \ell + \mathrm{E}_T^{miss}$ events [9].

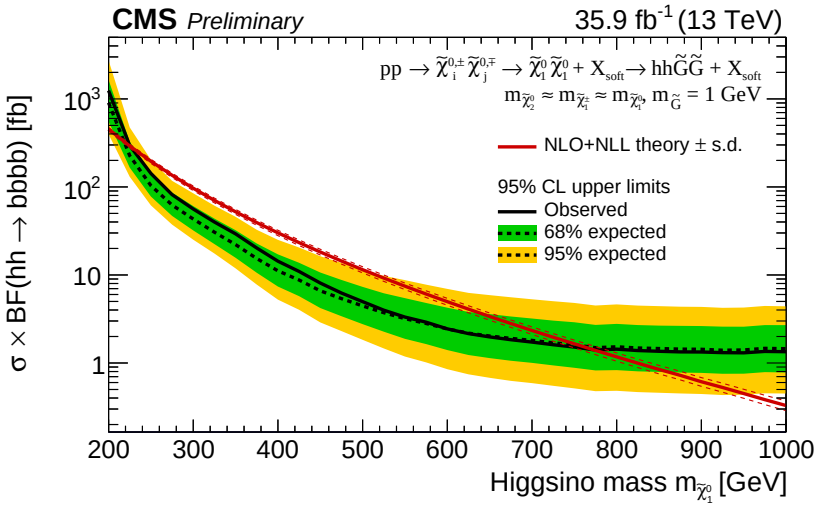


Figure 6 – Exclusion limit on the Higgsino pair production cross section as function of the Higgsino mass, obtained with multiple b quark jets final state [8].

is the effective mass m_{eff}, defined as

$$m_{eff} = \mathrm{E}_T^{miss} + \sum_{leptons} p_T + \sum_{jets} p_T \tag{3}$$

where jets should satisfy $p_T > 40$ GeV. An excess at large m_{eff} is expected in the presence of SUSY signal. The observed data are in agreement with the SM prediction (Fig.7), and exclusion limits are set in the ($\tilde{\chi}_1^{\pm}$,$\tilde{\chi}_1^0$) mass plane. Chargino $\tilde{\chi}_1^{\pm}$ masses below 1.14 TeV are excluded.

6 Conclusion

Various simplified SUSY models have been probed in various final states with data collected by the ATLAS and CMS experiments at $\sqrt{s} = 13$ TeV. No evidence of physics beyond the Standard Model has been observed so far. Exclusion limits have been set on SUSY particles masses. Further searches for new physics signatures are still ongoing, and will increase our knowledge of the possibility of the existence of SUSY-like particles.

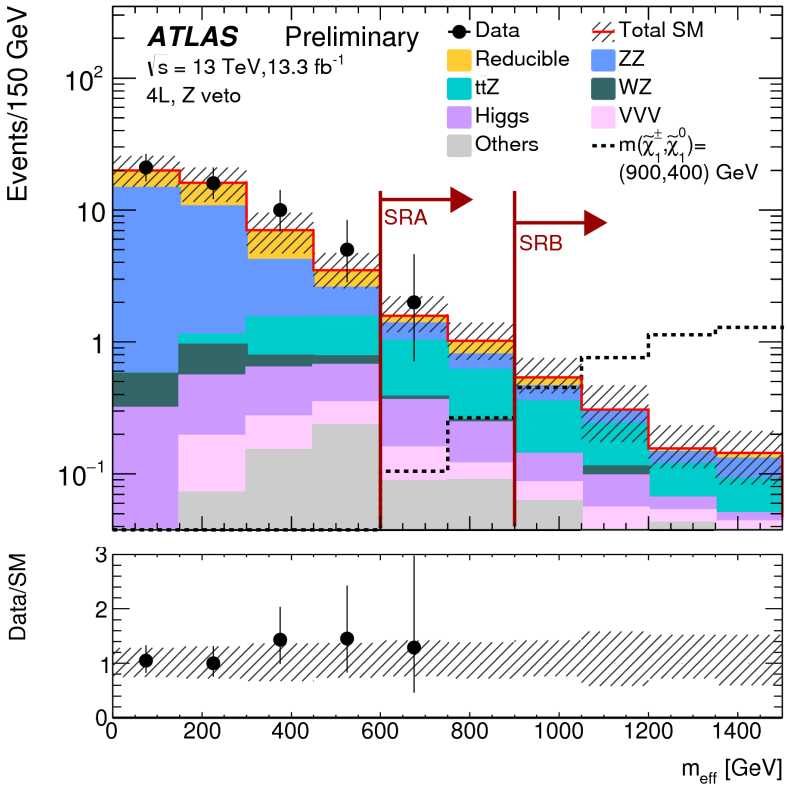


Figure 7 – Effective mass m_{eff} distribution in multilepton events in the context of RPV SUSY search [10].

A complete list of results published by the ATLAS and CMS experiments can be found online [11,12].

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