LEPTONIC SUSY SEARCHES AT THE LHC

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This paper summarizes recent results from the LHC on Supersymmetry searches using leptonic signatures. The public results were produced using data collected within 2011 and correspond to $4.7fb^{-1}$ and $2.05fb^{-1}$ of integrated luminosity from the CMS and ATLAS collaborations respectively. The searches cover a wide range of leptonic analyses using single-lepton, double-lepton final states, the latter split in Opposite- and Same-sign di-lepton final states, multi-lepton ones, as well as their extensions by requiring b-tagged jets in some cases. Overall, no New Physics excess has been observed with respect to the Standard Model expectations, whereas Exclusion limits have been produced to set constraints to a number of such physics models.

1 Introduction

The CMS [1] and ATLAS [2] collaborations have developed a robust set of analyses using the latest 2011 LHC data, in the search of New Physics and particularly the discovery of Supersymmetry (SUSY). In this proceedings, we give an overview of the SUSY analyses with leptons in the final state, accompanied by jets and Missing Transverse Energy (MET), and present their public results which were produced using data collected in 2011 and correspond to $4.7fb^{-1}$ and $2.05fb^{-1}$ of integrated luminosity, for CMS and ATLAS respectively.

Both CMS and ATLAS analyses have been evolved following standard cut-and-count techniques, whereas many of them have been extended in a non-standard way, for example using Artificial Neural Networks (ANN) or adding b-tagging information to probe more exclusive signatures. With respect to the Summer 2011, the present Analyses have acquired a factor 2 to 3 increase in luminosity, whereas in addition new methodologies that were not pursued before appear in a complementry way to extend the coverage of the SUSY phase space.

2 Single-lepton SUSY searches

The one-lepton + MET + jets signature is prominent in models based on SUSY. Such searches are complicated by the presence of Standard Model (SM) backgrounds that can share many of the features of SUSY events. These backgrounds arise mainly from the production of $t\bar{t}$ and W+jets, with smaller contributions from Z+jets, single-top production and QCD multijet events. To determine the contribution of these backgrounds, CMS and ATLAS use methods that are primarily based on control samples in the data, sometimes in conjunction with certain reliable information from simulated event samples.

The CMS analysis comprises two methods have been used to probe the event data sample [3]. One of them, the Lepton Spectrum (LS) method, uses the observed lepton transverse momentum (p_T) spectrum and other control samples to predict the MET spectrum associated with the SM backgrounds (figure 1), which applies to SUSY models in which the MET distribution is decoupled from the lepton

p_T spectrum. Twelve signal regions are considered, specified by three thresholds on H_T and four bins of MET. In the absence of any significant excess of observed events in the data, the results of the above analyses have been interpreted in the framework of the Constrained Minimal Supersymmetric SM (cMSSM), reporting exclusion regions as a function of $m_{1/2}$ and m_0, for $\tan\beta = 10$ (see figure 2). These results exclude gluino masses below ≈ 1.1 TeV for m_0 below ≈ 750 GeV.

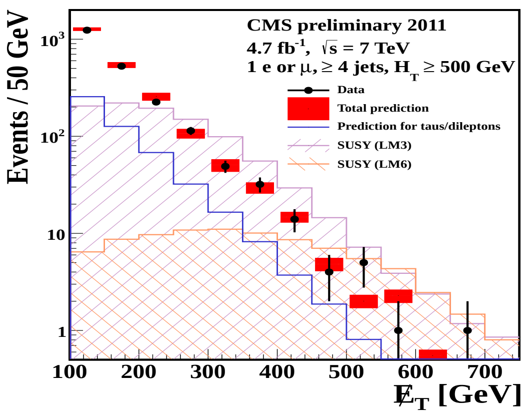

Figure 1: Observed MET distributions in data compared with predicted distributions (red bars) in the combined electron and muon channels, for $H_T > 500$ GeV.

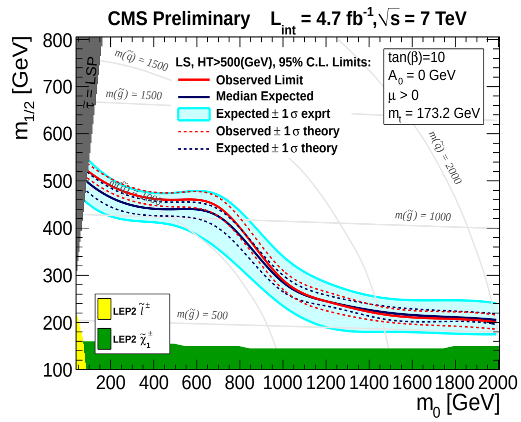

Figure 2: The 95% CL exclusion contours obtained from the $H_T > 500$ GeV search region are shown in the cMSSM $m_{1/2}$ vs m_0 plane.

The corresponding ATLAS analysis used 1.04 fb^{-1} of data of the first half of 2011. The search [4] is carried out in four distinct signal regions with either three or four jets and variations on the (missing) transverse momentum and effective mass cuts, resulting in optimized limits for various supersymmetry models.

3 Di-lepton SUSY searches in the opposite-sign and same-sign channels

We then proceed to the searches in final states with opposite-sign (OS) isolated lepton pairs accompanied by hadronic jets and missing transverse energy.

Because beyond the SM (BSM) physics is expected to have large hadronic activity and MET, the CMS analysis [5] defines two signal regions that reject all but $\approx 0.1\%$ of the dilepton $t\bar{t}$ events, by adding requirements of large MET and H_T. We perform counting experiments in these signal regions, and compare the observed yields with the predictions from two independent background estimation techniques based on data control samples, as well as with SM and BSM MC expectations. A complementary analysis is the search for a di-lepton edge which is sensitive to new physics models which do not have very large MET and H_T. Such analyses probe more exclusive signatures arising for example from SUSY events with the χ_2^o decaying to $\tilde{\ell}\ell \rightarrow \chi_1^o \ell^+ \ell^-$. The OS di-lepton inclusive analysis has also been extended to use ANN [6], which allowed complementarity in the SUSY phase space to probe lower MET/H_T regions[a].

An additional CMS search looks for evidence of BSM physics in final states containing a Z boson that decays to a pair of oppositely-charged isolated electrons or muons [7]. This strategy is favored in the search for SUSY models with the production of a Z boson in the decay $\chi_2^o \rightarrow \chi_1^o Z$. The dominant background consists of SM Z production accompanied by jets from initial-state radiation (Z + jets). Two complementary strategies are used to suppress the dominant Z + jets background, -arising primarily when jet energies are mismeasured-, and to estimate the remaining background from data control samples: the jet-Z balance method (JZB) and the MET template method.

[a]Public results correspond to an integrated luminosity of 2.2 fb^{-1}.

Overall, the above analyses find no evidence for anomalous yields beyond the SM expectations and place upper limits on the non-SM contributions to the yields in their signal regions. The results have been interpreted in the context of the CMSSM and simplified model spectra.

We turn now to the SUSY searches with same-sign (SS) isolated lepton pairs (including taus decaying hadronically), missing transverse energy, and hadronic jets. Such events in hadron collisions are very rare in the SM but appear very naturally in many new physics scenarios. A baseline selection region has been defined for each of the following three dilepton categories: inclusive di-leptons, high-p_T leptons, and tau di-leptons, each binned in the H_T-MET plane. Backgrounds in all of these searches are dominated by one or two jets mimicking the lepton signature ("fake" lepton background), which are estimated from data using multijet control samples with two SS leptons. Overall, no evidence for an excess over the background prediction has been observed. A search for SUSY with two same-sign leptons, jets and missing transverse momentum has also been performed using 2.05 fb^1 of ATLAS data[8]. With no events observed in the selected signal regions, limits have been derived in the context of simplified models where top quarks are produced in gluino decays and mSUGRA/CMSSM scenarios (see figure 3). In all these signal models, gluino masses below 550 GeV are excluded within the parameter space considered and gluino masses up to 700-750 GeV can be excluded depending on the model parameters.

While in general the hadronic jets in these anomalous processes can originate from light flavor, there is a range of well-established models predicting the presence of two to four b-quark jets in such events. These appear naturally in signatures of SUSY where bottom- and top- quark superpartners are lighter than other squarks, enhancing the fraction of strongly produced SUSY events with top and bottom quarks in the final states. A counting signature-based experiment[9] is performed by comparing the event yield with the expected signal and backgrounds. We observe no significant deviations from the SM expectations. We have used these results to set limits on the parameter space of two models of same-sign top pair production, two models of gluino decay into virtual or real stop quarks, a model of sbottom pair production, and a model of sbottom production from gluino decay (see figure 4).

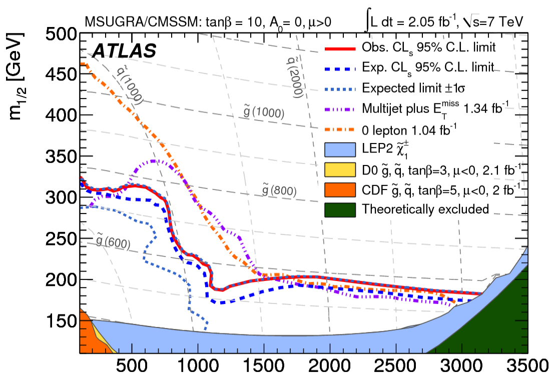

Figure 3: Expected and observed 95% CL exclusion limits in the MSUGRA/CMSSM (m_0, $m_{1/2}$) plane for $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$.

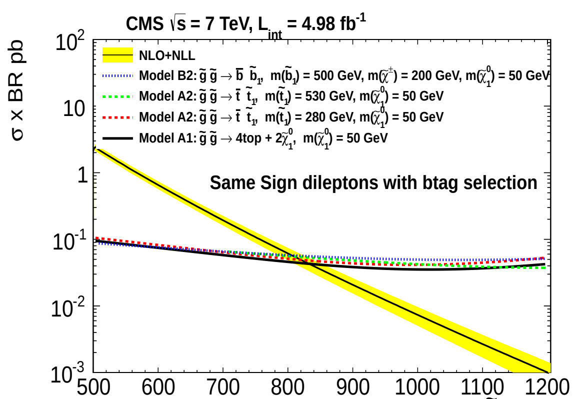

Figure 4: Gluino pair-production cross-section as a function of gluino mass compared with limits on the cross-section from various models.

4 Multi-lepton searches and the EWK interpretation

This following search focuses on the associated production and leptonic decays of charginos and neutrali- nos. The direct production of light charginos and neutralinos, at the LHC, can be abundant which in turn can give rise to a low-background signature with three SM leptons and sizable missing transverse momentum. The analysis has been based on $2.06 fb^1$ of data collected with the ATLAS detector[10]. No significant excess of events has been found in data. The null result is interpreted in the pMSSM and in simplified models. For the simplified models, degenerate lightest chargino and next-to-lightest neutralino masses are excluded up to 300 GeV for mass differences to the lightest neutralino up to 250 GeV.

Multilepton final states can also be produced in R-parity violating (RPV) scenarios. A relevant search looks for supersymmetric particles in final states with four or more leptons (electrons or muons) and missing transverse momentum. The ATLAS analysis [11] uses a sample corresponding to an integrated luminosity of 2.06 fb^1 of proton-proton data. After applying a Z boson veto for leptons pairs with the same flavour and opposite charge, no events are observed for 0.7 ± 0.8 events expected. Within the selection acceptance, we determine 95% C.L. exclusion limits in the cMSSM, as shown in figure 5.

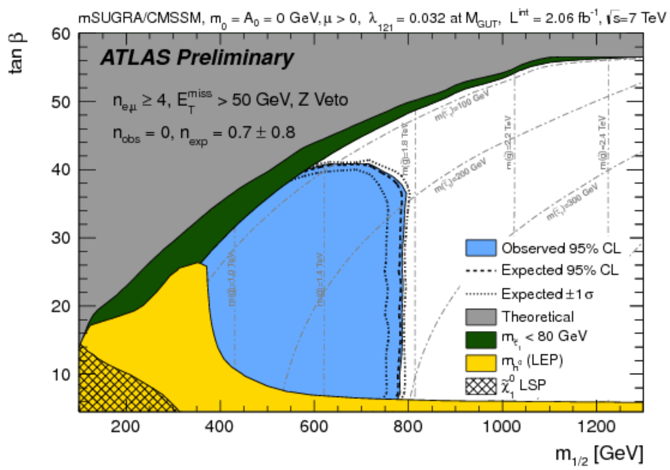

Figure 5: Expected and observed 95% CL exclusion limits in the mSUGRA/CMSSM ($m_{1/2}$, $\tan\beta$) plane for $m_0 = A_0 = 0$ and $\mu > 0$, as derived with the ATLAS multi-lepton analysis at $2.06 fb^{-1}$.

5 Tau channels

This note reports on the search for events with large MET, jets, and at least two hadronically decaying τ leptons [12], [13]. The dominant backgrounds are from top-pair plus single top events and W events, in which one real τ is correctly reconstructed and the other τ candidates are mis-reconstructed from hadronic activity in the final state. This background contribution is determined in a control region defined by inverting the effective mass (Meff) cut. No excess above the SM background expectation is observed and a 95 % CL visible cross section upper limit for new phenomena at 2.9 fb^{-1} is set. For a minimal model of gauge-mediated supersymmetry breaking (GMSB), limits on the production cross section are set. A 95 % CL lower limit of 32 TeV is set on the GMSB breaking scale Λ independent of $\tan\beta$. Finally, ATLAS results from a search in final states with one or more τ leptons, are interpreted in the context of GMSB models with Mmess = 250 TeV, $N_5 = 3$, $\mu > 0$, and $C_{grav} = 1$, excluding the production of supersymmetric particles up to $\Lambda = 40$ TeV for $\tan\beta > 15$ at 95% C.L.

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