

REVIEW ARTICLE

SUSY searches at ATLAS

Pascal Pralavorio[†], on behalf of the ATLAS Collaboration

CPPM, University Aix-Marseille and CNRS/IN2P3, Marseille, France

E-mail: [†]pralavor@cppm.in2p3.fr

Received December 6, 2012; accepted January 10, 2013

Despite the absence of experimental evidence, weak scale supersymmetry remains one of the best motivated and studied Standard Model extensions. The ATLAS experiment at the LHC searches for signs of supersymmetry in a large variety of signatures involving events with abnormal production of missing transverse momentum, jets, leptons, third generation fermions, gauge bosons or massive long-lived particles. A summary of the most recent results obtained in these searches is presented.

Keywords supersymmetry (SUSY), ATLAS, LHC

PACS numbers 14.80.Pq, 14.80.Nb, 14.80.Ly, 12.60.Jv

Contents

1	Introduction	248
2	Inclusive SUSY searches	248
2.1	Lepton-veto analyses	249
2.2	Leptonic/Photonic analyses	249
3	Natural SUSY searches	251
3.1	Third generation squarks	251
3.2	Weak gauginos and sleptons	252
4	Long-lived particles and R-parity violation	253
5	Beyond the MSSM	254
6	Conclusions	254
	References and notes	255

predicted to be close to the electroweak scale, i.e., within experimental reach. In this framework, the discovery of a new Higgs-like boson in early July [2, 3], may well be one of the neutral Higgs of the MSSM. The ATLAS experiment [4] have therefore developed a rich and coherent SUSY search strategy presented in this review (note that the MSSM Higgs searches are presented elsewhere [5]), all documented in Ref. [6]. The analyses are generally based on 5 fb^{-1} of $\sqrt{s}=7\text{ TeV}$ data and, for some, 6 fb^{-1} of $\sqrt{s}=8\text{ TeV}$ data. All limits reported below are given at 95% C.L.

2 Inclusive SUSY searches

1 Introduction

Supersymmetry (SUSY) [1] is one of the best motivated theories for physics beyond the Standard Model (SM) since it provides a solution to most of its shortcomings. The minimal extension to the SM that realizes $N=1$ supersymmetry (MSSM) predicts new particles, partners of the fundamental SM particles. These new particles, called sparticles, have the same quantum numbers except for the spin (half a unit of spin difference) and R-Parity (negative/positive for SUSY/SM particles). The SM Higgs sector is also enlarged and composed of three neutral and two charged scalar Higgs.

The MSSM is of particular interest for the LHC experiments since the masses of most of these new particles are

If squark and gluino masses are around the TeV scale or lower, the SUSY production at the LHC will be dominated by squark–squark, gluino–gluino and squark–gluino production. If R-parity is conserved, the lightest SUSY particle (LSP) is stable. In most models, the LSP is the massive lightest neutralino ($\tilde{\chi}_1^0$) or the approximately massless gravitino ($\tilde{G}$), reflecting the two possible SUSY breaking mechanisms: gravity or gauge mediation. Squarks and gluinos will decay, typically promptly, in long decay chains containing mainly quark and gluon jets, and finishing with the production of the LSP. SUSY events will therefore be characterized by multiple energetic jets as well as missing energy originated by the undetected LSPs. Depending on the sparticle spectrum between the squarks/gluinos and the LSP, charged lep-

ton(s) and/or photons can also appear in the cascade.

At the LHC, the sensitivity to squarks and gluinos depends on the ability to reduce the SM backgrounds by several orders of magnitude. The main backgrounds are multijet events with real or mis-measured missing energy, top quark pairs and weak gauge bosons produced in association with jets. Inclusive analyses are based on very powerful discriminating variables, which exploit the main characteristics of the SUSY decay chain: the scalar sum of the transverse energy of jets, H_T and the vectorial sum of calorimeter jet and muon transverse energy, E_T^{miss} , as well as various combinations like the effective mass variable, $m_{\text{eff}} = H_T + E_T^{miss}$, or the missing transverse momentum significance, $E_T^{miss}/\sqrt{H_T}$. After cuts, the estimation of the remaining background, even if tiny, generally drives the sensitivity. In ATLAS, it is estimated in two ways: for top and W/Z background where real E_T^{miss} is present, enriched background control regions are defined. Discriminating variable shape distributions are then checked to be in good agreement between data and Monte-Carlo (MC). This enables the MC to be extrapolated from these control regions to the signal region. As multijet events are affected by mis-measured E_T^{miss} , fully data-driven methods based on the jet response function [7] or the matrix method [8] are used instead. To increase the search sensitivity, the multijets+ E_T^{miss} searches are divided into lepton veto and leptonic/photonic analyses.

2.1 Lepton-veto analyses

In lepton veto analyses, a large spectrum of jet multiplicity is explored from 2 to 6 jets with m_{eff} as the discriminating variable. These analyses investigate squark-squark (2 jets or more), squark-gluino (3 jets or more) or gluino-gluino (4 jets or more) production. Five “tight” signal regions target the high mass gluinos/squarks with a large mass difference with the LSP [$\Delta M(\tilde{g}, \tilde{q} - \tilde{\chi}_1^0) > O(500)$ GeV]. Tight cuts are applied on m_{eff} . Six “medium/loose” signal regions cover more compressed spectra, as defined in Ref. [9], by relaxing the cuts on m_{eff} .

As illustrated in Fig. 1, none of the searches have observed a significant excess above the SM prediction. Therefore limits on new physics have been set. Two examples are provided in Fig. 2 and Fig. 3. In the first case, a constrained MSSM model where the SUSY breaking is mediated by gravity (MSUGRA/CMSSM), is chosen. Alternatively, a simplified MSSM model with only gluinos, first/second generation squarks and a massless LSP ($\tilde{\chi}_1^0$) is considered. Squarks and gluinos are forced to decay with 100% branching ratio via $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ and $\tilde{q} \rightarrow q\tilde{\chi}_1^0$. For both models, mass limits are close to or above 1 TeV for first/second generation squarks and gluinos. In the

case of equal squark and gluino masses, a mass limit of 1.5 TeV can be reached with $\sqrt{s} = 8$ TeV data [10]. In the 7 TeV analysis, loose and medium signal regions are sensitive to compressed SUSY spectra, for example $\Delta M(\tilde{g}, \tilde{q} - \tilde{\chi}_1^0) \sim 300$ GeV for gluino mass of 1 TeV [7].

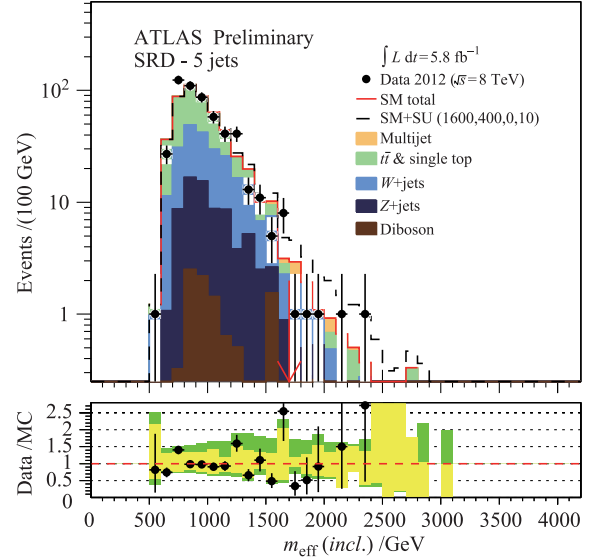


Fig. 1 Observed $m_{\text{eff}}(\text{incl.})$ distributions for the ≥ 5 -jet signal region. In the lower panels the yellow error band denotes the experimental and MC statistical uncertainties, while the green band shows the total uncertainty [10].

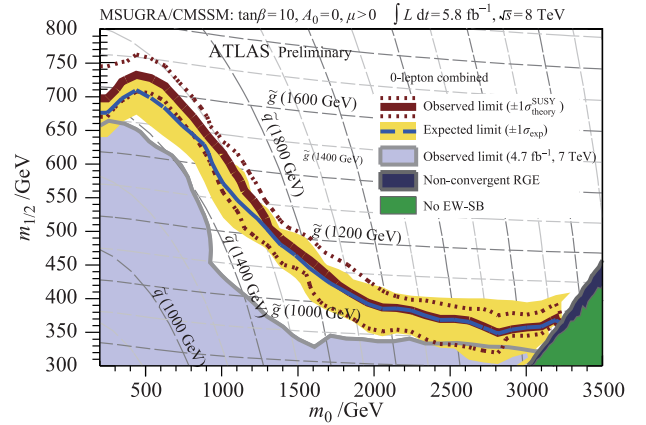


Fig. 2 Exclusion limits in the MSUGRA/CMSSM m_0 , $m_{1/2}$ plane for the lepton-veto analysis. Exclusion limits are obtained by using the signal region with the best expected sensitivity at each point. The dashed line shows the expected limits at 95% C.L., with the surrounding shaded band indicating the $\pm 1\sigma$ exclusions due to experimental uncertainties. Observed limits are indicated by the solid line representing the nominal limit and the dotted lines on either side are obtained by varying the cross-section by the theoretical scale and PDF uncertainties [10].

2.2 Leptonic/Photonic analyses

Asking for one lepton (e , μ or τ) or more reduce generally the sensitivity to SUSY signals because of the less favorable branching ratio to leptons. However it also

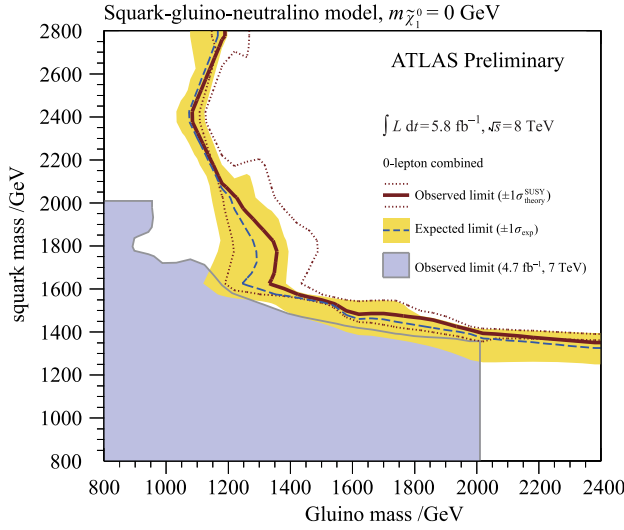


Fig. 3 A simplified MSSM scenario with only strong production of gluinos and first- and second-generation squarks, with direct decays to jets and massless neutralinos [10].

allows completely new analyses to be designed based on different triggers (leptonic compared to the jets+ E_T^{miss} trigger for the lepton veto analyses). Similarly, as the requirement of lepton(s) drastically reduces the multi-jet background, it is possible to soften the cuts on jets p_{TS} , E_T^{miss} and m_{eff} and therefore probe more compressed spectra. On the signal side, the presence of lepton(s) can be enhanced by the presence of sleptons or charginos $\tilde{\chi}_1^\pm$ in the cascade. In the MSUGRA/CMSSM model, a lepton-based analysis is shown to be competitive with a lepton-veto analysis at high m_0 where the gluino pair production dominates, see Fig. 4 [11]. An attractive possibility for lepton-based analyses is provided by the GMSB models where the LSP is the gravitino. In these models, the final states are largely driven by the

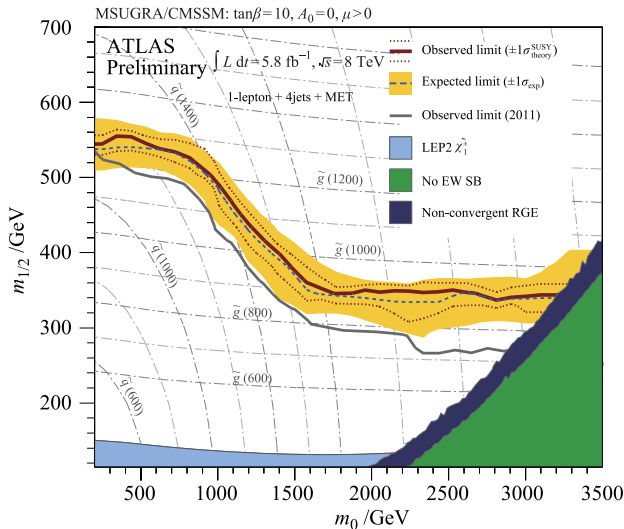


Fig. 4 Expected and observed 95% C.L. exclusion contour on the MSUGRA/CMSSM model for lepton-based (electron, muon) analysis [11].

coupling of the Next to Lightest SUSY Particle (NLSP) to the LSP. When the slepton is the NLSP, events would often contain two leptons (electron, muon or tau) of opposite sign. Present limits obtained in a constrained GMSB model with 7 TeV data are illustrated in Fig. 5 [8, 12]. In this case gluino masses below 1.2 TeV are excluded for all values of $\tan\beta$.

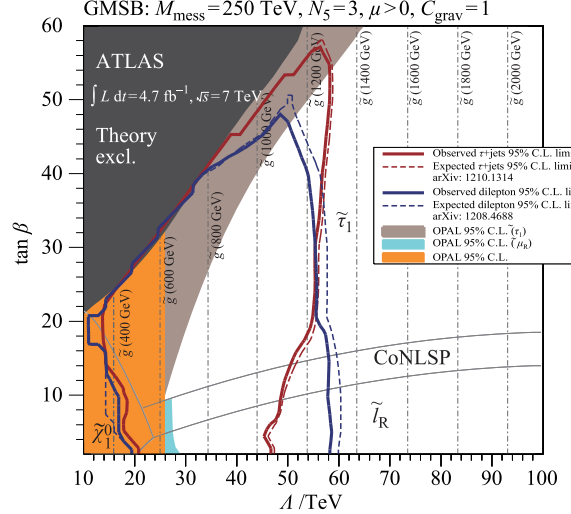


Fig. 5 Expected and observed 95% C.L. exclusion contour on the minimal GMSB model parameters Λ and $\tan\beta$ for di-lepton (electron, muon, tau) analyses [8, 12].

Another interesting GMSB-motivated analysis occurs for bino-like $\tilde{\chi}_1^0$ NLSP. In this case, two photons are required in the final states as well as large E_T^{miss} and H_T . Here again, limits on the gluino mass around 1.1 TeV are obtained, see Fig. 6. Limits for squarks are around 950 GeV [13].

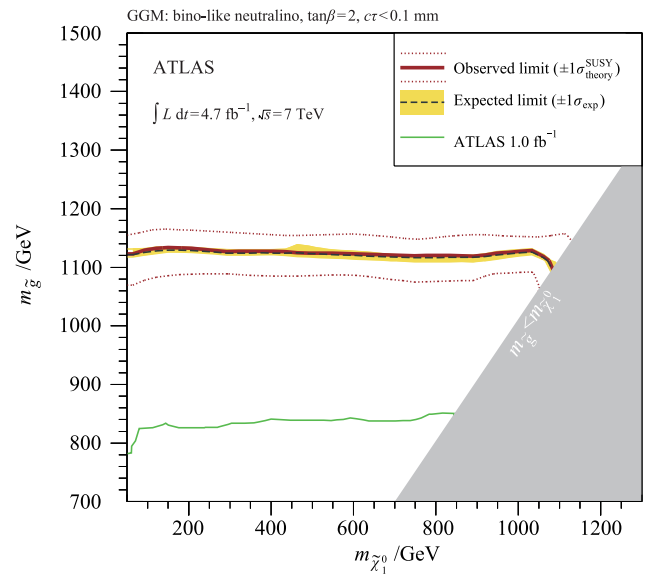


Fig. 6 Expected and observed 95% C.L. exclusion contour on the gluino mass as a function of the neutralino mass in the GGM model with a bino-like lightest neutralino NLSP. The other particles' masses are assumed to be decoupled [13].

3 Natural SUSY searches

The absence of any SUSY signal in inclusive searches indicates that the masses of gluinos and first/second generation squarks are probably above 1 TeV. However for the MSSM to solve the hierarchy problem, superpartners of top, bottom and weak gauge bosons need to be below 1 TeV to properly cancel the quadratic divergences of the Higgs mass radiative corrections. Therefore, even if the production cross-section is smaller than for gluinos and first/second generation of squarks, they may well be directly produced at the LHC with (generally) less complex final states. General characteristics of these analyses are the presence of b -jet(s) for stop and sbottom searches, and absence of jets for the weak gauge boson searches. Also, exclusive and dedicated analyses need to be designed to increase the search sensitivity.

3.1 Third generation squarks

The simplest final state is provided by direct sbottom production, where $\tilde{b} \rightarrow b\tilde{\chi}_1^0$. To fully exploit the simple topology, a jet veto is imposed on the third jet and a co-transverse mass (m_{CT}) [14, 15] is used instead of the effective mass m_{eff} to increase the sensitivity to SUSY signals. This can be seen by looking at the m_{CT} distribution (Fig. 7): while the top background is suppressed at high m_{CT} , a kinematical endpoint appears around 300 GeV for the signal model considered (diluted by initial and final state radiations). No deviation from SM expectation is observed and sbottom masses below 500 GeV are excluded for massless LSP as shown in Fig. 8 [16]. A

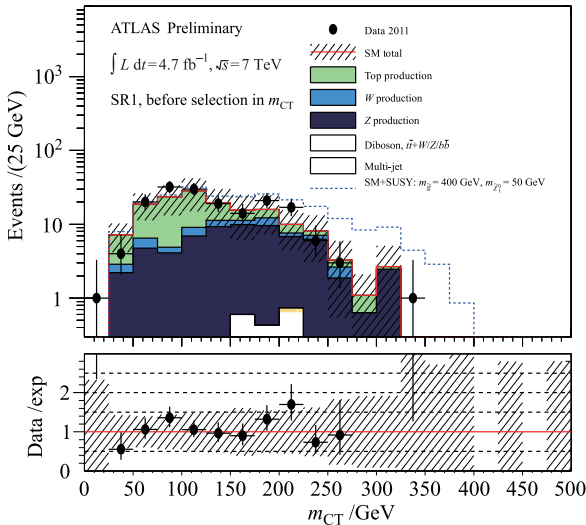


Fig. 7 m_{CT} distribution in the direct sbottom analysis at $\sqrt{s}=7$ TeV. The shaded band includes both detector and theoretical systematic uncertainties. The SM expectations are shown after rescaling to the fit results [16].

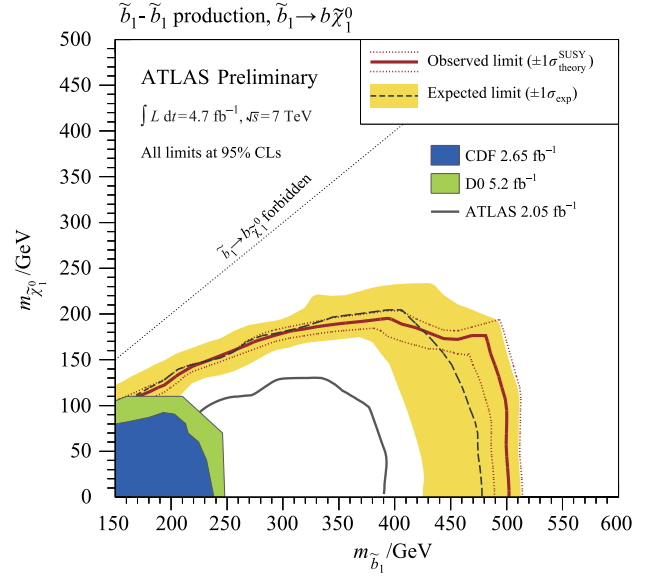


Fig. 8 Direct sbottom searches in the decay channel $\tilde{b} \rightarrow b\tilde{\chi}_1^0$ at $\sqrt{s}=7$ TeV [16].

3-lepton+jets+ E_T^{miss} channel is also designed to be sensitive to $\tilde{b} \rightarrow t\tilde{\chi}_1^\pm \rightarrow tW^\pm\tilde{\chi}_1^0$ decay. A sbottom mass limit of 350–400 GeV is obtained [17].

A huge effort is employed to search for direct stop production, the most pressing issue for the Higgs mass stability at high energy. Five exclusive analyses [18–22] are designed to probe the stop decay channels $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ [$m(\tilde{t}) > m(top) + m(\tilde{\chi}_1^0)$] and $\tilde{t} \rightarrow b\tilde{\chi}_1^\pm \rightarrow bW^\pm\tilde{\chi}_1^0$ [$m(\tilde{t}) < m(top) + m(\tilde{\chi}_1^0)$]. They can be divided into lepton veto analyses sensitive to high stop masses with massless LSPs and leptonic analyses which cover more compressed scenarios. In all cases, the dominant background comes from the top quark pair production and different discriminant variables are chosen in each analysis to maximize the sensitivity. The final status of the search at $\sqrt{s}=7$ TeV is shown in Fig. 9. Stop masses below 500 GeV are

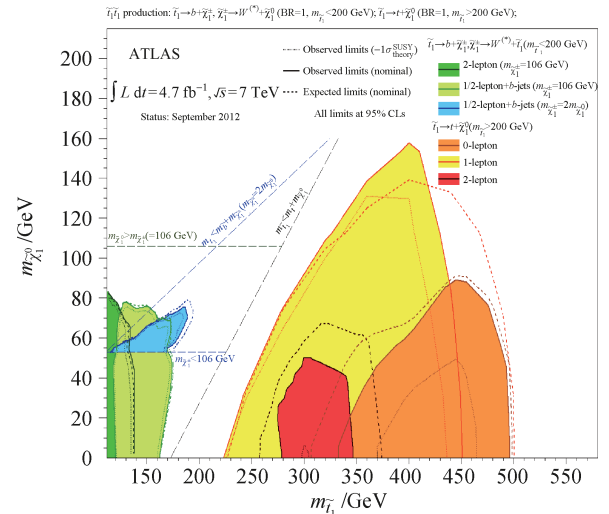


Fig. 9 Final status of direct stop searches at $\sqrt{s}=7$ TeV [18–22].

excluded for LSP masses below 80 GeV, except for a small mass window around the top mass.

Even if the gluino mass is above 1 TeV, it can still be that the dominant SUSY production comes from gluino-gluino provided the stop/sbottom are relatively heavy (>500 – 600 GeV). A particularly interesting case is the gluino mediated stop decay chain with subsequent decay $\tilde{t} \rightarrow t\chi_1^0$ giving four tops in the final state and high E_T^{miss} . Three spectacular signatures are therefore expected: an abundant source of same sign (SS) leptons; events with more than 6 jets (in fact up to 12 if all W 's decay hadronically) and lower E_T^{miss} ; and finally events with 4 b -jets. In all these cases, the SM background (especially the most dangerous one, $t\bar{t}$) is greatly reduced. Three dedicated analyses are designed to capture these signals. The results are shown in Figure 10 in a simplified model where gluino decays only to $t\bar{t}$. The two SS leptons [23] and 6–9 jets [24] analyses are complementary and exclude LSP masses below 350 GeV for gluino masses below 1 TeV, with 6 fb^{-1} at $\sqrt{s} = 8 \text{ TeV}$. Note that in both cases, these analyses are also sensitive to gluino mediated chargino decays and competitive with other inclusive searches. For comparison, the most powerful $\sqrt{s} = 7 \text{ TeV}$ analysis, asking for at least 3 b -jets [25], is also shown.

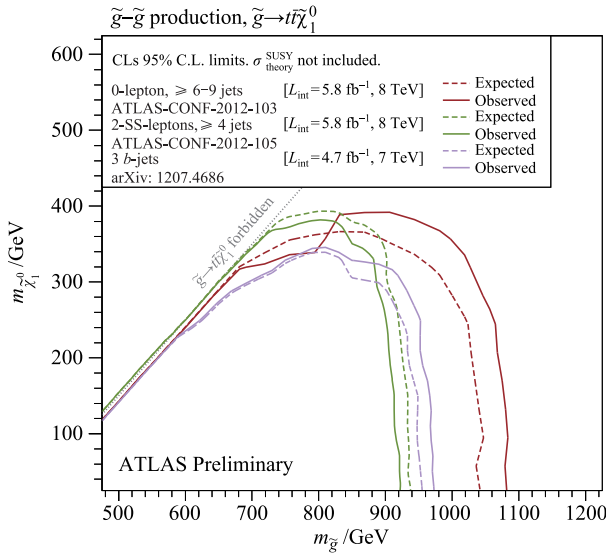


Fig. 10 Status of gluino mediated stop searches at $\sqrt{s} = 8 \text{ TeV}$ as of August 2012 [23–25].

3.2 Weak gauginos and sleptons

If all squarks and gluinos are above the TeV scale, weak gauginos with masses of few hundred GeV may be the only sparticles accessible at the LHC. As an example, at $\sqrt{s} = 7 \text{ TeV}$, the cross-section of the associated production $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm$ (with degenerate masses of 200 GeV) is above the 1 TeV gluino-gluino production cross-section by one

order of magnitude. Chargino pair production is searched for in events with two opposite sign dileptons and E_T^{miss} , using a jet veto, exploiting the decay $\tilde{\chi}^\pm \rightarrow l^\pm \nu \tilde{\chi}_1^0$. As happens for top quark pair production in the direct sbotom searches, the WW background is reduced efficiently by the discriminating variable m_{T2} [26, 27]. Charginos with masses between 110 and 360 GeV are excluded for a massless LSP in a model with an intermediate slepton/sneutrino between the $\tilde{\chi}^+$ and $\tilde{\chi}_1^0$, see Fig. 11 [28]. Presently no sensitivity is obtained for the case where the chargino decays via an on-shell or off-shell W instead of a slepton/sneutrino. As shown in Fig. 12, it is also possible to derive limits beyond LEP on the slepton (selectron or smuon) production with the same analysis [28]. The chargino can also be produced in a pair with the $\tilde{\chi}_2^0$, leading to three leptons and E_T^{miss} in the final states, in case of an intermediate slepton/sneutrino. Results are shown in Fig. 13 and degenerate $\tilde{\chi}_2^0/\tilde{\chi}_1^\pm$ masses can be excluded down to 500 GeV for an LSP mass of 200 GeV. In this case, some sensitivity exists when replacing the intermediate slepton by a $W^{(*)}$ [29]. A combination

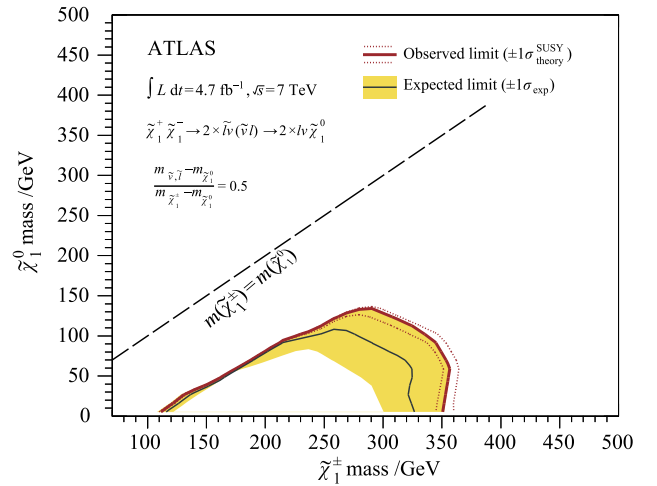


Fig. 11 Status of chargino searches at $\sqrt{s} = 7 \text{ TeV}$ [28].

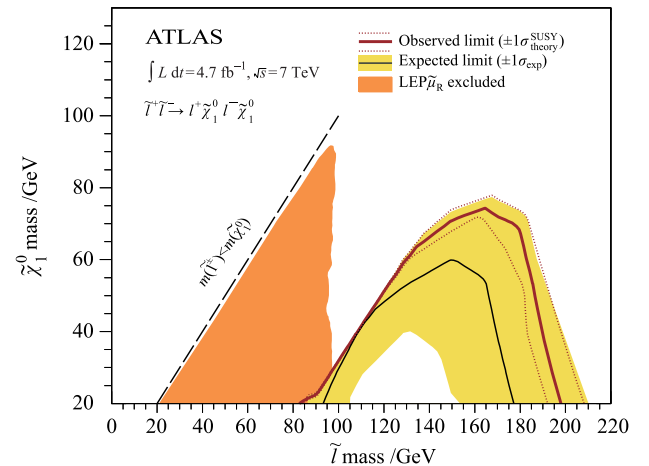


Fig. 12 Status of slepton searches at $\sqrt{s} = 7 \text{ TeV}$ [28].

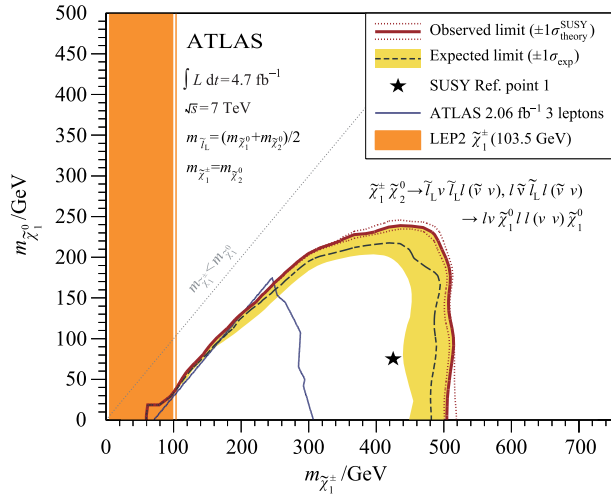


Fig. 13 Status of chargino/neutralino searches at $\sqrt{s} = 7$ TeV [29].

of dilepton and trilepton analyses is also interpreted in a more realistic model, the pMSSM [30] where strongly interacting particles are decoupled and the gaugino mass parameters (M_1 , M_2 and μ) are varied. An intermediate slepton is also supposed in this scenario [29].

4 Long-lived particles and R-parity violation

In view of the null results in all other SUSY searches, it is mandatory to fully explore the SUSY scenario predicting meta-stable or long-lived particles. These particles, not present in the Standard Model, would provide striking signatures in the detector and rely heavily on a detailed understanding of its performance. In SUSY, non-prompt particle decay can be caused by i) very weak R-Parity violation, i.e., one of the Yukawa coupling λ , λ' or $\lambda'' \leq O(10^{-5})$, ii) low mass difference between a SUSY particle and the LSP or iii) very weak coupling to the gravitino in GMSB models. All these possibilities have been explored by ATLAS.

In the first case, an analysis searching for displaced vertex (DV) with several tracks and one muon is performed. It is motivated by models with non-zero values of λ'_{2ij} causing the medium-lived neutralino to decay. A background-free signal region is chosen in the M_{DV} – N_{tracks} plane, where M_{DV} (N_{tracks}) is the reconstructed mass (number of tracks) of the displaced vertex. To increase the sensitivity to SUSY signals, a dedicated track reconstruction for particles from the displaced vertex is also implemented. This analysis, rather model independent, is sensitive to heavy particles that decay at radial distances between 4 and 180 mm from the pp interaction point in association with a high p_T muon [31].

In case $M(\tilde{\chi}_1^0) - M(\tilde{\chi}_1^\pm) \geq 140$ MeV, a meta-stable chargino will be produced and decay to undetectable par-

ticles, a soft pion and the LSP. This is, for example, the case in the AMSB models where soft SUSY breaking is caused by loop effects. Experimentally, some charginos will then have decay lengths exceeding a few tens of centimeters and their tracks may have no or few associated hits in the outer region of the tracking system. The continuous tracking of the outer part of the ATLAS inner detector, the straw tube transition radiation (TRT), gives sensitivity to this signature and removes the background (Fig. 14). With the additional requirement of an high isolated p_T track (> 50 GeV), regions beyond the LEP limits can be excluded in the lifetime-mass plane of the chargino, as shown in Fig. 15 [32]. Although originally motivated by AMSB, this result is largely model independent.

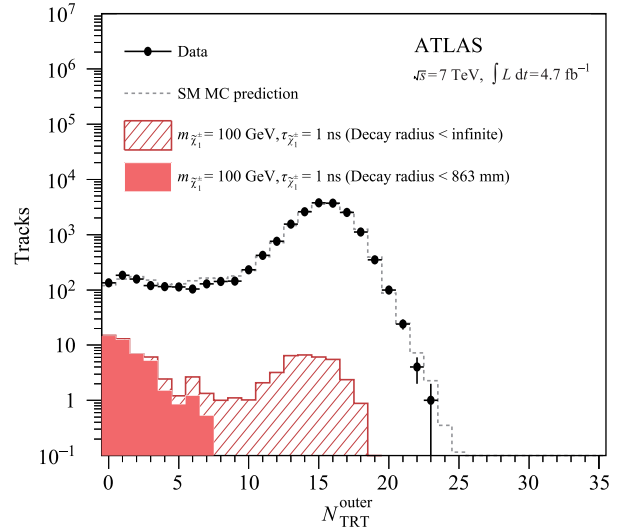


Fig. 14 Distribution of the Number of hit in the outer layers of the TRT for data and one typical signal [32].

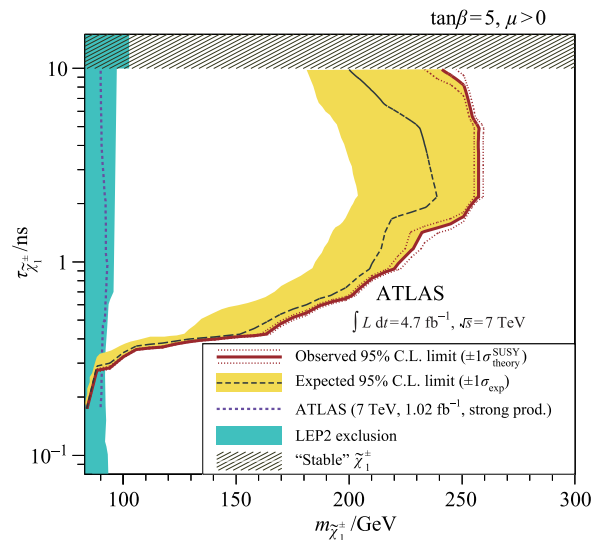


Fig. 15 The constraint on the lifetime-mass plane of the chargino in the AMSB model for $\tan \beta = 5$ and $\mu > 0$ [32].

If long-lived charged sleptons, quarks and gluinos are produced at LHC, they could travel with a speed lower than the speed of light, giving a late arrival in the calorimeters and/or muon spectrometer, as well as high ionisation energy loss in the pixel detector. The mass of these long-lived particles (LLP) could then be reconstructed by using the relation $m = p/(\beta\gamma)$. In ATLAS, two complementary approaches are followed: first, composite colorless bound states of a squark/gluino with quark/gluon (R-hadrons) are searched for by comparing the mass measurement extracted from the pixel detector with that from the calorimeter and/or muon spectrometer, or by considering only the pixel detector. Since these LLPs may emerge as charged (neutral) states from the pp collisions and become neutral (charged) after interactions with the detector material, this strategy covers most of the cases. Stable gluinos with masses below 1 TeV are excluded, as well as stable stop and sbottom below 600 and 700 GeV [33]. Second, long-lived charged sleptons are searched for by combining the β measurement from the calorimeter and muon spectrometer, since they would appear as slow muons. This scenario is generally motivated by GMSB models with very weak coupling between the slepton NSLP and the gravitino. If pair produced, a signature composed of two LLPs is obtained which is essentially background free. Masses of long-lived staus are excluded below 300 GeV [33]. Overall, the mass limits on long-lived sparticles, independent of the LSP mass, are typically stronger than the prompt counterpart.

Sizeable R-Parity violation in one of the Yukawa coupling (λ, λ' or $\lambda'' \sim O(10^{-4}-10^{-2})$) is also an attractive way to explain why SUSY has not been found yet. At the LHC, it can manifest itself through events with four or more leptons and no Z -boson, multijet resonances or Lepton Flavor Violation. In all cases, ATLAS results were updated with the full statistics shortly after this conference [6].

5 Beyond the MSSM

As discussed in previous sections, there is no evidence for any sparticles predicted by the MSSM and the parameter space, even if very large, is now significantly constrained. Looking for an extension of the MSSM model is therefore quite natural. In this respect, the gaugino sector is a place where spectacular change can happen when considering $N = 2$ SUSY theories: the gluino becomes a Dirac particle and scalar partners (“sgluons”) are predicted [34, 35]. Similar features appear in R-symmetric MSSM [36, 37]. At the LHC, the sgluons will be pair produced directly and decay in two gluons, giving a pair of

two-jet resonances. A unique pairing of the four highest- p_T jets is achieved for each event by minimizing the pairwise separation. A peak in the dijet mass distribution is then searched for, while the shape and the normalization of the multijet background is estimated by a data-driven method. Sgluons are excluded for masses below 300 GeV (Fig. 16) [38].

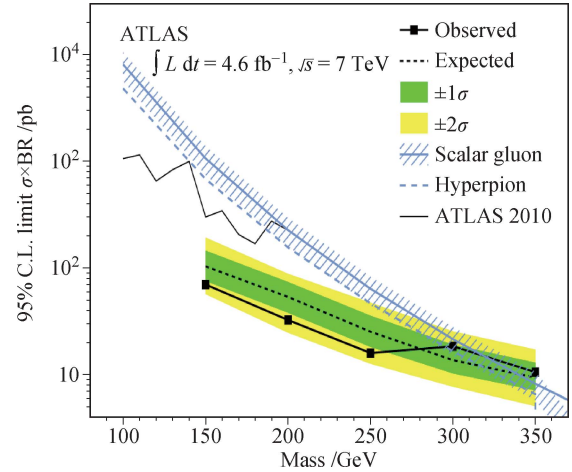


Fig. 16 Expected and observed 95% C.L. upper bounds on the product of the scalar pair production cross-section and the branching ratio to gluons as a function of the scalar mass [38].

6 Conclusions

ATLAS has developed a coherent and ambitious program to be sensitive to new particles predicted by weak-scale SUSY. More than 50 analyses have been completed at $\sqrt{s} = 7$ TeV and the first results start to appear for 8 TeV data. No sign of new physics has been observed. As a result, most of the sparticles of the MSSM have been constrained near the weak scale range (Fig. 17). Some of them, like the gluino, are found to be above 1 TeV in the vast majority of the models considered, even in case of rather compressed SUSY spectra. Weak gauginos and third generation squarks, required by naturalness arguments to be in the range 0.1–1 TeV, also begin to be excluded when looking at their direct production, although less stringently. Escape routes for SUSY, like meta-stable or long-lived particles R-parity violation signatures, are also covered but do not reveal yet any deviation from Standard Model.

With the discovery of a Higgs-like particle by ATLAS and CMS early July, the gauge hierarchy problem may be a reality (if the Higgs is really SM-like). Therefore if SUSY is to be a solution to this problem, new particles should be discovered at the LHC. This statement is starting to be seriously challenged by the experiment and will continue to be with the full analysis of the 2012 data at $\sqrt{s} = 8$ TeV as well as with the 13 TeV data in

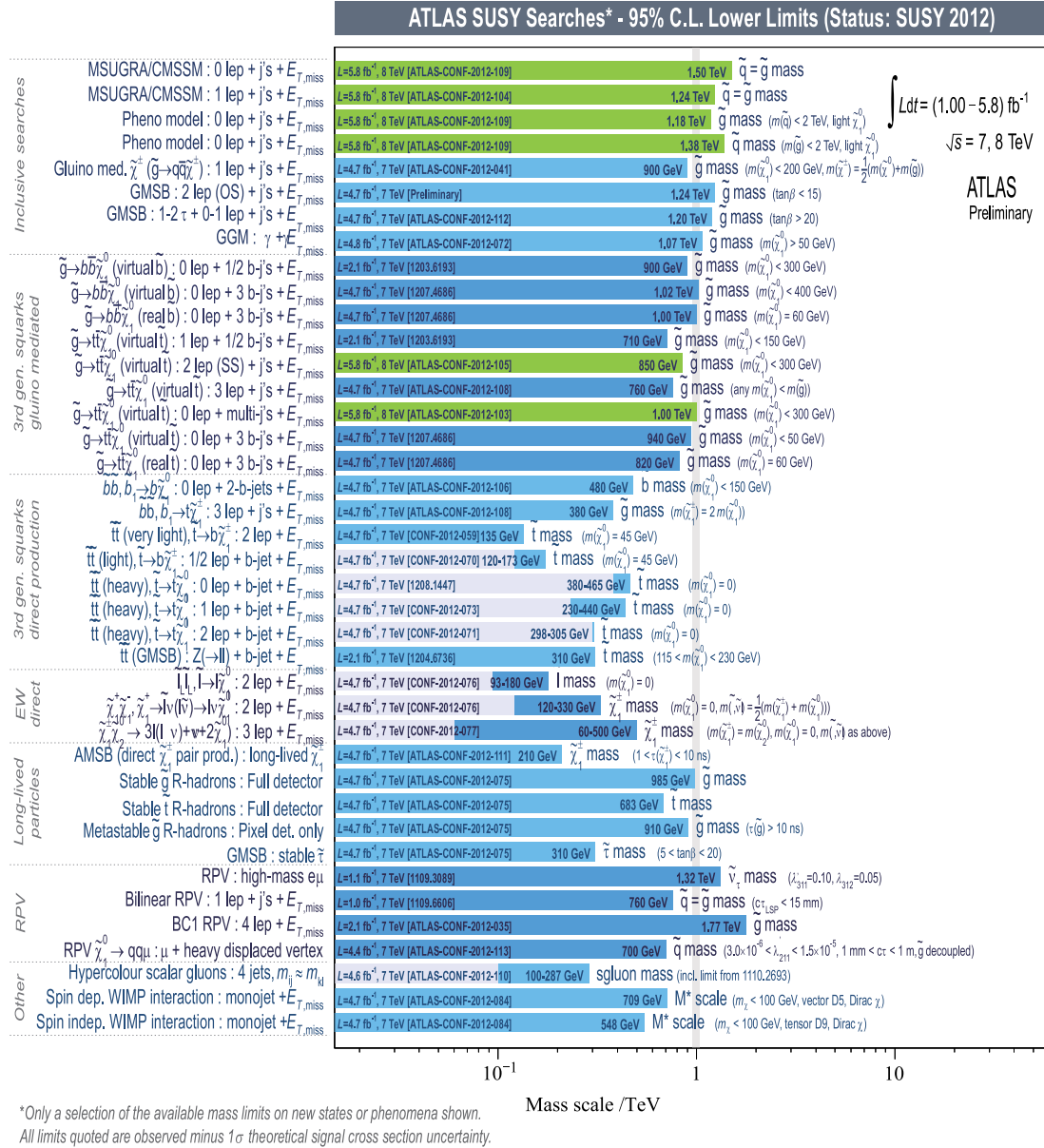


Fig. 17 Overall Status of ATLAS SUSY search results (August 2012).

2015.

References and notes

- S. P. Martin, arXiv: hep-ph/9709356, 1997, and references therein.
- ATLAS Collaboration, Phys. Lett. B, 2012, 716: 1
- CMS Collaboration, Phys. Lett. B, 2012, 716: 30
- ATLAS Collaboration, Journal of Instrumentation, 2008, 3: S08003
- S. Laplace, these proceedings
- <http://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults>
- ATLAS Collaboration, arXiv: 1208.0949, 2012
- ATLAS Collaboration, Phys. Rev. D, 2012, 86: 092002
- T. J. LeCompte and S. Martin, Phys. Rev. D, 2011, 84(1): 015004
- ATLAS Collaboration, ATLAS-CONF-2012-109, <http://cdsweb.cern.ch/record/1472710>
- ATLAS Collaboration, ATLAS-CONF-2012-104, <http://cdsweb.cern.ch/record/1472673>
- ATLAS Collaboration, Europhys. J. C, 2012, 72: 2215
- ATLAS Collaboration, Phys. Lett. B, 2012, 718: 411
- D. Tovey, J. High Energy Phys., 2008, 04: 034
- G. Polesello, et al., J. High Energy Phys., 2010, 03: 030
- ATLAS Collaboration, ATLAS-CONF-2012-106, <http://cdsweb.cern.ch/record/1472685>
- ATLAS Collaboration, ATLAS-CONF-2012-108, <https://cdsweb.cern.ch/record/1472687>
- ATLAS Collaboration, Phys. Rev. Lett., 2012, 109: 211802

19. ATLAS Collaboration, Phys. Rev. Lett., 2012, 109: 211803
20. ATLAS Collaboration, arXiv: 1209.4186, 2012
21. ATLAS Collaboration, Europhys. J. C, 2012, 72: 2237
22. ATLAS Collaboration, arXiv: 1209.2102, 2012
23. ATLAS Collaboration, ATLAS-CONF-2012-105, <http://cdsweb.cern.ch/record/1472674>
24. ATLAS Collaboration, ATLAS-CONF-2012-109, <http://cdsweb.cern.ch/record/1472710>
25. ATLAS Collaboration, Europhys. J. C, 2012, 72: 2174
26. C. Lester and D. J. Summers, Phys. Lett. B, 1999, 463(1): 99
27. A. Barr, C. Lester, and P. Stephens, J. Phys. G, 2003, 29(10): 2343
28. ATLAS Collaboration, arXiv: 1208.2884, 2012
29. ATLAS Collaboration, arXiv: 1208.3144, 2012
30. A. Djouadi, J. L. Kneur, and G. Moultaka, Comput. Phys. Commun., 2007, 176(6): 426
31. ATLAS Collaboration, arXiv: 1210.7451, 2012
32. ATLAS Collaboration, arXiv: 1210.2852, 2012
33. ATLAS Collaboration, arXiv: 1211.1597, 2012
34. P. Fayet, Nucl. Phys. B, 1976, 113(1): 135
35. S. Y. Choi, M. Drees, J. Kalinowski, J. M. Kim, E. Popena, and P. M. Zerwas, Phys. Lett. B, 2009, 672(3): 246
36. G. D. Kribs, E. Poppitz, and N. Weiner, Phys. Rev. D, 2008, 78(5): 055010
37. T. Plehn and T. M. P. Tait, J. Phys. G, 2009, 36(7): 075001
38. ATLAS Collaboration, arXiv: 1210.4826, 2012