PROCEEDINGS OF SCIENCE

Searches for Supersymmetry

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Since its first physics operation in 2010, the Large Hadron Collider at CERN has set a precedent in searches for supersymmetry. This proceeding report provides a brief overview on the current status of searches for supersymmetry at the LHC.

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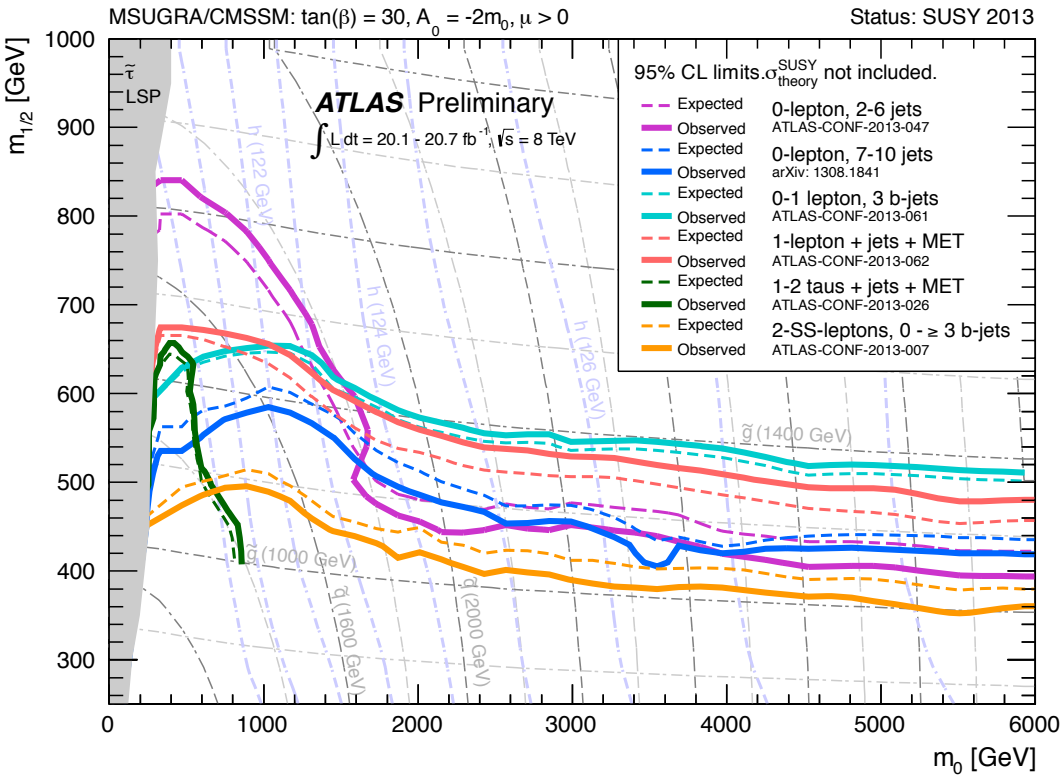

Figure 1: 95% C.L. limits for different ATLAS searches defined in the CMSSM

1. Introduction

The landscape of searches for Supersymmetry (SUSY) has changed dramatically since the Large Hadron Collider (LHC) at CERN began physics operation in 2010. By the end of 2011 the experiments CMS [1] and ATLAS [2] had collected about 5 fb^{-1} of integrated luminosity each at a center-of-mass energy of 7 TeV. In 2012 the LHC operated at a center-of-mass energy of 8 TeV and each experiment collected approximately 20 fb^{-1} of data at this energy.

In this proceeding report I will focus on the status of searches for SUSY at the LHC. A more detailed and comprehensive overview is provided in the September 2013 update of the experimental review for SUSY searches in the PDG [3]. For more details on LEP and Tevatron results see also earlier PDG reviews [4].

2. Summary of R-parity conserving searches

If the multiplicative quantum number of R-parity, $R = (-1)^{3(B-L)+2S}$, where B and L are baryon and lepton numbers and S is the spin, is conserved the lightest SUSY particle (LSP) is stable and often assumed to be a weakly interacting massive particle. The LSP escapes undetected through the experiment, leading to final states with several hadronic jets, large missing transverse energy, and possible leptons and photons in the final state.

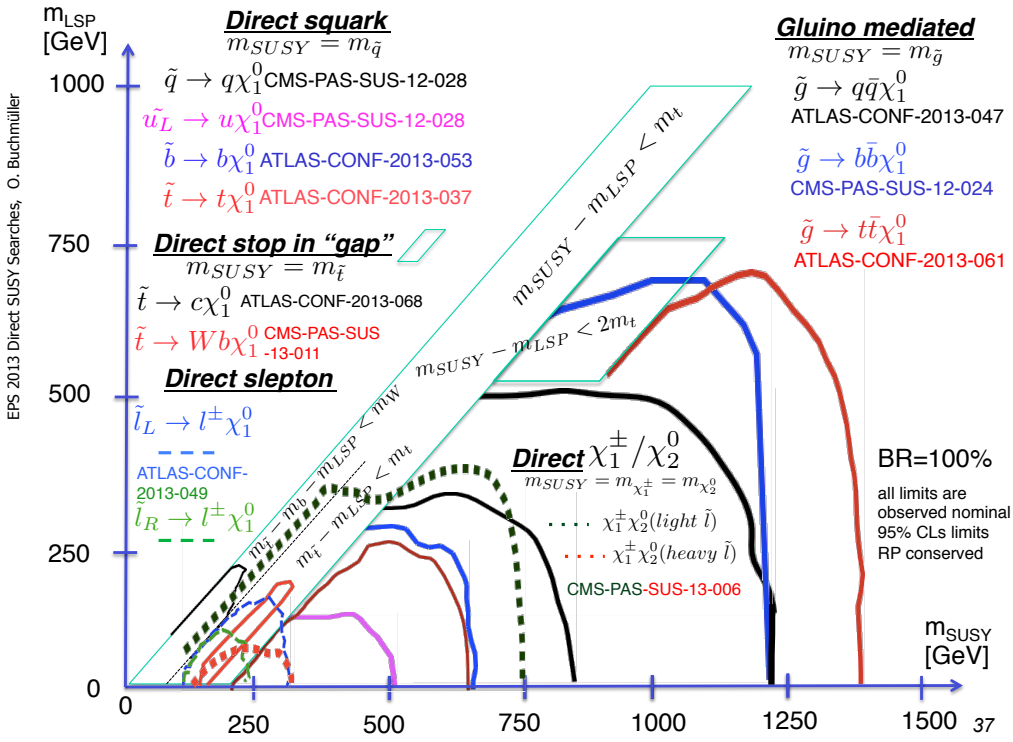

Figure 2: Illustrative summary plot for the most important simplified model limits.

ATLAS and CMS have performed many searches looking for R-parity conserving SUSY signatures. Figure 1 shows limits in the framework of the CMSSM, assuming $\tan\beta = 30$, $A_0 = -2m_0$, and $\mu > 0$, for several ATLAS searches. In this constrained SUSY model gluino masses below $\approx$1.3 TeV are excluded for all squark masses, while for equal gluino and squark masses, the limit is around 1.7 TeV. Furthermore, squark masses below 1.6 TeV are excluded for all gluino masses. The CMS collaboration has not yet provided an interpretation of their 8 TeV searches in the CMSSM but the performance is expected to be very similar.

Another important interpretation approach, even less dependent on fundamental assumptions, is the characterisation of the searches in terms of simplified models. Such models assume a limited set of SUSY particle production and decay modes and leave open the possibility to vary masses and other parameters freely. Today, ATLAS and CMS have adopted simplified models as the primary framework to provide interpretations of their searches. Figure 2 shows an illustrative overview of limits for the most important simplified models that are considered.

For gluino masses rather similar limits, ranging from 1.2 TeV to 1.4 TeV, are obtained from different model assumptions. This shows that the LHC is probing a large region in SUSY parameter space for direct gluino production at the 1 TeV scale and beyond.

Limits defined in simplified models on squark mass are not only much weaker but also vary strongly depending on the assumed properties of the decay chain. As shown in Figure 2, limits on direct squark production only go up 800 GeV under the assumption of an eightfold mass-

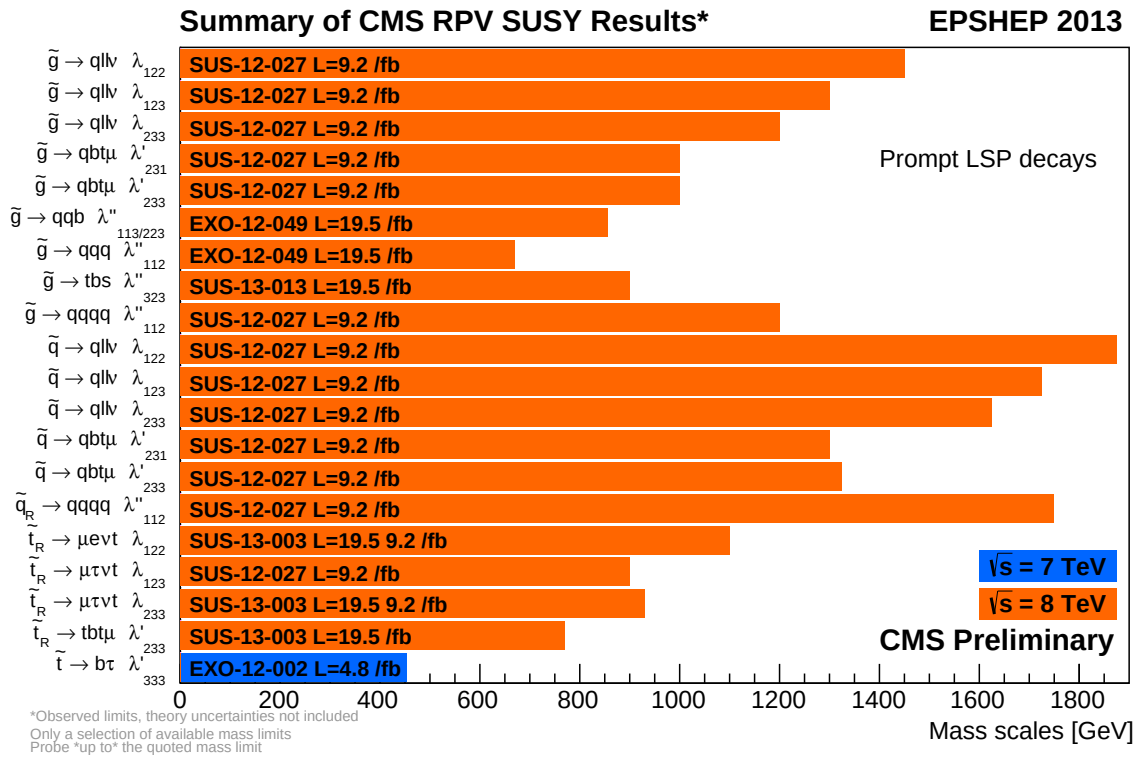

Figure 3: Summary plot for R-parity violating CMS searches. The corresponding ATLAS results are similar.

degeneracy for first and second generation squarks. If, however, only a single squark is assumed to be light, this limit weakens to only ≈ 450 GeV for the best possible scenario of very light neutralinos. For the production of single bottom squarks the best limit improves to around 650 GeV due to better control of the SM background via the identification of b quarks in the final state.

For top squarks the situation is even more complex because of the many different decay chains that must be considered. While in the best case limits of up to 700 GeV are possible, there are also regions in SUSY parameter space where even for light neutralinos top squarks above a few hundred GeV cannot be ruled out by the LHC searches.

Pair production of chargino, neutralinos, and sleptons at the LHC, for masses of several hundreds of GeV, is at least two orders of magnitude smaller than for coluored SUSY particles (e.g. top squark pair production). Therefore, high statistics data samples are required to constrain these SUSY particles. Today, depending on the assumed scenario limits on these particles vary from around 700 GeV in the most optimistic case to only a few hundred GeV for more pessimistic decay topologies. Much more data will be needed to push these limits above the 1 TeV scale.

Further results of SUSY searches can be obtained from the public result pages of ATLAS [5] and CMS [6].

3. Summary of R-parity violating searches

If R-parity is violated, new terms λ_{ijk}, λ'_{ijk} and λ''_{ijk} appear in the super potential, where ijk are

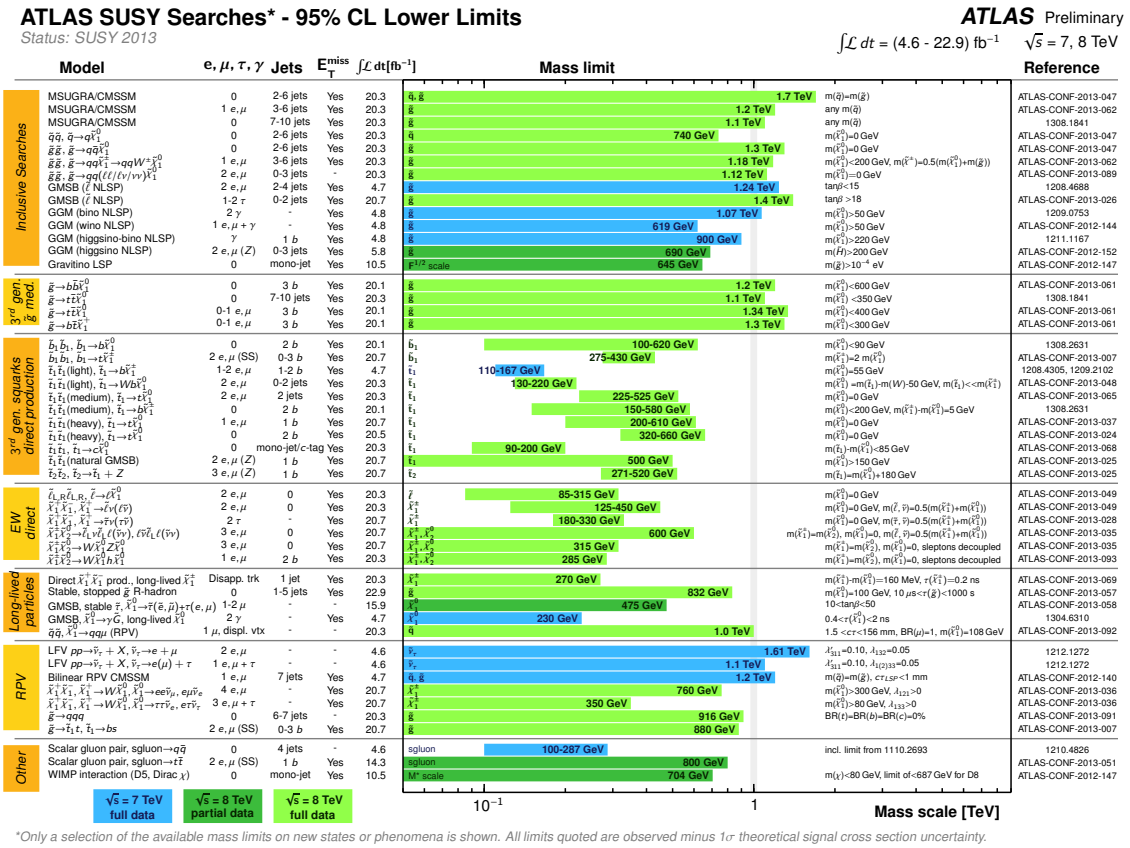

Figure 4: Summary table for the ATLAS searches. The corresponding summary from CMS is very similar.

generation indices; λ-type couplings appear between lepton superfields only, λ''-type are between quark superfields only, and λ'-type couplings connect the two.

Figure 3 shows a summary of R-parity violating SUSY searches from CMS. The corresponding ATLAS summary is similar. It is interesting to note that for many different signatures the LHC experiments already probe the 1 TeV scale.

4. Summary

A comprehensive overview of the current landscape of SUSY searches at the LHC is given in Figure 4. The plot shows exclusion mass limits of ATLAS for different searches and interpretation assumptions. The corresponding results from CMS are comparable.

The interpretation of results at the LHC has moved away from constrained models like the CMSSM towards a large set of simplified models, or the pMSSM. So far no significant sign of New Physics has been observed at the LHC. Limits on coloured SUSY particles range between 0.5 TeV to 1.4 TeV depending on the assumptions made for underlying production modes and corresponding decay chains. Limits on third generation squarks and electroweak gauginos only hold for light neutralinos, and are all well below the 1 TeV mass scale. Therefore. in general, SUSY below the 1 TeV scale is certainly not yet ruled out.

The forthcoming run of the LHC at $\sqrt{s} = 13$ TeV or higher will increase the production cross section for SUSY particles substantially and will thus present again a great opportunity for discovery.

References

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[2] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, *JINST* **3** (2008) S08003

[3] O. Buchmueller and P. De Jong, *Experimental review of searches for Supersymmetry (see also September 2013 Update)*, in: 2012 Review of Particle Physics (Particle Data Group) *Phys.Rev.* **D86** 010001 (2012).

[4] J.-F. Grivaz, *Supersymmetry, Part II (Experiment)*, in: 2010 Review of Particle Physics (Particle Data Group), *J. Phys.* **G37**, 075021 (2010).

[5] ATLAS public results on SUSY searches:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

[6] CMS public results on SUSY searches:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS