

SUSY Searches for Inclusive Squark and Gluino Production at the LHC

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A selection of recent searches for Supersymmetry conducted by the ATLAS and CMS collaborations is presented, summarizing the relevant results for inclusive squark and gluino production at the LHC. No indication for the existence of Supersymmetry in terms of an excess above the Standard Model background is seen by any analysis, therefore limits are reported on parameters of the various models used to interpret the findings.

1 Introduction

After a long and successful data-taking period from 2010 through 2012, the first run of the Large Hadron Collider (LHC) at CERN has come to an end. In 2012, both the ATLAS and the CMS collaboration have taken about 22 fb^{-1} of data at $\sqrt{s} = 8 \text{ TeV}$, about four times the data available from 2010 and 2011 at a lower center-of-mass energy of $\sqrt{s} = 7 \text{ TeV}$.

Already with the first proton-proton collision data from 2010 of about 35 pb^{-1} , the searches for inclusive squark and gluino production proved to be very successful in terms of mass reach, yielding exclusion limits that rapidly surpassed those of earlier experiments. Since then, the analyses have evolved and diversified, pushing the limits on the squark, gluino and lightest gaugino masses or mass parameters to higher and higher values, aiming at more complex topologies and giving additional interpretations in other supersymmetric models.

In these proceedings, the focus will be on strong production of the scalar partners of first and second generation quarks and the fermionic partners of the gluons. For a given supersymmetric mass scale, strong production has the largest production cross sections, thus allowing to target heavy initial supersymmetric particles, signatures with small branching ratios and long decay chains. Apart from one exception all analyses presented below assume R -parity conservation, which makes the lightest supersymmetric particle (LSP) stable. Missing transverse momentum (E_T^{miss}) is therefore an important part of the searched for signature, the other being jets with high transverse momentum produced in the decay chains starting from the heavy pair-produced squarks and gluinos. Only results by the ATLAS and the CMS collaborations are considered which have been made public on or before the 11th March 2013, the date at which the corresponding talk has been given. None of the analyses has seen any significant excess of events above the expected number from the Standard Model predictions, thus all analyses interpret their findings by reporting limits on supersymmetric particle masses or model parameters.

2 Searches with the Full 2012 Dataset

The ATLAS collaboration has made public results from two searches for Supersymmetry with inclusive squark (\tilde{q}) and gluino (\tilde{g}) production which make use of the full 2012 dataset.

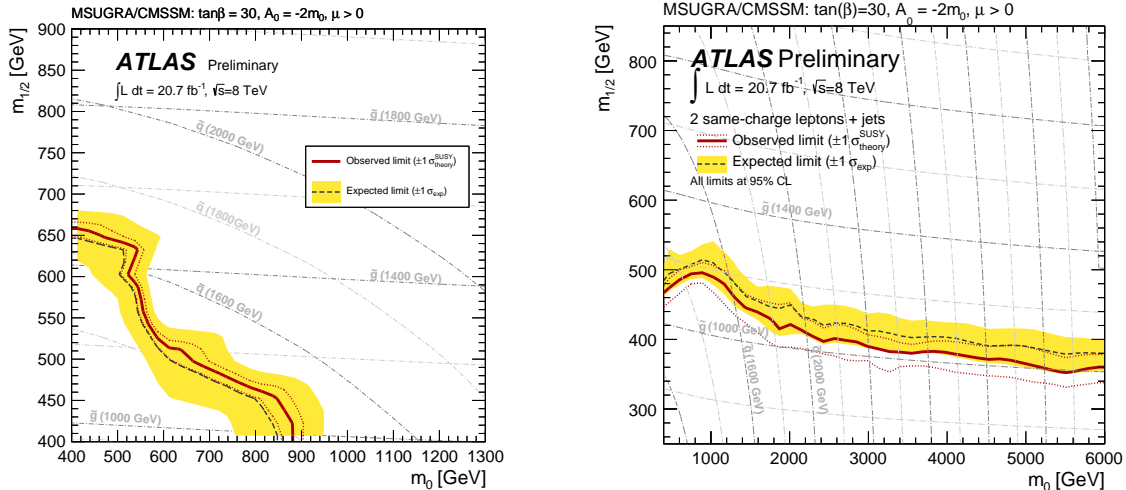


Figure 1: Expected and observed limits from the two ATLAS analyses making use of the full 2012 dataset. The plots show the interpretation of the tau + jets + E_T^{miss} results (left, ³) and same-sign leptons + jets + E_T^{miss} results (right, ⁴) in the mSUGRA/CMSSM framework. (Note the very different range on the horizontal axis.)

The first search ³ targets final states with exactly one, or two or more hadronically decaying tau leptons, together with jets and E_T^{miss} . The motivation for this search comes from models with gauge-mediated supersymmetry breaking (GMSB) where the scalar partner of the tau, the stau $\tilde{\tau}$, is the next-to-lightest supersymmetric particle (NLSP), leading to final states with many taus. As no excess is seen, the results are interpreted in terms of limits at 95% confidence level in three different models. The limits in the mSUGRA/CMSSM framework are shown in Figure 1, where this analysis is in particular powerful in the low m_0 region. The model parameters for the mSUGRA/CMSSM model have been chosen such that in a large part of the plane a 126 GeV Higgs can be accommodated. Not shown is the limit plot for the minimal GMSB model in the plane spanned by the parameters Λ , the SUSY breaking mass scale felt by the low-energy sector, and $\tan\beta$, the ratio of the MSSM Higgs vacuum expectation values. Here, the previous limits from 2011 data can be extended considerably, reaching now up to 70 TeV in Λ for high $\tan\beta > 50$ (corresponding to $m(\tilde{g})$ of about 1.5 TeV), and excluding values of Λ below 54 TeV ($m(\tilde{g}) \sim 1.2$ TeV) independent of $\tan\beta$. There is also a new interpretation in a model of natural gauge mediation, where independently of the $\tilde{\tau}$ mass, gluino masses up to 1.14 TeV can be excluded, provided the $\tilde{\tau}$ is the NLSP.

The second analysis ⁴ looks at final states with same-sign lepton pairs, together with 3 or more jets and E_T^{miss} . The motivation for this analysis is that the pair-produced gluinos have almost the same probability to give pairs of leptons with same charge or with opposite charge. Requiring a pair of leptons with same sign suppresses the background coming from Standard Model processes considerably, giving a very clean and powerful signature to look for new physics processes. The limits which are set in the same mSUGRA/CMSSM model with Higgs-compatible parameters used for the tau analysis are shown in Figure 1, excluding a large region of the mSUGRA/CMSSM parameter space. In addition, interpretations in a large number of simplified models are given, demonstrating the power and versatility of this search channel.

3 Searches with a Subset of 2012 Data

CMS has made public a study using 9.2 fb⁻¹ from the 2012 dataset ⁵, in which models with R -parity violation (RPV) are considered. As here the LSP is no longer stable, high particle multiplicities are characteristic for supersymmetric decays rather than large E_T^{miss} . Events with 3 or more isolated leptons are selected and classified with respect to the number of opposite-sign same-flavour (OSSF) lepton pairs, the invariant mass of the OSSF lepton pairs if present, the

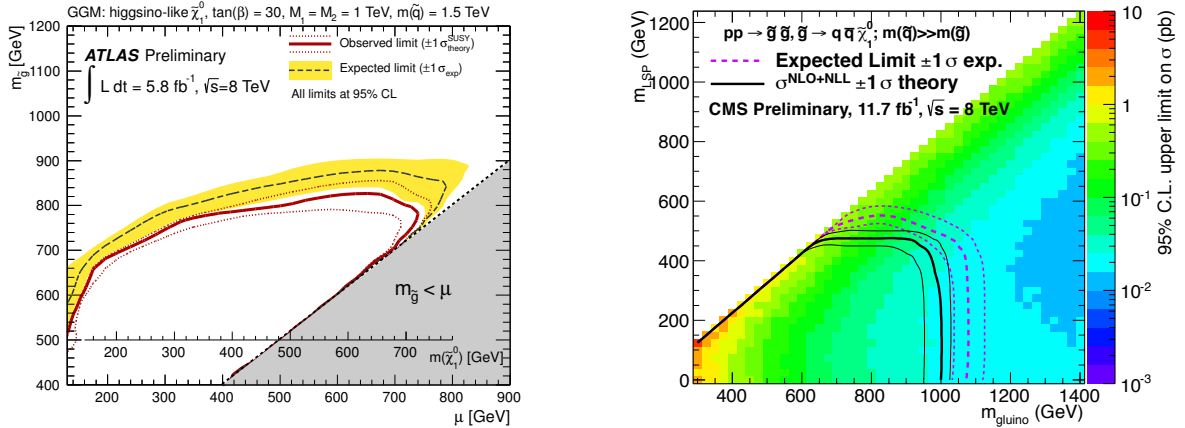


Figure 2: Left: Exclusion limits on the gluino mass and μ parameters for the GGM models with $c\tau_{\text{NLSP}} < 0.1 \text{ mm}$ ⁷. Right: Upper limit on the cross section at 95% confidence level as function of $m(\tilde{g})$ and $m(\tilde{\chi}_1^0)$. The solid black line indicates the observed excluded region¹¹.

presence of jets from bottom quarks, and the presence of a hadronically decaying tau. Together with a binning in S_T , defined as the scalar sum of E_T^{miss} and the transverse momentum (p_T) of jets and leptons, this gives in total 240 event classes, which are then combined to derive exclusion limits. Numerous models with different topologies are considered, probing all three RPV Yukawa couplings individually. In the RPV squark-gluino models, lower limits are set on $m(\tilde{g})$ and $m(\tilde{q})$ of the order of 1 to 2 TeV. In a CMSSM with RPV, $m_{1/2} < 1.15 \text{ TeV}$ is excluded. An update with the full 2012 dataset, limited to interpretations with light scalar top quarks and non-zero leptonic or semileptonic RPV Yukawa couplings, has been made public recently⁶.

Both ATLAS and CMS have analyses motivated from models of general gauge-mediation (GGM) with the lightest neutralino $\tilde{\chi}_1^0$ being the NLSP^{7,8}. ATLAS considers a higgsino-like $\tilde{\chi}_1^0$ which decays predominantly to a Z boson and the gravitino LSP. Thus, events with jets, E_T^{miss} and same-flavour leptons with an invariant mass compatible with a Z boson are selected. Limits are set in the plane spanned by the higgsino mass parameter μ , which is roughly equal to the neutralino mass, and the gluino mass. Now using 5.8 fb^{-1} of data, the limits for $\tan\beta = 1.5$ improve on the 2011 results from the same analysis considerably. At a larger value of $\tan\beta = 30$, the decay $\tilde{\chi}_1^0 \rightarrow h\tilde{G}$ also becomes relevant. The excluded area for this value of $\tan\beta$, however, shown in Figure 2, is barely smaller than that at $\tan\beta = 1.5$. CMS on the other hand considers a bino- or wino-like NLSP, such that the decay to photon plus gravitino or Z plus gravitino, respectively, dominates. Two separate analyses look for events with 1 photon and 2 or more jets, or 2 photons and 1 or more jet, each with a loose selection on E_T^{miss} . With respect to their exclusion limits in the squark and gluino mass plane, the two analyses are comparable, the one-photon channel giving stronger limits in the scenario with a wino-like neutralino where less photons are expected due to the competing $\tilde{\chi}_1^0 \rightarrow Z\tilde{G}$ decays becoming more probable. From 4 fb^{-1} of data, $m(\tilde{g}) < 1.1 \text{ TeV}$ and $m(\tilde{q}) < 1.25 \text{ TeV}$ for a bino-like and $m(\tilde{g}) < 750 \text{ GeV}$ and $m(\tilde{q}) < 850 \text{ GeV}$ for a wino-like neutralino with $m(\tilde{\chi}_1^0) = 375 \text{ GeV}$ are excluded.

The zero-lepton analyses are the latest in a series of inclusive searches for squark and gluino production. In ATLAS, this channel is split into two sub-channels with minimum jet multiplicities of 2 to 6 and 6 to 9, respectively. The most recent publications for both sub-channels use 5.8 fb^{-1} of 2012 data. High jet multiplicities are expected from decays of gluino pairs via off-shell stops, therefore this topology is targeted in the analysis of events with at least 6 to at least 9 jets⁹. The search with at least 2 to at least 6 jets¹⁰ targets final states where each initial squark yields one jet plus E_T^{miss} , and each initial gluino yields two jets plus E_T^{miss} . Selection cuts on the ratio of the effective mass m_{eff} , defined as the scalar sum of E_T^{miss} and the p_T of the jets, the ratio of $E_T^{\text{miss}}/m_{\text{eff}}$, and the minimum angle between jets and E_T^{miss} in the transverse plane are used to suppress the dominant multi-jet background. Events with electrons or muons are rejected. The

limits on $m(\tilde{q})$ and $m(\tilde{g})$ are found to be similar for the mSUGRA/CMSSM implementation and a simplified squark-gluino-neutralino MSSM model: Equal mass light-flavor squarks and gluinos with masses below 1.5 TeV can be excluded. (Note that the values of the parameters for the mSUGRA/CMSSM grid used here differ from those used in the interpretation of the full-search datasets described above.) The corresponding zero-lepton analysis from CMS¹¹ has a different approach to suppress the multi-jet background. It makes use of a kinematic variable computed from the jets in each event, denoted by α_T ¹², to select only events with significant genuine E_T^{miss} . In addition, selected events must have at least 2 jets, no isolated electrons, muons nor photons, and $H_T > 275$ GeV, where H_T is defined as the scalar sum of the transverse energies of the jets. The events are then categorised by the number of jets (2 to 3 or 4 or more) and the number of b -tagged jets and binned in H_T . Standard Model backgrounds are estimated from data control regions, which are mapped to the signal regions using transfer factors obtained from Monte Carlo. Systematic uncertainties on these transfer factors are derived from a set of closure tests. Simplified models are used to interpret the findings in terms of limits on squark or gluino and neutralino masses. With 11.7 fb^{-1} of integrated luminosity, in the models with gluino or squark pair production this search is reported to be sensitive up to $m(\tilde{q}, \tilde{g}) \approx 950$ GeV, $m(\tilde{\chi}_1^0) \approx 450$ GeV or $m(\tilde{q}, \tilde{g}) \approx 775$ GeV, $m(\tilde{\chi}_1^0) \approx 325$ GeV, respectively.

Finally, there is also an ATLAS result with 2012 data for the one-lepton channel with high jet multiplicity¹³, using 5.8 fb^{-1} . The results are interpreted in the same mSUGRA/CMSSM plane as used in the ATLAS zero-lepton analysis described above. Events with exactly one isolated electron or muon, 4 or more jets and large $E_T^{\text{miss}} > 250$ GeV are selected. Additional selection cuts on the transverse mass of the lepton, m_{eff} and $E_T^{\text{miss}}/m_{\text{eff}}$ are applied, after which $W + \text{jets}$ and $t\bar{t}$ production remain as dominant background processes in the signal region. The background reaching the signal region is estimated using a global fit. For equal squark and gluino masses, values up to 1.24 TeV are excluded in the mSUGRA/CMSSM interpretation, for large m_0 the limit on the gluino mass is about 900 GeV. CMS also made public a 2012 update of their one-lepton analysis with interpretations in models of direct top squark pair production.

Overall, there have been many interesting updates from both experiments, demonstrating already now how much the constraints on supersymmetric models can be extended using the full 2012 dataset. None of the analyses has reported any significant excess above the Standard Model background, but on the other hand many more important results will be made public in the course of 2013. And, of course, the new data at higher center-of-mass energy anticipated for 2015 after the restart of the LHC is eagerly awaited.

References

The publications listed below are freely available from the websites of the ATLAS and CMS experiments and the CERN Document Server (<http://cds.cern.ch>).

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