SUPERSYMMETRY, PART II (EXPERIMENT)

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II.1. Introduction

Supersymmetry (SUSY) [1–9] is one of the most compelling possible extensions of the Standard Model of particle physics (SM), and a leading contender for a new principle about nature that could be discovered at high-energy colliders such as the Large Hadron Collider (LHC).

On theoretical grounds SUSY is motivated as a generalization of space-time symmetries. A low-energy realization of SUSY, *i.e.*, SUSY at the TeV scale, is, however, not a necessary consequence. Instead, low-energy SUSY is motivated by the possible cancellation of quadratic divergences in radiative corrections to the Higgs boson mass [10–15]. Furthermore, it is intriguing that a weakly interacting, (meta)stable supersymmetric particle might make up some or all of the dark matter in the universe [16–18]. In addition, SUSY predicts that gauge couplings, as measured experimentally at the electroweak scale, unify at an energy scale $\mathcal{O}(10^{16})$GeV ("GUT scale") near the Planck scale [19–25].

In the minimal supersymmetric extension to the Standard Model, the so called MSSM [26,27,11], a supersymmetry transformation pairs bosons with fermions and therefore relates every particle in the SM to a supersymmetric partner with half a unit of spin difference, but otherwise with the same properties and quantum numbers. These are the "sfermions": squarks and sleptons, the "gauginos," and the partners of the Higgs doublets, the "higgsinos." The charged weak gauginos and higgsinos mix to "charginos," and the neutral ones mix to "neutralinos." The fact that such particles are not yet observed leads to the conclusion that, if supersymmetry is realized, it is a broken symmetry. A description of SUSY in the form of an effective Lagrangian with only "soft" SUSY-breaking terms and SUSY masses at the TeV scale maintains cancellation of quadratic divergences in particle physics models.

The phenomenology of SUSY is to a large extent determined by the SUSY-breaking mechanism and the SUSY-breaking scale. This determines the SUSY particle masses, the mass hierarchy, the field contents of physical particles, and their decay modes. In addition, phenomenology crucially depends on whether the multiplicative quantum number of R-parity [27], $R = (-1)^{3(B-L)+2S}$, where B and L are baryon and lepton numbers and S is the spin, is conserved or violated. If R-parity is conserved, SUSY particles, which have odd R-parity, are produced in pairs and the decays of each SUSY particle must involve an odd number of lighter SUSY particles. The lightest SUSY particle (LSP) is then stable and often assumed to be a weakly interacting massive particle (WIMP). If R-parity is violated, new terms λ_{ijk}, λ'_{ijk} and λ''_{ijk} appear in the superpotential, where ijk are generation indices; λ-type couplings appear between lepton superfields only, λ''-type are between quark superfields only, and λ'-type couplings connect the two. R-parity violation implies lepton and/or baryon number violation. More details of the theoretical framework of SUSY are discussed elsewhere in this volume [28].

Today low-energy data from flavor physics experiments, high-precision electroweak observables as well as astrophysical data impose strong constraints on the allowed SUSY parameter space. Examples of such data include measurements of precision electroweak observables, of the anomalous magnetic moment of the muon and of the cosmological dark matter relic density, as well as limits on rare B-meson and K-meson decays, on electric dipole moments, on proton decay, and on WIMP-nucleon scattering cross sections. These indirect constraints are often more sensitive to higher SUSY mass scales than experiments searching for direct SUSY particle (sparticle) production at colliders, but the interpretation of these results are often strongly model dependent. In contrast, direct searches for sparticle production at collider experiments are much less subject to interpretation ambiguities and therefore they play a crucial role in the discovery strategy for SUSY.

In the rest of this review we limit ourselves to direct searches, covering data analyses at LEP, HERA, the Tevatron and the LHC. With the advent of the LHC, the experimental situation is changing rapidly. Compared to earlier PDG reviews, more emphasis is given to LHC results; for more details on LEP and Tevatron constraints, see earlier PDG reviews [29]. The SUSY Higgs sector is covered elsewhere in this volume [30].

II.2. Experimental search program

The electron-positron collider LEP was operational at CERN between 1989 and 2000. In the initial phase, center-of-mass energies around the Z-peak were probed, but after 1995 the LEP experiments collected a significant amount of luminosity at higher center-of-mass energies, some 235 pb^{-1} per experiment at $\sqrt{s} \geq 204$ GeV, with a maximum $\sqrt{s}$ of 209 GeV.

Searches for new physics at e^+e^- colliders benefit from the clean experimental environment and the fact that momentum balance can be measured not only in the plane transverse to the beam, but also in the direction along the beam (up to the beam pipe holes), the longitudinal direction. Searches at LEP are dominated by the data samples taken at the highest center-of-mass energies. The LEP limits for electroweak gauginos and sleptons are still competitive.

Significant constraints on SUSY have been set by the CDF and D0 experiments at the Tevatron, a proton-antiproton collider at a center-of-mass energy of up to 1.96 TeV. CDF and

D0 have collected integrated luminosities between 10 and 11 fb^{-1} each up to the end of collider operations in 2011.

The electron-proton collider HERA provided collisions to the H1 and ZEUS experiments between 1992 and 2007, at a center-of-mass energy up to 318 GeV. A total integrated luminosity of approximately 0.5 fb^{-1} has been collected by each experiment. Since in *ep* collisions no annihilation process takes place, SUSY searches at HERA typically look for R-parity violating production of single SUSY particles.

The landscape of SUSY searches, however, has significantly changed since the Large Hadron Collider (LHC) at CERN has started proton-proton operation at a center-of-mass energy of 7 TeV in 2010. By the end of 2011 the experiments CMS and ATLAS had collected about 5 fb^{-1} of integrated luminosity each, and the LHCb experiment had collected approximately 1 fb^{-1}.

Proton-(anti)proton colliders produce interactions at higher center-of-mass energies than those available at LEP, and cross sections of QCD-mediated processes are larger, which is reflected in the higher sensitivity for SUSY particles carrying color charge: squarks and gluinos. Large backgrounds, however, pose challenges to trigger and analysis. Such backgrounds are dominated by multijet production processes, including, particularly at the LHC, those of top quark production, as well as jet production in association with vector bosons. The proton momentum is shared between its parton constituents, and in each collision only a fraction of the total center-of-mass energy is available in the hard parton-parton scattering. Since the parton momenta in the longitudinal direction are not known on an event-by-event basis, momentum conservation is restricted to the transverse plane, leading to the use in the experimental analyses of transverse variables, such as the missing transverse momentum, and the transverse mass. Proton-proton collisions at the LHC differ from proton-antiproton collisions at the Tevatron in the sense that there are no valence anti-quarks in the proton, and that gluon-initiated processes play a more dominant role. The increased center-of-mass energy of the LHC compared to the Tevatron significantly extends the kinematic reach for

SUSY searches. This is reflected foremost in the sensitivity for squarks and gluinos, but also for other SUSY particles.

The main production mechanisms of massive colored sparticles at hadron colliders are squark-squark, squark-gluino and gluino-gluino production; when "squark" is used "antisquark" is also implied. The typical SUSY search signature at hadron colliders contains high-p_{T} jets, which are produced in the decay chains of heavy squarks and gluinos, and significant missing momentum originating from the two lightest supersymmetric particles (LSP) produced at the end of the decay chain. Assuming R-parity conservation, the LSPs are neutral and weakly interacting massive particles which escape detection. Backgrounds to such searches arise from multijet events with real missing momentum, dominated by heavy flavor decays, but also from instrumental effects in multijet events such as non-uniform calorimeter response or jet mismeasurement. Selection variables designed to separate the SUSY signal from the backgrounds include H_{T}, $E_{\mathrm{T}}^{\mathrm{miss}}$ and m_{eff}. The quantities H_{T} and $E_{\mathrm{T}}^{\mathrm{miss}}$ refer to the measured energy and missing transverse momentum in the event, respectively. They are usually defined as the scalar (H_{T}) and negative vector sum $E_{\mathrm{T}}^{\mathrm{miss}}$ of the transverse jet energies or transverse calorimeter clusters energies measured in the event. The quantity m_{eff} is referred to as the effective mass of the event and is defined as $m_{\mathrm{eff}} = H_{\mathrm{T}} + |E_{\mathrm{T}}^{\mathrm{miss}}|$. The peak of the m_{eff} distribution for SUSY signal events correlates with the SUSY mass scale [31]. Additional reduction of multijet backgrounds can be achieved by demanding isolated leptons, multileptons or photons in the final states.

In the past few years alternative approaches have been developed to increase the sensitivity to pair production of heavy sparticles with masses around 1 TeV focusing on the kinematics of their decays, and to further suppress the background from multijet production. Prominent examples of these new approaches are searches using the α_{T} [32–34], *razor* [35], *stransverse mass* (m_{T2}) [36], and *contransverse mass* (m_{CT}) [37] variables.

II.3. Interpretation of results

Since the mechanism by which SUSY is broken is unknown, a general approach to SUSY via the most general soft SUSY breaking Lagrangian adds a significant number of new free parameters. For the minimal supersymmetric standard model, MSSM, *i.e.*, the model with the minimal particle content, these comprise 105 new parameters. A phenomenological analysis of SUSY searches leaving all these parameters free is not feasible. For the practical interpretation of SUSY searches at colliders several approaches are taken to reduce the number of free parameters.

One approach is to assume a SUSY breaking mechanism and lower the number of free parameters through the assumption of additional constraints. In particular, interpretations of experimental results are often done in constrained models of gravity mediated [38,39], gauge mediated [40,41], and anomaly mediated [42,43] SUSY breaking. The most popular model for interpretation of collider based SUSY searches is the constrained MSSM (CMSSM) [38,44,45], which in the literature is also referred to as minimal supergravity, or MSUGRA. The CMSSM is described by five parameters: the common sfermion mass m_0, the common gaugino mass $m_{1/2}$, and the common trilinear coupling parameter A_0, all expressed at the GUT scale, the ratio of the vacuum expectation values of the Higgs fields for up-type and down-type fermions $\tan\beta$, and the sign of the Higgsino mass parameter μ. In gauge mediation models, the paradigm of general gauge mediation (GGM) [46] is slowly replacing minimal gauge mediation, denoted traditionally as GMSB (gauge mediated SUSY breaking).

These constrained SUSY models are theoretically well motivated and provide a rich spectrum of experimental signatures. Therefore, they represent a useful framework to benchmark performance, compare limits or reaches and assess the expected sensitivity of different search strategies. However, with universality relations imposed on the soft SUSY-breaking parameters, they do not cover all possible kinematic signatures and mass relations of SUSY. For this reason, an effort has been made in the past years to complement the traditional constrained models with more flexible interpretation approaches.

One answer to study a broader and more comprehensive subset of the MSSM is via the phenomenological-MSSM, or pMSSM [47–49]. It is derived from the MSSM, using experimental data to eliminate parameters that are free in principle but have already been highly constrained by measurements of *e.g.*, flavor mixing and CP-violation. This effective approach reduces the number of free parameters in the MSSM to 19, making it a practical compromise between the full MSSM and highly constrained universality models such as the CMSSM.

Even less dependent on fundamental assumptions are interpretations in terms of so-called simplified models [50–53]. 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. Therefore, simplified models enable comprehensive studies of individual SUSY topologies without limitations on fundamental kinematic properties such as masses, production cross sections, and decay modes.

The landscape of SUSY searches and corresponding interpretations continues to change rapidly and this review covers results up to March 2012. Since none of the searches performed so far have shown significant excess above the SM background prediction, the interpretation of the presented results are exclusion limits on SUSY parameter space. This review will mainly focus on limits expressed in the context of CMSSM, gauge mediation, pMSSM and various simplified models.

II.4. Exclusion limits on gluino and squark masses

Gluinos and squarks are the SUSY partners of gluons and quarks, and thus carry color charge. Although limits on squark masses of the order 100 GeV have been set by the LEP experiments, hadron collider experiments are able to set much higher mass limits. The results of the LHC experiments now dominate the search for direct squark and gluino production. Pair production of these massive colored sparticles at hadron colliders generally involve both s-channel and t-channel parton-parton interactions. Since there is a negligible amount of bottom and top quark content in the proton, top- and bottom squark production proceeds through s-channel diagrams only with small cross sections. Experimental analyses of squark and/or gluino production typically assume the first and second generation squarks to be approximately degenerate in mass.

Assuming R-parity conservation, squarks will predominantly decay to a quark and a neutralino or chargino, if kinematically allowed. Other decay modes depend on the masses of the weak gauginos and may involve heavier neutralinos or charginos. For first and second generation squarks, the simplest decay modes involve two jets and missing momentum, with potential extra jets stemming from initial state radiation (ISR) or from decay modes with longer cascades. Similarly, gluino pair production leads to four jets and missing momentum, and possibly additional jets from ISR or cascades. Associated production of a gluino and a (anti)squark is also possible, in particular if squarks and gluinos have similar masses, typically leading to three or more jets in the final state. In cascades, isolated photons or leptons may appear from the decays of sparticles such as neutralinos or charginos. Final states are thus characterized by significant missing transverse momentum, and at least two, and possibly many more high p_{T} jets, which can be accompanied by one or more isolated objects like photons or leptons, including τ leptons, in the final state. Table 1 shows a schematic overview of characteristic final state signatures of gluino and squark production for different mass hierarchy assumptions.

Table 1: Typical search signatures at hadron colliders for direct gluino and first- and second-generation squark production assuming different mass hierarchies.

Mass Hierarchy	Main Production	Dominant Decay	Typical Signature
$m_{\tilde{q}} << m_{\tilde{g}}$	$\tilde{q}\tilde{q}, \tilde{q}\bar{\tilde{q}}$	$\tilde{q} \to q\tilde{\chi}_1^0$	$\geq$ 2 jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ + X
$m_{\tilde{q}} \approx m_{\tilde{g}}$	$\tilde{q}\tilde{g}, \bar{\tilde{q}}\tilde{g}$	$\tilde{q} \to q\tilde{\chi}_1^0$ $\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$	$\geq$ 3 jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ + X
$m_{\tilde{q}} >> m_{\tilde{g}}$	$\tilde{g}\tilde{g}$	$\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$	$\geq$ 4 jets + $E_{\mathrm{T}}^{\mathrm{miss}}$ + X

II.4.1 Exclusion limits on the gluino mass

Limits set by the Tevatron experiments on the gluino mass assume the framework of the CMSSM, with $\tan\beta = 5$ (CDF) or $\tan\beta = 3$ (D0), $A_0 = 0$ and $\mu < 0$, and amount to lower limits of about 310 GeV for all squark masses, or 390 GeV for the case $m_{\tilde{q}} = m_{\tilde{g}}$ [54,55].

At the LHC, limits on the gluino mass have been set using up to approximately 5 fb^{-1} of data. As shown in Fig. 1, in the framework of the CMSSM, gluino masses below 800 GeV are excluded by the ATLAS collaboration for all squark masses. For equal squark and gluino masses, the limit is about 1400 GeV [56]. Similar results are reported by the CMS collaboration [57]. These limits are dominated by hadronic searches, which veto any contribution from isolated leptons and, for CMS, isolated photons. Although these results are derived for $\tan\beta = 10$, $A_0 = 0$, and $\mu > 0$, they are only mildly dependent on the choice of these CMSSM parameters.

In a simplified model, assuming only gluino pair production and a single decay chain of $\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$, upper limits on gluino pair production are derived as a function of the gluino and neutralino (LSP) mass. As shown in Fig. 2, using the next to leading order cross section for gluino pair production as reference, the CMS collaboration excludes in this simplified model gluino masses below 900 GeV, for a massless neutralino. In scenarios where neutralinos are not very light, the efficiency of analyses is reduced by the fact that jets are less energetic, and there is less missing transverse momentum in the event. Therefore, limits on gluino masses are strongly affected by the assumption of the neutralino mass. For example, for a gluino mass of around 1 TeV the upper limit on the gluino pair production cross section in this simplified model ranges from a few 10^{-2} pb for a massless neutralino to about 1 pb for a neutralino of ≈ 800 GeV. Furthermore, for neutralino masses above $300 - 400$ GeV no general limit on the gluino mass can be set. Similar results have been obtained by ATLAS [60].

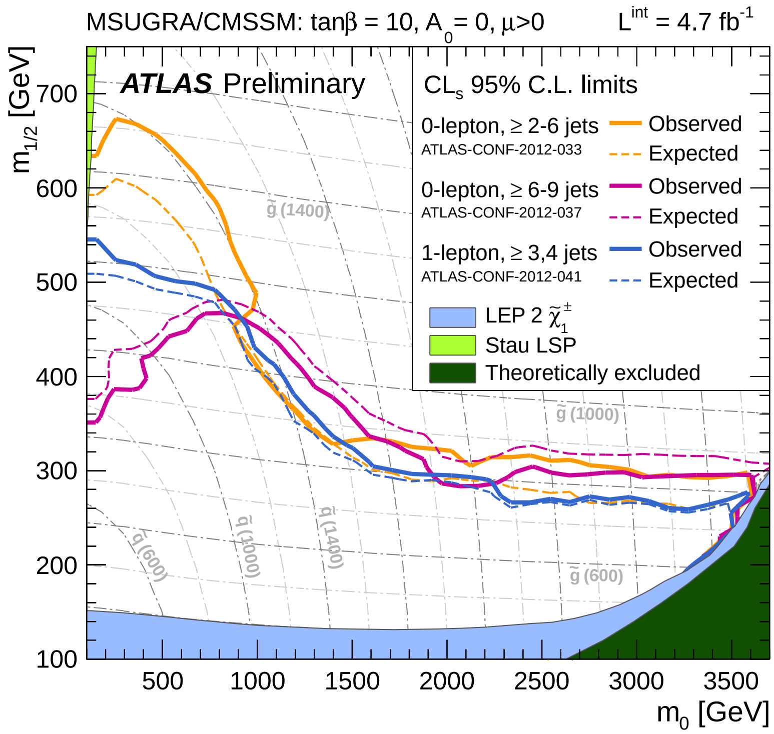

Figure 1: Limits, at 95% C.L., on the CMSSM parameters m_0 and $m_{1/2}$ derived from multi-jet analyes [56,58] and an analysis of jets and one isolated lepton [59] by the ATLAS experiment, for $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$.

If the gluino decay is suppressed, for example if squark masses are high, gluinos may live longer than typical hadronization times. It is expected that such gluinos will hadronize to semi-stable strongly interacting particles known as R-hadrons. Searches for R-hadrons exploit the typical signature of stable charged massive particles in the detector. As shown in Fig. 3, the CMS experiment excludes semi-stable gluino R-hadrons with masses below approximately 1 TeV [61]. The limits depend on the probability for gluinos to form bound states known as gluinoballs, as these are neutral and not observed in the tracking detectors. Similar limits are obtained by the ATLAS experiment [62].

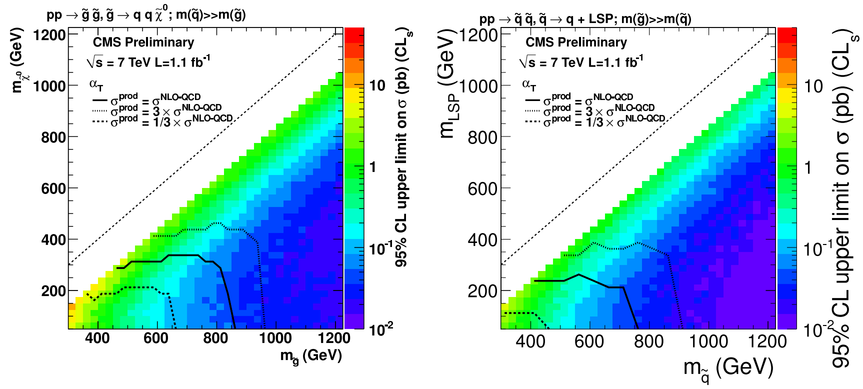

Figure 2: Upper limits, at 95% C.L., on the cross section of gluino pair production (left) or first- or second generation squark pair production (right) set by the CMS collaboration defined in the framework of simplified models assuming a single decay chain of $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$ (left) or $\tilde{q} \rightarrow q\tilde{\chi}_1^0$ (right). The contours illustrate where the reference cross section, calculated at next to leading order, and the upper limit on the cross section intersect. The reference cross section is scaled by a factor 3 or 1/3 to illustrate the effect of cross section or branching ratio variations. The diagonal part of $m_{\tilde{g}/\tilde{q}} - m_{\tilde{\chi}_1^0} < 200$ GeV is not kinematically accessible for the analysis and therefore no limit is provided.

Alternatively, since such R-hadrons are strongly interacting, they may be stopped in the calorimeter or in other material, and decay later into energetic jets. These decays are searched for by identifying the jets outside the time window associated with bunch-bunch collisions [63–65]. The CMS analysis sets limits at 95% C.L. on gluino production over 13 orders of magnitude of gluino lifetime. For a mass difference $m_{\tilde{g}} - m_{\tilde{\chi}_1^0} > 100$ GeV, assuming a 100% branching fraction for gluino decay to gluon + neutralino, gluinos with lifetimes from 10 μs to 1000 s and $m_{\tilde{g}} < 600$ GeV are excluded.

II.4.2. Exclusion limits on first and second generation squark masses

Limits on first and second generation squark masses set by the Tevatron experiments assume the CMSSM model, and

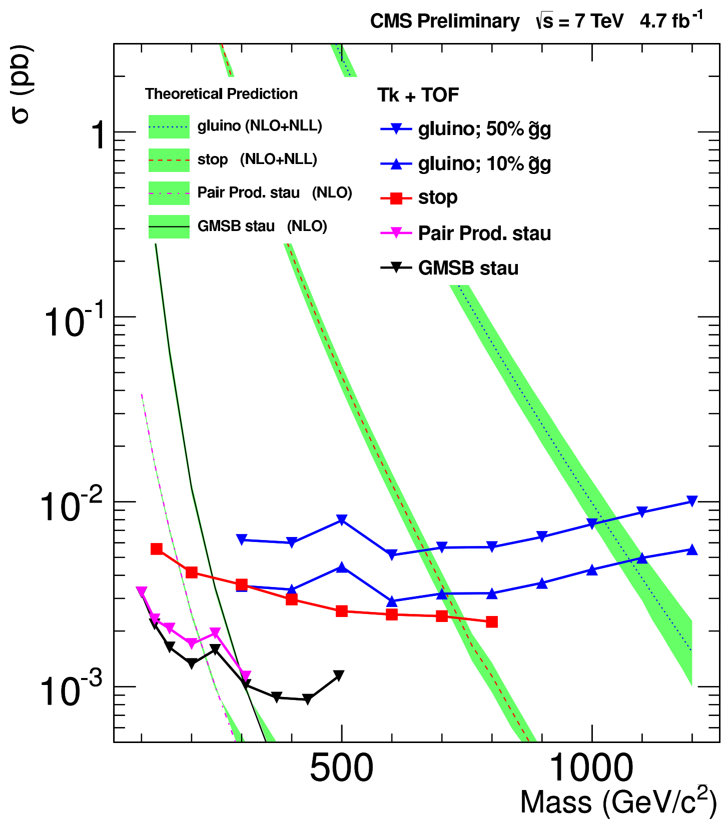

Figure 3: Observed 95% C.L. upper limits on the cross section for different combinations of models and scenarios considered: pair production of semi-stable tau sleptons, top squarks or gluinos. For gluinos, different fractions of gluinoball states produced after hadronization scenarios are indicated. The observed limits are compared with the predicted theoretical cross sections where the bands represent the theoretical uncertainties on the cross section values.

amount to lower limits of about 380 GeV for all gluino masses, or 390 GeV for the case $m_{\tilde{q}} = m_{\tilde{g}}$ [54,55].

At the LHC, limits on squark masses have been set using up to approximately 5 fb^{-1} of data. As for limits on the gluino mass, the highest sensitivity on squark production is obtained from fully-hadronic searches. As shown in Fig. 1, the ATLAS collaboration [56] excludes in the framework of the CMSSM squark masses below 1300 GeV for all gluino masses; for equal squark and gluino masses, the limit is about 1400 GeV. The limits obtained by CMS [57] are again very similar.

An interpretation of the CMS analysis using a simplified model characterizing squark pair production with only one decay chain of $\tilde{q} \to q\tilde{\chi}_1^0$ yields an exclusion of squark masses below 750 GeV for a massless neutralino (see Fig. 2). The effects of heavy neutralinos on squark limits are similar to those discussed in the gluino case (see section "Exclusion limits on the gluino mass") and only for neutralino masses below $200 - 300$ GeV squark masses can be excluded.

The ATLAS analysis [56] is also interpreted in the framework of a simplified model with only squark and gluino production, for a massless neutralino, and assuming that all other sparticles are very massive. Results are shown in Fig. 4. In this interpretation, squark masses below 1500 GeV are excluded for $m_{\tilde{g}} \approx m_{\tilde{q}}$, while for large gluino masses the limit is reduced to about 1400 GeV in squark mass. Increasing the neutralino mass to values above ~ 200 GeV again leads to a degradation of these limits.

An overview of exclusion limits on first and second generation squark and gluino masses from CMS for different simplified models [66] is shown in Fig. 5. Like for the other simplified model limits, the reference cross sections for the different processes are calculated at next to leading order precision. To illustrate the impact of the neutralino mass on the limits, two mass scenarios for $m_{\tilde{\chi}_1^0} = 0$ GeV (dark blue) and $m_{\rm mother} - m_{\tilde{\chi}_1^0}$ $= 200$ GeV (light blue) are presented. As expected, the simplified model exclusion limits vary strongly with the assumption on the mass splitting ($m_{\rm mother} - m_{\tilde{\chi}_1^0}$) between the mother sparticle and LSP. The exclusion limits are strongest for maximal mass splitting and significantly weaken for more compressed spectra. Depending on the simplified model, the least stringent limits for compressed spectra are in the range of 400 GeV to 550 GeV, while the most stringent ones for maximal splitting are in the range of 650 GeV to 900 GeV. The corresponding results of ATLAS are very similar [67].

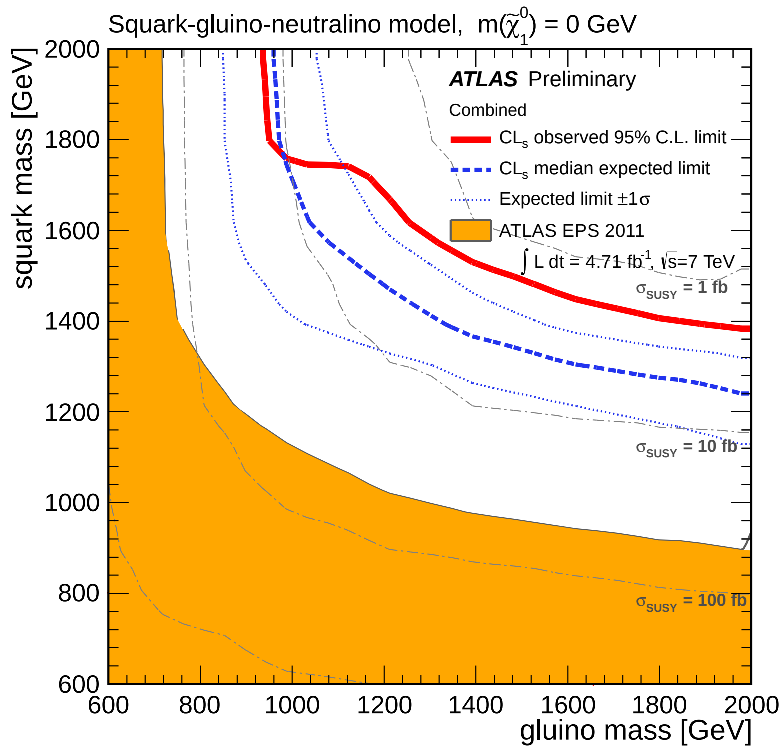

Figure 4: Limits on the masses of gluinos and first and second generation squarks, at 95% C.L., derived by ATLAS using simplified models with a massless neutralino, and assuming that the masses of all other SUSY particles are very large.

A summary of the most important first generation squark and gluino mass limits for different interpretations assuming R-parity conservation is shown in Table 2.

R-parity violating production of single squarks via a λ'-type coupling has been studied at HERA. In such models, a lower limit on the squark mass of the order of 275 GeV has been set for electromagnetic-strength-like couplings $\lambda' = 0.3$ [68].

II.4.3. Exclusion limits on third generation squark masses

TeV-scale SUSY is often motivated by naturalness arguments, most notably as a solution to stabilize quadratic divergences in radiative corrections to the Higgs boson mass. In this context, the most relevant terms for SUSY phenomenology arise from the interplay between the masses of the third generation

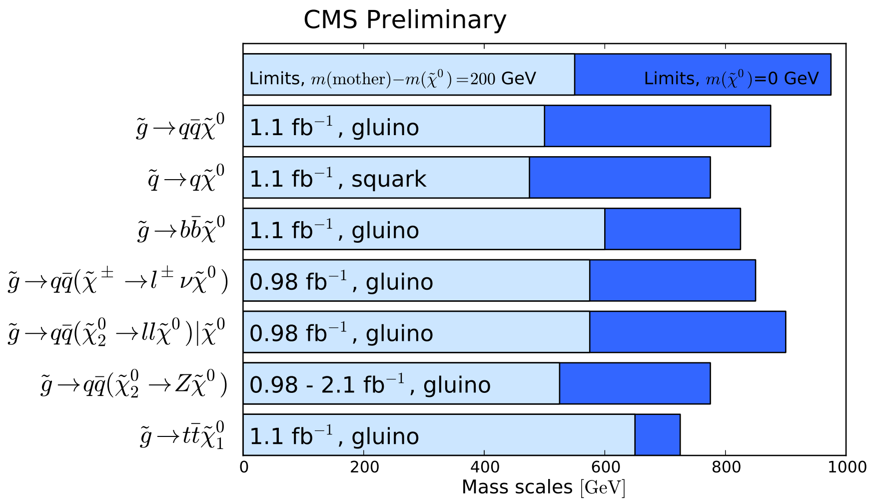

Figure 5: Exclusion limits, at 95% C.L., on first- or second generation squark and gluino masses from CMS for different simplified models. The reference cross sections for gluino and squark pair production are calculated at next to leading order precision and the branching fraction of their decays to daughter particles is assumed to be 100%. To show the impact of the neutralino mass on the limits, two mass scenarios are displayed: $m_{\tilde\chi^0_1} = 0$ GeV (dark blue) and $m_{\text{mother}} - m_{\tilde\chi^0_1} = 200$ GeV (light blue).

squarks and the (large) Yukawa coupling of the top quark to the Higgs boson. This motivates a potential constraint on the masses of the top squarks and the left-handed bottom squark. Due to the large top quark mass, significant mixing between $\tilde t_{\text{L}}$ and $\tilde t_{\text{R}}$ is expected, leading to a lighter mass state $\tilde t_1$ and a heavier mass state $\tilde t_2$. In much of MSSM parameter space, the lightest top squark ($\tilde t_1$) is also the lightest squark. Top squark masses below the top quark mass are not excluded.

In the absence of a SUSY discovery so far, searches for third generation squark production have become a major focus. Direct- and gluino mediated top and/or bottom squark production processes, leading to experimental signatures that are rich in jets originating from bottom quarks (b-jets), are either

Table 2: Summary of first- or second generation squark mass and gluino mass limits using different interpretation approaches assuming R-parity conservation. Masses in this table are provided in GeV.

Model	Assumption	$m_{\tilde{q}}$	$m_{\tilde{g}}$
CMSSM	$m_{\tilde{q}} \approx m_{\tilde{g}}$	1400	1400
	all $m_{\tilde{q}}$	-	800
	all $m_{\tilde{g}}$	1300	-
Simplified model $\tilde{g}\tilde{g}$	$m_{\tilde{\chi}_1^0}$ =0	-	900
	$m_{\tilde{\chi}_1^0} > 300$	-	no limit
Simplified model $\tilde{q}\tilde{q}$	$m_{\tilde{\chi}_1^0} = 0$	750	-
	$m_{\tilde{\chi}_1^0} > 250$	no limit	-
Simplified model $\tilde{g}\tilde{q}, \tilde{g}\bar{\tilde{q}}$	$m_{\tilde{\chi}_1^0}$= 0, $m_{\tilde{q}} \approx m_{\tilde{g}}$	1500	1500
	$m_{\tilde{\chi}_1^0}$= 0, all $m_{\tilde{g}}$	1400	-
	$m_{\tilde{\chi}_1^0}$= 0, all $m_{\tilde{q}}$	-	900

subject of re-interpretation of inclusive analyses or targets for dedicated third generation squark searches. This review contains results up to March 2012, but more results from the LHC experiments on the 2011 data sample are expected.

The top squark decay modes depend on the SUSY mass spectrum. If kinematically allowed, $\tilde{t} \to t\tilde{\chi}^0$ and $\tilde{t} \to b\tilde{\chi}^{\pm}$ are expected to dominate. If not, $\tilde{t} \to bf\bar{f}'\tilde{\chi}^0$ (where f and $\bar{f}'$ denote a fermion-antifermion pair with appropriate quantum numbers) or the two-body decay $\tilde{t} \to c\tilde{\chi}^0$ is open. For light sneutrinos, $\tilde{t} \to b\ell\tilde{\nu}$ needs to be taken into account.

Limits from LEP on the $\tilde{t}_1$ mass are > 96 GeV in the charm plus neutralino final state, and > 93 GeV in the lepton, b-quark and sneutrino final state [69].

Direct production of top squark pairs at hadron colliders is suppressed with respect to first generation squarks, due to the absence of t-quarks in the proton. At the LHC, for example, this suppression is typically a factor 100 at $m_{\tilde{t}} = 600$ GeV. Moreover, at the LHC, there is a very large background of top quark pair production, making experimental analysis of top squark pair production a challenge.

The Tevatron experiments have performed a number of searches for top squarks, often assuming direct pair production. In the $b\ell\tilde{\nu}$ decay channel, and assuming a 100% branching fraction, limits are set as $m_{\tilde{t}} > 210$ GeV for $m_{\tilde{\nu}} < 110$ GeV and $m_{\tilde{t}} - m_{\tilde{\nu}} > 30$ GeV, or $m_{\tilde{t}} > 235$ GeV for $m_{\tilde{\nu}} < 50$ GeV [70,71]. In the $\tilde{t} \rightarrow c\tilde{\chi}^0$ decay mode, a top squark with a mass below 180 GeV is excluded for a neutralino lighter than 95 GeV [72,73]. In both analyses, no limits on the top squark can be set for heavy sneutrinos or neutralinos. In the $\tilde{t} \rightarrow b\tilde{\chi}_1^{\pm}$ decay channel, searches for a relatively light top squark have been performed in the dilepton final state [74,75]. CDF sets limits in the $\tilde{t} - \tilde{\chi}_1^0$ mass plane for various branching fractions of the chargino decay to leptons and for two values of $m_{\tilde{\chi}_1^{\pm}}$. For $m_{\tilde{\chi}_1^{\pm}} = 105.8$ GeV and $m_{\tilde{\chi}_1^0} = 47.6$ GeV, top squarks between 128 and 135 GeV are excluded for W-like leptonic branching fractions of the chargino.

Top squarks may also be the product of gluino decays, if kinematically allowed: $\tilde{g} \rightarrow \tilde{t}t$. This leads to the characteristic "four tops" final state $tttt\tilde{\chi}_1^0\tilde{\chi}_1^0$, *i.e.*, a signature with as many as four isolated leptons, four b-jets, several light quark jets, and significant missing momentum from the neutrinos in the W decay and the two neutralinos. At the LHC, such final states are searched for in analyses demanding b-tagged jets and a lepton, or two leptons of the same charge (same-sign leptons), or many jets plus large missing momentum [76–78].

The interpretation of the results is performed in simplified models assuming specific decay modes, and MSSM production cross sections. Assuming the top squark is light enough, a simplified model with the decay chain $\tilde{g} \rightarrow \tilde{t}t$ and $\tilde{t} \rightarrow t\tilde{\chi}_1^0$ is used to characterize the reach of the searches, with gluino mass, stop mass and neutralino mass as free parameters. As shown in Fig. 6, a CMS search for same-sign lepton production accompanied with b-jets excludes gluino masses below some 850 GeV for top squark masses up to 650 GeV [78].

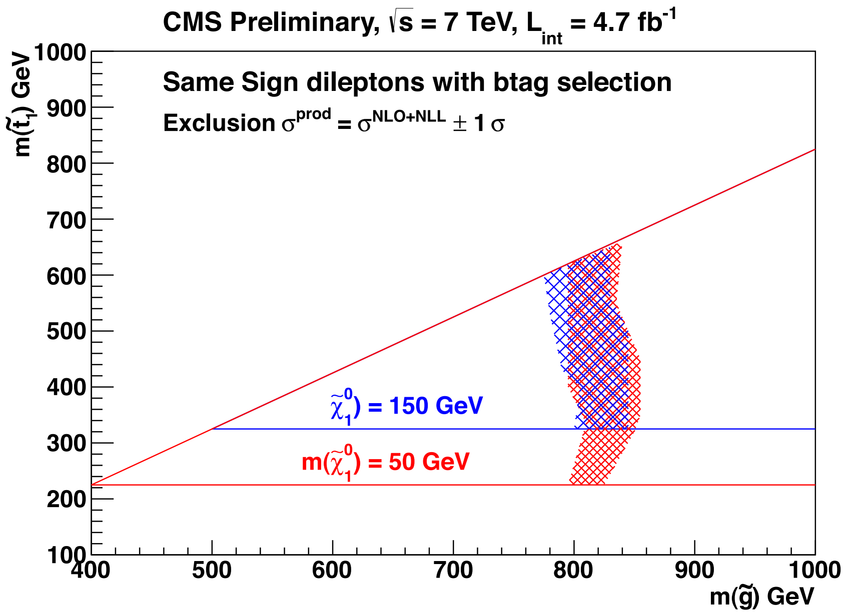

Figure 6: 95% C.L. exclusion in the stop-gluino mass plane for different choices of the neutralino mass. The used simplified model assumes the decay chain $\tilde{g} \to \tilde{t}t$, $\tilde{t} \to t\tilde{\chi}_1^0$. The bands represent the theoretical uncertainty on the gluino pair production cross-section.

Taking into account top squark decay via $\tilde{t} \to t\tilde{\chi}_1^0$, and thus assuming $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$, as shown in Fig. 7, an ATLAS analysis searching for multijet plus $E_{\mathrm{T}}^{\mathrm{miss}}$ final states excludes gluino masses below 880(830) GeV for $m_{\tilde{\chi}_1^0} < 100(200)$ GeV [58]. For neutralino masses above 250 GeV, no limit can be placed on the top squark mass for this scenario.

R-parity violating production of single top squarks has been searched for at HERA [79]. Top squarks are assumed to be produced via a λ' coupling and decay either to $b\tilde{\chi}_1^{\pm}$ or R-parity-violating to a lepton and a jet. Limits are set on λ'_{131} as a function of the top squark mass in an MSSM framework with gaugino mass unification at the GUT scale. Within a variant of the CMSSM with R-parity violation, and assuming $\tan\beta = 6$, $A_0 = 0$, $\mu < 0$, a top squark with mass below 260 GeV is excluded for $\lambda' = 0.3$.

Top squarks can also be long-lived and hadronize to a R-hadron, for example in the scenario where the top squark

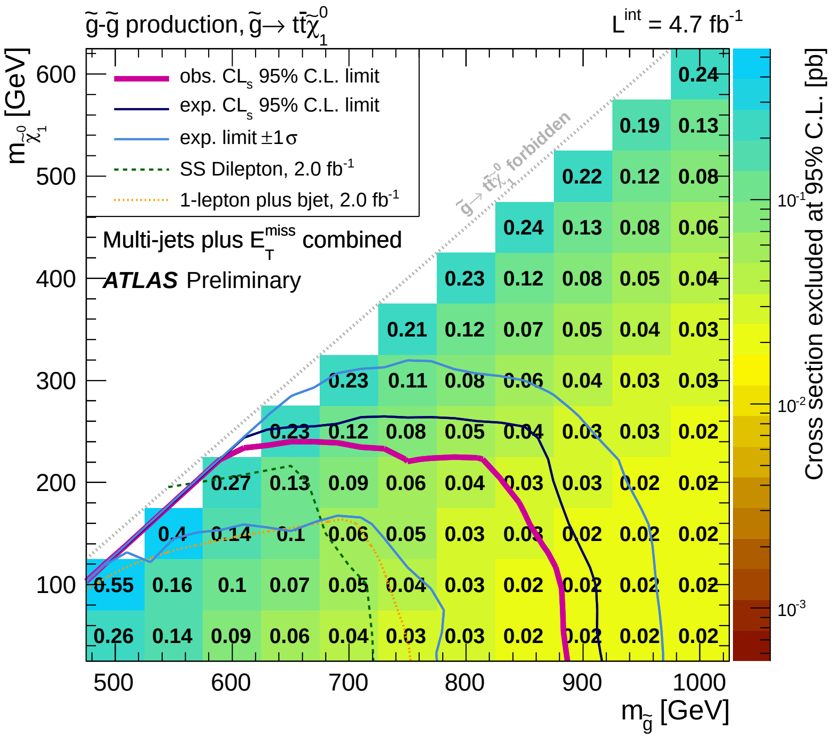

Figure 7: 95% C.L. upper limits on the cross section for gluino pair production as a function of gluino and neutralino mass. The used simplified model assumes the decay $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$. The contours illustrate where the reference cross section and the upper limit on the cross section intersect. Apart from the limit of the multijet analysis, also limits arising from a same-sign dilepton analysis, and a lepton plus b-jet analysis are shown.

is the next-to-lightest SUSY particle (NLSP), with a small mass difference to the LSP. Searches for massive stable charged particles are sensitive to such top squarks. As shown in Fig. 3 for the CMS analysis [61], the LHC experiments have set limits $m_{\tilde{t}} > 720$ GeV in such scenarios, surpassing the earlier Tevatron limits of about 300 GeV [80,81].

Bottom squarks are expected to decay predominantly to $b\tilde{\chi}^0$. Direct production of bottom squark pairs has been studied at the Tevatron and at the LHC. Limits from the Tevatron are $m_{\tilde{b}} > 247$ GeV for a massless neutralino [82,83]. The LHC experiments now surpass these limits; as shown in Fig. 8, ATLAS has set a limit of $m_{\tilde{b}} > 392$ GeV for the same scenario, and $m_{\tilde{b}} > 375$ GeV for $m_{\tilde{\chi}_1^0} < 100$ GeV [84].

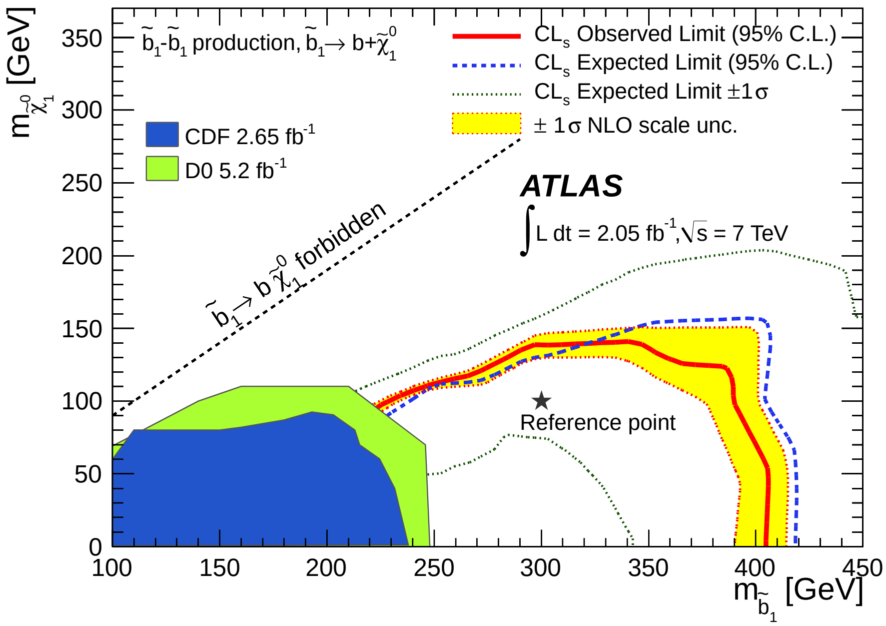

Figure 8: 95% C.L. exclusion contours in the sbottom-neutralino mass plane, for direct bottom squark pair production followed by the decay $\tilde{b} \to b\tilde{\chi}_1^0$.

Gluino pair production followed by $\tilde{g} \to \tilde{b}b$ has been searched for [85–86], and results exclude a gluino with a mass below 920 GeV for sbottom masses below 750 GeV and a light neutralino. Interpreting this search in a simplified model for gluino pair production and $\tilde{g} \to b\bar{b}\tilde{\chi}_1^0$ excludes a gluino with a mass below 900 GeV for neutralino masses below 300 GeV.

II.5. Exclusion limits on slepton masses

In models with slepton and gaugino mass unification at the GUT scale, the right-handed slepton, $\tilde{\ell}_{\mathrm{R}}$, is expected to be lighter than the left-handed slepton, $\tilde{\ell}_{\mathrm{L}}$. For tau sleptons there may be considerable mixing between the L and R states, leading to a significant mass difference between the lighter $\tilde{\tau}_1$ and the heavier $\tilde{\tau}_2$.

II.5.1. Exclusion limits on the masses of charged sleptons

The cleanest searches for selectrons, smuons and staus originate from the LEP experiments [87]. Smuon production only takes place via s-channel γ^*/Z exchange. Search results are often quoted for $\tilde{\mu}_\mathrm{R}$, since it is typically lighter than $\tilde{\mu}_\mathrm{L}$ and has a weaker coupling to the Z boson; limits are therefore conservative. Decays are expected to be dominated by $\tilde{\mu}_\mathrm{R} \to \mu\tilde{\chi}_1^0$, leading to two non-back-to-back muons and missing momentum. Limits are calculated in the MSSM under the assumption of gaugino mass unification at the GUT scale, and depend on the mass difference between the smuon and $\tilde{\chi}_1^0$. A $\tilde{\mu}_\mathrm{R}$ with a mass below 94 GeV is excluded for $m_{\tilde{\mu}_\mathrm{R}} - m_{\tilde{\chi}_1^0} > 10$ GeV. The selectron case is similar to the smuon case, except that an additional production mechanism is provided by t-channel neutralino exchange. The $\tilde{e}_\mathrm{R}$ lower mass limit is 100 GeV for $m_{\tilde{\chi}_1^0} < 85$ GeV. Due to the t-channel neutralino exchange, $\tilde{e}_\mathrm{R}\tilde{e}_\mathrm{L}$ pair production was possible at LEP, and a lower limit of 73 GeV was set on the selectron mass regardless of the neutralino mass. The potentially large mixing between $\tilde{\tau}_\mathrm{L}$ and $\tilde{\tau}_\mathrm{R}$ not only makes the $\tilde{\tau}_1$ light, but also decreases its coupling to the Z boson. LEP limits range between 87 and 93 GeV depending on the $\tilde{\chi}_1^0$ mass, for $m_{\tilde{\tau}} - m_{\tilde{\chi}_1^0} > 7$ GeV [87].

In gauge-mediated SUSY breaking models, sleptons can be (co-)NLSPs, *i.e.*, the next-to-lightest SUSY particles and almost degenerate in mass, decaying to a lepton and a gravitino. This decay can either be prompt, or the slepton can have a non-zero lifetime. Combining several analyses, lower mass limits on $\tilde{\mu}_\mathrm{R}$ of 96.3 GeV and on $\tilde{e}_\mathrm{R}$ of 66 GeV are set for all slepton lifetimes at LEP [88]. In a considerable part of parameter space in these models, the $\tilde{\tau}$ is the NLSP. The LEP experiments have set lower limits on the mass of such a $\tilde{\tau}$ between 87 and 97 GeV, depending on the $\tilde{\tau}$ lifetime. ATLAS has searched for final states with τs, jets and missing transverse momentum, and has interpreted the results in GMSB models setting limits on the model parameters [89,90]. CMS has interpreted a multilepton analysis in terms of limits on gauge mediation models with slepton (co-)NLSP [91].

Limits also exist on sleptons in R-parity violating models, both from LEP and the Tevatron experiments. From LEP, lower limits on $\tilde{\mu}_{\mathrm{R}}$ and $\tilde{e}_{\mathrm{R}}$ masses in such models are 97 GeV, and the limits on the stau mass are very close: 96 GeV [92].

Charged slepton decays may be kinematically suppressed, for example in the scenario of a NLSP slepton with a very small mass difference to the LSP. Such a slepton may appear to be a stable charged massive particle. Interpretation of searches at LEP for such signatures within GMSB models with stau NLSP or slepton co-NLSP exclude masses up to 99 GeV [93]. Searches of stable charged particles at the Tevatron [80,81] and at the LHC [94,61] are also interpreted in terms of limits on stable charged sleptons. As shown in Fig. 3, CMS excludes stable staus with masses below approximately 300 GeV [61].

II.5.2. Exclusion limits on sneutrino masses

The invisible width of the Z boson puts a lower limit on the sneutrino mass of about 45 GeV. Tighter limits are derived from other searches, notably for gauginos and sleptons, under the assumption of gaugino and sfermion mass universality at the GUT scale, and amount to approximately 94 GeV in the MSSM. It is possible that the lightest sneutrino is the LSP; however, a lefthanded sneutrino LSP is ruled out as a cold dark matter candidate [95,96].

Production of pairs of sneutrinos in R-parity violating models has been searched for at LEP [92]. Assuming fully leptonic decays via λ-type couplings, lower mass limits between 85 and 100 GeV are set. At the Tevatron [97,98] and at the LHC [99], searches have focused on scenarios with resonant production of a sneutrino, decaying to $e\mu$ final states (as well as to $\mu\tau$, and $e\tau$ for CDF). No signal has been seen, and limits have been set on sneutrino masses as a function of the value of relevant RPV couplings. As an example, the ATLAS analysis excludes a resonant tau sneutrino with a mass below 600 GeV for $\lambda_{312} > 0.01$ and $\lambda'_{311} > 0.01$ [99].

II.6. Exclusion limits on the masses of charginos and neutralinos

Charginos and neutralinos result from mixing of the charged wino and higgsino states, and the neutral bino, wino and higgsino states, respectively. The mixing is determined by a limited number of parameters. For charginos these are the wino mass parameter M_2, the Higgsino mass parameter μ, and $\tan\beta$, and for neutralinos these are the same parameters plus the bino mass parameter M_1. The mass states are four charginos $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^{\pm}$, and four neutralinos $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, $\tilde{\chi}_3^0$ and $\tilde{\chi}_4^0$, ordered in increasing mass. Depending on the mixing, the chargino and neutralino composition is dominated by specific states, which are referred to as bino-like ($M_1 << M_2, \mu$), wino-like ($M_2 << M_1, \mu$), or Higgsino-like ($\mu << M_1, M_2$). If gaugino mass unification at the GUT scale is assumed, a relation between M_1 and M_2 at the electroweak scale follows: $M_1 = 5/3\tan^2\theta_W M_2 \approx 0.5M_2$ (with θ_W the weak mixing angle), with consequences for the chargino-neutralino mass relation after mixing. Charginos and neutralinos carry no color charge, and only have electroweak couplings (neglecting gravity).

II.6.1. Exclusion limits on chargino masses

If kinematically allowed, two body decay modes such as $\tilde{\chi}^{\pm} \rightarrow \ell^{\pm}\tilde{\nu}$ are dominant. If not, three body decay $\tilde{\chi}^{\pm} \rightarrow f\bar{f}'\tilde{\chi}^0$ are mediated through virtual W bosons or sfermions. If sfermions are heavy, the W mediation dominates, and $f\bar{f}'$ are distributed with branching fractions similar to W decay products. If, on the other hand, sleptons are light enough to play a significant role in the decay mediation, leptonic final states will be enhanced.

At LEP, charginos have been searched for in fully-hadronic, semi-leptonic and fully leptonic decay modes [100,101]. A general lower limit on the lightest chargino mass of 103.5 GeV is derived, except in corners of phase space with low electron sneutrino mass, where destructive interference in chargino production, or two-body decay modes, play a role. The limit is also affected if the mass difference between $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$ is small; dedicated searches for such scenarios set a lower limit of 92 GeV.

At the Tevatron, charginos are searched for via production of a pair of charginos, or associated production of $\tilde{\chi}_1^{\pm} + \tilde{\chi}_2^0$. Decay modes involving multilepton final states provide the best discrimination against the large multijet background. Analyses look for at least three charged isolated leptons, or for two leptons with the same charge. Depending on the $\tilde{\chi}_1^\pm - \tilde{\chi}_1^0$ and/or $\tilde{\chi}_2^0 - \tilde{\chi}_1^0$ mass differences, leptons may be soft. In a recent CDF analysis, results are interpreted in CMSSM-inspired scenarios, with $\tan\beta = 3$, $A_0 = 0$ and $\mu > 0$, and assuming $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_2^0} = 2m_{\tilde{\chi}_1^0}$ [102]. Slepton masses are either assumed to be just above $m_{\tilde{\chi}^\pm}$, maximizing leptonic branching ratios in three-body chargino decays, or to be very large. In the first scenario, charginos with a mass below 168 GeV are excluded. D0 excludes a chargino below 130 GeV for the maximized leptonic branching fraction case for all $\tan\beta < 10$, and sets limits in the CMSSM $m_0 - m_{1/2}$ plane for $\tan\beta = 3$, $A_0 = 0$, and $\mu > 0$ [103].

At the LHC, the search strategy is similar to that at the Tevatron. In an ATLAS analysis of the three lepton final state [104], interpretation of the results is performed in the MSSM as well as using simplified models. In the MSSM, a scan over M_2 and μ is made for $M_1 = 100$ GeV and $\tan\beta = 6$, and M_2 values below 350 GeV are excluded for $|\mu| < 190$ GeV. The simplified models assume $\tilde{\chi}_1^\pm + \tilde{\chi}_2^0$ production, and $m_{\tilde{\chi}^\pm} = m_{\tilde{\chi}_2^0}$, leaving $m_{\tilde{\chi}^\pm}$ and $m_{\tilde{\chi}_1^0}$ free. In a scenario that favors leptonic decays of $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$, charginos with masses up to 300 GeV are excluded for massless neutralinos, and charginos up to 250 GeV are excluded for $m_{\tilde{\chi}_1^0} < 150$ GeV. More LHC results in these channels based on the 2011 data sample are expected.

In both the wino region (a characteristic of anomaly-mediated SUSY-breaking models) and the higgsino region of the MSSM, the mass splitting between $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^0$ is small. In such scenarios, charginos may be long-lived. Charginos decaying in the detectors away from the primary vertex could lead to signatures such as kinked-tracks, or apparently disappearing tracks, since, for example, the pion in $\tilde{\chi}_1^\pm \to \pi^\pm \tilde{\chi}_1^0$ might be too soft to be reconstructed. At the LHC, a search has been performed for such disappearing tracks, and interpreted with anomaly-mediated SUSY breaking models. For specific AMSB parameters, charginos with lifetimes between 0.2 and 90 ns are excluded for chargino masses up to 90 GeV, and limits reach up to 118 GeV for lifetimes around 1 ns [105].

Charginos with a lifetime longer than the time needed to pass through the detector appear as charged stable massive particles. Limits have been derived by the LEP experiments [93] and by D0 at the Tevatron [81]. D0 results exclude higgsino-like stable charginos below 217 GeV, and gaugino-like stable charginos below 267 GeV.

II.6.2. Exclusion limits on neutralino masses

In a considerable part of the MSSM parameter space, and in particular when demanding that the LSP carries no electric or color charge, the lightest neutralino $\tilde{\chi}_1^0$ is the LSP. If R-parity is conserved, such a $\tilde{\chi}_1^0$ is stable. Since it is weakly interacting, it will typically escape detectors unseen. Limits on the invisible width of the Z boson apply to neutralinos with a mass below 45.5 GeV, but depend on the Z-neutralino coupling. Such a coupling could be small or even absent; in such a scenario there is no general lower limit on the mass of the lightest neutralino [106]. In models with gaugino mass unification at high energy scales, a neutralino mass limit is derived from the chargino mass limit, and amounts to 47 GeV. Assuming a constraining model like the CMSSM, this limit increases to 50 GeV at LEP; however the strong constraints now set by the LHC increase such CMSSM-derived $\tilde{\chi}_1^0$ mass limits to well above 100 GeV.

Even though a LSP neutralino is only weakly interacting, collider experiments are not blind to neutralino pair production. Pair production of neutralinos accompanied by initial state radiation could lead to an observable final state. At LEP, final states with only a single isolated photon were studied, but backgrounds from neutrino pair production were too large. At hadron colliders, monojet final states have been used to set limits on the pair production cross section [107,108].

The lightest neutralino can decay in models with R-parity violation, or in cases where it is not the LSP, as in gauge mediation models. In the latter case, a NLSP neutralino will decay to a gravitino and a SM particle whose nature is determined by the neutralino composition. Final states with two high p_{T} photons and missing momentum are searched for, and interpreted in gauge mediation models with bino-like neutralinos [109–113]. Assuming only gluino pair production and a bino-like neutralino produced in gluino decay, limits on gluino masses of about 1 TeV are set for all neutralino masses, as shown in Fig. 9 for the CMS diphoton analysis.

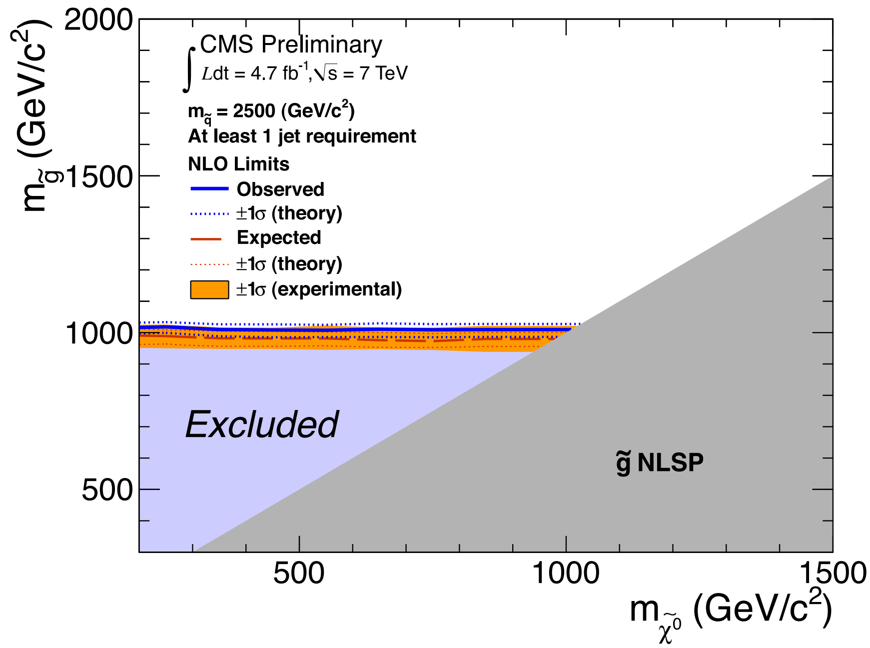

Figure 9: Observed 95% C.L. limits on the gluino mass as a function of the neutralino mass, in general gauge mediation models assuming only gluino pair production, with a bino-like neutralino produced in gluino decay, and a neutralino decay to photon plus gravitino.

Assuming the production of at least two neutralinos per event, neutralinos with large non-bino components can also be searched for in ZZ and γZ final states. Searches for final states with Z ($\rightarrow \ell^+\ell^-$) bosons and missing transverse momentum have been performed at the Tevatron [114] and at the LHC [115], and are interpreted in such models.

In gauge mediation models, NLSP neutralino decay need not be prompt, and experiments have searched for late decays. CDF have searched for delayed $\tilde{\chi}_1^0 \rightarrow \gamma Z$ decays using the timing of photon signals in the calorimeter [116], and exclude a neutralino with mass below 101 GeV with a lifetime of 5 ns. CMS has used converted photons to search for photon production away from the primary vertex [117]. Results are given as upper limits on the neutralino production cross section of order 0.12 − 0.24 pb for $c\tau$ between 5 and 25 cm. D0 has looked at the direction of showers in the electromagnetic calorimeter with a similar goal [118].

Heavier neutralinos, in particular $\tilde{\chi}_2^0$, have been searched for in their decays to the lightest neutralino plus a Z boson. Analyses include searches for Z production plus missing energy, Z plus jets plus missing energy, two Z bosons plus missing energy, and Z plus W production plus missing energy [118,119–122]. In $\tilde{\chi}_2^0$ decays to $\tilde{\chi}_1^0$ and a lepton pair, the lepton pair invariant mass distribution may show a structure that can be used to measure the $\tilde{\chi}_2^0 - \tilde{\chi}_1^0$ mass difference in case of a signal [123], but it can also be used in the search itself, in order to suppress background [124].

II.7. Global interpretations

Apart from the interpretation of the direct searches for sparticle production at colliders in terms of limits on masses of individual SUSY particles, model-dependent interpretations of allowed SUSY parameter space are derived from global SUSY fits. Typically these fits combine the results from collider experiments with indirect constraints on SUSY as obtained from low-energy experiments, flavor physics, high-precision electroweak results, and astrophysical data.

In the pre-LHC era these fits were mainly dominated by indirect constraints. Even for very constrained models like the CMSSM, the allowed parameter space, in terms of squark and gluino masses, ranged from several hundreds of GeV to a few TeV. For the theoretically well motivated class of constrained supergravity models like the CMSSM, global fits indicated that squarks and gluino masses in the range of 500 to 1000 GeV were the preferred region of parameter space, although values as high as few TeV were allowed with lower probabilities [125].

With ATLAS and CMS now probing mass scales around 1 TeV and even beyond, the importance of the direct searches for global analyses of allowed SUSY parameter space has significantly increased. For example, imposing the new experimental limits on constrained supergravity models pushes the most likely values of first generation squark and gluino masses beyond 1 TeV, typically resulting in overall values of fit quality significantly worse than those in the pre-LHC era [126]. Although these constrained models are not yet ruled out, the extended experimental limits impose tight constraints on the allowed parameter space.

For this reason, the emphasis of global SUSY fits has shifted more towards less-constrained SUSY models. Especially interpretations in the pMSSM [48,127,128] and in simplified models have been useful to generalize SUSY searches, for example in order to increase their sensitivity for compressed spectra where the mass of the LSP is much closer to squark and gluino masses than predicted by for example the CMSSM. As shown in Table 2, for neutralino masses above a few hundred GeV the current set of ATLAS and CMS searches cannot exclude the existence of light squarks and gluinos.

II.8. Summary and Outlook

Although the search for SUSY at the LHC has just begun, results of the ATLAS and CMS experiments are already probing direct production of colored SUSY particles at the 1 TeV mass scale. So far no evidence of new particle production has been observed in the data and therefore limits on allowed parameter space in various models have been set. While typically squark and gluino masses around 1 TeV and below are excluded in constrained models, weaker bounds on SUSY particle masses are obtained in less constrained scenarios demonstrating that SUSY below the 1 TeV scale is certainly not ruled out in general. For non-colored sparticles the impact of the LHC is to a large extent yet to come, and limits from LEP and the Tevatron are still competitive. An overview of the current landscape of SUSY searches and corresponding exclusion limits at the LHC is shown in Fig. 10 from the ATLAS experiment [67]. The corresponding results of the CMS experiment are similar [66].

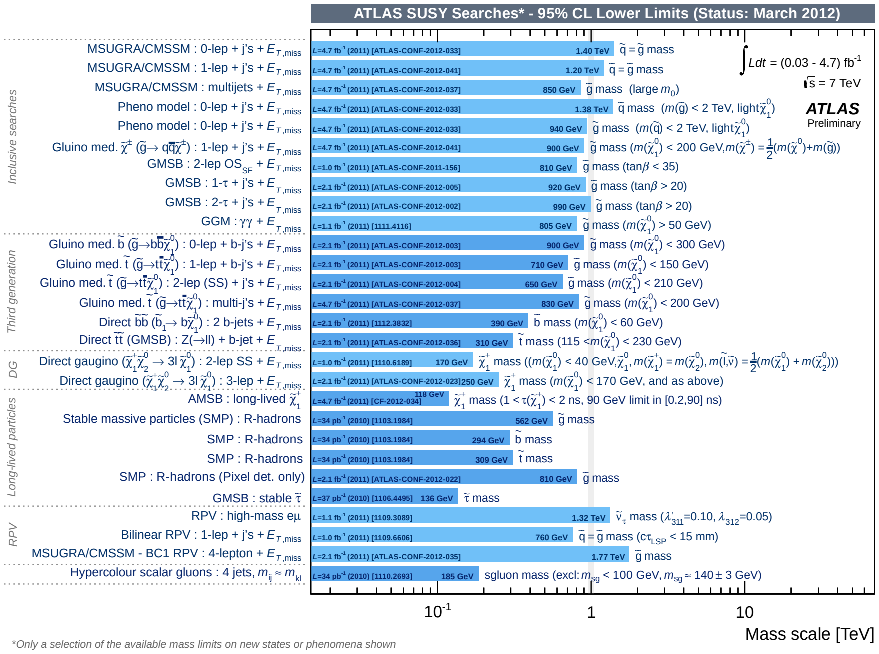

Figure 10: Overview of the current landscape of SUSY searches at the LHC. The plot shows exclusion mass limits of ATLAS for different searches and interpretation assumptions. The corresponding results of CMS are comparable.

Furthermore, the LHC experiments have reported significant constraints on the allowed mass range of a SM-like Higgs boson based on an analysis of 5 fb^{-1} of data [129,130]. A SM-like Higgs boson is excluded over a large mass range, except in a narrow window around 125 GeV or at a large mass above some 600 GeV. These results impose further tight bounds on the allowed SUSY parameter space, and the first studies of global analyses indicate (see *e.g.*, [131–133]) that the limits on the Higgs boson mass worsen the overall compatibility of the available data with constrained models like the CMSSM. Scenarios of rather light third generation squarks, however, perhaps accompanied with heavy neutralinos as realized in compressed spectra, or first generation squarks and gluinos with masses significantly above 1 TeV are still compatible with the present set of direct and indirect constraints.

Additional searches at the LHC in 2012, at a higher center-of-mass energy of 8 TeV, are expected to make further important steps in the experimental search for SUSY. Once the LHC reaches its full energy after 2013, even higher mass scales will be in reach.

Like the experimental landscape of SUSY searches, the field of global interpretations of allowed SUSY parameters is still rapidly changing. Yet, it seems reasonable to expect that the emphasis on interpretations in constrained SUSY models is now shifting towards more flexible models, which in turn motivates an even stronger experimental emphasis on searches for direct production of third generation squarks, of electroweak gauginos, or involving compressed $m_{\text{mother}} - m_{\tilde{\chi}_1^0}$ mass spectra. An increased emphasis on R-parity violating models and on models with long-lived particles can also be expected.

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