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Searches for gluino-mediated production of third generation squarks with the ATLAS detector

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Abstract. A summary on the searches for gluino-mediated production of third generation squarks with the ATLAS detector is presented. Several scenarios in the framework of *R*-parity conserving minimal supersymmetric extensions of the Standard Model are considered. The results are presented based on data corresponding to an integrated luminosity of 13-21 fb^{-1} collected in *pp* collisions at $\sqrt{s}$ = 8 TeV.

1 Introduction

Supersymmetry (SUSY) is one of the most theoretically promising candidates to solve some of the open questions of the Standard Model (SM). In order to provide a natural solution of the hierarchy problem, the gluino mass cannot be too heavy and sub-TeV stops and sbottoms are predicted. The scenarios considered by the analyses presented in this contribution target the gluino-mediated stop and sbottom production.

Simplified models based on a minimal supersymmetric extension of the SM are exploited. Only *R*-parity conserving models are considered and the lightest supersymmetric particle is expected to be the lightest neutralino ($\tilde{\chi}_1^0$), providing a good candidate for dark matter. For all models, $\tilde{g}\tilde{g}$ production is assumed. It is followed by decays of the gluinos via on-shell or off-shell stops and sbottoms (e.g. $\tilde{g} \to t\tilde{t}_1, b\tilde{b}_1$ with $\tilde{t}_1 \to t\tilde{\chi}_1^0$,$\tilde{b}_1 \to b\tilde{\chi}_1^0$). In general, for each scenario a 100% branching ratio for the considered decay is assumed.

The final states are expected to contain bottom and/or top quarks (an exception is given by a scenario assuming $\tilde{t}_1 \to c\tilde{\chi}_1^0$ decays). In addition, large missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$) is expected due to the LSP, which leaves the detector undetected. Results are presented for analyses based on the following main event selection criteria: three *b*-jets [1] (Sect. 2), two same-sign leptons [2] (Sect. 3), no leptons and 7-10 jets [3] (Sect. 4), no leptons and 2-6 jets [4] (Sect. 5). All results are presented based on data collected with the ATLAS detector [5] at a centre-of-mass energy of 8 TeV.

2 Final states with 3 *b*-jets and no leptons

This analysis aims at scenarios where the gluinos decay via off-shell stops (Gtt: $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$, $m_{\tilde{t}_1} > m_{\tilde{g}}$) or sbottoms (Gbb: $\tilde{g} \to b\bar{b}\tilde{\chi}_1^0$, $m_{\tilde{b}_1} > m_{\tilde{g}}$). Results are presented based on a dataset corresponding to an integrated luminosity of 12.8 fb^{-1} [1].

For both considered scenarios, four *b*-jets are expected in the final state. For the event selection it is required that at least three *b*-jets are reconstructed. In addition, a lepton veto (for electrons and muons), a harsh $E_{\mathrm{T}}^{\mathrm{miss}}$ threshold of 200 GeV and dedicated requirements to reduce contributions from multi-jet QCD processes are applied. Two classes of signal regions are exploited:

- SR4 with ≥ 4 jets, $m_{\mathrm{eff}}^{4\mathrm{j}} = \sum_{i\leq 4} p_{\mathrm{T}}(\mathrm{jet}_i) > 900, 1100, 1300$ GeV.
- SR6 with ≥ 6 jets, $m_{\mathrm{eff}}^{\mathrm{incl}} = \sum_{i} p_{\mathrm{T}}(\mathrm{jet}_i) > 1100, 1300, 1500$ GeV.

SR4 is optimised for the scenarios where the gluinos decay via off-shell sbottoms. Higher jet multiplicities due to the top decays are expected for the scenarios where the gluinos decay via off-shell stops, accounted for by SR6. In general, looser m_{eff} thresholds provide a higher significance for scenarios with small $\Delta m(\tilde{g}, \tilde{\chi}_1^0)$ splittings, while harsh m_{eff} thresholds yield higher significances for scenarios with large $\Delta m(\tilde{g}, \tilde{\chi}_1^0)$ splittings and gluino masses.

The dominant background contribution is $t\bar{t}$ production in association with light jets. The normalisation of this contribution is estimated from data by a profile likelihood fit in a top dominated control region (exactly two *b*-jets and relaxed $E_{\mathrm{T}}^{\mathrm{miss}}$ and m_{eff} thresholds compared to the signal regions). The irreducible background contribution from $t\bar{t}$ production in association with *b*-jets accounts for up to 25% of the total SM prediction. It is estimated from Monte Carlo (MC) simulation. Other background processes (single top, $t\bar{t} + W/Z$, W/Z and diboson production) contribute 10-20% to the total SM prediction and are also estimated using MC simulation.

Good agreement between the observed and the expected SM event yields is obtained for all selections. The m_{eff} distributions for SR4 and SR6 are shown in figure 1.

As no deviation from the SM expectation is observed, ex-

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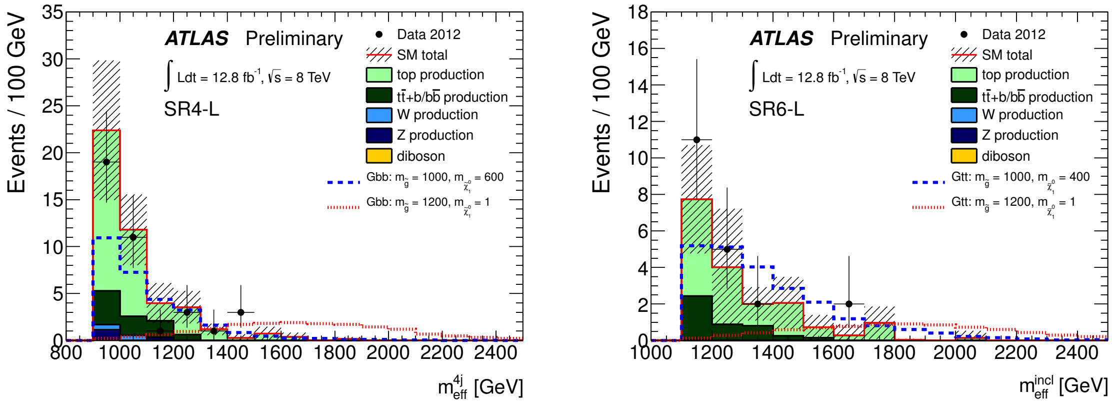

Figure 1. Distribution of $m_{\mathrm{eff}}^{4\mathrm{j}}$ for SR4 (left) and $m_{\mathrm{eff}}^{\mathrm{incl}}$ for SR6 (right) for the three b-jets analysis [1]. The loosest m_{eff} threshold is applied in each case. Contributions from $t\bar{t}$ +light jets, $t\bar{t}$ + W/Z and single top production are included in "top production". The distributions for dedicated Gbb or Gtt signal models are overlaid.

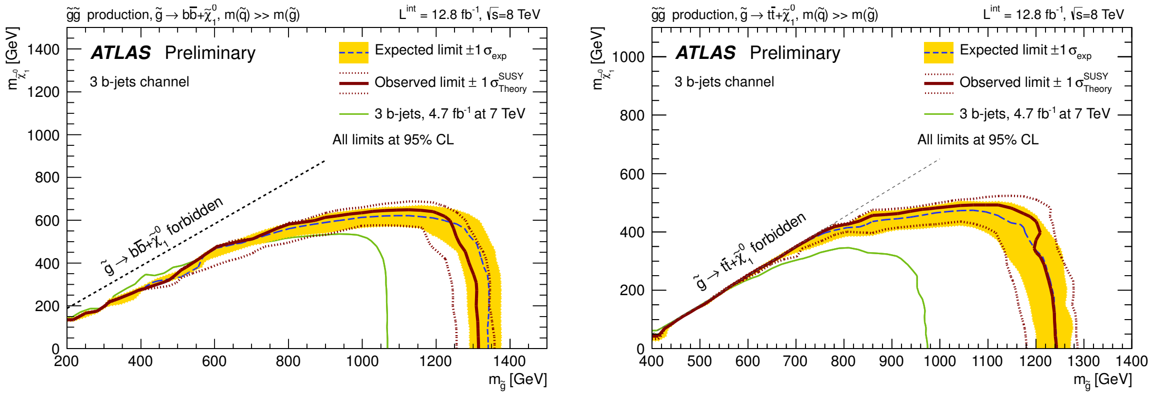

Figure 2. Expected and observed exclusion limits at 95% CL for the three b-jets analysis for scenarios assuming $\tilde{g}\tilde{g}$ production with $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ (left) and $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ (right) in the ($m_{\tilde{g}}$-$m_{\tilde{\chi}_1^0}$) plane [1].

clusion limits at 95% CL for the two considered scenarios are calculated. They are shown in figure 2.

3 Final states with two same-sign leptons

This analysis targets several scenarios with top quarks in the final state ($\tilde{g} \rightarrow t\tilde{t}_1, b\tilde{b}_1$ with $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0, \tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$, $\tilde{b}_1 \rightarrow t\tilde{\chi}_1^{\pm}$). Results are presented based on a dataset corresponding to an integrated luminosity of 20.7 fb^{-1} [2].
The event selection is based on requiring a lepton pair (ee, $e\mu$ or $\mu\mu$) with same sign. This is motivated by the fact that a high probability to form same-sign lepton pairs is given for pair-produced gluinos while a low background from SM processes is expected. Three signal regions with either a veto on b-jets (SR0b), $\geq$ 1 b-jet (SR1b) or $\geq$ 3 b-jets (SR3b) are exploited. The latter two are dominant for the third generation searches. For SR1b harsh thresholds are required on the kinematic variables ($m_{\mathrm{eff}} = E_{\mathrm{T}}^{\mathrm{miss}} + \sum_i (p_{\mathrm{T}}^{\mathrm{jet}})_i + \sum_{i\leq 2} (p_{\mathrm{T}}^{\mathrm{lepton}})_i > 700$ GeV, $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV, $m_{\mathrm{T}} = \sqrt{2p_{\mathrm{T}}^{\ell} \cdot E_{\mathrm{T}}^{\mathrm{miss}} - 2\mathbf{p}_{\mathrm{T}}^{\ell} \cdot \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}} > 100$ GeV) and the selection is powerful for scenarios with large mass splittings (e.g. large $\Delta m(\tilde{g}, \tilde{\chi}_1^0)$). Compressed scenarios (e.g. small $\Delta m(\tilde{g}, \tilde{\chi}_1^0)$) are covered by SR3b with loose selections on the kinematic variables. For the model dependent exclusion limits a shape fit on the m_{eff} variable is applied for SR0b and SR1b.
There are three types of background sources. The first contribution is given by processes with prompt same-sign leptons ($t\bar{t} + W/Z$, diboson), which is estimated from MC simulation. The second component is given by events with a mis-reconstructed ("fake") lepton. It is dominated by $t\bar{t}$ processes and estimated from data. The third component is given by events where the electron charge is mis-measured due to photon bremsstrahlung. It is dominated by dileptonic $t\bar{t}$ events. The charge-flip probability is estimated from data.
Good agreement between the observed and expected background event yields is obtained for all signal regions. The m_{eff} distribution for SR1b is shown in figure 3. The results are interpreted in four scenarios for gluino-mediated stop and sbottom production: $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ via an off-shell stop, $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ via an on-shell stop with $m_{\tilde{\chi}_1^0} = 60$ GeV, $\tilde{g} \rightarrow tb\tilde{\chi}_1^{\pm}$ via an off-shell sbottom or stop and with $m_{\tilde{\chi}_1^0} \approx m_{\tilde{\chi}_1^{\pm}}$, and $\tilde{g} \rightarrow tb\tilde{\chi}_1^{\pm}$ via an on-shell stop with $m_{\tilde{\chi}_1^0} = 60$ GeV and $m_{\tilde{\chi}_1^{\pm}} = 118$ GeV. Exclusion limits at 95% CL for the con-

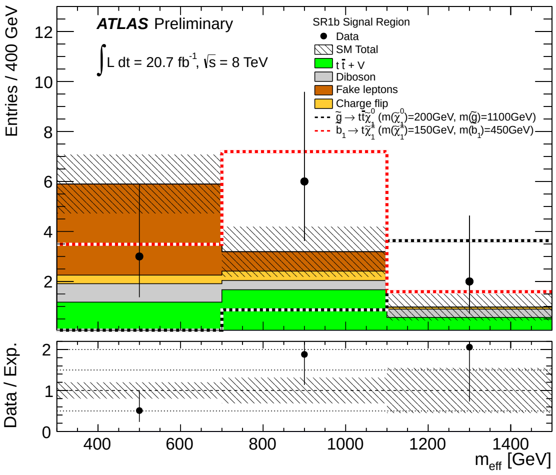

Figure 3. Distribution of m_{eff} for SR1b for the same-sign lepton analysis [2].

sidered scenarios are presented in figure 4. Compared to the results obtained for the analysis with three b-jets (see previous section), a better sensitivity is achieved for the compressed scenarios in case of the Gtt model.

4 Final states with no leptons (7-10 jets)

Interpretations for the gluino-mediated stop production are also provided by an analysis exploiting signal regions with no leptons, multi-jets and b-jets. Results are presented based on a dataset corresponding to an integrated luminosity of 20.3 fb^{-1} [3].
The relevant signal region selections are based on requiring 7, ..., $\geq$ 10 jets and 0, 1, $\geq$ 2 b-jets. In addition, it is required that $E_{\mathrm{T}}^{\mathrm{miss}} / \sqrt{H_{\mathrm{T}}} > 4$ GeV$^{1/2}$, where $H_{\mathrm{T}} = \sum_i (p_{\mathrm{T}}^{\mathrm{jet}})_i$.
The main background contributions are multi-jet, $t\bar{t}$ and W/Z+jets production processes. The multi-jet contribution and the normalisations of the $t\bar{t}$, W and Z contributions are estimated from data with the aid of dedicated control regions.
Good agreement between the observed and expected background event yields is obtained for all signal regions. In figure 5, exclusion limits at 95% CL are shown for scenarios considering the $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$ decay either via off-shell or on-shell stops.

5 Final states with no leptons (2-6 jets)

This analysis targets scenarios where the gluinos decay via $\tilde{g} \to t\tilde{t}_1 \to ct\tilde{\chi}_1^0$. Results are presented based on a dataset corresponding to an integrated luminosity of 20.3 fb^{-1} [4].
The signal regions are based on selections with $\geq$ 2, ..., $\geq$ 6 jets and harsh $m_{\mathrm{eff}} = E_{\mathrm{T}}^{\mathrm{miss}} + \sum_i (p_{\mathrm{T}}^{\mathrm{jet}})_i$ thresholds of at least 1000 GeV. The selections with $\geq$ 6 jets provide the highest significance for the considered scenario. The dominant SM background processes are W+jets, Z+jets, $t\bar{t}$, single top and multi-jet production.
Again good agreement between the observed and expected background event yields is obtained. The exclusion limit at 95% CL is shown in the ($m_{\tilde{g}}$-$m_{\tilde{t}_1}$) plane in figure 6, assuming a fixed stop-neutralino mass splitting of 20 GeV.

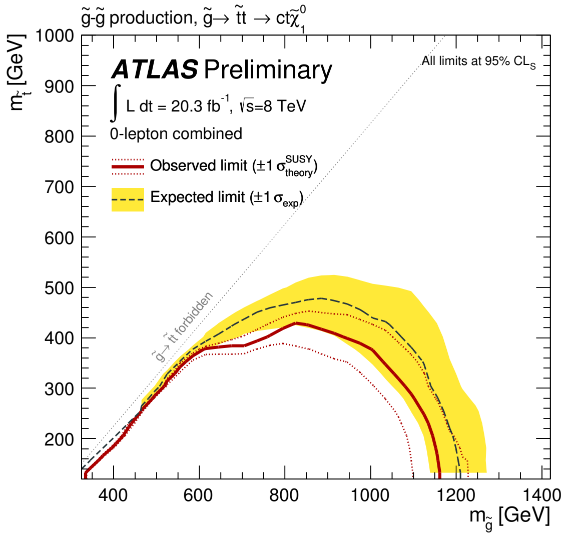

Figure 6. Expected and observed exclusion limits at 95% CL for the no-lepton analysis with 2-6 jets for the scenario assuming the $\tilde{g} \to ct\tilde{\chi}_1^0$ decay via a stop with $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) = 20$ GeV in the ($m_{\tilde{g}}$-$m_{\tilde{t}_1}$) plane [4].

6 Conclusions

Searches for gluino-mediated stop and sbottom production are presented in a variety of channels. No excess over the SM expectation is observed by any analysis. The results are therefore interpreted in several scenarios and gluino masses up to the TeV scale are excluded for a large range of LSP masses. A summary of the exclusion limits obtained for the scenario considering the decay of the gluino via an off-shell stop is shown in figure 7.

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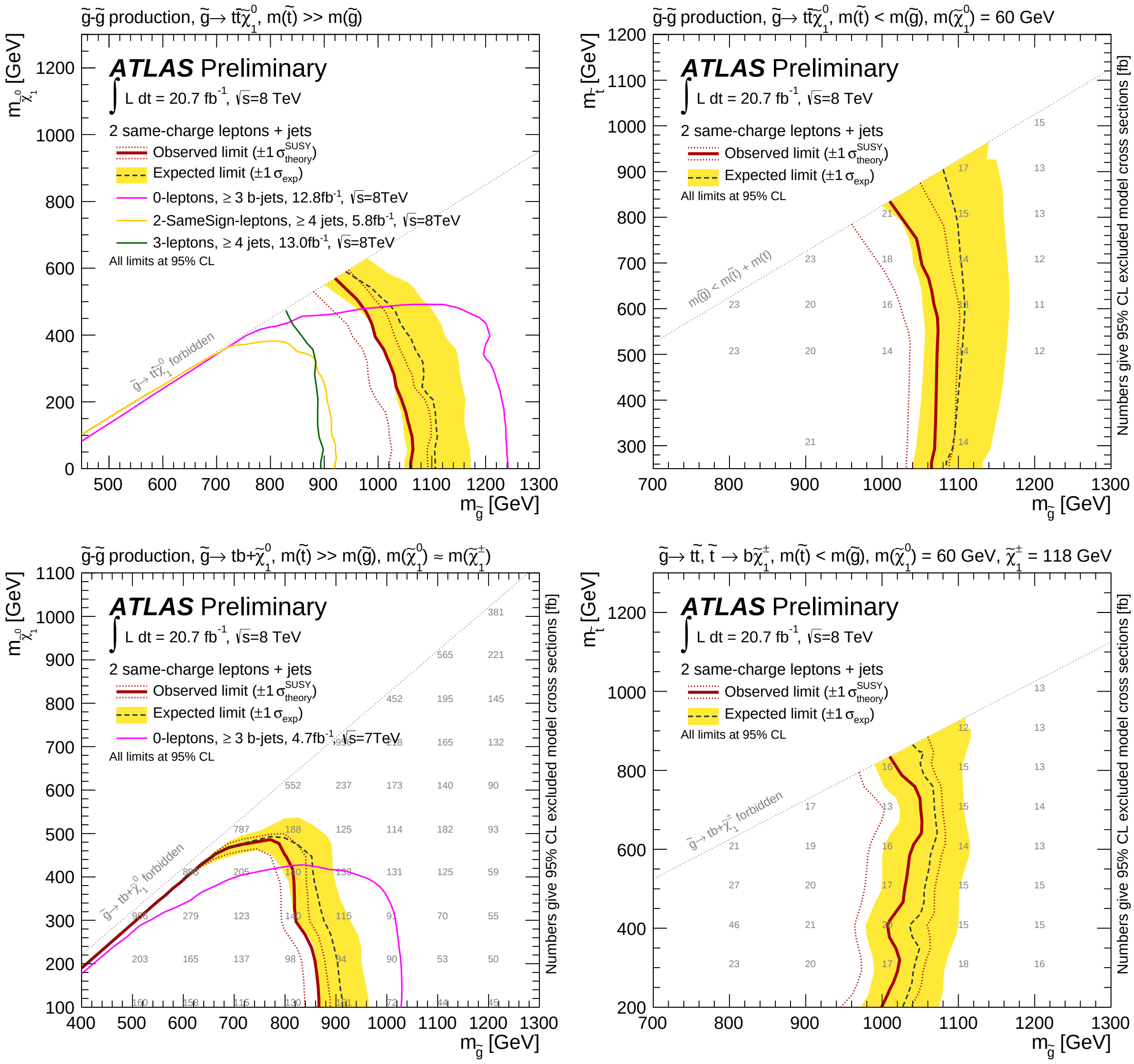

Figure 4. Expected and observed exclusion limits at 95% CL for the same-sign lepton analysis for scenarios assuming $\tilde{g}\tilde{g}$ production with $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$ via an off-shell stop (top left), $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$ via an on-shell stop with $m_{\tilde{\chi}_1^0} = 60$ GeV (top right), $\tilde{g} \to tb\tilde{\chi}_1^{\pm}$ via an off-shell sbottom or stop and with $m_{\tilde{\chi}_1^0} \approx m_{\tilde{\chi}_1^{\pm}}$ (bottom left), and $\tilde{g} \to tb\tilde{\chi}_1^{\pm}$ via an on-shell stop with $m_{\tilde{\chi}_1^0} = 60$ GeV and $m_{\tilde{\chi}_1^{\pm}} = 118$ GeV (bottom right) [2].

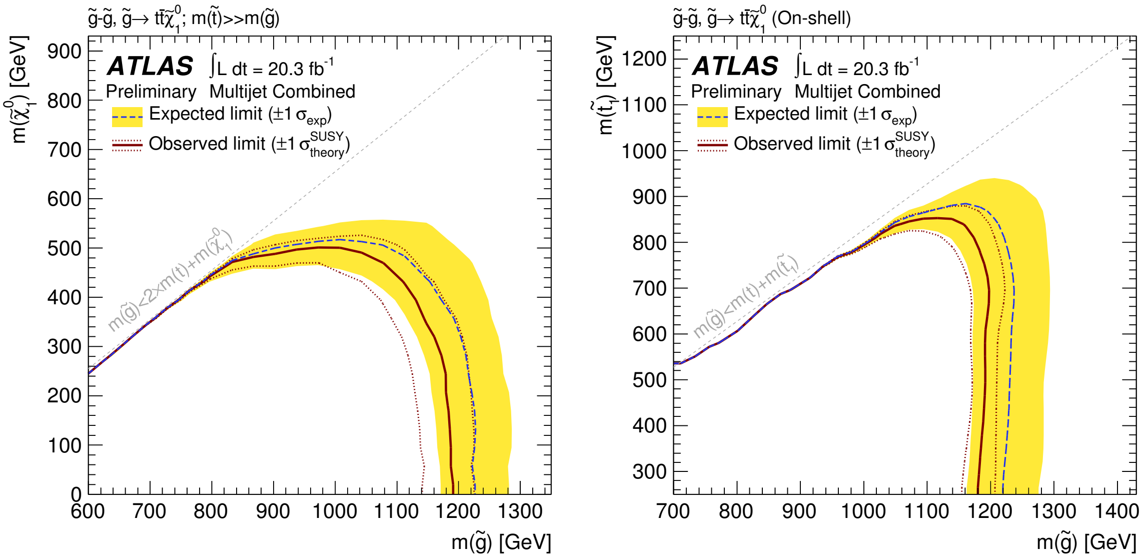

Figure 5. Expected and observed exclusion limits at 95% CL for the no-lepton analysis with 7-10 jets for scenarios assuming $\tilde{g}\tilde{g}$ production with $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}^0_1$ via an off-shell stop in the ($m_{\tilde{g}}$-$m_{\tilde{\chi}^0_1}$) plane (left) and $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}^0_1$ via an on-shell stop in the ($m_{\tilde{g}}$-$m_{\tilde{t}_1}$) plane (right) [3].

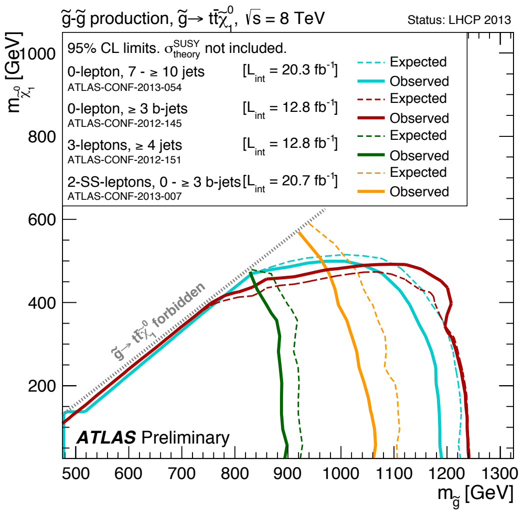

Figure 7. Expected and observed exclusion limits at 95% CL for several analyses for the scenario assuming $\tilde{g}\tilde{g}$ production with $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}^0_1$ via an off-shell stop in the ($m_{\tilde{g}}$-$m_{\tilde{\chi}^0_1}$) plane.