PROCEEDINGS OF SCIENCE

Searches for third generation squarks with the ATLAS detector

Steve Muanza[*†]
CPPM Marseille, CNRS/IN2P3 & Aix-Marseille University
E-mail: muanza@in2p3.fr

We present recent analyses (or updates) on searches for third generation squarks with the ATLAS detector obtained with the 2012 dataset representing about 20 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV. New or improved exclusions limits at the 95% C.L. and interpretations in several SUSY models are reported.

XXII. International Workshop on Deep-Inelastic Scattering and Related Subjects,
28 April - 2 May 2014
Warsaw, Poland

[*]Speaker.
[†]On behalf of the ATLAS collaboration

PoS(DIS2014)111

1. Introduction and Motivation

Supersymmetry (SUSY) is the most studied extension of the Standard Model (SM), see for instance the recent review by H.E. Haber in [1] and references therein.

In 2012, the ATLAS and CMS collaborations discovered a Higgs boson with a mass of $M_h \approx$125.5 GeV [2, 3]. To account for such a Higgs boson mass without an excessive fine-tuning, the radiative corrections to the Higgs boson mass impose constraints on the SUSY fields contributing the most to the corresponding loops. Namely, the following gauge interaction eigenstates fields: the higgsinos: $\tilde{\phi}_u^+, \tilde{\phi}_u^0, \tilde{\phi}_d^0, \tilde{\phi}_d^-$, the squarks: $\tilde{t}_L, \tilde{t}_R, \tilde{b}_L$, and the gluinos: $\tilde{g}$ ought to be relatively light. In this context, known as "Natural SUSY", one expects, in terms of mass eigenstates, the lightest squark to be either the lightest stop ($\tilde{t}_1$) or the lightest sbottom ($\tilde{b}_1$) and to have not too heavy gluinos ($\tilde{g}$), whereas 1st and 2nd generation squarks could have multi-TeV masses.

We describe the search strategy is section 2. We devote section 3 to present a (non-exhaustive) series of recent analyses (or analyses updates) and some of their interpretations, before concluding in section 4. All the reported searches are based on the 2012 dataset of pp collisions at $\sqrt{s} = 8$ TeV representing about 20 fb^{-1} of integrated luminosity. All the exclusion limits, derived using the CL$_S$ prescription [4], are given at the 95% C.L.

2. Search Strategy

One may start the search for 3rd generation squarks using its dominant production mechanism which proceeds through gluino pair production, followed by a subsequent decay of each gluino into a pair of heavy flavour quark+squark: $p+p \rightarrow \tilde{g}(\rightarrow \tilde{Q}+\bar{Q}+h.c.)+\tilde{g}(\rightarrow \tilde{Q}+\bar{Q}+h.c.)$ (where Q stands for the t or the b quark flavour and h.c. stands for hermitian conjugate). This mechanism is called the "gluino-mediated" production of stop and sbottom pairs as illustrated by the left-hand side (LHS) and the right-hand side (RHS) of figure 1, respectively.

However, in case gluinos are out of reach, one has also to consider the direct pair production of stops and sbottoms $p+p \rightarrow \tilde{Q}+\bar{\tilde{Q}}$. The latter has a smaller cross section than the gluino pair production, yet larger than those of electroweak SUSY processes. It is shown in figure 2 for stops (LHS) and sbottoms (RHS).

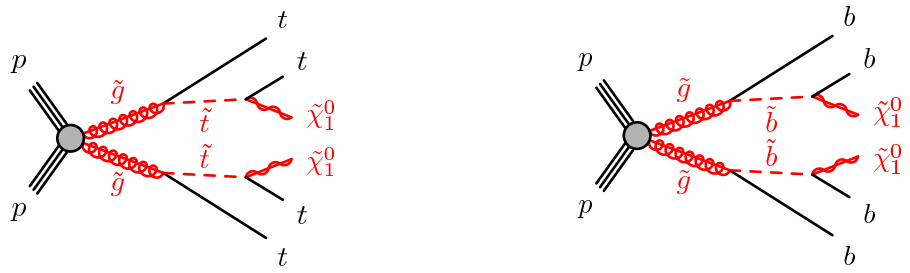

Figure 1: Leading order Feynman diagrams of gluino-mediated pair production of stop (LHS) and of sbottom (RHS). Particles and antiparticles are undifferenciated on these diagrams.

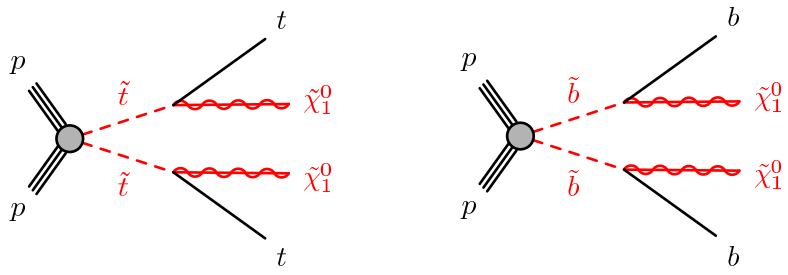

Figure 2: Leading order Feynman diagrams of stop (LHS) and sbottom (RHS) pair production. Particles and antiparticles are undifferenciated on these diagrams.

3. Search Channels

3.1 Multilepton Search

The search presented in this sub-section [5] is performed on the following inclusive topologies: $\ell^{\pm}\ell^{\pm}+[1/2/3]\text{b-}jets+\not{E}_T$, $(\ell^{\pm}=e^{\pm}/\mu^{\pm})$, $\ell^{\pm}\ell^{\pm}+[0]\text{b-}jets+\not{E}_T$ and $3\ell^{\pm}+[1/2/3]\text{b-}jets+\not{E}_T$, with $\ell^{\pm}=e^{\pm}/\mu^{\pm}$.

As for most analyses presented hereafter, the physics background is modelled using MC generators. Here the dominant processes are $t\bar{t}W$, $t\bar{t}Z$, WW and WZ.

In contrast, the instrumental background is estimated using data-driven methods. Here the main sources are hadrons faking isolated $\ell^{\pm}$, non-isolated $\ell^{\pm}$ from heavy flavour hadron decays faking isolated $\ell^{\pm}$, $e^{\pm}$ from $\gamma-$conversion as well as $e^{\pm}$ that are reconstructed with a flipped charge due to a hard asymmetric bremsstrahlung: $e^{\pm}\rightarrow e^{\pm}+\gamma\rightarrow e^{\mp}+e^{\pm}+e^{\pm}$, where the 3 electrons are ordered with decreasing p_T.

The two main kinematical variables used to discriminate the signal from the background are the transverse mass: $M_T=\sqrt{2p_T(\ell^{\pm})\not{E}_T[1-cos\Delta\phi(\ell^{\pm},\not{E}_T)]}$ and the effective mass: $M_{eff}=\not{E}_T+\sum_{leptons}p_T+\sum_{jets}p_T$. The distribution of M_T in the $e^{\pm}\mu^{\pm}+[0]\text{b-}jet+\not{E}_T$ topology and of M_{eff} in the $e^{\pm}e^{\pm}+[1/2/3]\text{b-}jets+\not{E}_T$ topology are compared between the data and the simulation on figure 3.

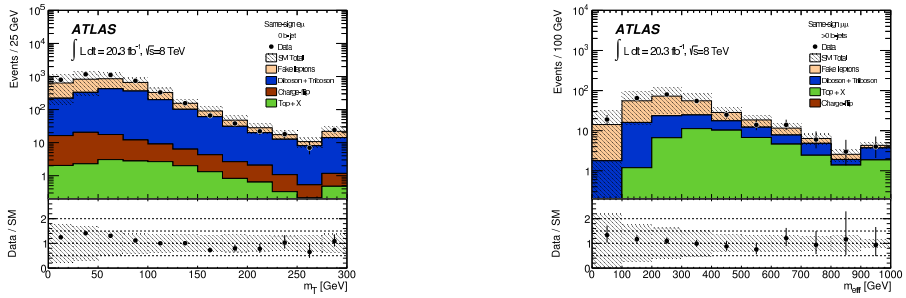

Figure 3: Distributions of M_T in the $e^{\pm}\mu^{\pm}+[0]\text{b-}jet+\not{E}_T$ topology (LHS) and of M_{eff} in the $e^{\pm}e^{\pm}+[1/2/3]\text{b-}jets+\not{E}_T$ topology (RHS)

After the final event selection, no excess is observed in the data with respect to the expectation from SM processes. Therefore exclusion limits are derived in various hypotheses. For example,

considering gluino-mediated production, the exclusion plots in figure 4 were derived supposing off-shell decays of the gluino: $\tilde{g} \to \tilde{t}_1^*(\to t + \chi_1^0) + \bar{t}$ (LHS) and on-shell ones: $\tilde{g} \to \tilde{t}_1(\to b + \chi_1^\pm) + \bar{t}$ (RHS).

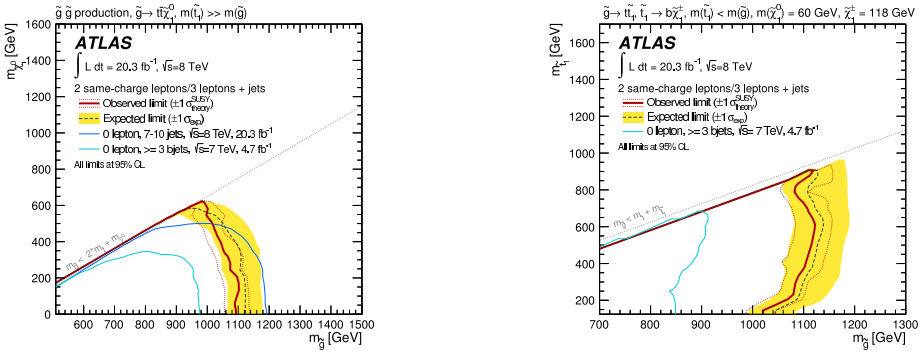

Figure 4: Exclusion limits for $\tilde{g} \to \tilde{t}_1^*(\to t + \chi_1^0) + \bar{t}$ (LHS) and $\tilde{g} \to \tilde{t}_1(\to b + \chi_1^\pm) + \bar{t}$ (RHS)

3.2 Search with 2 b−jets and No Leptons

This search [6], is based on the 2b-$jets + 0\ell^\pm + \not{E}_T$ topology. The limits in figure 5 suppose direct sbottom pair production with $\tilde{b}_1 \to b + \chi_1^0$ (LHS) and stop pair production with $\tilde{t}_1 \to b + \chi_1^\pm(\to W^* + \chi_1^0)$ with either $M(\chi_1^\pm) - M(\chi_1^0) = 5$ GeV (Center) or 20 GeV (RHS). For both stop pair productions, the chargino decays into soft tracks and $\not{E}_T$.

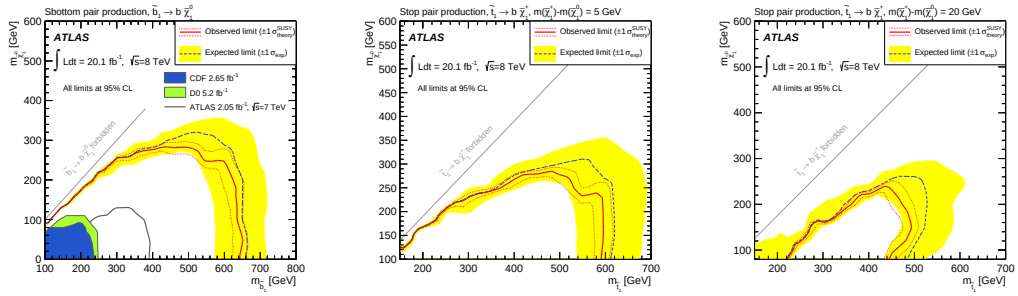

Figure 5: Exclusion limits for $p + p \to \tilde{b}_1 + \bar{\tilde{b}}_1$ with $\tilde{b}_1 \to b + \chi_1^0$ (LHS) and $p + p \to \tilde{t}_1 + \bar{\tilde{t}}_1$ with $\tilde{t}_1 \to b + Soft\ \ Tracks + \not{E}_T$ and $M(\chi_1^\pm) - M(\chi_1^0) = 5$ GeV (Center) or 20 GeV (RHS)

3.3 Search with All Hadronic $t\bar{t} + \not{E}_T$

In this sub-section, a direct stop pair production decaying into a fully hadronic $t\bar{t} + \not{E}_T$ final state is searched for [7]. The event selection is based on $\not{E}_T$ for the on-line criterion and on M_T, $\not{E}_T$ and a tau veto for the off-line cuts. The limit is presented in figure 6.

3.4 Search with c−jets+$\not{E}_T$

In this analysis [8], the production process is $p + p \to \tilde{t}_1 + \bar{\tilde{t}}_1$ followed by loop-induced decay $\tilde{t}_1 \to c + \chi_1^0$. The search topology is 2c-$jets + \not{E}_T$. The events are also selected with a $\not{E}_T$ trigger.

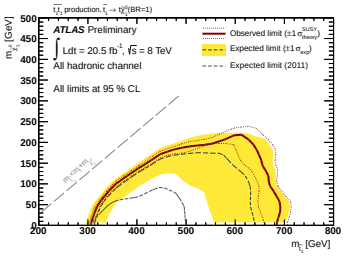

Figure 6: Exclusion limit for $p+p \rightarrow \tilde{t_1}+\bar{\tilde{t_1}}$ with $\tilde{t_1} \rightarrow t\bar{t}+\not{E}_T$

Off-line, 2 jets are c-tagged using a multivariate discriminator based on the tracks impact parameters and on the topological properties of the secondary and tertiary vertices. The performance of this c-tagger evaluated on a $t\bar{t}$ simulated sample are: $\varepsilon_c = 20\%$, $R_b \approx 5$, $R_{jets} \approx 140$. The limit is displayed in figure 7.

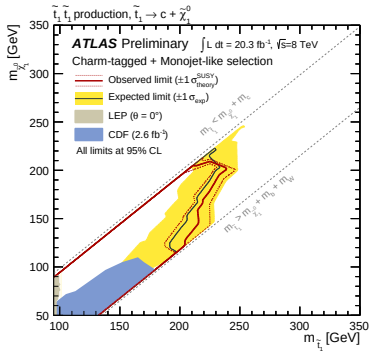

Figure 7: Exclusion limit for $p+p \rightarrow \tilde{t_1}+\bar{\tilde{t_1}}$ with $\tilde{t_1} \rightarrow c+\chi_1^0$

3.5 Search with 3b−jets+$\not{E}_T$

In this analysis [9], the search topology is $[0/1]\ell^{\pm}+jets+3\text{b-}jets+\not{E}_T$ and the main event selection variables are M_{eff} and $\not{E}_T/\sqrt{H_T}$.

The limit is displayed in figure 8 for gluino-mediated sbottom pair production.

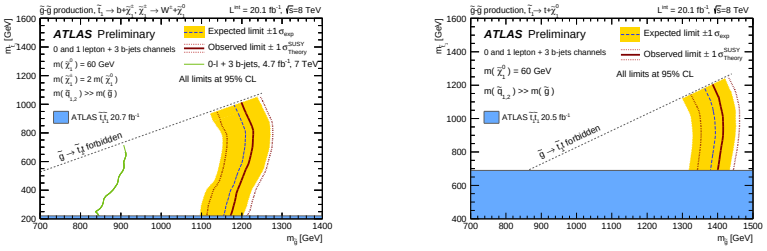

Figure 8: Exclusion limit for a gluino-mediated sbottom pair production, through on-shell sbottom: $\tilde{b}_1 \rightarrow b+\chi_1^0$ (LHS) and with an off-shell sbottom: $\tilde{g} \rightarrow b+\bar{b}+\chi_1^0$ (RHS)

4. Conclusion

A very extensive search program has been carried out with the ATLAS data of the LHC Run 1 to test the presence of third generation squarks. No significant excesses were observed in the data with respect to the expectations from SM processes. Therefore new or improved exclusion limits were derived. Figure 9 compiles these limits from searches for the lightest stop quark.

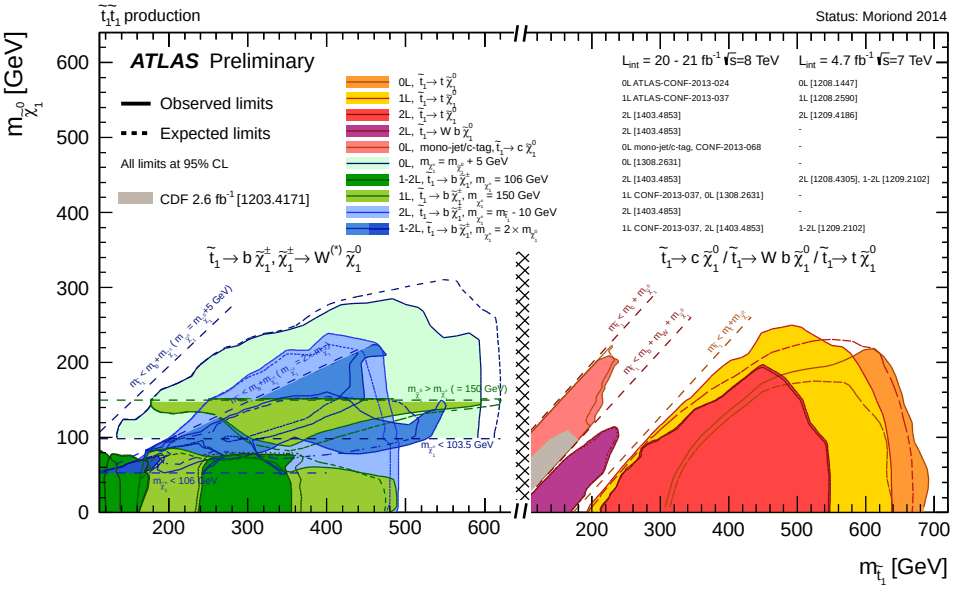

Figure 9: Summary plot of exclusion limits for stop searches in ATLAS. The datasets correspond to 4.7 fb^{-1} and about 20 fb^{-1} of pp collisions at $\sqrt{s} = 7$ and 8 TeV, respectively. The exclusion plane is $(M_{\tilde{t}_1}, M_{\tilde{\chi}_1^0})$ with masses expressed in GeV. Analyses that do not explicitely depend on the mass and decay of the $\tilde{\chi}_1^{\pm}$ are shown on the LHS of the figure, whereas the analyses of the stop decaying via the $\tilde{\chi}_1^{\pm}$ with different mass and decay hypotheses are displayed on the RHS.

References

[1] J. Beringer *et al.* [Particle Data Group Collaboration], Phys. Rev. D **86** (2012) 010001.

[2] ATLAS Collaboration, Phys. Lett. B **716** (2012) 1 [arXiv:1207.7214 [hep-ex]].

[3] CMS Collaboration, Phys. Lett. B **716** (2012) 30 [arXiv:1207.7235 [hep-ex]].

[4] A. L. Read, J. Phys. G **28** (2002) 2693.

[5] ATLAS Collaboration, arXiv:1404.2500 [hep-ex].

[6] ATLAS Collaboration, JHEP **1310** (2013) 189 [arXiv:1308.2631 [hep-ex]].

[7] ATLAS Collaboration, ATLAS-CONF-2013-024, `https://cds.cern.ch/record/1525880`

[8] ATLAS Collaboration, ATLAS-CONF-2013-068, `https://cds.cern.ch/record/1562880`

[9] ATLAS Collaboration, ATLAS-CONF-2013-061, `https://cds.cern.ch/record/1557778`