Status of the Fittino-ScyNet-SModelS Project

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Contents

Abstract

1   Introduction

This document summarizes the current status of the project. In addition, the results from a previous (unpublished) work are shown, since they are directly correlated and the current production of the Efficiency Maps (EM) is indeed based on those.

2   Previous Results: the ATLAS pMSSM-19

In this Section I summarize briefly the outcome of previous studies that I performed (or that I took part in), which are based on the work from ATLAS [] regarding the Run1 interpretation of SUSY searches within the pMSSM-19 work. Main key points of our `SModelS` analysis:

- we used the same SLHA points from ATLAS

- ATLAS gives information if the point is excluded or not (by their full recast of analyses)

- we could compare if a point could be excluded also by means of simplified models

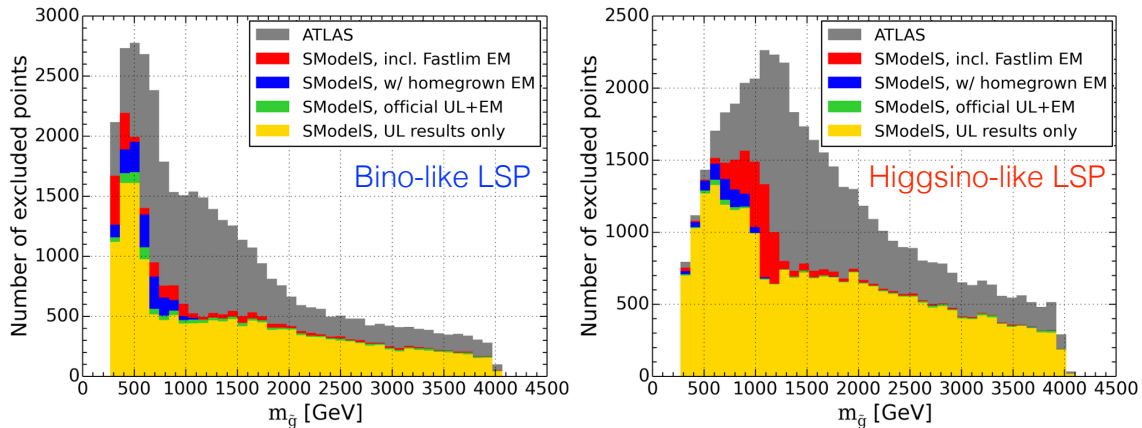- we could reach up to 55 or 63% exclusion only (see Fig. 1)

Figure 1. Distribution of excluded points using all the results implemented int the `SModelS` database, including results.

- the database included official results, but also EM I produced, and EM produced by `FastLim`

- we studied the most relevant missing topologies (see Fig. 2)

The extension of this study was part of my thesis, which focussed on two points:

1. of all the results included (i.e. of all the simplified model results in the database), which ones are ***really*** contribute to exclude at least a decent number of points?

2. can I use this information to choose smartly which EM to create and for which analysis, without guessing efficiencies "a priori" ?

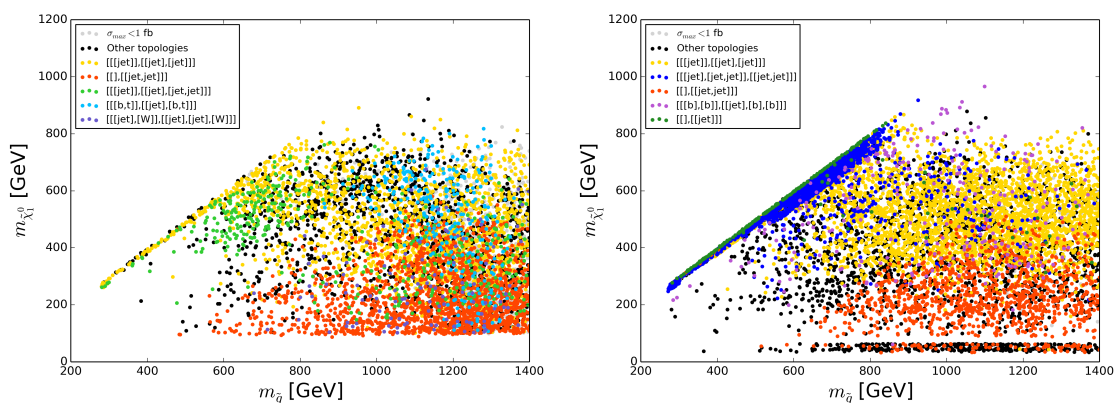These two are discussed briefly in the following.

Figure 2. Moste relevant missing topologies (ordered by frequency). Note the $3jet + E_T^{miss}$ topology, most frequent in both cases.

3 What excludes what?

After checking analysis by analysis, simplified model by simplified model, briefly the conclusion is that the most constraining simplified model results is a CMS upper limit result for the T2 topology (squark production and direct decay), in general, this T2 is efficiently constraining the pMSSM alone, without the need of model combination (with EM).

However, another aspect I wanted to clarify was the impact of `FastLim` results, for two reasons. The first one is that the `FastLim` results contain many different EMs results for the same analysis, so that you can efficiently combine different signals. The second is that the simplified models that they provide results for are "original", and such results cannot be found in official results. (Note that their models focused on natural SUSY scenarios, but also apply to the pMSSM as well in general). Fig. 3 shows the points excluded by the analysis ATLAS-CONF-2013-047 (i.e. the analysis superseded by ATLAS-SUSY-2013-02 mentioned above). The colours indicate the topologies that give the highest "best" r-value, or the "2nd-best" r-values, or in another words, they tell which model, contributing to the EMs combination, give the highest $\sigma \times BR$. Note that considering the topologies carrying the best r-value might not be enough to reach r-value>1, i.e. the r-values of each single simplified model is not necessarily >1.

Conclusion: if I want to extend the results for the ATLAS-SUSY-2013-02 with new EMs results, aiming at combining as many signals as possible, it makes sense to start from this simplified models, since they carry the highest constraining power.

3.1 To Clarify

I am not sure about the meaning of these entries in the results root file:

- ("SModelSCalculator_UnusedModel_0_Weight")

- ("SModelSCalculator_UnusedModel_0_Bracket")

- ("SModelSCalculator_UnusedModel_0_TxName")

- ("SModelSCalculator_UnusedModel_0_FractionOutsideGrid")

- ("SModelSCalculator_ConstraintOutsideGrid_0_Weight")

- ("SModelSCalculator_ConstraintOutsideGrid_0_Bracket")

- ("SModelSCalculator_ConstraintOutsideGrid_0_Bracket")

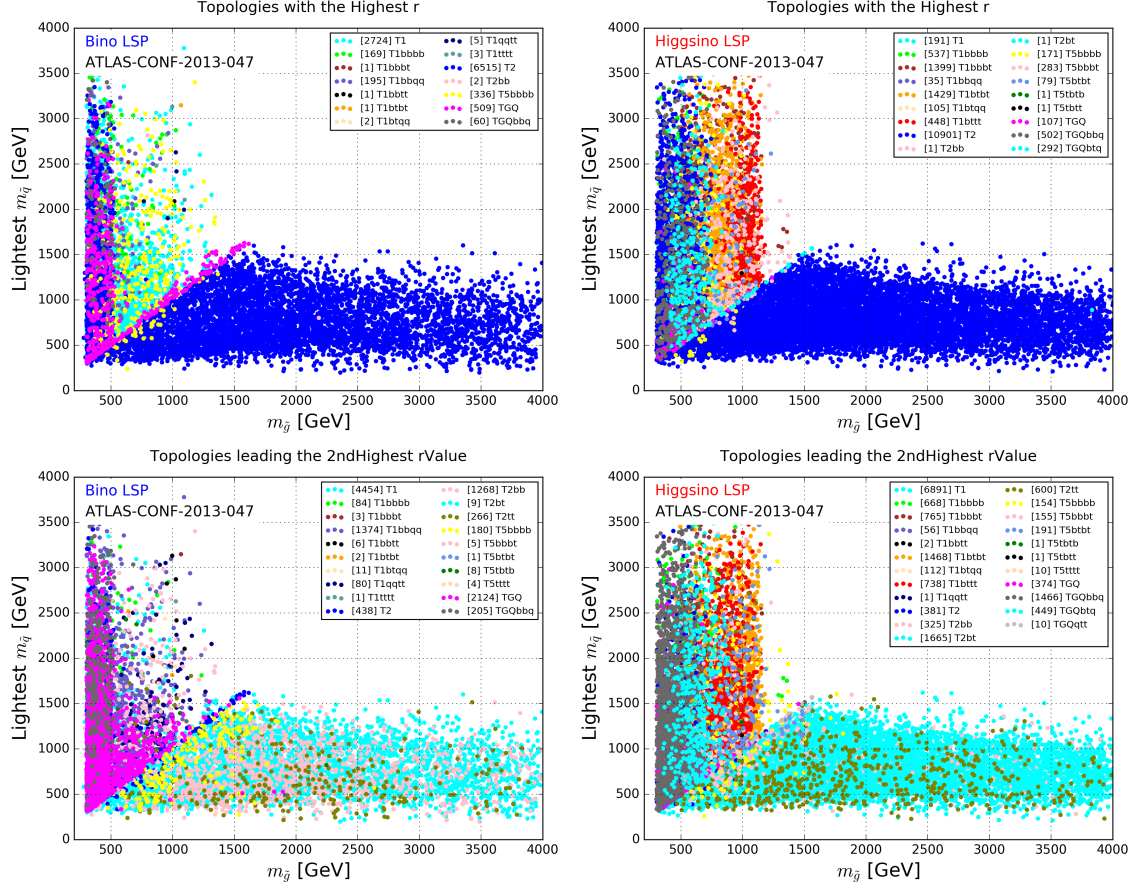- ("SModelSCalculator_MissingConstraint_0_Weight")

Figure 3. Points excluded by `FastLim` ATLAS-CONF-2013-047 results, with the colour code indicating the topologies leading the best and 2nd-best r-value. Note that the points might be excluded by combination of different simplified models results, i.e. considering only one result might not be enough to get r-value>1. The number in the legend reports the total number of points considered for the particular simplified model.
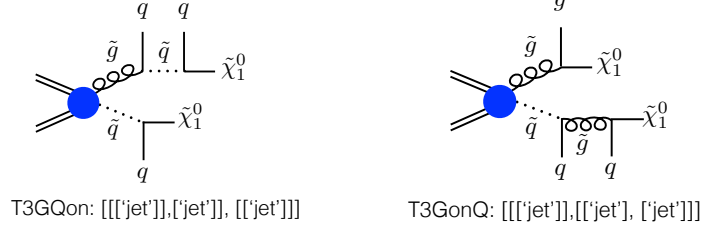
Figure 4. Diagrams for the T3GQ and T3QG simplified models.

4 New results: T3GQ Maps

In this Section I discuss briefly the topic of "T3GQ" maps. As I pointed out in the SModelS paper Section, the main missing topology, at least by frequency of appearance in Fig. 2 for both Bino and Higgsino-LSP cases if defined by the [[jet]],[[jet][jet]] constraint, i.e. one jet from one branch, two jets from the other in two distinct vertices. Important to remember: SModelS does not generally distinguish between gluon and light quark jets, i.e. jet can be either a quark or a gluon (in the decomposition procedure).

It was tested that this particular signature can originate from gluino-squark production, which benefits of a very large production cross section at the LHC. There are two possible distinct cases where we can have this simplified model: either the gluino is heavier than the lightest squark, so that gluinos decay with basically 100% branching to on-shell intermediate squark, or the other way around, where this time the gluino is lighter that the lightest squark so that we will have a cascade decay with an on-shell intermediate gluino. The first case generates always (since all the other SUSY particles are neglected), a $3jet + E_T^{miss}$ signature (see Fig. 4). The latter, only if the gluino loop-decays to gluon plus neutralino. If the mass splitting between the gluino and the lightest squark is small, however, you can also have a three-body decays to quark-antiquark-n1 via off-shell squark.

- I produced EMs results for the T3GQ model (which in SModelS> assumptions apply also to the T3QG case) for the ATLAS-SUSY-201-02 and CMS-SUS-13-012 "all-hadronic", 0-lepton final states searches

- I rerun the scan and checked any improvement. Results are in Fig.5

Fig. 4 shows the possible diagrams that lead to the $3jet+E_T^{miss}$ signature, from gluino-squark associated production decaying according to the two possible mass hierarchies.
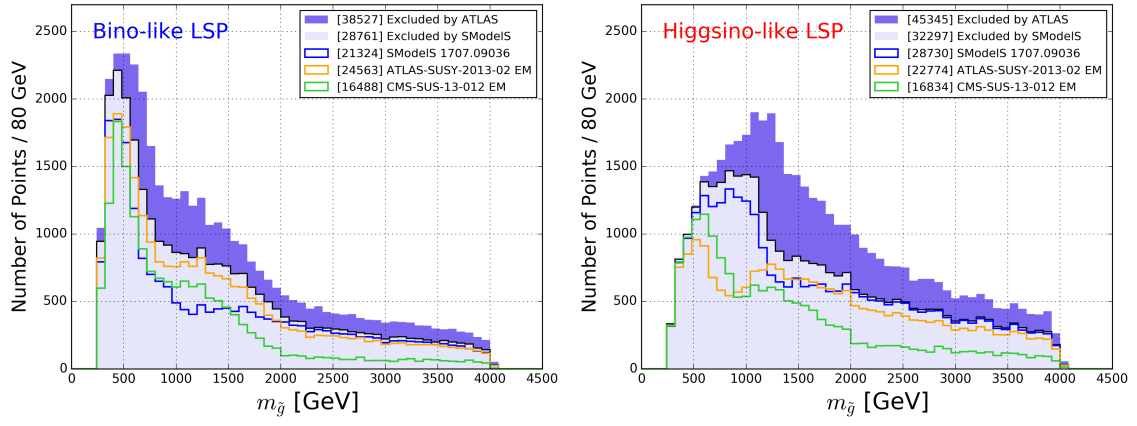
Figure 5. Improved constraints (on the same Bino - Higgsino like LSP datasets) coming from the addition of the T3GQ EMs.

5 Results

In this Section I summarize briefly the results from the first, preliminary scan of points that Bjorn provided.

5.1 Mass Distributions

In Fig. 6 the distributions of the masses of the scanned points are shown; in particular, all the coloured particles have very large masses exceeding 2 TeV, so that essentially only electroweak productions have reasonable cross sections. This configuration of mass parameters is very challenging for SModelS , since basically EMs for squark are produced up to around 1 TeV, and gluino EMs for up to 1.5 TeV (but cross sections should be very small in any case to contribute significantly).

Concerning the Electroweak simplified models, they are very poorly covered: only TSlep-Slep (slepton production and direct decay) and TChiWZ (chargino-neutralino2 production but strictly mass degenerate) are essentially covered.
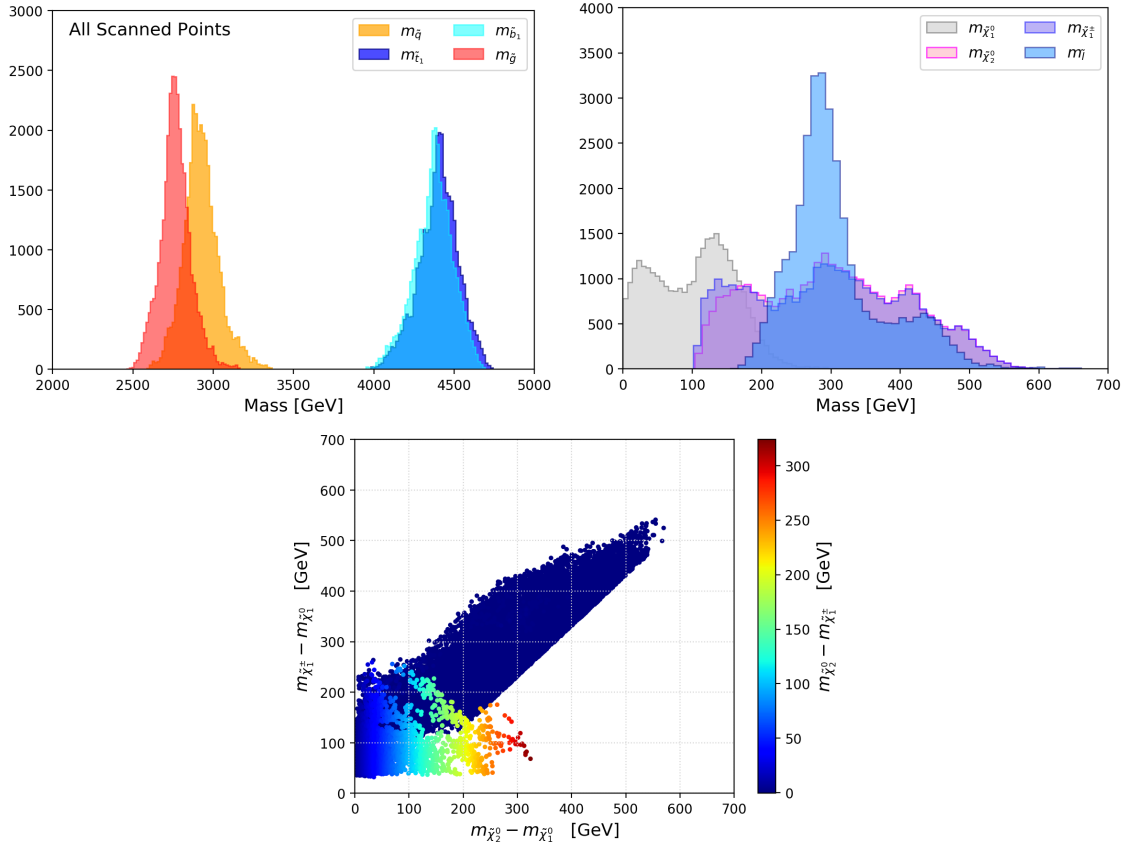

Figure 6. Distributions of the masses of the SUSY particles of the first set of points.

5.2 Missing TxNames and Missing Brackets

Here I list the most frequent (at least > 100 times) missing TxNames and missing brackets, with the largest weight ($\sigma \times BR$) for each point. I am not sure about the interpretation of the two definitions, so I hope Bjorn will clarify this.

```
('TChiChipmhiggs_W_', 136)
('TChiChipmZW_WW_', 144)
('TChiChipmqq_W_', 166)
('', 401)
('TChiChipm__', 540)
('TChiChipmmu__', 639)
('TChipChimWoff_Woff_', 950)
('TChiChipm_Woff_', 1341)
('TChiChipmZoff_Woff_', 1569)
('TSnuSnu__', 3249)
('TChiChipm_W_', 3621)
('TChiChi__', 5481)
('TChiChipme__', 8087)
```

```
('[[[W],[W]],[[Z],[W]]]', 160)
('[[[jet,jet]],[[photon]]]', 176)
('[[],[[l,nu]]]', 179)
('[[[W]],[[jet,jet]]]', 184)
('', 401)
('[[],[[W]]]', 1431)
('[[],[[jet,jet]]]', 1648)
('[[[jet,jet]],[[l,nu]]]', 1856)
('[[[W]],[[l,nu]]]', 2124)
('[[],[]]', 4794)
('[[],[[l]]]', 13435)
```

There are some things that I cannot explain, e.g.

- The difference between 'TChiChipme' and the '[[],[[l]]]' constraint? Are those referring to the same topology?

- Why "TChiChipmmu" is much less frequent than "TChiChipme"?

- What is "TSnuSnu" ?

6 Efficiency Maps Production

In Tab. 1 the overview of the EMs produced for the analysis ATLAS-SUSY-2013-02 is given.

Model	Mass Plane
Squark	
T2	-
3rd Generation	
T2bb	-
T2tt	-
T2bt	-
Gluino-Squark	
T3GQ	-
Gluino	
T1qqqq (Off.)	-
T1bbbb	-
T1btbt	-
T1bbqq (almost finished)	-
T3GGgbb	-
T3GGgqq	-
T5(qqqq)	-
T5bbbb	$x = (0.05, 0.50, 0.95)$
Electroweak	
TChiW	-

Table 1. Summary of EMs results for the analysis ATLAS-SUSY-2013-02. "Off" stands for official result (from the ATLAS Coll.).

Using the information from Section 3, the most useful EMs to be produced for the analysis ATLAS-SUSY-2013-02 should be:
for the Bino-like LSP case

- T1qqtt

- T1tttt

- T1bbtt

and for the Higgsino-like LSP case

-

- T1bbbt

- T1bttt

- T1btqq

- T1bttt

- T3GGgbt (aka TGQbtq)

- T5bbbt

- T5btbt

Going to the following most important missing topologies from Fig. 2, the other gluino-squark models after the T3GQ which is already done, are the ones giving the "[[jet][jet,jet]][[jet,jet]]" (Higgsino) and "[[jet]][[jet][jet,jet]]"(Bino) models. I believe these are the most important models to produce, however they will take a lot more time since they depend on three free parameters and the cross section is large even for large masses (e.g. heavy gluino-light squark) .

About the "[[]],[[jet,jet]]", which I call TGN: it can come from gluino-neutralino or pure electroweak processes. I have produced the maps for the model already, considering the gluino-neutralino case. Even though they will apply also to the EW case, I am not sure how valid is the simplified model assumption in this case (e.g. how much it depends on ISR?). Maybe it is a good test case. Also note that this topology is basically the off-shell version of the TChiW model "[[]],[[W]]".

7 Extra EMs results

In the following tables, EMs for other simplified models (with focus on third generation squarks) that I produced in the past and never used in publications are listed. They were mostly produced for the analysis CMS-SUS-13-012, which however is less constraining than ATLAS-SUSY-2013-02 due to the presence of 36 non overlapping signal regions, so they prove sensitive only to specific signals and it is hard to take advantage of signal combination with EMs results. However they cover a large fraction of scenarios like natural SUSY. I could not really test them with the ATLAS pMSSM scan since all the 3rd generation squarks were quite heavy.

It will make sense to re-produce them for ATLAS-02 as well. In particular, simplified models with Higgs decays should be important. In the past I was warned that generation of such models is tricky because of how the Higgs mass was handled by Pythia (???), but the person who told me that could not elaborate why (???).

Acknowledgments

Thanks!

Process	Txname	Decay	Mass Plane	Analyses
$pp \to \tilde{g}\tilde{g}$	T5WW	$\tilde{g} \to q\bar{q}'\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \to W^\pm \tilde{\chi}_1^0$	$x = (0.25)$	[1]
$pp \to \tilde{q}\tilde{q}^*$ $[\tilde{q} = (\tilde{u}, \tilde{d}, \tilde{c}, \tilde{s})_{L,R}]$	T6WW	$\tilde{q} \to q'\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \to W\tilde{\chi}_1^0$	$x = (0.50, 0.95)$ $\Delta M(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) = (5, 40, 75)$ GeV	[1]
$pp \to \tilde{b}_1\tilde{b}_1^*$	T6bbZZ	$\tilde{b}_1 \to b\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0$	$x = (0.25, 0.50, 0.95)$ $\Delta M(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = (5, 50, 75)$ GeV	[1]
	T6WWtt	$\tilde{b}_1 \to t\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm \to W\tilde{\chi}_1^0$	$x = (0.25, 0.50, 0.75)$ $\Delta M(\tilde{b}_1, \tilde{t}_1) = (5, 40, 75)$ GeV $\Delta M(\tilde{t}_1, \tilde{\chi}_1^0) = (90, 130, 165)$ GeV	[1]
	T6ttWW	$\tilde{b}_1 \to W\tilde{t}_1$, $\tilde{t}_1 \to t\tilde{\chi}_1^0$	$x = (0.25, 0.50, 0.75)$ $\Delta M(\tilde{b}_1, \tilde{\chi}_1^\pm) = (130, 165)$ GeV $\Delta M(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) = (5, 40, 75)$ GeV	[1]
$pp \to \tilde{b}_2\tilde{b}_2^*$	T6ZZbb	$\tilde{b}_2 \to Z\tilde{b}_1$, $\tilde{b}_1 \to b\tilde{\chi}_1^0$	$x = (0.10, 0.50, 0.95)$ $\Delta M(\tilde{b}_2, \tilde{b}_1) = (5, 50, 75)$ GeV	[1]
$pp \to \tilde{t}_1\tilde{t}_1^*$	T6ttZZ	$\tilde{t}_1 \to t\tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0$	$x = (0.50, 0.70)$ $\Delta M(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = (5, 45, 85)$ GeV $\Delta M(\tilde{t}_1, \tilde{\chi}_2^0) = (200)$ GeV	[1]
	T6WWbb	$\tilde{t}_1 \to W\tilde{b}_1$, $\tilde{b}_1 \to b\tilde{\chi}_1^0$	$x = (0.05, 0.50, 0.75)$ $\Delta M(\tilde{b}_1, \tilde{\chi}_1^0) = 5$ GeV $\Delta M(\tilde{t}_1, \tilde{b}_1) = (10, 40, 75)$ GeV	[1]
$pp \to \tilde{t}_2\tilde{t}_2^*$	T6ZZtt	$\tilde{t}_2 \to Z\tilde{t}_1$, $\tilde{t}_1 \to t\tilde{\chi}_1^0$	$x = (0.10, 0.50, 0.95)$ $\Delta M(\tilde{t}_2, \tilde{t}_1) = (5, 40, 80)$ GeV $\Delta M(\tilde{t}_1, \chi_1^0) = (90, 160)$ GeV	[1]
$pp \to \tilde{l}^+\tilde{l}^-$	TSlepSlepWW	$\tilde{l}^\pm \to \chi_1^\pm$, $\tilde{\chi}_1^\pm \to W^\pm \tilde{\chi}_1^0$	$x = (0.2, 0.50, 0.90)$ $\Delta M(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) = (10, 40, 75)$ GeV	[1],[4],[5]
$pp \to \tilde{g}\tilde{\chi}_1^0$	TGN	$\tilde{g} \to q\bar{q}\chi_1^0$	-	[1],[5]

Table 2. Additional unpublished EM results.[1]: CMS-SUS-13-012 (MA5) , [2]: ATLAS-SUSY-2013-04 (MA5), [4]: ATLAS-SUSY-2013-11 (MA5).