Constraining SUSY on Triangles

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Based on arXiv:1403.4295 (Anandakrishnan and Hill)

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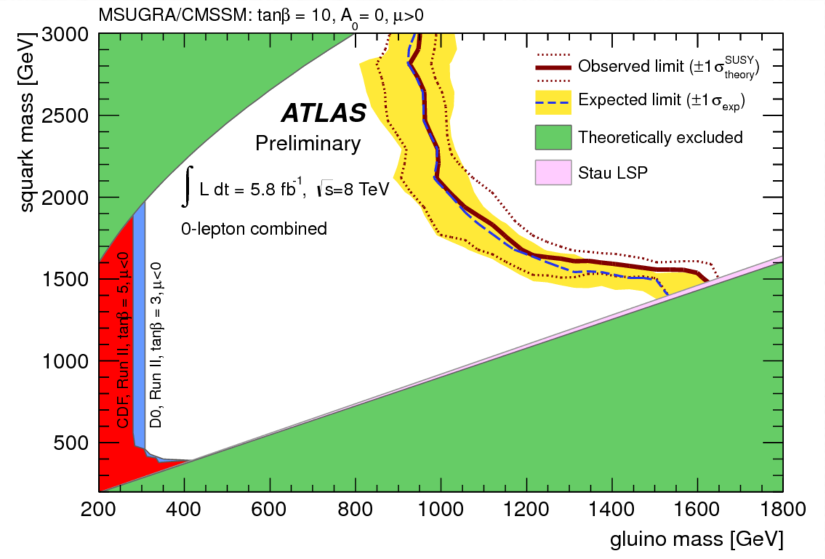
Motivation



ATLAS-CONF-2012-109

MODEL DEPENDENT RESULTS

- Model dependent presentation are full of assumptions.
- Not easy to translate exclusion limits to other models.

SIMPLIFIED MODEL SCENARIOS

- Simple model of a particle, $\tilde{X}$ and LSP.
- Few parameters, all other particles decoupled.
- $BR(\tilde{X} \rightarrow \text{LSP} + \text{A}) = 100\%$ where A is a set of Standard Model Particles.

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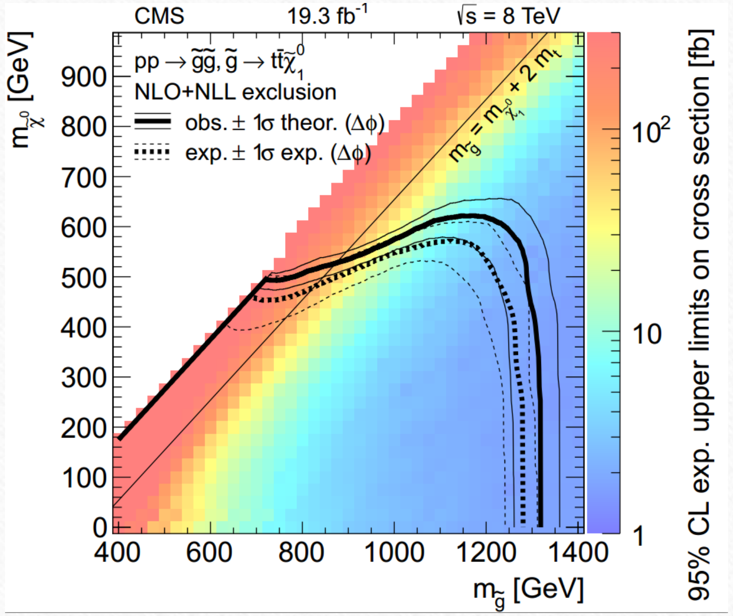

CMS: arXiv:1311.4397

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(Non-)Simplified Models

- How good is the assumption $BR(\tilde{X} \rightarrow \text{LSP} + \text{A}) = 100\%$.

  Example: Yukawa Unified SO(10) GUTS AA, Bryant, Raby (arXiv:1404.5628)

  $\tilde{g} \rightarrow t\,\bar{t}\,\tilde{\chi}_0^1(7\%);\ \tilde{g} \rightarrow b\,\bar{b}\,\tilde{\chi}_0^1(3\%);\ \tilde{g} \rightarrow t\,\bar{t}\,\tilde{\chi}_0^2(15\%);\ \tilde{g} \rightarrow b\,\bar{b}\,\tilde{\chi}_0^2(13\%);\ \tilde{g} \rightarrow t\,b\,\tilde{\chi}_\pm^1(60\%)$

- How do you reinterpret the limits for non-simplified scenarios easily?

- In the cases of non-simplified scenarios, the exclusion limits could be different from simplified models depending on the search and the model.

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Simplified Model Scenario

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a = 1 b = 1

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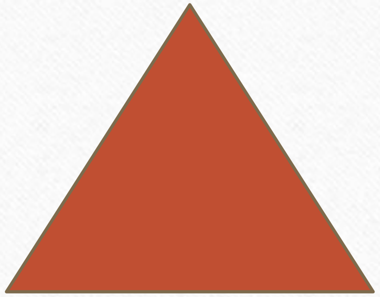
Model with three branching ratios

$$\mathrm{BR}(\tilde{X} \to A) = a$$
$$\mathrm{BR}(\tilde{X} \to B) = b$$
$$\mathrm{BR}(\tilde{X} \to C) = c$$

c = 1



a = 1 b = 1

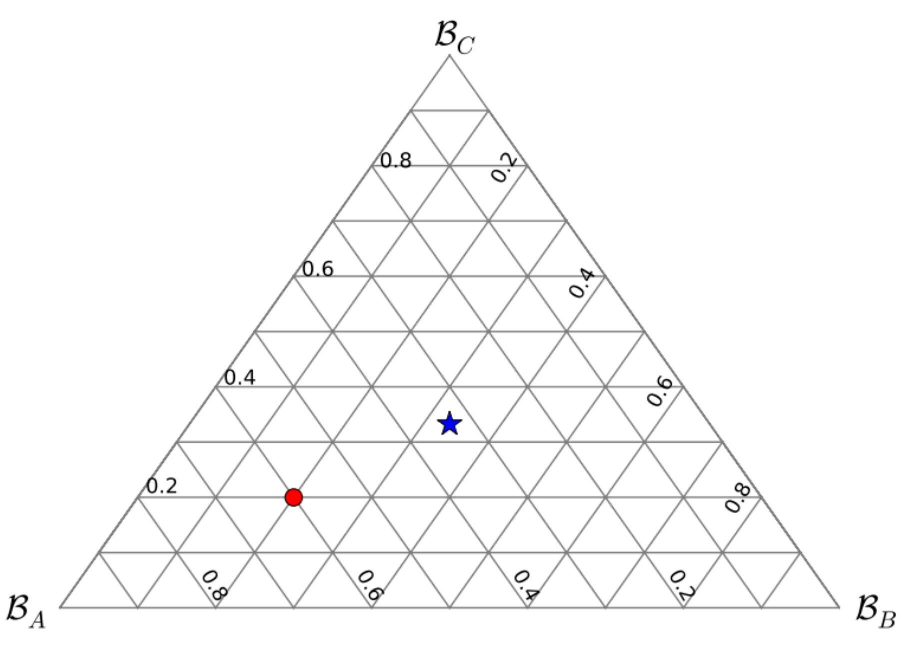
Points on the triangle

- Each point on the triangle is a unique model with a fixed ratio of branching fractions.

  Example: ★ (.33,.33.33);

  ● (.60,.20,.20)

- The vertices are the Simplified Model scenarios.
- Advocates of the triangle: Searches for T' quark (ATLAS & CMS), RPV violating SUSY(Marshall, Ovrut, Purves, Spinner - 2014)



Example: Gluino Decays

- Recast a CMS analysis to the utility of this approach.

Search for gluino mediated bottom- and top-squark production in multijet final states in pp collisions at 8 TeV

- For each point on the triangle:

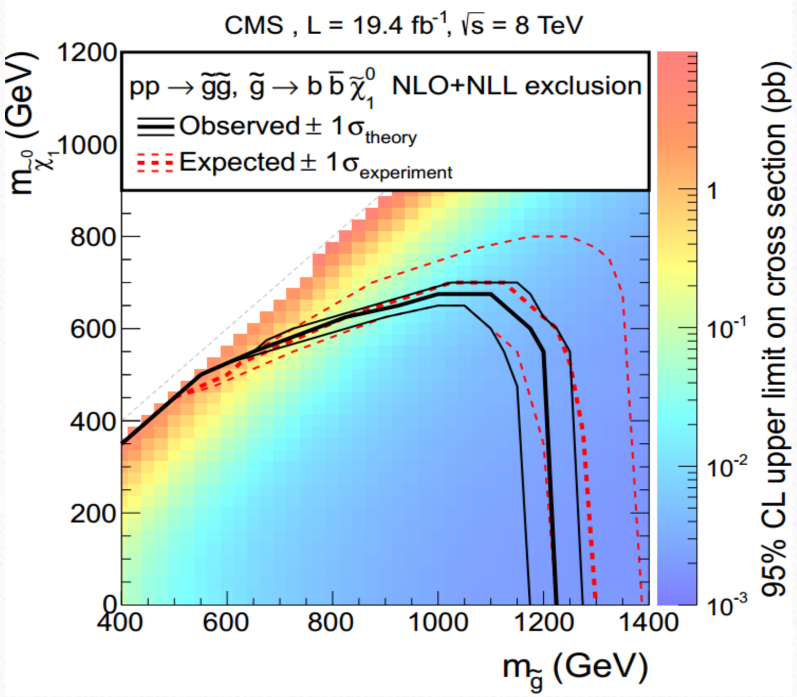
Pythia to generate events and shower; *Delphes* Detector Simulation, and custom C++ code to implement cuts from the analysis.

- Determine the highest gluino that is ruled out by the analysis and fill the triangle with contours or color maps.

Validation of the analysis at the vertices corresponding to SMS.

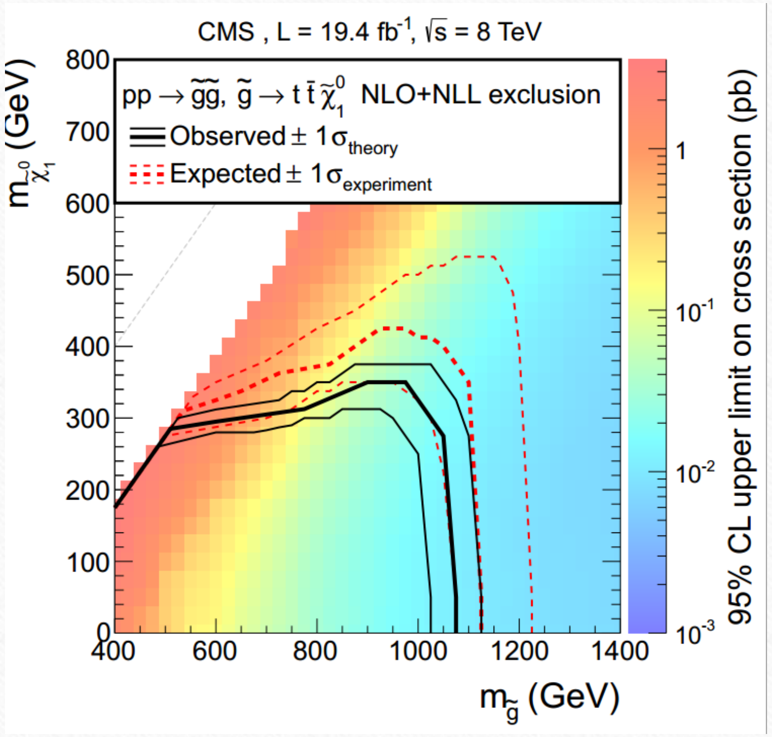
Exclusion Limits for SMS

- CMS search for gluinos in final states with jets, MET, $\Delta\phi$ variable, Lepton veto.
- Events in multiple signal regions.
- Upper limits for new physics events were interpreted in the context of Simplified Models.
- Gluino masses upto 1150 GeV ruled out for T1bbbb ($\tilde{g} \rightarrow b\ \bar{b}\ \tilde{\chi}^0$) SMS.



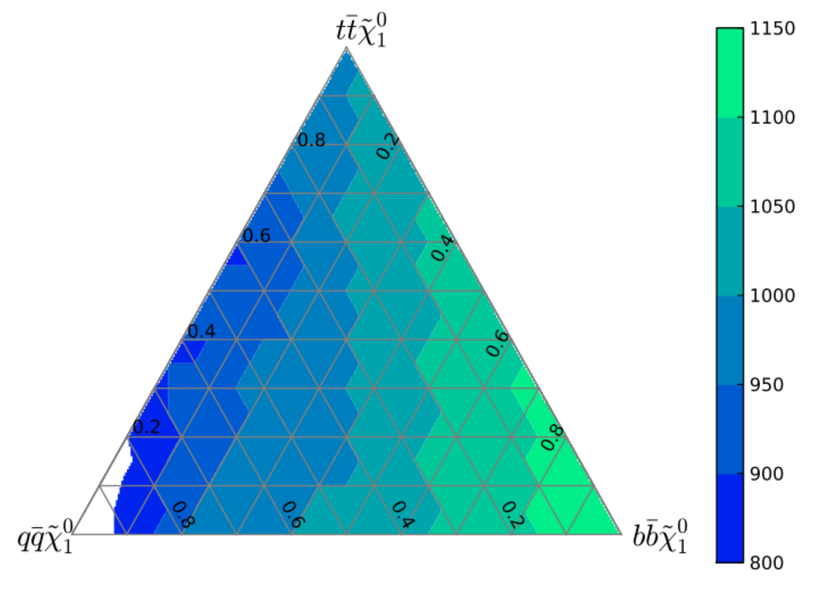
Exclusion Limits for SMS

- CMS search for gluinos in final states with (b-)jets, MET, $\Delta\phi$ variable.
- Events in multiple signal regions.
- Upper limits for new physics events were interpreted in the context of Simplified Models.
- Gluino masses upto 1050 GeV ruled out for T1bbbb ($\tilde{g} \rightarrow t\ \bar{t}\ \tilde{\chi}^0$) SMS.



Exclusion Limits on a Triangle

- Simplified Model validated at vertices.
- "Connected" simplified models and has a larger coverage of models.
- Wide coverage by choosing one vertex as a model with least sensitivity. In this case: T1qqqq ($\tilde{g} \rightarrow q\ \bar{q}\ \tilde{\chi}^0$) SMS.
- No limits on T1qqqq, but with 20% decays to b $\bar{b}\ \tilde{\chi}^0$, limits are close to 950 GeV.



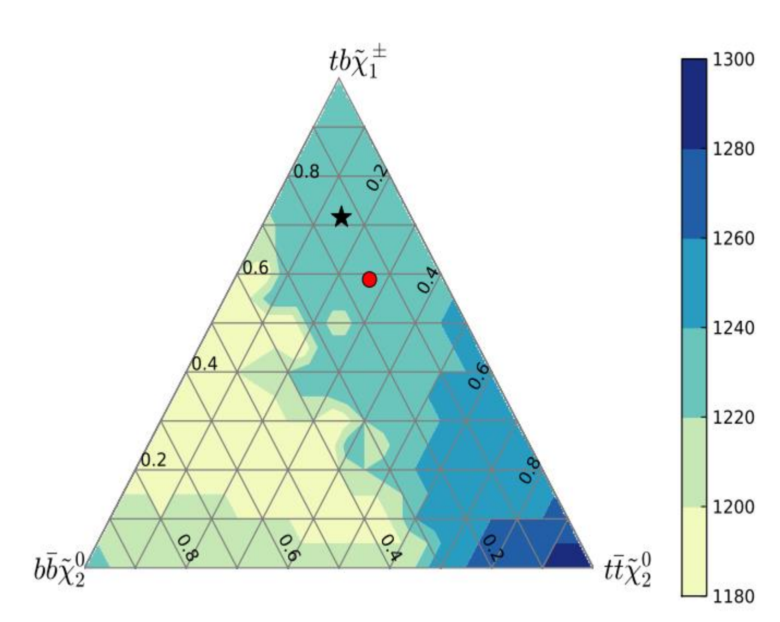
Example: Other Models

- Gluino in Yukawa-unified SO(10) GUT.
  AA, Bryant, Raby (arXiv:1404.5628)

- 6 main final states: $t\,\bar{t}\,\tilde{\chi}_0^1$; $b\,\bar{b}\,\tilde{\chi}_0^1$; $t\,\bar{t}\,\tilde{\chi}_0^2$; $b\,\bar{b}\,\tilde{\chi}_0^2$; $t\,b\,\tilde{\chi}_\pm^1$; $t\,b\,\tilde{\chi}_\pm^2$

- Many of the above final states look similar to the analysis (for the spectrum considered).

- Limits on the triangle match results obtained for benchmark models.



Example: Other Models

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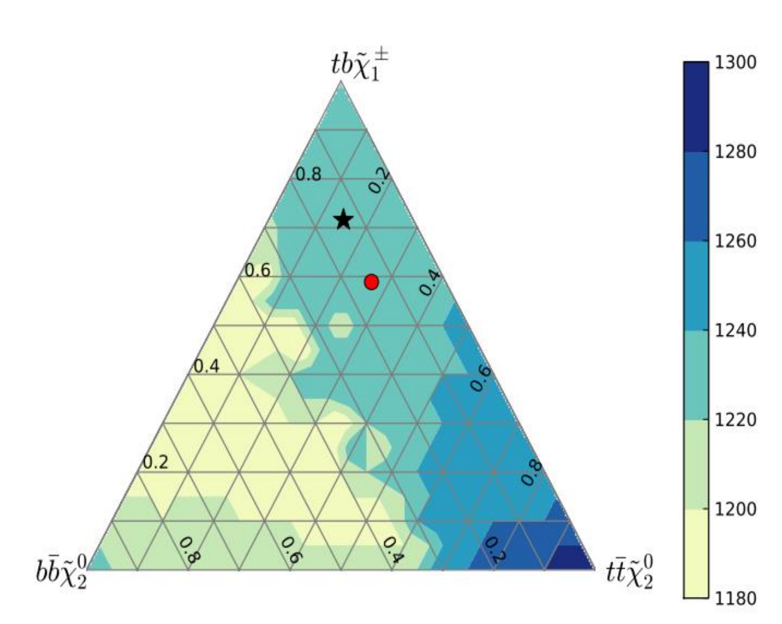
- 6 main final states: $t\,\bar{t}\,\tilde{\chi}_0^1$; $b\,\bar{b}\,\tilde{\chi}_0^1$; $t\,\bar{t}\,\tilde{\chi}_0^2$; $b\,\bar{b}\,\tilde{\chi}_0^2$; $t\,b\,\tilde{\chi}_{\pm}^1$; $t\,b\,\tilde{\chi}_{\pm}^2$
- The analysis (ATLAS-CONF-2013-061) has the same sensitivities to many of the final states (for the spectrum considered).
- Limits on the triangle match results obtained for benchmark models.



Summary

- Simplified Models extremely useful to place model independent limits.
- Connecting models to the SMS exclusion limits can be achieve on a triangle.
- Experimentalists: Can cover a larger model-space.
- Theorists: Can recast limits for specific branching ratio combinations.
- Shows search sensitivity for many models and highlights blind-spots on the model space.

*Triangle Python Script available on request.

To Divide the Rent, Start With a Triangle

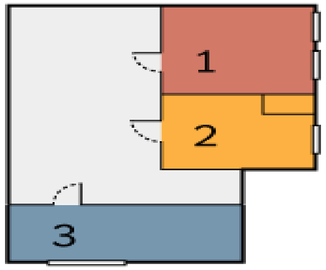
Sperner's Lemma and Rental Harmony

A mathematical theorem called Sperner's Lemma can be used to divide unequal assets fairly.

The Problem

Three friends **Ashwin**, **Bret** and **Chad** want to share an apartment.

The total rent is $3,000 but the rooms are different sizes. How can they choose rooms and divide the rent fairly?



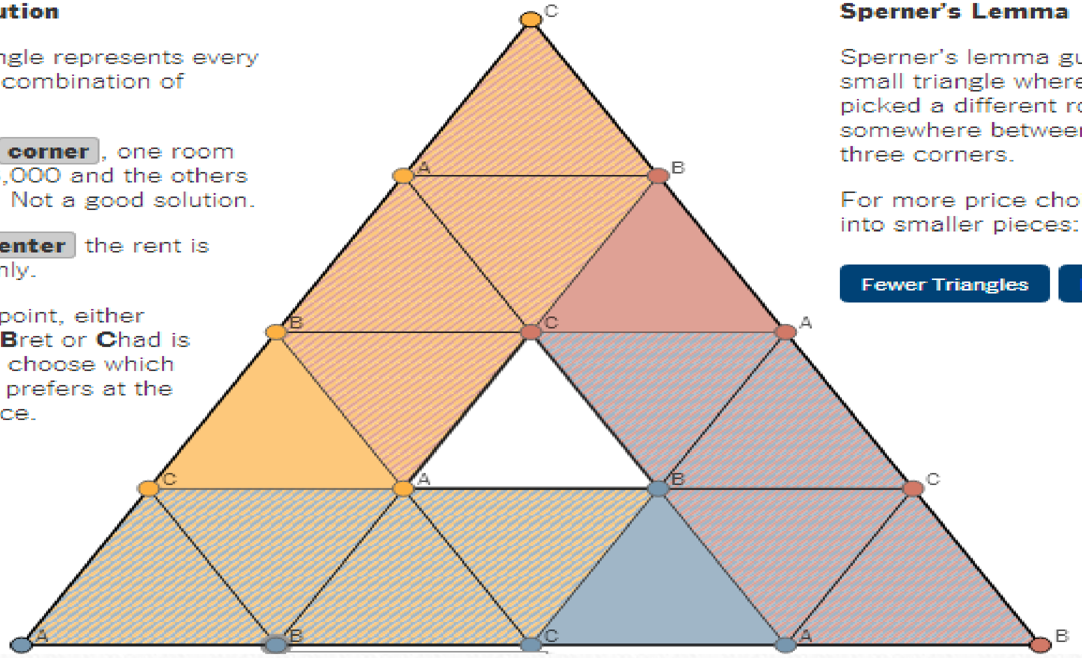
The Solution

This triangle represents every possible combination of prices.

At each **corner**, one room costs $3,000 and the others are free. Not a good solution.

In the **center** the rent is split evenly.

At each point, either **A**shwin, **B**ret or **C**had is asked to choose which room he prefers at the given price.



Sperner's Lemma

Sperner's lemma guarantees that there is a small triangle where every roommate has picked a different room. The "fair" price lies somewhere between the prices at those three corners.

For more price choices, divide the triangle into smaller pieces:

Fewer Triangles | More Triangles