New Topologies and Simplified Models from the pMSSM

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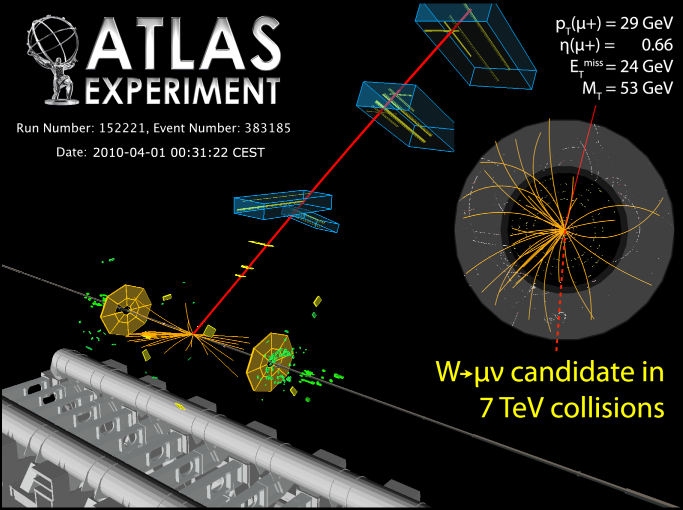
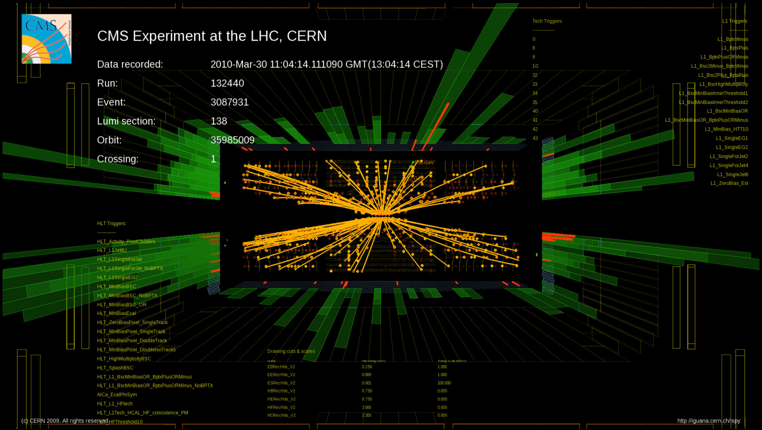
Argonne/ Northwestern

Workshop on Topologies for Early LHC Searches
September 22, 2010

The LHC is Here!

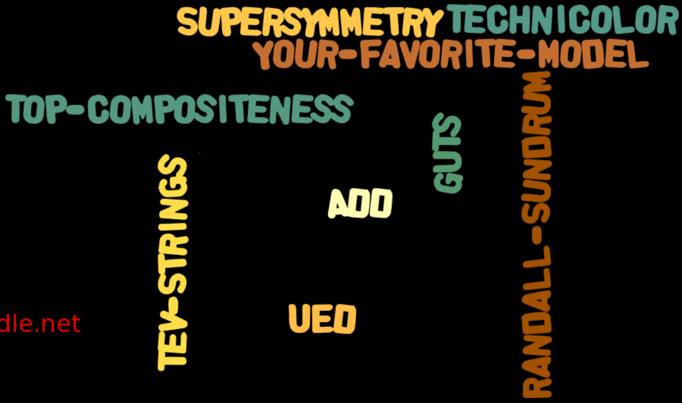


The LHC is Here!



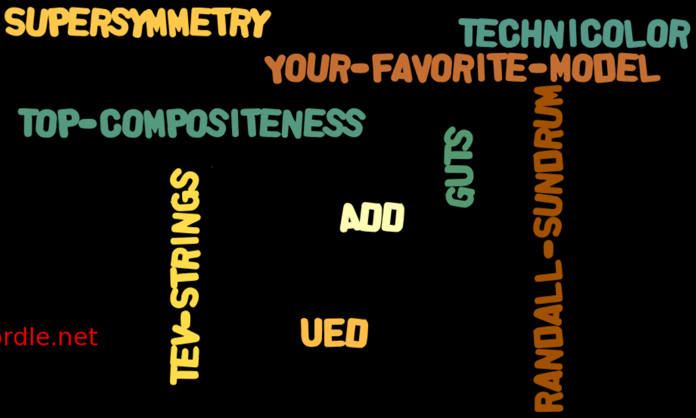
Our Theories Will Soon Be Confronted by Data

We Have a Wealth of Theoretical Ideas



wordle.net

Let's Focus on One Idea



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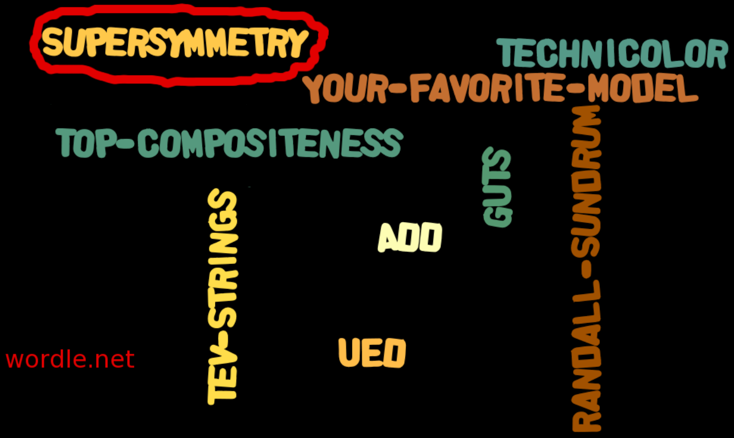
Let's Focus on One Idea



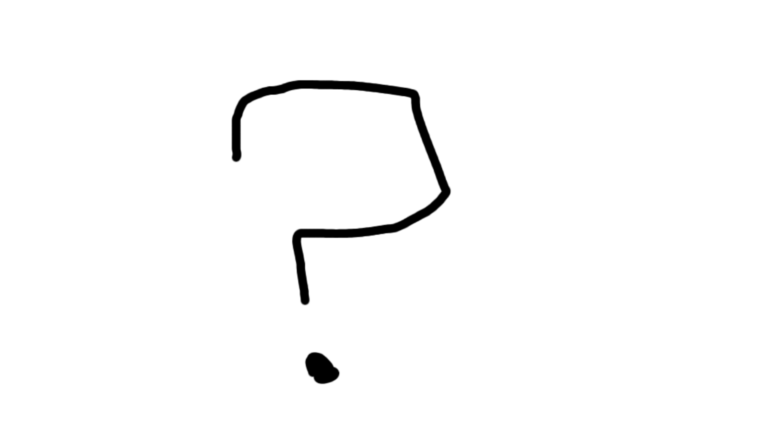
Even within SUSY

Many Ideas


GMSB
KKLT
Split-SUSY
mSUGRA
CMSSM
Your-Favorite-Model
XMSB
AMSB
wordle.net
Yuwaka-Unified

But even with so many ideas

Are we covering all of our bases?



But even with so many ideas

Are there potential SUSY signatures that have been missed?

One Way to Find Out

Berger, Gainer, Hewett, Rizzo
JHEP 0902:023,2009 [0812.0980]

Specifically

- Choose parameter space points in 19-parameter p(henomenological)MSSM
  - 10 (real) sfermion mass terms.
  - (First and second generation sfermions assumed degenerate.)
  - 3 gaugino masses.
  - Third generation trilinears (3).
  - μ, $\tan\beta$, m_A.

- 10 million points using flat priors
- 2 million points using log priors.

Parameter Ranges: Flat Priors

$$\begin{aligned}
100\,\mathrm{GeV} &\le m_{\tilde{f}} \le 1\,\mathrm{TeV}\,, \\
50\,\mathrm{GeV} &\le |M_{1,2},\mu| \le 1\,\mathrm{TeV}\,, \\
100\,\mathrm{GeV} &\le M_3 \le 1\,\mathrm{TeV}\,, \\
|A_{b,t,\tau}| &\le 1\,\mathrm{TeV}\,, \\
1 &\le \tan\beta \le 50\,, \\
43.5\,\mathrm{GeV} &\le m_A \le 1\,\mathrm{TeV}\,.
\end{aligned}$$

Parameter Ranges: Log Priors

$$
\begin{aligned}
100\,\mathrm{GeV} &\leq m_{\tilde{f}} \leq 3\,\mathrm{TeV}\,, \\
10\,\mathrm{GeV} &\leq |M_{1,2}, \mu| \leq 3\,\mathrm{TeV}\,, \\
100\,\mathrm{GeV} &\leq M_3 \leq 3\,\mathrm{TeV}\,, \\
10\,\mathrm{GeV} &\leq |A_{b,t,\tau}| \leq 3\,\mathrm{TeV}\,, \\
1 &\leq \tan\beta \leq 60\,, \\
43.5\,\mathrm{GeV} &\leq m_A \leq 3\,\mathrm{TeV}\,.
\end{aligned}
$$

Constraints

- LSP is lightest neutralino.
- No tachyons, CCB vacua.
- Higgs potential bounded from below.
- LSP thermal relic density **less than** WMAP limit.
- SUSY Contrib. to invisible width of the Z less than 2 MeV (LEP).
- $\Delta\rho$ in experimentally allowed range.
- $b \to s\gamma$ in experimentally allowed range.
- $B \to \mu\mu$ in experimentally allowed range.
- $g - 2$ in experimentally allowed range.
- $B \to \tau\nu$ in experimentally allowed range.

Constraints

- LEP charged particle constraint.
- LEP detector-stable charged particle constraint.
- LEP Higgs constraints.
- Tevatron Higgs constraints.
- Tevatron detector-stable charged particle constraints.
- Tevatron jet + missing energy constraints.
- Tevatron trilepton constraints.
- WIMP direct detection constraints.

Results

- $\sim 68,000/$ 10 million flat prior points are "okay"
- $\sim 2,000/$ 2 million log prior points are "okay"

Workshop goals include identifying new "topologies" and "simplified models".

- A "topology" is a specific particle production and decay chain.
- A "simplified model" is characterized by a short list of new particles together with a minimal Lagrangian specifying the interactions mediating their production and decay.

What new topologies do we have?

How many simplified models do we have?

Need a way to quantify.

One approach (for "counting" simplified models): look at the mass hierarchy of 4 lightest new particles (other than light SM-like Higgs)

- Feldman, Liu, and Nath
- Phys. Rev. Lett. 99 (2007) 251802 [arXiv:0707.1873]
- JHEP 04 (2008) 054 [arXiv:0802.4085]
- Phys. Lett. B 662 (2008) 190 [arXiv:0711.4591].

They find

- 16 hierarchies in mSUGRA with $\mu > 0$
- 6 hierarchies in mSUGRA with $\mu < 0$
- 15 additional hierarchies in NUSUGRA....

Our flat prior models: 1109

Our log prior models: 267

Example: most common hierarchy in flat prior set is
$m_{\chi_1^0} < m_{\chi_1^\pm} < m_{\chi_2^0} < m_{\chi_3^0}$

An Embarassment of Riches

- These model sets are large, contain many mass hierarchies/ simplified models.
- Need to find particularly interesting simplified models (or topologies)

Hard-to-Find Models

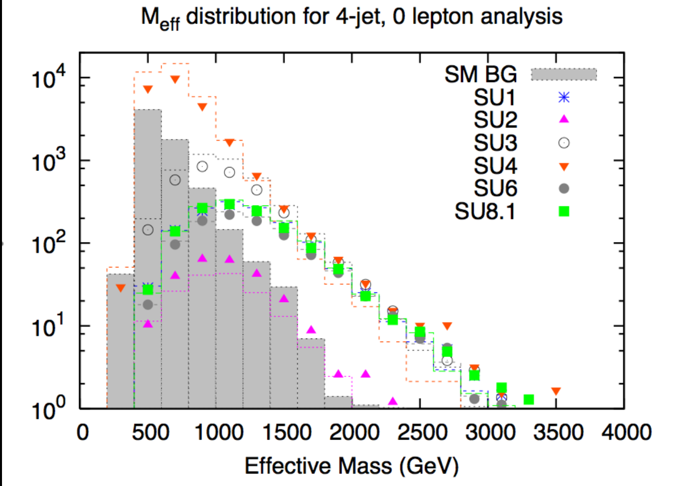
One way to find interesting simplified models from this model set is identify pMSSM models which are harder to observe at LHC.

Conley, Gainer, Hewett, Le, Rizzo (1009.2539)

SUSY w/o Prej. @ LHC

- Examine all $\sim 71,000$ pMSSM models using ATLAS inclusive SUSY analyses.
- 14 TeV (7 TeV coming soon), $1, 10\ \text{fb}^{-1}$.

SUSY w/o Prej. @ LHC



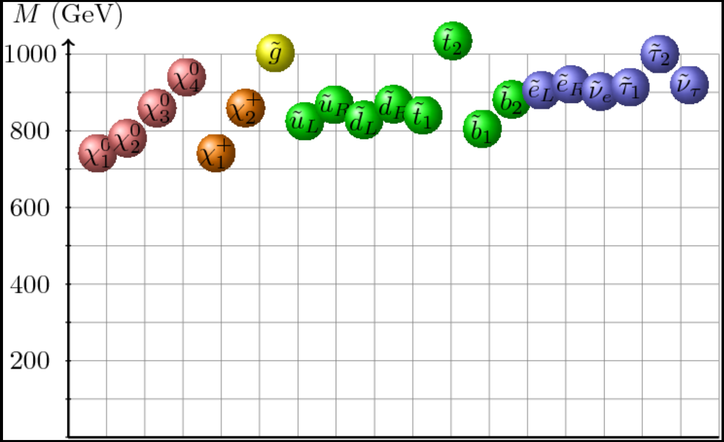
Analysis	50% error $1\ \text{fb}^{-1}$	50% error $10\ \text{fb}^{-1}$	20% error $1\ \text{fb}^{-1}$	20% error $10\ \text{fb}^{-1}$
4j0l	88.331	88.578	98.912	99.014
2j0l	87.616	87.774	98.75	98.802
1l4j	41.731	44.885	56.849	63.045
1l3j	64.058	70.907	69.725	81.111
1l2j	62.942	68.419	70.646	80.641
OSDL	6.0958	6.6796	15.262	18.659
SSDL	14.774	25.518	18.501	32.887
3lj	13.549	17.361	19.293	28.97
3lm	2.7406	2.9135	4.8844	5.8284
tau	83.51	86.505	96.928	98.695
b	73.983	76.939	91.672	94.867

Number of analyses	Flat, 1 fb^{-1}	Flat, 10 fb^{-1}	Log, 1 fb^{-1}	Log, 10 fb^{-1}
0	0.56754	0.36796	31.823	27.024
1	1.3458	0.98841	6.2704	6.5374
2	3.396	2.5141	8.9525	10.072
3	13.175	10.635	11.816	11.098
4	22.014	18.455	16.491	16.344
5	9.5512	10.3	5.6905	6.6135
6	15.227	16.929	6.0529	7.1456
7	20.081	17.697	6.7416	6.1954
8	7.6394	11.75	3.0083	4.371
9	3.9205	6.3569	1.5223	2.6226
10	2.0825	2.7943	1.0511	1.1783
11	1.0013	1.2116	0.57992	0.79818

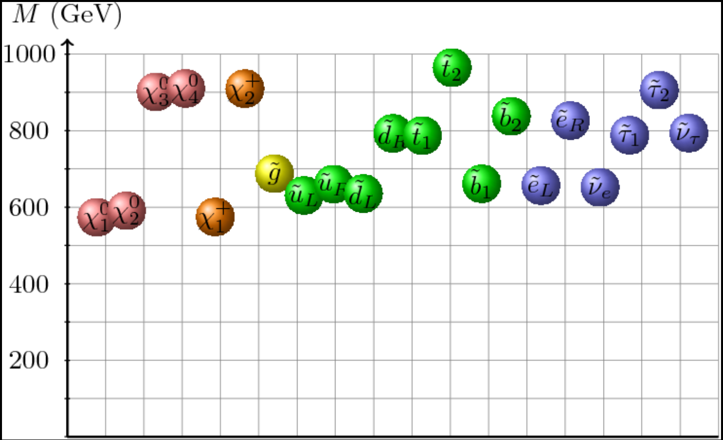
Invisible Models?

- Some models which do not show up in any of these analyses have detector-stable charginos.
- If these are the end of the decay chain; insufficient missing energy.
- But these would still be seen in early running.
- On the next three slides I will show models not seen in any analysis at 1 fb^{-1} (and sometimes with more luminosity).

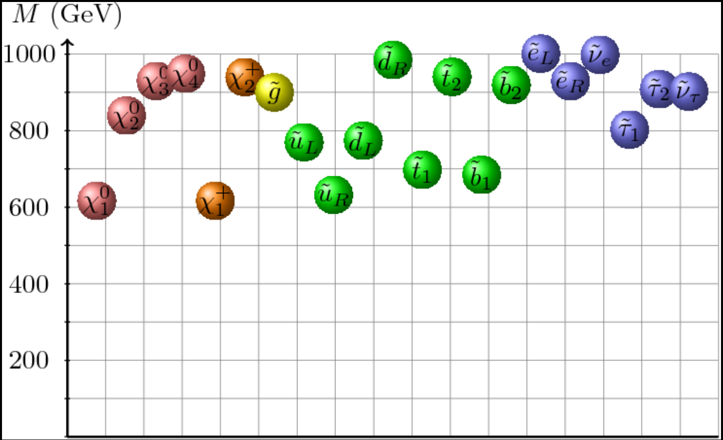
Example 1: 17158



Example 2: 7888



Example 3: 7105



It might also be interesting to build simplified models to study why particular analyses fail and how to optimize cuts for different regions of parameter space.

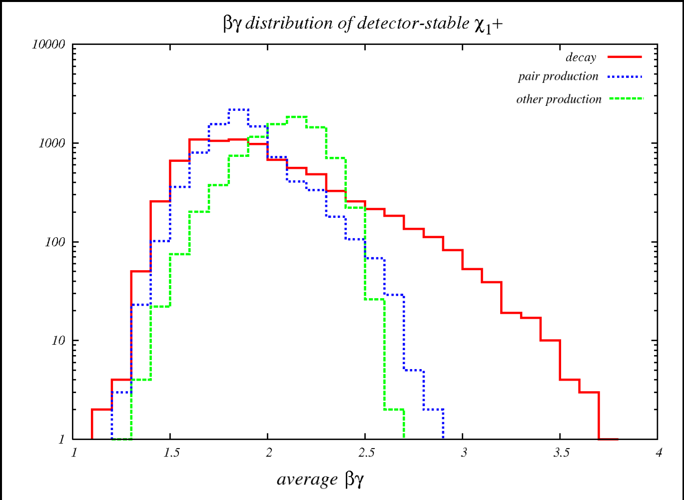
A word about topologies.

Interesting Topologies

In studying detector stable particles (of which there are relatively many) for our 14 TeV LHC paper, we saw that detector stable charginos from decays can be more boosted than those from the hard process.

My understanding is most experimental studies have focused on detector stable charginos produced in the hard process.

Boosted Detector-Stable Charginos



Boosted Charginos: Topologies

Squark and gluino production and (possibly cascade) decays to detector-stable charginos:

An interesting topology.

Conclusions

- "Low prejudice" approach to a very general model of new physics (the pMSSM) gives a large number of interesting possibilites for further LHC study.
- The approach which is the focus of this workshop- identifying simplified models, topologies, or new signatures may be a useful way to proceed.
- I've suggested ways in which this could be done.
- Too many pMSSM models to identify interesting regions in a model independent way; your ideas **VERY** welcome.