SUSY LHC signatures without prejudice

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arXiv:1008:4xxx
with J.S. Gainer, J.L. Hewett, M.P. Le, and T.G. Rizzo

Outline

Goal

In order to study the MSSM without theoretical prejudice Berger, Gainer, Hewett, and Rizzo (JHEP 0902:023)

- Adopted a set of phenomenologically motivated assumptions;
- Randomly scanned a broad range of parameter space;
- Checked each point against all experimental constraints;
- And thus obtained a general sample of viable MSSM models.

Our goal

To explore the properties and signatures of the MSSM through these models, especially at the LHC

Phenomological assumptions

- CP-conserving
- minimal flavor violation
- degenerate 1^{st} & 2^{nd} gen. sfermions
- neglect 1^{st} and 2^{nd} generation Yukawas

These assumptions are motivated by existing observational constraints.

Scanning the MSSM parameter space

After applying our assumptions

- We're left with 19 real, weak-scale parameters (pMSSM).
- We scan 10^7 random points (also separate, log prior scan).

$$100\,\mathrm{GeV} \leq m_{\tilde{f}} \leq 1\,\mathrm{TeV}$$
$$50\,\mathrm{GeV} \leq |M_{1,2}, \mu| \leq 1\,\mathrm{TeV}$$
$$100\,\mathrm{GeV} \leq M_3 \leq 1\,\mathrm{TeV}$$
$$|A_{b,t,\tau}| \leq 1\,\mathrm{TeV}$$
$$1 \leq \tan\beta \leq 50$$
$$43.5\,\mathrm{GeV} \leq m_A \leq 1\,\mathrm{TeV}$$

Enforcing theoretical and experimental constraints

Theoretical constraints

- No tachyons, no charge- or color-breaking minima, consistent EWSB
- LSP is lightest neutralino and thermal relic

Experimental constraints

- Precision electroweak and flavor measurements
- Relic density $<$ WMAP value
- Dark matter direct detection
- Detailed LEP and Tevatron sparticle and Higgs searches

$\sim 68,000$ of $10,000,000$ models survive all constraints.

Outline

ATLAS SUSY analyses

We pass our entire set of $\sim 7 \times 10^4$ models through a standard set of analyses (ATLAS CSC: arXiv:0901.0512), to see how they fare.

ATLAS analyses

- We use the ATLAS inclusive SUSY analyses.
- Multi-jet; 1-lepton + jets; SSDL; OSDL; trileptons; τ; b-jets.
- To check our analysis, we first compare to ATLAS results for the set of benchmark models they use.
- Then we will explore sensitivity of ATLAS (mSUGRA) analyses to our set of models.
- There are necessarily some differences between the ATLAS analysis and ours.

Comparison to ATLAS SUSY analyses

	ATLAS	**Us**
Spectrum & decays	ISASUGRA	SUSY-HIT[1]
Event generation, hadronization, and showering	HERWIG	PYTHIA
K-factors	Prospino	Prospino
Detector simulation	full GEANT	PGS4 LHC tune
Backgrounds	Generated large set of SM processes	Obtained from ATLAS

[1] negative QCD corrections turned off

Modifications to SUSY-HIT width and BR calculations

1. Turned off QCD corrections to avoid negative widths and BRs
2. Include 1st and 2nd generation particle masses
   1. 2 body decays: correct phase space
   2. 3 body decays: cutoff kinematically disallowed decays (consider hadronic final states)
3. Include exact formulae for close mass chargino decays and CKM-suppressed sbottom decays
4. Implement 4-body stop decays to different fermion pairs

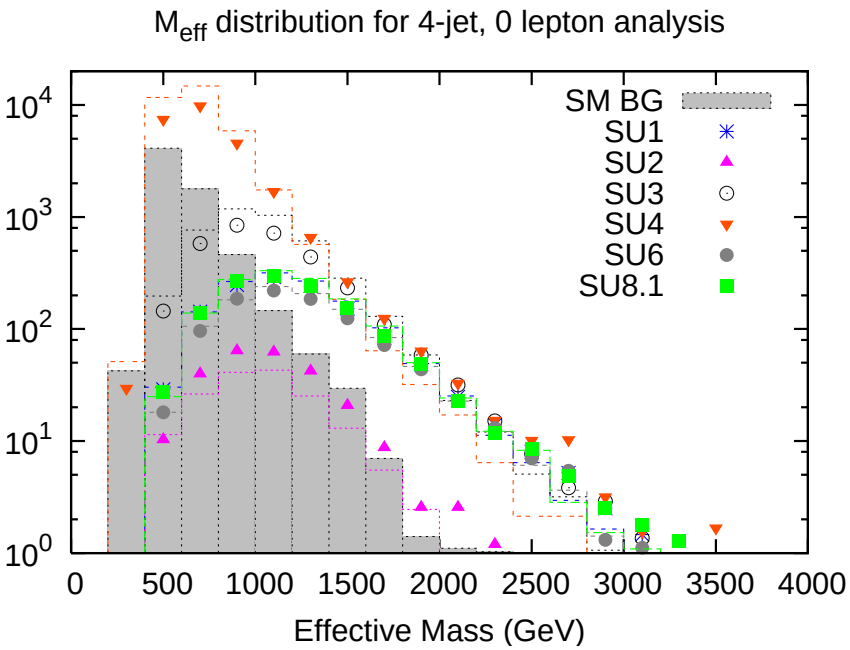
Verification of our analysis

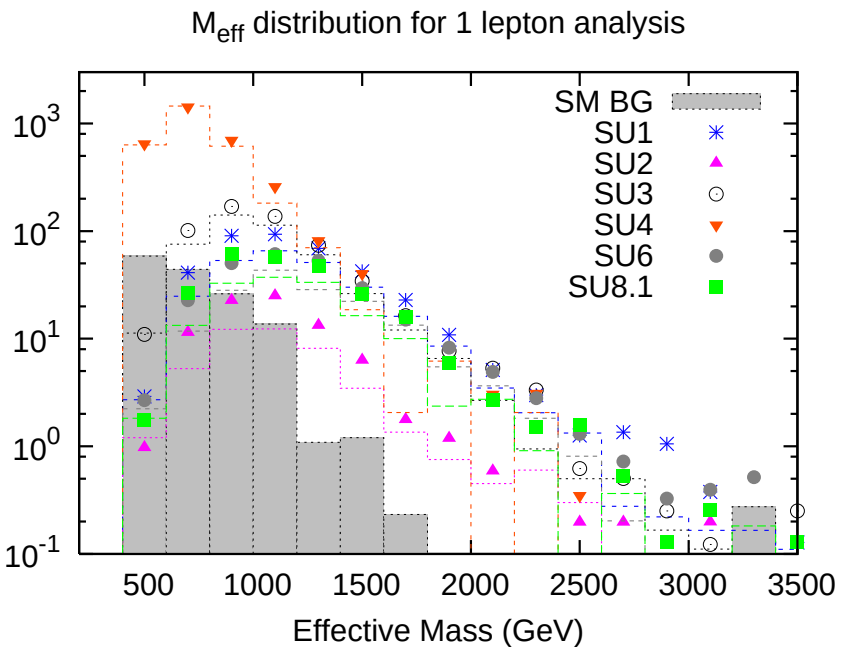
ATLAS benchmarks

ATLAS used a set of SUSY models in all its analyses. They are labeled SU1, 2, 3, 4, 6, 8.1, and 9.

- We generated spectra and decay tables for these benchmark points.
- We ran them through all the analyses and compared to ATLAS.
- The results suggest our analyses reproduce the ATLAS analyses faithfully.

Comparison of M_{eff} distributions with ATLAS



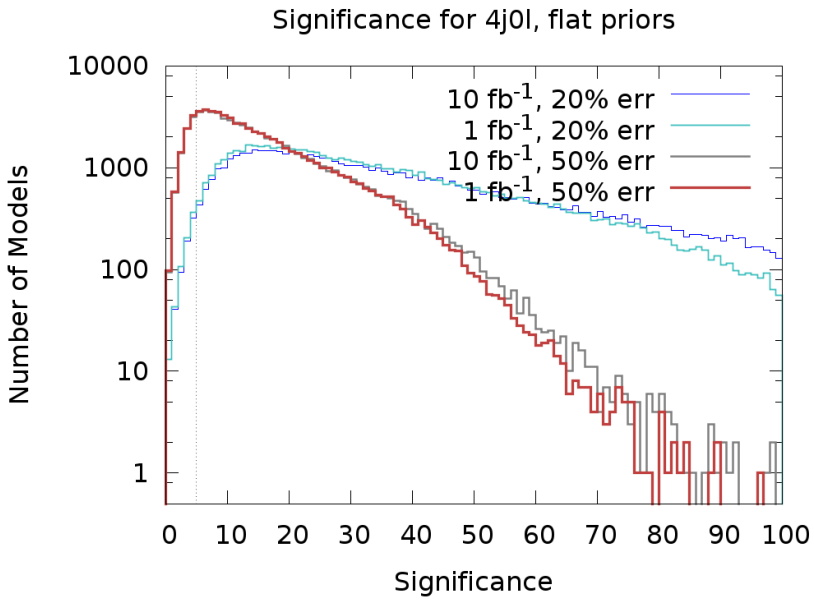


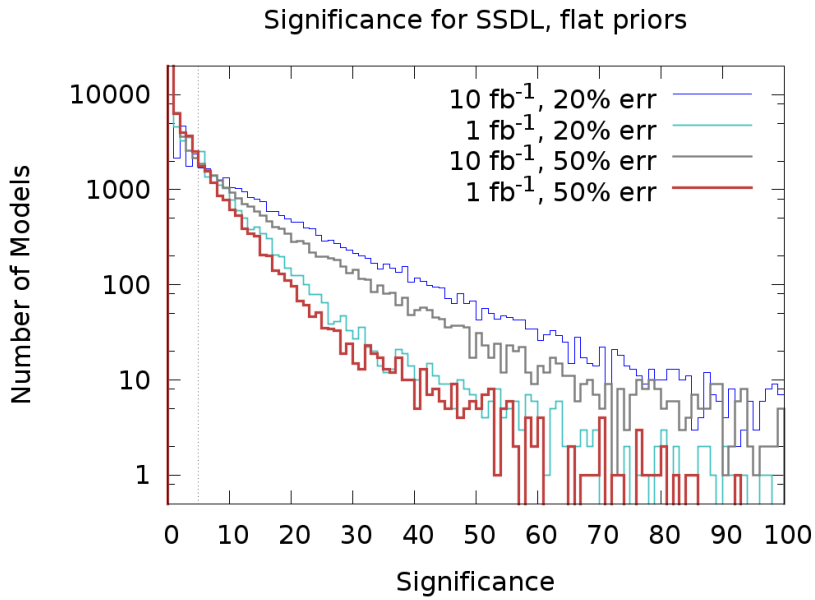
Outline

Global results: performance of analyses

Analysis	50%, 1 fb^{-1}	50%, 10 fb^{-1}	20%, 1 fb^{-1}	20%, 10 fb^{-1}
4 jets, 0 lep	88.331	88.578	98.912	99.014
2 jets, 0 lep	87.616	87.774	98.75	98.802
1 lep, 4 jets	41.731	44.885	56.849	63.045
1 lep, 3 jets	64.058	70.907	69.725	81.111
1 lep, 2 jets	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
3 lep + jet	13.549	17.361	19.293	28.97
3 lep + E_T^{miss}	2.7406	2.9135	4.8844	5.8284
τ	83.51	86.505	96.928	98.695
b-jet	73.983	76.939	91.672	94.867

Effect of systematic error and luminosity





At low luminosity, most of the SUSY analyses will already soon be systematics-limited!

Global results: missed and passed models

50% error

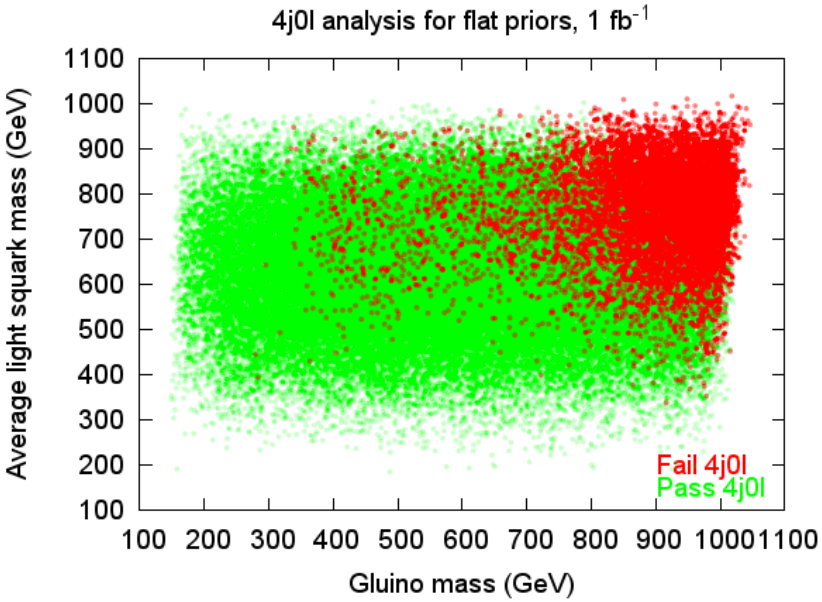
# analyses	1 fb^{-1}	10 fb^{-1}
0	0.56754	0.36796
1	1.3458	0.98841
2	3.396	2.5141
3	13.175	10.635
4	22.014	18.455
5	9.5512	10.3
6	15.227	16.929
7	20.081	17.697
8	7.6394	11.75
9	3.9205	6.3569
10	2.0825	2.7943
11	1.0013	1.2116

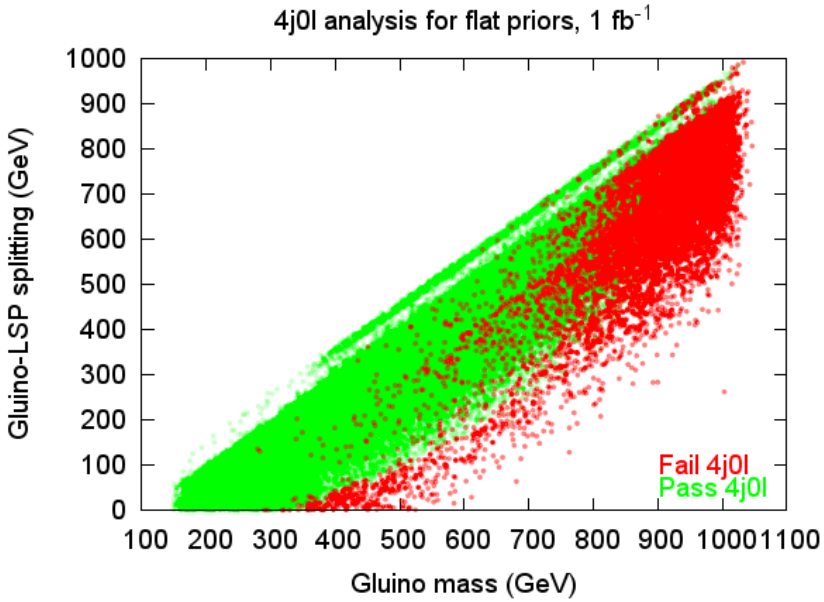
Global results: missed and passed models

20% error

# analyses	1 fb^{-1}	10 fb^{-1}
0	0.016411	0.0059733
1	0.077577	0.041813
2	0.57139	0.22848
3	4.9157	2.5939
4	22.083	13.719
5	5.9003	6.0883
6	11.173	14.751
7	30.085	24.238
8	9.4376	13.201
9	6.051	10.57
10	6.5538	10.175
11	3.1359	4.3874

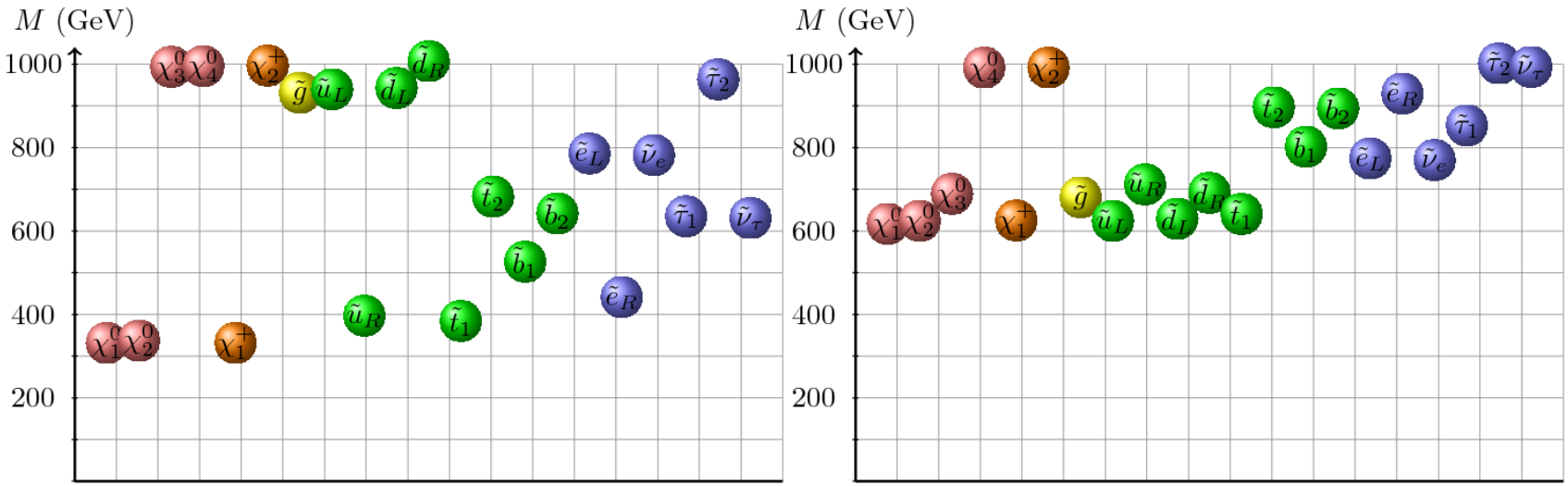
Why do models fail?





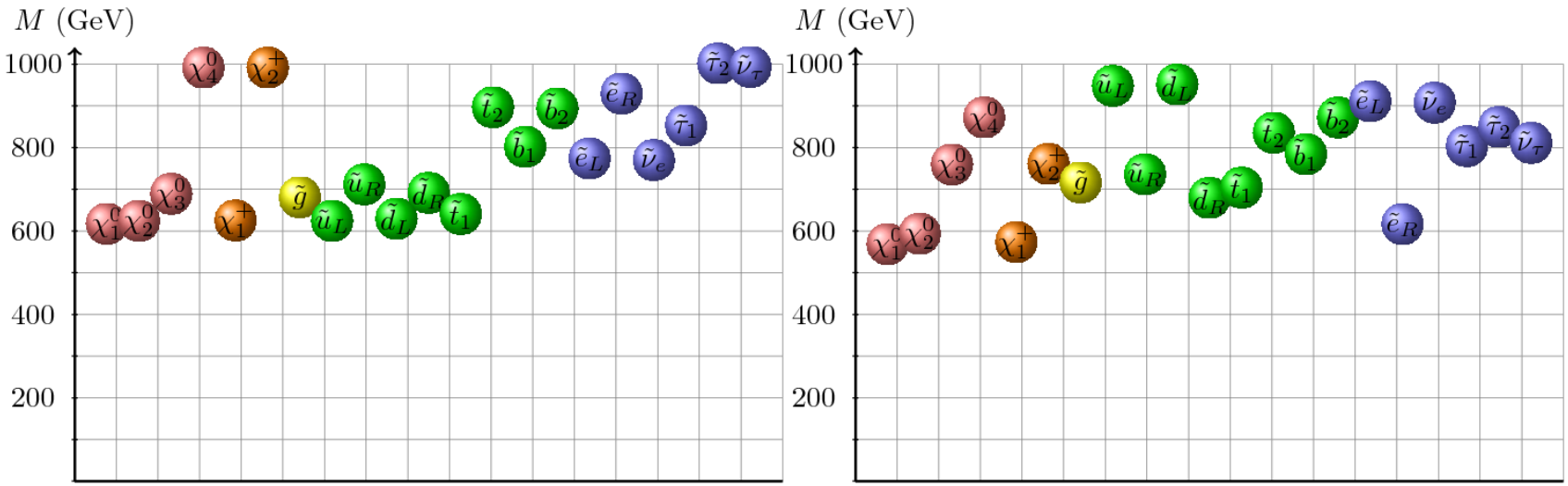
- Gluino and squark masses important, but not everything.
- Details of the spectrum and in particular branching ratios can matter.

Some failure spectra



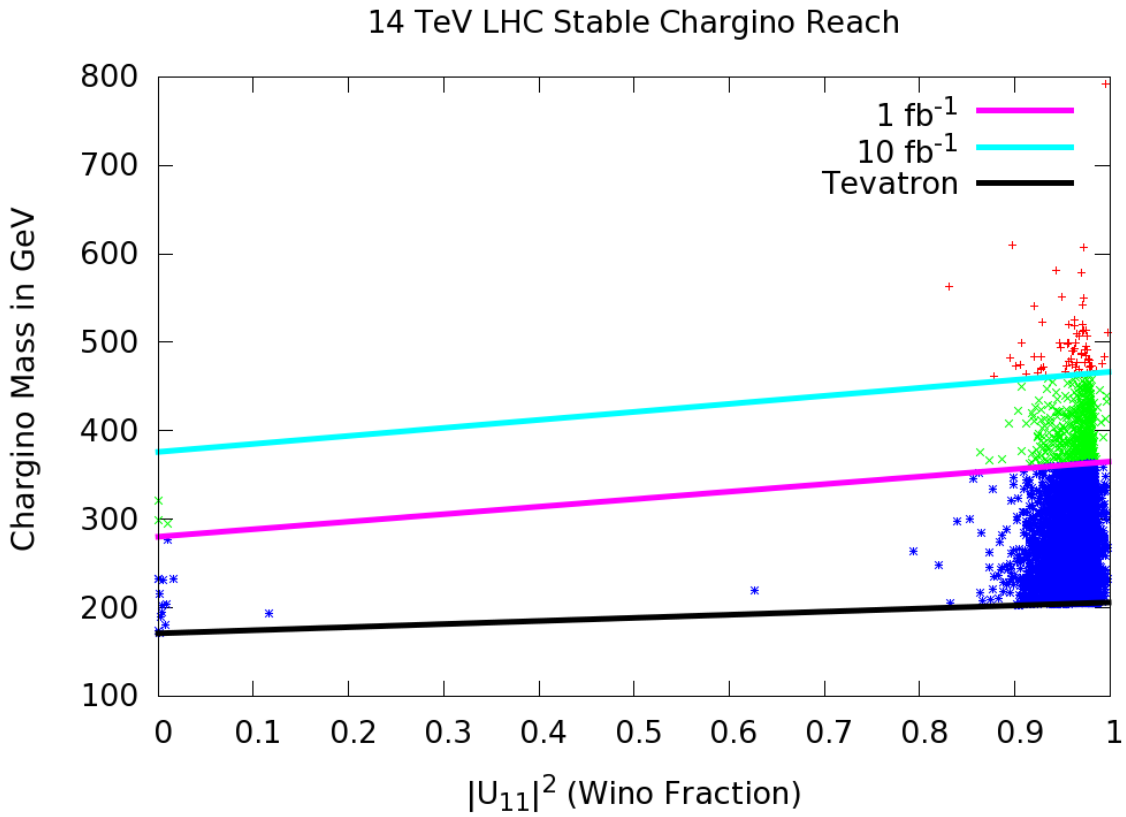
These models fail because of the stable chargino (left) and the overall heavy and compressed spectrum (right).

Sister models



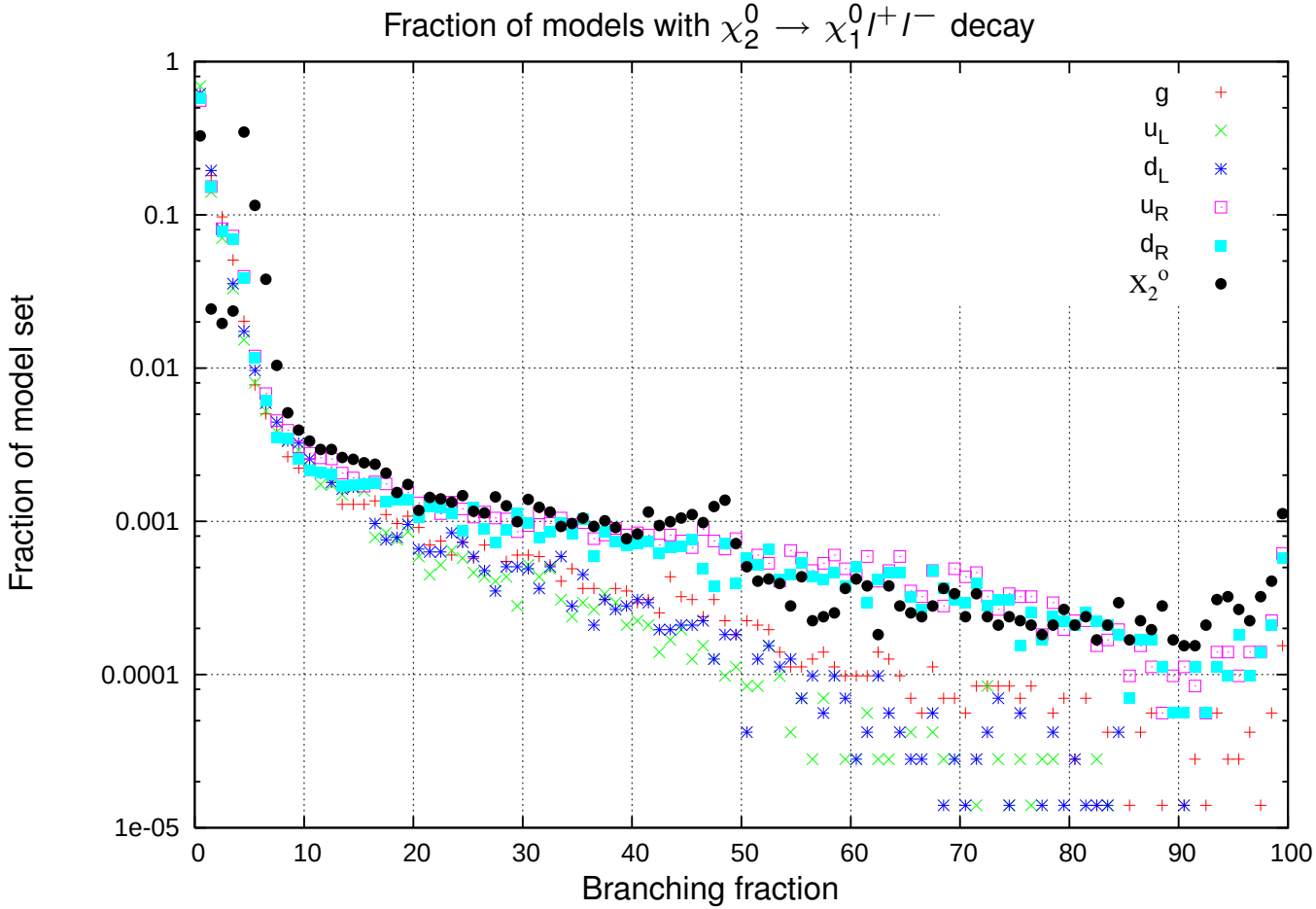
A failure model (left) and its sister (right).

Search for stable particles



- Search for stable sparticles can be a powerful complement to E_T^{miss}-based searches
- Production of stable particles in cascades deserves further study!

Classic decay modes?



This decay chain is fairly rare!

Summary and outlook

- We have examined the LHC signatures of a general set of viable MSSM models.
- Taken together, the standard SUSY searches have good coverage of this model set.
- There are, however, interesting exceptions and hard-to-find models: this suggests complementary analyses (e.g. stable particles).
- Reducing systematic error on backgrounds is crucial to improving the reach of the MSSM searches.