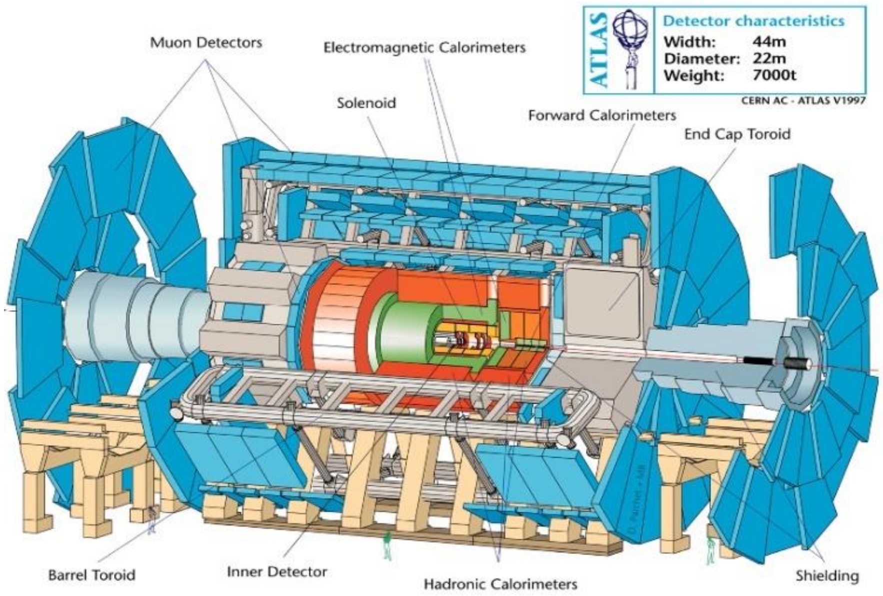
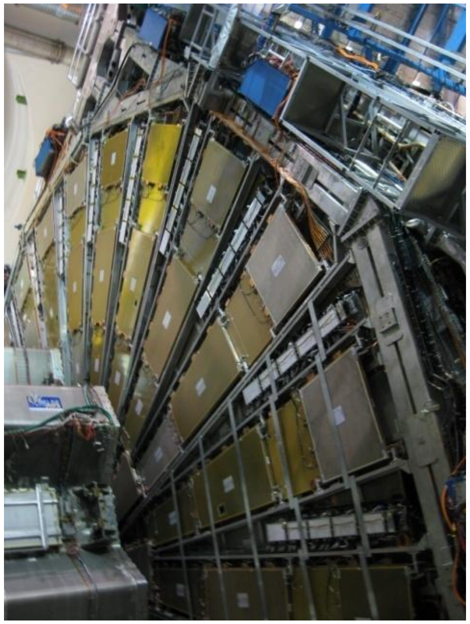
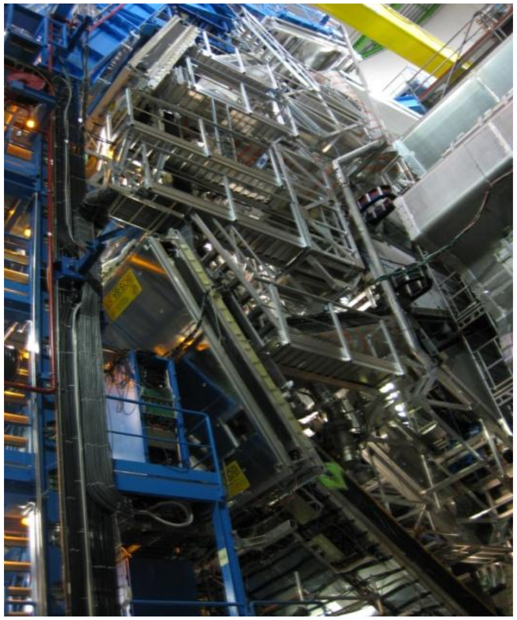
SUSY Without Prejudice at ATLAS







J.A. Conley, J. S. Gainer, J. L. Hewett,
M.-P. Le & TGR ; arXiv:1009.2539,1012.xxxx

10/26/2010

SLAC NATIONAL ACCELERATOR LABORATORY

Issues:

- The MSSM is very difficult to study due to the very large number of soft SUSY breaking parameters (~ 100).
- Analyses are generally limited to a specific SUSY breaking scenario having only a few parameters…can we do better?

Our Model Generation Assumptions :

- The most general, CP-conserving MSSM with R-parity
- Minimal Flavor Violation at the TeV scale
- The lightest neutralino is the LSP & a thermal relic.
- The first two sfermion generations are degenerate
- The first two generations have negligible Yukawa's.
- No assumptions about SUSY-breaking or unification

This leaves us with the pMSSM:

→ the MSSM with 19 real, TeV/weak-scale parameters…

19 pMSSM Parameters

10 sfermion masses: m_{Q_1}, m_{Q_3}, m_{u_1}, m_{d_1}, m_{u_3}, m_{d_3}, m_{L_1}, m_{L_3}, m_{e_1}, m_{e_3}

3 gaugino masses: M_1, M_2, M_3

3 tri-linear couplings: A_b, A_t, A_τ

3 Higgs/Higgsino: μ, M_A, $\tan\beta$

What are (aren't) the Goals of this Study???

- Prepare a large model sample, ~50k, satisfying 'all' experimental constraints.
- Examine the properties of the surviving 'models'.
- Do physics analyses with these models.

→ Our goal is NOT to find the 'best-fit' model(s) but to explore new physics that is somewhat different from what's seen in the more familiar SUSY breaking frameworks

How? Perform 2 Random Scans

Flat Priors

emphasizes moderate masses

$100\ \text{GeV} \leq m_{\text{sfermions}} \leq 1\ \text{TeV}$

$50\ \text{GeV} \leq |M_1, M_2, \mu| \leq 1\ \text{TeV}$

$100\ \text{GeV} \leq M_3 \leq 1\ \text{TeV}$

$\sim 0.5\ M_Z \leq M_A \leq 1\ \text{TeV}$

$1 \leq \tan\beta \leq 50$

$|A_{t,b,\tau}| \leq 1\ \text{TeV}$

Log Priors

emphasizes lower masses but also extends to higher masses

$100\ \text{GeV} \leq m_{\text{sfermions}} \leq 3\ \text{TeV}$

$10\ \text{GeV} \leq |M_1, M_2, \mu| \leq 3\ \text{TeV}$

$100\ \text{GeV} \leq M_3 \leq 3\ \text{TeV}$

$\sim 0.5\ M_Z \leq M_A \leq 3\ \text{TeV}$

$1 \leq \tan\beta \leq 60$

$10\ \text{GeV} \leq |A_{t,b,\tau}| \leq 3\ \text{TeV}$

- Flat Priors : 10^7 models scanned , ~ 68.4 K (0.68%) survive
- Log Priors : 2×10^6 models scanned , ~ 2.9 K (0.14%) survive

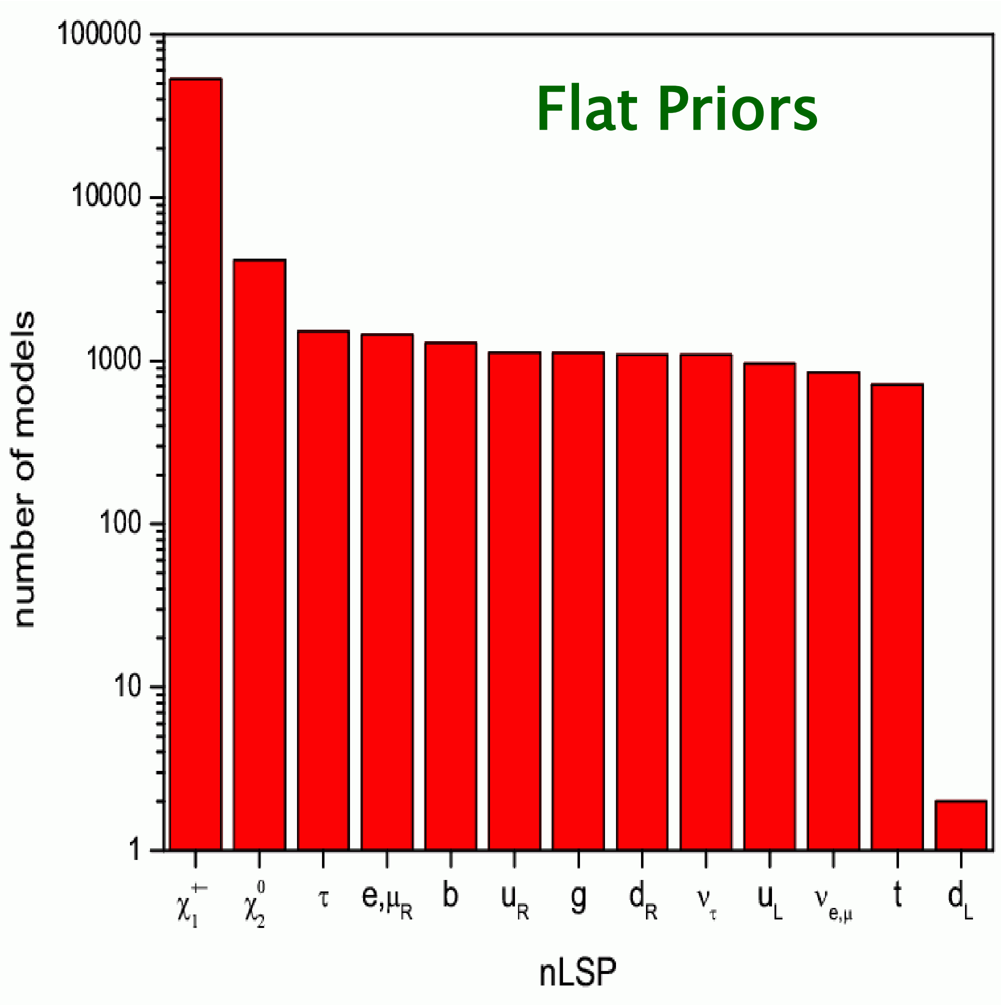
→Comparison of these two scans will show the prior sensitivity.

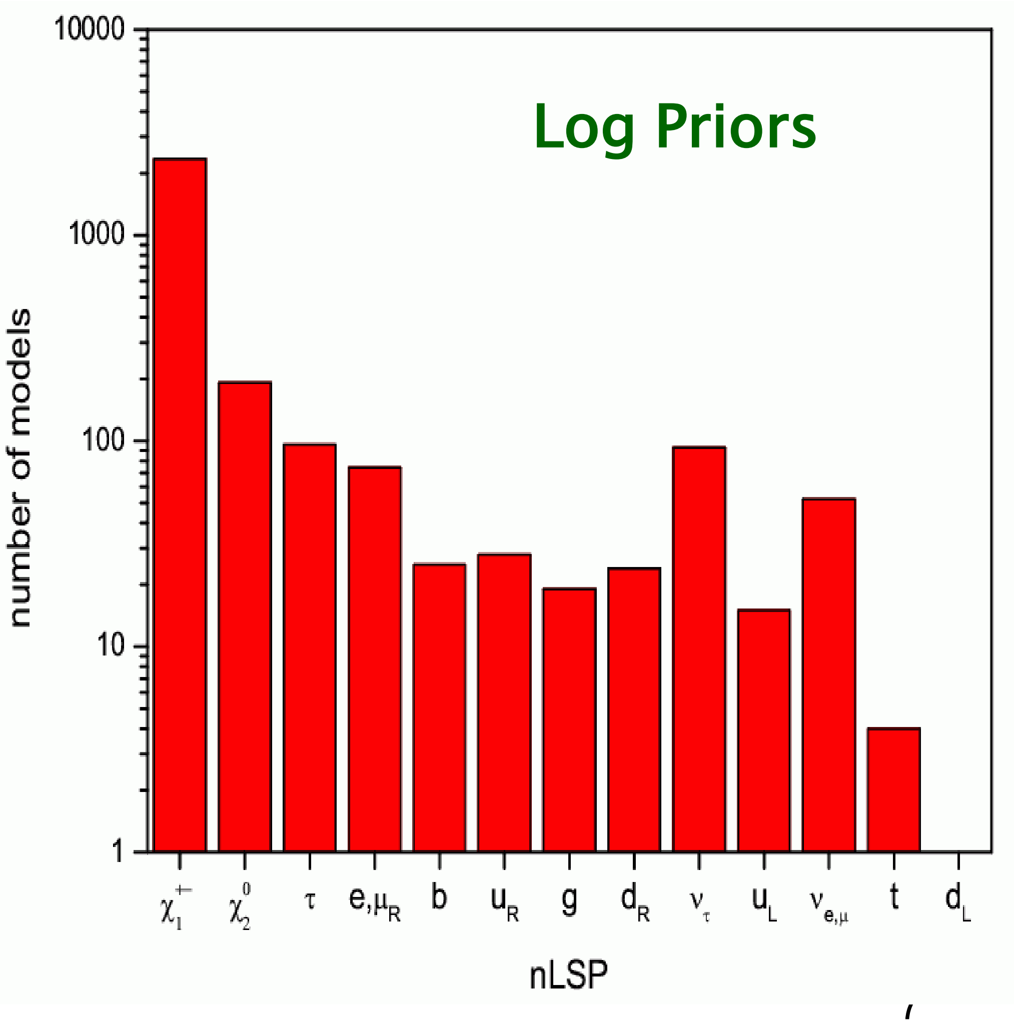
Some Constraints

- $\Delta\rho$ $b \rightarrow s\,\gamma$
- $\Delta(g\text{-}2)_\mu$ $\Gamma(Z\rightarrow \text{invisible})$
- Meson-Antimeson Mixing
- $B_s\rightarrow\mu\mu$ $B\rightarrow\tau\nu$

- Direct Detection Searches for Dark Matter
- Dark Matter density: $\Omega h^2 < 0.121$. We treat this only as an *upper bound* on the neutralino contribution
- LEP and Tevatron Direct Higgs & SUSY searches : there are *many* of these searches & they are quite complicated with many caveats…. These needed to be 'revisited' for the more general case considered here

→ Lots of differences with mSUGRA, e.g., the nLSP can be ANY of the 13 possibilities !





ATLAS SUSY Analyses w/ a Large Model Set

- We passed these models through the ATLAS inclusive MET analysis suites (@ both 14&7 TeV), designed for mSUGRA , to explore sensitivity to this far broader class of SUSY models

- We used the ATLAS SM backgrounds (Thanks!!!), with their associated systematic errors # & their statistical criterion for SUSY 'discovery', etc.

- We first verified that we can approximately reproduce the ATLAS results for their benchmark mSUGRA models with our analysis techniques for each channel. .beware of analysis differences

We use the exact expressions for Z_n as given by ATLAS without any approximations ..causing some numerical differences with the ATLAS CSC public results

ATLAS

ISASUGRA generates spectrum & sparticle decays

Partial NLO cross sections using PROSPINO & CTEQ6M

Herwig for fragmentation & hadronization

GEANT4 for full detector sim

US

SuSpect generates spectra with SUSY-HIT[#] for decays

NLO cross section for all 85 processes using PROSPINO[**] & CTEQ6.6M

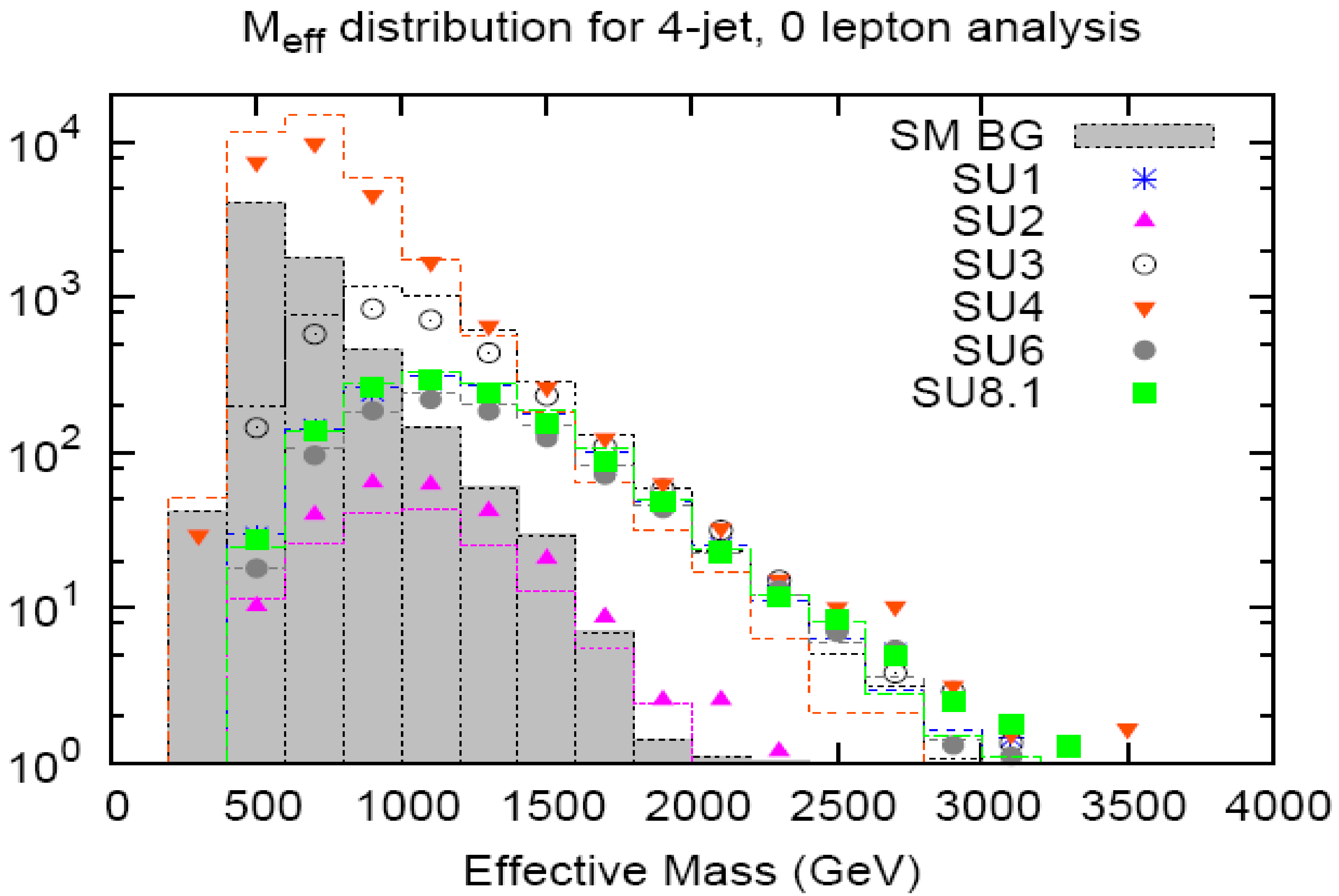
PYTHIA for fragmentation & hadronization

PGS4-ATLAS for fast detector simulation

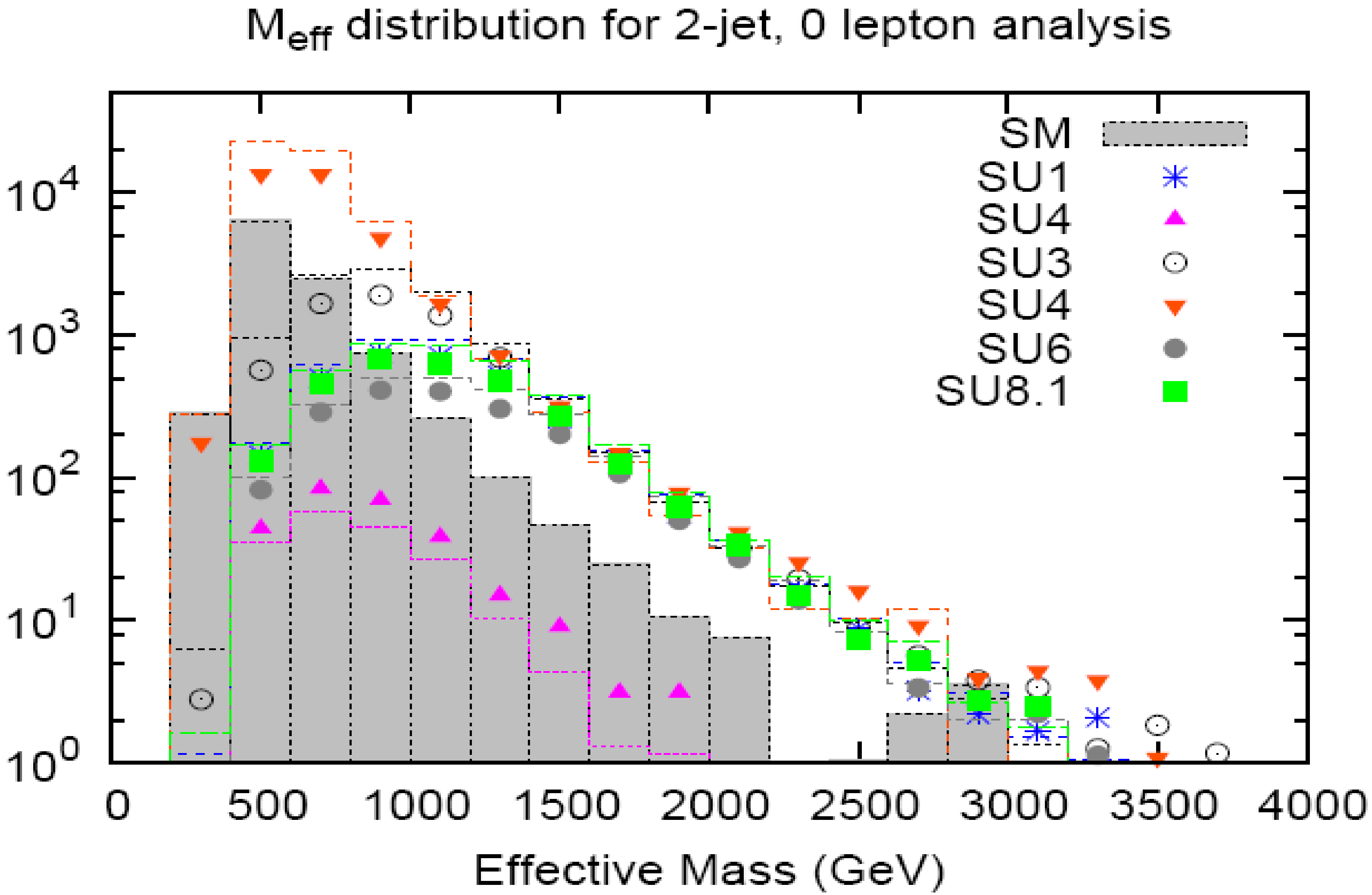
[**] version w/ negative K-factor errors corrected

[#] version w/o negative QCD corrections, with 1st & 2nd generation fermion masses & other very numerous PS fixes included. e.g., explicit small Δm chargino decays, etc.

14 TeV Benchmark Tests: Us vs Them Part I

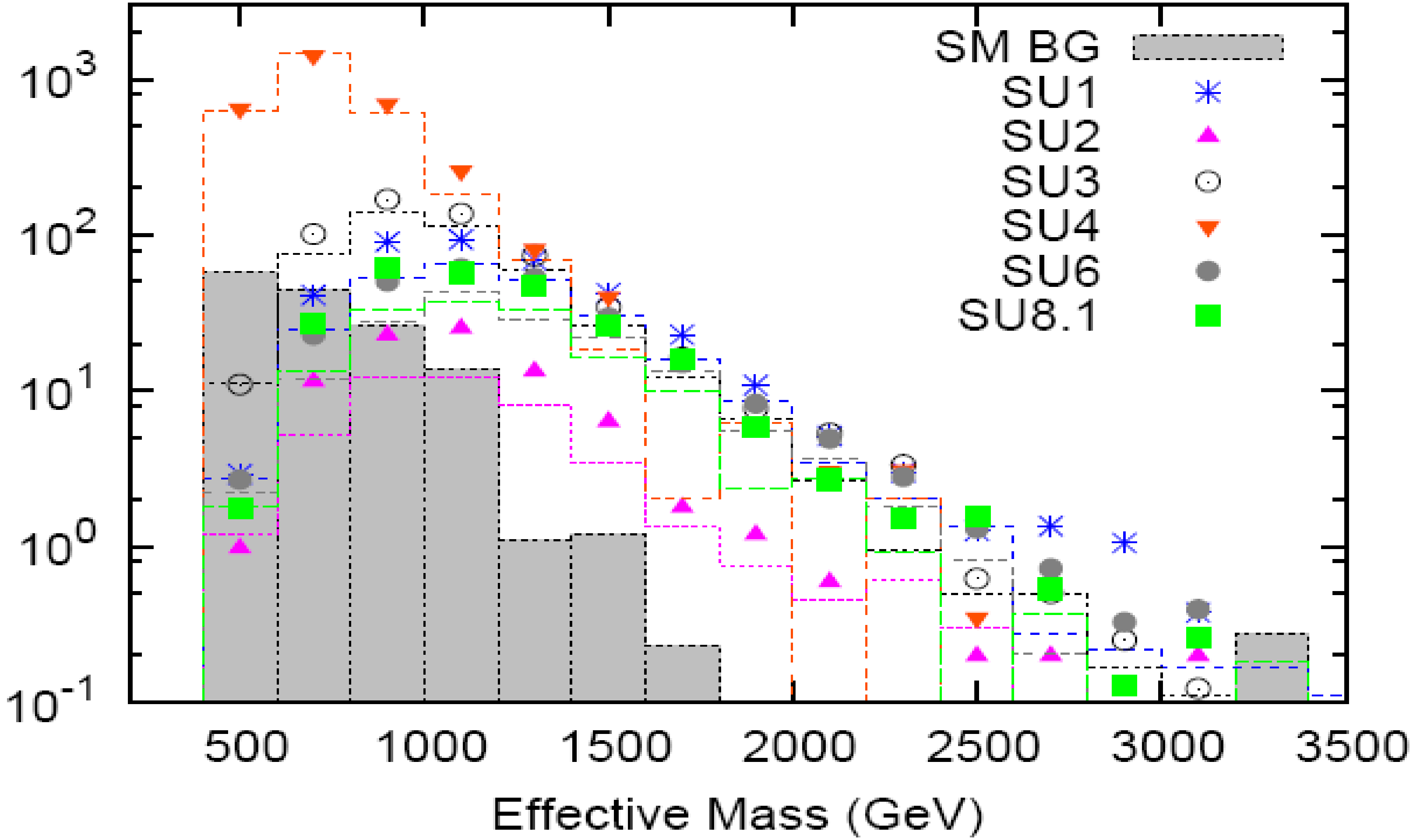


14 TeV Benchmark Tests: Us vs Them Part II



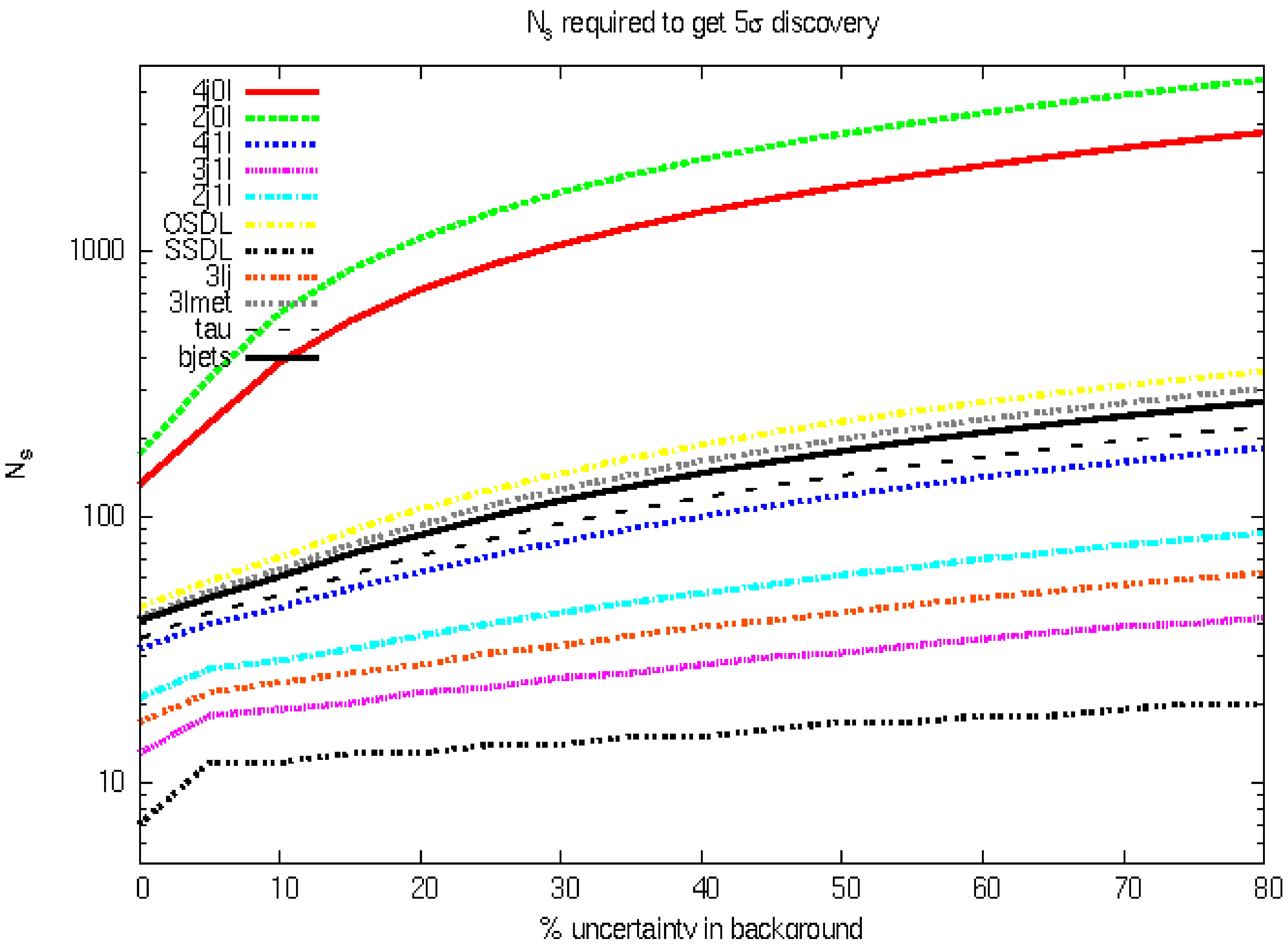
14 TeV Benchmark Tests: Us vs Them Part III

4j
M_{eff} distribution for ^1 lepton analysis

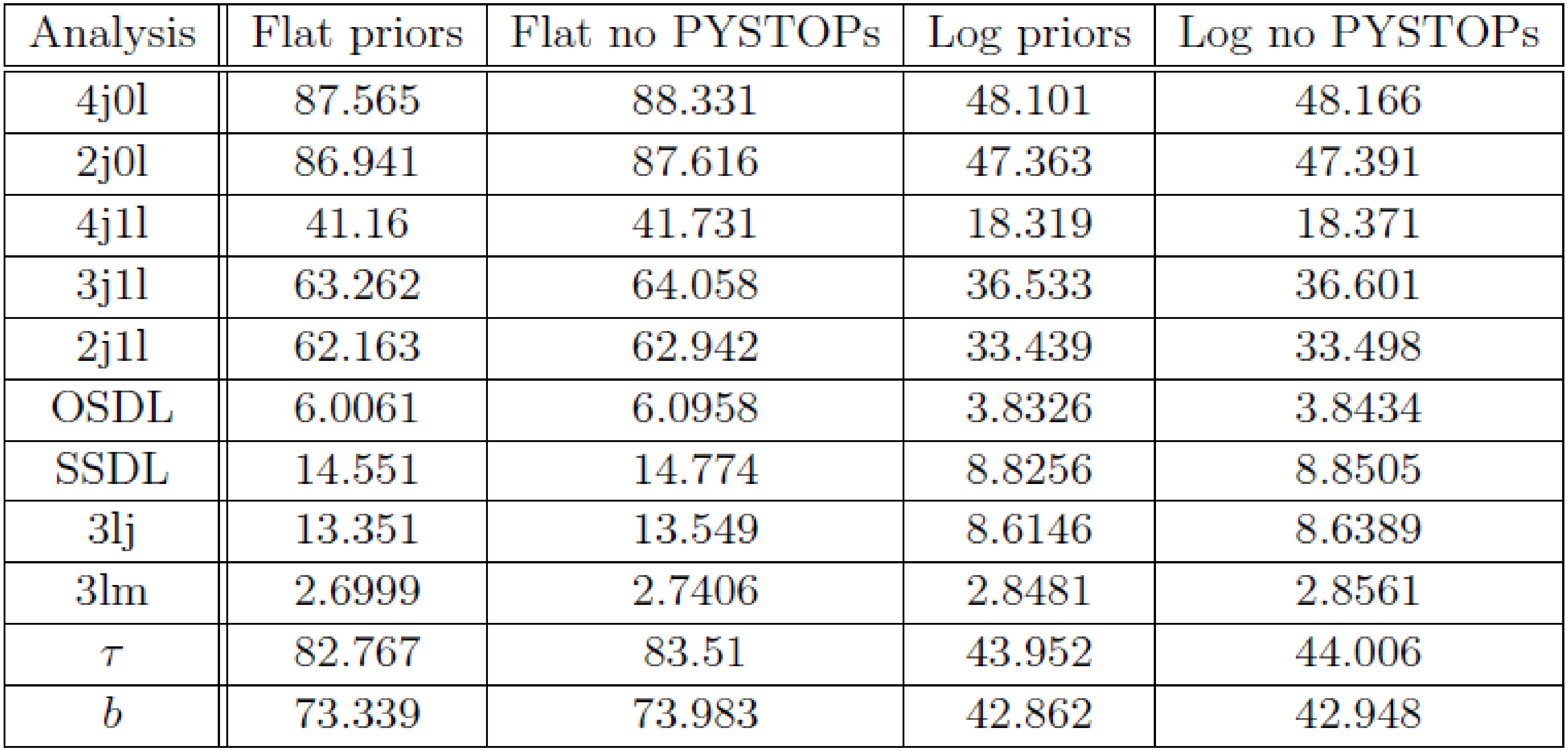


ATLAS 14TeV/ 1fb $^{-1}$ Backgrounds & 'Target' Signal Counts

ANALYSIS	BACKGROUND	S=5, δB=50%	δB=20%
4j0l	709	1759	721
2j0l	1206	2778	1129
4j1l	41.6	121	62
3j1l	7.2	44	28
2j1l	18.2	61	36
OSDL	84.7	230	108
SSDL	2.3	17	13
3l1j	12	44	28
3lm	72.5	198	94
τ	51	144	72
b	69	178	86


N_s required to get 5σ discovery
4j0l
2j0l
4j1l
3j1l
2j1l
OSDL
SSDL
3lj
3lmet
tau
bjets
N_s
1000
100
10
0
10
20
30
40
50
60
70
80
% uncertainty in background

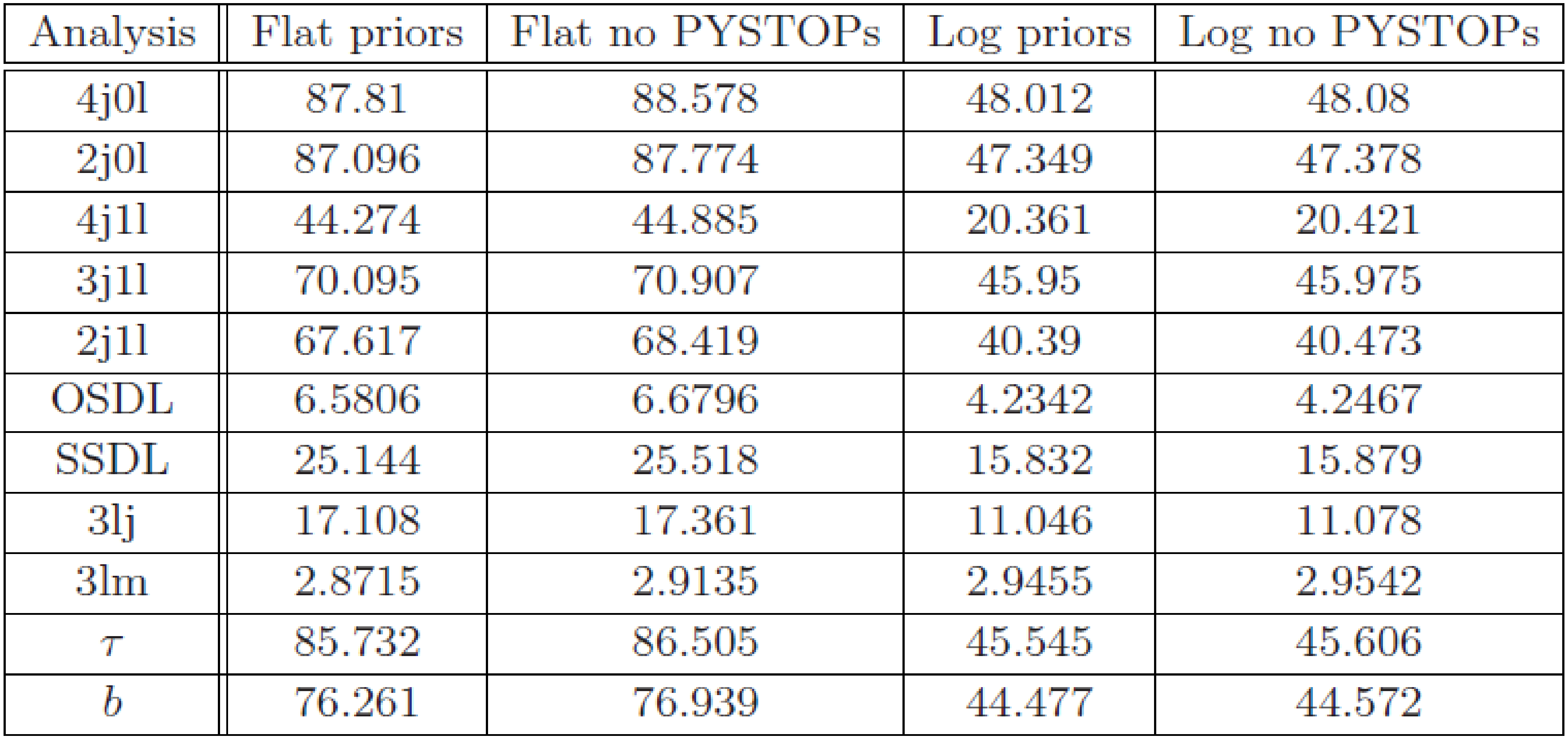
What fraction of models are ‘seen’ by any of these analyses assuming an integrated luminosity of $1\ \mathrm{fb}^{-1}$ & $\delta B=50\%$?



Analysis	Flat priors	Flat no PYSTOPs	Log priors	Log no PYSTOPs
4j0l	87.565	88.331	48.101	48.166
2j0l	86.941	87.616	47.363	47.391
4j1l	41.16	41.731	18.319	18.371
3j1l	63.262	64.058	36.533	36.601
2j1l	62.163	62.942	33.439	33.498
OSDL	6.0061	6.0958	3.8326	3.8434
SSDL	14.551	14.774	8.8256	8.8505
3lj	13.351	13.549	8.6146	8.6389
3lm	2.6999	2.7406	2.8481	2.8561
τ	82.767	83.51	43.952	44.006
b	73.339	73.983	42.862	42.948

A PYSTOP occurs for a model when PYTHIA cannot properly treat the hadronization in at least one of the decay chains it encounters.

What fraction of models are ‘seen’ by any of these analyses assuming an integrated luminosity of 10 fb^{-1} & $\delta B=50\%$?

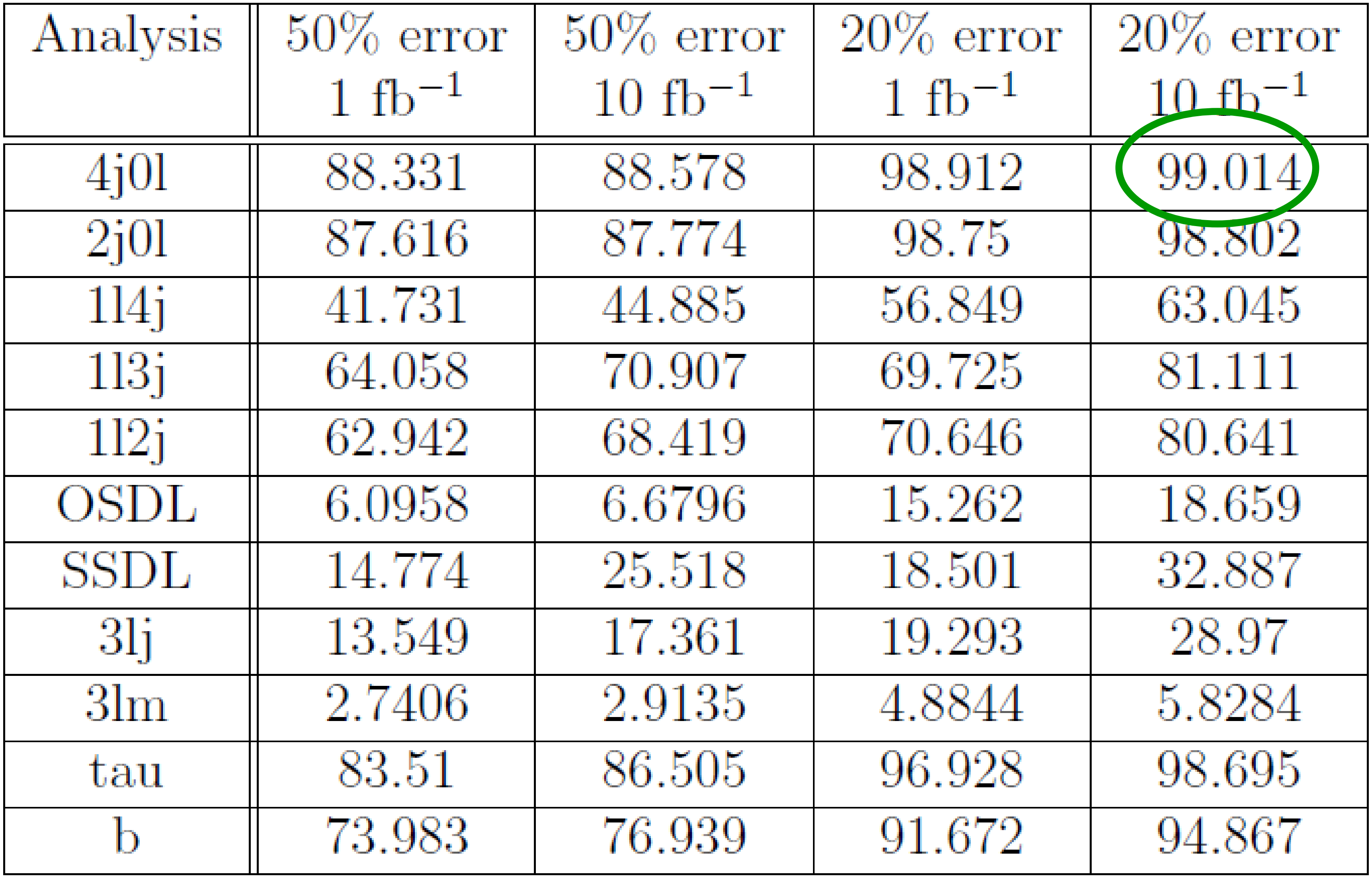


Analysis	Flat priors	Flat no PYSTOPs	Log priors	Log no PYSTOPs
4j0l	87.81	88.578	48.012	48.08
2j0l	87.096	87.774	47.349	47.378
4j1l	44.274	44.885	20.361	20.421
3j1l	70.095	70.907	45.95	45.975
2j1l	67.617	68.419	40.39	40.473
OSDL	6.5806	6.6796	4.2342	4.2467
SSDL	25.144	25.518	15.832	15.879
3lj	17.108	17.361	11.046	11.078
3lm	2.8715	2.9135	2.9455	2.9542
τ	85.732	86.505	45.545	45.606
b	76.261	76.939	44.477	44.572

Increasing the lumi DOES help in some cases…especially those with low backgrounds. The most interesting cases are when it doesn’t!

Changing the systematic error on the background can have a large effect

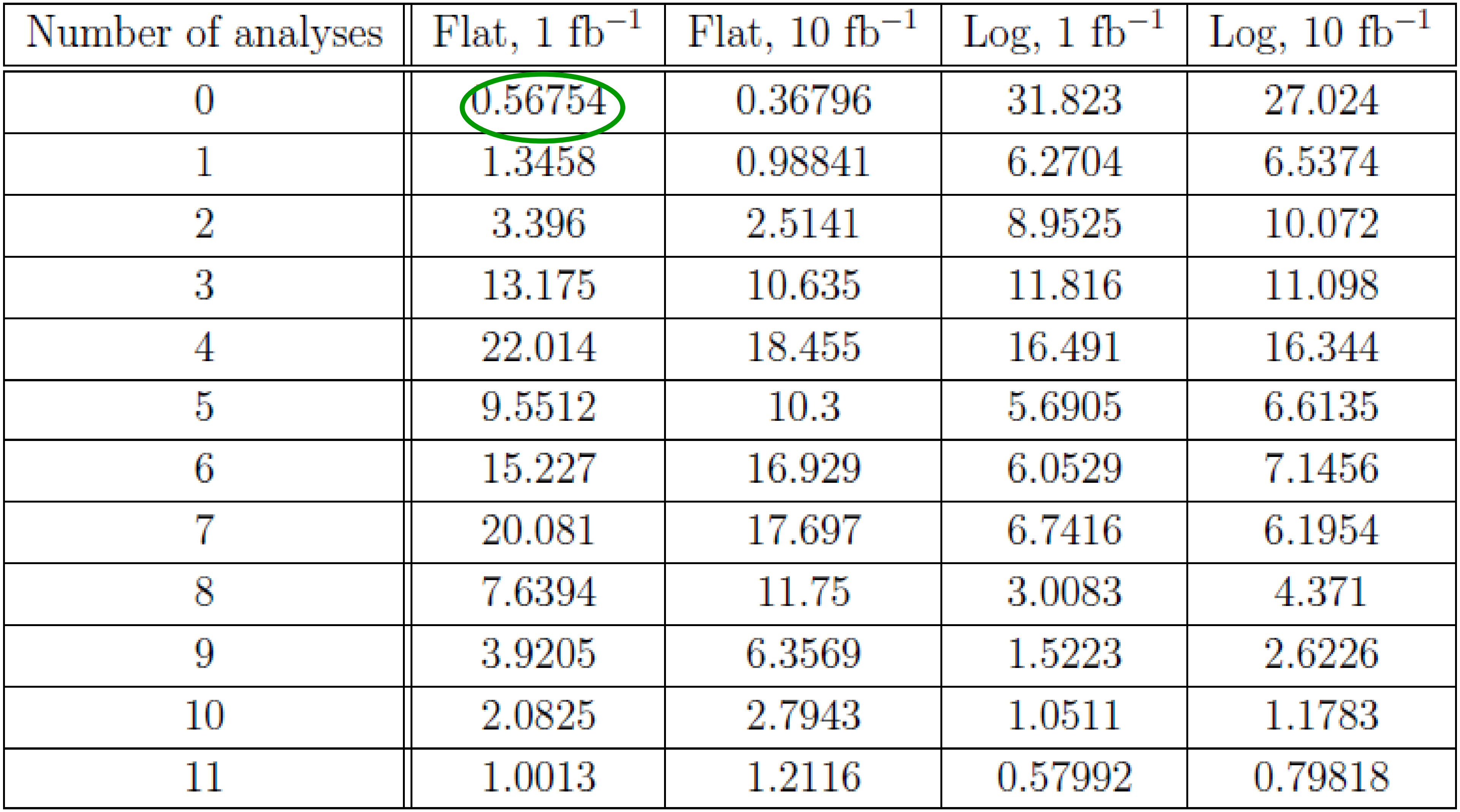
FLAT



Analysis	50% error 1 fb^{-1}	50% error 10 fb^{-1}	20% error 1 fb^{-1}	20% error 10 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

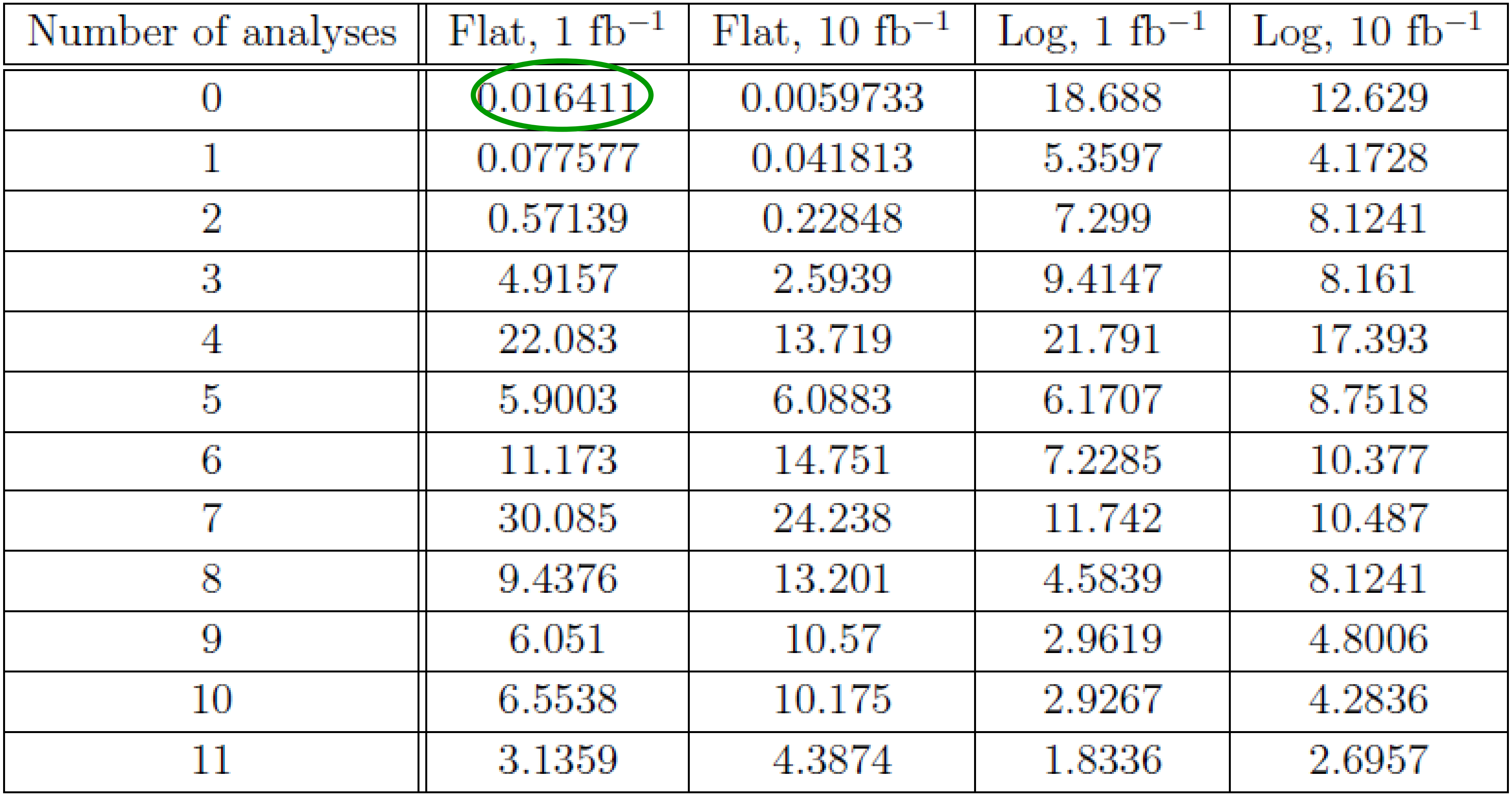
! !

The fraction of models ‘found’ by n different analyses for $\delta B=50\%$:



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

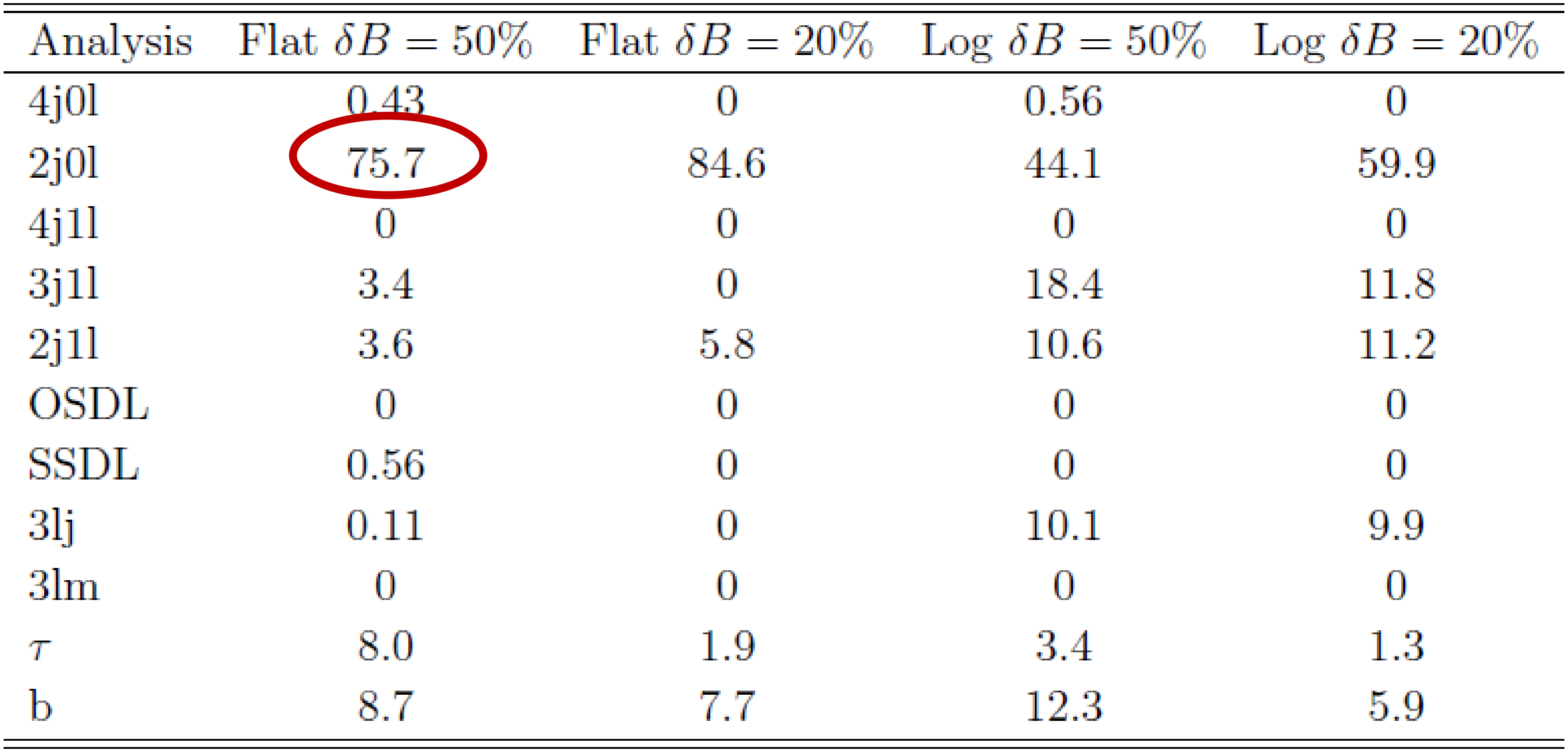
The fraction of models ‘found’ by n different analyses for δB=20% : Reducing systematic is the way to go !



Number of analyses	Flat, 1 fb^{-1}	Flat, 10 fb^{-1}	Log, 1 fb^{-1}	Log, 10 fb^{-1}
0	0.016411	0.0059733	18.688	12.629
1	0.077577	0.041813	5.3597	4.1728
2	0.57139	0.22848	7.299	8.1241
3	4.9157	2.5939	9.4147	8.161
4	22.083	13.719	21.791	17.393
5	5.9003	6.0883	6.1707	8.7518
6	11.173	14.751	7.2285	10.377
7	30.085	24.238	11.742	10.487
8	9.4376	13.201	4.5839	8.1241
9	6.051	10.57	2.9619	4.8006
10	6.5538	10.175	2.9267	4.2836
11	3.1359	4.3874	1.8336	2.6957

Question: If a model is found in only 1 analysis, which analysis is it ?

$1\ \text{fb}^{-1}$



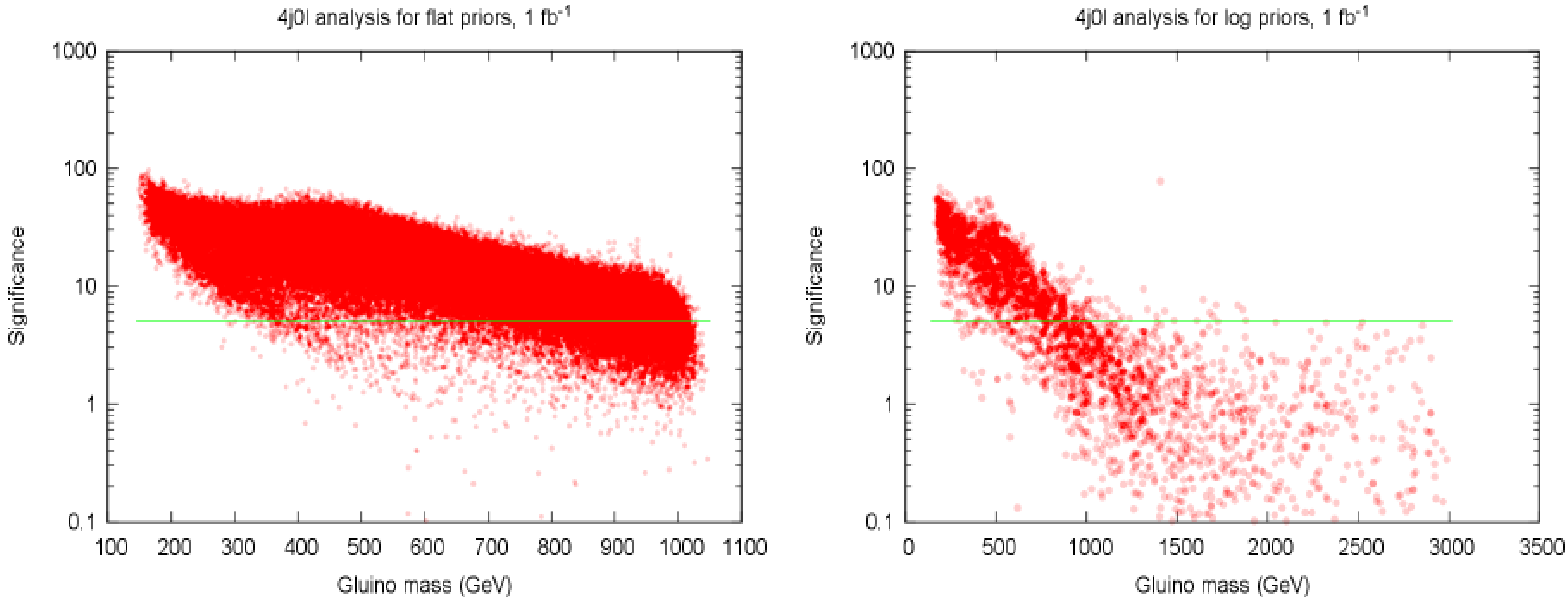
Analysis	Flat $\delta B = 50\%$	Flat $\delta B = 20\%$	Log $\delta B = 50\%$	Log $\delta B = 20\%$
4j0l	0.43	0	0.56	0
2j0l	75.7	84.6	44.1	59.9
4j1l	0	0	0	0
3j1l	3.4	0	18.4	11.8
2j1l	3.6	5.8	10.6	11.2
OSDL	0	0	0	0
SSDL	0.56	0	0	0
3lj	0.11	0	10.1	9.9
3lm	0	0	0	0
τ	8.0	1.9	3.4	1.3
b	8.7	7.7	12.3	5.9

Why 2j0l wins over 4j0l in this case has not yet been studied.

Why Do Models Get Missed by ATLAS?

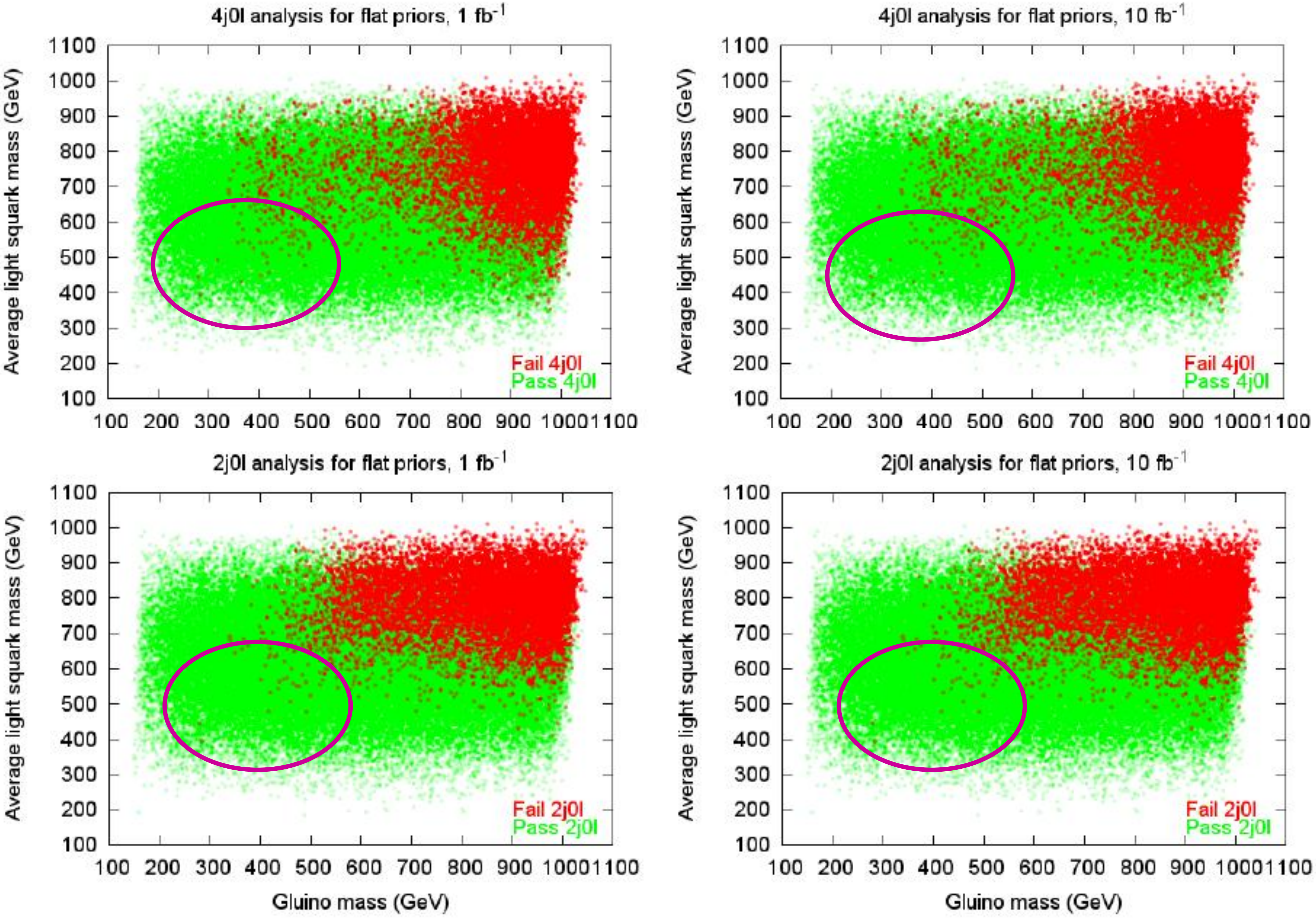
Missed Models: Is it 'just the mass' ??

There IS a GENERAL reduction in S as the gluino mass increases BUT there is also quite a spread in the significance at any fixed value of the mass by more than an order of magnitude.

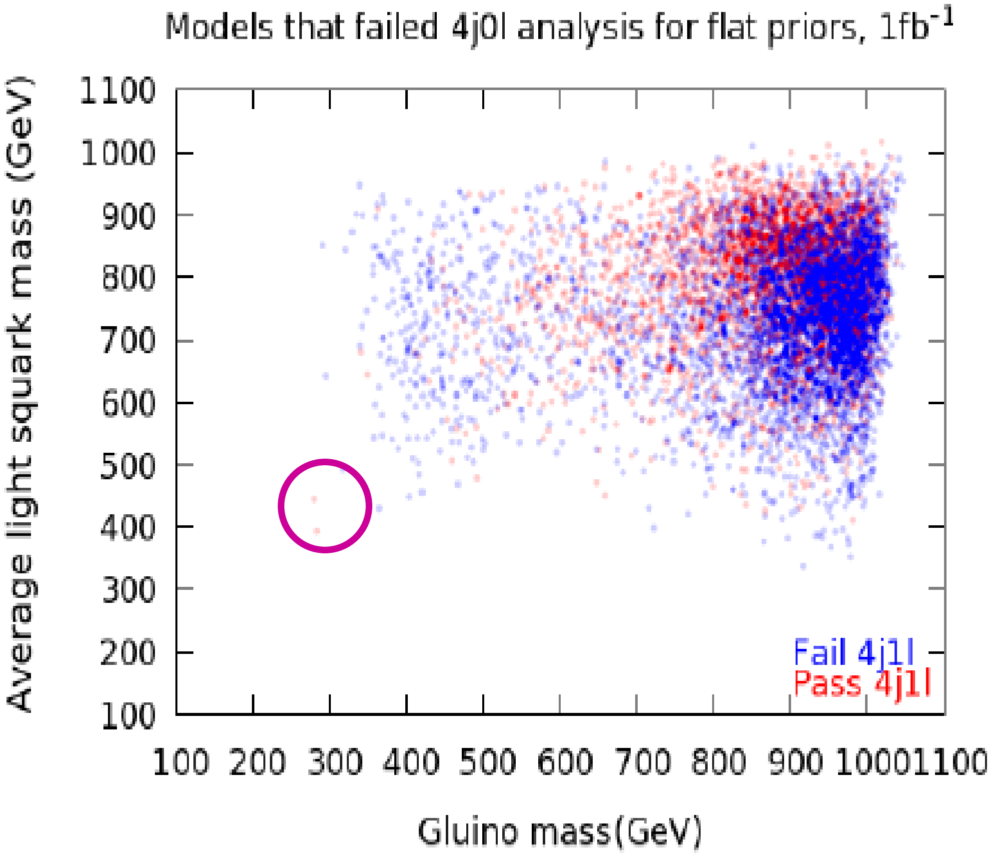


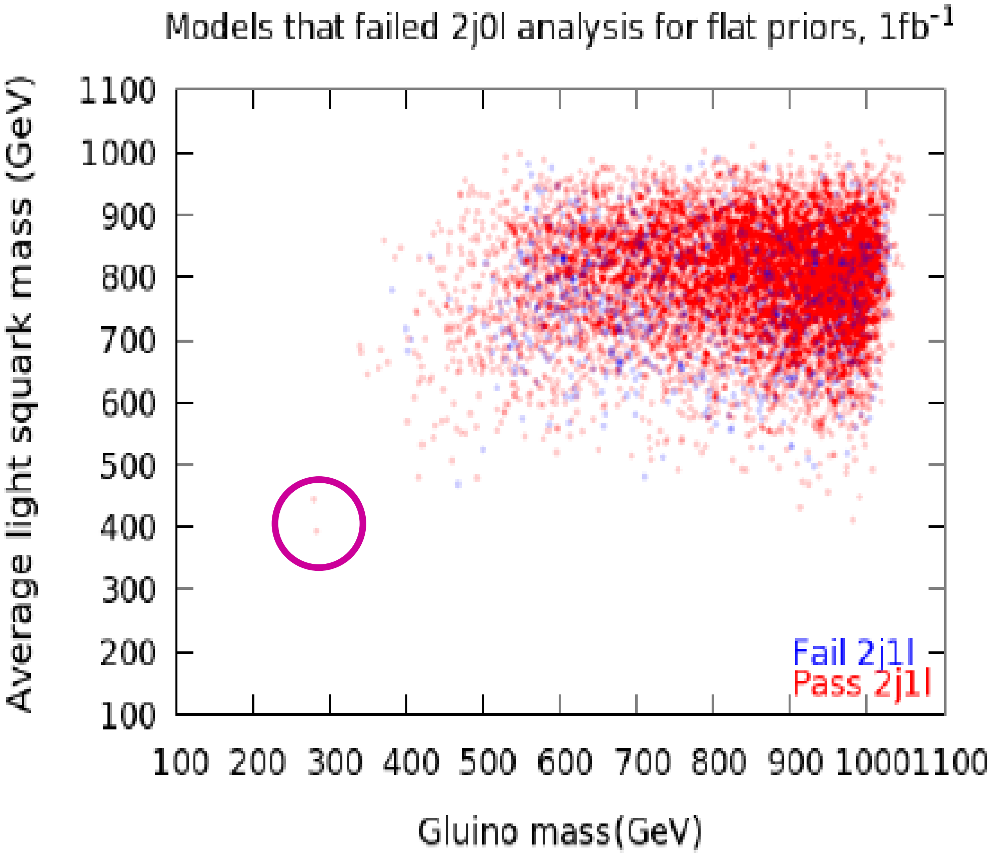
& similarly for the 2j0l analysis

Average Squark Mass vs. Gluino Mass

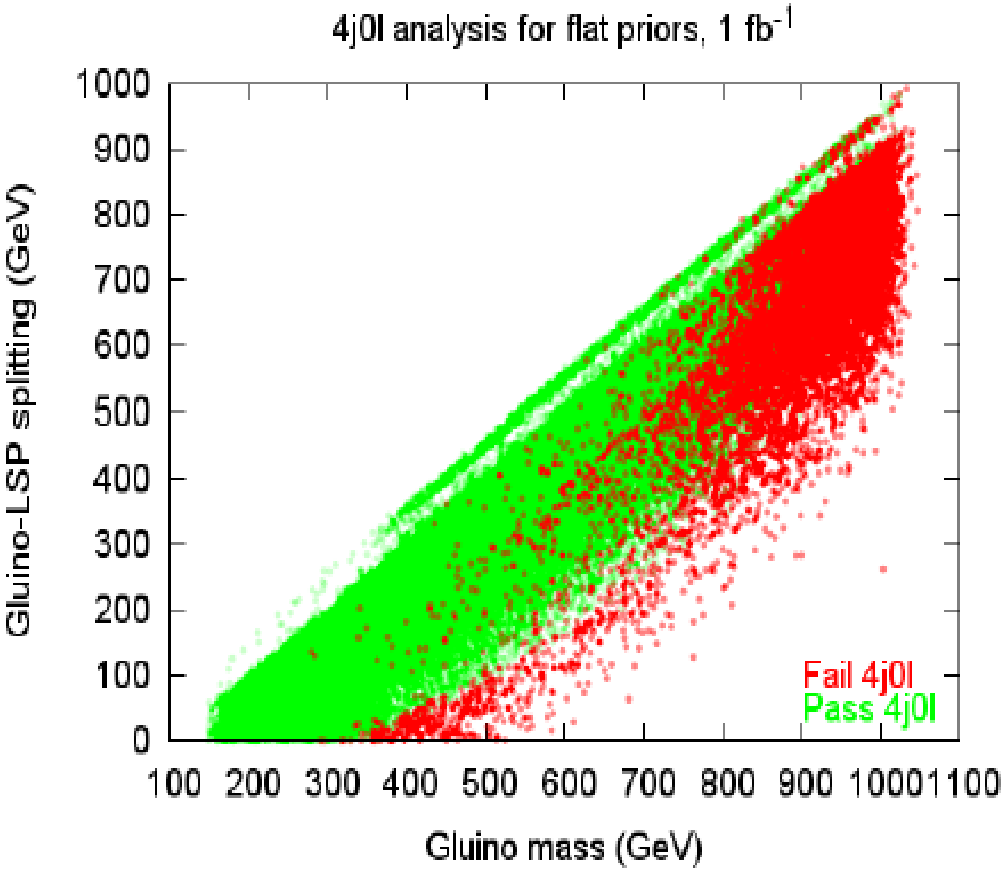


Some of the models that fail 4(2)j0l will be found in the corresponding 4(2)j1l analyses due to their high lepton fractions:

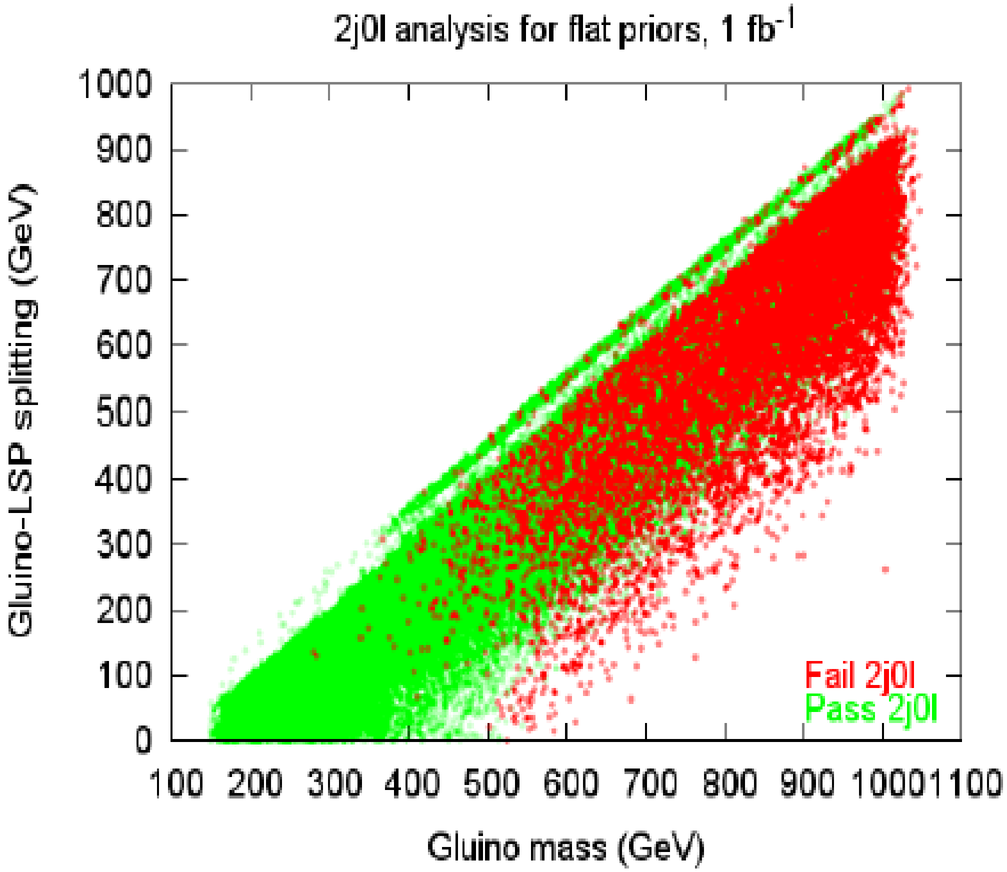




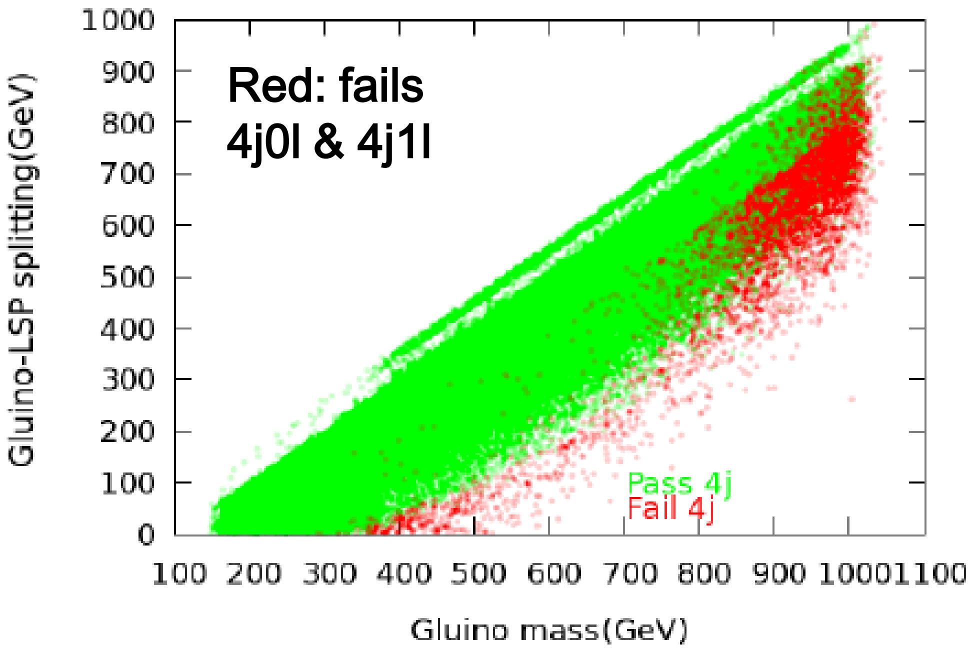
Sparticle mass splittings that result in soft jets can also lead to missed models



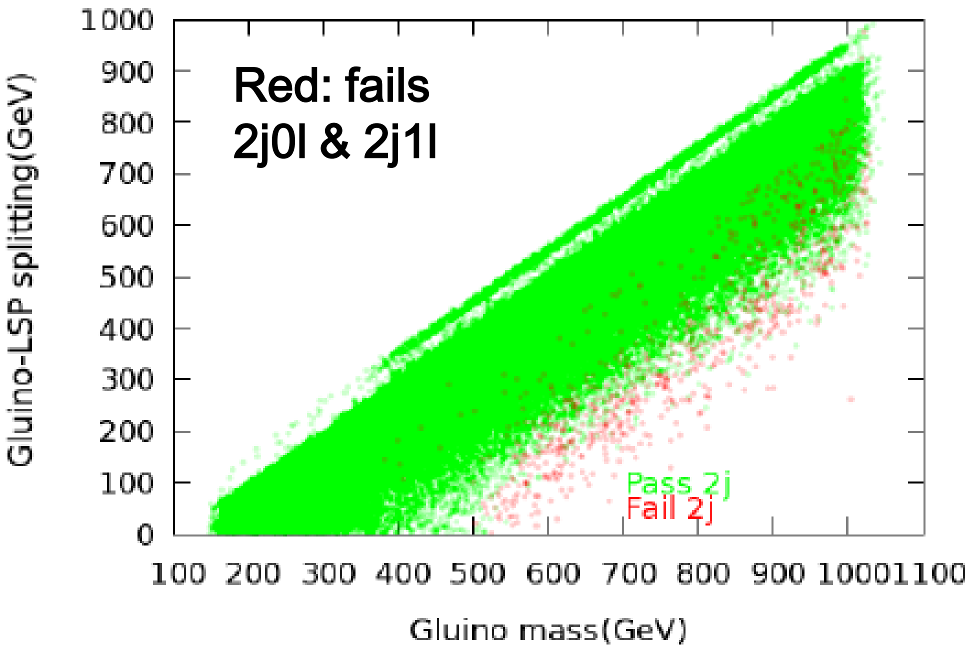
4j0l analysis for flat priors, 1 fb^{-1}



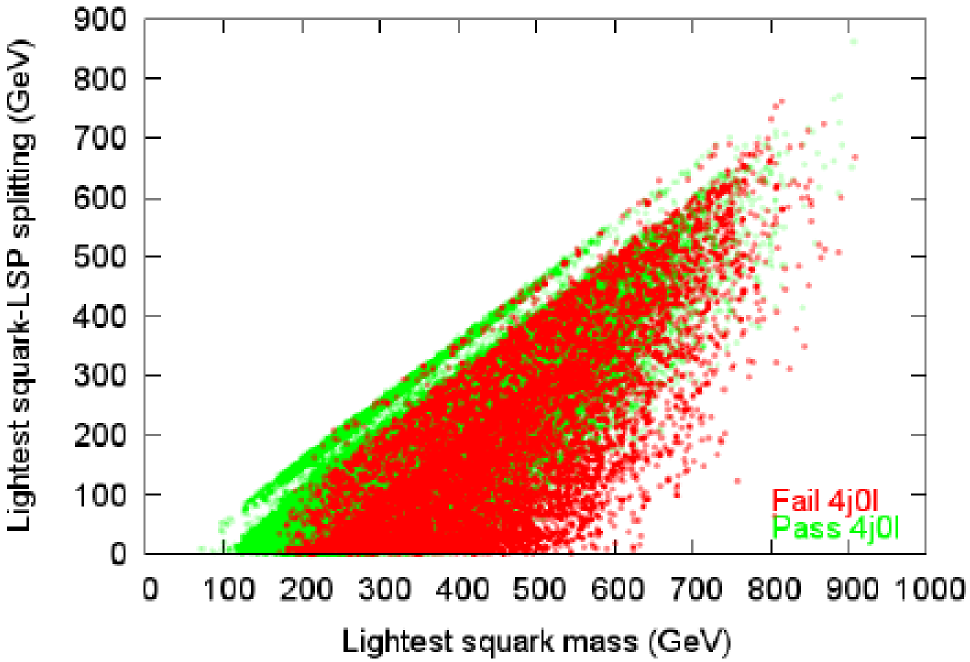
2j0l analysis for flat priors, 1 fb^{-1}

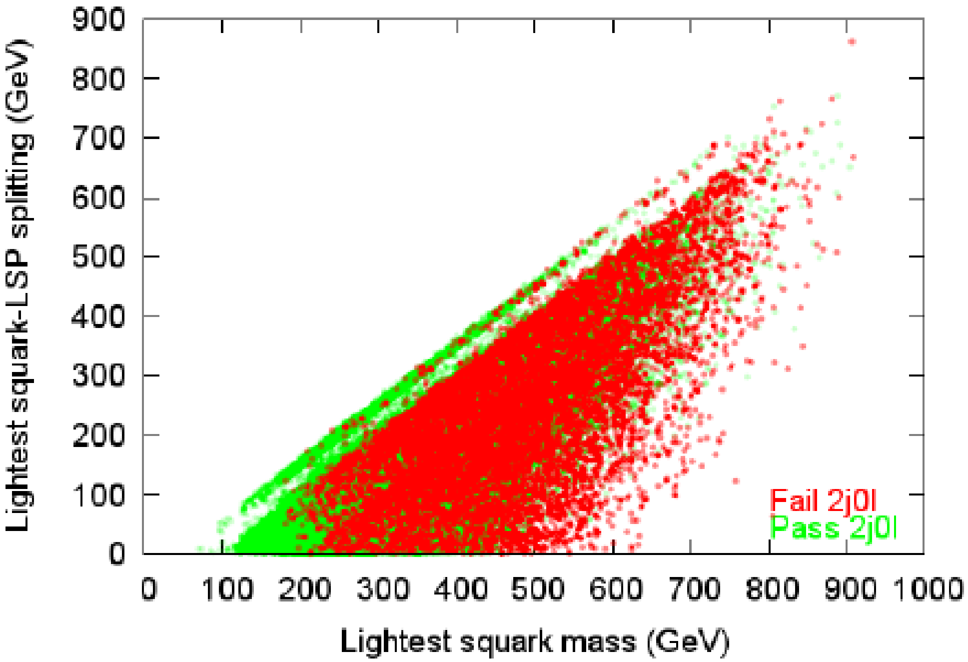

4j analysis for flat priors, $1fb^{-1}$

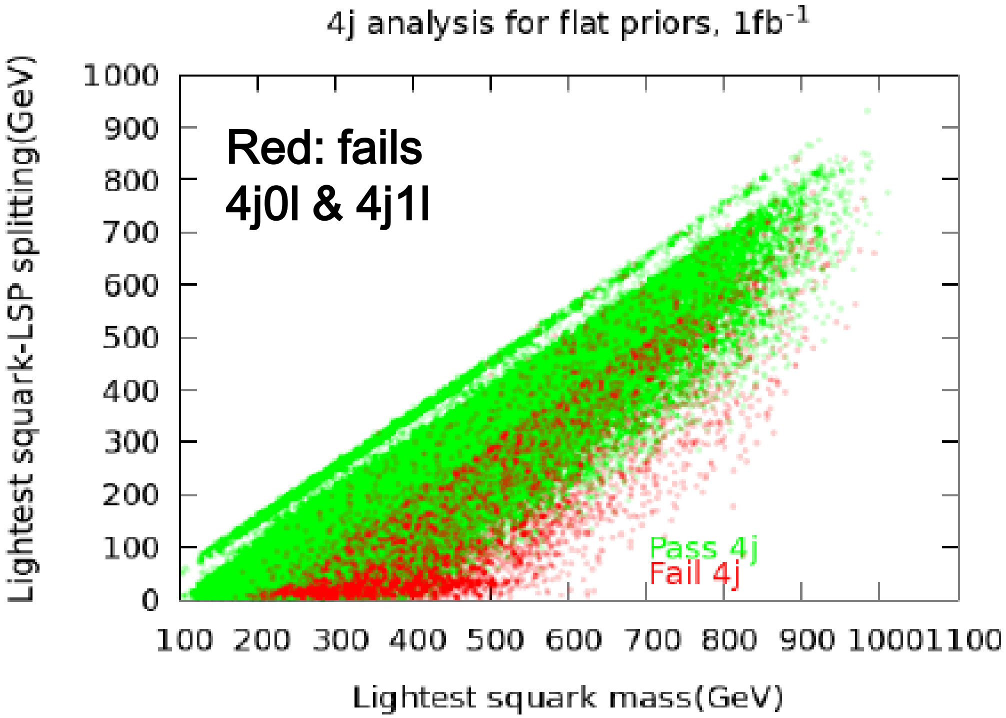
Red: fails 4j0l & 4j1l


2j analysis for flat priors, $1fb^{-1}$

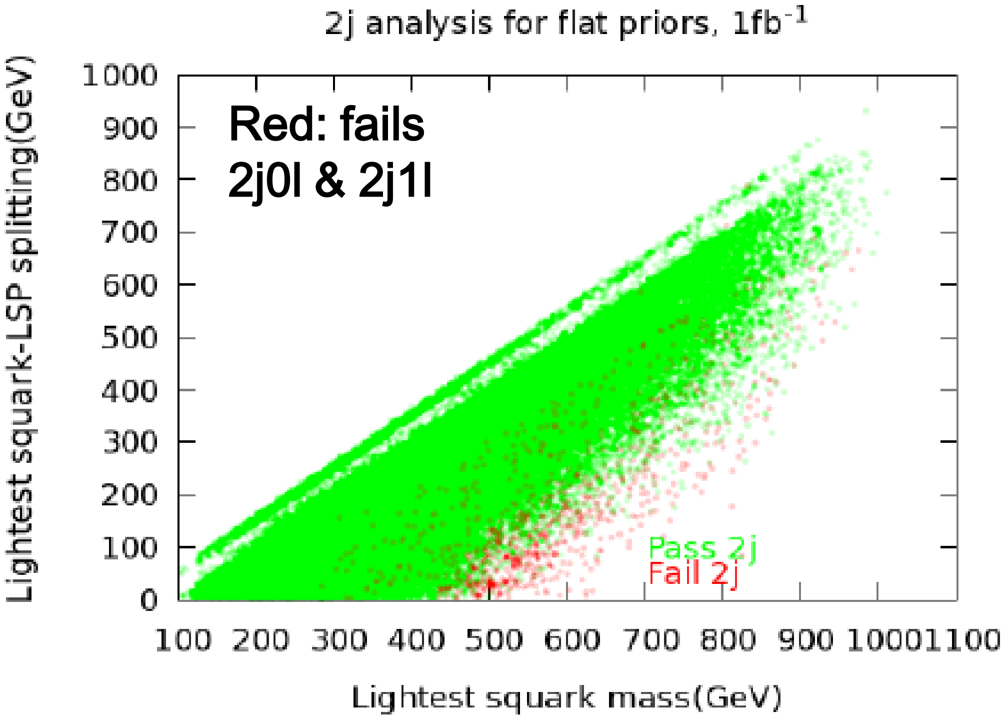
Red: fails 2j0l & 2j1l


4j0l analysis for flat priors, 1 fb^{-1}

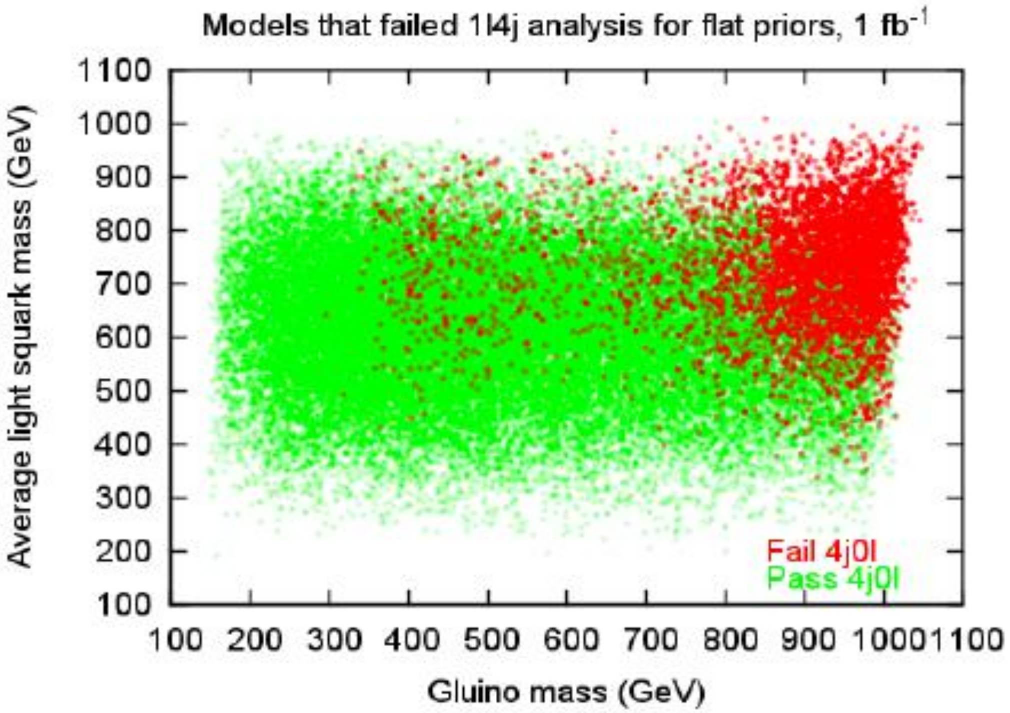

2j0l analysis for flat priors, 1 fb^{-1}

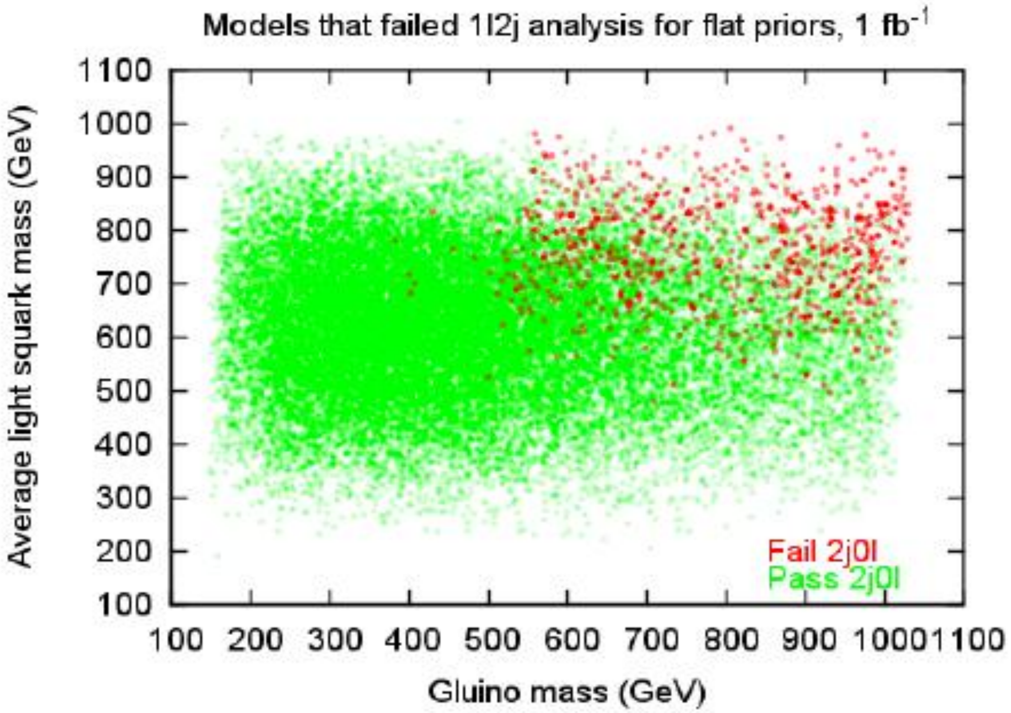

4j analysis for flat priors, 1fb^{-1}

**Red: fails
4j0l & 4j1l**


2j analysis for flat priors, 1fb^{-1}

**Red: fails
2j0l & 2j1l**


Models that failed 1l4j analysis for flat priors, 1 fb^{-1}


Models that failed 1l2j analysis for flat priors, 1 fb^{-1}

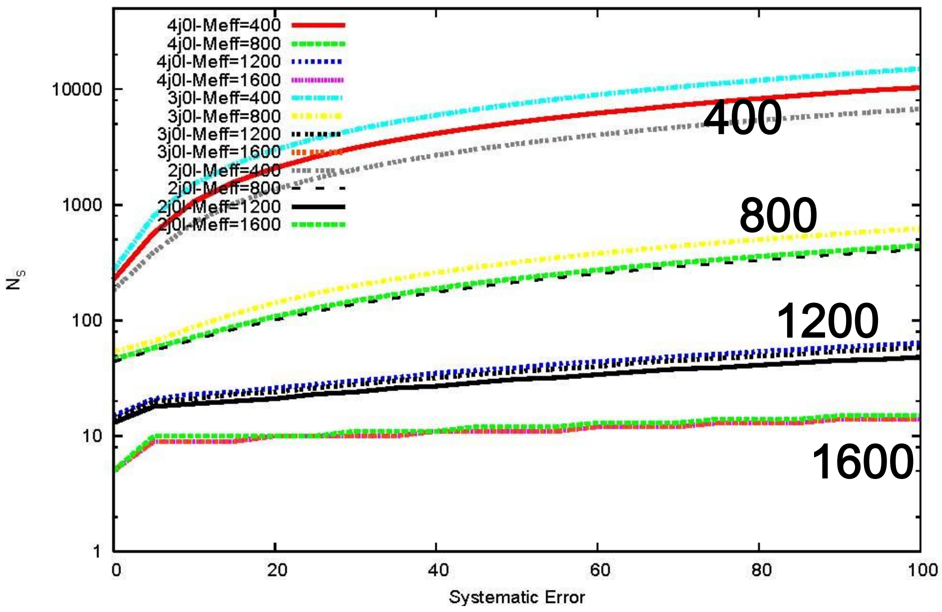
Preliminary Results @ 7 TeV

The Coverage is Surprisingly Good !!!

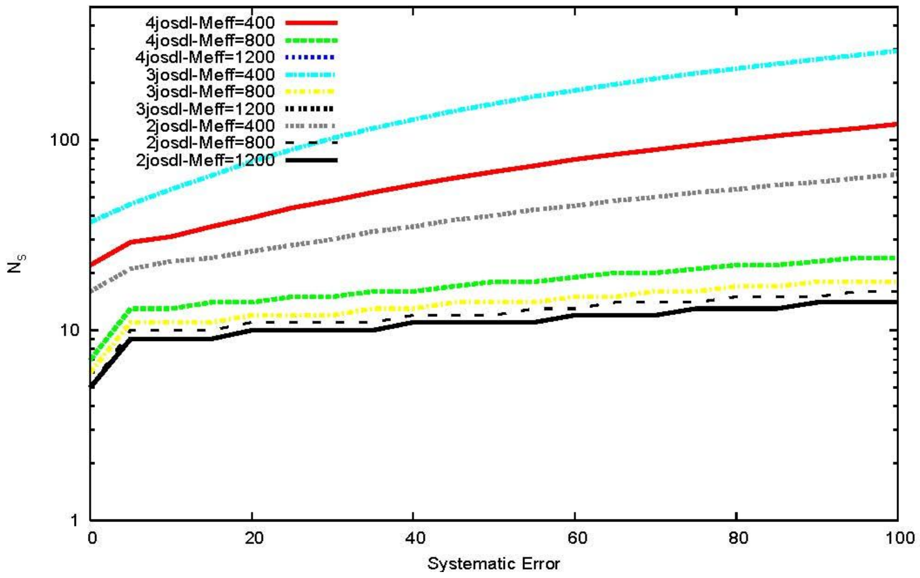
- How many signal events do we need to reach S=5?

Depends on the M_{eff} cut which is now ‘optimized’

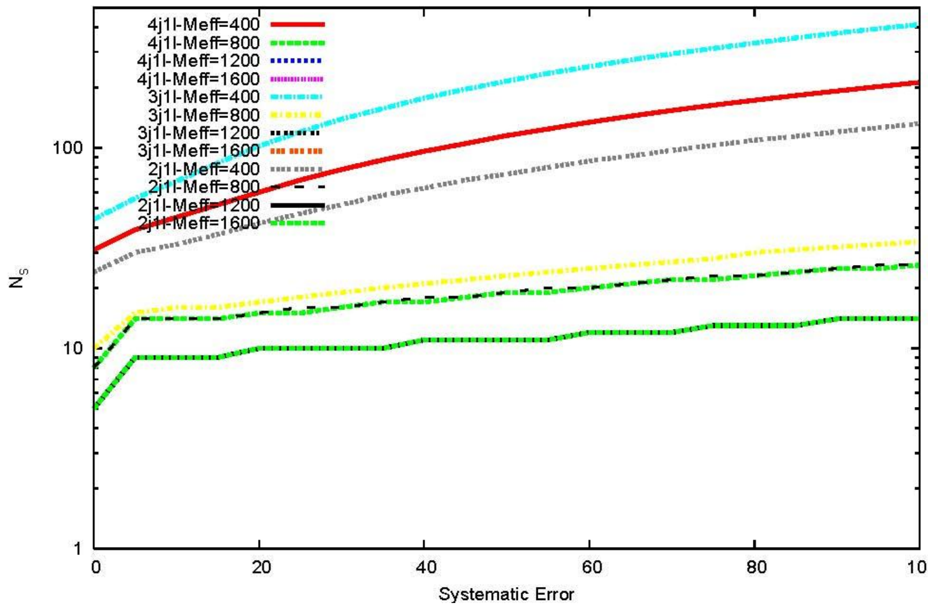
N_S required to get 5σ discovery with various M_{eff} cuts for nj0l



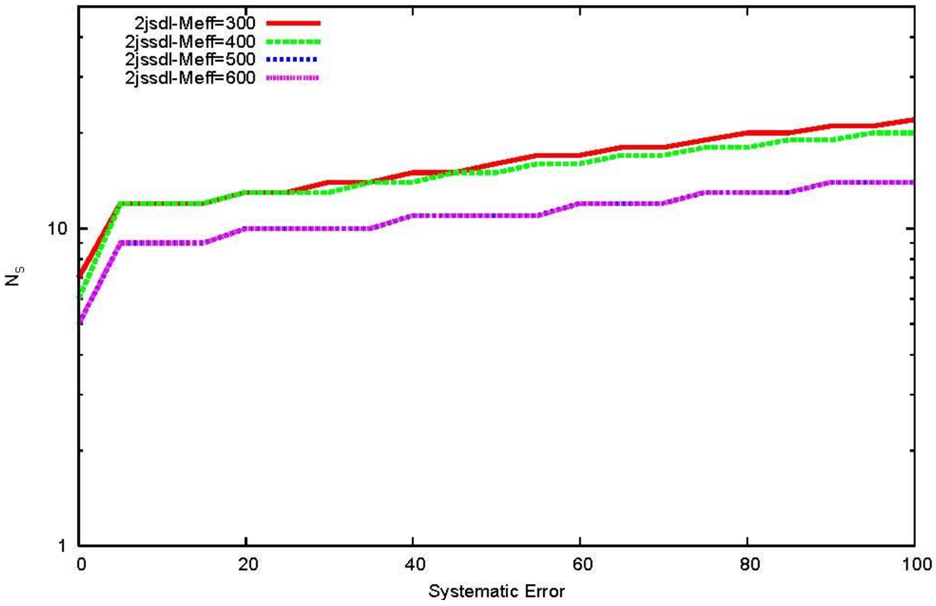
N_S required to get 5σ discovery with various M_{eff} cuts for njosdl

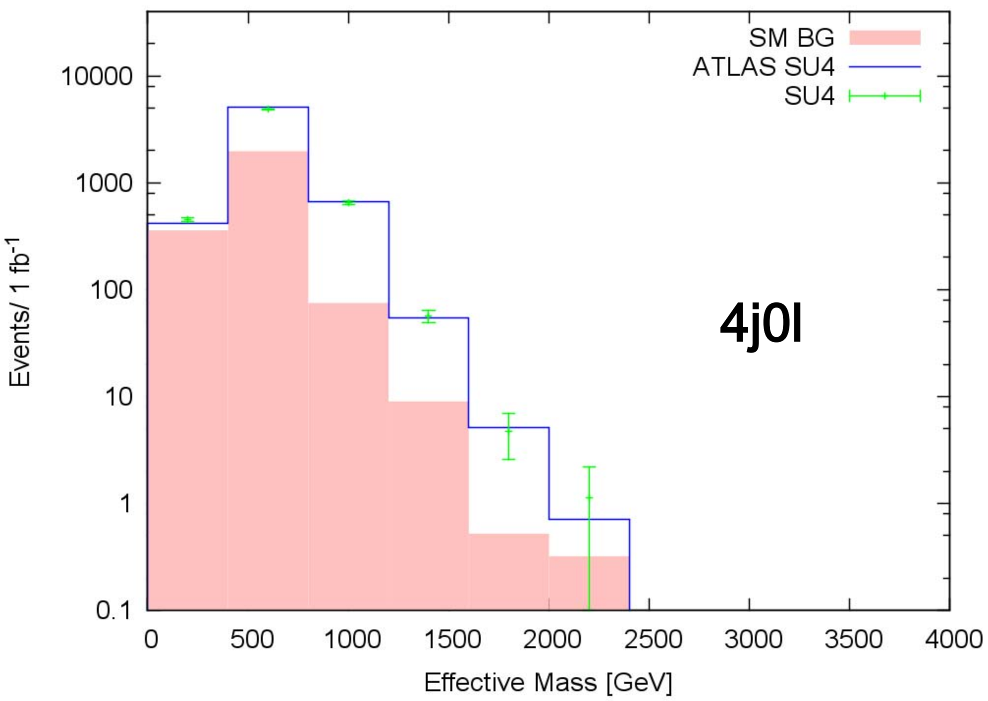


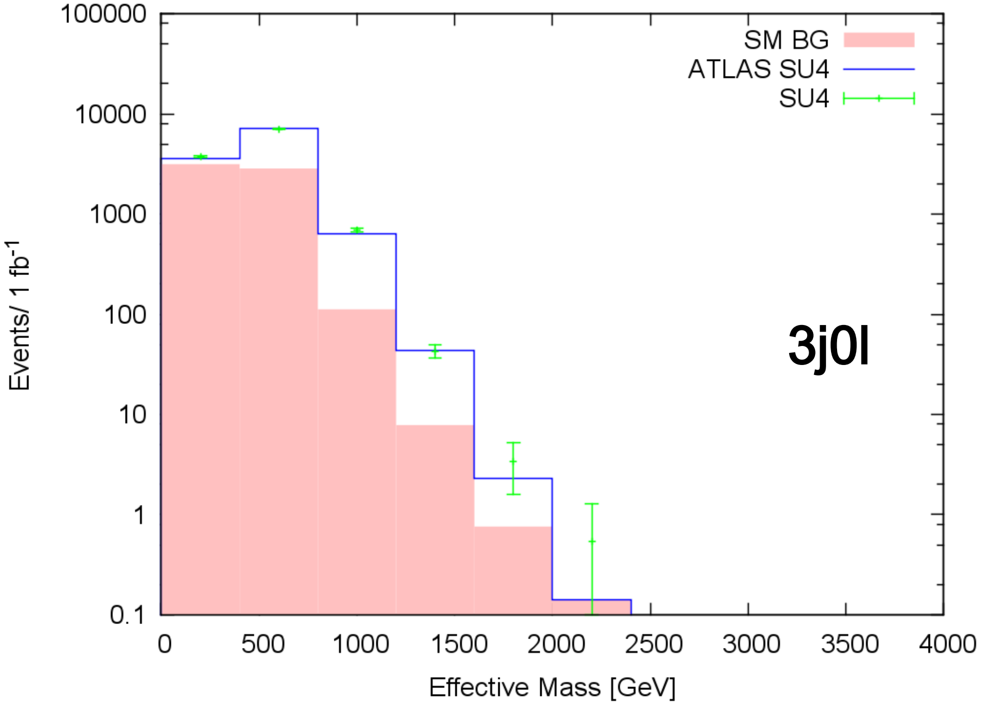
N_S required to get 5σ discovery with various M_{eff} cuts for nj1l



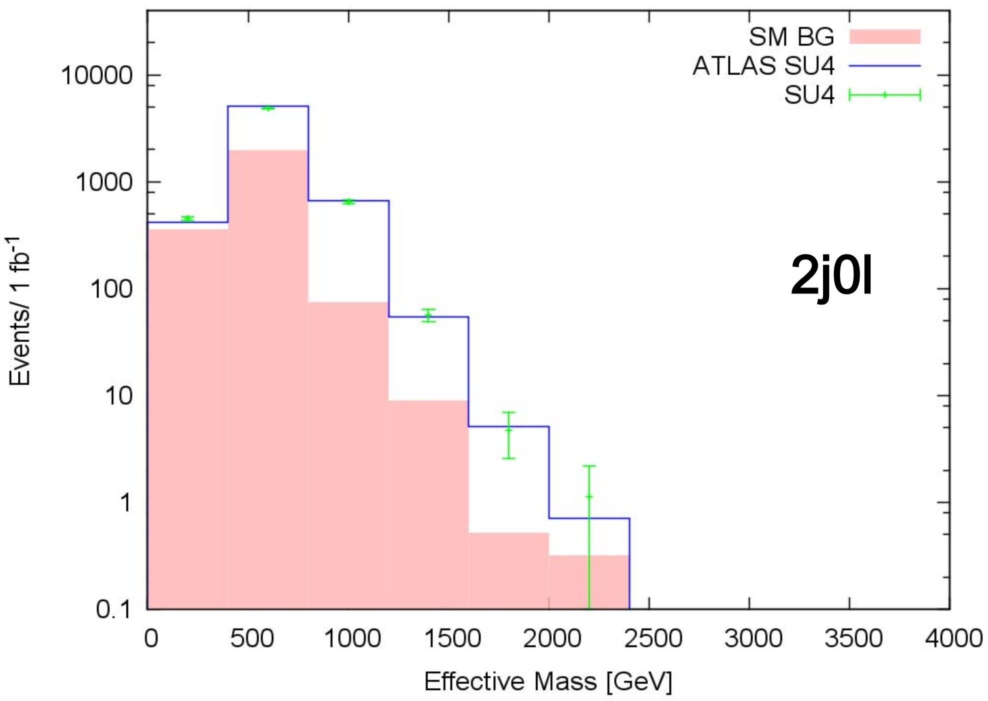
N_S required to get 5σ discovery with various M_{eff} cuts for 2jssdl

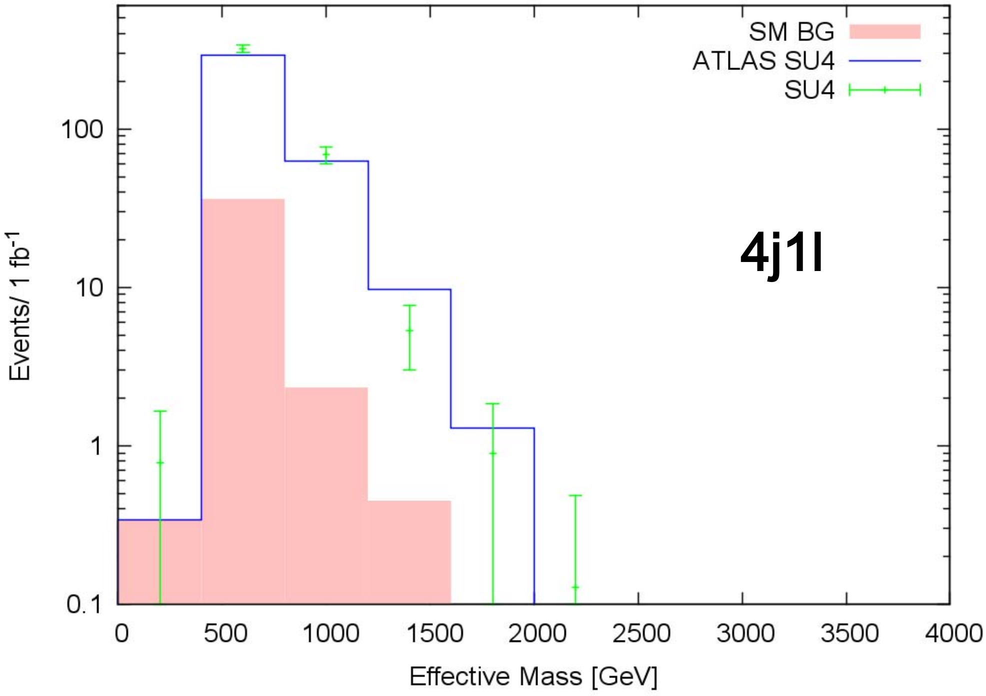






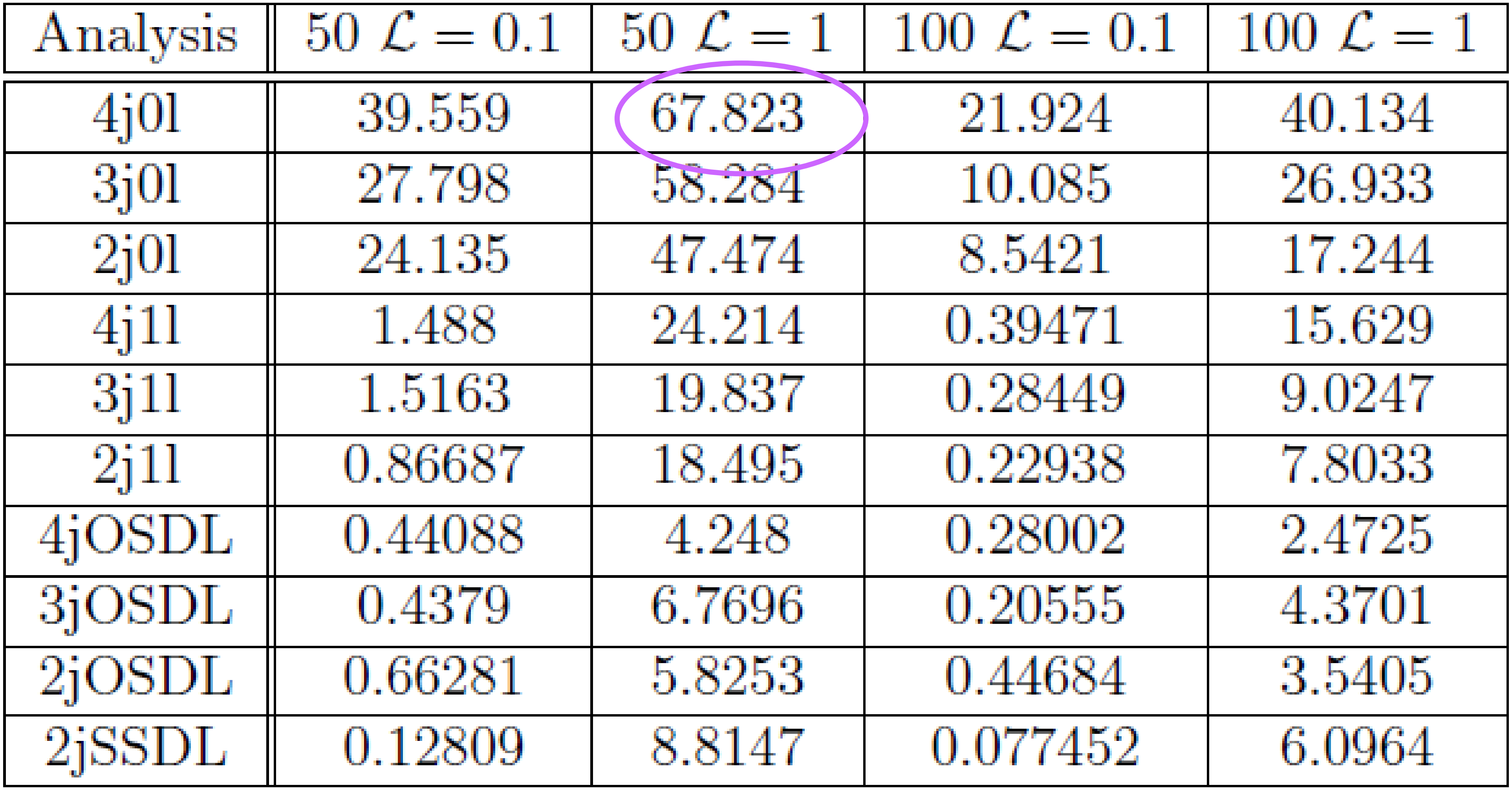
We again do a reasonable job matching ATLAS @ 7 TeV





7 TeV Flat Priors

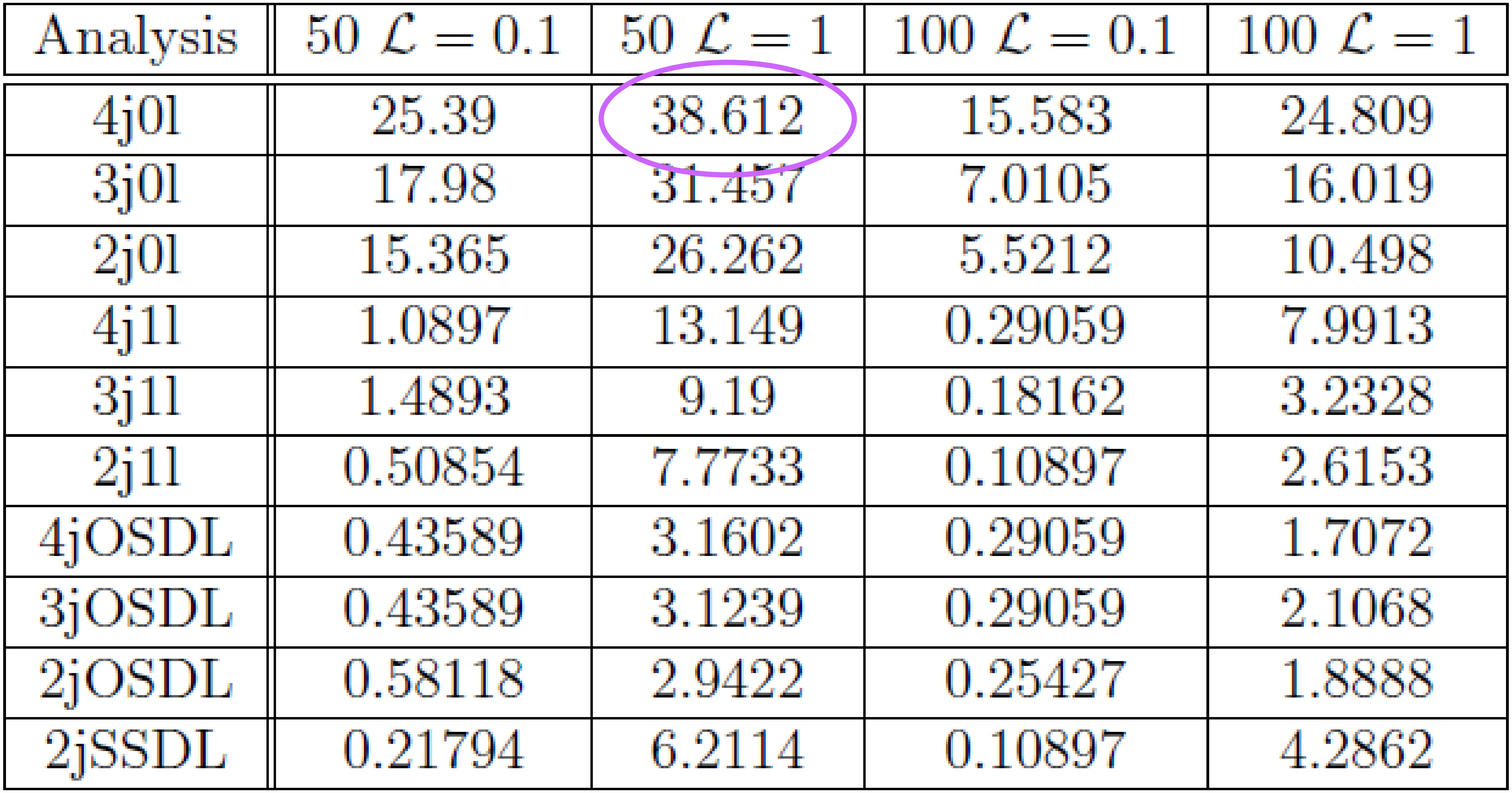
Fraction of model set found by a given search



Analysis	50 $\mathcal{L} = 0.1$	50 $\mathcal{L} = 1$	100 $\mathcal{L} = 0.1$	100 $\mathcal{L} = 1$
4j0l	39.559	67.823	21.924	40.134
3j0l	27.798	58.284	10.085	26.933
2j0l	24.135	47.474	8.5421	17.244
4j1l	1.488	24.214	0.39471	15.629
3j1l	1.5163	19.837	0.28449	9.0247
2j1l	0.86687	18.495	0.22938	7.8033
4jOSDL	0.44088	4.248	0.28002	2.4725
3jOSDL	0.4379	6.7696	0.20555	4.3701
2jOSDL	0.66281	5.8253	0.44684	3.5405
2jSSDL	0.12809	8.8147	0.077452	6.0964

7 TeV Log Priors

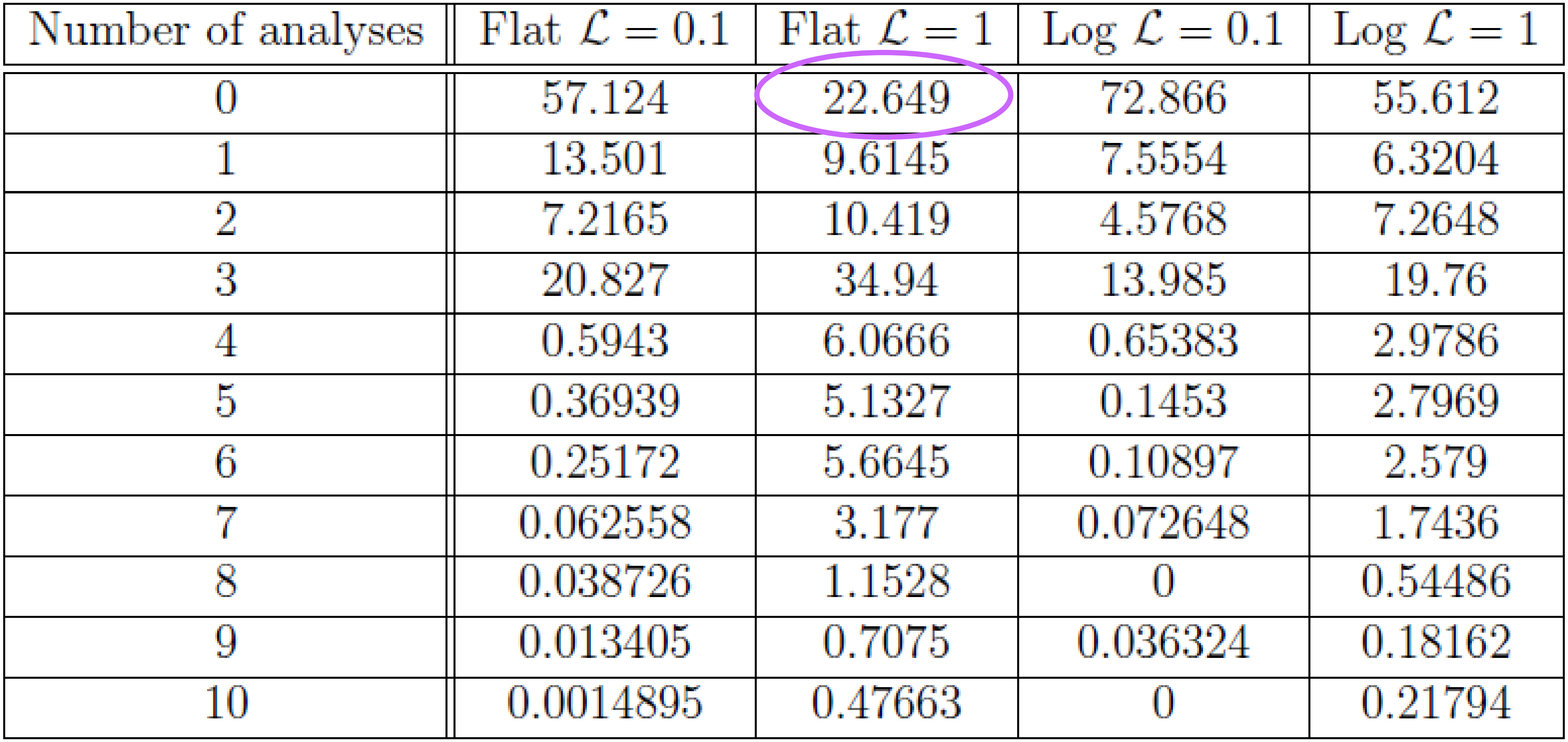
Fraction of model set found by a given search



Analysis	50 $\mathcal{L} = 0.1$	50 $\mathcal{L} = 1$	100 $\mathcal{L} = 0.1$	100 $\mathcal{L} = 1$
4j0l	25.39	38.612	15.583	24.809
3j0l	17.98	31.457	7.0105	16.019
2j0l	15.365	26.262	5.5212	10.498
4j1l	1.0897	13.149	0.29059	7.9913
3j1l	1.4893	9.19	0.18162	3.2328
2j1l	0.50854	7.7733	0.10897	2.6153
4jOSDL	0.43589	3.1602	0.29059	1.7072
3jOSDL	0.43589	3.1239	0.29059	2.1068
2jOSDL	0.58118	2.9422	0.25427	1.8888
2jSSDL	0.21794	6.2114	0.10897	4.2862

7 TeV & 50% Systematics

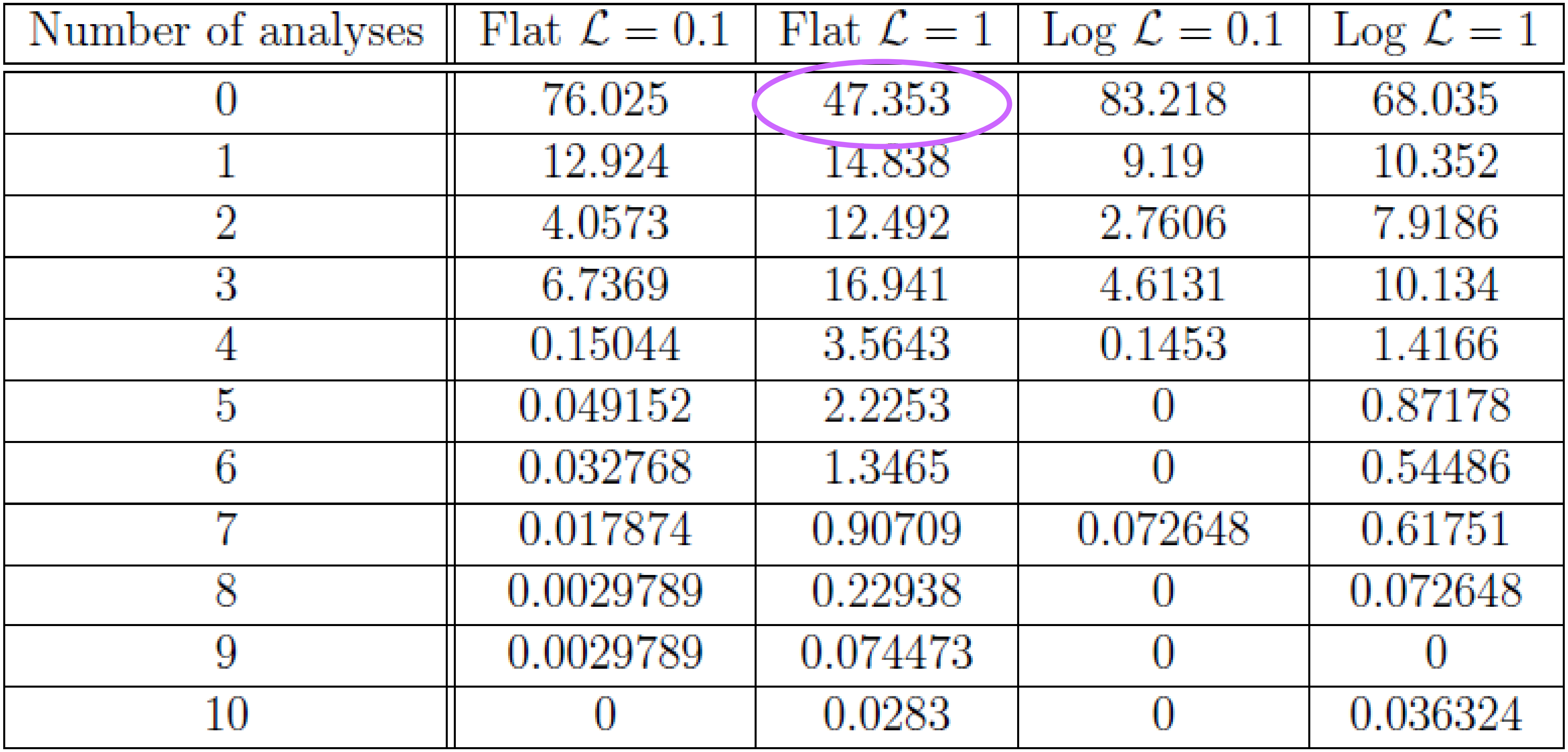
Fraction of models found in 'n' searches



Number of analyses	Flat $\mathcal{L} = 0.1$	Flat $\mathcal{L} = 1$	Log $\mathcal{L} = 0.1$	Log $\mathcal{L} = 1$
0	57.124	22.649	72.866	55.612
1	13.501	9.6145	7.5554	6.3204
2	7.2165	10.419	4.5768	7.2648
3	20.827	34.94	13.985	19.76
4	0.5943	6.0666	0.65383	2.9786
5	0.36939	5.1327	0.1453	2.7969
6	0.25172	5.6645	0.10897	2.579
7	0.062558	3.177	0.072648	1.7436
8	0.038726	1.1528	0	0.54486
9	0.013405	0.7075	0.036324	0.18162
10	0.0014895	0.47663	0	0.21794

7 TeV & 100% Systematics

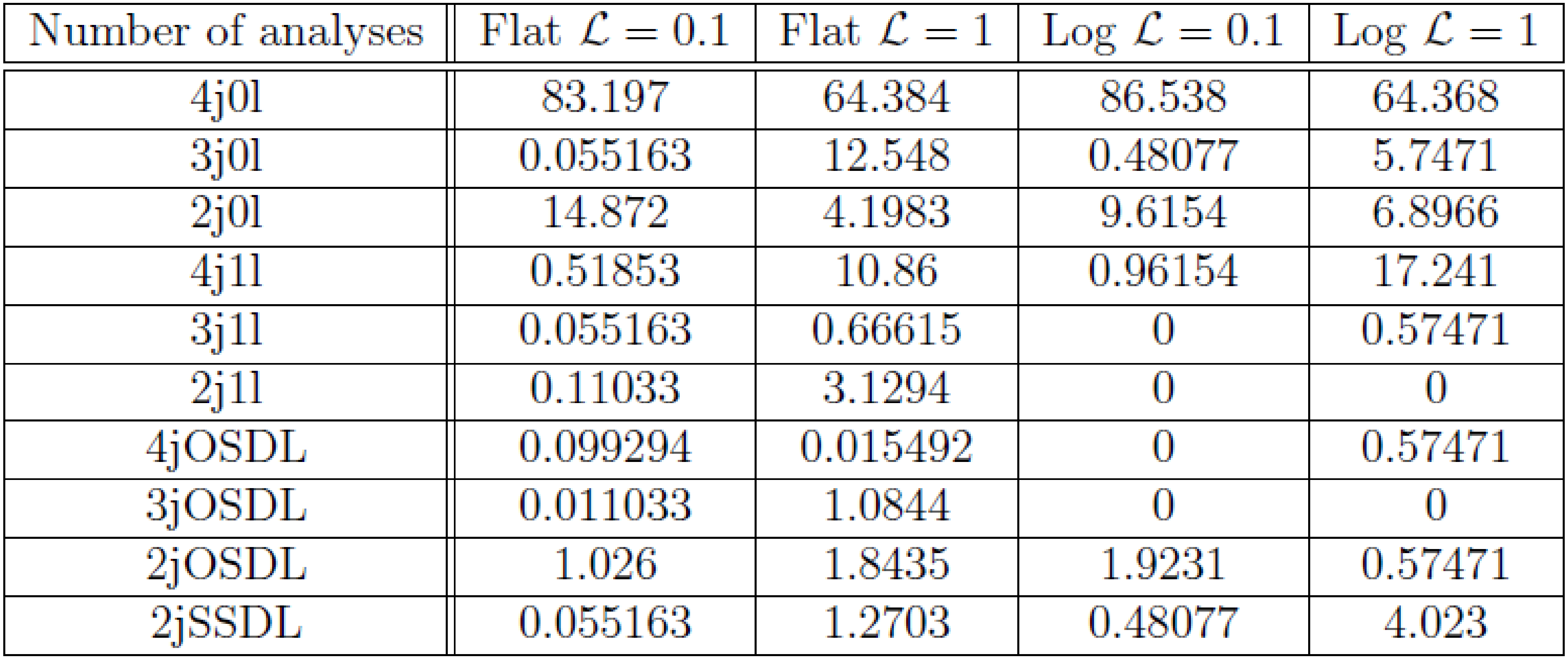
Fraction of models found in ‘n’ searches



Number of analyses	Flat $\mathcal{L} = 0.1$	Flat $\mathcal{L} = 1$	Log $\mathcal{L} = 0.1$	Log $\mathcal{L} = 1$
0	76.025	47.353	83.218	68.035
1	12.924	14.838	9.19	10.352
2	4.0573	12.492	2.7606	7.9186
3	6.7369	16.941	4.6131	10.134
4	0.15044	3.5643	0.1453	1.4166
5	0.049152	2.2253	0	0.87178
6	0.032768	1.3465	0	0.54486
7	0.017874	0.90709	0.072648	0.61751
8	0.0029789	0.22938	0	0.072648
9	0.0029789	0.074473	0	0
10	0	0.0283	0	0.036324

7 TeV & 50% Systematics

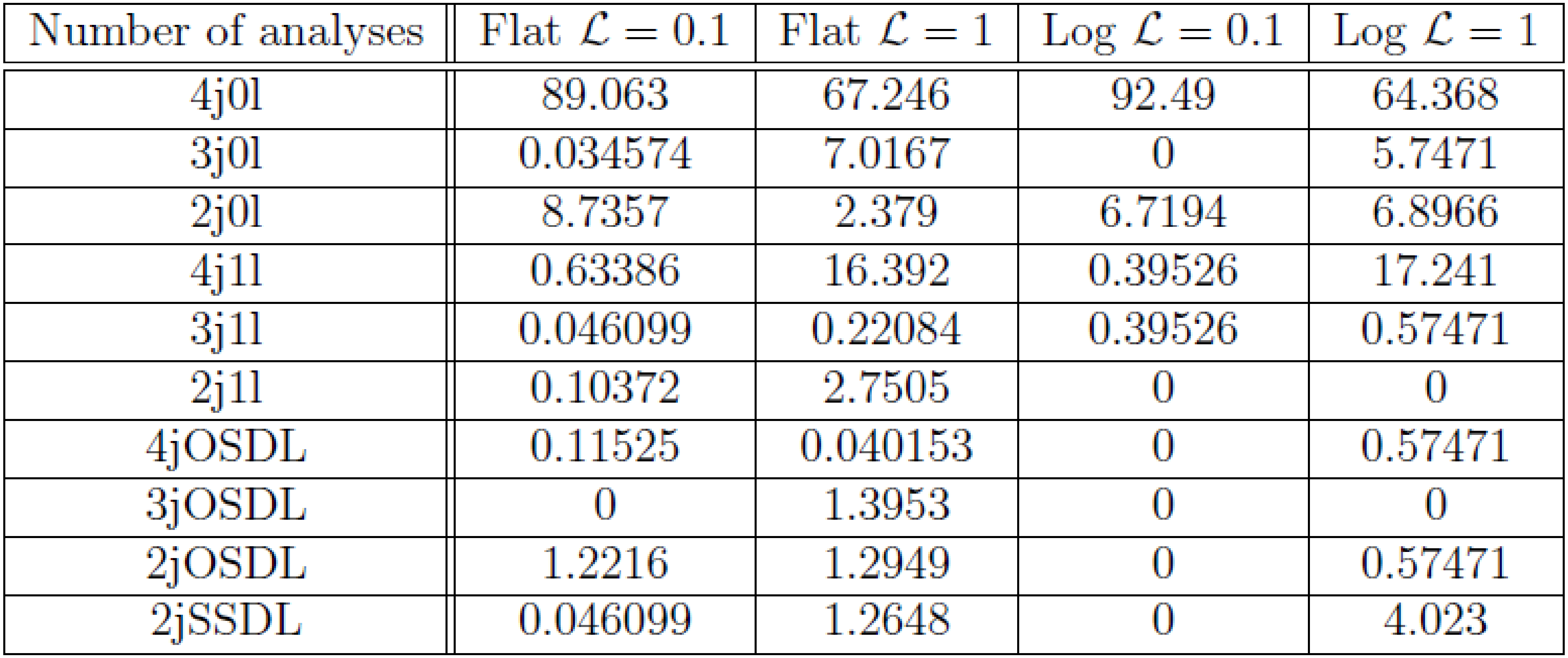
Which single search sees it ??



Number of analyses	Flat $\mathcal{L} = 0.1$	Flat $\mathcal{L} = 1$	Log $\mathcal{L} = 0.1$	Log $\mathcal{L} = 1$
4j0l	83.197	64.384	86.538	64.368
3j0l	0.055163	12.548	0.48077	5.7471
2j0l	14.872	4.1983	9.6154	6.8966
4j1l	0.51853	10.86	0.96154	17.241
3j1l	0.055163	0.66615	0	0.57471
2j1l	0.11033	3.1294	0	0
4jOSDL	0.099294	0.015492	0	0.57471
3jOSDL	0.011033	1.0844	0	0
2jOSDL	1.026	1.8435	1.9231	0.57471
2jSSDL	0.055163	1.2703	0.48077	4.023

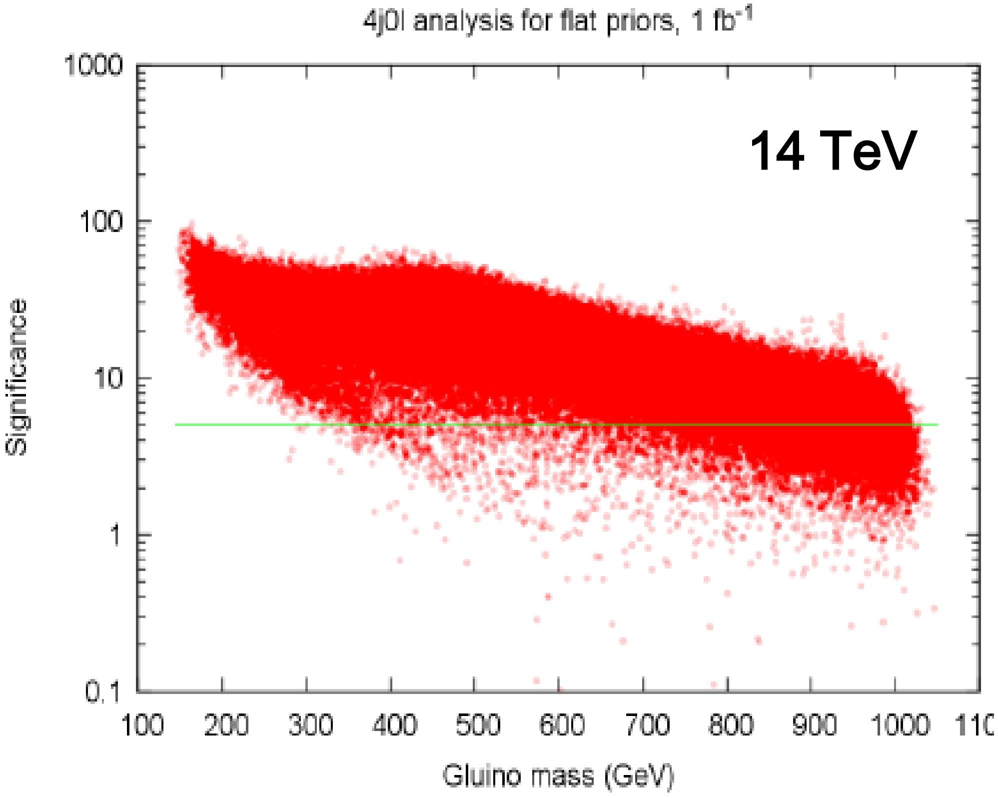
7 TeV & 100% Systematics

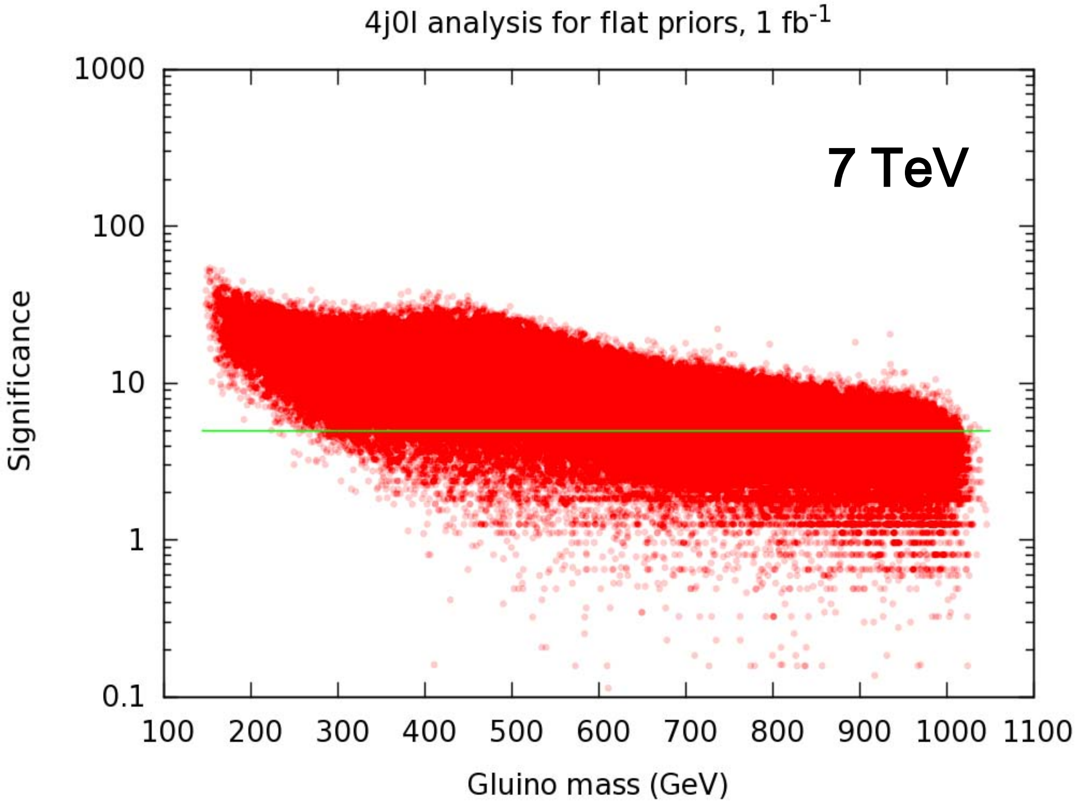
Which single search sees it ??



Number of analyses	Flat $\mathcal{L} = 0.1$	Flat $\mathcal{L} = 1$	Log $\mathcal{L} = 0.1$	Log $\mathcal{L} = 1$
4j0l	89.063	67.246	92.49	64.368
3j0l	0.034574	7.0167	0	5.7471
2j0l	8.7357	2.379	6.7194	6.8966
4j1l	0.63386	16.392	0.39526	17.241
3j1l	0.046099	0.22084	0.39526	0.57471
2j1l	0.10372	2.7505	0	0
4jOSDL	0.11525	0.040153	0	0.57471
3jOSDL	0	1.3953	0	0
2jOSDL	1.2216	1.2949	0	0.57471
2jSSDL	0.046099	1.2648	0	4.023

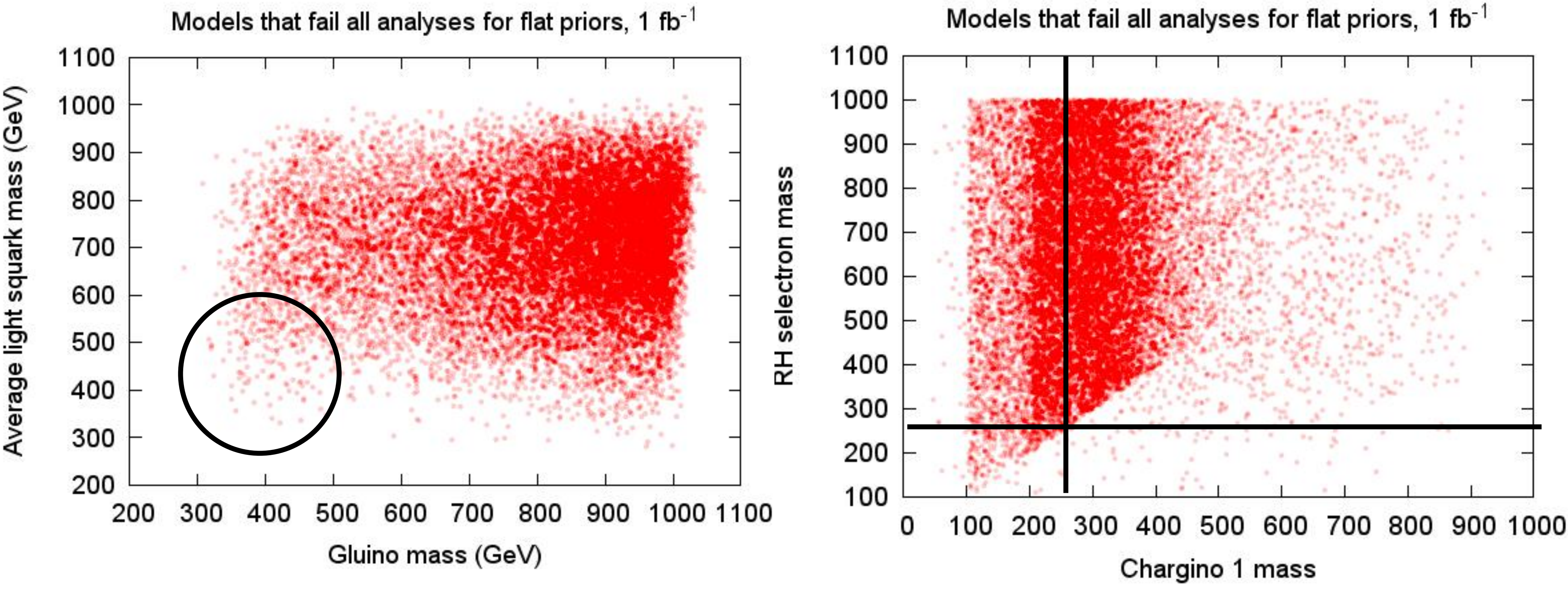
- Though differing in detail, the shapes of the ‘significance distribution’ for the 14 & 7 TeV cases are seen to be very similar for the same luminosity & systematic errors for the 4j0l analysis





- There are models that fail ALL analyses at 7 TeV with 1 fb^{-1} lumi & 50% systematic errors that have light squarks/gluinos

- There are many models that remain undiscovered with these same assumptions that have sleptons and/or charginos which are kinematically accessible at a 500 GeV LC



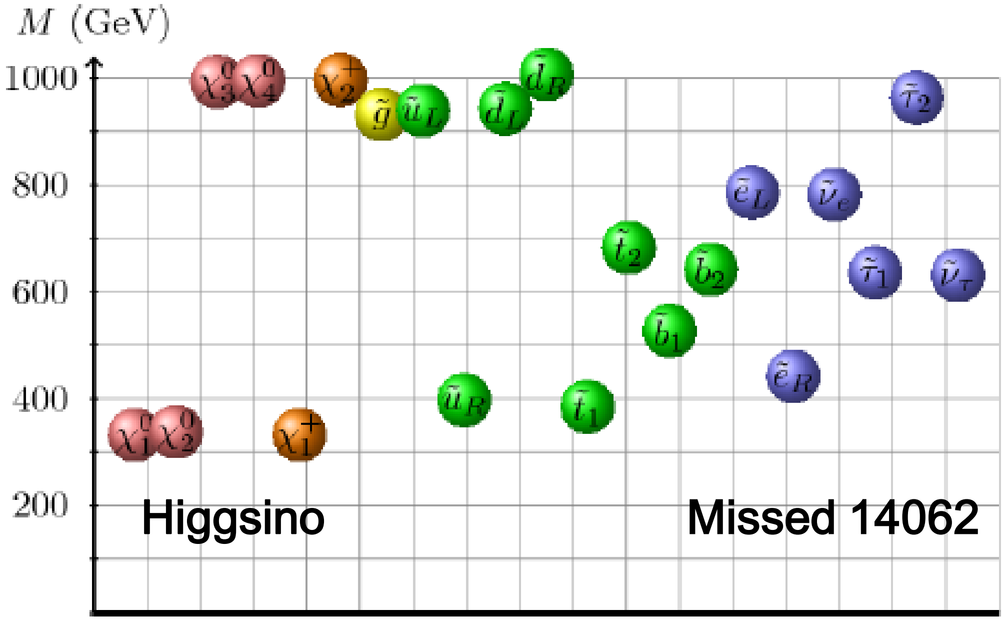
The Undiscovered SUSY :
Sample Failure Analyses

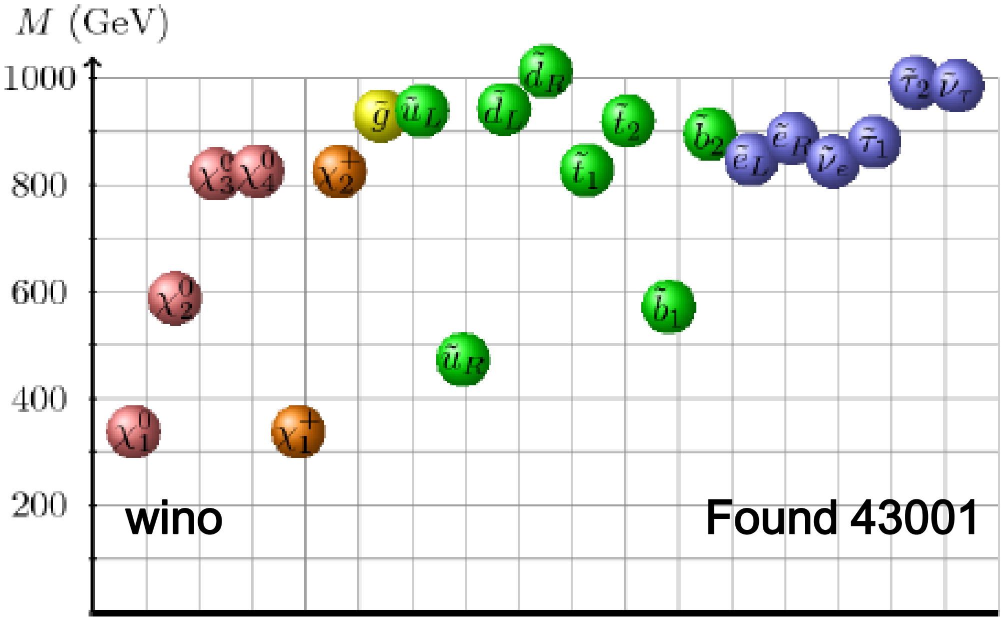
- Models with low MET due to stable charginos
- Models with low jet E_T' s due to spectrum compression
- Models with heavy mass spectra
- Models with …..

Based on the 14 TeV, 1 fb^{-1} & δB=20% missed model set….

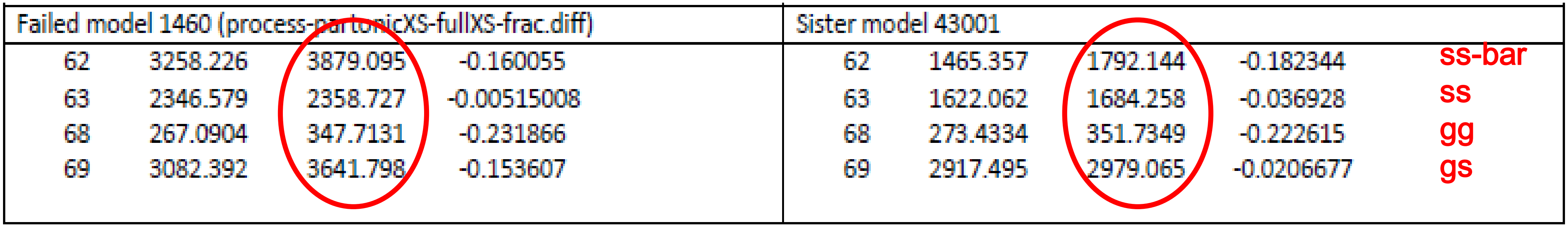
Case 1:

One way to understand why a given model is missed is to find an analog model with a 'similar' spectrum etc & explore the differences.

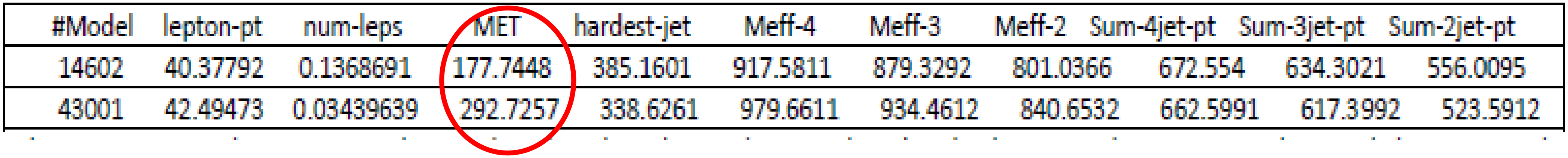




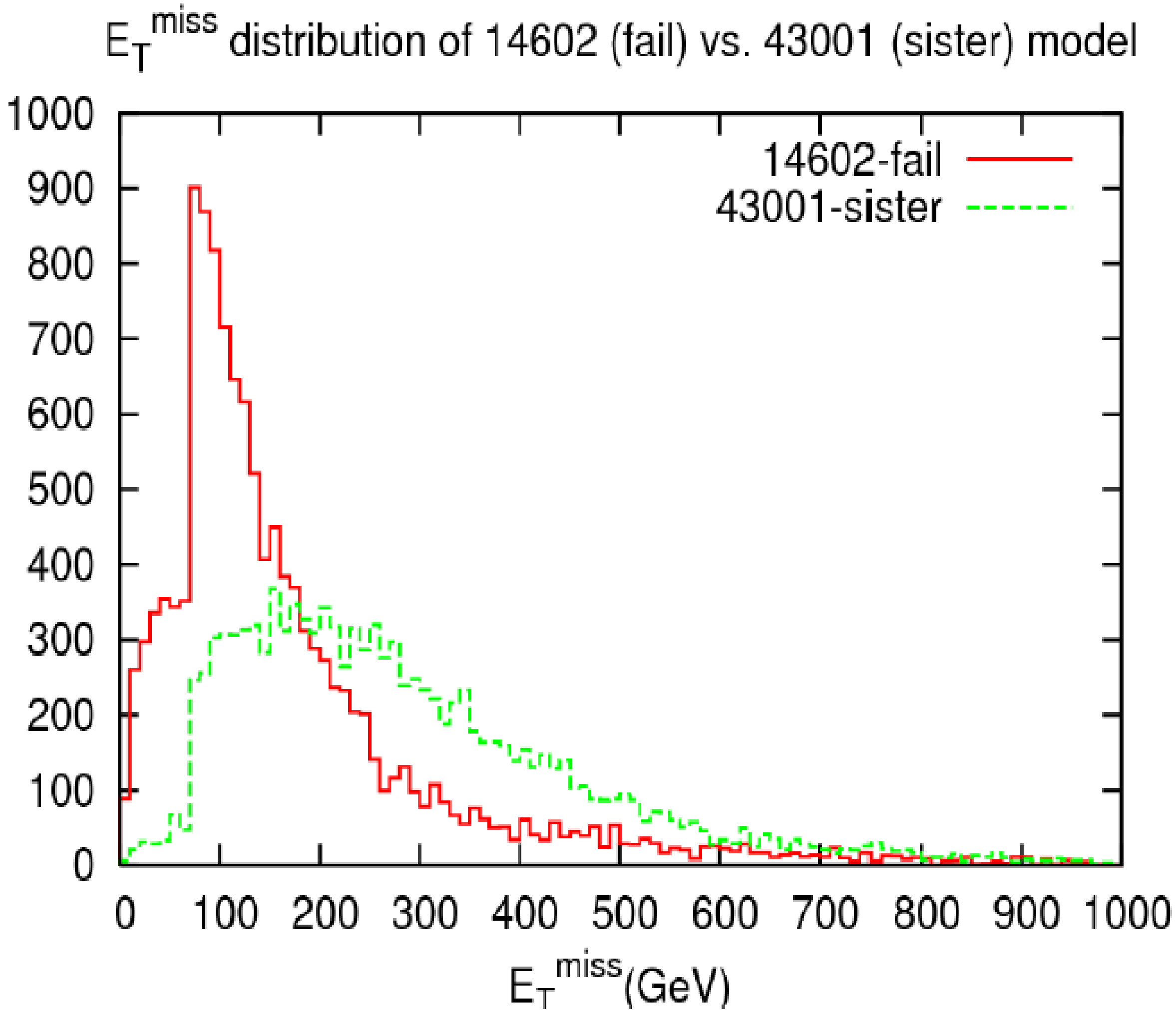
Both have 'detector-stable' charginos & comparable rates for squark & gluino production..in fact they're bigger for 14062!



Failed model 1460 (process-partonicXS-fullXS-frac.diff)				Sister model 43001				
62	3258.226	3879.095	-0.160055	62	1465.357	1792.144	-0.182344	ss-bar
63	2346.579	2358.727	-0.00515008	63	1622.062	1684.258	-0.036928	ss
68	267.0904	347.7131	-0.231866	68	273.4334	351.7349	-0.222615	gg
69	3082.392	3641.798	-0.153607	69	2917.495	2979.065	-0.0206677	gs



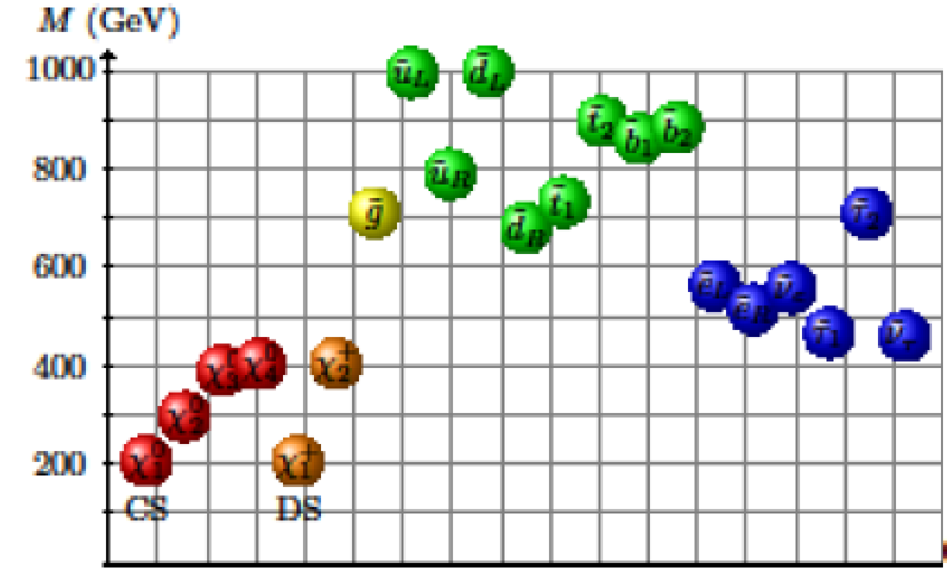
#Model	lepton-pt	num-leps	MET	hardest-jet	Meff-4	Meff-3	Meff-2	Sum-4jet-pt	Sum-3jet-pt	Sum-2jet-pt
14602	40.37792	0.1368691	177.7448	385.1601	917.5811	879.3292	801.0366	672.554	634.3021	556.0095
43001	42.49473	0.03439639	292.7257	338.6261	979.6611	934.4612	840.6532	662.5991	617.3992	523.5912



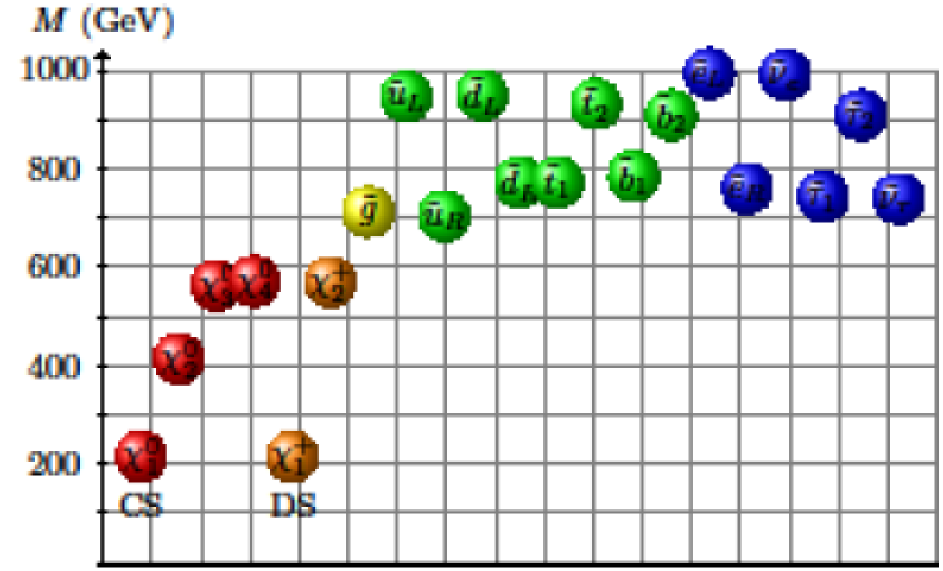
The important difference is mainly that the $\tilde{u}_R$ can directly decay to the (bino part of the) LSP producing MET in the sister model but not in the missed case. There it mostly goes to χ_2^0 which then decays to the stable chargino, so there is little MET.

Lesson: small spectrum changes can be very important.

Case 2:



43704



63170

Failed model 43704(process-partonicXS-fullXS-frac.diff)				Sister model 63170			
62	591.6537	552.6714	0.0705342	62	554.1683	598.2279	-0.0736501
63	919.5316	1007.283	-0.0871171	63	1136.412	1115.883	0.0183972
68	1689.407	2207.448	-0.234679	68	1574.955	2111.774	-0.254203
69	4117.824	4558.5	-0.0966714	69	4469.741	4868.156	-0.0818411

#Cut	lepton-pt	num-leps	MET	hardest-jet	Meff-4	Meff-3	Meff-2	Sum-4jet-pt	Sum-3jet-pt	Sum-2jet-pt
43704	46.50313	0.3305726	114.8049	424.9652	1070.408	996.6819	859.0967	893.2752	819.5494	681.9642
63170	74.5432	0.3209754	200.8012	368.0755	1090.669	1005.495	867.3606	819.9918	734.8182	596.6838

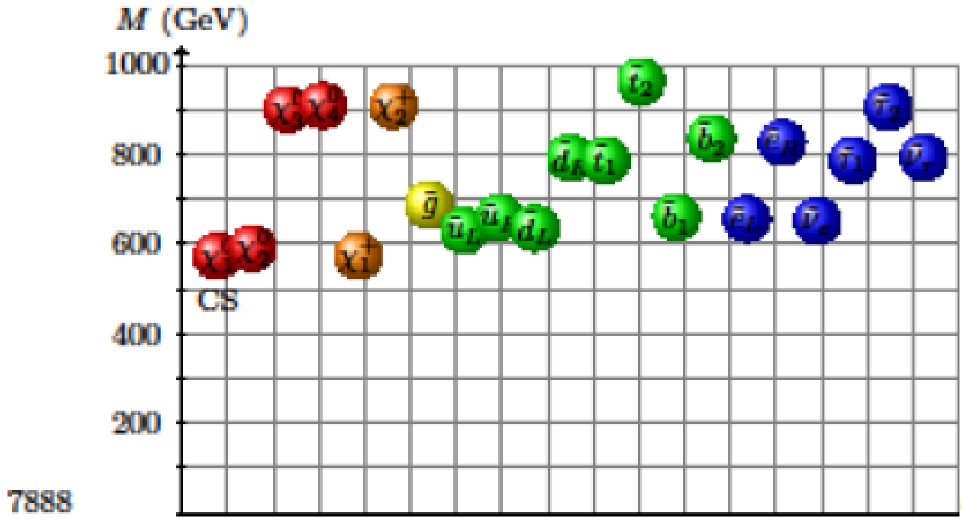
What went wrong ??

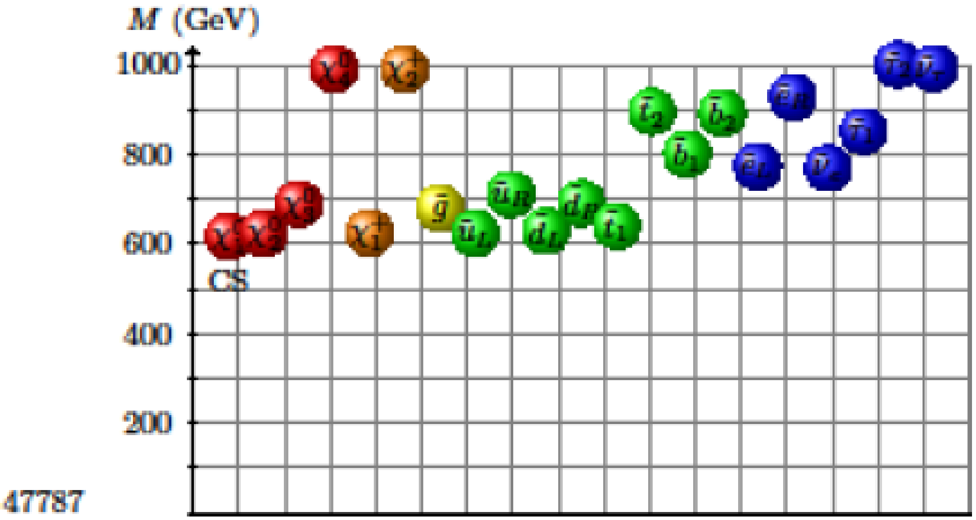
In 43704: gluinos→ d_R →χ_2^0 →W + stable chargino (~100%) as the χ_2^0 –LSP mass splitting is ~91 GeV

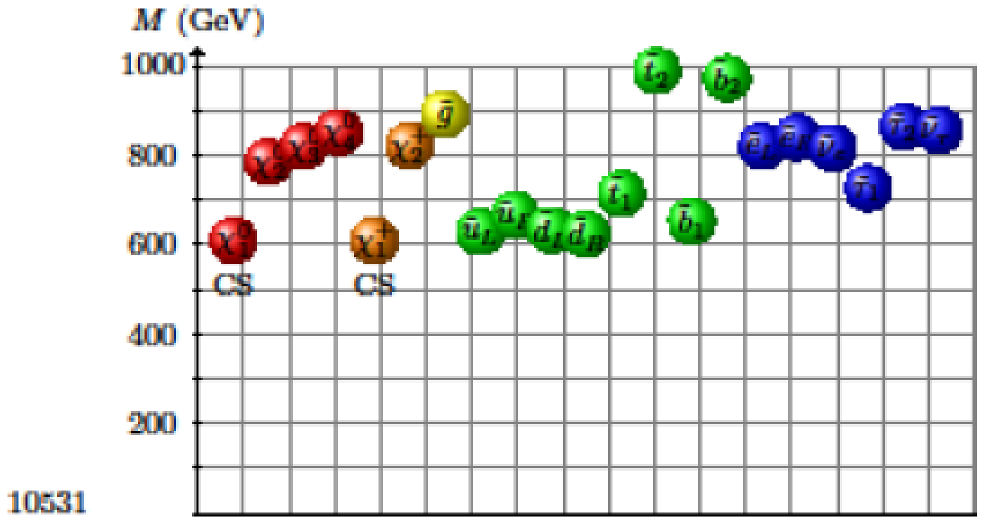
In 63170: gluinos→ u_R →χ_2^0 → Z/h + LSP (~30%) as the χ_2^0 –LSP mass splitting is larger ~198 GeV

- Again: a small spectrum change can have a large effect on the signal observability!

Case 3:

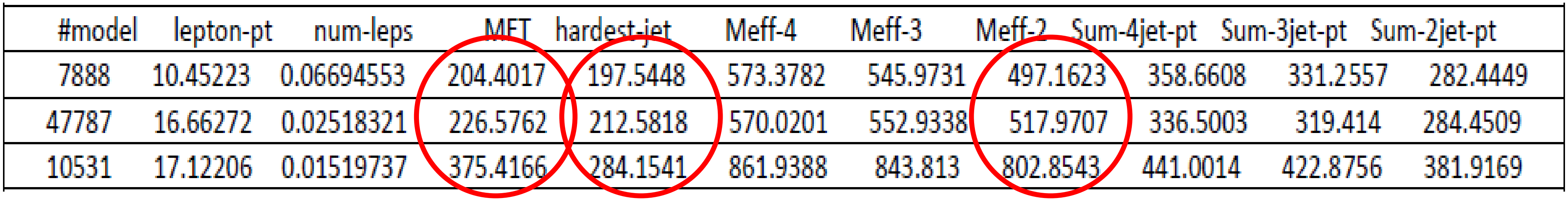






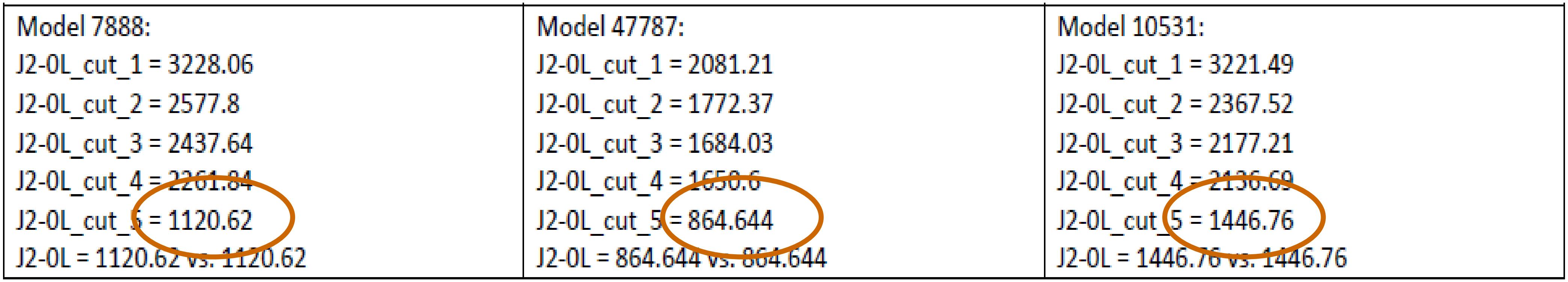
The 2 missed models produce more events than their found sister. But here the mass gap between the gluino & light squarks is critical !

Failed 7888(process-partonicXS-fullXS-frac.diff)				Failed model 47787				Sister model 10531 (parXS-fullXS)	
62	1727.895	1886.251	-0.083953	62	1800.651	1917.669	-0.061021	1963.142	2104.873
63	2334.176	2664.566	-0.123994	63	2386.946	2673.936	-0.107329	2361.901	2564.719
68	2110.194	2768.67	-0.237831	68	2302.222	2934.559	-0.215479	324.0471	462.8515
69	8403.199	9576.529	-0.122521	69	8499.471	9827.821	-0.135162	3656.663	4008.306



#model	lepton-pt	num-leps	MET	hardest-jet	Meff-4	Meff-3	Meff-2	Sum-4jet-pt	Sum-3jet-pt	Sum-2jet-pt
7888	10.45223	0.06694553	204.4017	197.5448	573.3782	545.9731	497.1623	358.6608	331.2557	282.4449
47787	16.66272	0.02518321	226.5762	212.5818	570.0201	552.9338	517.9707	336.5003	319.414	284.4509
10531	17.12206	0.01519737	375.4166	284.1541	861.9388	843.813	802.8543	441.0014	422.8756	381.9169

- 10531 gets at least one hard jet from each gluino decay to pass the 2j0l analysis while 7888 & 47787 do not since the mass splitting is so small
- Recall that 1129 events are needed for S=5 in 2j0l in this case
- Compressed, heavy spectrum → not enough hard jets

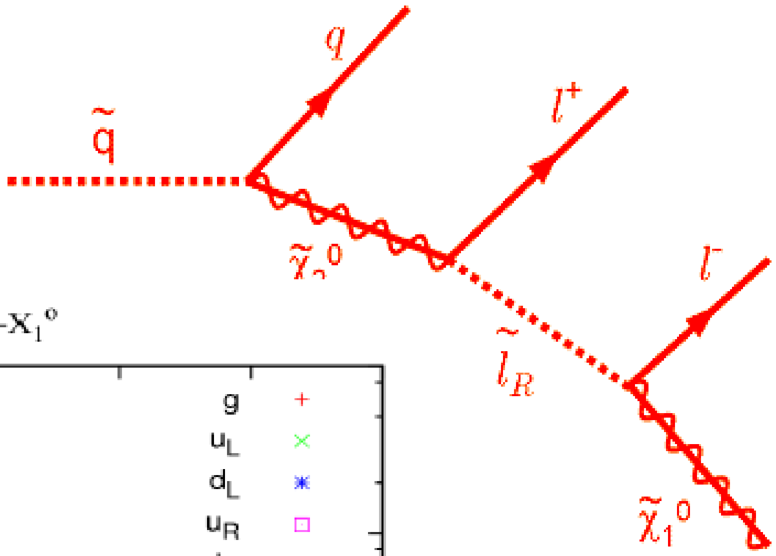


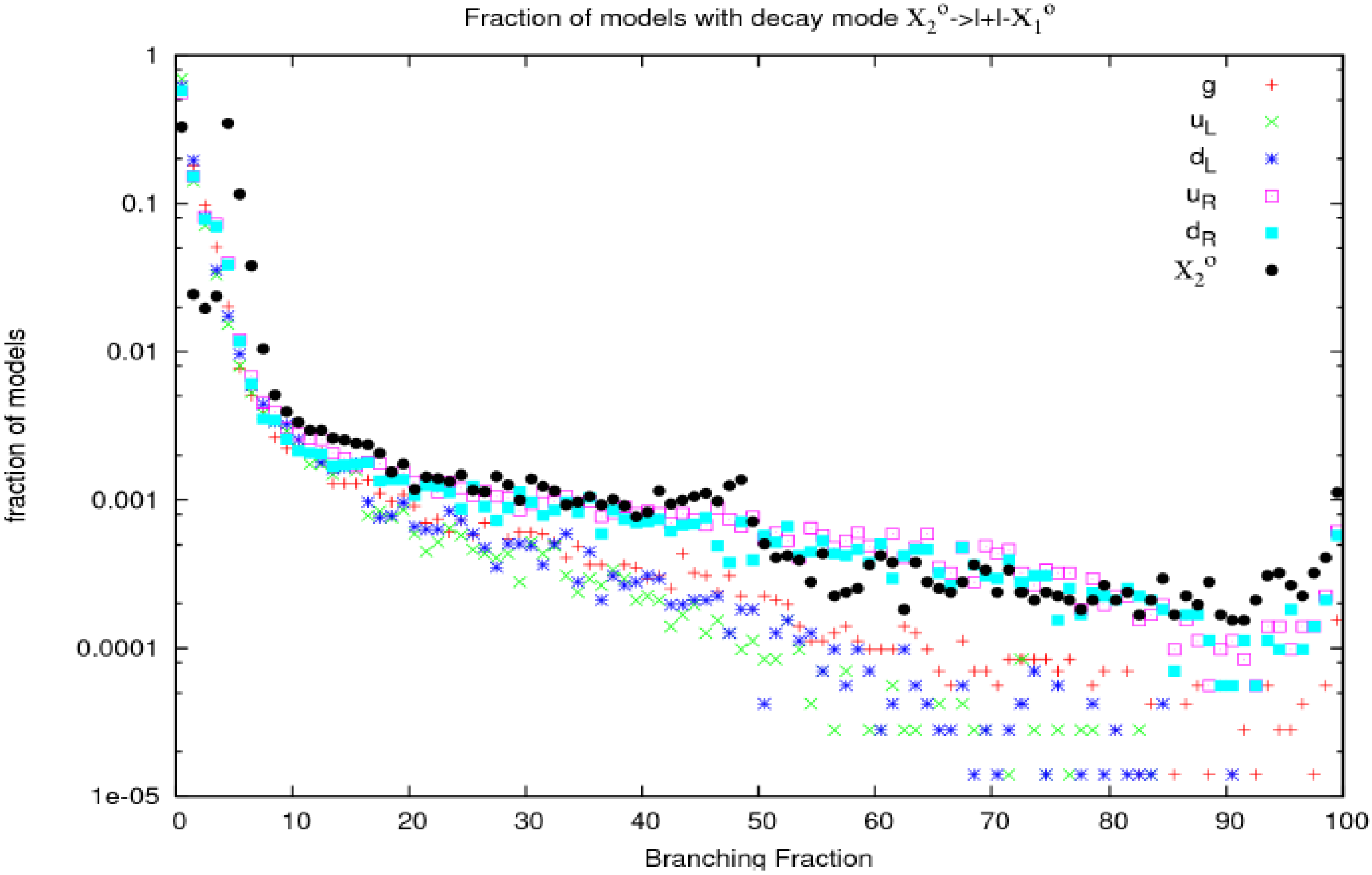
Model 7888: J2-0L_cut_1 = 3228.06 J2-0L_cut_2 = 2577.8 J2-0L_cut_3 = 2437.64 J2-0L_cut_4 = 2261.84 J2-0L_cut_5 = 1120.62 J2-0L = 1120.62 vs. 1120.62	Model 47787: J2-0L_cut_1 = 2081.21 J2-0L_cut_2 = 1772.37 J2-0L_cut_3 = 1684.03 J2-0L_cut_4 = 1650.6 J2-0L_cut_5 = 864.644 J2-0L = 864.644 vs. 864.644	Model 10531: J2-0L_cut_1 = 3221.49 J2-0L_cut_2 = 2367.52 J2-0L_cut_3 = 2177.21 J2-0L_cut_4 = 2136.69 J2-0L_cut_5 = 1446.76 J2-0L = 1446.76 vs. 1446.76

Just missed !

Passed !

How often do these ‘famous’ decay chains actually occur??

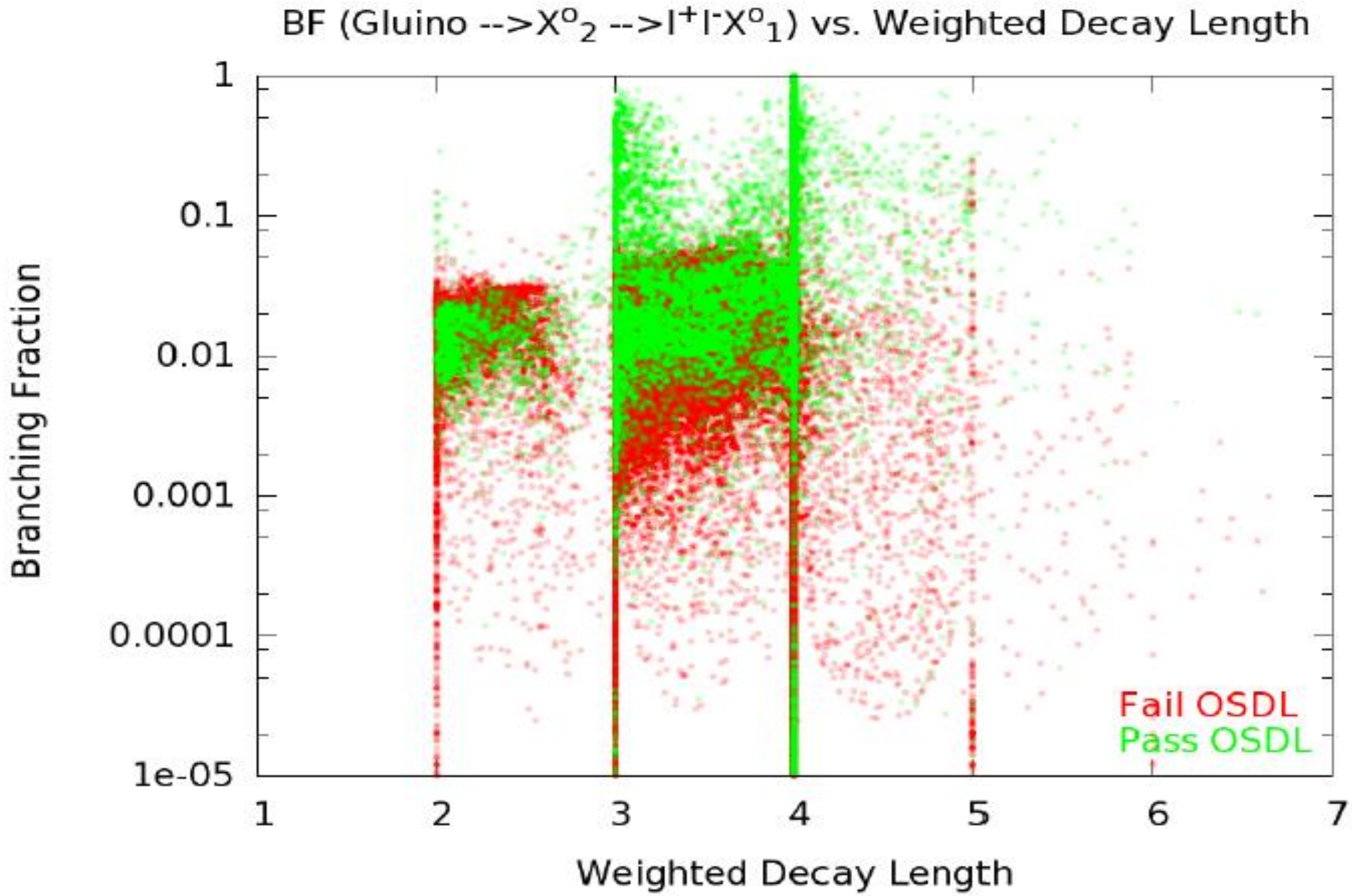




It appears that this is not GENERALLY a common mode

Gluino initiated cascades leading to X $l^+ l^-$ MET

Inclusive Branching fraction

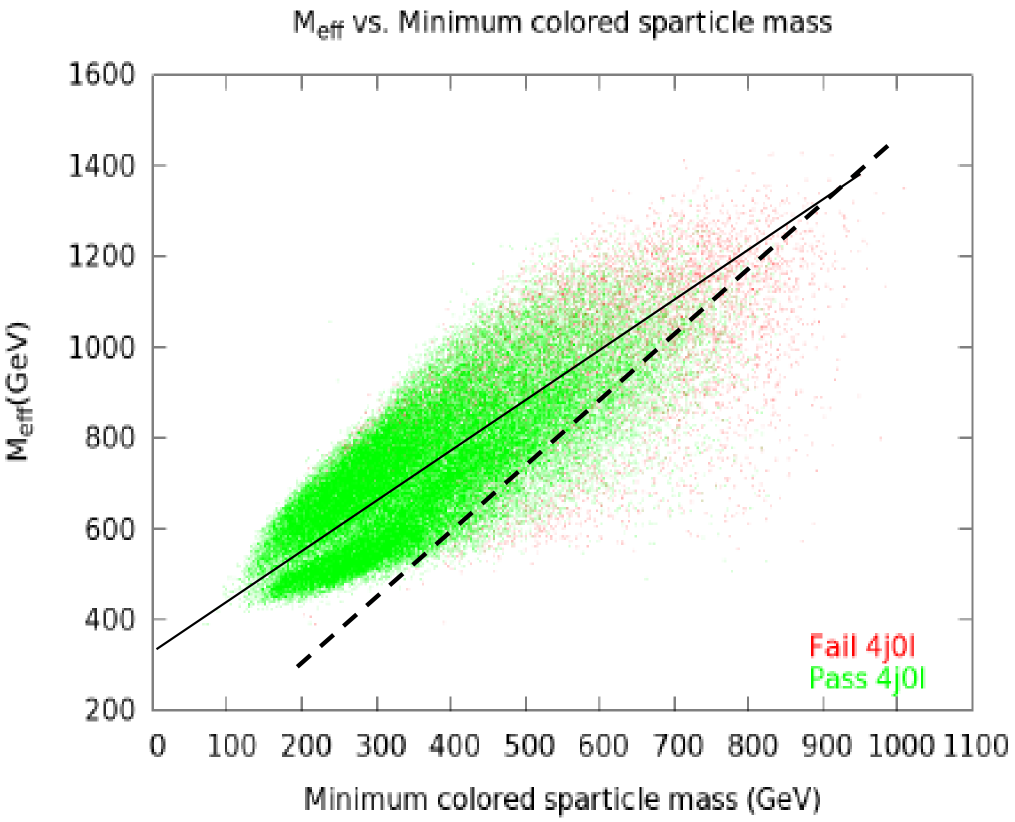


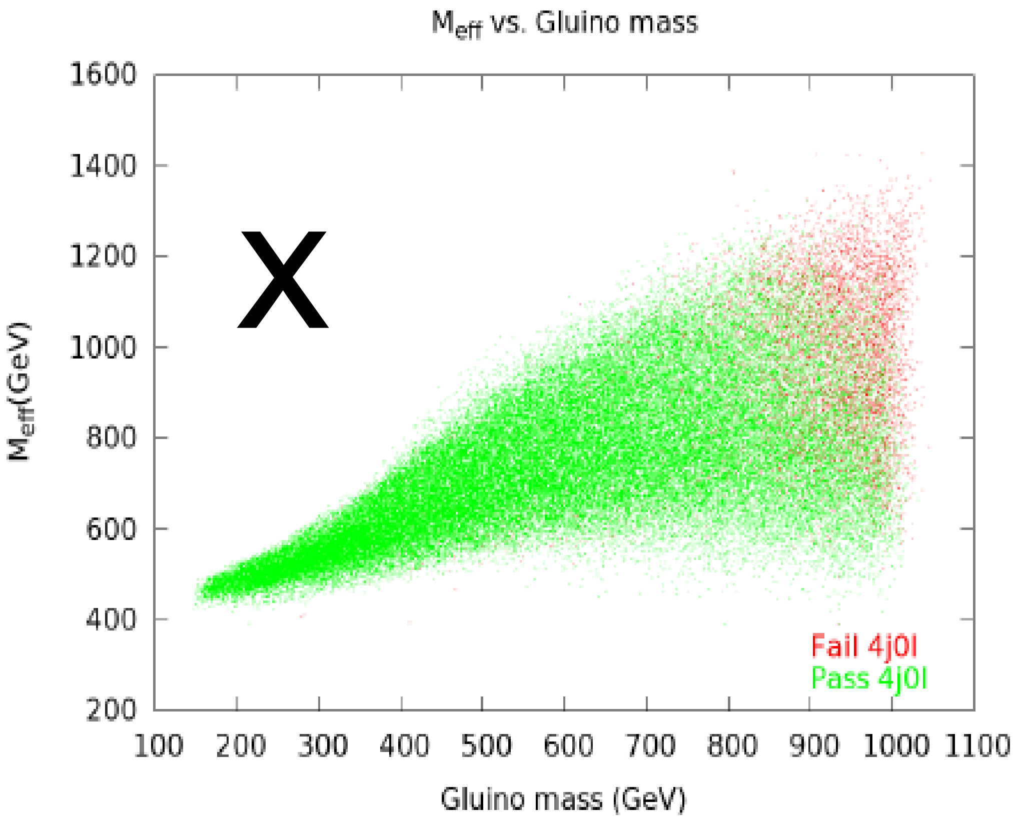
BF-weighted number of steps in decay chain

- Does M_{eff} value correlate w/ the lightest colored sparticle mass as it does in mSUGRA??

Yes…but in mSUGRA, one finds : $M_{eff} \sim 1.5\ M_{lightest}$

Not here..the slope is somewhat more shallow due to lighter mass states absent in mSUGRA


M_{eff} vs. Minimum colored sparticle mass


M_{eff} vs. Gluino mass

Summary

- The pMSSM has a richer phenomenology than any of the conventional SUSY breaking scenarios. The sparticle properties can be vastly different, e.g., the nLSP can be any other sparticle!

- Light partners can exist which have avoided LEP & Tevatron constraints and may also be difficult to observe in some analyses due to small mass differences or squirky spectra

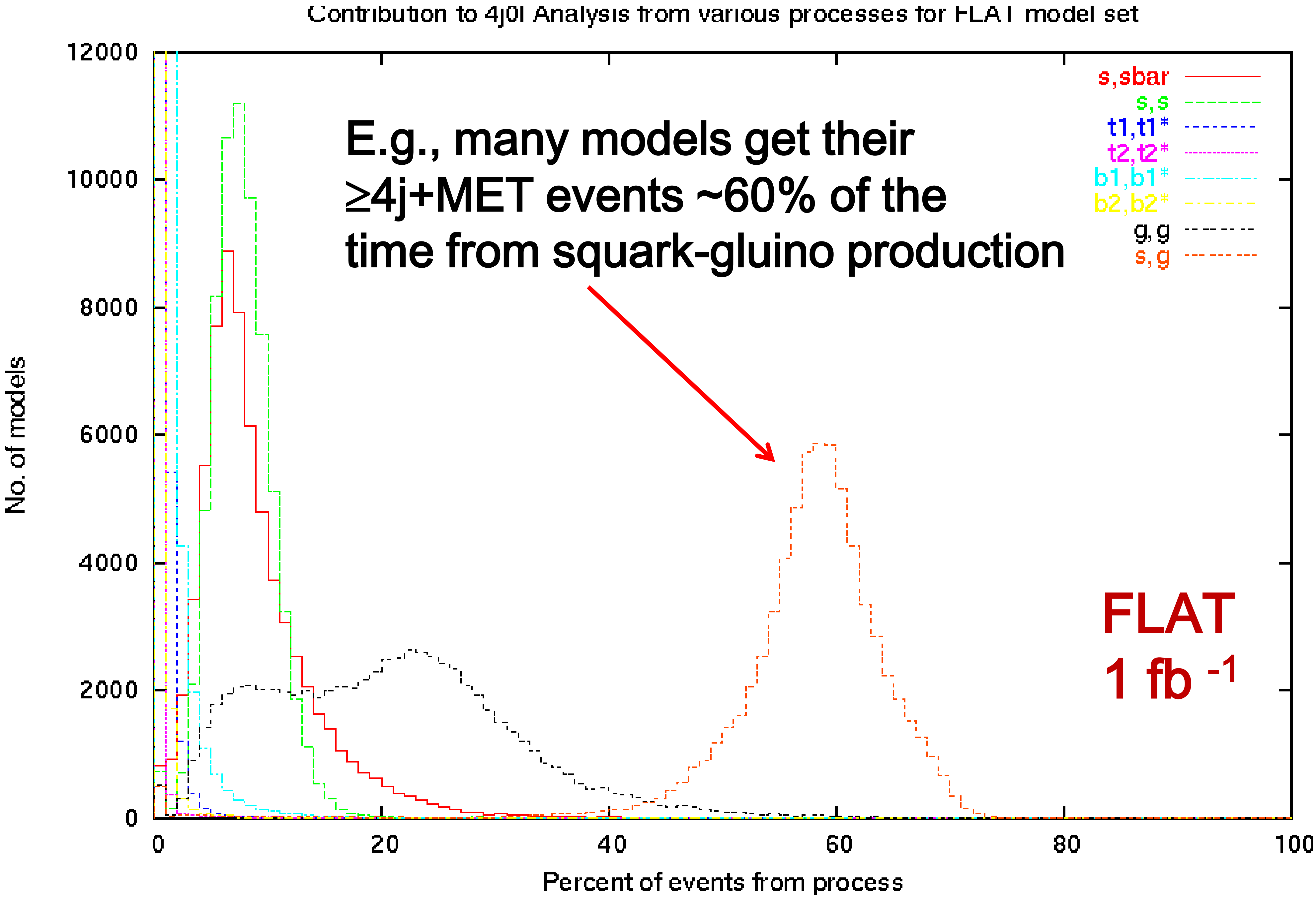
- SM background systematics, compressed mass spectra & processes with low signal rates or low MET due to unusual decays lead to models being missed by the inclusive analyses.

- Long-lived particle searches (& in cascades!) are important.

- The study of the complexities of these models is ongoing.

BACKUP SLIDES

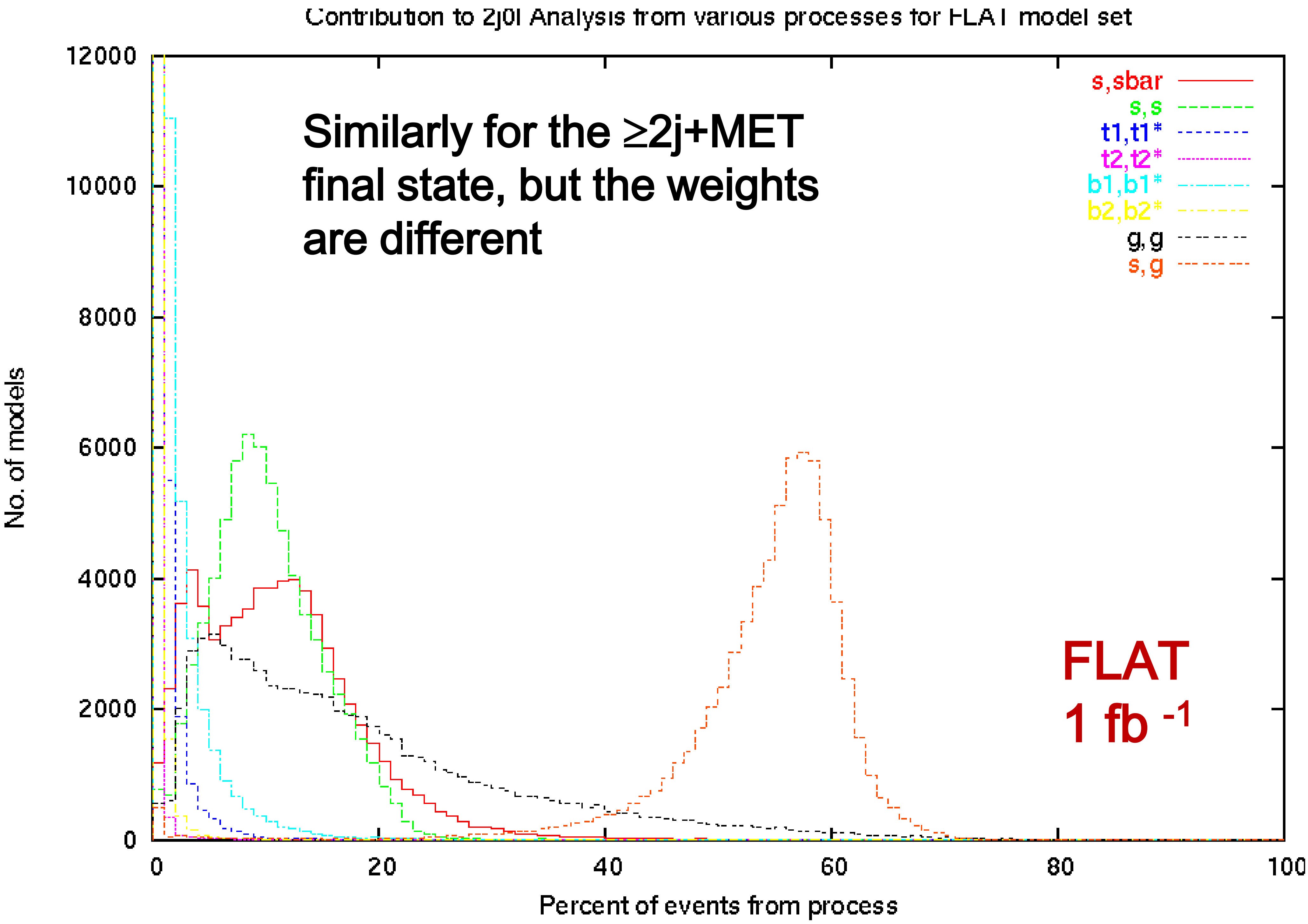
What processes produce the ≥4j/2j+MET events ???



E.g., many models get their ≥4j+MET events ~60% of the time from squark-gluino production

FLAT

1 fb $^{-1}$

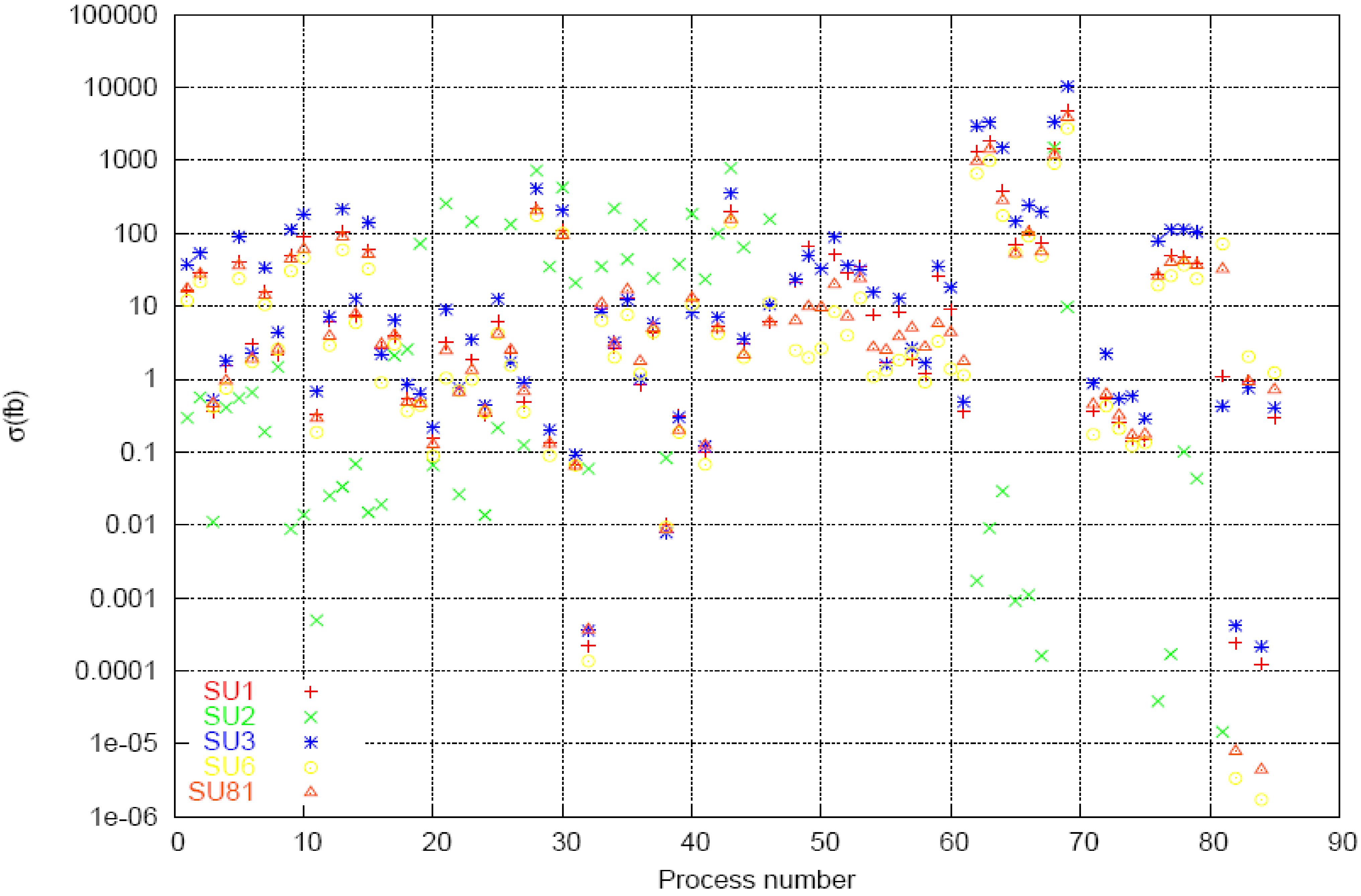


Similarly for the ≥2j+MET final state, but the weights are different

FLAT

1 fb $^{-1}$

Benchmark Model Process Cross Sections



ATLAS Significance Calculation

$$Z_n = \sqrt{2}\,\mathrm{erf}^{-1}(1-2p)\ , \tag{2}$$

where p is the probability that the background could have fluctuated by chance to the measured # of events $N_{\mathrm{data}} = N_{\mathrm{signal}} + N_b$ or above, and is given by

$$p = A \int_0^\infty db\, G(b; N_b, \delta N_b) \sum_{i=N_{\mathrm{data}}}^{\infty} \frac{e^{-b} b^i}{i!}\ , \tag{3}$$

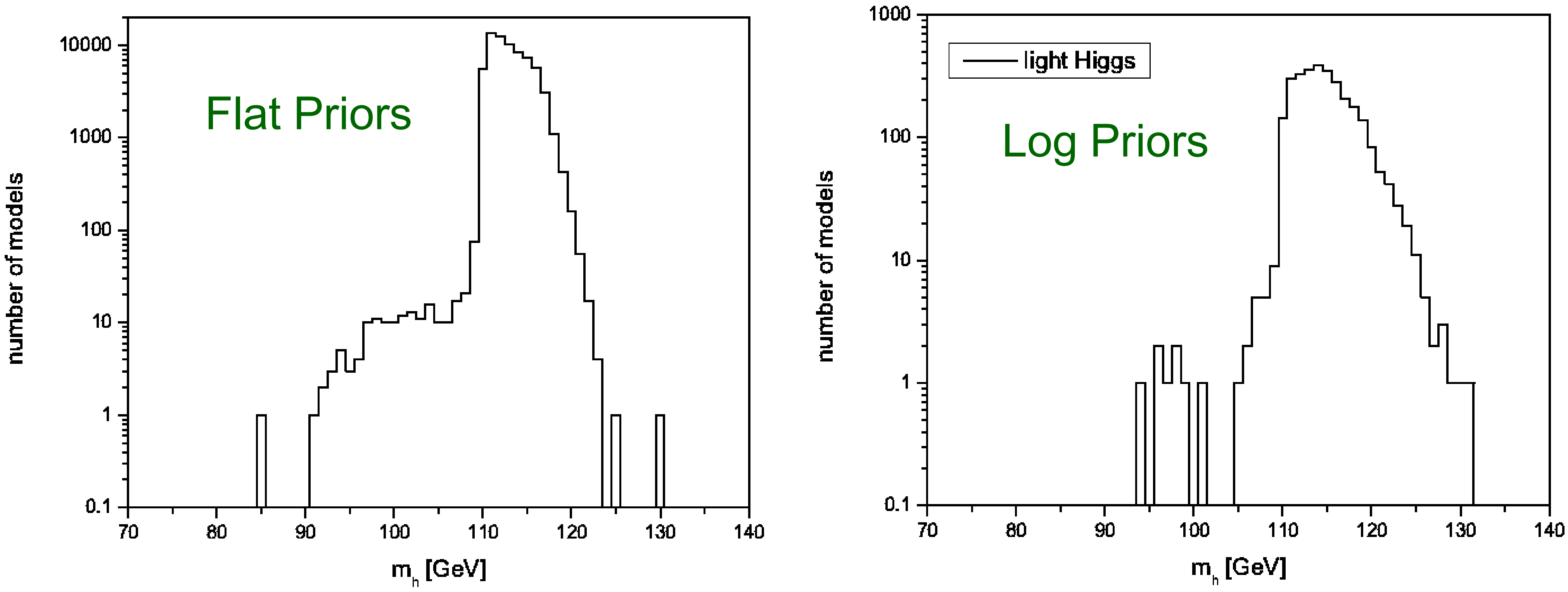
where G is a Gaussian with mean N_b and width δN_b evaluated at b, and δN_b is the systematic error on the number of background events. A is a normalization factor that ensures that the probability that the background could have fluctuated to *any* positive value is 1.

$$A = \left[\int_0^\infty db\, G(b; N_b, \delta N_b) \sum_{i=0}^{\infty} \frac{e^{-b} b^i}{i!}\right]^{-1} = \left[0.5\,\mathrm{erf}\left(N_b/(\sqrt{2}\,\delta N_b)\right)\right]^{-1}\ . \tag{4}$$

This formula can be implemented numerically, and then the results can be compared to those quoted by ATLAS. ATLAS claims to use a fractional systematic error of 0.2 for electroweak backgrounds, and 0.5 for QCD backgrounds. We thus use a total systematic background error given by

$$\delta N_b = \sqrt{\left(a_{\mathrm{QCD}} N_b^{\mathrm{QCD}}\right)^2 + \left(a_{\mathrm{EW}} N_b^{\mathrm{EW}}\right)^2}\ . \tag{5}$$

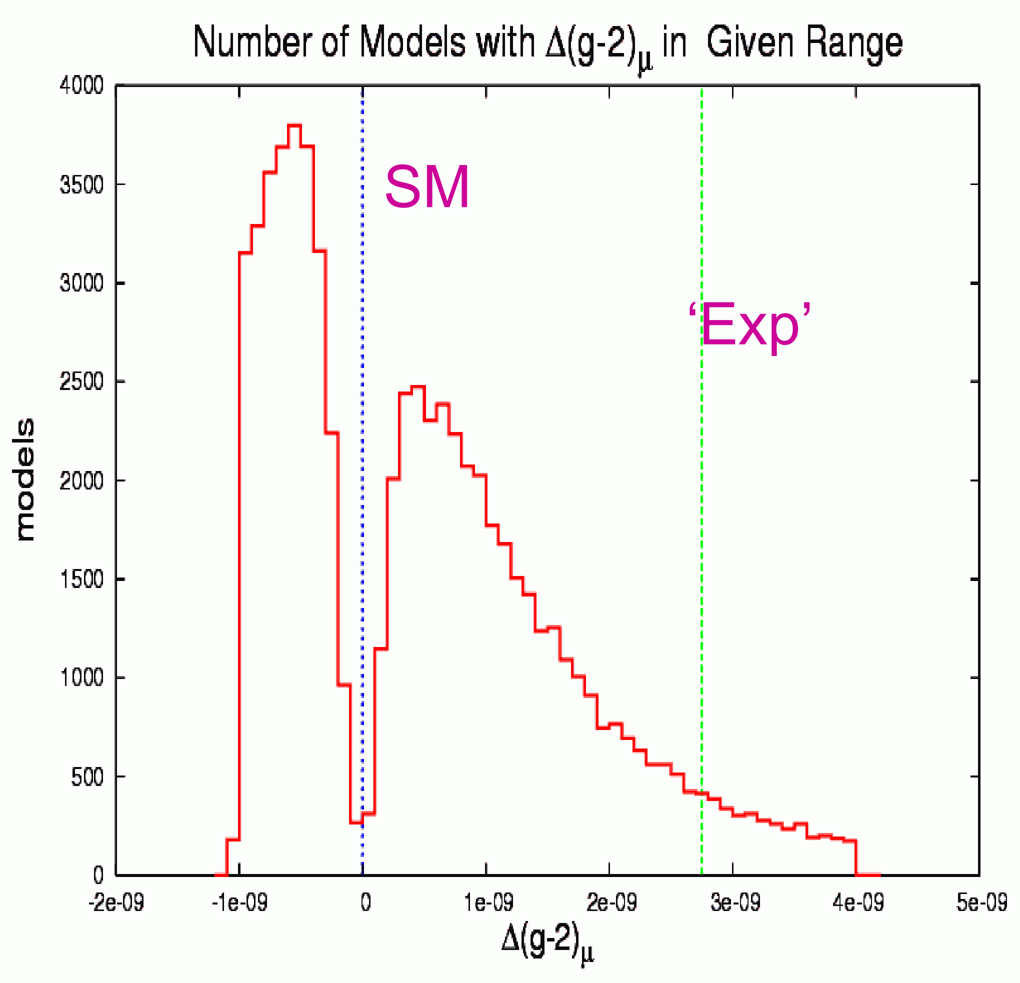
Light Higgs Mass Predictions



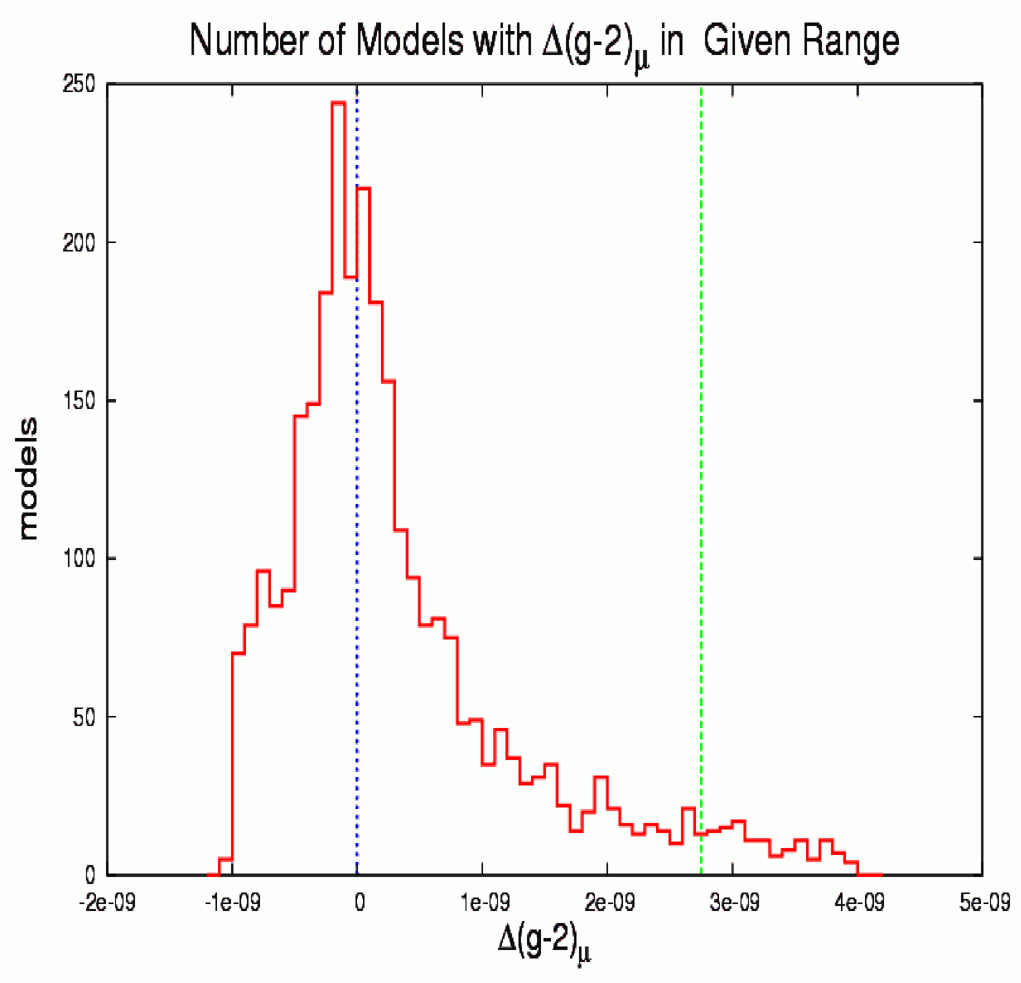
LEP Higgs mass constraints avoided by either reducing the ZZh coupling and/or reducing the, e.g., $h \rightarrow \bar{b}b$ branching fraction by decays to LSP pairs. We have both of these cases in our final model sets.

Predictions for $\Delta(g-2)_\mu$

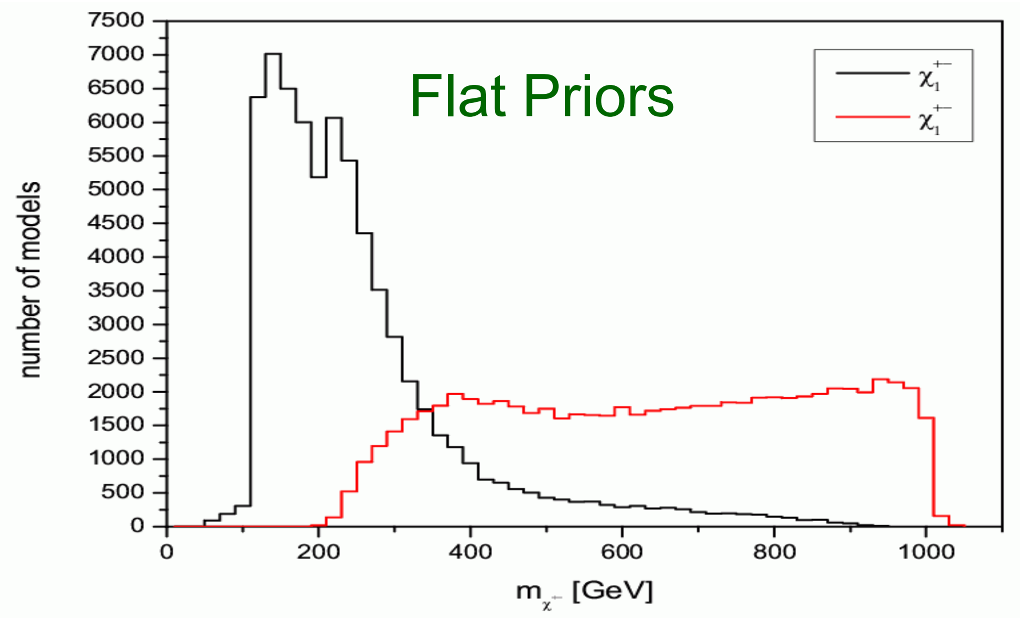
flat

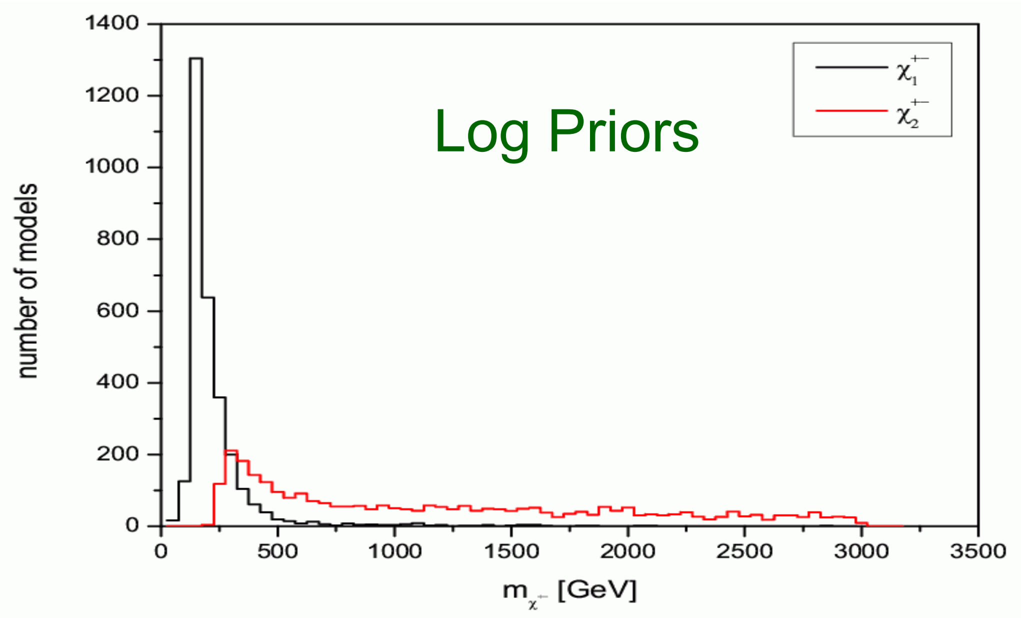


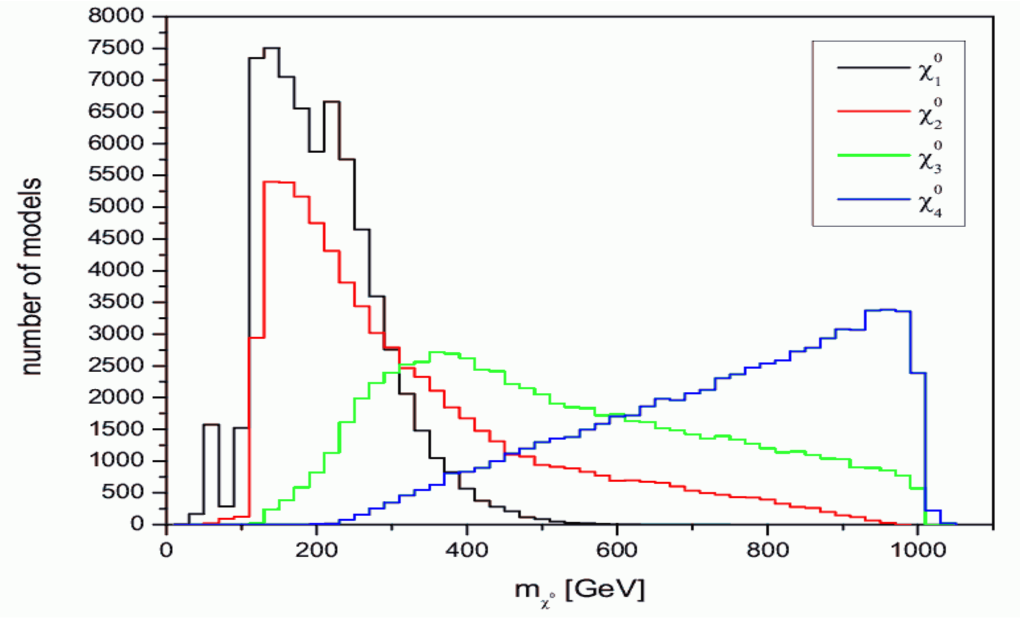
log

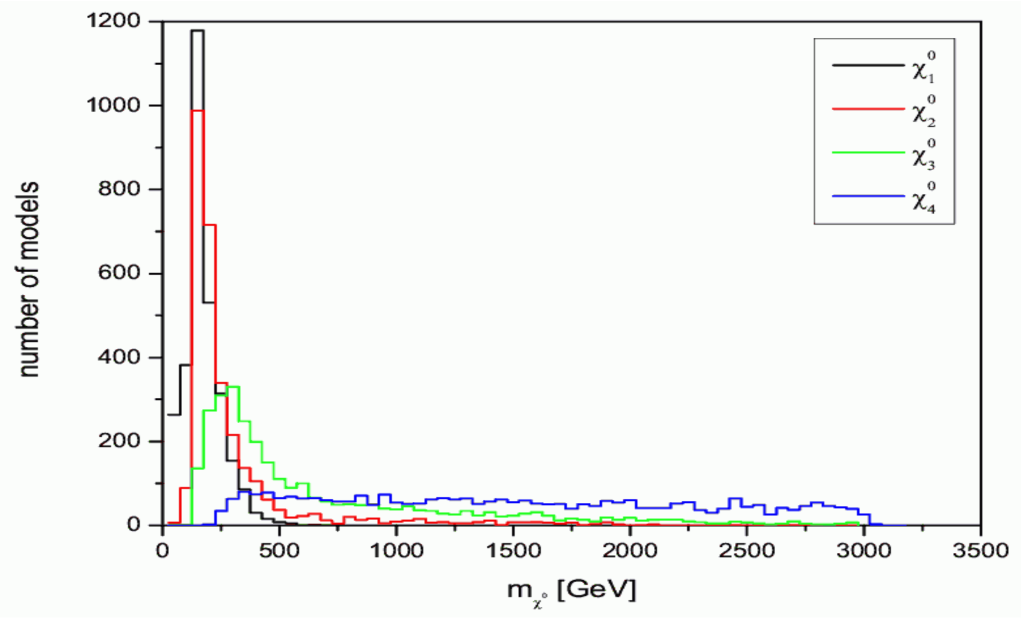


Distribution of Sparticle Masses By Species



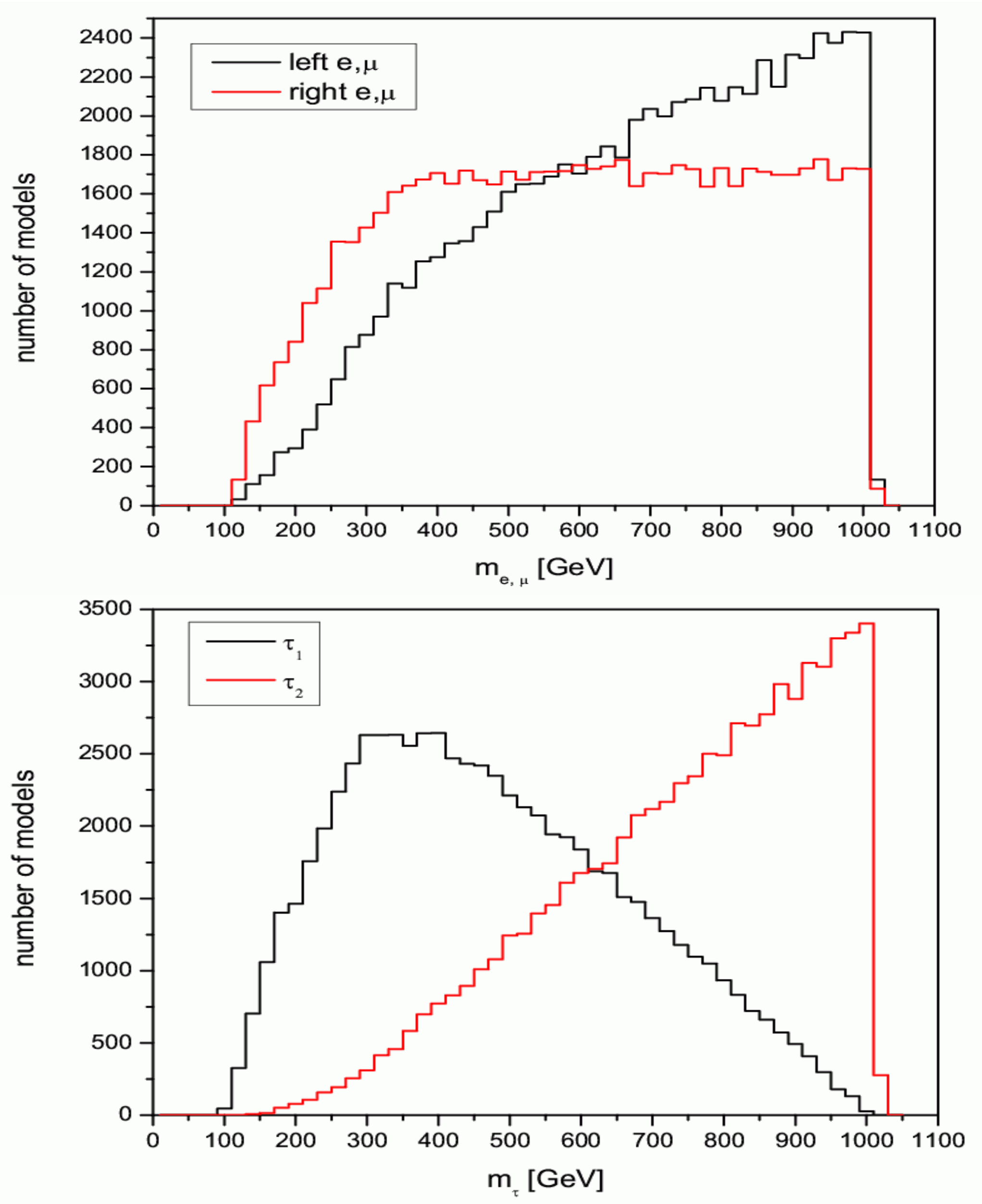




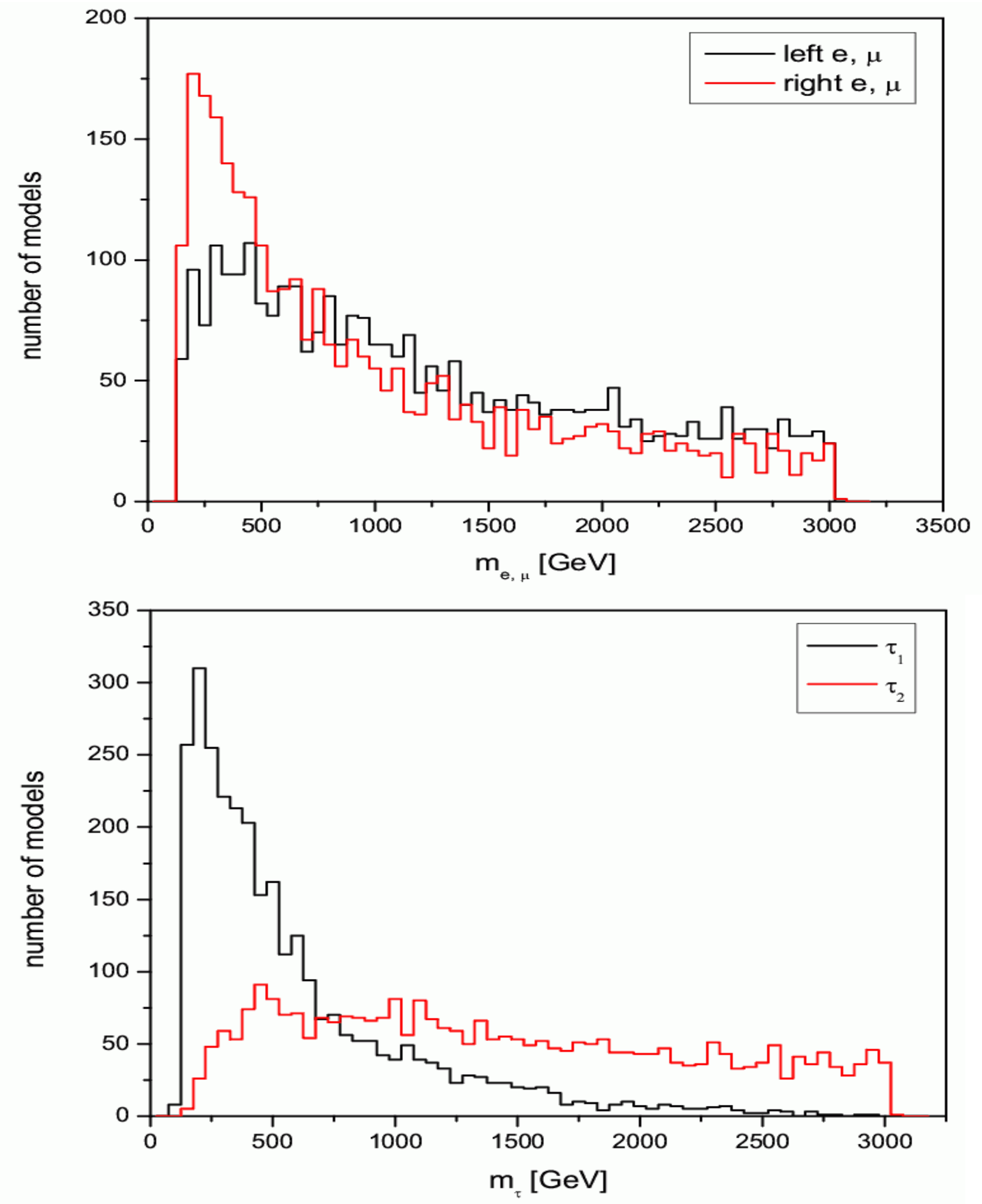


Distribution of Sparticle Masses By Species

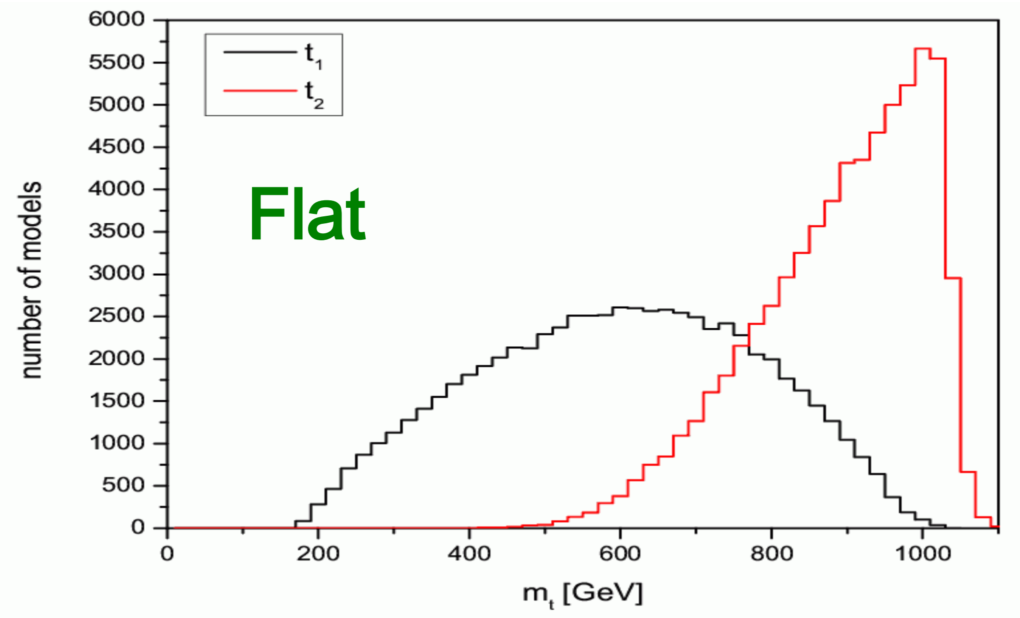
Flat Priors

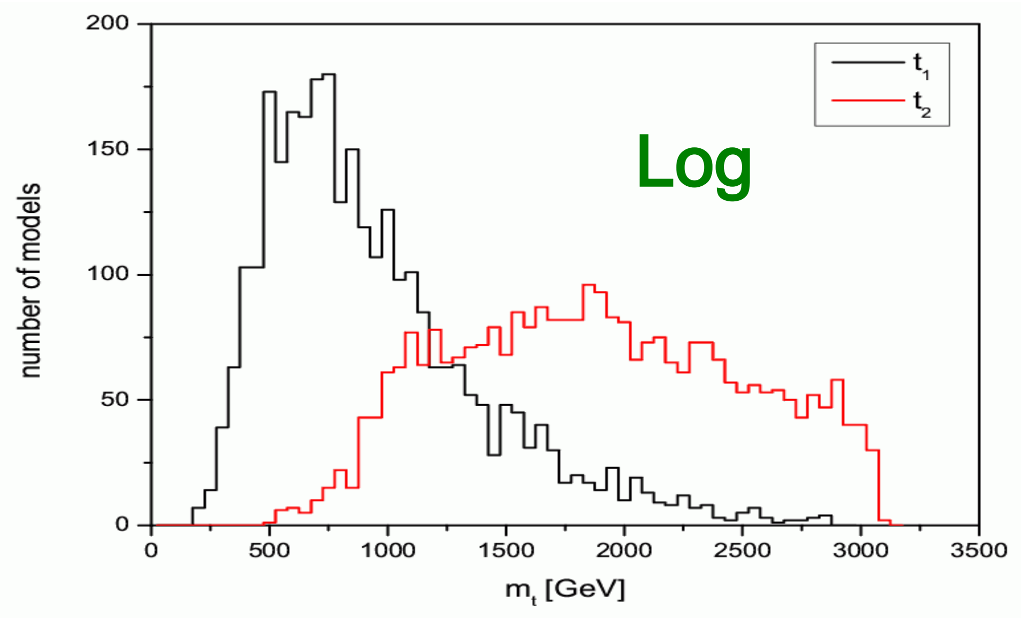


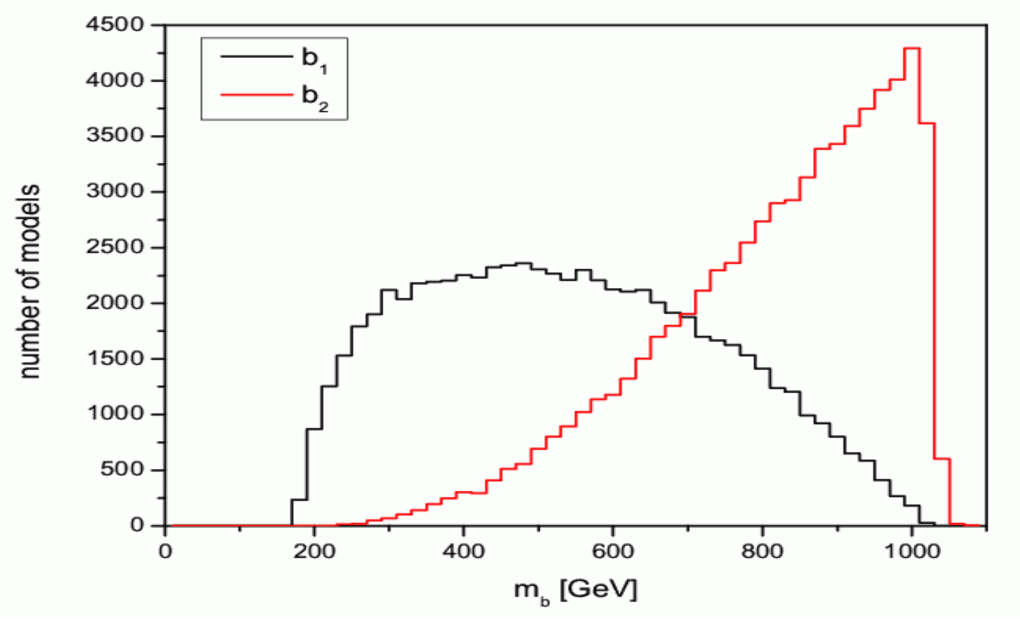
Log Priors

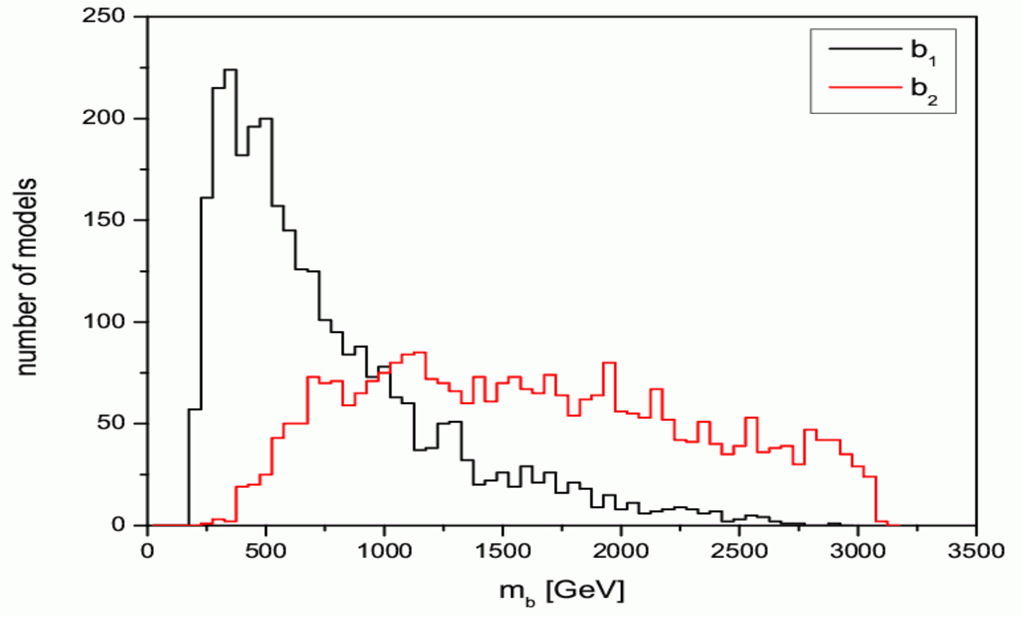


Distribution of Sparticle Masses By Species



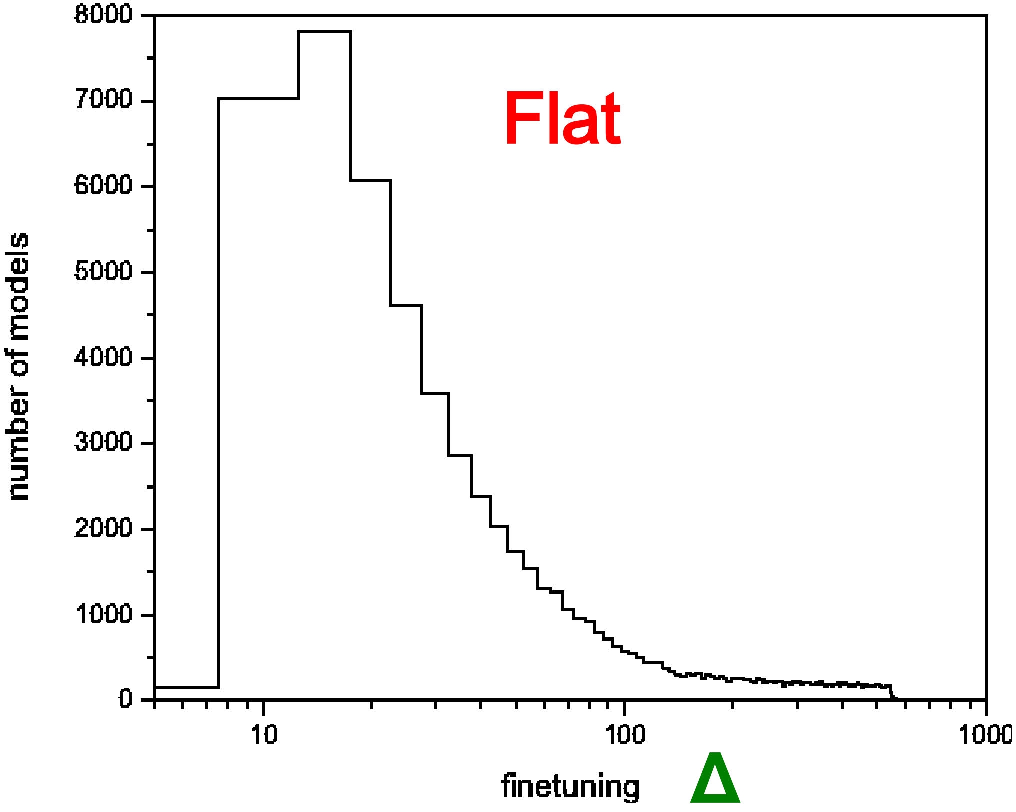


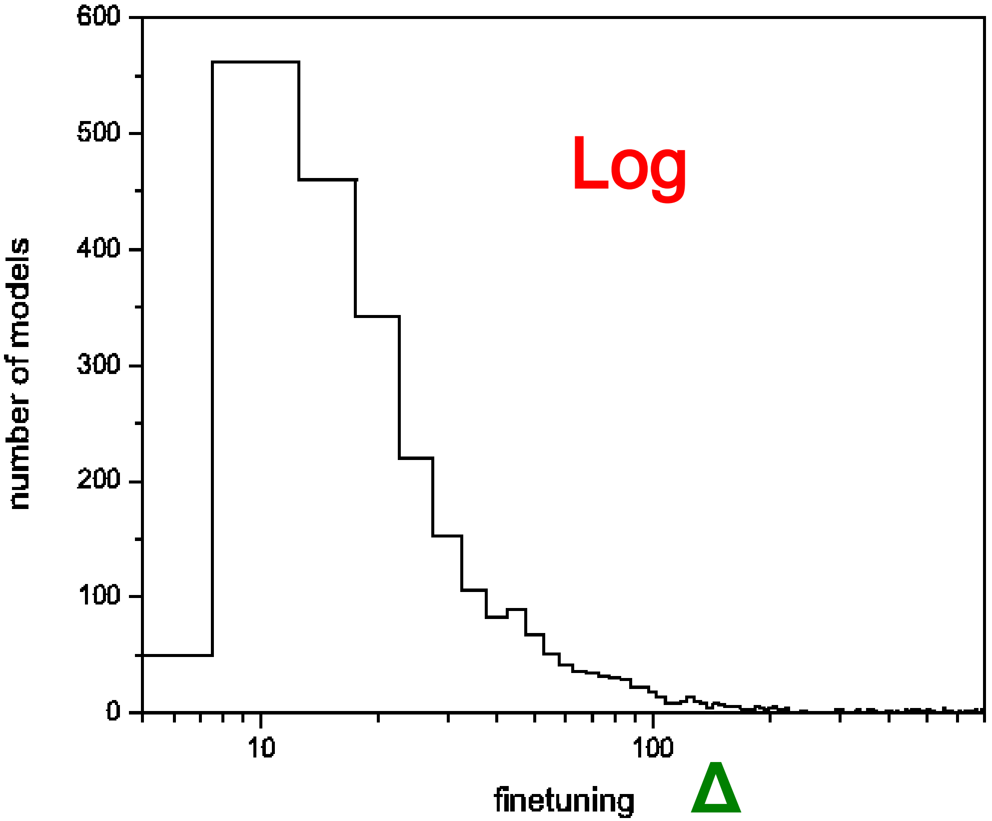


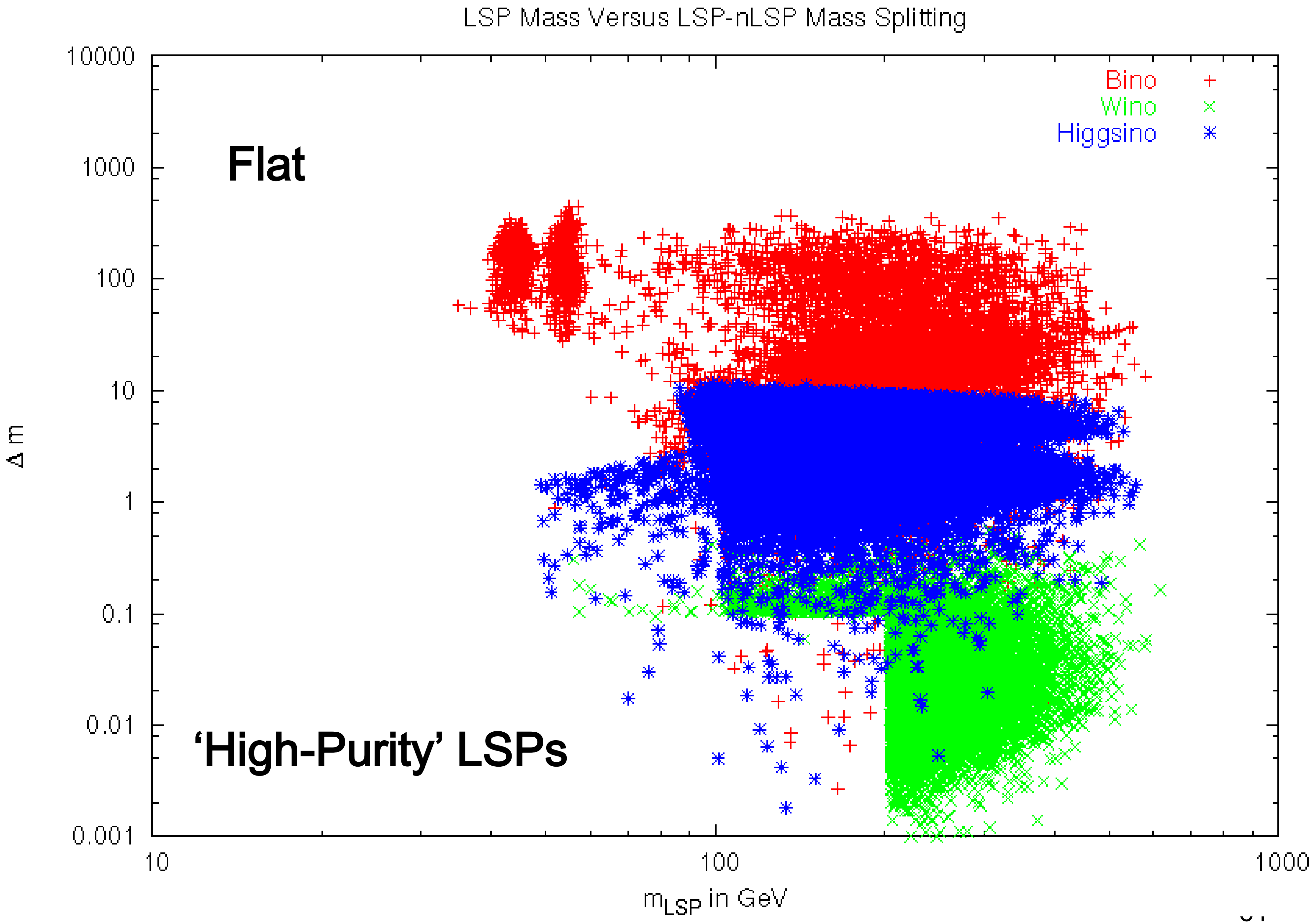


‘Fine-Tuning’ or Naturalness Criterion

We find that small values of `fine-tuning’ are very common !







Flat

‘High-Purity’ LSPs

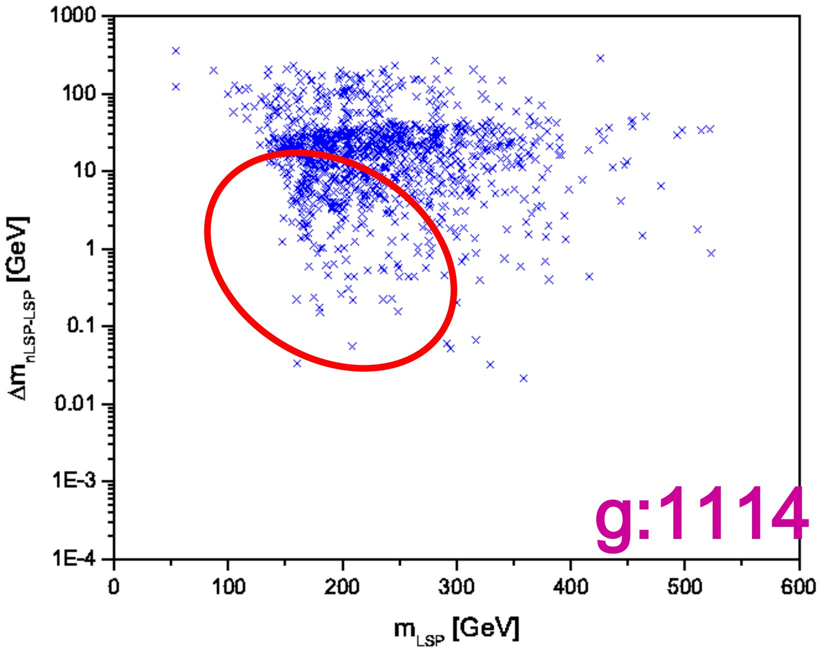
LSP Identity

Many models have LSPs which are close to the weak interaction eigenstates…

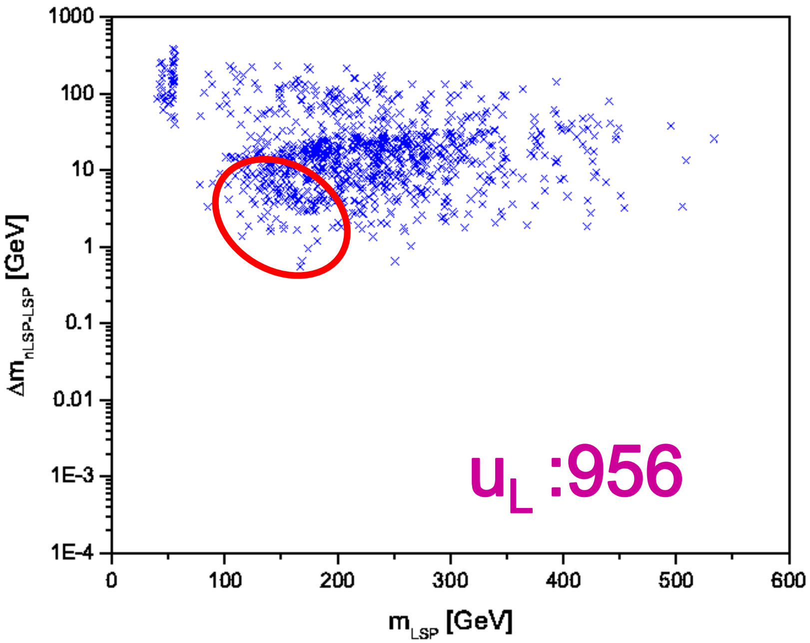
..e.g., for the flat case:

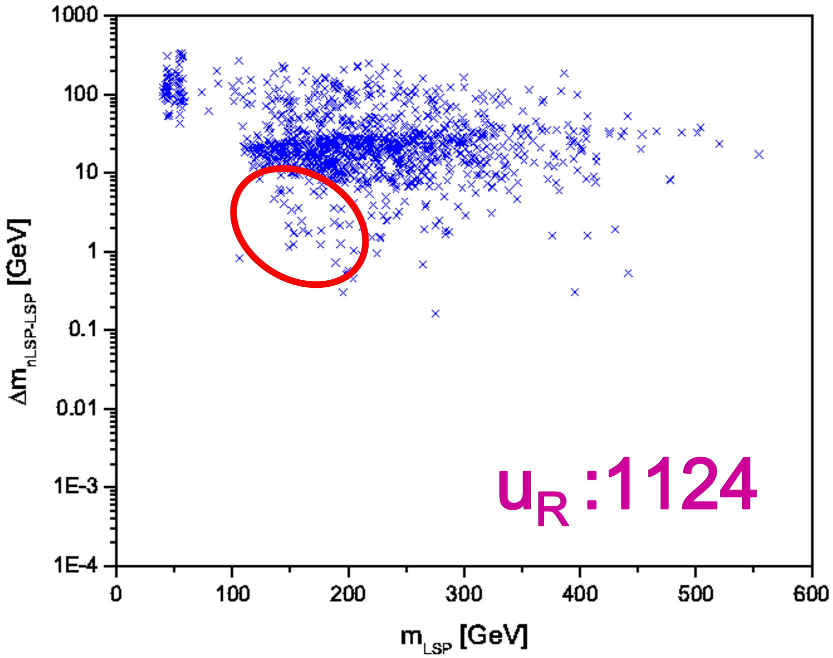
LSP Type	Definition	Percent of Models
Bino	$\|Z_{11}\|^2 > 0.95$	13.94
Mostly Bino	$0.8 < \|Z_{11}\|^2 \leq 0.95$	3.10
Wino	$\|Z_{12}\|^2 > 0.95$	14.16
Mostly Wino	$0.8 < \|Z_{12}\|^2 \leq 0.95$	9.14
Higgsino	$\|Z_{13}\|^2 + \|Z_{14}\|^2 > 0.95$	32.19
Mostly Higgsino	$0.8 < \|Z_{13}\|^2 + \|Z_{14}\|^2 \leq 0.95$	12.38
All other models		15.09

In some cases, but not exclusively, this can be due to the small splittings between the squarks and/or gluinos and other particles in the decay chain or the LSP itself (or even due to the complete absence of MET)



This can lead to soft jets in the final state that have insufficient p_T to pass any Tevatron analysis cuts





Tevatron II: CDF Tri-lepton Analysis

CDF RUN II Preliminary $\int \mathcal{L}dt = 2.0\ \mathrm{fb}^{-1}$: Search for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$

Channel	Signal	Background	Observed
3tight	2.25 ± 0.13(stat) ± 0.29(syst)	0.49 ± 0.04(stat) ± 0.08(syst)	1
2tight,1loose	1.61 ± 0.11(stat) ± 0.21(syst)	0.25 ± 0.03(stat) ± 0.03(syst)	0
1tight,2loose	0.68 ± 0.07(stat) ± 0.09(syst)	0.14 ± 0.02(stat) ± 0.02(syst)	0
Total Trilepton	4.5 ± 0.2(stat) ± 0.6(syst)	0.88 ± 0.05(stat) ± 0.13(syst)	1
2tight,1Track	4.44 ± 0.19(stat) ± 0.58(syst)	3.22 ± 0.48(stat) ± 0.53(syst)	4
1tight,1loose,1Track	2.42 ± 0.14(stat) ± 0.32(syst)	2.28 ± 0.47(stat) ± 0.42(syst)	2
Total Dilepton+Track	6.9 ± 0.2(stat) ± 0.9(syst)	5.5 ± 0.7(stat) ± 0.9(syst)	6

Table 3: Number of expected signal and background events and number of observed events in 2 fb^{-1}. Uncertainties are statistical(stat) and full systematics(syst). The signal is for the benchmark point described in section 5.

We need to perform the 3 tight lepton analysis ~ 10^5 times

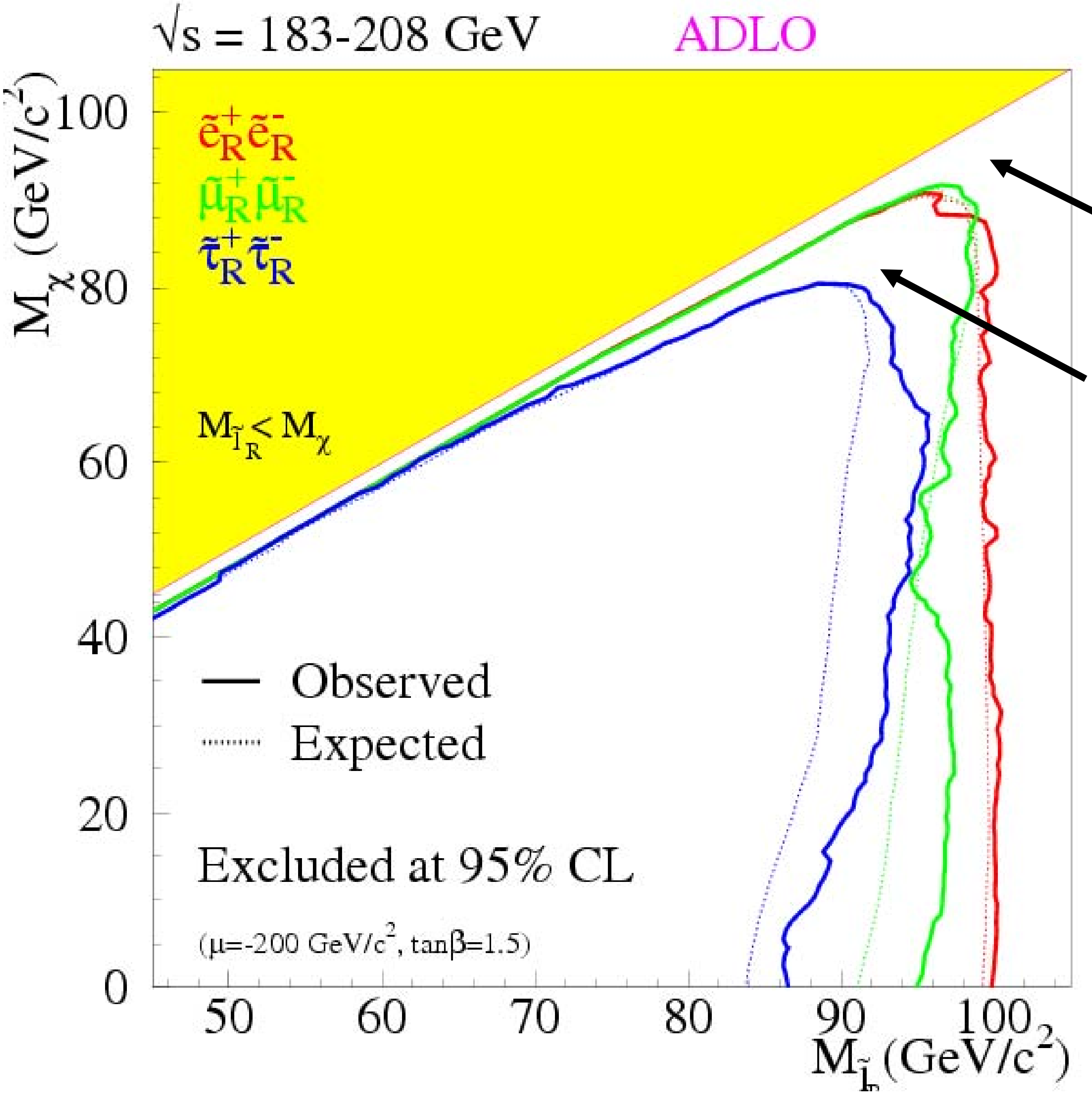
We perform this analysis using CDF-tuned PGS4, PYTHIA in LO plus a PROSPINO K-factor

→ Feldman-Cousins 95% CL Signal limit: 4.65 events

- This is the first SUSY analysis to include these constraints

The non-‘3-tight’ analyses are not reproducible w/o a better detector simulation

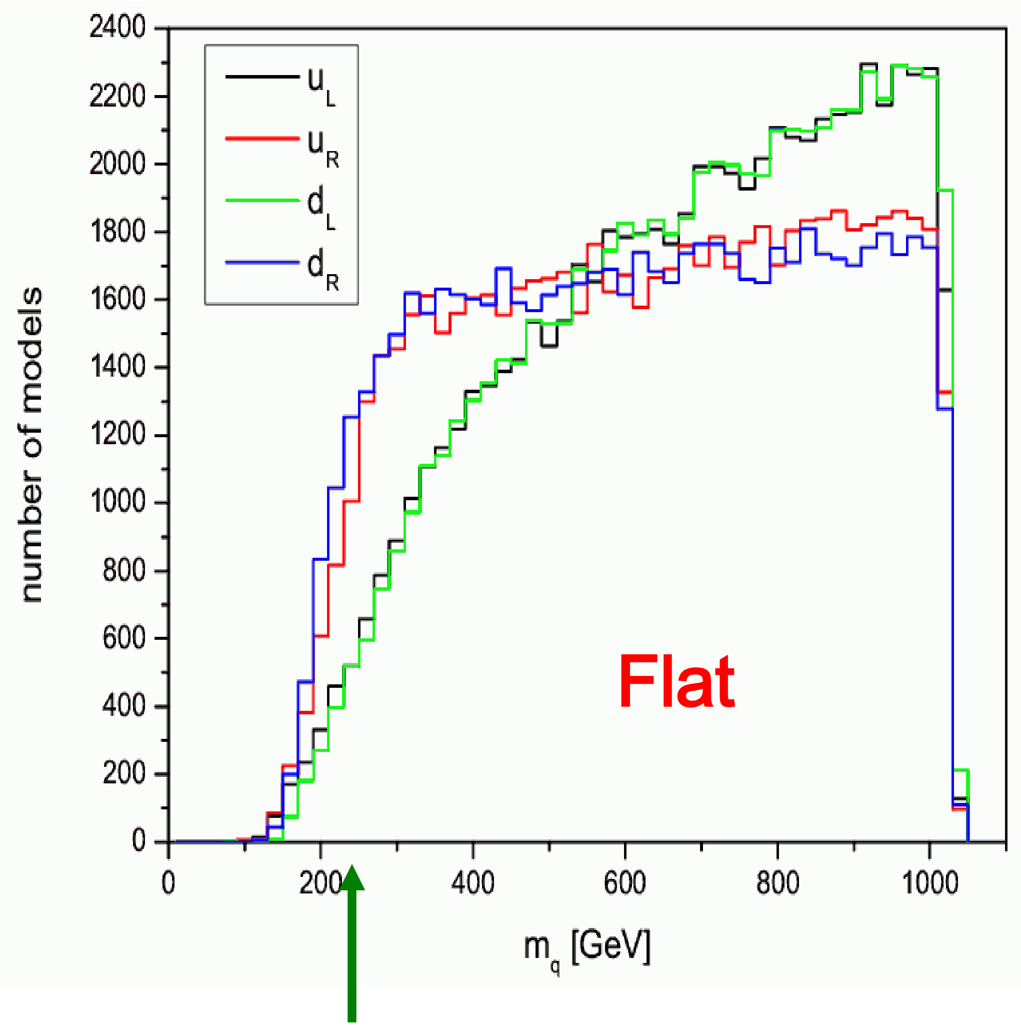
RH Sleptons

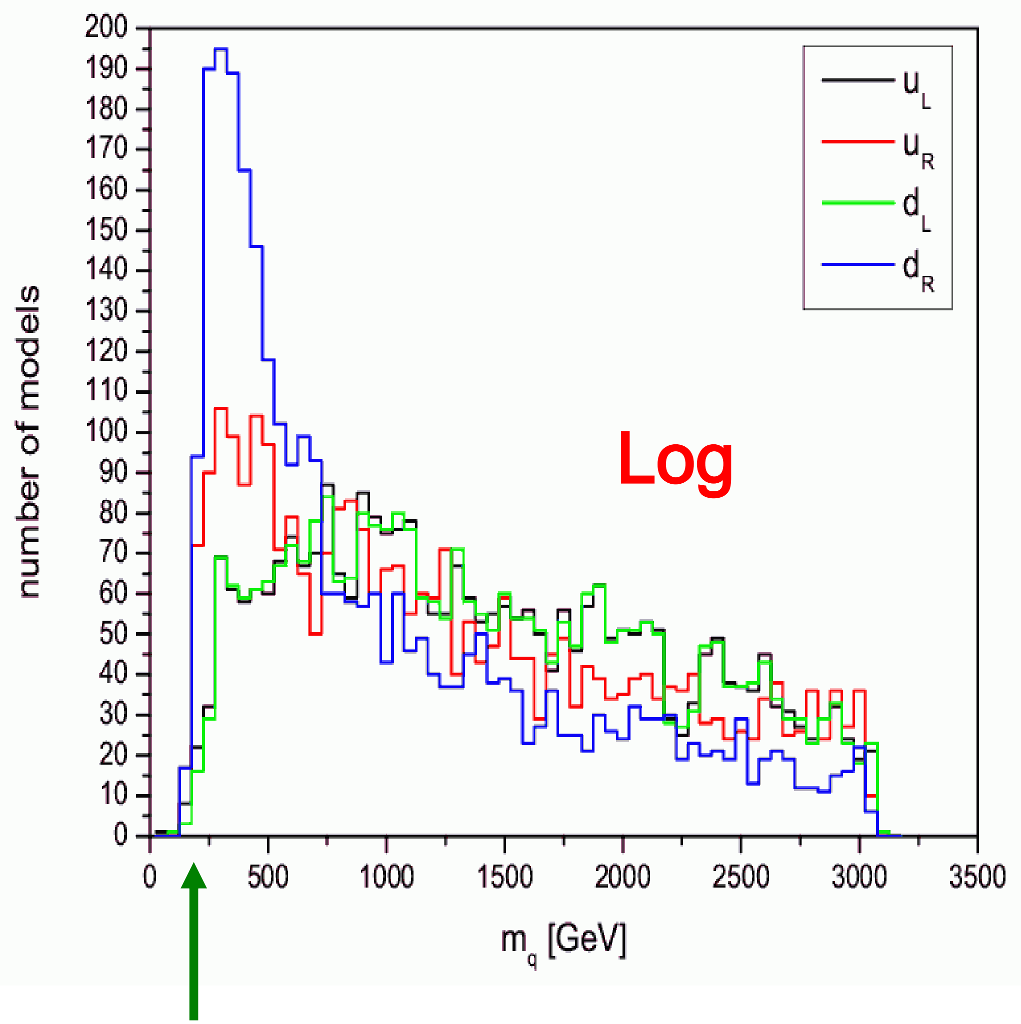


Note the holes where the leptons are too soft…

We need to allow for a mass gap w/ the LSP..light guys may slip through !

Squarks Can Also Be Light

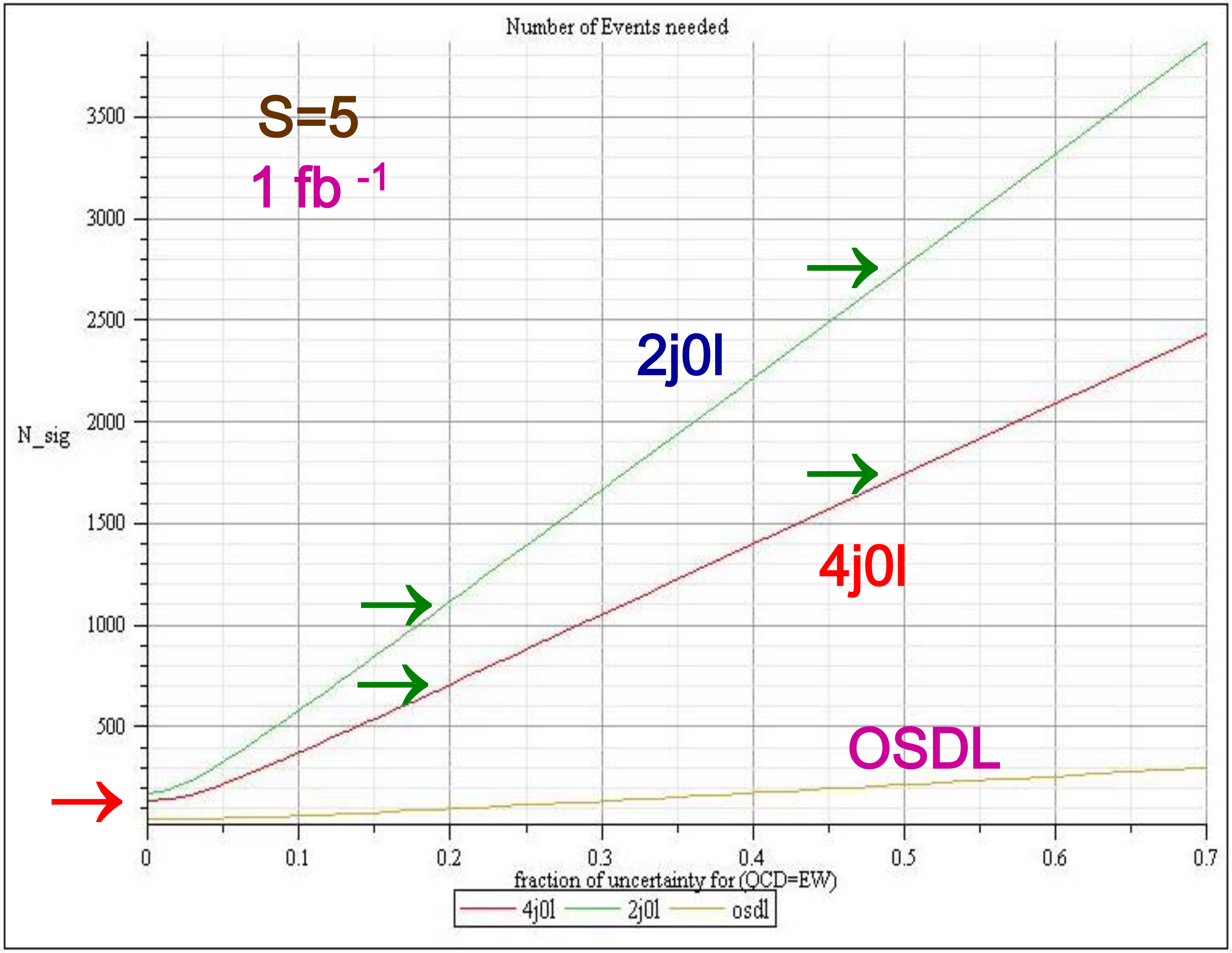




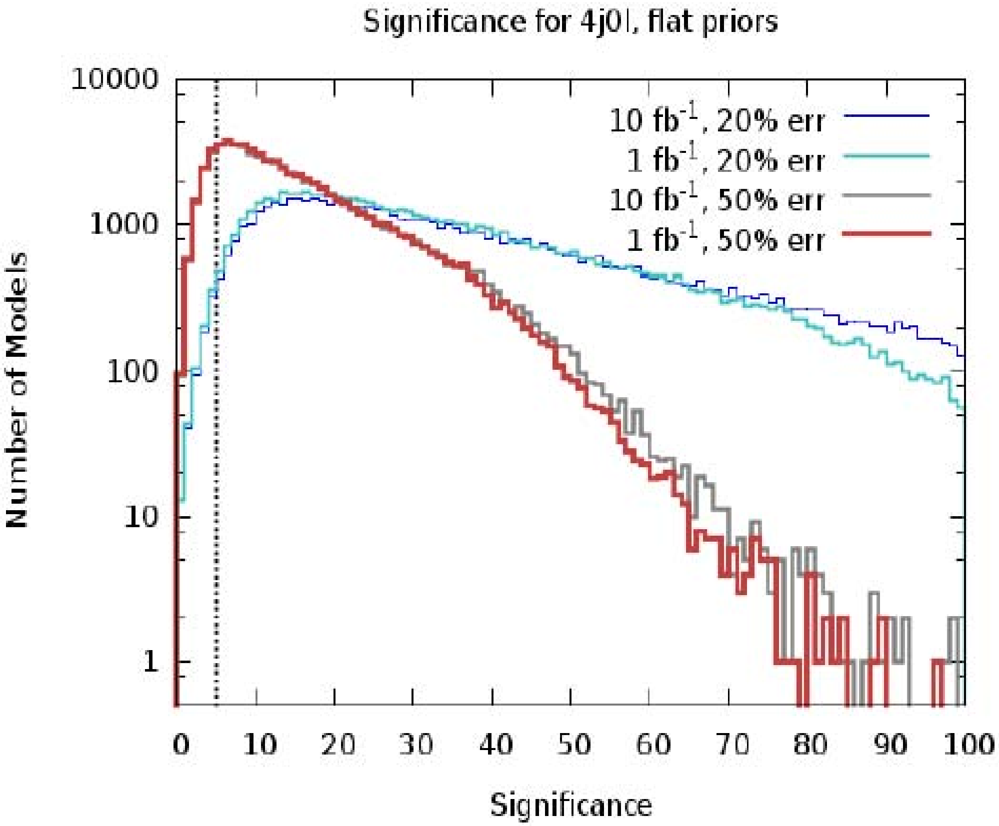
Light squarks can be missed by Tevatron searches for many reasons..

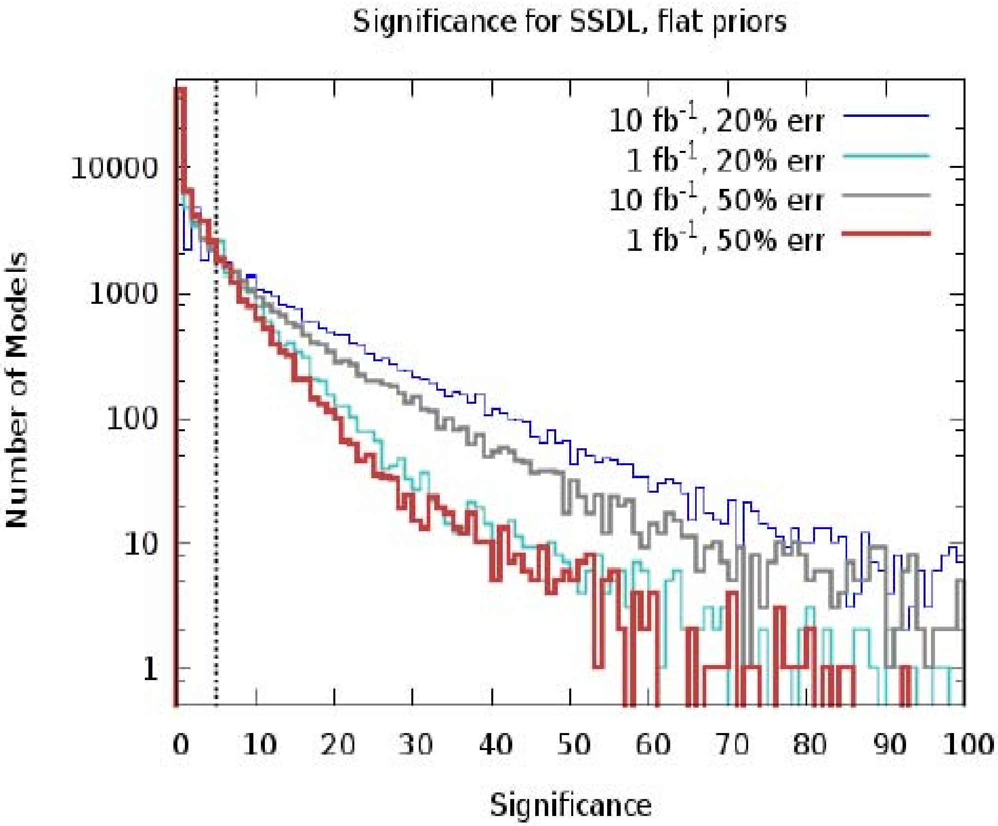
Background systematics are particularly important for both the 4j0l & 2j0l channels .. but somewhat less so for the others:

Required number of signal events for observation with S=5



How do the significances of analyses respond to changes in lumi or background systematics?

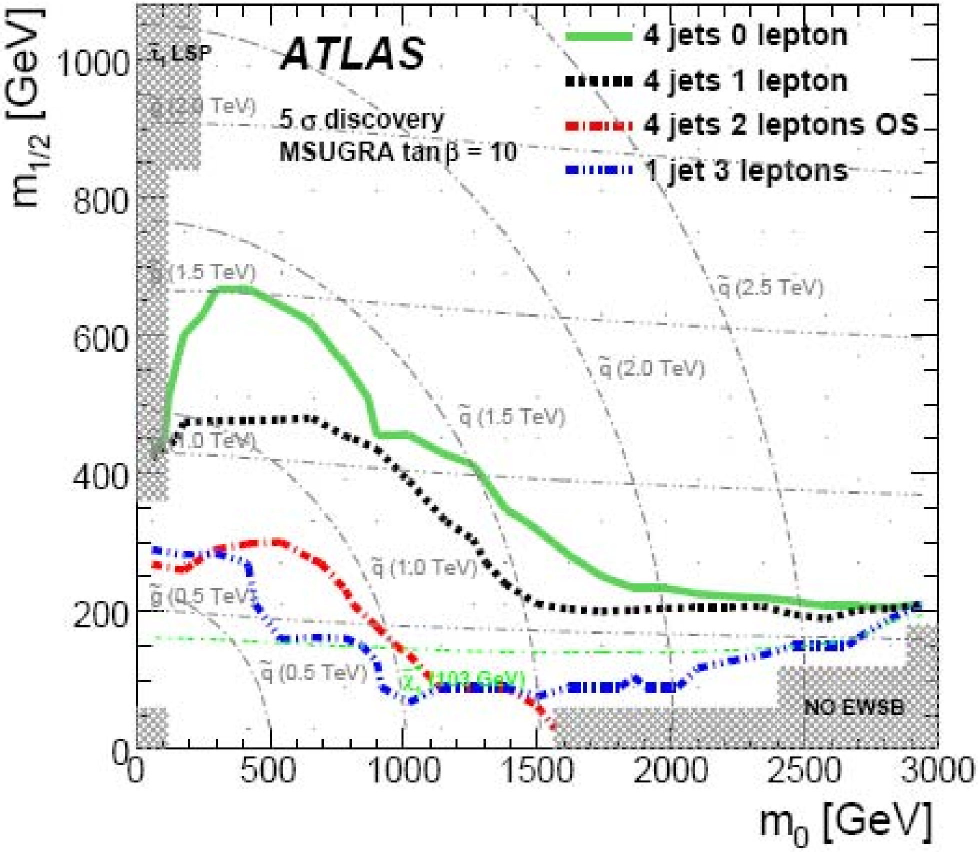


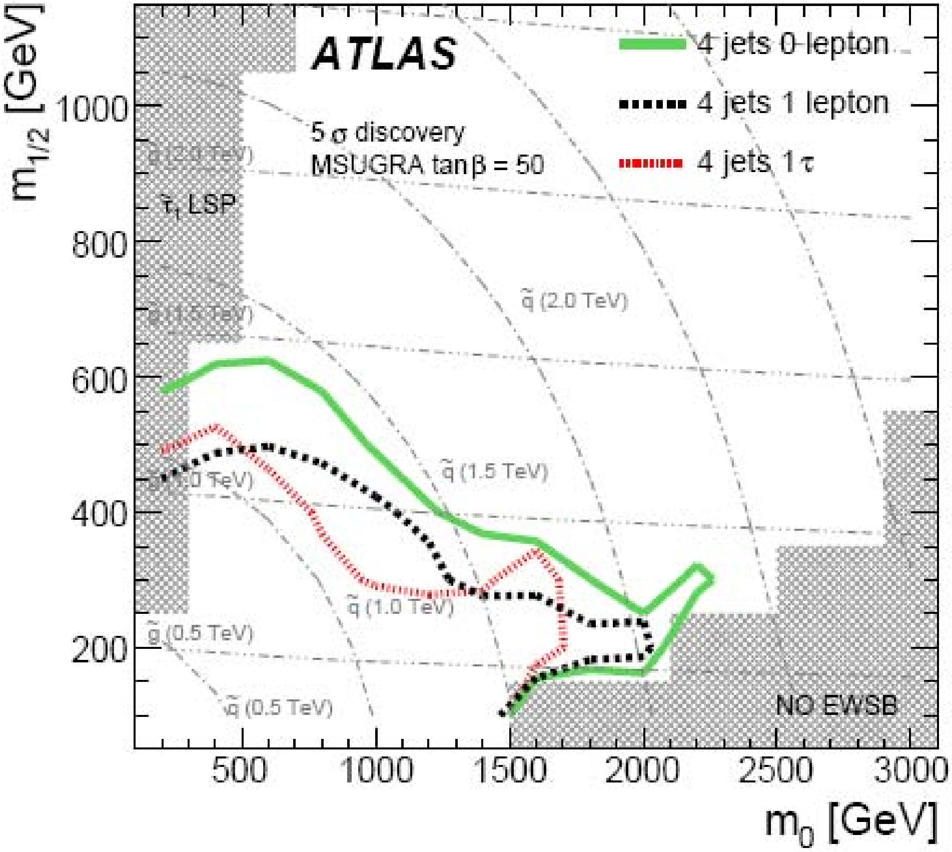


These results have some similarities to what ATLAS finds for the mSUGRA case but with some important differences:

- For mSUGRA, ATLAS finds somewhat comparable power in 4j0l & 4j1l analyses for both high & low tan β…but not us

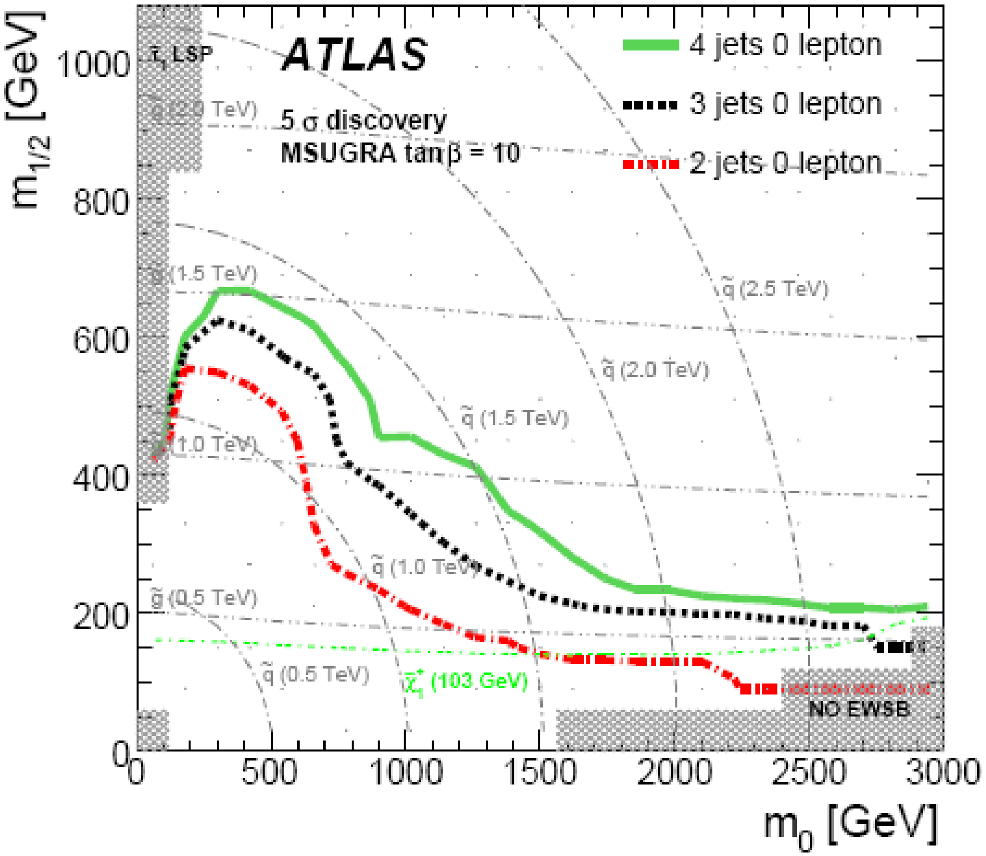
- For us, OSDL are less powerful than in the mSUGRA case

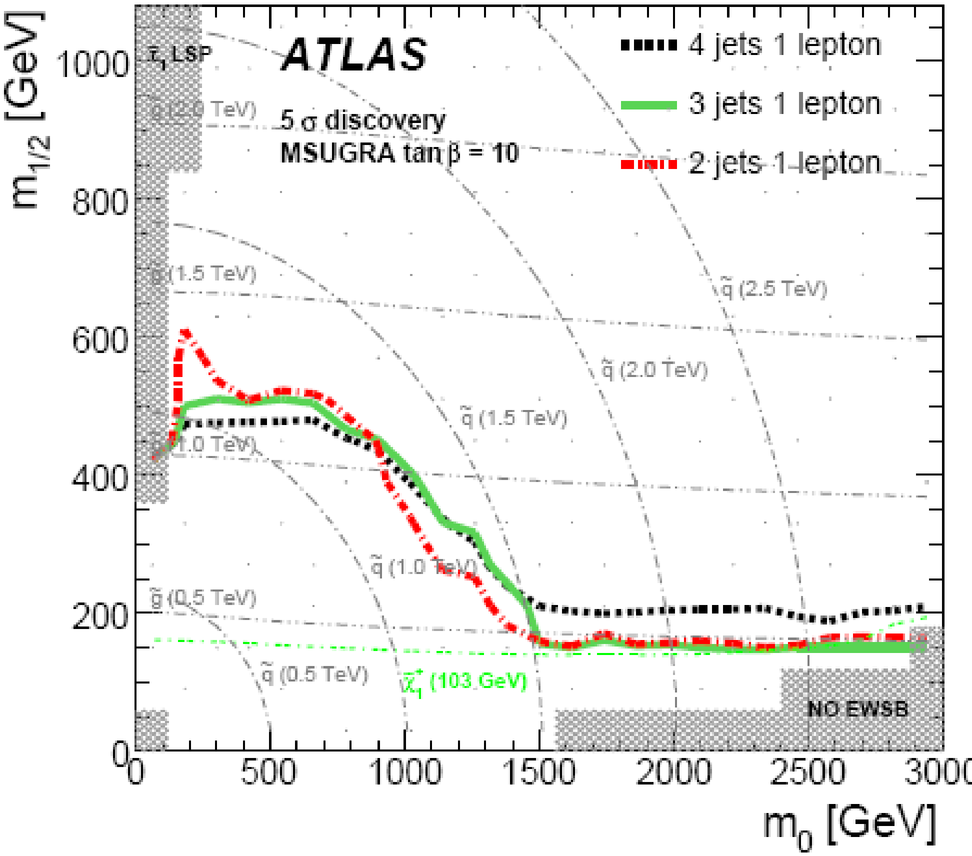




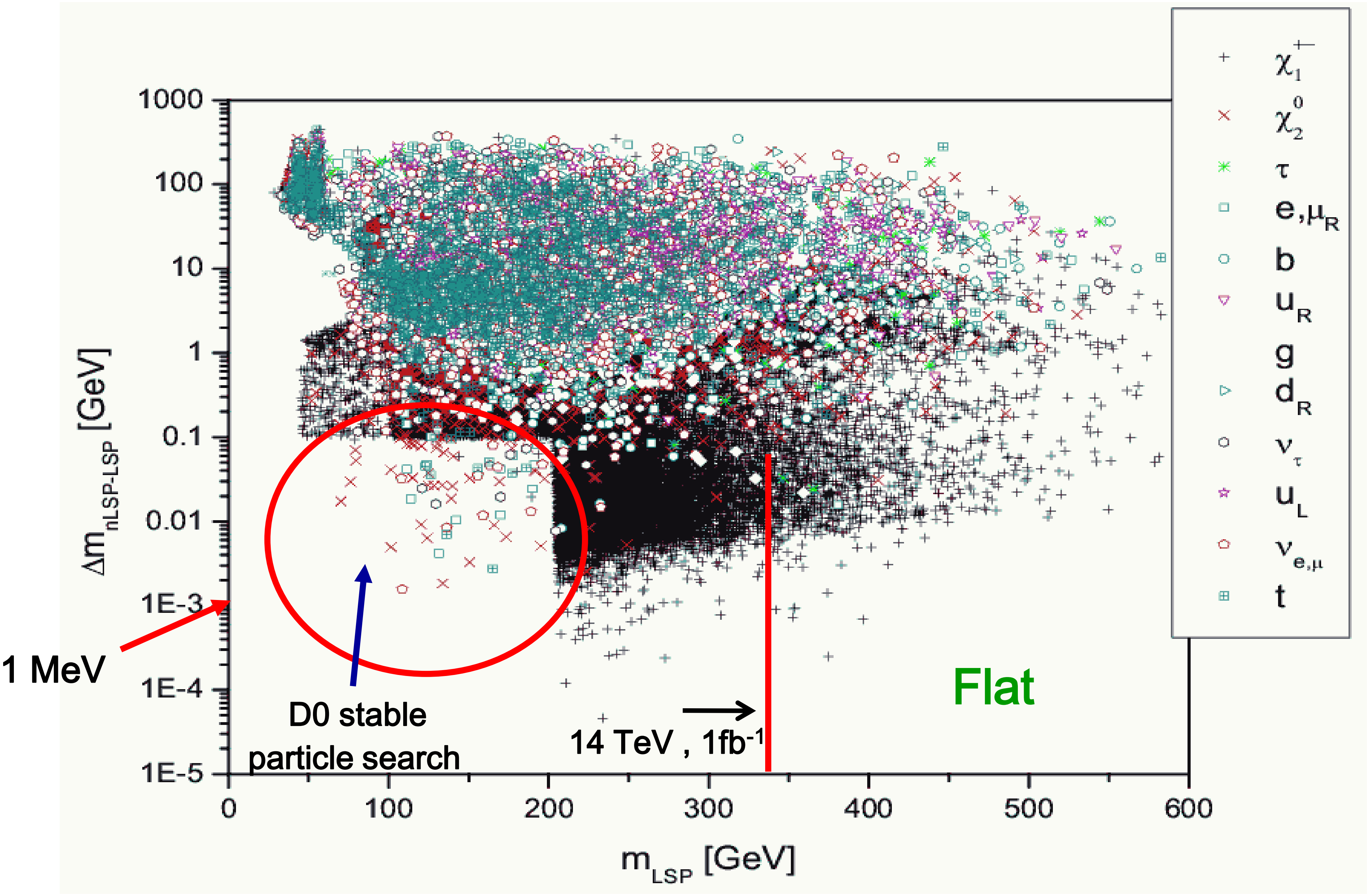
- For us the 4j0l & 2j0l searches give very comparable coverage but not so for the mSUGRA case . Note that <1 TeV gluinos are essentially never missed in mSUGRA

- For mSUGRA comparable reaches are found for (4,3,2)j1l searches..not so for us.





nLSP-LSP Mass Difference

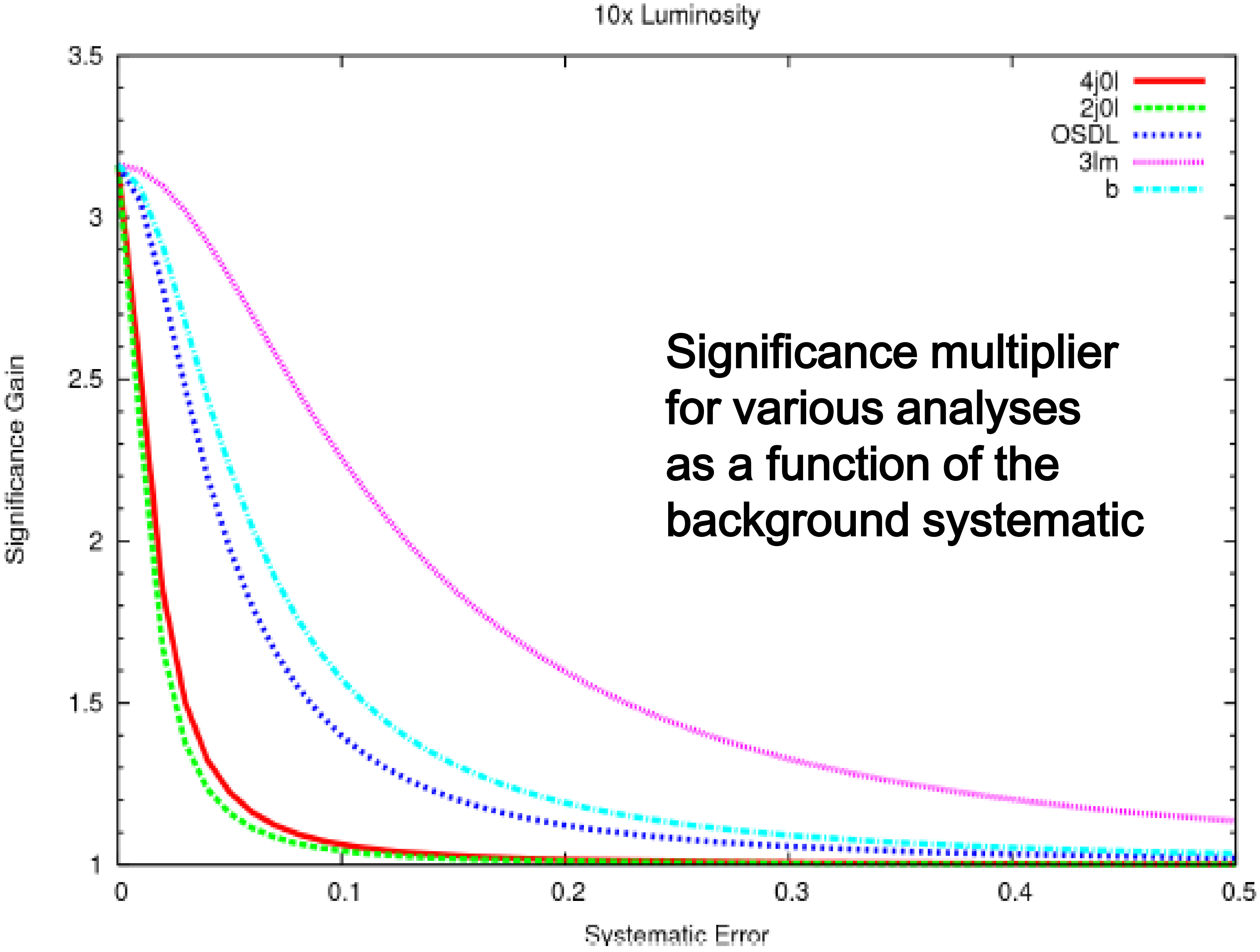


1 MeV

D0 stable particle search

14 TeV , 1fb^{-1}

Flat



Significance multiplier
for various analyses
as a function of the
background systematic