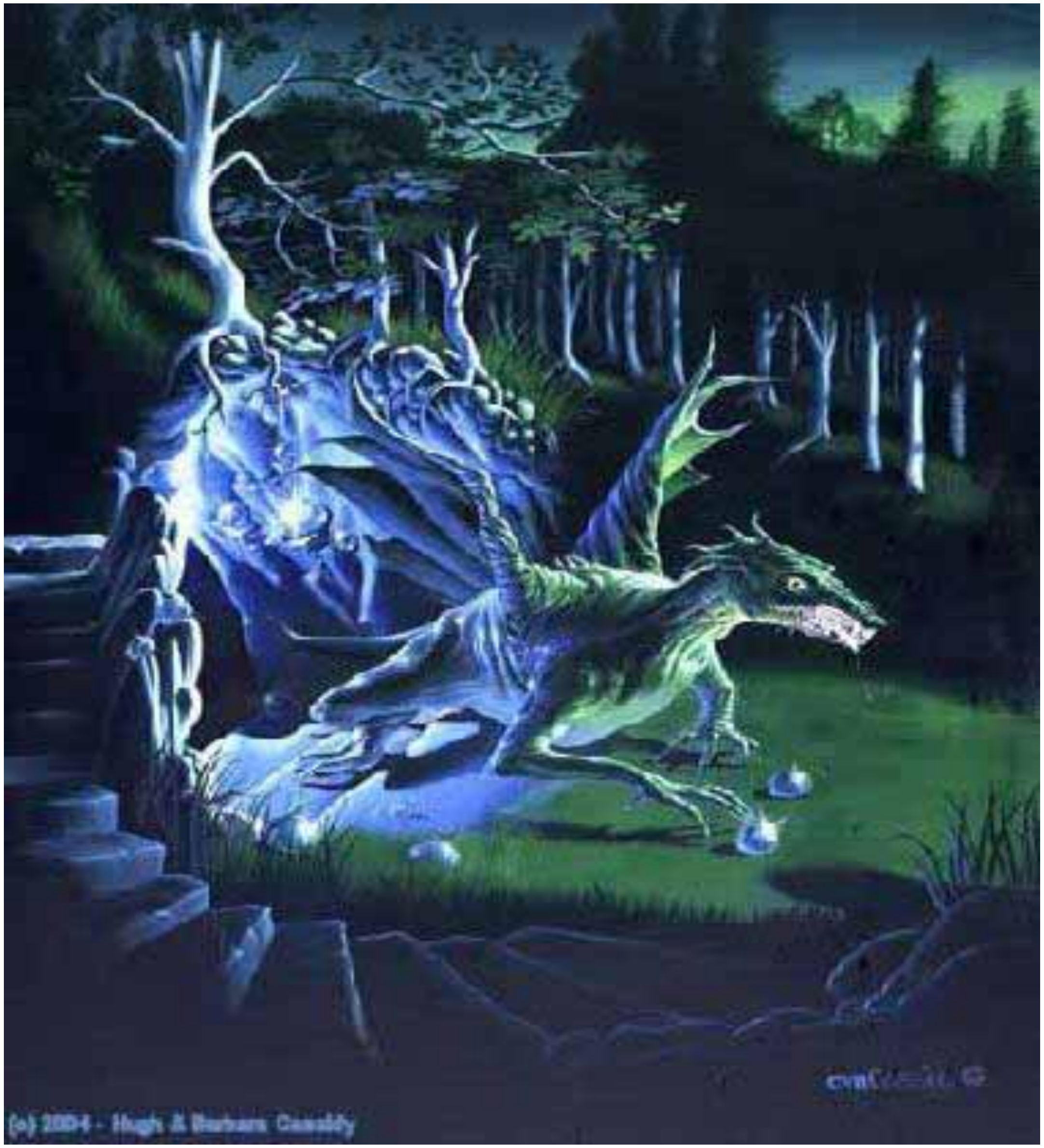
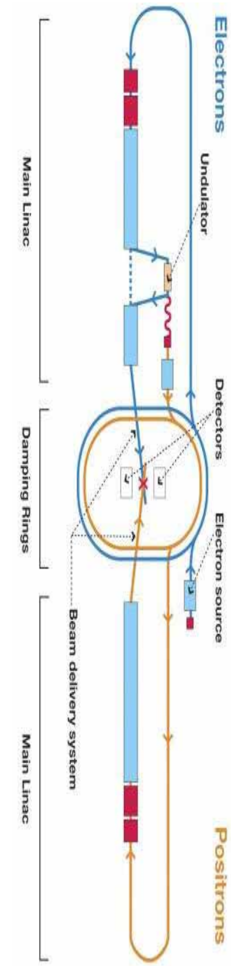
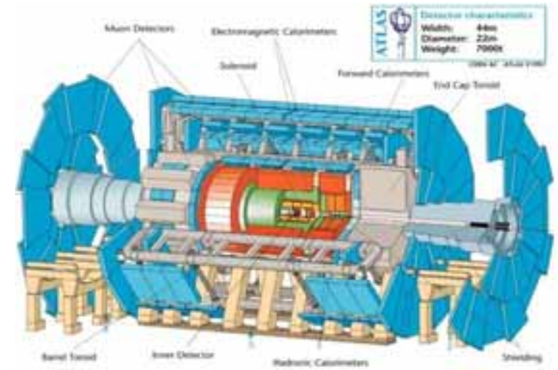
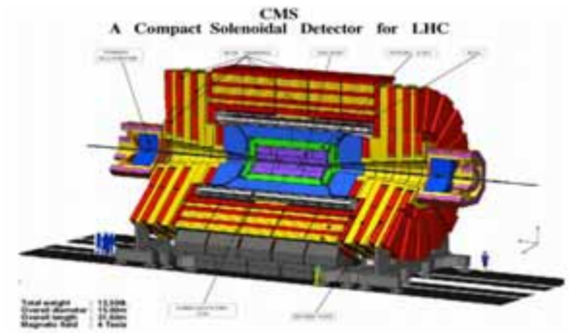
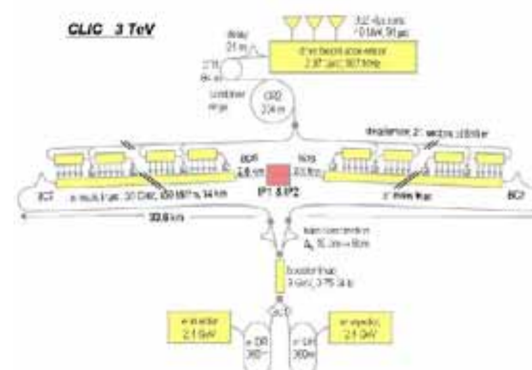
Emerging BSM @ the 7 TeV LHC & the LC









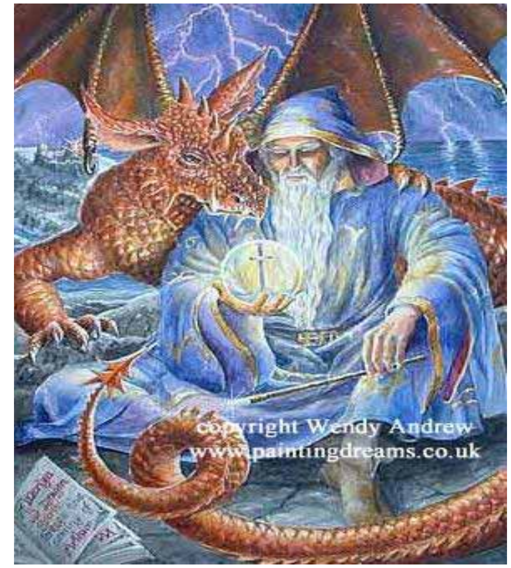


SLAC NATIONAL ACCELERATOR LABORATORY

T.G. Rizzo

03/16/11

THE QUESTIONS:



- How is electroweak symmetry broken?
- How is the hierarchy stabilized?
- What is the origin of flavor ?
- Are there more than 4 dimensions?
- ……

→ We have a lot of questions & we all believe that the LHC will provide at least some partial answers…

BUT WHEN ??

& what will it mean for the LC ?

When we consider LHC implications for the LC there are three different time scales:

(i) The 'classic' case : 14 TeV & 100+ fb^{-1} LHC….>2016??

(ii) The 'near horizon' : 7 TeV & ~5 fb^{-1} LHC…..2012

(iii) → But both ATLAS & CMS are already producing important BSM results right now using the first ~35-42 pb^{-1} of 7 TeV LHC data

(i) Has been discussed for many years & will not be considered here. Instead we will discuss (ii) & perhaps more to the point (iii)

• The role of the LC is to make detailed studies of any objects related to the new physics discovered at the LHC… either through direct production (e.g., Higgs, sleptons, gauginos) or via 'indirect' precision measurements (e.g,. Z' coupling determinations , etc)

• The 'canonical' version is LC500.. but LC1000 (or above) may be necessary to explore the NP found by the LHC .

→ The mass scale of NP is the <u>most critical</u> piece of info that the LHC can provide so that the necessary LC $\sqrt{s}$ can be 'determined' (i.e., <u>physics</u> 'determined' & not by $$)

• There is already some evidence along these lines

• <u>Warning</u>: Everything I say has some caveats !

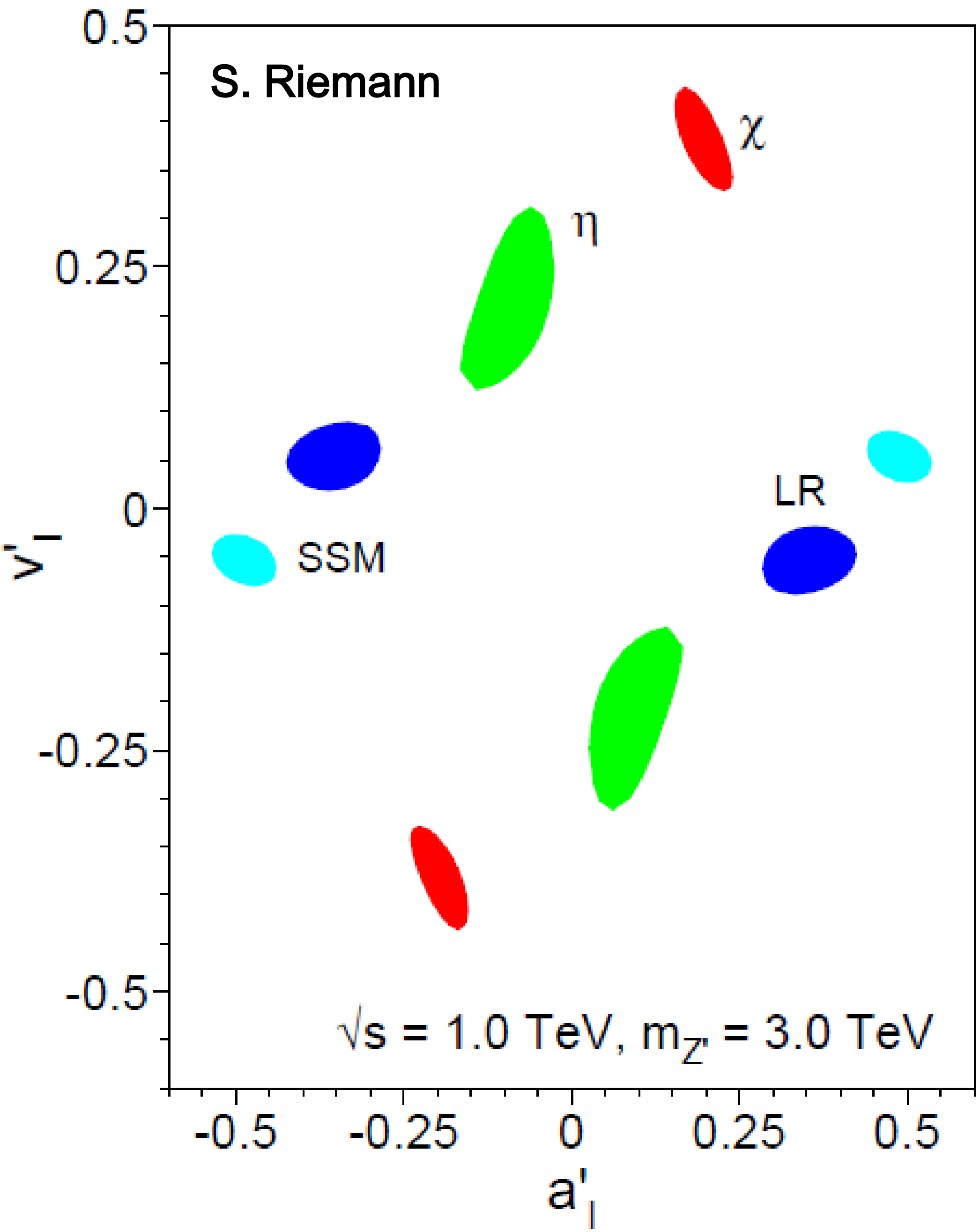
We will consider two traditional examples* :

- Indirect Z' coupling determination via 'contact' interactions
- Gaugino & slepton accessibility for detailed studies

→ These results seem to provide us with some evidence already that going to $\sqrt{s}$ = 1 TeV for the LC may be necessary

* One more will be left to some backup slides

ILC Indirect Z' Coupling Determinations



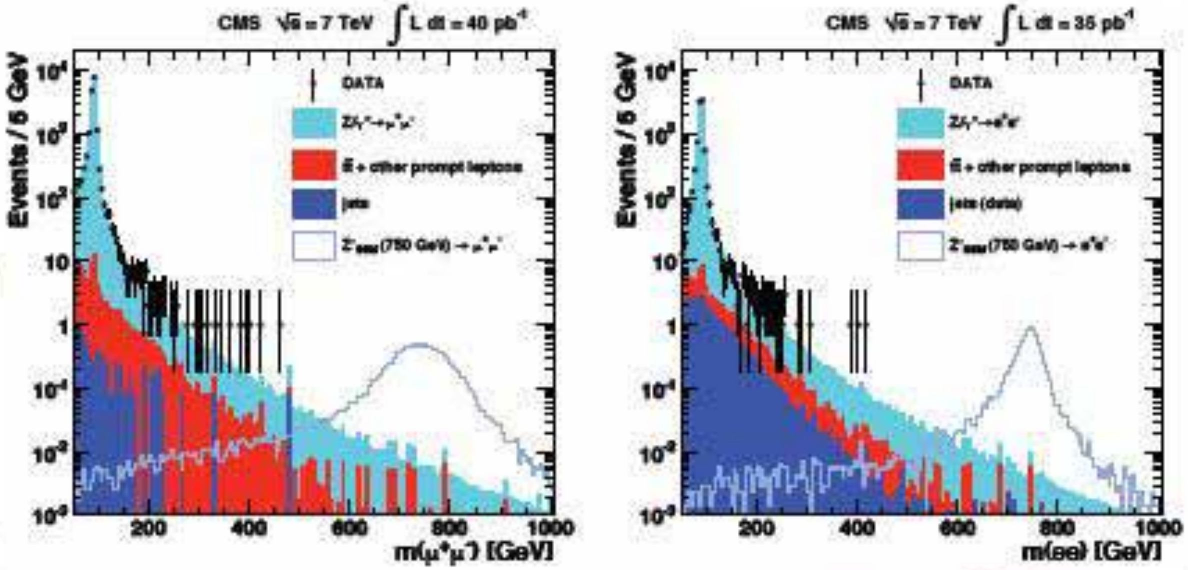
This has been 'bread & butter' LC physics for >2 decades & is quite mature.

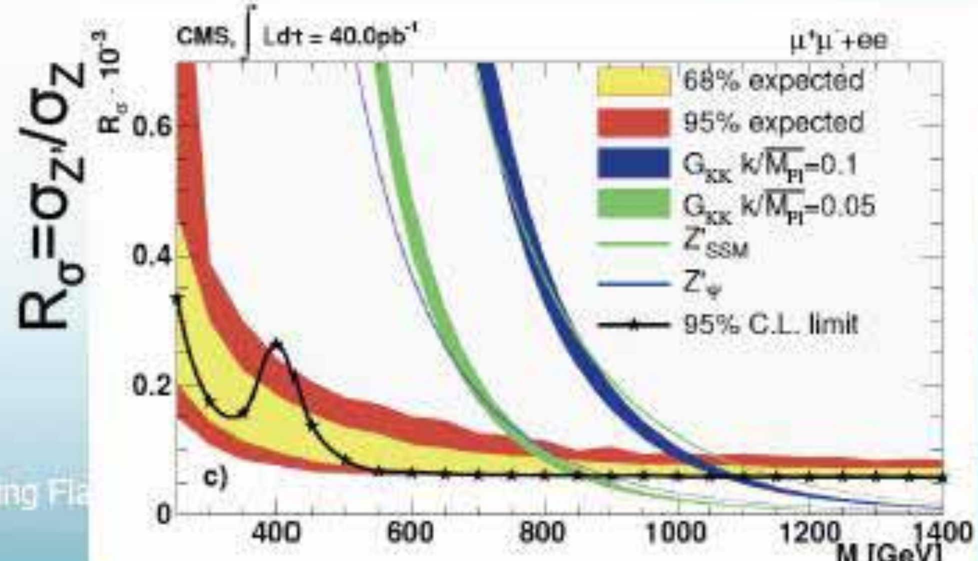
These studies tell us that if $M_{Z'} < 3\text{-}4\sqrt{s}$ & known from the LHC then interesting coupling info can be extracted aiding in Z' identification by detailed cross section and asymmetry measurements using polarized beams

Where are we now?

Z' searches

- Search for resonance in di-lepton mass distribution
  - Identify 2 muons with p_T>20 GeV or 2 electrons with p_T > 25 GeV
  - Dilepton invariant mass spectra consistent with SM expectations
  - No sign of new resonance
  - Z'_{SSM} with Standard-Model-like couplings can be excluded below 1140 GeV
  - Superstring-inspired Z'_ψ excluded below 887 GeV
  - RS Kaluza-Klein gravitons below 855–1079 GeV for couplings of 0.05–0.1
  - (all at 95% C.L.)

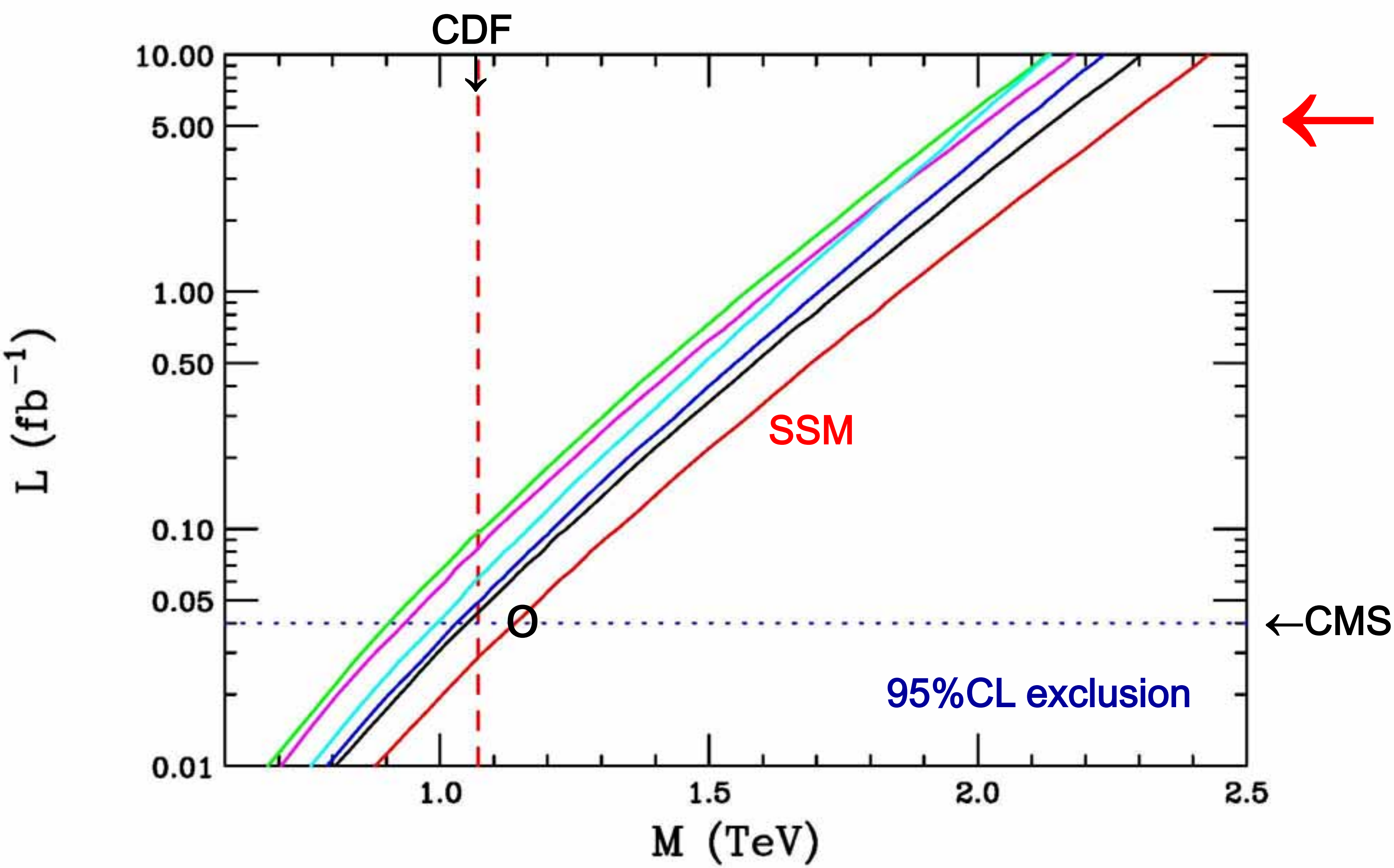




EXO-10-013

3/4/2011

CMS & ATLAS already exceed the Tevatron searches



If no Z' is seen with ~5 fb^{-1} then if one does exist it's too heavy/weakly coupled for LC500. In some models things may already be iffy due to internal relations.

Example

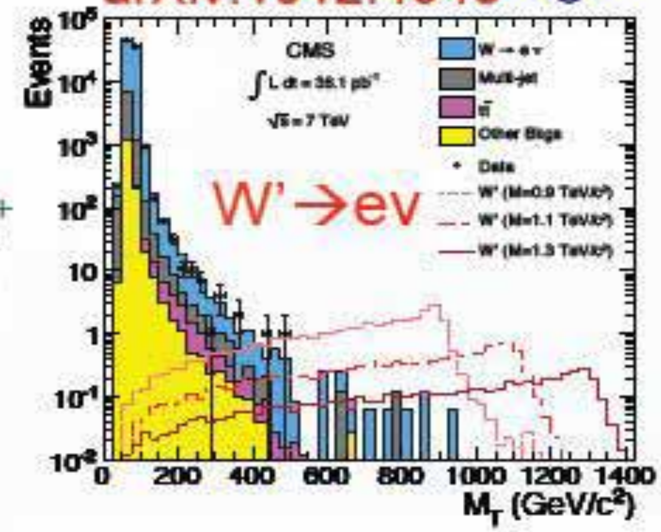
W' searches

arXiv:1012.4945

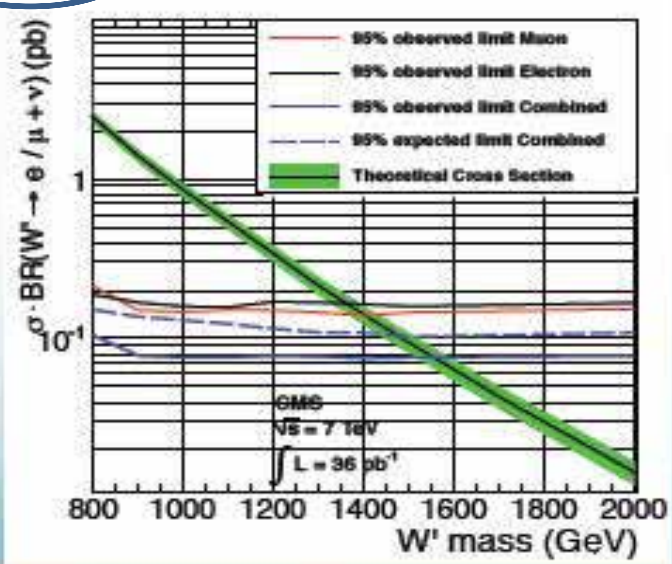
- W' a heavy analogue of SM W with same couplings
- identify high p_T lepton (e or μ), $p_T > 30$ GeV
- Search for peak/enhancement in transverse mass spectrum (e/μ + missing transverse energy)

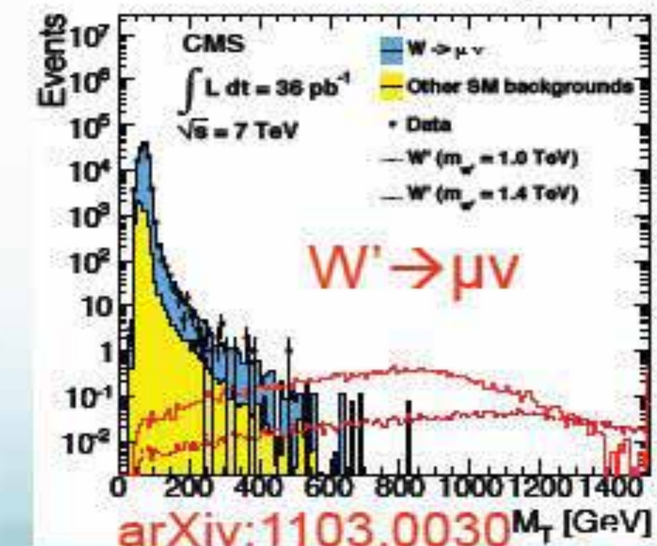
$$M_T = \sqrt{2 \cdot p_T \cdot E_T^{\text{miss}} \cdot (1 - \cos \Delta\phi_{\mu,\nu})}$$

- Data agree with SM expectation
  - from W'→eν channel exclude W' masses below 1.36 TeV
  - from W'→μ ν channel exclude W' masses below 1.40 TeV
- Combination of e and μ channel results in 95% CL exclusion of W' masses below 1.58 TeV



more stringent limit compared D0 & CDF (1.1 TeV)





arXiv:1103.0030

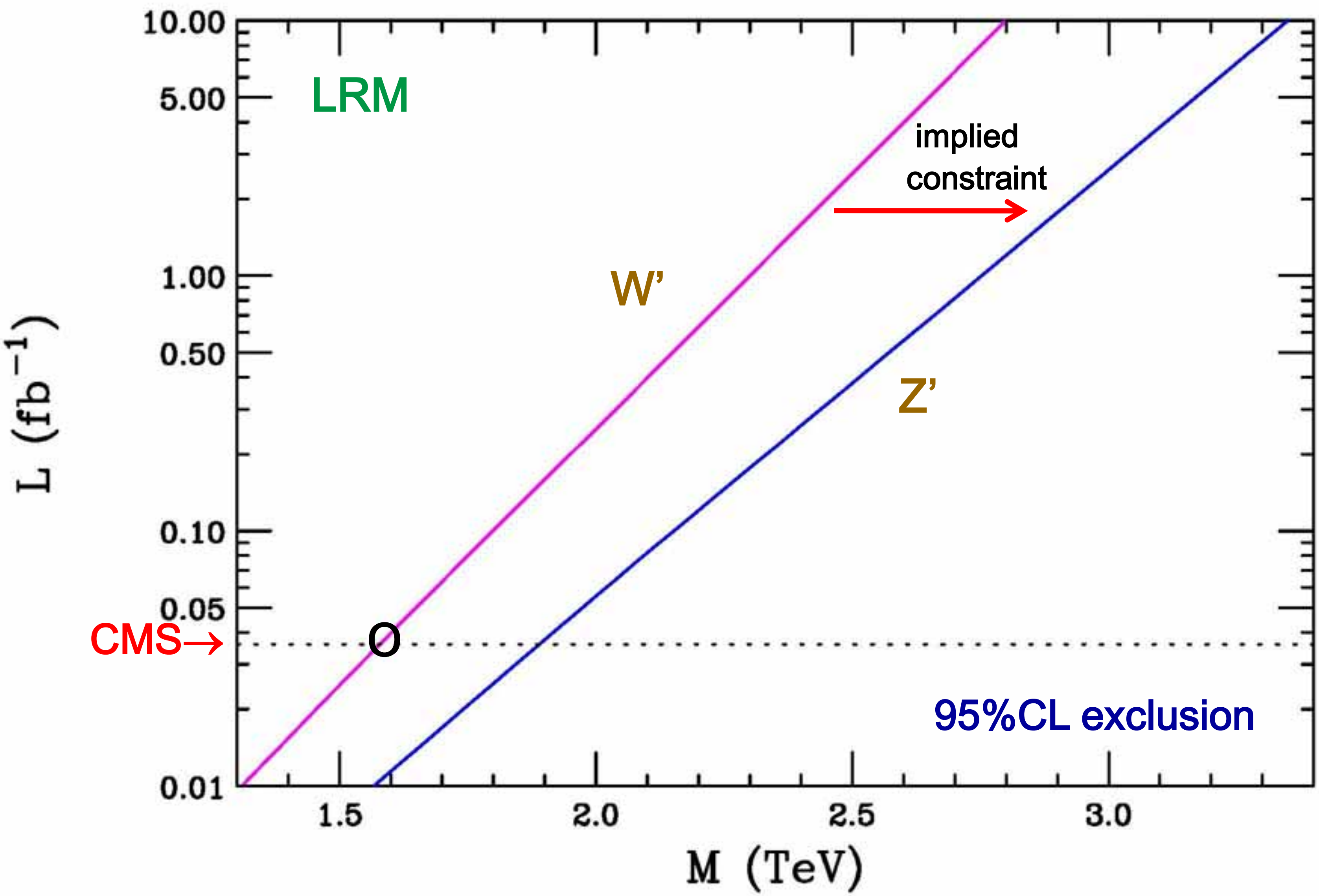
3/4/2011

La Thuile 2011

March 4th, 2011

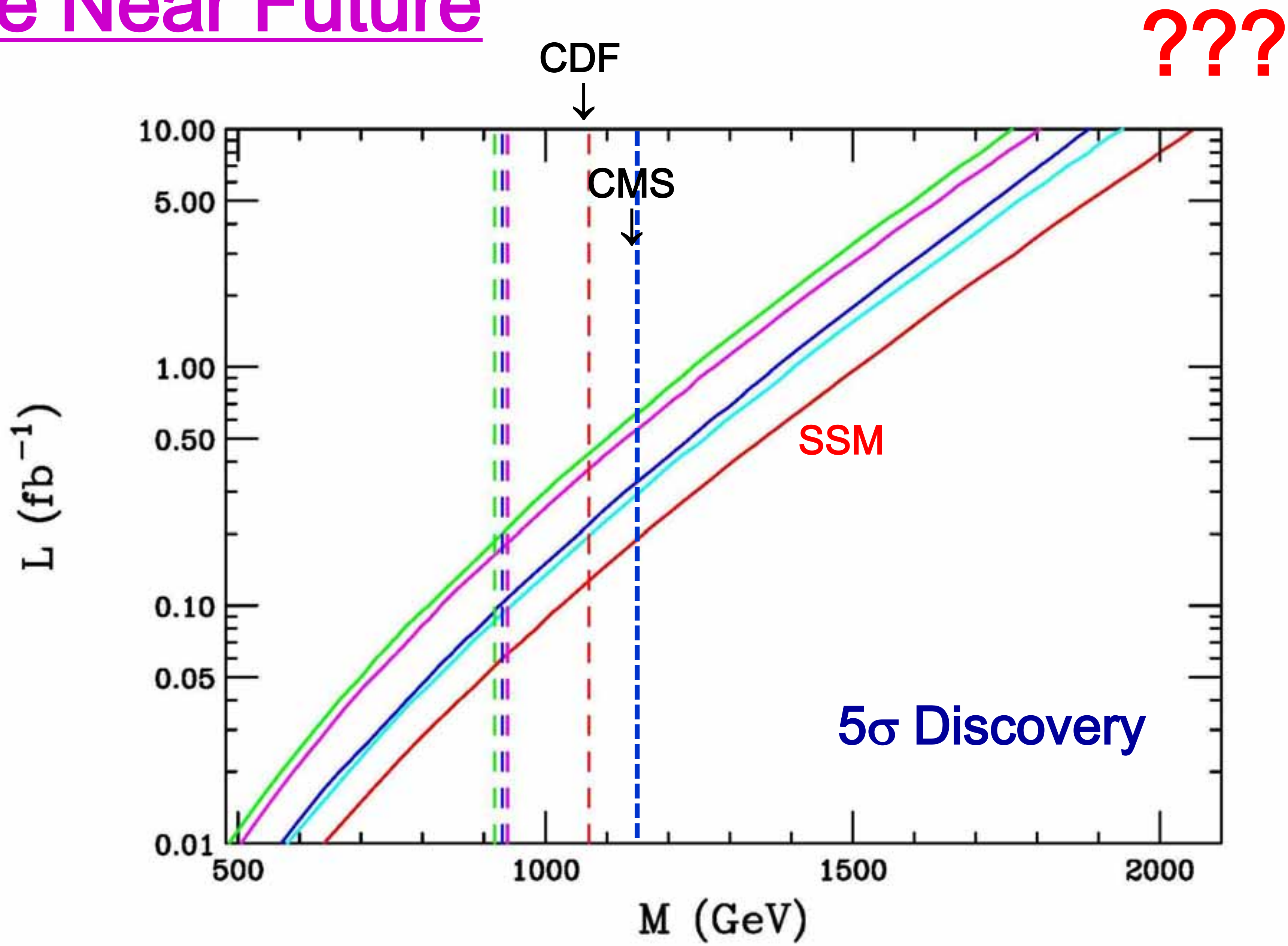
This is the vanilla LRM W'…. The LRM Z' is NOT independent!

The W' and Z' masses are linked in the LRM by SSB so constraining the W' also leads to a bound on Z' :



The vanilla LRM Z' is already >1.89 TeV ~3.8 √s of the LC500 & likely beyond the mass range to be probed there..

The Near Future



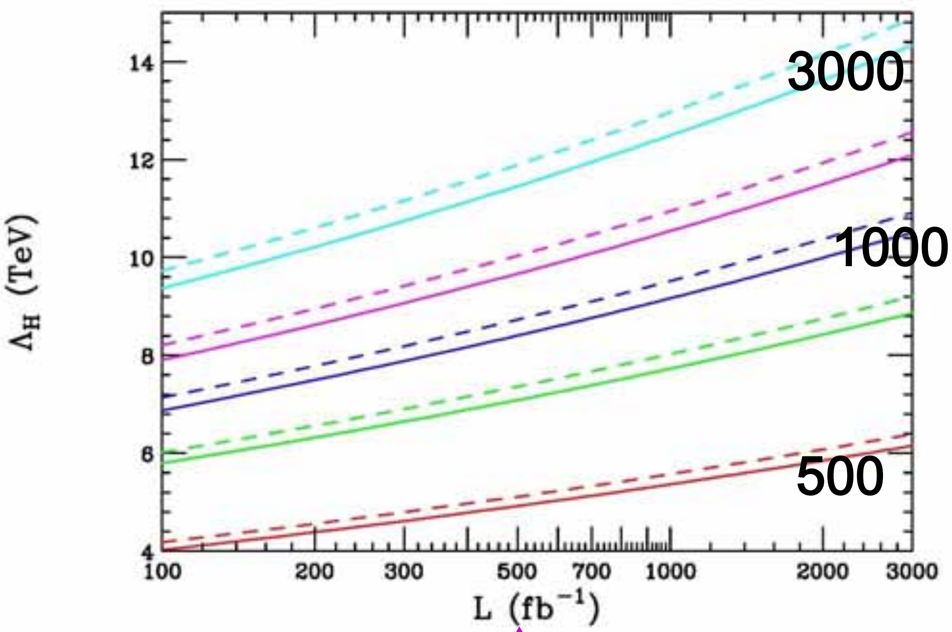
Discovery in the ~1.5-2 TeV range will be possible by the end of 2012

No likely discovery possible above CMS limit until ~200 pb^{-1} is achieved

BTW….ADD visibility at LC500 is almost excluded

Gravity is Universal !

LC Search Reach



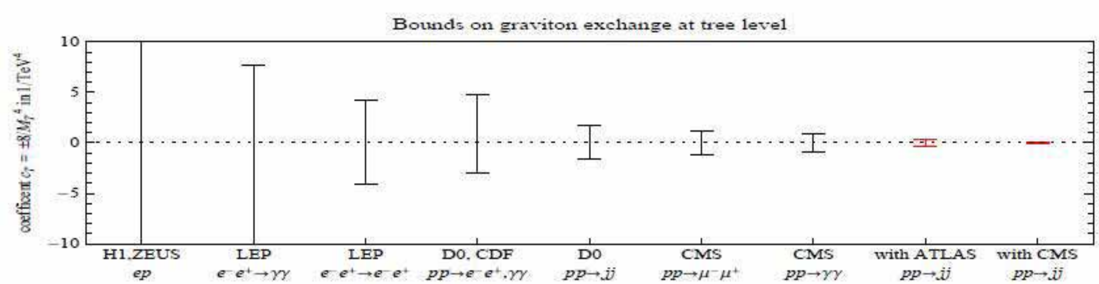
KK graviton exchange is a dim-8 contact int. that can be seen at both LHC & LC.

But the LC500 window is closing…

Bounds on M_T

Experiment	Process	+	−
LEP	$e^+e^- \to \gamma\gamma$	0.93 TeV	1.01 TeV
LEP	$e^+e^- \to e^+e^-$	1.18 TeV	1.17 TeV
CDF	$p\bar{p} \to e^+e^-, \gamma\gamma$	0.99 TeV	0.96 TeV
DØ	$p\bar{p} \to e^+e^-, \gamma\gamma$	1.28 TeV	1.14 TeV
DØ	$p\bar{p} \to jj$	1.48 TeV	1.48 TeV
CMS at 7 TeV with 34/pb	$pp \to \gamma\gamma$	1.72 TeV	1.70 TeV
CMS at 7 TeV with 40/pb	$pp \to \mu^-\mu^+$	1.6 TeV	1.6 TeV
ATLAS at 7 TeV with 3.1/pb	$pp \to jj$	2.2 TeV	2.1 TeV
CMS at 7 TeV with 36/pb	$pp \to jj$	4.2 TeV	3.4 TeV

LHC 95%CL exclusion in dijets is already approaching the LC500 discovery reach !



A.Strumia, Moriond11

→ Typical SUSY studies at the LC usually involve the (precision) determination of slepton and electroweak gaugino masses & couplings

To perform these studies both these types of sparticles must be, at the very least, kinematically accessible at a given $\sqrt{s}$. Let's assume this is a requirement..

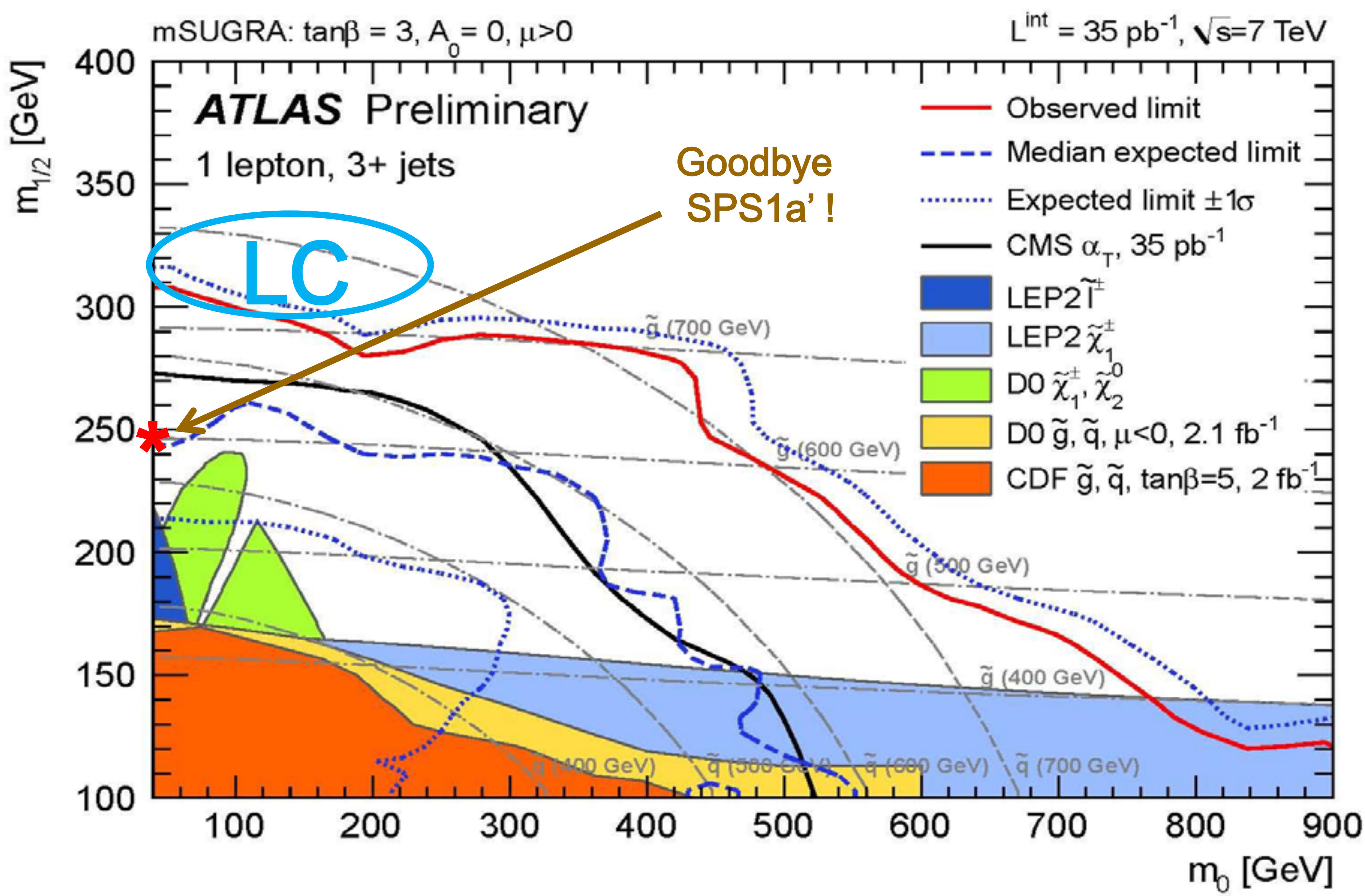
As the LHC lumi is accumulated & if SUSY is not seen life becomes quite tough for LC500 (as well as for some theorists!)

Already life has gotten tough in some scenarios like mSUGRA…

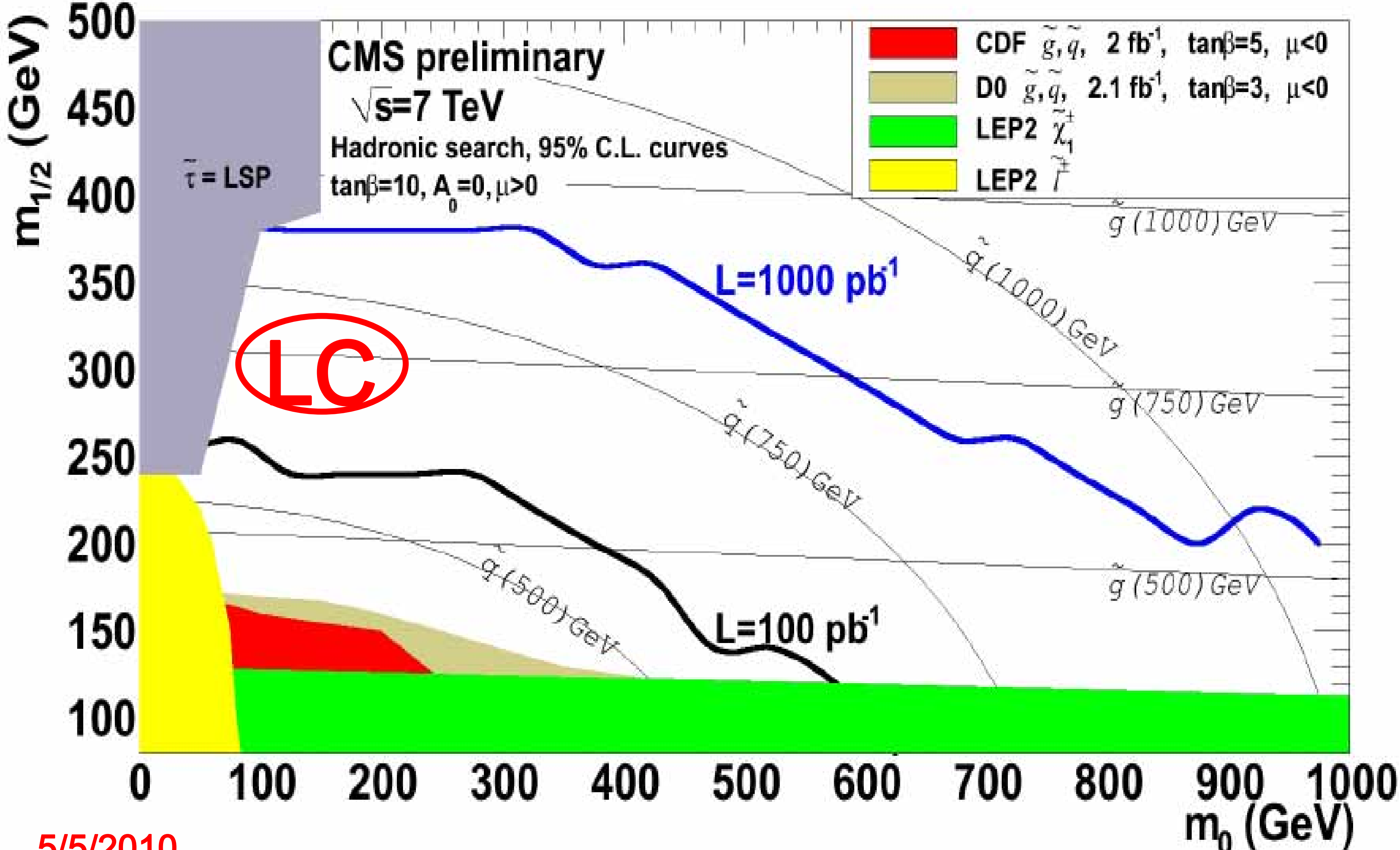
SUSY searches at the LHC have gotten real:

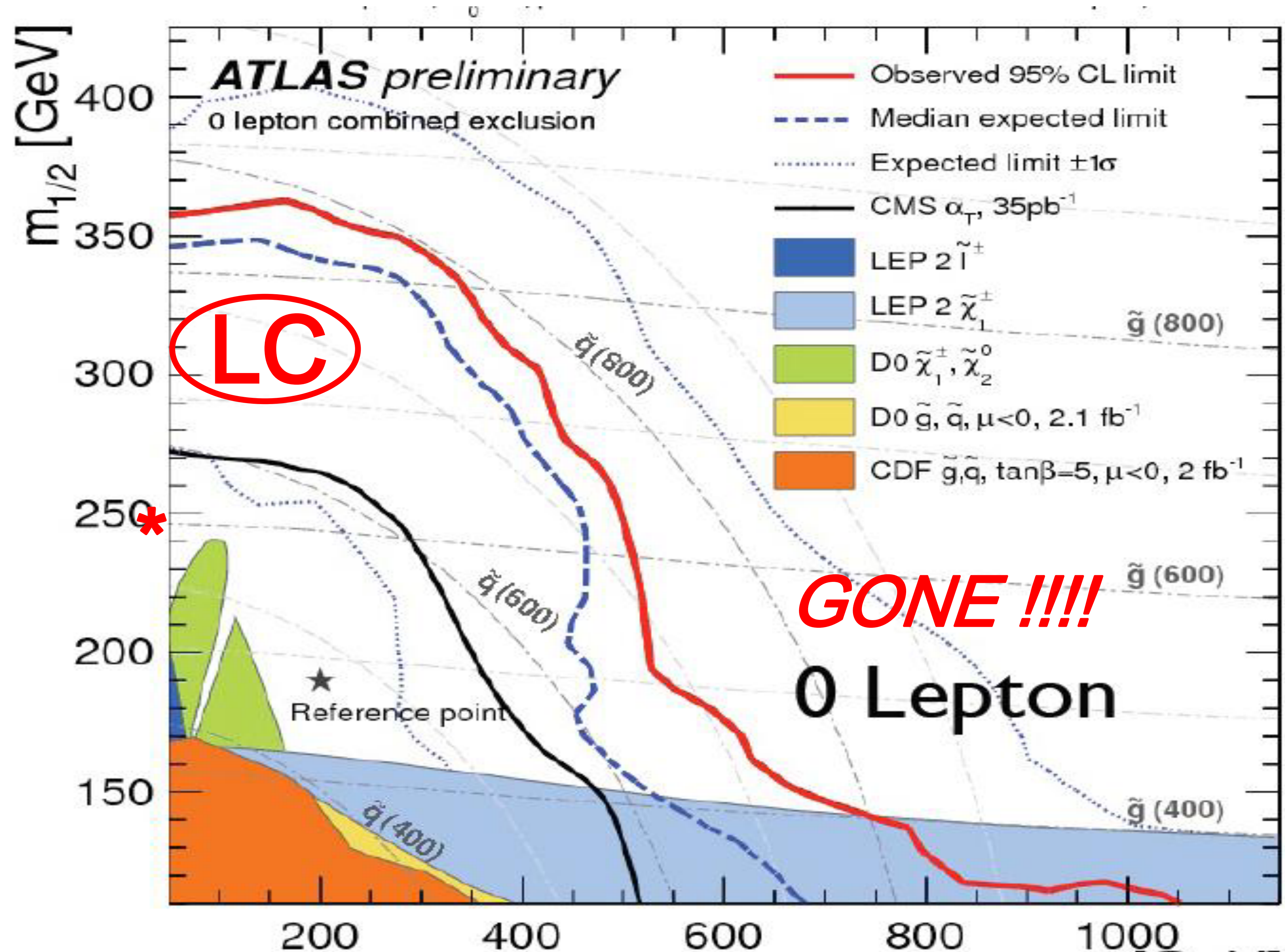
The Amazing Power of √s !

1/27/2011

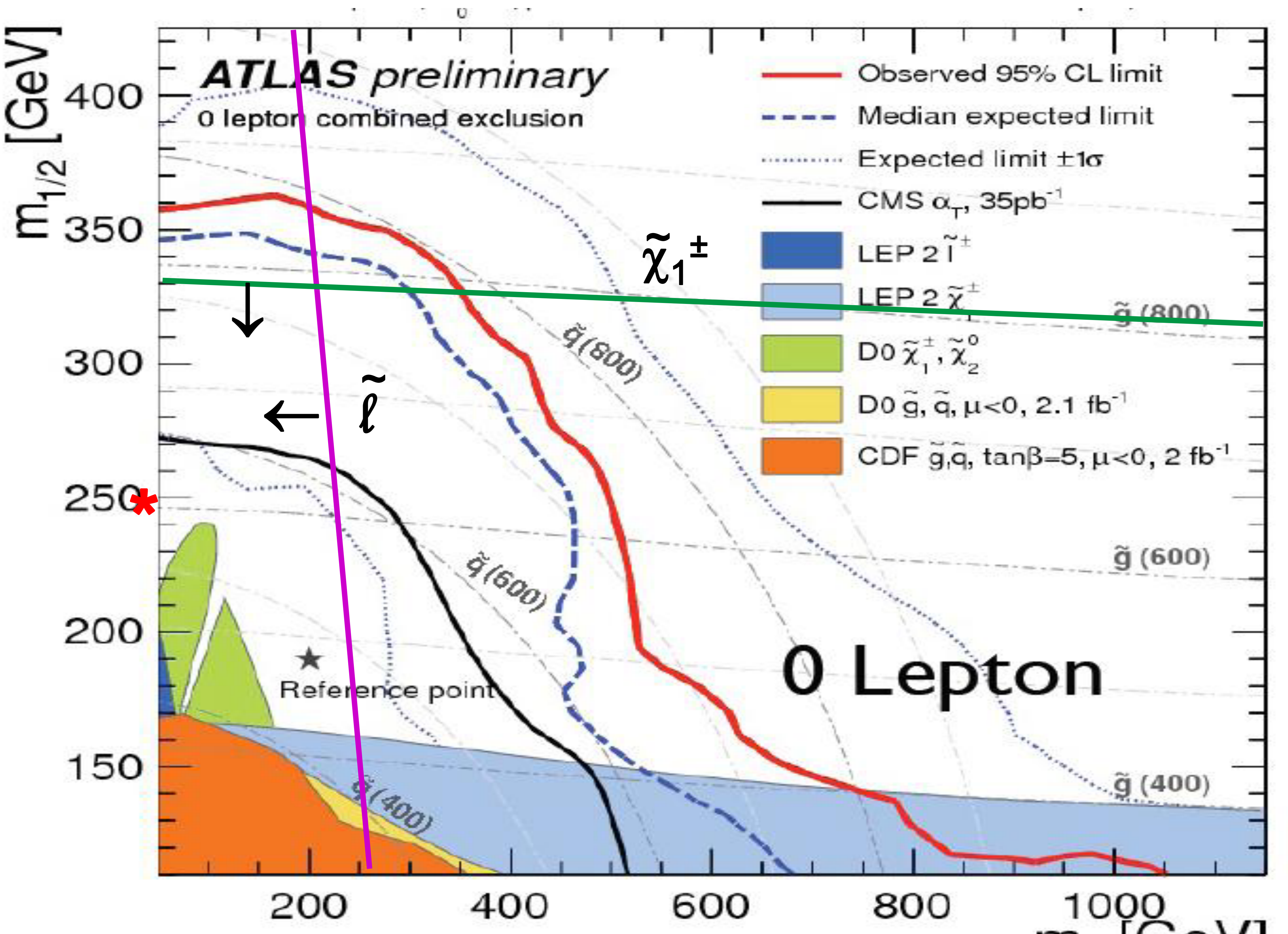


Expectation: If no signal @ 7 TeV w/ 1 fb^{-1}, then a 500 GeV LC is not a good place to study mSUGRA/CMSSM

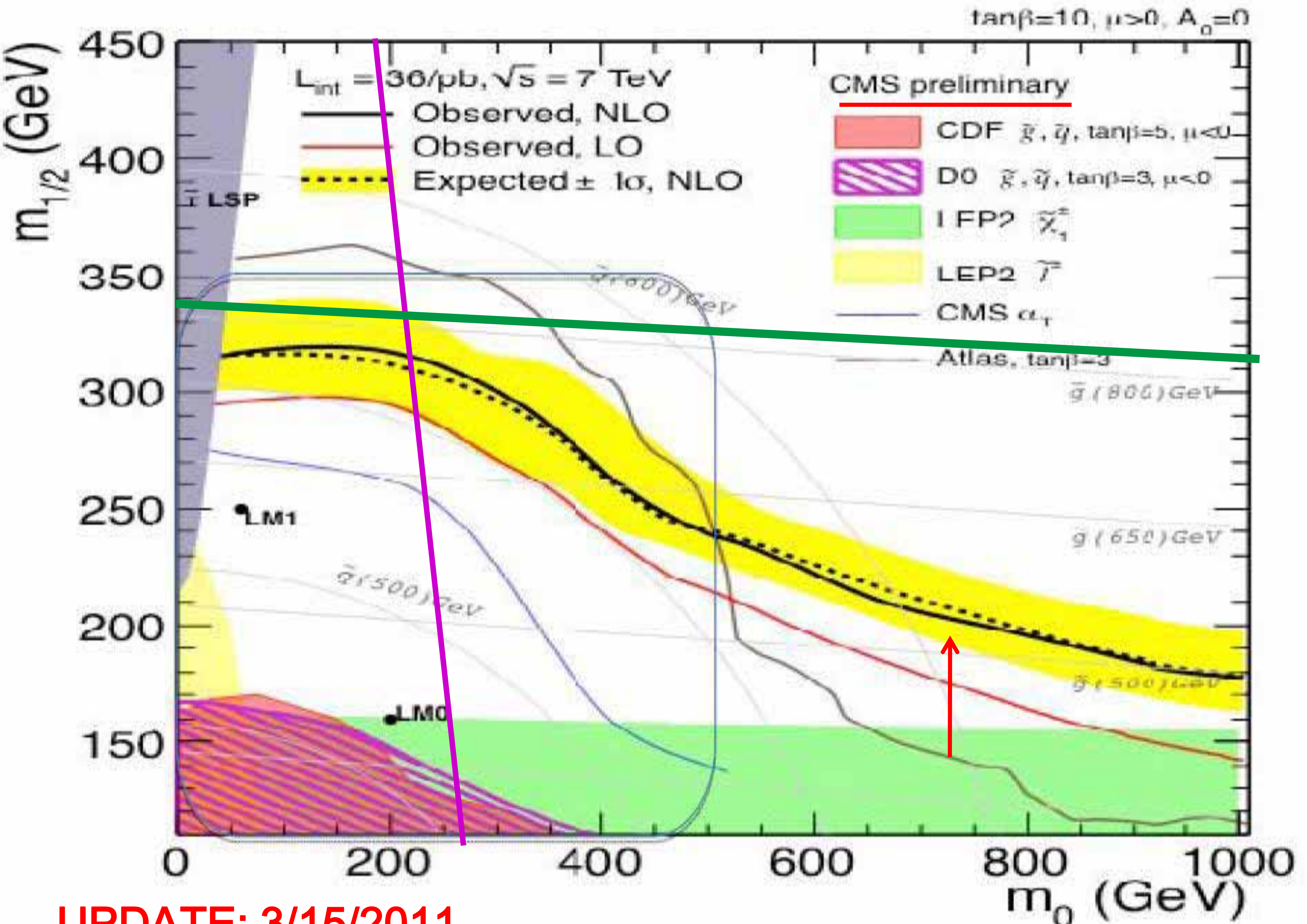




UPDATE: 2/17/2011

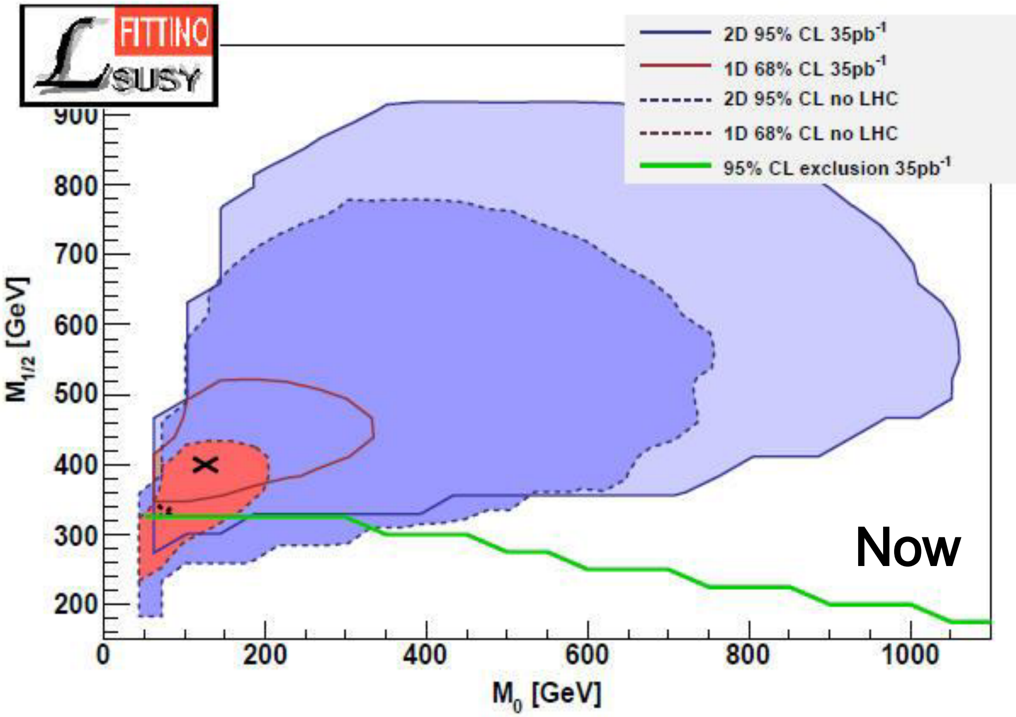


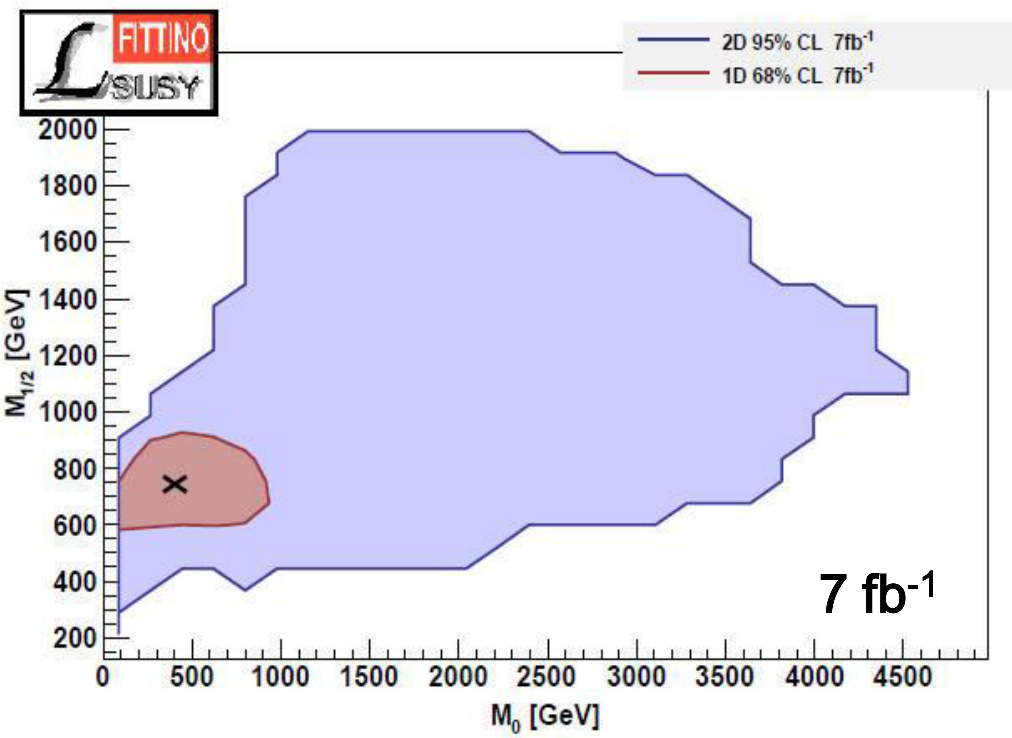
UL region terminated by stau LSP at $m_{1/2}$ ~700 GeV



UPDATE: 3/15/2011

mSUGRA FITS





If no signal is found then the mSUGRA best fits to data will be pushed upwards to higher & higher masses…

They tend to like smaller m_0 values & slide upwards as nothing is seen

P. Bechtle, Moriond11

So for mSUGRA the answer is *in* :

LC500 is NOT a great place to study mSUGRA !!

→ But remember SUSY ≠ mSUGRA !

- So the more important question is: 'Does a more general version of the MSSM allow for SUSY to remain 'accessible' at LC500 if the LHC sees nothing during 2011-12 @ 7 TeV ?'
- We can get a partial answer to this question based on a set of more general pMSSM models that some of us studied in detail for the LHC..but there's still a lot we don't know…

J.A. Conley, J. S. Gainer, J. L. Hewett, M.-P. Le & TGR
arXiv:1009.2539,1103.1697

Issues:

- The general MSSM is too difficult to study due to the large number of soft SUSY breaking parameters (~ 100).
- Analyses are limited to specific SUSY breaking scenarios having only a few parameters…can we be more general ?

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 & have negligible Yukawa's.
- No assumptions about SUSY-breaking or unification

This leaves us with the pMSSM:

→ the MSSM with 19 real, TeV-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, $\tan\beta$

How? Perform 2 Random Scans

Flat Priors

emphasizes moderate masses

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

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

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

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

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

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

Log Priors

emphasizes lower masses but also extends to higher masses

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

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

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

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

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

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

- Flat Priors : 10^7 models scanned , 68422 survive
- Log Priors : 2×10^6 models scanned , 2908 survive

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

Some Constraints

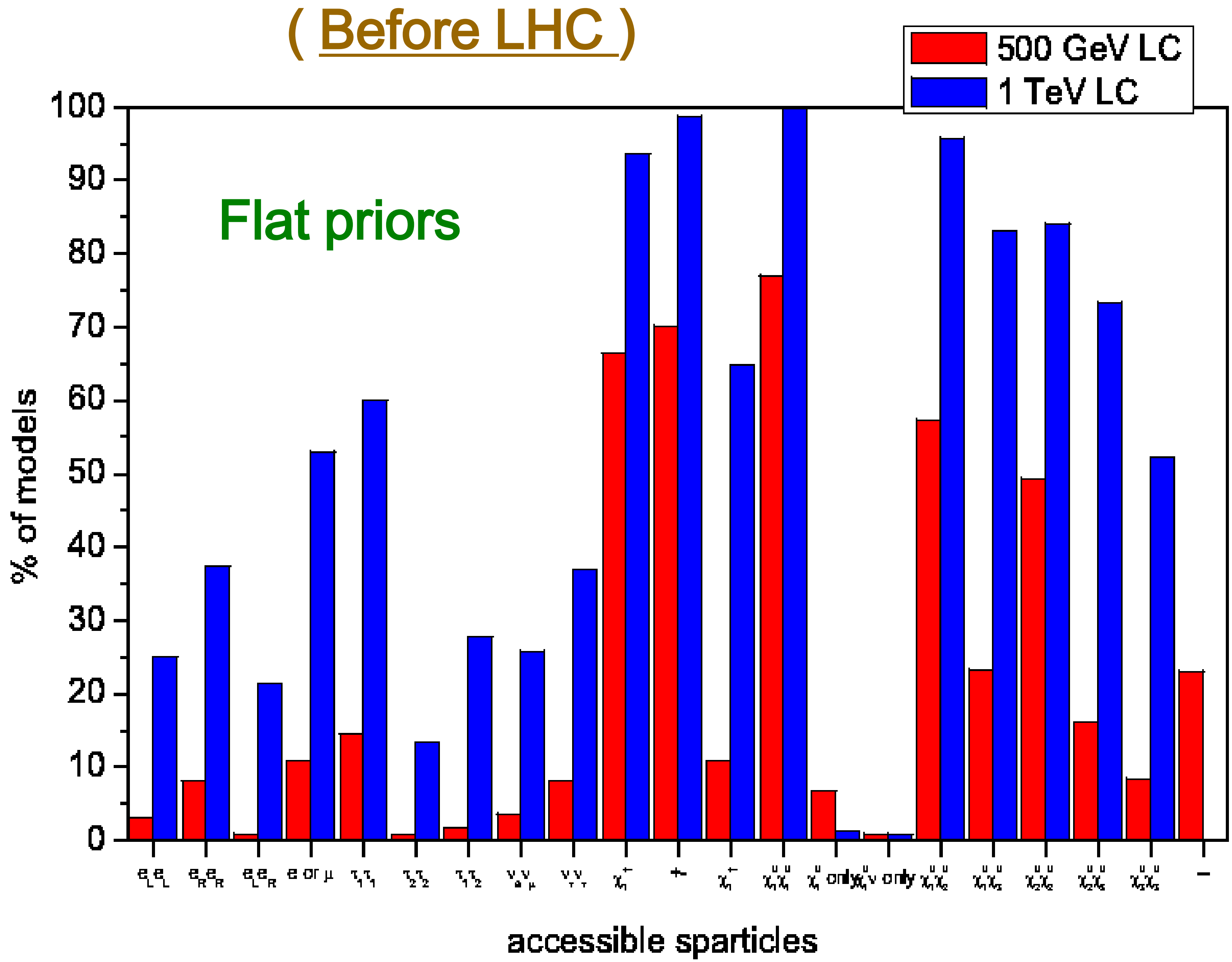
- W/Z ratio $\quad b \to s\,\gamma$
- $\Delta(g\text{-}2)_\mu$ $\quad \Gamma(Z \to \text{invisible})$
- Meson-Antimeson Mixing
- $B_s \to \mu\mu$ $\quad B \to \tau\nu$

- DM density: $\Omega h^2 < 0.121$. We treat this only as an *upper bound* on the neutralino thermal relic contribution

- Direct Detection Searches for DM (CDMS, XENON…)

- 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 → simulations limit model set size ~1 core-century for set generation

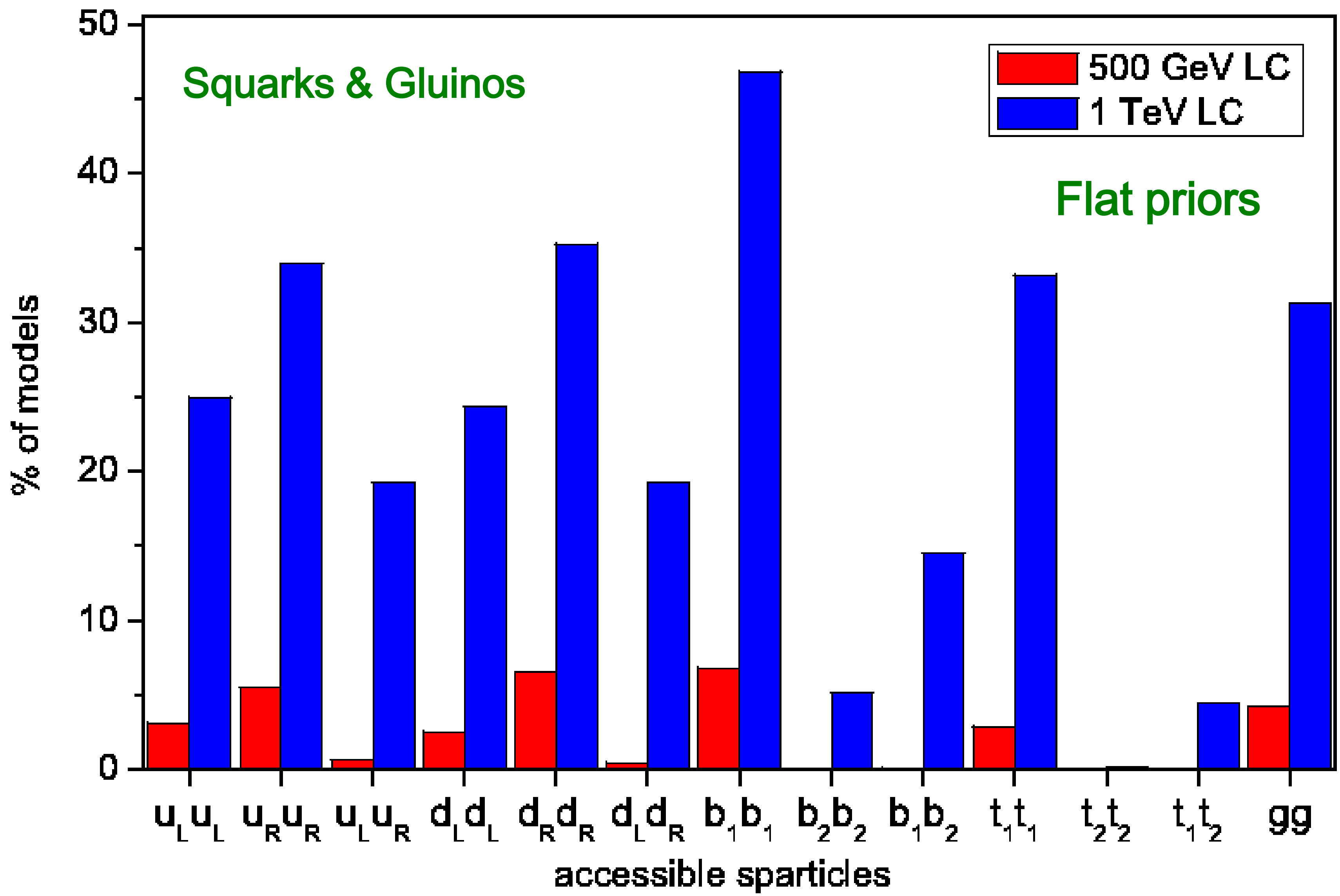
Model Set Kinematic Accessibility at the ILC : I



Final State
$\tilde{e}_L^+\tilde{e}_L^-$
$\tilde{e}_R^+\tilde{e}_R^-$
$\tilde{e}_L^\pm\tilde{e}_R^\mp$
$\tilde{\mu}_L^+\tilde{\mu}_L^-$
$\tilde{\mu}_R^+\tilde{\mu}_R^-$
Any selectron or smuon
$\tilde{\tau}_1^+\tilde{\tau}_1^-$
$\tilde{\tau}_2^+\tilde{\tau}_2^-$
$\tilde{\tau}_1^\pm\tilde{\tau}_2^\mp$
$\tilde{\nu}_{e\mu}\tilde{\nu}_{e\mu}^*$
$\tilde{\nu}_\tau\tilde{\nu}_\tau^*$
$\tilde{\chi}_1^+\tilde{\chi}_1^-$
Any charged sparticle
$\tilde{\chi}_1^\pm\tilde{\chi}_2^\mp$
$\tilde{\chi}_1^0\tilde{\chi}_1^0$
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ only
$\tilde{\chi}_1^0 + \tilde{\nu}$ only
$\tilde{\chi}_1^0\tilde{\chi}_2^0$
$\tilde{\chi}_1^0\tilde{\chi}_3^0$
$\tilde{\chi}_2^0\tilde{\chi}_2^0$
$\tilde{\chi}_2^0\tilde{\chi}_3^0$
$\tilde{\chi}_3^0\tilde{\chi}_3^0$
Nothing

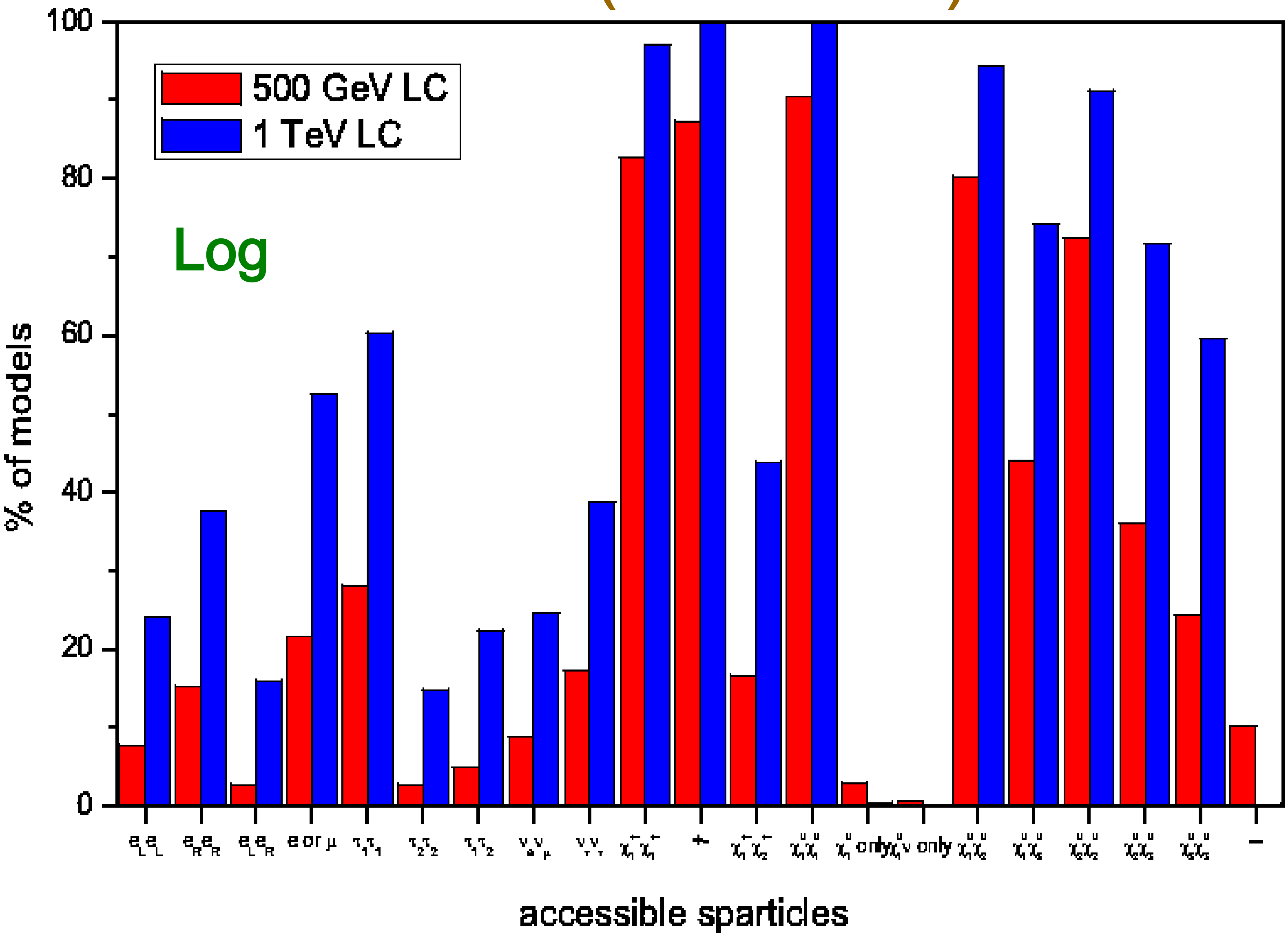
Model Set Kinematic Accessibility at the ILC : II

(Before LHC)



Model Set Kinematic Accessibility at the ILC : III

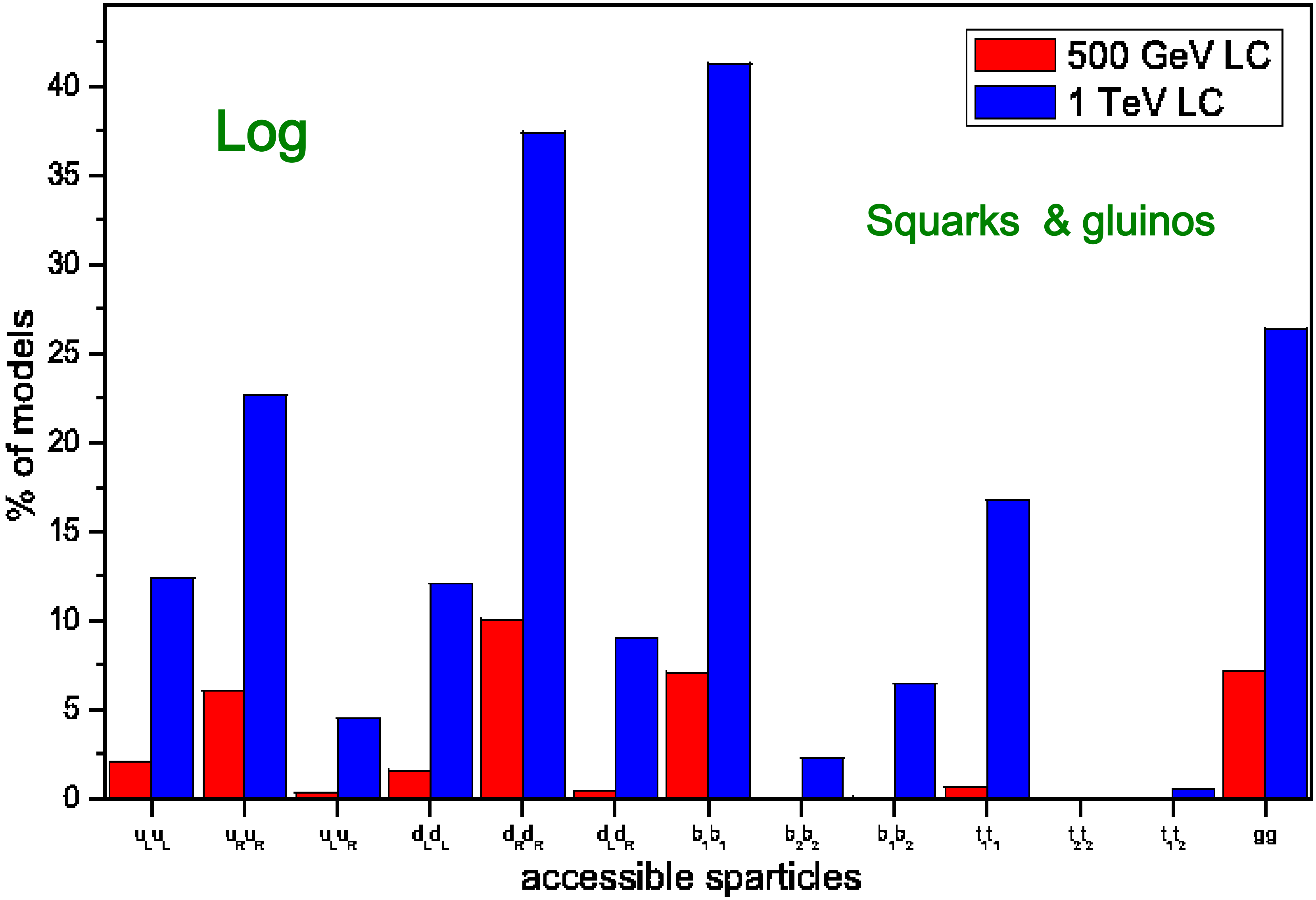
(Before LHC)



Final State
$\tilde{e}_L^+\tilde{e}_L^-$
$\tilde{e}_R^+\tilde{e}_R^-$
$\tilde{e}_L^\pm\tilde{e}_R^\mp$
$\tilde{\mu}_L^+\tilde{\mu}_L^-$
$\tilde{\mu}_R^+\tilde{\mu}_R^-$
Any selectron or smuon
$\tilde{\tau}_1^+\tilde{\tau}_1^-$
$\tilde{\tau}_2^+\tilde{\tau}_2^-$
$\tilde{\tau}_1^\pm\tilde{\tau}_2^\mp$
$\tilde{\nu}_{e\mu}\tilde{\nu}_{e\mu}^*$
$\tilde{\nu}_\tau\tilde{\nu}_\tau^*$
$\tilde{\chi}_1^+\tilde{\chi}_1^-$
Any charged sparticle
$\tilde{\chi}_1^\pm\tilde{\chi}_2^\mp$
$\tilde{\chi}_1^0\tilde{\chi}_1^0$
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ only
$\tilde{\chi}_1^0+\tilde{\nu}$ only
$\tilde{\chi}_1^0\tilde{\chi}_2^0$
$\tilde{\chi}_1^0\tilde{\chi}_3^0$
$\tilde{\chi}_2^0\tilde{\chi}_2^0$
$\tilde{\chi}_2^0\tilde{\chi}_3^0$
$\tilde{\chi}_3^0\tilde{\chi}_3^0$
Nothing

Model Set Kinematic Accessibility at the ILC : IV

(Before LHC)



ATLAS SUSY Analyses w/ a Large Model Set

- We passed these points through the ATLAS inclusive MET analyses (@ both 7 &14TeV !), designed for mSUGRA , to explore this broader class of models (~150 core-yrs)

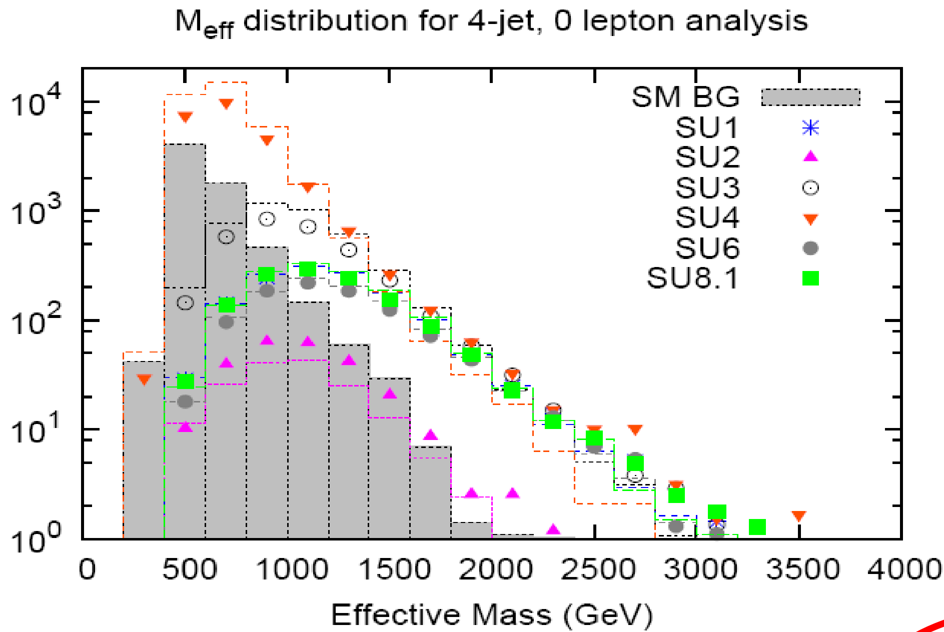
- We used the ATLAS SM backgrounds with their associated systematic errors, search analyses/cuts & criterion for SUSY discovery.

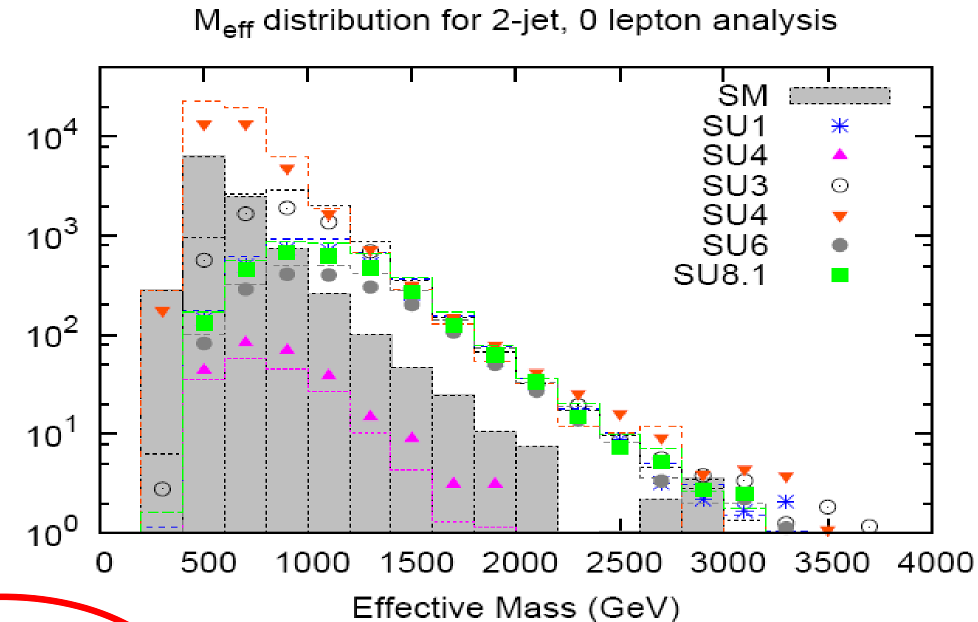
- We verified that we can approximately reproduce the 7 & 14 TeV ATLAS results for their benchmark mSUGRA models with our analysis techniques for each channel. ..BUT beware of some analysis differences:

ATLAS	US
ISASUGRA generates spectrum & sparticle decays	SuSpect generates spectra with SUSY-HIT# for decays
Partial NLO cross sections using PROSPINO & CTEQ6M	NLO cross section for all 85 processes using PROSPINO** & CTEQ6.6M
Herwig for fragmentation & hadronization	PYTHIA for fragmentation & hadronization
GEANT4 for full detector sim	PGS4-ATLAS for fast detector simulation

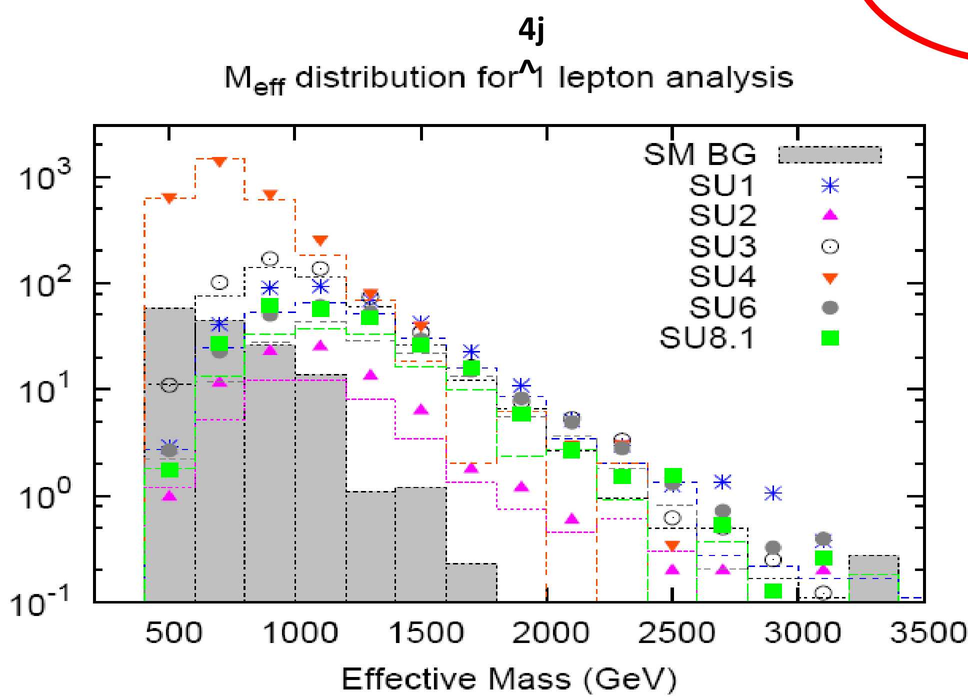
** version w/ negative K-factor errors corrected

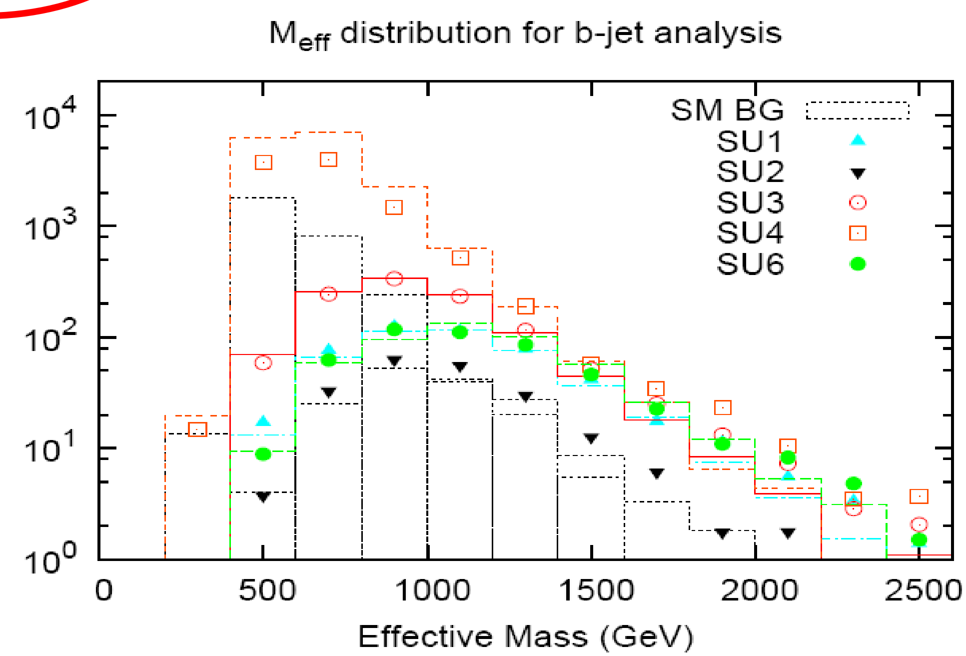
version w/o negative QCD corrections, with 1st & 2nd generation fermion masses & other very numerous PS fixes included. e.g., explicit small Δm chargino decays, etc.

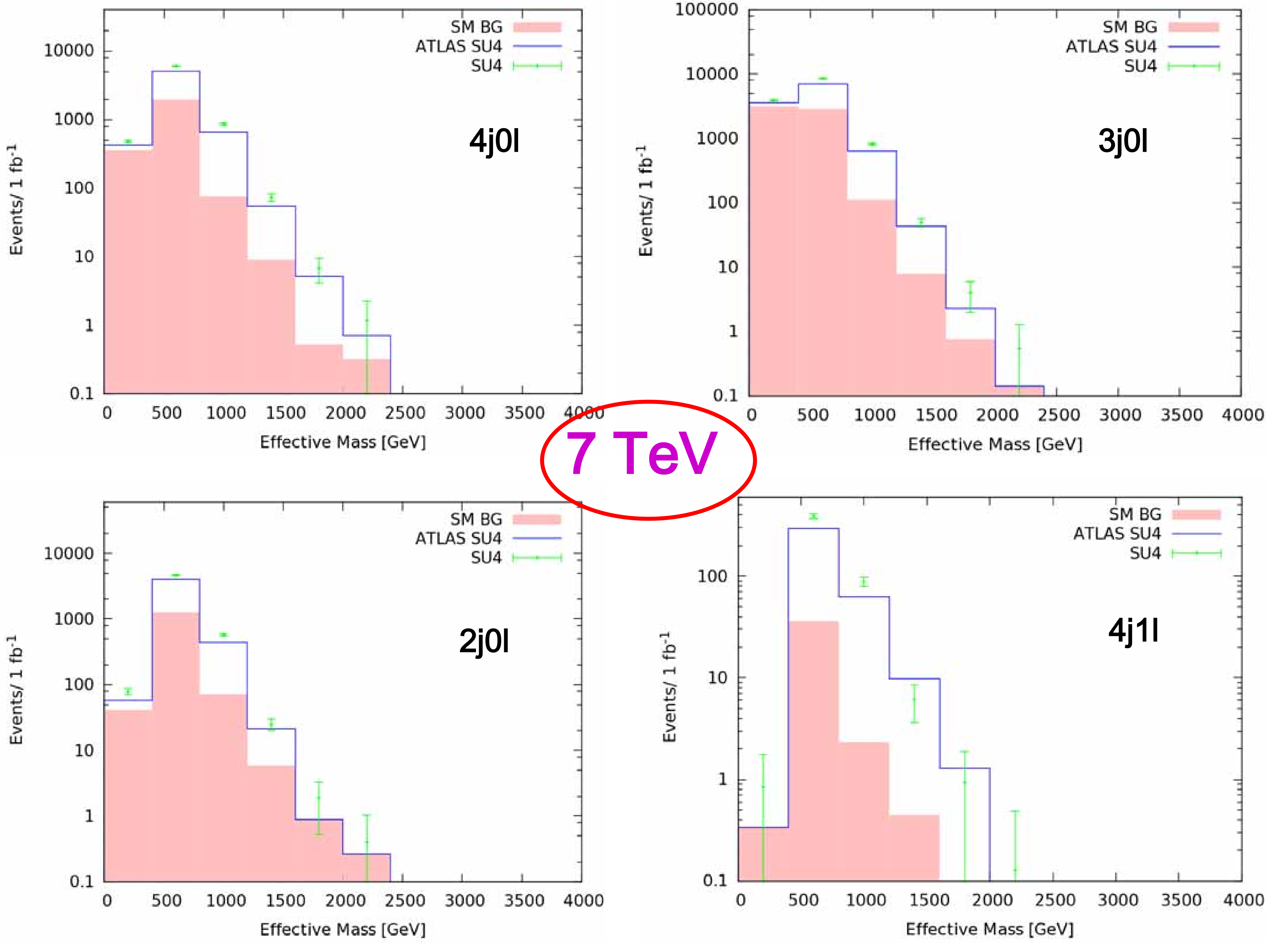

M_eff distribution for 4-jet, 0 lepton analysis
SM BG
SU1
SU2
SU3
SU4
SU6
SU8.1
Effective Mass (GeV)


M_eff distribution for 2-jet, 0 lepton analysis
SM
SU1
SU4
SU3
SU4
SU6
SU8.1
Effective Mass (GeV)

14 TeV

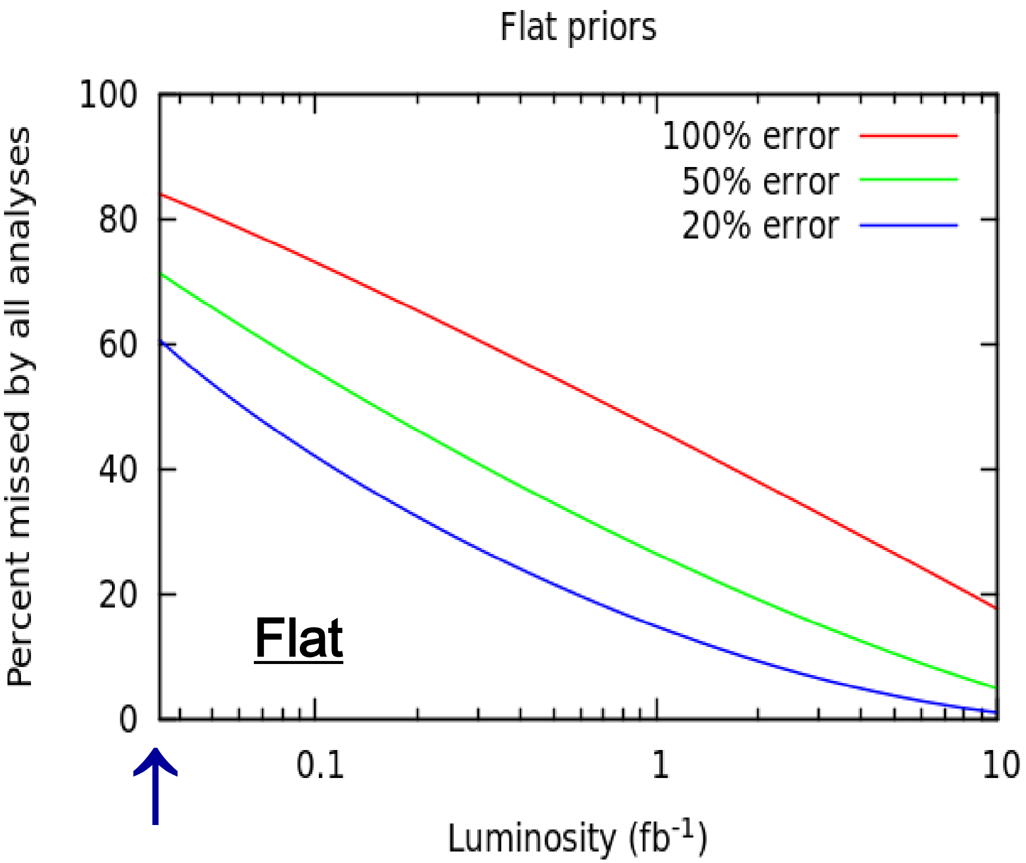

4j
M_eff distribution for ^1 lepton analysis
SM BG
SU1
SU2
SU3
SU4
SU6
SU8.1
Effective Mass (GeV)

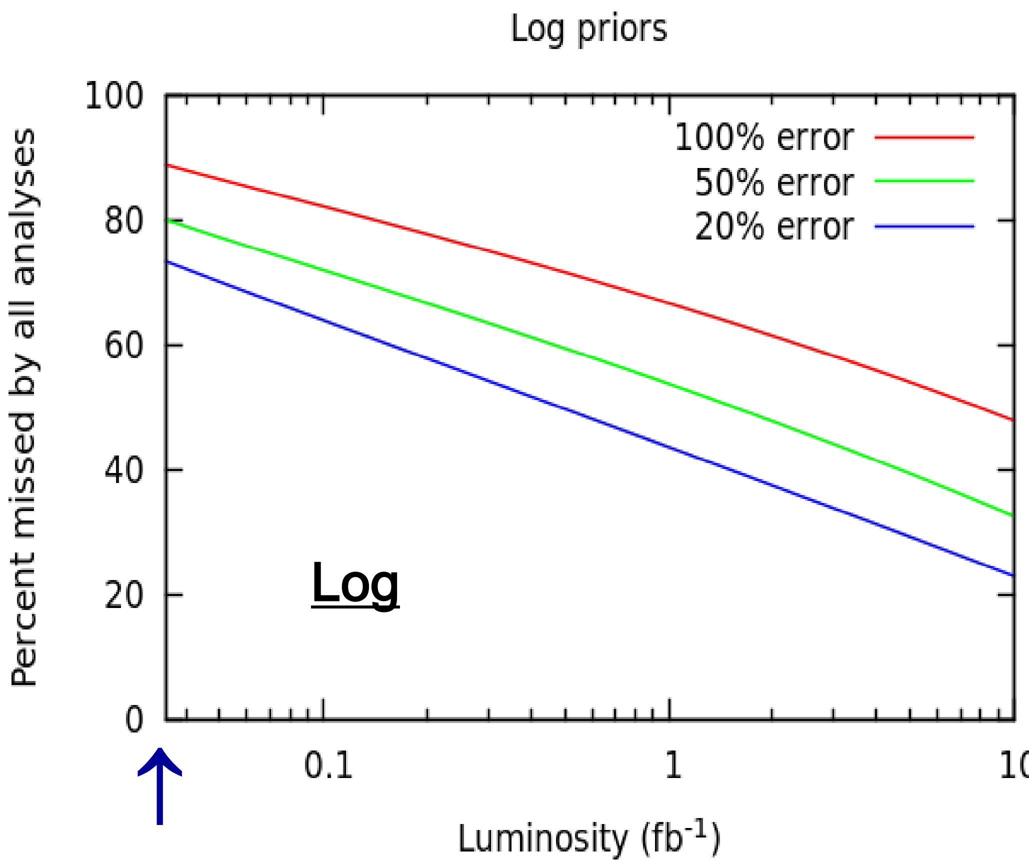

M_eff distribution for b-jet analysis
SM BG
SU1
SU2
SU3
SU4
SU6
Effective Mass (GeV)


4j0l
3j0l
2j0l
4j1l
7 TeV
SM BG
ATLAS SU4
SU4
Events/ 1 fb-1
Effective Mass [GeV]

How good is the pMSSM coverage @ 7 TeV as the luminosity evolves ??

The coverage is quite good for both model sets !





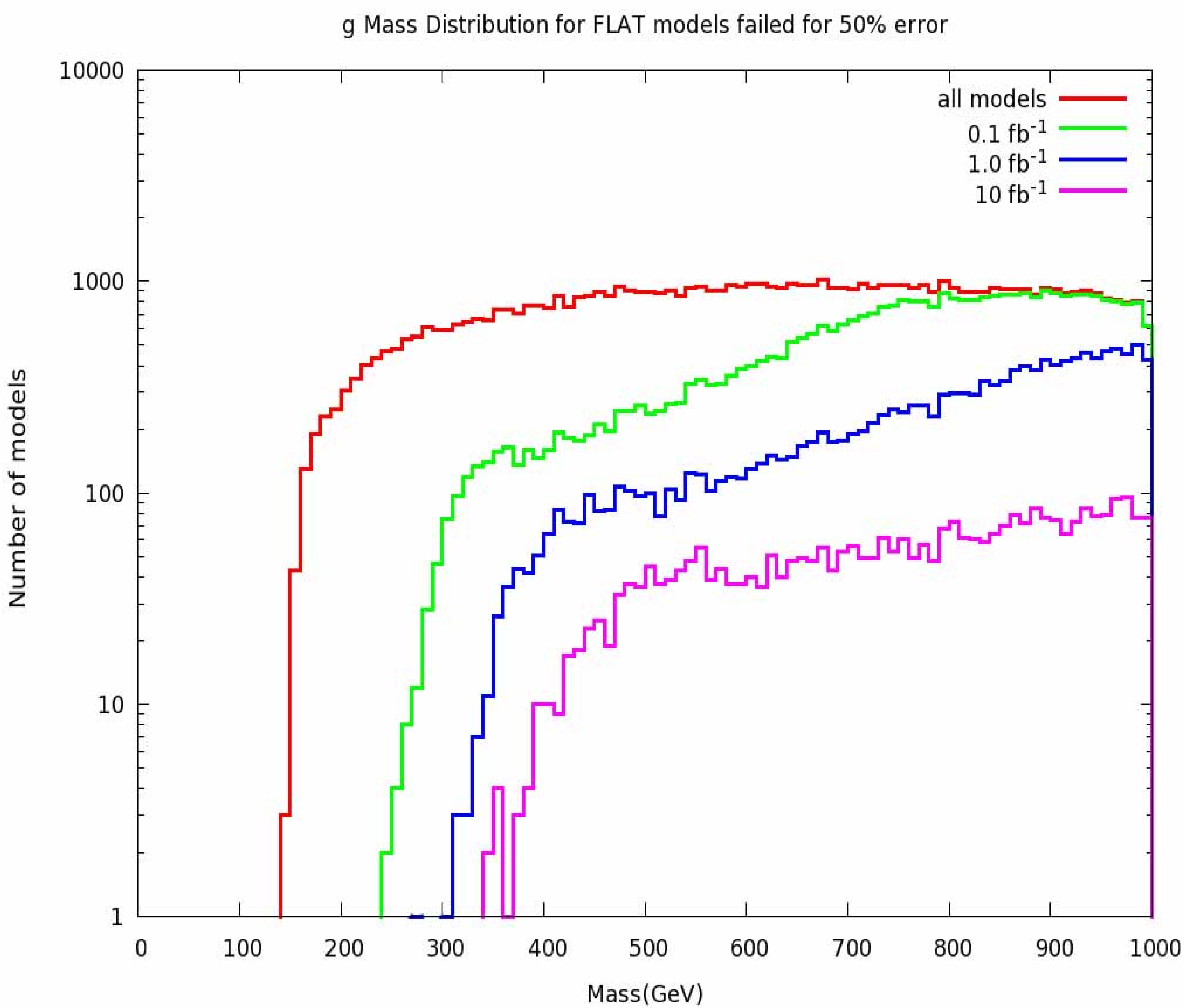
ATLAS pMSSM Model Coverage*
RIGHT NOW for ~35 pb $^{-1}$ @ 7 TeV

δB :	100%	50%	20%
FLAT:	16%	29%	39%
LOG :	11%	20%	27%

Wow! This is actually quite impressive as these LHC SUSY searches are just beginning !!!

* Fraction of models that SHOULD have been found but weren't if all ATLAS analyses were done as stated

• What do LHC searches do? If nothing is found they just 'remove' models from the 'allowed' set until few remain



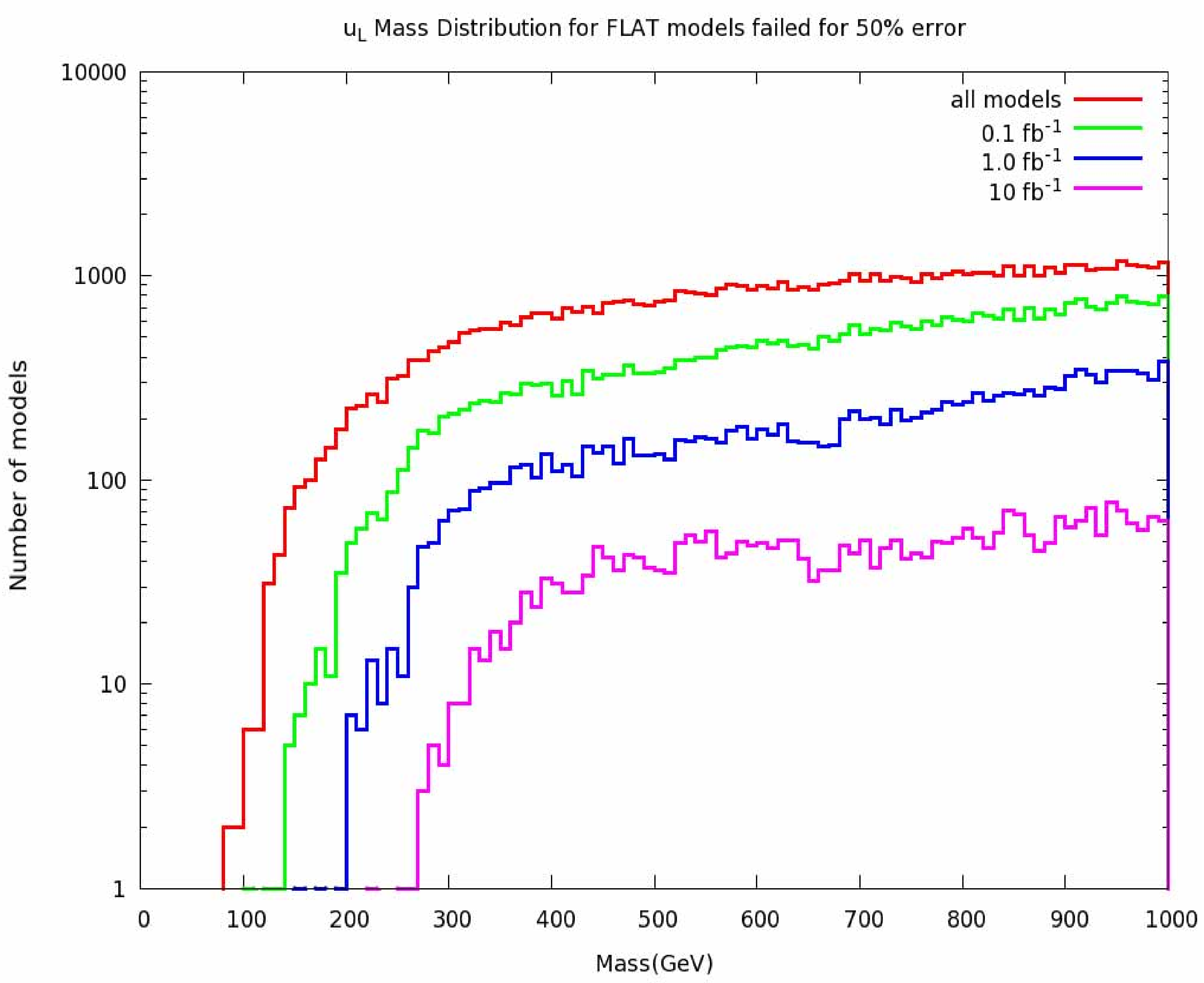
LHC SUSY searches are preferentially sensitive to squarks & gluinos

Here we see the gluino population falling as models are 'removed' ..

More models w/ lighter gluinos are removed

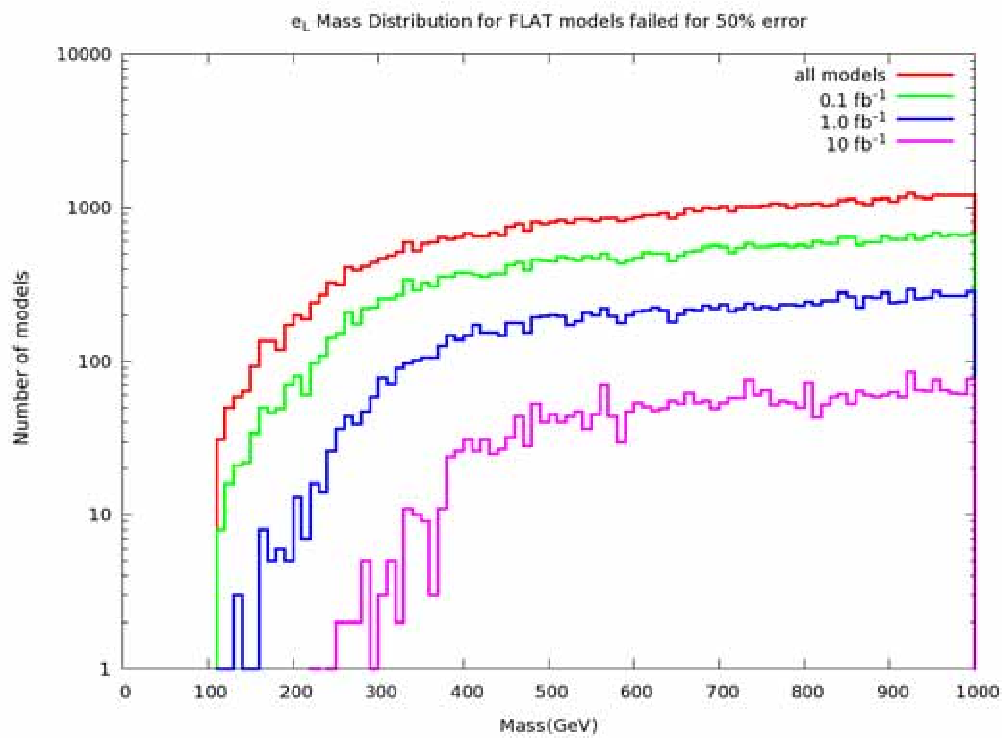
What about the other sparticles?

For the other colored sparticles we would expect to see the same effect as there is nothing special about gluinos.

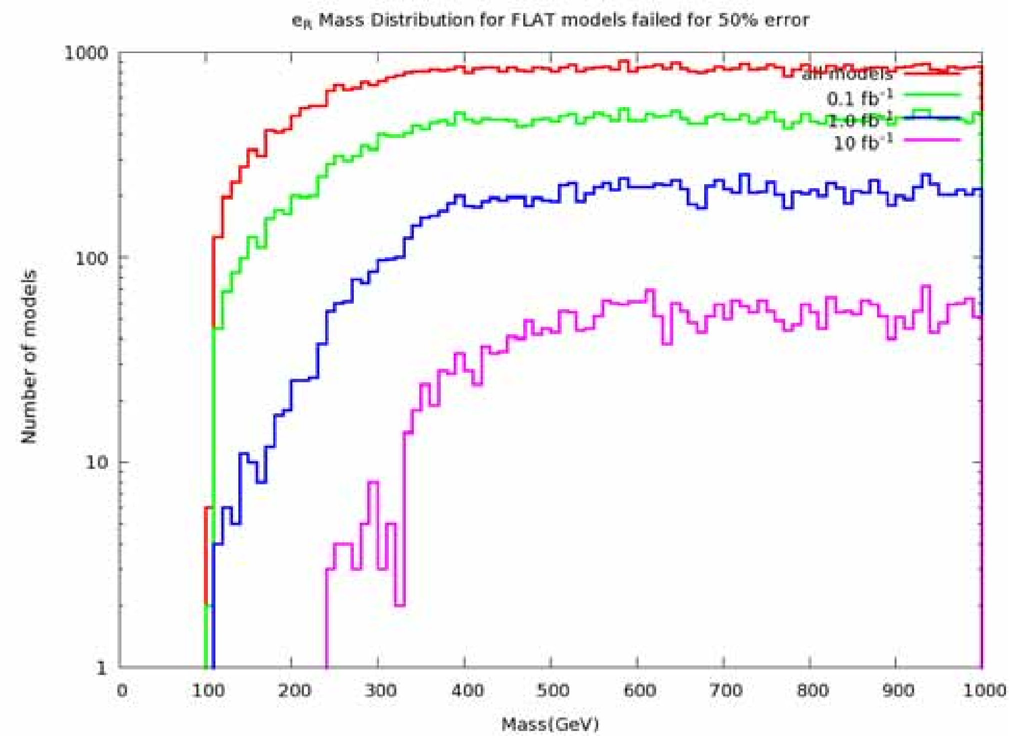


For squarks we also see the depletion of lighter states as the LHC lumi goes up.

But what about color singlets at they are not (much) directly produced at the LHC & are most relevant for the LC ?

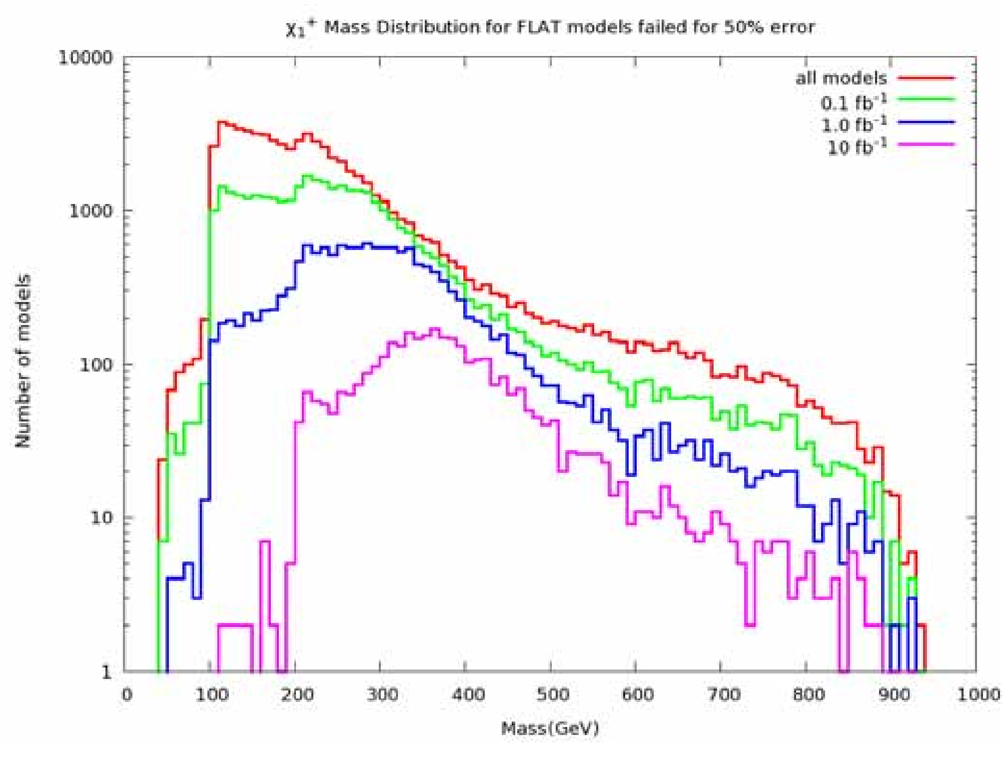


e_L Mass Distribution for FLAT models failed for 50% error
all models
0.1 fb^{-1}
1.0 fb^{-1}
10 fb^{-1}
Number of models
Mass(GeV)

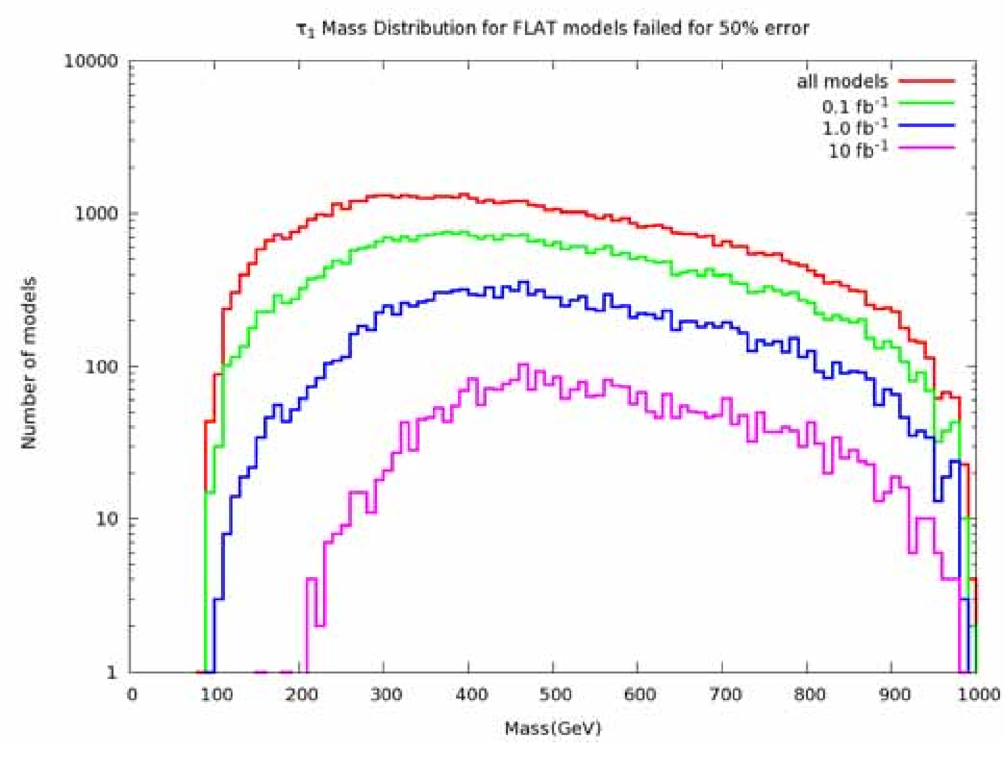


e_R Mass Distribution for FLAT models failed for 50% error
all models
0.1 fb^{-1}
1.0 fb^{-1}
10 fb^{-1}
Number of models
Mass(GeV)

FLAT

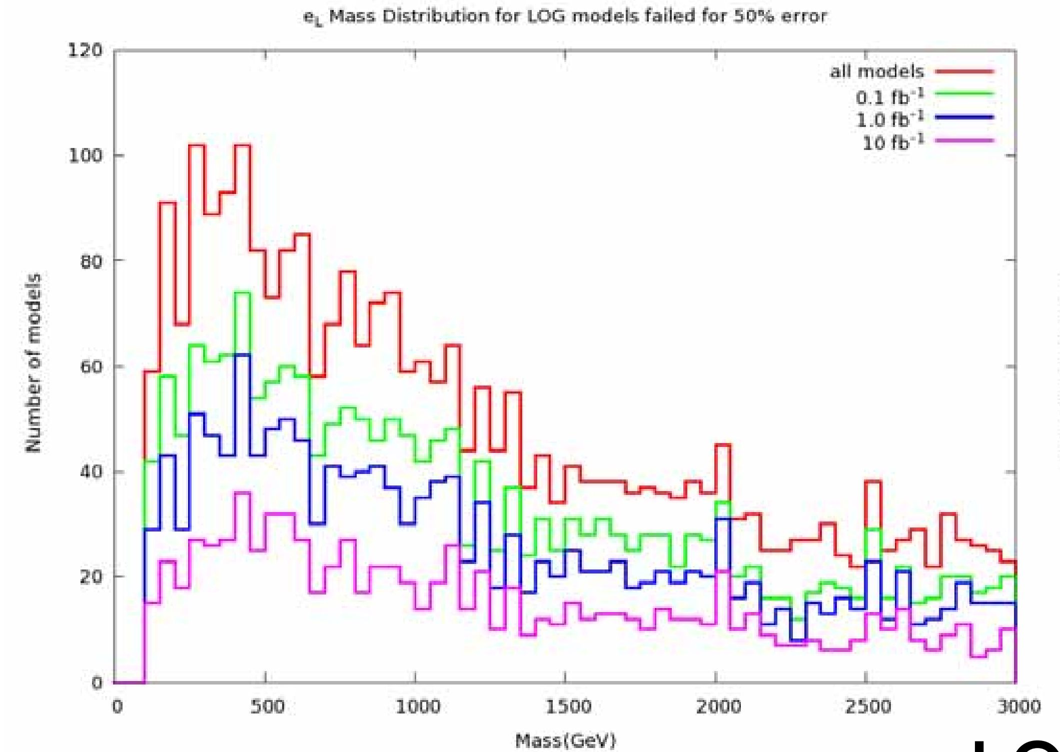


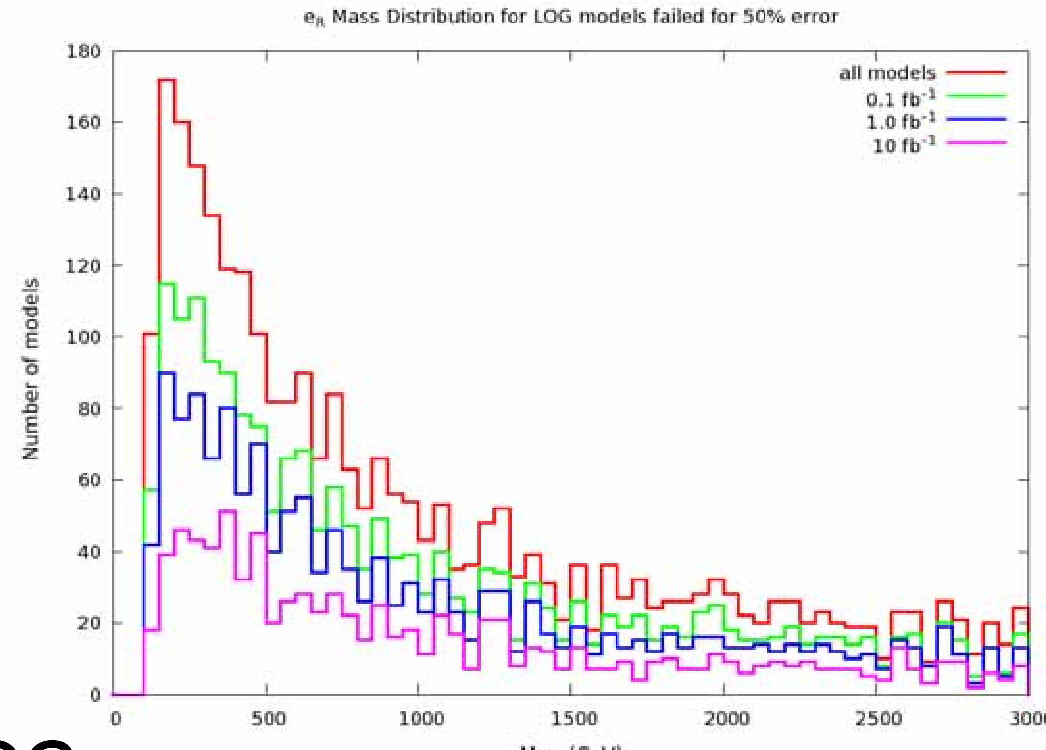
χ_1^+ Mass Distribution for FLAT models failed for 50% error
all models
0.1 fb^{-1}
1.0 fb^{-1}
10 fb^{-1}
Number of models
Mass(GeV)

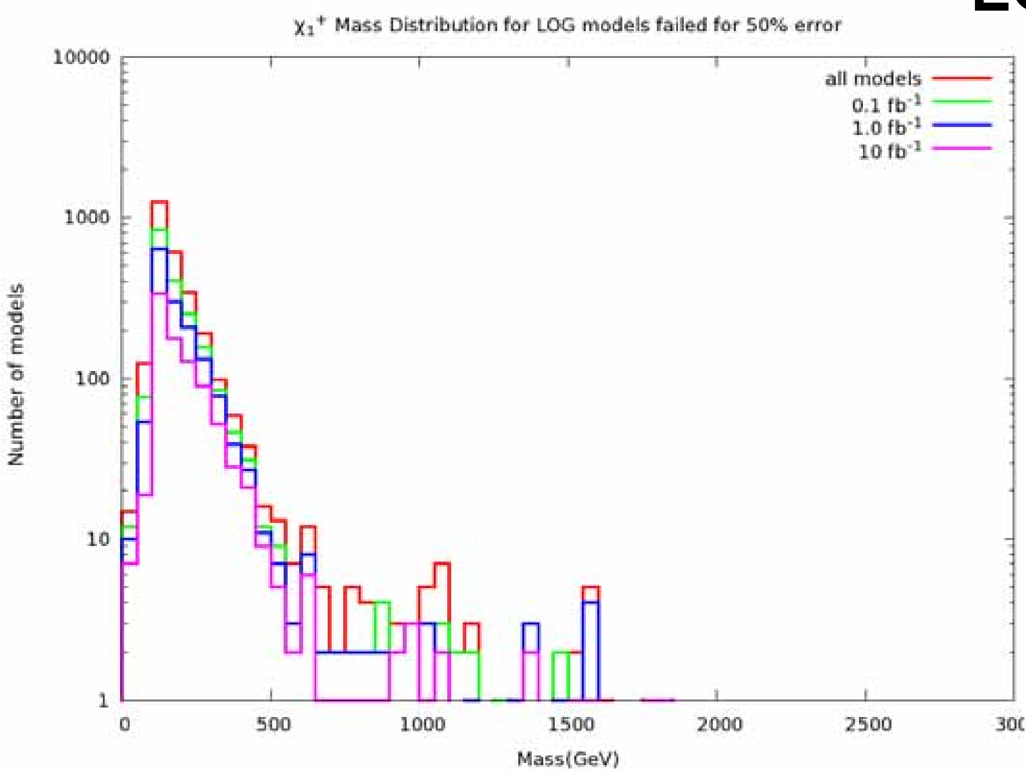


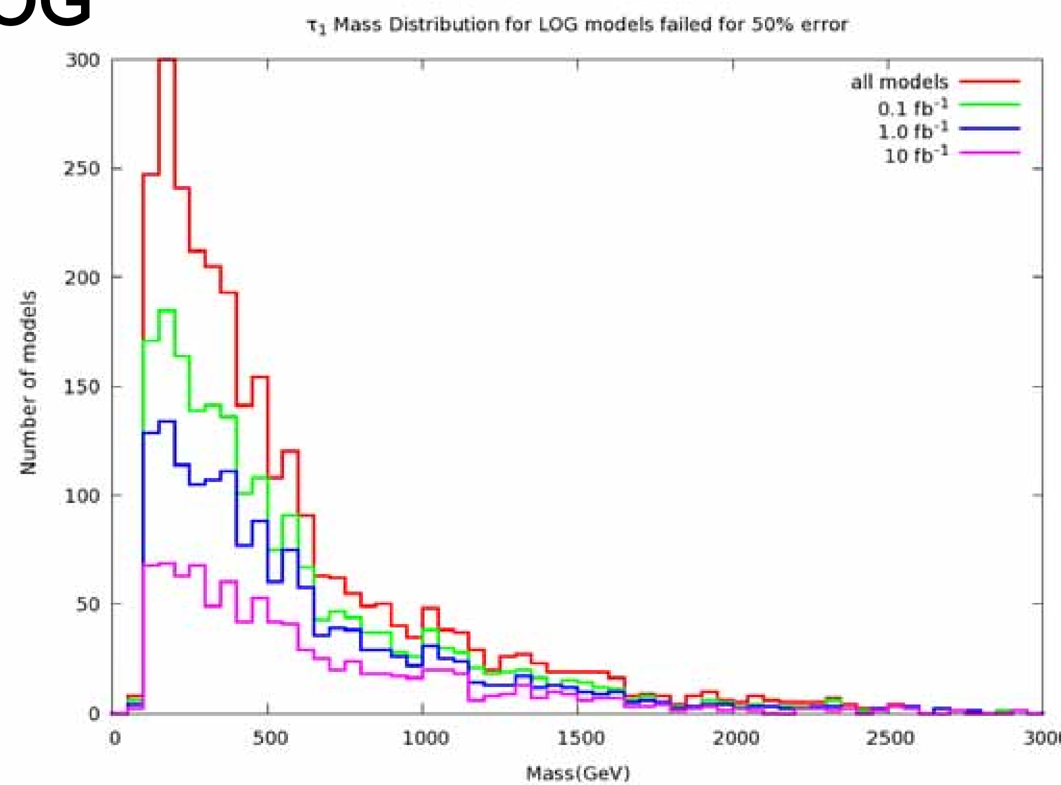
τ_1 Mass Distribution for FLAT models failed for 50% error
all models
0.1 fb^{-1}
1.0 fb^{-1}
10 fb^{-1}
Number of models
Mass(GeV)

LOG


e_L Mass Distribution for LOG models failed for 50% error
all models
0.1 fb-1
1.0 fb-1
10 fb-1
Number of models
Mass(GeV)


e_R Mass Distribution for LOG models failed for 50% error
all models
0.1 fb-1
1.0 fb-1
10 fb-1
Number of models


χ1+ Mass Distribution for LOG models failed for 50% error
all models
0.1 fb-1
1.0 fb-1
10 fb-1
Number of models
Mass(GeV)


τ1 Mass Distribution for LOG models failed for 50% error
all models
0.1 fb-1
1.0 fb-1
10 fb-1
Number of models
Mass(GeV)

	$\sqrt{s} = 500$ GeV		$\sqrt{s} = 1$ TeV	
Sparticle	Flat	Log	Flat	Log
$\tilde{e}_L$	107	101	3052	347
$\tilde{e}_R$	260	209	3938	565
$\tilde{\tau}_1$	730	381	7431	869
$\tilde{\tau}_2$	30	36	1288	207
$\tilde{\nu}_e$	151	117	3168	356
$\tilde{\nu}_\tau$	386	236	4366	553
$\tilde{\chi}_1^0$	5487	1312	14,510	1539
$\tilde{\chi}_2^0$	2738	1035	10,714	1395
$\tilde{\chi}_3^0$	429	352	5667	903
$\tilde{\chi}_4^0$	10	18	1267	202
$\tilde{\chi}_1^\pm$	4856	1208	13,561	1495
$\tilde{\chi}_2^\pm$	94	54	3412	456
$\tilde{g}$	0	0	1088	65
$\tilde{d}_L$	35	11	2459	117
$\tilde{d}_R$	220	96	3630	526
$\tilde{u}_L$	52	16	2545	123
$\tilde{u}_R$	124	64	3581	273
$\tilde{b}_1$	289	75	5553	590
$\tilde{b}_2$	1	0	409	21
$\tilde{t}_1$	93	9	3727	217
$\tilde{t}_2$	0	0	2	0

LC Implications

← In the set of 14623 (1546) FLAT(LOG) models NOT found at 7 TeV w/ 1 fb^{-1} & δB=50% we find there are….

This doesn't look too bad for 500 GeV or 1 TeV !

But →

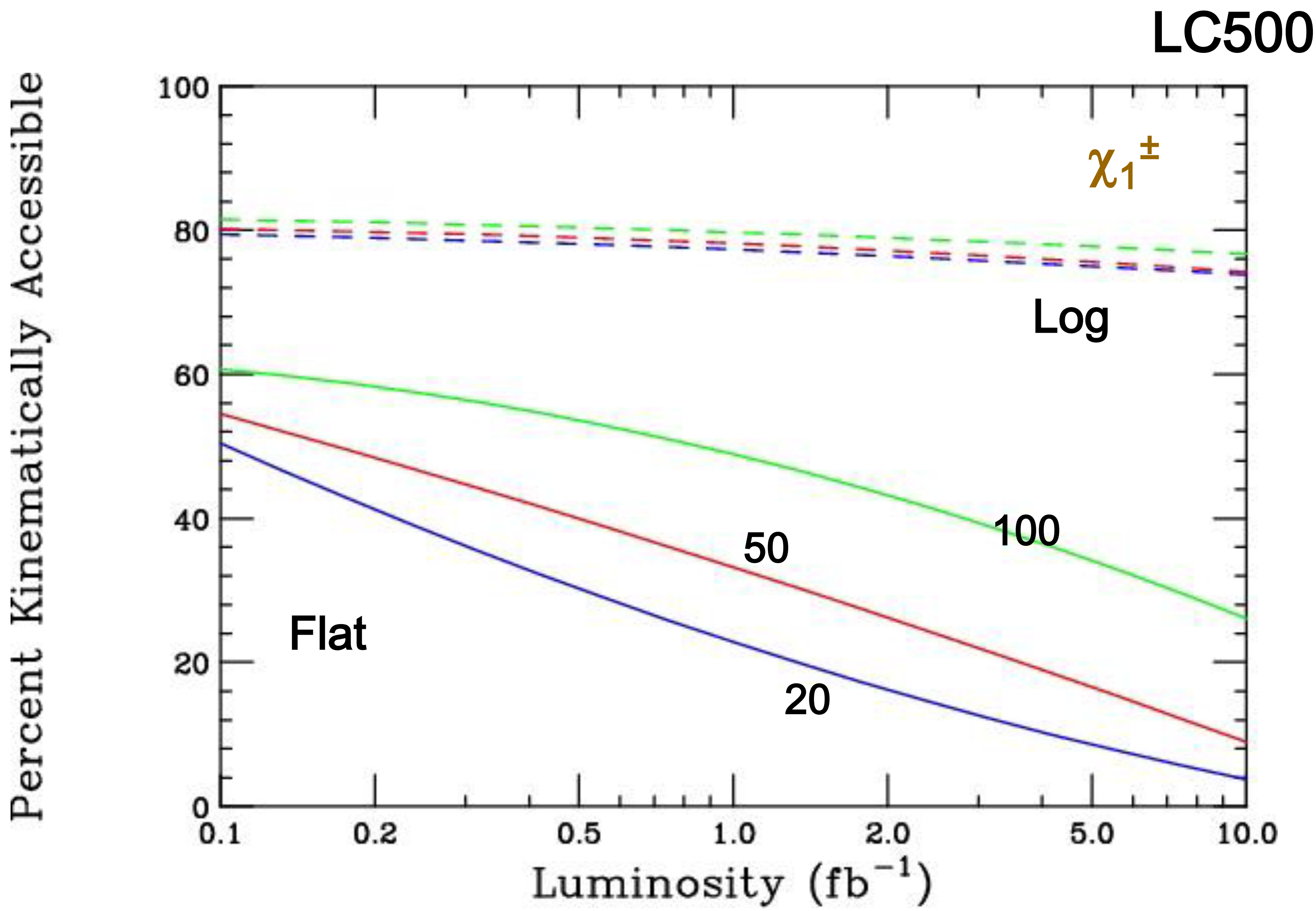
	$\sqrt{s} = 500$ GeV		$\sqrt{s} = 1$ TeV	
Sparticle	Flat	Log	Flat	Log
$\tilde{e}_L$	0	37	63	142
$\tilde{e}_R$	0	72	53	223
$\tilde{\tau}_1$	2	142	165	338
$\tilde{\tau}_2$	0	11	9	69
$\tilde{\nu}_e$	0	42	64	146
$\tilde{\nu}_\tau$	0	85	81	236
$\tilde{\chi}_1^0$	26	507	587	626
$\tilde{\chi}_2^0$	4	397	352	557
$\tilde{\chi}_3^0$	0	136	57	357
$\tilde{\chi}_4^0$	0	5	5	66
$\tilde{\chi}_1^\pm$	25	467	505	608
$\tilde{\chi}_2^\pm$	0	17	16	170
$\tilde{g}$	0	0	27	5
$\tilde{d}_L$	0	3	73	24
$\tilde{d}_R$	1	18	63	157
$\tilde{u}_L$	0	5	81	24
$\tilde{u}_R$	0	14	86	79
$\tilde{b}_1$	0	20	103	189
$\tilde{b}_2$	0	0	3	4
$\tilde{t}_1$	1	2	94	58
$\tilde{t}_2$	0	0	0	0

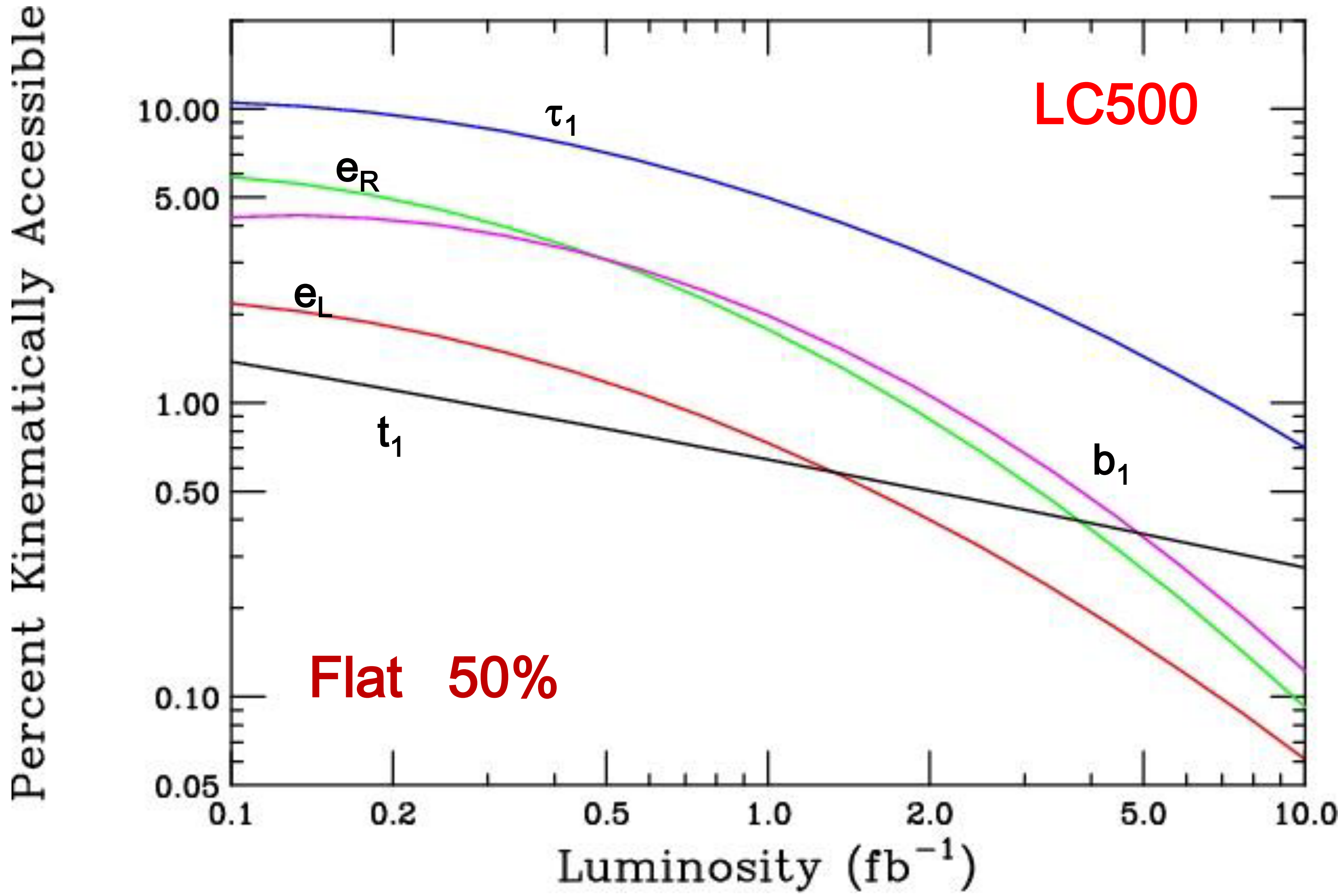
In the set of 672(663) FLAT(LOG) models NOT found @ 7 TeV w/ 10 fb^{-1} and δB=20% there are a lot fewer !

← Not a whole lot in the FLAT case at 500 GeV ! …so the SUSY @ the LC window depends where we end up & the spectrum shape details

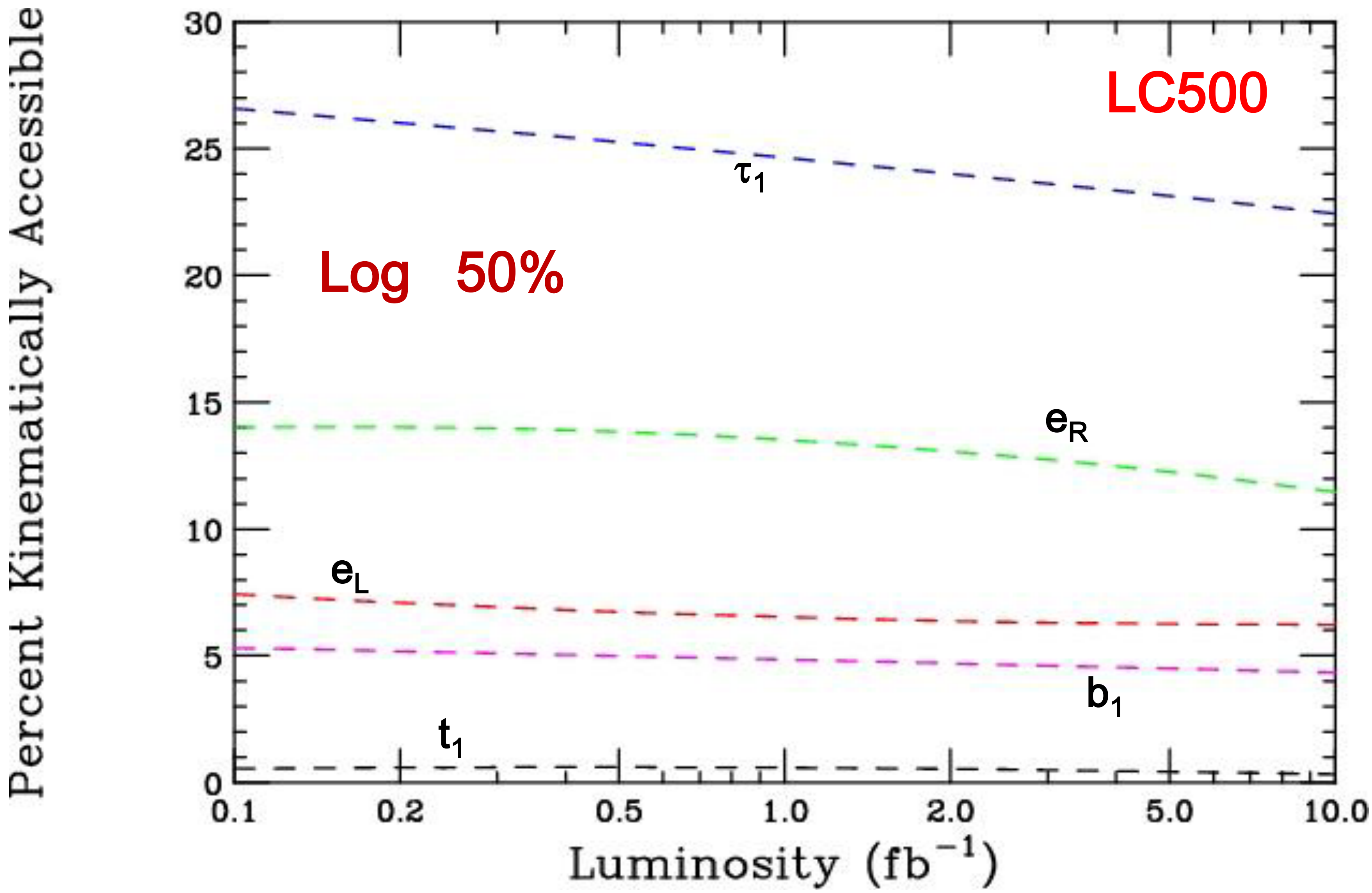
However, a 1TeV LC is vastly BETTER !

- Of course what's REALLY important is the fraction of the 'undiscovered' models which have kinematically accessible sparticles at the LC…



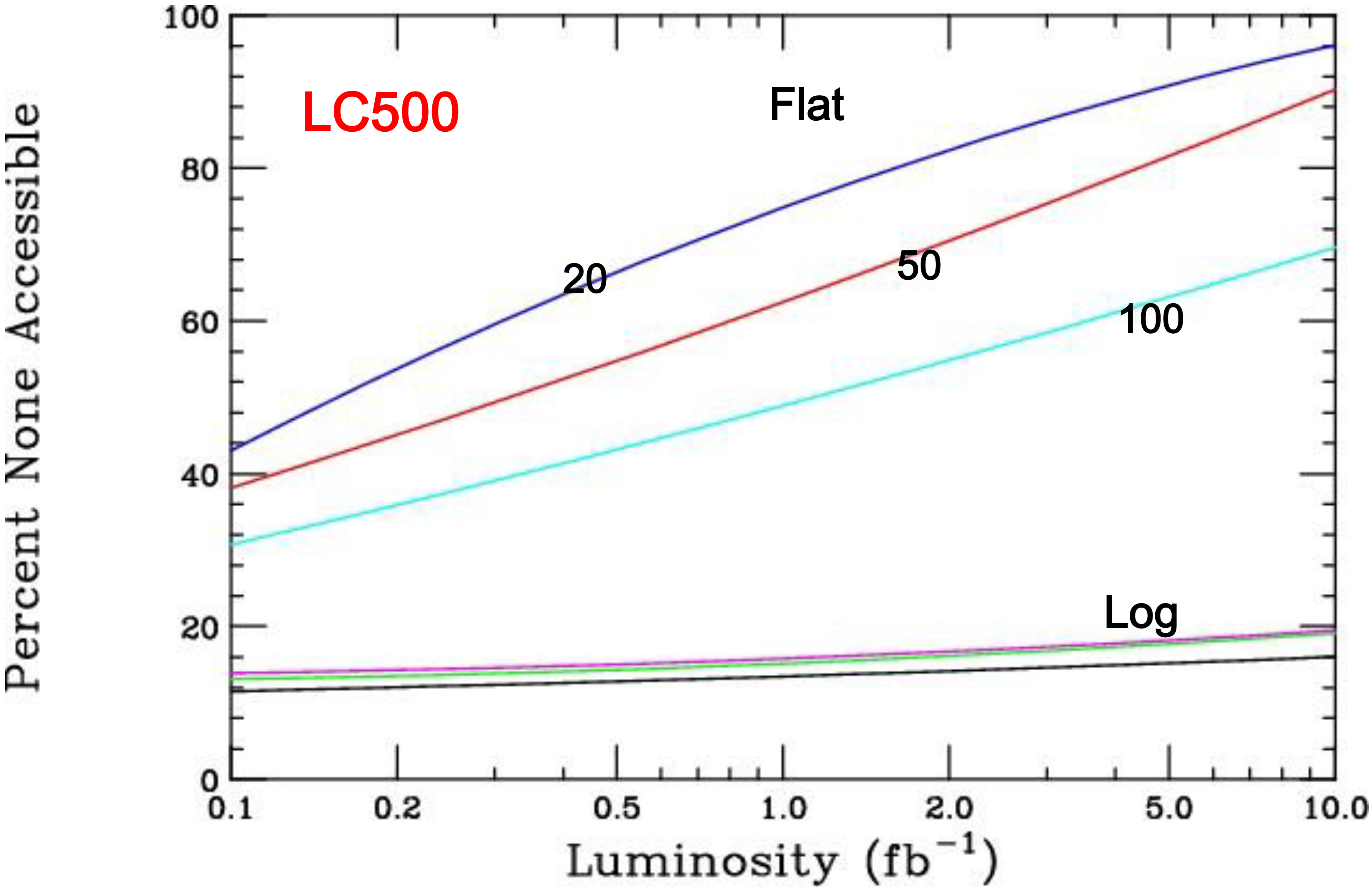


As the lumi increases the fraction of flat prior models with LC500 observable sparticles becomes very small <1%. However…

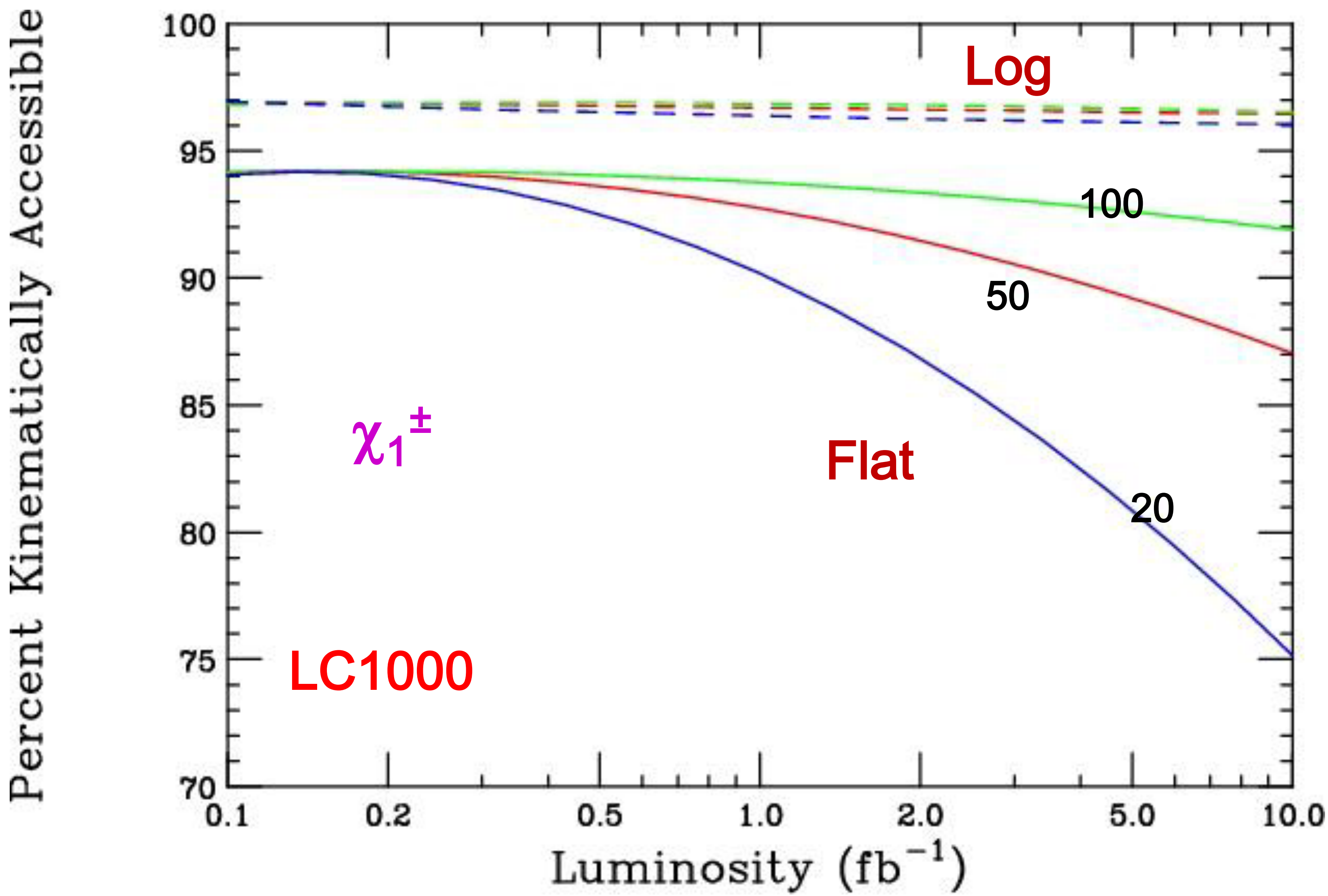


As the lumi increases the fraction of log prior models with LC500 observable particles declines quite slowly !

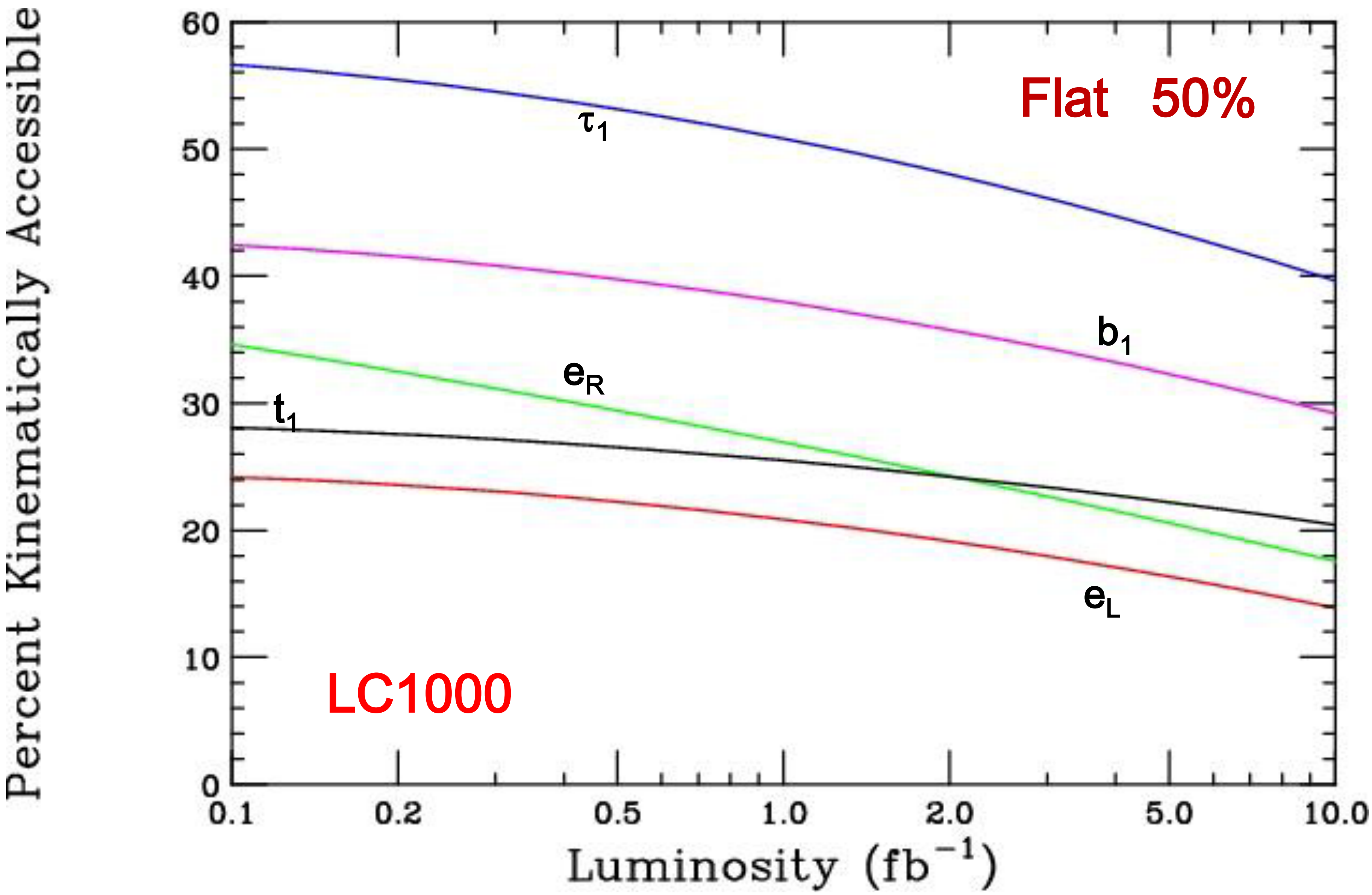
The fraction of models with NO sparticles accessible at LC500 grows rapidly for the flats but almost not at all for the logs

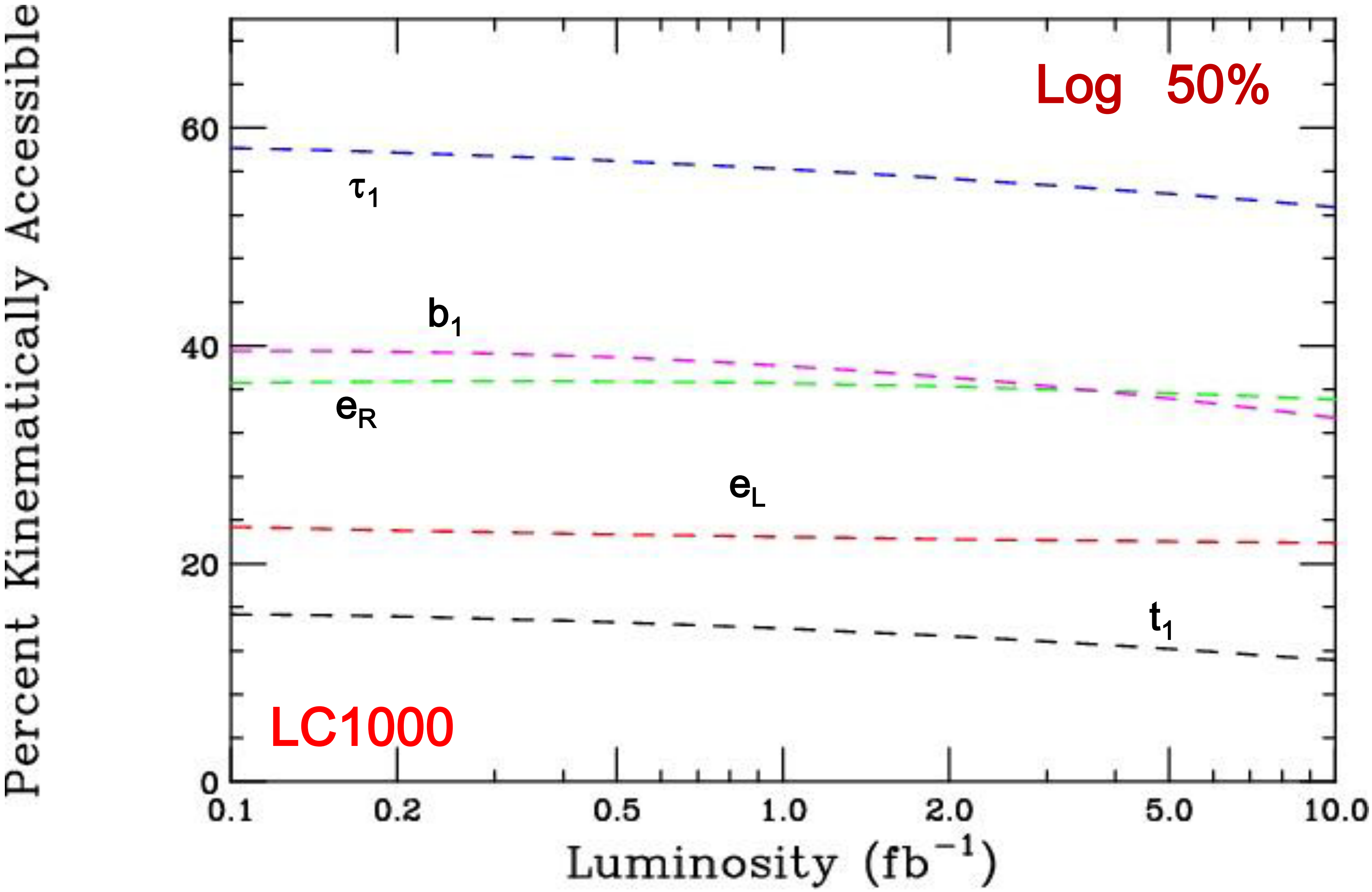


Things do change a lot at LC1000… a very large fraction of models have accessible charginos.



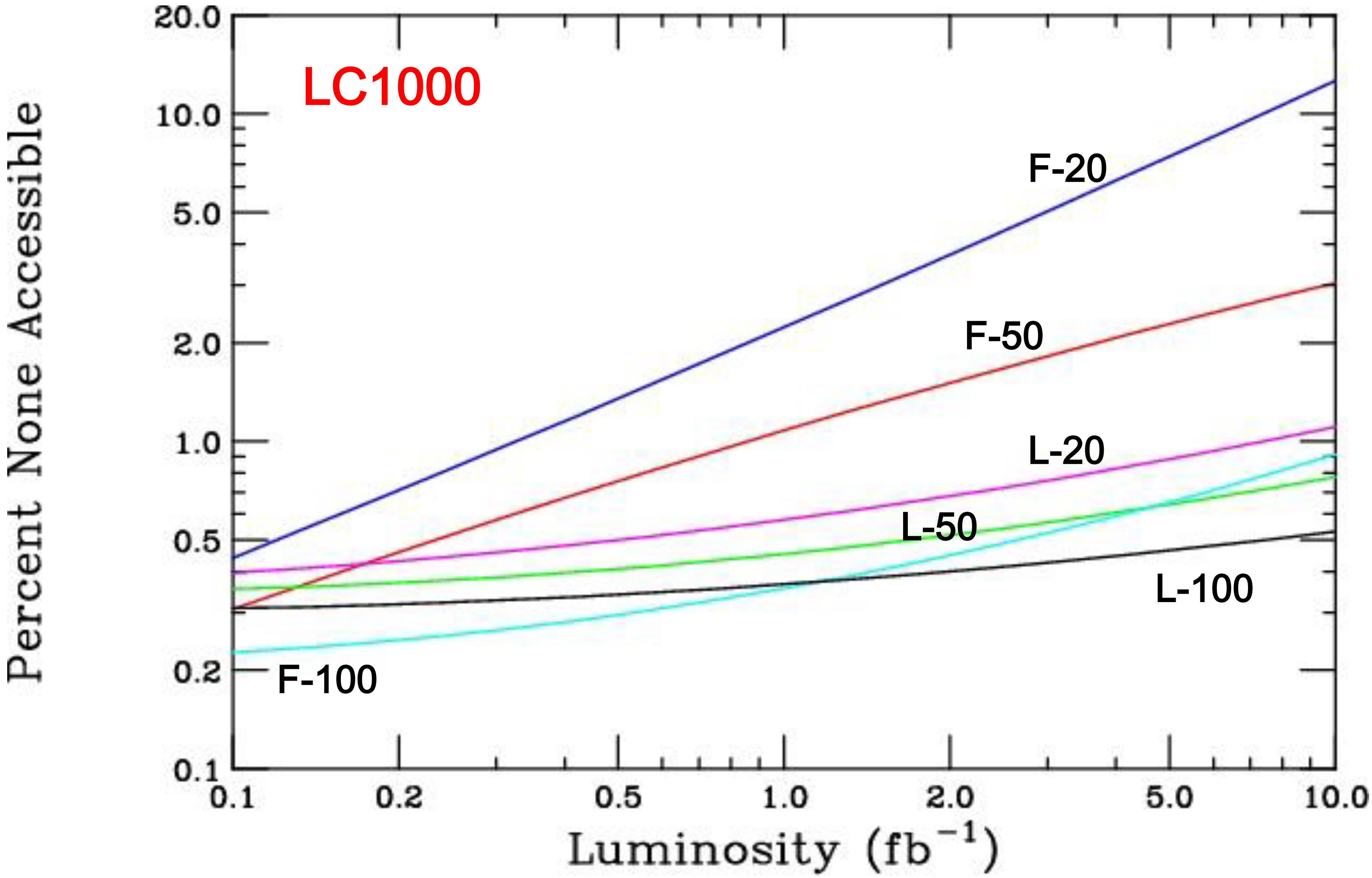
Other sparticles are also reasonably accessible at LC1000





For the Log case many sparticles are accessible at LC1000

The fraction of models w/o any SUSY accessible is small



- If nothing is seen, just how visible SUSY may or may not be at LC500 will depend on 2 factors that we presently don't know:

(i) What luminosity/background systematics will be achieved during the 7 TeV LHC 2011-12 run? (We just need to wait to find out…)

(ii) How are the many sparticles in the SUSY spectrum distributed ? (i.e., how is SUSY broken..who can say?)

→ If things are remotely like in the Flat prior case LC500 is NOT a good place for SUSY studies

Summary & Conclusions : I

- The LHC is already placing limits on BSM physics beyond the reach of the Tevatron since no new signals have yet been seen

- If a Z' is not seen by the time ~5 fb^{-1} is accumulated then it is likely to be beyond the range of LC500 to study either because it is too heavy or too weakly coupled

- ADD graviton exchange visibility is not likely at LC500

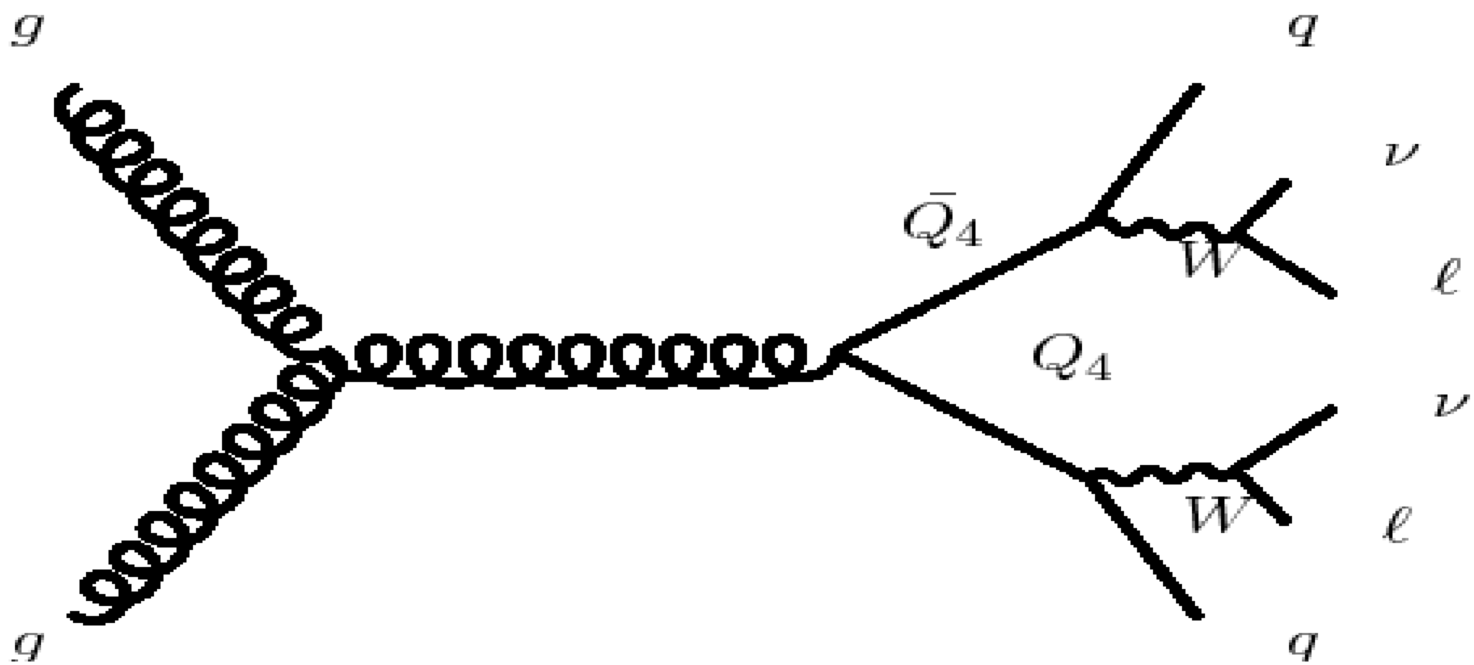
- 'Weak' constraints on some parts of a model can sometimes yield stronger constraints in another sector as in the LRM case

Summary & Conclusions : II

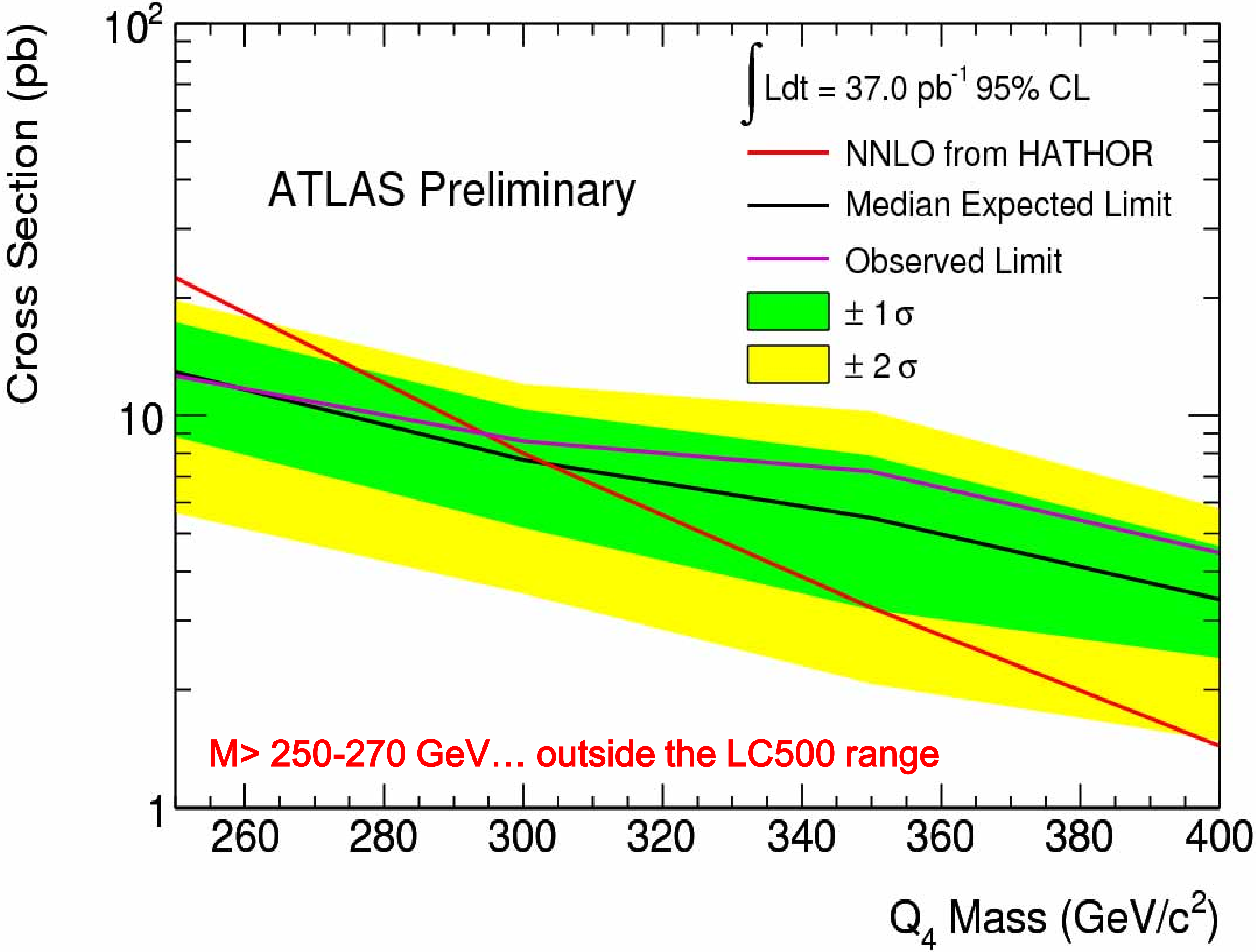
- LHC explorations of SUSY are underway & a fair bit of the mSUGRA parameter space is already excluded
- With ~35 pb^{-1}, a reasonable fraction of our pMSSM model space has also been 'covered' !
- Combined chargino + slepton studies at LC500 in mSUGRA are dead
- At best, LC500 looks 'iffy' for pMSSM SUSY studies BUT we don't know either the final performance of the LHC or what the sparticle spectrum looks like
- We're anxious to see more data & remember the caveats!

BACKUP SLIDES

Another possibility: 4th generation quark or, even more interestingly, an exotic vector-like quark decaying by mixing w/ ANY SM quark:



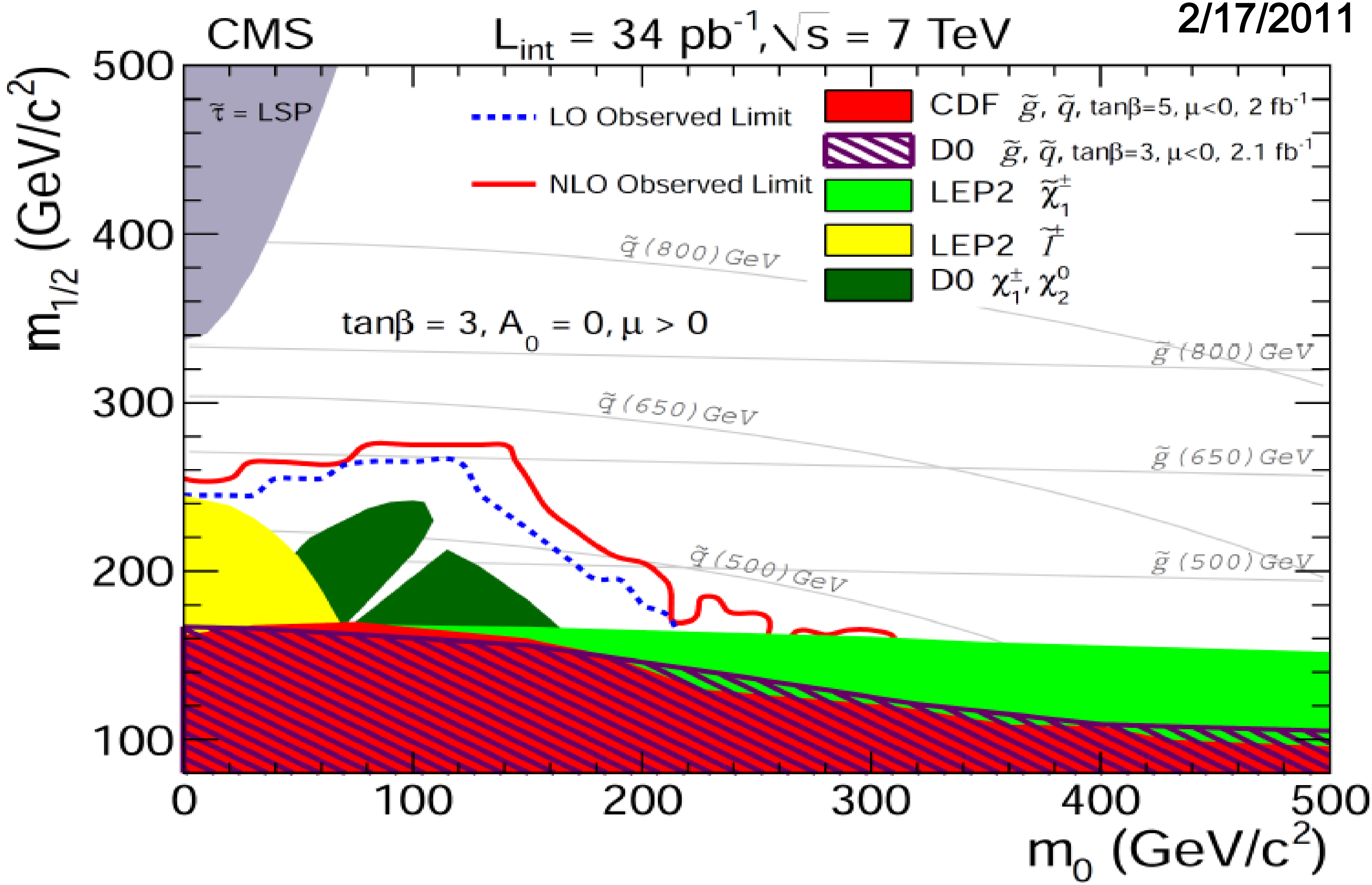
For exotics we need to use $\sigma \cdot B_W^2$



Cross Section (pb)
10^2
10
1
260
280
300
320
340
360
380
400
Q_4 Mass (GeV/c^2)
∫Ldt = 37.0 pb^-1 95% CL
NNLO from HATHOR
Median Expected Limit
Observed Limit
± 1σ
± 2σ
ATLAS Preliminary
M> 250-270 GeV… outside the LC500 range

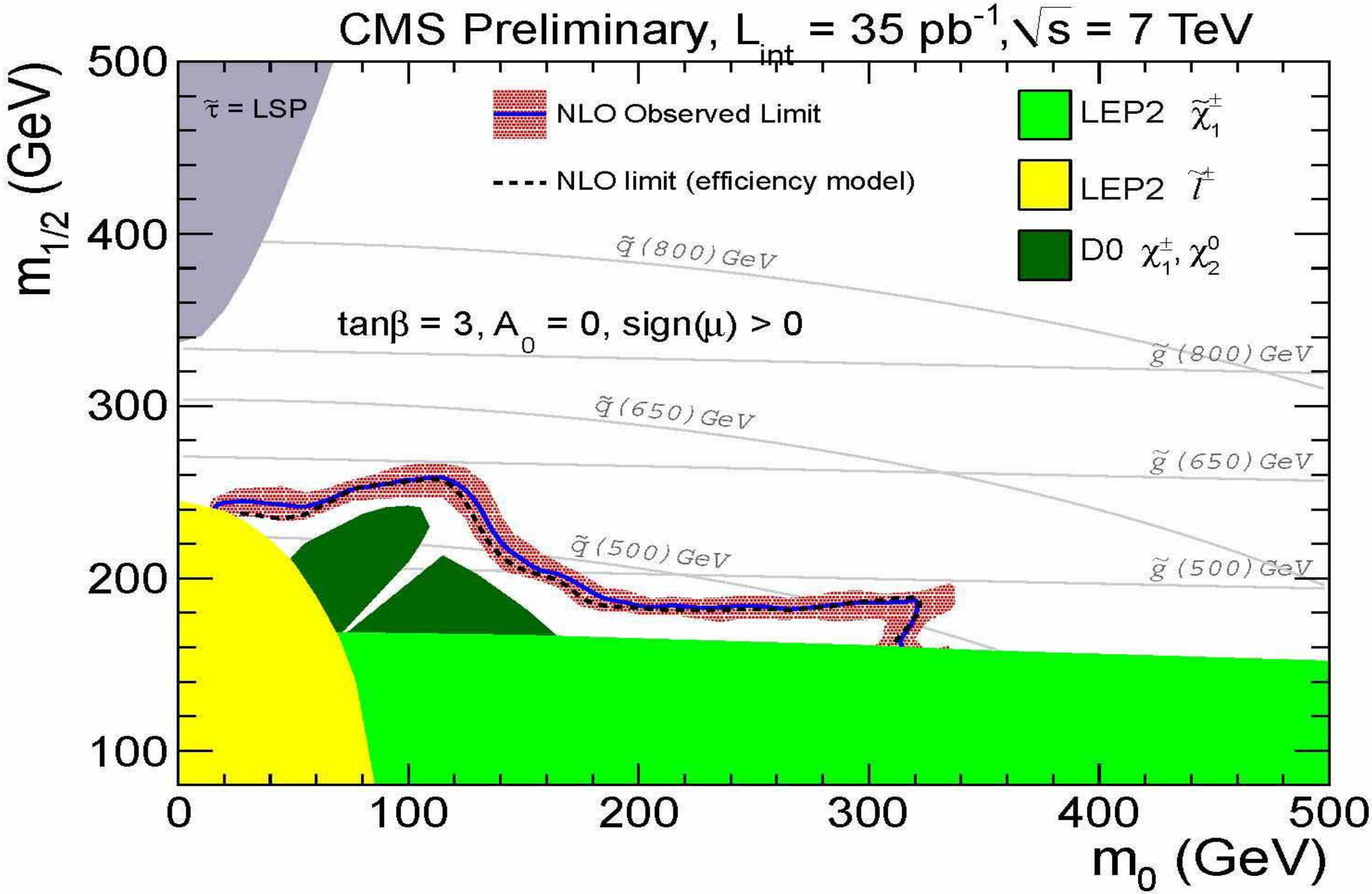
2jOSDL..more icing on the cake…

2/17/2011

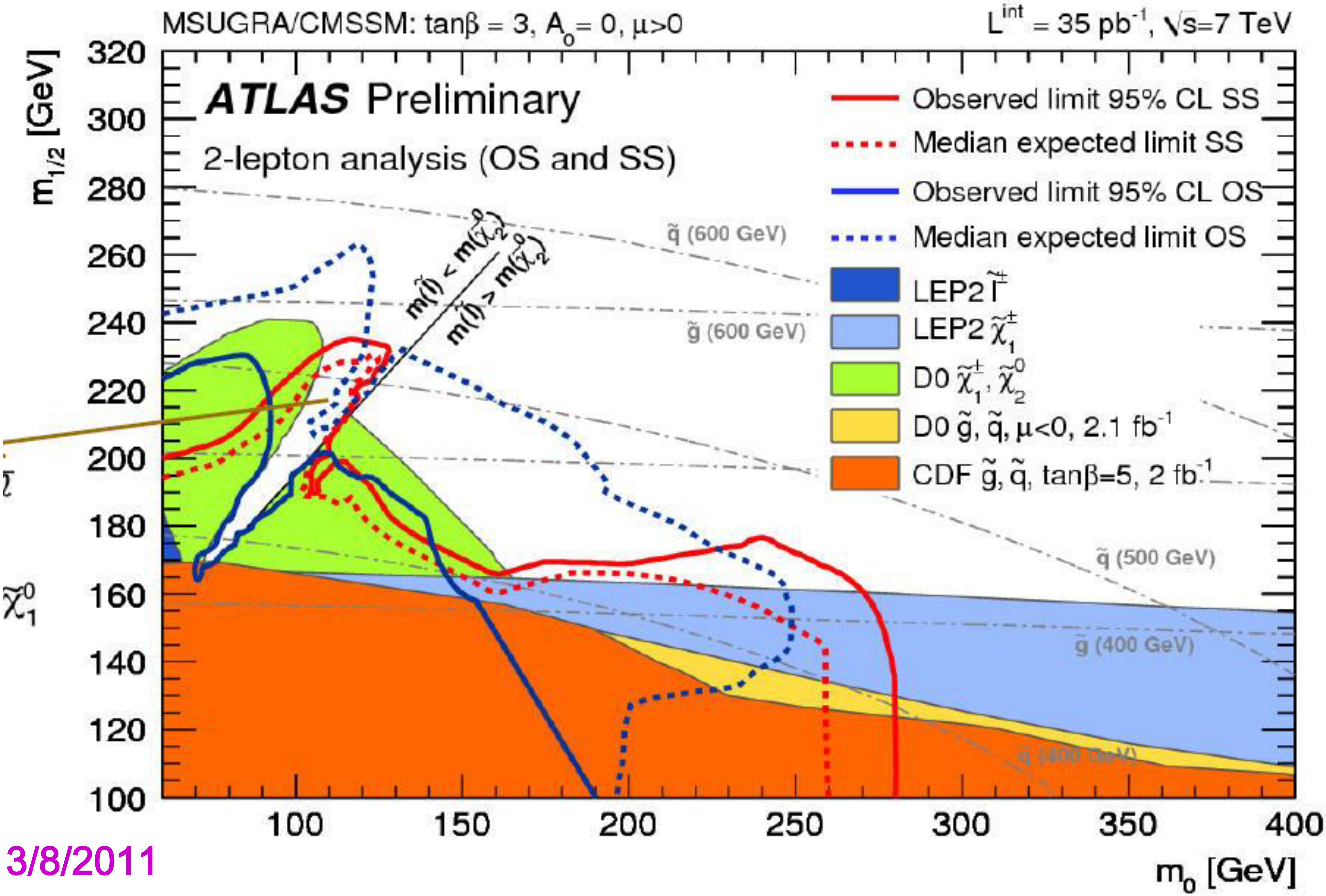


SSDL..even more icing on the cake…

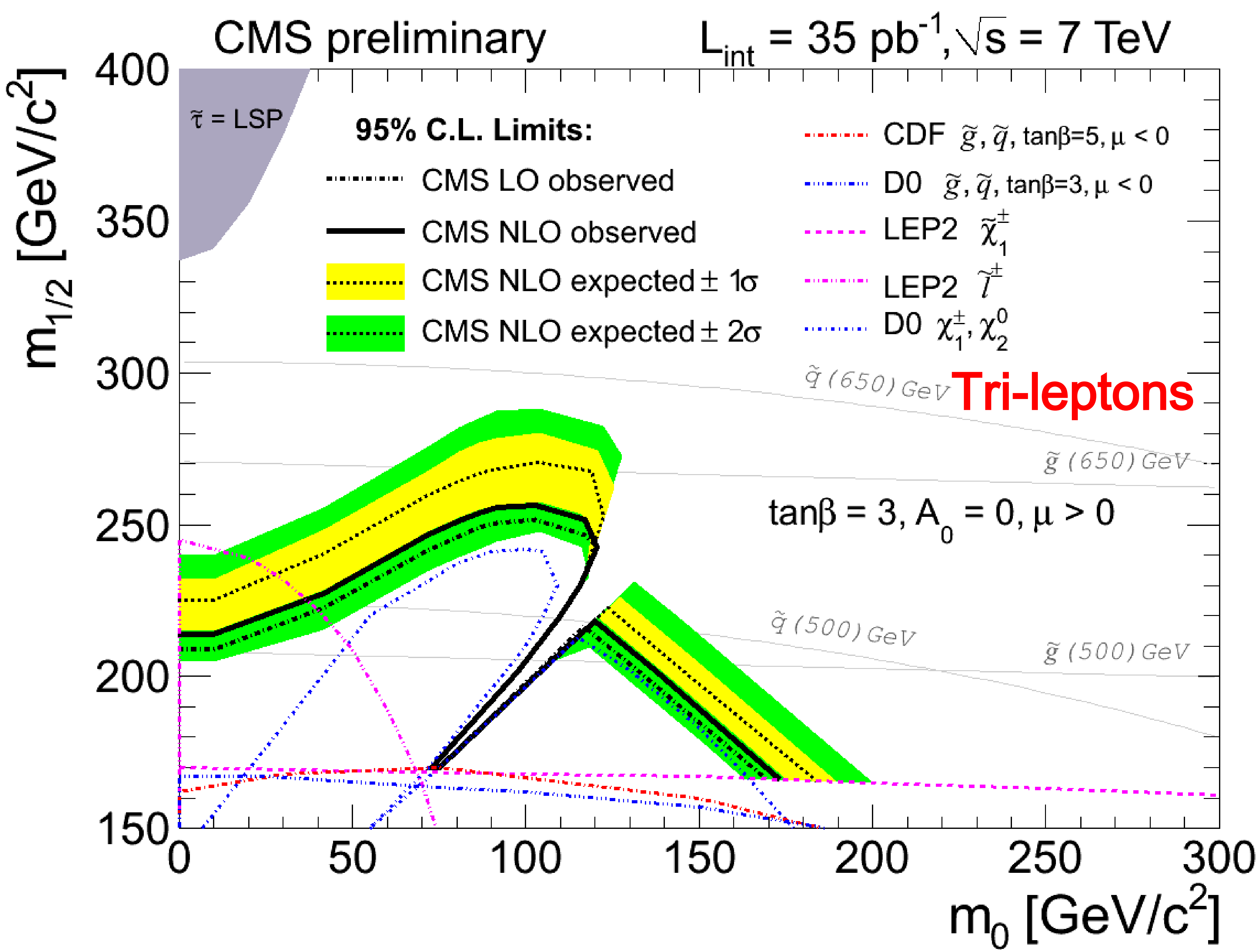
3/6/2011



..& the results keep right on coming !

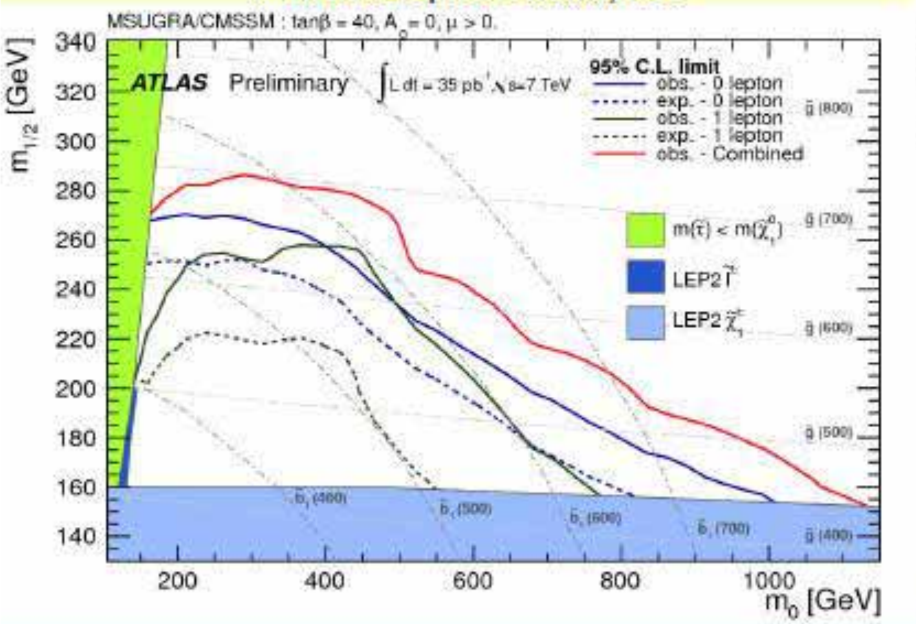


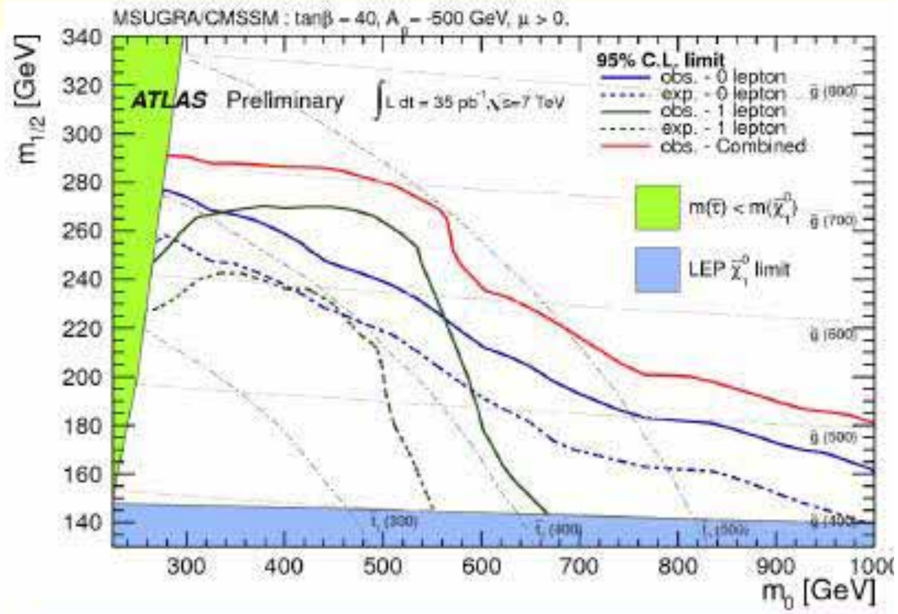
3/8/2011


CMS preliminary
L_{int} = 35 pb^{-1}, $\sqrt{s}$ = 7 TeV
$\tilde{\tau}$ = LSP
95% C.L. Limits:
CMS LO observed
CMS NLO observed
CMS NLO expected ± 1σ
CMS NLO expected ± 2σ
CDF $\tilde{g}, \tilde{q}$, tanβ=5, μ < 0
D0 $\tilde{g}, \tilde{q}$, tanβ=3, μ < 0
LEP2 $\tilde{\chi}_1^{\pm}$
LEP2 $\tilde{l}^{\pm}$
D0 $\chi_1^{\pm}, \chi_2^0$
$\tilde{q}$ (650) GeV
Tri-leptons
$\tilde{g}$ (650) GeV
tanβ = 3, A_0 = 0, μ > 0
$\tilde{q}$ (500) GeV
$\tilde{g}$ (500) GeV
$m_{1/2}$ [GeV/c^2]
m_0 [GeV/c^2]
400
350
300
250
200
150
0
50
100
150
200
250
300

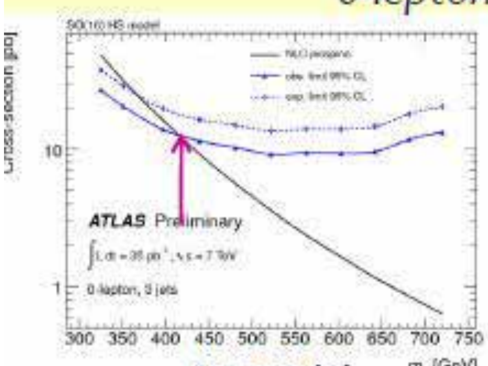
Specific SUSY models

0- and 1-lepton analyses

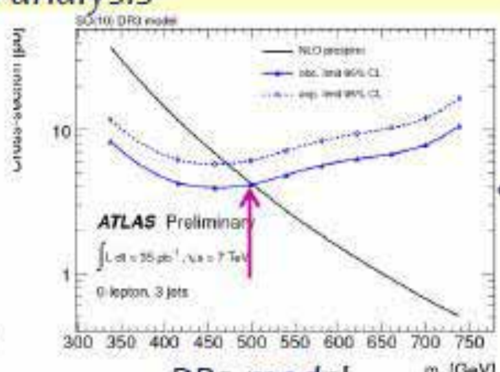




0-lepton analysis

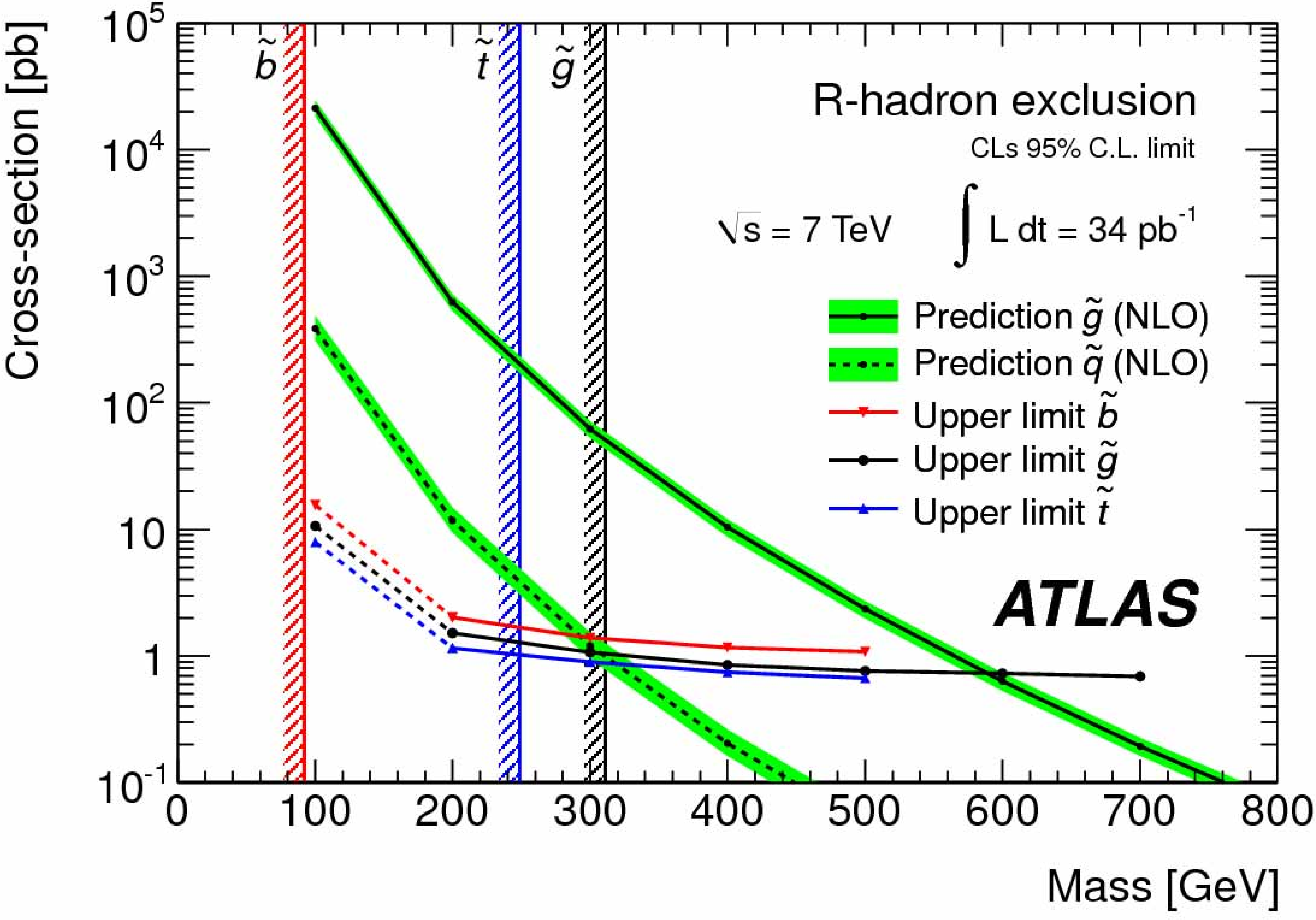


HS-model

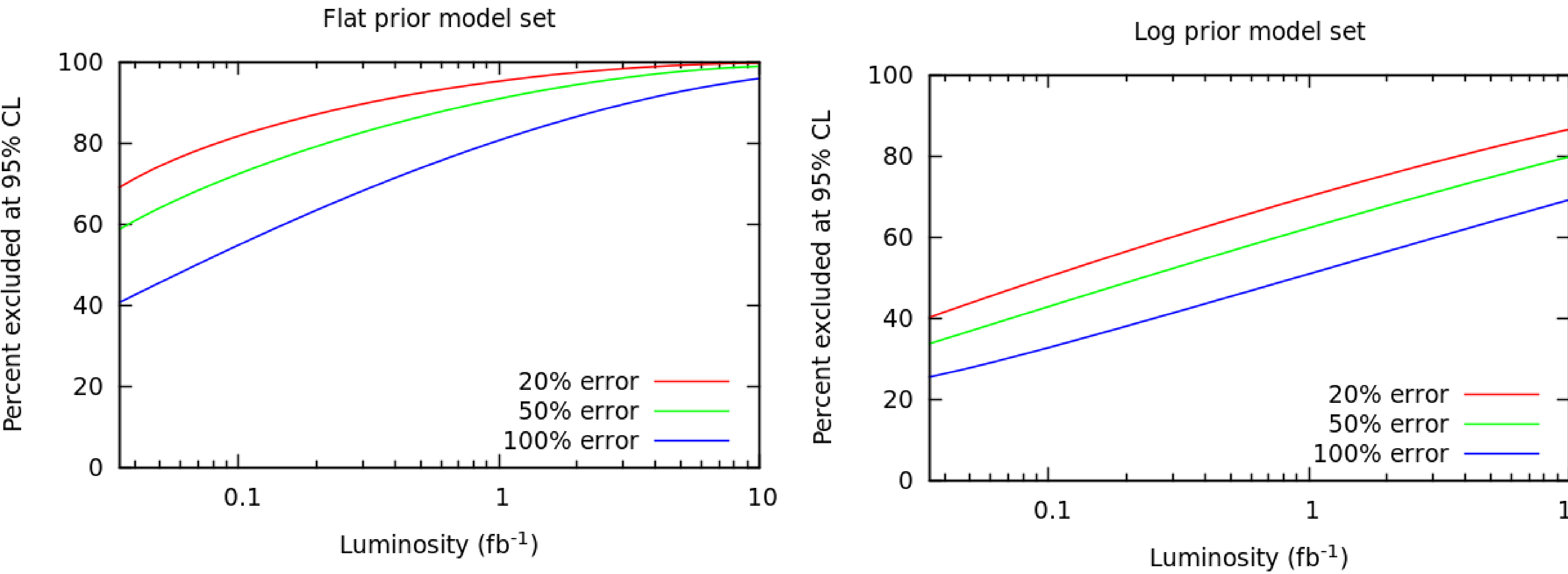


DR3-model

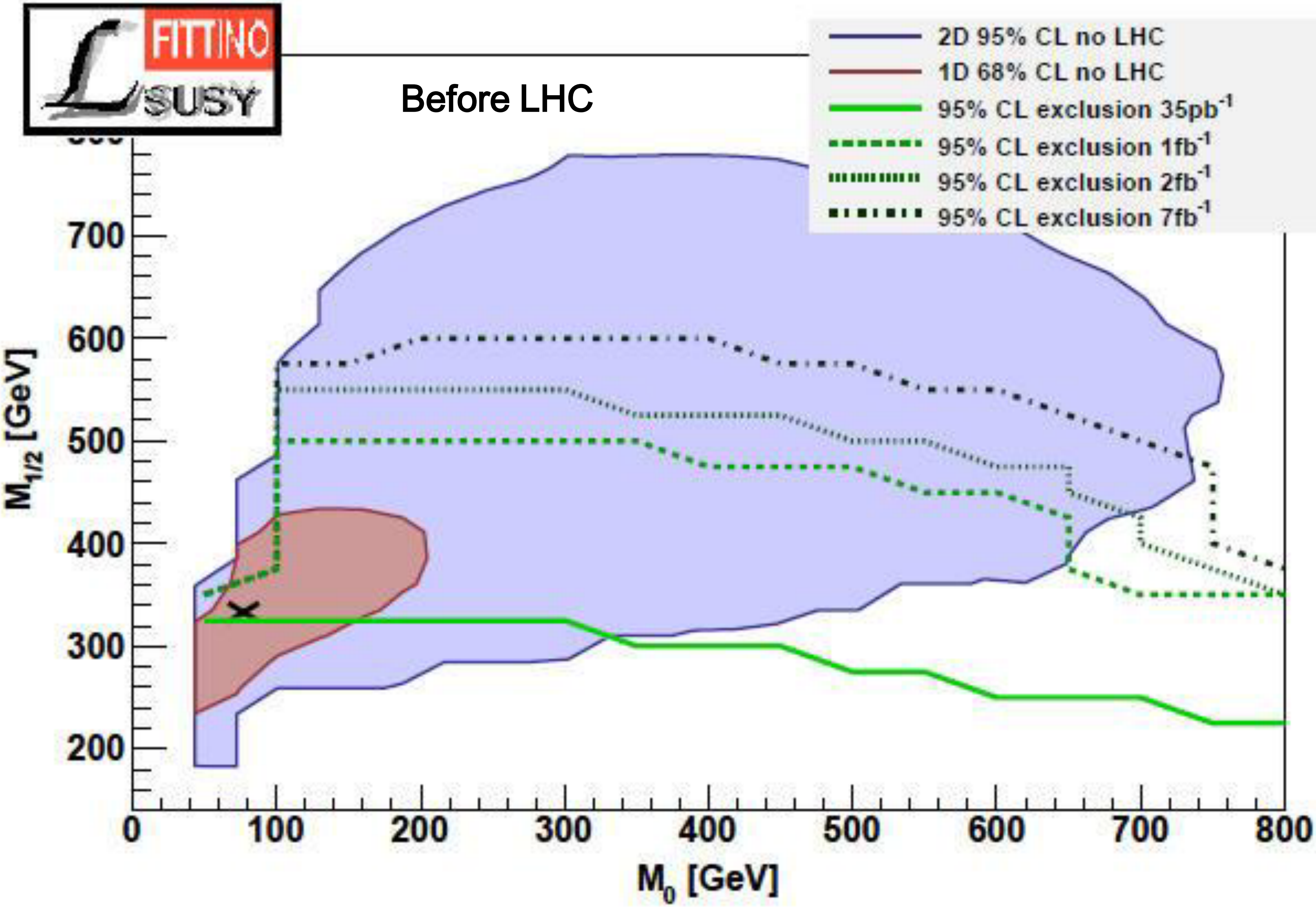
- **mSUGRA:** large tan β or low A_o values:
  - For each (m_o,$m_{1/2}$) sbottom/stop masses lower than in low tan β scenarios
  - **Exclude gluino masses up to 500 GeV for m_o < 1 TeV**
- **SO(10) models:** gluino pair production one of the dominant processes:
  - Gluino → $b\bar{b}\chi^o_1$ (DR3) or $b\bar{b}\chi^o_2$ (HS)
  - **Exclude masses up to 500(420) GeV**



R-hadron exclusion
CLs 95% C.L. limit
√s = 7 TeV
∫ L dt = 34 pb-1
Prediction g̃ (NLO)
Prediction q̃ (NLO)
Upper limit b̃
Upper limit g̃
Upper limit t̃
ATLAS
b̃
t̃
g̃
Cross-section [pb]
Mass [GeV]
10^5
10^4
10^3
10^2
10
1
10^-1
0
100
200
300
400
500
600
700
800

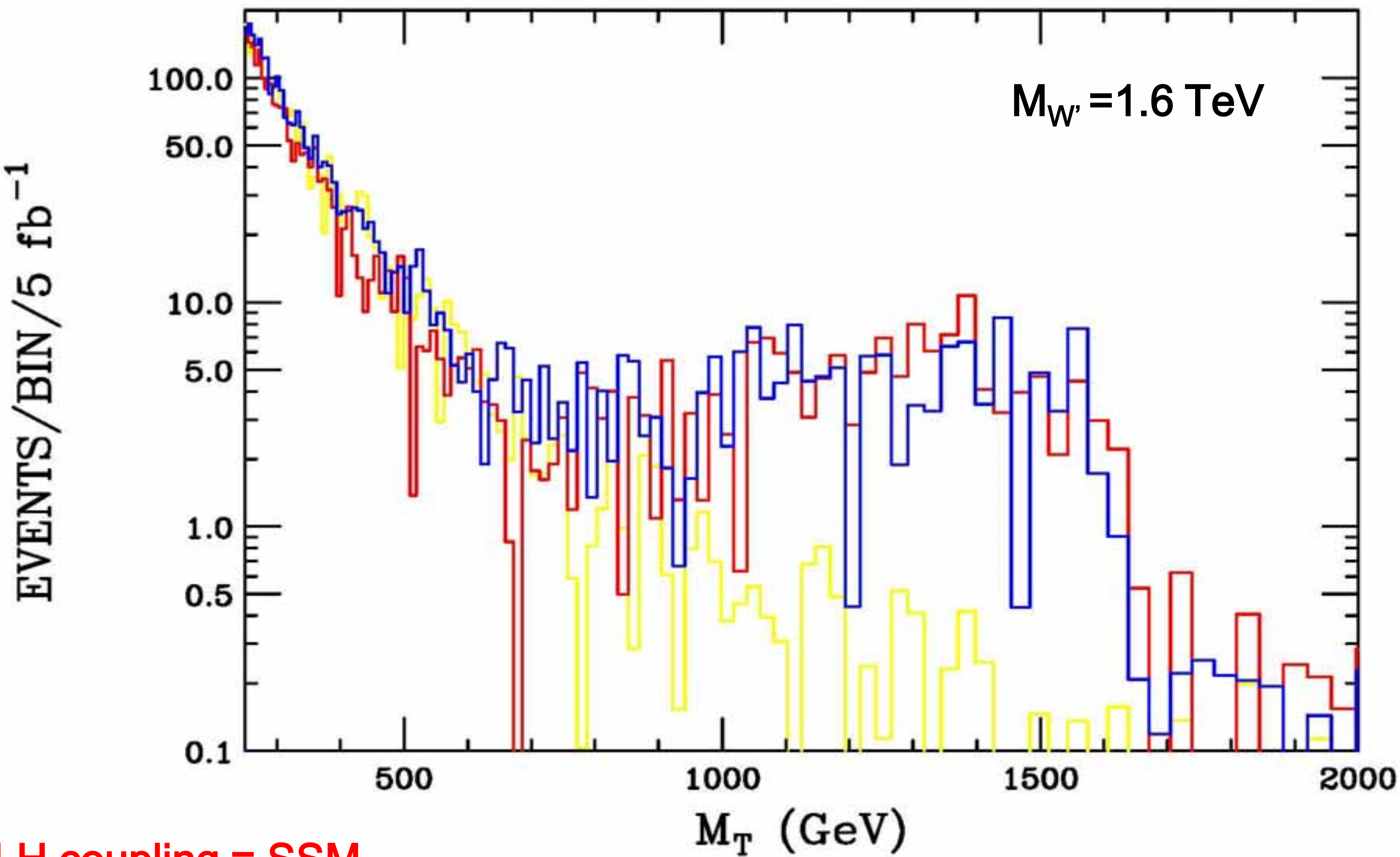


If we ask for the current 95% CL would-be EXCLUSION limits (assuming all these analyses were performed by ATLAS as stated..which they were not) then these model sets are even more constrained



FITTINO
SUSY
Before LHC
2D 95% CL no LHC
1D 68% CL no LHC
95% CL exclusion 35pb-1
95% CL exclusion 1fb-1
95% CL exclusion 2fb-1
95% CL exclusion 7fb-1
700
600
500
400
300
200
M1/2 [GeV]
0
100
200
300
400
500
600
700
800
M0 [GeV]

Note: W' production has some dependency on coupling helicity (& many other non-vanilla assumptions !)

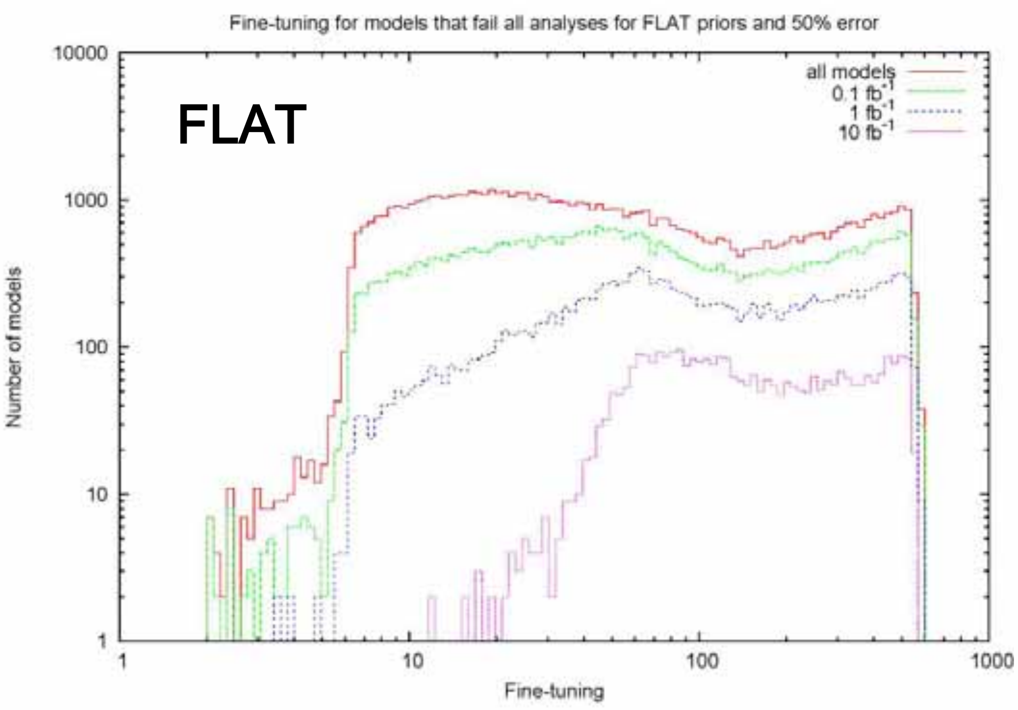


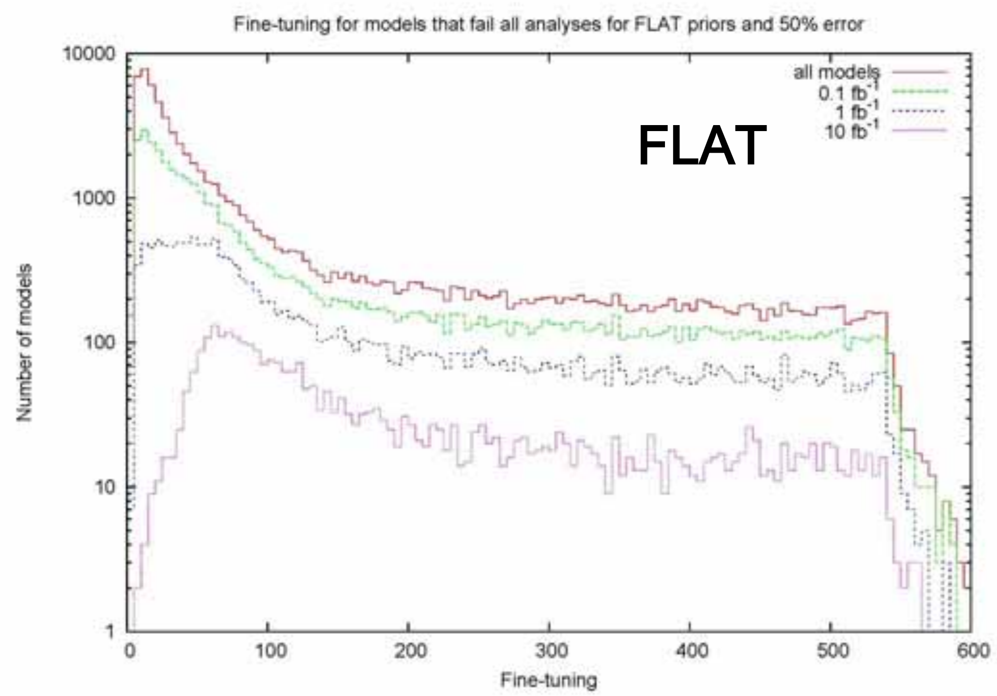
LH coupling = SSM
RH coupling = LRM
SM only

RH couplings do not interfere w/ the SM W !
LH couplings destructively interfere w/ SM

Fine-Tuning SUSY ?

- It is often claimed that if the LHC (@7 TeV) does not find anything then SUSY must be VERY fine-tuned & so ‘less likely’. Is this true for the pMSSM??





→ It is certainly true that models w/ low tuning do appear to 'suffer' more than those w/ larger values from null SUSY searches

• The amount of fine tuning in the LOG prior set is somewhat less influenced by null ATLAS searches due to spectrum differences