How Much SUSY Space is Left?

Comprehensive Study of a 19-parameter MSSM

J. Hewett, LCWS08

Is There Any Room Left for SUSY?

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IS HINCHLIFFE'S RULE TRUE?

Boris Peon

Abstract

Hinchliffe has asserted that whenever the title of a paper is a question with a yes/no answer, the answer is always no. This paper demonstrates that Hinchliffe's assertion is false, but only if it is true.

How Much SUSY Space is Right?

Comprehensive Study of a 19-parameter MSSM

J. Hewett, LCWS08

SLAC NATIONAL ACCELERATOR LABORATORY

Supersymmetry Without Prejudice

- The MSSM has ~140 parameters
- Studies/Searches incorporate simplified versions
  - Theoretical assumptions @ GUT scale
  - Assume specific SUSY breaking scenarios
  - Small number of well-studied benchmark points
- Studies incorporate various data sets

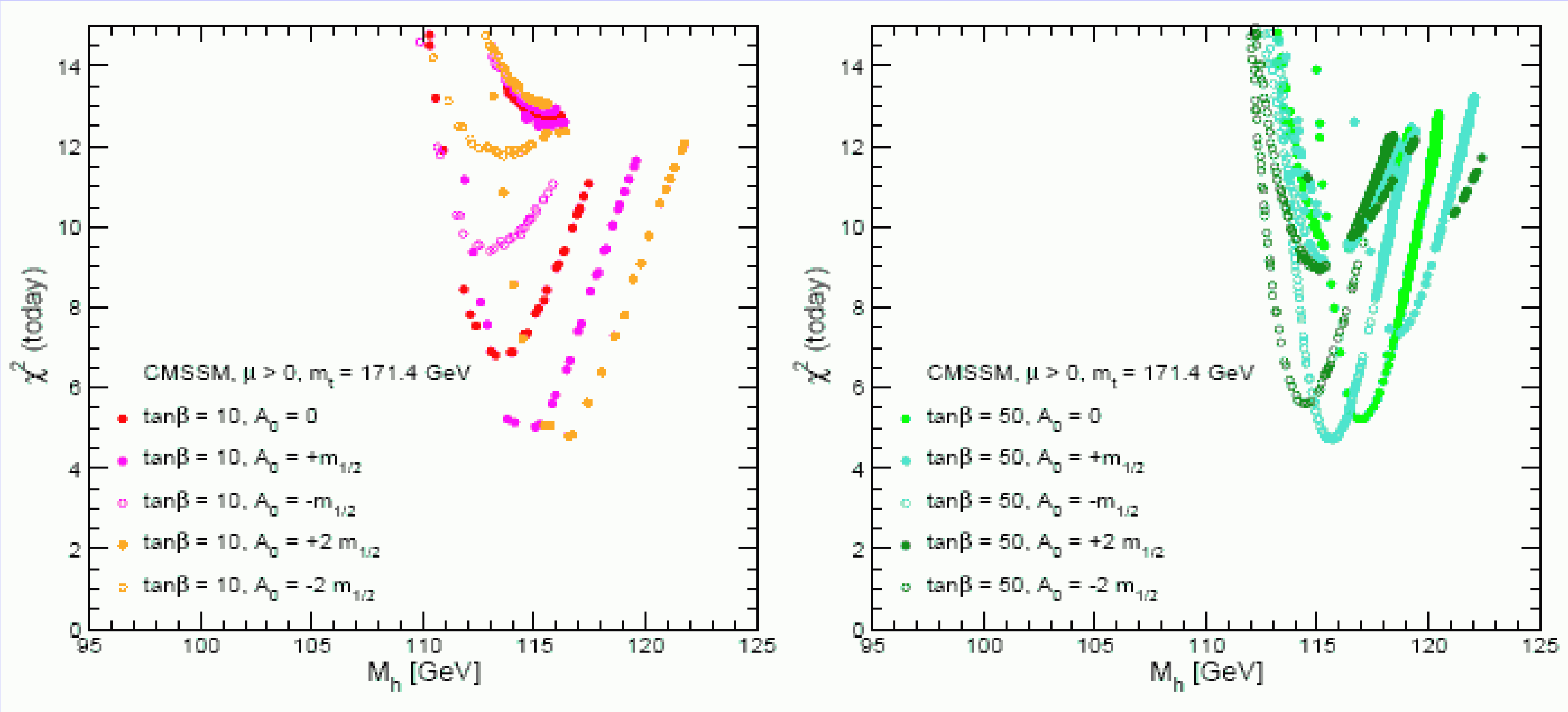
- Does this adequately describe the true breadth of the MSSM and all its possible signatures?

- The LHC is turning on, era of speculation will end, and we need to be ready for all possible signals
- Ready to determine underlying physics from LHC data and provide physics case for a Linear Collider

Most Analyses Assume CMSSM Framework

- CMSSM: m_0, $m_{1/2}$, A_0, tanβ, sign μ
- X^2 fit to some global data set

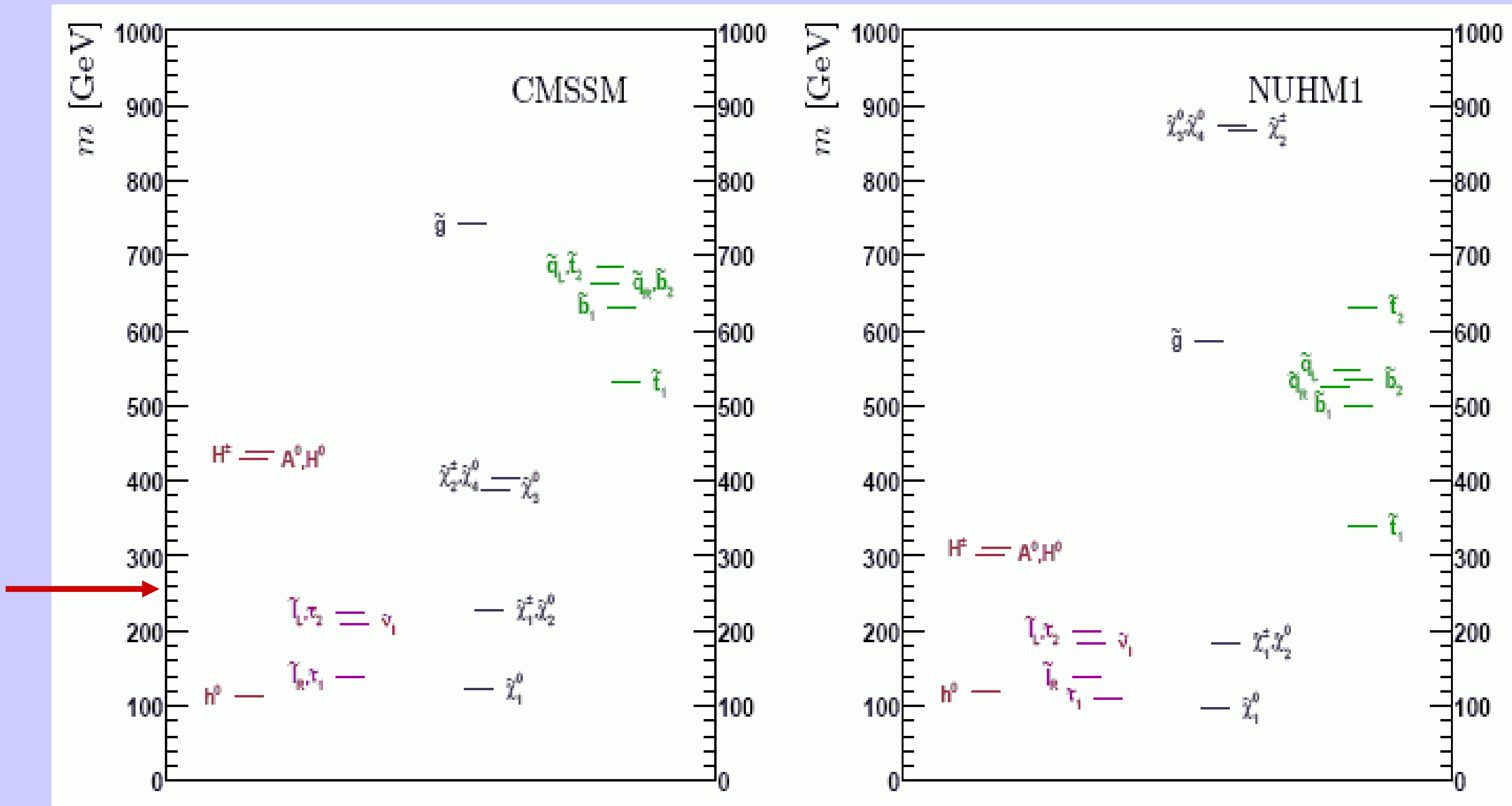
Prediction for Lightest Higgs Mass
Fit to EW precision, B-physics observables, & WMAP



Ellis etal arXiv:0706.0652

Spectrum for Best Fit CMSSM/NUHM Point

NUHM includes two more parameters: M_A, μ

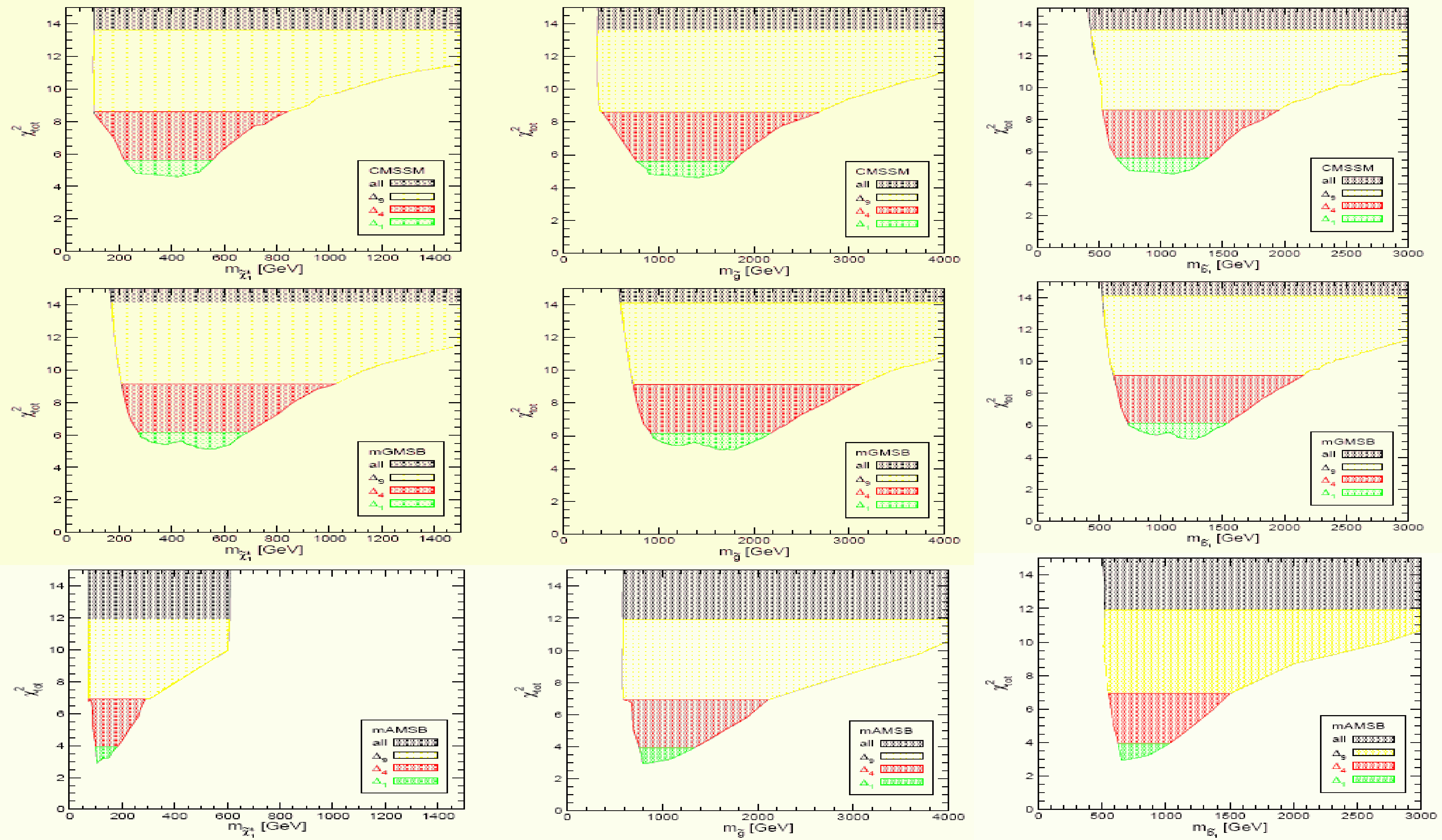


Buchmuller etal arXiv:0808.4128

Comparison of CMSSM to GMSB & AMSB

Heinemeyer etal arXiv:0805.2359

Lightest Chargino | Gluino | Lightest Sbottom

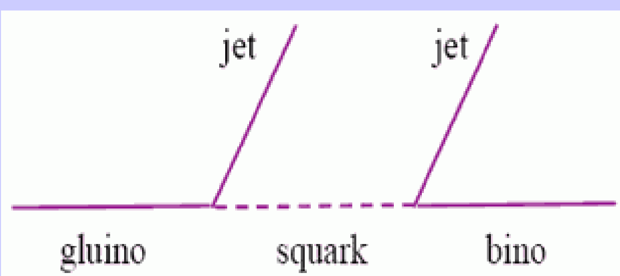


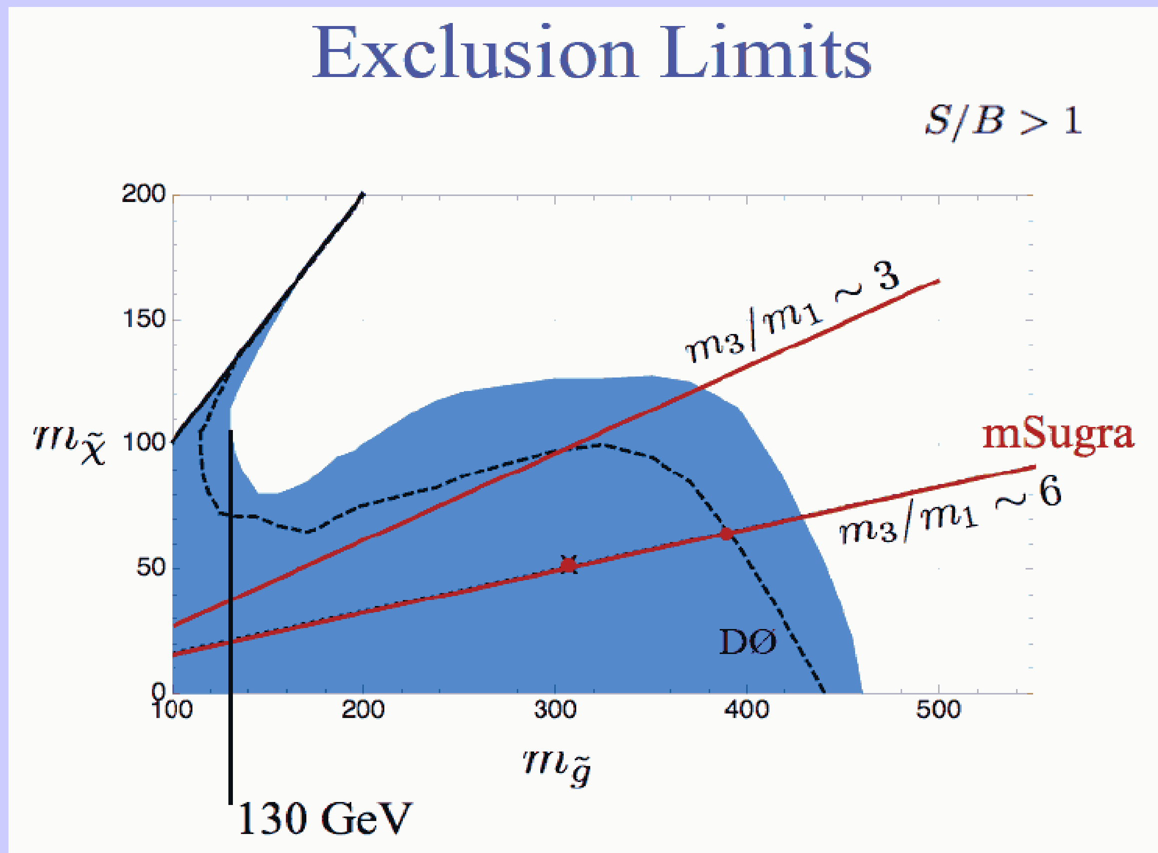
Gluinos at the Tevatron

Alwall, Le, Lisanti, Wacker arXiv:0803.0019

- Tevatron gluino/squark analyses performed solely for mSUGRA – constant ratio $m_{gluino} : m_{Bino} \simeq 6 : 1$

Gluino-Bino mass ratio determines kinematics





Comprehensive MSSM Analysis

Berger, Gainer, JLH, Rizzo, arXiv:0811.xxxx

- Study Most general CP-conserving MSSM
  - Minimal Flavor Violation
  - Lightest neutralino is the LSP
  - First 2 sfermion generations are degenerate w/ negligible Yukawas
  - No GUT, SUSY-breaking assumptions

- ⇒ pMSSM: 19 real, weak-scale parameters

  scalars:

  $m_{Q_1}, m_{Q_3}, m_{u_1}, m_{d_1}, m_{u_3}, m_{d_3}, m_{L_1}, m_{L_3}, m_{e_1}, m_{e_3}$

  gauginos: M_1, M_2, M_3

  tri-linear couplings: A_b, A_t, A_τ

  Higgs/Higgsino: $\mu, M_A, \tan\beta$

Perform 2 Random Scans

Linear Priors

10^7 points – emphasize 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

$2\text{x}10^6$ points – emphasize lower masses and extend to higher masses

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

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

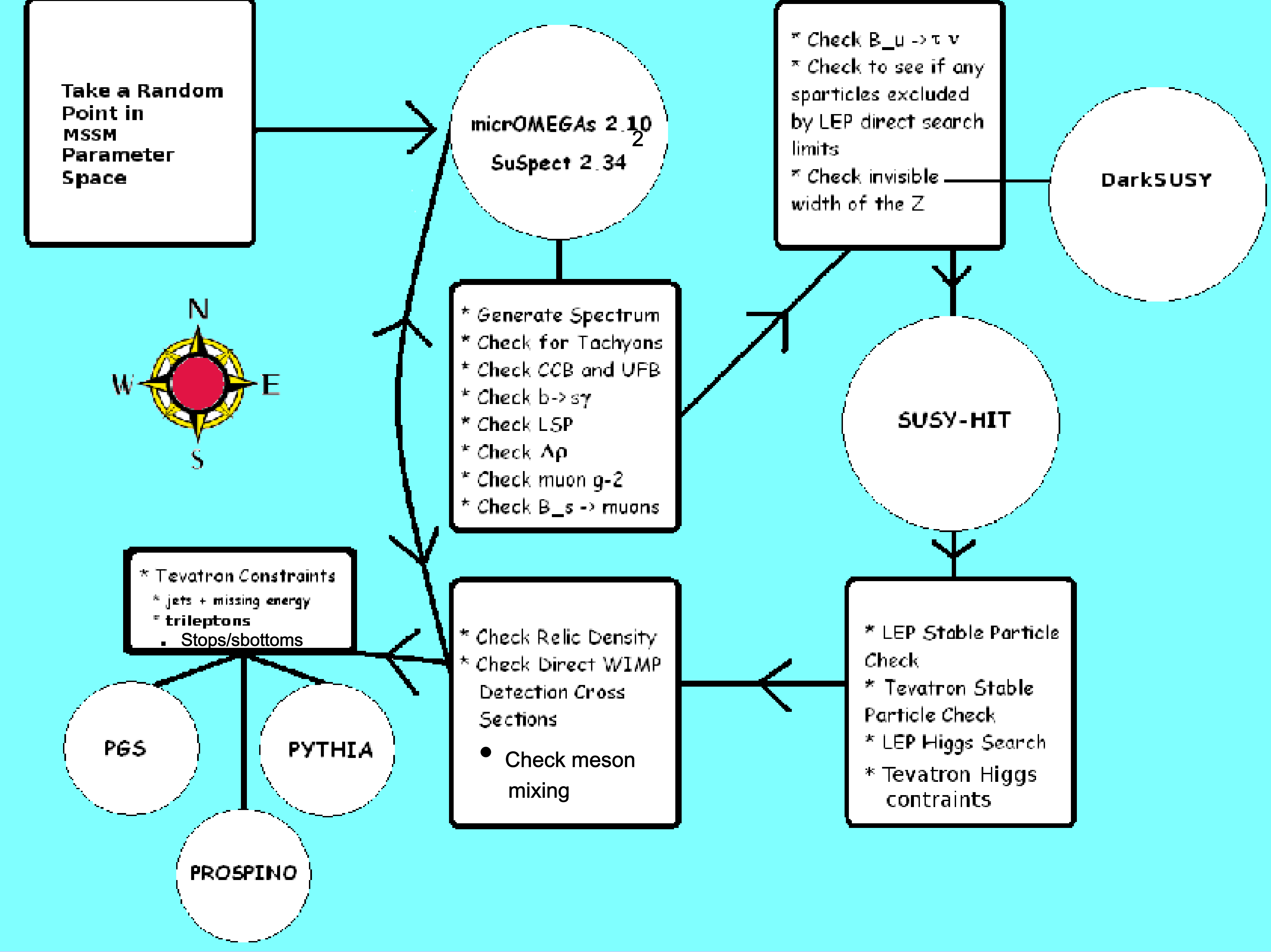
$100\ \text{GeV} \leq M_3 \leq 3\ \text{TeV}$

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

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

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

Absolute values account for possible phases
only Arg ($M_i\ \mu$) and Arg ($A_f\ \mu$) are physical


Take a Random Point in MSSM Parameter Space
micrOMEGAs 2.10
2
SuSpect 2.34
* Check B_u -> τ ν
* Check to see if any sparticles excluded by LEP direct search limits
* Check invisible width of the Z
DarkSUSY
N
W
E
S
* Generate Spectrum
* Check for Tachyons
* Check CCB and UFB
* Check b->sγ
* Check LSP
* Check Δρ
* Check muon g-2
* Check B_s -> muons
SUSY-HIT
* Tevatron Constraints
* jets + missing energy
* trileptons
Stops/sbottoms
* Check Relic Density
* Check Direct WIMP Detection Cross Sections
Check meson mixing
* LEP Stable Particle Check
* Tevatron Stable Particle Check
* LEP Higgs Search
* Tevatron Higgs contraints
PGS
PYTHIA
PROSPINO

Set of Experimental Constraints

- Theoretical spectrum Requirements (no tachyons, etc)
- Precision measurements:
  - $\Delta\rho$, $\Gamma(Z \to$ invisible$)$
  - $\Delta(g-2)_\mu$??? $(30.2 \pm 8.8) \times 10^{-10}$ (0809.4062)

    $(29.5 \pm 7.9) \times 10^{-10}$ (0809.3085)

    $\to$ $(-10$ to $40) \times 10^{-10}$ to be conservative..

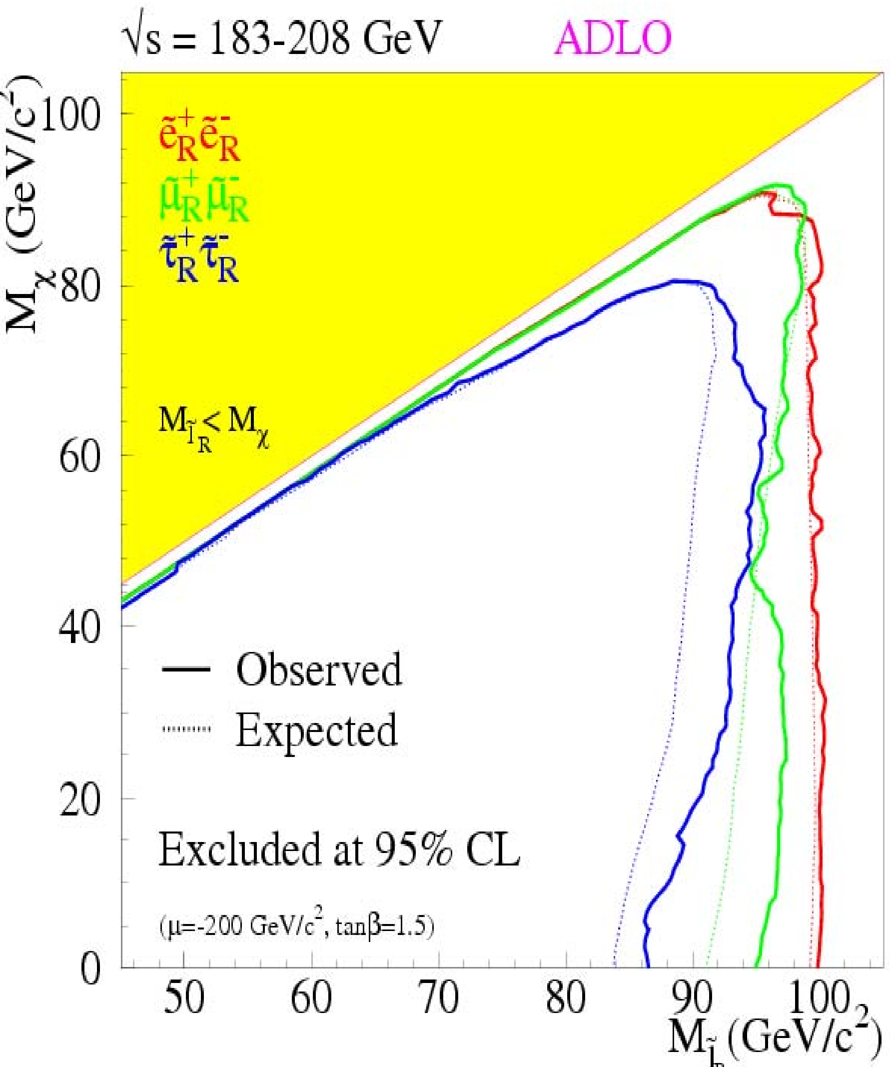
- Flavor Physics
  - $b \to s\,\gamma$, $B \to \tau\nu$, $B_s \to \mu\mu$
  - Meson-Antimeson Mixing : Constrains 1st/3rd sfermion mass ratios to be < 5 in MFV context

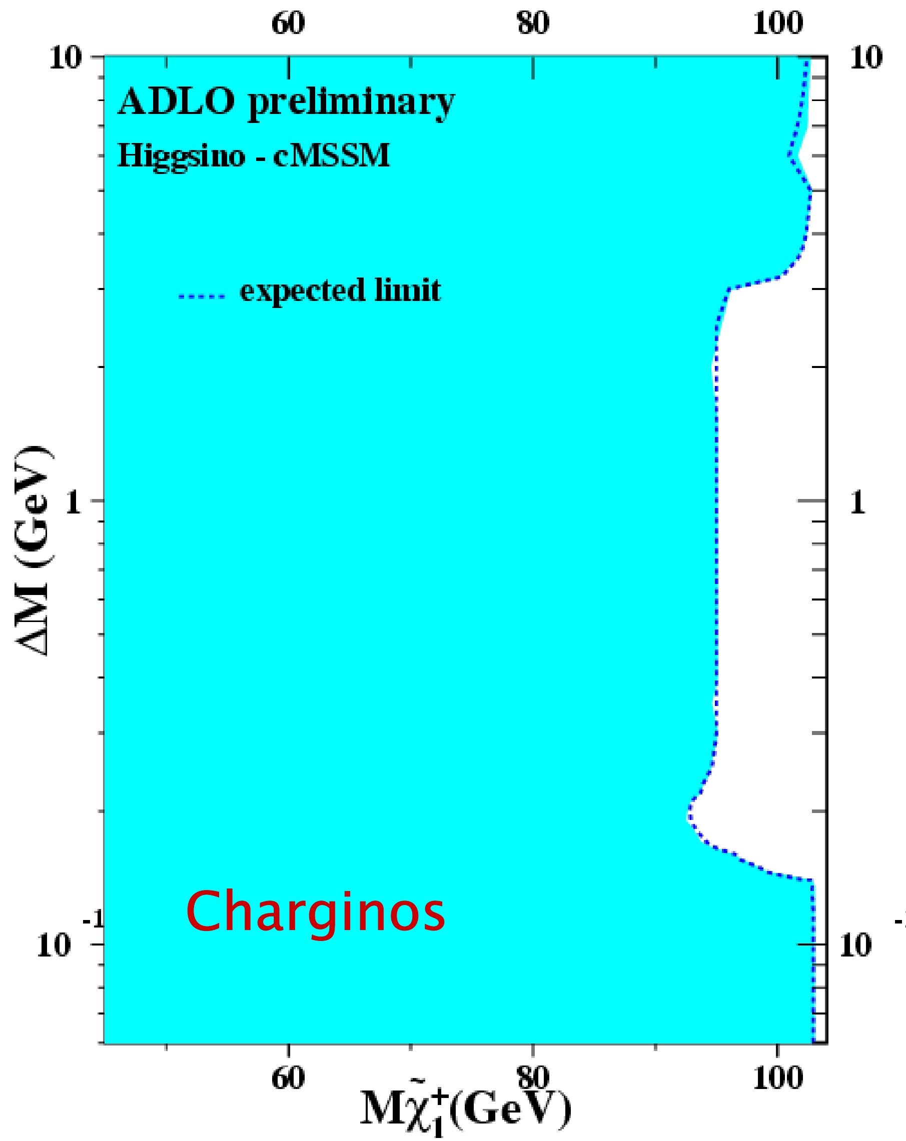
Set of Experimental Constraints Cont.

- Dark Matter
  - Direct Searches: CDMS, XENON10, DAMA, CRESST I
  - Relic density: $\Omega h2 < 0.1210 \rightarrow$ 5yr WMAP data
- Collider Searches: complicated with many caveats!
  - LEPII: Neutral & Charged Higgs searches
    Sparticle production
    Stable charged particles
  - Tevatron: Squark & gluino searches
    Trilepton search
    Stable charged particles
    BSM Higgs searches

Slepton & Chargino Searches at LEPII

Sleptons





Charginos

Tevatron Squark & Gluino Search

2,3,4 Jets + Missing Energy (D0)

TABLE I: Selection criteria for the three analyses (all energies and momenta in GeV); see the text for further details.

Preselection Cut	All Analyses		
$\not{E}_T$	≥ 40		
|Vertex z pos.|	< 60 cm		
Acoplanarity	$< 165°$		
Selection Cut	"dijet"	"3-jets"	"gluino"
Trigger	dijet	multijet	multijet
jet$_1$ p_T [a]	≥ 35	≥ 35	≥ 35
jet$_2$ p_T [a]	≥ 35	≥ 35	≥ 35
jet$_3$ p_T [b]	–	≥ 35	≥ 35
jet$_4$ p_T [b]	–	–	≥ 20
Electron veto	yes	yes	yes
Muon veto	yes	yes	yes
$\Delta\phi(\not{E}_T, \text{jet}_1)$	$\geq 90°$	$\geq 90°$	$\geq 90°$
$\Delta\phi(\not{E}_T, \text{jet}_2)$	$\geq 50°$	$\geq 50°$	$\geq 50°$
$\Delta\phi_{\min}(\not{E}_T, \text{any jet})$	$\geq 40°$	–	–
H_T	≥ 325	≥ 375	≥ 400
$\not{E}_T$	≥ 225	≥ 175	≥ 100

[a] First and second jets are also required to be central ($|\eta_{\det}| < 0.8$), with an electromagnetic fraction below 0.95, and to have CPF0 ≥ 0.75.

[b] Third and fourth jets are required to have $|\eta_{\det}| < 2.5$, with an electromagnetic fraction below 0.95.

Multiple analyses keyed to look for:

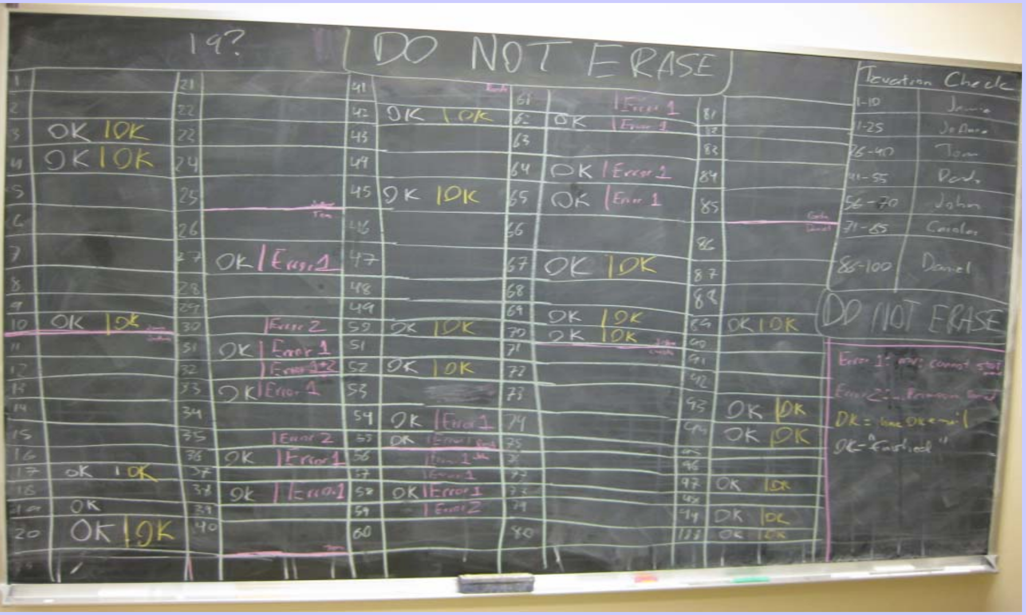
Squarks-> jet +MET

Gluinos -> 2 j + MET

Feldman-Cousins 95% CL
Signal limit: 8.34 events

For each model in our scan we run SuSpect -> SUSY-Hit -> PROSPINO -> PYTHIA -> D0-tuned PGS4 fast simulation and compare to the data

Survival Statistics



- Flat Priors:
  - 10^7 models scanned
  - 68.5K (0.68%) survive
- Log Priors:
  - 2 x10^6 models scanned
  - 3.0k (0.15%) survive

9999039	slha-okay.txt
7729165	error-okay.txt
3270330	lsp-okay.txt
3261059	deltaRho-okay.txt
2168599	gMinus2-okay.txt
617413	b2sGamma-okay.txt
594803	Bs2MuMu-okay.txt
592195	vacuum-okay.txt
582787	Bu2TauNu-okay.txt
471786	LEP-sparticle-okay.txt
471455	invisibleWidth-okay.txt
468539	susyhitProb-okay.txt
418503	stableParticle-okay.txt
418503	chargedHiggs-okay.txt
132877	directDetection-okay.txt
83662	neutralHiggs-okay.txt
73868	omega-okay.txt
73575	Bs2MuMu-2-okay.txt
72168	stableChargino-2-okay.txt
71976	triLepton-okay.txt
69518	jetMissing-okay.txt
68494	final-okay.txt

Fate of Benchmark Points!

ATLAS

SU1	OK
SU2	killed by LEP
SU3	killed by Ωh^2
SU4	killed by $b \rightarrow s\gamma$
SU8	killed by g-2

CMS

LM1	killed by Higgs
LM2	killed by g-2
LM3	killed by $b \rightarrow s\gamma$
LM4	killed by Ωh^2
LM5	killed by Ωh^2
LM6	OK
LM7	killed by LEP
LM8	killed by Ωh^2
LM9	killed by LEP
LM10	OK
HM2	killed by Ωh^2
HM3	killed by Ωh^2
HM4	killed by Ωh^2

Most well-studied models do not survive confrontation with the latest data.

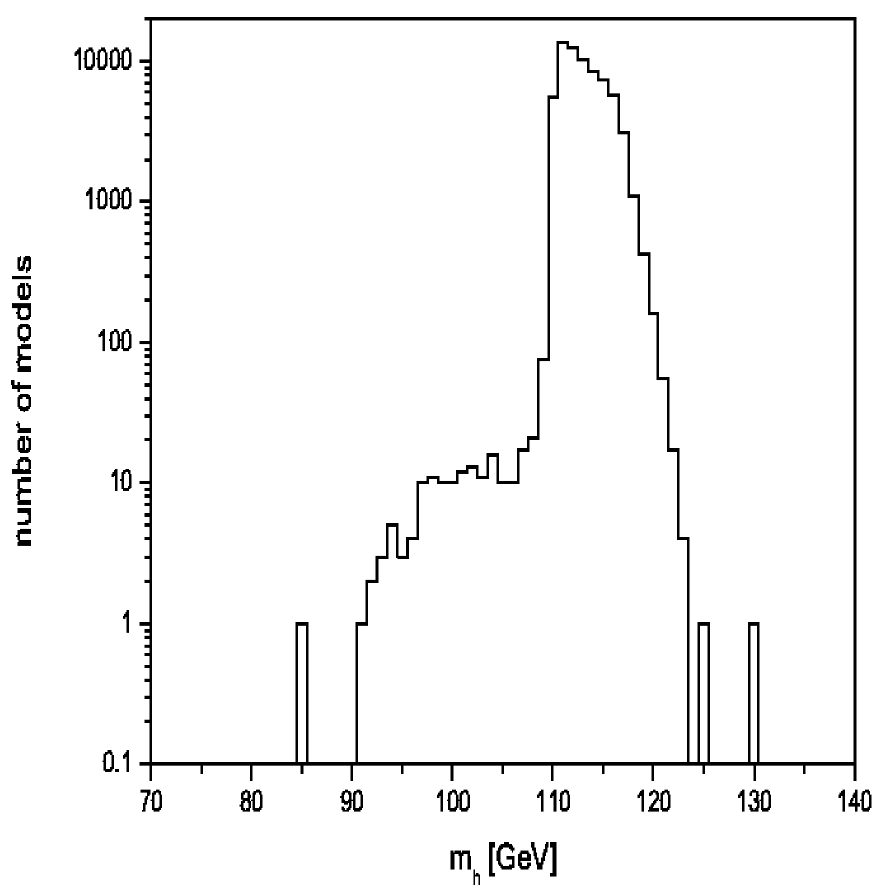
For many models this is not the unique source of failure

Similarly for the SPS Points

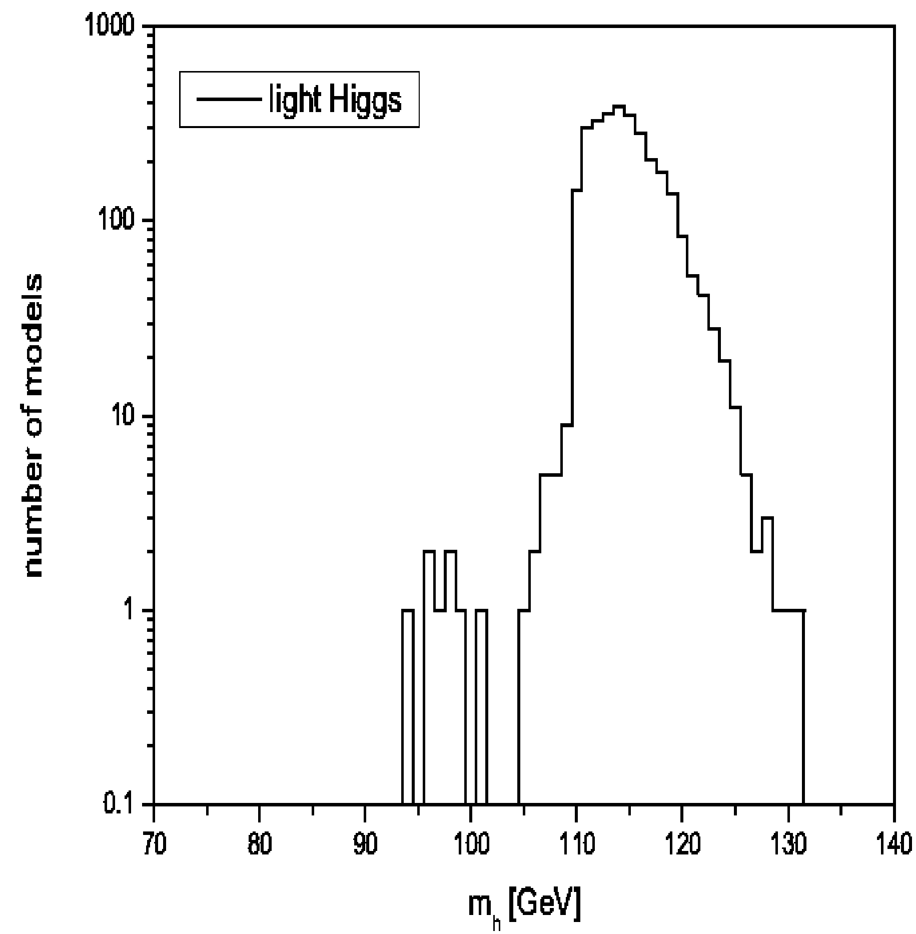
SPS1a	killed by b $\rightarrow s\gamma$
SPS1a'	OK
SPS1b	killed by b $\rightarrow s\gamma$
SPS2	killed by Ωh^2 (GUT) / OK(low)
SPS3	killed by Ωh^2 (low) / OK(GUT)
SPS4	killed by g-2
SPS5	killed by Ωh^2
SPS6	OK
SPS9	killed by Tevatron stable chargino

Predictions for Lightest Higgs Mass

Flat Priors

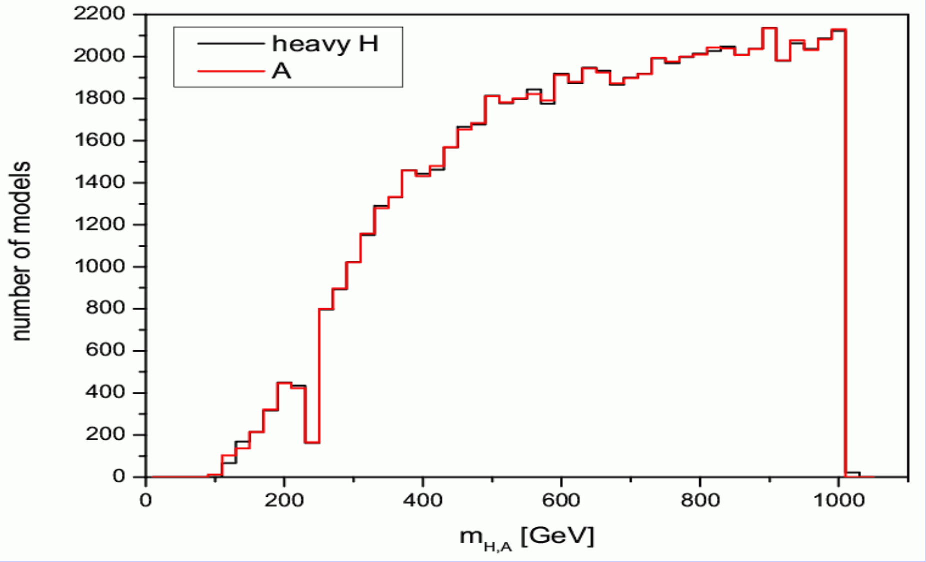


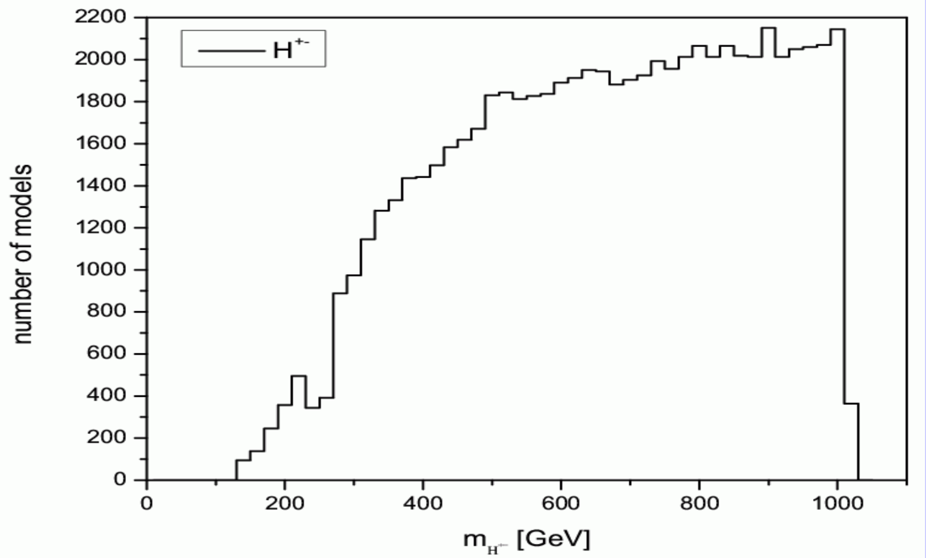
Log Priors



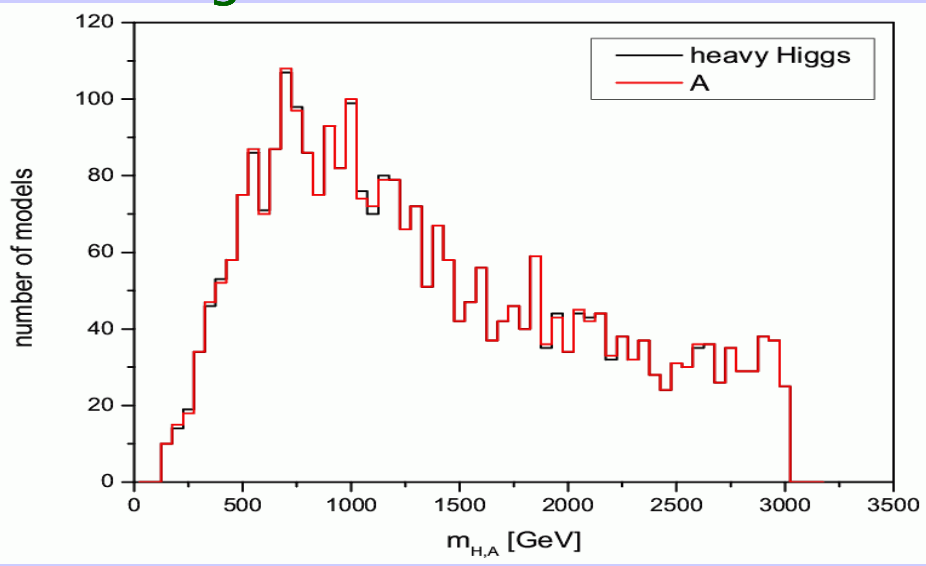
Predictions for Heavy & Charged Higgs

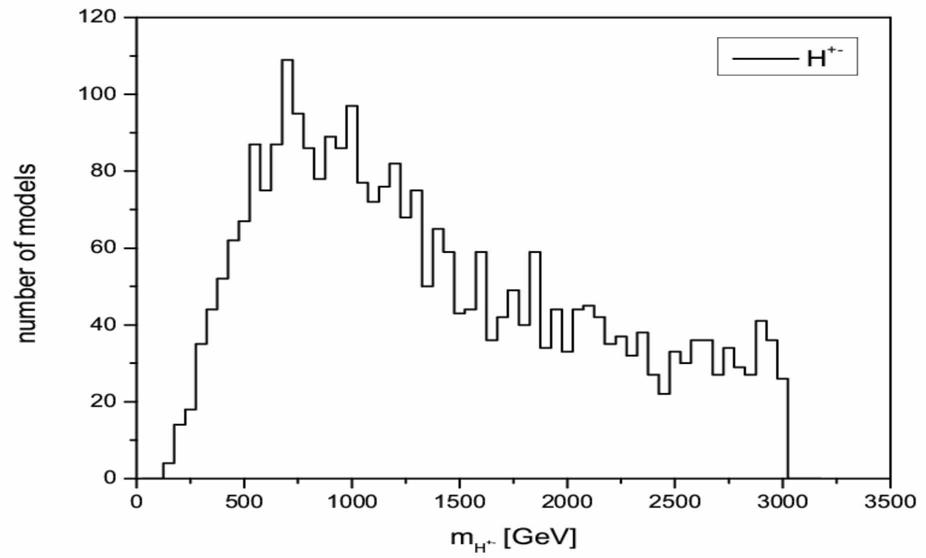
Flat Priors



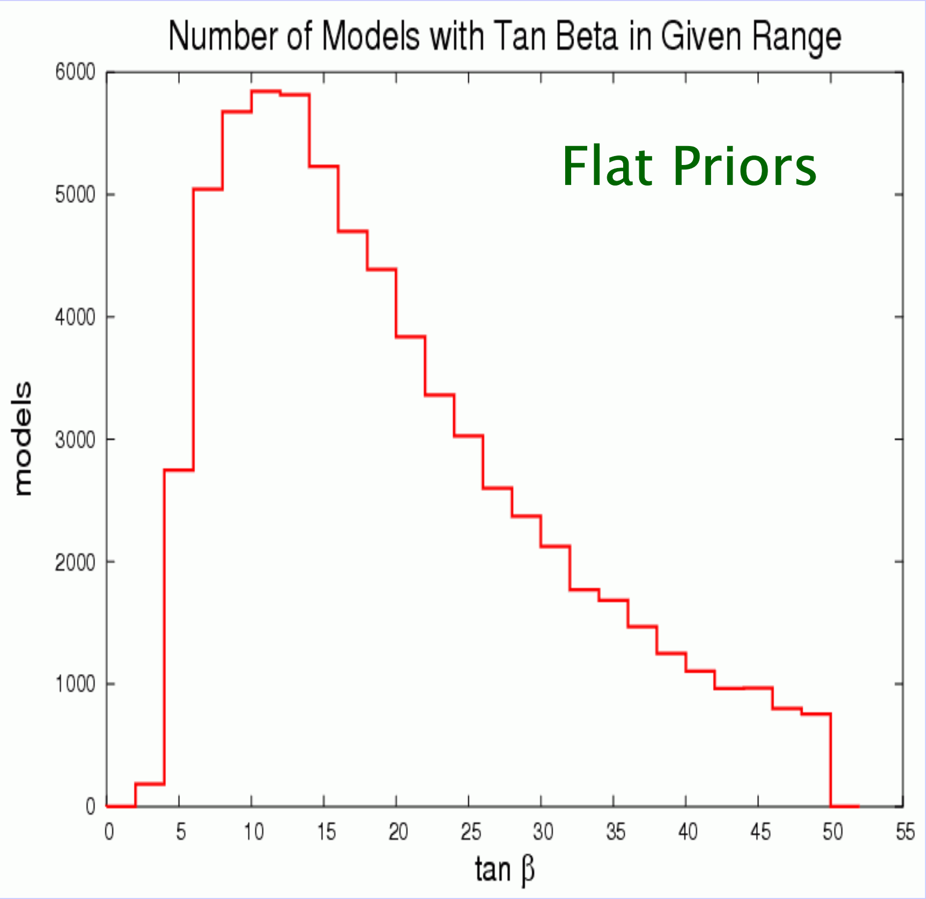


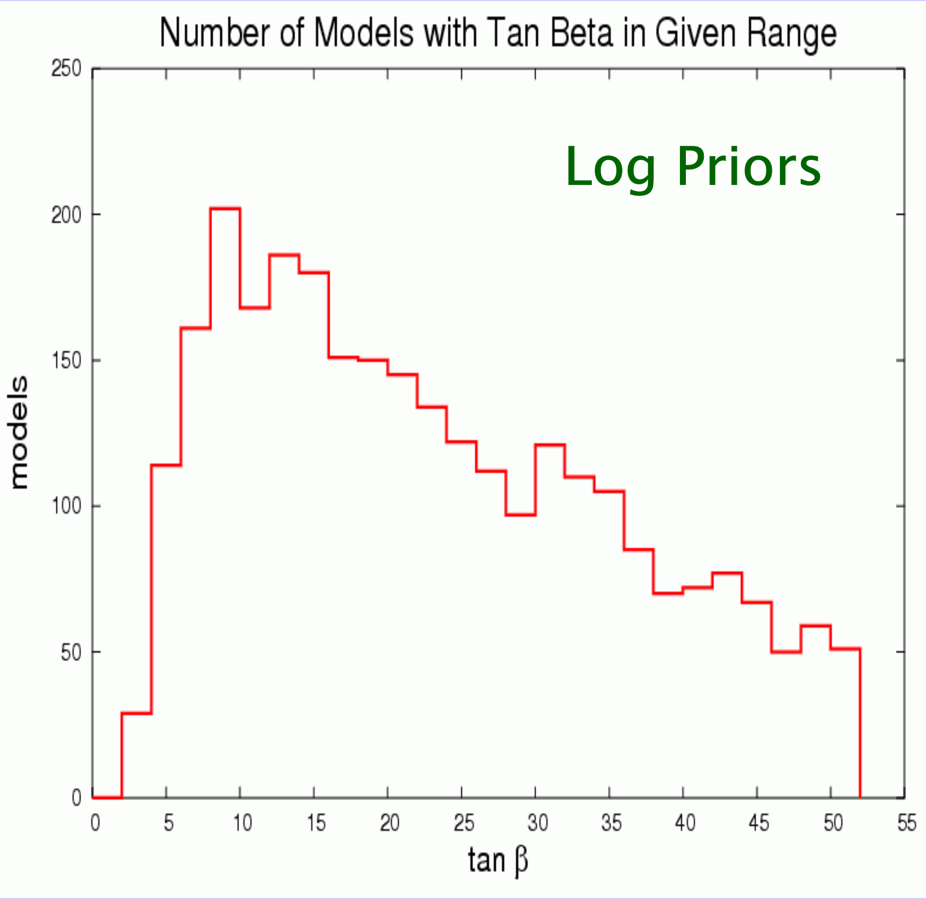
Log Priors





Distribution for tan beta

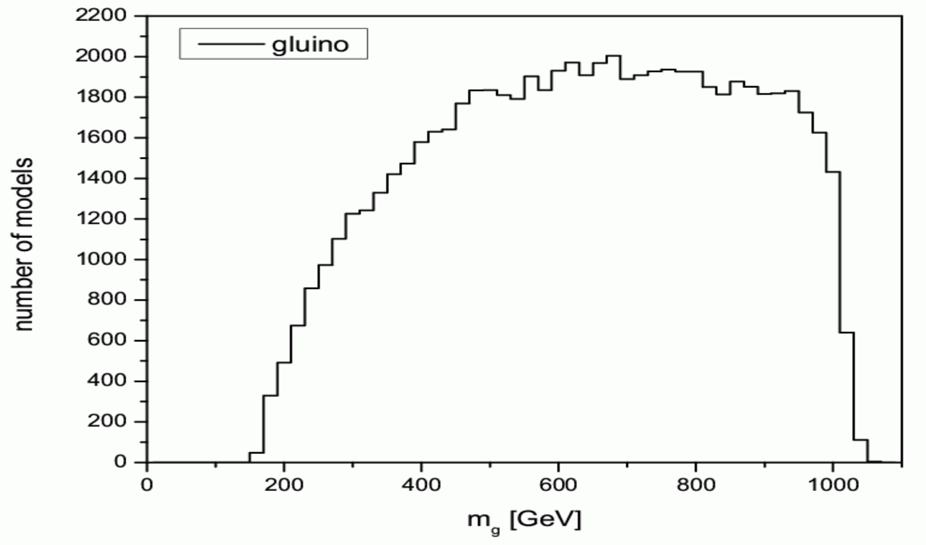


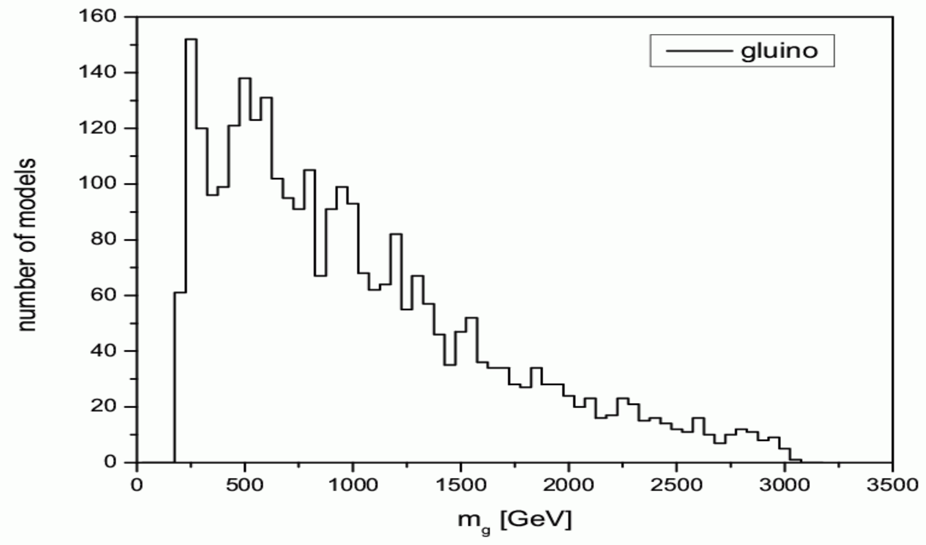


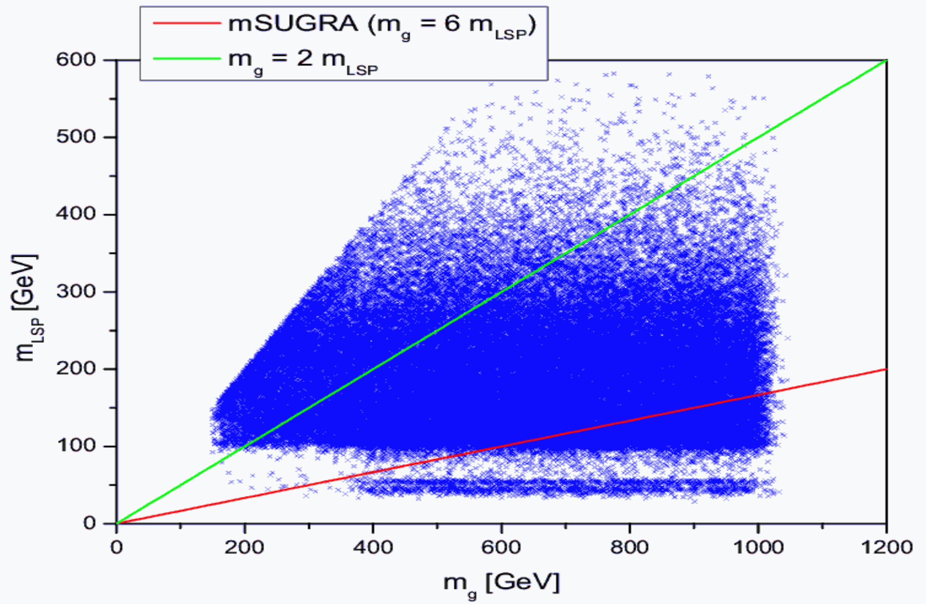
Distribution of Gluino Masses

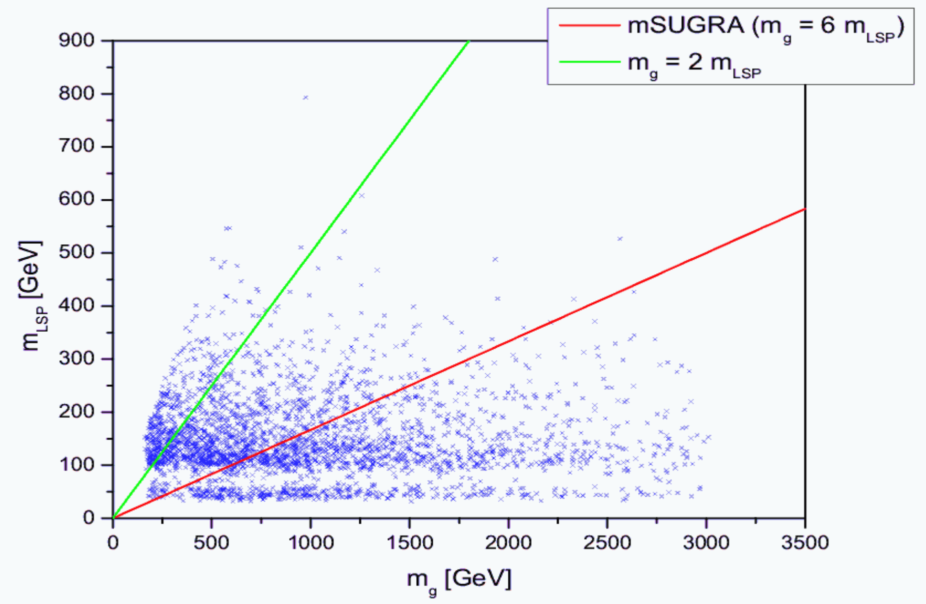
Flat Priors

Log Priors

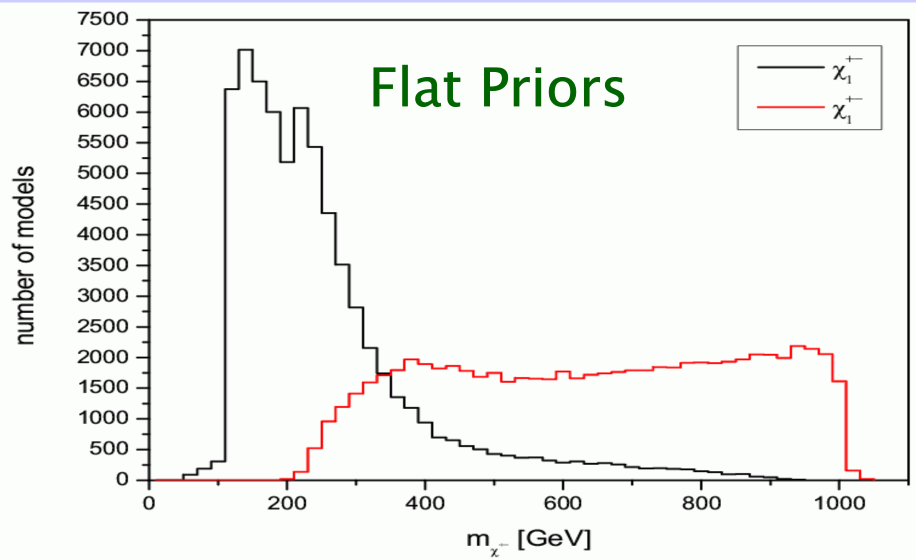


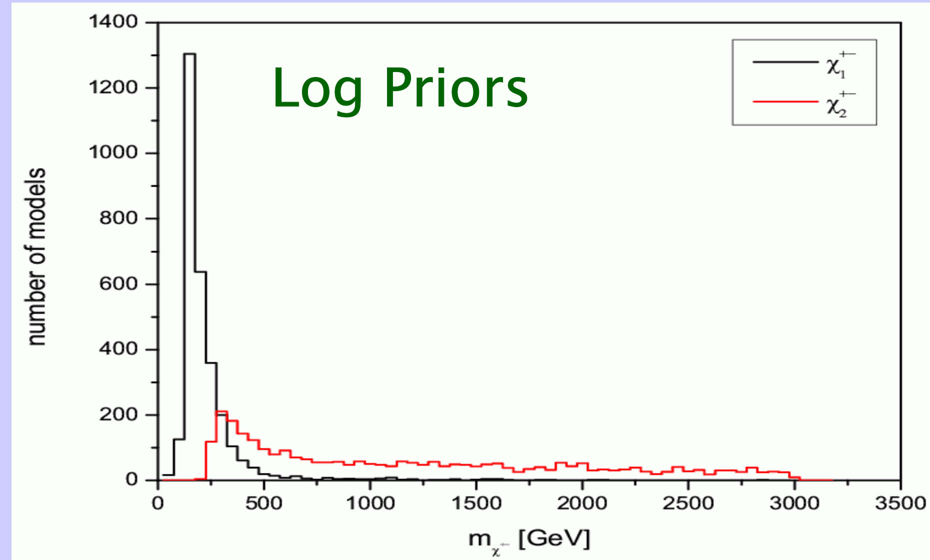


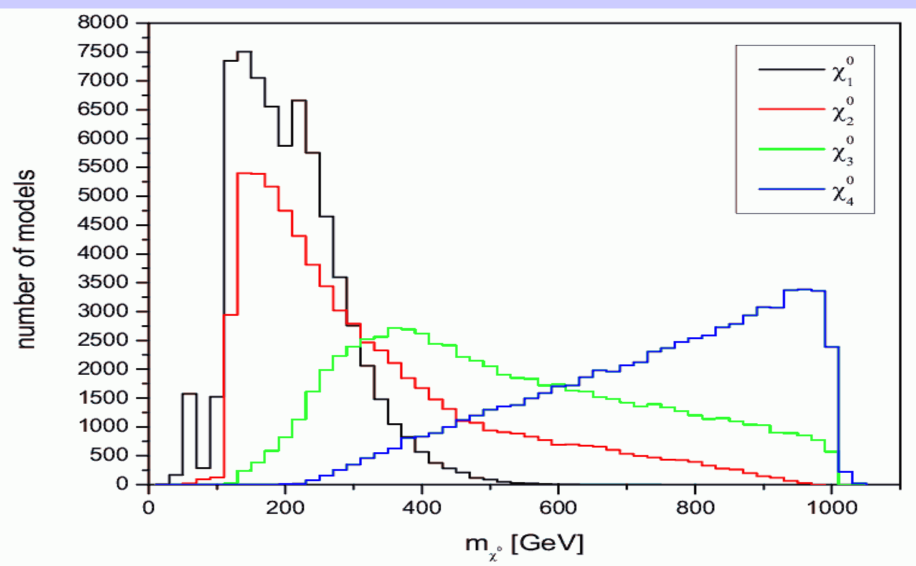


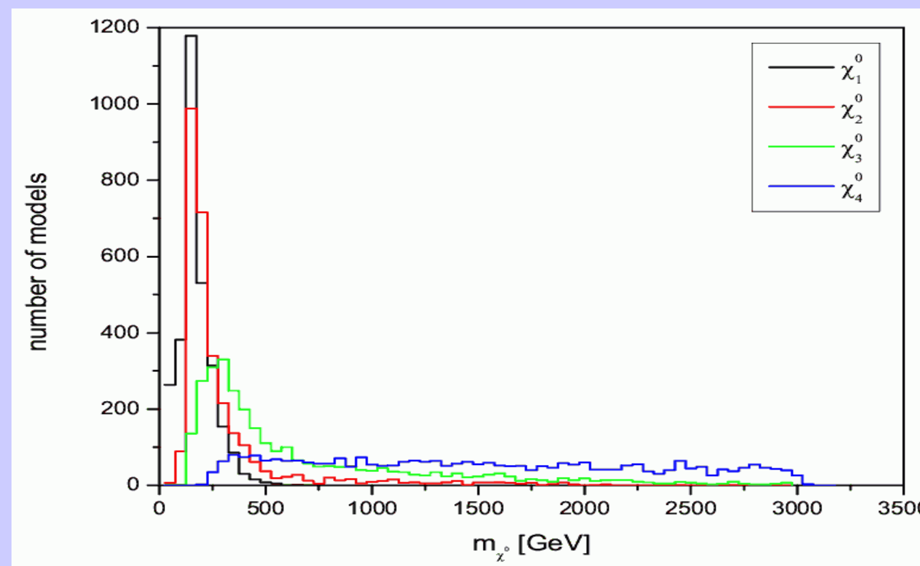


Distributions for EW Gaugino Masses

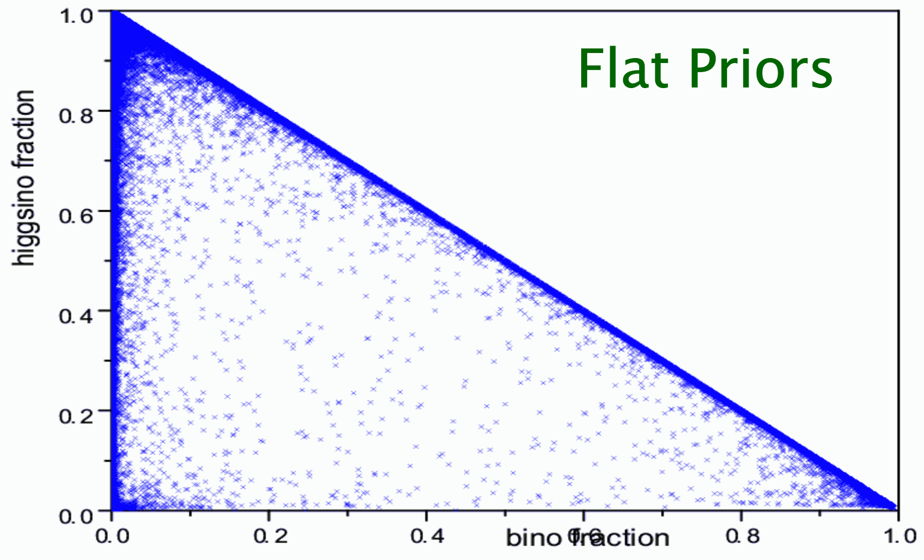


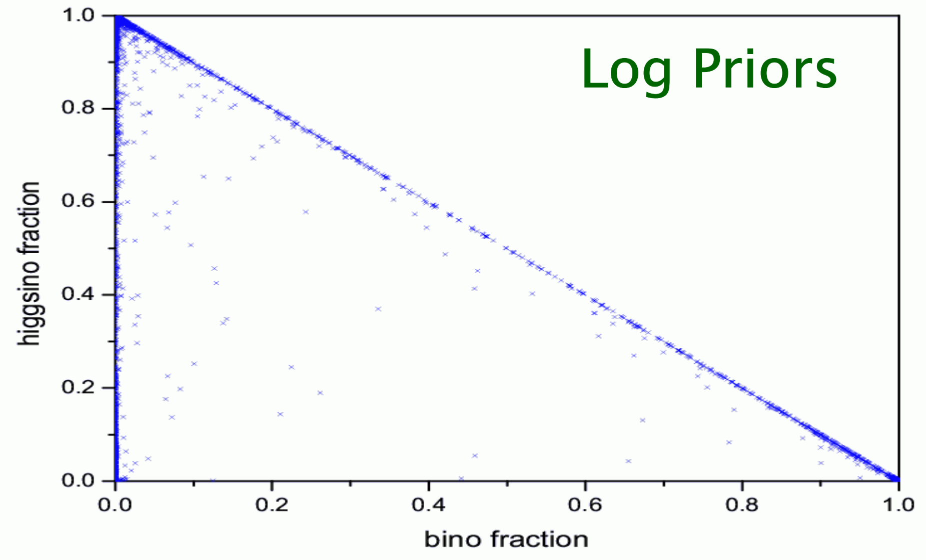


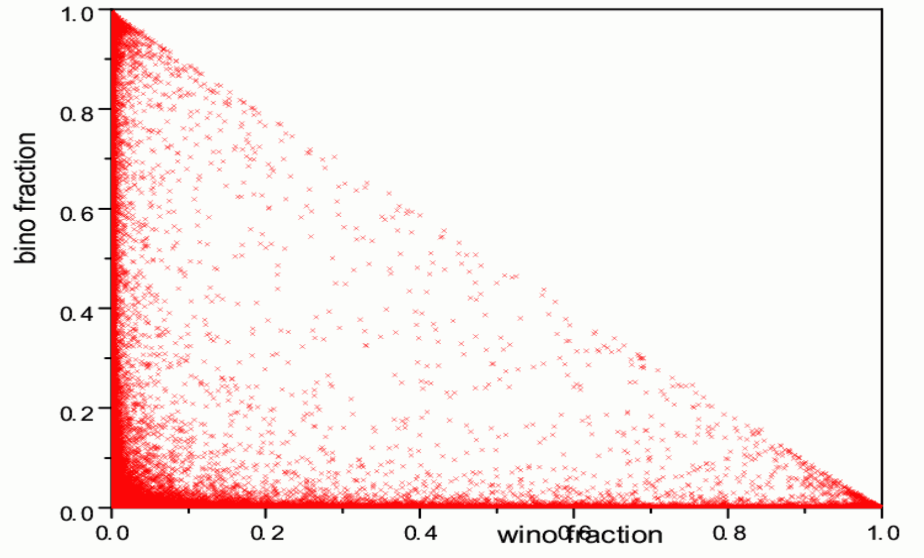


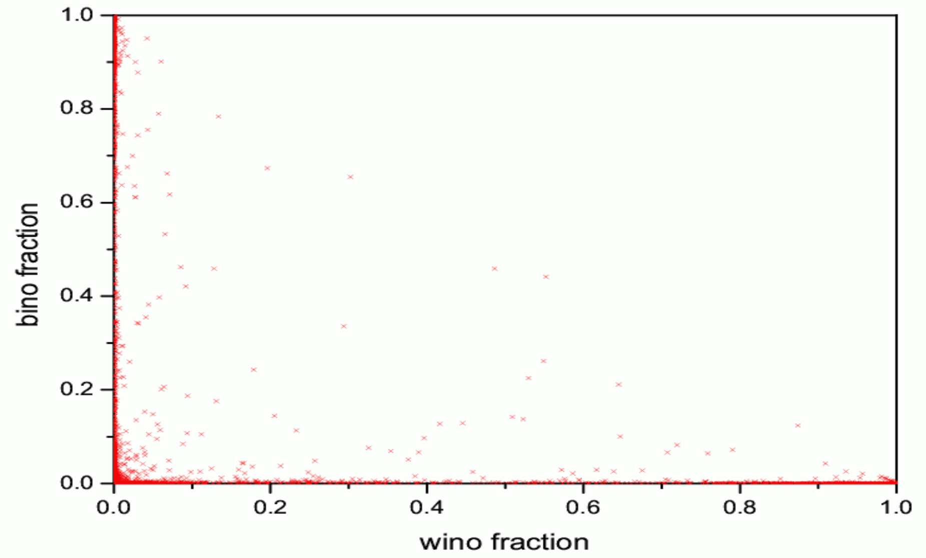


Composition of the LSP





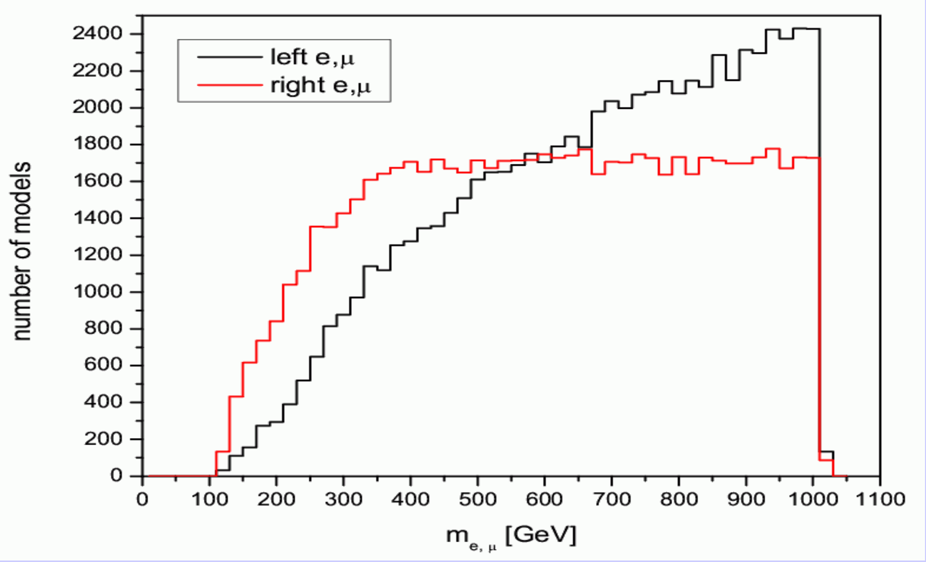


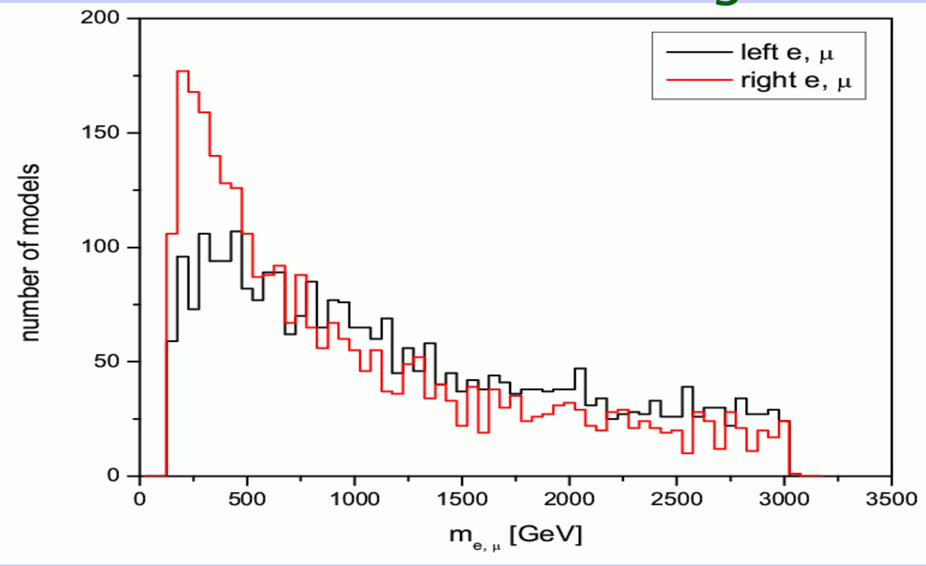


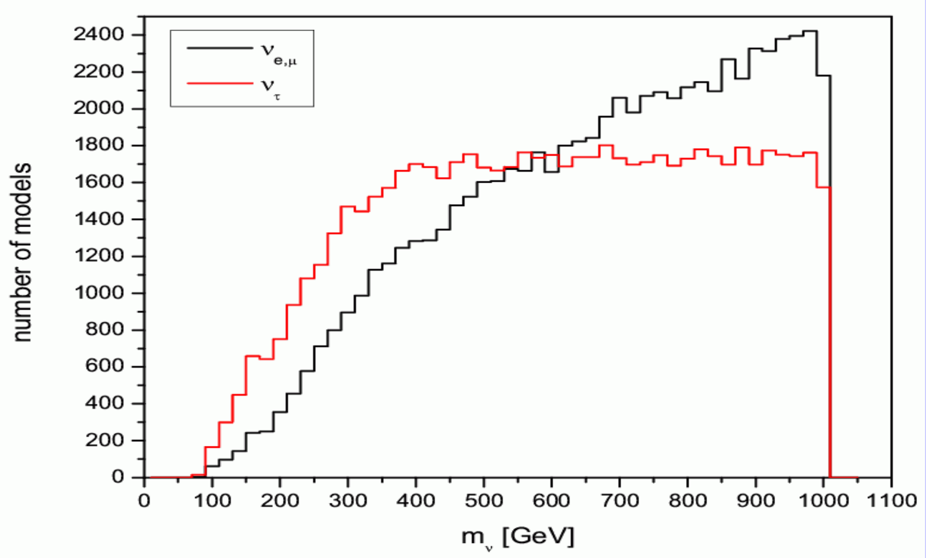
Distribution for Selectron/Sneutrino Masses

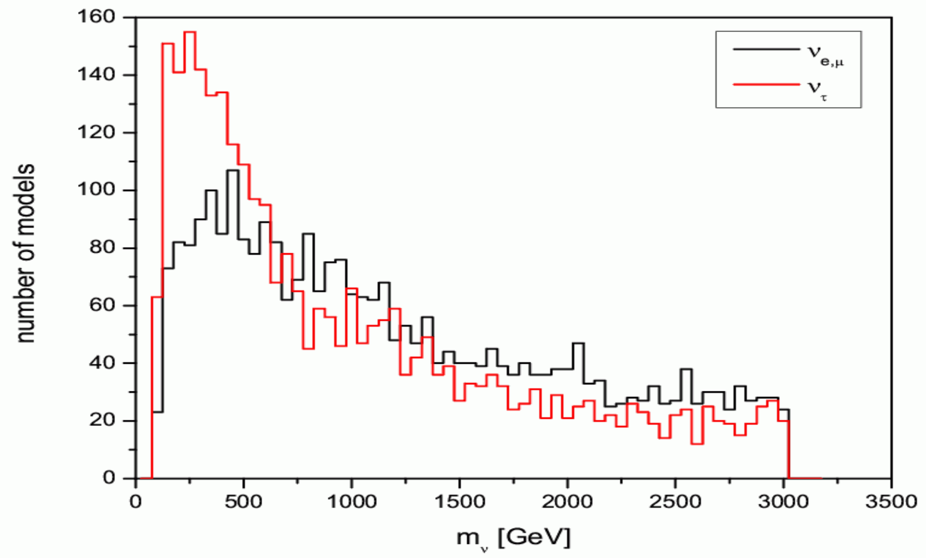
Flat Priors

Log Priors



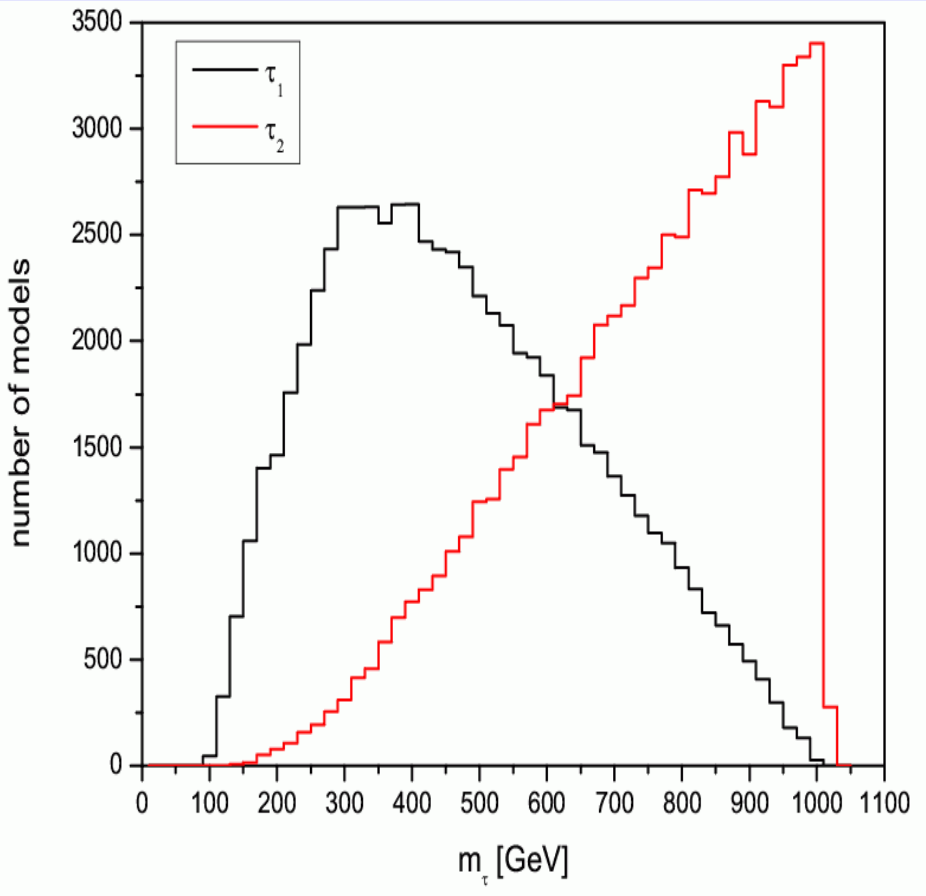




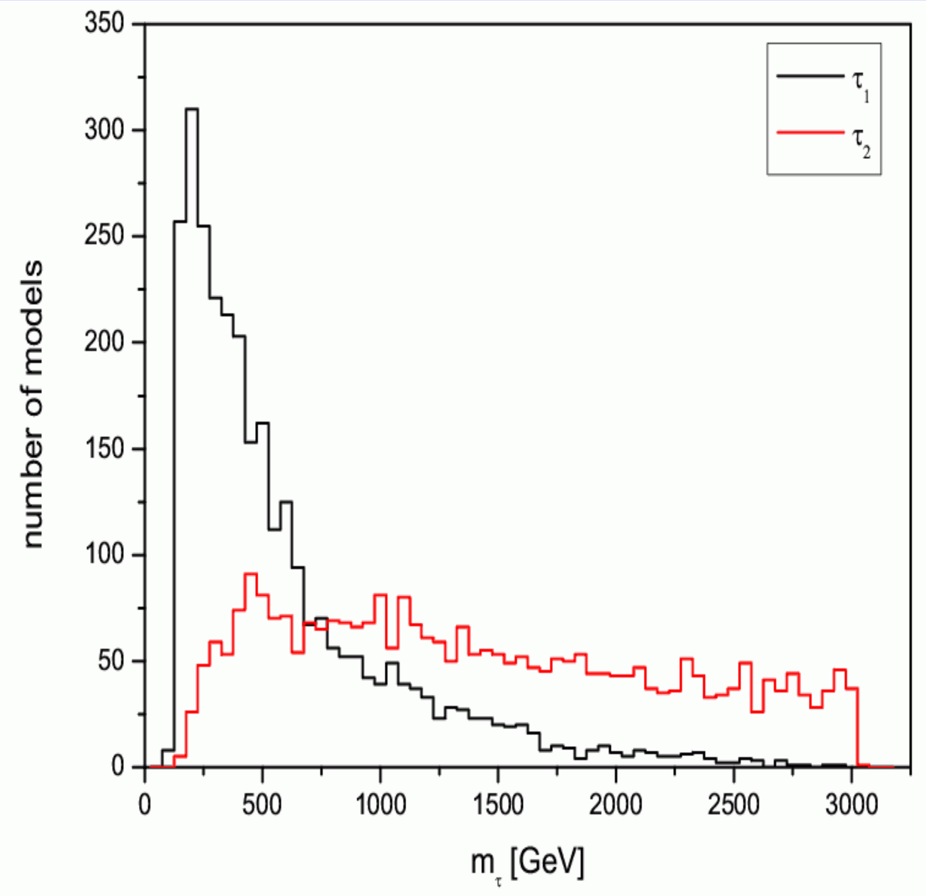


Distribution of Stau Masses

Flat Priors

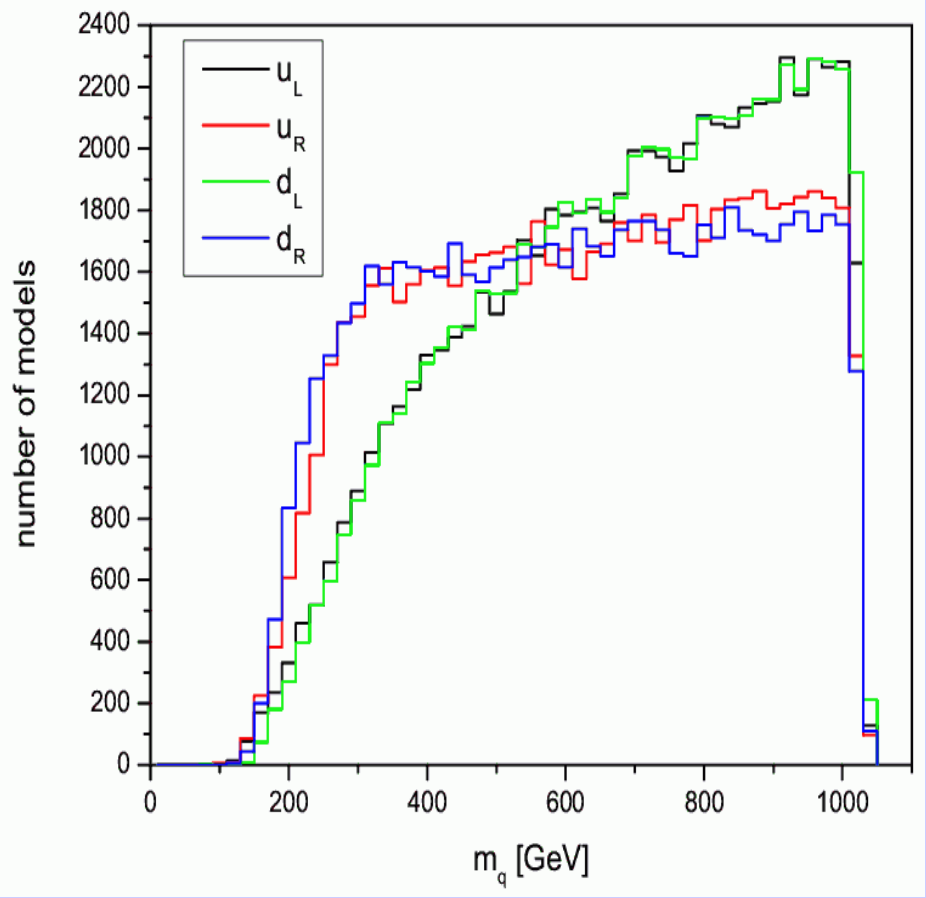


Log Priors

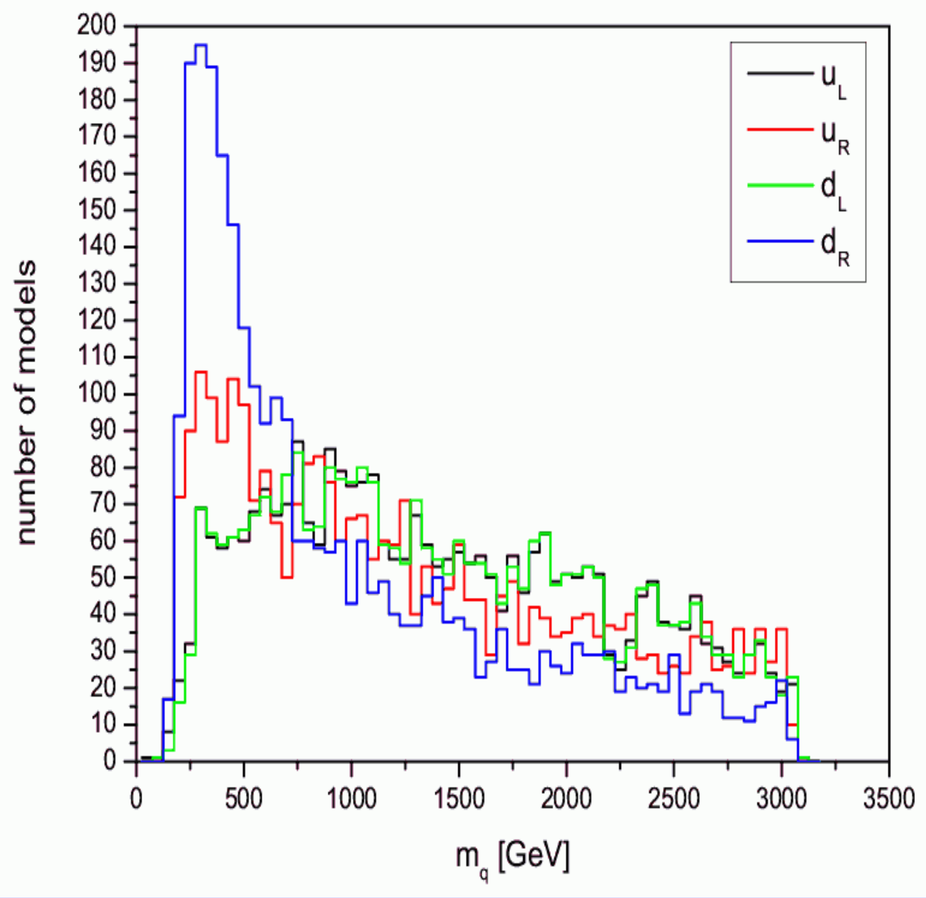


Distribution of Squark Masses

Flat Priors

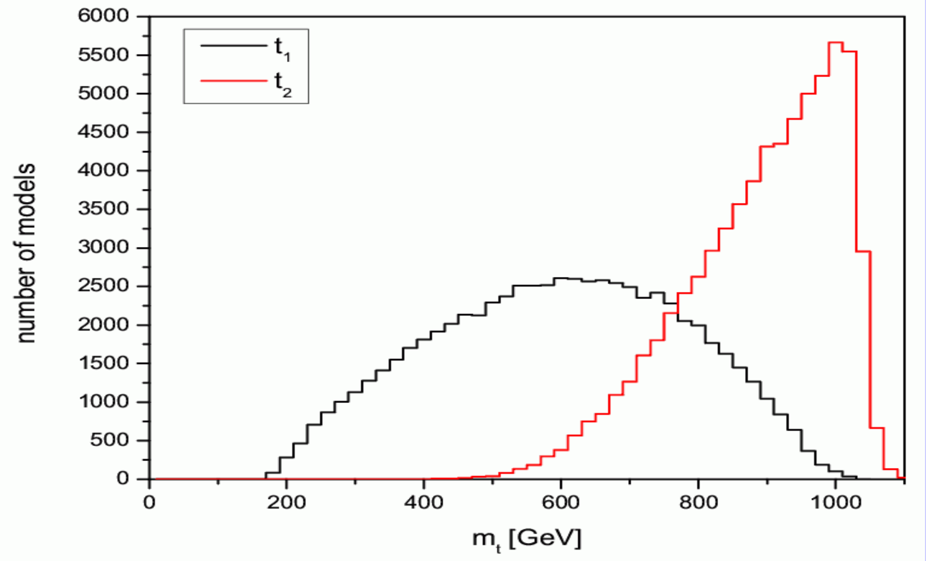


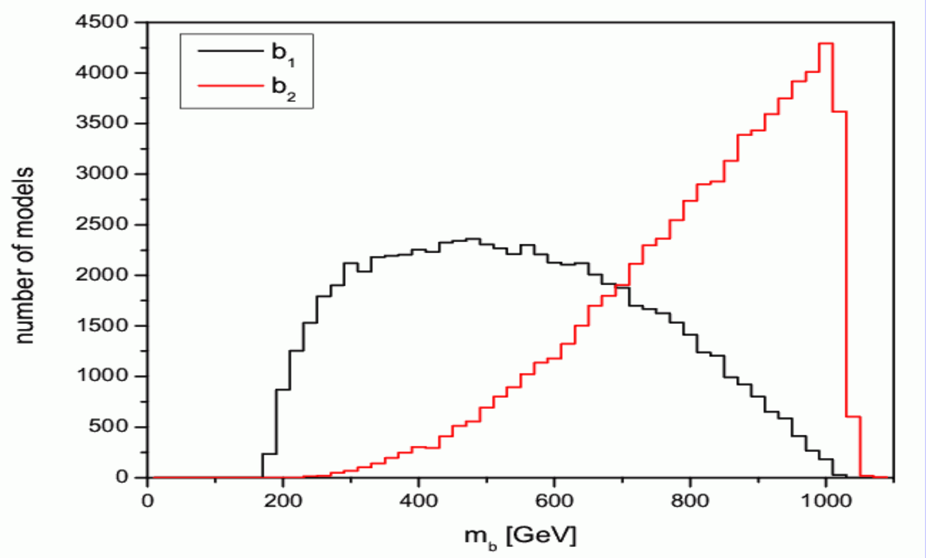
Log Priors



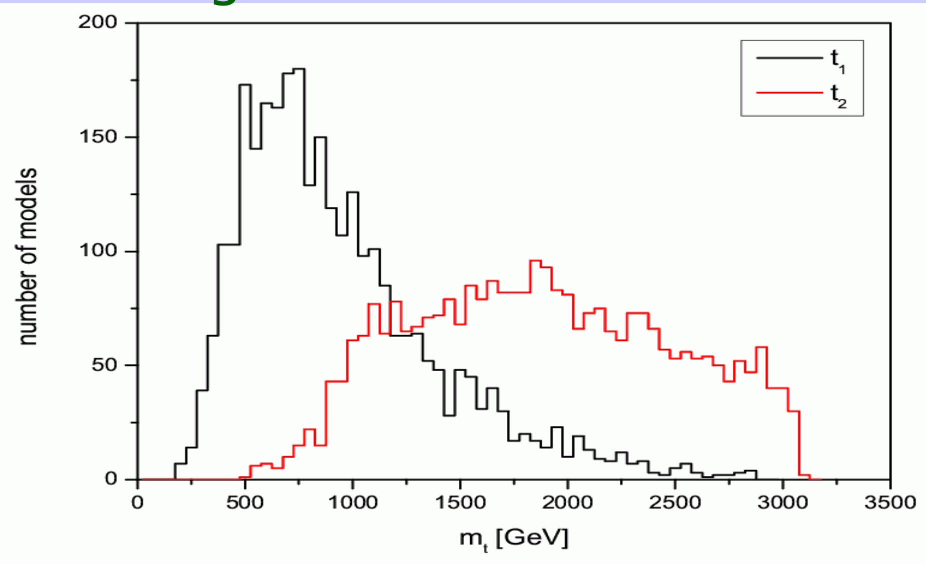
Distribution of Sbottom/Stop Masses

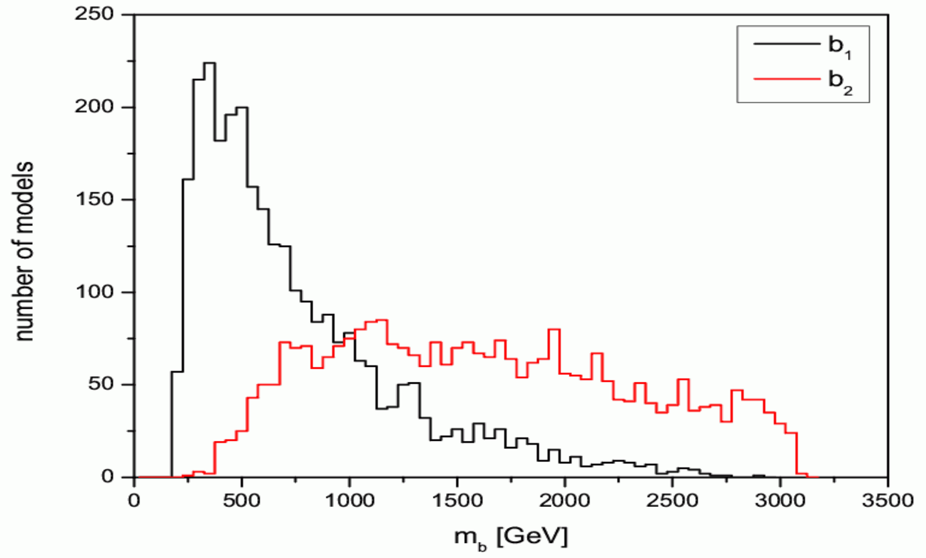
Flat Priors





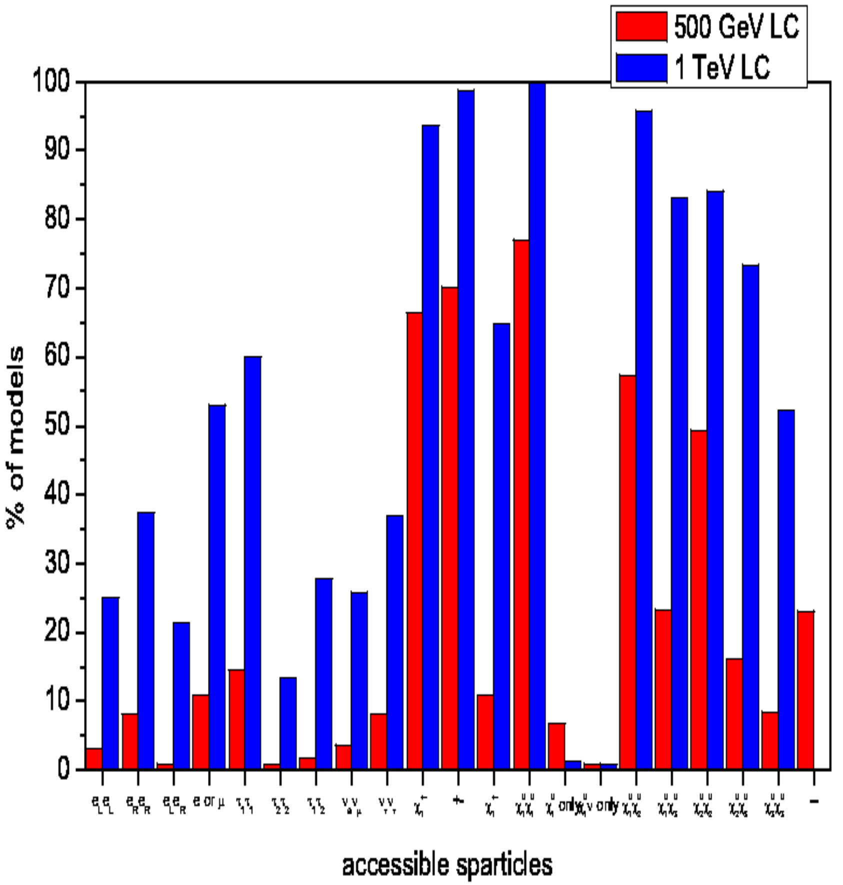
Log Priors



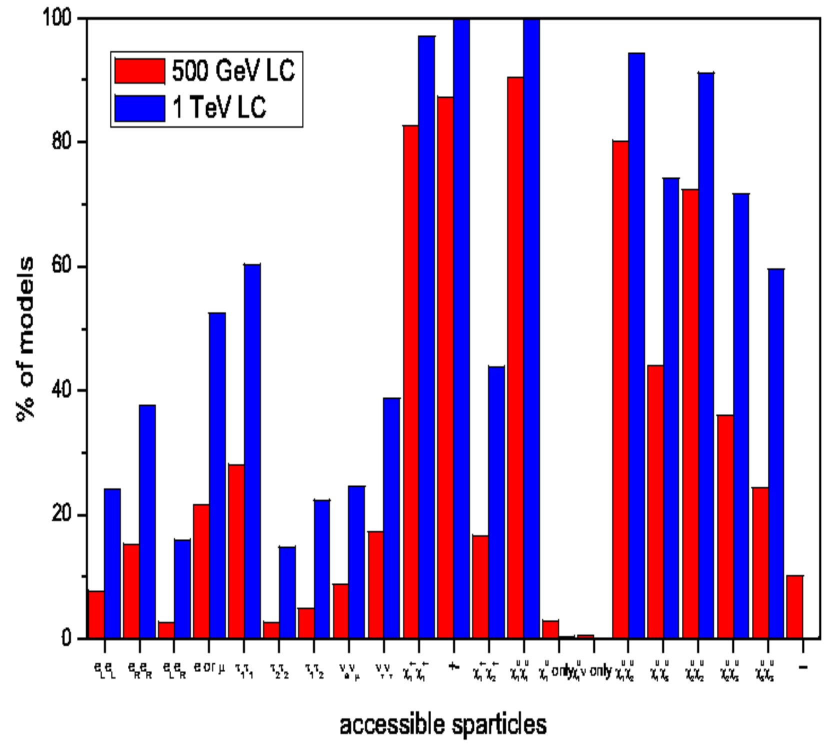


ILC Search Region: Sleptons and EW Gauginos

Flat Priors: $M_{SUSY} \leq 1$ TeV



Log Priors: $M_{SUSY} \leq 3$ TeV

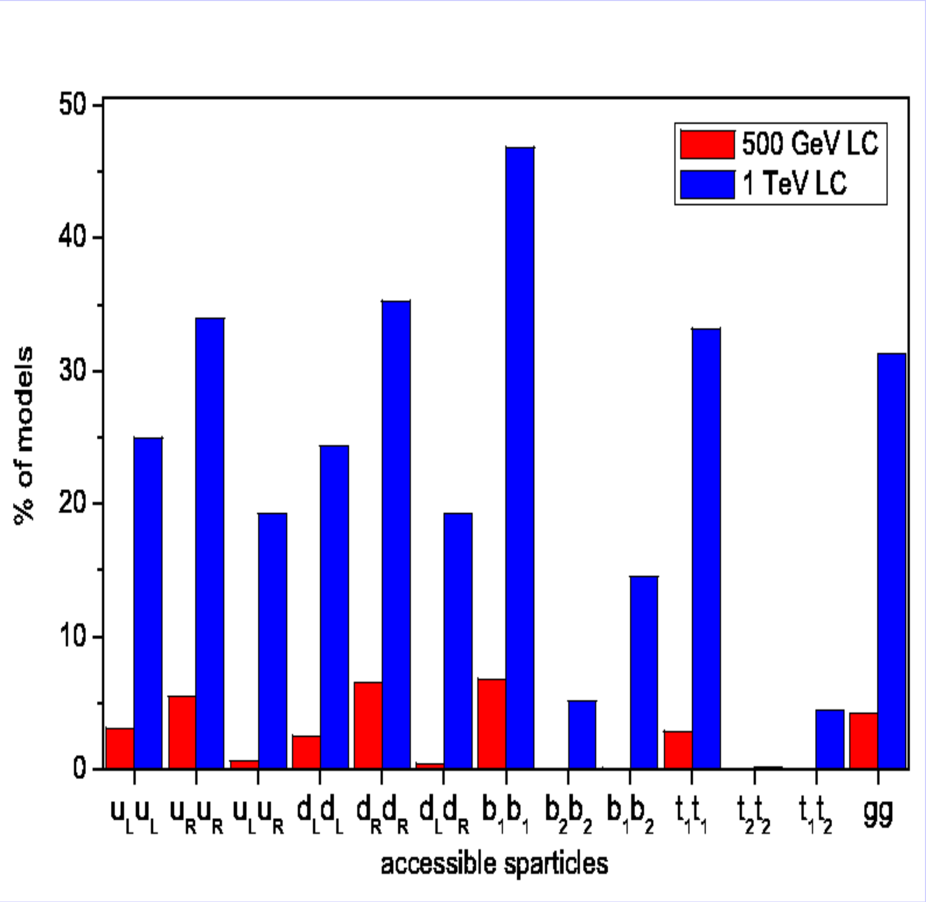


x-axis legend

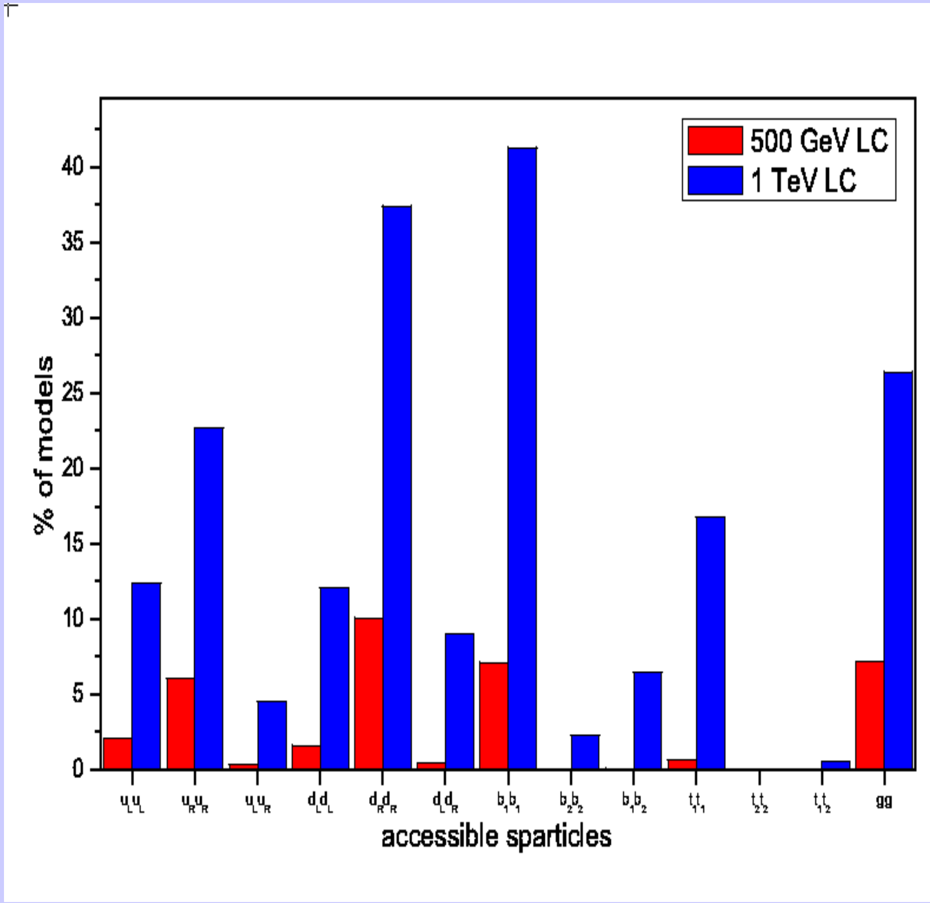
$\tilde{e}_L^+\tilde{e}_L^-$
$\tilde{e}_R^+\tilde{e}_R^-$
$\tilde{e}_L^\pm\tilde{e}_R^\mp$
$\tilde{\mu}_L^+\tilde{\mu}_L^-$
$\tilde{\mu}_R^+\tilde{\mu}_R^-$
Any selectron or smuon
$\tilde{\tau}_1^+\tilde{\tau}_1^-$
$\tilde{\tau}_2^+\tilde{\tau}_2^-$
$\tilde{\tau}_1^\pm\tilde{\tau}_2^\mp$
$\tilde{\nu}_{e\mu}\tilde{\nu}_{e\mu}^*$
$\tilde{\nu}_\tau\tilde{\nu}_\tau^*$
$\tilde{\chi}_1^+\tilde{\chi}_1^-$
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

ILC Search Region: Squarks and Gluinos

Flat Priors: $M_{SUSY} \leq 1$ TeV

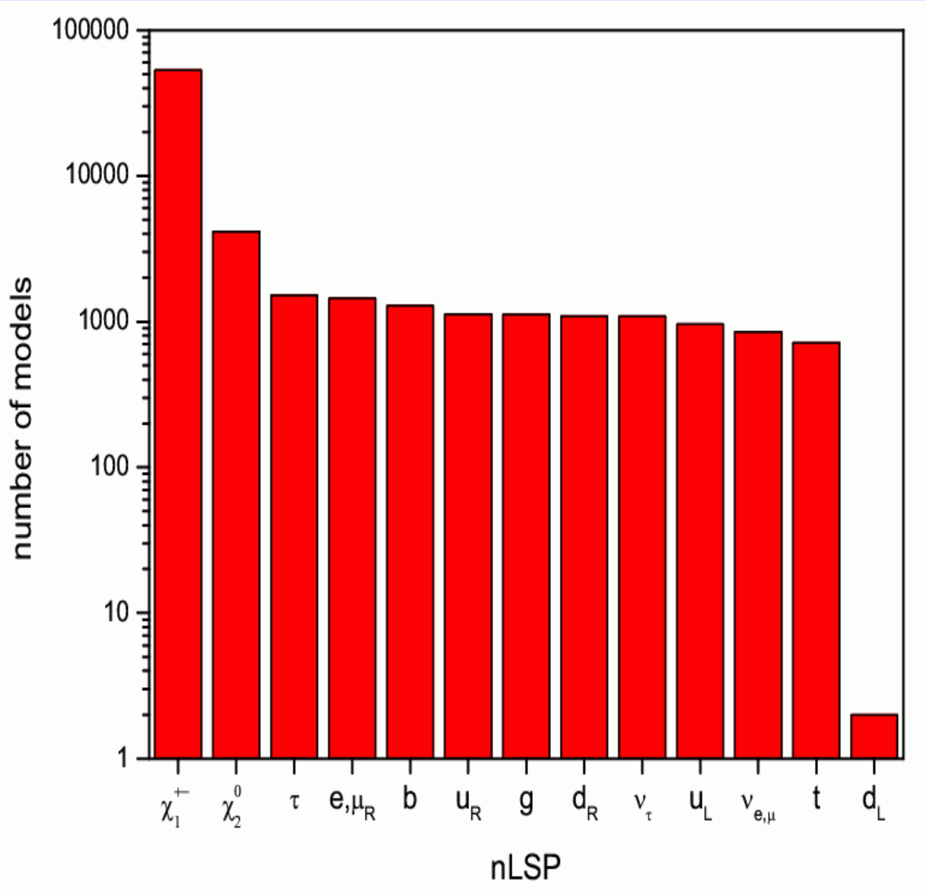


Log Priors: $M_{SUSY} \leq 3$ TeV

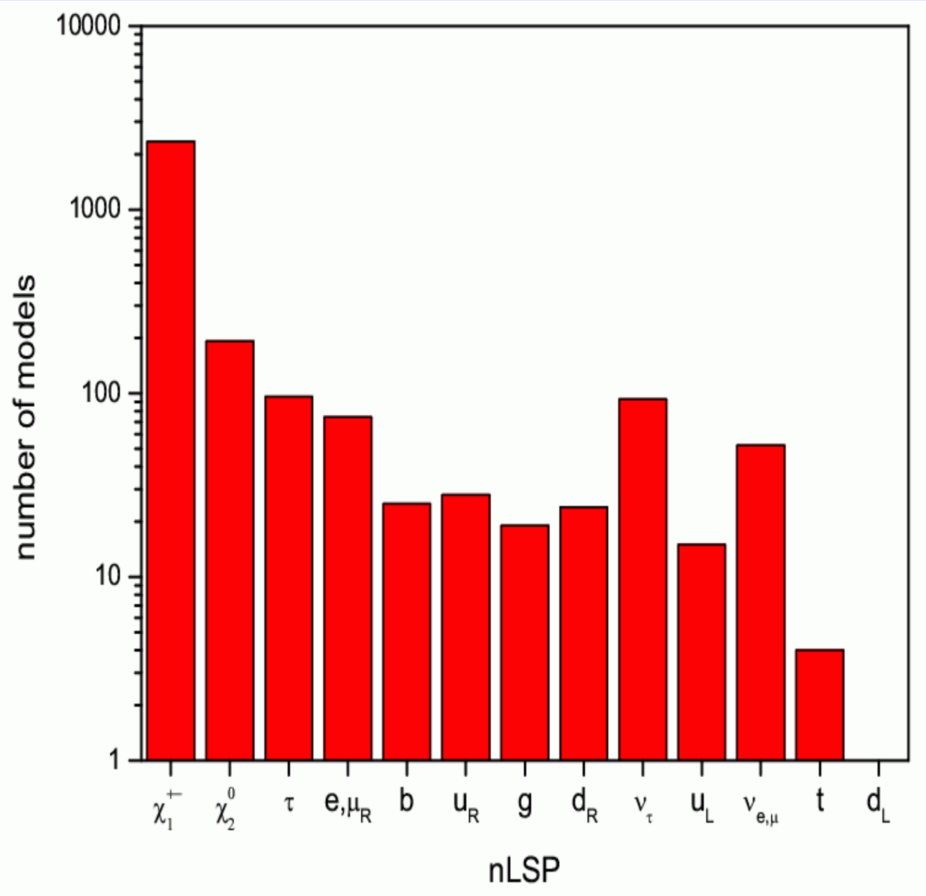


Character of the NLSP: it can be anything!

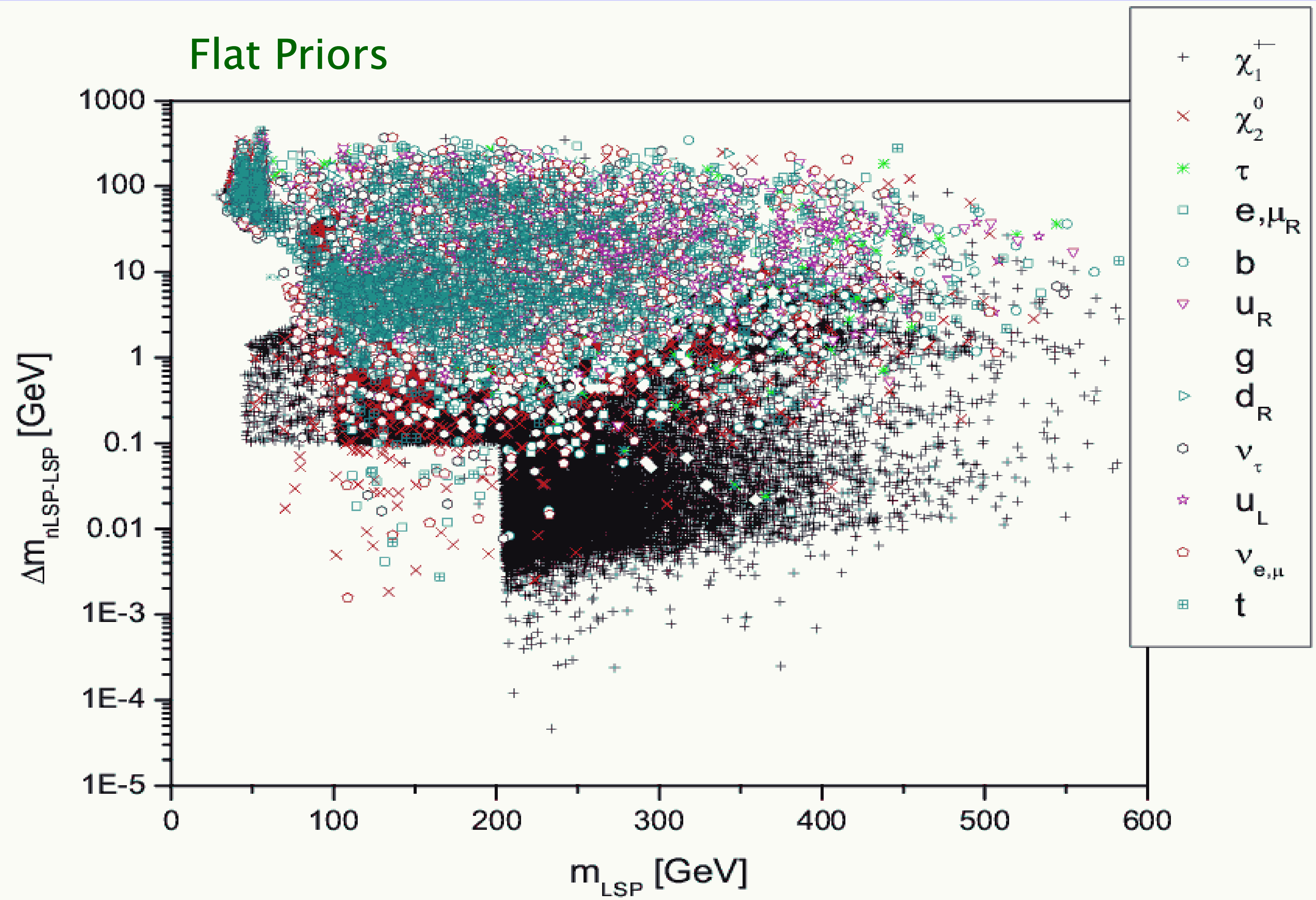
Flat Priors



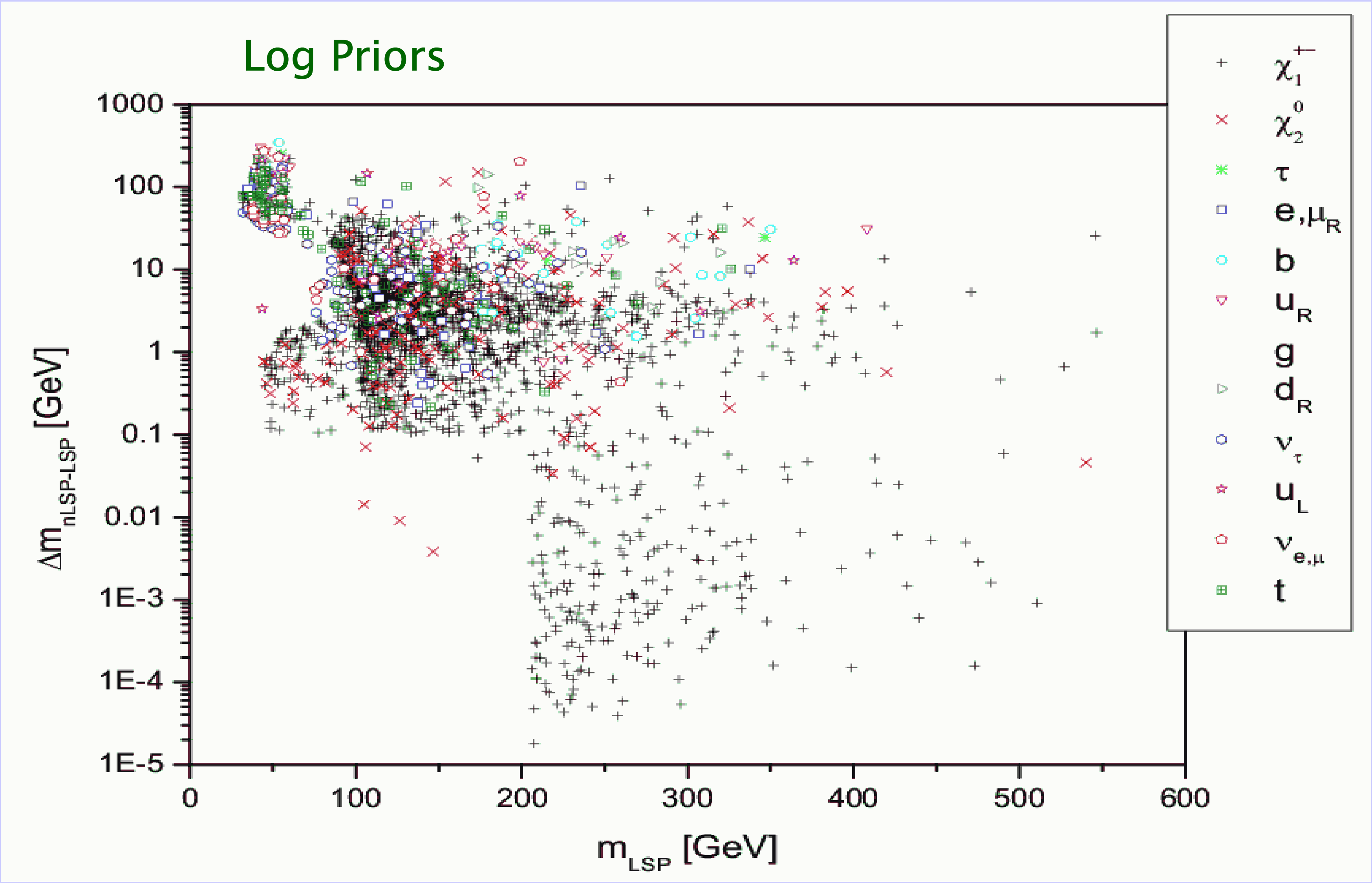
Log Priors



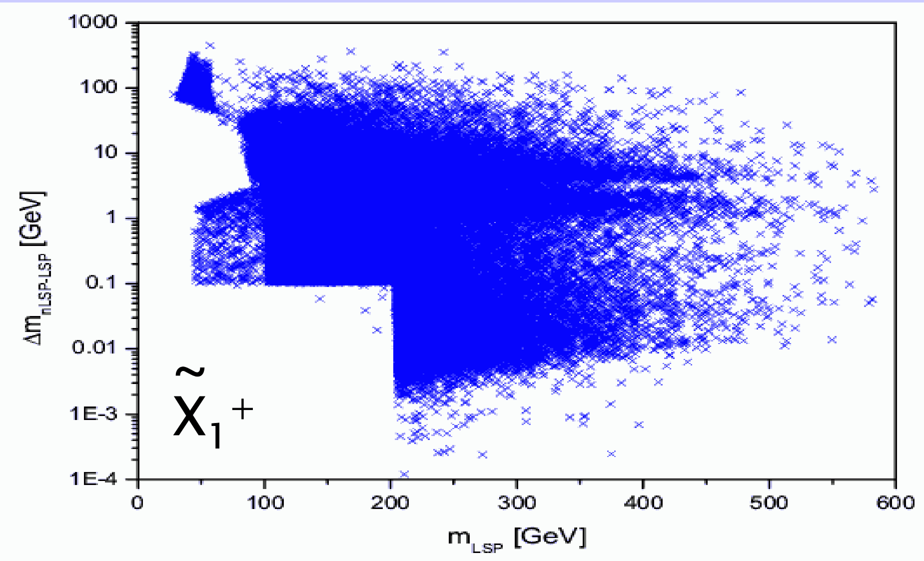
NLSP–LSP Mass Splitting

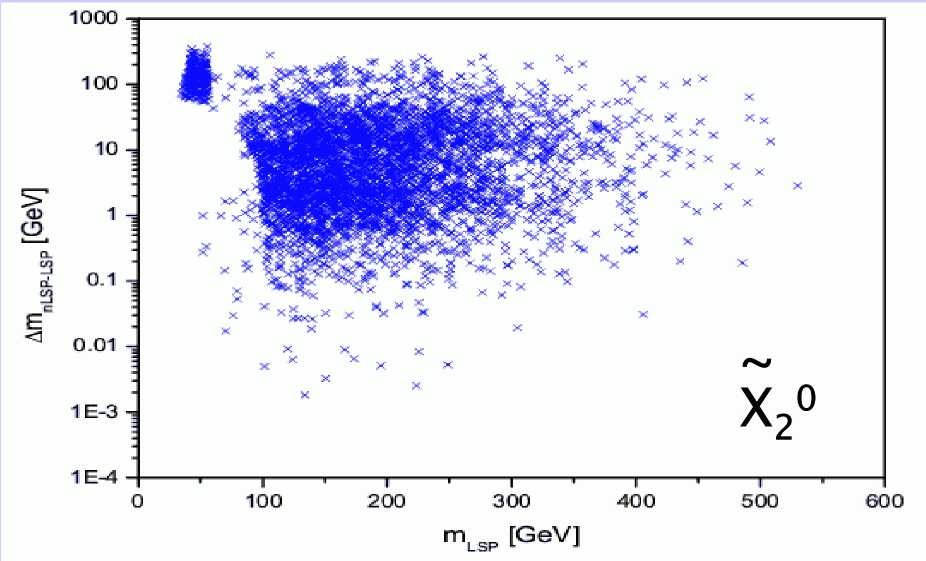


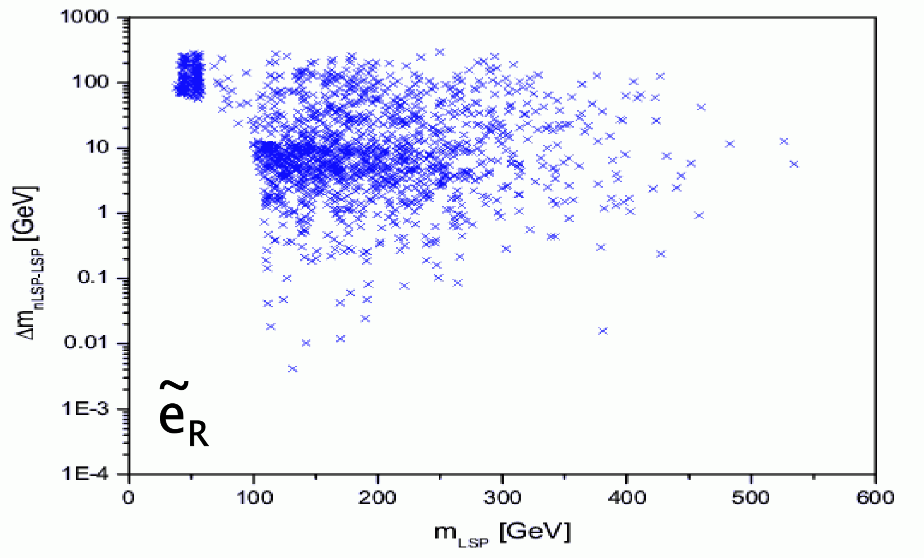
NLSP-LSP Mass Splitting

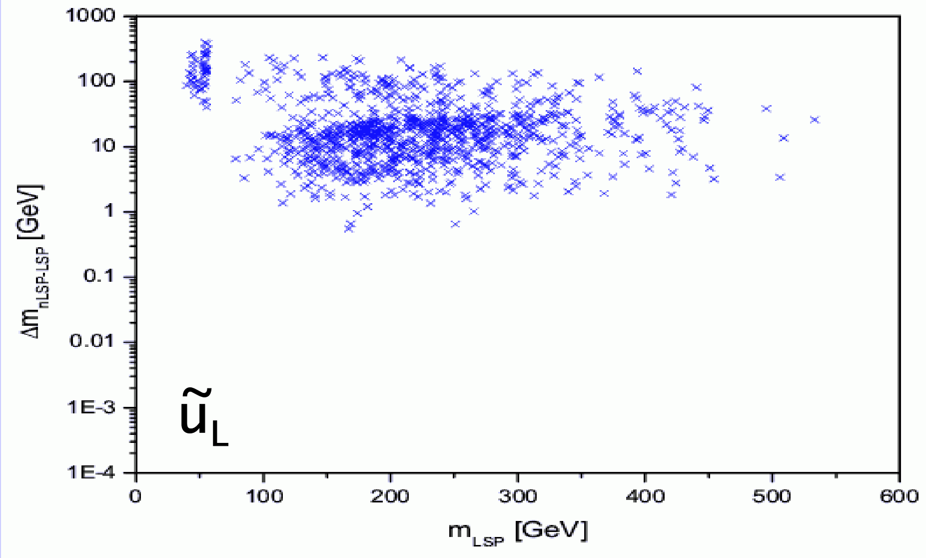


NLSP-LSP Mass Splitting: Details







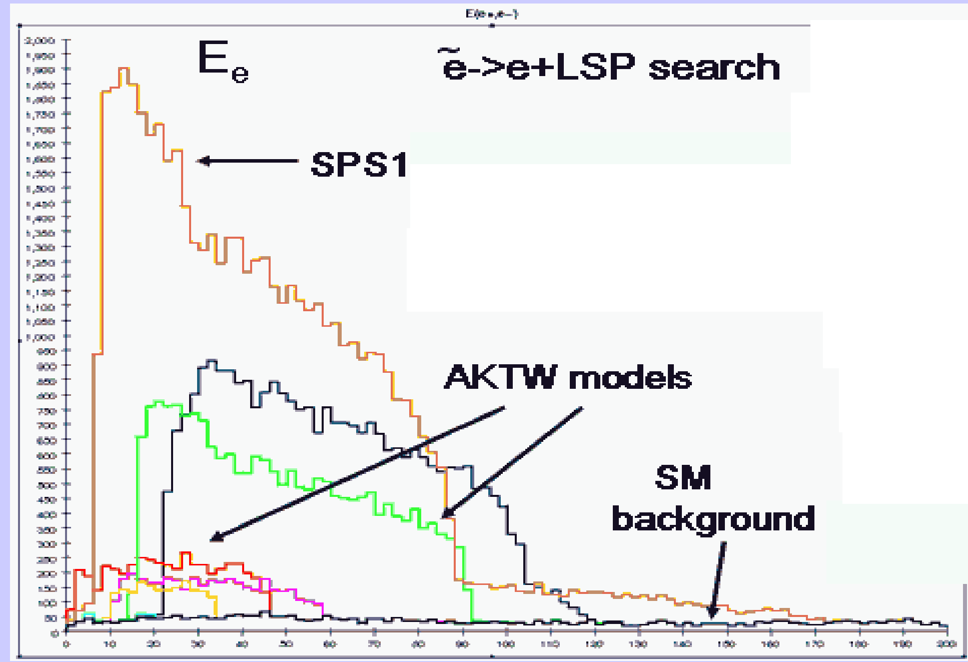


Study of LHC Inverse Problem

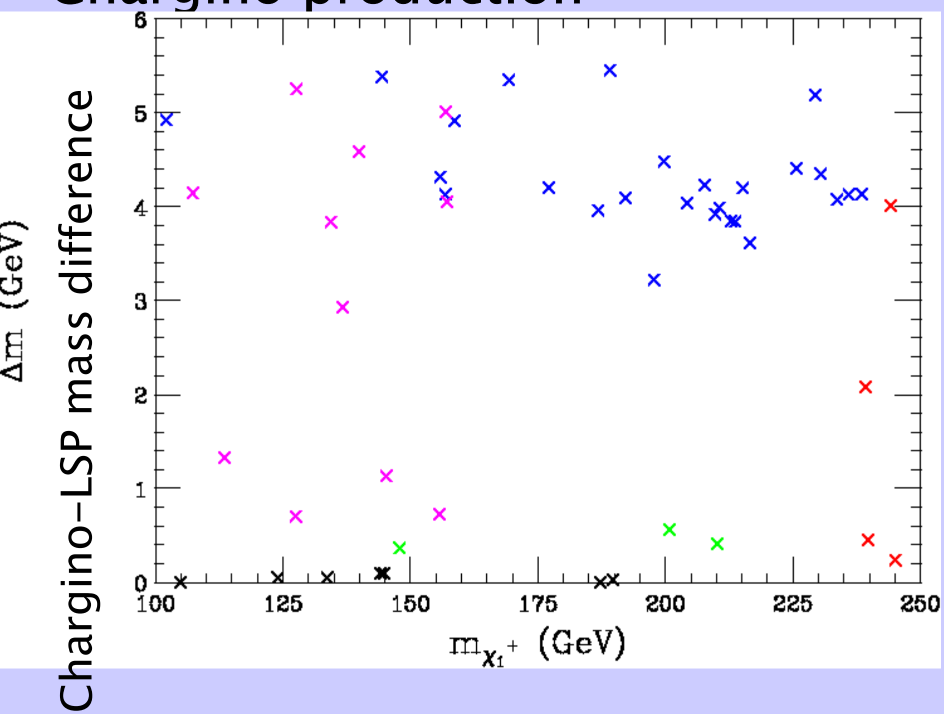
Berger etal arXiv:0712.2965

Selectron Production

Signal is much smaller than SPS1a’



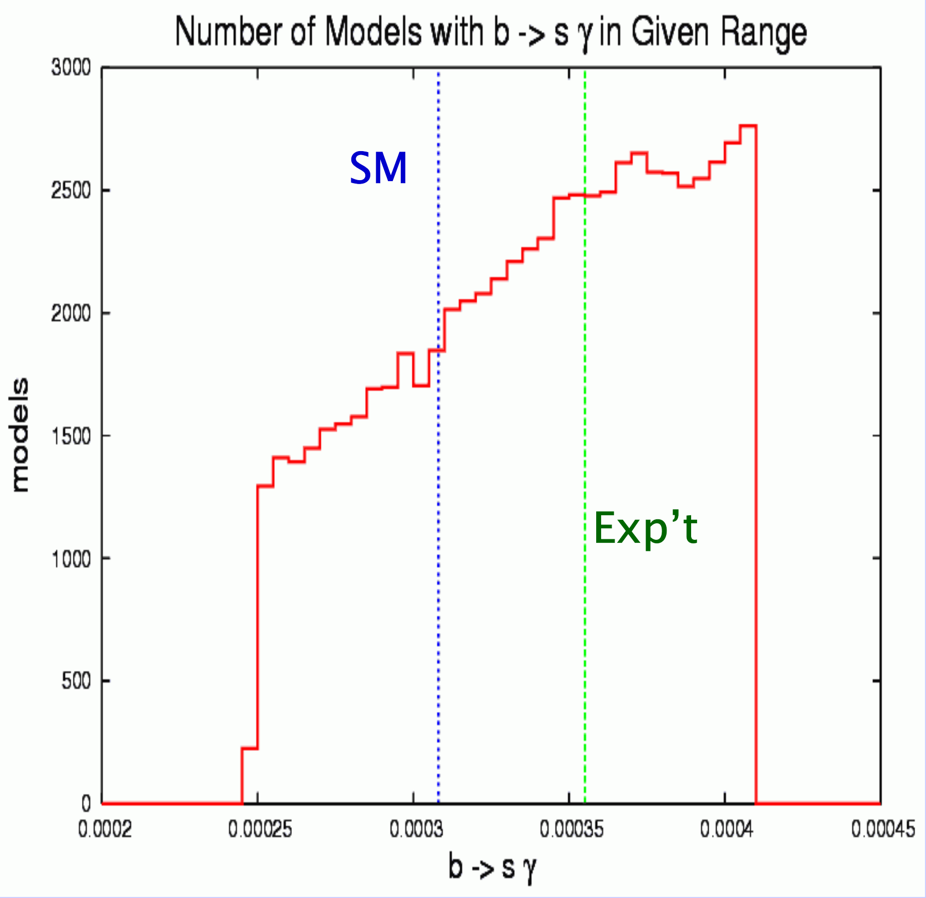
Chargino production



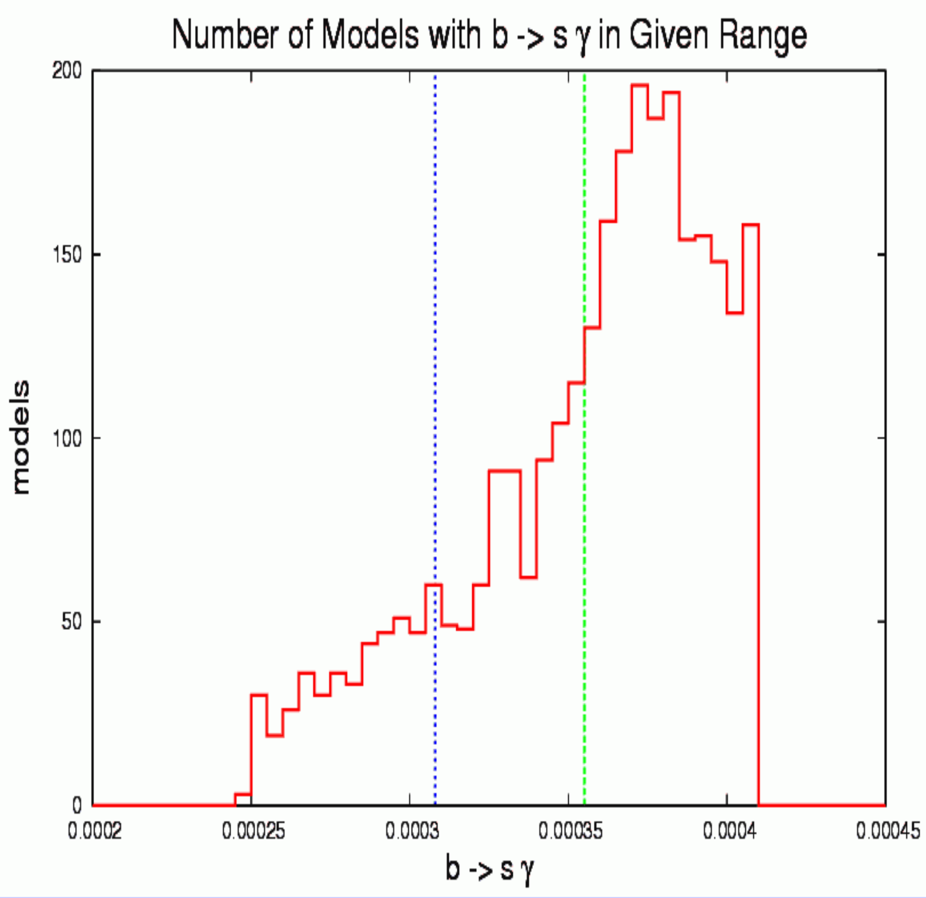
Many times charginos have small mass splittings with the LSP requiring many different searches: stable particles, photon tagging, soft jets, or a combination. Four are missed due to tiny phase space

Predictions for b→sγ

Flat Priors

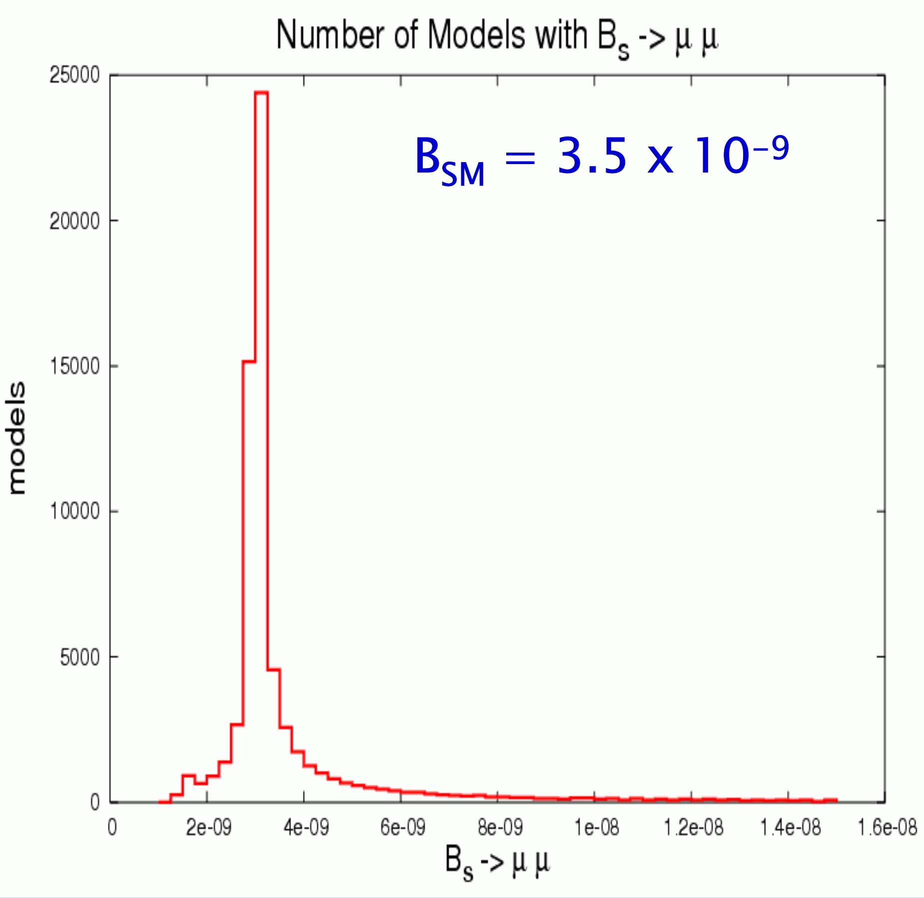


Log Priors

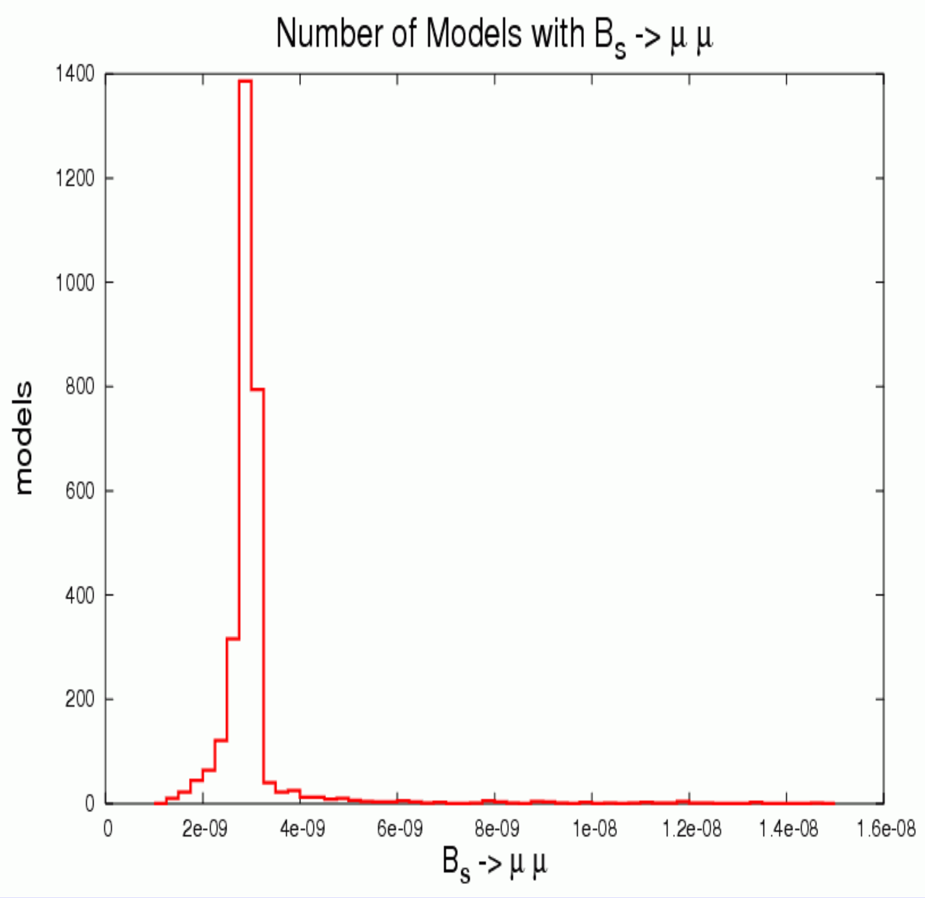


Predictions for $B_s \to \mu\mu$

Flat Priors

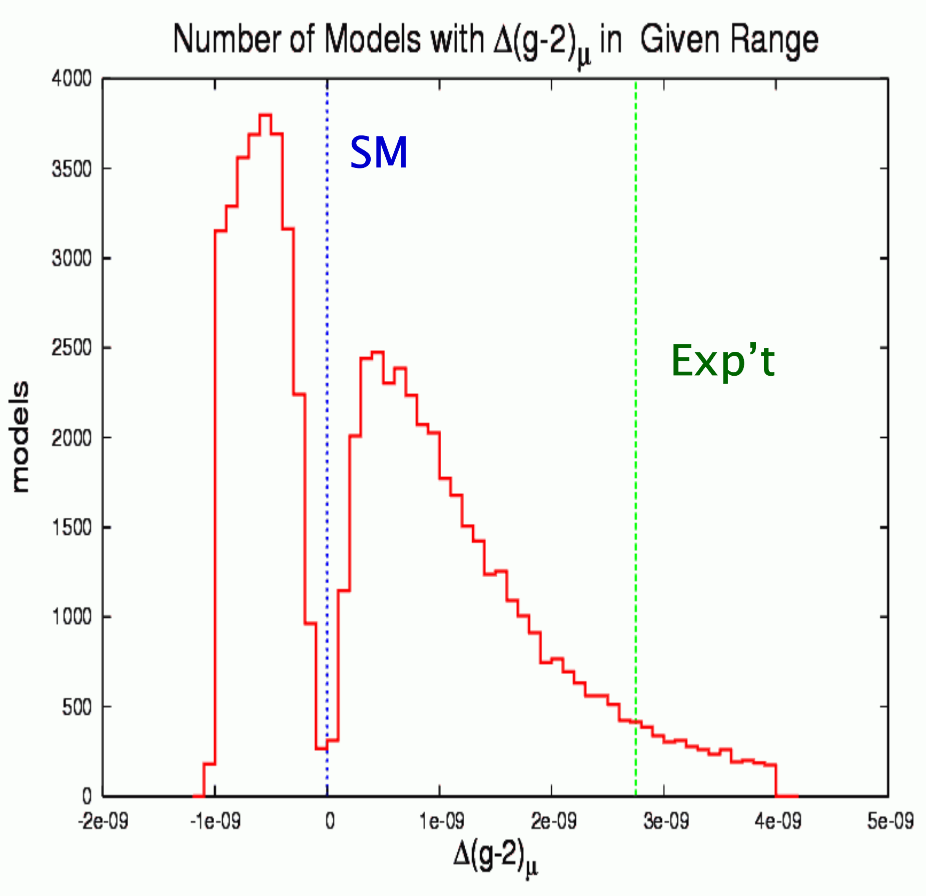


Log Priors

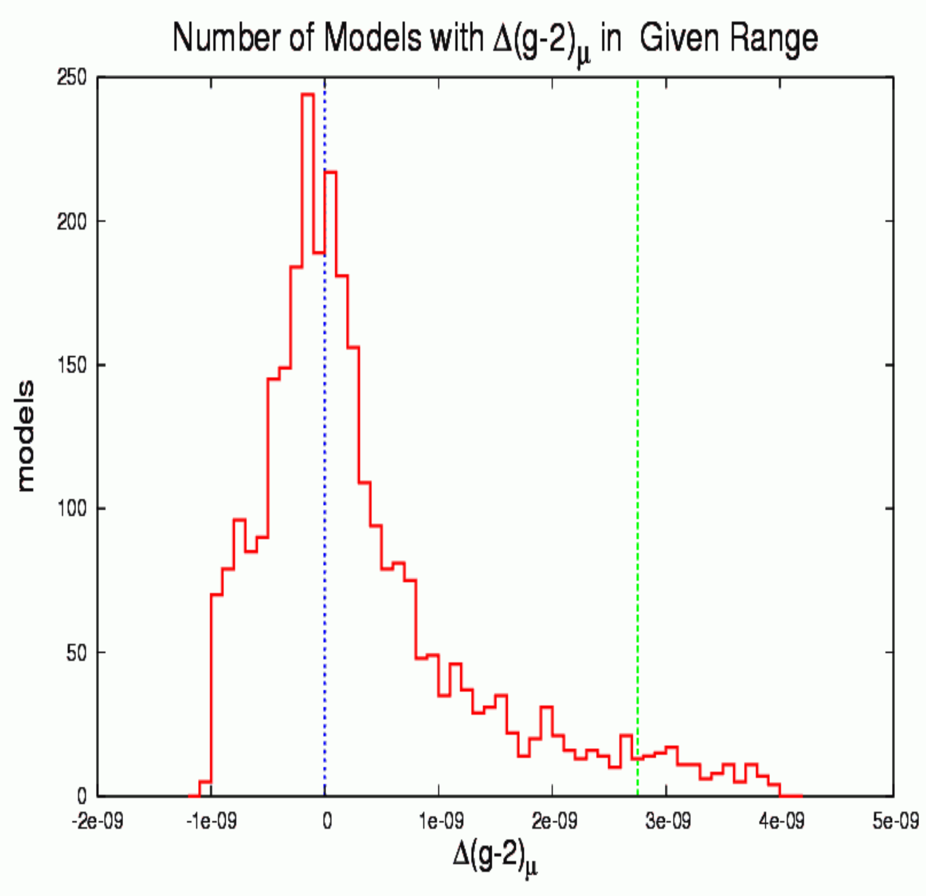


Predictions for $\Delta(g-2)_\mu$

Flat Priors



Log Priors



Naturalness Criterion

Barbieri, Giudice
Kasahara, Freese, Gondolo

$$m_Z^2 = -m_u^2 \left(1 - \frac{1}{\cos 2\beta}\right) - m_d^2 \left(1 + \frac{1}{\cos 2\beta}\right) - 2|\mu|^2,$$

$$\sin 2\beta = \frac{2b}{m_u^2 + m_d^2 + 2|\mu|^2}.$$

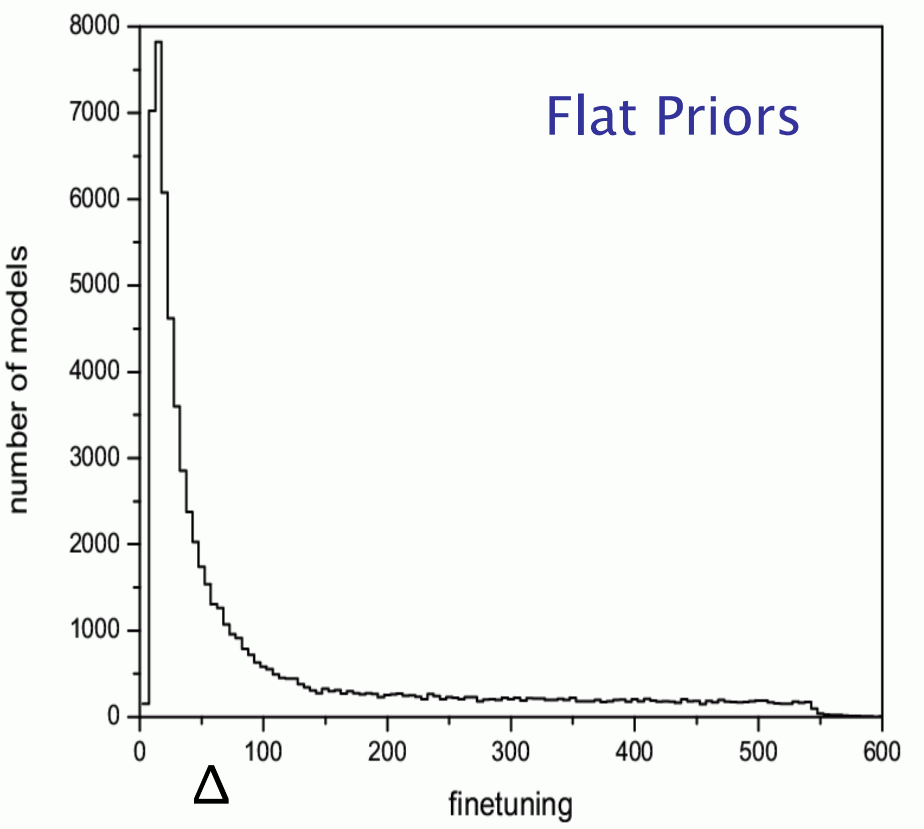
$$A(\xi) = \left| \frac{\partial \log m_Z^2}{\partial \log \xi} \right|$$

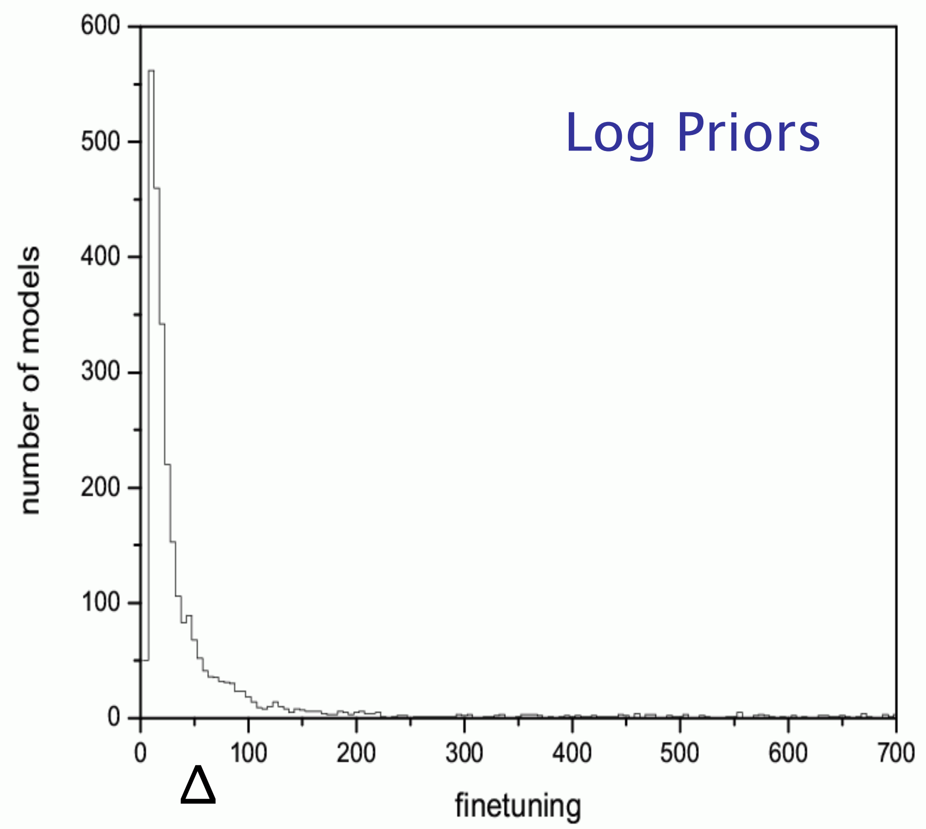
$$A(\mu) = \frac{4\mu^2}{m_Z^2} \left(1 + \frac{m_A^2 + m_Z^2}{m_A^2} \tan^2 2\beta\right),$$

$$A(b) = \left(1 + \frac{m_A^2}{m_Z^2}\right) \tan^2 2\beta,$$

$$A(m_u^2) = \left|\frac{1}{2}\cos 2\beta + \frac{m_A^2}{m_Z^2}\cos^2\beta - \frac{\mu^2}{m_Z^2}\right| \times \left(1 - \frac{1}{\cos 2\beta} + \frac{m_A^2 + m_Z^2}{m_A^2}\tan^2 2\beta\right),$$

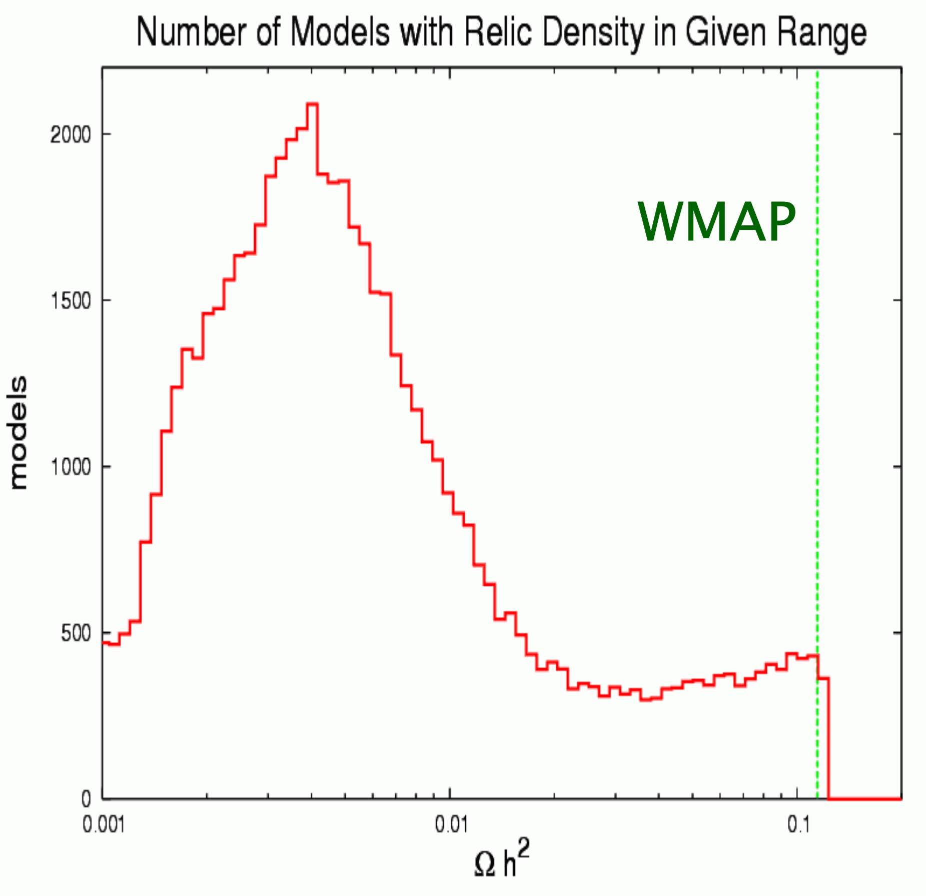
$$A(m_d^2) = \left|-\frac{1}{2}\cos 2\beta + \frac{m_A^2}{m_Z^2}\sin^2\beta - \frac{\mu^2}{m_Z^2}\right| \times \left|1 + \frac{1}{\cos 2\beta} + \frac{m_A^2 + m_Z^2}{m_A^2}\tan^2 2\beta\right|,$$



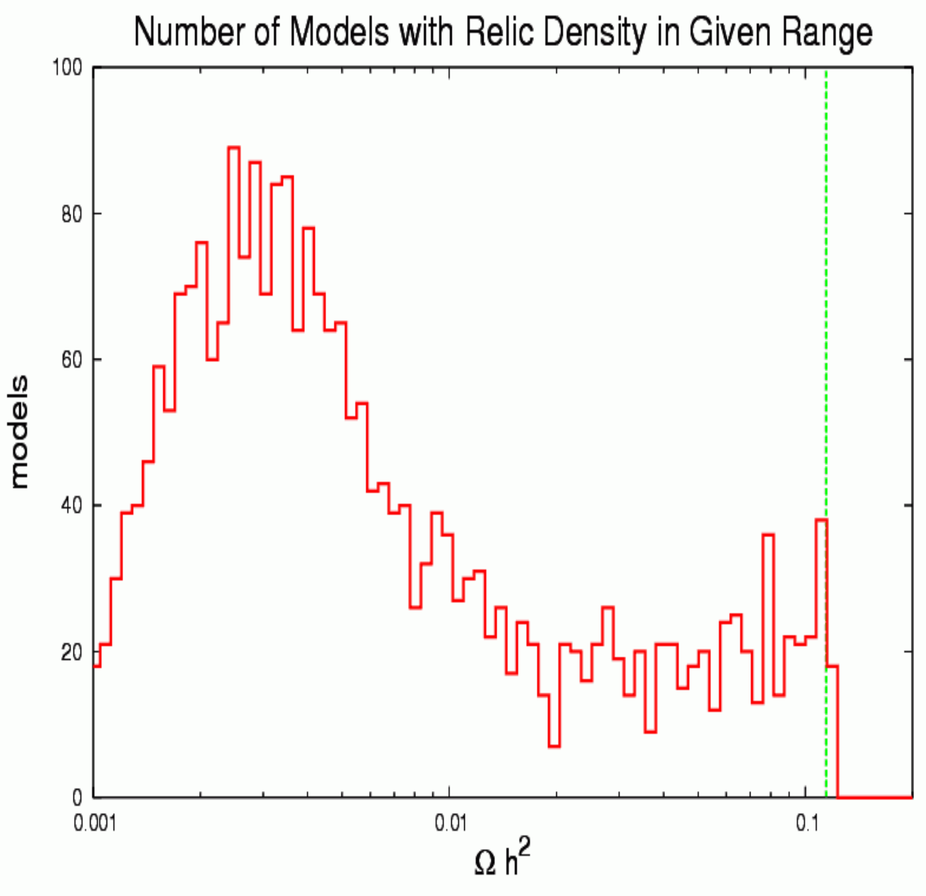


Predictions for Relic Density

Flat Priors

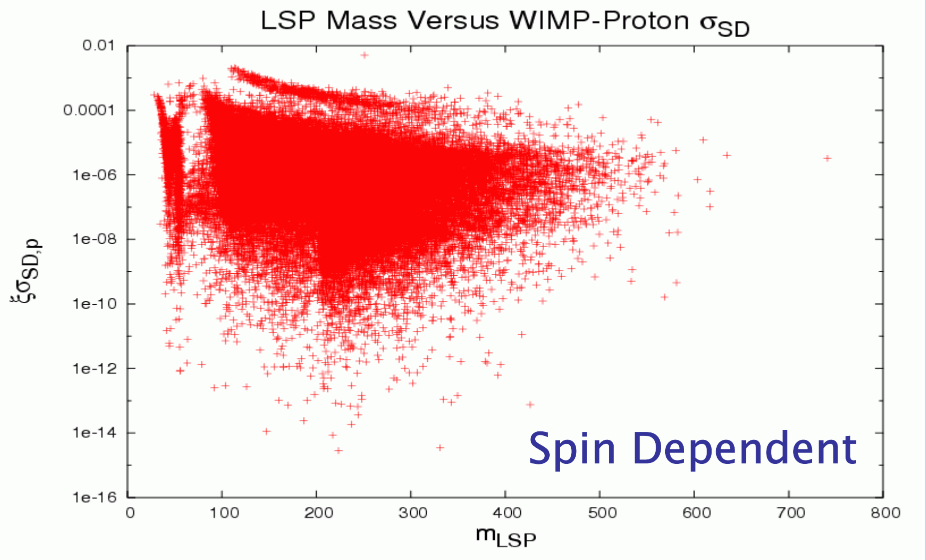


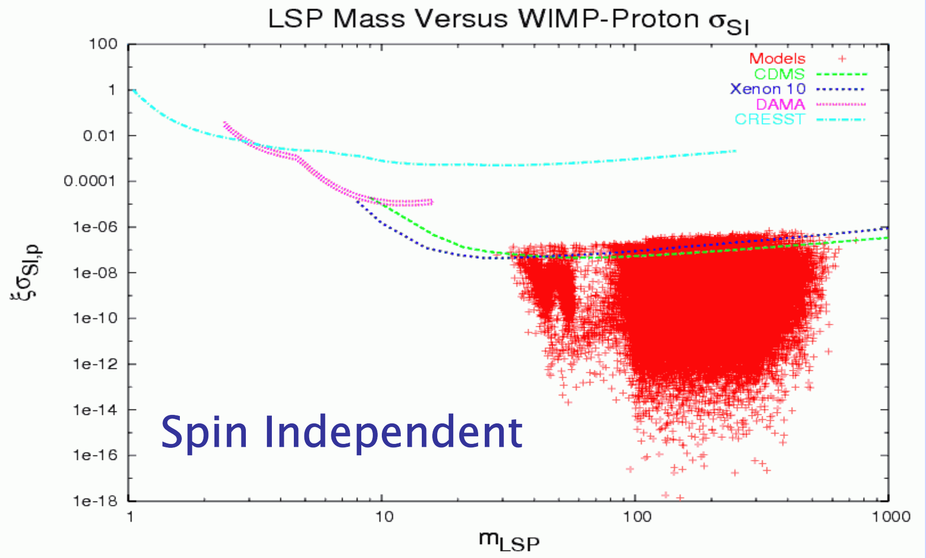
Log Priors



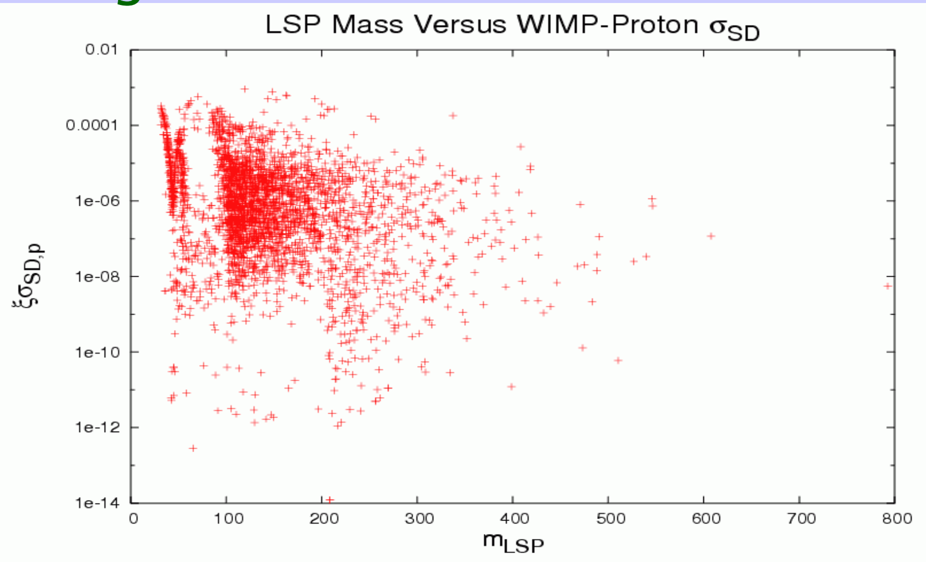
Dark Matter Direct Detection Cross Sections

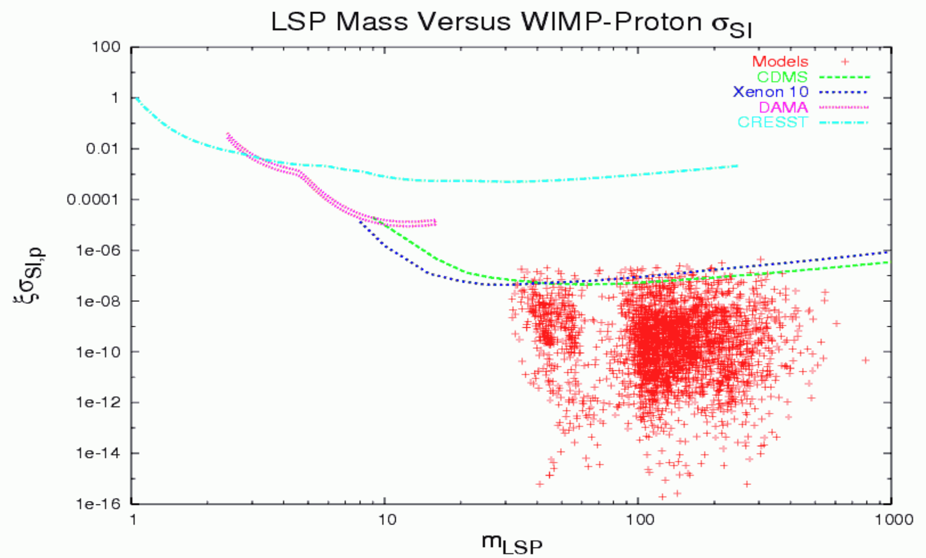
Flat Priors





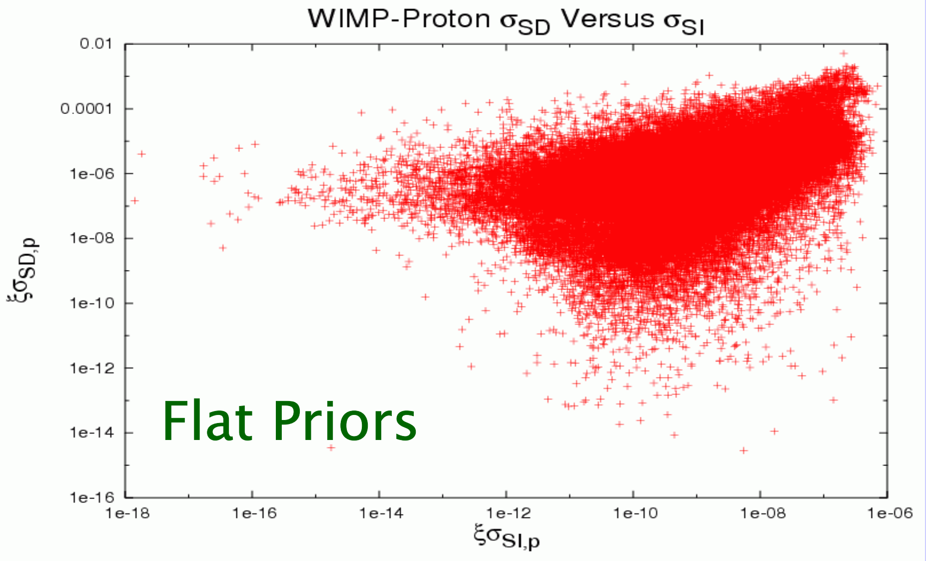
Log Priors

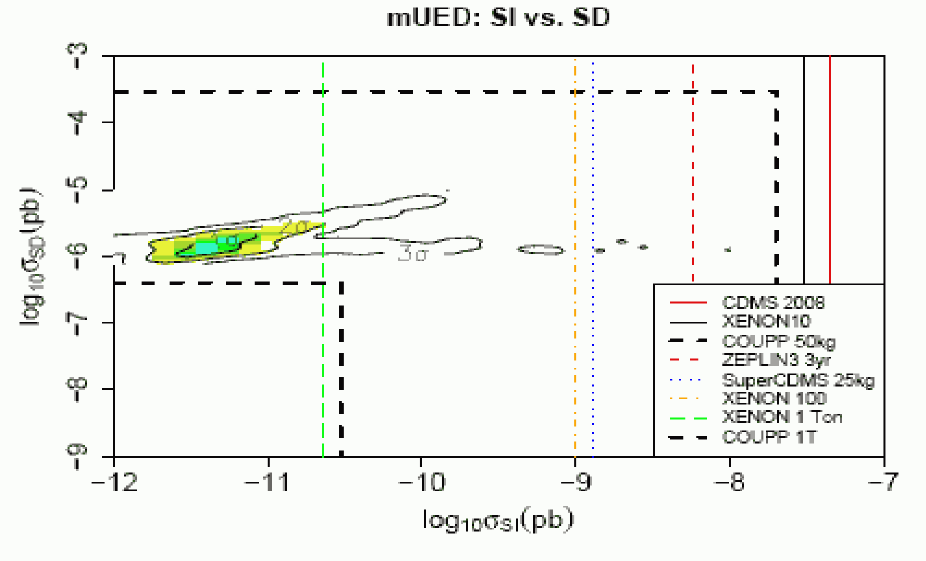


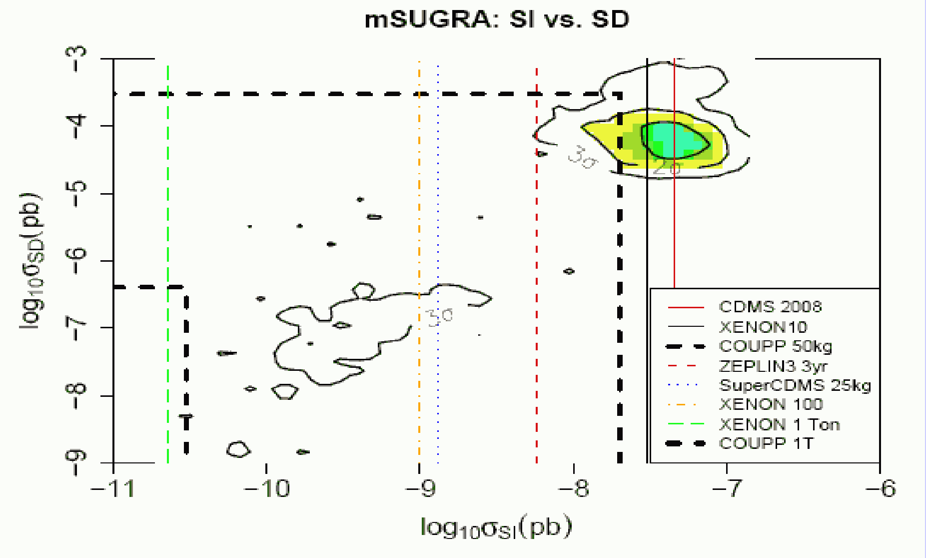


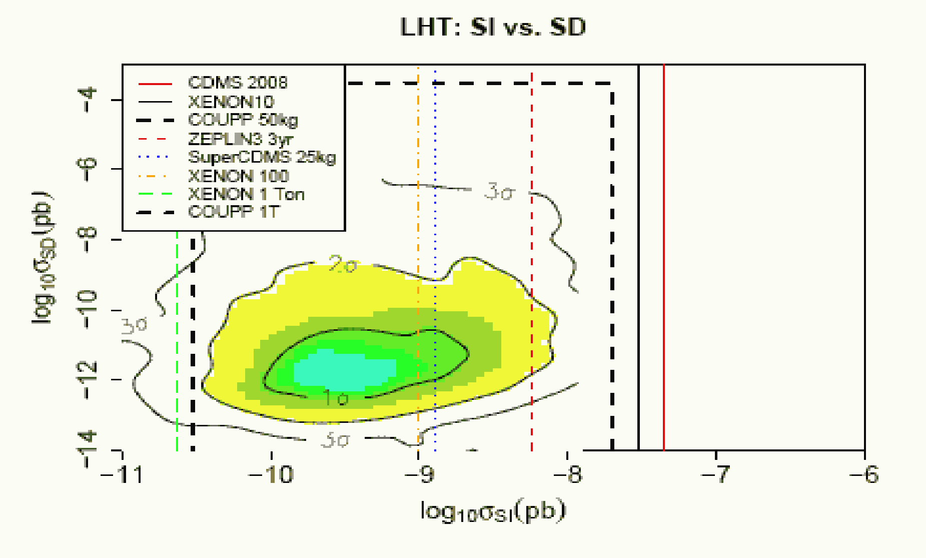
Distinguishing Dark Matter Models

Barger etal









Mass Pattern Classification

mSP	Mass Pattern	Linear	Log
mSP1	$\widetilde{\chi}_1^0 < \widetilde{\chi}_1^\pm < \widetilde{\chi}_2^0 < \widetilde{\chi}_3^0$	9.81	18.49
mSP2	$\widetilde{\chi}_1^0 < \widetilde{\chi}_1^\pm < \widetilde{\chi}_2^0 < A/H$	2.07	0.67
mSP3	$\widetilde{\chi}_1^0 < \widetilde{\chi}_1^\pm < \widetilde{\chi}_2^0 < \widetilde{\tau}_1$	5.31	6.60
mSP4	$\widetilde{\chi}_1^0 < \widetilde{\chi}_1^\pm < \widetilde{\chi}_2^0 < \widetilde{g}$	2.96	3.70
mSP5	$\widetilde{\chi}_1^0 < \widetilde{\tau}_1 < \widetilde{l}_R < \widetilde{\nu}_\tau$	0.02	0.13
mSP6	$\widetilde{\chi}_1^0 < \widetilde{\tau}_1 < \widetilde{\chi}_1^\pm < \widetilde{\chi}_2^0$	0.46	1.21
mSP7	$\widetilde{\chi}_1^0 < \widetilde{\tau}_1 < \widetilde{l}_R < \widetilde{\chi}_1^\pm$	0.02	0.03
mSP8	$\widetilde{\chi}_1^0 < \widetilde{\tau}_1 < A \sim H$	0.06	0.00
mSP9	$\widetilde{\chi}_1^0 < \widetilde{\tau}_1 < \widetilde{l}_R < A/H$	0.01	0.00
mSP10	$\widetilde{\chi}_1^0 < \widetilde{\tau}_1 < \widetilde{t}_1 < \widetilde{l}_R$	0.00	0.00 ←
mSP11	$\widetilde{\chi}_1^0 < \widetilde{t}_1 < \widetilde{\chi}_1^\pm < \widetilde{\chi}_2^0$	0.09	0.00
mSP12	$\widetilde{\chi}_1^0 < \widetilde{t}_1 < \widetilde{\tau}_1 < \widetilde{\chi}_1^\pm$	0.01	0.00
mSP13	$\widetilde{\chi}_1^0 < \widetilde{t}_1 < \widetilde{\tau}_1 < \widetilde{l}_R$	0.01	0.00
mSP14	$\widetilde{\chi}_1^0 < A \sim H < H^\pm$	0.35	0.10
mSP15	$\widetilde{\chi}_1^0 < A \sim H < \widetilde{\chi}_1^\pm$	0.01	0.03
mSP16	$\widetilde{\chi}_1^0 < A \sim H < \widetilde{\tau}_1$	0.08	0.00
mSP17	$\widetilde{\chi}_1^0 < \widetilde{\tau}_1 < \widetilde{\chi}_2^0 < \widetilde{\chi}_1^\pm$	0.18	0.40
mSP18	$\widetilde{\chi}_1^0 < \widetilde{\tau}_1 < \widetilde{l}_R < \widetilde{t}_1$	0.01	0.00
mSP19	$\widetilde{\chi}_1^0 < \widetilde{\tau}_1 < \widetilde{t}_1 < \widetilde{\chi}_1^\pm$	0.00	0.00
mSP20	$\widetilde{\chi}_1^0 < \widetilde{t}_1 < \widetilde{\chi}_2^0 < \widetilde{\chi}_1^\pm$	0.06	0.00
mSP21	$\widetilde{\chi}_1^0 < \widetilde{t}_1 < \widetilde{\tau}_1 < \widetilde{\chi}_2^0$	0.01	0.00
mSP22	$\widetilde{\chi}_1^0 < \widetilde{\chi}_2^0 < \widetilde{\chi}_1^\pm < \widetilde{g}$	0.27	0.51

Flat Priors   Log Priors

Linear Priors		Log Priors	
Mass Pattern	% of Models	Mass Pattern	% of Models
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\chi}_3^0$	9.82	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\chi}_3^0$	18.59
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\ell}_R$	5.39	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\nu}_\tau$	7.72
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\tau}_1$	5.31	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\ell}_R$	6.67
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\nu}_\tau$	5.02	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\tau}_1$	6.64
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{b}_1$	4.89	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{d}_R$	5.18
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{d}_R$	4.49	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\nu}_\ell$	4.50
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{u}_R$	3.82	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{b}_1$	3.76
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{g}$	2.96	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{g}$	3.73
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{\nu}_\ell$	2.67	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{u}_R$	2.74
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{u}_L$	2.35	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\nu}_\tau < \tilde{\tau}_1$	2.27
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\nu}_\tau < \tilde{\tau}_1$	2.19	$\tilde{\chi}_1^0 < \tilde{\chi}_2^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_3^0$	2.24
$\tilde{\chi}_1^0 < \tilde{\chi}_2^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_3^0$	2.15	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\ell}_R < \tilde{\chi}_2^0$	1.42
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < A$	2.00	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{u}_L$	1.32
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < \tilde{t}_1$	1.40	$\tilde{\chi}_1^0 < \tilde{\tau}_1 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0$	1.22
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\nu}_\ell < \tilde{\ell}_L$	1.37	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\tau}_1 < \tilde{\chi}_2^0$	1.19
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\tau}_1 < \tilde{\chi}_2^0$	1.35	$\tilde{\chi}_1^0 < \tilde{\chi}_2^0 < \tilde{\chi}_1^\pm < \tilde{\nu}_\tau$	1.15
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\ell}_R < \tilde{\chi}_2^0$	1.32	$\tilde{\chi}_1^0 < \tilde{\ell}_R < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0$	1.05
$A < H < H^\pm < \tilde{\chi}_1^0$	1.24	$\tilde{\chi}_1^0 < \tilde{\nu}_\tau < \tilde{\tau}_1 < \tilde{\chi}_1^\pm$	1.02
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{d}_R < \tilde{\chi}_2^0$	1.03	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\nu}_\ell < \tilde{\ell}_L$	0.95
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{u}_L < \tilde{d}_L$	0.95	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{d}_R < \tilde{\chi}_2^0$	0.71
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{b}_1 < \tilde{\chi}_2^0$	0.89	$\tilde{\chi}_1^0 < \tilde{\nu}_\tau < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0$	0.68
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{u}_R < \tilde{\chi}_2^0$	0.84	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\chi}_2^0 < A$	0.64
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < A < H$	0.74	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\nu}_\tau < \tilde{\chi}_2^0$	0.61
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{g} < \tilde{\chi}_2^0$	0.65	$\tilde{\chi}_1^0 < \tilde{\chi}_2^0 < \tilde{\chi}_1^\pm < \tilde{d}_R$	0.54
$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\tau}_1 < \tilde{\nu}_\tau$	0.51	$\tilde{\chi}_1^0 < \tilde{\chi}_1^\pm < \tilde{\tau}_1 < \tilde{\nu}_\tau$	0.54

We have many more classifications!

Flat Priors: 1109 Classes

Log Priors: 267 Classes

Summary

- We have studied the pMSSM, without GUT & SUSY breaking assumptions, subject to experimental constraints
- We have found a wide variety of model properties not found in mSUGRA/CMSSM
  - Colored sparticles can be very light
  - NLSP can be basically any sparticle
  - NLSP–LSP mass difference can be very small
- Wider variety of SUSY predictions for Dark Matter & Collider Signatures than previously thought – we will study these in detail in the future

For more details, see T. Rizzo, SUSY // session

How Much SUSY Space is Left?

Quite a lot!

J. Hewett, LCWS08

SLAC NATIONAL ACCELERATOR LABORATORY

The LHC Goes Mainstream: Random Clothing Store in Hong Kong

後記：
人類是何等渺小！

寫這篇稿的時候，中國的載人航天飛船「神七」已平安返回地球，令我想起曾經訪問過的一位前蘇聯太空人。他在太空站 MIR 逗留了好些日子，他告訴我，在太空最令他感動的事，是每日早上，在窗口看到美麗的地球，那代表海水的藍和陸地的綠，在黑漆的宇宙中，顯得分外明亮嬌麗。那一刻，他感覺到人類是何等渺小！縱然我們已經可以踏上太空，在月球闊步，回眸宇宙繁星，外面未知的世界，還是無限遠大，人類的好奇仍然大派用場，正如愛恩斯坦的名句：

The important thing is not t stop questioning ; curiosity h its own reason for existing.

（重要的是，不要停止發問；好奇心有它存在的理由。）

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