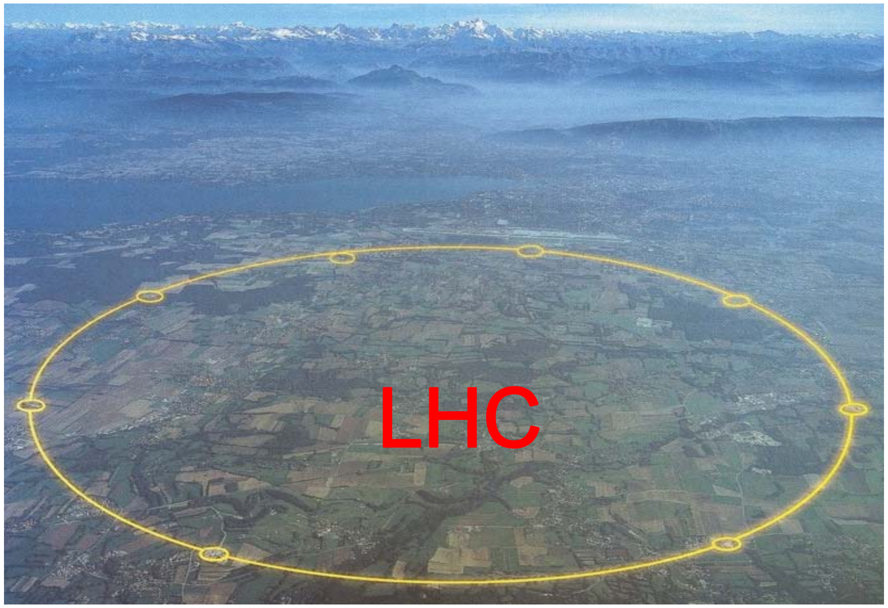
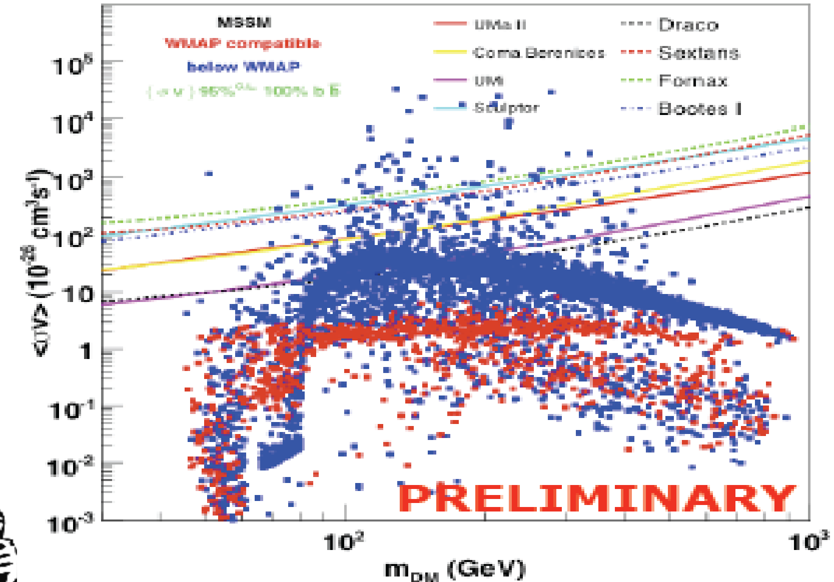
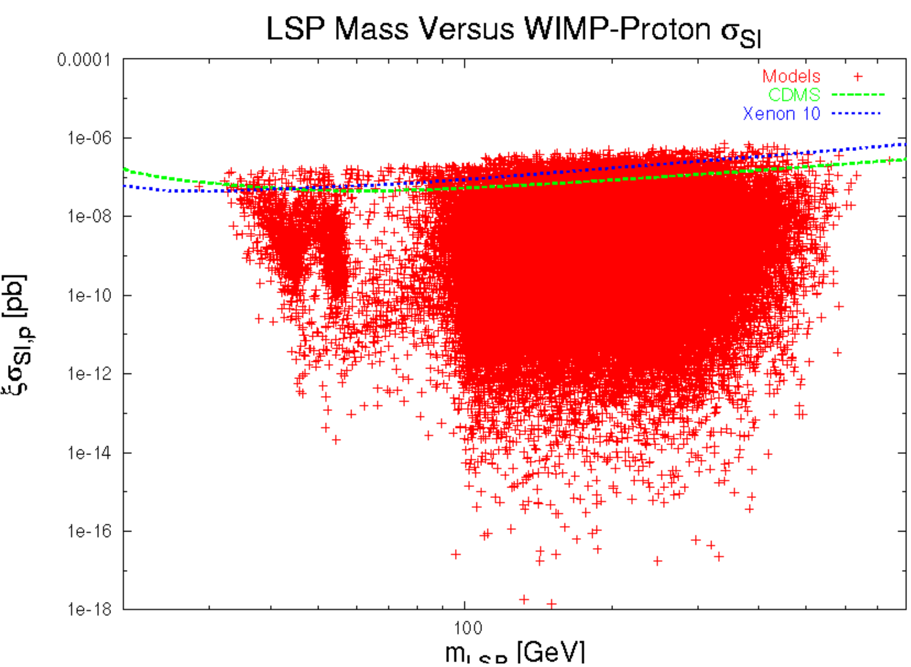
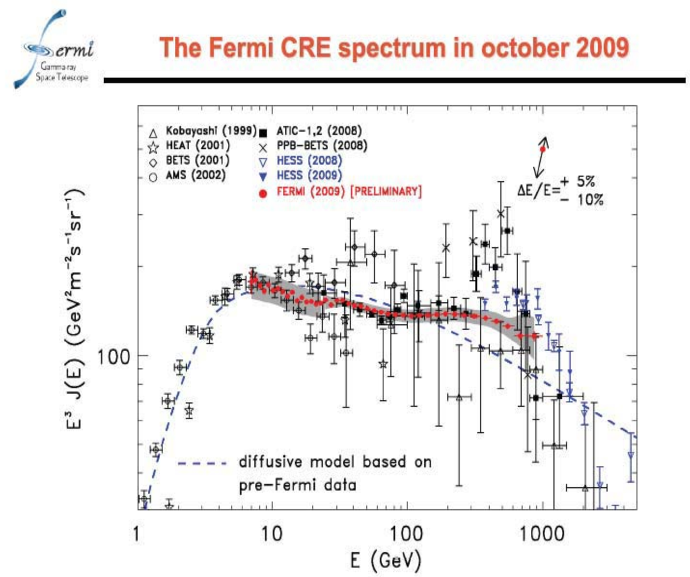
FERMI Impact on New Physics Searches









Extended Energy Range (7 GeV – 1 TeV) – One year statistics (8M evts)

T.G. Rizzo 12/17/09

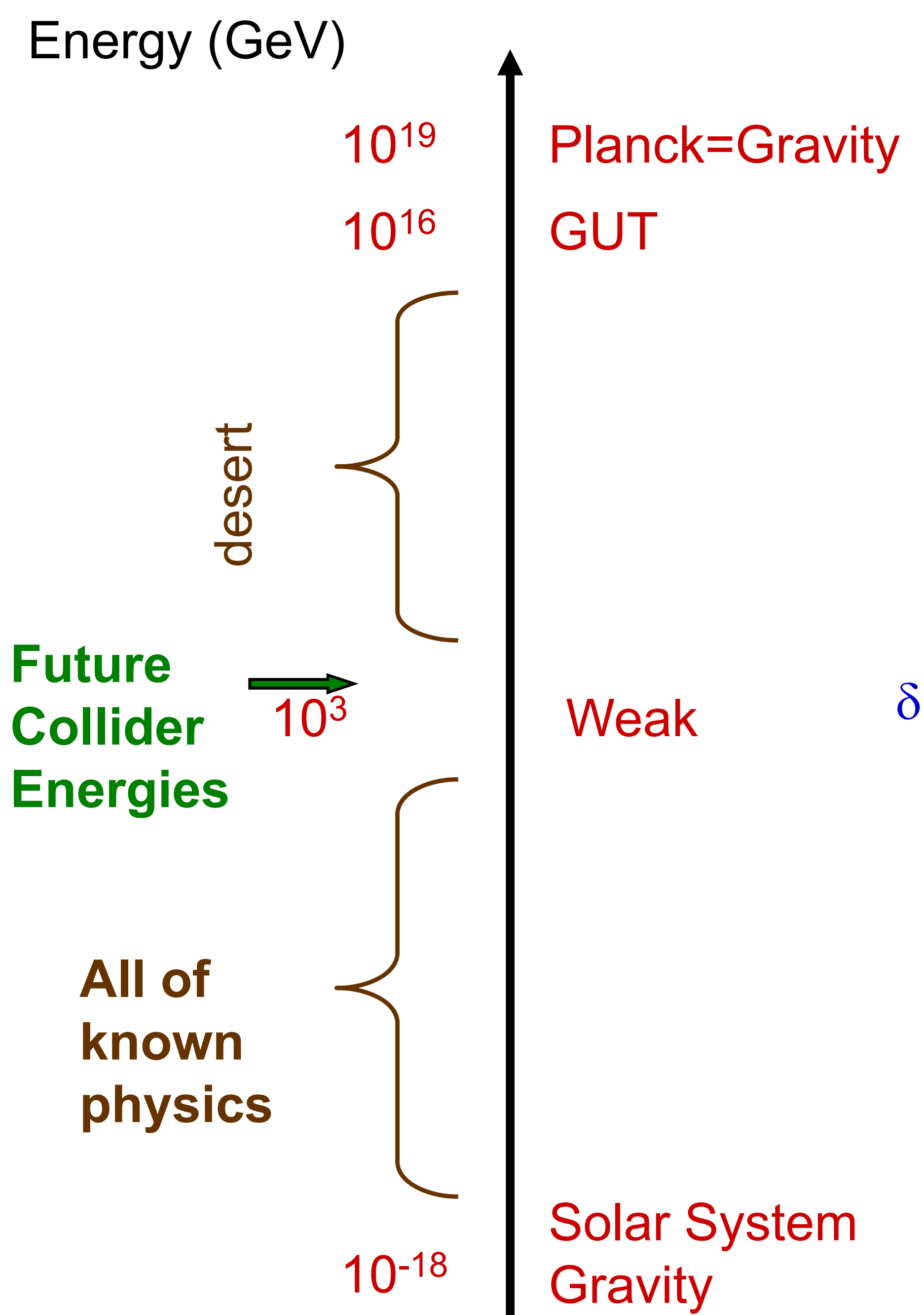
C. F. Berger, J.A. Conley, R.C. Cotta, J. S. Gainer, J. L. Hewett , M.-P. Le & TGR

- The Standard Model of particle physics provides a rather successful description of (almost) all strong, weak & electro-magnetic interaction data at the part-per-mille level or better.

- However, there are both experimental as well as theoretical reasons to expect that new physics must exist beyond the SM and some further motivation to expect that it lies near the TeV energy scale.

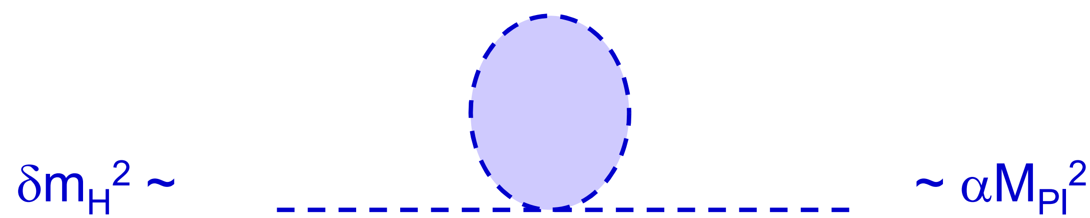
- One of the most obvious experimental issues with the SM is it lacks a candidate for a DM particle. However, such particles are, to some extent, a common feature of most new physics models that attempt to address some of the other outstanding issues of the SM such as the hierarchy problem.

The Hierarchy Problem



Quantum Corrections:

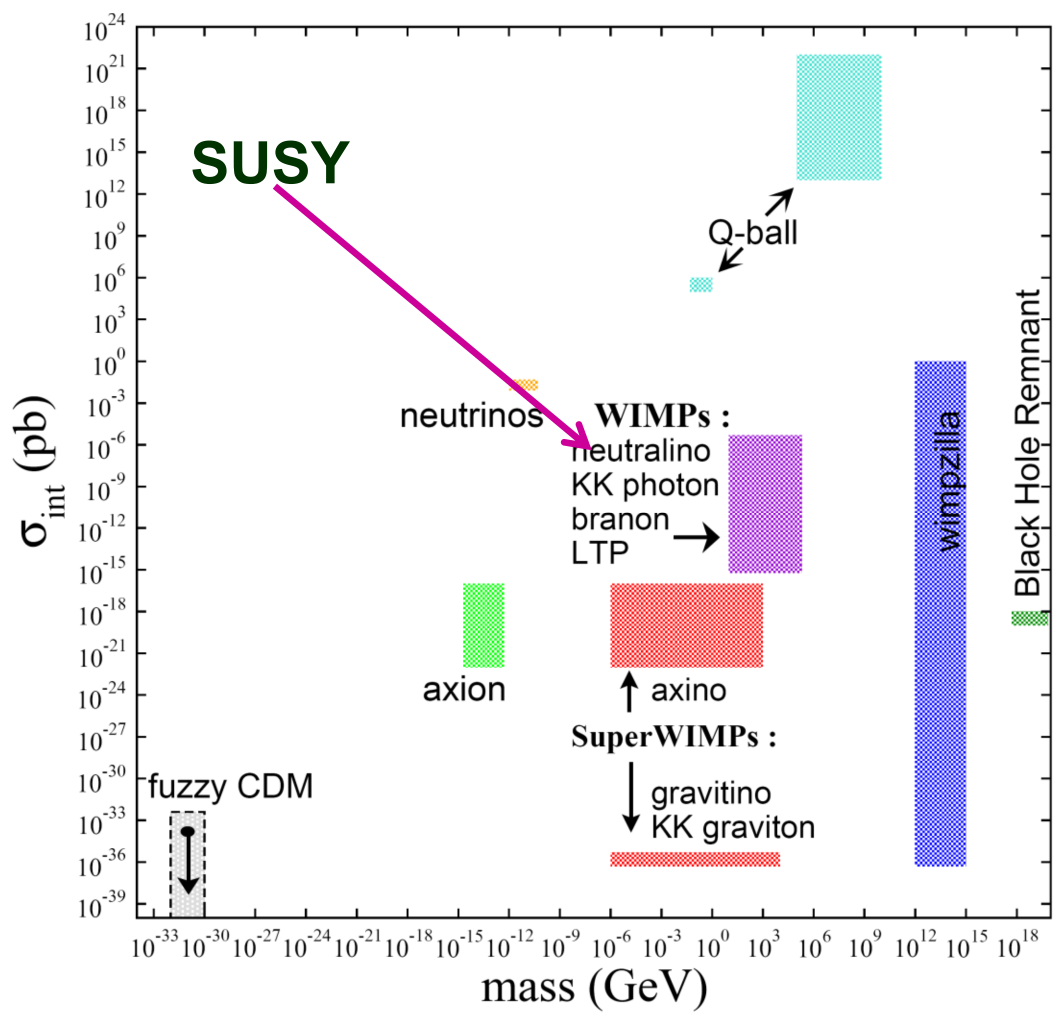
Loop effects want to drag the Weak Scale towards M_{Pl}



It is more ‘natural’ for the weak scale to be near the Planck scale than ~1 TeV … this is avoided by tuning the Higgs parameters to 1 part in 10^{32} !

SOME PARTICLE DARK MATTER CANDIDATES

- The observational constraints are no match for the creativity of theorists
- Masses and interaction strengths span many, many orders of magnitude, but not all candidates are equally motivated
- Weakly Interacting Massive Particle (WIMP)



HEPAP/AAAC DMSAG Subpanel (2007)

THE WIMP 'MIRACLE'

(1) Assume a new (heavy) particle χ is initially in thermal equilibrium:

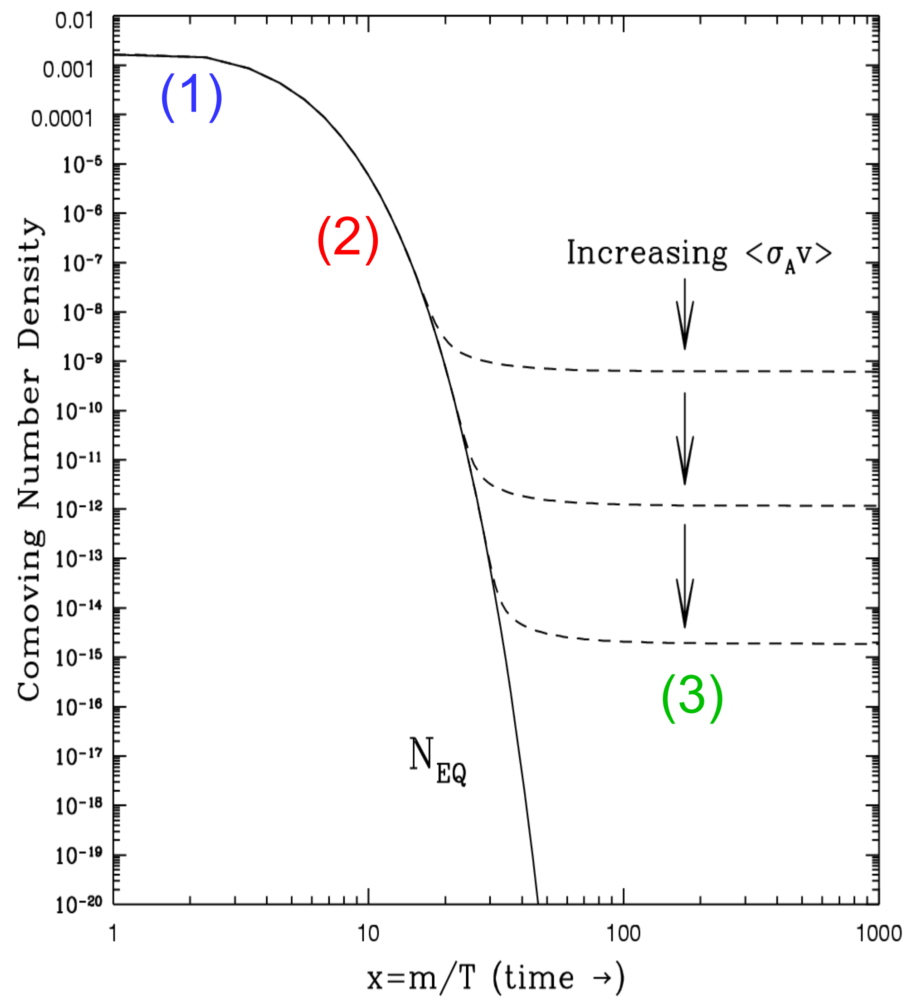
$$\chi\chi \leftrightarrow \bar{f}f$$

(2) **Universe cools:**

$$\chi\chi \ \substack{\rightarrow \\ \not\leftarrow} \ \bar{f}f$$

(3) **χs "freeze out":**

$$\chi\chi \ \substack{\not\rightarrow \\ \not\leftarrow} \ \bar{f}f$$

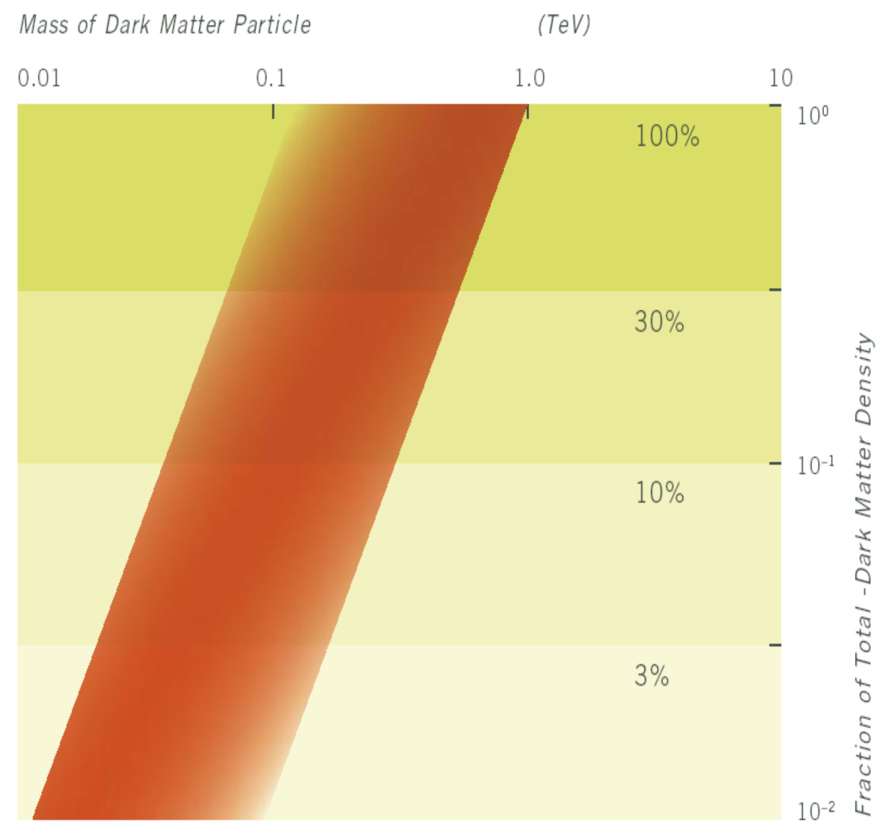


Zeldovich et al. (1960s)

- The amount of dark matter left over is inversely proportional to the annihilation cross section:

$$\Omega_{DM} \sim \langle\sigma_A v\rangle^{-1}$$

$$\sigma_A \sim \alpha^2 / m^2$$



HEPAP LHC/ILC Subpanel (2006)

[band width from k = 0.5 – 2, S and P wave]

Remarkable "coincidence": $\Omega_{DM} \sim 0.1$ for m ~ 100 GeV – 1 TeV; particle physics independently predicts particles with about the right density to be dark matter !

$\chi\chi \rightarrow$ photons, positrons , anti-protons…. 'in the sky' right now
may be seen by FERMI & other experiments

$\chi N \rightarrow \chi N$ (elastic) scattering may be detected on earth in deep
underground experiments like, e.g., CDMS (at 2pm??)

If χ is really a WIMP it may be directly produced at the LHC !

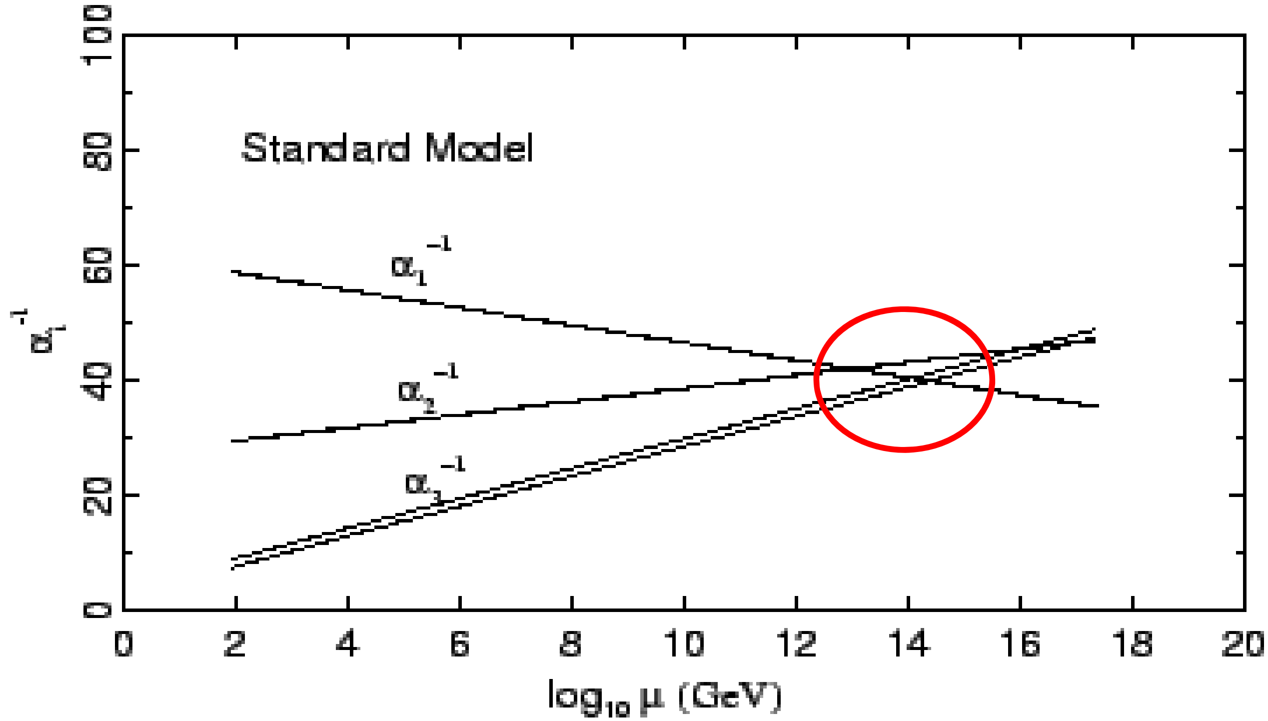
Of course, χ does not come by itself in any new physics model & there is usually a significant accompanying edifice of other interesting particles & interactions with many other observational predictions

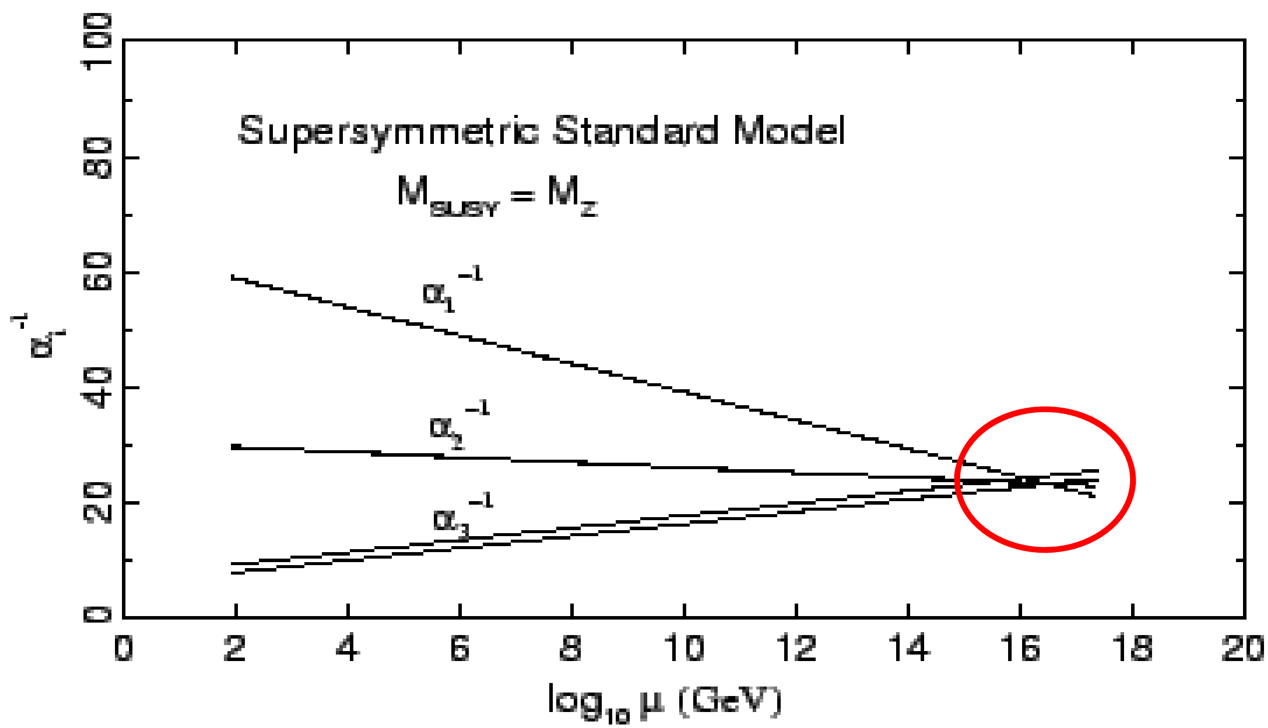
So this general picture can be tested in many ways….

- As the picture above shows there are many possible WIMP candidates in new physics models. Here we will focus on only one of them but most of the arguments made below will also be applicable to these other cases:

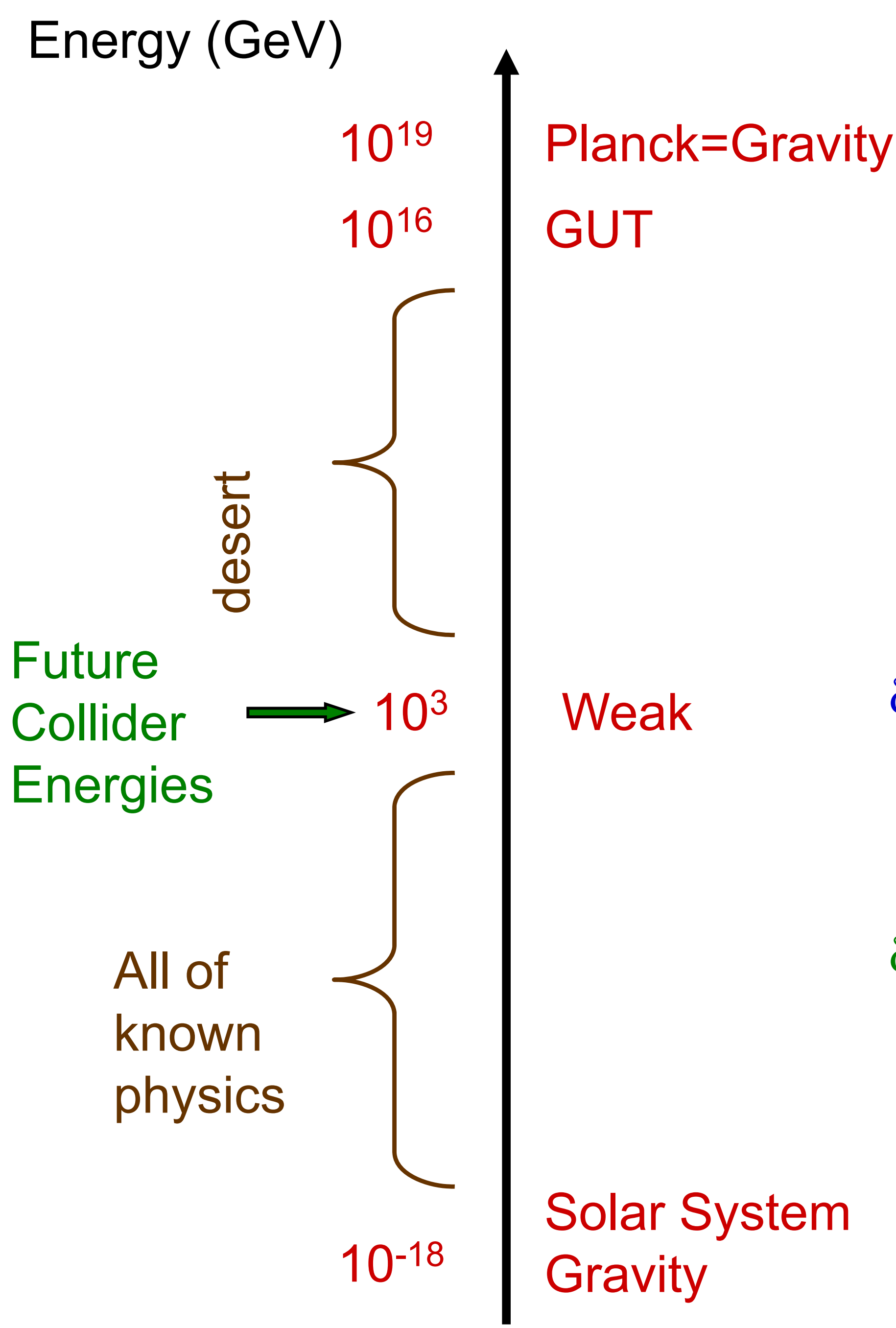
SUPERSYMMETRY

- This is the first & the most well-studied of the WIMP models & has a number of other nice features such as Grand Unification of the gauge coupling constants & it provides a solution to the hierarchy problem


Standard Model
α_1^{-1}
α_2^{-1}
α_3^{-1}
α_i^{-1}
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16
18
20
$\log_{10} \mu$ (GeV)

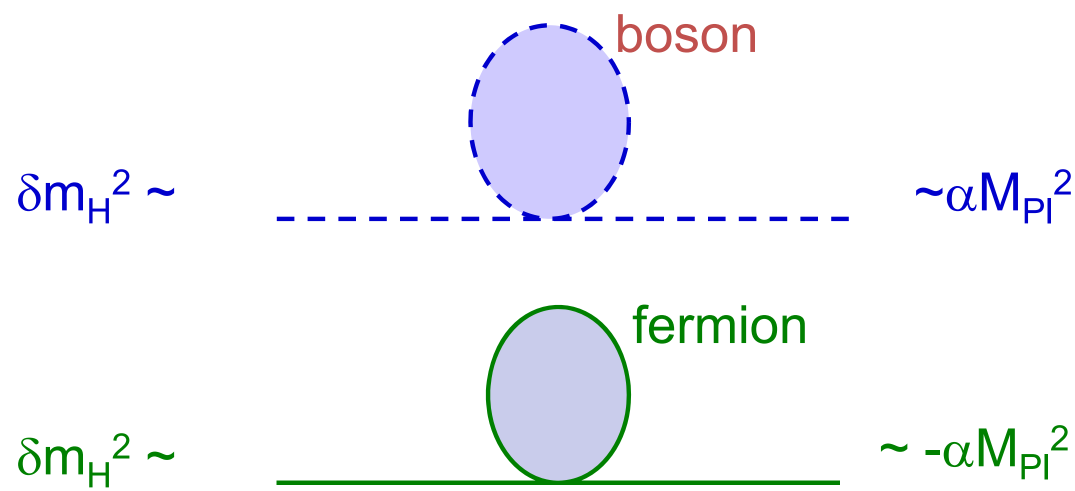

Supersymmetric Standard Model
$M_{SUSY} = M_Z$
α_1^{-1}
α_2^{-1}
α_3^{-1}
α_i^{-1}
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16
18
20
$\log_{10} \mu$ (GeV)

The Hierarchy Problem: Supersymmetry



Quantum Corrections:

Higher order effects drag Weak Scale to M_{Pl}

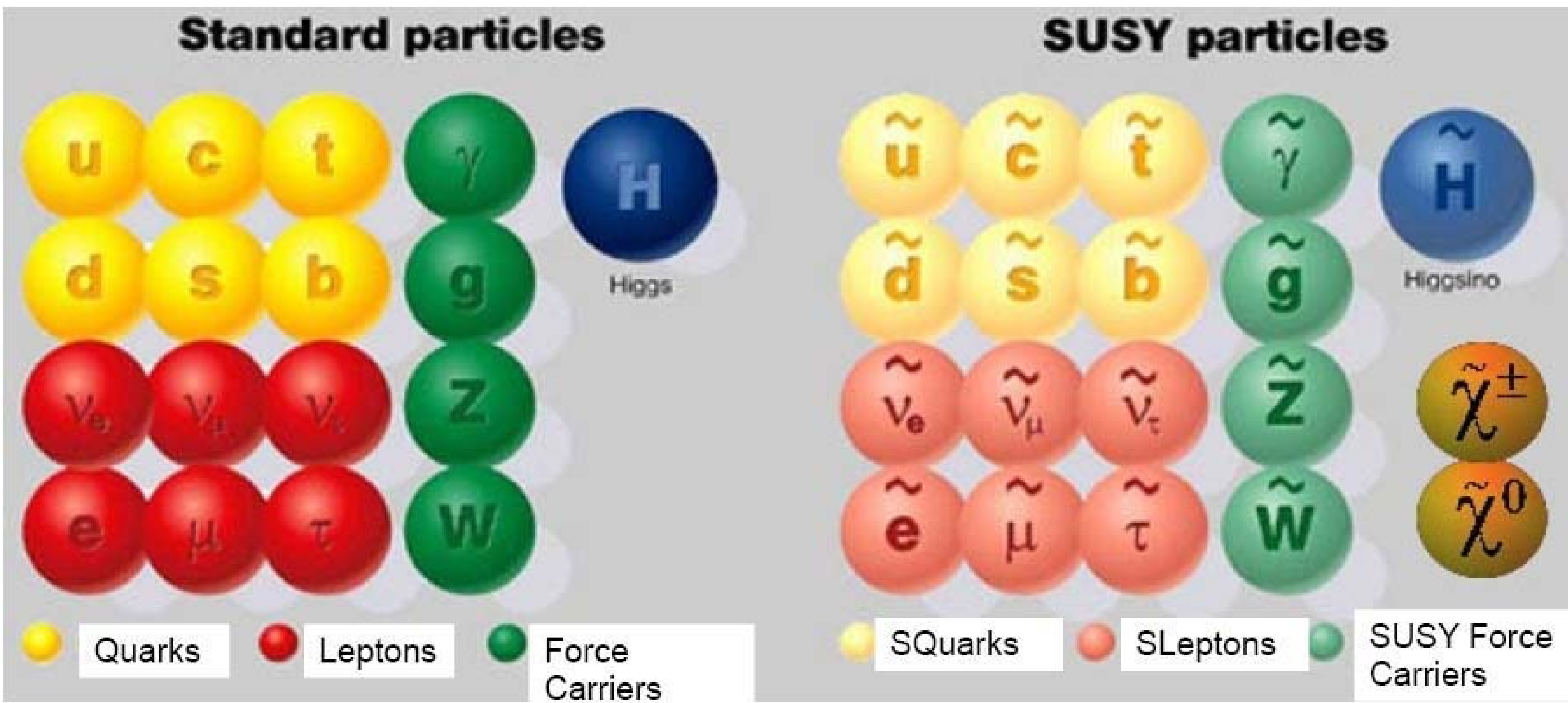


Largest effects cancel order by order in perturbation theory

Supersymmetry(SUSY), an extension of relativity, posits that for every SM particle there is an 'identical' copy which differs from it by ½ unit of intrinsic spin linking fermions & bosons.

→→→ SUSY is obviously a *broken symmetry*

This simplest version of SUSY is referred to as the MSSM



- The Lightest SUSY Particle is a stable WIMP & could be DM

- The breaking of SUSY leads to many unknowns & many different mechanisms for SUSY breaking have been discovered over the past two decades; surely more possibilities exist yet to be discovered. A priori, there is no way to choose from among these many possibilities although some have nicer features than others. In the end this will be an experimental issue !

- So we parameterize our ignorance by simultaneously considering all the possible 'soft' breaking terms that are allowed by the various symmetries of the SM & renormalizability.

- Although this is a fair & 'democratic' approach, it leads us to a theory which is difficult to test as there are now105 unknown free parameters to consider. This is too many to deal with in any practical way so what does one do??

- There are really only 2 possibilities:

(i) Consider only one or a few specific models of SUSY breaking such as mSUGRA, GMSB, AMSB, etc. The reason is that within such frameworks the number of parameters is significantly reduced. E.g., mSUGRA has only 4 parameters & a sign. The danger here is that we don't know how representative of all the possibilities these few models are…but this is the traditional approach.

(ii) Consider the largest possible subspace guided by as few prejudices as possible & the limits of current practicality . This is the path that we have followed in our study to try to capture as much of the physics of the general MSSM as possible.

FEATURE Analysis Assumptions :

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

This leaves us with the pMSSM:

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

What are they??

19 pMSSM Parameters

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}

gaugino masses: M_1, M_2, M_3

tri-linear couplings: A_b, A_t, A_τ

Higgs/Higgsino: μ, M_A, $\tan\beta$

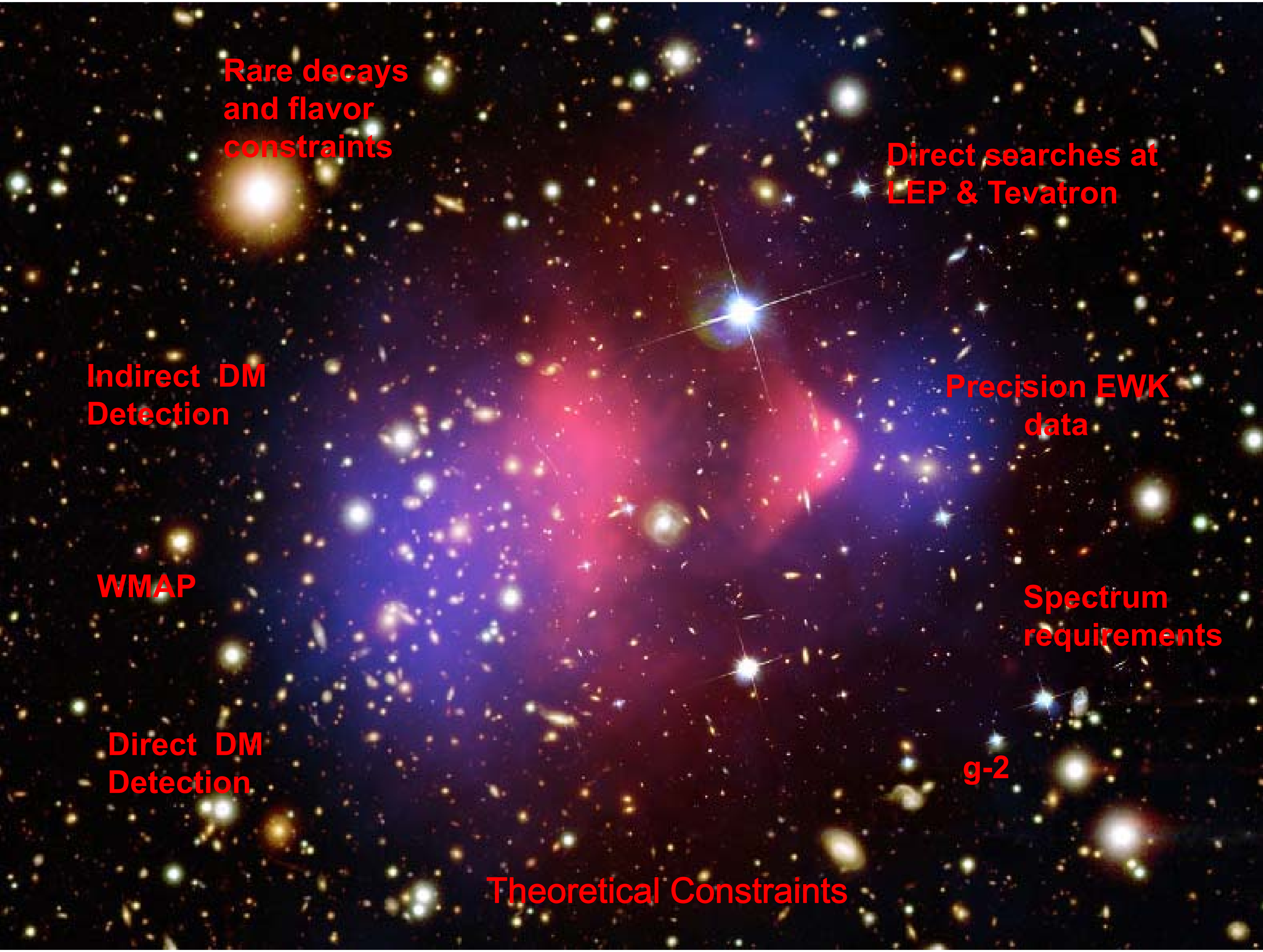
We now want to explore this parameter space as best we can to find allowed regions & to compare predictions with those from simpler scenarios.

• There are 2 possible goals/philosophies to follow:

(i) One can scan this parameter space & look for points that provide the 'most likely regions' based on theoretical & experimental input. This approach has become an art form recently as the technology has advanced from random scans to Markov-Chain MC to (multi-)nested sampling & genetic algorithms. [$] This is perhaps the best approach for the case of specific SUSY breaking scenarios with a few parameters that have been well-studied experimentally

(ii) Instead, if one is looking for new types of physics in the case of many new parameters not captured by a specific breaking framework we need only look for points that are 'allowed' by current constraints using cuts. These constraints arise from many places & one needs to listen to them *very* carefully...

$ For detailed refs, see P. Scott etal, arXiv: 0909.3300


Rare decays
and flavor
constraints
Direct searches at
LEP & Tevatron
Indirect DM
Detection
Precision EWK
data
WMAP
Spectrum
requirements
Direct DM
Detection
g-2
Theoretical Constraints

$\rightarrow$ Many different voices have to be carefully listened to if we are to finally arrive at the allowed points of this very large model parameter space. So far there are 6 of these voices:

- Voices from flavor physics: $b \rightarrow s\,\gamma$, **$B \rightarrow \tau\nu$,** $B_s \rightarrow \mu\mu$, meson-anti-meson mixing

- Voices from ‘precision data’: $\Gamma(Z\rightarrow$ invisible), $\Delta\rho$ [W-mass, Z-couplings, etc.] , muon(g-2) [controversy!]

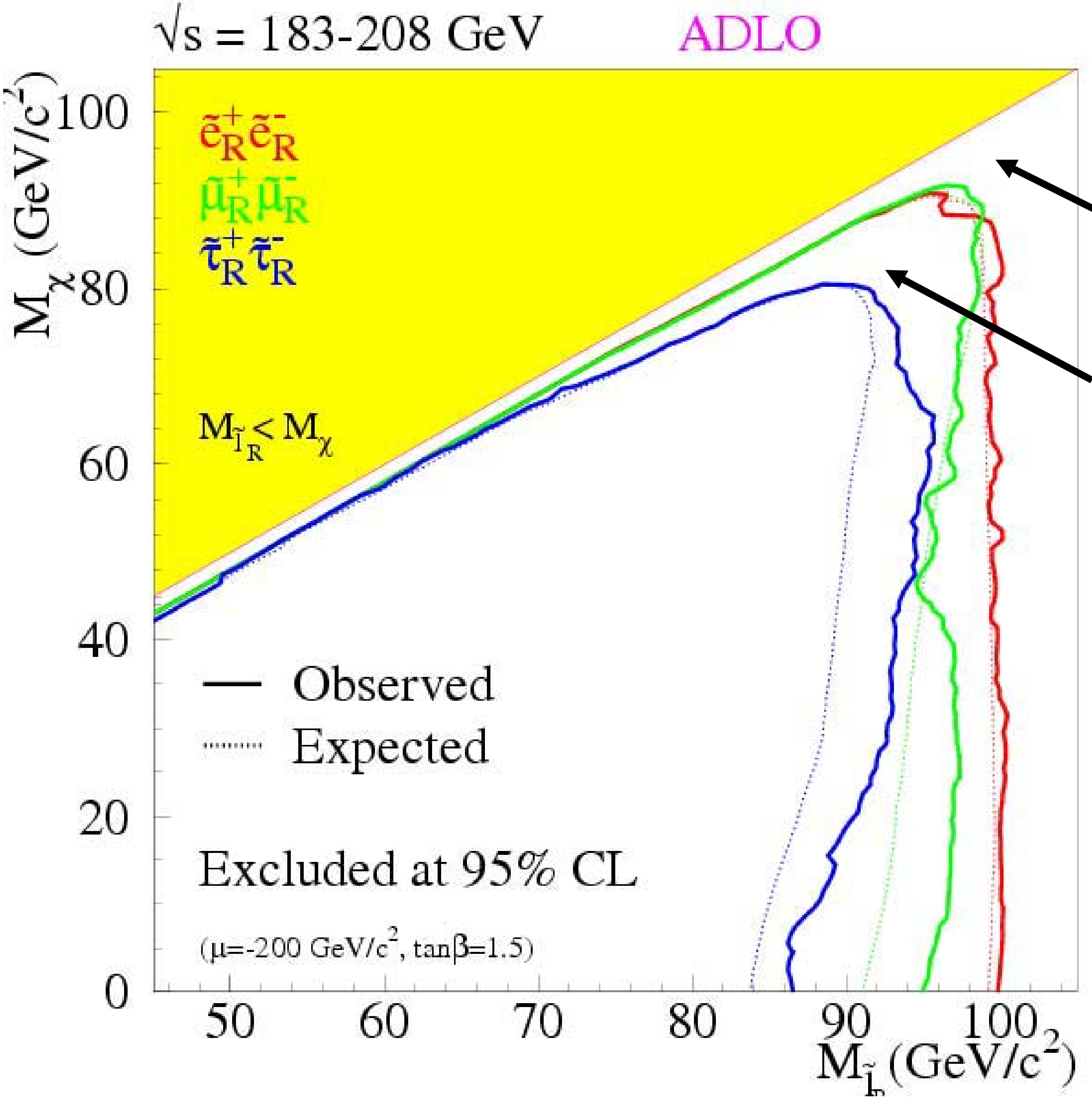
- Voices from theory: LSP is a colorless, neutral particle here assumed to be the neutralino; no tachyons & only stable potential minima not breaking color or charge

- Voices from the early universe: $\Omega h^2 < 0.1210$ → 5yr WMAP
  We treat this only as an *upper bound* on the LSP DM density to allow for multi-component DM, e.g., axions, etc. Recall the lightest neutralino is the LSP & a thermal relic here

- **Voices from Underground:** Direct Detection of Dark Matter
  → Spin-independent limits are completely dominant here. We allow for a factor of 4 in cross section uncertainties given the nuclear & other input parameter uncertainties

- Voices from direct Higgs &SUSY collider searches : there are *many* of these searches but they are very complex with many caveats—some only directly apply to *mSUGRA*. We need to be extremely cautious here in how these constraints are used.

RH Sleptons



Note the holes where the leptons are too soft…

We need to allow for a mass gap w/ the LSP & also in the squark case when soft jets are possible..light guys may slip through

Tevatron Constraints : I Squark & Gluino Search

- Ours is the first (& only) SUSY analysis to include these constraints in a model-independent way
- 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

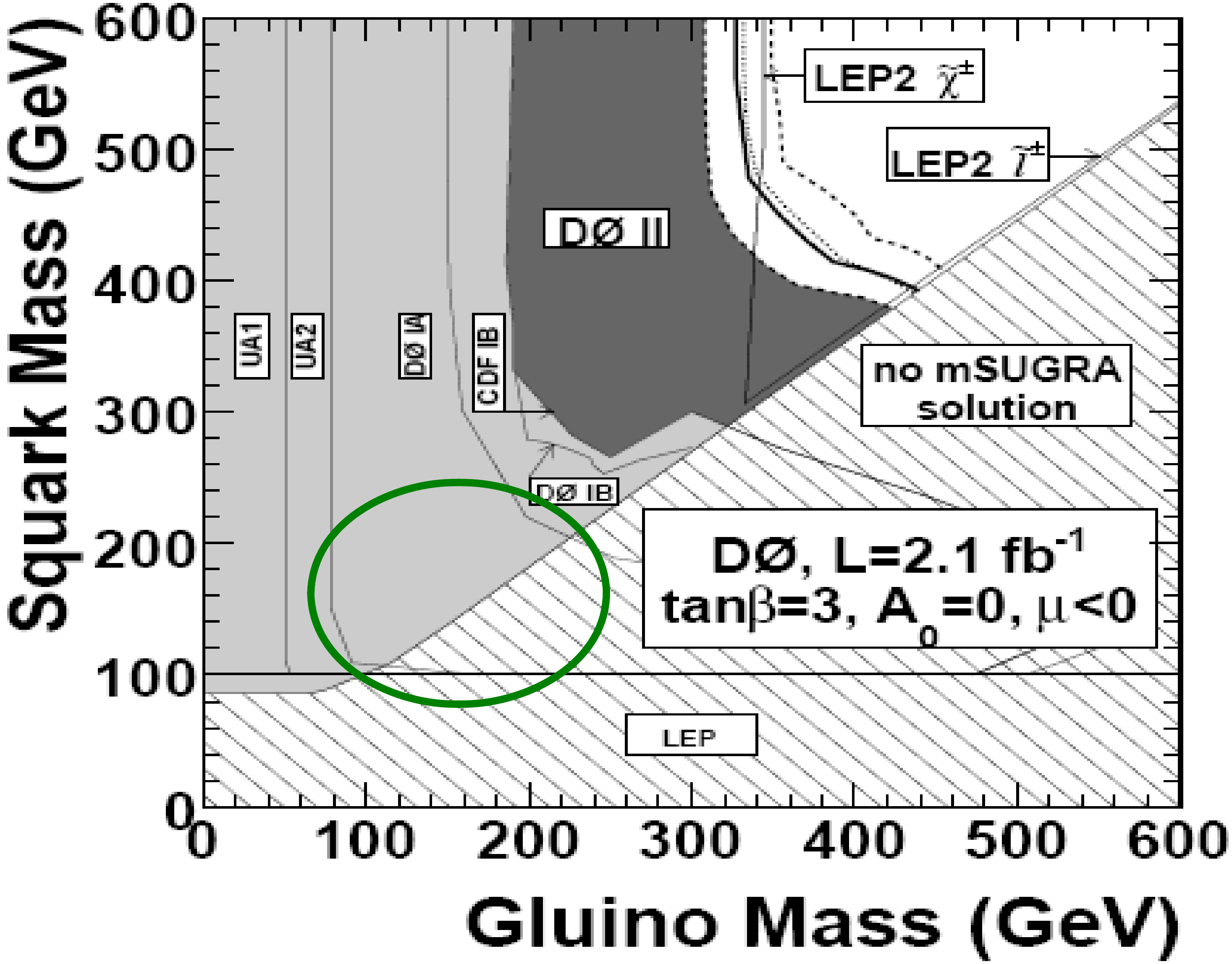
[a] First and second jets are also required to be central ($|\eta_{\rm det}| < 0.8$), with an electromagnetic fraction below 0.95, and to have CPF0 ≥ 0.75.
[b] Third and fourth jets are required to have $|\eta_{\rm det}| < 2.5$, with an electromagnetic fraction below 0.95.

Multiple analyses keyed to look for:

Squarks-> jet +MET
Gluinos -> 2 j + MET

The search is based on mSUGRA type sparticle spectrum assumptions which can be VERY far from our model points

This D0 search provides strong constraints in mSUGRA.. squarks & gluinos > 350-400 GeV…but the real limits can be *much weaker* on both these sparticles as we'll see !!



D0 benchmarks

TABLE II: For each analysis, information on the signal for which it was optimized (m_0, $m_{1/2}$, $m_{\tilde{g}}$, $m_{\tilde{q}}$, and nominal NLO cross section), signal efficiency, the number of events observed, the number of events expected from SM backgrounds, the number of events expected from signal, and the 95% C.L. signal cross section upper limit. The first uncertainty is statistical and the second is systematic.

Analysis	$(m_0, m_{1/2})$ (GeV)	$(m_{\tilde{g}}, m_{\tilde{q}})$ (GeV)	σ_{nom} (pb)	$\epsilon_{sig.}$ (%)	$N_{obs.}$	$N_{backgrd.}$	$N_{sig.}$	σ_{95} (pb)
"dijet"	(25,175)	(439,396)	0.072	$6.8 \pm 0.4^{+1.2}_{-1.2}$	11	$11.1 \pm 1.2^{+2.9}_{-2.3}$	$10.4 \pm 0.6^{+1.8}_{-1.8}$	0.075
"3-jets"	(197,154)	(400,400)	0.083	$6.8 \pm 0.4^{+1.4}_{-1.3}$	9	$10.7 \pm 0.9^{+3.1}_{-2.1}$	$12.0 \pm 0.7^{+2.5}_{-2.3}$	0.065
"gluino"	(500,110)	(320,551)	0.195	$4.1 \pm 0.3^{+0.8}_{-0.7}$	20	$17.7 \pm 1.1^{+5.5}_{-3.3}$	$17.0 \pm 1.2^{+3.3}_{-2.9}$	0.165

TABLE III: Definition of the analysis combinations, and number of events observed in the data and expected from the SM backgrounds.

Selection	"dijet"	"3-jets"	"gluino"	$N_{obs.}$	$N_{backgrd.}$
Combination 1	yes	no	no	8	9.4 ± 1.2 (stat.) $^{+2.3}_{-1.8}$ (syst.)
Combination 2	no	yes	no	2	4.5 ± 0.6 (stat.) $^{+0.7}_{-0.5}$ (syst.)
Combination 3	no	no	yes	14	12.5 ± 0.9 (stat.) $^{+3.6}_{-1.9}$ (syst.)
Combination 4	yes	yes	no	1	1.1 ± 0.3 (stat.) $^{+0.5}_{-0.3}$ (syst.)
Combination 5	yes	no	yes		kinematically not allowed
Combination 6	no	yes	yes	4	4.5 ± 0.6 (stat.) $^{+1.8}_{-1.3}$ (syst.)
Combination 7	yes	yes	yes	2	0.6 ± 0.2 (stat.) $^{+0.1}_{-0.2}$ (syst.)
At least one selection				31	32.6 ± 1.7 (stat.) $^{+9.0}_{-5.8}$ (syst.)

Combos of the 3 analyses

→ Feldman-Cousins 95% CL Signal limit: 8.34 events

SuSpect -> SUSY-Hit -> PROSPINO -> PYTHIA -> D0-tuned PGS4 fast simulation (to reproduce the benchmark points)…

redo this analysis ~ 10^5 times !

How? Perform 2 Random Scans

Linear Priors

10^7 points – 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

$2\text{x}10^6$ points – emphasizes lower masses but extends to higher masses

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

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

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

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

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

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

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

→This analysis required ~ 1 core-century of CPU time…this was the real limitation of this study.

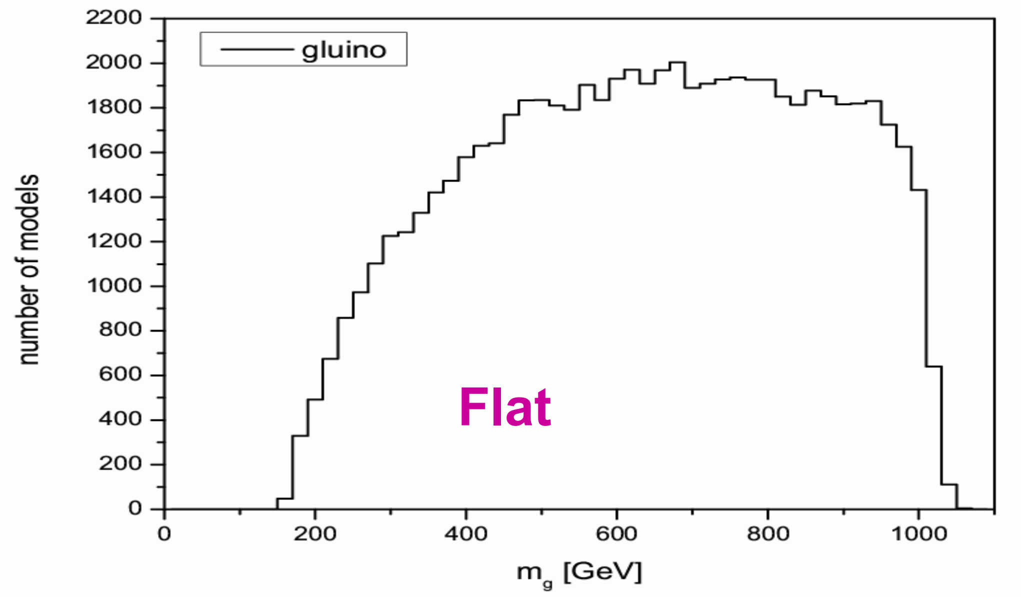
Survival Rates

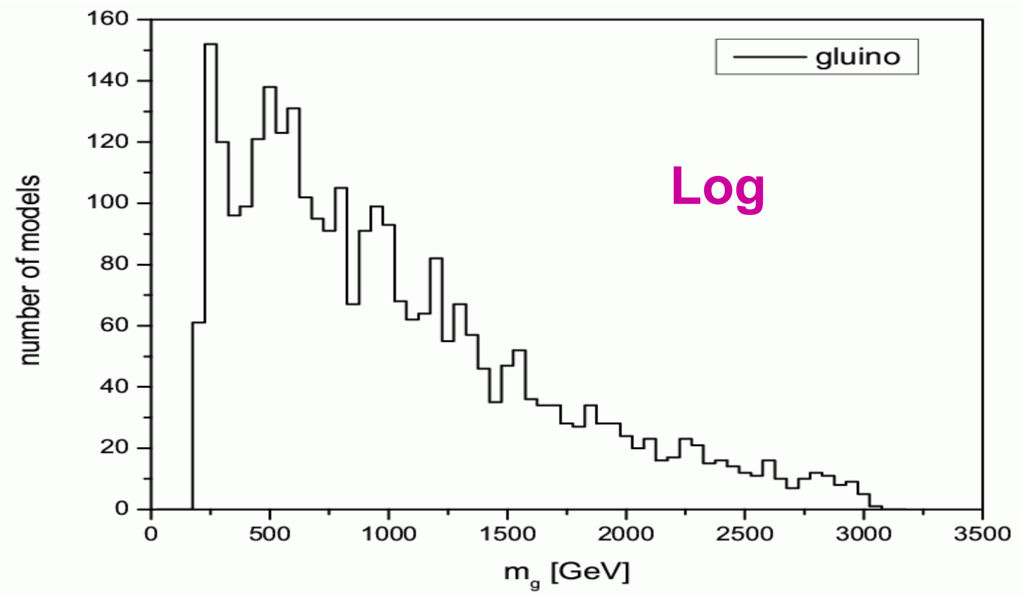
file	Description	Percent of Models Remaining
slha-okay.txt	SuSpect generates SLHA file	99.99 %
error-okay.txt	Spectrum tachyon, other error free	77.29%
lsp-okay.txt	LSP the lightest neutralino	32.70 %
deltaRho-okay.txt	$\Delta\rho$	32.61 %
gMinus2-okay.txt	$g - 2$	21.69 %
b2sGamma-okay.txt	$b \longrightarrow s\gamma$	6.17 %
Bs2MuMu-okay.txt	$B \longrightarrow \mu\mu$	5.95 %
vacuum-okay.txt	No CCB, potential not UFB	5.92 %
Bu2TauNu-okay.txt	$B \longrightarrow \tau\nu$	5.83 %
LEP-sparticle-okay.txt	LEP sfermion checks	4.72 %
invisibleWidth-okay.txt	Invisible Width of Z	4.71 %
susyhitProb-okay.txt	Heavy Higgs not problematic for SUSY-HIT	4.69 %
stableParticle-okay.txt	Tevatron stable chargino search	4.19 %
chargedHiggs-okay.txt	LEP/ Tevatron charged Higgs search	4.19 %
neutralHiggs-okay.txt	LEP neutral Higgs search	1.73 %
directDetection-okay.txt	WIMP direct detection	1.55 %
omega-okay.txt	Ωh^2	0.74 %
Bs2MuMu-2-okay.txt	$B \longrightarrow \mu\mu$	0.74 %
stableChargino-2-okay.txt	Tevatron stable chargino search	0.72 %
triLepton-okay.txt	Tevatron trilepton	0.72 %
jetMissing-okay.txt	Tevatron jet plus missing	0.70 %
final-okay.txt	Final after cutting models with e.g. light stop, sbottoms	0.68 %

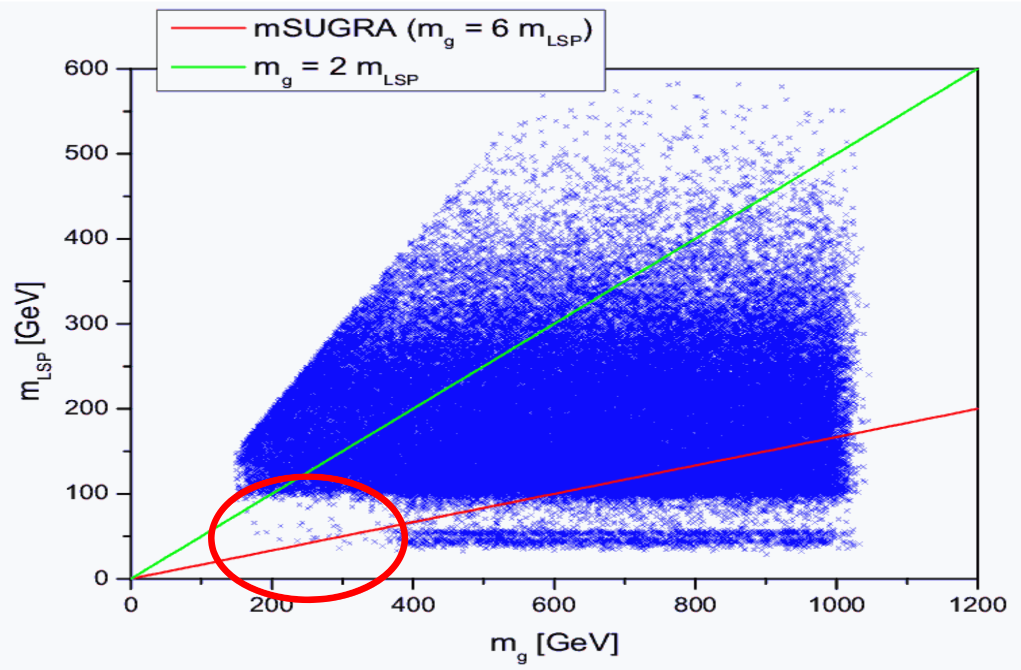
- Flat Priors : 10^7 models scanned , ~ 68.4 K (0.68%) survive
- Log Priors : $2\text{x}10^6$ models scanned , ~ 2.8 K (0.14%) survive

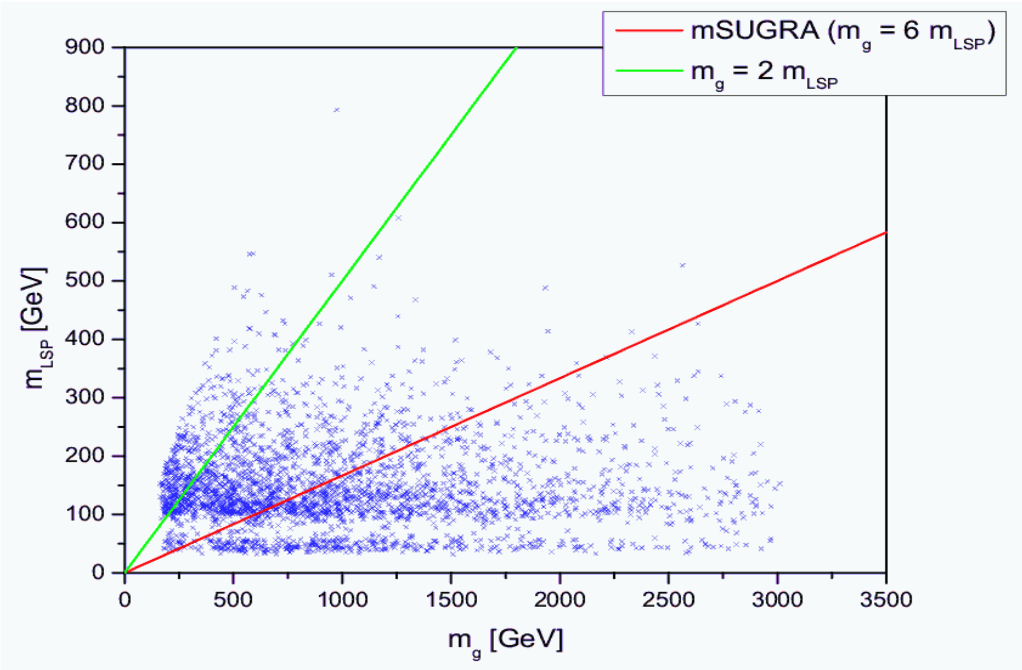
→ 71.2K models to study ! This is a HUGE model set…

Gluino Can Be Light !!

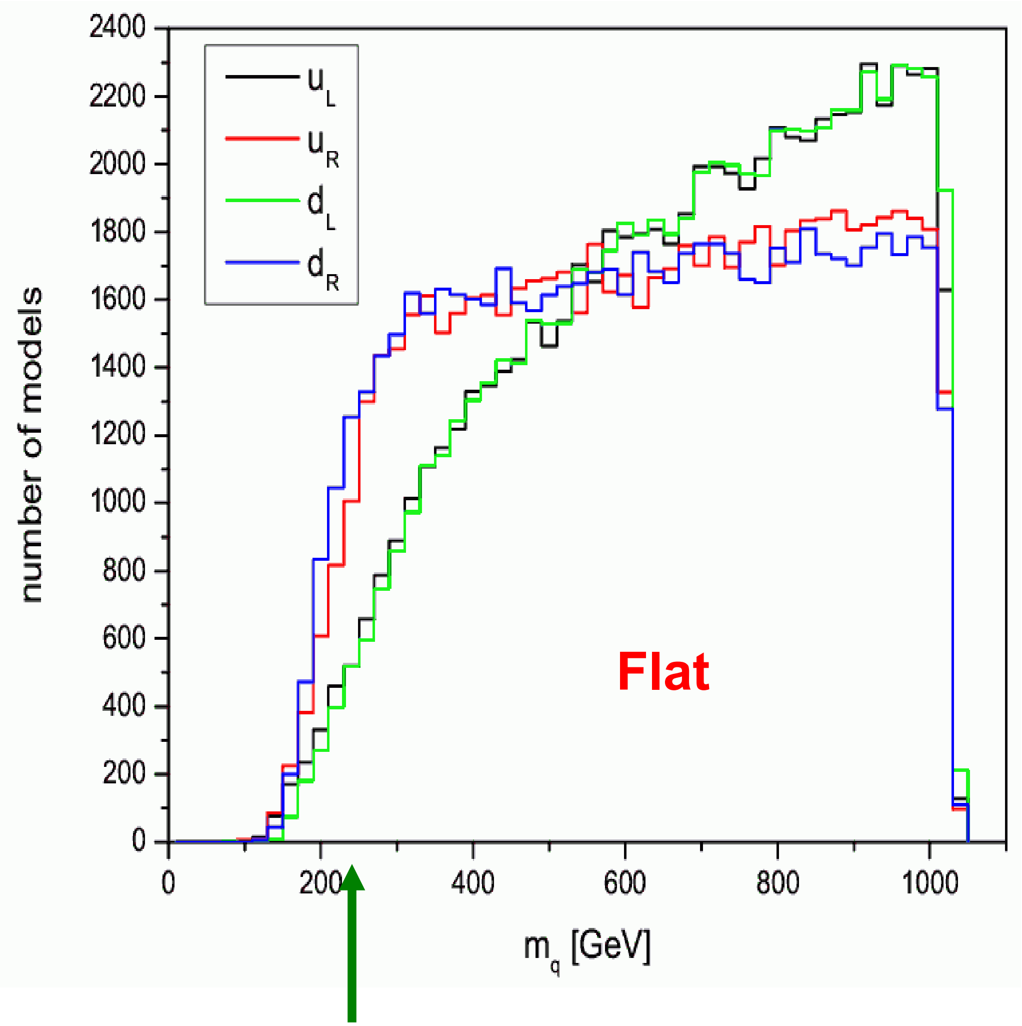


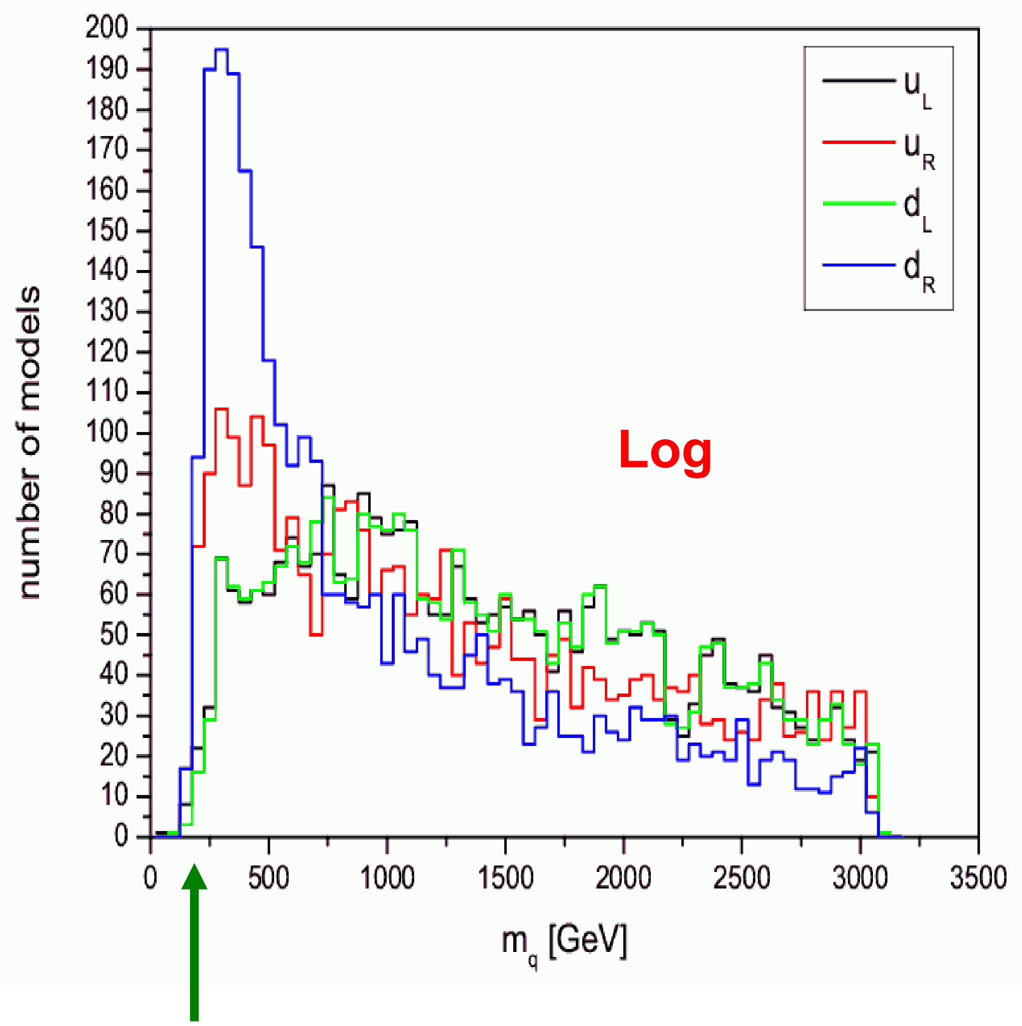






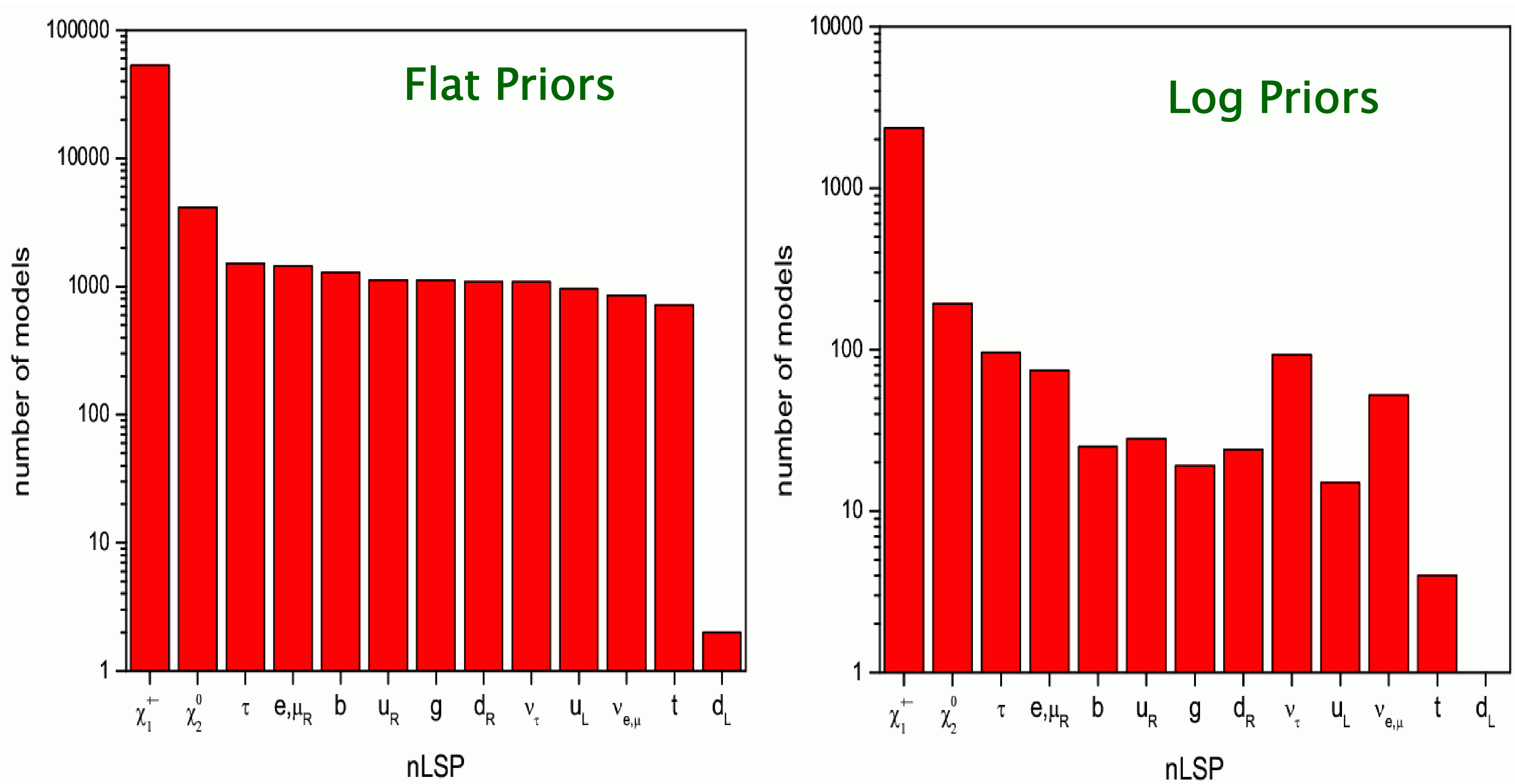
Squarks CAN Be Light !!!



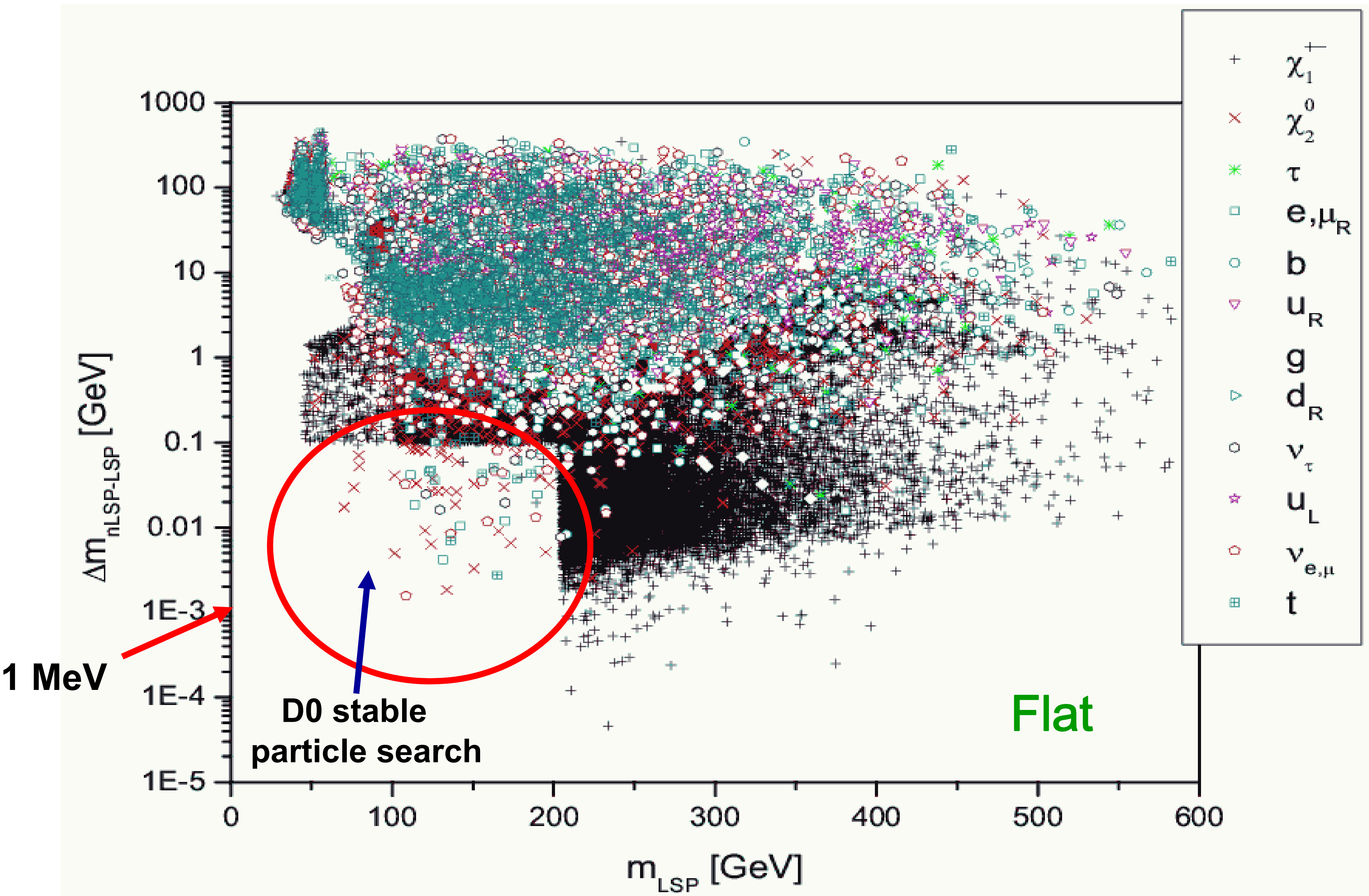


Light squarks can also be missed by Tevatron searches for numerous reasons as in the gluino case.

The identity of the nLSP is a critical factor in looking for SUSY signatures & in co-annihilation...who can play that role here????
Just about ANY of the 13 possibilities !



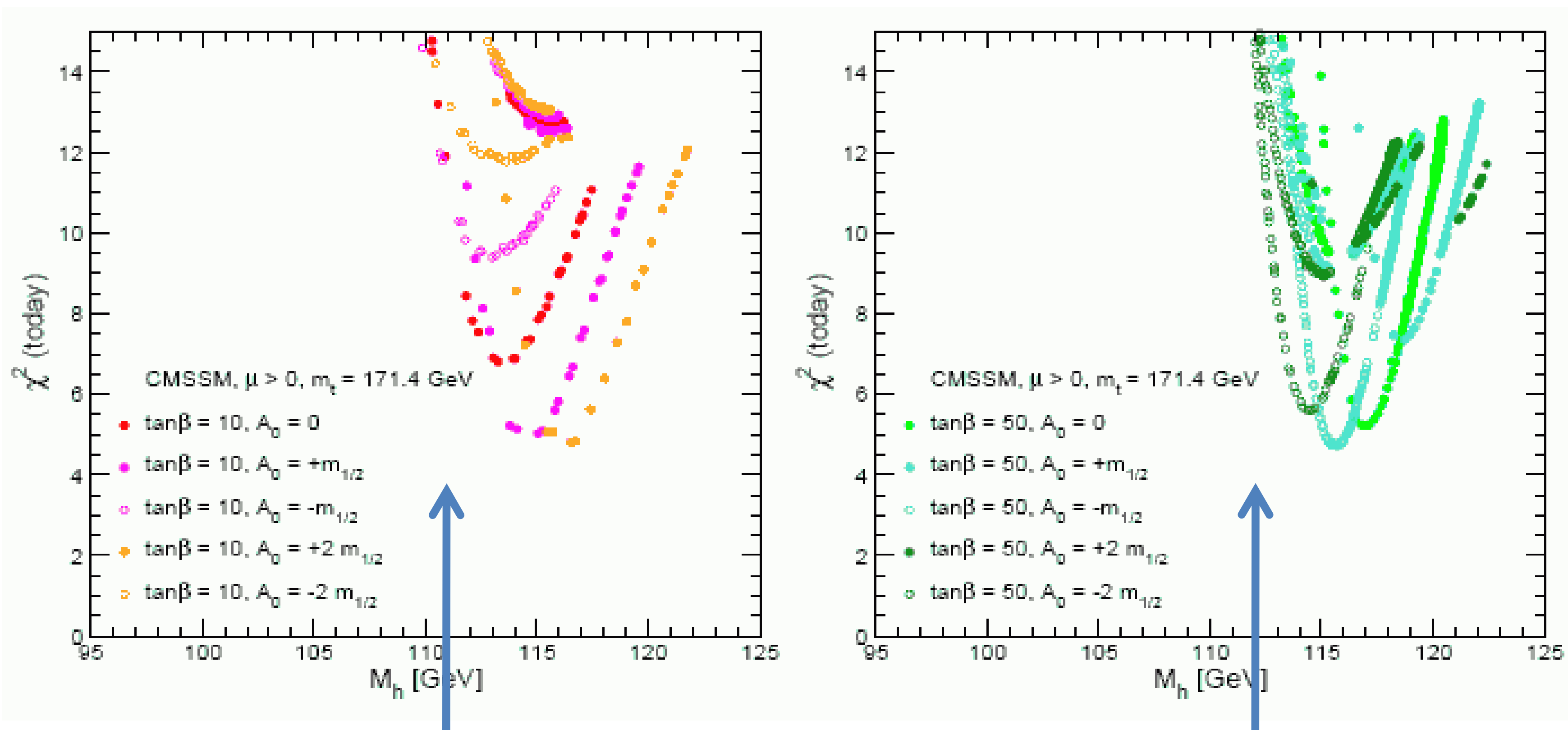
nLSP-LSP Mass Difference



Most Analyses Assume mSUGRA/ CMSSM Framework

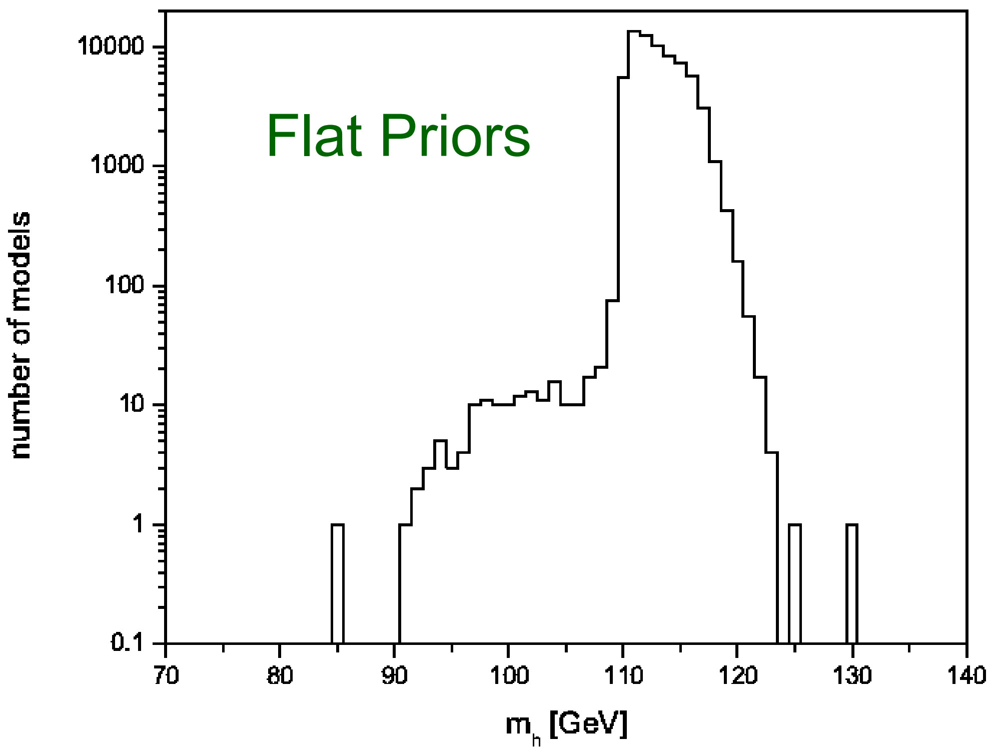
- CMSSM: m_0, $m_{1/2}$, A_0, $\tan\beta$, sign μ
- χ^2 fit to some global data set

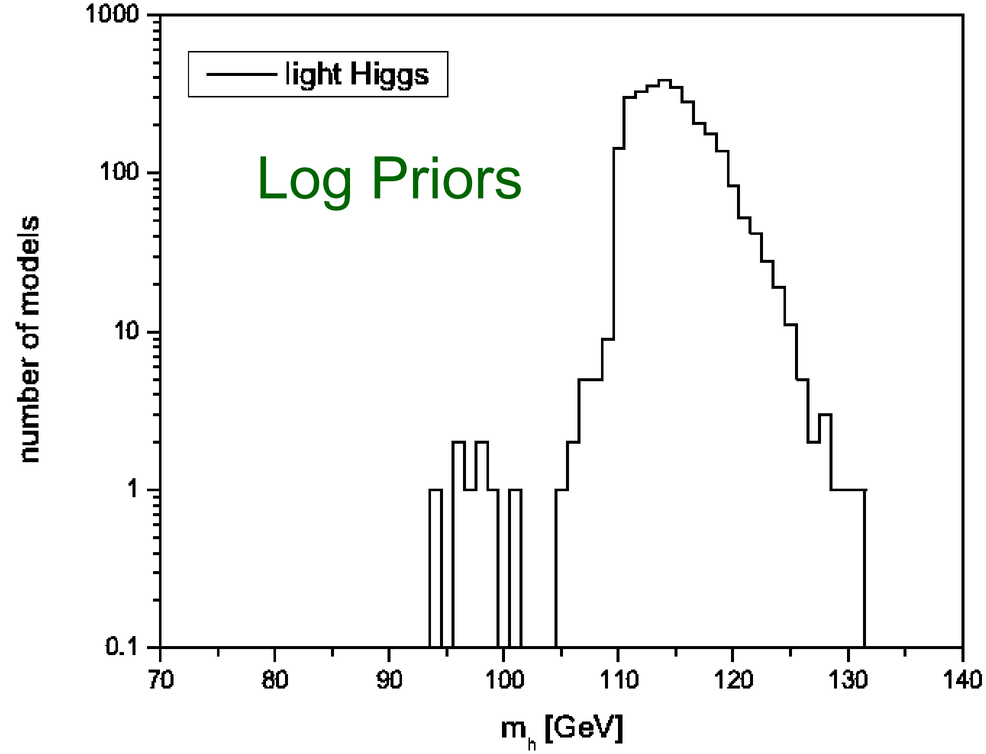
Prediction for Lightest Higgs Mass
Fit to EW precision, B-physics observables, & WMAP



Ellis etal arXiv:0706.0652

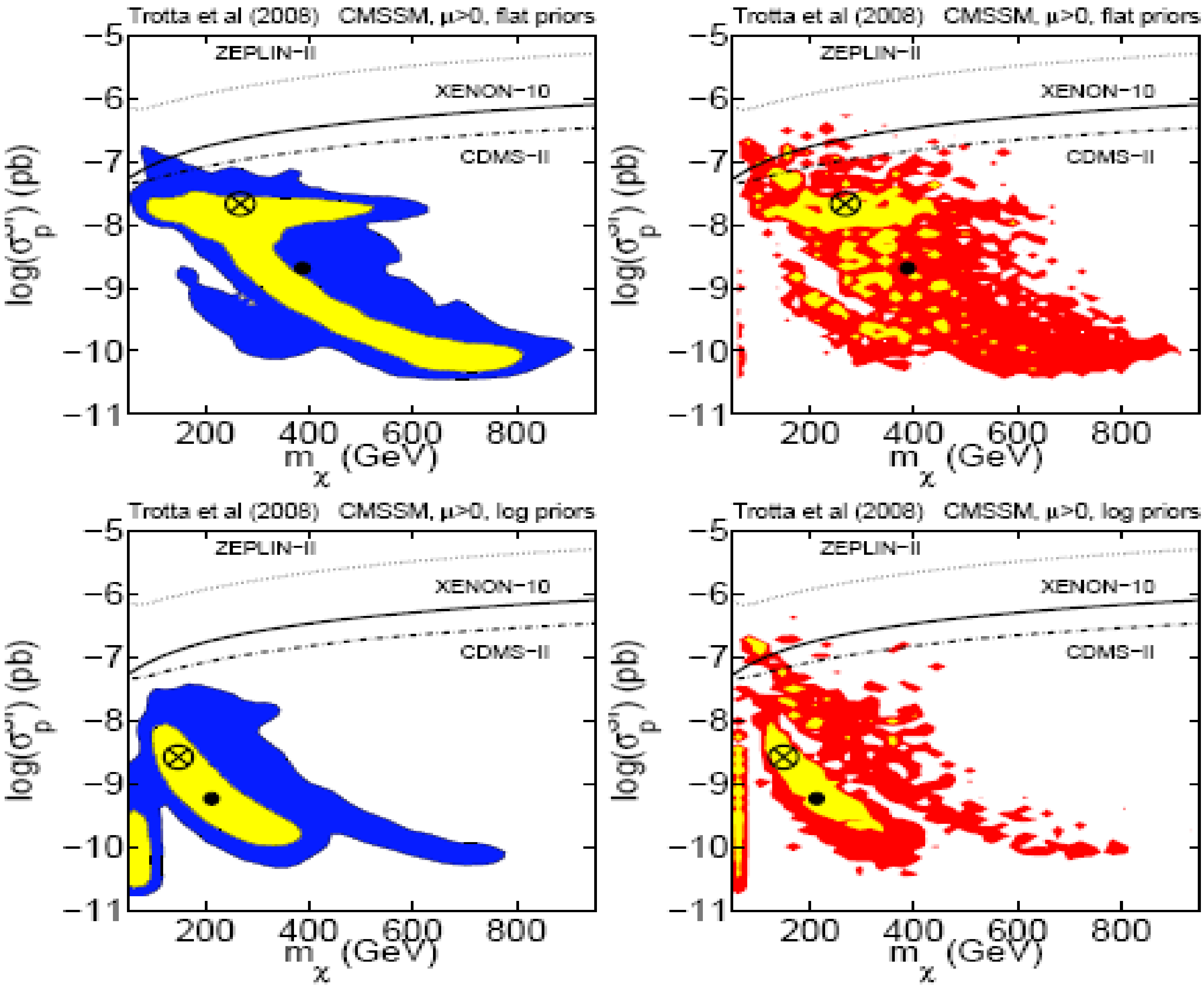
Light Higgs Mass Predictions





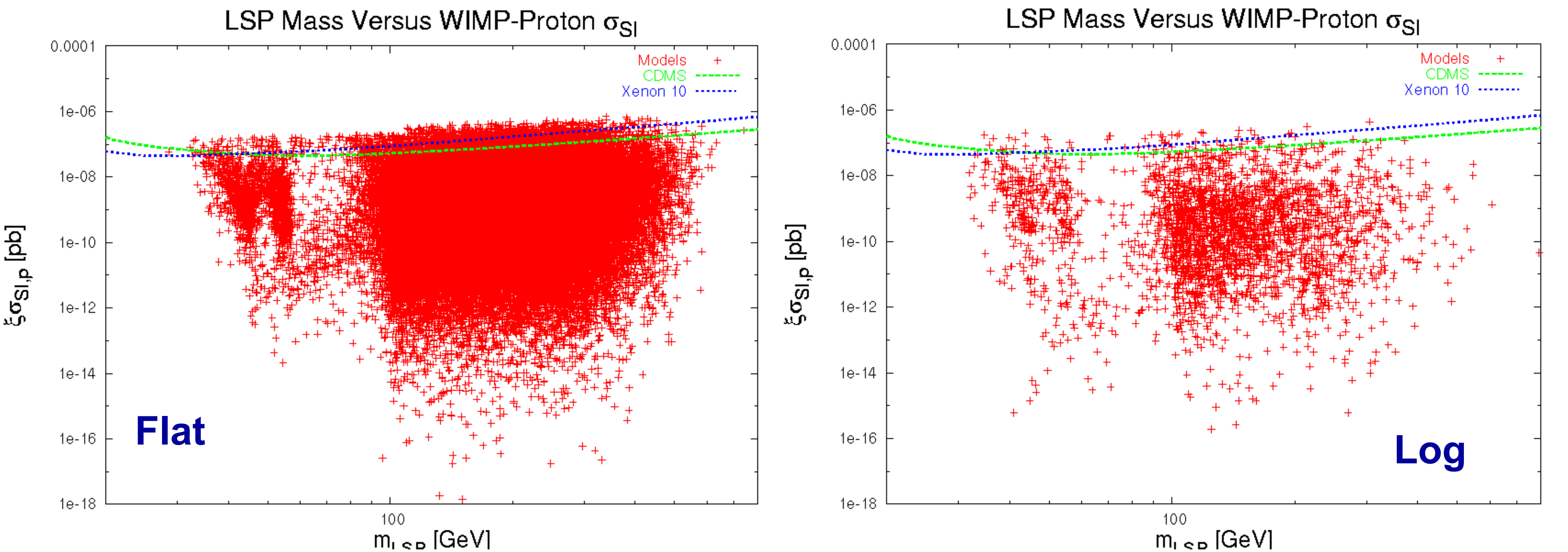
LEP Higgs mass constraints avoided by either reducing the ZZh coupling and/or reducing the, e.g., h →$b\bar{b}$ branching fraction by decays to LSP pairs. We have both of these cases in our final model sets.

Dark Matter Direct Detection in mSUGRA with Larger Mass Ranges Scanned…note prior dependence !!!



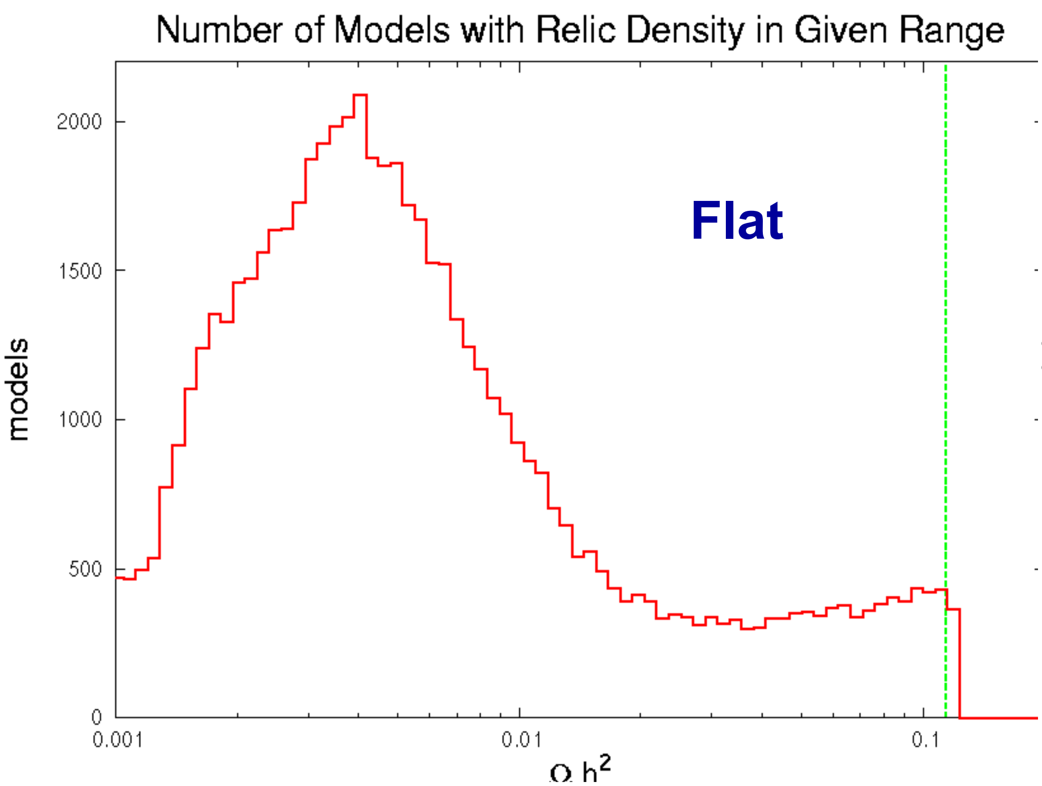
Direct Detection Expectations

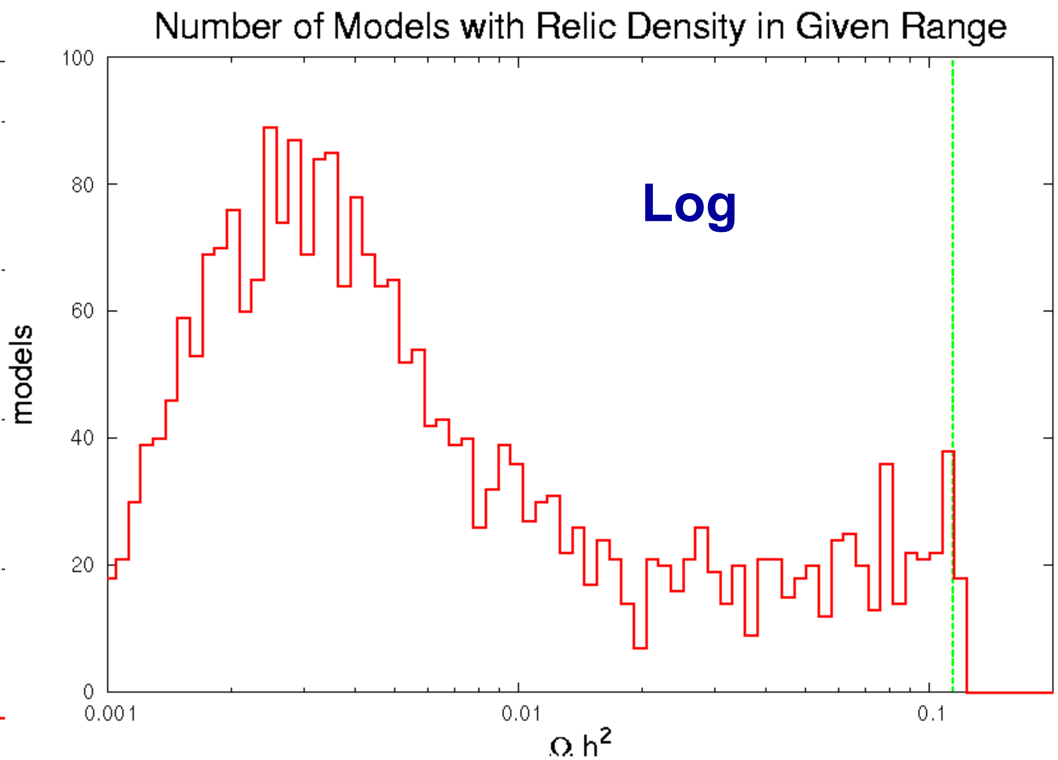
Extremely small cross sections are possible in either the flat or log prior cases…far smaller than expected in, e.g., mSUGRA….by many orders of magnitude!



Predicted Dark Matter Density : Ωh^2

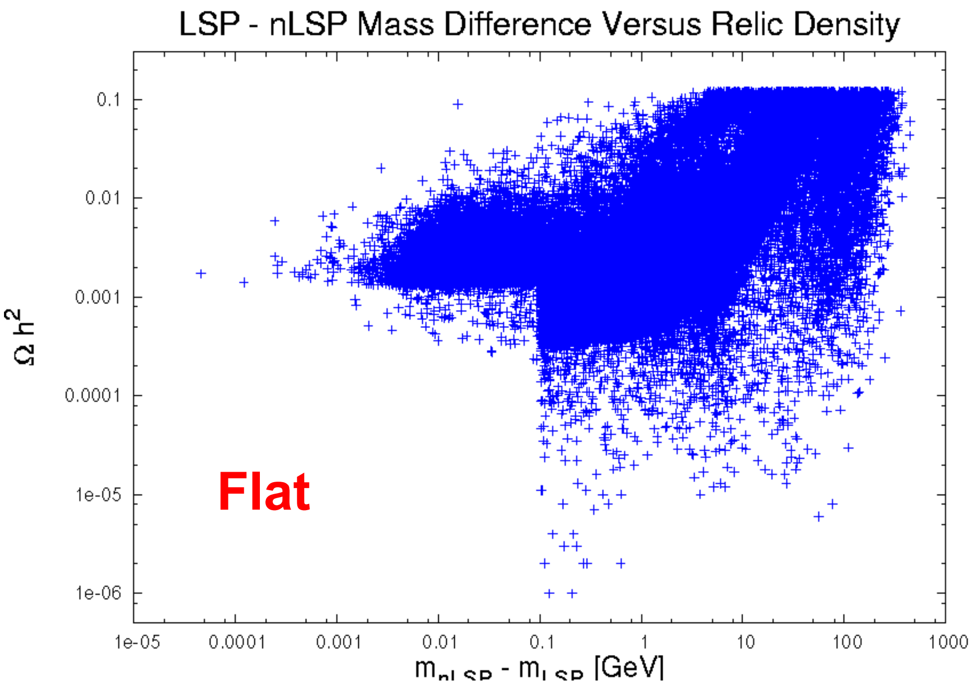
It is not always likely that the LSP is the dominant component of dark matter in the ‘conventional’ thermal relic cosmology…but it can be in many model cases.. (1240 + 76)

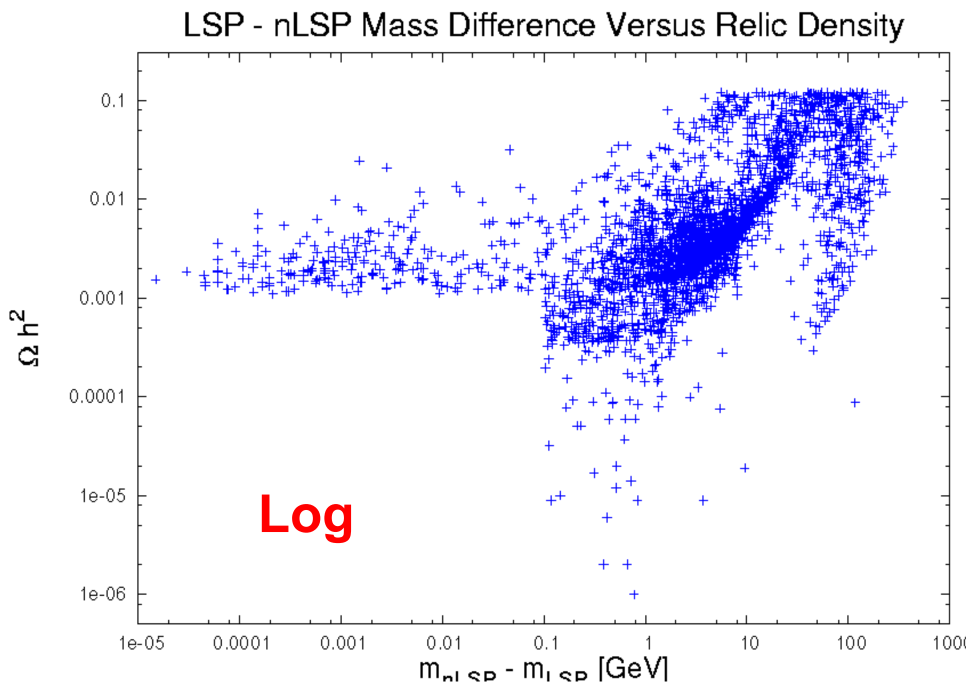




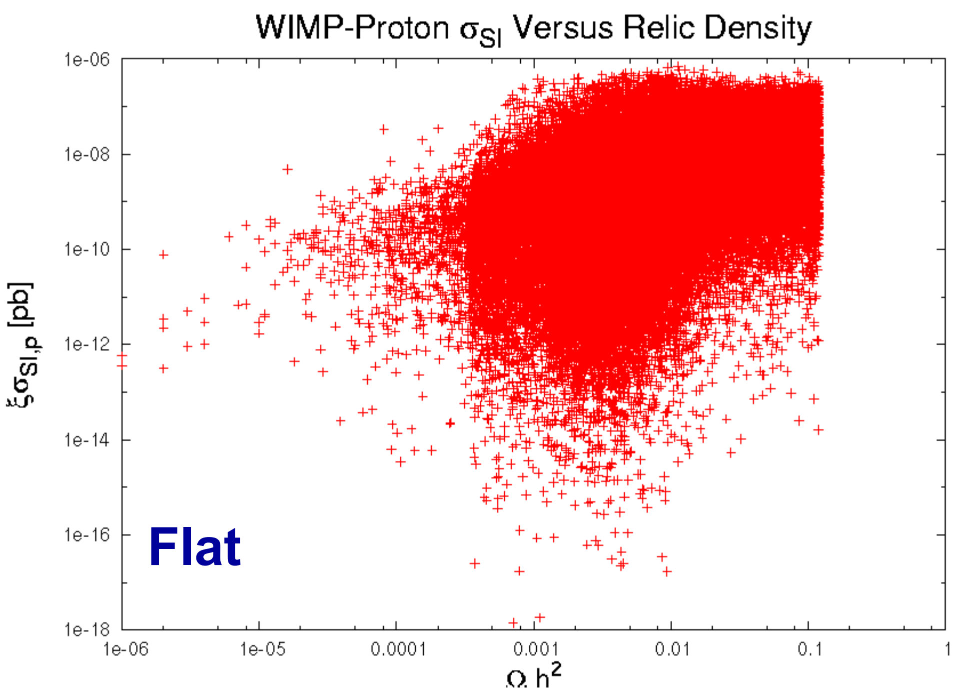
Correlation Between Dark Matter Density & the LSP-nLSP Mass Splitting

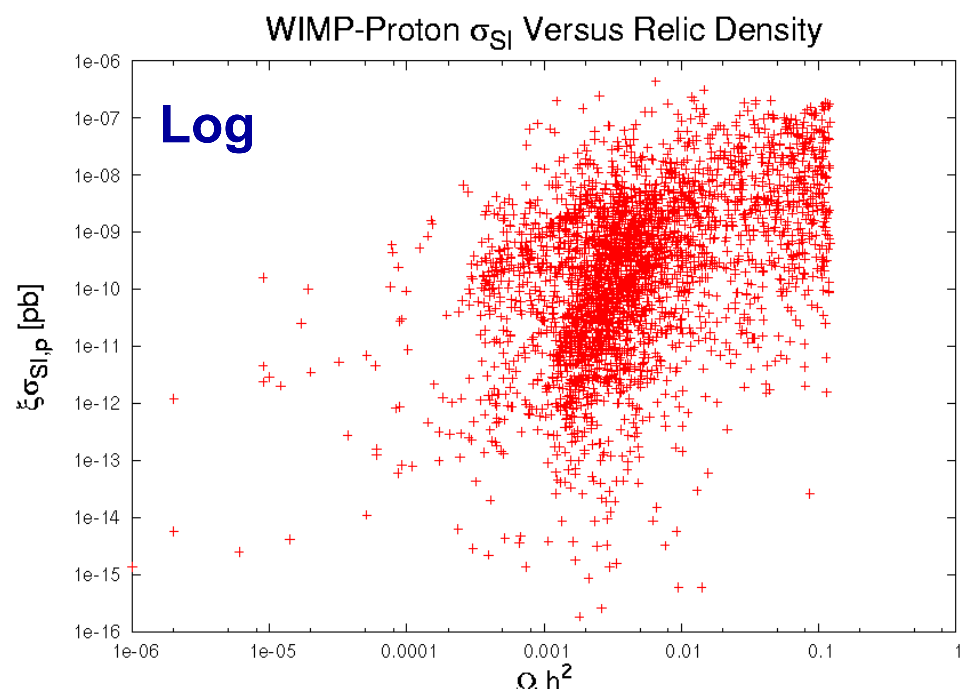
Small mass differences can lead to rapid co-annihilations reducing the dark matter density….





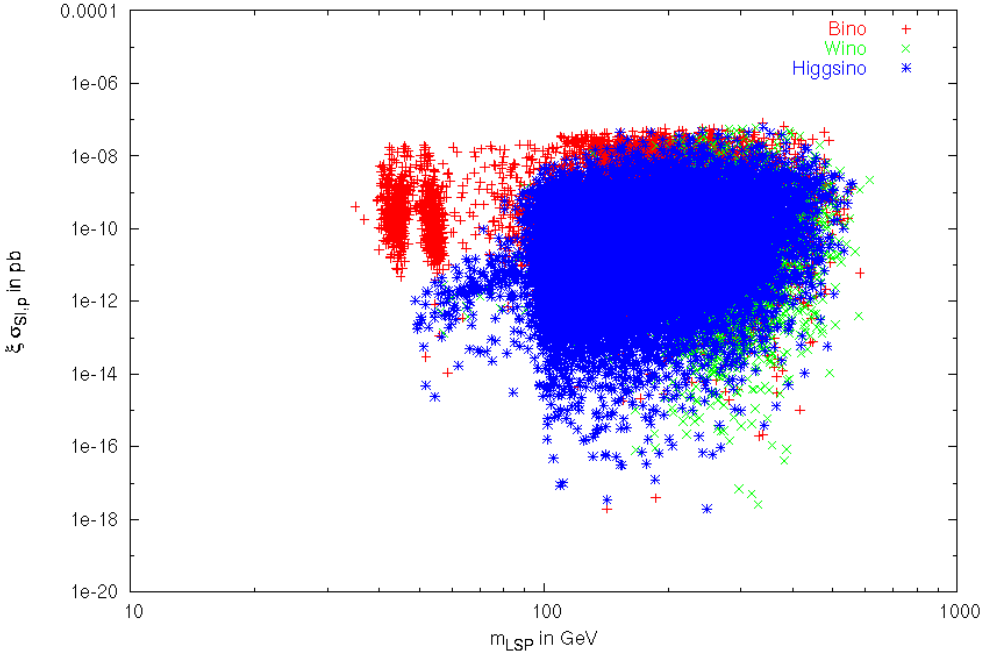
Dark Matter Density Correlation with the Direct Search Cross Section



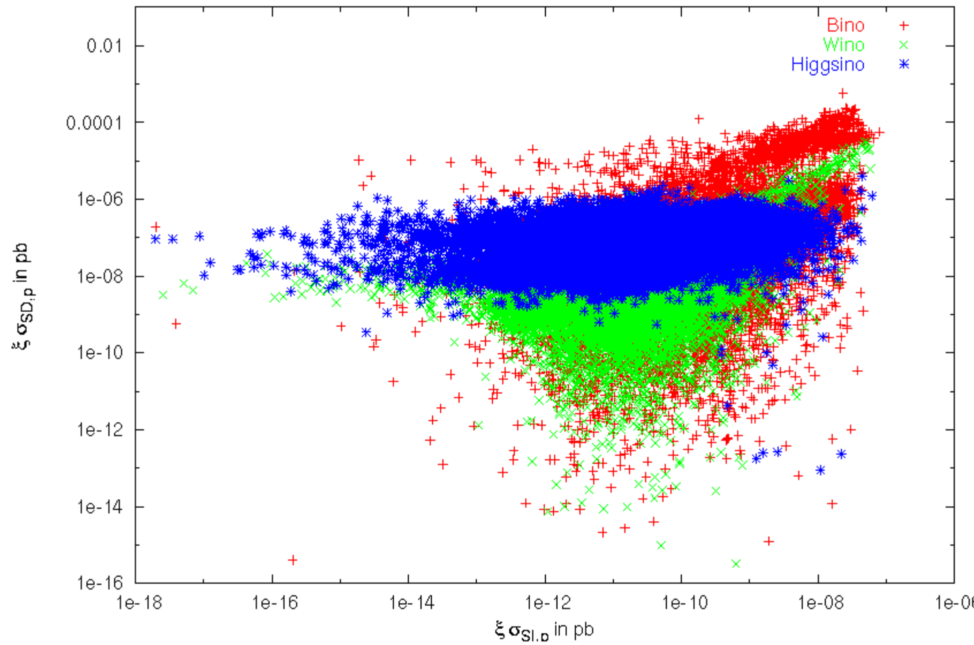


The correlation is there but is rather weak...

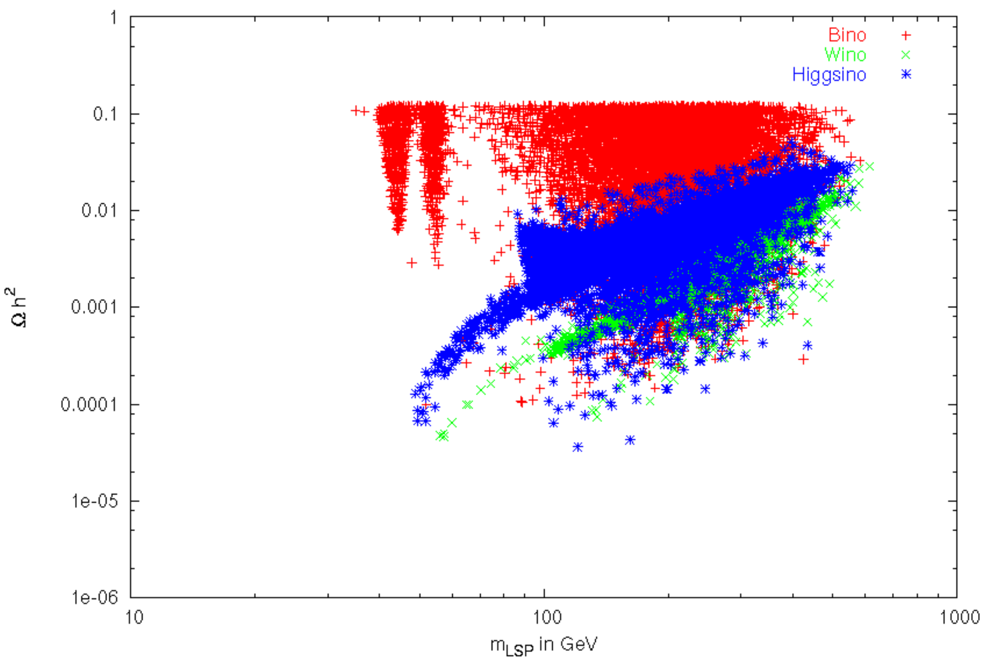
LSP Mass Versus Spin Independent WIMP-Proton σ



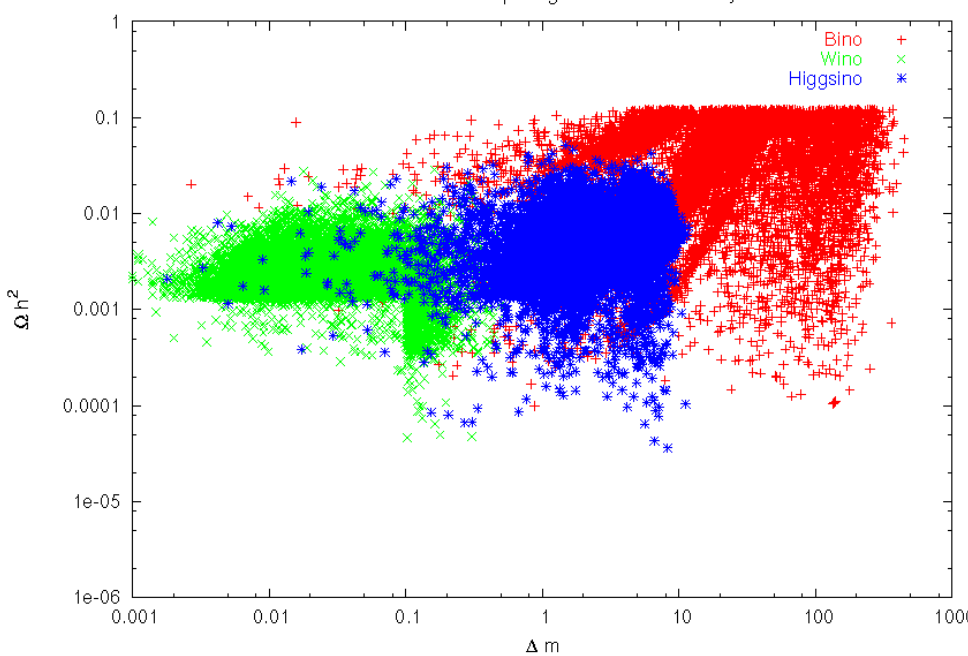
Spin Independent Versus Spin Dependent WIMP-Proton σ



LSP Mass Versus Relic Density



LSP-nLSP Mass Splitting Versus Relic Density



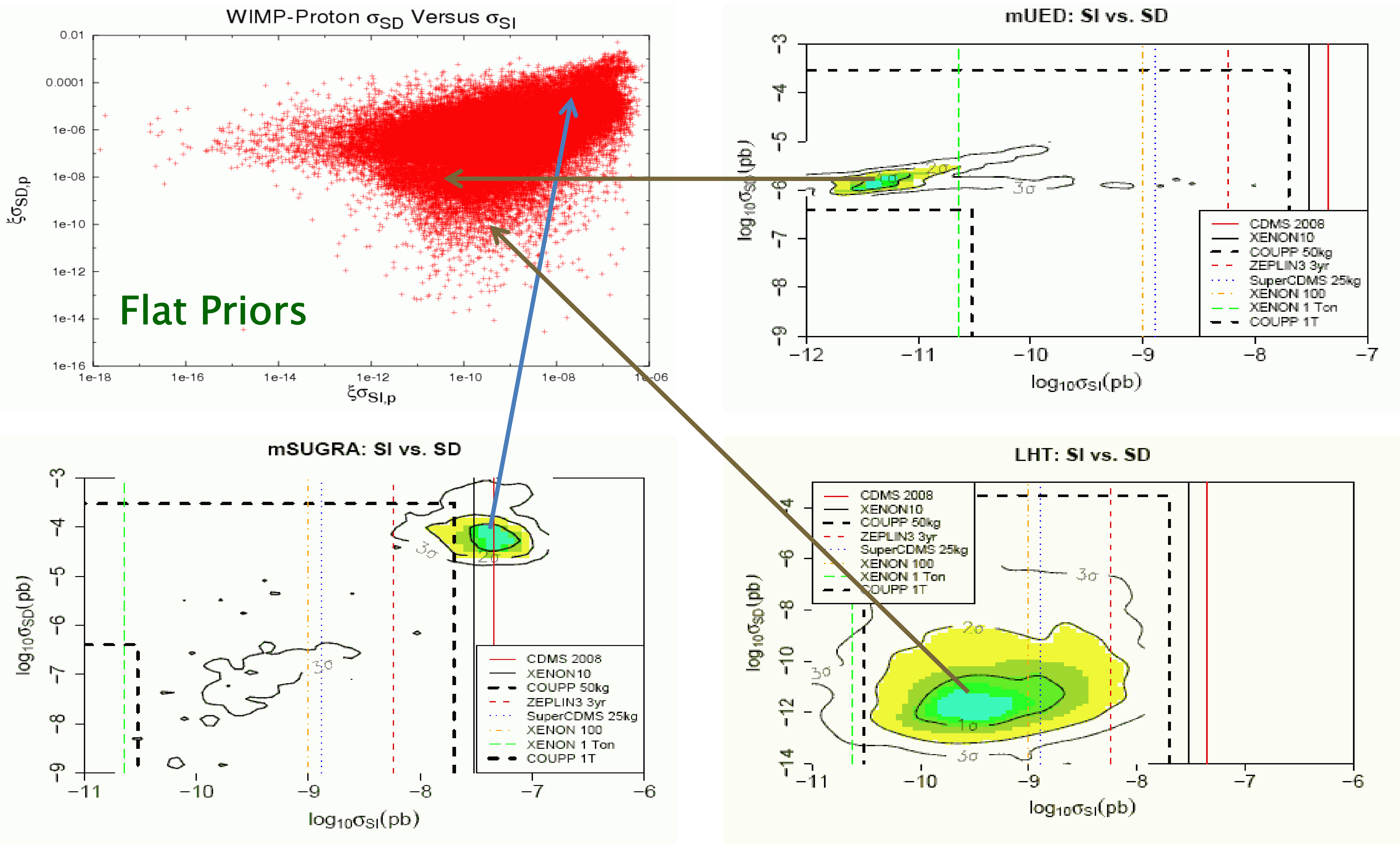
What fraction of the space is covered as, e.g., CDMS/XENON improve their search reaches??

Improvement in S.I. Cross Section Limit	Fraction of Models Excluded
4	0.032
10	0.071
40	0.19
100	0.31
400	0.52
1000	0.65
4000	0.81

The parameter space ‘coverage’ improves rather slowly…

Distinguishing Dark Matter Models

Barger etal



Voices in the Sky

What can FERMI/LAT do to probe this very large parameter space ?? This is something we really need to explore…but we have made some relatively ‘quick’ calculations to get a feel for things @.

LAT details and observation time determine Sensitivity (what flux values are excluded)

Yield Curve (DarkSUSY) Includes FSR, IB, gammas from hadronzn.

$$\frac{dN_\gamma}{dAdt} = \frac{1}{8\pi}\mathcal{L}_{\rm ann}(\rho^2(\vec{r}), D)\frac{\langle\sigma v\rangle}{m_\chi^2}\int_{E_{th}}^{E_{max}}\frac{dN_\gamma}{dE_\gamma}dE_\gamma \qquad (1)$$

FERMI derives this

$$\mathcal{L}_{\rm ann} = \int_0^{\Delta\Omega}\left\{\int_{LOS}\rho^2(\vec{r})ds\right\}d\Omega \qquad (2)$$

Model dependence !

Similarly for Cerenkov telescopes

Essig ,Sehgal & Strigari

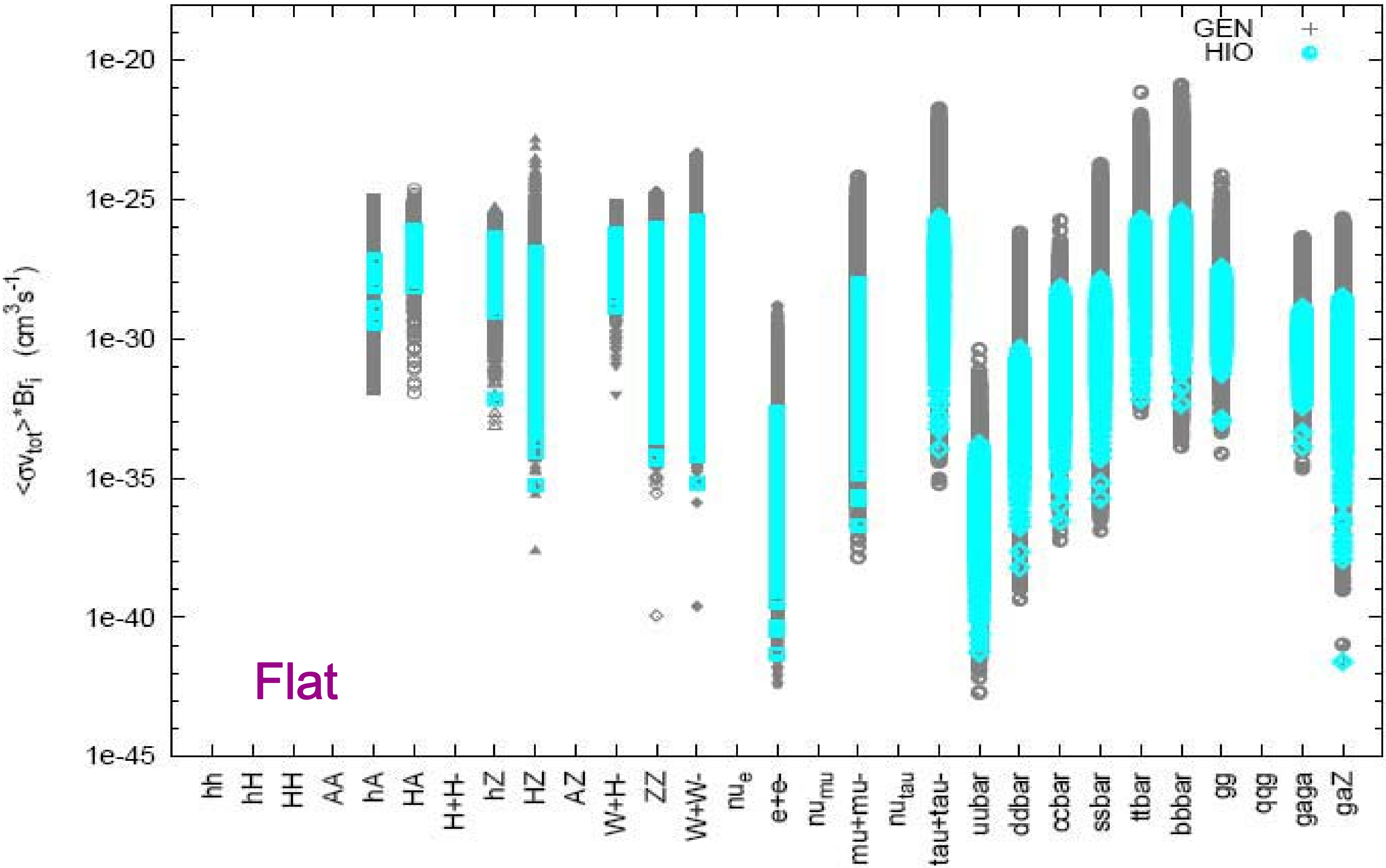
4

Dwarf	Vel. disp. [km s^{-1}]	$\mathcal{L}_{\rm ann}$ $\log_{10}[\mathcal{L}_{\rm ann}/({\rm GeV}^2{\rm cm}^{-5})]$	$\mathcal{L}_{\rm dec}$ $\log_{10}[\mathcal{L}_{\rm dec}/({\rm GeV\,cm}^{-2})]$	ACT	Flux limit [cm^{-2}s^{-1}]
Sagittarius	11.4	19.35 ± 1.66	18.73 ± 1.44	HESS	$\Phi(E > 250\ {\rm GeV}) < 3.6 \times 10^{-12}$
Draco	10.0	18.63 ± 0.60	17.51 ± 0.12	VERITAS	$\Phi(E > 200\ {\rm GeV}) < 2.4 \times 10^{-12}$
Ursa Minor	9.3	18.79 ± 1.26	17.55 ± 0.36	VERITAS	$\Phi(E > 200\ {\rm GeV}) < 2.4 \times 10^{-12}$
Willman 1	4.3	19.55 ± 0.98	17.51 ± 0.84	VERITAS	$\Phi(E > 200\ {\rm GeV}) < 2.4 \times 10^{-12}$

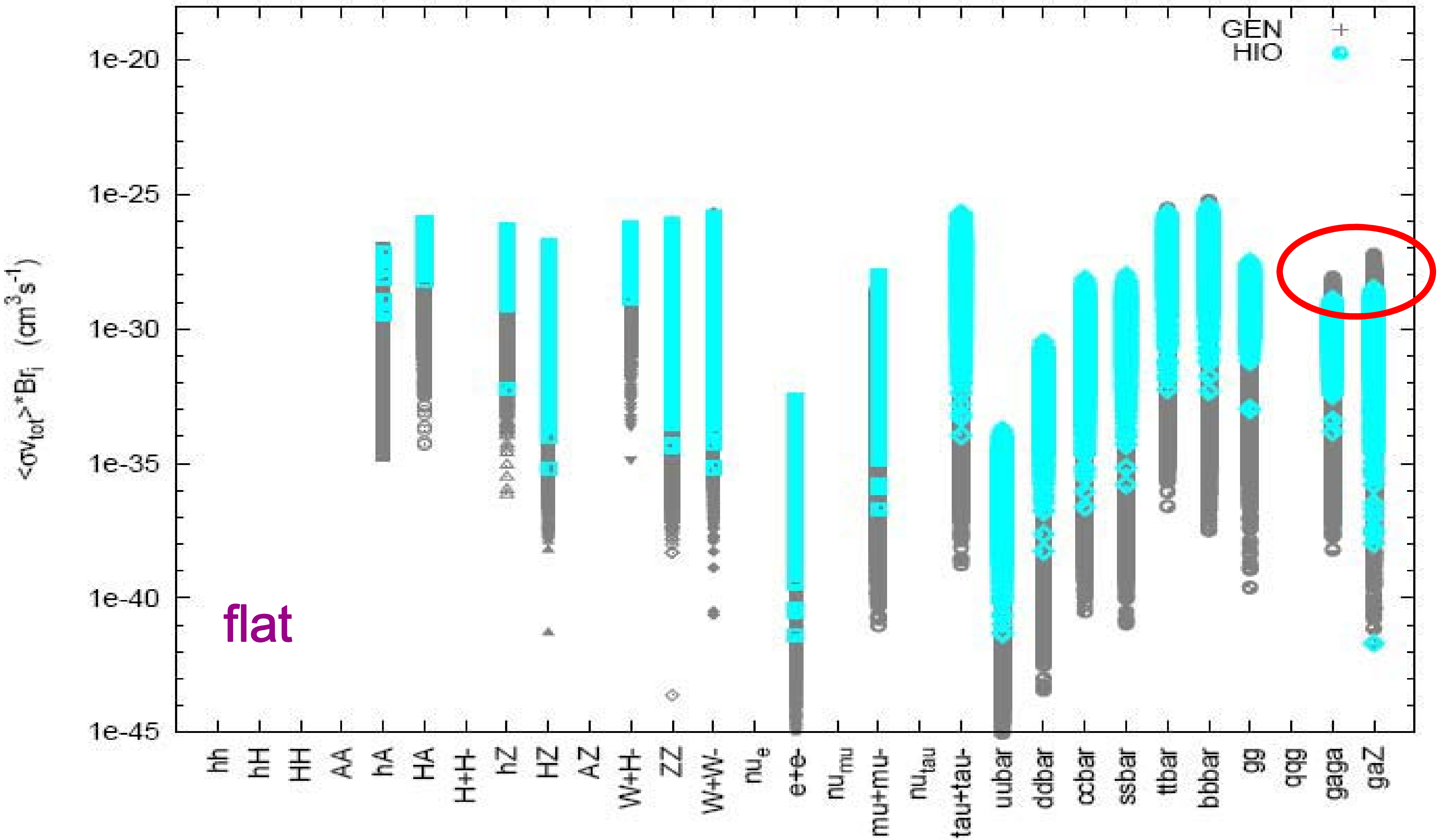
TABLE I: Line-of-sight stellar velocity dispersions and integrals over the mass density and density squared for four Milky Way

@ This is the work of Randy Cotta

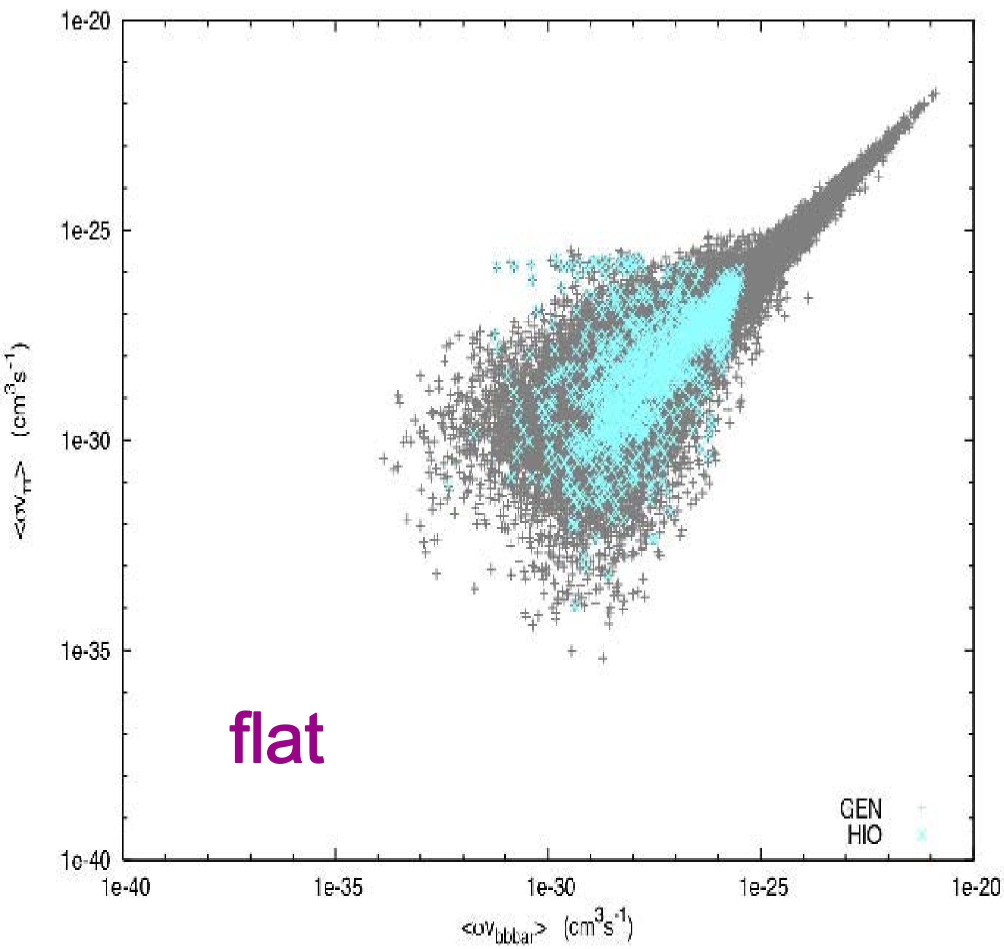
~1.4M Annihilation Cross Sections from DarkSUSY

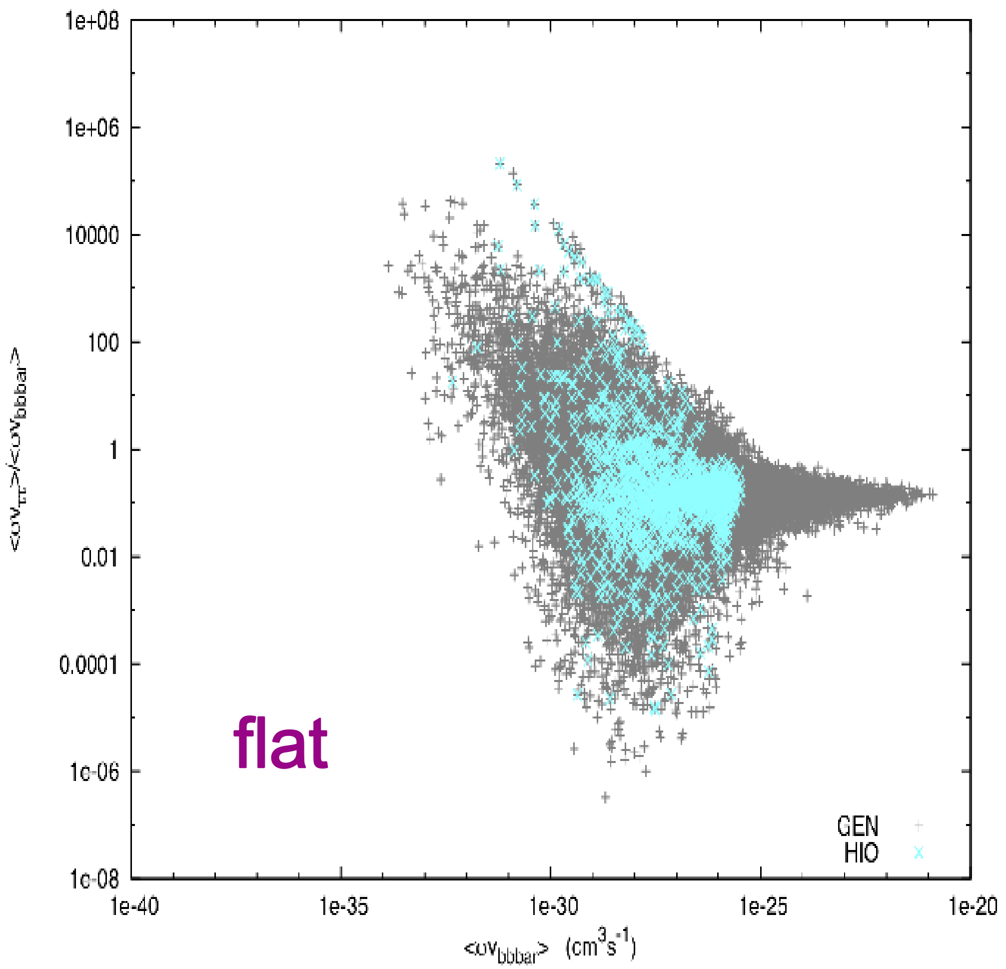


…& scaled by the predicted relic LSP relic density

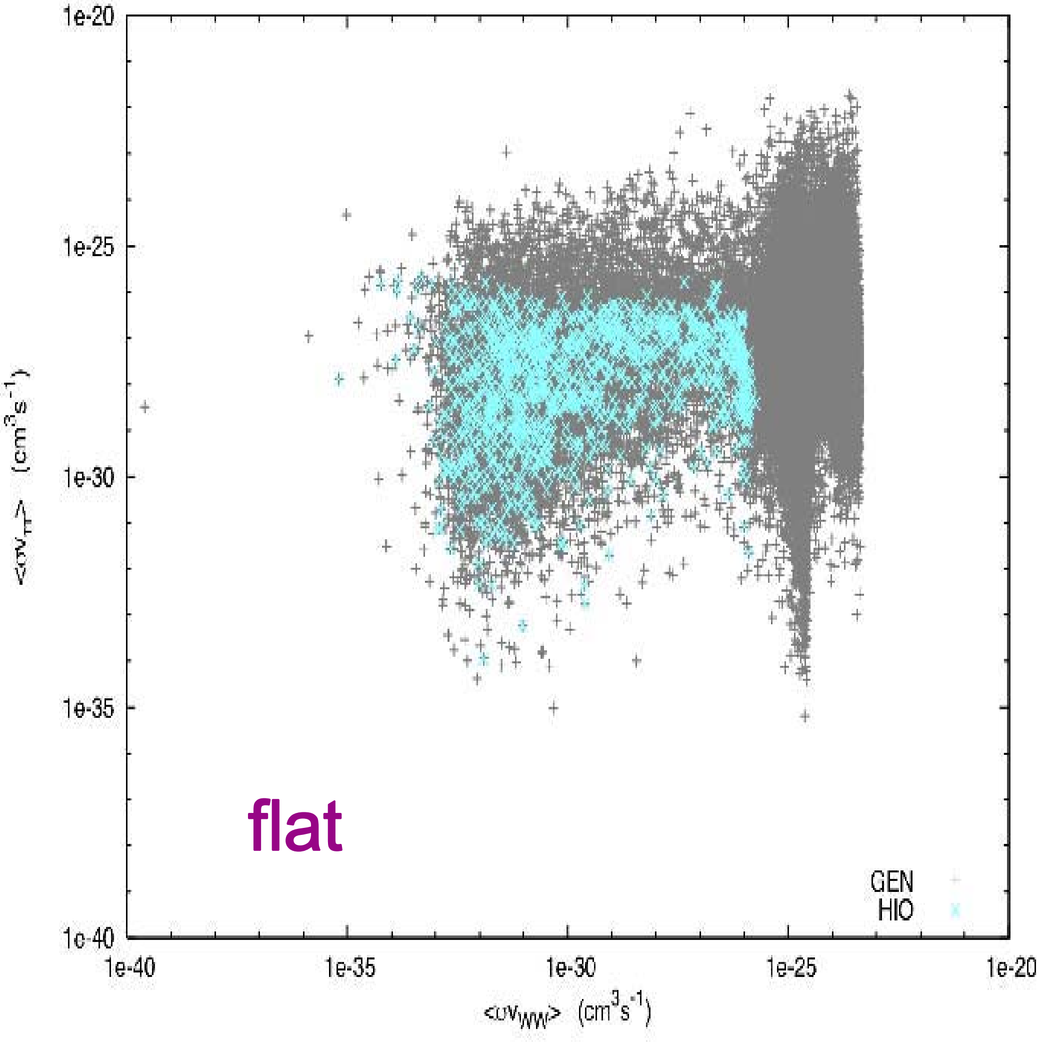


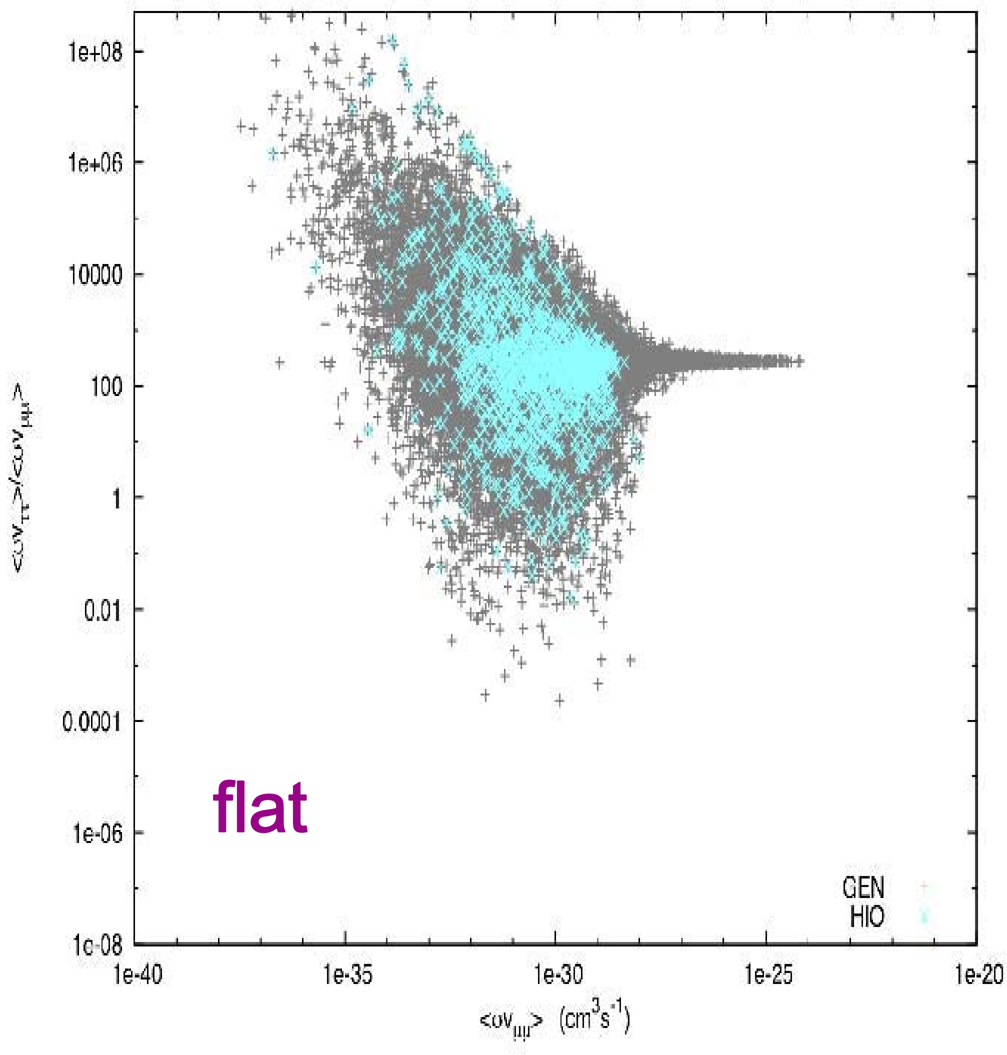
It is interesting to compare rates into b's and τ's



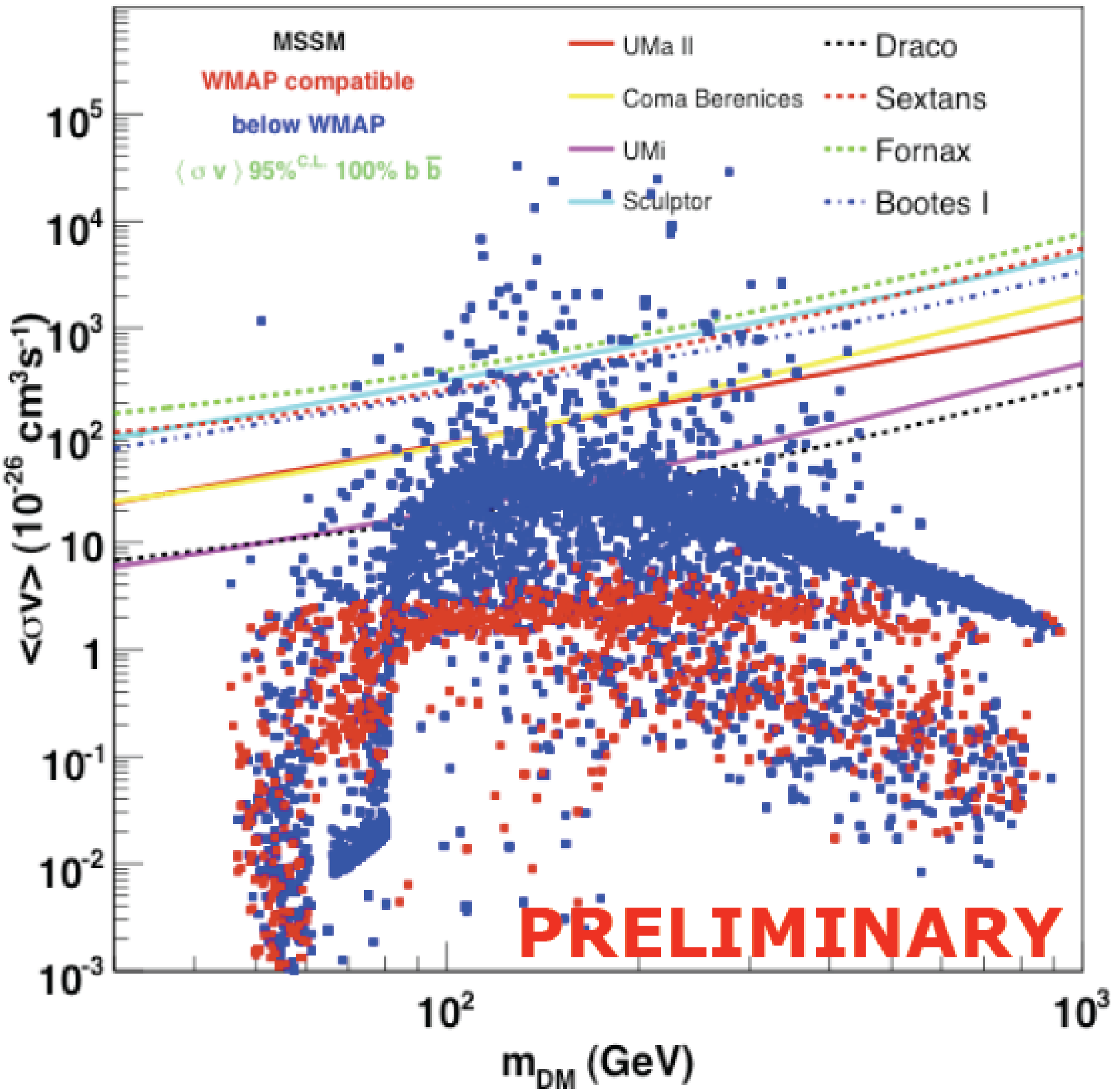


…as well as to other final states..



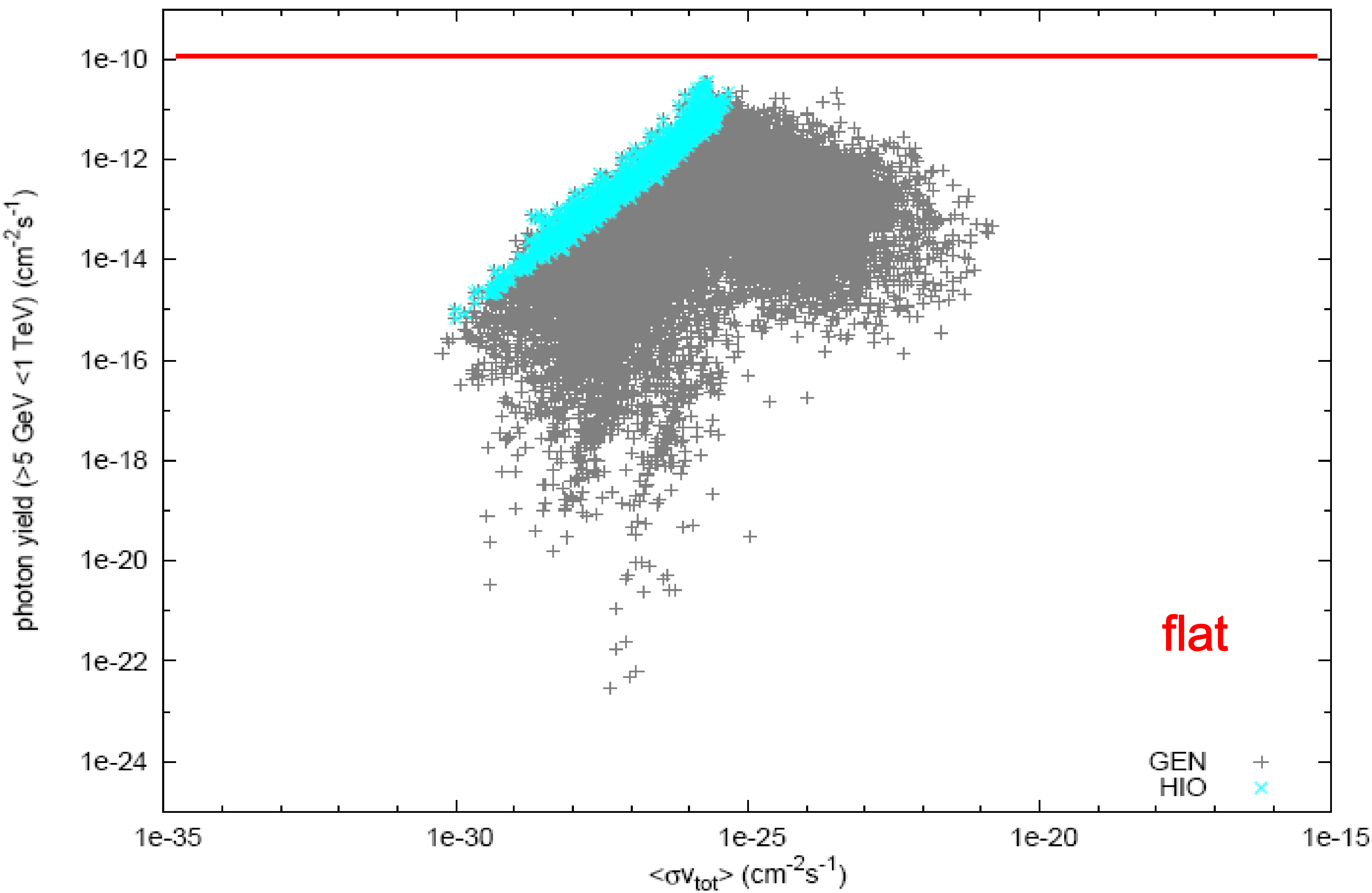


FERMI searches for DM annihilation in different channels & in different places constrains the theory model … e.g., here via the continuum photon yield:

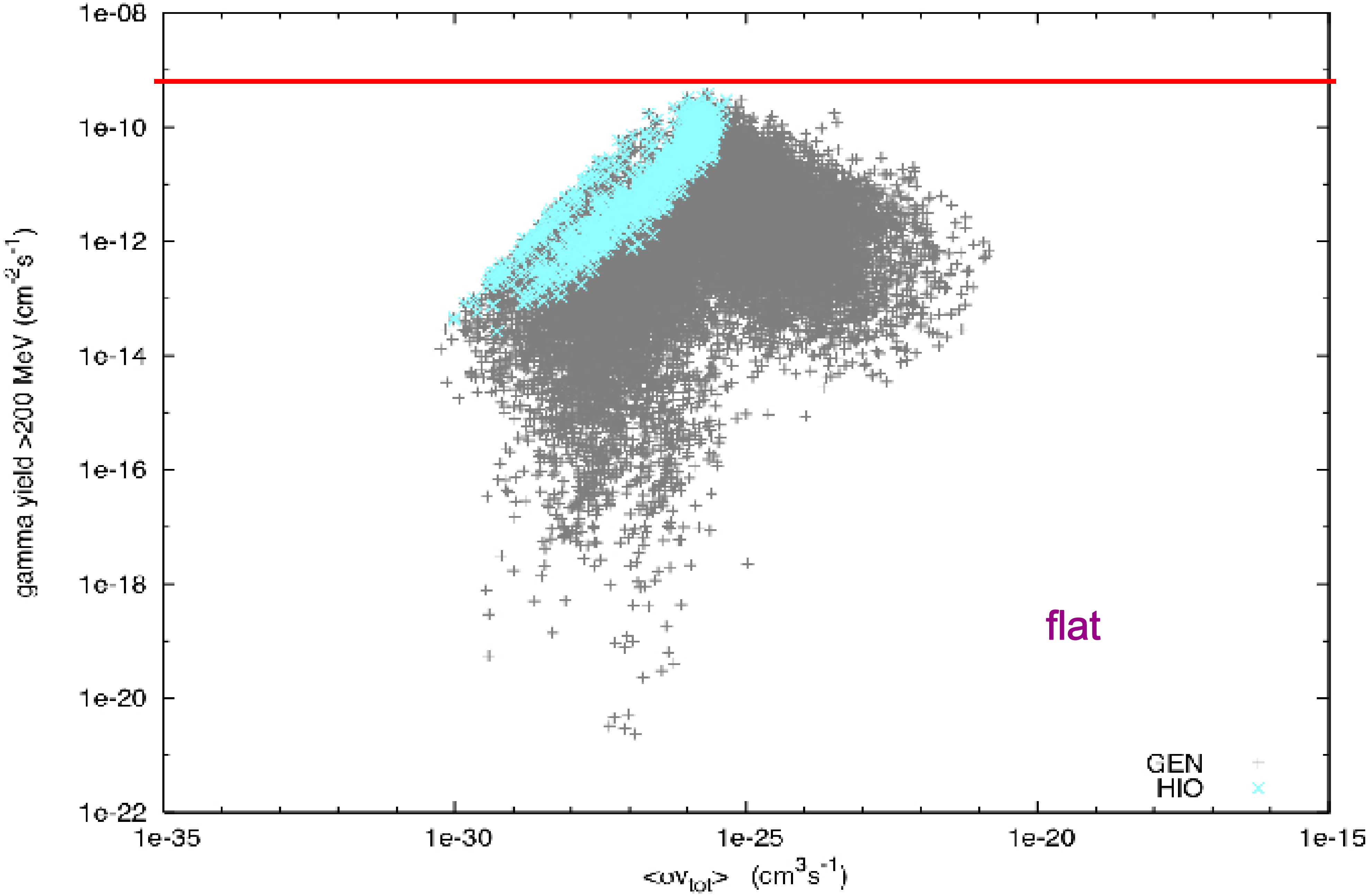


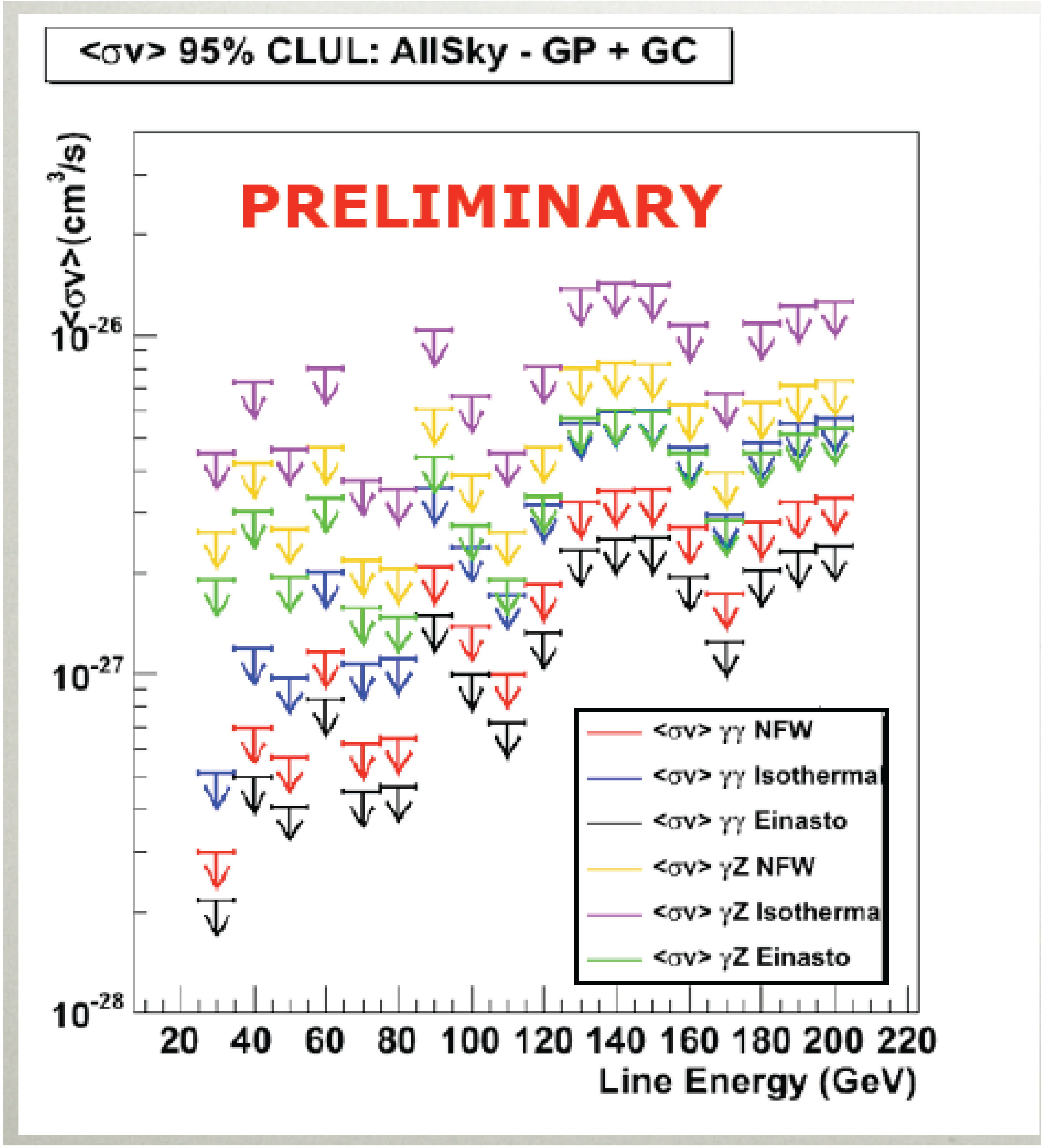
But in each of our models the DM annihilates into final states with different BF & so we must take this into account. This means that we really can't make a plot like this for our model set & we have to do something more general, e.g., just calculate the total yield curve…

1st pass present limits… close!



… & with a somewhat reduced threshold but with more background..still close!

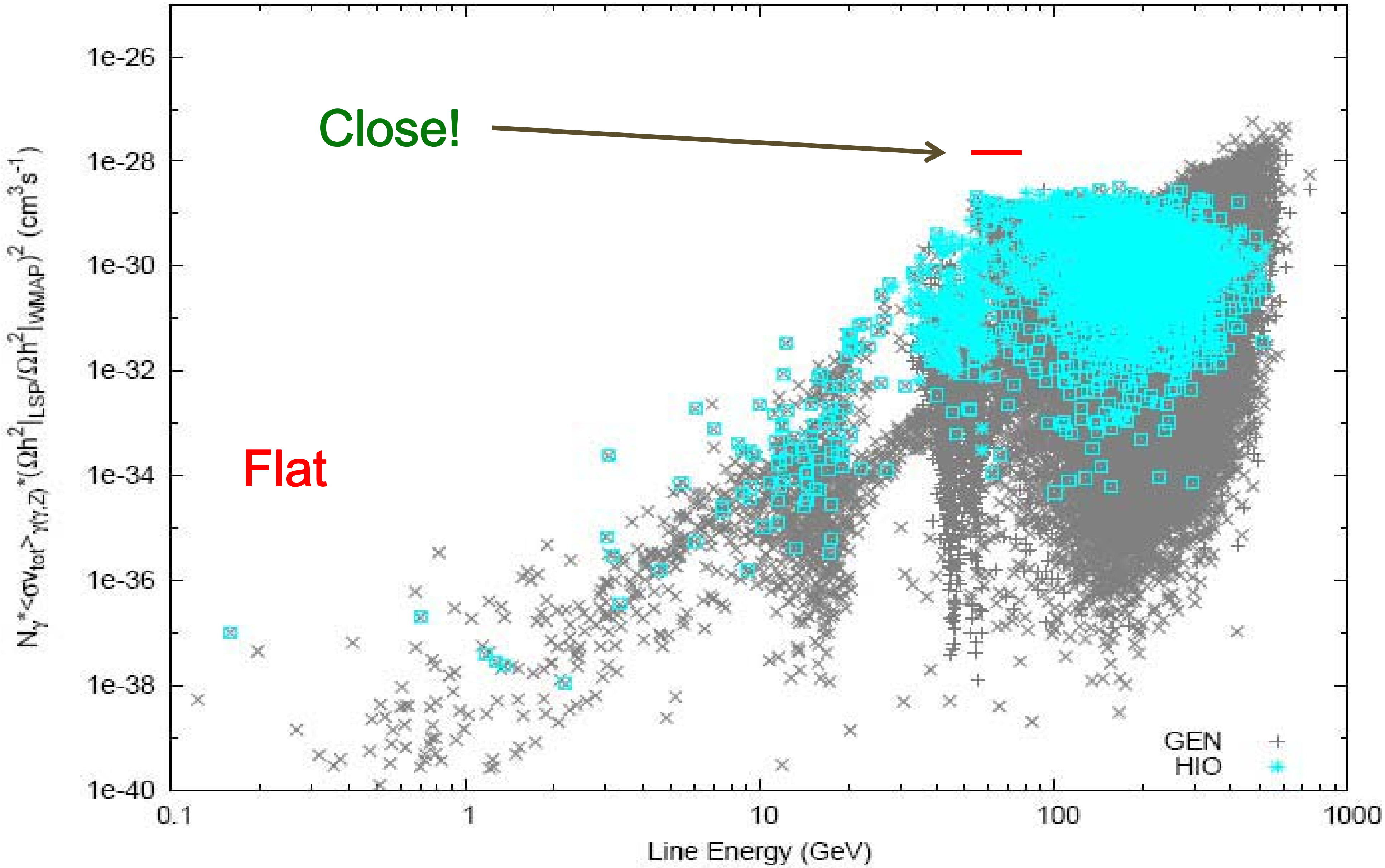




FERMI can also look for the discrete photon lines that occur via loops in SUSY

We can calculate this flux for all our models too…

Scaled <σv> in Our Flat Model Set



Summary & Prospects

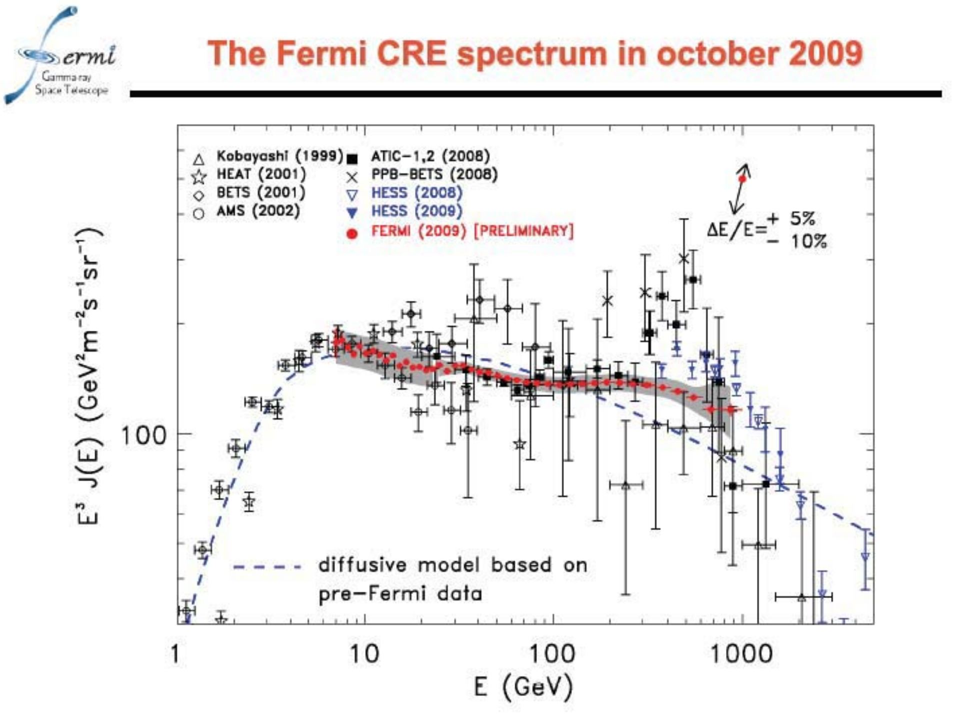
- Theories with WIMP DM candidates, such as SUSY, can be & must be probed in as many ways as possible to test the underlying theory.

- We have generated the most general set of SUSY models, from a well-motivated 19-dimensional parameter space, that are consistent with all experimental data by *including* the necessary detector simulations.

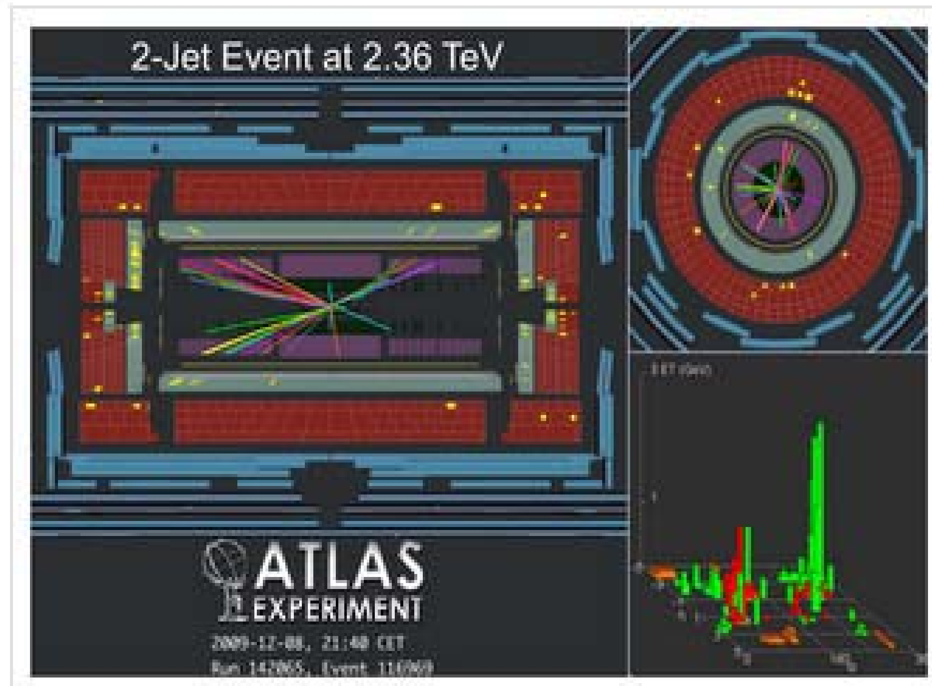
- Essentially identical results are obtained with both prior choices demonstrating that the results we obtain are robust unlike those from some other studies.

- FERMI can play a critical role in exploring the nature of the DM particle & the underlying theoretical construction.

This has been a difficult decade… but at least it seems to be ending well for humanity's exploration of the fundamental nature of the Universe….



Extended Energy Range (7 GeV – 1 TeV) – One year statistics (8M evts)



Let's hope this bodes well for the great discoveries that lie ahead..

"To explain all nature is too difficult a task for any one man or even for an age. Tis much better to do a little with certainty & leave the rest for others that come after than to explain all things by conjecture without making sure of anything."

Isaac Newton
1704