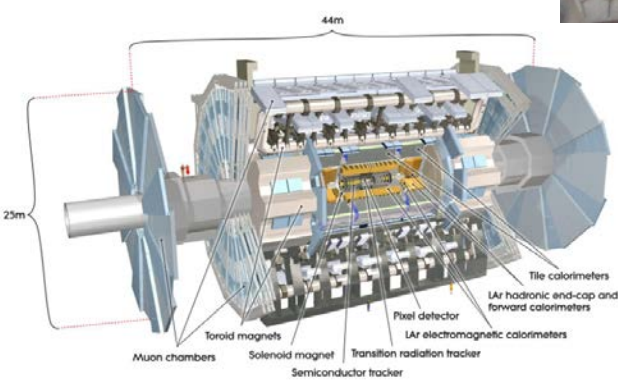
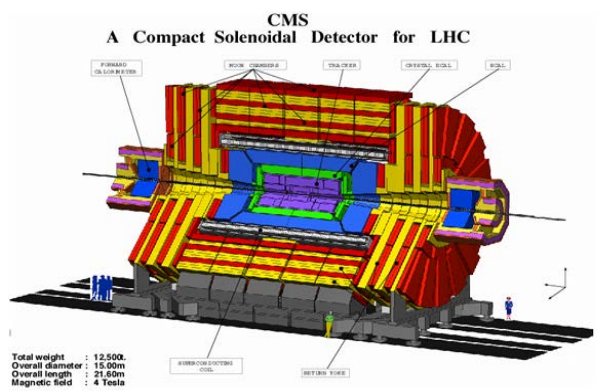
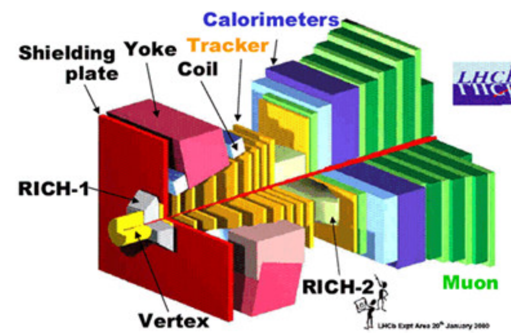
LHC Searches for Viable SUSY (Without Prejudice ?)







1206.4321, 1206.5800, 1211.1981, 1211.7106, 1305.1605, 1305.2419, 1305.6921, ...

SLAC NATIONAL ACCELERATOR LABORATORY

M.W. Cahill-Rowley, J.L. Hewett, A. Ismail, T.G. Rizzo

7/15/13

We live in amazing times: In the early 60's Higgs & friends posited a mechanism that led to our modern picture of EWSB

- Where was this boson? Is this really how nature works?? Can it be this 'simple' ? Only now are we getting some answers..

HHG '89 :

Although the Higgs mechanism [1] was used to introduce mass into the Standard Model [2,3] two decades ago, experimental sensitivity to a Standard Model Higgs boson remains extremely limited. Masses below about $2m_\mu$ can be excluded by a combination of low energy experimental data on nuclear transitions and rare decays of K mesons. Recent results in K and B decays probably rule out masses from $2m_\mu$ to $2m_\tau$. Upsilon decays are potentially sensitive to masses above $2m_\mu$, up to about 5 GeV, but uncertainties regarding the exact magnitude of the expected decay rate to Higgs prevent firm conclusions at this time; although no Higgs bosons have been observed in such decays. Certainly, it will be 1990 (at the earliest) before experiments begin to probe the mass region above 5 GeV, where one might most naively expect to find the Standard Model Higgs boson.

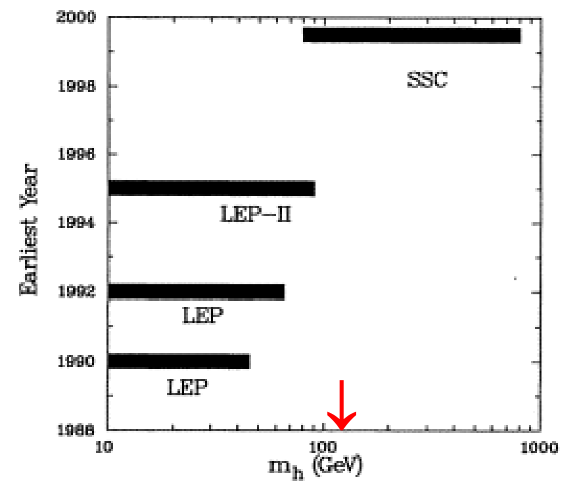
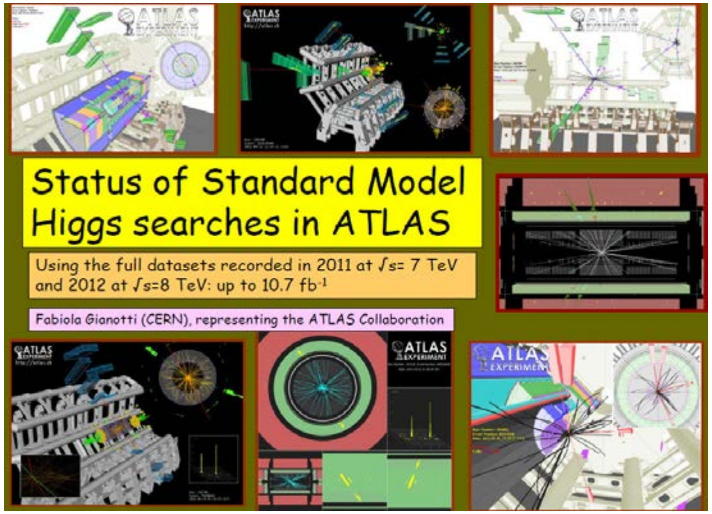
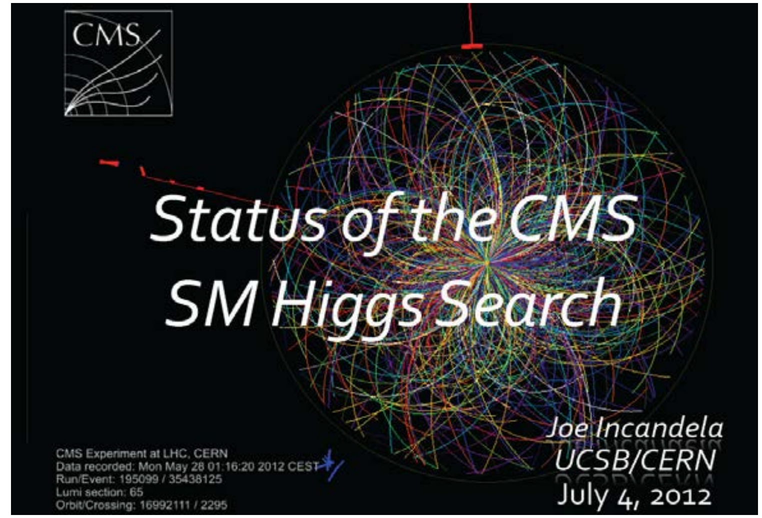


Figure 1.1 Survey of Higgs mass reach based on expected experimental data to be obtained at existing accelerators or colliders presently under construction as an estimated function of year.

Even though we knew the Higgs mass was tied to the EW scale telling us 'where to look', the range of ~3 to ~1000 GeV was still wide open.. This led to years of searches culminating 7/4/12:

~50 Years of Work by Many Thousands





→ Searches for 'NP' can be difficult even if we 'know' how & where to look & there's only 1 free parameter : m_H

- Neutrino masses, DM, Dark Energy, the Baryon Asymmetry.. & many other puzzles point to NP BSM. What? Where?

How do we find NP if we don't know what it is ?

1. Cast your net as widely as possible

ATLAS NOTE

ATLAS-CONF-2012-107

August 11, 2012

ATLAS-CONF-2012-107
13 August 2012

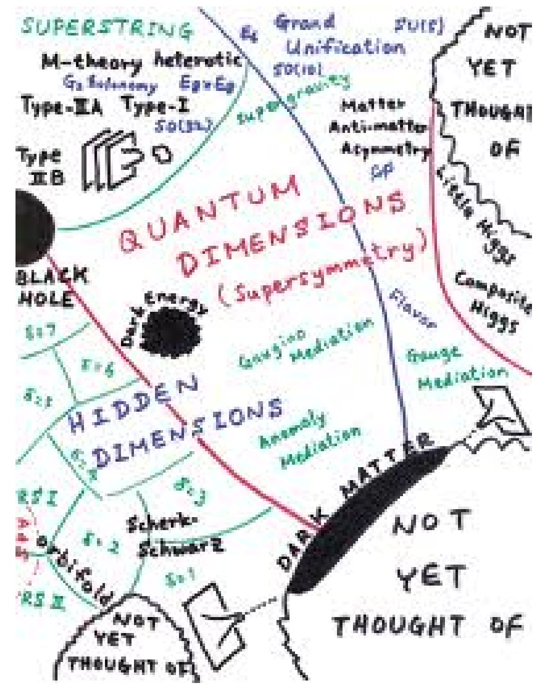
A general search for new phenomena with the ATLAS detector in pp collisions at $\sqrt{s} = 7$ TeV

The ATLAS Collaboration

Abstract

This note presents a model-independent general search for new physics in proton proton collisions at a centre-of-mass energy of 7 TeV with the ATLAS detector at the LHC. The data set, recorded by the ATLAS experiment during 2011, corresponds to a total integrated luminosity of 4.7 fb^{-1}. Event topologies involving isolated electrons, photons, muons, jets, b-jets and missing transverse momentum are investigated. The events are subdivided according to their final states into 655 exclusive analysis channels. For each channel, a search algorithm tests the compatibility of the effective mass distribution in data against the distribution in the Monte Carlo simulated background. Although this search approach is less sensitive than optimized searches for specific models it provides a more comprehensive investigation for new physics signals. No significant deviations between data and the Standard Model expectations have been observed.

Don't listen to theorists!
Just look for everything you can.. every way you can.. as deviations from the SM



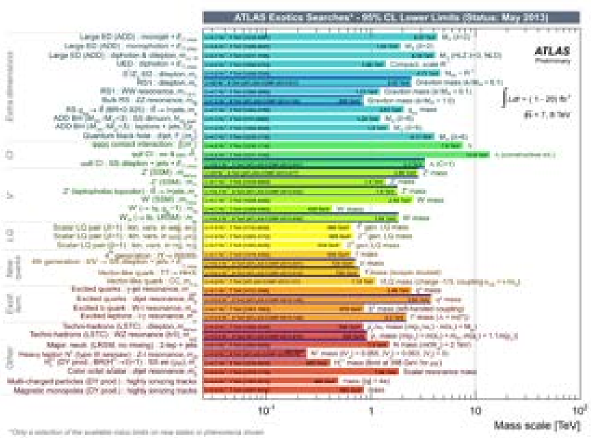
H Murayama

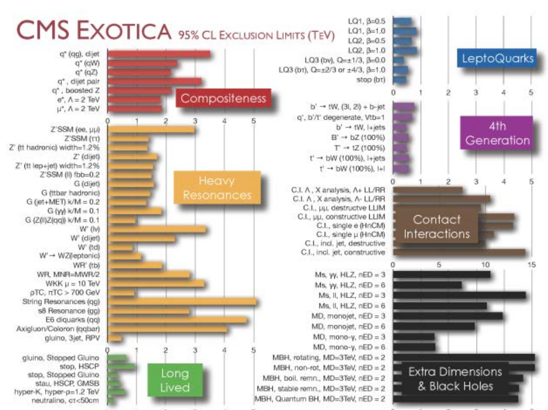
& don't stop ! 8 TeV results soon?

- Admittedly ‘what we haven’t thought of yet’ is likely a larger category than we’d like to admit as well as a function of time. Imagine the SSC turning on in ’98..

Many TH ideas since then..what if NP had been one of those?

2. The other extreme: assemble a long list of narrow but very specific models & go through them one by one. You may be lucky! But it doesn’t pay to become too attached to any one of these. This is a ‘learning experience’ that may help (even if all of them are wrong) when NP finally does appear.





…& don’t stop !

3. Explore as well as possible a very general, 'well-motivated' framework which leads to a wide range of predictions w/o making too many prejudiced assumptions about the details

BUT

Searches for new physics are & always have been full of time-dependent expectations & biases

SUSY provides a good example…

Table 11

Representative masses from low energy supergravity models. [We give model predictions of masses from four papers chosen at random: model I [9.42], model II [9.43], model III [9.45] and model IV [9.46]. We have picked only one given set of numbers per reference (although often more choices are given corresponding to different values of parameters). The models illustrate heavy scalar-quark and scalar-lepton masses (I), a light scalar-neutrino (II), a light gluino (III) and light scalar-lepton masses (IV). A heavy 'top'-quark is responsible for triggering SU(2)×U(1) breaking in models I and II. It is possible that the 'top'-quark could be identified with a new fourth generation. All masses are in GeV units.]

Particle	Symbol	I	II	III	IV
Charged scalar-leptons	$\tilde{\ell}$	154, 151	71	73	32, 22
Scalar-neutrino	$\tilde{\nu}$	140	16	71	32, 22
ũ, c̃ scalar-quarks	ũ, c̃	190, 187	136, 137	72–75	60–66
d̃, s̃, b̃ scalar-quarks	d̃, s̃, b̃	200, 192	155, 142	72–75	60–66
t̃ scalar-quarks	t̃	84	120–150	41, 100	95, 23
Charginos	$\tilde{\chi}_i^{\pm}$	33, 128	20–40	15, 121	79–87
Neutralinos	$\tilde{\chi}_i^0$	4, 55, 101, 102	20–40	3.2, 61, 66, 132	4.6, 23, 85, 108
Gluino	$\tilde{g}$	140	147	15	47
Charged Higgs	$H^{\pm}$	183	81	156	95
Neutral Higgs	H^0	58, 162, 182	23–89	4.6, 134, 163	4.5, 49, 105
Gravitino	$\tilde{g}_{3/2}$	145	50	72	15
Top quark	t	84	111	33	35

!!!

Haber & Kane '85

We've come a long way since then but with no discovery…

Being as model-independent as possible may prove valuable..

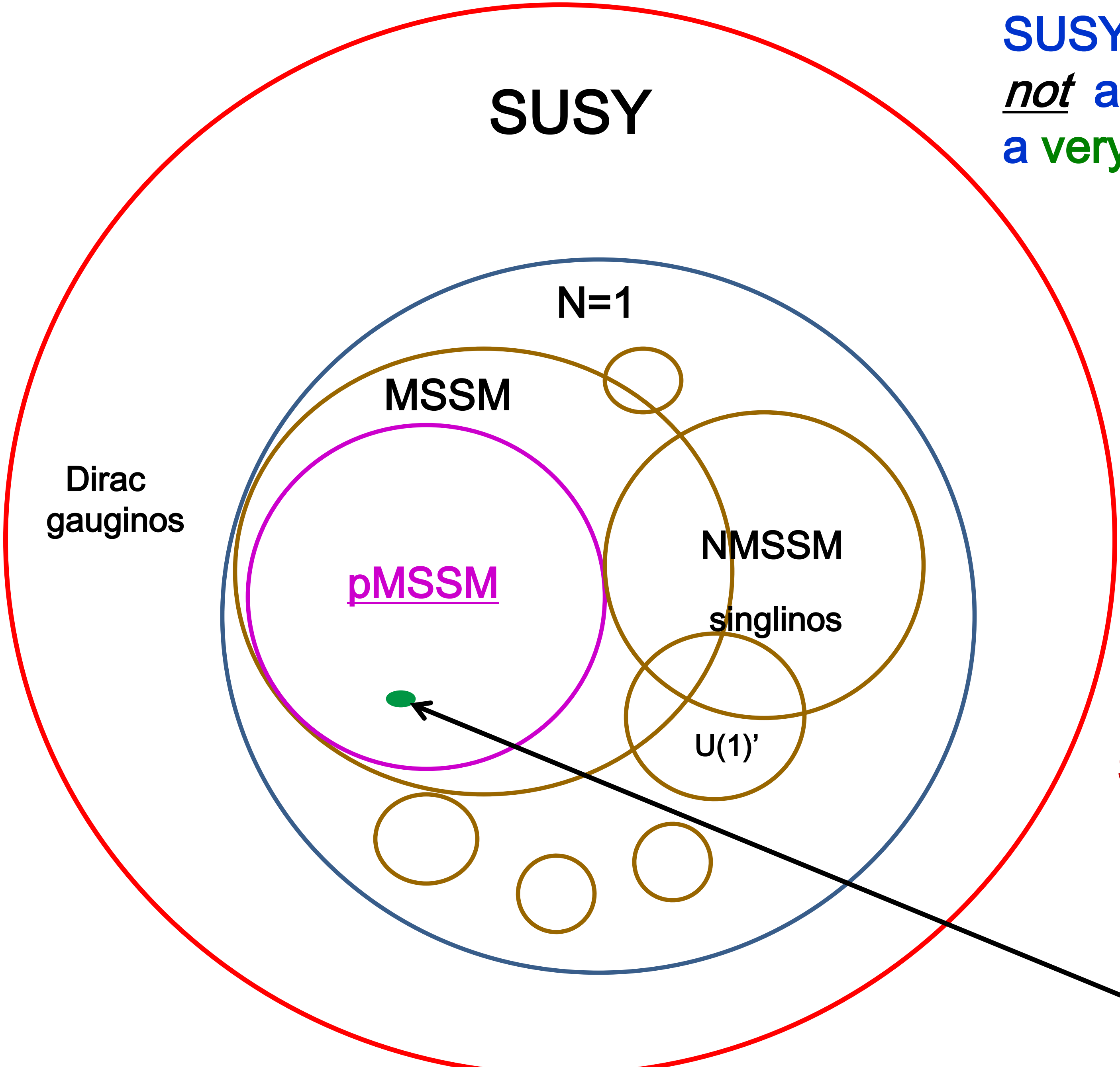
10/8/1871

Is SUSY up in flames???

SUSY survives !!!

SUSY is a very flexible framework with a lot of resilience due to parametric freedom

SUSY is complex; it is *not* a single model but a very large framework



Too big of a place to explore without SOME assumptions

mSUGRA

- SUSY ‘space’ is very large & we can’t explore it without SOME prejudices but we’d like to make them as weak as possible

What besides GU do we (you) want from SUSY? Our Prejudices

1. Give us some DM - but not too much (R-parity??)
2. Give us an ‘explanation’ for EWSB & the hierarchy w/o ‘too much’ FT (how much is that ??)
3. Avoid the obvious flavor & CP violation issues (MFV??)
4. Be accessible at the 14 TeV LHC (not TOO heavy ??)
5. Be sufficiently general & flexible to cover a wide range of possible phenomena without having ‘too many’ parameters

Our p(henomenological)MSSM

- General CP-conserving MSSM with R-parity
- MFV at the TeV scale (CKM)
- Lightest neutralino/gravitino is the LSP.
- 1st/2nd generation sfermions degenerate
- Ignore 1st/2nd generation A-terms &Yukawa's.
- No assumptions wrt SUSY-breaking
- WMAP used as upper bound on thermal relic density

→ the pMSSM with 19/20 parameters

- Two large ~225k model sets with either a neutralino (19) or gravitino (20) LSP

- Smaller (~10k) dedicated sets for low-FT studies & other analyses

$50 \text{ GeV} \leq |M_1| \leq 4 \text{ TeV}$

$100 \text{ GeV} \leq |M_2, \mu| \leq 4 \text{ TeV}$

$400 \text{ GeV} \leq M_3 \leq 4 \text{ TeV}$

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

$100 \text{ GeV} \leq M_A, l, e \leq 4 \text{ TeV}$

$400 \text{ GeV} \leq q_1, u_1, d_1 \leq 4 \text{ TeV}$

$200 \text{ GeV} \leq q_3, u_3, d_3 \leq 4 \text{ TeV}$

$|A_{t,b,\tau}| \leq 4 \text{ TeV}$

$1 \text{ eV} \leq m_{3/2} \leq 1 \text{ TeV}$ (log prior)

There's a LOT of space here ; we're going for breadth not depth !

Some Constraints

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

- Direct Detection of Dark Matter (SI & SD)
- WMAP Dark Matter density upper bound
- LEP and Tevatron Direct Higgs & SUSY searches
- LHC stable sparticle searches + $A \to \tau\tau$

- BBN energy deposition for gravitinos
- Relic ν's & diffuse photon bounds

- No tachyons or color/charge breaking minima
- Stable vacua only

In order to find viable SUSY models within this framework we need to determine how these various pMSSM model sets respond to the LHC SUSY searches (as well as, e.g., DM and other searches)

How can we do that if these searches are either based on specific SUSY breaking scenarios such as mSUGRA, GMSB, AMSB, or use Simplified Models to present their results??

Not Easily !!

Our pMSSM SUSY Search Approach

- Goal: implement the entire ATLAS SUSY suite at 7, 8 & 14 TeV w/ fast MC. By combining & comparing searches we gain a better understanding of the parameter space.
- Generate signal events for every model for all ~85 SUSY processes & then rescale to NLO w/ Prospino = CPU !
- Validate each signal region in every analysis using ATLAS benchmark models & use their limits as input
- Determine which models are excluded by each analysis & then combine results to determine what remains
- Note : we lag behind ATLAS by several months: 3/1/13 here

Preliminary Model Set Fractions Excluded by ATLAS Searches @ 7 TeV

Search	Reference	Neutralino	Gravitino	Low-FT
2-6 jets	ATLAS-CONF-2012-033	21.2%	17.8%	37.4%
multijets	ATLAS-CONF-2012-037	1.6%	2.3%	11.3%
1-lepton	ATLAS-CONF-2012-041	3.2%	5.3%	19.4%
HSCP	1205.0272	4.0%	16.9%	<0.1%
Disappearing Track	ATLAS-CONF-2012-111	2.6%	1.1%	<0.1%
Gluino $\to$ Stop/Sbottom	1207.4686	4.9%	4.1%	21.9%
Very Light Stop	ATLAS-CONF-2012-059	<0.1%	0.03%	0.3%
Medium Stop	ATLAS-CONF-2012-071	0.3%	4.9%	2.6%
Heavy Stop (0l)	1208.1447	3.7%	3.3%	17.9%
Heavy Stop (1l)	1208.2590	2.0%	2.3%	13.5%
GMSB Direct Stop	1204.6736	<0.1%	0.05%	0.8%
Direct Sbottom	ATLAS-CONF-2012-106	2.5%	2.8%	5.5%
3 leptons	ATLAS-CONF-2012-108	1.1%	5.9%	18.3%
1-2 leptons	1208.4688	4.1%	8.2%	21.3%
Direct slepton/gaugino (2l)	1208.2884	0.1%	1.2%	1.0%
Direct gaugino (3l)	1208.3144	0.4%	5.5%	8.0%
4 leptons	1210.4457	0.7%		15.5%
1 lepton + many jets	ATLAS-CONF-2012-140	1.3%		12.4%
1 lepton + γ	ATLAS-CONF-2012-144	<0.1%		<0.1%
γ + b	1211.1167	<0.1%		0.3%
$\gamma\gamma$ + MET	1209.0753	<0.1%		<0.1%
$B_s \to \mu\mu$	1211.2674	0.8%	3.1%	*
$A/H \to \tau\tau$	CMS-PAS-HIG-12-050	1.6%	0.07%	*

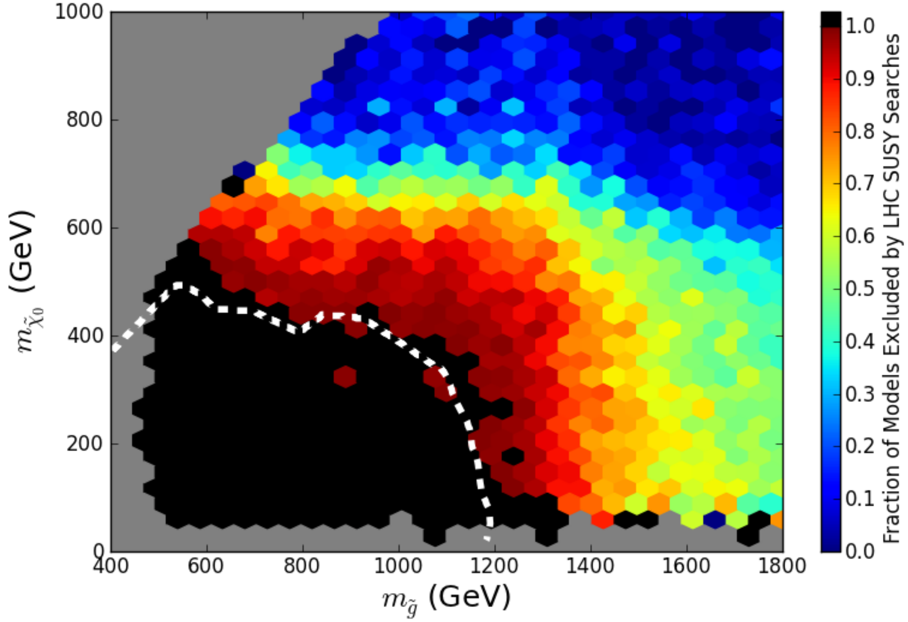
This is useful for comparing searches and model sets

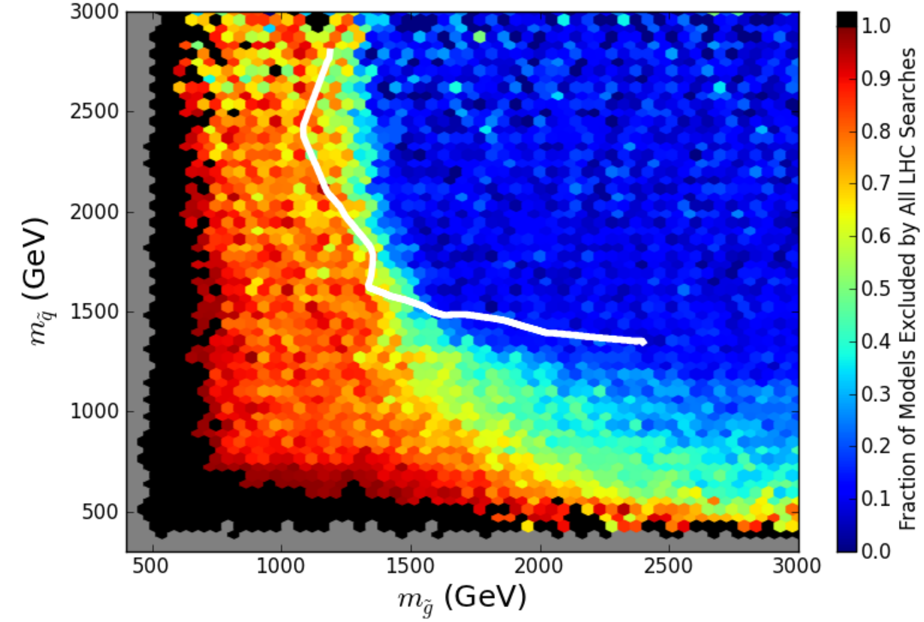
Preliminary Model Set Fractions Excluded by ATLAS Searches @ 8 TeV

Search	Reference	Neutralino	Gravitino	Low-FT
2-6 jets	ATLAS-CONF-2012-109	26.7%	21.8%	49.8%
multijets	ATLAS-CONF-2012-103	3.3%	4.1%	27.0%
1-lepton	ATLAS-CONF-2012-104	3.3%	5.4%	27.7%
SS dileptons	ATLAS-CONF-2012-105	4.9%	11.5%	42.8%
Medium Stop (2l)	ATLAS-CONF-2012-167	0.6%		9.4%
Medium/Heavy Stop (1l)	ATLAS-CONF-2012-166	3.8%		28.7%
Direct Sbottom (2b)	ATLAS-CONF-2012-165	6.2%		17.4%
3rd Generation Squarks (3b)	ATLAS-CONF-2012-145	10.8%		47.2%
3rd Generation Squarks (3l)	ATLAS-CONF-2012-151	1.9%		32.8%
3 leptons	ATLAS-CONF-2012-154	1.4%		38.5%
4 leptons	ATLAS-CONF-2012-153	3.0%		52.4%
Z + jets + MET	ATLAS-CONF-2012-152	0.3%		12.2%
Total Exclusions:		**~37%**	**~46%**	**~73%**

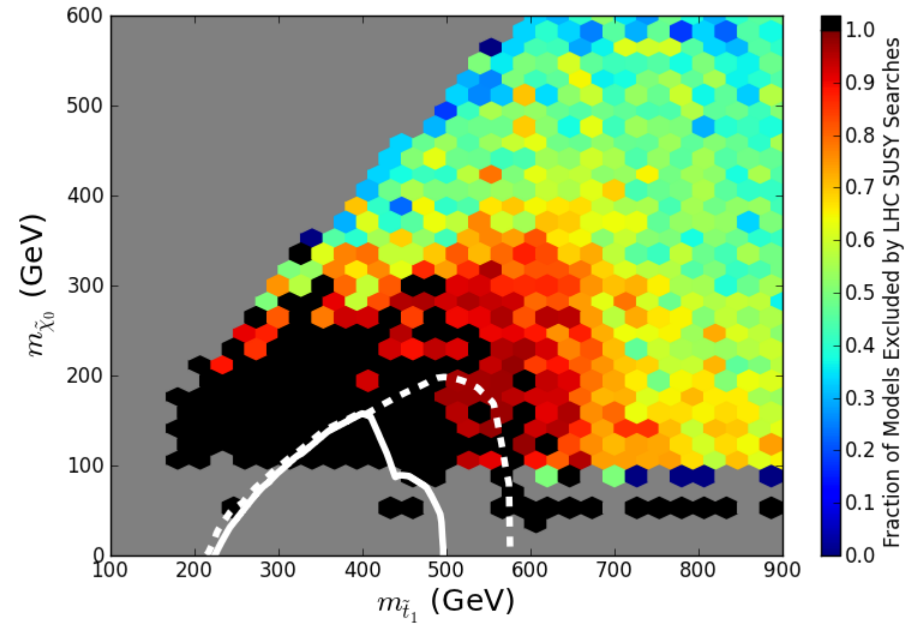
→ MORE analyses coming 'soon' (for Snowmass)

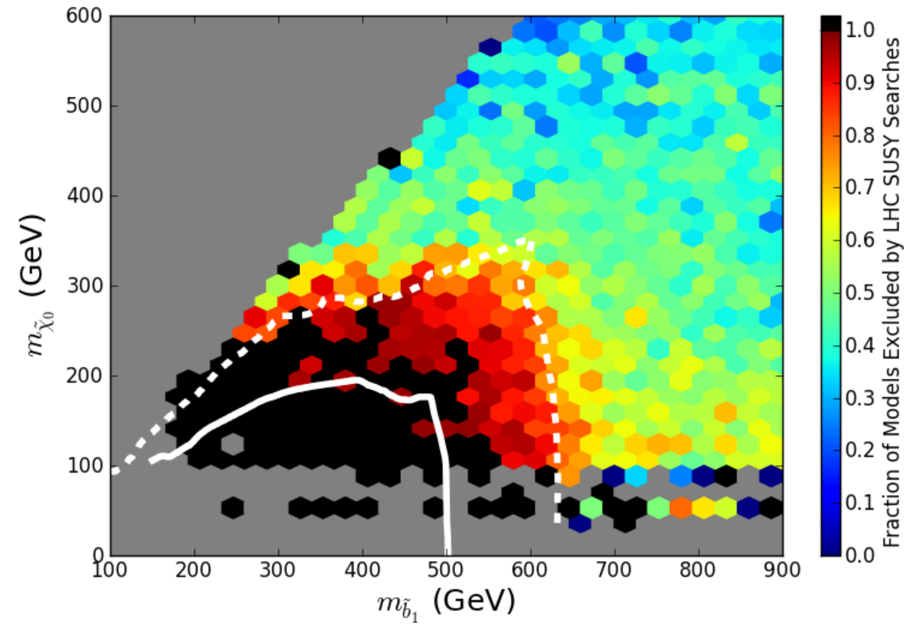
Of course search efficiencies & search comparisons are much more interesting (& meaningful) than simple exclusion fractions



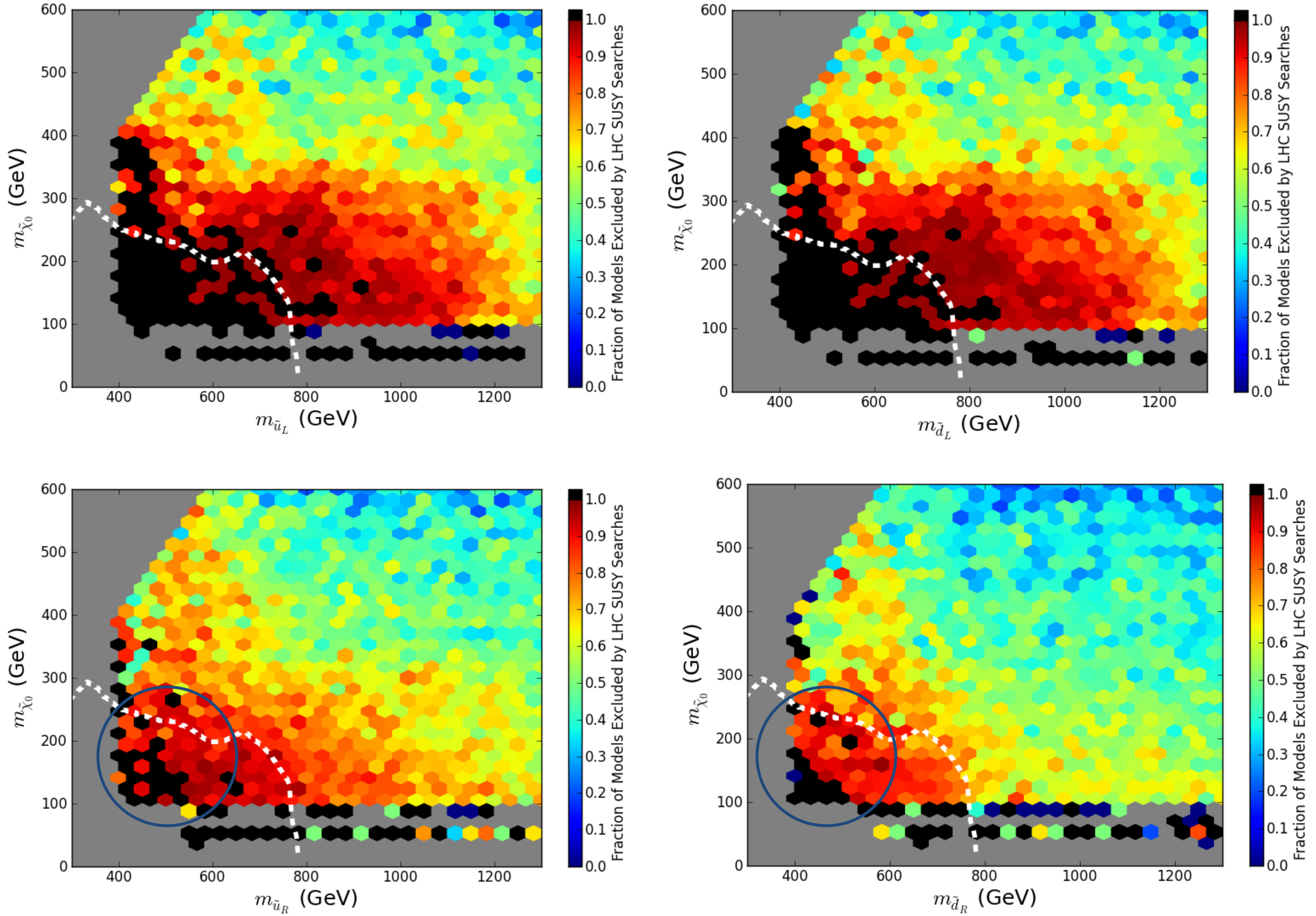


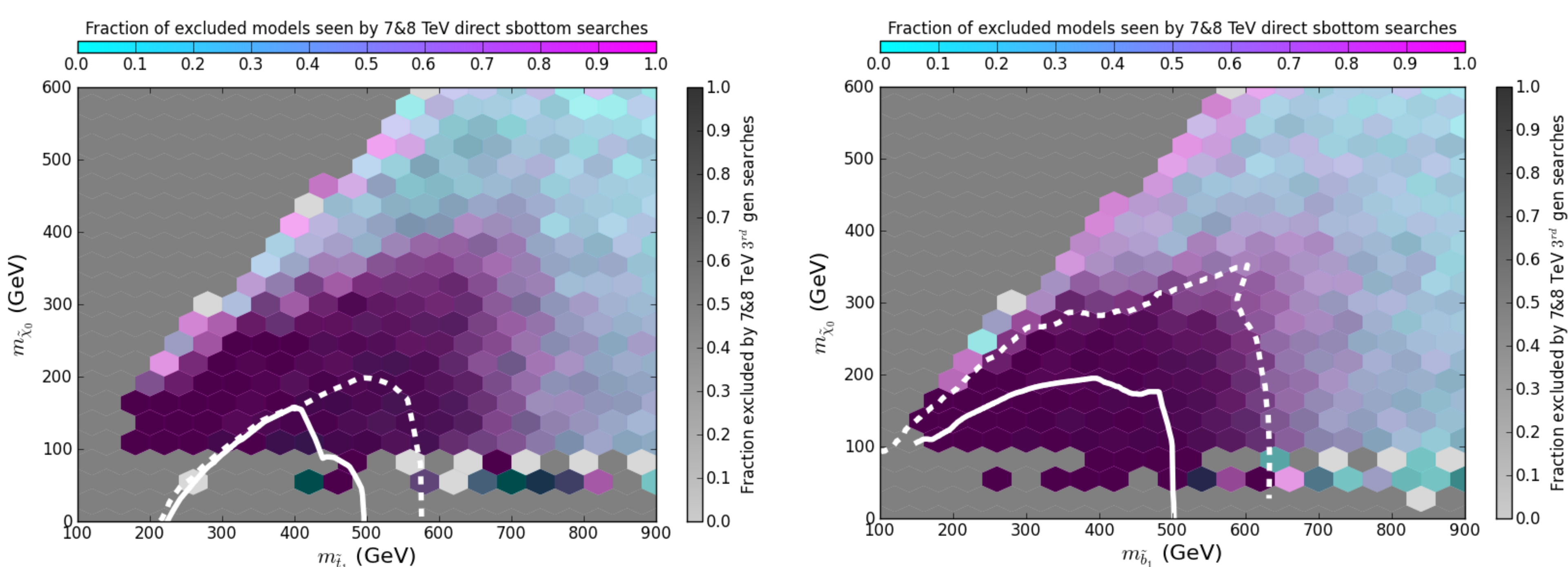
Search Efficiency for Neutralino LSP Set



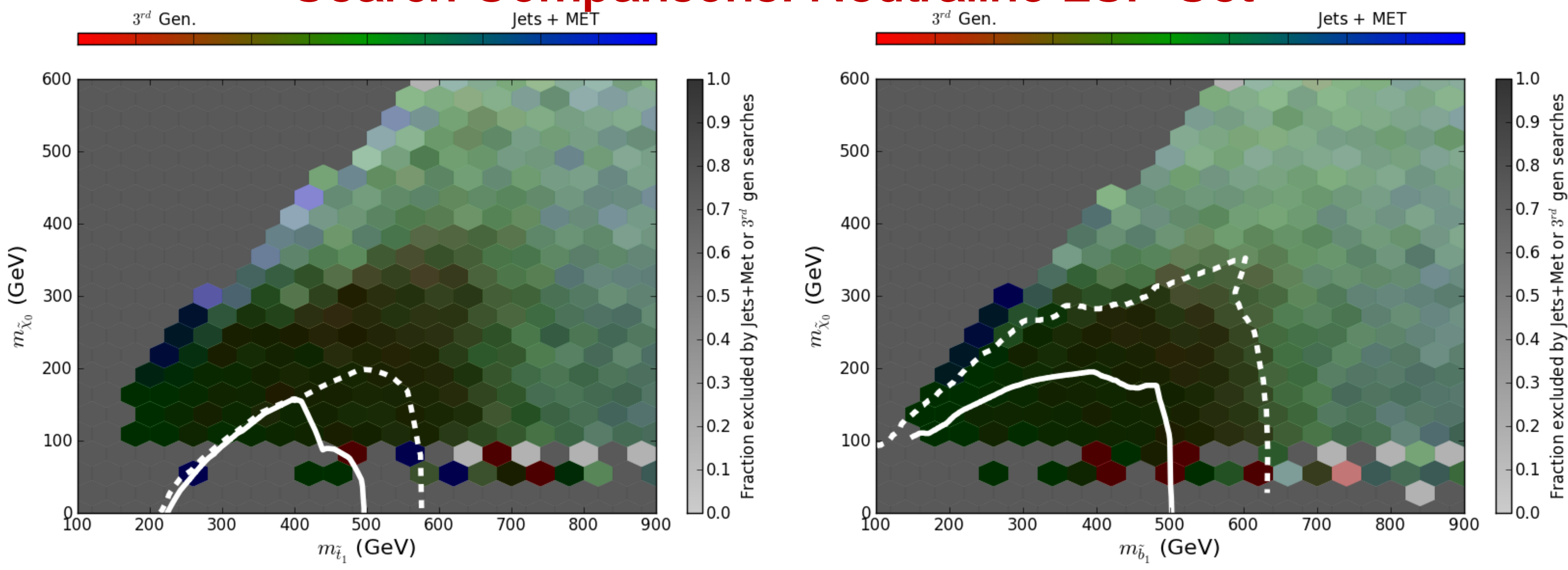


Neutralino Set Squark Results



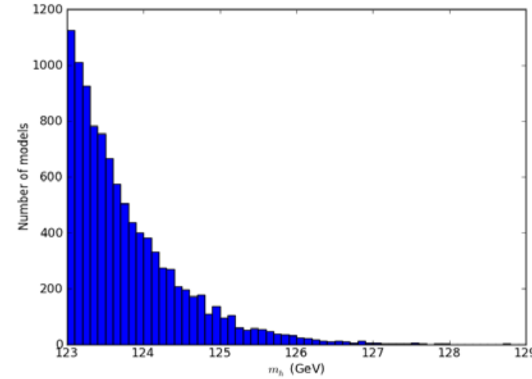


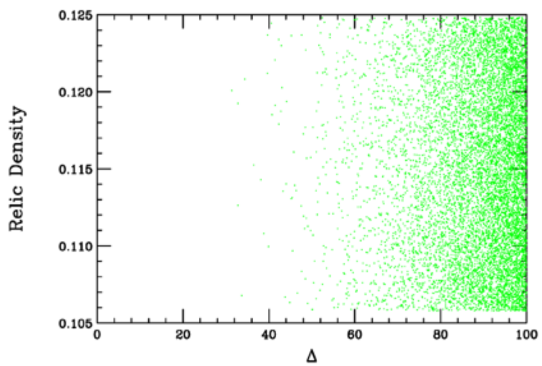
Search Comparisons: Neutralino LSP Set

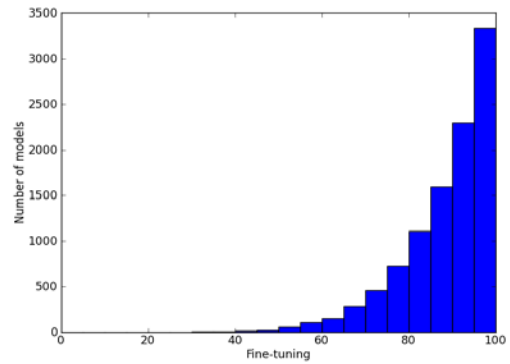


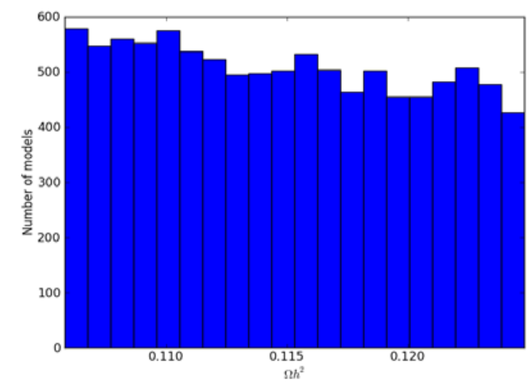
pMSSM Low-FT Neutralino LSP Model Set

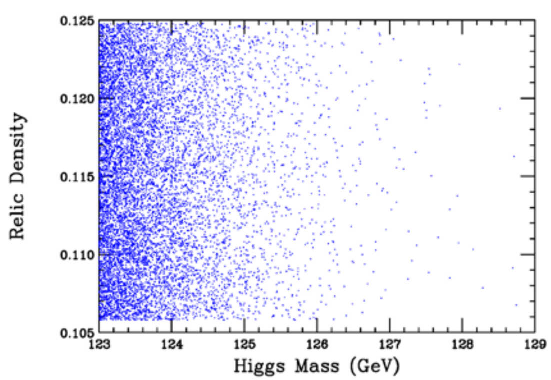
- 1/3 x 10^9 w/ low FT→ ~10.2k models
- m_h = 126 ± 3 GeV
- WMAP/Planck ± 5σ
- FT better than 1% (Δ_{EBG} <100)
- expected to be very susceptible to ATLAS

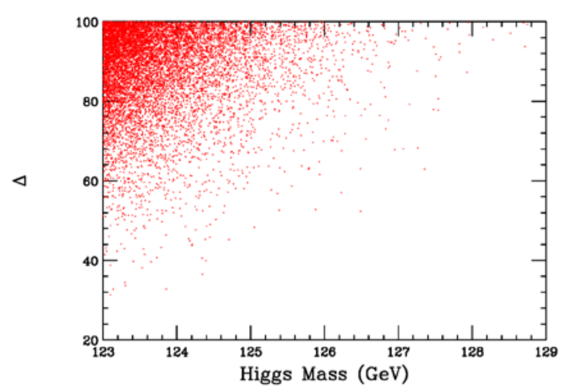


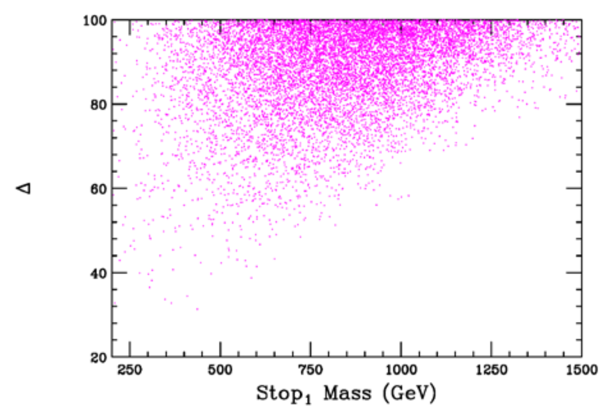


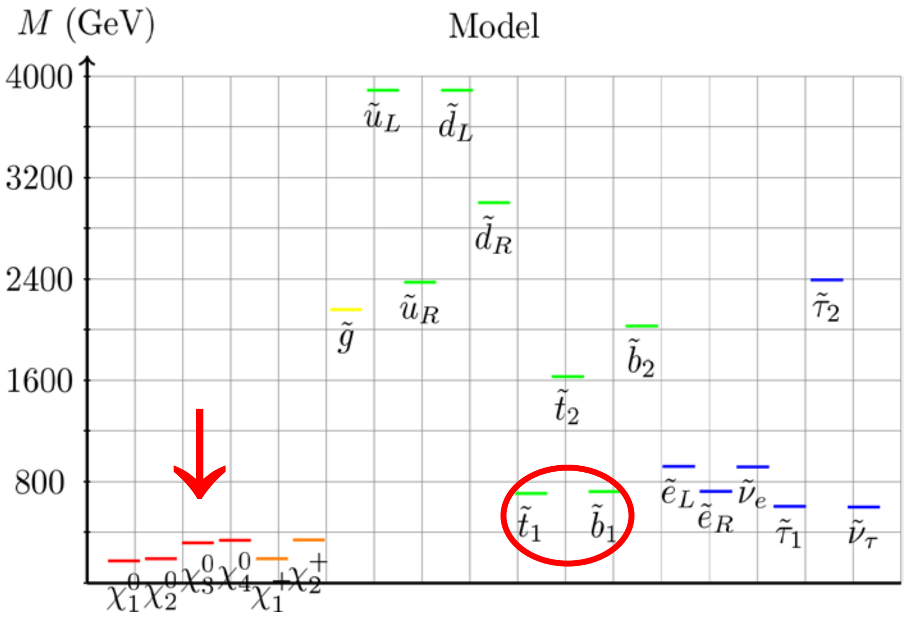








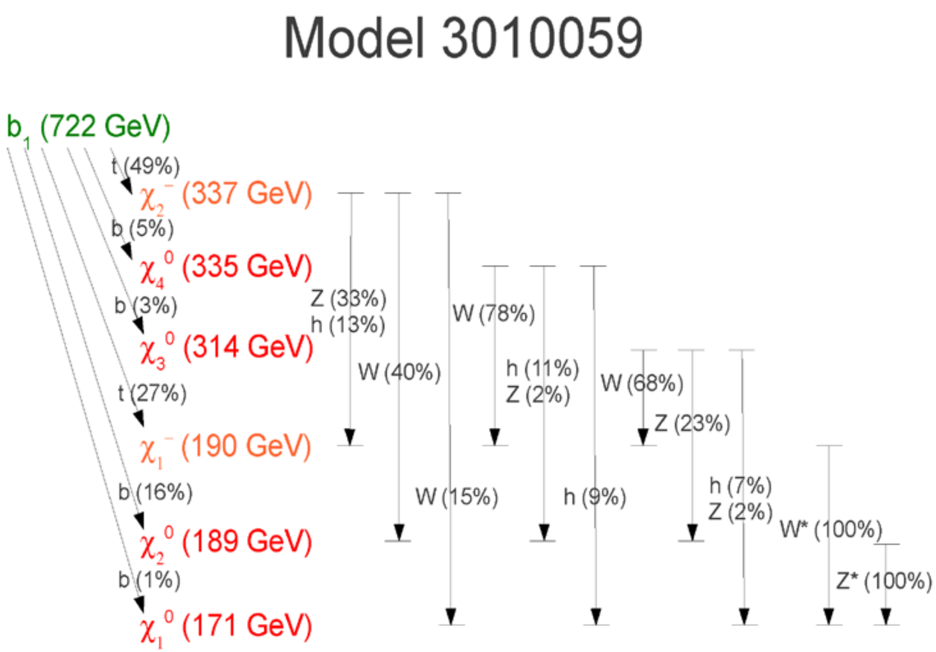


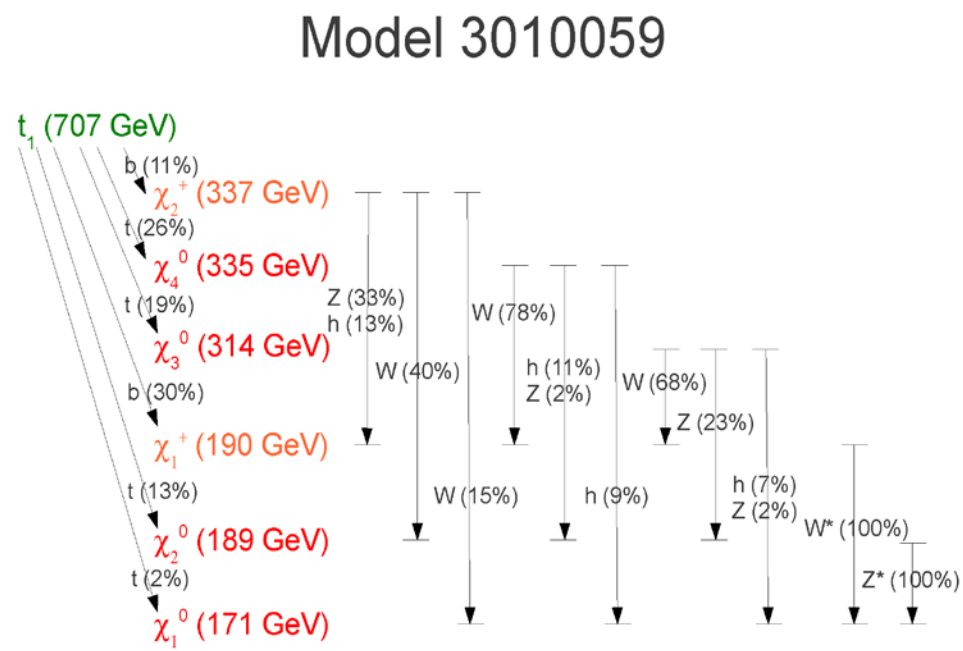


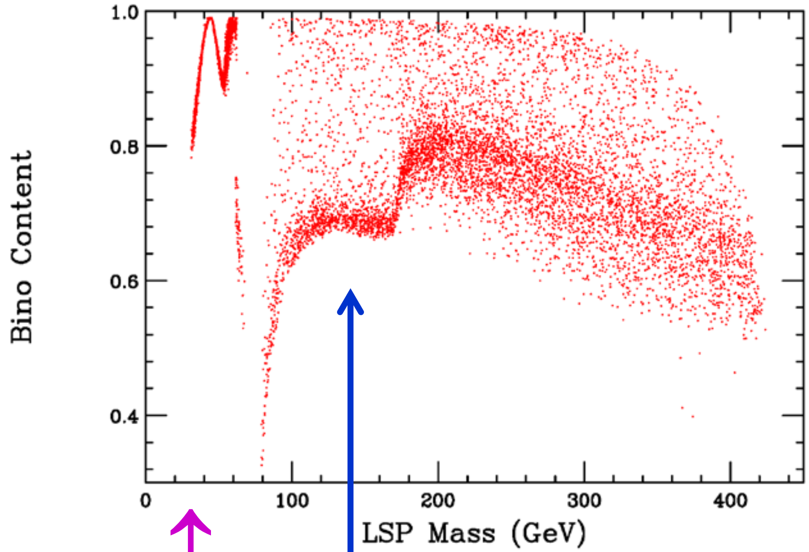
The necessity of both a light bino to get the right relic density & a light Higgsino for low-FT forces the stop decays to be quite complex !

~ 60% of models also have winos below the stop/sbottom → leptons!

~ 30% also have a light slepton below stop (co-annihilators) → *more* leptons!



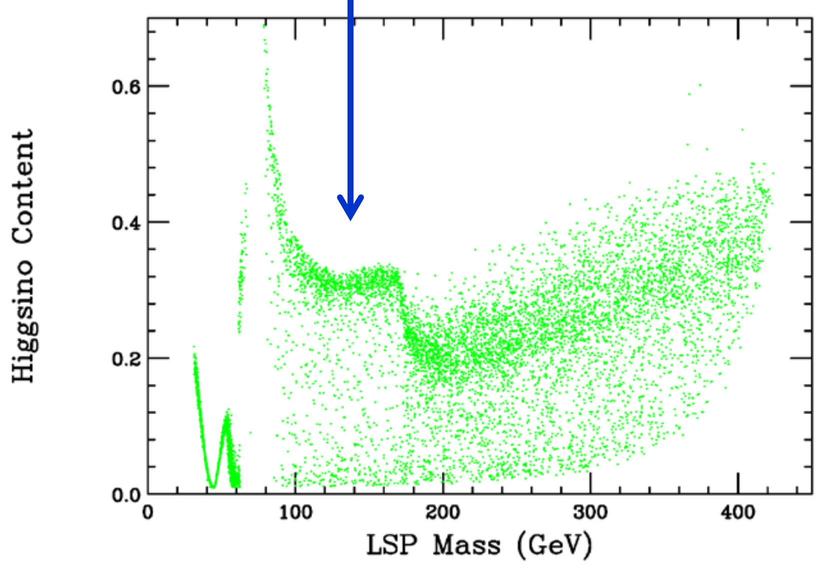


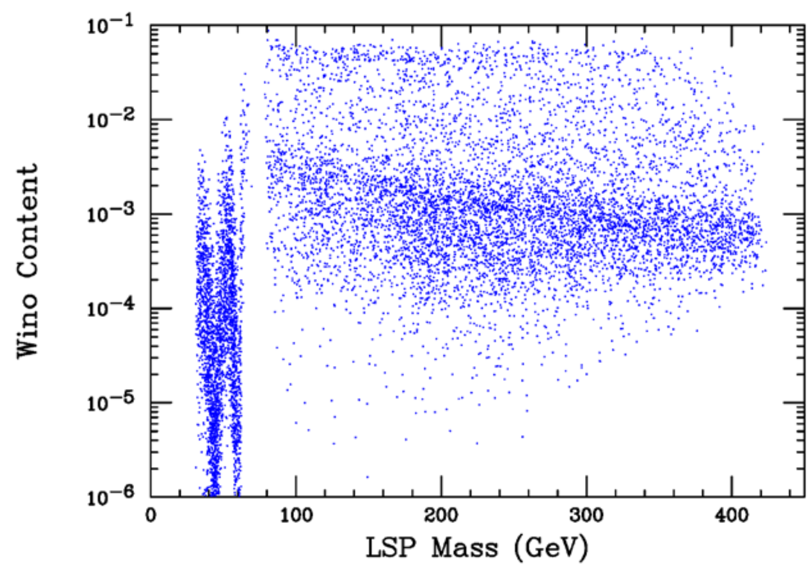


LSPs are seen to be mostly bino-Higgsino admixtures as was expected w/ an occasional small wino component

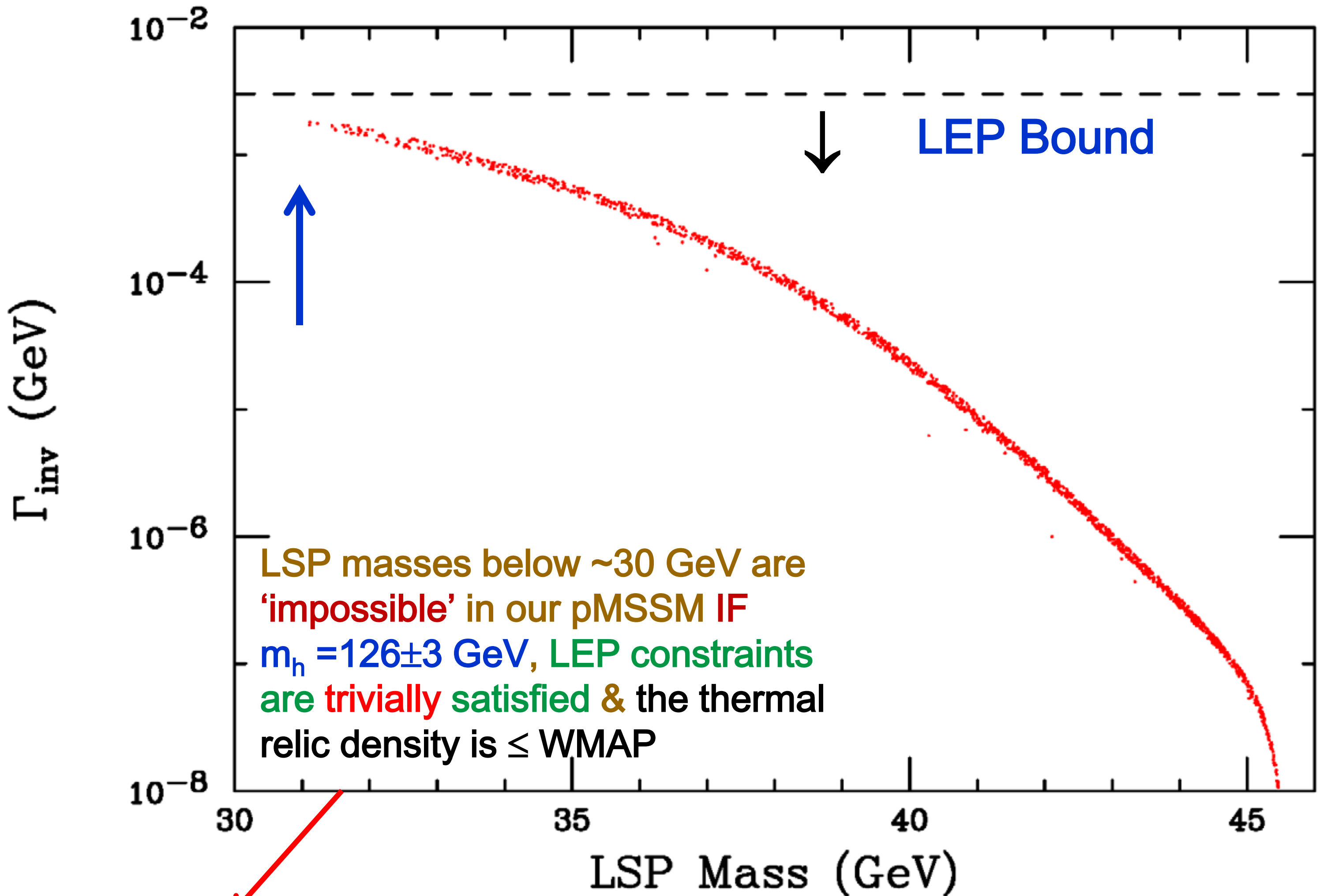
There's lots of physics in the patterns here that there's no time to discuss(see backups)

Essentially reflections !





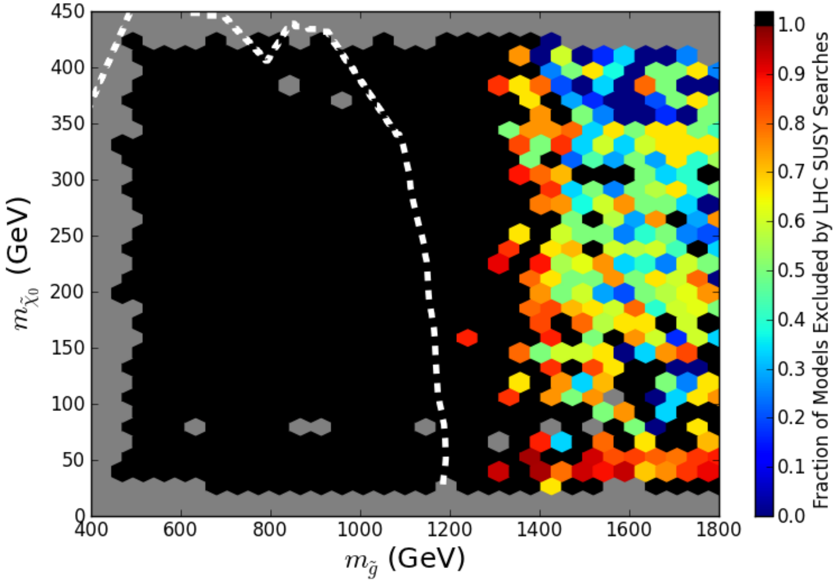
$\Gamma(Z \rightarrow \chi\chi)$

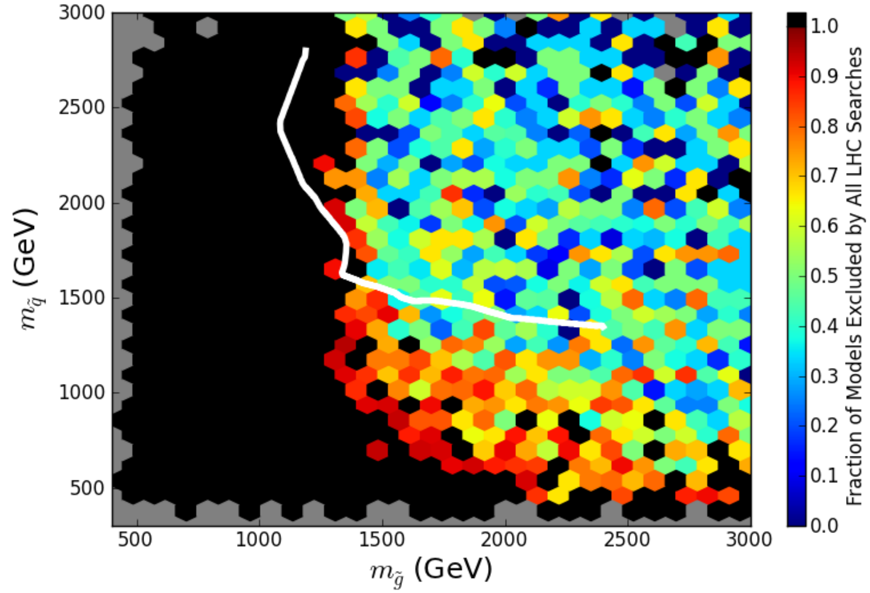


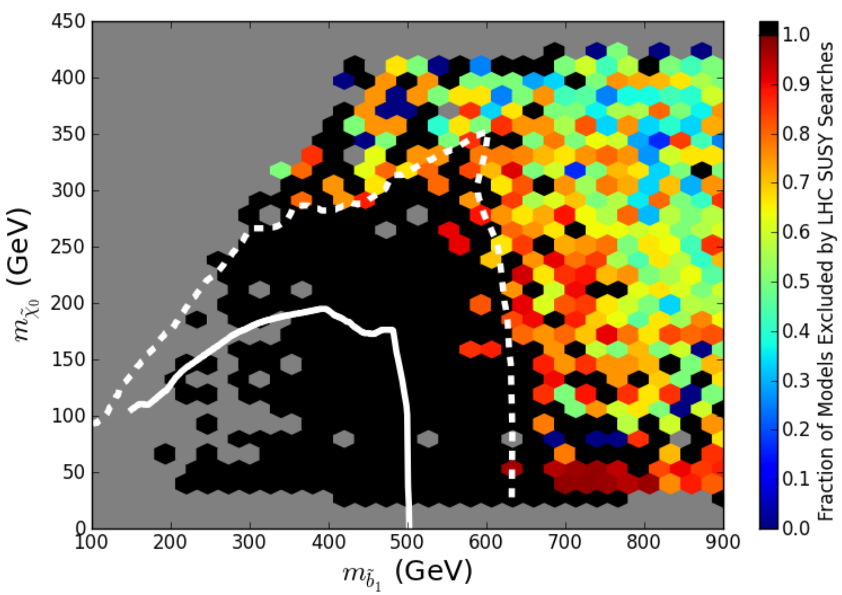
CDMS ?

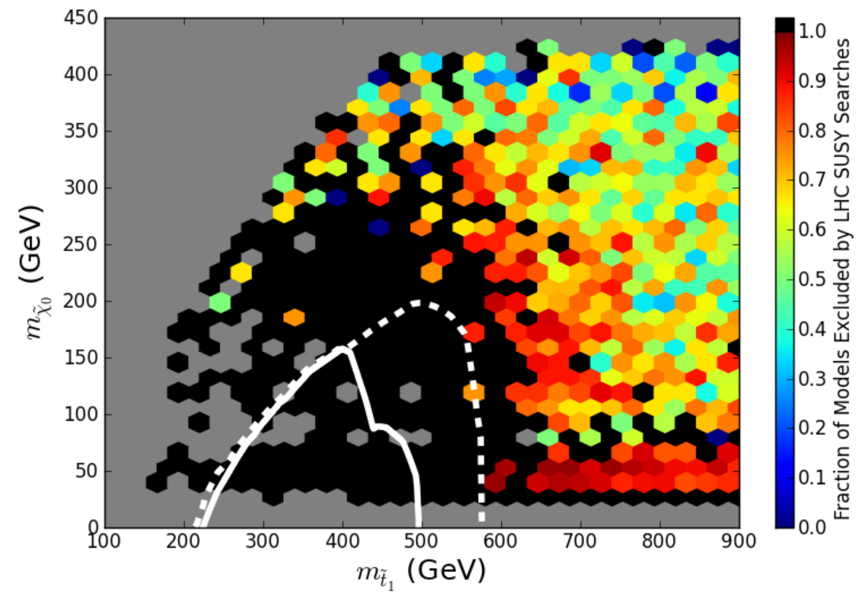
~15.7% of LSPs are in this mass range

Coverage quite different than the more general set…..

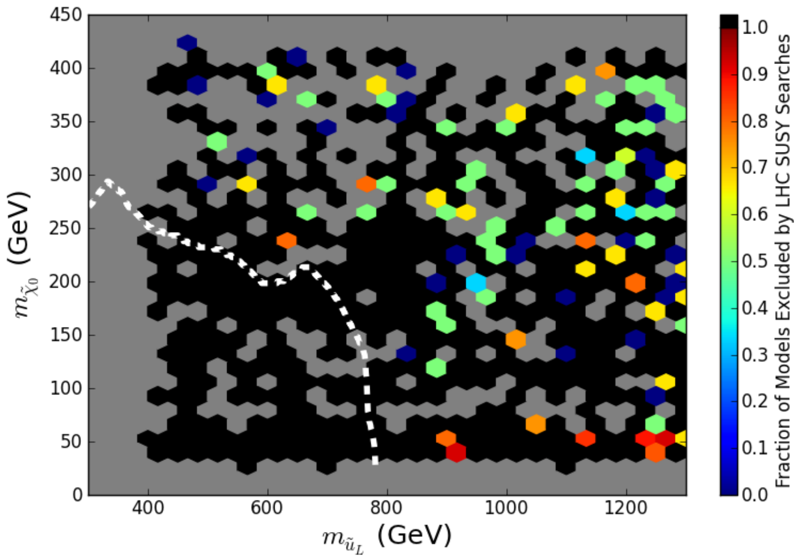


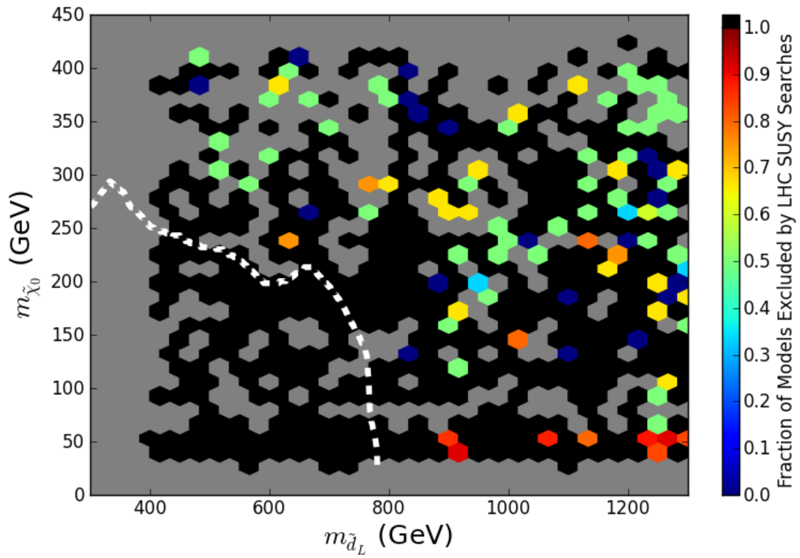


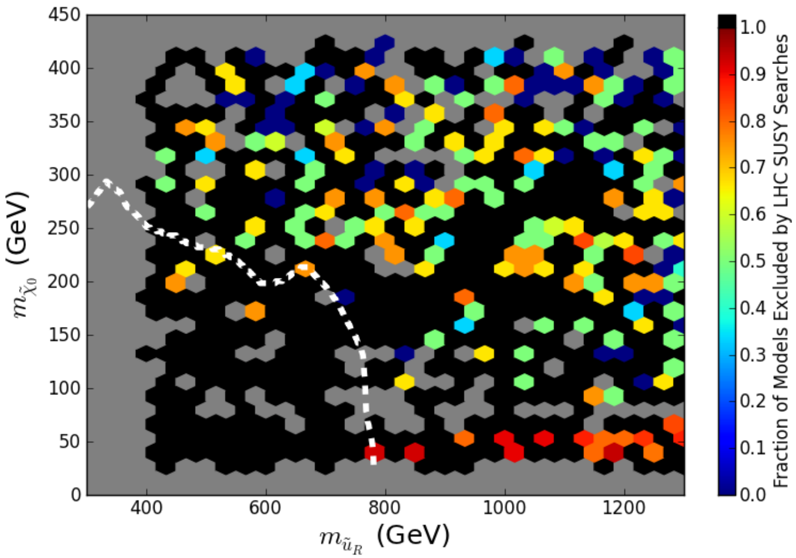


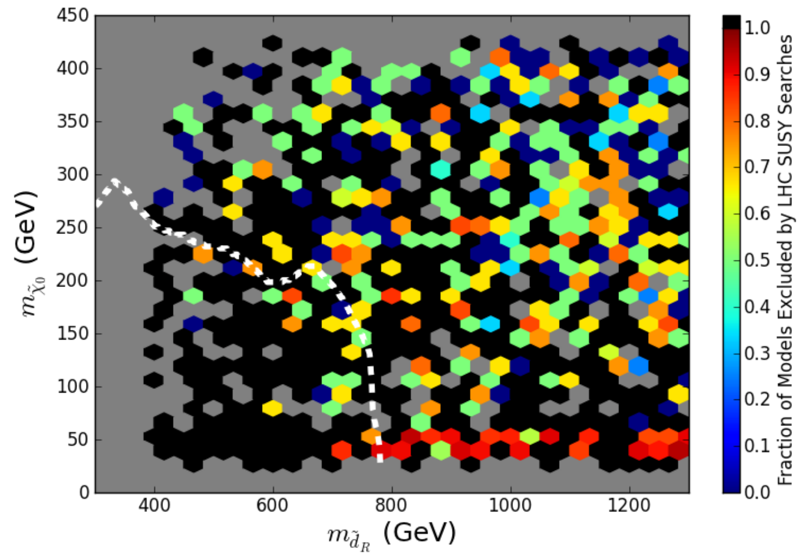


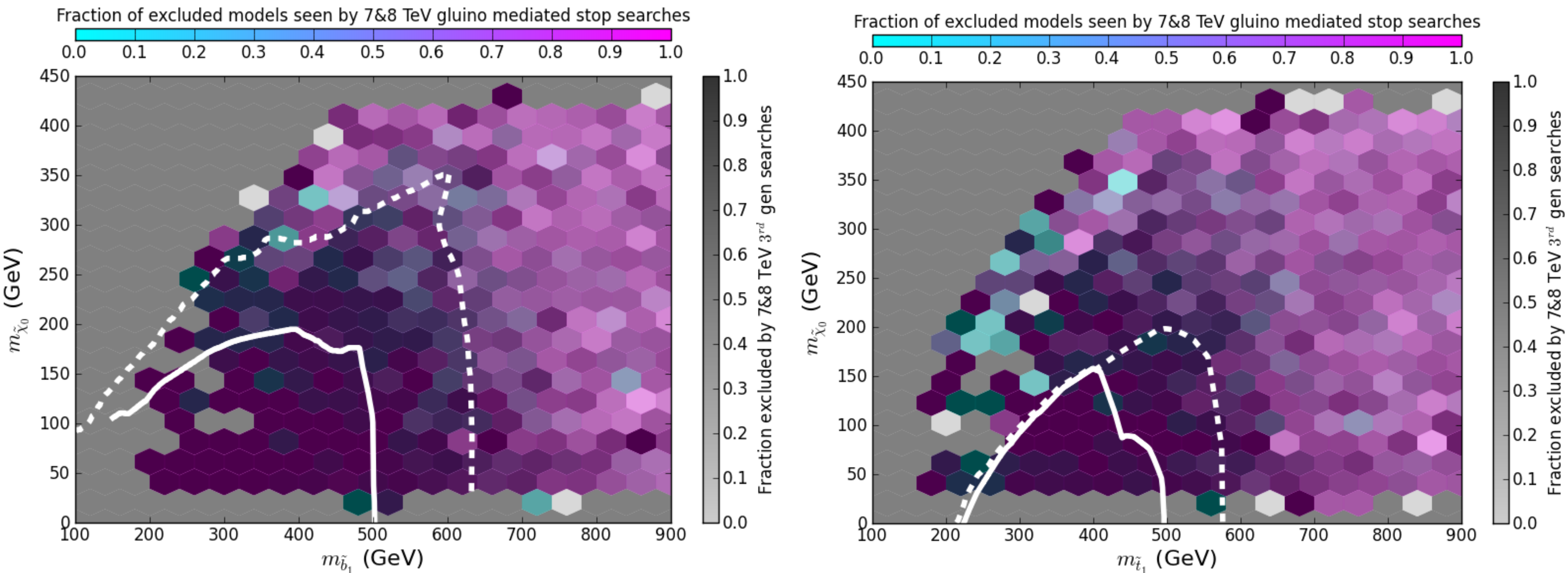
Low-FT Light Squark Results



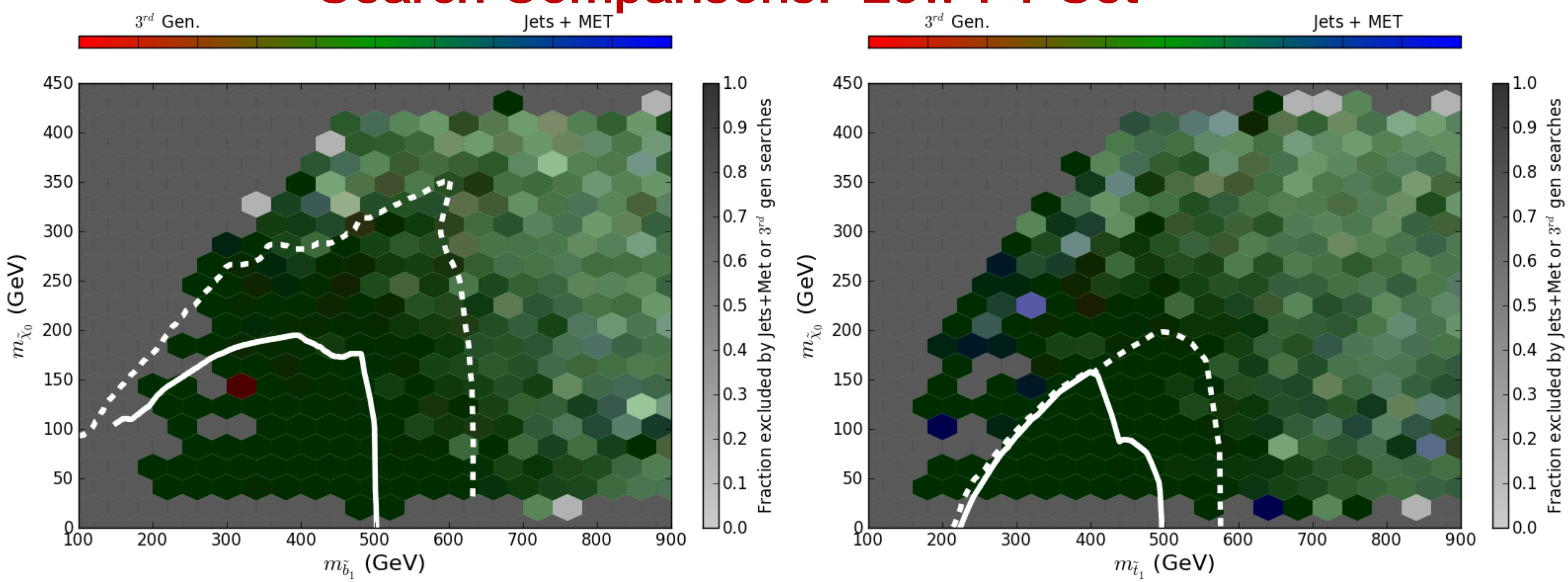




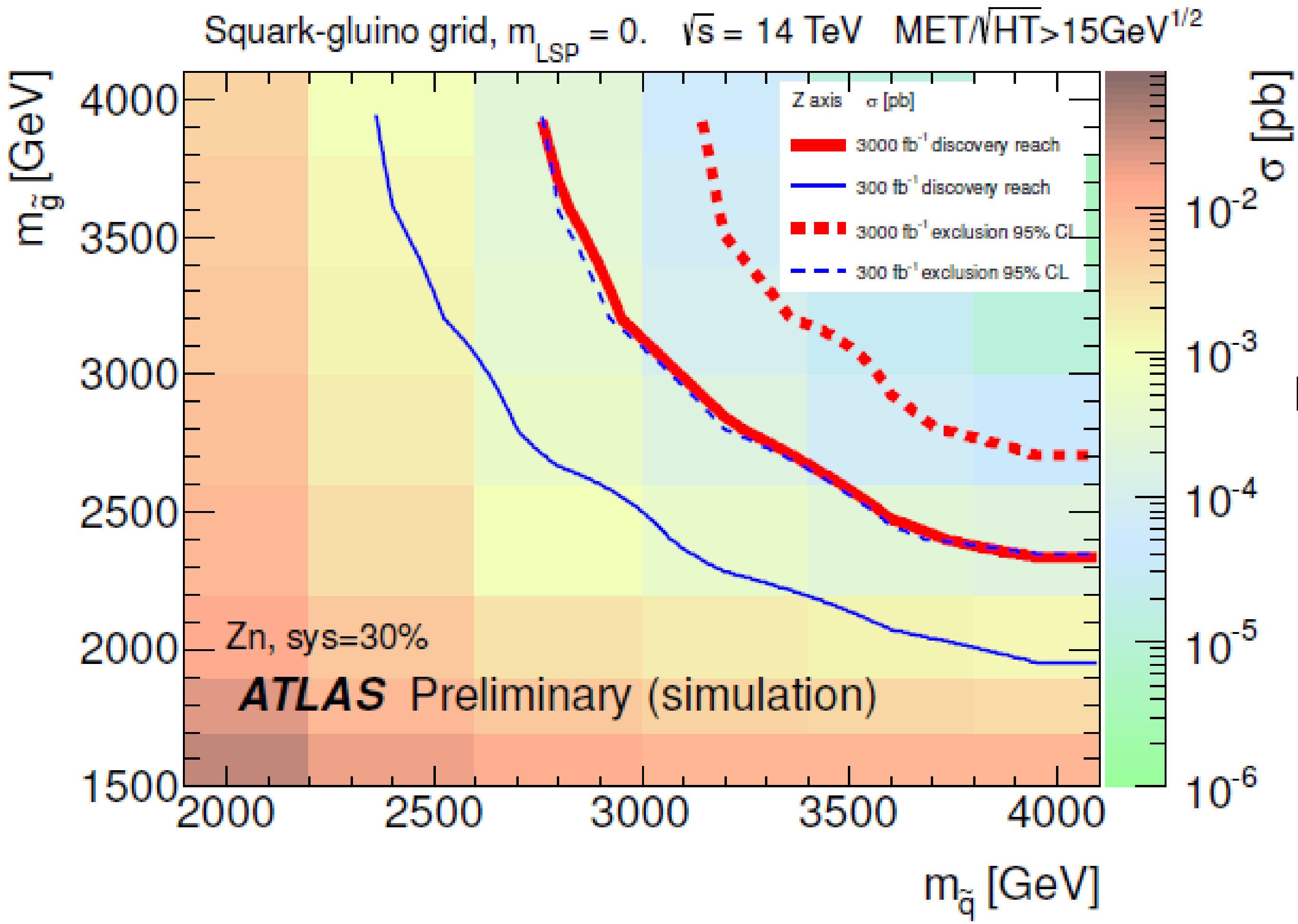




Search Comparisons: Low-FT Set



14 TeV: Jets plus MET Analysis From the ATLAS European Study



Simplified Model Result

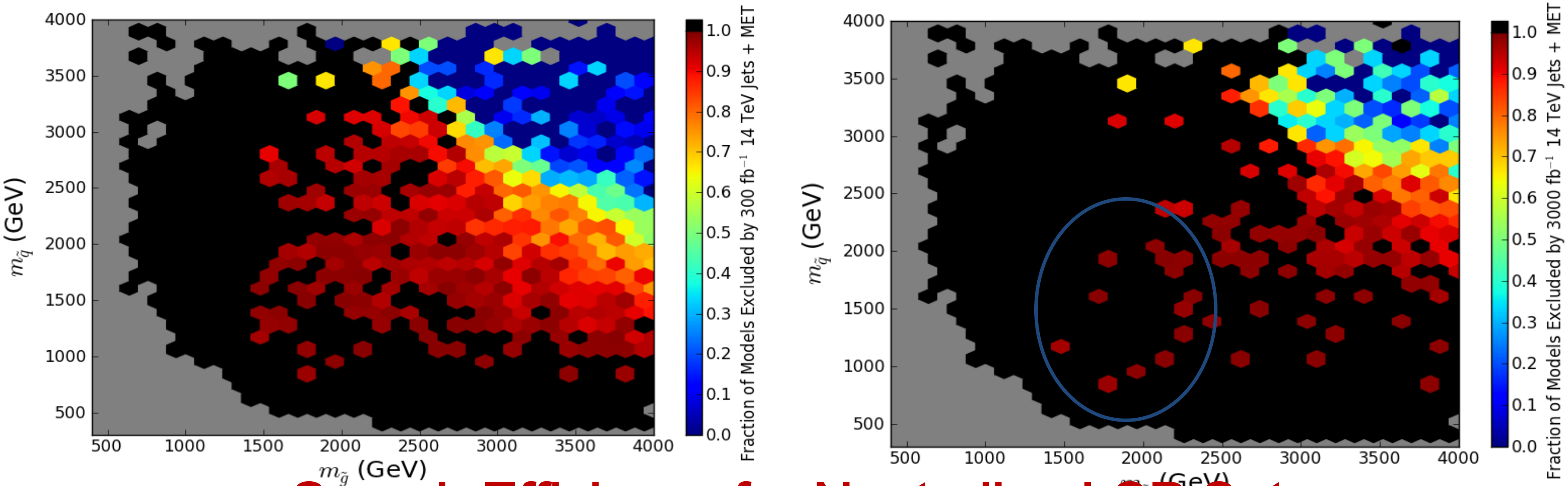
What happens in the pMSSM ?

- Jets plus MET is a very powerful search covering a large portion of pMSSM space as seen in the 7&8 TeV studies

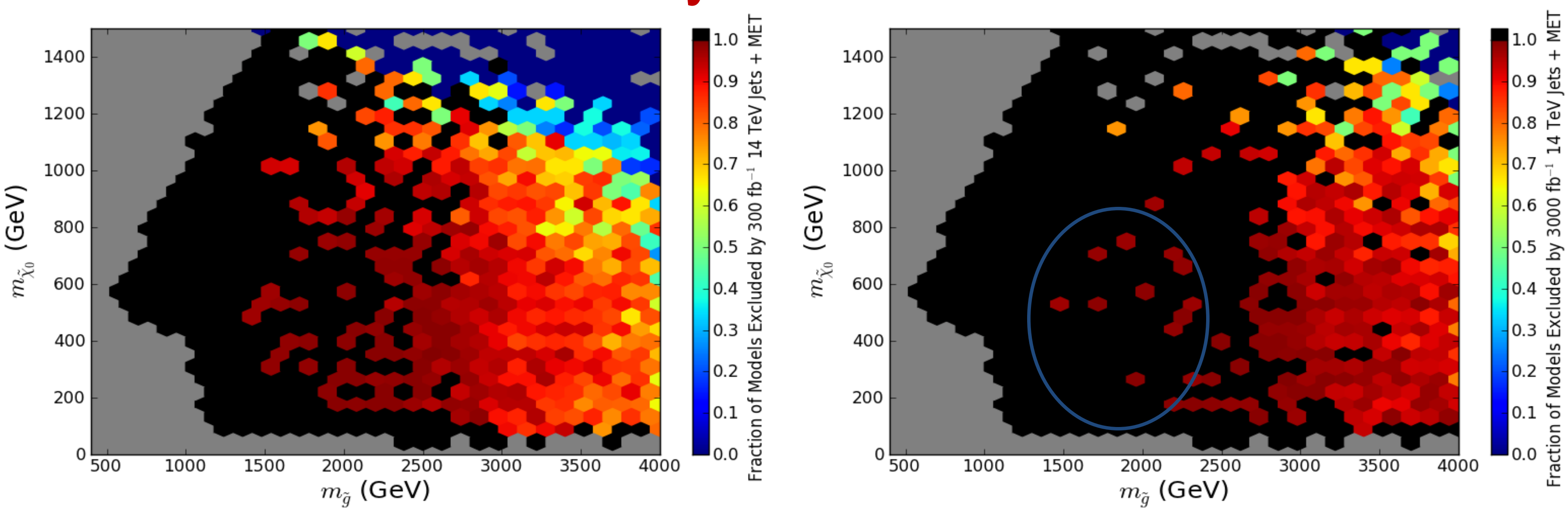
- We have ‘repeated’ this analysis @ 14 TeV, so far ‘only’ for the ~30.7k surviving neutralino LSP models which predict a Higgs mass of 126±3 GeV & passing all the 7/8 TeV searches and the corresponding set of ~2.7k surviving low-FT models (the gravitino model results are chugging away right now!)

- The results are likely somewhat overestimates of coverage as proper background systematics not fully accounted for by ATLAS but other analyses are still missing

- These results are ‘expensive’ : ~2 x 10^6 core-hrs so far & just now completed!

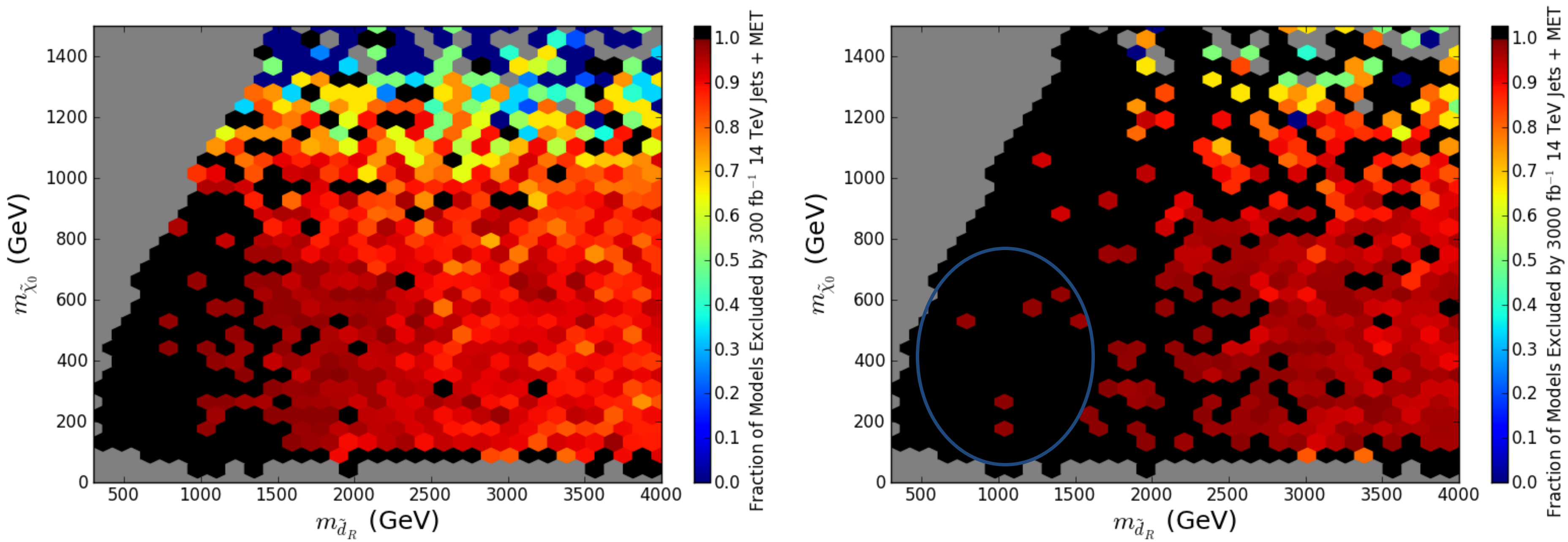


Search Efficiency for Neutralino LSP Set



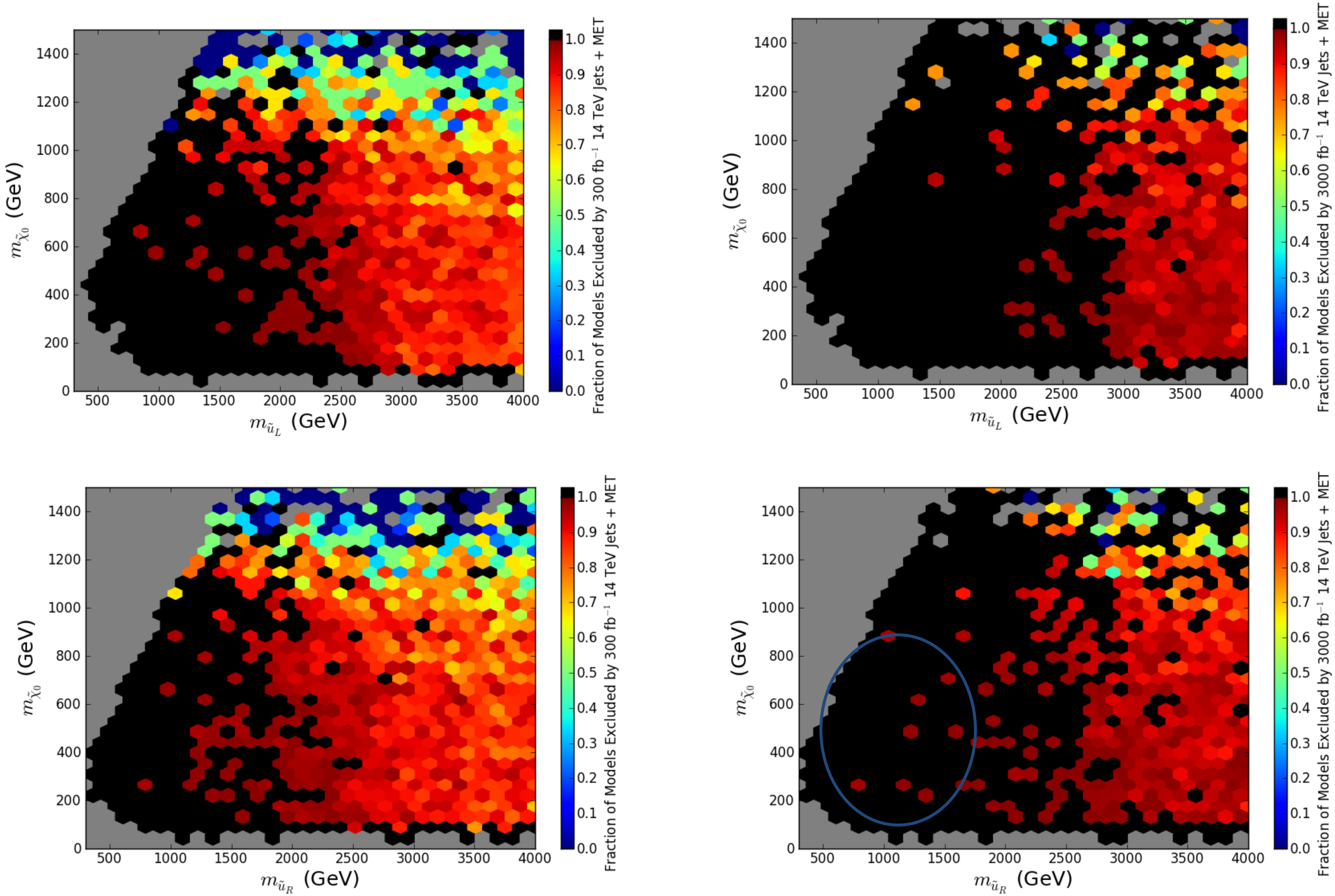
- For a luminosity of 300 (3000) fb^{-1} we find that 92.1(97.5)% of the models are killed by jets + MET @ 14 TeV ! Models w/ lepton-rich final states will survive

Some Preliminary 14 TeV Results (cont.)

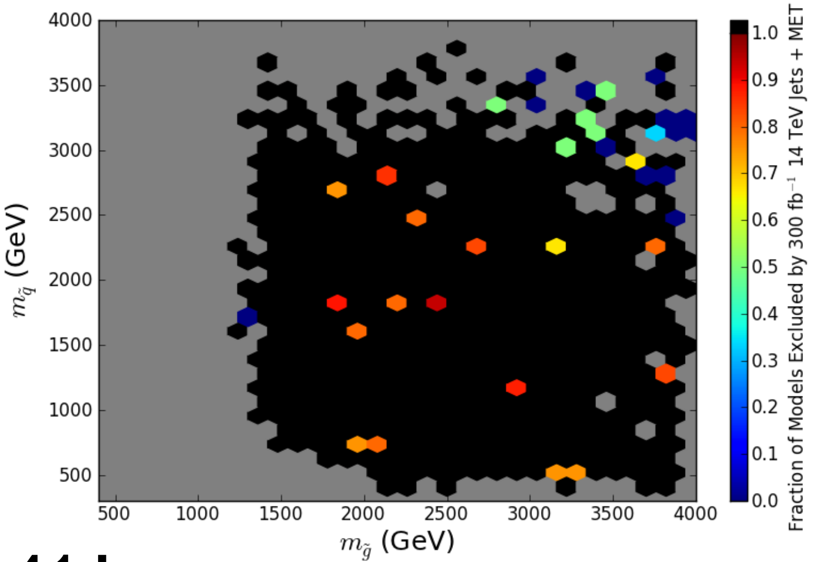


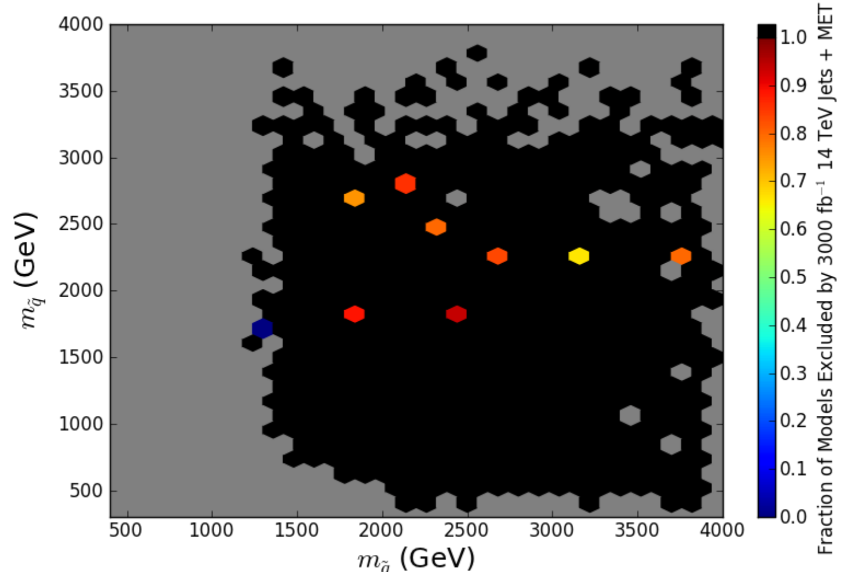
- Light RH-down squarks are the least constrained due to PDFs & being an iso-singlet & represent a 'worst-case' scenario. We see that some quite light guys remain…but this is only the results from a single analysis !

More 14 TeV Squark Results



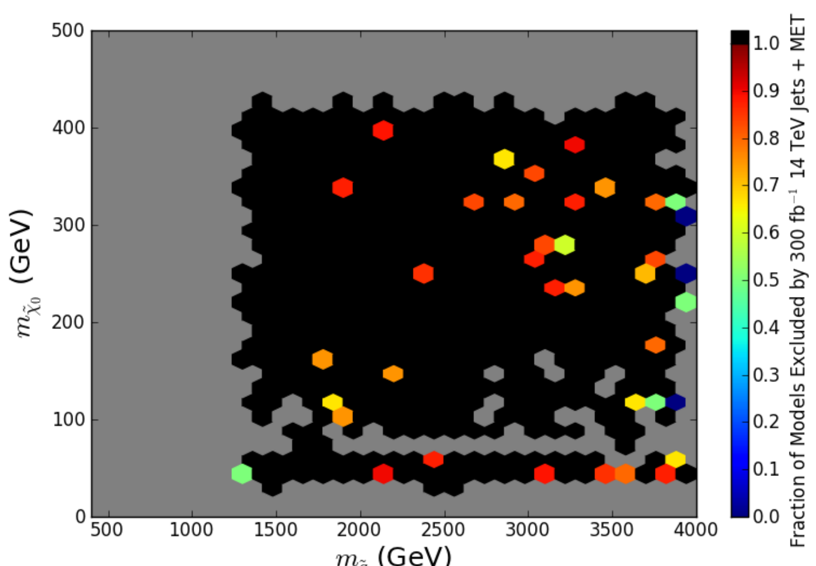
14 TeV Results for the Low-FT Model Set

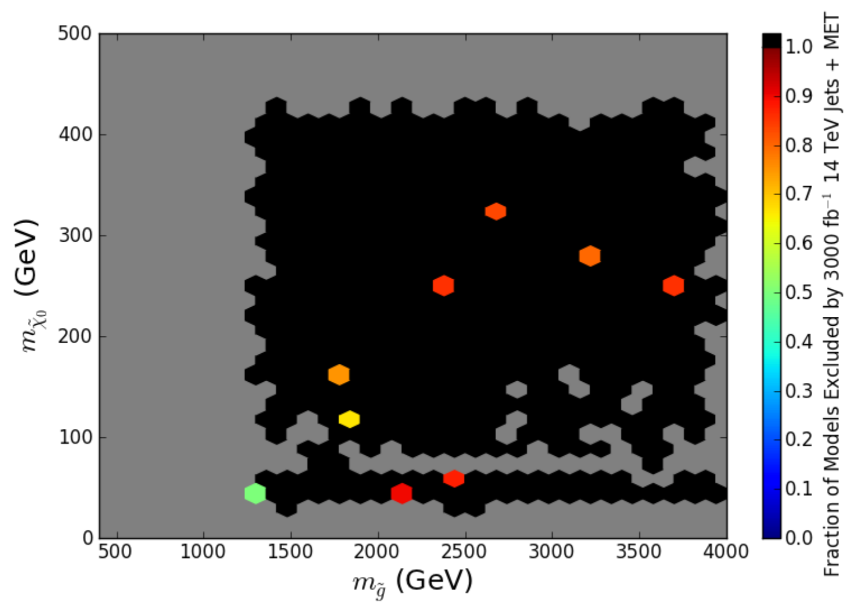




41 !

9 !



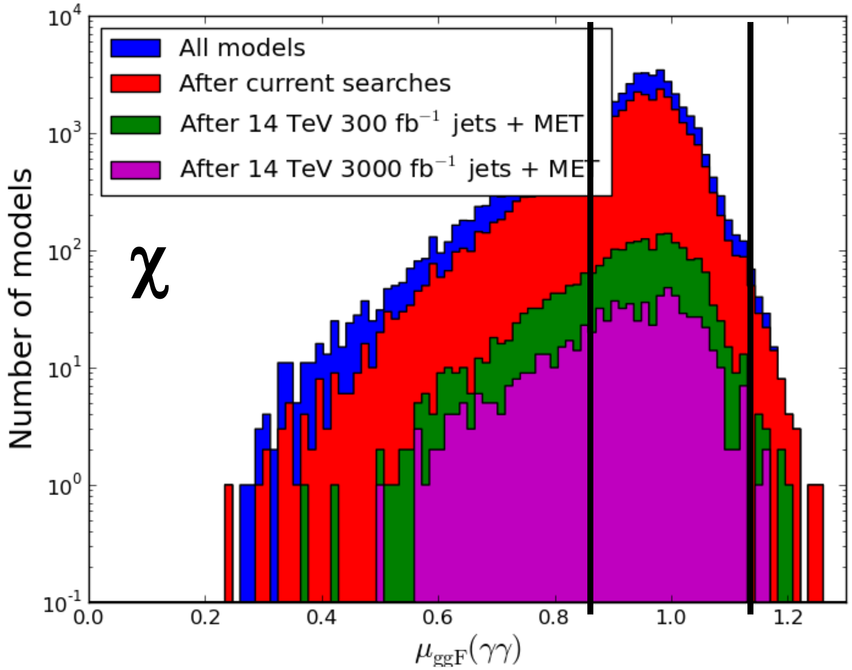


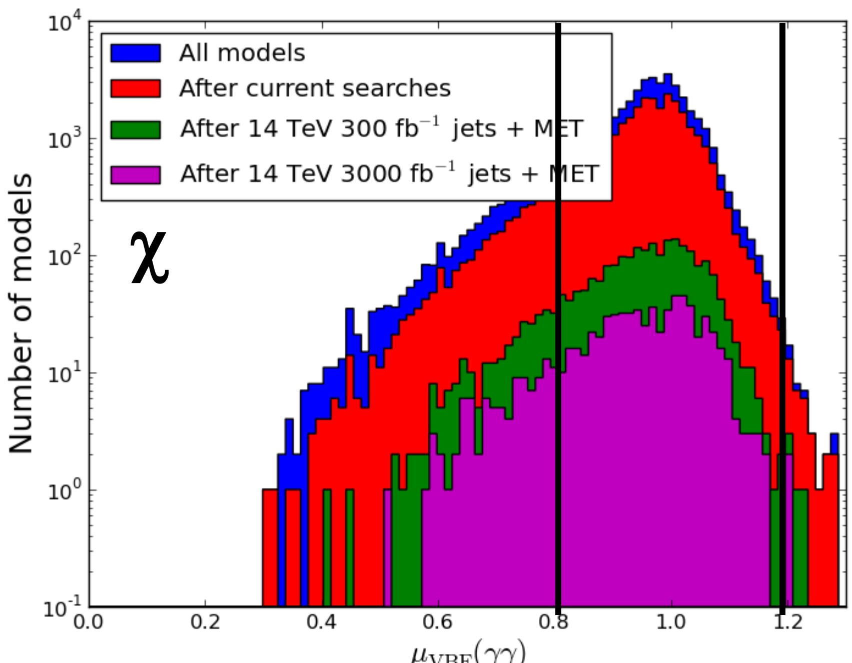
14 TeV Results for the Low-FT Model Set (cont.)

- Only 41 (9) models out of ~10.2k survive all the 7 & 8 TeV searches plus jets+MET @14 TeV with L= 300 (3000) fb^{-1} !

- Many of the surviving models apparently have high BFs into final states leading to high- p_T leptons & thus automatically fail the selection cuts of this single analysis. Adding more analyses at 14 TeV is important & will likely exclude a good fraction of these remainders

- It does seem very likely that the 14 TeV LHC will do quite well at excluding (or finding !!) models with low-FT





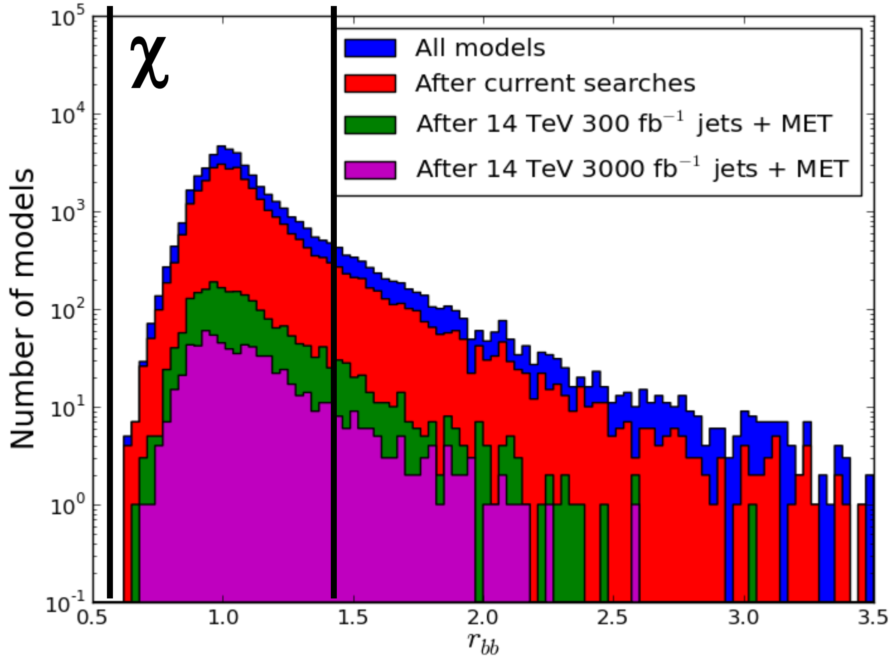
Reminder: the properties of the Higgs constrain SUSY

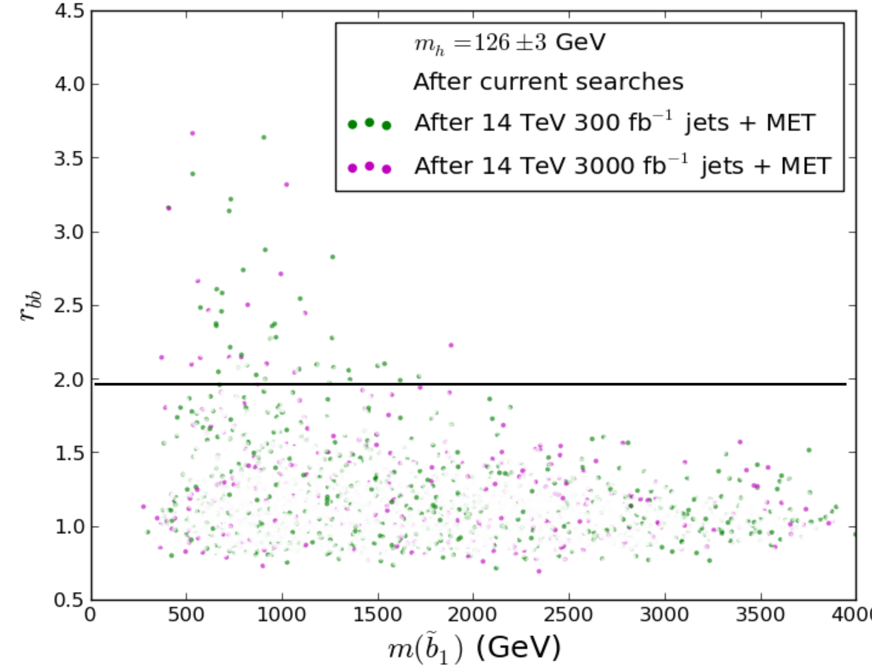
('suggestive' constraints)

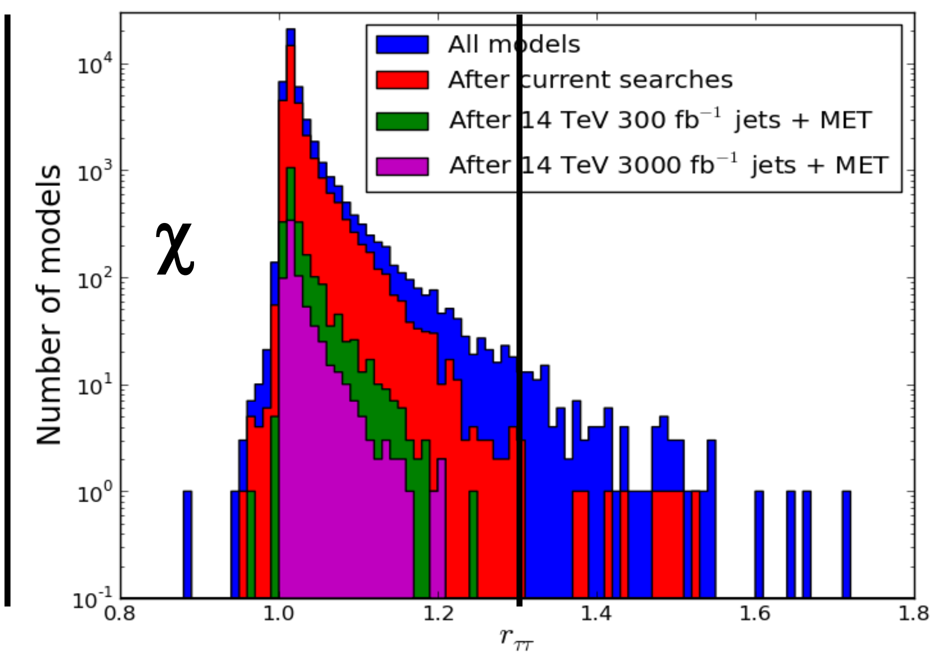
Note that the shapes of these distributions don' t significantly change & only the statistics are reduced

Furthermore we see that a determination at this level will remove SUSY models not accessible even w/ 3 ab^{-1} !

(Of course this was only for a single analysis but it's worth paying attention !)





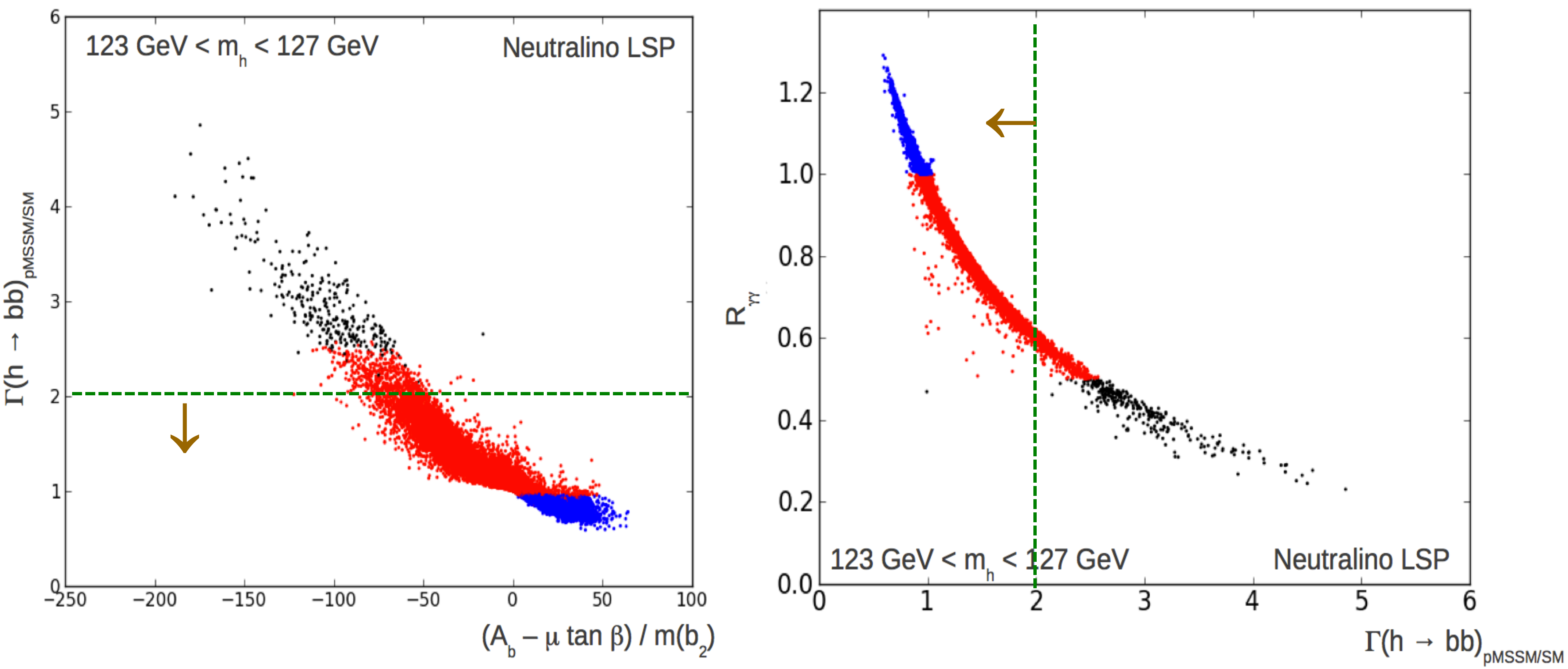


Similar sensitivities can be seen in other channels too

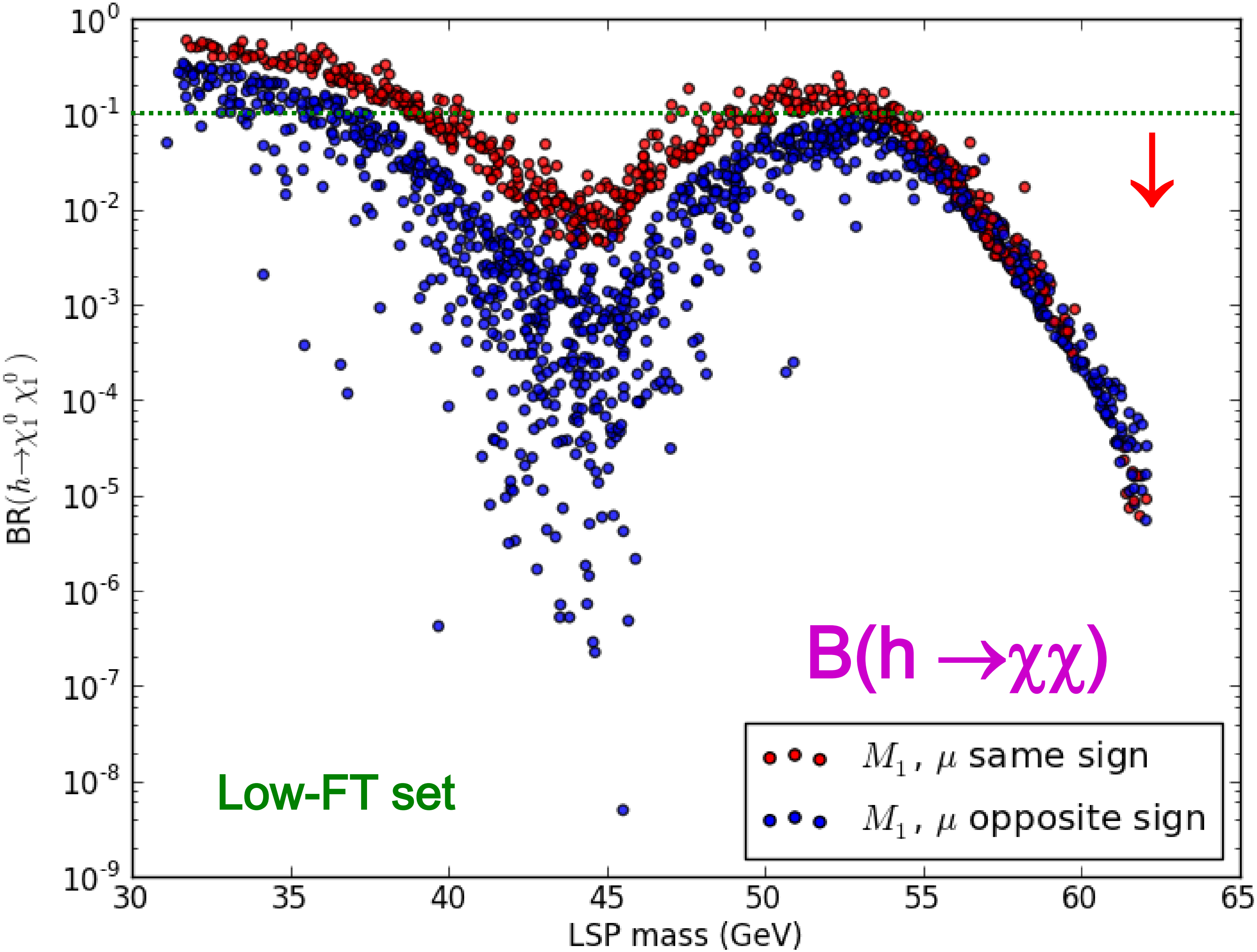
Present (CMS) data is already excluding models apparently not accessible w/ jets+ MET at 14 TeV .

Not directly impacting sparticle masses

- Although physical sparticle masses are not yet being constrained some combinations of the SUSY parameters ARE already being restricted by current BF measurements & these are correlated with other BF measurements



~31.4% of LSPs are in this mass range



Summary

- An exploration for BSM of any kind always requires some prejudice

- Duplication of ‘all’ ATLAS SUSY analyses gives a more detailed perspective of model coverage & viable model space within the pMSSM

- Each model set has it’s own properties & search sensitivities

- Low-FT models generally have complex stop/sbottom decays yet combining analyses fills in gaps yielding very significant coverage

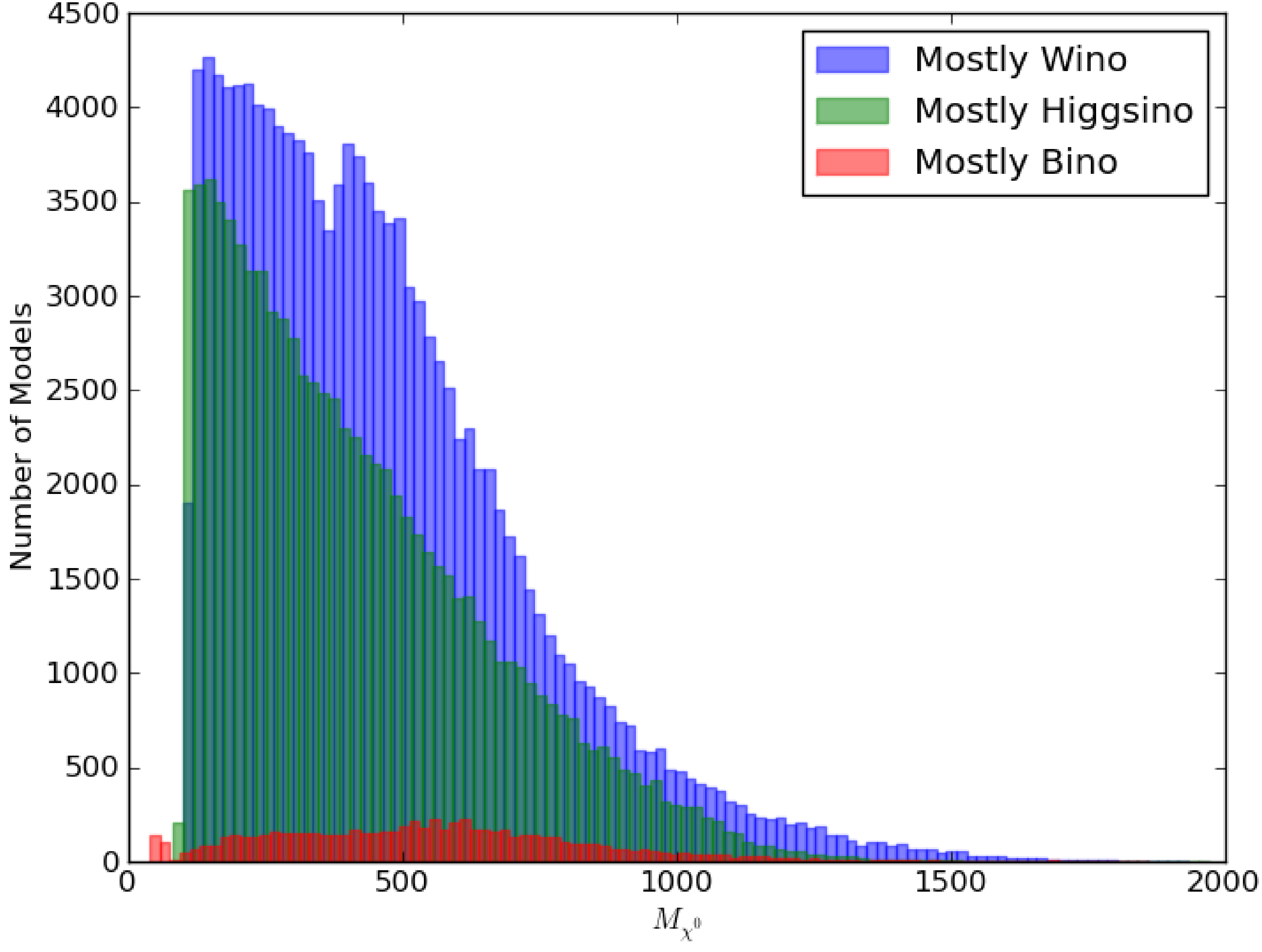
- 14 TeV searches will produce very significant pMSSM coverage particularly for the low-FT models

- Measurements of Higgs properties can also be used to constrain the pMSSM parameter space

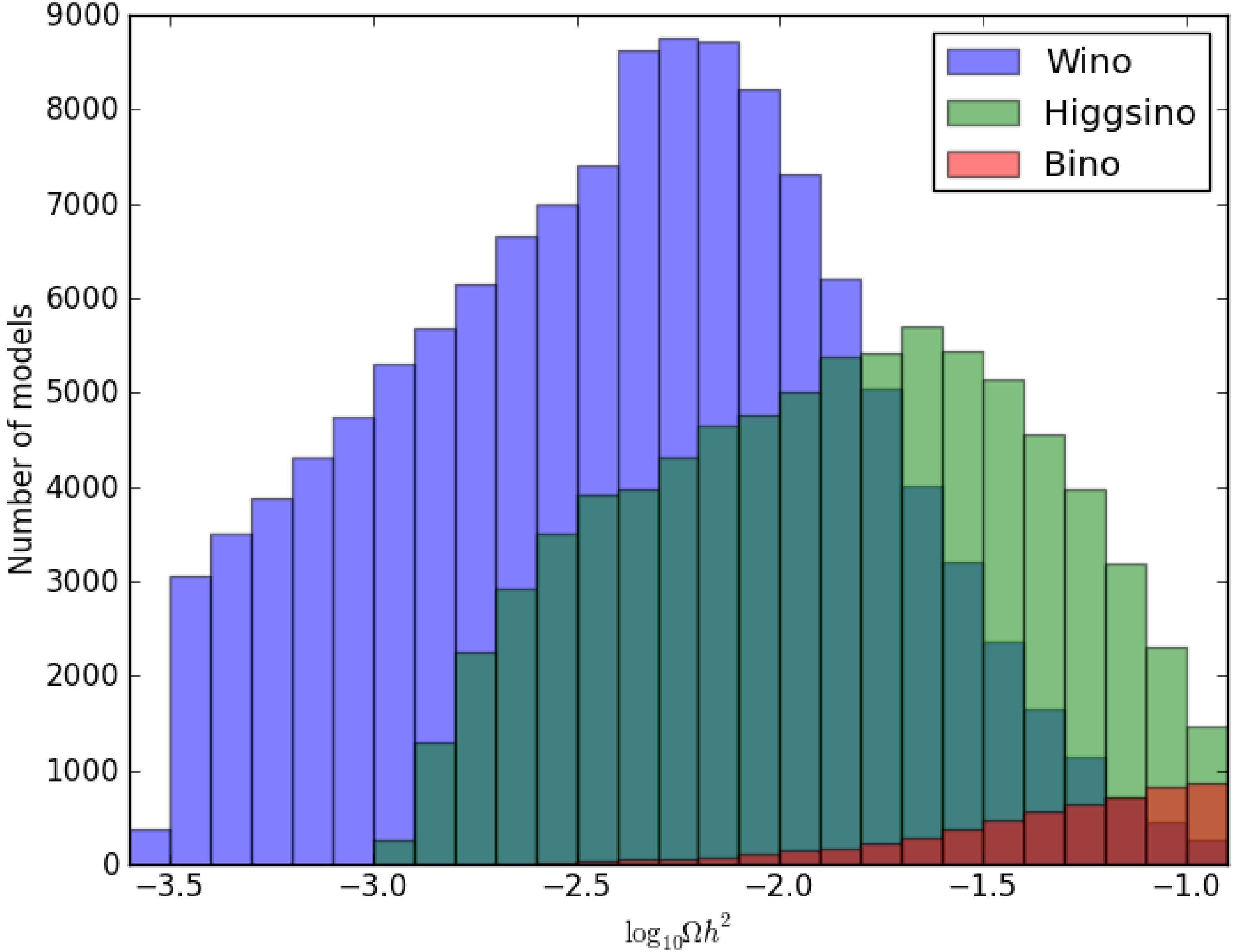
- Don’t forget about complementarity w/ , e.g., DM searches too !


VIVA LA FRANCE

BACKUPS

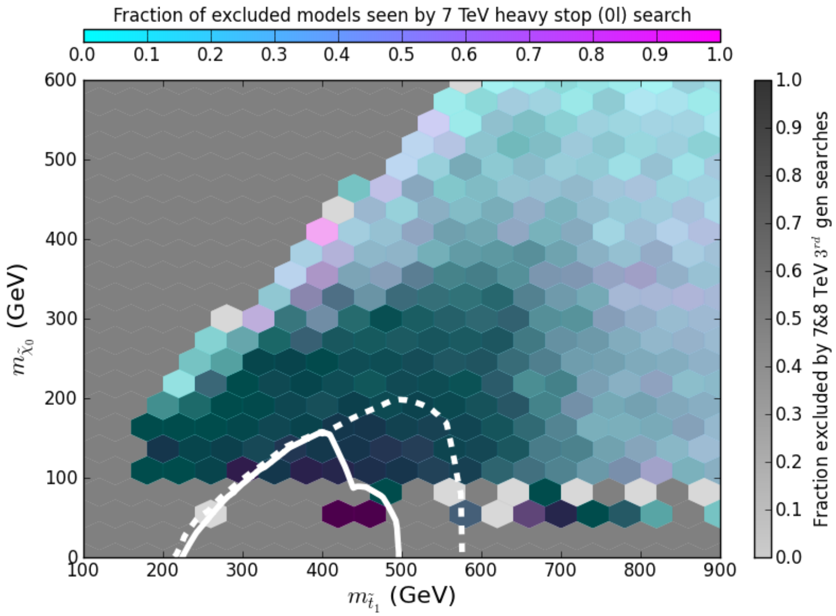


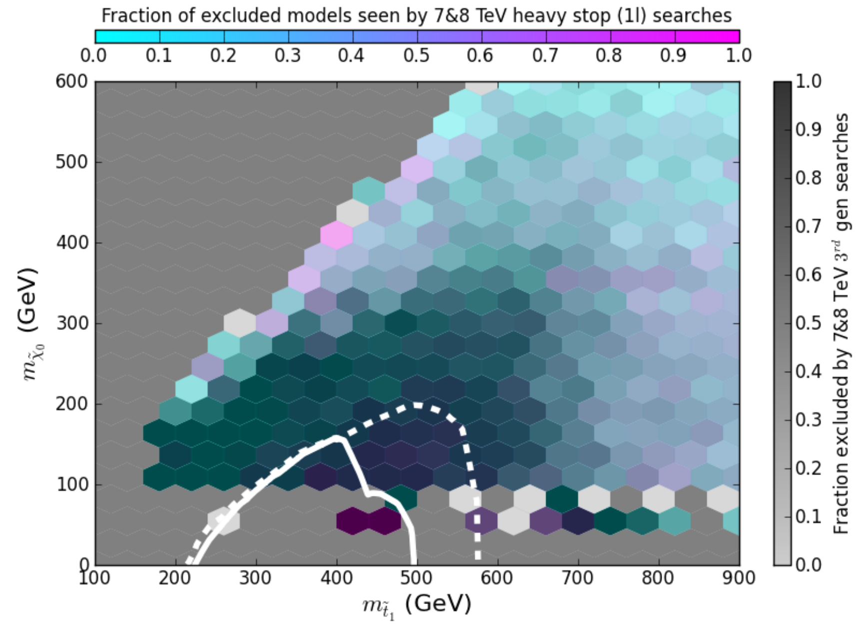
Mostly Wino
Mostly Higgsino
Mostly Bino
Number of Models
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
500
1000
1500
2000
M_{χ^0}

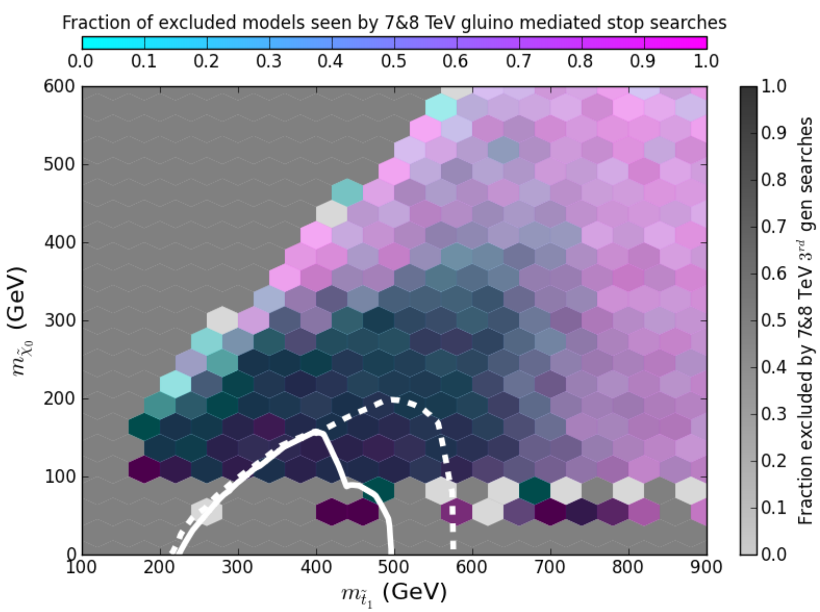


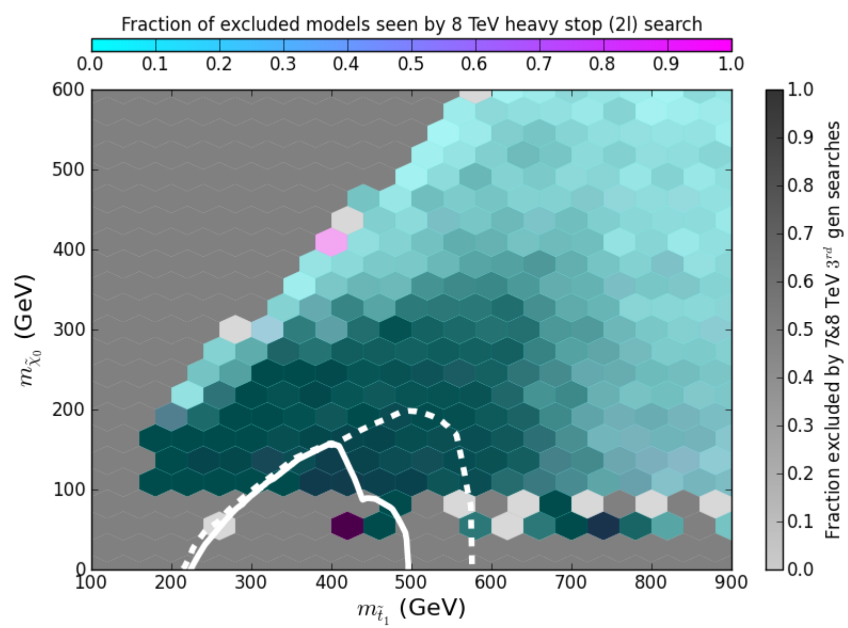
Wino
Higgsino
Bino
Number of models
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
−3.5
−3.0
−2.5
−2.0
−1.5
−1.0
$\log_{10}\Omega h^2$

Comparison of Stop Search Effectiveness

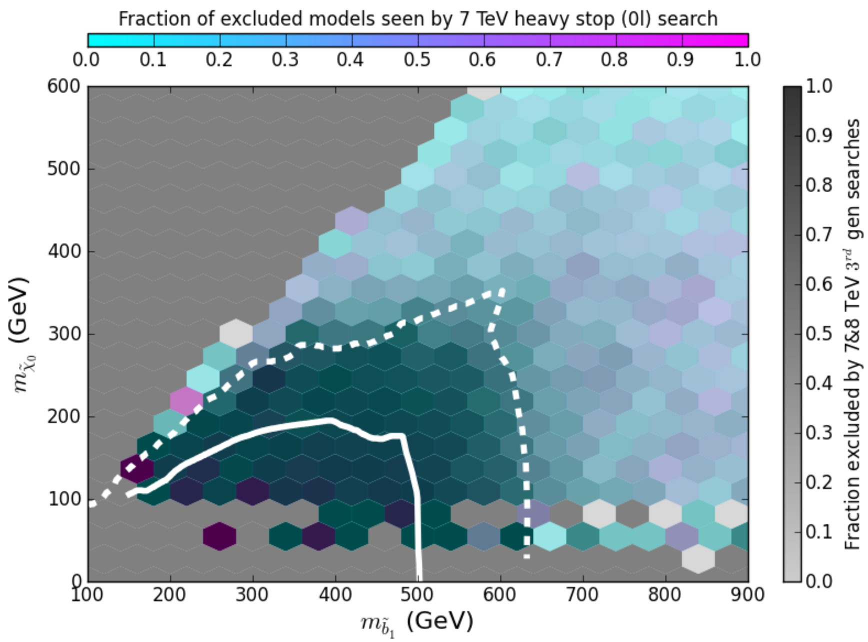


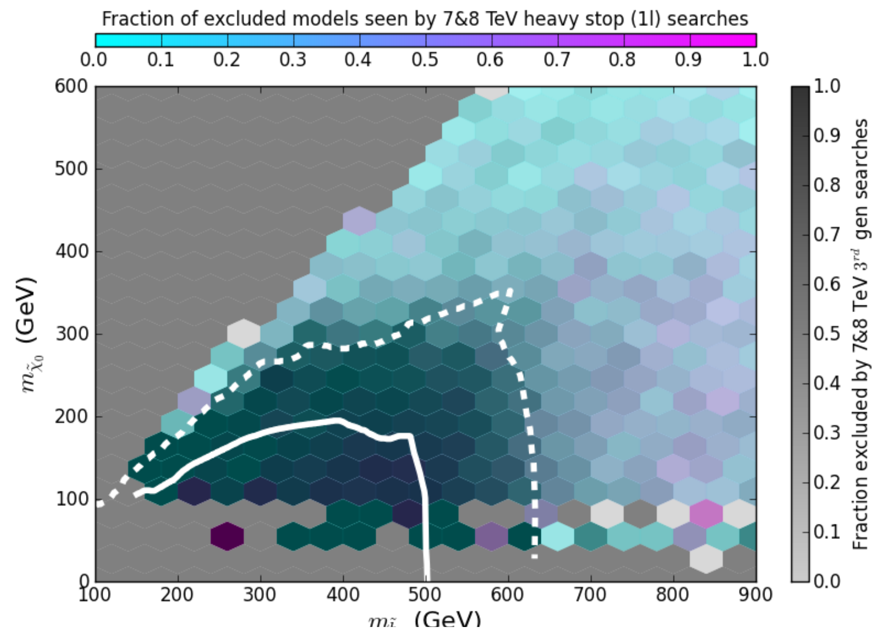


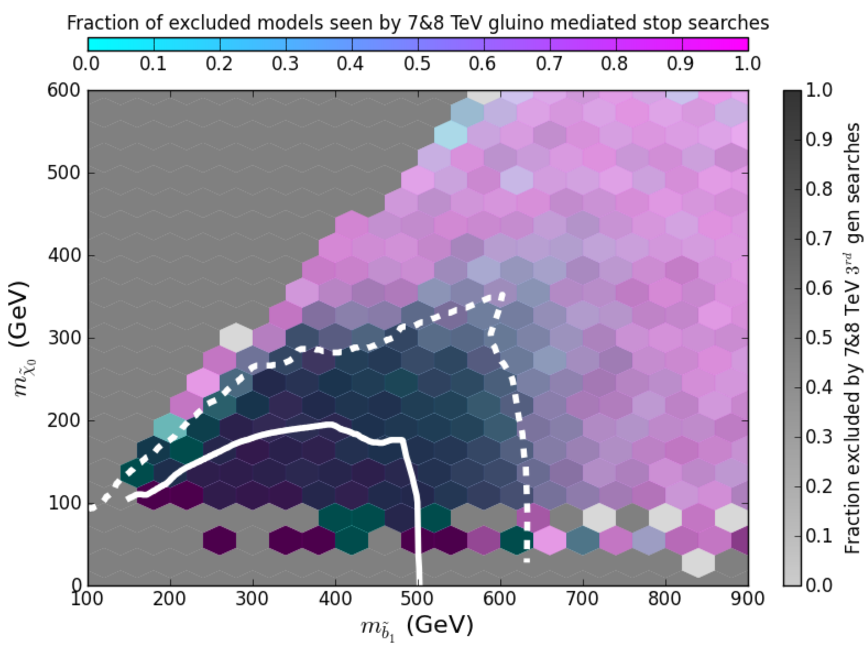


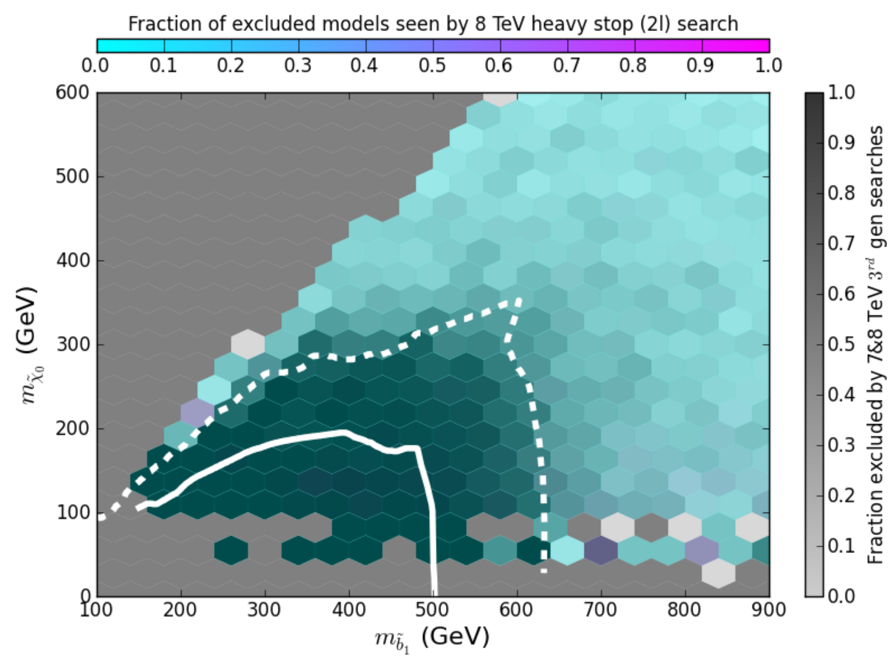


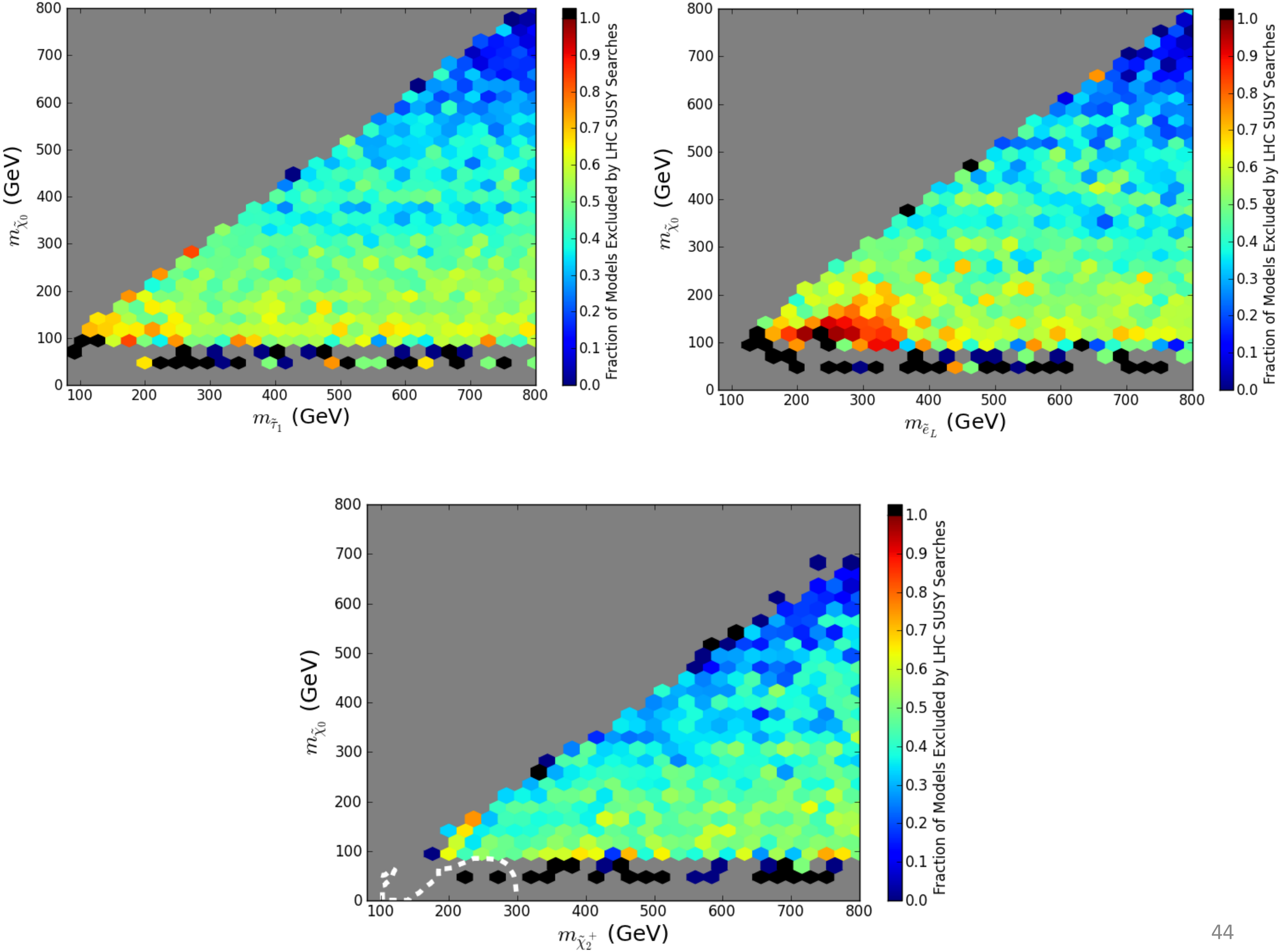
Comparison of Sbottom Search Effectiveness





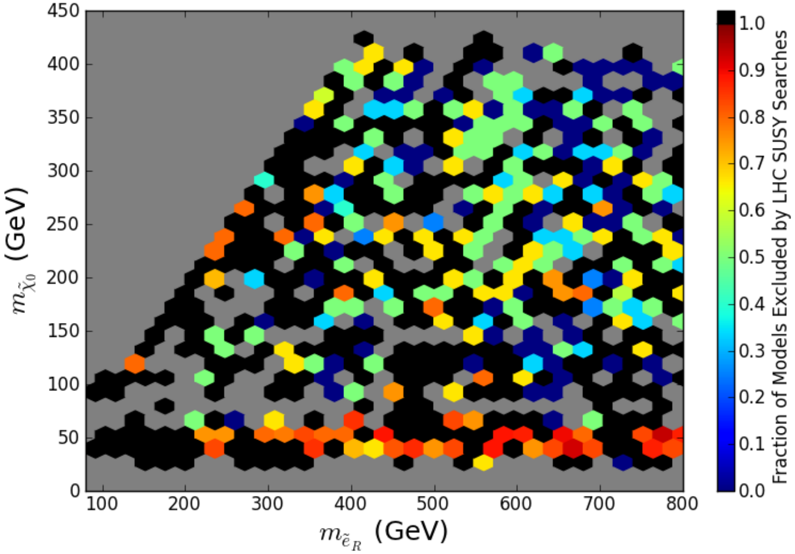


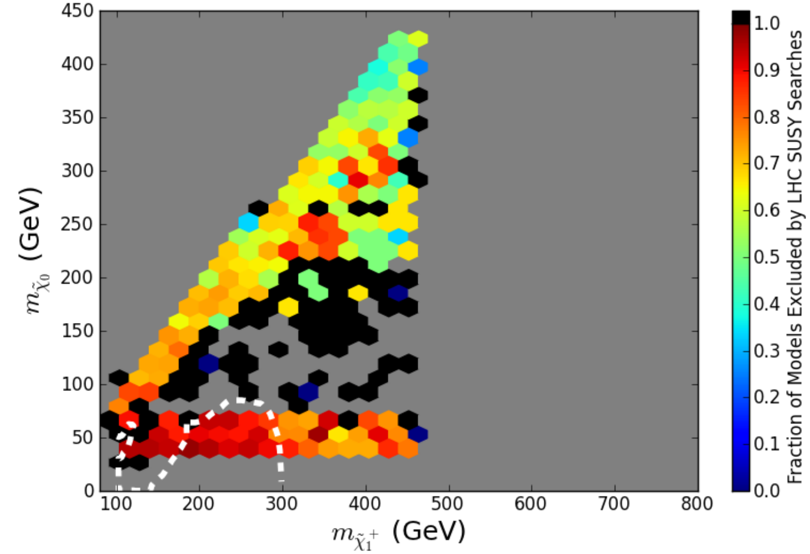


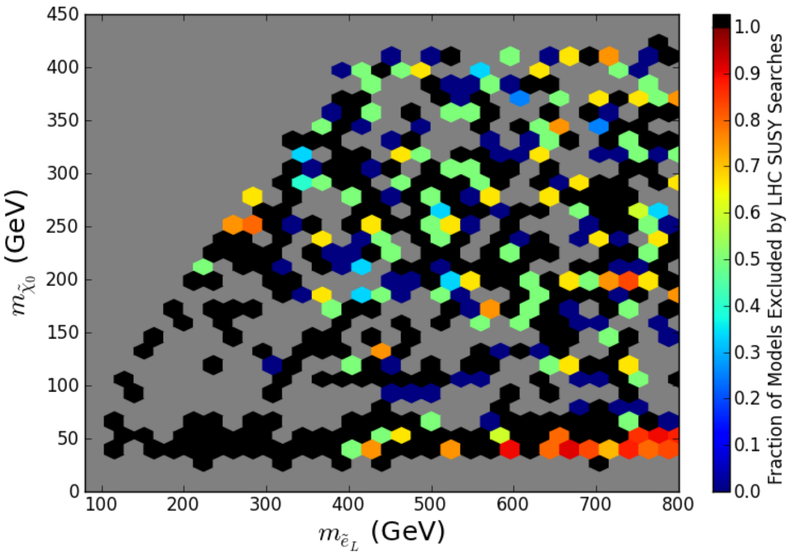


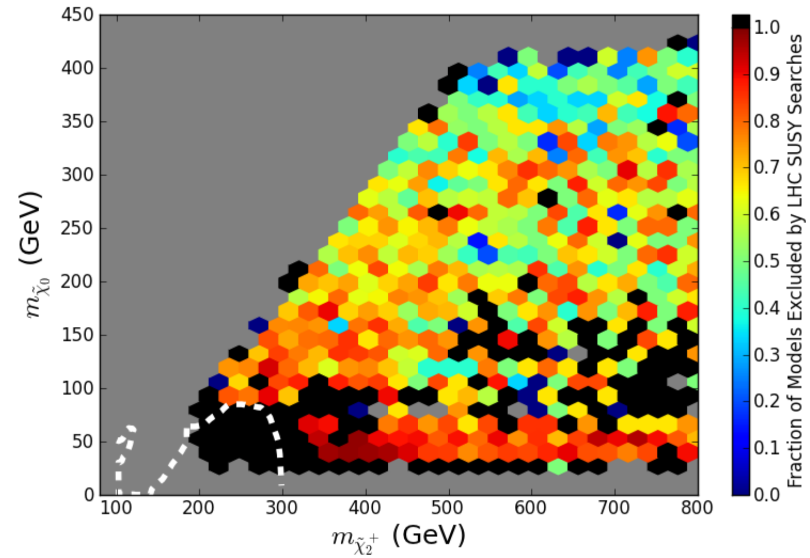
$m_{\tilde{\chi}_0}$ (GeV)
$m_{\tilde{\tau}_1}$ (GeV)
Fraction of Models Excluded by LHC SUSY Searches
$m_{\tilde{e}_L}$ (GeV)
$m_{\tilde{\chi}_2^+}$ (GeV)

More Low-FT Results

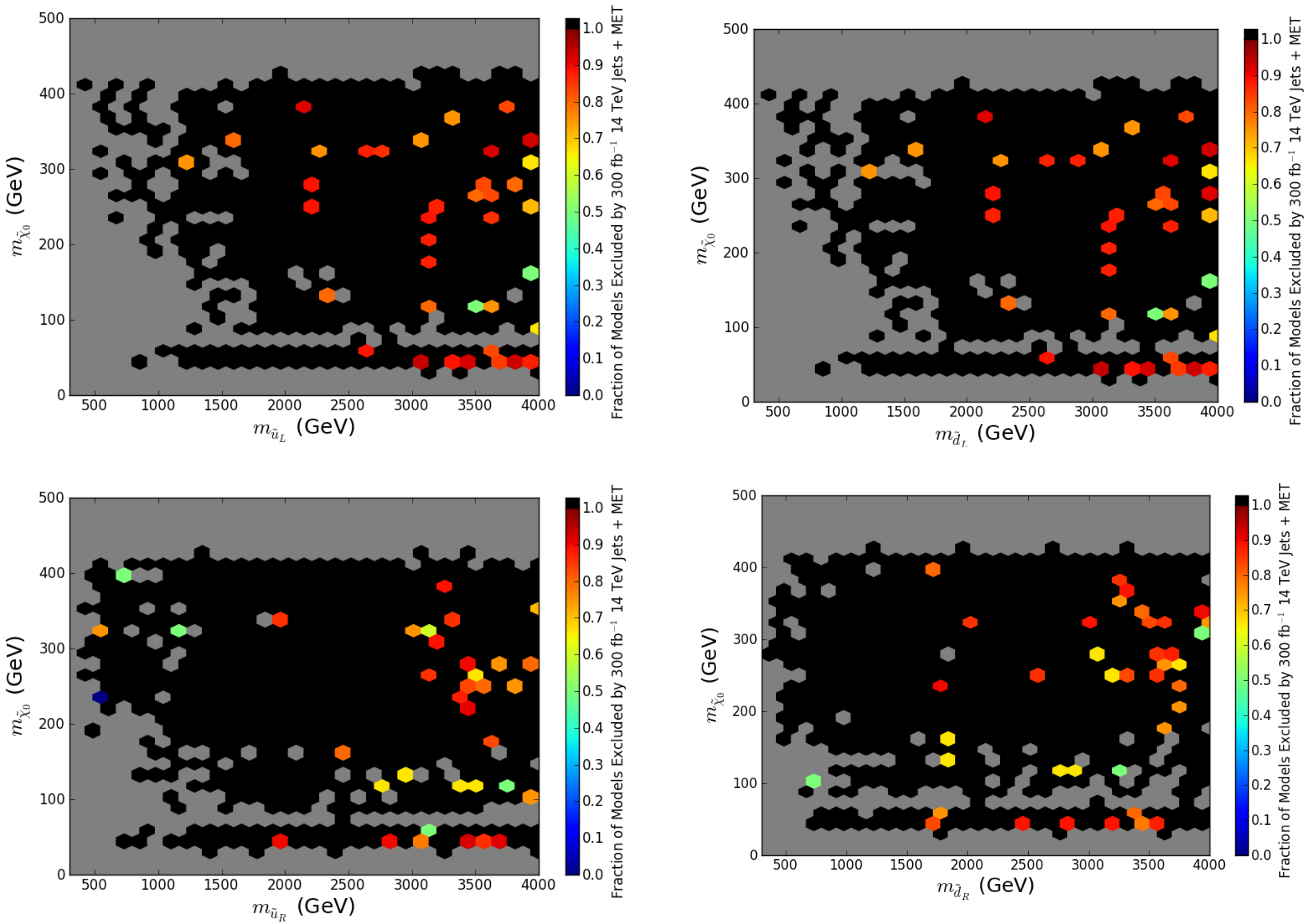




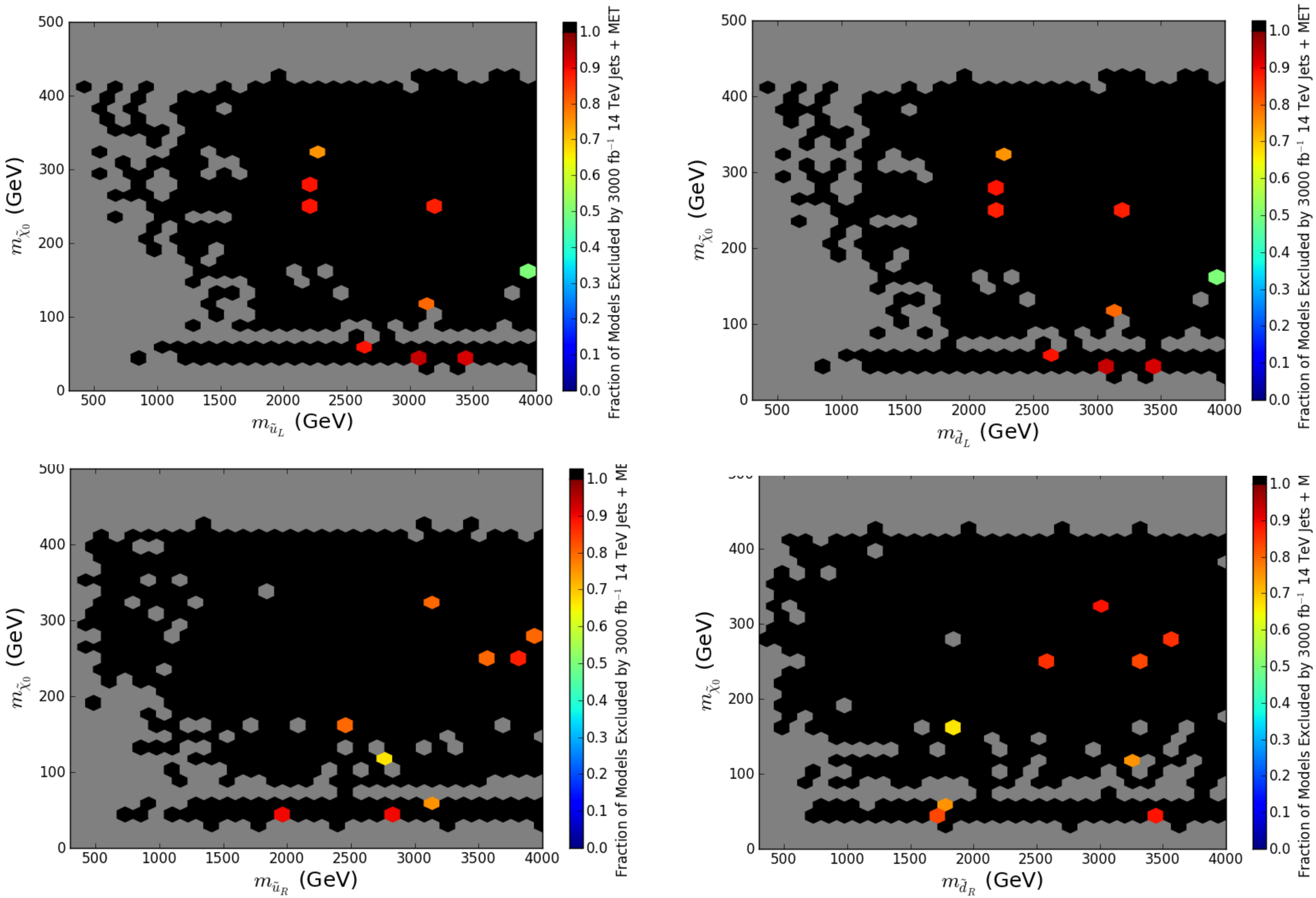




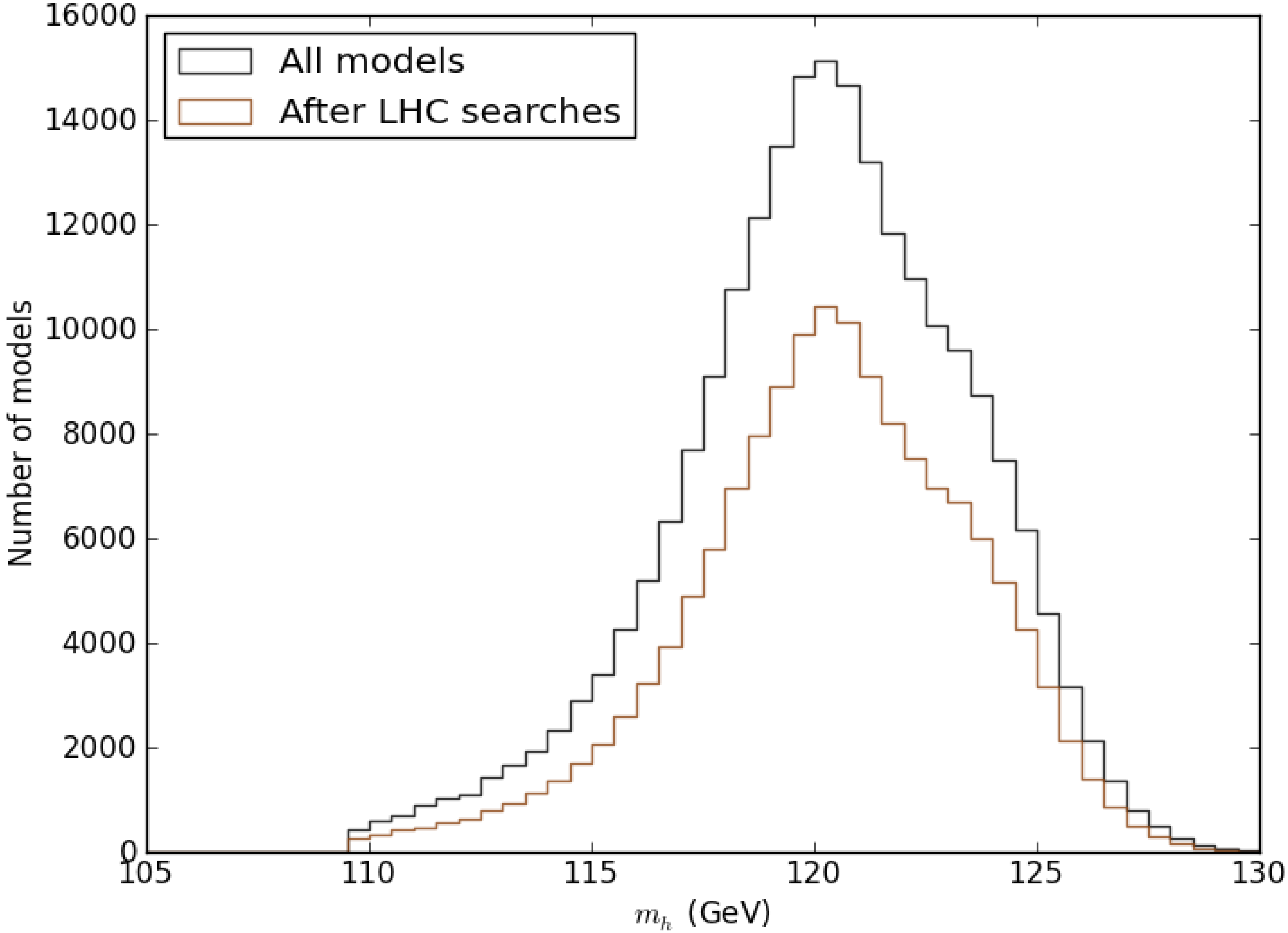
Low-FT Results @ 14 TeV



Low-FT Results @ 14 TeV (cont.)



As the SUSY searches are roughly independent of the value of the Higgs mass, the predicted mass of the Higgs is roughly independent of the SUSY searches as well !



Low Fine-tuning in the pMSSM ?

- m_h ~ 126 GeV in the MSSM requires large stop masses and/or mixings which then → significant FT expected

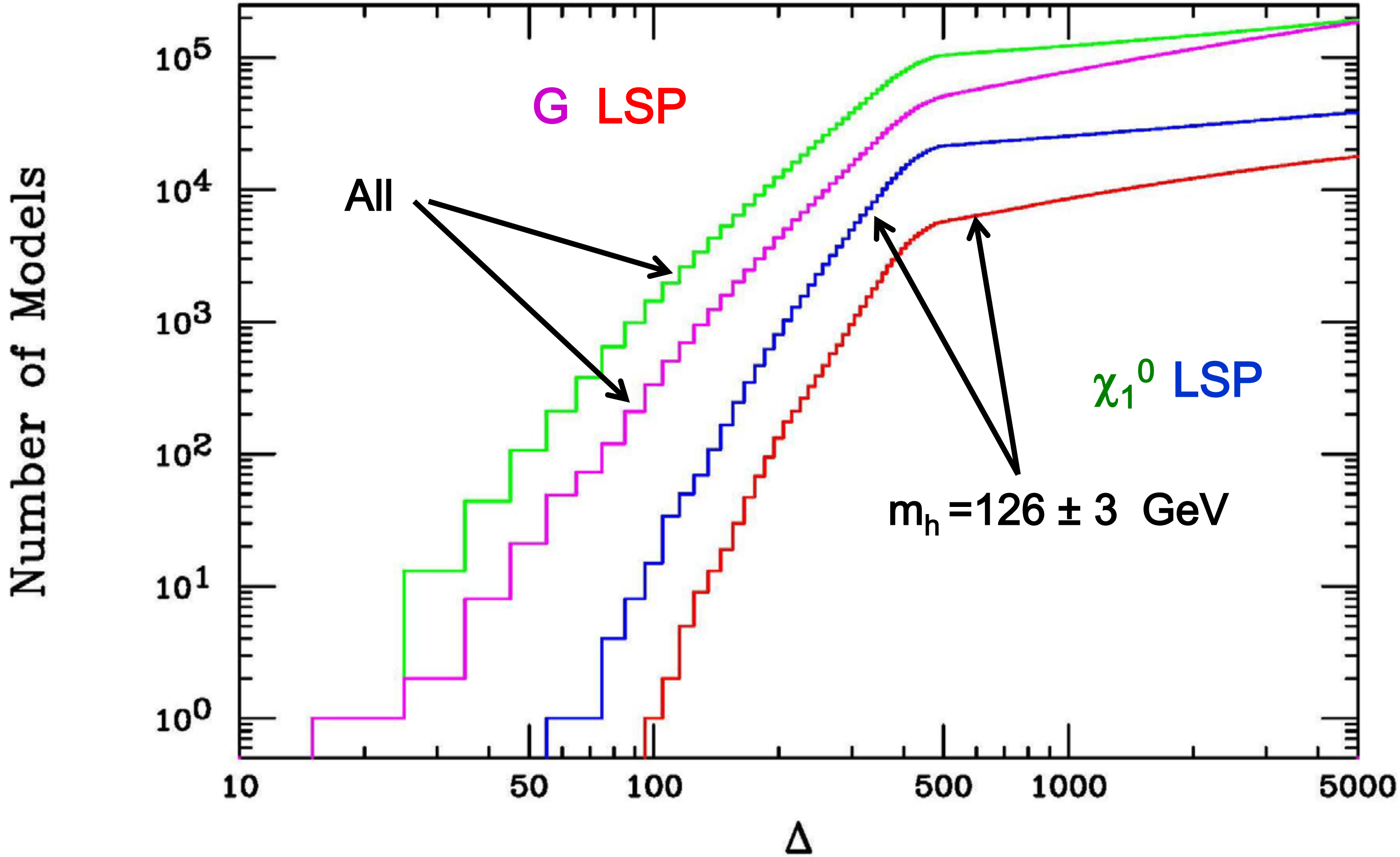
$$\frac{m_Z^2}{2} = \frac{(m_{H_d}^2 + \Sigma_d^d) - (m_{H_u}^2 + \Sigma_u^u)\tan^2\beta}{(\tan^2\beta - 1)} + \mu^2$$

- To quantify FT we ask how the value of M_Z depends upon any of the 19 parameters , { p_i }, up to (in some cases) the 2-loop, NLL level (c/o Martin & Vaughn). We follow the traditional FT analysis of Ellis et.al. & Barbieri & Giudice :

$$A_i = |\partial \ln M_Z^2 / \partial \ln p_i| , \qquad \Delta = \max \{A_i\}$$

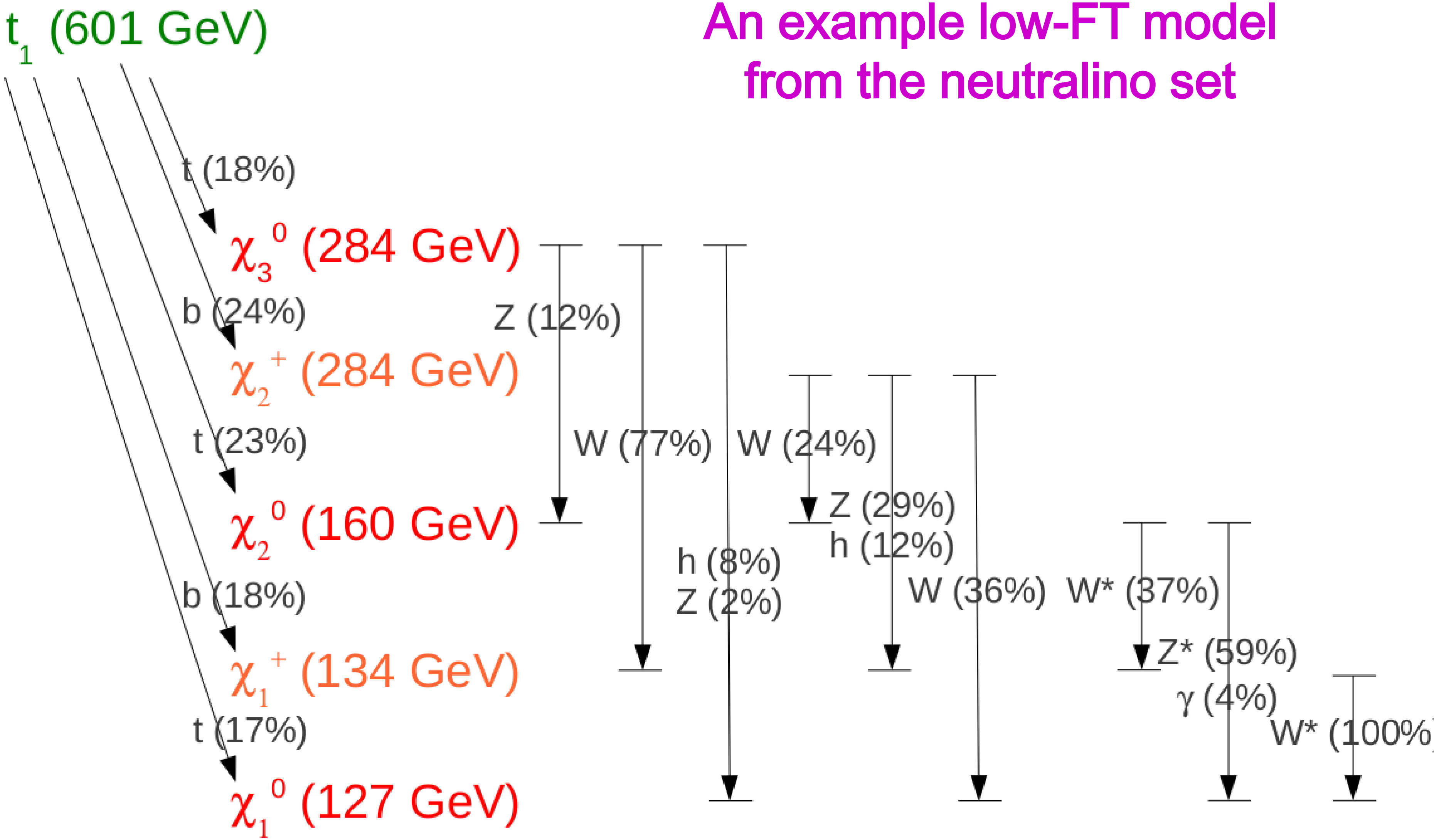
- How many models have Δ less than a specific value ?

Fine-tuning in the pMSSM



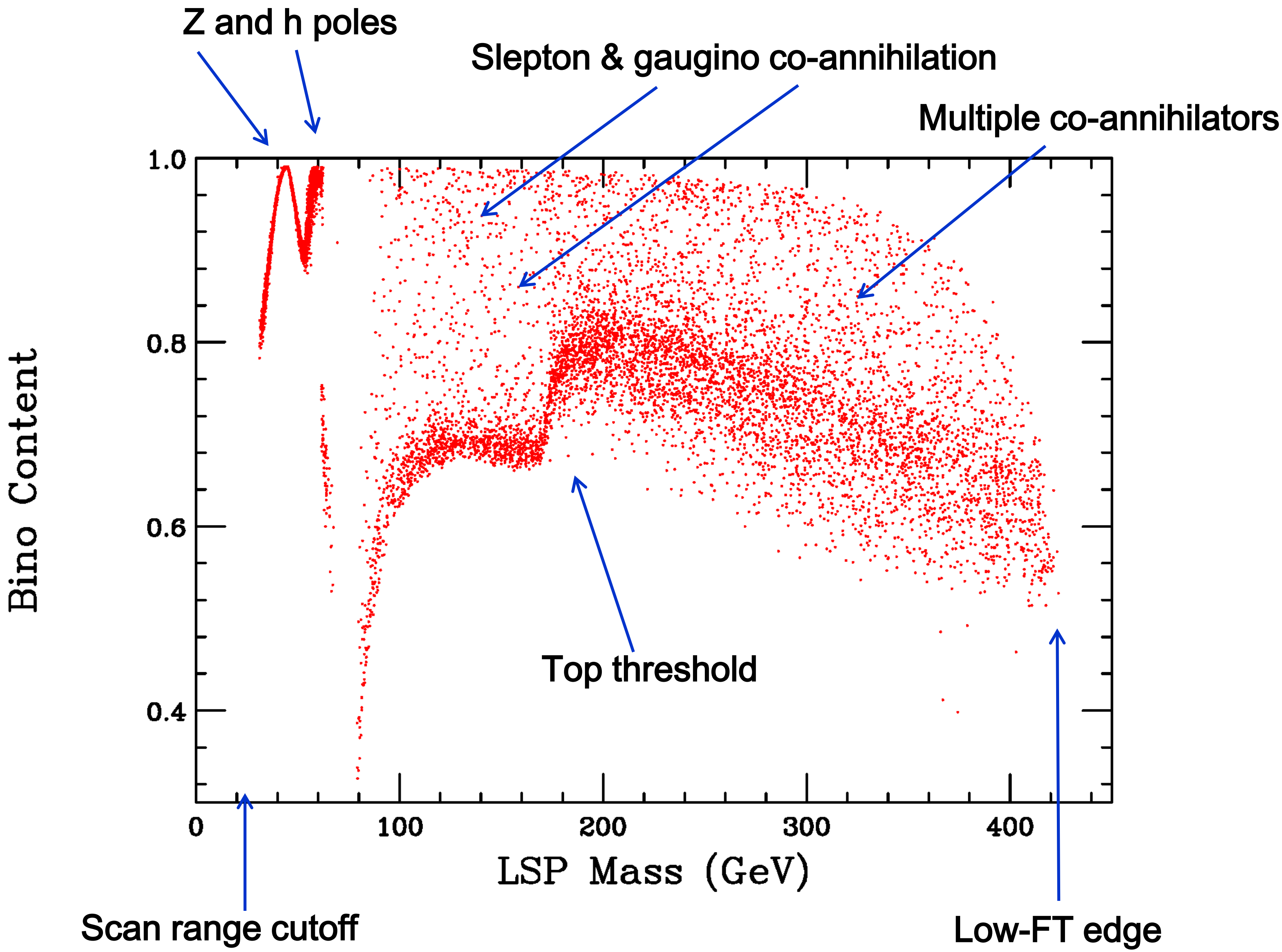
• As expected, the large Higgs mass 'cut' removes most of the models with the lowest FT values

An example low-FT model from the neutralino set

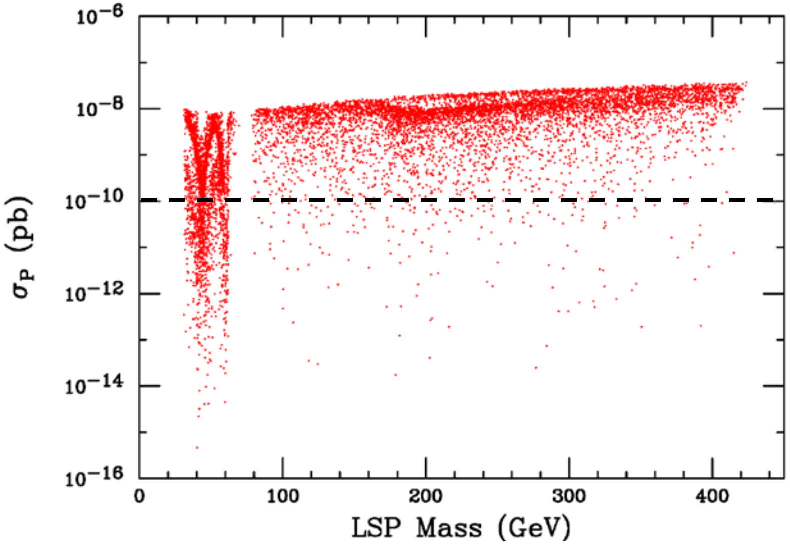


Lessons Learned

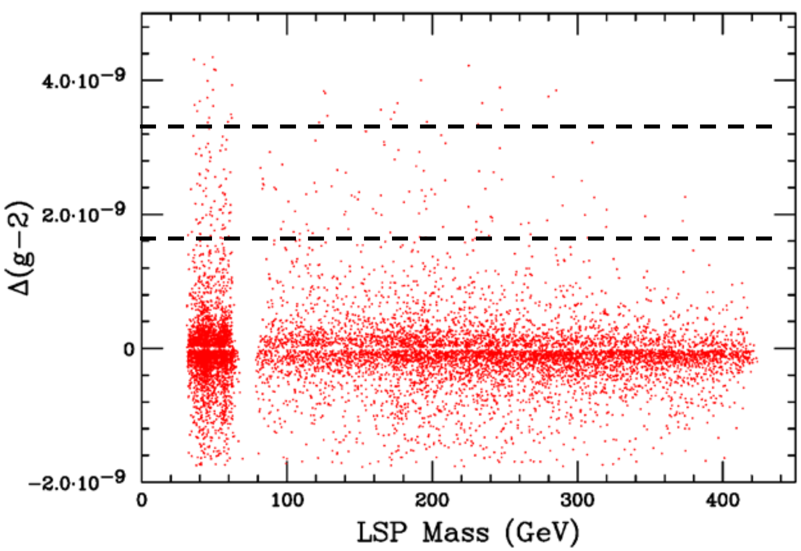
- Completely random scans are seen to produce few models with low FT values
- Furthermore, as expected, the large Higgs mass 'cut' is seen to remove most of the models with the lowest FT values
- The spectra of these low-FT models can make them difficult to see w/ any one existing search
- This is an important class of models. It is certainly worth performing dedicated scans to produce sets of low-FT models under various physics assumptions so that they can be studied in detail.



Z and h poles
Slepton & gaugino co-annihilation
Multiple co-annihilators
Top threshold
Scan range cutoff
Low-FT edge
Bino Content
LSP Mass (GeV)
1.0
0.8
0.6
0.4
0
100
200
300
400



- SI direct detection cross sections for these models, since the LSP is mostly well-tempered, almost all lie within ~100 below the present limits & will be found (or not) by XENON-1T



- Δ(g-2) of the muon CAN be large for some of these models if there are also light sleptons which do appear in some cases to get DM co-annihilation to work

pMSSM Low-FT Neutralino LSP Model Set

$\rightarrow\rightarrow$ Can we get models with the 'right' Higgs mass plus 'low'-FT & the 'right' relic density in the pMSSM ??

- Generate a low-FT set by adjusting the scan ranges of the more sensitive parameters (μ, A_t , m_{Q3} , m_{u3} , M_3 , $M_{1,2}$, etc.) such that the models already have low-FT < 100 & likely 'near correct' relic density: ~3.3 x 10^8 was 'sufficient'
- Impose an updated set of the usual flavor, precision, DD/ID, non-MET LHC, LEP, Tevatron & m_h constraints
- Impose WMAP/Planck relic density $\pm 5\sigma$ $\rightarrow$ ~10.2k models

Pre-LHC MET analyses, what do these models look like?

Some Numbers (again, pre-LHC MET Analyses !)

- ~1.4% of models have stop/sbottom BELOW the Higgsinos & winos. These are likely already excluded by the direct searches if sufficiently light unless compression occurs

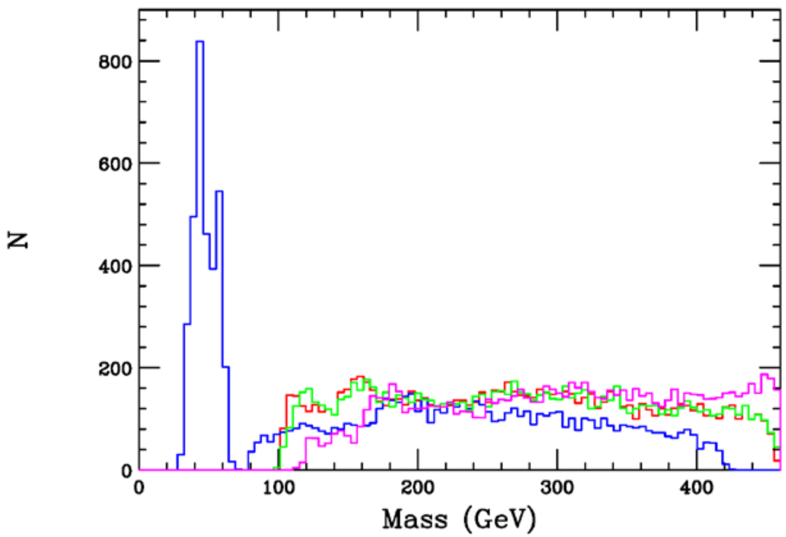
- ~59.5% of models have all gauginos & Higgsinos below the lightest stop/sbottom. ~16.4% of models have the winos lighter than the Higgsinos.

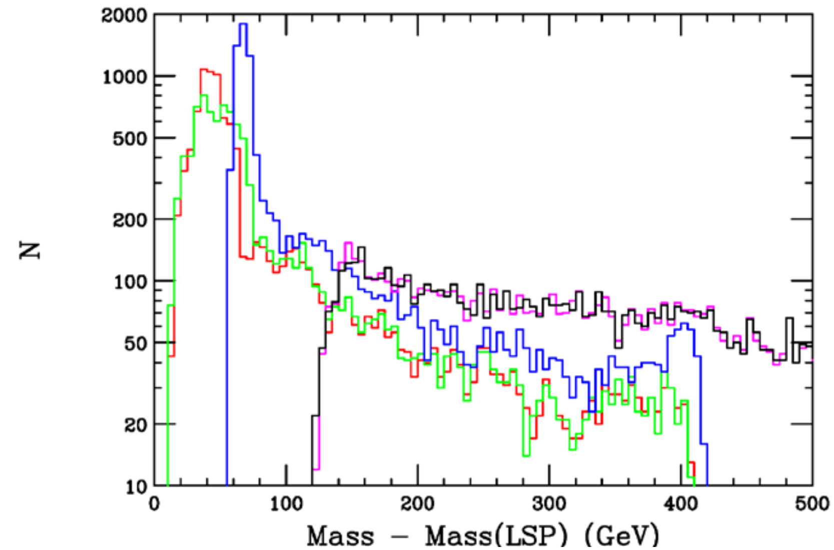
- ~11.0% of models have a sbottom lighter than the stop

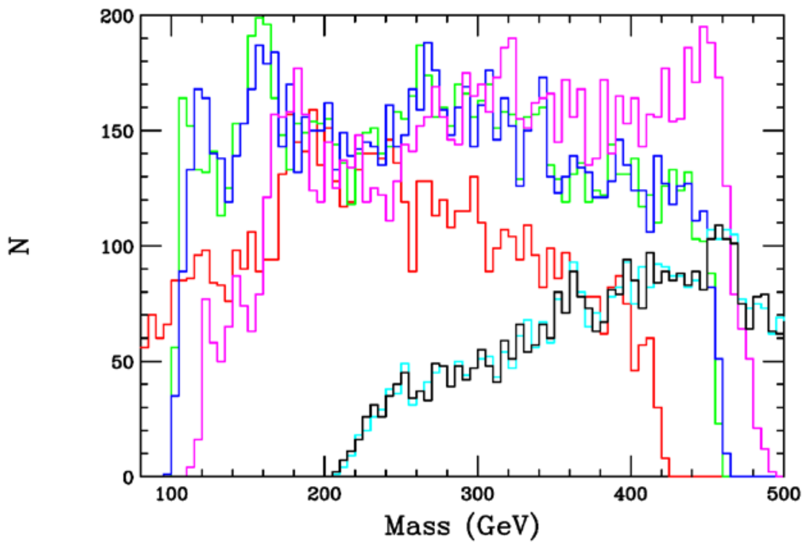
- ~30% of models have a light slepton of some kind below the stop/sbottom; it's most likely a mixed stau.

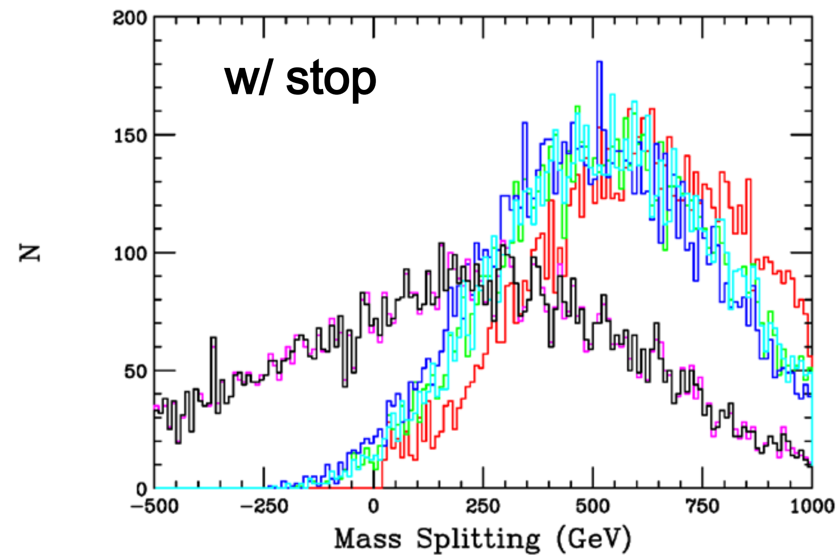
- ~15% of models have light squarks/gluinos below the stop or sbottom & so are likely excluded except for compression

Low-FT Model Gaugino Mass Spectra & Splittings



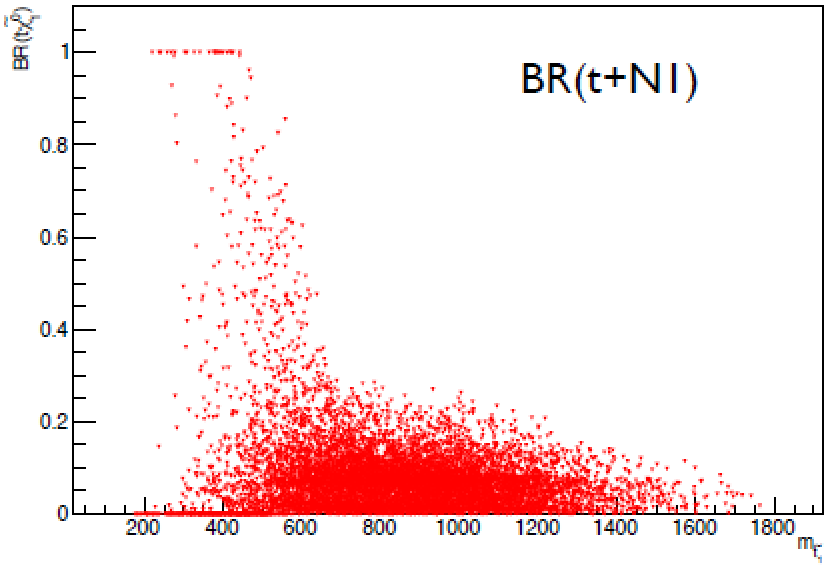


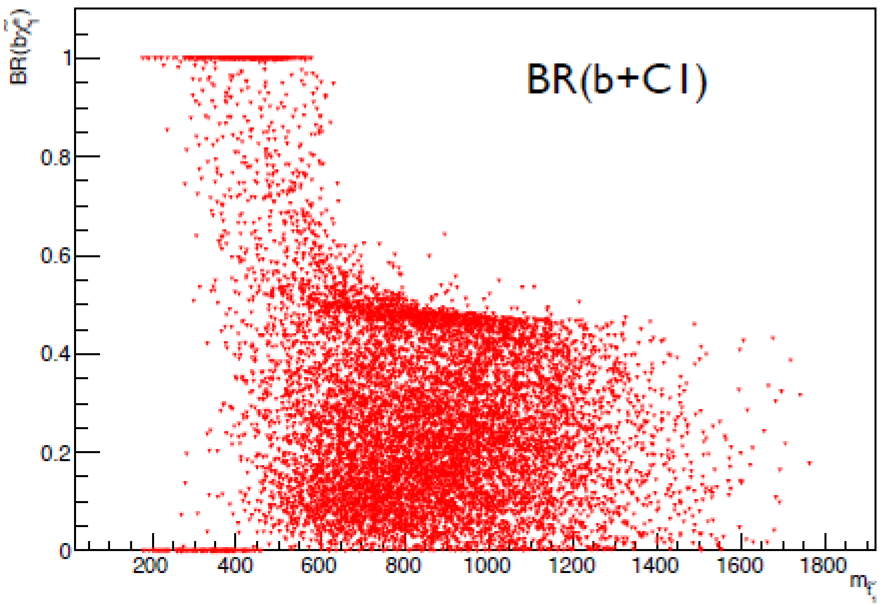


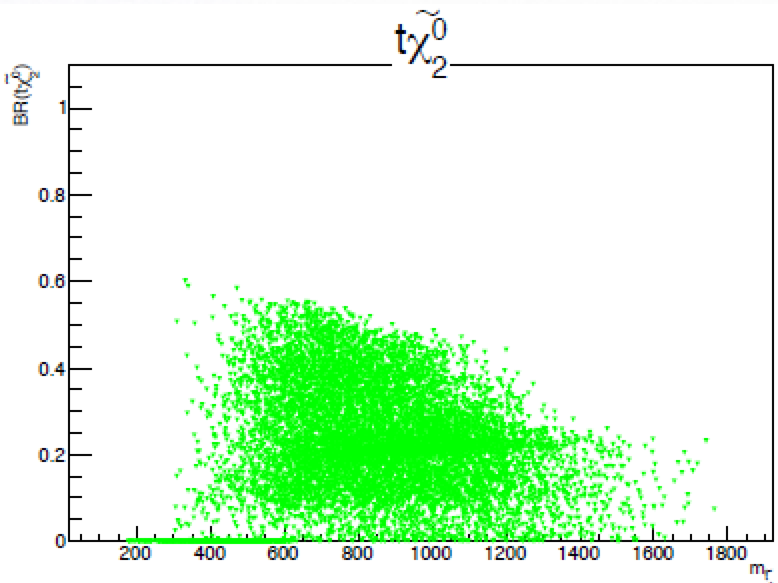


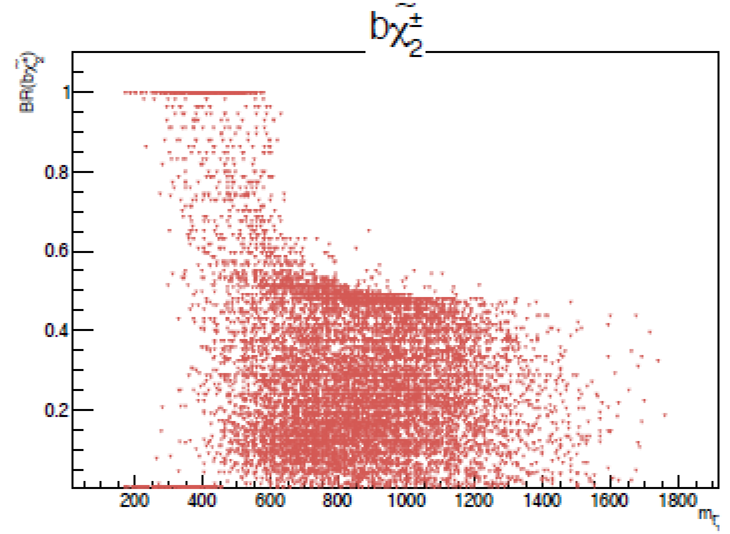
Phenomenological MSSM c/o ATLAS

BR VS stop mass



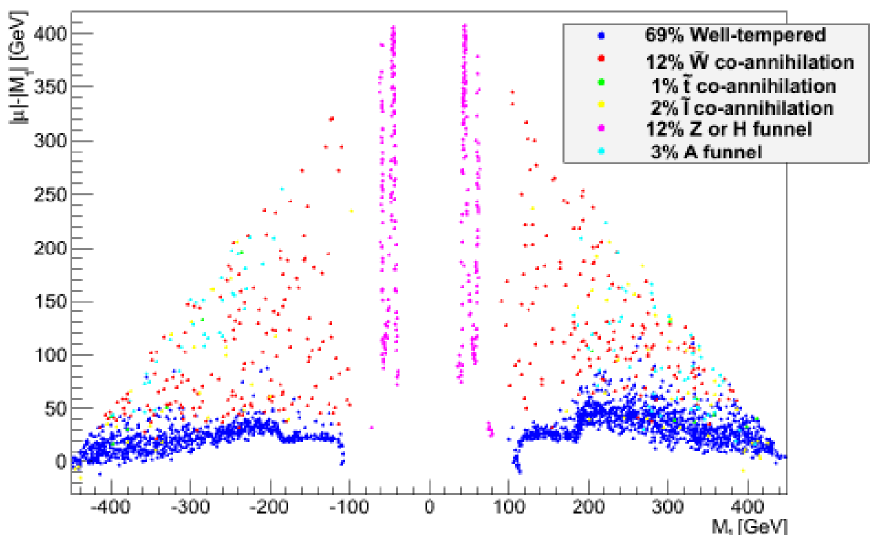




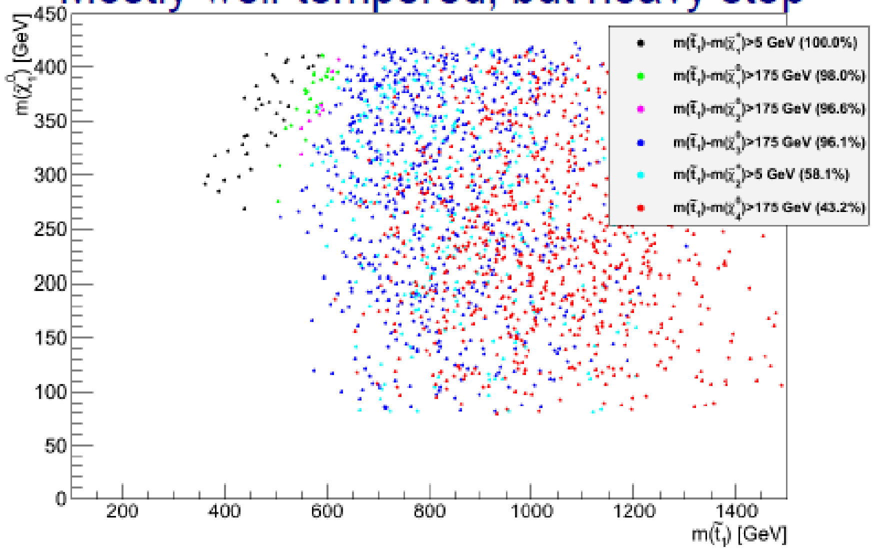


Models allowed or excluded by LHC

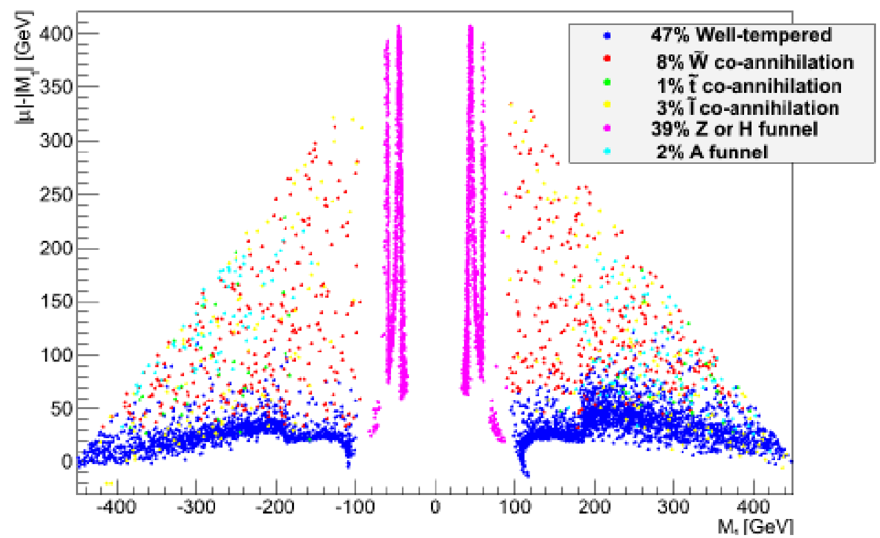
Allowed by LHC from SLAC emulation

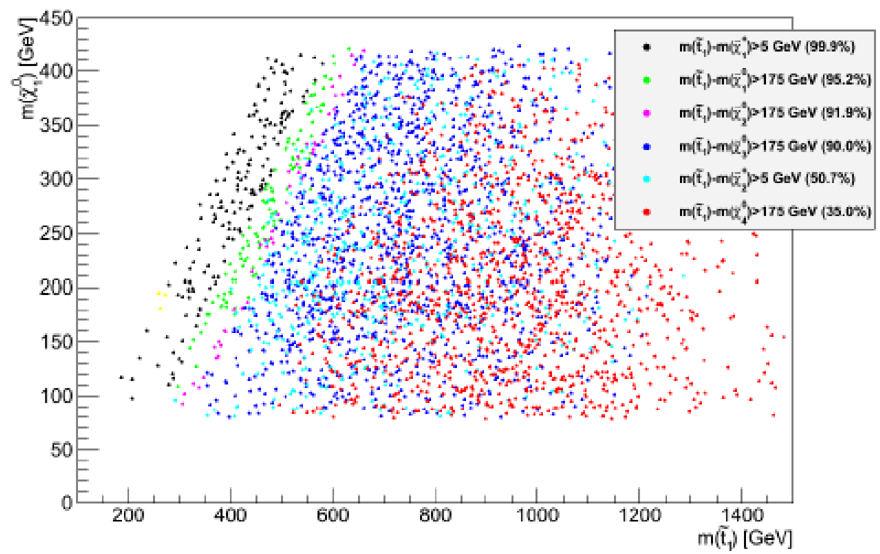


Mostly well-tempered, but heavy stop



Excluded by LHC from SLAC emulation





“Bino” ≡ $|N_{11}|^2 > .9$

- Significant Higgsino component in DM, since μ ≤ 450 GeV
- 172 models survive current collider limits and projected Xenon 1T limits