SUPERSYMMETRY WITH A SISTER HIGGS

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126

One number - but it tells us a lot!

THE PROBLEM OF THE HIGGS IN SUPERSYMMETRY

$$m_h^2 < m_Z^2 \cos^2 2\beta$$

$$+ \frac{3}{4\pi^2} \sin^2\beta\, y_t^2\, m_t^2 \log\left(\frac{m_{\tilde{t}}^2}{m_t^2}\right) + \text{A-terms}$$

stupid Higgs! Why can't you be 126 GeV?

THE QUARTIC PROBLEM

$$V(h) = -m_h^2 h^2 + \lambda h^4$$

$$v^2 \sim \frac{m_h^2}{\lambda} \curvearrowright m_h^2 \sim \lambda v^2$$

need a large quartic!

THE QUARTIC PROBLEM

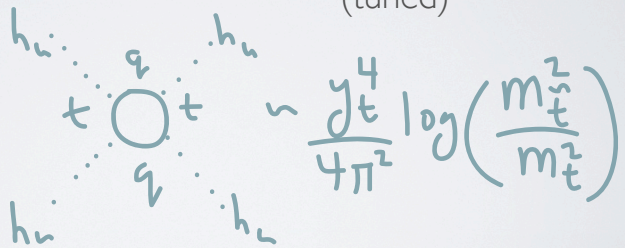
In the MSSM

hence the problem
So what are our options?

THE QUARTIC PROBLEM

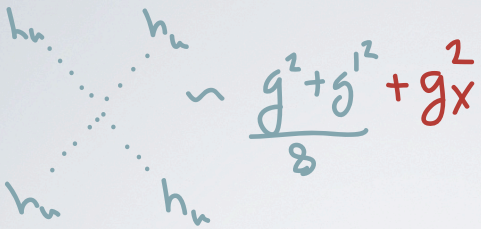
Stop loops correct this!

Con: requires very heavy stops (tuned)



Pro: very heavy SUSY consistent with data!

THE QUARTIC PROBLEM



Non decoupling D-term: involves charging Higgs under new groups

Pro: Heavy Higgs!

Con: If Higgs is charged, other things are charged. We've studied those things!
(e.g. the matter of the universe)
(Complicated, sometimes tuned)

THE NMSSM

$W = \lambda S H_u H_d$

$\Rightarrow V \sim \lambda^2 |h_u h_d|^2$

Great! Gives a quartic! What's the problem?

THE NMSSM

D-term

$\frac{g^2+g'^2}{8}(h_u^2-h_d^2)^2$

$\tan\beta \gg 1$

(i.e., h is mostly h_u)

NMSSM

$V \sim \lambda^2 |h_u h_d|^2$

$\tan\beta \sim 1$

(i.e., h is a mixture of h_u and h_d)

THE NMSSM

$$W = \lambda S H_u H_d$$

A complete standard model singlet?

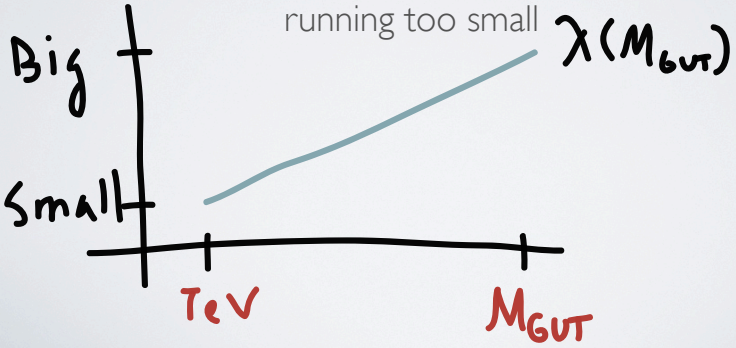
tadpoles? domain walls?

THE NMSSM

$W = \lambda S H_u H_d$

Yukawa couplings run weak at low energies

But gauge interactions keep it from running too small



THE NMSSM

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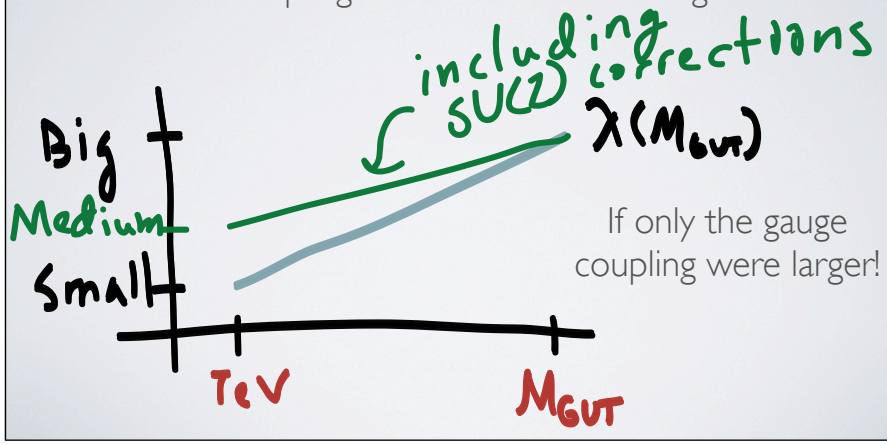
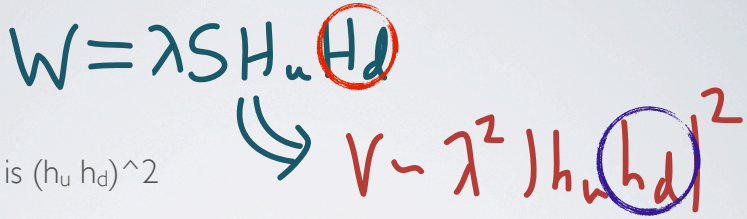


If only the gauge coupling were larger!

REEXAMINING NMSSM

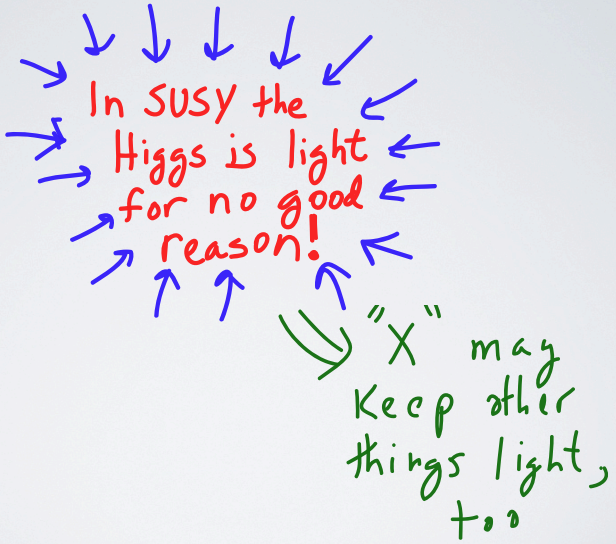


- quartic is $(h_u\ h_d)^2$
- must be at small tan beta
  => h_d has no large couplings
- why are we trying to identify that thing with h_d ?
  => because it's there
- Why not think of it as something totally different?

A SISTER HIGGS

- proposal: h_d is not h_d, it is something else
- ie S H_u Σ_d
- Σ_d has no direct couplings to any fermions,
- "sister Higgs": Higgs that participates in EWSB but without tree level renormalizable couplings to SM fermions

WHY A SISTER HIGGS?



How would you know it was there?

- You could be made out of it ⇒ check
- It could be light enough to produce ⇒ chiral matter
- It could be "there" there ⇒ DM
- It could break a meaningful symmetry ⇒ Higgs

Everything else is precision

- Absent anthropic arguments, the presence of the Higgs motivates extra "stuff"
- Broad categories of things may not have been found yet
- **I will embrace this "non-minimality"**

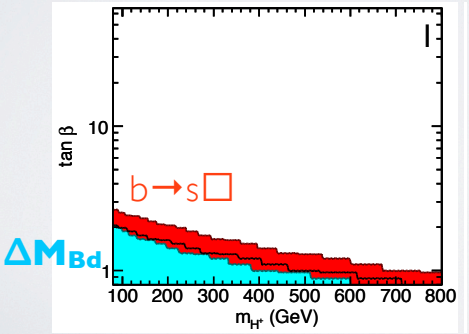
$S H_u H_d \Rightarrow \phi H_u \Sigma_d$

	ϕ	$\bar{\phi}$	H_u	H_d	Σ_u	Σ_d
$U(1)_Y$	0	0	$\frac{1}{2}$	$-\frac{1}{2}$	$\frac{1}{2}$	$-\frac{1}{2}$
$SU(2)_W$	1	1	2	2	2	2
G_s	R	$\bar{R}$	1	1	R	$\bar{R}$

For Completeness...

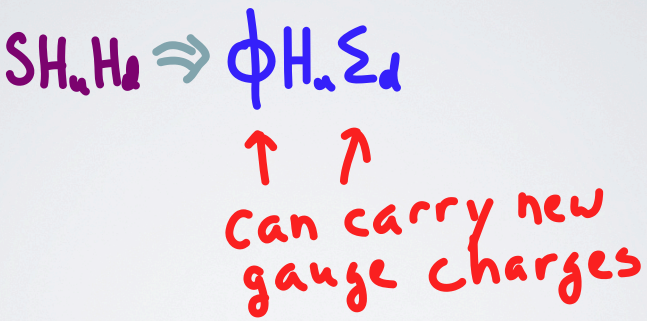
THE HIGGS YOU ALWAYS WANTED IT TO BE

- no new sources of FCNCs (couplings to fermions through mixing only)
- can be light (ie charged Higgs small contribution to bs gamma)

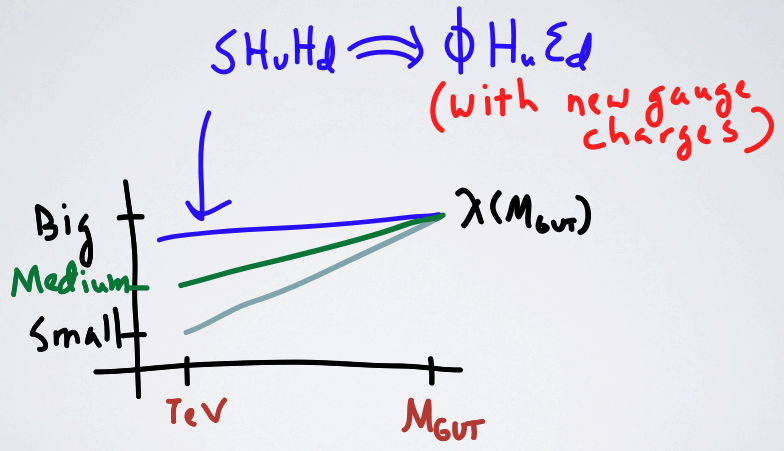


Type I 2HDM
Mahmoudi+Stal 0907.1791

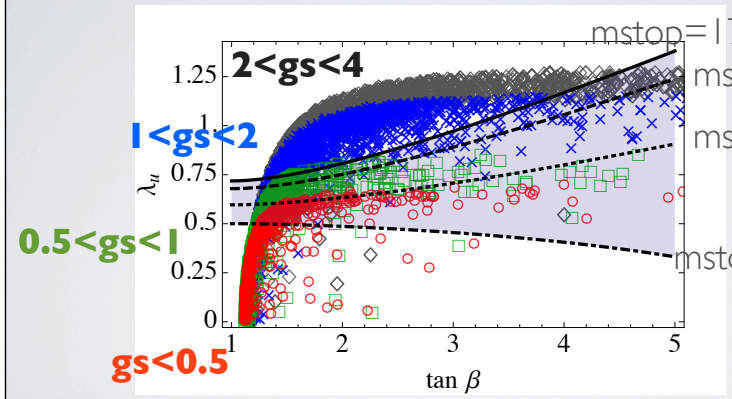
WHY A SISTER HIGGS



WHY A SISTER HIGGS



THE HIGGS MASS WITH A SISTER



MORE THAN A MODULE?

- Great, so we should feel ok about a 126 GeV Higgs in SUSY. What else?

PHENOMENOLOGY

- Z-primes
- RPV opportunities
- New colored states

LIGHT Z-PRIMES

Couples through mixing

$$\begin{pmatrix} m_{Z'}^2 & g g_s v^2 \cos^2\beta \\ g g_s v^2 \cos^2\beta & m_Z^2 \end{pmatrix}$$

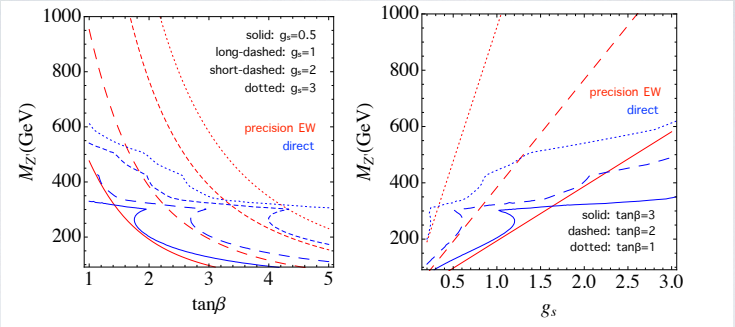
A sequential Z' is natural in this context

similar to "Higgsophilic Z'"

but without generating down-type masses

Fan, Krohn, Langacker, Yavin '11

LIGHT Z-PRIMES



A sequential Z' is natural in this context

R-PARITY VIOLATION WITH A SISTER

LLE UDD LH

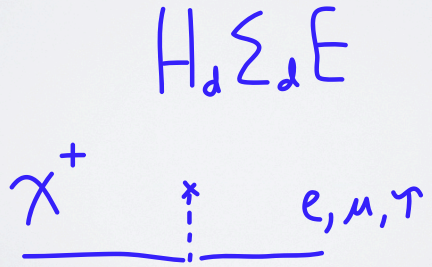
QLD $H_D^1 H_D^2 E$

↑ vanishes identically in MSSM

with a sister - doesn't vanish!

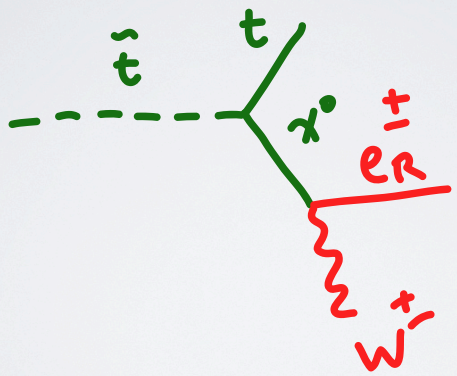
SHRPV PHENO

- No neutrino mass at tree level
- mu-> e gamma suppressed (right handed only)
- Dominant effect is chargino-lepton mixing



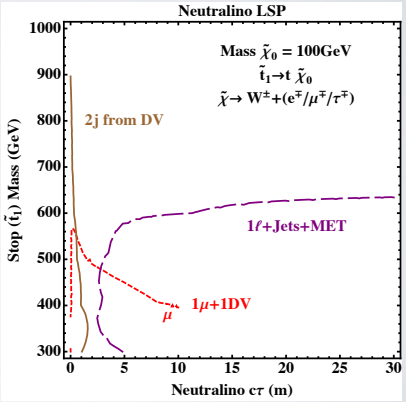
SHRPV PHENO

- Charged lepton (or tau) *always* in final state



DISPLACED LEPTONS WITH A SISTER HIGGS

- SUSY searches w/ leptons generally employ quality cuts
  (see Graham et al 1204.6038)
- If leptons are displaced, generally fail -> limits come from displaced searches



G-QUARKS

A "why now?" problem

g_s must be strongish at low energy

But why is the coupling strong near M_W?

G-QUARKS

Solution: make it conformal (strongish everywhere)

For G_s=SU(2), need 3 $2+\bar{2}$ fields => identify with color

Naturally unified multiplets with G_s-charged quarks

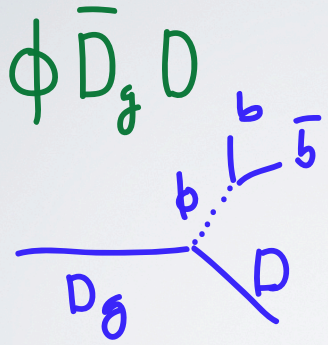
G-QUARKS

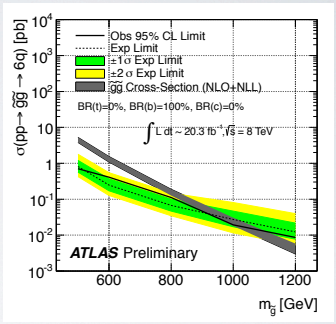
$$\begin{pmatrix} d_g \\ \Sigma_d \end{pmatrix}$$

$B_3 = 0$

(with G-quarks)

G-QUARKS





(b) (BR(t), BR(b), BR(c))=(0%,100%,0%)

Decay not like usual 4th gen but more like RPV gluino

Need recast of gluino searches - in progress

THE SIMPLICITY OF COMPLEXITY

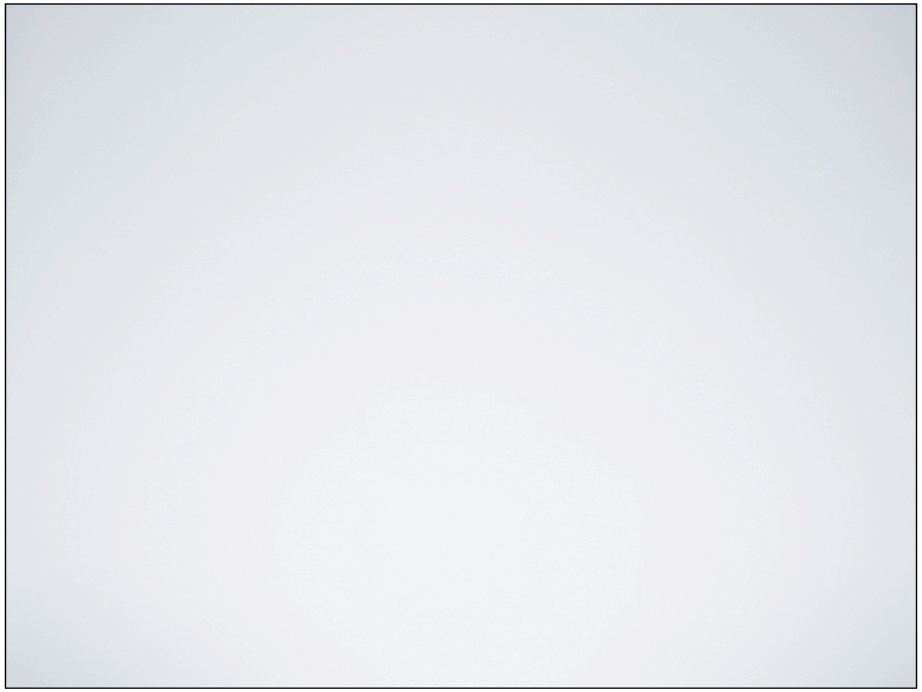
- Why not more stuff?

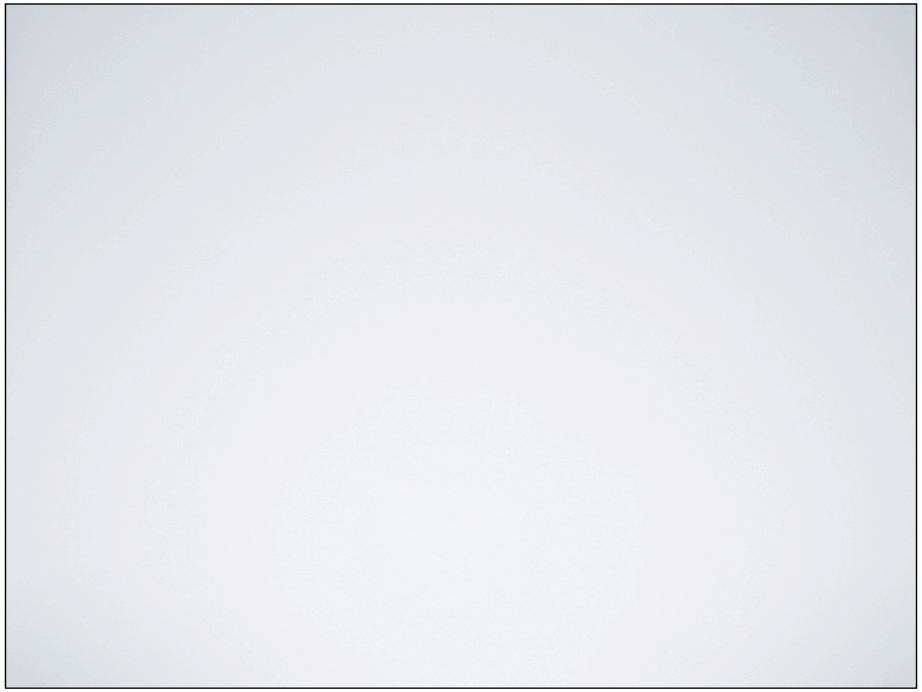
SUSY WITH A SISTER HIGGS

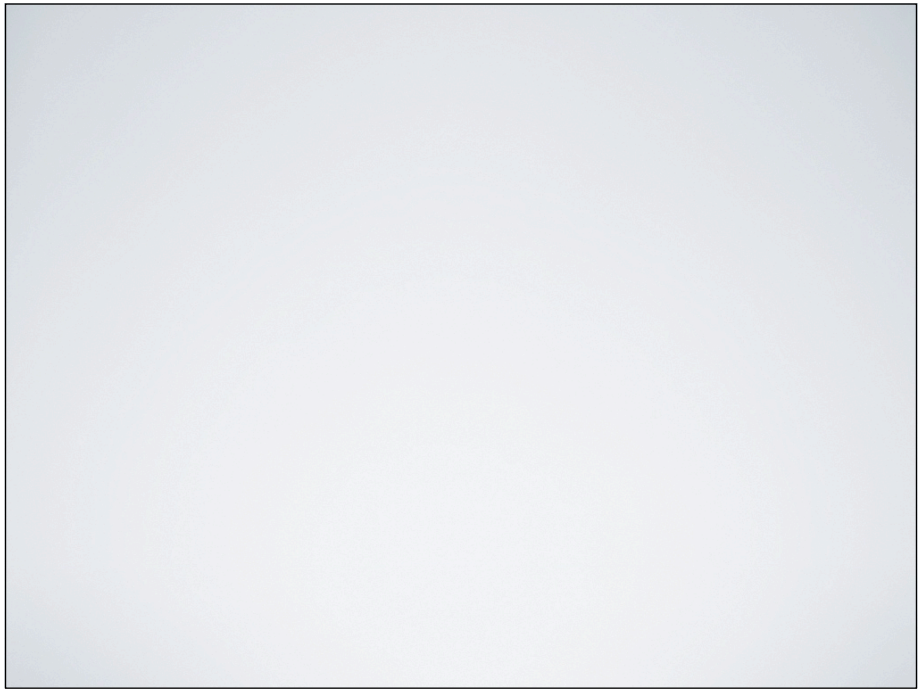
- The Higgs in SUSY is perplexing
- If there is a "reason" why it's light, likely other things around
- Simple addition: a Sister Higgs (Higgs with no renormalizable tree level couplings to SM fermions)
- If charged, Higgs mass can be "natural"

SUSY WITH A SISTER HIGGS

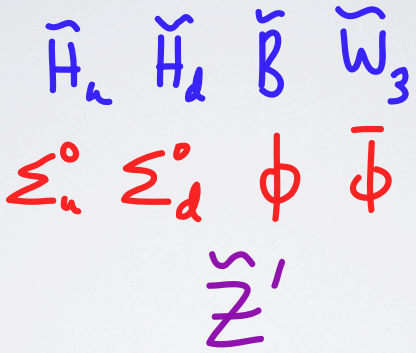
- But also comes with new phenomenology
- Old phenomenology more motivated:
  - sequential Z', extended Higgs sectors (pseudo-Type I)
- New phenomenology:
  - SHRPV - displaced leptons may hide SUSY
  - G-quarks - 4th gen that decay to tri-jets w/sub-resonances
- 126 may be the first clue of a lot more to come



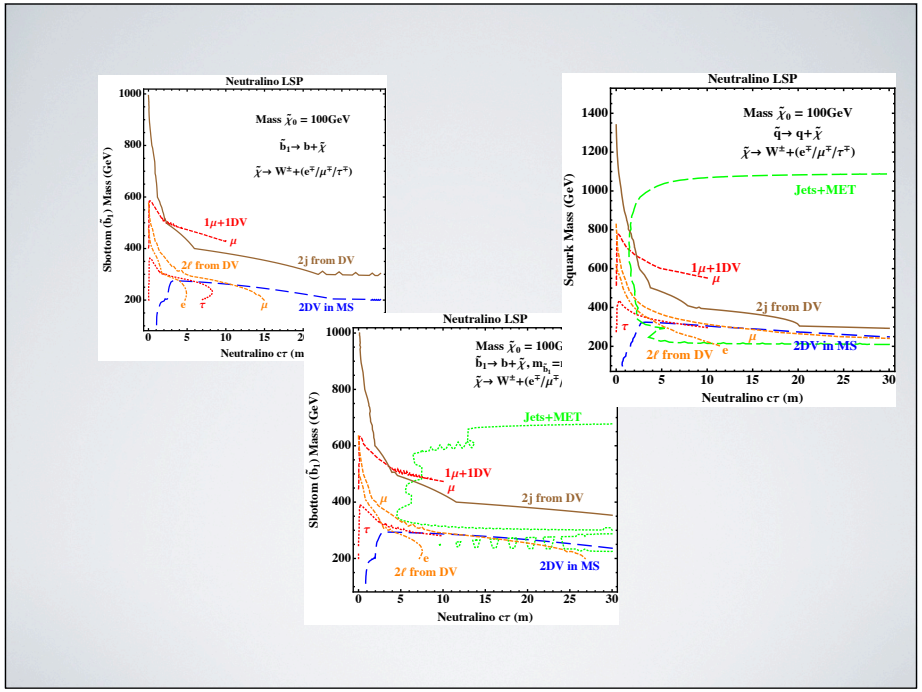




DM WITH A SISTER



In some (more complicated) scenarios,
can have RPV and DM


Neutralino LSP
Mass $\tilde{\chi}_0$ = 100GeV
$\tilde{b}_1 \rightarrow b + \tilde{\chi}$
$\tilde{\chi} \rightarrow W^{\pm} + (e^{\mp}/\mu^{\mp}/\tau^{\mp})$
Sbottom ($\tilde{b}_1$) Mass (GeV)
Neutralino cτ (m)
1μ+1DV
μ
2ℓ from DV
2j from DV
2DV in MS
e
τ
μ
Neutralino LSP
Mass $\tilde{\chi}_0$ = 100G
$\tilde{b}_1 \rightarrow b + \tilde{\chi}$, $m_{\tilde{b}_1}$ =
$\tilde{\chi} \rightarrow W^{\pm} + (e^{\mp}/\mu^{\mp}$
Sbottom ($\tilde{b}_1$) Mass (GeV)
Neutralino cτ (m)
Jets+MET
1μ+1DV
μ
2j from DV
μ
τ
e
2ℓ from DV
2DV in MS
Neutralino LSP
Mass $\tilde{\chi}_0$ = 100GeV
$\tilde{q} \rightarrow q + \tilde{\chi}$
$\tilde{\chi} \rightarrow W^{\pm} + (e^{\mp}/\mu^{\mp}/\tau^{\mp})$
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Neutralino cτ (m)
Jets+MET
1μ+1DV
μ
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