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Is the 125 GeV scalar the neutrino superpartner?

Based on arXiv:1211.4526, with F. Riva and A. Pomarol

Université Libre de Bruxelles,
07/06/13

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Is the 125 GeV scalar the neutrino superpartner?

or

"How to solve the debate about calling it Higgs, BEH, SM scalar… Simply call it slepton!"

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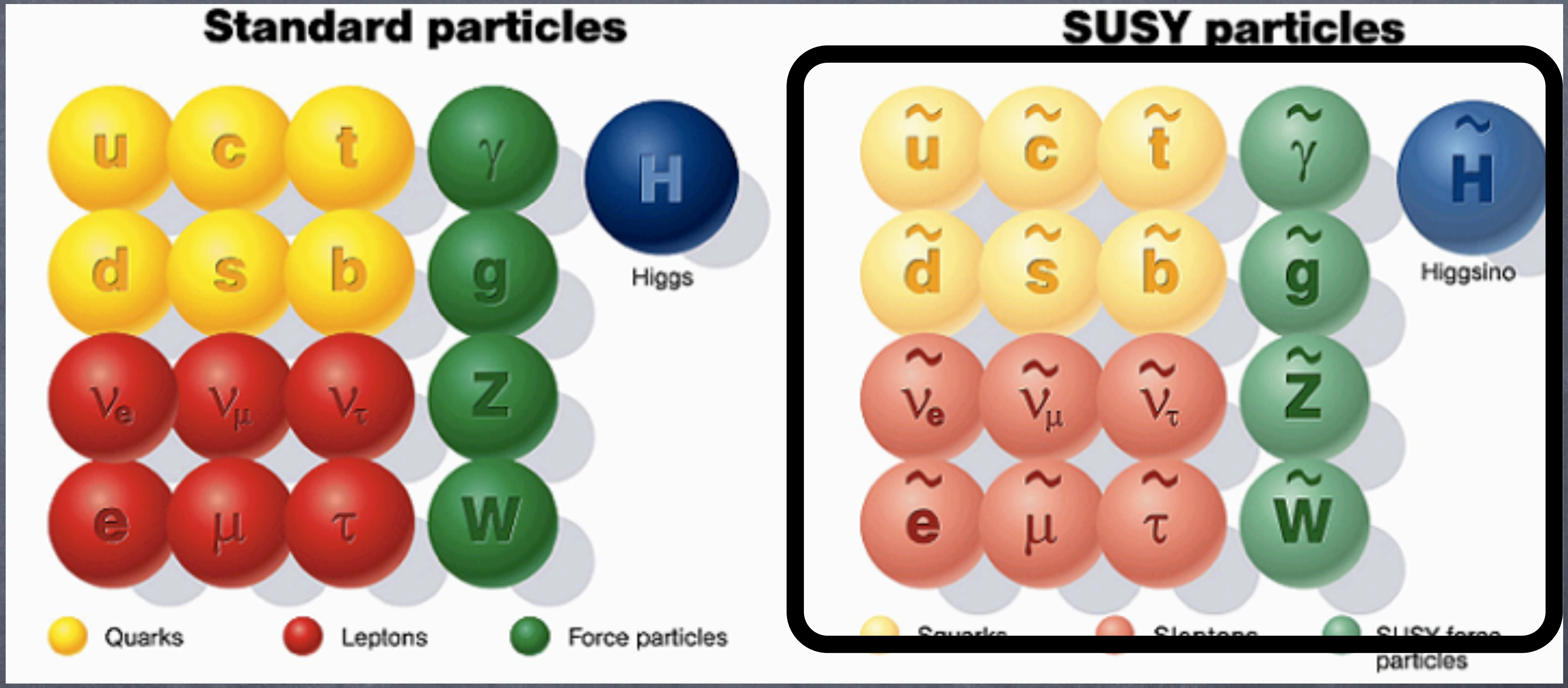
The recently discovered scalar particle ⇝ H
and the neutrino ν have the
same gauge quantum numbers:

$$L = \begin{pmatrix} \nu \\ l_L^- \end{pmatrix} = (1,2)_{1/2} \qquad H = \begin{pmatrix} h^0 \\ h^- \end{pmatrix} = (1,2)_{1\ \ 2}$$

can they be one the superpartner of the other?

$H \equiv \tilde{\nu}$: is it possible?

MSSM: we impose an R-parity, mainly to avoid fast p-decay



drawings by F. Riva

R=1

R=-1

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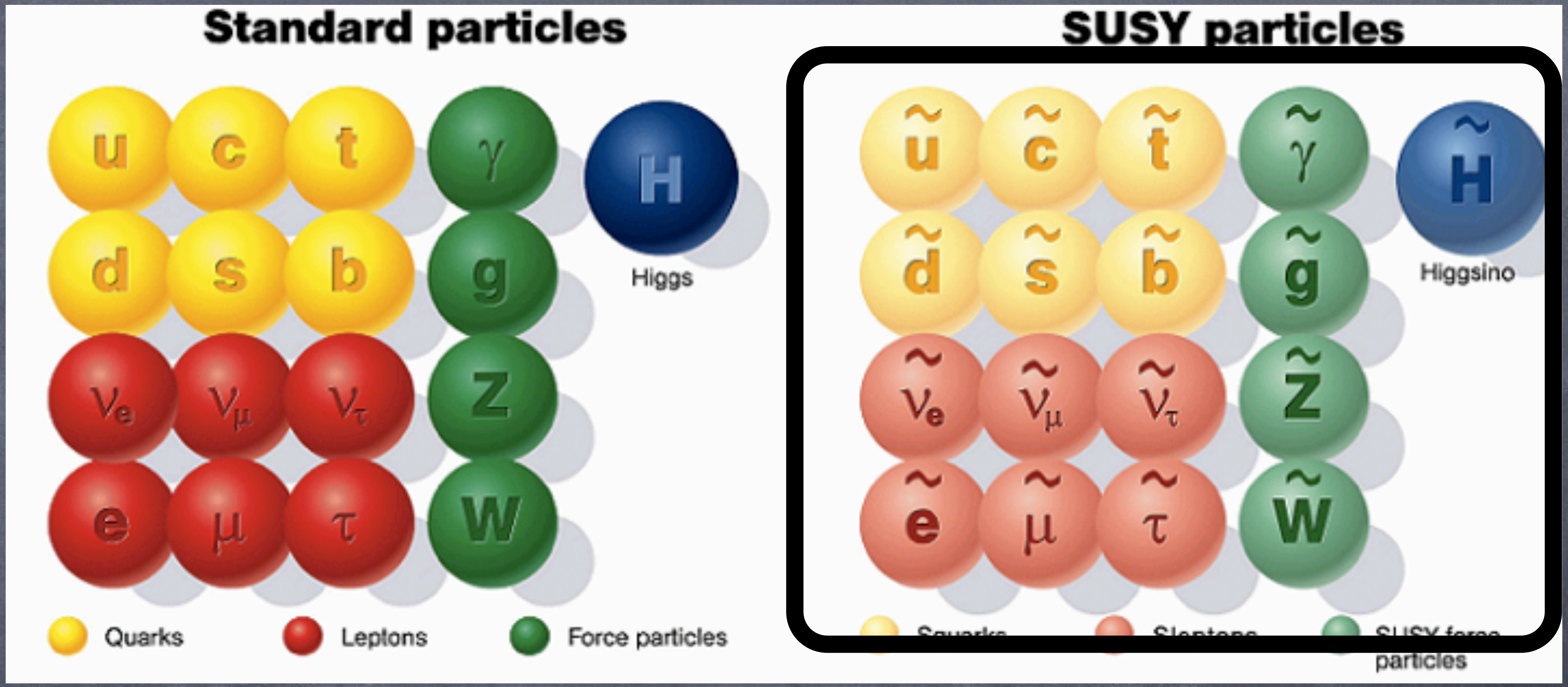


R=1

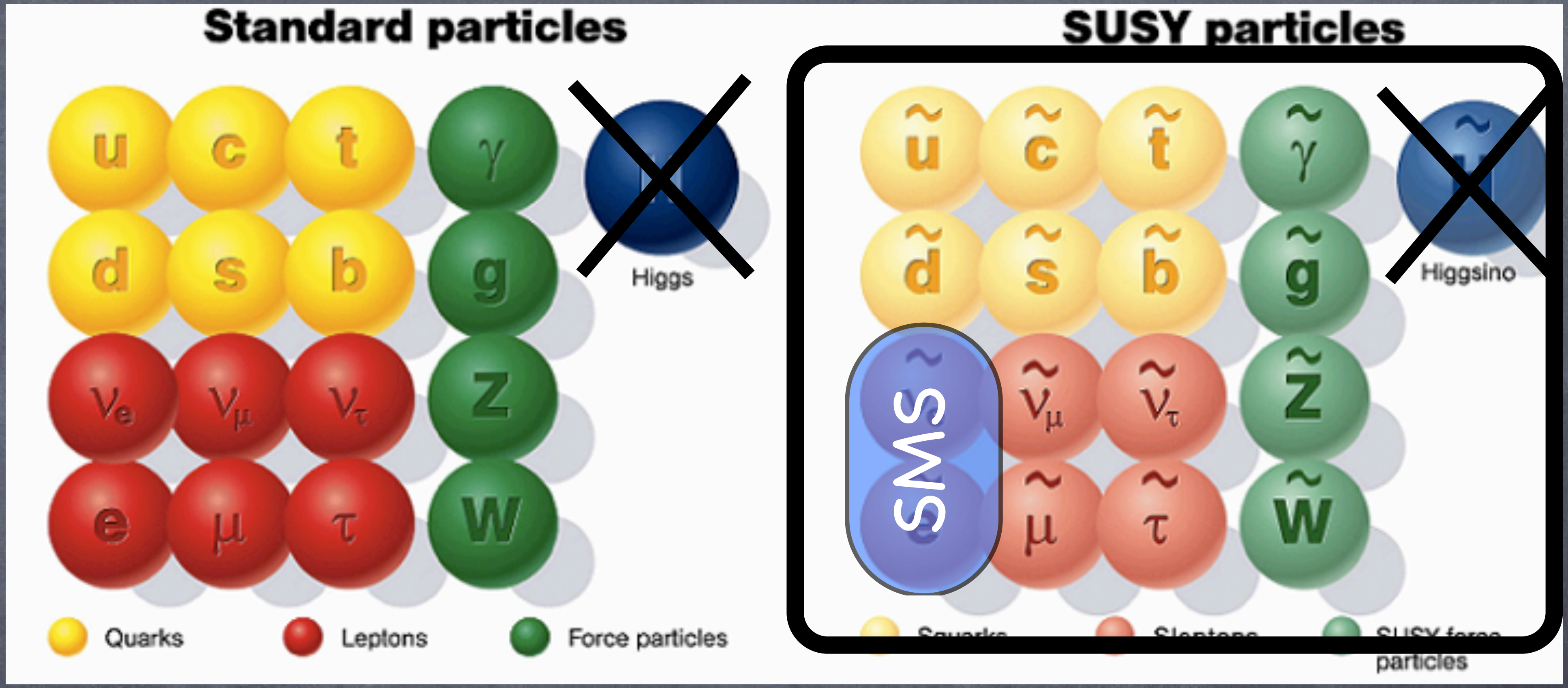
R=-1

Interesting pheno consequences:

stable LSP ⤳ a lot of MET @ LHC

$H \equiv \tilde{\nu}$: is it possible?

Higgs as a slepton: R-parity?



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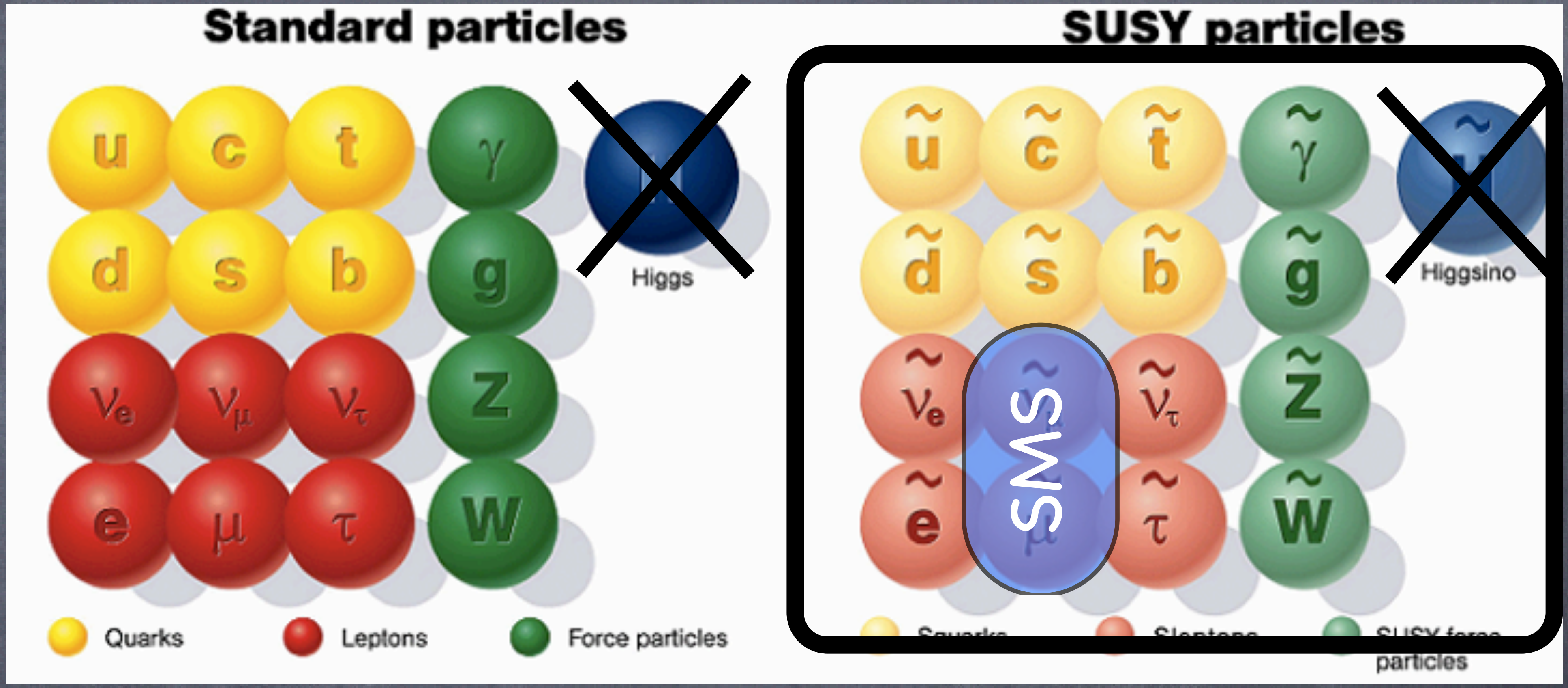

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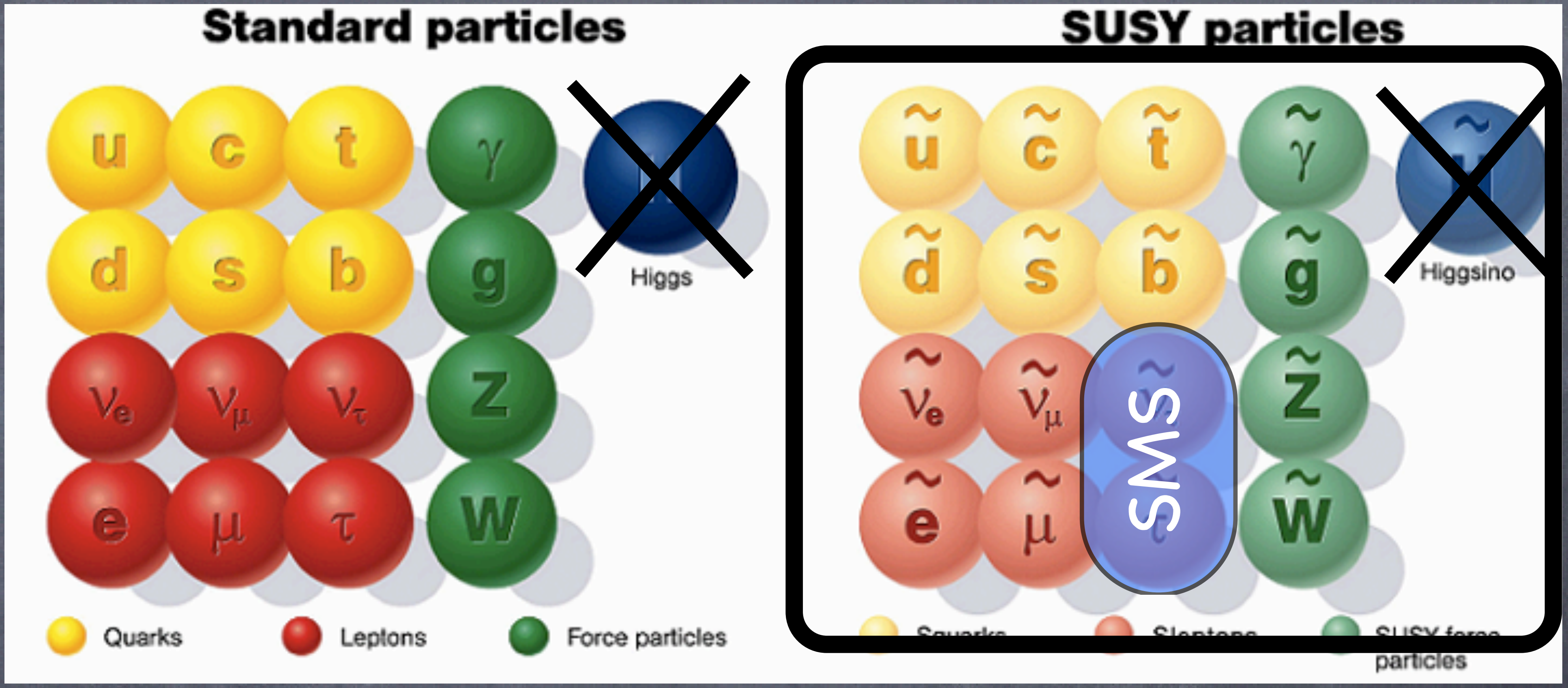

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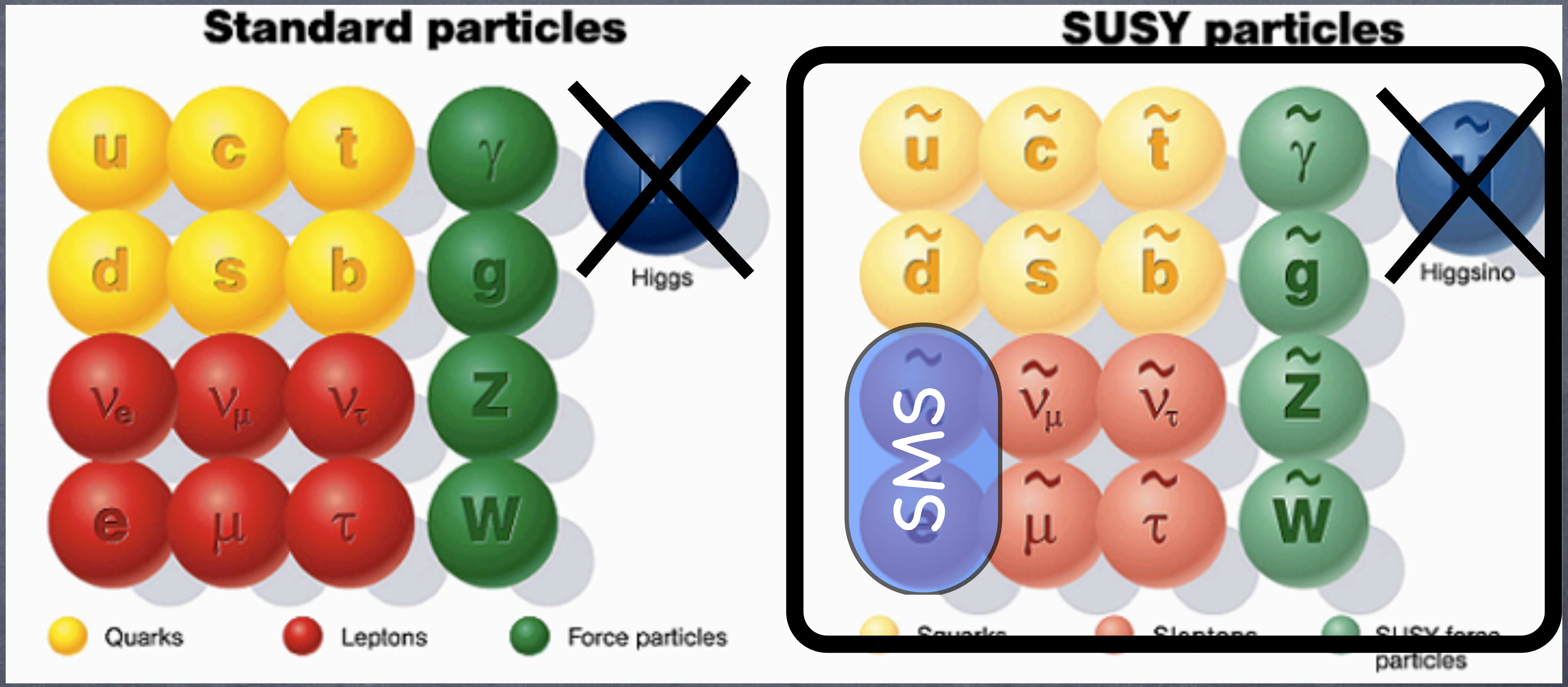
R=-1

$H \equiv \tilde{\nu}$: is it possible?

Higgs as a slepton: R-parity?   NO!



R=1   R=-1

The scalar vev breaks R-parity and L-number

- p-decay
- large neutrino masses

a new kind of R-parity needed

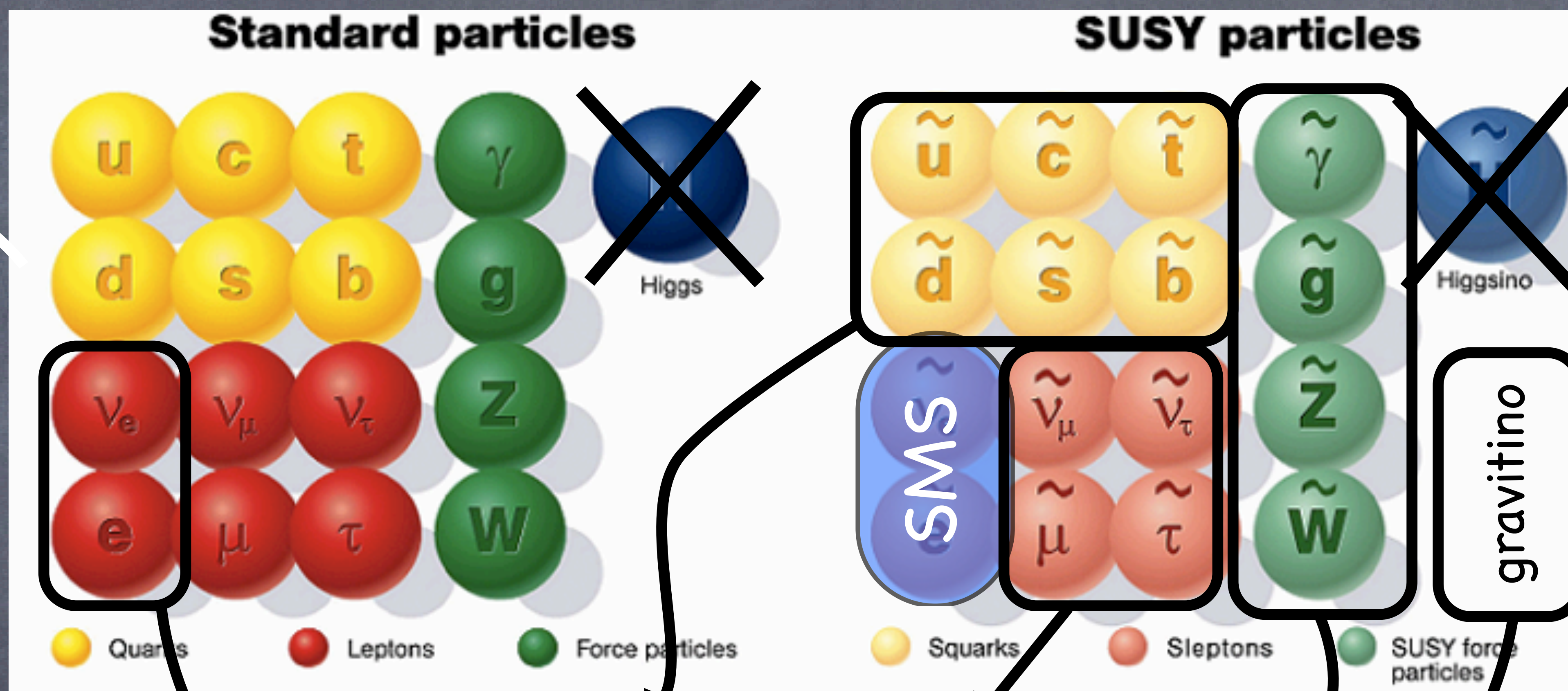
$H \equiv \tilde{\nu}$: is it possible?

Fayet 76
Gherghetta Pomarol 2003
Frugiuele Gregoire 2011

1. $U(1)_R$ symmetry as Lepton symmetry

Example:

R-charge = 0



R-charge = 1

- ✓ The scalar vev does not break $U(1)_L$
- ✓ Gauginos must have Dirac masses
- ✓ $U(1)_R$ will be broken by gravitino mass

$H \equiv \tilde{\nu}$: is it possible?

1985

Graham G Ross Grand Unified Theories Chapter 9

An obvious possibility is to identify the Higgs SU(2) doublet as a partner of a lepton doublet. However, this is not possible, for such an assignment in supersymmetry does not give an acceptable pattern of fermion masses. The reason is that supersymmetry restricts the possible forms of Yukawa couplings

$H \equiv \tilde{\nu}$: is it possible?

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Graham G Ross — Grand Unified Theories — Chapter 9

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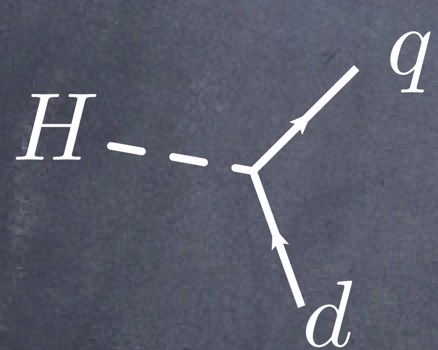
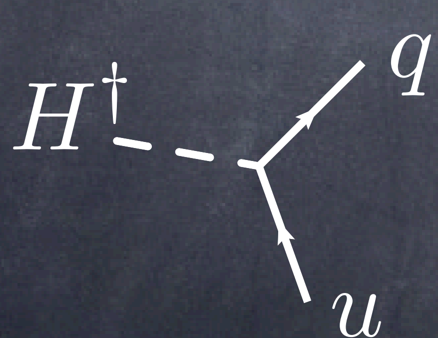


✓ Can be supersymmetrized



✗ Cannot be supersymmetrized:
(superpotential must be analytic)

$H \equiv \tilde{\nu}$: is it possible?

1985

Graham G Ross   Grand Unified Theories   Chapter 9

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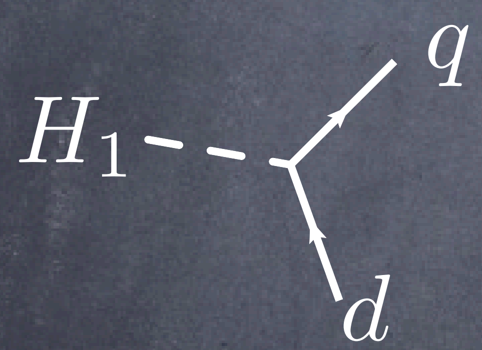

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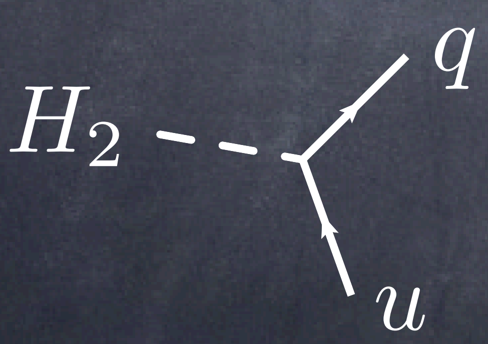

✓ Can be supersymmetrized

Two scalar doublets: - MSSM

- H_u + $L=H_d$

Frugiuele Gregoire 2011

$H \equiv \tilde{\nu}$: is it possible?

2. top Yukawa coupling: from ~~SUSY~~ sector
⤳ from the Kähler potential

Not a surprise: $m_H \approx 125$GeV requires ~~SUSY~~ :

$$(125\text{GeV})^2 = m_Z^2 \cos^2 2\beta + \delta m^2$$

SUSY: $< (91\text{GeV})^2$

~~SUSY~~: $\gtrsim (86\text{GeV})^2$

(In the MSSM large A-terms or heavy stops)

$H \equiv \tilde{\nu}$: advantages & consequences

- no Higgsinos ⤳ HiggsinolessMSSM

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minimal model with
natural low energy SUSY spectrum

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minimal model with
natural low energy SUSY spectrum

Moreover: No R-parity ⇒ no large MET in final states at the LHC

new final states at the LHC

The Higgsinoless MSSM

	$SU(3)_c \times SU(2)_L \times U(1)_Y$	$U(1)_R$
Q	$(3,2)_{\frac{1}{6}}$	$1+B$
U	$(\bar{3},1)_{-\frac{2}{3}}$	$1-B$
D	$(\bar{3},1)_{\frac{1}{3}}$	$1-B$
$L_{1,2}$	$(1,2)_{-\frac{1}{2}}$	$1-L$
$E_{1,2}$	$(1,1)_1$	$1+L$
$H \equiv L_3$	$(1,2)_{-\frac{1}{2}}$	0
E_3	$(1,1)_1$	2
W_a^α	$(8,1)_0+(1,3)_0+(1,1)_0$	1
Φ_a	$(8,1)_0+(1,3)_0+(1,1)_0$	0
$X \equiv \theta^2 F$	$(1,1)_0$	2

B≠0 q have $U(1)_R$ charge
safe from p-decay
(if B≠L and B≠1/3)

L≠0 all ν have $U(1)_R$ charge
ν masses protected

L≠1 no LLE and LQD in W:
strongly constrained

$U(1)_R$ ⇒ Dirac gaugino masses

Spurion ~~SUSY~~; q_R fixed in order not to break $U(1)_R$

The Higgsinoless MSSM

$$W = Y_d HQD + Y_{e\,ij} HL_iE_j$$

→ m_d

→ m_e (not for L_3)

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All the rest comes from SUSY breaking terms:

1. Y_t :

$$\int d^4\theta \; y_u \frac{X^\dagger}{M} \frac{H^\dagger QU}{\Lambda} = \int d^2\theta \; Y_u H^\dagger QU$$

$$Y_u = y_u \frac{F}{M\Lambda}$$

~~SUSY~~ mediation scale ↙ ↘ effective op. scale

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~~SUSY~~ mediation scale ↙ ↘ effective op. scale

$$Y_u \sim 1 \Rightarrow \Lambda \sim y_u \frac{F}{M}$$

$$m_{\tilde{q}} \sim \frac{F}{M} \lesssim \text{TeV} \Rightarrow \boxed{\Lambda \lesssim 4\pi \text{TeV}}$$

Low scale ~~SUSY~~

The Higgsinoless MSSM

$$W = Y_d HQD + Y_{e\,ij} HL_iE_j$$

→ m_d

→ m_e (not for L_3)

All the rest comes from SUSY breaking terms:

2. Y_{e3} :

$$\int d^4\theta \; y_3 \frac{X^\dagger X}{M^2} \frac{HD^\alpha HD_\alpha E_3}{\Lambda^2}$$

$$Y_e = y_3 \frac{F^2}{M^2\Lambda^2}$$

The Higgsinoless MSSM

$$W = Y_d HQD + Y_{e\,ij} HL_iE_j$$

→ m_d

→ m_e (not for L_3)

All the rest comes from SUSY breaking terms:

3. gaugino masses :

$$\int d^2\theta\ \frac{D^\alpha X}{M} W^a_\alpha \Phi_a \qquad m \sim \frac{F}{M}$$

The Higgsinoless MSSM

$$W = Y_d\, HQD + Y_{e\,ij}\, HL_i E_j$$

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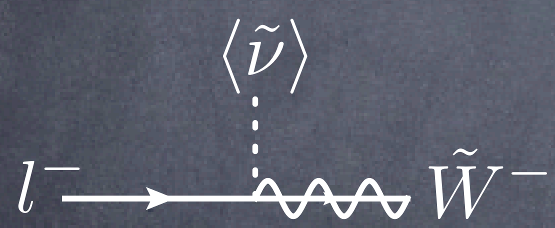

After EWSB winos mix with leptons

g_{Zll} modified ⇒ $$M_{\tilde{W}} \gtrsim \begin{cases} 2.5\,\mathrm{TeV} & l^-_L = e_L \\ 2\,\mathrm{TeV} & l^-_L = \mu_L \\ 1.8\,\mathrm{TeV} & l^-_L = \tau_L \end{cases}$$ ⇒ $$\frac{F}{M} \sim \mathrm{TeV}$$

The Higgsinoless MSSM

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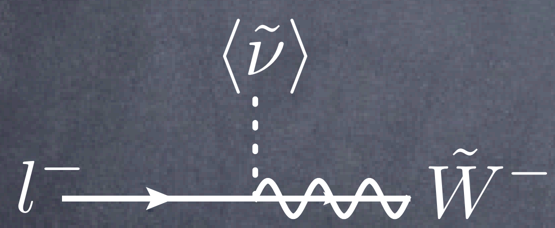

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(From universality constraints: $M_{\tilde{B}} \gtrsim 500$ GeV)

The Higgsinoless MSSM

$$W = Y_d HQD + Y_{e\,ij} HL_iE_j$$

→ m_d

→ m_e (not for L_3)

All the rest comes from SUSY breaking terms:

4. ~~SUSY~~ quartic coupl. : $$\int d^4\theta\, \lambda_H \frac{X^\dagger X}{M^2} \frac{|H|^4}{\Lambda^2} = \delta\lambda_h\, h^4 + \ldots$$

$U(1)_R$ forbids A-terms; low stop masses

⇒ additional quartic required to get $m_H \approx 125$GeV

$$\delta\lambda_h \sim 0.015$$

The Higgsinoless MSSM

$U(1)_R$ is broken by gravitino mass:

$$m_{3/2} \sim \frac{F}{M_{Pl}} \sim 10^{-3}\text{eV}\left(\frac{\sqrt{F}}{2\text{TeV}}\right)^2$$

Majorana ν mass ~ $m_{3/2}$ can be generated

The Higgsinoless MSSM

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Majorana ν mass ~ $m_{3/2}$ can be generated

– if other SUSY sources are present gravitinos can be heavy:

⇒ 2 scenarios: - gravitino L(R-charged)P

- neutrino L(R-charged)P

A natural spectrum

The presence of ~~SUSY~~ operators generates at the loop level other ~~SUSY~~ terms:

- is m_H OK?
- soft masses for scalars

$$\int d^4\theta \left\{ g_Q \frac{X^\dagger X}{M^2} Q^\dagger Q + g_U \frac{X^\dagger X}{M^2} U^\dagger U + g_H \frac{X^\dagger X}{M^2} H^\dagger H \right\}$$

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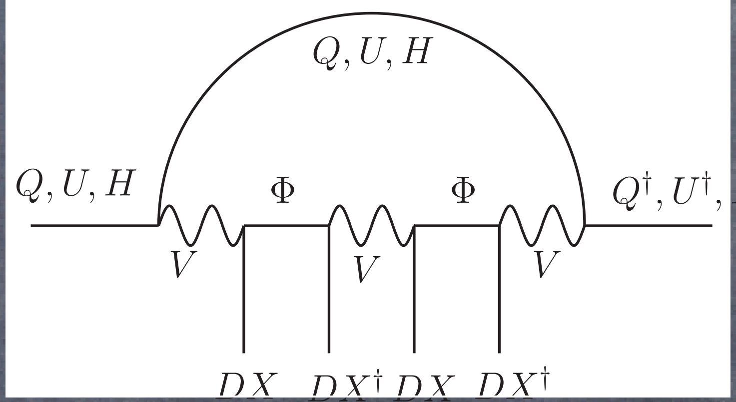
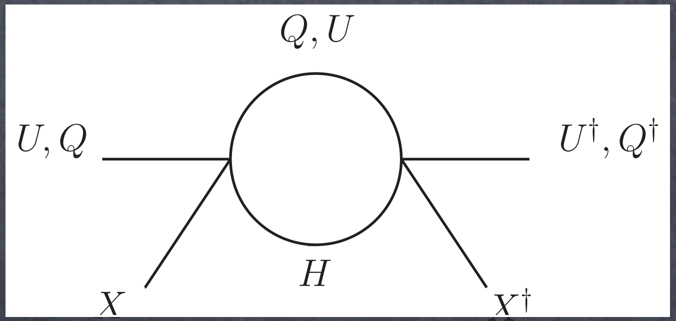
Squarks:



Finite contrib.

(SuperSoft SUSY breaking)
Fox, Nelson, Weiner 02

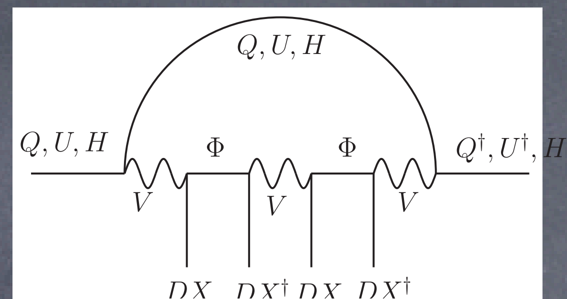


$\propto \Lambda^2$

A natural spectrum

(SuperSoft SUSY breaking)
Fox, Nelson, Weiner 02

Higgs



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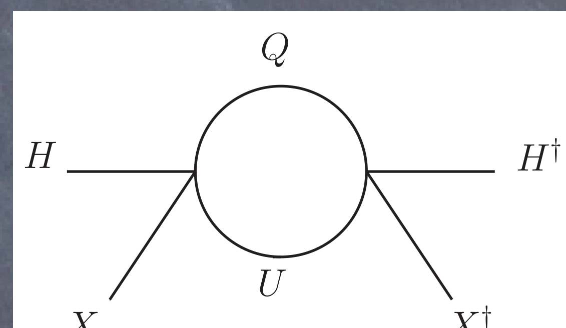
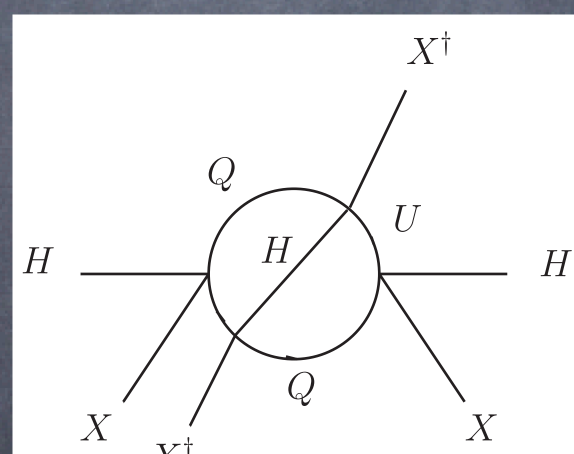


vanishes



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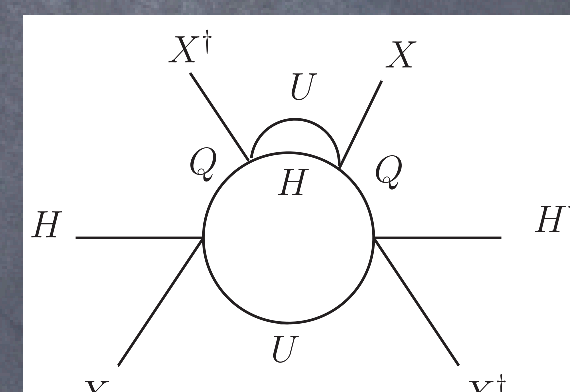
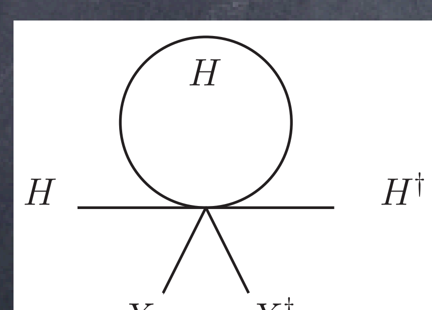


negative

$\propto \log\Lambda^2$



$\propto \Lambda^2$

A natural spectrum

$$m_{Q,U}^2 \simeq (400\ \text{GeV})^2 \left[\left(\frac{M_{\tilde{g}}}{2\ \text{TeV}} \right)^2 \ln \frac{M_{\Phi_{\tilde{g}}}^2}{M_{\tilde{g}}^2} + (0.15, 0.3) \left(\frac{\Lambda}{2\ \text{TeV}} \right)^2 \right]$$

naturally "light" 3rd gen. squarks

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- $$m_H^2 \simeq -(100\ \text{GeV})^2 \quad \left[1.9 \left(\frac{m_Q}{400\ \text{GeV}} \right)^2 \frac{\ln \frac{\Lambda}{m_Q}}{\ln 5} - 3.2 \left(\frac{M_{\tilde{W}}}{2\ \text{TeV}} \right)^2 \ln \frac{M_{\Phi_{\tilde{W}}}^2}{M_{\tilde{W}}^2} - \left(\frac{\delta\lambda}{0.015} \right) \left(\frac{\Lambda}{2\ \text{TeV}} \right)^2 \right]$$

EWSB can occur naturally

A natural spectrum

- $$m^2_{Q,U} \simeq (400\ \text{GeV})^2 \left[\left(\frac{M_{\tilde{g}}}{2\ \text{TeV}}\right)^2 \ln \frac{M^2_{\Phi_{\tilde{g}}}}{M^2_{\tilde{g}}} + (0.15, 0.3) \left(\frac{\Lambda}{2\ \text{TeV}}\right)^2 \right]$$

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  EWSB can occur naturally

- other sparticles: at least as heavier as the above

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  naturally "light" 3rd gen. squarks

- $$m_H^2 \simeq -(100\ \text{GeV})^2 \left[4.3 \left(\frac{m_Q}{600\ \text{GeV}} \right)^2 \frac{\ln \frac{\Lambda}{m_Q}}{\ln 5} - 3.2 \left(\frac{M_{\tilde{W}}}{2\ \text{TeV}} \right)^2 \ln \frac{M_{\Phi_{\tilde{W}}}^2}{M_{\tilde{W}}^2} - \left(\frac{\delta\lambda}{0.015} \right) \left(\frac{\Lambda}{2\ \text{TeV}} \right)^2 \right]$$

  EWSB can occur naturally

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Phenomenology: the Higgs

Only 1 scalar, tree-level couplings as in the SM.

Possible deviations from:

1. loops mediated by stops
2. higher dimensional operators
3. invisible decays

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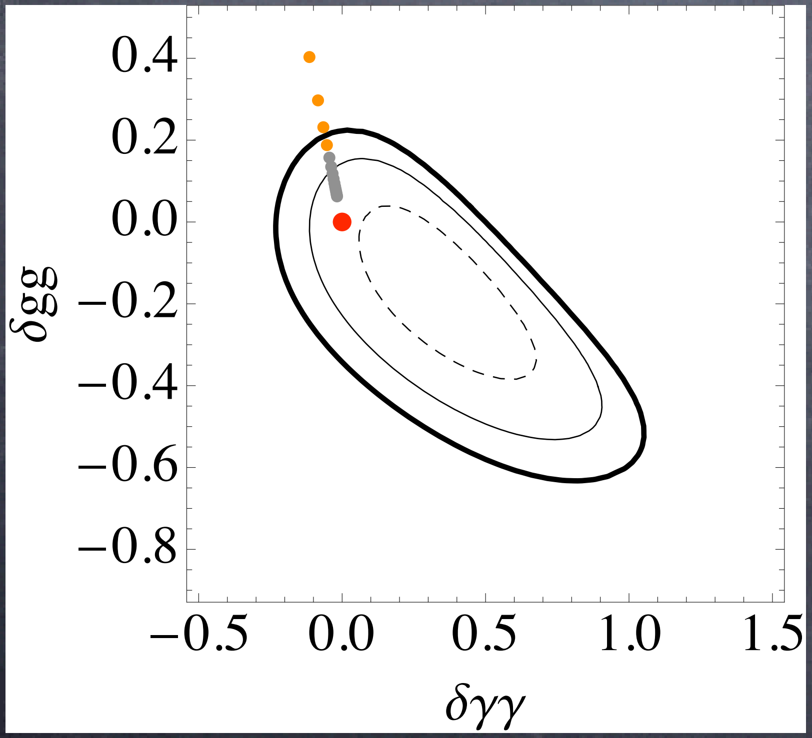
Only 1 scalar, tree-level couplings as in the SM.

Possible deviations from:

1. loops mediated by stops

$g_{H\gamma\gamma}$ ➢ $\Gamma(H\rightarrow\gamma\gamma)$ modified ← small effect

g_{Hgg} ➢ $\Gamma(H\rightarrow gg)$ and σ_{prod} modified ← sizable effect



Fit to Higgs data:

heavier stops are favored...

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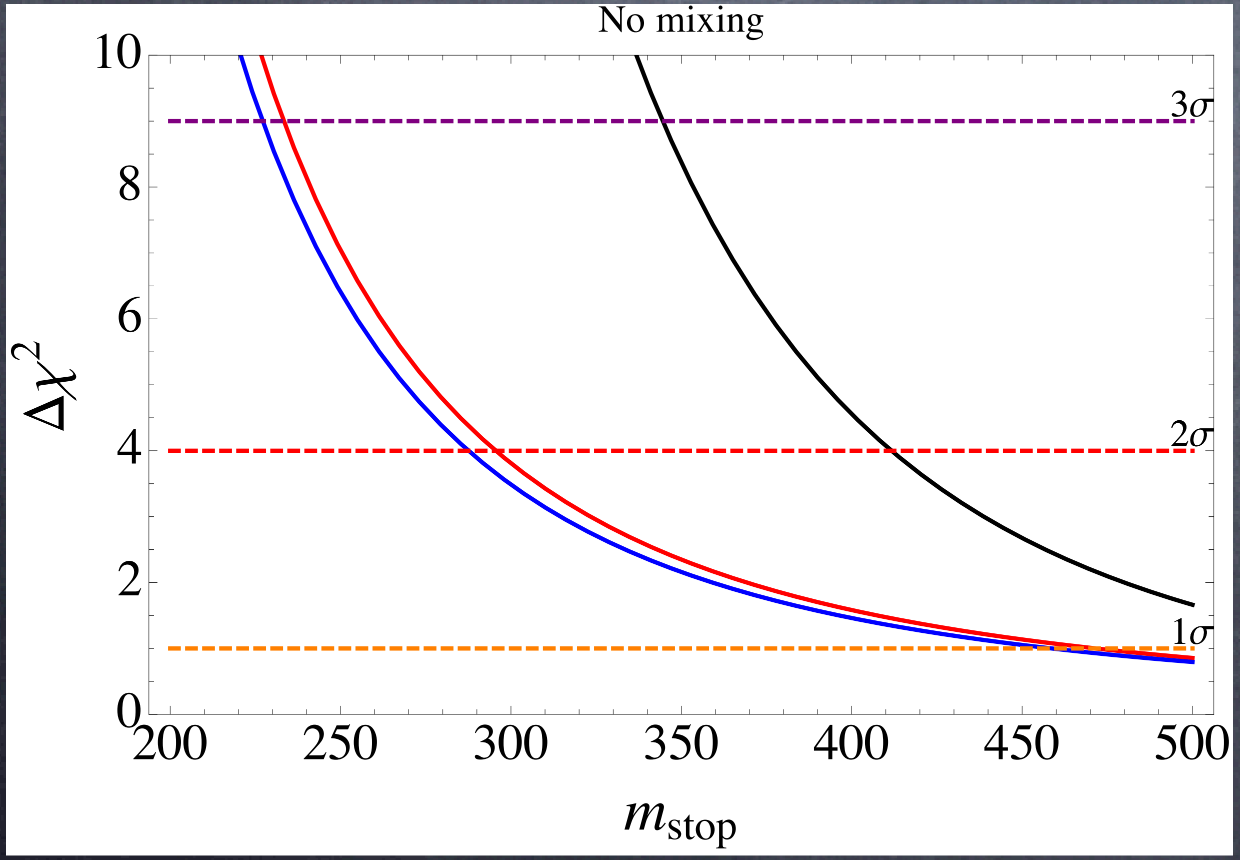


$m_{tR} \ll m_{tL}$	m>280 GeV
$m_{tL} \ll m_{tR}$	m>290 GeV
$m_{tL} = m_{tR}$	m>420 GeV

Stops lighter than tops seem to be excluded in our model from Higgs data fit

Courtesy of A. Falkowsky

Phenomenology: the Higgs

Only 1 scalar, tree-level couplings as in the SM.

Possible deviations from:

2. higher dimensional operators

from integrating out heavy sparticles
or ~~SUSY~~ physics

EWPT constrain it → small effect

Phenomenology: the Higgs

Only 1 scalar, tree-level couplings as in the SM.

Possible deviations from:

3. invisible decays

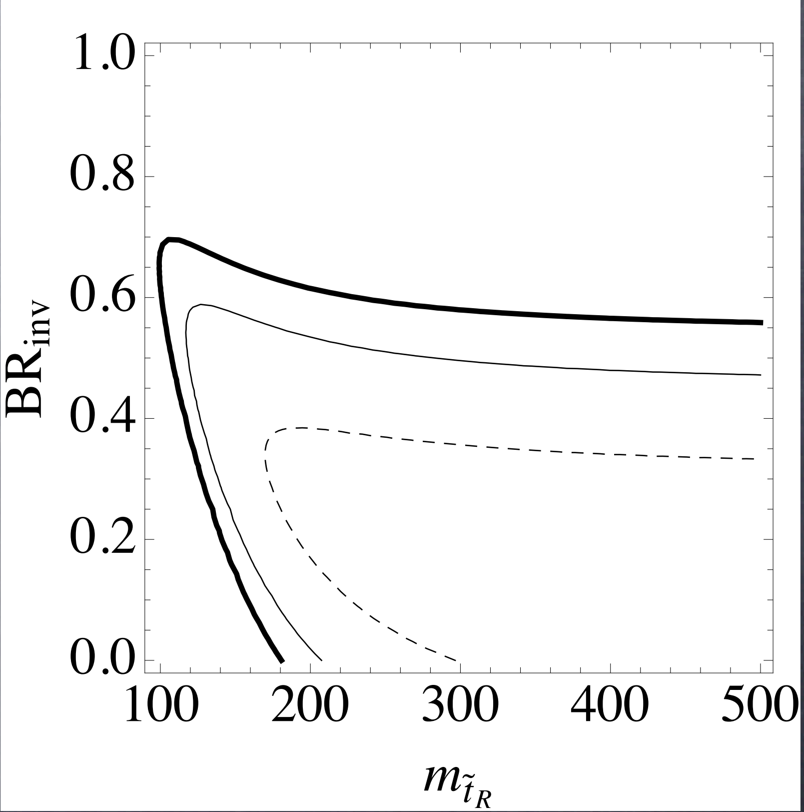
H and ν superpartners → interact with goldstino

- if the gravitino is light (LSP):

$$\Gamma(h \to \tilde{G}\nu_L) \simeq \frac{1}{16\pi}\frac{m_h^5}{F^2}$$

$\sqrt{F} \approx$ 1 TeV → $Br_{inv} \approx 10\%$

$Br_{inv} \neq 0$ lighter stops still allowed



Pheno: stops and sbottoms

No A-terms ⇒ prediction: $m^2_{\tilde{b}_L} = m^2_{\tilde{t}_L} - m^2_t + m^2_b$

Pheno: stops and sbottoms

No A-terms ⇒ prediction: $m^2_{\tilde{b}_L} = m^2_{\tilde{t}_L} - m^2_t + m^2_b$

Decay	Interaction
$\tilde{t}_L \to b_R \bar{l}^-_L$	$Y_d\, HQD\|_{\theta^2}$
$\tilde{t}_L \to t_R \bar{\nu}_L$	$\frac{1}{\Lambda^2}\|H\|^2\|Q\|^2\|_{\theta^4}$
$\tilde{t}_L \to t_L \tilde{G}$	$\frac{m_t^2 - m^2_{\tilde{t}_L}}{F}\, \tilde{t}^*_L \tilde{G}\, t_L$
$\tilde{b}_L \to b_R \bar{\nu}_L$	$Y_d\, QHD\|_{\theta^2}$
$\tilde{b}_L \to b_L \tilde{G}$	$\frac{m_b^2 - m^2_{\tilde{b}_L}}{F}\, \tilde{b}^*_L \tilde{G}\, b_L$

Decay	Interaction
$\tilde{t}_R \to t_L \nu_L$	$\frac{1}{\Lambda^2}\|H\|^2\|U\|^2\|_{\theta^4}$
$\tilde{t}_R \to t_R \bar{\tilde{G}}$	$\frac{m_t^2 - m^2_{\tilde{t}_R}}{F}\, \tilde{t}^*_R \bar{\tilde{G}}\, \bar{t}_L$
$\tilde{b}_R \to b_L \nu_L$	$Y_d\, QHD\|_{\theta^2}$
$\tilde{b}_R \to t_L\, l^-_L$	$Y_d\, QHD\|_{\theta^2}$
$\tilde{b}_R \to b_R \bar{\tilde{G}}$	$\frac{m_b^2 - m^2_{\tilde{b}_R}}{F}\, \tilde{b}^*_R \bar{\tilde{G}}\, \bar{b}_L$

Pheno: stops and sbottoms

No A-terms ⇒ prediction: $m_{\tilde{b}_L}^2 = m_{\tilde{t}_L}^2 - m_t^2 + m_b^2$

Decay	Interaction
$\tilde{t}_L \to b_R \bar{l}_L^-$	$Y_d HQD\|_{\theta^2}$
$\tilde{t}_L \to t_R \bar{\nu}_L$	$\frac{1}{\Lambda^2}\|H\|^2\|Q\|^2\|_{\theta^4}$
$\tilde{t}_L \to t_L \tilde{G}$	$\frac{m_t^2 - m_{\tilde{t}_L}^2}{F} \tilde{t}_L^* \tilde{G} t_L$
$\tilde{b}_L \to b_R \bar{\nu}_L$	$Y_d QHD\|_{\theta^2}$
$\tilde{b}_L \to b_L \tilde{G}$	$\frac{m_b^2 - m_{\tilde{b}_L}^2}{F} \tilde{b}_L^* \tilde{G} b_L$

Decay	Interaction
$\tilde{t}_R \to t_L \nu_L$	$\frac{1}{\Lambda^2}\|H\|^2\|U\|^2\|_{\theta^4}$
$\tilde{t}_R \to t_R \bar{\tilde{G}}$	$\frac{m_t^2 - m_{\tilde{t}_R}^2}{F} \tilde{t}_R^* \bar{\tilde{G}} \bar{t}_L$
$\tilde{b}_R \to b_L \nu_L$	$Y_d QHD\|_{\theta^2}$
$\tilde{b}_R \to t_L l_L^-$	$Y_d QHD\|_{\theta^2}$
$\tilde{b}_R \to b_R \bar{\tilde{G}}$	$\frac{m_b^2 - m_{\tilde{b}_R}^2}{F} \tilde{b}_R^* \bar{\tilde{G}} \bar{b}_L$

from the superpotential: leptoquark decays (jets + MET)

Pheno: stops and sbottoms

No A-terms ⇒ prediction: $$m^2_{\tilde{b}_L} = m^2_{\tilde{t}_L} - m^2_t + m^2_b$$

Decay	Interaction
$\tilde{t}_L \to b_R \bar{l}^-_L$	$Y_d\, HQD\vert_{\theta^2}$
$\tilde{t}_L \to t_R \bar{\nu}_L$	$\frac{1}{\Lambda^2}\vert H\vert^2\vert Q\vert^2\vert_{\theta^4}$
$\tilde{t}_L \to t_L \tilde{G}$	$\frac{m_t^2 - m_{\tilde{t}_L}^2}{F}\, \tilde{t}^*_L \tilde{G}\, t_L$
$\tilde{b}_L \to b_R \bar{\nu}_L$	$Y_d\, QHD\vert_{\theta^2}$
$\tilde{b}_L \to b_L \tilde{G}$	$\frac{m_b^2 - m_{\tilde{b}_L}^2}{F}\, \tilde{b}^*_L \tilde{G}\, b_L$

Decay	Interaction
$\tilde{t}_R \to t_L \nu_L$	$\frac{1}{\Lambda^2}\vert H\vert^2\vert U\vert^2\vert_{\theta^4}$
$\tilde{t}_R \to t_R \bar{\tilde{G}}$	$\frac{m_t^2 - m_{\tilde{t}_R}^2}{F}\, \tilde{t}^*_R \bar{\tilde{G}}\, \bar{t}_L$
$\tilde{b}_R \to b_L \nu_L$	$Y_d\, QHD\vert_{\theta^2}$
$\tilde{b}_R \to t_L l^-_L$	$Y_d\, QHD\vert_{\theta^2}$
$\tilde{b}_R \to b_R \bar{\tilde{G}}$	$\frac{m_b^2 - m_{\tilde{b}_R}^2}{F}\, \tilde{b}^*_R \bar{\tilde{G}}\, \bar{b}_L$

from the goldstino interactions: jets + MET

Pheno: stops and sbottoms

No A-terms ⇒ prediction: $m^2_{\tilde b_L} = m^2_{\tilde t_L} - m^2_t + m^2_b$

Decay	Interaction
$\tilde t_L \to b_R \bar l_L^-$	$Y_d\, HQD\vert_{\theta^2}$
$\tilde t_L \to t_R \bar\nu_L$	$\frac{1}{\Lambda^2}\vert H\vert^2\vert Q\vert^2\vert_{\theta^4}$
$\tilde t_L \to t_L \tilde G$	$\frac{m_t^2 - m_{\tilde t_L}^2}{F}\, \tilde t_L^* \tilde G\, t_L$
$\tilde b_L \to b_R \bar\nu_L$	$Y_d\, QHD\vert_{\theta^2}$
$\tilde b_L \to b_L \tilde G$	$\frac{m_b^2 - m_{\tilde b_L}^2}{F}\, \tilde b_L^* \tilde G\, b_L$

Decay	Interaction
$\tilde t_R \to t_L \nu_L$	$\frac{1}{\Lambda^2}\vert H\vert^2\vert U\vert^2\vert_{\theta^4}$
$\tilde t_R \to t_R \bar{\tilde G}$	$\frac{m_t^2 - m_{\tilde t_R}^2}{F}\, \tilde t_R^* \bar{\tilde G}\, \bar t_L$
$\tilde b_R \to b_L \nu_L$	$Y_d\, QHD\vert_{\theta^2}$
$\tilde b_R \to t_L l_L^-$	$Y_d\, QHD\vert_{\theta^2}$
$\tilde b_R \to b_R \bar{\tilde G}$	$\frac{m_b^2 - m_{\tilde b_R}^2}{F}\, \tilde b_R^* \bar{\tilde G}\, \bar b_L$

from higher-dim operators: jets + MET

Pheno: stops and sbottoms

No A-terms ⇒ prediction: $$m^2_{\tilde b_L} = m^2_{\tilde t_L} - m_t^2 + m_b^2$$

Decay	Interaction
$\tilde t_L \to b_R \bar l_L^-$	$Y_d\, HQD\vert_{\theta^2}$
$\tilde t_L \to t_R \bar\nu_L$	$\frac{1}{\Lambda^2}\vert H\vert^2\vert Q\vert^2\vert_{\theta^4}$
$\tilde t_L \to t_L \tilde G$	$\frac{m_t^2 - m_{\tilde t_L}^2}{F}\, \tilde t_L^* \tilde G\, t_L$
$\tilde b_L \to b_R \bar\nu_L$	$Y_d\, QHD\vert_{\theta^2}$
$\tilde b_L \to b_L \tilde G$	$\frac{m_b^2 - m_{\tilde b_L}^2}{F}\, \tilde b_L^* \tilde G\, b_L$

Decay	Interaction
$\tilde t_R \to t_L \nu_L$	$\frac{1}{\Lambda^2}\vert H\vert^2\vert U\vert^2\vert_{\theta^4}$
$\tilde t_R \to t_R \bar{\tilde G}$	$\frac{m_t^2 - m_{\tilde t_R}^2}{F}\, \tilde t_R^* \bar{\tilde G}\, \bar t_L$
$\tilde b_R \to b_L \nu_L$	$Y_d\, QHD\vert_{\theta^2}$
$\tilde b_R \to t_L l_L^-$	$Y_d\, QHD\vert_{\theta^2}$
$\tilde b_R \to b_R \bar{\tilde G}$	$\frac{m_b^2 - m_{\tilde b_R}^2}{F}\, \tilde b_R^* \bar{\tilde G}\, \bar b_L$

Only jets + MET

Pheno: stops and sbottoms

No A-terms ⇒ prediction: $m_{\tilde{b}_L}^2 = m_{\tilde{t}_L}^2 - m_t^2 + m_b^2$

Decay	Interaction
$\tilde{t}_L \rightarrow b_R \bar{l}_L^-$	$Y_d\, HQD|_{\theta^2}$
$\tilde{t}_L \rightarrow t_R \bar{\nu}_L$	$\frac{1}{\Lambda^2}|H|^2|Q|^2|_{\theta^4}$
$\tilde{t}_L \rightarrow t_L \tilde{G}$	$\frac{m_t^2 - m_{\tilde{t}_L}^2}{F}\, \tilde{t}_L^* \tilde{G}\, t_L$
$\tilde{b}_L \rightarrow b_R \bar{\nu}_L$	$Y_d\, QHD|_{\theta^2}$
$\tilde{b}_L \rightarrow b_L \tilde{G}$	$\frac{m_b^2 - m_{\tilde{b}_L}^2}{F}\, \tilde{b}_L^* \tilde{G}\, b_L$

Decay	Interaction
$\tilde{t}_R \rightarrow t_L \nu_L$	$\frac{1}{\Lambda^2}|H|^2|U|^2|_{\theta^4}$
$\tilde{t}_R \rightarrow t_R \bar{\tilde{G}}$	$\frac{m_t^2 - m_{\tilde{t}_R}^2}{F}\, \tilde{t}_R^* \bar{\tilde{G}}\, \bar{t}_L$
$\tilde{b}_R \rightarrow b_L \nu_L$	$Y_d\, QHD|_{\theta^2}$
$\tilde{b}_R \rightarrow t_L l_L^-$	$Y_d\, QHD|_{\theta^2}$
$\tilde{b}_R \rightarrow b_R \bar{\tilde{G}}$	$\frac{m_b^2 - m_{\tilde{b}_R}^2}{F}\, \tilde{b}_R^* \bar{\tilde{G}}\, \bar{b}_L$

Only jets + MET

Both jets + MET
and leptoquark decays

Pheno: stops and sbottoms

$\tilde{t}_R$ and $\tilde{b}_L$ decay only into top/bottom + MET

⇒ MSSM searches can be adapted

from $\tilde{b} \to b\chi_0$ with massless neutralino:

$$m_{\tilde{b}_L} > 650 \text{ GeV}$$

$$\to \quad m_{\tilde{t}_L} > 670 \text{ GeV}$$

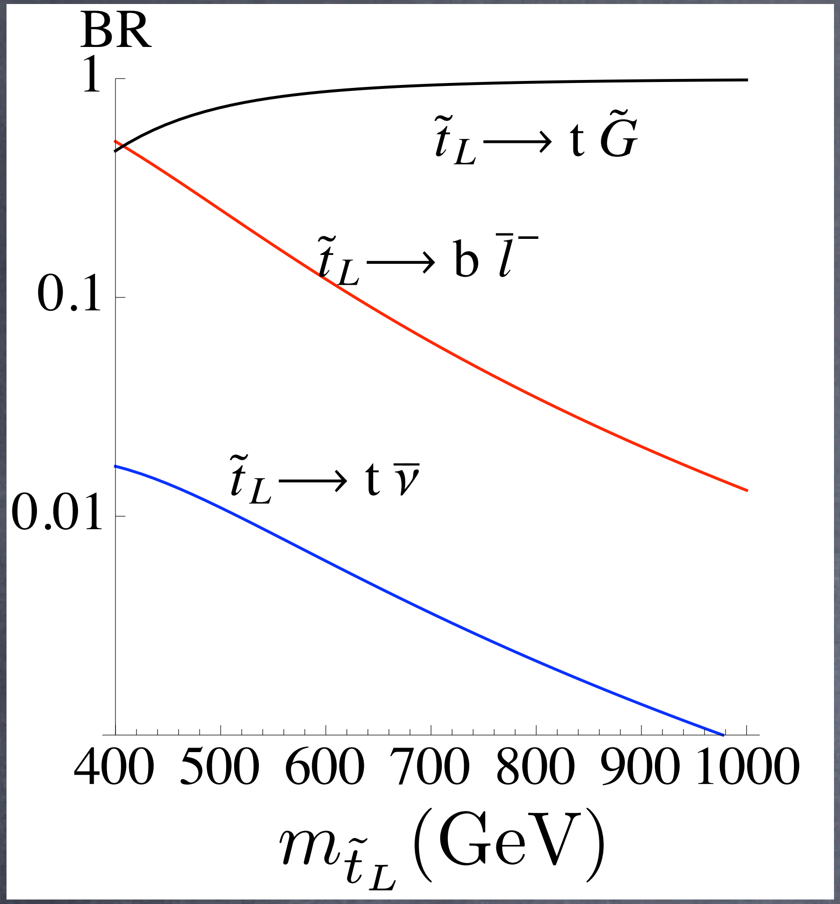
from $\tilde{t} \to t\chi_0$ with massless neutralino:

$$190 \text{ GeV} < m_{\tilde{t}_R} < 685 \text{ GeV}$$

stops lighter than tops in principle still allowed ($m_{\tilde{t}_R} > 150$ GeV)

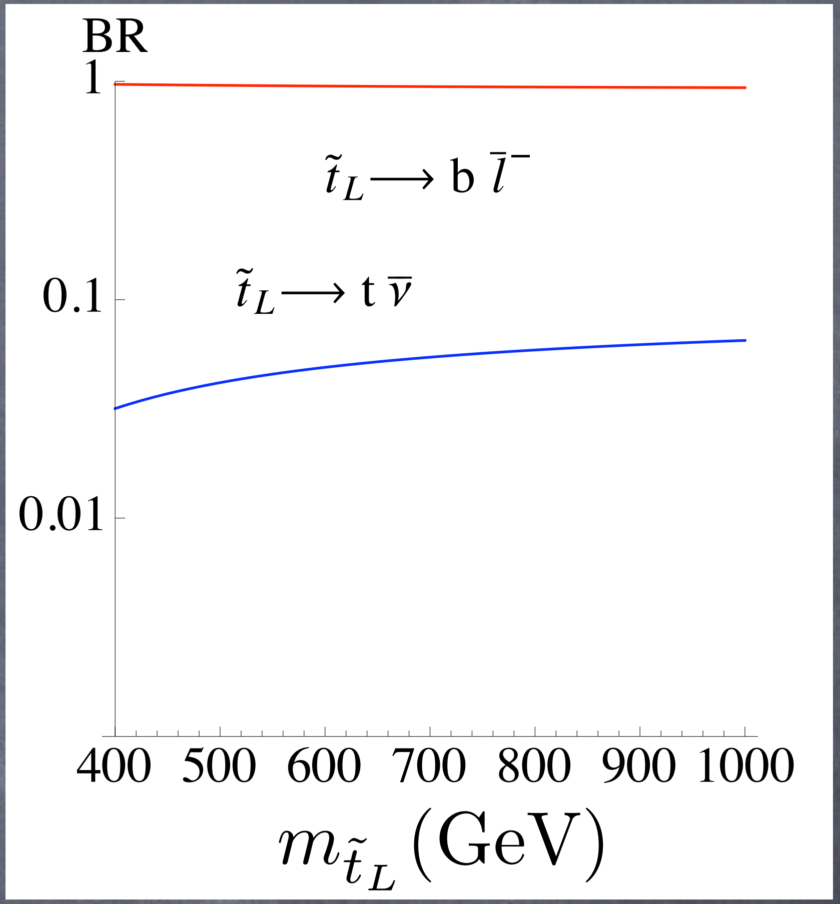
$\tilde{t}_L$

Pheno: stops and sbottoms



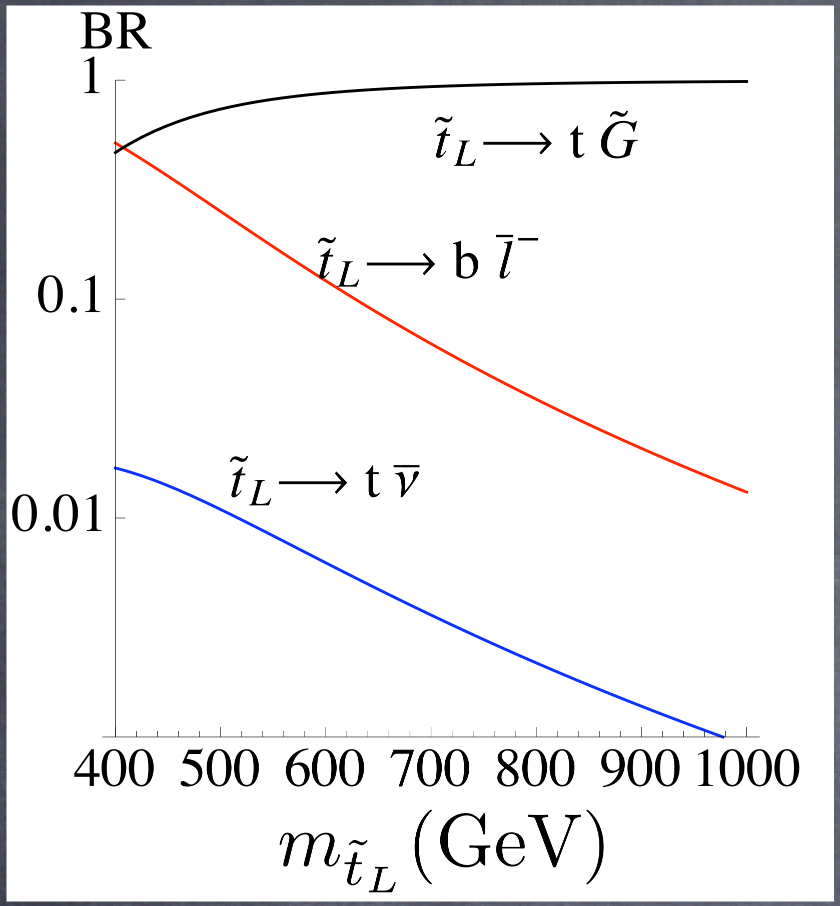
← light gravitino
or small F

heavy gravitino
or large F →



$\tilde{t}_L$

Pheno: stops and sbottoms



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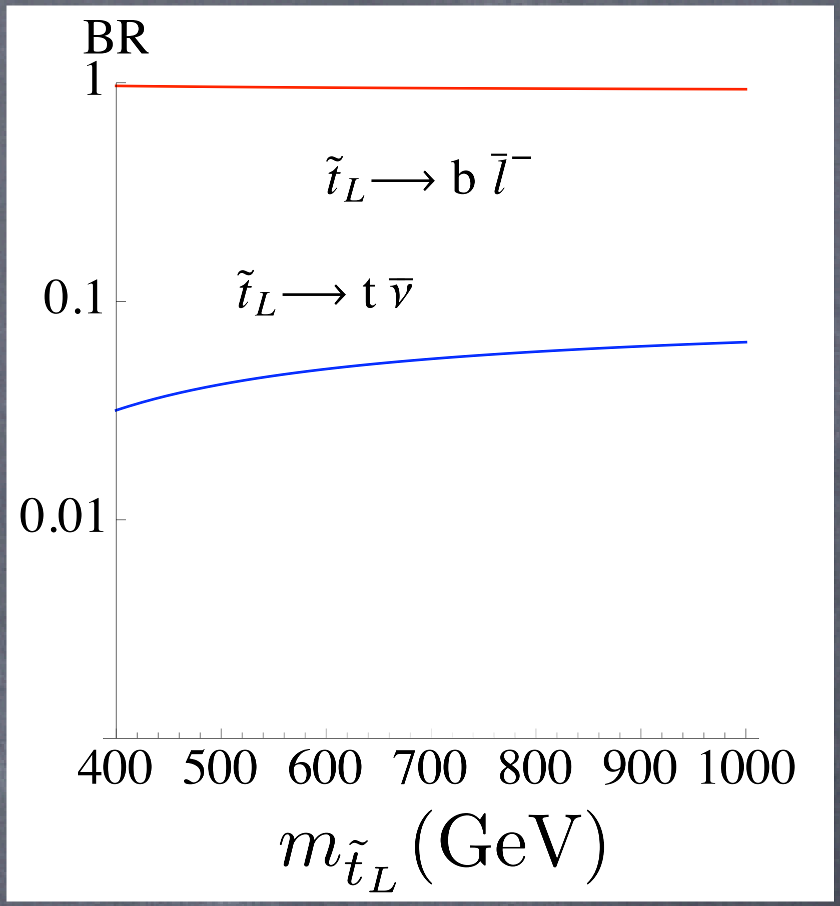
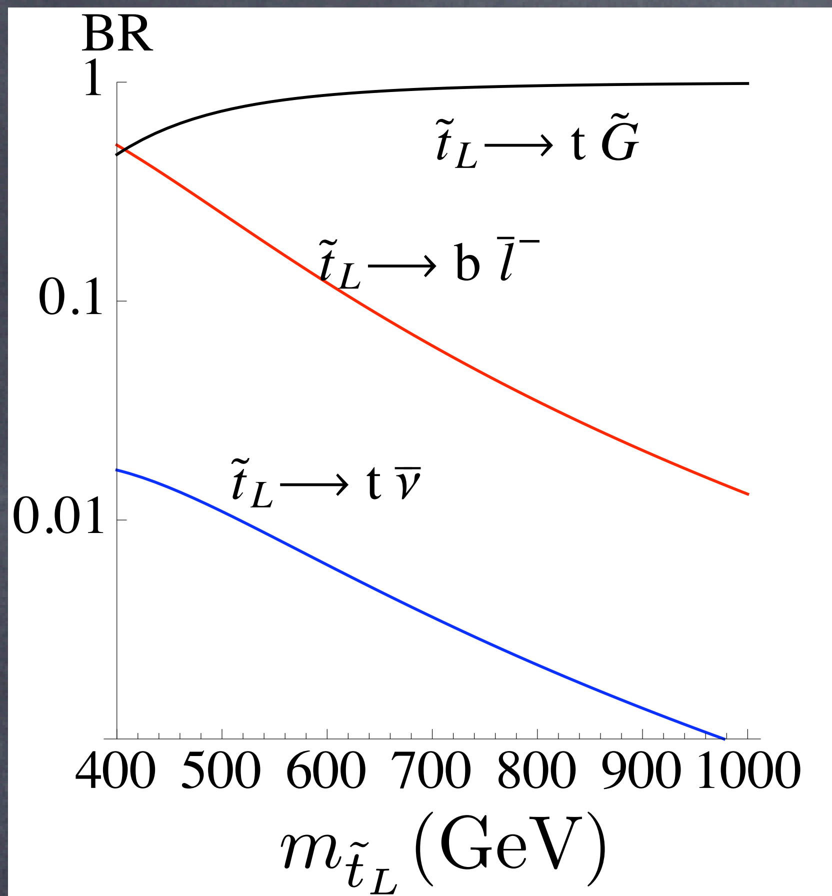


searches jets + MET:

$$190\ \text{GeV} < m_{\tilde{t}_L} < 685\ \text{GeV}$$

$\tilde{t}_L$

Pheno: stops and sbottoms



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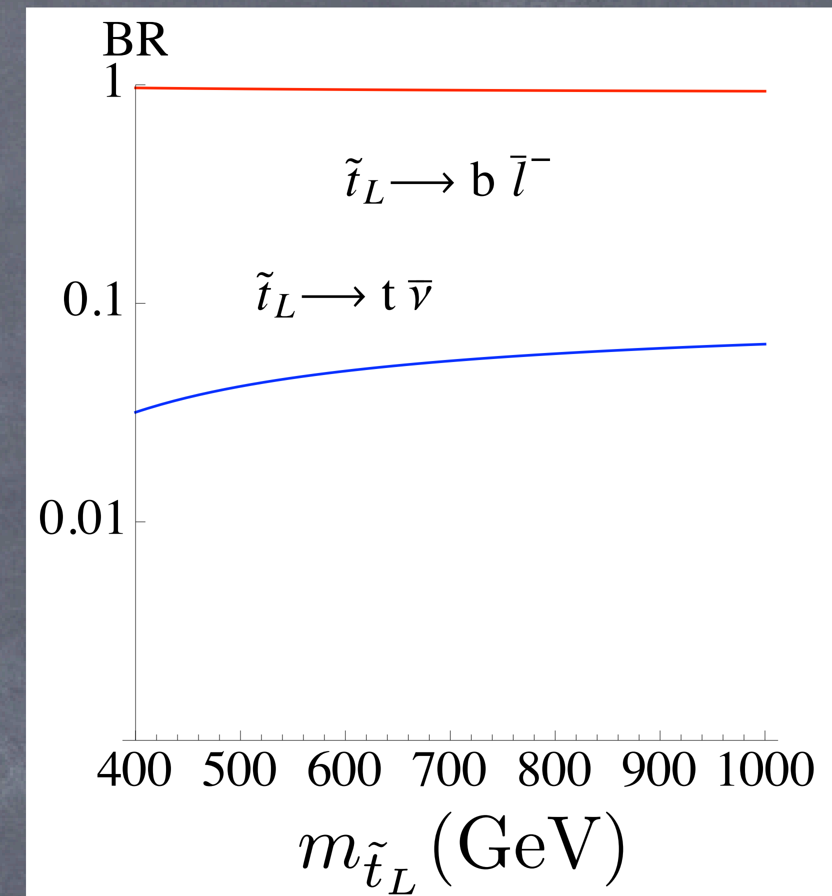


searches jets + MET:

$$190 \text{ GeV} < m_{\tilde{t}_L} < 685 \text{ GeV}$$

searches leptoquarks:

jet+e $m_{\tilde{t}_L} > 660$ GeV

jet+μ $m_{\tilde{t}_L} > 1070$ GeV

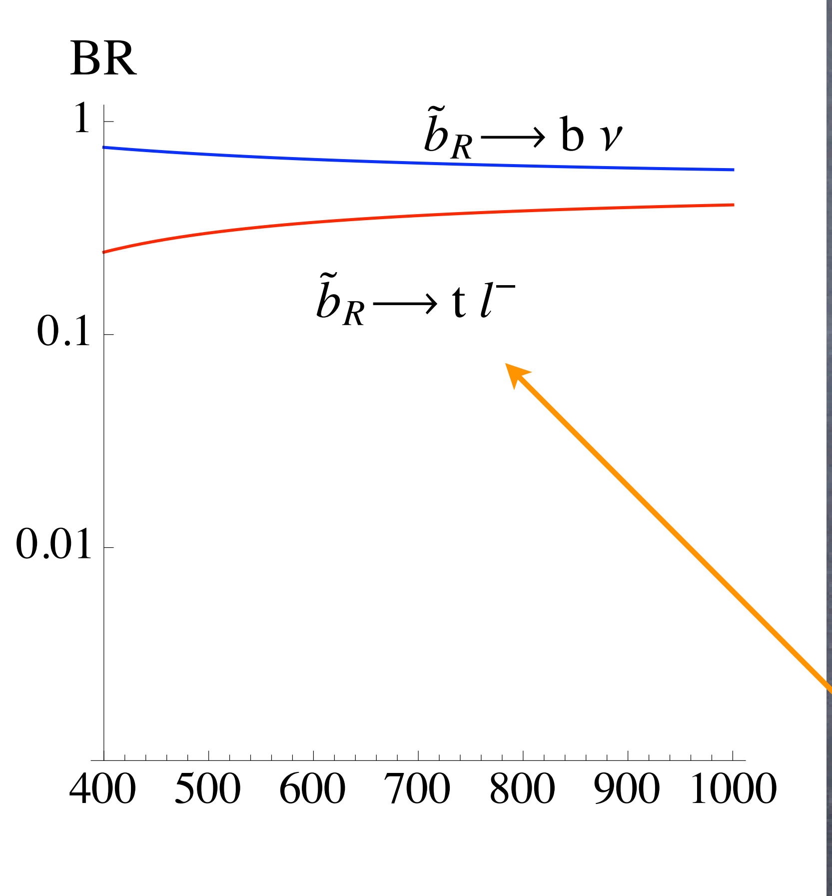
jet+τ $m_{\tilde{t}_L} > 534$ GeV

Look for b-jet + e/μ !!!

$\tilde{b}_R$

Pheno: stops and sbottoms

Light gravitino: b+MET dominates (factor ~10); otherwise:



Similar Br, both controlled by Y_b, bounds from b-jets+MET

$$m_{\tilde{b}_R} < 650 \text{ GeV}$$

Look for top + leptons!!!

LHC search strategy
(an example of how to distinguish from MSSM)

- b-jet + MET observed:
  - it's our $\tilde{b}_R$ only if observe also leptoquark decays @ same mass
  - it can be $\tilde{b}_L$ if observe $\tilde{t}_L$ @ slightly heavier mass

- t + MET observed:
  - it's our $\tilde{t}_L$ if observe also b+l decays
  - it can be $\tilde{t}_R$; look at top helicity

LHC search strategy

(an example of how to distinguish from MSSM)

> b-jet + MET observed:

– it's our $\tilde{b}_R$ onl ... ass

– it can be $\tilde{b}_L$ i

> t + MET obse

– it's our $\tilde{t}_L$ if o

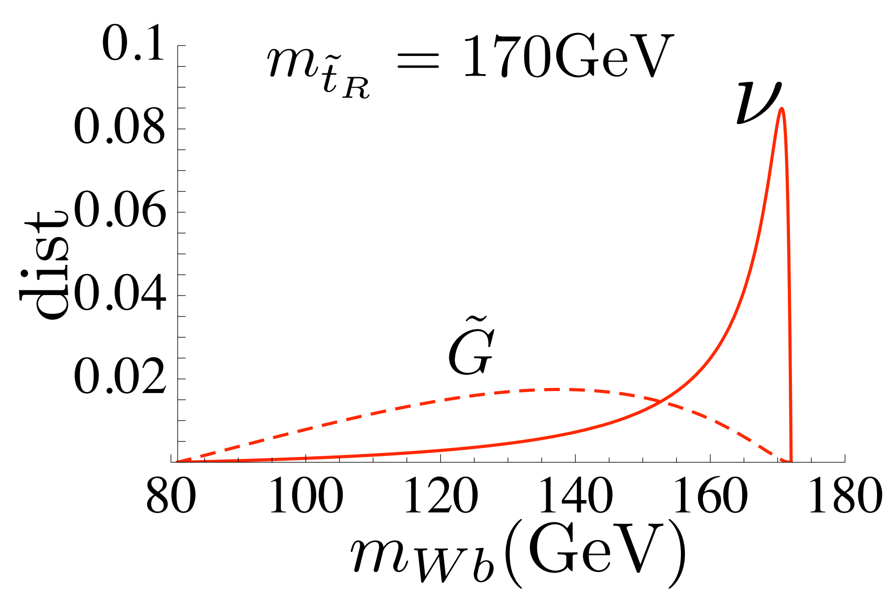
– it can be $\tilde{t}_R$;

Top helicity:

- $m_{\tilde{t}_R} \gg m_t$ $\quad \tilde{t}_R \to t_R \bar{\tilde{G}}$ **as MSSM**

  $\tilde{t}_R \to t_L \nu_L$

- $m_{\tilde{t}_R} < m_t$



Pheno: 1st and 2nd gen. squarks

- light gravitino (and $F \approx \text{TeV}^2$)

  $\tilde{q} \rightarrow q\tilde{G} \rightsquigarrow$ jets + MET m>830GeV

Pheno: 1st and 2nd gen. squarks

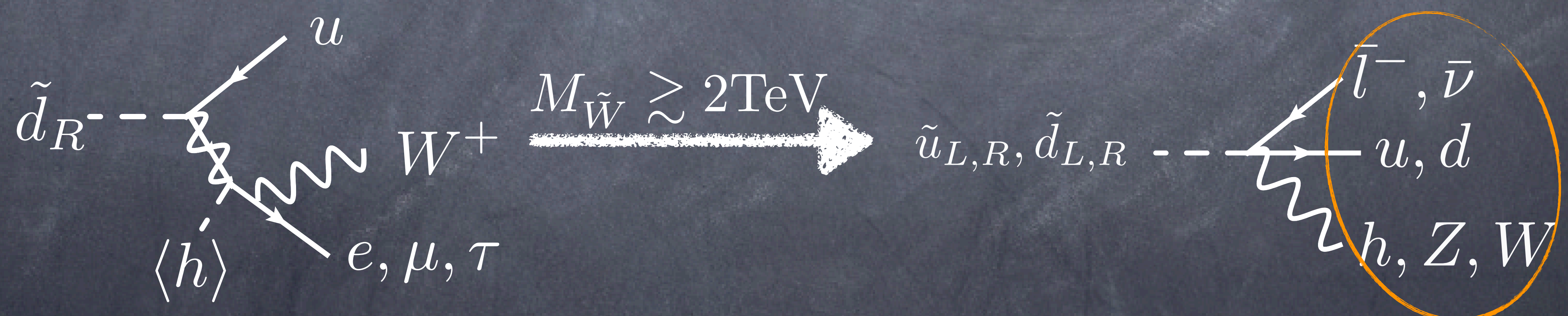
- light gravitino (and F≈TeV^2)

  $\tilde{q} \to q\tilde{G}$ ⇝ jets + MET   m>830GeV

- heavy gravitino (or F>>TeV^2)

  2-body decays suppressed by small Yukawas

  ⇒ 3-body decays can dominate



jet (no b-jets) + W/Z + MET/lepton   ← Look for them!!!

Pheno: sleptons

- light gravitino (and $F \approx TeV^2$)

  $\tilde{l} \to l\tilde{G}$ ⇝ leptons + MET   m>270GeV

  $\tilde{\nu} \to \nu\tilde{G}$ ⇝ MET ; monojet, dijet+MET

- heavy gravitino (or $F \gg TeV^2$)

  3-body decays can dominate

$\tilde{e}_L \to \nu_e + \bar{\nu}_L + W^-$	$\tilde{\mu}_L \to \nu_\mu + \bar{\nu}_L + W^-$	$\tilde{\tau}_L \to \tau + \bar{\nu}_L$
$\tilde{e}_R \to e + l_L^- + W^+$	$\tilde{\mu}_R \to \mu + \nu_L$ (50%) $\to \nu_\mu + l_L^-$ (50%)	$\tilde{\tau}_R \to \tau + \nu_L$ (50%) $\to \nu_\tau + l_L^-$ (50%)
$\tilde{\nu}_e \to e + \bar{l}_L^- + Z$	$\tilde{\nu}_\mu \to \mu + Z + \bar{l}_L^-$	$\tilde{\nu}_\tau \to \tau + \bar{l}_L^-$

↖ Look for these channels!!!

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Merci! :)