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Making the Sneutrino a Higgs with a $U(1)_R$ lepton number

In collaboration with Thomas Grégoire

hep-ph 1107.4634

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20/10/11

MSSM minimal SUSY extension of SM, but...
little hierarchy problem, flavor problem, small parameter space compatible with data..

Need to explore different SUSY scenarios/ SUSY breaking mechanism

Dirac gauginos

New Adjoints superfields for each SM gauge group

$\psi_{\tilde{B}} \quad \psi_{\tilde{W}} \quad \psi_{\tilde{g}}$

Supersoft SUSY breaking **(hep-ph/0206096)**

$$\int \frac{d^2\theta}{M} W'_\alpha W_i^\alpha \psi_i$$

supersoft operator

$W'_\alpha \sim D\theta_\alpha$

D term spurion

advantages..

supersoft=no log divergencies, gauginos heavier than scalars

possible to build R symmetric SUSY model (flavor, CP)

Dirac gauginos

Gauginos Majorana mass breaks R symmetry, Dirac gauginos do not.

Possible to build SUSY models with a R symmetry

Flavor problem ameloriated
MRSSM (hep ph 0712.2039)

Enlarged Higgs sector, two new doublets R_u R_d

Adjoints superfields

SuperField	R-charge
H_u	0
H_d	0
R_u	2
R_d	2
$\psi_{\tilde{W}}$	0
$\psi_{\tilde{B}}$	0
$\psi_{\tilde{G}}$	0

MMRSSM

MoreMinimalRSymmetricSUSYSM

Lepton number as R symmetry

hep-ph/0302001

Gherghetta-Pomarol

SM particles: just the electron and its neutrino carry R charge

SuperField	$U(1)_R$
Q_i	1
u_i^c	1
d_i^c	1
e^c	2
L_e	0

Ex: Q_i R charge 1, fermion R charge 1-1=0

L_e has R charge 0, fermion component 0-1=-1

SUSY partners carry R charge besides the electron scalar partners
Squarks are then leptoquarks!

The electronic sneutrino does not carry R charge/lepton number

⇒ a sneutrino VeV does not break lepton number

No Majorana mass for the neutrino induced

The electronic sneutrino does not carry R charge/lepton number

a sneutrino VeV does not break lepton number

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Sneutrino can play the role of the down type Higgs H_d

More minimal particle content than in the MRSSM

two higgs doublets instead of four!

MMRSSM Superpotential

$a = e \text{ or } \mu \text{ or } \tau$ $\quad H_d \to L_a$ $\quad$ higgsino mass

$$W = \mathbf{y}_u \bar{u} Q H_u - \mathbf{y}_d \bar{d} Q L_a - y_l l^c L L_a + \boxed{\mu H_u R_d}$$

$R(H_u) = 0$ $\quad R(R_d) = 2$ inert doublet

Minimal particle content just two higgs doublets!

SOHD hep-ph 1103.1647v2

MMRSSM Superpotential

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Down type Yukawa couplings= standard R_P violating couplings

$$\lambda_{ijk} L_i L_j l^c_k + \lambda'_{ijk} L_i Q_j d^c_k -$$

Standard lepton number a violation

R symmetry/lepton number forbids Majorana mass for neutrinos

Experimental constraints from EWPM

Gauginos carry lepton number

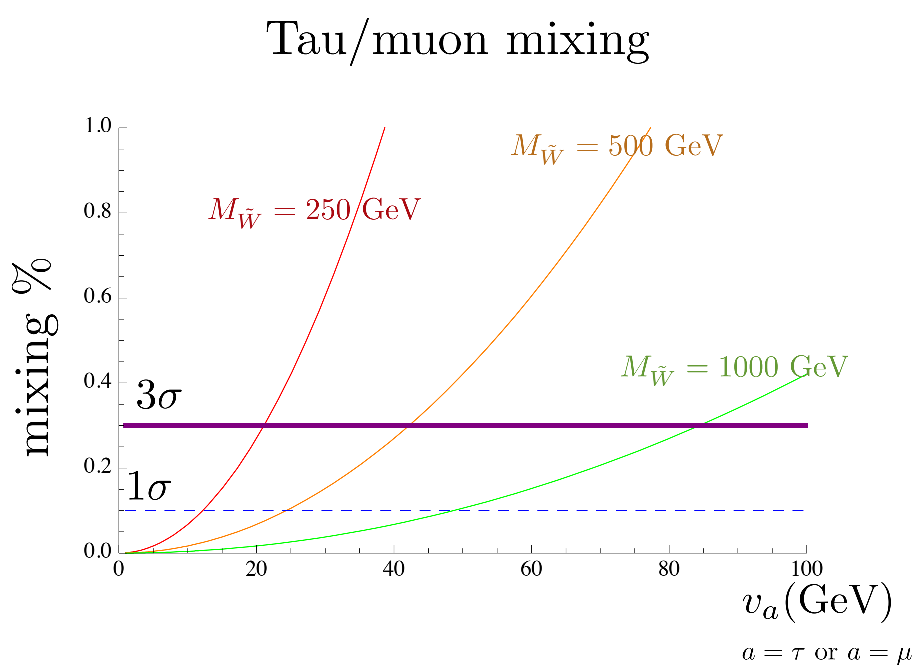
Lepton Mixing

$$l_a'^{\pm} = \cos\phi \; l_a^{\pm} + \sin\phi \; \psi_{\tilde{W}}^{\pm},$$

$$\nu_a' = c_\nu \nu_a + c_{\tilde{B}} \psi_{\tilde{B}} + c_{\tilde{W}} \psi_{\tilde{W}},$$

$$a = e, \mu, \tau$$

Constraints from gauge bosons coupling to leptons



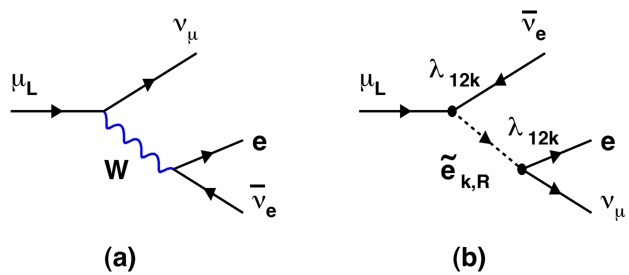
Heavier wino larger sneutrino VeV

no stringent bounds from lepton universality violation

Extra tree level contribution from down type Yukawa coupling

$y_d L_a Q d^c \qquad y_d L_a L_b e^c_b$

fig. hep-ph/0406039v2



$y_\mu L_e L_\mu \mu^c$

Contribution to G_F

Lower bound on the sneutrino VeV

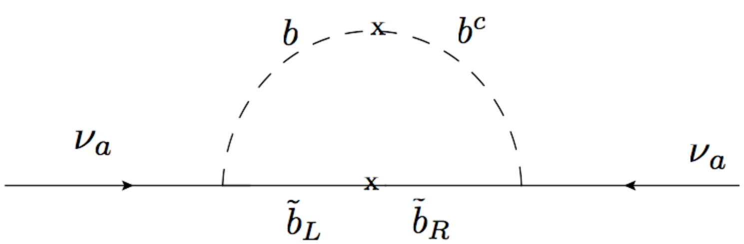
$y_\tau < 0.07 \qquad v_a > 15 \text{ GeV}$

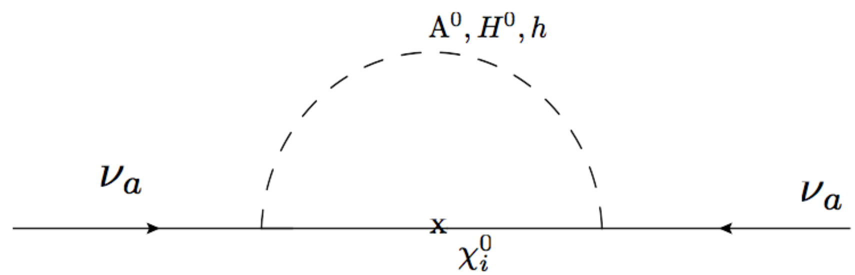
very high $\tan\beta$ excluded!

But R symmetry is not exact. Broken by gravitino mass

Majorana mass for gauginos and trilinear coupling generated through anomaly mediation

Neutrino mass generated





$$m_{\nu_a} < 1eV$$

Bounds on SUSY breaking Scale,

$$m_{3/2} < 1 \text{ MeV}$$

R symmetric gauge mediation

Gravitino LSP

(K.Benakli,M.GoodsellNucl.Phys. B816 (2009) 185–203,L.M Carpenter arXiv:1007.0017.)

μ / B_μ problem and $U(1)_R$

R symmetric gauge mediation

	MMRSSM	MSSM
μ term	$\mu H_u R_d$	$\mu H_u H_d$
B_μ term	$B_\mu h_u \tilde{l}_a$	$B_\mu h_u h_d$

Different fields

→ Different UV physics

Easier to generate

$$\mu^2 \sim B_\mu$$

μ/B_μ problem and $U(1)_R$

SUSY breaking spurion

μ → $\frac{1}{M}\int d^4\theta X^\dagger H_u R_d$ one loop

$m^2_{H_u}$ → $\frac{1}{M^2}\int d^4\theta (X^\dagger X) H_u^\dagger H_u$ one loop

$\mu^2 \sim B_\mu << m^2_{H_u}$ still fine tuning required

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$\int d^4\theta \frac{D^2(X^\dagger X)}{M} H_u R_d$ → Giudice,Dvali,Pomarol (1998)

R symmetric NMSSM

- R symmetry as lepton number allows to make the sneutrino the down type higgs!
- large parameter space for the sneutrino VeV

How does the MMRSSM look at the LHC?

Our R parity

$$R_a = (-1)^{3B+L_b+L_c+2s}$$

Lightest R_a odd particles charged lepton and neutrinos flavor a

Multileptons signature!

LHC pheno work in progress

Same signatures of Rp violating models, but there are distinctive features!

Possible to distinguish: Majorana vs Dirac gauginos

Ex same sign leptons signature absent when gauginos are Dirac

Copious leptoquark signatures

MMRSSM $y_b < 0.47$

MSSM with R_p violation $\lambda'_{133} = y_b < 10^{-4}$

$\tilde{b}_R \to b\nu_e$ or $\tilde{b}_R \to te$

$\tilde{t}_L \to be$

sizable branching ratio in the MMRSSM,
shorter decay chain!

Summary:

- MMRSSM has a minimal particle content for models with Dirac Gauginos
- The sneutrino is the down type Higgs
- Distinctive LHC phenomenology (copious leptoquark signatures, dirac gauginos)

Outlook

Generalize the idea to

$\mathrm{U}(1)_R$ total lepton number

All lepton superfields carry the same R charge, R(L)=0 and R(E)=2.

work in progress

with Grègoire, Kumar, Ponton dark matter

with Bertuzzo neutrino physics

BACKUP

L_a Yukawa coupling

$L_a L_a l_a^c$ null

$\int \frac{d^4\theta}{M} X^\dagger H_u^\dagger L_a l_a^c,$ need to be generated by SUSY breaking

$$W_{y_a} = M_X X_u X_d + y_1 X_d L_a l_a^c + y_2 H_u X_d \bar{\Phi} + y_3 X_u X_d \Phi,$$

$$y_a \sim \lambda \frac{y_1 y_2 y_3}{16\pi^2} \frac{F}{M_T^2}$$

$a = \tau$ $F \sim M_T^2$

low scale susy breaking