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MMRSSM: MoreMinimal MRSSM
Lepton number as R symmetry, sneutrino as down type Higgs

In collaboration with Thomas Grégoire

Pheno 2011, 09/05/11

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

Need to explore different SUSY breaking scenarios

SUPERSOFT SUSY BREAKING

(Fox, Nelson, Weiner, 2002)

no logs divergencies, gauginos heavier than scalars, ameliorate little hierarchy problem

R symmetric SUSY models

R symmetry

$U(1)_R$ continuous

It acts differently on the fermionic and bosonic component of a superfield

ChiralSuperField	R
bosonic component	R
fermionic component	$R-1$

$R(W^\alpha) = 1$

gauge boson 0
gauginos have R charge 1

Dirac gauginos

Majorana mass are forbidden by R symmetry.
Need to be Dirac fermions

How Dirac mass for the gauginos are generated?

SuperField	**R-charge**
$\psi_{\tilde{W}}$	0
$\psi_{\tilde{B}}$	0
$\psi_{\tilde{G}}$	0

New Adjoints superfields for each SM gauge group

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

supersoft operator

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

D term spurion

MRSSM

arXiv::0712.2039 [hep-ph]

MinimalRSymmetricSusySM

$R_p \subset U(1)_R$

Enlarged Higgs sector, two new doublets R_u R_d

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

Adjoints superfields for each SM gauge group to give Dirac mass to the gauginos

Is the MRSSM the more minimal R symmetric model?

Lepton number as R symmetry

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

No Majorana mass for the neutrino induced

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!

SOHD hep-ph 1103.1647v2

MMRSSM Superpotential

$$H_d \to L_a$$

$$a = e \text{ or } \mu \text{ or } \tau$$

higgsino mass

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

inert doublet

Down type Yukawa couplings= standard R_p violating couplings

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

just two higgs doublets!

Standard lepton number a violated

R symmetry/lepton number forbids Majorana mass for neutrinos

Experimental constraints from EWPM

1) Lepton Mixing

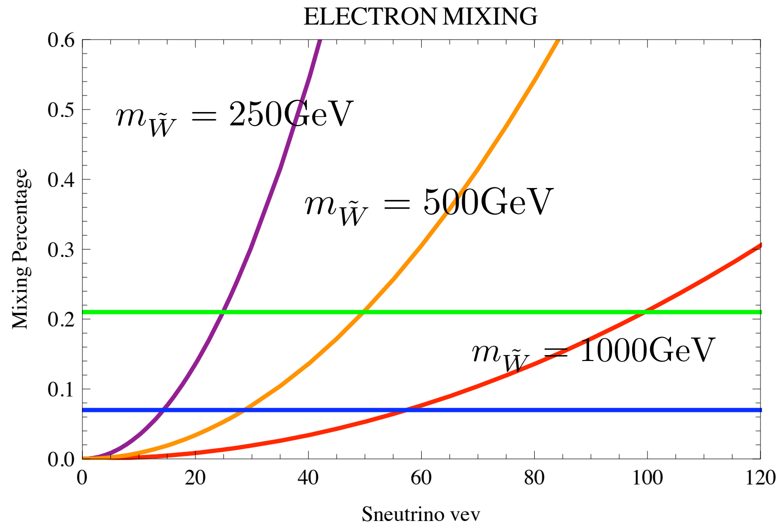
$a = e, \mu, \tau$

$$l'^{\pm}_a = \cos\phi \; l^{\pm}_a + \sin\phi \; \psi^{\pm}_{\tilde{W}},$$

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

$\cos\phi \sim -1 + g^2 \frac{v_a^2}{M_{\tilde{W}}^2}$ $\sin\phi \sim g \frac{v_a}{M_{\tilde{W}}}$ v_a sneutrino VeV

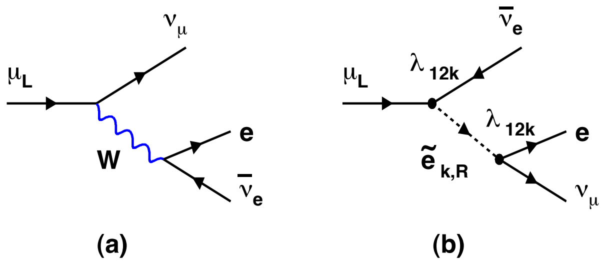
Constraints from gauge bosons coupling to leptons



Heavier wino bigger sneutrino VeV

2) Extra tree level contribution from down type Yukawa

fig. hep-ph/0406039v2



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

Contribution to G_F

Upper bound on the sneutrino VeV

$y_\tau < 0.07$ $v_a > 15\ \mathrm{GeV}$ very high $\tan\beta$ excluded!

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

How does it look the MMRSSM 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!

Typical signatures

$$\tilde{q} \to q\chi_1^0$$ **Neutralino NLSP**

$$\chi_1^0 \to W^{\pm} e^{\mp}$$

mixing lepton/chargino

$$\tilde{q} \to q\chi_1^0$$ **Right Stau NLSP**

$$\chi_1^0 \to \tau\tilde{\tau}_R \longrightarrow \begin{cases} e\nu_\tau \\ \tau\nu_e \end{cases}$$

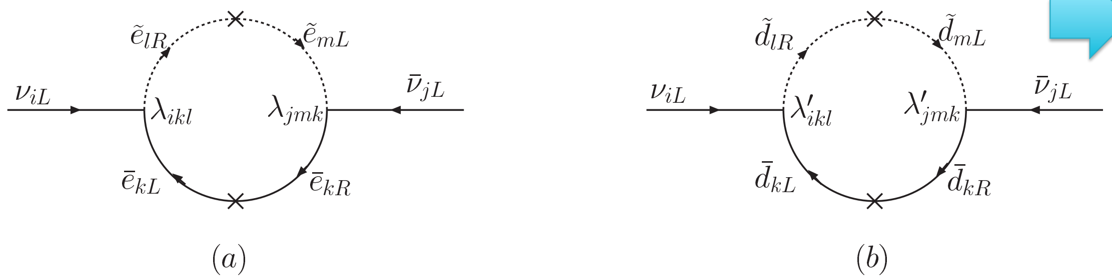
Same signatures of Rp violating models, but there are distinctive features!

Possible to distinguish: Majorana vs Dirac gauginos

Ex same sign leptons signature absent when gauginos are Dirac

or in the MMRSSM Stronger R_p violation

In the standard scenario trilinear R_p violating couplings induce neutrino mass, **in our case they don't (R symmetry lepton number)**.



left/right mixing forbids by R symmetry

fig. hep-ph/0406039v2

MMRSSM $y_b < 0.47$

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

Standard scenario more constrained!

Copious leptoquark signatures

MMRSSM $y_b < 0.47$

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

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

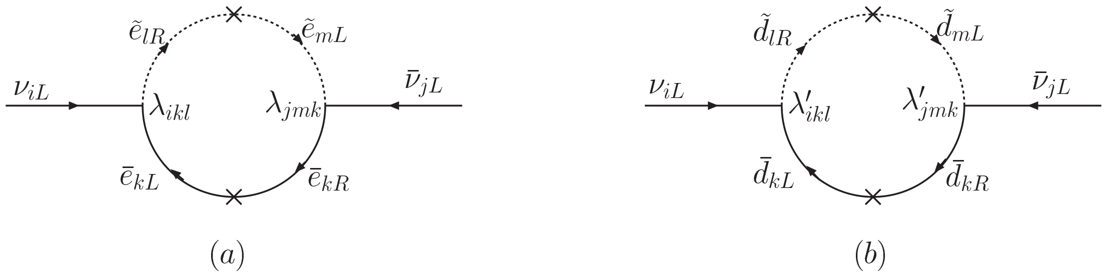
$\tilde{t}_L \rightarrow be$

sizable branching ratio in the MSSM,
shorter decay chain!

Conclusion

- MMRSSM has a minimal particle content
- The sneutrino is the down type Higgs
- Distinctive LHC phenomenology (copious leptoquark signatures, dirac gauginos)
- Naturalness of the model (mu problem, LEP bounds)
- Neutrino mass, and dark matter candidate

BACKUP



R symmetry forbids left/right mixing. No Majorana mass for the neutrino generated

But R symmetry is not exact. Broken by anomaly mediation

$$M_{\nu_a} = \frac{m_b v_u^2 m_{\frac{3}{2}}}{v_a (4\pi)^6 \Lambda^2} < 1 eV,$$

Bounds on SUSY breaking Scale, F <10^{16} (GeV)^2

R symmetric gauge mediation

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

$m_{3/2} < 1$ MeV

Gravitino LSP

EWSB

Same potential of the MSSM $h_d^0 \longrightarrow \tilde{\nu}_a$

$$V_{EW} = (\mu^2 + m_{H_u}^2)|H_u^0|^2 + m_{\tilde{\nu}_a}^2|\tilde{\nu}_a|^2 - B_\mu(H_u^0\tilde{\nu}_a + h.c.) + \frac{g^2+g'^2}{8}(|H_u^0|^2 - |\tilde{\nu}_a|^2)^2$$

no mu term for the sneutrino

R_d inert doublet

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

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

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

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

low scale susy breaking