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U(1)R as lepton number: third generation leptoquarks at the LHC

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hep-ph 1107.4634
hep-ph 1203.5340

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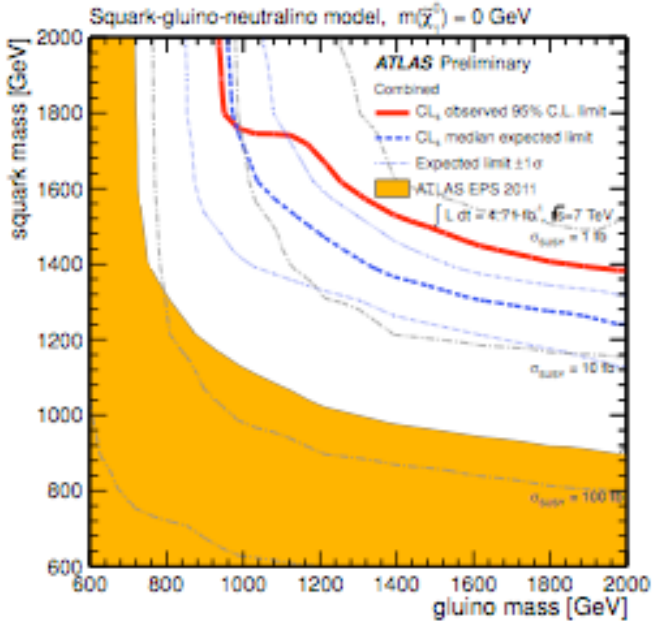
LHC stringent bounds on first/second generation squarks and gluino.



MSSM parameter space significantly constrained

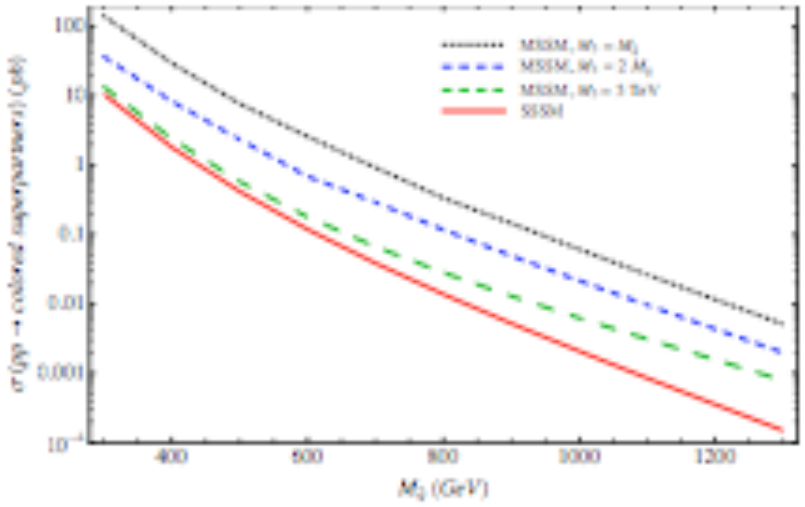
Need to explore different SUSY scenarios/ SUSY breaking mechanism

flavorful SUSY mediation, stealth SUSY, RPV..

Dirac gauginos

Squark production cross section lowered by heavy gluinos

MultiTeV Majorana gluinos problem for naturalness



hep ph 1203.4821

Dirac gluinos naturally heavier than scalars!

supersoft=no log divergencies, gauginos naturally heavier than scalars

(hep-ph/0206096)

Dirac gauginos

New Adjoints superfields for each SM gauge group $\psi_{\tilde{B}}$ $\psi_{\tilde{W}}$ $\psi_{\tilde{g}}$

We can now build models with a quasi exact R symmetry

SUSY flavor problems largely ameliorate

Advantages: hep ph 0712.2039

Larger CP violation (ew baryogenisis easier to accomodate) **hep ph 1107.1719**

R symmetric models

- MRSSM: R symmetry contains the standard Rp as discrete symmetry. R symmetric Higgs sector contains 4 doublets.

  hep ph 0712.2039

- $\mathrm{U}(1)_R$ as the lepton number. Sneutrino can play the down type higgs, just two doublets required. hep-ph 1107.4634

- $\mathrm{U}(1)_R$ baryon number **hep-ph 1110.6670**

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

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

single VeV basis: sneutrino flavor a down type higgs

$$\mathrm{W}= \mu H_u R_d + \lambda_S H_u \psi_{\tilde{B}} R_d + \lambda_T H_u \psi_{\tilde{W}} R_d + W_{yukawa} + W_{trilinear}$$

$$W_{Yukawa} = y^a_b L_a L_b e^c_b + y^a_c L_a L_c e^c_c + y^a_{di} L_a Q_i d^c_i,$$

$$W_{trilinear} = \sum_{i=a,b,c} \lambda_{bci} L_b L_c e^c_i + \sum_{ij} (\lambda'_{bij} L_b Q_i d^c_j + \lambda'_{cij} L_c Q_i d^c_j),$$

down type Yukawa couplings RPV couplings

U(1) lepton number for BSM particle violated

$$\lambda LLE^C \qquad \lambda' LQD^C$$

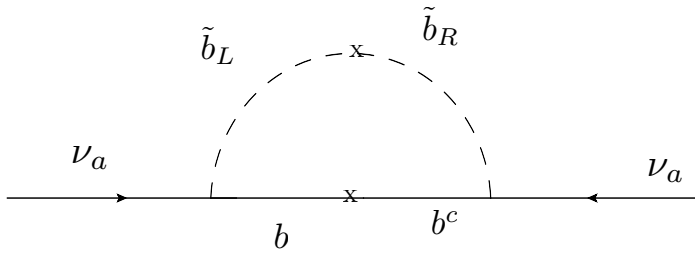
different constraints:
no bounds from neutrino physics!

$\lvert\lambda'_{i11}\lambda'_{j11}\rvert$		bounds from neutrino physics Barbier et al hep ph 040639	$5 \times 10^{-2}\ \tilde{d}^2\tilde{m}^{-1}$ $[m_\nu < 1\ \text{eV}]$
$\lvert\lambda'_{i12}\lambda'_{j21}\rvert$			$3 \times 10^{-3}\ \tilde{q}^2\tilde{m}^{-1}$ $[m_\nu < 1\ \text{eV}]$
$\lvert\lambda'_{i13}\lambda'_{j31}\rvert$			$8 \times 10^{-5}\ \tilde{q}^2\tilde{m}^{-1}$ $[m_\nu < 1\ \text{eV}]$
$\lvert\lambda'_{i22}\lambda'_{j22}\rvert$			$2 \times 10^{-4}\ \tilde{s}^2\tilde{m}^{-1}$ $[m_\nu < 1\ \text{eV}]$
$\lvert\lambda'_{i23}\lambda'_{j32}\rvert$			$5 \times 10^{-6}\ \tilde{q}^2\tilde{m}^{-1}$ $[m_\nu < 1\ \text{eV}]$
$\lvert\lambda'_{i33}\lambda'_{j33}\rvert$			$10^{-7}\ \tilde{b}^2\tilde{m}^{-1}$ $[m_\nu < 1\ \text{eV}]$ $(\tilde{m}^{d2}_{LR} = \tilde{m}\, M^d)$ (5.12)

These couplings could be larger, interesting pheno consequences!

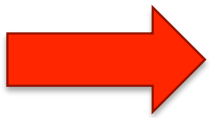
R symmetry is not exact. Broken by gravitino mass

Majorana mass for gauginos and trilinear coupling generated through anomaly or gravity mediation



Neutrino mass generated

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



Bounds on gravitino mass

$$\mathrm{m}_{3/2} < 100\ MeV$$

interesting implications for neutrino physics, hep-ph 1203.5340

connection with DM, work in progress

$U(1)_R$ lepton number and neutrino physics

hep-ph 1203.5340

R symmetry forbids Majorana mass for neutrinos

Majorana neutrino masses and mixings generated through the R symmetry breaking

Can we reproduce the correct pattern without additional degree of freedom?

Anomaly mediated R breaking

R preserving gravity mediation (hep ph **1008.1798**)

$$\mathcal{L}_{AM} = A^u \tilde{u}_r \tilde{q}_L H_u - A^d \tilde{d}_R \tilde{q}_L \tilde{l}_a - A^l \tilde{l}_a \tilde{l} \tilde{e}_R + M_{\lambda_{\tilde{B}}} \lambda_{\tilde{B}} \lambda_{\tilde{B}} + M_{\lambda_{\tilde{W}}} \lambda_{\tilde{W}} \lambda_{\tilde{W}} + M_{\lambda_{\tilde{g}}} \lambda_{\tilde{g}} \lambda_{\tilde{g}},$$

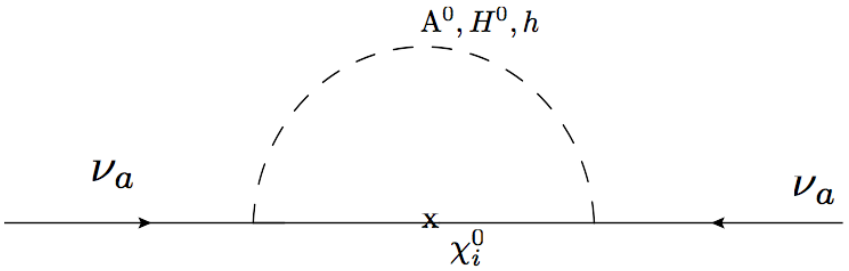
Majorana mass for the gauginos and scalar trilinear couplings (left/right mixing)

Neutrino masses at one loop

all three neutrino remain massless at tree level

same loops as RPV

different order of magnitude of parameters



$$m_{\nu_a} \simeq \frac{g^2}{4} \frac{M_M}{(16\pi^2)} \frac{m_Z^2}{m_D^2}$$

b_μ at EW scale

suppressed by the gauginos Majorana

Neutrino masses and mixings can be reproduced without the need of additional degrees of freedom

Normal or inverted hierarchy?

it depends crucially on the flavor a

Neutrino physics points out toward a gravitino in the mass range:

$$1MeV < m_{3/2} < 50MeV$$

gravitino DM candidate $\tilde{G} \to \nu_e \gamma$

$\tau > \tau_{universe}$ $\tau_{3/2} \sim 10^{28} - 10^{30} s$ work in progress

work in progress

LHC phenomenology

R symmetry
lepton number $\lambda'_{i33} \sim 1$

RPV MSSM $\lambda'_{i33} \sim 10^{-3}$

simple flavor ansatz: third generation couplings larger

$$\tilde{t}_L \to bl$$
$$\tilde{b}_L \to b\nu \quad \tilde{t}_L \to b\tau$$
$$\tilde{b}_R \to tt \qquad \tilde{b}_R \to tl$$

sizable branching ratio in the our framework, shorter decay chain!

Third generation leptoquarks

Signals with third generation quarks and leptons

tops, bottom and taus copiously produced at the LHC

$$\tilde{q} \to N_1 q$$

$$N_1 \to tb\tau$$

which is the smoking gun of the model?

how can we tell at the LHC that the RPV couplings are large?

Summarizing..

- Dirac gauginos interesting possibility to interpret LHC bounds
- R symmetry - R symmetry as lepton number
- The sneutrino is the down type Higgs
- Distinctive LHC phenomenology (copious leptoquark signatures)
- Interesting model building for neutrinos