A Theoretical Framework for R parity Violation

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based on

hep-th/0602238 Nucl. Phys.B, with R. Tatar (Liverpool)

hep-ph/0802.2584 with Kuriyama and Nakajima (Tokyo)

Symmetries

- Continuous symmetries
  - Lorentz, SU(3) x SU(2) x U(1), **supersymmetry**
  - chiral symmetry, baryon/lepton number
    - Yukawa couplings, SU(2) anomaly
- Discrete symmetries
  - Parity, charge conjugation, CP, **R-parity**
    - maximally broken in the Standard Model
- Truly fundamental: local continuous symmetries

R-parity

- Guarantees proton stability
  - Bilinear R-parity violation is not phenomenologically bad, except a little small coefficients required.

Hall-Suzuki '84

- Predicts LSP dark matter
  - Peccei-Quinn axion or semi-stable gravitino

- very small probability for discrete symmetries

Bilinear R-parity violation

- gauged U(1) symmetry → ~~$l\bar{5}.10.\bar{5}\hat{1}\ W$~~.
- spontaneous sym. breaking by FI $x^1\ 0, \langle f^+ \rangle^1\ 0,$
  - yet dim.-4 proton decay ops. absent if $\langle f^- \rangle = 0.$
- effective term $\mathrm{D}K = cZ^\dagger \langle f \rangle / M \bar{5} H(5).$
  - effective term → $\mathrm{D}W = c_i m_{3/2} \frac{\langle f \rangle}{M} L_i H_u = m_i L_i H_u.$

pheno constraints: $|m_i| \lesssim 10^{-5} - |m|.$ **(OK. for light gravitino)**

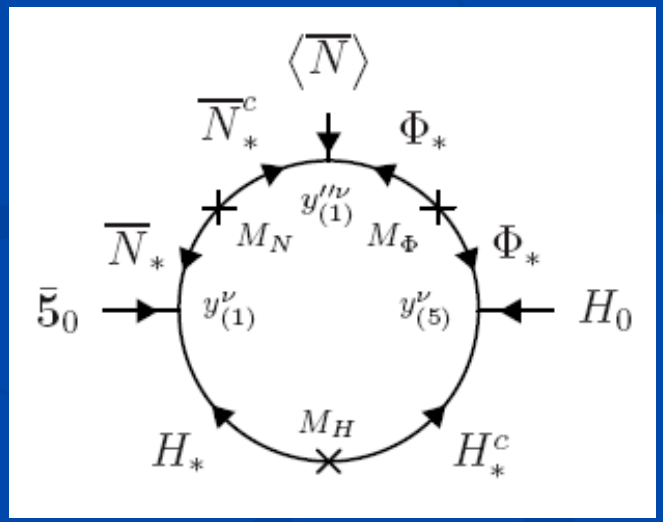
Giudice Rattazzi '97

needs a microscopic theory

Tatar TW 06, Kuriyama Nakajima TW '08

- gauged U(1) can be embedded in E_8. **(also in string th.)**
- the bilinear R-parity violation
  - highly suppressed at tree-level,
  - generated at 1-loop, UV-finite,

$$c : \frac{y^2}{16\pi^2}\frac{y\langle f\rangle}{M_{KK}}\left(\frac{M_{KK;1}}{M_{KK;2}}\right)^{1-3}, \qquad \langle f\rangle : O(M_{KK})$$

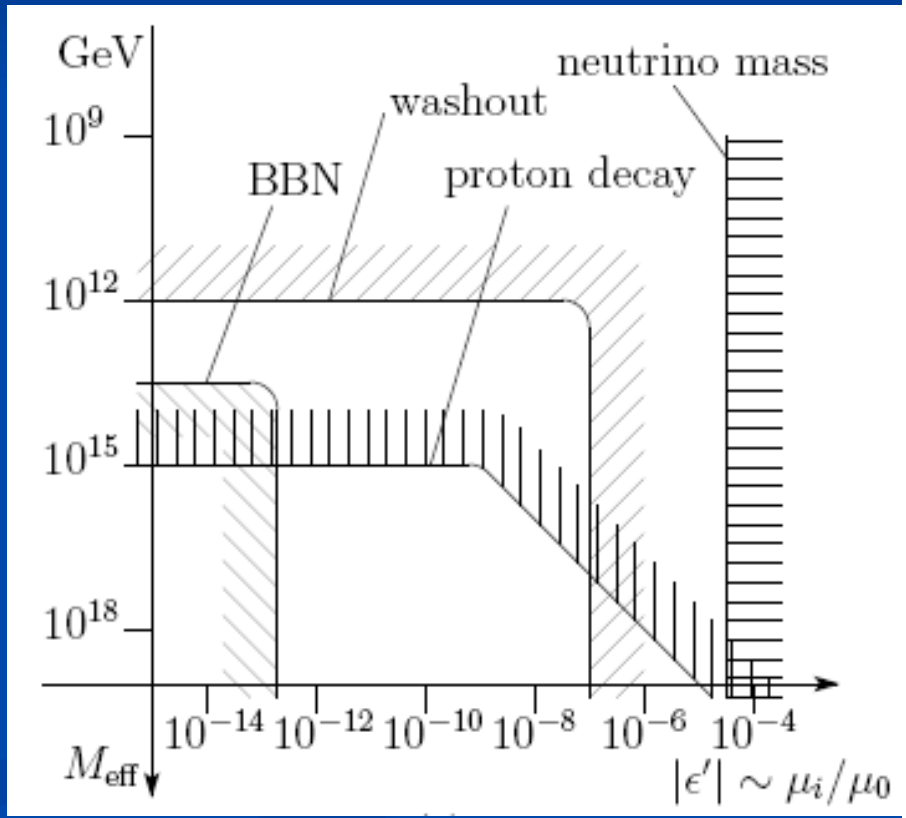


- various sources of suppression multiply, c can be small.
- do not expect ordinary flavour structure.

parameter space

- dim.-5 $\not{R}_p$ also generated.
- pheno constraints
  - neutrino masses
  - BBN,
  - washout $\Delta B/L$
    - flavour, cosmo dependent
  - proton decay
    - predicts B-L breaking

$$n \to l^- + M^+ .$$



pheno motivation: S. Matsumoto on Thu.

$\not{R}_p$ SUSY, $m_{3/2} > 100$MeV.

visible-sector LSP decay at the LHC

	within the beam pipe	tracker, E/H-cal, μ	outside the detectors
$\tilde{B}^0$	dominant decay modes $\tilde{B}^0 \to W^{\pm} l^m, Z n$	displaced vertices	as if no R-parity violation
$\tilde{y}$ (NMSSM)	$\tilde{y} \to n + s/a$ is also possible.		missing Et available
$\tilde{l}$	$\frac{Br(\tilde{l} \to n_{\mu} l)}{Br(\tilde{l} \to n_{m,e} t)} \gg O(1)$.		tracks of a heavy stable charged particle

Are we prepared?

some groups working on collider signals

- Case 1: vLSP is $\tilde{B}^0$, short lifetime,

  $\tilde{B}^0 \to W^{\pm} t^{(*)}, Z n$ is the dominant decay mode.

  eg. 4 hard jets + 2 W's + 2 tau-like jets

  overlapping cones, tau-tag,
  data driven bg estimation ....

reduced missing Et

- Case 2: vLSP is singlino, short lifetime,

  $\tilde{S} \to n + s/a, \quad s/a \to b\bar{b}, t\bar{t}.$

  e.g. 8 hard jets (incl. b/tau-like jets)

  maybe more final states
  due to the cascade decay down to $\tilde{S}$

back-up slides

Dimension 4 Proton Decay

- $SU(5)_{GUT}$ gauge symmetry allows

$$W = y^{u}\,10.10.H(5) + y^{d/e}\,\bar{5}.10.\bar{H}(\bar{5}) + /\,\bar{5}.10.\bar{5}.$$

up-type Yukawa **down-type/charged lepton Yukawa**

$$10 = \begin{pmatrix} \cdot & \bar{U} & Q \\ \bar{U} & \cdot & Q \\ Q & Q & \bar{E} \end{pmatrix} \qquad \bar{5} = \begin{pmatrix} \cdot & \cdot & \bar{D} \\ \cdot & \cdot & \bar{D} \\ \bar{D} & \bar{D} & L \end{pmatrix}$$

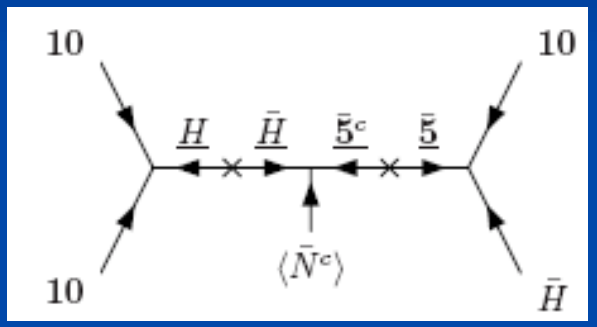
$$/\,\bar{5}.10.\bar{5} \to /\,L.\bar{E}.L + /\,'\bar{D}.Q.L + /\,''\bar{D}.\bar{U}.\bar{D}.$$

$$\Delta L = 1 \;\&\; \Delta B = 0.$$

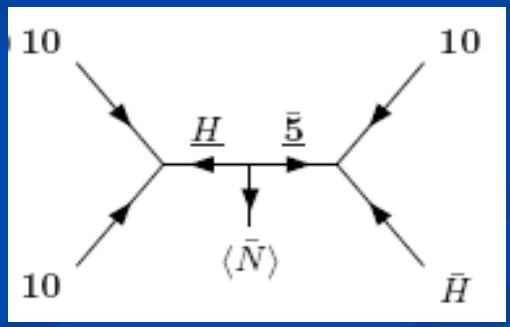
Too rapid proton decay unless $|/\,'/\,''| \lesssim 10^{-25}$.

Dim.-5 R-parity Violating Operators

- $W \sim 10.10.10.\bar{H} \rightarrow QQQH_d + Q\bar{U}\bar{E}H_d$ is generated.



(4+1 model)



(3+2 model)

- Vev insertion is not always holomorphic.
  - inverse power, complex conjugate vev,
- U(1) + holomorphy principle is not always applied.