A natural framework for baryonic R-parity violation in GUT

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CP^3 - Origins

Particle Physics & Origin of Mass

University of Southern Denmark

15 April 2013, Portoroz

Baryonic R-parity violation and GUT

- To appear soon, in collaboration with

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Andrea Romanino (SISSA, Trieste)

Outline

- SUSY with RPV
- GUT & Baryonic RPV: the problem
- A simple model in SO(10)
- Conclusions

MSSM with R-parity

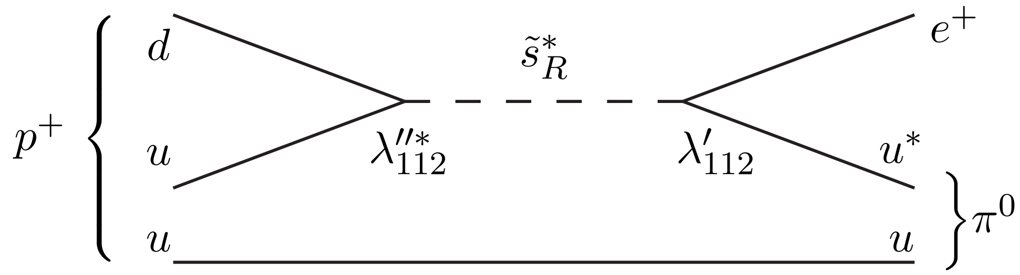
•Most generic superpotential

$$W_{RPC} = y_U^{ij}\hat{q}_i\hat{u}_j^c\hat{h}_u + y_D^{ij}\hat{h}_d\hat{q}_i\hat{d}_j^c + y_E^{ij}\hat{h}_d\hat{\ell}_i\hat{e}_j^c + \mu\,\hat{h}_u\hat{h}_d\,,$$

$$W_{RPV} = \mu^i\hat{h}_u\hat{\ell}_i + \tfrac{1}{2}\lambda^{ijk}\hat{\ell}_i\hat{\ell}_j\hat{e}_k^c + (\lambda')^{ijk}\hat{\ell}_i\hat{q}_j\hat{d}_k^c + \tfrac{1}{2}(\lambda'')^{ijk}\hat{u}_i^c\hat{d}_j^c\hat{d}_k^c$$

- B and L numbers violating couplings
- Dangerous contribution to the proton decay

$$\Gamma_{p\to e^+\pi^0} \sim m_{\rm proton}^5 \sum_{i=2,3} |\lambda'^{11i}\lambda''^{11i}|^2/m_{\tilde{d}_i}^4,$$



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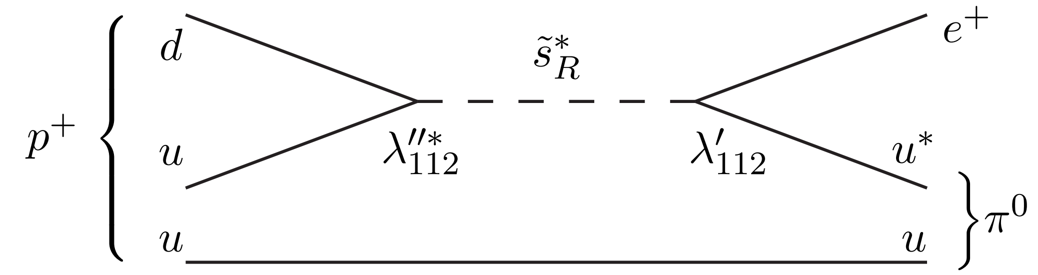

- Possible solution: MSSM + R-parity $\quad P_R = (-1)^{3(\mathrm{B-L})+2s} \quad P_M = (-1)^{3(\mathrm{B-L})}$

- Consequences:

  (i) Lightest SUSY particle stable, possible DM candidate
  (ii) SUSY particle pair produced at colliders
  (iii) Each S-particle decay chain ends with an odd numbers of LSP (missing energy @ LHC)

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3) R-Parity violation is welcome

R-parity conservation leads to the prototypical SUSY signal: missing energy.

$$m_{\tilde{q}}, m_{\tilde{g}} \gtrsim 1 \text{ TeV}$$

Bounds can be relaxed in the presence of RPV

R-parity violation @ LHC

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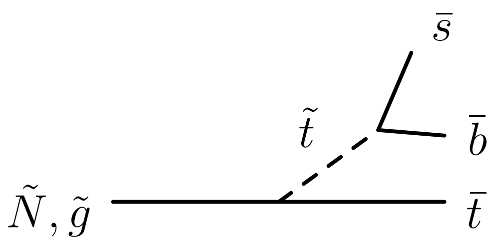
No missing energy!



$$\Gamma = \lambda_{ijk}^2 \frac{\alpha}{128\pi^2} \frac{m_{\tilde{\chi}_1^0}^5}{m_{\tilde{f}}^4}$$

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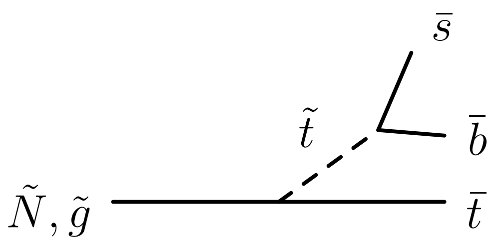

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$$L = 100\,\mu\mathrm{m}\,(\beta\gamma)\left(\frac{m_{\tilde{f}}}{500\ \mathrm{GeV}}\right)^4 \left(\frac{100\ \mathrm{GeV}}{m_\chi}\right)^5 \left(\frac{2\cdot 10^{-3}}{\lambda}\right)^2$$

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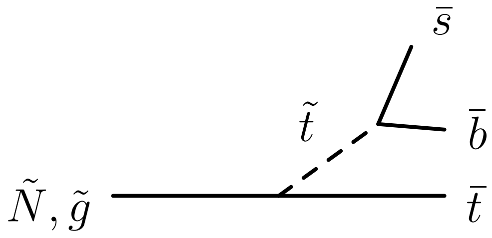

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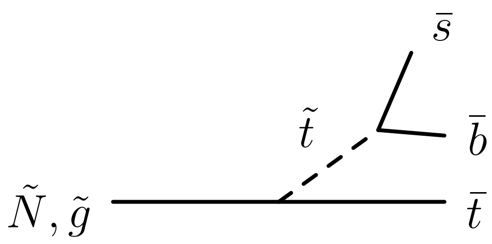

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L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-007]

$\tilde{g} \to \tilde{t}t, \ \tilde{t} \to bs$

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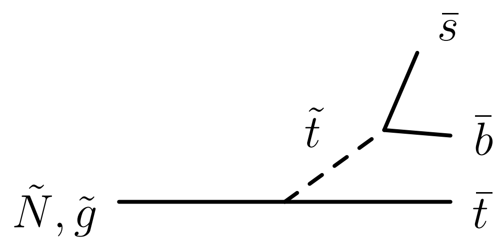

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- We improve on naturalness respect to RPC, but now, what about GUT?

RPV and GUT: the problem

- Is it possible to obtain the obtain the BNV operator without generating the LNV ones in GUT?

$$W_{\rm eff}^{\rm ren} = W_{\rm MSSM} + \lambda''_{ijk} u_i^c d_j^c d_k^c,$$

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- Previous attempts:
  1. Smirnov, Vissani (1996) - SU(5) + fine tuning
  2. Tamvakis(1996) - SU(5) + large representations
  3. Giudice-Rattazzi (1997) - Flipped SU(5)
  4. Bhattacherjee, et al. (2013) - SU(5)xSU(3)

RPV and SO(10)

- Consider SO(10) with matter in the $16_i = q_i \oplus u_i^c \oplus d_i^c \oplus \ell_i \oplus e_i^c \oplus \nu_i^c$
- To get the BNV operator we need a trilinear term in the 16, for example

$$\frac{16_H 16_i 16_j 16_k}{\Lambda} \xrightarrow[\langle 16_H \rangle]{} e^c \ell \ell + q d^c \ell + u^c d^c d^c$$

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- A possible way to project out the SU(2) doublets from the 16 is trough

$$\langle 45_R \rangle = V_R T_{3R} \qquad (\langle 45_R \rangle 16_i)_{16} = V_R \left(-\tfrac{1}{2} u_i^c + \tfrac{1}{2} d_i^c + \tfrac{1}{2} e_i^c - \tfrac{1}{2} \nu_i^c\right)$$

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- Finally we get $\dfrac{16_H (45_R 16_i)_{16} (45_R 16_j)_{16} 16_k}{\Lambda^3} \xrightarrow[\langle 16_H \rangle \langle 45_R \rangle]{} u^c d^c d^c$

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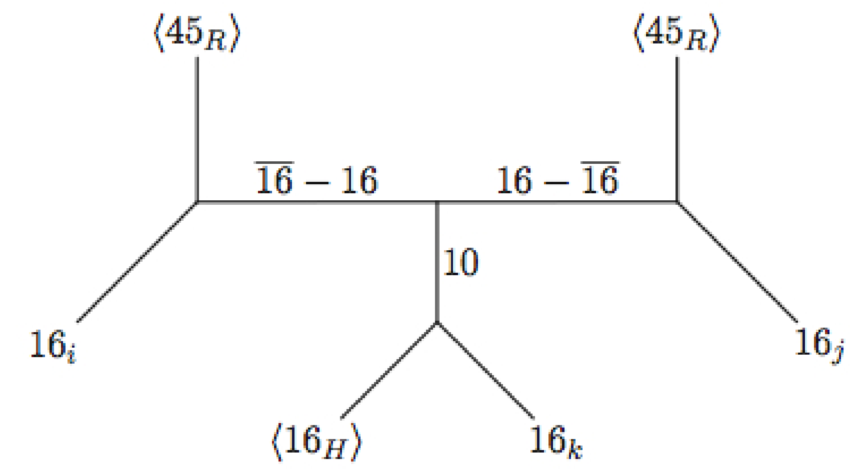
- This can be obtained in renormalizable theory



Baryonic RPV

$$W_{\Delta B=1} = \mu_{16} 16\, \overline{16} + \mu_{10} 10\, 10 + \alpha_i 16_i 45_R \overline{16} + \beta_i 16_i 16_H 10 + \eta\, 16\, 16\, 10$$

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- $\eta\, 16\, 16\, 10$ generates only baryonic RPV!

Yukawa sector

- MSSM chiral superfields are in non pure embedding of $16_i \oplus 16 \oplus \overline{16} \oplus 10$

- Assuming that the Higgs up and down are in 10_v , we get at the ren. level

$$W_Y = y_{ij} 16_i \, 16_j \, 10_v + z_i 16_i 16 \, 10_v$$

- Remember that light MSSM chiral superfields are "selected" by

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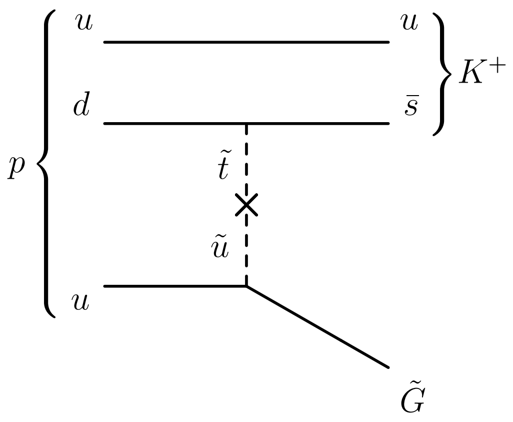
- Size of baryonic RPV couplings is related to structure of the flavor sector

$$\eta 16\, 16\, 10 \longrightarrow \begin{cases} 16 \rightarrow a_i u_i^c \\ 16 \rightarrow b_i d_i^c \\ 10 \rightarrow c_i d_i^c \end{cases} \longrightarrow \lambda''_{ijk} \propto a_i \left(b_j c_k - b_k c_j \right)$$

Phenomenological consequences

- Proton decay... depends on the gravitino mass

$$m_{\tilde{G}} > 1 \text{ GeV}$$



- Delta B=2 processes

$$\begin{aligned}
|\lambda''_{112}| &< \mathcal{O}(10^{-5}) \quad [NN \to KK]\,,\\
|\lambda''_{113}| &< \mathcal{O}(10^{-2}) \quad [n - \overline{n}]\,,\\
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$$m_{\tilde{f}} = 500 \text{ GeV}$$

- Flavor physics

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|\lambda''_{i12}\,\lambda''_{i23}| &< 0.8 \times 10^{-3} \quad [B^- \to \phi\pi^-]\,,
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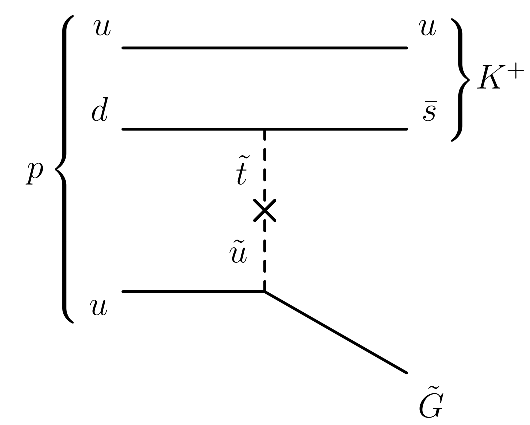

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|\lambda''_{i12}\,\lambda''_{i23}| &< 0.8 \times 10^{-3} \quad [B^- \to \phi\pi^-]\,,
\end{aligned}$$

- GUT correlation $\lambda''_{ijk} \propto a_i\,(b_j c_k - b_k c_j) \longrightarrow \dfrac{\lambda''_{i12}}{\lambda''_{j12}} = \dfrac{\lambda''_{i13}}{\lambda''_{j13}} = \dfrac{\lambda''_{i23}}{\lambda''_{j23}}$

- Natural to expect larger couplings with the heavier families like in MFV or Partial Compositeness [in progress]

Conclusions

- Baryonic RPV and GUT are compatible
- General framework: vector-like families + splitting mechanism
- Simple models can be constructed
- Flavor structure of the BNV couplings is non generic