The Fate of R-Parity

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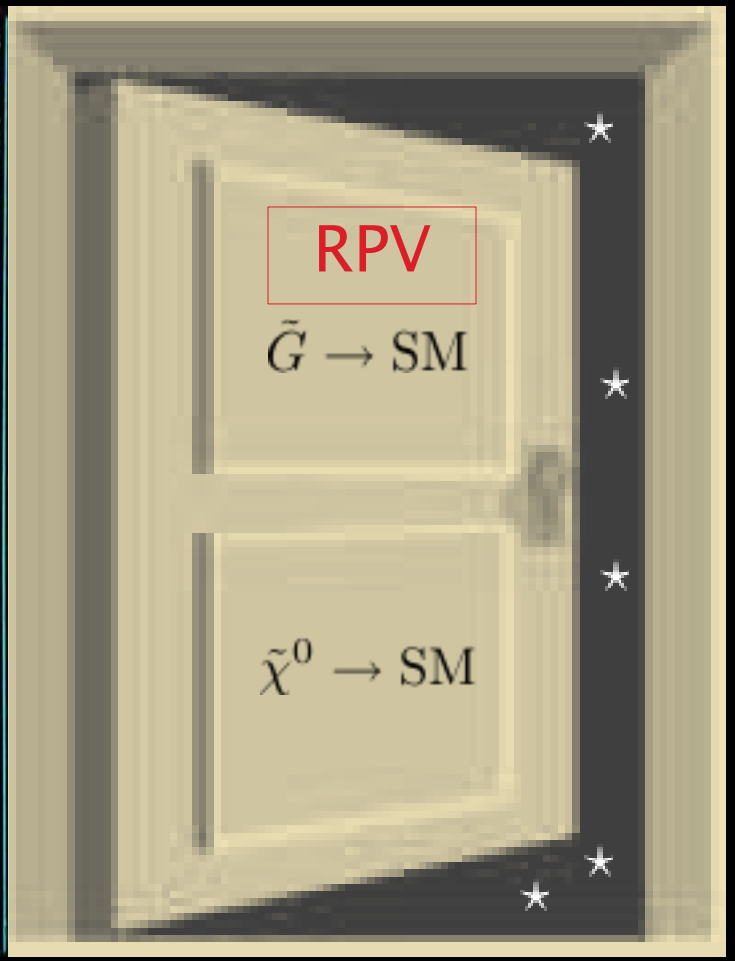
Planck 2010: CERN

References

- P. Fileviez Perez, S.S., **Phys.Lett.B673:251**, 2009
- V. Barger, P. Fileviez Perez, S.S., **Phys.Rev.Lett.**102:181802,2009
- P. Fileviez Perez, S.S., **Phys.Rev.**D80:015004,2009
- L. Everett, P. Fileviez Perez, S. S., **Phys.Rev.**D80:055007,2009
- P. Fileviez Perez, S. S., **arXiv:** 1005.4930

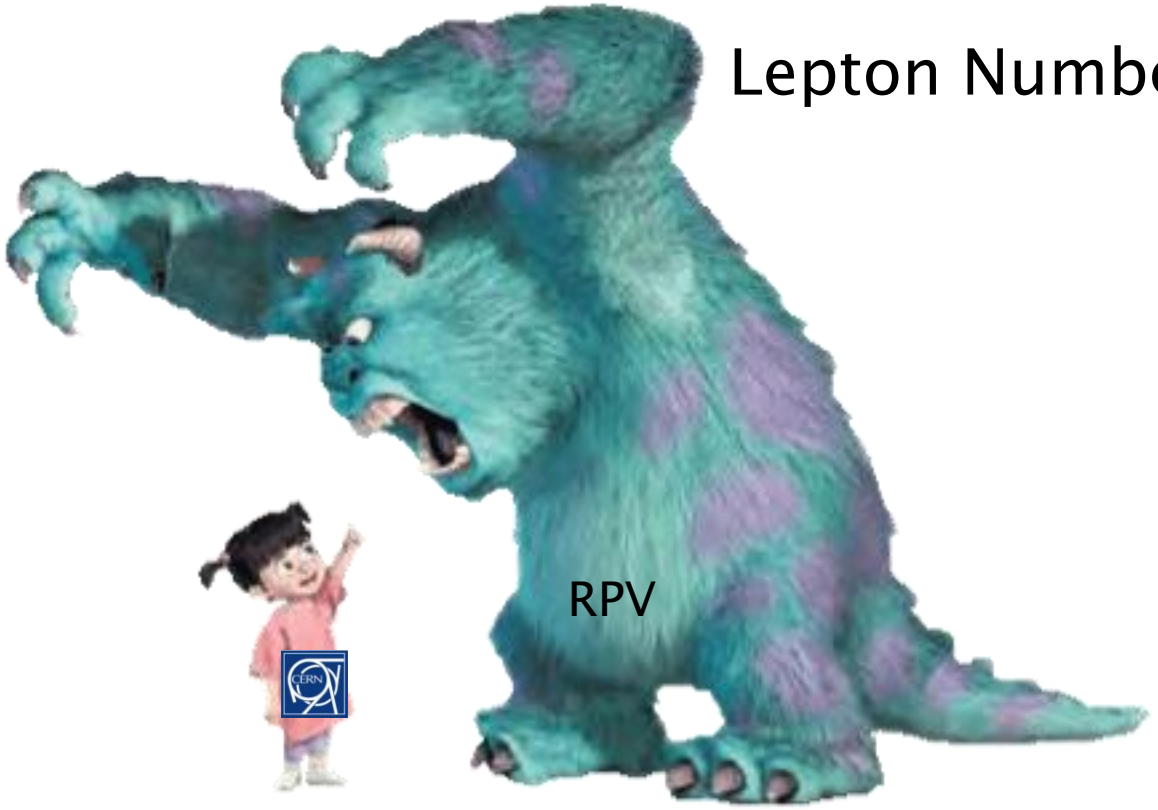
SUSY: Cosmo & Pheno hinges on status of R-parity.



RPC

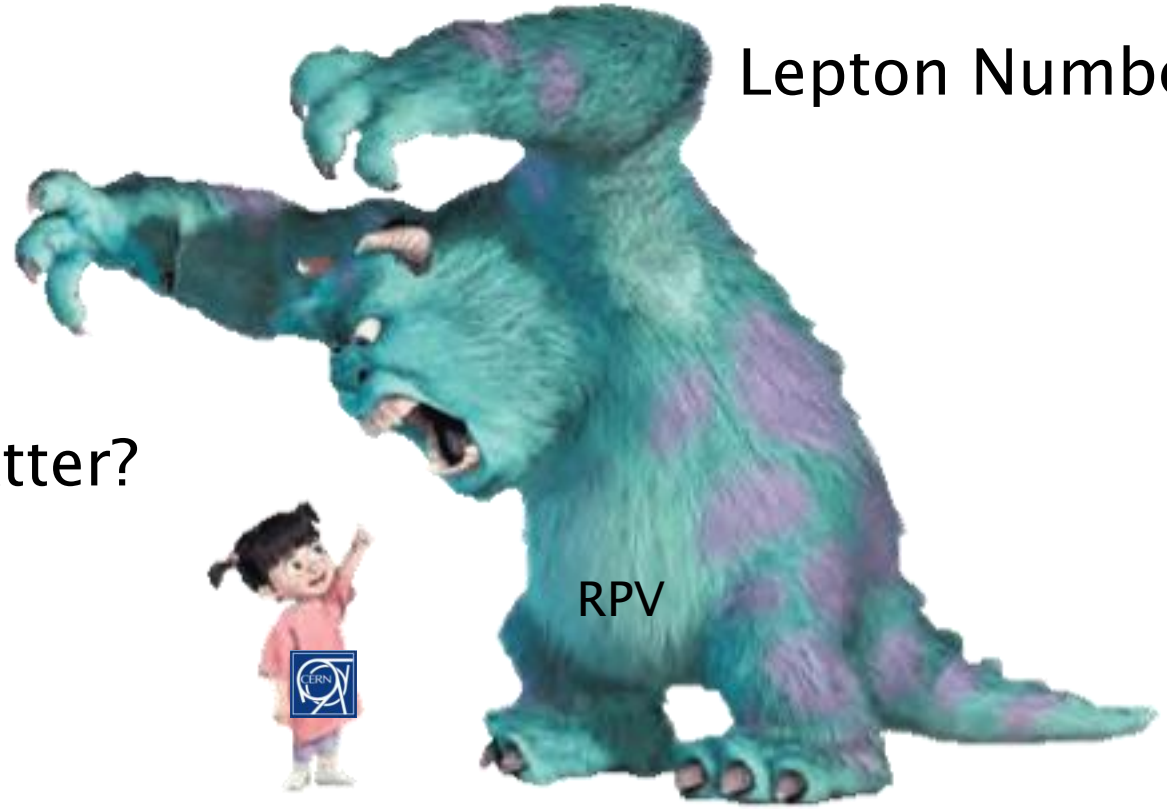
Stable
DM

R-Parity Violation Can Be Scary!



Lepton Number Violation?

R-Parity Violation Can Be Scary!



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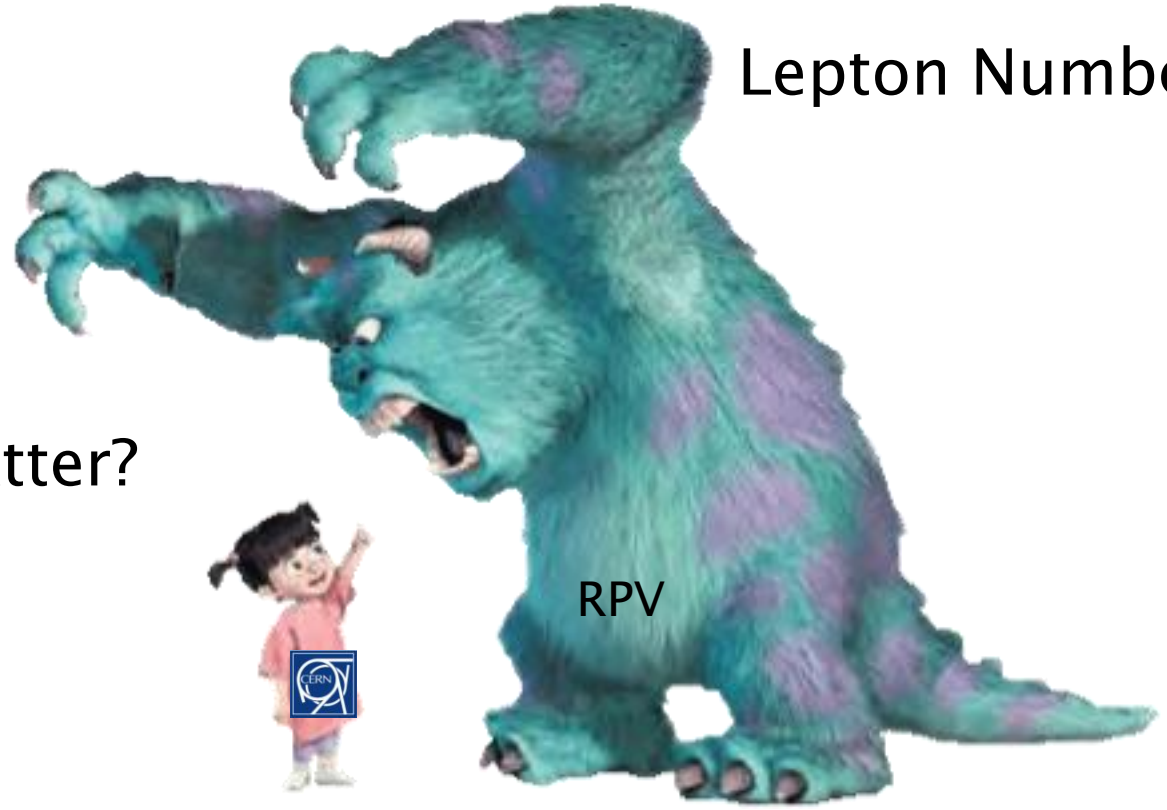

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No Proton decay!

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m_ν **and** lepton # is Safe!

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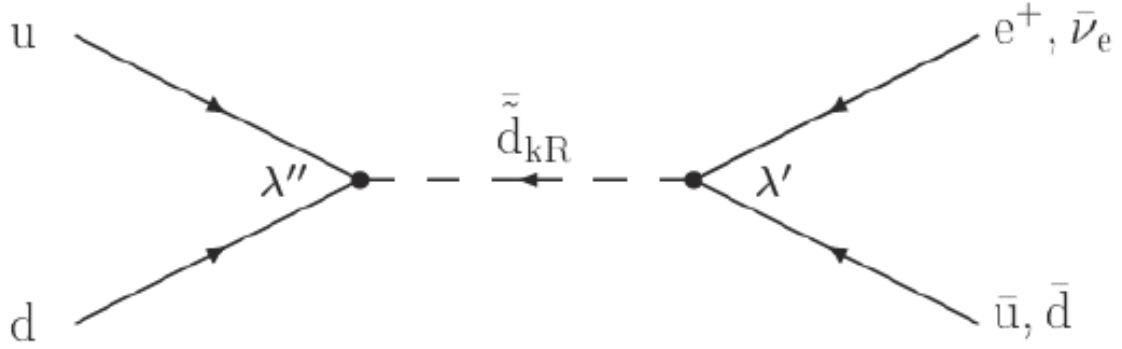
Dark Matter Candidate: gravitino LSP

B – L violation: proton decay

- MSSM does not have accidental *B–L:*

$$W \supset \lambda'' \hat{U}^C \hat{D}^c \hat{D}^C + \lambda' \hat{Q} \hat{L} \hat{D}^C$$

- Rapid proton decay



$\tau_p > 10^{32}$ years

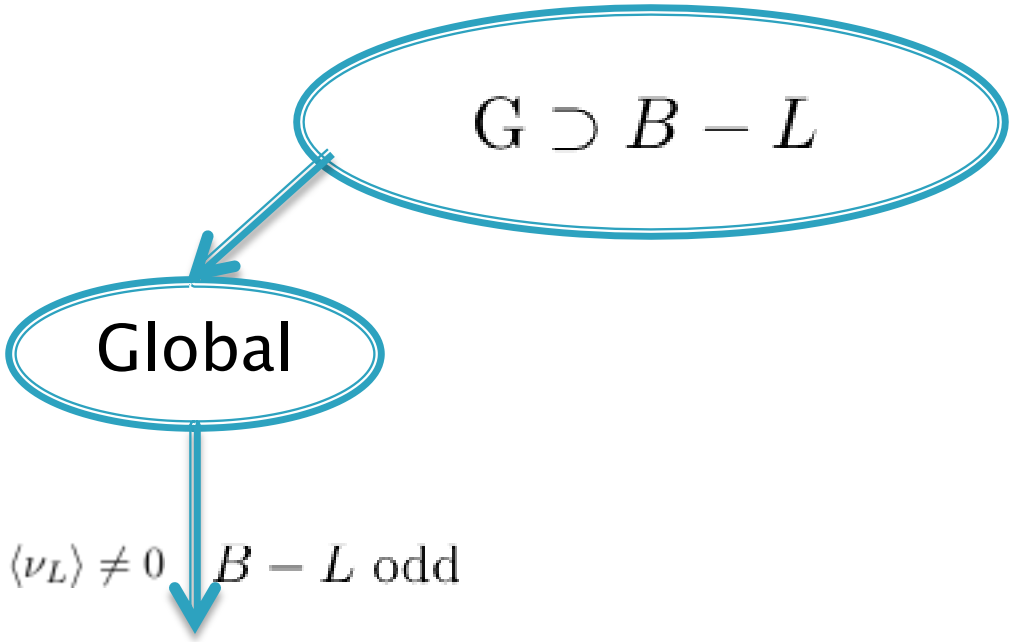
$|\lambda' \lambda''| < 10^{-26}$

- Impose $R = (-1)^{3(B-L)+2S}$
  - Discrete symmetry is unsatisfying!
  - Remember the connection to *B – L*

B-L and R-parity

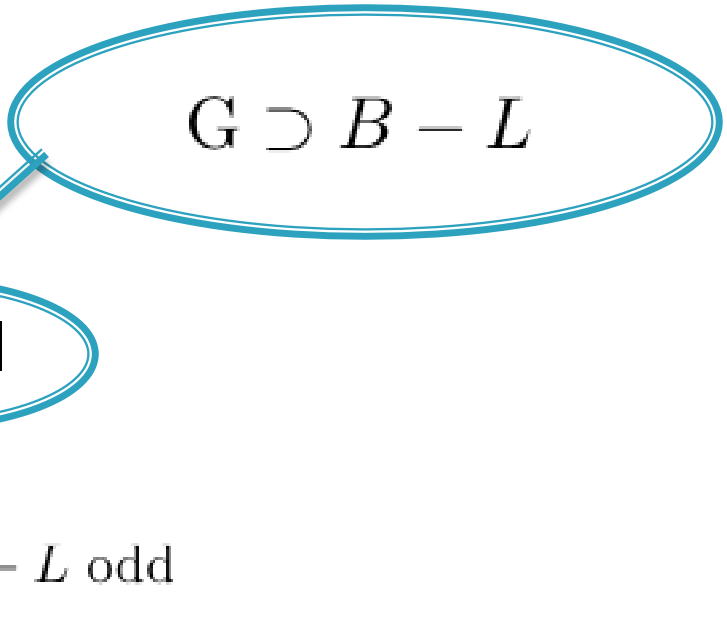
$$\mathrm{G} \supset B - L$$

B-L and R-parity



Breaking: $\langle \nu_L \rangle \neq 0$ $B - L$ odd

B-L and R-parity



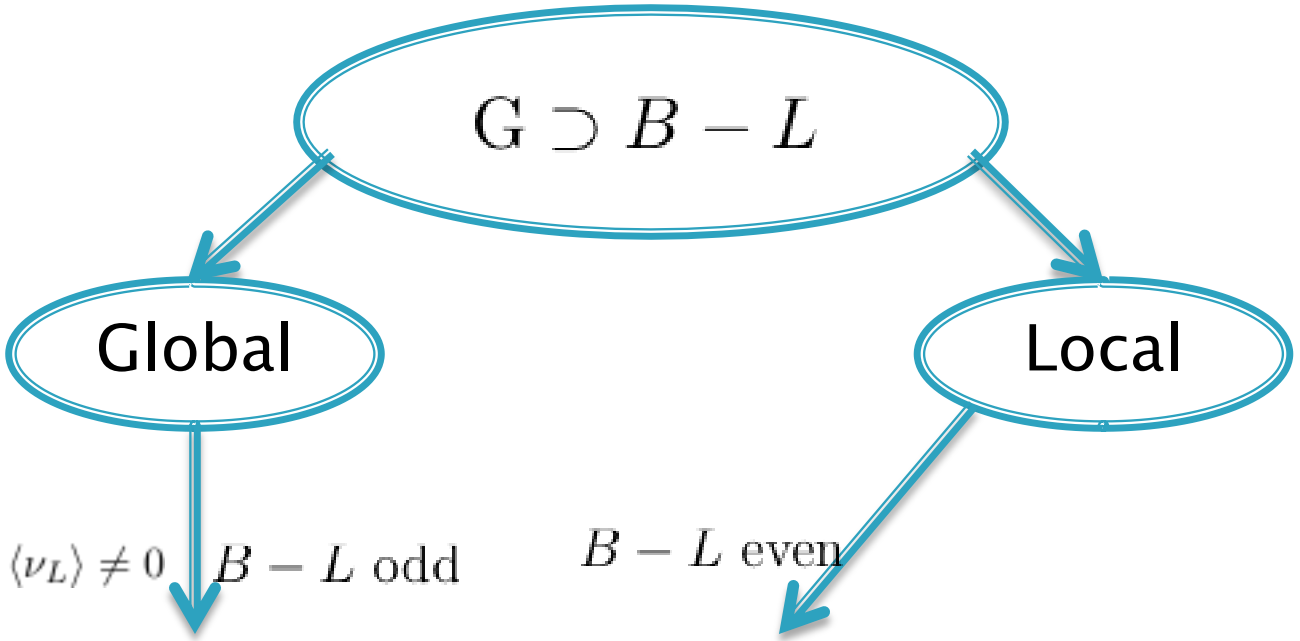
Breaking:

MSSM + RPV

Majoron Problem

Aulakh,Mohapatra'82
Masiero, Valle'90

B-L and R-parity



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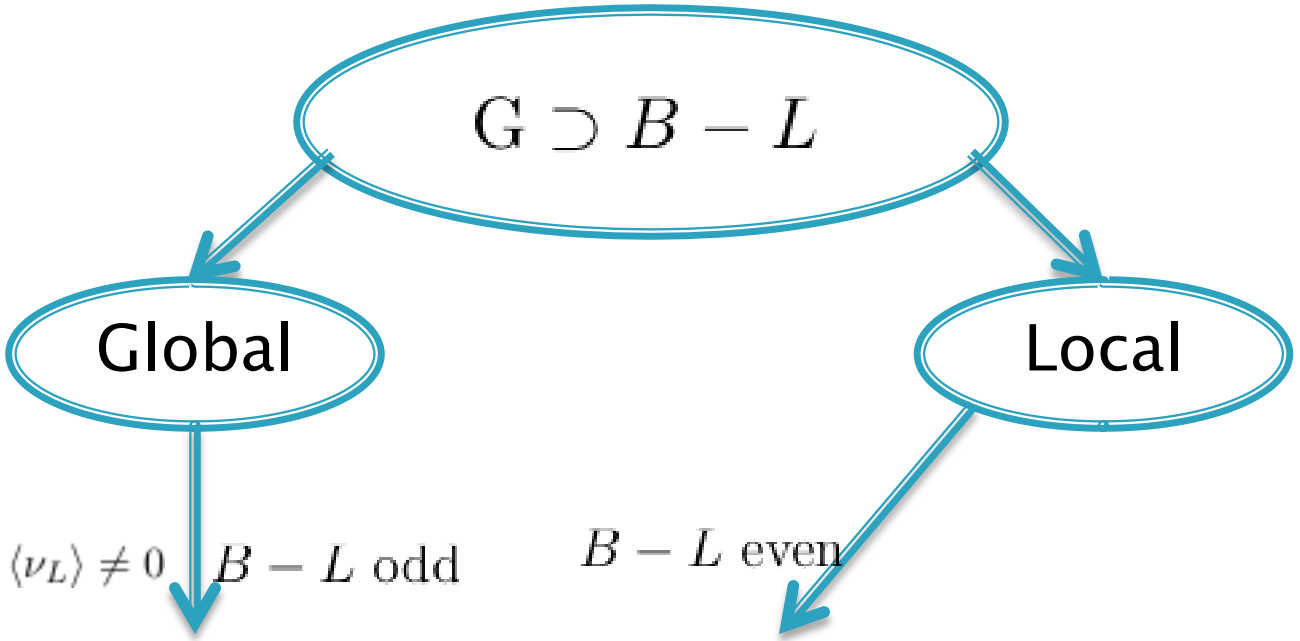

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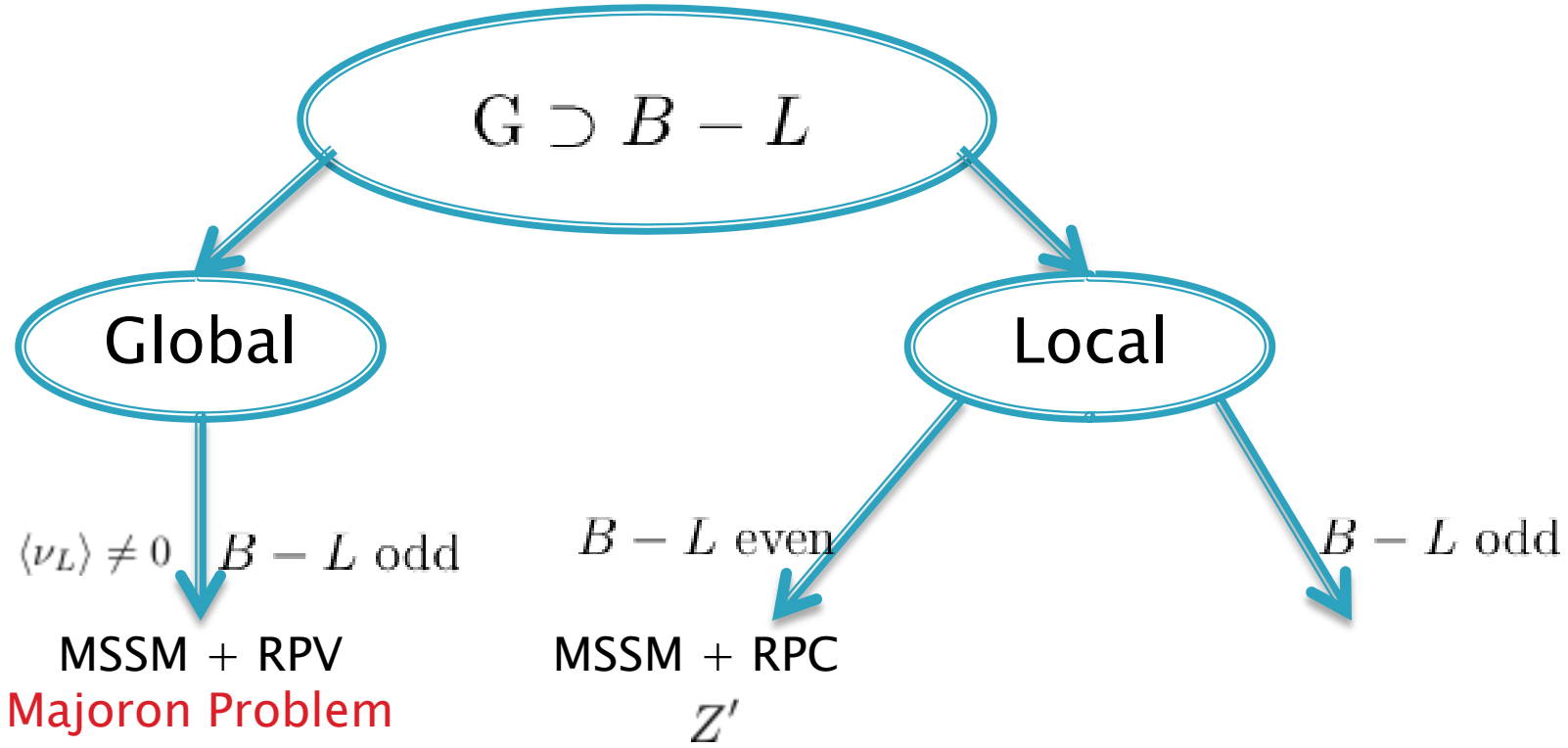

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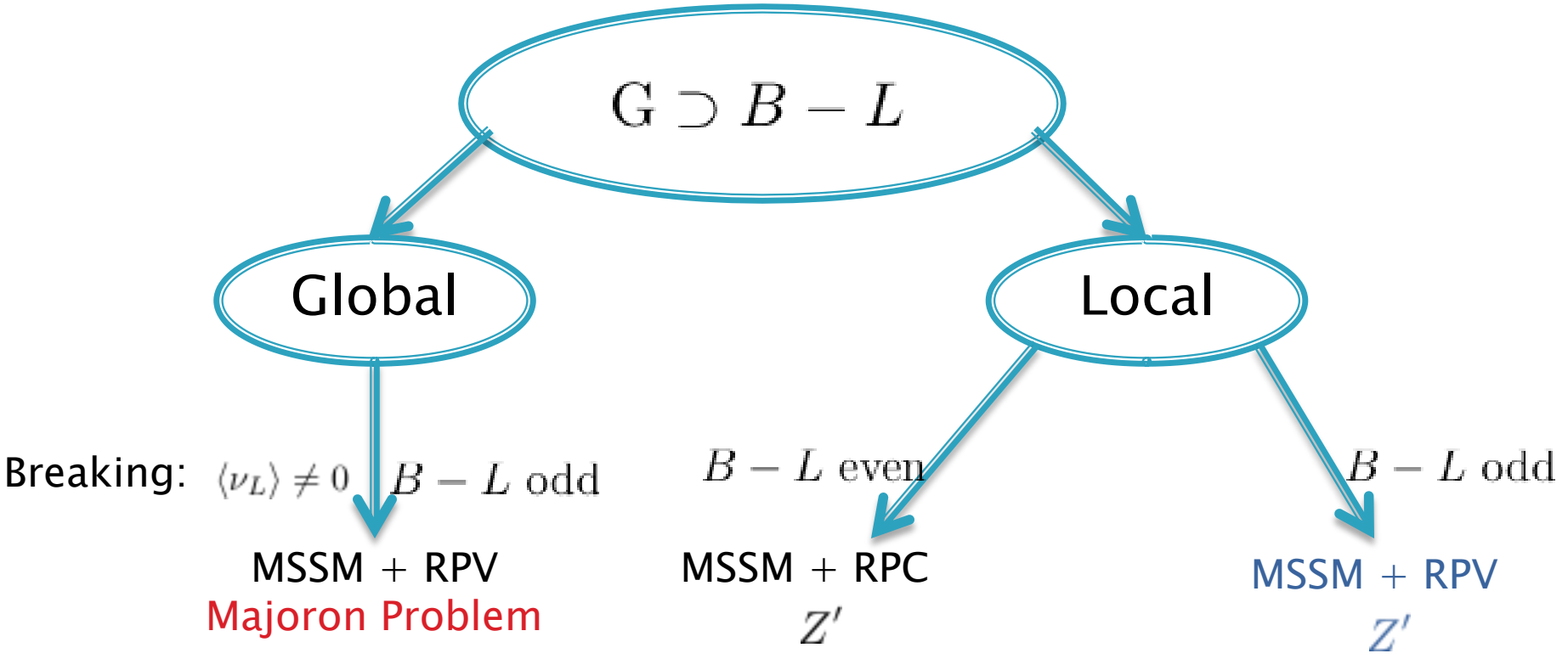

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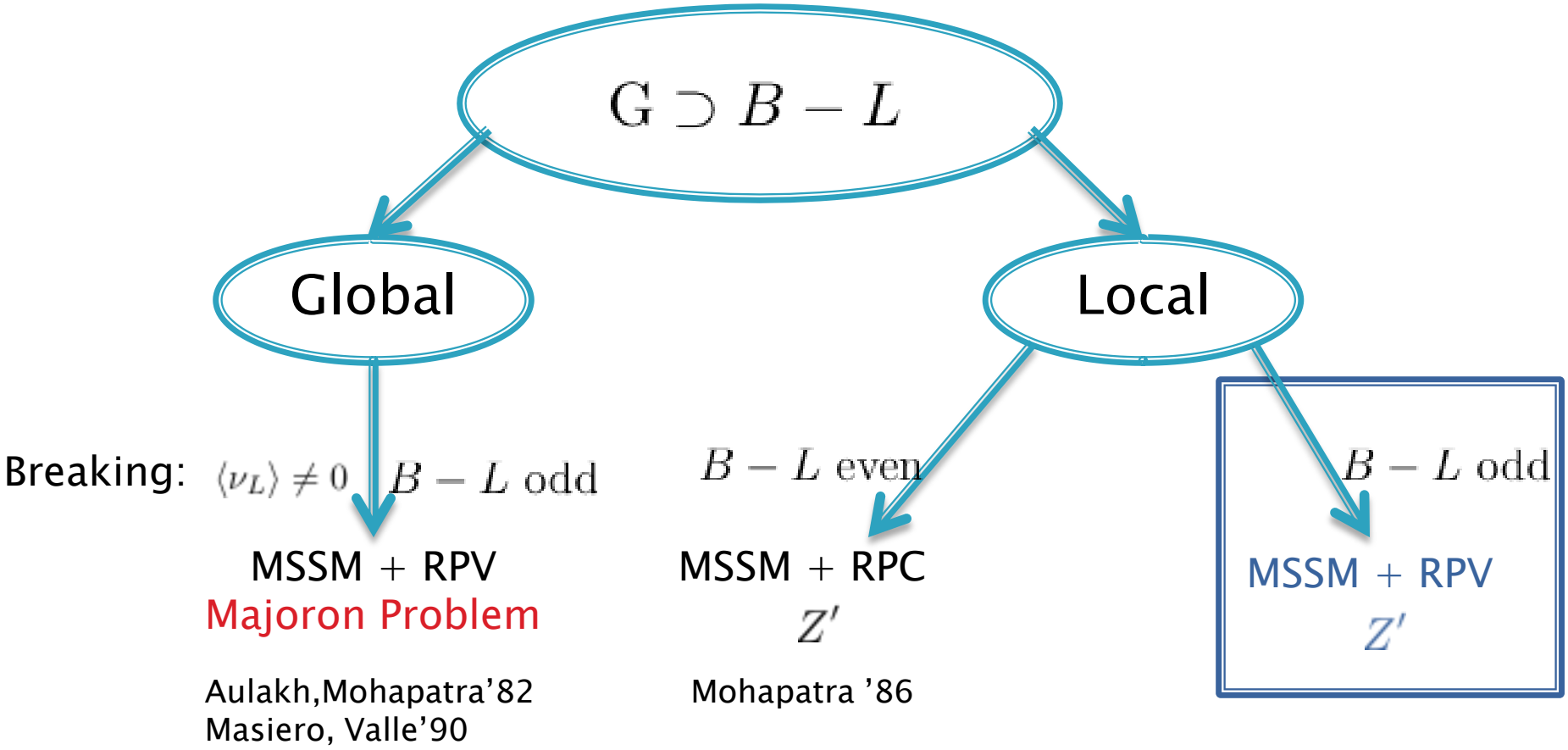

V. Barger, P. Fileviez Perez, S.S., **Phys.Rev.Lett.**102:181802,2009

Local B–L: $\mathrm{SM} \times U(1)_{B-L}$

$$\text{Quarks: } B-L=\pm\frac{1}{3}; \qquad \text{Leptons: } B-L=\pm 1$$

$\hat{N}^c \sim (1,1,0,1)$ – For anomaly cancellation

$$W_{B-L} = W_{\mathrm{MSSM}} + Y_\nu \hat{L}\hat{H}_u\hat{N}^C$$

But, how is *B–L* broken?

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But, how is *B–L* broken?

$$\left\langle \tilde{N}^C \right\rangle \equiv \frac{v_R}{\sqrt{2}} \neq 0 : \ \mathrm{SM}\otimes U(1)_{B-L} \rightarrow \mathrm{SM}$$

B-L Can be Broken in the Minimal Model!

- VEV: $v_R = \sqrt{\frac{-8M^2_{\tilde{N}^c}}{g^2_{BL}}}$ SM like VEV

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- Generate neutrinos masses.
- Only bilinear RPV; B conserved, no proton decay!

$$\lambda'' = 0 \quad \text{in} \quad \lambda'' \hat{U}^C \hat{D}^C \hat{D}^C,$$

Kuchimanchi, Mohapatra'95; Aulakh, Melfo, Senjanovic'98; Babu, Mohapatra'08

Higgs Sector For Left-Right: RPC

$$SU(2)_L \times SU(2)_R \times U(1)_{B-L}$$

$$\Delta = \begin{pmatrix} \frac{1}{\sqrt{2}}\Delta^+ & \Delta^{++} \\ \Delta^0 & -\frac{1}{\sqrt{2}}\Delta^+ \end{pmatrix} \sim (3,1,2) \qquad \Delta^c = \begin{pmatrix} \frac{1}{\sqrt{2}}\Delta^{c+} & \Delta^{c++} \\ \Delta^{c0} & -\frac{1}{\sqrt{2}}\Delta^{c+} \end{pmatrix} \sim (3,1,-2)$$

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Plus $S \sim (1,1,0)$ or nonrenormalizable term

P. Fileviez Perez, S.S., **Phys.Lett.B**673251, 2009

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Again, $\left\langle \tilde{L}^C \right\rangle = \left\langle \tilde{N}^c, \tilde{E}^C \right\rangle = (v_R, 0)$

The Simplest Supersymmetric Left-Right Model

Remaining Questions

- Why is right-handed sneutrino tachyonic?
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- Why is right-handed sneutrino tachyonic?
  - Would like to mimic the success of REWSB in MSSM.
  - But RSB not possible in the minimal model (no large Yukawas).
- What about even $B-L$ Higgs (canonical Model)
  - Maybe RPC more important than minimalism.
- Answers are related!

Canonical B-L Model

- Simplest extension with Yukawa couplings

$$\hat{X}, \hat{\bar{X}} \sim -2, 2$$
$$W \supset f \hat{N}^C \hat{N}^C \hat{X} + \mu_X \hat{X} \hat{\bar{X}}$$

- f can drive radiative symmetry breaking but

$$m_X^2 < 0 \text{ or } m_{\tilde{N}^C}^2 < 0$$

  - Or what is The Fate of R-parity?

P. Fileviez Perez, S.S., **arXiv: arXiv:** 1005.4930

The Fate of *R*-parity

- Depends solely on $m^2_{\tilde{N}^C}$

$$m^2_{\tilde{N}^C} > 0 \rightarrow \text{RPC} \qquad m^2_{\tilde{N}^C} < 0 \rightarrow \text{RPV}$$

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- RGEs (one family approximation):

$$X_X \equiv m^2_X + 2m^2_{\tilde{N}^C} + 4a^2_f$$

$$16\pi^2 \frac{dm^2_{\tilde{N}^C}}{dt} = \quad 8\ f^2 X_X - \ 3\ \ g_{BL^2} M^2_{BL}$$

$$16\pi^2 \frac{dm^2_X}{dt} = \quad 4\ f^2 X_X - \ 12\ g_{BL^2} M^2_{BL}$$

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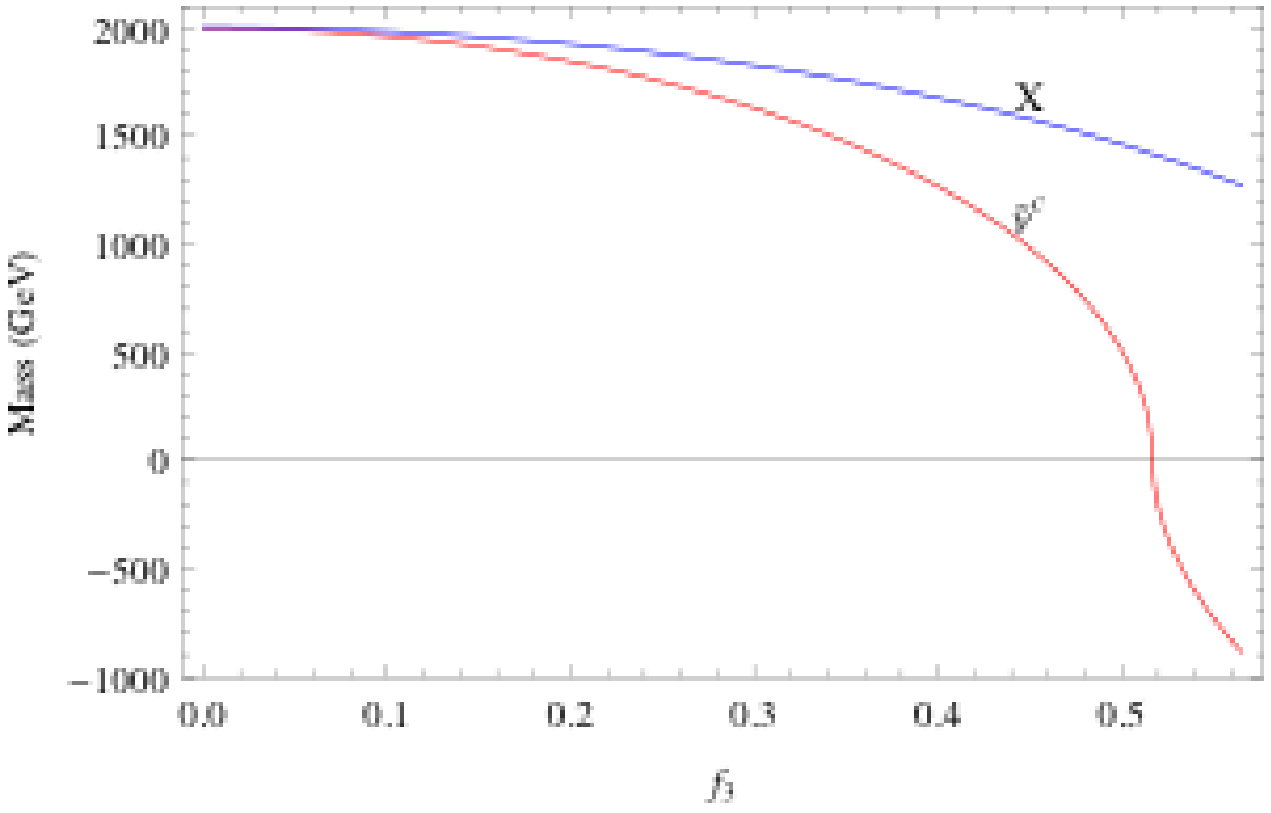
Favors R-parity Violation!!!

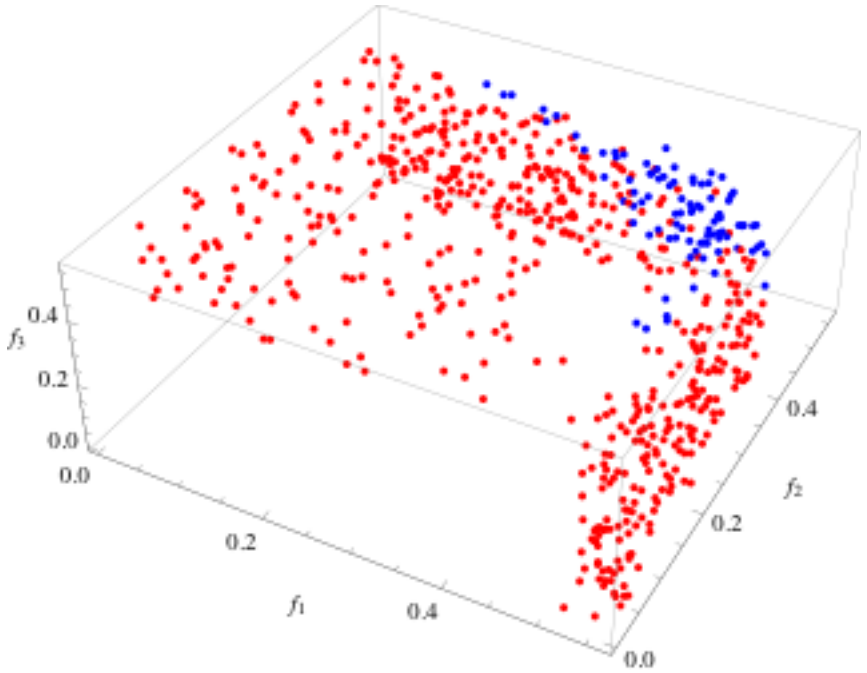
- Check if RSB is possible.
- MSUGRA boundary conditions
- Soft masses verses f_3:

$$m_0 = 2000 \text{ GeV}; \; M_{1/2} = 200 \text{ GeV}; \; A_0 = 0$$



Three Families

- m_X^2 enhanced by $tr\, f$; RSB and RPC possible



$$
\begin{aligned}
m_0 &= 2000\ \text{GeV}, \\
M_{1/2} &= 200\ \text{GeV}, \\
A_0 &= 0
\end{aligned}
$$

RPV 5 times more likely:

even in the canonical model, RPV is probable.

Conclusion

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- Minimal *B*-*L* models: R-parity violation.
- Add B-L even Higgs: radiative symmetry breaking but R-parity violation still very likely.
- In both cases R-parity violation is viable:
  - no proton decay.
  - TeV scale theories great for LHC.
  - dark matter still possible.