Bounds on R–Parity Violation from Rare Decay Data

Ben O'Leary

SUSY'07, Karlsruhe, 27/07/2007

Outline

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Implications of R–Parity Violation

Baryon and lepton number violation:

- Single sparticle production
- Lightest Supersymmetric Partner is unstable
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- HERA (sparticle–mass–dependent bounds on $\lambda'_{ijk}\lambda'_{lmn}$, or more usually λ'–dependent bounds on sparticle masses)

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Atomic parity violation data, $\mu \rightarrow e$ conversion in atoms, ...

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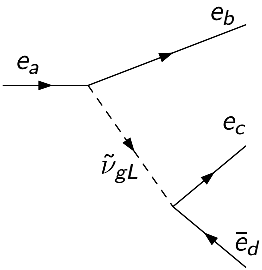
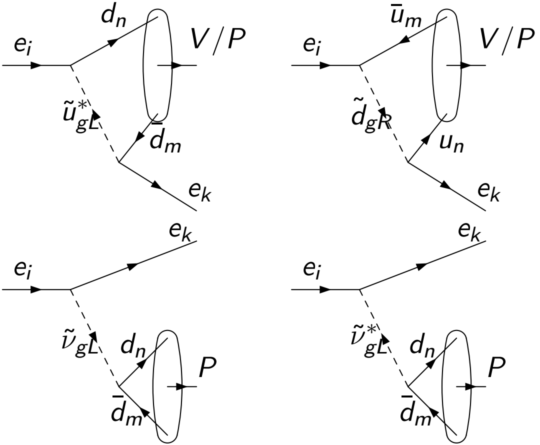
All λ''_{ijk} set to 0 (through baryon triality):

- prevents proton decay while allowing for neutrino mass
- lepton–number parity is not discrete gauge anomaly–free
- even R–Parity does not prevent proton decay through dimension–5 operators

Upper bounds on RPV




e_i
d_n
V/P
$\tilde{u}^*_{gL}$
$\bar{d}_m$
e_k
e_i
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V/P
$\tilde{d}_{gR}$
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Coupling combination	Bound	Decay
$\lambda_{g23}\lambda'_{g12}$	$1.0\times10^{-3}\ [\tilde{\nu}_{gL}]^2$	$\tau\to\mu K_S$
$\lambda_{g32}\lambda'_{g21}$		
$\lambda'_{1g1}\lambda'_{3g2}$	$2.3\times10^{-3}\ [\tilde{u}_{gL}]^2$	$\tau\to e K_S$
$\lambda'_{1g2}\lambda'_{2g2}$	$1.5\times10^{+2}\ [\tilde{u}_{gL}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$
$\lambda'_{1g2}\lambda'_{3g2}{}^{\dagger(-)}$	$1.2\times10^{-3}\ [\tilde{u}_{gL}]^2$	$\tau\to e\eta$
$\lambda'_{1g2}\lambda'_{3g2}$	$3.4\times10^{-3}\ [\tilde{u}_{gL}]^2$	$\tau\to e\phi$
$\lambda'_{2g2}\lambda'_{3g2}{}^{\dagger(-)}$	$1.6\times10^{-3}\ [\tilde{u}_{gL}]^2$	$\tau\to\mu\eta$

Table: Example coupling combinations which had no bounds previously.

Coupling combination	Bound	Bound
$\lambda_{g13}\ \lambda'_{g22}$, $\lambda_{g31}\ \lambda'_{g22}$	$4.6\times10^{-4}\ [\tilde{\nu}_{gL}]^2$ $\tau\to e\eta$	$1.6\times10^{-2}\ [\tilde{\nu}_{gL}]^2$ $\tau\to e\eta$
$\lambda_{g13}\ \lambda'_{g21}$, $\lambda_{g31}\ \lambda'_{g12}$	$9.7\times10^{-4}\ [\tilde{\nu}_{gL}]^2$ $\tau\to eK_S$	$8.5\times10^{-2}\ [\tilde{\nu}_{gL}]^2$ $\tau\to eK^0$

Table: Example coupling combinations which have improved by a factor of 30 or more compared to those published previously.

Not all bounds were improved, *e.g.*

Coupling combination	Bound	Bound
$\lambda_{121}\ \lambda'_{111}$	$1.2\times10^{-2}\ [\tilde{\nu}_{1L}]^2$ $\pi^0\rightarrow e\bar{\mu}$	$2.1\times10^{-8}\ [\tilde{\nu}_{1L}]^2$ $\mu\rightarrow e$ in ^{48}Ti
$\lambda_{211}\ \lambda'_{223}$	$2.3\times10^{-4}\ [\tilde{\nu}_{2L}]^2$ $B_s^0\rightarrow e\bar{e}$	$1.4\times10^{-4}\ [\tilde{\nu}_{2L}]^2$ $B_d^0\rightarrow K^0 e\bar{e}$

Summary and Outlook

R–Parity bans some awkward terms in the MSSM.

Allowing the R–Parity–violating terms can provide a mechanism for neutrino mass without adding a right–handed neutrino field.

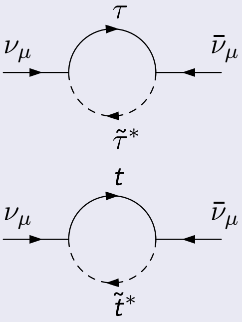
Allowing these terms also provides a variety of interesting new flavor physics, though severely constrained by experiment.

No strict lower bound exists for these couplings, but upper bounds could rule out neutrino mass from RPV; most upper bounds are still about an order of magnitude above the value consistent with neutrino masses.

Lower bounds

- P. Fayet, Nucl. Phys. B **90** (1975) 104.
- R. E. Marshak and R. N. Mohapatra, Phys. Lett. B **91** (1980) 222.
- R. Barbier *et al.*, Phys. Rept. **420** (2005) 1 [arXiv:hep-ph/0406039].
- H. K. Dreiner, M. Kramer and B. O'Leary, Phys. Rev. D **75** (2007) 114016 [arXiv:hep-ph/0612278].

Are there lower bounds on these couplings?



τ–$\tilde{\tau}$ loop contribution to muon neutrino mass:

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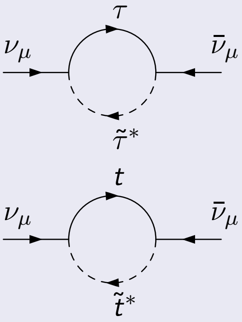

τ–$\tilde{\tau}$ loop contribution to muon neutrino mass:
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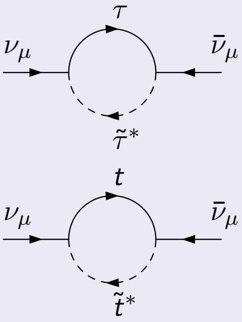

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Assuming $\mu \approx m_{\tilde{\tau}_L} \approx 100$ GeV, $\tan\beta \approx 30$, $m_{\nu_\mu} \approx 0.3$ eV,

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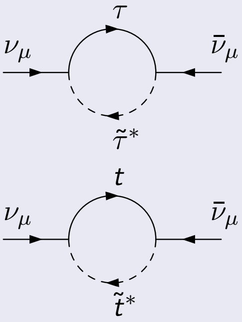

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$|\lambda_{233}|^2 \approx 10^{-5}(m_{\tilde{\tau}_L}/100 \text{ GeV})^2$

Proton decay

All λ's and λ''s present and of order 1, with sparticle masses of order 1 TeV, leads to proton decay with a disappointingly short lifetime ($\sim 10^{50}$ times too short (R. Barbier *et al.*, Phys. Rept. **420** (2005) 1 [arXiv:hep-ph/0406039])).

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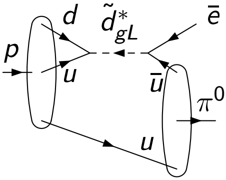

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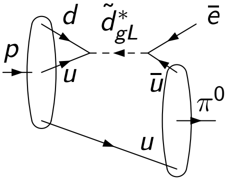


However, it is sufficient to enforce either lepton number conservation (though this is not anomaly–free) by setting $\lambda_{ijk} = \lambda'_{ijk} = 0$, or baryon number conservation by setting $\lambda''_{ijk} = 0$.

How Collider Bounds Compare to Decay Bounds

The OPAL collaboration published upper bounds on lepton flavor–violating two–to–two scatterings from the LEP2 run at $\sqrt{s}\sim$200 GeV (G. Abbiendi *et al.* [OPAL Collaboration], Phys. Lett. B **519** (2001) 23 [arXiv:hep-ex/0109011]).

These can be translated into upper bounds on λ–λ couplings as a function of the sneutrino mass.

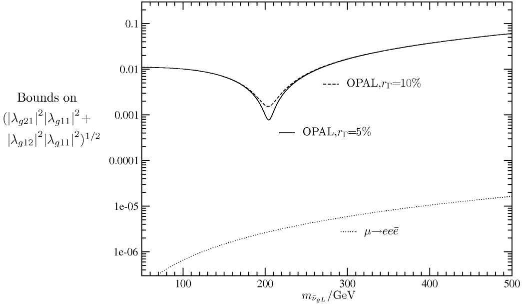
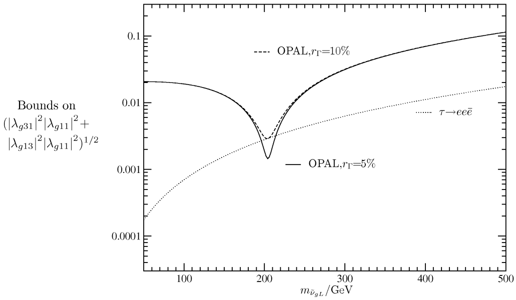


Figure: The bounds on $(|\lambda_{g21}|^2|\lambda_{g11}|^2+|\lambda_{g12}|^2|\lambda_{g11}|^2)^{1/2}$ as a function of $m_{\tilde{\nu}_{gL}}$ from the search for $e\bar{e}\rightarrow\mu\bar{e}/e\bar{\mu}$ by OPAL in the range 200 GeV $\leq\sqrt{s}\leq$209 GeV.



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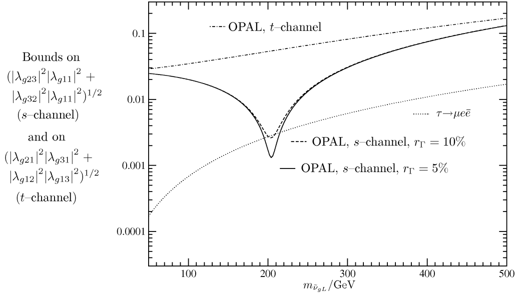

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"Right–handed" sneutrino vacuum expectation value:
$Y^{\nu}_{jk} H_u L_{jL} \nu^{c}_{kR} \rightarrow m'_{jk} e^{T}_{j} \tilde{h}^{+}_{u}$