TITLE :-

Top squark and neutralino decays in a R-parity violating model constrained by neutrino oscillation data.

[hep-ph/0509171]

By

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INTRODUCTION:

R-parity violating (L-violating) model can explain the origin of observed ν-oscillation

- Can we test such models at high energy colliders ?

PLAN OF THE TALK:

1) Too many RPV parameters.
   Select some Benchmark scenarios with a minimal set of panametens.
   The ν-mass matrix.

2) RPV panameter sets allowed by the oscillat data.
   The six generic scenarios.

3) Collider signals:
   a) Top squark decay (Tevatron + LHC)
   b) LSP decay. (LHC)

4) Potential of LHC + ILC Physics.

THE BENCHMARK SCENARIO & THE 2ℓ- MASS MATRIX :-

$$W_{\not R_p} = \mu_i \epsilon_{ab} L_i^a H_2^b + \lambda'_{ijk} \epsilon_{ab} L_i^a Q_j^b D_k^c$$

A minimal set of parameters that can explain oscillation data : μ_i , λ'_{i33} , $i = 1,2,3$

[Abada & Losada hep-ph/0007041 Subhendu Rakshit Mod. Phys. Lett. A19, 2239 (2004)]

$$M_{2\ell} = M_{2\ell}^{tree} + M_{2\ell}^{loop}$$

$$M_{2\ell}^{tree} = c\,\mu_i \mu_j$$

$$M_{\nu}^{loop} = K_2 \begin{pmatrix} \lambda'^2_{133} & \lambda'_{133}\lambda'_{233} & \lambda'_{133}\lambda'_{333} \\ \lambda'_{133}\lambda'_{233} & \lambda'^2_{233} & \lambda'_{233}\lambda'_{333} \\ \lambda'_{133}\lambda'_{333} & \lambda'_{233}\lambda'_{333} & \lambda'^2_{333} \end{pmatrix}$$

c depends on RPC EW gaugino sector.

K_2 depends on RPC squark sector.

We expect some of RPC parameters to be measured kinematically at LHC/ILC.

Our numerical result based on some representative choices of RPC parameters.

THE 2ν-OSCILLATION DATA :-

parameter	best fit	2σ	3σ	4σ
$\Delta m^2_{sol}[10^{-5}eV^2]$	8.1	7.5–8.7	7.2–9.1	7.0–9.4
$\Delta m^2_{atm}[10^{-5}eV^2]$	2.2	1.7–2.9	1.4–3.3	1.1–3.7
$\sin^2\theta_{12}$	0.30	0.25–0.34	0.23–0.38	0.21–0.41
$\sin^2\theta_{23}$	0.50	0.38–0.64	0.34–0.68	0.30–0.72
$\sin^2\theta_{13}$	0.000	≤ 0.028	≤ 0.047	≤ 0.068

Randomly generated 10^9 sets of six RPV parameters : μ_i , λ'_{i33}

Analytical + numerical results.

Six generic scenarios allowed by osc. data.

a1) $\lambda'_{333} > \lambda'_{133} \gtrsim \lambda'_{233}$ (small μ_1)

a2) $\lambda'_{233} > \lambda'_{133} \gtrsim \lambda'_{333}$

b1) $\lambda'_{133} \simeq \lambda'_{233} \gg \lambda'_{333}$ (small μ_2)

b2) $\lambda'_{233} > \lambda'_{333} \gg \lambda'_{333}$

c1) $\lambda'_{333} > \lambda'_{133} \gg \lambda'_{233}$ (small μ_3)

c2) $\lambda'_{333} > \lambda'_{233} \gg \lambda'_{133}$

- Each scenario has a characteristic hierarchy of λ' couplings.

$\Rightarrow$ hierarchy in BRs of RPV channels.

Restrictive Power of Osc. Data:-

Small no. of allowed solutions:

RPV parameters	Given ranges		Allowed ranges	
	Max	Min	Max	Min
$\mu_1[10^4 eV]$	50.0	0.001	19.0	0.10
$\mu_2[10^4 eV]$	300.0	1.0	134.0	90.0
$\mu_3[10^4 eV]$	300.0	1.0	178.0	89.0
$\lambda'_{133}[10^{-5}]$	12.0	0.001	4.32	3.2
$\lambda'_{233}[10^{-5}]$	12.0	0.001	9.52	0.01
$\lambda'_{333}[10^{-5}]$	12.0	0.001	9.67	0.002

[Allowed Ranges of RPV parameters]

RPC parameters:

$M_1 = 110$, $M_2 = 200$, $\mu = 400$, $\tan\beta = 5$

$M_{\tilde{q}} = 400$, $A_b = 1000$ [in GeV]

[Gaugino like]

$\lambda' \sim (10^{-4} - 10^{-5})$

- All direct RPV decays except LSP decays are practically unobservable.

BR-measurement of rare decay modes at ILC?

EXCEPTION:

Decay of the $\tilde{t}_1$ NLSP.

$\tilde{t}_1$ NLSP decay:

Competing modes:

$\tilde{t}_1 \rightarrow l_i^+ b$ [$i = 1, 2, 3$]

$\tilde{t}_1 \rightarrow c \tilde{\chi}_1^0$ [Loop decay suppressed width]

$\tilde{t}_1 \rightarrow f \bar{f}' b \tilde{\chi}_1^0$ [4-body decay suppressed width]

Choice of RPC parameters:

$M_1 = 110$, $M_2 = 200$, $\mu = 400$, $\tan\beta = 5$

$M_{\tilde{q}} = 400$, $A_b = 1000$, $A_t = 970$, $M_A = 300$

(Gaugino dominated model) [in GeV]

($M_1 < M_2 << \mu$) [Fig-1]

Mixed model:

($M_1 < M_2 \simeq \mu$) [in GeV]

$\mu = 210$

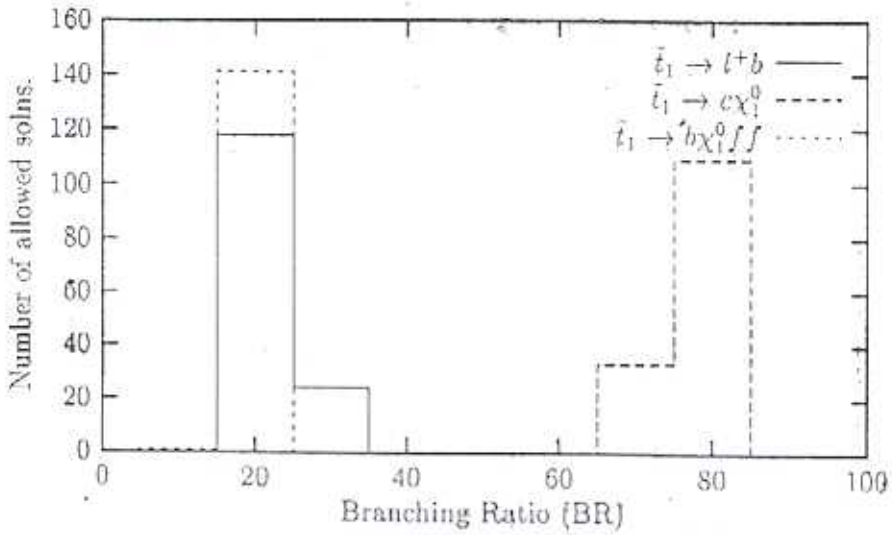

Figure 1: The branching ratios(%) of the three competing decay modes vs the number of allowed solutions in Model 2 (see text for the parameters used).

Loop decay dominates.

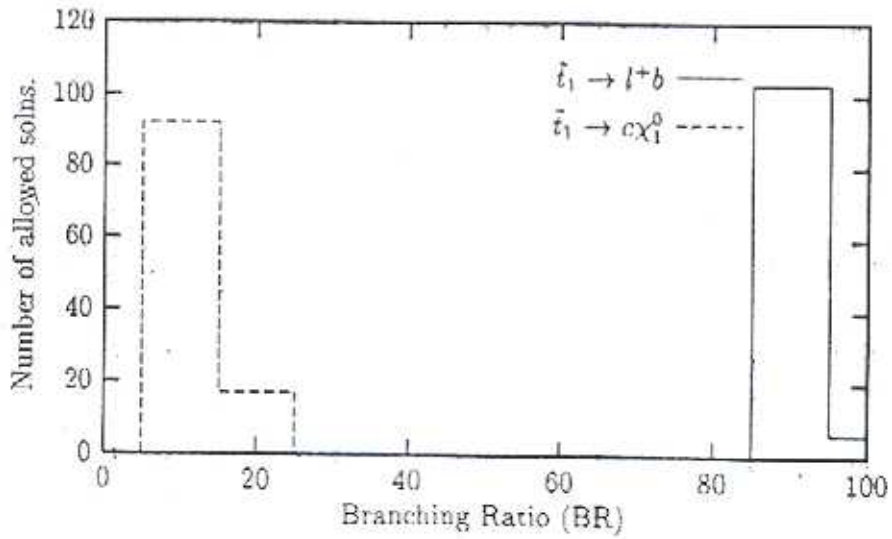

Figure 2: The branching ratios(%) of the two competing decay modes vs the number of allowed solutions in Model 3 (see text for the parameters used).

RPV decay dominates.

SIGNALS:

Sample RPV parameters allowed by Osc. data:

A) $\lambda'_{133} = 3.72 \times 10^{-5}$, $\lambda'_{233} = 3.3 \times 10^{-5}$, $\lambda'_{333} = 8.5 \times 10^{-5}$

B) $\lambda'_{133} = 4.2 \times 10^{-5}$, $\lambda'_{233} = 1.3 \times 10^{-5}$, $\lambda'_{333} = 8.3 \times 10^{-5}$

C) $\lambda'_{133} = 4.2 \times 10^{-5}$, $\lambda'_{233} = 8.6 \times 10^{-5}$, $\lambda'_{333} = 1.8 \times 10^{-5}$

RPC parameters :
(previous choice)

$L_{ij} \to l_i^+ \bar{b} l_j^- b$ [Observable at Tevatron
SPDas, A. Datta & M. Guchait.
hep-ph/0309168

$L_i \to l_i^+ b c \bar{c} b \bar{b} / l_i^- \bar{b} \bar{c} c b \bar{b}$

$L_{ij} \to$ Table-3

$L_i \to$ Table-4

$\mathcal{L} = 9\ fb^{-1}$

$\sigma(p\bar{p} \to \tilde{t}\tilde{t}^*) = 0.41\ pb.$

$m_{\tilde{t}} = 181.5\ GeV.$

	L_{11}	L_{12}	L_{13}	L_{22}	L_{23}	L_{33}
# of events (A)	3	5	34	2	27	91
# of events (B)	5	1	44	0	4	86
# of events (C)	5	46	2	97	8	0

Table-3 ; Typical Signal size at Tevatron Run-II. (L_{ij})

	L_1	L_2	L_3
# of events (A)	152	121	804
# of events (B)	206	20	789
# of events (C)	198	829	35

Table-4 ; Typical Signal size at Tevatron Run-II (L_i)

Signal size at LHC :

RPC parameters:

$M_1 = 310$, $M_2 = 400$, $\mu = 800$, $\tan\beta = 5$

$M_{\tilde{q}} = 550$, $A_b = 1000$, $A_t = 1350$, $M_A = 500$

Sample choice of RPV parameters:

A) $\lambda'_{133} = 2.92 \times 10^{-5}$, $\lambda'_{233} = 2.27 \times 10^{-5}$, $\lambda'_{333} = 6.27 \times 10^{-5}$

B) $\lambda'_{133} = 3.4 \times 10^{-5}$, $\lambda'_{233} = 6.6 \times 10^{-5}$, $\lambda'_{333} = 1.83 \times 10^{-5}$

C) $\lambda'_{133} = 3.39 \times 10^{-5}$, $\lambda'_{233} = 1.92 \times 10^{-5}$, $\lambda'_{333} = 6.48 \times 10^{-5}$

$\sigma(pp \to \tilde{t}_1 \tilde{t}_1^*) = 4.28$ pb.

$m_{\tilde{t}_1} = 350.65$ GeV

$\int L dt = 30\ fb^{-1}$

$L_{22} = 44696$

$L_{21} = 31817$

LSP Decay:

a) $m_{\tilde{\chi}_1^0} < m_t$

$\tilde{\chi}_1^0 \to 2f\,b\bar{b}$

i) L-violating nature can not be established.

ii) Mass reconstruction is difficult.

b) $m_{\tilde{\chi}_1^0} > m_t$.

$\tilde{\chi}_1^0 \to e\bar{b}t$

$\to \mu\bar{b}t$

$\to \tau\bar{b}t$

i) L-violating nature can be established.

ii) Mass reconstruction is possible.

In Table-5, BRs in Higgsino & Gaugino dominated model

In Table-6, Events at LHC from gaugino pair production.

Signal: $G_\alpha G_\beta \to l_i^\pm l_j^\pm \bar{b}\bar{b} + \not{H} X$

Decay modes	BR (%)in Higgsino model	BR (%)in Gaugino model
$\tilde{\chi}_1^0 \to \not{E}_T b\bar{b}$	12.5	79.7
$\tilde{\chi}_1^0 \to te\bar{b}$	19.3	3.7
$\tilde{\chi}_1^0 \to t\mu\bar{b}$	67.7	16.2
$\tilde{\chi}_1^0 \to t\tau\bar{b}$	0.5	0.4

Table - 5

RPC parameters: $M_1 = 710$, $M_2 = 800$, $\mu = 395$, $\tan\beta = 5$
$M_{\tilde{Q}} = 500$, $A_b = 1000$, $A_t = 800$, $M_A = 300$

RPV parameters: $\lambda'_{133} = 5.43 \times 10^{-5}$, $\lambda'_{233} = 10.19 \times 10^{-5}$
$\lambda'_{333} = 0.87 \times 10^{-5}$ [Higgsino dominated]

Gaugino pair	σ(pb)	L_{11}	L_{22}	L_{12}
$\tilde{\chi}_1^0\ \tilde{\chi}_2^0$	18.5×10^{-3}	206	2551	5808
$\tilde{\chi}_1^+\ \tilde{\chi}_1^-$	68.2×10^{-3}	762	9405	21416
$\tilde{\chi}_1^-\ \tilde{\chi}_2^0$	10.2×10^{-3}	113	1406	3200
$\tilde{\chi}_1^+\ \tilde{\chi}_2^0$	23.4×10^{-3}	261	3226	7348
$\tilde{\chi}_1^0\ \tilde{\chi}_1^-$	10.6×10^{-3}	118	1461	3328
$\tilde{\chi}_1^0\ \tilde{\chi}_1^+$	24.6×10^{-3}	274	3392	7724

Table - 6

Gaugino Model:

$M_1 = 388$, $M_2 = 500$, $\mu = 800$, $A_t = 870$

keeping all other parameters (RPC) same as that in the above case.

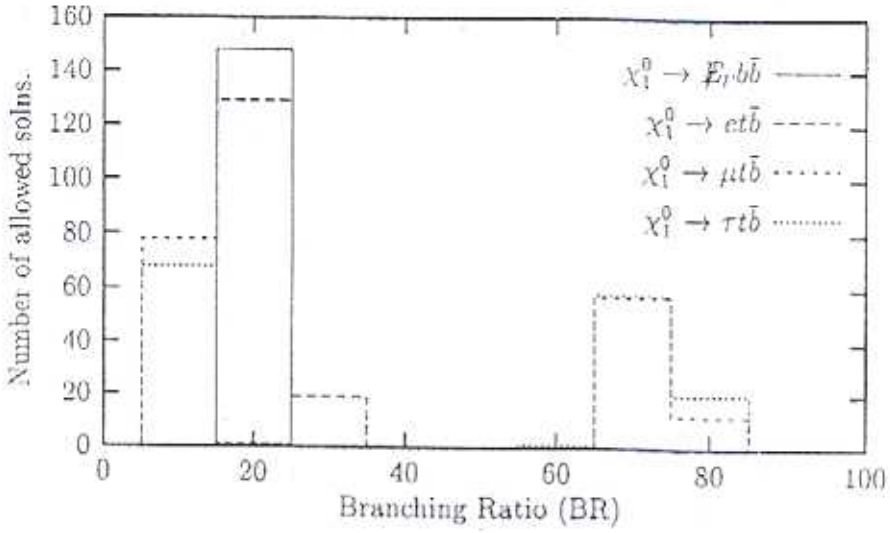

Figure 3: The branching ratios (%) of competing LSP decay modes vs the number of allowed solutions in Model 1 (see the text).

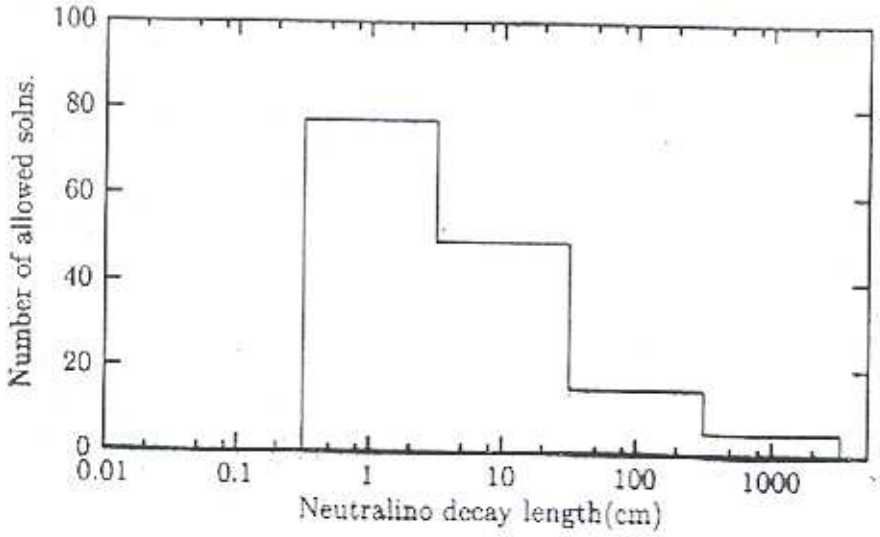

Figure 4: Neutralino decay length vs the number of allowed solutions in Model 1 (see the text for the parameters used).

FUTURE PROSPECTS :

- Mass reconstruction from invariant mass for fully visible events.

$$\tilde{t}_1 \longrightarrow \ell_i^+ b$$

$$\tilde{\chi}_1^\pm \longrightarrow jj'\tilde{\chi}_1^0 \longrightarrow e\bar{b}t \Big\} jj'e\bar{b}t$$

- Edges of various kinematical distributions $\longrightarrow$ Measure of RPC parameters.

- Determination of RPV parameters from BRs.

  $\Rightarrow$ Test the underlying model.

- Refine measurements at ILC.

  BRs can be estimated more accurately

  Measurement of rare decay modes.