BILINEAR R PARITY VIOLATION

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- Well–Motivated
- provides a predictive theoretical solution to atmospheric and solar neutrino anomalies
- General Implications
  - gauge & Yukawa coupling unification
  - $b \to s\gamma$ suppressed: lighter SUSY Higgs accessible at LEP2
- Collider Implications for small $\not{R}_p$
  - SUSY particle production as in the MSSM but
  - LSP decays inside detector
  - [redacted] effects @ LEP & LHC
  - $\tilde{\chi}_1^0$ decay patterns reflect the nu-anomalies
- $\not{R}_p$ in top/stop decays
- $\not{R}_p$ in charged/neutral SUSY Higgs/slepton decays
- [redacted]

*Supported by TMR project FMRX-CT96-0090 and PB98-0693

Motivation

- R-parity conservation is an **ad hoc** assumption in usual theory (MSSM) and $\not{R}_p$ may arise explicitly as unification remnant Hall & Suzuki, 1984 or spontaneously by $SU(2) \otimes U(1)$ doublet left sneutrino vevs as originally suggested

  C.S. Aulakh & R.N. Mohapatra. 1983 A. Santamaria & J. V. Phys.Lett.B195:423, 1987.

  but with ad hoc set of explicit breaking terms

  G.G. Ross & J. V. Phys.Lett.B151: 375,1985, J. Ellis, et al Phys.Lett.B150:142, 1985

  to comply with LEP data on Z width

- Preferrably we break R-parity through singlet right sneutrino vevs, either by gauging L-number, in which case there is an additional Z,

  M. C. G.-G. & J. V. Nucl. Phys. **B355** (1991) 330

  or within the $SU(2) \otimes U(1)$ scheme in which case the majoron is an $SU(2) \otimes U(1)$ singlet, with suppressed Z coupling:

  A. Masiero & J. V. Phys.Lett.B251:273-278,1990

  J. Romao, C. Santos, J. V. Phys.Lett.B288:311-320,1992

  J.C. Romao, A. Ioannisian, J. V. Phys.Rev.D55:427-430,1997

- In this case only Bilinear $\not{R}_p$ violation arises as the effective theory below the $\not{R}_p$ scale

- B-number conservation automatic

- may lead to successfull electroweak baryogenesis T. Multamaki and I. Vilja, 1998 or preserve the primordial B–asymmetry

- KeV majoron from gravity effects may provide dark matter V. Berezinsky & J. V., Phys. Lett. **B318** (1993) 360 [hep-ph/9309214]; A. D. Dolgov, S. Pastor & J. V., astro-ph/9506011.

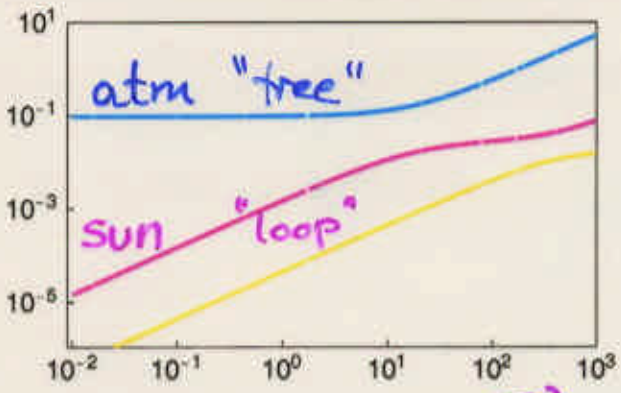
Minimal supergravity with Bilinear R parity breaking.

M. A. Diaz, J. C. Romao, J. V. Nucl. Phys. B524 (1998) 23-40. [hep-ph/9706315]

- Theoretically self-consistent: Trilinear $R_p \Rightarrow$ Bilinear R_p but not conversely
- Maybe the only violation permitted by higher symmetries

  J. M. Mira, E. Nardi, D. A. Restrepo & J. V. hep-ph/0007266
- provides a predictive theoretical solution to atmospheric and solar neutrino anomalies M. Hirsch, et al hep-ph/0004115, PRD in press, J . C. Romao, et al Phys. Rev. **D61** (2000) 071703 [hep-ph/9907499].

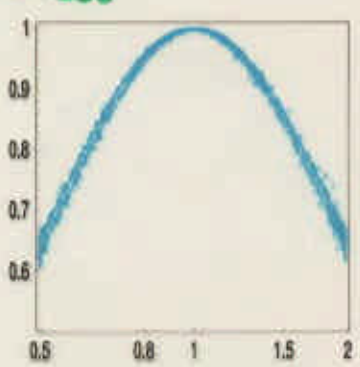
hierarchical



$\propto \frac{\vec{\epsilon}^2}{|\vec{\Lambda}|}$

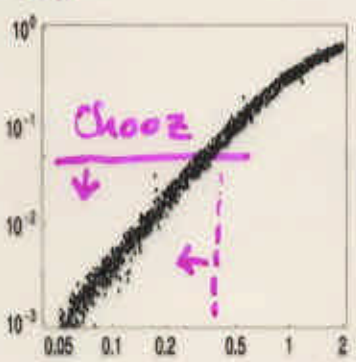
predictions:

$\sin^2 2\theta_{at}$



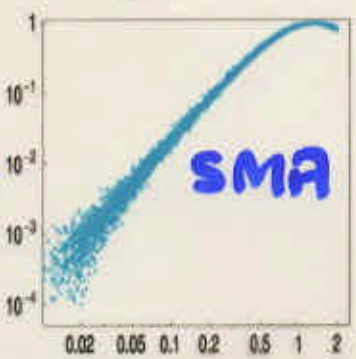
$\frac{\Lambda_\mu}{\Lambda_{e\tau}}$

K^2_{e3}



$\frac{\Lambda_e}{\Lambda_{\mu\tau}}$

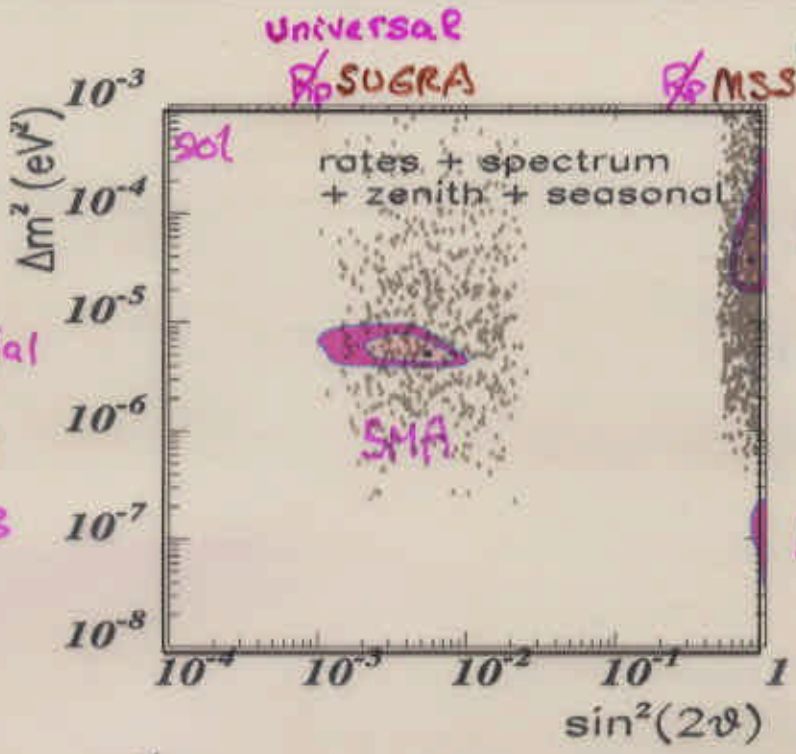
$\sin^2 2\theta_\odot$



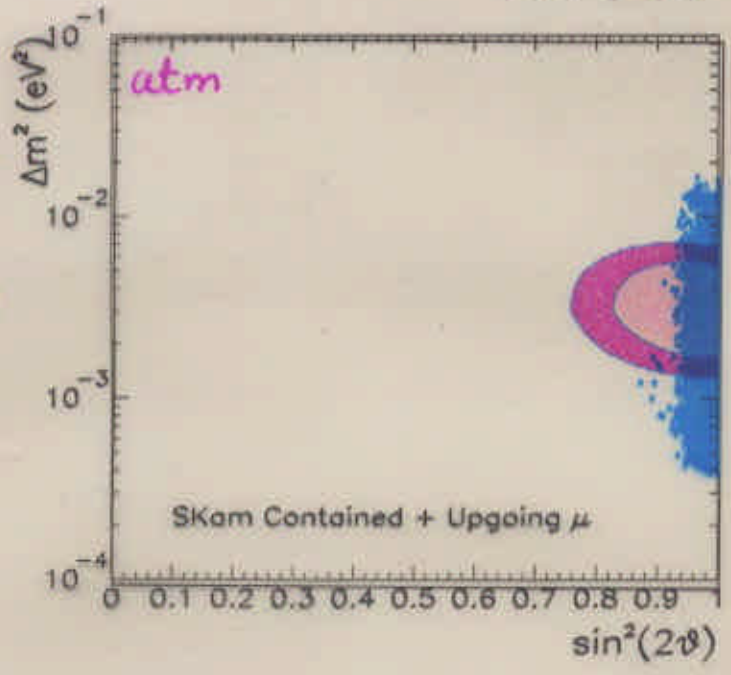
$\frac{\Lambda_e}{\Lambda_{\mu\tau}}$

Romão et al PRD61, 071703 (2000)
Hirsch et al hep-ph 0004115 PRD, in press

Solar and atmospheric neutrino problems: Fits versus bilinear R_p MSSM at 1-loop



Gonzalez-Garcia et al
hep-ph 9906469
NPB573(2000)3



52 kton-yr*

Fornengo, G-G & J.V.
hep-ph 0002197
NPB580(2000)58

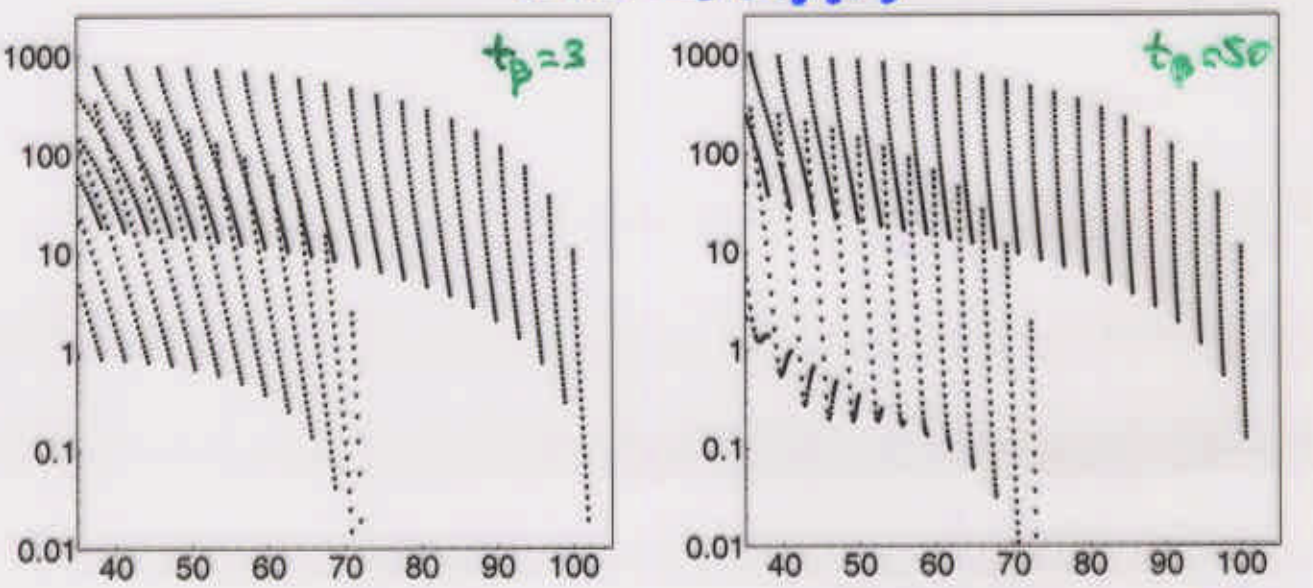
3-generation

* Updated / post-ν2000 plots in Gonzalez-Garcia's talk

small $\not{R}_p \Rightarrow$ SUSY particle production as in the MSSM

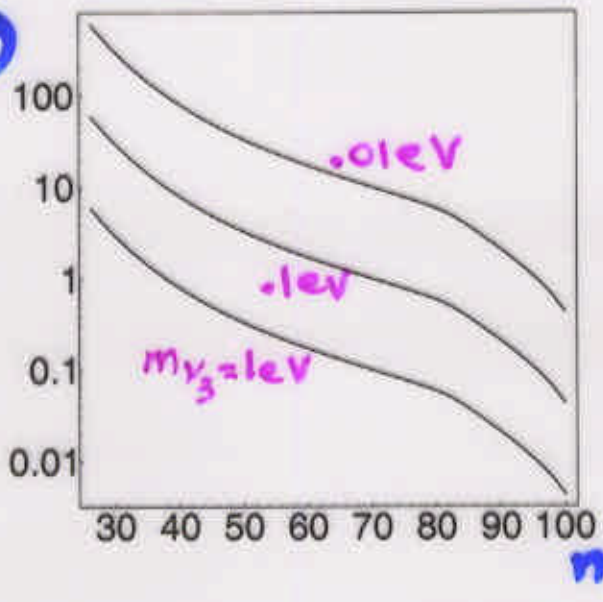
$e^+e^- \to \chi_1\chi_1$

σ / fb



but LSP ($\tilde{\chi}_1^0$) decays inside detector

$L(\chi_1)$ / cm



$\sqrt{s} = 205$

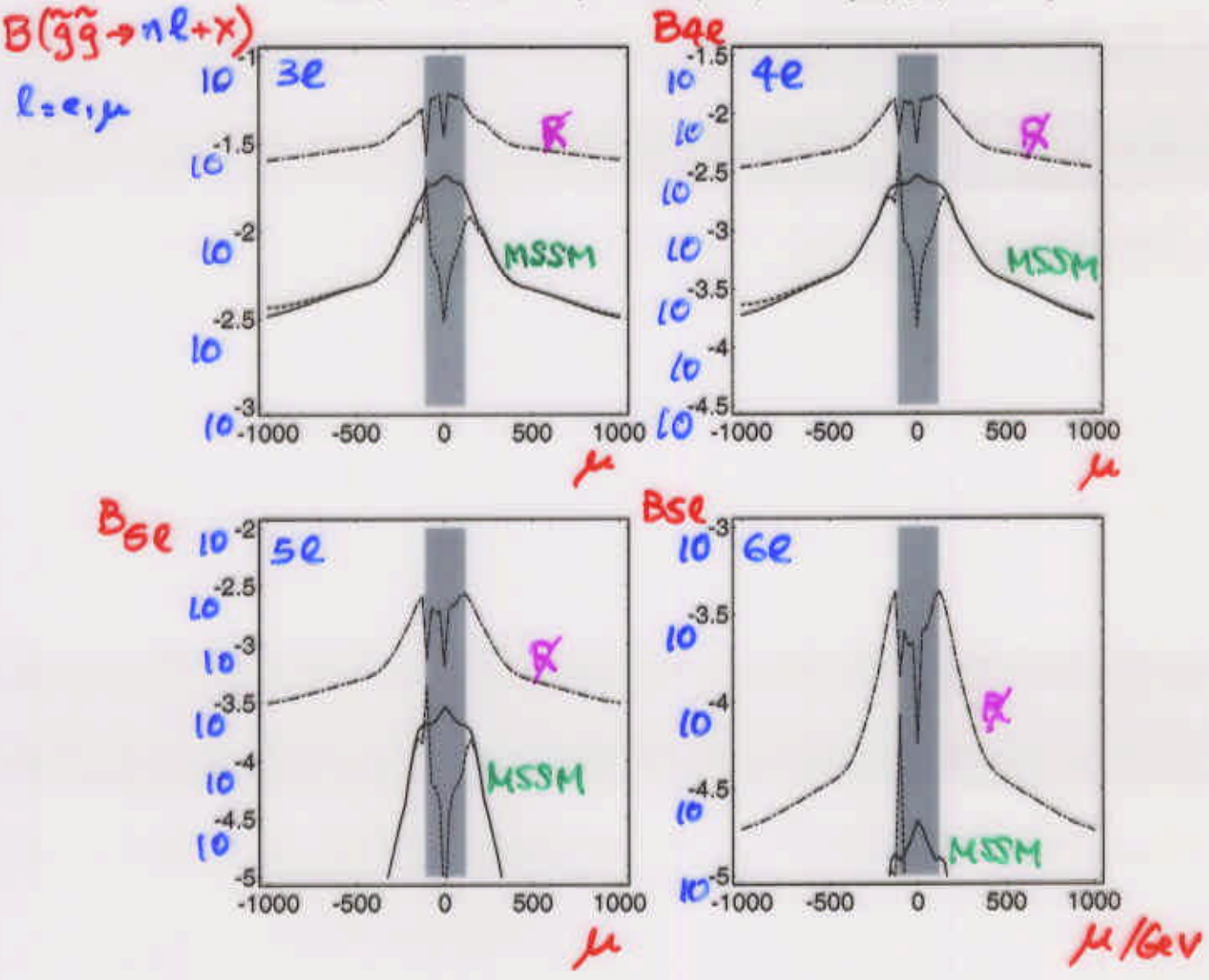
$90 < m_{\nu_2} < 270$

$50 < m_0 < 500$

A. Bartl, W. Porod, D. Restrepo, J. Romao and J. V., "Neutralino phenomenology at LEP2 in supersymmetry with bilinear breaking of R-parity," hep-ph/0007157

$\tilde{\chi}_1^0$ decays also leads to enhanced lepton multiplicities in gluino cascade decays at the LHC

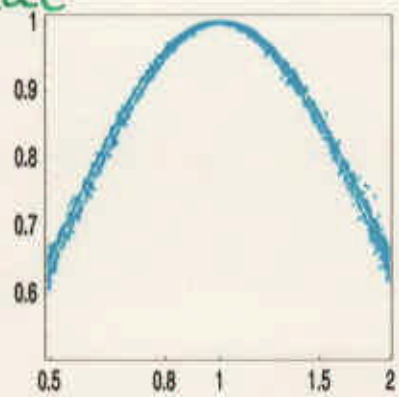
A. Bartl, et al., Nucl. Phys. B502 (1997) 19-36 [hep-ph/9612436]



$\tilde{\chi}_1^0$ decay patterns reflect the nu-anomalies

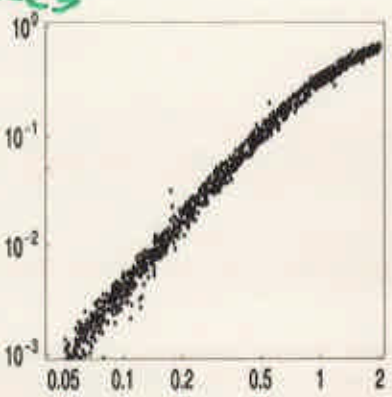
M. Hirsch, et al hep-ph/0004115, PRD in press, J . C. Romao, et al Phys. Rev. **D61** (2000) 071703 [hep-ph/9907499].

s^2_{2at}



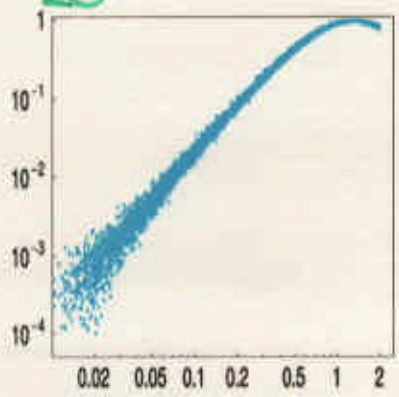
$\frac{\Lambda_\mu}{\Lambda_{e2}}$

K^2_{e3}

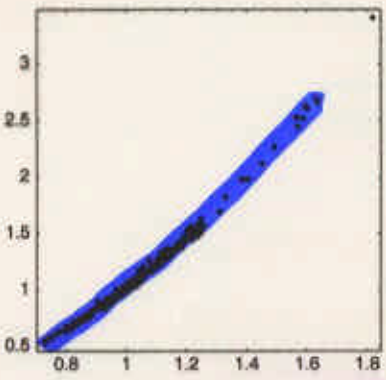


$\frac{\Lambda_e}{\Lambda_{\mu 2}}$

$s^2_{2\odot}$

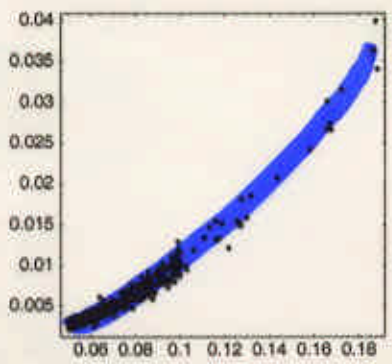


$\frac{B(\chi \to \mu q q')}{B(\chi \to \tau q q')}$



$\frac{\Lambda_\mu}{\Lambda_\tau}$

$\frac{B(\chi \to e q q')}{B(\chi \to \tau q q')}$

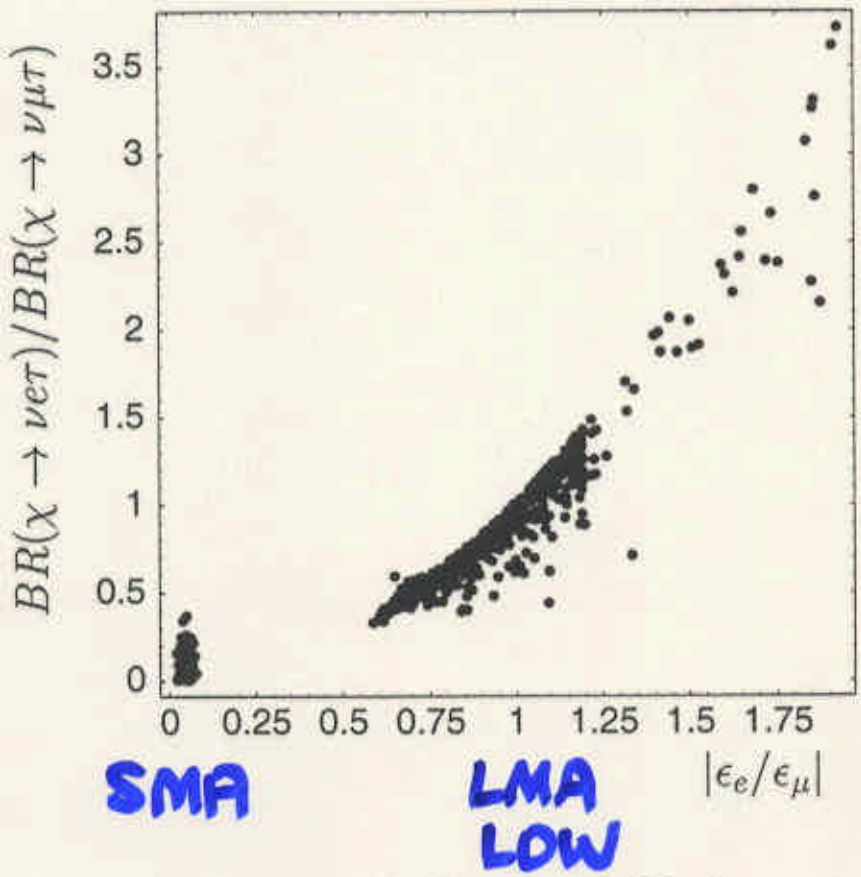


chooz

$\frac{\Lambda_e}{\Lambda_\tau}$

how about solar angle?

Leptonic Neutralino decay branching ratios

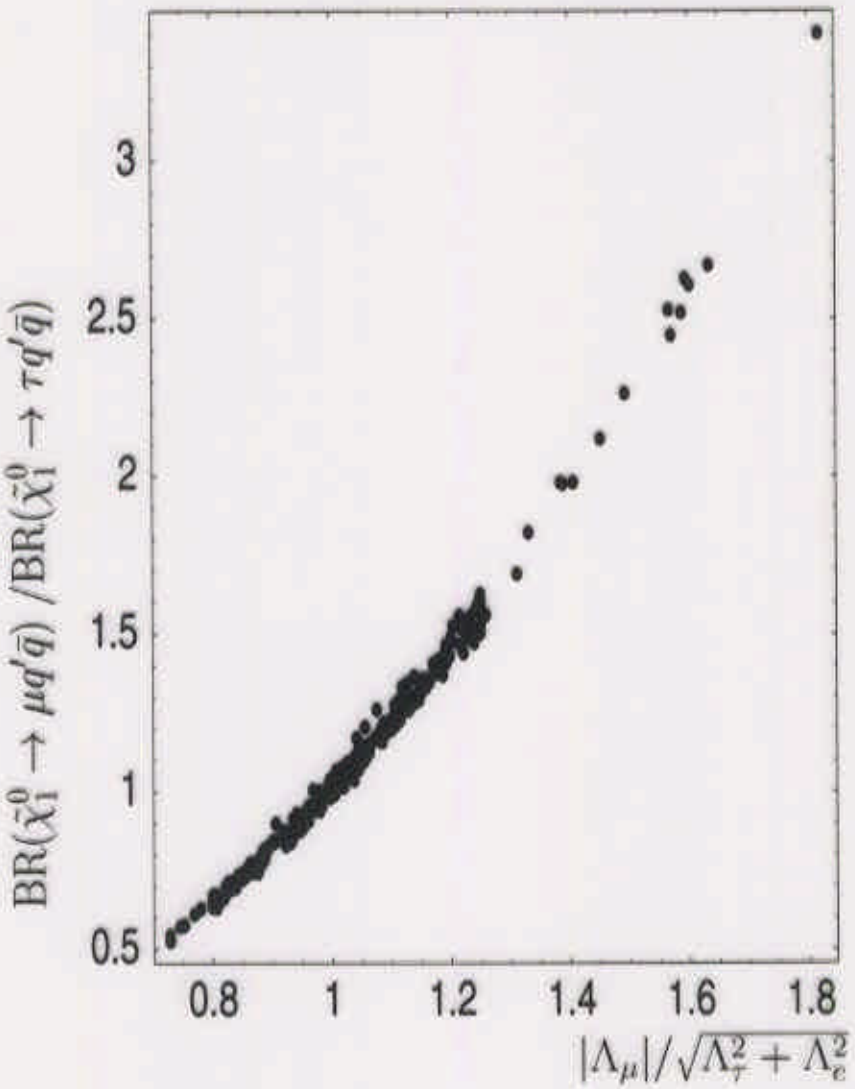


Ratio of branching ratios for leptonic LSP decays into muons and taus: $BR(\chi \to \nu e\tau)/BR(\chi \to \nu\mu\tau)$ as function of $|\epsilon_e/\epsilon_\mu|$.

Directly correlated with solar angle!

Preferred LMA & LOW soln's to ☺ ν-problem require (small) departure from universality of softs @ unification & imply $B(\chi \to \mu\tau\nu) \sim B(\chi \to e\tau\nu)$

Semileptonic Neutralino Decay Branching Ratios



Directly correlated with atmospheric angle

Generic Implications of Bilinear R_p

- Gauge unification with broken R parity.

  M.A. Diaz, J. Ferrandis, J.C. Romao, J. V., hep-ph/9906343, NPB in press

- Yukawa unification with broken R parity.

  M. A. Diaz, J. Ferrandis, J. C. Romao, J. V. Phys. Lett. B453 (1999) 263-26. [hep-ph/9801391]

- $b \to s\gamma$ suppressed: lighter SUSY Higgs accessible at LEP2

  M. A. Diaz, E. Torrente-Lujan, J. V., Nucl. Phys. B551 (1999) 78-92, hep-ph 9808412

- Neutrinoless double beta decay small for small R_p :

  M. Hirsch, J.C. Romao, J. V., hep-ph 0002264, PLB, in press

  M. Hirsch, J. V., Nucl. Phys. B557 (1999) 60-78, hep-ph 9812463

- $R\!\!\!/_p$ → any SUSY particle is phenomenologically allowed to be LSP (will depend on BC's on softs @ unification)

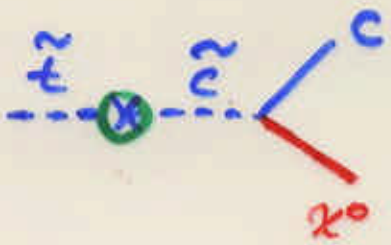
- if sleptons are LSP they will behave like $H^{0,\pm}$, i.e. $\tilde{\nu} \to b\bar{b}$ 

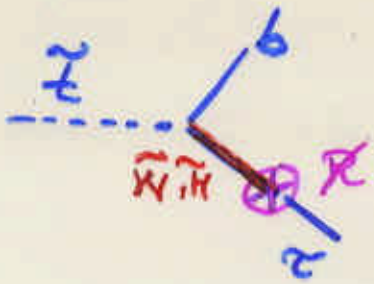
$\tilde{\tau} \to \tau\nu$

Campos et al NPB451(95)3
Akeroyd et al NPB529(98)3

apart from their production X-section

Ebdi et al

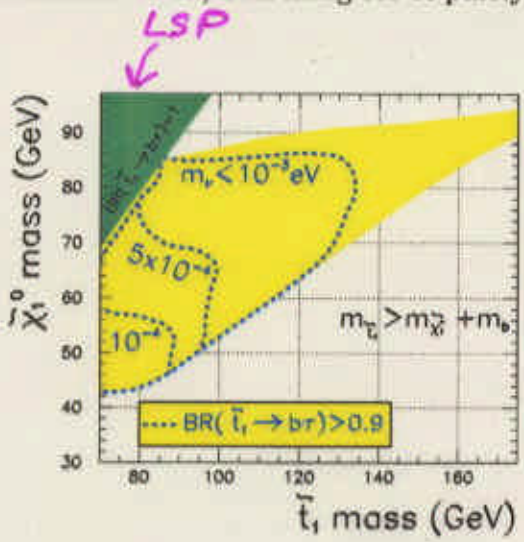


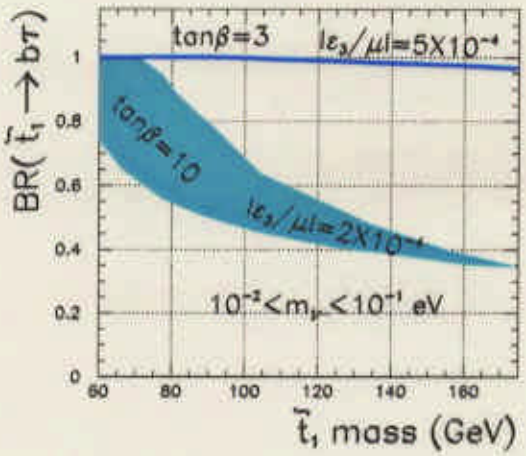


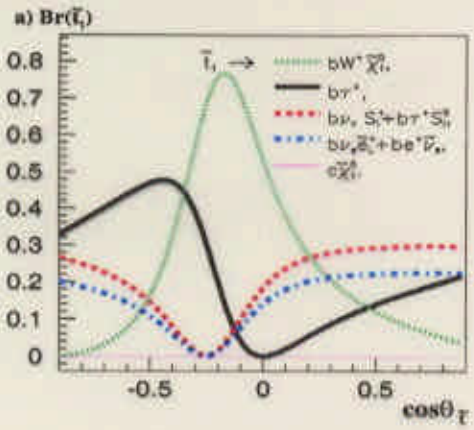
Stop decays

R parity violating decays of the top quark and the top squark at the Tevatron, de Campos, et al., hep-ph/9903245

Allanach *et al.*, Searching for R-parity violation at Run-II of the Tevatron, hep-ph/9906224.







A. Bartl, et al., Phys.Lett.B384:151-156,1996. [hep-ph/9606256]

Light stop: MSSM versus R parity violation, W. Porod, D. Restrepo, J. V. [hep-ph/0001033]

Two body decays of the lightest stop in supergravity with and without R parity

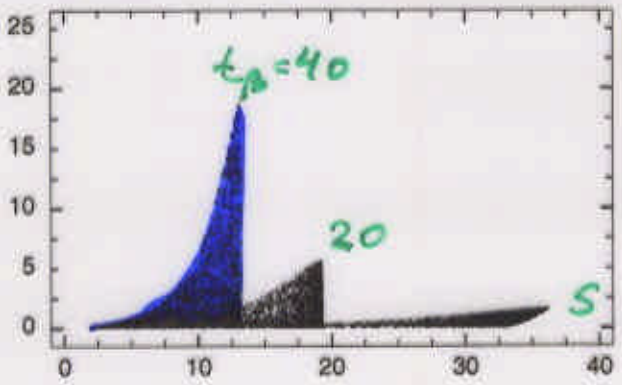
M. A. Diaz, D. A. Restrepo, J. V. [hep-ph/9908286] NPB in press

Top decays in models with bilinearly and spontaneously broken R parity.

L. Navarro, W. Porod, J. V. Phys. Lett. B459 (1999) 615-62. [hep-ph/9903474]

$\frac{B(t \to \tilde{\tau} b)}{\%}$

$m_\nu < 1 eV$



$\frac{\langle \tilde{\nu}_3 \rangle}{GeV}$

See also H. Dreiner and R. J. Phillips, Nucl. Phys. **B367** (1991) 591; Barger et al; T. Han and M. B. Magro, Phys. Lett. **B476** (2000) 79; J. Erler, J. L. Feng and N. Polonsky, Phys. Rev. Lett. **78** (1997) 3063 [hep-ph/9612397].

Conclusions

- MSSM + bilinear R-parity violation can explain the solar and atmospheric neutrino anomalies leading to predictions for neutralino decays at colliders

- $\sin^2 2\theta_{atm} \Leftrightarrow \mathrm{BR}(\mu qq') \;/\; \mathrm{BR}(\tau qq')$

- CHOOZ $\Leftrightarrow \mathrm{BR}(eqq') \;/\; \mathrm{BR}(\tau qq')$

- $\sin^2 2\theta_{sol} \Leftrightarrow \mathrm{BR}(\mu\tau\nu) \;/\; \mathrm{BR}(e\tau\nu)$