R-parity Violation

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Dubna, CALC 2009

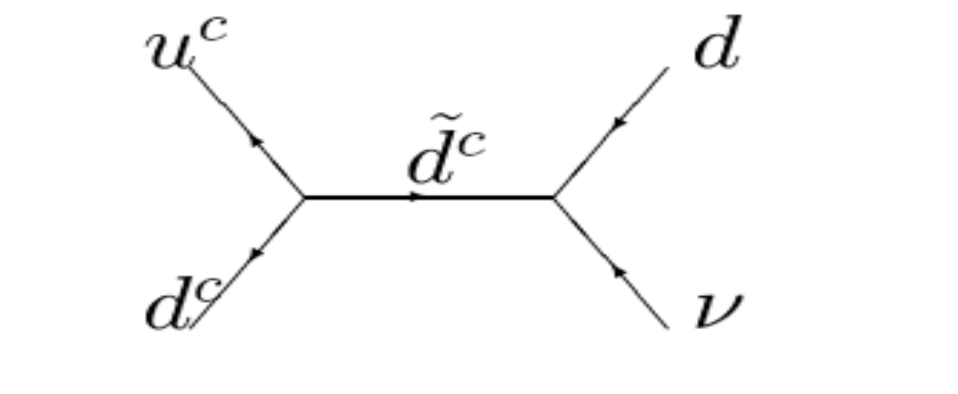
WHY R-violating SUSY?

In addition to couplings generating fermion masses,

$$h_{ij} L_i H_1 \bar{E}_j \qquad h'_{ij} Q_i H_1 \bar{D}_j \qquad h''_{ij} Q_i H_2 \bar{U}_j$$

also $$\lambda_{ijk} L_i L_j \bar{E}_k \qquad \lambda'_{ijk} L_i Q_j \bar{D}_k \qquad \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

- The first 2 violate *lepton number,* the 3rd *baryon number*
- If simultaneously present, unacceptable *p* decay



Structure of R-violating couplings

- $L_i L_j \bar{E}_k$
  [Superfield notation, SU(2) Doublet, Doublet, Singlet]
  This term gives: $L_i^- N_j \bar{E}_k$ or $N_i L_j^- \bar{E}_k$
  In component fields: Fermion-Fermion-Scalar Combinations
  The term $L_i^- N_j \bar{E}_k$ yields $\tilde{\ell}_i \nu_j \bar{e}_k$, $\ell_i \tilde{\nu}_j \bar{e}_k$, $\ell_i \nu_j \tilde{\bar{e}}_k$

- $L_i Q_j \bar{D}_k$
  [Superfield notation, SU(2) Doublet, Doublet, Singlet]
  Same as $LL\bar{E}$ with $L \to Q$, $\bar{E} \to \bar{D}$
  $L_i Q_j$-term gives: $\ell_i u_j$-term or $\nu_i d_j$-term
  u-type quarks couple to charged leptons, d-type to neutrinos

- $\bar{U}_i \bar{D}_j \bar{D}_k$: [Singlet-Singlet-Singlet]
  Simple combination of L-handed anti-quarks (R-handed quarks)

R-parity: SM particles: +1, SUSY: -1
Yukawas giving masses to fermions allowed: $\bar{f} f h_{1,2}$
All other terms forbidden: i.e. $\tilde{f}_i f_j \bar{f}_k$

Rp versus Rp-violation:

X If R-parity imposed, *(SM: +1 , SUSY: -1)*

forbids all terms with $\Delta L \neq 0$ and $\Delta B \neq 0$

LSP: stable, *dark matter candidate*

Colliders: Missing energy

✓ Can also allow subsets of operators:

Only $\Delta B \neq 0$ or $\Delta L \neq 0$

(p-decay needs both types of terms)

LSP: unstable *– lose (?) a dark matter candidate*

Colliders: Multi-lepton/jet events

i.e: Flavour-independent Discrete Symmetry ZN

(Ibanez, Ross)

SM fields have Z_N charges: $(a_Q, a_u, a_d, a_\ell, a_e)$

Higgs charges : such that fermion mass terms

are allowed $a_Q + a_d = a_\ell + a_e$

- Then, a symmetry is:

R-parity (-)	Bar.par. $(LL\bar{E}, LQ\bar{D})$	Lep.par. $(\bar{U}\bar{D}\bar{D})$
$2a_\ell + a_e \neq 0$	$2a_\ell + a_e = 0$	$2a_\ell + a_e \neq 0$
$2a_d + a_u \neq 0$	$2a_d + a_u \neq 0$	$2a_d + a_u = 0$

Note: If $2a_\ell + a_e = 0$ then $a_\ell + a_Q + a_d = 0$

Can go even further with flavour symmetries:

- Experimental bounds (see later) indicate:

  large hierarchies between $R\!\!\!/_p$ operators

- Similar hierarchies observed in fermion masses
- How are the two problems related?

- Generation of R-violating terms $\rightarrow$

  as for fermion masses through effective terms

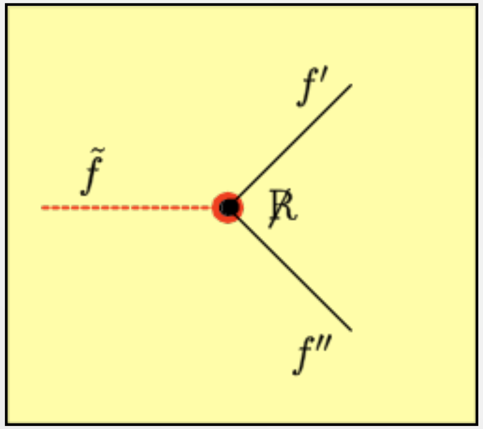
$$LL\bar{E}\left(\frac{<\theta>}{M}\right)^n, LQ\bar{D}\left(\frac{<\theta>}{M}\right)^n, \bar{U}\bar{D}\bar{D}\left(\frac{<\theta>}{M}\right)^n$$

As before n depends on charges of $L, \bar{E}, Q, \bar{U}, \bar{D}$

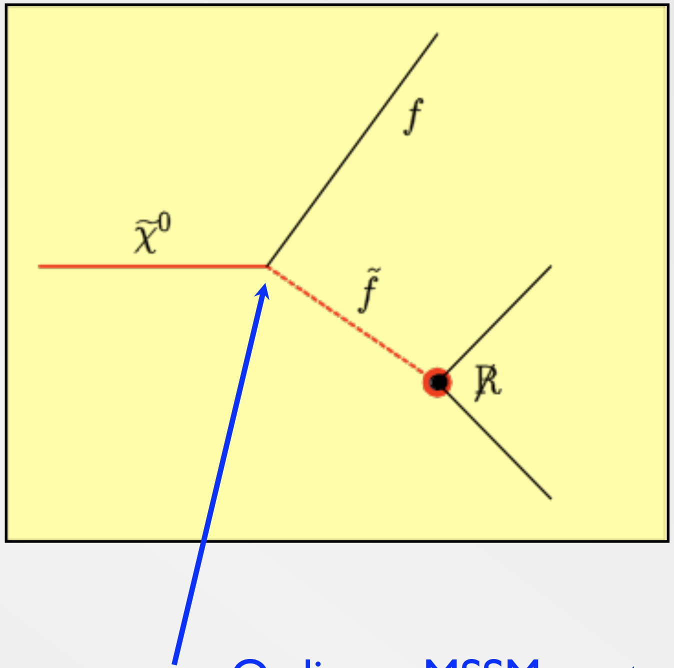
[Ben-Hamo,Binetruy,Bhattacharyya, Dudas, Ellis,

Nir,Lavignac,Lola,Ramond,Ross,Savoy,...]

R-violating signals: couplings & LSP decays



R-parity violating
coupling



Ordinary MSSM neutralino coupling
Neutr. Decays to 3 SM particles

For a Review, see Barbier et al., hep-ph/0406039 and Refs therein
See also Allanach, Dedes & Dreiner, hep-ph/9906209

Some of the earliest refs on R-violation

F. Zwirner, Phys. Lett. B132 (1983) 103

L. Hall and M. Suzuki, Nucl. Phys. B231 (1984) 419

J. Ellis et al, Phys. Lett. B150 (1985) 142

G. Ross and J. Valle, Phys. Lett. B151 (1985) 375

S. Dawson, Nucl. Phys. B261 (1985) 297

R. Barbieri and A. Masiero, Nucl. Phys. B267 (1986) 679

S. Dimopoulos and L.J. Hall, Phys. Lett. B207 (1987) 210

V. Barger, G.F. Giudice, and T. Han, Phys. Rev. D40 (1989) 2987

♦ Possible Signals

- Pair sparticle productions and R-violating decays
- Single superparticle productions
- Virtual processes

- Single sparticle productions possible for large Rp
- Otherwise MSSM productions, and Rp decays

♦ (neutral/charged) LSP decay to SM particles

for any $\lambda, \lambda', \lambda'' \geq 10^{-6}$, decay inside apparatus $\Rightarrow$

♦ Missing energy $\rightarrow$ multi-lepton/jet signals

otherwise: Standard missing energy signature

$$[h_{top} \approx O(1), h_{up} \approx O(10^{-5})]$$

Cosmology & R-parity violation

Initially thought that:

- ✓ ΔB operators in equilibrium at EPT would erase any pre-existing baryon asymmetry
- ✓ Constrain the couplings to be small, so that the relevant interactions are out of equilibrium
- ✓ Even ΔL bounded, since it can transform to ΔB

$$\Delta B(t) = \frac{1}{2}\Delta(B-L)_i + \frac{1}{2}\Delta(B+L)_i e^{-\gamma t}$$

- ✓ Very strict limits $\lambda \leq 10^{-8}$

  Preclude R-violation in Colliders

These constraints can be avoided, in either of the following:

- ✓ ΔB generated at/below EPT
- ✓ Rp is spontaneously broken at low Temperature
- ✓ ΔL couplings are family-dependent

  (then can avoid bounds in given flavour channels)

- ✓ Early leptogenesis ΔLi – ΔLj may occur in specific channels

  and then may transform to ΔB

More dangerous: Flavour-dependent Constraints from modifications of SM processes)

ijk	λ_{ijk}	Sources	ijk	λ''_{ijk}	Sources
121	0.05	CC univ.	112	10^{-6}	Double nucleon dec.
122	0.05	CC univ.	113	10^{-4}	n–$\bar{n}$ osc.
123	0.05	CC univ.	123	1.25	Perturb. unitar.
131	0.06	$\Gamma(\tau \to e\nu\bar{\nu})/\Gamma(\tau \to \mu\nu\bar{\nu})$	212	1.25	Perturb. unitar.
132	0.06	$\Gamma(\tau \to e\nu\bar{\nu})/\Gamma(\tau \to \mu\nu\bar{\nu})$	213	1.25	Perturb. unitar.
133	0.003	ν_e- mass	223	1.25	Perturb. unitar.
231	0.06	$\Gamma(\tau \to e\nu\bar{\nu})/\Gamma(\tau \to \mu\nu\bar{\nu})$	312	0.50	R_l (LEP1)
232	0.06	$\Gamma(\tau \to e\nu\bar{\nu})/\Gamma(\tau \to \mu\nu\bar{\nu})$	313	0.50	R_l (LEP1)
233	0.06	$\Gamma(\tau \to e\nu\bar{\nu})/\Gamma(\tau \to \mu\nu\bar{\nu})$	323	0.50	R_l (LEP1)

Upper limits on λ- and λ''-couplings for $\tilde{m} = 100$ GeV.

ijk	λ'_{ijk}	Sources	ijk	λ'_{ijk}	Sources	ijk	λ'_{ijk}	Sources
111	0.00035	$(\beta\beta)_{0\nu}$	211	0.09	R_π (π-dec.)	311	0.10	$\tau^- \to \pi^- \nu_\tau$
112	0.02	CC univ.	212	0.09	R_π (π-dec.)	312	0.10	$\tau^- \to \pi^- \nu_\tau$
113	0.02	CC univ.	213	0.09	R_π (π-dec.)	313	0.10	$\tau^- \to \pi^- \nu_\tau$
121	0.035	APV	221	0.18	D-dec.	321	0.20	D^0–$\bar{D}^0$
122	0.02	ν_e-mass	222	0.18	D-dec.	322	0.20	D^0–$\bar{D}^0$
123	0.20	D^0–$\bar{D}^0$	223	0.18	D-dec.	323	0.20	D^0–$\bar{D}^0$
131	0.035	APV	231	0.22	ν_μ DIS.	331	0.48	R_τ(LEP)
132	0.34	R_e (LEP)	232	0.36	R_μ (LEP)	332	0.48	R_τ(LEP)
133	0.0007	ν_e-mass	233	0.36	R_μ (LEP)	333	0.48	R_τ(LEP)

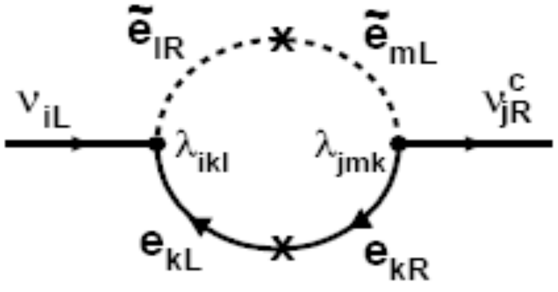
Upper limits on λ'-couplings for $\tilde{m} = 100$ GeV.

Combinations	Limits	Sources	Combinations	Limits	Sources
$\lambda'_{11k}\lambda''_{11k}$	10^{-22}	Proton dec.	$\lambda'_{ijk}\lambda''_{lmn}$	10^{-10}	Proton dec.
$\lambda_{1j1}\lambda_{1j2}$	7.10^{-7}	$\mu \to 3e$	$\lambda_{231}\lambda_{131}$	7.10^{-7}	$\mu \to 3e$
Im $\lambda'_{i12}\lambda'^{*}_{i21}$	8.10^{-12}	ϵ_K	$\lambda'_{i12}\lambda'_{i21}$	1.10^{-9}	Δm_K
$\lambda'_{i13}\lambda'_{i31}$	8.10^{-8}	Δm_B	$\lambda'_{1k1}\lambda'_{2k2}$	8.10^{-7}	$K_L \to \mu e$
$\lambda'_{1k1}\lambda'_{2k1}$	5.10^{-8}	μTi $\to e$Ti	$\lambda'_{11j}\lambda'_{21j}$	5.10^{-8}	μTi $\to e$Ti

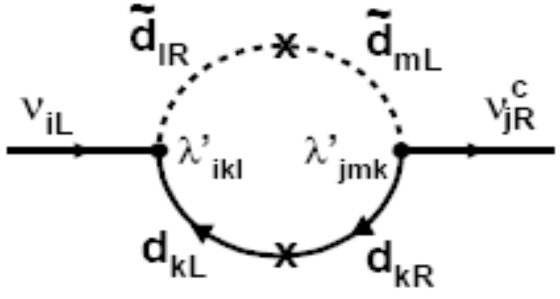
Upper limits on some important product couplings for $\tilde{m} = 100$ GeV.

Neutrinos in R-violating SUSY

<u>1-loop neutrino mass contributions:</u>



(a)



(b)

$$M^{\nu}_{ij}|_{\lambda} = \frac{1}{16\pi^2} \sum_{k,l,m} \lambda_{ikl}\lambda_{jmk}\, m_{e_k} \frac{(\tilde{m}^{e\,2}_{LR})_{ml}}{m^2_{\tilde{e}_{Rl}} - m^2_{\tilde{e}_{Lm}}} \ln\left(\frac{m^2_{\tilde{e}_{Rl}}}{m^2_{\tilde{e}_{Lm}}}\right) + (i \leftrightarrow j)$$

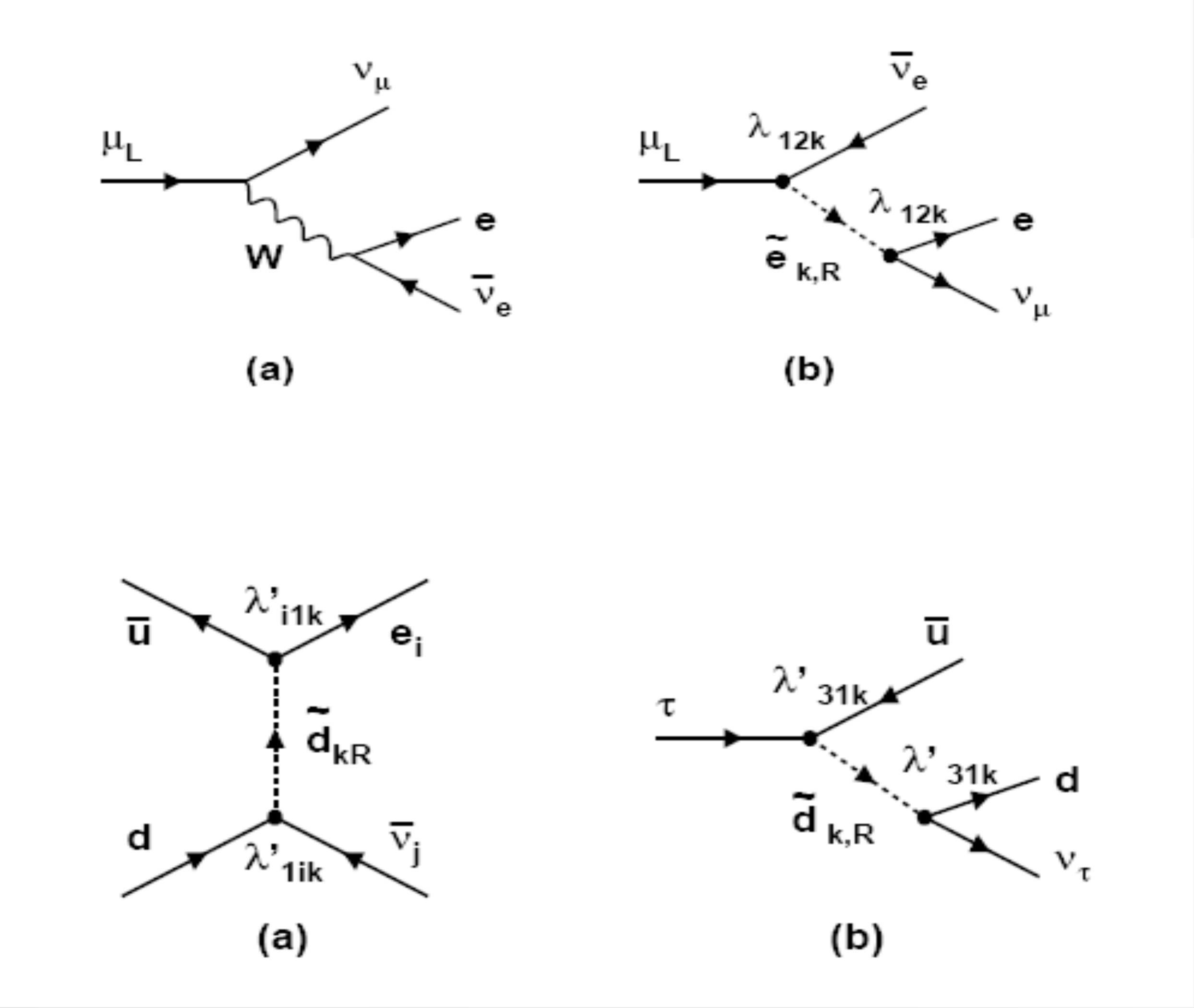
$$M^{\nu}_{ij}|_{\lambda'} = \frac{3}{16\pi^2} \sum_{k,l,m} \lambda'_{ikl}\lambda'_{jmk}\, m_{d_k} \frac{(\tilde{m}^{d\,2}_{LR})_{ml}}{m^2_{\tilde{d}_{Rl}} - m^2_{\tilde{d}_{Lm}}} \ln\left(\frac{m^2_{\tilde{d}_{Rl}}}{m^2_{\tilde{d}_{Lm}}}\right) + (i \leftrightarrow j)$$

Constraints on R-violating couplings from massive neutrinos

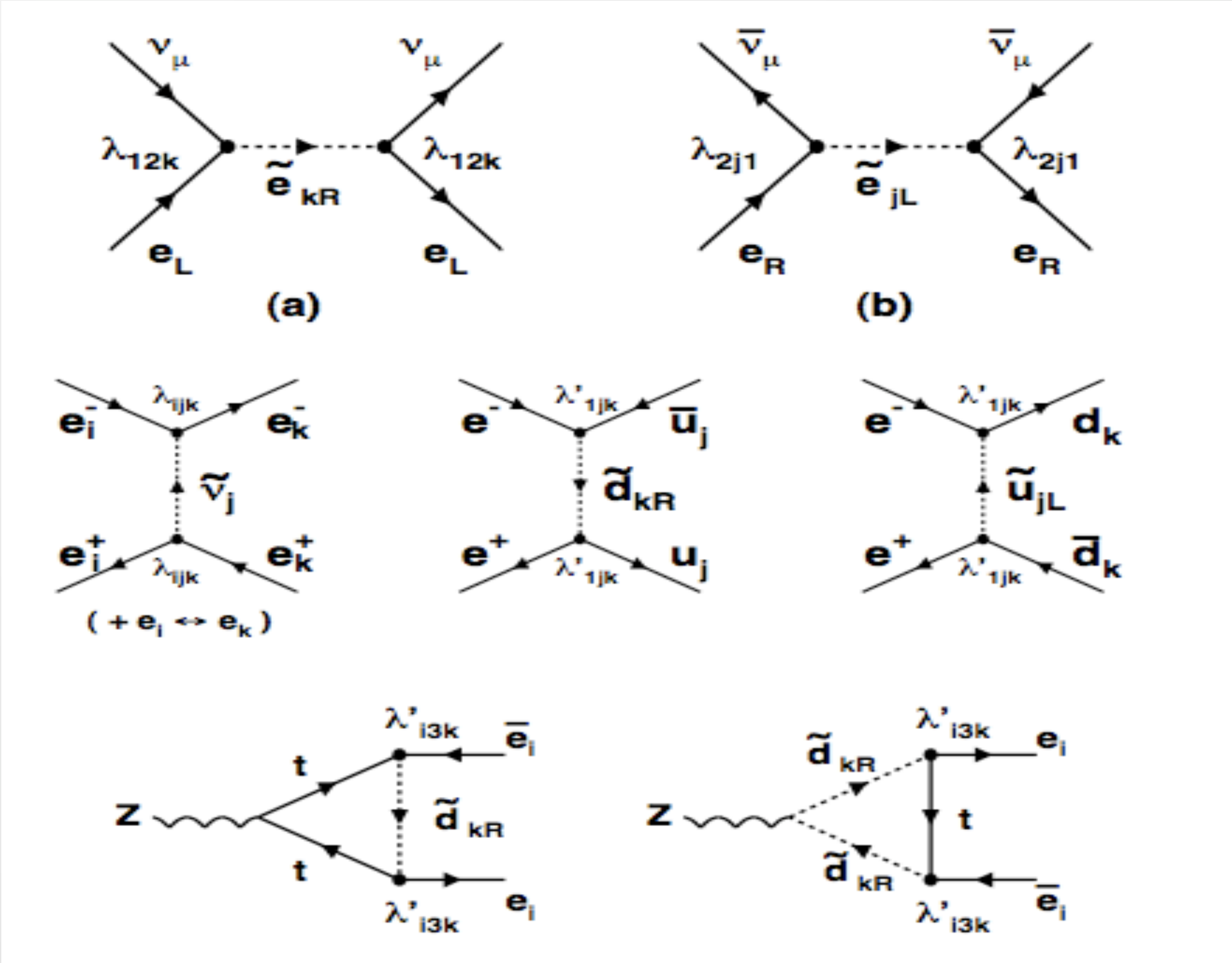
$$\lambda_{133} \leq 9.4 \times 10^{-4} \left(\frac{<m_\nu>}{0.35\ eV}\right)^{\frac{1}{2}} \left(\frac{\tilde{m}}{100\ GeV}\right)^{\frac{1}{2}}$$

$$\lambda'_{133} \leq 2.1 \times 10^{-4} \left(\frac{<m_\nu>}{0.35\ eV}\right)^{\frac{1}{2}} \left(\frac{4.5\ GeV}{m_b}\right) \left(\frac{\tilde{m}}{100\ GeV}\right)^{\frac{1}{2}}$$

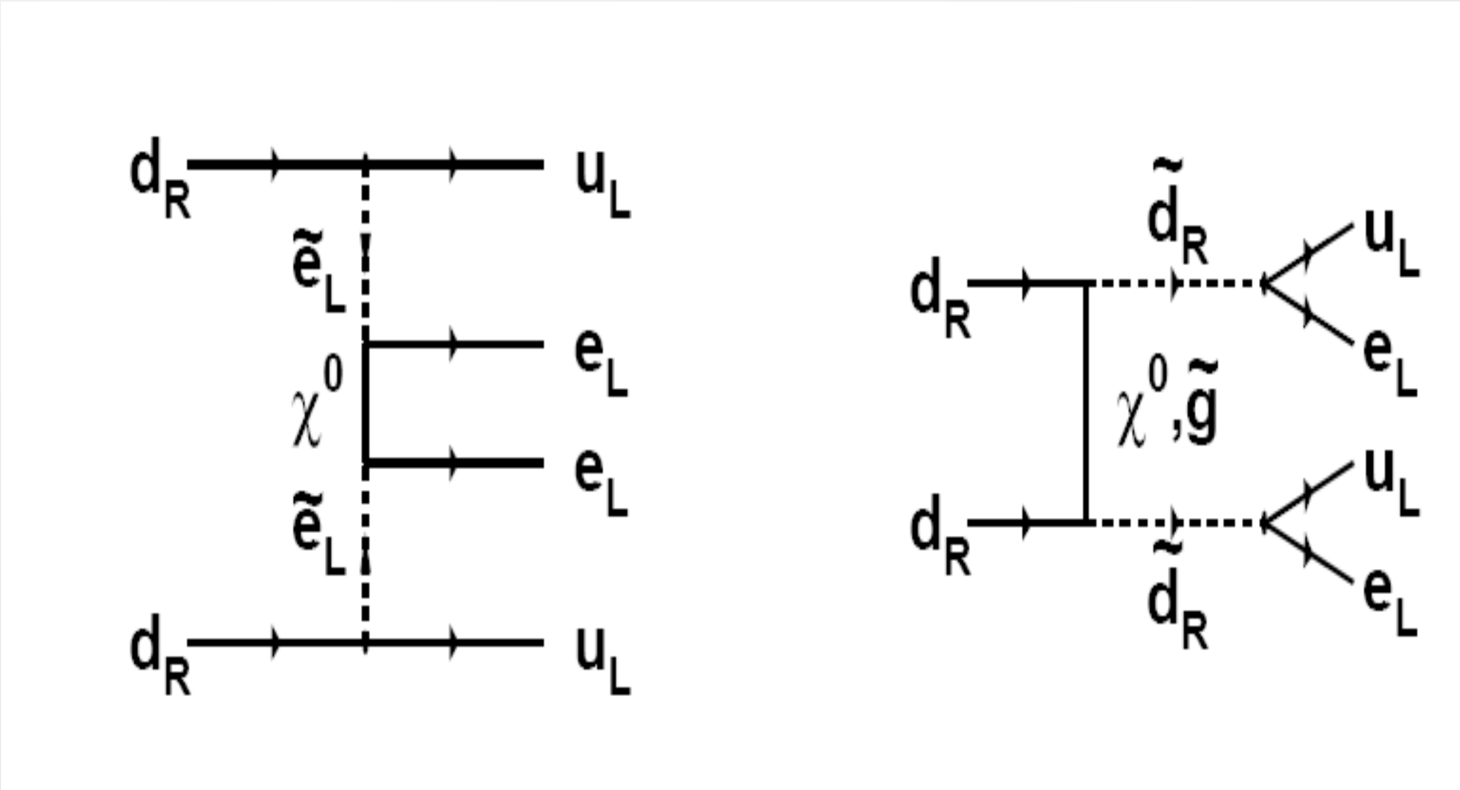
Charged Current Universality



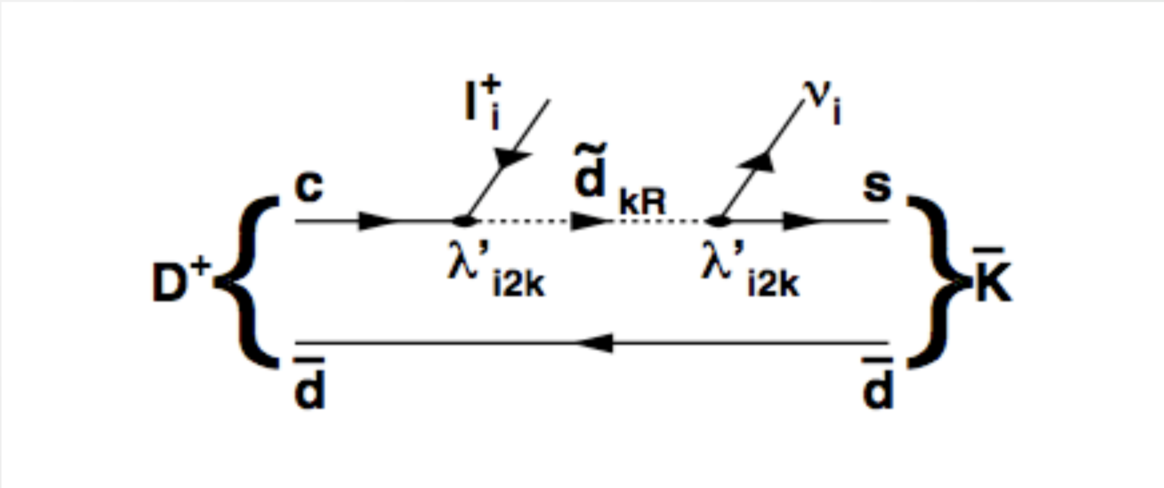
Neutral Current Interactions

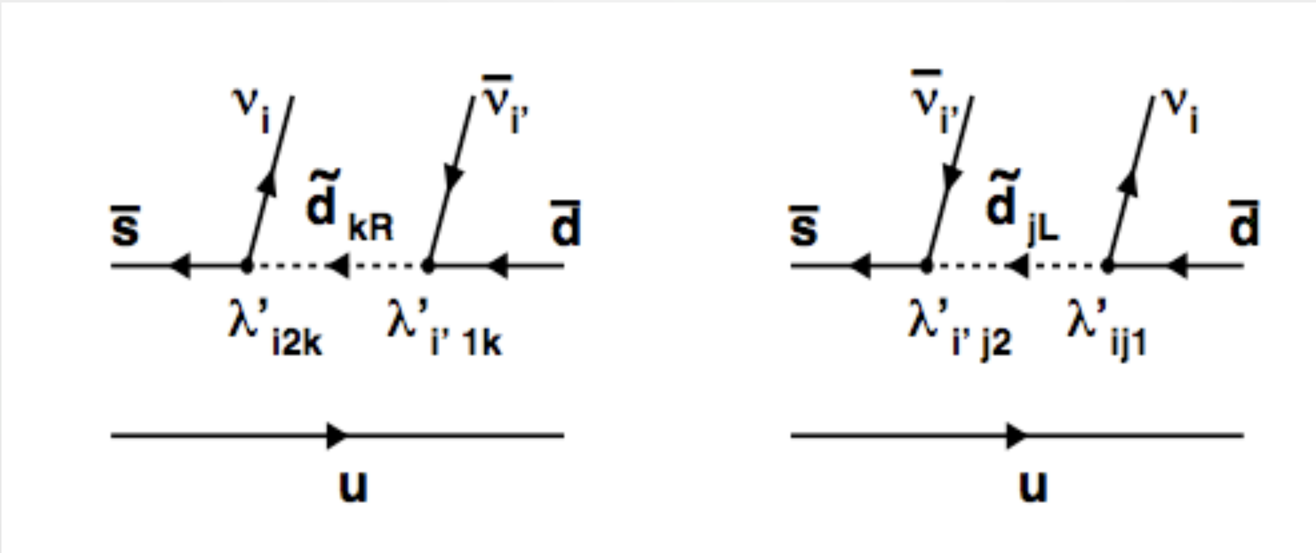


Neutrinoless Double Beta Decay

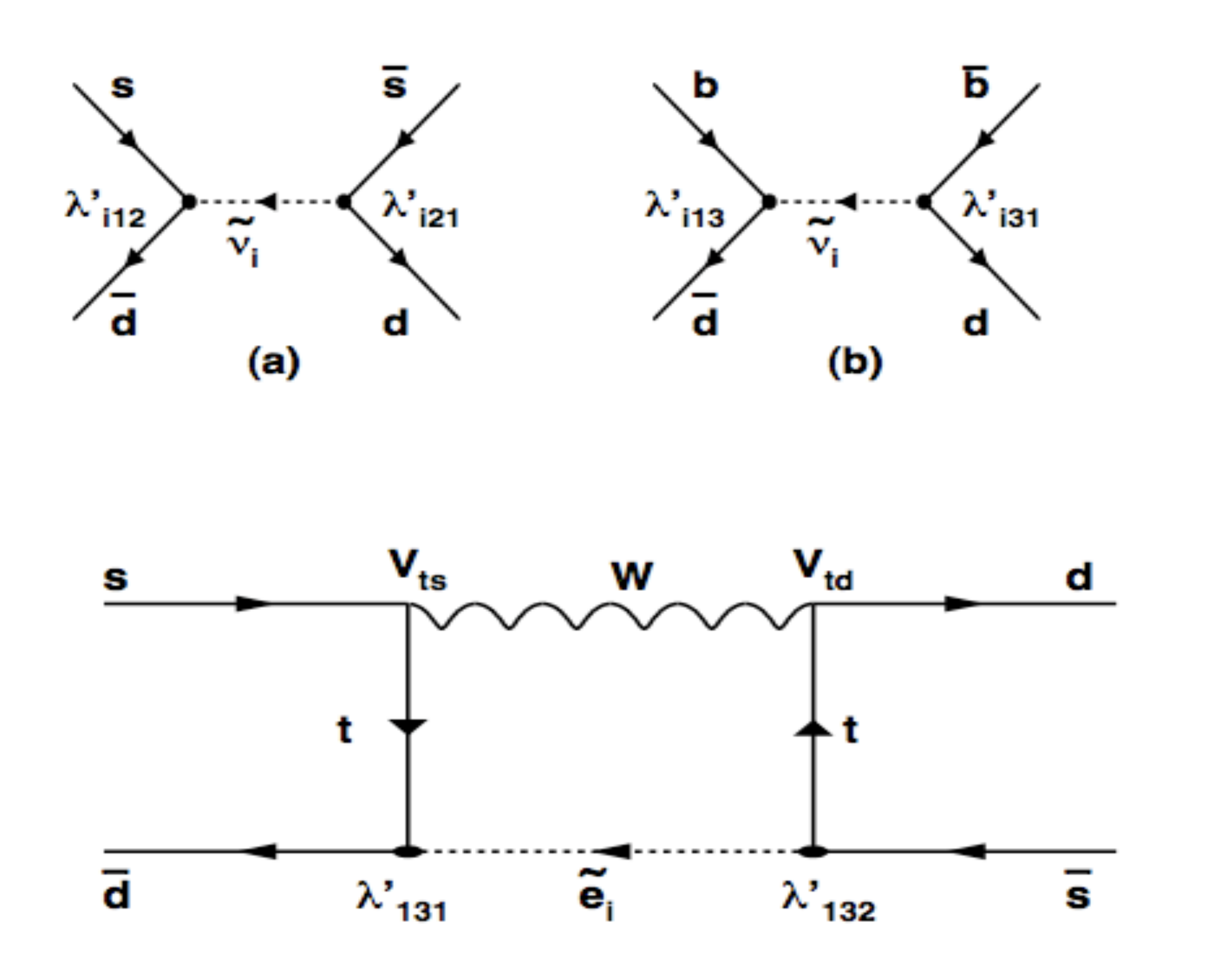


Rare Semi-leptonic decays

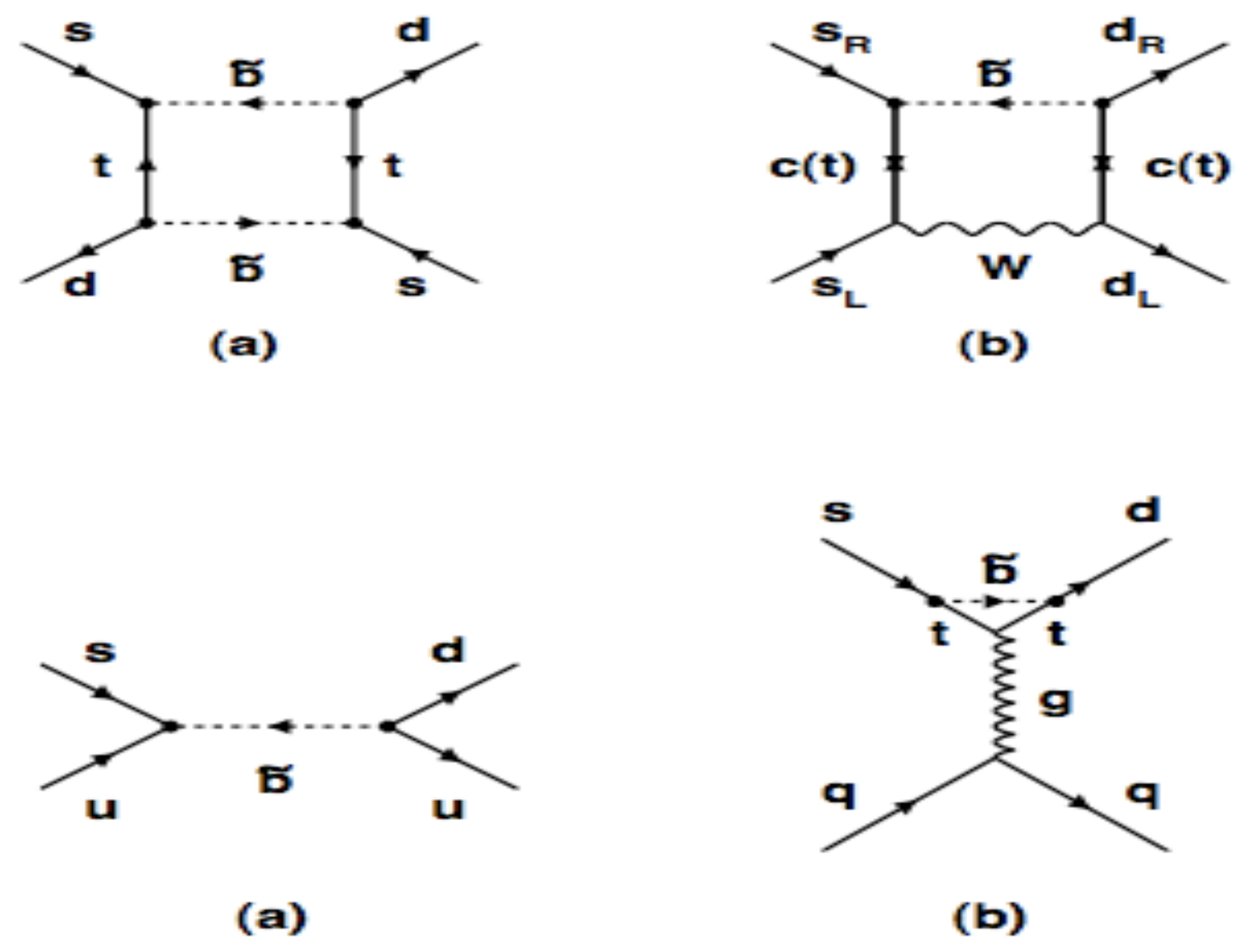




Hadron Flavour Changing Processes

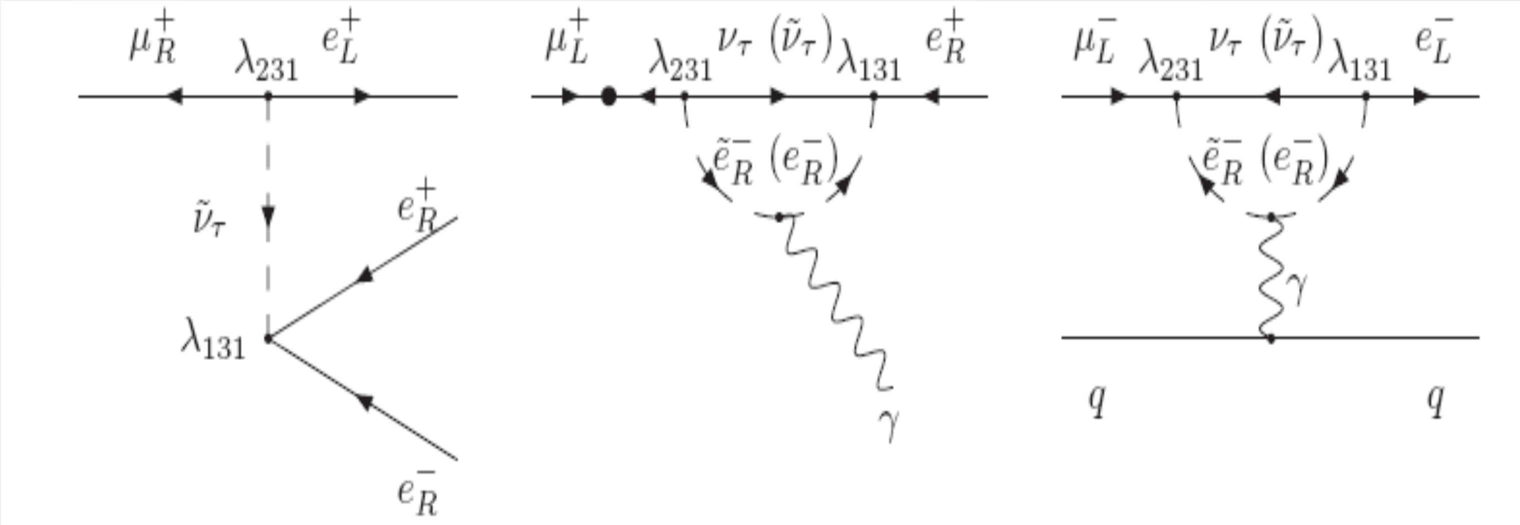


Kaon System



R-violation: Correlated Rates depending on coupling combinations

(A. de Gouvea, S.L, K. Tobe)

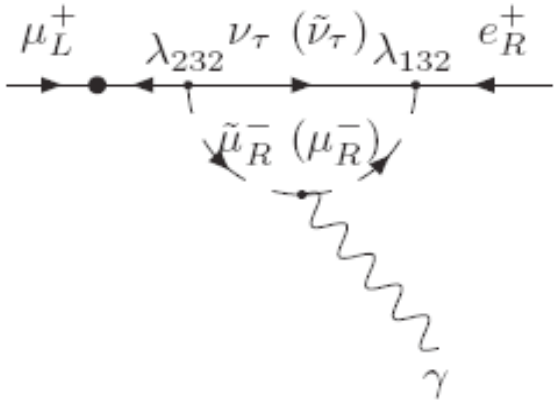


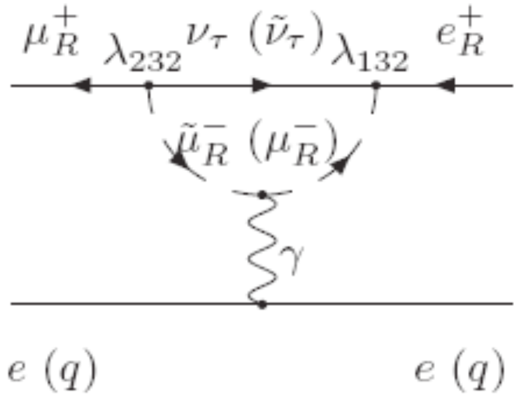
$$\frac{\mathrm{Br}(\mu^+ \to e^+\gamma)}{\mathrm{Br}(\mu^+ \to e^+e^-e^+)} = \frac{4\times 10^{-4}\left(1-\frac{m^2_{\tilde{\nu}_\tau}}{2m^2_{\tilde{e}_R}}\right)^2}{\beta} = 1\times 10^{-4}$$

$$\frac{\mathrm{R}(\mu^- \to e^- \text{ in Ti (Al)})}{\mathrm{Br}(\mu^+ \to e^+e^-e^+)} = 2\ (1)\times 10^{-3}$$

*To be compared with **160** and **0.92** in MSSM*
(where always 1-loop: on shell photon penguin dominates)

For all processes at loop level:

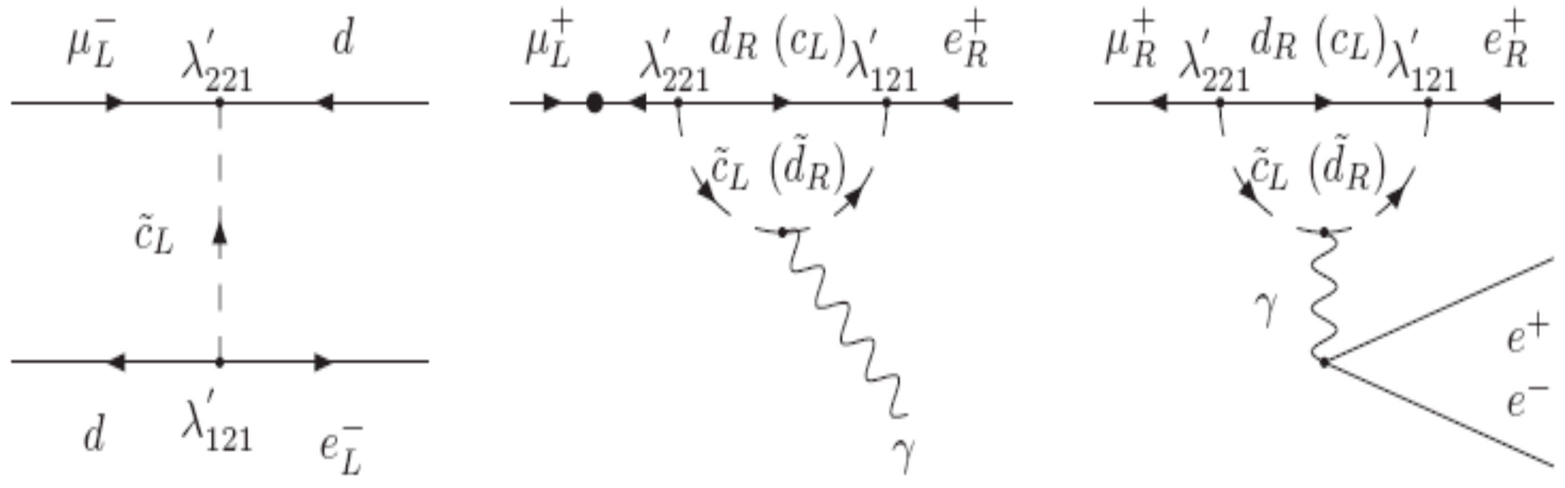




$$\frac{\mathrm{Br}(\mu^+ \longrightarrow e^+\gamma)}{\mathrm{Br}(\mu^+ \longrightarrow e^+e^-e^+)} = 1.2$$

$$\frac{\mathrm{R}(\mu^- \longrightarrow e^- \ \text{ in Ti (Al)})}{\mathrm{Br}(\mu^+ \longrightarrow e^+e^-e^+)} = 18$$

For:



$$\frac{\mathrm{Br}(\mu^+ \to e^+\gamma)}{\mathrm{Br}(\mu^+ \to e^+e^-e^+)} = 1.1,$$

$$\frac{\mathrm{R}(\mu^- \to e^- \text{ in Ti (Al)})}{\mathrm{Br}(\mu^+ \to e^+e^-e^+)} = 2\ (1) \times 10^5$$

	$\frac{Br(\mu\to e\gamma)}{Br(\mu\to 3e)}$	$\frac{R(\mu\to e \text{ in Ti})}{Br(\mu\to 3e)}$
Case (1)		
$\lambda_{131}\lambda_{231}$	1×10^{-4}	2×10^{-3}
$\lambda_{121}\lambda_{122}$	8×10^{-4}	7×10^{-3}
$\lambda_{131}\lambda_{132}$	8×10^{-4}	5×10^{-3}
Case (2)		
$\lambda_{132}\lambda_{232}$	1.2	18
$\lambda_{133}\lambda_{233}$	3.7	18
$\lambda_{231}\lambda_{232}$	3.6	18
$\lambda'_{122}\lambda'_{222}$	1.4	18
$\lambda'_{123}\lambda'_{223}$	2.2	18
Case (3)		
$\lambda'_{111}\lambda'_{211}$	0.4	3×10^{2}
$\lambda'_{112}\lambda'_{212}$	0.5	8×10^{4}
$\lambda'_{113}\lambda'_{213}$	0.7	1×10^{5}
$\lambda'_{121}\lambda'_{221}$	1.1	2×10^{5}
MSSM with ν_R	1.6×10^{2}	0.92

Distinct differences in LFV predictions between

(i) MSSM & R-violation

(ii) different combinations of (dominant) R-violating couplings

Collider search Strategies….

For ΔL, look for:

Modifications to SM Processes or Exotic Events

(like ΔLi , novel final state topologies,

isolated leptons in jet backgrounds without missing Energy)

More detailed analysis (sophisticated jet clustering algorithms)

required for detecting ΔB operators

(Butterworth,Ellis, Raklev, Salam)

…keeping in mind the constraints

Fermion mixing $\Rightarrow$ mixing of different operators

$\Rightarrow$ Correlations of experimental bounds

that depend on flavour charges

An example: $L_1 Q_2 \bar{D}_1$ cannot be very large

- If $V_{CKM}(1,2)$ arises from down sector:

  bounds from $K \rightarrow \pi \nu \bar{\nu}$

- If $V_{CMK}(1,2)$ arises from up sector:

  bounds from neutrinoless double beta decay

...and even more constraints in given models

- Strong constraints on products of couplings ie:

$$\lambda'_{i13}\lambda'_{i31} \leq 3.2 \cdot 10^{-7}$$
$$\lambda'_{i12}\lambda'_{i21} \leq 4 \cdot 10^{-9}$$

(+) Symmetric quark matrices $\Rightarrow$

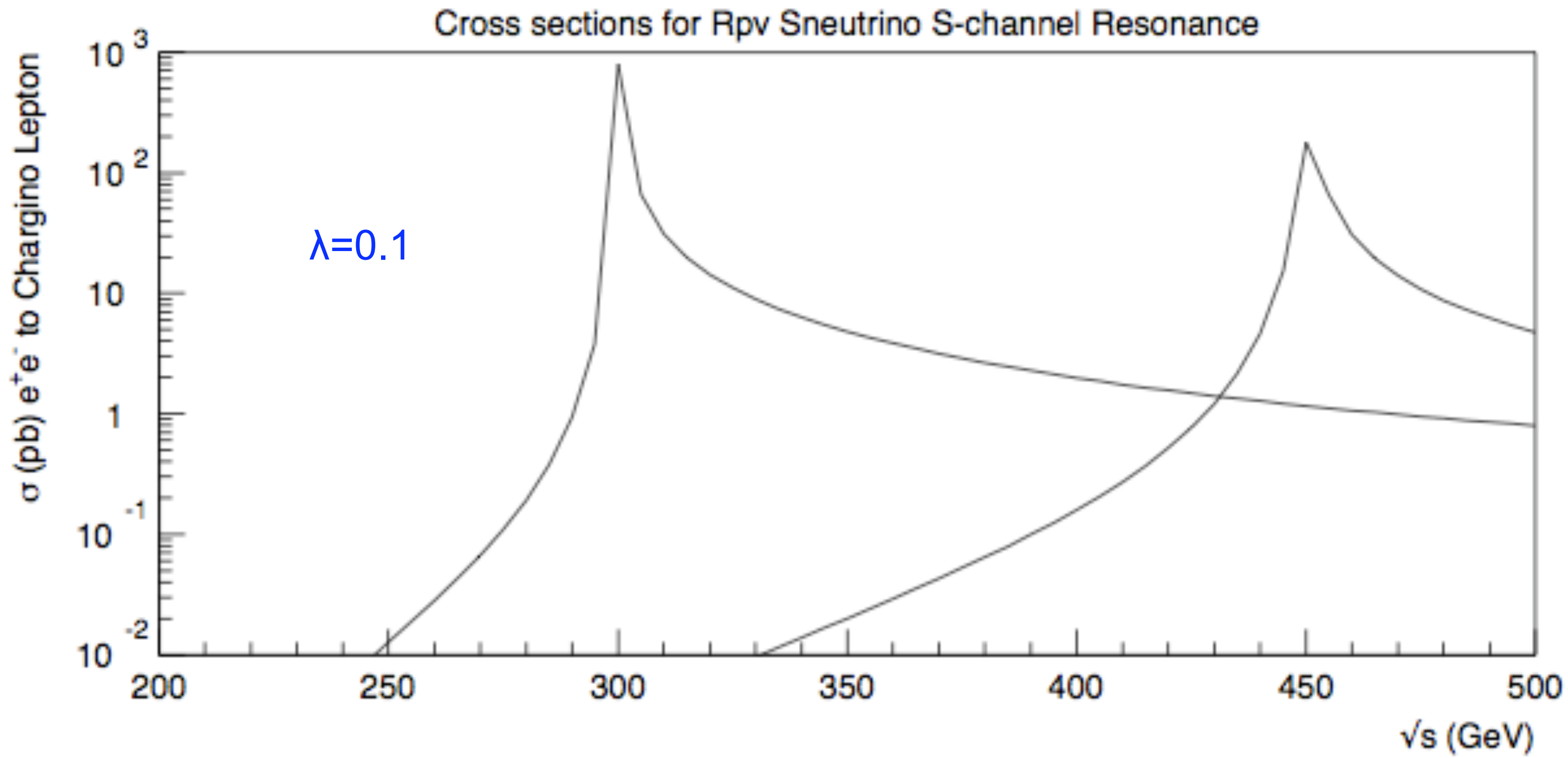
$$\lambda'_{i13} \leq 6 \cdot 10^{-4}$$
$$\lambda'_{i12} \leq 6 \cdot 10^{-5}$$

(also for couplings with $j \leftrightarrow k$)

Single sleptons at e+e- Colliders *(Dreiner, SL)*

$$e^+e^- \to (\tilde{\nu})^* \to f\bar{f}' \quad \text{and} \quad e^+e^- \to (\tilde{\nu})^* \to \begin{cases} \ell_i^\pm \, \tilde{\chi}^\mp \\ \nu_i \, \tilde{\chi}^0 \end{cases}$$

$$\to \quad \frac{8\pi}{m_{\tilde{\nu}}^2} B(\tilde{\nu} \to f\bar{f}) B(\tilde{\nu} \to \nu\tilde{\chi}^0) \text{ , as } s \to m_{\tilde{\nu}}^2$$



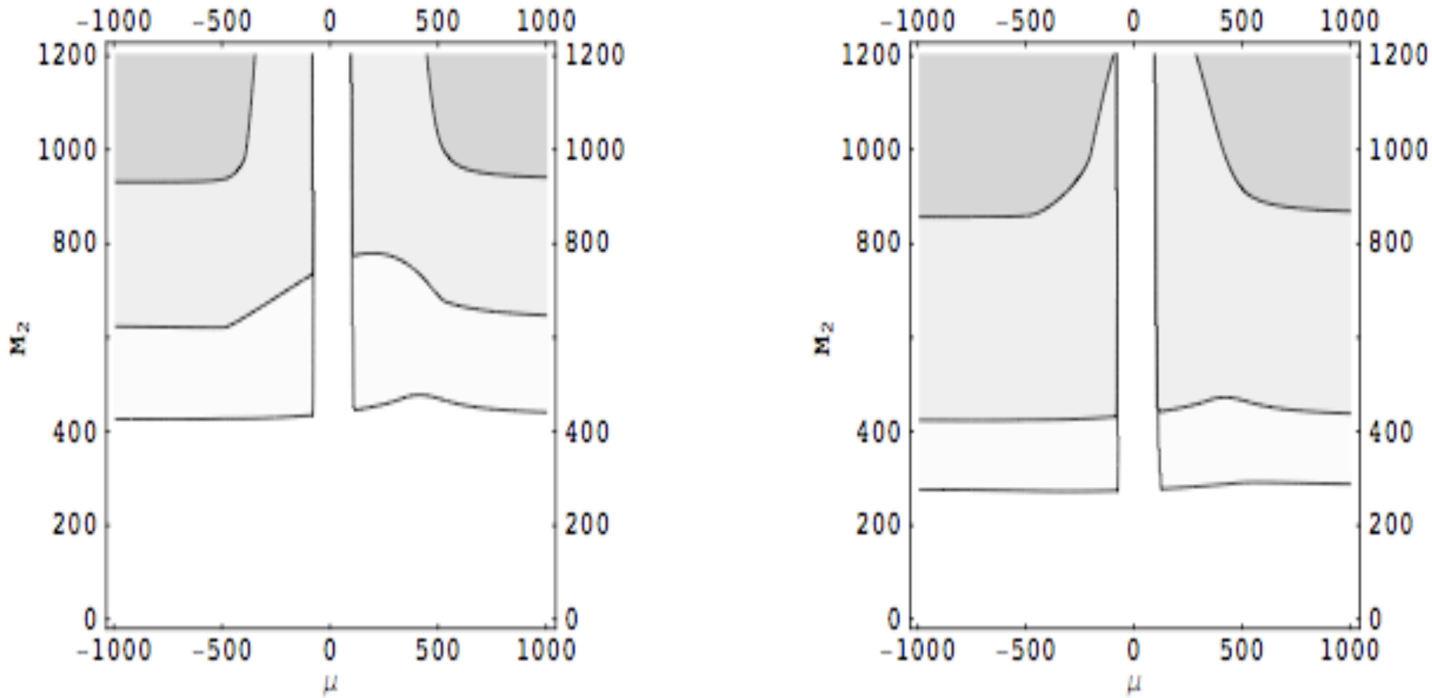
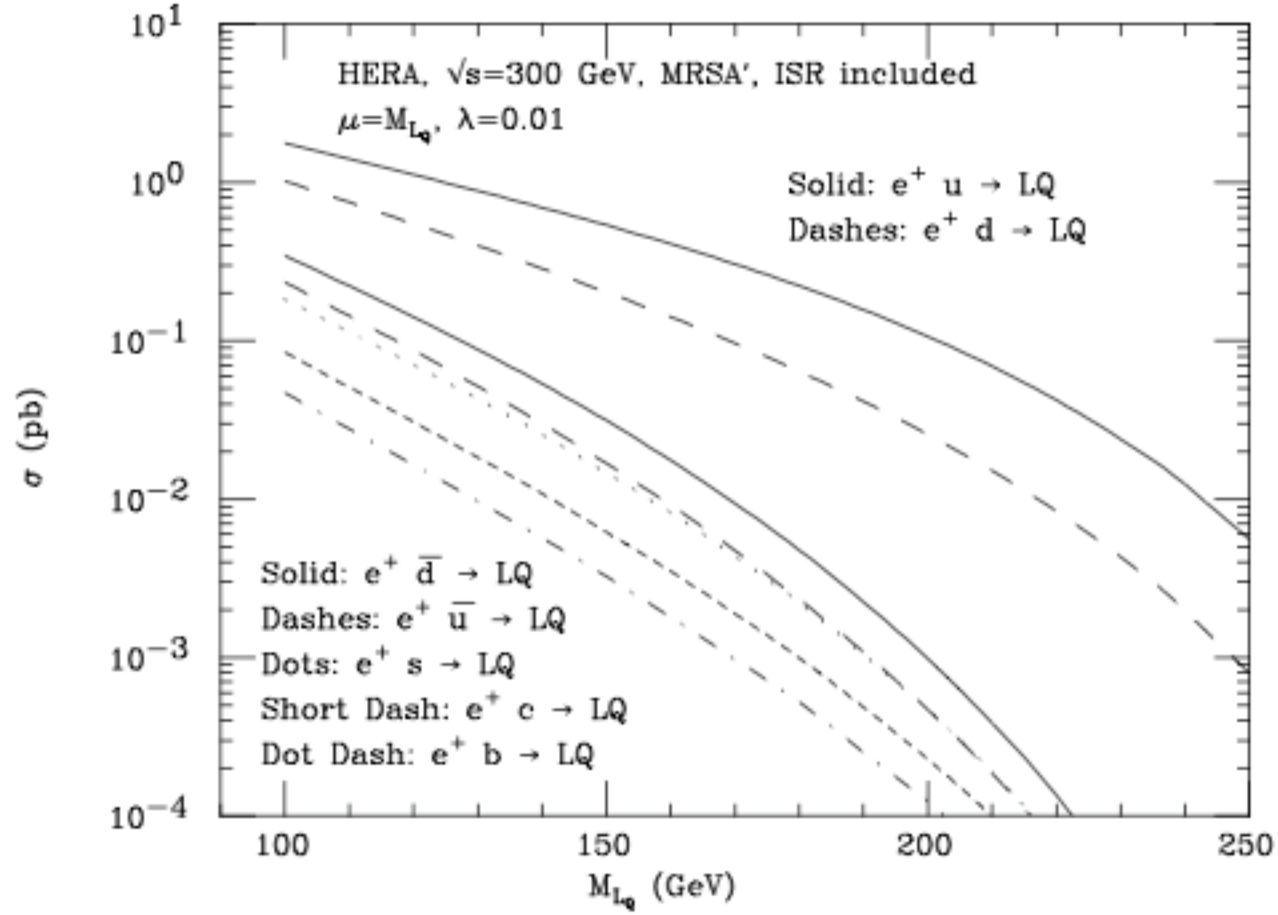


Figure 2: *$\mathcal{B}$ for $\tilde{\nu}$ decay to fermions for parameters most relevant for LC. We present contours for $\mathcal{B} \geq 0.9, 0.3, 0.1$, from the darker to the lighter areas respectively. We choose $\tan\beta = 2.0, m_{\tilde{\nu}} = 500$ GeV and $\lambda = 0.1$ (left) and 0.2 (right). The LEP 2 bound on charginos has been implemented.*

Single Leptoquark / squark productions at HERA

(Altarelli, Ellis, Guidice, SL, Mangano)



Cancellation effects in LH - squark decays

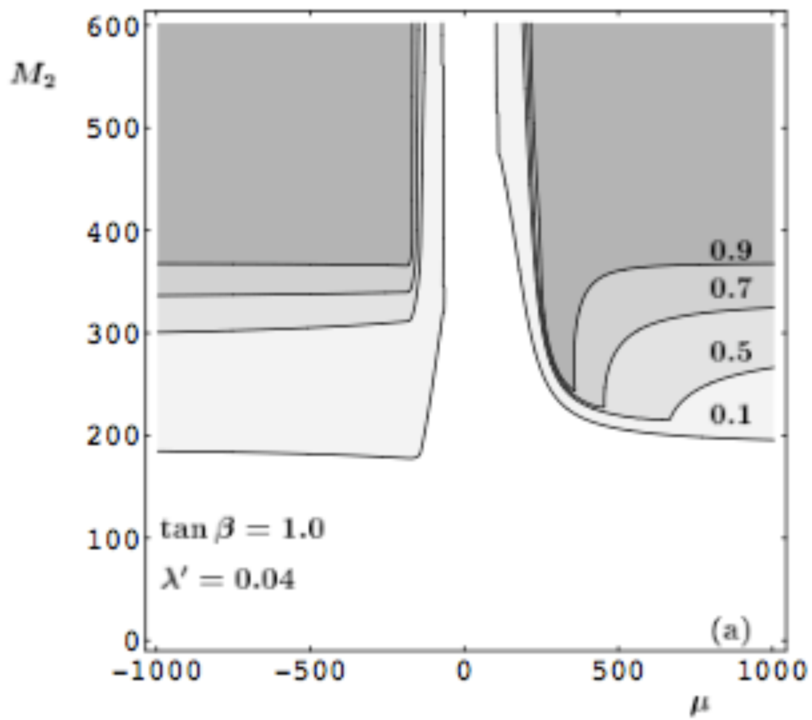
(Altarelli, Ellis, Guidice, SL, Mangano)

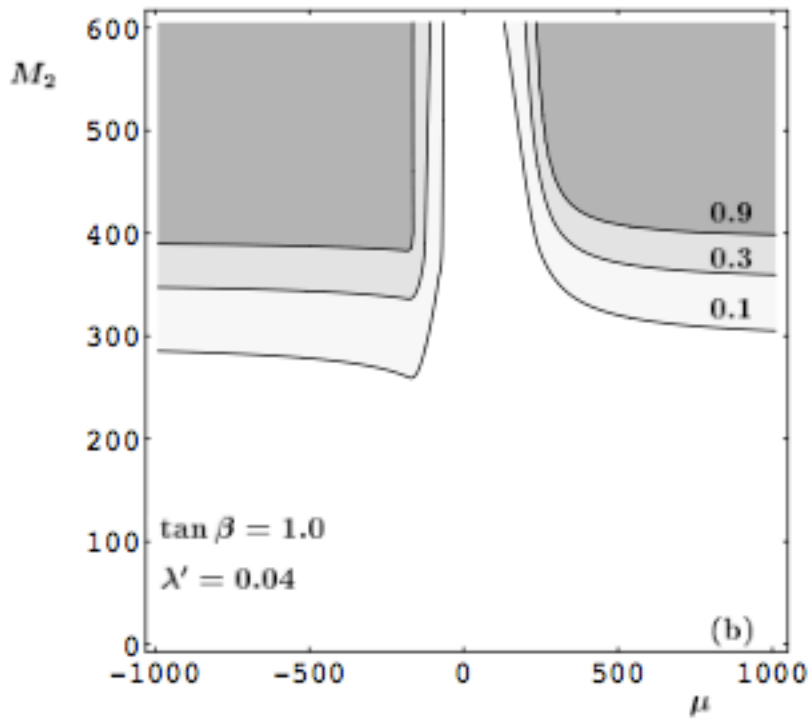
$$\Gamma(\tilde{c}_L \to e^+ d) = \frac{1}{16\pi}(\lambda'_{121})^2 m_{\tilde{c}_L}$$

$$\Gamma(\tilde{c}_L \to c\chi_i^0) = \frac{g^2}{32\pi}(A_i^2 + B_i^2)\, m_{\tilde{c}_L}\left(1 - \frac{m^2_{\chi_i^0}}{m^2_{\tilde{c}_L}}\right)^2$$

$$A_i = \frac{m_c N_{i4}}{M_W \sin\beta}, \quad B_i = N_{i2} + \frac{1}{3}\tan\theta_W N_{i1} \ .$$

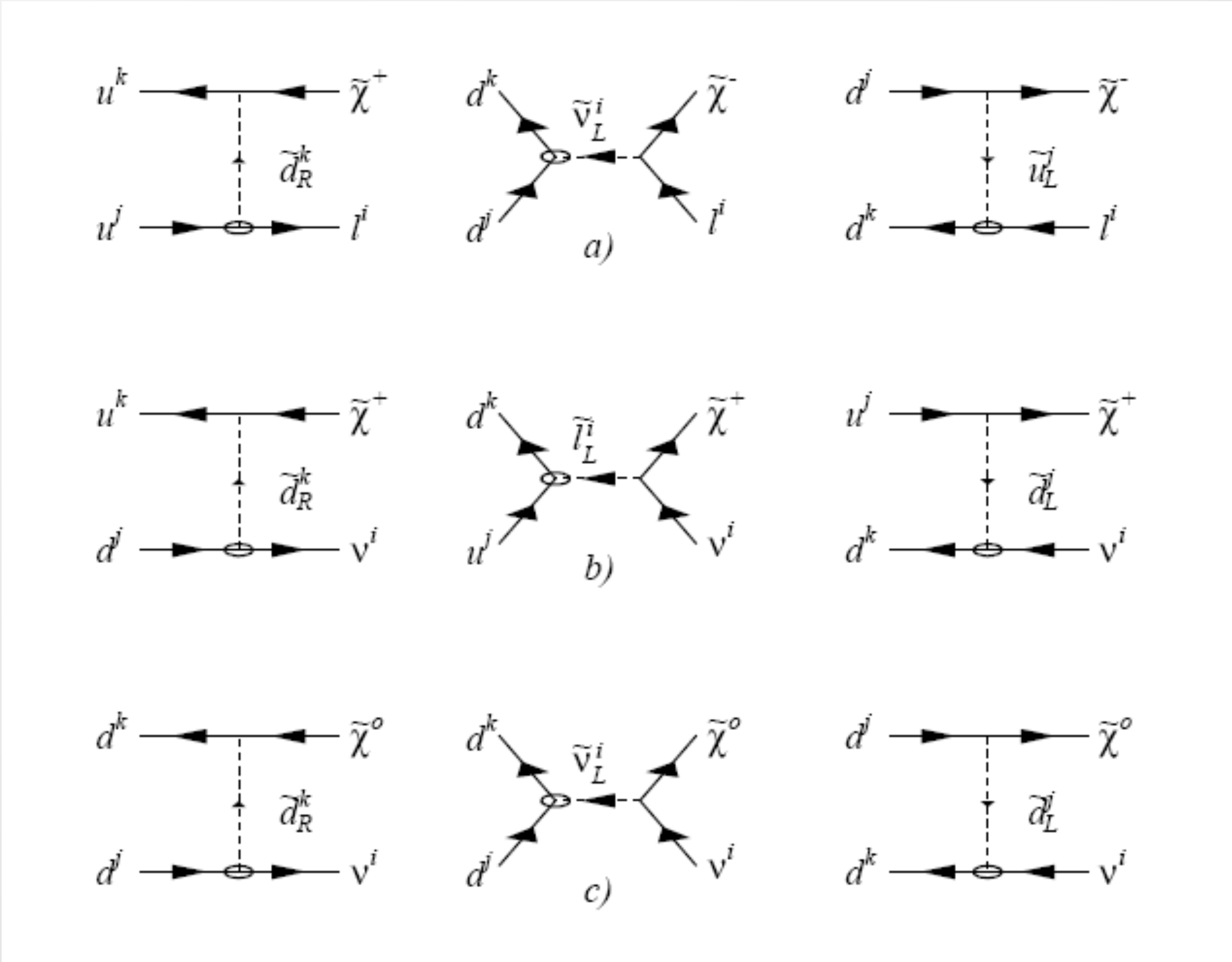
i.e. LH-squark (left) versus sneutrino decays (right)





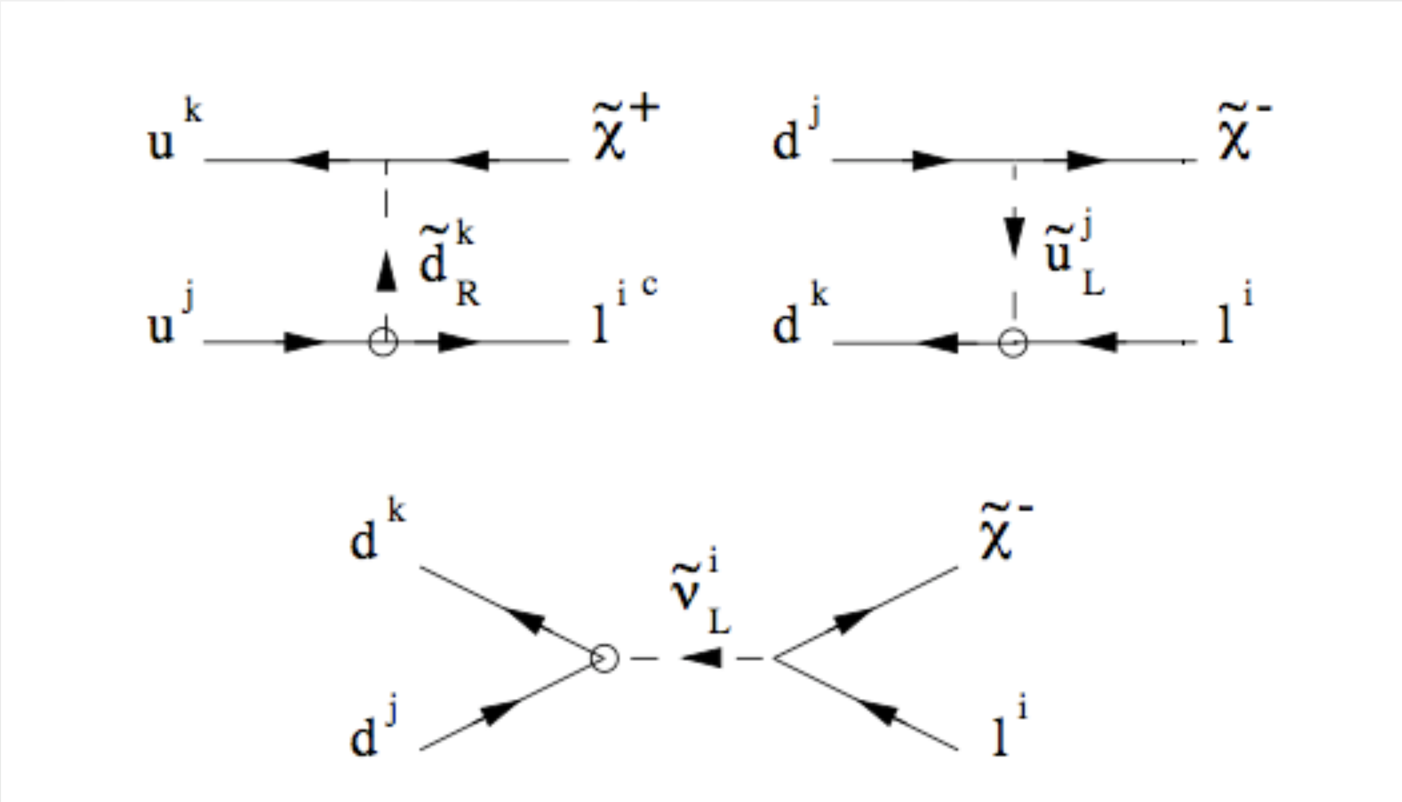
Due to cancellations,larger area where
Rp-violating decay of squarks to fermions dominates

i.e.Single Superparticle Productions at Hadron Colliders



Single Charginos at Tevatron

(Chemtob,Moreau,Deliot,Royon,Perez)



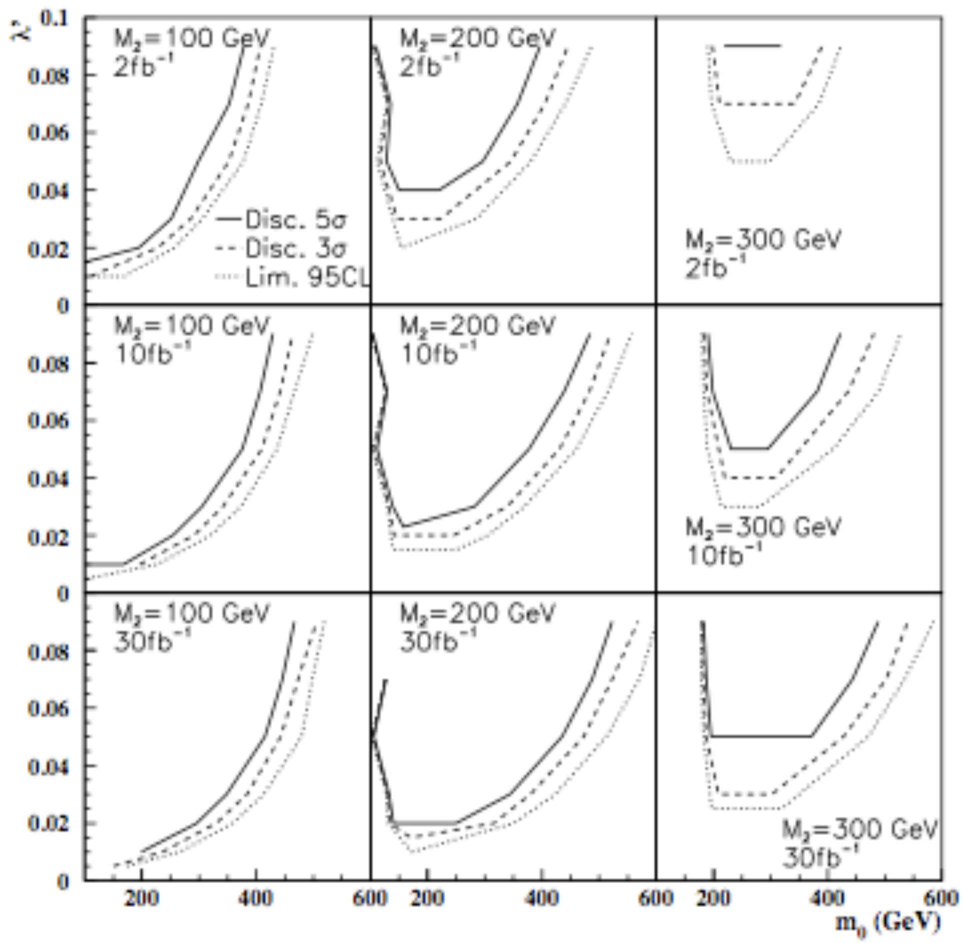
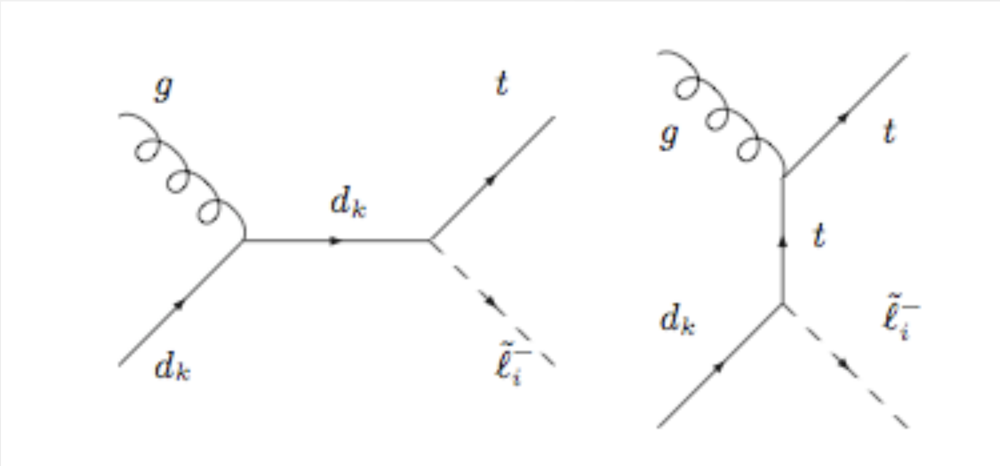
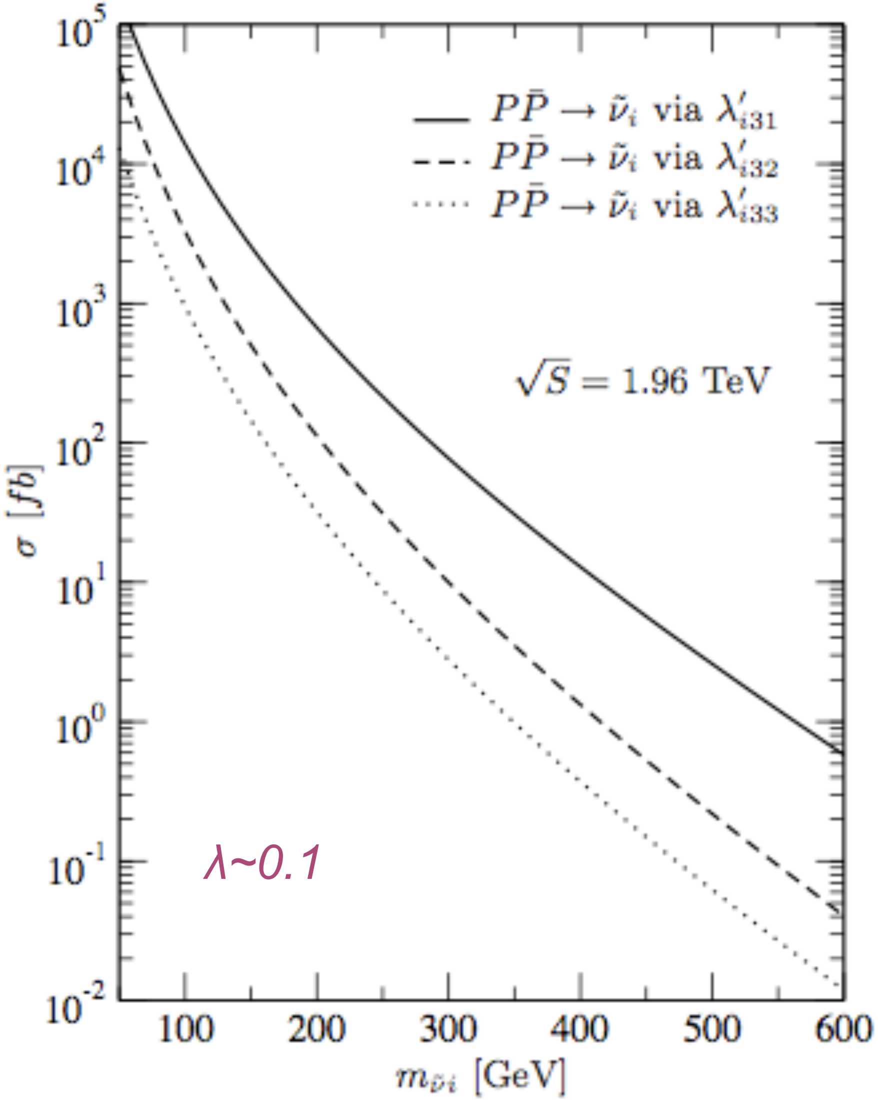


FIG. 2. Discovery contours at 5σ (full line), 3σ (dashed line) and limit at 95% $C.L.$ (dotted line) presented in the plane λ'_{211} versus the m_0 parameter, for different values of M_2 and of luminosity.

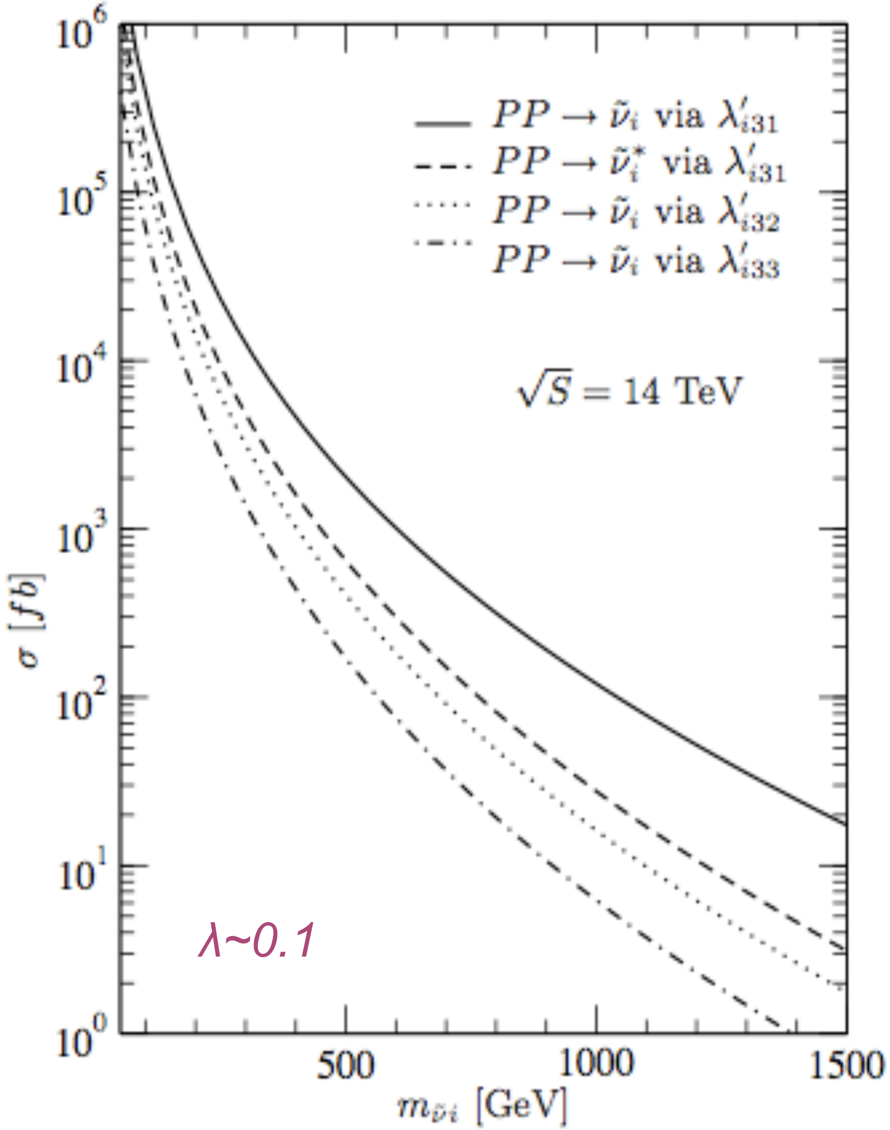
Single top-slepton production

(Bernhard, Dreiner, Grab, Richardson)





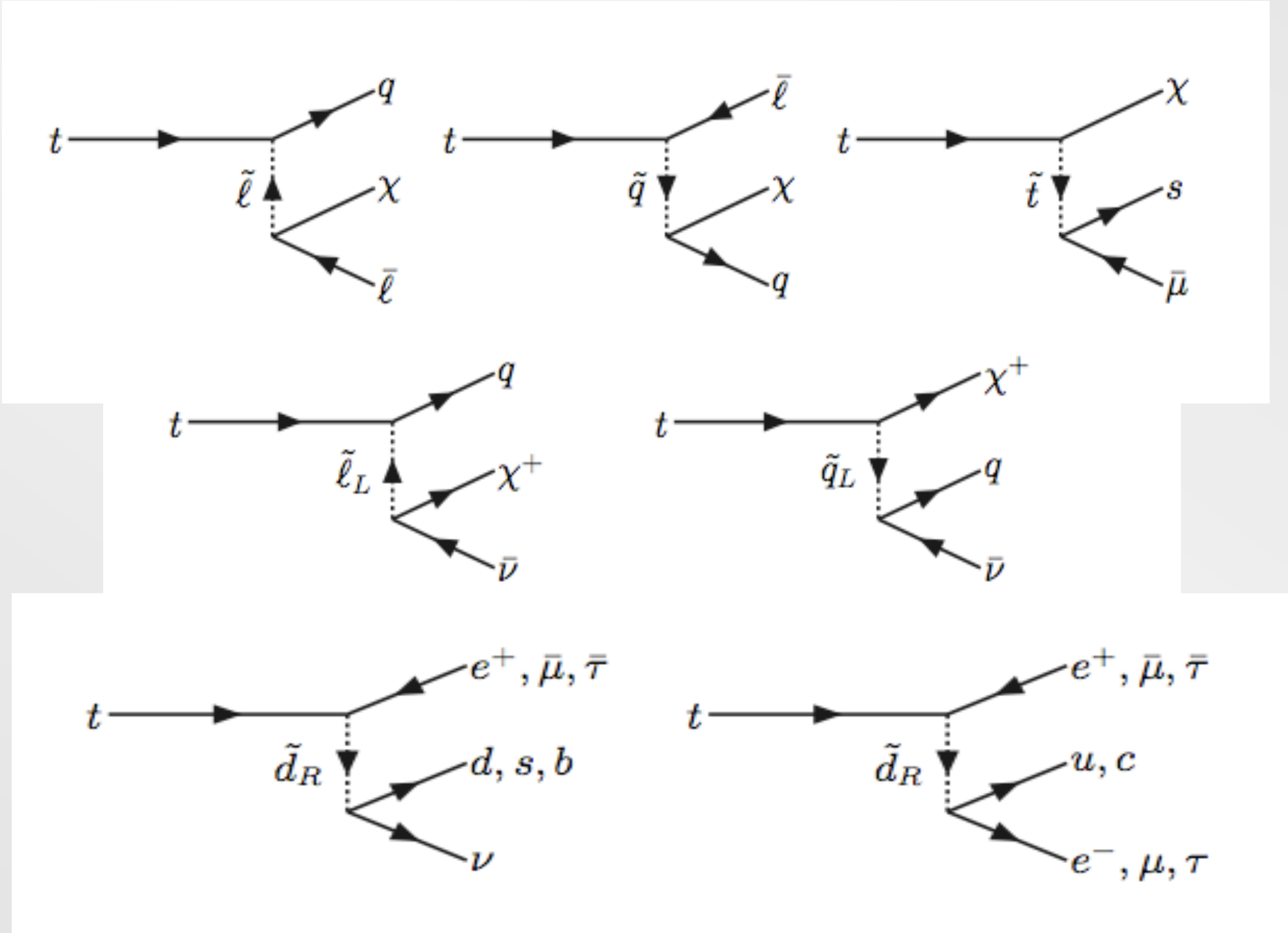
$P\bar{P} \to \tilde{\nu}_i$ via λ'_{i31}
$P\bar{P} \to \tilde{\nu}_i$ via λ'_{i32}
$P\bar{P} \to \tilde{\nu}_i$ via λ'_{i33}
$\sqrt{S} = 1.96$ TeV
λ~0.1
σ [fb]
10^5 10^4 10^3 10^2 10^1 10^0 10^{-1} 10^{-2}
100 200 300 400 500 600
$m_{\tilde{\nu}i}$ [GeV]



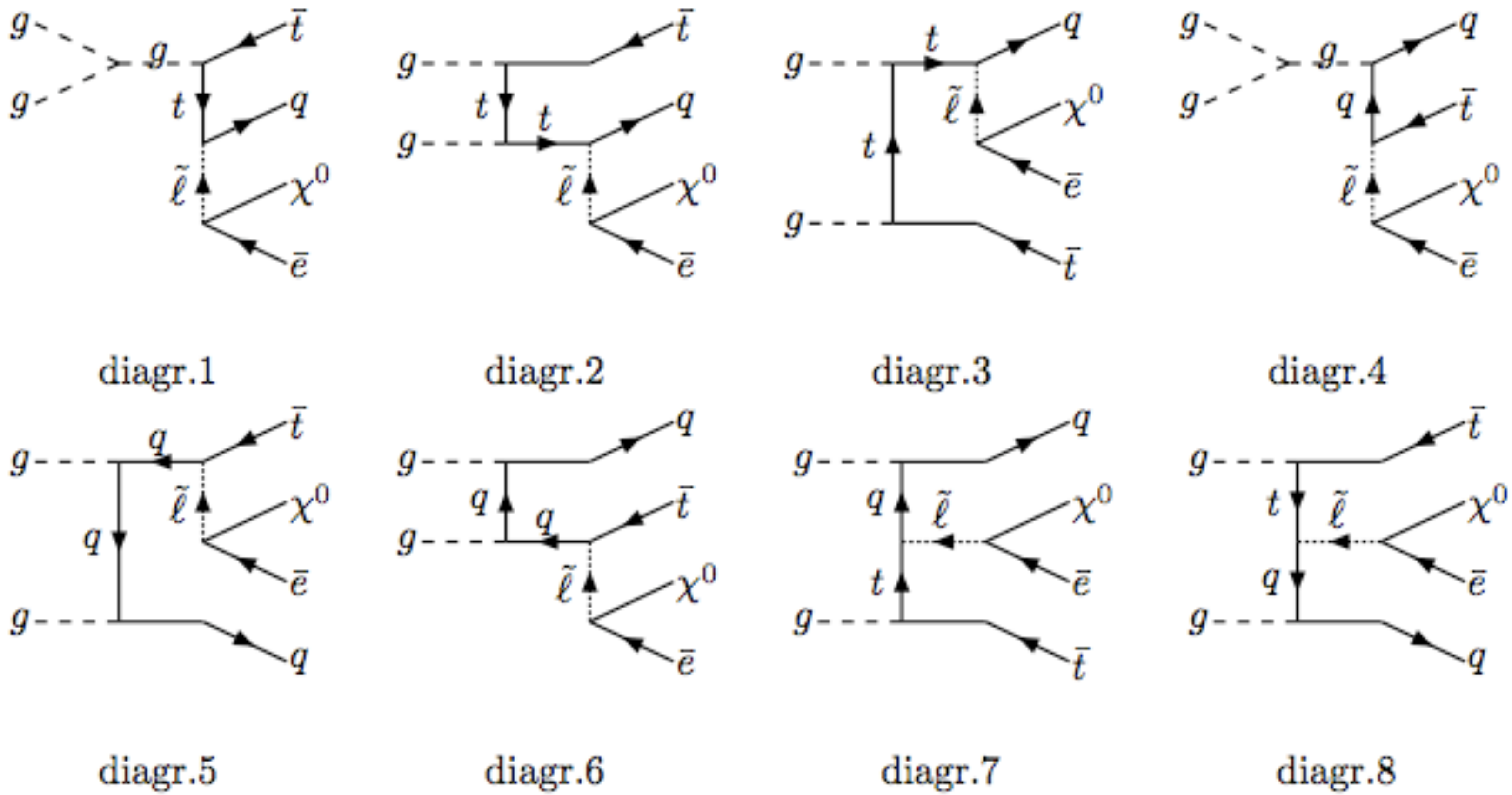
$PP \to \tilde{\nu}_i$ via λ'_{i31}
$PP \to \tilde{\nu}_i^*$ via λ'_{i31}
$PP \to \tilde{\nu}_i$ via λ'_{i32}
$PP \to \tilde{\nu}_i$ via λ'_{i33}
$\sqrt{S} = 14$ TeV
λ~0.1
σ [fb]
10^6 10^5 10^4 10^3 10^2 10^1 10^0
500 1000 1500
$m_{\tilde{\nu}i}$ [GeV]

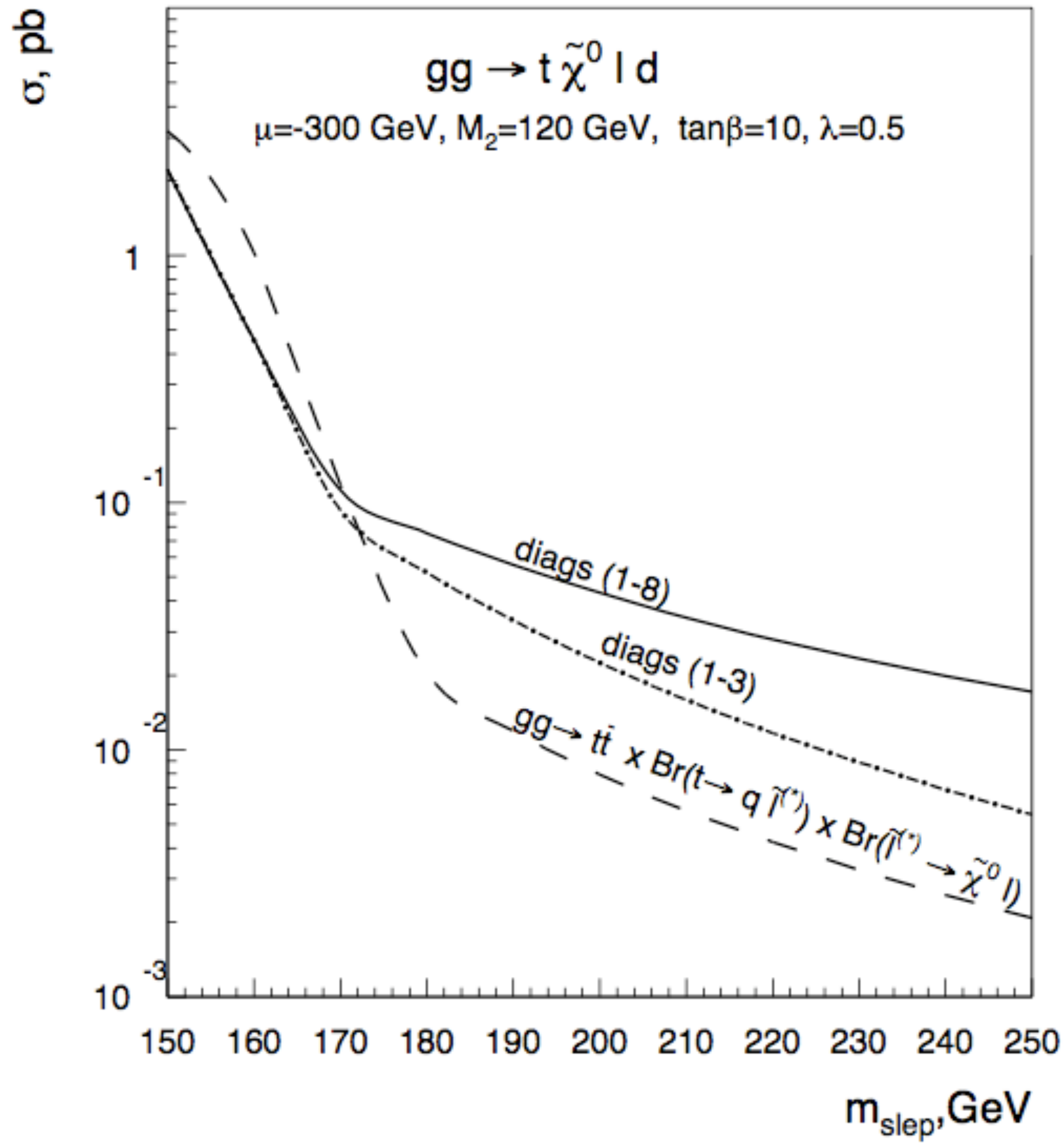
Rare Top Decays

(Belyaev, Ellis, SL)



(Belyaev,Genest,Leroy,Mehdiyev)





$gg \to t\tilde{\chi}^0 l d$
μ=-300 GeV, M_2=120 GeV, tanβ=10, λ=0.5
σ, pb
1
10^{-1}
10^{-2}
10^{-3}
diags (1-8)
diags (1-3)
$gg \to t\bar{t} \times Br(t \to q\,\tilde{l}^{(*)}) \times Br(\tilde{l}^{(*)} \to \tilde{\chi}^0 l)$
150
160
170
180
190
200
210
220
230
240
250
m_{slep},GeV

Effects in Dilepton productions at LHC
(Choudhury,Godbole,Polesello)

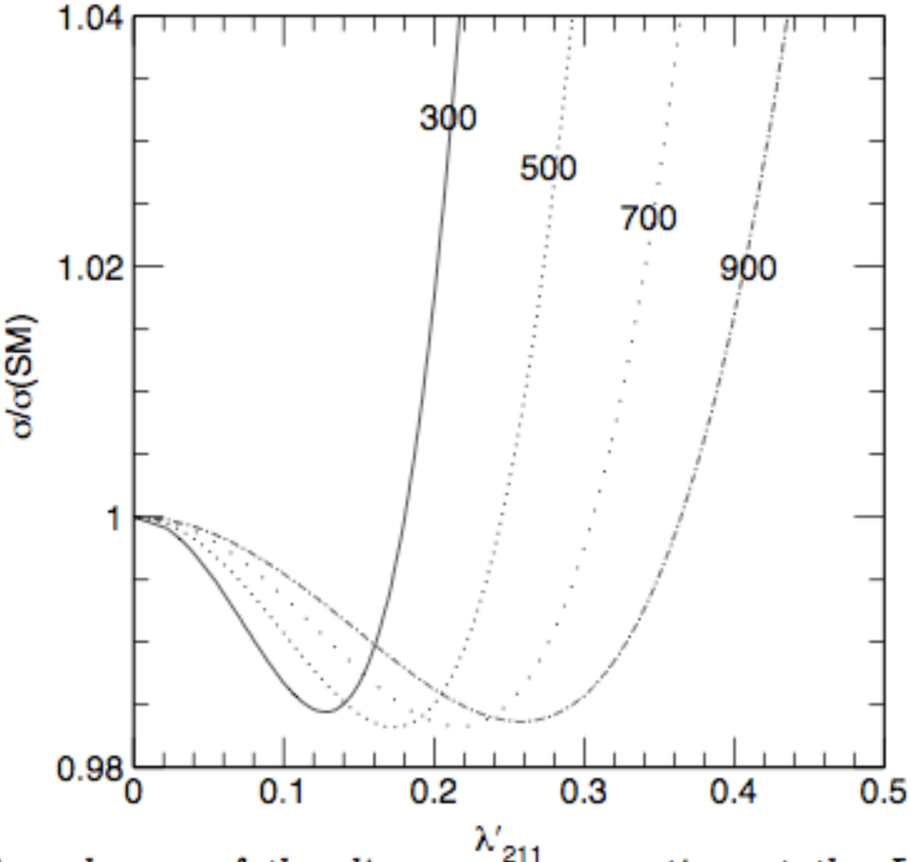


Figure 1: *Relative change of the dimuon cross section at the LHC as function of the coupling λ'_{211}. The assumed lower limit on the dilepton invariant mass is 500 GeV. The curves correspond to four different squark masses: 300, 500, 700 and 900 GeV respectively.*

SUSY Dark Matter if R-parity is violated?

In the MSSM, stable LSP a very good DM candidate

In R-violation, LSP unstable. Is all hope for SUSY DM lost?

-If LSP a gravitino, its decays very suppressed by Mp

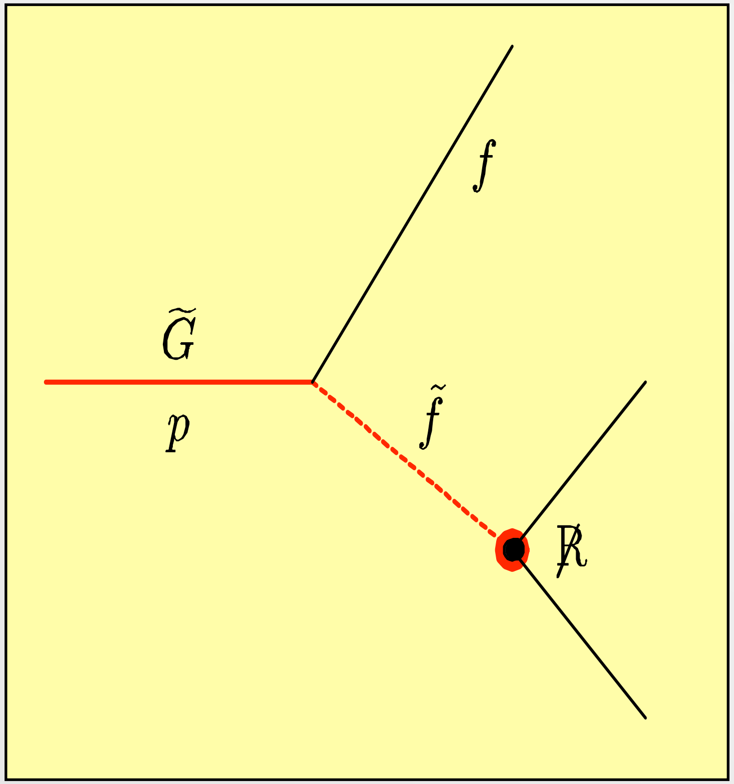
-The lighter the gravitino, the longer the lifetime

Questions: (i)*can gravitinos be DM even with broken R-parity?*
*(ii) Can we hope for **BOTH** DM,*
***AND** detectable R-violation in colliders?*

Answer: *depends on <u>how gravitinos decay</u> under R-violation*

3-body trilinear R-violating decays

Chemtob, Moreau



Suppressed by:

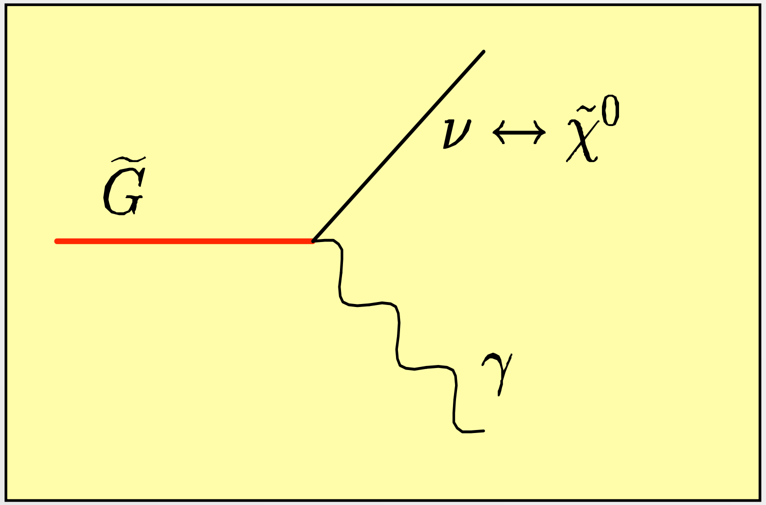
- Gravitino vertex (~1/Mp)

-Phase space / fermion masses

(for light gravitino and heavy fermions)

2-body bi-linear R-violating decays

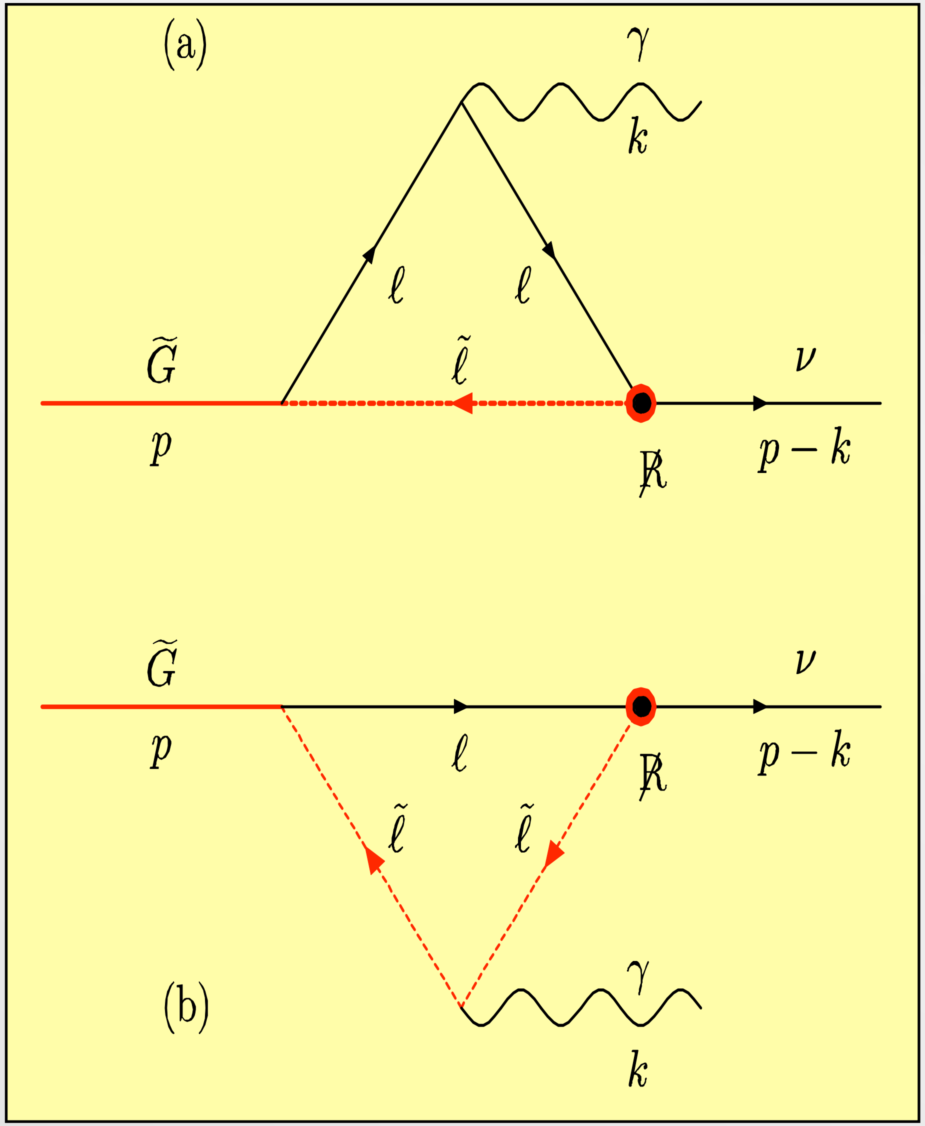
Takayama, Yamaguchi
Buchmuler et al.

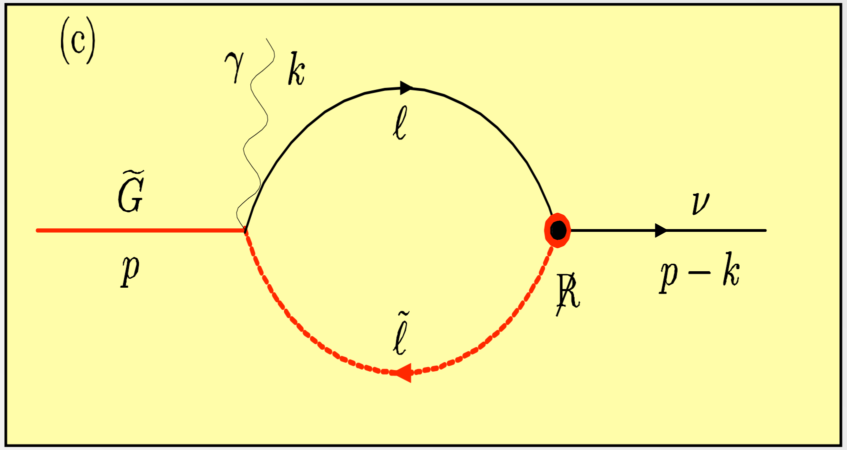


Suppressed by:

- *Gravitino vertex (~1/Mp)*
- *Neutralino-neutrino mixing (model dependent)*

Radiative 2-body trilinear R-violating decays





Suppressed by:

- *Gravitino vertex (~1/Mp)*
- *Loop factors (~ fermion mass)*

Radiative decays dominate for:

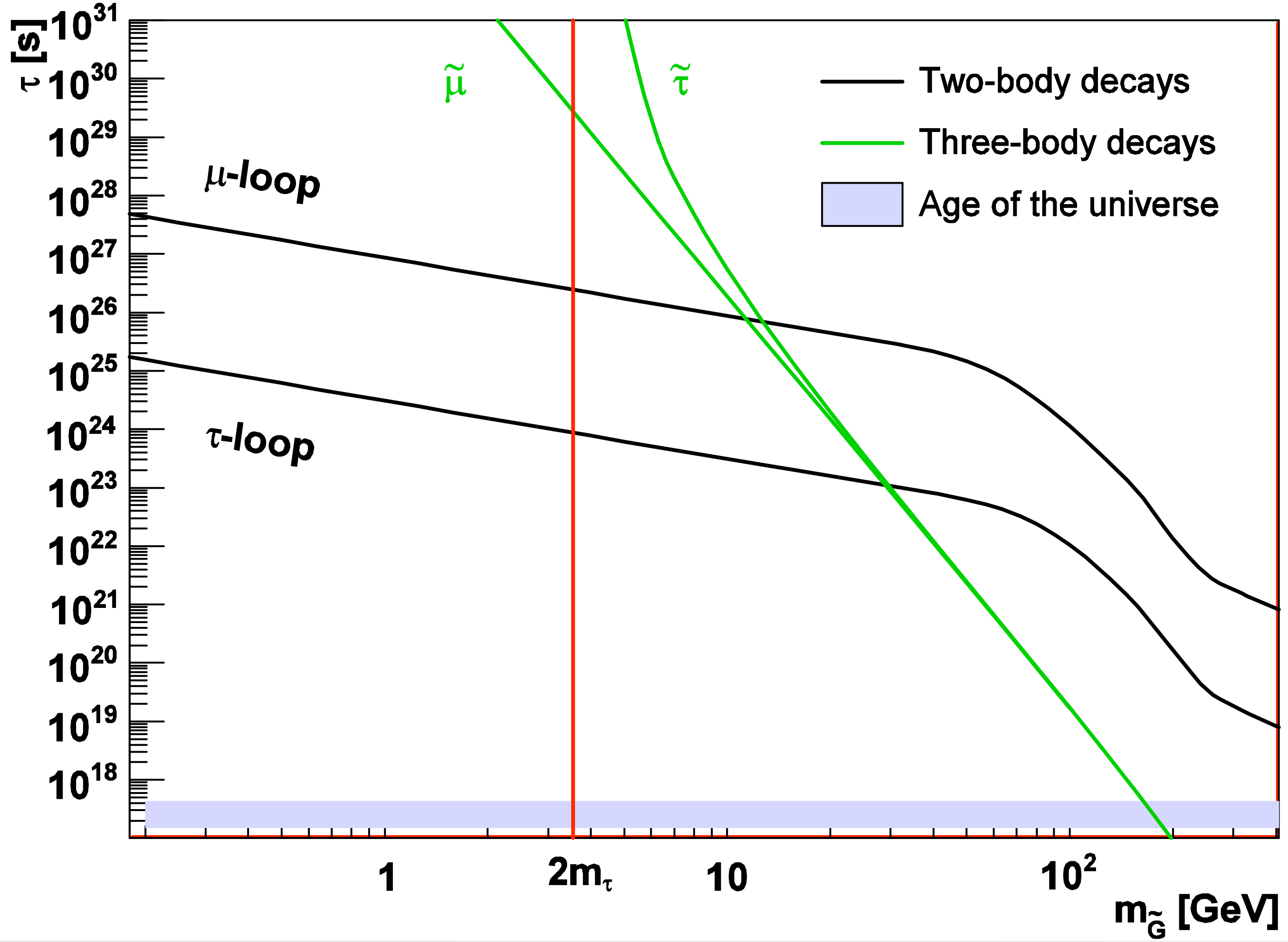
- Smaller gravitino masses
- R and L violation via operators of the 3rd generation
- Small neutrino-neutralino mixing

Large gravitino lifetime (can be DM), due to:

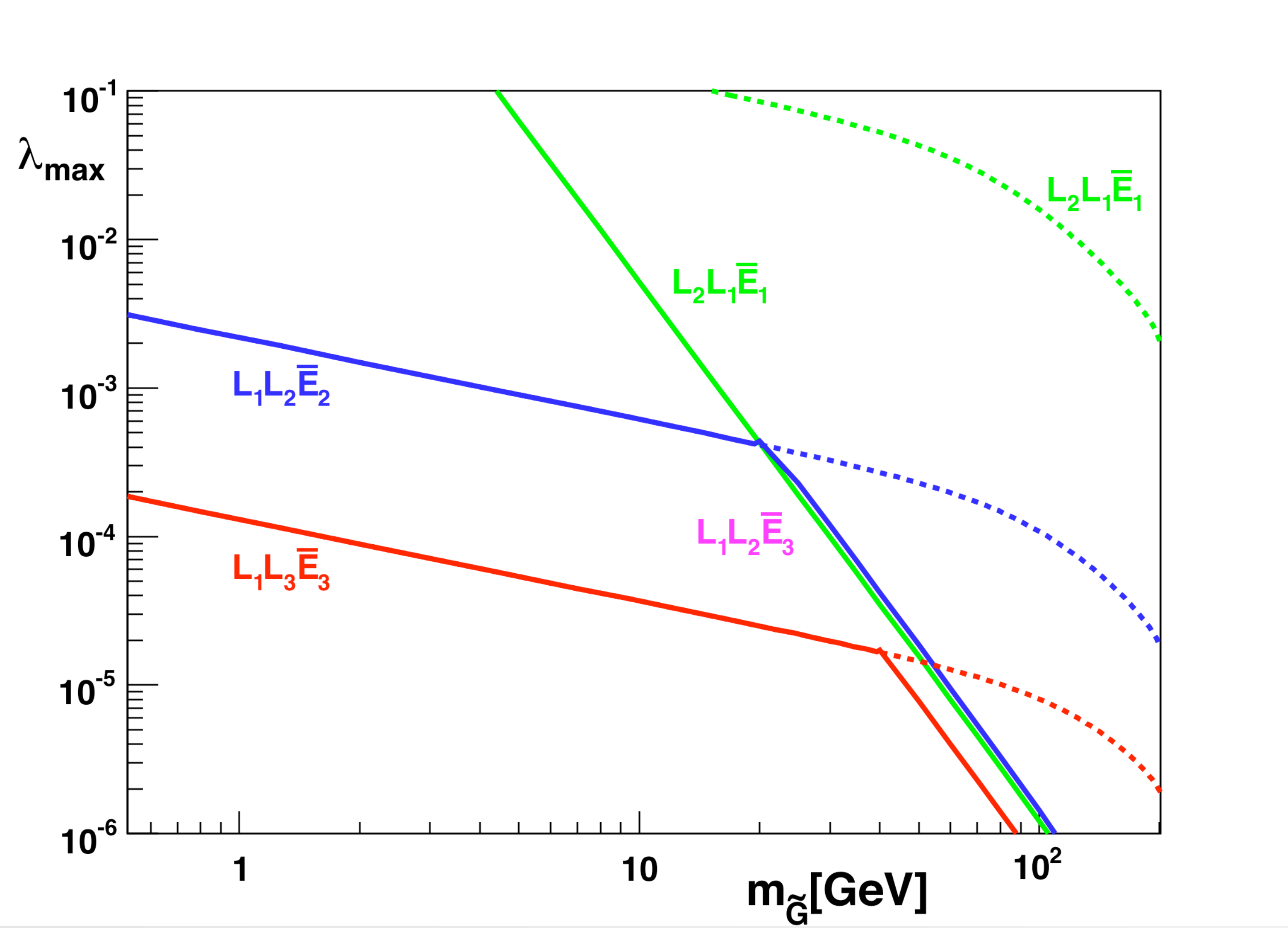
- Gravitational suppression of its couplings
- Smallness of R-violating vertices
- Loop, phase space, or mixing effects

$\bar{U}_3 \bar{D}_j \bar{D}_k$ *Maximum stability (neither radiative nor tree-level decays)!*

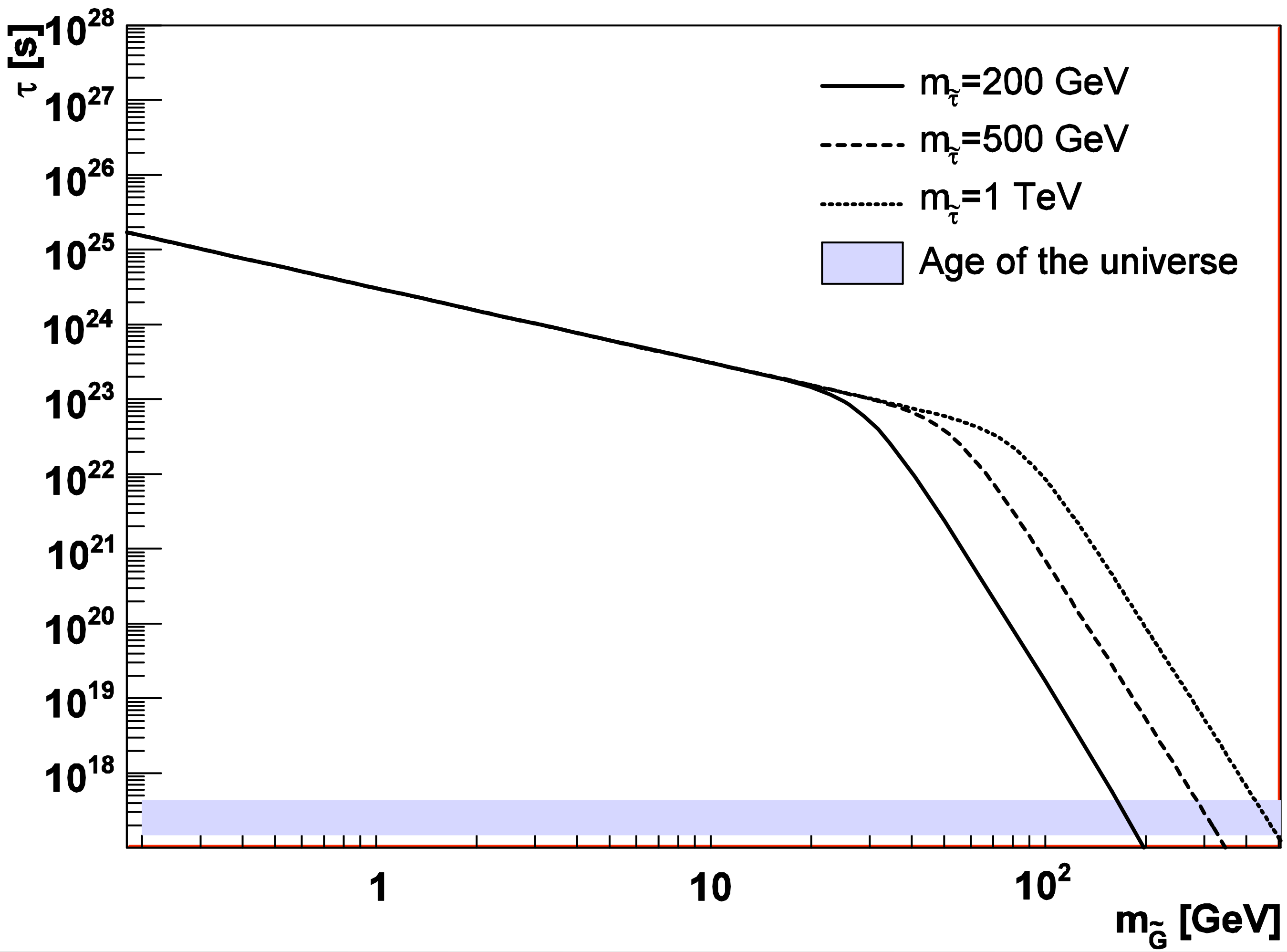
Radiative versus 3-body decays



Constraints from DM & Photon Spectra



Lifetime versus SUSY masses



NLSP decays

NLSP	$LL\bar{E}$	$LQ\bar{D}$	$\bar{U}\bar{D}\bar{D}$
χ^0	$\ell_i^\pm \ell_j^\mp \nu$	$q_j \bar{q}_k \ell^\pm (q_j \bar{q}_k \nu)$	$q_i q_j q_k (\bar{q}_i \bar{q}_j \bar{q}_k)$
$\tilde{\nu}$	$\ell_i^\pm \ell_j^\mp$ $\ell_i^\pm \ell_j^\mp \nu\nu$	$q_j \bar{q}_k$ $q_j \bar{q}_k \ell^\pm \nu (q_j \bar{q}_k \nu\nu)$	$\nu q_i q_j q_k (\nu \bar{q}_i \bar{q}_j \bar{q}_k)$
$\tilde{\tau}_R$	$\ell_i \nu$ $\ell_i^\pm \ell_j^\mp \nu\tau$	$q_j \bar{q}_k$ $q_j \bar{q}_k \ell^\pm \tau (q_j \bar{q}_k \nu\tau)$	$\tau q_i q_j q_k (\tau \bar{q}_i \bar{q}_j \bar{q}_k)$

- No source of suppression other than R-violating couplings
- Decay well before BBN compatible with gravitino DM

Conclusions

- ✓ R-violating SUSY equally motivated with MSSM
- ✓ Interesting signals but also strong bounds
- ✓ Possible to have both gravitino DM **AND**

  observable R-violation in colliders
- ✓ Distinct differences in LFV predictions between

  SM and SUSY, but also between MSSM & R-violation
- ✓ Results sensitive to flavour structure of R-violating operators

  Through Collider Searches

  ALSO probe Flavour Structure of Fundamental Theory