SPONTANEOUS BREAKING OF R-PARITY

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If supersymmetry is realized with spontaneous breaking of R-parity, there will be important consequences in several different areas which can be tested through different types of experiments. In this talk we review the phenomenological implications of these theories, with special emphasis on new signals at the present and future accelerators.

1 Introduction

So far most attention to the study of supersymmetric phenomenology has been made in the framework of the Minimal Supersymmetric Standard Model (MSSM) with conserved R-parity. R-parity is a discrete symmetry assigned as \( R_p = (-1)^{(3B+L+2S)} \), where \( L \) is the lepton number, \( B \) is the baryon number and \( S \) is the spin of the state. If R-parity is conserved all supersymmetric particles must always be pair-produced, while the lightest of them must be stable. Whether or not supersymmetry is realized with a conserved R-parity is an open dynamical question, sensitive to physics at a more fundamental scale.

The study of alternative supersymmetric scenarios where the effective low energy theory violates R-parity explicitly has received recently a lot of attention. Although highly constrained by proton stability, their systematic study at a phenomenological level is hardly possible, due to the large number of parameters characterizing these models, in addition to those of the MSSM.

As other fundamental symmetries, it could well be that R-parity is a symmetry at the Lagrangian level but is broken by the ground state. Such scenarios provide a very systematic way to include R parity violating effects, automatically consistent with low energy baryon number conservation.

In this review talk we will present a viable model for spontaneous breaking of R-parity and illustrate its phenomenological consequences.

2 A Viable Model for Spontaneous R-Parity Breaking

2.1 The Model

In the original proposal the content was just the MSSM and the breaking was induced by the \( \tilde{\nu}_\tau \) acquiring a vev, \( \langle \tilde{\nu}_\tau \rangle = v_L \). As a consequence the...
| Field | L | $e^c$ | $\nu^c$ | S | others |
|-------|---|-------|--------|---|--------|
| Lepton # | 1 | -1 | -1 | 1 | 0 |

Table 1: Lepton number assignments for the superfields in Eq. 1

Majoron ($J$) coupled to the $Z^0$ with gauge strength and the decay $Z^0 \to \rho_L J$ contributed with the equivalent of 1/2 a neutrino to the invisible $Z^0$ width. As this was ruled out but the LEP results, a possible way out was proposed. The idea was to enlarge the model and make $J$ mostly out of isosinglets. The model is defined by the Superpotential

$$W = h_u u^c Q H_u + h_d d^c Q H_d + h_e e^c L H_d$$
$$+ (h_0 H_u H_d - c^2) \Phi$$
$$+ h_\nu \nu^c L H_u + h \Phi \nu^c S$$

(1)

where the lepton number assignments are given in Table 1. The spontaneous breaking of R parity and lepton number is driven by

$$v_R = \langle \tilde{\nu}_{R \tau} \rangle \quad v_S = \langle \tilde{S}_\tau \rangle \quad v_L = \langle \tilde{\nu}_\tau \rangle$$

(2)

The electroweak breaking and fermion masses arise from

$$\langle H_u \rangle = v_u \quad \langle H_d \rangle = v_d$$

(3)

with $v^2 = v_u^2 + v_d^2$ fixed by the W mass. The Majoron is then given by the imaginary part of

$$\frac{v^2}{\sqrt{v_R^2 + v_S^2}} (v_u H_u - v_d H_d) + \frac{v_L}{\sqrt{v_{\tilde{\nu}_\tau}^2 + v_{\tilde{S}_\tau}^2}} \tilde{\nu}_\tau + \frac{v_R}{\sqrt{v_{\tilde{S}_\tau}^2 + v_{\tilde{\nu}_\tau}^2}} \tilde{S}_\tau$$

(4)

where $V = \sqrt{v_R^2 + v_S^2}$. Since the majoron is mainly an $SU(2) \otimes U(1)$ singlet it does not contribute to the invisible $Z^0$ decay width.

### 2.2 Tree Level Breaking

To study the breaking of R-parity in the model described in Eq. (1) we considered, for simplicity, the 1-generation case. The soft breaking terms are:

$$V_{SB} = \tilde{m}_0 \left[ -A h_0 \Phi H_u H_d - B e^2 \Phi + C h_\nu \tilde{\nu}^c \tilde{\nu} H_u + D h \Phi \tilde{\nu}^c S + \text{h.c.} \right]$$
$$+ \tilde{m}_u^2 |H_u|^2 + \tilde{m}_d^2 |H_d|^2 + \tilde{m}_L^2 |\tilde{\nu}|^2 + \tilde{m}_R^2 |\tilde{\nu}^c|^2 + \tilde{m}_S^2 |S|^2 + \tilde{m}_\Phi^2 |\Phi|^2$$

(5)
At unification scale we have $C = D = A$; $B = A - 2$ and universality of the soft masses $\tilde{m}_u^2 = \tilde{m}_d^2 = \cdots = \tilde{m}_0^2$. At low energy these relations will be modified by the renormalization group evolution. For simplicity we take

$$C = D = A \quad \text{and} \quad B = A - 2$$

but let the soft masses at the weak scale be arbitrary. Then the neutral scalar potential is given by

$$V_S = \frac{1}{8} \left( g^2 + g'^2 \right) \left( |H_u|^2 - |H_d|^2 - |\nu|^2 \right)^2 + |h_0 \Phi H_u|^2$$

$$+ |h_0 \Phi S + h_\nu \nu H_u|^2 + |h_0 \Phi \nu|^2 + | - h_0 \Phi H_d + h_\nu \nu |^2$$

$$+ |h_0 \Phi \nu|^2 + | - h_0 H_u H_d + h_\nu \nu S - \varepsilon^2 |^2 + V_{SB} \quad (7)$$

To find the solutions of the stationary equations we follow the following 3 step procedure:

1. **Finding solutions of the extremum equations**
   We start by taking random values for $h, h_0, h_\nu, \varepsilon^2$ and $\tilde{m}_0$ and $v_R, v_S$. Then choose $\tan \beta = \frac{v_u}{v_d}$ and fix $v_u, v_d$ by W mass relation,

$$m_W^2 = \frac{1}{2} g^2 (v_u^2 + v_d^2 + v_L^2) \quad (8)$$

Finally we solve the extremum equations exactly for $\tilde{m}_u^2, \tilde{m}_d^2, \cdots, \tilde{m}_0^2$. This is possible because they are linear equations on the mass squared terms.

2. **Showing that the solution is a minimum**
   To show that the solution is a true minimum we calculate the squared mass matrices for the real and imaginary parts of the scalar fields, $M_R^2$ and $M_I^2$ and find numerically the eigenvalues. The solution is a minimum if all nonzero eigenvalues are positive. A consistency check is that we should get two zero eigenvalues for $M_I^2$ corresponding to the Goldstone boson of the $Z^0$ and to the majoron $J$.

3. **Comparing with other minima**
   There are three kinds of minima to which we should compare our solution.

   - $v_u = v_d = v_L = v_R = v_S = 0$ \quad $v_F \neq 0$
   - $v_L = v_R = v_S = 0$ \quad $v_u, v_d, v_F \neq 0$
   - $v_u = v_d = v_L = 0$ \quad $v_R, v_S, v_F \neq 0$

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3 In a N=1 SUGRA model.
As a final result we found a large region in parameter space where our solution that breaks \( R_P \) and \( SU_2 \otimes U(1) \) is an absolute minimum.

2.3 Radiative Breaking

We considered the theory characterized by the following superpotential:

\[
W = h_u u^c Q H_u + h_d d^c Q H_d + h_e e^c L H_d \\
+ h_0 H_u H_d \Phi + h_\nu \nu^c LH_u + h \Phi \nu^c S + \lambda \Phi^3
\]

For this theory with the following boundary conditions at unification,

\[
A_u = A = A_0 = A_\nu = A_\lambda, \\
M^2_{H_u} = M^2_{H_d} = M^2_{\nu L} = M^2_{\nu e} = M^2_{Q} = m_0^2, \\
M^2_{\nu e} = C_{\nu e} m_0^2 ; M^2_S = C_S m_0^2 ; M^2_\Phi = C_\Phi m_0^2, \\
M_3 = M_2 = M_1 = M_{1/2}
\]

we run the RGE from the unification scale \( M_U \sim 10^{16} \) GeV down to the weak scale. In doing this we randomly give values at the unification scale. After running the RGE we have a complete set of parameters, Yukawa couplings and soft-breaking masses \( m_i^2(\text{RGE}) \) to study the minimization of the potential,

\[
V_{\text{total}} = \sum_i \left| \frac{\partial W}{\partial z_i} \right|^2 + V_D + V_{SB} + V_{RC}
\]

To solve the extremum equations we use the method described before, except that now the value of \( v_u \) is determined from \( m_{\text{top}} = h_t v_u \) for \( m_{\text{top}} = 175 \pm 5 \) GeV and \( v_d \) and tan(\( \beta \)) are then determined by \( m_W \). After doing this we end up with a set of points for which:

1. The Yukawa couplings and the gaugino mass terms are given by the RGE.
2. For a given set of \( m_i^2 \) each point is also a solution of the minimization of the potential that breaks R-Parity.
3. However, the \( m_i^2 \) obtained by the minimization of the potential differ from those obtained from the RGE \( m_i^2(\text{RGE}) \).

Our goal is to find solutions that obey

\[
m_i^2 = m_i^2(\text{RGE}) \quad \forall i
\]
To do that we define a function

$$\eta = \max \left( \frac{m_i^2}{m_i^2(RGE)}, \frac{m_i^2(RGE)}{m_i} \right) \quad \forall i$$

that has the property $\eta \geq 1$. We are then all set for a minimization procedure. We were not able to find solutions with strict universality. But if we relaxed the universality conditions on the squared masses of the singlet fields, as shown in Eq. (13), we got plenty of solutions.

3 Main Features of the Model

3.1 Chargino Mass Matrix

The form of the chargino mass matrix is common to a wide class of SUSY models with spontaneously broken R-parity and is given by

$$
\begin{pmatrix}
\epsilon_i^+ & \tilde{H}_u^+ & -iW_3^+ \\
e_{ij} h_{e_{ij}v_d} & -h_{\nu_{ij}v_{Rj}} & g_{v_iL_i} \\
H_d^- & -h_{e_{ij}v_{L_i}} & \mu & g_{v_d} \\
-iW^- & 0 & g_{v_u} & M_2
\end{pmatrix}
$$

As a consequence the usual charged leptons will mix with the MSSM charginos.

3.2 Neutralino Mass Matrix

Under reasonable approximations, we can truncate the neutralino mass matrix so as to obtain an effective $7 \times 7$ matrix.

$$
\begin{pmatrix}
\nu_i & \tilde{H}_u & \tilde{H}_d & -iW_3 & -iB \\
\nu_i & 0 & h_{\nu_{ij}v_{Rj}} & 0 & \frac{g}{\sqrt{2}} v_{L_i} - \frac{g'}{\sqrt{2}} v_{Li} \\
\tilde{H}_u & h_{\nu_{ij}v_{Rj}} & 0 & -\mu & -\frac{g}{\sqrt{2}} v_u \frac{g}{\sqrt{2}} v_u \\
\tilde{H}_d & 0 & -\mu & 0 & \frac{g}{\sqrt{2}} v_d - \frac{g'}{\sqrt{2}} v_d \\
-iW_3 & \frac{g}{\sqrt{2}} v_{L_i} & -\frac{g}{\sqrt{2}} v_u & \frac{g}{\sqrt{2}} v_d & M_2 & 0 \\
-iB & -\frac{g'}{\sqrt{2}} v_{L_i} & \frac{g'}{\sqrt{2}} v_u & -\frac{g'}{\sqrt{2}} v_d & 0 & M_1
\end{pmatrix}
$$

This matrix induces mixing between the neutrinos, considered as Majorana fermions, and the MSSM neutralinos. As a result of these mixings, both the charged and neutral current couplings are modified with respect to the MSSM. This will be very important in the phenomenological applications.
3.3 Experimental Constraints

While studying the phenomenology of these models there are many experimental constraints that have taken in account. These come from many different types of experiments. LEP searches puts limits on chargino masses and also in the amount of new contributions both to the total and invisible $Z^0$ width. From the hadron colliders there are restrictions on the gluino mass. Finally there are additional restrictions, which are more characteristic of broken R-parity models. They follow from laboratory experiments related to neutrino physics, cosmology and astrophysics. The most relevant are: neutrino-less double beta decay, neutrino oscillation searches, direct searches for anomalous peaks at $\pi$ and K meson decays, the limit on the tau neutrino mass and cosmological limits on the $\nu_\tau$ lifetime and mass.

4 Implications for Neutrino Physics

Here we briefly summarize the main results for neutrino physics.

- **Neutrinos have mass**
  Neutrinos are massless at Lagrangian level but get mass from the mixing with neutralinos.

- **Neutrinos mix**
  The coupling matrix $h_{\nu_{ij}}$ has to be non diagonal to allow
  \[ \nu_\tau \to \nu_\mu + J \] (16)
  and therefore evading the Critical Density Argument against $\nu'$s in the MeV range.

- **Avoiding BBN constraints on the $m_{\nu_\tau}$**
  In the SM BBN arguments rule out $\nu_\tau$ masses in the range
  \[ 0.5 \text{ MeV} < m_{\nu_\tau} < 35 \text{ MeV} \] (17)
  We have shown that SBRP models can evade that constraint due to new annihilation channels
  \[ \nu_\tau \nu_\tau \to JJ \] (18)
5 R-Parity Violation at LEP I

5.1 Higgs Physics

The structure of the neutral Higgs sector is more complicated than in the MSSM. However the main points are simple.

- **Reduced Production**
  Like in the MSSM the coupling of the Higgs to the $Z^0$ is reduced by a factor $\epsilon_B$
  \[ \epsilon_B = \frac{|g_{ZZh}|}{g_{SM_{ZZh}}} < 1 \quad (19) \]

- **Invisible decay**
  Unlike the SM and the MSSM where the Higgs decays mostly in $b\bar{b}$, here it can have invisible decay modes like $H \rightarrow J + J$
  \[ H \rightarrow J + J \quad (20) \]
  Depending on the parameters, the $BR(H \rightarrow \text{invisible})$ can be large. This will relax the mass limits obtained from LEP. We performed a model independent analysis of the LEP data taking $m_H, \epsilon_B$ and $BR(H \rightarrow \text{invisible})$ as independent parameters.

5.2 Chargino Production at the Z Peak

The more important is the possibility of the decay

\[ Z^0 \rightarrow \chi^\pm \tau^\mp \quad (21) \]

This decay is possible because $R_p$ is broken. We have shown that this branching ratio can be as high as $5 \times 10^{-5}$. Another important point is that the chargino has different decay modes with respect to the MSSM.

- 3-body decay \( \chi \rightarrow \chi^0 + f\bar{f} \)
- 2-body decay \( \chi \rightarrow \tau + J \)

5.3 Neutralino Production at the Z Peak

We have developed an event generator that simulates the processes expected for the LEP collider at $\sqrt{s} = M_Z$. Its main features are:
• **Production**

As far as the production is concerned, our generator simulates the following processes at the $Z$ peak:

\begin{align*}
e^+e^- &\rightarrow \chi\nu \\
e^+e^- &\rightarrow \chi\chi
\end{align*}

(22) (23)

• **Decay**

The second step of the generation is the decay of the lightest neutralino. The 2-body only contributes to the missing energy. The 3-body are:

\begin{align*}
\chi &\rightarrow \nu_Z \nu \rightarrow \nu_l l^- , \nu_\tau \nu \nu , \nu_\tau q_1 \overline{q_1} \\
\chi &\rightarrow \tau W^* \rightarrow \tau
\end{align*}

(24) (25)

• **Hadronization**

The last step of our simulation is made calling the PYTHIA software for the final states with quarks.

One of the cleanest and most interesting signals that can be studied is the process with missing transverse momentum + acoplanar muons pairs

$$p_T + \mu^+ \mu^-$$

(26)

The main source of background for this signal is the

$$Z \rightarrow \mu^+ \mu^- + \text{soft photons}$$

(27)

For definiteness we have imposed the cuts used by the OPAL experiment for their search for acoplanar dilepton events: (a) We select events with two muons with at least for one of the muons obeying $|\cos \theta|$ less than 0.7. (b) The energy of each muon has to be greater than a 6% of the beam energy. (c) The missing transverse momentum in the event must exceed 6% of the beam energy, $p_T > 3$ GeV. (d) The acoplanarity angle (the angle between the projected momenta of the two muons in the plane orthogonal to the beam direction) must exceed 20°. With these cuts we were able to calculate the efficiencies of our processes.

We used the data published by ALEPH in 95 and analyzed both the single production $e^+e^- \rightarrow \chi\nu$ and the double production $e^+e^- \rightarrow \chi\chi$ processes. For single production we get

$$N_{expd}(\chi\nu) = \sigma(e^+e^- \rightarrow \chi\nu)BR(\chi \rightarrow \nu_\tau \mu^+ \mu^-)\epsilon_{\chi\nu} L_{int}$$

(28)
Using the expression for the cross section we can write this expression in terms of the product $\text{BR}(Z \to \chi \nu) \times \text{BR}(\chi \to \nu_{\tau} \mu^+ \mu^-)$ and obtain a 95%CL limit on this R-parity breaking observable, as a function of the $\chi$ mass. This is shown in Figure 1. For the double production of neutralinos the number of expected $p_T + \mu^+ \mu^-$ events is

$$N_{\text{exp}}(\chi\chi) = \sigma(e^+e^- \to \chi\chi)2\text{BR}(\chi \to \text{invisible})\text{BR}(\chi \to \nu_{\tau} \mu^+ \mu^-)\epsilon_{\chi\chi} L_{\text{int}}$$

(29)

We can obtain an illustrative 95%CL limit on $\text{BR}(Z \to \chi\chi) \times \text{BR}(\chi \to \nu_{\tau} \mu^+ \mu^-) \times \text{BR}(\chi \to \text{invisible})$ as a function of the $\chi$ mass. This is also shown in Figure 1 where we can see that the models begin to be constrained by the LEP results.

Figure 1: On the left a comparison of the attainable limits on $\text{BR}(Z \to \chi \nu)\text{BR}(\chi \to \mu^+ \mu^- \nu)$ versus the lightest neutralino mass, with the maximum theoretical values expected in different R-parity breaking models. The solid line (a) is just for the $\mu^+ \mu^- \nu$ channel, while (b) corresponds to the improvement expected from including the $e^+e^- \nu$ channel, as well as the combined statistics of the four LEP experiments. The dashed line corresponds to a model with explicit R-parity violation, while the dotted one is calculated in the spontaneous R-parity-violation model. On the right the same for $\text{BR}(Z \to \chi\chi)\text{BR}(\chi \to \mu^+ \mu^- \nu)$.

6 R-Parity Violation at LEP II

6.1 Invisible Higgs

The previous LEP I analysis has been extended for LEP II. As a general framework we consider models with the interactions
\[ \mathcal{L}_{hZZ} = \epsilon_B \left( \sqrt{2} G_F \right)^{1/2} M_Z^2 Z_\mu Z^\mu h, \]
\[ \mathcal{L}_{hAZ} = -\epsilon_A \frac{g}{\cos \theta_W} Z^\mu h \partial_\mu A, \]

(30)

with \( \epsilon_{A(B)} \) being determined once a model is chosen. We also consider the possibility that the Higgs decays invisible

\[ h \rightarrow JJ \]  

(31)

and treat the branching fraction \( B \) for \( h \rightarrow JJ \) as a free parameter.

The following signals with \( p_T \) were considered:

\[ e^+e^- \rightarrow (Zh + Ah) \rightarrow b\bar{b} + p_T, \]
\[ e^+e^- \rightarrow Zh \rightarrow \ell^+\ell^- + p_T, \]

(32)

but also the more standard processes

\[ e^+e^- \rightarrow Zh \rightarrow \ell^+\ell^- + b\bar{b}, \]
\[ e^+e^- \rightarrow (Zh + Ah) \rightarrow b\bar{b} + b\bar{b}. \]

(33)

Using the above processes and after a careful study of the backgrounds and of the necessary cuts, it was possible to evaluate the limits on \( M_h, M_A, \epsilon_A, \epsilon_B, \) and \( B \) that can be obtained at LEP II. In Figure 2 are shown some of these limits.

### 6.2 Neutralinos and Charginos

At LEP II the production rates for \textit{R-Parity violation} processes will not be very large, compared with those at LEP I. Therefore we expect that the production rates will be like in the MSSM, via non R-parity breaking processes. However the decays will be modified much in the same way as in the LEP I case. This is specially important for the \( \chi_0 \) because it is invisible in the MSSM but visible here. Also the R-parity violating decays of the charginos

\[ \chi^- \rightarrow \tau^- + J \]

(34)

can have a substantial decay fraction compared with the usual MSSM decays

\[ \chi^- \rightarrow \chi^0 + f\bar{f} \]

(35)
7 Conclusions

There is a viable model for SBRP that leads to a very rich phenomenology, both at laboratory experiments, and at present (LEP) and future (LHC, LNC) accelerators. We have shown that the radiative breaking of both the Gauge Symmetry and R-Parity can be achieved. In these type of models neutrinos have mass and can decay thus avoiding the critical density argument. They also can evade the BBN limits on a $\nu_\tau$ on the MeV scale. Regarding Higgs Physics, the most important point is that the lightest Higgs boson can have a significant invisible decay fraction. This changes the standard analysis for the Higgs mass limits. We have illustrated how the existing data gathered by the LEP collaborations at the Z peak are sufficient to probe the spontaneously broken R-parity models. These results have been extended for the case of LEP II after they have collected $L = 500 pb^{-1}$ of data.

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References

1. H. Haber and G. Kane, *Phys. Rev.* **117**, 75 (1985); H. P. Nilles, *Phys. Rep.* **110**, 1 (1984).
2. G. Farrar and P. Fayet, *Phys. Lett.* **76B**, 575 (1978); *Phys. Lett.* **79B**, 442 (1978).

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

4. For a recent review see J. W. F. Valle, in *Physics Beyond the Standard Model*, lectures given at the VIII Jorge Andre Swieca Summer School (Rio de Janeiro, February 1995) and at V Taller Latinoamericano de Fenomenología de las Interacciones Fundamentales (Puebla, Mexico, October 1995); published in the proceedings [hep-ph/9603307].

5. F. Vissani and A. Yu. Smirnov, *Nucl. Phys.* **B460**, 37-56 (1996). R. Hempfling, *Nucl. Phys.* **B478**, 3 (1996); H.P. Nilles and N. Polonsky, *Nucl. Phys.* **B484**, 33 (1997). B. de Carlos, P.L. White, Phys.Rev. **D55** 4222-4239 (1997); T. Banks, T. Grossman, E. Nardi, Y. Nir, Phys. Rev. **D52** (1995) 5319; E. Nardi, Phys. Rev. **D55** (1997) 5772; S. Roy and B. Mukhopadhyaya, Phys. Rev. **D55**, 7020 (1997) [hep-ph/9612447].

6. C Aulakh, R Mohapatra, *Phys. Lett.* **B 119**, 136 (1983); A Santamaria, J W F Valle, *Phys. Lett.* **B 195**, 423 (1987); PRL **60**, 397 (1988); *Phys. Rev.* **D 39**, 1780 (1989).

7. A. Masiero, J.W.F. Valle, *Phys. Lett.* **B 251**, 273 (1990).

8. J. C. Romão, C. A. Santos, J. W. F. Valle, *Phys. Lett.* **B 288**, 311 (1992).

9. J. C. Romão, A. Ioannissyan and J. W. F. Valle, *Phys. Rev.* **D55**, 427 (1997).

10. P Nogueira, J C Romão, J W F Valle, *Phys. Lett.* **B 251**, 142 (1990)

11. J. C. Romão, J. W. F. Valle, *Nucl. Phys.* **B 381**, 87 (1992)

12. M C Gonzalez-Garcia, J C Romão, J W F Valle, *Nucl. Phys.* **B 391**, 100 (1993).

13. S. Bertolini and G. Steigman, *Nucl. Phys.* **B 387**, 193 (1990); M. Kawasaki et al, *Nucl. Phys.* **B 402**, 323 (1993); *Nucl. Phys.* **B 419**, 105 (1994); S. Dodelson, G. Gyuk and M.S. Turner, *Phys. Rev.* **D 49**, 5068 (1994).

14. A. D. Dolgov, S. Pastor, J.C. Romão and J. W. F. Valle, *Nucl. Phys.* **B 496**, 24 (1997)

15. A Lopez-Fernandez, J. Romão, F. de Campos and J. W. F. Valle, *Phys. Lett.* **B 312**, 240 (1993); Proceedings of Moriond ’94. pag.81-86, edited by J. Tran Thanh Van, Éditions Frontières, 1994.

16. J. C. Romão, Proceedings da *International Workshop on Elementary Particle Physics Present and Future*, Valencia (Spain), pages 282-294, edited by J. W. F. Valle and A. Ferrer, World Scientific 1996.

17. F. Campos, O. Éboli, J. Rosiek and J. Valle, *Phys. Rev.* **D 55**, 1316 (1997).