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Supersymmetric economical 3–3–1 model

P.V. Dong [a], D.T. Huong [a], M.C. Rodriguez [b], H.N. Long [a,*]

[a] *Institute of Physics, VAST, PO Box 429, Bo Ho, Hanoi 10000, Vietnam*
[b] *Fundação Universidade Federal do Rio Grande-FURG, Departamento de Física, Av. Itália, km 8, Campus Carreiros, 96201-900 Rio Grande, RS, Brazil*

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Abstract

The supersymmetric extension of the economical 3–3–1 model is presented. The constraint equations and the gauge boson identification establish a relation between the vacuum expectation values (VEVs) at the top and bottom elements of the Higgs triplet χ and its supersymmetric counterpart χ'. Because of this relation, the exact diagonalization of neutral gauge boson sector has been performed. The gauge bosons and their associated Goldstone ones mix in the same way as in non-supersymmetric version. This is also correct in the case of gauginos. The eigenvalues and eigenstates in the Higgs sector are derived. The model contains a heavy neutral Higgs boson with mass equal to those of the neutral non-Hermitian gauge boson X^0 and a charged scalar with mass equal to those of the W boson in the Standard Model, i.e., $m_{\varrho_1} = m_W$. This result is in good agreement with the present estimation: $m_{H^\pm} > 79.3$ GeV, CL $= 95\%$. We also show that the boson sector and the fermion sector gain masses in the same way as in the non-supersymmetric case.

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1. Introduction

Recent neutrino experimental results [1–3] establish the fact that neutrinos have masses and the Standard Model (SM) must be extended. The generation of neutrino masses is an important

* Corresponding author.
E-mail addresses: pvdong@iop.vast.ac.vn (P.V. Dong), dthuong@iop.vast.ac.vn (D.T. Huong), mcrodriguez@einstein.fisica.furg.br (M.C. Rodriguez), hnlong@iop.vast.ac.vn (H.N. Long).

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issue in any realistic extension of the SM. In general, the values of these masses (of the order of, or less than, 1 eV) that are needed to explain all neutrino oscillation data are not enough to put strong constraints on model building. It means that several models can induce neutrino masses and mixing compatible with experimental data. So, instead of proposing models built just to explain the neutrino properties, it is more useful to consider what are the neutrino masses that are predicted in any particular model which has motivation other than the explanation of neutrino physics.

The SM is exceedingly successful in describing leptons, quarks and their interactions. Nevertheless, the SM is not considered as the ultimate theory since neither the fundamental parameters, masses and couplings, nor the symmetry pattern are predicted. These elements are merely built into the model. Likewise, the spontaneous electroweak symmetry breaking is simply parametrized by a single Higgs doublet field.

Even though many aspects of the SM are experimentally supported to a very accuracy, the embedding of the model into a more general framework is to be expected. The argument is closely connected to the mechanism of the electroweak symmetry breaking. If the Higgs boson is light, the SM can naturally be embedded in a grand unified theory, the so-called GUT. The large energy gap between the low electroweak scale and the high GUT scale can be stabilized by supersymmetry. Supersymmetry actually provides the link between the experimentally explored interactions at electroweak energy scales and physics at scales close to the Planck scale $M_{\mathrm{pl}} \approx 10^{19}$ GeV where gravity is important.

On the other hand, the possibility of a gauge symmetry based on the following symmetry $\mathrm{SU}(3)_C \otimes \mathrm{SU}(3)_L \otimes \mathrm{U}(1)_X$ (3–3–1) [4–6] is particularly interesting, because it explains some fundamental questions that are eluded in the SM. The main motivations to study this kind of model are:

(1) The family number must be multiple of three;
(2) It explains why $\sin^2\theta_W < \frac{1}{4}$ is observed;
(3) It solves the strong CP problem;
(4) It is the simplest model that includes bileptons of both types: scalar and vectors ones;
(5) The model has several sources of CP violation.

In one of the 3–3–1 models [6] which is anomaly free, the particle content is given by[1]

$$\begin{aligned}
&L_{aL} = \left(\nu_a, l_a, \nu_a^c\right)_L^T \sim (\mathbf{3}, -1/3), \qquad l_{aR} \sim (\mathbf{1}, -1), \quad a = 1, 2, 3,\\
&Q_{1L} = (u_1, d_1, u')_L^T \sim (\mathbf{3}, 1/3), \qquad Q_{\alpha L} = (d_\alpha, -u_\alpha, d'_\alpha)_L^T \sim (\mathbf{3}^*, 0), \quad \alpha = 2, 3,\\
&u_{iR} \sim (\mathbf{1}, 2/3), \qquad d_{iR} \sim (\mathbf{1}, -1/3), \quad i = 1, 2, 3,\\
&u'_R \sim (\mathbf{1}, 2/3), \qquad d'_{\alpha R} \sim (\mathbf{1}, -1/3),
\end{aligned}$$

where the values in the parentheses denote quantum numbers based on the $(\mathrm{SU}(3)_L, \mathrm{U}(1)_X)$ symmetry. The exotic quarks u' and d'_α in this case take the same electric charges as of the usual quarks, i.e., $q_{u'} = 2/3$, $q_{d'_\alpha} = -1/3$. The spontaneous symmetry breaking in this model is achieved by two Higgs scalar triplets only

$$\chi = \left(\chi_1^0, \chi^-, \chi_2^0\right)^T \sim (\mathbf{3}, -1/3), \qquad \rho = \left(\rho_1^+, \rho^0, \rho_2^+\right)^T \sim (\mathbf{3}, 2/3) \tag{1}$$

[1] In this article the notation is slightly different from those in Ref. [7].