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Higgs phenomenology of supersymmetric economical 3–3–1 model

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Abstract

We explore the Higgs sector in the supersymmetric economical 3–3–1 model and find new features in this sector. The charged Higgs sector is revised, i.e., in difference of the previous work, the exact eigenvalues and states are obtained without any approximation. In this model, there are three Higgs bosons having masses equal to that of the gauge bosons—the W and extra X and Y. There is one scalar boson with mass of 91.4 GeV, which is closed to the Z boson mass and in good agreement with present limit: 89.8 GeV at 95% CL. The condition of eliminating for charged scalar tachyon leads to splitting of VEV at the first symmetry breaking, namely, $w \simeq w'$. The interactions among the Standard Model gauge bosons and scalar fields in the framework of the supersymmetric economical 3–3–1 model are presented. From these couplings, at some limit, almost scalar Higgs fields can be recognized in accordance with the Standard Model. The hadronic cross section for production of the bilepton charged Higgs boson at the CERN LHC in the effective vector boson approximation is calculated. Numerical evaluation shows that the cross section can exceed 35.8 fb.

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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 thus an impor-

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tant issue in any realistic extension of the SM. In general, the values of these masses which are of the order of, or less than, 1 eV 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. In such cases it is more useful to consider in any particular model motivation other than that can explain neutrino masses. In addition, although the SM is exceedingly successful in describing charged leptons, quarks and their interactions, it 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.

The embedding of the model into a more general framework is therefore expected. If the Higgs boson is light, the SM can naturally be embedded in a grand unified theory. The large energy gap between the low electroweak scale and the high grand unification scale can be stabilized by a supersymmetry (SUSY) transforming bosons into fermions and vice versa [4]. The existence of such a non-trivial extension is highly constrained by theoretical principles and 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. One of the intriguing features of the supersymmetric models is that the Higgs spectrum is quite constrained. This statement is consolidated by our analysis below.

On the other hand, the possibility of a gauge symmetry based on $\mathrm{SU}(3)_C \otimes \mathrm{SU}(3)_L \otimes \mathrm{U}(1)_X$ (3–3–1) [5–7] 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 solves the strong CP problem;
(3) It is the simplest model that includes bileptons of both types: scalar and vectors ones;
(4) The model has several sources of CP violation;
(5) The explanation of electric charge quantization [8].

In one of 3–3–1 models [7], the anomaly-free particle content is given by

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

where the values in the parentheses denote quantum numbers based on the $(\mathrm{SU}(3)_C, \mathrm{SU}(3)_L, \mathrm{U}(1)_X)$ symmetry. The exotic quarks u' and d'_α 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 is achieved by two Higgs scalar triplets only

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

with all the neutral components χ_1^0, χ_2^0 and ρ^0 developing the vacuum expectation values (VEVs). Such a scalar sector is minimal, therefore it has been called the economical 3–3–1 model [9,10].