Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Nuclear Physics B 756 (2006) 1–15
NUCLEAR PHYSICS B

# Searching for doubly charged Higgs bosons at the LHC in a 3-3-1 model

J.E. Cieza Montalvo [a], Nelson V. Cortez Jr. [b,*], J. Sá Borges [a], Mauro D. Tonasse [c]

[a] *Instituto de Física, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, 20559-900 Rio de Janeiro, RJ, Brazil*
[b] *Rua Justino Boschetti 40, 02205-050 São Paulo, SP, Brazil*
[c] *Campus Experimental de Registro, Universidade Estadual Paulista, Rua Tamekishi Takano 5, 11900-000 Registro, SP, Brazil*

Received 24 April 2006; received in revised form 12 August 2006; accepted 18 August 2006

Available online 7 September 2006

**Abstract**

Using a peculiar version of the $SU(3)_L \otimes U(1)_N$ electroweak model, we investigate the production of doubly charged Higgs boson at the Large Hadron Collider. Our results include branching ratio calculations for the doubly charged Higgs and for one of the neutral scalar bosons of the model.


*PACS:* 11.15.Ex; 12.60.Fr; 14.80.Cp

## 1. Introduction

In the last few years we have seen a tremendous experimental progress in the realm of the weak interactions. However, these advances do not attain the scalar sector yet. This is the sense in which LHC (Large Hadron Collider) facilities may shed some light especially on the Higgs boson. One of the main ingredients of the Standard Model is the Higgs mechanism which, in principle, explains how the particles gain masses through the introduction of an isodoublet scalar field. The scalar field is the responsible for the spontaneous breakdown of the gauge symmetry. After electroweak symmetry breaking, the interaction of this scalar with the gauge bosons and

* Corresponding author.
*E-mail address:* nelson.v.cortez@gmail.com (N.V. Cortez Jr.).

0550-3213/$ – see front matter 
doi:10.1016/j.nuclphysb.2006.08.013

fermions generate the mass of the particles. In this process there remains a single neutral scalar, manifesting itself as the Higgs particle.

The Standard Model possibly is a low energy effective theory which must be generalized by some GUT (grand unified theory). However, there are several motivations to extend the electroweak theory below the GUT scale. Supersymmetric models, for example, provide a solution to the hierarchy problem through the cancellation of the quadratic divergences *via* fermionic and bosonic loop contributions [1]. The little Higgs model, recently proposed, predicts that the Higgs boson is a pseudo-Goldstone boson of some approximate broken global symmetry [2]. Therefore, this model is also able to solve the naturalness problem of the Higgs mass. One of the main motivations for the left-right models and for the study of their phenomenological consequences is that in which the Higgs triplet representation furnishes a seesaw type neutrino mass matrix associated with the presence of a doubly charged Higgs boson [3]. Therefore, these models suggest a route to understanding the pattern of the neutrino masses.

Doubly charged Higgs bosons appear in several popular extensions of the Standard Model such as left-right symmetric models [3] and Higgs triplet models [4]. However, there is another interesting class of electroweak models which also predict particles like that. This class of models is called 3-3-1 models [5,6]. This is the simplest chiral extension of the Standard Model. It is able to solve the fermion family's replication problem through of a simple relation between the number of colors and the anomaly cancellation mechanism. It is important to notice that a solution to this problem is not furnished even in the context of the GUTs. The 3-3-1 models have other interesting features, as for example the upper bound on the Weinberg mixing angle, through the relation $\sin^2\theta_W < 1/4$. This feature does not happen in any kind of others electroweak models except GUTs, where the value of $\sin^2\theta_W$ is predicted. This result leads to an upper bound for the energy scale of the model when this parameter is evolved to high values [7]. In a similar fashion as occurs in left-right model, the seesaw mechanism can be naturally incorporated in some versions of the 3-3-1 models [8].

No Higgs bosons have yet been found. In the meantime, it is the last brick that is lacking to finish the construction of the building of the standard electroweak theory. Besides, it is possible that the Higgs sector brings to light a non-standard physics.

Since that the 3-3-1 models are good candidates for physics beyond the Standard Model, it is interesting to evaluate if the future accelerators will produce events in sufficient numbers to detect some of the 3-3-1 Higgs bosons. In particular, there is an increasing interest in the phenomenology associated with doubly charged Higgs bosons, a kind that appears in models that admit scalars in triplet representation of the gauge group [9]. Here we are interested in one of such version of the 3-3-1 models for which the scalar fields come only in triplet representation [6,8]. It predicts three new neutrals, four single charged and two doubly charged Higgs bosons. These scalars can be disclosed in relatively low energies, which make them interesting for searches in the next generation of particle accelerators.

Our work is organized as follows. In Section 2 we summarize the relevant features of the model, in Section 3 we present the cross section calculations and in Section 4 we give our conclusions.

## 2. Overview of the model

The underlying electroweak symmetry group is $\mathrm{SU}(3)_L \otimes \mathrm{U}(1)_N$, where $N$ is the quantum number of the U(1) group. Therefore, the left-handed lepton matter content is $(\nu'_a\ \ell'_a \mathrm{L}'_a)^{\mathrm{T}}_L$ transforming as $(\mathbf{3}, 0)$, where $a = e, \mu, \tau$ is a family index (we are using primes for the interaction