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Lepton flavor violating decays of Standard-Model-like Higgs in 3-3-1 model with neutral lepton

L.T. Hue [a], H.N. Long [b,c,*], T.T. Thuc [a], T. Phong Nguyen [d]

[a] *Institute of Physics, VAST, 10 Dao Tan, Ba Dinh, Hanoi, Viet Nam*
[b] *Theoretical Particle Physics and Cosmology Research Group, Ton Duc Thang University, Ho Chi Minh City, Viet Nam*
[c] *Faculty of Applied Sciences, Ton Duc Thang University, Ho Chi Minh City, Viet Nam*
[d] *Department of Physics, Cantho University, 3/2 Street, Ninh Kieu, Cantho, Viet Nam*

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Abstract

The one loop contribution to the lepton flavor violating decay $h^0 \to \mu\tau$ of the SM-like neutral Higgs (LFVHD) in the 3-3-1 model with neutral lepton is calculated using the unitary gauge. We have checked in detail that the total contribution is exactly finite, and the divergent cancellations happen separately in two parts of active neutrinos and exotic heavy leptons. By numerical investigation, we have indicated that the one-loop contribution of the active neutrinos is very suppressed while that of exotic leptons is rather large. The branching ratio of the LFVHD strongly depends on the Yukawa couplings between exotic leptons and $SU(3)_L$ Higgs triplets. This ratio can reach 10^{-5} providing large Yukawa couplings and constructive correlations of the $SU(3)_L$ scale (v_3) and the charged Higgs masses. The branching ratio decreases rapidly with the small Yukawa couplings and large v_3.

* Corresponding author.
E-mail addresses: lthue@iop.vast.ac.vn (L.T. Hue), hoangngoclong@tdt.edu.vn (H.N. Long), ttthuc@grad.iop.vast.ac.vn (T.T. Thuc), thanhphong@ctu.edu.vn (T. Phong Nguyen).

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1. Introduction

The observation the Higgs boson with mass around 125.09 GeV by experiments at the Large Hadron Collider (LHC) [1–5] again confirms the very success of the Standard Model (SM) at low energies of below few hundred GeV. But the SM must be extended to solve many well-known problems, at least the question of neutrino masses and neutrino oscillations which have been experimentally confirmed [6]. Neutrino oscillation is a clear evidence of lepton flavor violation in the neutral lepton sector which may give loop contributions to the rare lepton flavor violating (LFV) decays of charged leptons, Z and SM-like Higgs bosons. Therefore, these are the promoting subjects of new physics which have been hunted by recent experiments [7–9]. Especially, the latest experimental results of LFVHD have been reported recently by CMS and ATLAS. Defining $\mathrm{Br}(h^0 \to \mu\tau) \equiv \mathrm{Br}(h^0 \to \mu^+\tau^-) + \mathrm{Br}(h^0 \to \mu^-\tau^+)$, the upper bound $\mathrm{Br}(h^0 \to \mu\tau) < 1.5 \times 10^{-2}$ at 95% C.L. was announced by CMS, in agreement with 1.85×10^{-2} at 95% C.L. from ATLAS. These sensitivities are not far from the recent theoretical prediction and is hoped to be improved soon, as discussed in [10].

The LFVHD of the neutral Higgses have been investigated widely in the well-known models beyond the SM [11,12,10], including the supersymmetric (SUSY) models [13–15]. The SUSY versions usually predict large branching ratio of LFVHD which can reach 10^{-4} or higher, even up to 10^{-2} in recent investigation [13], provided the two following requirements: new LFV sources from sleptons and the large $\tan\beta$-ratio of two vacuum expectation values (vev) of two neutral Higgses. At least it is true for the LFVHD $h^0 \to \mu\tau$ under the restrict of the recent upper bound of $\mathrm{Br}(\tau \to \mu\gamma) < 10^{-8}$ [16]. In the non-SUSY $SU(2)_L \times U(1)_Y$ models beyond the SM such as the seesaw or general two Higgs doublet (THDM), the LFVHD still depends on the LFV decay of τ lepton. The reason is that the LFVHD is strongly affected by Yukawa couplings of leptons while the $SU(2)_L \times U(1)_Y$ contains only small Yukawa couplings of normal charged leptons and active neutrinos. Therefore, many of non-SUSY versions predict the suppressed signal of LFVHD.

Based on the extension of the $SU(2)_L \times U(1)_Y$ gauge symmetry of the SM to the $SU(3)_L \times U(1)_X$, there is a class of models called 3-3-1 models which inherit new LFV sources. Firstly, the particle spectra include new charged gauge bosons and charged Higgses, normally carrying two units of lepton number. Secondly, the third components of the lepton (anti-) triplets may be normal charged leptons [17,18] or new leptons [19–23] with non-zero lepton numbers. These new leptons can mix among one to another to create new LFV changing currents, except the case of normal charged leptons. The most interesting models for LFVHD are the ones with new heavy leptons corresponding to new Yukawa couplings that affect strongly to the LFVHD through the loop contributions. This property is different from the models based on the gauge symmetry of the SM including the SUSY versions. In the 3-3-1 models, if the new particles and the $SU(3)_L$ scale are larger than few hundred GeVs, the one-loop contributions to the LFV decays of τ always satisfy the recent experimental bound [24]. While this region of parameter space, even at the TeV values of the $SU(3)_L$ scale, favors the large branching ratios of LFVHD. The one-loop contributions on LFV processes in SUSY versions of 3-3-1 models were given in [25,14], but the non-SUSY contributions were not mentioned.

The 3-3-1 models were first investigated from interest of the simplest expansion of the $SU(2)_L$ gauge symmetry and the simplest lepton sector [17]. They then became more attractive by a clue of answering the flavor question coming from the requirement of anomaly cancellation for $SU(3)_L \times U(1)_X$ gauge symmetry [18]. The violation of the lepton number is a natural property of these models, leading to the natural presence of the LFV processes and neutrino oscillations.