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Nuclear Physics B 910 (2016) 293–308

NUCLEAR PHYSICS B

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Lepton flavor violating decays of neutral higgses in extended mirror fermion model

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Received 12 May 2016; received in revised form 22 June 2016; accepted 7 July 2016

Available online 12 July 2016

Editor: Hong-Jian He

Abstract

We investigate the one-loop induced charged lepton flavor violating decays of the neutral Higgses in an extended mirror fermion model with non-sterile electroweak-scale right-handed neutrinos and a horizontal A_4 symmetry in the lepton sector. It is demonstrated that for the 125 GeV scalar h there is tension between the recent LHC result $\mathcal{B}(h \to \tau\mu) \sim 1\%$ and the stringent limits on the rare processes $\mu \to e\gamma$ and $\tau \to (\mu/e)\gamma$ as well as the muon anomalous magnetic dipole moment Δa_μ from low energy experiments.

1. Motivation

As is well known, the conservation of lepton and baryon numbers are accidental global symmetries in the fundamental Lagrangian of Standard Model (SM). Flavor number conservation, on the other hand, is only a global symmetry of electromagnetism and strong interaction, while weak decays and neutrino oscillations break the flavor symmetry. Moreover, with just one Higgs

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http://dx.doi.org/10.1016/j.nuclphysb.2016.07.009

doublet in the SM, the Higgs couplings to the fermions are diagonal at the tree level. Thus in SM, proton decays are strictly forbidden, while $\mu \to e\gamma$, $h \to \tau\mu$, *etc.* can only be induced via weak interaction at loop level. Experimental limits for these processes are indeed very stringent. For example, for the proton lifetime we have the following bound [1]

$$\tau(p \to e^+\gamma) > 670 \times 10^{30} \text{ years}\,, \tag{1}$$

and for the branching fraction of $\mu^+ \to e^+\gamma$ we have the limit from the latest MEG result [2]

$$\mathcal{B}(\mu^+ \to e^+\gamma) < 4.2 \times 10^{-13}\ (90\%\,\text{CL})\,. \tag{2}$$

Search for charged lepton flavor violating (CLFV) Higgs decay $h \to \tau\mu$ at hadron colliders was proposed some time ago [3]. Recently both ATLAS [4] and CMS [5] experiments at the Large Hadron Collider (LHC) have reported the following best fit branching ratios

$$\mathcal{B}(h \to \tau\mu) = \begin{cases} 0.53 \pm 0.51\% \ \text{[ATLAS 8 TeV]}\,, \\ -0.76^{+0.81}_{-0.84}\% \ \text{[CMS 13 TeV]}\,. \end{cases} \tag{3}$$

However, at 95% confidence level (CL), the following upper limits can be deduced

$$\mathcal{B}(h \to \tau\mu) < \begin{cases} 1.43\%\ (95\%\,\text{CL})\ \text{[ATLAS 8 TeV]}\,, \\ 1.20\%\ (95\%\,\text{CL})\ \text{[CMS 13 TeV]}\,. \end{cases} \tag{4}$$

Despite low statistical significance the above best fit results in Eq. (3) are somewhat surprising. Recall that the charged lepton flavor changing Higgs couplings, which may lead to the above decay, are absent at tree level in SM. On the other hand, at one-loop this process can only be induced by the non-vanishing minuscule neutrino masses as implied by various neutrino oscillation experiments and thus the contribution is expected to be quite small. A positive measurement of this branching ratio in the near future at the percent level would be a clear indication of new physics beyond the SM.

Besides we have stringent limits for CLFV radiative decays like $\mu \to e\gamma$ in Eq. (2) as well as

$$\mathcal{B}(\tau \to \mu\gamma) < 4.4 \times 10^{-8}\,, \tag{5}$$

$$\mathcal{B}(\tau \to e\gamma) < 3.3 \times 10^{-8}\,, \tag{6}$$

both at 90% CL from the low energy data of BaBar experiment [6].

In [7], an up-to-date analysis of a previous calculation [8] of $\mu \to e\gamma$ in a class of mirror fermion models with non-sterile electroweak scale right-handed neutrinos [9] was presented for an extension of the models with a horizontal A_4 (the non-abelian discrete symmetry group of the regular tetrahedron) symmetry in the lepton sector [10]. It was demonstrated in [7] that although there exists parameter space relevant to electroweak physics that can accommodate the muon magnetic dipole moment anomaly $\Delta a_\mu = 288(63)(49) \times 10^{-11}$ [1], the current low energy limit Eq. (2) on the branching ratio $\mathcal{B}(\mu \to e\gamma)$ from MEG experiment [2] has disfavored those regions of parameter space.

Over the years, many authors had studied the flavor changing neutral current Higgs decays $h \to \overline{f}_i f_j (i \neq j)$ in both the SM [11] and its various extensions [12–14]. Recently large flux of works on new physics implications for the LHC result of lepton flavor violating Higgs decays Eq. (3) is easily noticed [15–45].

In this work, we present the one-loop calculation of CLFV decay of the neutral Higgses in the extended mirror fermion model [9,10]. In Section 2, we briefly review the extended model and demonstrate that tree level CLFV Higgs couplings are in general present in the model but