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Decay of standard model-like Higgs boson $H_1 \to Z\gamma$ in the simplest 3-3-1 model

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***Abstract* - The decays of the Higgs boson $H_1 \to Z\gamma$ are discussed in the simplest 3-3-1 model. Analytic formulas for one-loop contributions were constructed using well-known general results. We will show that new particles predicted by this simplest 3-3-1 model may give significant effects to this decay of the standard model-like Higgs boson. From numerical investigation, some details and properties of this decay are presented. They may be useful for comparing with the experimental results that will be detected in the future.**

Keywords-Higgs boson decays, rate decay, the beyond standard model, etc.

I. Introduction

After the discovery of the SM-like Higgs boson particle at LHC in 2012 [1], [3], the standard model has been confirmed again it's valid, although many problems are still unsolved in the SM framework. Hence, models beyond the SM have been introduced to explain them. The 3-3-1 models predicts many new particles including new gauge and Higgs bosons, therefore many affect strongly on the branching ratio (Br) of the SM-like Higgs boson decay into $Z\gamma$. Recent experimental data indicate that the SM-like Higgs boson decay Br($h \to \gamma\gamma$) is well consistent with the SM prediction, hence contributions from new physics to this decay must be small. In this work, we will discuss on Br($H_1 \to Z\gamma$) in the simplest 3-3-1 model introduced recently [4]. Because this model is simple for calculating relevant couplings, which contribute to the $h \to Z\gamma$ but not $h \to \gamma\gamma$. Hence, these couplings may affect significantly on the first decay, but still satisfy the experimental bound on the second. Numerical results will be presented.

The paper is organized as follows. In section II, we present the overview of the 3-3-1 simplest model. We also present the vertexes and its couplings which are relevant to the decay $h \to Z\gamma$ in Sec. III. Numerical results are discussed in this section. Finally, the summary is then given in Sec. IV.

II. The simplest 3-3-1 model review

The model based on the gauge group $SU(3)_L \times SU(2)_L \times U(1)_X$, was introduced in Ref. [4]. The electric charge operator of the model is $Q = \alpha T_3 + \beta T_8 + X$, where $\beta = 0$, T_a, $a = 1, \dots 8$ are the $SU(3)$ generators and X is the new charge of the group $U(1)_X$.

Fermions including leptons and quarks are assigned as follows

$$\begin{aligned}
&L_{aL} = (e_a,\ -\nu_a,\ E_a)^T_L \sim (3^*, -1)\,,\ e_{aR} \sim (1, -2)\,,\\
&\nu_{aR} \sim (1, 0)\,, \quad E_{aR} \sim (1, -1)\,,\\
&Q_{iL} = (u_i,\ d_i,\ U_i)^T_L \sim (3^*, -1)\,,\ i = 1, 2,\\
&Q_{3L} = (b,\ -t,\ T)^T_L \sim\sim (3^*, 1/3)\,,\\
&u_{iR},\ t_R \sim (1, 4/3)\,, \quad d_{iR}, ; b_R \sim (1, -2/3)\,,\\
&U_{iR}, T_R \sim (1, 1/3)\,,\ a = 1, 2, 3,
\end{aligned} \tag{1}$$

where we have introduced three new quarks U_1, U_2 and T with electric charges all equal to 1/6. There are totally nine EW gauge bosons, included in the following covariant derivative

$$D_\mu \equiv \partial_\mu - ig_3 T^a W^a_\mu - ig_1 \frac{Y}{2} B_\mu, \tag{2}$$

where g_3 and g_1 are coupling constants corresponding to the two groups $SU(3)_L$ and $U(1)_Y$, respectively. The matrix $W^a T^a$, with $T^a = \lambda_a/2$ corresponding to a triplet representation, can be written as

$$W^a_\mu T^a = \frac{1}{2}\begin{pmatrix} W^3_\mu + \frac{1}{\sqrt{3}} W^8_\mu & \sqrt{2} W^+_\mu & \sqrt{2} V^{+1/2}_\mu \\ \sqrt{2} W^-_\mu & -W^3_\mu + \frac{1}{\sqrt{3}} W^8_\mu & \sqrt{2} V'^{-1/2}_\mu \\ \sqrt{2} V^{-1/2}_\mu & \sqrt{2} V'^{+1/2}_\mu & -\frac{2}{\sqrt{3}} W^8_\mu \end{pmatrix}$$

where we have defined the mass eigenstates of the charged gauge bosons as

$$W_\mu^\pm = \frac{1}{\sqrt{2}}\left(W_\mu^1 \mp iW_\mu^2\right),$$
$$V_\mu^{\pm 1/2} = \frac{1}{\sqrt{2}}\left(W_\mu^4 \mp iW_\mu^5\right),$$
$$V_\mu^{\prime \mp 1/2} = \frac{1}{\sqrt{2}}\left(W_\mu^6 \mp iW_\mu^7\right). \tag{3}$$

We are now in the position to examine the FCNCs in the scalar sector. For this purpose, we need to consider Yukawa interactions. For the leptons, since the three families transform identically under the $SU(3)_L$ group, there is no FCNC because diagonalizing the mass matrices automatically makes the interactions diagonal. For the quark sector, it is more complicated because the third family transforms differently. The Lagrangian reads:

$$\begin{aligned}\mathcal{L}_{\text{yuk}} &= -Y^u_{ia}\bar{Q}_{iL}\eta u_{aR} - Y^d_{ia}\bar{Q}_{iL}\rho d_{aR} - Y^U_{ia}\bar{Q}_{iL}\chi U_{aR} \\ &- Y^d_{3a}\bar{Q}_{3L}\eta^* d_{aR} - Y^u_{3a}\bar{Q}_{3L}\rho^* u_{aR} \\ &- Y^U_{3a}\bar{Q}_{3L}\chi^* U_{aR} + H.c.,\end{aligned} \tag{4}$$

where $i = 1,2$; $a = 1,2,3$; $u_{aR} = u_R, c_R, t_R$; $d_{aR} = d_R, s_R, b_R$ and $U_{aR} = U_{1R}, U_{2R}, T_R$. To generate masses for gauge bosons and fermions, three scalar triplets are introduced as

$$\eta = (\eta^0,\ \eta^-,;\eta^{-1/2})^T \sim (3,-1),$$
$$\rho = (\rho^+,\ \rho^0,\ \rho^{+1/2})^T \sim (3,1),$$
$$\chi = (\chi^{+1/2},\ \chi'^{-1/2},\ \chi^0)^T \sim (3,0). \tag{5}$$

Only neutral components of Higgses develop VEVs as $\langle\eta^0\rangle = \frac{v'}{\sqrt{2}}$, $\langle\rho^0\rangle = \frac{v}{\sqrt{2}}$ and $\langle\chi^0\rangle = \frac{u}{\sqrt{2}}$. The relations between original and physical states of neutral gauge boson are

$$Z'_\mu = W^8_\mu, \quad \begin{pmatrix} Z_\mu \\ A_\mu \end{pmatrix} = \begin{pmatrix} c_W & -s_W \\ s_W & c_W \end{pmatrix}\begin{pmatrix} W^3_\mu \\ B_\mu \end{pmatrix}, \tag{6}$$

where $c_W = \cos\theta_W$, $s_W = \sin\theta_W$ with θ_W being the weak mixing angle read $s_W = \frac{g_1}{\sqrt{g_1^2+g_3^2}}$, where g_3 and g_1 are coupling constants corresponding to the two groups $SU(3)_L$ and $U(1)_Y$. The simple Higgs potential was discussed on [4], namely

$$\begin{aligned}\mathcal{V} &= \mu_1^2\eta^\dagger\eta + \mu_2^2\rho^\dagger\rho + \mu_3^2\chi^\dagger\chi + \lambda_1(\eta^\dagger\eta)^2 \\ &+ \lambda_2(\rho^\dagger\rho)^2 + \lambda_3(\chi^\dagger\chi)^2 \\ &+ \lambda_{12}(\eta^\dagger\eta)(\rho^\dagger\rho) + \lambda_{13}(\eta^\dagger\eta)(\chi^\dagger\chi) + \lambda_{23}(\rho^\dagger\rho)(\chi^\dagger\chi) \\ &+ \tilde{\lambda}_{12}(\eta^\dagger\rho)(\rho^\dagger\eta) + \tilde{\lambda}_{13}(\eta^\dagger\chi)(\chi^\dagger\eta) + \tilde{\lambda}_{23}(\rho^\dagger\chi)(\chi^\dagger\rho) \\ &+ \sqrt{2}f(\epsilon_{ijk}\eta^i\rho^j\chi^k + H.c.),\end{aligned} \tag{7}$$

where f is a mass parameter and is assumed to be real. This potential has been studied in Refs. [4]. Minimizing the potential with respect to u, v and v', we get

$$\begin{aligned}\mu_1^2 + \lambda_1 v'^2 + \frac{1}{2}\lambda_{12}v^2 + \frac{1}{2}\lambda_{13}u^2 &= -f\frac{vu}{v'}, \\ \mu_2^2 + \lambda_2 v^2 + \frac{1}{2}\lambda_{12}v'^2 + \frac{1}{2}\lambda_{23}u^2 &= -f\frac{v'u}{v}, \\ \mu_3^2 + \lambda_3 u^2 + \frac{1}{2}\lambda_{13}v'^2 + \frac{1}{2}\lambda_{23}v^2 &= -f\frac{vv'}{u}.\end{aligned} \tag{8}$$

The neutral scalars are defined as

$$\begin{aligned}\eta^0 &= \frac{1}{\sqrt{2}}(v' + h_1 + i\zeta_1), \\ \rho^0 &= \frac{1}{\sqrt{2}}(v + h_2 + i\zeta_2), \quad \chi^0 = \frac{1}{\sqrt{2}}(u + h_3 + i\zeta_3).\end{aligned} \tag{9}$$

Relations between mass eigenstates and the original states of the charged Higgs bosons are

$$\begin{pmatrix} \rho^\pm \\ \eta^\pm \end{pmatrix} = \frac{1}{\sqrt{2}}\begin{pmatrix} -1 & 1 \\ 1 & 1 \end{pmatrix}\begin{pmatrix} G_W^\pm \\ H^\pm \end{pmatrix},$$
$$\begin{pmatrix} \eta^{\pm 1/2} \\ \chi^{\pm 1/2} \end{pmatrix} = \begin{pmatrix} -s_X & c_X \\ c_X & s_X \end{pmatrix}\begin{pmatrix} G_V^{\pm 1/2} \\ H_1^{\pm 1/2} \end{pmatrix},$$
$$\begin{pmatrix} \rho^{\pm 1/2} \\ \chi'^{\pm 1/2} \end{pmatrix} = \begin{pmatrix} -s_X & c_X \\ c_X & s_X \end{pmatrix}\begin{pmatrix} G_V'^{\pm 1/2} \\ H_2^{\pm 1/2} \end{pmatrix},$$
$$\begin{pmatrix} h_1 \\ h_2 \\ h_3 \end{pmatrix} = \begin{pmatrix} -\frac{c_\alpha}{\sqrt{2}} & \frac{s_\alpha}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ -\frac{c_\alpha}{\sqrt{2}} & \frac{s_\alpha}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ s_\alpha & c_\alpha & 0 \end{pmatrix}\begin{pmatrix} H_1 \\ H_2 \\ H_3 \end{pmatrix}, \tag{10}$$

where $s_X = \frac{v}{\sqrt{v^2+u^2}}$, $c_X = \frac{u}{\sqrt{v^2+u^2}}$; $G_W^\pm$, $G_V^{\pm 1/2}$, and $G_V'^{\pm 1/2}$ are the goldstones eaten by gauge bosons W, $V^{\pm 1/2}$, and $V'^{\pm 1/2}$. The mixing parameters $s_\alpha = \sin\alpha$, $c_\alpha = \cos\alpha$ depend on many free parameter, but $s_\alpha \to 0$ and $c_\alpha \to -1$ when SM-like Higgs couplings are identified with the SM. The Feynman rules for the couplings of the decay $H_1 \to Z\gamma$ are given in Table 1, 2, 3 and 4.

Table 1: Feynman rules for couplings of Z boson to two fermions.

Vertex	g_L	g_R
$Z_\mu\overline{e_a}e_a$	$-\frac{1}{2} + s_W^2$	s_W^2
$Z_\mu\overline{E_a}E_a$	$\frac{1}{2}s_W^2$	$\frac{1}{2}s_W^2$
$Z_\mu\overline{u_a}u_a$	$\frac{1}{2} - \frac{2}{3}s_W^2$	$-\frac{2}{3}s_W^2$
$Z_\mu\overline{d_a}d_a$	$-\frac{1}{2} + \frac{1}{3}s_W^2$	$\frac{1}{3}s_W^2$
$Z_\mu\overline{U_a}U_a$	$-\frac{1}{6}s_W^2$	$-\frac{1}{6}s_W^2$

Table 2: Feynman rules for couplings of the SM-like Higgs boson to two fermions and Feynman rules for couplings of a photon to gauge boson (charge Higgs) and gauge boson (charge Higgs).

Vertex	Coupling
$H_1\overline{f_a}f_a$	$i\frac{gm_f c_\alpha}{2m_W}$
$H_2\overline{f_a}f_a$	$-i\frac{gm_f s_\alpha}{2m_W}$
$H_1\bar{F}F$	$-i\frac{m_U s_\alpha}{u}$
$H_2\bar{F}F$	$i\frac{m_U c_\alpha}{u}$
$A^\mu H^+H^-$	$ie\left(p_{H^+} - p_{H^-}\right)$
$A^\mu H_1^{+1/2}H_1^{-1/2}$	$ie/2\left(p_{H_1^{+1/2}} - p_{H_1^{-1/2}}\right)$
$A^\mu H_2^{+1/2}H_2^{-1/2}$	$ie/2\left(p_{H_2^{+1/2}} - p_{H_2^{-1/2}}\right)$
$A^\mu V^{+1/2\nu}V^{-1/2\lambda}$	$-ie/2\Gamma_{\mu\nu\lambda}(p_0,p_+,p_-)$
$A^\mu V'^{+1/2\nu}V'^{-1/2\lambda}$	$-ie/2\Gamma_{\mu\nu\lambda}(p_0,p_+,p_-)$
$A^\mu W^{+\nu}W^{-\lambda}$	$-ie\Gamma_{\mu\nu\lambda}(p_0,p_+,p_-)$

In here a new notation is $\Gamma_{\mu\nu\lambda}(p_0,p_+,p_-) \equiv (p_0 - p_+)_\lambda g_{\mu\nu} + (p_+ - p_-)_\mu g_{\nu\lambda} + (p_- - p_0)_\nu g_{\lambda\mu}$, where all momenta are incoming, and $p_{0,\pm}$ are respective momenta of h and

Table 3: Feynman rules for couplings of a neutral Higgs to gauge boson.

Vertex	Coupling
$H_1H_1^{\pm 1/2}V^{\mp 1/2\mu}$	$\mp ig\left(p_{H_1}-p_{H_1^{\pm 1/2}}\right)_\mu \left(\frac{2s_Xs_\alpha+\sqrt{2}c_Xc_\alpha}{4}\right)$
$H_2H_1^{\pm 1/2}V^{\mp 1/2\mu}$	$\mp ig\left(p_{H_2}-p_{H_1^{\pm 1/2}}\right)_\mu \left(\frac{\sqrt{2}c_Xs_\alpha-2s_Xc_\alpha}{4}\right)$
$H_1H_2^{\pm 1/2}V'^{\mp 1/2\mu}$	$\mp ig\left(p_{H_1}-p_{H_2^{\pm 1/2}}\right)_\mu \left(\frac{2s_Xs_\alpha+\sqrt{2}c_Xc_\alpha}{4}\right)$
$H_2H_2^{\pm 1/2}V'^{\mp 1/2\mu}$	$\mp ig\left(p_{H_2}-p_{H_2^{\pm 1/2}}\right)_\mu \left(\frac{\sqrt{2}c_Xs_\alpha-2s_Xc_\alpha}{4}\right)$
$H_1W^{+\mu}W^{-\nu}$	$-igm_Wc_\alpha g_{\mu\nu}$
$H_2W^{+\mu}W^{\nu}$	$igm_Ws_\alpha g_{\mu\nu}$
$H_1V^{+1/2\mu}V^{-1/2\nu}$	$ig^2\left(\frac{2us_\alpha-\sqrt{2}vc_\alpha}{4}\right)g_{\mu\nu}$
$H_2V^{+1/2\mu}V^{-1/2\nu}$	$ig^2\left(\frac{2uc_\alpha+\sqrt{2}vs_\alpha}{4}\right)g_{\mu\nu}$
$H_1V'^{+1/2\mu}V'^{-1/2\nu}$	$ig^2\left(\frac{2us_\alpha-\sqrt{2}vc_\alpha}{4}\right)g_{\mu\nu}$
$H_2V'^{+1/2\mu}V'^{-1/2\nu}$	$ig^2\left(\frac{2uc_\alpha+\sqrt{2}vs_\alpha}{4}\right)g_{\mu\nu}$
$H_1H^+H^-$	$-[2\sqrt{2}\lambda_1c_\alpha v-s_\alpha\lambda_{13}u+fs_\alpha]$
$H_2H^+H^-$	$[2\sqrt{2}\lambda_1s_\alpha v-c_\alpha\lambda_{13}u+fc_\alpha]$
$H_1H_1^{+1/2}H_1^{-1/2}$	$-[2\sqrt{2}\lambda_1c_X^2c_\alpha v-2s_\alpha s_X^2\lambda_3u$ $-\lambda_{23}(s_\alpha c_X^2u-\sqrt{2}c_\alpha s_X^2v)-\sqrt{2}fs_Xc_Xc_\alpha]$
$H_2H_1^{+1/2}H_1^{-1/2}$	$[2\sqrt{2}\lambda_1c_X^2s_\alpha v-2c_\alpha s_X^2\lambda_3u$ $-\lambda_{23}(c_\alpha c_X^2u-\sqrt{2}s_\alpha s_X^2v)-\sqrt{2}fs_Xc_Xs_\alpha]$
$H_1H_2^{+1/2}H_2^{-1/2}$	$-[2\sqrt{2}\lambda_1c_X^2c_\alpha v-2s_\alpha s_X^2\lambda_3u$ $-\lambda_{23}(s_\alpha c_X^2u-\sqrt{2}c_\alpha s_X^2v)-\sqrt{2}fs_Xc_Xc_\alpha]$
$H_2H_2^{+1/2}H_2^{-1/2}$	$[2\sqrt{2}\lambda_1c_X^2s_\alpha v-2c_\alpha s_X^2\lambda_3u$ $-\lambda_{23}(c_\alpha c_X^2u-\sqrt{2}s_\alpha s_X^2v)-\sqrt{2}fs_Xc_Xs_\alpha]$

Table 4: Feynman rules for couplings of the Z boson to two charge Higgs.

Vertex	Coupling
$Z_\mu H_1^+H_1^-$	$ig\left(p_{H_1^+}-p_{H_1^-}\right)_\mu\left(\frac{c_W^2-s_W^2}{2c_W}\right)$
$Z_\mu H_1^{+1/2}H_1^{-1/2}$	$ig\left(p_{H_1^{+1/2}}-p_{H_1^{-1/2}}\right)_\mu\left(\frac{s_X^2c_W^2-c_X^2s_W^2}{2c_W}\right)$
$Z_\mu H_2^{+1/2}H_2^{-1/2}$	$ig\left(p_{H_2^{+1/2}}-p_{H_2^{-1/2}}\right)_\mu\left(\frac{s_X^2c_W^2-c_X^2s_W^2}{2c_W}\right)$
$Z_\mu H_1^{+1/2}V^{1/2\lambda}$	$\frac{1}{2}ig^2v\frac{c_X}{c_W}g_{\mu\lambda}$
$Z_\mu H_2^{+1/2}V'^{-1/2\lambda}$	$\frac{1}{2}ig^2v\frac{c_X}{c_W}g_{\mu\lambda}$
$Z_\mu H^+W^{-\lambda}$	0
$Z_\mu V^{+1/2\nu}V^{-1/2\lambda}$	$ig/2c_W\Gamma_{\mu\nu\lambda}(p_0,p_+,p_-)$
$Z_\mu V'^{+1/2\nu}V'^{-1/2\lambda}$	$ig/2c_W\Gamma_{\mu\nu\lambda}(p_0,p_+,p_-)$
$Z_\mu W^{+\nu}W^{-\lambda}$	$igc_W\Gamma_{\mu\nu\lambda}(p_0,p_+,p_-)$

charged gauge and Higgs bosons with electric charges $\pm Q$. The decay $H_1\to Z\gamma$ is determined by

$$\mathrm{Br}^{331}(H_1\to Z\gamma)=\frac{\Gamma^{331}(H_1\to Z\gamma)}{\Gamma^{331}_{H_1}},$$
$$\Gamma^{331}(H_1\to Z\gamma)=\frac{m_{H_1}^3}{32\pi}\left(1-\frac{m_Z^2}{m_{H_1}^2}\right)^3|F_{21}^{331}|^2, \quad (11)$$

where $\Gamma^{331}_{H_1}$ is the total decay width of the SM-like Higgs boson H_1, and $\Gamma^{331}(H_1\to Z\gamma)$ is the partial decay width predict by the simplest 3-3-1 model. The form factor F_{21}^{331} and F_{21}^{SM}

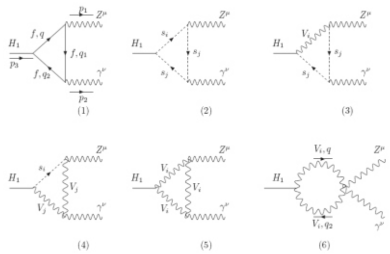

Fig. 1: One-loop diagrams contributing to the decay $H_1\to Z\gamma$ in the unitray gauge. Notations $f_{i,j}$, $S_{i,j}$ and $V_{i,j}$ are fermions, Higgs, and gauge bosons, respectively.

are written as

$$\begin{aligned}F_{21}^{331} &= F_{21,f_{ijj}}^{331}+F_{21,V_{ijj}}^{331}\\ &+ F_{21,S_{ijj}}^{331}+F_{21,VS_{jj}}^{331}+F_{21,SV_{jj}}^{331}\\ F_{21}^{SM} &= F_{21,W}^{SM}+F_{21,f}^{SM} \quad (12)\end{aligned}$$

where particular contributions are derived based on the general formulas in Ref. [5], namely

$$\begin{aligned}F_{21,f}^{331} &= -\frac{e\,Q_f\,N_cK_{LL,RR}^{f+}}{16\pi^2}\left[16\left(C_{12}+C_{22}.+C_2\right)+4C_0\right],\\
F_{21,H_{1,2}^{\pm 1/2}}^{331} &= K_{H_1S}\times[4(C_{12}+C_{22}+C_2)],\ S=H^\pm,H_{1,2}^{\pm 1/2},\\
F_{21,G}^{331} &= K_G\times\left[\frac{2(4m_G^2-m_Z^2)C_0}{m_G^2}\right]+\\
&+K_G\times\left[(8+\frac{(2m_G^2+m_{H_1}^2)(2m_G^2-m_Z^2)}{m_G^4})\right]\\
&\times[(C_{12}+C_{22}+C_2)],\\
F_{21,VSS}^{331} &= \frac{e\sqrt{2}g^2m_Z}{16\pi^2}\times\frac{c_X(2s_Xs_\alpha+\sqrt{2}c_Xc_\alpha)}{4}\\
&\times\left[2\left(1+\frac{-m_S^2+m_h^2}{m_V^2}\right)(C_{12}+C_{22}+C_2)\right]\\
&+\frac{e\sqrt{2}g^2m_Z}{16\pi^2}\times\frac{c_X(2s_Xs_\alpha+\sqrt{2}c_Xc_\alpha)}{4}\times\\
&\times[4(C_1+C_2+C_0)],\\
F_{21,SVV}^{331} &= \frac{e\sqrt{2}g^2m_Z}{16\pi^2}\times\frac{c_X(2s_Xs_\alpha+\sqrt{2}c_Xc_\alpha)}{4}\\
&\times\left[2\left(1+\frac{-m_S^2+m_h^2}{m_V^2}\right)(C_{12}+C_{22}+C_2)\right]\\
&-\frac{e\sqrt{2}g^2m_Z}{16\pi^2}\times\frac{c_X(2s_Xs_\alpha+\sqrt{2}c_Xc_\alpha)}{4}\times\\
&\times[4(C_1+C_2)], \quad (13)\end{aligned}$$

where $G=W,V,V'$, are gauge bosons; $K_{LL,RR}^{f+}=-\frac{gm_f^2c_\alpha}{2m_W}\left(T_f^3-2s_W^2Q_f\right)$ for fermions in SM, $m_{E_a}^2s_\alpha s_W^2/u$ for new lepton E_a, and $m_{U_a}^2s_\alpha s_W^2/(3u)$ for new quark U_a.

Other factors are

$$K_{H_1 H_{1,2}^{1/2}} = \frac{\lambda_{H_1 H_{1,2}^{1/2}}}{16\pi^2} \times \frac{e\, g(-c_X^2 s_W^2 + s_X^2 c_W^2)}{2c_W},$$
$$K_{H_1 H^\pm} = \frac{\lambda_{H_1 H^\pm}}{16\pi^2} \times \frac{2e\, g(1-2s_W^2)}{2c_W},$$
$$K_W = -\frac{2eg^2 c_W m_W c_\alpha}{16\pi^2},$$
$$K_V = K_{V'} = \frac{eg^3 c_W(2us_\alpha - \sqrt{2}vc_\alpha)}{128\pi^2}. \quad (14)$$

Notations $C_{0,i,ij}$ with $i,j = 1,2$ are Passarino-Veltman functions, see analytic formulas in Ref. [5]. The signal strength of the decay is

$$\mu_{Z\gamma}^{331} \equiv \frac{\sigma^{331}(pp \to H_1)}{\sigma^{\mathrm{SM}}(pp \to H_1)} \times \frac{\mathrm{Br}^{331}(H_1 \to Z\gamma)}{\mathrm{Br}^{\mathrm{SM}}(H_1 \to Z\gamma)}. \quad (15)$$

In order to numerically investigate the decay of the SM-like Higgs boson $H_1 \to Z\gamma$, we will use the following well-known experimental parameters as in [2]. In the SM, $\mathrm{Br}^{\mathrm{SM}}(H_1 \to Z\gamma) \simeq 1.57 \times 10^{-3}$ and $\Gamma_{H_1}^{\mathrm{SM}} \simeq 4,07.10^{-3}$ GeV with $m_{H_1} = 125.1$ GeV. Let us investigate the effect of self-couplings $\lambda_{1,12}$ on the signal strength $\mu_{Z\gamma}$ in the simplest 3-3-1 model. We will investigate $\mu_{Z\gamma}$ case $\lambda_1 = 1, \lambda_{12} = -1$ and $\lambda_1 = 1, \lambda_{12} = -0.5$.

Numerical illustrations for $\mu_{Z\gamma}^{331}$ in the simplest 3-3-1 model are shown in Fig. 2. The numerical survey results show that

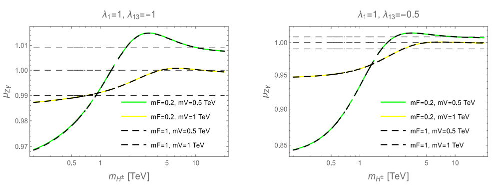

Fig. 2: The signal strength $\mu_{Z\gamma}^{331}$ in the simplest in case $\lambda_1 = 1,\, \lambda_{12} = -1 and \lambda_1 = 1, \lambda_{12} = -0.5$

there are two important features of $\mu_{Z\gamma}$. Firstly, $\mu_{Z\gamma}$ always returns the value of the SM when $|\lambda_{12}|$ is large enough. And secondly, $\mu_{Z\gamma}$ depends very strongly on λ_1. Namely, with large value of λ_1 will allow $\mu_{Z\gamma} < 1$ and big difference compared to that of the SM's value.

III. Conclusions

In the simplest 3-3-1 model, the signal strength of the decay $H_1 \to Z\gamma$ was investigated in the range from 100 GeV to $\mathcal{O}(10)$ TeV of the charged Higgs mass $m_{H^\pm}$. The $Br(H_1 \to Z\gamma)$ is the same as the SM prediction at large $m_{H^\pm}$. On the other hand, small $m_{H^\pm}$ predicts $\mu_{Z\gamma} < 1$, implying that the signal of this decay channel is difficult to observe in future experiments, where the recent upper bound is $\mu_{Z\gamma} < 6$. But these results have not been surveyed in all regions of the parameter space of model.

Tài liệu

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QUÁ TRÌNH PHÂN RÃ CỦA HẠT HIGGS BOSON TỰA MÔ HÌNH CHUẨN $H_1 \to Z\gamma$ TRONG MÔ HÌNH 3-3-1 TỐI GIẢN

Tóm tắt - Sự phân rã của Higgs boson $H_1 \to Z\gamma$ được nghiên cứu trong mô hình 3-3-1 tối giản. Công thức giải tích cho đóng góp bậc 1 vòng được xây dựng dựa trên các kết quả tổng quát đã được giới thiệu. Chúng tôi sẽ chỉ ra rằng các hạt mới được dự đoán bởi mô hình 3-3-1 tối giản có thể có những ảnh hưởng đáng kể đến sự phân rã này của Higgs boson tựa mô hình chuẩn. Từ kết quả giải số, một số kết quả cụ thể và đặc điểm của kênh rã này cũng sẽ được trình bày. Chúng có thể cần thiết để so sánh với các kết quả của thực nghiệm sẽ được phát hiện trong tương lai.