Explaining 750 GeV diphoton excess from top/bottom partner cascade decay in two-Higgs-doublet model extension

Xiao-Fang Han[1], Lei Wang[2,1], Lei Wu[3], Jin Min Yang[4,5], Mengchao Zhang[4]

[1] *Department of Physics, Yantai University, Yantai 264005, P. R. China*

[2] *IFIC, Universitat de València-CSIC,*
Apt. Correus 22085, E-46071 València, Spain

[3] *ARC Centre of Excellence for Particle Physics at the Terascale,*
School of Physics, The University of Sydney, NSW 2006, Australia

[4] *Institute of Theoretical Physics, Academia Sinica, Beijing 100190, China*

[5] *Department of Physics, Tohoku University, Sendai 980-8578, Japan*

Abstract

In this paper, we interpret the 750 GeV diphoton excess in the Zee-Babu extension of the two-Higgs-doublet model by introducing a top partner (T)/bottom partner (B). In the alignment limit, the 750 GeV resonance is identified as the heavy CP-even Higgs boson (H), which can be sizably produced via the QCD process $pp \to T\bar{T}$ or $pp \to B\bar{B}$ followed by the decay $T \to Ht$ or $B \to Hb$. The diphoton decay rate of H is greatly enhanced by the charged singlet scalars predicted in the Zee-Babu extension and the total width of H can be as large as 7 GeV. Under the current LHC constraints, we scan the parameter space and find that such an extension can account for the observed diphoton excess.

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I. INTRODUCTION

Very recently, both the ATLAS data with 3.2 fb^{-1} and the CMS data with 2.6 fb^{-1} [1] have reported an excess of the diphoton resonance (X) around 750 GeV. The local significances of their results are 3.6σ and 2.6σ in the respective experiments. Combining the 8 and 13 TeV data [2], the observed signal strength $\sigma_X \times Br(X \to \gamma\gamma)$ is 10.6 ± 2.9 fb for the ATLAS and 4.47 ± 1.86 fb for the CMS. Since there are no excesses observed in the dijet [3], $t\bar{t}$ [4], diboson or dilepton channels, understanding such an excess becomes a challenging task. So far, many new physics models have been proposed for this excess [2, 5–12], among which, a singlet scalar is usually introduced as the 750 GeV resonance.

Different from the previous singlet scalar explanations, we attempt to interpret the 750 GeV resonance as a heavy doublet Higgs boson, which is mainly from the QCD top partner (T) or bottom partner (B) pair production process followed by the decay $T \to Ht$ or $B \to Hb$. Obviously, such a scenario still needs the extra particles to enhance the 750 GeV Higgs decay into diphoton. Therefore, we introduce a top partner/bottom partner to the Zee-Babu extension [13] of the two-Higgs-doublet model (ZB-2HDM), where two extra charged singlet scalars can enhance the decay of diphoton mode and generate the neutrino mass. Considering the LHC Higgs data, our study will be focused on an interesting limit of this model, in which one of the neutral Higgs mass eigenstates is almost aligned with the direction of the scalar field vacuum expectation values. In this limit, the 125 GeV Higgs boson tends to have the gauge couplings as in the Standard Model (SM) and is easily consistent with the current Higgs data, while the heavy CP-even Higgs boson has very small couplings or no couplings to the SM particles .

Compared to the direct $gg \to H$ production, there are several benefits for the production of H from the QCD process $pp \to T\bar{T}/B\bar{B} \to HH + t\bar{t}/b\bar{b}$. Since the production of T/B and the decay of H are generally unrelated, it is easy to obtain a large branching ratio of $H \to \gamma\gamma$ by suppressing the 750 GeV Higgs coupling to the top quark. Moreover, if T/B is heavy enough, this can explain the tension between 8 TeV and 13 TeV data (the 8 TeV LHC did not give a clear excess). Although the cascade decays have other objects in the diphoton events, the status of whether or not there are other objects in the event is unclear at the moment. So, currently, the cascade decay is still a feasible way to interpret the 750 GeV diphoton.

Our work is organized as follows. In Sec. II we present the Zee-Babu extension of the 2HDM with the top/bottom partner. In Sec. III we perform the numerical calculations and discuss the 750 GeV diphoton production rate and the total width of the resonance in the allowed parameter space. Finally, we give our conclusion in Sec. IV.

II. MODEL

A. Two-Higgs-doublet model

The general Higgs potential is written as [14]

$$\begin{aligned}
V &= m_{11}^2(\Phi_1^\dagger\Phi_1) + m_{22}^2(\Phi_2^\dagger\Phi_2) - \left[m_{12}^2(\Phi_1^\dagger\Phi_2 + \text{h.c.})\right] \\
&+\lambda_1(\Phi_1^\dagger\Phi_1)^2 + \lambda_2(\Phi_2^\dagger\Phi_2)^2 + \lambda_3(\Phi_1^\dagger\Phi_1)(\Phi_2^\dagger\Phi_2) + \lambda_4(\Phi_1^\dagger\Phi_2)(\Phi_2^\dagger\Phi_1) \\
&+ \left[\lambda_5(\Phi_1^\dagger\Phi_2)^2 + \text{h.c.}\right] + \left[\lambda_6(\Phi_1^\dagger\Phi_1)(\Phi_1^\dagger\Phi_2) + \text{h.c.}\right] \\
&+ \left[\lambda_7(\Phi_2^\dagger\Phi_2)(\Phi_1^\dagger\Phi_2) + \text{h.c.}\right]. \qquad (1)
\end{aligned}$$

Here we focus on the CP-conserving case where all λ_i and m_{12}^2 are real. In the Higgs basis, the two complex scalar doublets with the hypercharge $Y = 1$ can be written as

$$\Phi_1 = \begin{pmatrix} G^+ \\ \frac{1}{\sqrt{2}}(v + \rho_1 + iG_0) \end{pmatrix}, \quad \Phi_2 = \begin{pmatrix} H^+ \\ \frac{1}{\sqrt{2}}(\rho_2 + iA) \end{pmatrix}. \qquad (2)$$

The Φ_1 field has the vacuum expectation value (VEV) v =246 GeV, and the VEV of Φ_2 field is zero. The G^0 and G^+ are the Nambu-Goldstone bosons which are eaten by the gauge bosons. The H^+ and A are the mass eigenstates of the charged Higgs boson and CP-odd Higgs boson, and their masses are given by

$$m_A^2 = m_{H^\pm}^2 + v^2(\frac{1}{2}\lambda_4 - \lambda_5). \qquad (3)$$

The physical CP-even Higgs bosons h and H are the linear combination of ρ_1 and ρ_2:

$$\begin{pmatrix} \rho_1 \\ \rho_2 \end{pmatrix} = \begin{pmatrix} \sin\theta & \cos\theta \\ \cos\theta & -\sin\theta \end{pmatrix} \begin{pmatrix} h \\ H \end{pmatrix} \qquad (4)$$

To satisfy the 125 GeV Higgs data, we focus on the so-called *alignment limit* [15], which corresponds to $\lambda_6 = 0$ and $\cos\theta = 0$. In this limit, the two CP-even Higgs masses are given as

$$m_h^2 = 2\lambda_1 v^2, \qquad m_H^2 = m_{H^\pm}^2 + v^2(\frac{1}{2}\lambda_4 + \lambda_5). \qquad (5)$$

The general Yukawa interactions without the tree-level FCNC can be given by [16]

$$
\begin{aligned}
-\mathcal{L} \;=&\; y_u\,\overline{Q}_L\,(\tilde{\Phi}_1 + \kappa_u \tilde{\Phi}_2)\,u_R + \,y_d\,\overline{Q}_L\,(\Phi_1 \,+\, \kappa_d\,\Phi_2)\,d_R \\
&+ y_l\,\overline{L}_L\,(\Phi_1 \,+\, \kappa_\ell\,\Phi_2)\,e_R \,+\, \text{h.c.}\,,
\end{aligned} \tag{6}
$$

where $Q_L^T = (u_L\,, d_L)$, $L_L^T = (\nu_L\,, l_L)$, and $\widetilde{\Phi}_{1,2} = i\tau_2\Phi^*_{1,2}$. y_u, y_d and y_ℓ are 3×3 matrices in family space, and κ_u, κ_d and κ_ℓ are the coupling constants. The couplings of neutral Higgs bosons normalized to the SM Higgs boson are give by

$$
\begin{aligned}
&y_V^h = \sin\theta, \quad y_f^h = \sin\theta + \cos\theta\kappa_f, \\
&y_V^H = \cos\theta, \quad y_f^H = \cos\theta - \sin\theta\kappa_f, \\
&y_V^A = 0, \qquad y_u^A = -i\gamma^5\kappa_u, \qquad y_{d,\ell}^A = i\gamma^5\kappa_{d,\ell},
\end{aligned} \tag{7}
$$

where V denotes Z and W, and f denotes u, d and ℓ.

B. Zee-Babu Extension

In order to enhance the branching ratio of the 750 GeV Higgs boson decay to diphoton, we can suppress the total width by taking a small heavy CP-even Higgs coupling to the top quark. However, the charged Higgs of 2HDM ($H^\pm$) can not enhance the branching ratio of diphoton for this case. A light $H^\pm$ can enhance the width of $H\to\gamma\gamma$, but the decay $H\to H^\pm W^\mp$ will be open and enhance the total width more sizably. Therefore, some additional particles are needed to enhance the 750 GeV Higgs decay into diphoton, such as vector-like fermions or the charged scalars. Since the amplitude of $H\to\gamma\gamma$ is proportional to the square of electric charge of the particle in the loop, the multi-charged particle can enhance $H\to\gamma\gamma$ sizably.

Here we take the approach of Zee-Babu model to introduce two the $SU(2)_L$ singlet scalar field π^+ and χ^{++} with hypercharge 1 and 2 [13], respectively. Besides enhancing the decay rate of $H\to\gamma\gamma$ sizably, this model can naturally give rise to the small neutrino Majorana mass.

The potential of the two singlet scalars can be written as

$$
\begin{aligned}
V \;=&\; m_\pi^2\pi^+\pi^- + m_\chi^2\chi^{++}\chi^{--} + k_1\Phi_1^\dagger\Phi_1\pi^+\pi^- + k_1'\Phi_1^\dagger\Phi_1\chi^{++}\chi^{--} \\
&+k_2\Phi_2^\dagger\Phi_2\pi^+\pi^- + k_2'\Phi_2^\dagger\Phi_2\chi^{++}\chi^{--} + k_3(\Phi_1^\dagger\Phi_2 + \Phi_2^\dagger\Phi_1)\pi^+\pi^- \\
&+k_4(\Phi_1^\dagger\Phi_2 + \Phi_2^\dagger\Phi_1)\chi^{++}\chi^{--} + k_5(\pi^+\pi^-)^2 + k_6(\chi^{++}\chi^{--})^2 + (\mu\pi^-\pi^-\chi^{++} + h.c.).
\end{aligned} \tag{8}
$$

The gauge invariance precludes the singlet Higgs fields from coupling to the quarks. The Yukawa coupling of singlets to leptons are

$$\mathcal{L} = f_{ab}\bar{L^C_{La}}L_{Lb}\pi^+ + g_{ab}\bar{E^C_{Ra}}E_{Rb}\chi^{++} + h.c.. \tag{9}$$

The trilinear μ term in Eq. (8) breaks the lepton number and gives rise to the neutrino Majorana mass contributions at the two-loop level. The detailed introductions on the neutrino mass can be found in [13]. Here we focus on the charged Higgs couplings to the heavy CP-even Higgs. Since the k_1 and k_1' terms of Eq. (8) that contain the 125 GeV Higgs couplings to charged Higgs are proportional to $\sin\theta$, we assume k_1 and k_1' to be very small and ignore them in our calculations. Then, after the Φ_1 acquires the VEV, the masses of π^+ and χ^{++} are m_π and m_χ, and the CP-even Higgs couplings to the charged Higgses are determined by k_3 and k_4 terms,

$$\begin{aligned} &h\pi^+\pi^- : -k_3\cos\theta v, \qquad h\chi^{++}\chi^{--} : -k_4\cos\theta v,\\ &H\pi^+\pi^- : k_3\sin\theta v, \qquad H\chi^{++}\chi^{--} : k_4\sin\theta v. \end{aligned} \tag{10}$$

Considering the constraints of perturbativity and stability of the potential, we simply take $0 \lesssim k_3 = k_4 \lesssim 4\pi$, and fix $m_\pi = m_\chi = 375$ GeV, which will give the maximal value of the form factor of scalar loop in the $H \to \gamma\gamma$.

C. Top/Bottom Partners

Next, we introduce the top partner to interact with Φ_2 in the 2HDM. The Yukawa interaction is given as

$$-\mathcal{L} = y_T\,\bar{Q}_{tL}\,\widetilde{\Phi}_2 T_R + m_T\bar{T}_L T_R + m_T'\bar{T}_L t_R + h.c. \tag{11}$$

where $Q_{tL}^T = (t_L\ b_L)^T$ and t_R are the left-handed $SU(2)$ doublet of third generation and the right-handed $SU(2)$ singlet of top quark, respectively, while T_R and T_L are two $SU(2)$ singlet top partners.

We obtain the mass matrix of top quark and the partner $(t,\ T)$,

$$\begin{pmatrix} \bar{t}_L & \bar{T}_L \end{pmatrix} \quad \begin{pmatrix} m_t & 0 \\ m_T' & m_T \end{pmatrix} \begin{pmatrix} t_R \\ T_R \end{pmatrix}. \tag{12}$$

In this paper, we assume m'_T to be very small so that there is no mixing between t and T. Due to the absence of the couplings of TtZ and $T\bar{b}W^+$, the current LHC constraints from the searches for the exotic quarks can be safely avoided.

From Eq. (11), we can obtain the top partner couplings to the Higgs bosons,

$$\begin{aligned}
&H\bar{t}_L T_R = H\bar{T}_R t_L : \ \frac{y_T}{\sqrt{2}}\sin\theta \\
&h\bar{t}_L T_R = h\bar{T}_R t_L : \ -\frac{y_T}{\sqrt{2}}\cos\theta \\
&A\bar{t}_L T_R = -A\bar{T}_R t_L : \ i\frac{y_T}{\sqrt{2}} \\
&H^-\bar{b}_L T_R = H^+\bar{T}_R t_L : y_T
\end{aligned} \tag{13}$$

If the Φ_1 has the interactions with Q_{TL} and T_R, the mixing of t and T will appear. Here we do not consider this case.

Similarly, we can introduce the bottom partner and the Yukawa interaction is given as

$$-\mathcal{L} = y_B\,\bar{Q}_{tL}\,\Phi_2 B_R + m_B\bar{B}_L B_R + m'_B\bar{B}_L b_R + h.c., \tag{14}$$

where B_R and B_L are two $SU(2)$ singlet bottom partners. When m'_B approaches to zero, there is no mixing between b and B, and the couplings $B\bar{b}Z$ and $B\bar{t}W^-$ are absent. From Eq. (14), we can obtain the bottom partner couplings to Higgses,

$$\begin{aligned}
&H\bar{b}_L B_R = H\bar{B}_R b_L : \ \frac{y_B}{\sqrt{2}}\sin\theta \\
&h\bar{b}_L B_R = h\bar{B}_R b_L : \ -\frac{y_B}{\sqrt{2}}\cos\theta \\
&A\bar{b}_L B_R = -A\bar{B}_R b_L : \ -i\frac{y_B}{\sqrt{2}} \\
&H^+\bar{t}_L B_R = H^-\bar{B}_R t_L : -y_B
\end{aligned} \tag{15}$$

III. NUMERICAL CALCULATIONS AND DISCUSSIONS

Since we focus on the 750 GeV diphoton data, we fix m_h = 125 GeV, m_H = 750 GeV, $\sin\theta = 1$, $k_d = k_\ell$=0. The last three choices can naturally satisfy the bounds from the measurements of the diboson, dijet and dilepton. The 125 GeV Higgs couplings to the new charged Higgs, T and B quark equals to zero for $\sin\theta = 1$.

A. T and B decay

As discussed above, the partners T and B have no couplings to the gauge bosons and 125 GeV Higgs in the parameter space taken in this paper. Therefore, T and B can be hardly constrained by the current experimental data of the exotic quark from the ATLAS [17] and CMS [18] searches. The main decay modes are $T \to tH$, $T \to tA$ and $T \to bH^+$ for the T quark, as well as $B \to bH$, $B \to bA$ and $B \to tH^-$ for the B quark. For $m_H = 750$ GeV, the oblique parameters favor $m_{H^\pm}$ and m_A to have the degenerate mass, especially for that their mass have sizable deviation from 750 GeV.

We take $m_B = 770$ GeV and $m_T = 940$ GeV, and plot their branching ratios versus m_A in Fig. 1. Since the widths of $T \to tH$, $T \to tA$ and $T \to bH^+$ are proportional to y_T^2, their branching ratios are independent on y_T, which also holds for the B quark and y_B. Both $Br(B \to bH)$ and $Br(T \to tH)$ are very small for m_A and $m_{H^\pm}$ are much smaller than m_H, and increase with m_A and $m_{H^\pm}$. For $m_B = 770$ GeV and $m_H = m_A = m_{H^\pm} = 750$ GeV, $B \to tH^-$ is kinematically forbidden, and $Br(B \to bH)$ and $Br(B \to bA)$ have the same value and equal to 50% nearly. For $m_T = 940$ GeV and $m_H = m_A = m_{H^\pm} = 750$ GeV, $T \to bH^+$ dominates over $T \to tH$ and $T \to tA$ since the former has an enhanced factor of 2 from the coupling, and $T \to tH$ and $T \to tA$ are suppressed by a large phase space. Only for $m_{H^\pm}$ and m_A are very closed to m_T and m_B, $T \to tH$ and $B \to bH$ are the dominant decay modes.

B. The production rate of 750 GeV diphoton resonance

In order to obtain the maximal production rate, we assume $m_A = m_{H^\pm}$ to be larger than m_B and m_T, which leads $Br(B \to bH)$=$Br(T \to tH)$=1. Also $H \to AZ$, $H \to H^\pm W^\mp$, $H \to AA$ and $H \to H^+H^-$ are kinematically forbidden for this case. The widths of $H \to WW$, ZZ, hh, $b\bar{b}$, $\tau\bar{\tau}$ are zero for $\cos\theta = 0$ and $\kappa_d = \kappa_\ell = 0$. Therefore, $H \to t\bar{t}$ is the dominant decay mode for a large k_u. Also the decays $H \to gg$, $H \to \gamma\gamma$, $H \to Z\gamma$ and $H \to ZZ$ are considered, and the last three modes can be sizably enhanced by the new charged scalars at the one-loop. Since the π^+ and χ^{++} are $SU(2)_L$ singlets, for the charged scalars give the dominant contributions to $H \to \gamma\gamma$, there is an approximate relation,

$$\Gamma(H \to \gamma\gamma) : \Gamma(H \to Z\gamma) : \Gamma(H \to ZZ) = 1 : 0.6 : 0.09. \tag{16}$$

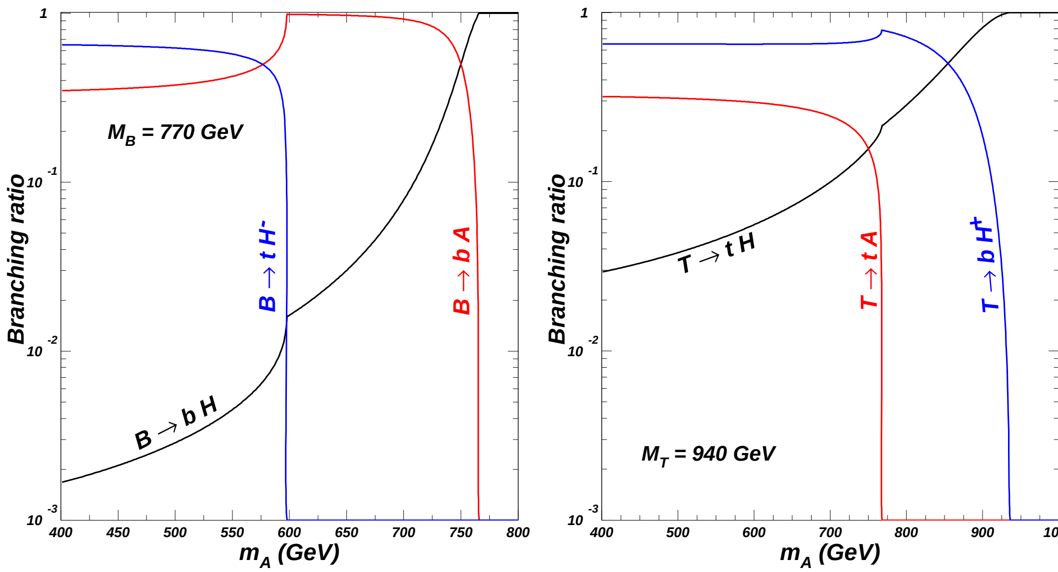

FIG. 1: The branching ratios of T and B versus m_A with $m_{H^\pm} = m_A$ and $m_H = 750$ GeV.

We define the production rate of the 750 GeV diphoton,

$$\begin{aligned} R_{\gamma\gamma} &\equiv \sigma(gg \to B\bar{B}\ (T\bar{T})) \times Br(B\bar{B}\ (T\bar{T}) \to HHb\bar{b}\ (t\bar{t})) \times Br(HH \to \gamma\gamma + X) \\ &\quad + \sigma(gg \to H) \times Br(H \to \gamma\gamma) \\ &= \sigma(gg \to B\bar{B}\ (T\bar{T})) \times Br(HH \to \gamma\gamma + X) + \sigma(gg \to H) \times Br(H \to \gamma\gamma). \quad (17) \end{aligned}$$

At the LHC, the cross sections of $gg \to B\bar{B}$ ($T\bar{T}$) with $m_B = 770$ GeV ($m_T = 940$ GeV) are approximate 240 (65) fb for $\sqrt{s}$=13 TeV and 28 (5.5) fb for $\sqrt{s}$=8 TeV [19].

In our calculations, we consider the relevant collider bounds from LHC searches at $\sqrt{s}$=8 TeV [20–23]:

$$\begin{aligned} &\sigma_{t\bar{t}} < 550 \text{ fb}, \qquad \sigma_{\gamma\gamma} < 2 \text{ fb}, \\ &\sigma_{Z\gamma} < 4 \text{ fb}, \qquad \sigma_{ZZ} < 12 \text{ fb}. \quad (18) \end{aligned}$$

Taking $k_4 = 4\pi$, $m_\pi = m_\chi = 375$ GeV, $m_T = 940$ GeV and $m_B = 770$ GeV, we project the surviving samples on the plane of $R_{\gamma\gamma}$ versus κ_u in Fig. 2. Since the heavy CP-even Higgs coupling to top quark is proportional to κ_u, the production rate from $gg \to H$ increases with κ_u. Since the cross section of $gg \to B\bar{B}$ ($T\bar{T}$) is independent on κ_u, and the total width of 750 GeV Higgs increases with κ_u, the production rate from $gg \to B\bar{B}$ ($T\bar{T}$) decreases with increasing of κ_u. The production rate from latter dominates over the former for the small κ_u, and equals to the former for $\kappa_u = 0.8$ (0.42). $R_{\gamma\gamma} > 1$ fb favors κ_u to be smaller than

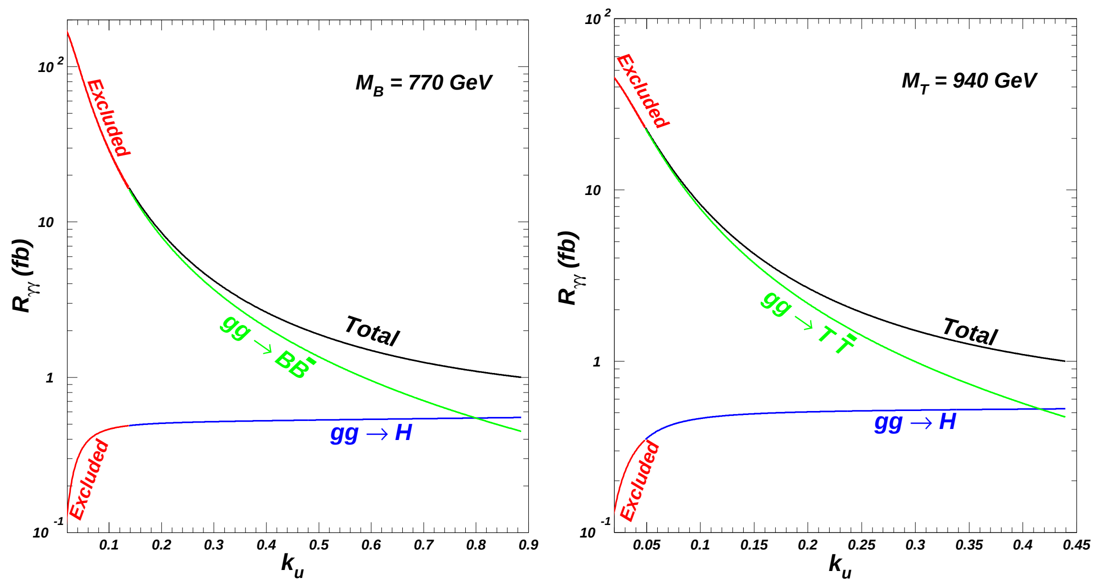

FIG. 2: The production rate of 750 GeV diphoton versus k_u for $m_B = 770$ GeV and $m_T = 940$ GeV. The heavy CP-even Higgs coupling to the new charged Higgs k_4 is fixed as 4π, and $m_\pi = m_\chi$ =375 GeV.

0.9 for $m_B = 770$ GeV and 0.45 for $m_T = 940$ GeV. Compared to the bottom partner, the top partner mass is required to be larger than 930 GeV to open the decay $T \to tH$. The cross section of $gg \to T\bar{T}$ with $m_T = 940$ GeV is 65 fb at the LHC with $\sqrt{s} = 13$ TeV, which is much smaller than that of $gg \to B\bar{B}$ with $m_B = 770$ GeV, 240 fb. Therefore, the constraints on $m_T = 940$ GeV are more strong than those on $m_B = 770$ GeV.

For a very small top Yukawa coupling, the total width of 750 GeV Higgs is very narrow, which leads a large $Br(H \to \gamma\gamma)$. Therefore, the very small κ_u is mainly excluded by the experimental data of the diphoton rate at the $\sqrt{s} = 8$ TeV, and the lower bound of κ_u is 0.14 for m_B= 770 GeV and 0.05 for $m_T = 940$ GeV.

In Fig. 3, we project the surviving samples on the planes of κ_4 versus κ_u, Γ_H versus κ_4 and Γ_H versus κ_u. The large $R_{\gamma\gamma}$ favors a small κ_u and a large k_4, and the former can suppress the total width of the 750 GeV Higgs, and the latter can enhance the decay $H \to \gamma\gamma$ via the charged Higgs couplings to the 750 GeV Higgs. $R_{\gamma\gamma} > 2$ fb favors $\kappa_u < 0.46$ and $k_4 > 0.05$ for $m_B = 770$ GeV, and $\kappa_u < 0.24$ and $k_4 > 1.0$ for $m_T = 940$ GeV. For $m_B = 770$ GeV, the total width can reach 7 GeV for $R_{\gamma\gamma} = 2$ fb, and be larger than 2 GeV for $R_{\gamma\gamma} < 6$ fb. For $m_T = 940$ GeV, the total width can reach 2 GeV for $R_{\gamma\gamma} = 2$ fb, and be larger than 0.8 GeV for $R_{\gamma\gamma} < 4$ fb.

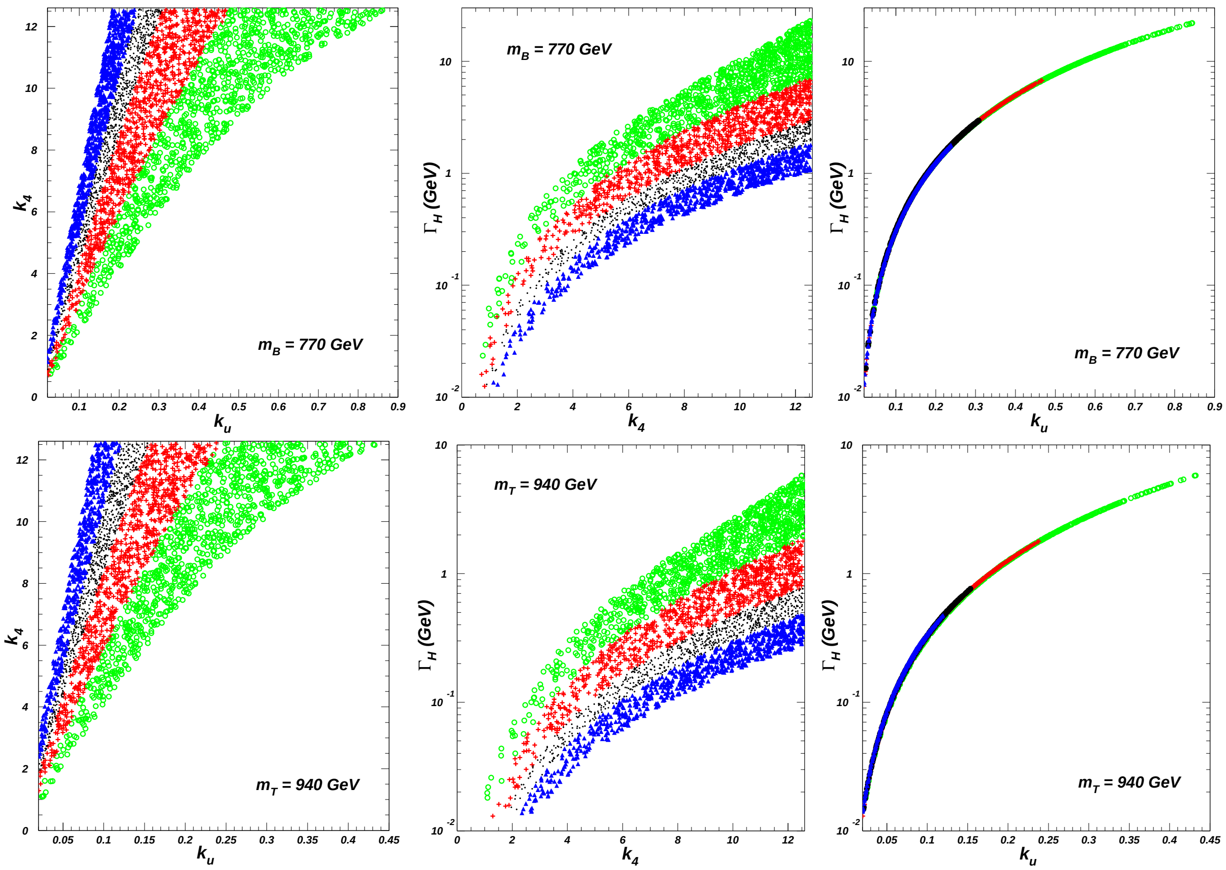

FIG. 3: The surviving samples projected on the planes of κ_4 versus κ_u, Γ_H versus κ_4 and Γ_H versus κ_u for $m_B = 770$ GeV and $m_T = 940$ GeV, with 1 fb $< R_{\gamma\gamma} <$ 2 fb for the circles (green), 2 fb $< R_{\gamma\gamma} <$ 4 fb for the pluses (red), 4 fb $< R_{\gamma\gamma} <$ 6 fb for the bullets (black) and 6 fb $< R_{\gamma\gamma} <$ 10 fb for the triangles (blue).

With the increasing of the mass of bottom partner and top partner, the cross section of $gg \to B\bar{B}$ ($T\bar{T}$) will decrease rapidly and be around 2 fb for $m_B = m_T = 1500$ GeV. For the enough small top quark Yakawa coupling to the 750 GeV Higgs, the 750 GeV Higgs will mainly decay into $\gamma\gamma$, $Z\gamma$ and ZZ, and $Br(H \to \gamma\gamma)$ is around 60%. Therefore, the production rate of the 750 GeV diphoton will reach 1.2 fb for $m_B = m_T = 1500$ GeV. For m_B and m_T are smaller than 1500 GeV, the more large production rate can be obtained. However, the total width of the 750 GeV Higgs is required to be very narrow to enhance the production rate. Therefore, the precise measurement of width at the LHC can be as a sensitive probe of the bottom partner and top partner.

IV. CONCLUSION

To accommodate the 750 GeV diphoton excess, we proposed an extension of 2HDM with the top and bottom partners. In addition, we took the approach of Zee-Babu model which introduces two scalar singlets (one is singly charged, the other is doubly charged) to naturally give a small neutrino Majorana mass. In this model, the production rate $R_{\gamma\gamma}$ of the 750 GeV diphoton is from both $gg \to B\bar{B}$ $(T\bar{T})$ and $gg \to H$, and the former dominates over the latter for a small top quark coupling with the 750 GeV Higgs, and is comparable to the latter for a large top Yukawa coupling.

For $m_B = 770$ GeV, $R_{\gamma\gamma} > 2$ fb favors $\kappa_u < 0.46$ and $k_4 > 0.05$, and the total width of the 750 GeV Higgs can reach 7 GeV for $R_{\gamma\gamma} = 2$ fb. For $m_T = 940$ GeV, $R_{\gamma\gamma} > 2$ fb favors $\kappa_u < 0.24$ and $k_4 > 1.0$, and the total width can reach 2 GeV for $R_{\gamma\gamma} = 2$ fb. To obtain enough large production rate of the 750 GeV diphoton, the total width tends to decrease with the increase of bottom partner and top partner masses. Therefore, the precise measurement of the width of the resonance at the LHC can be as a sensitive probe of these bottom partner and top partner.

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