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Gauged Two Higgs Doublet Model confronts the LHC 750 GeV diphoton anomaly

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Abstract

In light of the recent 750 GeV diphoton anomaly observed at the LHC, we study the possibility of accommodating the deviation from the standard model prediction based on the recently proposed Gauged Two Higgs Doublet Model. The model embeds two Higgs doublets into a doublet of a non-abelian gauge group $SU(2)_H$, while the standard model $SU(2)_L$ right-handed fermion singlets are paired up with new heavy fermions to form $SU(2)_H$ doublets, and $SU(2)_L$ left-handed fermion doublets are singlets under $SU(2)_H$. An $SU(2)_H$ scalar doublet, which provides masses to the new heavy fermions as well as the $SU(2)_H$ gauge bosons, can be produced via gluon fusion and subsequently decays into two photons with the new fermions circulating the triangle loops to account for the deviation from the standard model prediction.

1. Introduction

Recent results from LHC [1–3] exhibit an intriguing anomaly on the diphoton channel at the scale around 750 GeV. Numerous attempts [4–81] have been put forward to explain the excess, while Refs. [14,43,57] are based on two Higgs doublet models, similar to this work.

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In Ref. [78], a combined result from run I and II gives a cross section $\sigma(pp \to X \to \gamma\gamma) \sim \mathcal{O}(6)$ fb for a scalar particle X with mass around 750 GeV. In this paper, we will show that the newly proposed Gauged Two Higgs Doublet Model [82] (G2HDM) is able to provide a cross section with such magnitude.

G2HDM contains additional $SU(2)_H \times U(1)_X$ gauge symmetry, in which H_1 (identified as the Standard Model (SM) Higgs doublet) and H_2 comprise an $SU(2)_H$ doublet such that the two-doublet potential is as simple as the SM Higgs potential with just a quadratic mass term plus a quartic term. The cost to pay is to include additional scalars: one $SU(2)_H$ triplet Δ_H and one $SU(2)_H$ doublet Φ_H (that are all singlets under the SM gauge groups) with their vacuum expectation values (vevs) supplying masses to the $SU(2)_H \times U(1)_X$ gauge bosons. Moreover, the vev of the triplet induces the SM Higgs vev, breaking $SU(2)_L \times U(1)_Y$ down to $U(1)_Q$, while H_2 does not obtain any vev and the neutral component of H_2 could be a dark matter (DM) candidate, whose stability is protected by the $SU(2)_H$ gauge symmetry and Lorentz invariance, without resorting to an ad-hoc Z_2 symmetry. In order to write down $SU(2)_H \times U(1)_X$ invariant Yukawa couplings, we introduce heavy $SU(2)_L$ singlet Dirac fermions, the right-handed component of which is paired up with the SM right-handed fermions to comprise $SU(2)_H$ doublets. In this setup, the model is anomaly-free regarding all gauge groups involved.

In this work, we focus on the role of ϕ_2 which is a physical component in Φ_H and whose vev $\langle\phi_2\rangle = v_\Phi$ gives masses to the new heavy fermions. Since it couples to new colored fermions, it can be produced radiatively via gluon fusion and also decay radiatively into a pair of photons with the heavy charged fermions in loops. We will demonstrate that ϕ_2 can be a good candidate if LHC eventually could confirm the diphoton anomaly. Moreover, the observed width of the bump can be simply obtained from ϕ_2 decay into the additional fermions with $\mathcal{O}(1)$ Yukawa couplings.

The paper is organized as follows. First, we briefly discuss the G2HDM in Section 2 restraining ourselves only to those aspects most relevant to $\gamma\gamma$ mode. Next, in Section 3 we compute the diphoton cross section through ϕ_2 exchange and the partial decay width of ϕ_2 into the new heavy fermions. In Section 4, we briefly comment on implications of such the new heavy fermions in terms of collider searches, electron and muon magnetic dipole moment measurements, and the electroweak precision test data. Finally, we conclude in Section 5.

2. G2HDM setup

In this Section, we review the G2HDM (cf. Ref. [82]) with the particle content summarized in Table 1.

For the scalar sector, we have two Higgs doublets, H_1 and H_2, where H_1 is identified as the SM Higgs doublet and H_2 (with the same hypercharge $Y = 1/2$ as H_1) is the extra $SU(2)_L$ doublet. H_1 and H_2 transform as a doublet $H = (H_1\ H_2)^T$ under the additional gauge group $SU(2)_H \times U(1)_X$ with $U(1)_X$ charge $X(H) = 1$. Besides the doublet H, we also introduce $SU(2)_H$ triplet and doublet, Δ_H and Φ_H, which are *singlets* under $SU(2)_L$. The Higgs potential invariant under both $SU(2)_L \times U(1)_Y$ and $SU(2)_H \times U(1)_X$ can be written down easily as

$$V(H, \Delta_H, \Phi_H) = V(H) + V(\Phi_H) + V(\Delta_H) + V_{\rm mix}(H, \Delta_H, \Phi_H) \ , \tag{1}$$

with

$$\begin{aligned} V(H) &= \mu_H^2 H^\dagger H + \lambda_H \left(H^\dagger H\right)^2 , \\ &= \mu_H^2 \left(H_1^\dagger H_1 + H_2^\dagger H_2\right) + \lambda_H \left(H_1^\dagger H_1 + H_2^\dagger H_2\right)^2 , \end{aligned} \tag{2}$$