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750 GeV diphoton excess from E_6 in F-theory GUTs

Athanasios Karozas [b], Stephen F. King [a], George K. Leontaris [b,*], Andrew K. Meadowcroft [a]

[a] *Physics and Astronomy, University of Southampton, SO17 1BJ Southampton, United Kingdom*
[b] *Physics Department, Theory Division, Ioannina University, GR-45110 Ioannina, Greece*

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ABSTRACT

We interpret the 750–760 GeV diphoton resonance as one or more of the spinless components of a singlet superfield arising from the three 27-dimensional representations of E_6 in F-theory, which also contain three copies of colour-triplet charge $\mp 1/3$ vector-like fermions $D_i, \bar{D}_i$ and inert Higgs doublets to which the singlets may couple. For definiteness we consider (without change) a model that was proposed some time ago which contains such states, as well as bulk exotics, leading to gauge coupling unification. The smoking gun prediction of the model is the existence of other similar spinless resonances, possibly close in mass to 750–760 GeV, decaying into diphotons, as well as the three families of vector-like fermions $D_i, \bar{D}_i$.

1. Introduction

Recently ATLAS and CMS experiments have reported an excess of 14 and 10 diphoton events at an invariant mass around 750 GeV and 760 GeV from gathering data at LHC Run-II with pp collisions at the center of mass energy of 13 TeV [1,2]. The local significance of the ATLAS events is 3.9 σ while that of the CMS events is 2.6 σ, corresponding to cross sections $\sigma(pp \to \gamma\gamma) = 10.6$ fb and $\sigma(pp \to \gamma\gamma) = 6.3$ fb. ATLAS favours a width of $\Gamma \sim 45$ GeV, while CMS, while not excluding such a broad resonance, prefers a narrow width. The Landau–Yang theorem implies spin 0 or 2 are the only possibilities for a resonance decaying into two photons. The only modest diphoton excesses observed by ATLAS and CMS at this mass scale may be (at least partially) understood by the factor of 5 gain in cross-section due to gluon production. However there is no evidence for any coupling of the resonance into anything except gluons and photons (no final states such as $t\bar{t}$, $b\bar{b}$, $l\bar{l}$, ZZ, WW, etc., with missing E_T or jets have been observed).

If these facts are confirmed by future data, it will be the first indication for new physics at the TeV scale and possibly a harbinger of more exciting discoveries in the future. These findings also pose a challenging task for theoretical extensions of the Standard Model (SM) spectrum. Several interpretations have been suggested based on extensions of the Standard Model spectrum [3–117]. Many of these papers suggest a spinless singlet coupled to vector-like fermions [3,9,10,12,14,21,22,34,37,55,61,63,83,84,98,104,107,109]. Indeed, the observed resonance could be interpreted as a Standard Model scalar or pseudoscalar singlet state X with mass $m_X \sim 750$–760 GeV. The process of generating the two photons can take place by the gluon–gluon fusion mechanism according to the process

$$gg \to X \to \gamma\gamma$$

hence it requires production and decay of the particle X. In a renormalisable theory this interaction can be realised assuming vector-like multiplets $f + \bar{f}$ at the TeV scale, where f carry electric charge and colour. Such vector like pairs have not been observed at LHC, hence the mass of the fermion pair M_f is expected roughly to be at or above the TeV scale, $M_f \gtrsim 1$ TeV.

If this theoretical interpretation is adopted, effective field theory models derived in the context of String Theory are excellent candidates to accommodate the required states. Indeed, singlet scalar fields are the most common characteristic of String Theory effective models. These can be either scalar components of supermultiplets or of pseudoscalar nature such as axion fields having direct couplings to gluons and photons and therefore relevant to the observed process. However another aspect of string theory interests us here, namely that in the low energy spectrum of a wide class of string models vector-like supermultiplets either with the quantum numbers of ordinary matter or with exotic charges are generically present. Moreover, in specific constructions they can remain in the low energy spectrum and get a mass at the TeV scale. A particularly elegant possibility is that the low energy spectrum consists of the matter content of three complete 27-dimensional

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[*] Corresponding author.

E-mail addresses: akarozas@cc.uoi.gr (A. Karozas), king@soton.ac.uk (S.F. King), leonta@uoi.gr (G.K. Leontaris), a.meadowcroft@soton.ac.uk (A.K. Meadowcroft).

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representations of E_6, as in the E$_6$SSM [118], or minimal E$_6$SSM [119], minus the three right-handed neutrinos which have zero charge under the low energy gauged $U(1)_N$, and hence may get large masses. In both versions additional singlet and vector-like states from E_6 reside at the TeV scale, together with a Z'. In the original version [118] extra vector-like Higgs states are added for the purposes of unification, while in the minimal E$_6$SSM [119] they are not.

In this paper we will revisit an F-theory E_6 GUT model that has the TeV spectrum of the minimal E$_6$SSM, namely three complete 27-dimensional representations of E_6 minus the right-handed neutrinos [120,121] plus additional bulk exotics which provide the necessary states for unification [122]. Unification is achieved since the matter content is that of the MSSM supplemented by four families of $SU(5)$ $5+\bar{5}$ states, although in the present model all the extra states are incomplete $SU(5)$ multiplets and crucially there are three additional TeV scale singlet states (in addition to the three high mass right-handed neutrinos which are sufficient to realise the see-saw mechanism). Moreover some of the low energy singlets couple to three families of TeV scale vector-like matter with the quantum numbers of down-type quarks [121] called here $D,\bar{D}$. Unlike the E$_6$SSM, the extra gauged $U(1)_N$ may be broken at the GUT scale, leading to an NMSSM-like theory without an extra Z', but with extra vector-like matter, as in the NMSSM+ [125]. However, here we focus exclusively on the model in [122] where one of the three low energy singlets is responsible for the Higgs μ term, and acquires an electroweak scale vacuum expectation value (VEV), while the other two singlets do not couple to Higgs but do couple to vector-like quarks $D,\bar{D}$, acquiring a TeV scale VEV. These latter candidates are therefore candidates for the 750 GeV mass resonance, able to account for the ATLAS and CMS data, since they have couplings to $D,\bar{D}$, and may have the required couplings required to generate the process $pp\to X\to\gamma\gamma$ via loops of $D,\bar{D}$ and inert Higgsinos. We emphasise that these models were proposed before the recent ATLAS and CMS data, so the interpretation that we discuss is not based on *ad hoc* modifications to the Standard Model, but rather represents a genuine consequence of well motivated theoretical considerations.

The layout of the remainder of this paper is as follows. In the next section we review the basic features of the specific E_6 F-theory model focusing mainly on its spectrum and in particular on the properties of the predicted exotics. We start section 3 by writing down the Yukawa interactions related to the processes that interest us in this work. Next, we compute the corresponding cross sections and compare our findings with the recent experimental results. In section 4 we present our conclusions.

2. The F-theory model with extra vector-like matter

In F-theory constructions SM-singlets and vector-like quark or lepton type fields are ubiquitous. Many such pairs are expected to receive masses at a high scale, but it is possible that several of them initially remain massless, later acquiring TeV scale masses. To set the stage, we start with a short description on the origin of the SM spectrum and bulk vector-like states in F-theory GUTs in general. We choose E_6 as a working example where it was shown sometime ago [120–122] that scalars as well as vector-like fermion fields at the TeV scale are naturally accommodated. We start with the decomposition of the E_8-adjoint under the breaking $E_8\supset E_6\times SU(3)$

$$248\to(78,1)+(1,8)+(27,3)+(\overline{27},\bar{3})$$

and label with t_i the $SU(3)$ weights (subject to the tracelessness condition $t_1+t_2+t_3=0$). Along the $SU(3)$ Cartan subalgebra, $(1,8)$ decomposes to singlets $\theta_{ij}, i,j=1,2,3$ whilst the 27's are characterised by the three charges t_i. We impose a Z_2 monodromy $t_1=t_2$ thus, we have the correspondence

$$\begin{aligned}&(1,8)\to\theta_{13},\theta_{31},\theta_0;\\&(27,3)\to 27_{t_1},27_{t_3};\quad(\overline{27},\bar{3})\to\overline{27}_{-t_1},\overline{27}_{-t_3}\end{aligned}\tag{2.1}$$

Notice that because of the Z_2 monodromy we get the identifications $\theta_{12}=\theta_{21}\equiv\theta_0$, as well as $\theta_{23}=\theta_{13}$ and $\theta_{32}=\theta_{31}$ and analogously for the $27_{t_1}=27_{t_2}$. Additional bulk singlets θ_{kl} and vector-like pairs are obtained under further breaking of the symmetry down to $SU(5)$.

The $SU(5)$ breaking is realised by a non-trivial hypercharge flux. Hence, assuming M_{10},M_5 the number of flux units determining the chiral $SU(5)$ representations and N_Y hypercharge flux units, for given tenplet and fiveplet we get the following splittings.

$$10_{t_i}=\begin{cases}\text{Representation} & \text{flux units}\\ \#Q-\#\bar{Q} & =M^i_{10}\\ \#u^c-\#\bar{u}^c & =M^i_{10}-N^i_Y\\ \#e^c-\#\bar{e}^c & =M^i_{10}+N^i_Y\end{cases}\tag{2.2}$$

$$5_{t_i}=\begin{cases}\text{Representation} & \text{flux units}\\ \#d^c-\#\bar{d}^c & =M^i_5\\ \#\bar{\ell}-\#\ell & =M^i_5+N^i_Y\end{cases}\tag{2.3}$$

We observe that a non-trivial flux differentiates the SM content on a given matter curve. The various flux parameters are subject to restrictions coming from anomaly cancellation conditions and flux conservation [123,124].

The detailed derivation of the particular F-theory model we are interested in can be found in reference [122]. In the present note, we only present the E_6 origin of the low energy spectrum and the corresponding $SU(5)\times U(1)_N$ multiplets which are summarised in Table 1. The last column shows the 'charge' Q_N of the $U(1)_N$ abelian gauge factor contained in E_6 under which the right-handed neutrinos are singlets as in the E$_6$SSM [118]. Due to hypercharge flux conservation, the Standard Model massless states must assemble into complete $SU(5)$ multiplets. Indeed, referring to Table 1, the matter in the 27_{t_1} representation $(3D+2H_u)$ together with the H_u from the 27_{t_3} form three complete fiveplets. Similarly, the $3(\bar{D}+H_d)$ matter from 27_{t_1} forms three complete anti-fiveplets.

Without the bulk exotics the spectrum has the matter equivalent of three families of E_6 27-dimensional representations as in the minimal E$_6$SSM [119], which form an anomaly free set by themselves. Such a model was realised in F-theory context [121] while it was shown that unification can be successfully achieved with the inclusion of the bulk exotics [122] relevant to our present discussion. The total low energy spectrum, including bulk exotics, then has the matter content of the MSSM plus four extra vector-like $5+\bar{5}$ families plus three extra singlets, which do not affect the unification scale. Three right-handed neutrinos are present at high energies. Renormalisation Group analysis shows [122] that perturbative unification can be achieved as shown in Fig. 1. With this in mind, next we focus on the characteristic properties of the model which are required to accommodate the recent experimental data.

2.1. *Proton decay*

One of the main obstacles in realising a viable $SU(5)$ model is the appearance of colour triplets $D,\bar{D}$ in the Higgs fiveplets which can mediate proton decay. In simple field theory GUT models, a doublet–triplet splitting mechanism ensures the existence of light Higgs doublets, while coloured triplets acquire a GUT mass through

Table 1
The low energy spectrum for the F-theory E$_6$SSM-like model with TeV scale bulk exotics taken without change from [122]. The fields Q, u^c, d^c, L, e^c represent quark and lepton SM superfields in the usual notation. In this spectrum there are three families of H_u and H_d Higgs superfields, as compared to a single one in the MSSM. There are also three families of exotic D and $\overline{D}$ colour triplet superfields, where $\overline{D}$ has the same SM quantum numbers as d^c, and D has opposite quantum numbers. We have written the bulk exotics as X with a subscript that indicates the SM quantum numbers of that state. The superfields θ_{ij} are SM singlets, with the two θ_{34} singlets containing spin-0 candidates for the 750 GeV resonance.

E_6	$SU(5)$	Weights	TeV spectrum	$\sqrt{10}Q_N$
27_{t_1}	$\overline{5}$	t_1+t_5	$3(d^c+L)$	1
27_{t_1}	10	t_1	$3(Q+u^c+e^c)$	$\frac{1}{2}$
27_{t_1}	5	$-t_1-t_3$	$3D+2H_u$	-1
27_{t_1}	$\overline{5}$	t_1+t_4	$3(\overline{D}+H_d)$	$-\frac{3}{2}$
27_{t_1}	1	t_1-t_4	θ_{14}	$\frac{5}{2}$
27_{t_3}	5	$-2t_1$	H_u	$-\frac{1}{2}$
27_{t_3}	1	t_3-t_4	$2\theta_{34}$	$\frac{5}{2}$
78	$\overline{5}$	0	$2X_{H_d}+X_{d^c}$	$-\frac{3}{2}$
78	5	0	$2\overline{X}_{\overline{H}_d}+\overline{X}_{\overline{d^c}}$	$\frac{3}{2}$
1	1	$\pm(t_1-t_3)$	$\theta_{13},\theta_{31},\theta_0$	0

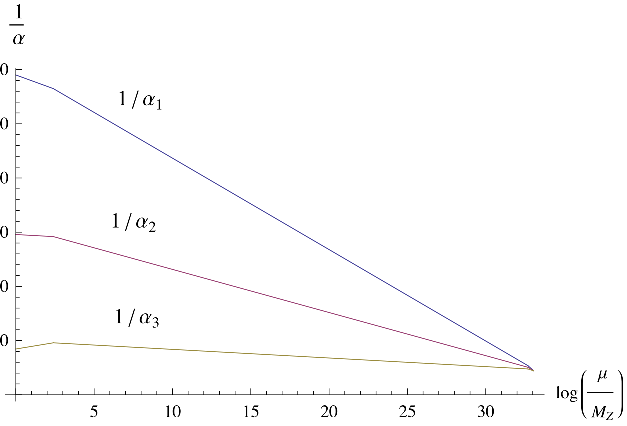

Fig. 1. Gauge coupling unification in the model in Table 1 with TeV scale bulk exotics with supersymmetry. The low energy matter content is equivalent to that of the MSSM plus four extra $5+\overline{5}$ families of $SU(5)$ at the TeV scale. Therefore we expect that the unification scale $M_{GUT}\sim 10^{16-17}$ is preserved, but the value of the coupling constant at that scale to be increased, exactly as indicated in this figure. However it is worth emphasising that the low energy matter content at the TeV scale, although equivalent to four extra $5+\overline{5}$ families, comes from incomplete multiplets, comprising $3(D+\bar{D})$ and $2(H_u+H_d)$ distributed amongst two different matter curves, plus $2X_{H_d}+X_{d^c}$ and $2\overline{X}_{\overline{H}_d}+\overline{X}_{\overline{d^c}}$ from the bulk. In addition there are extra singlets responsible for the 750 GeV signal which do not affect unification.

a term $\langle\Phi\rangle\bar{5}_{\bar{H}}5_H$. Yet, even a mass of $\langle\Phi\rangle\sim M_{GUT}$ is not adequate to suppress proton decay within the present experimental bounds.

In the present model the problem is apparently much more severe since there are colour triplets $D,\bar{D}$ at the TeV scale. However these TeV scale colour triplets do not give rise to proton decay diagrams, due to the conserved weights t_i which forbid the couplings which would be required in these diagrams. The leading proton decay diagram involves string scale colour triplets, and leads to sufficiently suppressed proton decay as discussed in [121]. Furthermore, because up and down Higgs fields are accommodated in different matter curves, a tree-level proton decay diagram realised for the corresponding Kaluza–Klein modes $D_{KK},\bar{D}_{KK}$ is also avoided.

3. Production and decay of the 750 GeV scalar/pseudoscalar

The terms in the superpotential which are responsible for generating the μ term and the exotic masses are [122]

$$W\sim\lambda\theta_{14}H_dH_u+\lambda_{\alpha\beta\gamma}\theta_{34}^{\alpha}H_d^{\beta}H_u^{\gamma}+\kappa_{\alpha jk}\theta_{34}^{\alpha}\overline{D}_jD_k \qquad (3.1)$$

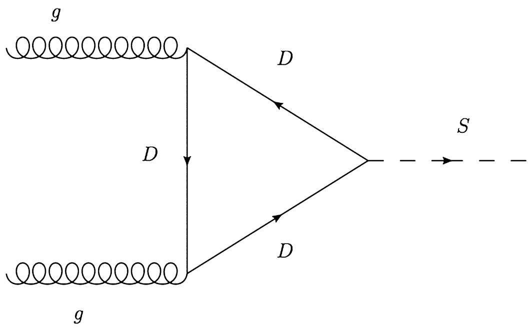

Fig. 2. The new singlet scalar/pseudoscalar $X\equiv\theta_{34}$ with mass 750 GeV is produced by gluon fusion due to its coupling to a loop of vector-like fermions $D,\bar{D}$ which are colour triplets and have electric charge $\mp 1/3$.

These couplings all originate from the $27_{t_1}27_{t_1}27_{t_3}$ E_6 coupling, which is the only coupling of this type and will also give rise to the Yukawa couplings of the model. This coupling is both invariant under the E_6 GUT group and balances the charges of the perpendicular group due to tracelessness of the $SU(3)$ remaining from the original E_8 point. Thus two of the singlets θ_{34}^{α} couple to all three of the colour triplet charge $\mp 1/3$ vector-like fermions $D_k,\overline{D}_j$ as well as two families of inert Higgs doublets H_d^{β},H_u^{γ} (which do not get VEVs) $(\alpha,\beta,\gamma=1,2)$. One or both (if they are degenerate) singlet scalars may have a mass of 750 GeV and be produced by gluon fusion at the LHC, decaying into two photons as shown in Figs. 2 and 3. A third singlet θ_{14} couples to the two Higgs doublets of the MSSM, and is responsible for the effective μ term as in the NMSSM. However this singlet does not couple to coloured fermions and so cannot be strongly produced at the LHC. It should also be mentioned in passing that the E_6 singlets can generate couplings such as $\theta_0X_d\bar{X}_{\bar{d}}$ from the E_6 invariant term $78\cdot 78\cdot 1$, which can give masses to bulk modes though we shall not discuss this further.

We therefore identify the 750 GeV scalar S with a spin-0 component of one of the F-theory singlets θ_{34}, which couples to three families of vector-like fermions $D_k,\overline{D}_j$ and two families of inert Higgs doublets H_d^{β},H_u^{γ}. The scalar components of θ_{34} are both assumed to develop TeV scale VEVs which are responsible for generating the vector-like fermion masses for $D_k,\overline{D}_j$. Since there are two complex singlets θ_{34}, the spectrum will therefore contain two scalars, two pseudoscalars and two complex Weyl fermions. The two scalars plus two pseudoscalars are all candidates for the observed 750 GeV resonance. If two or more of them are degenerate then this may lead to an initially unresolved broad resonance. Eventually all four states may be discovered with different masses around the TeV scale, providing a smoking gun signature of the model.

3.1. Cross section

We have seen that the spectrum of the F-theory derived model contains complex singlet superfields possessing scalar and pseudoscalar components. The superpotential in Eq. (3.1), below the scale of the VEVs of X and the SUSY breaking scale, gives rise to the low energy effective Lagrangian which contains terms like,

$$\mathcal{L}\sim\kappa_iX\bar{D}_iD_i+\lambda_{\alpha}XH_u^{\alpha}H_d^{\alpha}+M_i\bar{D}_iD_i+M_{H_\alpha}H_u^{\alpha}H_d^{\alpha}+\frac{1}{2}M^2X^2+\cdots$$

where X is a scalar or pseudoscalar field originating from the θ_{34} coupled to a vector pair of fermions identified with the fermionic components of the three coloured triplet pairs $D_i,\bar{D}_i$, while M_i are

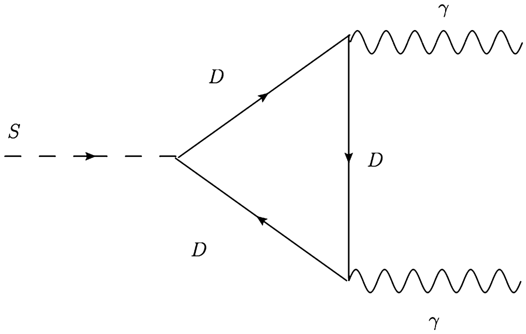

Fig. 3. The new singlet scalar/pseudoscalar $X \equiv \theta_{34}$ with mass 750 GeV is decays into a pair of photons due to its coupling to a loop of vector-like fermions $H, \overline{H}$ which are colour singlet inert Higgsinos with electric charge ±1 and $D, \overline{D}$ which are colour triplets and have electric charge $\mp 1/3$.

the three masses of the triplet fermions with $M_i \sim \kappa \langle \theta_{34} \rangle$ of (3.1) and M is the mass of the singlet field originating from a combination of soft SUSY breaking masses and the VEVs of the singlets. Similar couplings are also shown to the two families of vector-like inert Higgsinos, labelled by $\alpha = 1, 2$. Note that the aforementioned soft SUSY breaking is assumed to occur above the TeV scale.

The vector-like fermions generate loops diagrams which give rise to Effective Field Theory d-5 operators. For the scalar component $X \to S$

$$\mathcal{L}_{eff} \propto -\frac{1}{4} S \left(g_{S\gamma} F_{\mu\nu} F^{\mu\nu} + g_{Sg} G_{\mu\nu} G^{\mu\nu} \right) \tag{3.2}$$

and analogously for pseudoscalar $X \to A$,

$$\mathcal{L}_{eff} \propto -\frac{1}{4} A \left(g_{A\gamma} F_{\mu\nu} \tilde{F}^{\mu\nu} + g_{Ag} G_{\mu\nu} \tilde{G}^{\mu\nu} \right) . \tag{3.3}$$

A related mechanism has been already suggested as a plausible scenario in String derived models [83,107,109] where pseudoscalar fields such as axions and scalar fields such as the dilaton field have couplings of the above form. Here instead we regard the scalar and pseudoscalar as originating from a 27-dimensional matter superfield, coupling to vector-like extra quarks which also appear in the 27-rep of E_6.

We consider a scalar/pseudoscalar particle X originating from one of the two θ_{34} fields, coupling to three families of colour triplet charge $\mp 1/3$ extra vector-like quarks $D_i, \bar{D}_i$ and two families of Higgsinos $H^{\alpha}_{u/d}$ – as per Equation (3.1). The cross section for production of this scalar/pseudoscalar from gluon fusion, $\sigma(pp \to X \to \gamma\gamma)$, where X is a uncoloured boson with mass M and spin $J = 0$, can be written as [10]

$$\sigma(pp \to X \to \gamma\gamma) = \frac{1}{M\Gamma s} C_{gg} \Gamma(X \to gg) \Gamma(X \to \gamma\gamma) \tag{3.4}$$

where C_{gg} is the dimensionless partonic integral for gluon production, which at $\sqrt{s} = 13$ TeV is $C_{gg} = 2137$. Here $\Gamma = \Gamma(X \to gg) + \Gamma(X \to \gamma\gamma)$ since no other interactions contribute to the effect.

For the case in which a scalar/pseudoscalar resonance is produced from gluon fusion mediated by extra vector-like fermions $D_i, \bar{D}_i$ with mass M_i and charges Q_i, decaying into two photons by a combination of the same vector-like fermions and Higgsinos H^{α}_d and H^{α}_u, the corresponding decay widths read [10]:

$$\frac{\Gamma(X \to gg)}{M} = \frac{\alpha_3^2}{2\pi^3} \left| \sum_i C_{r_i} \kappa_i \frac{2M_i}{M} \mathcal{X}\left(\frac{4M_i^2}{M^2} \right) \right|^2 , \tag{3.5}$$

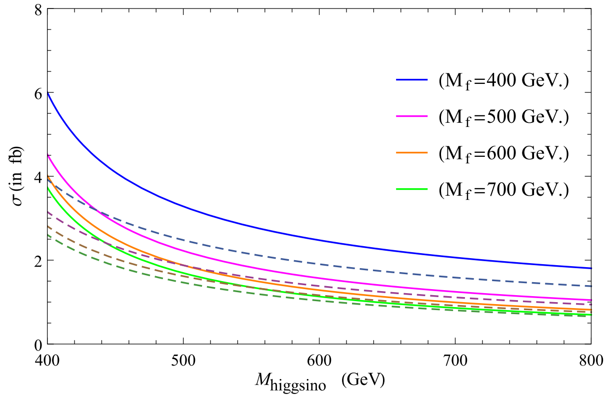

Fig. 4. The cross section $\sigma(pp \to X \to \gamma\gamma)$ (in fb units) in the parametric space of the Higgsinos $H^{\beta}_u / H^{\gamma}_d$, for a selection of masses of the vector-like $D_i/\overline{D}_i$ with all masses M_i set equal to M_f and the coupling y_f, with $y_f = 1$. The solid lines correspond to the Pseudoscalar candidate state, while the dashed lines of the same hue correspond to the Scalar option.

$$\frac{\Gamma(X \to \gamma\gamma)}{M} = \frac{\alpha^2}{16\pi^3} \left| \sum_i d_{r_i} Q_i^2 \kappa_i \frac{2M_i}{M} \mathcal{X}\left(\frac{4M_i^2}{M^2} \right) + \sum_{\alpha} d_{r_\alpha} Q_\alpha^2 \lambda_\alpha \frac{2M_{H\alpha}}{M} \mathcal{X}\left(\frac{4M_{H\alpha}^2}{M^2} \right) \right|^2 \tag{3.6}$$

The function $\mathcal{X}(t)$ takes a different form, depending on whether the particle is a scalar or a pseudoscalar – $\mathcal{S}$ or $\mathcal{P}$ respectively [126]:

$$\mathcal{P}(t) = \arctan^2(1/\sqrt{t-1}), \tag{3.7}$$

$$\mathcal{S}(t) = 1 + (1-t)\mathcal{P}(t) . \tag{3.8}$$

In the case in question with colour triplets of mass M_i mediating the process, $Q_i = 1/3$, $C_{r_i} = 1/2$, and $d_{r_i} = 3$, while the Higgsinos have $Q_i = d_{r_i} = 1$ and a mass of M_k. Combining the equations above we calculate the cross section for a scalar of mass $M = 750$ GeV at $\sqrt{s} = 13$ TeV. While the 750 GeV mass scale arises from an assumed soft SUSY breaking singlet scalar mass at that scale, the mass scale of the vector-like exotics in this model arise from singlet scalar VEVs, also assumed to be around the TeV scale. For simplicity we set all the masses of the vector-like fermions to be equal to degenerate (likewise for the Higgsinos), and all the couplings of the scalar singlet to the fermions to be equal to y_f. The results are presented in Fig. 4 and Fig. 5. Note also that the $\Gamma(X \to gg)/M$ take values in the region of 10^{-4} and 10^{-5} which is not excluded by searches for dijet resonances at Run 1.

In the computations of the cross sections presented above we have considered only the fermionic contributions while we have ignored the scalar ones. Masses of the scalar partners are related to supersymmetry breaking. Although the details of the SUSY breaking are not known, given the present experimental bounds on squark masses from the LHC, we assume that the scalar components of the exotic coloured fermions to be above $\mathcal{O}(1)$ TeV, whilst the corresponding coloured fermions are assumed to be somewhat lighter. Furthermore we know that loops of scalar bosons give smaller contributions to the anomalous loop amplitudes than do fermions of the same mass (see also similar reasoning in [127]). Given also that fermion components are lighter, we anticipate that the contribution of the latter dominates the cross section.

4. Conclusions

We have interpreted the 750–760 GeV diphoton resonance as one or more of the spinless components of two singlet superfields

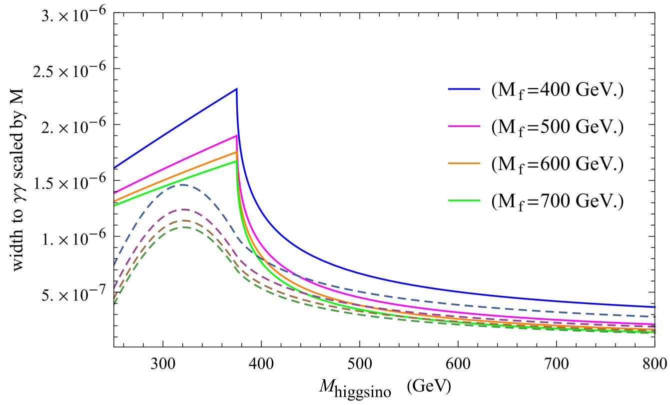

Fig. 5. The mass weighted width $\Gamma(X \to \gamma\gamma)$ in the parametric space of the Higgsinos H_u^β/H_d^γ, for a selection of masses of the vector-like $D_i/\overline{D}_i$ with masses M_f and the coupling y_f, with $y_f = 1$. The solid lines correspond to the Pseudoscalar candidate state, while the dashed lines of the same hue correspond to the Scalar option.

arising from the three 27-dimensional representations of E_6 in F-theory, which also contain three copies of colour-triplet charge $\mp 1/3$ vector-like fermions $D_i, \bar{D}_i$ as well as inert Higgsino doublets H_d^β, H_u^γ to which the singlets may couple. For definiteness we have considered (without change) a model that was proposed some time ago which contains such states, as well as bulk exotics, leading to gauge coupling unification.

In order to obtain a large enough cross-section, we require the resonance to be identified with one of the two pseudoscalar (rather than scalar) states. However even in this case, a sufficiently large cross-section requires quite light colour triplets and charged Higgsinos below a TeV, even with of order unit Yukawa couplings, which is one of the predictions of the model.

The smoking gun prediction of the model is the existence of other similar spinless resonances, possibly close in mass to 750–760 GeV, decaying into diphotons, as well as the three families of vector-like fermions $D_i, \bar{D}_i$ and two families of inert Higgsino doublets H_d^β, H_u^γ.

It is possible that two or more of the singlet spinless states may be close in mass, providing nearby resonances which could be initially mistaken for a single broad resonance in the current data. Indeed, from the 27 reps of the E_6 F-theory model there are two singlet superfields which couple to the vector-like fermions $D_i, \bar{D}_i$, so there could be up to four spinless resonances which can be searched for.

Further bulk singlets arising from the 78 reps of the E_6 F-theory model are also expected to be present in the low energy spectrum whose VEVs are responsible for the low energy exotic bulk masses of the $2X_{H_d}$, X_{d^c} and their vector partners. These bulk singlets are also candidates for the 750 GeV diphoton resonance, or may have similar masses.

In conclusion, realistic E_6 F-theory models generically contain extra low energy states which include a plethora of spinless singlets and vector-like fermions with various charges and colours, especially colour singlet unit charged states and colour triplets with charges $\mp 1/3$, which appear to have the correct properties to provide an explanation of the 750 GeV diphoton resonance indicated by the LHC Run 2 data. We have discussed an already existing model (without change) which is perfectly capable of accounting for these data, as well as furnishing many predictions of multiple other similar resonances as well as the exotic fermions and their superpartners which should be observable in future.

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