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Vector-like exotics in F-theory and 750 GeV diphotons

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Abstract

The recent excess in diphoton events around 750 GeV seen by the ATLAS and CMS experiments could be hinting at the existence of new vector-like charged matter around the TeV scale which couples to a singlet. Such a spectrum of exotics arises inevitably in certain classes of F-theory GUTs with hypercharge flux when the GUT symmetry is extended by a $U(1)$ symmetry under which the Higgs fields of the MSSM are not vector-like. The exotics are not vector-like under the $U(1)$ symmetry and therefore their mass is naturally related to its breaking scale. Previously this scale was taken to be close to the GUT scale which led to tension with proton decay, the μ-term magnitude, and too large R-parity violation. The 750 GeV excess provides new motivation for considering breaking the $U(1)$ around the TeV scale, which additionally alleviates the previous problems. We study the possible TeV-scale spectrum in such an $SU(5)$ GUT scenario and show that it is constrained and predictive. Gauge coupling unification can be retained at the accuracy of the MSSM at one loop even though typically the spectrum does not form complete GUT representations. For example the exotics cannot form a complete 10 multiplet but nonetheless happen to behave as one in the beta functions. We present an initial analysis of the diphoton production rates for the exotics spectra and find them compatible with data.

1. Introduction

Recently the ATLAS and CMS experiments reported a possible excess in the diphoton spectrum near an invariant mass of 750 GeV [1,2]. An economic explanation for such an excess is a

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new scalar field with a mass around 750 GeV that decays to two photons. The scalar, S, should couple to gluons for production and photons for decay, and a particularly simple way to do so is through the introduction of some new vector-like matter which carries colour and electric charge and couples to the singlet. The singlet can then be produced and decay through loops involving this new vector-like matter. Of the large number of scenarios that have been proposed in the literature to explain the observed excess, see for example [3,4], a significant fraction are in this class.

In this note we are interested in studying a possible ultraviolet origin for new vector-like charged matter near the TeV scale which couples to a singlet.[1] We retain the frameworks of low energy supersymmetry and high scale gauge coupling unification. Within this we are motivated by the observation that precisely such a spectrum of fields extending that of the Minimal Supersymmetric Standard Model (MSSM) arises inevitably when constructing a certain class of Grand Unified Theories (GUTs) in F-theory. F-theory is a very natural framework for implementing GUTs in string theory. One of the most interesting aspects of F-theory GUTs is that the breaking of the GUT symmetry group to that of the Standard Model is most naturally implemented through the introduction of hypercharge flux. In order for the hypercharge gauge field to stay massless this flux must be so-called globally trivial in F-theory [9,10]. This restriction has been shown to impose quite strong constraints on the possible spectrum of particles whenever there is also an additional $U(1)$ symmetry present [11–15]. The restrictions on the spectrum can be argued for by an analysis of anomalies and are therefore quite robust. One particular implication, emphasised in [13], is that if one attempts to construct the spectrum of the MSSM where the Higgs up and Higgs down have different charges under the additional $U(1)$ then the MSSM spectrum is inevitably extended by additional massless vector-like charged matter and additional singlets which couple to this matter. This prediction of new vector-like and singlet matter from F-theory has so far been considered a problem, and the natural solutions implemented in the literature to it is to give the new singlets a GUT-scale vev thereby making the vector-like matter which couples to them very massive. Doing this however leads to tension with proton decay constraints, and often also with the magnitude of the μ-term and matter parity violation, and so it is a simple though not completely clean solution [13,16]. If the singlet vev, and therefore vector-like matter mass, is kept near the TeV scale the aforementioned problems are alleviated. While this forms a motivation for studying the possibility of keeping the exotics near the TeV scale in itself, the hints of an LHC excess that can be possibly explained by these exotics make exploring this scenario even more worthwhile.

The presence of an additional $U(1)$ symmetry beyond the SM is also motivated by the μ-problem of the MSSM. If the up and down Higgs fields have different charges under the symmetry then the superpotential quadratic term is forbidden and is replaced by a cubic term involving a $U(1)$ charged singlet, as in the NMSSM. A TeV-scale μ-term can then be explained by a TeV-scale singlet vev. Therefore the breaking of the $U(1)$ symmetry occurs naturally at the TeV-scale in this scenario and since the new vector-like fields arise from hypercharge flux only due to the presence of precisely this $U(1)$ their mass can be naturally tied to the μ-term scale in this way. It is important to note that the $U(1)$ itself can be, but need not be, massless. It depends on if it obtains a Stuckelberg mass in string theory which is always so if it is anomalous but can be so, depending on the model, even if it is not. Even if massive though it remains as a perturbative effective global symmetry.

[1] See [5–8] for alternative ideas on a string theory origin.