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ScienceDirect
Nuclear Physics B 906 (2016) 231–240
NUCLEAR PHYSICS B
www.elsevier.com/locate/nuclphysb

750 GeV diphotons from a D3-brane

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Received 11 January 2016; received in revised form 23 February 2016; accepted 24 February 2016

Available online 8 March 2016

Editor: Tommy Ohlsson

Abstract

Motivated by the recently reported diphoton excess at 750 GeV observed by both CMS and ATLAS, we study string-based particle physics models which can accommodate this signal. Quite remarkably, although Grand Unified Theories in F-theory tend to impose tight restrictions on candidate extra sectors, the case of a probe D3-brane near an E-type Yukawa point naturally leads to a class of strongly coupled models capable of accommodating the observed signature. In these models, the visible sector is realized by intersecting 7-branes, and the 750 GeV resonance is a scalar modulus associated with motion of the D3-brane in the direction transverse to the Standard Model 7-branes. Integrating out heavy 3–7 string messenger states leads to dimension five operators for gluon fusion production and diphoton decays. Due to the unified structure of interactions, these models also predict that there should be additional decay channels to ZZ and $Z\gamma$. We also comment on models with distorted unification, where both the production mechanism and decay channels can differ.

1. Introduction

Recently, the LHC experiments CMS and ATLAS have both announced tentative evidence for a diphoton excess with a resonant mass near 750 GeV [1,2]. This signal is seen in the early

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http://dx.doi.org/10.1016/j.nuclphysb.2016.02.031
0550-3213/

data of the 13 TeV run, and appears to be compatible with the absence of a large signal in the earlier 7 and 8 TeV runs. Recall that the observed diphoton signal depends on the production cross section $\sigma_{pp\to s}$ for the resonance "s," as well as $B_{s\to\gamma\gamma} = \Gamma_{s\to\gamma\gamma}/\Gamma_{s\to\text{any}}$ its branching fraction to diphotons:

$$\sigma_{pp\to s} \times B_{s\to\gamma\gamma} \sim 5 \text{ fb}. \tag{1.1}$$

In the case of the ATLAS experiment, there is also an even more preliminary indication that this resonance may have a substantial width.

While the observed signal is on the order of three sigma (if one naively combines CMS and ATLAS), this is still far from meeting the threshold for discovery. Even so, it has already inspired a number of theoretical analyses (see e.g. [3–48]). One of the lessons which can already be drawn from these early phenomenological studies is that in general (but not always), models with some strongly coupled extra sector appear to fare better in generating a sufficiently large signal with a broader decay width. From this perspective, it is natural to ask whether there are UV motivated constructions of new physics which can accommodate the diphoton excess.

In this note we point out that string-based constructions from F-theory Grand Unified Theories (F-theory GUTs) naturally suggest particular strongly coupled extra sectors which can easily accommodate the diphoton excess. We stress that this is non-trivial, since the underlying exceptional gauge symmetries necessary for stringy unification tightly constrain both the structure of the visible sector matter content, as well as possible extra sectors. Indeed, experience from earlier constructions such as reference [49] shows that intersecting 7-branes can realize the visible sector, but little else. Rather, extra probe D3-branes must typically be included to get novel phenomenology from an extra sector [50]. The resulting physics is quite rich, and leads to several novel features. First, these models are strongly coupled, but nevertheless, preserve supersymmetric gauge coupling unification [51]. Additionally, depending on the mass scales available, they can lead to rather striking phenomenological signatures. One of our aims will be to show how this class of models can naturally interpolate between several of the simplified models presented which have been used to explain the diphoton excess.

2. Extra sector from a D3-brane

In more detail, we consider models of particle physics which embed in a supersymmetric Grand Unified Theory in F-theory known as an "F-theory GUT" [52,53]. For a review of the relevant particle physics constructions, see for example [54]. Though order TeV scale supersymmetry is not essential for most of our discussion, it is well motivated. It will also make details of the model more calculable, so we shall assume approximate supersymmetry in the extra sector as a convenient computational tool.

In these models, the visible sector is realized on a stack of intersecting 7-branes (i.e. spacetime filling branes which fill four extra dimensions). The extra sector is given by a D3-brane (i.e. a spacetime filling brane which is pointlike in the extra dimensions) probing the Standard Model (SM) stack. The same mechanism which generates subleading Yukawa couplings for the SM also generates a potential for D3-branes with a local minimum near the Yukawa point of the SM stack [50]. See Fig. 1 for a depiction.

In F-theory, grand unification requires unbroken exceptional gauge symmetries at subspaces of the internal dimensions, which in turn demands that the string coupling is order one. So, the extra sector on the D3-brane is always strongly coupled. If the D3-brane is at a generic