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Nuclear Physics B 911 (2016) 127–162

NUCLEAR PHYSICS B

www.elsevier.com/locate/nuclphysb

The di-photon excess in a perturbative SUSY model

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Received 18 June 2016; received in revised form 22 July 2016; accepted 23 July 2016

Available online 28 July 2016

Editor: Tommy Ohlsson

Abstract

We show that a 750 GeV di-photon excess as reported by the ATLAS and CMS experiments can be reproduced by the Minimal Dirac Gaugino Supersymmetric Standard Model (MDGSSM) without the need of any ad-hoc addition of new states. The scalar resonance is identified with the spin-0 partner of the Dirac bino. We perform a thorough analysis of constraints coming from the mixing of the scalar with the Higgs boson, the stability of the vacuum and the requirement of perturbativity of the couplings up to very high energy scales. We exhibit examples of regions of the parameter space that respect all the constraints while reproducing the excess. We point out how trilinear couplings that are expected to arise in supersymmetry-breaking mediation scenarios, but were ignored in the previous literature on the subject, play an important role.

1. Introduction

In the first presentation of LHC Run 2 data, both experiments ATLAS and CMS presented an excess in the di-photon mass spectrum for comparable invariant masses. The CMS analysis observed its largest excess in the di-photon mass spectrum based on 2.6 fb^{-1} of pp collisions at

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http://dx.doi.org/10.1016/j.nuclphysb.2016.07.027

$\sqrt{s} = 13$ TeV for an invariant mass of 760 GeV with a local significance of 2.6 σ and a global significance of smaller than 1.2 σ [1]. Similarly, the ATLAS collaboration reported the largest deviation from the background hypothesis for an invariant mass of 750 GeV using 3.2 fb^{-1} of data, leading to a local significance of 3.6 σ and a global significance of 2.0 σ taking into account the look-elsewhere-effect in the mass range of $m_{\gamma\gamma} \in [200\text{–}2000]$ GeV [2].

After updating and refining their analysis, CMS achieved an improved sensitivity by more than 20% and added a new data set which was taken with $B = 0$ T reaching as well a comparable 3.3 fb^{-1}. The modest excess at 750 GeV for the combined 8 and 13 TeV data remained with 3.4 σ (local) and 1.6 σ (global) significance [3]. ATLAS updated their 8 TeV analysis and confirmed the modest excess at 750 GeV in the Run I data set with a significance of 1.9 σ. Thus, the recent updates strengthen the hint for a new physics signal.

For the Spin-0 hypothesis and under the assumption of $\Gamma/m_\Phi = 0.014 \times 10^{-2}$ (with m_Φ the scalar singlet mass) the combined dataset of CMS with 3.3 fb^{-1} (13 TeV) and 19.7 fb^{-1} (8 TeV) gives the production cross-section times branching ratio into two photons to be

$$\sigma^{13\text{ TeV}} \cdot B_{\gamma\gamma} \approx 3.7 \pm 2 \text{ fb}, \tag{1.1}$$

while one analysis of the ATLAS data gives [4]

$$\sigma^{13\text{ TeV}} \cdot B_{\gamma\gamma} \approx 12 \pm 2 \text{ fb}. \tag{1.2}$$

An interpretation of this excess is that it is due to the production and subsequent decay of a scalar resonance of mass 750 GeV; while there have been many alternatives proposed (too many to mention here), we shall restrict to that case here as the most obvious and least tuned option in perturbative theories. The existence of such a particle with a mass close to the electroweak scale implies a new hierarchy problem that cannot obviously have an anthropic explanation, and this naturally strengthens the case for low-energy supersymmetry. However, the observed rate of diphoton production via the resonance is too large compared to what is expected from a heavy Higgs companion of the light Standard Model (SM)-like one, and in particular it is very difficult to justify in the Minimal Supersymmetric Standard Model (MSSM) (see e.g. [5–7][1]). In fact, the interpretation of the excess is challenging for most previously proposed supersymmetric extensions of the Standard Model, and of the perturbative models proposed since the announcement almost all invoke additional vector-like fermions and/or bosons. For an early review see [11]. In this work we shall show, on the other hand, that a previously proposed supersymmetric extension of the Standard Model called the Minimal Dirac Gaugino Supersymmetric Standard Model (MDGSSM) [12] contains all of the ingredients to explain the excess.

Since the proposal in [13] of extending the MSSM with extra states in the adjoint representation of the Standard Model to allow Dirac gaugino masses, this possibility has been subject to many studies due to their theoretical and phenomenological advantages: they allow simpler models of supersymmetry-breaking due to preserving an R-symmetry; their masses are supersoft [14] and supersafe from collider searches [15–17]; they ameliorate the SUSY flavour problem [18–20]; and contain new couplings which aid the naturalness of the Higgs mass [12,21–26]. Indeed, multiple realisations have been proposed that differ by the fate of R-symmetry, the presence or absence of additional states and interactions [14,22–24,27–63] (for a short introduction

[1] Note that although there have been several attempts to fit the excess in just the MSSM, such as in [8,9], they require a large fine-tuning of masses/parameters to be on resonance, and even then there remain questions about the viability of the scenario from e.g. vacuum stability constraints. In [10] it is unlikely that the enhancement of the chargino loop is valid once the width of the singlet is taken into account.