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Phenomenology of the utilitarian supersymmetric standard model

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Abstract

We study the 2010 specific version of the 2002 proposed $U(1)_X$ extension of the supersymmetric standard model, which has no μ term and conserves baryon number and lepton number separately and automatically. We consider in detail the scalar sector as well as the extra Z_X gauge boson, and their interactions with the necessary extra color-triplet particles of this model, which behave as leptoquarks. We show how the diphoton excess at 750 GeV, recently observed at the LHC, may be explained within this context. We identify a new fermion dark-matter candidate and discuss its properties. An important byproduct of this study is the discovery of relaxed supersymmetric constraints on the Higgs boson's mass of 125 GeV.

1. Introduction

Since the recent announcements [1,2] by the ATLAS and CMS Collaborations at the Large Hadron Collider (LHC) of a diphoton excess around 750 GeV, numerous papers [3] have appeared explaining its presence or discussing its implications. In this paper, we study the phenomenology of a model proposed in 2002 [4], which has exactly all the necessary and sufficient particles and interactions for this purpose. They were of course there for solving other issues in

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Table 1
Particle content of proposed model.

Superfield	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_X$
$Q=(u,d)$	3	2	1/6	0
u^c	3*	1	−2/3	1/2
d^c	3*	1	1/3	1/2
$L=(\nu,e)$	1	2	−1/2	1/3
e^c	1	1	1	1/6
N^c	1	1	0	1/6
ϕ_1	1	2	−1/2	−1/2
ϕ_2	1	2	1/2	−1/2
S_1	1	1	0	−1/3
S_2	1	1	0	−2/3
S_3	1	1	0	1
U	3	1	2/3	−2/3
D	3	1	−1/3	−2/3
U^c	3*	1	−2/3	−1/3
D^c	3*	1	1/3	−1/3

particle physics. However, the observed diphoton excess may well be a first revelation [5] of this model, including its connection to dark matter.

This 2002 model extends the supersymmetric standard model by a new $U(1)_X$ gauge symmetry. It replaces the μ term with a singlet scalar superfield which also couples to heavy color-triplet superfields which are electroweak singlets. The latter are not *ad hoc* inventions, but are necessary for the cancellation of axial-vector anomalies. It was shown in Ref. [4] how this was accomplished by the remarkable exact factorization of the sum of eleven cubic terms, resulting in two generic classes of solutions [6]. Both are able to enforce the conservation of baryon number and lepton number up to dimension-five terms. As such, the scalar singlet and the vectorlike quarks are indispensible ingredients of this 2002 model. They are thus naturally suited for explaining the observed diphoton excess. In 2010 [7], a specific version was discussed, which will be the subject of this paper as well. An important byproduct of this study is the discovery of relaxed supersymmetric constraints on the Higgs boson's mass of 125 GeV. This is independent of whether the diphoton excess is confirmed or not.

2. Model

Consider the gauge group $SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_X$ with the particle content of Ref. [4]. For $n_1 = 0$ and $n_4 = 1/3$ in Solution (A), the various superfields transform as shown in Table 1. There are three copies of $Q, u^c, d^c, L, e^c, N^c, S_1, S_2$; two copies of U, U^c, S_3; and one copy of ϕ_1, ϕ_2, D, D^c. The only allowed terms of the superpotential are thus trilinear, i.e.

$$Qu^c\phi_2, \quad Qd^c\phi_1, \quad Le^c\phi_1, \quad LN^c\phi_2, \quad S_3\phi_1\phi_2, \quad N^cN^cS_1, \tag{1}$$

$$S_3UU^c, \quad S_3DD^c, \quad u^cN^cU, \quad u^ce^cD, \quad d^cN^cD, \quad QLD^c, \quad S_1S_2S_3. \tag{2}$$

The absence of any bilinear term means that all masses come from soft supersymmetry breaking, thus explaining why the $U(1)_X$ and electroweak symmetry breaking scales are not far from that of supersymmetry breaking. As $S_{1,2,3}$ acquire nonzero vacuum expectation values (VEVs), the exotic (U, U^c) and (D, D^c) fermions obtain Dirac masses from $\langle S_3 \rangle$, which also generates the μ