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Gauged baryon and lepton numbers in supersymmetry with a 125 GeV Higgs

Tai-Fu Feng [a,*], Shu-Min Zhao [a], Hai-Bin Zhang [a,b], Yin-Jie Zhang [a], Yu-Li Yan [a]

[a] *Department of Physics, Hebei University, Baoding, 071002, China*
[b] *Department of Physics, Dalian University of Technology, Dalian, 116024, China*

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Abstract

Assuming that the Yukawa couplings between the Higgs and exotic quarks cannot be ignored, we analyze the signals of decay channels $h \to \gamma\gamma$ and $h \to VV^*$ $(V = Z, W)$ with the Higgs mass around 125 GeV in a supersymmetric extension of the standard model where baryon and lepton numbers are local gauge symmetries. Adopting some assumptions on relevant parameter space, we can account for the experimental data on Higgs from ATLAS and CMS naturally.

Keywords: Supersymmetry; Baryon and lepton numbers; Higgs

1. Introduction

The main destination of the Large Hadron Collider (LHC) is to understand the origin of the electroweak symmetry breaking, and searches the neutral Higgs predicted by the standard model (SM) and its various extensions. Recently, ATLAS and CMS have reported significant excess events which are interpreted probably to be related to the neutral Higgs with mass $m_{h_0} \sim 124$–126 GeV [1,2]. This implies that the Higgs mechanism to break electroweak symmetry possibly has a solid experimental cornerstone.

* Corresponding author.
E-mail addresses: fengtf@hbu.edu.cn (T.-F. Feng), smzhao@hbu.edu.cn (S.-M. Zhao).

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As the simplest soft broken supersymmetry theory, the minimal supersymmetric extension of the standard model (MSSM) [3] has drawn the attention from physicist for a long time. Furthermore, broken baryon number (B) can explain the origin of the matter–antimatter asymmetry in the Universe naturally. Since heavy majorana neutrinos contained in the seesaw mechanism can induce the tiny neutrino masses [4] to explain the neutrino oscillation experiment, lepton number (L) is also expected to be broken. Ignoring Yukawa couplings between Higgs doublets and exotic quarks, the authors of Refs. [5,6] investigate the predictions for the mass and decays of the lightest CP-even Higgs in a minimal local gauged B and L supersymmetric extension of the SM which is named BLMSSM. Since the new quarks are vector-like, one obtains that their masses can be above 500 GeV without assuming large couplings to the Higgs doublets in this model. Therefore, there are no Landau poles for the Yukawa couplings here. Additionally, Ref. [7] also examines two extensions of the SM where B and L are spontaneously broken gauge symmetries around TeV scale. Assuming that the Yukawa couplings between Higgs and exotic quarks cannot be ignored here, we investigate the lightest CP-even Higgs decay channels $h \to \gamma\gamma$, $h \to VV^*$ ($V = Z, W$) in the BLMSSM.

Our presentation is organized as follows. In Section 2, we briefly summarize the main ingredients of the BLMSSM, then present the mass squared matrices for neutral scalar sectors and the mass matrices for exotic quarks, respectively. We discuss the corrections on the mass squared matrix of CP-even Higgs from exotic fields in Section 3, and present the decay widths for $h^0 \to \gamma\gamma$, VV^* ($V = Z, W$) in Section 4. The numerical analyses are given in Section 5, and our conclusions are summarized in Section 6.

2. A supersymmtric extension of the SM where B and L are local gauge symmetries

When B and L are local gauge symmetries, one can enlarge the local gauge group of the SM to $SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_B \otimes U(1)_L$. In the supersymmetric extension of the SM proposed in Ref. [5,6], the exotic superfields include the new quarks $\hat{Q}_4 \sim (3, 2, 1/6, B_4, 0)$, $\hat{U}_4^c \sim (\bar{3}, 1, -2/3, -B_4, 0)$, $\hat{D}_4^c \sim (\bar{3}, 1, 1/3, -B_4, 0)$, $\hat{Q}_5^c \sim (\bar{3}, 2, -1/6, -(1 + B_4), 0)$, $\hat{U}_5 \sim (3, 1, 2/3, 1+B_4, 0)$, $\hat{D}_5 \sim (3, 1, -1/3, 1+B_4, 0)$, and the new leptons $\hat{L}_4 \sim (1, 2, -1/2, 0, L_4)$, $\hat{E}_4^c \sim (1, 1, 1, 0, -L_4)$, $\hat{N}_4^c \sim (1, 1, 0, 0, -L_4)$, $\hat{L}_5^c \sim (1, 2, 1/2, 0, -(3 + L_4))$, $\hat{E}_5 \sim (1, 1, -1, 0, 3 + L_4)$, $\hat{N}_5 \sim (1, 1, 0, 0, 3 + L_4)$ to cancel the B and L anomalies. The 'brand new' Higgs superfields $\hat{\Phi}_B \sim (1, 1, 0, 1, 0)$ and $\hat{\varphi}_B \sim (1, 1, 0, -1, 0)$ acquire nonzero vacuum expectation values (VEVs) to break Baryon number spontaneously. Meanwhile, nonzero VEVs of Φ_B and ϕ_B also induce the large masses for exotic quarks. In addition, the superfields $\hat{\Phi}_L \sim (1, 1, 0, 0, -2)$ and $\hat{\varphi}_L \sim (1, 1, 0, 0, 2)$ acquire nonzero VEVs to break Lepton number spontaneously. In order to avoid stability for the exotic quarks, the model also includes the superfields $\hat{X} \sim (1, 1, 0, 2/3 + B_4, 0)$, $\hat{X}' \sim (1, 1, 0, -(2/3 + B_4), 0)$. Actually, the lightest one can be a dark matter candidate. The superpotential of the model is written as

$$\mathcal{W}_{BLMSSM} = \mathcal{W}_{MSSM} + \mathcal{W}_B + \mathcal{W}_L + \mathcal{W}_X, \tag{1}$$

where $\mathcal{W}_{MSSM}$ is superpotential of the MSSM, and

$$\begin{aligned}
\mathcal{W}_B &= \lambda_Q \hat{Q}_4 \hat{Q}_5^c \hat{\Phi}_B + \lambda_U \hat{U}_4^c \hat{U}_5 \hat{\varphi}_B + \lambda_D \hat{D}_4^c \hat{D}_5 \hat{\varphi}_B + \mu_B \hat{\Phi}_B \hat{\varphi}_B \\
&\quad + Y_{u_4} \hat{Q}_4 \hat{H}_u \hat{U}_4^c + Y_{d_4} \hat{Q}_4 \hat{H}_d \hat{D}_4^c + Y_{u_5} \hat{Q}_5^c \hat{H}_d \hat{U}_5 + Y_{d_5} \hat{Q}_5^c \hat{H}_u \hat{D}_5, \\
\mathcal{W}_L &= Y_{e_4} \hat{L}_4 \hat{H}_d \hat{E}_4^c + Y_{\nu_4} \hat{L}_4 \hat{H}_u \hat{N}_4^c + Y_{e_5} \hat{L}_5^c \hat{H}_u \hat{E}_5 + Y_{\nu_5} \hat{L}_5^c \hat{H}_d \hat{N}_5 \\
&\quad + Y_\nu \hat{L} \hat{H}_u \hat{N}^c + \lambda_{N^c} \hat{N}^c \hat{N}^c \hat{\varphi}_L + \mu_L \hat{\Phi}_L \hat{\varphi}_L,
\end{aligned}$$