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Planck-scale induced left–right gauge theory at LHC and experimental tests

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Abstract

Recent measurements at LHC have inspired searches for TeV scale left–right gauge theory originating from grand unified theories. We show that inclusion of Planck-scale induced effects due to dim.5 operator not only does away with all the additional intermediate symmetries, but also it predicts the minimal set of light Higgs scalars tailored after neutrino masses and dilepton, or trilepton signals. The heavy-light neutrino mixings are predicted from charged fermion mass fits in $SO(10)$ and LFV constraints which lead to new predictions for dilepton or trilepton production signals. Including fine-structure constant matching and two-loop, and threshold effects predict $M_{W_R} = g_{2R}10^{4.3\pm1.5\pm0.2}$ GeV and proton lifetime $\tau_p = 10^{36.15\pm5.8\pm0.2}$ yrs with W_R gauge boson coupling $g_{2R} = 0.56$–0.57. Predictions on lepton flavour and lepton number violations are accessible to ongoing experiments. Current CMS data on di-electron excess at $\sqrt{s} = 8$ TeV are found to be consistent with W_R gauge boson mass $M_{W_R} \geq 1.9$–2.2 TeV which also agrees with the values obtained from dijet resonance production data. We also discuss plausible explanations for diboson production excesses observed at LHC and make predictions expected at $\sqrt{s} = 14$ TeV.

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1. Introduction

The standard model $SU(2)_L \times U(1)_Y \times SU(3)_C$ ($\equiv G_{213}$) partially unifies electromagnetic and weak interactions but fails to explain neutrino masses and why parity violation occurs only in weak interaction. Manifestly left–right symmetric (LRS) gauge theory [1–4] $SU(2)_L \times SU(2)_R \times U(1)_{B-L} \times SU(3)_C(g_{2L} = g_{2R})(\equiv G_{2213D})$ predicts a number of phenomena beyond the standard model including neutrino masses and parity violation. It also goes further to suggest that the right-handed (RH) neutrino (N), a member of its fundamental representation, could be a heavy Majorana fermion driving type-I seesaw mechanism for light neutrino masses and acting as a seed for baryogenesis via leptogenesis. As possible experimental evidence of LRS theory, it would be quite attractive to associate these RH neutrinos to be mediating dilepton production events recently observed at the Large Hadron Collider (LHC) [5,6] which can discriminate whether W_R gauge coupling is different from the standard W_L boson coupling [7].

There are a number of advantages of embedding the SM or the LRS models in GUTs which have attracted extensive investigations over the last four decades [2,7–10]. The most recent phenomenon has been the prediction of dark matter (DM) candidates including the stabilising symmetry, called the Matter Parity, in non-SUSY SO(10) [11]. In addition to unifying the strong, weak, and electromagnetic forces, the grand unified theory (GUT) is capable of addressing the issue of proton stability, and the origin of Parity and CP symmetries as part of gauge symmetries.

The minimal left–right symmetric GUT that unifies strong, weak, and electromagnetic interactions is $SO(10)$ that leaves out gravity.[1] Apart from fitting all charged fermion masses [12] and explaining the neutrino oscillation data, it would be quite interesting if spontaneous symmetry breaking of non-SUSY $SO(10)$ through any one of the following two minimal symmetry breaking chains gives the LHC verifiable W_R, Z_R bosons as well as the associated seesaw mechanism

$$\mathbf{SO(10)} \stackrel{\mathbf{M_U}}{\longrightarrow} \mathbf{G_{2213D}} \quad \mathbf{or} \quad \mathbf{G_{2213}} \stackrel{\mathbf{M_R}}{\longrightarrow} \mathbf{SM}. \tag{1}$$

In eq. (1) G_{2213} represents the same left-right gauge theory as in G_{2213D} but without the D-parity for which $g_{2L} \neq g_{2R}$ [7].

That the resonant W_R production accompanied by heavy RH Majorana neutrino exchange would manifest in like-sign dilepton signals at accelerator energies was suggested earlier [13]. An interesting interpretation of the LHC data [5,6] on the excess of events in the like-sign dilepton channel $pp \to eejj$ along with the reported ratio of 14:1 of opposite sign to the same sign dilepton signals has been made very recently in the context of minimal left-right symmetric model (MLRSM) with $g_{2L} = g_{2R}$ [14] which has the Higgs scalar bidoublet $\Phi(2,2,0,1)$ and the triplets $\Delta_L(3,1,-2,1) \oplus \Delta_R(1,3,-2,1)$ [4]. The light neutrino mass matrix in this theory [14] is governed by the type-I seesaw formula

$$\mathcal{M}_\nu = -M_D \tilde{M}_N^{-1} M_D^T. \tag{2}$$

Here $M_D =$ Dirac neutrino mass matrix, $\tilde{M}_N = f V_R =$ the RH neutrino mass matrix, $f =$ Majorana type Yukawa coupling of the triplets, and $V_R =< \Delta_R^0 >$ that breaks MLRSM to SM. There are several limitations of deriving this TeV scale MLRSM from SO(10): (i) It was noted [9,10] that when the GUT symmetry breaking proceeds through MLRSM, low-mass parity restoration with $M_{W_R} \sim \mathcal{O}(100\text{–}1000)$ GeV needs too large value of $\sin^2\theta_W(M_Z) \sim$ 0.27–0.31 in

[1] In the absence of any experimental evidence of supersymmetry so far, in this work we confine to non-supersymmetric (non-SUSY) models.