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A predictive 3-3-1 model with A_4 flavor symmetry

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Abstract

We propose a predictive model based on the $SU(3)_C \otimes SU(3)_L \otimes U(1)_X$ gauge group supplemented by the $A_4 \otimes Z_3 \otimes Z_4 \otimes Z_6 \otimes Z_{16}$ discrete group, which successfully describes the SM fermion mass and mixing pattern. The small active neutrino masses are generated via inverse seesaw mechanism with three very light Majorana neutrinos. The observed charged fermion mass hierarchy and quark mixing pattern are originated from the breaking of the $Z_4 \otimes Z_6 \otimes Z_{16}$ discrete group at very high scale. The obtained values for the physical observables for both quark and lepton sectors are in excellent agreement with the experimental data. The model predicts a vanishing leptonic Dirac CP violating phase as well as an effective Majorana neutrino mass parameter of neutrinoless double beta decay, with values $m_{\beta\beta} = 2$ and 48 meV for the normal and the inverted neutrino mass hierarchies, respectively.

1. Introduction

Despite the great success of the Standard Model (SM), recently confirmed by the discovery of the 126 GeV Higgs boson by LHC experiments [1–4], there are many aspects not yet explained such as the origin of the fermion mass and mixing hierarchy as well as the mechanism responsible for stabilizing the electroweak scale [5,6]. This discovery of the Higgs scalar field allows to

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consider extensions of the SM with additional scalar fields that can be useful to explain the existence of Dark Matter [7].

The Standard Model is a theory with many phenomenological achievements. However in the Yukawa sector of the SM there are many parameters related with the fermion masses with no clear dynamical origin. Because of this reason, it is important to study realistic models that allow to set up relations among all these parameters of the Yukawa sector. Discrete flavor symmetries allow to establish ansatz that explains the flavor problem, for recent reviews see Refs. [8–10]. These discrete flavor symmetries may be crucial in building models of fermion mixing that address the flavor problem. Non-abelian discrete flavor symmetries arise in string theories due to the discrete features of the fixed points of the orbifolds [11]. For instance, the discrete D_4 group is originated in the S^1/Z_2 orbifold [11].

Besides that, another of the greatest mysteries in particle physics is the existence of three fermion families at low energies. The quark mixing angles are small whereas the leptonic mixing angles are large. Models based on the gauge symmetry $SU(3)_C \otimes SU(3)_L \otimes U(1)_X$ have the feature of being vectorlike with three families of fermions and are therefore anomaly free [12–16]. When the electric charge is defined in the linear combination of the $SU(3)_L$ generators T_3 and T_8, it is a free parameter, independent of the anomalies (β). The choice of this parameter defines the charge of the exotic particles. Choosing $\beta = -\frac{1}{\sqrt{3}}$, the third component of the weak lepton triplet is a neutral field ν_R^C, which allows to build the Dirac matrix with the usual field ν_L of the weak doublet. If one introduces a sterile neutrino N_R in the model, then it is possible to generate light neutrino masses via inverse seesaw mechanism. The 3-3-1 models with $\beta = -\frac{1}{\sqrt{3}}$ have the advantage of providing an alternative framework to generate neutrino masses, where the neutrino spectrum includes the light active sub-eV scale neutrinos as well as sterile neutrinos which could be dark matter candidates if they are light enough or candidates for detection at the LHC, if their masses are at the TeV scale. This interesting feature makes the 3-3-1 models very interesting, since if the TeV scale sterile neutrinos are found at the LHC, these models can be very strong candidates for unraveling the mechanism responsible for electroweak symmetry breaking. Furthermore, the 3-3-1 models can provide an explanation for the 750 GeV diphoton excess recently reported by ATLAS and CMS [17] as well as for the 2 TeV diboson excess found by ATLAS [18].

Neutrino oscillation experiments [6,19–23] indicate that there are at least two massive active neutrinos and at most one massless active neutrino. In the mass eigenstates, it is necessary for the solar neutrinos oscillations that $\delta m^2_{sun} = m^2_{21} = m^2_2 - m^2_1$ where $m^2_2 - m^2_1 > 0$. For the atmospheric neutrinos oscillations it is required that $\delta m^2_{atm} = m^2_{31} = m^2_3 - m^2_1$ where the difference can be positive (normal hierarchy) or negative (inverted hierarchy). Neutrino oscillations do not give information neither on the absolute value of the neutrino mass nor on the Majorana or Dirac nature of the neutrino. However there are neutrino mass bounds arising from cosmology [24], tritium beta decay [25] and double beta decay [26–32,34,33].

The neutrino masses and mixings are known from neutrino oscillations, which depend on the squared neutrino mass differences and not on the absolute value of the neutrino masses. The global fits of the available data from the Daya Bay [19], T2K [20], MINOS [21], Double CHOOZ [22] and RENO [23] neutrino oscillation experiments, constrain the neutrino mass squared splittings and mixing parameters [35]. The current neutrino data on neutrino mixing parameters can be very well accommodated in the approximated tribimaximal mixing matrix,