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Implications of the Muon Anomalous Magnetic Moment for 3-3-1 Models

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Currently, studying the effects of new particles contributing to muon anomalous magnetic moment $(g-2)$ through virtual loops as evidence for new physics beyond the standard model attracts high interest. Therefore, we present the results of the Implications to g-2 to five models based on the gauge symmetry $\mathrm{SU(3)_C \times SU(3)_L \times U(1)_X}$ (3-3-1), widely detailed in the article [1]. We consider a current and projected accuracy to the g-2 experiment at FERMILAB to analyze these implications. In this way, we obtain the new Z' and W' gauge bosons' lower mass bounds in models 3-3-1 that contribute to the muon anomalous magnetic moment. Then, discuss like the analyzed models could accommodate $g-2$ according to the LHC bounds.

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1. Introduction

The muon anomalous magnetic moment (a_μ) cannot be explained only by considering the contributions of the Standard Model (SM), even considering the hadronic effects, there are discrepancies between the experimental and the theoretical values $\Delta a_\mu = a_\mu^{\exp} - a_\mu^{SM}$. Therefore, it is of great interest to analyze the effects of new particles contributing to $g-2$ through virtual loops. In this way, below we will make a quick review of the five models explored in [1] focused on the symmetry group $\mathcal{G}_{3-3-1} = \mathrm{SU(3)_C} \times \mathrm{SU(3)_L} \times \mathrm{U(1)_X}$ to analyze the new contributions to g-2. Furthermore, considering a more accurate analysis of the experimental values in the FERMILAB, we implemented a current discrepancy $\Delta a_\mu^c = (261 \pm 78) \times 10^{-11} (3.3\sigma)$[2, 3], and imposed a projected discrepancy $\Delta a_\mu^p = (261 \pm 34) \times 10^{-11} (5\sigma)$.

2. 3-3-1 Models

The models analyzed in this study are the following: 3-3-1 Minimal [4], 3-3-1 with right-handed neutrinos (r.h.n) [5], 3-3-1 with neutral lepton (LHN) [6, 7], economical 3-3-1 [8–10], and 3-3-1 with exotic leptons [11–13]. In the scalar sector, the 3-3-1 models contain between 2 or 3 scalar triplets (χ, η, ρ) to give the masses of the fermions and one scalar sextet to generate neutrino masses via a type II seesaw mechanism. The gauge symmetry $\mathcal{G}_{3-3-1}$ experiences the following Spontaneous Symmetry Breaking (SSB): $\mathrm{SU(3)_L} \times \mathrm{U(1)_X} \xrightarrow{\langle\chi\rangle} \mathrm{SU(2)_L} \times \mathrm{U(1)_Y} \xrightarrow{\langle\eta\rangle,\langle\rho\rangle} \mathrm{U(1)_{\mathbf{Q}}}$, where each scale field acquires a vacuum expectation value (vev) in different scales: $v_\chi \gg v_\eta, v_\rho$. The first SSB is in order of the TeV scale, and the second in order of the electroweak scale. Moreover, the 3-3-1 models contain leptonic fields,

$$\text{3-3-1 Minimal: } f_L^a = \begin{pmatrix} \nu^a \\ \ell^a \\ (\ell^c)^a \end{pmatrix}; \quad \text{3-3-1 r.h.n and Economical: } f_L^a = \begin{pmatrix} \nu^a \\ \ell^a \\ (\nu^c)^a \end{pmatrix}, \quad \ell_R^a;$$

$$\text{3-3-1 with exotic leptons: } f_{1L} = \begin{pmatrix} \nu_1 \\ \ell_1 \\ E_1^- \end{pmatrix}, f_{2,3L} = \begin{pmatrix} \nu_{2,3} \\ \ell_{2,3} \\ N_{2,3} \end{pmatrix}, f_{4L} = \begin{pmatrix} E_2^- \\ N_3 \\ N_4 \end{pmatrix}, f_{5L} = \begin{pmatrix} N_5 \\ E_3^+ \\ \ell_3^+ \end{pmatrix},$$

$$\ell_1^c, \ell_{2,3}^c, E_2^c, E_3^c; \quad \text{and} \quad \text{3-3-1 LHN: } f_L^a = \begin{pmatrix} \nu^a \\ \ell^a \\ N^a \end{pmatrix}, \quad \ell_R^a, \quad N_R^a,$$

where $a = 1, 2, 3$ is the generation index, ν and ℓ are the SM leptonic particles, ν^c is the r.h.n. In the 3-3-1 L. H. N model, N is the heavy neutral lepton, and in the 3-3-1 with Exotic Leptons model N and E are the exotic neutral and charged leptons, respectively. The relevant interactions of gauge fields and scalar fields with leptons in the 3-3-1 models to $g-2$ are illustrated in the Feynman diagrams in Figure 1. General analytical expressions to Δa_μ are taken from [14], which were adapted for the 3-3-1 models, and the *Mathematica numerical codes* are available at [15].

3. Results

To derive the results shown in Table 1, we added up all contributions to g-2 in each 3-3-1 model. Then, plotting this result together with the current and projected discrepancy bounds in plots Δa_μ

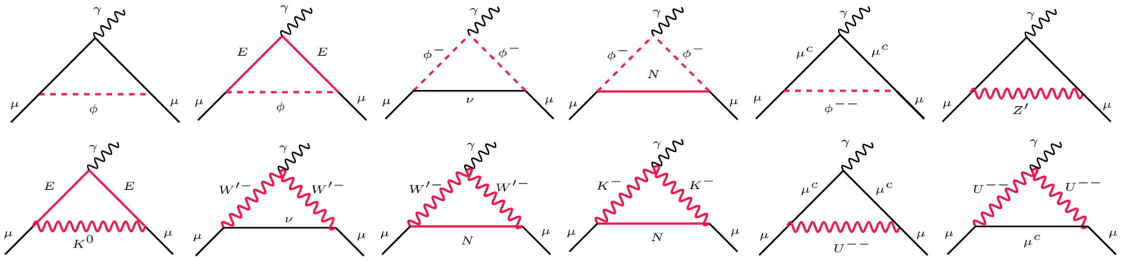

Figure 1: Feynman diagrams that contribute to $g-2$ in the 3-3-1 models, where $U^{\pm\pm}$, W'^{-}, K^{-}, K^{0} and Z' are new gauge bosons, with ϕ and ϕ^{-} are the neutral and singlet charged scalars fields.

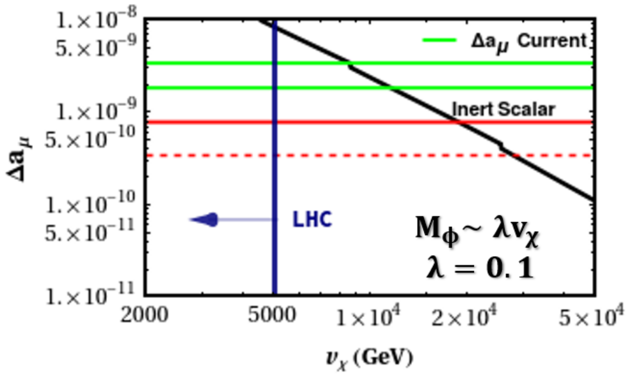

Figure 2: Contribution of the 3-3-1 LHN Model augmented by an inert scalar triplet. The green bands are delimited by Δa_μ^C and red bands are bounded by the projected 1σ bound by $78\times10^{-11} > \Delta a_\mu < 34\times10^{-11}$.

Model	LHC-13TeV	Δa_μ^c	Δa_μ^p
Minimal 3-3-1	$M_{Z'} > 3.7$ TeV [16] $M_{W'} > 3.2$ TeV [16]	$M_{Z'} > 434.5$ GeV $M_{W'} > 646$ GeV	$M_{Z'} > 632$ GeV $M_{W'} > 996.1$ GeV
3-3-1 r.h.n	$^*M_{Z'} > 2.64$ TeV [14] ——-	$M_{Z'} > 158$ GeV $M_{W'} > 133$ GeV	$M_{Z'} > 276.5$ GeV $M_{W'} > 239$ GeV
3-3-1 LHN for $M_N = 1$ GeV	$^*M_{Z'} > 2$ TeV [14] —-	$M_{Z'} > 160$ GeV $M_{W'} > 134.3$ GeV	$M_{Z'} > 285$ GeV $M_{W'} > 238.3$ GeV
3-3-1 LHN for $M_N = 100$ GeV	$^*M_{Z'} > 2$ TeV [14] ——	$M_{Z'} > 136.7$ GeV $M_{W'} > 114.2$ GeV	$M_{Z'} > 276.5$ GeV $M_{W'} > 231$ GeV
Economical 3-3-1	$^*M_{Z'} > 2.64$ TeV [14] ——	$M_{Z'} > 59.3$ GeV $M_{W'} > 49.5$ GeV	$M_{Z'} > 271.4$ GeV $M_{W'} > 226.7$ GeV
3-3-1 exotic leptons for $m_N(m_E) = 10(150)$ GeV	$^*M_{Z'} > 2.91$ TeV [17] ——	$M_{Z'} > 429$ GeV $M_{W'} > 359$ GeV	$M_{Z'} > 693$ GeV $M_{W'} > 579.6$ GeV
3-3-1 exotic leptons for $m_N(m_E) = 100(150)$ GeV	$^*M_{Z'} > 2.91$ TeV [17] ——	$M_{Z'} > 369$ GeV $M_{W'} > 309.1$ GeV	$M_{Z'} > 600$ GeV $M_{W'} > 501.4$ GeV

Table 1: Summary of the lower mass bounds on the Z' and W' bosons derived for the 3-3-1 models, where the LHC bounds at $\sqrt{s} = 13$ TeV are based on either $36fb^{-1}$ or $139fb^{-1}$ of the data, and Δa_μ^c (Δa_μ^p) is the current discrepancy (projected discrepancy) to a_μ.

vs v_χ, we obtained the v_χ lower bound by considering when the curves of the total contributions and discrepancies intersect. In this way, we derived the lower mass bounds of the new gauge boson because they depend on v_χ. Notice in Table 1 that none of the five models investigated here can accommodate the anomaly in agreement with existing bounds.Then we purpose an extended version of the 3-3-1 LHN Model to explain g-2 in 3-3-1 models by adding an inert scalar triplet allowing us to include the Lagrangian $\mathcal{L} \supset y_{ab}\bar{f}_a \phi e_{bR}$, taking $y_{22} = 1$. Such scalar triplet gets a mass from the quartic coupling in the scalar potential ($\lambda\phi^\dagger\phi\chi^\dagger\chi$), after the scalar triplet χ acquires a vev. The extended version of the 3-3-1 LHN Model successfully accommodates the a_μ anomaly for $v_\chi \sim 10$ TeV (see Figure 2), while being consistent with LHC constraint.

4. Conclusions

We concluded that none of the five models investigated here could accommodate the anomaly. We derived robust and complementary 1σ lower mass bounds on the masses of the new gauge bosons, namely the Z' and W' bosons, that contribute to muon anomalous magnetic moment assuming the anomaly is otherwise resolved. Besides, the 3-3-1 models must be extended to explain the anomaly observed in the muon anomalous magnetic moment. Therefore, we presented a plausible extension to the 3-3-1 LHN model, which features an inert scalar triplet.

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