The muon anomalous magnetic moment and a new light gauge boson.

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Abstract

It is shown that the 2.7 σ discrepancy between the predicted and recently measured value of the anomalous magnetic moment of positive muons could be explained by the existence of a new light gauge boson X with a mass $M_X \leq O(5)\ GeV$. Possible experimental searches of this particle are briefly discussed.

The recent precise measurement of the anomalous magnetic moment of the positive muon $a_\mu = (g-2)/2$ from Brookhaven AGS experiment 821 [1] gives result which is about 2.7σ higher than the Standard Model prediction

$$a_\mu^{exp} - a_\mu^{SM} = (43 \pm 16) \times 10^{-10} \tag{1}$$

This result may signals the existence of new physics beyond the Standard Model. At present the standard explanation of this result suggested in a few recently appeared papers is the supersymmetry with the chargino and sneutrino lighter than 800 GeV [2]. Note also possible explanations related with existence of leptoquarks [3] or existence of some exotic flavour-changing interactions [4]. All these explanations assume the existence of new particles with masses $\geq O(100)\ GeV$.

In this note we suggest that the recent BNL result gives an evidence for the existence of the physics with new light particle. As an example of the realization of this scenario we consider the model with light gauge boson X ($M_X \leq O(5)\ GeV$) and briefly discuss possible implications.

To be concrete besides standard $SU_c(3) \otimes SU(2)_L \otimes U(1)_Y$ gauge group consider additional $U(1)_X$ interaction which commutes with standard gauge group. In other words our model has $SU_c(3) \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_X$. We assume that all quarks have the same interaction with new gauge group $U(1)_X$ but the interactions of each lepton flavour with new X-boson could be different. In such

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model the standard Higgs doublet has zero X-charge so there is no mixing between X-boson and Z-boson. The interaction of X-boson with quarks and leptons can be written in the form

$$L_X = g_X[Q_{BX}B^\alpha + Q_{eX}L_e^\alpha + Q_{\mu X}L_\mu^\alpha + Q_{\tau X}L_\tau^\alpha]X_\alpha \tag{2}$$

where $B^\alpha = \sum_{q=u,d,s,...}\bar{q}\gamma^\alpha q$, $L_e^\alpha = \bar{e}\gamma^\alpha e + \bar{\nu}_{eL}\gamma^\alpha \nu_{eL}$. From the requirement of the absence of the γ_5 anomalies additional constraint $3Q_{BX} + Q_{eX} + Q_{\mu X} + Q_{\tau X} = 0$ arises. The X-boson gives additional contribution to the anomalous magnetic moment of lepton

$$\delta a_l = \frac{Q_{lX}^2 \alpha_X}{\pi}\int_0^1 \frac{x^2(1-x)}{x^2 + (1-x)M_X^2/m_l^2}, \tag{3}$$

where $\alpha_X = \frac{g_X^2}{4\pi}$ and M_X is the mass of the X-boson. For $M_X \ll m_\mu$ we find from the Brookhaven result (1) that $Q_{\mu,X}^2\alpha_X \approx (2.7 \pm 1) \times 10^{-10}$. For another limiting case $M_X \gg m_\mu$ Brookhaven result (1) leads to $Q_{\mu X}^2 \alpha_X \frac{m_\mu^2}{M_X^2} = (4.1 \pm 1.5) \times 10^{-8}$. To suppress the contribution of the X-boson to the anomalous magnetic moment of the electron we assume that $M_X \geq 10\ MeV$ or $Q_{eX} << Q_{\mu X}$.

The phenomenology of the light X-boson with masses $m_X \leq M_\pi$ has been studied in refs.[5] where untrivial bounds on the interaction of the X-boson with quarks and leptons have been derived. Note that if X-boson is lighter than π^0-meson it is possible to search for it in the decay $\pi^0 \to \gamma + X$ [6]. The typical branching ratio of the $\pi^0 \to \gamma + X$ is $O(10^{-5}) \times Q_{BX}^2$. Other manifestations of such light X-boson can be looked for in neutrino reactions, "beam dump" experiments and in the rare decays [5] (see also [7]).

Especially interesting is the case when X-boson interacts only with second and third generation leptons ($Q_{BX} = Q_{eX} = 0, Q_{\mu X} = -Q_{\tau X} = 1$) that makes the search for such particle not very easy. The best limit comes from the non observation of such X-boson at LEP in the decay $Z \to \mu^+\mu^- + X, \tau^+\tau^- + X$. One can obtain that $\alpha_X \leq O(10^{-4})$ that leads to the bound $M_X \leq O(5)\ GeV$ on the X-boson mass. The existence of such gauge interaction prohibits diagonal neutrino Majorana masses $\nu_\mu\nu_\mu$ and $\nu_\tau\nu_\tau$ and allows non diagonal mass term $\nu_\tau\nu_\mu$ that after diagonalization of the neutrino mass matrix leads to the maximal $\nu_\mu - \nu_\tau$ mixing. Such particle could be produced in the reaction $\mu + N \to \mu + X + ...$ and be detected through its decay into the muon pair $X \to \mu^+\mu^-$.

Note that massless X-bosons could be associated with muonic(leptonic) photons, introduced to explain conservation of the muon(lepton) number, see [8] and references therein. Interestingly, the existing experimental limit on coupling strength between the muonic photons and muons, $\alpha_\mu < (1.1 \div 2.3) \times 10^{-8}$ [9], is in the region of values required to explain the BNL discrepancy, $\alpha_\mu = (2.7 \pm 1.0) \times 10^{-8}$.

To conclude, the recent BNL result on precise measurements of the muon $g-2$ value can be explained by the existence of a new weakly interacting light gauge X-boson, thus still making it interesting for further experimental searches.

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