Physics Letters B 687 (2010) 201–203

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Electron and muon $g-2$ contributions from the T' Higgs sector

Chiu Man Ho [*], Thomas W. Kephart

Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, USA

ARTICLE INFO

Article history:
Received 20 February 2010
Accepted 15 March 2010
Available online 17 March 2010
Editor: T. Yanagida

Keywords:
Discrete flavor symmetry
Higgs
Anomalous magnetic moment

ABSTRACT

We study the experimental constraints from electron and muon $g-2$ factors on the Higgs masses and Yukawa couplings in the T' model, and thereby show that the discrepancy between the standard model prediction and experimental value of muon $g-2$ factor can be easily accommodated.

1. Introduction

The electron anomalous magnetic moment has been measured to an extremely high precision and agrees with the theoretical prediction calculated from the standard model (SM) [1], with the result

$$\Delta a_e = \left|a_e^{\mathrm{SM}} - a_e^{\mathrm{Expt}}\right| < 1\times 10^{-10}. \tag{1.1}$$

On the other hand, the most recent theoretical calculation of the muon anomalous magnetic moment gives [2]:

$$a_\mu^{\mathrm{SM}} = (11659183.4 \pm 4.9)\times 10^{-10}, \tag{1.2}$$

where the errors are dominated by the hadronic contribution. The corresponding most updated experimental value is [3]:

$$a_\mu^{\mathrm{Expt}} = (11659208.0 \pm 5.4 \pm 3.3)\times 10^{-10}. \tag{1.3}$$

This implies that a_μ^{SM} differs from a_μ^{Expt} by 3.1σ, and suggests that a contribution beyond standard model may be required. As we will show, this discrepancy between the theoretical and experimental values can be easily accommodated in the T' model [4–6] due to the existence of a new and unique Higgs coupling to the muon. While many authors have developed models that resolve this discrepancy [7], only a few have invoked a discrete flavor symmetry.

2. Higgs contributions to $g-2$ factors in the T' model

The T' model [4–6] relates quarks and electrons through a discrete flavor symmetry, the binary tetrahedral group T', whose irreducible representations are three singlets, three doublets and a triplet. The renormalizable T' model has led to successful predictions of the tribimaximal neutrino mixing matrix as well as the Cabibbo angle [5,6]. More details about the T' model, its variants and other related models can be found in the literature [8].

In the T' model, electrons and muons couple to the different components of the triplet Higgs H'_3 through the interaction terms $Y_e\bar{e}H'_{3,e}e$ and $Y_\mu\bar{\mu}H'_{3,\mu}\mu$. To compute the contribution of a virtual Higgs to the electron and muon $g-2$ factors, we need to study its contribution to the electron/muon–photon vertex. For $f=e,\mu$, the vertex function is given by

$$\begin{aligned}
&-ie\bar{u}(p')\Lambda_f^\nu(p',p)u(p)\\
&\quad=(-ie)(-iY_f)^2\int\frac{d^4k}{(2\pi)^4}\bar{u}(p')\frac{i}{k^2-M_{H_f}^2+i\epsilon}\\
&\qquad\times\frac{i(\not{p}'-\not{k}+m)}{(p'-k)^2-m^2+i\epsilon}\gamma^\nu\frac{i(\not{p}-\not{k}+m_f)}{(p-k)^2-m_f^2+i\epsilon}u(p),
\end{aligned}\tag{2.1}$$

where $\bar{u}(p')$ and $u(p)$ are the spinors obeying the equation of motions $\bar{u}(p')(\not{p}'-m_f)=(\not{p}-m_f)u(p)=0$, and M_{H_f} is the mass of the Higgs which couples to the electron or muon whose mass is denoted by m_f.

After some calculations, we obtain

$$\bar{u}(p')\Lambda_f^\nu(p,p')u(p) = F_f(q^2)\bar{u}(p')\frac{i\sigma^{\nu\alpha}q_\alpha}{2m_f}u(p)+\cdots, \tag{2.2}$$

---

[*] Corresponding author.
E-mail addresses: chiuman.ho@vanderbilt.edu (C.M. Ho), tom.kephart@gmail.com (T.W. Kephart).

0370-2693
doi:10.1016/j.physletb.2010.03.046

where $F_f(q^2)$ is the form factor associated with the electron or muon, and $\sigma^{\nu\alpha} = \frac{i}{2}[\gamma^\nu, \gamma^\alpha]$. The contributions from the T' Higgs sector to electron or muon anomalous magnetic moment is given by

$$\Delta a_f = \Delta\left(\frac{g_f - 2}{2}\right) = F_f\left(q^2 = 0\right), \tag{2.3}$$

$$= \frac{Y_f^2}{8\pi^2}\frac{m_f^2}{M_{H_f}^2}\int_0^1 dx \frac{(1-x^2)(1-x)}{x + (1-x)^2 \frac{m_f^2}{M_{H_f}^2}}. \tag{2.4}$$

For $m_f \ll M_{H_f}$, which is likely to be the case, there is a logarithmic divergence in the above integral as $x \to 0$. This divergence can be extracted by setting $1 - x \to 1$ and $1 - x^2 \to 1$ in the integrand. As a result, we obtain

$$\Delta a_f \approx \frac{Y_f^2}{4\pi^2}\left(\frac{m_f}{M_{H_f}}\right)^2 \ln\left(\frac{M_{H_f}}{m_f}\right). \tag{2.5}$$

Note that for a given value of Y_f, Δa_f is strictly decreasing when the ratio M_{H_f}/m_f increases.

The condition (1.1) implies that any combinations of Y_e and M_{H_e} must be such that

$$|\Delta a_e| < 1 \times 10^{-10}, \tag{2.6}$$

which imposes the following constraint

$$Y_e \lesssim 21.4\lambda_e \frac{M_{H_e}/m_e}{\sqrt{\ln(M_{H_e}/m_e)}}, \tag{2.7}$$

where $\lambda_e \sim 3 \times 10^{-6}$ is the corresponding electron Yukawa coupling in SM. We required the ratio $M_{H_e}/m_e \gg 1$ when we were deriving (2.5), but otherwise a free parameter. To have an assessment on the allowed range of Y_e, we need to have some experimental bounds on M_{H_e}. Apparently, we would have hoped that the LEP [9] bound on Higgs mass may help — due to the non-observation of the "Higgs-strahlung" process $e^+e^- \to HZ$ at LEP, a lower bound has been given to the SM Higgs, namely $M_{H_{\mathrm{SM}}} \geqslant 114.5$ GeV. However, in the T' model, all the Higgs singlets and triplets couple to Z. Thus, the LEP bound does not apply directly to any of the masses of the Higgs singlets and triplets. If we simply assume that $M_{H_e} \gtrsim 100$ GeV, then we require $Y_e \lesssim 3.5$ in order to satisfy the condition (1.1). In this case, the upper bound on the Yukawa coupling Y_e is very loose and any value of Y_e that is perturbatively small would be allowed.

For the muon anomalous magnetic moment, the discrepancy between the theoretical and experimental values can be accounted for easily in the T' model if

$$\Delta a_\mu \sim \left|a_\mu^{\mathrm{SM}} - a_\mu^{\mathrm{Expt}}\right| = (24.6 \pm 8.0) \times 10^{-10}, \tag{2.8}$$

leading to the constraint

$$Y_\mu \sim 0.52\lambda_\mu \frac{M_{H_\mu}/m_\mu}{\sqrt{\ln(M_{H_\mu}/m_\mu)}}, \tag{2.9}$$

where $\lambda_\mu \sim 0.0006$ is the corresponding muon Yukawa coupling in SM. It is obvious that $Y_\mu \gg \lambda_\mu$, for any choice of $M_{H_\mu}/m_\mu \gg 1$. For instance, if we assume that $M_{H_\mu} \gtrsim 100$ GeV, then in order to satisfy (2.9), we require $Y_\mu \gtrsim 0.13$.

3. Conclusions

In this Letter, we have computed the contributions to electron and muon $g - 2$ factors from the Higgs sector in the T' model. We then used the experimental data to constrain the T' model Higgs masses and Yukawa couplings.

If we assume that $M_{H_e} \gtrsim 100$ GeV, then the upper bound on the electron Yukawa coupling Y_e would be very loose and any value of Y_e consistent with the perturbation theory would be allowed.

Our main result is the demonstration that the discrepancy between the standard model and experimental values of muon anomalous $g - 2$ factor can be accounted for easily in the T' model. Assuming $M_{H_\mu} \gtrsim 100$ GeV, we found that the Yukawa coupling Y_μ should be much larger than the corresponding SM value in order to explain the discrepancy.

Acknowledgements

We thank Shinya Matsuzaki for useful comments. This work was supported by US DOE grant DE-FG05-85ER40226.

References

[1] D. Hanneke, S. Fogwell, G. Gabrielse, Phys. Rev. Lett. 100 (2008) 120801.
[2] M. Davier, A. Hoecker, B. Malaescu, C.Z. Yuan, Z. Zhang, arXiv:0908.4300 [hep-ph].
[3] G.W. Bennett, et al., Muon $g - 2$ Collaboration, Phys. Rev. D 73 (2006) 072003.
[4] P.H. Frampton, T.W. Kephart, Int. J. Mod. Phys. A 10 (1995) 4689, arXiv:hep-ph/9409330.
[5] P.H. Frampton, T.W. Kephart, JHEP 0709 (2007) 110, arXiv:0706.1186 [hep-ph].
[6] P.H. Frampton, T.W. Kephart, S. Matsuzaki, Phys. Rev. D 78 (2008) 073004, arXiv:0807.4713 [hep-ph].
[7] E. Ma, M. Raidal, Phys. Rev. Lett. 87 (2001) 011802;
E. Ma, M. Raidal, Phys. Rev. Lett. 87 (2001) 159901, arXiv:hep-ph/0102255, Erratum;
T.W. Kephart, H. Pas, Phys. Rev. D 65 (2002) 093014, arXiv:hep-ph/0102243;
Z.H. Xiong, J.M. Yang, Phys. Lett. B 508 (2001) 295, arXiv:hep-ph/0102259;
Z.z. Xing, Phys. Rev. D 64 (2001) 017304, arXiv:hep-ph/0102304;
T. Ibrahim, U. Chattopadhyay, P. Nath, Phys. Rev. D 64 (2001) 016010, arXiv:hep-ph/0102324;
J.R. Ellis, D.V. Nanopoulos, K.A. Olive, Phys. Lett. B 508 (2001) 65, arXiv:hep-ph/0102331;
X. Calmet, H. Fritzsch, D. Holtmannspotter, Phys. Rev. D 64 (2001) 037701, arXiv:hep-ph/0103012;
K. Choi, K. Hwang, S.K. Kang, K.Y. Lee, W.Y. Song, Phys. Rev. D 64 (2001) 055001, arXiv:hep-ph/0103048;
S. Rajpoot, arXiv:hep-ph/0103069;
C.A. de S. Pires, P.S. Rodrigues da Silva, Phys. Rev. D 64 (2001) 117701, arXiv:hep-ph/0103083;
E.O. Iltan, H. Sundu, Acta Phys. Slov. 53 (2003) 17, arXiv:hep-ph/0103105;
S. Baek, P. Ko, H.S. Lee, Phys. Rev. D 65 (2002) 035004, arXiv:hep-ph/0103218;
M. Raidal, Phys. Lett. B 508 (2001) 51, arXiv:hep-ph/0103224;
A. Dedes, H.E. Haber, arXiv:hep-ph/0105014;
E.O. Iltan, JHEP 0305 (2003) 065, arXiv:hep-ph/0304097;
H. Chavez, C.N. Ferreira, J.A. Helayel-Neto, Phys. Rev. D 74 (2006) 033006, arXiv:hep-ph/0410373;
A. Mondragon, M. Mondragon, E. Peinado, J. Phys. A 41 (2008) 304035, arXiv:0712.1799 [hep-ph].
[8] M. Schmaltz, Phys. Rev. D 52 (1995) 1643, arXiv:hep-ph/9411383;
L.J. Hall, H. Murayama, Phys. Rev. Lett. 75 (1995) 3985, arXiv:hep-ph/9508296;
C.D. Carone, R.F. Lebed, Phys. Rev. D 60 (1999) 096002, arXiv:hep-ph/9905275;
P.H. Frampton, A. Rasin, Phys. Lett. B 478 (2000) 424, arXiv:hep-ph/9910522;
R. Dermisek, S. Raby, Phys. Rev. D 62 (2000) 015007, arXiv:hep-ph/9911275;
G. Altarelli, F. Feruglio, New J. Phys. 6 (2004) 106, arXiv:hep-ph/0405048;
K.S. Babu, J. Kubo, Phys. Rev. D 71 (2005) 056006, arXiv:hep-ph/0411226;
N. Haba, K. Yoshioka, Nucl. Phys. B 739 (2006) 254, arXiv:hep-ph/0511108;
Y. Kajiyama, E. Itou, J. Kubo, Nucl. Phys. B 743 (2006) 74, arXiv:hep-ph/0511268;
C. Hagedorn, M. Lindner, R.N. Mohapatra, JHEP 0606 (2006) 042, arXiv:hep-ph/0602244;
T. Kobayashi, H.P. Nilles, F. Ploger, S. Raby, M. Ratz, Nucl. Phys. B 768 (2007) 135, arXiv:hep-ph/0611020;

M.C. Chen, K.T. Mahanthappa, Phys. Lett. B 652 (2007) 34, arXiv:0705.0714 [hep-ph];
M. Frigerio, E. Ma, Phys. Rev. D 76 (2007) 096007, arXiv:0708.0166 [hep-ph];
S. Sen, Phys. Rev. D 76 (2007) 115020, arXiv:0710.2734 [hep-ph];
G. Altarelli, arXiv:0711.0161 [hep-ph];
N. Kifune, J. Kubo, A. Lenz, Phys. Rev. D 77 (2008) 076010, arXiv:0712.0503 [hep-ph];
M. Honda, M. Tanimoto, Prog. Theor. Phys. 119 (2008) 583, arXiv:0801.0181 [hep-ph];
G. Altarelli, F. Feruglio, C. Hagedorn, JHEP 0803 (2008) 052, arXiv:0802.0090 [hep-ph];
F. Plentinger, G. Seidl, W. Winter, JHEP 0804 (2008) 077, arXiv:0802.1718 [hep-ph];
C. Luhn, Phys. Lett. B 670 (2009) 390, arXiv:0807.1749 [hep-ph];
P.H. Frampton, S. Matsuzaki, Mod. Phys. Lett. A 24 (2009) 2081, arXiv:0810.1029 [hep-ph];
D.A. Eby, P.H. Frampton, S. Matsuzaki, Phys. Lett. B 671 (2009) 386, arXiv:0810.4899 [hep-ph];
F. Bazzocchi, S. Morisi, Phys. Rev. D 80 (2009) 096005, arXiv:0811.0345 [hep-ph];
P.H. Frampton, S. Matsuzaki, Phys. Lett. B 679 (2009) 347, arXiv:0902.1140 [hep-ph];
D.A. Eby, P.H. Frampton, S. Matsuzaki, Phys. Rev. D 80 (2009) 053007, arXiv:0907.3425 [hep-ph];
M.C. Chen, K.T. Mahanthappa, F. Yu, arXiv:0907.3963 [hep-ph];
M.C. Chen, K.T. Mahanthappa, Phys. Lett. B 681 (2009) 444, arXiv:0904.1721 [hep-ph];
F. Feruglio, C. Hagedorn, Y. Lin, L. Merlo, Nucl. Phys. B 809 (2009) 218, arXiv:0807.3160 [hep-ph];
F. Feruglio, C. Hagedorn, Y. Lin, L. Merlo, Nucl. Phys. B 775 (2007) 120, arXiv:hep-ph/0702194.

[9] R. Barate, et al., LEP Collaborations, Phys. Lett. B 565 (2003) 61.