arXiv:hep-ph/0102131 v2 22 Feb 2001

BUHEP-01-3
hep-ph/0102131

New Model–Independent Limit on Muon Substructure

Kenneth Lane*

Department of Physics, Boston University,
590 Commonwealth Avenue, Boston, MA 02215

April 19, 2001

Abstract

If the discrepancy between the theoretical and newly measured values of the muon's anomalous magnetic moment is ascribed to muon substructure, there results an improved model–independent limit on its energy scale, $1.2\,\text{TeV} < \Lambda_\mu < 3.2\,\text{TeV}$ at 95% C.L.

*lane@physics.bu.edu

The Muon $(g-2)$ Collaboration has announced a new measurement of the anomalous magnetic moment of the positive muon [1],

$$a_{\mu^+} = \tfrac{1}{2}(g-2)_{\mu^+} = 11\ 659\ 202(14)(6) \times 10^{-10}\ (1.3\,\mathrm{ppm})\,. \tag{1}$$

The value currently expected in the standard model is [2]

$$a_\mu(\mathrm{SM}) = 11\ 659\ 159.6(6.7) \times 10^{-10}\ (0.57\,\mathrm{ppm})\,. \tag{2}$$

Using the world–average experimental value of the muon's anomalous moment, there is now a discrepancy with theory of 2.6 standard deviations:

$$\delta a_\mu \equiv a_\mu(\mathrm{exp}) - \mathrm{a}_\mu(\mathrm{SM}) = 43(16) \times 10^{-10}\,. \tag{3}$$

This error is smaller than that of previous measurements by about a factor of three [3].

If the muon is a composite fermion at the scale $\Lambda_\mu \gg m_\mu$, there is a contribution to its magnetic moment of [4]

$$\delta a_\mu(\Lambda_\mu) \simeq \frac{m_\mu^2}{\Lambda_\mu^2}\,. \tag{4}$$

If δa_μ is ascribed to muon substructure, the scale is $\Lambda_\mu \simeq 1.6\,\mathrm{TeV}$. It is more appropriate, however, to take advantage of the new smaller error by interpreting δa_μ to limit Λ_μ. For example, its 95% C.L. range is

$$1.2\,\mathrm{TeV} < \Lambda_\mu < 3.2\,\mathrm{TeV}\,. \tag{5}$$

If, as expected, analysis of the 2000 data for $g-2$ decreases its statistical error by half, but the central value and other errors do not change, this range will become $1.3\,\mathrm{TeV} < \Lambda_\mu < 2.3\,\mathrm{TeV}$

The importance of this bound is its model–independence. It requires no assumption on the compositeness of other quarks or leptons. Limits that do assume $\Lambda_e \simeq \Lambda_\mu$ and $\Lambda_{u,d} \simeq \Lambda_\mu$ come from $e^+e^- \to \mu^+\mu^-$ and $\bar{q}q \to \mu^+\mu^-$ [5]. They are $\Lambda_e \simeq \Lambda_\mu \gtrsim 4$–$5\,\mathrm{TeV}$ and $\Lambda_{u,d} \simeq \Lambda_\mu \gtrsim 3$–$4\,\mathrm{TeV}$ [6]. These lower bounds are more stringent, but they are also less incisive. There is no reason *a priori* for the equality of the first and second–generation lepton substructure scales.

Acknowledgements

I thank Robert Carey for a discussion of the new $g-2$ result of Ref. [1] and Estia Eichten, Bill Marciano, Jim Miller, and Lee Roberts for valuable comments. This research was supported in part by the Department of Energy under Grant No. DE–FG02–91ER40676.

References

[1] H. N. Brown, *et al.*, $(g-2)$ Collaboration, submitted to Physical Review Letters; hep-ex/0102017, v2.

[2] A. Czarnecki and W. J. Marciano, Nucl. Phys. (Proc. Supp.) **B76**, 245 (1999), and hep-ph/0010194 v2, and references therein.

[3] H. N. Brown *et al.*, $(g-2)$ Collaboration, Phys. Rev. **D62**, 091101 (2000); R. M. Carey, *et al.*, $(g-2)$ Collaboration, Phys. Rev. Lett. **82**, 1632 (1999); J. Bailey *et al.*, Nucl. Phys. **B150**, 1 (1979).

[4] E. Eichten, K. Lane and J. Preskill, Phys. Rev. Lett. **45**, 225 (1980); K. Lane, Physica Scripta **23**, 1005 (1981); further references are cited in Ref. [2]. Equation (4) represents a normalization of Λ_μ just as the conventional $4\pi/\Lambda^2$ does in contact interactions induced by substructure.

[5] E. J. Eichten, K. D. Lane, and M. E. Peskin, Phys. Rev. Lett. **50**, 811 (1983).

[6] D. E. Groom *et al.*, Review of Particle Physics, Eur. Phys. J. **C15**, 1 (2000).