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Searching for Physics Beyond the Standard Model with the World's Largest Penning Trap¹

B. LEE ROBERTS, Boston University

Measurements of the magnetic moments of the electron and muon were intertwined with the development of the modern physics of the 20th century, where $\vec{\mu} = g(Qe\hbar/2m)\vec{s}$ with $Q = \pm 1$ and $e > 0$. The g -value consists of a Dirac piece and the anomaly, $g = 2(1 + a)$ or $a = (g - 2)/2$. For point-like particles, a arises from radiative corrections. The simplest correction, $a = \alpha/2\pi \simeq 0.00116 \dots$, was first obtained by Schwinger. This result was also found to describe the muon's magnetic moment, indicating that the muon behaved like a heavy electron in a magnetic field. Loops containing all virtual particles that interact with the muon, including as yet undiscovered ones, can contribute to the muon anomaly. The relative contribution from heavier particles to the muon and electron anomalies scales as $(m_\mu/m_e)^2 \simeq 43,000$, giving the muon a distinct advantage in the search for effects from New Physics. E821 at the Brookhaven AGS obtained a relative precision of ± 0.54 ppm, half the magnitude of the contributions from the Z and W gauge bosons. This result differs from the Standard-Model prediction by $> 3\sigma$. To clarify whether this difference is a harbinger of New Physics beyond the Standard Model, E989 is being mounted at Fermilab with a design precision of 140 ppb. The 700 ton, 14 m diameter storage ring magnet will be shimmed to a point-to-point magnetic dipole field uniformity of ± 25 ppm over the 1.137 m^3 volume where the muon beam is stored, with the azimuthal averaged uniformity ≤ 1 ppm. Vertical focusing in the storage ring is provided by electrostatic quadrupoles placed with four-fold symmetry around the 44.7 m circumference of the storage ring. In this talk I will discuss the Standard-Model theory and the motivation for this new experiment, along with the experimental technique and outlook.

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