Background

In the presence of an external magnetic field, fermions acquire a magnetic moment

$$\mu = g \frac{Q}{2m} \hat{s}$$

where $g$ is the gyromagnetic ratio, $Q$ the electric charge, and $\hat{s}$ is the fermion’s spin vector. The anomalous part $\alpha$ of the magnetic moment is defined via the deviation of the gyromagnetic ratio: $g = 2(1 + \alpha)$.

The Fermilab E898 Muon g-2 experiment aims to measure $\alpha$ to a precision of 0.14 ppm\(^1\). The experiment stores muons inside a weak focusing ring, where a magnetic field and electrostatic quadrupoles (ESQs) provide inward radial and vertical focusing respectively. The magnetic field intensity corresponds to storing muons on the design radius (7.12 m) with a design momentum of 3.994 GeV/c. The measurement of $\alpha$ depends on the muon intrinsic spin precession frequency $\omega_0$, which is sensitive to the above fields. Due to a beam momentum spread of 0.1%, $\omega_0$ must be adjusted for the effect of a radial electric field. The correction relies on the equilibrium muon revolution frequency distribution, extracted via a modified Fourier analysis of the so-called fast rotation signal (FRS). The method was developed for E821 at BNL\(^2\), but we independently rederive several key results, as well as explore the numerical extension of the method, and compare simulation results to data from the recent commissioning run.

Theorerical Results

Background

- $\omega_0 = -\frac{q E}{m} \left[ a_0 \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \right]$ radial E-field contribution

- The FRS describes the beam intensity as seen by a detector at a fixed location in the ring. For a longitudinally point-like beam with momentum spread $\rho(\Delta)$, the FRS is given by

$$S_{\rho}(t) = \sum_{n=0}^{\infty} \rho \left(\frac{t}{nT + t_0} - \frac{nT}{t_0} \right)$$

If $t_0$ is the time when the center of mass of the beam first passes the detector. The muon revolution frequency distribution is given by the Fourier transform

$$\tilde{S}_\rho(\omega) = \frac{1}{\sqrt{\pi}} \int_{t_0}^{\infty} S_{\rho}(t) \cos(\omega(t - t_0)) \, dt$$

$$\rho(t) = \int_{t_0}^{\infty} \frac{\rho(\Delta)}{\Delta} \sin(\Delta t) \, d\Delta$$

The peaks obtained from simulation and real data feature a mismatch of ~75 kHz.

Future Work

- Studies on how muon losses and coherent betatron oscillations impact the frequency distribution.
- Most FRS data will come from calorimeter stations: must explore the analysis using calorimeter stations.

Simulation vs. Real Data

- Simulation conducted using the BMAD subroutine library; actual data acquired from scintillating-fiber beam monitor 2 in commissioning run #1835
- Predominantly protons in the fill

References


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