A Dedicated Period of Magnetic Field Systematics Studies in the Muon $g-2$ Experiment at Fermilab

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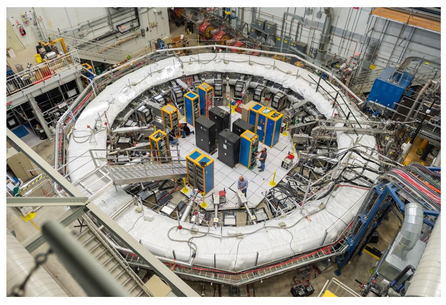
Muon $g-2$ Collaboration

Muon $g-2$

Searching for evidence of BSM physics in muons' spin precession in a magnetic field



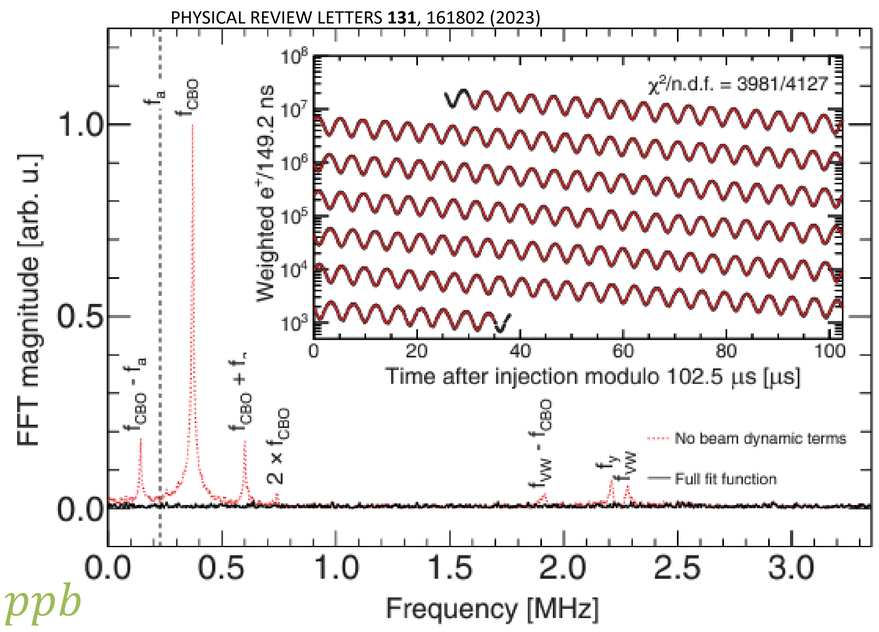
"known" constants

$$a_\mu = \frac{\omega_a}{\tilde{\omega}'_p(T_r)} * \frac{\mu'_p(T_r)}{\mu_e(H)} \frac{\mu_e(H)}{\mu_e} \frac{m_\mu}{m_e} \frac{g_e}{2}$$

Our measurements

$$R'_\mu = \frac{\omega_a}{\tilde{\omega}'_p(T_r)} = \frac{f_{clock} \cdot \omega_a^m \cdot (1 + C_e + C_p + C_{pa} + C_{dd} + C_{ml})}{f_{calib} \cdot \langle \omega'_p(\vec{r}) \times M(\vec{r}) \rangle \cdot (1 + B_q + B_k)}$$

Ultimate uncertainty goal: $\frac{\sigma_{a_\mu}}{a_\mu} \leq 140\ ppb$



Magnetic Field Systematics

- The Muon $g-2$ experiment is statistically limited; final systematic uncertainties are expected to be about a factor of 2 smaller than the final statistical uncertainty
- But some of the largest corrections come from the magnetic field characterization (materials and eddy currents different during field mapping than during muon data) → take some extra time to study them!

Run-2/3 $\tilde{\omega}'_p$ uncertainties

Description	Uncertainty (ppb) Run-2	Run-3a	Run-3b
Calibration probe		8.9	
Trolley calibration		17.8	
Spatial field maps	37.2	38.5	38.1
Tracking	17.3	16.5	17.8
Muon weighting	13.4	7.9	6.9
Transient booster		7	
Transient kicker	13.3		
Transient ESQ	19.5		
Subtotal uncorrelated	15.4	10.7	16.0
Subtotal correlated	51.3	52.0	50.6

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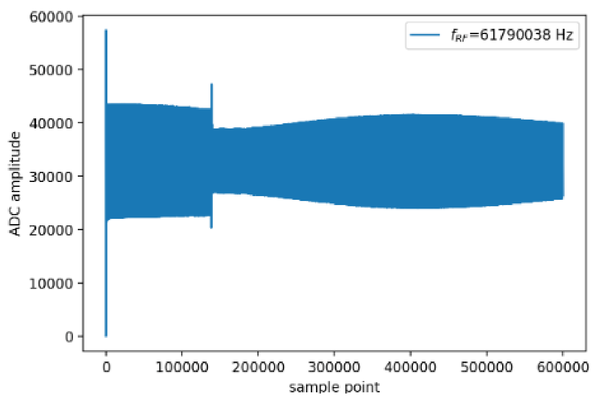
Large corrections + small claimed uncertainties

Largest field uncertainties

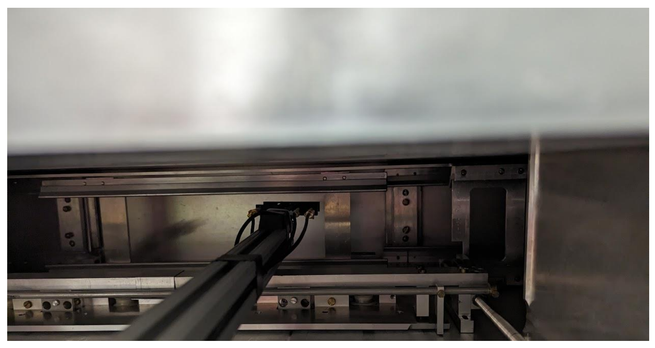
Smaller corrections with important testable assumptions

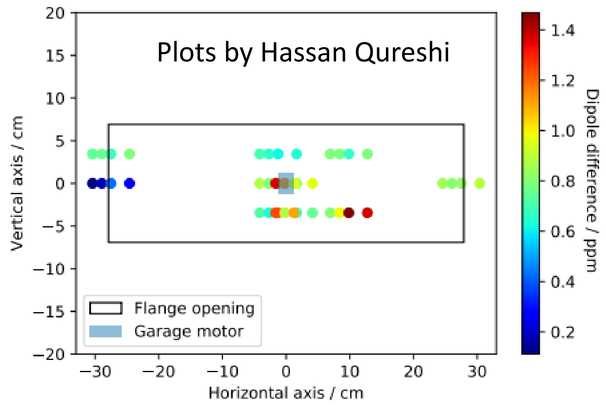
- **List of Post-Muon-Run Studies:**
  - Kicker transient spatial distribution
  - ESQ transient spatial distribution
  - Trolley garage and collimator configuration effects
  - Trolley calibration with Spin-Echo NMR
  - Calibration probe cross-calibrations
  - Calibration probe intrinsic and configuration effects
  - Fringe field measurement
  - Time-after-ramp effect
  - Trolley motion effects

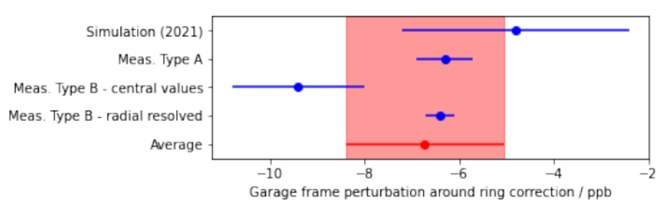
Spin-Echo NMR



Trolley Garage Configuration

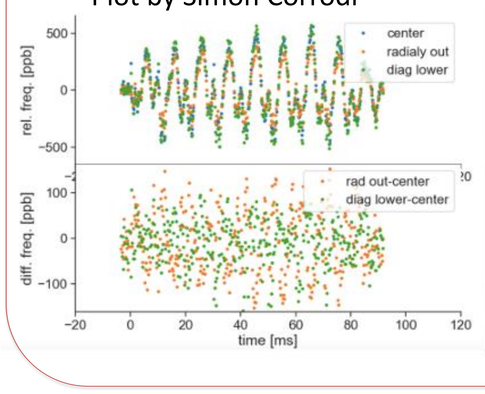


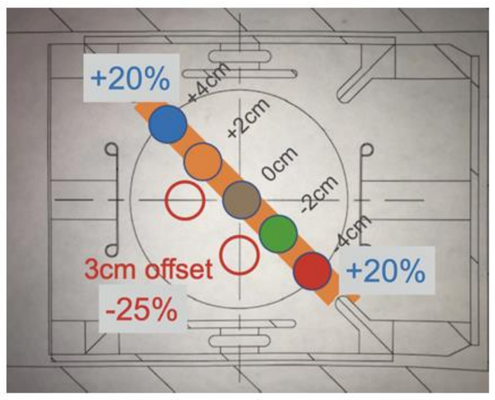




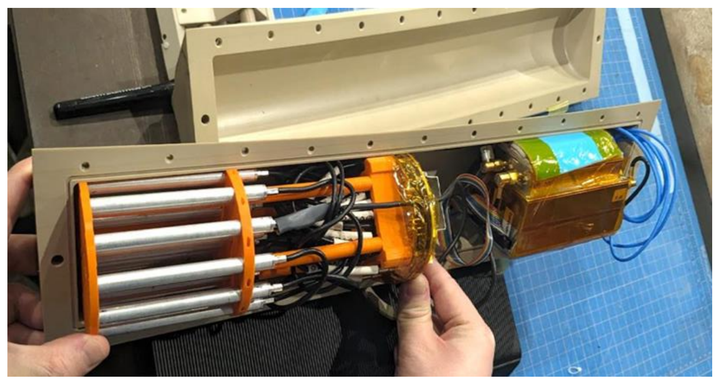
ESQ Transient

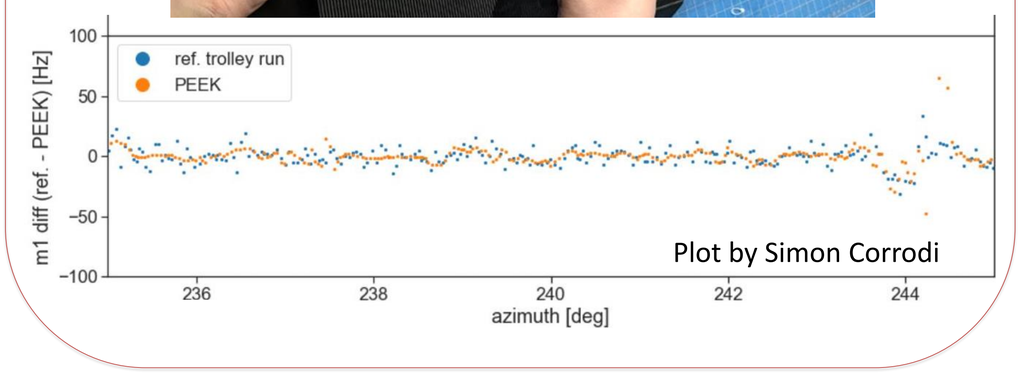
Plot by Simon Corrodi





Trolley Motion Effect





Calibration Probe Effects