Kicker Transient Field Measurements for Muon g-2

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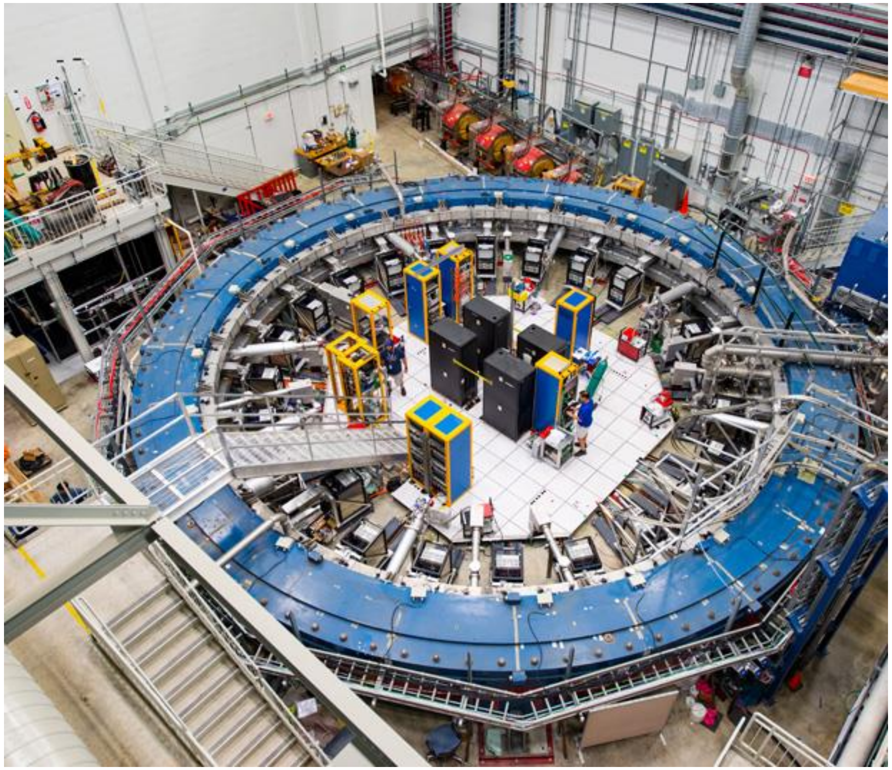
The g-2 Storage Ring Magnet

- We find g-2 by relating **anomalous precession frequency $\overrightarrow{w_a}$** to **magnetic field $\vec{B}$**.

$$\overrightarrow{w_a} = (g-2) * \frac{-q}{2m_\mu} * \vec{B}$$

- NMR probes measure $\vec{B}$, tracking fluctuations and drift during the experiment.
  - 378 probes arranged into 72 stations measure every 1.3 seconds.
  - Good at tracking long-term effects, but not built to see fast effects.
- **Fast Transient Fields** in the ring must be measured separately, with unique apparati.



The storage ring contains muon beams with a 1.45-Tesla magnetic field.

Kicker and Kicker Transient Field

- The **Kicker** kicks muon beams into the correct trajectory to orbit the storage ring, by making a 220-Gauss magnetic field for ~0.2 microseconds.
- This rapid change induces eddy currents in all surrounding metal, creating the smaller but longer-lived **Kicker Transient Field.**
- Measuring the kicker transient field is a large priority in g-2.
  - The earlier E821 experiment at BNL assigned 100 ppb uncertainty from limits on the kicker transient field.
  - In g-2, the goal for total $\vec{B}$ uncertainty is only 70 ppb!

A mockup of the kicker cage, used for tests and practice measurements.

Challenges in Measuring Kicker Transient

- Needs 1 mG resolution, and 1 MHz bandwidth.
- Must be vacuum-compatible below 10^-6 Torr.
- Must resist interference from vibrations when kicker activates.
- Cannot add any metal to measurement region, to avoid changing eddy currents.

The Faraday Effect

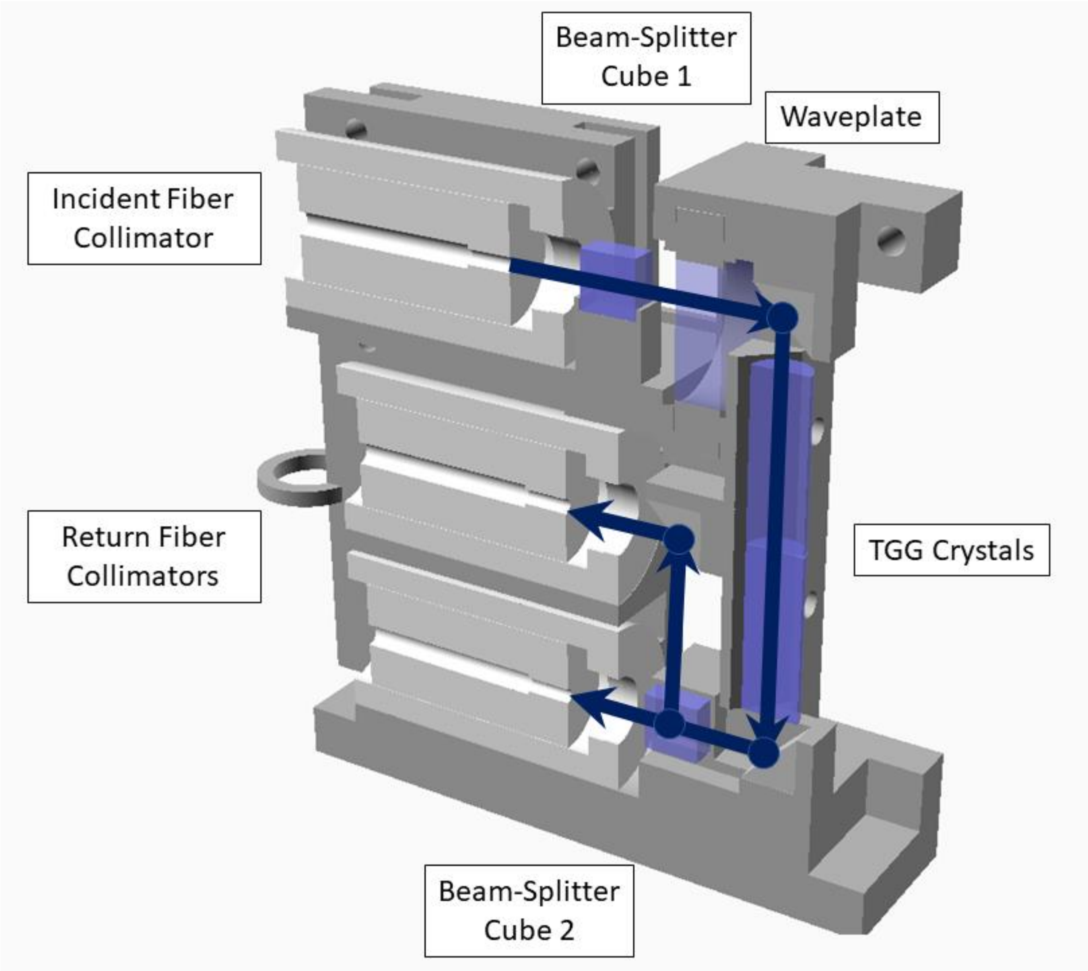
- **Faraday Effect** – When light travels through dielectric media, its polarization rotates proportionally to an external magnetic field.

$$d\varphi = v * \vec{B} \cdot \vec{L}$$

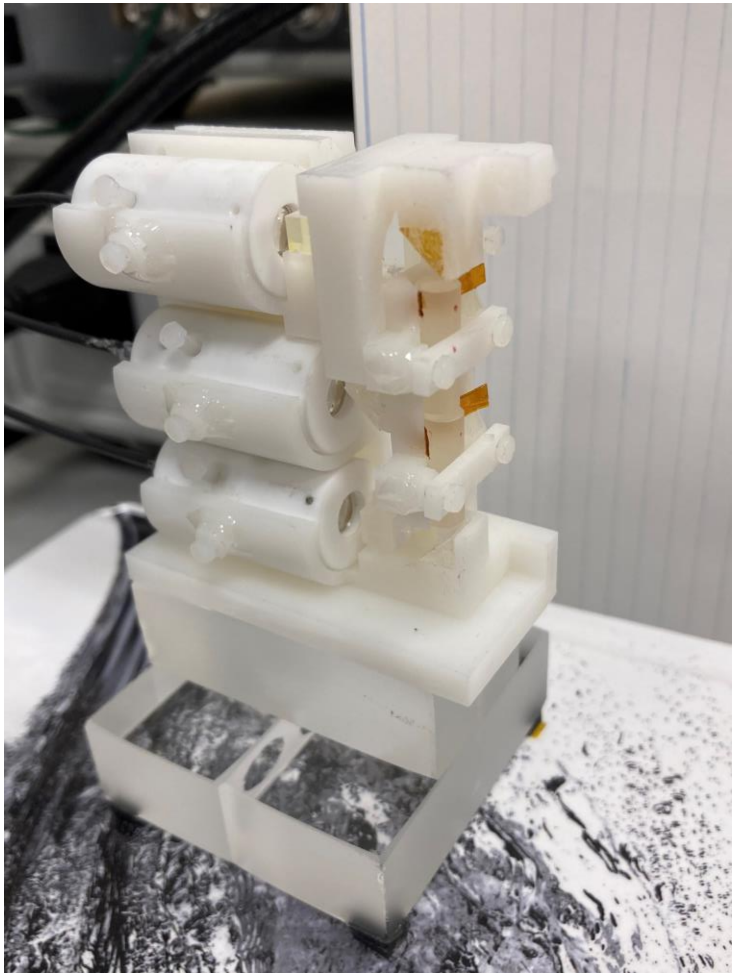
  – This happens because the medium gains different indices of refraction for RH and LH circular-polarized light.

- We measure the kicker transient field by sending laser light through TGG crystals inside the storage ring, then retrieving the light and measuring the polarization.
  – UMass team uses fiber optics to transport light. INFN and KAIST teams aim laser through free space.

UMass Fiber Optic Faraday Magnetometer



Cross-section Diagram



Photograph

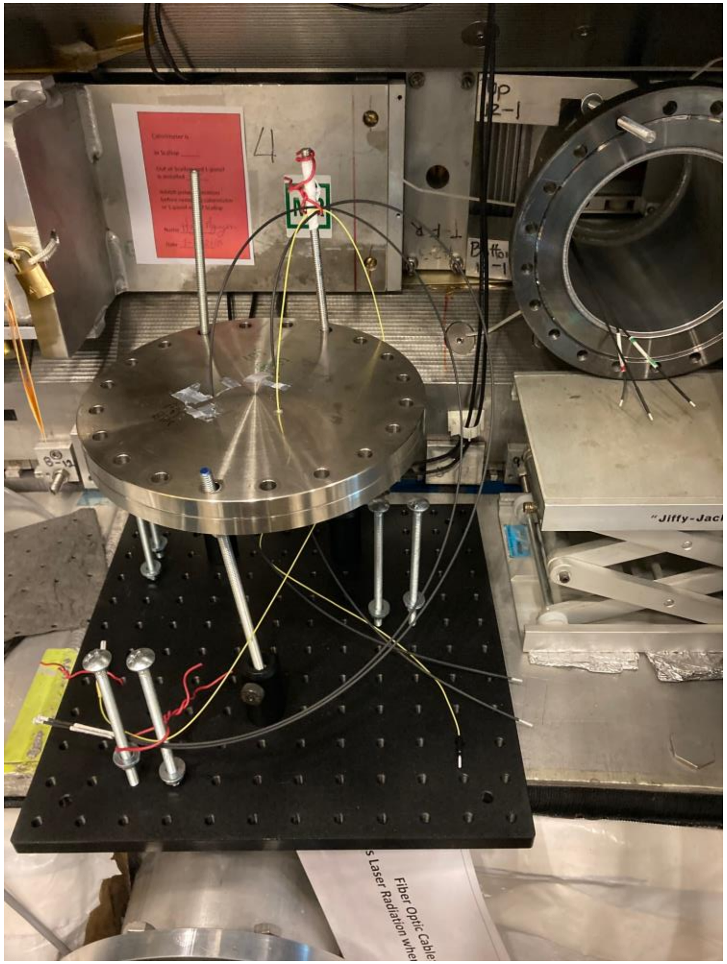
Vibration Suppression

- Vibrations are our biggest obstacle.
  - Just 1 milliradian (0.06 degrees) of crystal tilt is enough to overshadow the transient field signal!

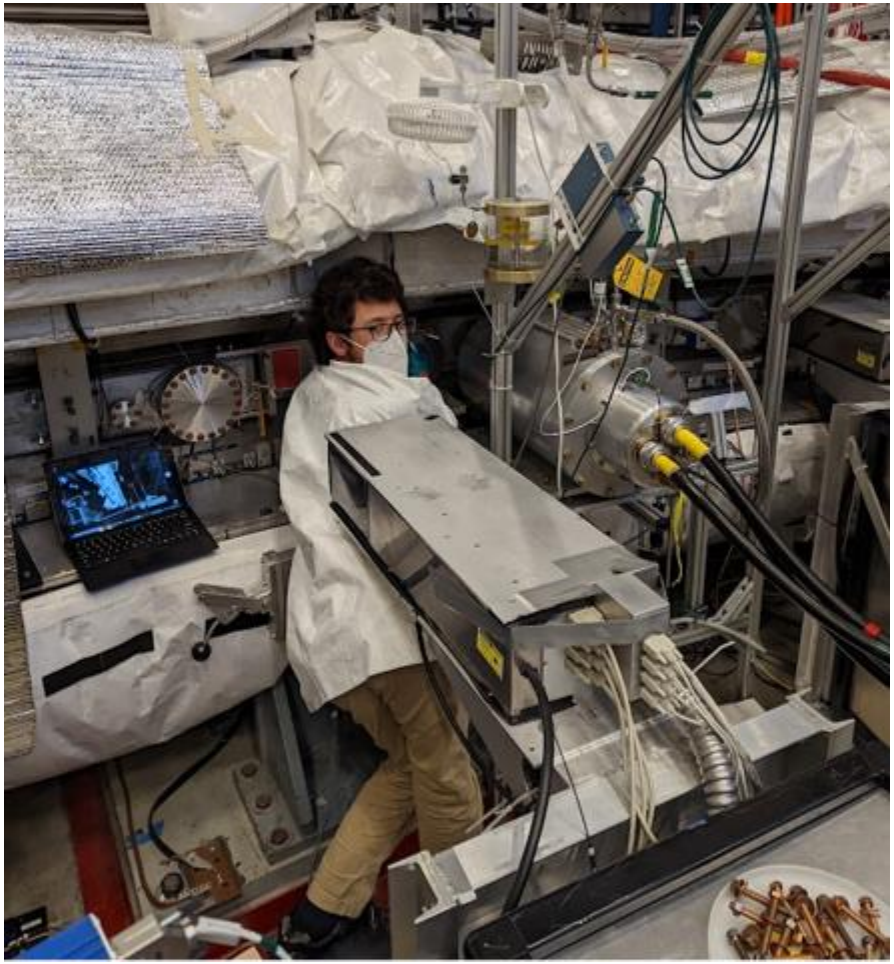
Mitigation techniques:

- Bridge across kicker cage.
- Sorbothane foundation.
- Silicone fiber-supporting bands.

Vacuum Flange

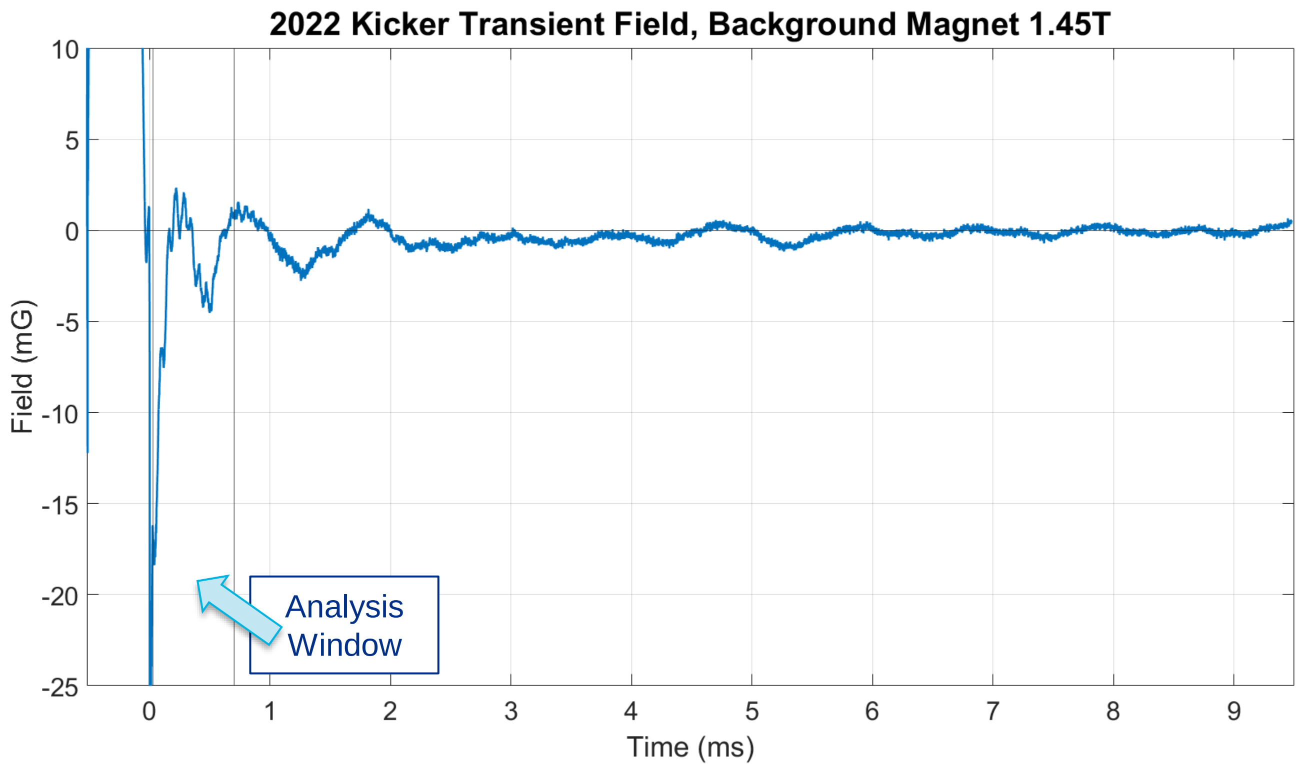


Fibers in the flange connect to fibers from the magnetometer.



The installation process requires patience, precision, and flexibility.

Results



- This is an average of 3.5 million measurements, collected over two weeks in 2022.
- Additional datasets under different conditions help us learn more about the field and sources of noise.

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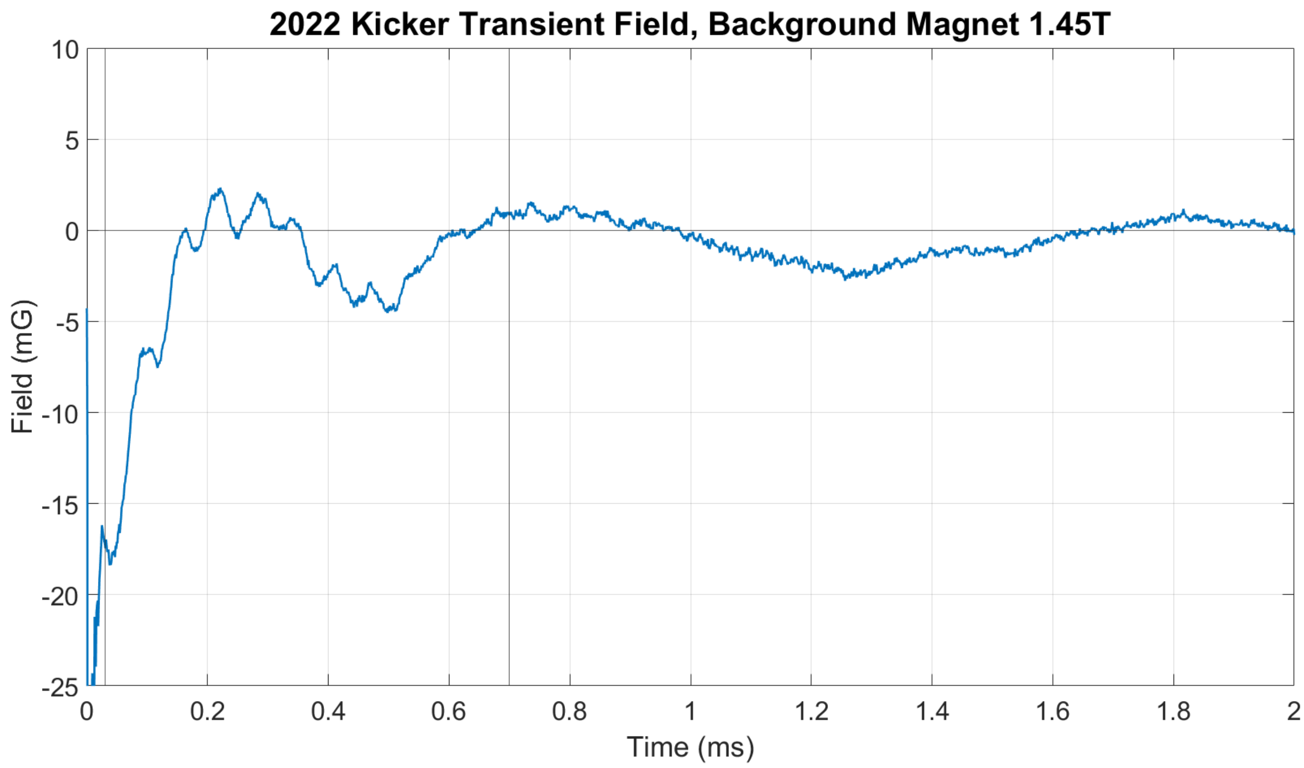

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Conclusion

- We are currently finalizing our results and uncertainties.
- Thank you for listening!
- Any questions or comments?