The Muon g-2 Straw Tracking Detectors

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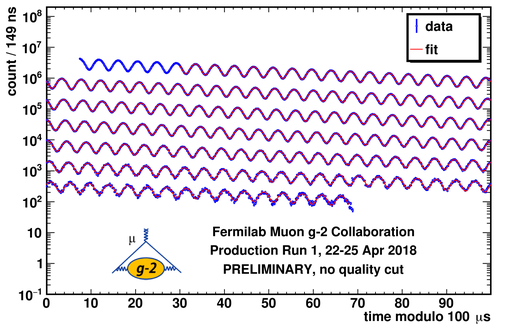
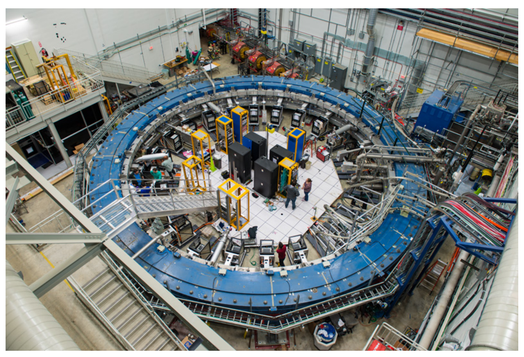
The g-2 Experiment

- Built to measure the muon anomalous magnetic moment to an uncertainty of 140 ppb and search for a muon electric dipole moment.
- Determine whether discrepancy from the Standard Model in the previous experiment $\Delta a_\mu(E821 - SM) = (255 \pm 80)\times 10^{-11}$ is a statistical fluctuation or indicates non-SM physics.
- A muon storage ring located at Fermilab, Illinois.
- 15m diameter storage ring.
- 1.45T uniform magnetic field.
- 24 calorimeters around the ring.
- 2 tracking stations.
- Storing 100s of billions of muons.





Role Of Tracking

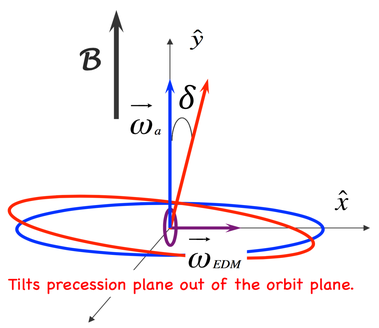
Main aims:

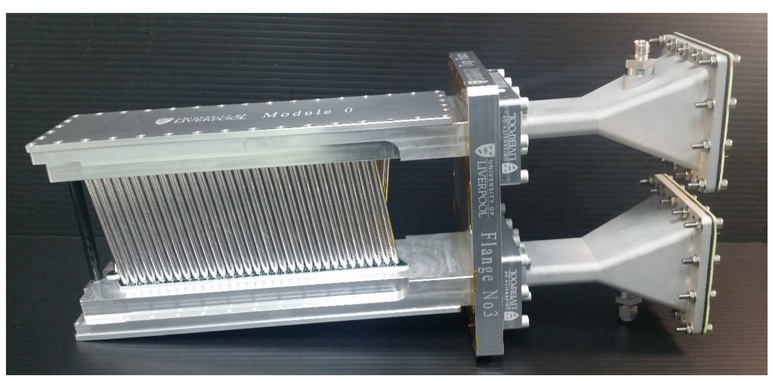
- Measure the momentum of e^+ from the μ^+ decay.
- Non destructive measurement of beam position and width throughout fill.
- Identify pileup in calorimeters.

Uncertainty	E821 value	E989 goal	Role of tracking
Magnetic field seen by muons	30 ppb	10 ppb	Measure beam profile on a fill by fill basis ensuring proper muon beam alignment
Beam dynamics corrections	50 ppb	30 ppb	Measure beam oscillation parameters as a function of time in the fill
Pileup correction	80 ppb	40 ppb	Isolate time windows with more than one positron hitting the calorimeter to verify calorimeter based pileup correction
Calorimeter gain stability	120 ppb	20 ppb	Measure positron momentum with better resolution than the calorimeter to verify calorimeter based gain measurement
Precession plane tilt	4.4 μRad	0.4 μRad	Measure up-down asymmetry in positron decay angle

Secondary aim:

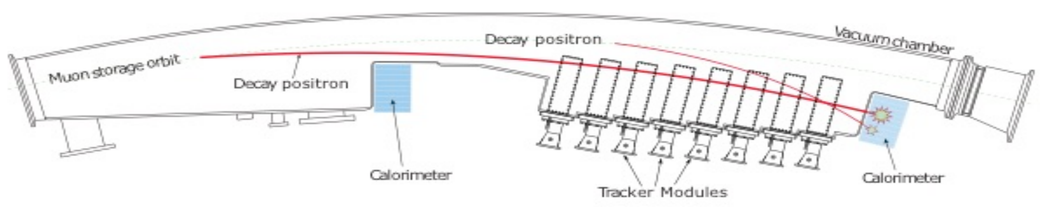
- To increase the limit of the EDM measurement by two orders of magnitude to a value of the order 10^{-21}e·cm.
- Determine if there is any tilt in the muon precession plane away from the vertical orientation.
- A tilt in the precession plane leads to an up-down asymmetry in the positron angle that can only be measured with the tracking detectors.

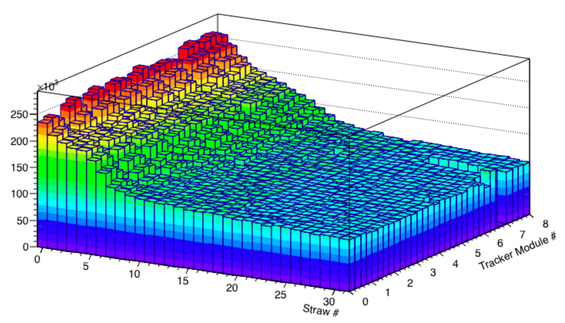




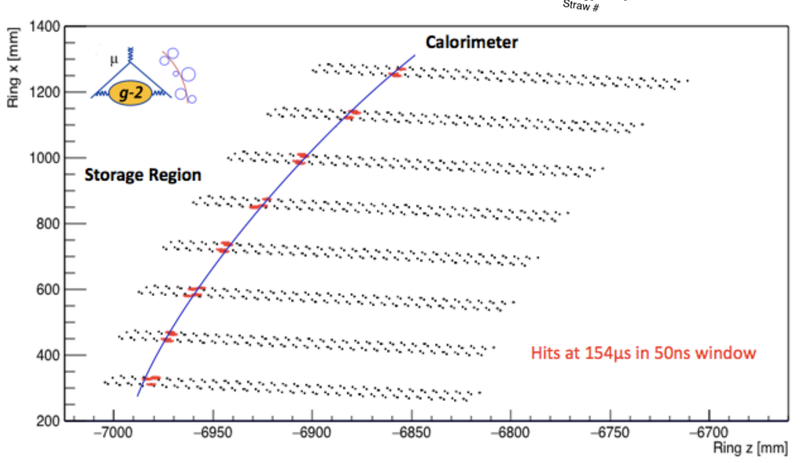
Trackers per station	8
Straws in each of the 4 layers	32
Straw material	Aluminized Mylar
Straw wall thickness	15 μm
Wire	25 μm gold-plated Tungsten
Straw length	9 cm
Stereo angle	$\pm$7.5° from vertical
Gas	50:50 Argon: Ethane
Pressure	1 Atm

Straw Tracking Detectors

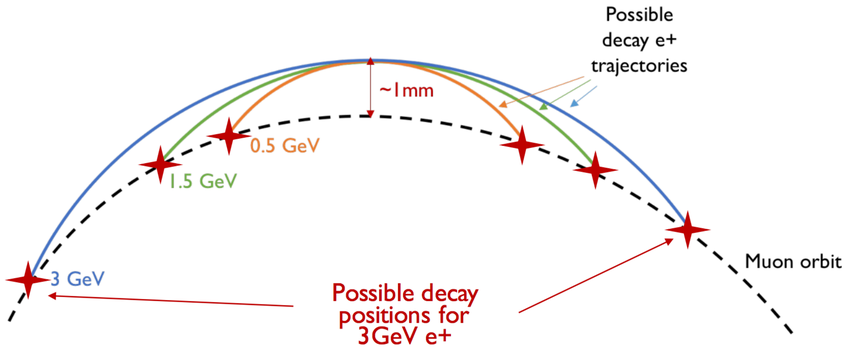




- 2 tracking stations placed at 180° and 270° around the storage ring.
- Polarized muons are injected into storage ring.
- Muons decay in the storage ring.
- Positrons pass through trackers on the way to calorimeters.
- We take positron hits from tracker and reconstruct track parameters at entry point: P_{tot}, P_x, P_y, x, y, t.
- Extrapolate back to beam and forwards to calorimeter.



- Extrapolate fitted tracks in detector back to the decay point using a Runga-Kutta algorithm.
- This swims the tracks through the varying magnetic field and stores positions and momenta step by step.
- Extrapolate to the radial tangent point where the positron momentum is parallel to the magic momentum (3.09 GeV/c).
- This is the estimated muon decay position.

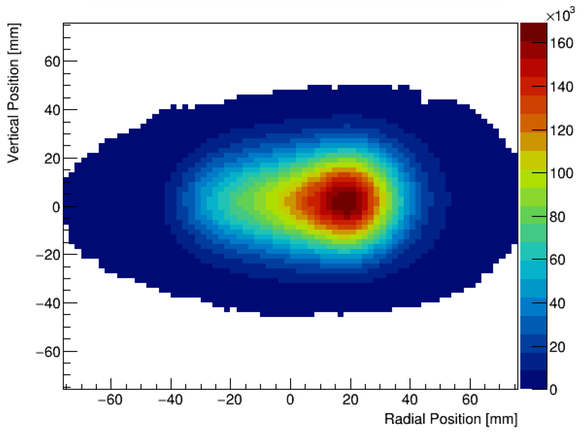


Beam Distribution

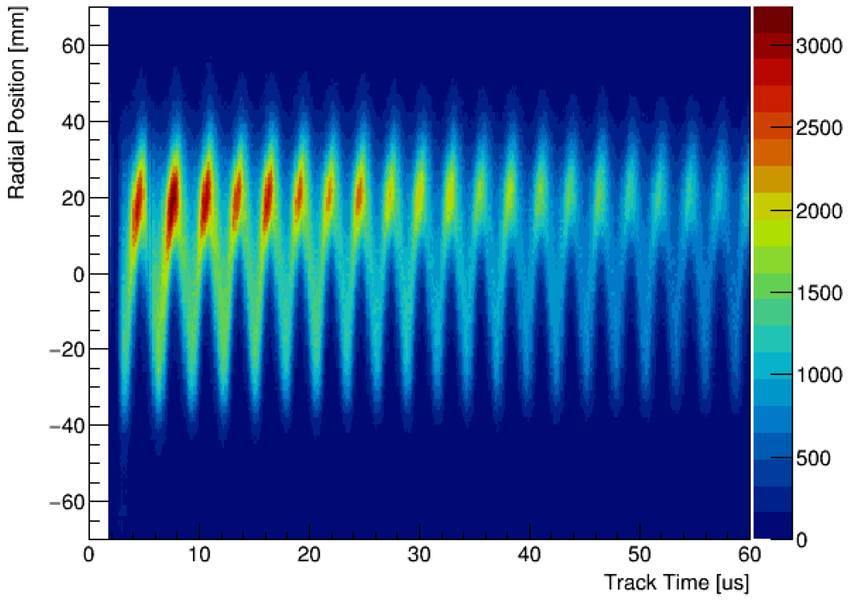
Tracking detectors measure characteristics of the muon beam:

- Momentum spread of the beam.
- Muon spatial distribution in fill.
- Width of beam in fill.

Vertical position vs radial position



Radial position vs time



- Data used to validate beam dynamics model and constrain systematics.