Improving Magnetic Field Uniformity in the Muon g-2 Storage Ring

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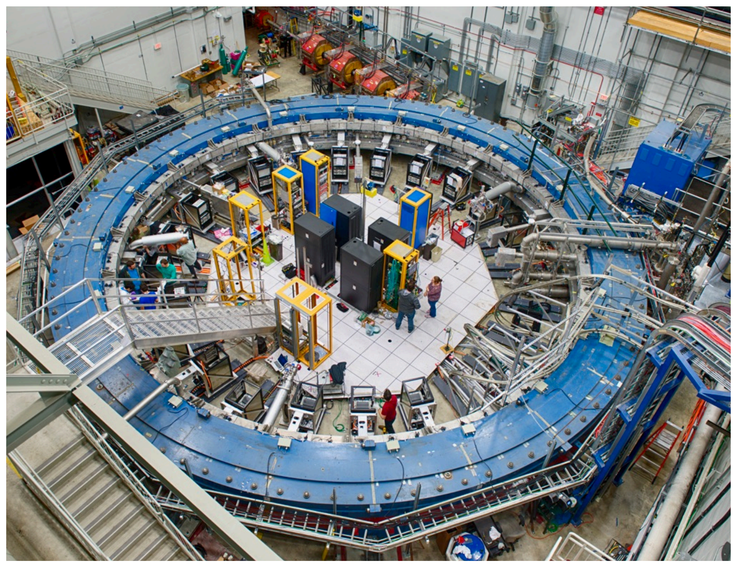
On behalf of the g-2 collaboration

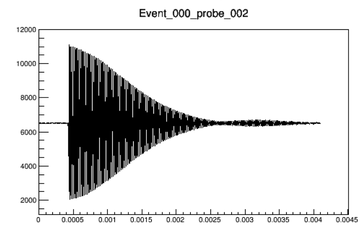
The Muon g-2 Experiment

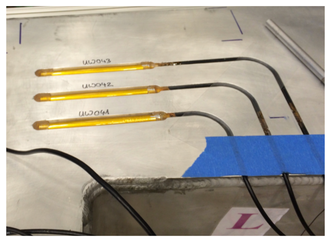
- Measure the anomalous magnetic moment of the muon to 140 parts per billion (ppb)
- Measure the difference between cyclotron and spin precession frequencies of muons in a highly uniform magnetic field
- Will shed light on 3.5 sigma standard deviation between Standard Model calculations and previous experiment



Magnetic Field Mapping and Uniformity

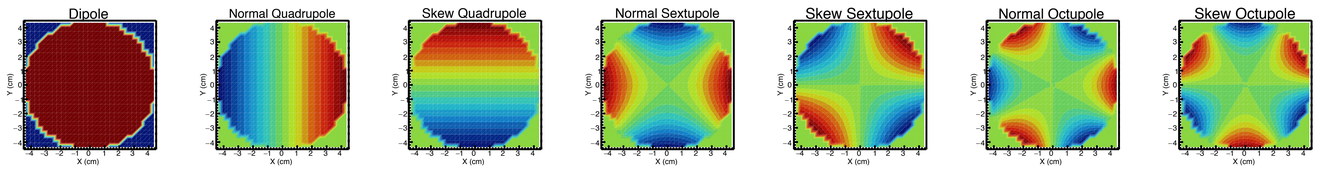
- Magnetic field measured using pulsed proton nuclear magnetic resonance (pNMR) probes
- Transverse fields measured with Hall probes
- Storage region field mapped every 3-4 days by trolley





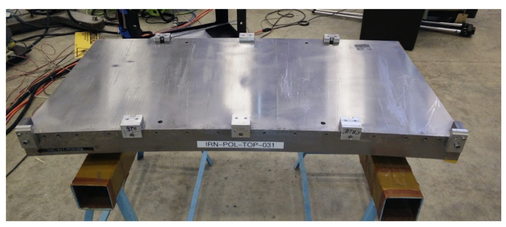
- Field drift monitored by 378 pNMR probes mounted outside of vacuum chambers
- B-field described by 2D multipoles
- Must be known to 70ppb with all azimuthally averaged multipoles smaller than 1ppm

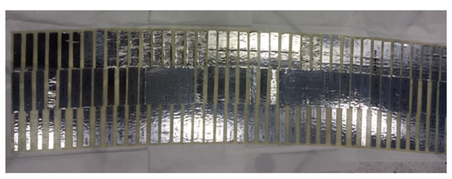
$$B(r,\theta) = B_0 + \sum_{n=0}^{4} \left(\frac{r}{r_0}\right)^n \left[a_n Cos(n\theta) + b_n Sin(n\theta)\right]$$

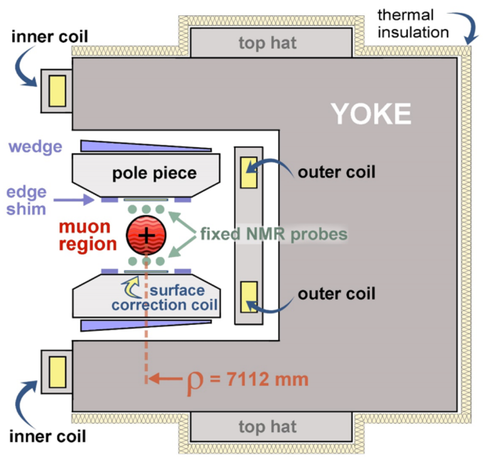


Passive Shimming

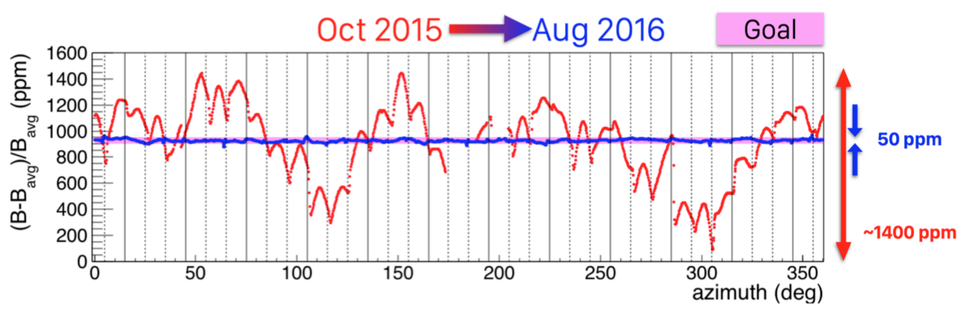
- Shimming: process of smoothing variations of the magnetic field
- Passive shimming: movement and addition of over 10,000 pieces of ferrous and nonferrous material
- October 2015: dipole variations of ±700ppm, 25ppm normal quadrupole moment
- August 2016: dipole variations of ±25ppm, all multipoles at couple of ppm level



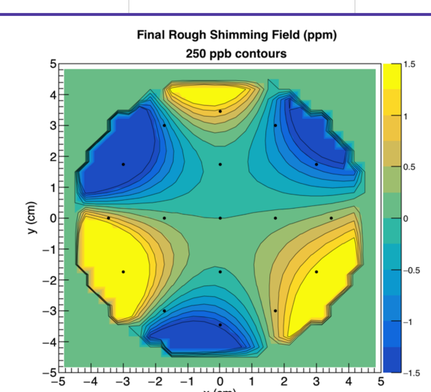
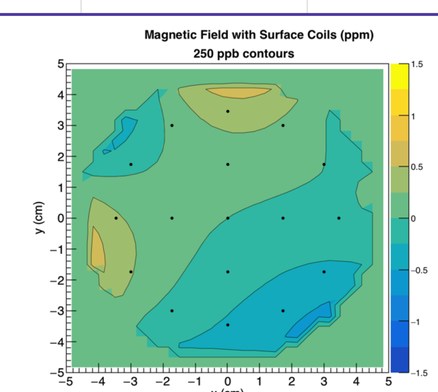




g-2 Magnet in Cross Section



Active Shimming

- Power supply feedback: regulation of main magnet current to keep dipole field constant
- Surface coils: two sets of 100 current carrying coils, above and below vacuum chambers
- Different radial dependence of currents targets different field multipoles
- Use linear combination of different configurations to minimize azimuthally averaged multipoles and transverse field components

Multipole	Normal, top	Normal, bottom	Skew, top	Skew, bottom
Dipole	—	—	1	1
Quadrupole	a	a	x	-x
Sextupole	ax	ax	x^2-a^2	$-x^2+a^2$
Octupole	$3ax^2-a^3$	$3ax^2-a^3$	x^3-3a^2x	$-x^3+3a^2x$
Decupole	ax^3-a^3x	ax^3-a^3x	$x^4+a^4-6a^2x^2$	$-x^4-a^4+6a^2x^2$