g-2 B; Precision is the Question

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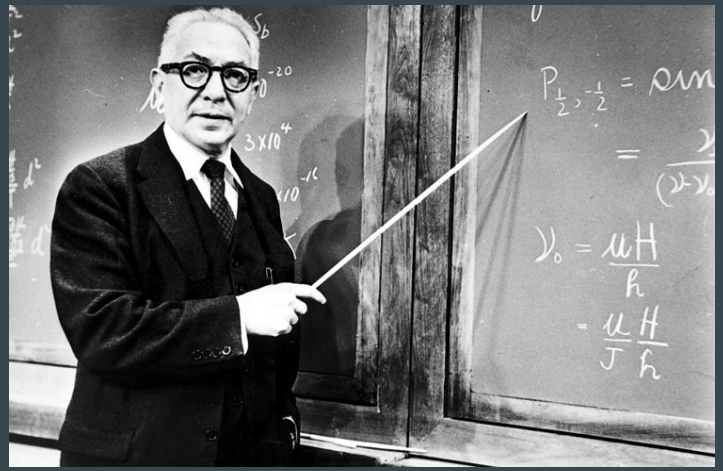
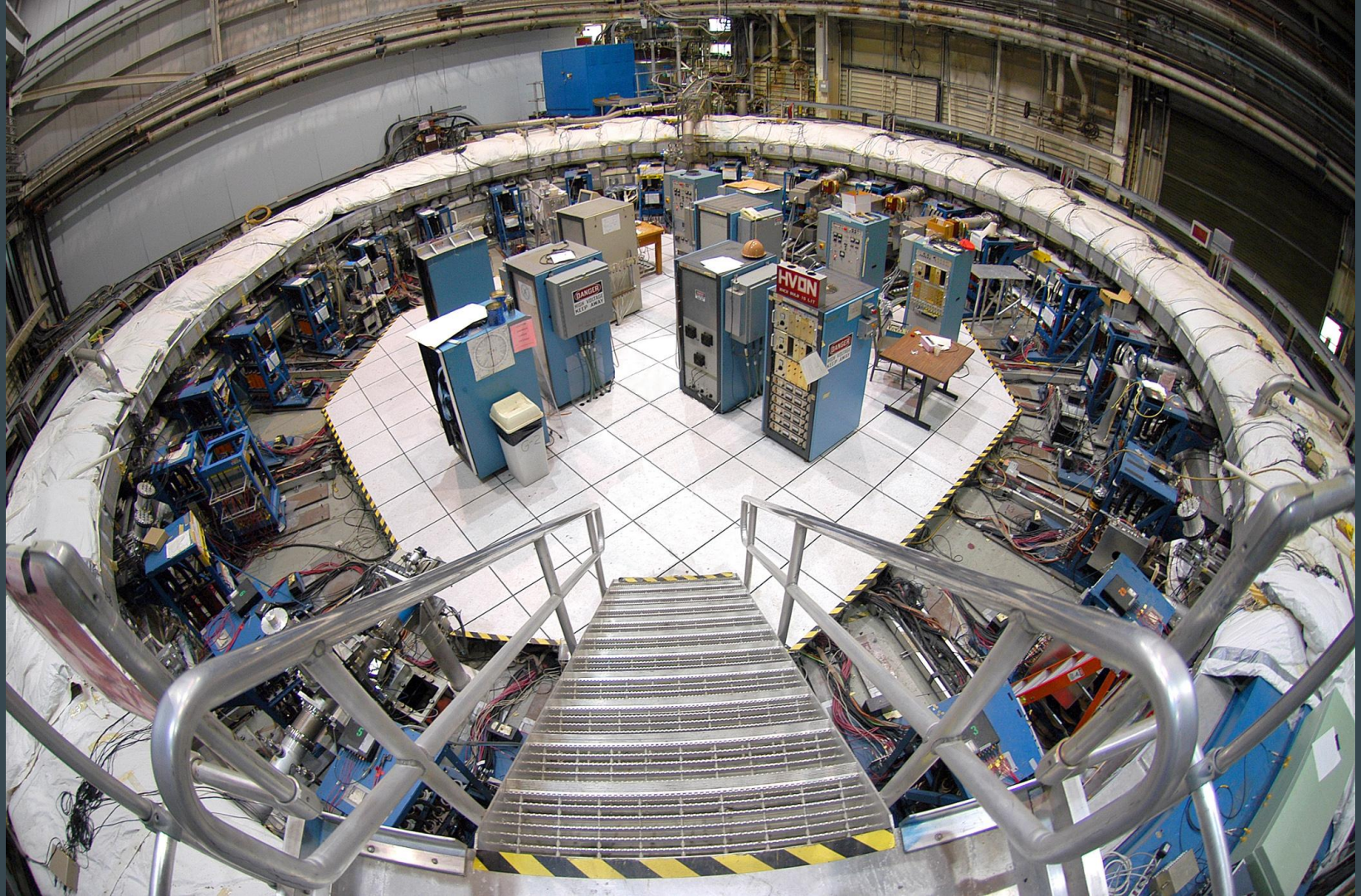
The Muon “who ordered that??” - I.I. Rabi



- Sibling to Electron & Tau
- 207 times Electron mass
- Spin ½
- Point-like
- Charged -1 (here +1)
- Decays to positron & neutrino pair
- Life of 2 microseconds
- Gyromagnetic “g” factor of 2 predicted by Dirac Equation


HVON
DANGER
DANGER

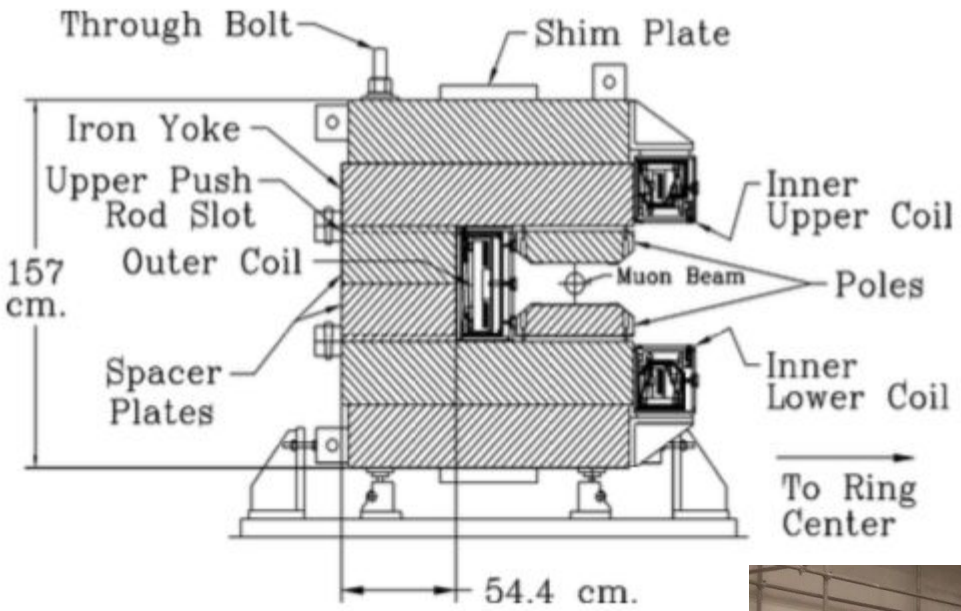
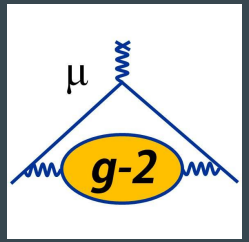


Fig. 2. A cross-section view of the magn

G-2

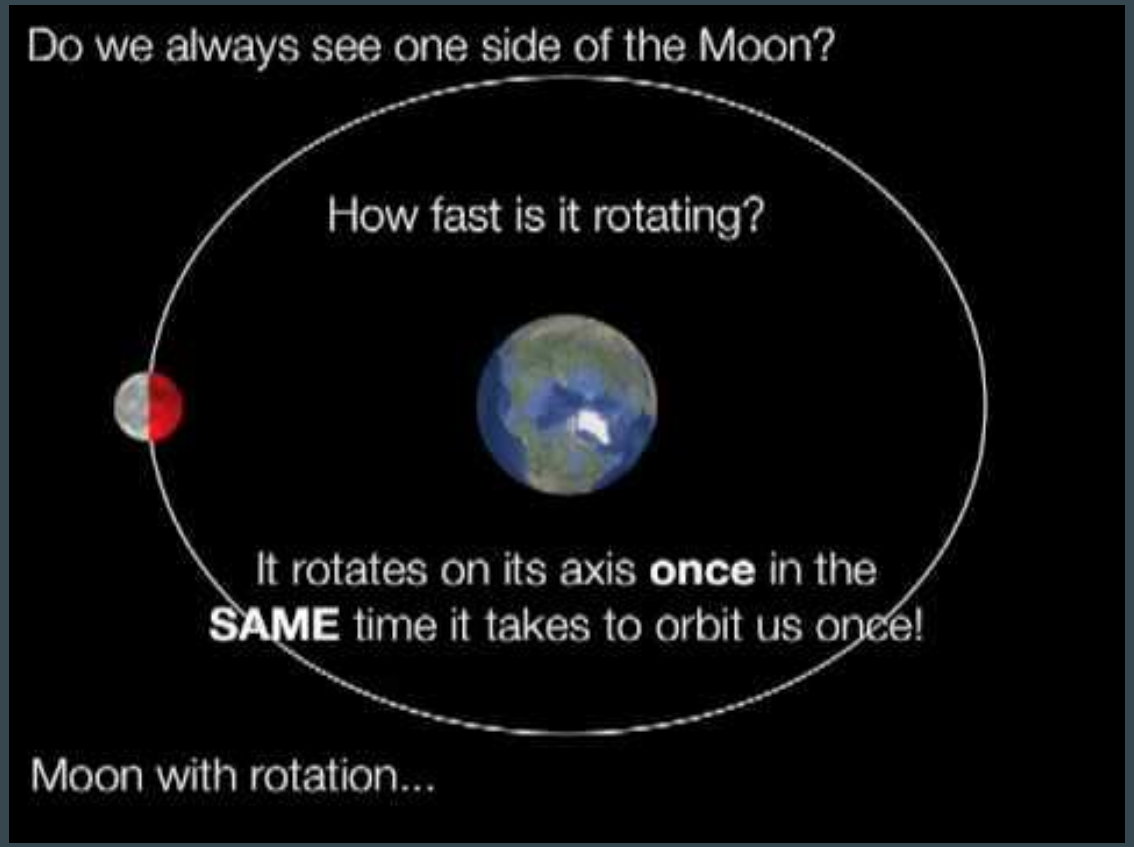


- Measures the anomaly of g
- 1.45 T B field sends charged particles in a circle
- 711 cm radius to beam
- Cyclotron = precession frequency (149 ns)
- Precession dependent on field strength
- Need an extremely precise & consistent field

Precession

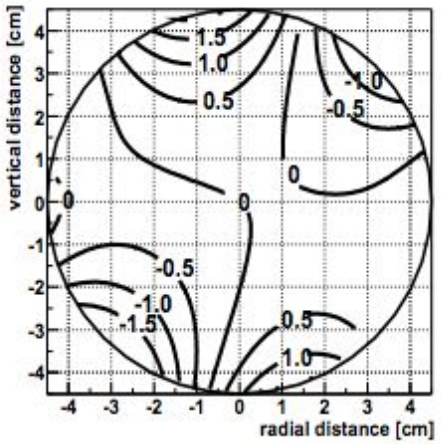
- Cyclotron (orbital) frequency is
  - $w_c = eB/mc$
- There is also the precession frequency
  - $W_p = g\,(e/2mc)\,B$
- Some value substitutions and algebra later...
  - $W_p = W_c$

Precession is essentially a synchronous orbit



Field at Brookhaven

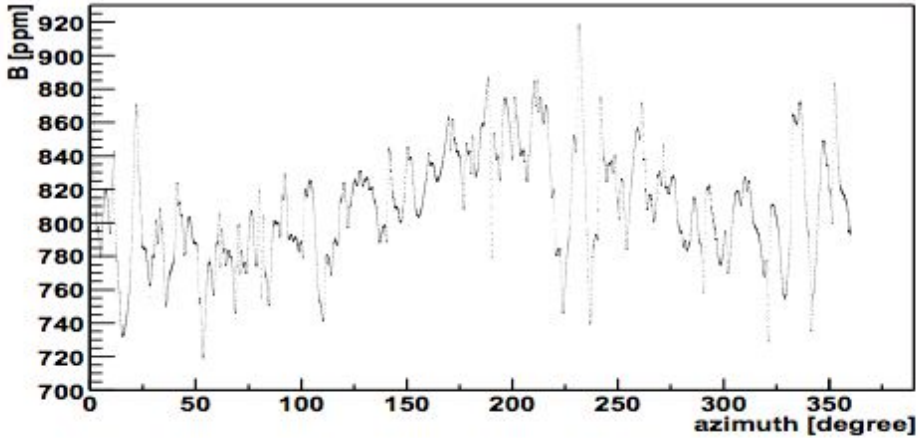
- +/- 200 ppm azimuthally
- +/- 1 ppm average
- Allowed accuracy of 540 ppb



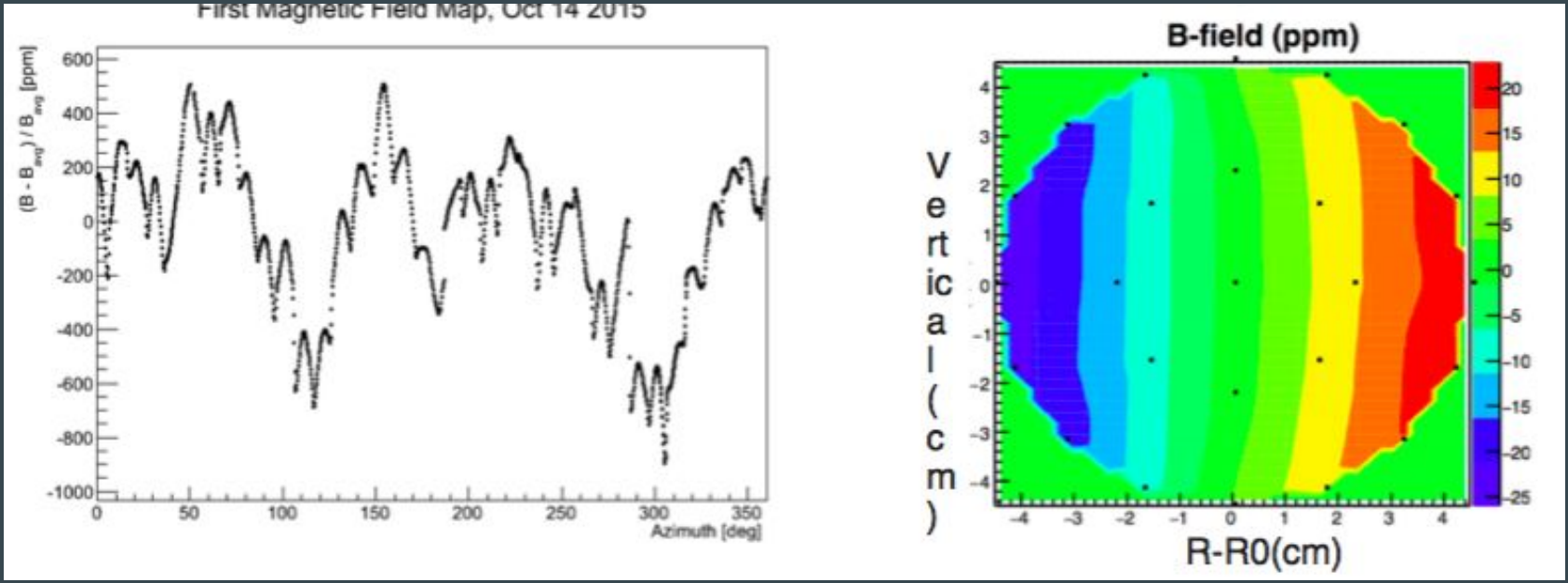
Multipoles (ppm)

	normal	skew
Quad	0.24	0.29
Sext	-0.53	-1.06
Octu	-0.10	-0.15
Decu	0.82	0.54

Fig. 13 : Contour plot of multipole expansion.



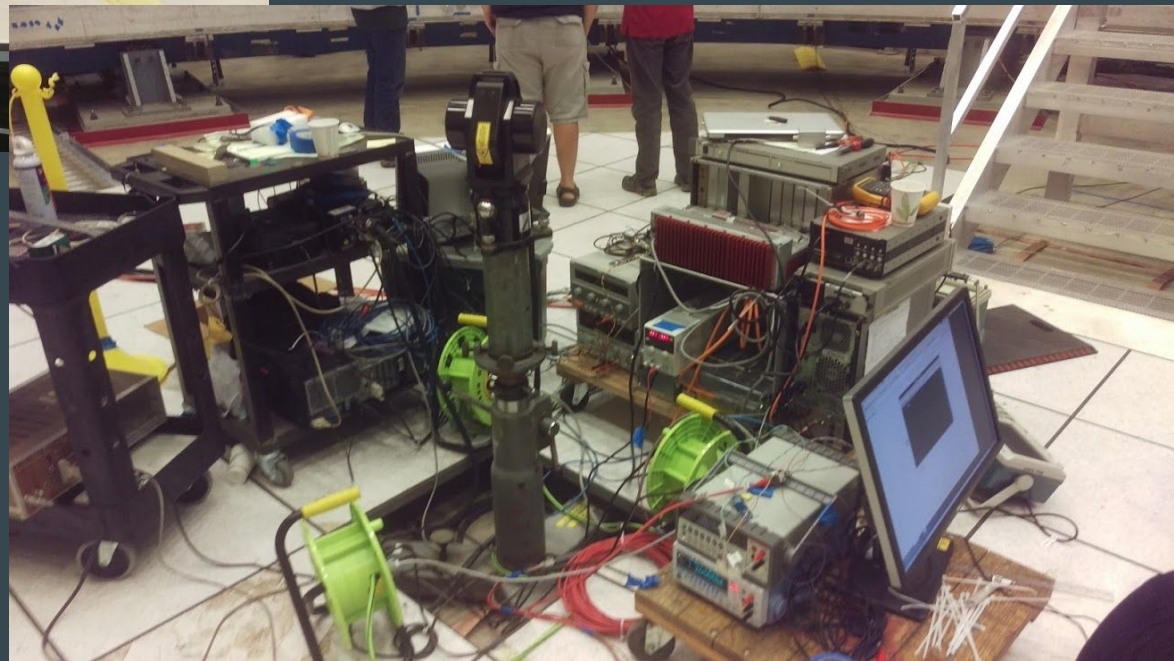
First Fermi Run

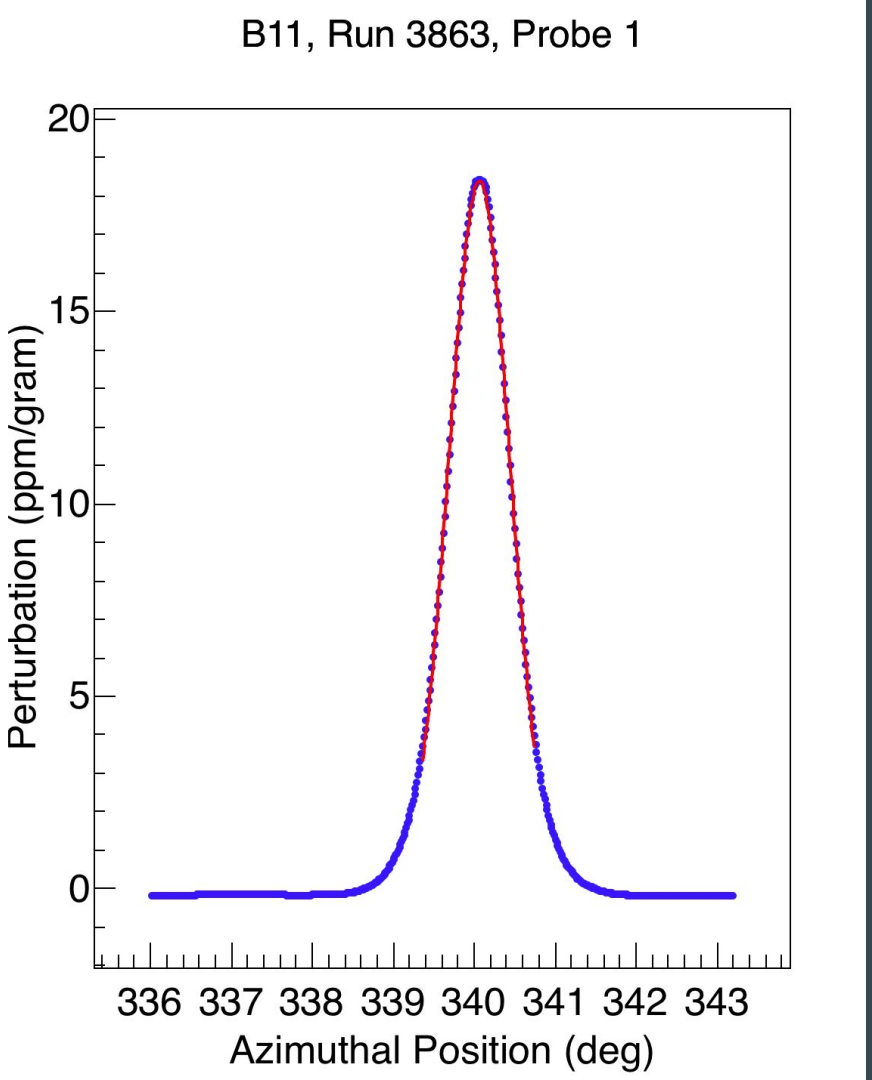


Field improvements

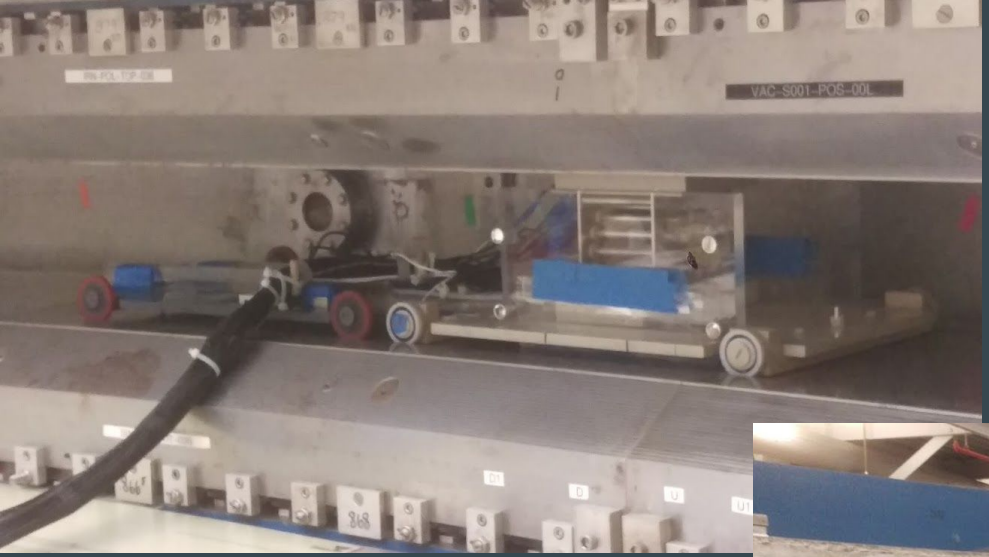
- CERN ground pole surfaces
- BNL shimmed poles, some laminations
- Fermi g-2 experiment:
  - Shim wedges underneath poles
  - Laminated sheets on pole surface
  - 3 rows of 41 soft iron foils (low coercivity)
  - 8856 foils total (some traded for gratings) laser cut by UW
  - “A gaussian distribution centered on .4g, with an upper limit of .69”
  - 25 NMR cart with laser tracking
  - Laser cut foils gige greater magnification for slim widths 36%max, <1% at 3.5mm


.1451 — .2820
.2821 — .4740



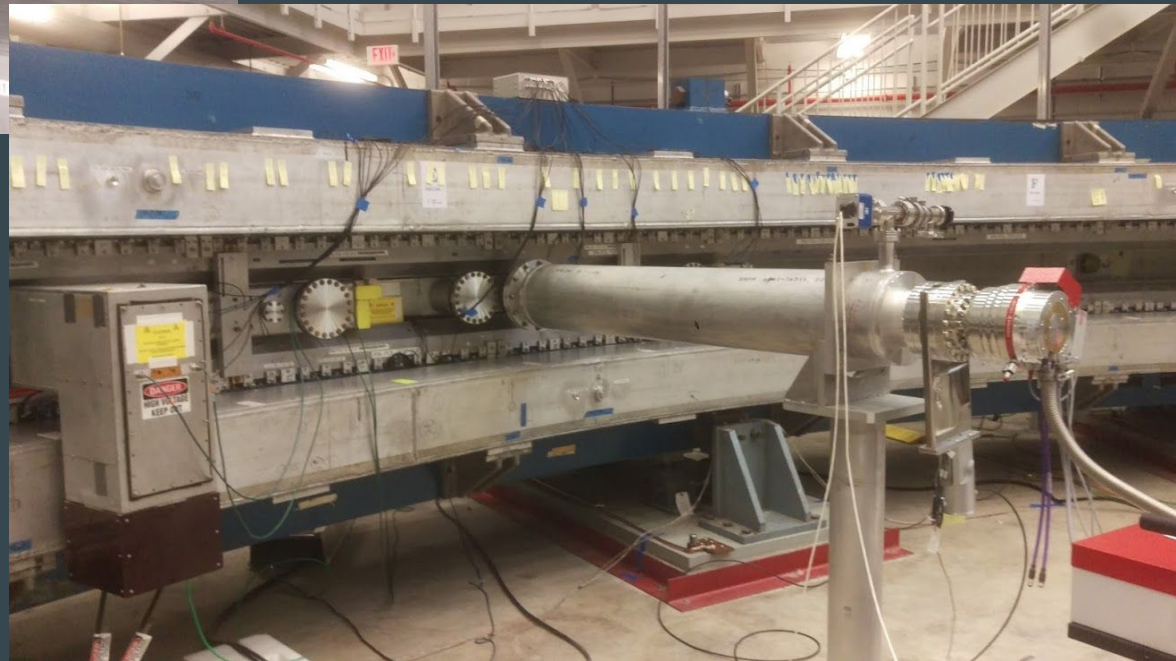

B11, Run 3863, Probe 1
Perturbation (ppm/gram)
20
15
10
5
0
336 337 338 339 340 341 342 343
Azimuthal Position (deg)


No signal



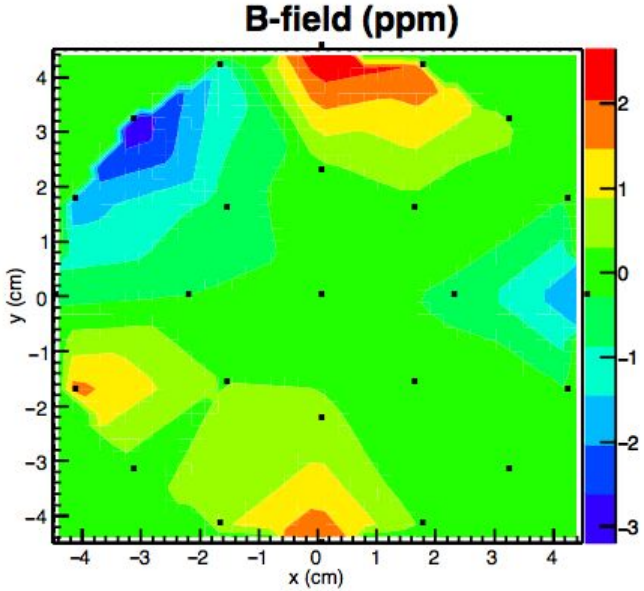
NMR Probe Cart

Vacuum Chamber

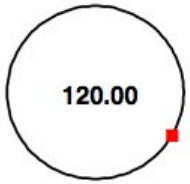


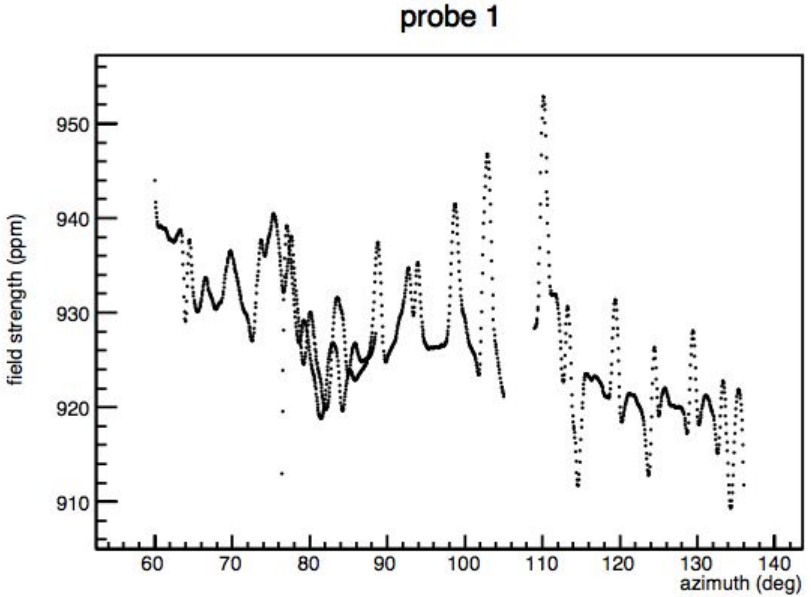
Field at Fermi

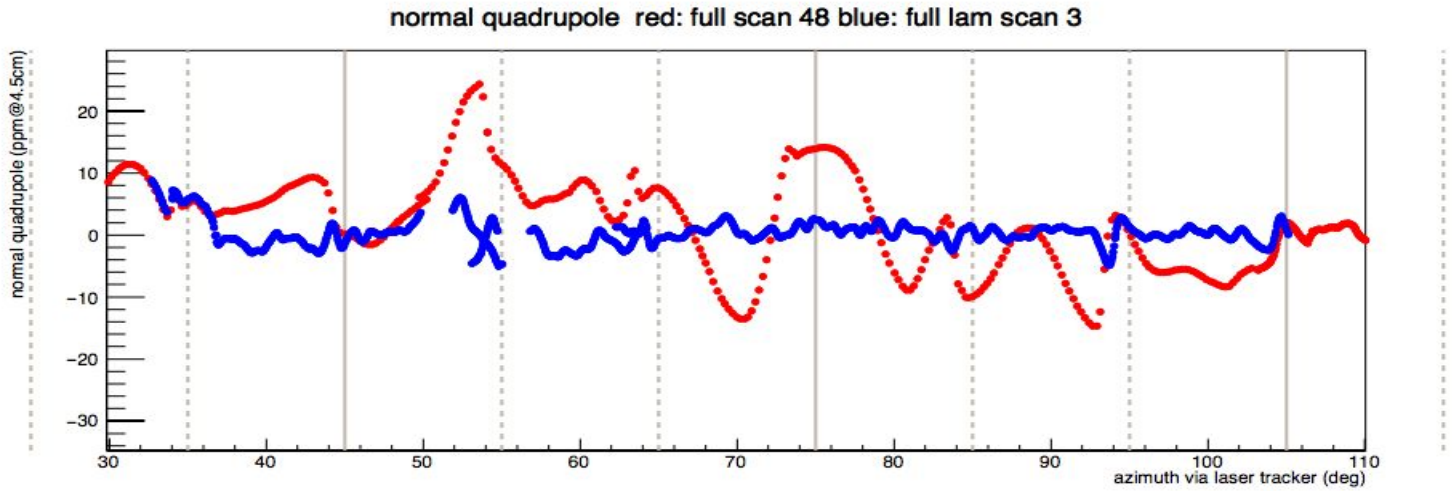
- Uncertainty of 140 ppb
- +/- 25ppm vs. azimuth, +/- .5ppm r, vertical azimuthally averaged

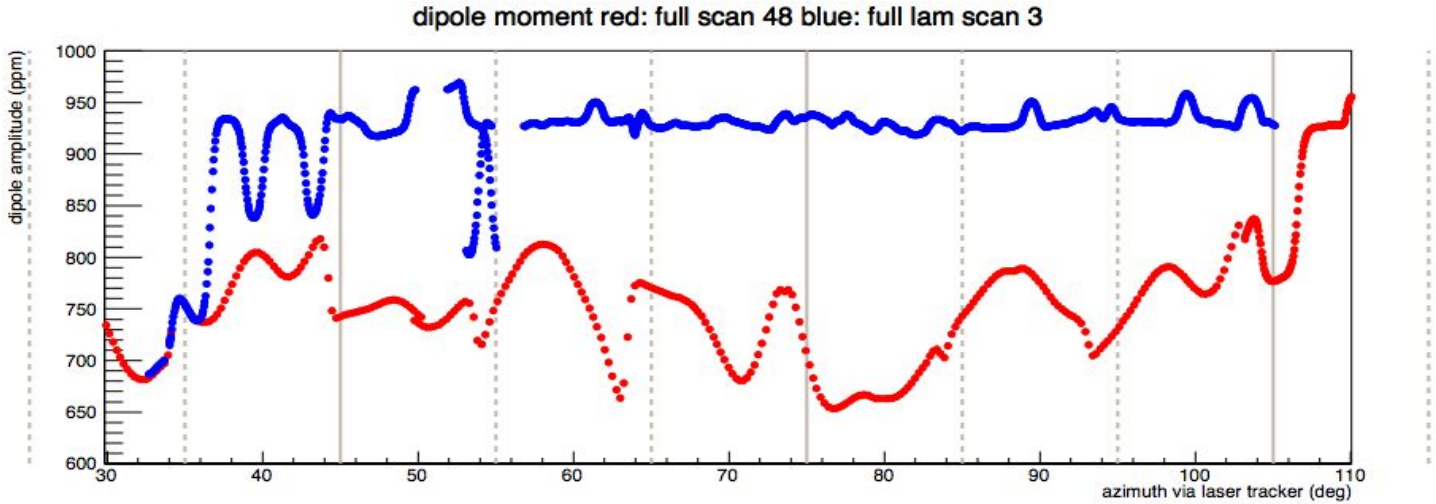


	Norm	Skew
Quad	0.20	-0.35
Sext	-1.11	1.12
Octu	-0.85	-0.72
Decu	0.63	-0.05
Dipole	-0.0	



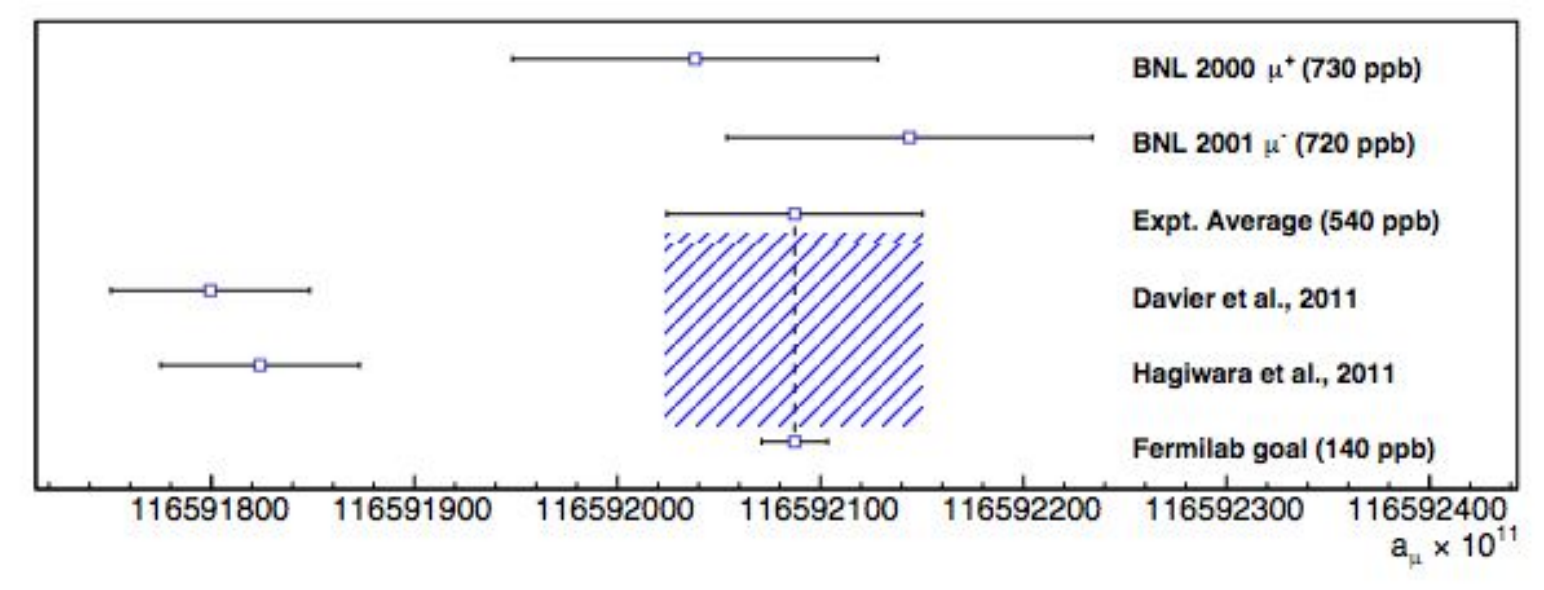



normal quadrupole red: full scan 48 blue: full lam scan 3
normal quadrupole (ppm@4.5cm)
20
10
0
−10
−20
−30
30
40
50
60
70
80
90
100
110
azimuth via laser tracker (deg)


dipole moment red: full scan 48 blue: full lam scan 3
dipole amplitude (ppm)
1000
950
900
850
800
750
700
650
600
30
40
50
60
70
80
90
100
110
azimuth via laser tracker (deg)

G-2 Implications

- SM anomaly contributions: QED, hadronic, weak interactions
- BNL results differed by 3σ from SM prediction
- New Physics!


BNL 2000 μ+ (730 ppb)
BNL 2001 μ- (720 ppb)
Expt. Average (540 ppb)
Davier et al., 2011
Hagiwara et al., 2011
Fermilab goal (140 ppb)
116591800
116591900
116592000
116592100
116592200
116592300
116592400
aμ × 10^11

Relevant figures

BNL measurement of w_{μ}**(exp)** = 11 659 204 (7) (5) * 10^{-10}

Muon mass = 105.6583715(35) MeV/c^2

Muon Lifetime = 2.2 microseconds

Cyclotron Frequency = 149 nanoseconds

$$\Delta t' = \gamma \Delta t = \frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}}$$