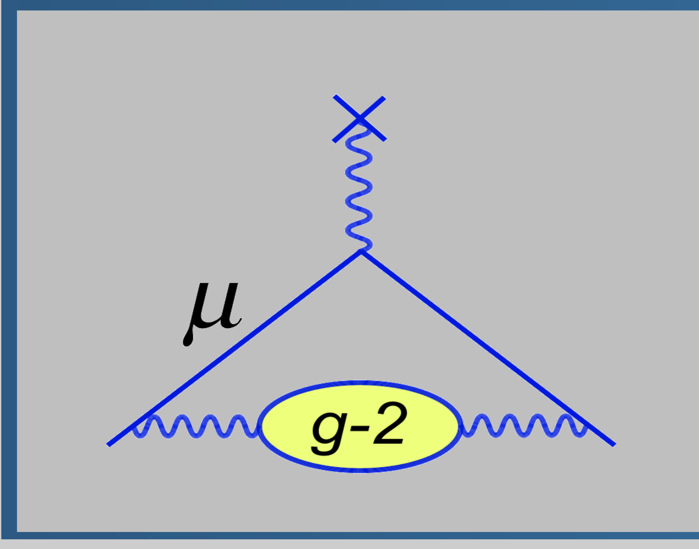
Extraction Of the Muon Radial Distribution in the Fermilab Muon g-2 Experiment



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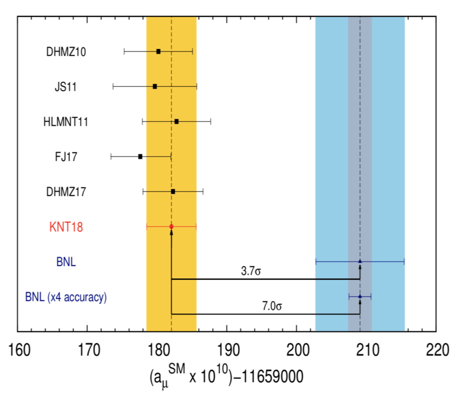
Introduction

The muon g-2 experiment gets its name from the fact that the gyromagnetic ratio g of the muon differs ever so slightly from the simple expectation of 2. The experiment uses the Fermilab accelerator complex to produce an intense beam of muons travelling at nearly speed of light. We are using the beam to precisely determine the g-2 of the muon.

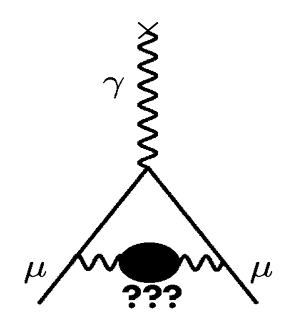
- ❖ Magnetic dipole moment $\vec{\mu} = g\,\frac{q}{2m}\vec{s}$
- ❖ From Dirac Equation **g = 2**
- ❖ From Hyperfine Structure Experiments **$g \neq 2$**
- ❖ Anomalous magnetic moment **$a = \frac{g-2}{2}$**



0.54ppm (measured by BNL) → 0.14ppm(FNAL goal)

- ❖ BNL g - 2 experiment (E821) results:
  $a_\mu^{exp} - a_\mu^{SM} = 27.05\ (7.26)\times10^{-10}$ > 3σ discrepency

New Physics ?

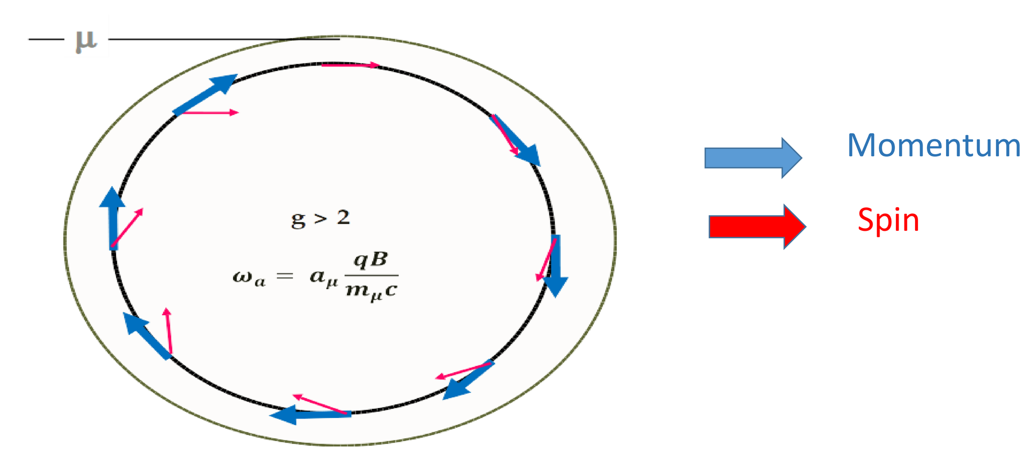


Beyond Standard Model ?

Measurement of a_μ

- ❖ Muon cyclotron frequency $\omega_c = \frac{eB}{\gamma mc}$
- ❖ Spin Precession Frequency $\omega_s = g\,\frac{eB}{2mc} + (1-\gamma)\frac{eB}{\gamma mc}$

1) Experimentally Measured **$\hbar\omega_p = 2\mu_p B$**
2) Anomalous precession frequency $\omega_a = a_\mu\,\frac{eB}{m_\mu c}$

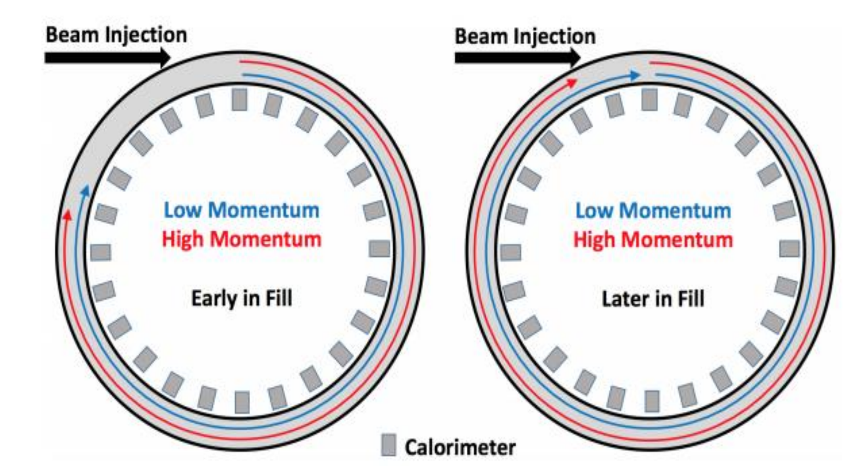


The anomalous magnetic moment $a_\mu = \frac{g_e}{2}\,\frac{m_\mu}{m_e}\,\frac{\omega_a / \langle\omega_p\rangle}{\mu_e/\mu_p}$

These two frequencies will be measured

De-bunching of the Beam

- ❖ The E-field correction to ω_a can be evaluated once the radial distribution is known
- ❖ The beam is not monoenergetic. Muons have a momentum/radial distribution over the whole aperture of the storage ring

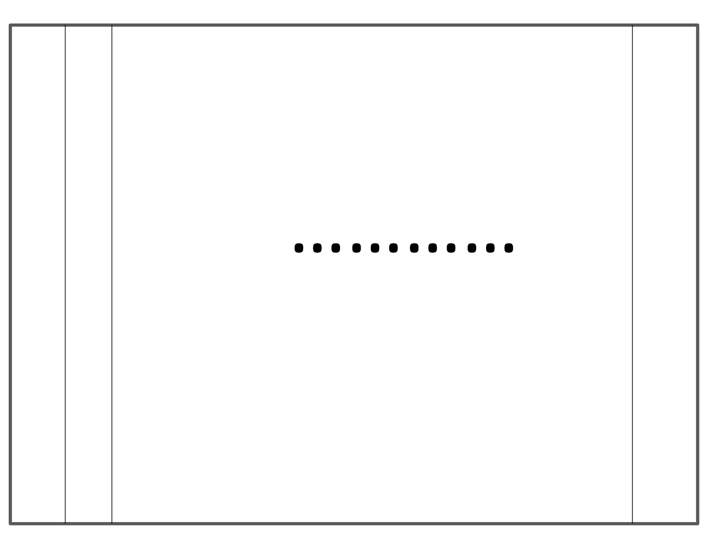


- ❖ The magic radius muons travel around the ring in about **149 ns**; Those muons at inner equilibrium radii will steadily move ahead of those at outer equilibrium radii. Beam debunching will cause the beam overlap at later times

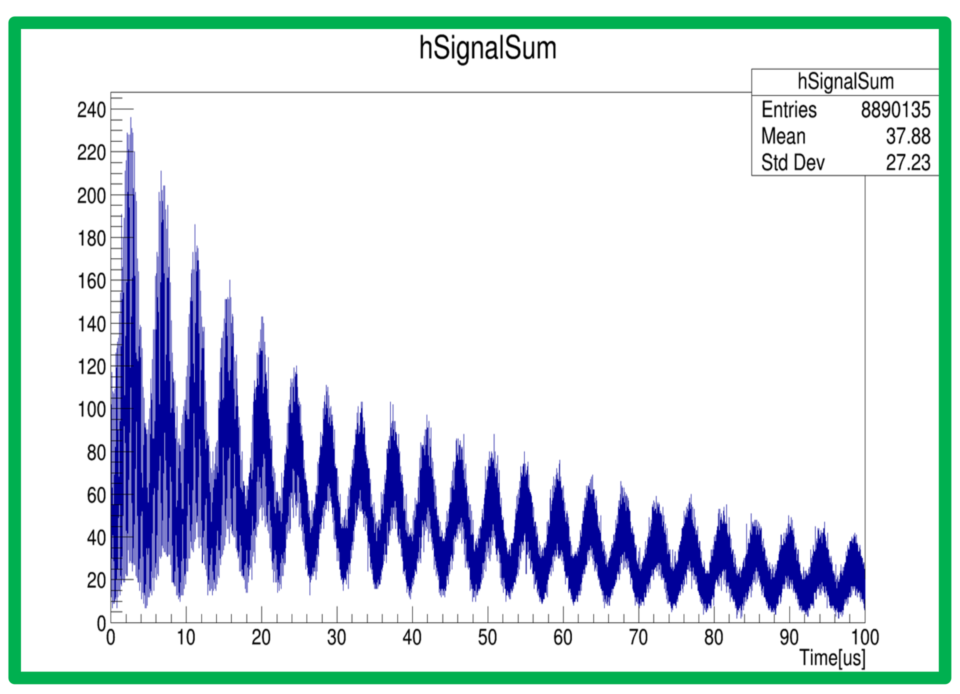
Results

Minimized Chi-squared analysis technique

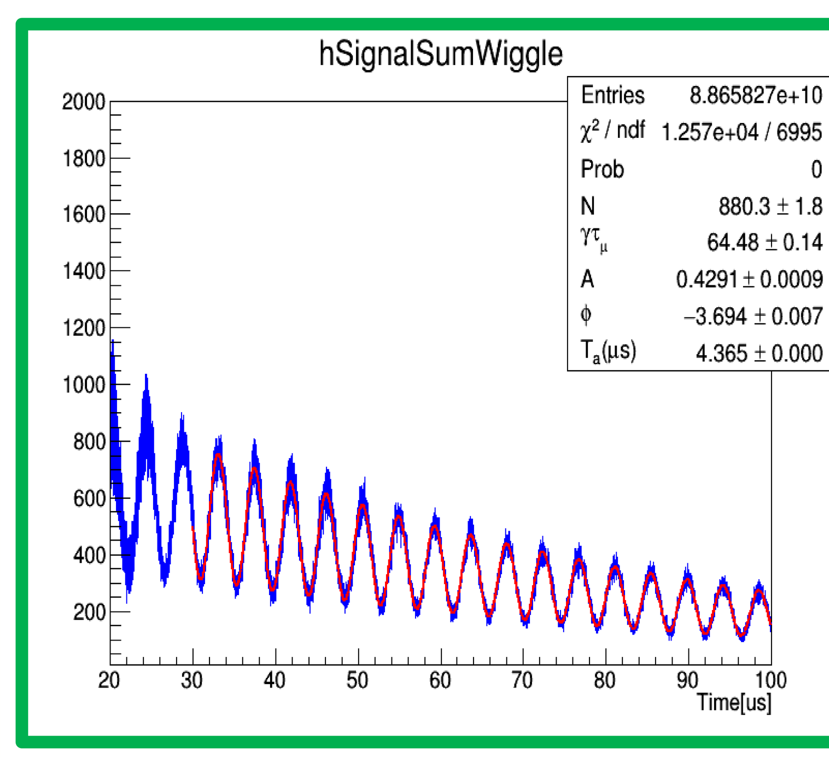
Two Sets of Bins :



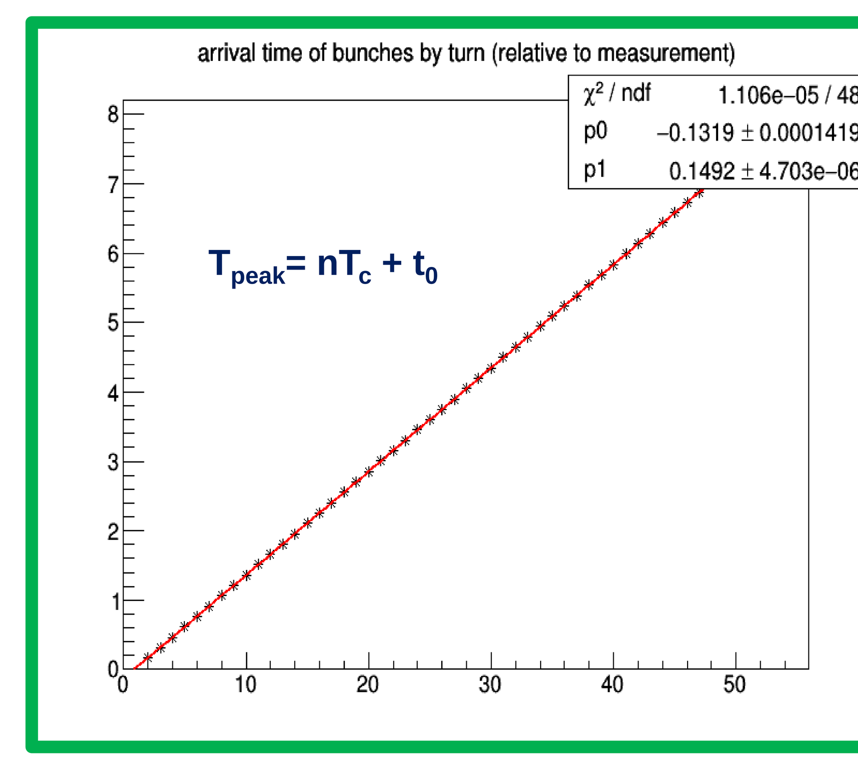
Radial bins (i) (Lx = 90 mm.)
(i.e. 50 bins w/width 1.8 mm.)



Time bins j
Decay positron histogram



Fitting the wiggle function to remove the g-2 frequency and muon lifetime



Each peak of the decay positron signal is fitted to a gaussian in order to find the arrival bunch time and then plotted as a function of the number of turns

$$\chi^2 = \sum_j \frac{(N_j - C_j)^2}{Z_j} = \sum_j \frac{(N_j - \sum_i f_i\,\beta_{ij})^2}{Z_j}$$

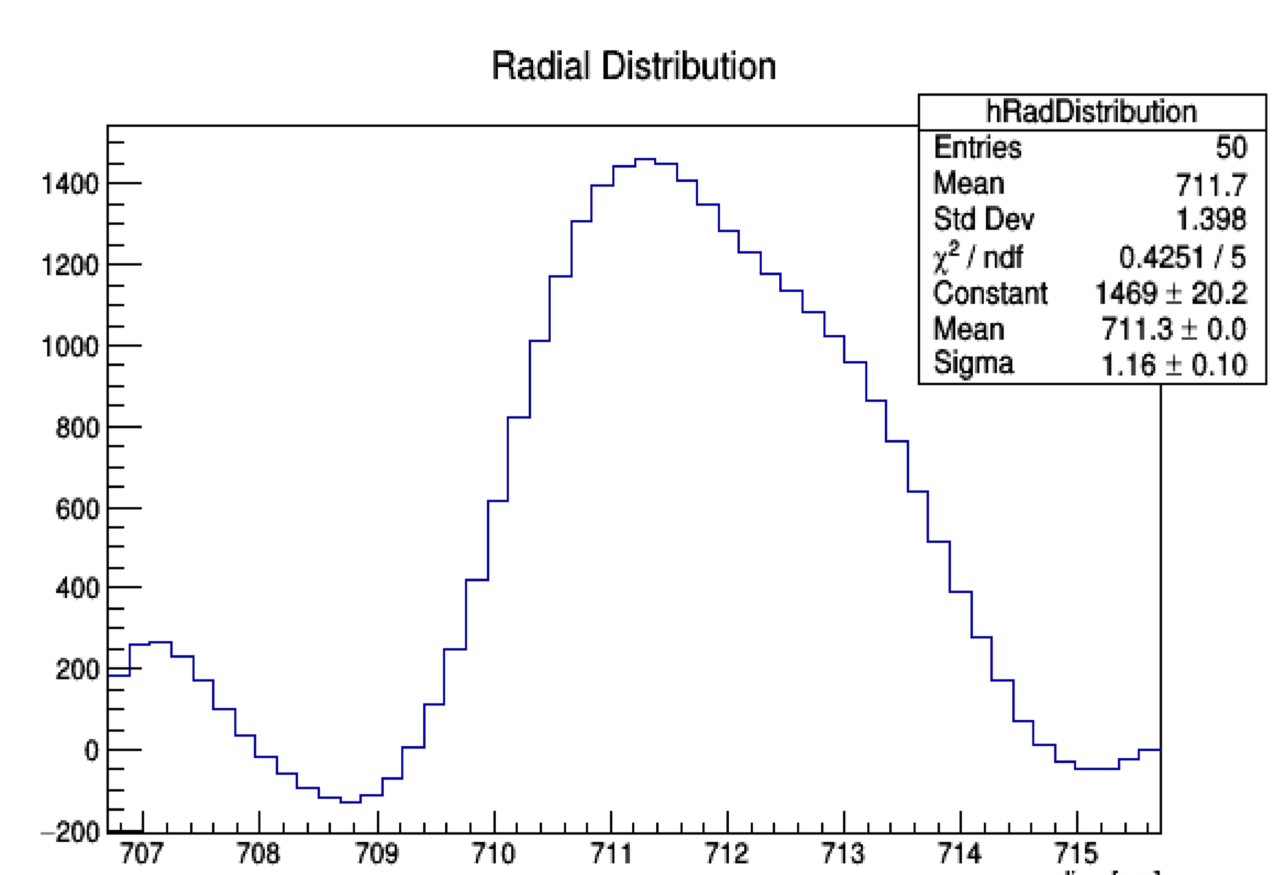
f_i → is the fraction of the beam contained in radial bin i

N_j : (N_{j_obs}) counts in time bin j , β_{ij} → contribution from the radial bin i to the counts in time bin j

C_j (N_{j_exp}) → expected counts in time bin j , Z_j → Weighting factor which should be equal to C_j

Geometry factor β_{ij} →

- ❖ contribution from the radial bin i to the counts in time bin j
- ❖ functions of ring geometry and apparent time structure of the injection bunch, t_0 and T_C



Equilibrium radial distribution

The mean of the radial distribution is **711.7 cm** ,which is **5 mm** more than the magic radius,this will introduce a large E-field correction

Summary

- ❖ The Fermilab Muon g-2 has just started it's first physics quality data taking phase.
- ❖ Distributions plotted with commissioning data from recent runs.
- ❖ With the data so far, we see that the mean of the radial distribution is **711.7 cm**, which is **5 mm** away from the magic radius, **711.2 cm**.

Users Meeting June 20 2018
Fermilab ,IL