A measurement of the positive muon anomalous magnetic moment to 0.46 ppm

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The anomalous magnetic moment of the muon …

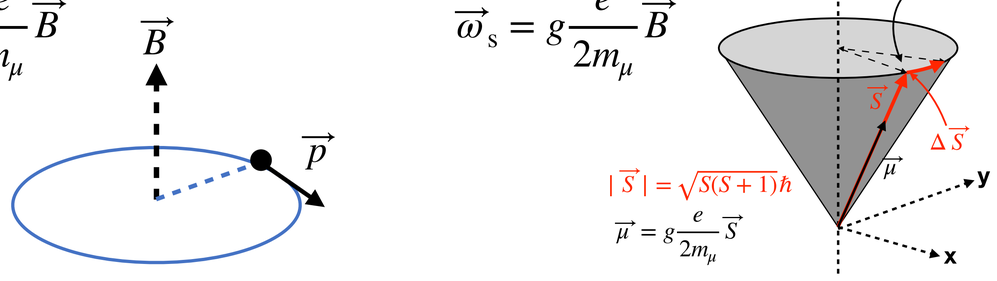
Characteristic frequencies for muons in $\vec{E}$ and $\vec{B}$ fields

Cyclotron frequency
Rotation of momentum vector

Larmor frequency
Precession of spin vector

non-relativistic situation:

$$\vec{\omega}_c = \frac{e}{m_\mu}\vec{B} \qquad \vec{\omega}_s = g\frac{e}{2m_\mu}\vec{B}$$



The anomalous spin precession frequency $\vec{\omega}_a = \vec{\omega}_s - \vec{\omega}_c$

$$\vec{\omega}_a = \frac{e}{m}\left[a_\mu\vec{B} - a_\mu\left(\frac{\gamma}{\gamma+1}\right)\left(\vec{\beta}\cdot\vec{B}\right)\vec{\beta} - \left(a_\mu - \frac{1}{\gamma^2-1}\right)\frac{\vec{\beta}\times\vec{E}}{c}\right]$$

Non-relativistic limit | Pitch correction | E-field correction

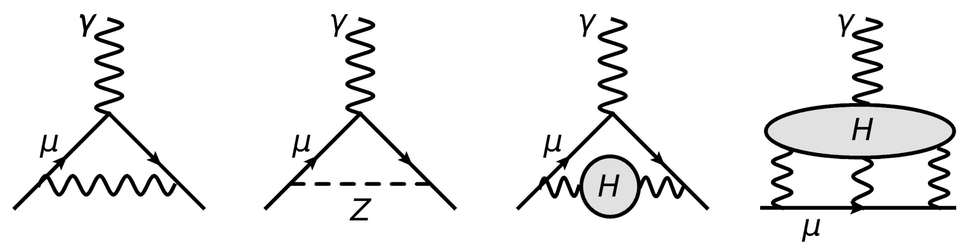
… is one of the most precise SM predictions.

The Standard Model (SM) of Particle Physics predicts

$$a_\mu = \frac{g_\mu - 2}{2} = a_{\mathrm{QED}} + a_{\mathrm{weak}} + a_{\mathrm{had}}$$

$$a_\mu(\mathrm{SM}) = 116\,591\,810\,(43) \times 10^{-11}\ (0.37\ \mathrm{ppm}) \quad [2]$$

Prediction of a_μ has contributions from all known interactions.
Uncertainty dominated by the hadronic physics contributions.



[1]

Quantum electro-dynamics | Electroweak interaction | Hadronic physics

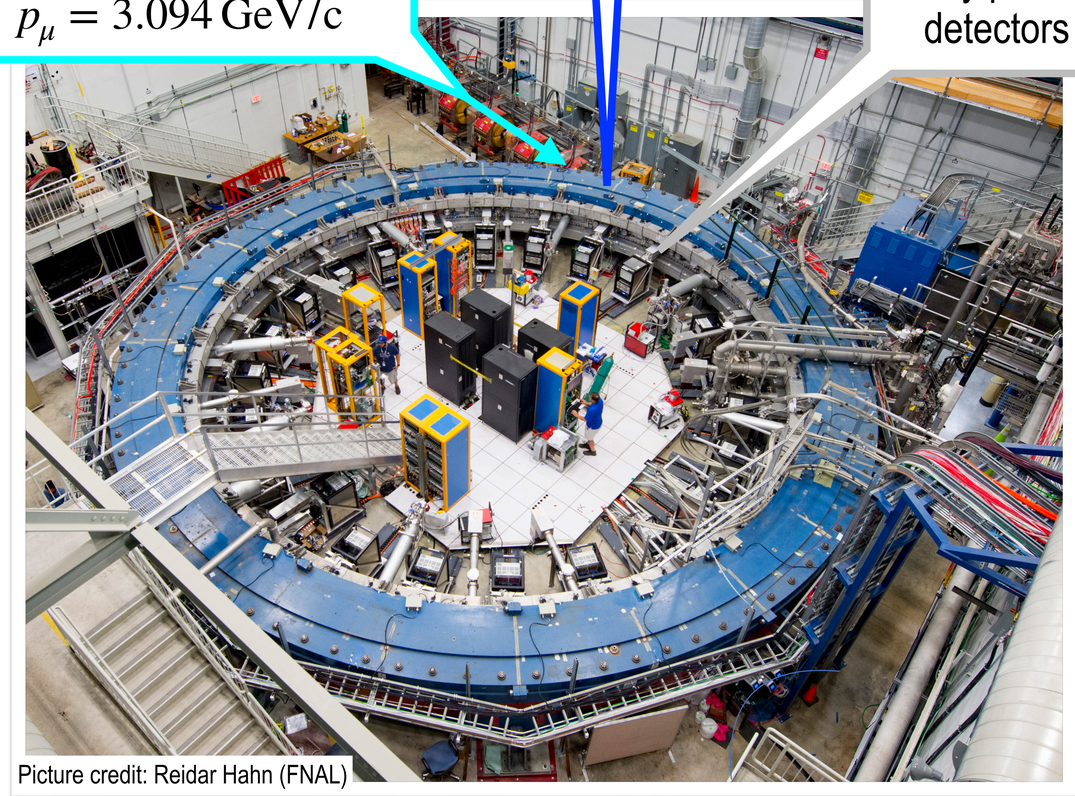
+ any so-far-unknown interactions and particles

The Muon g-2 experiment at Fermilab …

14-m diameter superconducting magnet with high-precision vertical B=1.45 T field

"Magic momentum" muons
$p_\mu = 3.094\,\mathrm{GeV/c}$

Decay positron detectors



Picture credit: Reidar Hahn (FNAL)

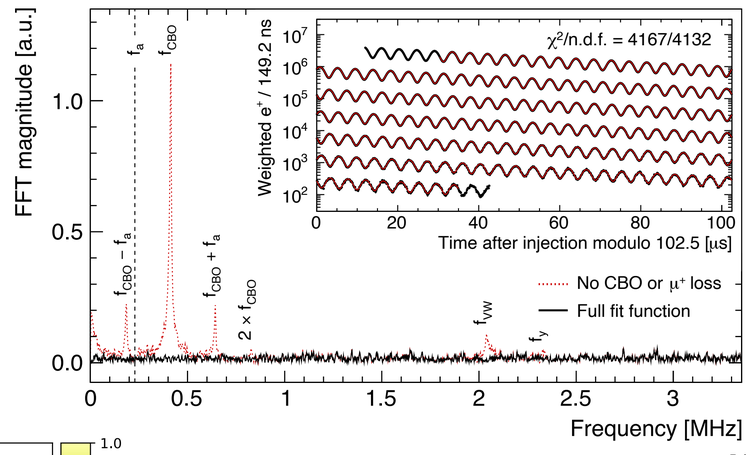
Effect of ω_a encoded in count rate of high-energy decay positrons!
Largest corrections due to complex beam dynamics:

Vertical muon motion "pitch correction" | Motional magnetic field "E-field correction"

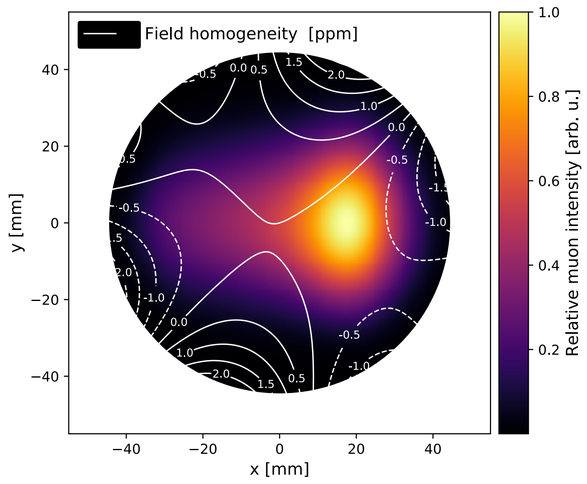
The magnetic field was determined with an uncertainty of 0.11 ppm.

… provides its most accurate measurement.

Determination of anomalous spin precession frequency …



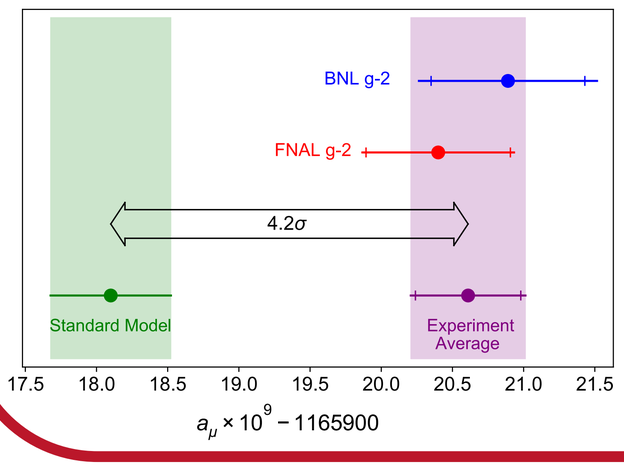
[1]



… **combined** with the magnetic field and beam dynamics measurements…

… results in the most precise measurement of a_μ:

$$a_\mu(\mathrm{FNAL}) = 116\,592\,040\,(54) \times 10^{-11}\ (0.46\ \mathrm{ppm})$$



4.2 σ tension between world average experimental value and SM prediction provides strong motivation to develop extensions of the SM.

[1] for figures and value a_μ

Reference: [1] B. Abi et al., Physical Review Letters, **126**, 141801, 2021
[2] T. Aoyama et al,. Physics Reports, Vol 887, p 1-166, 2020

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