A measurement of the positive muon anomalous magnetic moment to 127 ppb

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The anomalous magnetic moment of the muon …

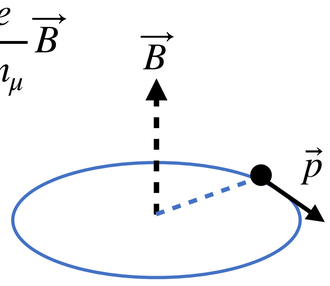
Characteristic frequencies for muons in $\vec{E}$ and $\vec{B}$ fields

Cyclotron frequency
Rotation of momentum vector

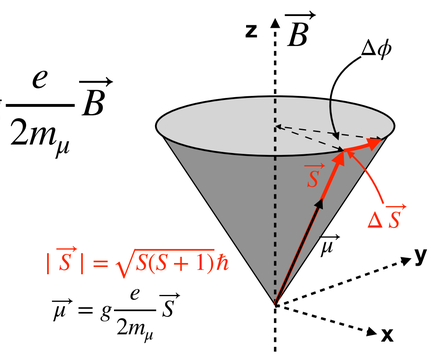
Larmor frequency
Precession of spin vector

non-relativistic situation:

$$\vec{\omega}_c = \frac{e}{m_\mu}\vec{B}$$



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



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

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

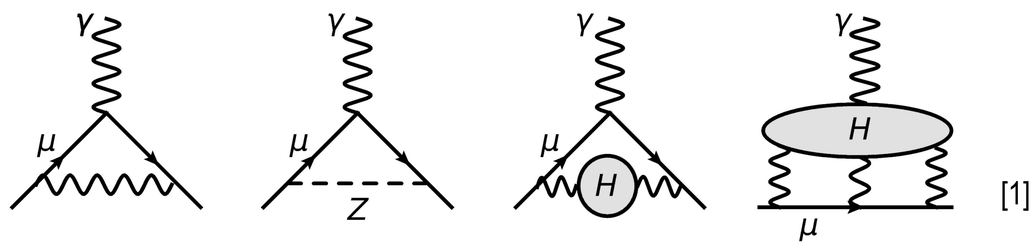
Non-relativistic limit | Pitch correction | E-field correction

… is one of the most precise SM predictions.

The Standard Model (SM) of Particle Physics predicts

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

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



[1]

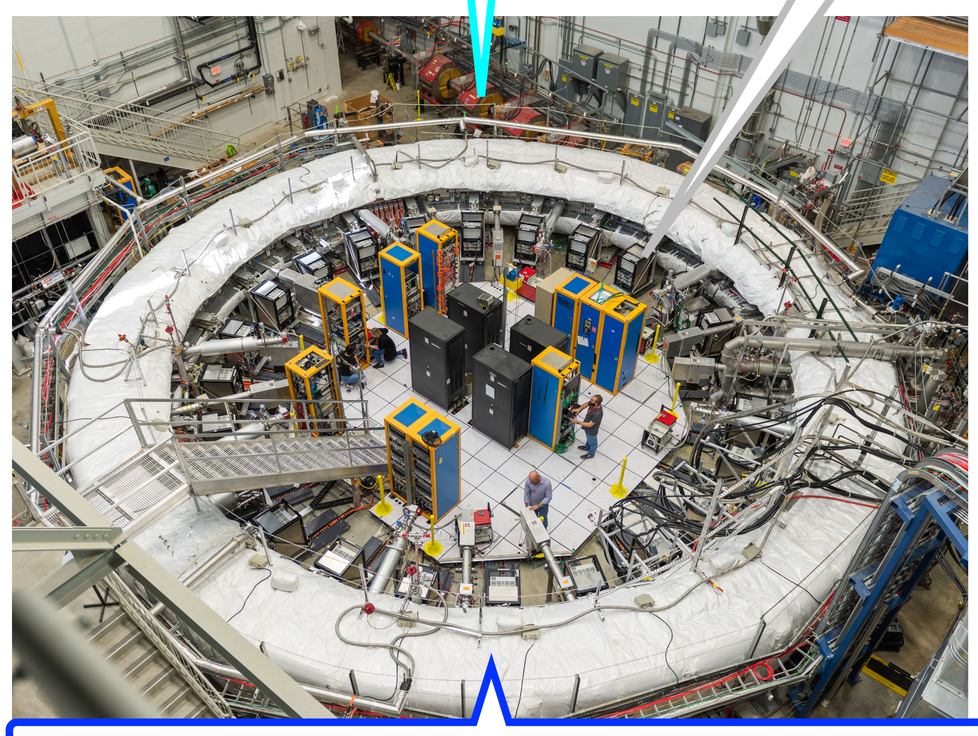
Quantum electro-dynamics | Electroweak interaction | Hadronic physics

For decades a tension between the experimental results and the theoretical predictions has been driving the development of novel and innovative techniques to achieve unprecedented precision on both sides, *experiment and theory*!

The Muon g-2 experiment at Fermilab …

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

Decay positron detectors



Picture credit: Ryan Postel (FNAL)

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

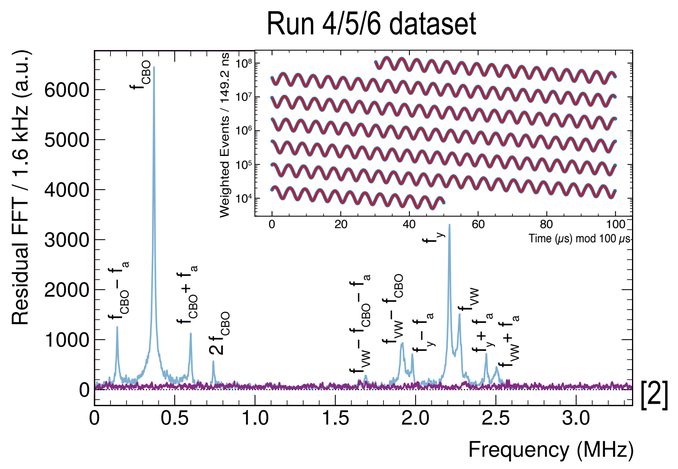
Effect of ω_a encoded in count rate of high-energy decay positrons!
Largest corrections due to complex beam dynamics:

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

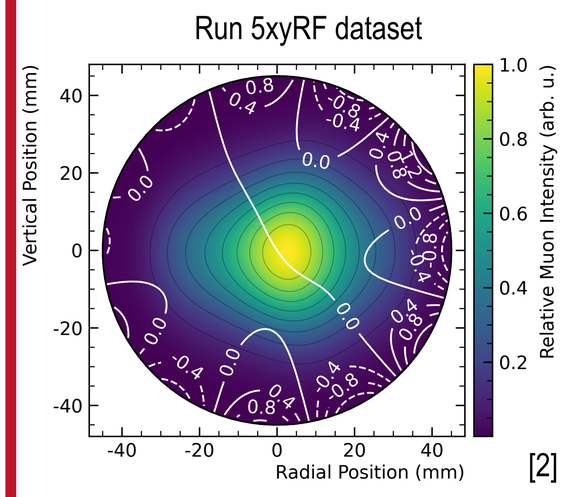
The magnetic field was determined with an uncertainty of 48 ppb.

… provides its most accurate measurement.

Determining the anomalous spin precession frequency…



[2]



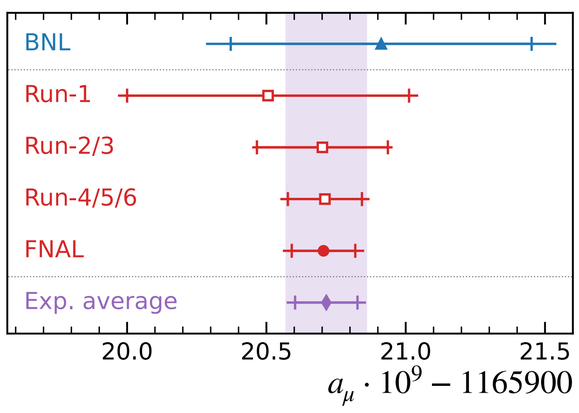
[2]

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

… from all run periods and settings results in the most precise value:

$$a_\mu = 1165920.705(148) \times 10^{-9}$$

The achieved 127 ppb uncertainty surpasses the original target uncertainty of 140 ppb.



$1165920.912(629) \times 10^{-9}$	540 ppb
$1165920.506(539) \times 10^{-9}$	460 ppb
$1165920.701(253) \times 10^{-9}$	210 ppb
$1165920.711(162) \times 10^{-9}$	139 ppb
$1165920.705(148) \times 10^{-9}$	127 ppb
$1165920.715(145) \times 10^{-9}$	124 ppb

Reference: [1] B. Abi et al., Physical Review Letters, **126**, 141801, 2021
[2] D. Aguillard et al., arXiv:2506.03069

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