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Final Result from the Fermilab Muon g-2 Experiment

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In quantum field theory, the magnetic moment of a charged spin-$\frac{1}{2}$ particle such as the muon deviates slightly from the Dirac value of 2 due to quantum loop corrections involving virtual particles. This deviation, known as the anomalous magnetic moment, $a = (g-2)/2$, is sensitive to all quantum effects, including potential contributions from particles beyond the Standard Model (SM). As such, precise measurements of the muon anomalous magnetic moment, a_μ served as powerful tests of the SM and valuable probes for new physics. The Muon g-2 experiment at Fermilab measures a_μ by observing the spin precession of muons stored in a uniform magnetic field. The key observable is the frequency difference ω_a between the muons's spin precession and cyclotron motion, which is directly proportional to a_μ. By determining ω_a and the magnetic field with high precision using nuclear magnetic resonance (NMR) probes, the experiment extracts a_μ with unprecedented accuracy. The Fermilab collaboration has now released its final result, achieving a record-breaking precision of 127 parts per billion (ppb), surpassing the original design goal of 140~ppb. This result is the most precise measurement of a_μ to date, based on a dataset more than three times larger than that used in the 2023 analysis and encompassing data collected from 2021 to 2023. The achievement reflects years of experimental upgrades and methodological advances. While earlier comparisons with the 2020 Muon g-2 Theory Initiative prediction indicated a significant discrepancy, recent developments in theoretical calculations, particularly from lattice QCD have narrowed the gap, prompting ongoing discussion about the true level of deviation. However, the final measurement thus sets a new benchmark for testing the SM and constraining possible extensions. In this talk, I will present an overview of the Fermilab Muon g-2 experiment, focusing on the key upgrades and refinements made during the 2021-2023 data-taking period that enabled this milestone result.

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