

Muon g-2 Experiment

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In News: Recently, Fermilab, the American particle accelerator, has released first results from its “muon g-2” experiment, spotting the anomalous behaviour of the elementary particle called the muon.

Muon g-2 Experiment

- The experiment, called Muon g-2 (g minus two), was conducted at the US Department of Energy’s Fermi National Accelerator Laboratory (Fermilab).
- It sought to find out whether the discrepancy would persist, or whether the new results would be closer to predictions.
- The muon g-2 experiment measured the extent of the anomaly, Fermilab announced that “g” deviated from the amount predicted by the Standard Model.

Findings

- The results, while diverging from the Standard Model prediction, strongly agree with the Brookhaven results, Accepted theoretical values for the muon are:
 - **g-factor:** 2.00233183620
 - **anomalous magnetic moment:** 0.00116591810
- The new experimental results (combined from the Brookhaven and Fermilab results) are:
 - **g-factor:** 2.00233184122
 - **anomalous magnetic moment:** 0.00116592061.

Quantity measured

- It is called the g-factor, a measure that derives from the magnetic properties of the muon. Because the muon is unstable, scientists study the effect it leaves behind on its surroundings.

- Muons act as if they have a tiny internal magnet. In a strong magnetic field, the direction of this magnet “wobbles” – just like the axis of a spinning top.
- The rate at which the muon wobbles is described by the g-factor, the quantity that was measured. This value is known to be close to 2, so scientists measure the deviation from 2. Hence the name g-2.

The g-factor

- The g-factor can be calculated precisely using the Standard Model.
- In the g-2 experiment, scientists measured it with high-precision instruments. They generated muons and got them to circulate in a large magnet.
- The muons also interacted with a “quantum foam” of subatomic particles “popping in and out of existence”, as Fermilab described it.
- These interactions affect the value of the g-factor, causing the muons to wobble slightly faster or slightly slower.
- Just how much this deviation will be (this is called anomalous magnetic moment), too, can be calculated with the Standard Model. But if the quantum foam contains additional forces or particles that are not accounted for by the Standard Model, that would tweak the g-factor further.

What is the Standard Model?

- The Standard Model of particle physics calculates this correction, called the anomalous magnetic moment.
- The Standard Model is a rigorous theory that predicts the behaviour of the building blocks of the universe.
- It lays out the rules for six types of quarks, six leptons, the Higgs boson, three fundamental forces, and how the subatomic particles behave under the influence of electromagnetic forces.

- The muon is one of the leptons. It is similar to the electron, but 200 times larger, and much more unstable, surviving for a fraction of a second.

Muon

- The muon is an elementary particle similar to the electron, with an electric charge of $-1 e$ and a spin of $1/2$, but with a much greater mass.
- It is classified as a lepton.
- The muon is a heavier cousin of the electron and is expected to have a value of 2 for its magnetic moment, labelled "g".
- The muon is not alone in the universe.
- It is embedded in a sea where particles are popping out and vanishing every instant due to quantum effects.
- So, its g value is altered by its interactions with these short-lived excitations