The HVP contribution to the anomalous magnetic moment of the muon

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Abstract

New particles can reveal their existence indirectly through tiny discrepancies in the properties of known particles from that expected in the Standard Model. The magnetic moment of the muon shows such a discrepancy, a tantalising 25 parts in 10^10, but with 3σ significance. The magnetic moment, μ, is given in terms of the spin, S, by:

μ = g e S/2m

\( a_\mu = \frac{g - 2}{2} \)

The difference of g from the naive value of 2 is called the ‘anomalous magnetic moment’, \( a_\mu \).

The anomalous magnetic moment is determined directly by measuring the spin precession as polarised muons circulate in a ring with a perpendicular magnetic field. Experiment E989 at Fermilab will start data-taking in 2017 and aims to reduce the experimental uncertainty by a factor of 4.

An improved theoretical uncertainty from the Standard Model is needed to match this. The largest uncertainty comes from the diagram containing a quark loop (see Fig. below): the Leading Order Hadronic Vacuum Polarisation (HVP) contribution.

\( G_{2j} \equiv \sum_{j,\bar{j}} t^{2j} Z_{\mu} j^4(\bar{x}, t) j^4(0, 0) \)

\( G_{2j} = (-1)^j (2j)! \Pi_{j=1}^{N} \tilde{\Pi}(k^2) = \sum_{j} k^{2j} \Pi_{j} \)

The plot above shows corrected and raw data as a function of u/d quark mass. Note how the corrected data have reduced volume, \( m_s \) and \( a_\mu \)-dependence. A simple fit (with distribution below) gives value 598(6)(8) x10^{-10} where 8 is the systematic uncertainty from missing QED and isospin effects.

Conclusions

Lattice QCD calculations of the HVP contribution to \( a_\mu \) are making fast progress. Our result is the accurate to date and shows a 3σ discrepancy with experiment. Ongoing work with MILC will improve statistics, use finer lattices, add QED and isospin effects and improve analysis of disconnected contributions.

References


These calculations used Darwin@Cambridge, a component of the UK STFC’s DiRAC facility.