The muon anomalous magnetic moment from chiral domain wall fermions

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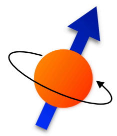
What is a muon?



- Elementary point-like particle
- Same electric charge as an electron
- Approximately **200** times heavier than an electron
- Like the electron, behaves as if it was intrinsically spinning about a vector $\vec{S}$

These properties combine to give it a magnetic moment

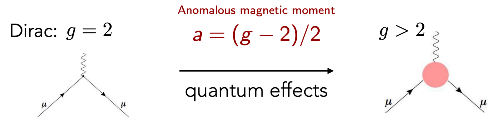
$$\vec{\mu} = g\left(\frac{e}{2m}\right)\vec{S}$$

such that when put in a magnetic field, it exhibits precession similar to a spinning top.

We can measure this precession **very** precisely.

The magnetic moment and quantum corrections

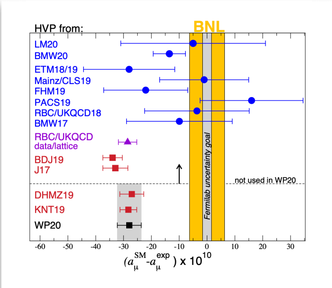
The g-factor in $\vec{\mu} = g\left(\frac{e}{2m}\right)\vec{S}$ describes the strength of coupling to a magnetic field, which can be computed from theory also **very** precisely.



The quantum effects arise from virtual particle contributions from all known **and unknown** particles.

By comparing high-precision experiments and theory, we have the potential to learn about such contributions of new particles.

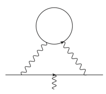
Status in 2020, before GCS allocations on Jülich Booster



Resolving the muon g-2 tension (1/4)

In parallel, developed first-principles high-precision methods for the hadronic vacuum polarization which was so-far obtained via analyticity and unitarity from hadronic e+e- decays.

In our **PRL121(2018)022003** introduced Euclidean windows to separate sources of uncertainties, which allowed for faster and more targeted progress.



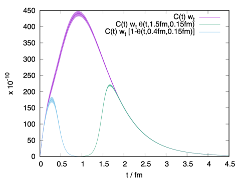
$$a_\mu^{\rm HVP\ LO} = \sum_{t=0}^{\infty} w_t C(t) \qquad C(t) = \frac{1}{3}\sum_{\vec{x}}\sum_{j=0,1,2}\langle J_j(\vec{x},t)J_j(0)\rangle \qquad J_\mu(x) = i\sum_f Q_f \overline{\Psi}_f(x)\gamma_\mu\Psi_f(x)$$

$$a_\mu = a_\mu^{\rm SD} + a_\mu^{\rm W} + a_\mu^{\rm LD}$$

Short-distance window contains most of discretization errors.

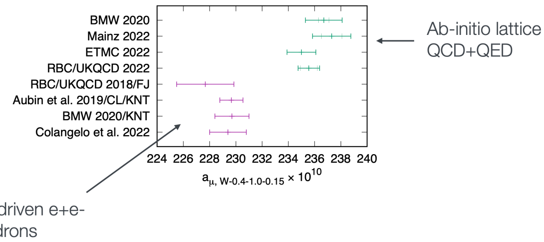
Long-distance contains most of statistical and finite-volume uncertainties.

Intermediate distance easy to calculate precisely!



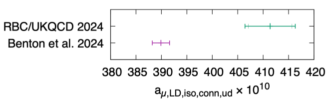
Resolving the muon g-2 tension (2/4)

Allowed for a clear demonstration of 3.8 σ tension of lattice QCD+QED with previous data-driven methods (plot from our **PRD108(2023)054507**, RBC/UKQCD 2022 below):



Resolving the muon g-2 tension (3/4)

In the long-distance window, the picture is even clearer (our arXiv:2410.20590, submitted to PRL):

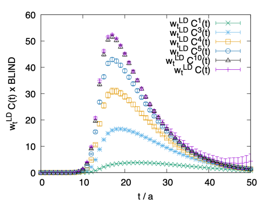


Taking the shifts of the intermediate and long-distance windows into account, standard model is consistent with muon g-2 experiment.

At same time, new e+e- experiment (CMD3) is in tension with previous results and consistent with lattice QCD+QED. Need to understand what went wrong in the e+e- experiments. This (plus tau data) is next focus.

Resolving the muon g-2 tension (4/4)

Many methodological improvements were needed to provide such a precise calculation of the long-distance window. Most importantly the reconstruction of finite-volume states by measuring two-pion and rho mixing:



Four-pion contributions needed 974 diagrams: