Searching for new physics in the magnetic moment of the muon

A vacuum is never completely empty space but teems with particles that are created fleetingly by quantum fluctuations in energy and then disappear. The heavier the particle, the less time its brief existence can last. In that time, however, the particle can interact with the much lighter particles in our everyday world and thereby reveal its existence through tiny discrepancies in the properties of these particles from that expected in the Standard Model. The magnetic moment of the muon shows such a discrepancy, a tantalizing 25±9 parts in 10^{10}. To pin this down more accurately a new experiment, E989 at Fermilab near Chicago, will reduce the experimental uncertainty by a factor of 4. An improved theoretical uncertainty from the Standard Model to match this needs lattice QCD calculations. This year HPQCD has developed a new method using DiRAC that will enable the accuracy needed to be achieved.

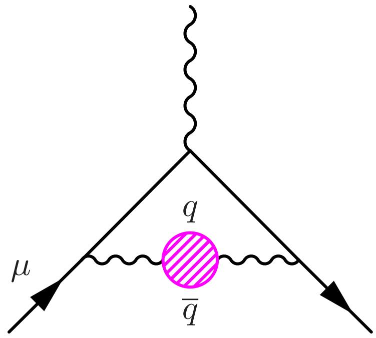

Figure 1. The interaction between a muon and a photon is complicated by the production of virtual particles.

The muon is a heavier cousin of the electron with the same electric charge and spin, so that it carries a magnetic moment. The 'gyromagnetic ratio', g, measures the ratio of magnetic moment to spin (in units of $e/2m$). Naively, $g = 2$ but this ignores the interactions of the muon with the cloud of virtual particles discussed above. The anomalous magnetic moment, $a_\mu = (g-2)/2$, can be measured very accurately from the difference between the circulation and spin precession frequencies as muons fly round a ring transverse to a magnetic field.

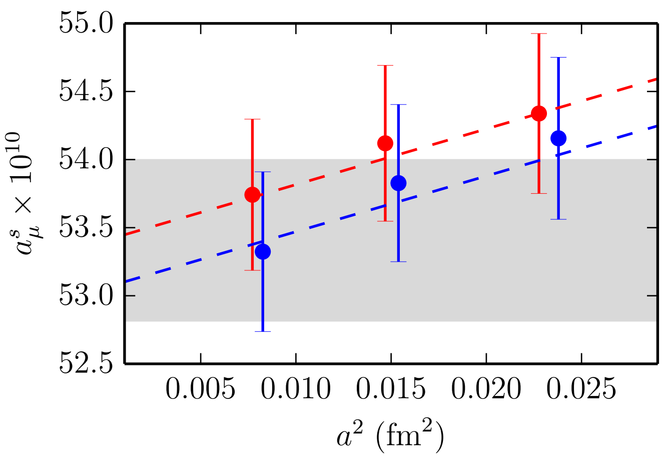

Figure 2 Our results for the strange quark HVP contribution to a_μ as a function of lattice spacing

The biggest effect in the Standard Model result for a_μ comes from Quantum Electrodynamics where very high order calculations can be done. The largest theoretical uncertainty is from Quantum Chromodynamics and the process of Fig. 1 in which a muon radiates a photon that briefly becomes a quark-antiquark pair. This 'hadronic vacuum polarisation' (HVP) contribution needs to be calculated to better than 0.5% in lattice QCD to reduce the theoretical uncertainty. Our new method (arXiv:1403.1778, Phys. Rev D89:114501) makes this possible, having achieved 1% for the first time for the strange quark HVP contribution. Our method has low systematic errors and DiRAC enabled high statistics on realistic gluon field configurations . The up/down quark calculation is now underway. Errors will be reduced by a further factor of 3 as we increase statistics by a factor of 10 in 2015.