HPQCD

Shining light on the structure of hadrons

Understanding matter at its deepest level is complicated by the fact that the fundamental constituents known as quarks are hidden from us. Instead of being available for experimental scrutiny, as electrons are, quarks are always bound together into particles called hadrons. We have to infer the properties of quarks, and that of the strong interaction that binds them, from experimental studies of hadrons. A window into the hadron is provided by striking it with a photon, the quantum carrier of the electromagnetic interaction. The photon can penetrate the hadron to interact with the quarks inside, but the bound state nature of the hadron is revealed by the fact that the struck quark must redistribute the photon's momentum between its fellow constituents for the hadron to change direction as momentum conservation requires (see Fig. 1). The hadron's electromagnetic form factor, $F(Q^2)$, parameterises this bound-state behavior as a function of the squared 3-momentum transferred from the photon. New experiments at Jefferson Lab in the USA will shortly be taking data to determine the electromagnetic form factor of hadrons called pi and K mesons up to much larger values of Q^2 than has been possible before. The aim is to reach a regime in Q^2 where the strong interaction becomes relatively weak and $F(Q^2)$ is expected to have simple behavior from QCD, the theory of the strong interaction. However, it is not at all clear where this regime begins. Hadron electromagnetic form factors can also be calculated using the numerical techniques of lattice QCD. The HPQCD collaboration has recently been able to reach a value of Q^2 of 7 GeV^2 for the determination of $F(Q^2)$ for a 'pseudopion', a particle like the pi meson but made of strange quarks instead of up and down quarks. This improves numerical speed and statistical accuracy, but still allows us to compare to high-Q^2 expectations. We find $Q^2F(Q^2)$ to be flat in Q^2 but in clear disagreement with the simple high Q^2 result from perturbative QCD (see Fig. 2).

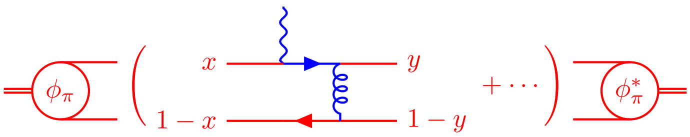

Figure 1. When a pi meson interacts with a photon (wavy blue line), momentum must be redistributed via gluon exchange (curly blue line).

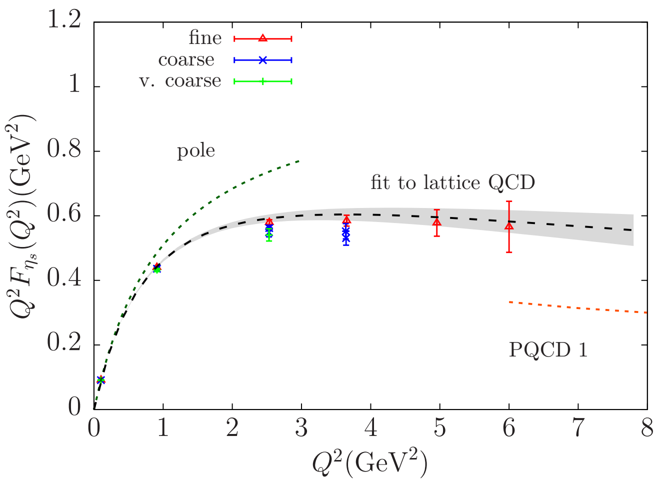

Figure 2. Lattice QCD results from arXiv:1701.04250 compared to a simple pole model at low Q^2 and leading-order perturbative QCD at high Q^2.

Calculations of $F(Q^2)$ for pi and K meson are underway to make direct predictions for the JLAB experiments. Darwin, and now CSD3, at Cambridge have proved ideal for this work since we can store intermediate quark propagators for re-use at multiple Q^2 values.