Stress-testing the Standard Model

It might seem surprising that particle physicists are so keen to find evidence of a flaw in their current best theory, the Standard Model. However, this could lead to a more complete theory of fundamental physics and is therefore a key aim of the field. The numerical methods of Lattice Quantum Chromodynamics have an important role here because they allow us to calculate accurately in the Standard Model the properties of bound states of quarks known as hadrons. Comparison to experiment is then a stringent test of the theory. This year on DiRAC we have done several such tests, but the Standard Model has passed each one.

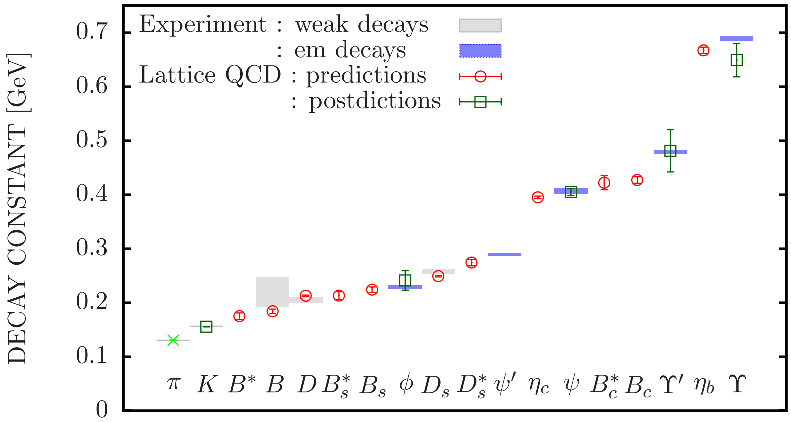

Figure 1. Determination of meson decay constants, compared to experimental results, where available. HPQCD, arXiv:1503.05762, 1408.5768

Figure 1 shows values for the decay constants of hadrons known as mesons. These consist of a quark and antiquark in a complicated soup of strongly interacting particles. The decay constant parameterises the probability for the quark and antiquark to annihilate against each other producing either a W boson of the weak interaction or a photon of electromagnetism. On DiRAC we have the flexibility to store intermediate results and so can cover the full range of mesons possible efficiently.

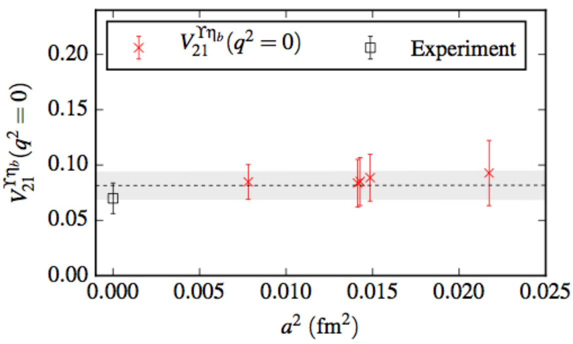

Figure 2. The vector form factor (from which the rate is determined) for Upsilon(2S) to etab(1S) decay, compared to experiment. HPQCD, arXiv:1508.01694

Another stringent Standard Model test is provided by electromagnetic transition rates of mesons. A radially excited Upsilon meson can emit a photon and become an eta_b meson but the process is relatively rare. This is because it requires the quark emitting the photon to flip its spin from being parallel to the antiquark (so that the Upsilon meson has spin 1) to being antiparallel (so that the resulting eta_b meson has no spin). This makes the process very sensitive to details of the interaction between quark and photon. Model calculations give results for the rate that vary by orders of magnitude. Using Lattice QCD enables us to control this calculation accurately and obtain an answer for the rate with a similar uncertainty to that from the experiment. Once again the Standard Model passes the test.