HPQCD: the charming strangeness of the W boson

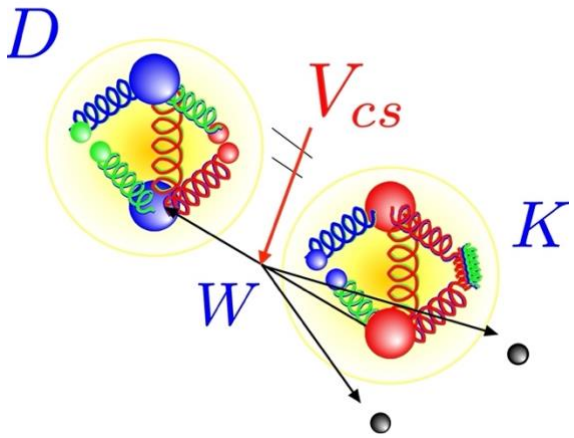

Figure 1. When the D meson emits a W boson to become a K meson, the underlying process is a charm quark transition to a strange quark. The coupling between c, s and W is called Vcs.

Theorists in the HPQCD collaboration have pinned down Vcs, a key parameter of the Standard Model, using STFC's DIRAC Data Intensive supercomputer at Cambridge. Vcs is determined from combining the theoretical calculation with results from particle physics experiments around the world for the proportion of D mesons that decay to a K meson in a process akin to nuclear beta decay (Figure 1). This rate depends on the coupling strength Vcs between the W boson of the weak interaction and the charm-strange quark pair, but also on the strong interaction physics, encoded by 'form factors', that binds the quarks inside the mesons while this process happens.

The numerical techniques of lattice QCD allow the form factors to be calculated, but in the past their uncertainty has limited the precision of Vcs. Using improved methods for handling quarks, developed by HPQCD, physicists in Cambridge and Glasgow have now obtained a value for Vcs of 0.9663(80), three times more accurate than previous work (arXiv:2104.09883). This allows Vcs to be distinguished from 1 for the first time (see Figure 2), giving tighter constraints on the possibilities for new physics beyond the Standard Model.

HPQCD has also improved the determination of the charm quark mass, achieving an accuracy of 0.5% and including the effect of the charm quark's electric charge for the first time. The mass (in the MSbar renormalisation scheme and at a scale of 3 GeV) is 0.984(5) GeV/c^2, a bit heavier than the proton (arXiv:2005.01845). In a linked paper, HPQCD also worked out accurately the ratio of masses for bottom and charm quarks (arXiv:2102.09609). These will be important for detailed experimental tests of whether the Higgs boson decays to different types of quarks with the rate that we expect in the Standard Model.

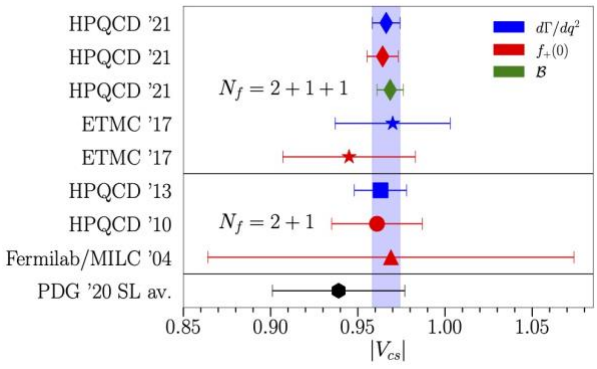

Figure 2. A comparison of HPQCD's new result for Vcs compared to earlier values, showing the big improvement in accuracy obtained. It is also now clear, for the first time, that the value of Vcs is below 1.

DiRAC's Data Analytic system in Cambridge has once again proved ideal for the numerically efficient methods HPQCD has developed for precision lattice QCD.