HPQCD

B meson oscillations

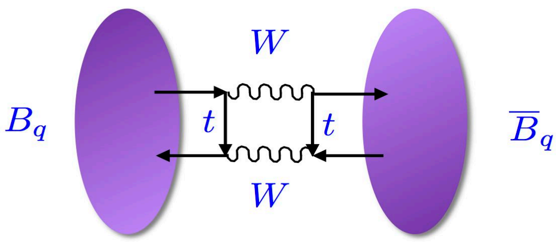

Figure 1. Oscillations between Bd or Bs mesons and their anti-particles occurs because of coupling via a 'box diagram' with W bosons and top quarks.

Watching the oscillations of two coupled pendulums (for example, attached to the same not-too-rigid support) provides insights into simple but rather counter-intuitive physics. Set one pendulum oscillating and, after a while, the other one will start up as the amplitude of the first dies down. Later still the amplitude of the second pendulum will die down and the first, rather astonishingly, start up again. The energy of the motion sloshes back and forth between the two pendulums because the swinging of either single pendulum is not a simple ('normal') mode of oscillation of the coupled system. Setting one pendulum in motion in fact sets both normal modes oscillating and these combine the motion of both pendulums in different ways. As time progresses the interference between the normal modes, which have different frequencies, results in this puzzling (at first sight) behaviour.

An analogous phenomenon occurs in the physics of particles that are bound states of a bottom quark and either an anti-strange or anti-down quark, known as a Bs or Bd meson respectively. We can distinguish these particles from their anti-particles by their decay processes in our particle detectors. However the B and anti-B are coupled together through the weak interaction process shown in Figure 1. The particles with simple time behaviour (the 'normal modes') are then mixtures of the B and anti-B. A particle produced as a B may oscillate back and forth into an anti-B (and decay as one in our detector) at a later time with a frequency that can be measured very accurately in experiments at the Large Hadron Collider at CERN. Calculation of the coupling induced by Figure 1 requires the numerical solution of the theory of the strong force (that holds the B and anti-B together) using the method known as lattice QCD. HPQCD has recently done the most accurate calculations of this to date (arXIv:1907.01025) using DiRAC. Comparison to the experimental results enables us to determine the coupling between W bosons, top quarks and strange or down quarks (Vts and Vtd) as shown in Figure 2. Our results agree well with the Standard Model expectation that the CKM matrix of W-boson couplings is unitary, and limit the room for new physics. We also predict the annihilation rate of Bs and Bd mesons to a μ+μ- pair, a key mode for new physics searches at LHC. HPQCD has also done the first lattice QCD calculation of the difference of decay rates of the two normal modes of the Bs (arXiv:1910. 00970).

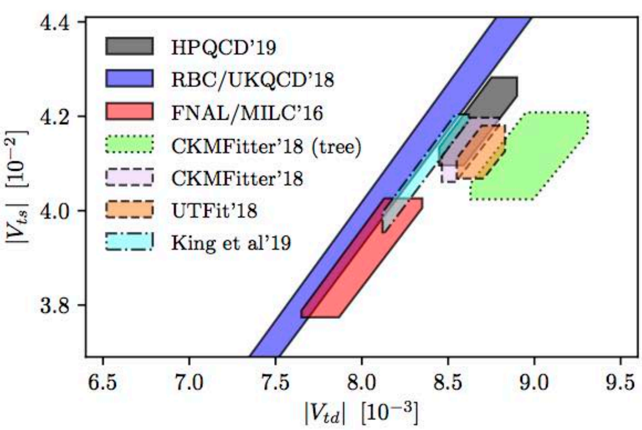

Figure 2. Values obtained for Vts and Vtd from experimental results for Bs/Bd oscillations and lattice QCD (solid lozenges) or assuming CKM unitarity (dashed). HPQCD's (black) is the most accurate direct result to date.