HPQCD: LUV is in the air!

Nuclear beta decay is the most well-known version of a process in which quarks emit weak interaction W bosons and change type or 'flavour' whilst bound by the strong interactions inside a hadron. In nuclear beta decay a neutron becomes a proton as one of its down quarks changes into an up quark. Other quarks undergo beta decay too and in the process provide insights into possible new physics beyond the Standard Model (SM). The W boson here is seen through its decay to a lepton and antineutrino. The SM W boson does not distinguish between leptons, except for effects that arise from their masses. This is known as Lepton (flavour) Universality (LU). Hints of lepton universality violation (LUV) have been seen in some beta decays – it is important to study others to pin this down. Accurate lattice QCD calculations of strong interaction effects are critical here for comparison to experiment.

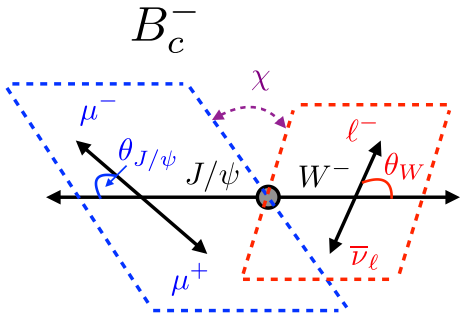

Figure 1. When the Bc emits a W boson to become a J/psi meson, different helicities of W boson affect the rate of decay in different kinematic regions of angles and momenta.

The beta decay of a Bc meson to a J/psi meson is a promising such process, currently being studied by the LHCb experiment at CERN. A Bc meson has no net spin but the J/psi charm and anti-charm quarks have their spins aligned for a total spin of 1. This means that the different spin alignments (helicities) of the W boson contribute to the angular distribution of the decay products in ways that may allow tests for new physics (Figure 1). HPQCD has calculated the amplitude for this process via different W helicities and covering the full range of possible J/psi momenta for the first time, using lattice QCD (Figure 2; PRL125:222003, PRD102:094518). This allowed us to determine the ratio of rates of production in the SM of tau leptons in the final state compared to mu (from the W) as 0.2582(38) with a 1.5% uncertainty. Initial LHCb results hint at disagreement, which might indicate LUV from new physics, but their large uncertainty masks any significance in the comparison. Using our results in the LHCb analysis should enable reduced experimental systematic errors. In another lattice QCD 'first' HPQCD also calculated the amplitudes for Bc to Bs and Bc to Bd beta decay (PRD102:014513). Here a charm quark transforms to an s quark or d quark; these are on LHCb's 'to-do' list to compare to c to s/d processes in D mesons.

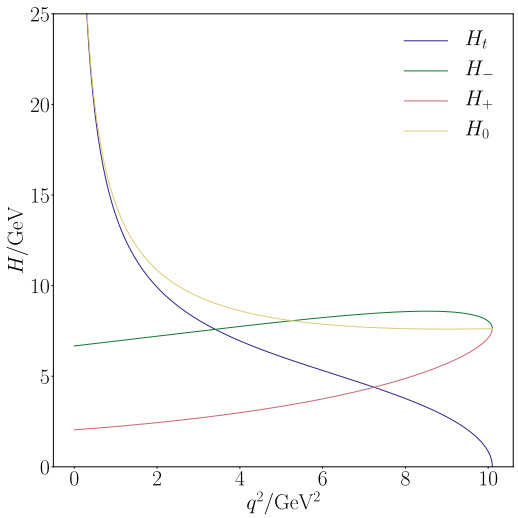

Figure 2. W Helicity amplitudes for Bc to J/psi decay vs squared momentum transfer. Ht appears with the lepton mass and so only contributes when the W decays to the heavy tau.

The HPQCD calculations were done on the DiRAC Data Analytic system in Cambridge; this is ideal for the numerically efficient methods we have developed to study b and c quarks using precision lattice QCD on very fine lattices.