Hadronic Parity Violation and Lattice QCD

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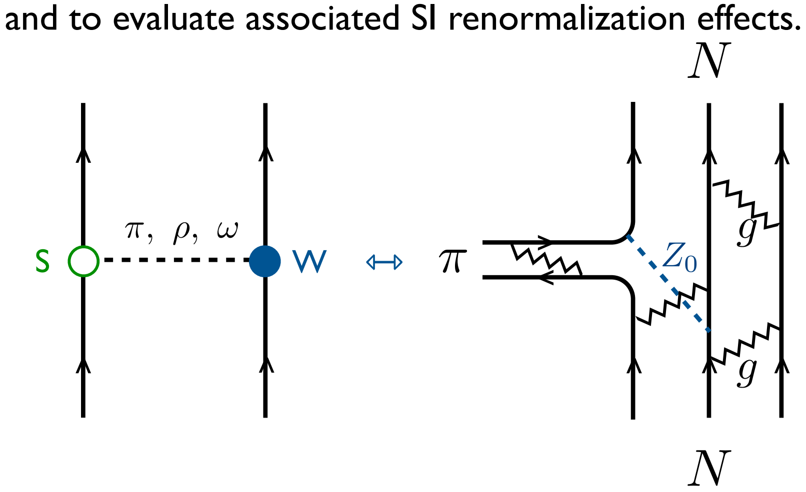
Abstract: The strangeness-conserving neutral weak current has not been isolated experimentally, but is the subject of a major experiment now mounted on the cold neutron beamline of the SNS. This interaction dominates the parity non-conserving (PNC) long-range weak interaction between nucleons. A CalLat goal is to evaluate the isovector πNN coupling corresponding to this interaction as well as the isotensor ρNN coupling: without the latter result, the most significant experiment in the field, the asymmetry in p+p scattering, looses impact. We describe our global analysis motivating this work, Wasem's recent Lattice QCD calculation of the PNC πNN coupling, and plans to improve this result and undertake similar LQCD calculations for the isotensor ρNN coupling.

Hadronic PNC

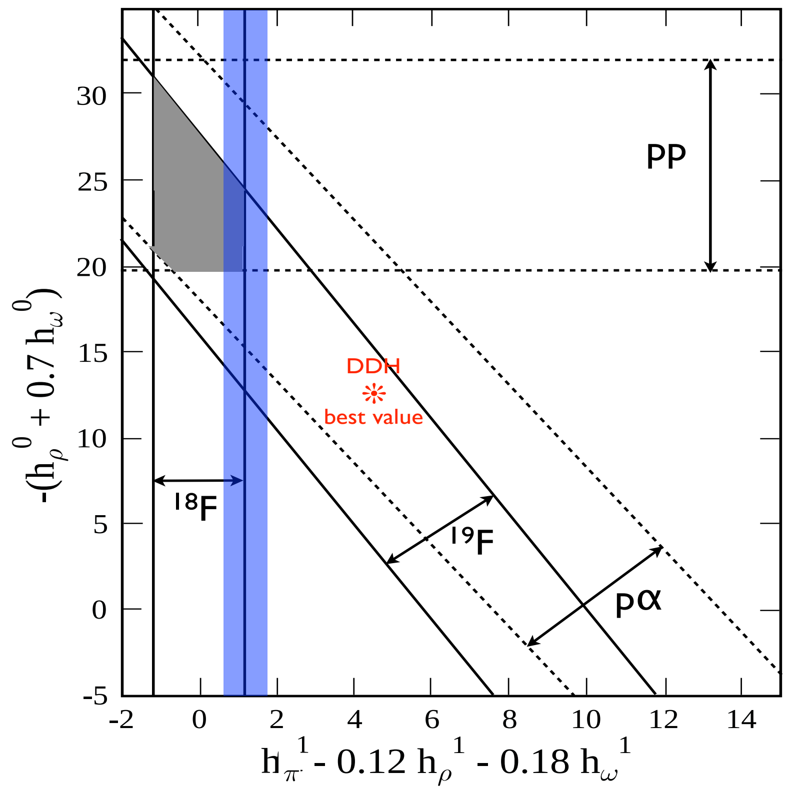
The elementary couplings of weak currents to quarks are determined by the Standard Model (SM). The strangeness-conserving hadronic weak interaction is only accessible through nucleon-nucleon and nuclear experiments, with PNC the filter that allows one to identify the weak interaction despite the dominance of the strong interaction (SI). However the SI acting in the nucleon will alter couplings. A key goal of the field has been to isolate the neutral current contribution and to evaluate associated SI renormalization effects.



The low-energy PNC NN interaction can be viewed as arising from meson exchange, with one strong and one weak vertex, with the latter modified by SI effects.

Global PNC Analysis

There are four sets of interpretable measurements constraining PNC: the longitudinal asymmetries for p+p and p+α, the photon circular polarization in 18F, and the photon asymmetry in 19F. For some time it has been believed that these measurements lead to an inconsistent description of PNC. The situation greatly improved in a recent global analysis in which we treated the low- and high-energy p+p measurements and other experiments in a unified framework.



The analysis shows that the isoscalar π coupling is suppressed by at least a factor of three and the isoscalar ρ/ω coupling is enhanced by a factor of two relative to SM estimates (DDH best values). The factor-of-six difference in the ratio of isospin I=0 to I=1 couplings is superficially reminiscent of the ΔI=1/2 rule describing the analogous I=1/2 to I=3/2 ratio in strangeness-changing weak hadronic decays.

An anomalously weak I=1 PNC coupling has been recently confirmed in lattice QCD calculations.

PNC Couplings from Lattice QCD

The blue band on the global analysis graph came from the first LQCD calculation of a PNC weak meson-nucleon coupling. The contractions performed by Wasem to obtain this result required approximately 6 months of running on LLNL's Edge GPU cluster.

This initial calculation was performed on a single ensemble of n_f=2+1 dynamical anisotropic clover gauge configurations for a lattice of dimension 2.5 fm, spacing 0.123 fm, and pion mass 389 MeV. The result includes only connected diagrams. The error on the band includes a qualitative estimate of the systematic uncertainties associated with these lattice parameters.

The improvement of this calculation and the extension of the work to the isotensor PNC ρNN coupling is one of the initial goals of the CalLat Collaboration. An LQCD calculation of the PNC πNN coupling at nearly physical π masses with the inclusion of quark-loop contributions appears within reach, given new machines such as LLNL's 20-pflop Sequoia. The isotensor PNC ρNN coupling contributes to the p+p asymmetry but is otherwise unconstrained by experiment. Consequently the p+p band in the figure has been enlarged due to "marginalizing" against this degree of freedom. A lattice calculation of the ρNN coupling, quite feasible because there are no costly quark-loop contributions, will tighten this band.

CalLat effective theory work will relate the LQCD results to the four measurements shown in the graph.