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$\triangle$ baryon spectroscopy using Hamiltonian Effective Field Theory and lattice QCD

Building on previous studies of the nucleon spectrum and the enigmatic Roper resonance, we investigate the closely related Δ baryon spectrum using a combination of lattice QCD and Hamiltonian Effective Field Theory (HEFT). We obtain effective masses for the ground state and first excitation of the spin-3/2 Δ baryon in full QCD using 2+1 flavour PACS-CS gauge field configurations on a $32^3 \times 64$ lattice with a spin projection technique to isolate the spin-3/2 states of interest. In order to compare with experiment, we use HEFT to connect between the finite volume of the lattice and the infinite volume of the real world.

HEFT describes a system with interactions between 3-quark bare basis states and meson-baryon two-particle non-interacting states. We take the relevant two-particle channels to be πN and $\pi\Delta$ in p-wave, and $\pi\Delta$ in f-wave. We constrain the Hamiltonian matrix parameters by fitting the relevant couplings, potentials, bare masses and regulator parameters to experimental phase shifts and inelasticities available through George Washington University's SAID partial waves database. The Hamiltonian can then be solved for its eigenvalues and eigenvectors on a finite volume; the eigenvalues allow us to match to the lattice results while the eigenvectors inform us on how much the bare states and two-particle channels contribute to those energies.

We find evidence to suggest the ground state $\Delta(1232)$ is predominantly a 3-quark state, while the 1st excitation $\Delta(1600)$ appears to be predominantly a dynamical state generated through strong rescattering of πN (p-wave), $\pi\Delta$ (p-wave) and $\pi\Delta$ (f-wave) channels, in contrast to traditional quark model expectations. The next 3-quark dominated state in the spectrum appears to lie around 2 GeV.

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