ID contributo: **107** Tipo: **non specificato**

New insights into the quark model from lattice QCD

mercoledì 19 ottobre 2022 11:15 (35 minuti)

The idea of dressing quark-model states in a coupled-channel analysis to describe scattering data has been around for decades. What's new are formalisms able to bring these descriptions to the finite-volume of lattice QCD where calculations of the excitation spectrum provide new constraints. This combination of lattice QCD and experiment demands that we reconsider our preconceived notions about the quark-model and its excitation spectrum.

This presentation will focus on recent advances in understanding the structure of baryons and their low-lying excitations. The results are founded on the first-principles approach of Lattice QCD, complemented by Hamiltonian effective field theory (HEFT), a nonperturbative extension of effective field theory incorporating the Luscher formalism.

After presenting the formalism in the context of the Delta resonance, we'll explore the low-lying odd-parity nucleon resonances where two nearby quark-model like states introduce new challenges in mixing multiple bare basis states. The formalism is then applied to the Lambda(1405) where evidence of a molecular meson-baryon state is apparent.

The results lead to a consideration of the even-parity Roper resonance and its isospin-3/2 Delta-resonance partner. Lattice QCD calculations indicate the first radial excitation of the nucleon lies at 1900 MeV, well above the resonance position of 1440 MeV. Using HEFT, experimental scattering data are brought to the finite volume of the lattice where lattice QCD results determine the nature of the Roper resonance. Finally, these techniques can be extended to the Delta-resonance spectrum providing new insight into the structure of the low-lying even-parity Delta(1600) resonance.

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Classifica Sessioni: Plenary