Baryon spectroscopy from lattice QCD

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Abstract

The formulation of QCD on a discrete space-time lattice allows us to study the non-perturbative aspects of QCD with numerical simulations. This thesis investigates the spectrum of baryon resonances in quenched lattice QCD.

Our investigation begins with high precision studies of the spectrum of nucleon and Δ resonances on a large $20^3 \times 40$ lattice. We use the Luscher-Weisz plaquette plus rectangle gauge action and the FLIC fermion action for near continuum results at finite lattice spacing. We extend this work to include a search for evidence of the N(1440) "Roper Resonance" in quenched lattice QCD, which should appear as the first even parity excited state of the nucleon. A correlation-matrix analysis with a basis of three nucleon interpolators is considered.

With a strong foundation in the study of nucleon resonances on the lattice, we extend our work to search for evidence of the existence of the $S = +1$, Θ^+ pentaquark having minimal quark content ($uudd\bar{s}$). Observations of the Θ^+ pentaquark were reported in several photo-production experiments, which caused tremendous interest from theorists in the field of high energy physics. Later, several non-observations of the Θ^+, particularly in high statistics experiments conducted by the CLAS collaboration have cast doubt on its existence. Currently there is no known law of nature that excludes the possible existence of a pentaquark state. It is therefore important to determine if the theory of QCD does allow the existence of the Θ^+. As a "first principles" approach to QCD, the lattice provides an unique opportunity to do this.

Key to this work is the formulation of a robust signature of a resonance on the lattice that can discriminate a Θ^+ pentaquark from other possible two-particle states. In our study we consider what we refer to as the standard lattice resonance signature, which is evidence of an attractive interaction between the constituents. We see that this resonance signature is universally observed in lattice studies of the nucleon resonances.

We explore the widest possible space of quantum numbers, with both spin-1/2 and spin-3/2, using an extensive set of local pentaquark interpolating fields. A highlight of this work is our exploratory study of the Θ^+ with spin-3/2, which was the first of its kind. We find evidence of the standard lattice resonance signature in the $I(J^P) = 0(3/2^+)$ channel.

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