Finite Volume Field Theory & QCD Spectroscopy

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2024 Modern Techniques in Hadron Spectroscopy

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U.S. DEPARTMENT OF ENERGY

ExoHad

Exotic Hadrons Topical Collaboration

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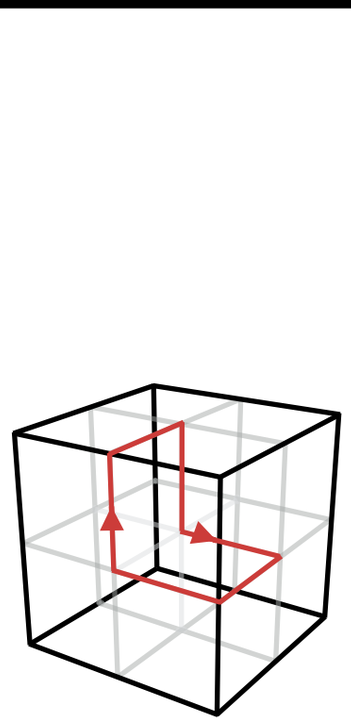
Chartered 1693

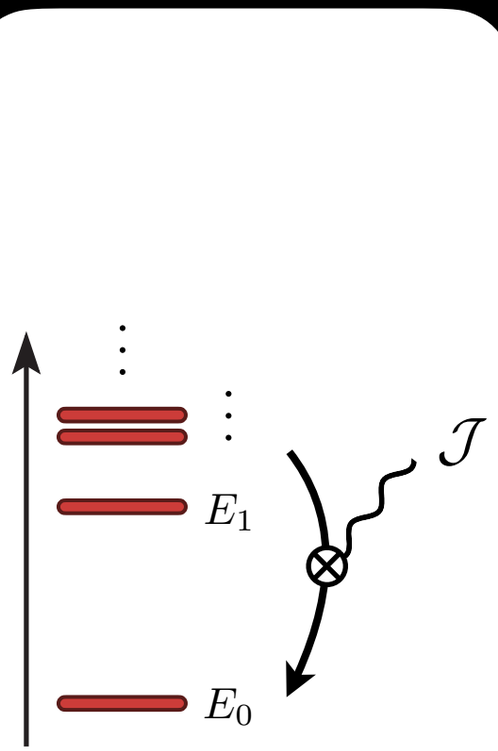
Hadron Dynamics from QCD

Quantum ChromoDynamics (QCD) is *the* theory of *all* observable hadronic phenomena

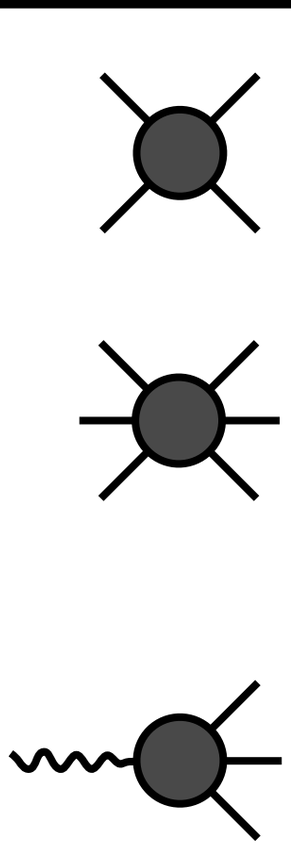
- Lattice QCD is tool to access low-energy physics
- Connect lattice QCD observables to scattering observables



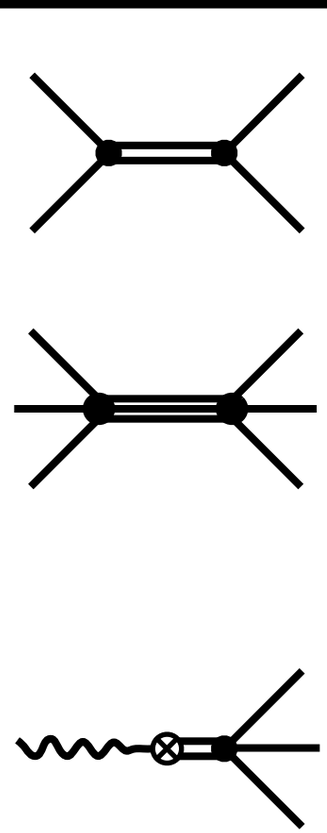
Lattice QCD



FV Spectra & Matrix Elements



Scattering & Transition Amplitudes

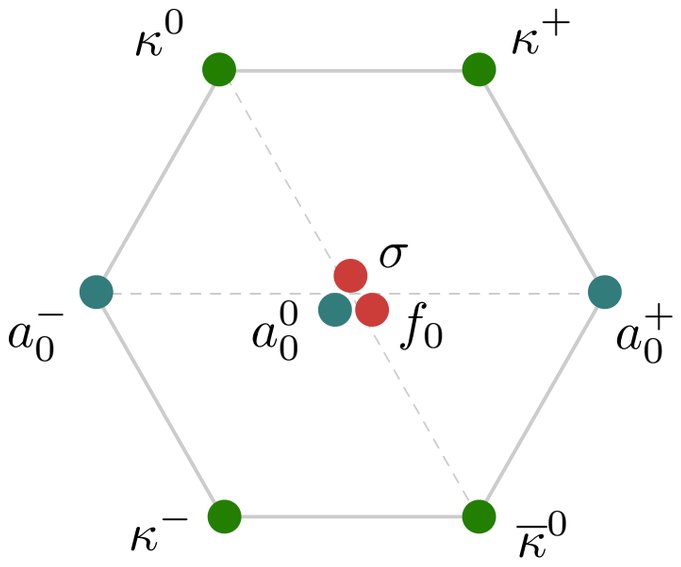


Bound & Resonant State Properties

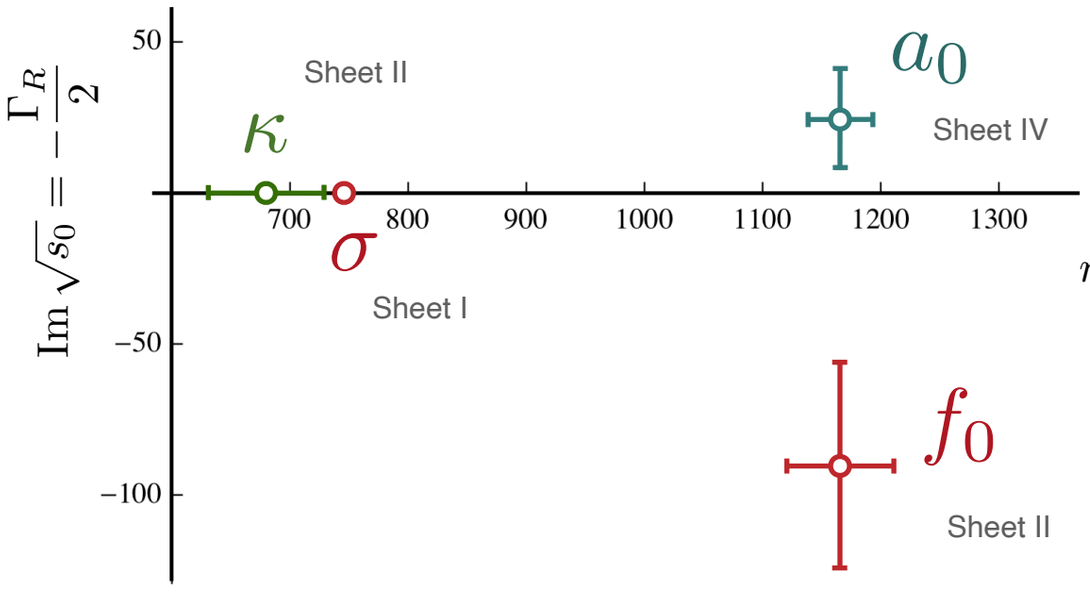
Hadron Dynamics from QCD

Has proven successful in accessing resonance physics from QCD

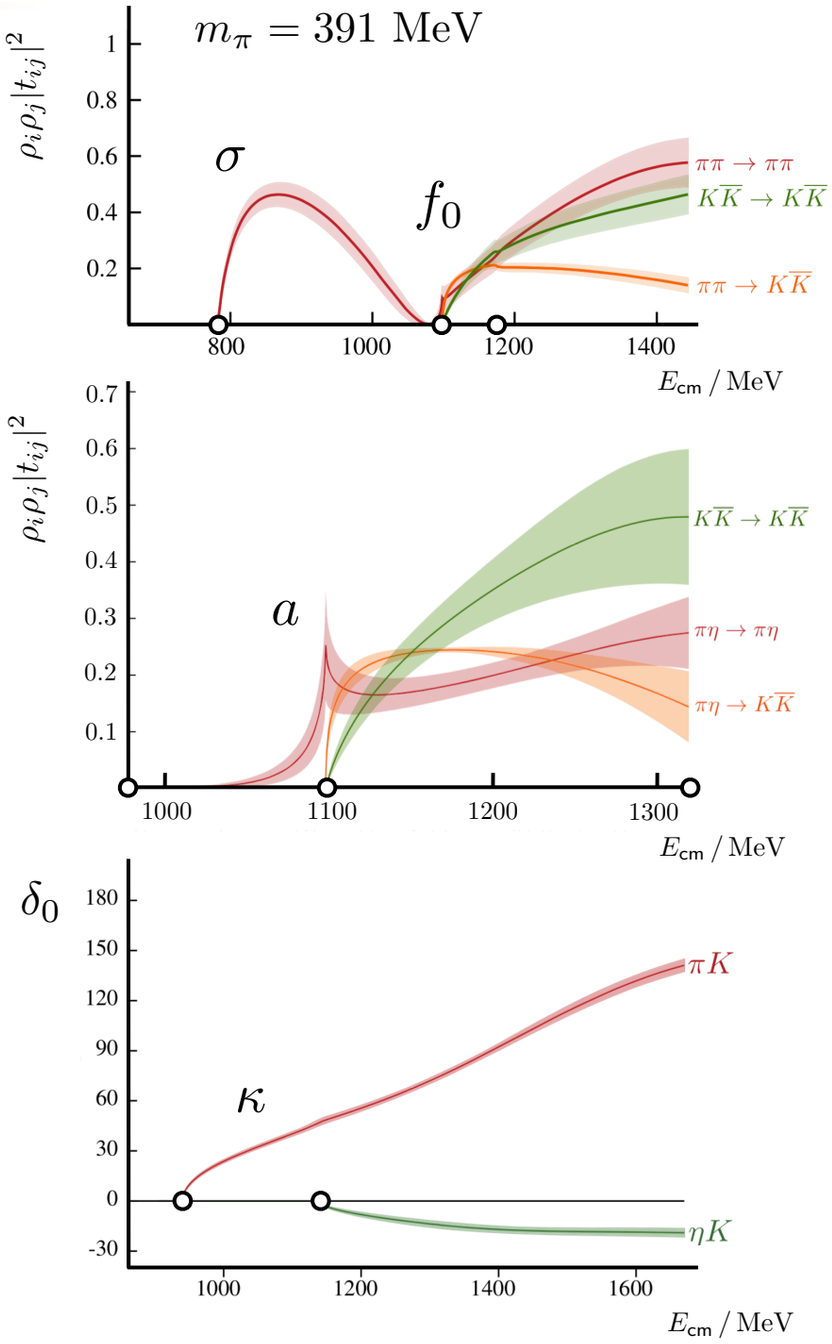
- e.g., the scalar nonet



$m_\pi = 391$ MeV



$m_R = \mathrm{Re}\sqrt{s_0}$



R.A. Briceño et al. [HadSpec]
Phys. Rev. **D97**, 054513 (2018)

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Phys. Rev. Lett. **113**, 182001 (2014)

A Reference (that I like)

arXiv:1706.06223 (2017)

Scattering processes and resonances from lattice QCD

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The vast majority of hadrons observed in nature are not stable under the strong interaction, rather they are *resonances* whose existence is deduced from enhancements in the energy dependence of scattering amplitudes. The study of hadron resonances offers a window into the workings of quantum chromodynamics (QCD) in the low-energy non-perturbative region, and in addition, many probes of the limits of the electroweak sector of the Standard Model consider processes which feature hadron resonances. From a theoretical standpoint, this is a challenging field: the same dynamics that binds quarks and gluons into hadron resonances also controls their decay into lighter hadrons, so a complete approach to QCD is required. Presently, lattice QCD is the only available tool that provides the required non-perturbative evaluation of hadron observables. In this article, we review progress in the study of few-hadron reactions in which resonances and bound-states appear using lattice QCD techniques. We describe the leading approach which takes advantage of the periodic finite spatial volume used in lattice QCD calculations to extract scattering amplitudes from the discrete spectrum of QCD eigenstates in a box. We explain how from explicit lattice QCD calculations, one can rigorously garner information about a variety of resonance properties, including their masses, widths, decay couplings, and form factors. The challenges which currently limit the field are discussed along with the steps being taken to resolve them.

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