Abstract

Quantum Chromodynamics (QCD) is the widely accepted theory governing the dynamics of quarks and gluons, the force carriers of the strong interaction. While many properties of hadrons, composite states of quarks bound by gluons, may be understood in terms of their quark content, gluons play a prominent role in mass generation, high-energy scattering processes, and the very nature of confinement itself. One of the most striking predictions of QCD is the existence of bound states comprised solely of valence gluons, known as glueballs. While their existence is supported by computer simulations, experimental evidence remains elusive, with theoretical computations often yielding conflicting results.

The development of high-energy colliders, culminating in the Large Hadron Collider (LHC) at CERN, has revealed a rich landscape of gluon-dominated phenomena. The Pomeron, initially postulated to explain rising total scattering cross sections in high-energy data, is now recognized as a fundamental prediction of QCD, reflecting collective gluon dynamics at high energies. Furthermore, the recent claim of the Odderon discovery at the LHC and Tevatron, the Pomeron's C-odd partner, has the potential to significantly deepen our understanding of the strong interaction by studying fundamental processes associated with it, though this claim is not without controversy.

Over the last three decades, a novel approach to understanding the fundamental nature of strongly coupled systems has emerged, known as the AdS/CFT correspondence. This duality, initially formulated between highly symmetric superstring and field theories, has found successful applications in less symmetric systems, which eventually led to the construction of holographic QCD. In this thesis, we explore the extent to which QCD in the confining phase may be described by a weakly coupled, higher-dimensional gravitational theory. We investigate glueball properties using holographic hadron spectroscopy within a type IIA superstring theory brane construction. This approach allows for the determination of glueball masses, decay channels, and mixing. We further apply holographic Regge physics through bottom-up models to analyze high-energy collider data, with a particular focus on the physics of the Pomeron and Odderon. By deepening our theoretical understanding and providing testable predictions for collider experiments, this research aims to contribute to our understanding of the strong interaction and rich gluon dynamics in the high-energy regime.