Abstract

Because QCD is strongly coupled at low energies, standard perturbative techniques are no longer applicable at this energy scale. In this thesis, we use effective models that have hadronic degrees of freedom. The guiding principle throughout is the implementation of the global symmetries of QCD and their anomalous, explicit, and spontaneous breaking patterns, notably chiral symmetry and dilatation symmetry.

First, the theory of a free scalar field coupled to a time-independent classical source is studied as a simplified model for dilaton production in a medium. We show that the time evolution in the theory is non-trivial, contrary to historical expectations. The theory exhibits nonperturbative particle production similar to the Schwinger mechanism, with interesting features such as non-exponential decay and the quantum Zeno effect.

Next, we introduce the extended Linear Sigma Model (eLSM) and apply it to (axial) tensor mesons, the tensor glueball, and charmonium states mixing with the vector glueball.

We confirm the quark-antiquark assignment of the standard tensor meson nonet by fitting their decays to data. Using chiral symmetry, we derive predictions for the masses and decays of axial tensor mesons which can be tested by experiments. The axial tensor mesons are predicted to be very broad states.

The eLSM is used to calculate decay ratios of the tensor glueball. We then compare these to experimental data on known candidates for the tensor glueball. This comparison shows that the $f_2(1950)$ is the most likely tensor glueball candidate in this framework. A rough estimate of the decay widths also indicates that the tensor glueball could be a relatively broad state.

Finally, the decays of the charmonium states J/ψ and $\psi(3686)$ into vector–pseudoscalar final states are investigated. These channels exhibit significant violations of the perturbative QCD "13% rule", most prominently in the $\rho\pi$ channel. We apply the eLSM, including electromagnetic effects and mixing with the vector glueball. It is shown that these ingredients allow for a successful phenomenological description of the observed ratios $\mathcal{B}(\psi(3686) \to h)/\mathcal{B}(J/\psi \to h)$.

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