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Hadron light-front wave functions based on AdS/QCD duality

Abstract

In the dissertation it is shown that the front-form (FF) theory equipped with the renormalization group procedure for effective particles (RGPEP) leads to two descriptions of the hadron. The one is called the complete and the other effective.

The hadron in the complete description is represented in the Fock space by the set of wave functions which, besides the dependence on momentum, spins, polarizations and colors, depend also on the renormalization group parameter λ. In this description hadrons satisfy the QCD eigenvalue equation for mass-square.

The hadron in effective description is described as a two body system made of the active constituent and the core. This system emerges from the description of the hadron interaction with the photon probe, and thus leads to the proper description of the hadron electromagnetic form-factor. The wave function describing the effective system is λ-independent and satisfies the effective Schrödinger-like equation, whose eigenvalue is the mass square of the hadron. In this approach, one averages over selected constituents and, at the same time, integrates over their spectators. That is done for every Fock sector of the hadron and contributions of all the sectors are summed to produce the final equation for one effective wave function. This approach is called the Ehrenfest approach.

The Ehrenfest description of the hadron dovetails with the LF-holography, which predicts the shape of the effective potential that can not be derived directly from the Ehrenfest approach alone. The LF-holography originating from the AdS/QCD correspondence, together with the other FF models of mesons, suggests the quadratic shape of the effective potential. It is shown, however, that the commonly accepted linear potential in the usual form of dynamics agrees with the quadratic potential in the FF dynamics.

Furthermore, it is observed that in the case of mesons the effective Ehrenfest wave function may approximate the wave function of the lowest Fock sector of meson at small λ. Assuming this relation and quadratic effective potential, the Ehrefest wave function for pion is found to lead to a good agreement with the experimental observables such as pion radius, pion decay constant and pion form factor up to $Q^2 = 1$ GeV^2.

Developed in this dissertation, the two hadrons scattering formalism allows one to describe the pion-nucleus diffractive scattering process. In this description the $\mathcal{W}$-transformation plays a key role, since it enables one to transform the hadron state written using one λ to the hadron state written using different λ. As a result, the suggested pion wave function reproduces very well the results of the E791 experiment, which measured the transverse and the longitudinal momentum distribution of two jets emerging from scattering of pion beam on the platinum target.