Recent progress in the "continuum QCD" approach.

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Introduction

The so called "continuum QCD" approach [1–3] is based on the Dyson-Schwinger equations of QCD. Nonperturbative by its nature it provides access to such phenomena as dynamical chiral symmetry breaking and confinement. In combination with covariant few-body dynamical equations it represents a reliable framework for description of hadron properties and scattering processes and their explanation on the microscopic quark-gluon level. An important tool is also the so called "gauging equations method" [4, 5], it represents a systematic way of constructing hadron matrix elements from the Green functions derived as the solutions of the above mentioned Dyson-Schwinger and covariant few-body equations. The idea of the method is coupling a current everywhere in a Green function; in the case of nonperturbative description it prescribes how to do this via given equation for a Green function. As a result one extracts full information encoded in the equation, besides one avoids the problem of very well hidden overcounting. In the case of conserved currents Ward-Takahashi identities are satisfied automatically. The method has been applied to describe nucleon form factors where the problem of overcounting was spotted and resolved for the first time. The scope of the approach is however more general, it applies to study generalized parton distributions [6], with appropriate choice of currents it offers a unified theoretical approach to a variety of reactions [3] such as Compton, πN and $\pi\pi$ scattering, pion photoproduction, strangeness and charm production processes; it also applies to crossed-channel reactions, for example exclusive $p\bar{p}$ annihilation into two photons that will be studied with the PANDA experiment at FAIR/GSI.

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Results

In the present note we report on further development of methods needed in the continuum QCD approach.

(i) We discuss the four-quark equations [7, 8] used for the tetraquark bound state [8] and their modification if the effect of $q\bar{q}$ annihilation needs to be taken into account. In the case of four quarks this effect does not exist, but even in this case one should be careful when constructing the kernel of the equations. This concerns even pair interaction approximation; subtractions are needed to avoid overcounting which in turn require a new rearrangement procedure, different from Faddeev's one. In the case of the $2q2\bar{q}$ system it is natural that the problem gets much more complicated. Just in this case we have constructed mathematically correct and physically transparent equations which can be treated with the help of the same well developed tools as ones used in [8].

(ii) We show that scattering amplitudes in the $2q2\bar{q}$ system can be generated also with the help of the gauging equations method, namely, models of the dressed quark propagator are presented whose gauging leads to amplitudes of practical interest. In (i) unitarity is respected at each step of the derivation, whereas in (ii) the leading principle is gauge and crossing invariance, therefore interrelation between unitarity, crossing invariance and gauge invariance is discussed.

(iii) A method is presented which allows constructing gauge invariant amplitudes where the underlying dynamics is revealed in a truly field theoretical way. As a transparent example a gauge invariant model is presented for the three photon decay amplitudes. In this view note that three-photon decay of orthopositronium provides a laboratory for precision QED tests [9], despite tiny decay rates, three-photon decays of vector quarkonia are of considerable theoretical interest as they can provide valuable information about underlying QCD dynamics [10]. Gauge invariance issue is not the only aim of the method, it is rather a result of a consistent, truly field theoretical, account of the underlying dynamics. In the resultant expression for the $\Phi \to n\gamma$ decay amplitudes all ingredients, the meson bound state wave function, dressed quark propagators and dressed quark currents, are determined by a universal kernel. Manifest gauge invariance is a direct result of such consistency relation between the ingredients.

References

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