Radiative decays of excited meson in the light cone sum rules

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Summary. — The contribution of the long distance effects, namely parity-conserved and parity-violated form factors in the radiative decays of excited $B^{*+} \rightarrow q\gamma$ and $D^{**} \rightarrow q\gamma$ are calculated in QCD light cone sum rule.

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1. - Introduction

The experimental and theoretical investigation of the heavy-flavored hadron physics is still an important theme in the existing literature. The observations of the inclusive decay $B \rightarrow X_s \gamma$ as well as the exclusive decay $B \rightarrow K^* \gamma$ [1] have placed the study of rare $B$ decays on a new footing. These flavor-changing neutral-current (FCNC) transitions represents an important class for testing the Standard Model (SM) at loop level [2] and a powerful tool for establishing “new physics” beyond it [3]. The heavy-flavor decays are also useful in the determination of Cabibbo-Kobayashi-Maskawa (CKM) matrix elements, and play an exceptional role in understanding the dynamics of QCD.

As is well known, the inclusive heavy-flavor decays like $b \rightarrow s\gamma$ can be easily evaluated within perturbative methods, but are more difficult to detect experimentally. Exclusive heavy-flavor decays, on the other hand, are more easy to detect, but require difficult non-perturbative calculations of matrix elements in order to yield useful results. This means that the dynamics of heavy-flavored hadron decays (exclusive decays) included the long-distance effects and their calculations are only possible in a non-perturbative framework.

In the radiative decays of the heavy-flavored meson decays, there are two different types of long-distance effects. The first is the penguin loops, which is responsible for $b \rightarrow s(\bar{d})$ transition and runs out at low momentum. Many papers in the literature are devoted to the analysis of such long-distance effect [4]. The main result of these works is that the long-distance contributions are very small in agreements with the general assumption that the short-distance penguin mechanism dominates in the exclusive decays. The second one is the weak annihilation mechanism (WA), which does not involve loops of heavy quarks, but takes place via weak annihilation (WA) of the initial
quarks. The way for estimating the long-distance effect via WA is to use a constituent quark model in which the photon and gluon are emitted from the light quark in the initial state [5]. In other words, the radiative $B \rightarrow M \gamma$ decays is modelled by the sum of all possible hadronic intermediate states [6]. Many non-perturbative approaches have been suggested for computing the matrix elements appearing in these long-distance effects: among them are lattice theory, heavy-quark effective theory, chiral perturbative theory, quark models, $1/N_c$ expansion and QCD sum rule method. The resulting theoretical predictions are very strongly model dependent. However, the QCD sum rule method occupies a special place, since it is based on the first principles of QCD, and the non-perturbative parameters describing the long-distance effects have universal perspective.

Recently, a new alternative and practically model-independent method has been suggested for the calculation of the long distance effects in the radiative heavy-meson decays [7-9]. This method is based on the light cone version of the QCD sum rules. It provides a reliable estimation of the long-distance effects, and is a quite successful for the investigation of the exclusive decays.

In the framework of the light cone QCD sum rules, the strong couplings $g_{\omega\gamma\gamma}$, $g_{\pi\gamma\gamma}$, $\pi A_\gamma^* \rightarrow \gamma$ transition form factor [11], $\Sigma \rightarrow \gamma$ decay [12], $g_{B_d \pi}$ coupling constants [13], $B$- and $D$-meson semileptonic decay form factors [14], radiative $B$- and $D$-meson decays [7,8,15] and the radiative $B \rightarrow \pi \gamma$ decay [8,9] are successfully investigated.

In this work we estimate the long-distance effects in the excited $B$- and $D$-meson ($0^+$) decays, in the framework of the light cone QCD sum rules.

The paper is organized as follows. In sect. 2 we derive the light cone QCD sum rules. In sect. 3 we carry out the numerical analysis and determine the transition form factors.

\section{Light cone sum rule}

The relevant effective Hamiltonian for $B^{**+} \rightarrow q^+ \gamma$ consists of two operators [16]:

$$H_W = \frac{G}{\sqrt{2}} V_{ub} V_{cd}^* \left\{ c_1 \bar{c}_\gamma \gamma \mu (1 - \gamma_5) \not{u} \not{c}_\gamma \gamma \mu (1 - \gamma_5) \not{b} + \right.$$ \hspace{2cm}

$$+ c_2 \bar{c}_\gamma \gamma \mu (1 - \gamma_5) \not{u} \not{c}_\gamma \gamma \mu (1 - \gamma_5) \not{b} \right\},$$

where $c_1$ and $c_2$ are the Wilson coefficients. Using the Fierz rearrangement formula the effective Hamiltonian, which describes $B^{**+} \rightarrow q^+ \gamma$ decay, can be rewritten in the following form:

$$H_W = \frac{G}{\sqrt{2}} V_{ub} V_{cd}^* \bar{a}_1 \not{c}_\gamma \gamma \mu (1 - \gamma_5) \not{u} \not{c}_\gamma \gamma \mu (1 - \gamma_5) \not{b},$$

where $a_1 = c_1 + c_2 / 3$. The value of the coefficient $a_1$ is extracted from two-body non-leptonic decay, using the factorization hypothesis [17]. The fits of the experimental results indicate that the value of $a_1$ [18] is close to its perturbative one. Therefore we can conclude that for $B^{**+} \rightarrow q^+ \gamma$ decay the factorization hypothesis works well.