LCDAs OF HEAVY HADRONS AND THEIR FIRST INVERSE MOMENTS

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INTRODUCTION

Doubly heavy baryons are denoted according their isospin I and heavy quark contents ($q = u, d$):
1. $I = 1/2$: $\Xi_{cc}(ccq)$, $\Xi_{bc}(bcq)$, $\Xi_{bb}(bbq)$
2. $I = 0$: $\Omega_{cc}(ccs)$, $\Omega_{cb}(cbs)$, $\Omega_{bb}(bbs)$

One of them, $\Xi_{cc}^{++}(ccu)$, is already observed by the LHCb [1, 2]

$$M_{\Xi_{cc}^{++}} = (3621.6 \pm 0.4)\ \text{MeV}$$
$$\Gamma_{\Xi_{cc}^{++}} = (2.56 \pm 0.27) \times 10^{-13}\ \text{s}$$

Its partner, $\Xi_{cc}^{+}(ccd)$, is under intensive search.

Doubly heavy baryon is dynamically similar to a heavy meson.

LIGHT-CONE BASIS

$$n_\pm^\mu = \frac{1}{\sqrt{2}}(1, 0, 0, \mp 1)$$
$$n_\pm^2 = 0, \quad (n_+ n_-) = 1$$
$$dz'^\mu = dz'_- n_+^\mu \qquad A_\pm = n_\pm^\mu A_\mu$$
$$A^\mu = A_+ n_-^\mu + A_- n_+^\mu + A_\perp^\mu$$

Wilson line between quarks

$$E(0, z) = \mathcal{P} \exp\left\{-i g_{\text{st}} \int_0^{z_-} A_+^a(z'_-)\, \frac{\lambda^a}{2}\, dz'_-\right\},$$

where g_{st} is the strong coupling and $A_\mu^a(z)$ is the gluonic field in the Fock-Schwinger gauge $A_+(z) = 0$. Consequently, $E(0, z) = 1$. Heavy quark or diquark is the static source of external field which is situated at the frame origin.

THEORETICAL ANALYSIS

The matrix element of the non-local current can be obtained in a similar way as it was done for the heavy meson (B-meson) [4]. In the heavy meson an antiquark Q^* is infinitely heavy and, hence, static while a light quark q is separated by a distance z from it ($z^2 = 0$) and determines a hadron dynamics. In the baryon considered a light quark is at a distance z from the center of the doubly heavy diquark: $\tilde{O}_0(t) = d(0)\, q(z)$ and $\tilde{O}_1^\mu(t) = \varepsilon^\mu(0)\, q(z)$, where $d(0)$ and $\varepsilon^\mu(0)$ are spin $S = 0$ or $S = 1$ doubly heavy diquarks QQ', being at rest, $t = (vz)$, and the Wilson line $E(0, z)$ is suppressed. For the Ξ_{bc}-baryon, the spinless diquark is assumed, vector diquark is considered in the forthcoming publication. Because of the heavy-quark symmetry, there are two Light-Cone Distribution Amplitudes (LCDAs) only entering the heavy meson wave-function [4]. The same is true for the Ξ_{bc}-baryon and two LCDAs $\tilde{\varphi}_+(t)$ and $\tilde{\varphi}_-(t)$ should be introduced:

$$\left\langle 0 \left| \tilde{O}_0(t) \right| \Xi_{bc} \right\rangle = i f_{\Xi_{bc}} \left\{ \tilde{\varphi}_+ + [\tilde{\varphi}_- - \tilde{\varphi}_+]\, \frac{\hat{z}}{2t} \right\} U(v).$$

In general, doubly heavy diquarks should be considered as states formed by two heavy quarks separated spatially by R. To form sum rules, one should use local currents in which heavy quarks should be in the same point. This means that diquarks are local.

In QCD Sum Rules (QCD-SRs), one starts from a vacuum average of two or more currents [4] like local and non-local interpolation currents of the Ξ_{bc}-baryon: $\left\langle 0 \left| \tilde{O}^{\Xi_{bc}}(t)\, J_{\Xi_{bc}}(-x) \right| \Xi_{bc} \right\rangle$. The procedure of transforming this matrix element into the QCD Sum Rules is the same as for the B-meson [4]. Following the same steps, we arrive to the sum rules for the leading twist LCDA $\varphi_+(\omega)$ which is the Fourier transform of the position-space $\tilde{\varphi}_+(t)$:

$$f_{\Xi_{bc}}^2 \varphi_+(\omega)\, e^{-\tau} = \frac{3\omega}{8\pi^2 \tau}\, e^{(\bar{\Lambda} - \omega/2)\tau} \left[1 - e^{-(\varepsilon_c - \omega/2)\tau}\right] - \frac{< \bar{q}q >}{8\tau}\, \tilde{f}_S\left(\frac{\omega}{2\tau}\right) e^{(\bar{\Lambda} - \omega/2)\tau},$$

where $\bar{\Lambda} = M_{\Xi_{bc}} - m_b - m_c$ is the effective baryon mass, m_b and m_c are the b- and c-quark masses, $< \bar{q}q >$ is the local light quark condensate, τ is the Borel parameter, ε_c is an effective QCD-SRs threshold. The function $\tilde{f}_S(\nu)$ is a shape of a non-local quark condensate. For $\tilde{f}_S(\nu)$, two models are suggested in [5, 6].

SUM RULES FOR $\lambda_{\Xi_{bc}}^{-1}$

To get these sum rules, one needs to integrate out the sum rules for $\varphi_+(\omega)$ with the $1/\omega$ weight factor. Such sum rules for the $B_{(s)}$-meson were derived in [3]. The analytical form of these sum rules obtained for the Ξ_{bc}-baryon will be presented in the forthcoming publication. One can also obtain s-quark corrections when apply this analysis to the strange Ω_{bc}-baryon, similar to the B_s-meson [3].

Numerical results and details of the analysis can be found in the forthcoming paper.

$$\lambda_{\Xi_{bc}}^{-1} = \frac{e^{\bar{\Lambda}\tau}}{4\pi^2 f_{\Xi_{bc}}^2} \left[1 - \frac{\pi^2 < \bar{q}q >}{\tau\, \Gamma(p-2)}\, \lambda^{(p-3)/2}\, K_{p-1}(2\sqrt{\lambda})\right]$$

CONCLUSIONS

The Heavy-Quark Symmetry is applied to the construction of LCDAs of doubly-heavy baryons on the light cone. Dynamically, these LCDAs are similar to the ones in the B-meson as both are determined by one light quark situated in a field of a static color source. There two LCDAs in the doubly-heavy baryon of which $\varphi_+(\omega)$ is the leading twist one. QCD Sum Rules for the calculation of its first inverse moment are discussed.

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