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CONDENSATE DEPENDENCE OF PROFILE FUNCTION OF AXIAL VECTOR MESON

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Abstract
The condensate dependence of axial vector meson-spinor interaction was considered in the hard-wall framework of AdS/QCD. Bulk-to boundary propagators for the bulk axial vector field was presented, which boundary values are corresponded to the a_1 meson respectively. The action was obtained from the bulk interaction Lagrangian, where was included condensate dependence of profile function of a_1 meson.
***Keywords**: Condensate, axial vector, meson, profile function*

I. INTRODUCTION

During the last few years applications of gauge/gravity duality [1, 2] to hadronic physics attracted a lot of attention and various holographic dual models of QCD were proposed in the literature. These models were able to incorporate such essential properties of QCD as confinement and chiral symmetry breaking and also to reproduce many of the static hadronic observables, with values rather close to the experimental ones. Within the framework of the AdS/QCD models, by modifying the theory in the 5-dimensional AdS bulk one may try to explain experimental results in different sectors of QCD.

There are two main models of AdS/QCD, which are called hard-wall and soft-wall models.

In the present paper, we will be interested in the hard-wall AdS/QCD model, where the confinement is modeled by sharp cutting of the AdS space along the extra fifth dimension at a wall located at some finite distance $z = z_0$. In the framework of this hard-wall model, it is possible to find form-factors and wave functions of mesons and baryons.

In general, the vector sector is less sensitive to the infrared (IR) effects, since this symmetry is not broken in QCD. However, the axial-vector sector appears to be very sensitive to the particular way the chiral symmetry is broken, or in other words, to the bulk content and the shape of the IR wall.

In this respect, one of the interesting objects to study in the holographic dual models of QCD is the axial vector meson.The properties of the axial vector meson were studied in various holographic approaches.

In this paper, working in the framework of the hard-wall model we describe a formalism to calculate the wave function of the a_1 meson. For this aim we consider condensate depends of profile function of a_1 meson.

II. HARD-WALL MODEL

In the hard-wall model the confinement is modeled by sharp cutting of the AdS space along the extra fifth dimension. Action for this model is [3]:

$$I = \int_0^{z_M} d^5x \sqrt{g}\, L, \tag{1}$$

where $g = |det g_{MN}|$ (M,N=1,2,3,4,5) and the metric of AdS/QCD is :

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$$ds^2 = \frac{1}{z^2}\left(-dz^2 + \eta_{\mu\nu} dx^\mu dx^\nu\right) \quad \mu,\nu = 0,1,2,3$$
$$g_{MN} dx^M dx^N = e^{2A(z)}\left(dz^2 + \eta_{\mu\nu} dx^\mu dx^\nu\right) \ , \tag{2}$$

where $\eta_{\mu\nu}$ is a Minkovskii metric

$$\eta_{\mu\nu} = diag(1,-1,-1,-1) \tag{3}$$

III. AXIAL VECTOR MESON AND ITS PROFIL FUNCTION

In the bulk of AdS space there are gauge fields A_L^M and A_R^M, which transform as a left and right chiral fields under $SU(N_F)_L \times SU(N_F)_R$. Besides gauge fields there is scalar field X , which transforms under bifundamental representation of gauge group $SU(N_F)_L \times SU(N_F)_R$. Action for these fields has a form:

$$I = \int d^5x \ \sqrt{g} \left\{-|DX|^2 + 3|X|^2 - \frac{1}{4g_5^2}\left(F_L^2 + F_R^2\right)\right\}. \tag{4}$$

Here 5-dimensional coupling constant is related with number of colors

$$g_5^2 = \frac{12\pi^2}{N_c} = 2\pi$$

We can get a vector and axial vector fields from these gauge fields by composing them as following:

$$V = \frac{1}{\sqrt{2}}(A_L + A_{R)}. \qquad A = \frac{1}{\sqrt{2}}(A_L - A_{R)}$$

In the holographic model of hadrons, QCD resonances correspond to Kaluza-Klein (KK) excitations in the sliced AdS background. In particular, vector mesons correspond to the KK modes of transverse vector gauge field in this model. Since the gauge symmetry in the vector sector of the Holographic model is not broken, similarly vector case, the axial-vector mesons are the modes of the transverse part of the axial-vector gauge field. Since the axial-vector gauge symmetry is broken in the 5D background, the longitudinal components have physical meaning and are related to the pion field as:

$$A^a_{M||}(x,z) = \partial_M \psi^a(x,z)$$

where $\psi^a(x,z)$is a pion field. We shall work in $A_5 = 0$ gauge.

Equation of motion for axial vector field will be obtained from the action (4) and has a form:

$$\partial_z^2 a_1^{`0} + \frac{1}{z}\partial_z a_1^0 + \left[\bar{\omega}_0^2 - g^2\left(m_q + \sigma z^2\right)^2 - \frac{1}{z^2}\right] a_1^{`0} = 0 \tag{5}$$

For finding mass spectrum in this case it is reasonable to apply the IR boundary condition to the asymptotic solution found at IR limit. For the IR asymptotic solution we shall take $z \to z_{IR}$ limit from (4) and set the $z = z_{IR}$ in the condensate term. Before doing this approximation let us compare numerically the last two terms in equations (4) when $z \to z_{IR}$. The approximate values are as follow:

$$z_{IR}^{-1} \approx 0.33\ GeV,\ z_{IR} \approx 3(GeV)^{-1},\ z_{IR}^4 \approx 81(GeV)^{-4}$$
$$\sigma \approx (0.3)^3(GeV)^3,\ g^2 = 4\pi^2/N_c \approx 13.2$$

Then

$$g^2\sigma^2(z_{IR})^4 \approx 0.06(GeV)^2,\ \ 1/(z_{IR})^2 = 0.1(GeV)^2 \tag{6}$$

Thus, the $1/z^2$ term contributes twice more than the $g^2\sigma^2 z^4$ term and so, we may make an approximation in (4) by setting $z = z_{IR}$ only in the condensate term and keeping the term $1/z^2$

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variable. At this limit the condensate term in the equations (4) becomes constant and the IR asymptotic solution of these equations is expressed in terms of Bessel function J_1:

$$a_{1s}^{a} = czJ_1(\bar{m}_a^s z) \tag{7}$$

Obviously, the UV boundary condition was applied on this solution. The mass spectrum $\bar{m}_a^s$ in (7) is expressed in terms of z_{IR} :

$$\bar{m}_0^s = \sqrt{(\bar{\omega}_0^s)^2 - g^2\left(m_q + \sigma(z_{IR})^2\right)^2} \approx \bar{\omega}_0^s - \frac{g^2\left(m_q + \sigma(z_{IR})^2\right)^2}{2\bar{\omega}_0^s}$$

after using from the boundary conditions (6) , we get the profile function for the axial-vector meson a_1 as:

$$A_1(z) = \frac{z\, J_1(\bar{m}_0^s z)}{\sqrt{\int_0^{z_M} dz\, z\left[J_1(\bar{m}_0^s z)\right]^2}} \tag{8}$$

where $J_1(\bar{m}_0^s z)$ is a first kind Bessel function, $\bar{\omega}_0^s$ is a vacuum mass of axial vector meson.

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