Unpolarized TMD of ρ meson in light-front holographic model

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Introduction

Study of 3-dimensional hadronic structure in partonic degree of freedom is the major goal of hadronic physics. To gather the such information, lots of experimental as well as theoretical efforts have been made in past years. The hadronic structure is encoded in generalized parton distributions (GPDs) and transverse momentum dependent parton distribution functions (TMDs). GPDs allow us to access partonic configurations with longitudinal momentum fraction and transverse position inside the hadron. The information about the longitudinal as well as transverse momentum of parton inside hadron is gathered from TMDs. Different scattering processes, such as Deep virtual compton scattering (DVCS), semi-inclusive deep inclusive scattering (SIDIS), Drell-Yan process helps in measuring GPDs and TMDs of hadrons. In the present work, we study the unpolarized TMD of ρ meson using the light-front holographic model.

Light-front holographic model

The light-front framework is ideal to study the hadronic structure due to simple vacuum of hadronic state. The light-front wave functions (LFWFs) relate the constituent partons to their hadron state and provide a very convenient way to study the different distribution functions. To obtain the LFWFs of hadrons, light-front holographic model is a recent approach among different approaches. In light-front holographic model, the light-front holographic wave function is obtained by mapping between AdS space and LFWF of QCD [1]. Further, the radial part of light-front holographic wave function is calculated from holographic Schrödinger equation for meson [3]. The light-front holographic wave function of ρ meson with minimal Fock state $|q\bar{q}\rangle$ is [2]

$$\psi_\rho(x, \mathbf{k}_T) = \frac{4\pi N_0}{\kappa\sqrt{x(1-x)}} \exp\left[\frac{-\mathbf{k}_T^2 - m^2}{2\kappa^2 x(1-x)}\right]. \quad (1)$$

Here κ is the AdS/QCD scale which is fixed by Regge trajectory. x and $\mathbf{k}_T$ are the longitudinal momentum fraction and transverse momentum of quark of mass m inside ρ meson, respectively.

Unpolarised TMD

The quark TMDs of hadron can be obtained from quark-quark correlator [4, 5]

$$\Phi^{[\Gamma]}(x, \mathbf{k}_T; S) = \int \frac{dy^- d^2\boldsymbol{y}_\perp}{2\pi^3} e^{ip\cdot y} \times \langle \rho(P;S) | \bar{\psi}(0)\, \Gamma \mathcal{W}[0,y] \psi(y)\, | \rho(P;S) \rangle \Big|_{\xi^+=0},$$

where Γ is the Dirac operator and $\mathcal{W}[0, y]$ is the gauge link operator. The ρ meson of mass M has momentum P and spin S.
The quark unpolarized TMD of ρ meson $f_{1\rho}(x, \mathbf{k}_T^2)$ can be obtained from the correlator as

$$\frac{1}{2}\Phi^{\gamma^+}(x, \mathbf{p}_T; S) = f_{1\rho}(x, \mathbf{k}_T^2) = \int \frac{dy^- d^2\boldsymbol{y}_\perp}{2\pi^3} e^{i(y^- k^+ - \boldsymbol{y}_\perp . \mathbf{k}_T)} \times \langle \rho(P) | \bar{\psi}(0)\, \gamma^+\, \psi(y) | \rho(P) \rangle \Big|_{y^+=0}. \quad (2)$$

The $f_{1\rho}(x, \mathbf{k}_T^2)$ also can be calculated from the overlap representation of LFWF as follow:

$$f_1(x, \mathbf{p}_T^2) = \frac{1}{(2\pi)^3} |\psi_\rho(x, \mathbf{k}_T^2)|^2. \quad (3)$$

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Result and Discussion

We have obtained the following result for unpolarized TMD of ρ meson with minimal quark-antiquark Fock state :

$$f_{1\rho}^{q}(x, \mathbf{k}_T^2) = \frac{N_0^2}{\pi\kappa^2\, x\,(1-x)} \exp\left[\frac{-\mathbf{k}_T^2 - m^2)}{\kappa^2 x(1-x)}\right]. \tag{4}$$

The unpolarized TMD of ρ meson $f_{1\rho}(x, \mathbf{k}_T^2)$ describes the distribution of unpolarized quark inside the unpolarized ρ meson. In this model, $f_{1\rho}(x, \mathbf{k}_T^2)$ is symmetric under the exchange of $x \rightarrow 1-x$ which can clearly seen from Eq. (4).

For numerical results, we have used the value

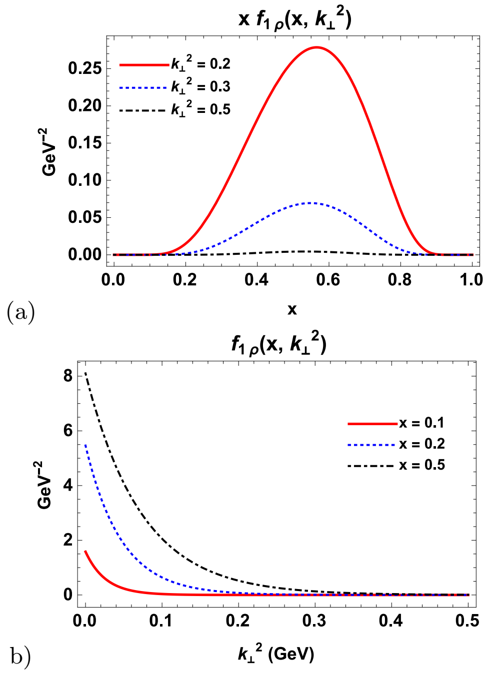

FIG. 1: Plot of unpolarized TMD of ρ meson $f_{1\rho}(x, \mathbf{k}_T)$ (a) as a function of x for the different values of $\mathbf{k}_T^2$ (in GeV^2) (b) as a function of $\mathbf{k}_T^2$ for the different values of x.

of parameter $\kappa = 0.54$ GeV [3]. In Fig. 1, we have shown the obtained result of unpolarized TMD of ρ meson $f_{1\rho}(x, \mathbf{k}_T)$. The $x f_{1\rho}(x, \mathbf{k}_T)$ as a function of x for the different values of $\mathbf{k}_T^2$ is shown in Fig. 1(a). With the increase in the square of transverse momentum $\mathbf{k}_T^2$, the peak of distribution shifts toward lower value of x. In Fig. 1(b), $f_{1\rho}(x, \mathbf{k}_T)$ as a function of $\mathbf{k}_T^2$ for the different values of x is shown. The amplitude of $f_{1\rho}(x, \mathbf{k}_T)$ decreases with increase in $\mathbf{k}_T^2$ for fixed x. This implies that the probability of finding an unpolarized quark with larger transverse momentum $\mathbf{k}_T$ inside an unpolarized ρ meson is less. To obtain the complete information of ρ meson TMD, the 3D plot the unpolarized TMD of ρ meson $f_{1\rho}(x, \mathbf{k}_T)$ has been shown in Fig. 2. The parton distribution is maximum at lower value of transverse momentum $\mathbf{k}_T$ as well as when longitudinal momentum is equally distributed between quark and antiquark.

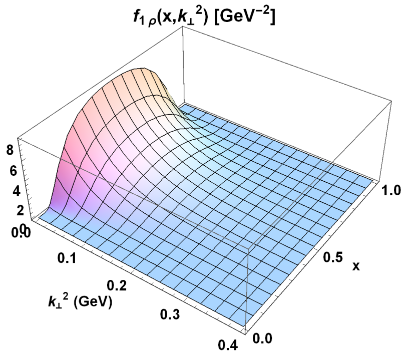

FIG. 2: 3D plot of unpolarized TMD of ρ meson.

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