Twist-2 GTMDs in light-front quark-diquark model

Satvir Kaur* and Harleen Dahiya
Department of Physics,
Dr. B. R. Ambedkar National Institute of Technology,
Jalandhar - 144011, INDIA

Introduction

To understand the structure of hadrons in terms of their composites viz. quarks and gluons more precisely is an extensive challenge. To overcome this task, generalized parton distributions (GPDs) and transverse-momentum dependent parton distributions (TMDs) [1] have derived a lot of attention. The three-dimensional partonic picture of hadrons is given by GPDs and TMDs. GPDs explain the longitudinal momentum and transverse position of partons while TMDs are significant in describing the longitudinal momentum and transverse momentum of partons. Generalized transverse-momentum dependent PDFs or GTMDs explains the five-dimensional picture of partonic structure of hadrons. GTMDs are entitled as *mother distributions* for the reason that they can reduce to GPDs and TMDs. Wigner distributions are the quantum analog of the classical phase distributions and can be studied as the Fourier transformation of GTMDs. Quark/gluon spin and angular momentum can be explained by Wigner distributions.

Quark Wigner distributions

Wigner distribution of quarks can be defined as [2]

$$\rho^{[\Gamma]}\left(\mathbf{b}_\perp,\mathbf{p}_\perp,x;\lambda,\lambda^{'}\right) = \int\frac{d^2\mathbf{\Delta}_\perp}{(2\pi)^2}e^{-i\mathbf{\Delta}_\perp.\mathbf{b}_\perp}W^{[\Gamma]}\left(\mathbf{\Delta}_\perp,\mathbf{p}_\perp,\mathbf{x};\lambda,\lambda^{'}\right),\quad(1)$$

where $W^{[\Gamma]}$ is correlator which relates GTMDs as

$$W^{[\Gamma]}\left(\mathbf{\Delta}_\perp,\mathbf{p}_\perp,\mathbf{x};\lambda,\lambda^{'}\right) = \frac{1}{2}\int\frac{dz^-}{(2\pi)}\frac{d^2z_T}{(2\pi)^2}e^{ip.z}$$
$$\times\langle P^{''};S|\overline{\psi}\left(-\frac{z}{2}\right)\Gamma\Omega_{\left[-\frac{z}{2},\frac{z}{2}\right]}\psi\left(\frac{z}{2}\right)|P^{'};S\rangle|_{z^+=0}.\quad(2)$$

Γ indicates Dirac γ-matrix, γ^+, $\gamma^+\gamma_5$, $i\sigma^{j+}\gamma_5$, where $j=1$ or 2.
We calculate the explicit expressions for quark Wigner distributions [4, 5] in impact-parameter space using LCWFs for scalar-diquark [3] as

$$\rho_{UT}\left(\mathbf{b}_\perp,\mathbf{p}_\perp,x\right) = \frac{1}{(2)\left(16\pi^3\right)}\int d\Delta_x d\Delta_y$$
$$\times\int dx\sin\left(\Delta_x b_x+\Delta_y b_y\right)\frac{(1-x)}{x^2}$$
$$\times\Delta_y\left(m+xM\right)\phi^\dagger\left(p_\perp^{''}\right)\phi\left(p_\perp^{'}\right),\quad(3)$$

$$\rho_{LT}\left(\mathbf{b}_\perp,\mathbf{p}_\perp,x\right) = -\frac{2}{\left(16\pi^3\right)}\int d\Delta_x d\Delta_y$$
$$\times\int dx\cos\left(\Delta_x b_x+\Delta_y b_y\right)\frac{1}{x^2}$$
$$\times p_x\left(m+xM\right)\phi^\dagger\left(p_\perp^{''}\right)\phi\left(p_\perp^{'}\right),\quad(4)$$

where

$$\mathbf{p}_\perp^{'} = \mathbf{p}_\perp-(1-x)\frac{\mathbf{\Delta}_\perp}{2},$$
$$\mathbf{p}_\perp^{''} = \mathbf{p}_\perp+(1-x)\frac{\mathbf{\Delta}_\perp}{2},\quad(5)$$

are initial and final momenta of quark. We have

$$\phi\left(\mathbf{p}_\perp^{'}\right) = -\frac{g_s}{\sqrt{1-x}}\frac{x(1-x)}{\mathbf{p}_\perp^{'2}+\mathbf{L}_s^2\left(m^2\right)},$$
$$\phi\left(\mathbf{p}_\perp^{''}\right) = -\frac{g_s}{\sqrt{1-x}}\frac{x(1-x)}{\mathbf{p}_\perp^{''2}+\mathbf{L}_s^2\left(m^2\right)},\quad(6)$$

*Electronic address: satvirkaur578@gmail.com

with
$L_s^2\left(m^2\right) = xM_s^2 + (1-x)\,m^2 - x\,(1-x)\,M^2$.

GTMDs

GTMDs can be calculated explicitly from Eq. 2 [6] and are expressed as follows

$$H_{1,2} = \frac{1}{(2)\,(16\pi)^3}\frac{(1-x)}{x^2}M\,(m+xM) \\ \phi^{\dagger}\left(p_{\perp}^{''}\right)\phi\left(p_{\perp}^{'}\right), \quad (7)$$

$$H_{1,7} = -\frac{2}{(16\pi^3)}\frac{1}{x^2}M\,(m+xM) \\ \phi^{\dagger}\left(p_{\perp}^{''}\right)\phi\left(p_{\perp}^{'}\right). \quad (8)$$

Results and Conclusions

Fig.1 shows a dipolar distribution ρ_{UT} in impact-parameter space and can be reduced to Boer-Mulders function $h_1^{\perp}$ (T-odd TMD) in the TMD limit and to $\tilde{H}_T$ in the IPD limit. The Wigner distribution ρ_{LT} in Fig.2 is circularly symmetric with the peak in negative direction. It reduces to T-even TMD $h_1^{\perp}$ in the TMD limit and to H_T and $\tilde{H}_T$ in the IPD limit.

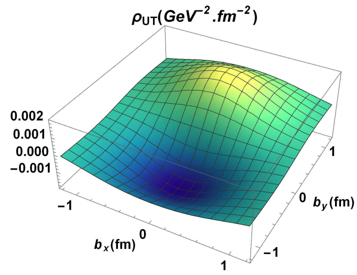

FIG. 1: Wigner distribution ρ_{UT} of quark with $\mathbf{p}_{\perp}$=0.3 $\widehat{x}$ GeV in impact-parameter space.

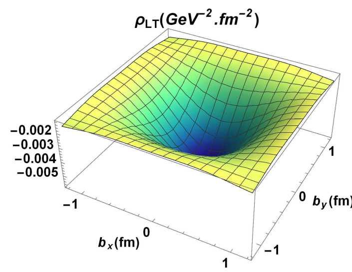

FIG. 2: Wigner distribution ρ_{LT} of quark with $\mathbf{p}_{\perp}$=0.3 $\widehat{x}$ GeVin impact-parameter space.

We plot the generalized transverse momentum dependent distributions (GTMDs) $H_{1,2}$ and $H_{1,7}$ at fixed value of $\Delta_{\perp}$ and different values of $p_{\perp}$ in Fig. 3 and Fig. 4 respectively.

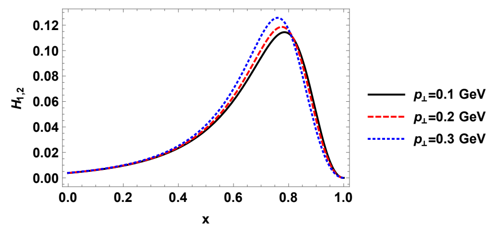

FIG. 3: GTMD $H_{1,2}\left(x,\boldsymbol{\Delta}_{\perp},\mathbf{p}_{\perp}\right)$ at different values of $\mathbf{p}_{\perp}$.

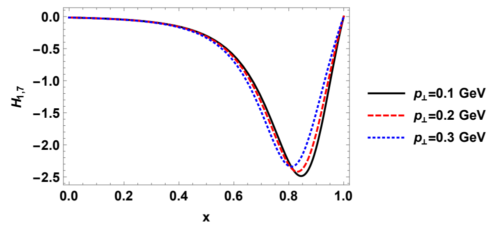

FIG. 4: GTMD $H_{1,7}\left(x,\boldsymbol{\Delta}_{\perp},\mathbf{p}_{\perp}\right)$ at different values of $\mathbf{p}_{\perp}$.

References

[1] S. Meissner, A. Metz, and K. Goeke Phys. Rev. D **76**, 034002 (2007).

[2] S. Meissner, A. Metz, and M. Schlegel, JHEP 0908, 056 (2009).

[3] Alessandro Bacchetta, Francesco Conti, and Marco Radici Phys. Rev. D **78**, 074010 (2008).

[4] D. Chakrabarti, T. Maji, C. Mondal, and A. Mukherjee, Eur. Phys. Jou. C **76**, 409 (2016).

[5] Narinder Kumar, Chandan Mondal, hep-ph/1705.03183 (2017).

[6] D. Chakrabarti, T. Maji, C. Mondal, and A. Mukherjee, hep-ph/1701.08551 (2017).