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Generalized TMDs for transversely polarized quark

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Introduction

Generalized parton distributions (GPDs) and transverse momentum dependent parton distributions (TMDs) are a useful tool to study the 3-dimensional spatial and momentum structure of hadrons. Generalized TMDs (GTMDs) are more generalized distributions with more information and can reduce to GPDs and TMDs under a certain limit. GTMDs for unpolarized and longitudinally polarized quark has been obtained in light-front dressed quark model [1]. Here we discuss and present the GTMDs of transversely polarized quark at zero skewness. It makes the description of GTMDs at twist-2 level complete in the light-front dressed quark model.

GTMDs in Dressed Quark Model

The GTMDs for quark are defined via the bilinear decomposition of most general bi-local quark-quark correlator, and for a transversely polarized quark in a proton-like bound state, it can be written as [2]

$$W^{[i\sigma^{+j}\gamma_5]}_{\lambda\lambda'} = \frac{1}{2m}\bar{u}(p',\lambda')\Big[-\frac{i\epsilon^{ij}_{\perp}p^i_{\perp}}{m}H_{1,1} - \frac{i\epsilon^{ij}_{\perp}\Delta^i_{\perp}}{m}H_{1,2} + \frac{mi\sigma^{j+}\gamma^5}{P^+}H_{1,3} + \frac{p^j_{\perp}i\sigma^{k+}\gamma^5 p^k_{\perp}}{mP^+} H_{1,4} + \frac{\Delta^j_{\perp}i\sigma^{k+}\gamma^5 p^k_{\perp}}{mP^+}H_{1,5} + \frac{\Delta^j_{\perp}i\sigma^{k+}\gamma^5\Delta^k_{\perp}}{mP^+}H_{1,6} + \frac{p^j_{\perp}i\sigma^{+-}\gamma^5}{m}H_{1,7} + \frac{\Delta^j_{\perp}i\sigma^{+-}\gamma^5}{m}H_{1,8}\Big]u(p,\lambda).$$

The functions $H_{1,i},\ i = 1, 2, \cdots 8$ are the GTMDs. The quark-quark correlator is defined as the off-diagonal matrix element of bi-local quark field [2]

$$W^{[\Gamma]}_{\lambda,\lambda'}(x,\xi,\mathbf{k}_{\perp},\mathbf{\Delta}_{\perp}) = \frac{1}{2}\int\frac{dz^-}{2\pi}\frac{d^2z_{\perp}}{(2\pi)^2}e^{ip\cdot z} \Big\langle p',\lambda'\Big|\overline{\psi}(-z/2)\mathcal{W}_{[-z/2,z/2]}\Gamma\psi(z/2)\Big|p,\lambda\Big\rangle\Big|_{z^+=0}.$$

We consider the bound state to be a quark dressed with a gluon. In the dressed quark model, the state $|p,\sigma\rangle$ can be expanded in the Fock state as [3]

$$\Big|p^+,p_{\perp},\sigma\Big\rangle = \Phi^{\sigma}(p)b^{\dagger}_{\sigma}(p)|0\rangle + \sum_{\sigma_1\sigma_2}\int[dp_1]\int[dp_2]\sqrt{16\pi^3p^+}\delta^3(p-p_1-p_2)\Phi^{\sigma}_{\sigma_1\sigma_2}(p;p_1,p_2)b^{\dagger}_{\sigma_1}(p_1)a^{\dagger}_{\sigma_2}(p_2)|0\rangle;$$

where $[dp] = \frac{dp^+d^2p_{\perp}}{\sqrt{16\pi^3p^+}}$. $b^{\dagger}(a^{\dagger})$ is creation operator for quark(gluon), and $\Phi^{\sigma}(p)$, $\Phi^{\sigma}_{\sigma_1\sigma_2}$ represents single particle and two-particle wave function respectively. We also need to choose the kinematics to evaluate the matrix element which we choose to be symmetric, where the initial and final four-momenta of the bound state is [4]

$$p = \left((1+\xi)p^+, \Delta_{\perp}/2, \frac{m^2+\Delta^2_{\perp}/4}{(1+\xi)p^+}\right);$$
$$p' = \left((1-\xi)p^+, -\Delta_{\perp}/2, \frac{m^2+\Delta^2_{\perp}/4}{(1-\xi)p^+}\right),$$

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where the four-momentum transfer from the target state is

$$\Delta = p' - p = \left(2\xi p^+, \Delta_\perp, \frac{t + \Delta_\perp^2}{2\xi p^+}\right),$$
$$\text{and} \quad t = -\frac{4\xi^2 m^2 + \Delta_\perp^2}{1 - \xi^2}.$$

To simplify the mathematical complexity involved in the derivation, we can choose the skewness of the process to be zero. This choice of skewness greatly simplifies the final expression of all GTMDs. Results of GTMDs for unpolarized and longitudinal polarized quark has been previously obtained [1]. We present for the first time the analytical expression of GTMDs for transversely polarized quark in light-front dressed quark model.

Results and Discussion

The analytical expressions of GTMDs for transversely polarized quark are

$$H_{1,1} = \frac{2m^2 N \Delta_\perp^2}{D^*(q'_\perp)D(q_\perp)x^2(k_2\Delta_1 - k_1\Delta_2)}$$
$$H_{1,2} = \frac{2m^2 N k_\perp \cdot \Delta_\perp}{D^*(q'_\perp)D(q_\perp)x^2(k_2\Delta_1 - k_1\Delta_2)}$$
$$H_{1,3} = \frac{N(4k_\perp^2 - (1-x)^2\Delta_\perp^2)}{D^*(q'_\perp)D(q_\perp)(1-x)^3 x}$$
$$H_{1,4} = 0$$
$$H_{1,5} = \frac{m^2 N \Delta_\perp^2}{D^*(q'_\perp)D(q_\perp)x^2(k_2\Delta_1 - k_1\Delta_2)}$$
$$H_{1,6} = -\frac{m^2 N k_\perp \cdot \Delta_\perp}{D^*(q'_\perp)D(q_\perp)x^2(k_2\Delta_1 - k_1\Delta_2)}$$
$$H_{1,7} = -\frac{2m^2 N k_\perp \cdot \Delta_\perp}{D^*(q'_\perp)D(q_\perp)x^2(1-x)(k_2\Delta_1 - k_1\Delta_2)}$$
$$H_{1,8} = \frac{2m^2 N k_\perp^2}{D^*(q'_\perp)D(q_\perp)x^2(1-x)(k_2\Delta_1 - k_1\Delta_2)}$$

where $D(k_\perp) = \left(m^2 - \frac{m^2 + k_\perp^2}{x} - \frac{k_\perp^2}{1-x}\right)$, and $N = \frac{g^2 C_f}{2(2\pi)^3}$, g is the strong coupling constant, and C_f is the color factor. The GTMD $H_{1,4}$ vanishes but only because we choose $\xi = 0$.

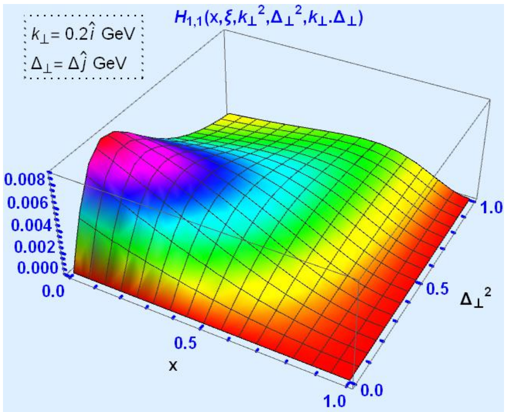

FIG. 1: Plot of GTMD $H_{1,1}$ as a function of x and $\Delta_\perp^2$.

For $\xi \neq 0$, $H_{1,4} \neq 0$. Fig.1 shows the behaviour of GTMD $H_{1,4}$ as a function of x and $\Delta_\perp^2$ for a fixed transverse momentum of quark ($k_\perp = 0.2$ GeV). The mass of quark is chosen as 3.3 MeV.

Conclusion

We derived the GTMDs of transversely polarized quark at twist-2 for $\xi = 0$. GTMD $H_{1,4}$ is found to be zero for $\xi = 0$. Application and extension of these results are presently going on and may be presented during the symposium.

Acknowledgments

VKO acknowledges the SVNIT Surat for the approval of the seed money project with the assigned project number 2021-22/DOP/05.

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