Gluon GTMD F_{14}^g for non-zero skewness

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Introduction

The concept of generalized transverse momentum-dependent parton distributions (GTMDs) extends beyond traditional transverse momentum-dependent parton distributions (TMDs), offering a broader perspective on hadron structure and their significance in the study of partons in bound states. The Fourier transform of GTMD leads to Wigner distributions, which contains the position as well as momentum space information of the partonic structure of hadrons. In article [1], Generalized TMDs (GTMDs) have been introduced and applied to analyze the spin and orbital angular momentum of partons. Gluons exhibit 16 GTMDs at the twist 2 level, and among them, F_{14}^g and G_{11}^g are particularly noteworthy for their ability to provide information about the orbital angular momentum (OAM) and spin of gluons. In this article, we focus on the GTMD F_{14}^g.

GTMDs and Dressed Quark Model

In ref.[2, 3], the GTMDs for quark and gluon were computed assuming zero skewness. However, it's crucial to acknowledge that skewness can significantly impact the results due to its valuable insights into longitudinal momentum transfer as calculated in ref.[4] for quark. For the analysis of gluon for non-zero skewness, we utilized the dressed quark model, representing a bound state consisting of quarks and gluons characterized by momentum (p) and helicity (σ)[3],

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

where, the functions Φ^σ and $\Phi^\sigma_{\sigma_1\sigma_2}$ represent the light-front wave functions for a single particle and two particles, respectively. Additionally, we use the notation $[dp] = \frac{dp^+d^2p_\perp}{\sqrt{16\pi^3p^+}}$. To derive GTMDs for gluons under non-zero skewness conditions, we adopted a decomposition approach for the gluon-gluon correlator function[1],

$$W^{\Delta S_z, c_p}_{\Lambda,\Lambda'} = \frac{\bar{u}(p',\Lambda')M^{\Delta S_z, c_p}u(p,\Lambda)}{2P^+\sqrt{1-\xi^2}}$$

Regarding the gluon operator, it's important to note that the spin-flip number (ΔS_z) is zero, and we have c_p=+1 when $\Gamma^{ij}=\delta^{ij}$. The parameterization of the GTMDs for unpolarized gluons ($\Gamma^{ij}=\delta^{ij}$) is [3]

$$M^{0,+} =(\frac{m}{P^+})^{t-1}\Big[\gamma^+(S^{0,+}_{t,ia} + \gamma_5\frac{i\epsilon_T^{k_T\Delta_T}}{m^2}S^{0,+}_{t,ib}) + i\sigma^{j+}(\frac{k_T^j}{m}P^{0,+}_{t,ia} + \frac{\Delta_T^j}{m}P^{0,+}_{t,ib})\Big].$$

Now, we can move forward to evaluate the GTMDs ($S^{0,+}_{t,ia}, S^{0,+}_{t,ib}, P^{0,+}_{t,ia}, P^{0,+}_{t,ib}$) by examining this parameterization in conjunction with the gluon-gluon correlator equation, which is expressed with respect to the overlap of two-particle LFWFs as

$$W^{(\delta_\perp^{ij})}_{\sigma\sigma'} = -\sum_{\sigma_1,\lambda_1,\lambda_2}\Big[\Psi^{*\sigma'}_{\sigma_1\lambda_1}(x'_g, q'_{\perp g})\Psi^\sigma_{\sigma_1\lambda_2}(y_g, q_{\perp g}) (\epsilon^1_{\lambda_2}\epsilon^{*1}_{\lambda_1} + \epsilon^2_{\lambda_2}\epsilon^{*2}_{\lambda_1})\Big]$$

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Results and Discussions

Our chosen kinematics are parameterized as

$$x'_g = 1 - \frac{x-\xi}{1-\xi} = \frac{x_g}{1-\xi},$$
$$q'_{\perp g} = -k_\perp + \frac{(1-x)}{(1-\xi)}\frac{\Delta_\perp}{2} = -k_\perp - \frac{x_g \Delta_\perp}{2(1-\xi)},$$
$$y_g = 1 - \frac{x+\xi}{1+\xi} = \frac{x_g}{1+\xi},$$
$$q_{\perp g} = -k_\perp - \frac{(1-x)}{(1+\xi)}\frac{\Delta_\perp}{2} = -k_\perp + \frac{x_g \Delta_\perp}{2(1+\xi)}.$$

We have derived the analytical expression for the GTMD F^g_{14} in our model, which is given by

$$F^g_{14} = 2m^2 \alpha_g \sqrt{1-\xi^2}(x_g^2 + \xi^2 - 1),$$

where,

$$\alpha_g = \frac{N\sqrt{1-\xi^2}}{D(q_{\perp g}, y_g) D^*(q'_{\perp g}, x'_g) x_g ((1-x_g)^2 - \xi^2)^{\frac{3}{2}}},$$
$$D(k_\perp, x_g) = \left(m^2 - \frac{m^2 + k_\perp^2}{x_g} - \frac{k_\perp^2}{1-x_g} \right),$$
$$N = \frac{g^2}{2(2\pi)^2}.$$

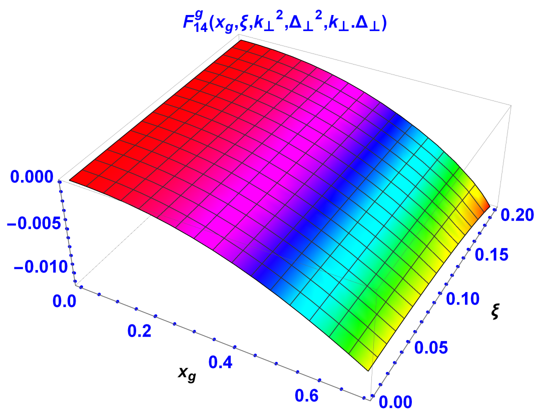

FIG. 1: GTMD F^g_{14} as the function of x_g and ξ for $k_\perp = 0.2\hat{i}$ GeV and $\Delta_\perp = 0.2\hat{j}$ GeV with $k_\perp.\Delta_\perp = 0$.

In the case of zero skewness, our results align with the reference [3]. The variation of $F^g_{1,4}$ with ξ does not influence the orbital angular momentum (OAM) and spin-orbit correlation of gluons, as these properties are defined for GTMDs in the $\xi \to 0$ limit. The OAM is related to this GTMD F^g_{14} defined as[1],

$$l^g_z = -\int dd x d^2 k_\perp \frac{k_\perp^2}{m^2} F^g_{1,4}.$$

Conclusion

Skewness plays a significant role in partonic structure of hadrons as it provides crucial insights into longitudinal momentum transfer to the target state. In this work, we did calculations for the GTMD F^g_{14} while accounting for skewness and analyzed its behaviour in $x_g - \xi$ space. Notably, this GTMD holds particular importance as it is directly linked to the orbital angular momentum (OAM) of gluons. The analytical expression of other GTMDs and their detailed analysis are presented in our recent preprint article on arxiv[5].

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