Single spin asymmetry in spectator model with axial-vector diquarks

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Introduction

Transverse momentum dependent parton distributions (TMDs) [1] contain information on both the longitudinal and the transverse momentum of partons in the hadron. They can be measured in a variety of reactions as in semi-inclusive deep inelastic scattering (SIDIS) [2, 3] and Drell-Yan production [4] where a final-state particle is observed with a transverse momentum.

In QCD, the understanding of single spin asymmetries in hadronic reactions are of great interest from past few years. One can calculate the single-spin asymmetries (SSA) from T-odd TMDs (Sivers and Boer-Mulders distribution functions) [5]. These functions are non zero only if we consider the final-state interactions (FSIs). The Sivers distribution function $f_{1T}^{\perp}$ gives the information about the parton transverse momentum distribution in the transversely polarized hadron [6, 7].

We have used the light front wave functions (LFWFs) model in which hadron of the mass M composed of quark of the mass m and axial vector diquark of the mass λ [8, 9]. We considered the pointlike form factor and the transverse polarization only for diquark propagator. In SIDIS process $\gamma^* p \longrightarrow q(qq)_1$ where a virtual photon is scattered by a transversely polarized proton, SSAs can be described by this model. The SSAs of the hadron is the result of the FSI between outgoing quark and target spectator system by one gluon exchange. This FSIs produce necessary phase needed to calculate SSAs.

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By using overlap representation of TMDs in terms of the LFWFs, one can get the Sivers distribution function and the unpolarized quark distributions which can be further used to calculate the single-spin Sivers asymmetry. The existence of the Sivers asymmetry require the overlaps of the LFWFs whose orbital angular momenta differ by $\triangle L_z = \pm 1$. From this condition, it is clear that the partons can not only occupy the available lower-energy orbitals but also the higher-energy orbitals [8]. Theoretically, SSAs simultaneously depends on FSIs, orbital angular momentum and interference between complex phases.

Methodology

For axial-vector diquark, the unpolarized quark distribution function f_1 and the Sivers distribution function $f_{1T}^{\perp}$ is given by [8, 9]:

$$\begin{aligned} f_1(x, \mathbf{p}_\perp) &= \frac{1}{2(2\pi)^3}\frac{(Mx+m)^2+p_\perp^2}{x^2} \\ &\times \frac{x^2(1-x)}{(p_\perp^2+B)^2}, \\ f_{1T}^{\perp}(x, \mathbf{p}_\perp) &= -\frac{1}{3}\frac{1}{2(2\pi)^3}\frac{M(Mx+m)}{x^2} \\ &\times \frac{e_1 e_2}{4\pi}\frac{x^2(1-x)}{(p_\perp^2+B)p_\perp^2} ln\Big(\frac{p_\perp^2+B}{B}\Big), \end{aligned}$$

where

$$B = -M^2 x(1-x) + m^2(1-x) + x\lambda^2.$$

In the above expression, M, m and λ are the nucleon, quark and the diquark masses respectively. e_1 and e_2 are the quark and diquark charges. To relate the calculations to QCD, one needs to fix $\mid \frac{e_1 e_2}{4\pi} \mid = -C_F \alpha_s$ with $C_F = \frac{4}{3}$.

The Sivers distribution function and the unpolarized quark distribution are related to the single spin asymmetry by [7, 10]:

$$P_y = -\frac{p_\perp^1}{M}\frac{f_{1T}^\perp(x,\mathbf{p}_\perp)}{f_1(x,\mathbf{p}_\perp)}.$$

Results and Discussion

In this work, we use the Sivers distribution function and the unpolarized quark distribution obtained by the LFWFs for axial-vector diquark with transverse polarization only [8, 9]. The FSIs induce the spin-dependent complex phase to the wave functions which are responsible for non zero value of the Sivers distribution function. We take parameters as α_s= 0.2, M = 0.94 GeV, m = 0.36 GeV and λ=0.8 GeV. With these parameters we calculated the single-spin Sivers asymmetries of proton in SIDIS which arise by a one-gluon final-state interactions.

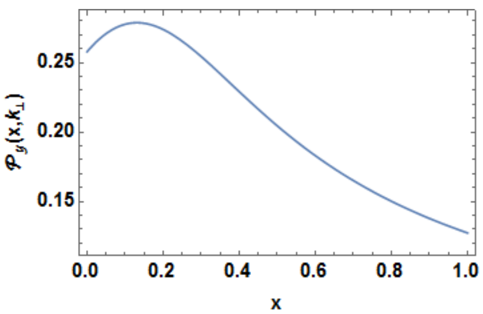

FIG. 1: Single-spin Sivers asymmetry P_y vs x at fixed value of $k_\perp$ = 0.4 GeV

In Fig. 1, we can see that beyond the maximum value of P_y (at x = 0.15), the P_y decreases with the increasing in the value of x. In Fig. 2, we can see the variation of P_y is maximum around $k_\perp$ = 1 and at higher value of $k_\perp$, it start decreasing. Brodsky *et.al* [5] has performed these calculation and plotted the results to predict the single spin asymmetry of the proton in quark scalar diquark model. The results predicted in the present work for the single-spin Sivers asymmetry of the proton in axial-vector diquark model are in reasonable agreement with their work.

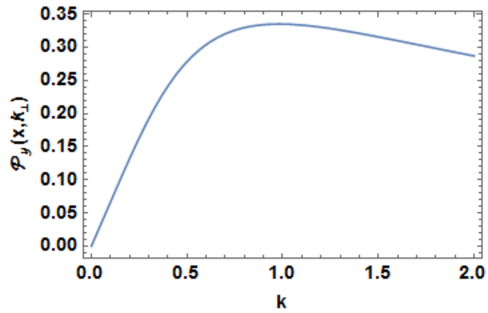

FIG. 2: Single-spin Sivers asymmetry P_y vs $k_\perp$ at fixed value of x = 0.15.

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