Generalized parton distributions of hyperons

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Introduction

In quantum chromodynamics, hadrons are considered to be composed of partons and the interactions among these partons make their internal structure complex. This complex internal structure can be explored via generalize parton distributions (GPDs) [1]. These distributions provide a three-dimensional (3D) insight of momentum distribution among constituent quarks of a hadron. Experimentally, GPDs can be accessed via deeply virtual compton scattering (DVCS) and depply virtual meson production (DVMP) processes.

Nucleons are the lightest members of an octet baryon with spin-parity quantum number $J^P = \left(\frac{1}{2}\right)^+$ and an enormous amount of theoretical as well as experimental work has been reported for them. However, other members of the octet baryon with same spin-parity quantum number are not explored via distribution functions. In this work, we have portrayed the 3D image of GPD for a strange hyperon in momentum-space with comparative analysis of distribution for u quark flavors between of Σ^+ and Ξ^o hyperons.

Quark-diquark model

We have chosen a light-cone framework to study the internal structure of Σ^+ baryon relativistically. With light-cone gauge $A^+ = 0$, a baryonic state can be expanded in multi-particle Fock-states $|\mathcal{N}\rangle$ as $|\mathcal{B}(P^+, \mathbf{P}_\perp^\mathbf{2})\rangle = \sum_\mathcal{N} \psi_\mathcal{N}(x_i, \mathbf{k}_{\perp i}, \lambda_i)|\mathcal{N}; x_i P^+, x_i \mathbf{P}_\perp + \mathbf{k}_{\perp i}, \lambda_i\rangle$, where $\mathbf{k}_{\perp i}$, x_i and λ_i represents the light-cone transverse momentum, fraction of longitudinal momentum and helicity carried by ith constituent quark flavor of a baryon X. The coefficient $\psi_\mathcal{N}(x_i, \mathbf{k}_{\perp i}, \lambda_i)$ represents the light-cone wave function (LCWF) of the Fock state. For a baryon, composed of three quarks is treated as a system of two-body, an active quark and a diquark. For relativistic quark flavor analysis, we consider an axial vector diquark ($\mathfrak{a}$), along with scalar diquark ($\mathfrak{s}$). For a baryon-quark-diquark vertex $\mathcal{Y}_{\mathfrak{s}(\mathfrak{a})}$, the LCWFs [2] for scalar and axial vector diquarks respectively are defined as

$$\begin{aligned}\psi^\lambda_{\lambda_q}(x, \mathbf{k}_\perp) &= \sqrt{\frac{k^+}{(P-k)^+}}\frac{1}{k^2 - m_q^2} \\ &\times \; \bar{u}(k, \lambda_q)\mathcal{Y}_\mathfrak{s} U(P, \lambda)\,, \qquad (1)\end{aligned}$$

$$\begin{aligned}\psi^\lambda_{\lambda_q\lambda_\mathfrak{a}}(x, \mathbf{k}_\perp) &= \sqrt{\frac{k^+}{(P-k)^+}}\frac{1}{k^2 - m_q^2} \\ &\times \; \bar{u}(k, \lambda_q)\epsilon^*_\mu \cdot \mathcal{Y}^\mu_\mathfrak{a} U(P, \lambda), \qquad (2)\end{aligned}$$

where $u(k, \lambda_q)$ and $U(P, \lambda)$ are the Dirac spinors for the quark and its parent baryon, respectively. $k(P)$ and $\lambda_q(\lambda)$ denotes the momenta and helicity of a quark flavor q (strange baryon), sequentially. The $4-$vector polarization of a diquark is represented by ϵ^*_μ.

Generalized Parton distributions

The off-forward matrix elements of the light-cone bilinear vector current defines the chiral-even unpolarized hadron GPDs and its quark-quark correlator [3] is expressed as

$$\begin{aligned}F^{\gamma^+}_{\lambda\lambda} &= \frac{1}{2}\int\frac{dy^-}{2\pi}e^{ixP^+y^-}\left\langle P', \lambda'\middle|\bar{\psi}\left(\frac{-y}{2}\right)\right. \\ &\times \; \gamma^+\,\psi\left(\frac{y}{2}\right)\left|P, \lambda\right\rangle\Big|_{y^+=0,\mathbf{y}_\perp=\mathbf{0}}, \qquad (3)\end{aligned}$$

and parametrized as

$$\begin{aligned}F^{\gamma^+}_{\lambda'\lambda} &= \frac{1}{2\bar{P}^+}\bar{u}(P', \lambda')\Big[H(x, \Delta_\perp)\,\gamma^+ \\ &+ \; E(x, \Delta_\perp)\,\frac{i\sigma^{+\alpha}(-\Delta_\alpha)}{2M_X}\Big]u(P, \lambda). \qquad (4)\end{aligned}$$

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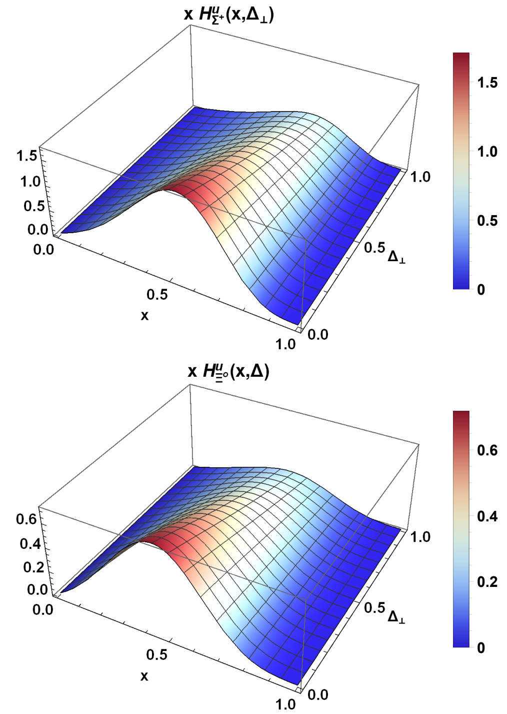

FIG. 1: Generalized parton distribution as a function of longitudinal momentum fraction x and momentum transfer $\Delta_\perp$ for u quark flavor of Σ^+ and Ξ^o, sequentially.

The overlap form of GPDs can be written as

$$H(x,\Delta_\perp) = \int \frac{d^2\mathbf{k}_\perp}{16\pi^3} \sum_{\lambda_q,\lambda_D} \psi^{\Uparrow *}_{\lambda_q \lambda_D}(x',\mathbf{k}'_\perp) \times \psi^{\Uparrow}_{\lambda_q \lambda_D}(x,\mathbf{k}_\perp), \quad (5)$$

where $\mathbf{k}'_\perp = \mathbf{k}_\perp + (1-x)\Delta_\perp$, $x' = x$ and $D = (\mathfrak{s},\mathfrak{a})$. GPD $H(x,\Delta_\perp)$ corresponds to the distribution of unpolarized quarks of unpolarized hadron. For the case of zero skewness, GPDs depend only on longitudinal momentum fraction x and momentum transfer $\Delta_\perp$ in momentum space. For flavor decomposition, we have used

$$f_u^{\Sigma^+} = \frac{3}{2} f^{\mathfrak{s}} + \frac{1}{2} f^{\mathfrak{a}}, \qquad f_u^{\Xi^o} = f^{\mathfrak{a}}, \quad (6)$$

which implies that the distribution of u quark flavor of Σ^+ involves the contribution of both scalar and axial vector diquarks, whereas u quark flavor of Ξ^o distribution solely depends on axial vector diquark [4].

For the present calculations, we have used the mass of a quark m_q, diquark $m_{qq'}$ and baryon M_X as input parametrs. The values of these parameters [4] in GeV are $m_u = 0.36$, $m_{\mathfrak{s}(us)} = 0.75$, $m_{\mathfrak{a}(us)} = 0.95$, $m_{\mathfrak{a}(ss)} = 1.10$ and $M_{\Sigma^+} = 1.189$ and $M_{\Xi^o} = 1.314$.

Chiral-even unpolarized GPD $H(x,\Delta_\perp)$ has been portrayed in Fig. 1 for u quark flavor of both hyperons as a function of x and $\Delta_\perp$. A general trend of a maximum amplitude at zero transfer of longitudinal momentum and fall off with its increment is present with a slow drift of peak towards higher value of longitudinal momentum fraction x for the both quark flavors.

The key differences between the distribution of unpolarized GPDs for u quark flavor of both hyperons imply that the distribution of u quark flavor of Ξ^o hyperon falls off more rapidly than u quark flavor of Σ^+ with increase of $\Delta_\perp$. At $\Delta_\perp = 0$, u quark flavor of Σ^+ and Ξ^o have peak values at $x = 0.530$ and 0.438 respectively. This difference arises due to the fact that diquark us of Σ^+ is lighter and tends to carry less longitudinal momentum fraction, whereas ss diquark of Ξ^o hyperon is comparatively heavier and has ability of carrying more longitudinal momentum fraction. In a nut shell, heavier quark flavor has capability of carrying larger longitudinal momentum fraction. Hence, u quark flavor of Ξ^o carry less longitudinal momentum fraction than u quark flavor of Σ^+.

References

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