Parton Densities and Fragmentation Functions from Polarized Λ Production in Semi-Inclusive DIS

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We consider the longitudinal polarization of Λ and ¯Λ produced in the current fragmentation region of polarized deep inelastic scattering. We show how the various cross sections can be used to test the underlying parton dynamics, and how one can extract information about certain parton densities which are poorly known, in particular the polarized strange density sum \(\Delta s(x) + \Delta \bar{s}(x)\), and about fragmentation functions which are totally unknown and which are difficult to access by other means. We show also how one can obtain information concerning the intriguing question as to whether \(s(x) = \bar{s}(x)\) and whether \(\Delta s(x) = \Delta \bar{s}(x)\).

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I. INTRODUCTION

As has been emphasized in several papers [1–10], measurements of the polarization of Λ baryons produced in high energy deep inelastic lepton-hadron collisions offer an excellent test of the dynamics of spin transfer from partons to hadrons.

In this paper we consider all possible semi-inclusive reactions involving unpolarized or longitudinally polarized leptons and nucleons, with or without the measurement of the longitudinal polarization of Λ or ¯Λ produced in the current fragmentation region. We draw the

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attention to another important aspect of such reactions, namely the information obtainable about the polarized parton densities, and about the unpolarized and polarized fragmentation functions \( D_q^{\Lambda}, \Delta D_q^{\Lambda} \) for a quark into a \( \Lambda \) (or \( \bar{\Lambda} \)). Despite recent progress \(^\text{[11]}\) some polarized parton densities are still relatively poorly determined. In principle, in semi-inclusive DIS, one can obtain information about the polarized strange quark density \( \Delta s(x) + \Delta \bar{s}(x) \), which is poorly known, and also about the interesting question as to whether \( s(x) \neq \bar{s}(x) \) and \( \Delta s(x) \neq \Delta \bar{s}(x) \).

Regarding the fragmentation functions \( D_q^{\Lambda} \) and \( \Delta D_q^{\Lambda} \) very little is known. Indeed the \( \Delta D_q^{\Lambda} \) are not constrained at all by the present \( e^+e^- \) data. These can, in principle, all be determined in semi-inclusive DIS. They could also be accessed in the reaction \( pp \rightarrow \Lambda X \) with a polarized proton beam or target \(^\text{[12]}\).

In this paper, as in \(^\text{[1]}\), we work in LO QCD. Given the preliminary state of experiments in this field it does not seem sensible at this point to undertake the extremely complicated NLO analysis \(^\text{[4]}\) or the somewhat simpler version given in \(^\text{[13]}\). However, as emphasized in \(^\text{[13]}\), it is important to remain vigilant about inaccuracies caused by using the LO formalism, and great attention should be paid to the various tests of the reliability of the LO treatment given in the following. For a more general discussion of this question and suggestions concerning the estimation of theoretical errors generated by the LO treatment, see Ref. \(^\text{[13]}\).

To really extract the maximum of information from these reactions one should try to study the triply-differential cross section \( d\sigma/dxdydz \) where \( x, y, z \) are the usual semi-inclusive DIS variables \(^\text{[1]}\). In this it is the \( y \)-dependence that tests the dynamics, whereas the parton densities and fragmentation functions emerge from the \( x \) and \( z \)-dependence.

In Section II we define precisely what cross sections and polarizations we wish to consider. As mentioned we deal only with longitudinal (helicity) polarization of the leptons, nucleons and \( \Lambda \)'s.

In Section III we introduce modified differential cross sections which are simply related to parton model soft functions and which allow tests of the underlying parton dynamics.

In Section IV we study in detail what information can be extracted about the parton densities and fragmentation functions. Conclusions follow in Section V.

II. THE INDEPENDENT OBSERVABLES OF THE REACTION

We consider the reaction

\[
\ell(\lambda) + N(\mu) \rightarrow H(h) + \ell' + X
\]

(1)

of a charged lepton \( \ell \) with helicity \( \lambda = \pm 1/2 \) on a nucleon \( N \) of helicity \( \mu = \pm 1/2 \) producing, semi-in inclusively, a spin 1/2 hyperon \( H \) with helicity \( h = \pm 1/2 \). The hyperon \( H \) is such that its polarization can be determined from its decay distribution. We consider kinematical regions where \( Z \) exchange is negligible.

The fundamental invariant differential cross section will be written as

\[
\frac{d\sigma_{Hh}^{\lambda\mu}}{dx\,dy\,dz},
\]

(2)

where \( x, y, z \) are the usual semi-inclusive DIS variables. In the following we do not include the differentials \( dx\,dy\,dz \) unless necessary for clarity.

The cross section for simply producing \( H \) from a given initial helicity state is given by

\[
d\sigma_{Hh}^{H\mu} = d\sigma_{\lambda h}^{H+} + d\sigma_{\lambda h}^{H-}.
\]

(3)
The longitudinal or helicity polarization of $H$, as produced from a given initial state $(\lambda\mu)$ is then given by

$$P_{H\lambda\mu} = \frac{d\sigma_{H+}^{\lambda\mu} - d\sigma_{H-}^{\lambda\mu}}{d\sigma_{H+}^{\lambda\mu}}. \quad (4)$$

Parity invariance of the strong and electromagnetic interactions implies that

$$d\sigma_{Hh}^{\lambda\mu} = d\sigma_{-H-\mu}^{\lambda\mu}, \quad (5)$$

so that

$$P_{-H-\lambda-\mu} = -P_{H\lambda\mu}. \quad (6)$$

Of course for an unpolarized initial state in a parity conserving theory, the longitudinal polarization must vanish, as is clear from (6). Thus $P^H$ really measures the spin transfer from either lepton or nucleon to $H$.

Cross sections or polarizations relevant to an unpolarized lepton and/or an unpolarized nucleon are indicated by a zero. For example, for an unpolarized lepton we have

$$d\sigma_{0\mu} = \frac{1}{2}(d\sigma_{H+0}^{++} + d\sigma_{H+0}^{++}) = \frac{1}{2}(d\sigma_{H+0}^{++} - d\sigma_{H-0}^{++}). \quad (7)$$

Because of (5), there will be only four independent cross sections or observables, instead of the original $2 \times 2 \times 2 = 8$.

We shall take as the four independent cross sections:

a) The unpolarized cross section

$$d\sigma^{H} \equiv d\sigma_{00}^{H} = \frac{1}{4}(d\sigma_{++}^{H} + d\sigma_{--}^{H} + d\sigma_{+-}^{H} + d\sigma_{-+}^{H}) = \frac{1}{2}(d\sigma_{++}^{H} + d\sigma_{-+}^{H}). \quad (8)$$

b) The target-spin dependent cross section difference

$$\Delta d\sigma^{H} \equiv d\sigma_{++}^{H} - d\sigma_{+-}^{H}. \quad (9)$$

c) The spin-transfer cross section from a polarized lepton with an unpolarized nucleon

$$d\sigma_{0+}^{H} - d\sigma_{0-}^{H} = d\sigma_{0+}^{H} - d\sigma_{0-}^{H} = P_{0+}^{H} d\sigma^{H}, \quad (10)$$

where we have chosen a positive helicity for the lepton and have used, via (5),

$$d\sigma_{0+}^{H} = d\sigma_{0+}^{H} = d\sigma_{0-}^{H} = d\sigma_{0+}^{H}. \quad (11)$$

Clearly, also via (5)

$$d\sigma_{0+}^{H} - d\sigma_{0+}^{H} = -d\sigma_{0-}^{H} - d\sigma_{0-}^{H}. \quad (12)$$

d) The spin-transfer cross section from a polarized nucleon with an unpolarized lepton

$$d\sigma_{0+}^{H} - d\sigma_{0+}^{H} \equiv d\sigma_{0+}^{H} - d\sigma_{0+}^{H} = P_{0+}^{H} d\sigma^{H}. \quad (13)$$
Since these are four linearly independent observables, all others can be written in terms of them. For example it is easy to see that

\[ d\sigma^{H_+ - H_-} = d\sigma^{H_0 - H_-} + d\sigma^{H_+ - H_-} \]  

(14)

and

\[ d\sigma^{H_+ - H_-} = d\sigma^{H_0 - H_-} - d\sigma^{H_+ - H_-} \]  

(15)

In terms of the hyperon polarization, (14) and (15) imply

\[ P^{H_+} = \frac{1}{2} \left( 1 + \frac{d\sigma^{H_+}}{d\sigma^{H_+}} \right) (P^{H_0} + P^{H_+}) \]  

(16)

and

\[ P^{H_-} = \frac{1}{2} \left( 1 + \frac{d\sigma^{H_-}}{d\sigma^{H_-}} \right) (P^{H_0} - P^{H_+}) \].  

(17)

Note that equations like (16) and (17) are not predictions of the detailed dynamics, but follow from parity invariance of the strong and electromagnetic interactions. Similar relations were given in [1].

III. THE DYNAMICAL MODEL

In LO pQCD, the general cross section (2) corresponding to the process in (1) is given by

\[ \frac{d\sigma^{H_\mu}}{dx dy dz} = \sum_{q, \lambda} e^2_q q^\mu_q(x) \frac{d\sigma^{\lambda \mu\lambda}}{dy} D^{H_\mu}_{q\lambda}(z), \]  

(18)

where the sum is over quarks and antiquarks, \( q^\mu(x) \) is the parton number density for quarks of helicity \( \lambda \) in a proton of helicity \( \mu \), while \( D^{H_\mu}_{q\lambda} \) is the fragmentation function for a quark \( q \) of helicity \( \lambda \) to fragment into hyperon \( H \) with helicity \( h \); \( d\sigma^{\lambda \mu\lambda}/dy \) is the lepton-quark (or antiquark) differential cross section for an initial state with the lepton having helicity \( \lambda \) and the quark (or antiquark) helicity \( \lambda \). The simple helicity structure of (18) reflects the fact that helicity is conserved for massless quarks in \( \ell q \rightarrow \ell q \).

There are two independent partonic cross sections

\[ \frac{d\tilde{\sigma}_{++}}{dy} = \frac{d\tilde{\sigma}_{-+}}{dy} = \frac{4\pi\alpha^2}{sxy^2}, \]  

(19)

\[ \frac{d\tilde{\sigma}_{+-}}{dy} = \frac{d\tilde{\sigma}_{-+}}{dy} = \frac{4\pi\alpha^2}{sxy^2} (1 - y)^2, \]  

(20)

where \( s \) is the squared centre of mass energy corresponding to the process in Eq. (1).

In order to simplify the expressions needed for the flavour analysis, we renormalize our four independent cross sections (8-10), (13), by dividing out certain common kinematic factors. Thus we work with

\[ d\tilde{\sigma}^H(x, z) = \left[ \frac{2\pi\alpha^2}{sx} \frac{1 + (1 - y)^2}{y^2} \right]^{-1} d\sigma^H = \sum_q e^2_q q(x) D^H_q(z), \]  

(21)

\[ a' \]
where \(q(x)\) and \(D^H_H(z)\) are the usual unpolarized parton density and fragmentation functions respectively, \(q(x) = q^+_u(x) + q^+_d(x), D^H_H(z) = D^H_q^+(z) + D^H_q^-(z)\).

(b')

\[
\Delta d\hat{\sigma}^H(x, z) = \left[\frac{4\pi\alpha^2}{s_x} \frac{y(2 - y)}{y^2}\right]^{-1} \Delta d\sigma^H = \sum_q e^2_q \Delta q(x) D^H_q(z),
\]

(22)

where \(\Delta q(x) = q^+_u(x) - q^+_d(x)\) is the usual longitudinally polarized parton density.

c')

\[
d\hat{\sigma}^{H_0^-H^-}(x, z) = \left[\frac{2\pi \alpha^2}{s_x} \frac{y(2 - y)}{y^2}\right]^{-1} d\sigma^{H_0^-H^-} = \sum_q e^2_q \Delta q(x) \Delta D^H_q(z),
\]

(23)

where

\[
\Delta D^H_q(z) = D^H_q^+(z) - D^H_q^-(z) = D^H_q^+(z) - D^H_q^-(z).
\]

(24)

d')

\[
d\hat{\sigma}^{H_0^-H^-}(x, z) = \left[\frac{2\pi \alpha^2}{s_x} \frac{1 + (1 - y)^2}{y^2}\right]^{-1} d\sigma^{H_0^-H^-} = \sum_q e^2_q \Delta q(x) \Delta D^H_q(z).
\]

(25)

We see that for each flavour, for a given hyperon \(H\) and for a given target, the four independent cross sections just correspond to different combinations of the four independent soft functions, \(q(x), \Delta q(x), D^H_q(z), \Delta D^H_q(z)\).

It should be noted that the fact that \(d\hat{\sigma}^H, \Delta d\hat{\sigma}^H, d\hat{\sigma}^{H_0^-H^-}, d\hat{\sigma}^{H_0^-H^-}\) depend only on \(x\) and \(z\) (neglecting the known and mild dependence on \(Q^2 = xy\), due to QCD evolution) is a direct consequence of the parton dynamics and should be tested experimentally.

IV. EXTRACTION OF PARTON DENSITIES AND FRAGMENTATION FUNCTIONS

We assume that the usual unpolarized parton densities \(u(x), d(x), \bar{u}(x), \bar{d}(x)\) are reasonably well known and can be used as input in the following expressions.

We consider the production of \(\Lambda\) and \(\bar{\Lambda}\) hyperons on both proton and neutron targets and show how one can systematically obtain information about the parton densities \(s(x), \bar{s}(x), \Delta s(x), \Delta \bar{s}(x)\) and about the fragmentation functions \(\Delta D^\Lambda_0(z), \Delta D^\bar{\Lambda}_0(z), \Delta D^\Lambda_3(z)\).

We shall assume good enough control over systematic errors to allow us to combine cross sections for different targets and for \(\Lambda\) and \(\bar{\Lambda}\) final particles. This is a non-trivial experimental issue, but well worth the effort, since it then becomes possible to obtain very simple expressions for the parton densities and fragmentation functions under study.
A. Unpolarized cross section

Using only charge conjugation invariance,

\[ D_q^\Lambda = D_{\bar{q}}^\Lambda, \]  

(26)

and isospin invariance,

\[ D_d^\Lambda = D_u^\Lambda, \]  

(27)

we obtain from (21) the well known relations [13]

\[ \frac{d\tilde{\sigma}^{\Lambda+\bar{\Lambda}}}{p} - \frac{d\tilde{\sigma}^{\Lambda+\bar{\Lambda}}}{n} = \frac{1}{3} [u(x) + \bar{u}(x) + d(x) + \bar{d}(x)] D_u^{\Lambda+\bar{\Lambda}}(z), \]  

(28)

\[ \frac{d\tilde{\sigma}^{\Lambda-\bar{\Lambda}}}{p} - \frac{d\tilde{\sigma}^{\Lambda-\bar{\Lambda}}}{n} = \frac{1}{3} [u_v(x) - d_v(x)] D_u^{\Lambda-\bar{\Lambda}}(z), \]  

(29)

where \( q_v(x) \) is a valence quark density.

Measurements of the cross section differences on the LHS of (28) and (29) thus enable a determination of \( D_u^{\Lambda+\bar{\Lambda}} \) and \( D_u^{\Lambda-\bar{\Lambda}} \) and therefore of the individual \( D_u^\Lambda \) and \( D_u^\bar{\Lambda} \).

Next we consider the combinations

\[ \frac{5}{9} [u(x) + \bar{u}(x) + d(x) + \bar{d}(x)] D_u^{\Lambda+\bar{\Lambda}}(z) \]

\[ + \frac{2}{9} [s(x) + \bar{s}(x)] D_u^{\Lambda+\bar{\Lambda}}(z), \]  

(30)

\[ \frac{5}{9} [u_v(x) + d_v(x)] D_u^{\Lambda-\bar{\Lambda}}(z) \]

\[ + \frac{2}{9} [s(x) - \bar{s}(x)] D_u^{\Lambda-\bar{\Lambda}}(z). \]  

(31)

Since we now know \( D_u^{\Lambda\pm\bar{\Lambda}} \), (30) and (31) allow a determination of the products

\[ S_1(x, z) \equiv [s(x) + \bar{s}(x)] D_u^{\Lambda+\bar{\Lambda}}(z) \]  

(32)

and

\[ S_2(x, z) \equiv [s(x) - \bar{s}(x)] D_u^{\Lambda-\bar{\Lambda}}(z). \]  

(33)

In usual DIS it is the combination \( (s + \bar{s}) \) that appears, so if this is taken as reasonably well determined we can extract information on \( D_u^{\Lambda+\bar{\Lambda}}(z) \) from Eq. (22). Of more interest is the question of whether the nucleon possesses intrinsic strange quarks, such that \( s(x) \neq \bar{s}(x) \) \[14\]. Since \( D_u^{\Lambda-\bar{\Lambda}}(z) \) is likely to be relatively large, a measurement of (33) should enable one to say whether \( (s - \bar{s}) \) is compatible with zero. For further discussion of the evaluation of \( (s - \bar{s}) \) see Ref. [13].

B. Cross section for unpolarized lepton and polarized nucleon target

Analogously to (28, 31) we now have from (22)

\[ \Delta \frac{d\tilde{\sigma}^{\Lambda+\bar{\Lambda}}}{p} - \Delta \frac{d\tilde{\sigma}^{\Lambda+\bar{\Lambda}}}{n} = \frac{1}{3} [\Delta u(x) + \Delta \bar{u}(x) - \Delta d(x) - \Delta \bar{d}(x)] D_u^{\Lambda+\bar{\Lambda}}(z), \]  

(34)

\[ \Delta \frac{d\tilde{\sigma}^{\Lambda-\bar{\Lambda}}}{p} - \Delta \frac{d\tilde{\sigma}^{\Lambda-\bar{\Lambda}}}{n} = \frac{1}{3} [\Delta u_v(x) - \Delta d_v(x)] D_u^{\Lambda-\bar{\Lambda}}(z), \]  

(35)

\[ \Delta = \frac{1}{3} \]
where $\Delta q_v$ is defined as $\Delta q - \Delta \bar{q}$. As stressed in [13], (34) and (28) provide a stringent test for the reliability of the LO treatment. By taking their ratio one obtains in LO

$$\Delta A_{p-n}^{\Lambda^+ + \bar{\Lambda}}(x, Q^2) = \frac{\Delta d\sigma_{\Lambda^+ + \bar{\Lambda}}}{d\sigma_{\Lambda^+ + \bar{\Lambda}}} \bigg|_p - \frac{\Delta d\sigma_{\Lambda^+ + \bar{\Lambda}}}{d\sigma_{\Lambda^+ + \bar{\Lambda}}} \bigg|_n = \frac{(g_1^p - g_1^n)_{LO}}{(F_1^p - F_1^n)_{LO}}(x, Q^2),$$

(36)

where $g_1$ and $F_1$ are the usual polarized and unpolarized DIS structure functions, here evaluated in LO. The crucial feature of (36) is that, in principle, the LHS depends on three variables $(x, z, Q^2)$, and only in LO should it be independent of $z$, the so called passive variable [13]. It is essential to test this feature in order to have any confidence in the LO treatment.

For the experimental situation under discussion in this subsection we can write equations analogous to (30) and (31) via the substitutions $d\tilde{\sigma} \rightarrow \Delta d\tilde{\sigma}$ and $q(x) \rightarrow \Delta q(x)$.

(37)

In this case we learn about the products

$$\Delta S_1(x, z) \equiv [\Delta s(x) + \Delta \bar{s}(x)] D_{\Lambda^+ + \bar{\Lambda}}^+ s(z),$$

(38)

and

$$\Delta S_2(x, z) \equiv [\Delta s(x) - \Delta \bar{s}(x)] D_{\Lambda^+ - \bar{\Lambda}}^- s(z).$$

(39)

Assuming $D_{\Lambda^+ + \bar{\Lambda}}^+$ has been determined as in Section A, (38) would give valuable information about $(\Delta s + \Delta \bar{s})$ which is only poorly determined from polarized DIS [11]. And (39) could provide an answer to the intriguing question as to whether or not $\Delta s(x) = \Delta \bar{s}(x)$, see comments after Eq. (33).

In addition the ratios

$$\frac{\Delta S_1(x, z)}{S_1(x, z)} = \frac{\Delta s(x) + \Delta \bar{s}(x)}{s(x) + \bar{s}(x)},$$

(40)

$$\frac{\Delta S_2(x, z)}{S_2(x, z)} = \frac{\Delta s(x) - \Delta \bar{s}(x)}{s(x) - \bar{s}(x)},$$

(41)

should be independent of the passive variable $z$.

C. Polarized $\Lambda$ and $\bar{\Lambda}$ production with polarized lepton and unpolarized nucleon

With a polarized lepton beam and unpolarized nucleon target, the difference between cross sections to produce $\Lambda$’s or $\bar{\Lambda}$’s with helicity $\pm 1/2$ is given by (23).

To simplify the notation, let us write

$$d\tilde{\sigma} \rightarrow \Delta d\tilde{\sigma} \quad \text{and} \quad q(x) \rightarrow \Delta q(x). \quad (37)$$

In this case we learn about the products

$$\Delta S_1(x, z) \equiv [\Delta s(x) + \Delta \bar{s}(x)] D_{\Lambda^+ + \bar{\Lambda}}^0 \equiv \Delta d\tilde{\sigma}_{\Lambda^+ + \bar{\Lambda}}^0,$$

(42)

Then, from (23) we obtain four equations analogous to (28), (29), (30), (31):

$$d\tilde{\sigma}_{\Lambda^+ + \bar{\Lambda}}^\pm \bigg|_p - d\tilde{\sigma}_{\Lambda^+ + \bar{\Lambda}}^\pm \bigg|_n = \frac{1}{3} [u(x) + \bar{u}(x) - d(x) - \bar{d}(x)] \Delta D_{\Lambda^+ + \bar{\Lambda}}^\pm s(z),$$

(43)

$$d\tilde{\sigma}_{\Lambda^- - \bar{\Lambda}}^\pm \bigg|_p - d\tilde{\sigma}_{\Lambda^- - \bar{\Lambda}}^\pm \bigg|_n = \frac{1}{3} [u(x) - d(x)] \Delta D_{\Lambda^- - \bar{\Lambda}}^\pm s(z),$$

(44)

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from which we can determine $\Delta D^u(z)$ and $\Delta D^\Lambda(z)$, and

$$d\hat{\sigma}^\Delta_\Lambda p + d\hat{\sigma}_0^\Delta_\Lambda|_n = \left[ \frac{5}{9} [u(x) + \bar{u}(x) + d(x) + \bar{d}(x)] \Delta D^\Lambda(z) + \frac{2}{9} [s(x) + \bar{s}(x)] \Delta D_s^\Lambda(z) \right],$$

$$d\hat{\sigma}^\Delta_\Lambda p + d\hat{\sigma}_0^\Delta_\Lambda|_n = \left[ \frac{5}{9} [u_\nu(x) + d_\nu(x)] \Delta D^\Lambda_\Lambda(z) + \frac{2}{9} [s(x) - \bar{s}(x)] \Delta D_s^\Lambda(z) \right],$$

yielding information on the products

$$S_3(x, z) = [s(x) + \bar{s}(x)] \Delta D^\Lambda_\Lambda(z),$$

$$S_4(x, z) = [s(x) - \bar{s}(x)] \Delta D^\Lambda_\Lambda(z).$$

Eq. (47) yields information on $\Delta D^\Lambda_\Lambda(z)$ and (48) provides a further test of whether $s(x) = \bar{s}(x)$.

D. Polarized $\Lambda$ and $\bar{\Lambda}$ production with polarized nucleon and unpolarized lepton

Analogous to (43) and (44), we have

$$d\hat{\sigma}^\Delta_\Lambda p + d\hat{\sigma}_0^\Delta_\Lambda|_n = \left[ \frac{1}{3} \Delta u(x) + \Delta \bar{u}(x) - \Delta d(x) - \Delta \bar{d}(x) \right].$$

The ratio of (49) and (43) provides a further test of the reliability of a LO treatment. One has

$$\frac{d\hat{\sigma}^\Delta_\Lambda p + d\hat{\sigma}_0^\Delta_\Lambda|_n}{d\hat{\sigma}^\Delta_\Lambda p + d\hat{\sigma}_0^\Delta_\Lambda|_n} = \text{function of } (x, z, Q^2) \text{ in principle} = \left( \frac{g^p - g^n}{F^p_1 - F^n_1} \right)_{LO}(x, Q^2),$$

in LO. The analogues of (45) and (46) are obtained by the substitution

$$d\hat{\sigma}^\Delta_\Lambda p + d\hat{\sigma}_0^\Delta_\Lambda|_n \rightarrow d\hat{\sigma}^\Delta_\Lambda p + d\hat{\sigma}_0^\Delta_\Lambda|_n \quad \text{and} \quad q(x) \rightarrow \Delta q(x),$$

and yield information on

$$\Delta S_3(x, z) = [\Delta s(x) + \Delta \bar{s}(x)] \Delta D^\Lambda_\Lambda(z),$$

$$\Delta S_4(x, z) = [\Delta s(x) - \Delta \bar{s}(x)] \Delta D^\Lambda_\Lambda(z).$$

The ratios
\[
\frac{\Delta S_3(x, z)}{S_3(x, z)} = \frac{\Delta s(x) + \Delta \bar{s}(x)}{s(x) + \bar{s}(x)}
\]

(55)

and

\[
\frac{\Delta S_4(x, z)}{S_4(x, z)} = \frac{\Delta s(x) - \Delta \bar{s}(x)}{s(x) - \bar{s}(x)}
\]

(56)

should be independent of \(z\) in LO and should equal the ratios \(\Delta S_1/S_1\) and \(\Delta S_2/S_2\) respectively, determined in Section B [see (40) and (41)].

V. CONCLUSIONS

The study of the angular distribution of the \(\Lambda \to p\pi\) decay allows a simple and direct measurement of the components of the \(\Lambda\) polarization vector. For \(\Lambda\)'s produced in the current fragmentation region in DIS processes, the components of the polarization vector are related to spin properties of the quark inside the nucleon, to spin properties of the quark hadronization, and to spin dynamics of the elementary interactions. All this information, concerning quark distribution functions, quark fragmentation functions and spin properties of elementary dynamics are essentially factorized in LO QCD and separated as depending on three different variables, respectively \(x, z, y\). The \(Q^2\)-evolution and dependence of distribution and fragmentation functions somewhat mix the three variables, but smoothly, keeping separated the main properties of each of the different aspects of the process. Moreover, such \(Q^2\)-dependence is perturbatively well known and under control. We have discussed all different longitudinal polarization states of spin-1/2 baryons, obtainable in the fragmentation of a quark in DIS with longitudinally polarized initial leptons and nucleons.

We have shown how one can extract new information, not attainable in unpolarized inclusive DIS, about parton densities, and new information, not extractable from \(e^+e^- \to \text{hadrons}\), about fragmentation functions. In particular one can learn about the poorly known polarized strange quark density \(\Delta s(x) + \Delta \bar{s}(x)\) and one can get some information relevant to the question as to whether \(s(x) = \bar{s}(x)\) and whether \(\Delta s(x) = \Delta \bar{s}(x)\).

The connection between the theoretical quantities and the combinations of measured cross sections is very simple, but the challenge will be an experimental one, namely to have sufficient control over systematic errors so as to permit the combining of different measurements. We hope this will soon be possible.

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