Up and Down Quark Contributions to Spin Content of $\Lambda$ from Fragmentation

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Abstract

We check the $u$ and $d$ quark contributions to the spin content of the $\Lambda$ by means of the $q \rightarrow \Lambda$ fragmentation and find that the $u$ and $d$ quarks of the $\Lambda$ are likely positively polarized. The parton distributions in the $\Lambda$ are given by a successful statistical model which can reproduce and correlate a vast body of polarized and unpolarized structure function and parton distribution data of the nucleon. With the Gribov-Lipatov relation between the quark distributions and fragmentation functions, the longitudinal spin transfer for the $\Lambda$ production in the polarized charged lepton deep inelastic scattering (DIS) process and the $\Lambda$-polarization in the neutrino (antineutrino) DIS process are predicted. The available experimental data suggests that the $u$ and $d$ quark contributions to the spin of the $\Lambda$ are positive. In addition, our results provide a collateral evidence for the SU(3) symmetry breaking in hyperon semileptonic decays of the octet baryons, which is very important for a deeper understanding of the proton 'spin crisis'.

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1 Introduction

In the naive quark model, the Λ spin is totally provided by the strange \((s)\) quark, and the \(u\) and \(d\) quarks are unpolarized. Based on novel results concerning the proton spin structure from DIS experiments, it was found that the \(u\) and \(d\) quarks of the Λ should be negatively polarized \([1]\). This analysis assumes, however, the SU(3) flavor symmetry for the weak decays in the baryon octet. Recently, it has been noticed that the effect of SU(3) symmetry breaking in hyperon semileptonic decay (HSD) should be significant \([2, 3]\). The effect has been estimated by the chiral quark soliton model \([2]\) and the large \(N_c\) QCD \([3]\). The consistent results were obtained separately by different approaches. The effect of SU(3) symmetry breaking in HSD on the spin content of the \(Λ\) was considered in the chiral quark soliton model \([4]\). It was found that the integrated polarized quark densities for the Λ hyperon should be \(\Delta U = \Delta D = -0.03 \pm 0.14\) and \(\Delta S = 0.74 \pm 0.17\) in the chiral limit case. When the strange quark mass correction is added, \(\Delta U = \Delta D = -0.02 \pm 0.17\) and \(\Delta S = 1.21 \pm 0.54\). Therefore, the SU(3) symmetry breaking allows the polarization of the \(u\) and \(d\) quarks in the \(Λ\) to be positive. However, there is a lack of experimental evidences to check the effect of the SU(3) symmetry breaking. It should be significant to clarify the polarization of \(u\) and \(d\) quarks in the \(Λ\). First, it reflects the spin structure of the \(Λ\) itself. Second, knowing how the SU(3) symmetry breaking in HSD to affect the spin content of the \(Λ\) can help us to have a deeper understanding of the proton spin ‘crisis’. Third, if the \(u\) and \(d\) quark contributions to the spin content of the \(Λ\) are transferred into the spin structure of quark fragmentation functions, they dominate the spin transfer to the \(Λ\) in the polarized charged lepton DIS process due to the charge factor for the \(u\) quark. Thus, this subject is very important for enriching the knowledge of hadron structure and hadronization mechanism.

Based on a perturbative QCD (pQCD) counting rules analysis \([5, 6]\) and an SU(6) quark diquark spectator model \([7]\), it was found \([8]\) that, although the \(u\) and \(d\) quarks of the \(Λ\) might be unpolarized or negatively polarized in the integrated Bjorken range \(0 \leq x \leq 1\), they should be positively polarized at large \(x\). However, neither the pQCD analysis nor the SU(6) quark diquark spectator model can allow to form a
clear judgement whether the $u$ and $d$ quark contributions to the spin content of the $\Lambda$ are zero, negative or positive. Recently, a statistical model for polarized and unpolarized parton distributions of the nucleon was presented by Bhalerao et al. [4]. The model can reproduce the almost all data on the nucleon structure functions $F_2^p(x, Q^2)$, $F_2^n(x) − F_2^p(x)$ and parton sum rules, which motives us to extend its application from the nucleon to the $\Lambda$.

In this Letter, we investigate the $u$ and $d$ quark contributions to the spin of the $\Lambda$ and check the effect of the SU(3) symmetry breaking in HSD by means of the statistical model. According to some constraints, we determine the parton density functions (PDFs) for the $\Lambda$ at an initial scale. Then we relate PDFs to fragmentation functions at the initial scale by using the Gribov-Lipatov relation between the quark distributions and fragmentation functions. Finally, we employ the evolved fragmentation functions to predict the longitudinal spin transfer to the $\Lambda$ in the polarized charged lepton DIS process and the $\Lambda$ polarization in the neutrino (antineutrino) DIS process. With the available experimental data, it is found that the $u$ and $d$ quark contributions to the spin of the $\Lambda$ are positive, which provides a collateral evidence for the SU(3) flavor symmetry breaking in HSD.

2 Quark distributions in the $\Lambda$

Recently, it has been found that the input-scale parton densities in the nucleon may be quasi-statistical in nature [10, 11, 12]. With a statistical model, a vast body of polarized and unpolarized nucleon structure functions and parton sum rules can be well described [4]. This motivates us to apply the same mechanism to other octet hyperons, especially to the $\Lambda$.

Following Ref. [4], the parton number density $dn^{\text{IMF}}/dx$ in the infinite-momentum frame (IMF) can be related to the density $dn/dE$ in the $\Lambda$ rest frame by

$$\frac{dn^{\text{IMF}}}{dx} = \frac{M_{\Lambda}^2 x}{2} \int_{xM_{\Lambda}/2}^{M_{\Lambda}/2} \frac{dE}{E^2} \frac{dn}{dE},$$

(1)

where $M_{\Lambda}$ is the mass of the $\Lambda$ and $E$ is the parton energy in the $\Lambda$ rest frame.
It should be pointed out that Eq. (1) is an assumption even for massless quarks since it assumes that quarks can be boosted using a purely kinematic transformation, which is in general not true in an interacting theory, especially not in a strongly interacting theory such as QCD. However, the reasonableness of the model has been tested by its successful application to the prediction of quark distributions of the nucleon. Extending the model from the nucleon to the \( \Lambda \) can provide an independent check of the same mechanism that produces the flavor and spin structure of the nucleon since the quark structure of the \( \Lambda \) is a new frontier with rich physics.

In consideration of the effects of the finite size of the \( \Lambda \), \( \frac{dn}{dE} \) can be expressed as the sum of the volume, surface and curvature terms,

\[
\frac{dn}{dE} = gf(E)(VE^2/2\pi^2 + aR^2 E + bR),
\]

with the usual Fermi or Bose distribution function \( f(E) = 1/[e^{(E-\mu)/T} \pm 1] \). In (2), \( g \) is the spin-color degeneracy factor, \( V \) is the \( \Lambda \) volume and \( R \) is the radius of a sphere with volume \( V \). The parameters \( a \) and \( b \) in (2) have been determined by fitting the structure function data for the proton. We choose the same values of them for the \( \Lambda \), i.e. \( a = -0.376 \) and \( b = 0.504 \). Then, \( n_{q(\bar{q})}^{\uparrow(\downarrow)} \) which denotes the number of quarks(antiquarks) and spin parallel (anti-parallel) to the \( \Lambda \) spin can be written as

\[
n_{q(\bar{q})}^{\uparrow(\downarrow)} = g \int_0^{M_{\Lambda}/2} \frac{VE^2/2\pi^2 + aR^2 E + bR}{e^{(E-\mu_{q(\bar{q})}^{\uparrow(\downarrow)}/T) + 1}} dE
\]

Similarly, the momentum fraction carried by the quark \( q \) (antiquark \( \bar{q} \)) and gluon \( G \) can be expressed as

\[
M_{q(\bar{q})}^{\uparrow(\downarrow)} = \frac{4g}{3M_{\Lambda}} \int_0^{M_{\Lambda}/2} \frac{E(VE^2/2\pi^2 + aR^2 E + bR)}{e^{(E-\mu_{q(\bar{q})}^{\uparrow(\downarrow)}/T) + 1}} dE
\]

\[
M_G^{\uparrow(\downarrow)} = \frac{4g}{3M_{\Lambda}} \int_0^{M_{\Lambda}/2} \frac{E(VE^2/2\pi^2 + aR^2 E + bR)}{e^{(E-\mu_G^{\uparrow(\downarrow)}/T) - 1}} dE
\]

Due to isospin symmetry, the \( u \) and \( d \) quarks in the \( \Lambda \) are expected to be equal. Hence, the quark numbers and the parton momentum fractions have to satisfy the following five constraints:
\[ n_u^\uparrow + n_u^\downarrow - n_\uparrow^\uparrow - n_\uparrow^\downarrow = 1, \]  
\[ n_u^\uparrow - n_u^\downarrow + n_\uparrow^\uparrow - n_\uparrow^\downarrow = \Delta U, \]  
\[ n_s^\uparrow + n_s^\downarrow - n_\uparrow^\uparrow - n_\uparrow^\downarrow = 1, \]  
\[ n_s^\uparrow - n_s^\downarrow + n_\uparrow^\uparrow - n_\uparrow^\downarrow = \Delta S, \]  
\[ \sum_q (M_q^\uparrow + M_q^\downarrow + M_q^\uparrow + M_q^\downarrow) + (M_G^\uparrow + M_G^\downarrow) = 1, \]

where the integrated polarized quark densities \( \Delta U \) and \( \Delta S \) are very important inputs for the spin structure of the \( \Lambda \). In order to describe the spin content of the \( \Lambda \), it is necessary to distinguish between \( \mu_{q(\overline{q})}^\uparrow \) and \( \mu_{q(\overline{q})}^\downarrow \). We assume that the gluon is not polarized at the initial scale and hence \( \mu_G^\uparrow = \mu_G^\downarrow = 0 \). Thus at input scale, \( \Delta G(x) = 0 \) and the gluon polarization comes from the QCD evolution. In addition, it has been noticed that \( \mu_{q(\overline{q})}^\uparrow = -\mu_{q(\overline{q})}^\downarrow \) and \( \mu_{q(\overline{q})}^\uparrow = -\mu_{q(\overline{q})}^\downarrow \). Therefore, by solving 5 coupled nonlinear equations (6)-(10), we can determine 5 unknowns, namely \( \mu_u^\uparrow, \mu_u^\downarrow, \mu_s^\uparrow, \mu_s^\downarrow \), and \( T \).

Recent analyses show that the SU(3) flavor symmetry breaking in HSD has a significant effect on the extraction of the contributions \( \Delta U \), \( \Delta D \) and \( \Delta S \) to the spin of the octet baryons. In order to check the effect of the SU(3) symmetry breaking, we adopt two sets of typical \( \Delta U \) and \( \Delta S \) for the \( \Lambda \). Set I: \( \Delta U = \Delta D = 0.10 \) and \( \Delta S = 0.74 \); Set II: \( \Delta U = \Delta D = -0.17 \) and \( \Delta S = 0.62 \). The set-I is built under the guidance of the results given by the chiral quark model [4] with the SU(3) symmetry breaking in HSD. The set-II is based on an assumption of the SU(3) flavor symmetry for the weak decays in the baryon octet [1, 13]. The corresponding solutions of \( \mu_u^\uparrow, \mu_u^\downarrow, \mu_s^\uparrow, \mu_s^\downarrow \), and \( T \) for the two sets of \( \Delta U \) and \( \Delta S \) are listed in Table 1. With these values, unpolarized and polarized parton distributions in the \( \Lambda \) can be obtained directly from (1).
Table 1  Chemical potentials ($\mu$) and temperature ($T$) (in MeV).

| Set | $\Delta U$ | $\Delta D$ | $\Delta S$ | $\mu^u_0$ | $\mu^d_0$ | $\mu^u_1$ | $\mu^d_1$ | $T$ |
|-----|-------------|-------------|-------------|-----------|-----------|-----------|-----------|-----|
| I   | 0.10        | 0.10        | 0.74        | 80.5      | 65.8      | 127.3     | 19.0      | 73.8|
| II  | -0.17       | -0.17       | 0.62        | 60.7      | 85.6      | 118.5     | 27.7      | 74.0|

3  Fragmentation functions for the $\Lambda$ polarization

Unfortunately, we can not check the obtained parton distributions of the $\Lambda$ by means of structure functions in DIS scattering since the $\Lambda$ can not be used as a target due to its short life time. Also one obviously can not produce a beam of charge-neutral $\Lambda$. What one can check with experiments is the quark to $\Lambda$ fragmentation, and therefore one needs a relation between the quark distributions and fragmentation functions. Recently, there has been progress in understanding the quark to $\Lambda$ fragmentation [8] by using the Gribov-Lipatov (GL) relation [14]

$$D^h_q(z) \sim z q_h(z)$$ (11)

in order to connect the fragmentation functions with the distribution functions. This relation, where $D^h_q(z)$ is the fragmentation function for a quark $q$ splitting into a hadron $h$ with longitudinal momentum fraction $z$, and $q_h(z)$ is the quark distribution of finding the quark $q$ inside the hadron $h$ carrying a momentum fraction $x = z$, is only known to be valid near $z \to 1$ at an energy scale $Q^2_0$ in leading order approximation [15]. However, with the GL relation, predictions of $\Lambda$ polarizations [8] based on quark distributions of the $\Lambda$ in the SU(6) quark diquark spectator model and in the pQCD based counting rules analysis, have been found to be supported by all available data from longitudinally polarized $\Lambda$ fragmentation in $e^+e^-$-annihilation [16, 17, 18], polarized charged lepton DIS [19, 20], and most recently, neutrino (antineutrino) DIS [21]. Thus we still use (11) as an Ansatz to relate the quark fragmentation functions for the $\Lambda$ to the corresponding quark distributions at an initial scale. Then, the quark fragmentation functions are evolved from the initial scale to the experimental energy scale. We used the evolution package of Ref. [22] suitable modified
Figure 1: The quark to Λ fragmentation functions. The solid and dashed lines are for set-I and set-II (see Table 1), respectively. The thin and thick lines represent the fragmentation functions at the initial scale and at $Q^2 = 10 \text{ GeV}^2$, respectively. Note that the thin and thick lines in (e) and (f) almost overlap.

for the evolution of fragmentation functions in leading order, taking the initial scale $Q_0^2 = M_\Lambda^2$ and $\Lambda_{QCD} = 0.3 \text{ GeV}$. In Fig. 1, the set-I (solid lines) and set-II (dashed lines) fragmentation functions are presented at two different scales. The fragmentation functions at the initial scale, which are related to the corresponding quark distributions via the GL relation, are presented with thin lines. The fragmentation functions at $Q^2 = 10 \text{ GeV}^2$ are shown in thick lines. From Fig. 1(b) where the solid and dashed lines almost overlap, we find that the two sets of unpolarized $u$ quark to Λ fragmentation functions are almost the same, although the corresponding polarized fragmentation functions are very different (see Fig. 1(d)). The thin and thick lines in Fig. 1(e)-(f) almost overlap, which indicates that the $Q^2$ dependence in the spin structure of the fragmentation functions is very weak.

We need some experimental data to check the obtained quark fragmentation functions for the Λ. There has been some recent progress in the measurements of polarized Λ production. The longitudinal Λ polarization in $e^+e^-$ annihilation at the Z-pole was
observed by several collaborations \cite{16, 17, 18}. The HERMES collaboration at DESY and the E665 Collaboration at FNAL \cite{20} reported their results for the longitudinal spin transfer to the Λ in polarized positron DIS \cite{19}. Very recently, the measurement results of Λ polarization in charged current interactions was obtained in NOMAD \cite{21}. Based on the available experimental data, we can check the prediction for the Λ polarization, especially in this work, the \(u\) and \(d\) quark contributions to the spin content of the Λ. In \(e^+e^-\) annihilation at the Z-pole, the Λ polarization is dominated by strange quark fragmentation. In order to show the \(u\) and \(d\) quark contributions to the spin content of the Λ, we focus our attention on the Λ electroproduction in which the longitudinal spin transfer to the Λ is dominated from the \(u\) quark due to the charge factor for the \(u\) quark.

For a longitudinally polarized charged lepton beam and an unpolarized target, the Λ polarization along its own momentum axis is given in the quark parton model by \cite{23}

\[
P_\Lambda(x, y, z) = P_B D(y) A^\Lambda(x, z),
\]

(12)

where \(P_B\) is the polarization of the charged lepton beam, which is of the order of 0.7 or so \cite{19, 20}. \(D(y)\), whose explicit expression is

\[
D(y) = \frac{1 - (1 - y)^2}{1 + (1 - y)^2},
\]

(13)

is commonly referred to as the longitudinal depolarization factor of the virtual photon with respect to the parent lepton, and

\[
A^\Lambda(x, z) = \frac{\sum_q e^2_q[q^N(x, Q^2)\Delta D^\Lambda_q(z, Q^2) + (q \rightarrow \bar{q})]}{\sum_q e^2_q[q^N(x, Q^2)D^\Lambda_q(z, Q^2) + (q \rightarrow \bar{q})]},
\]

(14)

is the longitudinal spin transfer to the Λ. Here \(y = \nu/E\) is the fraction of the incident lepton’s energy that is transferred to the hadronic system by the virtual photon. In Eq. (14), \(q^N(x, Q^2)\), the quark distribution of the proton, will be adopted as the CTEQ5 set 1 parametrization form \cite{24} in our numerical calculations.

Our predictions with the two sets of fragmentation functions are shown in Fig. 2. We find that both predictions are compatible in medium \(z\) to the data on the longitudinal spin transfer for the Λ production in the polarized charged lepton DIS process.
Figure 2: The $z$-dependence of the $\Lambda$ spin transfer in electron or positron (muon) DIS. The solid and dashed curves are for set-I and set-II (see Table 1), respectively. Note that for the HERMES data the $\Lambda$ polarization is measured along the virtual-photon momentum, whereas for E665 it is measured along the virtual-photon spin. The averaged value of the Bjorken variable is chosen as $x = 0.1$ (corresponding to the HERMES averaged value) and the calculated result is not sensitive to a different choice of $x$ in the small $x$ region (for example, $x = 0.005$ corresponding to the E665 averaged value). $Q^2 = 4 \text{ GeV}^2$ is used and the $Q^2$ dependence of the result is very weak.

Although the precision of the data is not sufficient to draw a clear distinction between the two predictions, it seems that the data favors somewhat the set-I prediction, i.e., the $u$ and $d$ quarks are likely positively polarized in the $\Lambda$. This is consistent with the analysis by Florian, Stratmann and Vogelsang [25]. In order to convert the spin structure of the $\Lambda$ into predictions for future experiments, authors of Ref. [25] made a QCD analysis of the polarized $\Lambda$ fragmentation function within three different scenarios. Scenario 1 corresponds to the SU(6) symmetric non-relativistic quark model, according to which the $u$ and $d$ quarks of the $\Lambda$ are not polarized; Scenario 2 is based on an SU(3) flavor symmetry analysis and leads to the prediction that the $u$ and $d$ quarks of the $\Lambda$ are negatively polarized. Scenario 3 is built on the assumption that all light quarks contribute equally to the $\Lambda$ polarization. It is very interesting that the best agreement with data was obtained within scenario 3 [19], which supports our present observation that the $u$ and $d$ quarks in the $\Lambda$ are likely positively polarized as well as the strange quark.

In addition, the scattering of a neutrino beam on a hadronic target provides a source of polarized quarks with specific flavor structure, and this particular property makes the neutrino (antineutrino) process an ideal laboratory to study the flavor-
Figure 3: The prediction of $z$-dependence for the $\Lambda$ polarization in the neutrino (antineutrino) DIS process. The solid and dashed curves are for set-I and set-II (see Table 1), respectively. We adopt the CTEQ5 set 1 quark distributions \[24\] for the target proton at $Q^2 = 4 \text{ GeV}^2$ with the Bjorken variable $x$ integrated over $0.02 \to 0.4$ and $y$ integrated over $0 \to 1$.

dependence of quark to hadron fragmentation functions, especially in the polarized case. We find that the $\Lambda$ polarization in the neutrino (anti-neutrino) DIS process can also be used to check the $u$ and $d$ quark contributions to the spin content of the $\Lambda$.

The longitudinal polarizations of the $\Lambda$ in its momentum direction, for the $\Lambda$ in the current fragmentation region can be expressed as,

$$P^\Lambda_{\nu}(x, y, z) = \frac{-[d(x) + \omega s(x)]\Delta D^\Lambda_u(z) - (1 - y)^2\overline{u}(x)[\Delta D^\Lambda_d(z) + \omega \Delta D^\Lambda_s(z)]}{[d(x) + \omega s(x)]\overline{D}^\Lambda_u(z) + (1 - y)^2\overline{u}(x)[\overline{D}^\Lambda_d(z) + \omega \overline{D}^\Lambda_s(z)]}, \quad (15)$$

$$P^\Lambda_{\bar{\nu}}(x, y, z) = \frac{-\overline{u}(x)[\Delta D^\Lambda_d(z) + \omega \Delta D^\Lambda_s(z)] - \overline{d}(x) + \omega \overline{s}(x)[\Delta D^\Lambda_u(z)]}{(1 - y)^2\overline{u}(x)[\overline{D}^\Lambda_d(z) + \omega \overline{D}^\Lambda_s(z)] + \overline{d}(x) + \omega \overline{s}(x)[\overline{D}^\Lambda_u(z)]}, \quad (16)$$

where the terms with the factor $\omega = \sin^2 \theta_c / \cos^2 \theta_c$ ($\theta_c$ is the Cabibbo angle) represent Cabibbo suppressed contributions.

The NOMAD data \[21\] on the $\Lambda$ polarization in the neutrino DIS process, which has much smaller errors than the data on the longitudinal spin transfer to the $\Lambda$ in polarized charged lepton DIS process and shows a weak dependence on $z$, can help us to distinguish two sets of predictions. In Fig. 3 we present our predictions for the $\Lambda$ polarization in the neutrino (antineutrino) DIS process and find that the set-I prediction is much closer to the experimental data than the set-II prediction. The data supports again the set-I that the integrated polarized $u$ and $d$ quark densities for the $\Lambda$ are positive.
4 Summary and Conclusion

We constrained the quark distributions of the Λ at an initial scale with two sets of typical ∆U and ∆S for the Λ. By means of the statistical model, we calculated quark distributions for a Λ in the rest frame and then used free boost transformations to relate the rest frame results to the IMF and made predictions about PDFs. Furthermore, we used the GL relation as an Ansatz to relate fragmentation functions to the corresponding PDFs at the initial scale. Finally, employing the evolved quark fragmentation functions of the Λ, we calculated the longitudinal spin transfer to the Λ in the polarized charged lepton DIS process and the Λ polarization in the neutrino (antineutrino) DIS process. It is found that the available polarized charged lepton DIS experimental data is not sufficient for us to distinguish two sets of the fragmentation functions, although the data favors somewhat the set-I prediction. Fortunately, the very recent NOMAD data on the Λ polarization in the neutrino DIS process, which has small errors, allow to draw a clear distinction between two sets of predictions. The experimental data favors obviously the set-I prediction, which indicates that the u and d quark contributions to the spin content of the Λ are likely positive.

In addition, our results reflect the importance of the SU(3) symmetry breaking in HSD. Recently, various theoretical analyses have arrived at the same conclusion that the flavor SU(3) symmetry breaking in HSD significantly affects the contributions ∆U, ∆D and ∆S of the light quarks to the spin of the octet baryons. However, there is a lack of experimental evidences to support the above conclusion. In our analysis, the set-I ∆U and ∆S for the Λ are allowed due to the SU(3) symmetry breaking in HSD and the set-II ∆U and ∆S are based on the assumption of the SU(3) flavor symmetry for the weak decays in the baryon octet. The set-I prediction is much better than the set-II prediction in explaining the NOMAD data on the Λ polarization in neutrino DIS process. Thus, our results provide a collateral evidence for the SU(3) symmetry breaking in HSD, which is very important for a deeper understanding of the proton ‘spin crisis’.

We would like to mention that our present knowledge on the Λ fragmentation functions is still poor and there are many unknowns to be explored before we can
arrive at some definite conclusion on the quark spin structure of the Λ. First, what one actually measures in experiments are quark to Λ fragmentation functions, and we used the GL relation Eq. (11) in order to relate the quark distributions inside Λ with the fragmentation functions of the same flavor quark to Λ. However, such a relation is only known to be valid in large $z$ region, and using it down to very small $z$ is questionable. Second, there are still uncertainties on the quark distributions of the Λ given by the statistical model since some assumptions are underlying the model. Despite the experimental uncertainties, it seems that the experimental data on the longitudinal spin transfer to the Λ in the polarized charged lepton DIS process shows a strong dependence on $z$, especially in low $z$ region. At the moment, it seems to be difficult to understand such a rather strong $z$ dependence in low $z$ region with the available models [8, 23], although the models can provide predictions which are compatible to the data in medium $z$ range. Thus, we need to improve our prediction with respect to the $z$ dependence. In order to provide a set of more realistic fragmentation functions for the Λ, further studies, such as revising the GL relation and improving the quark distributions of the Λ, are in progress. On the other hand, experimentally, the high statistics investigation of polarized Λ production is one of the main future goals of the HERMES Collaboration which will improve their detector for this purpose by adding so called Lambda-wheels. The physics of Λ polarization has been regarded as a strongly emphasized project in the COMPASS experiment [20]. Many efforts, both theoretically and experimentally, are being made in order to reduce the uncertainties in the spin structure of the Λ since the subject is crucial important for enriching the knowledge of hadron structure and hadronization mechanism.

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