THE POLARIZATION OF THE STRANGE SEA FROM INCLUSIVE AND SEMI-INCLUSIVE lp-DIS WITH CHARGED CURRENT

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Abstract

The distributions polarized strange quarks, anti-quarks and the contributions strange sea in the proton spin have been obtained from an analysis inclusive and semi-inclusive lp-DIS with charged current.

1 Introduction

The experimental investigations of the spin structure nucleon [1, 2, 3] in the SLAC, CERN, DESY showed that the quarks and anti-quarks carried only about a third him spin.

From data the COMPASS, HERMES, PHENIX, STAR obtained that the gluonic contribution is $|\Delta g| < 0,4$ in the measurable region [1, 2, 3, 4]. This value on one order less than expected for the explanation "spin crisis" of account the axial anomaly. However a significant contribution in Δg at small x not exclude. The missing spin of the proton can be carried as orbital angular momentums by the quarks and gluons. In this respect a measurements generalized parton distributions are perspective in the exclusive process of the deep inelastic virtual Compton scattering and production of the vector mesons [4, 5].

In view of the big uncertainty in measurements Δg one cannot make a definite conclusion about the quark–gluon contribution in the spin of the nucleon.

Moreover a role the polarized quark sea is not clear. The special interest represent a contribution him strange component. The EMC [6] has found that

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its first moment $(\Delta s + \Delta\overline{s})$ to be negative and this result has been confirmed with improved precision by recent measurements performed by HERMES [7] $(\Delta s + \Delta\overline{s} = -0,103 \pm 0,007 \pm 0,013)$ and by COMPASS [8]: $\Delta s + \Delta\overline{s} = -0,09 \pm 0,01 \pm 0,02$. The inclusive experiments provide a direct evaluation the first moment of $(\Delta s + \Delta\overline{s})$ only. The distribution $\Delta s(x)$ can be obtained from semi-inclusive experiments.

The last semi-inclusive data COMPASS [9] show that non-strange sea distributions depend very little on a choice the fragmentation functions in contrast $\Delta s(x)$. The non-strange sea distribution is consistent with zero for all values of x. The strange quark distribution can be to consistent as with zero as negative.

2 The cross sections and spin asymmetries lp-DIS with charged current

The cross sections inclusive lp-DIS with charged current

$$l^-(l^+) + p \rightarrow \nu(\overline{\nu}) + X, \qquad l = e, \mu \tag{1}$$

in Born approximation are [11]:

$$d^2\sigma_{l^-,l^+}/dxdy =$$
$$= \rho\left[\frac{1}{2}(y_1^+ F_2^{l^-,l^+} \pm y_1^- x F_3^{l^-,l^+}) + P_N x(y_1^+ g_6^{l^-,l^+} \pm y_1^- g_1^{l^-,l^+})\right]. \tag{2}$$

Here

$$\rho = \frac{G^2 s}{2\pi}\left(\frac{1}{1 + Q^2/m_W^2}\right)^2, \qquad y_1^\pm = 1 \pm y_1^2, \qquad y_1 = 1 - y;$$

$F_{2,3}$ and $g_{1,6}$ are the structure functions (SF) of proton; x, y are the scaling variables. G is Fermi constant, P_N is the degree of the longitudinal polarization of proton; $Q^2 = -(k - k')^2$, $S = 2pk$; $k(k')$ and p are momentum incoming (outcoming)lepton and proton respectively.

In quark – parton model (QPM) SF is expressed through the parton distributions [11, 12]:

$$F_2(x) = 2x\Big(\sum_q q(x) + \sum_{\overline{q}} \overline{q}(x)\Big),$$
$$F_3(x) = 2\Big(\sum_q q(x) - \sum_{\overline{q}} \overline{q}(x)\Big), \tag{3}$$
$$g_{1,6} = \sum_q \Delta q(x) \pm \sum_{\overline{q}} \Delta\overline{q}(x),$$

where $q = u, c, t$ $(q = d, s, b)$ and $\overline{q} = \overline{d}, \overline{s}, \overline{b}$ $(\overline{q} = \overline{u}, \overline{c}, \overline{t})$ for $l^-(l^+)$.

Then cross sections (2) can present in terms this distributions

$$d^2\sigma_{l^-}/dxdy =$$
$$= 2\rho x\Big[\sum_q q(x) + y_1^2 \sum_{\overline{q}} \overline{q}(x) + p_N\Big(\sum_q \Delta q(x) - y_1^2 \sum_{\overline{q}} \Delta\overline{q}(x)\Big)\Big],$$

(4)

$$d^2\sigma_{l^+}/dxdy =$$
$$= 2\rho x\Big[y_1^2 \sum_q q(x) + \sum_{\overline{q}} \overline{q}(x) + p_N\Big(y_1^2 \sum_q \Delta q(x) - \sum_{\overline{q}} \Delta\overline{q}(x)\Big)\Big].$$

The spin asymmetries determine as following combinations of cross sections

$$A^{DIS}_{l^-,l^+} = \frac{\sigma^{\downarrow\uparrow,\uparrow\uparrow}_{l^-,l^+} - \sigma^{\downarrow\downarrow,\uparrow\downarrow}_{l^-,l^+}}{\sigma^{\downarrow\uparrow,\uparrow\uparrow}_{l^-,l^+} + \sigma^{\downarrow\downarrow,\uparrow\downarrow}_{l^-,l^+}},$$
$$A^{DIS}_{\pm} = \frac{(\sigma^{\downarrow\uparrow}_{l^-} \pm \sigma^{\uparrow\uparrow}_{l^+}) - (\sigma^{\downarrow\downarrow}_{l^-} \pm \sigma^{\uparrow\downarrow}_{l^+})}{(\sigma^{\downarrow\uparrow}_{l^-} \pm \sigma^{\uparrow\uparrow}_{l^+}) + (\sigma^{\downarrow\downarrow}_{l^-} \pm \sigma^{\uparrow\downarrow}_{l^+})}, \tag{5}$$

where $\sigma \equiv d^2\sigma/dxdy$.

The first arrow notes the direction of lepton ($\downarrow$) or antilepton ($\uparrow$) spin and second – proton spin: $\uparrow$ $(P_N = +1)$, $\downarrow$ $(P_N = -1)$.

By [4] obtained the expressions for inclusive asymmetries [5] in QPM:

$$A_{l^-}^{DIS} = \frac{\sum\limits_{q=u,c,t} \Delta q(x) - y_1^2 \sum\limits_{\bar{q}=\bar{d},\bar{s},\bar{b}} \Delta \bar{q}(x)}{\sum\limits_{q=u,c,t} q(x) + y_1^2 \sum\limits_{\bar{q}=\bar{d},\bar{s},\bar{b}} \bar{q}(x)},$$
$$A_{l^+}^{DIS} = \frac{y_1^2 \sum\limits_{q=d,s,b} \Delta q(x) - \sum\limits_{\bar{q}=\bar{u},\bar{c},\bar{t}} \Delta \bar{q}(x)}{y_1^2 \sum\limits_{q=d,s,b} q(x) + \sum\limits_{\bar{q}=\bar{u},\bar{c},\bar{t}} \bar{q}(x)}, \quad (6)$$

$$A_{\pm}^{DIS} = \\ = \frac{\sum\limits_{q=u,c,t} \Delta q(x) - y_1^2 \sum\limits_{\bar{q}=\bar{d},\bar{s},\bar{b}} \Delta \bar{q}(x) \pm y_1^2 \sum\limits_{q=d,s,b} \Delta q(x) \mp \sum\limits_{\bar{q}=\bar{u},\bar{c},\bar{t}} \Delta \bar{q}(x)}{\sum\limits_{q=u,c,t} q(x) + y_1^2 \sum\limits_{\bar{q}=\bar{d},\bar{s},\bar{b}} \bar{q}(x) \pm y_1^2 \sum\limits_{q=d,s,b} q(x) \pm \sum\limits_{\bar{q}=\bar{u},\bar{c},\bar{t}} \bar{q}(x)}. \quad (7)$$

Now we consider the semi-inclusive lp-DIS

$$l^-(l^+) + p \to \nu(\bar{\nu}) + h + X, \qquad h = \pi, k, \ldots \quad (8)$$

The cross sections these processes can to obtain by a modification (4) through the replacements

$$\Delta q(x) \to \Delta q(x) D_q^h(z), \qquad q(x) \to q(x) D_q^h(z),$$

where $D_q^h(z)$ is the fragmentation function quark q to hadron h.

Then for the cross sections of processes (8) obtained

$$
\begin{aligned}
d^3\sigma^h_{l^-}/dx\,dy\,dz \equiv \sigma^h_{l^-} &= 2\rho x\Bigg[\sum_{q_i,q_j} q_i(x)D^h_{q_j}(z) + y_1^2\sum_{\overline{q_j},\overline{q_i}}\overline{q}_j(x)D^h_{\overline{q}_i}(z) + \\
&+ p_N\Big(\sum_{q_i,q_j}\Delta q_i(x)D^h_{q_j}(z) - y_1^2\sum_{\overline{q}_j,\overline{q}_i}\Delta\overline{q}_j(x)D^h_{\overline{q}_i}(z)\Big)\Bigg], \\
d^3\sigma^h_{l^+}/dx\,dy\,dz \equiv \sigma^h_{l^+} &= 2\rho x\Bigg[y_1^2\sum_{q_j,q_i} q_j(x)D^h_{q_i}(z) + \sum_{\overline{q_i},\overline{q_j}}\overline{q}_i(x)D^h_{\overline{q}_j}(z) + \\
&+ p_N\Big(y_1^2\sum_{q_j,q_i}\Delta q_j(x)D^h_{q_i}(z) - \sum_{\overline{q}_i,\overline{q}_j}\Delta\overline{q}_i(x)D^h_{\overline{q}_j}(z)\Big)\Bigg],
\end{aligned}
\tag{9}
$$

where $q_i = u,\ c,\ t;\qquad q_j = d,\ s,\ b.$

The polarization asymmetries $A^{h^+-h^-}$ for the processes (8) we obtain analogously (5) but through the difference cross sections $(\sigma^{h^+} - \sigma^{h^-})$ instead σ (see [13] and references therein).

3 The combining analysis of inclusive and semi-inclusive lp-DIS

Neglecting the contributions of heavy quarks and anti-quarks $(c,\ b,\ t)$ for inclusive asymmetries from (6), (7) have

$$
A^{DIS}_{l^-} = \frac{\Delta u(x) - y_1^2\Big[\Delta\overline{d}(x) + \Delta\overline{s}(x)\Big]}{u(x) + y_1^2\Big[\overline{d}(x) + \overline{s}(x)\Big]}, \tag{10}
$$

$$
A^{DIS}_{l^+} = \frac{y_1^2\Big[\Delta d(x) + \Delta s(x)\Big] - \Delta\overline{u}(x)}{y_1^2\Big[d(x) + s(x)\Big] + \overline{u}(x)}, \tag{11}
$$

$$
A^{DIS}_{-} = \frac{\Delta u(x) + \Delta\overline{u}(x) - y_1^2\Big[\Delta d(x) + \Delta\overline{d}(x) + \Delta s(x) + \Delta\overline{s}(x)\Big]}{u_V(x) - y_1^2 d_V(x)}, \tag{12}
$$

where $(\Delta)q_V(x) = (\Delta)q(x) - (\Delta)\overline{q}(x)$ are the distributions the valence quarks $(q = u, d)$.

If $h = \pi^+$, for semi-inclusive asymmetries $A^{\pi^+ - \pi^-}$ obtain in approach [13, 14] the following expressions independent from the fragmentation functions:

$$A_{l-}^{\pi^+ - \pi^-} = \frac{\Delta u(x) - y_1^2 \Delta \overline{d}(x)}{u(x) + y_1^2 \overline{d}(x)}, \tag{13}$$

$$A_{l+}^{\pi^+ - \pi^-} = \frac{y_1^2 \Delta d(x) - \Delta \overline{u}(x)}{y_1^2 d(x) + \overline{u}(x)}, \tag{14}$$

$$A_{+}^{\pi^+ - \pi^-} = \frac{\Delta u(x) + \Delta \overline{u}(x) - y_1^2 \left[\Delta d(x) + \Delta \overline{d}(x)\right]}{u_V(x) - y_1^2 d_V(x)}. \tag{15}$$

Then from (11), (14) and (10), (13) find the distributions of polarized strange quarks $\Delta s(x)$ and anti-quarks $\Delta \overline{s}(x)$

$$\Delta s(x) = \\ = \frac{1}{y_1^2}\left[A_{l+}^{DIS}\left(y_1^2\left(d(x) + s(x)\right) + \overline{u}(x)\right) - A_{l+}^{\pi^+ - \pi^-}\left(y_1^2 d(x) + \overline{u}(x)\right)\right], \tag{16}$$

$$\Delta \overline{s}(x) = \\ = \frac{1}{y_1^2}\left[A_{l-}^{\pi^+ - \pi^-}\left(u(x) + y_1^2 \overline{d}(x)\right) - A_{l-}^{DIS}\left(u(x) + y_1^2\left(d(x) + s(x)\right)\right)\right].$$

The correlations (12), (15) give a possibility to obtain $\left[\Delta s(x) + \Delta \overline{s}(x)\right]$ through the measurable asymmetries

$$\Delta s(x) + \Delta \overline{s}(x) = \frac{1}{y_1^2}\left(u_V(x) - y_1^2 d_V(x)\right)\left(A_{+}^{\pi^+ - \pi^-} - A_{-}^{DIS}\right). \tag{17}$$

The first moments from (16) and (17)

$$\Delta s(\Delta \bar{s}) = \int_0^1 \Delta s(x) \left[\Delta \bar{s}(x)\right] dx,$$

$$\Delta s + \Delta \bar{s} = \int_0^1 \left[\Delta s(x) + \Delta \bar{s}(x)\right] dx$$

are the contribution of strange sea in proton spin.

4 Conclusion

1. The expressions for the contributions of strange sea in proton spin have obtained from analysis inclusive and semi-inclusive lp-DIS with charged weak current.

2. These contributions are expressed only through the inclusive and semi-inclusive asymmetries lp-DIS, unpolarized parton distributions without supplementary measurable quantities (usually this axial charges a_3 and a_8).

3. The semi-inclusive asymmetries $A^{\pi^+ - \pi^-}$ are independent from the fragmentation functions that especially conveniently for an analysis the spin structure of proton.

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