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The Spin Structure of the Nucleon from Semi-Inclusive Deep Inelastic Neutrino Scattering with Neutral Current

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The asymmetries of semi-inclusive deep inelastic scattering of neutrino on polarized deuteron with the neutral current have been used for the extraction of valence quark, anti-quark and strange quark contributions to the nucleon spin.

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1. Introduction

The investigation of spin structure of the nucleon is one of the actual problems of particle physics. The present experiments [1] show, that total quark contribution to the nucleon spin is 0.30-0.35, the strange quark polarization is negative and have matter -8-10%. At the same time data of HERMES shows, that it can be close to zero. Existing experimental data specify, that gluon polarization has not big positive value as it earlier supposed. The orbital angular momentum of quarks and gluons contribution to the nucleon spin while experimental data are not present.

In the last years the information of the quarks and gluons contribution to the spin of nucleon receive from semi-inclusive experiments. However the semi-inclusive deep inelastic scattering (SIDIS) with charged leptons [2] allow to receive the valence quarks contribution. At the same time is important to know strange quarks contribution for the nucleon spin problem decision. The neutrino processes are the interest from this point of view. In article [4] the spin structure of the nucleon in $\nu(\bar{\nu})N$- DIS with the charged weak current was considered.

In the present work the approach [4] on the neutrino deep inelastic scattering with a neutral current extends.

2. The semi-inclusive $\nu(\bar{\nu})N$-DIS with neutral current

The differential cross sections of the semi-inclusive $\nu(\bar{\nu})N$-DIS with the neutral weak current in the quark-parton model are equal to the

$$\sigma^h_{\nu,\nu} = (\sigma^a_{\nu,\nu})^h + (\sigma^{pol}_{\nu,\bar{\nu}})^h, \qquad (1)$$

where

$$\sigma = \frac{d^3\sigma}{dxdydz}.$$

$$(\sigma^a_{\nu,\bar{\nu}})^h = \sigma_0 x\left[\sum_q \left(\frac{1}{2}a_q y_1^+ + b_q y_1\right)q(x)D^h_q(z) + \sum_{\bar{q}} \left(\frac{1}{2}a_q y_1^+ - b_q y_1^-\right)q(x)D^h_q(z)\right],$$

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$$(\sigma^{pol}_{\nu,\bar\nu})^h = \sigma_0 x P_N\left[\sum_q\left(\frac{1}{2}a_q y_1^- + b_q y_1^+\right)\Delta q(x)D_q^h(z) \pm \sum_{\bar q}\left(\frac{1}{2}a_q y_1^- - b_q y_1^+\right)\Delta\bar q(x)D_q^h(z)\right]. \quad (2)$$

Here

$$a_q = (g_V^2 + g_A^2)_q, \qquad b_q = (g_V g_A)_q,$$
$$(g_V)_u = \frac{1}{2} - \frac{4}{3}sin^2\theta_w, \qquad (g_A)_u = \frac{1}{2},$$
$$(g_V)_{d,s} - \frac{1}{2} + \frac{2}{3}sin^2\theta_w, \qquad (g_A)_{d,s} = -\frac{1}{2},$$

$\sigma_0 = G^2ME/\pi$, $x = \frac{Q^2}{2P\cdot q}$, $y = \frac{P\cdot q}{P\cdot k}$, $z = \frac{P\cdot P_h}{P\cdot q}$, $Q^2 = -q^2$, $q = k - k'$, E is the energy of incoming neutrino or antineutrino, $k(k')$, P, P_h - are the initial (final)lepton, the nucleon and hadron h four momenta respectively , G is Fermi constant, M is the nucleon mass, $y_1 = 1 - y$, P_N is degree longitudinal polarization of nucleon; $q(x), \Delta q(x)(\bar q(x), \Delta\bar q(x))$ is the unpolarized (polarized) quark (antiquark) function of contribution, $D_q^h(z)$ is the function fragmentation of quark q to the hadron h.

Define the polarization asymmetries in the form of

$$A^{h-\bar h}_{\nu,\bar\nu} = \frac{(\sigma^h_{\downarrow\uparrow,\uparrow\uparrow} - \sigma^{\bar h}_{\downarrow\downarrow,\uparrow\downarrow}) - (\sigma^h_{\downarrow\downarrow,\uparrow\downarrow} - \sigma^{\bar h}_{\downarrow\downarrow,\uparrow\downarrow})}{(\sigma^h_{\downarrow\uparrow,\uparrow\uparrow} + \sigma^h_{\downarrow\uparrow,\uparrow\uparrow}) + (\sigma^h_{\downarrow\downarrow,\uparrow\downarrow} - \sigma^h_{\downarrow\downarrow,\uparrow\downarrow})}. \quad (3)$$

The first arrow corresponds to the helicity of the neutrino ($\downarrow$) or antineutrino ($\uparrow$), and the second - to the spin direction of the nucleon: $\uparrow$ ($P_N = +1$) and $\downarrow$ ($P_N = -1$).

Set cross sections (1) in (3) received

$$A^{h-\bar h}_{\nu,\bar\nu} = \frac{\left(\sigma^{pol}_{\nu,\bar\nu}\right)^{h-h}}{\left(\sigma^a_{\nu,\bar\nu}\right)^{h\ \bar h}}, \quad (4)$$

where

$$\left(\sigma^{pol}_{\nu,\bar\nu}\right)^{h\ \bar h} = \left(\sigma^{pol}_{\nu,\bar\nu}\right)^{h} - \left(\sigma^{pol}_{\nu,\bar\nu}\right)^{\bar h};$$

$$\left(\sigma^{a}_{\nu,\nu}\right)^{h-h} = \left(\sigma^{a}_{\nu,\bar\nu}\right)^{h} + \left(\sigma^{a}_{\nu,\bar\nu}\right)^{\bar h}. \quad (5)$$

Consider the deuteron target. In this case the cross sections are equal to the expressions

$$(\sigma^{pol}_{\nu(\nu)d})^h = \frac{(\sigma^{pol}_{\nu(\nu)p})^h + (\sigma^{pol}_{\nu(\bar\nu)n})^h}{2}(1 \quad 1.5\omega),$$

$$(\sigma^{a}_{\nu(\nu)d})^h - \frac{(\sigma^{a}_{\nu(\bar\nu)p})^h + (\sigma^{a}_{\nu(\bar\nu)n})^h}{2}. \quad (6)$$

where $\omega \cong 0.05$ is a probability of D-state of the wave function of the deuteron.

Then from (2), (4), (5), (6) and consider the equation for the π-meson function of fragmentati

$$D_{u,d}^{\pi^+-\pi^-} = -D_{u,\bar{d}}^{\pi^+-\pi^-}, D_{\bar{d}}^{\pi^+-\pi^-} = -D_{u}^{\pi^+-\pi^-},$$

for the semi-inclusive νd-DIS asymmetries can be obtained as follows

$$A_{\nu d}^{\pi^+-\pi^-} = \frac{(y_1^+ + y_1^- N)[\Delta u_V(x) + \Delta d_V(x)] + 2y_1^+[\Delta\bar{u}(x) + \Delta\bar{d}(x)]}{y_1^- Q(x) + y_1^+ N q_V(x)}(1 - 1.5\omega),$$

where $N = \frac{10}{3} sin^2\theta_w$, $Q(x) = u(x) + u(x) + d(x) + \bar{d}(x)$, $q_V(x) = u_V(x) + d_V(x)$.

Similarly by asymmetries for semi-inclusive antineutrino DIS on polarized deuterons we receiv

$$A_{\bar{\nu} d}^{\pi^+-\pi^-} = \frac{(y_1^+ - y_1^- N)[\Delta u_V(x) + \Delta d_V(x)] + 2y_1^- N[\Delta\bar{u}(x) + \Delta\bar{d}(x)]}{y_1^+ N Q(x) + y_1^- q_V(x)}(1 - 1.5\omega).$$

The obtained asymmetries not depend on the function of fragmentation.Asymmetries (7), (8) cont the function of distribution of the polarized quarks $\Delta q(x)$ and antiquarks $\Delta\bar{q}(x)$. The first pa distribution moments as follows

$$\Delta q(\Delta\bar{q}) = \int_0^1 \Delta q(x)(\Delta\bar{q}(x))dx,$$

which correspond to the quark q (antiquark $\bar{q}$) contribution to the spin of nucleon.

Therefore from observable asymmetries (7), (8) the quark contributions to the nucleon spin ca defined as

$\Delta u_V + \Delta d_V =$

$$= \int_0^1 \frac{N y_1^- \left[y_1^- Q(x) + y_1^+ N q_V(x)\right] A_{\nu d}^{\pi^+-\pi^-} - y_1^+ \left[y_1^+ N Q(x) + y_1^- q_V(x)\right] A_{\bar{\nu} d}^{\pi^+-\pi^-}}{(1 - 1.5\omega)\left(2N y_1^+ y_1^- + (N y_1^-)^2 + (y_1^+)^2\right)} dx,$$

$\Delta\bar{u} + \Delta\bar{d} =$

$$= \int_0^1 \frac{(N y_1^- + y_1^+) \left[y_1^+ Q(x) + y_1^- q_V(x)\right] A_{\bar{\nu} d}^{\pi^+-\pi^-} - (y_1^+ - y_1^- N) \left[y_1^+ N q_V(x) + y_1^- Q(x)\right] A_{\nu d}^{\pi^+-\pi^-}}{2(1 - 1.5\omega)\left(2N y_1^+ y_1^- + (N y_1^-)^2 + (y_1^+)^2\right)} d$$

The strange quark contribution can be determinate using the additional measured quantity - axial charge a_8

$$a_8 = (\Delta u_V + \Delta d_V) + 2(\Delta u + \Delta\bar{d}) - 2(\Delta s + \Delta s).$$

Then ,using (9), (10), (11) the strange quark contributions is

$$\Delta s + \Delta\bar{s} = \frac{1}{2}\left(\left[\Delta u_V + \Delta d_V\right] + 2\left[\Delta\bar{u} + \Delta\bar{d}\right] - a_8\right).$$

3. Conclusion

1. Polarizing asymmetries $A_{\nu,\bar{\nu}}^{\pi^+-\pi^-}$ of $\nu(\bar{\nu})$- DIS with neutral current on the deuteron targets was received independent of functions of fragmentation.

2. The valence quark $(\Delta u_V + \Delta d_V)$, antiquarks $(\Delta\bar{u} + \Delta\bar{d})$ contribution to the nucleon spin is obtained from measurable asymmetries $A_{\nu(\bar{\nu})d}^{\pi^+-\pi^-}$. Using of the additional measurable quantity allows to receive information about strange quarks contribution $(\Delta s + \Delta\bar{s})$.

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