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The Spin Structure of Nucleon from Inclusive and Semi-Inclusive Neutrino DIS

E.S.Timoshin, S.I.Timoshin
Gomel State Technical University
Gomel State University

The spin structure of nucleon have been considered in context future neutrino DIS polarization experiments.

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1. Introduction

The experiments COMPASS and HERMES give for the total contributions of the quarks and antiquarks to the nucleon spin values 0.35 and 0.33 respectively [1] - [3].The contribution of the valence quarks are 0.40 [4]. Most experimental data show, that the polarization of strange quarks is negative -8-10%. However not exclude, that it consistent with zero [5] or have positive value [6]. The results of COMPASS [4] and analysis [7] indicate on asymmetry quark sea. The measurements of the gluon polarisation are going in experiments COMPASS, HERMES, at pp-collider RHIC. Their results exclude large positive value of gluon polarization how this have been propose earlier.

For final solution problem the nucleon spin necessary further investigations the spin structure of nucleon.

The deep inelastic scattering (DIS) neutrino on polarized targets presents the interest for a study of nucleon spin.

In present paper a approach for determination the contributions quark flavors (u,d,s) to the nucleon spin from measurable quantities $\nu(\bar\nu)N$-DIS with charged weak current has been supposed. Also an possibility determination polarization of the strange quarks from analysis inclusive and semi-inclusive neutrino DIS.

2. The contributions quark flavours in nucleon spin

The observable asymmetries inclusive $\nu(\bar\nu)N$-DIS with the charged weak current [8]are

$$A_{\nu,\bar\nu} = \frac{2x(y_1^+ g_6^{\nu,\bar\nu} \pm y_1^- g_1^{\nu,\bar\nu})}{y_1^+ F_2^{\nu,\bar\nu} \pm y_1^- xF_3^{\nu,\bar\nu}} \tag{1}$$

where

$F_{2,3}$ and $g_{1,6}$ are the structure functions (SF) of nucleon, $y_1^\pm = 1 \pm y_1^2$; $y_1 = 1-y$; x and y are the scaling variables.

In kinematic region small y, which are achieved new in experiments, SF g_6 will domain so value y_1^- is small.

Therefore the contribution SF g_1 can to neglect and from (1) we obtain directly SF $g_6^{\nu,\bar\nu}$ at certain $F_2^{\nu,\bar\nu}$ and $F_3^{\nu,\bar\nu}$.

In quark-parton model (QPM) SF $g_6^{\nu,\bar\nu}$ [8] are

$$g_6^{\nu,\bar\nu}(x) = \sum_q \Delta q(x) - \sum_{\bar q} \Delta\bar q(x), \tag{2}$$

where $q = d,s,b$ $(q = u,c,t)$ and $\bar q = \bar u,\bar c,\bar t$ $(\bar q = \bar d,\bar s,\bar b)$ for neutrino (antineutrino).

For DIS (anti)neutrino on polarized protons the first moments SF g_6 , i.e. $\Gamma_6^{\nu,\nu} = \int\limits_0^1 g_6^{\nu,\bar{\nu}}(x)dx$, are equal

$$\Gamma_6^{\nu p} = \Delta d + \Delta s - \Delta\bar{u}, \Gamma_6^{\nu p} = \Delta u - \Delta\bar{d} - \Delta\bar{s}. \tag{3}$$

Combining (3) have

$$\Gamma_6^{\nu p} + \Gamma_6^{\bar{\nu}p} = \Delta u_V + \Delta d_V, \tag{4}$$

$$\Gamma_6^{\nu p} - \Gamma_6^{\bar{\nu}p} = -(\Delta u + \Delta\bar{u}) + (\Delta d + \Delta d) + (\Delta s + \Delta\bar{s}). \tag{5}$$

The expression (4) is the contribution the valence quarks to the nucleon spin. From (5) and the measurable quantities

$$a_3 = (\Delta u + \Delta u) - (\Delta d + \Delta\bar{d}),$$

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

can to express the contributions quark flavours $(\Delta u + \Delta u)$, $(\Delta d + \Delta\bar{d})$, $(\Delta s + \Delta\bar{s})$.

In case deuteron target can to obtain the valence quarks contributions

$$\Delta u_V + \Delta d_V - \frac{\Gamma_6^{\nu d} + \Gamma_6^{\bar{\nu}d}}{1 - 1.5\omega} \tag{6}$$

and the strange quarks in nucleon spin

$$\Delta s + \Delta\bar{s} = \frac{\Gamma_6^{\nu d} - \Gamma_6^{\bar{\nu}d}}{1 - 1.5\omega}, \tag{7}$$

where

$\omega \simeq 0.05$ is the probability D-state in deuteron wave function.

The contribution of strange quarks is expressed here only through observable quantities $\nu(\bar{\nu})d$-DIS.

3. The analysis of inclusive and semi-inclusive $\nu(\bar{\nu})N$-DIS

The asymmetrics (1) written in form

$$A_{\nu,\bar{\nu}} = \frac{\sigma_0 x(y_1^+ g_6^{\nu,\nu} \pm y_1^- g_1^{\nu,\bar{\nu}})}{\sigma_{\nu,\bar{\nu}}^a}, \tag{8}$$

where $\sigma_{\nu,\nu}^a$ are unpolarized cross sections; $\sigma_0 - G^2ME/\pi$, G is Fermi constant, M is mass of nucleon, E is energy incoming neutrino (antineutrino).

In QPM the SF $g_1^{\nu,\bar{\nu}}$ [8] are

$$g_1^{\nu,\bar{\nu}}(x) = \sum_q \Delta q(x) + \sum_{\bar{q}} \Delta\bar{q}(x). \tag{9}$$

For proton target from (2), (8),(9) obtain

$$[\Delta d(x) - y_1^2 \Delta u(x)] + \Delta s(x) = \frac{A_{\nu p}\sigma^a_{\nu p}}{2\sigma_0 x},$$

(10)

$$[y_1^2 \Delta u(x) - \Delta\bar{d}(x)] - \Delta\bar{s}(x) = \frac{A_{\bar{\nu} p}\sigma^a_{\bar{\nu} p}}{2\sigma_0 x}.$$

The polarization asymmetries semi-inclusive $\nu(\bar{\nu})p$-DIS for production π-mesons independing from fragmentation functions have been obtained in [9]

$$A^{\pi^+ - \pi^-}_{\nu p} = \frac{\Delta d(x) - y_1^2 \Delta u(x)}{d(x) + y_1^2 \bar{u}(x)},$$

(11)

$$A^{\pi^+ - \pi^-}_{\bar{\nu} p} = \frac{y_1^2 \Delta u(x) - \Delta d(x)}{y_1^2 u(x) + \bar{d}(x)}.$$

Then from (10), (11) we extract the contributions of strange quarks and antiquarks only through observable quantities of neutrino processes

$$\Delta s = \int_0^1 \left[\frac{A_{\nu p}\sigma^a_{\nu p}}{2\sigma_0 x} - \Big(d(x) + y_1^2 u(x)\Big) A^{\pi^+ - \pi^-}_{\nu p}\right] dx,$$

(12)

$$\Delta\bar{s} = \int_0^1 \left[\Big(y_1^2 u(x) + \bar{d}(x)\Big) A^{\pi^+ - \pi^-}_{\bar{\nu} p} - \frac{A_{\bar{\nu} p}\sigma^a_{\bar{\nu} p}}{2\sigma_0 x}\right] dx.$$

Now we consider the deuteron target. In this case for inclusive processes $\nu(\bar{\nu})d$-DIS [8] obtain

$$\Delta u_V(x) + \Delta d_V(x) + \Big[\Delta s(x) + \Delta s(x)\Big] + y_1^{-}\Big[\Delta\bar{u}(x) + \Delta d(x)\Big] = \frac{A_{\nu d}\sigma^a_{\nu d}}{\sigma_0 x(1 - 1.5\omega)},$$

(13)

$$y_1^2\Big[\Delta u_V(x) + \Delta d_V(x)\Big] + \Big[\Delta s(x) + \Delta s(x)\Big] - y_1^{-}\Big[\Delta\bar{u}(x) + \Delta d(x)\Big] = \frac{A_{\bar{\nu} d}\sigma^a_{\bar{\nu} d}}{\sigma_0 x(1 - 1.5\omega)}$$

and semi-inclusive DIS [9]

$$\Delta u_V(x) + \Delta d_V(x) + y_1\Big[\Delta\bar{u}(x) + \Delta\bar{d}(x)\Big] = \frac{A^{\pi^+ - \pi^-}_{\nu d}}{1 - 1.5\omega}\Big[u_V(x) + d_V(x) + y_1^{\prime}\Big(u(x) + d(x)\Big)\Big],$$

(14)

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

$$+y_1^+\Big(\bar{u}(x)+\bar{d}(x)\Big)\Bigg],$$

The joint use (13) and (14) allows to express $(\Delta s+\Delta\bar{s})$ with help only the observable quantities of processes DIS neutrino

$$\Delta s+\Delta\bar{s}(x)=\frac{1}{1-1.5\omega}\int\limits_0^1\left[\frac{A_{\nu d}\sigma^a_{\nu d}}{\sigma_0 x}-A_{\nu d}^{\pi^+\ \pi^-}\Big(u_V(x)+d_V(x)+y_1^+(\bar{u}(x)+\bar{d}(x))\Big)\right]dx$$

and antineutrino

$$\Delta s+\Delta\bar{s}(x)=\frac{1}{1-1.5\omega}\int\limits_0^1\left[\frac{A_{\nu d}\sigma^a_{\nu d}}{\sigma_0 x}-A_{\bar{\nu}d}^{\pi^+-\pi^-}\Big(y_1^2(u_V(x)+d_V(x))+y_1^+(\bar{u}(x)+\bar{d}(x))\Big)\right]dx.$$

4. Conclusion

1. The SF $g_6^{\nu,\bar{\nu}}$ dominates in kinematic region small y. Here these SF can to extract directly from measurable asymmetries $A_{\nu,\bar{\nu}}$ of (anti)neutrino DIS on polarized targets with charged weak current.

2. The contributions of valence quarks and quark flavours have been expressed through $\Gamma_6^{\nu p}$, $\Gamma_6^{\bar{\nu}p}$, a_3, a_8. In case deuteron target $(\Delta u_V+\Delta d_V)$, $(\Delta s+\Delta\bar{s})$ have been obtained only through $\Gamma_6^{\nu p}$ and $\Gamma_6^{\bar{\nu}p}$.

3. The joint analysis the observable quantities of inclusive and semi-inclusive neutrino DIS allows to obtain the information about the polarization of strange quarks and antiquarks one additional data.

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