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The nucleon spin in deep inelastic lepton-nucleon scattering with neutral current

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The spin structure of nucleon in the processes deep inelastic scattering leptons on polarized nucleons with neutral current have been investigated.

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In present time is known that only about 30% of the nucleon spin is accounted by quarks and antiquarks. The quark contribution is dominated by the valence component [1, 2]. The polarization of strange quarks and antiquarks in the nucleon is not well known at present [3–6].

In present report we propose to use a measurable quantities of lN-DIS with neutral current (γ, Z *exchange*) for the extraction data about the contributions the quark flavors (u, d, s) in nucleon spin.

The cross sections of the inclusive DIS unpolarized leptons on polarized nucleons

$$l + N \overset{\gamma, Z}{\rightarrow} l + X \tag{1}$$

in Born approximation are

$$\sigma_{l^-, l^+} = \frac{4\pi\alpha^2 s}{Q^4}\left[\frac{y^+}{2}F_{2s} \mp \frac{y^-}{2}xF_{3s} + P_N x\left(y^+ g_{6s} \mp y^- g_{1s}\right)\right]. \tag{2}$$

Here $\sigma = d^2\sigma/dxdy$, $Q^2 = -q^2 = -(k-k')^2$, $s = 2pk$, $y^{\pm} = 1 \pm (1-y)^2$, $x = \frac{Q^2}{2p\cdot q}$, $y = \frac{p\cdot q}{p\cdot k}$, $k(k')$, p – 4 – momentum incoming (outcoming) lepton and nucleon respectively; P_N is the degree of the longitudinal polarization of nucleon; $F_{2s,3s}$ and $g_{1s,6s}$ are spin-average and spin-dependent structure functions (SF) of nucleon.

These SF give following expressions:

$$\begin{aligned} F_{2s} &= F_2^{\gamma} + \eta_{\gamma Z} g_V F_2^{\gamma Z} + \eta_Z (g_V^2 + g_A^2) F_2^Z, \\ F_{3s} &= -\eta_{\gamma Z} g_A F_3^{\gamma Z} - 2\eta_Z g_V g_A F_3^Z, \\ g_{1s} &= -\eta_{\gamma Z} g_A g_1^{\gamma Z} - 2\eta_Z g_V g_A g_1^Z, \\ g_{6s} &= \eta_{\gamma Z} g_V g_6^{\gamma Z} + \eta_Z (g_V^2 + g_A^2) g_6^Z. \end{aligned} \tag{3}$$

In (3) are
$\eta_{\gamma Z} = \frac{G m_Z^2}{2\sqrt{2}\pi\alpha} \cdot \frac{Q^2}{Q^2 + m_Z^2}$, $\eta_Z = \eta_{\gamma Z}^2$,
G is Fermi constant, m_Z is mass of Z-bozon; $g_V = -\frac{1}{2} + 2\sin^2\theta_W$, $g_A = -\frac{1}{2}$, θ_W is Weinberg angle. The expression for $F_2^{\gamma, \gamma Z, Z}$, $F_3^{\gamma Z, Z}$, $g_{1,6}^{\gamma Z, Z}$ are in [7].

The single spin asymmetries determine as following the combinations of the cross sections (2):

$$A^s_{l^-,l^+} = \frac{\sigma^{\uparrow}_{l^-,l^+} - \sigma^{\downarrow}_{l^-,l^+}}{\sigma^{\uparrow}_{l^-,l^+} + \sigma^{\downarrow}_{l^-,l^+}}, \tag{4}$$

where $\uparrow$ $(P_N = +1)$ and $\downarrow$ $(P_N = -1)$.
With help (2) from (4) obtain

$$A^s_{l^-,l^+} = \frac{2x\left(y^+ g_{6s} \mp y^- g_{1s}\right)}{y^+ F_{2s} \mp y^- x F_{3s}}. \tag{5}$$

From expressions (5) can to extract SF g_{1s} and g_{6s} through the single spin asymmetries $A^s_{l^-}$, $A^s_{l^+}$

$$\begin{aligned} g_{1s} &= \frac{1}{4xy^-}\Big[(A^s_{l^+} - A^s_{l^-})y^+ F_{2s} + (A^s_{l^+} + A^s_{l^-})y^- x F_{3s}\Big], \\ g_{6s} &= \frac{1}{4xy^+}\Big[(A^s_{l^+} + A^s_{l^-})y^+ F_{2s} + (A^s_{l^+} - A^s_{l^-})y^- x F_{3s}\Big]. \end{aligned} \tag{6}$$

For SF g_{1s} (3) in the quark-parton model (QPM) for case scattering on proton we obtain

$$g^p_{1s} = -a_u\big[\Delta u(x) + \Delta\overline{u}(x)\big] + a_d\Big[\big(\Delta d(x) + \Delta\overline{d}(x)\big) + \big(\Delta s(x) + \Delta\overline{s}(x)\big)\Big], \tag{7}$$

where

$$\begin{aligned} a_u &= \frac{2}{3} g_A \eta_{\gamma Z} g_{V,u} - g_V g_A \eta_Z \left(g^2_{V,u} + g^2_{A,u}\right), \\ a_d &= \frac{1}{3} g_A \eta_{\gamma Z} g_{V,d} - g_V g_A \eta_Z \left(g^2_{V,d} + g^2_{A,d}\right), \\ g_{V,u} &= \frac{1}{2} - \frac{4}{3}\sin^2\theta_W, \quad g_{A,u} = \frac{1}{2}, \\ g_{V,d} &= -\frac{1}{2} + \frac{2}{3}\sin^2\theta_W, \quad g_{A,d} = -\frac{1}{2}. \end{aligned}$$

The first moment SF g^p_{1s} is

$$\Gamma^p_{1s} = \int_0^1 g^p_{1s} dx = -a_u(\Delta u + \Delta\overline{u}) + a_d\big[(\Delta d + \Delta\overline{d}) + (\Delta s + \Delta\overline{s})\big], \tag{8}$$

where
$\Delta q(\Delta\overline{q}) = \int_0^1 \Delta q(x)\big(\Delta\overline{q}(x)\big)dx$ is the contribution quark q (antiquark $\overline{q}$) in nucleon spin.

For determination from (8) the contributions quark flavors (u, d, s) are necessary a complementary measurable quantities. For this goal can to use isovector axial charge a_3 ($a_3 = 1,2695 \pm 0,0029$) and octet axial charge a_8 ($a_8 = 0,585 \pm 0,025$) that have measure in neutron and hyperon β decay respectively. These measurable quantities in QPM are

$$\begin{aligned} a_3 &= (\Delta u + \Delta\overline{u}) - (\Delta d + \Delta\overline{d}), \\ a_8 &= (\Delta u + \Delta\overline{u}) + (\Delta d + \Delta\overline{d}) - 2(\Delta s + \Delta\overline{s}). \end{aligned} \tag{9}$$

Therefore from (8) and (9) obtain the contributions the quark flavors (u, d, s) in spin of nucleon

$$\begin{aligned} \Delta u+\Delta\overline{u} &= \frac{2\Gamma^p_{1s}+a_d(3a_3+a_8)}{2(2a_d-a_u)},\\ \Delta d+\Delta\overline{d} &= \frac{2\Gamma^p_{1s}+2a_ua_3+a_d(a_8-a_3)}{2(2a_d-a_u)},\\ \Delta s+\Delta\overline{s} &= \frac{2\Gamma^p_{1s}+a_u(a_8+a_3)-a_d(a_8-a_3)}{2(2a_d-a_u)}. \end{aligned} \tag{10}$$

Now consider the second SF g_{6s}. In QPM for g^p_{6s} obtain

$$g^p_{6s}=b_u\Delta u_V(x)+b_d\Delta d_V(x), \tag{11}$$

where

$$\begin{aligned} b_u &= \frac{2}{3}g_V\eta_\gamma z g_{A,u}+(g_V^2+g_A^2)\eta z g_{V,u}g_{A,u},\\ b_d &= -\frac{1}{3}g_V\eta_\gamma z g_{A,d}+(g_V^2+g_A^2)\eta z g_{V,d}g_{A,d};\\ \Delta q_V(x) &= \Delta q(x)-\Delta\overline{q}(x) \quad (q=u,d) \end{aligned}$$

is the distributions of valence quarks.

The first moment SF g^p_{6s} is

$$\Gamma^p_{6s}=\int\limits_0^1 g^p_{6s}dx=b_u\Delta u_V+b_d\Delta d_V, \tag{12}$$

where $q_V=\int\limits_0^1\Delta q_V(x)dx$; $q=u,d$ respective the contributions the valence quarks in nucleon spin.

Obviously the extraction Δu_V and Δd_V from (12) is possible by presence still one any correlation between them.

Thus the contributions the quark flavors $(\Delta u+\Delta\overline{u})$, $(\Delta d+\Delta\tilde{d})$, $(\Delta s+\Delta\overline{s})$ obtained through the first moment Γ^p_{1s} SF g^p_{1s} of DIS unpolarized leptons on longitudinal polarized protons with neutral current in electroweak theory.

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