An investigation of the proton spin in deep inelastic scattering induced by charged current

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The cross sections of virtual W-boson absorbtion by polarized nucleon are calculated. The virtual W-boson-nucleon asymmetries $A_1(x)$ and $A_6(x)$ are obtained. The possibilities to extract the information about the nucleon spin structure are discussed for the polarized deep inelastic scattering (DIS) of neutrino and electrons on nucleons.

In order to study nucleon spin stucture it has been recently proposed [1] to use the processes of neutrino DIS on polarized nucleons. The analysis of the possible polarization effects was performed using a set of observable quantities. In particular several schemes for determination of quark flavors contributions to the nucleon spin were proposed.

In this paper the other approach is considered to investigate nucleon spin in reactions of DIS induced by charged current

$$\overset{(-)}{\nu} + N \to l^{(\pm)} + X, \tag{1}$$

$$l^{(\pm)} + N \to \overset{(-)}{\nu} + X. \tag{2}$$

The total cross section of virtual W-boson absorption by polarized nucleon has been calculated. The cross sections $\sigma_{1/2(3/2)}$ and $\sigma_{-1/2(-3/2)}$ (the total angular momentum of W-boson-nucleon system is $\pm 1/2$ and $\pm 3/2$ respectively) are in the scaling limit only. They are

$$\sigma_{1/2(3/2)} \sim F_1(x) - F_3(x)/2 \pm g_1(x) \mp g_6(x),$$

$$\sigma_{-1/2(-3/2)} \sim F_1(x) + F_3(x)/2 \pm g_1(x) \pm g_6(x). \tag{3}$$

With formulae (3) we can obtain two virtual W-boson-nucleon polarization asymmetries

$$A_1(x) = \frac{(\sigma_{1/2} + \sigma_{-1/2}) - (\sigma_{3/2} + \sigma_{-3/2})}{(\sigma_{1/2} + \sigma_{-1/2}) + (\sigma_{3/2} + \sigma_{-3/2})} = \frac{2xg_1(x)}{F_2(x)}, \tag{4}$$

$$A_6(x) = \frac{(\sigma_{1/2} - \sigma_{-1/2}) - (\sigma_{3/2} - \sigma_{-3/2})}{(\sigma_{1/2} - \sigma_{-1/2}) + (\sigma_{3/2} - \sigma_{-3/2})} = \frac{2xg_6(x)}{xF_3(x)}. \tag{5}$$

For the process (1) the observable asymmetries $A_{\nu,\bar{\nu}}(x,y)$ [1] can be expressed through the asymmetries (4),(5)

$$A_{\nu,\bar{\nu}}(x,y) = \frac{y_1^+ A_6^{\nu,\bar{\nu}}(x) F_3^{\nu,\bar{\nu}}(x) \pm y_1^- A_1^{\nu,\bar{\nu}}(x) F_2^{\nu,\bar{\nu}}(x)}{y_1^+ F_2^{\nu,\bar{\nu}}(x) \pm y_1^- F_3^{\nu,\bar{\nu}}(x)}, \tag{6}$$

where x and y are the usual scaling variables, $y_1 = 1 - y$, $y_1^{\pm} = 1 \pm y_1^2$.

Within quark parton model (QPM) $g_{1,6}^{\nu,\bar{\nu}}(x)$ are obtained in the form

$$g_{1,6}^{\nu,\bar{\nu}}(x) = \sum_{q_i} \Delta q_i(x) \pm \sum_{\bar{q}_i} \Delta \bar{q}_i(x). \tag{7}$$

Here $q_i = (u,c,t)d,s,b$ and $\bar{q}_i = (\bar{d},\bar{s},\bar{b})\bar{u},\bar{c},\bar{t}$ in the case of (anti)neutrino scattering.

Consider the deutron polarized targed. Then

$$g_1^{\nu d}(x) = g_1^{\bar{\nu} d}(x) = 1/2[\Delta q(x) + \Delta \bar{q}(x)](1 - 3/2\omega_D) \tag{8}$$

and for the processes of leptoproduction we have

$$18/5 g_1^d(x) = [1/2(\Delta q(x) + \Delta \bar{q}(x)) - 3/5\Delta s(x)](1 - 3/2\omega_D), \tag{9}$$

where $\Delta q(x) = \Delta u(x) + \Delta d(x) + \Delta s(x)$, $\omega_D = 0.05$ is the D-wave state probability of the deuteron. Comparing (8) and (9), we obtain approximate equality

$$g_1^d(x) \approx 5/18 g_1^{\bar{\nu} d}(x), \tag{10}$$

and in a similar way to unpolarized case [2]

$$F_2^d(x) \approx 5/18 F_2^{\nu d}(x). \tag{11}$$

Therefore using (4), (10) and (11), we come to the conclusion that

$$A_1^{\overset{(-)}{\nu} d}(x) \approx A_1^d(x), \tag{12}$$

where $A_1^d(x)$ is virtual asymmetry of leptoproduction.

Now consider the other spin-dependent structure functions (SSF) $g_6(x)$. From (7) we obtain

$$g_6^{\nu d,\bar{\nu} d} = 1/2[\Delta q(x) - \Delta \bar{q}(x) \pm (\Delta s(x) + \Delta \bar{s}(x))](1 - 3/2\omega_D) \tag{13}$$

$$g_6^{\nu d} + g_6^{\bar{\nu} d} = [\Delta q(x) - \Delta \bar{q}(x)](1 - 3/2\omega_D) \equiv [\Delta q_{val}(x)(1 - 3/2\omega_D)$$

$$g_6^{\nu d} - g_6^{\bar{\nu} d} = [\Delta s(x) - \Delta \bar{s}(x)](1 - 3/2\omega_D). \tag{14}$$

When expressions (14) are integrated over x, the contributions of valence (Δq_{val}) and strange quarks to the nucleon spin are given by

$$\Delta q_{val} = (\Gamma_6^{\nu d} + \Gamma_6^{\bar{\nu} d}) \frac{1}{1 - 3/2\omega_D}, \tag{15}$$

$$\Delta s + \Delta \bar{s} = 1/2(\Gamma_6^{\nu d} - \Gamma_6^{\bar{\nu} d}) \frac{1}{1 - 3/2\omega_D}, \tag{16}$$

where $\Gamma_j = \int_0^1 g_j(x) dx$.

The individual contributions of u and d quarks can be obtained if some additional measurable quantity is used, e.g. $a_3 = g_A/g_V = F + D = 1.2573$ [3]. Within QPM

$$a_3 = (\Delta u + \Delta \bar{u})(\Delta d + \Delta \bar{d}). \tag{17}$$

Since $\Delta q + \Delta \bar{q} = 36/5 \frac{2\Gamma_1^d}{1-3/2\omega_D}$, then from (16),(17) we have

$$\Delta u + \Delta \bar{u} = 1/2[(36/5\Gamma_1^d - \Gamma_6^{\nu d} + \Gamma_6^{\bar{\nu} d})(1 - 3/2\omega_D) + a_3],$$
$$\Delta d + \Delta \bar{d} = 1/2[(36/5\Gamma_1^d - \Gamma_6^{\nu d} + \Gamma_6^{\bar{\nu} d})(1 - 3/2\omega_D) - a_3]. \tag{18}$$

The SSF $g_6^{\nu d, \bar{\nu} d}(x)$ can be found using (5),(6) and taking into account (12).

Now let us discuss briefly the process (2). All results obtained above for the reactions (1) are the same as for the process (2) with the substitution

$$F_i^{\bar{\nu}}, g_i^{\bar{\nu}} \to F_i^{e^-} g_i^{e^-}; \quad F_i^{\nu}, g_i^{\nu} \to F_i^{e^+} g_i^{e^+}.$$

Then the asymmetries of processes (1) and (2) are correlated

$$A_{\nu,\bar{\nu}}(x,y) = A_{e^+,e^-}(x,y); \quad A_{1,6}^{\nu,\bar{\nu}}(x) = A_{1,6}^{e^+,e^-}(x).$$

Thus, in this paper the spin effects are considered in polarization DIS (1) and (2) induced by charged current. The cross section of virtual W-boson absorption by polarized nucleon is calculated. The asymmetries $A_1(x)$ and $A_6(x)$ are obtained. The way to estimate the contributions of valence and individual quarks to the proton spin is suggested.

References

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