The Spin Structure of Proton in Electroweak Model

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1 Introduction

The spin of nucleon can to expess about a contributions its constituents

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta g + L_q + L_g,$$

where $\Delta\Sigma$ and Δg are the contributions polarization quarks and gluons respectively;L_q,L_g are the orbital angular moments quarks and gluons (see [1, 2]) for recent reviews).

The last data COMPASS [1] and HERMES [3] give for $\Delta\Sigma$ values 0.35 and 0.33, i.e. the total contributions of the quarks is regarding small. The polarization of the strange quarks from COMPASS [4] is order - 8%. However recent measurements HERMES [5] indicate that it consistent with zero.

The measurements the gluon polarization Δg are going now in experiments COMPASS, HERMES, PHENIX and STAR. Their results have until obvious character about value Δg. However data these experiments now disfavor a large positive value of the gluon polarization in the proton [6, 7, 8, 9].

The determination the magnitude of the orbital angular moments L_q,L_g is possible in exclusive processes, i.g. by measurements in the deep virtual Compton scattering.

For solution problem of the nucleon spin are require further precision measurements all his components.

In present talk we propose an approach for the determination the quark contributions in proton spin in deep inelastic scattering (DIS) polarized electrons or positrons on polarized protons

$$e^{\pm} + P \to e^{\pm} + X \tag{1}$$

in electroweak model, i. e. together with the contribution neutral weak current.

A such analysis can to done in $e^{\pm}P$ polarized DIS, which might be done at HERA (DESY) in the future [10].

2 The polarized *ep*-DIS in electroweak model

The cross sections of processes (1) were obtained in form

$$\sigma = \frac{4\pi\alpha^2 xS}{Q^4}\left[y^+F_1 - \frac{1}{2}P_e y^- F_3 + P_N(y^+ g_5 - P_e y^- g_1)\right]. \tag{2}$$

Here

$$\sigma = \frac{d^2\sigma}{dxdy},\ Q^2 = -q^2 = -(k-k_1)^2,\ x = \frac{Q^2}{2P\cdot q},$$

$$y = \frac{P\cdot q}{P\cdot k},\ S = 2P\cdot k,\ y^{\pm} = 1 \pm (1-y)^2,$$

$k(k_1)$ and P are the 4-momentums of incoming (outcoming) lepton and proton respectively, $P_e = -1(+1)$ for electron and proton (positron),P_N is degree longitudinal polarization of proton.

The F_1 ,F_3 and g_1 ,g_5 are unpolarized and polarized structure functions (SF) of proton

$$\begin{aligned} F_1 &= F_1^{\gamma} + \eta_{\gamma Z}F_1^{\gamma Z} + \eta_Z F_1^Z, \\ F_3 &= \eta_{\gamma Z}F_3^{\gamma Z} + \eta_Z F_3^Z, \\ g_1 &= g_1^{\gamma} + \eta_{\gamma Z}g_1^{\gamma Z} + \eta_Z g_1^Z, \\ g_5 &= \eta_{\gamma Z}g_5^{\gamma Z} + \eta_Z g_5^Z, \end{aligned} \tag{3}$$

where

$$\eta_{\gamma Z} = \frac{Gm_Z^2(g_V + g_A)}{2\sqrt{2}\pi\alpha}\frac{Q^2}{Q^2+m_Z^2},\ \eta_Z = \eta_{\gamma Z}^2,$$

G is Fermi constant, m_Z is mass of Z-bozon.

The $g_V = I_{3q} - 2e_q^2 sin^2\theta_w$ and $g_A = I_{3q}$ are the vector and the axial vector coupling constants respectively. In these quantities

$$I_{3q} = \begin{cases} \frac{1}{2} & for\ q = u,c,t, \\ -\frac{1}{2} & for\ q = d,s,b, \end{cases}$$

e_q is the charge of quark, θ_w is Weinberg angle.

For the SF obtained the following expressions in the quark - parton model (QPM) [11]:

$$F_1^Z(x) = \frac{1}{2}\sum_q (g_V^2 + g_A^2)_q[q(x) + \bar{q}(x)],$$

$$F_3^Z(x) = 2\sum_q (g_V^2 g_A^2)_q[q(x) - \bar{q}(x)],$$

$$g_1^Z(x) = \frac{1}{2}\sum_q (g_V^2 + g_A^2)_q[\Delta q(x) + \Delta\bar{q}(x)],$$

$$g_5^Z(x) = \sum_q (g_V g_A)_q[\Delta q(x) - \Delta\bar{q}(x)],$$

$$F_1^{\gamma Z}(x) = \sum_q e_q(g_V)_q[q(x) + \bar{q}(x)], \tag{4}$$

$$F_3^{\gamma Z}(x) = 2\sum_q e_q(g_A)_q[q(x) - \bar{q}(x)],$$

$$g_1^{\gamma Z}(x) = \sum_q e_q(g_V)_q[\Delta q(x) + \Delta\bar{q}(x)],$$

$$g_5^{\gamma Z}(x) = \sum_q e_q(g_A)_q[\Delta q(x) - \Delta\bar{q}(x)],$$

$$F_1^{\gamma}(x) = \frac{1}{2}\sum_q e_q^2[q(x) + \bar{q}(x)],$$

$$g_1^{\gamma}(x) = \frac{1}{2}\sum_q e_q^2[\Delta q(x) + \Delta\bar{q}(x)].$$

The polarization asymmetries are the following combinations of cross sections (2):

$$A_\pm = \frac{(\sigma^{\downarrow\uparrow} \pm \sigma^{\uparrow\uparrow}) - (\sigma^{\downarrow\downarrow} \pm \sigma^{\uparrow\downarrow})}{(\sigma^{\downarrow\uparrow} \pm \sigma^{\uparrow\uparrow}) + (\sigma^{\downarrow\downarrow} \pm \sigma^{\uparrow\downarrow})}, \quad A_{e^-,e^+} = \frac{\sigma^{\downarrow\uparrow,\uparrow\uparrow} - \sigma^{\downarrow\downarrow,\uparrow\downarrow}}{\sigma^{\downarrow\uparrow,\uparrow\uparrow} + \sigma^{\downarrow\downarrow,\uparrow\downarrow}}. \tag{5}$$

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

The asymmetries (5) in terms of SF are

$$A_{e^-,e^+} = \frac{y^+ g_5 \pm y^- g_1}{y^+ F_1 \pm \frac{y^-}{2} F_3}, \; A_+ = \frac{g_5}{F_1}, \; A_- = \frac{2g_1}{F_3}. \qquad (6)$$

With help the asymmetries (5), (6) can to obtain the polarized SF g_1 and g_5 as the data for SF F_1 ,F_3 are know from unpolarized experiments at HERA.

3 The spin structure of proton

An analysis the spin structure of proton we carry in the approach with the first moments of polarized SF g_1,g_5 :

$$\Gamma_{1,5} = \int_0^1 g_{1,5}(x)dx.$$

From (3),(4) for these moments we obtain restricting the three flavors (u,d,s)

$$\Gamma_1 = a_u(\Delta u + \Delta \bar{u}) + a_d[(\Delta d + \Delta \bar{d}) + (\Delta s + \Delta \bar{s}], \qquad (7)$$

$$\Gamma_5 = b_u \Delta u_V + b_d \Delta d_V. \qquad (8)$$

Here

$$a_u = \frac{2}{9} + \frac{2}{3}\eta_{\gamma Z} g_{V,u} + \frac{1}{2}\eta_Z (g_V^2 + g_A^2)_u,$$

$$a_d = \frac{1}{18} - \frac{1}{3}\eta_{\gamma Z} g_{V(d,s)} + \frac{1}{2}\eta_Z (g_V^2 + g_A^2)_{d,s},$$

$$b_u = \frac{2}{3}\eta_{\gamma Z} g_{A,u} + \eta_Z (g_V g_A)_u,$$

$$b_d = -\frac{1}{3}\eta_{\gamma Z} g_{A,d} + \eta_Z (g_V g_A)_d,$$

$$g_{V,u} = \frac{1}{2} - \frac{4}{3}\sin^2\theta_w, \; g_{A,u} = \frac{1}{2},$$

$$g_{V(d,s)} = -\frac{1}{2} + \frac{2}{3}\sin^2\theta_w, \; g_{A(d,s)} = -\frac{1}{2},$$

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

$$\Delta u_V = \Delta u - \Delta\bar{u},\ \Delta d_V = \Delta d - \Delta\bar{d}.$$

For determination from (7) the contributions the individual quark flavors can to use the isovector axial charge $a_3(a_3 = 1.2695 \pm 0.0029)$ and the octet axial charge $a_8(a_8 = 0.585 \pm 0.025)$, that are measured in neutron and hyperon beta-decays respectively. These measurable quantities in QPM are

$$a_3 = (\Delta u + \Delta\bar{u}) - (\Delta d + \Delta\bar{d}), \tag{9}$$

$$a_8 = (\Delta u + \Delta\bar{u}) + (\Delta d + \Delta\bar{d}) - 2(\Delta s + \Delta\bar{s}). \tag{10}$$

Then from these expressions and (7) obtain the contributions u, d, s flavours in proton spin

$$\Delta u + \Delta\bar{u} = \frac{\frac{2\Gamma_1}{a_d} + a_8 + 3a_3}{2(a_u + 2a_d)},$$

$$\Delta d + \Delta\bar{d} = \frac{2\Gamma_1 - 2a_u + a_d(a_8 - a_3)}{2(a_u + 2a_d)}, \tag{11}$$

$$\Delta s + \Delta\bar{s} = \frac{\left(1 - \frac{a_8}{a_3}\right) a_u + a_d - 2a_u + \frac{2\Gamma_1}{a_3}}{2(a_u + 2a_d)}.$$

The data HERMES [12] rather favour a symmetric sea $\Delta\bar{u} = \Delta\bar{d}$. In this case

$$a_3 = \Delta u_V - \Delta d_V. \tag{12}$$

Therefore from (8) and (12) we obtain separately the contributions of the valence quarks

$$\Delta u_V = \frac{\Gamma_5 + b_d a_3}{b_u + b_d},$$

$$\Delta d_V = \frac{\Gamma_5 - b_u a_3}{b_u + b_d}.$$

So, the quark contributions in the proton spin determined in frame electroweak theary for processes (1) at HERA collider.

4 Conclusion

Here an approach has proposed for determination the contributions of quark flavours (u, d, s) and valence quarks $(\Delta u_V, \Delta d_V)$ in proton spin from data polarization experiments (1) at HERA. With this goal we use the first moments of polarized SF g_1, g_5 the processes (1) taking into account the contributions from weak interaction.

The polarized SF g_1, g_5 can to extract from measurable asymmetries $A_{\pm}, A_{e^-,e^+}$.

References

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