The Semi-Inclusive Neutrino-Nucleon Scattering with Charged Current and Spin of Nucleon

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1 Introduction

The present experiments show, that the total quark contribution to the nucleon is small (see [1, 2] for recent reviews). HERMES gives $\Delta\Sigma = 0.330 \pm 0.025(exp.) \pm 0.028(evolv.) \pm 0.011(theo.)$ at $Q^2 = 5\ GeV^2$ and $\Delta\Sigma = 0.35 \pm 0.03(stat.) \pm 0.05(syst.)$ at $Q^2 = 3\ GeV^2$ from COMPASS.

The experiments measure the gluon polarization Δg , although the uncertainties are still large. However, all data indicate, that $\mid \Delta g \mid \leq 0.3$ at $Q^2 = 3\ GeV^2$.

In the present talk we an approach for determination of the quark contributions to the nucleon spin from measurable quantities of semi-inclusive deep inelastic scattering (SIDIS) neutrino (antineutrino) on the polarized targets with charged weak current.

2 The asymmetries and spin structure of the nucleon for case $h(\bar{h}) = K^+(K^-)$

The differential cross sections of the semi-inclusive $\nu(\bar{\nu})N$- DIS with the charged weak current

$$\nu(\bar{\nu}) + N \to \ell^-(\ell^+) + h + X \tag{1}$$

are equal to the

$$\frac{d^3\sigma^h_{\nu,\bar{\nu}}}{dxdydz} = (\sigma^a_{\nu,\bar{\nu}})^h + (\sigma^p_{\nu,\bar{\nu}})^h,$$

where

$$\sigma \equiv \frac{d^3\sigma}{dxdydz},$$

$$(\sigma_\nu^a)^h = 2\sigma_0 x \left(\sum_{q_i,q_j} q_i(x) D_{q_j}^h(z) + y_1^2 \sum_{q_j,q_i} \bar{q}_j(x) D_{\bar{q}_i}^h(z) \right),$$

$$(\sigma_\nu^p)^h = 2\sigma_0 x P_N \left(\sum_{q_j,q_i} \Delta q_i(x) D_{q_j}^h(z) - y_1^2 \sum_{q_j,q_i} \Delta\bar{q}_j(x) D_{\bar{q}_i}^h(z) \right), \quad (2)$$

$$(\sigma_{\bar\nu}^a)^h = 2\sigma_0 x \left(y_1^2 \sum_{q_j,q_i} q_i(x) D_{q_i}^h(z) + \sum_{q_i,q_j} \bar{q}_i(x) D_{\bar{q}_j}^h(z) \right),$$

$$(\sigma_{\bar\nu}^p)^h = 2\sigma_0 x P_N \left(y_1^2 \sum_{q_j,q_i} \Delta q_j(x) D_{q_i}^h(z) - \sum_{q_i,q_j} \Delta\bar{q}_i(x) D_{\bar{q}_j}^h(z) \right).$$

We define the polarization asymmetries as in semi-inclusive ℓN- DIS [3, 4] (ℓ-the charged lepton) in the form of

$$A_{\nu,\bar\nu}^{h-\bar h} = \frac{(\sigma_{\downarrow\uparrow,\uparrow\uparrow}^h - \sigma_{\downarrow\downarrow,\uparrow\downarrow}^{\bar h}) - (\sigma_{\downarrow\downarrow,\uparrow\downarrow}^h - \sigma_{\downarrow\downarrow,\uparrow\downarrow}^{\bar h})}{(\sigma_{\downarrow\uparrow,\uparrow\uparrow}^h + \sigma_{\downarrow\uparrow,\uparrow\uparrow}^{\bar h}) + (\sigma_{\downarrow\downarrow,\uparrow\downarrow}^h - \sigma_{\downarrow\downarrow,\uparrow\downarrow}^{\bar h})} = \frac{(\sigma_\nu^p)^h - (\sigma_\nu^p)^{\bar h}}{(\sigma_\nu^a)^h + (\sigma_\nu^a)^{\bar h}}. \quad (3)$$

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 $\downarrow$ $(P_N = -1)$.

Let's consider $h = K^+, \bar h = K^-$. From (3) for the case of a proton target for asymmetry we have

$$A_{\nu p}^{K^+-K^-} = \frac{\Delta d(x) D_u^{K^+-K^-}(z) + \Delta s(x) D_c^{K^+-K^-}(z) - y_1^2 \Delta\bar u(x) D_{\bar d}^{K^+-K^-(z)}}{d(x) D_u^{K^+-K^-}(z) + s(x) D_c^{K^+-K^-}(z) + y_1^2 \bar u(x) D_{\bar d}^{K^+-K^-}(z)} \quad (4)$$

If we consider the equations [6] for K- mesons fragmentation functions $D_c^{K^+-K^-} = 0$, $D_d^{K^+-K^-} = 0$,we will have asymmetry as follows:

$$A_{\nu p}^{K^+-K^-} = \frac{\Delta d(x)}{d(x)}. \quad (5)$$

Asymmetry for a neutron can be received from (5) by the replacement "u" $\leftrightarrow$ "d":

$$A_{\nu n}^{K^+-K^-} = \frac{\Delta u(x)}{u(x)}. \tag{6}$$

Let's consider the deuteron target. In this case the cross sections are equal to the expressions

$$\left(\sigma^p_{\nu(\bar\nu)d}\right)^h = \frac{\left(\sigma^p_{\nu(\bar\nu)p}\right)^h + \left(\sigma^p_{\nu(\bar\nu)n}\right)^h}{2}(1-1.5\omega),$$

$$\left(\sigma^a_{\nu(\bar\nu)d}\right)^h = \frac{\left(\sigma^a_{\nu(\bar\nu)p}\right)^h + \left(\sigma^a_{\nu(\bar\nu)n}\right)^h}{2}, \tag{7}$$

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

Then from (2), (3), (7) the semi-inclusive νd- DIS asymmetries can be obtained as follows:

$$A_{\nu d}^{K^+-K^-} = \frac{\Delta u(x) + \Delta d(x)}{u(x) + d(x)}(1-1.5\omega). \tag{8}$$

Similarly, by means of (2), (3),(7) we receive asymmetries for semi-inclusive antineutrino DIS polarized targets in form of

$$A_{\bar\nu p}^{K^+-K^-} = -\frac{\Delta\bar d(x)}{\bar d(x)}, \tag{9}$$

$$A_{\bar\nu n}^{K^+-K^-} = -\frac{\Delta\bar u(x)}{\bar u(x)}, \tag{10}$$

$$A_{\bar\nu d}^{K^+-K^-} = -\frac{\Delta\bar u(x) + \Delta\bar d(x)}{\bar u(x) + \bar d(x)}(1-1.5\omega). \tag{11}$$

Nucleon spin structure can be considered using the first parton distributions 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.

Then from (5),(6),(9),(10) the quark and antiquark contributions to the nucleon spin can be defined as

$$\Delta u = \int_0^1 u(x) A_{\nu n}^{K^+-K^-}(x,y,z)dx,$$

$$\Delta \bar{u} = -\int_0^1 \bar{u}(x) A_{\bar{\nu} n}^{K^+-K^-}(x,y,z)dx,$$

$$\Delta d = \int_0^1 d(x) A_{\nu p}^{K^+-K^-}(x,y,z)dx, \tag{12}$$

$$\Delta \bar{d} = -\int_0^1 \bar{d}(x) A_{\bar{\nu} p}^{K^+-K^-}(x,y,z)dx$$

From equations (8),(11) it is received

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

$$= \frac{1}{1-1.5\omega} \int_0^1 \frac{dx}{x} \left[A_{\nu d}^{K^+-K^-}(u(x)+d(x)) A_{\bar{\nu} d}^{K^+-K^-}(\bar{u}(x)+\bar{d}(x)) \right]. \tag{13}$$

For the separation the quark flavours contributions one can use the additional measured quantities, for example, the axial charges [7] $a_3 = 1.2695 \pm 0.0029$ and $a_8 = 0.585 \pm 0.25$,which in a quark-parton model are equal

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

$$a_8 = (\Delta u + \Delta \bar{u}) + (\Delta d + \Delta \bar{d}) - 2(\Delta s + \Delta \bar{s}). \tag{14}$$

The solution for (13),(14) can be obtained as the flavour contribution to each quark in form of:

$$\Delta u + \Delta \bar{u} = \frac{1}{2} \Bigg(\frac{1}{1-1.5\omega} \int_0^1 \frac{dx}{x} \Big[A_{\nu d}^{K^+-K^-}(u(x)+d(x)) -$$

$$- A_{\bar{\nu} d}^{K^+-K^-}(\bar{u}(x)+\bar{d}(x)) \Big] + a_3 \Bigg),$$

$$\Delta d + \Delta \bar{d} = \frac{1}{2} \Bigg(\frac{1}{1-1.5\omega} \int_0^1 \frac{dx}{x} \Big[A_{\nu d}^{K^+-K^-}(u(x)+d(x)) - \tag{15}$$

$$-A_{\bar{\nu}d}^{K^+-K^-}(\bar{u}(x)+\bar{d}(x))\Big] - a_3\Big),$$

$$\Delta s+\Delta\bar{s}=\frac{1}{2}\left(\frac{1}{1-1.5\omega}\int_0^1\frac{dx}{x}\Big[A_{\nu d}^{K^+-K^-}(u(x)+d(x))-\right.$$

$$\left.-A_{\bar{\nu}d}^{K^+-K^-}(\bar{u}(x)+\bar{d}(x))\Big] - a_8\right),$$

Valence quark contributions can be determined from (8),(11),(12) as

$$\Delta u_V+\Delta d_V=\frac{1}{1-1.5\omega}\int_0^1\frac{dx}{x}\Big[A_{\bar{\nu}d}^{K^+-K^-}(\bar{u}(x)+\bar{d}(x))+$$

$$+A_{\nu d}^{K^+-K^-}(u(x)+d(x))\Big], \tag{16}$$

$$\Delta u_V=\Delta u-\Delta\bar{u}=\int_0^1\Big[u(x)A_{\nu n}^{K^+-K^-}+\bar{u}(x)A_{\bar{\nu}n}^{K^+-K^-}\Big]dx, \tag{17}$$

$$\Delta d_V=\Delta d-\Delta\bar{d}=\int_0^1\Big[d(x)A_{\nu p}^{K^+-K^-}+\bar{d}(x)A_{\bar{\nu}p}^{K^+-K^-}\Big]dx. \tag{18}$$

3 The asymmetries and spin structure of the nucleon for case $h(\bar{h})=\Lambda(\bar{\Lambda})$

Let's consider $h=\Lambda,\bar{h}=\bar{\Lambda}$.

From the(3) for the proton targets we have

$$A_{\nu p}^{\Lambda-\bar{\Lambda}}=\frac{\Delta d(x)D_u^{\Lambda-\bar{\Lambda}}(z)+\Delta s(x)D_c^{\Lambda-\bar{\Lambda}}(z)-y_1^2\Delta\bar{u}(x)D_{\bar{d}}^{\Lambda-\bar{\Lambda}}(z)}{d(x)D_u^{\Lambda-\bar{\Lambda}}(z)+s(x)D_c^{\Lambda-\bar{\Lambda}}(z)+y_1^2\bar{u}(x)D_{\bar{d}}^{\Lambda-\bar{\Lambda}}(z)},$$

where $D^{\Lambda-\bar{\Lambda}}=D^{\Lambda}-D^{\bar{\Lambda}}$.

If it has been considered equations [6] for functions of a fragmentation Λ-hyperon $D_c^{\Lambda-\bar{\Lambda}} = 0$, $D_u^{\Lambda-\bar{\Lambda}} = D_d^{\Lambda-\bar{\Lambda}}$, we receive

$$A_{\nu p}^{\Lambda-\bar{\Lambda}} = \frac{y_1^2 \Delta\bar{u}(x) - \Delta d(x)}{d(x) - y_1^2 \bar{u}(x)}. \tag{19}$$

Asymmetry for the neutron can be obtained from (19) by"u" $\leftrightarrow$ "d" replacement:

$$A_{\nu n}^{\Lambda-\bar{\Lambda}} = \frac{y_1^2 \Delta\bar{d}(x) - \Delta u(x)}{u(x) - y_1^2 \bar{d}(x)}. \tag{20}$$

Asymmetry in case of deutron target with (7) has the following form

$$A_{\nu d}^{\Lambda-\bar{\Lambda}} = \frac{\Delta u(x) + \Delta d(x) + y_1^2(\Delta\bar{u}(x) + \Delta\bar{d}(x))}{u(x) + d(x) - y_1^2(\bar{u}(x) + \bar{d}(x))}(1 - 1.5\omega). \tag{21}$$

Similarly we receive the asymmetries for the antineutrino semi-inclusive DIS on polarized targets:

$$A_{\bar{\nu} p}^{\Lambda-\bar{\Lambda}} = \frac{y_1^2 \Delta u(x) + \Delta\bar{d}(x)}{y_1^2 u(x) + \bar{d}(x)}, \tag{22}$$

$$A_{\bar{\nu} n}^{\Lambda-\bar{\Lambda}} = \frac{y_1^2 \Delta d(x) + \Delta\bar{u}(x)}{y_1^2 d(x) + \bar{u}(x)}, \tag{23}$$

$$A_{\bar{\nu} d}^{\Lambda-\bar{\Lambda}} = \frac{y_1^2(\Delta u(x) + \Delta d(x)) + \Delta\bar{u}(x) + \Delta\bar{d}(x)}{y_1^2(u(x) + d(x)) - (\bar{u}(x) + \bar{d}(x))}(1 - 1.5\omega). \tag{24}$$

From (19),(20),(22),(23) we obtain the quark and antiquark contributions to the nucleon spin:

$$\Delta u = \int_0^1 \frac{A_{\bar{\nu} p}^{\Lambda-\bar{\Lambda}} y_1^2 (y_1^2 u(x) + \bar{d}(x)) - A_{\nu n}^{\Lambda-\bar{\Lambda}}(u(x) - y_1^2 \bar{d}(x))}{1 + y_1^4} dx,$$

$$\Delta\bar{u} = \int_0^1 \frac{A_{\nu p}^{\Lambda-\bar{\Lambda}} y_1^2 (d(x) - y_1^2 \bar{u}(x)) + A_{\bar{\nu} n}^{\Lambda-\bar{\Lambda}}(\bar{u}(x) + y_1^2 d(x))}{1 + y_1^4} dx,$$

$$\Delta d = \int_0^1 \frac{A_{\bar{\nu} n}^{\Lambda-\bar{\Lambda}} y_1^2 (y_1^2 d(x) + \bar{u}(x)) + A_{\nu p}^{\Lambda-\bar{\Lambda}}(d(x) - y_1^2 \bar{u}(x))}{1 + y_1^4} dx, \tag{25}$$

$$\Delta\bar{d} = \int_0^1 \frac{A_{\nu n}^{\Lambda-\bar{\Lambda}} y_1^2(u(x) - y_1^2\bar{d}(x)) + A_{\bar{\nu}p}^{\Lambda-\bar{\Lambda}}(y_1^2 u(x) + \bar{d}(x))}{1 + y_1^4} dx.$$

By means of (14),(25) it is possible to receive quarks flavours contributions as:

$$\Delta u + \Delta\bar{u} = \frac{1}{2}\Bigg(\frac{1}{(1-1.5\omega)(1+y_1^2)} \int_0^1 \frac{dx}{x}\Big[A_{\nu d}^{\Lambda-\bar{\Lambda}}(u(x) + d(x) -$$

$$-y_1^2(\bar{u}(x) + \bar{d}(x))) + A_{\bar{\nu}d}^{\Lambda-\bar{\Lambda}}(y_1^2(u(x) + d(x)) - (\bar{u}(x) + \bar{d}(x)))\Big] + a_3\Bigg),$$

$$\Delta d + \Delta\bar{d} = \frac{1}{2}\Bigg(\frac{1}{(1-1.5\omega)(1+y_1^2)} \int_0^1 \frac{dx}{x}\Big[A_{\nu d}^{\Lambda-\bar{\Lambda}}(u(x) + d(x) -$$

$$-y_1^2(\bar{u}(x) + \bar{d}(x))) + A_{\bar{\nu}d}^{\Lambda-\bar{\Lambda}}(y_1^2(u(x) + d(x)) - (\bar{u}(x) + \bar{d}(x)))\Big] - a_3\Bigg),$$

$$\Delta s + \Delta\bar{s} = \frac{1}{2}\Bigg(\frac{1}{(1-1.5\omega)(1+y_1^2)} \int_0^1 \frac{dx}{x}\Big[A_{\nu d}^{\Lambda-\bar{\Lambda}}(u(x) + d(x) -$$

$$-y_1^2(\bar{u}(x) + \bar{d}(x))) + A_{\bar{\nu}d}^{\Lambda-\bar{\Lambda}}(y_1^2(u(x) + d(x)) - (\bar{u}(x) + \bar{d}(x)))\Big] - a_8\Bigg),$$

and valence quark contribution

$$\Delta u_V = \frac{1}{1+y_1^4} \int_0^1 \Big[y_1^2(A_{\bar{\nu}p}^{\Lambda-\bar{\Lambda}}(y_1^2 u(x) + \bar{d}(x)) - A_{\nu p}^{\Lambda-\bar{\Lambda}}(d(x) - y_1^2\bar{u}(x))) -$$

$$-A_{\nu n}^{\Lambda-\bar{\Lambda}}(u(x) - y_1^2\bar{d}(x)) - A_{\bar{\nu}n}^{\Lambda-\bar{\Lambda}}(\bar{u}(x) + y_1^2 d(x))\Big] dx,$$

$$\Delta d_V = \frac{1}{1+y_1^4}\int\limits_0^1 \Big[y_1^2(A_{\bar{\nu}n}^{\Lambda-\bar{\Lambda}}(y_1^2 d(x)+\bar{u}(x)) - A_{\nu n}^{\Lambda-\bar{\Lambda}}(u(x)-y_1^2\bar{d}(x)))$$

$$+A_{\nu p}^{\Lambda-\bar{\Lambda}}(d(x)-y_1^2\bar{u}(x)) - A_{\bar{\nu}p}^{\Lambda-\bar{\Lambda}}(y_1^2 u(x)+\bar{d}(x))\Big]dx.$$

4 Conclusion

The obtained polarizations asymmetries $A_{\nu(\bar{\nu})}^{K^+-K^-}$,$A_{\nu(\bar{\nu})}^{\Lambda-\bar{\Lambda}}$ for SIDIS on the proton, neutron,deutron targets not depend on the functions of fragmentation.

The quark flavours (u, d, s) contributions to the nucleon spin is obtained from the measurable asymmetries semi-inclusive neutrino DIS on the polarized targets with charged current for the $K^{\pm}$-mesons and $\Lambda, \bar{\Lambda}$-hyperons production.

References

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