# DOUBLE SPIN ASYMMETRIES IN SEMI-INCLUSIVE DIS

**S.K. ABDULLAYEV, A.I. MUKHTAROV, M.Sh. GOJAYEV**
*Baku State University,*
*AZ -1148, Z. Khalilov, 23 Baku, Azerbaijan*

The general expressions for the effective cross-sections of semi-inclusive reactions $\ell^{\mp}(\lambda)N(h_N)\Rightarrow \ell^{\mp}hX$, $\nu_\mu(\bar{\nu}_\mu)N(h_N)\Rightarrow \nu_\mu(\bar{\nu}_\mu)hX$, $\nu_\mu(\bar{\nu}_\mu)N(h_N)\Rightarrow \mu^-(\mu^+)hX$, $\mu^-(\mu^+)(\lambda)N(h_N)\Rightarrow\ \Rightarrow \nu_\mu(\bar{\nu}_\mu)hX$ are obtained in the framework of quark-parton model. The double spin asymmetry $A_N^{h^+-h^-}=\dfrac{(\sigma_{\uparrow\uparrow}^{h^+}-\sigma_{\uparrow\uparrow}^{h^-})-(\sigma_{\uparrow\downarrow}^{h^+}-\sigma_{\uparrow\downarrow}^{h^-})}{(\sigma_{\uparrow\uparrow}^{h^+}-\sigma_{\uparrow\uparrow}^{h^-})+(\sigma_{\uparrow\downarrow}^{h^+}-\sigma_{\uparrow\downarrow}^{h^-})}$ where $\sigma_{\uparrow\uparrow}^{h^+}(\sigma_{\uparrow\downarrow}^{h^+})$ – is effective cross-section when spins of lepton and nucleon-target have parallel direction. It is shown that double spin asymmetries don't depend on the fragmentation function of quark to hadrons $h$

## 1. Introduction

The standard model (SM) of the electroweak interactions of the elementary particles has achieved a great success in the description of series of the experiments, which have been carried out in the various laboratories of the world. In particular, one of its exact checking has been alone on the $e^-e^+$-colliders LEP, SLC and TRISTAN, as the result of which the agreement with the experimental data has been obtained. Alongside with $e^-e^+$-annihilation the deep-inelastic scattering (DIS) processes of the polarized leptons on the polarized nucleons play the important role in the check of standard theory and they are intensive investigated experimentally at the present time [1-5].

High energy experiment with polarized beams and targets has opened a new window for revealing QCD dynamics and hadron structures. In this we study the hadron production in polarized semi-inclusive DIS off nucleon:

$$\ell^-(\lambda)+N(h_N)\Rightarrow \ell^-+h+X, \tag{1}$$

$$\ell^+(\lambda)+N(h_N)\Rightarrow \ell^++h+X, \tag{2}$$

$$\nu_\mu+N(h_N)\Rightarrow \nu_\mu+h+X, \tag{3}$$

$$\bar{\nu}_\mu+N(h_N)\Rightarrow \bar{\nu}_\mu+h+X, \tag{4}$$

$$\nu_\mu+N(h_N)\Rightarrow \mu^-+h+X, \tag{5}$$

$$\bar{\nu}_\mu+N(h_N)\Rightarrow \mu^++h+X, \tag{6}$$

$$\mu^-(\lambda)+N(h_N)\Rightarrow \nu_\mu+h+X, \tag{7}$$

$$\mu^+(\lambda)+N(h_N)\Rightarrow \bar{\nu}_\mu+h+X, \tag{8}$$

where $\lambda$ is the lepton spirality, $h_N$ is the longitudinal polarization of nucleon-target.

The cross-section for the production of a hadron $h$ in the current fragmentation region are given by

$$\frac{d\sigma(\lambda;h_N)}{dxdydz}=\sum_{q,h_q} f_{q(h_q)}^{N(h_N)}(x,Q^2)\frac{d\hat{\sigma}}{dy}D_q^h(z,Q^2), \tag{9}$$

where $f_{q(h_q)}^{N(h_N)}(x,Q^2)$ is the distribution function of polarized quarks in the polarized nucleon, $D_q^h(z,Q^2)$ is the fragmentation function of the quark into the detected hadron $h$, $d\hat{\sigma}/dy$ is the elementary cross-section. The usual DIS variables $x$, $y$ and $z$ defined as:

$$x=\frac{Q^2}{2P\cdot q},\ y=\frac{q\cdot P}{k\cdot P},\quad z=\frac{P_h\cdot P}{P\cdot q},$$

where $k$, $P$, $P_h$ and $q$ are the four-momenta of the initial lepton, the target nucleon, the production hadron, and the virtual bozon respectively.

## 2. Neutral current lepton processes $\ell^{\mp}N\Rightarrow \ell^{\mp}hX$

Let us consider first the processes $\ell^{\mp}N\Rightarrow \ell^{\mp}hX$; for them, there exist two possible elementary contributions;

$$\ell^-+q\Rightarrow \ell^-+q\,,\ \ell^-+\bar{q}\Rightarrow \ell^-+\bar{q}\,.$$

Taking under the considerations the exchange of $\gamma$ and $Z^0$, it is easy to make sure, that the spiralities of lepton and quark should be saved separately in subprocess $\ell^-+q\Rightarrow \ell^-+q$. That's why in this process only four spiral amplitudes $F_{RR}$, $F_{LL}$, $F_{RL}$ and $F_{LR}$, which describe following reactions:

$$\ell_R^-+q_R\Rightarrow \ell_R^-+q_R,\ \ell_L^-+q_L\Rightarrow \ell_L^-+q_L,$$

$$\ell_R^-+q_L\Rightarrow \ell_R^-+q_L,\ \ell_L^-+q_R\Rightarrow \ell_L^-+q_R.$$

The spiral amplitudes in SM are defined by expressions

$$F_{\alpha\beta}=\frac{Q_q}{xys}-\frac{g_\alpha^\ell g_\beta^q}{xys+M_z^2}\ (\alpha,\beta=L;R), \tag{10}$$

where $M_z$ – is mass of $Z^0$-bozon, $S$ – is the square of total energy of ($N$-system in their c.m.s., $Q_q$ – is quark electric charge $q$, $g_R^\ell$ and $g_L^\ell$ ($g_R^q$ and $g_L^q$) – are right and left neutral weak charges of lepton (quark) with $Z^0$ - bozon:

$$g_R^{\ell}=\sqrt{\frac{x_W}{1-x_W}}\ ;\ g_L^{\ell}=\frac{-1/2+x_W}{\sqrt{x_W(1-x_W)}}\ ;$$

$$g_R^{q}=-Q_q\sqrt{\frac{x_W}{1-x_W}}\ ;\ g_L^{q}=\frac{T_3-Q_q x_W}{\sqrt{x_W(1-x_W)}}\ . \quad (11)$$

Here $x_W=\sin^2\theta_W$ –is the Weinberg's parameter, $T_3$ – is third projection of the weak isospin of quark $q$.

Let's reduce the subprocess cross-sections $\ell^- q\Rightarrow\ell^- q$ at the definite values of initial and final particles:

$$\frac{d\hat{\sigma}}{dy}(\ell_R^- q_R\to\ell_R^- q_R)=4\pi\alpha^2 xsF_{RR}^2\,,$$

$$\frac{d\hat{\sigma}}{dy}(\ell_L^- q_L\to\ell_L^- q_L)=4\pi\alpha^2 xsF_{LL}^2\,,$$

$$\frac{d\hat{\sigma}}{dy}(\ell_R^- q_L\to\ell_R^- q_L)=4\pi\alpha^2 xs(1-y)^2F_{RL}^2\,,$$

$$\frac{d\hat{\sigma}}{dy}(\ell_L^- q_R\to\ell_L^- q_R)=4\pi\alpha^2 xs(1-y)^2F_{LR}^2\,. \quad (12)$$

The difference of $y$-dependences of the abovementioned cross-sections (12) connected with the difference of total spiralities of the system $\ell^- q$: for $\ell_R^- q_R$ and $\ell_L^- q_L$-collisions the total system spirality is equal to zero and $y$-dependence doesn't appear; for $\ell_R^- q_L$ and $\ell_L^- q_R$-collisions the total spirality is equal to one that leads to the characteristic $y$-dependence ~ $(1-y)^2$.

The differential cross-section of the elementary subprocess $\ell^- q\Rightarrow\ell^- q$ with taking under the consideration of the spiralities of the initial units can be imagined in the form (the spiralities of the final particles are the same, as of the initial ones, i.e. the spiralities of lepton and quark are saved separately):

$$\frac{d\hat{\sigma}}{dy}=\pi\alpha^2 xs\{(1+\lambda)(1+h_q)F_{RR}^2+(1-\lambda)(1-h_q)F_{LL}^2+(1-y)^2[(1+\lambda)(1-h_q)F_{RL}^2+(1-\lambda)(1+h_q)F_{LR}^2]\} \quad (13)$$

where $h_q$ is spirality of the initial quark.

The differential cross-section of subprocess $\ell^-\bar{q}\Rightarrow\ell^-\bar{q}$ can be obtained from (13) with the help of the elementary changes: $F_{RR}\Leftrightarrow F_{RL}$, $F_{LL}\Leftrightarrow F_{LR}$.

On the base of formulas (9) and (13), the expression for the differential cross-section of semi-inclusive reaction $\ell^- N\Rightarrow\ell^- hX$ has been obtained [6, 7]:

$$\frac{d\sigma^{(-)}(\lambda;h_N)}{dxdydz}=2\pi\alpha^2 sx\times$$

$$\times\sum_q\Big\{f_q^N(x,Q^2)D_q^h(z,Q^2)[(1+\lambda)(F_{RR}^2+(1-y)^2F_{RL}^2)+(1-\lambda)(F_{LL}^2+(1-y)^2F_{LR}^2)]+$$

$$+f_{\bar{q}}^N(x,Q^2)D_{\bar{q}}^h(z,Q^2)[(1+\lambda)(F_{RL}^2+(1-y)^2F_{RR}^2)+(1-\lambda)(F_{LR}^2+(1-y)^2F_{LL}^2)]+$$

$$+h_N\Delta f_q^N(x,Q^2)D_q^h(z,Q^2)[(1+\lambda)(F_{RR}^2-(1-y)^2F_{RL}^2)-(1-\lambda)(F_{LL}^2-(1-y)^2F_{LR}^2)]+$$

$$+h_N\Delta f_{\bar{q}}^N(x,Q^2)D_{\bar{q}}^h(z,Q^2)[(1+\lambda)(F_{RL}^2-(1-y)^2F_{RR}^2)-(1-\lambda)(F_{LR}^2-(1-y)^2F_{LL}^2)]\Big\}, \quad (14)$$

where

$$\Delta f_q^N(x,Q^2)=f_{q(+1)}^{N(+1)}(x,Q^2)-f_{q(-1)}^{N(+1)}(x,Q^2)\,,$$

$$f_q^N(x,Q^2)=f_{q(+1)}^{N(+1)}(x,Q^2)+f_{q(-1)}^{N(+1)}(x,Q^2)\,.$$

The differential cross-section of process $\ell^+ N\Rightarrow\ell^+ hX$ must be obtained from (14) with the help of the following exchanges:

$$F_{R\beta}\Leftrightarrow F_{L\beta}\,,\ (\beta=R;L).$$

We can now compute the so called "difference double spin asymmetry" $A_N^{h^+-h^-}$ which is expressed as

$$A_N^{h^+-h^-}=\frac{(\sigma_{\uparrow\uparrow}^{h^+}-\sigma_{\uparrow\uparrow}^{h^-})-(\sigma_{\uparrow\downarrow}^{h^+}-\sigma_{\uparrow\downarrow}^{h^-})}{(\sigma_{\uparrow\uparrow}^{h^+}-\sigma_{\uparrow\uparrow}^{h^-})+(\sigma_{\uparrow\downarrow}^{h^+}-\sigma_{\uparrow\downarrow}^{h^-})}\,, \quad (15)$$

where $\sigma_{\uparrow\uparrow}^{h^\pm}$ $(\sigma_{\uparrow\downarrow}^{h^\pm})$ – denotes the cross-sections (14) with parallel (antiparallel) orientations of here lepton and target nuclear spins.

Then, the expression for the double spin asymmetries look like:

$$A_p^{\pi^+-\pi^-} = \Big\{ \Delta u_\upsilon [F_{LL}^2(u) - (1-y)^2 F_{LR}^2(u)] - \Delta d_\upsilon [F_{LL}^2(d) - (1-y)^2 F_{LR}^2(d)] +$$

$$+ [1+(1-y)^2] \cdot [\Delta u_s (F_{LL}^2(u) - F_{LR}^2(u)) - \Delta d_s (F_{LL}^2(d) - F_{LR}^2(d))] \Big\} \times$$

$$\times \Big\{ u_\upsilon [F_{LL}^2(u) + (1-y)^2 F_{LR}^2(u)] - d_\upsilon [F_{LL}^2(d) + (1-y)^2 F_{LR}^2(d)] +$$

$$+ [1-(1-y)^2] \cdot [u_s (F_{LL}^2(u) - F_{LR}^2(u)) - d_s (F_{LL}^2(d) - F_{LR}^2(d))] \Big\}^{-1} . \quad (16)$$

$$A_p^{K^+-K^-} = \Big\{ \Delta u_\upsilon [F_{LL}^2(u) - (1-y)^2 F_{LR}^2(u)] + [1+(1-y)^2] \times$$

$$\times [\Delta u_s (F_{LL}^2(u) - F_{LR}^2(u)) - \Delta s_s (F_{LL}^2(s) - F_{LR}^2(s))] \Big\} \Big\{ u_\upsilon [F_{LL}^2(u) + (1-y)^2 \times$$

$$\times F_{LR}^2(u)] + [1-(1-y)^2] [u_s (F_{LL}^2(u) - F_{LR}^2(u)) - s_s (F_{LL}^2(s) - F_{LR}^2(s))] \Big\}^{-1} , \quad (17)$$

where $u_\upsilon$ and $d_\upsilon$ ($u_s$, $d_s$ and $S_s$) are distribution functions valence *u*- and *d*- (sea *u*-, *d*- and *s*-) quarks in proton.

The double spin asymmetries (16) and (17) have the remarkable property – they to be free of any fragmentation functions. When we do not consider weak interaction contributions in the processes $\ell^- N \Rightarrow \ell^- hX$ expressions for the difference asymmetries look like [6]:

$$A_p^{\pi^+-\pi^-} = f(y) \frac{4\Delta u_\upsilon - \Delta d_\upsilon}{4u_\upsilon - d_\upsilon},$$

$$A_n^{\pi^+-\pi^-} = f(y) \frac{4\Delta d_\upsilon - \Delta u_\upsilon}{4d_\upsilon - u_\upsilon},$$

$$A_p^{K^+-K^-} = f(y) \frac{\Delta u_\upsilon}{u_\upsilon},$$

$$A_n^{K^+-K^-} = f(y) \frac{\Delta d_\upsilon}{d_\upsilon},$$

$$A_d^{\pi^+-\pi^-} = A_d^{K^+-K^-} = f(y) \frac{\Delta u_\upsilon + \Delta d_\upsilon}{u_\upsilon + d_\upsilon},$$

$$f(y) = \frac{1-(1-y)^2}{1+(1-y)^2} \quad .(18)$$

The double spin asymmetries (18) contain only valence quark polarized densities.

**3. Neutral current neutrino processes $\nu_\mu(\bar{\nu}_\mu)N \Rightarrow \nu_\mu(\bar{\nu}_\mu)hX$**

There are two different kinds of elementary interactions contributing to neutral current neutrino processes

$\nu_\mu(\bar{\nu}_\mu)N \Rightarrow \nu_\mu(\bar{\nu}_\mu)hX$ :

$$\nu_\mu(\bar{\nu}_\mu) + q \Rightarrow \nu_\mu(\bar{\nu}_\mu) + q,$$
$$\nu_\mu(\bar{\nu}_\mu) + \bar{q} \Rightarrow \nu_\mu(\bar{\nu}_\mu) + \bar{q}. \quad (19)$$

As quarks spirality conserves in neglect of its masses, then the elementary subprocess $\nu_\mu + q \Rightarrow \nu_\mu + q$ is defined only by two spiral amplitudes $F_{LL}$ and $F_{LR}$, which describe following reactions:

$$\nu_L + q_L \Rightarrow \nu_L + q_L, \quad \nu_L + q_R \Rightarrow \nu_L + q_R. \quad (20)$$

The spiral amplitudes in SM are defined by following expressions

$$F_{LR} = \frac{g_L^\nu g_R^q}{xys + M_z^2}, \quad F_{LL} = \frac{g_L^\nu g_L^q}{xys + M_z^2}, \quad (21)$$

where $g_L^\nu = \dfrac{1}{2\sqrt{x_W(1-x_W)}}$.

Let's presents the subprocess cross-sections $\nu_\mu + q \Rightarrow \nu_\mu + q$, $\nu_\mu + \bar{q} \Rightarrow \nu_\mu + \bar{q}$, $\bar{\nu}_\mu + q \Rightarrow \bar{\nu}_\mu + q$, $\bar{\nu}_\mu + \bar{q} \Rightarrow \bar{\nu}_\mu + \bar{q}$ at the defined spiralities of initial and final particles:

$$\frac{d\hat{\sigma}}{dy}(\nu_L q_L) = \frac{d\hat{\sigma}}{dy}(\bar{\nu}_R \bar{q}_R) = 4\pi\alpha^2 xsF_{LL}^2,$$
$$\frac{d\hat{\sigma}}{dy}(\nu_L q_R) = \frac{d\hat{\sigma}}{dy}(\bar{\nu}_R \bar{q}_L) = 4\pi\alpha^2 xs(1-y)^2 F_{LR}^2,$$

$$\frac{d\hat{\sigma}}{dy}(\nu_L \bar{q}_L) = \frac{d\hat{\sigma}}{dy}(\bar{\nu}_R q_L) = 4\pi\alpha^2 xsF_{LL}^2,$$
$$\frac{d\hat{\sigma}}{dy}(\nu_L \bar{q}_R) = \frac{d\hat{\sigma}}{dy}(\bar{\nu}_R q_L) = 4\pi\alpha^2 xs(1-y)^2 F_{LR}^2 . \quad (22)$$

The differential cross-section of the elementary subprocess $\nu_\mu + q \Rightarrow \nu_\mu + q$ taking into consideration the spirality of initial quarks $h_q$ can be presented in the form

$$\frac{d\hat{\sigma}(\nu_\mu q)}{dy} = 2\pi\alpha^2 xs\left[(1-h_q)F_{LL}^2 + (1+h_q)(1-y)^2 F_{LR}^2\right]. \quad (23)$$

The following expression has been obtained on the base of formulas (9) and (23), for the differential cross-section of semi-inclusive reaction $\nu_\mu N \Rightarrow \nu_\mu hX$ [8]:

$$\frac{d\sigma}{dxdydz} = \pi\alpha^2 xs\sum_q\Big\{ f_q^N(x,Q^2)D_q^h(z,Q^2)[F_{LL}^2 + (1-y)^2 F_{LR}^2] +$$
$$+ f_{\bar{q}}^N(x,Q^2)D_{\bar{q}}^h(z,Q^2)[F_{LR}^2 + (1-y)^2 F_{LL}^2] - h_N \Delta f_q^N(x,Q^2)D_q^h(z,Q^2)\times$$
$$\times[F_{LL}^2 - (1-y)^2 F_{LR}^2] - h_N \Delta f_{\bar{q}}^N(x,Q^2)D_{\bar{q}}^h(z,Q^2)[F_{LR}^2 - (1-y)^2 F_{LL}^2]\Big\} . \quad (24)$$

The double spin asymmetries for the semi-inclusive reactions $\nu_\mu p \Rightarrow \nu_\mu \pi^\pm X$ and $\nu_\mu p \Rightarrow \nu_\mu K^\pm X$ similarly Eqs (16) and (17).

### 4. Charged current processes $\nu_\mu(\bar{\nu}_\mu)N \Rightarrow \mu^-(\mu^+)hX,\ \mu^-(\mu^+)N \Rightarrow \nu_\mu(\bar{\nu}_\mu)hX$

Let us consider the neutrino initiated processes $\nu_\mu N \Rightarrow \mu^- hX$: for them there exist four possible elementary contributions:

$$\nu_\mu + d \Rightarrow \mu^- + u, \quad \nu_\mu + s \Rightarrow \mu^- + u,$$
$$\nu_\mu + \bar{u} \Rightarrow \mu^- + \bar{d}, \quad \nu_\mu + \bar{u} \Rightarrow \mu^- + \bar{s}. \quad (25)$$

Neglecting quark masses, one find that there is only one non-zero helicity amplitude for each of the elementary processes in (25):

$$F_{LL} = \frac{1}{xys + M_W^2}\cdot\frac{U_{qq'}}{x_W}, \quad (26)$$

where $U_{ud} = \cos\theta_C$, $U_{us} = \sin\theta_C$, $\theta_C$ is the Cabibbo angle, $M_W$ is the mass of $W$-bozon.

For the elementary cross-section we obtain:

$$\frac{d\hat{\sigma}}{dy}(\nu_L q_L \Rightarrow \mu_L^- q'_L) = \pi\alpha^2 xsF_{LL}^2,$$
$$\frac{d\hat{\sigma}}{dy}(\nu_L \bar{q}_L \Rightarrow \mu_L^- \bar{q}'_R) = \pi\alpha^2 xsF_{LL}^2. \quad (27)$$

The differential cross-section of semi-inclusive reaction $\nu_\mu N \Rightarrow \mu^- hX$ must be written in the following form:

$$\frac{d\sigma}{dxdydz} = \frac{\pi\alpha^2}{2} xs\sum_{q,q'} F_{LL}^2\Big\{ f_q^N(x,Q^2)D_{q'}^h(z,Q^2) + (1-y)^2 f_{\bar{q}}^N(x,Q^2)D_{\bar{q}'}^h(z,Q^2) -$$
$$- h_N[\Delta f_q^N(x,Q^2)D_{q'}^h(z,Q^2) - (1-y)^2 \Delta f_{\bar{q}}^N(x,Q^2)D_{\bar{q}'}^h(z,Q^2)\Big\}. \quad (28)$$

If we explicitly perform the sum over flavours in the numerators and denominators of Eqs. (15), we obtain for double-spin asymmetries:

$$A_p^{\pi^+-\pi^-}(\nu_\mu p \Rightarrow \mu^- \pi X) = \frac{\Delta d_\upsilon + \Delta d_s(1+R) - (1-y)^2 \Delta\bar{u}_s}{d_\upsilon + d_s(1+R) + (1-y)^2 \Delta\bar{u}_s}, \quad (29)$$

$$A_p^{K^+-K^-}(\nu_\mu p \Rightarrow \mu^- KX) = \frac{\Delta d_\upsilon + \Delta d_s(1+R) - (1-y)^2 \Delta\bar{u}_s \cdot R}{d_\upsilon + d_s(1+R) + (1-y)^2 \Delta\bar{u}_s \cdot R}, \quad (30)$$

$$A_p^{\pi^+-\pi^-}(\bar{\nu}_\mu p \Rightarrow \mu^+ \pi X) = -\frac{(1-y)^2[\Delta u_\upsilon + \Delta u_s] - \Delta\bar{d}_s(1+R)}{(1-y)^2[u_\upsilon + u_s] + \bar{d}_s(1+R)}, \tag{31}$$

$$A_p^{\pi^+-\pi^-}(\bar{\nu}_\mu p \Rightarrow \mu^+ KX) = -\frac{(1-y)^2[\Delta u_\upsilon + \Delta u_s]R - \Delta\bar{d}_s(1+R)}{(1-y)^2[u_\upsilon + u_s]R + \bar{d}_s(1+R)}, \tag{32}$$

where $R = tg^2\theta_C \approx 0{,}056$ .

Similar results hold for the $\mu^- p \Rightarrow \nu_\mu hX$ and $\mu^+ p \Rightarrow \bar{\nu}_\mu hX$ processes; the contributing elementary interactions are:

$$\begin{aligned}
&\mu^- + u \Rightarrow \nu_\mu + d, \quad \mu^- + u \Rightarrow \nu_\mu + s,\\
&\mu^- + \bar{d} \Rightarrow \nu_\mu + u, \quad \mu^- + \bar{s} \Rightarrow \nu_\mu + \bar{u},\\
&\mu^+ + d \Rightarrow \bar{\nu}_\mu + u, \quad \mu^+ + s \Rightarrow \bar{\nu}_\mu + u,\\
&\mu^+ + \bar{u} \Rightarrow \bar{\nu}_\mu + \bar{d}, \quad \mu^+ + \bar{u} \Rightarrow \bar{\nu}_\mu + \bar{s},
\end{aligned}$$

with the same cross-sections as those computed Eqs. (27):

$$\frac{d\hat{\sigma}(\mu_L^- u_L \Rightarrow \nu_\mu d_L)}{dy} = \frac{d\hat{\sigma}(\mu_L^+ \bar{u}_R \Rightarrow \bar{\nu}_\mu \bar{d}_R)}{dy} = \frac{d\hat{\sigma}(\nu_\mu d_L \Rightarrow \mu_L^- u_L)}{dy} = \frac{d\hat{\sigma}(\bar{\nu}_\mu \bar{d}_R \Rightarrow \mu_R^+ u_R)}{dy},$$

$$\frac{d\hat{\sigma}(\mu_R^+ d_L \Rightarrow \bar{\nu}_\mu u_L)}{dy} = \frac{d\hat{\sigma}(\mu_L^- \bar{d}_R \Rightarrow \nu_\mu \bar{u}_R)}{dy} = \frac{d\hat{\sigma}(\bar{\nu}_\mu u_L \Rightarrow \mu_R^+ d_L)}{dy} = \frac{d\hat{\sigma}(\nu_\mu \bar{u}_R \Rightarrow \mu_L^- \bar{d}_R)}{dy}.$$

The analogues of Eqs. (29)-(32) are now

$$A_p^{\pi^+-\pi^+}(\mu^- p \Rightarrow \nu_\mu \pi X) = \frac{\Delta u_\upsilon + \Delta u_s - (1-y)^2 \Delta\bar{d}_s(1+R)}{u_\upsilon + u_s + (1-y)^2 \bar{d}_s(1+R)}, \tag{33}$$

$$A_p^{K^+-K^+}(\mu^- p \Rightarrow \nu_\mu KX) = \frac{(\Delta u_\upsilon + \Delta u_s)R - (1-y)^2 \Delta\bar{d}_s(1+R)}{(u_\upsilon + u_s)R + (1-y)^2 \bar{d}_s(1+R)}, \tag{34}$$

$$A_p^{\pi^+-\pi^+}(\mu^+ N \Rightarrow \bar{\nu}_\mu \pi X) = \frac{\Delta\bar{u}_s - (1-y)^2[\Delta d_\upsilon + \Delta d_s(1+R)]}{u_s + (1-y)^2[d_\upsilon + d_s(1+R)]}, \tag{35}$$

$$A_p^{\pi^+-\pi^+}(\mu^+ N \Rightarrow \bar{\nu}_\mu KX) = \frac{\Delta\bar{u}_s R - (1-y)^2[\Delta d_\upsilon + \Delta d_s(1+R)]}{u_s R + (1-y)^2[d_\upsilon + d_s(1+R)]}. \tag{36}$$

## 5. Numerical estimates

In the previous sections we have obtained explicit expressions for the double-spin asymmetries for hadron production in semi-inclusive DIS. We now use these formulae to give prediction in the case of $\pi^\pm$ and $K^\pm$ production, considering typical kinematical configurations of ongoing or planned experiments. The double-spin asymmetry values depend on the known SM dynamics, on the quark distribution functions, both unpolarized and polarized. Quark distribution functions in polarized nucleons the values of wich are defined from the experiment, present in the expression of double-spin asymmetries.

The set of collections of quark distribution functions in nucleons are present in references [9-12]. The distribution functions of valence and sea polarized quarks in nucleons, mentioned in the ref. [9] are used by us for the numerical estimations of double-spin asymmetries.

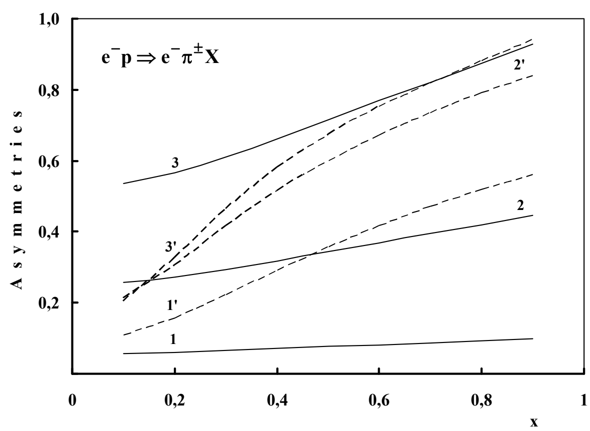


*Fig. 1.* The double-spin asymmetry $A_p^{\pi^+-\pi^-}$ for the pion production $ep \Rightarrow e\pi X$ , as a function of *x*, for different values *y*: *y=0.1* (1 and 1' lines), *y=0.4* (2 and 2' lines), *y=0.9* (3 and 3' lines).

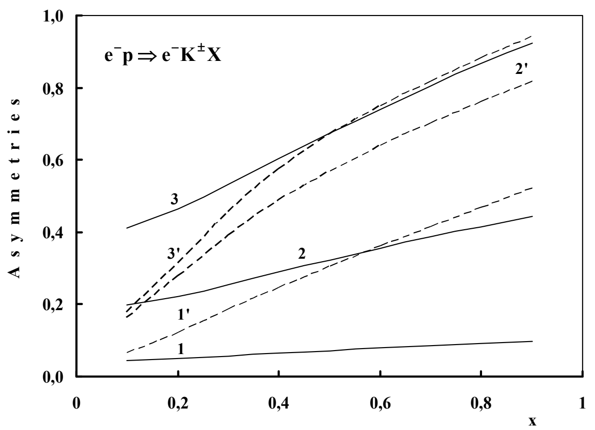


*Fig. 2.* The double-spin asymmetry $A_p^{K^+-K^-}$ for the kaon production $ep \Rightarrow eKX$, as a function of *x*, for different values *y*: *y=0.1* (1 and 1' lines), *y=0.4* (2 and 2' lines), *y=0.9* (3 and 3' lines).

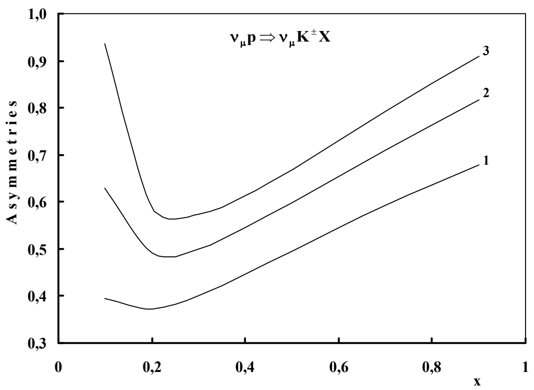


*Fig. 3.* The double-spin asymmetry $A_p^{K^+-K^-}$ for the kaon production $\nu_\mu p \Rightarrow \nu_\mu KX$, as a function of *x*, at fixed *y=0.1* (line 1), *y=0.4* (line 2), *y=0.7* (line 3).

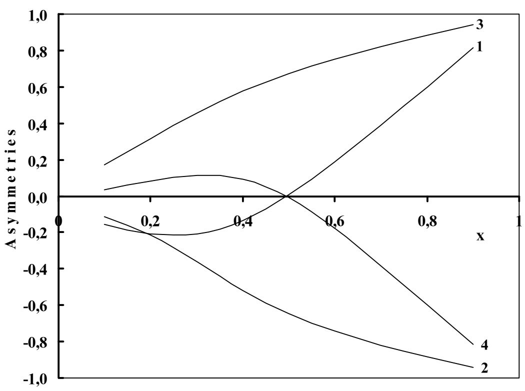


*Fig. 4.* The double-spin asymmetry $A_p^{\pi^+-\pi^-}$ as a function of *x*, at fixed *y=0.4* for $\nu_\mu p \Rightarrow \mu^-\pi X$ (line 1), $\bar{\nu}_\mu p \Rightarrow \mu^+\pi X$ (line 2), $\mu^- p \Rightarrow \nu_\mu \pi X$ (line 3) and $\mu^+ p \Rightarrow \bar{\nu}_\mu \pi X$ (line 4).

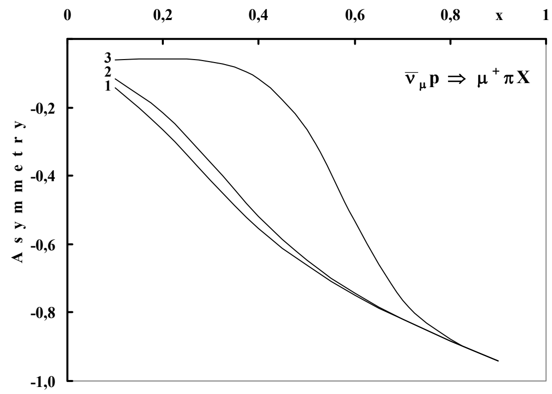


*Fig. 5.* The double-spin asymmetry $A_p^{\pi^+-\pi^-}$ for $\bar{\nu}_\mu p \Rightarrow \mu^+\pi X$ as a function of *x*, at fixed *y=0.1* (line 1), *y=0.4* (line 2) and *y=0.9* (line 3).

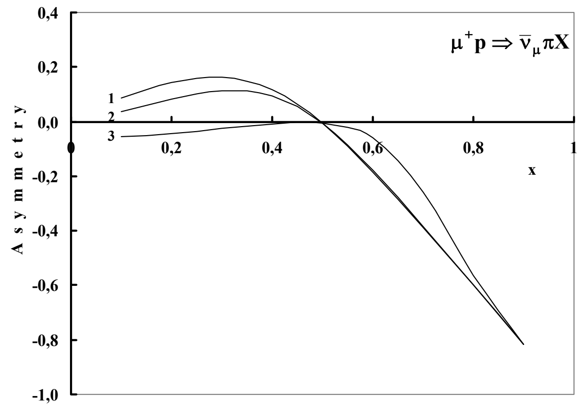


*Fig. 6.* The double-spin asymmetry $A_p^{\pi^+-\pi^-}$ for $\mu^+ p \Rightarrow \bar{\nu}_\mu \pi X$ as a function of *x*, at fixed *y=0.1* (line 1), *y=0.4* (line 2) and y=0.9 (line 3).

In figs. 1-6 we give estimates for $A_N^{h^+-h^-}$ for several processes, with different kinematical conditions, corresponding to typical experimental setups. Figs. 1 and 2 shows *x*-dependence of asymmetries $A_p^{\pi^+-\pi^-}$ and $A_p^{K^+-K^-}$ in semi-inclusive reactions $e^- p \Rightarrow e^-\pi X$ and $e^- p \Rightarrow e^- KX$ at energy $\sqrt{s}$ =300 *Gev* (*ep*-collider HERA), Weinberg parameter $x_W = 0,232$ and the fixed value *y=0,1* (1 and 1' lines), *y=0,4* (2 and 2' lines), *y=0,9* (3 and 3' lines). The solid (dashed) lines indicate the double-spin asymmetries for $\pi$ - or *K*-production in semi-inclusive DIS with one photon (photon and $Z^0$-bozon) exchange. As it is seen the double-spin asymmetries $A_p^{\pi^+-\pi^-}$ and $A_p^{K^+-K^-}$ are positive and increase monotonously with increase of *x*.

The fig. 3 illustrates the dependence of double-spin asymmetry $A_p^{K^+-K^-}$ in $\nu_\mu + p \Rightarrow \nu_\mu + K + X$ process on *x* at *y=0,1* (1 line), *y=0,4* (2 line), *y=0,7* (3 line).

The double-spin asymmetry $A_p^{\pi^+-\pi^-}$ for charge currents is shown in figs. 4, 5 and 6.

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**S.Q. Abdullayev, A.İ. Muxtarov, M.Ş. Qocayev**

## YARIMİNKLÜZİV DQES İKİSPİNLİ ASİMMETRİYALAR


Kvark-parton modeli çərçivəsində yarıinklüziv $\ell^{\mp}(\lambda)N(h_N) \Rightarrow \ell^{\mp}hX$, $\nu_\mu(\bar{\nu}_\mu)N(h_N) \Rightarrow \nu_\mu(\bar{\nu}_\mu)hX$, $\nu_\mu(\bar{\nu}_\mu)N(h_N) \Rightarrow \mu^-(\mu^+)hX$, $\mu^-(\mu^+)(\lambda)N(h_N) \Rightarrow \nu_\mu(\bar{\nu}_\mu)hX$ proseslərinin effektiv kəsikləri üçün ümumi ifadələr alınmışdır. İkispinli asimmetriya

$$A_N^{h^+-h^-} = \frac{(\sigma_{\uparrow\uparrow}^{h^+} - \sigma_{\uparrow\uparrow}^{h^-}) - (\sigma_{\uparrow\downarrow}^{h^+} - \sigma_{\uparrow\downarrow}^{h^-})}{(\sigma_{\uparrow\uparrow}^{h^+} - \sigma_{\uparrow\uparrow}^{h^-}) + (\sigma_{\uparrow\downarrow}^{h^+} - \sigma_{\uparrow\downarrow}^{h^-})}$$

təyin edilmişdir, burada $\sigma_{\uparrow\uparrow}^{h^+}(\sigma_{\uparrow\downarrow}^{h^+})$ – leptonla nuklon hədəfin spinləri paralel (antiparalel) olduğu halda prosesin effektiv kəsiyidir. Göstərilmişdir ki, ikispinli asimmetriyalar kvarkların *h* adronuna fraqmentasiya funksiyalarından asılı deyillər.


**С.К. Абдуллаев, А.И. Мухтаров, М.Ш.Годжаев**

## ДВУХСПИНОВЫЕ АСИММЕТРИИ В ПОЛУИНКЛЮЗИВНЫХ ГНР


В рамках кварк-партонной модели получены общие выражения для эффективных сечений полуинклюзивных реакций $\ell^{\mp}(\lambda)N(h_N) \Rightarrow \ell^{\mp}hX$, $\nu_\mu(\bar{\nu}_\mu)N(h_N) \Rightarrow \nu_\mu(\bar{\nu}_\mu)hX$, $\nu_\mu(\bar{\nu}_\mu)N(h_N) \Rightarrow \mu^-(\mu^+)hX$, $\mu^-(\mu^+)(\lambda)N(h_N) \Rightarrow \Rightarrow \nu_\mu(\bar{\nu}_\mu)hX$. Определена двухспиновая асимметрия

$$A_N^{h^+-h^-} = \frac{(\sigma_{\uparrow\uparrow}^{h^+} - \sigma_{\uparrow\uparrow}^{h^-}) - (\sigma_{\uparrow\downarrow}^{h^+} - \sigma_{\uparrow\downarrow}^{h^-})}{(\sigma_{\uparrow\uparrow}^{h^+} - \sigma_{\uparrow\uparrow}^{h^-}) + (\sigma_{\uparrow\downarrow}^{h^+} - \sigma_{\uparrow\downarrow}^{h^-})}$$

где $\sigma_{\uparrow\uparrow}^{h^+}(\sigma_{\uparrow\downarrow}^{h^+})$ – эффективное сечение процессов при параллельном (антипараллельном) направлении спинов лептона и нуклона мишени. Показано, что двухспиновые асимметрии не зависят от функции фрагментации кварков в адроны *h*.


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