STRUCTURE FUNCTIONS AND TWO-SPIN ASYMMETRIES IN SEMI-INCLUSIVE REACTIONS $\nu_\mu(\bar{\nu}_\mu)N \to \nu_\mu(\bar{\nu}_\mu)h^\pm X$

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The structure functions and longitudinal spin asymmetries in semi-inclusive reactions $\nu_\mu(\bar{\nu}_\mu)N \to \nu_\mu(\bar{\nu}_\mu)h^\pm X$ are investigated within the framework of the Standard Model. Expressions for the non-polarization and polarization structure functions of hadrons are obtained. Within the framework of the quark-parton model, all structure functions are determined and spin asymmetries are studied in detail.

Keywords: deep inelastic scattering, structure functions, quark-parton model, two-spin asymmetry.
PACS: 12.15.-y; 13.60.-r; 13.60.+e, 14.20.Dh

1. INTRODUCTION

The Standard Model (SM), based on a local gauge theory with a symmetry group $SU_C(3)\times SU_L(2)\times U_Y(1)$, describes well the physics of elementary particles [1, 2]. There is not a single experiment in particle physics, the results of which do not agree with the predictions of the Standard Model. One of the most accurate checks of the SM was performed at the LEP and SLC electron-positron colliders. Along with electron-positron annihilation, the processes of deep inelastic scattering of leptons by nucleons play an important role in the verification of the standard model and are currently being intensively studied theoretically and experimentally [3-11]. Experiments COMPASS, HERMES, EMC, EIC, ZEUS, carried out with polarized leptons and targets, open up new possibilities for studying the internal structure of nucleons. In [10, 11], within the framework of the quark-parton model, polarization asymmetries in the processes of deep inelastic scattering of leptons by nucleons were studied. However, in these works, the non-polarization and polarization structure functions of hadrons were not considered. In the present work, we study the production of a charged $\pi^\pm$- or $K^\pm$-hadron in deep-inelastic scattering of neutrinos (antineutrinos) by polarized nucleons:

$$\nu_\mu + N(h_N) \to \nu_\mu + h^\pm + X, \qquad (1)$$

$$\bar{\nu}_\mu + N(h_N) \to \bar{\nu}_\mu + h^\pm + X, \qquad (2)$$

where h_N – is the longitudinal polarization of the target nucleon, the $h^\pm = \pi^\pm,\ K^\pm,\ X-$ system of undetected hadrons. The non-polarization and polarization structure functions of hadrons are introduced and analytical expressions are obtained for the differential cross sections of processes (1)-(2) and spin asymmetries.

2. KINEMATIC VARIABLES OF REACTION $\nu_\mu(\bar{\nu}_\mu)N \to \nu_\mu(\bar{\nu}_\mu)h^\pm X$

The process of deep inelastic scattering of neutrinos (antineutrinos) by nucleons with the formation of a hadron h is described by the Feynman diagram shown in Fig. 1. The shaded area shows that the target nucleon has an internal structure, which is taken into account by introducing the structure functions.

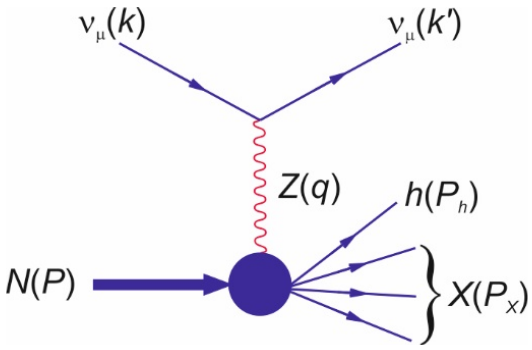

*Fig. 1.*Feynman diagram of a semi-inclusive reaction $\nu_\mu N \to \nu_\mu hX$

The semi-inclusive process $\nu_\mu + N \to \nu_\mu + h + X$ is described by the following invariant variables:

1) square of momentum transfer to hadrons

$$Q^2 = -q^2 = -(k-k')^2 \approx 4EE'\sin^2\frac{\theta}{2}, \qquad (3)$$

where $\theta-$ is the scattering angle of neutrinos, E and $E'-$ the energies of the initial and scattered neutrinos;

2) conventional kinematic variables of deep inelastic scattering

$$x = \frac{Q^2}{2(P\cdot q)},\quad y = \frac{(q\cdot P)}{(k\cdot P)}; \qquad (4)$$

3) scaling variable that determines the fraction of the energy carried away by the hadron h:

$$z = \frac{(P\cdot P_h)}{(P\cdot q)}; \qquad (5)$$

4) the square of the total energy of the neutrino and target nucleon in the center of mass system:

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$$S=(k+P)^2=\frac{Q^2}{xy}+M^2, \qquad (6)$$

where $M-$ is the nucleon mass.

In the lowest order of perturbation theory, the differential effective cross section for deep inelastic neutrino scattering (it is always left-handed) by polarized nucleons can be written in the form

$$\frac{d^3\sigma(h_N)}{dxdydz}=\frac{2\pi y\alpha^2}{Q^4}\eta_Z L_{\mu\nu}H_{\mu\nu}. \qquad (7)$$

Here

$$\eta_Z=\left(\frac{G_F M_Z^2}{2\sqrt{2}\pi\alpha}\right)^2\left(\frac{Q^2}{Q^2+M_Z^2}\right)^2, \qquad (8)$$

G_F- Fermi constant of weak interactions, M_Z – is the mass of a charged Z-boson, $L_{\mu\nu}$ and $H_{\mu\nu}$ are the neutrino and hadron tensors.

The neutrino tensor contains symmetric and anti-symmetric parts:

$$L_{\mu\nu}=8[k_\mu k'_\nu+k'_\mu k_\nu-(k\cdot k')g_{\mu\nu}-i\varepsilon_{\mu\nu\rho\sigma}k_\rho k'_\sigma]. \qquad (9)$$

3. STRUCTURE FUNCTIONS OF A NUCLEON

The hadronic tensor $H_{\mu\nu}$ contains three non-polarization (F_1, F_2 and F_3) and five polarization (g_1, g_2, g_3, g_4 and g_5) structure functions, depending on invariant variables x, z and Q^2.

$$\begin{aligned}H_{\mu\nu}&=\left(-g_{\mu\nu}+\frac{q_\mu q_\nu}{q^2}\right)F_1(x,z,Q^2)+\\&+\frac{\tilde{P}_\mu\tilde{P}_\nu}{(P\cdot q)}F_2(x,z,Q^2)-i\varepsilon_{\mu\nu\alpha\beta}\frac{q_\alpha P_\beta}{2(P\cdot q)}F_3(x,z,Q^2)+\\&+i\varepsilon_{\mu\nu\alpha\beta}\frac{q_\alpha}{(P\cdot q)}\left[S_\beta g_1(x,z,Q^2)+\left(S_\beta-\frac{(S\cdot q)}{(P\cdot q)}P_\beta\right)g_2(x,z,Q^2)\right]+\\&+\frac{1}{(P\cdot q)}\left[\frac{1}{2}(\tilde{P}_\mu\tilde{S}_\nu+\tilde{S}_\mu\tilde{P}_\nu)-\frac{(S\cdot q)}{(P\cdot q)}\tilde{P}_\mu\tilde{P}_\nu\right]g_3(x,z,Q^2)+\\&+\frac{(S\cdot q)}{(P\cdot q)}\left[\frac{\tilde{P}_\mu\tilde{P}_\nu}{(P\cdot q)}g_4(x,z,Q^2)+\left(-g_{\mu\nu}+\frac{q_\mu q_\nu}{q^2}\right)g_5(x,z,Q^2)\right]. \qquad (10)\end{aligned}$$

Here $S_\mu-$ is the 4-vector of nucleon polarization, a $\tilde{P}_\mu$ and $\tilde{S}_\mu$ are defined as:

$$\tilde{P}_\mu=P_\mu-\frac{(P\cdot q)}{q^2}q_\mu,\quad \tilde{S}_\mu=S_\mu-\frac{(S\cdot q)}{q^2}q_\mu.$$

If the target nucleon is not polarized, then the differential cross section for deep inelastic neutrino (anti-neutrino) scattering by a nucleon contains non-polarization structure functions F_1, F_2 and F_3:

$$\frac{d^3\sigma}{dxdydz}=\frac{4\pi\alpha^2}{xyQ^2}\eta_Z\left[xy^2F_1+\left(1-y-x^2y^2\frac{M^2}{Q^2}\right)F_2\pm xy\left(1-\frac{y}{2}\right)F_3\right], \qquad (11)$$

the «+» sign corresponds to neutrino scattering, and the «–» sign corresponds to antineutrino.

In the deeply inelastic region $Q^2>>M^2$, the differential cross section (11) usually takes the form

$$\frac{d^3\sigma}{dxdydz}=\frac{2\pi\alpha^2}{xyQ^2}\eta_Z\{[1+(1-y)^2]\cdot 2xF_1+[1-(1-y)^2]\cdot xF_3\pm(1-y)\cdot 2F_L\}, \qquad (12)$$

where the longitudinal structure function is:

$$F_L=F_2-2xF_1. \qquad (13)$$

If the nucleon is polarized, then the difference between the differential cross sections of reaction (1) for two values of the nucleon helicity is:

$$\frac{d^3\Delta\sigma}{dxdydz}=\frac{8\pi\alpha^2}{xyQ^2}\eta_Z\left\{\left[2-y-2x^2y^2\frac{M^2}{Q^2}\right]xyg_1+4x^3y^2\frac{M^2}{Q^2}g_2+2x^2y\frac{M^2}{Q^2}\times\right.$$

$$\times\left(1-y-x^2y^2\frac{M^2}{Q^2}\right)g_3+\left(1+2x^2y\frac{M^2}{Q^2}\right)\left[\left(1-y-x^2y^2\frac{M^2}{Q^2}\right)g_4+xy^2g_5\right]\Bigg\}. \qquad (14)$$

At $Q^2 >> M^2$, the contribution to the cross section of the polarization structure functions g_2 and g_3 vanishes:

$$\frac{d^3\Delta\sigma}{dxdydz}=\frac{8\pi\alpha^2}{xyQ^2}\eta_Z\{[1+(1-y)^2]\cdot xg_5+[1-(1-y)^2]\cdot xg_1+(1-y)g_L\}, \qquad (15)$$

where

$$g_L = g_4 - 2xg_5. \qquad (16)$$

Let us find the structure functions of hadrons in the quark-parton model. According to this model:

1) the nucleon consists of valence quarks and a quark-antiquark sea. In the region of deep-inelastic scattering, there is no interaction between partons, they behave like free particles;

2) in the Breit system, the momenta of partons are directed in the direction of the momentum of the nucleon and each parton carries a certain fraction of the momentum of the nucleon;

3) a neutral intermediate Z-boson interacts with a parton that has a fraction of the momentum of a nucleon x and transfers momentum q to it, and all other partons simply observe the process.

Parton subprocesses of deep inelastic reactions (1) and (2) are neutrino (antineutrino) quark and antiquark scattering:

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

The Feynman diagram of neutrino-quark scattering is shown in Fig. 2.

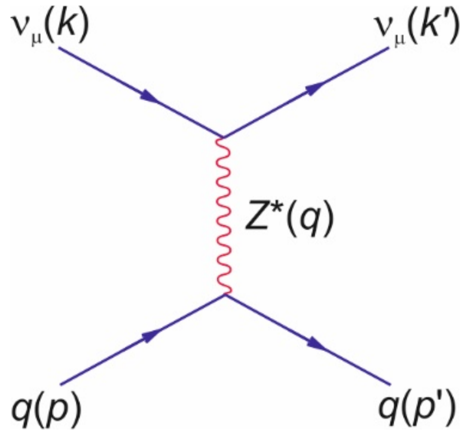

Fig. 2. Feynman diagram reaction $\nu_\mu q\to\nu_\mu q$.

Calculation of this diagram leads to the following structure functions:

$$F_1=\sum_q[g_L^2(q)+g_R^2(q)][f_q^N(x)D_q^h(z)+f_{\bar{q}}^N(x)D_{\bar{q}}^h(z)],$$

$$F_2=2x\sum_q[g_L^2(q)+g_R^2(q)][f_q^N(x)D_q^h(z)+f_{\bar{q}}^N(x)D_{\bar{q}}^h(z)],$$

$$F_3=\sum_q[g_L^2(q)-g_R^2(q)][f_q^N(x)D_q^h(z)-f_{\bar{q}}^N(x)D_{\bar{q}}^h(z)],$$

$$g_1=\sum_q[g_L^2(q)+g_R^2(q)][\Delta f_q^N(x)D_q^h(z)+\Delta f_{\bar{q}}^N(x)D_{\bar{q}}^h(z)],$$

$$g_4=2x\sum_q[g_L^2(q)-g_R^2(q)][-\Delta f_q^N(x)D_q^h(z)+\Delta f_{\bar{q}}^N(x)D_{\bar{q}}^h(z)], \qquad (17)$$

$$g_5=\sum_q[g_L^2(q)-g_R^2(q)][-\Delta f_q^N(x)D_q^h(z)+\Delta f_{\bar{q}}^N(x)D_{\bar{q}}^h(z)],$$

where $g_L(q)=\pm\frac{1}{2}-Q_q\sin^2\theta_W$ and $g_R(q)=-Q_q\sin^2\theta_W$ – are the left and right coupling constants of a quark with a Z-boson (the «±» sign corresponds to an up and down quark, respectively), $f_q^N(x)$ ($f_{\bar{q}}^N(x)$) – the distribution function of a quark q (antiquark $\bar{q}$) in a nucleon N, $D_q^h(z)$ ($D_{\bar{q}}^h(z)$) – is a function of fragmentation of a quark q (antiquark $\bar{q}$) into a hadron h, $\Delta f_q^N(x)=f_q^+(x)-f_q^-(x)$, ($\Delta f_{\bar{q}}^N(x)=f_{\bar{q}}^+(x)-f_{\bar{q}}^-(x)$), $f_q^+(x)$ ($f_{\bar{q}}^+(x)$)

and $f_q^-(x)$ ($f_{\bar q}^-(x)$) – determines the distribution of a quark q (antiquark $\bar q$) with positive and negative helicity in a nucleon with positive helicity.

In the quark-parton model, there are connections between the structure functions:

$$F_L = F_2 - 2xF_1 = 0, \quad g_L = g_4 - 2xg_5 = 0.$$

Thus, as in the case of non-polarization structure functions F_1 and F_3, there are only two polarization structure functions g_1 and g_5. Of these, F_1 and g_1 they preserve P-parity, a F_3 and g_5 – violate.

In the quark-parton model, the structure functions are only functions of the invariants x and z, and they do not depend on the square of the momentum transfer Q^2. This property is due to the fact that in the Breit system the transverse momenta of partons are very small. In quantum chromodynamics, the emission of hard gluons by quarks leads to a logarithmic violation of scaling. As the Q^2 increases, the number of emitted gluons increases, which leads to an increase in $q\bar q$-quark pairs and the gluon distribution density.

In deep inelastic scattering of neutrinos (antineutrinos) by a polarized nucleon target, the main observables are the two-spin asymmetries

$$A_N^{h\pm} = \frac{\sigma_{\uparrow\uparrow}^{h^\pm} - \sigma_{\uparrow\downarrow}^{h^\pm}}{\sigma_{\uparrow\uparrow}^{h^\pm} + \sigma_{\uparrow\downarrow}^{h^\pm}}, \tag{18}$$

$$A_N^{h^+-h^-} = \frac{(\sigma_{\uparrow\uparrow}^{h^+} - \sigma_{\uparrow\uparrow}^{h^-}) - (\sigma_{\uparrow\downarrow}^{h^+} - \sigma_{\uparrow\downarrow}^{h^-})}{(\sigma_{\uparrow\uparrow}^{h^+} - \sigma_{\uparrow\uparrow}^{h^-}) + (\sigma_{\uparrow\downarrow}^{h^+} - \sigma_{\uparrow\downarrow}^{h^-})}, \tag{19}$$

where $\sigma_{\uparrow\uparrow}^h$ and $\sigma_{\uparrow\downarrow}^h$ are the differential cross sections for the production of a semi-inclusive hadron h in the parallel (antiparallel) direction of the spins of the neutrino or antineutrino and the target nucleon.

The two-spin asymmetries $A_N^{h^+}$ and $A_N^{h^-}$ depend both on the distribution functions of quarks in a nucleon and on the functions of fragmentation of quarks into a hadron h.

For example, if we neglect the contribution of sea quarks, then for the asymmetry in the scattering of neutrinos on an isoscalar target, we can obtain the formula:

4. SPIN ASYMMETRIES

$$A_d^{\pi^+} = \frac{\Delta u_\upsilon(x) + \Delta d_\upsilon(x)}{u_\upsilon(x) + d_\upsilon(x)} \frac{D_u^{\pi^+}(z)[g_L^2(u) - (1-y)^2 g_R^2(u)] + D_d^{\pi^+}(z)[g_L^2(d) - (1-y)^2 g_R^2(d)]}{D_u^{\pi^+}(z)[g_L^2(u) + (1-y)^2 g_R^2(u)] + D_d^{\pi^+}(z)[g_L^2(d) + (1-y)^2 g_R^2(d)]}. \tag{20}$$

Here $u_\upsilon(x)$ and $d_\upsilon(x)$ – are the distribution functions of valence u- and d-quarks in a proton. Under the condition $y \to 1$, spin asymmetry (20) depends only on the distribution functions of valence u- and d-quarks in the proton:

$$A_d^{\pi^+}(y \to 1) = \frac{\Delta u_\upsilon(x) + \Delta d_\upsilon(x)}{u_\upsilon(x) + d_\upsilon(x)}. \tag{21}$$

Another two-spin asymmetry $A_N^{h^+-h^-}$ does not depend on the functions of quark fragmentation into a hadron h; they are the distribution functions of quarks in a nucleon (the contribution of sea quarks is not taken into account):

$$A_p^{\pi^+-\pi^-} = -\frac{\Delta u_\upsilon(x)[g_L^2(u) - (1-y)^2 g_R^2(u)] - \Delta d_\upsilon(x)[g_L^2(d) - (1-y)^2 g_R^2(d)]}{u_\upsilon(x)[g_L^2(u) + (1-y)^2 g_R^2(u)] + d_\upsilon(x)[g_L^2(d) + (1-y)^2 g_R^2(d)]}, \tag{22}$$

$$A_p^{K^+-K^-} = -\frac{\Delta u_\upsilon(x)[g_L^2(u) - (1-y)^2 g_R^2(u)]}{u_\upsilon(x)[g_L^2(u) + (1-y)^2 g_R^2(u)]}. \tag{23}$$

Under the condition $y \to 1$, the asymmetry $A_p^{K^+-K^-}$ depends only on the distribution functions of the valence u-quark in the proton

$$A_p^{K^+-K^-} = -\frac{\Delta u_\upsilon(x)}{u_\upsilon(x)}. \tag{24}$$

We have obtained expressions for the two-spin asymmetries $A_p^{\pi^+-\pi^-}$ и $A_p^{K^+-K^-}$ in processes $\nu_\mu + p \to \nu_\mu + \pi^\pm + X$ and $\nu_\mu + p \to \nu_\mu + K^\pm + X$ taking into account the contribution of sea quarks (integrated over the variable y):

$$A_p^{\pi^+-\pi^-}(\nu_\mu p) = \{\Delta u_\upsilon(x)[3g_L^2(u) - g_R^2(u)] - \Delta d_\upsilon(x)[3g_L^2(d) - g_R^2(d)] + 4\Delta u_s(x)[g_L^2(u) - g_R^2(u)] -$$

$$-4\Delta d_s(x)[g_L^2(d)-g_R^2(d)]\}\quad \{u_\upsilon(x)[3g_L^2(u)+g_R^2(u)]-d_\upsilon(x)[3g_L^2(d)+g_R^2(d)]+ + 2u_s(x)[g_L^2(u)-g_R^2(u)]-2d_s(x)[g_L^2(d)-g_R^2(d)]\}^{-1}; \quad (25)$$

$$A_p^{K^+-K^-}=\{\Delta u_\upsilon(x)[3g_L^2(u)-g_R^2(u)]+4\Delta u_s(x)[g_L^2(u)-g_R^2(u)]-4\Delta s(x)[g_L^2(u)-g_R^2(u)]\}\times \times\{u_\upsilon(x)[3g_L^2(u)+g_R^2(u)]+2u_s(x)[g_L^2(u)-g_R^2(u)]-2s(x)[g_L^2(d)-g_R^2(d)]\}^{-1}, \quad (26)$$

here $u_\upsilon(x)$, $d_\upsilon(x)$ and $s_s(x)$ – distribution function of valence u -, d - and sea s -quarks in a proton.

Formulas for asymmetries $A_p^{\pi^+-\pi^-}$ and $A_p^{K^+-K^-}$ in the processes of deep inelastic scattering of antineutrinos $\bar{\nu}_\mu + p \to \bar{\nu}_\mu + \pi^\pm + X$ and $\bar{\nu}_\mu + p \to \bar{\nu}_\mu + K^\pm + X$ are obtained from (25) and (26) by simple changes $g_L \leftrightarrow g_R$.

5. ANALYSIS OF THE OBTAINED RESULTS

We pass to the estimation of the spin asymmetries $A_N^{h^\pm}$ and $A_N^{h^+-h^-}$. For this purpose, we used the distribution functions of quarks in a proton given in [4, 12, 13]

In fig. 3 shows the dependence of the asymmetry $A_d^{\pi^+}(y\to 1)$ (formula (21)) on the variable x. As follows from the figure, this asymmetry is positive and monotonically increases with increasing variable x. With $x=0.1$ the asymmetry is 10%, and with $x=0.9$ the value it reaches 90%.

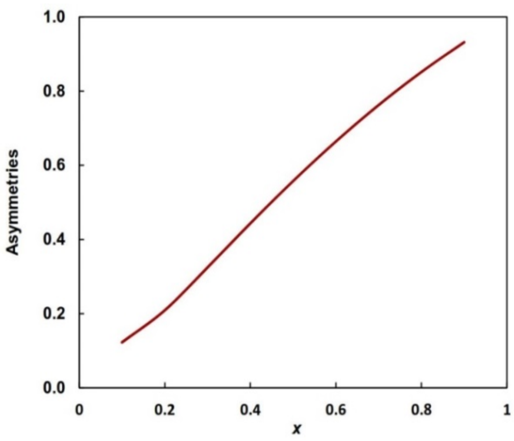

Fig. 3. Dependence of asymmetry $A_d^{\pi+}$ on variable x.

Fig. 4 illustrates the dependence of the two-spin asymmetry $A_p^{K^+-K^-}$ in processes $\nu_\mu + p \to \nu_\mu + K^\pm + X$ on the variable x at various fixed values y: $y=0.1$ (curve 1), $y=0,4$ (curve 2), and $y=0,4$ (curve 3). As you can see, with an increase in the variable x, the asymmetry first sharply decreases and, reaching a minimum near it $x\approx 0,2$, begins to grow. The graphs plotted at the Weinberg parameter $\sin^2\theta_W=0.232$ value. The figure also shows that an increase in the variable y leads to an increase in the two-spin asymmetry $A_p^{K^+-K^-}$.

In fig. 5 shows the dependence of asymmetry $A_p^{K^+-K^-}$ in processes $\nu_\mu + p \to \nu_\mu + K^\pm + X$ and $\bar{\nu}_\mu + p \to \bar{\nu}_\mu + K^\pm + X$ on a variable x. In the process $\nu_\mu + p \to \nu_\mu + K^\pm + X$, the asymmetry is positive and increases with the growth of the variable x. In the process $\bar{\nu}_\mu + p \to \bar{\nu}_\mu + K^\pm + X$, the asymmetr is negative and an increase x leads to a decrease in asymmetry.

CONCLUSION

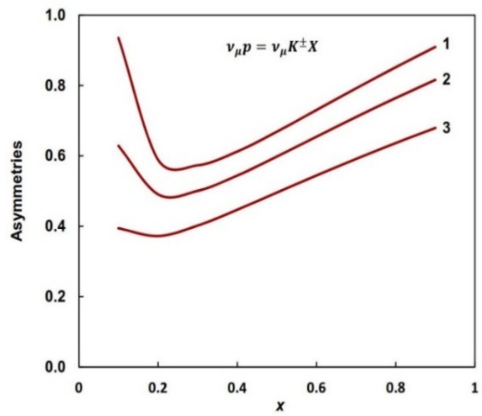

Fig. 4. Dependence of asymmetry $A_p^{K^+-K^-}(\nu_\mu p)$ at x.

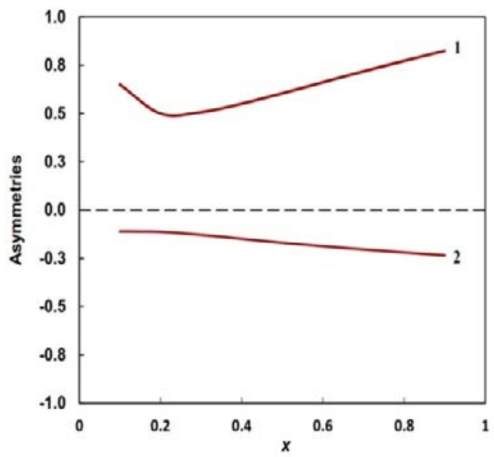

Fig. 5. Dependence of asymmetry $A_p^{K^+-K^-}$ on variable x in reactions $\nu_\mu p \to \nu_\mu K^\pm X$ (curve 1) and $\bar{\nu}_\mu p \to \bar{\nu}_\mu K^\pm X$ (curve 2).

By introducing non-polarization and polayrization structure functions, differential cross sections of deep inelastic processes $\nu_\mu + N \to \nu_\mu + h^\pm + X$ and $\overline{\nu}_\mu + N \to \overline{\nu}_\mu + h^\pm + X$ obtained. Two-spin asymmetries $A_N^{h^+}$, $A_N^{h^-}$ and $A_N^{h^+-h^-}$ are determined. In the quark-parton model, structure functions found, and the dependence of two-spin asymmetries on the invariant variable x is investigated. The results illustrated with graphs.

[1] *J. Beringer et al.* (Particle Data Group Collaboration). 2012, Phys. Rev., D 86, 010001.

[2] *S.K. Abdullaev.* Standard model, properties of leptons and quarks (in Azerb.). Baku, Zeka Print, 2017, 276 p.

[3] *P.J. Mulders.* Polarized structure functions. Progress in Particle and Nuclear Physics, 2005, №55, p.243-269.

[4] *D. De Florian, G.A. Navarro, R. Sassot.* Sea quarks and gluon polarization in the nucleon at NLO accuracy. Phys. Rev., 2005, v. D 71, 094018, p. 1-12

[5] *Y. Koike, J. Nagashima.* Double spin asymmetries for large-p_T hadron production in semi-inclusive DIS. arxiv: hep-ph/0302061, 2003, v.2, p.1-25.

[6] *I.A. Savin.* COMPASS results on the nucleon spin structure. Nuclear Physics B (Proceedings Supplements), 2011, 219-220, 94-101pp.

[7] *K. Nikolayev.* The polarized valence quark distribution from COMPASS. Spin-Praha-2007.

[8] HERMES Collaboration. Quark helicity distributions in the nucleon for up, down, and strange quarks from semi-inclusive deep-inelastic scattering. Phys. Rev., 2005, D71, p. 012003.

[9] COMPASS Collaboration *(Alexakhin, V.Yu. et al.)* The Deuteron Spin-dependent Structure Function g_1(d) and its First Moment Phys. Lett., 2007, B 647, p. 8-17.

[10] *S.K. Abdullayev.* Double-spin asymmetries in semi-inclusive DIS // Azerbaijan Journal of Physics, Fizika, Baku, 2013, V. XIX, №3, p.19-24.

[11] *S.K. Abdullayev, A.I. Mukhtarov, M.Sh. Gojayev.* Double-spin asymmetries in semi-inclusive DIS Azerbaijan Journal of Physics, Fizika, Baku, 2009, V. XV, №1, p.61-67.

[12] *D. De Florian, G.A. Navarro, R. Sassot.* Sea quarks and gluon polarization in the nucleon at NLO accuracy Phys. Rev., 2005, D71, p.094018-1-12.

[13] *D. De Florian, R. Sassot, M. Stratmann.* Global analysis of fragmentation functions for pions and kaons and their uncertainties Phys. Rev. 2007, v. D 75, p. 114010.

Received:19.10.2020