# THE POLARIZATION OF *B*-BARYON IN HALF-INCLUSIVE REACTIONS $\nu_\mu(\bar{\nu}_\mu)N \Rightarrow \nu_\mu(\bar{\nu}_\mu)BX$

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The investigation of the longitudinal polarization degree of $\Lambda^0$-hyperon in half-inclusive reactions $\nu_\mu(\bar{\nu}_\mu)N \Rightarrow \nu_\mu(\bar{\nu}_\mu)\Lambda X$ has been carried out within framework of the standard theory and quark parton model. The expression for the longitudinal polarization degree of $\Lambda^0$-hyperon has been obtained.

As it is known, the weak neutral currents (WNC) firstly are observed experimentally in the processes of the deep-inelastic scattering (DIC) of neutrino and anti-neutrino on nucleons $\nu_\mu(\bar{\nu}_\mu) + N \Rightarrow \nu_\mu(\bar{\nu}_\mu) + X$. The study of these and others lepton-nucleon's processes allows us to obtain the information about structure of WNC leptons and hadrons, about distribution functions of quarks and gluons in the nucleons.

Last time the new process class, which is the half-inclusive hadron creation in DID of polarized leptons on polarized nucleons $l^{\mp} + N \Rightarrow l^{\mp} + h + X$ is widely discussed [1-6]. The study of these processes is the source of the information about functions of distribution and fragmentation of polarized quarks and gluons.

Here the processes of half-inclusive creation of polarized *B*-baryon in DID of neutrino and anti-neutrino on polarized nucleons

$$\nu_\mu + N(h_N) \Rightarrow \nu_\mu + B(h_B) + X, \quad (1)$$

$$\bar{\nu}_\mu + N(h_N) \Rightarrow \bar{\nu}_\mu + B(h_B) + X, \quad (2)$$

where $h_N$ and $h_B$ are longitudinal polarizations of nucleon-target and baryon *B*. Within framework of quark-parton model the differential cross-section of half-inclusive reaction (1) can be written in the following form:

$$\frac{d\sigma(\nu_\mu N)}{dxdydz} = \sum_{q,h_q} f_{q(h_q)}^{N(h_N)}(x) \frac{d\hat{\sigma}(\nu_\mu q)}{dy} D_{q(h_q)}^{B(h_B)}(z), \quad (3)$$

where $f_{q(h_q)}^{N(h_N)}(x)$ is distribution function of polarized quark in polarized nucleon, $D_{q(h_q)}^{B(h_B)}(z)$ is fragmentation function of polarized quark in polarized baryon *B*, $\frac{d\hat{\sigma}(\nu_\mu q)}{dy}$ is differential cross-section of elementary processes $\nu_\mu + q \Rightarrow \nu_\mu + q$, $\nu_\mu + \bar{q} \Rightarrow \nu_\mu + \bar{q}$, $x$, $y$, and $z$ -usual kinematic variables of DID. As quarks' spirality conserves in neglect of its masses, then the elementary subprocess $\nu_\mu + q \Rightarrow \nu_\mu + q$ ($\bar{\nu}_\mu + q \Rightarrow \bar{\nu}_\mu + q$) is defined only by two spiral amplitudes $F_{LL}$ and $F_{LR}$ ($F_{RL}$ and $F_{RR}$,) which describe the following reactions:

$$\nu_L + q_L \Rightarrow \nu_L + q_L \; (\bar{\nu}_R + q_L \Rightarrow \bar{\nu}_R + q_L), \; \nu_L + q_R \Rightarrow \nu_L + q_R \; (\bar{\nu}_R + q_R \Rightarrow \bar{\nu}_R + q_R).$$

Index *L* or *R* means, that quark is left or right particle, but neutrino (anti-neutrino) is always left (right) particle. The spiral amplitudes in model of Weinberg-Salam are defined by the following expressions:

$$F_{LR} = F_{RR} = \frac{-Q_q x_W}{2x_W(1-x_W)},$$

$$F_{LL} = F_{RL} = \frac{T_3 - Q_q x_W}{2x_W(1-x_W)},$$

where $T_3$ is projection of weak isospin of q quark, *q*, $Q_q$ is its charge and $x_W = sin^2\theta_W$ is Weinberg parameter.

The square of amplitude of the process $\nu_L + q_L \Rightarrow \nu_L + q_L$ ($\bar{\nu}_R + q_R \Rightarrow \bar{\nu}_R + q_R$) leads to the isotropic distribution; the differential cross-section of the process doesn't depend on the dispersion angle of neutrino (anti-neutrino) in c.m. system. The square of amplitude of the reaction $\nu_L + q_R \Rightarrow \nu_L + q_R$ ($\bar{\nu}_R + q_L \Rightarrow \bar{\nu}_R + q_L$) leads to $(1-y)^2$ dependence of differential cross-section. This difference connects with the value of total spirality of neutrino (anti-neutrino)-quark system: the total spirality is equal to zero for collisions $\nu_L q_L$ and $\bar{\nu}_R q_R$, and the total spirality is equal to unit for collisions $\nu_L q_R$ and. $\bar{\nu}_R q_L$.

Let's present 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:

$$\frac{d\sigma(\nu_L q_L)}{dy}=\frac{d\sigma(\bar{\nu}_R\bar{q}_R)}{dy}=\frac{4\pi\alpha^2}{xs}\frac{1}{\left(y+M_z^2/xs\right)^2}F_{LL}^2,$$

$$\frac{d\sigma(\nu_L q_R)}{dy}=\frac{d\sigma(\bar{\nu}_R\bar{q}_L)}{dy}=\frac{4\pi\alpha^2}{xs}\frac{1}{\left(y+M_z^2/xs\right)^2}F_{LR}^2(1-y)^2,$$

$$\frac{d\sigma(\nu_L \bar{q}_L)}{dy}=\frac{d\sigma(\bar{\nu}_R\bar{q}_R)}{dy}=\frac{4\pi\alpha^2}{xs}\frac{1}{\left(y+M_z^2/xs\right)^2}F_{LL}^2,$$

$$\frac{d\sigma(\nu_L \bar{q}_R)}{dy}=\frac{d\sigma(\bar{\nu}_R q_L)}{dy}=\frac{4\pi\alpha^2}{xs}\frac{1}{\left(y+M_z^2/xs\right)^2}F_{LR}^2(1-y)^2. \quad (5)$$

Here $M_Z$ is $Z^0$-boson mass, $\sqrt{s}$ is sum energy of neutrino-nucleon in their c.m. system .

The differential cross-section of the elementary subprocess $\nu_\mu+q\Rightarrow\nu_\mu+q$ taking into consideration the spiralities of initial and final quarks $h_q$ and $h'_q$ can be presented in the form:

$$\frac{d\sigma(\nu_\mu q)}{dy}=\frac{\pi\alpha^2}{xs}\frac{1}{\left(y+M_z^2/xs\right)^2}\left[(1-h_q)(1-h'_q)F_{LL}^2+(1+h_q)(1+h'_q)(1-y)^2F_{LR}^2\right]. \quad (6)$$

The differential cross-section of subprocess $\nu_\mu+\bar{q}\Rightarrow\nu_\mu+\bar{q}$ can be obtained from formula (6) with the help of the replacements $F_{LL}\Leftrightarrow F_{LR}$.

The following expressions have been obtained on the base of formulas (3) and (6) for the differential cross-sections of half-inclusive reactions: $\nu_\mu+N\Rightarrow\nu_\mu+B+X$, $\bar{\nu}_\mu+N\Rightarrow\bar{\nu}_\mu+B+X$ :

$$\frac{d\sigma(\nu_\mu N\Rightarrow\nu_\mu BX)}{dxdydz}=\frac{\pi\alpha^2}{xs}\frac{1}{\left(y+M_z^2/xs\right)^2}\sum_q\Big\{\left[f_q^N(x)D_q^B(z)+h_Nh_B\Delta f_q^N(x)\Delta D_q^B(z)\right]\times$$
$$\times\left[F_{LL}^2+(1-y)^2F_{LR}^2\right]+\left[h_N\Delta f_q^N(x)D_q^B(z)+h_Bf_q^N(x)\Delta D_q^B(z)\right]\left[(1-y)^2F_{LR}^2-F_{LL}^2\right]+ \quad, \quad (7)$$
$$+\left[f_{\bar{q}}^N(x)D_{\bar{q}}^B(z)+h_Nh_B\Delta f_{\bar{q}}^N(x)\Delta D_{\bar{q}}^B(z)\right]\left[F_{LR}^2+(1-y)^2F_{LL}^2\right]+\left[h_N\Delta f_{\bar{q}}^N(x)D_{\bar{q}}^B(z)+\right.$$
$$\left.+h_Bf_{\bar{q}}^N(x)\Delta D_{\bar{q}}^B(z)\right]\left[(1-y)^2F_{LL}^2-F_{LR}^2\right]\Big\}$$

$$\frac{d\sigma(\bar{\nu}_\mu N\Rightarrow\bar{\nu}_\mu BX)}{dxdydz}=\frac{\pi\alpha^2}{xs}\frac{1}{\left(y+M_z^2/xs\right)^2}\sum_q\Big\{\left[f_q^N(x)D_q^B(z)+h_Nh_B\Delta f_q^N(x)\Delta D_q^B(z)\right]\times$$
$$\times\left[F_{RR}^2+(1-y)^2F_{RL}^2\right]+\left[h_N\Delta f_q^N(x)D_q^B(z)+h_Bf_q^N(x)\Delta D_q^B(z)\right]\left[(1-y)^2F_{RR}^2-F_{RL}^2\right]+ \quad, \quad (8)$$
$$+\left[f_{\bar{q}}^N(x)D_{\bar{q}}^B(z)+h_Nh_B\Delta f_{\bar{q}}^N(x)\Delta D_{\bar{q}}^B(z)\right]\left[F_{RL}^2+(1-y)^2F_{RR}^2\right]+\left[h_N\Delta f_{\bar{q}}^N(x)D_{\bar{q}}^B(z)+\right.$$
$$\left.+h_Bf_{\bar{q}}^N(x)\Delta D_{\bar{q}}^B(z)\right]\left[(1-y)^2F_{RL}^2-F_{RR}^2\right]\Big\}$$

where

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

$$D_q^B(z) = D_{q(+1)}^{B(+1)}(z) + D_{q(-1)}^{B(+1)}(z) \ , \quad \Delta D_q^B(z) = D_{q(+1)}^{B(+1)}(z) - D_{q(-1)}^{B(+1)}(z),$$

$f_q^N(x)$ and $D_q^B(z)$ are present themselves the usual quark distribution function in nucleon and quark fragmentation function in $B$ baryon, the summation on $q$ is carried out on all quarks and anti-quarks, which are present in $N$ nucleon.

Here we are interested in the longitudinal polarization degree of inclusive $B$ baryon

$$P_B(h_N) = \frac{d\sigma(h_N; h_B = 1) - d\sigma(h_N; h_B = -1)}{d\sigma(h_N; h_B = 1) + d\sigma(h_N; h_B = -1)}, \quad (9)$$

which can be measured on the angle distribution of decay products in $B \Rightarrow N + \pi$ reaction. Neglecting the contribution of anti-quarks, we have the following expression for the longitudinal polarization degree of baryon:

1) in $\nu_\mu + N \Rightarrow \nu_\mu + B + X$ reaction

$$P_B(h_N) = \frac{\sum_q \left\{ f_q^N(x)\left[(1-y)^2 F_{LR}^2 - F_{LL}^2\right] + h_N \Delta f_q^N(x)\left[F_{LL}^2 + (1-y)^2 F_{LR}^2\right]\right\} \Delta D_q^B(z)}{\sum_q \left\{ f_q^N(x)\left[F_{LL}^2 + (1-y)^2 F_{LR}^2\right] + h_N \Delta f_q^N(x)\left[(1-y)^2 F_{LR}^2 - F_{LL}^2\right]\right\} \Delta D_q^B(z)}, \quad (10)$$

2) in $\bar{\nu}_\mu + N \Rightarrow \bar{\nu}_\mu + B + X$ reaction

$$\bar{P}_B(h_N) = \frac{\sum_q \left\{ f_q^N(x)\left[F_{RR}^2 - (1-y)^2 F_{RL}^2\right] + h_N \Delta f_q^N(x)\left[F_{RR}^2 + (1-y)^2 F_{RL}^2\right]\right\} \Delta D_q^B(z)}{\sum_q \left\{ f_q^N(x)\left[F_{RR}^2 + (1-y)^2 F_{RL}^2\right] + h_N \Delta f_q^N(x)\left[F_{RR}^2 - (1-y)^2 F_{RL}^2\right]\right\} \Delta D_q^B(z)}. \quad (11)$$

The phenomenological parameters: quark distribution functions in polarized nucleons and fragmentation functions of polarized quark in polarized baryon $B$, the values of which are defined from the experiment, present in the expression of longitudinal polarization degree of baryon (10) and (11). The set of collections of quark distribution functions in nucleons are present in references [7-10]. The distribution functions of valent and sea polarized quarks in nucleons, mentioned in the ref [7] are used by us for the numerical estimations of polarizations of baryons (10) and (11).

The longitudinal polarization degrees of $\Lambda^0$ –hyperons in half-inclusive reactions $\nu_\mu + P \Rightarrow \nu_\mu + \Lambda^0 + X$ and $\bar{\nu}_\mu + P \Rightarrow \bar{\nu}_\mu + \Lambda^0 + X$ at the energy $\sqrt{s} = 9{,}6$ GeV (experiment NOMAD in CERN), Weinberg parameter $sin^2\theta_W$=0.232 have been calculated by us.

According to refs. [4,10], fragmentation functions of polarized quarks in polarized $\Lambda^0$ –hyperon are parameterized in the form

$$\Delta D_S^\Lambda(z,Q^2) = z^\alpha D_S^\Lambda(z,Q^2),$$
$$\Delta D_U^\Lambda(z,Q^2) = \Delta D_d^\Lambda(z,Q^2) = N_U \Delta D_S^\Lambda(z,Q^2),$$

And parameters $\alpha$ and $N_U$ are chosen as follows:

| Parameter | Variant 1 | Variant 2 | Variant 3 |
|---|---|---|---|
| $\alpha$ | 0.62 | 0.27 | 1.66 |
| $N_U$ | 0 | -0.2 | 1 |

The dependence of longitudinal polarization degree of $\Lambda^0$-hyperon in $\nu_\mu + P \Rightarrow \nu_\mu + \Lambda^0 + X$ reaction on variables $x$ ,$y$ or $z$ is given on the fig.1. As it is seen, in variant 1 longitudinal polarization degree of $\Lambda^0$-hyperon is small and almost doesn't depend on $x$, $y$ or $z$ (curves 1 on the figures). In variant 2 (curves 2 on the figures) the $\Lambda^0$-hyperon polarization is positive, and in variant 3 it increases on module with $x$, $y$ or $z$ increase. The analogical behavior of longitudinal polarization degree of $\Lambda^0$-hyperon is observed in the $\bar{\nu}_\mu + N \Rightarrow \bar{\nu}_\mu + \Lambda^0 + X$ reaction (see fig.2, where the dependence of longitudinal polarization degree of $\Lambda^0$-hyperon in $\bar{\nu}_\mu + P \Rightarrow \bar{\nu}_\mu + \Lambda^0 + X$ process on $x$, $y$ or $z$).

If nucleon-target isn't polarized, then longitudinal polarization degree of $B$ baryon is given by the expression:

1) in $\nu_\mu + N \Rightarrow \nu_\mu + B + X$ reaction

$$P_B = \frac{\sum_q \left\{ f_q^N(x)\Delta D_q^B(z)\left[(1-y)^2 F_{LR}^2 - F_{LL}^2\right]\right\}}{\sum_q \left\{ f_q^N(x) D_q^B(z)\left[F_{LL}^2 + (1-y)^2 F_{LL}^2\right]\right\}} \quad (13)$$

2) in $\bar{\nu}_\mu + N \Rightarrow \bar{\nu}_\mu + B + X$ reaction

$$\bar{P}_B = \frac{\sum_q \left\{ f_q^N(x)\Delta D_q^B(z)\left[F_{RR}^2 - (1-y)^2 F_{RL}^2\right]\right\}}{\sum_q \left\{ f_q^N(x) D_q^B(z)\left[F_{RR}^2 + (1-y)^2 F_{RL}^2\right]\right\}}. \quad (14)$$

The fig. 3(4) illustrates the dependence of longitudinal polarization degree of $\Lambda^0$-hyperon in $\nu_\mu + P \Rightarrow \bar{\nu}_\mu + \Lambda^0 + X$ ($\bar{\nu}_\mu + P \Rightarrow \bar{\nu}_\mu + \Lambda^0 + X$) process on $x$, $y$ or $z$.

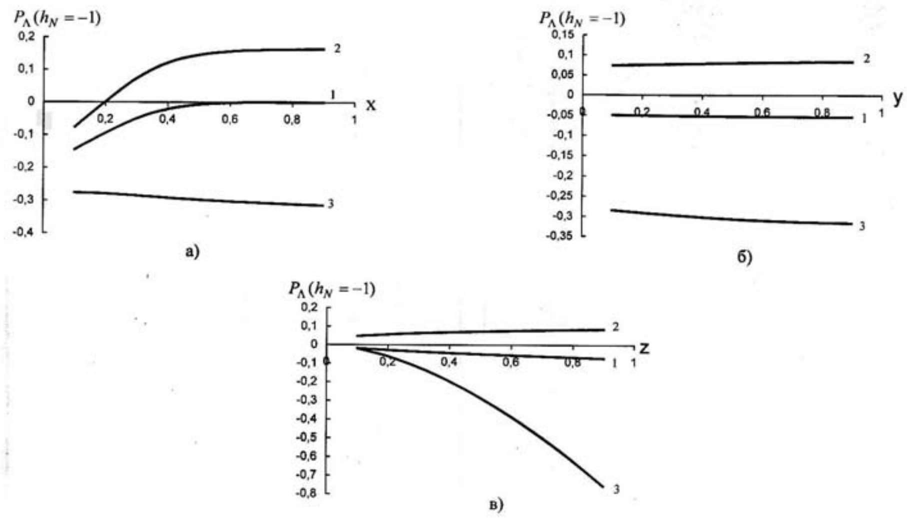


*Fig.1.* The dependence of longitudinal polarization degree $P_\Lambda(h_N=-1)$ on *x* at *y*=0,1 and *z*=0,5(a); on *y* at *x*=0,3 and *z*=0,5(b); on *z* at *x*=0,3 and *y*=0,1(c).

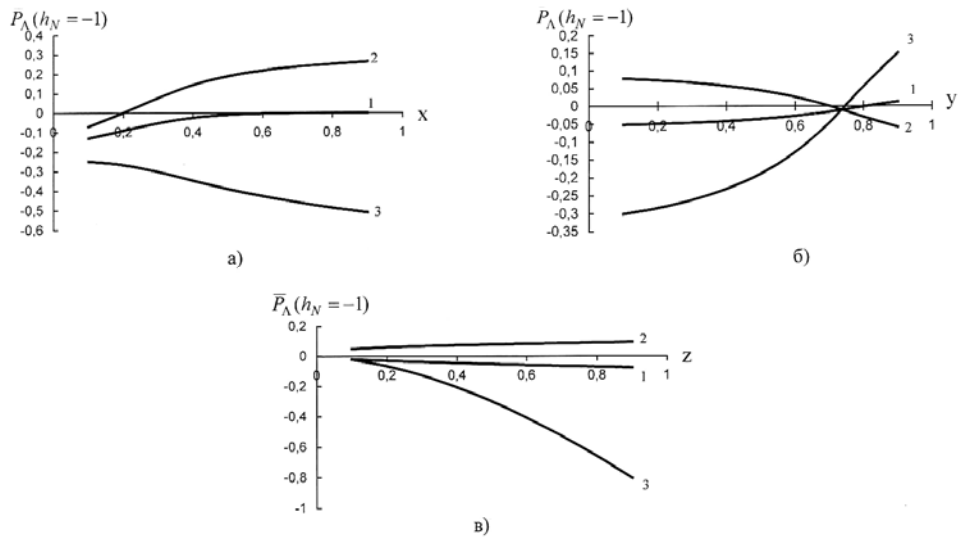


*Fig.2.* The dependence of longitudinal polarization degree $\overline{P}_\Lambda(h_N=-1)$ on *x* at *y*=0,1 and *z*=0,5(a); on y at *x*=0,3 and *z*=0,5(b); on *z* at *x*=0,3 and *y*=0,1(c).

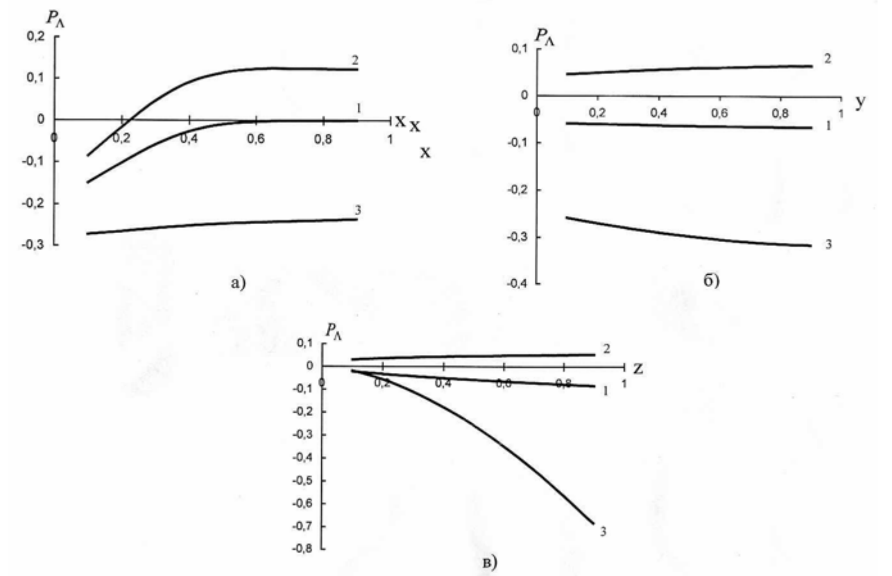


*Fig.3.* The dependence of longitudinal polarization $P_\Lambda$ on *x* at *y*=0,1 and *z*=0,5(a); on *y* at *x*=0,3 and *z*=0,5(b); on *z* at *x*=0,3 and *y*=0,1(c).

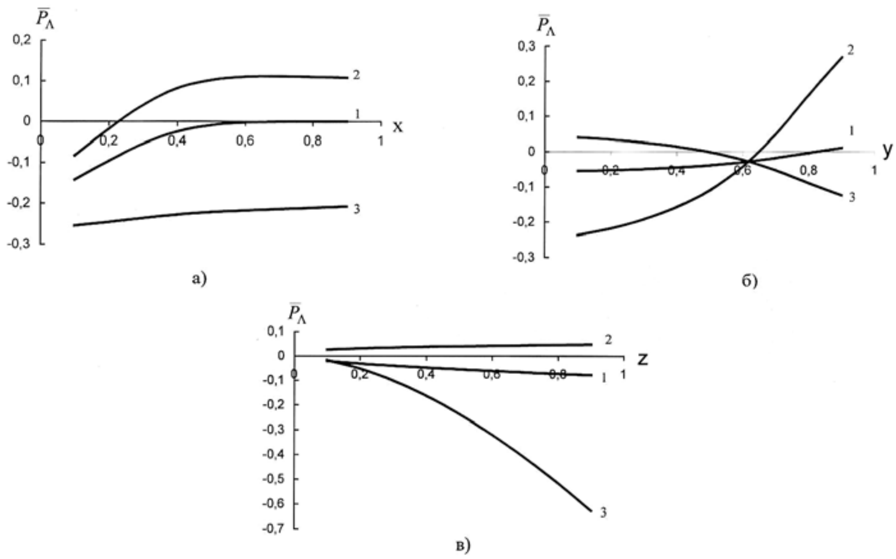


*Fig.4.* The dependence of longitudinal polarization degree $\overline{P}_\Lambda$ *x* at *y*=0,1 and *z*=0,5(a); on *y* at *x*=0,3 and *z*=0,5(b); on *z* at *x*=0,3 and *y*=0,1(c).


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## YARIMİNKLÜZİV $\nu_\mu(\bar{\nu}_\mu)N \Rightarrow \nu_\mu(\bar{\nu}_\mu)BX$ PROSESLƏRİNDƏ *B*-BARİONUN POLYARİZASİYASI

Standart nəzəriyyə çərçivəsində və kvark-parton modeltndə yarıminklüziv $\nu_\mu P \Rightarrow \nu_\mu \Lambda^0 X$ və $\bar{\nu}_\mu P \Rightarrow \bar{\nu}_\mu \Lambda^0 X$ proseslərində $\Lambda^0$-hiperonun uzununa polyarizasiya dərəcəsi hesablanmış və onun *x,y* və *z*- dəyişənlərindən asılılığı öyrənilmişdir.

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## ПОЛЯРИЗАЦИЯ *B*-БАРИОНА В ПОЛУИНКЛЮЗИВНЫХ РЕАКЦИЯХ $\nu_\mu(\bar{\nu}_\mu)N \Rightarrow \nu_\mu(\bar{\nu}_\mu)BX$

В рамках стандартной теории и в кварк партонной модели проведено исследование степени продольной поляризации $\Lambda^0$-гиперона в полуинклюзивных реакциях $\nu_\mu(\bar{\nu}_\mu)N \Rightarrow \nu_\mu(\bar{\nu}_\mu)\Lambda X$ . Получено выражение для степени продольной поляризации $\Lambda^0$-гиперона.

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