P-ODD ASYMMETRIES IN DEEP INELASTIC SCATTERINGS OF POLARIZED LEPTONS ON NUCLEI

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(Received July 1, 1985; revised version received October 10, 1985)

The P-odd asymmetries in deep inelastic scatterings (DIS) of polarized leptons on nuclei are considered in the framework of the standard model and the parton-flucton model (Tran Huu Phat, Le Si Hoi, Tran Duy Khuong, *Acta Phys. Austriaca* **57**, 33 (1985)). The model predictions, within the experimental errors, agree well with the present data.

PACS numbers: 13.60.Hb

In the last decade the consideration of spin dependent quantities has been developed intensively [2, 3] because the experimental as well as theoretical study of various spin asymmetries would clear up the deep structure of matter. Moreover, it is important to consider the contribution of nuclear effects, such as cumulation [4] and the distortion of the quark distributions of nucleons bound in nucleus [5], to the spin effect. In this respect, it is worth to investigate DIS of polarized leptons on nuclei,

$$l^- + A \to l^- + X, \tag{A}$$

$$l^+ + A \to l^+ + X. \tag{B}$$

Considering these processes the authors of the papers [6, 7] do not take into account the nuclear effect. Recently, Szwed and coworkers [8] proposed the polarized EMC ratio to testify the validity of various nuclear models.

Our model developed in [1, 9, 10] explained rather well the basic features of deep inelastic lepton-nucleus scatterings, such as the Q-dependence of the nuclear structure functions [1, 9] and the EMC effect [10]. The main aim of this paper is to consider the influence of the nuclear effect on the asymmetries of nuclear reactions at high energies.

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As is well known, the Lagrangian of the weak interactions in the standard model reads

$$\mathscr{L} = i\frac{g}{2}\cos\theta_W J^0_\alpha Z_\alpha, \tag{1.1}$$

where J^0_α is the weak current,

$$J^0_\alpha = \sum_{l=e,\mu} \bar{l}\gamma_\alpha(g_V+\gamma_5 g_A)l + J^z_\alpha, \tag{1.2}$$

$$g_V = -\tfrac{1}{3}+2\sin^2\theta_W, \quad g_A = -\tfrac{1}{2},$$

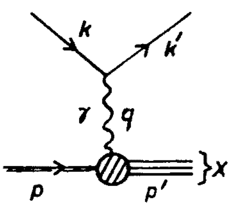
J^z_α is neutral current of hadrons,

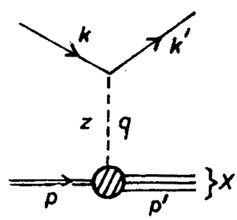
$$J^z_\alpha = \underset{q=u,d,\dots}{\mathrm{G}} \bar{q}\gamma_\alpha(\vartheta_q+a_q\gamma_5)q \tag{1.3}$$

$$\vartheta_u = \vartheta_c = \vartheta_t = \tfrac{1}{2}-\tfrac{4}{3}\sin^2\theta_W, \quad a_u = a_c = a_t = \tfrac{1}{2},$$

$$\vartheta_d = \vartheta_s = \vartheta_b = -\tfrac{2}{3}+\tfrac{2}{3}\sin^2\theta_W, \quad a_d = a_s = a_b = -\tfrac{1}{2}.$$

In the second order approximation with respect to the electromagnetic and weak interactions the preceding processes are described by the following diagrams





the cross sections of which are given by

$$\left(\frac{d\sigma_\mp}{dq^2 d\nu}\right)_{\lambda_P} = \frac{d\sigma^{em}}{dq^2 d\nu}\{1+\eta[(-g_V\alpha_V \mp g_A\alpha_A)+\lambda_P(g_V\alpha_A \pm g_A\alpha_V)]\}, \tag{1.4}$$

where $\sigma_-(\sigma_+)$ is the cross section for the process (A) ((B)), λ_P characterizes the polarization of leptons and the cross section $d\sigma^{em}/dq^2d\nu$ of DIS of unpolarized leptons on unpolarized nuclei as well as the parameters α_A, α_V are, respectively, defined as follows

$$\frac{d\sigma^{em}}{dq^2 d\nu} = \frac{2\pi\alpha^2}{q^4}\frac{M^2}{(p\cdot k)^2}L_{\alpha\beta}(k',k)W^{em}_{\alpha\beta}(p,q), \tag{1.5}$$

$$L_{\alpha\beta}(k',k) = k_\alpha k_\beta - \delta_{\alpha\beta}kk' + k'_\alpha k_\beta,$$

$$\alpha_{\mathrm{A}} = \frac{-x[1-(1-y)^2]\nu W_3^I}{2xy^2 M W_1^{\mathrm{em}} + 2(1-y)\nu W_2^{\mathrm{em}}}, \tag{1.6}$$

$$\alpha_{\mathrm{V}} = \frac{xy^2 M W_1^I + (1-y)\nu W_2^I}{xy^2 M W_2^{\mathrm{em}} + (1-y)\nu W_2^{\mathrm{em}}}. \tag{1.7}$$

The P-odd asymmetries are defined by the well-known quantities

$$A_{\mp} = \frac{1}{\lambda_{\mathrm{P}}} \frac{(d\sigma_{\mp}/dq^2 d\nu)_{\lambda_{\mathrm{P}}} - (d\sigma_{\mp}/dq^2 d\nu)_{-\lambda_{\mathrm{P}}}}{(d\sigma_{\mp}/dq^2 d\nu)_{\lambda_{\mathrm{P}}} + (d\sigma_{\mp}/dq^2 d\nu)_{-\lambda_{\mathrm{P}}}} = \eta(g_{\mathrm{V}}\alpha_{\mathrm{A}} \pm g_{\mathrm{A}}\alpha_{\mathrm{V}}), \tag{1.8}$$

which in the parton approximation are expressed simply in the form

$$\frac{A_{\mp}}{q^2} = \pm a_1(x) + a_2(x) \frac{1-(1-y)^2}{1+(1-y)^2}, \tag{1.9}$$

where

$$a_1(x) = \frac{G}{\sqrt{2}} \frac{1}{\pi\alpha} g_{\mathrm{A}} \frac{\sum e_q a_q (f_q(x) + f_{\bar{q}}(x))}{\sum e_q^2 (f_q(x) + f_{\bar{q}}(x))}, \tag{1.10}$$

$$a_2(x) = \frac{G}{\sqrt{2}} \frac{1}{\pi\alpha} g_{\mathrm{V}} \frac{\sum e_q a_q (f_q(x) - f_{\bar{q}}(x))}{\sum e_q^2 (f_q(x) + f_{\bar{q}}(x))}. \tag{1.11}$$

In our model [1] the quark distribution functions $f_q(x)$ in nucleus A are easily derived

$$u(x) = \sum_k \beta_k^A B_k(\lambda) \left[\frac{(1-x_k)^{6k-2}}{6} \left(1 + \frac{z}{A}\right) + \frac{\lambda}{12} \frac{(1-x_k)^{6k+2}}{1-(1-x_k)^4} + \frac{\lambda k}{(1-x_k)^2} \left(\frac{1}{2} - \frac{z}{A}\right) S_k \right], \tag{1.12}$$

$$d(x) = \sum_k \beta_k^A B_k(\lambda) \left[\frac{(1-x_k)^{6k-2}}{6} \left(2 - \frac{z}{A}\right) + \frac{\lambda}{12} \frac{(1-x_k)^{6k+2}}{1-(1-x_k)^4} + \frac{\lambda k}{(1-x_k)^2} \left(\frac{3}{2} - \frac{z}{A}\right) S_k \right], \tag{1.13}$$

$$\bar{u}(x) = \bar{d}(x) = \bar{S}(x) = S(x) = \sum_k \beta_k^A B_k(\lambda) \left[\frac{\lambda(1-x_k)^{6k+2}}{12[1-(1-x_k)^4]} - \frac{\lambda k S_k}{2(1-x_k)^2} \right], \tag{1.14}$$

where $x_k = x/k = q^2/2kM\nu$, M — nucleon mass, $\beta_k^A = N \dfrac{A!}{k!(A-k)!}\left(\dfrac{V_c}{AV_0}\right)^{k-1}$, $V_c = \frac{4}{3}\pi r_c^3$, $V_0 = \frac{4}{3}\pi r_0^3$, $r_c = 0.84$ fm, $r_0 = 1.2$ fm, N is the normalization constant,

$$B_k^{-1}(\lambda) = \frac{1-\lambda}{6k(6k-1)} + \frac{\lambda}{4}\left[\ln 2 + \frac{\pi}{2} - \sum_{n=0}^{(3k-3)/2} \frac{4}{(4n+1)(4n+2)}\right],$$

$$S_k = \tfrac{1}{4} \ln \frac{1+(1-x_k)^2}{1-(1-x_k)^2} - \tfrac{1}{2} \sum_{m=1}^{(3k+1)/2} \frac{(1-x_k)^{2(2m-1)}}{2m-1}$$

for odd k,

$$B_k^{-1}(\lambda) = \frac{1-\lambda}{6k(6k-1)} + \frac{\lambda}{4}\left[3 \ln 2 - \frac{\pi}{2} - \tfrac{1}{3} - \sum_{n=0}^{(3k-6)/2} \frac{4}{(4n+7)(4n+8)}\right],$$

$$S_k = \tfrac{1}{4} \ln \frac{1}{1-(1-x_k)^4} - \tfrac{1}{4} \sum_{m=1}^{3k/2} \frac{(1-x_k)^{4m}}{m}$$

for even k.

The expressions (1.12)–(1.14) correspond to the case when the incident energy is lower than the charm creation threshold. Substituting them into (1.10)–(1.11) one gets

$$a_1(x) = \frac{F_1(x)}{G(x)}, \qquad a_2(x) = \frac{F_2(x)}{G(x)} \tag{1.15}$$

where

$$F_1(x) = \frac{G}{\sqrt{2}} \frac{1}{\pi\alpha} g_A \sum_k \beta_k^A B_k(\lambda) \left\{ \frac{(1-x_k)^{6k-2}}{6} \left[\tfrac{2}{3} - \tfrac{4}{3} \sin_2^2 \theta_W \right.\right.$$
$$\left. + \frac{z}{A} \left(\tfrac{1}{6} - \tfrac{2}{3} \sin^2 \theta_W\right) \right] + \left(\tfrac{2}{3} - \tfrac{4}{3} \sin^2 \theta_W\right)$$
$$\left. \times \frac{\lambda}{6} \frac{(1-x_k)^{6k+2}}{1-(1-x_k)^4} + \frac{z}{A} \left(\tfrac{1}{6} - \tfrac{2}{3} \sin^2 \theta_W\right) \frac{\lambda k}{(1-x_k)^2} S_k \right\},$$

$$F_2(x) = \frac{G}{\sqrt{2}} \frac{1}{\pi\alpha} g_V \sum_k \beta_k^A B_k(\lambda) \left[\frac{(1-x_k)^{6k-2}}{6} \left(\tfrac{2}{3} + \frac{z}{6A} \right) \right.$$
$$\left. + \left(\tfrac{2}{3} + \frac{z}{6A} \right) \frac{\lambda k}{(1-x_k)^2} S_k \right],$$

$$G(x) = \sum_k \beta_k^A B_k(\lambda)\left[\frac{(1-x_k)^{6k-2}}{6}\left(\frac{2}{3}+\frac{z}{3A}\right)\right.$$

$$\left.+\frac{\lambda}{9}\frac{(1-x_k)^{6k+2}}{1-(1-x_k)^4}+\frac{z}{3A}\frac{\lambda k}{(1-x_k)^2}S_k\right].$$

For the energy being larger than the charm creation threshold the preceding formulae are replaced by

$$a_1(x) = \frac{\bar{F}_1(x)}{\bar{G}(x)}, \qquad a_2(x) = \frac{F_2(x)}{\bar{G}(x)},$$

where

$$\bar{F}_1(x) = \frac{G}{\sqrt{2}}\frac{1}{\pi\alpha}g_A \sum_k \beta_k^A B_k(\lambda)\left\{\frac{(1-x_k)^{6k-2}}{6}\left[\frac{2}{3}-\frac{4}{3}\sin^2\theta_W+\frac{z}{A}\left(\frac{1}{6}-\frac{2}{3}\sin^2\theta_W\right)\right]\right.$$

$$\left.+\left(\frac{1}{2}-\frac{10}{9}\sin^2\theta_W\right)\frac{\lambda(1-x_k)^{6k+2}}{4[1-(1-x_k)^4]}+\left(\frac{1}{6}-\frac{2}{3}\sin^2\theta_W\right)\left(\frac{z}{A}-\frac{1}{2}\right)\frac{\lambda k}{(1-x_k)^2}S_k\right\},$$

$$\bar{G}(x) = \sum_k \beta_k^A B_k(\lambda)\left[\frac{(1-x_k)^{6k-2}}{6}\left(\frac{2}{3}+\frac{z}{3A}\right)+\frac{5\lambda}{36}\frac{(1-x_k)^{6k+2}}{1-(1-x_k)^4}\right.$$

$$\left.+\left(\frac{z}{3A}-\frac{1}{6}\right)\frac{\lambda k}{(1-x_k)^2}S_k\right].$$

Next let us make the comparison with the experimental data measured by SLAC [12] in the interval $0.15 \leqslant y \leqslant 0.36$:

$$a_1 = (-9.7\pm2.6)\cdot10^{-5}\,\mathrm{GeV}^{-2}, \qquad a_2 = (4.9\pm8.1)\cdot10^{-5}\,\mathrm{GeV}^{-2},$$

the errors of which are rather large.

The predicted values for a_1 and a_2 multiplied by 10^5 GeV^2 are given in Tables I and II, respectively.

From Tables I and II we have three remarks:

— The calculated values for a_1 and a_2 agree with those of experimentai data within the errors; a_2 would be negative.

TABLE I

The predicted values for $a_1 \cdot 10^5$ GeV^2

λ \ x	0.01	0.10	0.20	0.40	1.00	1.80
0.0	−7.77	−6.99	−6.91	−6.88	−6.87	−6.87
0.5	−8.08	−7.26	−7.04	−6.91	−6.88	−6.87
0.9	−8.13	−7.38	−7.13	−6.94	−6.89	−6.87

TABLE II

The predicted values for $a_2 \cdot 10^5$ GeV^2

λ \ x	0.01	0.10	0.20	0.40	1.00	1.80
0.1	−0.715	−0.808	−0.949	−0.960	−0.964	−0.965
0.5	−0.225	−0.726	−0.861	−0.941	−0.959	−0.965
0.9	−0.195	−0.653	−0.810	−0.924	−0.953	−0.965

— a_1 and a_2 are nearly constant for $x > 0.4$ and vary strongly with λ in the low x region. This means that for $x \cong 0$ we have the scaling breakdown effect (because λ characterizes the polarization of parton vacuum, it depends on q^2).
— a_1 and a_2 are still defined in the cumulative region ($x > 1$), in which they are nearly independent of x.

As was mentioned above, the SLAC experiments are not exact enough. Recently DIS of polarized muons on unpolarized carbon nucleus [13] were examined. Instead of $A_\pm/q^2$, the new quantity $B(\lambda_P)$ is used

$$B(\lambda_P) = \frac{(d\sigma_+/dq^2dv)_{-\lambda_P} - (d\sigma_-/dq^2dv)_{\lambda_P}}{(d\sigma_+/dq^2dv)_{-\lambda_P} + (d\sigma_-/dq^2dv)_{\lambda_P}} = -\eta(\lambda_P g_V - g_A)\alpha_A$$

$$= -q^2 g(y)\left(\lambda_P + \frac{1}{4\sin^2\theta_W - 1}\right) a_2(x),$$

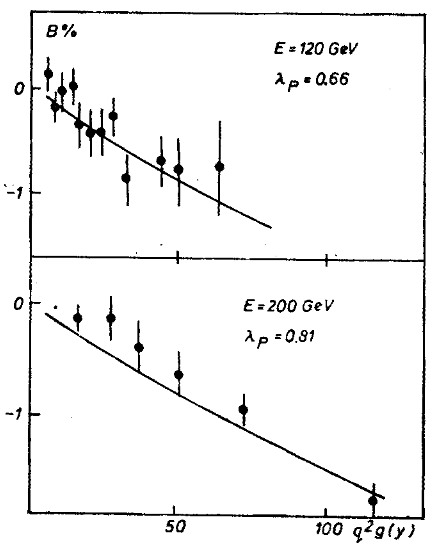


Fig. 1(2). The function $B(\lambda_P)$ is plotted versus $q^2g(y)$ with the incident energy $E = 120$ GeV (200 GeV), the polarization $\lambda_P = 0.66$ (0.81), the Weinberg angle $\sin^2\theta_W = 0.235$ and in the interval $0.4 < x < 2$

where

$$g(y) = \frac{1-(1-y)^2}{1+(1-y)^2}.$$

In Fig. 1 (2) the function $B(\lambda_P)$ is plotted vs $q^2g(y)$ with the incident energy $E = 120$ GeV (200 GeV), the polarization $\lambda_P = 0.66$ (0.81) and in the interval $0.4 < x \leqslant 2$, in which $a_2(x)$ can be considered to be constant. To fit in the experimental data, the Weinberg angle θ_W is chosen to be $\sin^2 \theta_W = 0.235$ which is in good agreement with other values of θ_W defined in different models.

It should be noticed that the valence quark approximation indicates that $B(\lambda_P)$ has constant decline vs $q^2(y)$, while in our model we predict that this decline varies strongly with λ in the low x region.

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To conclude, let us resume the main results obtained above. First, it is emphasized that the agreement of the calculated values for a_1, a_2 and $B(\lambda_P)$ with the data proves the validity of our model. In addition, the model predicts that:

1) a_1, a_2 and $B(\lambda_P)$ remain defined for $x > 1$.

2) For small x we have scaling breakdown effect (a_1, a_2 and B depend strongly upon λ).

To check these interesting predictions is one of the important problems of future experiments.

One of the authors (T.H.P.) expresses his sincere thanks to Prof. dr W. Królikowski for the fruitful discussions.

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