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E2-91-465

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DETERMINATION OF THE STRANGE QUARK'S CONTRIBUTION TO THE PROTON SPIN IN SEMI-INCLUSIVE DEEP INELASTIC ELECTROPRODUCTION OF K AND π MESONS

Submitted to "Physics Letters B"

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1991

where

$\Delta q_f(Q^2) = \int_0^1 dx[q_f^{(+)}(x,Q^2) - q_f^{(-)}(x,Q^2) - \bar{q}_f^{(+)}(x,Q^2) + \bar{q}_f^{(-)}(x,Q^2)]$

is the fraction of the proton spin carried by quarks and antiquarks of flavor f; $q_f^{(\pm)}(x,Q^2)$ stands for the density distribution of quarks with positive (+) and negative (-) helicities. It follows from Eq.(3) that

$$\sum_f \Delta q_f = 0.02 \pm 0.21$$

i.e. very small fraction of the proton spin is carried by quarks and antiquarks.

Taking into account, however, a new type of QCD correction, appearing because of the axial anomaly, leads to a new form of Δq defined as following [5]

$$\Delta q' = \Delta q - (\alpha_s(Q^2)/2\pi)\Delta G \tag{4}$$

where $\Delta G = \int_0^1 \Delta G(x,Q^2)dx$ is the fraction of the proton spin carried by gluons, $\Delta G(x,Q^2) = G^{(+)}(x,Q^2) - G^{(-)}(x,Q^2)$, $G^{(\pm)}(x,Q^2)$ - is the density distribution for polarized gluons. An interesting result following from Eq.(4) is that in the absence of strange quarks contribution $\Delta G = 5.5$ for $\alpha_s = 0.25$ and therefore, the proton spin is fully determined by the ΔG. If it is so then, as it has been shown by rough estimates, the gluon contribution is very large: $\Delta G = 3 \div 5$. That is, in its turn an evidence of a large but negative contribution of parton and/or gluon orbital angular momenta to make up for the ΔG

$$\frac{1}{2} = \frac{1}{2}\sum_f \Delta q_f + \Delta G + (L_z)_q + (L_z)_G .$$

Thus, it is only natural to search for a solution of the spin-crisis between two possible cases: $\Delta s \neq 0,\ \Delta G = 0$ and $\Delta s = 0,\ \Delta G \neq 0$.

The studies of the gluon contribution to $\int_0^1 dx g_1^p(x,Q^2)$ in production of heavy quark states, in photon- and lepton-nucleon interactions and in the direct photon emission in $\vec{p}\vec{p}$-collisions have been carried out in many works (see for ex. [6,7] and refer. there). As to the role of strange quarks polarization, it should be said that it is still not sufficiently studied. One possible source of information about the contribution of the strange quarks is the study of the longitudinal double spin asymmetry A_{LL} in the Drell-Yan processes. As it was shown in [8] the value of A_{LL} is about 0.1 if the contribution of s-quarks to the proton spin is negative and on the contrary it becomes large and negative in the absence of s-quarks. Another interesting aspect in this field is connected with the studies of semi-inclusive deep inelastic production. The idea of using semi-inclusive processes for separating the contribution of sea quarks has been first realised in [9]. An expression the authors have obtained for that contribution, however, is not sensitive enough to the value of the contribution of the strange sea. This sensitivity may be increased by measuring also the process of semi-inclusive production of K mesons. For this purpose in this paper deep inelastic semi-inclusive productions of the $K^{\pm}$, K^{o}, $\bar{K}^{o}$ and $\pi^{\pm}$ mesons in scattering of longitudinally polarized electrons or muons from the polarized targets

$$l(k,\lambda_1) + A(P,\vec{\xi}) \rightarrow l(k',\lambda'_1) + h(P^h) + X \qquad (5)$$

are studied, where A is a proton (p), neutron (n) or isoscalar (N) target with the polarization vector $\vec{\xi}$ and $\lambda_1(\lambda'_1)$ refers to the incoming(outgoing) lepton helicity.

The following kinematical variables are introduced:

$$x = Q^2/2P.q, \quad y = P.q/P.k, \quad z = P.P^h/P.q, \quad P_T \text{ and } \Phi.$$

Here x and y -are the Bjorken variables, $q = k - k'$ is the transferred momentum with that $Q^2 = -q^2$, P^h_T is the absolute value of the transverse component of hadron momentum $\vec{P}^h$ (orthogonal to $\vec{q}$), Φ- is the azimuthal angle between the scattering plane and the direction of $\vec{P}^h_T$.

In the QPM the cross-section of processes (5) may be written as

$$\frac{d\sigma(\lambda_1,\lambda_q)}{dxdydzdP_T^2d\Phi} = \frac{\alpha^2}{Q^2}\cdot\frac{1+\lambda_1\lambda'_1}{2}\,\delta(P_T^2)\sum_f e_{q_f}^2\int_{x_p}^{1}\frac{dx_p}{x_p}\int_{z_p}^{1}\frac{dz_p}{z_p}\times$$

$$\times\sigma(x_p,z_p;\,\lambda_1,\lambda_q)\,f_{q_f}^{(\lambda_q)}(x/x_p)\,D^h_{q_f}(z/z_p) \qquad (6)$$

where

$$\sigma(x_p,z_p\,;\,\lambda_1,\lambda_q) = \frac{1}{y}[1+(1-y)^2 \pm \lambda_1\lambda_q(1-y)^2]\delta(x_p-1)\times$$
$$\times\delta(z_p-1)$$

is the subprocess cross-section; $x_p = Q^2/2p_a.q$, $z_p = p_a.p_b/p_a.q$, p_a and p_b are the four momentum of the incoming and outgoing parton respectively; plus and minus refer to the parton and antiparton respectively; $D^h_q(z,Q^2)$-is the fragmentation function of parton to hadron h. It should be noted that the final hadrons in processes (5) may be produced as a result of either current quarks fragmentation, or gluons fragmentation (QCD type events). Since it is always possible to suppress the second mechanism by choosing the kinematical regime, we will be interested here only in the first mechanism. Then integrating Eq.(6) over P^h_T, Φ and summing up over the quark helicities ($\lambda_q = \pm 1$) one can find

$$\frac{d\sigma^h(\lambda_1,\xi)}{dxdydz} = \frac{2\pi\alpha^2}{Q^2}\cdot\frac{1+\lambda_1\lambda'_1}{2}\cdot\frac{1}{y}\Big\{[1+(1-y)^2]N(x,z,Q^2) +$$
$$+\lambda_1\xi[1-(1-y)^2]\Delta N(x,z,Q^2)\Big\}. \qquad (7)$$

For the difference between the cross-section of meson production we have from Eq.(7)

$$\Delta\sigma^h = d\sigma^h(+,+) - d\sigma^h(+,-) = \sigma_o\Delta N(x,z,Q^2) \qquad (8)$$

In Eqs.(7) and (8) we have used the following notaition

$$\sigma_o = \frac{4\pi\alpha^2}{Q^2}\cdot\frac{1-(1-y)^2}{y},$$

$$N^h(x,z,Q^2) = \sum_f e^2_{q_f} q_f(x,Q^2) D^h_{q_f}(z), \qquad (9)$$

$$\Delta N^h(x,z,Q^2) = \sum_f e^2_{q_f} \Delta q_f(x,Q^2) D^h_{q_f}(z).$$

Let us assume that we are interested in the production of strange mesons $K^{\pm}, K^o$ and $\overline{K}^o$ from the longitudinally polarized proton . For this case we have from Eq.(9)

$$\Delta N_p^{K^\pm} = \frac{4}{9}\Delta u\, D_u^{K^\pm} + \frac{1}{9}\Delta d\, D_d^{K^\pm} + \frac{1}{9}\Delta s\, D_s^{K^\pm} - \frac{4}{9}\Delta\bar{u}\, D_u^{K^\mp} - \frac{1}{9}\Delta\bar{d}\, D_d^{K^\mp} - \frac{1}{9}\Delta\bar{s}\, D_s^{K^\mp} + \frac{4}{9}(\Delta c - \Delta\bar{c}) D_c^K, \qquad (10)$$

$$\Delta N_p^{K^o,\overline{K}^o} = \frac{4}{9}\Delta u\, D_d^{K^\pm} + \frac{1}{9}\Delta d\, D_u^{K^\pm} + \frac{1}{9}\Delta s\, D_s^{K^\pm} - \frac{4}{9}\Delta\bar{u}\, D_d^{K^\mp} - \frac{1}{9}\Delta\bar{d}\, D_u^{K^\mp} - \frac{1}{9}\Delta\bar{s}\, D_s^{K^\mp} + \frac{4}{9}(\Delta c - \Delta\bar{c}) D_c^K. \qquad (11)$$

If the produced mesons are $\pi^{\pm}$ - ones then

$$\Delta N_p^{\pi^\pm} = \frac{1}{9}(4\Delta u - \Delta\bar{d}) D_u^{\pi^\pm} + \frac{1}{9}(\Delta d - 4\Delta\bar{u}) D_u^{\pi^\mp} + \frac{1}{9}(\Delta s - \Delta\bar{s}) D_s^{\pi} + \frac{4}{9}(\Delta c - \Delta\bar{c}) D_c^{\pi}. \qquad (12)$$

Notice that in deriving Eqs.(10)-(12) we have used the relationships following from the invariance requirement under the charge conjugate and isospin reflection

$$D_{u,d}^{K^+(K^-)} = D_{d,u}^{K^o(\overline{K}^o)}, \quad D_{\bar{u},\bar{d}}^{K^+(K^-)} = D_{\bar{d},\bar{u}}^{K^o(\overline{K}^o)} = D_{u,d}^{K^-(K^+)} = D_{d,u}^{\overline{K}^o(K^o)}$$

$$D_s^{K^+} = D_s^{K^o} = D_{\bar{s}}^{K^-} = D_{\bar{s}}^{\overline{K}^o}, \quad D_s^{\overline{K}^o} = D_{\bar{s}}^{K^+} = D_s^{K^-} = D_{\bar{s}}^{K^o}, \qquad (13)$$

$$D_c^K = D_c^{K^+} = D_c^{K^-} = D_c^{K^o} = D_c^{\overline{K}^o} = D_{\bar{c}}^{K^+} = D_{\bar{c}}^{K} = D_{\bar{c}}^{K^o} = D_{\bar{c}}^{\overline{K}^o},$$

$$D_u^{\pi^\pm} = D_d^{\pi^\mp} = D_{\bar{d}}^{\pi^\pm} = D_{\bar{u}}^{\pi^\mp};\ D_{s,c} = D_{s,c}^{\pi^+} = D_{s,c}^{\pi^-} = D_{\bar{s},\bar{c}}^{\pi^+} = D_{\bar{s},\bar{c}}^{\pi^-}.$$

Different combinations of measured quantities ($\Delta\sigma^{K^\pm}, \Delta\sigma^{K^o}, \Delta\sigma^{\overline{K}^o}$) or ($\Delta\sigma^{\pi^+}$, $\Delta\sigma^{\pi^-}$) do not allow to isolate the pure strange quarks contribution to $\int_0^1 g_1^p(x,Q^2)dx$ in the case of a proton target. But such a possibility arizes at their joint (i.e. $\Delta\sigma^K$ and $\Delta\sigma^\pi$) consideration. Omitting the contribution of c-quarks one can construct with the aid of Eqs.(8), (10) - (12) the following combination

$$(\Delta s - \Delta\bar{s})(D_s^{K^+} + D_s^{K^-}) = \frac{9}{2\sigma_o}\Big\{\Delta\sigma^{K^o} + \Delta\sigma^{\overline{K}^o} + \Delta\sigma^{K^+} + \Delta\sigma^{K^-} - [(D_u^{K^+} + D_u^{K^-} + D_d^{K^+} + D_d^{K^-})/(D_u^{\pi^+} + D_u^{\pi^-})](\Delta\sigma^{\pi^+} + \Delta\sigma^{\pi^-})\Big\}. \qquad (14)$$

It is clear that this combination is very convenient from the experimental point of view since it does not require separation K^o and $\overline{K}^o$ mesons. Measurement of his magnitude in future experiments would allow to determine the contribution of polarized s-quarks to the proton spin independently from other components.If insted of the proton target we use the isoscalar one and consider production of strange quarks only it might be shown that there is one more favourable combination giving a possibility to study Δs separately. Really, having determined the differential cross section averaged over proton and neutron

$$d\sigma_N = (d\sigma_p + d\sigma_n)/2$$

where $d\sigma_p = d\sigma_n(u \Leftrightarrow d)$ it is not difficult to obtain

$$\Delta\sigma_N^{K^0} + \Delta\sigma_N^{\overline{K}^0} - \frac{1}{4}(\Delta\sigma_N^{K^+} + \Delta\sigma_N^{K^-}) = \frac{\sigma_0}{18}\left[\frac{15}{4}(D_u^{K^0} + D_u^{\overline{K}^0})(\Delta u + \Delta d + \right.$$

$$\left. + \frac{3}{2}(\Delta s - \Delta\bar{s})(D_s^{K^-} + D_s^{K^+}) + 6(\Delta c - \Delta\bar{c})\right]. \qquad (15)$$

Having passed in Eq.(15) to limit $z \to 1$ and omitting the c-quark contribution one can find

$$(\Delta s - \Delta\bar{s})(D_s^{K^+} + D_s^{K^-}) = \frac{12}{\sigma_0}\left[\Delta\sigma_N^{K^0} + \Delta\sigma_N^{\overline{K}^0} - \frac{1}{4}(\Delta\sigma_N^{K^+} + \Delta\sigma_N^{K^-})\right]. \qquad (16)$$

Finally, if the detected mesons are only the charged $K^\pm$ and $\pi^\pm$ mesons then it is possible to determine another relationship, similar to (15)

$$(\Delta s - \Delta\bar{s})(D_s^{K^+} + D_s^{K^-}) = \frac{9}{\sigma_0}\left[(\Delta\sigma^{K^+} + \Delta\sigma^{K^-} - \frac{4}{5}\cdot\frac{\Delta\sigma^{\pi^+} + \Delta\sigma^{\pi^-}}{D_u^{\pi^+} + D_u^{\pi^-}}\right.$$

$$\left.(D_u^{K^+} + D_u^{K^-} + \frac{1}{4}D_d^{K^+} + \frac{1}{4}D_d^{K^-})\right], \qquad (17)$$

valid for all values of z.

Note that the values of the fragmentation functions in Eqs. (14)-(17) are extracted from the experiments with unpolarized beams. For small $z \approx 0.13-0.35$ the accuracy of the measured values of $D_q^h(z)$ is about 10-15% and it achieves 50-55% at $z = 0.5-0.65$. In oder to estimate the absolute precisios $\delta\Delta s/|\Delta s|$ depending on $\delta(\Delta\sigma^{K,\pi})/|\Delta\sigma^{K,\pi}|$ we make the used in [10] assumptions

$$D_s^{K^+} + D_s^{K^-} = 2D_u^{K^-}, \quad D_d^{K^+} = D_d^{K^-} = D_u^{K^-}$$

having as one might expect very slight influence on the values of D^π and D^K. The dependence $\delta(\Delta s)/|\Delta s|$ is given in fig.1. As it is seen in the fig. the values of $\delta(\Delta s)/|\Delta s|$ change in the range 0.22 - 0.55 as $\delta(\Delta\sigma^K)/|\Delta\sigma^K|$ varies in the interval 0.1 - 0.30.

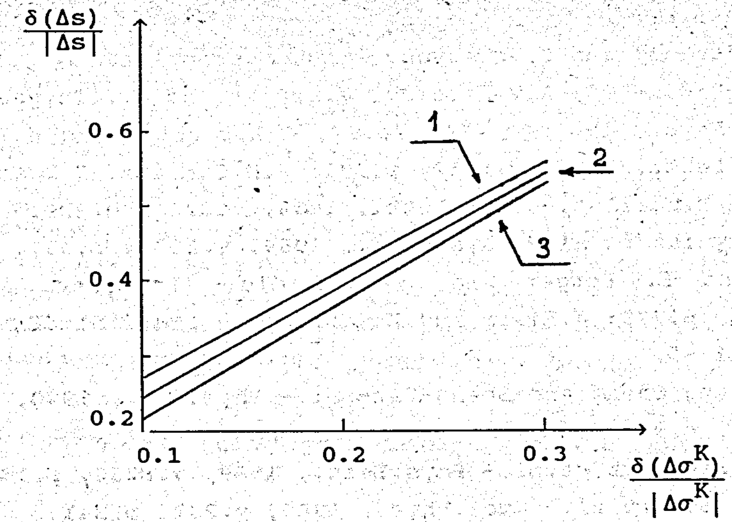

Fig.1. Dependence of $\delta\Delta s/|\Delta s|$ on $\delta(\Delta\sigma^K)/|\Delta\sigma^K|$ at the values of $z = 0.13$ (curve 1), 0.18 (curve 2) and 0.25 (curve 3).

Thus a conclusion is drawn that precise measurements of $\Delta\sigma^K$ and $\Delta\sigma^\pi$, especially at small z could provide some additional important information on the spin-dependent structure function of the proton, though it is not excluded that performing such experiments may appear a rather difficult experimental problem.

We are very grateful to L.Frankfurt who has discussed the basic idea of the paper with one of us (A.E.) and also to Lech Mankiewicz for useful information.

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Received by Publishing Department
on October 25, 1991.