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ENERGY DEPENDENCE OF THE COULOMB-NUCLEAR INTERFERENCE AT SMALL MOMENTUM TRANSFERS

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Now, the high energy physics is mostly the spin physics and most of the experiments require the knowledge of the polarization of beams with high accuracy. There are large spin programs at RHIC and LHC. These programs include measurements of the spin correlation parameters in the diffraction range of elastic proton-proton scattering. There is a proposal to use the Coulomb-nucleon interference (CNI) effects [1] to measure very exactly and faster the beam polarization [2, 3, 4]. This effect appears from the interference of the imaginary part of the hadron spin-nonflip amplitude and the real part of the electromagnetic spin-flip amplitude determined by the charge-magnetic moment interaction. The objections against this project say that possible unknown hadron spin-flip amplitudes can give sufficiently large contributions to the CNI effect.

Determination of the structure of the hadron scattering amplitude is an important task for both the theory and experiment. Perturbative Quantum Chromodynamics cannot be used in the calculation of the real and imaginary parts of the scattering amplitude in the diffraction range. A worse situation is for the spin-flip parts of the scattering amplitude in the domain of small momentum transfers. On the one hand, the usual representation says that the spin-flip amplitude is dying at superhigh energies, and on the other hand we have different non-perturbative models which lead to a non-dying spin-flip amplitude at superhigh energies [5, 6].

Note that the interference of the hadronic and electromagnetic amplitudes may give an important contribution not only at very small momentum transfers but also in the range of the diffraction minimum [7]. But for that one should know the phase of the interference of the Coulomb and hadron amplitude at sufficiently large momentum transfers too.

Unfortunately, we practically have no experimental data on the measurement of the spin correlation parameters at very small momentum transfers except the unique experiment [8] but with large errors. After the first paper [9] a number of papers appeared which consider these questions and try to estimate a possible contribution of the hadron spin-flip amplitude to the CNI effect [10, 11, 12]. This problem was a central point at the Workshop on polarimeters and was discussed at the Spin Conference [13].

But the question remains unclear as we have very different conclusions.

On the one hand, our difficulty is in most part defined by the lack of experimental data at high energies and small transfer momenta. We should examine the available experimental data at different energies and in different domains of momentum transfers. In most analyses the experimental data at $p_L = 45.5\ GeV/c$ and with $0.06 < |t| < 0.5\ GeV^2$ and the data at $p_L = 200\ GeV/c$ with $0.003 < |t| < 0.05$ are used. These experimental data overlap on the axis of momentum transfers but are measured at different energies. In most analyses this energy difference is not considered. Of course, we have plenty of experimental data in the domain of small momentum transfers at low energies $3 < p_L < 12\ GeV/c$. But at these energies we have many contributions to the hadron spin-flip amplitudes coming from different regions exchange. Now we cannot exactly calculate all contributions and find their energy dependences. But great amount of the experimental material allows us to make full phenomenological analyses and obtain the size and form of the different parts of the hadron scattering amplitude at one low energy. The difficulty is that we do not know the energy dependence of such amplitudes and individual contributions of the asymptotic non-dying spin-flip amplitudes.

Now we do not know exactly, also from a theoretical viewpoint, the dependence of the different parts of the scattering amplitude on s and t. So, usually we take the suppositions that the imaginary and real parts of the spin-nonflip amplitude have the exponential behavior with the same slope, and the imaginary and real parts of the spin-flip amplitudes, without the kinematic factor $\sqrt{|t|}$, have the same behavior with t in the examined domain of momentum transfers. For example, in [9, 12] the spin-flip amplitude was chosen in the form

$$F_f^N = \sqrt{-t}/m_p(b + ia)F_{nf}^N. \qquad (1)$$

That is not so in respect to the t dependence shown in Ref. [11], where they multiply the exponential form by the special function dependent on t. Moreover, we take mostly the energy independence of the ratio of the spin-flip parts to the spin-nonflip parts of the scattering amplitude. All this is our theoretical uncertainty.

In this paper we show that these suppositions are mostly wrong and we have to introduce different dependences on s and t in the spin-nonflip parts and spin-flip parts of the hadron scattering amplitude. We treat of a possibility of estimating the size of the hadron spin-flip amplitude from the available experimental data, the influence of the hadron spin-flip amplitude on the CNI effect and a possibility of estimating this contribution from the experimental data on measurement of the analyzing power in the nucleon-nucleon elastic scattering.

The differential cross sections measured in an experiment are described by the square of the scattering amplitude

$$d\sigma/dt = \pi(F_c^2(t) + (1+\rho^2)\ Im F_h^2(s,t) \mp 2(\rho + \alpha\varphi)\ \ F_c(t)\ Im F_h(s,t)), \qquad (2)$$

where $F_c = \mp 2\alpha G^2/|t|$ is the Coulomb amplitude; α is the fine-structure constant and $G^2(t)$ is the proton electromagnetic form factor squared; $Re\ F_h(s,t)$ and $Im\ F_h(s,t)$ are the real and imaginary parts of the nuclear amplitude. $\rho(s,t) = Re\ F(s,t)/Im\ F(s,t)$. Just this formula is used to fit experimental data to evaluate the ratio of the real to imaginary part of the forward spin-nonflip amplitude $\rho(s,t)$.

Numerous discussions of the value of ρ measured by the UA4 [14] and UA4/2 [15] Collaborations at $\sqrt{s} = 540\ GeV$ have revealed the ambiguity in the definition of this parameter [16], which in most part is connected with the dependence of the form of the real and imaginary parts of the scattering amplitude on t. As a result, it has been shown that we have some trouble in the definition of the total cross sections and the value of the real part of the scattering amplitude. Of course, we should develop new experimental and theoretical methods to obtain exact values of the hadron differential cross sections and the structure of the hadron spin-nonflip amplitude [17, 18].

The majority of theoretical models describe the hadron scattering at small angles with the use of the eikonal approximation where the amplitude of pp-scattering is

$$\begin{aligned} M(s,t) = M_0(s,t) &+ M_1(s,t)(\sigma_1 + \sigma_2)\cdot\hat{\mathbf{n}} + \mathbf{M_2(s,t)}(\sigma_1\cdot\hat{\mathbf{n}})(\sigma_2\cdot\hat{\mathbf{n}}) \\ &+ M_3(s,t)(\sigma_1\cdot\hat{\mathbf{q}})(\sigma_2\cdot\hat{\mathbf{q}}) + \mathbf{M_4(s,t)}(\sigma_1\cdot\hat{\mathbf{l}})(\sigma_2\cdot\hat{\mathbf{l}}), \qquad (3)\end{aligned}$$

with

$$\hat{\mathbf{l}} \equiv \frac{\mathbf{p}+\mathbf{p}'}{|\mathbf{p}+\mathbf{p}'|}, \quad \hat{\mathbf{q}} \equiv \frac{\mathbf{p}-\mathbf{p}'}{|\mathbf{p}-\mathbf{p}'|}, \quad \hat{\mathbf{n}} \equiv \frac{\mathbf{p}\times\mathbf{p}'}{|\mathbf{p}\times\mathbf{p}'|}.$$

In the eikonal representation, if the terms are taken into account to the first order in spin-dependent eikonal phases, one can write

$$\begin{aligned} M_0(s,t) = & \quad i\int \rho d\rho J_0(\rho q)(1-e^{-\chi_c(\rho)}), \quad M_1(s,t) = i\int \rho^2 d\rho J_1(\rho q) e^{-\chi_c(\rho)}\chi_{ls}(\rho), \\ M_2(s,t) = & \quad M_3(s,t) = M_4(s,t) = i\int \rho d\rho J_0(\rho q) e^{-\chi_c(\rho)}\chi_{ss}(\rho), \end{aligned} \tag{4}$$

where the eikonal function $\chi(\vec{\rho})$ is the sum of the spin-independent central term χ_c and spin-orbit - χ_{ls} and spin-spin terms χ_{ss} [19].

Using ordinary relations (see, for example, [20]) we can obtain the helicity amplitudes for small scattering angles

$$\begin{aligned} F_1(s,t) &= M_0(s,t) - M_2(s,t), \quad F_2(s,t) = 2M_2(s,t), \\ F_3(s,t) &= M_0(s,t) + M_2(s,t), \quad f_4(s,t) = 0, \quad F_5(s,t) = iM_1(s,t). \end{aligned} \tag{5}$$

For the electromagnetic helicity amplitudes, one takes the usual one-photon approximations (see [21]) with the Coulomb-hadron phase [7] calculated for the whole diffraction range. As a result, the total helicity amplitudes can be written as $F_i(s,t) = F_N^i(s,t) + F_C^i(t) expi\phi$. The differential cross sections and spin correlation parameters are

$$\frac{d\sigma}{dt} = 2\pi(|F_1|^2 + |F_2|^2 + |F_3|^2 + |F_4|^2 + 4|F_5|^2). \tag{6}$$

$$A_N\frac{d\sigma}{dt} = -4\pi Im[(F_1 + F_2 + F_3 - F_4)F_5^*]. \tag{7}$$

In this paper, we suppose that we know the differential cross sections of the elastic nucleon scattering sufficiently well. With the usual high energy approximation for the spiral amplitudes at very small momentum transfers we suppose that $F_1 = F_3$ and we can neglect the contributions of F_2 and F_4.

At the present moment we have, as has been noted above, that in some models the hadron asymptotical spin-flip amplitude is not dying at superhigh energy. But most part of the experimental data of the analyzing power at small t lie at low energies. Hence, we should take the low energy spin amplitudes and build the continuous transition to the asymptotic amplitudes.

As asymptotic amplitudes let us take those calculated in Ref. [6]. In [22] on the basis of sum rules it has been shown that the main contribution to a hadron interaction at large distances comes from the triangle diagram with the 2π -meson exchange in the t-channel. As a result, the hadron amplitude can be represented as a sum of central and peripheral parts of the interaction:

$$T(s,t) \propto T_c(s,t) + T_p(s,t), \tag{8}$$

where $T_c(s,t)$ describes the interaction between the central parts of hadrons, and $T_p(s,t)$ is the sum of contributions of diagrams corresponding to the interactions of the central part of one hadron on the meson cloud of the other. The contribution of these diagrams to the scattering amplitude with an $N(\Delta$-isobar) in the intermediate state looks like [6]

$$\begin{aligned} T_{N(\Delta)}^{\lambda_1\lambda_2}(s,t) = & \frac{g^2_{\pi NN(\Delta)}}{i(2\pi)^4}\int d^4q T_{\pi N}(s,t)\varphi_{N(\Delta)}[(k-q),q^2]\varphi_{N(\Delta)}[(p-q),q^2] \\ & \times\frac{\Gamma^{\lambda_1\lambda_2}(q,p,k,)}{[q^2-M^2_{N(\Delta)}+i\epsilon][(k-q)^2-\mu^2+i\epsilon][(p-q)^2-\mu^2+i\epsilon]}. \end{aligned} \tag{9}$$

Here $\lambda_1 and \lambda_2$ are the helicities of nucleons; $T_{\pi N}$ is the πN-scattering amplitude; Γ is a matrix element of the numerator of the representation of the diagram; φ are vertex functions chosen in the dipole form with the parameters $\beta_{N(\Delta)}$:

$$\varphi_{N(\Delta)}(l^2, q^2 \propto M^2_{N(\Delta)}) = \frac{\beta^4_{N(\Delta)}}{(\beta^2_{N(\Delta)} - l^2)^2}. \tag{10}$$

The model with the N and Δ contribution provides a self-consistent picture of the differential cross sections and spin phenomena of different hadron processes at high energies. Really, parameters in the amplitude determined from, for example, elastic pp-scattering, allow one to obtain a wide range of results for elastic meson-nucleon scattering and charge-exchange reaction $\pi^-p \to \pi^0 n$ at high energies.

It is essential that the model predicts large polarization effects for all considered reactions at high and superhigh energies [6]. The predictions are in good agreement with the experimental data in the energy region available for experiment. Also note that just the effect of large distances determines a large value of the spin-flip amplitude of the charge-exchange reaction [23].

The model takes into account the $s \to u$ crossing diagrams in the scattering amplitude, which leads to the asymptotic equality of the proton-proton and proton-antiproton cross sections as $s \to \infty$. An important property of this model is that it can be applied to the proton-antiproton scattering at sufficiently low energies. Thus, the behavior of the proton-proton and proton-antiproton differential cross sections at $p_L = 40\ GeV$ and $p_L = 1850\ GeV$ acquires a natural explanation [24]. Our results weakly depend on the model for the spin-nonflip amplitude. Different models must give the same differential cross sections in a wide range of momentum transfers and energies. Moreover, they must describe the energy dependence of $\rho(s)$. Basically, only the behavior of the real part of spin-nonflip amplitudes in the range of the diffraction minimum may depend on the model and leads to different predictions.

As a low energy amplitude let us take the one obtained in Ref. [19] where the full analysis of experimental data has been carried out and the full set of the helicity spin amplitudes and their eikonals of the proton-proton scattering at $p_L = 6\ GeV/c$ has been extracted.

Let us take the eikonal of the spin-nonflip amplitudes in the form similar to the form and size obtained in [19] at $p_L = 6\ GeV/c$:

$$\begin{aligned} 1 - e^{\chi_c(b)} &= h_1 e^{-C_1 b^2} - h_2 e^{-C_2 b^2} + h_3 e^{-C_3 b^2} \\ &\quad + i\,(h_4 e^{-C_4 b^2} - h_5 e^{-C_5 b^2} + h_6 e^{-C_6 b^2}) \end{aligned} \qquad (11)$$

and for the hadron spin-flip amplitude

$$\chi_{ls}(b) = h_{ls}[1 + b\ e^{\mu(s)(b-b_0)}]^{-1}, \qquad (12)$$

where h_i, c_i, h_{ls} and b_0 are the parameters obtained in Ref. [19]. As we know, these amplitudes reproduce the analyzing power at $p_L = 6\ GeV/c$. In fact, these amplitudes are a sum of terms falling, constant and probable growing with energy. But this form has no energy dependence of the parameters which change the form of these amplitudes

with increasing energy in both the spin-nonflip and spin-flip parts. To take the energy dependence of some part of the amplitude (11, 12), let us multiply (12) by the falling term s_1/s and to take into account the change of the form of (12) with energy, let us introduce the energy dependence into the parameter $\mu \to \mu_s$:

$$\mu(s) = \mu_0(\log s_1/\log s), \qquad (13)$$

where μ_0 and s_1 correspond to the values of Ref. [19]. The amplitude of the dynamical model (DM) also includes the falling, constant and the increasing terms, but it is not suitable to describe the low-energy data. So this is not a simple task to sew these two amplitudes, low energy phenomenological and high energy model amplitudes. To obtain the smooth transform to our model representation, let us multiply amplitudes (11, 12) by the function $fs^{nf,fl}_{ex}$ quickly decreasing with energy, multiply our model amplitudes by the factor $f^{nf,fl}_{th}$:

$$fs^{nf}_{ex}(s) = exp(-[s^{nf}/s]^2), \quad fs^{nf}_{th}(s) = 1 - exp(-[s^{nf}/s]^2), \qquad (14)$$

$$fs^{fl}_{ex}(s) = exp(-[\frac{s^{fl}}{s}]^2), \quad fs^{fl}_{th}(s) = 1 - exp(-[\frac{s^{fl}}{s}]^2), \qquad (15)$$

and multiply the falling term of the DM amplitudes by an additional function

$$1 - exp(-[\sqrt{s^{fl}}/\sqrt{s}])$$

. In this case, we obtain that the analyzing power at $p_L = 6\ GeV/c$ is described only by the amplitudes obtained in Ref. [19] and at superhigh energies only by the DM amplitude. In the domain of approximately $6 \leq p_L \leq 200\ GeV/c$ the analyzing power has both the contributions. The parameters s^{nf} and s^{fl} were chosen to obtain the description of experimental data A_N of elastic proton-proton scattering available in this energy range ($p_L \leq 6\ GeV/c$ and $|t| \leq 1\ GeV^2$)

$$s^{nf} = 44\ GeV^2, \quad s^{fl} = 64\ GeV^2.$$

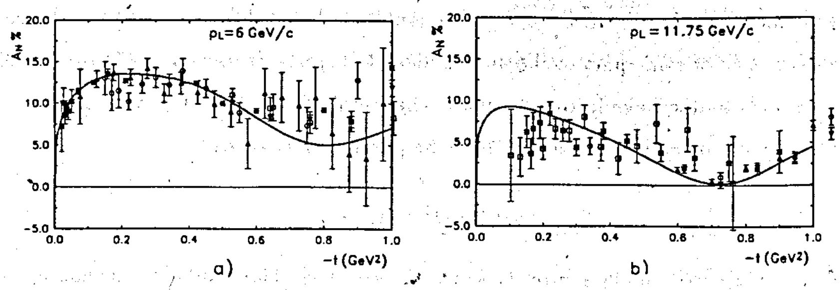

Fig.1: The analyzing power A_N of *pp*-scattering calculated at a) $p_L = 6\ GeV/c$; b) at $p_L = 11.75\ GeV/c$ (the full line is our calculations; the experimental data Ref. [25, 26, 27])

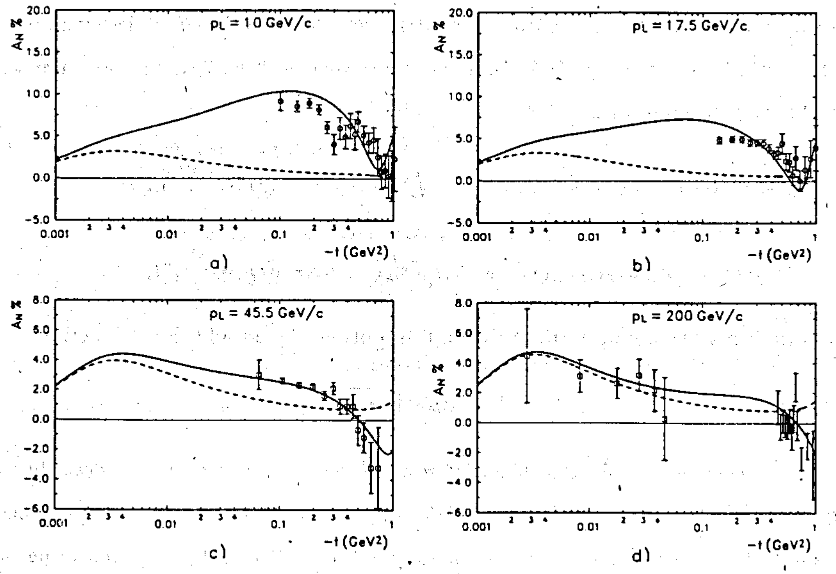

Fig.2: The analyzing power A_N of *pp*-scattering calculated at a) $p_L = 10\ GeV/c$; b) at $p_L = 17.5\ GeV/c$; c) at $p_L = 45.5\ GeV/c$; d) at $p_L = 200\ GeV/c$ (the full line is our calculations, dashed line is the calculation without the contributions of the hadron spin-flip amplitude; the experimental data Ref. [28, 29, 8, 30])

The calculated analyzing power at $p_L = 6\ GeV/c$ is shown in Fig.1 a. Of course, in the original phenomenological analysis made in [19] six parts of the amplitudes with the exchange spin were used, but it can be seen that a good description of experimental data on the analyzing power can be reached only with one hadron spin-flip amplitude.

The experimental data at $p_L = 11.75\ GeV/c$ seriously differ from those at $p_L = 6\ GeV/c$ but our calculations reproduce them sufficiently well (Fig. 1b). In Figs. 2(a,b) we show our calculations and experimental data at $p_L = 10\ GeV/c$ and $17.5\ GeV/c$. From these figures we notice that our energy dependence was chosen correctly and we may hope that further we will obtain correct values of the analyzing power.

Really, our calculations at $p_L = 45.5\ GeV/c$ show the satisfactory description of the experimental data (see Fig. 2c). At this energy both of our parts of the amplitude give important contributions. The contributions to the analyzing power of the amplitudes (11, 12) are approximately twice as large as the contributions of the model amplitudes. From Fig. 2c we can see that in the region $|t| \approx 0.2\ GeV^2$ the contributions from the hadron spin-flip amplitudes are most important.

At last, Fig. 2d shows our calculations at $p_L = 200\ GeV/c$. At this energy, the contributions of the phenomenological amplitudes are already very small and can be compared with the contributions of the model amplitudes only at $|t| = 0.5\ GeV^2$ where both the contributions are very small.

Finally, we describe the experimental data at $p_L = 45.5\ GeV/c$ and $p_L = 200\ GeV/c$ by the different amplitudes and our descriptions have different forms that are clearly seen from the comparison of Fig. 2c and Fig. 2d. The chosen energy dependence of the hadron spin-dependent amplitude allows us to describe all available experimental material. Hence, we can try to continue our calculations and extend them to higher energies. The contributions of the hadron spin-flip amplitudes to the analyzing power of the Coulomb-nucleon interference at different points of transfer momenta are shown in Figs. 3(a,b). The full line shows the contribution at the points of the maximum of the CNI. It can be seen that practically after $p_L = 200\ GeV/c$ its relative contribution is approximately a constant $\sim 3\%$. The most important relative contribution is at

$|t| \simeq 0.2\ GeV^2$ where it is very large up to $\sqrt{s} = 100\ GeV$ and has a heavy energy dependence.

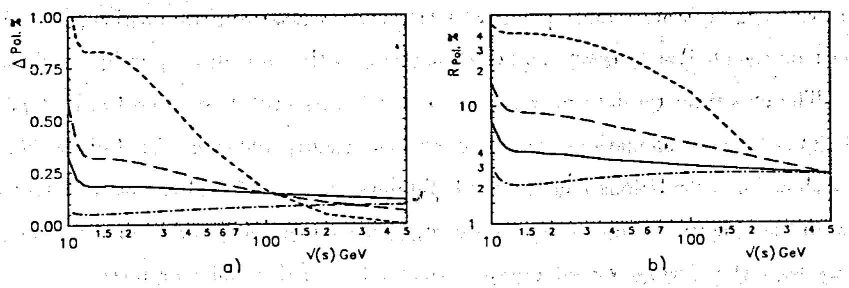

Fig.3: a) The additional contributions of the hadron spin-flip amplitudes to the CNI effect;
b) the relative contributions of the hadron spin-flip amplitudes to the CNI effect
(our calculations at t_{max}, $|t| = 0.001\ GeV^2$, $|t| = 0.01\ GeV^2$, $|t| = 0.1\ GeV^2$ are shown by the full, dot-dashed, long-dashed and dashed lines respectively)

It is very important to note that we obtain the different energy dependences of the additional contributions ΔA_N to the pure CNI effect at the different points of momentum transfers. The contribution at $|t| = 0.1\ GeV^2$ has a clear downfall with growing $\sqrt{s}$ but in the range of maximum of the CNI effect we have the additional contributions which are nearly independent of energy. So, we cannot make the conclusion about energy dependence of ΔA_N at the place of maximum of CNI, measuring the energy dependence of the analyzing power at other points of the transfer momentum. But this is one of the central points of many other analyses of the CNI effect.

Now let us examine the ratio of the real and imaginary parts of the spin-flip amplitude, without the kinematic factor $\sqrt{|t|}$, to the separate parts of the hadron spin-nonflip amplitude (see Figs. 4(a,b) and 5(a,b)). It is clear that this ratio can be regarded as a constant only up to $|t| \leq 0.1\ GeV^2$. Moreover, this ratio has a very strong energy dependence.

So, at low energies the ratio of real parts of the hadron spin-flip to spin-nonflip amplitude has a "zero" at $|t| \sim 0.5\ GeV^2$. Then, this "zero" goes out to larger transfer momenta but at higher energies it returns to the region of small momentum transfers.

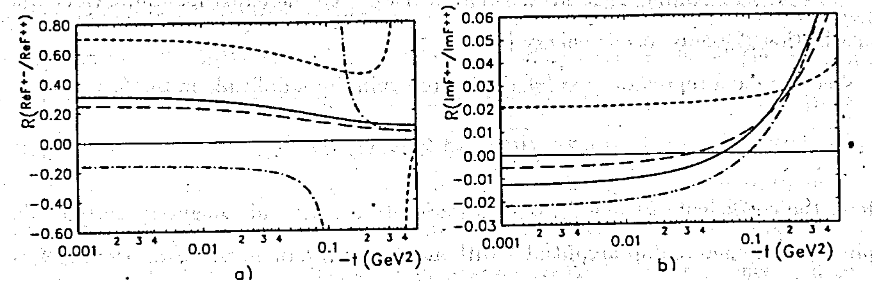

Fig.4: a) The ratio, without kinematic factor $\sqrt{|t|}$, of the real part of the spin-flip to the real part of spin-nonflip amplitude. b) The ratio, without kinematic factor $\sqrt{|t|}$, of the imaginary part of the spin-flip to the imaginary part of spin-nonflip amplitudes

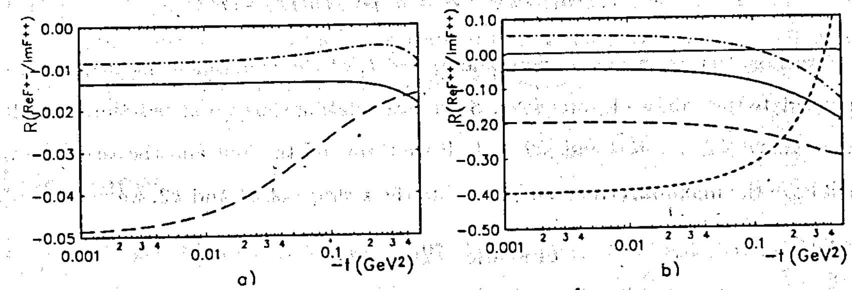

Fig.5: The ratio of the real parts of a) the spin-flip, without kinematic factor $\sqrt{|t|}$, and b) spin-nonflip to the imaginary part of the spin-nonflip amplitude at $\sqrt{s} = 4.93,\ 9.3,\ 19.4$ and $50\ GeV$ are shown by the short-dashed, dashed, full and dot-dashed lines, respectively

Hence, we cannot carry out our analysis of experimental data at different energies and different regions of momentum transfers using the same form of the hadron spin-flip amplitude. Note that we obtain that the imaginary part of the hadron spin-flip amplitude, without the kinematic factor $\sqrt{|t|}$, is smaller than the imaginary part of the spin-nonflip amplitude. But this kind of ratio for the real parts is not so far from unity.

Now let us examine what we can obtain if we take the experimental data on the polarization A_N only at one energy [8].

Let us take a representation for the hadron spin-flip amplitude in the form

$$fh_5 = \sqrt{|t|}(k2\rho + ik1) Imfh_1. \quad (16)$$

Here, the coefficients $k1$ and $k2$ are the ratio of the real and imaginary parts of the spin-flip and spin-nonflip amplitudes without the kinematic factor $\sqrt{|t|}$. Hence, if we have $k1 = k2$, the phase between fh_1 and fh_5 is zero and the interference between these two amplitudes is zero. These coefficients are related to R and I in the paper [9] as

$$I = Imfh_5/Imfh_1 = k1, \quad R = Refh_5/Imfh_1 = \rho k2 . \quad (17)$$

If we take the experimental points at t_i and t_j of the experiment [8] in pairs we can calculate the values $k1_{ij}$ and $k2ij$. Such a calculation shows that practically in all cases we have $|k2| >> |k1|$ and $|k2| \sim 1$. If we throw off the first and the last points, which have the maximal errors, and calculate the average of $\bar{k}1$ and $\bar{k}2$, we obtain

$$\bar{k}1 \sim 0.1, \quad \bar{k}2 \sim 1.3 .$$

This means that if we drop the kinematic factor $\sqrt{|t|}$, the imaginary part of spin-flip amplitude is smaller than the imaginary part of the hadron spin-nonflip amplitude, but the real part is the same order as the real part of spin-nonflip amplitude. It coincides qualitatively with our model calculation. It is interesting that if we calculate our coefficients $k1$ and $k2$ with two different values $\rho_1 = 0.04$ and $\rho_2 = 0.02$, we obtain approximately double growth of $k2$ in the second case. This means that the real part of the hadron spin-flip amplitude keeps the same size in both cases.

In fact, this conclusion is made from the analysis of Ref. [9]. If we recalculate their values R to our $k2$, we obtain $k2_{ak}$ changing near unity for all its variants and the middle of all variants is $\bar{k2}_{ak} = 1.04$. Of course, these evaluations are very rough as errors of the experiment [8] are very large. But we think that it may be a valuable indication of the relative structure of the spin-flip amplitude.

It is obvious from our analysis that the examining of the contributions of the hadron spin-flip amplitudes in the CNI effect should take into account the energy dependence of all parts of the hadron scattering amplitude and its dependence on momentum transfers. Our descriptions of all available experimental data give about 3.5% the predictions for RHIC energies for the contributions of the hadron spin-flip amplitude to the maximum of the CNI effect. But, of course, this estimation has a very large theoretical indefiniteness which is connected with other possible contributions from other sources of the hadron spin-flip at high energies. However, this estimation shows that these contributions may be sufficiently small and we can use this effect to measure the beam polarization. More accurate estimations can be made only after a new experiment in this domain of transfer momenta at energies $\sqrt{s} = 40 \div 50\ GeV$.

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References

[1] J. Schwinger, Phys.Rev., **73** (1948) 407; L.I.Lapidus, Nucl. and Part., **9** (1978) 84; N.H.Battimore, E.Gotsman, E.Leader, Phis.Rev. **D 18** (1978) 694.

[2] N.Akchurin, A.Bravar, M.Conte, A.Penzo, U.of Iowa Report 93-04.

[3] W. Guryn *et al.*, *Total and Differential Cross Sections and Polarization Effects in pp Elastic Scattering at RHIC* (unpublished).

[4] S.B.Nurushev, A.G.Ufimtsev, Proc. "Hera-N", Dubna, 1996.

[5] C. Bourrely, J. Soffer and T. T. Wu, Phys. Rev. D **19**, 3249 (1979); M. Anselmino and S. Forte, Phys. Rev. Lett. **71**, 223 (1993); A. E. Dorokhov, N. I. Kochelev and Yu. A. Zubov, Int. Jour. Mod. Phys. **A8**, 603 (1993);

[6] S.V.Goloskokov, S.P.Kuleshov, O.V.Selyugin, Z.Phys.**C50** (1991) 455.

[7] O.V. Selyugin, Int. Jour. Mod. Phys. **A 12** (1997) 1379.

[8] N.Akchurin et al., Phys.Rev. **D 48** (1993) 326.

[9] N.Akchurin, N.H.Buttimore, A.Penzo, Phys.Rev. **D 51** (1995) 3944.

[10] A.D.Krish, S.M.Troshin, hep-ph/9610537.

[11] C.Bourrely, J.Soffer, hep-ph/9611234.

[12] T.L. Truemán, hep-ph-9610316; High Energy Polarimetry Workshop, Amsterdam, 9 September, 1996 and RHIC Spin Collaboration meeting, Marseile, 17 September, 1996 .

[13] N.H. Buttimore, Proc. XII High Energy Spin Physics, Amsterdam, 10-14 September, 1996.

[14] UA4 Coll., M. Bozzo et al., *Phys.Lett.* **B 147**, 392 (1984).

[15] UA4/2 Coll., C. Augier et al., *Phys. Lett.* **B 316** (1993) 448.

[16] O.V. Selyugin, *Phys. Lett.* **B 333** (1994) 245.

[17] P. Gauron, B. Nicolescu, O.V. Selyugin, *Phys. Lett.* **B390** (1997) 405.

[18] P. Gauron, B. Nicolescu, O.V. Selyugin, in Proc. of the 6th Blois Workshop *Frontiers in Strong Interactions - 6th Int. Conf. on Elastic and Diffractive Scattering*, Château de Blois, 20-24 June 1995, Ed. Frontieres.

[19] M.Sawamoto, S.Wakaizumi, Progress of Theor.Phys. **62** (1979) 1293.

[20] J.Bystricky, F.Lehar, Le J. de Physique **39** (1978) 1; G. Lechanoine-LeLuc, F.Lehar, Rev. Mod. Phys. **65** (1993) 47.

[21] S.B.Nurushev, A.P.Potylitsin, G.M.Radutsky, Proc. V Workshop on HESP, Protvino, 1993, p.321.

[22] S.V. Goloskokov, S.P. Kuleshov, O.V. Selyugin, Yad.Fiz., **46**, 597 (1987).

[23] S.V. Goloskokov, S.P. Kuleshov, O.V. Selyugin, Yad.Fiz., **52**, 561 (1990).

[24] S.V. Goloskokov, S.P. Kuleshov, O.V. Selyugin, Yad.Fiz., **46**, (1987) 195.

[25] D.Miller et al., Phys.Rev. **D 16** (1977) 2016; M.Borghini et al. Phys.Lett. **B 31** (1970) 405; R.Diebold et al., Phys.Rev.Lett. **35** (1975) 632 ; D.R.Rust et al., Phys.Lett. **B 58** (1975) 114; R.D.Klem et al., Phys.Rev. **D 15** (1977) 602; J.R.O'Fallon et al., Phys.Rev. **D 17** (1978) 24.

[26] M.Borghini et al.,Phys.Lett. **B 24** (1966) 77.

[27] S.L.Kramer et al., Phys.Rev. **D 17** (1978) 1709; K.Abe et al., Phys.Lett. **B 63** (1976) 239.

[28] M.Borghini et al.,Phys.Lett. **B 36** (1971) 501.

[29] A. Gaudot et al., Phys.Lett. **B 61** (1976) 103.

[30] G. Fidegaro et al., Phys.Rev. **B 105** (1981) 309.

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