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O.V.Selyugin*

ODDERON CONTRIBUTION IN DIFFRACTION REACTIONS

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*E-mail: selyugin@thsun1.jinr.dubna.su

1 Introduction

Some approaches to diffractive processes are connected with t he t-channel point of view. There exist some problems of the Regge theory in the asymptotic limit $s \to \infty$ and models with the Froissart-type asymptotic behavior of the scattering amplitude. Usually, the process is defined as diffractive if it is determined at high energies by the Pomeranchuk singularity at $j = 1$ - Pomeron with $C = +1$. Besides, the charge conjugation partner of Pomeron with $C = -1$, Odderon, exists. For the maximal Odderon [1] the Intercept odderons equals the intercept of Pomeron. The recent calculation of the odderon intercept gives it as follows [2]:

$$\alpha_{odd}(0) = 1 - (9\alpha_s/2\pi)\varepsilon, \tag{1}$$

where ε is the odderon energy. However, it is to be noted that all such calculations are made in the Leading Logarithmic Approximation (LLA). In this approach, the Pomeron intercept is calculated with $\varepsilon \sim 0.16$. As a result, the odderon intercept will be sufficiently smaller than 1. Note that in the case of Pomeron this calculation gives the pomeron intercept significant by larger than 1, but the calculation of the next to Leading Logarithmic Approximation [3] has a different sign and reduces the pomeron intercept. Very likely that this calculation in the case of odderon leads to increasing the intercept, and finally we will have both the intercepts near 1.

Recently, the observation of a large-rapidity-gap in the deep-inelastic electron-proton scattering has initiated great interest in "diffraction" in inelastic processes. In these processes the pomeron plays an important role in the diffractive vector-meson production. In the early 90s it was noted that the odderon would play an important role in the pseudoscalar meson production [4]. Now we have some works which analyze this contribution and its interference with a competitor-process $\gamma^*\gamma^* \to PSV$-meson [5]. If we wont to estimate this contribution, we should know the odderon intercept and the coupling constant. In [5] the calculations were made under some assumption of the odderon intercept ($\alpha(0) = 0.8;\ 1.;\ 1.08$). The coupling constant was estimated from the supposition that $\rho_{\bar{p}p} - \rho_{pp} < 0.05$ as $\sqrt{s} > 100\ GeV$.

Note that the calculation in that work is practically independent of the odderon intercept. It enters into formula (44) for the definition of the coupling constant of odderon practically at one s with one sign and into the final calculation with the opposite sign.

Besides, the estimation of the odderon coupling is sufficiently broad.

2 Data

Let us try to improve this estimation. We have the experimental data for the pp and $\bar{p}p$-elastic scattering at $\sqrt{s} = 52.8\ GeV$. For this energy we have

$$\Delta\rho = \rho_{\bar{p}p} - \rho_{pp}; \quad \Delta\sigma_{tot} = \sigma_{tot}^{\bar{p}p} - \sigma_{tot}^{pp}$$

and

$$\Delta d\sigma/dt(-t_{min}) = d\sigma/dt(-t_{min})|_{\bar{p}p} - d\sigma/dt(-t_{min})|_{pp}$$

is the difference of differential cross sections at the point of the diffraction minimum. Let us use these data to obtain the bound on the odderon coupling.

The analysis includes not only the contribution of pomeron and odderon but also the second reggeon. If an analysis is carried out without the reggeon contribution, the picture will be contradictory between these three cases. So, we include into our examination two energies $\sqrt{s_1} = 9.78\ GeV$ and $\sqrt{s_2} = 52.8\ GeV$ with specific pictures of the differential cross sections.

The experimental values are

$$\sqrt{s} = 52.8 \quad \sigma_{tot}^{pp} = 42.38 \pm 0.15\ mb \quad [9] \qquad \sigma_{tot}^{\bar{p}p} = 43.32 \pm 0.34\ mb \quad [9]$$

$$\sqrt{s} = 52.8 \quad \sigma_{tot}^{pp} = 42.90 \pm 0.30\ mb \quad [10] \qquad \sigma_{tot}^{\bar{p}p} = 44.71 \pm 0.46\ mb \quad [12]$$

$$\sqrt{s} = 52.8 \quad \sigma_{tot}^{pp} = 42.46 \pm 0.26\ mb \quad [13]$$

$$\sqrt{s} = 52.8 \quad \sigma_{tot}^{pp} = 43.01 \pm 0.27\ mb \quad [12]\,.$$

So, the arithmetical mean is

$$\Delta\sigma_{tot}(\sqrt{s} = 52.8) = 1.34 \pm 0.2\ mb\,.$$

For $\rho(0)$

$$\sqrt{s} = 52.8 \quad \rho^{pp} = 0.077 \pm 0.009 \quad [9]$$

$$\sqrt{s} = 52.9 \quad \rho^{pp} = 0.078 \pm 0.010 \quad [14]$$

$$\sqrt{s} = 52.6 \quad \rho^{\bar{p}p} = 0.106 \pm 0.016 \quad [9]\,.$$

The arithmetical mean of $\Delta\rho$ is

$$\Delta\rho = 0.03 \pm 0.01\ mb$$

$$\sqrt{s} = 9.78\ \ |t| = 1.4\quad d\sigma/dt(-t_{min})|_{pp} = 0.08 \pm 0.1\ 10^{-4}\ mb\ \ [10]$$

$$\sqrt{s} = 9.78\ \ |t| = 1.5\quad d\sigma/dt(-t_{min})|_{pp} = 0.12 \pm 0.12\ 10^{-4}\ mb\ \ [10]$$

$$\sqrt{s} = 9.78\ \ |t| = 1.5\quad d\sigma/dt(-t_{min})|_{\bar{p}p} = 2.32 \pm 0.65\ 10^{-4}\ mb\ \ [10]$$

$$\sqrt{s} = 9.78\ \ |t| = 1.6\quad d\sigma/dt(-t_{min})|_{\bar{p}p} = 1.95 \pm 0.37\ 10^{-4}\ mb\ \ [10]$$

$$\sqrt{s} = 52.8\ \ |t| = 1.4 d\sigma/dt(-t_{min})|_{pp} = 2.25 \pm 0.20\ 10^{-5}\ mb\ \ [11]$$

$$\sqrt{s} = 52.8\ \ |t| = 1.6 d\sigma/dt(-t_{min})|_{\bar{p}p} = 4.80 \pm\ \ 10^{-5}\ 1.90\ mb\ \ [10]$$

$$\sqrt{s} = 9.78\ \ \sigma_{tot}^{pp} = 38.20 \pm 0.05[12]\qquad \sqrt{s} = 9.78\ \ \sigma_{tot}^{\bar{p}p} = 43.93 \pm 0.1[12]$$

$$\sqrt{s} = 9.78\ \ \sigma_{tot}^{pp} = 37.87 \pm 0.12[15]\ .$$

Hence the $\Delta\sigma_{tot}(\sqrt{s} = 9.78) = 1.34$ and $\Delta\rho(\sqrt{s} = 9.78) = -0.107$.

3 Method 1 ($\Delta\sigma_{tot}$)

Let us start with the data on σ_{tot}.

$$\sigma_{tot}^{pp} = \sigma_{tot}^{pom} + \sigma_{tot}^{r+} - \sigma_{tot}^{odd} - \sigma_{tot}^{r-}; \qquad (2)$$
$$\sigma_{tot}^{\bar{p}p} = \sigma_{tot}^{pom} + \sigma_{tot}^{r+} + \sigma_{tot}^{odd} + \sigma_{tot}^{r-},$$

where $(r+)$ is the cross-even contribution of the second reggeon and $(r-)$ is the cross-odd contribution. The second reggeon $\sigma_{tot}^{r+(-)}$ (plus and mines correspond to cross-even and cross-odd parts of the second reggeon) is

$$\sigma_{tot}^{r+} = a\ s^{-0.5}, \qquad \sigma_{tot}^{r-} = b\ s^{-0.5}, \qquad (3)$$

and the pomeron and odderon are

$$\sigma_{tot}^{pom} = P\ s^{\alpha+}; \qquad \sigma_{tot}^{odd} = D\ s^{\alpha--\delta}, \qquad (4)$$

where δ is the value by which the intercept of the real part of odderon grows faster than its imaginary part. The difference of $\sigma_{tot}^{+(-)}$ at s_1 and s_2 is

$$\Delta\sigma_{tot}(s_1) = 2\ (b\ s_1^{-0.5} + D\ s_1^{\alpha_- - \delta});$$
$$\Delta\sigma_{tot}(s_2) = 2\ (b\ s_2^{-0.5} + D\ s_2^{\alpha_- - \delta}). \tag{5}$$

And for b and D

$$b = \frac{\Delta\sigma_{tot}(s_1)s_2^{\alpha_- - \delta} - \Delta\sigma_{tot}(s_2)s_1^{\alpha_- - \delta}}{2(s_2^{\alpha_- - \delta}s_1^{-0.5} - s_1^{\alpha_- - \delta}s_2^{-0.5})} \tag{6}$$

$$D = \frac{\Delta\sigma_{tot}(s_2)s_1^{-0.5} - \Delta\sigma_{tot}(s_1)s_2^{-0.5}}{2(s_1^{\alpha_- - \delta}s_2^{-0.5} - s_2^{\alpha_- - \delta}s_1^{-0.5})}\ . \tag{7}$$

The arithmetic mean difference of $\Delta\sigma_{tot}$ is

$$\Delta\sigma_{tot}(s_1) = 5.73\ mb; \qquad \Delta\sigma_{tot}(s_2) = 1.34\ mb.$$

For the maximal odderon the real part grows with $\alpha_- = 0.08$. In this case, the imaginary part either does not grow or grows very slowly. Take for the first examination $\alpha_- - \delta = 0$.

As a result,

$$b = 26.3 \qquad D = 0.17.$$

Hence

$$\frac{ImF_{odd}(s_2)}{ImF_{pom}(s_2)} = \frac{k(\beta_{odd})^2 s_2^{\alpha_-}}{(\beta_{pom})^2 s_2^{\alpha_+}} = \frac{0.17}{43}, \tag{8}$$

where

$$k = ImF_{odd}(s_2)/ReF_{odd}(s_2). \tag{9}$$

Using the local dispersion relations one can obtain that

$$k = (\pi/2)\ /\ \ln s_2/s_0. \tag{10}$$

Here $s_0 = 1\ GeV^2$ and

$$C_{odd} = \frac{(\beta_{odd})^2}{(\beta_{pom})^2} = 0.02. \tag{11}$$

Defining

$$C_{odd}^s(s) = C_{odd}s^{\alpha_-}, \tag{12}$$

one takes account of the energy dependence $\alpha_- = 0.08$ and denotes $\sqrt{s_3} = 250\ GeV$

$$C^s_{odd}(s_2) \ = 0.037; \quad C^s_{odd}(s_3) \ = 0.043. \tag{13}$$

If one takes the "minimal" odderon with the energy dependence of the imaginary part with $\alpha_- - \delta = -0.2$, one obtains

$$b \ = \ 23.8 \qquad D \ = \ 1.07.$$

Hence

$$\frac{ImF_{odd}(s_2)}{ImF_{pom}(s_2)} = \frac{k\ (\beta_{odd})^2 s_2^{-0.1}}{(\beta_{pom})^2 s_2^{0.08}}, \tag{14}$$

and

$$C_{Odd} = \frac{(\beta_{odd})^2}{(\beta_{pom})^2} \ = \ 0.106. \tag{15}$$

If one takes account of the energy dependence $\alpha_- = -0.1$

$$C^s_{odd}(s_2) \ = 0.047; \quad C^s_{odd}(s_3) \ = 0.035. \tag{16}$$

We have obtained that the ratio of the odderon contribution to reggion at $\sqrt{s} = 52.8\ GeV$ is

$$R_r^{odd} = (0.107(s_2)^{-02})/(23.8(s_2)^{-0.5}) = 0.47. \tag{17}$$

Note that this value is the ratio of the imaginary parts of the odderon and reggion exchanges.

For the "middle" odderon with the energy dependence of imaginary part with $\alpha_- - \delta = -0.1$, we obtain

$$b \ = \ 25.44 \qquad D \ = \ 0.416;$$

and

$$C_{Odd} = \frac{(\beta_{odd})^2}{(\beta_{pom})^2} \ = \ 0.041. \tag{18}$$

In that case the real part of odderon practically does not change with energy and

$$C^s_{odd}(s_2) \ = 0.041; \quad Cs_{odd}(s_3) \ = 0.041. \tag{19}$$

The ratio of the odderon contribution to reggion at $\sqrt{s} = 52.8\ GeV$ is

$$R_r^{odd} = (0.416(s_2)^{-0.1})/(25.44(s_2)^{-0.5}) = 0.41. \tag{20}$$

Hence, the odderon contribution is one-half or one-third of the cross-odd contribution to the total cross section in the case of maximal odderon and is practical the same in the case of "minimal" odderon:

4 Method 2 ($\Delta\rho(0)$)

Now let us treat the second set of values. The ratio of real to imaginary parts of the scattering amplitude is

$$\Delta\rho = \frac{ReF_{cross-even} + ReF_{cross-odd}}{ImF_{cross-even} + ImF_{cross-odd}} - \frac{ReF_{cross-even} - ReF_{cross-odd}}{ImF_{cross-even} - ImF_{cross-odd}} \, . \tag{21}$$

In some approximation at high energies we obtain

$$\Delta\rho \sim 2\,\frac{ReF_{cross-odd}}{ImF_{cross-even}} = 2\,\frac{ReF_{r-} + ReF_{odd}}{ImF_{pom} + ImF_{r+}} \, . \tag{22}$$

We can consider two cases. In the first, as in [16],

$$ImF_{r+} \sim -ReF_{r-}. \tag{23}$$

The other case (2_b) was obtained in work [17]

$$ImF_{r+} \sim -3ReF_{r-}. \tag{24}$$

The imaginary part $ImF_{pom}(s_2)$ of pomeron is connected with $\sigma^{pp}_{tot}(s_2)$

$$ImF_{pom}(s_2) \sim \sigma^{pp}_{tot}/(4\pi 0.39); \quad ImF_{pom}(s_1) = ImF_{pom}(s_2) s^{-\alpha_+(0)}. \tag{25}$$

And we have for the first case (2_{1a})

$$\Delta\rho(s_1)/2\;(ImF_{pom}(s_1) - b\; s_1^{-0.5}) = D_1\; s_1^{\alpha_-(0)} + b\; s_1^{-0.5}; \tag{26}$$
$$\Delta\rho(s_2)/2\;(ImF_{pom}(s_2) - b\; s_2^{-0.5}) = D_1\; s_2^{\alpha_-(0)} + b\; s_2^{-0.5}.$$

For the "maximal" odderon $\alpha_-(0) = 0.08$ and

$$b_{1a} = -5.56; \qquad D_{1a} = 0.126. \tag{27}$$

For the "middle" odderon $\alpha_-(0) = 0.$ and

$$b_{2a} = -6.28; \qquad D_{2a} = 0.25. \tag{28}$$

For the "minimal" odderon $\alpha_-(0) = -0.1$ and

$$b_{3a} = -7.73; \qquad D_{3a} = 0.618 . \tag{29}$$

Hence,

$$C_{Odd}^{2-1a} = 0.027; \quad C_{Odd}^{2-1b} = 0.054; \quad C_{Odd}^{2-1c} = 0.133. \tag{30}$$

For the energies s_2 and s_3

$$\begin{aligned} C_{Odd}^{2-1a}(s_2) = 0.05; &\quad C_{Odd}^{2-1a}(s_3) = 0.065; \\ C_{Odd}^{2-1b}(s_2) = 0.054; &\quad C_{Odd}^{2-1b}(s_3) = 0.054; \\ C_{Odd}^{2-1c}(s_2) = 0.06; &\quad C_{Odd}^{2-1c}(s_3) = 0.044 . \end{aligned} \tag{31}$$

For the case $(2-2)$

$$b_{2a} = -6.45; \qquad D_{2a} = 0.137. \tag{32}$$

For the "middle" odderon $\alpha_-(0) = 0.$ and

$$b_{2b} = -7.4; \qquad D_{2b} = 0.28. \tag{33}$$

For the "minimal" odderon $\alpha_-(0) = -0.1$ and

$$b_{3c} = -9.3; \qquad D_{3c} = 0.7. \tag{34}$$

Hence,

$$C_{Odd}^{2-2a} = 0.03; \quad C_{Odd}^{2-2b} = 0.06; \quad C_{Odd}^{2-2c} = 0.15. \tag{35}$$

For the energies s_2 and s_3

$$\begin{aligned} C_{Odd}^{2-2a}(s_2) = 0.05; &\quad C_{Odd}^{2-2a}(s_3) = 0.07; \\ C_{Odd}^{2-2b}(s_2) = 0.06; &\quad C_{Odd}^{2-2b}(s_3) = 0.06; \\ C_{Odd}^{2-2c}(s_2) = 0.068 &\quad C_{Odd}^{2-2c}(s_3) = 0.05 . \end{aligned} \tag{36}$$

It is easily seen that in this method we obtain the odderon contribution larger by a factor of $1.8 \div 2.1$ than the reggeon contribution at the energy s_2 . It is clearly understood that in this case the odderon contribution is determined by the real part of the odderon which is 5 times as larger as the imaginary part at $\sqrt{s} = 52.8 GeV$. So it coincides with the results obtained by the first method from $\Delta\sigma_{tot}$ if we take into account the ratio of the imaginary to real parts of the odderon amplitude.

5 Method 3 ($\Delta ReF(s, t_{min})$

Now let us examine the region of diffraction minimum. Here the imaginary part of the scattering amplitude changes its sign and the diffraction minimum is filled by the real part of the amplitude. The differential cross sections for proton-proton and proton-antiproton elastic scattering at the energies s_1 and s_2 are a very different picture. The $\bar{p}p$ -scattering at $\sqrt{s_1} = 9.78\ GeV$ has a very sharp minimum and the measured $\rho_{\bar{p}p}(s_1) \simeq 0 \div -0.05$. The pp-scattering has a "shoulder" and $\rho_{pp}(s_1) \simeq -0.16$. At $\sqrt{s_2} = 52.8\ GeV$ the behavior of the differential cross section becomes opposite

$$\begin{aligned} (ReF_+(t_{min}) + ReF_-(t_{min}))^2 &= 4.8\ 10^{-5}\ mb/GeV^2 \\ (ReF_+(t_{min}) - ReF_+(t_{min}))^2 &= 2.2\ 10^{-5}\ mb/GeV^2. \end{aligned} \tag{37}$$

The contributions of the cross-even and cross-odd parts can have a different sign. As a result, one can obtain eight solutions for pomeron and odderon contributions.

We can obtain separately the contribution of pomeron, odderon and reggions. However, for obtaining the ratio of odderon-pomeron coupling, it is needed to extend our results to the point $t = 0$. Note that at the point of diffraction minimum the energy dependence of different parts of the scattering amplitude depend, on the one hand, on the whole energy behaviour of the scattering amplitude at $t = 0$, and on the other hand, on the real parts at the point of diffraction minimum.

The real part of the odderon amplitude is taken in the same form as the imaginary part of pomeron amplitude proposed by Landshoft [18].

$$Re(F_{odd}(s,t)) = \frac{h_{odd}}{\sqrt{0.39\ \pi}}\ (\alpha' s)^{(\epsilon_0^{odd} + \alpha' t)}\ G(t)^2. \tag{38}$$

The real part of the pomeron amplitude is obtained by using the local dispersion relations [19, 20]

$$Re(F_{pom}(s,t)) = \frac{h_{pom}}{\sqrt{0.39\ \pi}}\ (\epsilon_0 + \alpha' t)\ G(t)^2, \tag{39}$$

where

$$G(t) = \frac{4m^2 - 2.8t}{4m^2 - t}\left(\frac{1}{1 - t/0.71}\right)^2 \tag{40}$$

with $\epsilon_0 = 0.08$, and $\alpha' = 0.25$

First, we choose the solutions with the negative sign of the real part of pomeron at the point of diffraction minimum. Using the local dispersion relations, we obtain the first zero in the real part of the pomeron amplitude at small t and the second after the diffraction bump. Some different phenomenological models give the same result, for example [17]. The four solutions satisfy this criterion.

As another criterion for choosing one solution, one takes the corresponding ratio of the real-imaginary parts of the pomeron amplitude at the point $t = 0$. Two of the obtained solutions lead to the small real part of the pomeron amplitude and, respectively, to the very small magnitude of $\rho(t = 0)$ and to the large odderon amplitude. The other two solutions lead to the real part of the pomeron amplitude which give the $\rho(t = 0) = 0.08$ and to the small odderon amplitude with practically the same magnitude $H_{odd} = 0.2\ mb^{1/2}/GeV$. Our criteria satisfy the solutions with the plus or mines sign in the root at $\sqrt{s} = 9.78\ GeV$ and with the negative signs of both the roots at $\sqrt{s} = 52.8\ GeV$ This gives for the maximal odderon

$$C_{odd} = 0.038 \quad C^s_{odd}(s_1) = 0.07 \quad C^s_{odd}(s_1) = 0.09$$

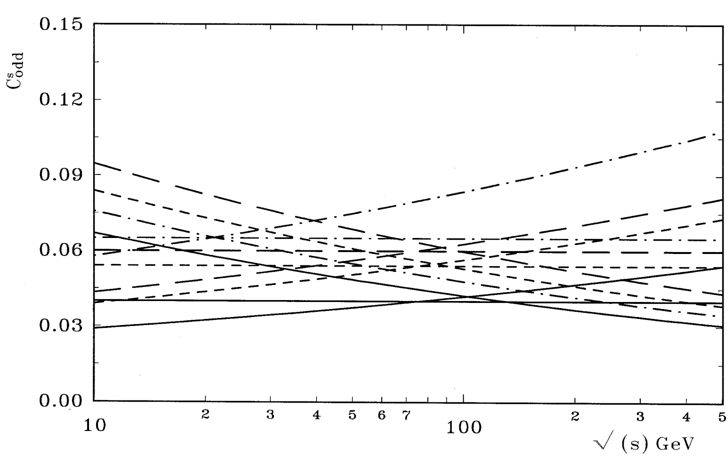


Fig.1. The energy dependence of C^s_{odd} (solid, short dash, long dash and dot-dash lines correspond to the variants 1, 2a, 2b, 3).

For three cases $(3_a, 3_b, 3_c)$ which are, respectively, "maximal" odderon, "middle" odderon and "minimal" odderon, the result is reported in Table 1 and on Fig. 1 (solid, short dash, long dash and dot-dash lines correspond to the variants 1, 2a, 2b, 3).

Table 1: The $C^s_{Odd}(s)(NN)$

Var.	C_{Odd}	$C^s_{Odd}(\sqrt{s} = 52.8\ GeV)$	$C^s_{Odd}(\sqrt{s} = 250\ GeV)$
1_a	0.02	0.038	0.048
1_b	0.04	0.04	0.04
1_c	0.106	0.047	0.035
2_{1a}	0.027	0.05	0.065
2_{1b}	0.054	0.054	0.054
2_{1c}	0.133	0.06	0.044
2_{2a}	0.03	0.05	0.07
2_{2b}	0.06	0.06	0.06
2_{2c}	0.15	0.07	0.05
3_a	0.04	0.07	0.09
3_b	0.065	0.065	0.065
3_c	0.12	0.05	0.04

6 Odderon contribution into A_N

Now let us examine an additional odderon contribution to the analyzing power of the $pp-$ and $\bar{p}p$ elastic scattering using the previous determination of the odderon amplitude. The differential cross section and spin parameters A_N and A_{NN} are defined as

$$\frac{d\sigma}{dt} = \frac{2\pi}{s^2}(|\phi_1|^2 + |\phi_2|^2 + |\phi_3|^2 + |\phi_4|^2 + 4|\phi_5|^2), \tag{41}$$

$$A_N \frac{d\sigma}{dt} = -\frac{4\pi}{s^2} Im[(\phi_1 + \phi_2 + \phi_3 - \phi_4)\phi_5^*)], \tag{42}$$

and

$$A_{NN} \frac{d\sigma}{dt} = \frac{4\pi}{s^2}[Re(\phi_1\phi_2^* - \phi_3\phi_4^*) + 2|\phi_5|^2], \tag{43}$$

in the framework of the usual helicity representation.

At small angles, the total helicity amplitudes can be written as $\Phi_i(s,t) = \phi_i^h(s,t) + \phi_i^{em}(t) \exp \varphi(s,t)$ where $\phi_i^h(s,t)$ is the pure strong interaction of hadrons, $\phi_i^{em}(t)$ is the electromagnetic interaction of hadrons and $\varphi(s,t)$ is the electromagnetic-hadron interference phase factor. So, for determining the hadron spin-flip amplitude it is needed to take into account all electromagnetic and interference electromagnetic-hadron contributions to the physical effects. In this domain, the analyzing power A_N is determined by the Coulomb-hadron interference effects. At present, the spin effects owing to the Coulomb-nucleon interference (CNI) at very small transfer momenta are widely discussed in the aspect of future spin experiments at RHIC and LHC. These effects are worse understood in the domain of the diffraction dip. In many aspects, this is due to the fact that we do not know the Coulomb-hadron interference phase for not small transfer momenta and its impact on the magnitude of the spin effects.

In [21], the phase ν_c of the pure Coulomb amplitude in the second Born approximation with the form factor in the monopole and dipole forms has been calculated in a wide region of t. It was shown that the behavior of ν_c at not small t sharply differed from the behavior of ν_c obtained in [22]. We can calculate the total phase factor that can be used in the whole diffraction range of the elastic hadron scattering [23].

The total phase factor is

$$\varphi(s,t) = \ln \frac{q^2}{4} + 2\gamma + \frac{1}{F_h(s,q)} \int_0^{\infty} \tilde{\chi}_c(\rho)(1 - \exp(\chi_h(\rho,s))J_0(\rho,q)d\rho, \tag{44}$$

with

$$\tilde{\chi}_c(\rho) = 2\rho \ln \rho + 2\rho K_0(\rho\Lambda)[1 + \frac{5}{24}\Lambda^2\rho^2] + \frac{\Lambda\rho}{12} K_1(\rho\Lambda)[11 + \frac{5}{4}\Lambda^2\rho^2]. \tag{45}$$

Our eikonal representation for the $\varphi(s,t)$ (44) is valid in a wide region of t. If we take the correct hadron scattering eikonal that describes the experimental differential cross section including the domain of the diffraction dip, we can calculate the $\varphi(s,t)$ for that region of t , for example, [17]. Note, that the calculated term has a real and a non-small imaginary part.

Let us calculate, using the obtained $\varphi(s,t)$, an additional contribution to the analyzing power A_N^{ad} and double spin correlation parameter A_{NN}^{ad} owing to the electromagnetic-hadron interference and with taking account of the possible odderon contribution in the diffraction dip domain of the proton-proton elastic scattering. For that take the odderon amplitude in the simplest form with the intercept $\alpha_{odd} = 1$

$$F_{odd}(s,t) = \beta_{odd}\ exp(0.25\ t) G_d^2, \tag{46}$$

where G_d is the dipole form factor and $\beta_{odd} = 0.2$ that corresponds to the middle line on Fig.1.

At first let us regard the pure Coulomb-hadron interference A_N^{ad} and then the other case with taking into account the hadron spin-flip amplitude calculated in the dynamic peripheral model [17]. The calculations of the size of A_N^{ad} in the diffraction dip domain at HERA energy $\sqrt{s} = 40\ GeV$ and $\sqrt{s} = 500\ GeV$ are shown on Fig.2 (a,b).

The obtained analyzing power has the positive and negative maxima and change its sign in the position of the diffraction minimum. At this energy $\sqrt{s} = 40\ GeV$, the differential cross section has the clearly represented diffraction minimum. It leads to a sufficiently large polarization effect. In the region below the diffraction minimum, we obtain a positive non-small contribution which changes the size of the spin correlation parameter owing to the hadron-spin-flip amplitude. Especially, it is to be noted that the positive part of A_N^{ad} heavily changes the point where A_N changes its sign. At the last RHIC energy $\sqrt{s} = 500\ GeV$ the magnitude of A_N^{ad} is small (Fig.2 b), but it needs to be taken into account when the true hadron spin-flip amplitude is examined.

Now let us examine such an additional contribution to the double spin correlation parameter. It is clear that the large contribution to A_{NN}^{ad} comes from the interference of the electromagnetic amplitudes ϕ_1^{em} and ϕ_2^{em}; but in our case, it is cancelled completely by the contribution of $2|\phi_5^{em}|^2$). So, we have the magnitude of A_{NN}^{ad} dependent on both the real part of the hadron spin-non-flip amplitude and the odderon contribution.

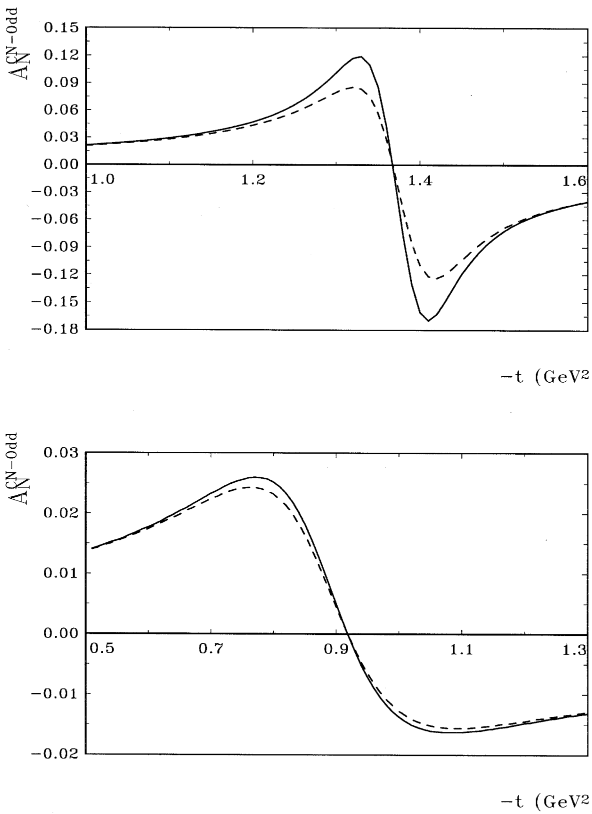


Fig.2. (a,b) The calculated A_N^{ad} for a) $\sqrt{s} = 40\ GeV$ and b) $\sqrt{s} = 500\ GeV$ (dashed and solid lines - without and with the odderon contribution).

Our calculation of A_{NN}^{ad} $\sqrt{s} = 40\ GeV$ is shown in Fig. 3. Of course, the form and size of A_{NN}^{ad} are mostly defined by the form and size of the diffraction minimum. It is very important that this contribution has the negative sign and it will reduce the magnitude of the double spin correlation parameter owing to the hadron spin-flip amplitude.

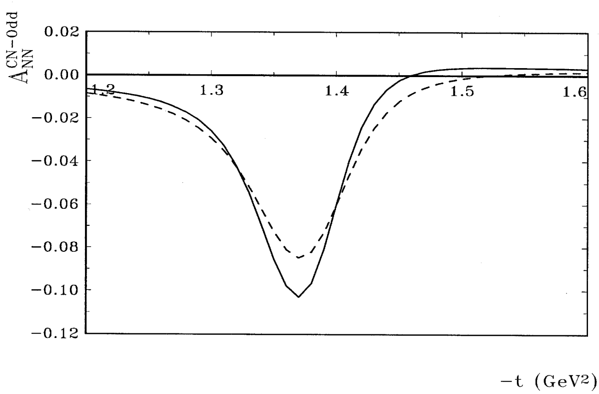
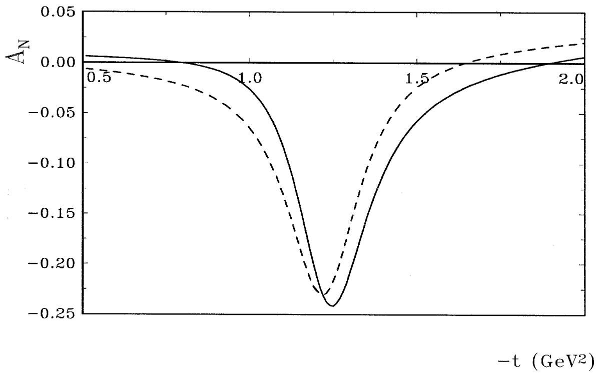


Fig.3. The calculated A_{NN}^{ad} for a) $\sqrt{s} = 40\ GeV$ (dashed and solid lines - without and with the odderon contribution).

The calculations of the A_N and A_{NN} at $\sqrt{s} = 100\ GeV$ with taking into account the model hadron-spin0flip amplitude are shown in Fig. 4(a,b). It is clear that the magnitude of the A_N at the point of the diffraction minimum does not change its value, but the negative maximum changes its position and slightly grows. The magnitude of A_{NN} is reduced by A_{NN}^{ad} by about 30% of its value and the position of maximum also slightly moves to large momentum transfer.

7 Conclusions

The extraction of the odderon coupling from the available experimental data on the elastic hadron scattering shows the remarkable coincidence of the magnitudes of the odderon coupling obtained in different ways. Of course, the errors of the obtained values are large. However, an essential result of this work consists in that we have not used any fitting procedures and involve as little theoretical assumptions as possible. The results of calculation by three methods are very close to each other. We have defined the odderon coupling in the nucleon-nucleon scattering. The case of single pseudoscalar meson production in the $\gamma * N$ scattering requires a careful analysis. Now there are minimum five models of pomeron interaction. For the odderon, the situation is more complicated.



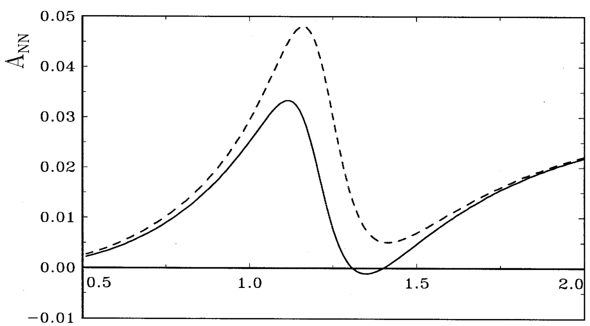


Fig.4 (b). The calculated A_{NN} for $\sqrt{s} = 100\ GeV$ (dashed and solid lines - without and with the odderon contribution).

One can there regard the interaction of odderon with quark constituents of γ^* or, on the contrary, the interaction of gamma with the constituents of odderon. In the case of creation of π-meson, we have a very nonperturbative object at small q $\gamma*(q) \to (q\bar{q})$ as $r_\perp \sim 1/m$ is very large. In this case it can be treated as an interaction of a π-meson with a nucleon. If

$$(\beta_{odd,\pi}\ \beta_{odd,N})/(\beta_{odd,N})^2 \sim (\beta_{pom,\pi}\ \beta_{pom,N})\ (\beta_{pom,N})^2 = 2/3, \tag{47}$$

the coefficient $C_{odd}(\pi N)$ for the creation of a single π-meson will be obtained by multiplying the calculated value of $C_{odd}(NN)$ from the table by factor 2/3.

Besides, one should mention the importance of t dependence of the odderon amplitude, since the relative maximum of the interference between the $\gamma^*\gamma^*$ and $\gamma^*odderon$ amplitudes will be in the region of $p_\perp^2$ where both the amplitudes will be equal. In the case of large effective α'_-, this region will be that where both the amplitudes are small and the effect is very difficult to observe. So, the researches are necessary which can reveal the possible bounds on the t-dependence of the odderon amplitude.

Using the eikonal representation we obtain the terms corresponding to the electromagnetic-hadron interference in the second Born approximation taking into account the hadron form factor in a wide region of transfer momenta up to the diffraction dip domain. It allows us to calculate an additional contribution to the analyzing power A_N and double spin correlation parameter A_{NN} owing to the odderon contributions. As a result, we obtain, in the domain of the diffraction minimum, not small spin correlation effects due to the interference of the spin-non-flip elastic scattering amplitude and the electromagnetic spin-flip amplitude.

In spite of the large contribution of the hadron-spin-flip amplitude, we can see that taking account of the odderon contributions leads to visible changes in spin correlation effects. So, the precise measurement of A_N and A_NN in the region of the diffraction minimum and the treatment of their energy dependence can give some additional information which allows one to define the sign and magnitude of the odderon contribution. One should mention the importance of the t dependence of the odderon amplitude, and, therefore, researches are necessary which can reveal possible bounds on the t-dependence of the odderon amplitude.

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Селюгин О.В. E2-2001-228
Оддеронный вклад в дифракционные реакции

Величина нуклон-оддеронной связи определена несколькими способами из имеющихся экспериментальных данных по упругому нуклон-нуклонному рассеянию. Проанализирован возможный оддеронный вклад в спиновые эффекты упругого адронного рассеяния при высоких энергиях.

Работа выполнена в Лаборатории теоретической физики им. Н.Н.Боголюбова ОИЯИ.

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Selyugin O.V. E2-2001-228
Odderon Contribution in Diffraction Reactions

The magnitude of the nucleon-odderon coupling is extracted in some possible ways from the available experimental data on the elastic nucleon-nucleon scattering. The possible odderon contribution to spin effects of the elastic hadron scattering at high energies is analyzed.

The investigation has been performed at the Bogoliubov Laboratory of Theoretical Physics, JINR.

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