Vol. B12 (1981) ACTA PHYSICA POLONICA No 4

PROPERTIES OF THE REGGE EXCHANGE AMPLITUDES WITH THE A_1 QUANTUM NUMBERS

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(*Received October 28, 1980*)

Evidences for the Regge exchange amplitudes with the A_1 quantum numbers are studied. In particular, properties of the A_1NN, $A_1\rho\pi$ and $A_1\varepsilon\pi$ vertices are determined. We find that the polarization effects observed in the NN elastic scattering and the vector meson production on the polarized target are both consistent with the hypothesis of the A_1 Regge pole with the theoretically predicted strength and helicity structure. Through the analysis of ρ–ω interference effect we determine the relative phase of the A_1 and Z (2^{--}) trajectories. It appears to be opposite to that expected for exchange degenerate pair.

PACS numbers: 13.85.Hd, 13.85.-t, 12.40.Mm

1. *Introduction*

The recent results of the very high statistics study of the diffractive $\pi^-p \to \pi^+\pi^-\pi^-p$ process at 63 GeV/c [1] and charge exchange process $\pi^-p \to \pi^+\pi^-\pi^0n$ at 8.45 GeV/c [2] for the first time bring the firm evidence for the long searched A_1 resonance with the mass contained in 1.2–1.3 GeV region. Therefore, it seems to be a proper time for a thorough analysis of the existing experimental evidences for Regge exchange amplitudes with the A_1 quantum numbers.

The subject has been already discussed in the literature [3–5] where the existence of such exchange has been established. In this paper we discuss properties of the A_1 exchange observed in the reaction $\pi^-p_\uparrow \to \pi^+\pi^-n$ [18] and its interference with the opposite C-parity partner, Z-trajectory, with exchange quantum numbers $J^{PC} = 2^{--}, 4^{--}, \ldots$ This trajectory has been proposed by Irving [11] in order to explain $\pi^-p \to \omega n$ data at 6 GeV/c [12]. A_1–Z interference effects are studied through ϱ–ω interference in the process $\pi^-p \to \pi^+\pi^-n$ at 6 and 17 GeV/c [14, 15].

In Section 2, the A_1NN coupling constant, the $A_1\varrho\pi$ vertex properties and $A_1 \to \varepsilon\pi$ decay width are determined. The results are compared with the phenomenological predictions.

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In Section 3, the Regge pole parametrization of the production amplitudes for processes $\pi p \to \varrho^0 n$ and $\pi^- p \to \omega n$ is used for calculation of the ϱ–ω interference in the reaction $\pi^- p \to \pi^+\pi^- n$. Comparison with the data allows us to determine the relative sign of the A_1 and Z exchanges. The paper ends with conclusions contained in Section 4.

2. *Experimental determination of the A_1NN and $A_1\varrho\pi$ vertices*

There are two processes from which one can extract an evidence for the A_1 exchange:

(*i*) NN elastic scattering with polarized beam and target, as discussed in Ref. [3],

(*ii*) vector meson production on polarized target, as discussed in Ref. [5].

In the first process the difference between the total cross sections for parallel and antiparallel spin orientations measures directly a contribution from A_1+Z trajectories [3]. If A_1 and Z were exactly exchange degenerate (EXD) then the quantity

$$\Delta\sigma_L = \sigma_T(\tfrac{1}{2}, -\tfrac{1}{2}) - \sigma_T(\tfrac{1}{2}, \tfrac{1}{2})$$

would vanish. If we assume A_1 exchange to be the major contribution to $\Delta\sigma_L$ its measured value can be related to $g_{A_1\bar{p}p}$ — A_1 nucleon coupling constant, as discussed in Ref. [4].

In the process $\pi^- p_\uparrow \to \pi^+\pi^- n$ the additional observables, due to the polarization of the target, are sensitive to the presence of an exchange with quantum numbers of the A_1. However, even here the question of EXD of the A_1–Z trajectories is crucial for determination of the A_1NN vertex due to the fact that parametrizations with [6] and without [7] Nonsense Wrong Signature Zero (NWSZ) in the low t region give completely different results as far as A_1NN coupling is concerned. As long as the parameters of the A_1 trajectory are ambiguous, both parametrizations are accepted by the data. These facts are easy to understand. The above mentioned parametrizations differ from each other by the factor $(1-e^{i\pi\alpha})$ giving NWSZ at $\alpha(t) = 0$. Large polarization observed in the $\pi^- p_\uparrow \to \pi^+\pi^- n$ data [18] at low t values can be explained either by adopting parametrization without NWSZ or by pushing the point at which $\alpha_{A_1}(t) = 0$ far from physical t region. This can be achieved by assuming, as in Ref. [5], $\alpha^0_{A_1} \approx -0.3$ instead of $\alpha^0_{A_1} \approx 0$. In this case the coupling constant is enhanced by the factor $s^{-\alpha_{A_1}^0}/\sin\frac{\alpha^0_{A_1}\pi}{2}$ which at 17 GeV/c is ≈ 6.4. The motivation for the presence of NWSZ factor in the amplitude is based on the existence of the exchange degenerate trajectory which in view of the above mentioned measurement of $\Delta\sigma_L$ and the analysis presented in Section 3 of this paper is not the case for A_1. Therefore, we do not include NWSZ in the A_1 exchange parametrization.

In the ϱ region the reaction $\pi^- p \to \pi^+\pi^- n$ is described by eight independent amplitudes which we denote by L_f^λ and L_n^λ. L stands for the orbital momentum of the di-pion system (L = S, P), λ for its helicity. Nucleon helicity flip and nonflip amplitudes are labelled by f and n, respectively.

Our Regge parametrization is the following:

$$S_f^0 = \pi^0_{fs}, \qquad S_n^0 = A^0_{1s} + \pi^0_{sn},$$

$$P_f^0 = \pi_f^0, \qquad P_n^0 = A_1^0 + \pi_n^0,$$

$$P_f^- = \pi_f^- + C, \qquad P_n^- = A_1^- + \pi_n^-,$$

$$P_f^+ = A_{2f}^+ + C, \qquad P_n^+ = A_{2n}^+,$$

where π, A_1 and A_2 trajectories are labelled with the upper index for naturality exchanged (0, +, −) and lower index for flip and nonflip contributions (f, n). Index s denotes the contribution of a given exchange to the S wave production. The π-exchange pole terms are parametrized as

$$\pi_f^0 = \frac{\sqrt{-t'}\,\beta_\pi}{m_\pi^2 - t} e^{c_\pi^0(t-m_\pi^2)} e^{-i\pi\alpha_\pi/2}(s/s_0)^{\alpha_\pi(t)-1},$$

$$\pi_f^- = \frac{2\beta_\pi}{m_\varrho} \frac{-t'}{m_\pi^2 - t} e^{c_\pi^1(t-m_\pi^2)} e^{-i\pi\alpha_\pi/2}(s/s_0)^{\alpha_\pi(t)-1},$$

$$\frac{\pi_n^0}{\pi_f^0} = \frac{\pi_n^-}{\pi_f^-} = -r_\pi,$$

where $t' = t - t_{min}$, $r_\pi = \sqrt{t_{min}/t}$, $s_0 = 1$ GeV². The contributions to the nonflip pion exchange have been retained as they play important part in the description of the 6 GeV data for ϱ production and the ϱ–ω interference.

The A_2 and A_1 exchange terms are parametrized with the standard Regge pole formula [7] without NWSZ factor[1]

$$R_{n,x} = \beta_R^{n,x} e^{-i\pi\alpha_R/2}(\sqrt{-t'})^{(n+x)/2} e^{c_R t}(s/s_0)^{\alpha_R(t)-1}. \tag{2.1}$$

We use also the phenomenological constraint

$$\beta_{A_2 n}/\beta_{A_2 f} = -4(\mathrm{GeV}/c)^{-1}.$$

Thus our parametrization is precisely that of Ref. [5] except for the NWSZ factor in A_2 and A_1 Regge poles. Also the A_1 cut has not been explicitly introduced.

The parametrization of the production amplitudes gives also the parametrization of the measured t dependence of the angular distribution moments [5]. Free parameters of the model can be found by the fitting procedure. Namely, we fit the above model to the t-dependence in the range 0.0–1.0 of the previously published [8] angular distribution moments for the dipion system in the reaction $\pi^- p_\uparrow \to \pi^+\pi^- n$ at 17.2 GeV/c, integrated over the ππ effective mass range 0.71÷0.83 GeV. In Table I we show the results of the fit. Table II lists these parameters of the model which are not free. Here A_1 trajectory parameters are set somewhat arbitrarily due to the fact that we have really very little information on this matter. A_1 mass is still ambiguously determined due to the strong dependence on background estimation procedure [1, 2]. We take $m_{A_1} = 1.2$ and $\alpha'_{A_1} = \alpha'_\pi = 0.7$, hence $\alpha^0_{A_1} \approx 0$.

[1] For explanation of the notation see Appendix.

TABLE I

Fitted parameters for the model of $\pi p_{\uparrow} \to \pi^+\pi^- n$ process in the ρ region at 17.2 GeV/c

Parameter	Fitted value	Error
β_π^0	211.4 [$\mu b^{1/2}$]	1.4
C_π^0	4.22[GeV^{-2}]	0.05
C_π^1	3.04[GeV^{-2}]	0.07
β_{A_2}	273.2 [$\mu b^{1/2}$]	0.4
C_{A_2}	3.25[GeV^{-2}]	0.01
$\beta_{A_1}^0$	221.5[$\mu b^{1/2}$]	1.0
$\beta_{A_1}^1$	153.0 [$\mu b^{1/2}$]	2.1
$C_{A_1}^0$	8.8 [GeV^{-2}]	0.06
$C_{A_1}^1$	4.6 [GeV^{-2}]	0.05
$\beta_{A_1 s}$	83.5 [$\mu b^{1/2}$]	0.7
$C_{A_1 s}$	8.4 [GeV^{-2}]	1.5
$\Delta = \arg(P^0 - S)$	0.46[rad]	0.03
$\beta_{\pi\,\mathrm{cut}}$	−257.3 [$\mu b^{1/2}$]	3.1
$C_{\pi\,\mathrm{cut}}$	2.8 [GeV^{-2}]	0.13

In Table I $\beta_{A_1}^0$ and $\beta_{A_1}^1$ are of special interest. They are the strength of A_1 coupling and helicity structure of the $A_1 \varrho\pi$ vertex. In our model we do not include explicitly the A_1 cut amplitude but allow for different exponential slope in t for overall flip and nonflip contributions. The strength of the unabsorbed amplitudes can be retrived using the well tested phenomenological formula for the cut correction factor [7]:

$$C_{n,x} = \frac{1-A^{n+1}}{x+1},$$

where

$$A = \frac{m_{\mathrm{exch}}}{m_{\mathrm{exch}}+0.515\ \mathrm{GeV}}.$$

TABLE II

Trajectory parameters and other constants not fitted in the model

Parameter	α_π^0	α_π'	$\alpha_{A_1}^0$	α_{A_1}'	$\alpha_{A_2}^0$	α_{A_2}'	α_B^0	α_B'	$\alpha_{\pi\,\mathrm{cut}}^0$	$\alpha_{\pi\,\mathrm{cut}}'$
Value	−0.014	0.7	0.0	0.7	0.43	0.74	−0.14	0.7	−0.0	0.35

Parameter	$\alpha_{B\,\mathrm{cut}}^0$	$\alpha_{B\,\mathrm{cut}}'$	α_Z^0	$R = \beta_{A_2 n}/\beta_{A_2 f}$	$\beta_{\bar{B}}/\beta_B^0$	α_ρ^0	α_ρ'	s_0
Value	−0.14	0.35	0.0	−4 GeV/c	1.48 GeV/c	0.5	0.9	1 GeV^2

Given the helicity structure of the $A_1\varrho\pi$ vertex, $g^0_{A_1\pi\varrho}$ can be related to the width of $A_1 \approx 300$ MeV [1] through the formulas [4]

$$\Gamma_{A_1} = \frac{q}{24\pi}\left[2g_s^2 + \left(\frac{g_s m_{A_1} E_\varrho + \frac{1}{2} g_d p_\varrho^2}{m_{A_1} m_\varrho}\right)^2\right],$$

$$g^1_{A_1\varrho\pi} = g_d/4m_{A_1},$$

$$g^0_{A_1\varrho\pi} = \frac{m_{A_1}}{\sqrt{2}\, m_\varrho}\left(g_s - g_d \frac{E_\varrho}{2m_{A_1}}\right),$$

where p_ϱ and E_ϱ are ϱ momentum and energy in A_1 rest system for the $A_1 \to \varrho\pi$ decay, respectively. Using these formulas and the values of $\beta^0_{A_1}$ and $\beta^1_{A_1}$ from Table I corrected for absorption, we get $g_d/g_s \approx -6.2$. This result falls within the limits set on this quantity by the broken $SU(6)_W$ and D/S measured for $B \to \omega\pi$ decay [9,10] $g_d/g_s \approx -8.2 \div -2.5$. Having $g^0_{A_1\varrho\pi}$ and A_1 coupling strength corrected for absorption

$$\tilde{\beta}^0_{A_1} = \beta^0_{A_1}/c_{0,0} = g^0_{A_1\varrho\pi} g_{A_1 p\bar{n}}/m^2_{A_1}$$

we calculate $g_{A_1 p\bar{n}}$ [2]. Our result is compared in Table III with Kane's [4] estimation from NN elastic scattering and with the estimation from meson dominance on the axial vector weak current [4]. If we take into account many uncertainties involved in the experimental and theoretical determination of the g_{A_1NN} coupling constant, the comparison made in Table III seems to be fairly good. The polarization effects observed in the NN elastic scattering and the vector meson production on the polarized target are both consistent

TABLE III

Experimental and theoretical estimations of the s-channel helicity g_{A_1NN}

Source	Assumptions involved	$g_{A_1 p\bar{n}}$	Ref.
$\Delta\sigma_L = \sigma_T(\frac{1}{2}, \frac{1}{2}) - \sigma_T(\frac{1}{2}, -\frac{1}{2})$	$\alpha^0_{A_1} \approx 0.0$ $\mathrm{Im}(Z) \approx 0.0$ Phenomenological cut correction	16.1 ± 1.0	[4]
$\pi \bar{p}_\uparrow \to \pi^+\pi^- n$	No NWSZ in A_1 Regge pole exchange Phenomenological cut correction	17.3	This paper
Meson dominance of axial weak current	$m_{A_1} = 1.2$ GeV	15.0	[4]

with the hypothesis of the A_1 Regge pole with the theoretically predicted strength and helicity structure, provided the parametrization without NWSZ is adopted. If the NWSZ factor is present in the A_1 exchange amplitude, as in Ref. [5], the A_1NN coupling constant

[2] Our procedure of coupling constant determination is explained in the Appendix.

determined in the same way is larger by an order of magnitude and in complete disagreement with the prediction of the axial weak current [4]. Using g_{A_1NN} determined as above and A_1 coupling strength for the S wave production amplitude we can estimate $g_{A_1\varepsilon\pi} \approx 4.0$ and $A_1 \to \varepsilon\pi$ decay width

$$\Gamma_{A_1\to\varepsilon\pi} = \frac{p_\varepsilon^2 g_{A_1\varepsilon\pi}^2}{6\pi m_{A_1}^2} \approx 50 \text{ MeV}.$$

In the above calculation we assume that ε is a resonance ≈ 800 MeV, corresponding to the "up" solution [19] for S wave phase shift in $\pi\pi$ elastic scattering. This result is not in contradiction to the recent partial wave analysis in 3π system [1] where the intensity of $1^+S(\varrho\pi)$ wave relative to $1^+P(\varepsilon\pi)$ in the A_1 region is ≈ 0.2.

3. *A_1–Z trajectories and ϱ–ω interference effects*

In this Section we present an argument against the exchange degeneracy of the A_1 and Z trajectories, thus justifying the Regge parametrization for the A_1 exchange which has been used in the previous Section.

The existence of the Z meson ($J^{PC} = 2^{--}$) and its Regge trajectory has been proposed [11] in order to explain high statistics data at 6 GeV/c which show a large nonflip component in $\sigma_0(\omega n)$. The Irving [11] model employing B, Z and ϱ Regge poles and cuts describes salient features of the data. However, from his analysis nothing can be said about the phase of Z trajectory. In the present analysis we use ϱ–ω interference data at 6 and 17 GeV/c and the information about A_1 exchange derived from $\pi^- p_\uparrow \to \pi^+\pi^- n$ experiment on the polarized target. The phase of Z exchange relative to B and π determined in this way appears to be opposite to that expected from EXD argument.

First we attempt to obtain a good parametrization of the process $\pi p \to \omega n$ at 6 GeV/c [12] in order to use it in the description of the ϱ–ω interference effect. Six independent amplitudes for the $\pi p \to \omega n$ process are parametrized as follows

$$P_n^0 = Z_n^0, \qquad P_f^0 = B_f^0,$$

$$P_n^- = Z_n^-, \qquad P_f^- = B_f^- + C_f^-,$$

$$P_n^+ = \varrho_n^+, \qquad P_f^+ = \varrho_f^+ + C_f^+.$$

This is in fact the Irving and Michael model [13] with a few minor changes made in order to obtain better description of the data. They are as follows

(*i*) All Regge poles are parametrized as in formula (2.1);

(*ii*) β_B^-/β_B^0 is taken from Ref. [9] instead of the helicity structure derived from π–B EXD;

(*iii*) β_Z^-/β_Z^0 is the free parameter of the fit;

(*iv*) We allow for different t dependence of Z^- and Z^0 in order to account for absorption effects.

In Table IV we list the results of the fit, in Table II we list the values of parameters which are fixed in the model. The parameters of Z trajectory, in absence of any better guide, were taken the same as for A_1 trajectory, i.e. we assume weak exchange degeneracy.

TABLE IV

Fitted parameters for the model of $\pi^- p \to \omega n$ at 6 GeV/c

Parameter	Fitted value	Error
β_B^0	739.8 [$\mu b^{1/2}$]	13.5
$C_B^0 = C_B^-$	4.41[GeV^{-2}]	0.03
β_Z^-	112.3 [$\mu b^{1/2}$ GeV^{-1}]	2.8
β_Z^-	148.8 [$\mu b^{1/2}$]	3.1
C_Z^-	2.49[GeV^{-2}]	0.05
$C_Z^0 = C_B^0$	4.41[GeV^{-2}]	0.03
$\beta_{B\,cut}$	−105.6 [$\mu b^{1/2}$ GeV^{-1}]	5.9
$C_{B\,cut}$	2.02[GeV^{-2}]	0.11
β_ρ	469.9 [$\mu b^{1/2}$]	14.3
C_ρ	5.72[GeV^{-2}]	0.04

Having parametrizations of the $\pi^- p \to \omega n$ process at 6 GeV/c and $\pi^- p \to \varrho^0 n$ at 17.2 GeV/c, we can extrapolate each one to the other energy and calculate ϱ–ω interference effects at 6 and 17 GeV/c. Looking at Fig. 1 we can judge the precision of our parametrization of both $\pi p \to \omega n$ and $\pi p \to \varrho^0 n$ processes by its predictions for the ratios of the projected cross sections:

$$\sigma_0 = \varrho_{00} d\sigma/dt,$$

$$\sigma_+ = (\varrho_{11} + \varrho_{1-1}) d\sigma/dt,$$

$$\sigma_- = (\varrho_{11} - \varrho_{1-1}) d\sigma/dt$$

measured at 6 GeV/c.

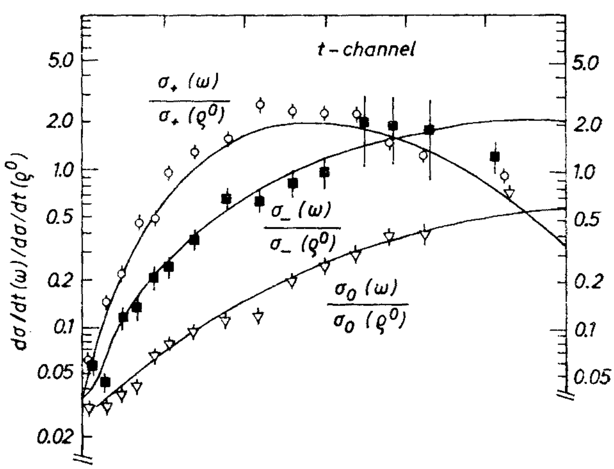

Fig. 1. Ratios of ω to ϱ^0 production cross section components: σ_0 (triangles), σ_+ (circles) and σ_- (squares) for p_{LAB} = 6 GeV/c [14]. The curves are the predicted ratios calculated on the base of our parametrization

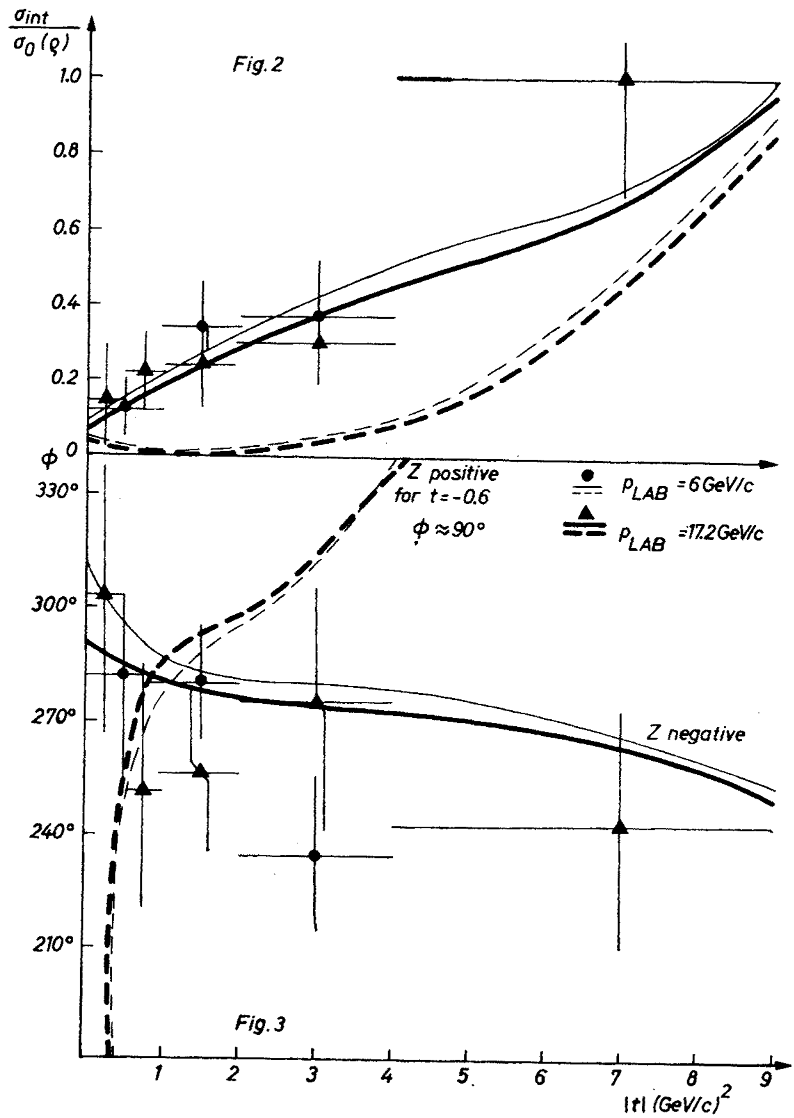

Fig. 2. Ratio $\sigma_{\text{int}}/\sigma_0(\rho) = |P(\rho)P(\omega)|/|P(\rho)|^2$ for $p_{\text{LAB}} = 17.2$ GeV/c (triangles) and 6 GeV/c (circles). The curves are the predicted ratios for Z positive (dashed line) and Z negative (solid line)

Fig. 3. Relative phase of ω and ρ^0 production amplitudes for $p_{\text{LAB}} = 17.2$ GeV/c (triangles) and 6 GeV/c (circles). The curves are the predicted phases for Z positive (dashed line) and Z negative (solid line)

The study of the ϱ–ω interference is based on the high statistics data at 6 GeV/c [14] and the CERN-Munich experiment on polarized target at 17.2 GeV/c [15]. Due to the polarization information we were able to study the ϱ–ω interference at 17.2 GeV/c in a model independent way. At first the model independent analysis was performed for S and P wave in five t bins (0.0÷0.05, 0.05÷0.1, 0.1÷0.2, 0.2÷0.4, 0.4÷1.0) in the ϱ mass region (600÷900 MeV) divided into 20 and 10 MeV bins (fine binning in the ϱ–ω mass region). The formalism for this analysis was described in Ref. [16].

Having the S and P wave model independent amplitudes, we calculate the ϱ–ω interference effect following reference [17], where P wave has been extracted from the data under the assumption of the flip dominance for unnatural parity exchange. As the result of this analysis we get six quantities as a function of the momentum transfer: $\xi^\lambda|A^\lambda_\omega/A^\lambda_\varrho|$ — the ratio of the ω and ϱ production amplitudes multiplied by the coherence factor[3]

$$\xi_\lambda = \frac{|A^\lambda_{++}(\varrho)A^\lambda_{++}(\omega)+A^\lambda_{+-}(\varrho)A^\lambda_{+-}(\omega)|}{\sqrt{|A^\lambda_{++}(\varrho)|^2+|A^\lambda_{+-}(\varrho)|^2}\sqrt{|A^\lambda_{++}(\omega)|^2+|A^\lambda_{+-}(\omega)|^2}};$$

ϕ^λ — the relative phase of the ϱ and ω production amplitudes. Index λ is for naturality being exchanged (0, +, −). A comparison between our results from the model independent amplitudes and the results of Ref. [17] does not show any significant differences except for ϕ^0 in the lowest t bin ($t < 0.05$). This fact justifies our use of the ϱ–ω interference results at 6 GeV/c obtained under assumption of the nucleon helicity flip domination for the unnatural parity exchange [14].

The results of the ϱ–ω interference analysis for helicity zero amplitudes at 6 and 17.2 GeV/c are presented in Figs 2 and 3 together with the predictions derived from our parametrization of the ϱ and ω production processes. Because the relative sign of B and Z exchanges is not a priori known we plot the curves with both signs. As we can see from Figs 2 and 3, the positive sign of Z coupling constant corresponding to A_1–Z EXD is excluded by ϱ–ω interference data. On the other hand, parametrization with the opposite sign of Z-exchange describes the data fairly well. It should be stressed that the general trends in the ϱ–ω interference patterns are stable against changes in A_1 and Z trajectory parameters.

We conclude that the A_1 trajectory exchange observed in $\pi^-p_\uparrow \to \pi^+\pi^-n$ process cannot be exchange degenerate with the Regge trajectory responsible for an amplitude with exchange quantum numbers in series $J^{PC} = 2^{--}, 4^{--}$ observed in $\pi p \to \omega n$ processes.

4. *Conclusions*

The investigation of the $\pi^-p_\uparrow \to \pi^+\pi^-n$ process shows that the observed there amplitude with exchange quantum numbers $1^{++}, 3^{++}$ has indeed the properties predicted theoretically and is consistent with polarization measurements in NN elastic scattering. However, this consistency can be achieved only if one abandons the idea of NWSZ at $\alpha_{A_1}(t) = 0$. This observation is supported by our results of the analysis of ϱ–ω interference effect where we determine the phase of Z trajectory to be opposite to that expected for trajectory EXD with A_1.

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[3] In principle coherence factor itself could be determined from the data, but in practice ρ–ω interference pattern appears to be very little sensitive to it.

The authors thank the members of CERN-Munich collaboration for permission to use the data on the ϱ–ω interference coming from the experiment on a polarized target. They would also like to thank Dr K. Rybicki for careful reading of the manuscript and remarks and Dr A.C. Irving for discussion.

APPENDIX

Notation, convention and coupling constant estimation

For a binary process a+b → c+d the s-channel helicity amplitude $M_{\lambda_c\lambda_d;\lambda_a\lambda_b}$ is characterized by the net helicity flip

$$n = |m_b - m_a|,$$

where $m_a = \lambda_c - \lambda_a$, $m_b = \lambda_d - \lambda_b$ and an even non-negative integer x

$$x = |m_b| + |m_a| - n.$$

Let us consider the pole term of the Reggeon exchange of spin J and mass m_e. Then the amplitude is

$$R^e_{n,x}(s, t) = |R^e_{n,x}| e^{-i\pi(\alpha(t)-J)/2},$$

$$|R^e_{n,x}| = (-t')^{(n+x)/2} g_{eac} g_{ebd} \left(\frac{s}{s_0}\right)^{\alpha(t)} \frac{s_0^J}{m_e^2 - t}.$$

The amplitude has a correct form at $\alpha(t = m_e^2) = J$. s_0, the essentially free parameter, we put equal 1 GeV^2, as usual in the Regge pole phenomenology. The propagator $1/(m_e^2 - t)$ is explicitly kept only for pion exchange (but is accounted for in coupling constant determination). The amplitude in formula (2.1) contains the normalizing factor

$$N = \left(\frac{389.3}{16\pi s^2}\right)^{1/2},$$

therefore, its modulus squared gives directly the cross section in μb and

$$\beta = 2.78 \frac{g_{eac} g_{ebd}}{m_e^2}. \tag{A1}$$

For A_1 and Z we do not introduce explicitly the cut term in order to reduce the number of free parameters to which the data are not sensitive. Instead, when calculating a coupling constant, we account for the absorption dividing $\beta_{n,x}$ by $C_{n,x}$ which sets the scale for the effect of absorption. $C_{n,x} = 1$ indicates no decrease in the amplitude at $t' = 0$ from the pure Regge pole result.

By studying the full absorption model a phenomenological formula for $C_{n,x}$ has been derived [7]:

$$C_{n,x} = \frac{\xi(1-A^{n+1})}{x+1},$$

where

$$A = \frac{m_e}{m_e+0.515\ \mathrm{GeV}},$$

$$\xi = \begin{cases} -1 & \text{for } x > 0, \quad n = 0 \\ +1 & \text{otherwise.} \end{cases}$$

The other effects of absorption are contained in a constant term in the exponential slope in t: $c = \tilde{c}+\alpha' \ln(s/s_0)$. We have dropped zero structure of the A_1 and Z exchange amplitudes $J_n(R_e\sqrt{-t})$ which we could not trace directly in the observed angular distribution moments. The t-dependence of the amplitude which we connect with the absorption is dropped when extrapolating to the pole. Thus, practically, a coupling strength is determined at $t' = 0$ and the pole extrapolation is reflected by presence of $1/m_e^2$ factor in formula (A1). Such procedure for the coupling constant determination has been tested [7] in many reactions giving satisfactory results.

For the determination of the $\mathrm{A_1 p\bar{n}}$ coupling constant we use the ratio

$$\frac{\beta^0_{\mathrm{A}_1}}{\beta^0_\pi} = \frac{g_{\mathrm{A_1 p\bar{n}}}\, g^0_{\mathrm{A_1 \varrho\pi}}/m^2_{\mathrm{A}_1}}{g_{\pi\mathrm{p\bar{n}}}\, g_{\varrho\pi\pi}}$$

and known values of $g_{\pi\mathrm{p\bar{n}}}$ and $g_{\varrho\pi\pi}$ [6]. In this way we are not dependent on the absolute normalization. In fact, β_π resulting from the fit is 10% low but within the errors (4% in the cross section, 20% in the amplitude).

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