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[1]R. Rubinstein, A. Ashmore, C. J. S. Demerell, W. R. Frisken, J. Orear, D. P. Owen, F. C. Peterson, A. L. Read, D. G. Ryan, and D. H. White, in Proceedings of the Topical Conference on High Energy Collisions of Hadrons, CERN, 1968 (to be published); M. L. Perl, ibid.; J. V. Allaby, A. N. Diddens, A. Klovning, E. Lillethun, E. J. Sacharidis, K. Schliipmann, and A. M. Wetherall, ibid.; M. Longo, ibid.; V. Barger, ibid.

[2]The Pomeranchuk amplitude is chosen to resemble a fixed pole with $\alpha_P(t) \simeq 1$ in order to give the observed trend towards decreasing shrinkage in $d\sigma(pp)/dt$ at higher energies and the nonshrinkage in $d\sigma(\pi^\pm p)/dt$. We need no specific hypothesis about the nature of the Pomeranchuk J-plane singularity (i.e., moving pole, fixed pole, branch cuts, etc.).

[3]This differs from the traditional assignment of linear amplitude zeros at nonsense wrong-signature points. Such a wrong-signature nonsense zero for ω would lead to $d\sigma(\bar{p}p)/dt > d\sigma(pp)/dt$ in some t range. We make no pretense of understanding the dynamical origin of the empirically required behavior at right- and wrong-signature exceptional points.

[4]In the special case $\alpha = 0$ a qualitatively similar prescription has been used by C. B. Chiu, S. Y. Chu, and L. L. Wang, Phys. Rev. 161, 1563 (1967).

[5]V. Barger and L. Durand, III, Phys. Rev. Letters 19, 1295 (1967).

[6]According to present theoretical ideas, an indefinitely falling hadron trajectory implies that the hadron is not composed of elementary objects (such as quarks) but is instead a composite of the hadrons. Cf. G. F. Chew, University of California Radiation Laboratory Report No. UCRL-17483, 1967 (unpublished).

POLARIZATION IN $\pi^- p \to \eta n$ AND THE RATIO OF F TO D COUPLING OF $N_\gamma(2650)$

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We explain the results of recent polarization measurements in the reaction $\pi^- p \to \eta n$ at intermediate energies by using a simple interference model. A possible determination of the ratio of F to D coupling of $N_\gamma(2650)$ is discussed and the conclusion drawn is unaffected in spite of the ambiguity regarding the sign of the A_2 residue associated with the spin-flip amplitude.

The polarization in $\pi^- p \to \eta n$ has recently been measured[1] at 3.20, 3.47, and 5.00 GeV/c. The results show a significantly large polarization at 3.20 GeV/c in the region of $0.14 < |t| < 0.25$. This paper attempts to explain these results and possibly to deduce the ratio of F to D coupling of $N_\gamma(2650)$. A Regge-pole model of the $\pi^- p \to \eta n$ process has been discussed by several authors[2,3] and we have adopted a similar method.

The polarization at 5.00[1] and 11.9 GeV/c[4] may be consistent with zero although the experimental errors are not as small as those in the πp charge-exchange polarization. At high energy where the direct-channel contributions can be ignored, we assume that the reaction $\pi^- p \to \eta n$ is dominated by one Regge-pole exchange, the A_2, in the t channel. At lower energies, we assume a simple interference model[5] of the A_2 pole exchange in the t channel and a resonance in the direct channel.

Scattering amplitudes, $f^{\eta n}$ (nonflip) and $g^{\eta n}$ (spin flip), are given, respectively, by

$$f^{\eta n} = f_A^{\eta n} + f_{\text{res}}^{\eta n} \tag{1}$$

and

$$g^{\eta n} = g_A^{\eta n} + g_{\text{res}}^{\eta n}. \tag{2}$$

The amplitudes due to the exchange of the A_2 Regge pole are given by

$$f_A^{\eta n} = -(Mm/4\pi s^{\frac{1}{2}})F(s,t)a_A(t)b_{1A}^{\eta n}(t) \tag{3}$$

and

$$g_A^{\eta n} = (m/16\pi)F(s,t)a_A(t) \times [b_{1A}^{\eta n}(t) - a_A(t)b_{2A}^{\eta n}(t)]\sin\theta, \tag{4}$$

where

$$F(s,t) = -\frac{1+\exp[-i\pi\alpha_A(t)]}{\sin\pi\alpha_A(t)}\left(\frac{S-M^2-m^2+\frac{1}{2}t}{2M_{AV}m_{AV}}\right)^{\alpha_A(t)},$$

M = nucleon mass, m = pion mass, $M_{AV} = 1.40$ and $m_{AV} = 0.70$,[6] $\alpha_A(t) = \alpha_A(0) + \alpha_A'(0)t$ is the A_2 trajectory, and $b_{1A}^{\eta n}(t)$ and $b_{2A}^{\eta n}(t)$ are the residues of the A_2 Regge pole. The direct-channel contributions, $f_{res}^{\eta n}$ and $g_{res}^{\eta n}$, are related to equivalent terms in the πp charge-exchange reaction by the factor g_{N_γ}, the ratio of the $N_\gamma \eta n$ and $N_\gamma \pi^0 n$ couplings, as

$$f_{res}^{\eta n} = g_{N_\gamma} f_{res}^{\pi^0 n}$$

and

$$g_{res}^{\eta n} = g_{N_\gamma} g_{res}^{\pi^0 n}. \tag{5}$$

We first establish the values of Regge residues $b_{1A}^{\eta n}$ and $b_{2A}^{\eta n}$ by analyzing available differential cross-section data at high energy where the resonance effect can be ignored. The sign of these residues cannot be obtained from the $\pi^- p \to \eta n$ differential cross section alone. Therefore, we also analyze the differential cross sections for $K^- p \to \bar{K}^0 n$ process in which both ρ and A_2 are exchanged. Scattering amplitudes due to the exchange of these two poles are given as

$$f^{K^0 n} = f_A^{K^0 n} + f_\rho^{K^0 n} \tag{6}$$

and

$$g^{K^0 n} = g_A^{K^0 n} + g_\rho^{K^0 n}. \tag{7}$$

By assuming the validity[3] of SU(3) symmetry for Regge-pole residues, we have

$$b_{1\rho}^{K^0 n} = -2^{-\frac{1}{2}} b_{1\rho}^{\pi^0 n} \text{ and } b_{2\rho}^{K^0 n} = -2^{-\frac{1}{2}} b_{2\rho}^{\pi^0 n},$$

where the residues in the case of πp charge-exchange process are known[5] and $b_{1\rho}^{\pi^0 n} = 34$ and $b_{2\rho}^{\pi^0 n} = -350$ in the region of $0 < |t| < 0.2$. We obtain Regge residues $b_{1A}^{K^0 \pi}$ and $b_{2A}^{K^0 n}$ which are assumed to be constant in $0 < |t| < 0.2$ by fitting the differential cross sections[7] for $K^- p \to K^0 n$ to the above expressions. By making use of the SU(3) coefficient, we have

$$b_{1A}^{\eta n} = (\tfrac{2}{3})^{\frac{1}{2}} b_{1A}^{K^0 n} \text{ and } b_{2A}^{\eta n} = (\tfrac{2}{3})^{\frac{1}{2}} b_{1A}^{K^0 n}.$$

These values are used as initial guess values for the four-parameter [b_{1A}, b_{2A}, $\alpha_A(0)$, and and $\alpha_A'(0)$] search in fitting the $\pi^- p \to \eta n$ differential cross sections[8] to Eqs. (3) and (4). Results are shown in Table I.

Polarization in the $\pi^- p \to \eta n$ process due to a particular resonance at its resonant energy is given by

$$P = \frac{2[(\mathrm{Im} f_{res}^{\eta n})(\mathrm{Re} g_A^{\eta n}) - (\mathrm{Im} g_{res}^{\eta n})(\mathrm{Re} f_A^{\eta n})]}{|f^{\eta n}|^2 + |g^{\eta n}|^2}. \tag{8}$$

We now discuss the sign of polarization in Eq. (8) at 3.20 GeV/c. From Table I we have $\mathrm{Re} f_A^{\eta n} < 0$ and $\mathrm{Re} g_A^{\eta n} < 0$. Since the contribution of the direct channel is only from the $T = \frac{1}{2}$ state, the only significant resonance to be considered at 3.20 GeV/c is $N(2650)$, and the immediately neighboring resonances of $N(2190)$ and $N(3020)$ can be ignored. The quantum state of $N(2650)$ has been established[5] as a $J = l - \frac{1}{2}$

Table I. Regge residues of the A_2. $\alpha_A = 0.40 + 0.49t$.

	Values of Regge residues [mb$^{1/2}$ (GeV/c)$^{-1}$]	No. of data	χ^2
$b_{1A}^{\eta n}$	-73	32[b]	20
$b_{2A}^{\eta n}$	-1070		
$(\frac{2}{3})^{\frac{1}{2}} b_{1A}^{K^0 n} = b_{1A}^{\eta n}$	-90[a]	Four data at $t = 0$[c]	0.8
$(\frac{2}{3})^{\frac{1}{2}} b_{1A}^{K^0 n} = b_{1A}^{\eta n}$	-85	12[c]	6
$(\frac{2}{3})^{\frac{1}{2}} b_{2A}^{K^0 n} = b_{2A}^{\eta n}$	-830		

[a]The minus sign was obtained from the fact that $\sigma_T(K^- p) > \sigma_T(K^- n)$ [see W. Galbraith et al., Phys. Rev. 138, B913 (1965)]. Also the ratio of the real to the imaginary part of the forward-scattering amplitude in $K^- p \to K^0 n$ is compatible with zero (Ref. 7).

[b]Ref. 9.

[c]Ref. 7.

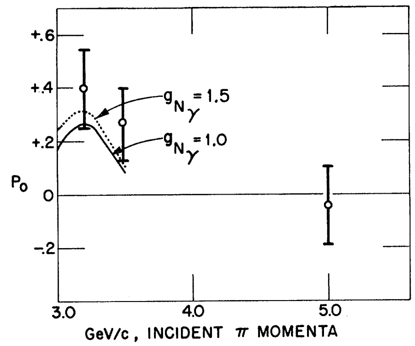

FIG. 1. Polarization in $\pi^- p \to \eta n$ at $|t| \approx 0.2$; solid curve calculated for $g_{N_\gamma} = 1.0$ and dotted curve for $g_{N_\gamma} = 1.5$.

state, and thus we have $\mathrm{Im} f_{\mathrm{res}}^{\eta n} < 0$ and $\mathrm{Im} g_{\mathrm{res}}^{\eta n} > 0$ in the region of $0 < |t| < 0.2$. Thus, Eq. (8) provides a definite positive polarization at 3.20 GeV/c. This gives a good qualitative explanation of the experimental data.[1]

It is also possible to obtain the factor g_{N_γ} in Eq. (2) by fitting Eq. (8) to the polarization data in $\pi^- p \to \eta n$ at 3.20 and 3.47 GeV/c.[1] The polarization calculated[9] by two possible values of g_{N_γ} is shown in Fig. 1, where the experimental data are also plotted. The differential cross sections calculated by Eqs. (1) and (2) with values of g_{N_γ} as 1.0 and 1.5 are in good agreement with the experimental data.[8] However, this is no longer true with values of g_{N_γ} higher than about 1.5. Since the ratio g_{N_γ} is related to the ratio of F and D coupling of N_γ resonance as[10]

$$g_{N_\gamma} = -3^{-1/2}(1-4f),$$

where $f+d=1$, the ratio F/D should be bigger than 2.3.[11] It is thus demonstrated that the ratio F/D can be obtained through the polarization data in $\pi^- p \to \eta n$ around the resonance. However, for more precise determination of the ratio we obviously need better data. It is also desirable to have polarization measurements around $N(2190)$. We could thus compare the ratio F/D of N_γ at different resonances.

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[1]D. D. Drobnis, J. Lales, R. C. Lamb, R. A. Lundy, A. Moretti, R. C. Niemann, T. B. Novey, J. Simanton, A. Yokosawa, and D. D. Yovanovitch, Phys. Rev. Letters 20, 274 (1968).

[2]R. J. N. Phillips and W. Rarita, Phys. Rev. 140, B200 (1965), and Phys. Rev. Letters 15, 807 (1965), and Phys. Letters 19, 598 (1965); R. K. Logan and L. Sertorio, Nuovo Cimento 52A, 1022 (1967).

[3]D. D. Reeder and K. V. L. Sarma, Nuovo Cimento 51A, 169 (1967).

[4]I. Mannelli and P. Sonderegger, private communication.

[5]Details of a similar model have been discussed by R. C. Lamb, R. A. Lundy, T. B. Novey, A. Yokosawa, and D. D. Yovanovitch, Phys. Rev. Letters 20, 353 (1968).

[6]R. C. Arnold, private communication.

[7]P. Astbury et al., Phys. Letters 23, 396 (1966).

[8]O. Guisan et al., Phys. Letters 18, 200 (1965).

[9]Resonance parameters of $N(2650)$ used in this calculation are similar to those used in Ref. 5.

[10]A. W. Martin and K. C. Wali, Phys. Rev. 130, 2455 (1963).

[11]It should be noted here that we reach the same conclusion about the ratio F/D even if we adopt the alternative solution of $b_{2A}^{\eta n} > 0$ since the first term in Eq. (8) is much smaller than the second term due to the fact that the average of $|\mathrm{Im} f_{\mathrm{res}}^{\eta n}| \approx 0$ in the region of $0.14 < |t| < 0.25$.

DETERMINATION OF THE *KNY* COUPLING CONSTANTS USING MODIFIED DISPERSION RELATIONS*

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The *KNY* coupling constants are determined using a new procedure which includes a criterion for checking the self-consistency of the necessary extrapolation into the unphysical region.

Several determinations of the *KNY* coupling constants have been made using forward *KN* dispersion relations in which the imaginary part of the scattering amplitude in the unphysical region is found by extrapolation from the experimentally accessible physical region. Most recently, Kim[1] has performed this extrapolation using multichannel effective-range the-