Reaction $K^- n \to \pi^- \Lambda^0$ in the New Interference Model

Raj Kumar, B. K. Agarwal, and C. P. Singh
Physics Department, Allahabad University, Allahabad, India
(Received 19 April 1971; revised manuscript received 21 July 1971)

Experimental data on angular distribution and polarization for the process $K^- n \to \pi^- \Lambda^0$ at 3.0 GeV/c are explained on the basis of the new interference model.

I. INTRODUCTION

Experimental data on angular distribution and polarization are available[1-3] for the reaction

$$K^- + n \to \pi^- + \Lambda^0 \tag{1}$$

at intermediate energies. Several unsuccessful attempts[4,5] have been made in the literature to explain both these data for the reaction (1) on the basis of the Regge-pole model by assuming that $K^*(890)$ and $K^{**}(1420)$ trajectories are not exchange degenerate. To assume exchange degeneracy for the trajectory K^* and K^{**} and also to get a nonvanishing polarization, one will have to move out of the pure Regge-pole model. Meyers *et al.*[6] have attempted a calculation with exchange degeneracy and absorption correction in which Pomeranchukon contribution is included. They also find a poor fit for both differential cross section and polarization.

The reaction (1) appears to pose a problem. It is difficult to explain the observed data either without exchange degeneracy in the pure Regge-pole or with exchange degeneracy in some kind of modified model. All attempts made so far to understand the behavior of reaction (1) in the intermediate-energy range have been unsuccessful.

The K^*-K^{**} exchange degeneracy in the $K\pi \to K\pi$ channel is expected in the duality scheme as $(\pi^+ K^+)$ is an exotic resonance. The exchange degeneracy of ρ-A_2 and ω-P' also suggests K^*-K^{**} degeneracy by SU(3) analogy.[7] Evidence for this is further provided by the duality diagram of Harari[8] which is nonplanar for the process (1). This implies that all the helicity amplitudes are purely real, and the polarization should vanish at high energies. The presence of polarization has led to suggestions that either the K^* and K^{**} trajectories are not exchange degenerate, or 3.0 GeV/c is not a high-enough momentum, or cuts are important.[7] However, polarization can be calculated with K^*-K^{**} degenerate trajectories if interference between the s-channel resonances and t-channel Regge poles is considered.

In the intermediate-momentum region (~2–5 GeV/c) it is well known that oscillations due to s-channel resonances are superimposed in the production angular distributions over the peripheral effects (forward and/or backward peakings) of exchange poles. Barger and Cline[9] have utilized this fact to construct an interference model in this energy region. This model, however, suffers from a serious double-counting effect. Recently Coulter *et al.*[10] have overcome this difficulty, by considering the behavior of terms in a Veneziano amplitude[11] in which the Euler beta function, which has poles in s and t, is replaced by a sum of s-channel resonances and by keeping the asymptotic form of the other contributions. The net effect is to replace the signature-term part of the Regge amplitude by a sum of s-channel resonances. This "new interference model" provides[12] a self-consistent method of adding contributions from the crossed-channel Regge trajectories and direct-channel resonances without double counting.

In this note, we intend to apply the "new interference model" to the reaction (1) at 3 GeV/c, assuming strong exchange degeneracy of K^* and K^{**} trajectories for evaluating the Regge contributions in the crossed channel. The resonance contribution is taken from the resonance $\Sigma(2595)$ which lies close to the c.m. energy of 2610 MeV.

II. FORMALISM

In the new interference model the spin-nonflip and the spin-flip amplitudes are given as

$$A' = A'_{\text{Regge}} + A'_{\text{resonance}} , \tag{2}$$

$$B' = B_{\text{Regge}} + B_{\text{resonance}} , \tag{3}$$

where A' is related[13] to the invariant amplitudes A and B as follows:

$$A' = A + \frac{s-u+\Delta}{4\overline{m}^2 - t}\,\overline{m}B, \tag{4}$$

$$\Delta = \frac{(m_1 - m_2)(\mu_1{}^2 - \mu_2{}^2)}{2\overline{m}} . \tag{5}$$

Here m_1 (m_2) is the mass of the initial (final) baryon, $\overline{m}$ is the average of the two external baryon masses, μ_1 (μ_2) is the mass of the initial (final) meson, and s, t, u are the usual Mandelstam variables. After omitting the term with the signature factor, we parametrize the Regge amplitude in the

t channel as follows:

$$A'_{\text{Regge}} = \frac{\beta_1}{\Gamma(\alpha)} \frac{1}{\sin\pi\alpha} \left(\frac{s}{s_0}\right)^{\alpha}, \tag{6}$$

$$B_{\text{Regge}} = \frac{\beta_2}{\Gamma(\alpha)} \frac{1}{\sin\pi\alpha} \left(\frac{s}{s_0}\right)^{\alpha-1}. \tag{7}$$

Here β_1 and β_2 are the spin-nonflip and spin-flip residue functions, respectively, α is the Regge-exchange-degenerate $K^*(890)$ and $K^{**}(1420)$ trajectory parameter, and s_0 is the scaling factor.

For getting the resonance contribution, we can relate A and B with the center-of-mass invariant amplitudes f_1 and f_2 as

$$A_{\text{resonance}} = 4\pi\left(\frac{|\vec{q}_1|}{|\vec{q}_2|}\right)^{1/2}\left(\frac{W+\overline{m}}{(E_1+m_1)^{1/2}(E_2+m_2)^{1/2}} f_1 - \frac{W-\overline{m}}{(E_1-m_1)^{1/2}(E_2-m_2)^{1/2}} f_2\right), \tag{8}$$

$$B_{\text{resonance}} = 4\pi\left(\frac{|\vec{q}_1|}{|\vec{q}_2|}\right)^{1/2}\left(\frac{1}{(E_1+m_1)^{1/2}(E_2+m_2)^{1/2}} f_1 + \frac{1}{(E_1-m_1)^{1/2}(E_2-m_2)^{1/2}} f_2\right), \tag{9}$$

where $|\vec{q}_1|$ and $|\vec{q}_2|$ and the initial and final center-of-mass momenta, respectively, and E_1 and E_2 are the initial and final baryon center-of-mass energies, respectively. In terms of the partial-wave amplitudes, f_1 and f_2 can be written as

$$f_1 = \sum_{l=0}^{\infty} [f_{l+}P_{l+1}'(\cos\theta) - f_{l-}P_{l-1}'(\cos\theta)], \tag{10}$$

$$f_2 = \sum_{l=1}^{\infty} [f_{l-} - f_{l+}] P_l'(\cos\theta). \tag{11}$$

Here θ is the center-of-mass scattering angle between the initial and final mesons, and the prime denotes the derivative. Now the partial-wave amplitudes can be obtained by using a Breit-Wigner formula for the resonance scattering:

$$f_{l\pm} = \frac{1}{2|\vec{q}_1|} \frac{\phi(\Gamma_1\Gamma_2)^{1/2}}{(W_r - W) - \frac{1}{2}i\Gamma}. \tag{12}$$

Here Γ is the total width of the resonance, Γ_1 and Γ_2 are the partial decay widths in the K^-n and $\Lambda^0\pi$ channels, respectively, ϕ is the sign of the resonant amplitude, W_r is the mass of the resonance, and the c.m. energy W has been used for $\sqrt{s}$.

In terms of A' and B, the differential cross section[13] and polarization[14] are given by

$$\frac{d\sigma}{dt} = \frac{1}{64\pi s|\vec{q}_1|^2}\left((4\overline{m}^2 - t)|A'|^2 + \frac{4s|\vec{q}_1|^2|\vec{q}_2|^2\sin^2\theta}{4\overline{m}^2 - t}|B|^2\right), \tag{13}$$

$$P\frac{d\sigma}{dt} = -\frac{|\vec{q}_1|}{|\vec{q}_2|}\frac{1}{16\pi W}\sin\theta\,\mathrm{Im}(A'B^*). \tag{14}$$

In our calculations we have taken the scaling factor s_0 as 1 GeV^2. The trajectory α is given by the

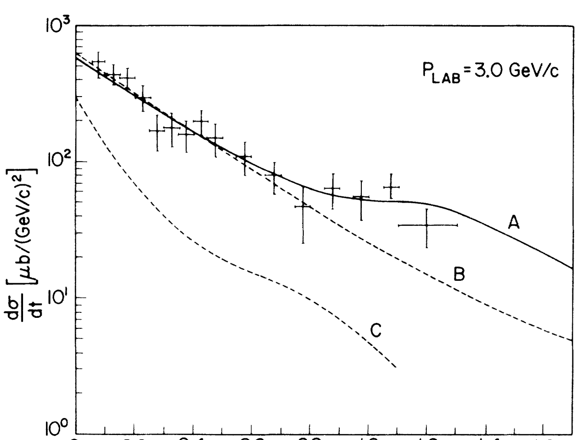

FIG. 1. The production angular distribution for the reaction $K^-n \to \pi^-\Lambda^0$ at an incident kaon momentum of 3.0 GeV/c. The experimental data have been taken from Barloutaud *et al.*[1] The curve A represents our calculation. The curve B represents the pure Regge-pole (without signature term) prediction. The curve C represents the calculation of Meyers *et al.*[6]

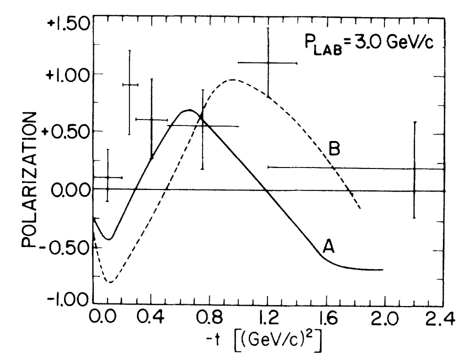

FIG. 2. The polarization for the reaction $K^-n \to \pi^-\Lambda^0$ at an incident kaon momentum of 3.0 GeV/c. The experimental data have been taken from Barloutaud *et al.*[1] The curve A represents our calculation. The curve B represents the calculation of Meyers *et al.*[6]

Chew-Frautschi plot,

$$\alpha = 0.24 + 0.9t. \quad (15)$$

The residue functions are found to be

$$\beta_1 = +40.0 \text{ GeV}^{-1},$$
$$\beta_2 = -300.0 \text{ GeV}^{-2}. \quad (16)$$

The resonance parameters[15] are $\Gamma = 140$ MeV, $\phi\sqrt{\Gamma_1\Gamma_2} = -0.01$ GeV, and $J^P = \frac{9}{2}^+$.

III. DISCUSSION

The results of our calculation together with the experimental data are shown in Figs. 1 and 2. The angular distribution at an incident momentum of 3.0 GeV/c, Fig. 1, is in reasonable agreement with the experimental data. The polarization, Fig. 2, is also of the right order of magnitude, suggesting that the imaginary part of the amplitude is dominated by resonance of mass $m \sim s^{1/2}$.

The success of the new interference model in explaining both the differential cross section and polarization in the intermediate-energy range suggests that the basic assumptions behind it are right and merit more attention.

ACKNOWLEDGMENT

R. K. and C. P. S. are grateful to the Council of Scientific and Industrial Research, New Delhi, for financial support.

[1]R. Barloutaud, Doung Nhu Hoa, J. Griselin, D. W. Merrill, J. C. Scheuer, W. Hoogland, J. C. Kluyver, A. Minguzzi-Rauzi, A. M. Rossi, B. Baher, E. Hirsch, J. Goldberg, and M. Laloum, Nucl. Phys. B9, 493 (1969).

[2]David J. Crennell, Uri Karshon, Kwan Wu Lai, John S. O'Neall, J. Michael Scarr, Robert M. Lea, Thomas G. Schumann, and Ernest M. Urvater, Phys. Rev. Letters 23, 1347 (1969).

[3]W. L. Yen, A. C. Ammann, D. D. Carmony, R. L. Eisner, A. F. Garfinkel, L. J. Gutay, R. V. Lakshmi, D. H. Miller, and G. W. Tautfest, Phys. Rev. Letters 22, 963 (1969).

[4]D. D. Reeder and K. V. L. Sarma, Phys. Rev. 172, 1566 (1968).

[5]P. A. Collins, B. J. Hartley, R. W. Moore, and K. J. Moriarty, Nucl. Phys. B20, 331 (1970).

[6]C. Meyers, Y. Noirot, M. Rimpault, and P. Salin, Nucl. Phys. B23, 99 (1970).

[7]J. D. Jackson, Rev. Mod. Phys. 42, 12 (1970).

[8]H. Harari, Phys. Rev. Letters 22, 562 (1969).

[9]V. Barger and D. Cline, Phys. Rev. 155, 1792 (1967).

[10]P. W. Coulter, E. S. Ma, and G. L. Shaw, Phys. Rev. Letters 23, 106 (1969).

[11]G. Veneziano, Nuovo Cimento 57A, 190 (1968).

[12]Toshiaki Karasuno and Shigeo Minami, Phys. Rev. D 2, 1320 (1970).

[13]A. D. Martin and C. Michael, Phys. Letters 32B, 297 (1970).

[14]M. Imachi, K. Kinoshita, Kunio Shiga, F. Toyoda, and M. Uehara, Progr. Theoret. Phys. (Kyoto) 43, 444 (1970).

[15]Matts Roos, Claude Bricman, A. Barbaro-Galtieri, L. R. Price, A. Rittenberg, A. H. Rosenfeld, N. Barash-Schmidt, Paul Söding, C. Y. Chien, C. G. Wohl, and T. Lasinki, Phys. Letters 33B, 1 (1970).