Study of K-N ($\bar{K}$-N) Scattering Based on the New Interference Model

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K-N ($\bar{K}$-N) elastic scattering is described by the new interference model in which the scattering amplitude consists of the direct-channel resonance amplitude and the Regge amplitude without the signature factor. In our study, the requirement of duality is taken into consideration. The existence of the exotic resonance Z^* is discussed, and its effects on $K^{\pm}$-p scattering are examined.

I. INTRODUCTION

By means of the Regge-pole theory, many authors[1] have tried to analyze the experimental data for elastic K-N ($\bar{K}$-N) scattering at high energy. However, they did not consider the requirement of duality in their analyses, because the duality concept[2] has been pointed out only recently. It is the purpose of this paper to estimate the differential cross section and the polarization of recoil nucleons in the reaction by taking into account the effects of duality.

For the reaction in an intermediate energy region, Coulter *et al.*[3] proposed a new interference model which is free from double counting. We have previously discussed the new interference model and have shown that the experimental data for π^-p charge-exchange scattering[4] at 2–18 GeV or the K-N ($\bar{K}$-N) total cross section[5] can be explained well by the model. As the new interference model is consistent with duality, we use this model in our study of K-N ($\bar{K}$-N) scattering.

Paying attention to the fact that in the K-N system there is no resonance except for the exotic resonance Z^*, one of the authors[6] previously tried to describe $\bar{K}$-N backward scattering at 1–2 GeV/c in terms of the direct-channel resonance amplitude. Recently, experimental results for K^--p backward scattering from 1 to 2.5 GeV/c have been reported by Carroll *et al.*[7] The main features of their data are the following: (i) The 180° cross section decreases very rapidly with increasing K^- laboratory momentum. The $d\sigma/du$ at $u=0$ drops faster than any other known elastic backward cross section at comparable energies and has approximately an s^{-10} dependence. (ii) There is a backward dip at all energies in the region 1–2.5 GeV/c and the cross section drops off smoothly towards 180°. Carroll *et al.*[7] have attempted a fitting to their data either by a pure resonance model without background or by a Z^*-exchange model alone. Even if the Z^* really exists, however, it is questionable to explain the results for the reaction at low energies, such as 1–2.5 GeV/c, by a pure Regge-exchange model. Moreover, the observed dip-bump structure for $d\sigma/d\Omega(180°)$ cannot be explained by the Z^*-exchange amplitude alone. In Sec. II we describe K^--p backward scattering in terms of the direct-channel resonance amplitude and the Regge amplitude without the signature factor.

Dikmen[8] has studied the elastic forward diffraction peak in kaon-nucleon scattering on the basis of his model of the Pomeranchukon exchange plus direct-channel resonances. As was pointed out by Coulter *et al.*,[3] his model is generally insufficient to describe

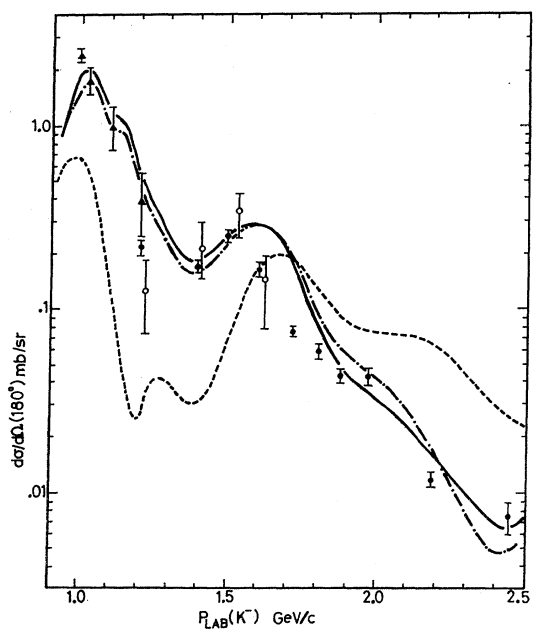


FIG. 1. Energy dependence of $d\sigma/d\Omega(180°)$ for K^--p elastic scattering. Solid (dashed) curve shows the results in a pure resonance model with the modified parameters (the parameters listed in Particle Properties Tables). Dash-dotted curve shows the results in the new interference model. For the experimental data, see Ref. 7.

[1] See for example, R. J. N. Phillips and W. Rarita, Phys. Rev. **139**, 1336 (1965).
[2] C. Schmid, Phys. Rev. Letters **20**, 689 (1968).
[3] P. W. Coulter, E. S. Ma, and G. L. Shaw, Phys. Rev. Letters **23**, 106 (1969).
[4] S. Minami, Nuovo Cimento Letters **3**, 124 (1970).
[5] T. Karasuno, Nuovo Cimento Letters **2**, 749 (1969).
[6] S. Minami, Phys. Rev. **155**, 1678 (1967).
[7] A. S. Carroll, J. Fischer, A. Lundby, R. H. Phillips, C. L. Wang, F. Lobkowicz, A. C. Melissinos, Y. Nagashima, C. A. Smith, and S. Tewksbury, Phys. Rev. Letters **23**, 887 (1969). In order to reproduce their experimental results for backward scattering, they have attempted not only to modify the elasticities of resonances but also to make different spin-parity assignments for the high-mass resonances.
[8] F. N. Dikmen, Nuovo Cimento Letters **1**, 544 (1969). According to his conclusion, it seems to be necessary to assume a Pomeranchuk trajectory with a slope $a_1=0.7$ [$\alpha_P(t)=1+0.7t$] in order to explain the elastic forward diffraction peaks in pion-nucleon and kaon-nucleon scattering.

scattering, because the Regge-exchange amplitude without the signature factor is not taken into account in his treatment. So far as elastic $\bar{K}$-N forward scattering is concerned, however, it can easily be shown that the results based on the new interference model are accidently reduced to those based on Dikmen's model. In K-N elastic scattering, on the other hand, the amplitude in his model comes from the contributions of the Pomeranchuk trajectory only and cannot give any reliable results for the differential cross section or the polarization of recoil nucleons. In Sec. III, forward K-N ($\bar{K}$-N) scattering is described in terms of the new interference model.

Recently, Kato *et al.*[9] have performed a phase-shift analysis of K^+-p elastic scattering data from 0.86 to 1.95 GeV/c and have obtained four possible solutions. It seems that three of their solutions indicate resonant-like behavior in the $P_{3/2}$ partial wave. We try to examine in Sec. IV their solutions from the viewpoint of the new interference model.

II. BACKWARD K^--p ELASTIC SCATTERING

If there is no resonance in the K-N system, needless to say, the direct-channel resonance amplitude is mainly responsible for the behavior of the differential cross section for the reaction in the backward direction. In Fig. 1 are shown the results for $d\sigma/d\Omega(180°)$, when we use the resonance parameters listed in Particle Properties Tables[10] (cf. Table I and Fig. 1 in Ref. 6).

TABLE I. Resonance parameters used for resonance fit. Values in parentheses are those taken from the Particle Properties Tables (see Ref. 10).

Resonance	J^P	Width (GeV)	Elasticity
$\Lambda(1520)$	$\frac{3}{2}^-$	0.014 (0.016)	0.49 (0.45)
$\Lambda'(1670)$	$\frac{1}{2}^-$	0.020 (0.025)	0.18 (0.14)
$\Lambda'(1700)$	$\frac{3}{2}^-$	0.028 (0.040)	0.21 (0.25)
$\Lambda(1745)$	$\frac{1}{2}^+$	0.147	0.40
$\Lambda(1750)$	$\frac{1}{2}^-$	0.110	0.20
$\Lambda(1815)$	$\frac{5}{2}^+$	0.082 (0.075)	0.80 (0.65)
$\Lambda(1830)$	$\frac{5}{2}^-$	0.041 (0.080)	0.08 (0.10)
$\Lambda(1860)$	$\frac{7}{2}^+$	0.040	0.15
$\Lambda(2100)$	$\frac{7}{2}^-$	0.140 (0.140)	0.24 (0.30)
$\Lambda(2350)$	$\frac{9}{2}^+$	0.160 (0.210)	0.09 (0.12)
$\Sigma(1660)$	$\frac{3}{2}^-$	0.050	0.06
$\Sigma(1765)$	$\frac{5}{2}^-$	0.100 (0.100)	0.34 (0.46)
$\Sigma(1780)$	$\frac{5}{2}^+$	0.123	0.12
$\Sigma(1915)$	$\frac{5}{2}^+$	0.060 (0.060)	0.07 (0.10)
$\Sigma(2030)$	$\frac{7}{2}^+$	0.176 (0.120)	0.23 (0.10)
$\Sigma(2250)$	$\frac{9}{2}^-$	0.200 (0.200)	0.12 (0.08)
$\Sigma(2455)$	$\frac{9}{2}^+$	0.100 (0.120)	0.05 (0.06)
$\Sigma(2595)$	$\frac{11}{2}^-$	0.140 (0.140)	0.01 (0.04)

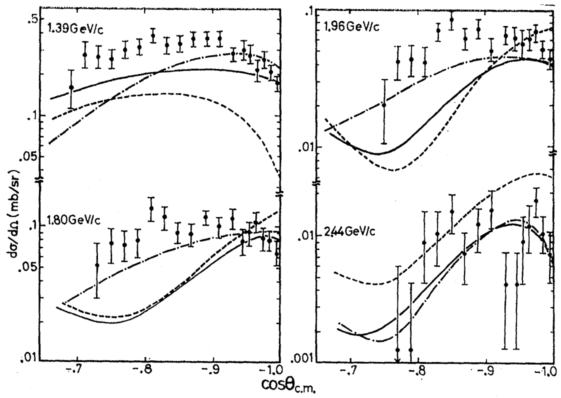


FIG. 2. Differential cross sections of K^--p elastic scattering in the backward direction. Solid (dashed) curve shows the results in a pure resonance model with the modified parameters (the parameters listed in Particle Properties Tables). Dash-dotted curve shows the results in the new interference model. For the experimental data, see Ref. 7.

But there are the following differences between the theoretical and experimental values of $d\sigma/d\Omega(180°)$: (i) In an energy region from 1.1 to 1.6 GeV/c, the theoretical values are considerably smaller than the observed ones, and (ii) the observed peak at about 1.7 GeV/c is not so pronounced as the predicted one. These facts may suggest the following: (a) It is necessary to change the values of the resonance parameters within experimental errors, (b) there is an additional resonance which has a large effect on K^--p elastic scattering at 1.1–1.6 GeV/c although it has not yet been established, or (c) there exist some exotic resonances (Z^*'s).

First of all, we try to modify the values of the resonance parameters within experimental errors so that good fits to the data may be obtained. The solid curves in Figs. 1 and 2 show the results for backward K^--p scattering when we use a pure resonance model with modified values of the parameters (see Table I). Although the behavior of the backward K^--p cross section can be reproduced by the direct-channel effects alone, we now take into account the effects not only of the resonance amplitude but also of the Regge amplitude due to a Z^* trajectory, as an alternative explanation of the experimental results for backward scattering.

For the Z^* with a mass 1910 MeV, some authors[11,12] have made the assignment $J^P=\frac{1}{2}^+$, and others[9,13,14]

[9] S. Kato, P. Koehler, T. Novey, A. Yokosawa, and G. Burleson, Phys. Rev. Letters **24**, 615 (1970).

[10] N. Barash-Schmidt, A. Barbaro-Galtieri, L. R. Price, A. H. Rosenfeld, P. Söding, C. G. Wohl, M. Roos, and G. Conforto, Rev. Mod. Phys. **41**, 109 (1969).

[11] R. J. Abrams, R. L. Cool, G. Giacomelli, T. F. Kycia, B. A. Leontić, K. K. Li, and D. N. Michael, Phys. Rev. Letters **19**, 259 (1967).

[12] A. T. Lea, B. R. Martin and G. C. Oades, Phys. Rev. **165**, 1770 (1968).

[13] G. A. Rebka, Jr., J. Rothberg, A. Etkin, P. Glodis, J. Greenberg, V. W. Hughes, K. Kondo, D. C. Lu, S. Mori, and P. A. Thompson, Phys. Rev. Letters **24**, 160 (1970).

[14] R. Levi Setti, in *Proceedings of the Lund International Conference on Elementary Particles, 1969*, edited by G. van Dardel (Berlingska, Lund, Sweden, 1969).

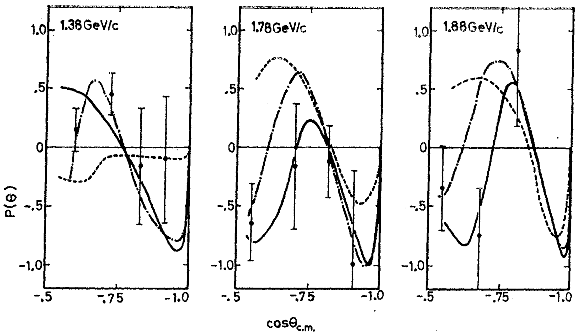


FIG. 3. Polarization of recoil protons in elastic K^--p backward scattering. Solid (dashed) curve shows the results in a pure resonance model with the modified parameters (the parameters listed in Particle Properties Tables). Dash-dotted curve shows the results in the new interference model.

the assignment $J^P=\frac{3}{2}^+$. We here assume a $Z^*(1910)$ with $\frac{3}{2}^+$ and consider the Z^* trajectory $\alpha(u)=-2.9+1.2u$ to which the $Z^*(1910)$ belongs. This trajectory is more or less different from the $\alpha(u)=-3.73+1.1u$ given by Carroll *et al.*[7] [In the case where the $Z^*(1910)$ has spin parity $J^P=\frac{1}{2}^+$, the conclusion mentioned in this paper does not suffer any large change, if we adopt $\alpha(u)=-3.2+u$ as the Z^* trajectory.]

As is well known, the Regge-exchange amplitude

$$f+i(\boldsymbol{\sigma}\cdot\boldsymbol{n})g\sin\theta$$

due to the Z^* trajectory is expressed as follows[15]:

$$f=(\gamma_1/\sqrt{s})[(E_s+M)-\cos\theta\,(E_s-M)]R(u,s)\,, \quad (1)$$

$$g=-(\gamma_2/\sqrt{s})(E_s-M)R(u,s)\,, \quad (2)$$

where

$$R(u,s)=\frac{1+i\tau e^{-i\pi\alpha}}{\Gamma(\alpha+\frac{1}{2})\cos\pi\alpha}\left(\frac{s}{s_0}\right)^{\alpha-1/2} \quad (3)$$

and

$$E_s=(s+M^2-\mu^2)/2\sqrt{s}=s'/2\sqrt{s}\,.$$

In scattering at 180°,

$$f=(s'/s)\gamma_1\frac{1+i\tau e^{-i\pi\alpha}}{\Gamma(\alpha+\frac{1}{2})\cos\pi\alpha}\left(\frac{s}{s_0}\right)^{\alpha-1/2}. \quad (4)$$

In the expression (4), the second term with the signature factor corresponds to the asymptotic form of the resonance amplitude.[3] The total amplitude in the new interference model is obtained by adding the first term in Eq. (4) to the direct-channel resonance amplitude.

In order to obtain the best fit to the data for backward K^--p scattering, we have attempted to readjust the resonance parameters in the new interference model. The results are summarized as follows: Indeed the energy dependence of $d\sigma/d\Omega$ at 180° can be explained satisfactorily by employing the remodified values of resonance parameters, but the experimental results for the angular distribution cannot be reproduced with these values of parameters, and vice versa. It seems to be the resonance parameters mentioned in Table I that give nice fits to the data available at present from various points of view. This means that the effects of the direct-channel resonances on backward K^--p scattering at 1–2.5 GeV/c are much larger than those of the Z^*. This statement may also be supported by the facts that (i) the Z^* is regarded as an exotic resonance and its $\alpha_{Z^*}(0)$ would have a small value, (ii) the differential cross sections of backward K^--p scattering *at high energy* are much smaller than those of backward K^+-p scattering,[16] and (iii) $d\sigma/du$ for K^+-p scattering has a pronounced backward peak, while there is no backward peak in K^--p scattering.[7,16] The dash-dotted curves in Figs. 1 and 2 show the results when $\gamma_1\cong 0.5$ GeV^{-1}, $\gamma_2\cong 40\,(e^{-1.5u}-1)$ GeV^{-1}, $s_0=0.05$ GeV^2, and the values of the resonance parameters mentioned in Table I are adopted.

From the above study, we can say that either the direct-channel resonance model or the new interference model can give nice fits to the data for the differential cross section in the backward direction. Then, the following question arises: Which interpretation is correct? If the Z^* really exists, we should adopt the new interference model. In order to discriminate between them, we estimate the polarization $P(\theta)$ of recoil nucleons for K^--p backward scattering, although the existence of the Z^* might be confirmed by other experiments. In Fig. 3 are shown the predicted values of the $P(\theta)$. It may be difficult from the experimental data at present to determine which model is promising. An answer to this problem would be given by measurement of $P(\theta)$ at $\cos\theta=x\cong-0.65$, because there is a large difference between the predicted values of $P(x\cong-0.65)$ in the two models.

III. FORWARD K-N ($\bar{K}$-N) SCATTERING

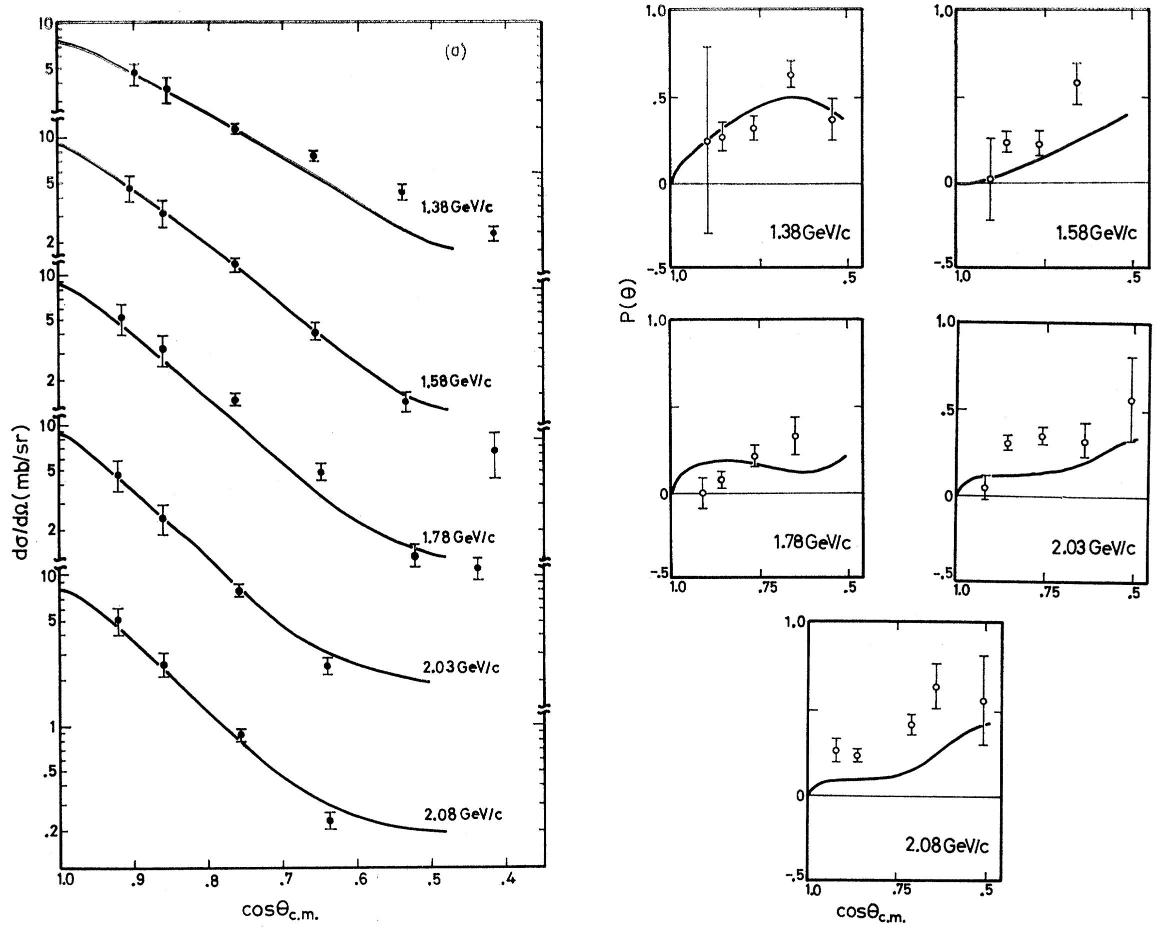
It may be supposed that the contributions from the exotic resonance Z^* to forward K-N ($\bar{K}$-N) scattering at high energy are much smaller than those from the Regge-exchange amplitude. In this section we study forward K-N ($\bar{K}$-N) scattering without any consideration about the effects of the Z^*. (The effects of the Z^* on K^+-p elastic scattering are discussed in Sec. IV.) As is well known, each Regge pole gives a spin-nonflip term A and a spin-flip term B of the form[17]

$$A_i=C_i(t)\frac{1}{8\pi\sqrt{s}}\frac{1+\tau e^{-i\pi\alpha_i}}{\Gamma(\alpha_i)\sin\pi\alpha_i}\left(\frac{s}{s_0}\right)^{\alpha_i}, \quad (5)$$

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

[16] J. Banaigs, J. Berger, C. Bonnel, J. Duflo, L. Goldzahl, F. Plouin, W. F. Baker, P. J. Carlson, V. Chabaud, and A. Lundby, Phys. Letters 24B, 317 (1967).

[17] S. C. Frautschi, M. Gell-Mann, and F. Zachariasen, Phys. Rev. 126, 2204 (1962).



(a) (b)

FIG. 4. (a) Differential cross sections and (b) polarization of recoil protons in elastic K^--p forward scattering. Experimental data are from Ref. 21.

$$B_i = D_i(t)\frac{\sin\theta}{8\pi\sqrt{s_0}}\frac{1+\tau e^{-i\pi\alpha_i}}{\Gamma(\alpha_i)\sin\pi\alpha_i}\left(\frac{s}{s_0}\right)^{\alpha_i}. \quad (6)$$

The various amplitudes of present interest for K-N ($\bar{K}$-N) scattering have the forms[1]

$$A(K^-p\to K^-p)=A_P+A_{P'}-A_\omega-A_\rho+A_R, \quad (7)$$

$$A(K^-n\to K^-n)=A_P+A_{P'}-A_\omega+A_\rho-A_R, \quad (8)$$

$$A(K^+p\to K^+p)=A_P+A_{P'}+A_\omega+A_\rho+A_R, \quad (9)$$

$$A(K^+n\to K^+n)=A_P+A_{P'}+A_\omega-A_\rho-A_R, \quad (10)$$

$$A(K^-p\to \bar{K}^0n)=-2A_\rho+2A_R, \quad (11)$$

$$A(K^+n\to K^0p)=2A_\rho+2A_R. \quad (12)$$

(Note that the definition of A_i and B_i in this paper is different from that in Ref. 1.) Owing to the exchange degeneracy for the ρ and R trajectories (the P' and ω trajectories)[2,18] derived from the requirement of duality by using the fact that there is no resonance in the K-N system,

$$\alpha_\rho(t)=\alpha_R(t), \qquad \alpha_{P'}(t)=\alpha_\omega(t),$$
$$C_\rho(t)=C_R(t), \qquad D_\rho(t)=D_R(t), \quad (13)$$

and

$$C_{P'}(t)=C_\omega(t), \qquad D_{P'}(t)=D_\omega(t), \quad (14)$$

the amplitude for forward K^+-n charge-exchange scattering (K^--p charge-exchange scattering) turns out to be the Regge amplitude without (with) the signature factor corresponding to the sum of the first terms (the second terms) in Eqs. (5) and (6).

TABLE II. Values of $C_i(t)$ and $D_i(t)$ in Eqs. (5) and (6), respectively, when the scaling factor s_0 is equal to 1 GeV^2.

Trajectory	$C_i(t)$	$D_i(t)$
P	$-44e^{1.92t}$	$(-44e^{1.92t}+23)\times1.5e^{1.75t}$
$\rho(R)$	11.5/4	$(11.5/4)\times2.05e^{-0.15t}$
$P'(\omega)$	34.5/4	$(34.5/4)\times2.05e^{-0.15t}$

[18] T. Kawai and T. Saito, Progr. Theoret. Phys. (Kyoto) **41**, 1057 (1969).

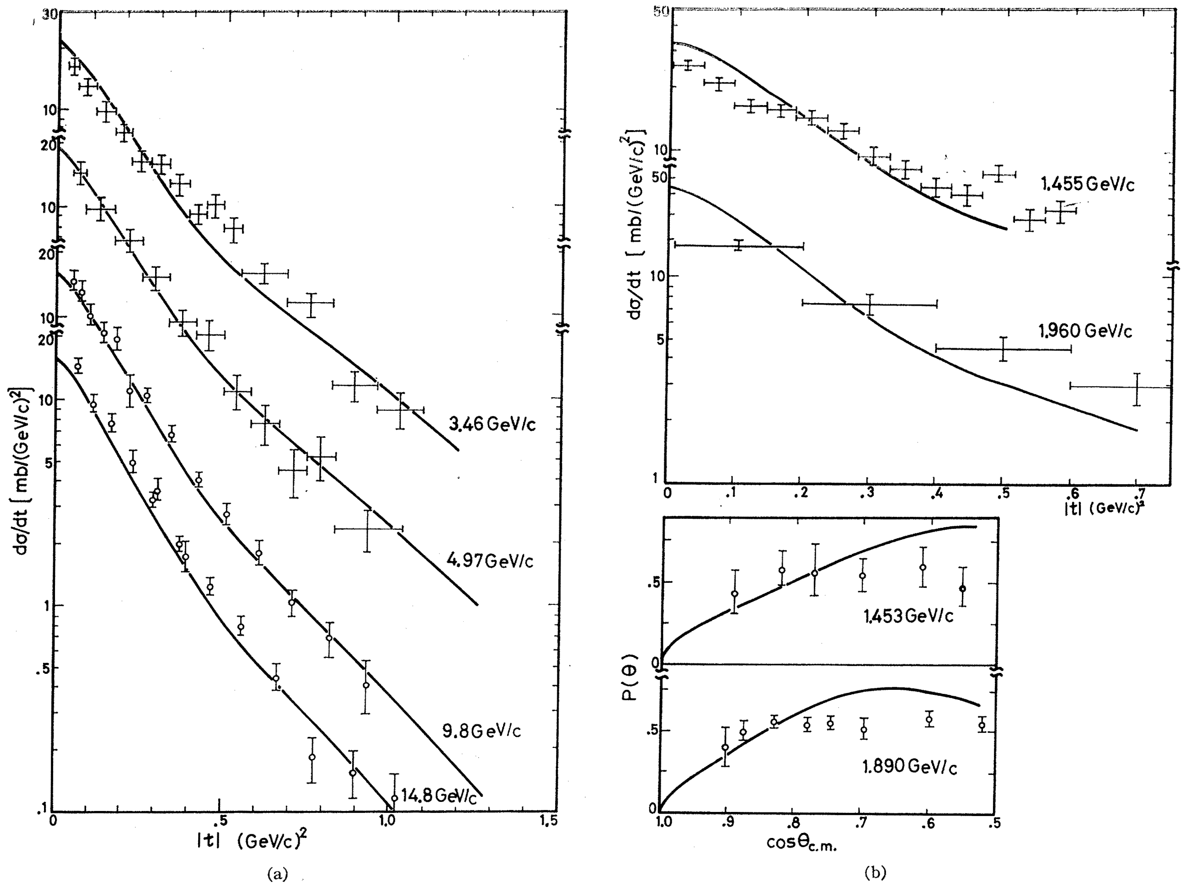


FIG. 5. Differential cross sections and polarization of recoil protons in elastic K^+-p forward scattering. Experimental data are from Ref. 20.

Because of the relations (13) and (14), the Regge amplitudes with the signature factor for the ρ trajectory have the same phase as those for the R trajectory. This leads to the conclusion that $d\sigma/d\Omega$ for K^+-n charge-exchange scattering is equal to that for K^--p charge-exchange scattering. This relation does not necessarily hold in the new interference model, because we estimate the scattering amplitude by using the direct-channel resonance amplitude instead of the Regge amplitude with the signature factor, although the former amplitude approaches the latter amplitude as the incident energy increases. It should be noted that Dikmen's model[8] gives zero amplitude for K^+-n charge-exchange scattering, since the scattering amplitude in his model is expressed by the effects due to the Pomeranchukon exchange plus direct-channel resonances.

TABLE III. Parameters of Z^* given in Ref. 9.

Solution No.	Mass (MeV)	Total width (MeV)	Elasticity
I	1880±90	∼130	∼0.10
II	1980±100	180–250[a]	0.30–0.45[a]
III	1950±100	∼180	∼0.28

[a] In our estimation of the resonance amplitude, we assume that the width and elasticity of the resonance in solution II are equal to 210 MeV and 0.37, respectively.

In our study of forward K-N ($\bar{K}$-N) scattering, the Regge parameters are determined as follows: For the trajectories, we assume

$$\alpha_\rho(t)=\alpha_R(t)=\alpha_{P'}(t)=\alpha_\omega(t)\cong 0.5+0.9t \qquad (15)$$

and

$$\alpha_P(t)=1+0.3t. \qquad (16)$$

The values of residues are estimated by tracing the procedure mentioned below. (a) The C_ρ ($=C_R$) and D_ρ ($=D_R$) are determined so that the experimental $d\sigma/dt$ for the $K^+n\to K^0p$ reaction[19] may be reproduced. (b) The C_P is determined from the experimental values[20] of the K^+-p total cross section (or the imaginary part of

[19] Y. Goldschmidt-Clermont *et al.*, Phys. Letters **27B**, 602 (1968); I. Butterworth *et al.*, Phys. Rev. Letters **15**, 734 (1965); W. Rarita and B. Schwartzchild, Phys. Rev. **162**, 1378 (1967); A. A. Hirata *et al.*, Phys. Rev. Letters **21**, 1485 (1968); **21**, 1728(E) (1968).

[20] L. R. Price, N. Barash-Schmidt, O. Benary, R. W. Bland, A. H. Rosenfeld, and C. G. Wohl, LRL Report No. UCRL-20 000 K^+N, 1969 (unpublished).

the forward scattering amplitude of the K^+-p elastic scattering), since the Regge amplitude due to the ρ, R, P', and ω trajectories is real in the case of K^+-p elastic scattering. (c) The D_P is determined from the experimental $d\sigma/dt$ for K^--p elastic scattering[21] by making use of the value of C_P estimated above and the direct-channel resonance amplitude, where it should be noted that the amplitude for elastic K^--p forward scattering is described in terms of the effects of the Pomeranchukon exchange plus direct-channel resonances. (d) The $C_{P'}$ $(=C_\omega)$ and $D_{P'}$ $(=D_\omega)$ are determined so that the experimental $d\sigma/dt$ for K^+-p elastic scattering[20] in a small-$|t|$ region may be reproduced. The values of residues thus obtained are shown in Table II.

Thus, we can calculate the differential cross section and the polarization of recoil nucleons in K-N ($\bar{K}$-N) scattering in the forward direction. The results in the new interference model are shown in Figs. 4–7. (See Ref. 22 for the experimental data shown in Fig. 7.) It must be noted that in the new interference model, (i) the scattering amplitudes $\sum' f_i$ except for the P-exchange amplitude f_P are real and nearly pure imaginary in K^+-p and K^--p elastic scattering, respectively, in the forward direction because $\alpha_\rho(0)=\alpha_R(0)=\alpha_{P'}(0)=\alpha_\omega(0) \cong 0.5$, and (ii) the real part of the Regge amplitude due to the P exchange is so small in the forward direction that it may be neglected compared with its imaginary part because $\alpha_P(t)=1+0.3t$. Therefore, the interference effects between f_P and $\sum' f_i$ in K^--p elastic scattering are much larger than those in K^+-p elastic scattering. This gives rise to the difference between the properties of the forward diffraction peaks in K^+-p and K^--p elastic scattering. That is, the observed shrinkage (nonshrinkage) of the forward peak for K^+-p (K^--p) elastic scattering would be closely tied to the amount of the interference effects. In p-p and $\bar{p}$-p elastic scattering also, there is the situation similar to the above.

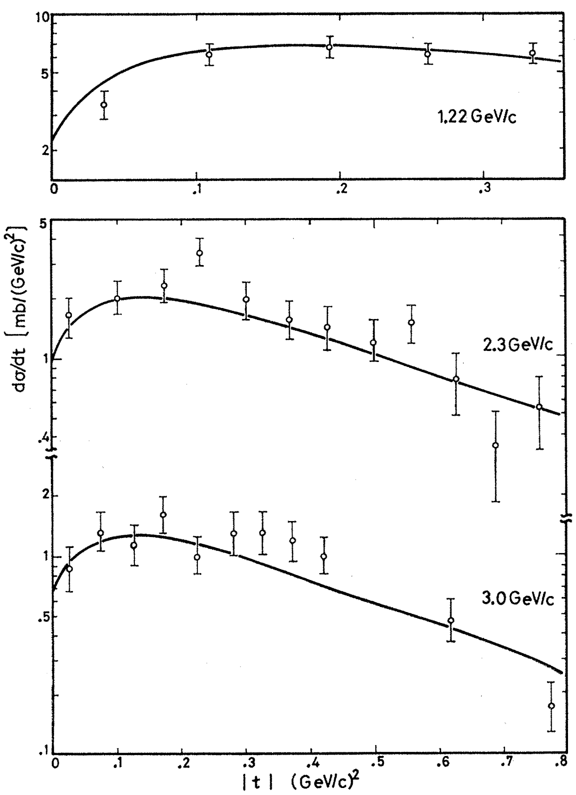


FIG. 6. Values of $d\sigma/dt$ for K^+-n charge-exchange scattering in the forward direction. Experimental data are from Ref. 19.

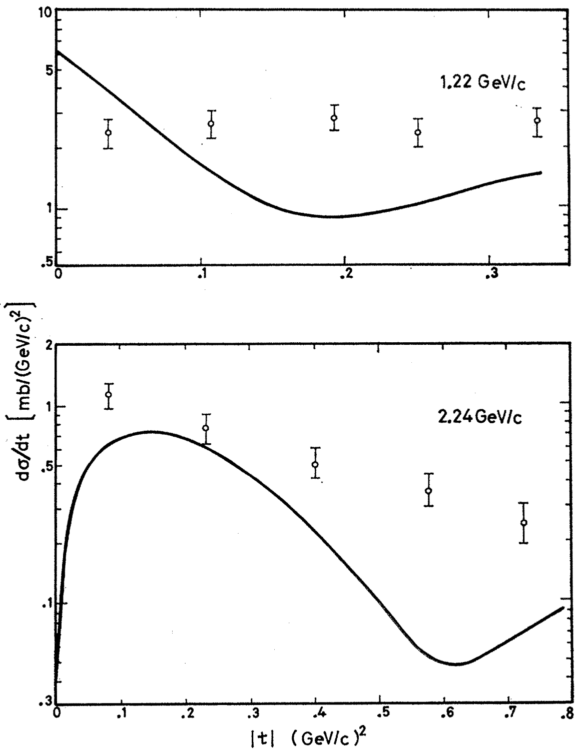


FIG. 7. Values of $d\sigma/dt$ for K^--p charge-exchange scattering in the forward direction. Experimental data are from Ref. 22.

IV. K^+-p ELASTIC SCATTERING AND POSSIBLE Z^*

One of the topics in the field of resonance is whether the exotic resonance really exists. The results of phase-shift analyses for K^+-p elastic scattering at 0.8–2.0 GeV/c have been reported by many authors.[9,12–14] Particularly, we are interested in the four possible solutions obtained by Kato *et al.*[9] Their solutions I–III yield a $P_{3/2}$ partial wave with a behavior consistent with the Breit-Wigner resonance formula, and the $D_{5/2}$ partial wave may resonate in solution IV.

[21] C. Daum, F. C. Erné, J. P. Lagnaux, J. C. Sens, M. Steuer, and F. Udo, Nucl. Phys. **B6**, 273 (1968).

[22] C. G. Wohl, LRL Report No. UCRL-16288, 1965 (unpublished); G. W. London *et al.*, Phys. Rev. **143**, 1034 (1966).

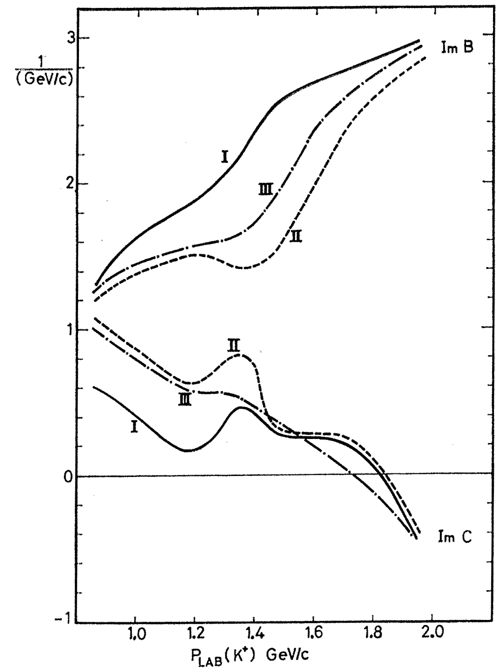


FIG. 8. Imaginary parts of the nonresonance amplitudes B and C for K^+-p elastic scattering at 0° and 180°, respectively. Solid, dashed, and dash-dotted curves show, respectively, the values in the solutions I, II, and III given by Kato *et al.* (Ref. 9).

They have also given the values of resonance parameters in solutions I–III (cf. Table III) with which nice fits to the data can be obtained. Then, the resonance amplitude A_{res} for K^+-p elastic scattering at 0° can be estimated by

$$A_{\mathrm{res}}=(J+\tfrac{1}{2})A_l^{\mathrm{res}}/k$$
$$=(J+\tfrac{1}{2})\frac{\Gamma_{\mathrm{el}}[(\omega_r-\omega)+\frac{1}{2}i\Gamma]}{2k[(\omega_r-\omega)^2+(\frac{1}{2}\Gamma)^2]}\,. \tag{17}$$

Using their results for their phase-shift analysis, we can also see the values of both the real and imaginary parts of the scattering amplitude due to each partial wave.

Since the imaginary part comes from the second term in Eq. (4) which is associated with the resonance amplitude, we can examine which solution is the most suitable from the viewpoint of the new interference model. Let us consider the nonresonance amplitudes B and C at $\theta=0°$ and 180°, respectively:

$$(1/k)\sum(J+\tfrac{1}{2})A_{l\pm}{}^{\mathrm{nonres}}=B\,, \tag{18}$$

$$(1/k)\sum(-1)^l(J+\tfrac{1}{2})A_{l\pm}{}^{\mathrm{nonres}}=C\,, \tag{19}$$

where

$$\begin{aligned} A_{l\pm}{}^{\mathrm{nonres}}&=A_{l+}-A_{l+}{}^{\mathrm{res}} && \text{for } P_{3/2} \text{ waves}\\ &=A_{l\pm} && \text{for other waves}. \end{aligned} \tag{20}$$

When there is a resonance Z^* in the K^+-p system, the relations (13) and (14) do not hold in the strict sense of the word. As a rough approximation, we here assume the exchange degeneracy for the Regge trajectories as in Sec. III. Then, the B consists of the P-exchange amplitude $f_P(\theta=0°)$ and the sum of the Regge amplitudes $\sum' F_i(\theta=0°)$ without the signature factor for the ρ, R, P', and ω trajectories. Since the $\sum' F_i(\theta=0°)$ is real and $\alpha_P(0)=1$, the imaginary part of B has an E_L dependence, where E_L is the total kaon energy in the laboratory system. The C, on the other hand, ought to be real because it can be expressed by the sum of the Regge amplitudes without the signature factor for the baryon trajectories with strangeness $S=-1$. We show in Fig. 8 the values of ImB and ImC in the solutions I–III. For the energy dependence of ImB, there is no large difference between them. Although ImC is not equal to zero in each case because of our rough approximation mentioned above, its deviation from zero in solution I seems to be more insignificant than that in solution II or III. Thus it may be said that the solution I would be the most favorable.

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