meson production in deuterium), and all cross sections are extrapolated to zero pion energies.

Using the simplest assumptions of (a) the constancy with pion energy of the charge exchange scattering amplitude, $(\alpha_3-\alpha_1)/\eta=0.28$, and (b) a linear extrapolation of the photoproduction data, along with a value of $R=1.34$, the resultant value of P is found to be 2.5 ± 0.4,[18] in poor agreement with the measured values given in Table III. Cini, Gatto, Goldwasser, and Ruderman[4] have shown, however, that, by modifying the extrapolation procedures, a lower value of P is obtained. In particular: (a) an extrapolation of low-energy charge exchange data by use of an s-wave effective range type approximation, inferred from dispersion relations, reduces the zero-energy amplitude to 0.24 (thus lowering the cross section by 20%), and (b) an extrapolation of $\sigma(\gamma+p\rightarrow n+\pi^+)$, taking into account the contribution of the direct interaction term, increases the cross section at threshold by 15%. The resultant value of P is 1.43.

There is at present no further experimental check of the validity of these extrapolations. In particular, it has been pointed out[19] that the experimental data of Adamovich *et al.*[20] on $\sigma(\gamma+d\rightarrow p+p+\pi^-)$, combined with Baldin's calculation,[2] are not consistent with the threshold parameters of Cini *et al.*, and that the extrapolated curve for $\sigma(\gamma+p\rightarrow n+\pi^+)$ does not fit the published experimental data at higher energies. Nevertheless, although further experimental data are needed for a decisive conclusion, it appears that there is no longer an obvious inconsistency among the results.

[18] G. Puppi, *1958 Annual International Conference on High-Energy Physics at CERN*, edited by B. Ferretti (CERN Information Service, Geneva, 1958), Session 2, p. 49.

V. ACKNOWLEDGMENTS

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[19] Beneventano, Bernardini, Stoppini, and Tau, Nuovo cimento **10**, 1109 (1958).

[20] Adamovich, Kuzmicheva, Larinova, and Kharlamov, J. Exptl. Theoret. Phys. U.S.S.R. **35**, 27 (1958) [translation: Soviet Phys. JETP **35**, 21 (1959)].

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Method for the Determination of Strange Particle Parities and Coupling Constants

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A general method for determining parities and coupling constants of strange particles directly from angular distributions is described. A reasonably detailed discussion is given of what can be gleaned by this method from the processes of associated production by photons on nucleons and by pions on protons, and from the absorption and charge exchange scattering of charged K mesons on nucleons. If the relative parity of K^+ to K^0 is odd then strange particle parities may be obtained from all these processes, while if this relative parity is even only photoproduction processes may be used to determine parities. Once these relative parities have been determined then coupling constants may be obtained from all the processes.

1. INTRODUCTION

At present it is impossible to give a useful approximate solution to the field equations which correspond to a given strong-interaction Hamiltonian for the strange particles. Thus it is not very easy to choose that interaction for the strange particles which best fits the experimental data, from the many that satisfy the usual selection rules. In particular it has not been easy to obtain unambiguous values for the relative parities of the strange particles, where these are defined,[1] or for their coupling constants, using a suitable strong interaction.

It may be useful to approach these problems from a more general viewpoint. It is possible, as has been argued quite suggestively by Landau and others[2] that there may be a fundamental inconsistency in the concept of a point interaction. We will be well-advised at present to obtain results which depend as little as possible on the point interaction concept, but exist in the general framework of quantum field theory which is being developed at present by Wightman and others.[3] Such results may easily be particularized to the case of any renormalizable point interaction which we venture to consider. More generally they will have a validity far

[1] P. T. Matthews, Nuovo cimento **6**, 642 (1957).

[2] Landau, Abrikosov, and Khalatnikov, Doklady Akad. Nauk S.S.S.R. **96**, 261 (1954).

[3] A. S. Wightman, Phys. Rev. **101**, 860 (1956); and lecture notes at the Lille Conference, 1957 (unpublished).

exceeding such particular results as are obtained by present approximation procedures applied to point interactions.

In this paper we will consider the problem of how to obtain the relative parities and coupling constants of the strange particles from experiment, using only the general formalism of quantum field theory as described in reference 3.

Our general method uses analyticity properties of scattering and production amplitudes in the momentum transfer variable which were first suggested by Chew[4] for nucleon-nucleon scattering and are very similar to corresponding properties used in the dispersion relations. Only a heuristic proof of these properties has been given so far, and from this we expect that a rigorous proof can be given. Our method has already been applied to pion-nucleon interactions to obtain an estimate of the coupling constant[4] and the charged and neutral pion parity,[5] and to associated production by pions to give tentative values for the relative parity of K^+ to K^0, of K^+ to $(\bar{\Lambda}N)$, and of Λ to Σ, and some imprecise inequalities between coupling constants.[6] A reasonably detailed discussion of the theoretical foundation of our method is given in these references, so we will only give a brief sketch of the main idea here. The main purpose of this paper is to discuss those experiments which appear, from our viewpoint, to be particularly useful to us for obtaining parity and coupling constant values for the strange particles, and also which seem reasonably feasible for present or planned apparatus.

2. THEORETICAL DISCUSSION

Let us consider associated production by pions as a typical process. We denote by k, q, p, p' the pion, K-meson, nucleon, and Y-particle four-momenta respectively. We neglect spin and isotopic spin variables, which are unimportant for the present discussion. The associated production amplitude is a function $M_1(W,\Delta^2)$ of the invariants $W=-(k+p)^2$ and $\Delta^2=(k-q)^2$. To obtain some understanding of the behavior of M_1 as a function of Δ^2, for fixed W, we relate associated production to the annihilation process $N+\bar{Y}\rightarrow\pi+K$. If k, q, p, p' are the pion, K-meson, nucleon, and anti-Y-particle four-momenta, then the annihilation amplitude is a function $M_2'(W',\Delta'^2)$ of the invariants $W'=-(p+p')^2$ and $\Delta'^2=(p-k)^2$. Since the production and annihilation processes are related by the transformation $p'\rightarrow -p'$, $k\rightarrow -k$, then

$$M_2(W',\Delta'^2)=M_1(-\Delta'^2,\,-W').$$

From the analyticity behavior of $M_2(W',\Delta'^2)$, for fixed Δ'^2 in W' we obtain analyticity behavior of $M_1(W,\Delta^2)$

[4] G. Chew, Phys. Rev. **112**, 1380 (1958); Moravcsik, Taylor, and Uretsky, Phys. Rev. **113**, 689 (1959).

[5] J. G. Taylor (to be published).

[6] J. G. Taylor Nuclear Phys. **9**, 357 (1959).

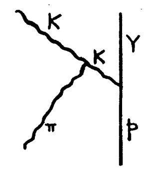

FIG. 1. Diagram for the process giving the Born term singularity at $\cos\theta=\alpha_0$, in associated production by pions, enhancing forward K-production.

in Δ^2, for fixed W. But the analyticity behavior of M_2 in W is just that investigated and used (though in our case not rigorously proved) in dispersion relations, so we obtain the analyticity behavior of M_1 in Δ^2. In the center-of-mass system we denote by θ the angle between the pion and K-meson directions, and then M_1 is analytic in the cut $\cos\theta$ plane, with simple poles at $\cos\theta=\alpha_0=(2k_0q_0-m_\pi^2)/2kq$ and $\cos\theta=\beta_0=(-m_{Y'}^2+m_N^2+m_K^2-2q_0p_0)/2kq$, arising from intermediate states composed of a single K-meson or a single Y' particle, respectively, and branch points from $\cos\theta=\alpha_1=(k_0q_0+m_\pi m_K)/kq$ to $+\infty$ and $\cos\theta=\beta_1=[-(m_{Y'}+m_\pi)^2+m_N^2+m_K^2-2q_0p_0]/2kq$ to $-\infty$ arising from intermediate states with at least one pion and one K meson, or one pion and one Y' particle. m_α is the rest mass of the particle α.

We expect to be able to write

$$M_1(W,\cos\theta)=\frac{g(W,\cos\theta)}{(\alpha_0-\cos\theta)}+f(W,\cos\theta), \tag{1}$$

where the dispersion relations for $M_2(W',\Delta'^2)$ imply that the first term on the right-hand side of Eq. (1) is the renormalized Born term corresponding to the process of Fig. 1, so that $g(W,\cos\theta)$ is known, and $f(W,\cos\theta)$ has no singularity at $\cos\theta=\alpha_0$. For high pion energies α_0 is close to 1, so the replacement of $(\alpha_0-\cos\theta)^{-1}$ by the first few terms of its expansion in powers of $\cos\theta$ will be a poor approximation, especially near $\cos\theta=1$. Though α_1 is also close to unity for high pion energy, the contribution from the branch line from α_1 to $+\infty$ is not expected to give its major contribution at or very close to α_1, unless fortuitous cancellation occurs. It seems reasonable, then to replace $f(W,\cos\theta)$ by a polynomial in $\cos\theta$ of not very high degree.

Expressions for the production amplitude similar to Eq. (1) have been written down many times in the past, on the basis of perturbation theory. Our heuristic derivation of this equation is much more general than this, and in fact no specific interaction scheme is needed at all, let alone the use of perturbation theory. Of course we haven't rigorously proved the analyticity properties which we have conjectured so far, using similar properties and tools to those used in proving the dispersion relations.[7] This is very likely to be because our present methods are inadequate. Our conjecture seems reason-

[7] Bogoliubov, Medvedev, and Polivanov, Institute for Advanced Study lecture notes (unpublished); Bremermann, Oehme, and Taylor, Phys. Rev. **109**, 2178 (1958).

able from the heuristic argument we have given already, so the lack of proof need not prevent us from having reasonable faith in our conjecture.*

3. METHOD

We will use the representation of Eq. (1) to discuss what can be gleaned about parity and coupling constants from the differential cross sections for associated production by photons on nucleons and pions on protons and from the absorption and charge exchange scattering of charged K-mesons on nucleons. We can write the cross section for these processes, neglecting spin, as

$$\frac{d\sigma}{d\Omega}=K(W)\frac{|g(W,\cos\theta)|^2}{(\alpha_0-\cos\theta)^2}+\mathrm{Re}\frac{g(W,\cos\theta)\bar{f}(W,\cos\theta)}{(\alpha_0-\cos\theta)}+|f(W,\cos\theta)|^2, \quad (2)$$

where $K(W)$ is a known function of the energy W. The other Born term with singularity at $\cos\theta=\beta_0$ is not written explicitly in Eq. (2), though it will be necessary to discuss it explicitly in cases when the Born term with singularity at $\cos\theta=\alpha_0$ is zero due to charge or strangeness conservation.

Let us return to discussing the associated production of Λ hyperons by pions on protons. The only term which is known completely on the right-hand side of Eq. (2) is the first. This is explicitly, after summation over the Λ and proton spins,

$$K(W)|g(W,\cos\theta)|^2=\frac{m_K{}^2f_r{}^2G_r{}^2}{2k^3q(p_0+k_0)^2}(p_0'p_0-kq\cos\theta\pm m_\Lambda m_N), \quad (3)$$

where f_r, G_r are the rationalized renormalized coupling constants for the interactions with energy densities $2m_Kf\bar{\phi}_K\phi_K\phi_\pi$ and $iG\bar{\psi}_\Lambda\Gamma\psi_N\phi_K$, and the plus or minus sign occurs in Eq. (3) according as $\Gamma=1$ or γ_5, i.e., according as K^+ is a scalar or pseudoscalar. To separate it from the other term in Eq. (2), we consider the function

$$F(\cos\theta)=(\alpha_0-\cos\theta)^2(d\sigma/d\Omega). \quad (4)$$

From Eqs. (2) and (3) and the discussion of the last section on the position of the singularities of $f(W,\cos\theta)$, we see that

$$F(\alpha_0)=\frac{m_K{}^2f_r{}^2G_r{}^2}{4k^3q(p_0+k_0)^2}[(m_\Lambda\pm m_N)^2-m_K{}^2]. \quad (5)$$

Thus if $F(\alpha_0)\neq0$ we can conclude that the relative parity $p(K)$ of K^+ to K^0 is odd, assuming conservation of parity in the $KK\pi$ interaction. If $F(\alpha_0)=0$ we cannot conclude anything about $p(K)$, nor use this pole term further, so it will be necessary to use the pole term at $\cos\theta=\beta_0$. Let us assume, for the sake of argument, that $F(\alpha_0)\neq0$. If $F(\alpha_0)>0$ then the K^+ parity is even, while if $F(\alpha_0)<0$ the K^+ parity is odd (we assume Λ, p, n have even parity[1]). Thus from the sign of $F(\alpha_0)$ we may fix the parity of K^+. The value of $F(\alpha_0)$ may now be used to evaluate the product f_rG_r.

If we use the pole at $\cos\theta=\beta_0$, and hence consider the function

$$G(\cos\theta)=(\beta_0-\cos\theta)^2(d\sigma/d\Omega), \quad (6)$$

then the sign of the residue $G(\beta_0)$ does not enable us to distinguish between alternative parity assignments. It will be necessary to obtain the correct parity assignments from the sign of $F(\alpha_0)$ or by some independent method, and then we may obtain the product of coupling constants from the value of $G(\beta_0)$.

Thus the main point of the method is to evaluate $F(\alpha_0)$, $G(\beta_0)$ from the values of $F(\cos\theta)$, $G(\cos\theta)$ as obtained from Eqs. (4) and (6) and the experimental values of $d\sigma/d\Omega$ in the physical range $|\cos\theta|<1$. In Table I we have listed various parities and products of coupling constants which may be obtained from values of $F(\alpha_0)$ and $G(\beta_0)$ for the reactions of associated production of hyperons by photons and charged pions on protons, negative K-meson absorption on protons and K-nucleon charge exchange scattering. In order to make certain entries on the table completely clear, certain remarks need to be made. These remarks need to be discussed in association with the main practical problem with which we are faced in applying this method: How do we obtain the values of $F(\alpha_0)$ and $G(\beta_0)$? This will be discussed in detail in the next section.

4. EXTRAPOLATION PROCEDURE

The first thing that may be done is to estimate qualitatively if there is any peaking in $d\sigma/d\Omega$ which may be regarded as due to the Born term. In columns 2 and 6 we have noted processes for which the contribution from the pole term at $\cos\theta=\alpha_0$ or β_0 is linear in $\cos\theta$. If we find that $F(\cos\theta)$ or $G(\cos\theta)$ are appreciably linear near $\cos\theta=1$ or $\cos\theta=-1$, respectively, then we may suspect that this linearity is caused mainly by the corresponding pole term. This approach was used in reference 6, though the results obtained from such evidence were only put forward as being tentative, and were mainly intended to show what results might be obtainable with more reliable data. It has recently been pointed out[8] that such an approach may lead to very fallacious results, and so while such linearity may be used to show that the Born term might be contributing importantly, so that such an angular distribution would be useful to consider in more detail, we certainly will not use linearity or other possible shapes of $F(\cos\theta)$ without a further detailed analysis.

* *Note added in proof.*—The analyticity properties have been proved, under certain mass restrictions, by J. Gurson and J. G. Taylor (submitted to Nuovo cimento).

[8] G. Feldman and T. Fulton, Phys. Rev. Letters 3, 64 (1959).

This further detailed analysis will be along lines similar to those used in obtaining the value of the pion-nucleon coupling constant in photoproduction.[4] We will assume that $F(\cos\theta)$ is well represented by a polynomial in $\cos\theta$ of order r in the physical region. This assumption is certainly correct for the pole term contribution while our discussion of $f(\cos\theta)$ in Sec. 2 shows that we expect this to be correct for the remaining contribution to $F(\cos\theta)$. A fit by the method of least squares of this polynomial to the experimental values of $F(\cos\theta)$ in the range $|\cos\theta|<1$ is then achieved. The value r required to obtain a best fit of the polynomial over this range is then obtained by a statistical analysis. A unique value of r is difficult to obtain by this method alone, so we may also use physical arguments to fix the value r on angular momentum grounds. It is to be expected that a small range of values of r fitting both criteria will exist. We then choose the least of these values of r, assuming they give roughly the same values for $F(\alpha_0)$ or $G(\beta_0)$, since the error in $F(\alpha_0)$ rapidly increases with r.

In order to obtain the most accurate values of $F(\alpha_0)$ or $G(\beta_0)$ we must consider the various factors which determine the size of the error:

(1) r increases with the energy of the incoming particle, so that not too high an energy is desirable.

(2) α_0 and β_0 decrease with energy, so that the distance of extrapolation is smallest for a high energy.

(3) The actual values of $F(\alpha_0)$ and $G(\beta_0)$ for given parities and coupling constants, decrease with increasing energy so that the relative error in the extrapolated value of $F(\alpha_0)$ and $G(\beta_0)$ will also increase for given error in $d\sigma/d\Omega$.

Thus factors (1) and (3) work against (2). As in the case of photoproduction, it seems most accurate in most cases to work below energies for which D waves (other than from the pole term) will be important in the final state, though this is not so for the pole term at β_0 for which D waves need to be tolerated.

For reactions (1) to (4), pion laboratory momenta of 1.3 to 1.4 Bev/c would seem most desirable. At such energies we will use a quartic polynomial for $F(\cos\theta)$, though possible interference terms with D waves could be taken account by a fifth order polynomial. The value of α_0 for these energies is between 1.6 and 1.4. It does also seem useful to extrapolate at about 1.9 to 2.0 Bev/c since the residue $F(\alpha_0)$ is only one third of its value at 1.4 Bev/c while α_0 has decreased to 1.2. At this energy we expect $F(\cos\theta)$ to be of sixth order.

It is possible that $p(K)$ is even, so that the pole term at α_0 will vanish. We then will have to consider the pole term at β_0 and the function $G(\cos\theta)$ defined by Eq. (6). As we have already remarked the value of $G(\beta_0)$ will only give us information on coupling constants but none about parities. Since β_0 is larger than α_0 it will be necessary to choose higher pion energies to perform the extrapolations. For reactions (1) to (4) a possible energy for this would seem to be 2 Bev. No higher than D waves would be expected from all but the pole term at β_0 at this energy, so that a sixth order polynomial for $G(\cos\theta)$ could be chosen for the extrapolation, with $\beta_0=-1.8$. This value of β_0 is still some way from the physical region, so that accurate data will be necessary, especially in the backward direction. We note that a power series expansion in $\cos\theta$ about the origin for the scattering amplitude minus the pole term at β_0 is not expected to converge at $\cos\theta=\alpha_0$ due to the singularity of the pole term at α_0 there. A more accurate way of obtaining $G(\beta_0)$ from $G(\cos\theta)$ would be to expand $G(\cos\theta)$ about $\cos\theta=-0.5$, for 2-Bev pions. The pole term at $\cos\theta=\beta_0$ would lie inside the circle of convergence of radius 1.5, while the points $\cos\theta=\alpha_0$ and β_1 lie on the circumference of this circle.

The pole term at α_0 in reactions (5) and (6) are very similar to the meson current term in pion photoproduction which was used in reference 4 to obtain a value for the pion-nucleon coupling constant. The value of the residue at α_0 is

$$F(\alpha_0)=\tfrac{1}{4}e^2f_r^2[(m_N\pm m_Y)^2-m_K^2]\frac{q(1-\alpha_0^2)}{k^3(p_0+k_0)^2},$$

where $\alpha_0=q_0/q$ is the reciprocal of the K-meson velocity, e is the charge of the K meson, and the positive or negative sign occurs for scalar or pseudoscalar K^+ mesons. Data at 1.0-Bev photon energy have been used to obtain $F(\alpha_0)$.[9] However, at this energy $\alpha_0=2.6$, while since the Born term contribution to $F(\cos\theta)$ is cubic in $\cos\theta$ then at least a third order polynomial will be necessary to perform the extrapolation to α_0. This gives rise to a large error in $F(\alpha_0)$.[9] One way to avoid this would be to use 1.3-Bev photons, with $\alpha_0=1.3$ and a fourth or fifth order polynomial for $F(\cos\theta)$. This may not be impossible with present machines. The main advantage of this process over the others discussed in this paper is that the presence of the pole term at α_0 is independent of the requirement that $p(K)$ is odd.

The pole term at β_0 in reactions (5), (6), and (7) will be very difficult to use at present, since even at 1.3 Bev, $\beta_0=-3.5$. It will be necessary to go up to a photon energy of above 2.0 Bev, with $\beta_0>-2$, using a sixth or higher order polynomial for $G(\cos\theta)$, before reliable values are expected to be obtained.

The pole term at α_0 in reactions (8) to (11) may be best determined at 700 Mev/c incoming K-meson momentum, since then α_0 is about 1.6, while a polynomial of order 5 should suffice for $F(\cos\theta)$. The pole term at $\cos\theta=\beta_0$ will require a K-meson momentum of at least 1 Bev/c, for which $\beta_0>-2$, with at least a sixth order polynomial for $G(\cos\theta)$.

In reactions (12) and (13) the pole term at α_0 should be important even at low energies. For example, for a K-meson momentum of 350 Mev/c we have that $\alpha_0=1.23$, while at 750 Mev/c we have $\alpha_0=1.05$. At

[9] M. J. Moravcsik, Phys. Rev. Letters 2, 352 (1959).

TABLE I. Table of results that may be obtained from the strong interaction process listed in column 1. Column 2 describes the method used for testing the presence of the Born term with singularity at $\cos\theta=\alpha_0$, column 6 that at $\cos\theta=\beta_0$. Column 4 gives the relative parities which may be deduced from the sign of $F(\alpha_0)$. Column 5 gives the combinations of coupling constants obtainable from $F(\alpha_0)$ using the parities obtained in column 4, while column 8 gives those combinations of coupling constants obtainable from $F(\beta_0)$. The entry for column 8 denotes the product of coupling constants which may be obtained from $F(\beta_0)$ evaluated at the pole due to an intermediate Y hyperon. We denote by (ABC) the renormalized coupling constant for the interaction between A, B and C particles, and $\mu(A)$ the anomalous magnetic moment for a fermion A.

1. Process	2. Test for α_0	3. Remarks	4. $p(\alpha_0)$	5. $C(\alpha_0)$	6. Test for β_0	7. Remarks	8. $C(\beta_0)$	9. Expected peaking of produced boson
1. $\pi^-+p\to K^0+\Lambda^0$	F linear near $\theta=0$ or $F(\alpha_0)\neq0$	If present, then $p(K)$ odd	K^+: $(\bar\Lambda^0 p)$	$f(K^+\bar\Lambda^0 p)$	F constant near $\theta=\pi$, or $F(\beta_0)\neq0$.	...	$(K^0\bar\Sigma^+p)(\pi^+\bar\Lambda^0\Sigma^+)$	Forward[a]
2. $\pi^-+p\to K^0+\Sigma^0$	F linear near $\theta=0$ or $F(\alpha_0)\neq0$	If present, then $p(K)$ odd	K^+: $(\bar\Sigma^0 p)$	$f(K^+\bar\Sigma^0 p)$	F constant near $\theta=\pi$, or $F(\beta_0)\neq0$	...	$(K^0\bar\Sigma^+p)(\pi^+\bar\Sigma^0\Sigma^+)$	Forward[a]
3. $\pi^++p\to K^++\Sigma^+$	F linear near $\theta=0$ or $F(\alpha_0)\neq0$	If absent, then $(K^0\bar\Sigma^+p)=0$	K^0: $(\bar\Sigma^+ p)$	$f(K^0\bar\Sigma^+ p)$	F constant near $\theta=\pi$, or $F(\beta_0)\neq0$	Two contributions, from int. states of Λ^0 or Σ^0	$(K^+\bar\Lambda^0p)(\pi^+\Sigma^+\bar\Lambda^0)$ and $(K^+\bar\Sigma^0p)(\pi^+\bar\Sigma^0\Sigma^+)$	Forward[a]
4. $\pi^-+p\to K^++\Sigma^-$	Absent by charge conservation	...	...	...	F constant near $\theta=\pi$, or $F(\beta_0)\neq0$	Two contributions, from int. states of Λ^0 or Σ^0	$(K^+\bar\Lambda^0p)(\pi^+\Sigma^+\bar\Lambda^0)$ and $(K^+\bar\Sigma^0p)(\pi^+\bar\Sigma^0\Sigma^+)$	Backward
5. $\gamma+p\to K^++\Lambda^0$	$F(\alpha_0)\neq0$ only	Born contribution to F cubic in $\cos\theta$	K^+: $(\bar\Lambda^0 p)$	$(K^+\bar\Lambda^0 p)$	$F(\beta_0)\neq0$ only	Two contributions, from int. states of Λ^0 or Σ^0	$\mu(\Lambda)(K^+\bar\Lambda^0p)$ and $(\gamma\Sigma^0\bar\Lambda^0)(K^+\bar\Sigma^0p)$	Forward
6. $\gamma+p\to K^++\Sigma^0$	$F(\alpha_0)\neq0$ only	Born contribution to F cubic in $\cos\theta$	K^+: $(\bar\Sigma^0 p)$	$(K^+\bar\Sigma^0 p)$	$F(\beta_0)\neq0$ only	Two contributions from int. states of Λ^0 or Σ^0	$\mu(\Sigma^0)(K^+\bar\Sigma^0p)$ and $(\gamma\Lambda^0\bar\Sigma^0)(K^+\bar\Lambda^0p)$	Forward
7. $\gamma+p\to K^0+\Sigma^+$	Absent, since neutral K^0	...	...	...	$F(\beta_0)\neq0$ only	...	Involves $(K^0\bar\Sigma^+p)$ and $\mu(\Sigma^+)(K^0\bar\Sigma^+p)$ quadratically	Backward
8. $K^-+p\to\pi^0+\Lambda^0$	F linear near $\theta=0$, or $F(\alpha_0)\neq0$	If present K^+:K^- parity odd	K^+: $(\bar\Lambda^0 p)$	$(K^+\bar\Lambda^0p)(K^-K^+\pi^0)$	F constant near $\theta=\pi$, or $F(\beta_0)\neq0$	...	$(K^+\bar\Lambda^0p)$	Backward
9. $K^-+p\to\pi^0+\Sigma^0$	F linear near $\theta=0$, or $F(\alpha_0)\neq0$	If present, K^+:K^- parity odd	K^+: $(\bar\Sigma^0 p)$	$(K^+\bar\Sigma^0p)(K^-K^+\pi^0)$	F constant near $\theta=\pi$, or $F(\beta_0)\neq0$	...	$(K^+\bar\Sigma^0p)$	Backward
10. $K^-+p\to\pi^++\Sigma^-$	Absent by charge conservation	...	...	...	F constant near $\theta=\pi$, or $F(\beta_0)\neq0$	...	$(K^+\bar\Sigma^-n)$	Backward
11. $K^-+p\to\pi^-+\Sigma^+$	F linear near $\theta=0$, or $F(\alpha_0)\neq0$	If present, $p(K)$ odd	K^0: $(\bar\Sigma^+ p)$	$f(K^0\bar\Sigma^+p)$	Absent by charge conservation	...	...	Forward
12. $K^-+p\to\bar K^0+n$	F linear near $\theta=0$, or $F(\alpha_0)\neq0$	If present, $p(K)$ odd	...	f	Absent by strangeness conservation	...	...	Forward
13. $K^++n\to K^0+p$	F linear near $\theta=0$, or $F(\alpha_0)\neq0$	If present, $p(K)$ odd	...	f	F constant near $\theta=\pi$, or $F(\beta_0)\neq0$	Two contributions from int. states of Λ_0, Σ^0		Forward

[a] Unless $p(K)$ is even.

the lower of these energies we may expect only S waves, other than from the pole term, with a second order polynomial for $F(\cos\theta)$, while at the higher energy a fourth order polynomial is to be expected. The pole term at β_0 may be used at or above 2-Bev K-meson energies when α_0 is less than 2, and $G(\cos\theta)$ may be represented by a sixth order polynomial or higher, expanded about $\cos\theta$ near -0.5.

5. CONCLUSION

If charge conjugation is valid, and we do not consider the cascade doublet, there are four possible independent parities of the strange particles which may be determined from experiment. We are free to fix the parities of p, n, Λ, say, by some convention, and then the parities of Σ^+, Σ^0, K^+, K^0 can be determined from experiment. From Table I and the discussion of Secs. 3 and 4 a reasonable way to determine these parities would seem to be as follows. The value of $p(K)$ (K^+ to K^0 parity) is first determined from associated production by pions on protons or the absorption of K^- on protons (processes 1, 2, 3, and 11, of Table I), the latter process constituting the most reliable test for $p(K)$. If $p(K)$ is even then we may obtain parities by our methods only from associated production by photons on nucleons, and we see from Table I that only two of the remaining three parities may be so determined. If $p(K)$ is odd we may also use the other processes of Table I with singularity at $\cos\theta=\alpha_0$, and so obtain all three remaining parities.

The situation in the case of the coupling constants is more complicated. If we assume only charge symmetry then there are eleven possible coupling constants to be determined. We cannot determine the three couplings of π^0 to $\bar{\Lambda}^0\Lambda^0$, $\bar{\Sigma}^0\Sigma^0$ and $\bar{\Sigma}^+\bar{\Sigma}^-$ by our methods, so we are left with eight constants to determine. We may obtain the two couplings of K^+ to $\bar{\Lambda}^0p$ and $\bar{\Sigma}^0p$ directly from associated production by photons, whatever the value of $p(K)$. If $p(K)$ is odd we may also determine the coupling of K^0 to $\bar{\Sigma}^+p$, and the $(K^+\bar{K}^0\pi)$ coupling constant, from the singularities at $\cos\theta=\alpha_0$. The use of the singularities at $\cos\theta=\beta_0$ is more difficult since a higher energy is necessary than in the case of α_0 to get β_0 close to the physical region. However, if this proves possible we see that we may also determine the two couplings of π^+ to $\bar{\Sigma}^0\Sigma^+$ and $\bar{\Lambda}^0\Sigma^+$ and the anomalous magnetic moments of Σ and Λ^0. There are also processes involving pion, photon, and K-meson interactions with neutrons which may be used to obtain parities and coupling constants for strange particles. These will not be discussed here (other than K charge-exchange scattering) since there does not seem to be any possibility of obtaining accurate data for them at present. The use of hyperon-baryon scattering in this context has been discussed recently.[10]

We have not given any detailed discussion of the dependence on $\cos\theta$ of the remainder of the amplitude apart from the Born terms at α_0 and β_0. This discussion will be needed, at least for the two-particle intermediate-state contributions, since these contributions may be varying quite rapidly with $\cos\theta$ near $\cos\theta=\alpha_0$, β_0. Not till this discussion has been given will an accurate method for extrapolating to the poles be obtained. It is to be hoped that such a discussion will be given soon.

[10] S. Barshay and S. L. Glashow, Phys. Rev. Letters 2, 371 (1959).