DETERMINATION OF THE RELATIVE Σ - Λ PARITY AND OF THE RATIO OF ASYMMETRY COEFFICIENTS α_Λ TO α_0 IN HYPERON DECAY FROM THE PION-HYPERON RESONANCE

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Recent evidence[1] for the existence of a pion-hyperon resonance Y^* of isospin 1 and mass ~1370 Mev leads to the possibility of determining the relative Σ - Λ parity and the ratio of asymmetry coefficients α_Λ (in $\Lambda \rightarrow p+\pi^-$) to α_0 (in $\Sigma^+ \rightarrow p+\pi^0$). In this Letter some experiments are proposed which allow the determination of the above-mentioned quantities by measuring only up/down asymmetries.

In what follows we shall suppose that the following conditions are satisfied:

(I) The isobar Y^* is a "good" resonance, meaning that it is reasonably narrow and pronounced so that experimental conditions can be chosen under which the resonant process dominates.

(II) In the "decay" of Y^*, for instance,

$$\underset{(I=1)}{Y^{*+}} \rightarrow \left\{\begin{array}{lr} \Lambda+\pi^+ & (a) \\ \quad \searrow p+\pi^- & (a') \\ \Sigma^0+\pi^+ & (b) \\ \quad \searrow \Lambda+\gamma & (b') \\ \qquad \searrow p+\pi^- & (b'') \\ \Sigma^+ +\pi^0 & (c) \\ \quad \searrow p+\pi^0 & (c') \end{array}\right.$$

the branching ratio[2] $(b)/(a)=(c)/(a)$ is not too small.

Preliminary experiments seem to indicate that assumptions (I) and (II) are reasonable.

In pion phenomena the 33 resonance has played an eminent role in helping to understand pion physics. Should our assumptions be confirmed experimentally, then the Y^* resonance(s) may play a corresponding role in strange particle physics.

Consider, for instance, the reaction caused by monoenergetic pions:

$$\pi^+ + p \rightarrow K^+ + Y^{*+}, \tag{1}$$

with subsequent and immediate decay of Y^* according to (a), (b), and (c). Therefore what is actually observed is, for instance, the reaction

$$\pi^+ + p \rightarrow K^+ + \pi + \Lambda(\Sigma). \tag{2}$$

[It is clear that for our purpose one could also use

$$K^- + p \rightarrow \pi^- + Y^{*+}, \text{ etc...}$$

instead of (1).] Knowing the position of the resonance Y^*, it is possible to select[3] among (2) the K^+ associated with the resonant channel (1). The analysis which follows will always refer to such processes. In this way the plane formed by the incident π^+ and the outgoing K^+ is fixed once and for all. This plane S we shall refer to as the production plane.

Now let us define the quantities P_Λ and P_Σ as the "average" polarization of Λ's and Σ's coming via resonant reaction (1). This means that an average is made over all directions of hyperons, keeping the energy and direction of the associated K^+ fixed. As a consequence $\vec{P}_\Lambda$ and $\vec{P}_\Sigma$ are normal to the plane S.

Calling $\Pi(\Lambda)$, $\Pi(\Sigma)$, and $\Pi(Y^*)$ the parity of Λ, Σ, and Y^*, respectively (only relative parities are relevant), the following statements can be proved[4]:

(i) If $\Pi(\Lambda)=\Pi(\Sigma)$, then

$$P_\Lambda/P_\Sigma = +1, \tag{3}$$

for arbitrary spin J of Y^*.

(ii) If $\Pi(\Lambda)=-\Pi(\Sigma)$, then

$$P_\Lambda/P_\Sigma = \begin{cases} -1/3 \ (-5/3) \\ -3 \ (-3/5) \end{cases}$$

$$\text{for } J=1/2 \ (3/2) \text{ and } \begin{cases} \Pi(\Lambda)=\Pi(Y^*) \\ \Pi(\Lambda)=-\Pi(Y^*). \end{cases} \tag{4}$$

In general $P_\Lambda/P_\Sigma<0$ for any J and $\Pi(Y^*)$.[5]

As a result of (3) and (4) it is then sufficient to measure the sign of P_Λ/P_Σ in order to get the relative Σ - Λ parity.

However, what can be most easily measured is the up/down asymmetries with respect to the production plane S of the pions coming from the hyperon decays (a'), (b''), and (c'). Such measurements will provide us with, e.g., the ratio

$$\alpha_\Lambda P_\Lambda/\alpha_0 P_{\Sigma^+} \equiv n, \text{ etc.} \tag{5}$$

If we suppose that α_Λ/α_0 is known from other experiments, then by measuring n one obtains P_Λ/P_Σ and hence the Σ - Λ parity.

However, and this is to be stressed, it is possible to obtain separately P_Λ/P_Σ and α_Λ/α_0 by considering the whole set of reactions (a), (b), and (c). This is essentially due to the fact that the same intermediate Y^* (because of the chosen experimental conditions) decays into the 3 channels.

(A) First of all, it is well known that in the decay $\Sigma^0 \to \Lambda + \gamma$ one has the relation $P_\Lambda = -\frac{1}{3} P_{\Sigma^0}$ if an average is made over all directions of Λ's, independently of the Σ - Λ relative parity.[6] Now let us consider the Λ's coming from reactions (a) and (b'). By measuring the up/down asymmetry in the decay of the Λ's in both cases, one can get the ratio

$$\frac{\alpha_\Lambda P_\Lambda}{\alpha_\Lambda P_{\Lambda \mathrm{ind}}} = \frac{\alpha_\Lambda P_\Lambda}{\alpha_\Lambda(-\frac{1}{3}P_{\Sigma^0})} = -3\frac{P_\Lambda}{P_{\Sigma^0}}, \tag{6}$$

where P_Λ is the polarization of the Λ's produced in the direct reaction (a) and $P_{\Lambda \mathrm{ind}}$ is the polarization of the Λ's produced in the indirect reaction (b'). A measurement of (6) is therefore a measurement of the ratio of the Λ to Σ polarizations from which, as we have seen, the Σ - Λ parity can be deduced without ever using the knowledge of the α's.

(B) From the fact that Y^* is in a pure state of isotopic spin $I = 1$, it follows that in reactions (b) and (c) we have $P_{\Sigma^+} = P_{\Sigma^0}$. As a consequence the measured ratio of the up/down asymmetries in the decays (a') and (c') gives

$$\frac{\alpha_\Lambda P_\Lambda}{\alpha_0 P_{\Sigma^+}} = \frac{\alpha_\Lambda P_\Lambda}{\alpha_0 P_{\Sigma^0}} \left[= \frac{\alpha_\Lambda}{\alpha_0}\left(-\frac{P_\Lambda}{3P_{\Lambda \mathrm{ind}}}\right)\right]. \tag{7}$$

P_Λ / P_{Σ^0} being known from the previous experiment, one obtains α_Λ/α_0 directly.

A few concluding remarks are perhaps necessary. First of all, too much significance should not be attached to the actual numbers given in (3) and (4). The interference effect caused by other channels than the resonating one considered in (1) or (1′), and also the fact that the intermediate state Y^* has an extremely short lifetime ($\sim 10^{-23}$ sec), may bring about substantial corrections. However, it is felt that the difference in sign still survives after corrections and that is the significant piece of information for the Σ - Λ parity. As for the ratio α_Λ/α_0, its absolute value is already known to be ~ 1 but its sign is particularly important to determine because of its bearing on the proposed theories of weak interactions for nonleptonic decays of strange particles.[7]

It should also be noted that the proposed experiment can provide a check of the internal consistency of the whole scheme. For instance, a necessary condition for the validity of our assumption (I) is that the branching ratio for the cross sections $\sigma(\pi^+ + p \to K^+ + \Sigma^0 + \pi^+)$ and $\sigma(\pi^+ + p \to K^+ + \Sigma^+ + \pi^0)$ be not too far from 1, etc.

In conclusion, it appears that provided conditions (I) and (II) are confirmed by experiment and provided the observed polarizations are large enough,[8] one can get the relative Σ - Λ parity and the sign of α_Λ/α_0 by measuring only the up/down asymmetries in the hyperon decays (a'), (b''), and (c').

Whatever the situation turns out to be, the experimental investigation of the reaction considered here will give useful information on the position, width, spin, etc.,[9] of the resonance(s), and can shed some light on the understanding of strange particle interactions.

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[1]Reported by M. L. Good at Tenth Annual Rochester Conference on High-Energy Nuclear Physics, August, 1960 (to be published).

[2]$(b)/(a) = (c)/(a) = 1/4$ if the restricted (or global) symmetry is valid [in which, however, $\Pi(\Lambda) = \Pi(\Sigma)$ is assumed]. Kinematical factors, including the Σ - Λ mass difference, would give $\sim 1/20$ if Y^* is the $p_{3/2}$ pion-hyperon resonance (analogous to the 33 resonance of the π - N system). Nevertheless there is no strong reason to believe such predictions.

[3]For this reason among others the use of a hydrogen bubble chamber seems more suitable.

[4]The situation here is analogous to the one considered in nuclear physics in the decay of the compound nucleus, etc.

[5]Formulas (3) and (4) are special cases of the more general relation,

$$P_\Lambda[P_\Sigma] = \begin{Bmatrix} 1 \\ -J/(J+1) \end{Bmatrix} \times P_{Y^*}$$

$$\text{for } \Pi(\Lambda)[\Pi(\Sigma)] = \begin{Bmatrix} (-1)^{J+\frac{1}{2}} \\ (-1)^{J-\frac{1}{2}} \end{Bmatrix} \Pi(Y^*),$$

where P_{Y^*} is the polarization of Y^* which is of course normal to the plane S.

[6]R. Gatto, Phys. Rev. 109, 610 (1958); G. Feldman and T. Fulton, Nuclear Phys. 8, 106 (1958).

[7]B. d'Espagnat and J. Prentki, Phys. Rev. 114, 1366 (1959); S. Bludman, Phys. Rev. 115, 468 (1959); S. Treiman, Nuovo cimento 15, 916 (1960); A. Pais, Nuovo cimento (to be published).

[8]If $\Pi(\Lambda) = \Pi(\Sigma) = (-1)^{J+\frac{1}{2}}\Pi(Y^*)$ were the case, the experiment would be easiest; otherwise the polarizations of hyperons are smaller and better statistics is of course required. This follows from footnote 5.

[9]The determination of the spin of Y^* can be obtained by standard methods which shall not be discussed here.