Λ AND Σ^0 PRODUCTION IN PERIPHERAL REACTIONS

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A suppression of Σ^0 production relative to Λ production by a factor of 27 is predicted in transitions with baryon spin flip in several simple models using SU(6) wave functions for the baryons. Possible experiments to detect this factor are suggested.

A strong suppression of Σ^0 production relative to Λ production in peripheral reactions is predicted both from a quark model[1] and from a meson-exchange model with higher symmetries. This difference results from properties of the SU(6) baryon wave functions in the $\underline{56}$ representation which have small matrix elements for simple transition operators between the nucleon and the Σ^0. Experimental verification of this Σ^0 suppression should provide a sensitive test for the baryon wave function.

Consider reactions of the form

$$A+N\rightarrow B+Y, \qquad (1)$$

where N is a nucleon, Y is a Λ or Σ^0 hyperon or a $Y_1^{*0}(1385)$, and A and B are any particles which are allowed to participate in such a reaction. In either a quark model or a one-meson-exchange model, the transition-matrix element describing Reaction (1) can be written as the sum of a few terms, each of which splits into two factors,

$$\langle BY|T|AN\rangle = \langle B|T_1|A\rangle\langle Y|T_2|N\rangle. \qquad (2)$$

In a one-meson-exchange model this factorization represents the independence of the two vertices describing the emission and the absorption of the exchanged meson. If more than one meson can be exchanged, such as K and $K^*(890)$, there is one term of type (2) for each meson state which can be exchanged. In the quark model the amplitude is expressed as the sum of the individual two-body quark-quark and quark-antiquark amplitudes. The strangeness exchange requires the transitions of a nonstrange quark in N into a strange quark in Y and a similar exchange of strangeness by a single quark or antiquark in the transition from A to B. Thus factorization also occurs in this model and T_1 and T_2 are both single-quark transition operators. The number of terms of type (2) depends upon the number of independent spin amplitudes.

In a reaction which is described by the relation (2), the branching ratios of Λ, Σ^0, and Y_1^* production are determined completely by the properties of the operator T_2. In the quark model T_2 describes a single-quark transition with a uniquely defined change in electric charge and strangeness. There are four such operators. Three are components of a vector in spin space and describe spin-flip transitions; the fourth is a scalar and describes transitions without spin flip. Since each of these operators connects different polarization states, the contribution of each operator can be isolated by polarization measurements on the initial and final baryon. If SU(6) wave functions are used for the baryon, the SU(6) transformation properties of these operators are determined by the requirement that they be single-quark operators with specified changes in electric charge and strangeness. They must transform like the four members of the representation $\underline{35}$ which transform under SU(3) like the appropriate K-meson state and which are three components of a spin vector and a spin scalar.

In a meson-exchange model with SU(6) wave functions for the baryons, the operator T_2 has the transformation properties of the exchanged meson if the baryon vertex is assumed to be invariant under the collinear group[2] $SU(6)_W$. Thus for K and $K^*(890)$ exchange, T_2 is also required in this model to transform like the same four members of a $\underline{35}$ described above. The same predictions for the Λ/Σ^0 production ratio are thus obtained in both the quark model and the meson-exchange model with $SU(6)_W$ symmetry for the baryon vertex.

The matrix elements of an SU(6) $\underline{35}$ between two members of the same SU(6) $\underline{56}$ supermultiplet are easily obtained from standard tables or calculated directly, since such matrix elements are proportional to matrix elements of the corresponding SU(6) generators. For the spin-flip transition one obtains the result

$$\bar{\sigma}(\Lambda)=27\bar{\sigma}(\Sigma^0) \text{ (with baryon spin flip)}, \tag{3}$$

where $\bar{\sigma}$ is the cross section multiplied by the appropriate kinematic factors to take into account the difference is phase space resulting from the different masses in the final states. If no polarization measurement is made one obtains the following sum rule for the incoherent sums of the spin flip and spin-nonflip cross sections:

$$\bar{\sigma}(\Lambda)=3[\bar{\sigma}(\Sigma^0)+\bar{\sigma}(Y_1^*)]. \tag{4}$$

From Eq. (4) one also obtains the inequality

$$\bar{\sigma}(\Lambda)\geq 3\bar{\sigma}(\Sigma^0). \tag{5}$$

Thus the Λ production is predicted always to be at least 3 times greater than Σ^0 production in any peripheral reaction.

The factor 27 in the spin-flip transition is particularly striking.[3] It would be of great interest to check experimentally whether this large suppression factor is present in Σ^0 production with spin flip. The measurement of spin-flip events is particularly feasible when A is a π or K meson and B is a vector meson whose alignment can be determined by the angular distribution of its decay product. We choose the z axis perpendicular to the production plane. If S is the total spin of the meson and baryon in the reaction, angular momentum and parity conservation require that S_z change only by multiples of two units. Thus if the vector meson is produced in a state with $S_z=\pm1$, the $\Delta S_z=0,2$ selection rule requires a spin flip in the baryon state. Thus the result (3) can be restated as follows: For vector-meson production in the aligned state $S_z=\pm1$ with respect to an axis perpendicular to the production plane, $\bar{\sigma}(\Lambda)/\bar{\sigma}(\Sigma^0)=27$.

If the observed Λ-to-Σ^0 branching ratio without polarization measurement is closer to the value 3 than to the value 27, the Σ^0 component must be dominated by the spin-nonflip transition. In this case the vector mesons emitted with Σ^0's should be aligned in the $S_z=0$ state perpendicular to the production plane.

The case of ρ or ω production together with Λ or Σ^0 in K^-p reactions is of particular interest. The application of the quark or the meson-exchange models to the operator T_1 in relation (2) leads[4] to the relation $\bar{\sigma}(\omega)=\bar{\sigma}(\rho)$ which now is found to be in good agreement with experiment.[5] The success of the model for the meson states provides additional evidence supporting its use for the baryons.

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[3]The factor 27 has also been noted in the ratio of Λ and Σ^0 photoproduction in a quark description by A. M. Baldin, Zh. Eksperim. i Teor. Fiz.—Pis'ma Redakt. 3, 265 (1966) [translation: JETP Letters 3, 171 (1966)]. Here the transition is described as pure baryon spin flip, because the spin generator σ appears explicitly in the coupling used. The results (3)-(5) of the present paper clearly apply to photoproduction (particle A is a photon) in any model where the baryon transition is described by a single-quark operator or a 35 of SU(6).

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