PROCESSES INVOLVING ANTIHYPERONS

D. AMATI, Theoretical Physics Institute, The University, Naples, Italy

B. VITALE, Physics Institute, The University, Catania, Italy

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THE 10 Bev proton accelerator, which will soon start operating in the Soviet Union, will make it possible to study experimental phenomena involving antihyperons. We here discuss some processes which may profitably be investigated when antihyperons become available.

1. GENERAL REMARKS

To explain the decay processes of some heavy mesons and the transmutation of one heavy meson into another (Lee-Orear theory) without postulating a direct coupling of these mesons with each other or with the pion field, one is forced to introduce the virtual creation and annihilation of baryon-antibaryon pairs. In fast processes there is conservation of strangeness, and therefore a heavy meson with $S \neq 0$ (for example a K-particle) cannot produce a nucleon-antinucleon pair. Nucleon-antihyperon or hyperon-antinucleon pairs can simultaneously conserve strangeness and the difference between baryon and antibaryon number. The latter conservation law makes it impossible to identify antihyperons with hyperons even when they are neutral.

The analysis of antihyperon creation and interaction processes can yield useful information about the quantum numbers (isotopic spin, z-component of isotopic spin, strangeness, etc.) usually assigned to antiparticles. The chief aim of the following discussion is to determine the consequences of the conservation of a chosen system of quantum numbers in the most important fast processes involving antihyperons.

To assign a definite set of quantum numbers to antihyperons and to analyze their creation and interaction processes, we must start from the following assumptions: (a) The total isotopic spin and its z-component are conserved in all fast processes involving antihyperons $\overline{H}$, nucleons N, heavy mesons K and pions; the strangeness is then also conserved. (b) The z-component of isotopic spin has equal magnitude and opposite sign for each particle and its antiparticle. (c) The strangeness has equal magnitude and opposite sign for particle and antiparticle.

Assumption (a) is connected with the notion that all the interactions responsible for the processes here considered are charge-independent. Assumptions (b) and (c) follow from the formal relations[1] between T_3, the charge conjugation operator C, and the strangeness S.

2. CREATION PROCESSES

The physically allowed creation processes are limited by the conservation of the strangeness which is assigned to antibaryons by assumption (b). The study of direct production of hyperon-antihyperon pairs in nucleon-nucleon collisions is highly inconvenient; the short life-time of hyperons (and presumably of antihyperons) makes it difficult to extract a beam of them from the accelerator; and in any case we should obtain a mixture of hyperons and antihyperons. Moreover, the thresholds of direct processes are rather high (around 7 Bev for production of $\Lambda - \overline{\Lambda}$ pairs on nucleons at rest).

It would be much better to use the indirect process

$$K + N \rightarrow \overline{H} + N + N. \qquad (1)$$

This process can occur in a K-meson beam outside the accelerator, and it produces only antihyperons. The threshold is about 4 Bev for the K-meson kinetic energy, and K-mesons of this energy can be produced by protons with kinetic energy a little over 5 Bev. If process (1) occurs in a K-meson beam passing through a liquid hydrogen bubble-chamber, the interaction and decay of antihyperons can also be observed in the chamber. A rough estimate indicates that a significant number of $\overline{H}$ can be obtained from a primary 10 Bev proton beam of intensity equal to that of the proton beam in the bevatron.

3. INTERACTION PROCESSES

We predict that the strong interaction between antihyperon and nucleon will give rise to the following "fast" process,

$$\overline{H} + N \rightarrow K + \pi. \tag{2}$$

In reaction (2), $\overline{K}$ cannot be produced in the absorption of $\overline{H}$. In general, $\overline{K}$ cannot be created except in processes where a $K-\overline{K}$ pair appears together with the K. If $\overline{H}$ is captured into excited fragments, as H is, then a characteristic feature of the annihilation of these fragments will be the absence of $\overline{K}$.

In addition to (2), there will be charge-exchange processes and processes of the type

$$\overline{\Sigma} + N \rightarrow \Lambda^0 + N; \tag{3}$$

These must be considered probable, in view of the observed production of antineutrons by charge-exchange between antiprotons and nucleons.[2]

Next we consider in more detail the interactions of $\overline{\Sigma^+}$. Being negative, this particle after losing energy by ionization and stopping, will be captured in a nucleus or in hydrogen. As an example we consider the interaction with a deuteron. The deuteron having zero isotopic spin, the initial state is an eigenstate of isotopic spin. Among the possible reactions are

$$\overline{\Sigma}^+ + d \rightarrow n + \pi^- + K^+, \tag{4a}$$

$$n + \pi^0 + K^0, \tag{4b}$$

$$p + \pi^- + K^0. \tag{4c}$$

In the initial state T = 1. The $\pi - N$ resonance will strongly influence those final configurations in the reactions (4) which have $T = 3/2$. For such configurations, the ratios between the cross-sections for the three processes will be given by

$$\sigma(a) : \sigma(b) : \sigma(c) = 9 : 2 : 1 \tag{5}$$

and the corresponding K^+/K^0 ratio will be 3. Recent experiments indicate a strong interaction in the $K - N$ system with T = 1. Because of the high energy of the products of the reactions (4), it is possible that the strong $K - N$ interaction with T = 1 will dominate the effect of the $\pi - N$ resonance. In the limiting case of a pure $K - N$ final state with T = 1, the ratios of the cross-sections will be

$$\sigma(a) : \sigma(b) : \sigma(c) = 1 : 2 : 1; \tag{6}$$

and the K^+/K^0 ratio will be $1/3$.

The $\overline{H} - N$ annihilation may give information concerning the existence of two K-particles of opposite parity or the alternative possibility that only one K-particle exists with non-conservation of parity in its decay. In the latter case, the ratios between the decay modes τ and θ will be the same as for heavy mesons produced in other processes ($\pi - N$ or $N - N$ collisions, etc.).

If there are two heavy mesons with opposite parity, the ratios between the decay modes should vary. If an annihilation takes place from a state of definite total and orbital angular momentum, only one of the K-mesons should be observed in the annihilation products

[1] B. D'Espagnat and J. Prentki, Nucl. Phys. **1**, 33 (1956); V. Votruba, Nucl. Phys. **2**, 98 (1956); G. Gyorgyi, Nucl. Phys. **2**, 267 (1956); J. V. Lepore, Phys. Rev. **101**, 1206 (1956); B. J. Malenka and H. Primakoff, Phys. Rev. **105**, 338 (1957).

[2] Cork, Lambertson, Piccioni and Wenzel, Phys. Rev. **104**, 1193 (1956).

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