π^--MESIC DECAY OF THE $_\Lambda H^3$ HYPERNUCLEUS

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Submitted to JETP editor February 4, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **39**, 78-79 (July, 1960)

The ratio of the lifetimes of the decays $_\Lambda H^3 \rightarrow He^3 + \pi^-$ and $_\Lambda H^3 \rightarrow d + p + \pi^-$ is considered in the impulse approximation, with the interaction in the proton — deuteron system taken into account. It is shown that for a spin $j = 1/2$ of the $_\Lambda H^3$ hypernucleus the value of this ratio is in good agreement with the experimental value.

As is known, the study of the different channels of decay of hypernuclei can supply information on the character of the Λ-nucleon forces and the spin of hypernuclei.[1-3] Picasso and Rosati[1] showed that the ratio of the half-lives for

$$H^3_\Lambda \rightarrow He^3 + \pi^-, \qquad (1)$$

$$H^3_\Lambda \rightarrow d + p + \pi^- \qquad (2)$$

indicates that for the spin of the $_\Lambda H^3$ hypernucleus the value $1/2$ is a preferable one; however, full agreement on the values of this ratio obtained from experiment is still lacking.

In the present article we shall show that, by taking into account the effect of the interaction in the final state, which has not been done in references 1 and 2, one may obtain better agreement between theory and the experimental data. The interaction of π mesons with other decay products at the energies considered is small, since the basic effect is associated with the interaction in the proton — deuteron system.

The amplitude of the Λ-particle decay in a hypernucleus has the form

$$M = g_s + g_p(\sigma \mathbf{k}) / k_0,$$

where k_0 is the π-meson momentum in the decay of a free Λ particle ($\sim$101 Mev/c).

The square of the matrix element of the decay (2) as a function of the spin j of the $_\Lambda H^3$ hypernucleus, after averaging over the spin states (our choice of the wave function for the p — d system was analogous to that of Buckingham and Massey[4]), takes the form

$$|M_{if}|^2 = \left(g_s^2 + \frac{1}{9} g_p^2 \frac{k^2}{k_0^2}\right) |I^d|^2 + \frac{8}{9} g_p^2 \frac{k^2}{k_0^2} |I^q|^2 \text{ for } j = 1/2,$$

$$|M_{if}|^2 = \frac{4}{9} g_p^2 \frac{k^2}{k_0^2} |I^d|^2 + \left(g_s^2 + \frac{5}{9} g_p^2 \frac{k^2}{k_0^2}\right) |I^q|^2 \text{ for } j = 3/2. \qquad (3)$$

Here

$$I^{q,d} = \int \Psi^{q,d+}_{\mathbf{k}_f}(\mathbf{r}_\Lambda, \mathbf{r}_p, \mathbf{r}_n) \Psi_d(r_n r_p) e^{-2i\mathbf{k}\rho/3} \Psi_{H^3_\Lambda} \times (\mathbf{r}_\Lambda, \mathbf{r}_p, \mathbf{r}_n) d\mathbf{r}_\Lambda d\mathbf{r}_p d\mathbf{r}_n,$$

$$\Psi^{q,d}_{\mathbf{k}_f} = e^{i\mathbf{k}_f \rho} + (k_f \rho)^{-1} e^{-i\mathbf{k}_f \rho} \times \sum_l (-1)^l (2l+1) \exp\{-i\delta_l^{q,d}\} \sin \delta_l^{q,d} P_l(\cos\theta),$$

$\delta_l^{q,d}$ are the phase shifts in the states with spins $3/2$ and $1/2$ (reference 5), $\mathbf{k}$ is the π-meson momentum, $\mathbf{k}_f$ is the relative momentum of the p — d system, $\boldsymbol{\rho} = \mathbf{r}_\Lambda - 1/2(\mathbf{r}_p + \mathbf{r}_n)$.

We took into account for the p — d system only states with $l = 0$ and $l = 1$, since at the energies under consideration the phase shifts for $l \geq 2$ are small. Thus, inclusion of the interaction in the final state leads to the probability of decay (2) being dependent on the spin of the $_\Lambda H^3$ hypernucleus (cf. reference 1). In the absence of such an interaction $I^q = I$, and from (3) we find that the probability of this decay does not depend on j (conclusion from reference 1).

For a decay of the type (1) the square of the matrix elements was calculated by Picasso and Rosati:[1]

$$|M_{if}|^2 = \frac{1}{12} (9g_s^2 + g_p^2 k^2/k_0^2) |I|^2 \text{ for } j = 1/2,$$

$$|M_{if}|^2 = \frac{1}{3} g_p^2 (k^2/k_0^2) |I|^2 \quad \text{for } j = 3/2. \qquad (4)$$

Here

$$I = \int \Psi^+_{He_3}(\mathbf{r}_\Lambda, \mathbf{r}_p, \mathbf{r}_n) e^{-i\mathbf{k}\mathbf{r}_\Lambda} \Psi_{H^3_\Lambda}(\mathbf{r}_\Lambda, \mathbf{r}_p, \mathbf{r}_n) d\mathbf{r}_\Lambda d\mathbf{r}_p d\mathbf{r}_n.$$

Using (2) and (3), one may calculate, as in reference 1, the ratio of the lifetimes w^j of decays (1) and (2) for the two spin values of j of the $_\Lambda H^3$ hypernucleus. The wave functions $\Psi_{_\Lambda H^3}$ and Ψ_{He^3} were taken the same as in reference 1. The account of the Coulomb interaction was similar to that used by Tang.[6] In accordance with recent data, the ratio $x = g_s^2/g_p^2$

was limited to the values $1 \leq x \leq 5$. With a change of x in the given limits, the ratio of the lifetimes of decays (1) and (2) changes within the following limits:

$$0.67 \geqslant w^{1/2} \geqslant 0.53; \qquad 1.42 \leqslant w^{1/2} \leqslant 5.31.$$

Thus the spin value $j = 1/2$ for the $_\Lambda H^3$ hyperfragment is in satisfactory agreement with experiment, which gives $w_{exp} \lesssim 1$. Here, the agreement is better than in the case of Picasso and Rosati, who obtained for the same x values of $w^{1/2}$ greater than unity.

In conclusion, I thank Professor D. D. Ivanenko for his interest in this work, and also N. S. Il'ina for performing the numerical calculations.

[1] L. E. Picasso and S. Rosati, Nuovo cimento **11**, 711 (1959).
[2] M. Leon, Phys. Rev. **113**, 1604 (1959).
[3] R. H. Dalitz, Phys. Rev. **112**, 605 (1958).
[4] R. A. Buckingham and H. S. W. Massey, Proc. Roy. Soc. (London) **A179**, 123 (1942).
[5] H. S. W. Massey, Progr. in Nuclear Phys. **3**, 249 (1953).
[6] Y. C. Tang, Nuovo cimento **10**, 780 (1958).

Translated by E. Marquit
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