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NOTE ON THE GAMMA DECAY OF NEUTRAL PIONS *

J. Tiomno

Centro Brasileiro de Pesquisas Físicas and
Faculdade Nacional de Filosofia
Rio de Janeiro, D. F.

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We have recently proposed [1] a theory of the strong interactions of K- and Π-mesons with barions which is completely symmetrical in all barions and in all mesons. In this theory, which is formulated in a generalized seven dimensional isotopic spin space [2, 3], the strong interactions are described by the following term in the Lagrangean density:

$$i g \psi \gamma_5 \Gamma_r \psi \phi_r \qquad (1)$$

where repeated "r" indices mean summation from r = 1 to 7. The hermitian field ϕ_r describe the four K-mesons and the three Π-mesons. The 8-component isospinor describes the 8 kinds of barions ($P, N, \Xi_0, \Xi_-, \Sigma_+, \Sigma_-, \Sigma_0, \Lambda$). The matrices Γ_r are seven anticommuting matrices operating in the 8-isospinor ψ, defined

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in reference 2. The theory at this stage is completely invariant under exchange of all barions and of all mesons and thus imply that the barion mass multiplet as well as the meson mass multiplet are completely degenerate. The introduction of the electromagnetic interaction as well as of a further interaction with Π-mesons of the same strength of the electromagnetic one (both of them being not invariant under rotations in the generalized isotopic spin space) are shown to produce mass splittings both for the barion and meson multiplets of the correct order of magnitude.

In the present Note we wish to concentrate our attention on the strong Π-mesons interactions and to consider the consequences for the lifetime of Π_0 mesons for disintegration into two photons.

The terms of (1) which describe the interactions of Π-mesons [4] take the following form in the usual notation:

$$ig\,[\bar{N}\gamma_5\vec{\tau}N + \bar{\Xi}\gamma_5\vec{\tau}\,\Xi\,]\cdot\vec{\Pi} -$$

$$- ig\,[\,\frac{1}{i}\,\vec{\bar{\Sigma}}\wedge\vec{\Sigma} + i\,(\bar{\Lambda}\,\vec{\Sigma} - \vec{\bar{\Sigma}}\,\Lambda)\,]\cdot\vec{\Pi} \qquad (2)$$

where:

$$N = \begin{pmatrix} P \\ n \end{pmatrix}, \qquad \Xi = \begin{pmatrix} \Xi_0 \\ \Xi_- \end{pmatrix}$$

Gell-Mann [5] and Schwinger [6] have developed, independently, a theory in which the Π-mesons also interact symmetrically with all barions. Their interaction Lagrangean density seem however to differ from expression (2) in the signs of the terms in Λ, Σ which are opposite to ours. The main difference, however, between their theory and ours is that their interactions with K-mesons are not symmetrical in all barions and have a smaller strength then the interactions of Π-mesons.

Now that we have well defined theories of the interactions of Π-mesons with barions it is tempting to see which are the consequences for problems such as the decay of Π_0-meson and, in particular, to find which of the two above referred theories is in better agreement with the observed value for the lifetime. The consequences of the usual meson theory to the γ-instabili lity of Π_0-mesons first pointed out by Sakata and Tamikawa (before the discovery of Π-mesons) have been examined by Fin kelstein, Steinberger and others.[7] A value much smaller then the experimental one[(7)], has been, however, found as given by

$$\frac{1}{\tau} = A \frac{g^2}{4\pi} \left(\frac{\mu}{M}\right)^2 \quad \text{with} \quad A = \left(\frac{\alpha}{4\Pi}\right)^2 \mu \; , \qquad (\hbar = c = 1) \qquad (3)$$

where α is the fine structure constant, g is the strength of the coupling of pion and nucleon fields (PS - PS) and μ and M are the masses of Π_0 and nucleons, respectively. The experimental value of $\frac{g^2}{4\pi} = 13$ leads to a lifetime τ = 5×10^{-17} sec to be compared with the experimental value 5×10^{-15} sec of reference 8.

Kinoshita[9] suggested that if the Π_0 meson interacted also with a hyperon with the same strength as with protons a partial cancelation might occur and we could have, instead of (4):

$$\frac{1}{\tau} = A \frac{g^2}{4\pi} \left(\frac{\mu}{M} - \frac{\mu}{M'}\right) \qquad (5)$$

Actually if we assume interaction (2) (or Gell-Mann- Schwinger's one) we find:

$$\frac{1}{\tau} = A \frac{g^2}{4\pi} \left[\frac{\mu}{M_N} - \frac{\mu}{\Xi_-} \mp \left(\frac{\mu}{M_{\Sigma+}} - \frac{\mu}{M_{\Sigma-}} \right) \right] \quad (6)$$

where the sign - or + correspond respectively to our interaction (2) and to Gell-Mann - Schwinger interaction. It is seen that we cannot distinguish between these theories as $M_{\Sigma-} - M_{\Sigma+} \ll M_{\Sigma}$. On the other hand we find from (6) for the lifetime of π_0 the value

$$\tau = 6 \times 10^{-16} \text{sec} \quad (7)$$

which should be compared with the more recent experimental determination [10]

$$\tau_{exp} \cong 4 \times 10^{-16} \text{sec} \quad (8)$$

Thus we see that the agreement of the theory with experiment has improved and this may be considered an argument in favour of the symmetrical interaction (2), at least in what refers to nucleons and cascade particles. The question of the sign of the terms in Σ and Λ (and thus the choice between the two theories) should be decided from other experimental results, in particular, from the scattering of Σ by protons.

We should express our aknowledgements to the U.S. Office of Naval Research who made possible our attendance to the Rochester Conference.

1. Communication to the Seventh International Conference on High Energy Nuclear Physics, Rochester April, 1957. A more detailed analysis of this theory will be published elsewhere.

2. J. Tiomno, On the theory of hyperons and K-mesons, Nuovo Cimento, impress.

3. A similar theory of a 7-dimensional isotopic spin space, starting from somewhat different considerations, has been developed independently by M. Neuman whom we aknowledge for a private communication.

4. The terms of interactions of barions with K- sons in (1) have been analized in detail in reference (2) and shown to be equivalent to the interaction used in Schwinger's earlier theory (J. Schwinger, Phys. Rev. 104, 254, 1956).

5. M. Gell-Mann, Communications to the Rochester Conference, April 1957.

6. J. Schwinger, Communications to the Rochester Conference, April 1957.

7. S. Sakata and Y. Tanikawa, Phys. Rev. 57, 548, 1940; R. J. Finkelstein, Phys. Rev. 72, 415, 1947; J. Steinberger, Phys. Rev. 76, 1180, 1949; H. Fukuda and Y. Miyamoto, Progr. Theor. Phys. Japan, 4, 347, 1949.

8. B. M. Anand, Proc. Roy. Soc. (London) A 220, 183, 1953.

9. T. Kinoshita, Phys. Rev. 94, 1384, 1954.

10. J. Orear as referred by L. W. Alvarez in the Rochester Conference. April, 1957 and private communication.