THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

Laboratory of Theoretical Physics

P - 133.

V.G. Soloviev

THE LAGRANGIAN INTERACTION AND OPERATORS OF BARYON AND MESON FIELDS

15.I.1958.

THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

Laboratory of Theoretical Physics

P - 133.

V.G. Soloviev

THE LAGRANGIAN INTERACTION AND OPERATORS OF BARYON AND MESON FIELDS

15.I.1958.

In the present note we shall not be concerned with the isotopic structure of the Lagrangian of baryon and meson strong interaction but shall adhere to its mathematical form given in[1]. Let us just note that if the particles under consideration belong to the same isotopic multiplet their wave functions in all the transformations behave in a similar manner.

Let us consider the properties of the wave functions of particles with spin 0 describing π and K-mesons and those with spin ½ describing the baryons under the operations of space inversion P, time reversal T and the operation of charge conjugation C if in these transformations the Lagrangians of the form

$$L = g\bar{\Psi}_1 O \Psi_2 \theta_i + g^* \bar{\Psi}_2 O \Psi_1 \theta_i^* \qquad (1)$$

must remain invariant as well as the Lagrangians corresponding to the modes of decay $\pi^0 \to 2\gamma$, $K \to 2\pi$, $K \to 3\pi$. Ψ_i, θ_i are the operators of the fields with spin ½ and 0 whereas the matrix O may be either I or γ_5. Under the operations P, T, TC, PCT θ and Ψ are transformed in the following way:

$$\theta' = \delta_P \theta, \quad \theta' = \delta_T \theta^*, \quad \theta' = \delta_{TC} \theta, \quad \theta' = \delta_{PCT} \theta, \qquad (2)$$

$$\Psi' = \eta_P S_P^{-1} \Psi, \quad \Psi' = \eta_T S_T^{-1} \bar{\Psi}, \quad \Psi' = \eta_{TC} S_{TC}^{-1} \Psi, \quad \Psi' = \eta_{PCT} S_{PCT}^{-1} \Psi, \qquad (3)$$

and $\delta_P = \pm 1$, $\delta_{TC} = \pm 1$, $\delta_{PCT} = 1$, $\delta_T \delta_T^* = 1$,

the phase η_P, η_{TC}, η_{PCT} may assume the values both $\eta = \pm 1$

1. A. Salam Nuclear Physics 2, 173 (1956)

and $\eta = \pm i$ whereas satisfies the condition $\eta\eta^* = 1$.

Let us investigate the restrictions on the phase η and δ which are laid by the conditions of the Lagrangian invariance under P, C, T. The effective Lagrangian $e^2 g \pi^0 (HE)$ corresponding to the decay of π^0-meson into two γ-quanta is invariant with respect to P, C, T when $\delta_P^{\pi} = -1$, $\delta_C^{\pi} = 1$, $\delta_T^{\pi} = -1$, From the invariance of the Lagrangian $c(K\pi^*\pi^0 \pm K^*\pi\pi^0)$ with respect to T which corresponds to the decay $K \to 2\pi$ follows that $\delta_T^K = \pm 1$ from here $\delta_C^K = \pm 1$. It follows from the invariance of (1) with respect to P, TC, PCT, that the wave functions of all the baryons must belong to the one of the two classes: either to the class $\eta = \pm 1$ or to the class $\eta = \pm i$ It follows from the invariance of (1) with respect to operations of T and C that the phase η_T, η_C of all the baryons may differ only by their sings. This is in agreement with the assumptions given in [2].

2. P. Roman Nucl. Physics 4, 564 (1957).

Let us agree to determine the phase Λ, Σ and Ξ hyperons with respect to the nucleon phase and denote them through ε_i; ε may assume the values $\pm$ 1. Since under the operation PCT the wave functions θ_i and the bilinear combinations $\bar{\psi}_i O \psi_i$ remain invariable it follows from here that $\varepsilon_{PCT} = 1$ for Λ, Σ and Ξ hyperons.

Let us consider the Lagrangians which are invariant under T and PC but which may not be invariant with respect to the operation P. They are the Lagrangians corresponding to the decay Λ, Σ Ξ-hyperons and K-mesons as well as strong interactions if one will follow the hypothesis suggested in[3].

3. V.G. Soloviev JETP 33, 537 (1957).

In this case there are two forms of Lagrangians, namely:

$$L_1 = g_1(\bar{\Psi}_1 \gamma_5 \Psi_2 \theta + \bar{\Psi}_2 \gamma_5 \Psi_1 \theta^*) + i g_1'(\bar{\Psi}_1 \Psi_2 \theta - \bar{\Psi}_2 \Psi_1 \theta^*), \quad (4)$$

$$L_2 = g_2(\bar{\Psi} \Psi_2 \theta + \bar{\Psi}_2 \Psi_1 \theta^*) + i g_2'(\bar{\Psi}_1 \gamma_5 \Psi_2 \theta - \bar{\Psi}_2 \gamma_5 \Psi_1 \theta^*). \quad (5)$$

If $\Psi_1 \neq \Psi_2$ then the substitution[4] $\Psi_2 \to -i\Psi_2;\ g_2' \to g_1,\ g_2 \to -g_1'$

4. The author of the note is grateful to Chou Kuang Chao who drew his attention to the possibility of such a substitution.

transforms (5) into (4). From the equivalence of the Lagrangians (4) and (5) corresponding to the processes in which K-mesons participate as well as from the fact that the phase δ^{π} for π-mesons are known follows that the Lagrangian of baryon and meson strong interaction invariant with respect to T is determined quite definitely.

The part of this Lagrangian invariant with respect to P is given in[1] whereas the other is given in[5].

5. V.G. Soloviev JETP 33, 796 (1957).

If the parity is considered to be conserved in strong interactions then for an determination of the Lagrangian baryon and meson interaction of the form given in [1] it is necessary to know the following sets of the phase

$$(\varepsilon_p^{\Lambda} \cdot \varepsilon_p^{\Sigma}), (\varepsilon_p^{\Lambda} \cdot \delta_p^{K}), \varepsilon_p^{\Xi} \quad (6)$$

Note in conclusion as is shown in [6] that charge conjugacy C

6. A. Pais, R. Jost Phys. Rev. 87, 871 (1952).

prohibits a mixture of scalar and vector couplings of scalar mesons with nucleons. But it is correct only for the interactions involving the peaks where the fermion changes none of its main characteristics: mass, electric charge, strangeness. If K-mesons are considered to be scalar particles and $\varepsilon_p^1 = \varepsilon_p^2$ then the Lagrangian interaction for them may be written in the form which involves the gradient coupling, namely:

$$L = g(\bar{\psi}_1 K \psi_2 + K^* \bar{\psi}_2 \psi_1) + i g' \left(\bar{\psi}_1 \gamma_\mu \frac{\partial K}{\partial x_\mu} \psi_2 - \frac{\partial K^*}{\partial x_\mu} \bar{\psi}_2 \gamma_\mu \psi_1 \right). \quad (7)$$

References

1. A. Salam, Nuclear Physics 2, 173 (1956).
2. P. Roman, Nuclear Physics, 4, 564 (1957).
3. V.G. Soloviev, JETP, 33, 537 (1957).
4. V.G. Soloviev, JETP, 33, 796 (1957).
5. A. Pais, R. Jost, Phys. Rev., 87, 871 (1952).

1958, January.