In case (1b)

$$W_{njl}(k_N;\theta) = (2j+1)\{[(\varphi_{sv} - \varphi_{ta})\,C_{njl}(k_N) + \varphi_{ta}\,D_{njl}(k_N)] + [(-\eta_{sv} + \eta_{ta})\,E_{njl}(k_N) + \eta_{ta}\,F_{njl}(k_N)]\cos\theta\}. \quad (3)$$

The total effect due to all closed subshells in the nucleus is obtained by summation of (2) and (3) over n, j, and ℓ. Formulas (2) and (3) describe also the absorption of a μ^- mesons by a single proton located in above the closed shells (in this case the factor $(2j+1)$ must be omitted). One would expect these formulas to be a good approximation for the twice-magic nuclei (for example, ${}_{20}Ca^{40}$). The details of the calculation and numerical estimates for specific nuclei will be given in a separate article.

We are sincerely grateful to I. S. Shapiro for attention to this work and for discussion of the result.

[1] Shapiro, Dolinskii, and Blokhintsev, Dokl. Akad. Nauk. SSSR **116**, 946 (1957), Soviet Phys. "Doklady" **2**, 475 (1957); Nucl. Physics **4**, 273 (1957).

[2] Berestetskii, Dolginov, and Ter-Martirosian, J. Exptl. Theoret. Phys. (U.S.S.R.) **20**, 527 (1950).

[3] A. Sommerfeld, Atomic Structure and Spectral Lines Vol. 2. (Russian Transl.) GITTL, Moscow, 1956 [Probably: Methuen, London, 1929].

[4] A. Simon and T. A. Welton, Phys. Rev. **90**, 1036 (1953).

Translated by J. G. Adashko
148

POSSIBLE ASYMMETRY OF PARTICLES AND ANTIPARTICLES IN WEAK INTERACTIONS

A. A. ANSEL'M and V. M. SHEKHTER

Leningrad Physico-Technical Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor December 9, 1957

J. Exptl. Theoret. Phys. (U.S.S.R.) **34**, 761-762 (March, 1958)

RECENT experimental data concerning the $\beta - \nu$ correlation[1] show that the positron decays of Ne^{19} and A^{35} may be explained as a mixture of A and V covariants of the β-interaction, while the electron decays of He^6 and the free neutron are dependent on T and, evidently, S covariants. Analogously, associated with the positron decays of Co^{58}, experiment gives a weak interference due to Fermi and Gamow-Teller interactions, while this interference is strong in the electron decays of Au^{198} and Sc^{46}. If we consider that all the experiments are valid, then the indicated facts sharply contradict existing theory. Indeed, if we assume that the processes $n \rightleftarrows p + e^- + \overline{\nu}'$ and $p \rightleftarrows n + e^+ + \nu$ occur as a result of different interactions, this indicates a denial of the symmetry of particles and antiparticles in weak interactions. In addition, antiparticles no longer bear an exact resemblance to the particles with opposite charge. For example, their masses may differ by the order of magnitude of g^2, the square of the weak-interaction constant.

The self-adjoint relativistic invariant Hamiltonian for β decay, in which e^-, e^+, ν, and ν' enter asymmetrically, may be written in the form

$$\begin{aligned} H = \sum_{i=1}^{5} \overline{(\Psi_p O_i \Psi_n)}\,[\Phi^{+}_{\overline{e}}\gamma_4 O_i (g_i + g'_i\gamma_5)\,\Phi^{+}_{\overline{\nu}} \\ + \Phi^{+}_{\overline{e}}\gamma_4 O_i (f_i + f'_i\gamma_5)\,\Phi_\nu + \Phi_{e+}\gamma_4 O_i (\lambda_i + \lambda'_i\gamma_5)\,\Phi^{+}_{\overline{\nu}} \\ + \Phi_{e+}\gamma_4 O_i (\mu_i + \mu'_i\gamma_5)\,\Phi_\nu] + \sum_{i-1}^{5} (\bar{\Psi}_n O_i \Psi_p)\cdot \\ \times [\Phi_{\overline{\nu}}\gamma^4 (g^*_i - g'^*_i\gamma_5)\,O_i\Phi_{\overline{e}} + \Phi^{+}_{\nu}\gamma_4 (f^*_i - f'^*_i\gamma_5)\,O_i\Phi_{e^-} \\ + \Phi_{\overline{\nu}}\gamma_4 (\lambda^*_i - \lambda'^*_i\gamma_5)\,O_i\Phi^{+}_{e+} + \Phi^{+}_{\nu}\gamma_4 (\mu^*_i - \mu'^*_i\gamma_5)\,O_i\Phi^{+}_{e+}]. \end{aligned} \quad (1)$$

In addition, in the case of the neutrino field, $\Phi_\nu(x)$ and $\Phi^{+}_{\overline{\nu}}(x)$ are respectively the positive and negative frequency components of $\Psi_\nu(x)$, so that

$$\begin{aligned} \Phi_\nu &= -i\int S^+(x-x')\,\gamma_4\psi_\nu(x')\,d^3x', \\ \Phi^{+}_{\overline{\nu}} &= -i\int S^-(x-x')\,\gamma_4\psi_\nu(x')\,d^3x' \quad (x_0 = x_0') \end{aligned} \quad (2)$$

and analogously for electrons.

In (1), g_i, g'_i and μ^*_i, μ'^*_i refer to β^- and β^+ decays (the experiments may be satisfied, letting g_T, $g_S (g_\nu?)$ and μ_A, μ_V be unequal to zero), f^*_i, f'^*_i describe K capture, and λ^*_i, λ'^*_i describe the absorption of an antineutrino by a proton. It is easily seen that upon reflection of the spatial coordinates (P) the Hamiltonian preserves its form if the unprimed constants remain unchanged while the primed ones change sign; with reversal of time (T) it is necessary to substitute for every constant its complex conjugate; with charge conjugation (C), $g_i \rightleftarrows \mu^*_i$, $g'_i \rightleftarrows -\mu'^*_i$, $f_i \rightleftarrows \lambda^*_i$, $f'_i \rightleftarrows -\lambda'^*_i$. From this it is evident that the Hamiltonian (1) is invariant under PTC only when $g_i = \mu_i$, $g'_i = \mu'_i$, $f_i = \lambda_i$, $f'_i = \lambda'_i$. We obtain the usual theory of β decay if, in addition, $g_i = f_i$, $g'_i = f'_i$.

A similar breakdown into positive and negative frequency components may be carried out as well for the nucleon operators in (1). It is not clear, however, whether this has meaning, since as a result of the strong interaction with π mesons, β decay may pass through a virtual antinucleon state. In the presence of an external Coulomb field it must be contained in the projection operators $S^{\pm}$.

The Hamiltonian appears to be nonlocal, which leads to the fact that $[H(x_1), H(x_2)] \neq 0$ when x_1 and x_2 are separated by a space-like interval. Precisely speaking, instead of the function $S(x_1 - x_2)$, this commutator contains $S^{\pm}(x_1 - x_2)$, which do not vanish outside of the light cone. In the case where the operators S^+ and S^- refer to electrons, this indicates a violation of causality in weak interactions at distances of the order $\hbar/m_e c$; for a neutrino field there is no such localization (when the mass is equal to zero, the $S^{\pm}(x_1 - x_2)$ diminish outside of the light cone as $|x_1 - x_2|^{-3}$). This situation appears to raise a serious objection to ideas which have been expressed. However, since in weak interactions the theoretical principles previously considered absolute (conservation of parity and invariance with respect to charge conjugation) are in general violated, it becomes expedient to make an experimental verification of the developed scheme. In particular, it would be useful to compare carefully the β decay and K capture probabilities in the same nucleus with the values predicted by ordinary theory.

An analogous although more difficult experiment is the comparison of β decay with the absorption of an antineutron by a proton.*

After completion of the present paper, K. A. Ter-Martirosian informed the authors that similar considerations have been developed in an article by Arnovit and Feldman (at present unpublished).

We are grateful to V. N. Grilov and to K. A. Ter-Martirosian for their comments.

*If we maintain symmetry between the electron and positron then $g_i \lambda_i$, $f_i = \mu_i$, and the processes $\bar{\nu} + p = n + e^+$ and $n = p + e^- + \bar{\nu}$ must occur as a result of one and the same interaction.

[1] Perrmannsfeldt, Maxson, Stahelin, and Allen, Phys. Rev. **107**, 641 (1957).

[2] F. Boehm and A. H. Wapstra, Phys. Rev. **106**, 1364 (1957); Ambler, Hayward, Hopes, Hudson, and Wu, Phys. Rev. **106**, 1361 (1957); Postma, Huiskamp, Miedonia, Steenlaud, Tolhek, and Gorter, Physica **23**, 259 (1957); F. Boehm and A. H. Wapstra, Phys. Rev. **107**, 1462 (1957).

[3] Cowan, Reines, Harrison, Kruse, and McGuire, Science **124**, 103 (1956).

Translated by J. S. Wood
149

LIFETIME OF THE K_2^0 MESON

I. Iu. KOBZAREV and L. B. OKUN'

Submitted to JETP editor December 11, 1957

J. Exptl. Theoret. Phys. (U.S.S.R.) **34**, 763-764 (March, 1958)

GELL-MANN and Pais[1] predicted the existence of the long-lived neutral K meson (K_2^0), which was later discovered experimentally. In connection with the establishment of the noninvariance of weak interactions under space inversion and charge conjugation, the original arguments of Gell-Mann and Pais have to be modified, as was shown in a series of papers.[2] Below we shall assume that the weak interactions are invariant under time reversal and that the K_2^0 meson has negative "time-parity".

The following decays of K_2^0 will be possible (we shall denote the respective probabilities by w_n, where n is the number of the reaction):

1) $K_2^0 \to e^+ + \nu + \pi^-$, 4) $K_2^0 \to \mu^- + \nu + \pi^+$,
2) $K_2^0 \to e^- + \tilde{\nu} + \pi^+$, 5) $K_2^0 \to \pi^+ + \pi^- + \pi^0$,
3) $K_2^0 \to \mu^+ + \nu + \pi^-$, 6) $K_2^0 \to \pi^0 + \pi^0 + \pi^0$.

The decays 1, 2 and 3, 4 are the analogs of the decays

7) $K^+ \to e^+ + \nu + \pi^0$, 8) $K^+ \to \mu^+ + \nu + \pi^0$,

whereas the decays 5, 6 are analogous to the τ^+ decays

9) $K^+ \to \pi^+ + \pi^+ + \pi^-$, 10) $K^+ \to \pi^+ + \pi^0 + \pi^0$.

Here it is essential that in the decays 5, 6, as in the decays 9, 10, the outgoing π mesons are in the S state.

It has been shown[3] that if the decays of all strange particles take place by way of the decays of Λ hyperons, then the rule $\Delta T = \frac{1}{2}$, considered earlier in connection with the π-mesonic decays of strange particles, applies also to their leptonic decays. We use this rule to calculate the probabilities of the different decays of the K_2^0 meson, and