Capture of the Ξ^- in He^4 can lead to a series of inelastic processes; included in the possible reactions is the production of hypernuclei containing two Λ hyperons

$$\Xi^- + He^4 \rightarrow \begin{matrix} p + (\Lambda\Lambda nn), \\ n + (\Lambda\Lambda np), \ldots \end{matrix}$$

The existence of such hypernuclei should lead to a characteristic cascade decay.

We note that the ratio of cross sections for inelastic and elastic interactions on He^4 will depend on the relative parity of the Ξ and nucleon (in the case of negative parity of the Ξ, inelastic scattering will be suppressed since one of the particles produced in the inelastic scattering must be emitted in a P-state, and the energy given up in this case is small (30 Mev minus the binding energy of He^4 plus the binding energy of the fragments produced)).

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ON THE POLARIZATION OF THE ELECTRONS EMITTED IN THE DECAY OF MU MESONS

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Expressions have been obtained for the energy spectrum, the angular distribution, and the polarization of the electrons emitted in the decay of polarized μ mesons. The calculations have been carried out for a decay interaction Hamiltonian of the most general form, characterized by ten complex constants, It is shown that the experiments carried out up to the present time are insufficient to test the validity of the predictions made in Refs. 4 and 5; in addition to these experiments, it is necessary to measure the sign of the polarization of the decaying μ mesons.

THE experimental data from studies of the spectrum, angular asymmetry, and polarization of the electrons from the decay of polarized μ mesons are in evident agreement with the predictions of the theory of the two-component neutrino, proposed by Salam,[1] Landau,[2] and Lee and Yang.[3] Within the framework of this theory, if we take into account the experimentally observed spectrum of the electrons, out of the ten complex constants C and C′ which describe the decay of the μ meson in the general case [cf. Eq. (I) of the Appendix] only four are different from zero:

$$C_V = C_A' \neq 0, \quad C_A = C_V' \neq 0; \tag{1}$$

$$C_S = C_S' = C_P = C_P' = C_T = C_T' = 0. \tag{2}$$

It can be hoped that more precise experimental data will be found to be in agreement with the more restrictive hypothesis of Feynman and Gell-Mann[4] and Marshak and Sudarshan[5] about the two-component nature of the electronic interaction, according to which

$$C_V = \pm C_V', \quad C_A = \pm C_A'. \tag{3}$$

In this latter case the distribution of the electrons from the decay of stationary μ mesons must be proportional to

$$(1 \mp \boldsymbol{\zeta}\mathbf{n})(3 - 2\varepsilon \pm \boldsymbol{\eta}\mathbf{n}(1 - 2\varepsilon))\varepsilon^2 d\varepsilon. \tag{4}$$

Here ϵ is the energy of the electron divided by its maximum possible energy, $\mathbf{n}$ is the unit vector in the direction of motion of the electron, $\boldsymbol{\zeta}$ is the unit vector in the direction of the spin of the electron in the rest system of the electron, and $\boldsymbol{\eta}$ is the unit vector in the direction of the spin of the

μ meson in the rest system of the μ meson.

The formula (4) is obtained from Eq. (II) of the Appendix if the conditions (1), (2), and (3) are fulfilled and if we neglect the mass m_e of the electron in comparison with its energy.

The first factor in Eq. (4) indicates that the electrons must be completely longitudinally polarized. It has been established experimentally[6,7] that the positrons from the decay of μ^+ mesons are polarized in the direction of motion. Therefore the lower signs in Eq. (4) must be assigned to the decay of the μ^+ meson, and the upper signs to the decay of the μ^- meson. Furthermore, since the positrons with large energies emerge predominantly backward relative to the momentum of the μ^+ meson,[8] and according to Eq. (4) they emerge along the spin of the μ^+ meson, if Eq. (4) is valid we can conclude that the spin of a μ^+ meson produced in the decay of a π^+ meson is directed oppositely to its momentum. An experimental test of this prediction is very important.

It is of interest to ascertain to what extent the experimental verification of Eq. (4) would carry with it the two-component nature of the neutrino. In other words, suppose the electron enters the interaction through only two components ($C_i = \pm C_i'$. In this case, are the conditions (1) and (2) not only sufficient for the formula (4) to be valid, but also necessary?

As for the condition (1), it is obvious that if we dispense with it, postulating, for example, that $C_A = C_A' = 0$, $C_V = \pm C_V' \neq 0$, then Eq. (4) will hold as before. Thus the condition (1) is not a necessary one for the validity of Eq. (4), and the experimental confirmation of this formula does not mean that the neutrino is a two-component particle.

As for the condition (2), from the results of a number of researches[9-12] it follows that one can get just the same spectrum and angular asymmetry of the electrons as in the formula (4) if one assumes that $C_V = C_V' = C_A = C_A' = 0$ and chooses the constants C_S, C_S', C_P, C_P', C_T, C_T' in a suitable way. It is obvious that if one is not interested in the angular asymmetry of the electrons it is not hard to get also the required (experimentally observed) sign for their polarization. The question arises: cannot a happily chosen combination of the S, P, and T interaction types give a formula in complete agreement with Eq. (4)?

An analysis of Eq. (II) gives a negative answer to this question. Actually, by combining the S, P, and T types, one can get the formula

$$(1 \mp \boldsymbol{\zeta}\mathbf{n})\,(3 - 2\varepsilon \mp \boldsymbol{\eta}\mathbf{n}\,(1 - 2\varepsilon))\,\varepsilon^2 d\varepsilon, \tag{5}$$

which differs from Eq. (4) by the sign of the angular asymmetry of the electrons if the sign of their polarization is prescribed. Consequently, if it is shown that the polarization of the μ^+ mesons from the decay of π^+ mesons agrees with the consequence of the two-component theory of the neutrino as stated above, this will mean that the formula (5) is incorrect. Thus the condition (2) is a necessary one for the validity of the formula (4).

We have carried through the investigation of the necessity of the conditions (1) and (2) on the assumption that the condition of the two-component nature of the electronic interaction is valid. If it turns out that this latter condition is not borne out by experiment, then a consideration like that set forth above can be easily carried through by means of Eq. (II) for this more general case.

APPENDIX

We present here the result of the calculation of the angular asymmetry and polarization of the electrons emitted in the decay of polarized μ mesons. The calculation is carried out for the case in which the Hamiltonian has the following form:

$$H = \sum_{i=S,\,V,\,T,\,A,\,P} (\bar{\psi}_e\,(C_i + C'_i\gamma_5)\,O_i\psi_\mu)\,(\bar{\psi}_\nu O_i\psi_\nu),$$

$$O_S = 1,\ O_V = -i\gamma_\alpha,\ O_T = \frac{i}{2\sqrt{2}}(\gamma_\alpha\gamma_\beta - \gamma_\beta\gamma_\alpha),$$
$$O_A = \gamma_\alpha\gamma_5,\ \ O_P = \gamma_5, \qquad \gamma_5 = i\gamma_0\gamma_1\gamma_2\gamma_3. \tag{I}$$

It is convenient to carry through the calculation by using the method of Lenard[13] and the spin projection operators of Michel and Wightman.[14] The probability that in the decay of a μ meson with its spin directed along $\boldsymbol{\eta}$ an electron is emitted in the direction $\mathbf{n}$ with energy ϵ and with spin directed along $\boldsymbol{\zeta}$ is given by the following formula:

$$d^2W / d\varepsilon d\Omega = (\mu w^4 / 96\pi^4)\sqrt{\varepsilon^2 - u^2}\,\{3S + 2V + 2T\},$$
$$S = (C_S C_S^* + C_P' C_P'^*)\,(1-\varepsilon)\,(\varepsilon + u)\,\{1 + [\boldsymbol{\eta}\boldsymbol{\zeta} - (\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})] + (\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})\}$$
$$+ (C_S' C_S'^* + C_P C_P^*)\,(1-\varepsilon)\,(\varepsilon - u)\,\{1 - [\boldsymbol{\eta}\boldsymbol{\zeta} - (\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})] + (\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})\}$$
$$+ (C_S C_S'^* + C_S' C_S^* + C_P C_P'^* + C_P' C_P^*)\,(1-\varepsilon)\sqrt{\varepsilon^2 - u^2}\,\{\boldsymbol{\eta}\mathbf{n} + \boldsymbol{\zeta}\mathbf{n}\}$$
$$+ i\,(C_S' C_S^* - C_S C_S'^* + C_P C_P'^* - C_P' C_P^*)\,(1-\varepsilon)\sqrt{\varepsilon^2 - u^2}\,\boldsymbol{\zeta}\,[\boldsymbol{\eta}\times\mathbf{n}],$$
$$V = (C_V C_V^* + C_A' C_A'^*)\,(\varepsilon - u)\,\{(3 - 2\varepsilon + u) + (1 + u)\,[\boldsymbol{\eta}\boldsymbol{\zeta} - (\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})]$$
$$- (1 - 2\varepsilon - u)(\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})\} + (C_V' C_V'^* + C_A C_A^*)\,(\varepsilon + u)\,\{(3 - 2\varepsilon - u)$$

$$
\begin{aligned}
&- (1-u)\,[\boldsymbol{\eta\zeta} - (\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})] - (1-2\varepsilon+u)(\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})\} \\
&+ (C_V C_V'^{*} + C_V' C_V^{*} + C_A C_A'^{*} + C_A' C_A^{*}) \sqrt{\varepsilon^2 - u^2}\,\{(1-2\varepsilon+v)\,\boldsymbol{\eta}\mathbf{n} \\
&- (3-2\varepsilon-v)\,\boldsymbol{\zeta}\mathbf{n}\} + i\,(C_V' C_V^{*} - C_V C_V'^{*} + C_A C_A'^{*} - C_A' C_A^{*}) \sqrt{\varepsilon^2 - u^2}\,(1-v)\,\boldsymbol{\zeta}\,[\boldsymbol{\eta}\times\mathbf{n}], \\
&T = (C_T C_T^{*} + C_T' C_T'^{*})\,\{\varepsilon(3-\varepsilon) - 2u^2 - u(1-\varepsilon)\,[\boldsymbol{\eta\zeta} - (\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})] \\
&- [\varepsilon(1+\varepsilon) - 2u^2]\,(\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})\} + (C_T C_T'^{*} + C_T' C_T^{*}) \sqrt{\varepsilon^2 - u^2} \\
&\times \{(3-\varepsilon-2v)\,\mathbf{n}\boldsymbol{\zeta} - (1+\varepsilon-2v)\,\mathbf{n}\boldsymbol{\eta}\}; \\
&\varepsilon = E_e/w, \quad u = m_e/w, \quad v = m_e^2/m_\mu w, \quad w = (m_\mu^2 + m_e^2)/2m_\mu.
\end{aligned}
\tag{II}
$$

The expression proportional to $\boldsymbol{\zeta}[\mathbf{n}\times\boldsymbol{\eta}]$ determines the transverse polarization of the electrons, perpendicular to the plane $\boldsymbol{\eta}\mathbf{n}$. For conservation of the parity with respect to time reversal, when all the constants C and C′ are real, it can be seen from Eq. (II) that this type of polarization is absent. The expression proportional to $[\boldsymbol{\eta\zeta} - (\boldsymbol{\eta}\mathbf{n})(\boldsymbol{\zeta}\mathbf{n})]$ determines the transverse polarization of the electrons in the plane $\boldsymbol{\eta}\mathbf{n}$.

If we stipulate that the formula (II) describes the decay of the μ^+ meson, then in order to get the formula for the μ^- meson we must make the replacements

$$
\begin{aligned}
&C_S,\ C_A,\ C_P,\ C_V',\ C_T' \rightarrow C_S^{*},\ C_A^{*},\ C_P^{*},\ C_V'^{*},\ C_T'^{*} \\
&C_S',\ C_A',\ C_P',\ C_V,\ C_T \rightarrow -C_S'^{*},\ -C_A'^{*},\ -C_P'^{*},\ -C_V^{*},\ -C_T^{*}.
\end{aligned}
$$

Various special cases of the formula (II) have been obtained previously in a number of papers. Thus, if we average Eq. (II) with respect to the spin states of the μ meson and the electron ($\boldsymbol{\eta} = 0$, $\boldsymbol{\zeta} = 0$), then we have the expression for the electron spectrum first obtained by Tiomno, Wheeler, and Rau[15] and by Michel.[16] If we average Eq. (II) only over the polarizations of the electron ($\boldsymbol{\zeta} = 0$), we get the expression obtained by Rudik and one of the present writers[9] (on the assumption $m_e = 0$), by Bouchiat and Michel[10] ($m_e \neq 0$), by Kinoshita and Sirlin[11] ($m_e = 0$), and by Larsen, Lubkin, and Tausner[12] ($m_e = 0$). If we assume that the conditions (1) and (2) hold, then from Eq. (II) we get a formula analogous to those contained in the papers of Kinoshita and Sirlin[17] ($m_e = 0$), Überall,[18] and Candlin ($m_e \neq 0$). A formula analogous to Eq. (II) for the case when only the tensor interaction is absent has been obtained by Sharp and Bach[20] ($m_e \neq 0$).

If we set all the primed constants C′ equal to zero and take $m_e = 0$, Eq. (II) goes over into the formula obtained by one of the present writers[21] for the Hamiltonian conserving parity.

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