ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

Лаборатория теоретической физики

M.A. Markov

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# ON WEAK INTERACTION THEORY



Дубна 1962 год

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The possibilities of different formulations of the limitations for four-fermion weak interactions leading to the observable forbiddenesses are considered.

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There are at present reasons to believe that the modern formulations of the weak interaction theory may be in future essentially modified.

The development of the theory may follow different ways (the intermidiate meson etc ), but ultimately, it seems, the question as to 'why is the parity conserved in weak interactions and not in strong ones' must be answered.

According to the modern phenomenological description of weak interactions, they are reduced to the four-fermion contact interactions.

As is well-known this formulation proves to be too general; it includes a number of possibilities which are not brought into effect in nature

$$( \mu^+ \to e^+ + e^- + e^+, \quad \Lambda \to n + \mu^+ + e^- \quad etc ).$$

Therefore, the four-fermion formulation of the theory is restricted by some postulating requirements.

One of such requirements is that the interaction Lagrangian should be written down in terms of the charged currents.

This idea proved to be heuristically fruitful. At any rate, the attempt to ascribe the physical sense to this limitation has led one to the hypothesis of the intermediate meson and made it possible to arrange some interesting experiments.

It is not ruled out, that the analysis of other postulating limitations of the four-fermion interactions may become valuable from the heuristic point of view.

These limitations must lead to the same observable forbiddenesses as well as the theory presently adopted, though some consequences of them which are to be checked experimentally may be different from the latter one.

Consider one of these possibilities.

Postulate 1.

' The Lagrangian of weak interactions consists of four different fermion functions.'

$$L = \dots \bar{\psi}_1 \dots \psi_2 \dots \bar{\psi}_3 \dots \psi_4 + c.\ c. \tag{1}$$

In terms of the particles this means that the interaction involve four particles necessarily different by its nature.

In terms of the Feynman graphs the corresponding vertex is represented by four different lines, for instance,

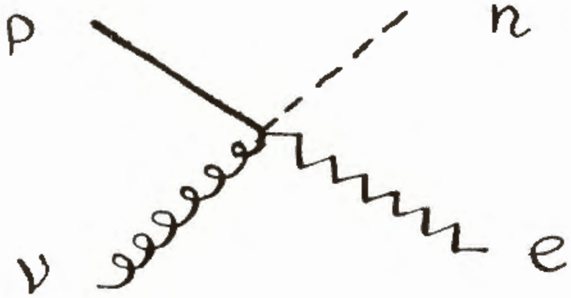



Fig. 1.

The particle and anti-particle are represented by the same line.

Corollaries:

a) the first postulate forbids the decays of the mode

$$\Lambda^o \to n + e^+ + e^-$$
$$\mu^+ \to e^+ + e^- + e^+ \qquad (2)$$
$$\mu^+ \to e^+ + \gamma \qquad etc$$

b) the consequence of the first postulate is that the muon and electron neutrinos are not identical:

$$\nu_\mu \neq \nu_e \qquad (\mu \to e + \nu_\mu + \nu_e)$$

c) the interactions of the type are forbidden

$$(e\nu)(e\nu), (\mu\nu)\ (\mu\nu), (pn)\ (pn), (\Lambda p)(\Lambda p) \qquad etc \qquad (3)$$

which are allowed in the framework of the modern formulation of weak interactions (Marshak-Sudarshan, Feynman and Gell-Mann ).

Postulate II.

'Muon and electron numbers are conserved separately'.

According to the first and the second postulates only the charged electrons and muon currents must enter the inte- :ation Lagrangian

$$j_e^\gamma = \bar{\psi}_e \gamma (1 + \gamma_5) \psi_{\nu_e} ; \; j_\mu^\gamma = \bar{\psi}_\mu \gamma (1 + \gamma_5) \psi_{\nu_\mu} . \qquad (4)$$

The second postulate forbids the decays of the mode

$$\Lambda \to n + \mu^- + e^+ \qquad (5)$$

It would be very attractive to explain some specific features of weak interactions by the participotion of such a peculiar particle as neutrino.

Unfortunately, the existence of weak non-leptonic decays is one of the essential arguments against such standpoint.

However, as far as the hypothesis of the neutrino nature of weak interactions seems rather seducive, it is hardly reasonable to be very quick in making negative statements and to refuse to discuss other even slightest possibilities.

Consider the situation concerning the non-leptonic decays more carefully.

## 2. *Weak Non- Leptonic Decays*

Weak non-leptonic decays of particles seem to be most naturally accounted for the interaction of baryon currents

$$j_n^{\gamma} \, j_{\Lambda}^{\gamma} \qquad (6)$$

here
$$j_n^{\gamma} = \bar{\psi}_p \gamma (1 + \gamma_5) \psi_n \, ; \quad j_{\Lambda}^{\gamma} = \bar{\psi}_p \gamma (1 + \gamma_5) \psi_{\Lambda}$$

As for the decay, for example, of a $\Lambda^0$ particle it may be represented by graph II

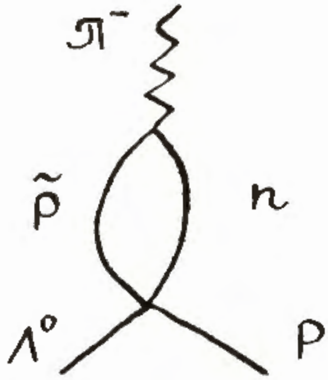



Fig. II.

But, strictly speaking, there is no theory of the non-leptonic decays available since the picture of type II is still purely illustrative.

It is even not for the fact that strong interactions do not make it possible to carry out concrete calculations.

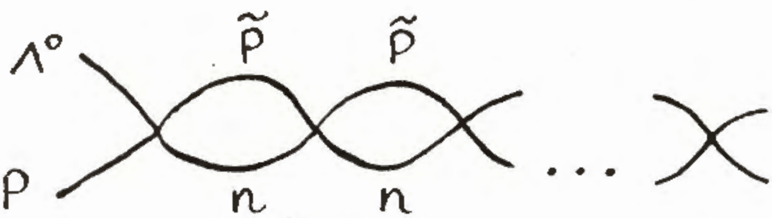



Fig . III.

As is known, it is the graphs of type II which are discussed in connection with the idea that strong interactions reduce to an infinite chain of weak ones.

It appears desirable to reserve the graphs of type II for the future theory of strong interactions.

At present it cannot be definitely said that the graphs of type IV or V which are complicated because of strong interactions are not able to account for the non-leptonic weak interactions.

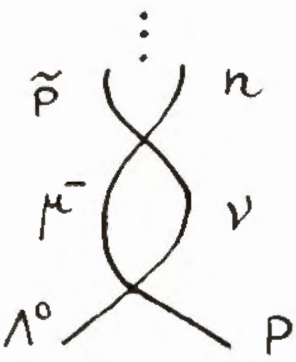
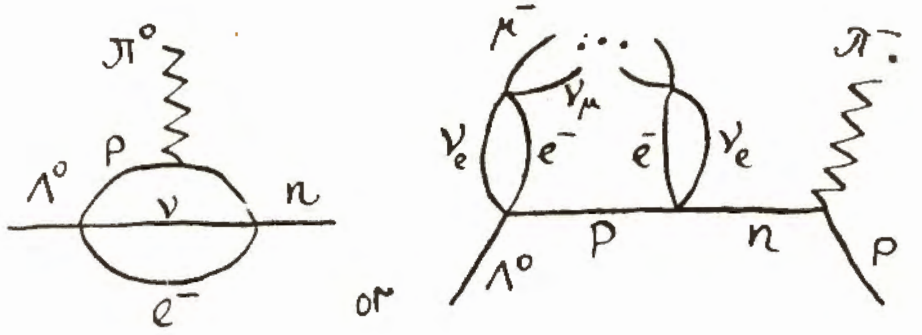



Fig. IV.




F i g. V.

In interpreting the graphs of type IV and V the problems arise which cannot be still solved within the framework of the modern theory. Unknown are yet the magnitudes of the permissible momenta of the intermidiate states in these processes ( the factors of type $G^2 k^4_{max}$ where $G$ is the constant of weak interactions $K_{max}$ is the maximum momentum of the intermediate states), there are no methods so far of calculating the probabilities of the effects for great values of these factors when the perturbation theory is no longer applicable, the problems are still obscure which concern the bare charged constants of weak interactions' i.e., those of unrenormalized theories, and, in general, the reasons for the mass and charge renormalization procedure seem doubtful.

In other words, one cannot consider the possibility of extending postulate to the non-leptonic decays to be absolutely out of question. This could be formulated as follows:

P o s t u l a t e III:

'The presence of neutrino function is necessary in the Lagrangian of weak interactions ( 1 ) '.

## 3. *S t r o n g I n t e r a c t i o n s*

It should be noted that graphs II and III are typical for the well-known attempts to reduce strong interactions to weak ones.

It is very likely that all the interactions are based on the four-fermion interactions, but the character of weak interactions is determined by the neutrino properties and may be understood in view of the pecularities of the interactions involving four different fermions.

Strong interactions may also be based on weak interactions of fermions, namely baryons having , may be, the same constant G. As far as no neutrino is involved in this interaction its formulation must take into account the parity conservation and may contain, in contrast to the 'truly' weak interactions, the baryons of the same nature*. The previous consideration increases interest in the possibility of an experimental check of the truly weak interactions of the type

$$(np)(np), \quad (e\nu)(e\nu).$$

Most of the possible effects of the type $(e\nu)(e\nu)$ (neutrino emission in the lasers, macroscopic energy emission as neutrino pairs by cosmic bodies for cosmic hours etc ) have been treated in the paper by Komar and the author/2/.

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* It seems that the cases with particles of the same nature in ( 1 ) essentially differ from the interaction involving four different particles since in summing the graphs of the chain approximation they depend upon the intermediate momentum. In the case V-A the higher degrees of the intermediate momentum drop.

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