ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

Лаборатория ядерных проблем

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E 980

SMALL PROBABILITY OF THE $\mu \to e + \gamma$ AND $\mu \to e + e + e$ PROCESSES AND NEUTRAL CURRENTS IN WEAK INTERACTIONS

Phys. Lett, 1962, v1, n7, p287-288.
ЖЭТФ, 1962, т43, в.4, с1521-1523.
CERN, 1962, Abstr. n111.

Дубна 1962 год

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Submitted to JETP

During the last fifteen years many unsuccessful attempts were made to observe the $\mu \to e + \gamma$ decay[1]. The probability of this process, according to the most precise data, is less than $6.10^{-8}\,a$ with a 90% confidence level (a is the probability of the $\mu \to e + \nu + \tilde{\nu}$ processes). The $\mu \to e + e + e$ process has not yet been observed either[3], its probability by the latest data being less than $2.6 \times 10^{-7}\,a$.[4] The absence of these processes (U processes) may be due to the existence of two types of neutrinos (muon and electron) having different lepton charges.

The question as to whether there are in nature two types of neutrinos can be unambiguously solved experimentally[5], and is likely to be answered soon. Here we wish to point out that an extremely small probability of the U processes might be accounted for even in the case when there is only one type of neutrinos in nature, if we assume that, besides the well-known 'charged currents'[6], in weak interactions there are also 'neutral currents'.

Consider the case when the four-fermion interaction is local (i.e., when there are no intermediate bosons). As an example, Fig. 1 shows two typical diagrams which can lead to the unobserved U processes. The diagrams involving baryons do not practically contribute to the rate of the U processes because of the strong interaction form-factor cut-off. The U decay processes appear in the second order of the perturbation theory. They are due to the existence of the interactions of the types $(\bar{e}\nu)(\bar{\nu}e)$ and $(\bar{\mu}\nu)(\bar{\nu}\mu)$, which is essential in the Feynman and Gell-Mann's theory[6]. According to Ioffe[7], the upper limits for the rate of the U processes require surprisingly small values of the cut-off parameter ($\Lambda \lesssim 20$ BeV). If the interactions of the type $(\bar{e}\nu)(\bar{\nu}e)$ are absent, the U processes arise in the third order of the weak interaction constant G (see, e.g., the diagram in Fig. 2 for the $\mu \to e + e + e$ process). In this case the parameter Λ turns out to be substantially greater so that the difficulties connected with the small probability of the U processes are overcome, at least partially. Note, however, that it is highly unnatural that the 'diagonal' terms of type $(\bar{e}\nu)(\bar{\nu}e)$ are not present in the weak interaction Lagrangian . Such an assumption would lead to a violation of the Feynman and Gell-Mann conception of the interaction between two currents as the source of the four-fermion weak interaction. It is, however, possible, to conserve this idea and to forbid, at the same time, the U processes. This comes out of a proposal made in 1958 by Bludman[8]. However, the significance of Bludman's scheme of weak interactions in relation to the small probabilities of the U processes was not recognized[9].

According to the Bludman's theory, the weak interaction Lagrangian is supposed to consist of two parts: the 'charged' one, connected with the 'charged currents' $e\nu$, $\mu\nu$, pn, $p\Lambda$, and the 'neutral' one, containing 'symmetrical neutral' currents $\nu\nu$, ee, $\mu\mu$, nn, pp, $\Lambda\Lambda$.

In this scheme the $\nu + e \to \nu + e$ process does not exist because the term of the 'charged' Lagrangian $(\bar{e}\nu)(\bar{\nu}e)$ and that of the 'neutral' Lagrangian $(\bar{e}e)(\bar{\nu}\nu)$ cancel out.

It should be emphasized that the absence of the processes of type $K \to \pi + e + e$ by no means gives arguments against the above scheme, since the currents under consideration must be symmetrical: both the current μe and the current Λn are ruled out. Note also, that the neutral symmetrical currents we are considering have nothing to do with the rule $\Delta T = ½$ for the non-leptonic processes in strange particle decays.

The question may be asked as to whether the introduction of symmetrical neutral currents contradicts the available experimental data. The consequences of the scheme under study are the following:

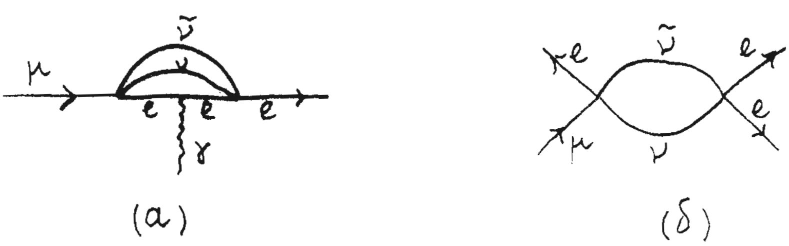
1. There must occur some weak processes, for instance, electron scattering on protons[10] and on electrons[11] without conservation of parity. There are no experimental data on this problem, and it is extremely difficult to obtain such data.

2. As it was already mentioned, the processes of the first order in the weak interaction constant of the type $\nu + e \to \nu + e$ must be absent. The related experiments have not yet been attempted. Should it turned out that there is no such process, this would not necessarily refute the conception of the interaction between two currents in spite of frequent assertions to the contrary in the literature.

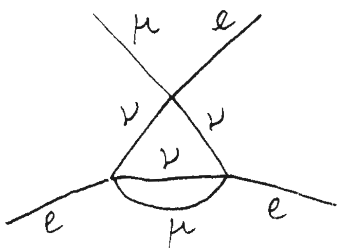
3. Excited nuclei must emit $\nu\tilde{\nu}$ pairs. This effect is practically unobservable in the laboratory because of the 'competition' of electromagnetic processes . However, it would undoubtedly have important consequences in astrophysics, since it gives a powerful mechanism for energy losses in stars. In this mechanism the emission of $\nu\tilde{\nu}$ pairs by stars is characterized by a process of the order of G (not Ge^2 , like in the case when $\nu - e$ scattering takes place[12]).

In conclusion it should be noted that if the experiments indicate the existence in nature of only one type of neutrino, then the small probability of the U process would provide arguments in favour of the existence of symmetrical neutr al currents in weak interactions.

The autrhor takes the pleasure in thanking V.N . Bayer, S.M. Bilenki, S.S. Gerstein, L.B. Okun' and R.M. Ryndin for discussions.



F i g. 1. Typical diagrams for the processes (a) $\mu \to e + \gamma$ and (b) $\mu \to e + e + e$.



F i g. 2. Third order diagram for the $\mu \to e + e + e$ process.

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Received by Publishing Department

on May 5, 1962.