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S.M.Bilenky, B.Pontecorvo

ON "FAST" AND "SLOW" NEUTRINOS

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Биленький С.М., Понтекорво Б.

О "быстрых" и "медленных" нейтрино

Релятивистские нейтрино ведут себя как $\nu_e, \nu_\mu, \nu_\tau \ldots$; нерелятивистские - как ν_1, ν_2, ν_3 /ν_i - нейтрино с массой m_i /.

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Bilenky S.M., Pontecorvo B.

The possible existence of neutrino oscillations /1/ raises some questions. Lepton mixing implies finite neutrino masses /2/. In such a case the field of neutrinos ν_ℓ $(\ell = e, \mu, \tau \ldots)$ taking part in the weak charged current is

$$\nu_\ell = \sum_i U_{\ell i} \nu_i \, , \tag{1}$$

where ν_i is the field operator of neutrino with definite mass m_i, and U is a unitary mixing matrix. For neutrinos we are working with in a Laboratory, the coherence conditions are fulfilled and the state vector of these "phenomenological" neutrinos is

$$|\nu_\ell>_{\vec{p}} = \sum_i U^*_{\ell i} \, |\nu_i>_{\vec{p}} \, , \tag{2}$$

where $|\vec{p}| >> m_i$ is the neutrino momentum. As is well-known relation (2) implies neutrino oscillations.

The phenomenon of neutrino oscillations has a well-known analog: the $K^\circ \to \bar{K}^\circ$ oscillations. The eigenstates of the strong interaction are K° and $\bar{K}^\circ$ just as, for the case of neutrinos, the eigenstates of the weak interaction are ν_e, ν_μ, ν_τ .... The mass eigenstates are K_L and K_S, whereas in the case of neutrinos, the mass eigenstates are ν_1, ν_2, ν_3,... . Since it is perfectly clear under what conditions one should talk either of $K^\circ, \bar{K}^\circ$ or K_L, K_S, we will not discuss this point further. Less obvious is the question under what conditions neutrinos behave as $\nu_1, \nu_2, \nu_3, \ldots$.

In this note we make an attempt to reply to this question, which in our opinion, has at least some instructial significance. As far as relativistic neutrinos are concerned (as already stated) the $\nu_e, \nu_\mu, \nu_\tau, \ldots$ are eigenstates of weak interaction, whereas neutrinos $\nu_1, \nu_2, \nu_3 \ldots$ have no physical meaning in the sense that they are not detectable as such. On the other hand if neutrino masses are different from zero there must exist nonrelativistic neutrinos (for example, the relict neutrino). Here the situation is inverted. In the nonrelativistic case neutrinos $\nu_e, \nu_\mu, \nu_\tau, \ldots$ lose their physical meaning, as they cannot undergo the usual weak interaction, changing them into charged leptons. They are not detectable as such. Nonrelativistic particles $\nu_1, \nu_2, \nu_3, \dots$ with definite masses, on the contrary, acquire a difinite physical meaning: they undergo the neutral current interaction without changing nature. Nonrelativistic neutrinos are just $\nu_1, \nu_2, \nu_3, \dots$ *.

In conclusion we stress again that if neutrinos are relativistic they will behave in general as $\nu_e, \nu_\mu, \nu_\tau, \dots$ (in the conditions where $\nu_1, \nu_2, \nu_3, \dots$ as such lose their physical meaning). If they are not relativistic they will behave in general as $\nu_1, \nu_2, \nu_3, \dots$, (whereas $\nu_e, \nu_\mu, \nu_\tau, \dots$ as such lose their physical meaning). The function of (nonrelativistic) $\nu_1, \nu_2, \nu_3, \dots$ is gravity, the function of relativistic $\nu_e, \nu_\mu, \nu_\tau, \dots$ is weak interaction.

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REFERENCES

1. Pontecorvo B. Zhurn.Eksp.Teor.Fiz., 1967, 53, p.1717.
   Bilenky S.M., Pontecorvo B. Phys.Rep., 1978,41, p.226.
2. Lubimov V.A. et al. Preprint ITEP, 1980, No 62.

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*Of course, it is possible to imagin a situation where particles ν_1 (or $\nu_2, \dots$) are relativistic. Such particles can be analysed in terms of $\nu_e, \nu_\mu, \nu_\tau, \dots$ components but will not undergo oscillations.

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