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ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ
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ON A POSSIBILITY OF DISCOVERING THE NEUTRAL CURRENTS IN NEUTRINO EXPERIMENTS

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ON A POSSIBILITY OF DISCOVERING THE NEUTRAL CURRENTS IN NEUTRINO EXPERIMENTS

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The weak interaction scheme containing a product of neutral currents together with the product of charged currents[1,2] was suggested and discussed by many authors[3-6]. The schemes of this type, for example, in[3], are as beautiful as the Feynman and Gell-Mann scheme and do not lead to the appearence of the experimentally unobservable decays of the type $\mu \to 3e$, $K \to \pi + 2e(2\nu)$ ect., since they contain the symmetrical neutral currents $(\nu\nu)$, (ee) ect. and do not contain the asymmetrical currents (μe), $(K\pi)$ etc.[6] The experimental discovery of neutral currents in weak interactions is very important both from the point of view of checking the correctness of the weak interaction schemes and from the point of view of the application to the astrophysical phenomena (because the existence of the neutral currents can lead to a very effective mechanism of the neutrino emission by stars[6]). However the experiments on the parity non-conservation effects in the electron-nucleus[4] and electron-electron[5] scatterings suggested for discovering the neutral currents are very difficult. We would notice that the neutrino experiments may be a more real method. The existence in the weak interaction Lagrangian of the terms of the type

$$L' = \frac{G}{\sqrt{2}} \bar{\nu} \gamma_\mu (1+\gamma_5) \nu \bar{N} \gamma_\mu (1+\gamma_5) \tau_3 N \tag{1}$$

which was supposed in the papers of Bludman[3] and Zeldovich[4] must lead to the appearence of the stars without charged leptons in the scattering of high-energy neutrino on nucleus owing to the interaction

$$\nu + N \to \nu + N . \tag{2}$$

At 1 BeV neutrino energy the cross section of the above process must be of the order of $10^{-38}\,\mathrm{cm}^2$ and therefore this process may be undoubtedly observed in the neutrino experiments carried out at present. On the other hand there is apparently a possibility of checking the existence of the interaction (2) in the experiments with low-energy antineutrino (from reactor). Indeed, the interaction (2) must lead to the excitation of the nuclear levels.

$$\tilde{\nu} + Z \to \tilde{\nu} + Z^* \tag{3}$$

which may be observed owing to the characteristic radiation $Z^* \to Z + \gamma$. The differential cross section of neutrino and antineutrino scattering at the angle θ with the nucleus excitation in the case of the interactions (1) is

$$\frac{d\sigma}{d\Omega} = \frac{G^2}{(2\pi)^2} [\, a\,(1+\cos\theta) + b\,(1 - 1/3\,\cos\theta)\,](\,E_\nu - \Delta E\,)^2 , \tag{4}$$

where

$$a = |\int d^3r < Z^* | \sum_A \tau_3 e^{i\vec{k}\vec{r}} | Z > |^2 . \tag{5}$$

$$b = |\int d^3r < Z^* | \sum_A \tau_3 \vec{\sigma}\, e^{i\vec{k}\vec{r}} | Z > |^2 , \tag{6}$$

ΔE is the excitation energy of nucleus, E_ν – is the energy of neutrino or antineutrino. From the formula (5) one can see that in the case of reactor antineutrino ($kr \ll 1$) the vector part gives no contribution to the cross section, since $a = 0$ because of the orthogonality of the wave functions of Z and Z*. The total cross section is

$$\sigma = \frac{G^2}{\pi}\, b\,(\,E_\nu - \Delta E\,)^2 . \tag{7}$$

This cross section is of the same order as the cross section of the process $\tilde{\nu} + p \to e^+ + n$ in the experiments[7,8]. As an example we have considered the excitation of the nucleus L_i^7. The L_i^7 ground state has $J = \frac{3}{2}^-$, $T = ½$ and the first excited one has $J = \frac{1}{2}^-$, $T = \frac{1}{2}$, the excitation energy is $\Delta E \doteq 480$ KeV. In the calculation of b the wave functions of the ground and excited states have been obtained by mixing the configurations by the two-body potential in the form of Resenfeld exchange variant with the parameters $\xi = -2{,}1$ MeV, $L/K \doteq 6$ and $K = -0.9$[9]. We have obtained $b = 2.56$. The cross section (7) must be averaged over the antineutrino spectrum $\rho_\nu(E)$ from reactor. For estimating from below we assume that $\rho_\nu(E) \approx \rho_e(E)$ [*] and take $\rho_\nu(E)$ from Ref. [8]. We obtain the following value of the cross section per fission

$$\sigma'_{Li^7} \geq \int_{E=\Delta E} \rho_e(E)\,\sigma(E)\,dE \approx 2.10^{-42}\ \mathrm{cm}^2 . \tag{8}$$

(The cross section of the process $\tilde{\nu} + p \to e^+ + n$ with reactor antineutrino is $\approx 6.7\ 10^{-43}\ \mathrm{cm}^2$). It should be noted that the excited nucleus in the process (3) will be, generally speaking, polarized along the direction of antineutrino momentum so that the following γ - radiation will also have definite polarization properties. In principle this effect might be used to separate the process (9) from the background.

Let us note that the interaction (1) used by us is the consequence of the Bludman scheme[3] which supposes the identity of muon and electron neutrinos. It is not difficult to generalize this scheme to the case $\nu_\mu \neq \nu_e$. In this case the coupling constant in the neutral current product (1) is G/2 and the above given cross sections decrease by a factor of 4. At the same time the process $\nu_e + e \to \nu_e + e$ which is forbidden in the scheme[3] arises (cf. also[5]). However in contrast to the Feynman and Gell-Mann scheme this process has the coupling constant G/2 (but not G). Analogously the process $\nu_\mu + e \to \nu_\mu + e$ must have the constant – G/2. From this point of view the experimental studies of the scattering $\nu + e \to \nu + e$ both with reactor neutrino and with neutrino from $\pi \to \mu + \nu$ decay are very interesting.

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[*] It follows from Ref. [8] that in the region $E_\nu \gg 1$ MeV $\rho_\nu(E)$ can exceed $\rho_e(E)$ by a factor of 1.5.