$$\sigma = \frac{2e^2}{h^3} \frac{(n_e - n_h)^2}{\sum_l g_l^2 \cos^2 a_l / R_l} ,$$

where α_i is the angle between the Umklapp vector $\vec{g}_i$ corresponding to the i-th neck and an arbitrary fixed direction.

The resistance of the neck R differs essentially in two limiting cases: 1) the characteristic width of the neck r_0 is of the order of the radius of curvature ρ of the neck (see the figure) and 2) $r_0 \ll \rho$. In the former case $R_1 = (1/\pi D)\ln p_0/r_0$, where D is the diagonal component of the tensor $\hat{D}$ along the generator of the neck, p_0 is the characteristic radius of the large group. In the second case $R_2 = (1/2D)\sqrt{\rho/r_0}$, and it turns out that the characteristic length of the neck is $\ell \sim \sqrt{\rho r_0}$.

We note that the presence of necks of the second type in the intermediate region of temperatures, when $\ell \gg q \sim T/s \gg r_0$, the developed approach remains in force, but the diffusion has a one-dimensional character. It turns out that in this case the resistance of the neck is $R \approx R_2 T/sr_0 \sim T^{-4}$. Accordingly, the resistance of the metal will also be proportional to T^4, thus differing from the Bloch law T^5, which is valid only when $T \ll sr_0$. This result may explain the experimentally known T^4 law for aluminum.

We note finally that the diffusion equation (1) can be solved only in the case of weak coupling, under the condition that the Harrison sphere is intersected only by one pair of Bragg planes.

[1] R. Peierls, Quantum Theory of Solids, Oxford, 1955.

POSSIBLE METHOD OF MEASURING THE ELECTROMAGNETIC FORM FACTOR OF THE NEUTRINO

V.I. Andryushin, S.M. Bilen'kii, and S.S. Gershtein
Joint Institute for Nuclear Research
Submitted 8 April 1971
ZhETF Pis. Red. 13, No. 10, 573 - 576 (20 May 1971)

A study of the electromagnetic neutrino interaction is one of the important problems of weak-interaction physics. The calculation of the electromagnetic form factor of the neutrino induced by weak interaction is dealt with in [1 - 3]. Since the weak-interaction theory is non-renormalizable, the results of the calculations depend on the cutoff parameter. The induced form factor of the neutrino depends also on whether these exists an intermediate boson, and on the electromagnetic interaction of the intermediate boson.

Some information concerning the electromagnetic radius of the neutrino can be obtained from astrophysical data. It is shown in [4] that the electromagnetic radius of ν_e and also the radius of ν_μ (in the case when the mass of ν_μ is smaller than 1 keV), does not exceed 4×10^{-14} cm.

In the present article we discuss a method that makes it possible, in principle, to obtain complete information on the electromagnetic form factor of the neutrino, including the dependence of the form factor on the square of the momentum transfer. The method is based on a comparison of the cross section of the process due to the electromagnetic interaction of the neutrino with the nucleus, with the cross section of the analogous process due to the electron.

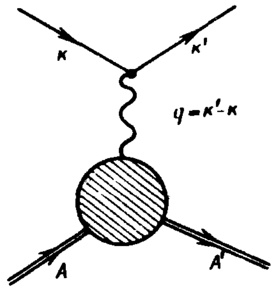

Fig. 1

Let us consider the reaction

$$\nu + A \to \nu + A'. \tag{1}$$

Here A is the initial nucleus and A' is any possible final hadron state (see Fig. 1).

The matrix element of the process (1) is

$$< f|S|i > = i < k'|i_\alpha|k > \frac{1}{q^2} < A'|i_\alpha|A > (2\pi)^4 \delta(P' - P), \tag{2}$$

where P (P') is the total 4-momentum of the initial (final) states;

$$< k'|i_\alpha|k > = \frac{i e}{(2\pi)^3} \bar{u}(k') i_\alpha (1 + \gamma_5) u(k) F(q^2), \tag{3}$$

$$q = k' - k.$$

Since the charge of the neutrino is equal to zero, we have

$$F(q^2) = \frac{G}{\sqrt{2}} q^2 R(q^2), \tag{4}$$

where $R(0) \neq 0$ ($G \approx 10^{-5} M_p^{-2}$ is the weak-interaction constant).

Let us consider the process

$$e + A \to e + A', \tag{5}$$

where A and A' are the same hadron states as in (1). We assume that the energy of the initial and final electrons is much larger than the electron mass. If the single-phonon approximation is valid, then the matrix element of the process (5) differs from the expression (2) only in the lepton factor. It is easily seen that the differential cross sections of the processes (1) and (5) are connected by the relation:

$$\left(\frac{d\sigma}{dq^2}\right)_\nu = 2G^2[R(q^2)]^2 \left(\frac{d\sigma}{dq^2}\right)_e q^4. \tag{6}$$

Thus, independent measurements of the cross sections $(d\sigma/dq^2)_\nu$ and $(d\sigma/dq^2)_e$ would make it possible to obtain information on the electromagnetic form factor of the neutrino.

The differential cross section $(d\sigma/dq^2)_\nu$ has the following general form:

$$\left(\frac{d\sigma}{dq^2}\right)_\nu = 2\pi z^2 \alpha^2 G^2 R^2 \frac{1}{E^2} \int_{\frac{q^2}{2M}}^{E - \frac{q^2}{4E}} [2q^2 w_1 + (4E^2 - q^2 - 4E\omega) w_2] d\omega. \tag{7}$$

Here E is the energy of the incoming particle in the laboratory system, $\omega = pq/M = (E - E')$ is the laboratory energy transferred to the hadron system, M is the mass of the initial hadron, and w_1 and w_2 are functions of q^2 and ω, defined

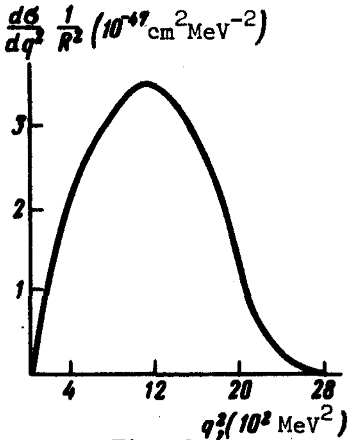

Fig. 2

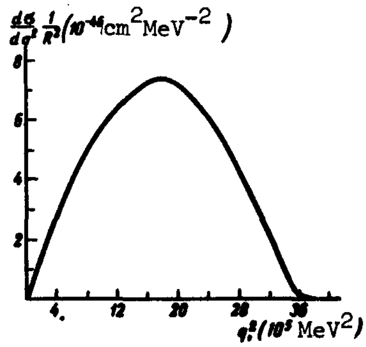

Fig. 3

Fig. 2. Cross section for the excitation of giant resonance on the nucleus Ta^{181} by electromagnetic interaction of a neutrino of energy 30 MeV, q^2 - square of momentum transfer, $R(q^2)$ - electromagnetic form factor of the neutrino.

Fig. 3. Cross section for the excitation of giant resonance on Ta^{181} by a neutrino of energy 100 MeV.

in [5]. In order to obtain on the basis of [6] information on the electromagnetic form factor of the neutrino, it is necessary to investigate the processes (1) and (5) that are optimal in the sense of the value of the cross section and the possibility of registration. From this point of view we consider it to be highly promising to study the scattering of the neutrino in the region of the giant resonance[1] and the investigation of the nuclear-fission process due to scattering of neutrinos of medium energy[2]. Intense fluxes of such neutrinos can be obtained with "meson factory" type of accelerators.

We present results of the calculation of $(d\sigma/dq^2)_\nu$ for the processes of excitation of giant resonance and nuclear fission. To avoid the uncertainties connected with nuclear matrix elements, we use the connection between the first terms of the expansions of the functions w_1 and w_2 with the cross section σ_γ for total photoabsorption. We have [5]

$$w_1 = \frac{\omega}{a \cdot z^2 (2\pi)^2} \sigma_\gamma + 0(q^2),$$

$$w_2 = \frac{q^2}{a \cdot z^2 (2\pi)^2 \omega} \sigma_\gamma + 0(q^4). \tag{8}$$

By way of an example, we calculated the cross section for the excitation of giant resonance on the nucleus Ta^{181} by neutrinos of energy 30 and 100 MeV. We used the data of [6]. The results of the calculations are shown in Figs. 2 and

---

[1])Excitation of giant resonance due to the usual weak neutrino interaction was considered in [6].

[2])The cross section for elastic scattering of neutrinos by heavy nuclei, according to estimates of [2], can be 10^{-40} - 10^{-41} cm^2. However, at medium neutrino energies, this process is very difficult to detect in view of the smallness of the recoil energies of the nuclei.

3. For the total cross section of the process we obtain:

$$\sigma_\nu = 5.4 \cdot 10^{-44} \overline{R^2}\ \mathrm{cm}^2\ (E = 30\ \mathrm{MeV}),$$

$$\sigma_\nu = 1.7 \cdot 10^{-41} \overline{R^2}\ \mathrm{cm}^2\ (E = 100\ \mathrm{MeV})$$

($\overline{R^2}$ is the value of R^2 at the average point).

We note that the values of $R(q^2)$ calculated in [1 - 3] are different for ν_e and ν_μ in the q^2 interval considered by us, and can range from ~1 to ~10^{-2}. Similarly, from data on the photofission of nuclei [7] we estimated the cross section for the fission of nuclei by neutrinos. For Bi^{209} at a neutrino energy ~250 MeV we have $\sigma_\nu = 10^{-42}\overline{R^2}$ cm^2.

In conclusion, we note the following: 1) the cross section of the process (1) at high energies in the deeply inelastic region is proportional to the energy and can reach a considerable value (on the order of α^2 times the total cross section of the weak interaction of the neutrino), 2) the process (1) can be due to weak interaction with neutral currents.

In principle there is a possibility of distinguishing between the interaction with the neutral currents and the electromagnetic interaction of the neutrino. To this end it is necessary to compare the cross sections of the processes (1) with electronic and muonic neutrinos. If the process is due to neutral currents and universality takes place, then the cross sections are equal. If the processes are due to the electromagnetic interaction of the neutrino, the cross sections can differ noticeably.

In conclusion, we are deeply grateful to V.M. Lobashov, B.M. Pontecorvo, V.F. Solov'ev, V.N. Folomeshkin, and R.A. Eramzhyan for useful discussions and S.I. Bilen'kaya for help with the numerical calculations.

[1] Ya.B. Zel'dovich and A.M.Perelomov, Zh. Eksp. Teor. Fiz. 39, 1115 (1960) [Sov. Phys.-JETP 12, 777 (1961)].
[2] A.M. Perelomov, Proceedings of International School of Theoretical Physics at JINR, 1964.
[3] J. Bernstein and T.D. Lee, Phys. Rev. Lett. 11, 512 (1963).
[4] J. Bernstein, M. Ruderman, and G. Feinberg, Phys. Rev. 132, 1227 (1963).
[5] S.D. Drell and J.D. Walecka, Ann. of Phys. 28, 18 (1964).
[6] V.B. Belyaev, JINR Preprint 926, Dubna, 1962; H. Ueberall, Phys. Rev. 139B, 1239 (1965).
[7] L.G. Moretto, R.C. Gatti, et al., Phys. Rev. 179, 1176 (1969).

POSSIBILITY OF TWO-PROTON AND TWO-NEUTRINO RADIOACTIVE DECAY FROM MANY-PARTICLE ISOMERIC STATES OF NUCLEI

V.I. Gol'danskii and L.K. Peker
Institute of Chemical Physics, USSR Academy of Sciences; Institute of Metrology
Submitted 9 April 1971
ZhETF Pis. Red. 13, No. 10, 577 - 578 (20 May 1971)

In the first experiment of "true" proton radioactivity, i.e., decay whose observable delay is connected not with prior emission of the positron but with the penetration of the proton itself through the potential barrier, observed in 1970 by the CERNY group [1, 2], the emission of the proton occurs not from the ground state but from the three-particle state Co^{53m} ($19/2^-$, T = 1/2)$p(f_{7/2}^{-1})n(f_{7/2}^{-2})_{+6}$.