I consider searches for hadronic isomers to be timely both with high-energy accelerators and in cosmic rays.

In conclusion, it is a pleasure to thank J. Bjorken and K. Tolstov, who advised me of the Japanese paper, and D. Bardin, S. Bilen'kii, S. Gershtein, V. Grishin, V. Gribov, L. Okun', S. Polikanov, V. Solov'ev, and D. Shirkov for discussions.

[1] See "Review of Particle Properties," Rev. Mod. Phys., April, 1971.
[2] Yu. Bushin et al., Yad. Fiz. 10, 585 (1969) [Sov. J. Nuc. Phys. 10, 337 (1970)].
[3] B. Pontecorvo, ibid. 11, 846 (1970) [11, 473 (1970)]; A. Dem'yanov et al., ibid. 13, 786 (1971) [13, 447 (1971)].
[4] Yu. Kobzarev and L. Okun', Zh. Eksp. Teor. Fiz. 30, 798 (1956) [Sov. Phys.-JETP 3, 954 (1956)].
[5] K. Niu and E. Mikumo, Preprint 1971.

LIMITATIONS ON CURRENTS OF THE SECOND CLASS IN THE PROCESS $\nu_\mu + n \to p + \mu^-$

G.A. Lobov
Submitted 11 February 1972
ZhETF Pis. Red. 15, No. 6, 357 - 359 (20 March 1972)

The presently available experimental data on the total cross section of "elastic" neutrino scattering, $\nu_\mu + n \to p + \mu^-$ [1], yield the upper bound of the tensor constant of a current of the second class and mass limitations for the axial-vector form factor in weak interactions.

To this end, we represent the hadronic weak-interaction current in the form

$$J_\mu = \frac{G}{\sqrt{2}}\bar{p}\left[(f_V\gamma_\mu + f_M\sigma_{\mu\lambda}q_\lambda) + if_s q_\mu + (f_A\gamma_\mu + if_p q_\mu)\gamma_5 + f_T\sigma_{\mu\lambda}q_\lambda\gamma_5\right]n \tag{1}$$

$$= J_\mu^{V(1)} + J_\mu^{V(2)} + J_\mu^{A(1)} + J_\mu^{A(2)},$$

where $q_\lambda = (n - p)_\lambda$ is the momentum transfer, $G = 10^{-5}M^{-2}$ the weak-interaction constant, and M the nucleon mass.

In expression (1), the vector and axial-vector currents of the second class [2], $J_\mu^{V(2)}$ and $J_\mu^{A(2)}$, have G-parities opposite to the G-parities of the corresponding first-class currents $J_\mu^{V(1)}$ and $J_\mu^{A(1)}$. When T-invariance is violated, the constants of the current (1) become complex. In a model in which T-invariance of weak interaction is violated only by second-class currents [4], the imaginary part of the tensor constant f_T is of the order of

$$\mathrm{Im} f_T \sim M^{-1}. \tag{2}$$

This value does not contradict experiments on the measurement of T-odd correlations in decays of a polarized neutron [4] and of the nucleus F^{19} [5]:

$$\mathrm{Im}\, f_T = (20 \pm 20)M^{-1}[4],$$
$$\mathrm{Im} f_T = (4 \pm 28)M^{-1}[5]. \tag{3}$$

Using formula (1), we obtain the following expression for the differential cross section of the process $\nu_\mu + n \to p + \mu^-$ at neutrino energies $E_\nu > M$:

$$\frac{d\sigma}{dt} = \frac{G^2}{2\pi}\left\{f_V^2 + f_A^2 + t(f_M^2 + |f_T|^2)\right\}, \tag{4}$$

where $t = -q^2 > 0$.

The condition $E_\nu > M$ makes it possible to disregard in [4] a number of additional term whose order of magnitude is smaller than M/E_ν or $(M/E_\nu)^2$. The total cross section of the process $\nu_\mu + n \to p + \mu^-$ is obtained by integrating (4) with respect to t from 0 to $t_{max} = S - 2M^2 + M^4S^{-1}$, where $S = (p_\nu + p_n)^2 = M^2 + 2ME_\nu$. To carry out this integration, we assume that all the form factors in (4) have the same dependence on the momentum transfer t as the vector form factor f_V:

$$f_V = F_V(t);\quad f_A = f_A(0)F_A(t);\quad f_A(0) = 1.26,$$
$$f_M = \frac{\mu_p - \mu_n}{2M}F_V(t);\quad f_T = f_T(0)F_A(t), \tag{5}$$

where μ_p and μ_n are the anomalous magnetic moments of the proton and neutron,

$$F_V(t) = F_A(t) = \left(1 + \frac{t}{(0.84)^2}\right)^{-2} \tag{6}$$

is the weak-interaction vector form factor in the "dipole" approximation.

Using the experimental value of the total cross section of the process $\nu_\mu + n \to p + \mu^-$ at $2.5\ \text{GeV} \leq E_\nu \leq 3\ \text{GeV}$ [1], $\sigma = (1 \pm 0.3) \times 10^{-38}\ \text{cm}^2$, we obtain the following upper bound for the tensor constant of the second-class current:

$$|f_T(0)| \leqslant 2.7M^{-1}. \tag{7}$$

This result does not agree with the tensor constant obtained from a comparison of the values of $(ft)^\pm$ for $\beta^\pm$ decays of mirror nuclei with $8 \leq A \leq 30$ [6]:

$$\mathrm{Re}\, f_T(0) = 3.6M^{-1}. \tag{8}$$

If we assume the value (8) for the tensor constant, then the total cross section of the process $\nu_\mu + n \to p + \mu^-$ agrees with the experimental value $\sigma = (1 \pm 0.3) \times 10^{-38}\ \text{cm}^2$ if the axial vector form factor is of the form

$$F_A(t) = \left(1 + \frac{t}{M_A^2}\right)^{-2} \tag{9}$$

with a mass

$$0.52\ \text{GeV} \leqslant M_A \leqslant 0.75\ \text{GeV}. \tag{10}$$

This mass M_A, which is smaller than $M_V = 0.84$ GeV, is not very probable, since the closest diagram contributing to the vector form factor is apparently a diagram with two pions in the intermediate state, whereas for the axial-vector form factor the diagram has three pions. Thus the tensor constant (8) of the second-class current contradicts the experimental data on the total cross section of the process $\nu_\mu + n \to p + \mu^-$ and the present notions concerning the contributions of different intermediate states to the vector and axial-vector weak-interaction form factors. We note that the limitations (7) and (10) can be considerably strengthened if the accuracy of the neutrino experiment is increased.

If T-invariance of weak interaction is violated only by second-class currents [3], there should exist in the process $\nu_\mu + n \to p + \mu^-$ a proton polarization perpendicular to the scattering plane:

$$\mathbf{P} = \frac{2t^{1/2} f_A \operatorname{Im} f_T}{[f_V^2 + f_A^2 + t(f_M^2 + |f_T|^2)]} [\mathbf{n}_p \times \mathbf{n}_\mu], \tag{11}$$

where n_p and n_μ are unit vectors along the proton and muon momenta, respectively. At $t = 1\ (\mathrm{GeV}/c)^2$ and $\operatorname{Im} f_T = M^{-1}$ the polarization is $P \simeq 30\%$. Thus, measurement of the proton polarization in the process $\nu_\mu + n \to p + \mu^-$ might serve as a check on the models [3] of T-invariance violation in weak interaction by second-class currents.

The author is deeply grateful to S.S. Gershtein and I.S. Shapiro for a discussion of the work and a number of valuable remarks, and also to V.S. Kaftanov and V.D. Khovanskii for a discussion of the neutrino-experiment data.

[1] I. Budagov et al., Lett. Nuovo Cim. 2, 689 (1969); M. Holder et al., Nuovo Cim. 58A, 338 (1969); R.L. Kustom et al., Phys. Rev. Lett. 22, 1016 (1969); H.H. Chen et al., Phys. Rev. D4, 99 (1971).

[2] S. Weinberg, Phys. Rev. 112, 1375 (1958)

[3] N. Cabbibo, Phys. Lett. 12, 137 (1964); G.A. Lobov, Yad. Fiz. 2, 716 (1965) [Sov. J. Nuc. Phys. 2, 512 (1966)].

[4] B.G. Erozolimskii, L.N. Bondarenko, Yu.A. Mostovoi, B.A. Obinyakov, V.P. Zakharova, and V.A. Titov, Yad. Fiz. 11, 1049 (1970) [Sov. J. Nuc. Phys. 11, 583 (1970)].

[5] F. Calaprice, E. Commins, H. Gibbs, and G. Wick, Phys. Rev. 184, 1117 (1969).

[6] D.H. Wilkinson, Phys. Lett. 31B, 447 (1970).

E R R A T A

The following corrections are to be made in the article by V. G. Baryshevskii et al., Vol. 15, No. 2: 1) On p. 79, in the first line after formula (2), read ... $r_0 = e^2/m_e c^2$ ... instead of ... $r_0 = \ell^2/m_b c^2$... 2) In the two lines above the table on p. 80, read ..."the direction of rotation of the polarization plane"... instead of ..."the direction of the polarization plane"... 3) In the second line below the table on p. 80, read ... $|\vec{n}| = 2/26 \approx 7.69\times10^{-2}$... instead of ... $\approx 7.85\times10^{-2}$... The numerical coefficient in (5) remains unchanged.

In the article by A. A. Chaban, Vol. 15, No. 2, p. 74, line 35 from the top, read ... $\exp[i(kx \pm \omega t)]$... instead of ... $\exp[i(kx + \omega t)]$...

In the article by Ya. B. Zel'dovich et al., Vol. 15, No. 3, p. 111, frames "c" and "d" of Fig. 3 should be interchanged, and the scale in frame "c" should be 5 mrad.