ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

ДУБНА

E2 - 7416

S.M.Bilenky, N.A.Dadajan

POSSIBLE TEST FOR NEUTRAL CURRENTS AT LOW ENERGIES

1973

ЛАБОРАТОРИЯ
ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

E2 - 7416

S.M.Bilenky, N.A.Dadajan

POSSIBLE TEST FOR NEUTRAL CURRENTS AT LOW ENERGIES

Submitted to ЯФ

A wide class of modern renormalizable theories of weak and electromagnetic interactions, based on spontaneously broken gauge symmetries, essentially contains weak neutral currents to the first order in G. This makes the existence of neutral currents a vital problem.

Presently, high energy neutrino beams are used to study the processes, which could have been induced by neutral currents. Existing data, however, are not precise enough to make a definite conclusion about neutral currents. /I,2/

In the present note a possible method of investigating weak neutral currents with $\Delta S=0$ by means of low energy neutrino beams $/\leqslant$ IOO MeV/ is discussed.

We consider excitation of nuclear giant dipole states by neutrinos. The calculations performed show that this process is valid for detection of neutral currents in the hamiltonian of weak interactions, if any.

Let us consider as an example the neutral current arising in the Weinberg theory. /3,4/ The interaction between neutrinos and neutral hadronic current with $\Delta S=0$ takes the form

$$\mathcal{H}_o = \frac{G}{\sqrt{2}} \sum_{\ell=e,\mu} \left(\bar{\nu}_\ell \gamma_\alpha (1+\gamma_5) \nu_\ell \right) \mathcal{J}_\alpha^{z}, \qquad /I/$$

where

$$\mathcal{J}_\alpha^{z} = \mathcal{J}_\alpha^{3} - 2\sin^2\theta_W \, \mathcal{J}_\alpha^{em} . \qquad /2/$$

Here $\mathcal{J}_\alpha^{em}$ is the operator of electromagnetic current of hadrons, $\mathcal{J}_\alpha^{3}$ is the third component of V-A hadronic weak current, $\sin^2\theta_W$ parameter in the Weinberg theory and $G \approx 10^{-5} M_p^{-2}$ is the constant of weak interactions.

We consider the processes

$$\nu(\bar{\nu}) + A \to \nu(\bar{\nu}) + A', \qquad /3/$$

where A and A' are any hadrons or nuclei. For the matrix element one has

$$\langle f|S|i\rangle = -i\frac{G}{\sqrt{2}}\langle k'|j_\alpha^{\ell}|k\rangle\langle p'|J_\alpha^{z}|p\rangle(2\pi)^4\delta(p'+k'-p-k). \qquad /4/$$

Here k and k' represent the four-momenta of the incident and outgoing neutrinos /antineutrinos/, p and p' represent the four-momenta of the particles A and A' respectively, j_α^{ℓ} is the leptonic current. For the differential cross section we obtain

$$\left(\frac{d^2\sigma}{dq^2\,d\nu}\right)_{\nu(\bar{\nu})} = \frac{G^2}{4\pi}\frac{M^2}{(pk)^2}\left(m_{\alpha\beta} \pm e_{\alpha\beta\rho\sigma}k_\rho k'_\sigma\right)a_{\alpha\beta}^{zz}, \qquad /5/$$

where M is the mass of the initial hadron A, $m_{\alpha\beta} = k_\alpha k'_\beta - \delta_{\alpha\beta}kk' + k_\beta k'_\alpha$, $q = k-k'$, $\nu = -\frac{pq}{M}$ is the laboratory energy, transferred to the hadronic system and $a_{\alpha\beta}^{zz}$ is defined as

$$\sum\int\langle p'|J_\alpha^{z}|p\rangle\langle p|J_\beta^{z}|p'\rangle\delta(p'-p-q)d\Gamma = \frac{1}{(2\pi)^6}\left(\frac{M}{p_0}\right)a_{\alpha\beta}^{zz}. \qquad /6/$$

We can rewrite the neutral current in the following way

$$J_\alpha^{z} = V_\alpha^{z} + A_\alpha^{z}. \qquad /7/$$

Here

$$V_\alpha^{z} = (1-2\sin^2\theta_W)J_\alpha^{em} - J_\alpha^{S} \qquad /8/$$

an A_α^{z} is the axial part of the current J_α^{3}, J_α^{S} is the isoscalar part of the electromagnetic current. It is evident from /5/, that interference between vector and axial vector parts of the current J_α^{z}

does not contribute to the sum of the cross sections of the processes /3/. Thus one has

$$\left(\frac{d^2\sigma}{dq^2 d\nu}\right)_{\nu} + \left(\frac{d^2\sigma}{dq^2 d\nu}\right)_{\bar{\nu}} = \frac{G^2}{2\pi}\frac{M^2}{(pK)^2} m_{\alpha\beta}\left(a^{VV}_{\alpha\beta} + a^{AA}_{\alpha\beta}\right), \qquad /9/$$

where $a^{VV}_{\alpha\beta}$ /$a^{AA}_{\alpha\beta}$/ is the contribution to $a^{ZZ}_{\alpha\beta}$ of the vector /axial/ part of the neutral current.

In the case of giant dipole resonance, as is shown in /5/, the isoscalar part of the electromagnetic current does not contribute to the matrix element of the process. One finds

$$a^{VV}_{\alpha\beta} = (1 - 2\sin^2\theta_W)^2 a^{em}_{\alpha\beta}. \qquad /10/$$

The tensor $a^{em}_{\alpha\beta}$ has, as is well known, the following general form

$$a^{em}_{\alpha\beta} = W_1^{em}\left(\delta_{\alpha\beta} - \frac{q_\alpha q_\beta}{q^2}\right) + \frac{1}{M^2} W_2^{em}\left(p_\alpha - \frac{pq}{q^2}q_\alpha\right)\left(p_\beta - \frac{pq}{q^2}q_\beta\right), \qquad /11/$$

where W_1^{em} and W_2^{em} are functions of q^2 and ν. As far as we are dealing with low energies, we take into account the first terms of the expansion W_i^{em} in q^2. We have

$$W_1^{em} = \frac{\nu}{(2\pi)^2\alpha}\sigma_\gamma(\nu) + O(q^2),$$
$$W_2^{em} = \frac{q^2}{\nu^2}\frac{\nu}{(2\pi)^2\alpha}\sigma_\gamma(\nu) + O(q^4), \qquad /12/$$

where σ_γ is the total cross section of photoabsorption and $\alpha = \frac{e^2}{4\pi}$. Omitting the contribution of the axial part of the current we obtain the following inequality in this approximation for the sum of the total cross sections of the processes /3/

$$\sigma_\nu + \sigma_{\bar\nu} \geqslant (1-2\sin^2\theta_W)^2\sigma_0 \,, \qquad /13/$$

where

$$\sigma_0 = \frac{G^2}{2(2\pi)^3\alpha}\cdot\frac{1}{E^2}\int_0^{4E^2} q^2 dq^2 \int_{q^2/2M}^{E-\frac{q^2}{4E}} \nu\left[2+\frac{1}{\nu^2}(4E^2-4E\nu-q^2)\right]\sigma_\gamma(\nu)\,d\nu \,; \qquad /14/$$

E is the neutrino /antineutrino/ energy in the laboratory system. We have calculated σ_0 for the set of heavy deformed nuclei. For these nuclei the photonuclear giant dipole cross section is approximated by the sum of the two Lorentz curves /7/

$$\sigma_\gamma(\nu) = \sum_{i=a,b}\sigma_i\,\frac{(\Gamma_i\nu)^2}{(\nu^2-E_i)^2+(\Gamma_i\nu)^2} \,. \qquad /15/$$

In the table we show the numerical values of σ_0 for eight nuclei and energies E = 30,50,100 MeV. The parameters of the Lorentz curves were taken from a review /7/. The values σ_0, calculated from equation /14/ has been plotted in figure as a function of E for two nuclei V^{51} and Ta^{181}.

The table and the figure show that studying the process of excitation of the giant dipole states by a neutrino beam from mesons factories one may answer the question of the existence of weak neutral currents predicted by Weinberg-type theories.

We would like to thank S.I.Bilenkaja for her help in making numerical calculations, as well as S.S.Gerahtein, Ya.A.Smorodinsky and R.A.Eramjan for many valuable discussions.

References

1. D.C.Cundy, preprint RL-73-018, 1973.
2. C.Baltay, Neutrino 72, Hungary 1972, p. 199.
3. S.Weinberg, Phys. Rev. Lett., 27, 1688 (1971).
4. S.Weinberg, Phys. Rev., D5, 1412 (1972).
5. M.Gell-Mann and V.Telegdi, Phys. Rev., 91, 169 (1953).
6. S.D.Drell and J.D.Walecka, Annals of Phys., 28, 18 (1964).
7. E.Hayward, Nuclear Structure and Electromagnetic Interactions, 1964, p. 179.

Received by Publishing Department
on August 28, 1973.

Table

E(MeV)	30	50	IOO
V^{5I}	I.4 IO^{-42}	2.5 IO^{-4I}	7.I IO^{-40}
Mn^{55}	I.6 IO^{-42}	2.7 IO^{-4I}	7.3 IO^{-40}
Co^{59}	I.9 IO^{-42}	3.I IO^{-4I}	8.4 IO^{-40}
Rh^{IO3}	6.I IO^{-42}	9.0 IO^{-4I}	2.3 IO^{-39}
In^{II5}	8.9 IO^{-42}	I.0 IO^{-40}	3.2 IO^{-39}
Tb^{I59}	I.3 IO^{-4I}	I.8 IO^{-40}	4.5 IO^{-39}
Ho^{I65}	I.6 IO^{-4I}	2.2 IO^{-40}	5.4 IO^{-39}
Ta^{I8I}	I.7 IO^{-4I}	2.3 IO^{-40}	5.5 IO^{-39}

Values of σ_o for energies E =30,50,IOO MeV.

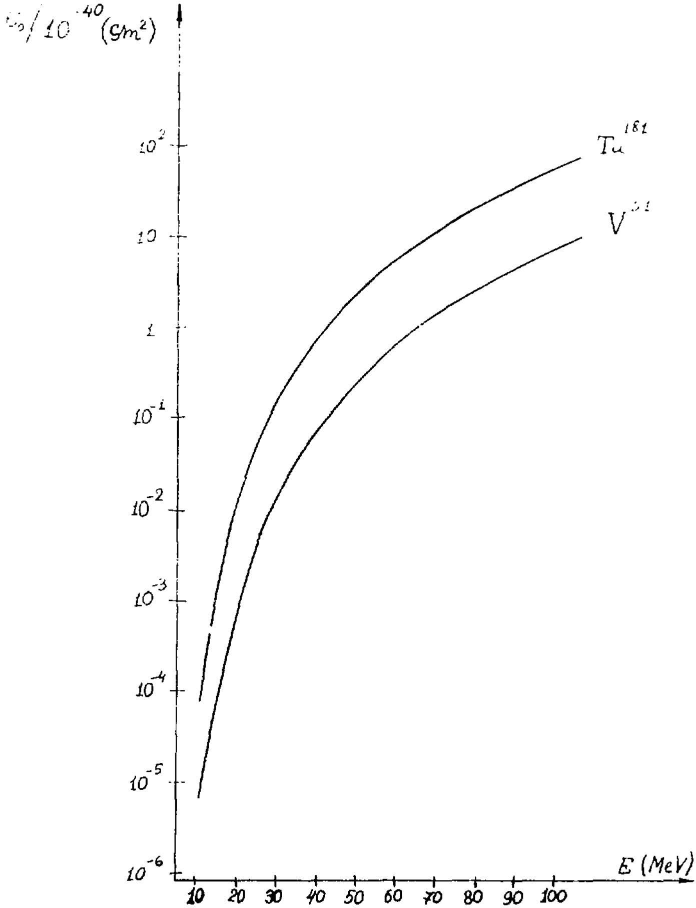

Fig. I. σ_0 as a function of E for V^{51} and Ta^{181}.