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PARITY VIOLATION IN ELECTROEXCITATION OF GIANT RESONANCE AND THE STRUCTURE OF NEUTRAL WEAK CURRENT

ԵՐԵՎԱՆ 1982 ЕРЕВАН

The results of experiments at SLAC [1,2] where P-odd asymmetry in deep-inelastic scattering of longitudinally polarized electrons on deuterium was measured, and a number of optical-rotation experiments in atomic bismuth [3,4,5] and thallium [6] undoubtedly testify the existence of parity-non-conservation in electron-nucleon interaction. The basic task of the theory and experiment is to define the structure of this interaction.

In numerical estimates of the observed P-odd effects in atomic bismuth there is still no agreement between different experimental groups [7,8]. In this connection the further investigation of P-odd effects in lepton-nucleon processes is particularly important for understanding the structure of neutral weak currents as well as for the check of gauge theories of weak and electromagnetic interactions.

It has been shown [9-11] that the parity-violating part of weak interaction due to the neutral currents may be detected by studying P-odd effects in scattering of polarized electrons on nuclei with excitation of discrete levels of the latter. One of such effects is the difference in differential cross sections in the scattering of left- and right-polarized initial electrons on nuclei. The knowledge of nuclear quantum numbers and, therefore, of selection rules allows to investigate in detail the structure of neutral currents in processes of electroexcitation of nuclear levels*).

We discuss in this paper the P-odd asymmetry arising due to interference of electromagnetic and weak amplitudes in inelastic scattering of polarized electrons on even-even nuclei with excitation of the giant resonance levels:

$$e + A \rightarrow e + A^* , \tag{1}$$

here A^* is the excited state of the nucleus A. Numerical estimates are obtained for the asymmetry in Weinberg-Salam model [14]. Nuclear matrix elements are calculated in a generalized Goldhaber-Teller model [15,16].

It is also shown that the measurement of P-odd asymmetry in inelastic scattering of electrons with excitation of different giant resonance levels allows to determine in a model-independent way the structure of the parity violating Lagrangian. It should be noted that the model-independent analysis of the available data on P-odd effects in deep-inelastic scattering of polarized electrons on deuterium and in atomic systems doesn't yet allow to determine unambiguously the structure of the parity violating $e-N$ Lagrangian [17,18]

*) High precision experiments with polarized electrons at relatively low energies (E = 100- 800 MeV) in which P-odd asymmetries of the order 10^{-5}- 10^{-7} will be measured are in preparation at present [12,13]

Assume for the parity violating effective Lagrangian of interaction the following general form [19] :

$$\mathcal{L}^{PV} = -\frac{G}{\sqrt{2}}\left\{\bar{e}\gamma_\alpha e[\tilde{\beta} A_\alpha^3 + \tilde{\delta} A_\alpha^0] + \bar{e}\gamma_\alpha\gamma_5 e[\tilde{\alpha} V_\alpha^3 + \tilde{\gamma} V_\alpha^0]\right\}. \tag{2}$$

Here V_α^3 and V_α^0 (A_α^3 and A_α^0) are the third component of isovector and isoscalar parts of vector (axial) weak neutral hadronic current. $\tilde{\alpha}, \tilde{\beta}, \tilde{\gamma}, \tilde{\delta}$ are four real constants that should be defined from experiment. In the Weinberg-Salam theory the values $\tilde{\alpha}, \tilde{\beta}, \tilde{\gamma}$ and $\tilde{\delta}$ are:

$$\tilde{\alpha} = -(1-2\sin^2\theta_W); \qquad \tilde{\gamma} = \frac{2}{3}\sin^2\theta_W;$$
$$\tilde{\beta} = -(1-4\sin^2\theta_W); \qquad \tilde{\delta} = 0 \tag{3}$$

The P-odd asymmetry for the scattering of electrons with longitudinal polarization λ on a nonpolarized target is defined in the following way:

$$\mathcal{A} = \frac{\frac{d\sigma}{d\Omega}_{\lambda=1} - \frac{d\sigma}{d\Omega}_{\lambda=-1}}{\frac{d\sigma}{d\Omega}_{\lambda=1} + \frac{d\sigma}{d\Omega}_{\lambda=-1}} , \tag{4}$$

where $\left(\frac{d\sigma}{d\Omega}\right)_\lambda$ is the differential cross section for right- or left-hand polarized electrons. The leading contribution to the asymmetry is given by the interference of weak amplitude, conditioned by the interaction (2). and of corresponding electromagnetic amplitude.

Using the multipole analysis for a unified description of semi-leptonic weak and electromagnetic processes on nuclei [20] we shall obtain the differential cross section of the process (1). It turns out [21] that the expression for differential cross section includes the same nuclear matrix elements of multipole operators that define all electromagnetic and weak transitions between the ground and excited states of nucleus. We shall consider the transitions from a ground state of well-studied even-even nuclei (e.g., ^{12}C, ^{16}O, ^{40}Ca) to the negative parity levels 1^-, 2^- with the isospin $T = 0.1$.

Nuclear matrix elements for these transitions are easily calculated in the generalized Goldhaber-Teller model [15].

Standard calculations result in the following expressions for differential cross sections for various giant resonance levels:

$$\left(\frac{d\sigma}{d\Omega}\right)^{1^-,T=1,S=0} = \sigma_M\left\{1+2\lambda\rho\tilde{\alpha}\right\}\cdot\left\{1+\left(\frac{1}{2}+tg^2\frac{\theta}{2}\right)\frac{2\delta^2}{\bar{q}^2-\delta^2}\right\}\cdot[m]^2,$$

$$\left(\frac{d}{d\Omega}\right)^{1^-,T=1,S=1} = \sigma_m\left\{\left(\frac{q^2}{2\bar{q}^2}+tg^2\frac{\theta}{2}\right)\frac{\bar{q}^2}{M^2}\frac{\mu_T}{2}+2\lambda\rho\left[\tilde{\alpha}\left(\frac{q^2}{2\bar{q}^2}+tg^2\frac{\theta}{2}\right)\frac{\bar{q}^2}{M^2}\frac{\mu_T}{2}-\right.\right.$$

$$\left.\left.-\tilde{\beta}\,tg^2\frac{\theta}{2}\,\frac{E+E'}{M}\,\frac{g_A}{2}\right]\times\frac{\mu_T}{2}\right\}\cdot[m]^2,$$

$$\left(\frac{d\sigma}{d\Omega}\right)^{1^-,T=0,S=1} = \sigma_M\left\{\left(\frac{q^2}{2\bar{q}^2}+tg^2\frac{\theta}{2}\right)\frac{\bar{q}^2}{M^2}\frac{\mu_s}{2}+2\lambda\rho\left[\tilde{\gamma}\left(\frac{q^2}{2\bar{q}^2}+tg^2\frac{\theta}{2}\right)\times\right.\right.$$

$$\left.\left.\times\frac{\bar{q}^2}{M^2}\frac{\mu_s}{2}-\tilde{\delta}\,tg^2\frac{\theta}{2}\,\frac{E+E'}{M}\right]\frac{\mu_s}{2}\right\}\cdot[m]^2;$$

$$\left(\frac{d\sigma}{d\Omega}\right)^{2^-,T=1,S=1} = \left(\frac{d\sigma}{d\Omega}\right)^{1^-,T=1,S=1},$$

$$\left(\frac{d\sigma}{d\Omega}\right)^{2^-,T=0,S=1} = \left(\frac{d\sigma}{d\Omega}\right)^{1^-,T=0,S=1}. \qquad (5)$$

Here $q = K - K'$, where K and K' are the four momenta of initial and final electrons; and the nucleus excitation energy is $\delta = E - E'$, where E and E' are the energies of initial and final electrons; λ is the longitudinal polarization of initial electrons,

$$\rho = \frac{G}{\sqrt{2}}\,\frac{q^2}{2\pi\alpha}\,; \qquad \sigma_M = \frac{\alpha^2\cos^2\frac{\theta}{2}}{4E^2\sin^4\frac{\theta}{2}}$$

$\mu_T = 4.706$, $\mu_s = 0.88$ are isovector and isoscalar magnetic moments of a nucleon; $g_A = -1.23$ is the axial-vector constant, M is the nucleon mass

$$[m^2]^{*)} = \frac{\bar{q}^2}{2\pi M\delta A}\cdot F_0^2(\bar{q}^2),$$

$F_0(\bar{q}^2)$ is the elastic formfactor of nucleus, A is the

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*) It should be noted that in the generalized Goldhaber-Teller model the nuclear structure of matrix elements of the multipole operators is expressed via ground-state charge formfactor $F_0(\bar{q}^2)$.

atomic number of nucleus. From (4) and (5) we obtain:

$$(\mathcal{A})^{1^-, T=1, S=0} = 2\rho\tilde{\alpha} \; ; \qquad (6)$$

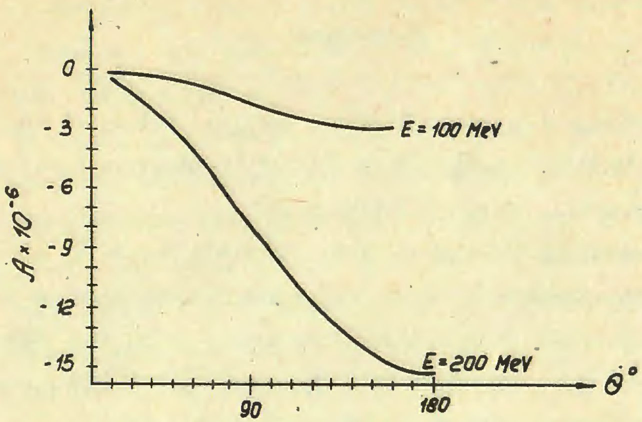
$$(\mathcal{A})^{1^-, T=1, S=1} = 2\rho\left(\tilde{\alpha} - \tilde{\beta}\,\frac{2M\,tg^2\frac{\theta}{2}\,(E+E')g_A}{(1+2tg^2\frac{\theta}{2})\bar{q}^2\mu_T}\right) ; \qquad (7)$$

$$(\mathcal{A})^{1^-, T=0, S=1} = 2\rho\left(\tilde{\gamma} - \tilde{\delta}\,\frac{4M\,tg^2\frac{\theta}{2}\,(E+E')}{(1+2tg^2\frac{\theta}{2})\bar{q}^2\mu_S}\right) . \qquad (8)$$

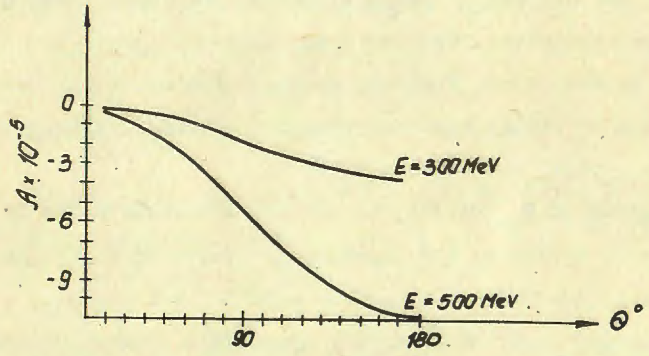
Thus the information on the parameters $\tilde{\alpha}, \tilde{\beta}, \tilde{\gamma}, \tilde{\delta}$ may be obtained from the measurements of asymmetry on different giant resonance levels. As is seen from (6), the measurement of the asymmetry $(\mathcal{A})^{1^-, T=1, S=0}$ defines the constant $\tilde{\alpha}$. The asymmetry $(\mathcal{A})^{1^-,(2^-), T=1, S=1}$ (7) is expressed through $\tilde{\alpha}$ and $\tilde{\beta}$. For an accurate measurement of $\tilde{\beta}$ one should estimate the value of kinematic factor at $\tilde{\beta}$. As is seen from (7), this value slowly varies with the scattering angle $\tilde{\theta}$ and drops with the increase of initial energy of polarized electrons. Measuring the asymmetry arising at electroexcitation of isoscalar levels ($T = 0$) of giant resonance [22] it will be possible to define the combination of the constants $\tilde{\gamma}$ and $\tilde{\delta}$ (8). Numerical estimations for the value of discussed asymmetry are obtained in the Weinberg-Salam model (with $\sin^2\theta_W = 0{,}23$ which is consistent with the results of Stanford [1] and neutrino experiments [23]). In fig. 1(a,b) the dependence of the value of expected asymmetry on the scattering angle θ is presented. This asymmetry is summed up over giant resonance levels $1^-, T=1;\ S=0;\ 1^-, T=0,1;\ S=1;\ 2^-, T=0,1;\ S=1$. For the initial energy E of polarized electrons the following values were taken: E = 100; 200; 300; 500 (MeV). For the excitation energy δ we have taken the mean value equal to 20 MeV [15]. As is seen from fig. 1, the asymmetry increases by the absolute value with θ and E. For example, for E = 200 and $\theta = 150^\circ$, $\mathcal{A} = -1{,}4 \times 10^{-5}$; $\theta = 70^\circ$ $\mathcal{A} = -0{,}5 \times 10^{-5}$.

Figure Captions

Fig. 1(a,b) Dependence of the asymmetry $\mathcal{A}$, summed up over the levels 1^-, T = 1, S = 0., 1^-, T = 0,1 ; S = 1; 2^-, T = 0,1; S = 1 on the scattering angle θ. Results are presented for initial electrons energies: E=100, 200 (MeV) - (fig. 1a); E=300, 500 (MeV) - (fig. 1b).



a)



b)

References

1. Prescott, C.Y., Atwood, W.B., Cottrell R.L.A. et al. Parity Non-Conservation in Inelastic Electron Scattering.- Phys.Lett., 1978, vol. 77B, p.347
2. Prescott, C.Y., Atwood, W.B., Cottrell R.L.A. et al. Further Measurements of Parity Non-Conservation in Inelastic Electron Scattering.- Phys.Lett., 1979, vol. 84B,p.524
3. Барков Л.М., Золотарев М.С. Измерение оптической активности паров висмута.Письма в ЖЭТФ, 1978,т.28,с.544.
4. Barkov, L.M., Zolotarev, M.S. Parity Violation in Atomic Bismuth.- Phys.Lett., 1979, vol. 85B, p.308
5. Hollister,J.H., Apperson,G.R., Lewis, L.L. et al. Measurement of Parity Nonconservation in Atomic Bismuth.- Phys.Rev.Lett., 1981, vol. 46, p.643
6. Bucksbaum, P.H., Commins, E.D., Hunter, L.R. Observations of Parity Nonconservation in Atomic Thallium.- Phys. Rev., 1981, vol. D24, p.1134
7. Fortson, E.N., Wilets, M. Parity Nonconservation in Atoms: Status of Theory and Experiment. Univ. of Washington, preprint. 1980
8. Хриплович И.Б. Несохранение четности в атомных явлениях. М:.Наука 1981.
9. Feinberg, G. Polarized Electron-Nucleus Scattering and Parity-Violating Neutral-Current Interactions.- Phys.Rev., 1975, vol. D12, p.3575

10. Walecka, J.D. Semi-Leptonic Weak and Electromagnetic Interactions in Nuclei: Parity Violations in Electron Scattering and Weak Neutral Currents.- Nucl.Phys., 1977, vol. A285, p.349
11. Bernabeu, J., Eramzhyan, R.A. The Axial Isoscalar Neutral Current from Inelastic Electron-Nuclear Scattering TH. 2533-CERN 1978
12. Otten, B.W. et al. Univ. of Mainz Proposal and Proc. Topical Meeting on Intermediate Energy Physics; Experiments and Experimental Methods. Zuoz, Switzerland, 1976 vol.1, p.62
13. Hughes, V.W. et al. Yale Univ. Proposal for MIT-BATES 1977
14. Weinberg, S. A Model of Leptons.- Phys.Rev.Lett., 1967, vol. 19, p.1264;
Salam, A. Proc. of the Eighth Nobel Symposium, J.Wiley, N.Y., 1968
15. Uberall, H. The Giant Resonance in Inelastic Electron Scattering.- Nuovo Cimento, 1966, vol. 41, p.25;
16. Uberall, H. Collective Nuclear Vibrations Induced by High-Energy Neutrinos.- Phys.Rev., 1965, vol. 137B,p.502
17. Sakurai, J.J. Status of Neutral Currents UCLA/78/TEP/18
18. Потков С.Т. Экспериментальный статус стандартной теории электрослабых взаимодействий. XIV Международная школа ОИЯИ по физике высоких энергий молодых ученых,Дубна, 1980.

19. Hung, P.Q., Sakurai, J.J. Evidence for Factorization and Coupling Constant Determination in Neutral-Current Processes.- Phys.Lett., 1979, vol. 88B, p.91

20. Walecka, J.D. Semi-Leptonic Weak Interactions in Nuclei, in Muon Physics, vol. 2, ed. V.W.Hughes and C.S.Wu Academic Press, N.Y., 1975. p. 113

21. Donnely,T.W., Dubach, J., Haxton, W.C. Semi-Leptonic Weak and Electromagnetic Interactions in the Goldhaber-Teller Model.- Nucl.Phys., 1975, vol. A251, p.353

22. Speth, J. Electromagnetic Excitations of Giant Resonances: in "Lecture Notes in Physics" 108, Proceedings, Mainz 1979, p. 266

23. Holder, M., Knobloch, J., May, J. et al. Study of Inclusive Neutral Current Interactions of Neutrinos and Antineutrinos. Phys.Lett., 1977, vol. 72B, p.254.

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НАРУШЕНИЕ ЧЕТНОСТИ В ЭЛЕКТРОВОЗБУЖДЕНИИ
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НЕЙТРАЛЬНЫХ СЛАБЫХ ТОКОВ

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