ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

ДУБНА

6/XII-76

E2 - 10040

E.Kh.Khristova

THE PARITY VIOLATING ASYMMETRY IN THE ANNIHILATION $e^+e^- \to \mu^+\mu^-$ AND THE SIGN OF THE CONSTANT G

1976

E2 - 10040

E.Kh.Khristova

THE PARITY VIOLATING ASYMMETRY IN THE ANNIHILATION $e^+e^- \to \mu^+\mu^-$ AND THE SIGN OF THE CONSTANT G

Submitted to ЯФ

In ref.[1] it has been shown that the discovery of weak neutral currents with charged leptons would make it possible to determine experimentally the sign of the weak coupling constant G. The sign of G is closely connected with the existence of the intermediate vector bosons. The theories with W-bosons predict **positive** sign of this constant[2]. An important class of the above theories are the unified gauge theories of weak and electromagnetic interactions. The undoubtful success of these theories associated with the proof of their renormalizability[3] poses the important question of their experimental verification. Thus the sign determination of the constant G is of fundamental importance for the theory of weak interaction.

The deep inelastic scattering of leptons on nucleons has been considered in ref.[1]. It has been shown that the observation of the P -violating effects due to the interference of weak and electromagnetic interactions would permit the determination of the sign of G. Here, however, a number of assumptions have been made about the structure of the hadronic neutral current.

In the present paper we shall discuss the possibility of determination of the sign of G in the pure lepton process

$$e^+e^- \to \mu^+\mu^- . \qquad (1)$$

The absence of hadrons and of the related problem of strong interactions in this case facilitates the experimental determination of the sign of G.

For the Hamiltonian of the weak interaction of leptons we accept the expression

$$\mathcal{H} = \frac{G}{\sqrt{2}} J_\alpha J_\alpha^+ , \qquad (2)$$

where

$$J_\alpha = \bar{e}\gamma_\alpha (c_V + c_A \gamma_5) e + \bar{\nu}_e \gamma_\alpha (1 + \gamma_5) \nu_e + (e \to \mu),$$

c_V and c_A being constants. In Hamiltonian (2), the two-component structure of neutrino and the $\mu - e$ universality are taken into account in accordance with the modern V-A theory. The effective leptonic neutral current Hamiltonian in the theory of Weinberg and Salam/4/ has the structure of eq. (2).

Further on we shall be interested in the linear in G terms. Such a term can be separated considering the P -violating asymmetry. At $E \gg m$, $E \gg \mu$ (E is the energy of the initial lepton in the c.m.s., m and μ are the masses of the electron and μ-muon, respectively) such an asymmetry arises only when longitudinally polarized initial beams are used; the possibility of obtaining such beams in the planned storage ring experiments at high energies has been pointed out in refs./5/

The differential cross section of process (1) in the one-photon approximation and in the lowest order in G assuming the longitudinal polarization of the initial leptons has the form/6/ in the c.m.s.

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 (1 - \lambda_+ \lambda_- + (\lambda_- - \lambda_+) A), \qquad (3)$$

Here $(d\sigma/d\Omega)_0$ is the cross section for the unpolarized particles, λ_+ and λ_- are the longitudinal polarizations of e^+ and e^-. The considered parity violating asymmetry, A, to the linear in the parameter β terms, equals

$$A = 2\beta c_V c_A \frac{(1 + \cos\theta)^2}{1 + \cos^2\theta} , \qquad (4)$$

where $\beta = \frac{G}{\sqrt{2}} \frac{q^2}{4\pi\alpha}$, q^2 is the squared momentum transferred, θ is the angle between directions of e^- and μ^-. Asymmetry A (4) depends also on the product $c_V c_A$ in addition to G and kinematical variables. Information on $c_V c_A$ may be obtained from current experiments on $\nu_\mu e$ and $\tilde{\nu}_\mu e$ -scattering. Provided the interaction Hamiltonian is of form (2) the total cross sections of these processes are, resp.:

$$\begin{aligned} \sigma(\nu_\mu e) &= \sigma_0 (c_+^2 + \tfrac{1}{3} c_-^2), \\ \sigma(\tilde{\nu}_\mu e) &= \sigma_0 (c_-^2 + \tfrac{1}{3} c_+^2), \end{aligned} \qquad (5)$$

where $\sigma_0 = \frac{G^2}{\pi} s$, $c_+ = \frac{1}{2}(c_V + c_A)$, $c_- = \frac{1}{2}(c_V - c_A)$.
From (5) we get

$$2 c_V c_A = \frac{3}{\sigma_0} (\sigma(\nu_\mu e) - \sigma(\tilde{\nu}_\mu e)). \qquad (6)$$

Thus, all the quantities but G in asymmetry A can be expressed in terms of the experimental observables.

The total cross section of annihilation of the longitudinally polarized e^+ and e^- into the pair $\mu^+\mu^-$ has the form

$$\sigma = \sigma_0 (1 - \lambda_+ \lambda_- - (\lambda_- - \lambda_+) \mathcal{A}). \qquad (7)$$

The integral asymmetry $\mathcal{A}$ then takes the very simple form

$$\mathcal{A} = 2\beta c_V c_A = \frac{G}{\sqrt{2}} \frac{q^2}{4\pi\alpha} \frac{3}{\sigma_0} (\sigma(\nu_\mu e) - \sigma(\tilde{\nu}_\mu e)). \qquad (8)$$

Now let us evaluate the asymmetry $\mathcal{A}$ in the Weinberg-Salam model /3,4/. The constants c_V and c_A in this case are defined, resp., by the expressions

$$C_V = -1 + 4\sin^2\Theta_W\,, \quad C_A = -1\,. \tag{9}$$

Inserting (9) into (8) gives

$$\alpha = 1{,}54 \cdot 10^{-4}\,\frac{q^2}{M}\,(1 - 4\sin^2\Theta_W).$$

At energy of the lepton beam $\bar{E} = 14$ GeV/7/ and for the experimentally most probable Weinberg angle $\sin^2\Theta_W = 0.40$/8/ the asymmetry α equals 7%.

Thus, the analysis performed indicates that in the case if the assumption on the existence of weak neutral currents and charged leptons is valid, there appears a real possibility of answering experimentally the question about sign of the fundamental constant of weak interaction G.

In conclusion the author has a pleasure to thank sincerely S.M.Bilenky for the suggested scheme and useful discussions.

References

1. С.М.Биленький, Н.А,Дадаян, Е.Х.Христова. ЯФ, 2I, 360 (I975).
2. Я.Б.Зельдович. Киевская конференция по физике высоких энергий, I959 г. т. II, стр. 309.
3. G.t'Hooft. Nucl.Phys., B33, 173 (1971); B35, 167 (1971).
   G.t'Hooft and M.Veltman. Nucl.Phys., B50, 318 (1972).
4. S.Weinberg. Phys.Rev.Lett., 19, 1264 (1967); 27, 1688 (1971); A.Salam, Elementary Particle Physics, Stockholm, 1968.
5. R.Schwitters, B.Richter, PEP Summer Study, 1974, p. 384, LBL/SLAC.
   V.Luth. Rapporteur's Summary at the Intern. Conf. on Itigh Energy Physics, Palermo (1975).

6. Mc.Donald. Nucl.Phys., B75, 343 (1974).
7. C.Pellrgrim et al. Proceedings of the Eighth Intern. Conf. on Itigh Energy Accelerators at CERN (1971) p. L 53.
8. H.Faissner. Preprint PITHA- 85 (1975) Invited Talk at the Intern. Conf. on Itigh Energy Physics at Palermo on June 24th 1975.

Received by Publishing Department
on August 16, 1976.