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

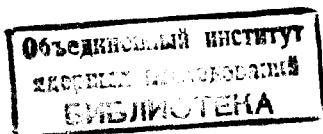
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In ref.^{/1/} it has been shown that the discovery of weak neutral currents with charged leptons would make it possible to determine experimentally the sign of the weak coupling constant G . The sign of G is closely connected with the existence of 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

$$e^+e^- \rightarrow \mu^+\mu^- \quad (1)$$

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

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

where

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

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.

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

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

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

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 $\bar{\nu}_\mu e$ -scattering. Provided the interaction Hamiltonian is of form (2) the total cross sections of these processes are, resp.:

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

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

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

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

$$\sigma = \sigma_0 (1 - \lambda_+ \lambda_- - (\lambda_- - \lambda_+) \alpha). \quad (7)$$

The integral asymmetry α then takes the very simple form

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

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

$$C_V = -1 + 4 \sin^2 \theta_W, \quad C_A = -1. \quad (9)$$

Inserting (9) into (8) gives

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

At energy of the lepton beam $E = 14 \text{ GeV}^{17/}$ and for the experimentally most probable Weinberg angle $\sin^2 \theta_W = 0.40^{18/}$ 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.

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