[17]Saclay-Orsay-Bari-Bologna Collaboration, Nuovo Cimento 37, 361 (1965).

[18]Aachen-Berlin-Birmingham-Bonn-Hamburg-London (Imperial College)-München Collaboration, Phys. Rev. 138, B897 (1965).

[19]Details of results to be published. For description of method see V. J. Stenger, University of Hawii Report No. UH-511-30-68 (unpublished). See also J. Friedman and R. Ross, Alvarez Group Memo No. P-102 (unpublished).

[20]W. D. Walker, M. A. Thompson, W. J. Robertson, B. Y. Oh, Y. Y. Lee, R. W. Hartung, A. F. Garfinkel, A. R. Erwin, and J. L. Davis, Phys. Rev. Letters 20, 133 (1968).

MODEL OF THE FINITE SELF-MASSES OF LEPTONS

Hidezumi Terazawa
Department of Physics, University of Tokyo, Tokyo, Japan
(Received 23 December 1968)

We consider a model of the weak interactions with scalar intermediate bosons $C^\pm$ with a negative metric in addition to the usual weak vector bosons $B^\pm$. With this modification, problems of divergence and high-energy behavior are greatly reduced. If the logarithmic weak and electromagnetic self-mass divergences are assumed to cancel each other, the coupling constant g and the mass m_B of the weak boson can be predicted.

Recently several authors[1,2] have proposed new approaches to determine the Cabibbo angle through the requirement that weak self-masses of hadrons be free of quadratic divergences. How about the self-masses of leptons? The purpose of this Letter is to consider a model of the weak interaction with less divergences and to show a few results from the model. Details and other effects will be discussed elsewhere.

We assume the existence of charged scalar $C^\pm$ bosons (mass m_C) with a negative metric[3] in addition to the usual charged, weak, intermediate vector bosons $B^\pm$ (mass m_B), and a fundamental Lagrangian for the weak interaction of the form

$$\mathfrak{L}_{\rm wk}=gJ_\lambda^{\;+}[B_\lambda+(1/m_B)\partial_\lambda C]+\text{H.c.}, \tag{1}$$

where J_λ is the weak current [e.g., $i\bar{\Psi}_e\gamma_\lambda(1+\gamma_5)\times\Psi_{\nu_e}+i\bar{\Psi}_\mu\gamma_\lambda(1+\gamma_5)\Psi_{\nu_\mu}$ for leptons] and g is a coupling constant. For simplicity we will take $m_B=m_C$ in the following although a variation of the $C^\pm$ mass keeps most of the following results unchanged.

It is easily seen that the effect of $C^\pm$ cancels the $k_\lambda k_\mu/m_B^2$ term in the $B^\pm$ propagator so that the effective propagator of these bosons becomes $\delta_{\lambda\mu}/(k^2+m_B^2)$. The effective Fermi interaction becomes better-behaved at high energies as follows[5]:

$$\mathfrak{L}_{\rm eff}=g^2\int d^4x'\,J_\lambda^{\;+}(x)\Delta_{\lambda\mu}(x-x')J_\mu(x'), \tag{2}$$

where

$$\Delta_{\lambda\mu}(x-x')=\frac{1}{(2\pi)^4}\int d^4k\,e^{ik(x-x')}\frac{\delta_{\lambda\mu}}{k^2+m_B^{\;2}}. \tag{3}$$

The relation between the coupling constant g and the Fermi coupling constant G ($Gm_p^{\;2}\simeq10^{-5}$) is

$$g^2/m_B^{\;2}=G/\sqrt{2}. \tag{4}$$

The weak self-masses of leptons come to have only logarithmic divergences and are calculated to be

$$\delta m_l^{\;\rm wk}=-\frac{g^2}{16\pi^2}m_l\ln\frac{\Lambda^2}{m_B^{\;2}}+\cdots \quad \text{for } l=e \text{ or } \mu \tag{5}$$

and

$$\delta m_\nu^{\;\rm wk}=0 \quad \text{for the neutrinos}, \tag{6}$$

where Λ is a cutoff energy. Moreover, if the divergences are assumed to cancel those of electromagnetic self-masses of leptons[6] $\delta m_l^{\rm e.m.}=3e^2[16\pi^2 m_l\ln(\Lambda^2/m_l^2)]^{-1}$, i.e.,

$$\delta m_l=\delta m_l^{\;\rm e.m.}+\delta m_l^{\;\rm wk}=\text{finite}, \tag{7}$$

the coupling constant g can be predicted to be

$$g^2=3e^2. \tag{8}$$

From this relation and Eq. (4), the mass of $B^\pm$ can also be determined:

$$m_B=(3\sqrt{2}\,e^2/G)^{1/2}\simeq200m_p. \tag{9}$$

This mass being so large, a direct proof of this model ($p+\bar{p}\to B^\pm+\pi^\mp$, $\mu+\mu\to B+\mu+\nu_\mu$, etc.) will not be completed until a p-$\bar{p}$ colliding-beam machine with energies more than 100 GeV/beam is available. From Eqs. (6), (8), and (9), the finite self-masses of the electron and muon becomes

$$\delta m_l \simeq \frac{3e^2}{16\pi^2} m_l \ln\left(\frac{m_B}{m_l}\right)^2$$

$$(\simeq 0.045 m_e \text{ for } e), \qquad (10)$$

which shows that the mass of the weak boson plays the role of an effective cutoff energy of quantum electrodynamics.

In conclusion we note that this model suggests the following possibility: The weak interaction is not weak but strong enough to compete with the electromagnetic interaction; namely, the weak interaction behaves like a weak interaction only because the masses of intermediate bosons are much heavier than those of known particles. We also note that masses of weak particles (leptons and intermediate bosons) and hadrons keep their balance, e.g., $m_B m_e \simeq m_\pi m_p$.

The author would like to express his sincere gratitude to Professor H. Miyazawa for his encouragement, valuable comments, and reading of the manuscript, and to Professor K. Nishijima for critical comments. He also wishes to thank Dr. M. Suzuki for useful discussions.

---

[1]R. Gatto, G. Sartori, and M. Tonin, Phys. Letters 28B, 128 (1968), and CERN Report No. TH 964, 1968 (unpublished).

[2]N. Cabibbo and L. Maiani, Phys. Letters 28B, 131 (1968).

[3]A possibility of the negative-metric states as unstable particles has been discussed by Lee and Wick. See T. D. Lee and G. C. Wick (to be published).

[4]This Lagrangian is similar to that in Stueckelberg formalism, but our model is not the same as it because $C^\pm$ is independent of $B^\pm$ in our case. See E. C. G. Stueckelberg, Helv. Phys. Acta 11, 225 (1938).

[5]For example, T. D. Lee and C. S. Wu, Ann. Rev. Nucl. Sci. 15, 381 (1965).

[6]A similar idea was proposed about twenty years ago by Sakata and Hara. See S. Sakata and O. Hara, Progr. Theoret. Phys. 2, 30 (1947).

DISCREPANCY BETWEEN THE VECTOR-DOMINANCE MODEL AND PION PRODUCTION BY POLARIZED PHOTONS*

R. Diebold
Stanford Linear Accelerator Center, Stanford University, Stanford, California

and

J. A. Poirier
Department of Physics, University of Notre Dame, Notre Dame, Indiana

(Received 18 December 1968)

The helicity density matrix for the process $\pi^- p \to \pi^+\pi^- n$ has been studied as a function of $M_{\pi\pi}$. The ratio $\rho_{1-1}^{\text{hel}}/\rho_{11}^{\text{hel}}$ shows no variation with $M_{\pi\pi}$ and it thus seems unlikely that the large discrepancy between the vector-dominance prediction and the observed asymmetry of single pions produced by linearly polarized photons could be the result of density-matrix distortion caused by background interference.

The vector-dominance model has been successfully used[1] to relate single-pion photoproduction,

$$\gamma p \to \pi^+ n, \qquad (1a)$$

$$\gamma n \to \pi^- p, \qquad (1b)$$

to ρ^0 production by pions,

$$\pi^- p \to \rho^0 n. \qquad (2)$$

By taking the sum of the two photoproduction cross sections, the $\omega\rho$ interference terms drop out; since the ω term itself is expected to be only a few percent, it is neglected, giving the ρ-dominance prediction

$$\frac{\sigma^+ + \sigma^-}{2} = \frac{\pi\alpha}{\gamma_\rho^{\,2}}\left[\rho_{11}\frac{d\sigma}{dt}\right]_{\pi^- p \to \rho^0 n}, \qquad (3)$$

where σ^+ and σ^- are $d\sigma/dt$ for Reactions (1a) and (1b), respectively.

Recently, experiments on Reactions (1a)[2] and (1b)[3,4] have been performed using linearly polarized γ rays produced coherently from crystals. These experiments yield the asymmetries

$$A^\pm = (\sigma_\perp^{\ \pm} - \sigma_\parallel^{\ \pm})/(\sigma_\perp^{\ \pm} + \sigma_\parallel^{\ \pm}), \qquad (4)$$