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# Fifth Interaction and Weak Interaction

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*Abstract*

The effect of the fifth interaction, which is supposed to explain the mass of the muon, has been examined through weak interaction. It has been found that the value of the universal weak coupling is modified by 15%. Taking into account other shortcomings, it may be concluded that the muon does not share this new interaction.

The success of the Okubo-Gellman mass formula led Neeman (1964) to postulate the existence of a fifth interaction mediated by a neutral vector meson of mass $M_X$. This meson is coupled to strangeness. As the mass difference of $\Lambda$ and nucleon is of the same order of the magnitude as the mass difference of muon and electron, it was very tempting to assume that this fifth interaction is shared by only one of the leptons, namely, muon, thus making it much heavier than the rest of the members of the lepton family.

Neeman has shown that this would change the ratio of the decay rates $\pi \to \mu + \bar{\nu}_\mu$ and $\pi \to e + \bar{\nu}_e$ by 30%, while the experimental uncertainty is only 2%. These decays have strongly interacting particle pion, and although the strong vertex cancels while calculating the two ratios, the mere presence of a strongly interacting particle reduces the seriousness of this objection.

The second discrepancy comes when we observe that this interaction would change the value of $g$ of the muon by a quantity given by

$$\delta = \frac{1}{3\pi}\frac{g_X{}^2}{4\pi}\frac{m^2\mu}{M_X{}^2}$$

where $m_\mu$ is the mass of the muon and $g_X$ is the coupling constant of the new interaction. By taking a sufficient large mass for $M_X$ we can make $\delta$ of the desired order.

What we want to show here is the change in the weak coupling constant $g$ due to this new interaction. If $\sqrt{Z_6}$† is the wave function renormalization

† Our notations and relations for Lehman representation are those given in Hamilton, J. (1959). *Theory of Elementary Particles*, especially page 316. Clarendon Press, Oxford.

because of the new interaction, then the modified coupling constant $g_m$ for the decay

$$\mu \rightarrow e + \bar{\nu}_e + \bar{\nu}_\mu$$

would be given by

$$g_m = \sqrt{(Z_6)}\, g \tag{1}$$

where $Z_6$ is related to mass renormalization in Lehman representation by

$$\delta m_\mu = Z_6 \int_0^\infty [m_\mu \rho_1(m^2) + m\rho_2(m^2)^\mu dm^2$$

Obviously, for a large mass renormalization $\delta m_\mu$ the wave function renormalization $\sqrt{Z_6}$ would be large also. In the first order of non-vanishing perturbation theory we have

$$Z_6 = 1 + \frac{1}{4\pi}\frac{g_\chi^2}{4\pi}\log\frac{\Lambda^2}{M_\chi^2}$$

and from this and equation (1) we have

$$\frac{g - g_m}{g} = \frac{1}{8\pi}\frac{g_\chi^2}{4\pi}\log\frac{\Lambda^2}{M_\chi^2} \tag{2}$$

while in the same order of perturbation theory we have

$$1 = \frac{\delta m_\mu}{m_\mu} = \frac{3}{4\pi}\frac{g_\chi^2}{4\pi}\log\frac{\Lambda^2}{M_\chi^2} \tag{3}$$

where it has been assumed that this fifth interaction is responsible for the mass difference of muon and electron. From (2) and (3) we see that the modified coupling constant changes by 15% or more.

As is well known (Hamilton, 1959), the discrepancy in the value of weak coupling constant is only 2%, and if the radiative correction is taken into account, then this discrepancy practically vanishes. It is important to note that whereas for the two troubles pointed out by Neeman himself, there is a sneaky way to get out, this present objection involving only weakly interacting particles and in its expression for the ratio of cut-off and the mass of $\chi$-meson puts a serious limitation on the fifth interaction, that is, it cannot be applied to explain the mass difference of muon and electron in its present form.

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*References*

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