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Speculative Relation Between the Fine-Structure and Fermi Coupling Constants*

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It is pointed out that there exists a peculiar coincidence among several different predictions for the intermediate-boson mass: Both of the masses given by Lee and by the author are very close to $\alpha^{-1}M_p$ (where α is the fine-structure constant and M_p is the proton mass). By taking it seriously, we obtain the following two relations: $\alpha = (GM_p^{\,2}/6\sqrt{2}\pi)^{1/3} \simeq 1/137.5$ for the Fermi coupling constant G and $\sin\theta = 1/3$ for the Cabibbo angle θ.

The possible existence of the hypothetical charged and neutral intermediate bosons, $W^{\pm}$ and W^0, was examined in great detail by Lee and Yang[1] more than ten years ago. Since that time no evidence for such particles has been discovered.[2] One finds, in the present intermediate-boson theory, no convincing prediction of the mass and the decay branching ratio.[3] Reasonable estimates of these quantities must be available before one can decide whether or not the existence of the intermediate boson can be excluded by experiment. The purpose of this short note is to point out a peculiar coincidence which exists among the predicted masses of the intermediate boson and to obtain speculative relations between the electromagnetic and weak coupling constants.

Let us begin with a review of the theoretical work on the intermediate-boson mass (see Table I). These attempts may be classified into the following two types. In the first class of attempts, an underlying SU(2) [or SU(3)] symmetry of the electromagnetic and weak interactions has been introduced. Such a symmetry (or a broken symmetry) was first examined by Glashow[4] and then assumed to be exact by Weinberg,[5] who could obtain the lower bounds of the intermediate-boson masses, i.e.,

$$M_{W^{\pm}} \geq (\sqrt{2}\,e^2/8G)^{1/2} \simeq 39.74 M_p$$

and

$$M_{W^0} \geq (\sqrt{2}\,e^2/4G)^{1/2} \simeq 56.20 M_p\,,$$

where $e^2/4\pi = \alpha \simeq 1/137.036$, G is the Fermi coupling constant, and M_p is the proton mass ($GM_p^{\,2} \simeq 1.026\times 10^{-5}$). More recently, Schechter and Ueda,[6] in their unified theory of the weak and electromagnetic interactions of leptons and hadrons, have predicted the intermediate-boson mass to be $M_{W^{\pm}} = (\sqrt{2}\,e^2/8G)^{1/2}$. The same value has been proposed independently by Lee[7] by a simpler formulation of the underlying theoretical hypothesis. Lee has derived, in another paper,[8] a lower bound of the mass

$$M_{W^{\pm}} \geq [(4\sqrt{2}\,e^2 \sec^2\theta)/3G]^{1/2} \simeq 133.7 M_p$$

(where θ is the Cabibbo angle,[9] $\theta \simeq 0.24$) by assuming SU(3) symmetry between the charged intermediate-boson field $W_\mu^{\pm}$ and the derivative of the electromagnetic field $\partial F_{\mu\nu}/\partial x_\nu$. In that paper, he has noticed that his lower bound is very close to $\alpha^{-1}M_p$.

In the second class of attempts to obtain a definite prediction of the weak-boson mass, the following model of the weak interactions for leptons has been proposed: The scalar part of the intermediate-boson field has a negative metric,[10] and the logarithmic weak and electromagnetic self-mass divergences cancel each other.[11] By making these as-

TABLE I. Predicted values of the intermediate-boson mass.

	$M_{W^\pm}$	$M_{W^\pm}/M_p$	$M_{W^\pm}$ (GeV)	M_{W^0}	M_{W^0}/M_p	M_{W^0} (GeV)
Glashow (Ref. 4)				$\gg M_{W^\pm}$		
Weinberg (Ref. 5)	$\geq(\sqrt{2}e^2/8G)^{1/2}$	≥39.74	≥37.29	$\geq(\sqrt{2}e^2/4G)^{1/2}$	≥56.20	≥52.74
Schechter and Ueda (Ref. 6)	$(\sqrt{2}e^2/8G)^{1/2}$	39.74	37.29	$\gg M_{W^\pm}$		
Lee (Ref. 7)				$=M_{W^\pm}$		
Lee (Ref. 8)	$\geq(4\sqrt{2}e^2\sec^2\theta/3G)^{1/2}$	≥133.7	≥125.4			
Terazawa (Ref. 12)	$(3e^2/\sqrt{2}G)^{1/2}$	137.7	129.1			
Pestieau and Roy (Ref. 13)	$(7\sqrt{2}e^2/12G)^{1/2}$	85.85	80.56	$(49\sqrt{2}e^2/66G)^{1/2}$	96.86	90.88
Fukuda (Ref. 14)	$(9e^2/\sqrt{2}G)^{1/2}$	238.4	235.7			
Haller, Landovitz, and Goldberg (Ref. 16)	$\gg(6\sqrt{2}\pi/G)^{1/2}$	≫1612	≫1512			

sumptions, the present author[12] has predicted the intermediate-boson mass to be $(3e^2/\sqrt{2}G)^{1/2} \simeq 137.7M_p$. Pestieau and Roy[13] have generalized this model by adopting Glashow's unified theory.[4] They have obtained different predictions for the masses, i.e.,

$$M_{W^\pm}=(7\sqrt{2}\,e^2/12G)^{1/2}\simeq 85.85M_p$$

and

$$M_{W^0}=(49\sqrt{2}\,e^2/66G)^{1/2}\simeq 96.86M_p\,.$$

They have also found that Glashow's speculation, that the mass of the neutral weak bosons is considerably higher than that of the charged ones, is not borne out. Another generalization of the model has been made by Fukuda.[14] He has introduced an arbitrary value of ξ which describes, in the ξ-limiting theory of Lee and Yang,[15] the ratio of the mass of the usual vector boson to that of the additional scalar boson. By so doing, he has obtained the following results: (1) The mass of the usual weak boson is arbitrary. (2) In order to cancel the logarithmic divergence of the electromagnetic self-mass of leptons against that of the weak self-mass, the additional scalar boson with a negative metric must have the universal mass proposed by the present author. Furthermore, he has predicted the mass of the usual weak boson to be $(9e^2/\sqrt{2}G)^{1/2} \simeq 238.4M_p$ by making an additional assumption which seems less reliable. Finally, we should mention the remark made by Haller, Landovitz, and Goldberg[16] that for very massive bosons, i.e., $M_{W^\pm} \gg (6\sqrt{2}\pi/G)^{1/2} \simeq 1612M_p$, the indefinite metric of the space does not conflict with requirements of probability conservation.

A list of the predicted values of the intermediate-boson mass is presented in Table I. By glancing at the table, one can make the following observation: There exists a peculiar coincidence, namely, the mass given by Lee[8] and the one given by the present author[12] are both very close to $\alpha^{-1}M_p \simeq 128.6$ GeV. Notice that these two predictions are the direct consequences of two completely independent assumptions. The quantity $\alpha^{-1}M_p$ is reminiscent of Nambu's proposition[17]: The masses of the elementary particles heavier than the electron are given by the following rule. If they are bosons, their masses are close to an integer (n) times the so-called Nambu unit, $\alpha^{-1}M_e \simeq 70.03$ MeV, where M_e is the electron mass; if fermions, their masses are close to a half integer (n) times the same unit. For the stable particles, we find that his rule still

TABLE II. Comparison between the masses of the stable particles predicted by Nambu's proposition and those from the present experimental data.

	η	Predicted (GeV)	Experimental (GeV)
μ	$\frac{3}{2}$	0.1050	0.1057
π	2	0.1401	0.1396 ($\pi^\pm$) 0.1350 (π^0)
K	7	0.4902	0.4938 ($K^\pm$) 0.4978 (K^0)
(η	8	0.5602	0.549)
N	$\frac{27}{2}$	0.9454	0.9383 (p) 0.9396 (n)
Λ	16	1.120	1.116
Σ	17	1.191	1.189 (Σ^+) 1.192 (Σ^0) 1.197 (Σ^-)
Ξ	19	1.331	1.315 (Ξ^0) 1.321 (Ξ^-)
Ω	24	1.681	1.673

agrees with the present data[18] with very good accuracy if we ignore the distinction between bosons and fermions heavier than the nucleon (see Table II).[19] Remembering that the electron and the proton are the only known massive particles that are stable in a strict sense, we prefer to give a special meaning to the quantity $\alpha^{-1}M_p$ in analogy to the interpretation given by Nambu to the unit $\alpha^{-1}M_e$. Therefore, there is some sense in taking the above-mentioned coincidence seriously to obtain

$$(3e^2/\sqrt{2}G)^{1/2} = [(4\sqrt{2}\,e^2 \sec^2\theta)/3G]^{1/2} = \alpha^{-1}M_p. \tag{1}$$

These equalities give the following two independent relations:

$$\alpha = (GM_p{}^2/6\sqrt{2}\,\pi)^{1/3} \simeq 1/137.5 \tag{2}$$

and

$$\sin\theta = \tfrac{1}{3}, \tag{3}$$

both of which are not far from agreement with the experimental data.

Unfortunately, even if heavy particles having mass of the order $\alpha^{-1}M_p$ exist, they cannot be produced by the presently available accelerators and will not be able to be produced even by the National Accelerator Laboratory machine, which will have a maximum laboratory energy of 500 GeV. Only cosmic-ray experiments will be in a position to detect them until either a colliding-beam machine with total c.m. energy greater than 130 GeV or a proton synchrotron with laboratory energy greater than 10 000 GeV becomes available.

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