

# Masses of Weak and Higgs Bosons as Composites

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**Abstract:** We show that the masses of weak and Higgs bosons as composite systems of basic hidden particles, estimated under hypothetical hidden couplings, are consistent with the experimental masses. This coupling can also yield the finite self-energy of the electron and the weak interaction. We predict a charged Higgs boson with a mass of about 113 GeV. The essential boson for producing mass is shown to be the basic hidden scalar boson, which is a constituent of the Higgs boson.

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## 1 Introduction

The ATLAS and CMS collaborations have recently reported that the LHC experiment detected Higgs bosons with a mass of 124–126 GeV [1–5]. According to the standard model, the Higgs boson induces particle mass, but the physics of the Higgs field is not yet clear. Therefore, it is useful to investigate this mass problem from another standpoint. Here, we propose a theory beyond the standard model and speculate that the origins of mass and decay should be equivalent because the mass changes during the decay of an unstable particle.

On the other hand, according to astronomy, most of the universe is occupied by dark matter and dark energy, which should play an important role in the cosmic structure. In analogy with this, we previously proposed a hypothetical hidden

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coupling mediated by a hidden scalar boson that can produce mass and a weak interaction. The resulting mass values compare favorably with experimental particle data [6–9]. However, the masses estimated by our theoretical expansion, which considers the weak and Higgs bosons as composites of basic particles, deviate from current data [9–12].

In this study, we re-estimate the masses of the weak and Higgs bosons in such a way that our expansion of the gauge boson ensures that the W boson mass fits the experimental data. We then deduce favorable masses for the Z and Higgs bosons corresponding to current data. Consequently, we predict the existence of a charged Higgs boson with a mass of about 113 GeV. Our aim in this study is to show that the essential boson yielding mass is not the Higgs boson itself but rather the hidden scalar boson, which is a constituent of the Higgs boson.

## 2 Fundamental hidden coupling

We have speculated that there are both real and hidden particles. The basic particles are leptons  $l_\lambda$  ( $\lambda = e, \mu, \tau$ ); the proton p; hidden neutrinos  $h_\lambda$ , which may be the light Majorana neutrino; and the hidden scalar boson  $\phi(\phi^0, \phi^-)$ , which has mass  $M(M_0, M_-)$  and exchanges real and hidden particles. Furthermore, a new quantum number  $z$  was assigned to these particles, namely,  $z = 1$  for p;  $z = 0$  for muonic leptons and  $h_\mu$ ;  $z = -1$  for electronic leptons,  $h_e$ , and  $\phi$ ; and  $z = -2$  for tauonic leptons and  $h_\tau$  [6–9].

The hidden particle is postulated to be a hypothetical particle that we cannot directly observe, but we can indirectly understand its existence by hidden couplings, which can deduce interactions through the composite structure of the intermediate boson.

We then assume the following hidden couplings  $K_i$  between  $h_\lambda$  and the proton or leptons, considering the connection between mass and the weak interaction [9, 12]:

$$K_1 = (f/\sqrt{2})[\bar{h}_\mu O_- l_e \phi^* + \bar{l}_e O_+ h_\mu \phi], \quad (1)$$

$$K_2 = (f/\sqrt{2})[\bar{h}_e O_- \nu_\mu \phi^0 + \bar{\nu}_\mu O_+ h_e \phi^{0*}], \quad (2)$$

$$K_3 = (f/\sqrt{2})[\bar{h}_e O_- l_\tau \phi^* + \bar{l}_\tau O_+ h_e \phi], \quad (3)$$

$$K_4 = (f/\sqrt{2})[\bar{h}_\tau O_- \nu_e \phi^0 + \bar{\nu}_e O_+ h_\tau \phi^{0*}], \quad (4)$$

$$K_5 = (f/\sqrt{2})[\bar{h}_\mu O_{-A} p \phi^- + \bar{p} O_{+A} h_\mu \phi^{-*}], \quad (5)$$

$$O_\pm = 1 \pm \gamma_5, \quad O_{\pm A} = 1 \pm C_A^\pm \gamma_5,$$

$$C_A^+ C_A^- = 1, \quad C_A^+ + C_A^- = 2C_A, \quad (6)$$

where  $C_A$  is the renormalization factor of the axial vector current of the proton. The total  $z$  number and charge at each vertex of these couplings are conserved. Note that there is no  $\phi^+(z = -1)$  term, but  $\phi^+(z = 1) = \phi^{-*}$ .

The coupling constant  $f$  is determined so that the self-energy of the electron is finite. According to coupling (1) and Fig. 1a, the self-energy of the electron is given by

$$\Delta m_\phi = [f^2 m_e / (4\pi)^2] [\ln(\Lambda/M_-) - 1/4]. \quad (7)$$

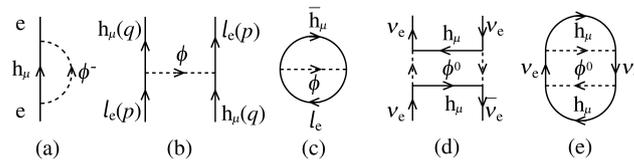
On the other hand, the self-energy given by the electromagnetic interaction in quantum electrodynamics is

$$\Delta m_\gamma = [3\alpha m_e / (4\pi)] [2\ln(\Lambda/m_e) + 1/2]. \quad (8)$$

To cancel the divergence  $\Lambda$  from the sum of (7) and (8), we assume [6–8]

$$f^2/4\pi = -6\alpha. \quad (9)$$

Under condition (9), the couplings (1)–(5) are not Hermitian conjugates, so these couplings are not observable. This is expected because they define interactions between real particles and hidden particles that we cannot observe. The hidden particle is believed to be a type of dark matter, which can be detected indirectly by the curvature of space-time. Thus, we assume that the hidden particles  $h_\lambda$  and  $\phi$  cannot be observed owing to their finite electromagnetic self-energy. The boson  $\phi$  interchanges real and hidden particles. The resultant particle mass and interaction Hamiltonian will indirectly verify the existence of these couplings.



**Fig. 1** Diagrams illustrating (a) the self-energy of the electron according to coupling (1), (b,c) the equivalent internal energies between  $l_e$  and  $h_\mu$ , and (d, e) the equivalent internal energies for the neutrino pairs in a composite system because initial and final states are equal like those in Fig. 1b.

### 3 Pion mass and electroweak interaction

To study the hidden couplings [1–5], we assume a different composite model of pion based on the quark model as follows. To determine the hidden boson mass  $M$ , we estimate the mass of the pion, which is a composite of the basic fermions corresponding to the decay products [6–8]. We assume pions to be composite systems  $\pi^- = (e\bar{\nu}_e h_\mu \bar{h}_\mu)$  and  $\pi^0 = (\nu_e \bar{\nu}_e h_\mu \bar{h}_\mu)$ , considering the conservation of lepton number.

In a composite system, the final state resulting from the interaction process between the constituents must be equal to the initial state. This process is possible for hidden couplings and will be repeated so a composite state is conserved until

it decays. For example, coupling (1) for  $l_e$  and  $h_\mu$  produces equal initial and final states, as shown in Fig. 1b. Thus, the line representing the initial particle connects with that representing the final particle and forms a loop, as shown in Fig. 1c. Similarly, the coupling for a neutrino pair can produce a final state that is equal to the initial state, as shown in Fig. 1d, forming a loop, as shown in Fig. 1e. The internal energies between the constituents are then given by couplings (1)–(4) and Figs. 1b–e, in consideration of the lepton helicity, as follows [6–9, 12]:

$$E(l_e \bar{h}_\mu) = (6\alpha/r) \exp(-Mr) = V(r), \quad (10)$$

$$E(\nu_\lambda \bar{\nu}_\lambda) = E(h_\lambda \bar{h}_\lambda) = [3(6\alpha/M_0)^2/2]\delta(r). \quad (11)$$

When the pion has the expansion  $r = r_1$ , (11) vanishes, and the pion masses are then given as [6–8]

$$m(\pi^-) = V_1^- + V_1^0 + m_e, \quad m(\pi^0) = 2V_1^0, \quad (12)$$

$$V_1^s = (6\alpha/r_1) \exp(-M_s r_1), \quad s = 0, -. \quad (13)$$

If these masses are equal to the experimental masses  $m(\pi^-) = 139.6 \text{ MeV}$  and  $m(\pi^0) = 135.0 \text{ MeV}$ , then we have

$$M_0 = 15.3 \text{ GeV}, \quad M_- = 14.9 \text{ GeV}, \quad (14)$$

$$r_1 = 1/7.4 m_p, \quad (15)$$

considering the Fermi weak coupling constant (19) [6–8]. The expansion (15) may be associated with the fractional charge of the quark [9].

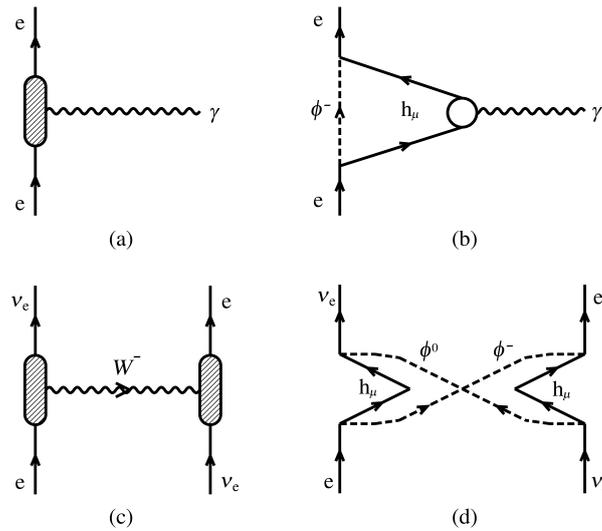
As shown in Figs. 1c and 1e, two fermions form a bubble in a composite. Therefore, the internal energy is generally the bubble energy induced by  $\phi$ . Thus, we can speculate that a lepton or hidden neutrino would behave as if it had the internal energy as effective mass in the composite system. Using this composite model, we have deduced that the hadron masses are in fair agreement with the experimental data [6–9].

However, there remains the question of why such a composite system is metastable. The answer is as follows. In a charged system satisfying (1), the component pair  $(h_\mu \bar{h}_\mu)$  can create an electron pair mediated by virtual  $\phi^-$  particles with probability  $P_1$  that is proportional to  $f^4$ . Then, one can suppose the following potential:

$$U_n(r) = (n/2)V(r)(1+c) - \alpha/r, \quad (16)$$

where  $n$  is the number of  $\phi$  particles between constituents and  $c$  is the higher order correction factor of (10) [9]. The charged particle vibrates inside the valley of the potential in (16), and it will be in a stable state at the minimal point  $r_n$  given by

$$\exp(Mr_n) = 3n(1 + Mr_n)(1 + c). \quad (17)$$



**Fig. 2** Correspondence of interactions in our hidden model to the standard model (SM). The electromagnetic interaction diagrams of the electron in (a) SM and (b) our hidden model. Diagrams of the Fermi weak interaction between the electron and electronic neutrino in (c) SM and (d) our hidden model.

As the condition to form a composite is  $1/3 \leq n \leq 4$ , we assume the quantum number for the expansion of the system

$$n = 1/3, 1/2, 1, 2, 4, \quad (18)$$

which yields, e.g.,  $r_{1/2} = 0.074/m_p$ ,  $r_2 = 0.198/m_p$ , and  $r_4 = 0.253/m_p$ . These ranges will give the favorable composite masses listed in Table I.

Similarly, in a neutral system, the component neutrino pair can create an electron pair with probability  $P_2$ , which is proportional to  $f^8$ , through virtual  $(h_\mu \bar{h}_\mu)$  particles as per (1). Therefore, the neutral bubble will vibrate inside the valley of the potential in (16) with the probability  $P_1 P_2$ . Hence, the lifetime of the neutral composite will be shorter than that of the charged composite, except for the system including pairing charged particles.

Next, we show that the electroweak interaction can be deduced from hidden couplings through the composite structure of the photon and weak boson. L. de Broglie proposed that the photon is composed of a neutrino pair [13]. We then suppose that the photon has a similar structure, as shown in Fig. 1e. Because of (11), this system will have a vanishing mass for the nonlocal structure if the essential mass  $m(\nu_\lambda) = 0$ . Thus, the electromagnetic interaction Hamiltonian of the electron is given approximately by [9, 11]

$$H_{\text{em}} = e_1 (\bar{e}_L \gamma_\mu e_L) A_\mu, \quad (19)$$

$$e_1 = (3\alpha/\pi) \ln(M_P/M_-) = 0.95e_0, \quad (20)$$

from (1), (2), (9), and Fig. 2b, where the Planck mass  $M_P$  is a cutoff momentum,

and  $e_0$  is the elementary charge.

On the other hand, the Fermi weak interaction Hamiltonian between the electron and electronic neutrino is similarly given by Fig. 2d as

$$H_W = (G_F/\sqrt{2})(\bar{e}_L\gamma_\mu\nu_{eL})(\bar{\nu}_{eL}\gamma_\mu e_L), \quad (21)$$

$$G_F/\sqrt{2} = (6\alpha/M)^2 \quad (22)$$

at the low-energy limit. The charged and neutral current interaction Hamiltonians can be similarly deduced from the composite structures of the weak bosons, which are defined below [9, 12].

In Table I, we list some examples of particle masses evaluated using our composite model, e.g.,  $n = (p e \bar{\nu}_e)$  by Heisenberg,  $K$  or  $\eta = (\pi \pi)$ , and  $\Sigma = (n \pi)$  [6, 9].

**Table 1** Examples of particle masses evaluated under our composite model.

Particle	Number for expansion	Experimental mass(MeV) <sup>a</sup>	Theoretical mass (MeV)
$K^+$	1, 4	494	487
$\eta$		547	539
$n$	1/2	939.6	939.4
$\Sigma^0$	1, 2	1193	1185
$\Xi^0$		1315	1311
$\psi(1S)$	1/2, 1	3097	3197
$\psi(2S)$		3686	3790
$B^-$		5279	5316
$\Upsilon(1S)$		9460	9622
$\Upsilon(3S)$		10355	10522

<sup>a</sup>Reference [15].

## 4 W boson

The charged current interaction, e.g., the  $e - \nu_e$  scattering process, according to the standard theory is illustrated in Fig. 2c. This interaction can also be interpreted as Fig. 2d under (1) [10, 11]. Therefore, we can treat W bosons as composites:

$$W_\lambda^+ = (\phi^{-*} h_\lambda \bar{h}_\lambda \phi^0), \quad W_\lambda^- = (\phi^- h_\lambda \bar{h}_\lambda \phi^{0*}), \quad \lambda = e, \mu, \tau. \quad (23)$$

These masses should be given by the sum of the internal energies under hidden couplings (1)–(5) and the component masses. Similar to the pion case, the initial

and final states are equal, as shown in Figs. 3–6. Using (1)–(5) and (9), we can obtain the positive internal energies  $E_{11}$  from diagrams similar to Fig. 1c, and we can obtain  $E_{12}$  and  $E_2$  from those similar to Fig. 1e.

If the expansion of the weak boson is  $r_0$ , then we have the following internal energies from Figs. 3a–3f and Fig. 4:

$$E(\phi^* h_\mu) = E(\phi h_\mu) = E_1 = E_{11} + E_{12}, \quad (24)$$

$$E_{11} = (6\alpha/r_0) \exp(-mr_0),$$

$$E_{12}^s = [(6\alpha)^2/\pi r_0] \times \int_0^1 \exp[-M_s r_0 \sqrt{1 + (1 - xy)/(1 - x)}] \times x dx dy / (1 - x),$$

$$E_2^s = E(\phi^{s*} \phi^s) = [(6\alpha)^2/\pi r_0] \exp(-M_s r_0) \ln(M_P/M_s), \quad (25)$$

where  $m$  is the virtual fermion mass, and the Planck mass  $M_P$  is the cutoff momentum. For example, the mass of  $W_\mu^+$  is given by

$$\begin{aligned} m(W_\mu^+) &= E(\phi^{-*} h_\mu) + E(\phi^{-*} \bar{h}_\mu) + E(\phi^0 h_\mu) \\ &\quad + E(\phi^0 \bar{h}_\mu) + E(\phi^{-*} \phi^0) + E(h_\mu \bar{h}_\mu) \\ &\quad + M_0 + M_- + \Delta m_w \\ &= E_{1(p)}^- + E_{11(p)}^- + E_1^- + E_{11}^- + E_1^0 + E_{11}^0 \\ &\quad + 2E_2^{0-} + M_0 + M_- + \Delta m_w, \end{aligned} \quad (26)$$

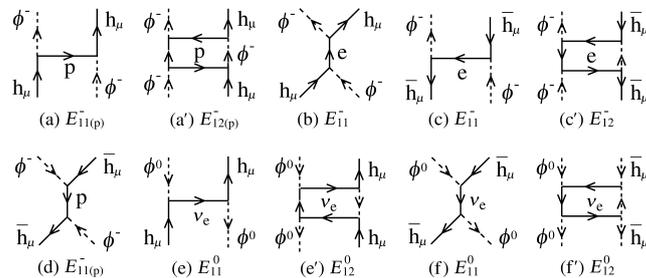
$$E_1^s = E_{11} + E_{12}^s,$$

$$E_{1(p)}^- = E_{11(p)}^- + E_{12(p)}^- = aE_{11}^- + bE_{12}^-,$$

$$E(\phi^{-*} \phi^0) = 2E_2^{0-} = E_2^0 + E_2^-,$$

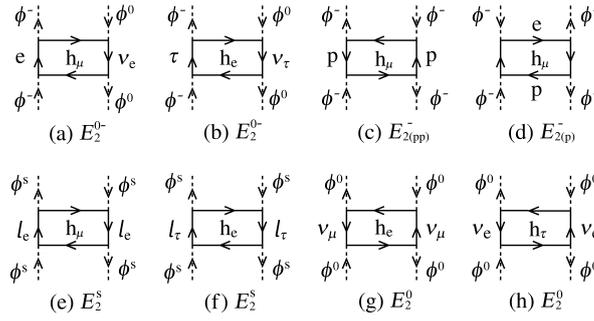
$$a = (1 + C_A)/2, \quad b = (1 + C_A^2)/2,$$

where  $\Delta m_w = (0.033 - 0.039)m(W)$  is the self-energy of  $W$  predicted by Sirlin [14].



**Fig. 3** Internal interactions between hidden bosons and neutrinos, which are constituents of  $W_\mu$  and  $Z_\mu$ .

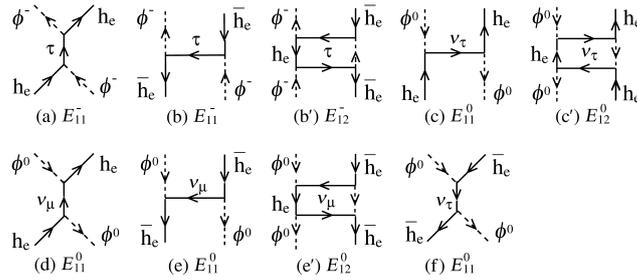
We then have  $m(W_\mu^-) = m(W_\mu^+)$ . Similarly, according to couplings (2)–(4) and Figs. 4–6, we have the following masses of  $W_e$  and  $W_\tau$ :



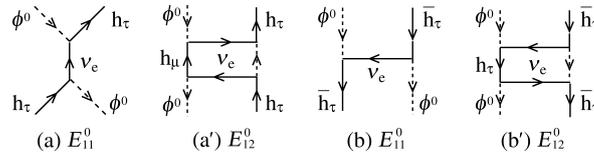
**Fig. 4** Internal interactions between two hidden bosons.

$$m(W_e) = E_1^- + E_{11}^- + 2(E_1^0 + E_{11}^0 + E_2^{0-}) + M_0 + M_- + \Delta m_w, \quad (27)$$

$$m(W_\tau) = 2(E_1^0 + E_2^0) + M_0 + M_- + \Delta m_w. \quad (28)$$



**Fig. 5** Internal interactions between the constituents of  $W_e$  and  $Z_e$ .



**Fig. 6** Internal interactions between the constituents of  $W_\tau$  and  $Z_\tau$ .

If the expansion of the weak boson is

$$r_{1/3} = r_0 = 1/194m_p, \quad (29)$$

the internal energies are, e.g.,  $E_{11} = 7.972$  GeV,  $E_1^0 = 8.405$  GeV,  $E_2^0 = 4.205$  GeV,  $E_2^- = 4.217$  GeV, and  $E_{12}^- = 0.442$  GeV. Thus, the bare masses of  $W_\lambda$  are 89.71 GeV for  $W_\mu$ , 87.76 GeV for  $W_e$ , and 55.43 GeV for  $W_\tau$  from (14) and (24)–(29) because  $C_A = 1.24$ . We suppose that the component pair  $(\bar{h}_\lambda h_\lambda)$  continuously oscillates

between the three  $\lambda$  generations, with equal possibilities in the composite state of hidden particles that we cannot observe. Hence, the mean mass of  $W$  is

$$m(W) = [m(W_\mu) + m(W_e + m(W_\tau))]/3 = (80.2 - -80.7) \text{ GeV}, \quad (30)$$

which is consistent with the experimental mass of  $m(W) = 80.419 \pm 0.056 \text{ GeV}$  [15].

## 5 Z boson

We suppose that the  $Z$  boson consists of the following composite, similar to the  $W$  boson case:

$$Z_\lambda^0 = (\phi^{0*} h_\lambda \bar{h}_\lambda \phi^0) \text{ or } Z_\lambda^- = (\phi^{-*} h_\lambda \bar{h}_\lambda \phi^-). \quad (31)$$

According to Figs. 3–6, the masses of these composites are

$$m(Z_\mu^0) = 3E_1^0 + E_{11}^0 + 4E_2^0 + 2M_0, \quad (32)$$

$$m(Z_\mu^-) = 2(E_1^- + E_{1(p)}^-) + E_{11}^- + E_{11(p)}^- + \Sigma E_2^- + 2M_-, \quad (33)$$

$$m(Z_e^0) = 4(E_1^0 + E_{11}^- + E_2^0) + 2M_0, \quad (34)$$

$$m(Z_e^-) = 2(E_1^0 + E_{11}^-) + \Sigma E_2^- + 2M_-, \quad (35)$$

$$m(Z_\tau^0) = 4(E_1^0 + E_2^0) + 2M_0, \quad (36)$$

$$\begin{aligned} \Sigma E_2^- &= 2E_2^- + E_{2(p)}^- + E_{2(pp)}^- \\ &= (2 + a + b)E_2^-. \end{aligned} \quad (37)$$

The boson  $Z_\tau^- = (\phi^{-*} h_\tau \bar{h}_\tau \phi^-)$  does not exist because there is no coupling between  $h_\tau$  and  $\phi^-$ . From (25) and (31)–(37), we have the theoretical masses  $m(Z_\mu^0) = 80.61 \text{ GeV}$ ,  $m(Z_\mu^-) = 101.66 \text{ GeV}$ ,  $m(Z_e^0) = 112.93 \text{ GeV}$ ,  $m(Z_e^-) = 81.04 \text{ GeV}$ , and  $m(Z_\tau^0) = 81.07 \text{ GeV}$ . Thus, the mean mass of  $Z$  is

$$m(Z) = [m(Z_\mu^0) + m(Z_\mu^-) + m(Z_e^0) + m(Z_e^-) + m(Z_\tau^0)]/5 = 91.5 \text{ GeV}, \quad (38)$$

which is close to the experimental mass of  $m(Z) = 91.1882 \pm 0.0022 \text{ GeV}$  [15]. These results imply that the expansion of the gauge boson in (29) is fairly reasonable.

## 6 Higgs boson

According to the standard theory, the Higgs boson yields the particle mass; however, our hidden scalar boson  $\phi$  can produce many particle masses [6, 7, 9–11]. If Higgs boson was a composite  $(\phi^0 \bar{\phi}^0)$ , this mass would be  $2(M_0 + E_2^0) = 39 \text{ GeV}$ , which is too small to fit the LHC data. Considering that the composite structures of the pion and weak boson consist of two particle pairs, we assume that the Higgs boson

is composed of two particle pairs. Therefore, we suppose that the Higgs boson is composed of our hidden scalar bosons:

$$\begin{aligned} H_1^0 &= (\phi^{0*} \phi^0 \phi^{0*} \phi^0), & H_2^0 &= (\phi^{-*} \phi^- \phi^{0*} \phi^0), \\ \text{or } H_3^0 &= (\phi^{-*} \phi^- \phi^{-*} \phi^-). \end{aligned} \quad (39)$$

Each constituent of these scalar bosons has a hidden characteristic that produces mass. From Fig. 4, these masses are given as

$$\begin{aligned} m(H_1^0) &= 4(4E_2^0 + M_0), \\ m(H_2^0) &= 4(E_2^{0-} + E_2^0) + \Sigma E_2^- + 2(M_0 + M_-), \\ m(H_3^0) &= 4(\Sigma E_2^- + M_-). \end{aligned} \quad (40)$$

Then, if (25) is used, the mean mass will be given by

$$\begin{aligned} m(H) &= [m(H_1^0) + m(H_2^0) + m(H_3^0)]/3 \\ &= 124.9 \text{ GeV}, \end{aligned} \quad (41)$$

which is consistent with the present data of 124–126 GeV [1]. This implies that the expansion of the Higgs boson is equal to that of the weak boson. Furthermore, we can consider a charged Higgs boson as

$$H_1^+ = (\phi^{-*} \phi^0 \phi^{0*} \phi^0) \text{ or } H_2^+ = (\phi^{-*} \phi^0 \phi^{-*} \phi^-). \quad (42)$$

These will then have the following masses:

$$\begin{aligned} m(H_1^+) &= 2(4E_2^0 + 2E_2^{0-}) + 3M_0 + M_-, \\ m(H_2^+) &= 2(\Sigma E_2^- + 2E_2^{0-}) + 3M_- + M_0, \end{aligned} \quad (43)$$

and (25) gives the mean mass as

$$m(H^\pm) = [m(H_1^\pm) + m(H_2^\pm)]/2 = 112.6 \text{ GeV}. \quad (44)$$

We cannot directly detect the essential mass generator  $\phi$  that is not observable. However, the Higgs boson can be produced as the composite of mass generators by the LHC experiment.

## 7 Conclusions

Under hypothetical hidden couplings, which are not observable, we showed that the masses of the weak and Higgs bosons are consistent with the experimental data when these composites are given using the expansion in (29). The probabilities  $P_1$  and  $P_2$  of creating an electron pair in the charged and neutral systems must be estimated to study the connection with the lifetimes of pions. Furthermore, these hidden couplings can produce the electroweak interaction through the composite

structures of the photon and weak boson. It is important to note that any weak or Higgs bosons that can be produced consist of two pairs of basic particles. Moreover, we predicted a charged Higgs boson mass of about 113 GeV. If the LHC experiment can confirm this boson, our composite model would be verified. In other words, this confirmation would indicate that the Higgs boson is a unique particle including only mass generators because its constituents cannot be observed. The nature of the Higgs field may be connected with these hidden couplings. Thus, it might be reasonable to consider that there are real and hidden particles mediated by a hidden scalar boson that induces mass. Furthermore, we have previously shown that the masses of many hadrons and baryons consisting of composites of basic particles, which are deduced from hidden couplings, compare favorably with the experimental masses, although some topics remain as future studies [6–9]. Consequently, we can conclude that the essential mass generator is the hidden scalar boson defined by couplings (1)–(5), which should induce broken symmetry.

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