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# Excess Higgs to gauge boson couplings

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**Abstract** – We predict slightly enhanced signal strengths in the Higgs coupling to the intermediate $W$ and $Z$ gauge bosons with a three percent excess relative to those of the Standard Model. The base of the prediction is a slightly different electroweak energy scale. The modified electroweak energy scale follows from an intrinsic conception of baryon dynamics that links to electroweak decays. Here electroweak interactions are fostered by a spontaneous symmetry break in baryonic configurations described on an intrinsic $U(3)$ configuration space. The electroweak flavour degrees of freedom become intermingled with the colour degrees of freedom via a spontaneous $U(2)$ pairing of two toroidal degrees of freedom in the intrinsic dynamics. The intrinsic potential thereby shapes the Higgs potential. This leads to the up-down quark mixing matrix element modifying the gauge boson couplings relative to the Standard Model expectations.



**Introduction.** – The Standard Model of particle physics [1] relies on the Higgs mechanism [2–5] to lend masses to three of its four gauge fields. The sizes of the masses $m_{\mathrm{W}}$ and $m_{\mathrm{Z}}$ of the related field quanta follow from the strengths of the coupling constants of the electroweak theory and from the size of the electroweak energy scale. In the same token follow the couplings to the Higgs particle of the three massive gauge fields $W^{\pm}, Z$. The crucial parameters are two coupling strengths $g, g'$ in the electroweak Lagrangian and two coefficients $\mu, \lambda$ in the Higgs potential [6] together with the electroweak energy scale $v$ related to the vacuum expectation value $\varphi_0 = v/\sqrt{2}$ of the Higgs field after symmetry break. The first four of these parameters are usually considered as independent fitting parameters with $v$ to follow from $\mu$ and $\lambda$. Experimentally $v_{\mathrm{SM}}$ is determined from the Fermi coupling constant $G_{\mathrm{F}\mu}$ in muon decay and $\mu$ is determined from the Higgs mass. The relation among $v, \mu$ and $\lambda$ can then be used to predict the experimental value of $\lambda$ which determines the Higgs self-coupling.

In the present work we make do with just two parameters, namely the fine structure coupling $\alpha$ to set the coupling strengths and the electron mass $m_e$ at the base of the energy scale. This is possible by connecting strong and electroweak scales and structures and in that way settle the scale and the shape of the Higgs potential. We settle the electroweak scale by fitting the Higgs potential to an intrinsic potential from baryon dynamics where flavour degrees of freedom get intermingled with colour degrees of freedom. This leads to the relations [7]

$$\frac{v}{\sqrt{2}} = \frac{2\pi}{\alpha(m_W)} \frac{\pi}{\alpha_e} m_e c^2 \tag{1}$$

and

$$\mu = m_H c^2 = \frac{1}{\sqrt{2}} \frac{2\pi}{\alpha(m_W)} \frac{\pi}{\alpha_e} m_e c^2. \tag{2}$$

The Standard Model electroweak scale $v_{\mathrm{SM}}$ comes out as

$$\sqrt{\frac{\hbar c^3}{G_{\mathrm{F}\mu}\sqrt{2}}} \equiv v_{\mathrm{SM}} = v\sqrt{V_{ud}} \tag{3}$$

because our $v$ is determined from neutron beta decay where the Fermi constant is

$$G_{\mathrm{F}\beta} = G_{\mathrm{F}\mu} V_{ud}. \tag{4}$$

The relation (4) is most easily understood from an effective Lagrangian for beta decay described on p. 311 in [8],

$$\frac{G_{\mathrm{F}}}{\sqrt{2}}[\overline{e}\gamma_\lambda(1+\gamma_5)\nu_e+\overline{\mu}(1+\gamma_5)\nu_\mu]J^\lambda+\text{ h.c.}, \qquad (5)$$

where "h.c." stands for the Hermitian conjugate and where the hadronic "current" is

$$J^\lambda=\begin{pmatrix}\overline{u}\\ \overline{c}\\ \overline{t}\end{pmatrix}^T\gamma^\lambda(1+\gamma_5)V\begin{pmatrix}d\\ s\\ b\end{pmatrix} \qquad (6)$$

with quark mixing matrix [1,9]

$$V=\begin{pmatrix}V_{ud} & V_{us} & V_{ub}\\ V_{cd} & V_{cs} & V_{cb}\\ V_{td} & V_{ts} & V_{tb}\end{pmatrix}. \qquad (7)$$

The matrix element $V_{ud}$ generalizes the Cabibbo angle term $\cos\theta_{\mathrm{C}}\approx V_{ud}$ in

$$J^\lambda=\overline{u}\gamma^\lambda(1+\gamma_5)d\cos\theta_{\mathrm{C}}+\overline{u}\gamma^\lambda(1+\gamma_5)s\sin\theta_{\mathrm{C}} \qquad (8)$$

from before beauty $b$ and top flavours $t$ were introduced.

For the signal strength of the Higgs to gauge bosons relative to the Standard Model we find in the present work

$$\mu_{HWW}=\mu_{HZZ}=\left(\frac{v}{v_{\mathrm{SM}}}\right)^2=\frac{1}{V_{ud}}\approx 1.03. \qquad (9)$$

We thus expect a three percent excess in the $H\to WW^*$ and $H\to ZZ^*$ signal strengths.

**From strong to electroweak energy scale.** – Our strong energy scale $\Lambda=\hbar c/a$ is introduced from a model for the baryon mass spectrum where baryons are considered as stationary states on an intrinsic $U(3)$ configuration space [10],

$$\frac{\hbar c}{a}\left[-\frac{1}{2}\Delta+\frac{1}{2}d^2(e,u)\right]\Psi(u)=\mathcal{E}\Psi(u). \qquad (10)$$

The configuration variable $u\in U(3)$ is excitable by nine generators $T_j,S_j,M_j,j=1,2,3$ related to kinematic generators in laboratory space. Thus,

$$u=e^{i(\theta_jT_j+\alpha_jS_j/\hbar+\beta_jM_j/\hbar)},\qquad \theta_j,\alpha_j,\beta_j\in\mathbb{R} \qquad (11)$$

with diagonal colour generators $iT_j$ proportional to parametric momenta $p_j$,

$$iT_j=\frac{\partial}{\partial\theta_j},\qquad p_j=-i\hbar\frac{1}{a}\frac{\partial}{\partial\theta_j}. \qquad (12)$$

The off-diagonal generators are $S_j$ for intrinsic spin and $M_j$ are like Laplace-Runge-Lenz generators (see p. 236 in [11]) and take care of flavour, *e.g.*,

$$S_3=a\theta_1p_2-a\theta_2p_1,\qquad M_3/\hbar=\theta_1\theta_2+\frac{a^2}{\hbar^2}p_1p_2. \qquad (13)$$

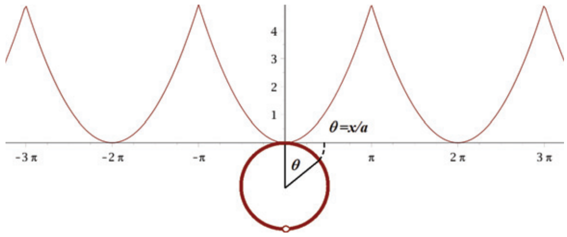


Fig. 1: Projection from intrinsic space to periodic potential (16) in parameter space. The length scale $a$ for baryon dynamics is $\approx 1\,\mathrm{fm}$. Figure taken from [12].

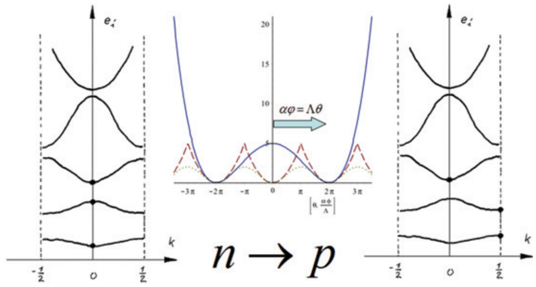


Fig. 2: Left and right: reduced zone schemes (p. 160 in [13]) for Bloch wave numbers $\kappa$ for the neutron state (left) and the proton state (right) [7]. Middle: Higgs potential (solid, blue line) matching the Manton-inspired potential [14] (dashed, red line) and the Wilson-inspired potential [15] (dotted, green line). The Manton- and Wilson-inspired potentials yield the same value for the Higgs mass and the electroweak energy scale, whereas only the Manton-inspired potential gives a satisfactory reproduction of the baryon spectrum [7]. Figure adapted from [16].

The potential

$$\frac{1}{2}d^2(e,u)=\frac{1}{2}\mathrm{Tr}\;\chi^2,\qquad u=e^{i\chi} \qquad (14)$$

is half the squared shortest geodetic distance from the neutral element $e$ of $U(3)$, *i.e.*, the *origo* of the space of the dynamical (angular) variables $\theta_j,\alpha_j,\beta_j$. The potential only depends on the eigenvalues $e^{i\theta_j}$ of $u$ because these are unchanged by diagonalization as is the trace. The potential can therefore be expressed as a sum of periodic potentials $w$ depending only on the *eigenangles* $\theta_j$ as

$$\frac{1}{2}d^2(e,u)=\sum_{j=1}^{3}w(\theta_j), \qquad (15)$$

where (see fig. 1)

$$w(\theta)=\frac{1}{2}(\theta-n2\pi)^2,\qquad \theta\in[(2n-1)\pi,(2n+1)\pi],\quad n\in\mathbb{Z}. \qquad (16)$$

The periodicity of the potential opens for a spontaneous symmetry break of the wave function $\Psi$ by introducing Bloch wave functions. We take this symmetry break, which introduces an extra winding in the wave function, to be related to the creation of electric charge, *e.g.*, in the $n\to p$ decay and to be mediated by the Higgs mechanism.

Strictly speaking we see the Higgs potential as shaped to forth order by the periodic intrinsic potential (16), see fig. 2.

We get the length scale $a$ from the classical electron radius $r_e$ as a projection of the intrinsic toroidal degrees of freedom, see fig. 1,

$$x_j = a\theta_j. \tag{17}$$

Thus,

$$r_e = a\pi, \quad \frac{e^2}{4\pi\epsilon_0 r_e} \equiv m_e c^2. \tag{18}$$

We think heuristically of the electron as a "peel-off" from the neutron, leaving a "charge-scarred" proton [10]. If we stay in this topological picture, we should note that the structure in the peeling-off is guided by the centrifugal potential

$$C = \sum_{i<j,k\neq i,j}^{3} \frac{(S_k^2 + M_k^2)/\hbar^2}{8\sin^2\frac{1}{2}(\theta_i - \theta_j)} \tag{19}$$

hidden in the Laplacian [17]

$$\Delta = \sum_{j=1}^{3} \frac{1}{J^2}\frac{\partial}{\partial\theta_j} J^2 \frac{\partial}{\partial\theta_j} - \sum_{i<j,k\neq i,j}^{3} \frac{(S_k^2 + M_k^2)/\hbar^2}{8\sin^2\frac{1}{2}(\theta_i - \theta_j)}. \tag{20}$$

Here the "Jacobian"

$$J = \prod_{i<j}^{3} 2\sin\frac{1}{2}(\theta_i - \theta_j) \tag{21}$$

scales the measure on the intrinsic space as seen from parameter space. The Jacobian secures a uniform probability distribution for the characteristic function $u \to 1$ on the Lie group configuration space when represented in the parameter space.

The centrifugal potential (19) is only integrable if the spontaneous symmetry breaks in the wave function parametrization run pairwise as period doublings in the toroidal angles $\theta_j$, *i.e.*, the $U(2)$ of the Higgs mechanism is "born" from a subspace of $U(3)$.

In the decay

$$n \to p + e + \overline{\nu}_e, \tag{22}$$

we assume an exchange of one quantum of action $h$ from the strong interaction dynamics into the electroweak Higgs sector through the fine structure coupling $\alpha$. Thus, a $2\pi$ shift in a dynamical eigenangle $\theta$ from one trough in the potential to the neighbouring corresponds to a spontaneous symmetry breaking in the Higgs field from $\phi = 0$ to $\phi = \phi_0$. This relates the strong and electroweak energy scales in fig. 2 by

$$\Lambda 2\pi = \alpha\varphi_0, \qquad \Lambda = \frac{\hbar c}{a} \sim hc = \alpha\varphi_0 a. \tag{23}$$

One may think of $hc$ as a unit of *space action.*

The Higgs potential is shaped by [7]

$$\frac{1}{2}(\theta - 2\pi)^2 \to \frac{1}{2}\varphi_0^2(\phi - \phi_0)^2 \tag{24}$$

to yield a fit to fourth order (see fig. 2)

$$V(\phi) = \frac{1}{2}\delta^2\varphi_0^2 - \frac{1}{2}\mu^2\phi^2 + \frac{1}{4}\lambda^2\phi^4, \tag{25}$$

with coefficients

$$\delta^2 = \frac{1}{4}\varphi_0^2, \qquad \mu^2 = \frac{1}{2}\varphi_0^2, \qquad \lambda^2 = \frac{1}{2}. \tag{26}$$

**Coupling strengths.** – With the Higgs field vacuum expectation value after symmetry break

$$\varphi_0 = \frac{2\pi}{\alpha(m_W)}\Lambda \tag{27}$$

from (23), we can determine the size of the Higgs couplings to the massive gauge bosons[1]. We let the generalized derivative

$$D_\mu = \partial_\mu - ig' B_\mu I_0 - ig\mathbf{W}_\mu \cdot \mathbf{I} \tag{28}$$

with *a priori* gauge fields $B_\mu$ and $W_\mu^1, W_\mu^2, W_\mu^3$ act on the Higgs field

$$\phi = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ v + h(x) \end{pmatrix} \tag{29}$$

with $I_k = \frac{\tau_k}{2}, k = 0,1,2,3$ where $\tau_k, k = 1,2,3$ are $2\times 2$ isospin matrices and $\tau_0$ is the identity matrix, *i.e.*,

$$\begin{aligned} Y &= -2I_0 = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}, \quad & 2I_1 &= \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \\ 2I_2 &= \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, & 2I_3 &= \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}. \end{aligned} \tag{30}$$

We square to get for the Lagrangian

$$(D_\mu\phi)^\dagger(D_\mu\phi) \in \mathcal{L}. \tag{31}$$

In the first step we have

$$\begin{aligned} &[\partial_\mu - ig' B_\mu I_0 - ig\mathbf{W}_\mu \cdot \mathbf{I}]\frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ v + h(x) \end{pmatrix} = \\ &\frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ \partial_\mu h \end{pmatrix} \\ &-\frac{i}{2\sqrt{2}}\begin{bmatrix} g' B_\mu + gW_\mu^3 & g(W_\mu^1 - iW_\mu^2) \\ g(W_\mu^1 + iW_\mu^2) & g' B_\mu - gW_\mu^3 \end{bmatrix}\begin{pmatrix} 0 \\ v + h \end{pmatrix}. \end{aligned} \tag{32}$$

The square is structured as

$$(D_\mu\phi)^\dagger(D_\mu\phi) = \frac{1}{2}\partial^\mu h\partial_\mu h + \frac{1}{8}(0 \quad v+h)[\cdots]^\dagger[\cdots]\begin{pmatrix} 0 \\ v+h \end{pmatrix}, \tag{33}$$

which reduces to (cf. p. 276 in [18])

$$\begin{aligned} (D_\mu\phi)^\dagger(D_\mu\phi) = {}& \frac{1}{2}\partial^\mu h\partial_\mu h + \frac{(v+h)^2}{8}g^2[(W_\mu^1)^2 + (W_\mu^2)^2] \\ &+ \frac{(v+h)^2}{8}[g' B_\mu - gW_\mu^3]^2. \end{aligned} \tag{34}$$

[1] We use the fine structure coupling at $W$ energies here and in (23) because $W$ is involved virtually in the neutron decay.

The fields $W^1$ and $W^2$ combine into particle and antiparticle fields of opposite electric charges

$$W^{\pm} \equiv \frac{1}{\sqrt{2}}(W^1 \mp iW^2), \tag{35}$$

see, *e.g.*, Aitchison and Hey, p. 383 in [18] and p. 186 in [19]. Thus,

$$\frac{(v+h)^2}{8}g^2[(W^1_\mu)^2+(W^2_\mu)^2] = \frac{(v+h)^2}{4}g^2 W^+_\mu W^{\mu -} \tag{36}$$

and we get the mass squared

$$m_W^2 c^4 = \frac{g^2 v^2}{4} \tag{37}$$

for the fields $W^+$ and $W^-$. From (36) we also read off the coupling for $H \to WW^*$

$$g_{HWW} = \frac{2v}{4}g^2 = \frac{2m_W^2 c^4}{v}. \tag{38}$$

Both the mass and the coupling expressions look standard, but now expressed in $v$ instead of in $v_{\rm SM}$.

The last term in (34) is not diagonal in the mass terms for the fields $B$ and $W^3$ because of the two different coupling strengths involved. It diagonalizes into two redefined boson fields, see, for example, [20] and p. 277 in [18]

$$Z \equiv \frac{g'B - gW^3}{\sqrt{g'^2+g^2}}, \qquad A \equiv \frac{gB + g'W^3}{\sqrt{g'^2+g^2}}. \tag{39}$$

The second-order term is thereby rewritten as

$$\frac{(v+h)^2}{8}[g'B_\mu - gW^3_\mu]^2 = \frac{(v+h)^2}{4}(g'^2+g^2)\frac{Z_\mu Z^\mu}{2} \tag{40}$$

with masses squared

$$m_Z^2 c^4 = \frac{(g'^2+g^2)v^2}{4}, \qquad m_A^2 c^4 = 0. \tag{41}$$

From (40) we read off the coupling for $H \to ZZ^*$

$$g_{HZZ} = \frac{2v}{4}(g'^2+g^2) = \frac{2m_Z^2 c^4}{v}. \tag{42}$$

Again we note that the expression uses our $v$

$$v = \sqrt{2}\varphi_0 = \sqrt{2}\frac{2\pi}{\alpha(m_W)}\frac{\pi}{\alpha_e}m_e c^2 \tag{43}$$

with $\varphi_0$ determined from (27).

**Electroweak mixing angle.** – As implied in the previous section, we want the set of four gauge fields to contain the massless $U(1)$ gauge field $A_\gamma$ of quantum electrodynamics but we have no guarantee that $A_\gamma$ equals the *a priori* $U(1)$ gauge field $B$ because both generators $I_0$ and $I_3$ are diagonal. We thus anticipate a transformation from the *a priori* fields $B, W^3$ into physical spacetime fields $Z, A_\gamma$ given by

$$\begin{pmatrix} Z \\ A_\gamma \end{pmatrix} = \begin{pmatrix} \cos\theta_W & \sin\theta_W \\ -\sin\theta_W & \cos\theta_W \end{pmatrix}\begin{pmatrix} W^3 \\ B \end{pmatrix} \equiv \Theta \begin{pmatrix} W^3 \\ B \end{pmatrix}. \tag{44}$$

The condition on the *electroweak mixing angle* $\theta_W$ is that $A_\gamma$ remains massless after the spontaneous symmetry break in accordance with the infinite range of electromagnetic interactions. This requirement puts a constraint on the ratio between the two coupling constants $g, g'$. To find the constraint, we write the mass term coefficient on $\phi$ in (33) from the diagonal generators in (30) as

$$\begin{aligned}(gW^3, g'B)\begin{pmatrix} I_3 \\ I_0 \end{pmatrix} &= (W^3, B)\begin{pmatrix} gI_3 \\ g'I_0 \end{pmatrix} \\ &= (W^3, B)\Theta^{-1}\Theta\begin{pmatrix} gI_3 \\ g'I_0 \end{pmatrix}.\end{aligned} \tag{45}$$

Expressed in the "rotated" fields $Z, A_\gamma$ this means

$$(gW^3, g'B)\begin{pmatrix} I_3 \\ I_0 \end{pmatrix} = \begin{pmatrix} Z \\ A_\gamma \end{pmatrix}^T \Theta \begin{pmatrix} gI_3 \\ g'I_0 \end{pmatrix}. \tag{46}$$

From this we read off the $Z$ and $A_\gamma$ field generators

$$\begin{aligned} I_Z &= g\cos\theta_W I_3 + g'\sin\theta_W I_0, \\ I_\gamma &= -g\sin\theta_W I_3 + g'\cos\theta_W I_0 \end{aligned} \tag{47}$$

and require from the vanishing mass term in (34)

$$\frac{1}{2}m_\gamma^2 c^4 = (\phi_0 I_\gamma)^\dagger I_\gamma \phi_0 = 0 \tag{48}$$

which is fulfilled provided

$$g\sin\theta_W + g'\cos\theta_W = 0 \quad \text{or} \quad \tan\theta_W = -\frac{g'}{g}. \tag{49}$$

To determine the absolute coupling strengths $g, g'$ we look again at the photon field generator $I_\gamma$. It couples to $I_3$ with the strength $-g\sin\theta_W$ and to $I_0$ with the strength $g'\cos\theta_W$. If we assume both these strengths to equal the elementary unit of charge $e$ characteristic of quantum electrodynamics, we get the relations

$$g = -|e|/\sin\theta_W, \qquad g' = |e|/\cos\theta_W, \tag{50}$$

where we have chosen a sign convention such that $g, g' > 0$ and $\sin\theta_W < 0$.

The electroweak mixing angle $\theta_W$ remains an *ad hoc* parameter in the Standard Model which is why the $Z$ (and $W$) masses could not be predicted accurately. Given $\theta_W$, the $Z$ mass follows

$$\frac{1}{2}m_Z^2 c^4 = (\phi_0 I_Z)^\dagger I_Z \phi_0 = \frac{g^2+g'^2}{4}\varphi_0^2 \tag{51}$$

with $I_Z$ from (47). We namely have in the "lower" component of $I_Z$

$$\begin{aligned} &-\frac{1}{2}g\cos\theta_W + \frac{1}{2}g'\sin\theta_W = \\ &-\frac{1}{2}g\frac{g}{\sqrt{g^2+g'^2}} + \frac{1}{2}g'\frac{-g'}{\sqrt{g^2+g'^2}} \\ &= -\frac{1}{2}\sqrt{g^2+g'^2}. \end{aligned} \tag{52}$$

With this and (50) we get for the $Z$ mass

$$\frac{1}{2}m_Z^2c^4 = \frac{e^2}{4\sin^2\theta_W\cos^2\theta_W}\varphi_0^2. \tag{53}$$

The charged boson fields

$$W_\mu^\pm \equiv \frac{1}{\sqrt{2}}(W_\mu^1 \mp iW_\mu^2)$$

in (35) expand on

$$I_\pm = (I_1 \pm iI_2). \tag{54}$$

With these rephrasings similar to p. 248 in [21], we have

$$g(W^1I_1 + W^2I_2) = \frac{g}{\sqrt{2}}(W^+I_+ + W^-I_-). \tag{55}$$

To get the masses of $W^\pm$ we exploit the isospin algebra

$$\frac{1}{2}(I_+I_- + I_-I_+) = I_1^2 + I_2^2 = \mathbf{I}^2 - I_3^2. \tag{56}$$

Applied to the Higgs field this yields

$$(\mathbf{I}^2 - I_3^2)\phi_0 = \left(\frac{1}{2}\left(\frac{1}{2}+1\right) - \left(\frac{1}{2}\right)^2\right)\phi_0 = \frac{1}{2}\phi_0 \tag{57}$$

and —after some lines of algebra squaring (55)— we get

$$m_W^2c^4 = g^2\frac{1}{2}\varphi_0^2 = \frac{g^2v^2}{4} \to m_Wc^2 = 80.36(2)\,\mathrm{GeV}. \tag{58}$$

For the numerical value we used $g^2 = e^2/\sin^2\theta_W$, *i.e.*, $g^2 = 4\pi\alpha_e/\sin^2\theta_W$ with $\alpha_e = e^2/(4\pi\epsilon_0\hbar c) = 1/137.035999139(31)$ [1] and we anticipated $\sin^2\theta_W = 2/9$ from (62) [22][2]. Further, we used the electroweak energy scale $v$ determined by (39) with $\alpha^{-1}(m_W) = 127.984(18)$ obtained by sliding [16] from $\alpha^{-1}(m_Z) = 127.950(10)$ [1]. We might had started from $\alpha_\mathrm{e}$ and worked iteratively towards $\alpha(m_W)$. Since the fine structure coupling only changes logarithmically with energy, this iteration quickly converges.

*Weinberg mixing angle from quark generators.* We hint at the origin of the electroweak mixing angle. We express the $I_0$ and $I_3$ of (47) in the equivalent base of $u$ and $d$ flavour quark generators $T_u, T_d$ [10,22],

$$T_u = \begin{pmatrix} \frac{2}{3} & 0 \\ 0 & -1 \end{pmatrix}, \qquad T_d = \begin{pmatrix} -\frac{1}{3} & 0 \\ 0 & -1 \end{pmatrix} \tag{59}$$

acting in the 2-dimensional representation space of the Higgs field, where

$$\phi_0 = \begin{pmatrix} 0 \\ \varphi_0 \end{pmatrix} \tag{60}$$

and where we suppress the "inactive" component of the quark generators to have their two-dimensional editions. We then have

$$2I_0 = \frac{2}{3}T_u - \frac{5}{3}T_d, \qquad 2I_3 = \frac{4}{3}T_u - \frac{1}{3}T_d. \tag{61}$$

We now substitute $\theta_W$ in (47) by $\theta_{ud}$ defined by

$$\cos^2\theta_{ud} = \mathrm{Tr}\ T_uT_d = \frac{7}{9} \tag{62}$$

as in [22]. This yields the $Z$ boson mass from rewriting $I_Z$ in (47) and letting it operate on $\phi_0$. Thus,

$$2I_Z = g\cos\theta_{ud}\left(\frac{4}{3}T_u - \frac{1}{3}T_d\right) + g'\sin\theta_{ud}\left(\frac{2}{3}T_u - \frac{5}{3}T_d\right) \tag{63}$$

operating on $\phi_0$ means

$$\left(\frac{2I_Z}{g\cos\theta_{ud}}\right)\begin{pmatrix} 0 \\ \varphi_0 \end{pmatrix} = \left[\left(\frac{4}{3}T_u - \frac{1}{3}T_d\right) + \frac{g'}{g}\tan\theta_{ud}\left(\frac{2}{3}T_u - \frac{5}{3}T_d\right)\right]\begin{pmatrix} 0 \\ \varphi_0 \end{pmatrix}. \tag{64}$$

Exploiting $\tan\theta_{ud} = -\frac{g'}{g}$ from the zero mass constraint on the photon field in (48) we rewrite to get

$$\left(\frac{2I_Z}{g\cos\theta_{ud}}\right) = \left(\frac{4}{3} - \frac{2}{3}\tan^2\theta_{ud}\right)T_u - \left(\frac{1}{3} - \frac{5}{3}\tan^2\theta_{ud}\right)T_d \tag{65}$$

and, thus,

$$\left(\frac{2I_Z}{g\cos\theta_{ud}}\right)\begin{pmatrix} 0 \\ \varphi_0 \end{pmatrix} = \left[-\left(\frac{4}{3} - \frac{2}{3}\tan^2\theta_{ud}\right) + \left(\frac{1}{3} - \frac{5}{3}\tan^2\theta_{ud}\right)\right]\phi_0 \tag{66}$$

which reduces to

$$\left(\frac{2I_Z}{g\cos\theta_{ud}}\right)\begin{pmatrix} 0 \\ \varphi_0 \end{pmatrix} = [-1 - \tan^2\theta_{ud}]\phi_0 = \frac{-1}{\cos^2\theta_{ud}}\phi_0. \tag{67}$$

Multiplying by $\cos\theta_{ud}$ and squaring we get

$$\left[\left(\frac{2I_Z}{g}\right)\begin{pmatrix} 0 \\ \varphi_0 \end{pmatrix}\right]^2 = \frac{1}{\cos^2\theta_{ud}}\varphi_0^2. \tag{68}$$

With

$$\frac{1}{2}m_Z^2c^4 = (I_Z\phi_0)^2 = \left(\frac{g}{2}\right)^2\left[\left(\frac{2I_Z}{g}\right)\begin{pmatrix} 0 \\ \varphi_0 \end{pmatrix}\right]^2 \tag{69}$$

we get

$$m_Z^2c^4 = 2\left(\frac{g}{2}\right)^2\frac{1}{\cos^2\theta_{ud}}\varphi_0^2 = \frac{g^2v^2}{4\cos^2\theta_{ud}} \tag{70}$$

[2]The experimentally extracted $\sin^2\theta_W$ depends on the renormalization prescription, see p. 163 in [1].

in accordance with standard expressions (51). For $\cos^2\theta_{ud} = \frac{7}{9}$ and $v$ from (43) eq. (70) yields

$$m_Z c^2 = 91.12(2)\,\text{GeV}. \tag{71}$$

Combining (58) with (70) we get as expected to compare with experiment [1]

$$\begin{aligned}\frac{m_W^2}{m_Z^2} &= \frac{1}{1/\cos^2\theta_{ud}} = 0.7777\cdots \\ &\approx \left(\frac{80.379(12)\,\text{GeV}}{91.1876(21)\,\text{GeV}}\right)^2 = 0.7771(3).\end{aligned} \tag{72}$$

Interpreted as the result of iterations, the values in (71) and (72) with their per mille level discrepancies show the consistency of using $T_u$ and $T_d$ as relevant projection generators.

It is as if the selection of the mixing angle $\theta_W = \theta_{ud}$ is guided by the fixation of the quark generators from the strong interaction sector. This may be a coincidence but we rather think that it is a consequence of the interrelation between the electroweak and strong interactions as they meet in the neutron to proton decay and in other weak baryonic decays. The suspicion is supported by the derivation of the Cabibbo angle from intermingled flavour and colour degrees of freedom in [22].

**Gauge boson couplings relative to the standard model.** – The Higgs to gauge boson couplings (38) and (42) may look completely like those predicted from the Standard Model. But one should note, that our $v$ differs from $v_{\text{SM}}$ by $\sqrt{V_{ud}}$ as mentioned in (3). If we take as an example the quartic Higgs self-coupling, the Standard Model expression in the notation of (25) is [1]

$$\lambda_{\text{SM}}^2 = \left(\frac{m_H c^2}{v_{\text{SM}}}\right)^2 \tag{73}$$

and the intrinsic prediction $\lambda^2 = 1/2$ from (26) if expressed in terms of $\mu$ and $\lambda$ is

$$\lambda^2 = \left(\frac{\mu}{v}\right)^2. \tag{74}$$

Comparing these two expressions gives

$$\frac{g_{HHHH}}{g_{HHHH,\text{SM}}} = \frac{\lambda^2}{\lambda_{\text{SM}}^2} = \frac{v_{\text{SM}}^2}{v^2} = V_{ud}. \tag{75}$$

The standard expressions in (38) and (42)

$$g_{HWW} = \frac{2m_W^2 c^4}{v}, \qquad g_{HZZ} = \frac{2m_Z^2 c^4}{v} \tag{76}$$

hide the role of $v$ in the boson masses. If in (76) we used instead the expressions from (37) and (41)

$$m_W c^2 = \frac{gv}{2}, \qquad m_Z c^2 = \frac{(\sqrt{g'^2+g^2})v}{2} \tag{77}$$

we would infer for signal strength ($\mu \sim \Gamma(H \to WW) \sim g_{HWW}^2$) [23]

$$\begin{aligned}\mu_{HWW} &= \left(\frac{g_{HWW}}{g_{HWW,\text{SM}}}\right)^2 = \left(\frac{(gv/2)^2/v}{(gv_{\text{SM}}/2)^2/v_{\text{SM}}}\right)^2 \\ &= \left(\frac{v}{v_{\text{SM}}}\right)^2 = \frac{1}{V_{ud}} \approx 1.03\end{aligned} \tag{78}$$

and likewise for $\mu_{HZZ}$. This corresponds to a three percent increase in the Higgs to gauge boson signal strength relative to Standard Model expectations. A comparison with experiment must await higher statistics than what is presently available from the LHC [24].

**Conclusion.** – In our intrinsic conception of electroweak decays, an interrelation between strong and electroweak degrees of freedom is shaped specifically by the requirement of paired Bloch phase factors with half odd-integer Bloch wave vectors which select a $U(2)$ subgroup in the baryonic $U(3)$ configuration space. From this conception, we find the Higgs field couplings modified by the up-down quark mixing matrix element and thus expect the Higgs particle to couple slightly more strongly to the intermediate gauge bosons $W$ and $Z$ than predicted in the Standard Model.

* * *

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