Singlet Extended Standard Model
Lagrangian, Rotations and Interactions for eigenstates 'EWSB' including Renormalization Group Equations including one-loop Self-Energies

SARAH 4.6.0

November 18, 2015

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References: **arXiv: 1309.7223** , **Comput.Phys.Commun.184:1792-1809,2011 (1207.0906)** , **Comput.Phys.Commun.182:**
833,2011 (1002.0840) , **Comput.Phys.Commun.181:1077-1086,2010 (0909.2863)** , **arXiv: 0806.0538**
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Contents

1 Fields

1.1 Gauge Fields

Name	$SU(N)$	Coupling	Name
B	$U(1)$	g_1	hypercharge
W	SU(2)	g_2	left
g	SU(3)	g_3	color

1.2 Matter Superfields

Name	Spin	Generations	$(U(1) \otimes \mathrm{SU}(2) \otimes \mathrm{SU}(3))$
H	0	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1})$
s	0	1	$(0, \mathbf{1}, \mathbf{1})$
q	$\frac{1}{2}$	3	$(\frac{1}{6}, \mathbf{2}, \mathbf{3})$
l	$\frac{1}{2}$	3	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1})$
d	$\frac{1}{2}$	3	$(\frac{1}{3}, \mathbf{1}, \overline{\mathbf{3}})$
u	$\frac{1}{2}$	3	$(-\frac{2}{3}, \mathbf{1}, \overline{\mathbf{3}})$
e	$\frac{1}{2}$	3	$(1, \mathbf{1}, \mathbf{1})$

2 Lagrangian

2.1 Input Lagrangian for Eigenstates GaugeES

$$L = 0 \tag{1}$$

2.2 Gauge fixing terms

2.2.1 Gauge fixing terms for eigenstates 'GaugeES'

$$L_{GF} = -\frac{1}{2}|\partial_\mu B|^2 \xi_B^{-1} - \frac{1}{2}|\partial_\mu g|^2 \xi_g^{-1} - \frac{1}{2}|\partial_\mu W|^2 \xi_W^{-1} \tag{2}$$

2.2.2 Gauge fixing terms for eigenstates 'EWSB'

$$\begin{aligned} L_{GF} = &-\frac{1}{2}|\partial_\mu g|^2 \xi_g^{-1} - \frac{1}{2}|\partial_\mu \gamma|^2 \xi_\gamma^{-1} - |-\frac{i}{2} g_2 H^+ v \xi_{W^+} + \partial_\mu W^+|^2 \xi_{W^+}^{-1} \\ &-\frac{1}{2}|-\frac{1}{2} A^0 v \xi_Z \Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W \Big) + \partial_\mu Z|^2 \xi_Z^{-1} \end{aligned} \tag{3}$$

2.3 Fields integrated out

None

3 Renormalization Group Equations

3.1 Gauge Couplings

$$\beta^{(1)}_{g_1} = \frac{41}{10} g_1^3 \tag{4}$$

$$\beta^{(2)}_{g_1} = \frac{1}{50} g_1^3 \Big(135 g_2^2 + 199 g_1^2 - 25 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 440 g_3^2 - 75 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 85 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\Big) \tag{5}$$

$$\beta^{(1)}_{g_2} = -\frac{19}{6} g_2^3 \tag{6}$$

$$\beta^{(2)}_{g_2} = \frac{1}{30} g_2^3 \Big(- 15 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 175 g_2^2 + 27 g_1^2 + 360 g_3^2 - 45 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 45 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\Big) \tag{7}$$

$$\beta^{(1)}_{g_3} = -7 g_3^3 \tag{8}$$

$$\beta^{(2)}_{g_3} = -\frac{1}{10} g_3^3 \Big(- 11 g_1^2 + 20 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 20 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 260 g_3^2 - 45 g_2^2\Big) \tag{9}$$

3.2 Quartic scalar couplings

$$\beta^{(1)}_{\lambda_S} = 36 \lambda_S^2 + \kappa_2^2 \tag{10}$$

$$\begin{aligned}\beta^{(2)}_{\lambda_S} = &+ \frac{6}{5} g_1^2 \kappa_2^2 + 6 g_2^2 \kappa_2^2 - 4 \kappa_2^3 - 20 \kappa_2^2 \lambda_S - 816 \lambda_S^3 - 6 \kappa_2^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 2 \kappa_2^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) \\ &- 6 \kappa_2^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\end{aligned} \tag{11}$$

$$\beta^{(1)}_{\kappa_2} = \frac{1}{10} \kappa_2 \Big(120 \lambda_S + 20 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 40 \kappa_2 - 45 g_2^2 + 60 \lambda + 60 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 60 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 9 g_1^2\Big) \tag{12}$$

$$\begin{aligned}\beta^{(2)}_{\kappa_2} = &+ \frac{1671}{400} g_1^4 \kappa_2 + \frac{9}{8} g_1^2 g_2^2 \kappa_2 - \frac{145}{16} g_2^4 \kappa_2 + \frac{3}{5} g_1^2 \kappa_2^2 + 3 g_2^2 \kappa_2^2 - \frac{21}{2} \kappa_2^3 - 72 \kappa_2^2 \lambda_S - 120 \kappa_2 \lambda_S^2 \\ &+ \frac{36}{5} g_1^2 \kappa_2 \lambda + 36 g_2^2 \kappa_2 \lambda - 36 \kappa_2^2 \lambda - 15 \kappa_2 \lambda^2 \\ &+ \frac{1}{4} \kappa_2 \Big(16 \Big(10 g_3^2 - 3 \kappa_2 - 9 \lambda\Big) + 45 g_2^2 + 5 g_1^2\Big) \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{1}{4} \kappa_2 \Big(15 g_1^2 + 15 g_2^2 - 16 \Big(3 \lambda + \kappa_2\Big)\Big) \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) \\ &+ \frac{17}{4} g_1^2 \kappa_2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{4} g_2^2 \kappa_2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 40 g_3^2 \kappa_2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 12 \kappa_2^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\ &- 36 \kappa_2 \lambda \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{27}{2} \kappa_2 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 21 \kappa_2 \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - \frac{9}{2} \kappa_2 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) \\ &- \frac{27}{2} \kappa_2 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\end{aligned} \tag{13}$$

$$\beta^{(1)}_{\lambda} = + \frac{27}{100} g_1^4 + \frac{9}{10} g_1^2 g_2^2 + \frac{9}{4} g_2^4 + \kappa_2^2 - \frac{9}{5} g_1^2 \lambda - 9 g_2^2 \lambda + 12 \lambda^2 + 12 \lambda \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 4 \lambda \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)$$

$$+ 12\lambda\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 12\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 4\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) - 12\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big) \tag{14}$$

$$\begin{aligned}
\beta_\lambda^{(2)} =& -\frac{3411}{1000}g_1^6 - \frac{1677}{200}g_1^4g_2^2 - \frac{289}{40}g_1^2g_2^4 + \frac{305}{8}g_2^6 - 4\kappa_2^3 + \frac{1887}{200}g_1^4\lambda + \frac{117}{20}g_1^2g_2^2\lambda - \frac{73}{8}g_2^4\lambda - 5\kappa_2^2\lambda \\
&+ \frac{54}{5}g_1^2\lambda^2 + 54g_2^2\lambda^2 - 78\lambda^3 \\
&+ \frac{1}{10}\Big(225g_2^2\lambda - 45g_2^4 + 80\Big(10g_3^2 - 9\lambda\Big)\lambda + 9g_1^4 + g_1^2\Big(25\lambda + 54g_2^2\Big)\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) \\
&- \frac{3}{10}\Big(15g_1^4 + 5\Big(16\lambda^2 - 5g_2^2\lambda + g_2^4\Big) - g_1^2\Big(22g_2^2 + 25\lambda\Big)\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - \frac{171}{50}g_1^4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\
&+ \frac{63}{5}g_1^2g_2^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - \frac{9}{2}g_2^4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + \frac{17}{2}g_1^2\lambda\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + \frac{45}{2}g_2^2\lambda\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\
&+ 80g_3^2\lambda\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 72\lambda^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + \frac{8}{5}g_1^2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 64g_3^2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) \\
&- 3\lambda\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 42\lambda\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - \frac{24}{5}g_1^2\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) - \lambda\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) \\
&- \frac{16}{5}g_1^2\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big) - 64g_3^2\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big) - 3\lambda\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big) + 60\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger Y_dY_d^\dagger\Big) \\
&+ 12\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 24\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger Y_dY_d^\dagger\Big) - 12\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_u^\dagger Y_uY_d^\dagger\Big) \\
&+ 20\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger Y_eY_e^\dagger\Big) + 60\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger Y_uY_u^\dagger\Big)
\end{aligned} \tag{15}$$

3.3 Yukawa Couplings

$$\begin{aligned}
\beta_{Y_u}^{(1)} =& -\frac{3}{2}\Big(-Y_uY_u^\dagger Y_u + Y_uY_d^\dagger Y_d\Big) \\
&+ Y_u\Big(3\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 3\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 8g_3^2 - \frac{17}{20}g_1^2 - \frac{9}{4}g_2^2 + \mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\Big)
\end{aligned} \tag{16}$$

$$\begin{aligned}
\beta_{Y_u}^{(2)} =& +\frac{1}{80}\Big(20\Big(11Y_uY_d^\dagger Y_dY_d^\dagger Y_d - 4Y_uY_u^\dagger Y_uY_d^\dagger Y_d + 6Y_uY_u^\dagger Y_uY_u^\dagger Y_u - Y_uY_d^\dagger Y_dY_u^\dagger Y_u\Big) \\
&+ Y_uY_u^\dagger Y_u\Big(1280g_3^2 - 180\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 223g_1^2 - 480\lambda - 540\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 540\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + 675g_2^2\Big) \\
&+ Y_uY_d^\dagger Y_d\Big(100\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 1280g_3^2 + 300\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 300\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 43g_1^2 + 45g_2^2\Big)\Big) \\
&+ \frac{1}{600}Y_u\Big(1187g_1^4 - 270g_1^2g_2^2 - 3450g_2^4 + 760g_1^2g_3^2 + 5400g_2^2g_3^2 - 64800g_3^4 + 150\kappa_2^2 + 900\lambda^2 \\
&+ 375\Big(32g_3^2 + 9g_2^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 1125\Big(g_1^2 + g_2^2\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 1275g_1^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\
&+ 3375g_2^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + 12000g_3^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 4050\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) + 900\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) \\
&- 1350\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) - 4050\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)\Big)
\end{aligned} \tag{17}$$

$$\beta_{Y_d}^{(1)} = \frac{1}{4}\Big(6\Big(-Y_dY_u^\dagger Y_u + Y_dY_d^\dagger Y_d\Big)$$

$$- Y_d\Big(- 12\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 12\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 32 g_3^2 - 4\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 9 g_2^2 + g_1^2\Big)\Big) \tag{18}$$

$$\begin{aligned}\beta_{Y_d}^{(2)} = &+\frac{1}{80}\Big(20\Big(11 Y_d Y_u^\dagger Y_u Y_u^\dagger Y_u - 4 Y_d Y_d^\dagger Y_d Y_u^\dagger Y_u + 6 Y_d Y_d^\dagger Y_d Y_d^\dagger Y_d - Y_d Y_u^\dagger Y_u Y_d^\dagger Y_d\Big)\\ &+ Y_d Y_d^\dagger Y_d\Big(1280 g_3^2 - 180\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 187 g_1^2 - 480\lambda - 540\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 540\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 675 g_2^2\Big)\\ &+ Y_d Y_u^\dagger Y_u\Big(100\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 1280 g_3^2 + 300\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 300\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 45 g_2^2 - 79 g_1^2\Big)\Big)\\ &+ Y_d\Big(- \frac{127}{600} g_1^4 - \frac{27}{20} g_1^2 g_2^2 - \frac{23}{4} g_2^4 + \frac{31}{15} g_1^2 g_3^2 + 9 g_2^2 g_3^2 - 108 g_3^4 + \frac{1}{4}\kappa_2^2 + \frac{3}{2}\lambda^2\\ &+ \frac{5}{8}\Big(32 g_3^2 + 9 g_2^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{15}{8}\Big(g_1^2 + g_2^2\Big)\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + \frac{17}{8} g_1^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{8} g_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\\ &+ 20 g_3^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{27}{4}\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) + \frac{3}{2}\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - \frac{9}{4}\mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{27}{4}\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big)\end{aligned} \tag{19}$$

$$\beta_{Y_e}^{(1)} = \frac{3}{2} Y_e Y_e^\dagger Y_e + Y_e\Big(3\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 3\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{9}{4} g_1^2 - \frac{9}{4} g_2^2 + \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)\Big) \tag{20}$$

$$\begin{aligned}\beta_{Y_e}^{(2)} = &\frac{1}{400}\Big(15\Big(40 Y_e Y_e^\dagger Y_e Y_e^\dagger Y_e\\ &+ Y_e Y_e^\dagger Y_e\Big(129 g_1^2 - 160\lambda - 180\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 180\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 225 g_2^2 - 60\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)\Big)\Big)\\ &+ 2 Y_e\Big(1371 g_1^4 + 270 g_1^2 g_2^2 - 1150 g_2^4 + 50\kappa_2^2 + 300\lambda^2 + 125\Big(32 g_3^2 + 9 g_2^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big)\\ &+ 375\Big(g_1^2 + g_2^2\Big)\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 425 g_1^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 1125 g_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 4000 g_3^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\\ &- 1350\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) + 300\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 450\mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - 1350\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big)\Big)\end{aligned} \tag{21}$$

3.4 Trilinear Scalar couplings

$$\beta_{\kappa_1}^{(1)} = 2\kappa_1\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 4\kappa_1\kappa_2 + 6\kappa_1\lambda + 6\kappa_1\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 6\kappa_1\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{9}{10} g_1^2\kappa_1 - \frac{9}{2} g_2^2\kappa_1 \tag{22}$$

$$\begin{aligned}\beta_{\kappa_1}^{(2)} = &+\frac{1671}{400} g_1^4\kappa_1 + \frac{9}{8} g_1^2 g_2^2\kappa_1 - \frac{145}{16} g_2^4\kappa_1 + \frac{3}{5} g_1^2\kappa_1\kappa_2 + 3 g_2^2\kappa_1\kappa_2 - \frac{23}{2}\kappa_1\kappa_2^2 - 24\kappa_1\kappa_2\lambda_S + 12\kappa_1\lambda_S^2\\ &+ \frac{36}{5} g_1^2\kappa_1\lambda + 36 g_2^2\kappa_1\lambda - 36\kappa_1\kappa_2\lambda - 15\kappa_1\lambda^2\\ &+ \frac{1}{4}\kappa_1\Big(16\Big(10 g_3^2 - 3\kappa_2 - 9\lambda\Big) + 45 g_2^2 + 5 g_1^2\Big)\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{1}{4}\kappa_1\Big(15 g_1^2 + 15 g_2^2 - 16\Big(3\lambda + \kappa_2\Big)\Big)\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)\\ &+ \frac{17}{4} g_1^2\kappa_1\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{4} g_2^2\kappa_1\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 40 g_3^2\kappa_1\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 12\kappa_1\kappa_2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\\ &- 36\kappa_1\lambda\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{27}{2}\kappa_1\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 21\kappa_1\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - \frac{9}{2}\kappa_1\mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big)\\ &- \frac{27}{2}\kappa_1\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\end{aligned} \tag{23}$$

3.5 Scalar Mass Terms

$$\beta^{(1)}_{M_S} = 4\Big(3\lambda_S M_S + \kappa_2\mu + \kappa_1^2\Big) \tag{24}$$

$$\begin{aligned}\beta^{(2)}_{M_S} = &+\frac{24}{5}g_1^2\kappa_1^2 + 24g_2^2\kappa_1^2 - 20\kappa_1^2\kappa_2 - 24\kappa_1^2\lambda_S - 2\kappa_2^2 M_S - 120\lambda_S^2 M_S + \frac{24}{5}g_1^2\kappa_2\mu + 24g_2^2\kappa_2\mu \\ &- 8\kappa_2^2\mu - 24\Big(\kappa_2\mu + \kappa_1^2\Big)\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 8\Big(\kappa_2\mu + \kappa_1^2\Big)\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 24\kappa_1^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\ &- 24\kappa_2\mu\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\end{aligned} \tag{25}$$

$$\beta^{(1)}_{\mu} = 2\kappa_1^2 + 2\mu\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 6\mu\lambda + 6\mu\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 6\mu\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{9}{10}g_1^2\mu - \frac{9}{2}g_2^2\mu + \kappa_2 M_S \tag{26}$$

$$\begin{aligned}\beta^{(2)}_{\mu} = &+\frac{3}{10}g_1^2\kappa_1^2 + \frac{3}{2}g_2^2\kappa_1^2 - 6\kappa_1^2\kappa_2 - 2\kappa_2^2 M_S + \frac{1671}{400}g_1^4\mu + \frac{9}{8}g_1^2 g_2^2\mu - \frac{145}{16}g_2^4\mu - \frac{1}{2}\kappa_2^2\mu \\ &- 18\kappa_1^2\lambda + \frac{36}{5}g_1^2\mu\lambda + 36g_2^2\mu\lambda - 15\mu\lambda^2 \\ &+ \Big(-6\kappa_1^2 + \frac{1}{4}\mu\Big(-144\lambda + 160g_3^2 + 45g_2^2 + 5g_1^2\Big)\Big)\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\ &- \frac{1}{4}\Big(-3\mu\Big(-16\lambda + 5g_1^2 + 5g_2^2\Big) + 8\kappa_1^2\Big)\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 6\kappa_1^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{17}{4}g_1^2\mu\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\ &+ \frac{45}{4}g_2^2\mu\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 40g_3^2\mu\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 36\mu\lambda\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{27}{2}\mu\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) \\ &- 21\mu\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - \frac{9}{2}\mu\mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{27}{2}\mu\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\end{aligned} \tag{27}$$

3.6 Vacuum expectation values

$$\beta^{(1)}_{v} = \frac{1}{20}v\Big(15g_2^2\mathrm{Xi} - 20\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 3g_1^2\mathrm{Xi} + 45g_2^2 - 60\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 60\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 9g_1^2\Big) \tag{28}$$

$$\begin{aligned}\beta^{(2)}_{v} = &\frac{1}{800}v\Big(-1293g_1^4 - 270g_1^2 g_2^2 + 6775g_2^4 - 200\kappa_2^2 + 18g_1^4\mathrm{Xi} + 180g_1^2 g_2^2\mathrm{Xi} + 2250g_2^4\mathrm{Xi} + 18g_1^4\mathrm{Xi}^2 \\ &+ 180g_1^2 g_2^2\mathrm{Xi}^2 - 450g_2^4\mathrm{Xi}^2 - 1200\lambda^2 - 20\Big(45g_2^2\Big(2\mathrm{Xi} + 5\Big) + 800g_3^2 + g_1^2\Big(18\mathrm{Xi} + 25\Big)\Big)\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\ &- 60\Big(5g_2^2\Big(2\mathrm{Xi} + 5\Big) + g_1^2\Big(2\mathrm{Xi} + 25\Big)\Big)\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 1700g_1^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 4500g_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\ &- 16000g_3^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 360g_1^2\mathrm{Xi}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 1800g_2^2\mathrm{Xi}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 5400\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) \\ &- 1200\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) + 1800\mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) + 5400\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big)\end{aligned} \tag{29}$$

4 Field Rotations

4.1 Rotations in gauge sector for eigenstates 'EWSB'

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \end{pmatrix} = Z^{\gamma Z} \begin{pmatrix} \gamma_\rho \\ Z_\rho \end{pmatrix} \tag{30}$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho} \end{pmatrix} = Z^{W} \begin{pmatrix} W^+_\rho \\ W^+_\rho \end{pmatrix} \tag{31}$$

$$\tag{32}$$

The mixing matrices are parametrized by

$$Z^{\gamma Z} = \begin{pmatrix} \cos\Theta_W & -\sin\Theta_W \\ \sin\Theta_W & \cos\Theta_W \end{pmatrix} \tag{33}$$

$$Z^{W} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ i\frac{1}{\sqrt{2}} & -i\frac{1}{\sqrt{2}} \end{pmatrix} \tag{34}$$

$$\tag{35}$$

4.2 Rotations in Mass sector for eigenstates 'EWSB'

4.2.1 Mass Matrices for Scalars

- **Mass matrix for Higgs**, Basis: $(H, \mathrm{Sing}), (H, \mathrm{Sing})$

$$m_h^2 = \begin{pmatrix} \frac{3}{2}v^2\lambda + \mu & \kappa_1 v \\ \kappa_1 v & \frac{1}{2}\kappa_2 v^2 + M_S \end{pmatrix} \tag{36}$$

This matrix is diagonalized by Z^H:

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \tag{37}$$

with

$$H = \sum_j Z^H_{j1} h_j\,, \qquad \mathrm{Sing} = \sum_j Z^H_{j2} h_j \tag{38}$$

4.2.2 Mass Matrices for Fermions

- **Mass matrix for Down-Quarks**, Basis: $(d_{L,\alpha_1}), \left(d^*_{R,\beta_1}\right)$

$$m_d = \begin{pmatrix} \frac{1}{\sqrt{2}} v \delta_{\alpha_1\beta_1} Y_d^T \end{pmatrix} \tag{39}$$

This matrix is diagonalized by U_L^d and U_R^d

$$U_L^{d,*} m_d U_R^{d,\dagger} = m_d^{dia} \tag{40}$$

with

$$d_{L,i\alpha} = \sum_{t_2} U^{d,*}_{L,ji} D_{L,j\alpha} \tag{41}$$

$$d_{R,i\alpha} = \sum_{t_2} U^{d}_{R,ij} D^{*}_{R,j\alpha} \tag{42}$$

- **Mass matrix for Up-Quarks**, Basis: $\left(u_{L,\alpha_1}\right), \left(u^*_{R,\beta_1}\right)$

$$m_u = \left(\begin{array}{c} -\frac{1}{\sqrt{2}} v \delta_{\alpha_1\beta_1} Y_u^T \end{array} \right) \tag{43}$$

This matrix is diagonalized by U^u_L and U^u_R

$$U^{u,*}_L m_u U^{u,\dagger}_R = m^{dia}_u \tag{44}$$

with

$$u_{L,i\alpha} = \sum_{t_2} U^{u,*}_{L,ji} U_{L,j\alpha} \tag{45}$$

$$u_{R,i\alpha} = \sum_{t_2} U^{u}_{R,ij} U^{*}_{R,j\alpha} \tag{46}$$

- **Mass matrix for Leptons**, Basis: $\left(e_L\right), \left(e^*_R\right)$

$$m_e = \left(\begin{array}{c} \frac{1}{\sqrt{2}} v Y_e^T \end{array} \right) \tag{47}$$

This matrix is diagonalized by U^e_L and U^e_R

$$U^{e,*}_L m_e U^{e,\dagger}_R = m^{dia}_e \tag{48}$$

with

$$e_{L,i} = \sum_{t_2} U^{e,*}_{L,ji} E_{L,j} \tag{49}$$

$$e_{R,i} = \sum_{t_2} U^{e}_{R,ij} E^{*}_{R,j} \tag{50}$$

5 Vacuum Expectation Values

$$H^0 = \frac{1}{\sqrt{2}} H + \frac{1}{\sqrt{2}} v + i \frac{1}{\sqrt{2}} A^0 \tag{51}$$

6 Tadpole Equations

$$\frac{\partial V}{\partial H} = \frac{1}{2} v^3 \lambda + \mu v \tag{52}$$

7 Particle content for eigenstates 'EWSB'

Name	Type	complex/real	Generations	Indices
H^+	Scalar	complex	1	
A^0	Scalar	real	1	
h	Scalar	real	2	generation, 2
ν	Fermion	Dirac	3	generation, 3
d	Fermion	Dirac	3	generation, 3, color, 3
u	Fermion	Dirac	3	generation, 3, color, 3
e	Fermion	Dirac	3	generation, 3
g	Vector	real	1	color, 8, lorentz, 4
γ	Vector	real	1	lorentz, 4
Z	Vector	real	1	lorentz, 4
W^+	Vector	complex	1	lorentz, 4
η^G	Ghost	real	1	color, 8
η^γ	Ghost	real	1	
η^Z	Ghost	real	1	
η^+	Ghost	complex	1	
η^-	Ghost	complex	1	

8 One Loop Self-Energy and One Loop Tadpoles for eigenstates 'EWSB'

8.1 One Loop Self-Energy

- **Self-Energy for Higgs** (h)

$$\begin{aligned}\Pi_{i,j}(p^2) = &+\frac{1}{2}B_0\Big(p^2,m^2_{A^0},m^2_{A^0}\Big)\Gamma^*_{\check{h}_j,A^0,A^0}\Gamma_{\check{h}_i,A^0,A^0} + 2\Big(-\frac{1}{2}\text{rMS} + B_0\Big(p^2,m^2_Z,m^2_Z\Big)\Big)\Gamma^*_{\check{h}_j,Z,Z}\Gamma_{\check{h}_i,Z,Z} + B_0\Big(p^2,m^2_{H^+},m^2_{H^+}\Big)\Gamma^*_{\check{h}}\\
&+ 4\Big(-\frac{1}{2}\text{rMS} + B_0\Big(p^2,m^2_{W^+},m^2_{W^+}\Big)\Big)\Gamma^*_{\check{h}_j,W^-,W^+}\Gamma_{\check{h}_i,W^-,W^+} - B_0\Big(p^2,m^2_{\eta^+},m^2_{\eta^+}\Big)\Gamma_{\check{h}_i,\bar{\eta^+},\eta^+}\Gamma_{\check{h}_j,\bar{\eta^+},\eta^+}\\
&- B_0\Big(p^2,m^2_{\eta^-},m^2_{\eta^-}\Big)\Gamma_{\check{h}_i,\bar{\eta^-},\eta^-}\Gamma_{\check{h}_j,\bar{\eta^-},\eta^-} - B_0\Big(p^2,m^2_{\eta^Z},m^2_{\eta^Z}\Big)\Gamma_{\check{h}_i,\bar{\eta^Z},\eta^Z}\Gamma_{\check{h}_j,\bar{\eta^Z},\eta^Z} - \frac{1}{2}A_0\Big(m^2_{A^0}\Big)\Gamma_{\check{h}_i,\check{h}_j,A^0,A^0}\\
&- A_0\Big(m^2_{H^+}\Big)\Gamma_{\check{h}_i,\check{h}_j,H^-,H^+} + \Gamma^*_{\check{h}_j,Z,A^0}\Gamma_{\check{h}_i,Z,A^0}F_0\Big(p^2,m^2_{A^0},m^2_Z\Big)\\
&+ 2\Gamma^*_{\check{h}_j,W^-,H^+}\Gamma_{\check{h}_i,W^-,H^+}F_0\Big(p^2,m^2_{H^+},m^2_{W^+}\Big) + 4\Gamma_{\check{h}_i,\check{h}_j,W^-,W^+}\Big(-\frac{1}{2}\text{rMS}m^2_{W^+} + A_0\Big(m^2_{W^+}\Big)\Big)\end{aligned}$$

$$
\begin{aligned}
&+ 2\Gamma_{\check{h}_i,\check{h}_j,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\Big(m_Z^2\Big)\Big) - \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{h_a}^2\Big)\Gamma_{\check{h}_i,\check{h}_j,h_a,h_a} \\
&+ \frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{2} B_0\Big(p^2, m_{h_a}^2, m_{h_b}^2\Big)\Gamma^*_{\check{h}_j,h_a,h_b}\Gamma_{\check{h}_i,h_a,h_b} \\
&- 6\sum_{a=1}^{3} m_{d_a}\sum_{b=1}^{3} B_0\Big(p^2, m_{d_a}^2, m_{d_b}^2\Big)m_{d_b}\Big(\Gamma^{L*}_{\check{h}_j,\bar{d}_a,d_b}\Gamma^{R}_{\check{h}_i,\bar{d}_a,d_b} + \Gamma^{R*}_{\check{h}_j,\bar{d}_a,d_b}\Gamma^{L}_{\check{h}_i,\bar{d}_a,d_b}\Big) \\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3} G_0\Big(p^2, m_{d_a}^2, m_{d_b}^2\Big)\Big(\Gamma^{L*}_{\check{h}_j,\bar{d}_a,d_b}\Gamma^{L}_{\check{h}_i,\bar{d}_a,d_b} + \Gamma^{R*}_{\check{h}_j,\bar{d}_a,d_b}\Gamma^{R}_{\check{h}_i,\bar{d}_a,d_b}\Big) \\
&- 2\sum_{a=1}^{3} m_{e_a}\sum_{b=1}^{3} B_0\Big(p^2, m_{e_a}^2, m_{e_b}^2\Big)m_{e_b}\Big(\Gamma^{L*}_{\check{h}_j,\bar{e}_a,e_b}\Gamma^{R}_{\check{h}_i,\bar{e}_a,e_b} + \Gamma^{R*}_{\check{h}_j,\bar{e}_a,e_b}\Gamma^{L}_{\check{h}_i,\bar{e}_a,e_b}\Big) \\
&+ \sum_{a=1}^{3}\sum_{b=1}^{3} G_0\Big(p^2, m_{e_a}^2, m_{e_b}^2\Big)\Big(\Gamma^{L*}_{\check{h}_j,\bar{e}_a,e_b}\Gamma^{L}_{\check{h}_i,\bar{e}_a,e_b} + \Gamma^{R*}_{\check{h}_j,\bar{e}_a,e_b}\Gamma^{R}_{\check{h}_i,\bar{e}_a,e_b}\Big) \\
&- 6\sum_{a=1}^{3} m_{u_a}\sum_{b=1}^{3} B_0\Big(p^2, m_{u_a}^2, m_{u_b}^2\Big)m_{u_b}\Big(\Gamma^{L*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{R}_{\check{h}_i,\bar{u}_a,u_b} + \Gamma^{R*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{L}_{\check{h}_i,\bar{u}_a,u_b}\Big) \\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3} G_0\Big(p^2, m_{u_a}^2, m_{u_b}^2\Big)\Big(\Gamma^{L*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{L}_{\check{h}_i,\bar{u}_a,u_b} + \Gamma^{R*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{R}_{\check{h}_i,\bar{u}_a,u_b}\Big)
\end{aligned} \tag{53}
$$

- **Self-Energy for Down-Quarks** (d)

$$
\begin{aligned}
\Sigma^S_{i,j}(p^2) = &+\sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m_{d_b}^2, m_{h_a}^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,h_a,d_b}m_{d_b}\Gamma^{R}_{\check{\bar{d}}_i,h_a,d_b} \\
&+ \sum_{a=1}^{3} B_0\Big(p^2, m_{d_a}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,d_a,A^0}m_{d_a}\Gamma^{R}_{\check{\bar{d}}_i,d_a,A^0} - \frac{16}{3}\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{d_b}^2, 0\Big)\Big)\Gamma^{R*}_{\check{\bar{d}}_j,g,d_b}m_{d_b}\Gamma^{L}_{\check{\bar{d}}_i,g,d_b} \\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{d_b}^2, 0\Big)\Big)\Gamma^{R*}_{\check{\bar{d}}_j,\gamma,d_b}m_{d_b}\Gamma^{L}_{\check{\bar{d}}_i,\gamma,d_b} - 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{d_b}^2, m_Z^2\Big)\Big)\Gamma^{R*}_{\check{\bar{d}}_j,Z,d_b}m_{d_b}\Gamma^{L}_{\check{\bar{d}}_i,Z,d_b} \\
&+ \sum_{b=1}^{3} B_0\Big(p^2, m_{u_b}^2, m_{H^+}^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,H^-,u_b}m_{u_b}\Gamma^{R}_{\check{\bar{d}}_i,H^-,u_b} \\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{u_b}^2, m_{W^+}^2\Big)\Big)\Gamma^{R*}_{\check{\bar{d}}_j,W^-,u_b}m_{u_b}\Gamma^{L}_{\check{\bar{d}}_i,W^-,u_b}
\end{aligned} \tag{54}
$$

$$
\begin{aligned}
\Sigma^R_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{h_a}^2\Big)\Gamma^{R*}_{\check{\bar{d}}_j,h_a,d_b}\Gamma^{R}_{\check{\bar{d}}_i,h_a,d_b} - \frac{1}{2}\sum_{a=1}^{3} B_1\Big(p^2, m_{d_a}^2, m_{A^0}^2\Big)\Gamma^{R*}_{\check{\bar{d}}_j,d_a,A^0}\Gamma^{R}_{\check{\bar{d}}_i,d_a,A^0} \\
&- \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{L*}_{\check{\bar{d}}_j,g,d_b}\Gamma^{L}_{\check{\bar{d}}_i,g,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{L*}_{\check{\bar{d}}_j,\gamma,d_b}\Gamma^{L}_{\check{\bar{d}}_i,\gamma,d_b}
\end{aligned}
$$

$$
\begin{aligned}
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_Z^2\Big)\Gamma^{L*}_{\check{\tilde{d}}_j,Z,d_b}\Gamma^{L}_{\check{\tilde{d}}_i,Z,d_b} - \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{H^+}^2\Big)\Gamma^{R*}_{\check{\tilde{d}}_j,H^-,u_b}\Gamma^{R}_{\check{\tilde{d}}_i,H^-,u_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{W^+}^2\Big)\Gamma^{L*}_{\check{\tilde{d}}_j,W^-,u_b}\Gamma^{L}_{\check{\tilde{d}}_i,W^-,u_b} \qquad (55)\\
\Sigma^L_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{h_a}^2\Big)\Gamma^{L*}_{\check{\tilde{d}}_j,h_a,d_b}\Gamma^{L}_{\check{\tilde{d}}_i,h_a,d_b} - \frac{1}{2}\sum_{a=1}^{3} B_1\Big(p^2, m_{d_a}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\tilde{d}}_j,d_a,A^0}\Gamma^{L}_{\check{\tilde{d}}_i,d_a,A^0} \\
&- \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{R*}_{\check{\tilde{d}}_j,g,d_b}\Gamma^{R}_{\check{\tilde{d}}_i,g,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{R*}_{\check{\tilde{d}}_j,\gamma,d_b}\Gamma^{R}_{\check{\tilde{d}}_i,\gamma,d_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_Z^2\Big)\Gamma^{R*}_{\check{\tilde{d}}_j,Z,d_b}\Gamma^{R}_{\check{\tilde{d}}_i,Z,d_b} - \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{H^+}^2\Big)\Gamma^{L*}_{\check{\tilde{d}}_j,H^-,u_b}\Gamma^{L}_{\check{\tilde{d}}_i,H^-,u_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{W^+}^2\Big)\Gamma^{R*}_{\check{\tilde{d}}_j,W^-,u_b}\Gamma^{R}_{\check{\tilde{d}}_i,W^-,u_b} \qquad (56)
\end{aligned}
$$

- **Self-Energy for Up-Quarks** (u)

$$
\begin{aligned}
\Sigma^S_{i,j}(p^2) = &+\sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m_{u_b}^2, m_{h_a}^2\Big)\Gamma^{L*}_{\check{\tilde{u}}_j,h_a,u_b} m_{u_b}\Gamma^{R}_{\check{\tilde{u}}_i,h_a,u_b} \\
&+ \sum_{a=1}^{3} B_0\Big(p^2, m_{u_a}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\tilde{u}}_j,u_a,A^0} m_{u_a}\Gamma^{R}_{\check{\tilde{u}}_i,u_a,A^0} + \sum_{b=1}^{3} B_0\Big(p^2, m_{d_b}^2, m_{H^+}^2\Big)\Gamma^{L*}_{\check{\tilde{u}}_j,H^+,d_b} m_{d_b}\Gamma^{R}_{\check{\tilde{u}}_i,H^+,d_b} \\
&- \frac{16}{3}\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{u_b}^2, 0\Big)\Big)\Gamma^{R*}_{\check{\tilde{u}}_j,g,u_b} m_{u_b}\Gamma^{L}_{\check{\tilde{u}}_i,g,u_b} - 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{u_b}^2, 0\Big)\Big)\Gamma^{R*}_{\check{\tilde{u}}_j,\gamma,u_b} m_{u_b}\Gamma^{L}_{\check{\tilde{u}}_i,\gamma,u_b} \\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{d_b}^2, m_{W^+}^2\Big)\Big)\Gamma^{R*}_{\check{\tilde{u}}_j,W^+,d_b} m_{d_b}\Gamma^{L}_{\check{\tilde{u}}_i,W^+,d_b} \\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{u_b}^2, m_Z^2\Big)\Big)\Gamma^{R*}_{\check{\tilde{u}}_j,Z,u_b} m_{u_b}\Gamma^{L}_{\check{\tilde{u}}_i,Z,u_b} \qquad (57)\\
\Sigma^R_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{h_a}^2\Big)\Gamma^{R*}_{\check{\tilde{u}}_j,h_a,u_b}\Gamma^{R}_{\check{\tilde{u}}_i,h_a,u_b} - \frac{1}{2}\sum_{a=1}^{3} B_1\Big(p^2, m_{u_a}^2, m_{A^0}^2\Big)\Gamma^{R*}_{\check{\tilde{u}}_j,u_a,A^0}\Gamma^{R}_{\check{\tilde{u}}_i,u_a,A^0} \\
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{H^+}^2\Big)\Gamma^{R*}_{\check{\tilde{u}}_j,H^+,d_b}\Gamma^{R}_{\check{\tilde{u}}_i,H^+,d_b} - \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big)\Gamma^{L*}_{\check{\tilde{u}}_j,g,u_b}\Gamma^{L}_{\check{\tilde{u}}_i,g,u_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big)\Gamma^{L*}_{\check{\tilde{u}}_j,\gamma,u_b}\Gamma^{L}_{\check{\tilde{u}}_i,\gamma,u_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{W^+}^2\Big)\Gamma^{L*}_{\check{\tilde{u}}_j,W^+,d_b}\Gamma^{L}_{\check{\tilde{u}}_i,W^+,d_b}
\end{aligned}
$$

$$- \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_Z^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,Z,u_b}\Gamma^{L}_{\check{\bar{u}}_i,Z,u_b} \tag{58}$$

$$\begin{aligned}
\Sigma^L_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{h_a}^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,h_a,u_b}\Gamma^{L}_{\check{\bar{u}}_i,h_a,u_b} - \frac{1}{2}\sum_{a=1}^{3} B_1\Big(p^2, m_{u_a}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,u_a,A^0}\Gamma^{L}_{\check{\bar{u}}_i,u_a,A^0}\\
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{H^+}^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,H^+,d_b}\Gamma^{L}_{\check{\bar{u}}_i,H^+,d_b} - \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big)\Gamma^{R*}_{\check{\bar{u}}_j,g,u_b}\Gamma^{R}_{\check{\bar{u}}_i,g,u_b}\\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big)\Gamma^{R*}_{\check{\bar{u}}_j,\gamma,u_b}\Gamma^{R}_{\check{\bar{u}}_i,\gamma,u_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{W^+}^2\Big)\Gamma^{R*}_{\check{\bar{u}}_j,W^+,d_b}\Gamma^{R}_{\check{\bar{u}}_i,W^+,d_b}\\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_Z^2\Big)\Gamma^{R*}_{\check{\bar{u}}_j,Z,u_b}\Gamma^{R}_{\check{\bar{u}}_i,Z,u_b}
\end{aligned} \tag{59}$$

- **Self-Energy for Leptons** (e)

$$\begin{aligned}
\Sigma^S_{i,j}(p^2) = &+\sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m_{e_b}^2, m_{h_a}^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,h_a,e_b} m_{e_b}\Gamma^{R}_{\check{\bar{e}}_i,h_a,e_b}\\
&+\sum_{a=1}^{3} B_0\Big(p^2, m_{e_a}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,e_a,A^0} m_{e_a}\Gamma^{R}_{\check{\bar{e}}_i,e_a,A^0} - 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{e_b}^2, 0\Big)\Big)\Gamma^{R*}_{\check{\bar{e}}_j,\gamma,e_b} m_{e_b}\Gamma^{L}_{\check{\bar{e}}_i,\gamma,e_b}\\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{e_b}^2, m_Z^2\Big)\Big)\Gamma^{R*}_{\check{\bar{e}}_j,Z,e_b} m_{e_b}\Gamma^{L}_{\check{\bar{e}}_i,Z,e_b}\\
&+\sum_{b=1}^{3} B_0\Big(p^2, m_{\nu_b}^2, m_{H^+}^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,H^-,\nu_b} m_{\nu_b}\Gamma^{R}_{\check{\bar{e}}_i,H^-,\nu_b}\\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{\nu_b}^2, m_{W^+}^2\Big)\Big)\Gamma^{R*}_{\check{\bar{e}}_j,W^-,\nu_b} m_{\nu_b}\Gamma^{L}_{\check{\bar{e}}_i,W^-,\nu_b}
\end{aligned} \tag{60}$$

$$\begin{aligned}
\Sigma^R_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_{h_a}^2\Big)\Gamma^{R*}_{\check{\bar{e}}_j,h_a,e_b}\Gamma^{R}_{\check{\bar{e}}_i,h_a,e_b} - \frac{1}{2}\sum_{a=1}^{3} B_1\Big(p^2, m_{e_a}^2, m_{A^0}^2\Big)\Gamma^{R*}_{\check{\bar{e}}_j,e_a,A^0}\Gamma^{R}_{\check{\bar{e}}_i,e_a,A^0}\\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, 0\Big)\Gamma^{L*}_{\check{\bar{e}}_j,\gamma,e_b}\Gamma^{L}_{\check{\bar{e}}_i,\gamma,e_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_Z^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,Z,e_b}\Gamma^{L}_{\check{\bar{e}}_i,Z,e_b}\\
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{H^+}^2\Big)\Gamma^{R*}_{\check{\bar{e}}_j,H^-,\nu_b}\Gamma^{R}_{\check{\bar{e}}_i,H^-,\nu_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{W^+}^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,W^-,\nu_b}\Gamma^{L}_{\check{\bar{e}}_i,W^-,\nu_b}
\end{aligned} \tag{61}$$

$$\Sigma^L_{i,j}(p^2) = -\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_{h_a}^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,h_a,e_b}\Gamma^{L}_{\check{\bar{e}}_i,h_a,e_b} - \frac{1}{2}\sum_{a=1}^{3} B_1\Big(p^2, m_{e_a}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,e_a,A^0}\Gamma^{L}_{\check{\bar{e}}_i,e_a,A^0}$$

$$
\begin{aligned}
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, 0\Big)\Gamma^{R*}_{\tilde{e}_j,\gamma,e_b}\Gamma^{R}_{\tilde{e}_i,\gamma,e_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_Z^2\Big)\Gamma^{R*}_{\tilde{e}_j,Z,e_b}\Gamma^{R}_{\tilde{e}_i,Z,e_b} \\
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{H^+}^2\Big)\Gamma^{L*}_{\tilde{e}_j,H^-,\nu_b}\Gamma^{L}_{\tilde{e}_i,H^-,\nu_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{W^+}^2\Big)\Gamma^{R*}_{\tilde{e}_j,W^-,\nu_b}\Gamma^{R}_{\tilde{e}_i,W^-,\nu_b} \qquad (62)
\end{aligned}
$$

- **Self-Energy for Charged Higgs** (H^+)

$$
\begin{aligned}
\Pi(p^2) = &+4|\Gamma_{H^-,W^+,\gamma}|^2\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, 0, m_{W^+}^2\Big)\Big) + 4|\Gamma_{H^-,Z,W^+}|^2\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{W^+}^2, m_Z^2\Big)\Big) \\
&- B_0\Big(p^2, m_{\eta^z}^2, m_{\eta^-}^2\Big)\Gamma_{H^+,\eta^-,\bar{\eta^z}}\Gamma_{H^-,\bar{\eta^-},\eta^z} - B_0\Big(p^2, m_{\eta^+}^2, m_{\eta^z}^2\Big)\Gamma_{H^+,\eta^z,\bar{\eta^+}}\Gamma_{H^-,\bar{\eta^z},\eta^+} \\
&- \frac{1}{2}A_0\Big(m_{A^0}^2\Big)\Gamma_{H^+,H^-,A^0,A^0} - A_0\Big(m_{H^+}^2\Big)\Gamma_{H^+,H^-,H^-,H^+} + |\Gamma_{H^-,W^+,A^0}|^2 F_0\Big(p^2, m_{A^0}^2, m_{W^+}^2\Big) \\
&+ |\Gamma_{H^-,\gamma,H^+}|^2 F_0\Big(p^2, m_{H^+}^2, 0\Big) + |\Gamma_{H^-,Z,H^+}|^2 F_0\Big(p^2, m_{H^+}^2, m_Z^2\Big) + 4\Gamma_{H^+,H^-,W^-,W^+}\Big(-\frac{1}{2}\mathrm{rMS}m_{W^+}^2 + A_0\Big(m_{W^+}^2\Big)\Big) \\
&+ 2\Gamma_{H^+,H^-,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\Big(m_Z^2\Big)\Big) - \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{h_a}^2\Big)\Gamma_{H^+,H^-,h_a,h_a} \\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^L_{H^-,\bar{d}_a,u_b}|^2 + |\Gamma^R_{H^-,\bar{d}_a,u_b}|^2\Big)G_0\Big(p^2, m_{d_a}^2, m_{u_b}^2\Big) \\
&+ \sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^L_{H^-,\bar{e}_a,\nu_b}|^2 + |\Gamma^R_{H^-,\bar{e}_a,\nu_b}|^2\Big)G_0\Big(p^2, m_{e_a}^2, m_{\nu_b}^2\Big) \\
&- 6\sum_{a=1}^{3} m_{d_a}\sum_{b=1}^{3} B_0\Big(p^2, m_{d_a}^2, m_{u_b}^2\Big)m_{u_b}\Big(\Gamma^{L*}_{H^-,\bar{d}_a,u_b}\Gamma^{R}_{H^-,\bar{d}_a,u_b} + \Gamma^{R*}_{H^-,\bar{d}_a,u_b}\Gamma^{L}_{H^-,\bar{d}_a,u_b}\Big) \\
&- 2\sum_{a=1}^{3} m_{e_a}\sum_{b=1}^{3} B_0\Big(p^2, m_{e_a}^2, m_{\nu_b}^2\Big)m_{\nu_b}\Big(\Gamma^{L*}_{H^-,\bar{e}_a,\nu_b}\Gamma^{R}_{H^-,\bar{e}_a,\nu_b} + \Gamma^{R*}_{H^-,\bar{e}_a,\nu_b}\Gamma^{L}_{H^-,\bar{e}_a,\nu_b}\Big) \\
&+ \sum_{b=1}^{2}|\Gamma_{H^-,H^+,h_b}|^2 B_0\Big(p^2, m_{H^+}^2, m_{h_b}^2\Big) + \sum_{b=1}^{2}|\Gamma_{H^-,W^+,h_b}|^2 F_0\Big(p^2, m_{h_b}^2, m_{W^+}^2\Big) \qquad (63)
\end{aligned}
$$

- **Self-Energy for Pseudo-Scalar Higgs** (A^0)

$$
\begin{aligned}
\Pi(p^2) = &- B_0\Big(p^2, m_{\eta^+}^2, m_{\eta^+}^2\Big)\Gamma^2_{A^0,\bar{\eta^+},\eta^+} - B_0\Big(p^2, m_{\eta^-}^2, m_{\eta^-}^2\Big)\Gamma^2_{A^0,\bar{\eta^-},\eta^-} - \frac{1}{2}A_0\Big(m_{A^0}^2\Big)\Gamma_{A^0,A^0,A^0,A^0} \\
&- A_0\Big(m_{H^+}^2\Big)\Gamma_{A^0,A^0,H^-,H^+} + 2|\Gamma_{A^0,W^-,H^+}|^2 F_0\Big(p^2, m_{H^+}^2, m_{W^+}^2\Big) + 4\Gamma_{A^0,A^0,W^-,W^+}\Big(-\frac{1}{2}\mathrm{rMS}m_{W^+}^2 + A_0\Big(m_{W^+}^2\Big)\Big) \\
&+ 2\Gamma_{A^0,A^0,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\Big(m_Z^2\Big)\Big) + \sum_{a=1}^{2}|\Gamma_{A^0,h_a,A^0}|^2 B_0\Big(p^2, m_{h_a}^2, m_{A^0}^2\Big) - \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{h_a}^2\Big)\Gamma_{A^0,A^0,h_a,h_a}
\end{aligned}
$$

$$
\begin{aligned}
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^{L}_{A^0,\bar{d}_a,d_b}|^2 + |\Gamma^{R}_{A^0,\bar{d}_a,d_b}|^2\Big)G_0\Big(p^2, m^2_{d_a}, m^2_{d_b}\Big)\\
&+ \sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^{L}_{A^0,\bar{e}_a,e_b}|^2 + |\Gamma^{R}_{A^0,\bar{e}_a,e_b}|^2\Big)G_0\Big(p^2, m^2_{e_a}, m^2_{e_b}\Big)\\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^{L}_{A^0,\bar{u}_a,u_b}|^2 + |\Gamma^{R}_{A^0,\bar{u}_a,u_b}|^2\Big)G_0\Big(p^2, m^2_{u_a}, m^2_{u_b}\Big)\\
&- 6\sum_{a=1}^{3} m_{d_a}\sum_{b=1}^{3}B_0\Big(p^2, m^2_{d_a}, m^2_{d_b}\Big)m_{d_b}\Big(\Gamma^{L*}_{A^0,\bar{d}_a,d_b}\Gamma^{R}_{A^0,\bar{d}_a,d_b} + \Gamma^{R*}_{A^0,\bar{d}_a,d_b}\Gamma^{L}_{A^0,\bar{d}_a,d_b}\Big)\\
&- 2\sum_{a=1}^{3} m_{e_a}\sum_{b=1}^{3}B_0\Big(p^2, m^2_{e_a}, m^2_{e_b}\Big)m_{e_b}\Big(\Gamma^{L*}_{A^0,\bar{e}_a,e_b}\Gamma^{R}_{A^0,\bar{e}_a,e_b} + \Gamma^{R*}_{A^0,\bar{e}_a,e_b}\Gamma^{L}_{A^0,\bar{e}_a,e_b}\Big)\\
&- 6\sum_{a=1}^{3} m_{u_a}\sum_{b=1}^{3}B_0\Big(p^2, m^2_{u_a}, m^2_{u_b}\Big)m_{u_b}\Big(\Gamma^{L*}_{A^0,\bar{u}_a,u_b}\Gamma^{R}_{A^0,\bar{u}_a,u_b} + \Gamma^{R*}_{A^0,\bar{u}_a,u_b}\Gamma^{L}_{A^0,\bar{u}_a,u_b}\Big)\\
&+ \sum_{b=1}^{2}|\Gamma_{A^0,Z,h_b}|^2 F_0\Big(p^2, m^2_{h_b}, m^2_Z\Big)
\end{aligned}
\tag{64}
$$

- **Self-Energy for Z-Boson** (Z)

$$
\begin{aligned}
\Pi(p^2) = {}& +2|\Gamma_{Z,W^-,H^+}|^2 B_0\Big(p^2, m^2_{W^+}, m^2_{H^+}\Big) + |\Gamma_{Z,\eta^+,\eta^+}|^2 B_{00}\Big(p^2, m^2_{\eta^+}, m^2_{\eta^+}\Big) + |\Gamma_{Z,\eta^-,\eta^-}|^2 B_{00}\Big(p^2, m^2_{\eta^-}, m^2_{\eta^-}\Big)\\
&- 4|\Gamma_{Z,H^-,H^+}|^2 B_{00}\Big(p^2, m^2_{H^+}, m^2_{H^+}\Big) + \frac{1}{2}A_0\Big(m^2_{A^0}\Big)\Gamma_{Z,Z,A^0,A^0} + A_0\Big(m^2_{H^+}\Big)\Gamma_{Z,Z,H^-,H^+}\\
&- |\Gamma_{Z,W^-,W^+}|^2\Big(10B_{00}\Big(p^2, m^2_{W^+}, m^2_{W^+}\Big) + 2A_0\Big(m^2_{W^+}\Big) - 2\mathrm{rMS}\Big(2m^2_{W^+} - \frac{1}{3}p^2\Big) + B_0\Big(p^2, m^2_{W^+}, m^2_{W^+}\Big)\Big(2m^2_{W^+} + 4p^2\Big)\Big)\\
&- 4\sum_{a=1}^{2}|\Gamma_{Z,h_a,A^0}|^2 B_{00}\Big(p^2, m^2_{A^0}, m^2_{h_a}\Big) + \frac{1}{2}\sum_{a=1}^{2}A_0\Big(m^2_{h_a}\Big)\Gamma_{Z,Z,h_a,h_a}\\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big[\Big(|\Gamma^{L}_{Z,\bar{d}_a,d_b}|^2 + |\Gamma^{R}_{Z,\bar{d}_a,d_b}|^2\Big)H_0\Big(p^2, m^2_{d_a}, m^2_{d_b}\Big)\\
&+ 4B_0\Big(p^2, m^2_{d_a}, m^2_{d_b}\Big)m_{d_a}m_{d_b}\Re\Big(\Gamma^{L*}_{Z,\bar{d}_a,d_b}\Gamma^{R}_{Z,\bar{d}_a,d_b}\Big)\Big]\\
&+ \sum_{a=1}^{3}\sum_{b=1}^{3}\Big[\Big(|\Gamma^{L}_{Z,\bar{e}_a,e_b}|^2 + |\Gamma^{R}_{Z,\bar{e}_a,e_b}|^2\Big)H_0\Big(p^2, m^2_{e_a}, m^2_{e_b}\Big)\\
&+ 4B_0\Big(p^2, m^2_{e_a}, m^2_{e_b}\Big)m_{e_a}m_{e_b}\Re\Big(\Gamma^{L*}_{Z,\bar{e}_a,e_b}\Gamma^{R}_{Z,\bar{e}_a,e_b}\Big)\Big]\\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big[\Big(|\Gamma^{L}_{Z,\bar{u}_a,u_b}|^2 + |\Gamma^{R}_{Z,\bar{u}_a,u_b}|^2\Big)H_0\Big(p^2, m^2_{u_a}, m^2_{u_b}\Big)\\
&+ 4B_0\Big(p^2, m^2_{u_a}, m^2_{u_b}\Big)m_{u_a}m_{u_b}\Re\Big(\Gamma^{L*}_{Z,\bar{u}_a,u_b}\Gamma^{R}_{Z,\bar{u}_a,u_b}\Big)\Big]
\end{aligned}
$$

$$
\begin{aligned}
&+\sum_{a=1}^{3}\sum_{b=1}^{3}\Big[\Big(|\Gamma^{L}_{Z,\bar{\nu}_a,\nu_b}|^2+|\Gamma^{R}_{Z,\bar{\nu}_a,\nu_b}|^2\Big)H_0\Big(p^2,m^2_{\nu_a},m^2_{\nu_b}\Big)\\
&+4B_0\Big(p^2,m^2_{\nu_a},m^2_{\nu_b}\Big)m_{\nu_a}m_{\nu_b}\Re\Big(\Gamma^{L*}_{Z,\bar{\nu}_a,\nu_b}\Gamma^{R}_{Z,\bar{\nu}_a,\nu_b}\Big)\Big]\\
&+\sum_{b=1}^{2}|\Gamma_{Z,Z,h_b}|^2B_0\Big(p^2,m^2_Z,m^2_{h_b}\Big)+2\mathrm{rMS}m^2_{W^+}\Gamma^{1}_{Z,Z,W^-,W^+}-A_0\Big(m^2_{W^+}\Big)\Big(4\Gamma^{1}_{Z,Z,W^-,W^+}+\Gamma^{2}_{Z,Z,W^-,W^+}+\Gamma^{3}_{Z,Z,W^-,W^+}\Big)
\end{aligned}
\tag{65}
$$

- **Self-Energy for W+ - Boson** (W^+)

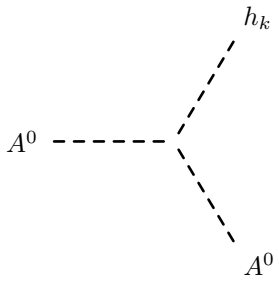
$$
\begin{aligned}
\Pi(p^2)=\;&2\mathrm{rMS}m^2_{W^+}\Gamma^{1}_{W^+,W^-,W^-,W^+}+3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big[\Big(|\Gamma^{L}_{W^-,\bar{d}_a,u_b}|^2+|\Gamma^{R}_{W^-,\bar{d}_a,u_b}|^2\Big)H_0\Big(p^2,m^2_{d_a},m^2_{u_b}\Big)\\
&+4B_0\Big(p^2,m^2_{d_a},m^2_{u_b}\Big)m_{d_a}m_{u_b}\Re\Big(\Gamma^{L*}_{W^-,\bar{d}_a,u_b}\Gamma^{R}_{W^-,\bar{d}_a,u_b}\Big)\Big]-4|\Gamma_{W^-,H^+,A^0}|^2B_{00}\Big(p^2,m^2_{A^0},m^2_{H^+}\Big)-4\sum_{b=1}^{2}|\Gamma_{W^-,H^+,h_b}|^2B_{00}\Big(p\\
&+4B_0\Big(p^2,m^2_{e_a},m^2_{\nu_b}\Big)m_{e_a}m_{\nu_b}\Re\Big(\Gamma^{L*}_{W^-,\bar{e}_a,\nu_b}\Gamma^{R}_{W^-,\bar{e}_a,\nu_b}\Big)\Big]+\sum_{b=1}^{2}|\Gamma_{W^-,W^+,h_b}|^2B_0\Big(p^2,m^2_{W^+},m^2_{h_b}\Big)
\end{aligned}
\tag{66}
$$

8.2 Tadpoles

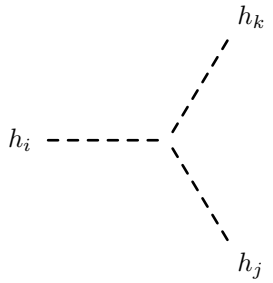
$$
\begin{aligned}
\delta t^{(1)}_h=\;&-\frac{1}{2}A_0\Big(m^2_{A^0}\Big)\Gamma_{\check{h}_i,A^0,A^0}+A_0\Big(m^2_{\eta^+}\Big)\Gamma_{\check{h}_i,\eta^-,\eta^+}+A_0\Big(m^2_{\eta^-}\Big)\Gamma_{\check{h}_i,\eta^-,\eta^-}+A_0\Big(m^2_{\eta^Z}\Big)\Gamma_{\check{h}_i,\eta^Z,\eta^Z}\\
&-A_0\Big(m^2_{H^+}\Big)\Gamma_{\check{h}_i,H^-,H^+}+4\Gamma_{\check{h}_i,W^-,W^+}\Big(-\frac{1}{2}\mathrm{rMS}m^2_{W^+}+A_0\Big(m^2_{W^+}\Big)\Big)+2\Gamma_{\check{h}_i,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m^2_Z+A_0\Big(m^2_Z\Big)\Big)\\
&-\frac{1}{2}\sum_{a=1}^{2}A_0\Big(m^2_{h_a}\Big)\Gamma_{\check{h}_i,h_a,h_a}+6\sum_{a=1}^{3}A_0\Big(m^2_{d_a}\Big)m_{d_a}\Big(\Gamma^{L}_{\check{h}_i,\bar{d}_a,d_a}+\Gamma^{R}_{\check{h}_i,\bar{d}_a,d_a}\Big)\\
&+2\sum_{a=1}^{3}A_0\Big(m^2_{e_a}\Big)m_{e_a}\Big(\Gamma^{L}_{\check{h}_i,\bar{e}_a,e_a}+\Gamma^{R}_{\check{h}_i,\bar{e}_a,e_a}\Big)\\
&+6\sum_{a=1}^{3}A_0\Big(m^2_{u_a}\Big)m_{u_a}\Big(\Gamma^{L}_{\check{h}_i,\bar{u}_a,u_a}+\Gamma^{R}_{\check{h}_i,\bar{u}_a,u_a}\Big)
\end{aligned}
\tag{67}
$$

9 Interactions for eigenstates 'EWSB'

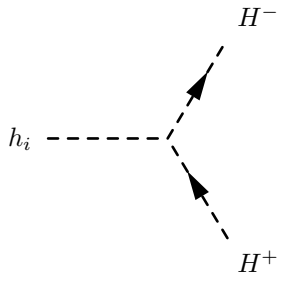
9.1 Three Scalar-Interaction



$$-i\Big(\kappa_1 Z^H_{k2} + v\lambda Z^H_{k1}\Big) \tag{68}$$

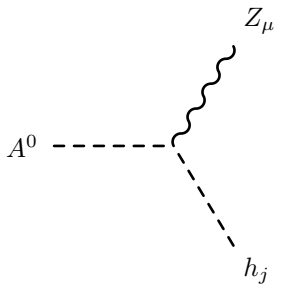


$$\begin{aligned}&-i\Big(Z^H_{i2}\Big(\kappa_2 v Z^H_{j2} Z^H_{k1} + Z^H_{j1}\Big(\kappa_1 Z^H_{k1} + \kappa_2 v Z^H_{k2}\Big)\Big)\\&+ Z^H_{i1}\Big(Z^H_{j1}\Big(3v\lambda Z^H_{k1} + \kappa_1 Z^H_{k2}\Big) + Z^H_{j2}\Big(\kappa_1 Z^H_{k1} + \kappa_2 v Z^H_{k2}\Big)\Big)\Big)\end{aligned} \tag{69}$$

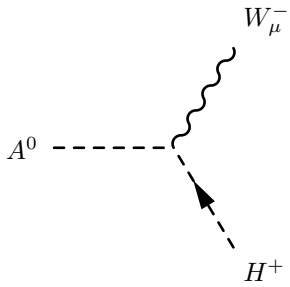


$$-i\Big(\kappa_1 Z^H_{i2} + v\lambda Z^H_{i1}\Big) \tag{70}$$

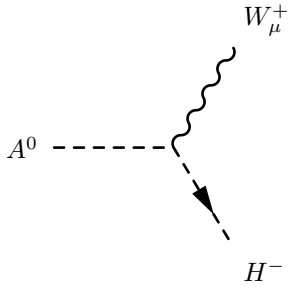
9.2 Two Scalar-One Vector Boson-Interaction



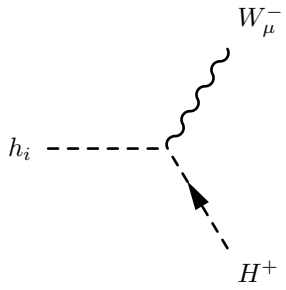
$$-\frac{1}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big) Z_{j1}^{H}\Big(-p_\mu^{h_j} + p_\mu^{A^0}\Big) \tag{71}$$



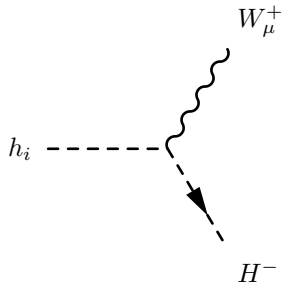
$$\frac{1}{2} g_2 \Big(-p_\mu^{H^+} + p_\mu^{A^0}\Big) \tag{72}$$



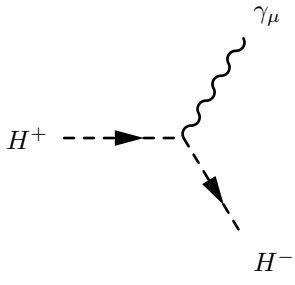
$$\frac{1}{2} g_2 \Big(-p_\mu^{H^-} + p_\mu^{A^0}\Big) \tag{73}$$



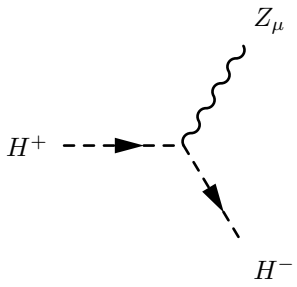
$$\frac{i}{2}g_2 Z_{i1}^H \Big(- p_\mu^{H^+} + p_\mu^{h_i} \Big) \tag{74}$$



$$-\frac{i}{2}g_2 Z_{i1}^H \Big(- p_\mu^{H^-} + p_\mu^{h_i} \Big) \tag{75}$$

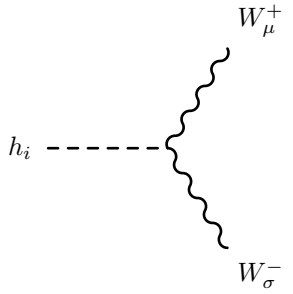


$$-\frac{i}{2}\Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W\Big)\Big(- p_\mu^{H^-} + p_\mu^{H^+} \Big) \tag{76}$$

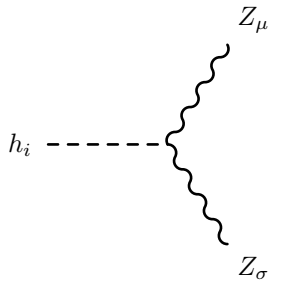


$$-\frac{i}{2}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(-p_\mu^{H^-}+p_\mu^{H^+}\Big) \tag{77}$$

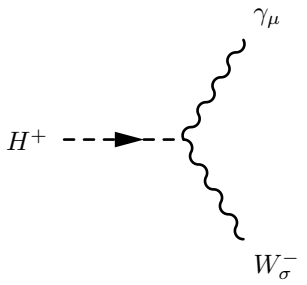
9.3 One Scalar-Two Vector Boson-Interaction



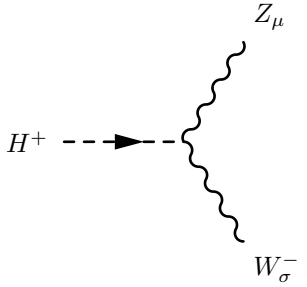
$$\frac{i}{2}g_2^2 v Z_{i1}^H\Big(g_{\sigma\mu}\Big) \tag{78}$$



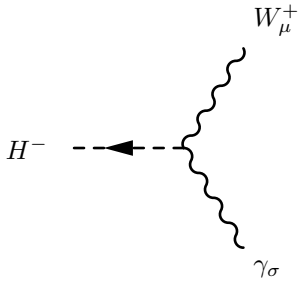
$$\frac{i}{2}v\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 Z_{i1}^H\Big(g_{\sigma\mu}\Big) \tag{79}$$



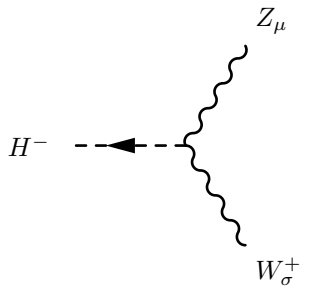
$$\frac{i}{2} g_1 g_2 v \cos\Theta_W \Big(g_{\sigma\mu} \Big) \tag{80}$$



$$-\frac{i}{2} g_1 g_2 v \sin\Theta_W \Big(g_{\sigma\mu} \Big) \tag{81}$$

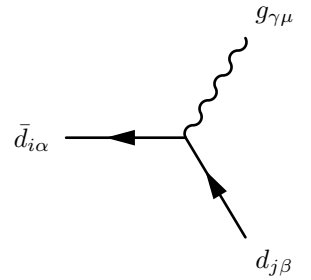


$$\frac{i}{2} g_1 g_2 v \cos\Theta_W \Big(g_{\sigma\mu} \Big) \tag{82}$$



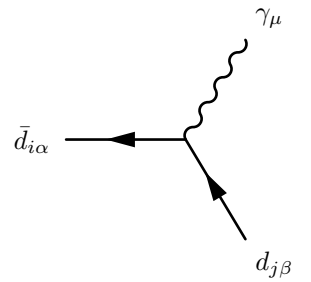
$$-\frac{i}{2}g_1 g_2 v \sin\Theta_W\Big(g_{\sigma\mu}\Big) \tag{83}$$

9.4 Two Fermion-One Vector Boson-Interaction



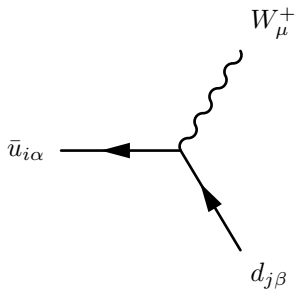
$$-\frac{i}{2}g_3\delta_{ij}\lambda^{\gamma}_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{84}$$

$$+\ -\frac{i}{2}g_3\delta_{ij}\lambda^{\gamma}_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{85}$$

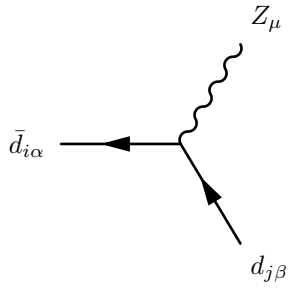


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{86}$$

$$+\ \frac{i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{87}$$

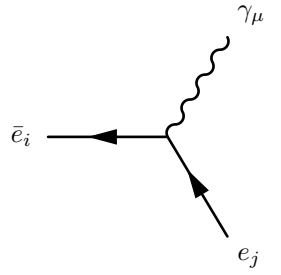


$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}U^{d,*}_{L,ja}U^{u}_{L,ia}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{88}$$



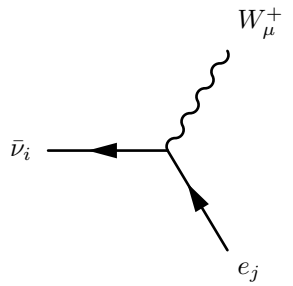
$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2\cos\Theta_W+g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{89}$$

$$+\ -\frac{i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{90}$$

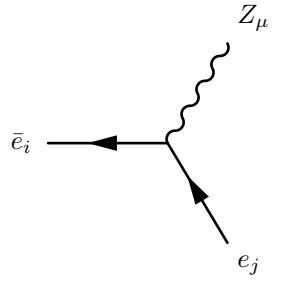


$$\frac{i}{2}\delta_{ij}\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{91}$$

$$+\ ig_1\cos\Theta_W\delta_{ij}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{92}$$

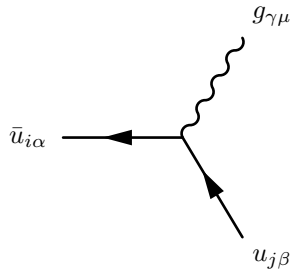


$$-i\frac{1}{\sqrt{2}}g_2 U^{e,*}_{L,ji}\Theta_{i,3}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{93}$$



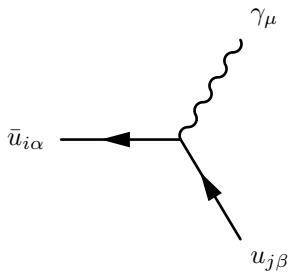
$$\frac{i}{2}\delta_{ij}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{94}$$

$$+\ -ig_1\delta_{ij}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{95}$$



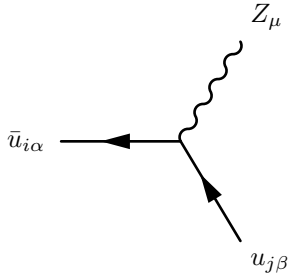
$$-\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{96}$$

$$+\ -\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{97}$$



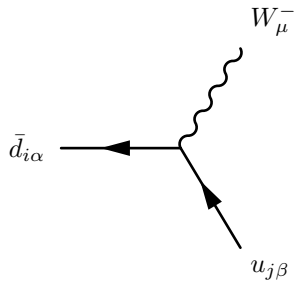
$$- \frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2 \sin\Theta_W + g_1 \cos\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{98}$$

$$+ \; -\frac{2i}{3} g_1 \cos\Theta_W \delta_{\alpha\beta}\delta_{ij}\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{99}$$

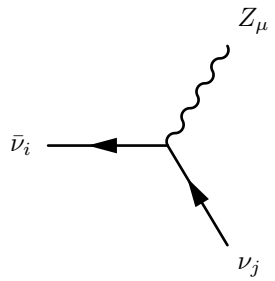


$$- \frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2 \cos\Theta_W - g_1 \sin\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{100}$$

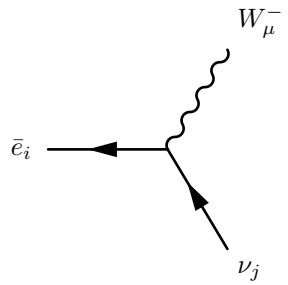
$$+ \; \frac{2i}{3} g_1 \delta_{\alpha\beta}\delta_{ij} \sin\Theta_W \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{101}$$



$$- \, i\frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^{3} U^{u,*}_{L,ja} U^{d}_{L,ia} \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{102}$$

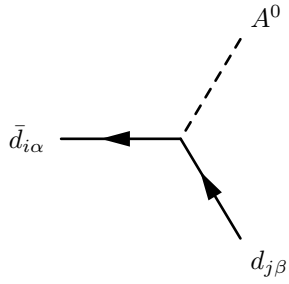


$$-\frac{i}{2}\delta_{ij}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{103}$$



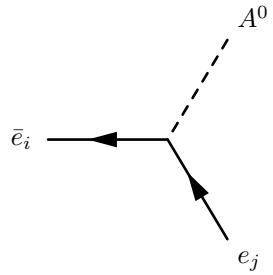
$$-i\frac{1}{\sqrt{2}}g_2\Theta_{j,3}U^e_{L,ij}\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{104}$$

9.5 Two Fermion-One Scalar Boson-Interaction



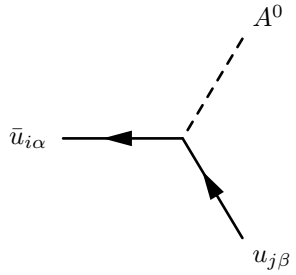
$$-\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U^{d,*}_{L,jb}\sum_{a=1}^{3}U^{d,*}_{R,ia}Y_{d,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{105}$$

$$+\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ab}U^d_{R,ja}U^d_{L,ib}\Big(\frac{1+\gamma_5}{2}\Big) \tag{106}$$



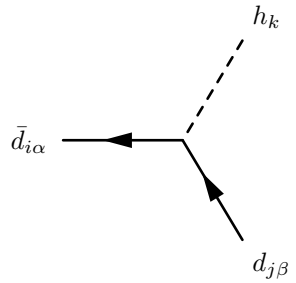
$$-\frac{1}{\sqrt{2}}\sum_{b=1}^{3}U^{e,*}_{L,jb}\sum_{a=1}^{3}U^{e,*}_{R,ia}Y_{e,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{107}$$

$$+\frac{1}{\sqrt{2}}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{e,ab}U^{e}_{R,ja}U^{e}_{L,ib}\Big(\frac{1+\gamma_5}{2}\Big) \tag{108}$$



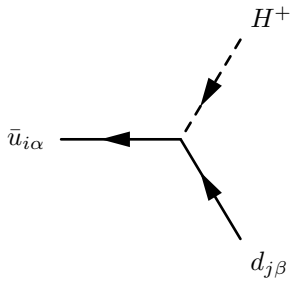
$$-\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U^{u,*}_{L,jb}\sum_{a=1}^{3}U^{u,*}_{R,ia}Y_{u,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{109}$$

$$+\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{u,ab}U^{u}_{R,ja}U^{u}_{L,ib}\Big(\frac{1+\gamma_5}{2}\Big) \tag{110}$$



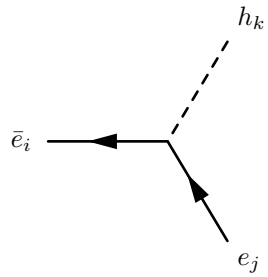
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}U_{R,ia}^{d,*}Y_{d,ab}Z_{k1}^{H}\Big(\frac{1-\gamma_5}{2}\Big) \tag{111}$$

$$+\ -i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{R,ja}^{d}U_{L,ib}^{d}Z_{k1}^{H}\Big(\frac{1+\gamma_5}{2}\Big) \tag{112}$$



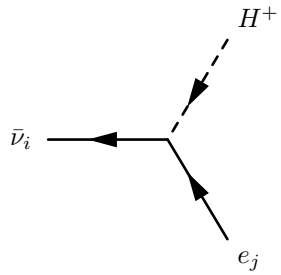
$$- i\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}U_{R,ia}^{u,*}Y_{u,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{113}$$

$$+\ -i\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{R,ja}^{d}U_{L,ib}^{u}\Big(\frac{1+\gamma_5}{2}\Big) \tag{114}$$

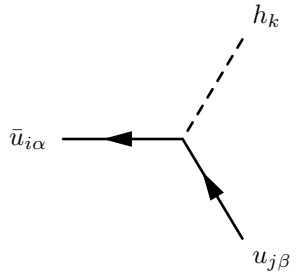


$$- i\frac{1}{\sqrt{2}}\sum_{b=1}^{3}U_{L,jb}^{e,*}\sum_{a=1}^{3}U_{R,ia}^{e,*}Y_{e,ab}Z_{k1}^{H}\Big(\frac{1-\gamma_5}{2}\Big) \tag{115}$$

$$+\ -i\frac{1}{\sqrt{2}}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^{*}U_{R,ja}^{e}U_{L,ib}^{e}Z_{k1}^{H}\Big(\frac{1+\gamma_5}{2}\Big) \tag{116}$$

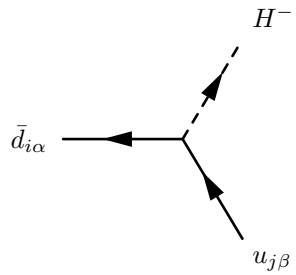


$$+ \; -i \sum_{a=1}^{3} Y^*_{e,ai} U^e_{R,ja} \Big(\frac{1+\gamma_5}{2} \Big) \tag{118}$$



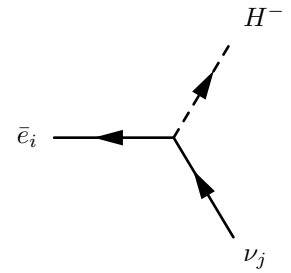
$$i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} U^{u,*}_{L,jb} \sum_{a=1}^{3} U^{u,*}_{R,ia} Y_{u,ab} Z^H_{k1} \Big(\frac{1-\gamma_5}{2} \Big) \tag{119}$$

$$+ \; i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} \sum_{a=1}^{3} Y^*_{u,ab} U^u_{R,ja} U^u_{L,ib} Z^H_{k1} \Big(\frac{1+\gamma_5}{2} \Big) \tag{120}$$



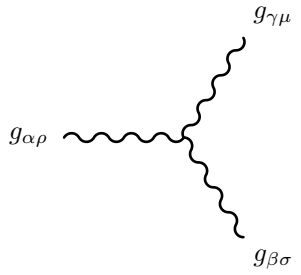
$$- i\delta_{\alpha\beta}\sum_{b=1}^{3} U_{L,jb}^{u,*}\sum_{a=1}^{3} U_{R,ia}^{d,*} Y_{d,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{121}$$

$$+\ -i\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{u,ab}^{*} U_{R,ja}^{u} U_{L,ib}^{d}\Big(\frac{1+\gamma_5}{2}\Big) \tag{122}$$

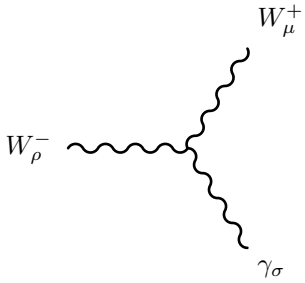


$$- i\sum_{a=1}^{3} U_{R,ia}^{e,*} Y_{e,aj}\Big(\frac{1-\gamma_5}{2}\Big) \tag{123}$$

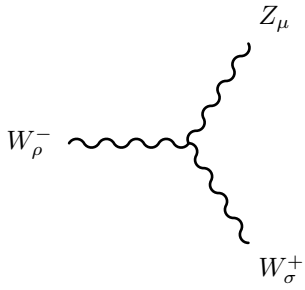
9.6 Three Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma}\Big(g_{\rho\mu}\Big(-p_\sigma^{g_{\gamma\mu}}+p_\sigma^{g_{\alpha\rho}}\Big)+g_{\rho\sigma}\Big(-p_\mu^{g_{\alpha\rho}}+p_\mu^{g_{\beta\sigma}}\Big)+g_{\sigma\mu}\Big(-p_\rho^{g_{\beta\sigma}}+p_\rho^{g_{\gamma\mu}}\Big)\Big) \tag{124}$$

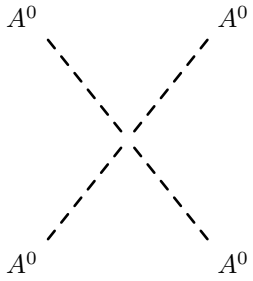


$$- ig_2 \sin\Theta_W \Big(g_{\rho\mu} \Big(- p_\sigma^{W_\mu^+} + p_\sigma^{W_\rho^-} \Big) + g_{\rho\sigma} \Big(- p_\mu^{W_\rho^-} + p_\mu^{\gamma_\sigma} \Big) + g_{\sigma\mu} \Big(- p_\rho^{\gamma_\sigma} + p_\rho^{W_\mu^+} \Big) \Big) \tag{125}$$

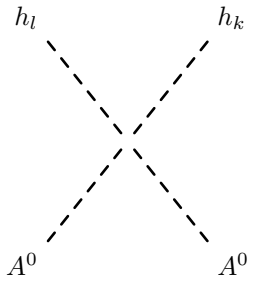


$$ig_2 \cos\Theta_W \Big(g_{\rho\mu} \Big(- p_\sigma^{Z_\mu} + p_\sigma^{W_\rho^-} \Big) + g_{\rho\sigma} \Big(- p_\mu^{W_\rho^-} + p_\mu^{W_\sigma^+} \Big) + g_{\sigma\mu} \Big(- p_\rho^{W_\sigma^+} + p_\rho^{Z_\mu} \Big) \Big) \tag{126}$$

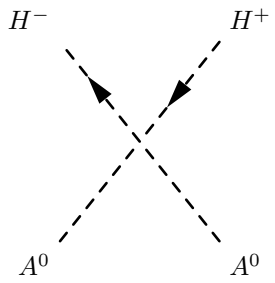
9.7 Four Scalar-Interaction



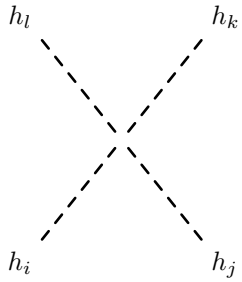
$$- 3i\lambda \tag{127}$$



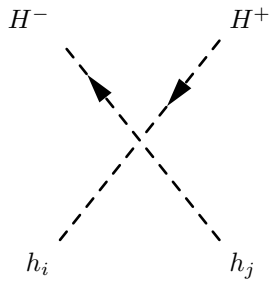
$$- i \Big(\kappa_2 Z_{k2}^H Z_{l2}^H + \lambda Z_{k1}^H Z_{l1}^H \Big) \tag{128}$$



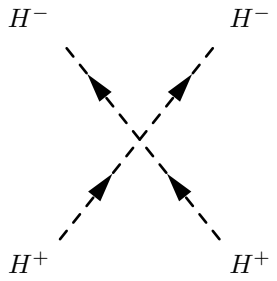
$$-i\lambda \tag{129}$$



$$\begin{aligned}&-i\Big(Z^H_{i1}\Big(\kappa_2 Z^H_{j2}\Big(Z^H_{k1}Z^H_{l2}+Z^H_{k2}Z^H_{l1}\Big)+Z^H_{j1}\Big(3\lambda Z^H_{k1}Z^H_{l1}+\kappa_2 Z^H_{k2}Z^H_{l2}\Big)\Big)\\&+Z^H_{i2}\Big(\kappa_2 Z^H_{j1}\Big(Z^H_{k1}Z^H_{l2}+Z^H_{k2}Z^H_{l1}\Big)+Z^H_{j2}\Big(12\lambda_S Z^H_{k2}Z^H_{l2}+\kappa_2 Z^H_{k1}Z^H_{l1}\Big)\Big)\Big)\end{aligned} \tag{130}$$

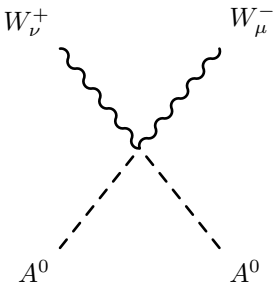


$$-i\Big(\kappa_2 Z^H_{i2}Z^H_{j2}+\lambda Z^H_{i1}Z^H_{j1}\Big) \tag{131}$$

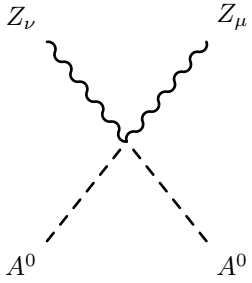


$$-2i\lambda \tag{132}$$

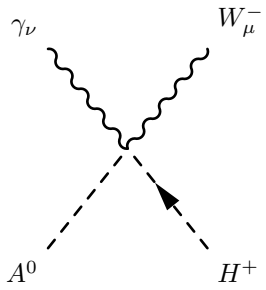
9.8 Two Scalar-Two Vector Boson-Interaction



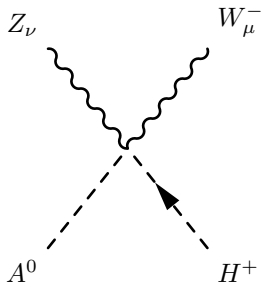
$$\frac{i}{2}g_2^2\Big(g_{\mu\nu}\Big) \tag{133}$$



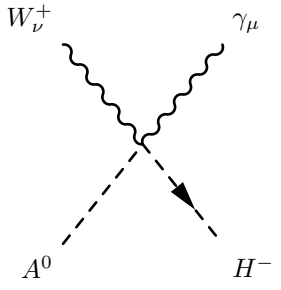
$$\frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(g_{\mu\nu}\Big) \tag{134}$$



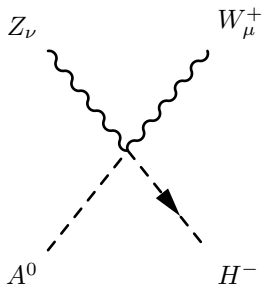
$$\frac{1}{2} g_1 g_2 \cos\Theta_W \Big(g_{\mu\nu} \Big) \tag{135}$$



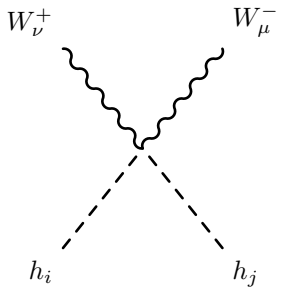
$$-\frac{1}{2} g_1 g_2 \sin\Theta_W \Big(g_{\mu\nu} \Big) \tag{136}$$



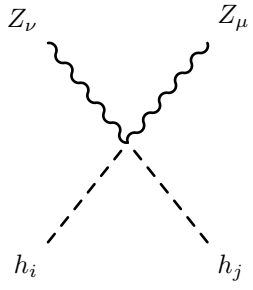
$$-\frac{1}{2} g_1 g_2 \cos\Theta_W \Big(g_{\mu\nu} \Big) \tag{137}$$



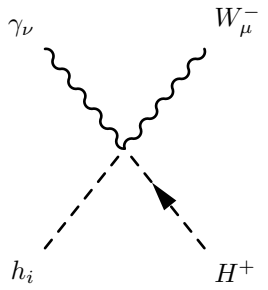
$$\frac{1}{2}g_1 g_2 \sin\Theta_W \Big(g_{\mu\nu}\Big) \tag{138}$$



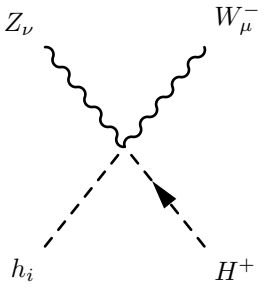
$$\frac{i}{2}g_2^2 Z_{i1}^H Z_{j1}^H \Big(g_{\mu\nu}\Big) \tag{139}$$



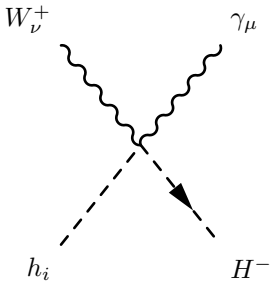
$$\frac{i}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 Z_{i1}^H Z_{j1}^H \Big(g_{\mu\nu}\Big) \tag{140}$$



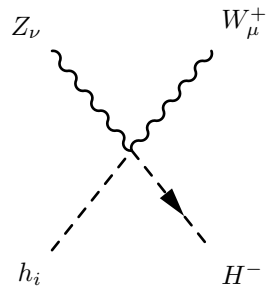
$$\frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i1}^H \Big(g_{\mu\nu} \Big) \tag{141}$$



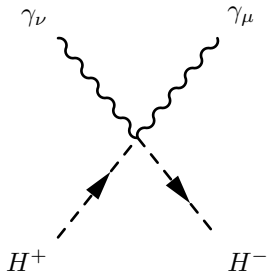
$$-\frac{i}{2} g_1 g_2 \sin\Theta_W Z_{i1}^H \Big(g_{\mu\nu} \Big) \tag{142}$$



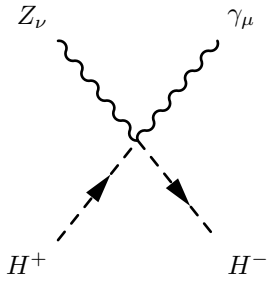
$$\frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i1}^H \Big(g_{\mu\nu} \Big) \tag{143}$$



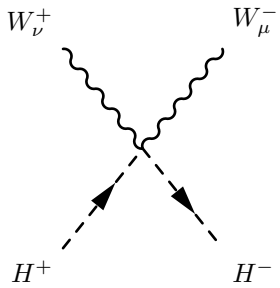
$$-\frac{i}{2}g_1 g_2 \sin\Theta_W Z_{i1}^H \Big(g_{\mu\nu}\Big) \tag{144}$$



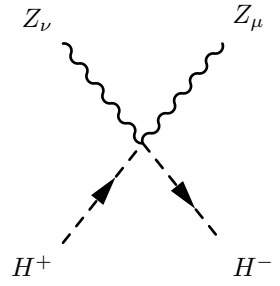
$$\frac{i}{2}\Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W\Big)^2 \Big(g_{\mu\nu}\Big) \tag{145}$$



$$-\frac{i}{4}\Big(-2g_1 g_2 \cos 2\Theta_W + \Big(-g_2^2 + g_1^2\Big)\sin 2\Theta_W\Big)\Big(g_{\mu\nu}\Big) \tag{146}$$

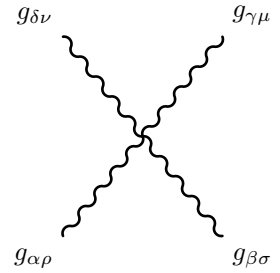


$$\frac{i}{2}g_2^2\Big(g_{\mu\nu}\Big) \tag{147}$$



$$\frac{i}{2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(g_{\mu\nu}\Big) \tag{148}$$

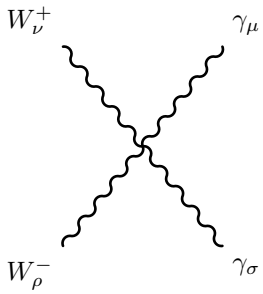
9.9 Four Vector Boson-Interaction



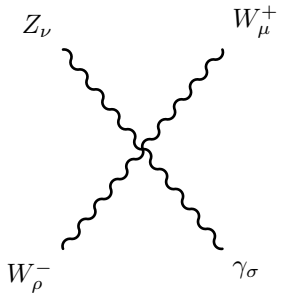
$$-ig_3^2\Big(\sum_{a=1}^{8} f_{\alpha,\delta,a}f_{\beta,\gamma,a} + \sum_{a=1}^{8} f_{\alpha,\gamma,a}f_{\beta,\delta,a}\Big)\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{149}$$

$$+\ ig_3^2\Big(-\sum_{a=1}^{8} f_{\alpha,\beta,a}f_{\gamma,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\delta,a}f_{\beta,\gamma,a}\Big)\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{150}$$

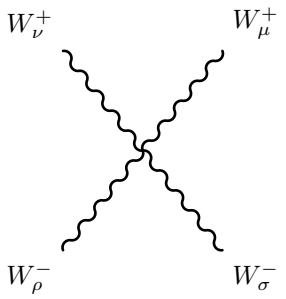
$$+\ ig_3^2\Big(\sum_{a=1}^{8} f_{\alpha,\gamma,a}f_{\beta,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\beta,a}f_{\gamma,\delta,a}\Big)\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{151}$$



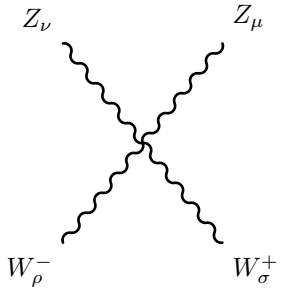
$$ig_2^2 \sin\Theta_W^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{152}$$
$$+\ ig_2^2 \sin\Theta_W^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{153}$$
$$+\ -2ig_2^2 \sin\Theta_W^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{154}$$



$$ig_2^2 \cos\Theta_W \sin\Theta_W\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{155}$$
$$+\ -ig_2^2 \sin 2\Theta_W\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{156}$$
$$+\ ig_2^2 \cos\Theta_W \sin\Theta_W\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{157}$$

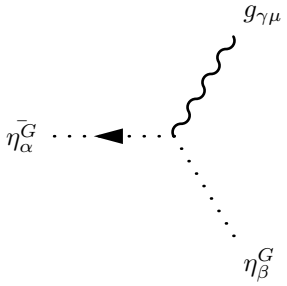


$$2ig_2^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{158}$$
$$+\ -ig_2^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{159}$$
$$+\ -ig_2^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{160}$$

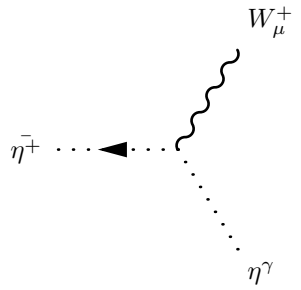


$$-\ 2ig_2^2\cos\Theta_W^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{161}$$
$$+\ ig_2^2\cos\Theta_W^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{162}$$
$$+\ ig_2^2\cos\Theta_W^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{163}$$

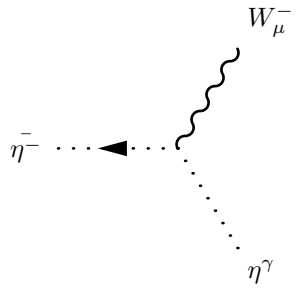
9.10 Two Ghosts-One Vector Boson-Interaction



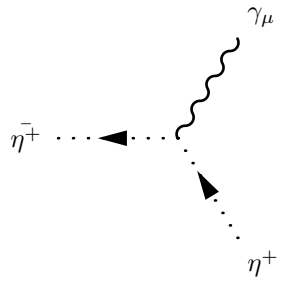
$$g_3 f_{\alpha,\beta,\gamma}\left(p_\mu^{\eta_\beta^G}\right) \tag{164}$$



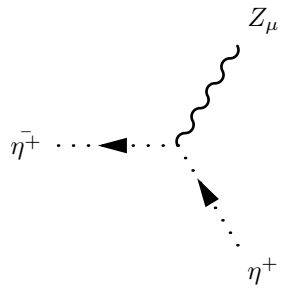
$$-ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{165}$$



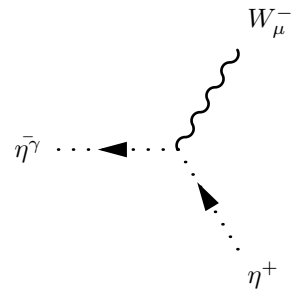
$$ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{166}$$



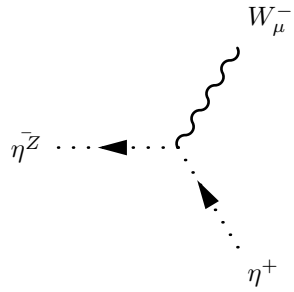
$$ig_2 \sin\Theta_W\left(p_\mu^{\eta^+}\right) \tag{167}$$



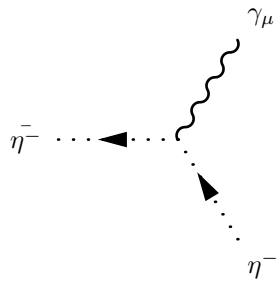
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{168}$$



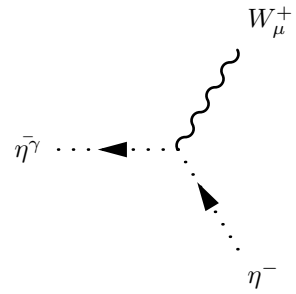
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{169}$$



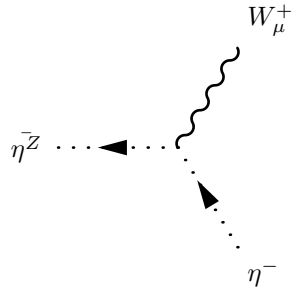
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{170}$$



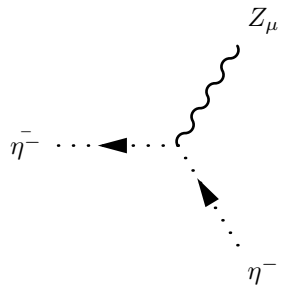
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^-}\right) \tag{171}$$



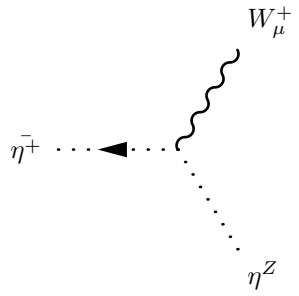
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^-}\right) \tag{172}$$



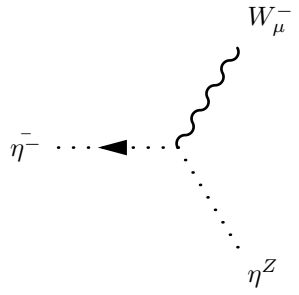
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{173}$$



$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{174}$$

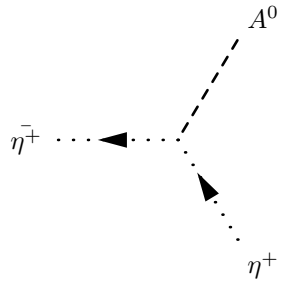


$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{175}$$

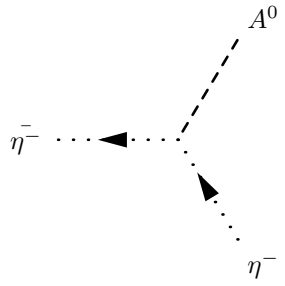


$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{176}$$

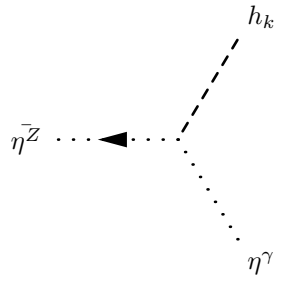
9.11 Two Ghosts-One Scalar-Interaction



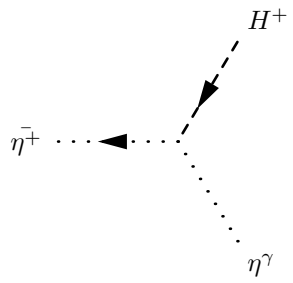
$$\frac{1}{4}g_2^2 v \xi_{W^+} \tag{177}$$



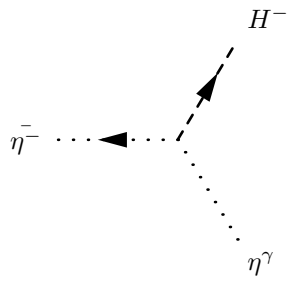
$$-\frac{1}{4}g_2^2 v \xi_{W^+} \tag{178}$$



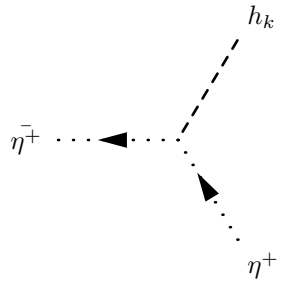
$$\frac{i}{8}v\xi_Z\Big(2g_1 g_2 \cos 2\Theta_W + \Big(-g_2^2 + g_1^2\Big)\sin 2\Theta_W\Big)Z_{k1}^H \tag{179}$$



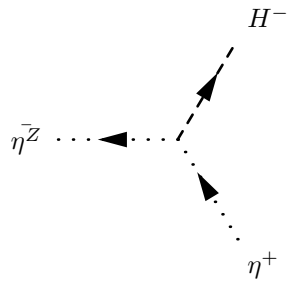
$$-\frac{i}{4}g_2 v \xi_{W^+}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big) \tag{180}$$



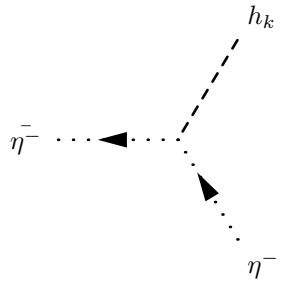
$$-\frac{i}{4}g_2 v \xi_{W^+}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big) \tag{181}$$



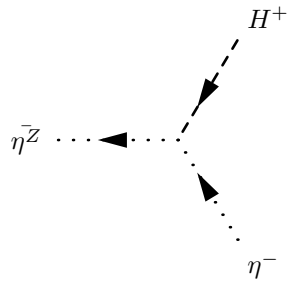
$$-\frac{i}{4}g_2^2 v \xi_{W^+} Z^H_{k1} \tag{182}$$



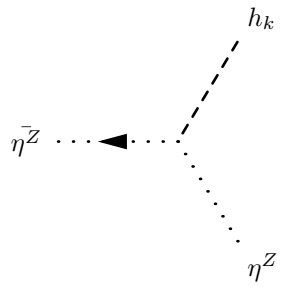
$$\frac{i}{4}g_2 v \xi_Z \Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W \Big) \tag{183}$$



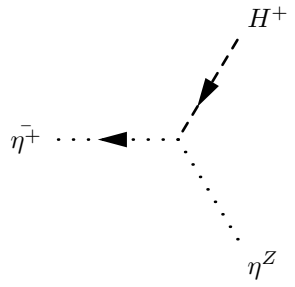
$$-\frac{i}{4}g_2^2 v \xi_{W^+} Z^H_{k1} \tag{184}$$



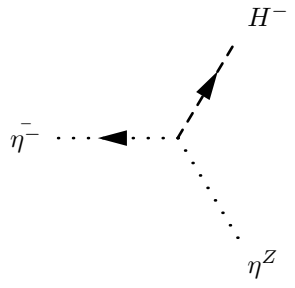
$$\frac{i}{4}g_2 v \xi_Z \Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W \Big) \tag{185}$$



$$-\frac{i}{4}v\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 Z^H_{k1} \tag{186}$$



$$-\frac{i}{4}g_2v\xi_{W^+}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big) \tag{187}$$



$$-\frac{i}{4}g_2v\xi_{W^+}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big) \tag{188}$$

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10 Clebsch-Gordan Coefficients