Flipped Two Higgs Doublet Model
Lagrangian, Rotations and Interactions for eigenstates 'EWSB' including Renormalization Group Equations including one-loop Self-Energies

SARAH 4.6.0

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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	$(U(1) \otimes \mathrm{SU}(2) \otimes \mathrm{SU}(3))$
H1	0	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1})$
H2	0	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1})$
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'

$$\begin{aligned} L_{GF} = &-\frac{1}{2}|\partial_\mu g|^2 \xi_g^{-1} - \frac{1}{2}|\partial_\mu \gamma|^2 \xi_\gamma^{-1} - |\frac{i}{2} g_2 \Big(v_1 H_1^{+,*} + v_2 H_2^{+,*} \Big) \xi_{W^-} + \partial_\mu W^-|^2 \xi_{W^-}^{-1} \\ &-\frac{1}{2}|\frac{1}{2}\Big(2\partial_\mu Z - \Big(\sigma_1 v_1 + \sigma_2 v_2\Big)\xi_Z \Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big)|^2 \xi_Z^{-1} \end{aligned} \tag{3}$$

2.3 Fields integrated out

None

3 Renormalization Group Equations

3.1 Gauge Couplings

$$\beta_{g_1}^{(1)} = \frac{21}{5} g_1^3 \tag{4}$$

$$\beta_{g_1}^{(2)} = \frac{1}{50} g_1^3 \Big(180 g_2^2 + 208 g_1^2 - 25 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 440 g_3^2 - 75 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 85 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\Big) \tag{5}$$

$$\beta_{g_2}^{(1)} = -3 g_2^3 \tag{6}$$

$$\beta_{g_2}^{(2)} = \frac{1}{10} g_2^3 \Big(120 g_3^2 + 12 g_1^2 - 15 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 15 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 5 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 80 g_2^2\Big) \tag{7}$$

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

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

3.2 Quartic scalar couplings

$$\begin{aligned}\beta_{\lambda_5}^{(1)} = & -\frac{9}{5} g_1^2 \lambda_5 - 9 g_2^2 \lambda_5 + 4 \lambda_1 \lambda_5 + 4 \lambda_2 \lambda_5 + 8 \lambda_3 \lambda_5 + 12 \lambda_4 \lambda_5 + 6 \lambda_5 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 2 \lambda_5 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) \\ & + 6 \lambda_5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\end{aligned} \tag{10}$$

$$\begin{aligned}\beta_{\lambda_5}^{(2)} = & + \frac{1413}{200} g_1^4 \lambda_5 + \frac{57}{20} g_1^2 g_2^2 \lambda_5 - \frac{231}{8} g_2^4 \lambda_5 - \frac{12}{5} g_1^2 \lambda_1 \lambda_5 - 28 \lambda_1^2 \lambda_5 - \frac{12}{5} g_1^2 \lambda_2 \lambda_5 - 28 \lambda_2^2 \lambda_5 \\ & + \frac{48}{5} g_1^2 \lambda_3 \lambda_5 + 36 g_2^2 \lambda_3 \lambda_5 - 80 \lambda_1 \lambda_3 \lambda_5 - 80 \lambda_2 \lambda_3 \lambda_5 - 28 \lambda_3^2 \lambda_5 + \frac{72}{5} g_1^2 \lambda_4 \lambda_5 + 72 g_2^2 \lambda_4 \lambda_5 \\ & - 88 \lambda_1 \lambda_4 \lambda_5 - 88 \lambda_2 \lambda_4 \lambda_5 - 76 \lambda_3 \lambda_4 \lambda_5 - 32 \lambda_4^2 \lambda_5 + 6 \lambda_5^3 \\ & + \frac{1}{4} \Big(16 \Big(10 g_3^2 - 6 \lambda_1 - 6 \lambda_3 - 9 \lambda_4\Big) + 45 g_2^2 + 5 g_1^2\Big) \lambda_5 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\ & + \frac{1}{4} \Big(15 g_1^2 + 15 g_2^2 - 16 \Big(2 \lambda_2 + 2 \lambda_3 + 3 \lambda_4\Big)\Big) \lambda_5 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + \frac{17}{4} g_1^2 \lambda_5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{4} g_2^2 \lambda_5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\ & + 40 g_3^2 \lambda_5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 24 \lambda_2 \lambda_5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 24 \lambda_3 \lambda_5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 36 \lambda_4 \lambda_5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\ & - \frac{3}{2} \lambda_5 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 33 \lambda_5 \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - \frac{1}{2} \lambda_5 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{3}{2} \lambda_5 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\end{aligned} \tag{11}$$

$$\begin{aligned}\beta_{\lambda_1}^{(1)} = & + \frac{27}{200} g_1^4 + \frac{9}{20} g_1^2 g_2^2 + \frac{9}{8} g_2^4 - \frac{9}{5} g_1^2 \lambda_1 - 9 g_2^2 \lambda_1 + 24 \lambda_1^2 + 2 \lambda_3^2 + 2 \lambda_3 \lambda_4 + \lambda_4^2 + \lambda_5^2 + 12 \lambda_1 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\ & - 6 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big)\end{aligned} \tag{12}$$

$$\beta_{\lambda_1}^{(2)} = -\frac{3537}{2000}g_1^6 - \frac{1719}{400}g_1^4g_2^2 - \frac{303}{80}g_1^2g_2^4 + \frac{291}{16}g_2^6 + \frac{1953}{200}g_1^4\lambda_1 + \frac{117}{20}g_1^2g_2^2\lambda_1 - \frac{51}{8}g_2^4\lambda_1 + \frac{108}{5}g_1^2\lambda_1^2$$
$$+ 108g_2^2\lambda_1^2 - 312\lambda_1^3 + \frac{9}{10}g_1^4\lambda_3 + \frac{15}{2}g_2^4\lambda_3 + \frac{12}{5}g_1^2\lambda_3^2 + 12g_2^2\lambda_3^2 - 20\lambda_1\lambda_3^2 - 8\lambda_3^3 + \frac{9}{20}g_1^4\lambda_4$$
$$+ \frac{3}{2}g_1^2g_2^2\lambda_4 + \frac{15}{4}g_2^4\lambda_4 + \frac{12}{5}g_1^2\lambda_3\lambda_4 + 12g_2^2\lambda_3\lambda_4 - 20\lambda_1\lambda_3\lambda_4 - 12\lambda_3^2\lambda_4 + \frac{6}{5}g_1^2\lambda_4^2$$
$$+ 3g_2^2\lambda_4^2 - 12\lambda_1\lambda_4^2 - 16\lambda_3\lambda_4^2 - 6\lambda_4^3 - \frac{3}{5}g_1^2\lambda_5^2 - 14\lambda_1\lambda_5^2 - 20\lambda_3\lambda_5^2 - 22\lambda_4\lambda_5^2$$
$$+ \frac{1}{20}\Big(-5\Big(64\lambda_1\Big(-5g_3^2+9\lambda_1\Big) - 90g_2^2\lambda_1 + 9g_2^4\Big) + 9g_1^4 + g_1^2\Big(50\lambda_1 + 54g_2^2\Big)\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)$$
$$- 2\Big(2\lambda_3^2 + 2\lambda_3\lambda_4 + \lambda_4^2 + \lambda_5^2\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 12\lambda_3^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 12\lambda_3\lambda_4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)$$
$$- 6\lambda_4^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 6\lambda_5^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + \frac{4}{5}g_1^2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 32g_3^2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)$$
$$- 3\lambda_1\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 9\lambda_1\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) + 30\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger Y_dY_d^\dagger\Big) + 6\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger Y_dY_d^\dagger\Big) \tag{13}$$

$$\beta_{\lambda_4}^{(1)} = +\frac{9}{5}g_1^2g_2^2 - \frac{9}{5}g_1^2\lambda_4 - 9g_2^2\lambda_4 + 4\lambda_1\lambda_4 + 4\lambda_2\lambda_4 + 8\lambda_3\lambda_4 + 4\lambda_4^2 + 8\lambda_5^2 + 6\lambda_4\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)$$
$$+ 2\lambda_4\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 6\lambda_4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + 12\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) \tag{14}$$

$$\beta_{\lambda_4}^{(2)} = -\frac{657}{50}g_1^4g_2^2 - \frac{42}{5}g_1^2g_2^4 + 6g_1^2g_2^2\lambda_1 + 6g_1^2g_2^2\lambda_2 + \frac{6}{5}g_1^2g_2^2\lambda_3 + \frac{1413}{200}g_1^4\lambda_4 + \frac{153}{20}g_1^2g_2^2\lambda_4$$
$$- \frac{231}{8}g_2^4\lambda_4 + \frac{24}{5}g_1^2\lambda_1\lambda_4 - 28\lambda_1^2\lambda_4 + \frac{24}{5}g_1^2\lambda_2\lambda_4 - 28\lambda_2^2\lambda_4 + \frac{12}{5}g_1^2\lambda_3\lambda_4 + 36g_2^2\lambda_3\lambda_4$$
$$- 80\lambda_1\lambda_3\lambda_4 - 80\lambda_2\lambda_3\lambda_4 - 28\lambda_3^2\lambda_4 + \frac{24}{5}g_1^2\lambda_4^2 + 18g_2^2\lambda_4^2 - 40\lambda_1\lambda_4^2 - 40\lambda_2\lambda_4^2 - 28\lambda_3\lambda_4^2$$
$$+ \frac{48}{5}g_1^2\lambda_5^2 + 54g_2^2\lambda_5^2 - 48\lambda_1\lambda_5^2 - 48\lambda_2\lambda_5^2 - 48\lambda_3\lambda_5^2 - 26\lambda_4\lambda_5^2$$
$$+ \Big(4\Big(10g_3^2\lambda_4 - 3\Big(2\lambda_1\lambda_4 + 2\lambda_3\lambda_4 + 2\lambda_5^2 + \lambda_4^2\Big)\Big) + \frac{45}{4}g_2^2\lambda_4 + g_1^2\Big(\frac{27}{5}g_2^2 + \frac{5}{4}\lambda_4\Big)\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)$$
$$+ \Big(-4\Big(2\lambda_2\lambda_4 + 2\lambda_3\lambda_4 + 2\lambda_5^2 + \lambda_4^2\Big) + \frac{15}{4}g_2^2\lambda_4 + \frac{3}{20}g_1^2\Big(25\lambda_4 + 44g_2^2\Big)\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)$$
$$+ \frac{63}{5}g_1^2g_2^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + \frac{17}{4}g_1^2\lambda_4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + \frac{45}{4}g_2^2\lambda_4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + 40g_3^2\lambda_4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)$$
$$- 24\lambda_2\lambda_4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 24\lambda_3\lambda_4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 12\lambda_4^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 24\lambda_5^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)$$
$$- \frac{27}{2}\lambda_4\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) + \frac{4}{5}g_1^2\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) + 64g_3^2\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)$$
$$- 24\lambda_3\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 33\lambda_4\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - \frac{9}{2}\lambda_4\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) - \frac{27}{2}\lambda_4\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)$$
$$- 12\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 12\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger Y_dY_d^\dagger\Big) - 24\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_u^\dagger Y_uY_d^\dagger\Big) \tag{15}$$

$$\beta_{\lambda_3}^{(1)} = +\frac{27}{100}g_1^4 - \frac{9}{10}g_1^2g_2^2 + \frac{9}{4}g_2^4 - \frac{9}{5}g_1^2\lambda_3 - 9g_2^2\lambda_3 + 12\lambda_1\lambda_3 + 12\lambda_2\lambda_3 + 4\lambda_3^2 + 4\lambda_1\lambda_4 + 4\lambda_2\lambda_4 + 2\lambda_4^2$$
$$+ 2\lambda_5^2 + 6\lambda_3\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 2\lambda_3\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 6\lambda_3\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 12\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) \tag{16}$$

$$\beta_{\lambda_3}^{(2)} = -\frac{3537}{1000}g_1^6 + \frac{909}{200}g_1^4g_2^2 + \frac{33}{40}g_1^2g_2^4 + \frac{291}{8}g_2^6 + \frac{27}{10}g_1^4\lambda_1 - 3g_1^2g_2^2\lambda_1 + \frac{45}{2}g_2^4\lambda_1 + \frac{27}{10}g_1^4\lambda_2$$
$$- 3g_1^2g_2^2\lambda_2 + \frac{45}{2}g_2^4\lambda_2 + \frac{1773}{200}g_1^4\lambda_3 + \frac{33}{20}g_1^2g_2^2\lambda_3 - \frac{111}{8}g_2^4\lambda_3 + \frac{72}{5}g_1^2\lambda_1\lambda_3 + 72g_2^2\lambda_1\lambda_3$$
$$- 60\lambda_1^2\lambda_3 + \frac{72}{5}g_1^2\lambda_2\lambda_3 + 72g_2^2\lambda_2\lambda_3 - 60\lambda_2^2\lambda_3 + \frac{6}{5}g_1^2\lambda_3^2 + 6g_2^2\lambda_3^2 - 72\lambda_1\lambda_3^2 - 72\lambda_2\lambda_3^2$$
$$- 12\lambda_3^3 + \frac{9}{10}g_1^4\lambda_4 - \frac{9}{5}g_1^2g_2^2\lambda_4 + \frac{15}{2}g_2^4\lambda_4 + \frac{24}{5}g_1^2\lambda_1\lambda_4 + 36g_2^2\lambda_1\lambda_4 - 16\lambda_1^2\lambda_4 + \frac{24}{5}g_1^2\lambda_2\lambda_4$$
$$+ 36g_2^2\lambda_2\lambda_4 - 16\lambda_2^2\lambda_4 - 12g_2^2\lambda_3\lambda_4 - 32\lambda_1\lambda_3\lambda_4 - 32\lambda_2\lambda_3\lambda_4 - 4\lambda_3^2\lambda_4 - \frac{6}{5}g_1^2\lambda_4^2$$
$$+ 6g_2^2\lambda_4^2 - 28\lambda_1\lambda_4^2 - 28\lambda_2\lambda_4^2 - 16\lambda_3\lambda_4^2 - 12\lambda_4^3 + \frac{12}{5}g_1^2\lambda_5^2 - 36\lambda_1\lambda_5^2 - 36\lambda_2\lambda_5^2$$
$$- 18\lambda_3\lambda_5^2 - 44\lambda_4\lambda_5^2$$
$$+ \frac{1}{20}\Big(-5\Big(-45g_2^2\lambda_3 + 8\Big(-20g_3^2\lambda_3 + 3\Big(2\lambda_3^2 + 4\lambda_1\Big(3\lambda_3 + \lambda_4\Big) + \lambda_4^2 + \lambda_5^2\Big)\Big) + 9g_2^4\Big) + 9g_1^4 + g_1^2\Big(25\lambda_3 - 54g_2^2\Big)\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)$$
$$- \frac{1}{20}\Big(45g_1^4 + 5\Big(-15g_2^2\lambda_3 + 3g_2^4 + 8\Big(2\lambda_3^2 + 4\lambda_2\Big(3\lambda_3 + \lambda_4\Big) + \lambda_4^2 + \lambda_5^2\Big)\Big) + g_1^2\Big(66g_2^2 - 75\lambda_3\Big)\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)$$
$$- \frac{171}{100}g_1^4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - \frac{63}{10}g_1^2g_2^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - \frac{9}{4}g_2^4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + \frac{17}{4}g_1^2\lambda_3\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)$$
$$+ \frac{45}{4}g_2^2\lambda_3\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + 40g_3^2\lambda_3\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 72\lambda_2\lambda_3\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 12\lambda_3^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)$$
$$- 24\lambda_2\lambda_4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 6\lambda_4^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 6\lambda_5^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - \frac{27}{2}\lambda_3\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)$$
$$- \frac{4}{5}g_1^2\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 64g_3^2\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) + 15\lambda_3\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)$$
$$- \frac{9}{2}\lambda_3\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) - \frac{27}{2}\lambda_3\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big) + 18\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_u^\dagger Y_uY_d^\dagger\Big) + 18\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger Y_dY_d^\dagger\Big)$$
$$+ 36\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_u^\dagger Y_uY_d^\dagger\Big) \tag{17}$$

$$\beta_{\lambda_2}^{(1)} = +\frac{27}{200}g_1^4 + \frac{9}{20}g_1^2g_2^2 + \frac{9}{8}g_2^4 - \frac{9}{5}g_1^2\lambda_2 - 9g_2^2\lambda_2 + 24\lambda_2^2 + 2\lambda_3^2 + 2\lambda_3\lambda_4 + \lambda_4^2 + \lambda_5^2 + 4\lambda_2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)$$
$$+ 12\lambda_2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 2\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) - 6\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big) \tag{18}$$

$$\beta_{\lambda_2}^{(2)} = -\frac{3537}{2000}g_1^6 - \frac{1719}{400}g_1^4g_2^2 - \frac{303}{80}g_1^2g_2^4 + \frac{291}{16}g_2^6 + \frac{1953}{200}g_1^4\lambda_2 + \frac{117}{20}g_1^2g_2^2\lambda_2 - \frac{51}{8}g_2^4\lambda_2 + \frac{108}{5}g_1^2\lambda_2^2$$
$$+ 108g_2^2\lambda_2^2 - 312\lambda_2^3 + \frac{9}{10}g_1^4\lambda_3 + \frac{15}{2}g_2^4\lambda_3 + \frac{12}{5}g_1^2\lambda_3^2 + 12g_2^2\lambda_3^2 - 20\lambda_2\lambda_3^2 - 8\lambda_3^3 + \frac{9}{20}g_1^4\lambda_4$$
$$+ \frac{3}{2}g_1^2g_2^2\lambda_4 + \frac{15}{4}g_2^4\lambda_4 + \frac{12}{5}g_1^2\lambda_3\lambda_4 + 12g_2^2\lambda_3\lambda_4 - 20\lambda_2\lambda_3\lambda_4 - 12\lambda_3^2\lambda_4 + \frac{6}{5}g_1^2\lambda_4^2$$
$$+ 3g_2^2\lambda_4^2 - 12\lambda_2\lambda_4^2 - 16\lambda_3\lambda_4^2 - 6\lambda_4^3 - \frac{3}{5}g_1^2\lambda_5^2 - 14\lambda_2\lambda_5^2 - 20\lambda_3\lambda_5^2 - 22\lambda_4\lambda_5^2$$
$$- 6\Big(2\lambda_3^2 + 2\lambda_3\lambda_4 + \lambda_4^2 + \lambda_5^2\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)$$
$$- \frac{3}{20}\Big(15g_1^4 - 2g_1^2\Big(11g_2^2 + 25\lambda_2\Big) + 5\Big(-10g_2^2\lambda_2 + 64\lambda_2^2 + g_2^4\Big)\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - \frac{171}{100}g_1^4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)$$

$$+\frac{63}{10}g_1^2g_2^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-\frac{9}{4}g_2^4\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+\frac{17}{2}g_1^2\lambda_2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+\frac{45}{2}g_2^2\lambda_2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)$$
$$+80g_3^2\lambda_2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-144\lambda_2^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-9\lambda_2\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)-\frac{12}{5}g_1^2\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)$$
$$-\lambda_2\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)-\frac{8}{5}g_1^2\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)-32g_3^2\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)-3\lambda_2\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)$$
$$+6\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_u^\dagger Y_uY_d^\dagger\Big)+10\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger Y_eY_e^\dagger\Big)+30\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger Y_uY_u^\dagger\Big) \tag{19}$$

3.3 Yukawa Couplings

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

$$\begin{aligned}\beta_{Y_u}^{(2)}=&+Y_uY_d^\dagger Y_d\Big(-2\lambda_3+2\lambda_4+\frac{16}{3}g_3^2+\frac{33}{16}g_2^2-\frac{41}{240}g_1^2-\frac{9}{4}\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\Big)\\&+\frac{1}{80}\Big(-20\Big(-6Y_uY_u^\dagger Y_uY_u^\dagger Y_u+Y_uY_d^\dagger Y_dY_d^\dagger Y_d+Y_uY_d^\dagger Y_dY_u^\dagger Y_u\Big)\\&+Y_uY_u^\dagger Y_u\Big(1280g_3^2-180\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)+223g_1^2-540\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+675g_2^2-960\lambda_2\Big)\Big)\\&+Y_u\Big(\frac{1267}{600}g_1^4-\frac{9}{20}g_1^2g_2^2-\frac{21}{4}g_2^4+\frac{19}{15}g_1^2g_3^2+9g_2^2g_3^2-108g_3^4+6\lambda_2^2+\lambda_3^2+\lambda_3\lambda_4+\lambda_4^2+\frac{3}{2}\lambda_5^2\\&+\frac{15}{8}\Big(g_1^2+g_2^2\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)+\frac{1}{8}\Big(160g_3^2+17g_1^2+45g_2^2\Big)\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-\frac{9}{4}\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)\\&-\frac{9}{4}\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)-\frac{27}{4}\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)\Big)\end{aligned} \tag{21}$$

$$\beta_{Y_d}^{(1)}=\frac{1}{4}\Big(2\Big(3Y_dY_d^\dagger Y_d+Y_dY_u^\dagger Y_u\Big)-Y_d\Big(-12\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)+32g_3^2+9g_2^2+g_1^2\Big)\Big) \tag{22}$$

$$\begin{aligned}\beta_{Y_d}^{(2)}=&+\frac{1}{240}\Big(60\Big(6Y_dY_d^\dagger Y_dY_d^\dagger Y_d-Y_dY_u^\dagger Y_uY_d^\dagger Y_d-Y_dY_u^\dagger Y_uY_u^\dagger Y_u\Big)\\&+3Y_dY_d^\dagger Y_d\Big(1280g_3^2+187g_1^2-540\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)+675g_2^2-960\lambda_1\Big)\\&+Y_dY_u^\dagger Y_u\Big(1280g_3^2-180\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-480\lambda_3+480\lambda_4+495g_2^2-53g_1^2-540\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)\Big)\Big)\\&+Y_d\Big(-\frac{113}{600}g_1^4-\frac{27}{20}g_1^2g_2^2-\frac{21}{4}g_2^4+\frac{31}{15}g_1^2g_3^2+9g_2^2g_3^2-108g_3^4+6\lambda_1^2+\lambda_3^2+\lambda_3\lambda_4+\lambda_4^2+\frac{3}{2}\lambda_5^2\\&+\frac{5}{8}\Big(32g_3^2+9g_2^2+g_1^2\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-\frac{27}{4}\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)-\frac{9}{4}\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)\Big)\end{aligned} \tag{23}$$

$$\beta_{Y_e}^{(1)}=\frac{1}{4}\Big(6Y_eY_e^\dagger Y_e+Y_e\Big(12\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+4\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-9\Big(g_1^2+g_2^2\Big)\Big)\Big) \tag{24}$$

$$\begin{aligned}\beta_{Y_e}^{(2)}=&+\frac{3}{80}\Big(40Y_eY_e^\dagger Y_eY_e^\dagger Y_e+Y_eY_e^\dagger Y_e\Big(129g_1^2-180\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+225g_2^2-320\lambda_2-60\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\Big)\Big)\\&+Y_e\Big(\frac{1449}{200}g_1^4+\frac{27}{20}g_1^2g_2^2-\frac{21}{4}g_2^4+6\lambda_2^2+\lambda_3^2+\lambda_3\lambda_4+\lambda_4^2+\frac{3}{2}\lambda_5^2+\frac{15}{8}\Big(g_1^2+g_2^2\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\&+\frac{1}{8}\Big(160g_3^2+17g_1^2+45g_2^2\Big)\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-\frac{9}{4}\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)-\frac{9}{4}\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)-\frac{27}{4}\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)\Big)\end{aligned} \tag{25}$$

3.4 Scalar Mass Terms

$$\beta^{(1)}_{m_{12}} = 2\lambda_3 m_{12} + 4\lambda_4 m_{12} + 6\lambda_5 m_{12} + 6 m_{12}\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 6 m_{12}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{9}{10} g_1^2 m_{12} - \frac{9}{2} g_2^2 m_{12} \tag{26}$$

$$\begin{aligned}
\beta^{(2)}_{m_{12}} = &+\frac{1377}{400} g_1^4 m_{12} + \frac{9}{8} g_1^2 g_2^2 m_{12} - \frac{243}{16} g_2^4 m_{12} + 6\lambda_1^2 m_{12} + 6\lambda_2^2 m_{12} + \frac{12}{5} g_1^2 \lambda_3 m_{12} + 12 g_2^2 \lambda_3 m_{12} - 12\lambda_1\lambda_3 m_{12} \\
&- 12\lambda_2\lambda_3 m_{12} + \frac{24}{5} g_1^2 \lambda_4 m_{12} + 24 g_2^2 \lambda_4 m_{12} - 12\lambda_1\lambda_4 m_{12} - 12\lambda_2\lambda_4 m_{12} - 6\lambda_3\lambda_4 m_{12} + \frac{36}{5} g_1^2 \lambda_5 m_{12} \\
&+ 36 g_2^2 \lambda_5 m_{12} - 12\lambda_1\lambda_5 m_{12} - 12\lambda_2\lambda_5 m_{12} - 12\lambda_3\lambda_5 m_{12} - 12\lambda_4\lambda_5 m_{12} + 3\lambda_5^2 m_{12} \\
&+ \frac{1}{8}\Big(16\Big(10 g_3^2 - 3\Big(2\lambda_4 + 3\lambda_5 + \lambda_3\Big)\Big) + 45 g_2^2 + 5 g_1^2\Big) m_{12}\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\
&+ \frac{1}{8}\Big(15 g_1^2 + 15 g_2^2 - 16\Big(2\lambda_4 + 3\lambda_5 + \lambda_3\Big)\Big) m_{12}\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + \frac{17}{8} g_1^2 m_{12}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{8} g_2^2 m_{12}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ 20 g_3^2 m_{12}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 6\lambda_3 m_{12}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 12\lambda_4 m_{12}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 18\lambda_5 m_{12}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&- \frac{27}{4} m_{12}\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - \frac{33}{2} m_{12}\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - \frac{9}{4} m_{12}\mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{27}{4} m_{12}\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)
\end{aligned} \tag{27}$$

$$\beta^{(1)}_{m_1^2} = 12\lambda_1 m_1^2 + 2\lambda_4 m_2^2 + 4\lambda_3 m_2^2 + 6 m_1^2\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - \frac{9}{10} g_1^2 m_1^2 - \frac{9}{2} g_2^2 m_1^2 \tag{28}$$

$$\begin{aligned}
\beta^{(2)}_{m_1^2} = &+\frac{1737}{400} g_1^4 m_1^2 + \frac{9}{8} g_1^2 g_2^2 m_1^2 - \frac{123}{16} g_2^4 m_1^2 + \frac{72}{5} g_1^2 \lambda_1 m_1^2 + 72 g_2^2 \lambda_1 m_1^2 - 60\lambda_1^2 m_1^2 - 2\lambda_3^2 m_1^2 \\
&- 2\lambda_3\lambda_4 m_1^2 - 2\lambda_4^2 m_1^2 - 3\lambda_5^2 m_1^2 + \frac{9}{10} g_1^4 m_2^2 + \frac{15}{2} g_2^4 m_2^2 + \frac{24}{5} g_1^2 \lambda_3 m_2^2 + 24 g_2^2 \lambda_3 m_2^2 \\
&- 8\lambda_3^2 m_2^2 + \frac{12}{5} g_1^2 \lambda_4 m_2^2 + 12 g_2^2 \lambda_4 m_2^2 - 8\lambda_3\lambda_4 m_2^2 - 8\lambda_4^2 m_2^2 - 12\lambda_5^2 m_2^2 \\
&+ \frac{1}{4}\Big(160 g_3^2 - 288\lambda_1 + 45 g_2^2 + 5 g_1^2\Big) m_1^2\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 4\Big(2\lambda_3 + \lambda_4\Big) m_2^2\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 24\lambda_3 m_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&- 12\lambda_4 m_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{27}{2} m_1^2\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - \frac{9}{2} m_1^2\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big)
\end{aligned} \tag{29}$$

$$\beta^{(1)}_{m_2^2} = 12\lambda_2 m_2^2 + 2\lambda_4 m_1^2 + 2 m_2^2\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 4\lambda_3 m_1^2 + 6 m_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{9}{10} g_1^2 m_2^2 - \frac{9}{2} g_2^2 m_2^2 \tag{30}$$

$$\begin{aligned}
\beta^{(2)}_{m_2^2} = &+\frac{9}{10} g_1^4 m_1^2 + \frac{15}{2} g_2^4 m_1^2 + \frac{24}{5} g_1^2 \lambda_3 m_1^2 + 24 g_2^2 \lambda_3 m_1^2 - 8\lambda_3^2 m_1^2 + \frac{12}{5} g_1^2 \lambda_4 m_1^2 + 12 g_2^2 \lambda_4 m_1^2 \\
&- 8\lambda_3\lambda_4 m_1^2 - 8\lambda_4^2 m_1^2 - 12\lambda_5^2 m_1^2 + \frac{1737}{400} g_1^4 m_2^2 + \frac{9}{8} g_1^2 g_2^2 m_2^2 - \frac{123}{16} g_2^4 m_2^2 + \frac{72}{5} g_1^2 \lambda_2 m_2^2 \\
&+ 72 g_2^2 \lambda_2 m_2^2 - 60\lambda_2^2 m_2^2 - 2\lambda_3^2 m_2^2 - 2\lambda_3\lambda_4 m_2^2 - 2\lambda_4^2 m_2^2 - 3\lambda_5^2 m_2^2 \\
&- 12\Big(2\lambda_3 + \lambda_4\Big) m_1^2\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{3}{4}\Big(-32\lambda_2 + 5 g_1^2 + 5 g_2^2\Big) m_2^2\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + \frac{17}{4} g_1^2 m_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ \frac{45}{4} g_2^2 m_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 40 g_3^2 m_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 72\lambda_2 m_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{9}{2} m_2^2\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) \\
&- \frac{9}{2} m_2^2\mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{27}{2} m_2^2\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)
\end{aligned} \tag{31}$$

3.5 Vacuum expectation values

$$\beta^{(1)}_{v_1} = \frac{3}{20}v_1\Big(-20\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)+\Big(5g_2^2+g_1^2\Big)\Big(3+\mathrm{Xi}\Big)\Big) \tag{32}$$

$$\begin{aligned}\beta^{(2)}_{v_1} = \frac{1}{800}v_1\Big(&-1359g_1^4-270g_1^2g_2^2+6225g_2^4-4800\lambda_1^2-800\lambda_3^2-800\lambda_3\lambda_4-800\lambda_4^2-1200\lambda_5^2+18g_1^4\mathrm{Xi}\\&+180g_1^2g_2^2\mathrm{Xi}+2250g_2^4\mathrm{Xi}+18g_1^4\mathrm{Xi}^2+180g_1^2g_2^2\mathrm{Xi}^2-450g_2^4\mathrm{Xi}^2\\&-20\Big(45g_2^2\Big(2\mathrm{Xi}+5\Big)+800g_3^2+g_1^2\Big(18\mathrm{Xi}+25\Big)\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)+5400\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)+1800\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)\Big)\end{aligned} \tag{33}$$

$$\beta^{(1)}_{v_2} = \frac{1}{20}v_2\Big(-20\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)+3\Big(-20\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+\Big(5g_2^2+g_1^2\Big)\Big(3+\mathrm{Xi}\Big)\Big)\Big) \tag{34}$$

$$\begin{aligned}\beta^{(2)}_{v_2} = \frac{1}{800}v_2\Big(&-1359g_1^4-270g_1^2g_2^2+6225g_2^4-4800\lambda_2^2-800\lambda_3^2-800\lambda_3\lambda_4-800\lambda_4^2-1200\lambda_5^2+18g_1^4\mathrm{Xi}\\&+180g_1^2g_2^2\mathrm{Xi}+2250g_2^4\mathrm{Xi}+18g_1^4\mathrm{Xi}^2+180g_1^2g_2^2\mathrm{Xi}^2-450g_2^4\mathrm{Xi}^2-60\Big(5g_2^2\Big(2\mathrm{Xi}+5\Big)+g_1^2\Big(2\mathrm{Xi}+25\Big)\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\&-20\Big(45g_2^2\Big(2\mathrm{Xi}+5\Big)+800g_3^2+g_1^2\Big(18\mathrm{Xi}+85\Big)\Big)\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+1800\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)+1800\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\\&+5400\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)\Big)\end{aligned} \tag{35}$$

4 Field Rotations

4.1 Rotations in gauge sector for eigenstates 'EWSB'

$$\begin{pmatrix} B_\rho \\ W_{3\rho}\end{pmatrix} = Z^{\gamma Z}\begin{pmatrix}\gamma_\rho \\ Z_\rho\end{pmatrix} \tag{36}$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho}\end{pmatrix} = Z^{W}\begin{pmatrix}W_\rho^- \\ W_\rho^-\end{pmatrix} \tag{37}$$

$$\tag{38}$$

The mixing matrices are parametrized by

$$Z^{\gamma Z} = \begin{pmatrix}\cos\Theta_W & -\sin\Theta_W \\ \sin\Theta_W & \cos\Theta_W\end{pmatrix} \tag{39}$$

$$Z^{W} = \begin{pmatrix}\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}}\end{pmatrix} \tag{40}$$

$$\tag{41}$$

4.2 Rotations in Mass sector for eigenstates 'EWSB'

4.2.1 Mass Matrices for Scalars

- **Mass matrix for Higgs**, Basis: $(\phi_1, \phi_2), (\phi_1, \phi_2)$

$$m_h^2 = \begin{pmatrix} \frac{1}{2}\Big(6\lambda_1 v_1^2 + v_2^2\Big(\lambda_3 + \lambda_4 + \Re\Big(\lambda_5\Big)\Big)\Big) + m_1^2 & \frac{1}{2}v_1 v_2\Big(2\Big(\lambda_3 + \lambda_4\Big) + 2\Re\Big(\lambda_5\Big)\Big) + \Re\Big(m_{12}\Big) \\ \frac{1}{2}v_1 v_2\Big(2\Big(\lambda_3 + \lambda_4\Big) + 2\Re\Big(\lambda_5\Big)\Big) + \Re\Big(m_{12}\Big) & \frac{1}{2}\Big(6\lambda_2 v_2^2 + v_1^2\Big(\lambda_3 + \lambda_4 + \Re\Big(\lambda_5\Big)\Big)\Big) + m_2^2 \end{pmatrix} \tag{42}$$

This matrix is diagonalized by Z^H:

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \tag{43}$$

with

$$\phi_1 = \sum_j Z_{j1}^H h_j\,, \qquad \phi_2 = \sum_j Z_{j2}^H h_j \tag{44}$$

- **Mass matrix for Pseudo-Scalar Higgs**, Basis: $(\sigma_1, \sigma_2), (\sigma_1, \sigma_2)$

$$m_{A^0}^2 = \begin{pmatrix} \frac{1}{2}\Big(2\lambda_1 v_1^2 + v_2^2\Big(-\Re\Big(\lambda_5\Big) + \lambda_3 + \lambda_4\Big)\Big) + m_1^2 & v_1 v_2\Re\Big(\lambda_5\Big) + \Re\Big(m_{12}\Big) \\ v_1 v_2\Re\Big(\lambda_5\Big) + \Re\Big(m_{12}\Big) & \frac{1}{2}\Big(2\lambda_2 v_2^2 + v_1^2\Big(-\Re\Big(\lambda_5\Big) + \lambda_3 + \lambda_4\Big)\Big) + m_2^2 \end{pmatrix} + \xi_Z m^2(Z) \tag{45}$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} \frac{1}{4}v_1^2\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 & \frac{1}{4}v_1 v_2\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 \\ \frac{1}{4}v_1 v_2\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 & \frac{1}{4}v_2^2\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 \end{pmatrix} \tag{46}$$

This matrix is diagonalized by Z^A:

$$Z^A m_{A^0}^2 Z^{A,\dagger} = m_{2,A^0}^{dia} \tag{47}$$

with

$$\sigma_1 = \sum_j Z_{j1}^A A_j^0\,, \qquad \sigma_2 = \sum_j Z_{j2}^A A_j^0 \tag{48}$$

- **Mass matrix for Charged Higgs**, Basis: $\left(H_1^{+,*}, H_2^{+,*}\right), \left(H_1^+, H_2^+\right)$

$$m_{H^-}^2 = \begin{pmatrix} \frac{1}{2}\lambda_3 v_2^2 + \lambda_1 v_1^2 + m_1^2 & \frac{1}{2}\Big(\lambda_4 + \lambda_5\Big)v_1 v_2 + m_{12}^* \\ \frac{1}{2}v_1 v_2\Big(\lambda_4 + \lambda_5^*\Big) + m_{12} & \frac{1}{2}\lambda_3 v_1^2 + \lambda_2 v_2^2 + m_2^2 \end{pmatrix} + \xi_{W^-} m^2(W^-) \tag{49}$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4}g_2^2 v_1^2 & \frac{1}{4}g_2^2 v_1 v_2 \\ \frac{1}{4}g_2^2 v_1 v_2 & \frac{1}{4}g_2^2 v_2^2 \end{pmatrix} \tag{50}$$

This matrix is diagonalized by Z^+:

$$Z^+ m^2_{H^-} Z^{+,\dagger} = m^{dia}_{2,H^-} \tag{51}$$

with

$$H^+_1 = \sum_j Z^+_{j1} H^+_j \,, \qquad H^+_2 = \sum_j Z^+_{j2} H^+_j \tag{52}$$

4.2.2 Mass Matrices for Fermions

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

$$m_d = \left(\begin{array}{c} \frac{1}{\sqrt{2}} v_1 \delta_{\alpha_1 \beta_1} Y^T_d \end{array} \right) \tag{53}$$

This matrix is diagonalized by U^d_L and U^d_R

$$U^{d,*}_L m_d U^{d,\dagger}_R = m^{dia}_d \tag{54}$$

with

$$d_{L,i\alpha} = \sum_{t_2} U^{d,*}_{L,ji} D_{L,j\alpha} \tag{55}$$

$$d_{R,i\alpha} = \sum_{t_2} U^d_{R,ij} D^*_{R,j\alpha} \tag{56}$$

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

$$m_u = \left(\begin{array}{c} -\frac{1}{\sqrt{2}} v_2 \delta_{\alpha_1 \beta_1} Y^T_u \end{array} \right) \tag{57}$$

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

$$U^{u,*}_L m_u U^{u,\dagger}_R = m^{dia}_u \tag{58}$$

with

$$u_{L,i\alpha} = \sum_{t_2} U^{u,*}_{L,ji} U_{L,j\alpha} \tag{59}$$

$$u_{R,i\alpha} = \sum_{t_2} U^u_{R,ij} U^*_{R,j\alpha} \tag{60}$$

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

$$m_e = \left(\begin{array}{c} \frac{1}{\sqrt{2}} v_2 Y^T_e \end{array} \right) \tag{61}$$

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

$$U^{e,*}_L m_e U^{e,\dagger}_R = m^{dia}_e \tag{62}$$

with

$$e_{L,i} = \sum_{t_2} U^{e,*}_{L,ji} E_{L,j} \tag{63}$$

$$e_{R,i} = \sum_{t_2} U^{e}_{R,ij} E^{*}_{R,j} \tag{64}$$

5 Vacuum Expectation Values

$$H^0_1 = \frac{1}{\sqrt{2}}\phi_1 + \frac{1}{\sqrt{2}}v_1 + i\frac{1}{\sqrt{2}}\sigma_1 \tag{65}$$

$$H^0_2 = \frac{1}{\sqrt{2}}\phi_2 + \frac{1}{\sqrt{2}}v_2 + i\frac{1}{\sqrt{2}}\sigma_2 \tag{66}$$

6 Tadpole Equations

$$\frac{\partial V}{\partial \phi_1} = \frac{1}{4}\Big(2v_2\Big(m_{12} + m^*_{12}\Big) + v_1\Big(4\Big(\lambda_1 v_1^2 + m_1^2\Big) + v_2^2\Big(2\Big(\lambda_3 + \lambda_4\Big) + \lambda_5 + \lambda^*_5\Big)\Big)\Big) \tag{67}$$

$$\frac{\partial V}{\partial \phi_2} = \frac{1}{4}\Big(2v_1\Big(m_{12} + m^*_{12}\Big) + 4\lambda_2 v_2^3 + v_2\Big(4m_2^2 + v_1^2\Big(2\Big(\lambda_3 + \lambda_4\Big) + \lambda_5 + \lambda^*_5\Big)\Big)\Big) \tag{68}$$

7 Particle content for eigenstates 'EWSB'

Name	Type	complex/real	Generations	Indices
h	Scalar	real	2	generation, 2
A^0	Scalar	real	2	generation, 2
H^-	Scalar	complex	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) = &+2\Big(-\frac{1}{2}\text{rMS} + B_0\Big(p^2, m_Z^2, m_Z^2\Big)\Big)\Gamma^*_{\check{h}_j,Z,Z}\Gamma_{\check{h}_i,Z,Z} + 4\Big(-\frac{1}{2}\text{rMS} + B_0\Big(p^2, m_{W^-}^2, m_{W^-}^2\Big)\Big)\Gamma^*_{\check{h}_j,W^+,W^-}\Gamma_{\check{h}_i,W^+,W^-} \\
&- B_0\Big(p^2, m_{\eta^-}^2, m_{\eta^-}^2\Big)\Gamma_{\check{h}_i,\bar{\eta^-},\eta^-}\Gamma_{\check{h}_j,\bar{\eta^-},\eta^-} - B_0\Big(p^2, m_{\eta^+}^2, m_{\eta^+}^2\Big)\Gamma_{\check{h}_i,\bar{\eta^+},\eta^+}\Gamma_{\check{h}_j,\bar{\eta^+},\eta^+} \\
&- B_0\Big(p^2, m_{\eta^Z}^2, m_{\eta^Z}^2\Big)\Gamma_{\check{h}_i,\bar{\eta^Z},\eta^Z}\Gamma_{\check{h}_j,\bar{\eta^Z},\eta^Z} + 4\Gamma_{\check{h}_i,\check{h}_j,W^+,W^-}\Big(-\frac{1}{2}\text{rMS}m_{W^-}^2 + A_0\Big(m_{W^-}^2\Big)\Big) \\
&+ 2\Gamma_{\check{h}_i,\check{h}_j,Z,Z}\Big(-\frac{1}{2}\text{rMS}m_Z^2 + A_0\Big(m_Z^2\Big)\Big) - \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{A_a^0}^2\Big)\Gamma_{\check{h}_i,\check{h}_j,A_a^0,A_a^0} \\
&- \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} 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_{A_a^0}^2, m_{A_b^0}^2\Big)\Gamma^*_{\check{h}_j,A_a^0,A_b^0}\Gamma_{\check{h}_i,A_a^0,A_b^0} \\
&+ \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^-} \\
&+ \sum_{a=1}^{2}\sum_{b=1}^{2} B_0\Big(p^2, m_{h_a}^2, m_{A_b^0}^2\Big)\Gamma^*_{\check{h}_j,h_a,A_b^0}\Gamma_{\check{h}_i,h_a,A_b^0} + \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)
\end{aligned}
$$

$$
\begin{aligned}
&- 6\sum_{a=1}^{3} m_{u_a} \sum_{b=1}^{3} B_0\Big(p^2, m_{u_a}^2, m_{u_b}^2\Big) m_{u_b} \Big(\Gamma^{L*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{R}_{\check{h}_i,\bar{u}_a,u_b} + \Gamma^{R*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{L}_{\check{h}_i,\bar{u}_a,u_b}\Big) \\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3} G_0\Big(p^2, m_{u_a}^2, m_{u_b}^2\Big)\Big(\Gamma^{L*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{L}_{\check{h}_i,\bar{u}_a,u_b} + \Gamma^{R*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{R}_{\check{h}_i,\bar{u}_a,u_b}\Big) \\
&+ \sum_{b=1}^{2} \Gamma^{*}_{\check{h}_j,Z,A_b^0}\Gamma_{\check{h}_i,Z,A_b^0} F_0\Big(p^2, m_{A_b^0}^2, m_Z^2\Big) + 2\sum_{b=1}^{2} \Gamma^{*}_{\check{h}_j,W^+,H_b^-}\Gamma_{\check{h}_i,W^+,H_b^-} F_0\Big(p^2, m_{H_b^-}^2, m_{W^-}^2\Big)
\end{aligned} \tag{69}
$$

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

$$
\begin{aligned}
\Pi_{i,j}(p^2) = &-B_0\Big(p^2, m_{\eta^-}^2, m_{\eta^-}^2\Big)\Gamma_{\check{A}_i^0,\eta^-,\eta^-}\Gamma_{\check{A}_j^0,\eta^-,\eta^-} - B_0\Big(p^2, m_{\eta^+}^2, m_{\eta^+}^2\Big)\Gamma_{\check{A}_i^0,\eta^+,\eta^+}\Gamma_{\check{A}_j^0,\eta^+,\eta^+} \\
&+ 4\Gamma_{\check{A}_i^0,\check{A}_j^0,W^+,W^-}\Big(-\frac{1}{2}\mathrm{rMS}m_{W^-}^2 + A_0\Big(m_{W^-}^2\Big)\Big) + 2\Gamma_{\check{A}_i^0,\check{A}_j^0,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_{A_a^0}^2\Big)\Gamma_{\check{A}_i^0,\check{A}_j^0,A_a^0,A_a^0} - \sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big)\Gamma_{\check{A}_i^0,\check{A}_j^0,H_a^+,H_a^-} \\
&- \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{h_a}^2\Big)\Gamma_{\check{A}_i^0,\check{A}_j^0,h_a,h_a} + \frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{2} B_0\Big(p^2, m_{A_a^0}^2, m_{A_b^0}^2\Big)\Gamma^{*}_{\check{A}_j^0,A_a^0,A_b^0}\Gamma_{\check{A}_i^0,A_a^0,A_b^0} \\
&+ \sum_{a=1}^{2}\sum_{b=1}^{2} B_0\Big(p^2, m_{H_a^-}^2, m_{H_b^-}^2\Big)\Gamma^{*}_{\check{A}_j^0,H_a^+,H_b^-}\Gamma_{\check{A}_i^0,H_a^+,H_b^-} \\
&+ \sum_{a=1}^{2}\sum_{b=1}^{2} B_0\Big(p^2, m_{h_a}^2, m_{A_b^0}^2\Big)\Gamma^{*}_{\check{A}_j^0,h_a,A_b^0}\Gamma_{\check{A}_i^0,h_a,A_b^0} \\
&+ \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{A}_j^0,h_a,h_b}\Gamma_{\check{A}_i^0,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{A}_j^0,\bar{d}_a,d_b}\Gamma^{R}_{\check{A}_i^0,\bar{d}_a,d_b} + \Gamma^{R*}_{\check{A}_j^0,\bar{d}_a,d_b}\Gamma^{L}_{\check{A}_i^0,\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{A}_j^0,\bar{d}_a,d_b}\Gamma^{L}_{\check{A}_i^0,\bar{d}_a,d_b} + \Gamma^{R*}_{\check{A}_j^0,\bar{d}_a,d_b}\Gamma^{R}_{\check{A}_i^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_{e_a}^2, m_{e_b}^2\Big) m_{e_b} \Big(\Gamma^{L*}_{\check{A}_j^0,\bar{e}_a,e_b}\Gamma^{R}_{\check{A}_i^0,\bar{e}_a,e_b} + \Gamma^{R*}_{\check{A}_j^0,\bar{e}_a,e_b}\Gamma^{L}_{\check{A}_i^0,\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{A}_j^0,\bar{e}_a,e_b}\Gamma^{L}_{\check{A}_i^0,\bar{e}_a,e_b} + \Gamma^{R*}_{\check{A}_j^0,\bar{e}_a,e_b}\Gamma^{R}_{\check{A}_i^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_{u_a}^2, m_{u_b}^2\Big) m_{u_b} \Big(\Gamma^{L*}_{\check{A}_j^0,\bar{u}_a,u_b}\Gamma^{R}_{\check{A}_i^0,\bar{u}_a,u_b} + \Gamma^{R*}_{\check{A}_j^0,\bar{u}_a,u_b}\Gamma^{L}_{\check{A}_i^0,\bar{u}_a,u_b}\Big)
\end{aligned}
$$

$$+3\sum_{a=1}^{3}\sum_{b=1}^{3}G_0\Big(p^2,m_{u_a}^2,m_{u_b}^2\Big)\Big(\Gamma^{L*}_{\check{A}_j^0,\bar{u}_a,u_b}\Gamma^{L}_{\check{A}_i^0,\bar{u}_a,u_b}+\Gamma^{R*}_{\check{A}_j^0,\bar{u}_a,u_b}\Gamma^{R}_{\check{A}_i^0,\bar{u}_a,u_b}\Big)$$
$$+\sum_{b=1}^{2}\Gamma^{*}_{\check{A}_j^0,Z,h_b}\Gamma_{\check{A}_i^0,Z,h_b}F_0\Big(p^2,m_{h_b}^2,m_Z^2\Big)+2\sum_{b=1}^{2}\Gamma^{*}_{\check{A}_j^0,W^+,H_b^-}\Gamma_{\check{A}_i^0,W^+,H_b^-}F_0\Big(p^2,m_{H_b^-}^2,m_{W^-}^2\Big) \tag{70}$$

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

$$\begin{aligned}
\Pi_{i,j}(p^2) =& +4\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,0,m_{W^-}^2\Big)\Big)\Gamma^{*}_{\check{H}_j^+,W^-,\gamma}\Gamma_{\check{H}_i^+,W^-,\gamma}+4\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{W^-}^2,m_Z^2\Big)\Big)\Gamma^{*}_{\check{H}_j^+,Z,W^-}\Gamma_{\check{H}_i^+,Z,W^-}\\
&-B_0\Big(p^2,m_{\eta^z}^2,m_{\eta^+}^2\Big)\Gamma_{\check{H}_i^+,\bar{\eta^+},\eta^z}\Gamma_{\check{H}_j^-,\eta^+,\bar{\eta^z}}-B_0\Big(p^2,m_{\eta^-}^2,m_{\eta^z}^2\Big)\Gamma_{\check{H}_i^+,\bar{\eta^z},\eta^-}\Gamma_{\check{H}_j^-,\eta^z,\bar{\eta^-}}\\
&+4\Gamma_{\check{H}_i^-,\check{H}_j^+,W^+,W^-}\Big(-\frac{1}{2}\mathrm{rMS}m_{W^-}^2+A_0\Big(m_{W^-}^2\Big)\Big)+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_{A_a^0}^2\Big)\Gamma_{\check{H}_i^-,\check{H}_j^+,A_a^0,A_a^0}-\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}A_0\Big(m_{h_a}^2\Big)\Gamma_{\check{H}_i^-,\check{H}_j^+,h_a,h_a}+\sum_{a=1}^{2}\sum_{b=1}^{2}B_0\Big(p^2,m_{H_a^-}^2,m_{A_b^0}^2\Big)\Gamma^{*}_{\check{H}_j^+,H_a^-,A_b^0}\Gamma_{\check{H}_i^+,H_a^-,A_b^0}\\
&+\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_{u_a}\sum_{b=1}^{3}B_0\Big(p^2,m_{u_a}^2,m_{d_b}^2\Big)m_{d_b}\Big(\Gamma^{L*}_{\check{H}_j^+,\bar{u}_a,d_b}\Gamma^{R}_{\check{H}_i^+,\bar{u}_a,d_b}+\Gamma^{R*}_{\check{H}_j^+,\bar{u}_a,d_b}\Gamma^{L}_{\check{H}_i^+,\bar{u}_a,d_b}\Big)\\
&+3\sum_{a=1}^{3}\sum_{b=1}^{3}G_0\Big(p^2,m_{u_a}^2,m_{d_b}^2\Big)\Big(\Gamma^{L*}_{\check{H}_j^+,\bar{u}_a,d_b}\Gamma^{L}_{\check{H}_i^+,\bar{u}_a,d_b}+\Gamma^{R*}_{\check{H}_j^+,\bar{u}_a,d_b}\Gamma^{R}_{\check{H}_i^+,\bar{u}_a,d_b}\Big)\\
&-2\sum_{a=1}^{3}m_{\nu_a}\sum_{b=1}^{3}B_0\Big(p^2,m_{\nu_a}^2,m_{e_b}^2\Big)m_{e_b}\Big(\Gamma^{L*}_{\check{H}_j^+,\bar{\nu}_a,e_b}\Gamma^{R}_{\check{H}_i^+,\bar{\nu}_a,e_b}+\Gamma^{R*}_{\check{H}_j^+,\bar{\nu}_a,e_b}\Gamma^{L}_{\check{H}_i^+,\bar{\nu}_a,e_b}\Big)\\
&+\sum_{a=1}^{3}\sum_{b=1}^{3}G_0\Big(p^2,m_{\nu_a}^2,m_{e_b}^2\Big)\Big(\Gamma^{L*}_{\check{H}_j^+,\bar{\nu}_a,e_b}\Gamma^{L}_{\check{H}_i^+,\bar{\nu}_a,e_b}+\Gamma^{R*}_{\check{H}_j^+,\bar{\nu}_a,e_b}\Gamma^{R}_{\check{H}_i^+,\bar{\nu}_a,e_b}\Big)\\
&+\sum_{b=1}^{2}\Gamma^{*}_{\check{H}_j^+,W^-,A_b^0}\Gamma_{\check{H}_i^+,W^-,A_b^0}F_0\Big(p^2,m_{A_b^0}^2,m_{W^-}^2\Big)+\sum_{b=1}^{2}\Gamma^{*}_{\check{H}_j^+,W^-,h_b}\Gamma_{\check{H}_i^+,W^-,h_b}F_0\Big(p^2,m_{h_b}^2,m_{W^-}^2\Big)\\
&+\sum_{b=1}^{2}\Gamma^{*}_{\check{H}_j^+,\gamma,H_b^-}\Gamma_{\check{H}_i^+,\gamma,H_b^-}F_0\Big(p^2,m_{H_b^-}^2,0\Big)+\sum_{b=1}^{2}\Gamma^{*}_{\check{H}_j^+,Z,H_b^-}\Gamma_{\check{H}_i^+,Z,H_b^-}F_0\Big(p^2,m_{H_b^-}^2,m_Z^2\Big)
\end{aligned} \tag{71}$$

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

$$\Sigma^{S}_{i,j}(p^2)=+\sum_{a=1}^{2}\sum_{b=1}^{3}B_0\Big(p^2,m_{d_b}^2,m_{h_a}^2\Big)\Gamma^{L*}_{\check{d}_j,h_a,d_b}m_{d_b}\Gamma^{R}_{\check{d}_i,h_a,d_b}$$

$$
\begin{aligned}
&+\sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m_{u_b}^2, m_{H_a^-}^2\Big)\Gamma^{L*}_{\tilde{\tilde{d}}_j,H_a^-,u_b} m_{u_b}\Gamma^{R}_{\tilde{\tilde{d}}_i,H_a^-,u_b}\\
&+\sum_{a=1}^{3} m_{d_a}\sum_{b=1}^{2} B_0\Big(p^2, m_{d_a}^2, m_{A_b^0}^2\Big)\Gamma^{L*}_{\tilde{\tilde{d}}_j,d_a,A_b^0}\Gamma^{R}_{\tilde{\tilde{d}}_i,d_a,A_b^0}\\
&-\frac{16}{3}\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{d_b}^2,0\Big)\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,g,d_b} m_{d_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,g,d_b} - 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{d_b}^2,0\Big)\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,\gamma,d_b} m_{d_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,\gamma,d_b}\\
&-4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{u_b}^2,m_{W^-}^2\Big)\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,W^-,u_b} m_{u_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,W^-,u_b}\\
&-4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{d_b}^2,m_Z^2\Big)\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,Z,d_b} m_{d_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,Z,d_b} \qquad (72)
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^R_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{h_a}^2\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,h_a,d_b}\Gamma^{R}_{\tilde{\tilde{d}}_i,h_a,d_b}\\
&-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{H_a^-}^2\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,H_a^-,u_b}\Gamma^{R}_{\tilde{\tilde{d}}_i,H_a^-,u_b}\\
&-\frac{1}{2}\sum_{a=1}^{3}\sum_{b=1}^{2} B_1\Big(p^2, m_{d_a}^2, m_{A_b^0}^2\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,d_a,A_b^0}\Gamma^{R}_{\tilde{\tilde{d}}_i,d_a,A_b^0} - \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{L*}_{\tilde{\tilde{d}}_j,g,d_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,g,d_b}\\
&-\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{L*}_{\tilde{\tilde{d}}_j,\gamma,d_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,\gamma,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{W^-}^2\Big)\Gamma^{L*}_{\tilde{\tilde{d}}_j,W^-,u_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,W^-,u_b}\\
&-\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_Z^2\Big)\Gamma^{L*}_{\tilde{\tilde{d}}_j,Z,d_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,Z,d_b} \qquad (73)
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^L_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{h_a}^2\Big)\Gamma^{L*}_{\tilde{\tilde{d}}_j,h_a,d_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,h_a,d_b}\\
&-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{H_a^-}^2\Big)\Gamma^{L*}_{\tilde{\tilde{d}}_j,H_a^-,u_b}\Gamma^{L}_{\tilde{\tilde{d}}_i,H_a^-,u_b}\\
&-\frac{1}{2}\sum_{a=1}^{3}\sum_{b=1}^{2} B_1\Big(p^2, m_{d_a}^2, m_{A_b^0}^2\Big)\Gamma^{L*}_{\tilde{\tilde{d}}_j,d_a,A_b^0}\Gamma^{L}_{\tilde{\tilde{d}}_i,d_a,A_b^0} - \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,g,d_b}\Gamma^{R}_{\tilde{\tilde{d}}_i,g,d_b}\\
&-\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,\gamma,d_b}\Gamma^{R}_{\tilde{\tilde{d}}_i,\gamma,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{W^-}^2\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,W^-,u_b}\Gamma^{R}_{\tilde{\tilde{d}}_i,W^-,u_b}\\
&-\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_Z^2\Big)\Gamma^{R*}_{\tilde{\tilde{d}}_j,Z,d_b}\Gamma^{R}_{\tilde{\tilde{d}}_i,Z,d_b} \qquad (74)
\end{aligned}
$$

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

$$
\begin{aligned}
\Sigma^{S}_{i,j}(p^2) = &+\sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m^2_{d_b}, m^2_{H^-_a}\Big)\Gamma^{L*}_{\check{u}_j,H^+_a,d_b} m_{d_b}\Gamma^{R}_{\check{u}_i,H^+_a,d_b} \\
&+\sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m^2_{u_b}, m^2_{h_a}\Big)\Gamma^{L*}_{\check{u}_j,h_a,u_b} m_{u_b}\Gamma^{R}_{\check{u}_i,h_a,u_b} \\
&+\sum_{a=1}^{3} m_{u_a}\sum_{b=1}^{2} B_0\Big(p^2, m^2_{u_a}, m^2_{A^0_b}\Big)\Gamma^{L*}_{\check{u}_j,u_a,A^0_b}\Gamma^{R}_{\check{u}_i,u_a,A^0_b} \\
&-\frac{16}{3}\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m^2_{u_b}, 0\Big)\Big)\Gamma^{R*}_{\check{u}_j,g,u_b} m_{u_b}\Gamma^{L}_{\check{u}_i,g,u_b} - 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m^2_{u_b}, 0\Big)\Big)\Gamma^{R*}_{\check{u}_j,\gamma,u_b} m_{u_b}\Gamma^{L}_{\check{u}_i,\gamma,u_b} \\
&-4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m^2_{u_b}, m^2_{Z}\Big)\Big)\Gamma^{R*}_{\check{u}_j,Z,u_b} m_{u_b}\Gamma^{L}_{\check{u}_i,Z,u_b} \\
&-4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m^2_{d_b}, m^2_{W^-}\Big)\Big)\Gamma^{R*}_{\check{u}_j,W^+,d_b} m_{d_b}\Gamma^{L}_{\check{u}_i,W^+,d_b}
\end{aligned} \tag{75}
$$

$$
\begin{aligned}
\Sigma^{R}_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m^2_{d_b}, m^2_{H^-_a}\Big)\Gamma^{R*}_{\check{u}_j,H^+_a,d_b}\Gamma^{R}_{\check{u}_i,H^+_a,d_b} \\
&-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m^2_{u_b}, m^2_{h_a}\Big)\Gamma^{R*}_{\check{u}_j,h_a,u_b}\Gamma^{R}_{\check{u}_i,h_a,u_b} \\
&-\frac{1}{2}\sum_{a=1}^{3}\sum_{b=1}^{2} B_1\Big(p^2, m^2_{u_a}, m^2_{A^0_b}\Big)\Gamma^{R*}_{\check{u}_j,u_a,A^0_b}\Gamma^{R}_{\check{u}_i,u_a,A^0_b} - \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m^2_{u_b}, 0\Big)\Gamma^{L*}_{\check{u}_j,g,u_b}\Gamma^{L}_{\check{u}_i,g,u_b} \\
&-\sum_{b=1}^{3} B_1\Big(p^2, m^2_{u_b}, 0\Big)\Gamma^{L*}_{\check{u}_j,\gamma,u_b}\Gamma^{L}_{\check{u}_i,\gamma,u_b} - \sum_{b=1}^{3} B_1\Big(p^2, m^2_{u_b}, m^2_{Z}\Big)\Gamma^{L*}_{\check{u}_j,Z,u_b}\Gamma^{L}_{\check{u}_i,Z,u_b} \\
&-\sum_{b=1}^{3} B_1\Big(p^2, m^2_{d_b}, m^2_{W^-}\Big)\Gamma^{L*}_{\check{u}_j,W^+,d_b}\Gamma^{L}_{\check{u}_i,W^+,d_b}
\end{aligned} \tag{76}
$$

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

$$- \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{W^-}^2\Big)\Gamma^{R*}_{\tilde{\bar{u}}_j, W^+, d_b}\Gamma^{R}_{\tilde{\bar{u}}_i, W^+, d_b} \tag{77}$$

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

$$\begin{aligned}
\Sigma^S_{i,j}(p^2) = &+ \sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m_{e_b}^2, m_{h_a}^2\Big)\Gamma^{L*}_{\tilde{\bar{e}}_j, h_a, e_b} m_{e_b}\Gamma^{R}_{\tilde{\bar{e}}_i, h_a, e_b} \\
&+ \sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m_{\nu_b}^2, m_{H_a^-}^2\Big)\Gamma^{L*}_{\tilde{\bar{e}}_j, H_a^-, \nu_b} m_{\nu_b}\Gamma^{R}_{\tilde{\bar{e}}_i, H_a^-, \nu_b} \\
&+ \sum_{a=1}^{3} m_{e_a}\sum_{b=1}^{2} B_0\Big(p^2, m_{e_a}^2, m_{A_b^0}^2\Big)\Gamma^{L*}_{\tilde{\bar{e}}_j, e_a, A_b^0}\Gamma^{R}_{\tilde{\bar{e}}_i, e_a, A_b^0} \\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{e_b}^2, 0\Big)\Big)\Gamma^{R*}_{\tilde{\bar{e}}_j, \gamma, e_b} m_{e_b}\Gamma^{L}_{\tilde{\bar{e}}_i, \gamma, e_b} \\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{\nu_b}^2, m_{W^-}^2\Big)\Big)\Gamma^{R*}_{\tilde{\bar{e}}_j, W^-, \nu_b} m_{\nu_b}\Gamma^{L}_{\tilde{\bar{e}}_i, W^-, \nu_b} \\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{e_b}^2, m_Z^2\Big)\Big)\Gamma^{R*}_{\tilde{\bar{e}}_j, Z, e_b} m_{e_b}\Gamma^{L}_{\tilde{\bar{e}}_i, Z, e_b}
\end{aligned} \tag{78}$$

$$\begin{aligned}
\Sigma^R_{i,j}(p^2) = &- \frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_{h_a}^2\Big)\Gamma^{R*}_{\tilde{\bar{e}}_j, h_a, e_b}\Gamma^{R}_{\tilde{\bar{e}}_i, h_a, e_b} \\
&- \frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{H_a^-}^2\Big)\Gamma^{R*}_{\tilde{\bar{e}}_j, H_a^-, \nu_b}\Gamma^{R}_{\tilde{\bar{e}}_i, H_a^-, \nu_b} \\
&- \frac{1}{2}\sum_{a=1}^{3}\sum_{b=1}^{2} B_1\Big(p^2, m_{e_a}^2, m_{A_b^0}^2\Big)\Gamma^{R*}_{\tilde{\bar{e}}_j, e_a, A_b^0}\Gamma^{R}_{\tilde{\bar{e}}_i, e_a, A_b^0} - \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, 0\Big)\Gamma^{L*}_{\tilde{\bar{e}}_j, \gamma, e_b}\Gamma^{L}_{\tilde{\bar{e}}_i, \gamma, e_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{W^-}^2\Big)\Gamma^{L*}_{\tilde{\bar{e}}_j, W^-, \nu_b}\Gamma^{L}_{\tilde{\bar{e}}_i, W^-, \nu_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_Z^2\Big)\Gamma^{L*}_{\tilde{\bar{e}}_j, Z, e_b}\Gamma^{L}_{\tilde{\bar{e}}_i, Z, e_b}
\end{aligned} \tag{79}$$

$$\begin{aligned}
\Sigma^L_{i,j}(p^2) = &- \frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_{h_a}^2\Big)\Gamma^{L*}_{\tilde{\bar{e}}_j, h_a, e_b}\Gamma^{L}_{\tilde{\bar{e}}_i, h_a, e_b} \\
&- \frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{H_a^-}^2\Big)\Gamma^{L*}_{\tilde{\bar{e}}_j, H_a^-, \nu_b}\Gamma^{L}_{\tilde{\bar{e}}_i, H_a^-, \nu_b} \\
&- \frac{1}{2}\sum_{a=1}^{3}\sum_{b=1}^{2} B_1\Big(p^2, m_{e_a}^2, m_{A_b^0}^2\Big)\Gamma^{L*}_{\tilde{\bar{e}}_j, e_a, A_b^0}\Gamma^{L}_{\tilde{\bar{e}}_i, e_a, A_b^0} - \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, 0\Big)\Gamma^{R*}_{\tilde{\bar{e}}_j, \gamma, e_b}\Gamma^{R}_{\tilde{\bar{e}}_i, \gamma, e_b}
\end{aligned}$$

$$- \sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{W^-}^2\Big)\Gamma^{R*}_{\tilde{\bar{e}}_j, W^-, \nu_b}\Gamma^{R}_{\tilde{\bar{e}}_i, W^-, \nu_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_Z^2\Big)\Gamma^{R*}_{\tilde{\bar{e}}_j, Z, e_b}\Gamma^{R}_{\tilde{\bar{e}}_i, Z, e_b} \tag{80}$$

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

$$\begin{aligned}
\Pi(p^2) = {} & +|\Gamma_{Z,\bar{\eta^-},\eta^-}|^2 B_{00}\Big(p^2, m_{\eta^-}^2, m_{\eta^-}^2\Big) + |\Gamma_{Z,\bar{\eta^+},\eta^+}|^2 B_{00}\Big(p^2, m_{\eta^+}^2, m_{\eta^+}^2\Big) \\
& - |\Gamma_{Z,W^+,W^-}|^2\Big(10B_{00}\Big(p^2, m_{W^-}^2, m_{W^-}^2\Big) + 2A_0\Big(m_{W^-}^2\Big) - 2\mathrm{rMS}\Big(2m_{W^-}^2 - \frac{1}{3}p^2\Big) + B_0\Big(p^2, m_{W^-}^2, m_{W^-}^2\Big)\Big(2m_{W^-}^2 + 4p^2\Big)\Big) \\
& + \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{A_a^0}^2\Big)\Gamma_{Z,Z,A_a^0,A_a^0} + \sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big)\Gamma_{Z,Z,H_a^+,H_a^-} + \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{h_a}^2\Big)\Gamma_{Z,Z,h_a,h_a} \\
& - 4\sum_{a=1}^{2}\sum_{b=1}^{2} |\Gamma_{Z,h_a,A_b^0}|^2 B_{00}\Big(p^2, m_{A_b^0}^2, m_{h_a}^2\Big) - 4\sum_{a=1}^{2}\sum_{b=1}^{2} |\Gamma_{Z,H_a^+,H_b^-}|^2 B_{00}\Big(p^2, m_{H_a^-}^2, m_{H_b^-}^2\Big) \\
& + 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_{d_a}^2, m_{d_b}^2\Big) \\
& + 4B_0\Big(p^2, m_{d_a}^2, m_{d_b}^2\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_{e_a}^2, m_{e_b}^2\Big) \\
& + 4B_0\Big(p^2, m_{e_a}^2, m_{e_b}^2\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_{u_a}^2, m_{u_b}^2\Big) \\
& + 4B_0\Big(p^2, m_{u_a}^2, m_{u_b}^2\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] \\
& + \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_{\nu_a}^2, m_{\nu_b}^2\Big) \\
& + 4B_0\Big(p^2, m_{\nu_a}^2, m_{\nu_b}^2\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] \\
& + 2\sum_{b=1}^{2} |\Gamma_{Z,W^+,H_b^-}|^2 B_0\Big(p^2, m_{W^-}^2, m_{H_b^-}^2\Big) + \sum_{b=1}^{2} |\Gamma_{Z,Z,h_b}|^2 B_0\Big(p^2, m_Z^2, m_{h_b}^2\Big) + 2\mathrm{rMS}m_{W^-}^2\Gamma^1_{Z,Z,W^+,W^-} \\
& - A_0\Big(m_{W^-}^2\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{81}$$

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

$$\Pi(p^2) = 2\mathrm{rMS}m_{W^-}^2\Gamma^1_{W^-,W^+,W^+,W^-} + 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big[\Big(|\Gamma^L_{W^+,\bar{u}_a,d_b}|^2 + |\Gamma^R_{W^+,\bar{u}_a,d_b}|^2\Big)H_0\Big(p^2, m_{u_a}^2, m_{d_b}^2\Big)$$

$$+ 4B_0\Big(p^2, m^2_{u_a}, m^2_{d_b}\Big) m_{d_b} m_{u_a} \Re\Big(\Gamma^{L*}_{W^+,\bar{u}_a,d_b}\Gamma^{R}_{W^+,\bar{u}_a,d_b}\Big)\Big] - 4\sum_{a=1}^{2}\sum_{b=1}^{2} |\Gamma_{W^+,H^-_a,A^0_b}|^2 B_{00}\Big(p^2, m^2_{A^0_b}, m^2_{H^-_a}\Big) - 4\sum_{a=1}^{2}\sum_{b=1}^{2} |\Gamma_{W^+,H}$$

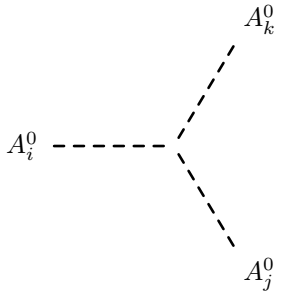
$$+ 4B_0\Big(p^2, m^2_{\nu_a}, m^2_{e_b}\Big) m_{e_b} m_{\nu_a} \Re\Big(\Gamma^{L*}_{W^+,\bar{\nu}_a,e_b}\Gamma^{R}_{W^+,\bar{\nu}_a,e_b}\Big)\Big] + \sum_{b=1}^{2} |\Gamma_{W^+,\gamma,H^-_b}|^2 B_0\Big(p^2, 0, m^2_{H^-_b}\Big) + \sum_{b=1}^{2} |\Gamma_{W^+,W^-,h_b}|^2 B_0\Big(p^2, m^2_W \tag{82}$$

8.2 Tadpoles

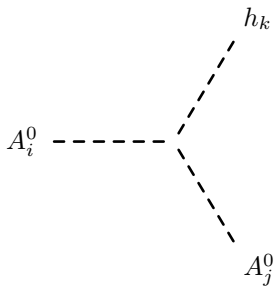
$$\begin{aligned}
\delta t_h^{(1)} = &+ A_0\Big(m^2_{\eta^-}\Big)\Gamma_{\check{h}_i,\eta^-,\eta^-} + A_0\Big(m^2_{\eta^+}\Big)\Gamma_{\check{h}_i,\eta^-,\eta^+} + A_0\Big(m^2_{\eta^z}\Big)\Gamma_{\check{h}_i,\eta^-,\eta^z} \\
&+ 4\Gamma_{\check{h}_i,W^+,W^-}\Big(-\frac{1}{2}\mathrm{rMS}m^2_{W^-} + A_0\Big(m^2_{W^-}\Big)\Big) + 2\Gamma_{\check{h}_i,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m^2_{Z} + A_0\Big(m^2_{Z}\Big)\Big) - \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m^2_{A^0_a}\Big)\Gamma_{\check{h}_i,A^0_a,A^0_a} \\
&- \sum_{a=1}^{2} A_0\Big(m^2_{H^-_a}\Big)\Gamma_{\check{h}_i,H^+_a,H^-_a} - \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m^2_{h_a}\Big)\Gamma_{\check{h}_i,h_a,h_a} \\
&+ 6\sum_{a=1}^{3} A_0\Big(m^2_{d_a}\Big) m_{d_a}\Big(\Gamma^{L}_{\check{h}_i,\bar{d}_a,d_a} + \Gamma^{R}_{\check{h}_i,\bar{d}_a,d_a}\Big) \\
&+ 2\sum_{a=1}^{3} A_0\Big(m^2_{e_a}\Big) m_{e_a}\Big(\Gamma^{L}_{\check{h}_i,\bar{e}_a,e_a} + \Gamma^{R}_{\check{h}_i,\bar{e}_a,e_a}\Big) \\
&+ 6\sum_{a=1}^{3} A_0\Big(m^2_{u_a}\Big) m_{u_a}\Big(\Gamma^{L}_{\check{h}_i,\bar{u}_a,u_a} + \Gamma^{R}_{\check{h}_i,\bar{u}_a,u_a}\Big)
\end{aligned} \tag{83}$$

9 Interactions for eigenstates 'EWSB'

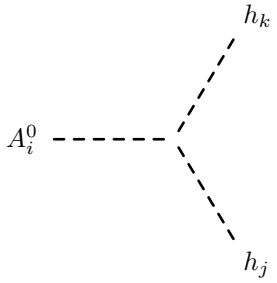
9.1 Three Scalar-Interaction



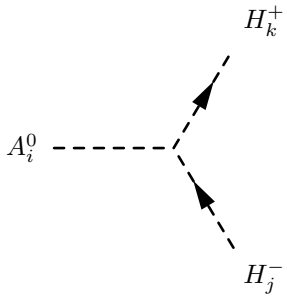
$$\begin{aligned}
&\frac{1}{2}\Big(-\lambda_5^* + \lambda_5\Big)\Big(Z^A_{i2}\Big(-v_1 Z^A_{j2} Z^A_{k1} + Z^A_{j1}\Big(-v_1 Z^A_{k2} + v_2 Z^A_{k1}\Big)\Big) \\
&+ Z^A_{i1}\Big(v_2 Z^A_{j1} Z^A_{k2} + Z^A_{j2}\Big(-v_1 Z^A_{k2} + v_2 Z^A_{k1}\Big)\Big)\Big)
\end{aligned} \tag{84}$$



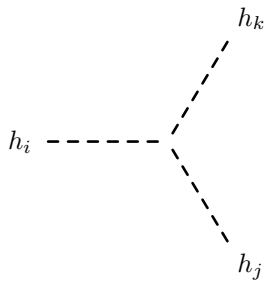
$$-\frac{i}{2}\Big(Z_{i2}^{A}\Big(\Big(\lambda_5+\lambda_5^*\Big)Z_{j1}^{A}\Big(v_1Z_{k2}^{H}+v_2Z_{k1}^{H}\Big)+Z_{j2}^{A}\Big(4\lambda_2v_2Z_{k2}^{H}+v_1\Big(2\lambda_3+2\lambda_4-\lambda_5-\lambda_5^*\Big)Z_{k1}^{H}\Big)\Big)$$
$$+Z_{i1}^{A}\Big(\Big(\lambda_5+\lambda_5^*\Big)Z_{j2}^{A}\Big(v_1Z_{k2}^{H}+v_2Z_{k1}^{H}\Big)+Z_{j1}^{A}\Big(4\lambda_1v_1Z_{k1}^{H}+v_2\Big(2\lambda_3+2\lambda_4-\lambda_5-\lambda_5^*\Big)Z_{k2}^{H}\Big)\Big)\Big) \tag{85}$$



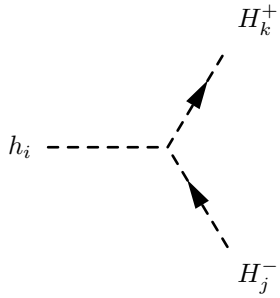
$$-\frac{1}{2}\Big(-\lambda_5^*+\lambda_5\Big)\Big(-Z_{i1}^{A}\Big(v_2Z_{j1}^{H}Z_{k2}^{H}+Z_{j2}^{H}\Big(v_1Z_{k2}^{H}+v_2Z_{k1}^{H}\Big)\Big)+Z_{i2}^{A}\Big(v_1Z_{j2}^{H}Z_{k1}^{H}+Z_{j1}^{H}\Big(v_1Z_{k2}^{H}+v_2Z_{k1}^{H}\Big)\Big)\Big) \tag{86}$$



$$-\frac{1}{2}\Big(-v_1Z_{i2}^{A}+v_2Z_{i1}^{A}\Big)\Big(\Big(-\lambda_4+\lambda_5^*\Big)Z_{j1}^{+}Z_{k2}^{+}+\Big(-\lambda_5+\lambda_4\Big)Z_{j2}^{+}Z_{k1}^{+}\Big) \tag{87}$$

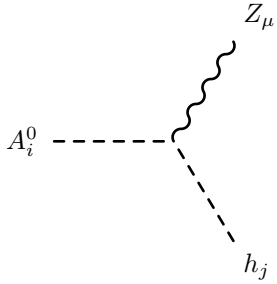


$$-\frac{i}{2}\Big(Z_{i2}^{H}\Big(\Big(2\lambda_3+2\lambda_4+\lambda_5+\lambda_5^*\Big)Z_{j1}^{H}\Big(v_1Z_{k2}^{H}+v_2Z_{k1}^{H}\Big)+Z_{j2}^{H}\Big(12\lambda_2v_2Z_{k2}^{H}+v_1\Big(2\lambda_3+2\lambda_4+\lambda_5+\lambda_5^*\Big)Z_{k1}^{H}\Big)\Big)$$
$$+Z_{i1}^{H}\Big(\Big(2\lambda_3+2\lambda_4+\lambda_5+\lambda_5^*\Big)Z_{j2}^{H}\Big(v_1Z_{k2}^{H}+v_2Z_{k1}^{H}\Big)+Z_{j1}^{H}\Big(12\lambda_1v_1Z_{k1}^{H}+v_2\Big(2\lambda_3+2\lambda_4+\lambda_5+\lambda_5^*\Big)Z_{k2}^{H}\Big)\Big)\Big) \tag{88}$$

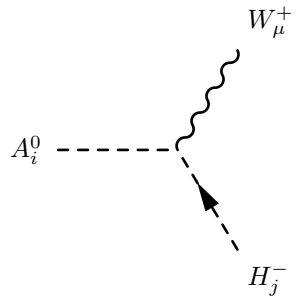


$$-\frac{i}{2}\Big(Z_{i2}^{H}\Big(Z_{j1}^{+}\Big(2\lambda_3v_2Z_{k1}^{+}+v_1\Big(\lambda_4+\lambda_5^*\Big)Z_{k2}^{+}\Big)+Z_{j2}^{+}\Big(4\lambda_2v_2Z_{k2}^{+}+\Big(\lambda_4+\lambda_5\Big)v_1Z_{k1}^{+}\Big)\Big)$$
$$+Z_{i1}^{H}\Big(Z_{j1}^{+}\Big(4\lambda_1v_1Z_{k1}^{+}+v_2\Big(\lambda_4+\lambda_5^*\Big)Z_{k2}^{+}\Big)+Z_{j2}^{+}\Big(2\lambda_3v_1Z_{k2}^{+}+\Big(\lambda_4+\lambda_5\Big)v_2Z_{k1}^{+}\Big)\Big)\Big) \tag{89}$$

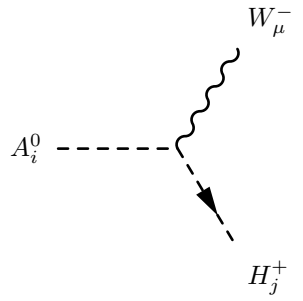
9.2 Two Scalar-One Vector Boson-Interaction



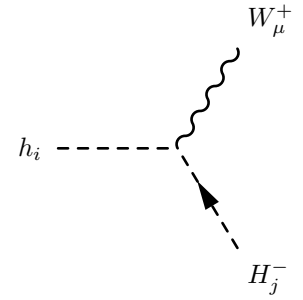
$$-\frac{1}{2}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(Z^A_{i1}Z^H_{j1}+Z^A_{i2}Z^H_{j2}\Big)\Big(-p^{h_j}_{\mu}+p^{A^0_i}_{\mu}\Big) \tag{90}$$



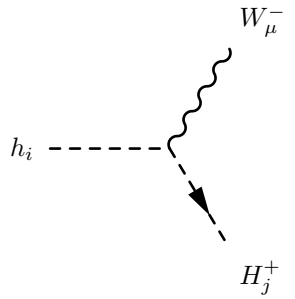
$$\frac{1}{2}g_2\Big(Z^A_{i1}Z^+_{j1}+Z^A_{i2}Z^+_{j2}\Big)\Big(-p^{H^-_j}_{\mu}+p^{A^0_i}_{\mu}\Big) \tag{91}$$



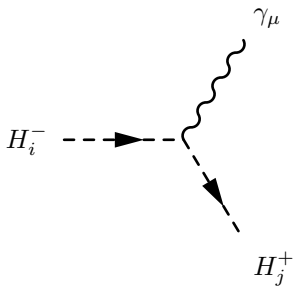
$$\frac{1}{2}g_2\Big(Z^A_{i1}Z^+_{j1}+Z^A_{i2}Z^+_{j2}\Big)\Big(-p^{H^+_j}_{\mu}+p^{A^0_i}_{\mu}\Big) \tag{92}$$



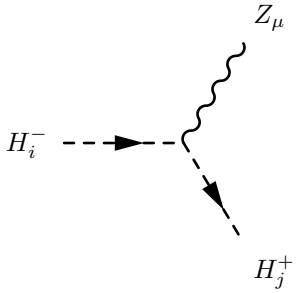
$$-\frac{i}{2}g_2\Big(Z^H_{i1}Z^+_{j1}+Z^H_{i2}Z^+_{j2}\Big)\Big(-p^{H^-_j}_{\mu}+p^{h_i}_{\mu}\Big) \tag{93}$$



$$\frac{i}{2}g_2\Big(Z_{i1}^H Z_{j1}^+ + Z_{i2}^H Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{h_i}\Big) \tag{94}$$

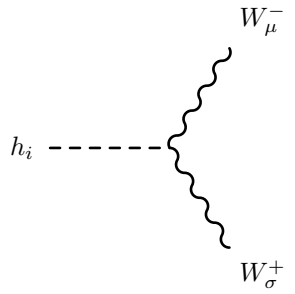


$$\frac{i}{2}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{95}$$

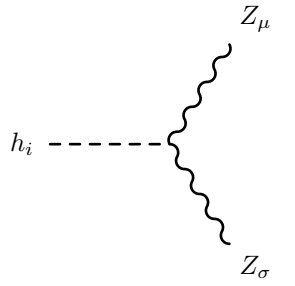


$$\frac{i}{2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{96}$$

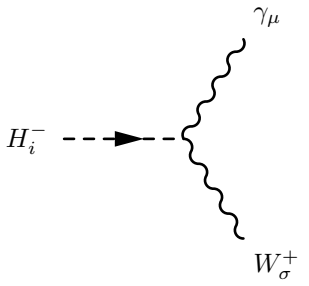
9.3 One Scalar-Two Vector Boson-Interaction



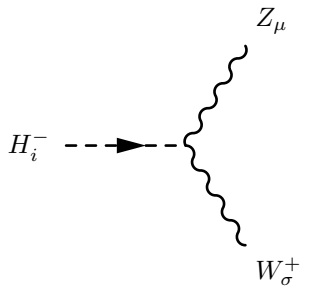
$$\frac{i}{2}g_2^2\Big(v_1 Z_{i1}^H + v_2 Z_{i2}^H\Big)\Big(g_{\sigma\mu}\Big) \tag{97}$$



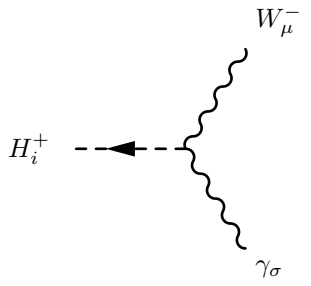
$$\frac{i}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2\Big(v_1 Z_{i1}^H + v_2 Z_{i2}^H\Big)\Big(g_{\sigma\mu}\Big) \tag{98}$$



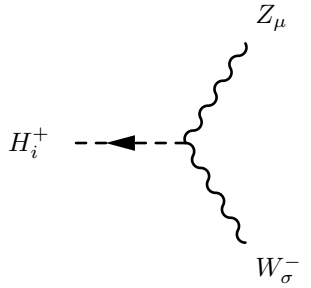
$$\frac{i}{2}g_1 g_2 \cos\Theta_W\Big(v_1 Z_{i1}^+ + v_2 Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{99}$$



$$-\frac{i}{2}g_1 g_2 \sin\Theta_W \Big(v_1 Z_{i1}^+ + v_2 Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{100}$$

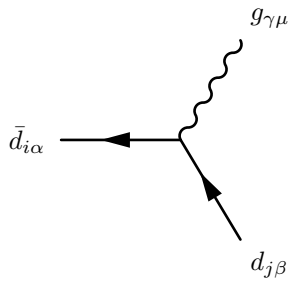


$$\frac{i}{2}g_1 g_2 \cos\Theta_W \Big(v_1 Z_{i1}^+ + v_2 Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{101}$$



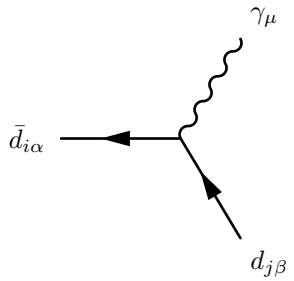
$$-\frac{i}{2}g_1 g_2 \sin\Theta_W \Big(v_1 Z_{i1}^+ + v_2 Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{102}$$

9.4 Two Fermion-One Vector Boson-Interaction



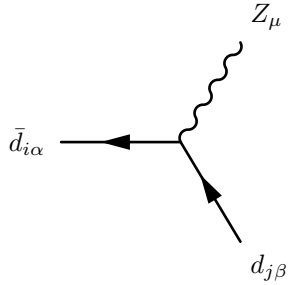
$$-\frac{i}{2}g_3\delta_{ij}\lambda^{\gamma}_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{103}$$

$$+\ -\frac{i}{2}g_3\delta_{ij}\lambda^{\gamma}_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{104}$$



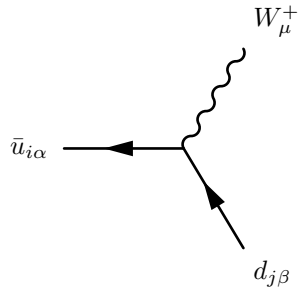
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{105}$$

$$+\ \frac{i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{106}$$

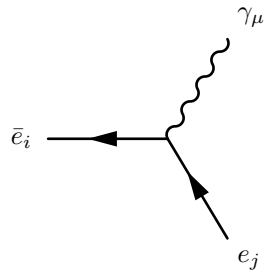


$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2\cos\Theta_W + g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{107}$$

$$+\ -\frac{i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{108}$$

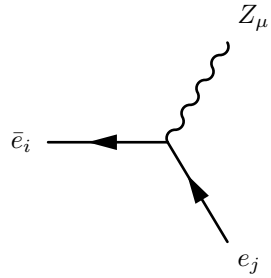


$$-\,i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}U^{d,*}_{L,ja}U^{u}_{L,ia}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{109}$$



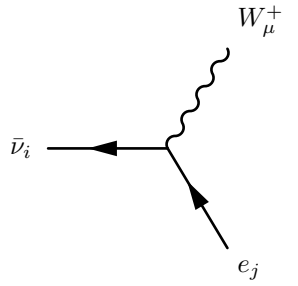
$$\frac{i}{2}\delta_{ij}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{110}$$

$$+\ ig_1\cos\Theta_W\delta_{ij}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{111}$$

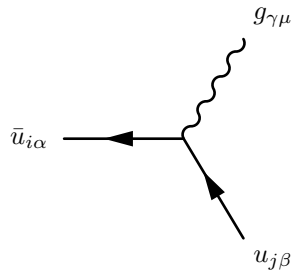


$$\frac{i}{2}\delta_{ij}\Big(- g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{112}$$

$$+ \; -ig_1\delta_{ij}\sin\Theta_W\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{113}$$

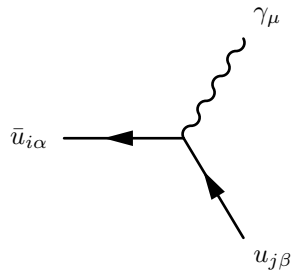


$$- \, i\frac{1}{\sqrt{2}}g_2 U^{e,*}_{L,ji}\Theta_{i,3}\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{114}$$



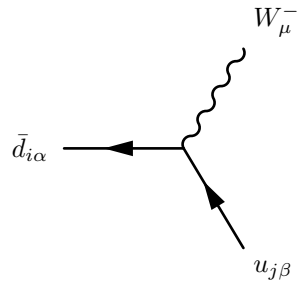
$$- \, \frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{115}$$

$$+ \; -\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{116}$$

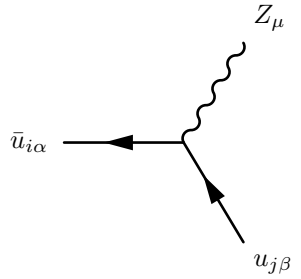


$$- \frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2 \sin\Theta_W + g_1 \cos\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{117}$$

$$+ \; -\frac{2i}{3} g_1 \cos\Theta_W \delta_{\alpha\beta}\delta_{ij}\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{118}$$

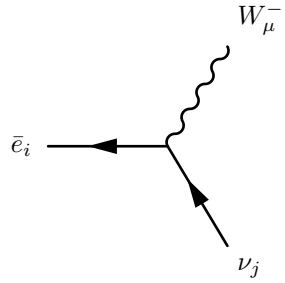


$$- i\frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^{3} U^{u,*}_{L,ja} U^{d}_{L,ia}\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{119}$$

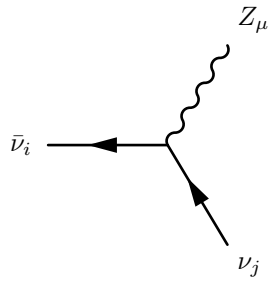


$$- \frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2 \cos\Theta_W - g_1 \sin\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{120}$$

$$+ \; \frac{2i}{3} g_1 \delta_{\alpha\beta}\delta_{ij} \sin\Theta_W \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{121}$$

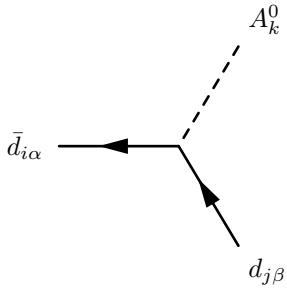


$$-i\frac{1}{\sqrt{2}}g_2\Theta_{j,3}U^{e}_{L,ij}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{122}$$



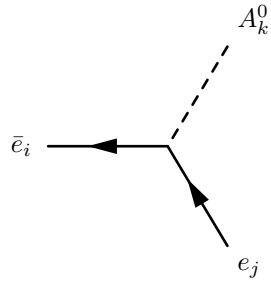
$$-\frac{i}{2}\delta_{ij}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{123}$$

9.5 Two Fermion-One Scalar Boson-Interaction



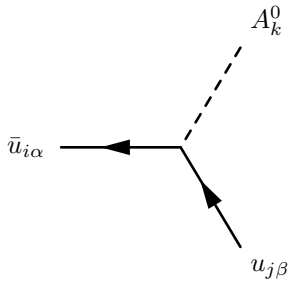
$$-\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U^{d,*}_{L,jb}\sum_{a=1}^{3}U^{d,*}_{R,ia}Y_{d,ab}Z^{A}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{124}$$

$$+\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{d,ab}U^{d}_{R,ja}U^{d}_{L,ib}Z^{A}_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{125}$$



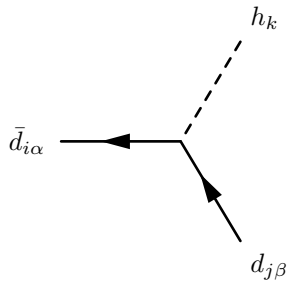
$$- \frac{1}{\sqrt{2}} \sum_{b=1}^{3} U^{e,*}_{L,jb} \sum_{a=1}^{3} U^{e,*}_{R,ia} Y_{e,ab} Z^{A}_{k2} \Big(\frac{1-\gamma_5}{2} \Big) \tag{126}$$

$$+ \frac{1}{\sqrt{2}} \sum_{b=1}^{3} \sum_{a=1}^{3} Y^{*}_{e,ab} U^{e}_{R,ja} U^{e}_{L,ib} Z^{A}_{k2} \Big(\frac{1+\gamma_5}{2} \Big) \tag{127}$$



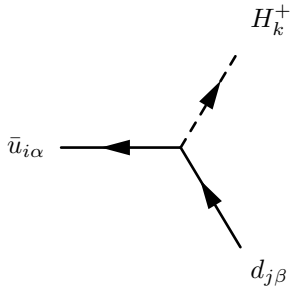
$$- \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} U^{u,*}_{L,jb} \sum_{a=1}^{3} U^{u,*}_{R,ia} Y_{u,ab} Z^{A}_{k2} \Big(\frac{1-\gamma_5}{2} \Big) \tag{128}$$

$$+ \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} \sum_{a=1}^{3} Y^{*}_{u,ab} U^{u}_{R,ja} U^{u}_{L,ib} Z^{A}_{k2} \Big(\frac{1+\gamma_5}{2} \Big) \tag{129}$$



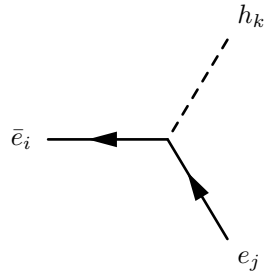
$$- i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} U^{d,*}_{L,jb} \sum_{a=1}^{3} U^{d,*}_{R,ia} Y_{d,ab} Z^{H}_{k1} \Big(\frac{1-\gamma_5}{2} \Big) \tag{130}$$

$$+ -i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} \sum_{a=1}^{3} Y^{*}_{d,ab} U^{d}_{R,ja} U^{d}_{L,ib} Z^{H}_{k1} \Big(\frac{1+\gamma_5}{2} \Big) \tag{131}$$



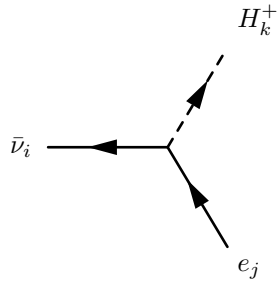
$$- i\delta_{\alpha\beta} \sum_{b=1}^{3} U_{L,jb}^{d,*} \sum_{a=1}^{3} U_{R,ia}^{u,*} Y_{u,ab} Z_{k2}^{+} \Big(\frac{1-\gamma_5}{2} \Big) \tag{132}$$

$$+ \; -i\delta_{\alpha\beta} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{d,ab}^{*} U_{R,ja}^{d} U_{L,ib}^{u} Z_{k1}^{+} \Big(\frac{1+\gamma_5}{2} \Big) \tag{133}$$



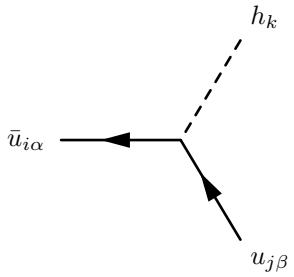
$$- i \frac{1}{\sqrt{2}} \sum_{b=1}^{3} U_{L,jb}^{e,*} \sum_{a=1}^{3} U_{R,ia}^{e,*} Y_{e,ab} Z_{k2}^{H} \Big(\frac{1-\gamma_5}{2} \Big) \tag{134}$$

$$+ \; -i \frac{1}{\sqrt{2}} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{e,ab}^{*} U_{R,ja}^{e} U_{L,ib}^{e} Z_{k2}^{H} \Big(\frac{1+\gamma_5}{2} \Big) \tag{135}$$



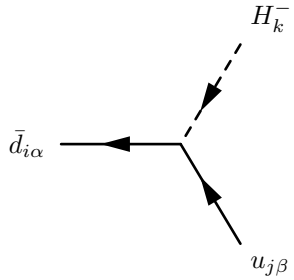
$$(136)$$

$$+ \; -i \sum_{a=1}^{3} Y^{*}_{e,ai} U^{e}_{R,ja} Z^{+}_{k2} \Big(\frac{1+\gamma_5}{2} \Big) \tag{137}$$



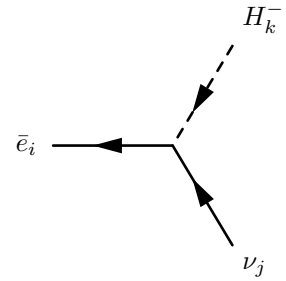
$$i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} U^{u,*}_{L,jb} \sum_{a=1}^{3} U^{u,*}_{R,ia} Y_{u,ab} Z^{H}_{k2} \Big(\frac{1-\gamma_5}{2} \Big) \tag{138}$$

$$+ \; i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} \sum_{a=1}^{3} Y^{*}_{u,ab} U^{u}_{R,ja} U^{u}_{L,ib} Z^{H}_{k2} \Big(\frac{1+\gamma_5}{2} \Big) \tag{139}$$



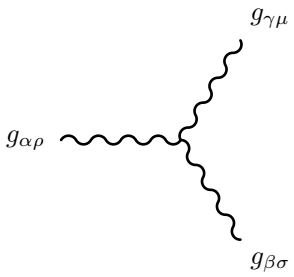
$$- \, i \delta_{\alpha\beta} \sum_{b=1}^{3} U^{u,*}_{L,jb} \sum_{a=1}^{3} U^{d,*}_{R,ia} Y_{d,ab} Z^{+}_{k1} \Big(\frac{1-\gamma_5}{2} \Big) \tag{140}$$

$$+ \; -i \delta_{\alpha\beta} \sum_{b=1}^{3} \sum_{a=1}^{3} Y^{*}_{u,ab} U^{u}_{R,ja} U^{d}_{L,ib} Z^{+}_{k2} \Big(\frac{1+\gamma_5}{2} \Big) \tag{141}$$

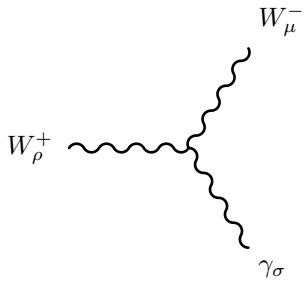


$$-i\sum_{a=1}^{3} U_{R,ia}^{e,*} Y_{e,aj} Z_{k2}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{142}$$

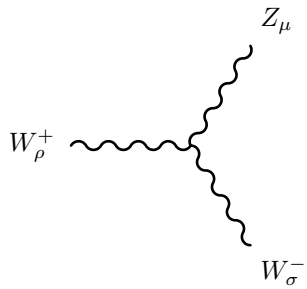
9.6 Three Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma}\Big(g_{\rho\mu}\Big(-p_\sigma^{g_{\gamma\mu}}+p_\sigma^{g_{\alpha\rho}}\Big)+g_{\rho\sigma}\Big(-p_\mu^{g_{\alpha\rho}}+p_\mu^{g_{\beta\sigma}}\Big)+g_{\sigma\mu}\Big(-p_\rho^{g_{\beta\sigma}}+p_\rho^{g_{\gamma\mu}}\Big)\Big) \tag{143}$$

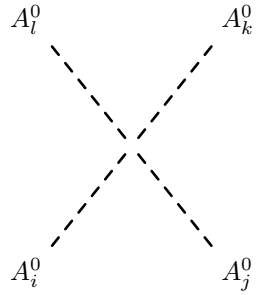


$$ig_2\sin\Theta_W\Big(g_{\rho\mu}\Big(-p_\sigma^{W_\mu^-}+p_\sigma^{W_\rho^+}\Big)+g_{\rho\sigma}\Big(-p_\mu^{W_\rho^+}+p_\mu^{\gamma_\sigma}\Big)+g_{\sigma\mu}\Big(-p_\rho^{\gamma_\sigma}+p_\rho^{W_\mu^-}\Big)\Big) \tag{144}$$

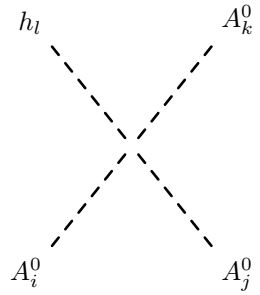


$$- ig_2 \cos\Theta_W \Big(g_{\rho\mu} \Big(- p_\sigma^{Z_\mu} + p_\sigma^{W_\rho^+} \Big) + g_{\rho\sigma} \Big(- p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-} \Big) + g_{\sigma\mu} \Big(- p_\rho^{W_\sigma^-} + p_\rho^{Z_\mu} \Big) \Big) \tag{145}$$

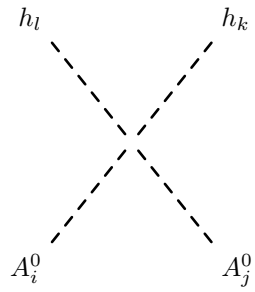
9.7 Four Scalar-Interaction



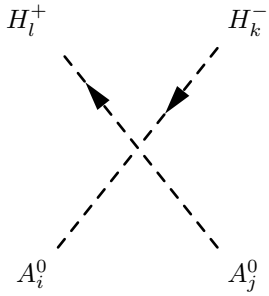
$$\begin{aligned}
&- \frac{i}{2} \Big(Z_{i2}^A \Big(\Big(2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^* \Big) Z_{j1}^A \Big(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \Big) \\
&+ Z_{j2}^A \Big(12\lambda_2 Z_{k2}^A Z_{l2}^A + \Big(2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^* \Big) Z_{k1}^A Z_{l1}^A \Big) \Big) \\
&+ Z_{i1}^A \Big(\Big(2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^* \Big) Z_{j2}^A \Big(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \Big) \\
&+ Z_{j1}^A \Big(12\lambda_1 Z_{k1}^A Z_{l1}^A + \Big(2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^* \Big) Z_{k2}^A Z_{l2}^A \Big) \Big) \Big)
\end{aligned} \tag{146}$$



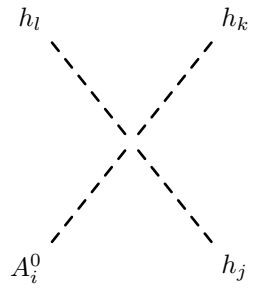
$$- \frac{1}{2}\Big(- \lambda_5^* + \lambda_5\Big)\Big(Z_{i2}^A\Big(Z_{j1}^A\Big(- Z_{k1}^A Z_{l2}^H + Z_{k2}^A Z_{l1}^H\Big) + Z_{j2}^A Z_{k1}^A Z_{l1}^H\Big)$$
$$+ Z_{i1}^A\Big(- Z_{j1}^A Z_{k2}^A Z_{l2}^H + Z_{j2}^A\Big(- Z_{k1}^A Z_{l2}^H + Z_{k2}^A Z_{l1}^H\Big)\Big)\Big) \tag{147}$$



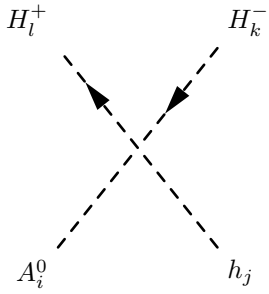
$$- \frac{i}{2}\Big(Z_{i2}^A\Big(\Big(\lambda_5 + \lambda_5^*\Big)Z_{j1}^A\Big(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H\Big) + Z_{j2}^A\Big(\Big(2\lambda_3 + 2\lambda_4 - \lambda_5 - \lambda_5^*\Big)Z_{k1}^H Z_{l1}^H + 4\lambda_2 Z_{k2}^H Z_{l2}^H\Big)\Big)$$
$$+ Z_{i1}^A\Big(\Big(\lambda_5 + \lambda_5^*\Big)Z_{j2}^A\Big(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H\Big) + Z_{j1}^A\Big(\Big(2\lambda_3 + 2\lambda_4 - \lambda_5 - \lambda_5^*\Big)Z_{k2}^H Z_{l2}^H + 4\lambda_1 Z_{k1}^H Z_{l1}^H\Big)\Big)\Big) \tag{148}$$



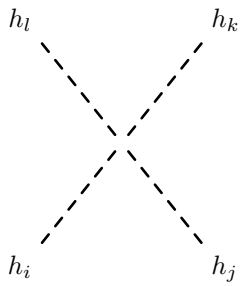
$$- \frac{i}{2}\Big(Z_{i2}^A\Big(2Z_{j2}^A\Big(2\lambda_2 Z_{k2}^+ Z_{l2}^+ + \lambda_3 Z_{k1}^+ Z_{l1}^+\Big) + Z_{j1}^A\Big(\Big(\lambda_4 + \lambda_5^*\Big)Z_{k1}^+ Z_{l2}^+ + \Big(\lambda_4 + \lambda_5\Big)Z_{k2}^+ Z_{l1}^+\Big)\Big)$$
$$+ Z_{i1}^A\Big(2Z_{j1}^A\Big(2\lambda_1 Z_{k1}^+ Z_{l1}^+ + \lambda_3 Z_{k2}^+ Z_{l2}^+\Big) + Z_{j2}^A\Big(\Big(\lambda_4 + \lambda_5^*\Big)Z_{k1}^+ Z_{l2}^+ + \Big(\lambda_4 + \lambda_5\Big)Z_{k2}^+ Z_{l1}^+\Big)\Big)\Big) \tag{149}$$



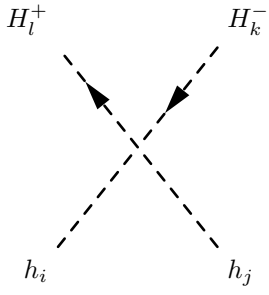
$$
\begin{aligned}
&-\frac{1}{2}\Big(-\lambda_5^*+\lambda_5\Big)\Big(Z_{i2}^A\Big(Z_{j1}^H\Big(Z_{k1}^H Z_{l2}^H+Z_{k2}^H Z_{l1}^H\Big)+Z_{j2}^H Z_{k1}^H Z_{l1}^H\Big)\\
&-Z_{i1}^A\Big(Z_{j1}^H Z_{k2}^H Z_{l2}^H+Z_{j2}^H\Big(Z_{k1}^H Z_{l2}^H+Z_{k2}^H Z_{l1}^H\Big)\Big)\Big)
\end{aligned}
\tag{150}
$$



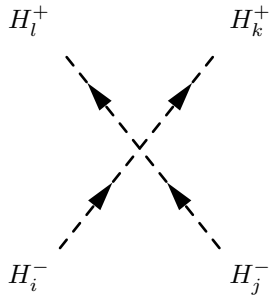
$$
\frac{1}{2}\Big(-Z_{i1}^A Z_{j2}^H+Z_{i2}^A Z_{j1}^H\Big)\Big(\Big(-\lambda_4+\lambda_5^*\Big)Z_{k1}^+ Z_{l2}^+ +\Big(-\lambda_5+\lambda_4\Big)Z_{k2}^+ Z_{l1}^+\Big)
\tag{151}
$$



$$
\begin{aligned}
&-\frac{i}{2}\Big(Z_{i2}^H\Big(\Big(2\lambda_3+2\lambda_4+\lambda_5+\lambda_5^*\Big)Z_{j1}^H\Big(Z_{k1}^H Z_{l2}^H+Z_{k2}^H Z_{l1}^H\Big)\\
&+Z_{j2}^H\Big(12\lambda_2 Z_{k2}^H Z_{l2}^H+\Big(2\lambda_3+2\lambda_4+\lambda_5+\lambda_5^*\Big)Z_{k1}^H Z_{l1}^H\Big)\Big)\\
&+Z_{i1}^H\Big(\Big(2\lambda_3+2\lambda_4+\lambda_5+\lambda_5^*\Big)Z_{j2}^H\Big(Z_{k1}^H Z_{l2}^H+Z_{k2}^H Z_{l1}^H\Big)\\
&+Z_{j1}^H\Big(12\lambda_1 Z_{k1}^H Z_{l1}^H+\Big(2\lambda_3+2\lambda_4+\lambda_5+\lambda_5^*\Big)Z_{k2}^H Z_{l2}^H\Big)\Big)\Big)
\end{aligned}
\tag{152}
$$

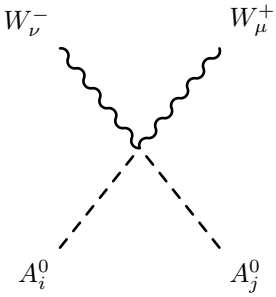


$$
\begin{aligned}
&-\frac{i}{2}\Big(Z_{i2}^{H}\Big(2Z_{j2}^{H}\Big(2\lambda_2 Z_{k2}^{+}Z_{l2}^{+}+\lambda_3 Z_{k1}^{+}Z_{l1}^{+}\Big)+Z_{j1}^{H}\Big(\Big(\lambda_4+\lambda_5^{*}\Big)Z_{k1}^{+}Z_{l2}^{+}+\Big(\lambda_4+\lambda_5\Big)Z_{k2}^{+}Z_{l1}^{+}\Big)\Big)\\
&+Z_{i1}^{H}\Big(2Z_{j1}^{H}\Big(2\lambda_1 Z_{k1}^{+}Z_{l1}^{+}+\lambda_3 Z_{k2}^{+}Z_{l2}^{+}\Big)+Z_{j2}^{H}\Big(\Big(\lambda_4+\lambda_5^{*}\Big)Z_{k1}^{+}Z_{l2}^{+}+\Big(\lambda_4+\lambda_5\Big)Z_{k2}^{+}Z_{l1}^{+}\Big)\Big)\Big)
\end{aligned}
\tag{153}
$$

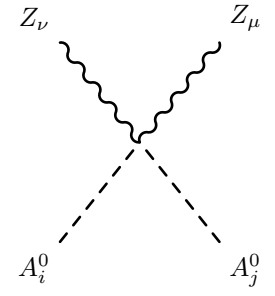


$$
\begin{aligned}
&-i\Big(Z_{i2}^{+}\Big(2Z_{j2}^{+}\Big(2\lambda_2 Z_{k2}^{+}Z_{l2}^{+}+\lambda_5 Z_{k1}^{+}Z_{l1}^{+}\Big)+\Big(\lambda_3+\lambda_4\Big)Z_{j1}^{+}\Big(Z_{k1}^{+}Z_{l2}^{+}+Z_{k2}^{+}Z_{l1}^{+}\Big)\Big)\\
&+Z_{i1}^{+}\Big(2Z_{j1}^{+}\Big(2\lambda_1 Z_{k1}^{+}Z_{l1}^{+}+\lambda_5^{*}Z_{k2}^{+}Z_{l2}^{+}\Big)+\Big(\lambda_3+\lambda_4\Big)Z_{j2}^{+}\Big(Z_{k1}^{+}Z_{l2}^{+}+Z_{k2}^{+}Z_{l1}^{+}\Big)\Big)\Big)
\end{aligned}
\tag{154}
$$

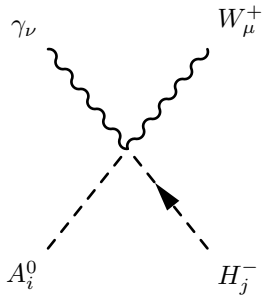
9.8 Two Scalar-Two Vector Boson-Interaction



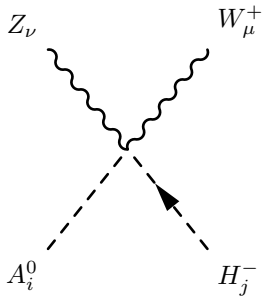
$$
\frac{i}{2}g_2^2\Big(Z_{i1}^{A}Z_{j1}^{A}+Z_{i2}^{A}Z_{j2}^{A}\Big)\Big(g_{\mu\nu}\Big)
\tag{155}
$$



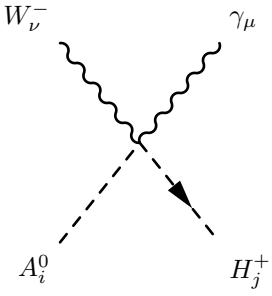
$$\frac{i}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 \Big(Z^A_{i1} Z^A_{j1} + Z^A_{i2} Z^A_{j2}\Big)\Big(g_{\mu\nu}\Big) \tag{156}$$



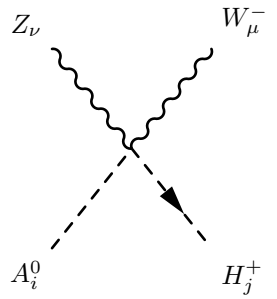
$$-\frac{1}{2} g_1 g_2 \cos\Theta_W \Big(Z^A_{i1} Z^+_{j1} + Z^A_{i2} Z^+_{j2}\Big)\Big(g_{\mu\nu}\Big) \tag{157}$$



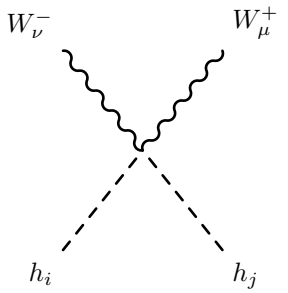
$$\frac{1}{2} g_1 g_2 \sin\Theta_W \Big(Z^A_{i1} Z^+_{j1} + Z^A_{i2} Z^+_{j2}\Big)\Big(g_{\mu\nu}\Big) \tag{158}$$



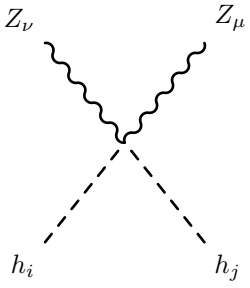
$$\frac{1}{2} g_1 g_2 \cos\Theta_W \Big(Z^A_{i1} Z^+_{j1} + Z^A_{i2} Z^+_{j2}\Big)\Big(g_{\mu\nu}\Big) \tag{159}$$



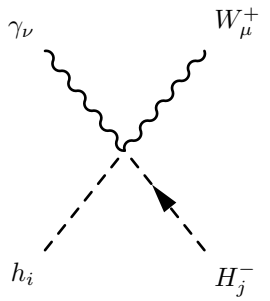
$$-\frac{1}{2}g_1 g_2 \sin\Theta_W \Big(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{160}$$



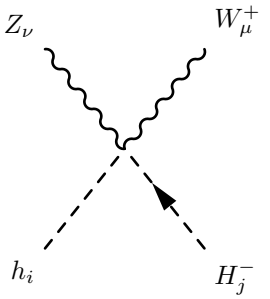
$$\frac{i}{2}g_2^2\Big(Z_{i1}^H Z_{j1}^H + Z_{i2}^H Z_{j2}^H\Big)\Big(g_{\mu\nu}\Big) \tag{161}$$



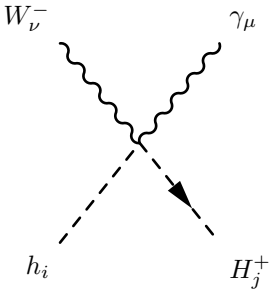
$$\frac{i}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2\Big(Z_{i1}^H Z_{j1}^H + Z_{i2}^H Z_{j2}^H\Big)\Big(g_{\mu\nu}\Big) \tag{162}$$



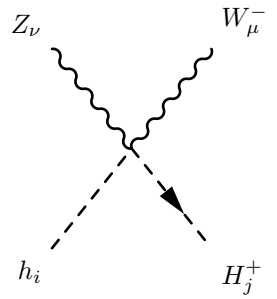
$$\frac{i}{2}g_1 g_2 \cos\Theta_W \Big(Z_{i1}^H Z_{j1}^+ + Z_{i2}^H Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{163}$$



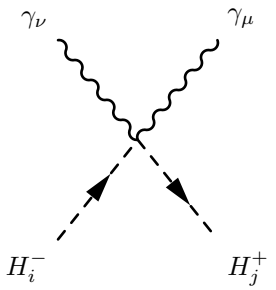
$$-\frac{i}{2}g_1 g_2 \sin\Theta_W \Big(Z_{i1}^H Z_{j1}^+ + Z_{i2}^H Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{164}$$



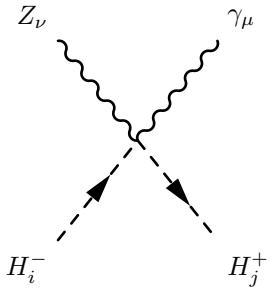
$$\frac{i}{2}g_1 g_2 \cos\Theta_W \Big(Z_{i1}^H Z_{j1}^+ + Z_{i2}^H Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{165}$$



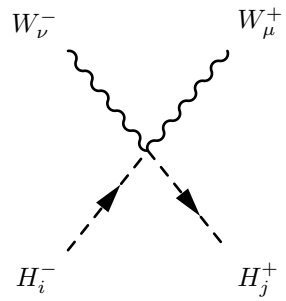
$$-\frac{i}{2}g_1 g_2 \sin\Theta_W \Big(Z_{i1}^H Z_{j1}^+ + Z_{i2}^H Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{166}$$



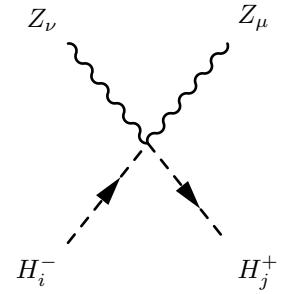
$$\frac{i}{2}\Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W\Big)^2 \Big(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{167}$$



$$-\frac{i}{4}\Big(-2g_1 g_2 \cos 2\Theta_W + \Big(-g_2^2 + g_1^2\Big)\sin 2\Theta_W\Big)\Big(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{168}$$

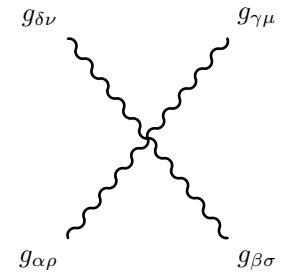


$$\frac{i}{2}g_2^2\Big(Z_{i1}^+Z_{j1}^+ + Z_{i2}^+Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{169}$$



$$\frac{i}{2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(Z_{i1}^+Z_{j1}^+ + Z_{i2}^+Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{170}$$

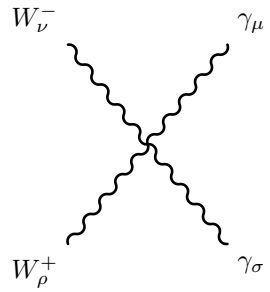
9.9 Four Vector Boson-Interaction



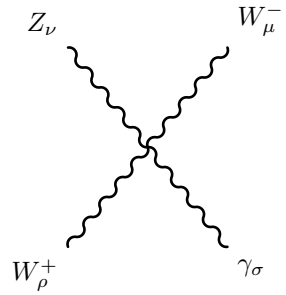
$$-ig_3^2\Big(\sum_{a=1}^{8} f_{\alpha,\delta,a}f_{\beta,\gamma,a} + \sum_{a=1}^{8} f_{\alpha,\gamma,a}f_{\beta,\delta,a}\Big)\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{171}$$

$$+\ ig_3^2\Big(-\sum_{a=1}^{8} f_{\alpha,\beta,a}f_{\gamma,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\delta,a}f_{\beta,\gamma,a}\Big)\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{172}$$

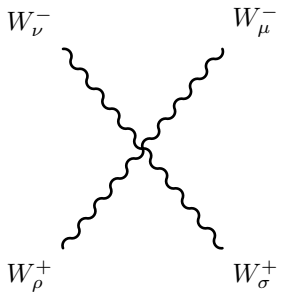
$$+\ ig_3^2\Big(\sum_{a=1}^{8} f_{\alpha,\gamma,a}f_{\beta,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\beta,a}f_{\gamma,\delta,a}\Big)\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{173}$$



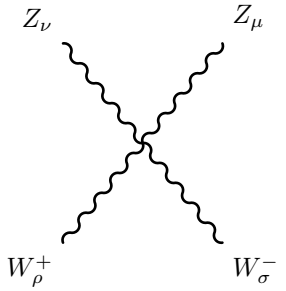
$$ig_2^2 \sin\Theta_W^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{174}$$
$$+\ ig_2^2 \sin\Theta_W^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{175}$$
$$+\ -2ig_2^2 \sin\Theta_W^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{176}$$



$$ig_2^2 \cos\Theta_W \sin\Theta_W\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{177}$$
$$+\ -ig_2^2 \sin 2\Theta_W\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{178}$$
$$+\ ig_2^2 \cos\Theta_W \sin\Theta_W\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{179}$$

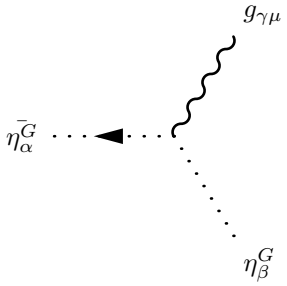


$$2ig_2^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{180}$$
$$+\ -ig_2^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{181}$$
$$+\ -ig_2^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{182}$$

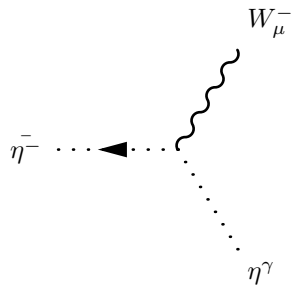


$$-\ 2ig_2^2\cos\Theta_W^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{183}$$
$$+\ ig_2^2\cos\Theta_W^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{184}$$
$$+\ ig_2^2\cos\Theta_W^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{185}$$

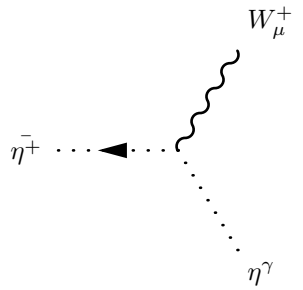
9.10 Two Ghosts-One Vector Boson-Interaction



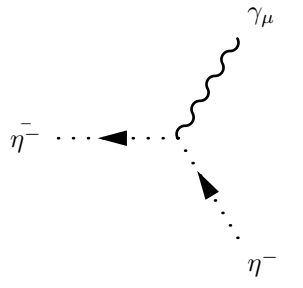
$$g_3 f_{\alpha,\beta,\gamma}\left(p_\mu^{\eta_\beta^G}\right) \tag{186}$$



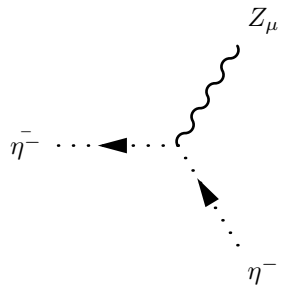
$$ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{187}$$



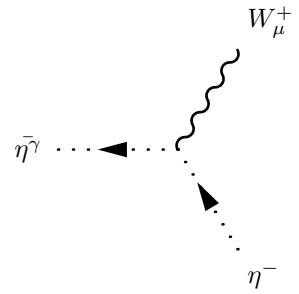
$$-ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{188}$$



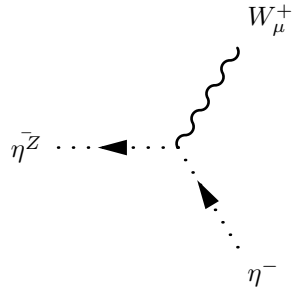
$$-ig_2 \sin\Theta_W\left(p_\mu^{\eta^-}\right) \tag{189}$$



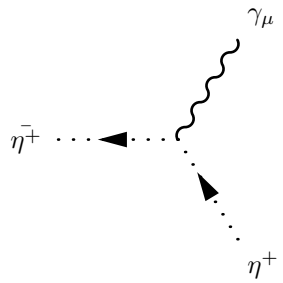
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{190}$$



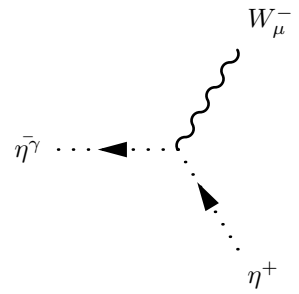
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^-}\right) \tag{191}$$



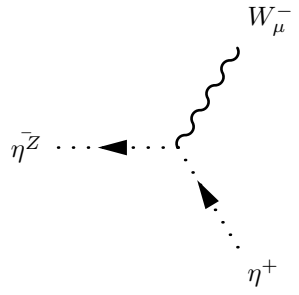
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{192}$$



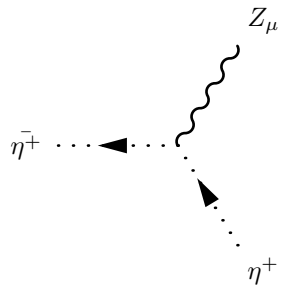
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{193}$$



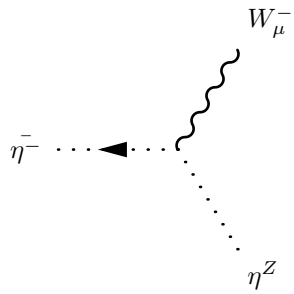
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{194}$$



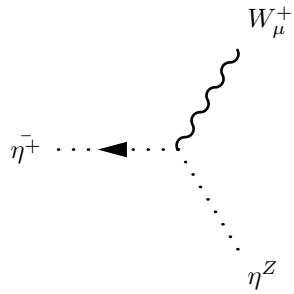
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{195}$$



$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{196}$$

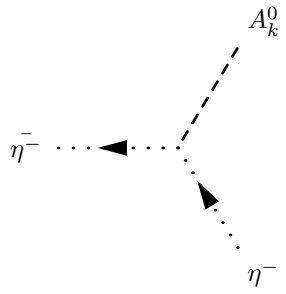


$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{197}$$

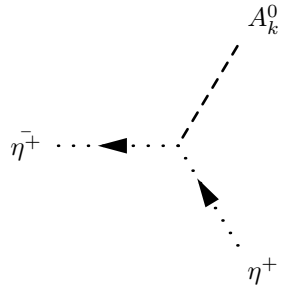


$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{198}$$

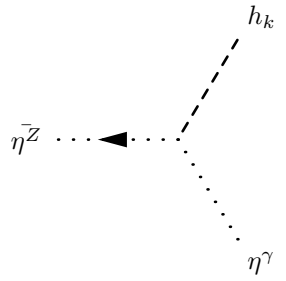
9.11 Two Ghosts-One Scalar-Interaction



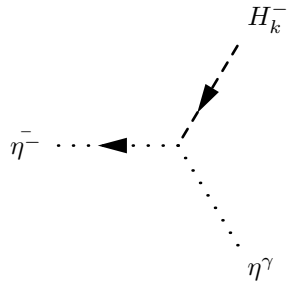
$$-\frac{1}{4}g_2^2\xi_{W^-}\Big(v_1 Z_{k1}^A + v_2 Z_{k2}^A\Big) \tag{199}$$



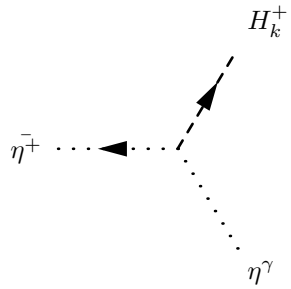
$$\frac{1}{4}g_2^2\xi_{W^-}\Big(v_1 Z_{k1}^A + v_2 Z_{k2}^A\Big) \tag{200}$$



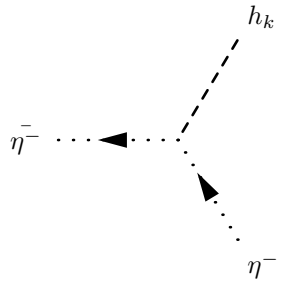
$$\frac{i}{8}\xi_Z\Big(2g_1g_2\cos 2\Theta_W + \Big(-g_2^2+g_1^2\Big)\sin 2\Theta_W\Big)\Big(v_1 Z_{k1}^H + v_2 Z_{k2}^H\Big) \tag{201}$$



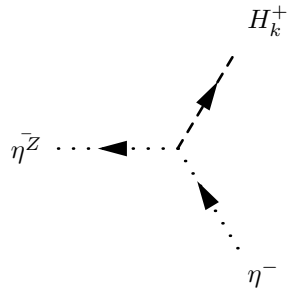
$$-\frac{i}{4}g_2\xi_{W^-}\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)\Big(v_1Z_{k1}^+ + v_2Z_{k2}^+\Big) \tag{202}$$



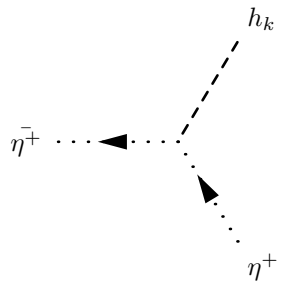
$$-\frac{i}{4}g_2\xi_{W^-}\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)\Big(v_1Z_{k1}^+ + v_2Z_{k2}^+\Big) \tag{203}$$



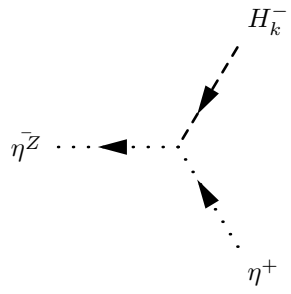
$$-\frac{i}{4}g_2^2\xi_{W^-}\Big(v_1Z_{k1}^H + v_2Z_{k2}^H\Big) \tag{204}$$



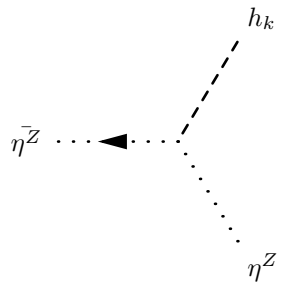
$$\frac{i}{4}g_2\xi_Z\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(v_1Z_{k1}^+ + v_2Z_{k2}^+\Big) \tag{205}$$



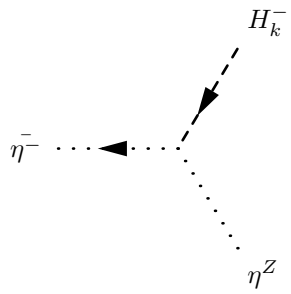
$$-\frac{i}{4}g_2^2\xi_{W^-}\Big(v_1Z_{k1}^H + v_2Z_{k2}^H\Big) \tag{206}$$



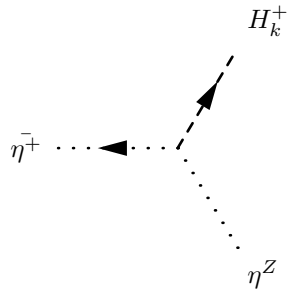
$$\frac{i}{4}g_2\xi_Z\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(v_1Z_{k1}^+ + v_2Z_{k2}^+\Big) \tag{207}$$



$$-\frac{i}{4}\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2\Big(v_1Z^H_{k1}+v_2Z^H_{k2}\Big) \tag{208}$$



$$-\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_1Z^+_{k1}+v_2Z^+_{k2}\Big) \tag{209}$$



$$-\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_1Z^+_{k1}+v_2Z^+_{k2}\Big) \tag{210}$$

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10 Clebsch-Gordan Coefficients