Inert 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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833,2011 (1002.0840) , **Comput.Phys.Commun.181:1077-1086,2010 (0909.2863)** , **arXiv: 0806.0538**
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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	$(U(1) \otimes \mathrm{SU}(2) \otimes \mathrm{SU}(3))$
Hd	0	1	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1})$
Hu	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'

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

2.3 Fields integrated out

None

3 Renormalization Group Equations

3.1 Gauge Couplings

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

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

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

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

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

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

3.2 Quartic scalar couplings

$$\beta^{(1)}_{Lambda5} = 2 Lambda5 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 4 Lambda1 Lambda5 + 4 Lambda2 Lambda5 - 4 Lambda4 Lambda5 + 6 Lambda5 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 6 La \tag{10}$$

$$\begin{aligned}\beta^{(2)}_{Lambda5} = & + \frac{1413}{200} g_1^4 Lambda5 + \frac{57}{20} g_1^2 g_2^2 Lambda5 - \frac{231}{8} g_2^4 Lambda5 - \frac{12}{5} g_1^2 Lambda1 Lambda5 - 28 Lambda1^2 Lambda5 - \frac{12}{5} g_1^2 Lar \\ & - \frac{24}{5} g_1^2 Lambda4 Lambda5 - 36 g_2^2 Lambda4 Lambda5 + 8 Lambda1 Lambda4 Lambda5 + 8 Lambda2 Lambda4 Lambda5 + 20 \\ & + \frac{1}{4}\Big(15 g_1^2 + 15 g_2^2 + 16\Big(- 2 Lambda1 - 2 Lambda3 + Lambda4\Big)\Big) Lambda5 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + \frac{17}{4} g_1^2 Lambda5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{4} g_2^2 L \\ & + 40 g_3^2 Lambda5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 24 Lambda1 Lambda5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 24 Lambda3 Lambda5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 12 Lambda4 Lambda5 \mathrm{Tr} \\ & + 3 Lambda5 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) - \frac{1}{2} Lambda5 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{3}{2} Lambda5 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\end{aligned} \tag{11}$$

$$\begin{aligned}\beta^{(1)}_{Lambda1} = & + \frac{27}{200} g_1^4 + \frac{9}{20} g_1^2 g_2^2 + \frac{9}{8} g_2^4 - \frac{9}{5} g_1^2 Lambda1 - 9 g_2^2 Lambda1 + 24 Lambda1^2 + 2 Lambda3^2 + 2 Lambda3 Lambda4 + Lambda \\ & + 12 Lambda1 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 6 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 2 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - 6 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\end{aligned} \tag{12}$$

$$\begin{aligned}\beta^{(2)}_{Lambda1} = & - \frac{3537}{2000} g_1^6 - \frac{1719}{400} g_1^4 g_2^2 - \frac{303}{80} g_1^2 g_2^4 + \frac{291}{16} g_2^6 + \frac{1953}{200} g_1^4 Lambda1 + \frac{117}{20} g_1^2 g_2^2 Lambda1 - \frac{51}{8} g_2^4 Lambda1 + \frac{108}{5} g_1^2 Lambda1^2 \\ & + \frac{9}{10} g_1^4 Lambda3 + \frac{15}{2} g_2^4 Lambda3 + \frac{12}{5} g_1^2 Lambda3^2 + 12 g_2^2 Lambda3^2 - 20 Lambda1 Lambda3^2 - 8 Lambda3^3 + \frac{9}{20} g_1^4 Lam\end{aligned}$$

$$
\begin{aligned}
&- 20 Lambda1 Lambda3 Lambda4 - 12 Lambda3^2 Lambda4 + \frac{6}{5} g_1^2 Lambda4^2 + 3 g_2^2 Lambda4^2 - 12 Lambda1 Lambda4^2 - 16 \\
&+ \frac{1}{20}\Big(- 5\Big(64 Lambda1\Big(- 5 g_3^2 + 9 Lambda1\Big) - 90 g_2^2 Lambda1 + 9 g_2^4\Big) + 9 g_1^4 + g_1^2\Big(50 Lambda1 + 54 g_2^2\Big)\Big) \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\
&- \frac{3}{20}\Big(15 g_1^4 - 2 g_1^2\Big(11 g_2^2 + 25 Lambda1\Big) + 5\Big(- 10 g_2^2 Lambda1 + 64 Lambda1^2 + g_2^4\Big)\Big) \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - \frac{171}{100} g_1^4 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ \frac{63}{10} g_1^2 g_2^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{9}{4} g_2^4 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{17}{2} g_1^2 Lambda1 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{2} g_2^2 Lambda1 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ 80 g_3^2 Lambda1 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 144 Lambda1^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{4}{5} g_1^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 32 g_3^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) \\
&- 3 Lambda1 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 42 Lambda1 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) - \frac{12}{5} g_1^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - Lambda1 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) \\
&- \frac{8}{5} g_1^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) - 32 g_3^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) - 3 Lambda1 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) + 30 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) \\
&+ 6 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) - 12 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger Y_d Y_d^\dagger\Big) - 6 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) \\
&+ 10 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) + 30 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) \qquad (13)
\end{aligned}
$$

$$
\beta^{(1)}_{Lambda4} = 2 Lambda4 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 4 Lambda1 Lambda4 + 4 Lambda2 Lambda4 + 4 Lambda4^2 + 6 Lambda4 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 6 Lambda4 \mathrm{Tr} \qquad (14)
$$

$$
\begin{aligned}
\beta^{(2)}_{Lambda4} &= + \frac{657}{50} g_1^4 g_2^2 + \frac{42}{5} g_1^2 g_2^4 - 6 g_1^2 g_2^2 Lambda1 - 6 g_1^2 g_2^2 Lambda2 - \frac{6}{5} g_1^2 g_2^2 Lambda3 + \frac{1413}{200} g_1^4 Lambda4 + \frac{129}{20} g_1^2 g_2^2 Lambda4 - \frac{23}{8} \\
&+ \frac{24}{5} g_1^2 Lambda1 Lambda4 - 28 Lambda1^2 Lambda4 + \frac{24}{5} g_1^2 Lambda2 Lambda4 - 28 Lambda2^2 Lambda4 + \frac{12}{5} g_1^2 Lambda3 La \\
&- 40 Lambda2 Lambda4^2 - 28 Lambda3 Lambda4^2 - \frac{48}{5} g_1^2 Lambda5^2 - 54 g_2^2 Lambda5^2 + 48 Lambda1 Lambda5^2 + 48 Lamba \\
&+ \Big(4\Big(10 g_3^2 Lambda4 - 3 Lambda4^2 - 6 Lambda1 Lambda4 - 6 Lambda3 Lambda4 + 6 Lambda5^2\Big) + \frac{45}{4} g_2^2 Lambda4 + g_1^2\Big(- \\
&+ \Big(- 4\Big(2 Lambda1 Lambda4 + 2 Lambda3 Lambda4 - 2 Lambda5^2 + Lambda4^2\Big) + \frac{15}{4} g_2^2 Lambda4 + g_1^2\Big(\frac{15}{4} Lambda4 - \frac{33}{5} \\
&+ \frac{17}{4} g_1^2 Lambda4 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{4} g_2^2 Lambda4 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 40 g_3^2 Lambda4 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 24 Lambda1 Lambda4 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 24 \\
&- 12 Lambda4^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 24 Lambda5^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{27}{2} Lambda4 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) + 27 Lambda4 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) - \frac{9}{2} Lam \\
&- \frac{27}{2} Lambda4 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) \qquad (15)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(1)}_{Lambda3} &= + \frac{27}{100} g_1^4 + \frac{9}{10} g_1^2 g_2^2 + \frac{9}{4} g_2^4 - \frac{9}{5} g_1^2 Lambda3 - 9 g_2^2 Lambda3 + 12 Lambda1 Lambda3 + 12 Lambda2 Lambda3 + 4 Lambda3^2 + \\
&+ 2 Lambda3 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 6 Lambda3 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \qquad (16)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(2)}_{Lambda3} &= - \frac{3537}{1000} g_1^6 - \frac{1719}{200} g_1^4 g_2^2 - \frac{303}{40} g_1^2 g_2^4 + \frac{291}{8} g_2^6 + \frac{27}{10} g_1^4 Lambda1 + 3 g_1^2 g_2^2 Lambda1 + \frac{45}{2} g_2^4 Lambda1 + \frac{27}{10} g_1^4 Lambda2 + 3 g_1^2 g_2^2 \\
&+ \frac{1773}{200} g_1^4 Lambda3 + \frac{57}{20} g_1^2 g_2^2 Lambda3 - \frac{111}{8} g_2^4 Lambda3 + \frac{72}{5} g_1^2 Lambda1 Lambda3 + 72 g_2^2 Lambda1 Lambda3 - 60 Lambd
\end{aligned}
$$

$$
\begin{aligned}
&- 72 Lambda1 Lambda3^2 - 72 Lambda2 Lambda3^2 - 12 Lambda3^3 + \frac{9}{10} g_1^4 Lambda4 - 3 g_1^2 g_2^2 Lambda4 + \frac{15}{2} g_2^4 Lambda4 + \frac{24}{5} \\
&- 12 g_2^2 Lambda3 Lambda4 - 32 Lambda1 Lambda3 Lambda4 - 32 Lambda2 Lambda3 Lambda4 - 4 Lambda3^2 Lambda4 + \frac{12}{5} g \\
&- 84 Lambda2 Lambda5^2 - 66 Lambda3 Lambda5^2 + 4 Lambda4 Lambda5^2 \\
&+ \frac{1}{20}\Big(- 5\Big(- 45 g_2^2 Lambda3 + 8\Big(- 20 g_3^2 Lambda3 + 3\Big(2 Lambda3^2 + 4 Lambda1\Big(3 Lambda3 + Lambda4\Big) + 5 Lambda5^2 - \\
&- \frac{1}{20}\Big(- 3 g_1^2\Big(22 g_2^2 + 25 Lambda3\Big) + 45 g_1^4 + 5\Big(- 15 g_2^2 Lambda3 + 3 g_2^4 + 8\Big(2 Lambda3^2 + 4 Lambda1\Big(3 Lambda3 + Lambd \\
&+ \frac{63}{10} g_1^2 g_2^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{9}{4} g_2^4 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{17}{4} g_1^2 Lambda3 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{4} g_2^2 Lambda3 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ 40 g_3^2 Lambda3 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 72 Lambda1 Lambda3 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 12 Lambda3^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 24 Lambda1 Lambda4 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&- 30 Lambda5^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{27}{2} Lambda3 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 21 Lambda3 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) - 24 Lambda4 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) \\
&- \frac{9}{2} Lambda3 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{27}{2} Lambda3 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) \qquad (17)
\end{aligned}
$$

$$
\beta^{(1)}_{Lambda2} = 24 Lambda2^2 + 2 Lambda3^2 + 2 Lambda3 Lambda4 - 9 g_2^2 Lambda2 + \frac{27}{200} g_1^4 + \frac{9}{20} g_1^2\Big(- 4 Lambda2 + g_2^2\Big) + \frac{9}{8} g_2^4 + Lamb \qquad (18)
$$

$$
\begin{aligned}
\beta^{(2)}_{Lambda2} = &- \frac{3537}{2000} g_1^6 - \frac{1719}{400} g_1^4 g_2^2 - \frac{303}{80} g_1^2 g_2^4 + \frac{291}{16} g_2^6 + \frac{1953}{200} g_1^4 Lambda2 + \frac{117}{20} g_1^2 g_2^2 Lambda2 - \frac{51}{8} g_2^4 Lambda2 + \frac{108}{5} g_1^2 Lambda2^2 \\
&+ \frac{9}{10} g_1^4 Lambda3 + \frac{15}{2} g_2^4 Lambda3 + \frac{12}{5} g_1^2 Lambda3^2 + 12 g_2^2 Lambda3^2 - 20 Lambda2 Lambda3^2 - 8 Lambda3^3 + \frac{9}{20} g_1^4 Lam \\
&- 20 Lambda2 Lambda3 Lambda4 - 12 Lambda3^2 Lambda4 + \frac{6}{5} g_1^2 Lambda4^2 + 3 g_2^2 Lambda4^2 - 12 Lambda2 Lambda4^2 - 16 \\
&- 6\Big(2 Lambda3^2 + 2 Lambda3 Lambda4 + Lambda4^2 + Lambda5^2\Big) \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 2\Big(2 Lambda3^2 + 2 Lambda3 Lambda4 + La \\
&- 6 Lambda4^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 6 Lambda5^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \qquad (19)
\end{aligned}
$$

3.3 Yukawa Couplings

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

$$
\begin{aligned}
\beta^{(2)}_{Y_e} = &+ \frac{3}{80}\Big(40 Y_e Y_e^\dagger Y_e Y_e^\dagger Y_e \\
&+ Y_e Y_e^\dagger Y_e\Big(129 g_1^2 - 180 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 180 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 225 g_2^2 - 320 Lambda1 - 60 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)\Big)\Big) \\
&+ Y_e\Big(\frac{1449}{200} g_1^4 + \frac{27}{20} g_1^2 g_2^2 - \frac{21}{4} g_2^4 + 6 Lambda1^2 + Lambda3^2 + Lambda3 Lambda4 + Lambda4^2 + \frac{3}{2} Lambda5^2 + \frac{5}{8}\Big(32 g_3^2 + 9 g_2^2 + \\
&+ \frac{15}{8}\Big(g_1^2 + g_2^2\Big) \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + \frac{17}{8} g_1^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{8} g_2^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 20 g_3^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&- \frac{27}{4} \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) + \frac{3}{2} \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) - \frac{9}{4} \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{27}{4} \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big) \qquad (21)
\end{aligned}
$$

$$\beta^{(1)}_{Y_d} = \frac{1}{4}\Big(6\Big(- Y_u Y_u^\dagger Y_d + Y_d Y_d^\dagger Y_d\Big)$$
$$- Y_d\Big(- 12\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 12\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 32 g_3^2 - 4\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 9 g_2^2 + g_1^2\Big)\Big) \tag{22}$$

$$\beta^{(2)}_{Y_d} = +\frac{1}{80}\Big(20\Big(11 Y_u Y_u^\dagger Y_u Y_u^\dagger Y_d - 4 Y_u Y_u^\dagger Y_d Y_d^\dagger Y_d + 6 Y_d Y_d^\dagger Y_d Y_d^\dagger Y_d - Y_d Y_d^\dagger Y_u Y_u^\dagger Y_d\Big)$$
$$+ Y_d Y_d^\dagger Y_d\Big(1280 g_3^2 - 180\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 187 g_1^2 - 540\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 540\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 675 g_2^2 - 960 Lambda1\Big)$$
$$+ Y_u Y_u^\dagger Y_d\Big(100\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 1280 g_3^2 + 300\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 300\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 45 g_2^2 - 79 g_1^2\Big)\Big)$$
$$+ Y_d\Big(- \frac{113}{600} g_1^4 - \frac{27}{20} g_1^2 g_2^2 - \frac{21}{4} g_2^4 + \frac{31}{15} g_1^2 g_3^2 + 9 g_2^2 g_3^2 - 108 g_3^4 + 6 Lambda1^2 + Lambda3^2 + Lambda3 Lambda4 + Lambda4^2 + \frac{3}{2}$$
$$+ \frac{5}{8}\Big(32 g_3^2 + 9 g_2^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{15}{8}\Big(g_1^2 + g_2^2\Big)\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + \frac{17}{8} g_1^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{8} g_2^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)$$
$$+ 20 g_3^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{27}{4}\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) + \frac{3}{2}\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) - \frac{9}{4}\mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{27}{4}\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big) \tag{23}$$

$$\beta^{(1)}_{Y_u} = -\frac{3}{2}\Big(- Y_u Y_u^\dagger Y_u + Y_d Y_d^\dagger Y_u\Big)$$
$$+ Y_u\Big(3\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 3\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 8 g_3^2 - \frac{17}{20} g_1^2 - \frac{9}{4} g_2^2 + \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)\Big) \tag{24}$$

$$\beta^{(2)}_{Y_u} = +\frac{1}{80}\Big(20\Big(11 Y_d Y_d^\dagger Y_d Y_d^\dagger Y_u - 4 Y_d Y_d^\dagger Y_u Y_u^\dagger Y_u + 6 Y_u Y_u^\dagger Y_u Y_u^\dagger Y_u - Y_u Y_u^\dagger Y_d Y_d^\dagger Y_u\Big)$$
$$+ Y_u Y_u^\dagger Y_u\Big(1280 g_3^2 - 180\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 223 g_1^2 - 540\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 540\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 675 g_2^2 - 960 Lambda1\Big)$$
$$+ Y_d Y_d^\dagger Y_u\Big(100\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 1280 g_3^2 + 300\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 300\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 43 g_1^2 + 45 g_2^2\Big)\Big)$$
$$+ Y_u\Big(\frac{1267}{600} g_1^4 - \frac{9}{20} g_1^2 g_2^2 - \frac{21}{4} g_2^4 + \frac{19}{15} g_1^2 g_3^2 + 9 g_2^2 g_3^2 - 108 g_3^4 + 6 Lambda1^2 + Lambda3^2 + Lambda3 Lambda4 + Lambda4^2 + \frac{3}{2} L$$
$$+ \frac{5}{8}\Big(32 g_3^2 + 9 g_2^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{15}{8}\Big(g_1^2 + g_2^2\Big)\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + \frac{17}{8} g_1^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + \frac{45}{8} g_2^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)$$
$$+ 20 g_3^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{27}{4}\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) + \frac{3}{2}\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) - \frac{9}{4}\mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - \frac{27}{4}\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big) \tag{25}$$

3.4 Scalar Mass Terms

$$\beta^{(1)}_{m^2_{H_d}} = -\frac{9}{10} g_1^2 m^2_{H_d} - \frac{9}{2} g_2^2 m^2_{H_d} + 12 Lambda1 m^2_{H_d} + 4 Lambda3 m^2_{H_u} + 2 Lambda4 m^2_{H_u} + 6 m^2_{H_d}\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 2 m^2_{H_d}\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)$$
$$+ 6 m^2_{H_d}\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \tag{26}$$

$$\beta^{(2)}_{m^2_{H_d}} = +\frac{1737}{400} g_1^4 m^2_{H_d} + \frac{9}{8} g_1^2 g_2^2 m^2_{H_d} - \frac{123}{16} g_2^4 m^2_{H_d} + \frac{72}{5} g_1^2 Lambda1 m^2_{H_d} + 72 g_2^2 Lambda1 m^2_{H_d} - 60 Lambda1^2 m^2_{H_d} - 2 Lambda3^2 m^2_{H_d}$$
$$- 2 Lambda4^2 m^2_{H_d} - 3 Lambda5^2 m^2_{H_d} + \frac{9}{10} g_1^4 m^2_{H_u} + \frac{15}{2} g_2^4 m^2_{H_u} + \frac{24}{5} g_1^2 Lambda3 m^2_{H_u} + 24 g_2^2 Lambda3 m^2_{H_u} - 8 Lambda3^2 m^2_{H_u}$$
$$+ 12 g_2^2 Lambda4 m^2_{H_u} - 8 Lambda3 Lambda4 m^2_{H_u} - 8 Lambda4^2 m^2_{H_u} - 12 Lambda5^2 m^2_{H_u} + \frac{1}{4}\Big(160 g_3^2 - 288 Lambda1 + 45 g_2^2 + 5$$

$$+\frac{3}{4}\Big(-32Lambda1+5g_1^2+5g_2^2\Big)m_{H_d}^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)+\frac{17}{4}g_1^2m_{H_d}^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+\frac{45}{4}g_2^2m_{H_d}^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)$$
$$+40g_3^2m_{H_d}^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-72Lambda1m_{H_d}^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-\frac{27}{2}m_{H_d}^2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)-21m_{H_d}^2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_uY_u^\dagger\Big)$$
$$-\frac{9}{2}m_{H_d}^2\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)-\frac{27}{2}m_{H_d}^2\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big) \tag{27}$$

$$\beta^{(1)}_{m_{H_u}^2}=2Lambda4m_{H_d}^2+4Lambda3m_{H_d}^2-\frac{3}{10}\Big(15g_2^2+3g_1^2-40Lambda2\Big)m_{H_u}^2 \tag{28}$$

$$\beta^{(2)}_{m_{H_u}^2}=+\frac{9}{10}g_1^4m_{H_d}^2+\frac{15}{2}g_2^4m_{H_d}^2+\frac{24}{5}g_1^2Lambda3m_{H_d}^2+24g_2^2Lambda3m_{H_d}^2-8Lambda3^2m_{H_d}^2+\frac{12}{5}g_1^2Lambda4m_{H_d}^2+12g_2^2Lambd$$
$$-8Lambda4^2m_{H_d}^2-12Lambda5^2m_{H_d}^2+\frac{1737}{400}g_1^4m_{H_u}^2+\frac{9}{8}g_1^2g_2^2m_{H_u}^2-\frac{123}{16}g_2^4m_{H_u}^2+\frac{72}{5}g_1^2Lambda2m_{H_u}^2+72g_2^2Lambda2m_{H_u}^2$$
$$-60Lambda2^2m_{H_u}^2-2Lambda3^2m_{H_u}^2-2Lambda3Lambda4m_{H_u}^2-2Lambda4^2m_{H_u}^2-3Lambda5^2m_{H_u}^2-12\Big(2Lambda3+L$$
$$-24Lambda3m_{H_d}^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-12Lambda4m_{H_d}^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \tag{29}$$

3.5 Vacuum expectation values

$$\beta_v^{(1)}=\frac{1}{20}v\Big(15g_2^2\mathrm{Xi}-20\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)+3g_1^2\mathrm{Xi}+45g_2^2-60\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-60\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+9g_1^2\Big) \tag{30}$$

$$\beta_v^{(2)}=\frac{1}{800}v\Big(-1359g_1^4-270g_1^2g_2^2+6225g_2^4-4800Lambda1^2-800Lambda3^2-800Lambda3Lambda4-800Lambda4^2-1200Lam$$
$$+18g_1^4\mathrm{Xi}^2+180g_1^2g_2^2\mathrm{Xi}^2-450g_2^4\mathrm{Xi}^2-20\Big(45g_2^2\Big(2\mathrm{Xi}+5\Big)+800g_3^2+g_1^2\Big(18\mathrm{Xi}+25\Big)\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)$$
$$-60\Big(5g_2^2\Big(2\mathrm{Xi}+5\Big)+g_1^2\Big(2\mathrm{Xi}+25\Big)\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-1700g_1^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-4500g_2^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)$$
$$-16000g_3^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-360g_1^2\mathrm{XiTr}\Big(Y_uY_u^\dagger\Big)-1800g_2^2\mathrm{XiTr}\Big(Y_uY_u^\dagger\Big)+5400\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)$$
$$-1200\mathrm{Tr}\Big(Y_dY_d^\dagger Y_uY_u^\dagger\Big)+1800\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)+5400\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)\Big) \tag{31}$$

4 Field Rotations

4.1 Rotations in gauge sector for eigenstates 'EWSB'

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \end{pmatrix}=Z^{\gamma Z}\begin{pmatrix} \gamma_\rho \\ Z_\rho \end{pmatrix} \tag{32}$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho} \end{pmatrix}=Z^{W}\begin{pmatrix} W_\rho^+ \\ W_\rho^+ \end{pmatrix} \tag{33}$$

$$\tag{34}$$

The mixing matrices are parametrized by

$$Z^{\gamma Z} = \begin{pmatrix} \cos\Theta_W & -\sin\Theta_W \\ \sin\Theta_W & \cos\Theta_W \end{pmatrix} \tag{35}$$

$$Z^{W} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ i\frac{1}{\sqrt{2}} & -i\frac{1}{\sqrt{2}} \end{pmatrix} \tag{36}$$

$$\tag{37}$$

4.2 Rotations in Mass sector for eigenstates 'EWSB'

4.2.1 Mass Matrices for Scalars

- **Mass matrix for Charged Higgs**, Basis: $\Big(\mathrm{Hup}, \mathrm{conj}\Big(\mathrm{Hdm}\Big)\Big), \Big(\mathrm{conj}\Big(\mathrm{Hup}\Big), \mathrm{Hdm}\Big)$

$$m^2_{H^-} = \begin{pmatrix} \frac{1}{2}\Big(Lambda3 + Lambda4\Big)v^2 + m^2_{H_u} & 0 \\ 0 & Lambda1 v^2 + m^2_{H_d} \end{pmatrix} + \xi_{W^+} m^2(W^+) \tag{38}$$

Gauge fixing contributions:

$$m^2(\xi_{W^+}) = \begin{pmatrix} 0 & 0 \\ 0 & \frac{1}{4}g_2^2 v^2 \end{pmatrix} \tag{39}$$

This matrix is diagonalized by Z^+:

$$Z^+ m^2_{H^-} Z^{+,\dagger} = m^{dia}_{2,H^-} \tag{40}$$

with

$$\mathrm{Hup} = \sum_j Z^+_{j1} H^-_j\,, \qquad \mathrm{Hdm} = \sum_j Z^+_{j2} H^+_j \tag{41}$$

4.2.2 Mass Matrices for Fermions

- **Mass matrix for Down-Quarks**, Basis: $\Big(\mathrm{dL}\Big(\{\mathrm{cm1}\}\Big)\Big), \Big(\mathrm{conj}\Big(\mathrm{dR}\Big(\{\mathrm{cn1}\}\Big)\Big)\Big)$

$$m_d = \begin{pmatrix} \frac{1}{\sqrt{2}} v Y_d \delta_{\alpha_1\beta_1} \end{pmatrix} \tag{42}$$

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

$$U^{d,*}_L m_d U^{d,\dagger}_R = m^{dia}_d \tag{43}$$

with

$$\mathrm{dL}\Big(\{\mathrm{gt1}, \mathrm{ct1}\}\Big) = \sum_{t_2} U^{d,*}_{L,ji} \mathrm{DL}\Big(\{\mathrm{gt2}, \mathrm{ct1}\}\Big) \tag{44}$$

$$\mathrm{dR}\Big(\{\mathrm{gt1}, \mathrm{ct1}\}\Big) = \sum_{t_2} U^{d}_{R,ij} \mathrm{conj}\Big(\mathrm{DR}\Big(\{\mathrm{gt2}, \mathrm{ct1}\}\Big)\Big) \tag{45}$$

- **Mass matrix for Up-Quarks**, Basis: $\Big(\mathrm{uL}\Big(\{\mathrm{cm1}\}\Big)\Big), \Big(\mathrm{conj}\Big(\mathrm{uR}\Big(\{\mathrm{cn1}\}\Big)\Big)\Big)$

$$m_u = \left(\begin{array}{c} \frac{1}{\sqrt{2}} v Y_u \delta_{\alpha_1 \beta_1} \end{array} \right) \tag{46}$$

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

$$U_L^{u,*} m_u U_R^{u,\dagger} = m_u^{dia} \tag{47}$$

with

$$\mathrm{uL}\Big(\{\mathrm{gt1}, \mathrm{ct1}\}\Big) = \sum_{t_2} U_{L,ji}^{u,*} \mathrm{UL}\Big(\{\mathrm{gt2}, \mathrm{ct1}\}\Big) \tag{48}$$

$$\mathrm{uR}\Big(\{\mathrm{gt1}, \mathrm{ct1}\}\Big) = \sum_{t_2} U_{R,ij}^{u} \mathrm{conj}\Big(\mathrm{UR}\Big(\{\mathrm{gt2}, \mathrm{ct1}\}\Big)\Big) \tag{49}$$

- **Mass matrix for Leptons**, Basis: $(\mathrm{eL}), \Big(\mathrm{conj}\Big(\mathrm{eR}\Big)\Big)$

$$m_e = \left(\begin{array}{c} \frac{1}{\sqrt{2}} v Y_e \end{array} \right) \tag{50}$$

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

$$U_L^{e,*} m_e U_R^{e,\dagger} = m_e^{dia} \tag{51}$$

with

$$\mathrm{eL}\Big(\{\mathrm{gt1}\}\Big) = \sum_{t_2} U_{L,ji}^{e,*} \mathrm{EL}\Big(\{\mathrm{gt2}\}\Big) \tag{52}$$

$$\mathrm{eR}\Big(\{\mathrm{gt1}\}\Big) = \sum_{t_2} U_{R,ij}^{e} \mathrm{conj}\Big(\mathrm{ER}\Big(\{\mathrm{gt2}\}\Big)\Big) \tag{53}$$

5 Vacuum Expectation Values

$$\mathrm{Hd0} = \frac{1}{\sqrt{2}} h + \frac{1}{\sqrt{2}} v + i \frac{1}{\sqrt{2}} A^0 \tag{54}$$

$$\mathrm{Hu0} = \frac{1}{\sqrt{2}} H + i \frac{1}{\sqrt{2}} A^0 \tag{55}$$

6 Tadpole Equations

$$\frac{\partial V}{\partial h} = v\Big(Lambda1 v^2 + m_{H_d}^2\Big) \tag{56}$$

$$\frac{\partial V}{\partial H} = 0 \tag{57}$$

7 Particle content for eigenstates 'EWSB'

Name	Type	complex/real	Generations	Indices
A^0	Scalar	real	1	
h	Scalar	real	1	
A^0	Scalar	real	1	
H	Scalar	real	1	
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 Charged Higgs** (H^-)

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

$$
\begin{aligned}
&+\Gamma^{*}_{\check{H}_j^+,W^+,h}\Gamma_{\check{H}_i^+,W^+,h}F_0\Big(p^2,m_h^2,m_{W^+}^2\Big)+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)+\sum_{a=1}^{2}B_0\Big(p^2,m_{H_a^-}^2,m_{A^0}^2\Big)\Gamma^{*}_{\check{H}_j^+,H_a^-,A^0}\Gamma_{\check{H}_i^+,H_a^-,A^0}\\
&+\sum_{a=1}^{2}B_0\Big(p^2,m_{H_a^-}^2,m_H^2\Big)\Gamma^{*}_{\check{H}_j^+,H_a^-,H}\Gamma_{\check{H}_i^+,H_a^-,H}+\sum_{a=1}^{2}B_0\Big(p^2,m_{H_a^-}^2,m_h^2\Big)\Gamma^{*}_{\check{H}_j^+,H_a^-,h}\Gamma_{\check{H}_i^+,H_a^-,h}\\
&-\sum_{a=1}^{2}A_0\Big(m_{H_a^-}^2\Big)\Gamma_{\check{H}_i^-,\check{H}_j^+,H_a^+,H_a^-}\\
&-6\sum_{a=1}^{3}m_{d_a}\sum_{b=1}^{3}B_0\Big(p^2,m_{d_a}^2,m_{u_b}^2\Big)m_{u_b}\Big(\Gamma^{L*}_{\check{H}_j^+,\bar{d}_a,u_b}\Gamma^{R}_{\check{H}_i^+,\bar{d}_a,u_b}+\Gamma^{R*}_{\check{H}_j^+,\bar{d}_a,u_b}\Gamma^{L}_{\check{H}_i^+,\bar{d}_a,u_b}\Big)\\
&+3\sum_{a=1}^{3}\sum_{b=1}^{3}G_0\Big(p^2,m_{d_a}^2,m_{u_b}^2\Big)\Big(\Gamma^{L*}_{\check{H}_j^+,\bar{d}_a,u_b}\Gamma^{L}_{\check{H}_i^+,\bar{d}_a,u_b}+\Gamma^{R*}_{\check{H}_j^+,\bar{d}_a,u_b}\Gamma^{R}_{\check{H}_i^+,\bar{d}_a,u_b}\Big)\\
&-2\sum_{a=1}^{3}m_{e_a}\sum_{b=1}^{3}B_0\Big(p^2,m_{e_a}^2,m_{\nu_b}^2\Big)m_{\nu_b}\Big(\Gamma^{L*}_{\check{H}_j^+,\bar{e}_a,\nu_b}\Gamma^{R}_{\check{H}_i^+,\bar{e}_a,\nu_b}+\Gamma^{R*}_{\check{H}_j^+,\bar{e}_a,\nu_b}\Gamma^{L}_{\check{H}_i^+,\bar{e}_a,\nu_b}\Big)\\
&+\sum_{a=1}^{3}\sum_{b=1}^{3}G_0\Big(p^2,m_{e_a}^2,m_{\nu_b}^2\Big)\Big(\Gamma^{L*}_{\check{H}_j^+,\bar{e}_a,\nu_b}\Gamma^{L}_{\check{H}_i^+,\bar{e}_a,\nu_b}+\Gamma^{R*}_{\check{H}_j^+,\bar{e}_a,\nu_b}\Gamma^{R}_{\check{H}_i^+,\bar{e}_a,\nu_b}\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{58}
$$

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

$$
\begin{aligned}
\Sigma^{S}_{i,j}(p^2)=&+\sum_{a=1}^{2}\sum_{b=1}^{3}B_0\Big(p^2,m_{u_b}^2,m_{H_a^-}^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,H_a^+,u_b}m_{u_b}\Gamma^{R}_{\check{\bar{d}}_i,H_a^+,u_b}\\
&+\sum_{b=1}^{3}B_0\Big(p^2,m_{d_b}^2,m_{A^0}^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,A^0,d_b}m_{d_b}\Gamma^{R}_{\check{\bar{d}}_i,A^0,d_b}+\sum_{b=1}^{3}B_0\Big(p^2,m_{d_b}^2,m_h^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,h,d_b}m_{d_b}\Gamma^{R}_{\check{\bar{d}}_i,h,d_b}\\
&-\frac{16}{3}\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{d_b}^2,0\Big)\Big)\Gamma^{R*}_{\check{\bar{d}}_j,g,d_b}m_{d_b}\Gamma^{L}_{\check{\bar{d}}_i,g,d_b}-4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{d_b}^2,0\Big)\Big)\Gamma^{R*}_{\check{\bar{d}}_j,\gamma,d_b}m_{d_b}\Gamma^{L}_{\check{\bar{d}}_i,\gamma,d_b}\\
&-4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{d_b}^2,m_Z^2\Big)\Big)\Gamma^{R*}_{\check{\bar{d}}_j,Z,d_b}m_{d_b}\Gamma^{L}_{\check{\bar{d}}_i,Z,d_b}\\
&-4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{u_b}^2,m_{W^+}^2\Big)\Big)\Gamma^{R*}_{\check{\bar{d}}_j,W^-,u_b}m_{u_b}\Gamma^{L}_{\check{\bar{d}}_i,W^-,u_b}
\end{aligned}
\tag{59}
$$

$$
\Sigma^{R}_{i,j}(p^2)=-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3}B_1\Big(p^2,m_{u_b}^2,m_{H_a^-}^2\Big)\Gamma^{R*}_{\check{\bar{d}}_j,H_a^+,u_b}\Gamma^{R}_{\check{\bar{d}}_i,H_a^+,u_b}
$$

$$
\begin{aligned}
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{A^0}^2\Big)\Gamma^{R*}_{\check{\bar{d}}_j,A^0,d_b}\Gamma^{R}_{\check{\bar{d}}_i,A^0,d_b} - \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_h^2\Big)\Gamma^{R*}_{\check{\bar{d}}_j,h,d_b}\Gamma^{R}_{\check{\bar{d}}_i,h,d_b}\\
&- \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{L*}_{\check{\bar{d}}_j,g,d_b}\Gamma^{L}_{\check{\bar{d}}_i,g,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{L*}_{\check{\bar{d}}_j,\gamma,d_b}\Gamma^{L}_{\check{\bar{d}}_i,\gamma,d_b}\\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_Z^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,Z,d_b}\Gamma^{L}_{\check{\bar{d}}_i,Z,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{W^+}^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,W^-,u_b}\Gamma^{L}_{\check{\bar{d}}_i,W^-,u_b} \qquad (60)\\
\Sigma^{L}_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{H_a^-}^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,H_a^+,u_b}\Gamma^{L}_{\check{\bar{d}}_i,H_a^+,u_b}\\
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,A^0,d_b}\Gamma^{L}_{\check{\bar{d}}_i,A^0,d_b} - \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_h^2\Big)\Gamma^{L*}_{\check{\bar{d}}_j,h,d_b}\Gamma^{L}_{\check{\bar{d}}_i,h,d_b}\\
&- \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{R*}_{\check{\bar{d}}_j,g,d_b}\Gamma^{R}_{\check{\bar{d}}_i,g,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big)\Gamma^{R*}_{\check{\bar{d}}_j,\gamma,d_b}\Gamma^{R}_{\check{\bar{d}}_i,\gamma,d_b}\\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_Z^2\Big)\Gamma^{R*}_{\check{\bar{d}}_j,Z,d_b}\Gamma^{R}_{\check{\bar{d}}_i,Z,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{W^+}^2\Big)\Gamma^{R*}_{\check{\bar{d}}_j,W^-,u_b}\Gamma^{R}_{\check{\bar{d}}_i,W^-,u_b} \qquad (61)
\end{aligned}
$$

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

$$
\begin{aligned}
\Sigma^{S}_{i,j}(p^2) = &+\sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m_{d_b}^2, m_{H_a^-}^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,H_a^-,d_b} m_{d_b}\Gamma^{R}_{\check{\bar{u}}_i,H_a^-,d_b}\\
&+ \sum_{b=1}^{3} B_0\Big(p^2, m_{u_b}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,A^0,u_b} m_{u_b}\Gamma^{R}_{\check{\bar{u}}_i,A^0,u_b} + \sum_{b=1}^{3} B_0\Big(p^2, m_{u_b}^2, m_h^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,h,u_b} m_{u_b}\Gamma^{R}_{\check{\bar{u}}_i,h,u_b}\\
&- \frac{16}{3}\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{u_b}^2, 0\Big)\Big)\Gamma^{R*}_{\check{\bar{u}}_j,g,u_b} m_{u_b}\Gamma^{L}_{\check{\bar{u}}_i,g,u_b} - 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{u_b}^2, 0\Big)\Big)\Gamma^{R*}_{\check{\bar{u}}_j,\gamma,u_b} m_{u_b}\Gamma^{L}_{\check{\bar{u}}_i,\gamma,u_b}\\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{d_b}^2, m_{W^+}^2\Big)\Big)\Gamma^{R*}_{\check{\bar{u}}_j,W^+,d_b} m_{d_b}\Gamma^{L}_{\check{\bar{u}}_i,W^+,d_b}\\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{u_b}^2, m_Z^2\Big)\Big)\Gamma^{R*}_{\check{\bar{u}}_j,Z,u_b} m_{u_b}\Gamma^{L}_{\check{\bar{u}}_i,Z,u_b} \qquad (62)\\
\Sigma^{R}_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{H_a^-}^2\Big)\Gamma^{R*}_{\check{\bar{u}}_j,H_a^-,d_b}\Gamma^{R}_{\check{\bar{u}}_i,H_a^-,d_b}\\
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{A^0}^2\Big)\Gamma^{R*}_{\check{\bar{u}}_j,A^0,u_b}\Gamma^{R}_{\check{\bar{u}}_i,A^0,u_b} - \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_h^2\Big)\Gamma^{R*}_{\check{\bar{u}}_j,h,u_b}\Gamma^{R}_{\check{\bar{u}}_i,h,u_b}
\end{aligned}
$$

$$
\begin{aligned}
&- \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big)\Gamma^{L*}_{\check{\bar{u}}_j,g,u_b}\Gamma^{L}_{\check{\bar{u}}_i,g,u_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big)\Gamma^{L*}_{\check{\bar{u}}_j,\gamma,u_b}\Gamma^{L}_{\check{\bar{u}}_i,\gamma,u_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{W^+}^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,W^+,d_b}\Gamma^{L}_{\check{\bar{u}}_i,W^+,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_Z^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,Z,u_b}\Gamma^{L}_{\check{\bar{u}}_i,Z,u_b} \qquad (63)
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^{L}_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{H_a^-}^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,H_a^-,d_b}\Gamma^{L}_{\check{\bar{u}}_i,H_a^-,d_b} \\
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,A^0,u_b}\Gamma^{L}_{\check{\bar{u}}_i,A^0,u_b} - \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_h^2\Big)\Gamma^{L*}_{\check{\bar{u}}_j,h,u_b}\Gamma^{L}_{\check{\bar{u}}_i,h,u_b} \\
&- \frac{4}{3}\sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big)\Gamma^{R*}_{\check{\bar{u}}_j,g,u_b}\Gamma^{R}_{\check{\bar{u}}_i,g,u_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big)\Gamma^{R*}_{\check{\bar{u}}_j,\gamma,u_b}\Gamma^{R}_{\check{\bar{u}}_i,\gamma,u_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{W^+}^2\Big)\Gamma^{R*}_{\check{\bar{u}}_j,W^+,d_b}\Gamma^{R}_{\check{\bar{u}}_i,W^+,d_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_Z^2\Big)\Gamma^{R*}_{\check{\bar{u}}_j,Z,u_b}\Gamma^{R}_{\check{\bar{u}}_i,Z,u_b} \qquad (64)
\end{aligned}
$$

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

$$
\begin{aligned}
\Sigma^{S}_{i,j}(p^2) = &+\sum_{a=1}^{2}\sum_{b=1}^{3} B_0\Big(p^2, m_{\nu_b}^2, m_{H_a^-}^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,H_a^+,\nu_b} m_{\nu_b}\Gamma^{R}_{\check{\bar{e}}_i,H_a^+,\nu_b} \\
&+ \sum_{b=1}^{3} B_0\Big(p^2, m_{e_b}^2, m_{A^0}^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,A^0,e_b} m_{e_b}\Gamma^{R}_{\check{\bar{e}}_i,A^0,e_b} + \sum_{b=1}^{3} B_0\Big(p^2, m_{e_b}^2, m_h^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,h,e_b} m_{e_b}\Gamma^{R}_{\check{\bar{e}}_i,h,e_b} \\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{e_b}^2, 0\Big)\Big)\Gamma^{R*}_{\check{\bar{e}}_j,\gamma,e_b} m_{e_b}\Gamma^{L}_{\check{\bar{e}}_i,\gamma,e_b} - 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{e_b}^2, m_Z^2\Big)\Big)\Gamma^{R*}_{\check{\bar{e}}_j,Z,e_b} m_{e_b}\Gamma^{L}_{\check{\bar{e}}_i,Z,e_b} \\
&- 4\sum_{b=1}^{3}\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{\nu_b}^2, m_{W^+}^2\Big)\Big)\Gamma^{R*}_{\check{\bar{e}}_j,W^-,\nu_b} m_{\nu_b}\Gamma^{L}_{\check{\bar{e}}_i,W^-,\nu_b} \qquad (65)
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^{R}_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{H_a^-}^2\Big)\Gamma^{R*}_{\check{\bar{e}}_j,H_a^+,\nu_b}\Gamma^{R}_{\check{\bar{e}}_i,H_a^+,\nu_b} \\
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_{A^0}^2\Big)\Gamma^{R*}_{\check{\bar{e}}_j,A^0,e_b}\Gamma^{R}_{\check{\bar{e}}_i,A^0,e_b} - \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_h^2\Big)\Gamma^{R*}_{\check{\bar{e}}_j,h,e_b}\Gamma^{R}_{\check{\bar{e}}_i,h,e_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, 0\Big)\Gamma^{L*}_{\check{\bar{e}}_j,\gamma,e_b}\Gamma^{L}_{\check{\bar{e}}_i,\gamma,e_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_Z^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,Z,e_b}\Gamma^{L}_{\check{\bar{e}}_i,Z,e_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{W^+}^2\Big)\Gamma^{L*}_{\check{\bar{e}}_j,W^-,\nu_b}\Gamma^{L}_{\check{\bar{e}}_i,W^-,\nu_b} \qquad (66)
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^L_{i,j}(p^2) = &-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{3} B_1\Big(p^2, m^2_{\nu_b}, m^2_{H^-_a}\Big)\Gamma^{L*}_{\tilde{e}_j,H^+_a,\nu_b}\Gamma^{L}_{\tilde{e}_i,H^+_a,\nu_b} \\
&- \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m^2_{e_b}, m^2_{A^0}\Big)\Gamma^{L*}_{\tilde{e}_j,A^0,e_b}\Gamma^{L}_{\tilde{e}_i,A^0,e_b} - \frac{1}{2}\sum_{b=1}^{3} B_1\Big(p^2, m^2_{e_b}, m^2_{h}\Big)\Gamma^{L*}_{\tilde{e}_j,h,e_b}\Gamma^{L}_{\tilde{e}_i,h,e_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m^2_{e_b}, 0\Big)\Gamma^{R*}_{\tilde{e}_j,\gamma,e_b}\Gamma^{R}_{\tilde{e}_i,\gamma,e_b} - \sum_{b=1}^{3} B_1\Big(p^2, m^2_{e_b}, m^2_{Z}\Big)\Gamma^{R*}_{\tilde{e}_j,Z,e_b}\Gamma^{R}_{\tilde{e}_i,Z,e_b} \\
&- \sum_{b=1}^{3} B_1\Big(p^2, m^2_{\nu_b}, m^2_{W^+}\Big)\Gamma^{R*}_{\tilde{e}_j,W^-,\nu_b}\Gamma^{R}_{\tilde{e}_i,W^-,\nu_b}
\end{aligned} \tag{67}
$$

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

$$
\begin{aligned}
\Pi(p^2) = &+\frac{1}{2}|\Gamma_{A^0,A^0,A^0}|^2 B_0\Big(p^2, m^2_{A^0}, m^2_{A^0}\Big) + |\Gamma_{A^0,H,A^0}|^2 B_0\Big(p^2, m^2_{H}, m^2_{A^0}\Big) + \frac{1}{2}|\Gamma_{A^0,H,H}|^2 B_0\Big(p^2, m^2_{H}, m^2_{H}\Big) \\
&+ |\Gamma_{A^0,h,A^0}|^2 B_0\Big(p^2, m^2_{h}, m^2_{A^0}\Big) - B_0\Big(p^2, m^2_{\eta^+}, m^2_{\eta^+}\Big)\Gamma^2_{A^0,\bar{\eta^+},\eta^+} - B_0\Big(p^2, m^2_{\eta^-}, m^2_{\eta^-}\Big)\Gamma^2_{A^0,\bar{\eta^-},\eta^-} \\
&- \frac{1}{2}A_0\Big(m^2_{A^0}\Big)\Gamma_{A^0,A^0,A^0,A^0} - \frac{1}{2}A_0\Big(m^2_{A^0}\Big)\Gamma_{A^0,A^0,A^0,A^0} - \frac{1}{2}A_0\Big(m^2_{H}\Big)\Gamma_{A^0,A^0,H,H} - \frac{1}{2}A_0\Big(m^2_{h}\Big)\Gamma_{A^0,A^0,h,h} \\
&+ |\Gamma_{A^0,Z,h}|^2 F_0\Big(p^2, m^2_{h}, m^2_{Z}\Big) + 4\Gamma_{A^0,A^0,W^-,W^+}\Big(-\frac{1}{2}\mathrm{rMS}m^2_{W^+} + A_0\Big(m^2_{W^+}\Big)\Big) + 2\Gamma_{A^0,A^0,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m^2_{Z} + A_0\Big(m^2_{Z}\Big)\Big) \\
&- \sum_{a=1}^{2} A_0\Big(m^2_{H^-_a}\Big)\Gamma_{A^0,A^0,H^+_a,H^-_a} + 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^L_{A^0,\bar{d}_a,d_b}|^2 + |\Gamma^R_{A^0,\bar{d}_a,d_b}|^2\Big)G_0\Big(p^2, m^2_{d_a}, m^2_{d_b}\Big) \\
&+ \sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^L_{A^0,\bar{e}_a,e_b}|^2 + |\Gamma^R_{A^0,\bar{e}_a,e_b}|^2\Big)G_0\Big(p^2, m^2_{e_a}, m^2_{e_b}\Big) \\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^L_{A^0,\bar{u}_a,u_b}|^2 + |\Gamma^R_{A^0,\bar{u}_a,u_b}|^2\Big)G_0\Big(p^2, m^2_{u_a}, m^2_{u_b}\Big) \\
&- 6\sum_{a=1}^{3} m_{d_a}\sum_{b=1}^{3} B_0\Big(p^2, m^2_{d_a}, m^2_{d_b}\Big)m_{d_b}\Big(\Gamma^{L*}_{A^0,\bar{d}_a,d_b}\Gamma^{R}_{A^0,\bar{d}_a,d_b} + \Gamma^{R*}_{A^0,\bar{d}_a,d_b}\Gamma^{L}_{A^0,\bar{d}_a,d_b}\Big) \\
&- 2\sum_{a=1}^{3} m_{e_a}\sum_{b=1}^{3} B_0\Big(p^2, m^2_{e_a}, m^2_{e_b}\Big)m_{e_b}\Big(\Gamma^{L*}_{A^0,\bar{e}_a,e_b}\Gamma^{R}_{A^0,\bar{e}_a,e_b} + \Gamma^{R*}_{A^0,\bar{e}_a,e_b}\Gamma^{L}_{A^0,\bar{e}_a,e_b}\Big) \\
&- 6\sum_{a=1}^{3} m_{u_a}\sum_{b=1}^{3} B_0\Big(p^2, m^2_{u_a}, m^2_{u_b}\Big)m_{u_b}\Big(\Gamma^{L*}_{A^0,\bar{u}_a,u_b}\Gamma^{R}_{A^0,\bar{u}_a,u_b} + \Gamma^{R*}_{A^0,\bar{u}_a,u_b}\Gamma^{L}_{A^0,\bar{u}_a,u_b}\Big) \\
&+ 2\sum_{b=1}^{2}|\Gamma_{A^0,W^-,H^-_b}|^2 F_0\Big(p^2, m^2_{H^-_b}, m^2_{W^+}\Big)
\end{aligned} \tag{68}
$$

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

$$
\begin{aligned}
\Pi(p^2) = &+\frac{1}{2}|\Gamma_{h,A^0,A^0}|^2 B_0\Big(p^2, m^2_{A^0}, m^2_{A^0}\Big) + \frac{1}{2}|\Gamma_{h,A^0,A^0}|^2 B_0\Big(p^2, m^2_{A^0}, m^2_{A^0}\Big) + |\Gamma_{h,H,A^0}|^2 B_0\Big(p^2, m^2_{H}, m^2_{A^0}\Big) \\
&+ \frac{1}{2}|\Gamma_{h,H,H}|^2 B_0\Big(p^2, m^2_{H}, m^2_{H}\Big) + \frac{1}{2}|\Gamma_{h,h,h}|^2 B_0\Big(p^2, m^2_{h}, m^2_{h}\Big) + 4|\Gamma_{h,W^-,W^+}|^2\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m^2_{W^+}, m^2_{W^+}\Big)\Big) \\
&+ 2|\Gamma_{h,Z,Z}|^2\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m^2_{Z}, m^2_{Z}\Big)\Big) - B_0\Big(p^2, m^2_{\eta^+}, m^2_{\eta^+}\Big)\Gamma^2_{h,\bar{\eta^+},\eta^+} - B_0\Big(p^2, m^2_{\eta^-}, m^2_{\eta^-}\Big)\Gamma^2_{h,\bar{\eta^-},\eta^-} \\
&- B_0\Big(p^2, m^2_{\eta^Z}, m^2_{\eta^Z}\Big)\Gamma^2_{h,\bar{\eta^Z},\eta^Z} - \frac{1}{2}A_0\Big(m^2_{A^0}\Big)\Gamma_{h,h,A^0,A^0} - \frac{1}{2}A_0\Big(m^2_{A^0}\Big)\Gamma_{h,h,A^0,A^0} \\
&- \frac{1}{2}A_0\Big(m^2_{H}\Big)\Gamma_{h,h,H,H} - \frac{1}{2}A_0\Big(m^2_{h}\Big)\Gamma_{h,h,h,h} + |\Gamma_{h,Z,A^0}|^2 F_0\Big(p^2, m^2_{A^0}, m^2_{Z}\Big) \\
&+ 4\Gamma_{h,h,W^-,W^+}\Big(-\frac{1}{2}\mathrm{rMS}m^2_{W^+} + A_0\Big(m^2_{W^+}\Big)\Big) + 2\Gamma_{h,h,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m^2_{Z} + A_0\Big(m^2_{Z}\Big)\Big) \\
&- \sum_{a=1}^{2} A_0\Big(m^2_{H^-_a}\Big)\Gamma_{h,h,H^+_a,H^-_a} + \sum_{a=1}^{2}\sum_{b=1}^{2}|\Gamma_{h,H^+_a,H^-_b}|^2 B_0\Big(p^2, m^2_{H^-_a}, m^2_{H^-_b}\Big) \\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^L_{h,\bar{d}_a,d_b}|^2 + |\Gamma^R_{h,\bar{d}_a,d_b}|^2\Big)G_0\Big(p^2, m^2_{d_a}, m^2_{d_b}\Big) \\
&+ \sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^L_{h,\bar{e}_a,e_b}|^2 + |\Gamma^R_{h,\bar{e}_a,e_b}|^2\Big)G_0\Big(p^2, m^2_{e_a}, m^2_{e_b}\Big) \\
&+ 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big(|\Gamma^L_{h,\bar{u}_a,u_b}|^2 + |\Gamma^R_{h,\bar{u}_a,u_b}|^2\Big)G_0\Big(p^2, m^2_{u_a}, m^2_{u_b}\Big) \\
&- 6\sum_{a=1}^{3} m_{d_a}\sum_{b=1}^{3} B_0\Big(p^2, m^2_{d_a}, m^2_{d_b}\Big)m_{d_b}\Big(\Gamma^{L*}_{h,\bar{d}_a,d_b}\Gamma^R_{h,\bar{d}_a,d_b} + \Gamma^{R*}_{h,\bar{d}_a,d_b}\Gamma^L_{h,\bar{d}_a,d_b}\Big) \\
&- 2\sum_{a=1}^{3} m_{e_a}\sum_{b=1}^{3} B_0\Big(p^2, m^2_{e_a}, m^2_{e_b}\Big)m_{e_b}\Big(\Gamma^{L*}_{h,\bar{e}_a,e_b}\Gamma^R_{h,\bar{e}_a,e_b} + \Gamma^{R*}_{h,\bar{e}_a,e_b}\Gamma^L_{h,\bar{e}_a,e_b}\Big) \\
&- 6\sum_{a=1}^{3} m_{u_a}\sum_{b=1}^{3} B_0\Big(p^2, m^2_{u_a}, m^2_{u_b}\Big)m_{u_b}\Big(\Gamma^{L*}_{h,\bar{u}_a,u_b}\Gamma^R_{h,\bar{u}_a,u_b} + \Gamma^{R*}_{h,\bar{u}_a,u_b}\Gamma^L_{h,\bar{u}_a,u_b}\Big) \\
&+ 2\sum_{b=1}^{2}|\Gamma_{h,W^-,H^-_b}|^2 F_0\Big(p^2, m^2_{H^-_b}, m^2_{W^+}\Big)
\end{aligned}
\tag{69}
$$

- **Self-Energy for A0** (A^0)

$$
\begin{aligned}
\Pi(p^2) = &+|\Gamma_{A^0,A^0,A^0}|^2 B_0\Big(p^2, m^2_{A^0}, m^2_{A^0}\Big) + |\Gamma_{A^0,H,A^0}|^2 B_0\Big(p^2, m^2_{H}, m^2_{A^0}\Big) + |\Gamma_{A^0,h,A^0}|^2 B_0\Big(p^2, m^2_{h}, m^2_{A^0}\Big) \\
&+ |\Gamma_{A^0,h,H}|^2 B_0\Big(p^2, m^2_{h}, m^2_{H}\Big) - \frac{1}{2}A_0\Big(m^2_{A^0}\Big)\Gamma_{A^0,A^0,A^0,A^0} - \frac{1}{2}A_0\Big(m^2_{A^0}\Big)\Gamma_{A^0,A^0,A^0,A^0} - \frac{1}{2}A_0\Big(m^2_{H}\Big)\Gamma_{A^0,A^0,H,H} \\
&- \frac{1}{2}A_0\Big(m^2_{h}\Big)\Gamma_{A^0,A^0,h,h} + |\Gamma_{A^0,Z,H}|^2 F_0\Big(p^2, m^2_{H}, m^2_{Z}\Big) + 4\Gamma_{A^0,A^0,W^-,W^+}\Big(-\frac{1}{2}\mathrm{rMS}m^2_{W^+} + A_0\Big(m^2_{W^+}\Big)\Big)
\end{aligned}
$$

$$+ 2\Gamma_{A^0,A^0,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\Big(m_Z^2\Big)\Big) - \sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big)\Gamma_{A^0,A^0,H_a^+,H_a^-}$$
$$+ \sum_{a=1}^{2}\sum_{b=1}^{2} |\Gamma_{A^0,H_a^+,H_b^-}|^2 B_0\Big(p^2, m_{H_a^-}^2, m_{H_b^-}^2\Big) + 2\sum_{b=1}^{2} |\Gamma_{A^0,W^-,H_b^-}|^2 F_0\Big(p^2, m_{H_b^-}^2, m_{W^+}^2\Big) \tag{70}$$

- **Self-Energy for H0** (H)

$$\Pi(p^2) = +|\Gamma_{H,A^0,A^0}|^2 B_0\Big(p^2, m_{A^0}^2, m_{A^0}^2\Big) + |\Gamma_{H,H,A^0}|^2 B_0\Big(p^2, m_H^2, m_{A^0}^2\Big) + |\Gamma_{H,h,A^0}|^2 B_0\Big(p^2, m_h^2, m_{A^0}^2\Big)$$
$$+ |\Gamma_{H,h,H}|^2 B_0\Big(p^2, m_h^2, m_H^2\Big) - \frac{1}{2}A_0\Big(m_{A^0}^2\Big)\Gamma_{H,H,A^0,A^0} - \frac{1}{2}A_0\Big(m_{A^0}^2\Big)\Gamma_{H,H,A^0,A^0} - \frac{1}{2}A_0\Big(m_H^2\Big)\Gamma_{H,H,H,H}$$
$$- \frac{1}{2}A_0\Big(m_h^2\Big)\Gamma_{H,H,h,h} + |\Gamma_{H,Z,A^0}|^2 F_0\Big(p^2, m_{A^0}^2, m_Z^2\Big) + 4\Gamma_{H,H,W^-,W^+}\Big(-\frac{1}{2}\mathrm{rMS}m_{W^+}^2 + A_0\Big(m_{W^+}^2\Big)\Big)$$
$$+ 2\Gamma_{H,H,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\Big(m_Z^2\Big)\Big) - \sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big)\Gamma_{H,H,H_a^+,H_a^-}$$
$$+ \sum_{a=1}^{2}\sum_{b=1}^{2} |\Gamma_{H,H_a^+,H_b^-}|^2 B_0\Big(p^2, m_{H_a^-}^2, m_{H_b^-}^2\Big) + 2\sum_{b=1}^{2} |\Gamma_{H,W^-,H_b^-}|^2 F_0\Big(p^2, m_{H_b^-}^2, m_{W^+}^2\Big) \tag{71}$$

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

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

$$
\begin{aligned}
&+ 4B_0\Big(p^2, m_{u_a}^2, m_{u_b}^2\Big) m_{u_a} m_{u_b} \Re\Big(\Gamma^{L*}_{Z,\bar{u}_a,u_b} \Gamma^{R}_{Z,\bar{u}_a,u_b}\Big)\Big] \\
&+ \sum_{a=1}^{3}\sum_{b=1}^{3}\Big[\Big(|\Gamma^{L}_{Z,\bar{\nu}_a,\nu_b}|^2 + |\Gamma^{R}_{Z,\bar{\nu}_a,\nu_b}|^2\Big) H_0\Big(p^2, m_{\nu_a}^2, m_{\nu_b}^2\Big) \\
&+ 4B_0\Big(p^2, m_{\nu_a}^2, m_{\nu_b}^2\Big) m_{\nu_a} m_{\nu_b} \Re\Big(\Gamma^{L*}_{Z,\bar{\nu}_a,\nu_b} \Gamma^{R}_{Z,\bar{\nu}_a,\nu_b}\Big)\Big] \\
&+ 2\sum_{b=1}^{2} |\Gamma_{Z,W^-,H_b^-}|^2 B_0\Big(p^2, m_{W^+}^2, m_{H_b^-}^2\Big) + 2\mathrm{rMS} m_{W^+}^2 \Gamma^{1}_{Z,Z,W^-,W^+} - A_0\Big(m_{W^+}^2\Big)\Big(4\Gamma^{1}_{Z,Z,W^-,W^+} + \Gamma^{2}_{Z,Z,W^-,W^+} + \Gamma^{3}_{Z,Z,W}
\end{aligned}
\tag{72}
$$

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

$$
\begin{aligned}
\Pi(p^2) = {} & 2\mathrm{rMS} m_{W^+}^2 \Gamma^{1}_{W^+,W^-,W^-,W^+} + 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big[\Big(|\Gamma^{L}_{W^-,\bar{d}_a,u_b}|^2 + |\Gamma^{R}_{W^-,\bar{d}_a,u_b}|^2\Big) H_0\Big(p^2, m_{d_a}^2, m_{u_b}^2\Big) \\
&+ 4B_0\Big(p^2, m_{d_a}^2, m_{u_b}^2\Big) m_{d_a} m_{u_b} \Re\Big(\Gamma^{L*}_{W^-,\bar{d}_a,u_b} \Gamma^{R}_{W^-,\bar{d}_a,u_b}\Big)\Big] + 2 - 4\sum_{a=1}^{2} |\Gamma_{W^-,H_a^-,A^0}|^2 B_{00}\Big(p^2, m_{A^0}^2, m_{H_a^-}^2\Big) - 4\sum_{a=1}^{2} |\Gamma_{W^-,H_a^-,h} \\
&+ 4B_0\Big(p^2, m_{e_a}^2, m_{\nu_b}^2\Big) m_{e_a} m_{\nu_b} \Re\Big(\Gamma^{L*}_{W^-,\bar{e}_a,\nu_b} \Gamma^{R}_{W^-,\bar{e}_a,\nu_b}\Big)\Big] + \sum_{b=1}^{2} |\Gamma_{W^-,\gamma,H_b^-}|^2 B_0\Big(p^2, 0, m_{H_b^-}^2\Big) + \sum_{b=1}^{2} |\Gamma_{W^-,Z,H_b^-}|^2 B_0\Big(p^2, m_Z^2,
\end{aligned}
\tag{73}
$$

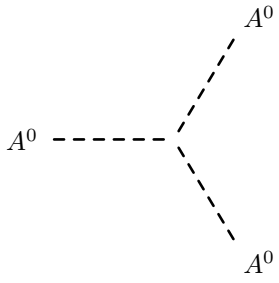
8.2 Tadpoles

$$
\begin{aligned}
\delta t_h^{(1)} = {} & -\frac{1}{2} A_0\Big(m_{A^0}^2\Big)\Gamma_{h,A^0,A^0} - \frac{1}{2} A_0\Big(m_{A^0}^2\Big)\Gamma_{h,A^0,A^0} - \frac{1}{2} A_0\Big(m_H^2\Big)\Gamma_{h,H,H} - \frac{1}{2} A_0\Big(m_h^2\Big)\Gamma_{h,h,h} \\
&+ A_0\Big(m_{\eta^+}^2\Big)\Gamma_{h,\eta^+,\eta^+} + A_0\Big(m_{\eta^-}^2\Big)\Gamma_{h,\eta^-,\eta^-} + A_0\Big(m_{\eta^Z}^2\Big)\Gamma_{h,\eta^Z,\eta^Z} \\
&+ 4\Gamma_{h,W^-,W^+}\Big(-\frac{1}{2}\mathrm{rMS} m_{W^+}^2 + A_0\Big(m_{W^+}^2\Big)\Big) + 2\Gamma_{h,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS} m_Z^2 + A_0\Big(m_Z^2\Big)\Big) - \sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big)\Gamma_{h,H_a^+,H_a^-} \\
&+ 6\sum_{a=1}^{3} A_0\Big(m_{d_a}^2\Big) m_{d_a}\Big(\Gamma^{L}_{h,\bar{d}_a,d_a} + \Gamma^{R}_{h,\bar{d}_a,d_a}\Big) \\
&+ 2\sum_{a=1}^{3} A_0\Big(m_{e_a}^2\Big) m_{e_a}\Big(\Gamma^{L}_{h,\bar{e}_a,e_a} + \Gamma^{R}_{h,\bar{e}_a,e_a}\Big) \\
&+ 6\sum_{a=1}^{3} A_0\Big(m_{u_a}^2\Big) m_{u_a}\Big(\Gamma^{L}_{h,\bar{u}_a,u_a} + \Gamma^{R}_{h,\bar{u}_a,u_a}\Big)
\end{aligned}
\tag{74}
$$

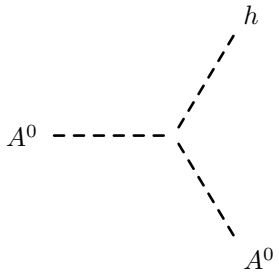
$$
\delta t_H^{(1)} = -\sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big)\Gamma_{H,H_a^+,H_a^-} \tag{75}
$$

9 Interactions for eigenstates 'EWSB'

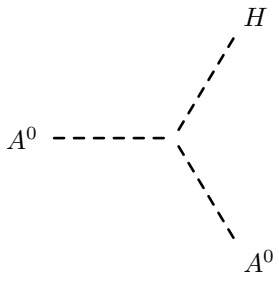
9.1 Three Scalar-Interaction



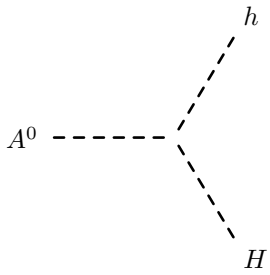
$$\frac{1}{2}v\Big(-Lambda5+Lambda5^*\Big) \tag{76}$$



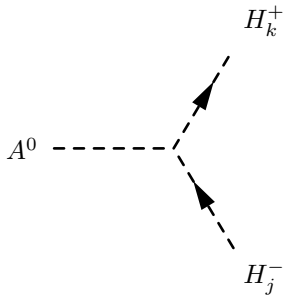
$$-\frac{i}{2}v\Big(2Lambda3-Lambda5-Lambda5^*\Big) \tag{77}$$



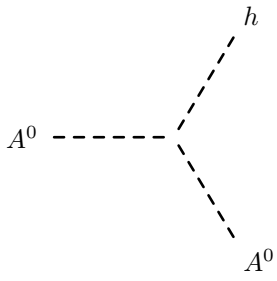
$$\frac{i}{2}v\Big(Lambda5+Lambda5^*\Big) \tag{78}$$



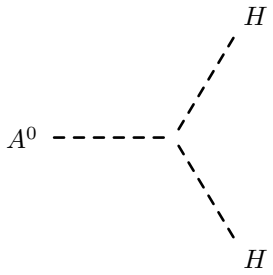
$$\frac{1}{2}v\Big(- Lambda5^* + Lambda5\Big) \tag{79}$$



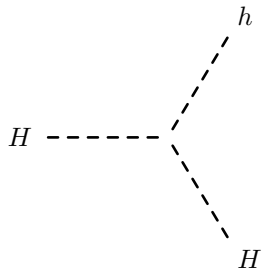
$$\frac{1}{2}v\Big(- \Big(Lambda4 + Lambda5\Big)Z^+_{j1}Z^+_{k2} + \Big(Lambda4 + Lambda5^*\Big)Z^+_{j2}Z^+_{k1}\Big) \tag{80}$$



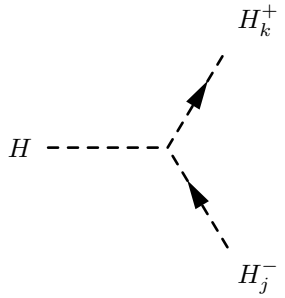
$$- 2iLambda1v \tag{81}$$



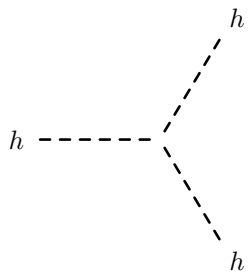
$$\frac{1}{2}v\Big(- Lambda5^* + Lambda5\Big) \tag{82}$$



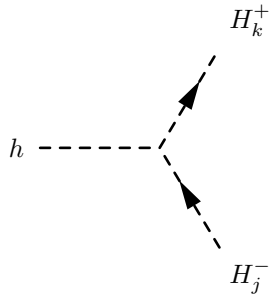
$$-\frac{i}{2}v\Big(2Lambda3 + Lambda5 + Lambda5^*\Big) \tag{83}$$



$$-\frac{i}{2}v\Big(\Big(- Lambda5 + Lambda4\Big)Z_{j1}^+Z_{k2}^+ + \Big(- Lambda5^* + Lambda4\Big)Z_{j2}^+Z_{k1}^+\Big) \tag{84}$$

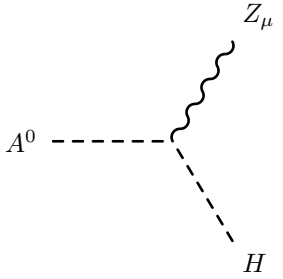


$$-6iLambda1v \tag{85}$$

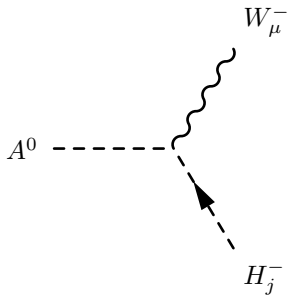


$$-iv\Big(2Lambda1Z_{j2}^{+}Z_{k2}^{+}+\Big(Lambda3+Lambda4\Big)Z_{j1}^{+}Z_{k1}^{+}\Big) \tag{86}$$

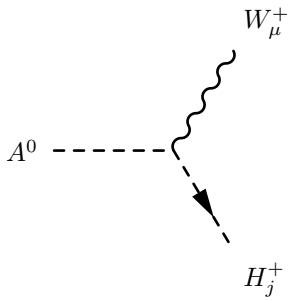
9.2 Two Scalar-One Vector Boson-Interaction



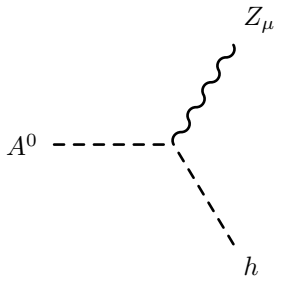
$$\frac{1}{2}\Big(-g_1\sin\Theta_W-g_2\cos\Theta_W\Big)\Big(-p_\mu^H+p_\mu^{A^0}\Big) \tag{87}$$



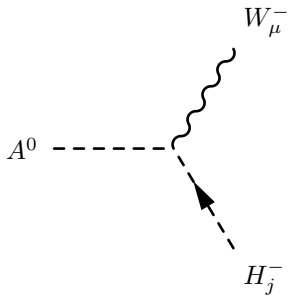
$$\frac{1}{2}g_2 Z_{j1}^{+}\Big(- p_\mu^{H_j^-} + p_\mu^{A^0}\Big) \tag{88}$$



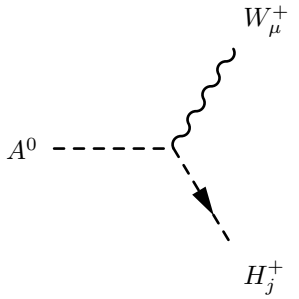
$$\frac{1}{2}g_2 Z_{j1}^{+}\Big(- p_\mu^{H_j^+} + p_\mu^{A^0}\Big) \tag{89}$$



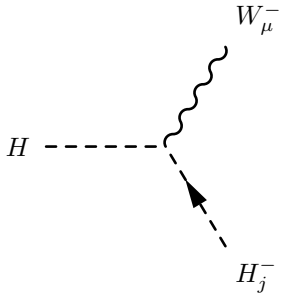
$$\frac{1}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big(- p_\mu^{h} + p_\mu^{A^0}\Big) \tag{90}$$



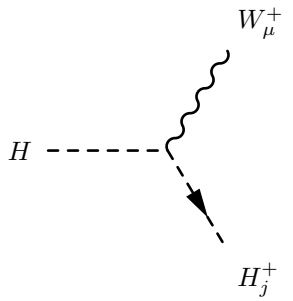
$$\frac{1}{2}g_2 Z_{j2}^{+}\Big(- p_\mu^{H_j^-} + p_\mu^{A^0}\Big) \tag{91}$$



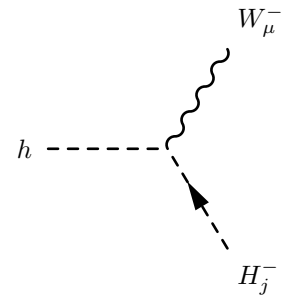
$$\frac{1}{2}g_2 Z_{j2}^{+}\Big(- p_\mu^{H_j^+} + p_\mu^{A^0}\Big) \tag{92}$$



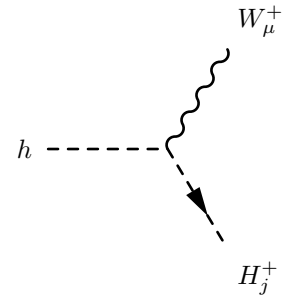
$$\frac{i}{2}g_2 Z_{j1}^{+}\Big(- p_\mu^{H_j^-} + p_\mu^{H}\Big) \tag{93}$$



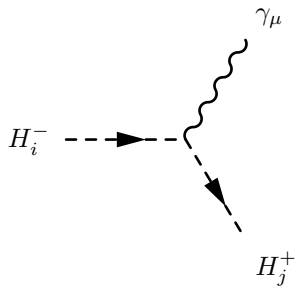
$$-\frac{i}{2}g_2 Z_{j1}^+\Big(-p_\mu^{H_j^+}+p_\mu^H\Big) \tag{94}$$



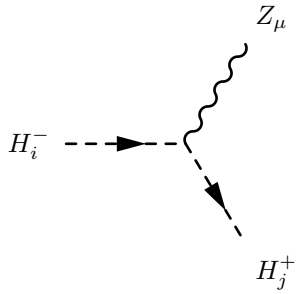
$$-\frac{i}{2}g_2 Z_{j2}^+\Big(-p_\mu^{H_j^-}+p_\mu^h\Big) \tag{95}$$



$$\frac{i}{2}g_2 Z_{j2}^+\Big(-p_\mu^{H_j^+}+p_\mu^h\Big) \tag{96}$$

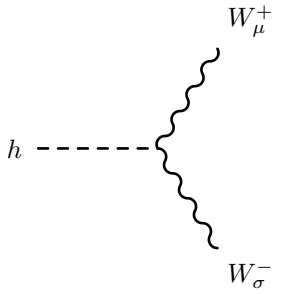


$$-\frac{i}{2}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(Z_{i1}^+Z_{j1}^+ + Z_{i2}^+Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{97}$$

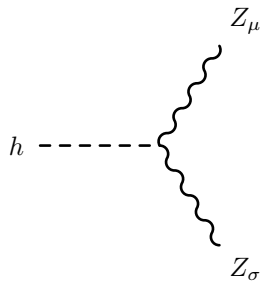


$$-\frac{i}{2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(Z_{i1}^+Z_{j1}^+ + Z_{i2}^+Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{98}$$

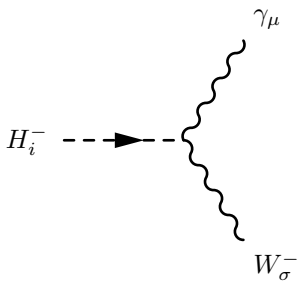
9.3 One Scalar-Two Vector Boson-Interaction



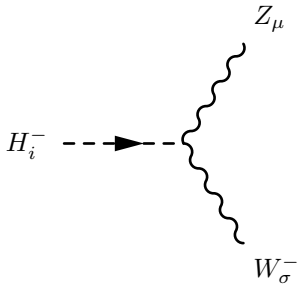
$$\frac{i}{2}g_2^2 v\Big(g_{\sigma\mu}\Big) \tag{99}$$



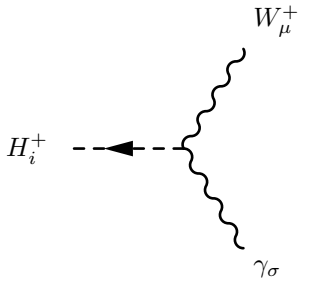
$$\frac{i}{2}v\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(g_{\sigma\mu}\Big) \tag{100}$$



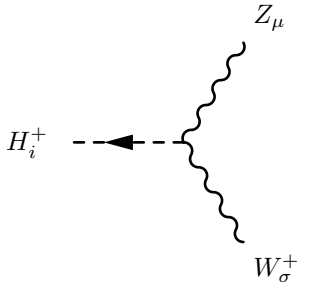
$$-\frac{i}{2}g_1g_2v\cos\Theta_W Z_{i2}^+\Big(g_{\sigma\mu}\Big) \tag{101}$$



$$\frac{i}{2}g_1g_2v\sin\Theta_W Z_{i2}^+\Big(g_{\sigma\mu}\Big) \tag{102}$$

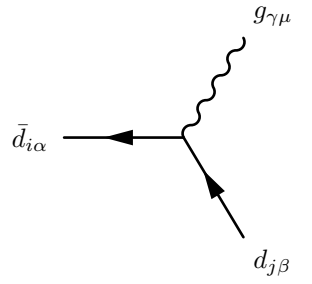


$$-\frac{i}{2}g_1 g_2 v \cos\Theta_W Z_{i2}^+\Big(g_{\sigma\mu}\Big) \tag{103}$$



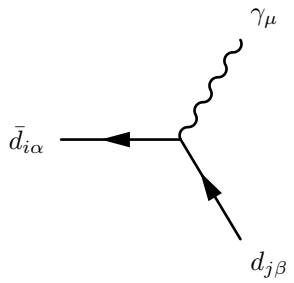
$$\frac{i}{2}g_1 g_2 v \sin\Theta_W Z_{i2}^+\Big(g_{\sigma\mu}\Big) \tag{104}$$

9.4 Two Fermion-One Vector Boson-Interaction



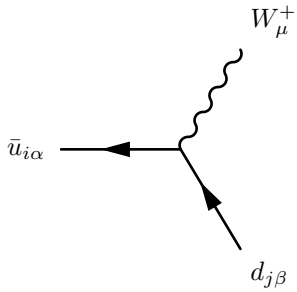
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^{\gamma}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{105}$$

$$+\ -\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^{\gamma}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{106}$$

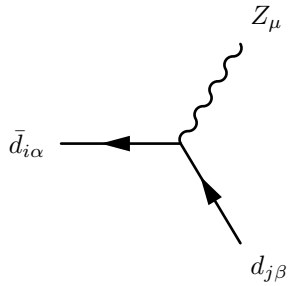


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{107}$$

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

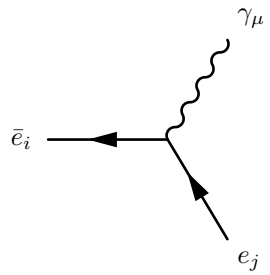


$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}U^{d,*}_{L,ja}U^{u}_{L,ia}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{109}$$



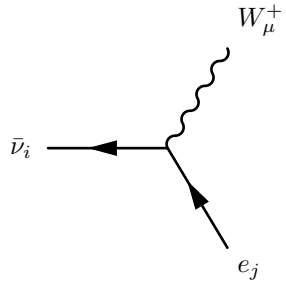
$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2\cos\Theta_W+g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{110}$$

$$+\ -\frac{i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{111}$$

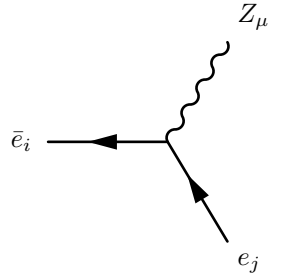


$$\frac{i}{2}\delta_{ij}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{112}$$

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

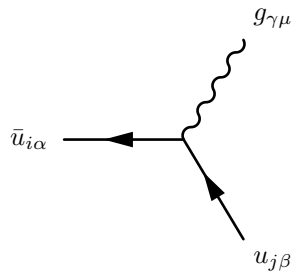


$$-\ i\frac{1}{\sqrt{2}}g_2U^{e,*}_{L,ji}\Theta_{i,3}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{114}$$



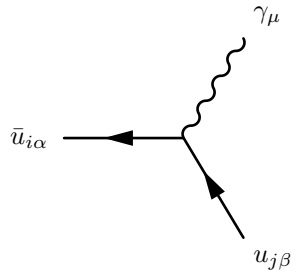
$$\frac{i}{2}\delta_{ij}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{115}$$

$$+\ -ig_1\delta_{ij}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{116}$$



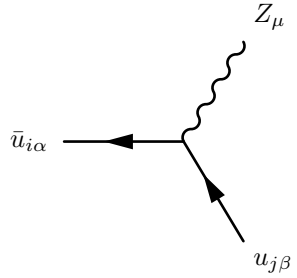
$$- \frac{i}{2} g_3 \delta_{ij} \lambda^{\gamma}_{\alpha,\beta} \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{117}$$

$$+ \; - \frac{i}{2} g_3 \delta_{ij} \lambda^{\gamma}_{\alpha,\beta} \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \Big) \tag{118}$$



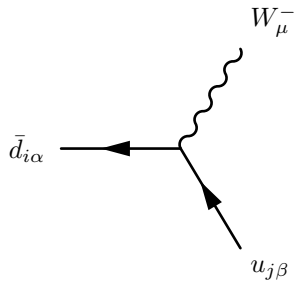
$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \Big(3 g_2 \sin\Theta_W + g_1 \cos\Theta_W \Big) \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{119}$$

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

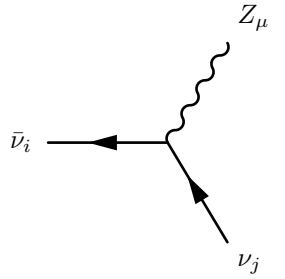


$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \Big(3 g_2 \cos\Theta_W - g_1 \sin\Theta_W \Big) \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{121}$$

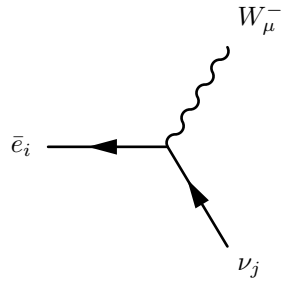
$$+ \; \frac{2i}{3} g_1 \delta_{\alpha\beta} \delta_{ij} \sin\Theta_W \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \Big) \tag{122}$$



$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}U_{L,ja}^{u,*}U_{L,ia}^{d}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{123}$$

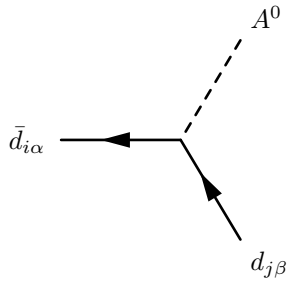


$$-\frac{i}{2}\delta_{ij}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{124}$$



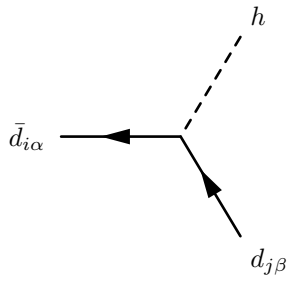
$$-i\frac{1}{\sqrt{2}}g_2\Theta_{j,3}U_{L,ij}^{e}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{125}$$

9.5 Two Fermion-One Scalar Boson-Interaction



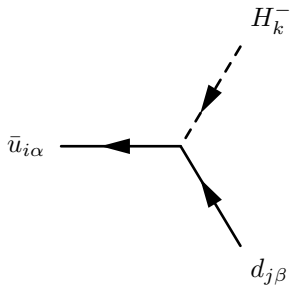
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{R,ib}^{d,*}\sum_{a=1}^{3}U_{L,ja}^{d,*}Y_{d,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{126}$$

$$+\ -\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{L,ia}^{d}U_{R,jb}^{d}\Big(\frac{1+\gamma_5}{2}\Big) \tag{127}$$



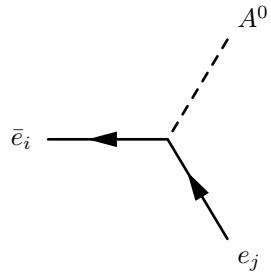
$$-\,i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{R,ib}^{d,*}\sum_{a=1}^{3}U_{L,ja}^{d,*}Y_{d,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{128}$$

$$+\ -i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{L,ia}^{d}U_{R,jb}^{d}\Big(\frac{1+\gamma_5}{2}\Big) \tag{129}$$



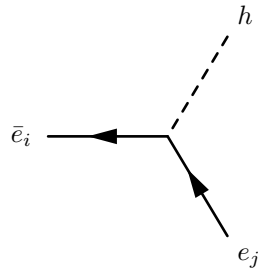
$$- i\delta_{\alpha\beta} \sum_{b=1}^{3} U_{R,ib}^{u,*} \sum_{a=1}^{3} U_{L,ja}^{d,*} Y_{u,ab} Z_{k2}^{+} \Big(\frac{1-\gamma_5}{2} \Big) \tag{130}$$

$$+ \ i\delta_{\alpha\beta} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{d,ab}^{*} U_{L,ia}^{u} U_{R,jb}^{d} Z_{k2}^{+} \Big(\frac{1+\gamma_5}{2} \Big) \tag{131}$$



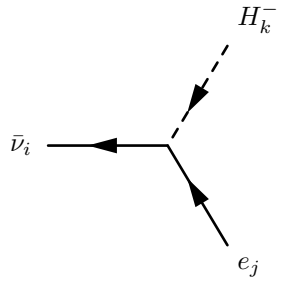
$$\frac{1}{\sqrt{2}} \sum_{b=1}^{3} U_{R,ib}^{e,*} \sum_{a=1}^{3} U_{L,ja}^{e,*} Y_{e,ab} \Big(\frac{1-\gamma_5}{2} \Big) \tag{132}$$

$$+ \ -\frac{1}{\sqrt{2}} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{e,ab}^{*} U_{L,ia}^{e} U_{R,jb}^{e} \Big(\frac{1+\gamma_5}{2} \Big) \tag{133}$$



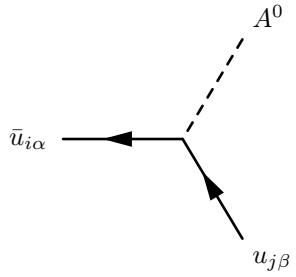
$$- i\frac{1}{\sqrt{2}} \sum_{b=1}^{3} U_{R,ib}^{e,*} \sum_{a=1}^{3} U_{L,ja}^{e,*} Y_{e,ab} \Big(\frac{1-\gamma_5}{2} \Big) \tag{134}$$

$$+ \ -i\frac{1}{\sqrt{2}} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{e,ab}^{*} U_{L,ia}^{e} U_{R,jb}^{e} \Big(\frac{1+\gamma_5}{2} \Big) \tag{135}$$



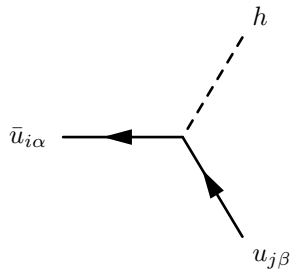
$$+ \; i \sum_{a=1}^{3} Y^*_{e,ia} U^e_{R,ja} Z^+_{k2} \Big(\frac{1+\gamma_5}{2} \Big) \tag{136}$$

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



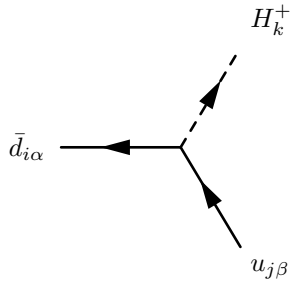
$$- \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} U^{u,*}_{R,ib} \sum_{a=1}^{3} U^{u,*}_{L,ja} Y_{u,ab} \Big(\frac{1-\gamma_5}{2} \Big) \tag{138}$$

$$+ \; \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} \sum_{a=1}^{3} Y^*_{u,ab} U^u_{L,ia} U^u_{R,jb} \Big(\frac{1+\gamma_5}{2} \Big) \tag{139}$$



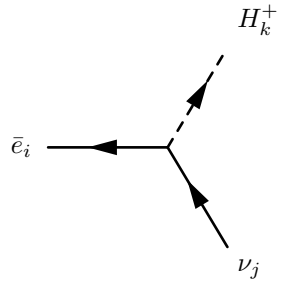
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{R,ib}^{u,*}\sum_{a=1}^{3}U_{L,ja}^{u,*}Y_{u,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{140}$$

$$+\ -i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^{*}U_{L,ia}^{u}U_{R,jb}^{u}\Big(\frac{1+\gamma_5}{2}\Big) \tag{141}$$



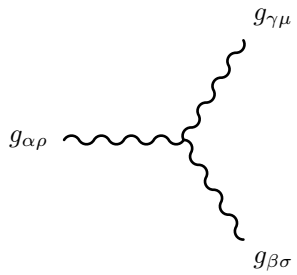
$$i\delta_{\alpha\beta}\sum_{b=1}^{3}U_{R,ib}^{d,*}\sum_{a=1}^{3}U_{L,ja}^{u,*}Y_{d,ab}Z_{k2}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{142}$$

$$+\ -i\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^{*}U_{L,ia}^{d}U_{R,jb}^{u}Z_{k2}^{+}\Big(\frac{1+\gamma_5}{2}\Big) \tag{143}$$

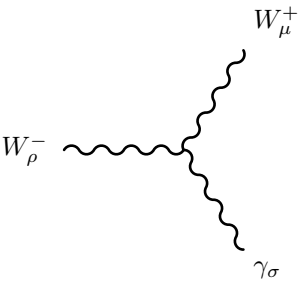


$$i\sum_{a=1}^{3}U_{R,ia}^{e,*}Y_{e,ja}Z_{k2}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{144}$$

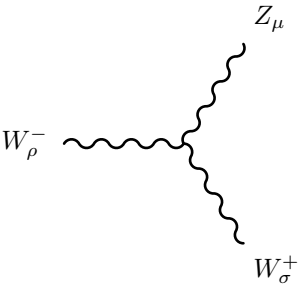
9.6 Three Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma}\Big(g_{\rho\mu}\Big(-p_\sigma^{g_{\gamma\mu}}+p_\sigma^{g_{\alpha\rho}}\Big)+g_{\rho\sigma}\Big(-p_\mu^{g_{\alpha\rho}}+p_\mu^{g_{\beta\sigma}}\Big)+g_{\sigma\mu}\Big(-p_\rho^{g_{\beta\sigma}}+p_\rho^{g_{\gamma\mu}}\Big)\Big) \tag{145}$$

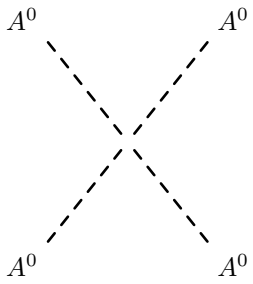


$$-ig_2\sin\Theta_W\Big(g_{\rho\mu}\Big(-p_\sigma^{W_\mu^+}+p_\sigma^{W_\rho^-}\Big)+g_{\rho\sigma}\Big(-p_\mu^{W_\rho^-}+p_\mu^{\gamma_\sigma}\Big)+g_{\sigma\mu}\Big(-p_\rho^{\gamma_\sigma}+p_\rho^{W_\mu^+}\Big)\Big) \tag{146}$$

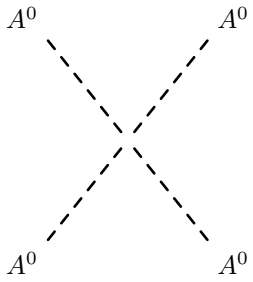


$$ig_2\cos\Theta_W\Big(g_{\rho\mu}\Big(-p_\sigma^{Z_\mu}+p_\sigma^{W_\rho^-}\Big)+g_{\rho\sigma}\Big(-p_\mu^{W_\rho^-}+p_\mu^{W_\sigma^+}\Big)+g_{\sigma\mu}\Big(-p_\rho^{W_\sigma^+}+p_\rho^{Z_\mu}\Big)\Big) \tag{147}$$

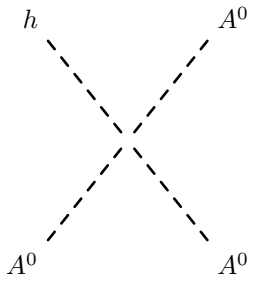
9.7 Four Scalar-Interaction



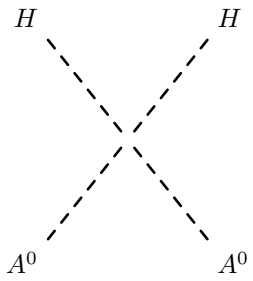
$$-6iLambda2 \tag{148}$$



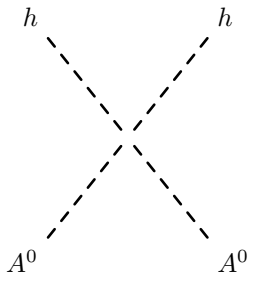
$$-\frac{i}{2}\Big(2Lambda3 + Lambda5 + Lambda5^*\Big) \tag{149}$$



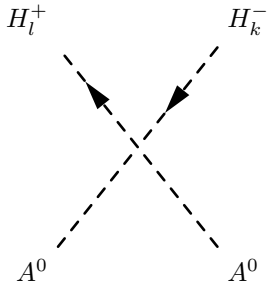
$$\frac{1}{2}\Big(-Lambda5 + Lambda5^*\Big) \tag{150}$$



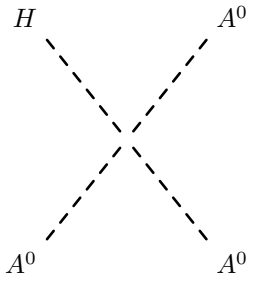
$$-2iLambda2 \tag{151}$$



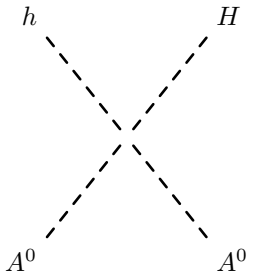
$$-\frac{i}{2}\Big(2Lambda3 - Lambda5 - Lambda5^{*}\Big) \tag{152}$$



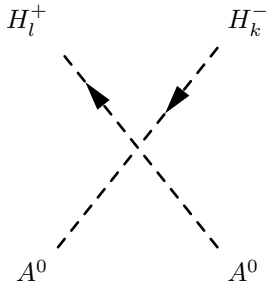
$$-i\Big(2Lambda2Z_{k1}^{+}Z_{l1}^{+} + \Big(Lambda3 + Lambda4\Big)Z_{k2}^{+}Z_{l2}^{+}\Big) \tag{153}$$



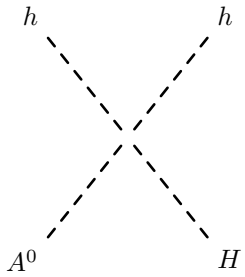
$$\frac{1}{2}\Big(- Lambda5 + Lambda5^{*}\Big) \tag{154}$$



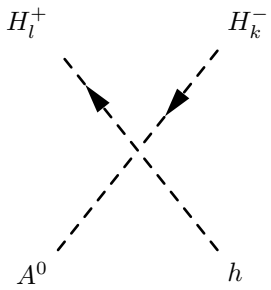
$$\frac{i}{2}\Big(Lambda5 + Lambda5^{*}\Big) \tag{155}$$



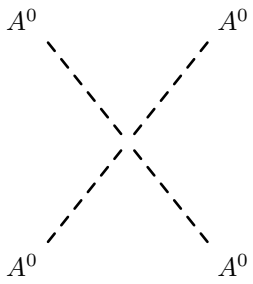
$$\frac{i}{2}\Big(\Big(- Lambda5 + Lambda4\Big) Z_{k1}^{+} Z_{l2}^{+} + \Big(- Lambda5^{*} + Lambda4\Big) Z_{k2}^{+} Z_{l1}^{+}\Big) \tag{156}$$



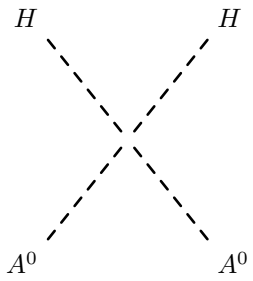
$$\frac{1}{2}\Big(- Lambda5^{*} + Lambda5\Big) \tag{157}$$



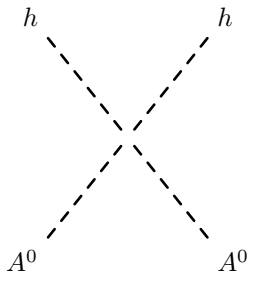
$$\frac{1}{2}\Big(- \Big(Lambda4 + Lambda5\Big) Z_{k1}^{+} Z_{l2}^{+} + \Big(Lambda4 + Lambda5^{*}\Big) Z_{k2}^{+} Z_{l1}^{+}\Big) \tag{158}$$



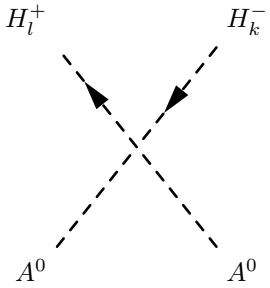
$$- 6 i Lambda1 \tag{159}$$



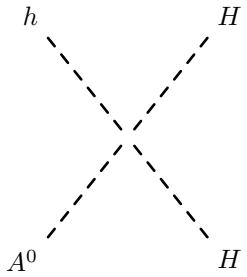
$$-\frac{i}{2}\Big(2Lambda3 - Lambda5 - Lambda5^{*}\Big) \tag{160}$$



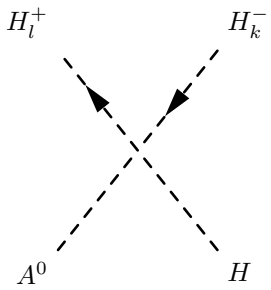
$$-2iLambda1 \tag{161}$$



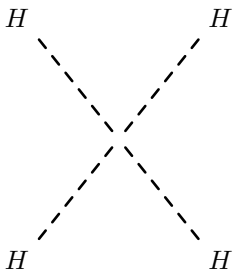
$$-i\Big(2Lambda1Z^{+}_{k2}Z^{+}_{l2} + \Big(Lambda3 + Lambda4\Big)Z^{+}_{k1}Z^{+}_{l1}\Big) \tag{162}$$



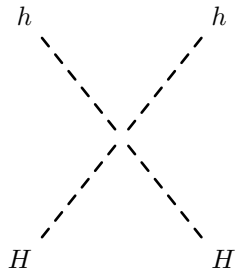
$$\frac{1}{2}\Big(- Lambda5^{*} + Lambda5\Big) \tag{163}$$



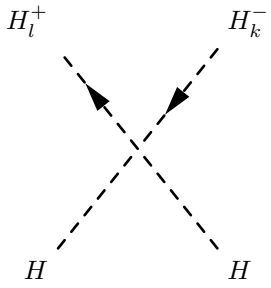
$$\frac{1}{2}\Big(- \Big(Lambda4 + Lambda5\Big) Z_{k1}^{+} Z_{l2}^{+} + \Big(Lambda4 + Lambda5^{*}\Big) Z_{k2}^{+} Z_{l1}^{+}\Big) \tag{164}$$



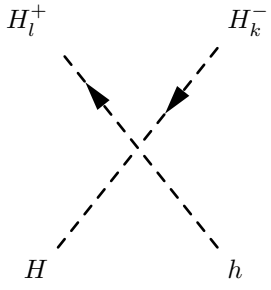
$$- 6 i Lambda2 \tag{165}$$



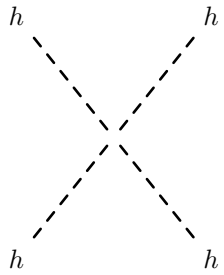
$$-\frac{i}{2}\Big(2Lambda3 + Lambda5 + Lambda5^*\Big) \tag{166}$$



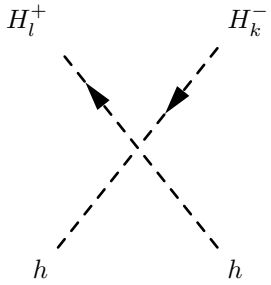
$$-i\Big(2Lambda2Z_{k1}^+Z_{l1}^+ + \Big(Lambda3 + Lambda4\Big)Z_{k2}^+Z_{l2}^+\Big) \tag{167}$$



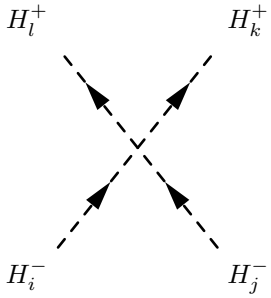
$$-\frac{i}{2}\Big(\Big(-Lambda5 + Lambda4\Big)Z_{k1}^+Z_{l2}^+ + \Big(-Lambda5^* + Lambda4\Big)Z_{k2}^+Z_{l1}^+\Big) \tag{168}$$



$$-6iLambda1 \tag{169}$$

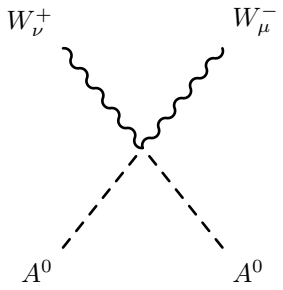


$$-i\Big(2Lambda1Z_{k2}^{+}Z_{l2}^{+}+\Big(Lambda3+Lambda4\Big)Z_{k1}^{+}Z_{l1}^{+}\Big) \tag{170}$$

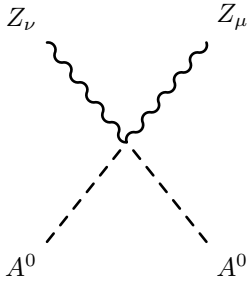


$$\begin{aligned}&-i\Big(Z_{i2}^{+}\Big(2Lambda5^{*}Z_{j2}^{+}Z_{k1}^{+}Z_{l1}^{+}+4Lambda1Z_{j2}^{+}Z_{k2}^{+}Z_{l2}^{+}+Lambda3Z_{j1}^{+}\Big(Z_{k1}^{+}Z_{l2}^{+}+Z_{k2}^{+}Z_{l1}^{+}\Big)\Big)\\&+Z_{i1}^{+}\Big(2Z_{j1}^{+}\Big(2Lambda2Z_{k1}^{+}Z_{l1}^{+}+Lambda5Z_{k2}^{+}Z_{l2}^{+}\Big)+Lambda3Z_{j2}^{+}\Big(Z_{k1}^{+}Z_{l2}^{+}+Z_{k2}^{+}Z_{l1}^{+}\Big)\Big)\Big)\end{aligned} \tag{171}$$

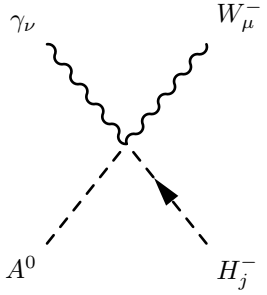
9.8 Two Scalar-Two Vector Boson-Interaction



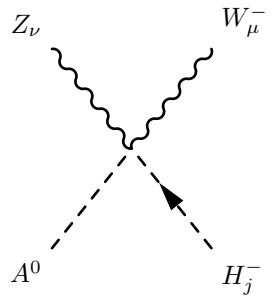
$$\frac{i}{2}g_2^2\Big(g_{\mu\nu}\Big) \tag{172}$$



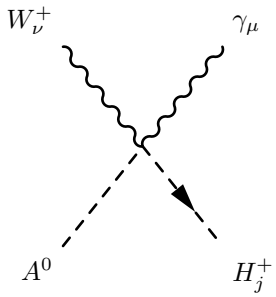
$$\frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(g_{\mu\nu}\Big) \tag{173}$$



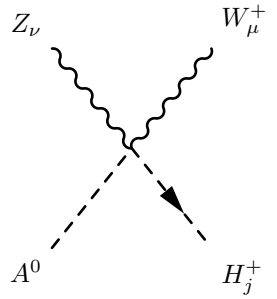
$$\frac{1}{2}g_1 g_2\cos\Theta_W Z_{j1}^+\Big(g_{\mu\nu}\Big) \tag{174}$$



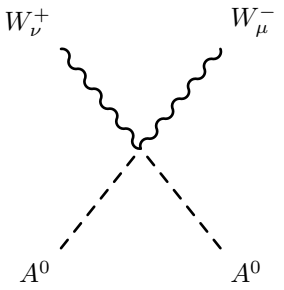
$$-\frac{1}{2}g_1 g_2 \sin\Theta_W Z_{j1}^+ \Big(g_{\mu\nu}\Big) \tag{175}$$



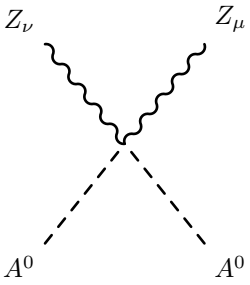
$$-\frac{1}{2}g_1 g_2 \cos\Theta_W Z_{j1}^+ \Big(g_{\mu\nu}\Big) \tag{176}$$



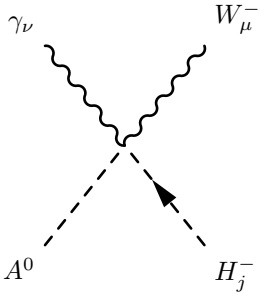
$$\frac{1}{2}g_1 g_2 \sin\Theta_W Z_{j1}^+ \Big(g_{\mu\nu}\Big) \tag{177}$$



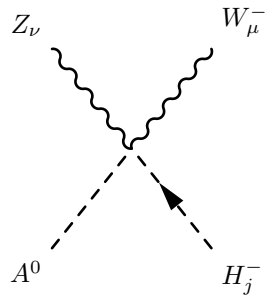
$$\frac{i}{2}g_2^2\Big(g_{\mu\nu}\Big) \tag{178}$$



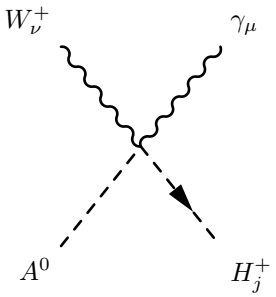
$$\frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(g_{\mu\nu}\Big) \tag{179}$$



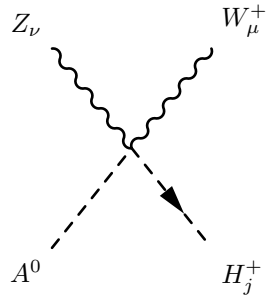
$$\frac{1}{2}g_1 g_2\cos\Theta_W Z_{j2}^+\Big(g_{\mu\nu}\Big) \tag{180}$$



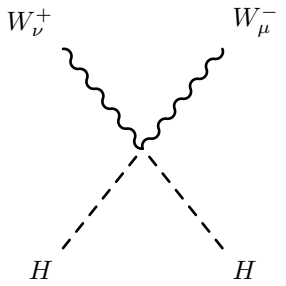
$$-\frac{1}{2}g_1 g_2 \sin\Theta_W Z_{j2}^{+}\Big(g_{\mu\nu}\Big) \tag{181}$$



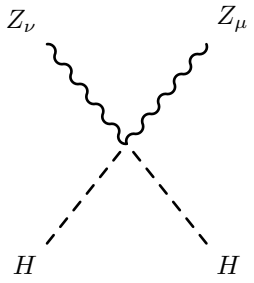
$$-\frac{1}{2}g_1 g_2 \cos\Theta_W Z_{j2}^{+}\Big(g_{\mu\nu}\Big) \tag{182}$$



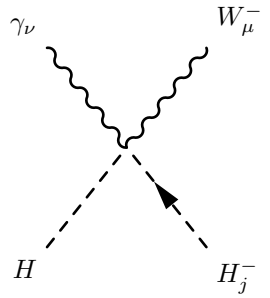
$$\frac{1}{2}g_1 g_2 \sin\Theta_W Z_{j2}^{+}\Big(g_{\mu\nu}\Big) \tag{183}$$



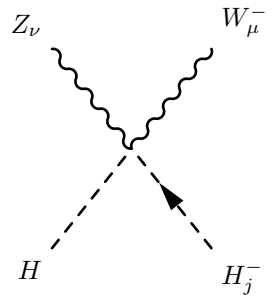
$$\frac{i}{2}g_2^2\Big(g_{\mu\nu}\Big) \tag{184}$$



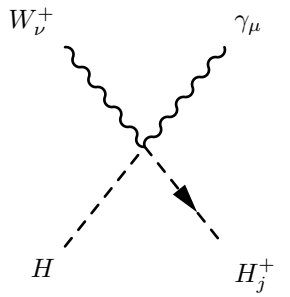
$$\frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(g_{\mu\nu}\Big) \tag{185}$$



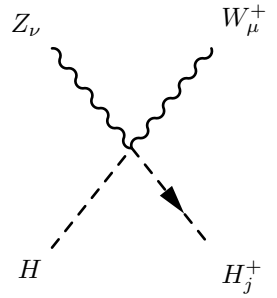
$$\frac{i}{2}g_1g_2\cos\Theta_W Z_{j1}^+\Big(g_{\mu\nu}\Big) \tag{186}$$



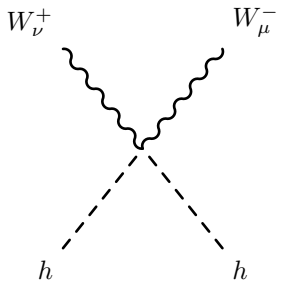
$$-\frac{i}{2}g_1 g_2 \sin\Theta_W Z_{j1}^+ \Big(g_{\mu\nu}\Big) \tag{187}$$



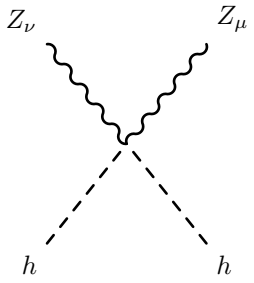
$$\frac{i}{2}g_1 g_2 \cos\Theta_W Z_{j1}^+ \Big(g_{\mu\nu}\Big) \tag{188}$$



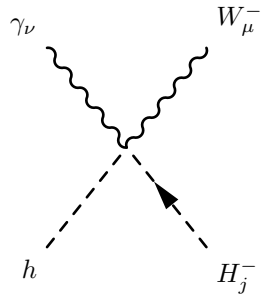
$$-\frac{i}{2}g_1 g_2 \sin\Theta_W Z_{j1}^+ \Big(g_{\mu\nu}\Big) \tag{189}$$



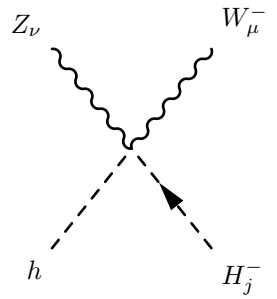
$$\frac{i}{2}g_2^2\Big(g_{\mu\nu}\Big) \tag{190}$$



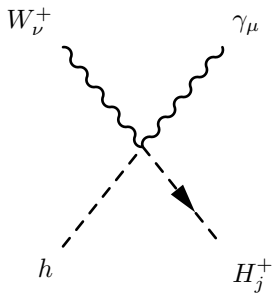
$$\frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(g_{\mu\nu}\Big) \tag{191}$$



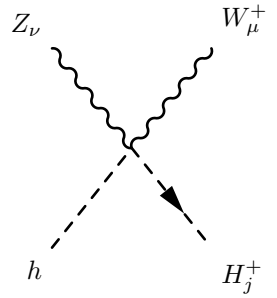
$$-\frac{i}{2}g_1g_2\cos\Theta_W Z_{j2}^+\Big(g_{\mu\nu}\Big) \tag{192}$$



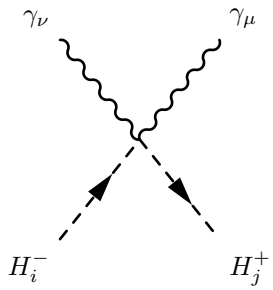
$$\frac{i}{2} g_1 g_2 \sin\Theta_W Z_{j2}^+ \Big(g_{\mu\nu} \Big) \tag{193}$$



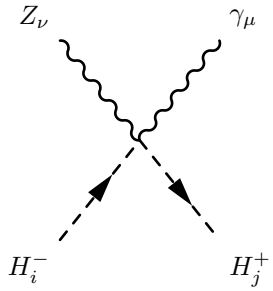
$$-\frac{i}{2} g_1 g_2 \cos\Theta_W Z_{j2}^+ \Big(g_{\mu\nu} \Big) \tag{194}$$



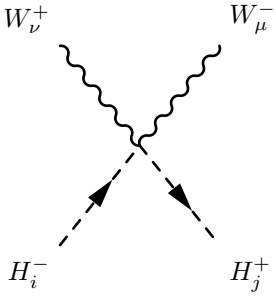
$$\frac{i}{2} g_1 g_2 \sin\Theta_W Z_{j2}^+ \Big(g_{\mu\nu} \Big) \tag{195}$$



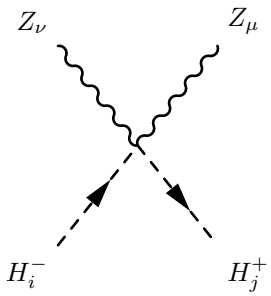
$$\frac{i}{2}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)^2\Big(Z_{i1}^+Z_{j1}^+ + Z_{i2}^+Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{196}$$



$$-\frac{i}{4}\Big(-2g_1g_2\cos 2\Theta_W + \Big(-g_2^2+g_1^2\Big)\sin 2\Theta_W\Big)\Big(Z_{i1}^+Z_{j1}^+ + Z_{i2}^+Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{197}$$

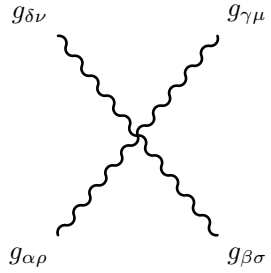


$$\frac{i}{2}g_2^2\Big(Z_{i1}^+Z_{j1}^+ + Z_{i2}^+Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{198}$$



$$\frac{i}{2}\Big(- g_1 \sin\Theta_W + g_2 \cos\Theta_W \Big)^2 \Big(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{199}$$

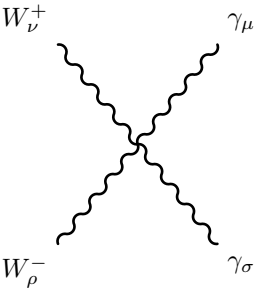
9.9 Four Vector Boson-Interaction



$$- ig_3^2 \Big(\sum_{a=1}^{8} f_{\alpha,\delta,a} f_{\beta,\gamma,a} + \sum_{a=1}^{8} f_{\alpha,\gamma,a} f_{\beta,\delta,a} \Big) \Big(g_{\rho\sigma} g_{\mu\nu} \Big) \tag{200}$$

$$+ ig_3^2 \Big(- \sum_{a=1}^{8} f_{\alpha,\beta,a} f_{\gamma,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\delta,a} f_{\beta,\gamma,a} \Big) \Big(g_{\rho\mu} g_{\sigma\nu} \Big) \tag{201}$$

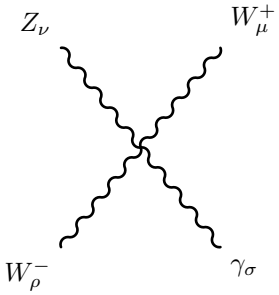
$$+ ig_3^2 \Big(\sum_{a=1}^{8} f_{\alpha,\gamma,a} f_{\beta,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\beta,a} f_{\gamma,\delta,a} \Big) \Big(g_{\rho\nu} g_{\sigma\mu} \Big) \tag{202}$$



$$ig_2^2 \sin\Theta_W^2 \Big(g_{\rho\sigma} g_{\mu\nu}\Big) \tag{203}$$

$$+\ ig_2^2 \sin\Theta_W^2 \Big(g_{\rho\mu} g_{\sigma\nu}\Big) \tag{204}$$

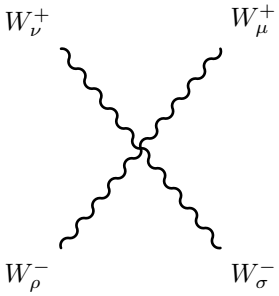
$$+\ -2ig_2^2 \sin\Theta_W^2 \Big(g_{\rho\nu} g_{\sigma\mu}\Big) \tag{205}$$



$$ig_2^2 \cos\Theta_W \sin\Theta_W \Big(g_{\rho\sigma} g_{\mu\nu}\Big) \tag{206}$$

$$+\ -ig_2^2 \sin 2\Theta_W \Big(g_{\rho\mu} g_{\sigma\nu}\Big) \tag{207}$$

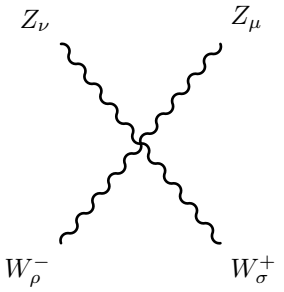
$$+\ ig_2^2 \cos\Theta_W \sin\Theta_W \Big(g_{\rho\nu} g_{\sigma\mu}\Big) \tag{208}$$



$$2ig_2^2 \Big(g_{\rho\sigma} g_{\mu\nu}\Big) \tag{209}$$

$$+\ -ig_2^2 \Big(g_{\rho\mu} g_{\sigma\nu}\Big) \tag{210}$$

$$+\ -ig_2^2 \Big(g_{\rho\nu} g_{\sigma\mu}\Big) \tag{211}$$

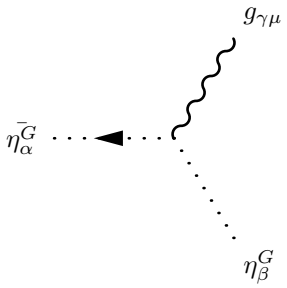


$$- 2ig_2^2 \cos\Theta_W^2 \left(g_{\rho\sigma} g_{\mu\nu}\right) \tag{212}$$

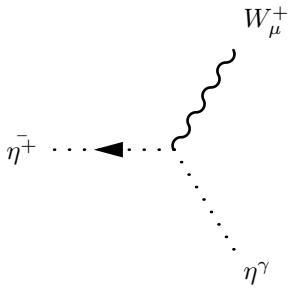
$$+ \ ig_2^2 \cos\Theta_W^2 \left(g_{\rho\mu} g_{\sigma\nu}\right) \tag{213}$$

$$+ \ ig_2^2 \cos\Theta_W^2 \left(g_{\rho\nu} g_{\sigma\mu}\right) \tag{214}$$

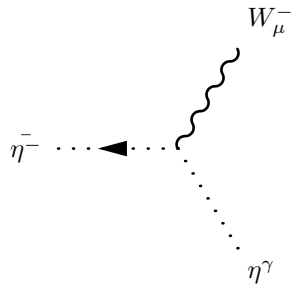
9.10 Two Ghosts-One Vector Boson-Interaction



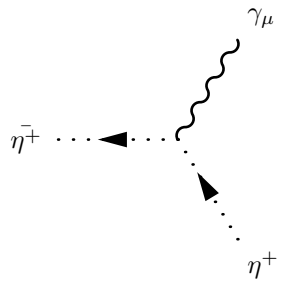
$$g_3 f_{\alpha,\beta,\gamma} \left(p_\mu^{\eta^G_\beta}\right) \tag{215}$$



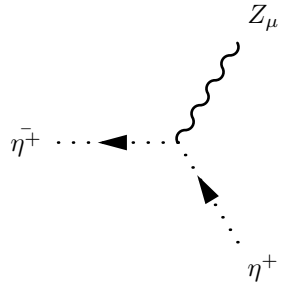
$$- ig_2 \sin\Theta_W \left(p_\mu^{\eta^\gamma}\right) \tag{216}$$



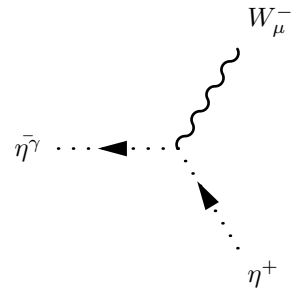
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^\gamma}\right) \tag{217}$$



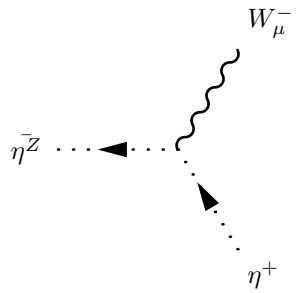
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{218}$$



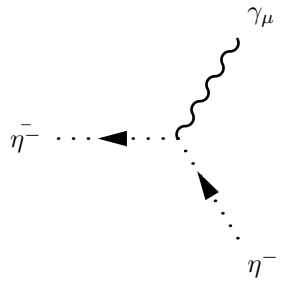
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{219}$$



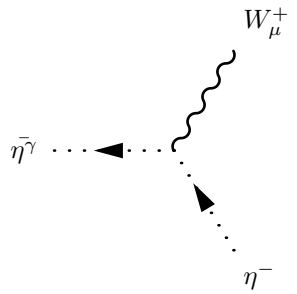
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{220}$$



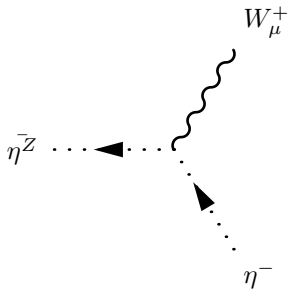
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{221}$$



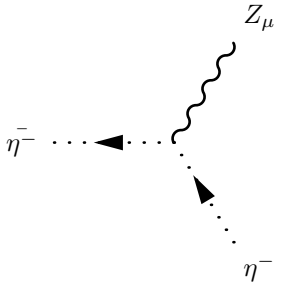
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^-}\right) \tag{222}$$



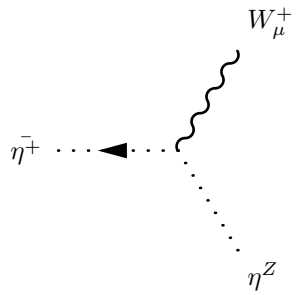
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^-}\right) \tag{223}$$



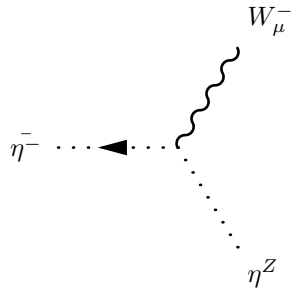
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{224}$$



$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{225}$$

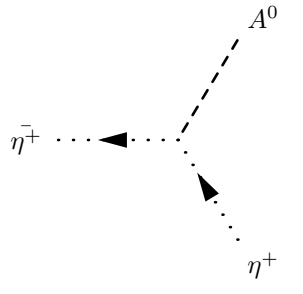


$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{226}$$

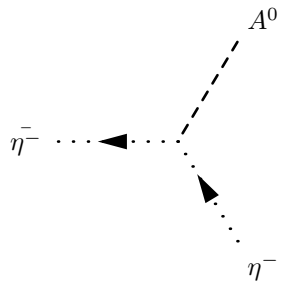


$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{227}$$

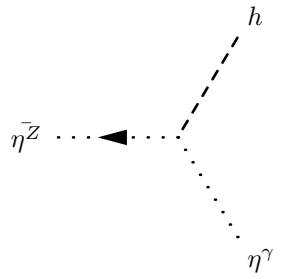
9.11 Two Ghosts-One Scalar-Interaction



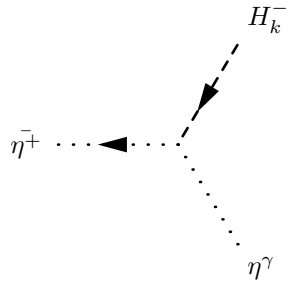
$$-\frac{1}{4} g_2^2 v \xi_{W^+} \tag{228}$$



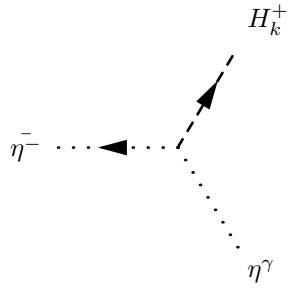
$$\frac{1}{4}g_2^2 v \xi_{W^+} \tag{229}$$



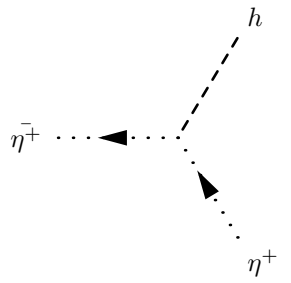
$$\frac{i}{8}v\xi_Z\Big(2g_1g_2\cos 2\Theta_W + \Big(-g_2^2+g_1^2\Big)\sin 2\Theta_W\Big) \tag{230}$$



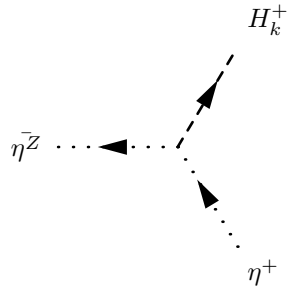
$$\frac{i}{4}g_2 v \xi_{W^+}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)Z_{k2}^+ \tag{231}$$



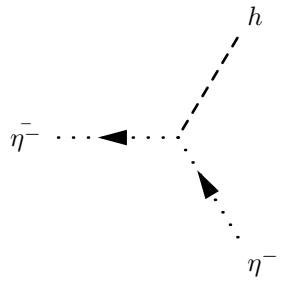
$$\frac{i}{4} g_2 v \xi_{W^+} \Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W \Big) Z_{k2}^+ \tag{232}$$



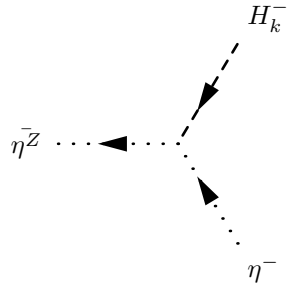
$$-\frac{i}{4} g_2^2 v \xi_{W^+} \tag{233}$$



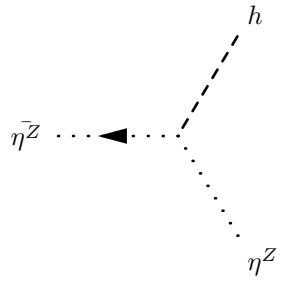
$$-\frac{i}{4} g_2 v \xi_Z \Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W \Big) Z_{k2}^+ \tag{234}$$



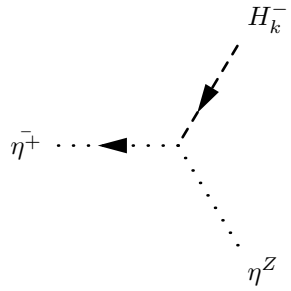
$$-\frac{i}{4}g_2^2 v\xi_{W^+} \tag{235}$$



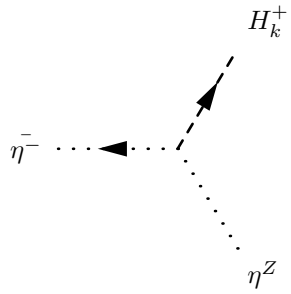
$$-\frac{i}{4}g_2 v\xi_Z\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)Z^+_{k2} \tag{236}$$



$$-\frac{i}{4}v\xi_Z\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2 \tag{237}$$



$$\frac{i}{4}g_2 v \xi_{W^+}\Big(- g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big) Z^+_{k2} \tag{238}$$



$$\frac{i}{4}g_2 v \xi_{W^+}\Big(- g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big) Z^+_{k2} \tag{239}$$

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10 Clebsch-Gordan Coefficients