

N2HDM

Lagrangian, Rotations and Interactions for eigenstates 'EWSB'

including one-loop Self-Energies

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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	$(U(1) \otimes SU(2) \otimes SU(3))$
H1	0	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1})$
H2	0	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1})$
S	0	1	$(0, \mathbf{1}, \mathbf{1})$
q	$\frac{1}{2}$	3	$(\frac{1}{6}, \mathbf{2}, \mathbf{3})$
l	$\frac{1}{2}$	3	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1})$
d	$\frac{1}{2}$	3	$(\frac{1}{3}, \mathbf{1}, \mathbf{\bar{3}})$
u	$\frac{1}{2}$	3	$(-\frac{2}{3}, \mathbf{1}, \mathbf{\bar{3}})$
e	$\frac{1}{2}$	3	$(1, \mathbf{1}, \mathbf{1})$

2 Lagrangian

2.1 Input Lagrangian for Eigenstates GaugeES

$$\begin{aligned}
L = & -\frac{1}{2}m_S^2 S^2 - \frac{1}{8}\lambda_6 S^4 - m_1^2 |H_1^0|^2 - \frac{1}{2}\lambda_7 S^2 |H_1^0|^2 - m_1^2 |H_1^+|^2 - \frac{1}{2}\lambda_7 S^2 |H_1^+|^2 \\
& - m_2^2 |H_2^0|^2 - \frac{1}{2}\lambda_8 S^2 |H_2^0|^2 - m_2^2 |H_2^+|^2 - \frac{1}{2}\lambda_8 S^2 |H_2^+|^2 - \frac{1}{2}\lambda_1 |H_1^0|^4 - \frac{1}{2}\lambda_1 |H_1^+|^4 \\
& - \frac{1}{2}\lambda_2 |H_2^0|^4 - \frac{1}{2}\lambda_2 |H_2^+|^4 + H_2^0 m_{12} H_1^{0,*} - \frac{1}{2}H_2^{0,2} \lambda_5 H_1^{0,*2} + H_2^+ m_{12} H_1^{+,*} - H_1^+ \lambda_1 |H_1^0|^2 H_1^{+,*} \\
& - H_2^0 H_2^+ \lambda_5 H_1^{0,*} H_1^{+,*} - \frac{1}{2}H_2^{+,2} \lambda_5 H_1^{+,*2} - H_2^0 \lambda_3 |H_1^0|^2 H_2^{0,*} - H_2^0 \lambda_4 |H_1^0|^2 H_2^{0,*} \\
& - H_2^0 \lambda_3 |H_1^+|^2 H_2^{0,*} - H_1^0 H_2^+ \lambda_4 H_1^{+,*} H_2^{0,*} - H_2^+ \lambda_3 |H_1^0|^2 H_2^{+,*} - H_2^+ \lambda_3 |H_1^+|^2 H_2^{+,*} \\
& - H_2^+ \lambda_4 |H_1^+|^2 H_2^{+,*} - H_2^+ \lambda_2 |H_2^0|^2 H_2^{+,*} - H_1^+ H_2^0 \lambda_4 H_1^{0,*} H_2^{+,*} - \frac{1}{2}H_1^{0,2} H_2^{0,*2} \lambda_5 \\
& - H_1^0 H_1^+ H_2^{0,*} H_2^{+,*} \lambda_5 - \frac{1}{2}H_1^{+,2} H_2^{+,*2} \lambda_5 + H_1^0 H_2^{0,*} m_{12}^* + H_1^+ H_2^{+,*} m_{12}^* \\
& - H_1^0 d_{L,k\gamma}^* Y_{d,jk}^* \delta_{\beta\gamma} d_{R,j\beta} - H_1^+ u_{L,k\gamma}^* Y_{d,jk}^* \delta_{\beta\gamma} d_{R,j\beta} - H_1^0 e_{L,k}^* Y_{e,jk}^* e_{R,j} \\
& - H_1^+ \nu_{L,k}^* Y_{e,jk}^* e_{R,j} + H_2^{+,*} d_{L,k\gamma}^* Y_{u,jk}^* \delta_{\beta\gamma} u_{R,j\beta} - H_2^{0,*} u_{L,k\gamma}^* Y_{u,jk}^* \delta_{\beta\gamma} u_{R,j\beta}
\end{aligned}$$

$$\begin{aligned}
& -H_1^{0,*} d_{R,j\beta}^* \delta_{\beta\gamma} d_{L,k\gamma} Y_{d,jk} - H_1^{+,*} d_{R,j\beta}^* \delta_{\beta\gamma} u_{L,k\gamma} Y_{d,jk} - H_1^{0,*} e_{R,j}^* e_{L,k} Y_{e,jk} \\
& -H_1^{+,*} e_{R,j}^* \nu_{L,k} Y_{e,jk} + H_2^+ u_{R,j\beta}^* \delta_{\beta\gamma} d_{L,k\gamma} Y_{u,jk} - H_2^0 u_{R,j\beta}^* \delta_{\beta\gamma} u_{L,k\gamma} Y_{u,jk}
\end{aligned} \tag{1}$$

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'

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

2.3 Fields integrated out

None

3 Field Rotations

3.1 Rotations in gauge sector for eigenstates 'EWSB'

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \end{pmatrix} = Z^{\gamma Z} \begin{pmatrix} \gamma_\rho \\ Z_\rho \end{pmatrix} \tag{4}$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho} \end{pmatrix} = Z^W \begin{pmatrix} W_\rho^- \\ W_\rho^- \end{pmatrix} \tag{5}$$

$$\tag{6}$$

The mixing matrices are parametrized by

$$Z^{\gamma Z} = \begin{pmatrix} \cos \Theta_W & -\sin \Theta_W \\ \sin \Theta_W & \cos \Theta_W \end{pmatrix} \tag{7}$$

$$Z^W = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} \end{pmatrix} \tag{8}$$

$$\tag{9}$$

3.2 Rotations in Mass sector for eigenstates 'EWSB'

3.2.1 Mass Matrices for Scalars

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

$$m_h^2 = \begin{pmatrix} m_{\phi_1\phi_1} & m_{\phi_2\phi_1} & \lambda_7 v_1 v_S \\ m_{\phi_1\phi_2} & m_{\phi_2\phi_2} & \lambda_8 v_2 v_S \\ \lambda_7 v_1 v_S & \lambda_8 v_2 v_S & m_{\phi_S\phi_S} \end{pmatrix} \quad (10)$$

$$m_{\phi_1\phi_1} = \frac{1}{2} \left(3\lambda_1 v_1^2 + \lambda_7 v_S^2 + v_2^2 \left(\lambda_3 + \lambda_4 + \Re(\lambda_5) \right) \right) + m_1^2 \quad (11)$$

$$m_{\phi_1\phi_2} = \frac{1}{2} v_1 v_2 \left(2 \left(\lambda_3 + \lambda_4 \right) + 2\Re(\lambda_5) \right) - \Re(m_{12}) \quad (12)$$

$$m_{\phi_2\phi_2} = \frac{1}{2} \left(3\lambda_2 v_2^2 + \lambda_8 v_S^2 + v_1^2 \left(\lambda_3 + \lambda_4 + \Re(\lambda_5) \right) \right) + m_2^2 \quad (13)$$

$$m_{\phi_S\phi_S} = \frac{1}{2} \left(3\lambda_6 v_S^2 + \lambda_7 v_1^2 + \lambda_8 v_2^2 \right) + m_S^2 \quad (14)$$

This matrix is diagonalized by Z^H :

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \quad (15)$$

with

$$\phi_1 = \sum_j Z_{j1}^H h_j, \quad \phi_2 = \sum_j Z_{j2}^H h_j, \quad \phi_S = \sum_j Z_{j3}^H h_j \quad (16)$$

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

$$m_{A^0}^2 = \begin{pmatrix} m_{\sigma_1\sigma_1} & -\Re(m_{12}) + v_1 v_2 \Re(\lambda_5) \\ -\Re(m_{12}) + v_1 v_2 \Re(\lambda_5) & m_{\sigma_2\sigma_2} \end{pmatrix} + \xi_Z m^2(Z) \quad (17)$$

$$m_{\sigma_1\sigma_1} = \frac{1}{2} \left(\lambda_1 v_1^2 + \lambda_7 v_S^2 + v_2^2 \left(-\Re(\lambda_5) + \lambda_3 + \lambda_4 \right) \right) + m_1^2 \quad (18)$$

$$m_{\sigma_2\sigma_2} = \frac{1}{2} \left(\lambda_2 v_2^2 + \lambda_8 v_S^2 + v_1^2 \left(-\Re(\lambda_5) + \lambda_3 + \lambda_4 \right) \right) + m_2^2 \quad (19)$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} \frac{1}{4} v_1^2 \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 & \frac{1}{4} v_1 v_2 \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 \\ \frac{1}{4} v_1 v_2 \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 & \frac{1}{4} v_2^2 \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 \end{pmatrix} \quad (20)$$

This matrix is diagonalized by Z^A :

$$Z^A m_{A^0}^2 Z^{A,\dagger} = m_{2,A^0}^{dia} \quad (21)$$

with

$$\sigma_1 = \sum_j Z_{j1}^A A_j^0, \quad \sigma_2 = \sum_j Z_{j2}^A A_j^0 \quad (22)$$

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

$$m_{H^-}^2 = \begin{pmatrix} \frac{1}{2}(\lambda_1 v_1^2 + \lambda_3 v_2^2 + \lambda_7 v_S^2) + m_1^2 & \frac{1}{2}v_1 v_2(\lambda_4 + \lambda_5^*) - m_{12}^* \\ \frac{1}{2}(\lambda_4 + \lambda_5)v_1 v_2 - m_{12} & \frac{1}{2}(\lambda_2 v_2^2 + \lambda_3 v_1^2 + \lambda_8 v_S^2) + m_2^2 \end{pmatrix} + \xi_{W^-} m^2(W^-) \quad (23)$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4}g_2^2 v_1^2 & \frac{1}{4}g_2^2 v_1 v_2 \\ \frac{1}{4}g_2^2 v_1 v_2 & \frac{1}{4}g_2^2 v_2^2 \end{pmatrix} \quad (24)$$

This matrix is diagonalized by Z^+ :

$$Z^+ m_{H^-}^2 Z^{+, \dagger} = m_{2,H^-}^{dia} \quad (25)$$

with

$$H_1^+ = \sum_j Z_{j1}^+ H_j^+, \quad H_2^+ = \sum_j Z_{j2}^+ H_j^+ \quad (26)$$

3.2.2 Mass Matrices for Fermions

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

$$m_d = \left(\frac{1}{\sqrt{2}} v_1 \delta_{\alpha_1 \beta_1} Y_d^T \right) \quad (27)$$

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

$$U_L^{d,*} m_d U_R^{d,\dagger} = m_d^{dia} \quad (28)$$

with

$$d_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{d,*} D_{L,j\alpha} \quad (29)$$

$$d_{R,i\alpha} = \sum_{t_2} U_{R,ij}^d D_{R,j\alpha}^* \quad (30)$$

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

$$m_u = \left(\frac{1}{\sqrt{2}} v_2 \delta_{\alpha_1 \beta_1} Y_u^T \right) \quad (31)$$

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

$$U_L^{u,*} m_u U_R^{u,\dagger} = m_u^{dia} \quad (32)$$

with

$$u_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{u,*} U_{L,j\alpha} \quad (33)$$

$$u_{R,i\alpha} = \sum_{t_2} U_{R,ij}^u U_{R,j\alpha}^* \quad (34)$$

- **Mass matrix for Leptons**, Basis: $(e_L), (e_R^*)$

$$m_e = \left(\frac{1}{\sqrt{2}} v_1 Y_e^T \right) \quad (35)$$

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

$$U_L^{e,*} m_e U_R^{e,\dagger} = m_e^{dia} \quad (36)$$

with

$$e_{L,i} = \sum_{t_2} U_{L,ji}^{e,*} E_{L,j} \quad (37)$$

$$e_{R,i} = \sum_{t_2} U_{R,ij}^e E_{R,j}^* \quad (38)$$

4 Vacuum Expectation Values

$$H_1^0 = \frac{1}{\sqrt{2}} \phi_1 + \frac{1}{\sqrt{2}} v_1 + i \frac{1}{\sqrt{2}} \sigma_1 \quad (39)$$

$$H_2^0 = \frac{1}{\sqrt{2}} \phi_2 + \frac{1}{\sqrt{2}} v_2 + i \frac{1}{\sqrt{2}} \sigma_2 \quad (40)$$

$$S = \phi_S + v_S \quad (41)$$

5 Tadpole Equations

$$\frac{\partial V}{\partial \phi_1} = \frac{1}{4} \left(-2v_2 (m_{12} + m_{12}^*) + v_1 \left(2(\lambda_1 v_1^2 + \lambda_7 v_S^2) + 4m_1^2 + v_2^2 (2(\lambda_3 + \lambda_4) + \lambda_5 + \lambda_5^*) \right) \right) \quad (42)$$

$$\frac{\partial V}{\partial \phi_2} = \frac{1}{4} \left(-2v_1 (m_{12} + m_{12}^*) + v_2 \left(2(\lambda_2 v_2^2 + \lambda_8 v_S^2) + 4m_2^2 + v_1^2 (2(\lambda_3 + \lambda_4) + \lambda_5 + \lambda_5^*) \right) \right) \quad (43)$$

$$\frac{\partial V}{\partial \phi_S} = \frac{1}{2} v_S (2m_S^2 + \lambda_6 v_S^2 + \lambda_7 v_1^2 + \lambda_8 v_2^2) \quad (44)$$

6 Particle content for eigenstates 'EWSB'

Name	Type	complex/real	Generations	Indices
h	Scalar	real	3	generation, 3
A^0	Scalar	real	2	generation, 2
H^-	Scalar	complex	2	generation, 2

ν	Fermion	Dirac	3	generation, 3
d	Fermion	Dirac	3	generation, 3, color, 3
u	Fermion	Dirac	3	generation, 3, color, 3
e	Fermion	Dirac	3	generation, 3
g	Vector	real	1	color, 8, lorentz, 4
γ	Vector	real	1	lorentz, 4
Z	Vector	real	1	lorentz, 4
W^-	Vector	complex	1	lorentz, 4
η^G	Ghost	real	1	color, 8
η^γ	Ghost	real	1	
η^Z	Ghost	real	1	
η^-	Ghost	complex	1	
η^+	Ghost	complex	1	

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

7.1 One Loop Self-Energy

- Self-Energy for Higgs (h)

$$\begin{aligned}
16\pi^2 \Pi_{i,j}(p^2) = & +2\left(-\frac{1}{2}\text{rMS} + B_0(p^2, m_Z^2, m_Z^2)\right)\Gamma_{\check{h}_j, Z, Z}^* \Gamma_{\check{h}_i, Z, Z} + 4\left(-\frac{1}{2}\text{rMS} + B_0(p^2, m_{W^-}^2, m_{W^-}^2)\right)\Gamma_{\check{h}_j, W^+, W^-}^* \Gamma_{\check{h}_i, W^+, W^-} \\
& - B_0(p^2, m_{\eta^-}^2, m_{\eta^-}^2)\Gamma_{\check{h}_i, \eta^-, \eta^-} \Gamma_{\check{h}_j, \eta^-, \eta^-} - B_0(p^2, m_{\eta^+}^2, m_{\eta^+}^2)\Gamma_{\check{h}_i, \eta^+, \eta^+} \Gamma_{\check{h}_j, \eta^+, \eta^+} \\
& - B_0(p^2, m_{\eta^Z}^2, m_{\eta^Z}^2)\Gamma_{\check{h}_i, \eta^Z, \eta^Z} \Gamma_{\check{h}_j, \eta^Z, \eta^Z} + 4\Gamma_{\check{h}_i, \check{h}_j, W^+, W^-} \left(-\frac{1}{2}\text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2)\right) \\
& + 2\Gamma_{\check{h}_i, \check{h}_j, Z, Z} \left(-\frac{1}{2}\text{rMS} m_Z^2 + A_0(m_Z^2)\right) - \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_a^0}^2) \Gamma_{\check{h}_i, \check{h}_j, A_a^0, A_a^0} \\
& - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\check{h}_i, \check{h}_j, H_a^+, H_a^-} + \frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{A_a^0}^2, m_{A_b^0}^2) \Gamma_{\check{h}_j, A_a^0, A_b^0}^* \Gamma_{\check{h}_i, A_a^0, A_b^0} \\
& + \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{H_a^-}^2, m_{H_b^-}^2) \Gamma_{\check{h}_j, H_a^+, H_b^-}^* \Gamma_{\check{h}_i, H_a^+, H_b^-} - \frac{1}{2} \sum_{a=1}^3 A_0(m_{h_a}^2) \Gamma_{\check{h}_i, \check{h}_j, h_a, h_a} \\
& + \sum_{a=1}^3 \sum_{b=1}^2 B_0(p^2, m_{h_a}^2, m_{A_b^0}^2) \Gamma_{\check{h}_j, h_a, A_b^0}^* \Gamma_{\check{h}_i, h_a, A_b^0} + \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{h_a}^2, m_{h_b}^2) \Gamma_{\check{h}_j, h_a, h_b}^* \Gamma_{\check{h}_i, h_a, h_b}
\end{aligned}$$

$$\begin{aligned}
& -6 \sum_{a=1}^3 m_{d_a} \sum_{b=1}^3 B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_b} \left(\Gamma_{\tilde{h}_j, \tilde{d}_a, d_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{d}_a, d_b}^R + \Gamma_{\tilde{h}_j, \tilde{d}_a, d_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{d}_a, d_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{d_a}^2, m_{d_b}^2) \left(\Gamma_{\tilde{h}_j, \tilde{d}_a, d_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{d}_a, d_b}^L + \Gamma_{\tilde{h}_j, \tilde{d}_a, d_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{d}_a, d_b}^R \right) \\
& - 2 \sum_{a=1}^3 m_{e_a} \sum_{b=1}^3 B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_b} \left(\Gamma_{\tilde{h}_j, \tilde{e}_a, e_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{e}_a, e_b}^R + \Gamma_{\tilde{h}_j, \tilde{e}_a, e_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{e}_a, e_b}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{e_a}^2, m_{e_b}^2) \left(\Gamma_{\tilde{h}_j, \tilde{e}_a, e_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{e}_a, e_b}^L + \Gamma_{\tilde{h}_j, \tilde{e}_a, e_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{e}_a, e_b}^R \right) \\
& - 6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_b} \left(\Gamma_{\tilde{h}_j, \tilde{u}_a, u_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{u}_a, u_b}^R + \Gamma_{\tilde{h}_j, \tilde{u}_a, u_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{u}_a, u_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{u_a}^2, m_{u_b}^2) \left(\Gamma_{\tilde{h}_j, \tilde{u}_a, u_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{u}_a, u_b}^L + \Gamma_{\tilde{h}_j, \tilde{u}_a, u_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{u}_a, u_b}^R \right) \\
& + \sum_{b=1}^2 \Gamma_{\tilde{h}_j, Z, A_b^0}^* \Gamma_{\tilde{h}_i, Z, A_b^0} F_0(p^2, m_{A_b^0}^2, m_Z^2) + 2 \sum_{b=1}^2 \Gamma_{\tilde{h}_j, W^+, H_b^-}^* \Gamma_{\tilde{h}_i, W^+, H_b^-} F_0(p^2, m_{H_b^-}^2, m_{W^-}^2) \quad (45)
\end{aligned}$$

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

$$\begin{aligned}
16\pi^2 \Pi_{i,j}(p^2) = & -B_0(p^2, m_{\eta^-}^2, m_{\eta^-}^2) \Gamma_{\tilde{A}_i^0, \eta^-, \eta^-} \Gamma_{\tilde{A}_j^0, \eta^-, \eta^-} - B_0(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \Gamma_{\tilde{A}_i^0, \eta^+, \eta^+} \Gamma_{\tilde{A}_j^0, \eta^+, \eta^+} \\
& + 4\Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, W^+, W^-} \left(-\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, Z, Z} \left(-\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& - \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_a^0}^2) \Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, A_a^0, A_a^0} - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, H_a^+, H_a^-} \\
& + \frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{A_a^0}^2, m_{A_b^0}^2) \Gamma_{\tilde{A}_j^0, A_a^0, A_b^0}^* \Gamma_{\tilde{A}_i^0, A_a^0, A_b^0} \\
& + \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{H_a^-}^2, m_{H_b^-}^2) \Gamma_{\tilde{A}_j^0, H_a^+, H_b^-}^* \Gamma_{\tilde{A}_i^0, H_a^+, H_b^-} - \frac{1}{2} \sum_{a=1}^3 A_0(m_{h_a}^2) \Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, h_a, h_a} \\
& + \sum_{a=1}^3 \sum_{b=1}^2 B_0(p^2, m_{h_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{A}_j^0, h_a, A_b^0}^* \Gamma_{\tilde{A}_i^0, h_a, A_b^0} \\
& + \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{h_a}^2, m_{h_b}^2) \Gamma_{\tilde{A}_j^0, h_a, h_b}^* \Gamma_{\tilde{A}_i^0, h_a, h_b} \\
& - 6 \sum_{a=1}^3 m_{d_a} \sum_{b=1}^3 B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_b} \left(\Gamma_{\tilde{A}_j^0, \tilde{d}_a, d_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{d}_a, d_b}^R + \Gamma_{\tilde{A}_j^0, \tilde{d}_a, d_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{d}_a, d_b}^L \right)
\end{aligned}$$

$$\begin{aligned}
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{d_a}^2, m_{d_b}^2) \left(\Gamma_{\tilde{A}_j^0, \tilde{d}_a, d_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{d}_a, d_b}^L + \Gamma_{\tilde{A}_j^0, \tilde{d}_a, d_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{d}_a, d_b}^R \right) \\
& - 2 \sum_{a=1}^3 m_{e_a} \sum_{b=1}^3 B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_b} \left(\Gamma_{\tilde{A}_j^0, \tilde{e}_a, e_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{e}_a, e_b}^R + \Gamma_{\tilde{A}_j^0, \tilde{e}_a, e_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{e}_a, e_b}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{e_a}^2, m_{e_b}^2) \left(\Gamma_{\tilde{A}_j^0, \tilde{e}_a, e_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{e}_a, e_b}^L + \Gamma_{\tilde{A}_j^0, \tilde{e}_a, e_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{e}_a, e_b}^R \right) \\
& - 6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_b} \left(\Gamma_{\tilde{A}_j^0, \tilde{u}_a, u_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{u}_a, u_b}^R + \Gamma_{\tilde{A}_j^0, \tilde{u}_a, u_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{u}_a, u_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{u_a}^2, m_{u_b}^2) \left(\Gamma_{\tilde{A}_j^0, \tilde{u}_a, u_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{u}_a, u_b}^L + \Gamma_{\tilde{A}_j^0, \tilde{u}_a, u_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{u}_a, u_b}^R \right) \\
& + 2 \sum_{b=1}^2 \Gamma_{\tilde{A}_j^0, W^+, H_b^-}^* \Gamma_{\tilde{A}_i^0, W^+, H_b^-} F_0(p^2, m_{H_b^-}^2, m_{W^-}^2) + \sum_{b=1}^3 \Gamma_{\tilde{A}_j^0, Z, h_b}^* \Gamma_{\tilde{A}_i^0, Z, h_b} F_0(p^2, m_{h_b}^2, m_Z^2) \quad (46)
\end{aligned}$$

• Self-Energy for Charged Higgs (H^-)

$$\begin{aligned}
16\pi^2 \Pi_{i,j}(p^2) = & +4 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, 0, m_{W^-}^2) \right) \Gamma_{\tilde{H}_j^+, W^-, \gamma}^* \Gamma_{\tilde{H}_i^+, W^-, \gamma} + 4 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{W^-}^2, m_Z^2) \right) \Gamma_{\tilde{H}_j^+, Z, W^-}^* \Gamma_{\tilde{H}_i^+, Z, W^-} \\
& - B_0(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \Gamma_{\tilde{H}_i^+, \eta^+, \eta^+} \Gamma_{\tilde{H}_j^-, \eta^+, \eta^+} - B_0(p^2, m_{\eta^-}^2, m_{\eta^-}^2) \Gamma_{\tilde{H}_i^+, \eta^-, \eta^-} \Gamma_{\tilde{H}_j^-, \eta^-, \eta^-} \\
& + 4 \Gamma_{\tilde{H}_i^-, \tilde{H}_j^+, W^+, W^-} \left(-\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2 \Gamma_{\tilde{H}_i^-, \tilde{H}_j^+, Z, Z} \left(-\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& - \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_a^0}^2) \Gamma_{\tilde{H}_i^-, \tilde{H}_j^+, A_a^0, A_a^0} - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{H}_i^-, \tilde{H}_j^+, H_a^-, H_a^-} \\
& + \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{H_a^-}^2, m_{A_b^0}^2) \Gamma_{\tilde{H}_j^+, H_a^-, A_b^0}^* \Gamma_{\tilde{H}_i^+, H_a^-, A_b^0} \\
& + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{H_a^-}^2, m_{h_b}^2) \Gamma_{\tilde{H}_j^+, H_a^-, h_b}^* \Gamma_{\tilde{H}_i^+, H_a^-, h_b} - \frac{1}{2} \sum_{a=1}^3 A_0(m_{h_a}^2) \Gamma_{\tilde{H}_i^-, \tilde{H}_j^+, h_a, h_a} \\
& - 6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{d_b}^2) m_{d_b} \left(\Gamma_{\tilde{H}_j^+, \tilde{u}_a, d_b}^{L*} \Gamma_{\tilde{H}_i^+, \tilde{u}_a, d_b}^R + \Gamma_{\tilde{H}_j^+, \tilde{u}_a, d_b}^{R*} \Gamma_{\tilde{H}_i^+, \tilde{u}_a, d_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{u_a}^2, m_{d_b}^2) \left(\Gamma_{\tilde{H}_j^+, \tilde{u}_a, d_b}^{L*} \Gamma_{\tilde{H}_i^+, \tilde{u}_a, d_b}^L + \Gamma_{\tilde{H}_j^+, \tilde{u}_a, d_b}^{R*} \Gamma_{\tilde{H}_i^+, \tilde{u}_a, d_b}^R \right) \\
& - 2 \sum_{a=1}^3 m_{\nu_a} \sum_{b=1}^3 B_0(p^2, m_{\nu_a}^2, m_{e_b}^2) m_{e_b} \left(\Gamma_{\tilde{H}_j^+, \tilde{\nu}_a, e_b}^{L*} \Gamma_{\tilde{H}_i^+, \tilde{\nu}_a, e_b}^R + \Gamma_{\tilde{H}_j^+, \tilde{\nu}_a, e_b}^{R*} \Gamma_{\tilde{H}_i^+, \tilde{\nu}_a, e_b}^L \right)
\end{aligned}$$

$$\begin{aligned}
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{\nu_a}^2, m_{e_b}^2) \left(\Gamma_{\check{H}_j^+, \bar{\nu}_a, e_b}^{L*} \Gamma_{\check{H}_i^+, \bar{\nu}_a, e_b}^L + \Gamma_{\check{H}_j^+, \bar{\nu}_a, e_b}^{R*} \Gamma_{\check{H}_i^+, \bar{\nu}_a, e_b}^R \right) \\
& + \sum_{b=1}^2 \Gamma_{\check{H}_j^+, W^-, A_b^0}^* \Gamma_{\check{H}_i^+, W^-, A_b^0} F_0(p^2, m_{A_b^0}^2, m_{W^-}^2) + \sum_{b=1}^2 \Gamma_{\check{H}_j^+, \gamma, H_b^-}^* \Gamma_{\check{H}_i^+, \gamma, H_b^-} F_0(p^2, m_{H_b^-}^2, 0) \\
& + \sum_{b=1}^2 \Gamma_{\check{H}_j^+, Z, H_b^-}^* \Gamma_{\check{H}_i^+, Z, H_b^-} F_0(p^2, m_{H_b^-}^2, m_Z^2) + \sum_{b=1}^3 \Gamma_{\check{H}_j^+, W^-, h_b}^* \Gamma_{\check{H}_i^+, W^-, h_b} F_0(p^2, m_{h_b}^2, m_{W^-}^2) \quad (47)
\end{aligned}$$

• Self-Energy for Down-Quarks (d)

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\check{d}_j, H_a^-, u_b}^{L*} m_{u_b} \Gamma_{\check{d}_i, H_a^-, u_b}^R \\
& + \sum_{a=1}^3 m_{d_a} \sum_{b=1}^2 B_0(p^2, m_{d_a}^2, m_{A_b^0}^2) \Gamma_{\check{d}_j, d_a, A_b^0}^{L*} \Gamma_{\check{d}_i, d_a, A_b^0}^R \\
& + \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\check{d}_j, h_a, d_b}^{L*} m_{d_b} \Gamma_{\check{d}_i, h_a, d_b}^R \\
& - \frac{16}{3} \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, 0) \right) \Gamma_{\check{d}_j, g, d_b}^{R*} m_{d_b} \Gamma_{\check{d}_i, g, d_b}^L - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, 0) \right) \Gamma_{\check{d}_j, \gamma, d_b}^{R*} m_{d_b} \Gamma_{\check{d}_i, \gamma, d_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_{W^-}^2) \right) \Gamma_{\check{d}_j, W^-, u_b}^{R*} m_{u_b} \Gamma_{\check{d}_i, W^-, u_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_Z^2) \right) \Gamma_{\check{d}_j, Z, d_b}^{R*} m_{d_b} \Gamma_{\check{d}_i, Z, d_b}^L \quad (48)
\end{aligned}$$

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^R(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\check{d}_j, H_a^-, u_b}^{R*} \Gamma_{\check{d}_i, H_a^-, u_b}^R \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{d_a}^2, m_{A_b^0}^2) \Gamma_{\check{d}_j, d_a, A_b^0}^{R*} \Gamma_{\check{d}_i, d_a, A_b^0}^R \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\check{d}_j, h_a, d_b}^{R*} \Gamma_{\check{d}_i, h_a, d_b}^R - \frac{4}{3} \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, 0) \right) \Gamma_{\check{d}_j, g, d_b}^{L*} \Gamma_{\check{d}_i, g, d_b}^L \\
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, 0) \right) \Gamma_{\check{d}_j, \gamma, d_b}^{L*} \Gamma_{\check{d}_i, \gamma, d_b}^L - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, m_{W^-}^2) \right) \Gamma_{\check{d}_j, W^-, u_b}^{L*} \Gamma_{\check{d}_i, W^-, u_b}^L \\
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, m_Z^2) \right) \Gamma_{\check{d}_j, Z, d_b}^{L*} \Gamma_{\check{d}_i, Z, d_b}^L \quad (49)
\end{aligned}$$

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{d}_j, H_a^-, u_b}^{L*} \Gamma_{\tilde{d}_i, H_a^-, u_b}^L \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{d_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{d}_j, d_a, A_b^0}^{L*} \Gamma_{\tilde{d}_i, d_a, A_b^0}^L \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\tilde{d}_j, h_a, d_b}^{L*} \Gamma_{\tilde{d}_i, h_a, d_b}^L - \frac{4}{3} \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, g, d_b}^{R*} \Gamma_{\tilde{d}_i, g, d_b}^R \\
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, \gamma, d_b}^{R*} \Gamma_{\tilde{d}_i, \gamma, d_b}^R - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{d}_j, W^-, u_b}^{R*} \Gamma_{\tilde{d}_i, W^-, u_b}^R \\
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, m_Z^2) \right) \Gamma_{\tilde{d}_j, Z, d_b}^{R*} \Gamma_{\tilde{d}_i, Z, d_b}^R \tag{50}
\end{aligned}$$

• **Self-Energy for Up-Quarks** (u)

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{u}_j, H_a^+, d_b}^{L*} m_{d_b} \Gamma_{\tilde{u}_i, H_a^+, d_b}^R \\
& + \sum_{a=1}^3 m_{u_a} \sum_{b=1}^2 B_0(p^2, m_{u_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{u}_j, u_a, A_b^0}^{L*} \Gamma_{\tilde{u}_i, u_a, A_b^0}^R \\
& + \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{L*} m_{u_b} \Gamma_{\tilde{u}_i, h_a, u_b}^R \\
& - \frac{16}{3} \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, g, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, g, u_b}^L - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, \gamma, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, \gamma, u_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_Z^2) \right) \Gamma_{\tilde{u}_j, Z, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, Z, u_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{u}_j, W^+, d_b}^{R*} m_{d_b} \Gamma_{\tilde{u}_i, W^+, d_b}^L \tag{51}
\end{aligned}$$

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^R(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{u}_j, H_a^+, d_b}^{R*} \Gamma_{\tilde{u}_i, H_a^+, d_b}^R \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{u_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{u}_j, u_a, A_b^0}^{R*} \Gamma_{\tilde{u}_i, u_a, A_b^0}^R \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{R*} \Gamma_{\tilde{u}_i, h_a, u_b}^R - \frac{4}{3} \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, g, u_b}^{L*} \Gamma_{\tilde{u}_i, g, u_b}^L
\end{aligned}$$

$$\begin{aligned}
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, \gamma, u_b}^{L*} \Gamma_{\tilde{u}_i, \gamma, u_b}^L - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, m_Z^2) \right) \Gamma_{\tilde{u}_j, Z, u_b}^{L*} \Gamma_{\tilde{u}_i, Z, u_b}^L \\
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{u}_j, W^+, d_b}^{L*} \Gamma_{\tilde{u}_i, W^+, d_b}^L \tag{52}
\end{aligned}$$

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{u}_j, H_a^+, d_b}^{L*} \Gamma_{\tilde{u}_i, H_a^+, d_b}^L \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{u_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{u}_j, u_a, A_b^0}^{L*} \Gamma_{\tilde{u}_i, u_a, A_b^0}^L \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{L*} \Gamma_{\tilde{u}_i, h_a, u_b}^L - \frac{4}{3} \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, g, u_b}^{R*} \Gamma_{\tilde{u}_i, g, u_b}^R \\
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, \gamma, u_b}^{R*} \Gamma_{\tilde{u}_i, \gamma, u_b}^R - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, m_Z^2) \right) \Gamma_{\tilde{u}_j, Z, u_b}^{R*} \Gamma_{\tilde{u}_i, Z, u_b}^R \\
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{u}_j, W^+, d_b}^{R*} \Gamma_{\tilde{u}_i, W^+, d_b}^R \tag{53}
\end{aligned}$$

• Self-Energy for Leptons (e)

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{\nu_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{L*} m_{\nu_b} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^R \\
& + \sum_{a=1}^3 m_{e_a} \sum_{b=1}^2 B_0(p^2, m_{e_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{e}_j, e_a, A_b^0}^{L*} \Gamma_{\tilde{e}_i, e_a, A_b^0}^R \\
& + \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{L*} m_{e_b} \Gamma_{\tilde{e}_i, h_a, e_b}^R \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, 0) \right) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, \gamma, e_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{e}_i, W^-, \nu_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, m_Z^2) \right) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, Z, e_b}^L \tag{54}
\end{aligned}$$

$$16\pi^2 \Sigma_{i,j}^R(p^2) = -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{R*} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^R$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{e_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{e}_j, e_a, A_b^0}^{R*} \Gamma_{\tilde{e}_i, e_a, A_b^0}^R \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{R*} \Gamma_{\tilde{e}_i, h_a, e_b}^R - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{e_b}^2, 0) \right) \Gamma_{\tilde{e}_j, \gamma, e_b}^{L*} \Gamma_{\tilde{e}_i, \gamma, e_b}^L \\
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{L*} \Gamma_{\tilde{e}_i, W^-, \nu_b}^L - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{e_b}^2, m_Z^2) \right) \Gamma_{\tilde{e}_j, Z, e_b}^{L*} \Gamma_{\tilde{e}_i, Z, e_b}^L
\end{aligned} \tag{55}$$

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^L(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{L*} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{e_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{e}_j, e_a, A_b^0}^{L*} \Gamma_{\tilde{e}_i, e_a, A_b^0}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{L*} \Gamma_{\tilde{e}_i, h_a, e_b}^L - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{e_b}^2, 0) \right) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} \Gamma_{\tilde{e}_i, \gamma, e_b}^R \\
& - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} \Gamma_{\tilde{e}_i, W^-, \nu_b}^R - \sum_{b=1}^3 \left(\frac{1}{2} \text{rMS} + B_1(p^2, m_{e_b}^2, m_Z^2) \right) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} \Gamma_{\tilde{e}_i, Z, e_b}^R
\end{aligned} \tag{56}$$

• **Self-Energy for Z-Boson** (Z)

$$\begin{aligned}
16\pi^2 \Pi(p^2) &= |\Gamma_{Z, \eta^-, \eta^-}|^2 B_{00}(p^2, m_{\eta^-}^2, m_{\eta^-}^2) + |\Gamma_{Z, \eta^+, \eta^+}|^2 B_{00}(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \\
& - |\Gamma_{Z, W^+, W^-}|^2 \left(10B_{00}(p^2, m_{W^-}^2, m_{W^-}^2) + 2A_0(m_{W^-}^2) - 2\text{rMS}(2m_{W^-}^2 - \frac{1}{3}p^2) + B_0(p^2, m_{W^-}^2, m_{W^-}^2) \right) (2m_{W^-}^2 + \\
& + \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_a^0}^2) \Gamma_{Z, Z, A_a^0, A_a^0} + \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{Z, Z, H_a^+, H_a^-} \\
& - 4 \sum_{a=1}^2 \sum_{b=1}^2 |\Gamma_{Z, H_a^+, H_b^-}|^2 B_{00}(p^2, m_{H_a^-}^2, m_{H_b^-}^2) + \frac{1}{2} \sum_{a=1}^3 A_0(m_{h_a}^2) \Gamma_{Z, Z, h_a, h_a} \\
& - 4 \sum_{a=1}^3 \sum_{b=1}^2 |\Gamma_{Z, h_a, A_b^0}|^2 B_{00}(p^2, m_{A_b^0}^2, m_{h_a}^2) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z, \bar{d}_a, d_b}^L|^2 + |\Gamma_{Z, \bar{d}_a, d_b}^R|^2 \right) H_0(p^2, m_{d_a}^2, m_{d_b}^2) \right. \\
& + 4B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_a} m_{d_b} \Re \left(\Gamma_{Z, \bar{d}_a, d_b}^{L*} \Gamma_{Z, \bar{d}_a, d_b}^R \right) \left. \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z, \bar{e}_a, e_b}^L|^2 + |\Gamma_{Z, \bar{e}_a, e_b}^R|^2 \right) H_0(p^2, m_{e_a}^2, m_{e_b}^2) \right.
\end{aligned}$$

$$\begin{aligned}
& + 4B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_a} m_{e_b} \Re(\Gamma_{Z, \bar{e}_a, e_b}^{L*} \Gamma_{Z, \bar{e}_a, e_b}^R) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[(|\Gamma_{Z, \bar{u}_a, u_b}^L|^2 + |\Gamma_{Z, \bar{u}_a, u_b}^R|^2) H_0(p^2, m_{u_a}^2, m_{u_b}^2) \right. \\
& + 4B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_a} m_{u_b} \Re(\Gamma_{Z, \bar{u}_a, u_b}^{L*} \Gamma_{Z, \bar{u}_a, u_b}^R) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[(|\Gamma_{Z, \bar{\nu}_a, \nu_b}^L|^2 + |\Gamma_{Z, \bar{\nu}_a, \nu_b}^R|^2) H_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) \right. \\
& + 4B_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) m_{\nu_a} m_{\nu_b} \Re(\Gamma_{Z, \bar{\nu}_a, \nu_b}^{L*} \Gamma_{Z, \bar{\nu}_a, \nu_b}^R) \\
& + 2 \sum_{b=1}^2 |\Gamma_{Z, W^+, H_b^-}|^2 B_0(p^2, m_{W^-}^2, m_{H_b^-}^2) + \sum_{b=1}^3 |\Gamma_{Z, Z, h_b}|^2 B_0(p^2, m_Z^2, m_{h_b}^2) + 2\text{rMS} m_{W^-}^2 \Gamma_{Z, Z, W^+, W^-}^1 \\
& \left. - A_0(m_{W^-}^2) (4\Gamma_{Z, Z, W^+, W^-}^1 + \Gamma_{Z, Z, W^+, W^-}^2 + \Gamma_{Z, Z, W^+, W^-}^3) \right] \tag{57}
\end{aligned}$$

• **Self-Energy for W-Boson** (W^-)

$$\begin{aligned}
16\pi^2 \Pi(p^2) = & 2\text{rMS} m_{W^-}^2 \Gamma_{W^-, W^+, W^+, W^-}^1 + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[(|\Gamma_{W^+, \bar{u}_a, d_b}^L|^2 + |\Gamma_{W^+, \bar{u}_a, d_b}^R|^2) H_0(p^2, m_{u_a}^2, m_{d_b}^2) \right. \\
& + 4B_0(p^2, m_{u_a}^2, m_{d_b}^2) m_{d_b} m_{u_a} \Re(\Gamma_{W^+, \bar{u}_a, d_b}^{L*} \Gamma_{W^+, \bar{u}_a, d_b}^R) \\
& - 4 \sum_{a=1}^2 \sum_{b=1}^2 |\Gamma_{W^+, H_a^-, A_b^0}|^2 B_{00}(p^2, m_{A_b^0}^2, m_{H_a^-}^2) - 4 \sum_{a=1}^2 \sum_{b=1}^3 |\Gamma_{W^+, \gamma, H_b^-}|^2 B_0(p^2, 0, m_{H_b^-}^2) \\
& + 4B_0(p^2, m_{\nu_a}^2, m_{e_b}^2) m_{e_b} m_{\nu_a} \Re(\Gamma_{W^+, \bar{\nu}_a, e_b}^{L*} \Gamma_{W^+, \bar{\nu}_a, e_b}^R) \\
& \left. + \sum_{b=1}^2 |\Gamma_{W^+, \gamma, H_b^-}|^2 B_0(p^2, 0, m_{H_b^-}^2) + \sum_{b=1}^2 |\Gamma_{W^+, Z, H_b^-}|^2 B_0(p^2, 0, m_{H_b^-}^2) \right] \tag{58}
\end{aligned}$$

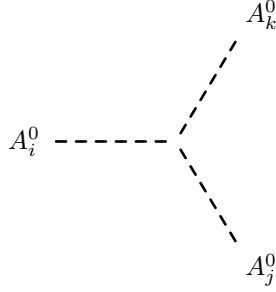
7.2 Tadpoles

$$\begin{aligned}
16\pi^2 \delta t_h^{(1)} = & + A_0(m_{\eta^-}^2) \Gamma_{\tilde{h}_i, \eta^-, \eta^-} + A_0(m_{\eta^+}^2) \Gamma_{\tilde{h}_i, \eta^+, \eta^+} + A_0(m_{\eta^Z}^2) \Gamma_{\tilde{h}_i, \eta^Z, \eta^Z} \\
& + 4\Gamma_{\tilde{h}_i, W^+, W^-} \left(-\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\tilde{h}_i, Z, Z} \left(-\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) - \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_a^0}^2) \Gamma_{\tilde{h}_i, A_a^0, A_a^0} \\
& - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{h}_i, H_a^+, H_a^-} - \frac{1}{2} \sum_{a=1}^3 A_0(m_{h_a}^2) \Gamma_{\tilde{h}_i, h_a, h_a} \\
& + 6 \sum_{a=1}^3 A_0(m_{d_a}^2) m_{d_a} \left(\Gamma_{\tilde{h}_i, \bar{d}_a, d_a}^L + \Gamma_{\tilde{h}_i, \bar{d}_a, d_a}^R \right) \\
& + 2 \sum_{a=1}^3 A_0(m_{e_a}^2) m_{e_a} \left(\Gamma_{\tilde{h}_i, \bar{e}_a, e_a}^L + \Gamma_{\tilde{h}_i, \bar{e}_a, e_a}^R \right)
\end{aligned}$$

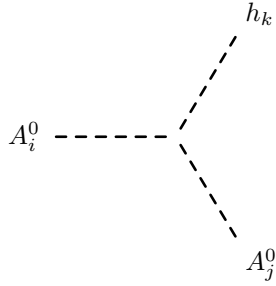
$$+ 6 \sum_{a=1}^3 A_0(m_{u_a}^2) m_{u_a} \left(\Gamma_{\tilde{h}_i, \bar{u}_a, u_a}^L + \Gamma_{\tilde{h}_i, \bar{u}_a, u_a}^R \right) \quad (59)$$

8 Interactions for eigenstates 'EWSB'

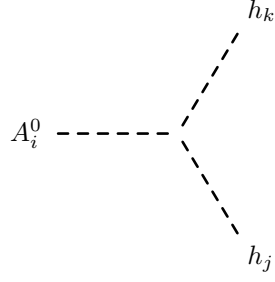
8.1 Three Scalar-Interaction



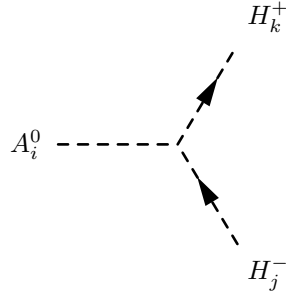
$$\begin{aligned} & \frac{1}{2} \left(-\lambda_5^* + \lambda_5 \right) \left(-Z_{i1}^A \left(v_2 Z_{j1}^A Z_{k2}^A + Z_{j2}^A \left(-v_1 Z_{k2}^A + v_2 Z_{k1}^A \right) \right) \right. \\ & \left. + Z_{i2}^A \left(v_1 Z_{j2}^A Z_{k1}^A + Z_{j1}^A \left(v_1 Z_{k2}^A - v_2 Z_{k1}^A \right) \right) \right) \end{aligned} \quad (60)$$



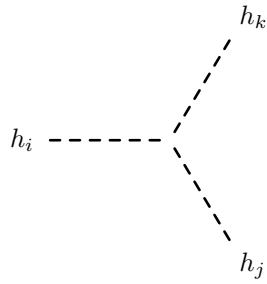
$$\begin{aligned} & -\frac{i}{2} \left(Z_{i1}^A \left(\left(\lambda_5 + \lambda_5^* \right) Z_{j2}^A \left(v_1 Z_{k2}^H + v_2 Z_{k1}^H \right) \right. \right. \\ & + Z_{j1}^A \left(2\lambda_1 v_1 Z_{k1}^H + 2\lambda_7 v_S Z_{k3}^H + v_2 \left(2\lambda_3 + 2\lambda_4 - \lambda_5 - \lambda_5^* \right) Z_{k2}^H \right) \Big) \\ & + Z_{i2}^A \left(\left(\lambda_5 + \lambda_5^* \right) Z_{j1}^A \left(v_1 Z_{k2}^H + v_2 Z_{k1}^H \right) \right. \\ & \left. \left. + Z_{j2}^A \left(2 \left(\lambda_2 v_2 Z_{k2}^H + \lambda_8 v_S Z_{k3}^H \right) + v_1 \left(2\lambda_3 + 2\lambda_4 - \lambda_5 - \lambda_5^* \right) Z_{k1}^H \right) \right) \right) \end{aligned} \quad (61)$$



$$\frac{1}{2} \left(-\lambda_5^* + \lambda_5 \right) \left(-Z_{i1}^A \left(v_2 Z_{j1}^H Z_{k2}^H + Z_{j2}^H \left(v_1 Z_{k2}^H + v_2 Z_{k1}^H \right) \right) + Z_{i2}^A \left(v_1 Z_{j2}^H Z_{k1}^H + Z_{j1}^H \left(v_1 Z_{k2}^H + v_2 Z_{k1}^H \right) \right) \right) \quad (62)$$

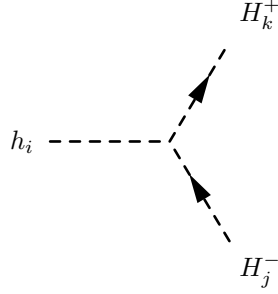


$$- \frac{1}{2} \left(-v_1 Z_{i2}^A + v_2 Z_{i1}^A \right) \left(\left(-\lambda_4 + \lambda_5 \right) Z_{j1}^+ Z_{k2}^+ + \left(-\lambda_5^* + \lambda_4 \right) Z_{j2}^+ Z_{k1}^+ \right) \quad (63)$$



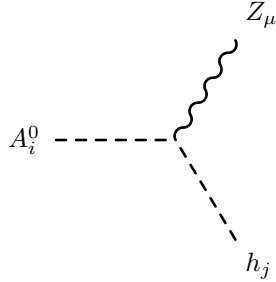
$$\begin{aligned} & -\frac{i}{2} \left(2Z_{i3}^H \left(\lambda_7 Z_{j1}^H \left(v_1 Z_{k3}^H + v_S Z_{k1}^H \right) + \lambda_8 Z_{j2}^H \left(v_2 Z_{k3}^H + v_S Z_{k2}^H \right) \right. \right. \\ & + Z_{j3}^H \left(3\lambda_6 v_S Z_{k3}^H + \lambda_7 v_1 Z_{k1}^H + \lambda_8 v_2 Z_{k2}^H \right) \left. \right) \\ & + Z_{i1}^H \left(\left(2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^* \right) Z_{j2}^H \left(v_1 Z_{k2}^H + v_2 Z_{k1}^H \right) + 2\lambda_7 Z_{j3}^H \left(v_1 Z_{k3}^H + v_S Z_{k1}^H \right) \right) \end{aligned}$$

$$\begin{aligned}
& + Z_{j1}^H \left(2\lambda_7 v_S Z_{k3}^H + 6\lambda_1 v_1 Z_{k1}^H + v_2 \left(2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^* \right) Z_{k2}^H \right) \\
& + Z_{i2}^H \left(\left(2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^* \right) Z_{j1}^H \left(v_1 Z_{k2}^H + v_2 Z_{k1}^H \right) + 2\lambda_8 Z_{j3}^H \left(v_2 Z_{k3}^H + v_S Z_{k2}^H \right) \right. \\
& \left. + Z_{j2}^H \left(2\lambda_8 v_S Z_{k3}^H + 6\lambda_2 v_2 Z_{k2}^H + v_1 \left(2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^* \right) Z_{k1}^H \right) \right)
\end{aligned} \tag{64}$$

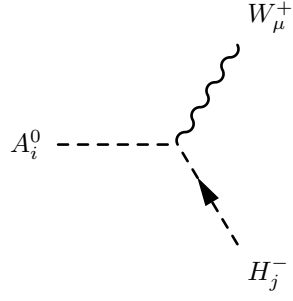


$$\begin{aligned}
& - \frac{i}{2} \left(2v_S Z_{i3}^H \left(\lambda_7 Z_{j1}^+ Z_{k1}^+ + \lambda_8 Z_{j2}^+ Z_{k2}^+ \right) \right. \\
& + Z_{i2}^H \left(Z_{j1}^+ \left(2\lambda_3 v_2 Z_{k1}^+ + \left(\lambda_4 + \lambda_5 \right) v_1 Z_{k2}^+ \right) + Z_{j2}^+ \left(2\lambda_2 v_2 Z_{k2}^+ + v_1 \left(\lambda_4 + \lambda_5^* \right) Z_{k1}^+ \right) \right) \\
& \left. + Z_{i1}^H \left(Z_{j1}^+ \left(2\lambda_1 v_1 Z_{k1}^+ + \left(\lambda_4 + \lambda_5 \right) v_2 Z_{k2}^+ \right) + Z_{j2}^+ \left(2\lambda_3 v_1 Z_{k2}^+ + v_2 \left(\lambda_4 + \lambda_5^* \right) Z_{k1}^+ \right) \right) \right)
\end{aligned} \tag{65}$$

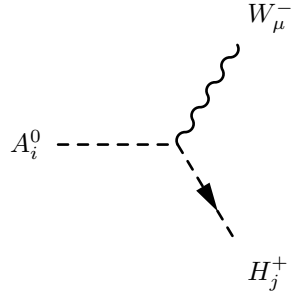
8.2 Two Scalar-One Vector Boson-Interaction



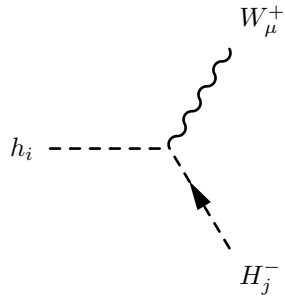
$$- \frac{1}{2} \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left(Z_{i1}^A Z_{j1}^H + Z_{i2}^A Z_{j2}^H \right) \left(-p_\mu^{h_j} + p_\mu^{A_i^0} \right) \tag{66}$$



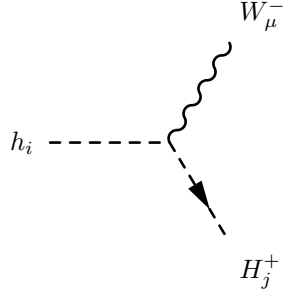
$$\frac{1}{2}g_2\left(Z_{i1}^AZ_{j1}^+ + Z_{i2}^AZ_{j2}^+\right)\left(-p_\mu^{H_j^-} + p_\mu^{A_i^0}\right) \quad (67)$$



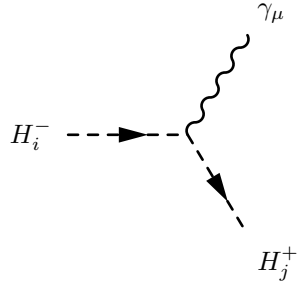
$$\frac{1}{2}g_2\left(Z_{i1}^AZ_{j1}^+ + Z_{i2}^AZ_{j2}^+\right)\left(-p_\mu^{H_j^+} + p_\mu^{A_i^0}\right) \quad (68)$$



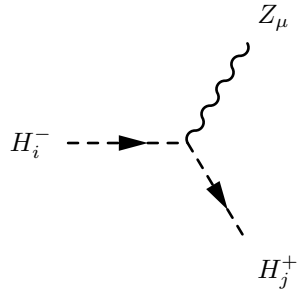
$$-\frac{i}{2}g_2\left(Z_{i1}^HZ_{j1}^+ + Z_{i2}^HZ_{j2}^+\right)\left(-p_\mu^{H_j^-} + p_\mu^{h_i}\right) \quad (69)$$



$$\frac{i}{2} g_2 \left(Z_{i1}^H Z_{j1}^+ + Z_{i2}^H Z_{j2}^+ \right) \left(-p_\mu^{H_j^+} + p_\mu^{h_i} \right) \quad (70)$$

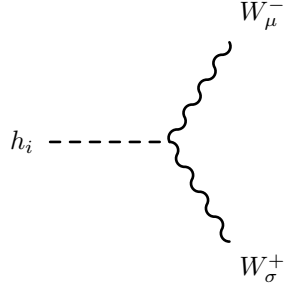


$$\frac{i}{2} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) \left(-p_\mu^{H_j^+} + p_\mu^{H_i^-} \right) \quad (71)$$

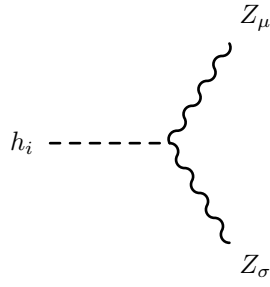


$$\frac{i}{2} \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) \left(-p_\mu^{H_j^+} + p_\mu^{H_i^-} \right) \quad (72)$$

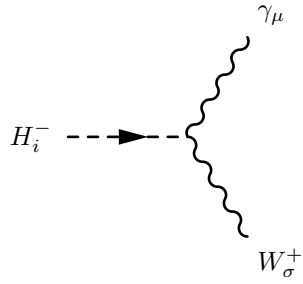
8.3 One Scalar-Two Vector Boson-Interaction



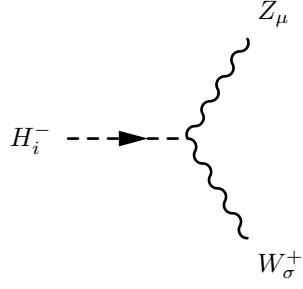
$$\frac{i}{2}g_2^2\left(v_1Z_{i1}^H+v_2Z_{i2}^H\right)\left(g_{\sigma\mu}\right) \quad (73)$$



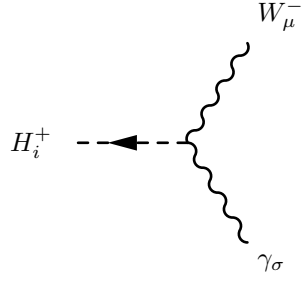
$$\frac{i}{2}\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)^2\left(v_1Z_{i1}^H+v_2Z_{i2}^H\right)\left(g_{\sigma\mu}\right) \quad (74)$$



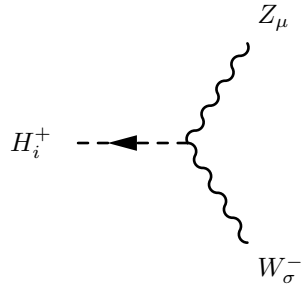
$$\frac{i}{2}g_1g_2\cos\Theta_W\left(v_1Z_{i1}^++v_2Z_{i2}^+\right)\left(g_{\sigma\mu}\right) \quad (75)$$



$$-\frac{i}{2}g_1g_2\sin\Theta_W\left(v_1Z_{i1}^+ + v_2Z_{i2}^+\right)\left(g_{\sigma\mu}\right) \quad (76)$$

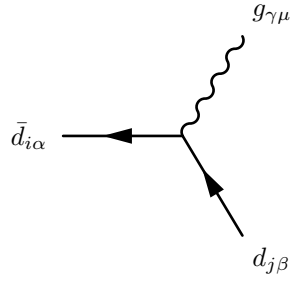


$$\frac{i}{2}g_1g_2\cos\Theta_W\left(v_1Z_{i1}^+ + v_2Z_{i2}^+\right)\left(g_{\sigma\mu}\right) \quad (77)$$



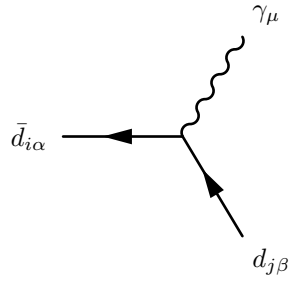
$$-\frac{i}{2}g_1g_2\sin\Theta_W\left(v_1Z_{i1}^+ + v_2Z_{i2}^+\right)\left(g_{\sigma\mu}\right) \quad (78)$$

8.4 Two Fermion-One Vector Boson-Interaction



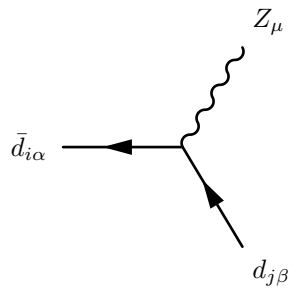
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (79)$$

$$+\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (80)$$



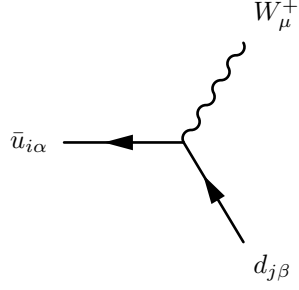
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (81)$$

$$+\frac{i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (82)$$

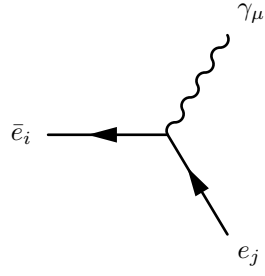


$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (83)$$

$$+ -\frac{i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (84)$$

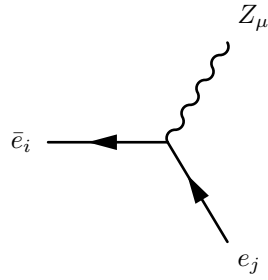


$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3U_{L,ja}^{d,*}U_{L,ia}^u\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (85)$$



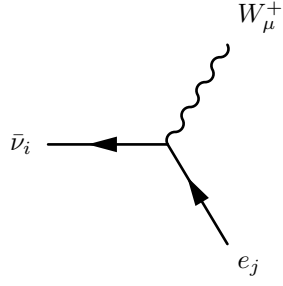
$$\frac{i}{2}\delta_{ij}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (86)$$

$$+ ig_1\cos\Theta_W\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (87)$$

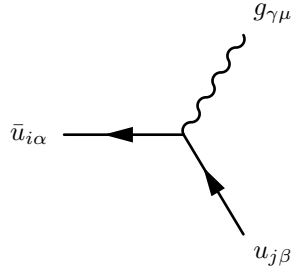


$$\frac{i}{2}\delta_{ij}\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (88)$$

$$+ -ig_1\delta_{ij}\sin\Theta_W\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (89)$$

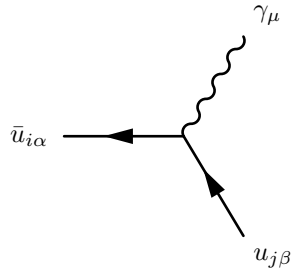


$$-i\frac{1}{\sqrt{2}}g_2U_{L,ji}^{e,*}\Theta_{i,3}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (90)$$



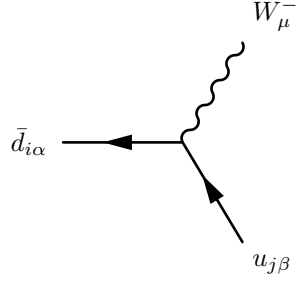
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (91)$$

$$+ -\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (92)$$

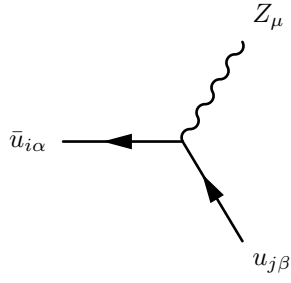


$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \left(3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (93)$$

$$+ - \frac{2i}{3} g_1 \cos \Theta_W \delta_{\alpha\beta} \delta_{ij} \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (94)$$

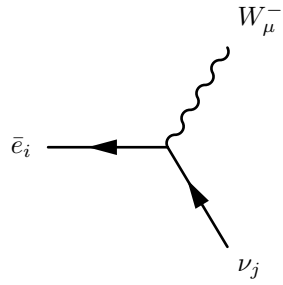


$$- i \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^3 U_{L,ja}^{u,*} U_{L,ia}^d \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (95)$$

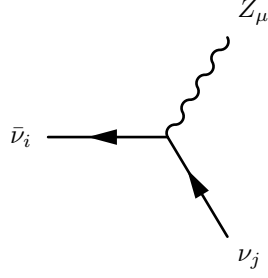


$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \left(3g_2 \cos \Theta_W - g_1 \sin \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (96)$$

$$+ \frac{2i}{3} g_1 \delta_{\alpha\beta} \delta_{ij} \sin \Theta_W \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (97)$$

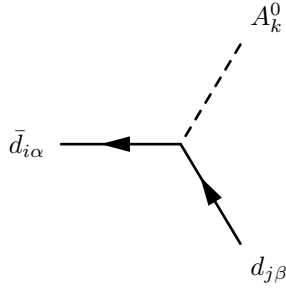


$$-i \frac{1}{\sqrt{2}} g_2 \Theta_{j,3} U_{L,ij}^e \left(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (98)$$



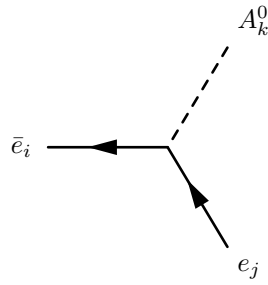
$$- \frac{i}{2} \delta_{ij} \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (99)$$

8.5 Two Fermion-One Scalar Boson-Interaction



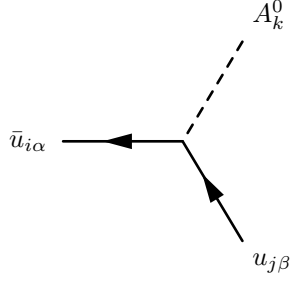
$$- \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^A \left(\frac{1-\gamma_5}{2} \right) \quad (100)$$

$$+ \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d Z_{k1}^A \left(\frac{1+\gamma_5}{2} \right) \quad (101)$$



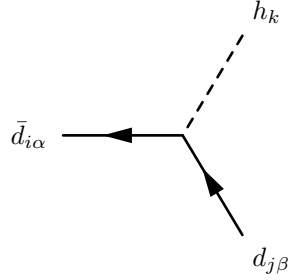
$$- \frac{1}{\sqrt{2}} \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} Z_{k1}^A \left(\frac{1-\gamma_5}{2} \right) \quad (102)$$

$$+ \frac{1}{\sqrt{2}} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e Z_{k1}^A \left(\frac{1+\gamma_5}{2} \right) \quad (103)$$



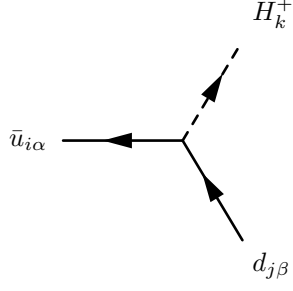
$$\frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} Z_{k2}^A \left(\frac{1-\gamma_5}{2} \right) \quad (104)$$

$$+ -\frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^u Z_{k2}^A \left(\frac{1+\gamma_5}{2} \right) \quad (105)$$



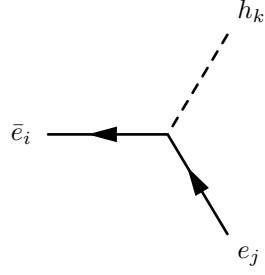
$$- i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^H \left(\frac{1-\gamma_5}{2} \right) \quad (106)$$

$$+ -i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d Z_{k1}^H \left(\frac{1+\gamma_5}{2} \right) \quad (107)$$



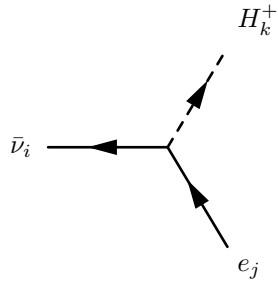
$$i\delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} Z_{k2}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (108)$$

$$+ -i\delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^u Z_{k1}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (109)$$



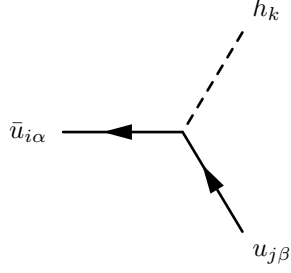
$$-i \frac{1}{\sqrt{2}} \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} Z_{k1}^H \left(\frac{1-\gamma_5}{2} \right) \quad (110)$$

$$+ -i \frac{1}{\sqrt{2}} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e Z_{k1}^H \left(\frac{1+\gamma_5}{2} \right) \quad (111)$$



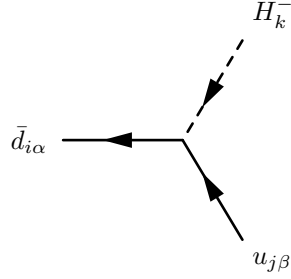
(112)

$$+ -i \sum_{a=1}^3 Y_{e,ai}^* U_{R,ja}^e Z_{k1}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (113)$$



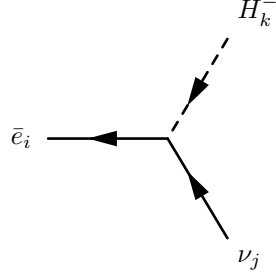
$$- i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} Z_{k2}^H \left(\frac{1-\gamma_5}{2} \right) \quad (114)$$

$$+ -i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^u Z_{k2}^H \left(\frac{1+\gamma_5}{2} \right) \quad (115)$$



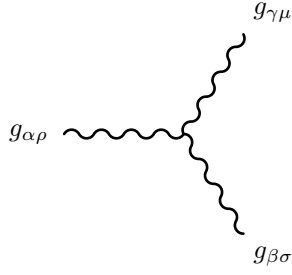
$$- i \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (116)$$

$$+ i \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^d Z_{k2}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (117)$$

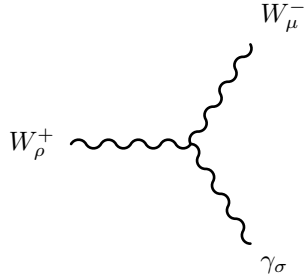


$$-i \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,aj} Z_{k1}^+ \left(\frac{1 - \gamma_5}{2} \right) \quad (118)$$

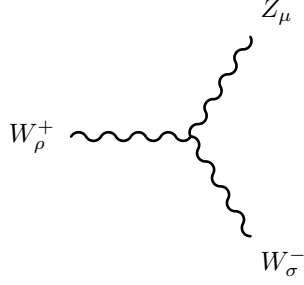
8.6 Three Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma} \left(g_{\rho\mu} \left(-p_\sigma^{g\gamma\mu} + p_\sigma^{g\alpha\rho} \right) + g_{\rho\sigma} \left(-p_\mu^{g\alpha\rho} + p_\mu^{g\beta\sigma} \right) + g_{\sigma\mu} \left(-p_\rho^{g\beta\sigma} + p_\rho^{g\gamma\mu} \right) \right) \quad (119)$$

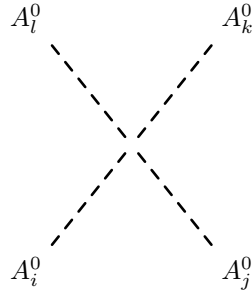


$$ig_2 \sin \Theta_W \left(g_{\rho\mu} \left(-p_\sigma^{W_\mu^-} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W_\rho^+} + p_\mu^{\gamma_\sigma} \right) + g_{\sigma\mu} \left(-p_\rho^{\gamma_\sigma} + p_\rho^{W_\mu^-} \right) \right) \quad (120)$$

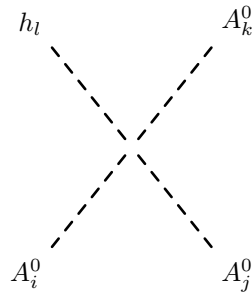


$$-ig_2 \cos \Theta_W \left(g_{\rho\mu} \left(-p_\sigma^{Z_\mu} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-} \right) + g_{\sigma\mu} \left(-p_\rho^{W_\sigma^-} + p_\rho^{Z_\mu} \right) \right) \quad (121)$$

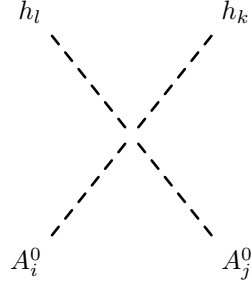
8.7 Four Scalar-Interaction



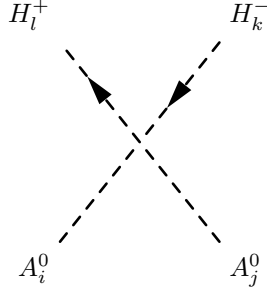
$$\begin{aligned} & -\frac{i}{2} \left(Z_{i2}^A \left((2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^*) Z_{j1}^A (Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A) \right. \right. \\ & + Z_{j2}^A \left((2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^*) Z_{k1}^A Z_{l1}^A + 6\lambda_2 Z_{k2}^A Z_{l2}^A \right) \Big) \\ & + Z_{i1}^A \left((2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^*) Z_{j2}^A (Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A) \right. \\ & + Z_{j1}^A \left((2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^*) Z_{k2}^A Z_{l2}^A + 6\lambda_1 Z_{k1}^A Z_{l1}^A \right) \Big) \Big) \end{aligned} \quad (122)$$



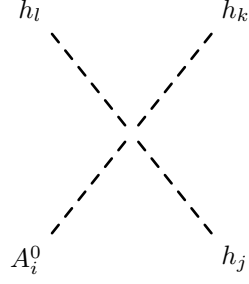
$$\begin{aligned}
& \frac{1}{2} \left(-\lambda_5^* + \lambda_5 \right) \left(Z_{i2}^A \left(Z_{j1}^A \left(-Z_{k1}^A Z_{l2}^H + Z_{k2}^A Z_{l1}^H \right) + Z_{j2}^A Z_{k1}^A Z_{l1}^H \right) \right. \\
& \left. + Z_{i1}^A \left(-Z_{j1}^A Z_{k2}^A Z_{l2}^H + Z_{j2}^A \left(-Z_{k1}^A Z_{l2}^H + Z_{k2}^A Z_{l1}^H \right) \right) \right)
\end{aligned} \tag{123}$$



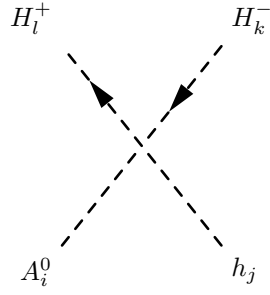
$$\begin{aligned}
& -\frac{i}{2} \left(Z_{i1}^A \left(\left(\lambda_5 + \lambda_5^* \right) Z_{j2}^A \left(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) \right. \right. \\
& + Z_{j1}^A \left(2\lambda_1 Z_{k1}^H Z_{l1}^H + \left(2\lambda_3 + 2\lambda_4 - \lambda_5 - \lambda_5^* \right) Z_{k2}^H Z_{l2}^H + 2\lambda_7 Z_{k3}^H Z_{l3}^H \right) \\
& + Z_{i2}^A \left(\left(\lambda_5 + \lambda_5^* \right) Z_{j1}^A \left(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) \right. \\
& \left. \left. + Z_{j2}^A \left(2 \left(\lambda_2 Z_{k2}^H Z_{l2}^H + \lambda_8 Z_{k3}^H Z_{l3}^H \right) + \left(2\lambda_3 + 2\lambda_4 - \lambda_5 - \lambda_5^* \right) Z_{k1}^H Z_{l1}^H \right) \right) \right)
\end{aligned} \tag{124}$$



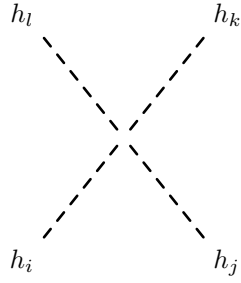
$$\begin{aligned}
& -\frac{i}{2} \left(Z_{i2}^A \left(2Z_{j2}^A \left(\lambda_2 Z_{k2}^+ Z_{l2}^+ + \lambda_3 Z_{k1}^+ Z_{l1}^+ \right) + Z_{j1}^A \left(\left(\lambda_4 + \lambda_5 \right) Z_{k1}^+ Z_{l2}^+ + \left(\lambda_4 + \lambda_5^* \right) Z_{k2}^+ Z_{l1}^+ \right) \right) \right. \\
& \left. + Z_{i1}^A \left(2Z_{j1}^A \left(\lambda_1 Z_{k1}^+ Z_{l1}^+ + \lambda_3 Z_{k2}^+ Z_{l2}^+ \right) + Z_{j2}^A \left(\left(\lambda_4 + \lambda_5 \right) Z_{k1}^+ Z_{l2}^+ + \left(\lambda_4 + \lambda_5^* \right) Z_{k2}^+ Z_{l1}^+ \right) \right) \right)
\end{aligned} \tag{125}$$



$$\begin{aligned}
& \frac{1}{2} \left(-\lambda_5^* + \lambda_5 \right) \left(Z_{i2}^A \left(Z_{j1}^H \left(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) + Z_{j2}^H Z_{k1}^H Z_{l1}^H \right) \right. \\
& \left. - Z_{i1}^A \left(Z_{j1}^H Z_{k2}^H Z_{l2}^H + Z_{j2}^H \left(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) \right) \right)
\end{aligned} \tag{126}$$

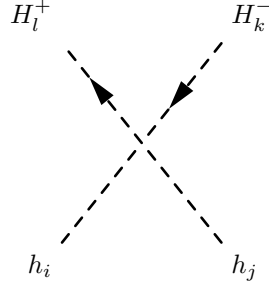


$$\frac{1}{2} \left(-Z_{i1}^A Z_{j2}^H + Z_{i2}^A Z_{j1}^H \right) \left(\left(-\lambda_4 + \lambda_5 \right) Z_{k1}^+ Z_{l2}^+ + \left(-\lambda_5^* + \lambda_4 \right) Z_{k2}^+ Z_{l1}^+ \right) \tag{127}$$

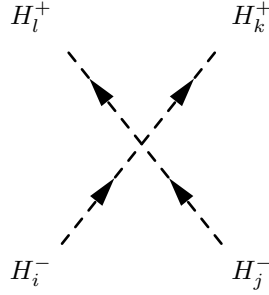


$$\begin{aligned}
& -\frac{i}{2} \left(2Z_{i3}^H \left(\lambda_7 Z_{j1}^H \left(Z_{k1}^H Z_{l3}^H + Z_{k3}^H Z_{l1}^H \right) + \lambda_8 Z_{j2}^H \left(Z_{k2}^H Z_{l3}^H + Z_{k3}^H Z_{l2}^H \right) \right) \right. \\
& \left. + Z_{j3}^H \left(3\lambda_6 Z_{k3}^H Z_{l3}^H + \lambda_7 Z_{k1}^H Z_{l1}^H + \lambda_8 Z_{k2}^H Z_{l2}^H \right) \right)
\end{aligned}$$

$$\begin{aligned}
& + Z_{i1}^H \left((2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^*) Z_{j2}^H (Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H) + 2\lambda_7 Z_{j3}^H (Z_{k1}^H Z_{l3}^H + Z_{k3}^H Z_{l1}^H) \right. \\
& + Z_{j1}^H \left((2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^*) Z_{k2}^H Z_{l2}^H + 2\lambda_7 Z_{k3}^H Z_{l3}^H + 6\lambda_1 Z_{k1}^H Z_{l1}^H \right) \\
& + Z_{i2}^H \left((2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^*) Z_{j1}^H (Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H) + 2\lambda_8 Z_{j3}^H (Z_{k2}^H Z_{l3}^H + Z_{k3}^H Z_{l2}^H) \right. \\
& \left. \left. + Z_{j2}^H \left((2\lambda_3 + 2\lambda_4 + \lambda_5 + \lambda_5^*) Z_{k1}^H Z_{l1}^H + 2\lambda_8 Z_{k3}^H Z_{l3}^H + 6\lambda_2 Z_{k2}^H Z_{l2}^H \right) \right) \right) \quad (128)
\end{aligned}$$

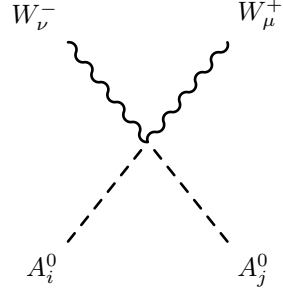


$$\begin{aligned}
& - \frac{i}{2} \left(2Z_{i3}^H Z_{j3}^H (\lambda_7 Z_{k1}^+ Z_{l1}^+ + \lambda_8 Z_{k2}^+ Z_{l2}^+) \right. \\
& + Z_{i2}^H \left(2Z_{j2}^H (\lambda_2 Z_{k2}^+ Z_{l2}^+ + \lambda_3 Z_{k1}^+ Z_{l1}^+) + Z_{j1}^H \left((\lambda_4 + \lambda_5) Z_{k1}^+ Z_{l2}^+ + (\lambda_4 + \lambda_5^*) Z_{k2}^+ Z_{l1}^+ \right) \right) \\
& \left. + Z_{i1}^H \left(2Z_{j1}^H (\lambda_1 Z_{k1}^+ Z_{l1}^+ + \lambda_3 Z_{k2}^+ Z_{l2}^+) + Z_{j2}^H \left((\lambda_4 + \lambda_5) Z_{k1}^+ Z_{l2}^+ + (\lambda_4 + \lambda_5^*) Z_{k2}^+ Z_{l1}^+ \right) \right) \right) \quad (129)
\end{aligned}$$

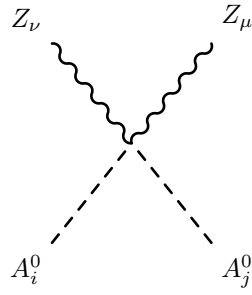


$$\begin{aligned}
& - i \left(Z_{i2}^+ \left(2\lambda_2 Z_{j2}^+ Z_{k2}^+ Z_{l2}^+ + 2\lambda_5^* Z_{j2}^+ Z_{k1}^+ Z_{l1}^+ + (\lambda_3 + \lambda_4) Z_{j1}^+ (Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+) \right) \right. \\
& \left. + Z_{i1}^+ \left(2Z_{j1}^+ (\lambda_1 Z_{k1}^+ Z_{l1}^+ + \lambda_5 Z_{k2}^+ Z_{l2}^+) + (\lambda_3 + \lambda_4) Z_{j2}^+ (Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+) \right) \right) \quad (130)
\end{aligned}$$

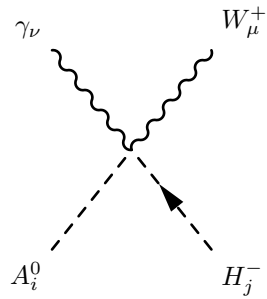
8.8 Two Scalar-Two Vector Boson-Interaction



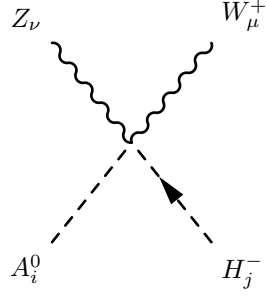
$$\frac{i}{2}g_2^2\left(Z_{i1}^AZ_{j1}^A+Z_{i2}^AZ_{j2}^A\right)\left(g_{\mu\nu}\right) \quad (131)$$



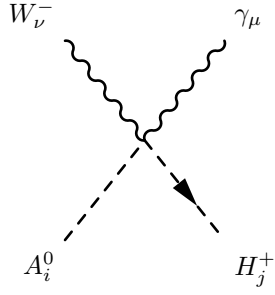
$$\frac{i}{2}\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)^2\left(Z_{i1}^AZ_{j1}^A+Z_{i2}^AZ_{j2}^A\right)\left(g_{\mu\nu}\right) \quad (132)$$



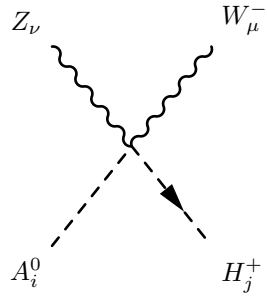
$$-\frac{1}{2}g_1g_2\cos\Theta_W\left(Z_{i1}^AZ_{j1}^++Z_{i2}^AZ_{j2}^+\right)\left(g_{\mu\nu}\right) \quad (133)$$



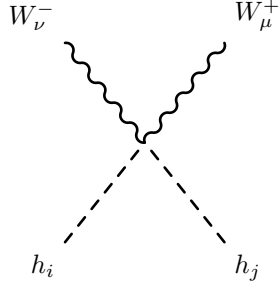
$$\frac{1}{2}g_1g_2\sin\Theta_W\left(Z_{i1}^AZ_{j1}^++Z_{i2}^AZ_{j2}^+\right)\left(g_{\mu\nu}\right) \quad (134)$$



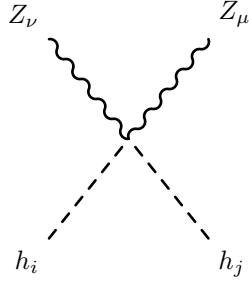
$$\frac{1}{2}g_1g_2\cos\Theta_W\left(Z_{i1}^AZ_{j1}^++Z_{i2}^AZ_{j2}^+\right)\left(g_{\mu\nu}\right) \quad (135)$$



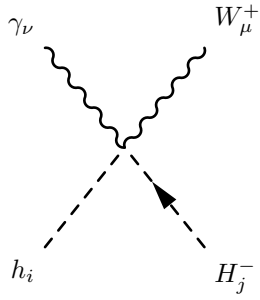
$$-\frac{1}{2}g_1g_2\sin\Theta_W\left(Z_{i1}^AZ_{j1}^++Z_{i2}^AZ_{j2}^+\right)\left(g_{\mu\nu}\right) \quad (136)$$



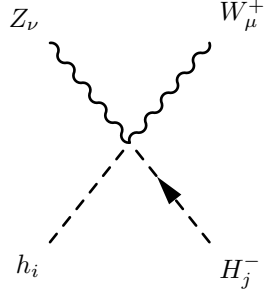
$$\frac{i}{2}g_2^2\left(Z_{i1}^HZ_{j1}^H+Z_{i2}^HZ_{j2}^H\right)\left(g_{\mu\nu}\right) \quad (137)$$



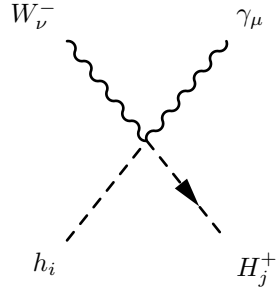
$$\frac{i}{2}\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)^2\left(Z_{i1}^HZ_{j1}^H+Z_{i2}^HZ_{j2}^H\right)\left(g_{\mu\nu}\right) \quad (138)$$



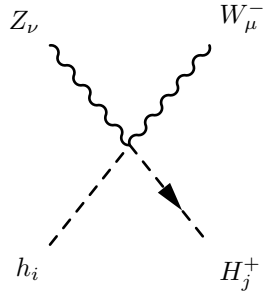
$$\frac{i}{2}g_1g_2\cos\Theta_W\left(Z_{i1}^HZ_{j1}^++Z_{i2}^HZ_{j2}^+\right)\left(g_{\mu\nu}\right) \quad (139)$$



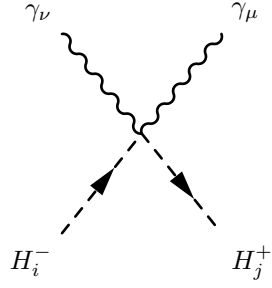
$$-\frac{i}{2}g_1g_2\sin\Theta_W\left(Z_{i1}^HZ_{j1}^++Z_{i2}^HZ_{j2}^+\right)\left(g_{\mu\nu}\right) \quad (140)$$



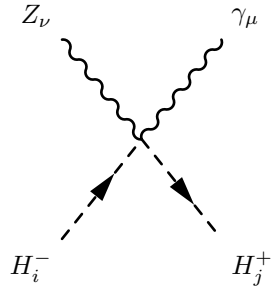
$$\frac{i}{2}g_1g_2\cos\Theta_W\left(Z_{i1}^HZ_{j1}^++Z_{i2}^HZ_{j2}^+\right)\left(g_{\mu\nu}\right) \quad (141)$$



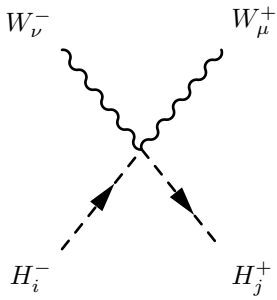
$$-\frac{i}{2}g_1g_2\sin\Theta_W\left(Z_{i1}^HZ_{j1}^++Z_{i2}^HZ_{j2}^+\right)\left(g_{\mu\nu}\right) \quad (142)$$



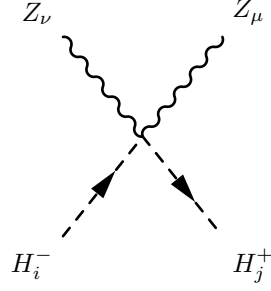
$$\frac{i}{2} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right)^2 \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (143)$$



$$-\frac{i}{4} \left(-2g_1 g_2 \cos 2\Theta_W + \left(-g_2^2 + g_1^2 \right) \sin 2\Theta_W \right) \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (144)$$

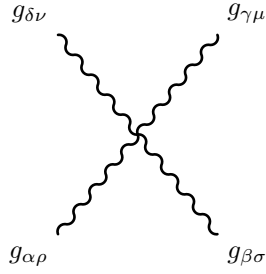


$$\frac{i}{2} g_2^2 \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (145)$$



$$\frac{i}{2} \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (146)$$

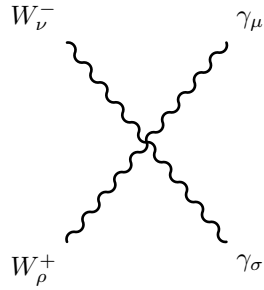
8.9 Four Vector Boson-Interaction



$$-ig_3^2 \left(\sum_{a=1}^8 f_{\alpha,\delta,a} f_{\beta,\gamma,a} + \sum_{a=1}^8 f_{\alpha,\gamma,a} f_{\beta,\delta,a} \right) (g_{\rho\sigma} g_{\mu\nu}) \quad (147)$$

$$+ ig_3^2 \left(-\sum_{a=1}^8 f_{\alpha,\beta,a} f_{\gamma,\delta,a} + \sum_{a=1}^8 f_{\alpha,\delta,a} f_{\beta,\gamma,a} \right) (g_{\rho\mu} g_{\sigma\nu}) \quad (148)$$

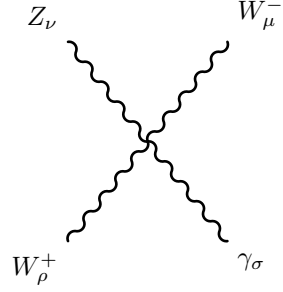
$$+ ig_3^2 \left(\sum_{a=1}^8 f_{\alpha,\gamma,a} f_{\beta,\delta,a} + \sum_{a=1}^8 f_{\alpha,\beta,a} f_{\gamma,\delta,a} \right) (g_{\rho\nu} g_{\sigma\mu}) \quad (149)$$



$$ig_2^2 \sin \Theta_W^2 (g_{\rho\sigma} g_{\mu\nu}) \quad (150)$$

$$+ ig_2^2 \sin \Theta_W^2 (g_{\rho\mu} g_{\sigma\nu}) \quad (151)$$

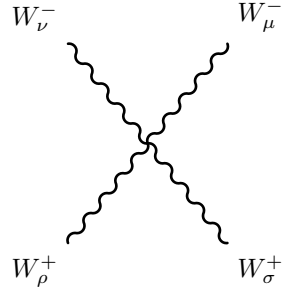
$$+ -2ig_2^2 \sin \Theta_W^2 (g_{\rho\nu} g_{\sigma\mu}) \quad (152)$$



$$ig_2^2 \cos \Theta_W \sin \Theta_W (g_{\rho\sigma} g_{\mu\nu}) \quad (153)$$

$$+ -ig_2^2 \sin 2\Theta_W (g_{\rho\mu} g_{\sigma\nu}) \quad (154)$$

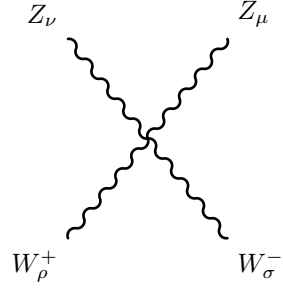
$$+ ig_2^2 \cos \Theta_W \sin \Theta_W (g_{\rho\nu} g_{\sigma\mu}) \quad (155)$$



$$2ig_2^2 (g_{\rho\sigma} g_{\mu\nu}) \quad (156)$$

$$+ -ig_2^2 (g_{\rho\mu} g_{\sigma\nu}) \quad (157)$$

$$+ -ig_2^2 (g_{\rho\nu} g_{\sigma\mu}) \quad (158)$$

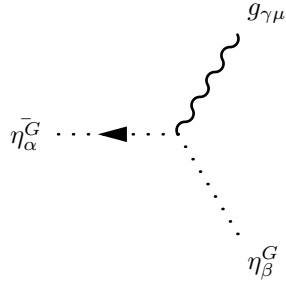


$$- 2ig_2^2 \cos \Theta_W^2 \left(g_{\rho\sigma} g_{\mu\nu} \right) \quad (159)$$

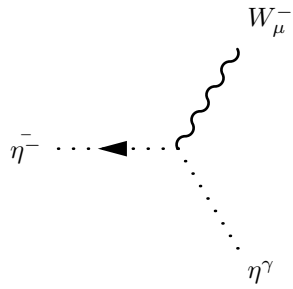
$$+ ig_2^2 \cos \Theta_W^2 \left(g_{\rho\mu} g_{\sigma\nu} \right) \quad (160)$$

$$+ ig_2^2 \cos \Theta_W^2 \left(g_{\rho\nu} g_{\sigma\mu} \right) \quad (161)$$

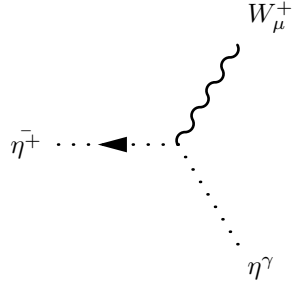
8.10 Two Ghosts-One Vector Boson-Interaction



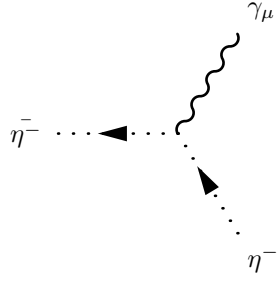
$$g_3 f_{\alpha,\beta,\gamma} \left(p_\mu^{\eta_\beta^G} \right) \quad (162)$$



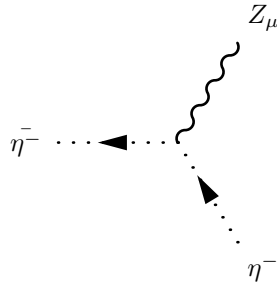
$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^\gamma} \right) \quad (163)$$



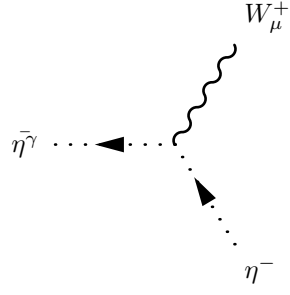
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^\gamma}) \quad (164)$$



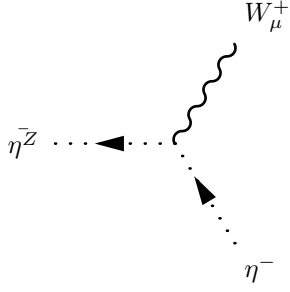
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^-}) \quad (165)$$



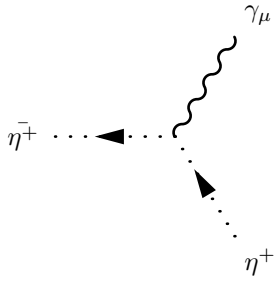
$$-ig_2 \cos \Theta_W (p_\mu^{\eta^-}) \quad (166)$$



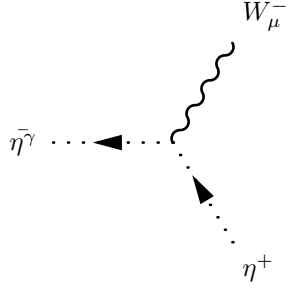
$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^-} \right) \quad (167)$$



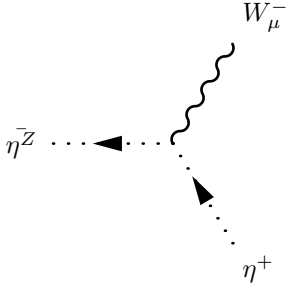
$$ig_2 \cos \Theta_W \left(p_\mu^{\eta^-} \right) \quad (168)$$



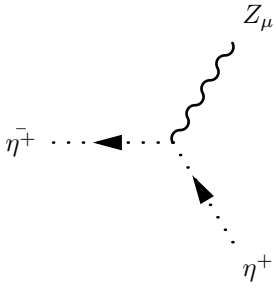
$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^+} \right) \quad (169)$$



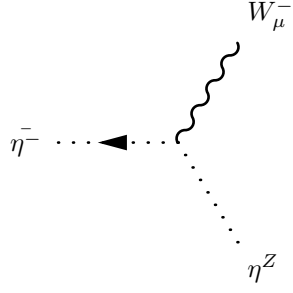
$$-ig_2 \sin \Theta_W (p_{\mu}^{\eta^{+}}) \quad (170)$$



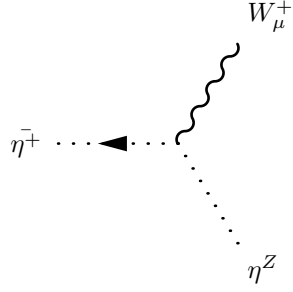
$$-ig_2 \cos \Theta_W (p_{\mu}^{\eta^{+}}) \quad (171)$$



$$ig_2 \cos \Theta_W (p_{\mu}^{\eta^{+}}) \quad (172)$$

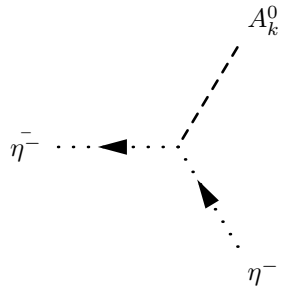


$$ig_2 \cos \Theta_W \left(p_\mu^{\eta^Z} \right) \quad (173)$$

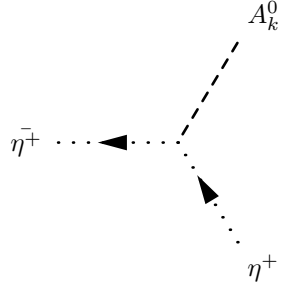


$$-ig_2 \cos \Theta_W \left(p_\mu^{\eta^Z} \right) \quad (174)$$

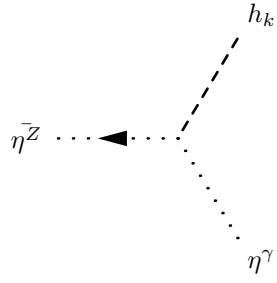
8.11 Two Ghosts-One Scalar-Interaction



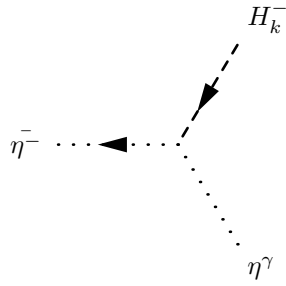
$$-\frac{1}{4}g_2^2 \xi_{W^-} \left(v_1 Z_{k1}^A + v_2 Z_{k2}^A \right) \quad (175)$$



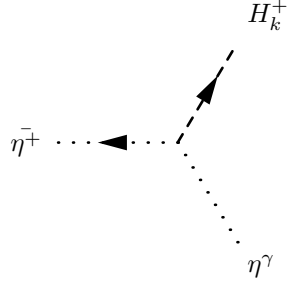
$$\frac{1}{4}g_2^2\xi_{W-}\left(v_1Z_{k1}^A+v_2Z_{k2}^A\right) \quad (176)$$



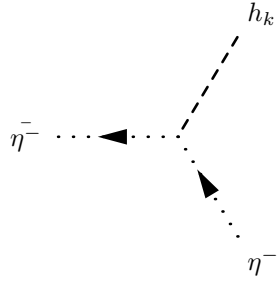
$$\frac{i}{8}\xi_Z\left(2g_1g_2\cos 2\Theta_W+\left(-g_2^2+g_1^2\right)\sin 2\Theta_W\right)\left(v_1Z_{k1}^H+v_2Z_{k2}^H\right) \quad (177)$$



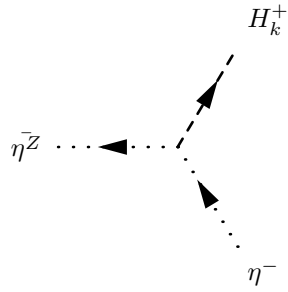
$$-\frac{i}{4}g_2\xi_{W-}\left(g_1\cos \Theta_W+g_2\sin \Theta_W\right)\left(v_1Z_{k1}^++v_2Z_{k2}^+\right) \quad (178)$$



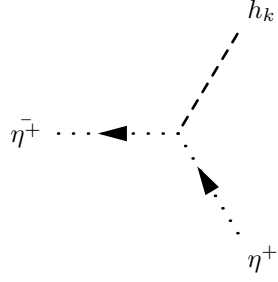
$$-\frac{i}{4}g_2\xi_{W^-}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)\left(v_1Z_{k1}^++v_2Z_{k2}^+\right) \quad (179)$$



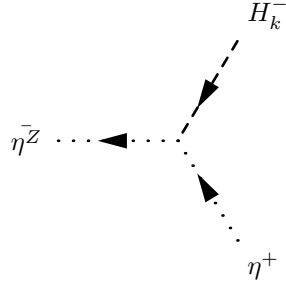
$$-\frac{i}{4}g_2^2\xi_{W^-}\left(v_1Z_{k1}^H+v_2Z_{k2}^H\right) \quad (180)$$



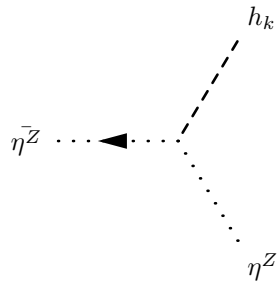
$$\frac{i}{4}g_2\xi_Z\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(v_1Z_{k1}^++v_2Z_{k2}^+\right) \quad (181)$$



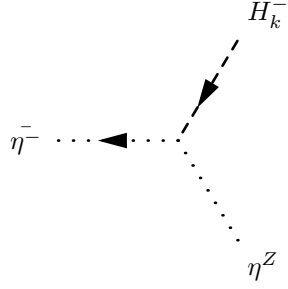
$$-\frac{i}{4}g_2^2\xi_{W^-}\left(v_1Z_{k1}^H+v_2Z_{k2}^H\right) \quad (182)$$



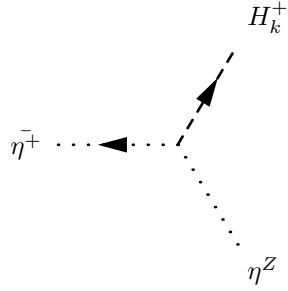
$$\frac{i}{4}g_2\xi_Z\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(v_1Z_{k1}^++v_2Z_{k2}^+\right) \quad (183)$$



$$-\frac{i}{4}\xi_Z\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)^2\left(v_1Z_{k1}^H+v_2Z_{k2}^H\right) \quad (184)$$



$$-\frac{i}{4}g_2\xi_{W-}\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(v_1Z_{k1}^++v_2Z_{k2}^+\right) \quad (185)$$



$$-\frac{i}{4}g_2\xi_{W-}\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(v_1Z_{k1}^++v_2Z_{k2}^+\right) \quad (186)$$

9 Clebsch-Gordan Coefficients