

U(1)B extension for Bariogenesis Lagrangian, Rotations and Interactions for eigenstates 'EWSB'

SARAH 4.12.3

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

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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
VBp	$U(1)$	g_B	U1B

1.2 Matter Superfields

Name	Spin	Generations	$(U(1) \otimes SU(2) \otimes SU(3) \otimes U(1))$
H	0	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1}, 0)$
bi	0	1	$(0, \mathbf{1}, \mathbf{1}, 5)$
bj	0	1	$(0, \mathbf{1}, \mathbf{1}, 5)$
S1	0	2	$(-1, \mathbf{1}, \mathbf{1}, -1)$
S2	0	2	$(-1, \mathbf{1}, \mathbf{1}, 4)$
q	$\frac{1}{2}$	3	$(\frac{1}{6}, \mathbf{2}, \mathbf{3}, -\frac{5}{9})$
l	$\frac{1}{2}$	3	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1}, 0)$
d	$\frac{1}{2}$	3	$(\frac{1}{3}, \mathbf{1}, \mathbf{\bar{3}}, \frac{5}{9})$
u	$\frac{1}{2}$	3	$(-\frac{2}{3}, \mathbf{1}, \mathbf{\bar{3}}, \frac{5}{9})$
e	$\frac{1}{2}$	3	$(1, \mathbf{1}, \mathbf{1}, 0)$
v	$\frac{1}{2}$	2	$(0, \mathbf{1}, \mathbf{1}, -5)$
x3	$\frac{1}{2}$	1	$(0, \mathbf{1}, \mathbf{1}, 3)$
x4	$\frac{1}{2}$	1	$(0, \mathbf{1}, \mathbf{1}, 2)$
x5	$\frac{1}{2}$	1	$(1, \mathbf{1}, \mathbf{1}, 1)$
x6	$\frac{1}{2}$	1	$(-1, \mathbf{1}, \mathbf{1}, -6)$
lp	$\frac{1}{2}$	1	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1}, -1)$
lpp	$\frac{1}{2}$	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1}, 6)$

2 Lagrangian

2.1 Input Lagrangian for Eigenstates GaugeES

$$\begin{aligned}
L = & -\mu'_i |\text{BiD}|^2 - \mu_h |H^0|^2 - \mu_h |H^+|^2 - \mu'_j |S|^2 + \text{BiD}^2 \lambda_2 \text{conj}(\text{BiD})^2 + H^0 \lambda_3 |\text{BiD}|^2 H^{0,*} + H^{0,2} l_h H^{0,*},2 \\
& + H^+ \lambda_3 |\text{BiD}|^2 H^{+,*} + 2H^+ l_h |H^0|^2 H^{+,*} + H^{+,2} l_h H^{+,*},2 + \lambda_5 S |H^0|^2 S^* + \lambda_5 S |H^+|^2 S^* + \lambda_4 S^2 S^{*,2}
\end{aligned}$$

$$\begin{aligned}
& -H^0 d_{L,k\gamma}^* Y_{d,jk}^* \delta_{\beta\gamma} d_{R,j\beta} - H^+ u_{L,k\gamma}^* Y_{d,jk}^* \delta_{\beta\gamma} d_{R,j\beta} - \lambda_{c1} \text{conj}(\text{BiD}) \text{conj}(\text{ep}(2)) \text{ep}(1) - \lambda_{c2} S^* \text{conj}(\text{ep}(2)) \text{ep}(1) \\
& - \lambda_g H^{0,*} \text{conj}(\text{x5R}(2)) \text{ep}(1) - \lambda_{c1} \text{conj}(\text{BiD}) \text{conj}(\text{ep}(1)) \text{ep}(2) - \lambda_{c2} S^* \text{conj}(\text{ep}(1)) \text{ep}(2) - \lambda_g H^{0,*} \text{conj}(\text{x5R}(1)) \text{ep}(2) \\
& - S \lambda_{c2} \text{conj}(\text{ep}(2)) \text{ep}(1) - \lambda_h H^{0,*} \text{conj}(\text{x6L}(2)) \text{ep}(1) - \text{BiD} \lambda_{c1} \text{conj}(\text{ep}(1)) \text{ep}(2) - S \lambda_{c2} \text{conj}(\text{ep}(1)) \text{ep}(2) - \lambda_h H^{0,*} \text{conj}(\text{x6L}(1)) \text{ep}(2) \\
& - H^0 e_{L,k}^* Y_{e,jk}^* e_{R,j} - H^+ \nu_{L,k}^* Y_{e,jk}^* e_{R,j} + \lambda_{d,ij}^* \text{conj}(\text{vp}(2)) \text{conj}(\text{eL}(\{\text{gt}2\})(1)) \text{s1}(\{\text{gt}1\}) + \lambda_{d,ij}^* \text{conj}(\text{vp}(1)) \text{conj}(\text{eL}(\{\text{gt}2\})(2)) \\
& - \text{conj}(\text{ep}(1)) \lambda_{d,ij}^* \text{conj}(\text{vL}(\{\text{gt}2\})(2)) \text{s1}(\{\text{gt}1\}) - \text{BiD} \text{conj}(\text{s2}(\{\text{gt}2\})) \lambda_{fi,ij} \text{s1}(\{\text{gt}1\}) - S \text{conj}(\text{s2}(\{\text{gt}2\})) \lambda_{fj,ij} \text{s1}(\{\text{gt}1\}) \\
& - \text{conj}(\text{s1}(\{\text{gt}1\})) \mu_{1,ij} \text{s1}(\{\text{gt}2\}) - \text{conj}(\text{x5R}(2)) \text{conj}(\text{vR}(\{\text{gt}3\})(1)) \lambda_{e,ik} \text{s2}(\{\text{gt}1\}) - \text{conj}(\text{x5R}(1)) \text{conj}(\text{vR}(\{\text{gt}3\})(2)) \\
& - |H^0|^2 \text{conj}(\text{s2}(\{\text{gt}1\})) \lambda_{7,ij} \text{s2}(\{\text{gt}2\}) - |H^+|^2 \text{conj}(\text{s2}(\{\text{gt}1\})) \lambda_{7,ij} \text{s2}(\{\text{gt}2\}) - \text{conj}(\text{s2}(\{\text{gt}1\})) \mu_{2,ij} \text{s2}(\{\text{gt}2\}) - H^{+,*} d_{L,k}^* \\
& + H^{0,*} u_{L,k\gamma}^* Y_{u,jk}^* \delta_{\beta\gamma} u_{R,j\beta} - \lambda_{c1} \text{conj}(\text{BiD}) \text{conj}(\text{vpp}(2)) \text{vp}(1) - \lambda_{c2} S^* \text{conj}(\text{vpp}(2)) \text{vp}(1) - \lambda_g H^{+,*} \text{conj}(\text{x5R}(2)) \text{vp}(1) - \\
& - \lambda_{c2} S^* \text{conj}(\text{vpp}(1)) \text{vp}(2) - \lambda_g H^{+,*} \text{conj}(\text{x5R}(1)) \text{vp}(2) - \text{BiD} \lambda_{c1} \text{conj}(\text{vp}(2)) \text{vpp}(1) - S \lambda_{c2} \text{conj}(\text{vp}(2)) \text{vpp}(1) - \lambda_h H^{0,*} \text{conj}(\text{x6L}(2)) \text{vpp}(1) \\
& - \text{BiD} \lambda_{c1} \text{conj}(\text{vp}(1)) \text{vpp}(2) - S \lambda_{c2} \text{conj}(\text{vp}(1)) \text{vpp}(2) - \lambda_h H^{+,*} \text{conj}(\text{x6L}(1)) \text{vpp}(2) - \lambda_{a1} \text{conj}(\text{BiD}) \text{conj}(\text{x4R}(2)) \text{x3L}(1) \\
& - \lambda_{a1} \text{conj}(\text{BiD}) \text{conj}(\text{x4R}(1)) \text{x3L}(2) - \lambda_{a2} S^* \text{conj}(\text{x4R}(1)) \text{x3L}(2) - \text{BiD} \lambda_{a1} \text{conj}(\text{x3L}(2)) \text{x4R}(1) - S \lambda_{a2} \text{conj}(\text{x3L}(2)) \text{x4R}(1) \\
& - S \lambda_{a2} \text{conj}(\text{x3L}(1)) \text{x4R}(2) - H^0 \lambda_g^* \text{conj}(\text{ep}(2)) \text{x5R}(1) - H^+ \lambda_g^* \text{conj}(\text{vp}(2)) \text{x5R}(1) - \lambda_{b1} \text{conj}(\text{BiD}) \text{conj}(\text{x6L}(2)) \text{x5R}(1) \\
& - H^0 \lambda_g^* \text{conj}(\text{ep}(1)) \text{x5R}(2) - H^+ \lambda_g^* \text{conj}(\text{vp}(1)) \text{x5R}(2) - \lambda_{b1} \text{conj}(\text{BiD}) \text{conj}(\text{x6L}(1)) \text{x5R}(2) - \lambda_{b2} S^* \text{conj}(\text{x6L}(1)) \text{x5R}(2) \\
& - H^+ \lambda_h \text{conj}(\text{vpp}(2)) \text{x6L}(1) - \text{BiD} \lambda_{b1} \text{conj}(\text{x5R}(2)) \text{x6L}(1) - S \lambda_{b2} \text{conj}(\text{x5R}(2)) \text{x6L}(1) - H^0 \lambda_h \text{conj}(\text{ep}(1)) \text{x6L}(2) - \\
& - \text{BiD} \lambda_{b1} \text{conj}(\text{x5R}(1)) \text{x6L}(2) - S \lambda_{b2} \text{conj}(\text{x5R}(1)) \text{x6L}(2) - H^{0,*} d_{R,j\beta}^* \delta_{\beta\gamma} d_{L,k\gamma} Y_{d,jk} - H^{+,*} d_{R,j\beta}^* \delta_{\beta\gamma} u_{L,k\gamma} Y_{d,jk} \\
& - H^{0,*} e_{R,j}^* e_{L,k} Y_{e,jk} - H^{+,*} e_{R,j}^* \nu_{L,k} Y_{e,jk} - H^+ u_{R,j\beta}^* \delta_{\beta\gamma} d_{L,k\gamma} Y_{u,jk} + H^0 u_{R,j\beta}^* \delta_{\beta\gamma} u_{L,k\gamma} Y_{u,jk} \\
& + \text{conj}(\text{s1}(\{\text{gt}1\})) \lambda_{d,ij} \text{vp}(2) \text{eL}(\{\text{gt}2\})(1) + \text{conj}(\text{s1}(\{\text{gt}1\})) \lambda_{d,ij} \text{vp}(1) \text{eL}(\{\text{gt}2\})(2) - \text{conj}(\text{s1}(\{\text{gt}1\})) \text{ep}(2) \lambda_{d,ij} \text{vL}(\{\text{gt}2\})(1) \\
& - \lambda_{e,ik}^* \text{conj}(\text{s2}(\{\text{gt}1\})) \text{x5R}(1) \text{vR}(\{\text{gt}3\})(2) \tag{1}
\end{aligned}$$

2.2 Gauge fixing terms

2.2.1 Gauge fixing terms for eigenstates 'GaugeES'

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

2.2.2 Gauge fixing terms for eigenstates 'EWSB'

$$\begin{aligned}
L_{GF} = & -\frac{1}{2} |\partial_\mu g|^2 \xi_g^{-1} - \frac{1}{2} |\partial_\mu \gamma|^2 \xi_\gamma^{-1} - \frac{i}{2} g_2 v H^{+,*} \xi_{W^-} + \partial_\mu W^-|^2 \xi_{W^-}^{-1} \\
& - \frac{1}{2} |\xi_Z| - \frac{1}{2} \xi_Z \left(- \left(10 g_B \text{sigma} B v x + g_{BY} \text{sigma} H v \right) \sin \Theta'_W + \left(10 g_Y \text{sigma} B v x + g_1 \text{sigma} H v \right) \cos \Theta'_W \sin \Theta_W + g_2 \text{sigma} H v \right)
\end{aligned}$$

$$-\frac{1}{2}|\frac{1}{2}\left(2\partial_\mu Z' + \xi_{Z'}\left(\left(10g_B\text{sigmaB}vx + g_{BY}\text{sigmaH}v\right)\cos\Theta'_W + \left(10g_{YB}\text{sigmaB}vx\sin\Theta_W + g_1\text{sigmaH}v\sin\Theta_W + g_2\text{sigmaH}v\cos\Theta_W\right)\right)\right| \quad (3)$$

2.3 Fields integrated out

None

3 Field Rotations

3.1 Rotations in gauge sector for eigenstates 'EWSB'

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \\ \text{VBp}(\{\text{lt1}\}) \end{pmatrix} = Z^{\gamma Z Z'} \begin{pmatrix} \gamma_\rho \\ Z_\rho \\ Z'_\rho \end{pmatrix} \quad (4)$$

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

(6)

The mixing matrices are parametrized by

$$Z^{\gamma Z Z'} = \begin{pmatrix} \cos \Theta_W & -\cos \Theta'_W \sin \Theta_W & \sin \Theta_W \sin \Theta'_W \\ \sin \Theta_W & \cos \Theta_W \cos \Theta'_W & -\cos \Theta_W \sin \Theta'_W \\ 0 & \sin \Theta'_W & \cos \Theta'_W \end{pmatrix} \quad (7)$$

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

(9)

3.2 Rotations in Mass sector for eigenstates 'EWSB'

3.2.1 Mass Matrices for Scalars

- Mass matrix for Higgs, Basis: $(\phi_H, \phi_B), (\phi_H, \phi_B)$

$$m_h^2 = \begin{pmatrix} -3l_h v^2 - \frac{1}{2}\lambda_3 v x^2 + \mu_h & -\lambda_3 v v x \\ -\lambda_3 v v x & -3\lambda_2 v x^2 - \frac{1}{2}\lambda_3 v^2 + \mu'_i \end{pmatrix} \quad (10)$$

This matrix is diagonalized by Z^H :

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \quad (11)$$

with

$$\text{phiH} = \sum_j Z_{j1}^H h_j, \quad \text{phiB} = \sum_j Z_{j2}^H h_j \quad (12)$$

- **Mass matrix for Pseudo-Scalar Higgs**, Basis: $(\text{sigmaH}, \text{sigmaB}), (\text{sigmaH}, \text{sigmaB})$

$$m_{A_h}^2 = \begin{pmatrix} -\frac{1}{2}\lambda_3 vx^2 - l_h v^2 + \mu_h & 0 \\ 0 & -\frac{1}{2}\lambda_3 v^2 - \lambda_2 vx^2 + \mu'_i \end{pmatrix} + \xi_Z m^2(Z) + \xi_{Z'} m^2(Z') \quad (13)$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} m_{\text{sigmaHsigmaH}} & m_{\text{sigmaBsigmaH}} \\ m_{\text{sigmaHsigmaB}} & m_{\text{sigmaBsigmaB}} \end{pmatrix} \quad (14)$$

$$m_{\text{sigmaHsigmaH}} = \frac{1}{4}v^2 \left(\cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W) - g_{BY} \sin \Theta'_W \right)^2 \quad (15)$$

$$m_{\text{sigmaHsigmaB}} = \frac{5}{2}v vx \left(\cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W) - g_{BY} \sin \Theta'_W \right) \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right) \quad (16)$$

$$m_{\text{sigmaBsigmaB}} = 25vx^2 \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right)^2 \quad (17)$$

$$m^2(\xi_{Z'}) = \begin{pmatrix} m_{\text{sigmaHsigmaH}} & m_{\text{sigmaBsigmaH}} \\ m_{\text{sigmaHsigmaB}} & m_{\text{sigmaBsigmaB}} \end{pmatrix} \quad (18)$$

$$m_{\text{sigmaHsigmaH}} = \frac{1}{4}v^2 \left((g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right)^2 \quad (19)$$

$$m_{\text{sigmaHsigmaB}} = \frac{5}{2}v vx \left(g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right) \left((g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) \quad (20)$$

$$m_{\text{sigmaBsigmaB}} = 25vx^2 \left(g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right)^2 \quad (21)$$

This matrix is diagonalized by Z^A :

$$Z^A m_{A_h}^2 Z^{A,\dagger} = m_{2,A_h}^{dia} \quad (22)$$

with

$$\text{sigmaH} = \sum_j Z_{j1}^A A_{h,j}, \quad \text{sigmaB} = \sum_j Z_{j2}^A A_{h,j} \quad (23)$$

- **Mass matrix for Charged Higgs**, Basis: $(H^{+,*}, s1, s2), (H^+, \text{conj}(s1), \text{conj}(s2))$

$$m_{H^-}^2 = \begin{pmatrix} -\frac{1}{2}\lambda_3 vx^2 - l_h v^2 + \mu_h & 0 & 0 \\ 0 & \frac{1}{2}\lambda_6 v^2 + \mu_1 & \frac{1}{\sqrt{2}}\lambda_{fi} vx \\ 0 & \frac{1}{\sqrt{2}}vx \lambda_{fi}^T & \frac{1}{2}\lambda_7 v^2 + \mu_2 \end{pmatrix} + \xi_{W^-} m^2(W^-) \quad (24)$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4}g_2^2v^2 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad (25)$$

This matrix is diagonalized by Z^+ :

$$Z^+ m_{H^-}^2 Z^{+, \dagger} = m_{2, H^-}^{dia} \quad (26)$$

with

$$H^+ = \sum_j Z_{j1}^+ H_j^+, \quad s1(\{\text{gt}1\}) = \sum_j Z_{ji}^+ H_j^-, \quad s2(\{\text{gt}1\}) = \sum_j Z_{ji}^+ H_j^- \quad (27)$$

3.2.2 Mass Matrices for Fermions

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

$$m_d = \left(\frac{1}{\sqrt{2}} v \delta_{\alpha_1 \beta_1} Y_d^T \right) \quad (28)$$

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

$$U_L^{d,*} m_d U_R^{d, \dagger} = m_d^{dia} \quad (29)$$

with

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

$$d_{R, i\alpha} = \sum_{t_2} U_{R, ij}^d D_{R, j\alpha}^* \quad (31)$$

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

$$m_u = \left(-\frac{1}{\sqrt{2}} v \delta_{\alpha_1 \beta_1} Y_u^T \right) \quad (32)$$

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

$$U_L^{u,*} m_u U_R^{u, \dagger} = m_u^{dia} \quad (33)$$

with

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

$$u_{R, i\alpha} = \sum_{t_2} U_{R, ij}^u U_{R, j\alpha}^* \quad (35)$$

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

$$m_e = \left(\frac{1}{\sqrt{2}} v Y_e^T \right) \quad (36)$$

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

$$U_L^{e,*} m_e U_R^{e,\dagger} = m_e^{dia} \quad (37)$$

with

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

$$e_{R,i} = \sum_{t_2} U_{R,ij}^e E_{R,j}^* \quad (39)$$

- **Mass matrix for Neutrinos**, Basis: $(\nu_L, V_R^*), (\nu_L, V_R^*)$

$$m_\nu = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \quad (40)$$

This matrix is diagonalized by U^V :

$$U^{V,*} m_\nu U^{V,\dagger} = m_\nu^{dia} \quad (41)$$

with

$$\nu_{L,i} = \sum_j U_{ji}^{V,*} V_{L,j}, \quad V_{R,i} = \sum_j U_{ji}^V V_{L,j}^* \quad (42)$$

- **Mass matrix for FeD**, Basis: $(e_p, x6_L), (x5_R^*, ep_p^*)$

$$m_{eD} = \begin{pmatrix} \frac{1}{\sqrt{2}} v \lambda_g & \frac{1}{\sqrt{2}} v x \lambda_{c1} \\ \frac{1}{\sqrt{2}} v x \lambda_{b1} & \frac{1}{\sqrt{2}} v \lambda_h \end{pmatrix} \quad (43)$$

This matrix is diagonalized by UD_L^e and UD_R^e

$$UD_L^{e,*} m_{eD} UD_R^{e,\dagger} = m_{eD}^{dia} \quad (44)$$

with

$$e_p = \sum_{t_2} UD_{L,j1}^{e,*} \text{ELD}(\{\text{gt}2\}), \quad x6_L = \sum_{t_2} UD_{L,j2}^{e,*} \text{ELD}(\{\text{gt}2\}) \quad (45)$$

$$x5_R = \sum_{t_2} UD_{R,1j}^e \text{conj}(\text{ERD}(\{\text{gt}2\})), \quad ep_p = \sum_{t_2} UD_{R,2j}^e \text{conj}(\text{ERD}(\{\text{gt}2\})) \quad (46)$$

4 Vacuum Expectation Values

$$H^0 = \frac{1}{\sqrt{2}}\text{phiH} + \frac{1}{\sqrt{2}}v + i\frac{1}{\sqrt{2}}\text{sigmaH} \quad (47)$$

$$\text{BiD} = \frac{1}{\sqrt{2}}\text{phiB} + \frac{1}{\sqrt{2}}vx + i\frac{1}{\sqrt{2}}\text{sigmaB} \quad (48)$$

5 Tadpole Equations

$$\frac{\partial V}{\partial \text{phiH}} = -l_h v^3 + v \left(-\frac{1}{2}\lambda_3 v x^2 + \mu_h \right) \quad (49)$$

$$\frac{\partial V}{\partial \text{phiB}} = \left(-\frac{1}{2}\lambda_3 v^2 + \mu'_i \right) vx - \lambda_2 v x^3 \quad (50)$$

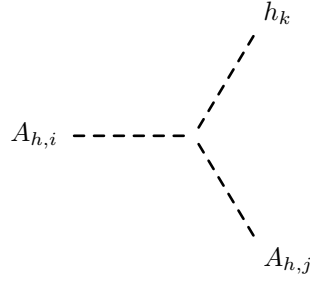
6 Particle content for eigenstates 'EWSB'

Name	Type	complex/real	Generations	Indices
S	Scalar	complex	1	
h	Scalar	real	2	generation, 2
A_h	Scalar	real	2	generation, 2
H^-	Scalar	complex	5	generation, 5
χ^0	Fermion	Dirac	1	
ν^d	Fermion	Dirac	1	
d	Fermion	Dirac	3	generation, 3, color, 3
u	Fermion	Dirac	3	generation, 3, color, 3
e	Fermion	Dirac	3	generation, 3
ν	Fermion	Majorana	5	generation, 5
eD	Fermion	Dirac	2	generation, 2
g	Vector	real	1	color, 8, lorentz, 4
γ	Vector	real	1	lorentz, 4
Z	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	

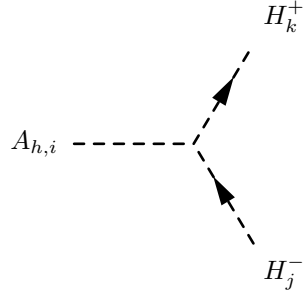
$\eta^{Z'}$	Ghost	real	1
η^-	Ghost	complex	1
η^+	Ghost	complex	1

7 Interactions for eigenstates 'EWSB'

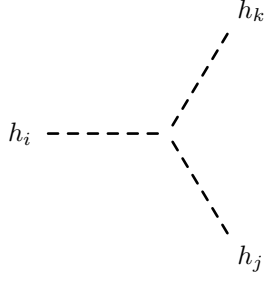
7.1 Three Scalar-Interaction



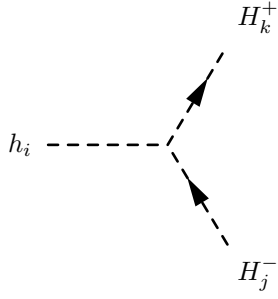
$$i \left(Z_{i1}^A Z_{j1}^A \left(2l_h v Z_{k1}^H + \lambda_3 v x Z_{k2}^H \right) + Z_{i2}^A Z_{j2}^A \left(2\lambda_2 v x Z_{k2}^H + \lambda_3 v Z_{k1}^H \right) \right) \quad (51)$$



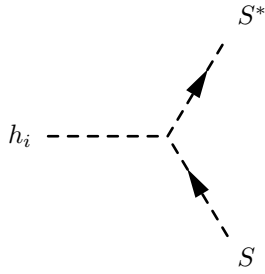
$$-\frac{1}{\sqrt{2}} \left(- \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{fi,ab} Z_{j1+a}^+ Z_{k3+b}^+ + \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{fi,ab} Z_{k1+a}^+ Z_{j3+b}^+ \right) Z_{i2}^A \quad (52)$$



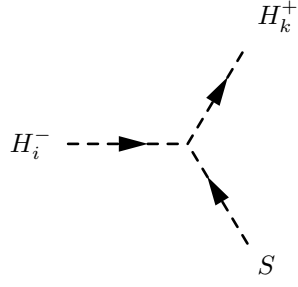
$$\begin{aligned}
& i \left(Z_{i2}^H \left(\lambda_3 Z_{j1}^H \left(vx Z_{k1}^H + v Z_{k2}^H \right) + Z_{j2}^H \left(6\lambda_2 vx Z_{k2}^H + \lambda_3 v Z_{k1}^H \right) \right) \right. \\
& \left. + Z_{i1}^H \left(\lambda_3 Z_{j2}^H \left(vx Z_{k1}^H + v Z_{k2}^H \right) + Z_{j1}^H \left(6l_h v Z_{k1}^H + \lambda_3 vx Z_{k2}^H \right) \right) \right)
\end{aligned} \tag{53}$$



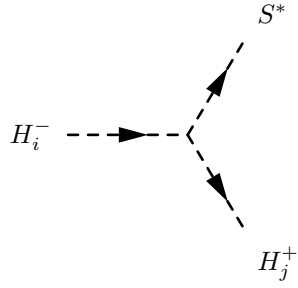
$$\begin{aligned}
& i \left(-v \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{6,ab} Z_{k1+a}^+ Z_{j1+b}^+ Z_{i1}^H - v \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{7,ab} Z_{k3+a}^+ Z_{j3+b}^+ Z_{i1}^H \right. \\
& - \frac{1}{\sqrt{2}} \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{fi,ab} Z_{k1+a}^+ Z_{j3+b}^+ Z_{i2}^H - \frac{1}{\sqrt{2}} \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{fi,ab} Z_{j1+a}^+ Z_{k3+b}^+ Z_{i2}^H + 2l_h v Z_{i1}^H Z_{j1}^+ Z_{k1}^+ \\
& \left. + \lambda_3 vx Z_{i2}^H Z_{j1}^+ Z_{k1}^+ \right)
\end{aligned} \tag{54}$$



$$i\lambda_5 v Z_{i1}^H \quad (55)$$

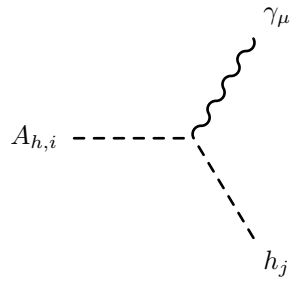


$$-i \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{fj,ab} Z_{i1+a}^+ Z_{k3+b}^+ \quad (56)$$

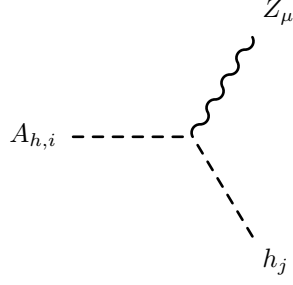


$$-i \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{fj,ab} Z_{j1+a}^+ Z_{i3+b}^+ \quad (57)$$

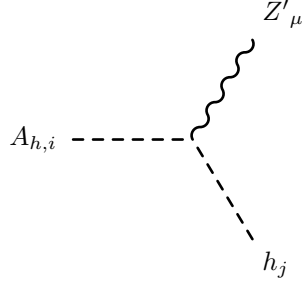
7.2 Two Scalar-One Vector Boson-Interaction



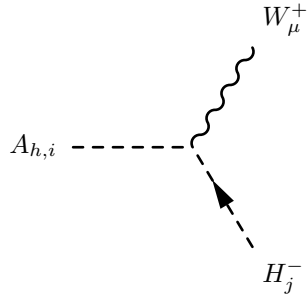
$$\frac{1}{2} \left(10 g_{YB} \cos \Theta_W Z_{i2}^A Z_{j2}^H + \left(g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) Z_{i1}^A Z_{j1}^H \right) \left(-p_\mu^{h_j} + p_\mu^{A_{h,i}} \right) \quad (58)$$



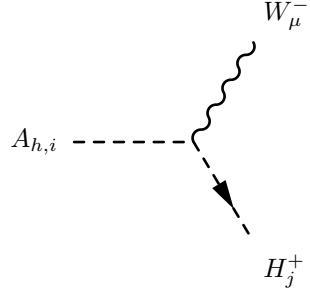
$$\begin{aligned} & \frac{1}{2} \left(- \left(g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right) Z_{i1}^A Z_{j1}^H \right. \\ & \left. - 10 \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right) Z_{i2}^A Z_{j2}^H \right) \left(-p_\mu^{h_j} + p_\mu^{A_{h,i}} \right) \end{aligned} \quad (59)$$



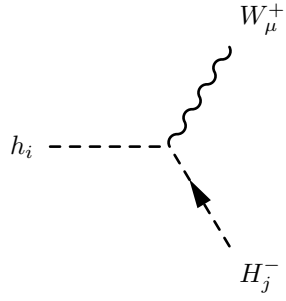
$$\begin{aligned} & \frac{1}{2} \left(\left(\left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) Z_{i1}^A Z_{j1}^H \right. \\ & \left. + 10 \left(g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right) Z_{i2}^A Z_{j2}^H \right) \left(-p_\mu^{h_j} + p_\mu^{A_{h,i}} \right) \end{aligned} \quad (60)$$



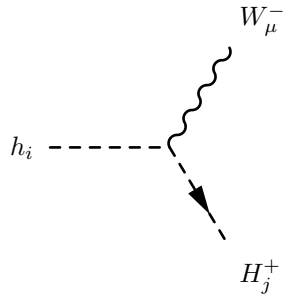
$$\frac{1}{2}g_2 Z_{i1}^A Z_{j1}^+ \left(-p_\mu^{H_j^-} + p_\mu^{A_{h,i}} \right) \quad (61)$$



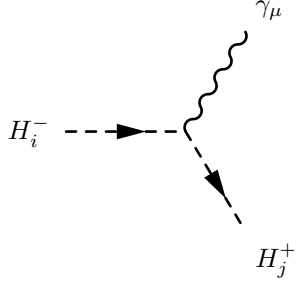
$$\frac{1}{2}g_2 Z_{i1}^A Z_{j1}^+ \left(-p_\mu^{H_j^+} + p_\mu^{A_{h,i}} \right) \quad (62)$$



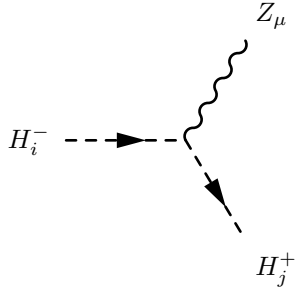
$$-\frac{i}{2}g_2 Z_{i1}^H Z_{j1}^+ \left(-p_\mu^{H_j^-} + p_\mu^{h_i} \right) \quad (63)$$



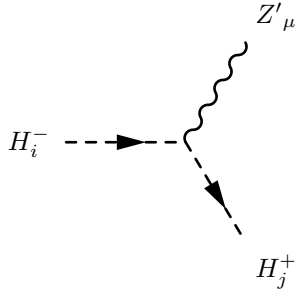
$$\frac{i}{2}g_2 Z_{i1}^H Z_{j1}^+ \left(-p_\mu^{H_j^+} + p_\mu^{h_i} \right) \quad (64)$$



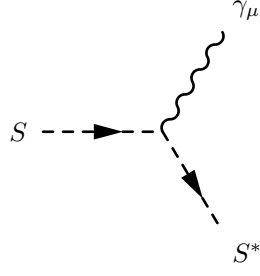
$$\begin{aligned}
& \frac{i}{2} \left(2 \left(g_1 + g_{YB} \right) \cos \Theta_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 2 \left(-4g_{YB} + g_1 \right) \cos \Theta_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \right. \\
& \left. + \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) Z_{i1}^+ Z_{j1}^+ \right) \left(-p_\mu^{H_j^+} + p_\mu^{H_i^-} \right)
\end{aligned} \tag{65}$$



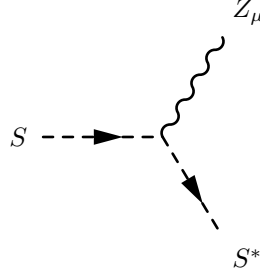
$$\begin{aligned}
& -\frac{i}{2} \left(2 \left(\left(g_1 + g_{YB} \right) \cos \Theta'_W \sin \Theta_W - \left(g_{BY} + g_B \right) \sin \Theta'_W \right) \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \right. \\
& + 2 \left(- \left(-4g_B + g_{BY} \right) \sin \Theta'_W + \left(-4g_{YB} + g_1 \right) \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& \left. - \left(-g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W + g_{BY} \sin \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right) \left(-p_\mu^{H_j^+} + p_\mu^{H_i^-} \right)
\end{aligned} \tag{66}$$



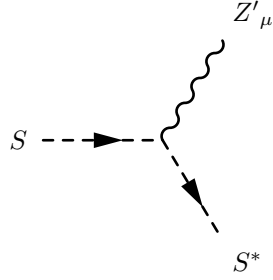
$$\begin{aligned}
& \frac{i}{2} \left(2 \left((g_1 + g_{YB}) \sin \Theta_W \sin \Theta'_W + (g_{BY} + g_B) \cos \Theta'_W \right) \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \right. \\
& + 2 \left((-4g_B + g_{BY}) \cos \Theta'_W + (-4g_{YB} + g_1) \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& \left. + \left((g_1 \sin \Theta_W - g_2 \cos \Theta_W) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right) \left(-p_\mu^{H_j^+} + p_\mu^{H_i^-} \right)
\end{aligned} \tag{67}$$



$$-5ig_{YB} \cos \Theta_W \left(-p_\mu^{S^*} + p_\mu^S \right) \tag{68}$$

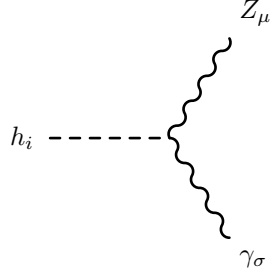


$$5i \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right) \left(-p_\mu^{S^*} + p_\mu^S \right) \tag{69}$$

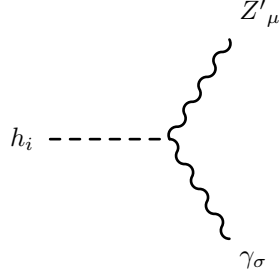


$$-5i\left(g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W\right)\left(-p_\mu^{S*} + p_\mu^S\right) \quad (70)$$

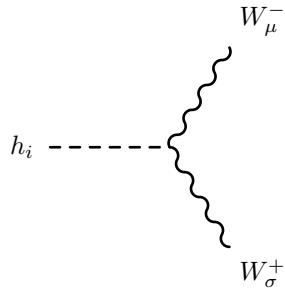
7.3 One Scalar-Two Vector Boson-Interaction



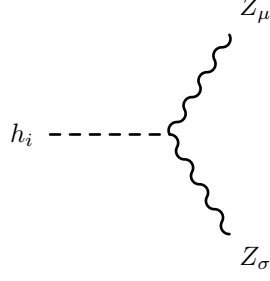
$$\begin{aligned} & \frac{i}{2} \left(-v \left(g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \left(g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right) Z_{i1}^H \right. \\ & \left. - 50g_{YB}vx \left(-2g_B \cos \Theta_W \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin 2\Theta_W \right) Z_{i2}^H \right) (g_{\sigma\mu}) \end{aligned} \quad (71)$$



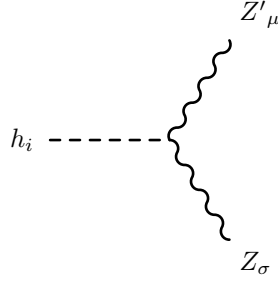
$$\begin{aligned} & \frac{i}{2} \left(v \left(g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \left(\left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) Z_{i1}^H \right. \\ & \left. + 50g_{YB}vx \left(2g_B \cos \Theta_W \cos \Theta'_W + g_{YB} \sin 2\Theta_W \sin \Theta'_W \right) Z_{i2}^H \right) (g_{\sigma\mu}) \end{aligned} \quad (72)$$



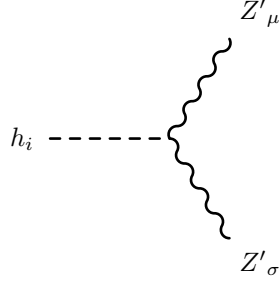
$$\frac{i}{2}g_2^2vZ_{i1}^H(g_{\sigma\mu}) \quad (73)$$



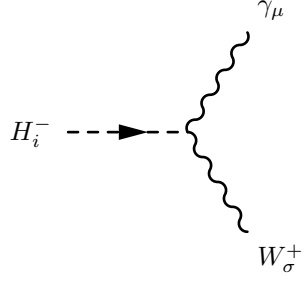
$$\begin{aligned} & \frac{i}{2} \left(v \left(g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right)^2 Z_{i1}^H \right. \\ & \left. + 100vx \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right)^2 Z_{i2}^H \right) (g_{\sigma\mu}) \end{aligned} \quad (74)$$



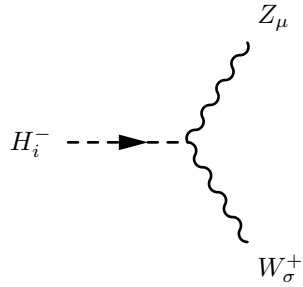
$$\begin{aligned} & \frac{i}{2} \left(-v \left(g_1 g_{BY} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \right. \\ & + \cos \Theta'_W \left(g_1^2 \sin \Theta_W^2 - g_{BY}^2 \right) \sin \Theta'_W - g_1 g_{BY} \sin \Theta_W \sin \Theta'^2_W \\ & + g_2 \cos \Theta_W \left(g_1 \sin \Theta_W \sin 2\Theta'_W + g_{BY} \cos \Theta'^2_W - g_{BY} \sin \Theta'^2_W \right) \left. \right) Z_{i1}^H \\ & + 50vx \left(-2g_B g_{YB} \cos \Theta'^2_W \sin \Theta_W + 2g_B g_{YB} \sin \Theta_W \sin \Theta'^2_W + g_B^2 \sin 2\Theta'_W \right. \\ & \left. - g_{YB}^2 \sin \Theta_W^2 \sin 2\Theta'_W \right) Z_{i2}^H \left. \right) (g_{\sigma\mu}) \end{aligned} \quad (75)$$



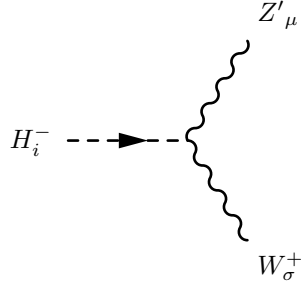
$$\begin{aligned} & \frac{i}{2} \left(v \left(\left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right)^2 Z_{i1}^H \right. \\ & \left. + 100 v x \left(g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right)^2 Z_{i2}^H \right) (g_{\sigma\mu}) \end{aligned} \quad (76)$$



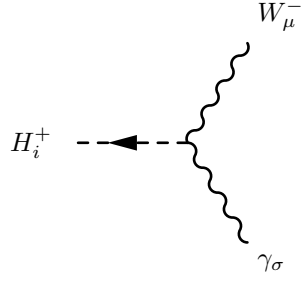
$$\frac{i}{2} g_1 g_2 v \cos \Theta_W Z_{i1}^+ (g_{\sigma\mu}) \quad (77)$$



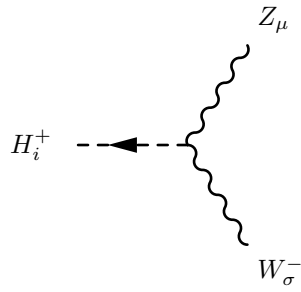
$$\frac{i}{2} g_2 v \left(-g_1 \cos \Theta'_W \sin \Theta_W + g_{BY} \sin \Theta'_W \right) Z_{i1}^+ (g_{\sigma\mu}) \quad (78)$$



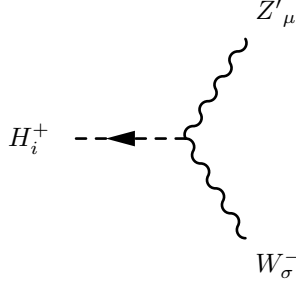
$$\frac{i}{2}g_2v\left(g_1\sin\Theta_W\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)Z_{i1}^+\left(g_{\sigma\mu}\right) \quad (79)$$



$$\frac{i}{2}g_1g_2v\cos\Theta_WZ_{i1}^+\left(g_{\sigma\mu}\right) \quad (80)$$

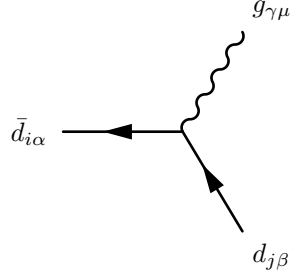


$$\frac{i}{2}g_2v\left(-g_1\cos\Theta'_W\sin\Theta_W+g_{BY}\sin\Theta'_W\right)Z_{i1}^+\left(g_{\sigma\mu}\right) \quad (81)$$



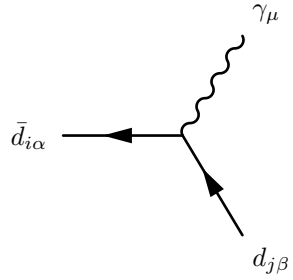
$$\frac{i}{2}g_2v\left(g_1\sin\Theta_W\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)Z_{i1}^+\left(g_{\sigma\mu}\right) \quad (82)$$

7.4 Two Fermion-One Vector Boson-Interaction



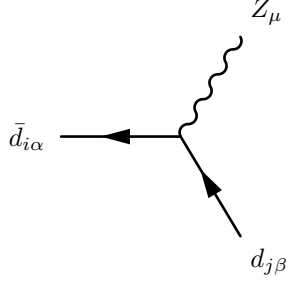
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (83)$$

$$+\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (84)$$



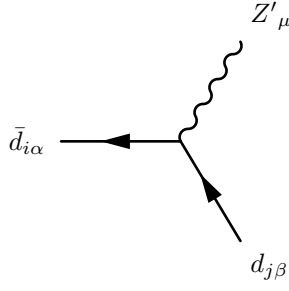
$$-\frac{i}{18}\delta_{\alpha\beta}\delta_{ij}\left(\left(-10g_{YB}+3g_1\right)\cos\Theta_W-9g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (85)$$

$$+\frac{i}{9}\left(3g_1+5g_{YB}\right)\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (86)$$



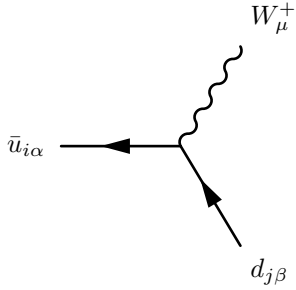
$$\frac{i}{18} \delta_{\alpha\beta} \delta_{ij} \left((10g_B - 3g_{BY}) \sin \Theta'_W + (-10g_{YB} + 3g_1) \cos \Theta'_W \sin \Theta_W + 9g_2 \cos \Theta_W \cos \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (87)$$

$$+ -\frac{i}{9} \delta_{\alpha\beta} \delta_{ij} \left((3g_1 + 5g_{YB}) \cos \Theta'_W \sin \Theta_W - (3g_{BY} + 5g_B) \sin \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (88)$$

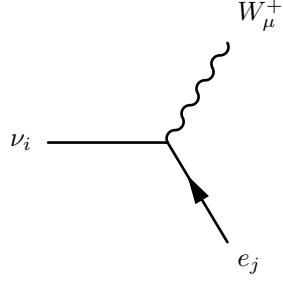


$$- \frac{i}{18} \delta_{\alpha\beta} \delta_{ij} \left((-10g_B + 3g_{BY}) \cos \Theta'_W + ((-10g_{YB} + 3g_1) \sin \Theta_W + 9g_2 \cos \Theta_W) \sin \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (89)$$

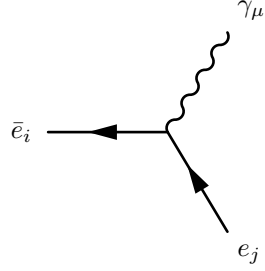
$$+ \frac{i}{9} \delta_{\alpha\beta} \delta_{ij} \left((3g_1 + 5g_{YB}) \sin \Theta_W \sin \Theta'_W + (3g_{BY} + 5g_B) \cos \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (90)$$



$$- i \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^3 U_{L,ja}^{d,*} U_{L,ia}^u \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (91)$$

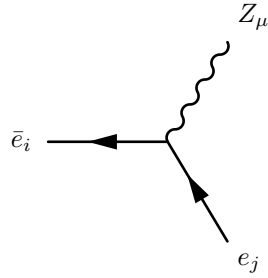


$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 U_{L,ja}^{e,*} U_{ia}^V \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (92)$$



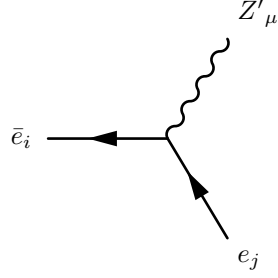
$$\frac{i}{2} \delta_{ij} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (93)$$

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



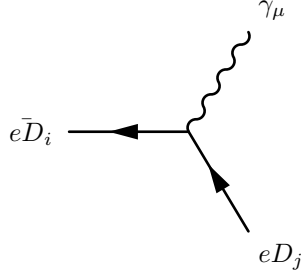
$$\frac{i}{2} \delta_{ij} \left(-g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W + g_{BY} \sin \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (95)$$

$$+ -i \delta_{ij} \left(g_1 \cos \Theta'_W \sin \Theta_W - g_{BY} \sin \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (96)$$



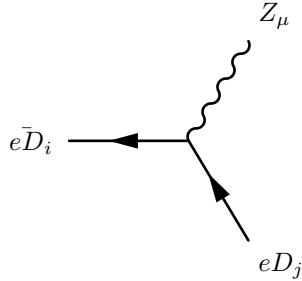
$$\frac{i}{2}\delta_{ij}\left(\left(g_1\sin\Theta_W - g_2\cos\Theta_W\right)\sin\Theta'_W + g_{BY}\cos\Theta'_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (97)$$

$$+ i\delta_{ij}\left(g_1\sin\Theta_W\sin\Theta'_W + g_{BY}\cos\Theta'_W\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (98)$$



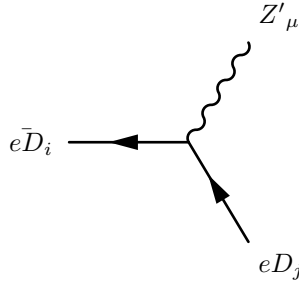
$$\frac{i}{2}\left(2\left(6g_{YB} + g_1\right)UD_{L,j2}^{e,*}\cos\Theta_W UD_{L,i2}^e + UD_{L,j1}^{e,*}\left(\left(2g_{YB} + g_1\right)\cos\Theta_W + g_2\sin\Theta_W\right)UD_{L,i1}^e\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (99)$$

$$+ \frac{i}{2}\left(2\left(g_1 + g_{YB}\right)UD_{R,i1}^{e,*}\cos\Theta_W UD_{R,j1}^e + UD_{R,i2}^{e,*}\left(\left(12g_{YB} + g_1\right)\cos\Theta_W + g_2\sin\Theta_W\right)UD_{R,j2}^e\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (100)$$



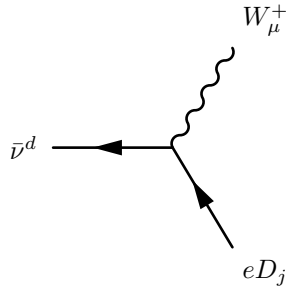
$$\begin{aligned}
& \frac{i}{2} \left(UD_{L,j1}^{e,*} \left((2g_B + g_{BY}) \sin \Theta'_W - (2g_{YB} + g_1) \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) UD_{L,i1}^e \right. \\
& + 2UD_{L,j2}^{e,*} \left((6g_B + g_{BY}) \sin \Theta'_W - (6g_{YB} + g_1) \cos \Theta'_W \sin \Theta_W \right) UD_{L,i2}^e \left. \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (101)
\end{aligned}$$

$$\begin{aligned}
& + \frac{i}{2} \left(2UD_{R,i1}^{e,*} \left((g_1 + g_{YB}) \cos \Theta'_W \sin \Theta_W - (g_{BY} + g_B) \sin \Theta'_W \right) UD_{R,j1}^e \right. \\
& - UD_{R,i2}^{e,*} \left((12g_B + g_{BY}) \sin \Theta'_W - (12g_{YB} + g_1) \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) UD_{R,j2}^e \left. \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (102)
\end{aligned}$$



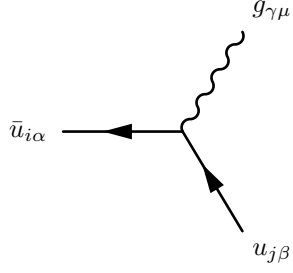
$$\begin{aligned}
& \frac{i}{2} \left(UD_{L,j1}^{e,*} \left((2g_B + g_{BY}) \cos \Theta'_W + ((2g_{YB} + g_1) \sin \Theta_W - g_2 \cos \Theta_W) \sin \Theta'_W \right) UD_{L,i1}^e \right. \\
& + 2UD_{L,j2}^{e,*} \left((6g_B + g_{BY}) \cos \Theta'_W + (6g_{YB} + g_1) \sin \Theta_W \sin \Theta'_W \right) UD_{L,i2}^e \left. \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (103)
\end{aligned}$$

$$\begin{aligned}
& + \frac{i}{2} \left(2UD_{R,i1}^{e,*} \left((g_1 + g_{YB}) \sin \Theta_W \sin \Theta'_W + (g_{BY} + g_B) \cos \Theta'_W \right) UD_{R,j1}^e \right. \\
& + UD_{R,i2}^{e,*} \left((12g_B + g_{BY}) \cos \Theta'_W + ((12g_{YB} + g_1) \sin \Theta_W - g_2 \cos \Theta_W) \sin \Theta'_W \right) UD_{R,j2}^e \left. \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (104)
\end{aligned}$$



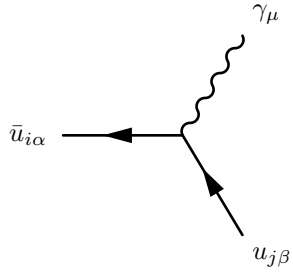
$$- i \frac{1}{\sqrt{2}} g_2 UD_{L,j1}^{e,*} \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (105)$$

$$+ -i \frac{1}{\sqrt{2}} g_2 UD_{R,j2}^e \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (106)$$



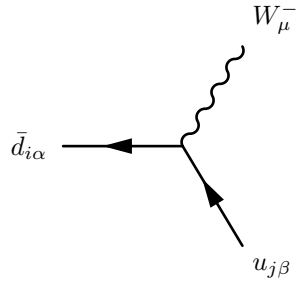
$$- \frac{i}{2} g_3 \delta_{ij} \lambda_{\alpha,\beta}^\gamma \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (107)$$

$$+ - \frac{i}{2} g_3 \delta_{ij} \lambda_{\alpha,\beta}^\gamma \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (108)$$

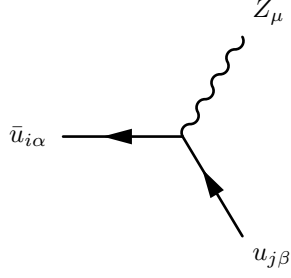


$$- \frac{i}{18} \delta_{\alpha\beta} \delta_{ij} \left((-10g_{YB} + 3g_1) \cos \Theta_W + 9g_2 \sin \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (109)$$

$$+ - \frac{i}{9} \left(-5g_{YB} + 6g_1 \right) \cos \Theta_W \delta_{\alpha\beta} \delta_{ij} \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (110)$$

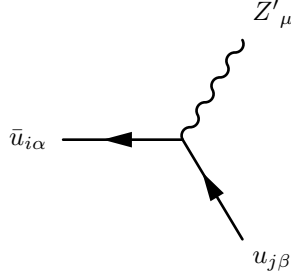


$$- i \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^3 U_{L,ja}^{u,*} U_{L,ia}^d \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (111)$$



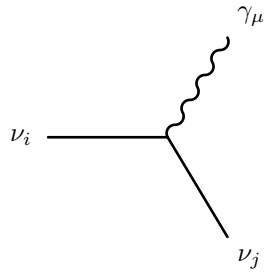
$$-\frac{i}{18}\delta_{\alpha\beta}\delta_{ij}\left(\left(-10g_B+3g_{BY}\right)\sin\Theta'_W-\left(-10g_{YB}+3g_1\right)\cos\Theta'_W\sin\Theta_W+9g_2\cos\Theta_W\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (112)$$

$$+\frac{i}{9}\delta_{\alpha\beta}\delta_{ij}\left(\left(5g_B-6g_{BY}\right)\sin\Theta'_W+\left(-5g_{YB}+6g_1\right)\cos\Theta'_W\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (113)$$



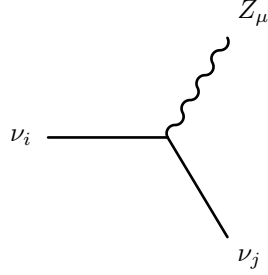
$$-\frac{i}{18}\delta_{\alpha\beta}\delta_{ij}\left(\left(-10g_B+3g_{BY}\right)\cos\Theta'_W+\left(\left(-10g_{YB}+3g_1\right)\sin\Theta_W-9g_2\cos\Theta_W\right)\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (114)$$

$$+ -\frac{i}{9}\delta_{\alpha\beta}\delta_{ij}\left(\left(-5g_B+6g_{BY}\right)\cos\Theta'_W+\left(-5g_{YB}+6g_1\right)\sin\Theta_W\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (115)$$



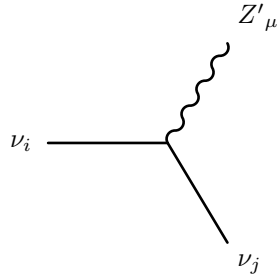
$$\frac{i}{2} \left(10 g_{YB} \cos \Theta_W \sum_{a=1}^2 U_{j3+a}^{V,*} U_{i3+a}^V + \left(g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \sum_{a=1}^3 U_{ja}^{V,*} U_{ia}^V \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (116)$$

$$+ -\frac{i}{2} \left(10 g_{YB} \cos \Theta_W \sum_{a=1}^2 U_{i3+a}^{V,*} U_{j3+a}^V + \left(g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \sum_{a=1}^3 U_{ia}^{V,*} U_{ja}^V \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (117)$$



$$-\frac{i}{2} \left(10 \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^2 U_{j3+a}^{V,*} U_{i3+a}^V + \left(g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right) \sum_{a=1}^3 U_{ja}^{V,*} U_{ia}^V \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (118)$$

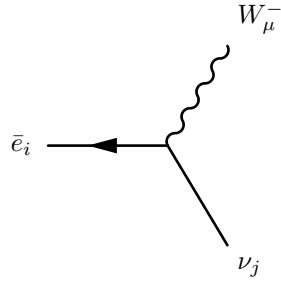
$$+\frac{i}{2} \left(10 \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^2 U_{i3+a}^{V,*} U_{j3+a}^V + \left(g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right) \sum_{a=1}^3 U_{ia}^{V,*} U_{ja}^V \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (119)$$



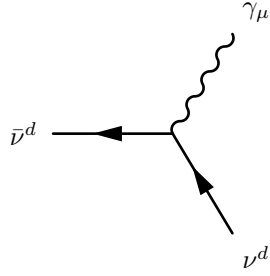
$$\frac{i}{2} \left(10 \left(g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^2 U_{j3+a}^{V,*} U_{i3+a}^V \right)$$

$$+ \left((g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) \sum_{a=1}^3 U_{ja}^{V,*} U_{ia}^V \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (120)$$

$$+ -\frac{i}{2} \left(10 (g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W) \sum_{a=1}^2 U_{i3+a}^{V,*} U_{j3+a}^V \right. \\ \left. + \left((g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) \sum_{a=1}^3 U_{ia}^{V,*} U_{ja}^V \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (121)$$

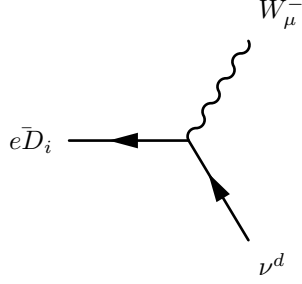


$$- i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 U_{ja}^{V,*} U_{L,ia}^e \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (122)$$



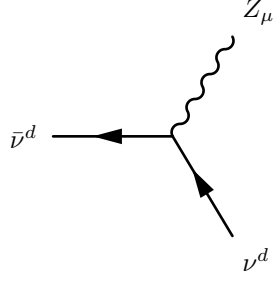
$$\frac{i}{2} \left((2g_{YB} + g_1) \cos \Theta_W - g_2 \sin \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (123)$$

$$+ \frac{i}{2} \left((12g_{YB} + g_1) \cos \Theta_W - g_2 \sin \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (124)$$



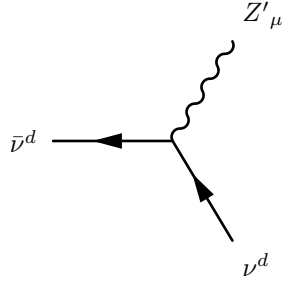
$$-i \frac{1}{\sqrt{2}} g_2 U D_{L,i1}^e \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (125)$$

$$+ -i \frac{1}{\sqrt{2}} g_2 U D_{R,i2}^{e,*} \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (126)$$



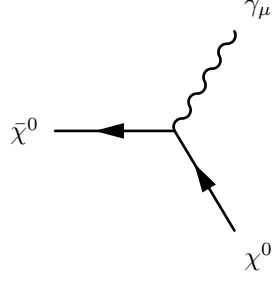
$$- \frac{i}{2} \left(- (2g_B + g_{BY}) \sin \Theta'_W + (2g_{YB} + g_1) \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (127)$$

$$+ - \frac{i}{2} \left(- (12g_B + g_{BY}) \sin \Theta'_W + (12g_{YB} + g_1) \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (128)$$



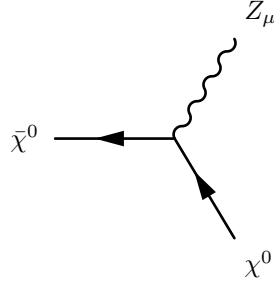
$$\frac{i}{2} \left((2g_B + g_{BY}) \cos \Theta'_W + \left((2g_{YB} + g_1) \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (129)$$

$$+ \frac{i}{2} \left((12g_B + g_{BY}) \cos \Theta'_W + \left((12g_{YB} + g_1) \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (130)$$



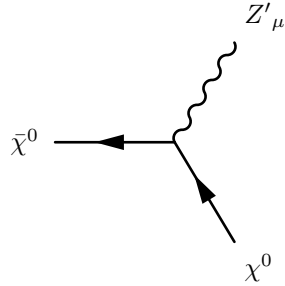
$$- 3ig_{YB} \cos \Theta_W \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (131)$$

$$+ 2ig_{YB} \cos \Theta_W \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (132)$$



$$3i \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (133)$$

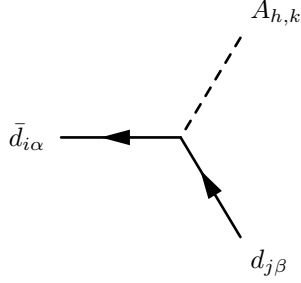
$$+ -2i \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (134)$$



$$- 3i \left(g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (135)$$

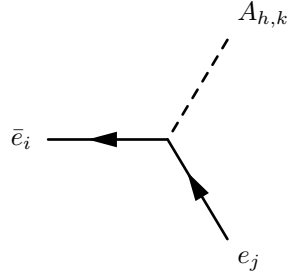
$$+ 2i \left(g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (136)$$

7.5 Two Fermion-One Scalar Boson-Interaction



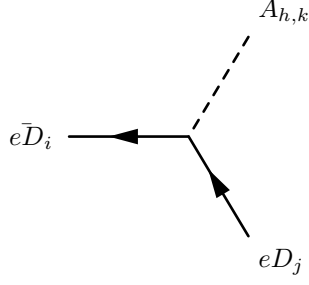
$$- \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^A \left(\frac{1 - \gamma_5}{2} \right) \quad (137)$$

$$+ \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d Z_{k1}^A \left(\frac{1 + \gamma_5}{2} \right) \quad (138)$$



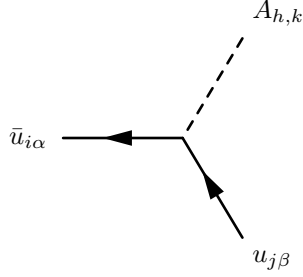
$$- \frac{1}{\sqrt{2}} \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} Z_{k1}^A \left(\frac{1 - \gamma_5}{2} \right) \quad (139)$$

$$+ \frac{1}{\sqrt{2}} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e Z_{k1}^A \left(\frac{1 + \gamma_5}{2} \right) \quad (140)$$



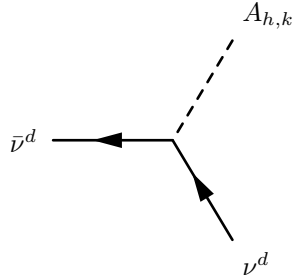
$$-\frac{1}{\sqrt{2}} \left(UD_{R,i1}^{e,*} \left(-\lambda_{b1} UD_{L,j2}^{e,*} Z_{k2}^A + \lambda_g UD_{L,j1}^{e,*} Z_{k1}^A \right) + UD_{R,i2}^{e,*} \left(\lambda_{c1} UD_{L,j1}^{e,*} Z_{k2}^A - \lambda_h UD_{L,j2}^{e,*} Z_{k1}^A \right) \right) \left(\frac{1-\gamma_5}{2} \right) \quad (141)$$

$$+ \frac{1}{\sqrt{2}} \left(-\lambda_{b1} UD_{R,j1}^e UD_{L,i2}^e Z_{k2}^A + \lambda_g^* UD_{R,j1}^e UD_{L,i1}^e Z_{k1}^A + UD_{R,j2}^e \left(\lambda_{c1} UD_{L,i1}^e Z_{k2}^A - \lambda_h UD_{L,i2}^e Z_{k1}^A \right) \right) \left(\frac{1+\gamma_5}{2} \right) \quad (142)$$



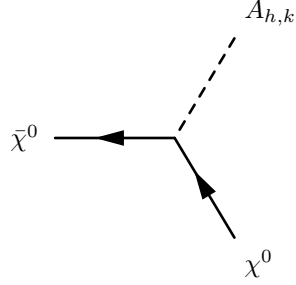
$$-\frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} Z_{k1}^A \left(\frac{1-\gamma_5}{2} \right) \quad (143)$$

$$+ \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^u Z_{k1}^A \left(\frac{1+\gamma_5}{2} \right) \quad (144)$$



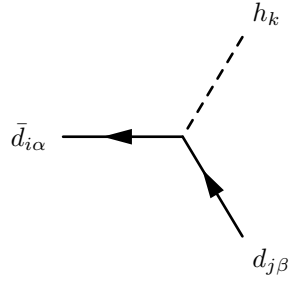
$$- \frac{1}{\sqrt{2}} \lambda_{c1} Z_{k2}^A \left(\frac{1 - \gamma_5}{2} \right) \quad (145)$$

$$+ \frac{1}{\sqrt{2}} \lambda_{c1} Z_{k2}^A \left(\frac{1 + \gamma_5}{2} \right) \quad (146)$$



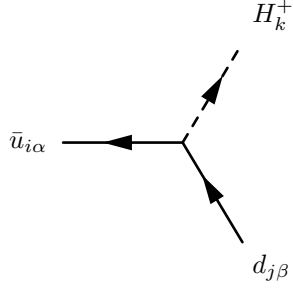
$$- \frac{1}{\sqrt{2}} \lambda_{a1} Z_{k2}^A \left(\frac{1 - \gamma_5}{2} \right) \quad (147)$$

$$+ \frac{1}{\sqrt{2}} \lambda_{a1} Z_{k2}^A \left(\frac{1 + \gamma_5}{2} \right) \quad (148)$$



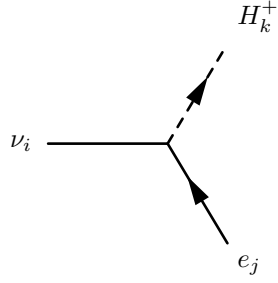
$$- i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^H \left(\frac{1 - \gamma_5}{2} \right) \quad (149)$$

$$+ -i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d Z_{k1}^H \left(\frac{1 + \gamma_5}{2} \right) \quad (150)$$



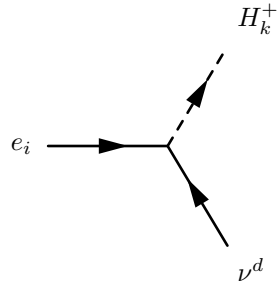
$$-i\delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} Z_{k1}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (151)$$

$$+ -i\delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^u Z_{k1}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (152)$$

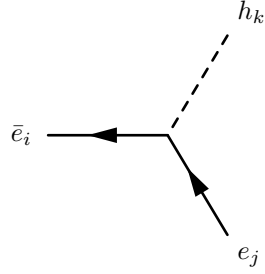


$$(153)$$

$$+ -i \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{ib}^V Z_{k1}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (154)$$

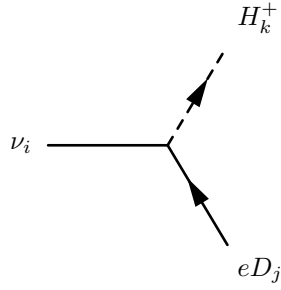


$$i \sum_{b=1}^3 U_{L,ib}^{e,*} \sum_{a=1}^2 \lambda_{d,ab} Z_{k1+a}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (155)$$



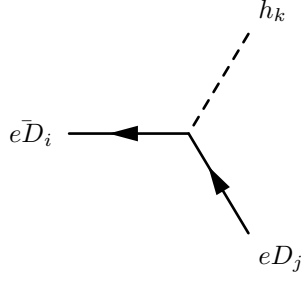
$$-i \frac{1}{\sqrt{2}} \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} Z_{k1}^H \left(\frac{1-\gamma_5}{2} \right) \quad (156)$$

$$+ -i \frac{1}{\sqrt{2}} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e Z_{k1}^H \left(\frac{1+\gamma_5}{2} \right) \quad (157)$$



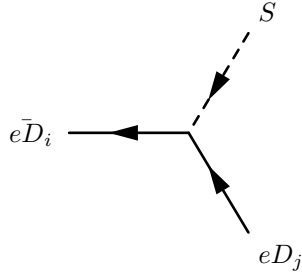
$$-i U D_{L,j1}^{e,*} \sum_{b=1}^3 U_{ib}^{V,*} \sum_{a=1}^2 \lambda_{d,ab} Z_{k1+a}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (158)$$

$$+ -i \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{e,ab}^* Z_{k3+a}^+ U_{i3+b}^V U D_{R,j1}^e \left(\frac{1+\gamma_5}{2} \right) \quad (159)$$



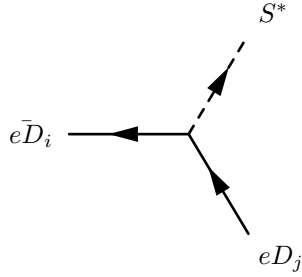
$$i \frac{1}{\sqrt{2}} \left(-UD_{R,i1}^{e,*} \left(\lambda_{b1} UD_{L,j2}^{e,*} Z_{k2}^H + \lambda_g UD_{L,j1}^{e,*} Z_{k1}^H \right) - UD_{R,i2}^{e,*} \left(\lambda_{c1} UD_{L,j1}^{e,*} Z_{k2}^H + \lambda_h UD_{L,j2}^{e,*} Z_{k1}^H \right) \right) \left(\frac{1-\gamma_5}{2} \right) \quad (160)$$

$$+ -i \frac{1}{\sqrt{2}} \left(\lambda_{b1} UD_{R,j1}^e UD_{L,i2}^e Z_{k2}^H + \lambda_g^* UD_{R,j1}^e UD_{L,i1}^e Z_{k1}^H + UD_{R,j2}^e \left(\lambda_{c1} UD_{L,i1}^e Z_{k2}^H + \lambda_h UD_{L,i2}^e Z_{k1}^H \right) \right) \left(\frac{1+\gamma_5}{2} \right) \quad (161)$$



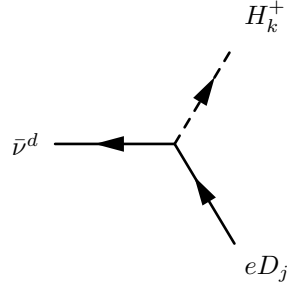
$$-i \lambda_{b2} UD_{R,i1}^{e,*} UD_{L,j2}^{e,*} \left(\frac{1-\gamma_5}{2} \right) \quad (162)$$

$$+ -i \lambda_{c2} UD_{R,j2}^e UD_{L,i1}^e \left(\frac{1+\gamma_5}{2} \right) \quad (163)$$



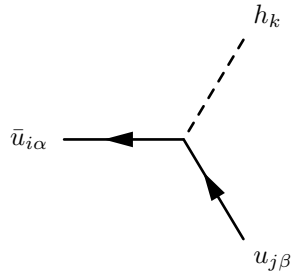
$$-i \lambda_{c2} UD_{R,i2}^{e,*} UD_{L,j1}^{e,*} \left(\frac{1-\gamma_5}{2} \right) \quad (164)$$

$$+ -i\lambda_{b2}UD_{R,j1}^eUD_{L,i2}^e\left(\frac{1+\gamma_5}{2}\right) \quad (165)$$



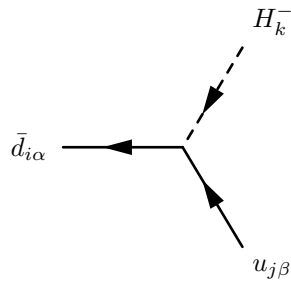
$$-i\lambda_hUD_{L,j2}^{e,*}Z_{k1}^+\left(\frac{1-\gamma_5}{2}\right) \quad (166)$$

$$+ -i\lambda_g^*UD_{R,j1}^eZ_{k1}^+\left(\frac{1+\gamma_5}{2}\right) \quad (167)$$



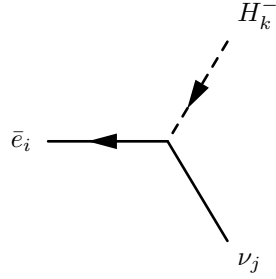
$$i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^3U_{L,jb}^{u,*}\sum_{a=1}^3U_{R,ia}^{u,*}Y_{u,ab}Z_{k1}^H\left(\frac{1-\gamma_5}{2}\right) \quad (168)$$

$$+ i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^3\sum_{a=1}^3Y_{u,ab}^*U_{R,ja}^uU_{L,ib}^uZ_{k1}^H\left(\frac{1+\gamma_5}{2}\right) \quad (169)$$

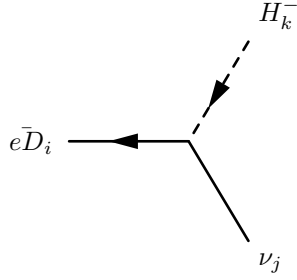


$$-i\delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (170)$$

$$+ -i\delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^d Z_{k1}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (171)$$

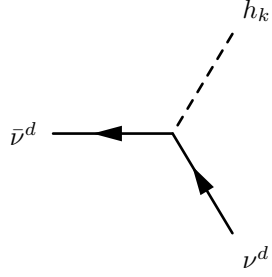


$$-i \sum_{b=1}^3 U_{jb}^{V,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} Z_{k1}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (172)$$



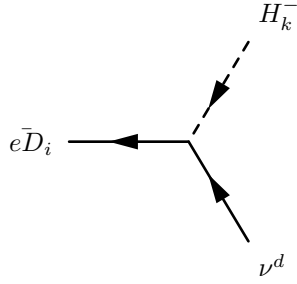
$$-iUD_{R,i1}^{e,*} \sum_{b=1}^2 U_{j3+b}^{V,*} \sum_{a=1}^2 \lambda_{e,ab} Z_{k3+a}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (173)$$

$$+ -i \sum_{b=1}^3 \sum_{a=1}^2 \lambda_{d,ab}^* Z_{k1+a}^+ U_{jb}^V UD_{L,i1}^e \left(\frac{1+\gamma_5}{2} \right) \quad (174)$$



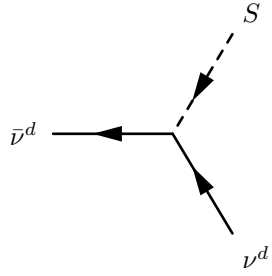
$$-i\frac{1}{\sqrt{2}}\lambda_{c1}Z_{k2}^H\left(\frac{1-\gamma_5}{2}\right) \quad (175)$$

$$+ -i\frac{1}{\sqrt{2}}\lambda_{c1}Z_{k2}^H\left(\frac{1+\gamma_5}{2}\right) \quad (176)$$



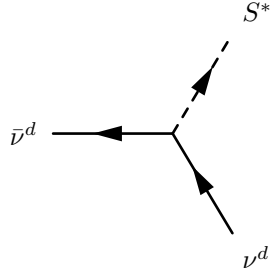
$$-i\lambda_g UD_{R,i1}^{e,*}Z_{k1}^+\left(\frac{1-\gamma_5}{2}\right) \quad (177)$$

$$+ -i\lambda_h UD_{L,i2}^e Z_{k1}^+\left(\frac{1+\gamma_5}{2}\right) \quad (178)$$

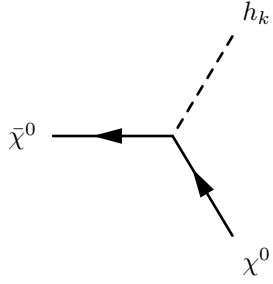


$$(179)$$

$$+ -i\lambda_{c2}\left(\frac{1+\gamma_5}{2}\right) \quad (180)$$

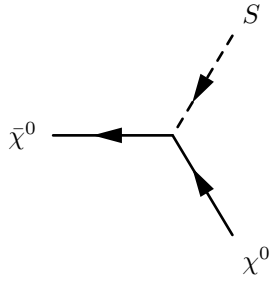


$$-i\lambda_{c2}\left(\frac{1-\gamma_5}{2}\right) \quad (181)$$



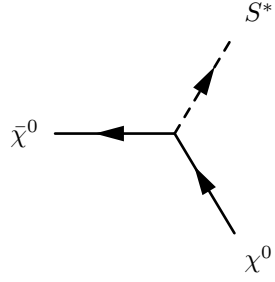
$$-i\frac{1}{\sqrt{2}}\lambda_{a1}Z_{k2}^H\left(\frac{1-\gamma_5}{2}\right) \quad (182)$$

$$+ -i\frac{1}{\sqrt{2}}\lambda_{a1}Z_{k2}^H\left(\frac{1+\gamma_5}{2}\right) \quad (183)$$

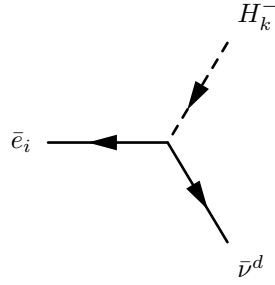


$$+ -i\lambda_{a2}\left(\frac{1+\gamma_5}{2}\right) \quad (184)$$

$$+ -i\lambda_{a2}\left(\frac{1+\gamma_5}{2}\right) \quad (185)$$



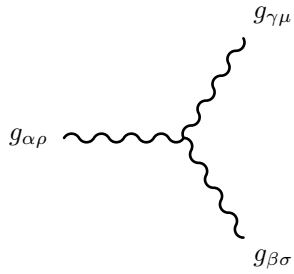
$$-i\lambda_{a2}\left(\frac{1-\gamma_5}{2}\right) \quad (186)$$



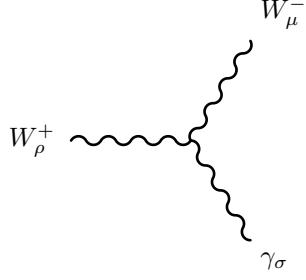
$$(187)$$

$$+i\sum_{b=1}^3\sum_{a=1}^2\lambda_{d,ab}^*Z_{k1+a}^+U_{L,ib}^e\left(\frac{1+\gamma_5}{2}\right) \quad (188)$$

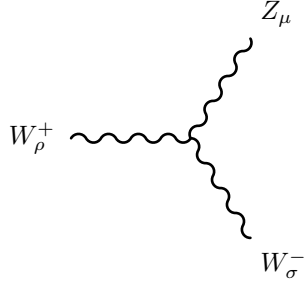
7.6 Three Vector Boson-Interaction



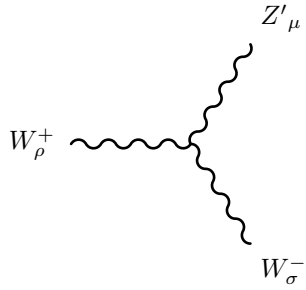
$$g_3f_{\alpha,\beta,\gamma}\left(g_{\rho\mu}\left(-p_\sigma^{g_{\gamma\mu}}+p_\sigma^{g_{\alpha\rho}}\right)+g_{\rho\sigma}\left(-p_\mu^{g_{\alpha\rho}}+p_\mu^{g_{\beta\sigma}}\right)+g_{\sigma\mu}\left(-p_\rho^{g_{\beta\sigma}}+p_\rho^{g_{\gamma\mu}}\right)\right) \quad (189)$$



$$ig_2 \sin \Theta_W \left(g_{\rho\mu} \left(-p_\sigma^{W^-} + p_\sigma^{W^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W^+} + p_\mu^{\gamma_\sigma} \right) + g_{\sigma\mu} \left(-p_\rho^{\gamma_\sigma} + p_\rho^{W^-} \right) \right) \quad (190)$$

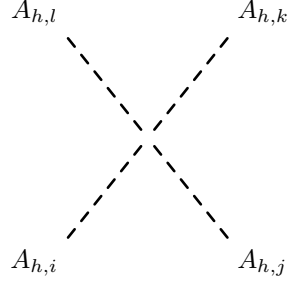


$$-ig_2 \cos \Theta_W \cos \Theta'_W \left(g_{\rho\mu} \left(-p_\sigma^{Z_\mu} + p_\sigma^{W^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W^+} + p_\mu^{W_\sigma^-} \right) + g_{\sigma\mu} \left(-p_\rho^{W_\sigma^-} + p_\rho^{Z_\mu} \right) \right) \quad (191)$$

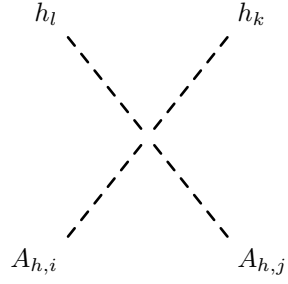


$$ig_2 \cos \Theta_W \sin \Theta'_W \left(g_{\rho\mu} \left(-p_\sigma^{Z'_\mu} + p_\sigma^{W^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W^+} + p_\mu^{W_\sigma^-} \right) + g_{\sigma\mu} \left(-p_\rho^{W_\sigma^-} + p_\rho^{Z'_\mu} \right) \right) \quad (192)$$

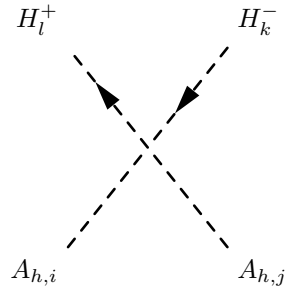
7.7 Four Scalar-Interaction



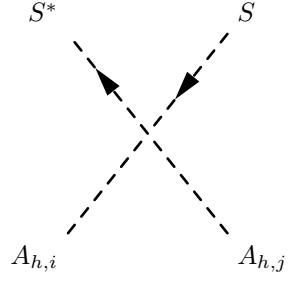
$$\begin{aligned}
& i \left(Z_{i2}^A \left(\lambda_3 Z_{j1}^A \left(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \right) + Z_{j2}^A \left(6\lambda_2 Z_{k2}^A Z_{l2}^A + \lambda_3 Z_{k1}^A Z_{l1}^A \right) \right) \right. \\
& \left. + Z_{i1}^A \left(\lambda_3 Z_{j2}^A \left(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \right) + Z_{j1}^A \left(6l_h Z_{k1}^A Z_{l1}^A + \lambda_3 Z_{k2}^A Z_{l2}^A \right) \right) \right)
\end{aligned} \tag{193}$$



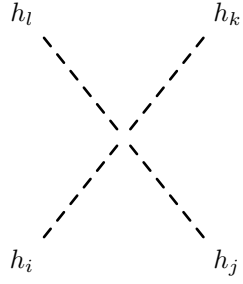
$$i \left(Z_{i1}^A Z_{j1}^A \left(2l_h Z_{k1}^H Z_{l1}^H + \lambda_3 Z_{k2}^H Z_{l2}^H \right) + Z_{i2}^A Z_{j2}^A \left(2\lambda_2 Z_{k2}^H Z_{l2}^H + \lambda_3 Z_{k1}^H Z_{l1}^H \right) \right) \tag{194}$$



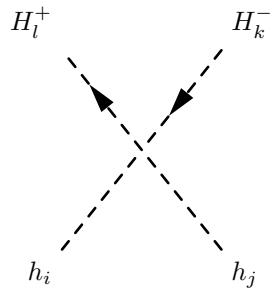
$$\begin{aligned}
& i \left(- \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{6,ab} Z_{l1+a}^+ Z_{k1+b}^+ Z_{i1}^A Z_{j1}^A - \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{7,ab} Z_{l3+a}^+ Z_{k3+b}^+ Z_{i1}^A Z_{j1}^A \right. \\
& \left. + \left(2l_h Z_{i1}^A Z_{j1}^A + \lambda_3 Z_{i2}^A Z_{j2}^A \right) Z_{k1}^+ Z_{l1}^+ \right)
\end{aligned} \tag{195}$$



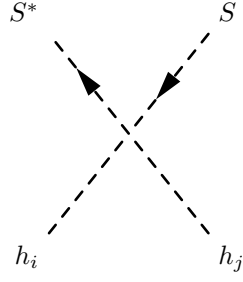
$$i\lambda_5 Z_{i1}^A Z_{j1}^A \quad (196)$$



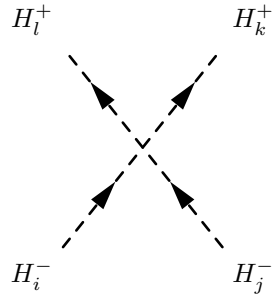
$$\begin{aligned} & i \left(Z_{i2}^H \left(\lambda_3 Z_{j1}^H \left(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) + Z_{j2}^H \left(6\lambda_2 Z_{k2}^H Z_{l2}^H + \lambda_3 Z_{k1}^H Z_{l1}^H \right) \right) \right. \\ & \left. + Z_{i1}^H \left(\lambda_3 Z_{j2}^H \left(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) + Z_{j1}^H \left(6\lambda_h Z_{k1}^H Z_{l1}^H + \lambda_3 Z_{k2}^H Z_{l2}^H \right) \right) \right) \end{aligned} \quad (197)$$



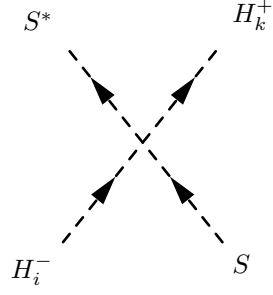
$$\begin{aligned} & i \left(- \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{6,ab} Z_{l1+a}^+ Z_{k1+b}^+ Z_{i1}^H Z_{j1}^H - \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{7,ab} Z_{l3+a}^+ Z_{k3+b}^+ Z_{i1}^H Z_{j1}^H \right. \\ & \left. + \left(2l_h Z_{i1}^H Z_{j1}^H + \lambda_3 Z_{i2}^H Z_{j2}^H \right) Z_{k1}^+ Z_{l1}^+ \right) \end{aligned} \quad (198)$$



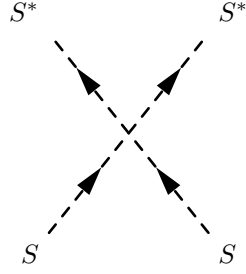
$$i\lambda_5 Z_{i1}^H Z_{j1}^H \quad (199)$$



$$\begin{aligned}
& i \left(- \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{6,ab} Z_{l1+a}^+ Z_{j1+b}^+ Z_{i1}^+ Z_{k1}^+ - \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{7,ab} Z_{l3+a}^+ Z_{j3+b}^+ Z_{i1}^+ Z_{k1}^+ \right. \\
& - \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{6,ab} Z_{l1+a}^+ Z_{i1+b}^+ Z_{j1}^+ Z_{k1}^+ - \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{7,ab} Z_{l3+a}^+ Z_{i3+b}^+ Z_{j1}^+ Z_{k1}^+ \\
& - \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{6,ab} Z_{k1+a}^+ Z_{j1+b}^+ Z_{i1}^+ Z_{l1}^+ - \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{7,ab} Z_{k3+a}^+ Z_{j3+b}^+ Z_{i1}^+ Z_{l1}^+ \\
& - \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{6,ab} Z_{k1+a}^+ Z_{i1+b}^+ Z_{j1}^+ Z_{l1}^+ - \sum_{b=1}^2 \sum_{a=1}^2 \lambda_{7,ab} Z_{k3+a}^+ Z_{i3+b}^+ Z_{j1}^+ Z_{l1}^+ \\
& \left. + 4l_h Z_{i1}^+ Z_{j1}^+ Z_{k1}^+ Z_{l1}^+ \right) \quad (200)
\end{aligned}$$

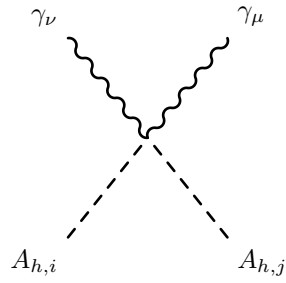


$$i\lambda_5 Z_{i1}^+ Z_{k1}^+ \quad (201)$$

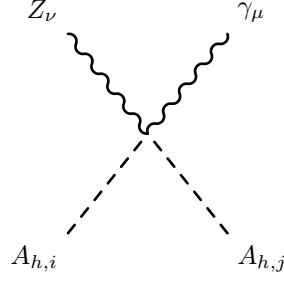


$$4i\lambda_4 \quad (202)$$

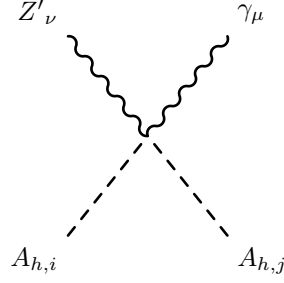
7.8 Two Scalar-Two Vector Boson-Interaction



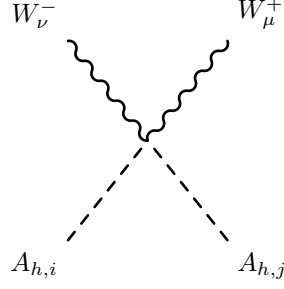
$$\begin{aligned} & \left(+\frac{i}{2}g_1^2 \cos \Theta_W^2 Z_{i1}^A Z_{j1}^A - ig_1 g_2 \cos \Theta_W \sin \Theta_W Z_{i1}^A Z_{j1}^A \right. \\ & \left. + \frac{i}{2}g_2^2 \sin \Theta_W^2 Z_{i1}^A Z_{j1}^A + 50ig_Y^2 \cos \Theta_W^2 Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu}) \end{aligned} \quad (203)$$



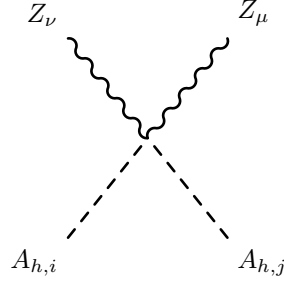
$$\begin{aligned}
& \left(-\frac{i}{2}g_1g_2 \cos \Theta_W^2 \cos \Theta'_W Z_{i1}^A Z_{j1}^A - \frac{i}{2}g_1^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i1}^A Z_{j1}^A \right. \\
& + \frac{i}{2}g_2^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_1g_2 \cos \Theta'_W \sin \Theta_W^2 Z_{i1}^A Z_{j1}^A \\
& + \frac{i}{2}g_1g_{BY} \cos \Theta_W \sin \Theta'_W Z_{i1}^A Z_{j1}^A - \frac{i}{2}g_{BY}g_2 \sin \Theta_W \sin \Theta'_W Z_{i1}^A Z_{j1}^A \\
& \left. - 50ig_Y^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i2}^A Z_{j2}^A + 50ig_Bg_{YB} \cos \Theta_W \sin \Theta'_W Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu})
\end{aligned} \tag{204}$$



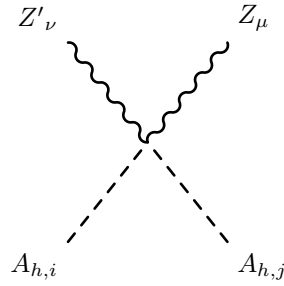
$$\begin{aligned}
& \left(+\frac{i}{2}g_1g_{BY} \cos \Theta_W \cos \Theta'_W Z_{i1}^A Z_{j1}^A - \frac{i}{2}g_{BY}g_2 \cos \Theta'_W \sin \Theta_W Z_{i1}^A Z_{j1}^A \right. \\
& + \frac{i}{2}g_1g_2 \cos \Theta_W^2 \sin \Theta'_W Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_1^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W Z_{i1}^A Z_{j1}^A \\
& - \frac{i}{2}g_2^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W Z_{i1}^A Z_{j1}^A - \frac{i}{2}g_1g_2 \sin \Theta_W^2 \sin \Theta'_W Z_{i1}^A Z_{j1}^A \\
& \left. + 50ig_Bg_{YB} \cos \Theta_W \cos \Theta'_W Z_{i2}^A Z_{j2}^A + 25ig_Y^2 \sin 2\Theta_W \sin \Theta'_W Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu})
\end{aligned} \tag{205}$$



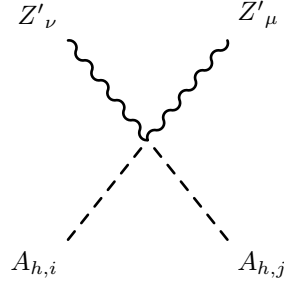
$$\frac{i}{2}g_2^2 Z_{i1}^A Z_{j1}^A (g_{\mu\nu}) \quad (206)$$



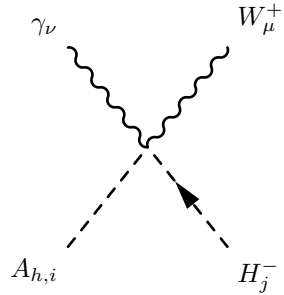
$$\begin{aligned} & \left(+\frac{i}{2}g_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 Z_{i1}^A Z_{j1}^A + ig_1 g_2 \cos \Theta_W \cos \Theta_W'^2 \sin \Theta_W Z_{i1}^A Z_{j1}^A \right. \\ & + \frac{i}{2}g_1^2 \cos \Theta_W'^2 \sin \Theta_W^2 Z_{i1}^A Z_{j1}^A - ig_{BY} g_2 \cos \Theta_W \cos \Theta_W' \sin \Theta_W' Z_{i1}^A Z_{j1}^A \\ & - ig_1 g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_{BY}^2 \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A \\ & + 50ig_{YB}^2 \cos \Theta_W'^2 \sin \Theta_W^2 Z_{i2}^A Z_{j2}^A - 100ig_B g_{YB} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' Z_{i2}^A Z_{j2}^A \\ & \left. + 50ig_B^2 \sin \Theta_W'^2 Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu}) \end{aligned} \quad (207)$$



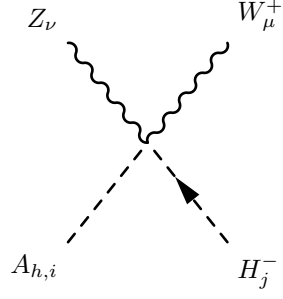
$$\begin{aligned}
& \left(-\frac{i}{2}g_{BY}g_2 \cos \Theta_W \cos \Theta_W'^2 Z_{i1}^A Z_{j1}^A - \frac{i}{2}g_1 g_{BY} \cos \Theta_W'^2 \sin \Theta_W Z_{i1}^A Z_{j1}^A \right. \\
& + \frac{i}{2}g_{BY}^2 \cos \Theta_W' \sin \Theta_W' Z_{i1}^A Z_{j1}^A - \frac{i}{2}g_2^2 \cos \Theta_W'^2 \cos \Theta_W' \sin \Theta_W' Z_{i1}^A Z_{j1}^A \\
& - \frac{i}{2}g_1^2 \cos \Theta_W' \sin \Theta_W'^2 \sin \Theta_W' Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_{BY}g_2 \cos \Theta_W \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A \\
& + \frac{i}{2}g_1 g_{BY} \sin \Theta_W \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A - \frac{i}{2}g_1 g_2 \cos \Theta_W \sin \Theta_W \sin 2\Theta_W' Z_{i1}^A Z_{j1}^A \\
& - 50ig_B g_Y B \cos \Theta_W'^2 \sin \Theta_W Z_{i2}^A Z_{j2}^A + 50ig_B g_Y B \sin \Theta_W \sin \Theta_W'^2 Z_{i2}^A Z_{j2}^A \\
& \left. + 25ig_B^2 \sin 2\Theta_W' Z_{i2}^A Z_{j2}^A - 25ig_Y^2 \sin \Theta_W'^2 \sin 2\Theta_W' Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu})
\end{aligned} \tag{208}$$



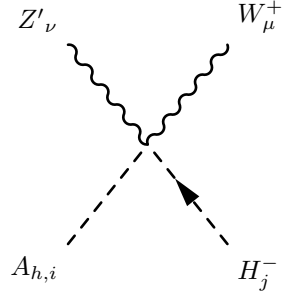
$$\begin{aligned}
& \left(+\frac{i}{2}g_{BY}^2 \cos \Theta_W'^2 Z_{i1}^A Z_{j1}^A + ig_{BY}g_2 \cos \Theta_W \cos \Theta_W' \sin \Theta_W' Z_{i1}^A Z_{j1}^A \right. \\
& + ig_1 g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_2^2 \cos \Theta_W'^2 \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A \\
& + ig_1 g_2 \cos \Theta_W \sin \Theta_W \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_1^2 \sin \Theta_W'^2 \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A \\
& + 50ig_B^2 \cos \Theta_W'^2 Z_{i2}^A Z_{j2}^A + 100ig_B g_Y B \cos \Theta_W' \sin \Theta_W \sin \Theta_W' Z_{i2}^A Z_{j2}^A \\
& \left. + 50ig_Y^2 \sin \Theta_W'^2 \sin \Theta_W'^2 Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu})
\end{aligned} \tag{209}$$



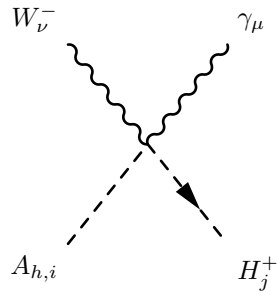
$$-\frac{1}{2}g_1 g_2 \cos \Theta_W Z_{i1}^A Z_{j1}^+ (g_{\mu\nu}) \tag{210}$$



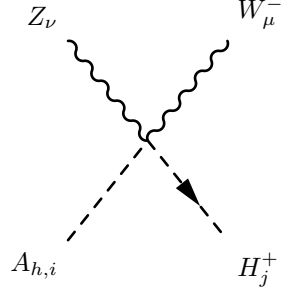
$$\left(\frac{1}{2} g_1 g_2 \cos \Theta'_W \sin \Theta_W Z_{i1}^A Z_{j1}^+ - \frac{1}{2} g_{BY} g_2 \sin \Theta'_W Z_{i1}^A Z_{j1}^+ \right) (g_{\mu\nu}) \quad (211)$$



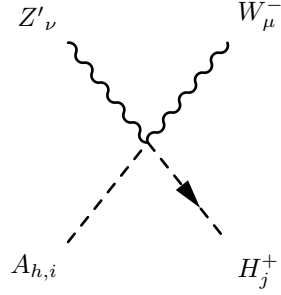
$$\left(-\frac{1}{2} g_1 g_2 \sin \Theta_W \sin \Theta'_W Z_{i1}^A Z_{j1}^+ - \frac{1}{2} g_{BY} g_2 \cos \Theta'_W Z_{i1}^A Z_{j1}^+ \right) (g_{\mu\nu}) \quad (212)$$



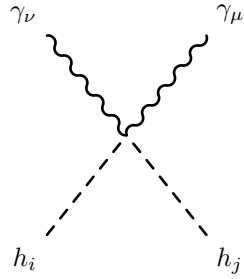
$$\frac{1}{2} g_1 g_2 \cos \Theta_W Z_{i1}^A Z_{j1}^+ (g_{\mu\nu}) \quad (213)$$



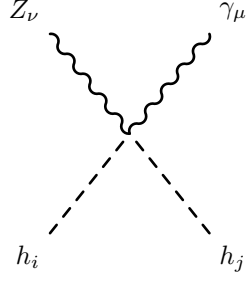
$$\left(-\frac{1}{2}g_1g_2 \cos \Theta'_W \sin \Theta_W Z_{i1}^A Z_{j1}^+ + \frac{1}{2}g_{BY}g_2 \sin \Theta'_W Z_{i1}^A Z_{j1}^+ \right) (g_{\mu\nu}) \quad (214)$$



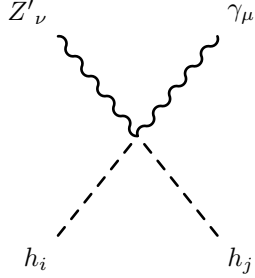
$$\left(\frac{1}{2}g_1g_2 \sin \Theta_W \sin \Theta'_W Z_{i1}^A Z_{j1}^+ + \frac{1}{2}g_{BY}g_2 \cos \Theta'_W Z_{i1}^A Z_{j1}^+ \right) (g_{\mu\nu}) \quad (215)$$



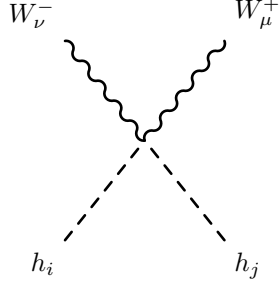
$$\begin{aligned} & \left(+\frac{i}{2}g_1^2 \cos \Theta_W^2 Z_{i1}^H Z_{j1}^H - ig_1g_2 \cos \Theta_W \sin \Theta_W Z_{i1}^H Z_{j1}^H \right. \\ & \left. + \frac{i}{2}g_2^2 \sin \Theta_W^2 Z_{i1}^H Z_{j1}^H + 50ig_Y^2 \cos \Theta_W^2 Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu}) \end{aligned} \quad (216)$$



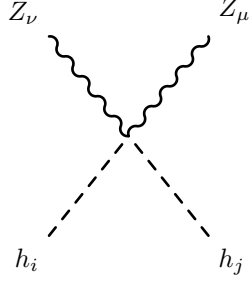
$$\begin{aligned}
& \left(-\frac{i}{2}g_1g_2\cos\Theta_W^2\cos\Theta'_W Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_1^2\cos\Theta_W\cos\Theta'_W\sin\Theta_W Z_{i1}^H Z_{j1}^H \right. \\
& + \frac{i}{2}g_2^2\cos\Theta_W\cos\Theta'_W\sin\Theta_W Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_1g_2\cos\Theta'_W\sin\Theta_W^2 Z_{i1}^H Z_{j1}^H \\
& + \frac{i}{2}g_1g_{BY}\cos\Theta_W\sin\Theta'_W Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_{BY}g_2\sin\Theta_W\sin\Theta'_W Z_{i1}^H Z_{j1}^H \\
& \left. - 50ig_Y^2\cos\Theta_W\cos\Theta'_W\sin\Theta_W Z_{i2}^H Z_{j2}^H + 50ig_Bg_{YB}\cos\Theta_W\sin\Theta'_W Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu})
\end{aligned} \tag{217}$$



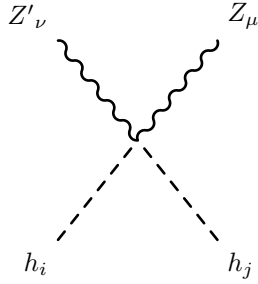
$$\begin{aligned}
& \left(+\frac{i}{2}g_1g_{BY}\cos\Theta_W\cos\Theta'_W Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_{BY}g_2\cos\Theta'_W\sin\Theta_W Z_{i1}^H Z_{j1}^H \right. \\
& + \frac{i}{2}g_1g_2\cos\Theta_W^2\sin\Theta'_W Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_1^2\cos\Theta_W\sin\Theta_W\sin\Theta'_W Z_{i1}^H Z_{j1}^H \\
& - \frac{i}{2}g_2^2\cos\Theta_W\sin\Theta_W\sin\Theta'_W Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_1g_2\sin\Theta_W^2\sin\Theta'_W Z_{i1}^H Z_{j1}^H \\
& \left. + 50ig_Bg_{YB}\cos\Theta_W\cos\Theta'_W Z_{i2}^H Z_{j2}^H + 25ig_Y^2\sin 2\Theta_W\sin\Theta'_W Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu})
\end{aligned} \tag{218}$$



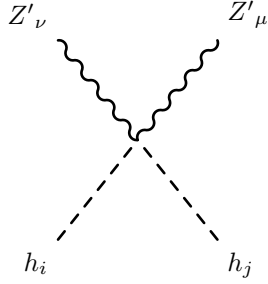
$$\frac{i}{2}g_2^2 Z_{i1}^H Z_{j1}^H (g_{\mu\nu}) \quad (219)$$



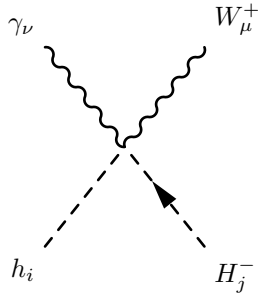
$$\begin{aligned} & \left(+ \frac{i}{2}g_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 Z_{i1}^H Z_{j1}^H + i g_1 g_2 \cos \Theta_W \cos \Theta_W'^2 \sin \Theta_W Z_{i1}^H Z_{j1}^H \right. \\ & + \frac{i}{2}g_1^2 \cos \Theta_W'^2 \sin \Theta_W^2 Z_{i1}^H Z_{j1}^H - i g_{BY} g_2 \cos \Theta_W \cos \Theta_W' \sin \Theta_W' Z_{i1}^H Z_{j1}^H \\ & - i g_1 g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_{BY}^2 \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H \\ & + 50 i g_{YB}^2 \cos \Theta_W'^2 \sin \Theta_W^2 Z_{i2}^H Z_{j2}^H - 100 i g_B g_{YB} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' Z_{i2}^H Z_{j2}^H \\ & \left. + 50 i g_B^2 \sin \Theta_W'^2 Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu}) \end{aligned} \quad (220)$$



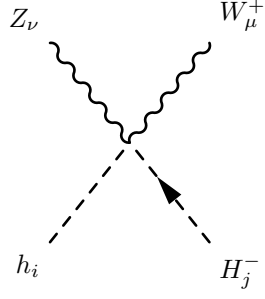
$$\begin{aligned}
& \left(-\frac{i}{2}g_{BY}g_2 \cos \Theta_W \cos \Theta_W'^2 Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_1 g_{BY} \cos \Theta_W'^2 \sin \Theta_W Z_{i1}^H Z_{j1}^H \right. \\
& + \frac{i}{2}g_{BY}^2 \cos \Theta'_W \sin \Theta'_W Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_2^2 \cos \Theta_W'^2 \cos \Theta'_W \sin \Theta'_W Z_{i1}^H Z_{j1}^H \\
& - \frac{i}{2}g_1^2 \cos \Theta'_W \sin \Theta_W'^2 \sin \Theta'_W Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_{BY}g_2 \cos \Theta_W \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H \\
& + \frac{i}{2}g_1 g_{BY} \sin \Theta_W \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_1 g_2 \cos \Theta_W \sin \Theta_W \sin 2\Theta'_W Z_{i1}^H Z_{j1}^H \\
& - 50ig_B g_{YB} \cos \Theta_W'^2 \sin \Theta_W Z_{i2}^H Z_{j2}^H + 50ig_B g_{YB} \sin \Theta_W \sin \Theta_W'^2 Z_{i2}^H Z_{j2}^H \\
& \left. + 25ig_B^2 \sin 2\Theta'_W Z_{i2}^H Z_{j2}^H - 25ig_{YB}^2 \sin \Theta_W'^2 \sin 2\Theta'_W Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu})
\end{aligned} \tag{221}$$



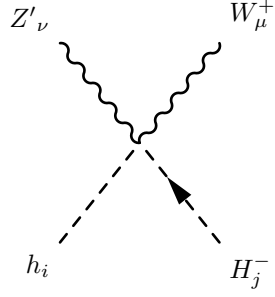
$$\begin{aligned}
& \left(+\frac{i}{2}g_{BY}^2 \cos \Theta_W'^2 Z_{i1}^H Z_{j1}^H + ig_{BY}g_2 \cos \Theta_W \cos \Theta'_W \sin \Theta'_W Z_{i1}^H Z_{j1}^H \right. \\
& + ig_1 g_{BY} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_2^2 \cos \Theta_W'^2 \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H \\
& + ig_1 g_2 \cos \Theta_W \sin \Theta_W \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_1^2 \sin \Theta_W'^2 \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H \\
& + 50ig_B^2 \cos \Theta_W'^2 Z_{i2}^H Z_{j2}^H + 100ig_B g_{YB} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W Z_{i2}^H Z_{j2}^H \\
& \left. + 50ig_{YB}^2 \sin \Theta_W'^2 \sin \Theta_W'^2 Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu})
\end{aligned} \tag{222}$$



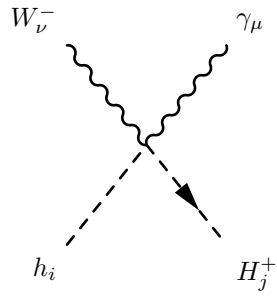
$$\frac{i}{2}g_1 g_2 \cos \Theta_W Z_{i1}^H Z_{j1}^+ (g_{\mu\nu}) \tag{223}$$



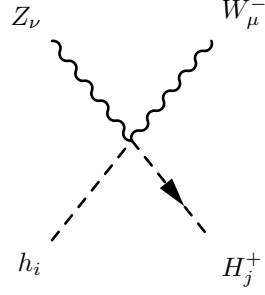
$$\left(-\frac{i}{2}g_1g_2\cos\Theta'_W\sin\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2}g_{BY}g_2\sin\Theta'_W Z_{i1}^H Z_{j1}^+ \right) (g_{\mu\nu}) \quad (224)$$



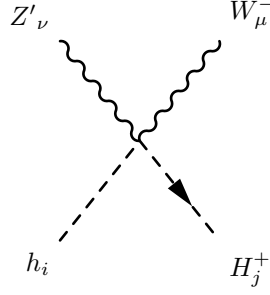
$$\left(\frac{i}{2}g_1g_2\sin\Theta_W\sin\Theta'_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2}g_{BY}g_2\cos\Theta'_W Z_{i1}^H Z_{j1}^+ \right) (g_{\mu\nu}) \quad (225)$$



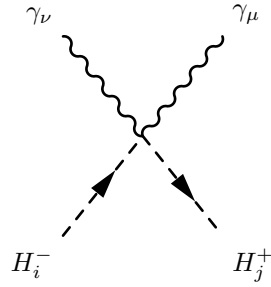
$$\frac{i}{2}g_1g_2\cos\Theta_W Z_{i1}^H Z_{j1}^+ (g_{\mu\nu}) \quad (226)$$



$$\left(-\frac{i}{2}g_1g_2\cos\Theta'_W\sin\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2}g_{BY}g_2\sin\Theta'_W Z_{i1}^H Z_{j1}^+ \right) (g_{\mu\nu}) \quad (227)$$

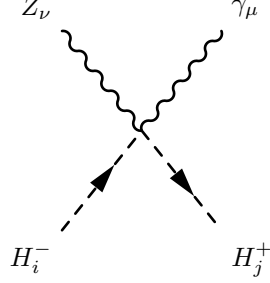


$$\left(\frac{i}{2}g_1g_2\sin\Theta_W\sin\Theta'_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2}g_{BY}g_2\cos\Theta'_W Z_{i1}^H Z_{j1}^+ \right) (g_{\mu\nu}) \quad (228)$$



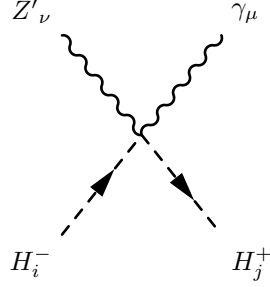
$$\begin{aligned} & \left(+2ig_1^2\cos\Theta_W^2\sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 4ig_1g_{YB}\cos\Theta_W^2\sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \right. \\ & \left. + 2ig_{YB}^2\cos\Theta_W^2\sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 2ig_1^2\cos\Theta_W^2\sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \right) \end{aligned}$$

$$\begin{aligned}
& -16ig_1g_{YB} \cos \Theta_W^2 \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ + 32ig_Y^2 \cos \Theta_W^2 \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& + \frac{i}{2}g_1^2 \cos \Theta_W^2 Z_{i1}^+ Z_{j1}^+ + ig_1g_2 \cos \Theta_W \sin \Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2}g_2^2 \sin \Theta_W^2 Z_{i1}^+ Z_{j1}^+ \Big) (g_{\mu\nu})
\end{aligned} \tag{229}$$



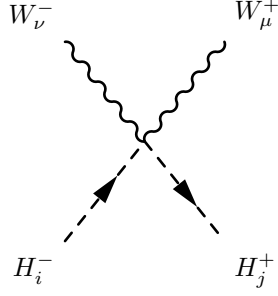
$$\begin{aligned}
& \left(-2ig_1^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \right. \\
& -4ig_1g_{YB} \cos \Theta_W \cos \Theta'_W \sin \Theta_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& -2ig_Y^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& +2ig_1g_{BY} \cos \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ +2ig_1g_B \cos \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& +2ig_{BY}g_{YB} \cos \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ +2ig_Bg_{YB} \cos \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& -2ig_1^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& +16ig_1g_{YB} \cos \Theta_W \cos \Theta'_W \sin \Theta_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& -32ig_Y^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& +2ig_1g_{BY} \cos \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ -8ig_1g_B \cos \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& \left. -8ig_{BY}g_{YB} \cos \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ +32ig_Bg_{YB} \cos \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \right)
\end{aligned}$$

$$\begin{aligned}
& + \frac{i}{2} g_1 g_2 \cos \Theta_W^2 \cos \Theta'_W Z_{i1}^+ Z_{j1}^+ - \frac{i}{2} g_1^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i1}^+ Z_{j1}^+ \\
& + \frac{i}{2} g_2^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i1}^+ Z_{j1}^+ - \frac{i}{2} g_1 g_2 \cos \Theta'_W \sin \Theta_W^2 Z_{i1}^+ Z_{j1}^+ \\
& + \frac{i}{2} g_1 g_{BY} \cos \Theta_W \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_{BY} g_2 \sin \Theta_W \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ \Big) (g_{\mu\nu})
\end{aligned} \tag{230}$$

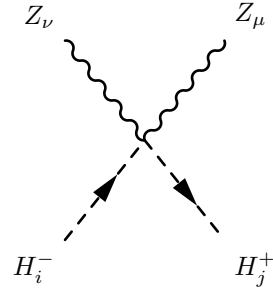


$$\begin{aligned}
& \left(+ 2ig_1 g_{BY} \cos \Theta_W \cos \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 2ig_1 g_B \cos \Theta_W \cos \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \right. \\
& + 2ig_{BY} g_{YB} \cos \Theta_W \cos \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 2ig_B g_{YB} \cos \Theta_W \cos \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 2ig_1^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 4ig_1 g_{YB} \cos \Theta_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 2ig_{YB}^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 2ig_1 g_{BY} \cos \Theta_W \cos \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ - 8ig_1 g_B \cos \Theta_W \cos \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& - 8ig_{BY} g_{YB} \cos \Theta_W \cos \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ + 32ig_B g_{YB} \cos \Theta_W \cos \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& + 2ig_1^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& - 16ig_1 g_{YB} \cos \Theta_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& \left. + 32ig_{YB}^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ + \frac{i}{2} g_1 g_{BY} \cos \Theta_W \cos \Theta'_W Z_{i1}^+ Z_{j1}^+ \right)
\end{aligned}$$

$$\begin{aligned}
& + \frac{i}{2} g_{BY} g_2 \cos \Theta'_W \sin \Theta_W Z_{i1}^+ Z_{j1}^+ - \frac{i}{2} g_1 g_2 \cos \Theta_W^2 \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ \\
& + \frac{i}{2} g_1^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ - \frac{i}{2} g_2^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ \\
& + \frac{i}{2} g_1 g_2 \sin \Theta_W^2 \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ \Big(g_{\mu\nu} \Big)
\end{aligned} \tag{231}$$

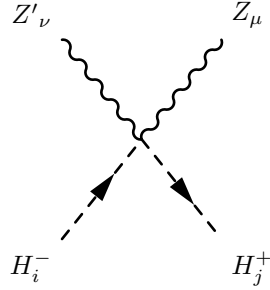


$$\frac{i}{2} g_2^2 Z_{i1}^+ Z_{j1}^+ \Big(g_{\mu\nu} \Big) \tag{232}$$



$$\begin{aligned}
& \left(+ 2i g_1^2 \cos \Theta_W'^2 \sin \Theta_W^2 \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 4i g_1 g_{YB} \cos \Theta_W'^2 \sin \Theta_W^2 \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \right. \\
& + 2i g_{YB}^2 \cos \Theta_W'^2 \sin \Theta_W^2 \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& - 4i g_1 g_{BY} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& - 4i g_1 g_B \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& \left. - 4i g_{BY} g_{YB} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \right)
\end{aligned}$$

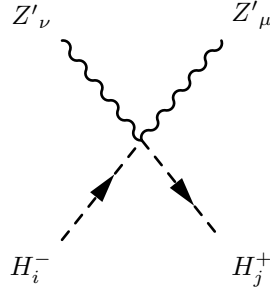
$$\begin{aligned}
& -4ig_B g_Y g_B \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 2ig_{BY}^2 \sin \Theta'^2_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 4ig_{BY} g_B \sin \Theta'^2_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 2ig_B^2 \sin \Theta'^2_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 2ig_1^2 \cos \Theta'^2_W \sin \Theta_W^2 \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ - 16ig_1 g_Y g_B \cos \Theta'^2_W \sin \Theta_W^2 \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& + 32ig_{YB}^2 \cos \Theta'^2_W \sin \Theta_W^2 \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& - 4ig_1 g_{BY} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& + 16ig_1 g_B \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& + 16ig_{BY} g_Y g_B \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& - 64ig_B g_Y g_B \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ + 2ig_{BY}^2 \sin \Theta'^2_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& - 16ig_{BY} g_B \sin \Theta'^2_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ + 32ig_B^2 \sin \Theta'^2_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& + \frac{i}{2} g_2^2 \cos \Theta_W^2 \cos \Theta'^2_W Z_{i1}^+ Z_{j1}^+ - ig_1 g_2 \cos \Theta_W \cos \Theta'^2_W \sin \Theta_W Z_{i1}^+ Z_{j1}^+ \\
& + \frac{i}{2} g_1^2 \cos \Theta'^2_W \sin \Theta_W^2 Z_{i1}^+ Z_{j1}^+ + ig_{BY} g_2 \cos \Theta_W \cos \Theta'_W \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ \\
& - ig_1 g_{BY} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_{BY}^2 \sin \Theta'^2_W Z_{i1}^+ Z_{j1}^+ \Big) (g_{\mu\nu})
\end{aligned} \tag{233}$$



$$\left(-2ig_1 g_{BY} \cos \Theta'^2_W \sin \Theta_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ - 2ig_1 g_B \cos \Theta'^2_W \sin \Theta_W \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \right.$$

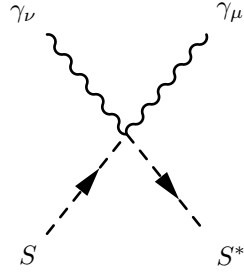
$$\begin{aligned}
& -2ig_{BY}g_{YB}\cos\Theta_W'^2\sin\Theta_W\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^+-2ig_Bg_{YB}\cos\Theta_W'^2\sin\Theta_W\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^+ \\
& +2ig_{BY}^2\cos\Theta_W'\sin\Theta_W'\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^++4ig_{BY}g_B\cos\Theta_W'\sin\Theta_W'\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^+ \\
& +2ig_B^2\cos\Theta_W'\sin\Theta_W'\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^+ \\
& -2ig_1^2\cos\Theta_W'\sin\Theta_W'^2\sin\Theta_W'\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^+ \\
& -2ig_{YB}^2\cos\Theta_W'\sin\Theta_W'^2\sin\Theta_W'\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^+ \\
& +2ig_1g_{BY}\sin\Theta_W\sin\Theta_W'^2\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^++2ig_1g_B\sin\Theta_W\sin\Theta_W'^2\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^+ \\
& +2ig_{BY}g_{YB}\sin\Theta_W\sin\Theta_W'^2\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^++2ig_Bg_{YB}\sin\Theta_W\sin\Theta_W'^2\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^+ \\
& -2ig_1g_{YB}\sin\Theta_W'^2\sin2\Theta_W'\sum_{a=1}^2Z_{i1+a}^+Z_{j1+a}^+-2ig_1g_{BY}\cos\Theta_W'^2\sin\Theta_W\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+ \\
& +8ig_1g_B\cos\Theta_W'^2\sin\Theta_W\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^++8ig_{BY}g_{YB}\cos\Theta_W'^2\sin\Theta_W\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+ \\
& -32ig_Bg_{YB}\cos\Theta_W'^2\sin\Theta_W\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^++2ig_{BY}^2\cos\Theta_W'\sin\Theta_W'\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+ \\
& -16ig_{BY}g_B\cos\Theta_W'\sin\Theta_W'\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+ \\
& -2ig_1^2\cos\Theta_W'\sin\Theta_W'^2\sin\Theta_W'\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+ \\
& +16ig_1g_{YB}\cos\Theta_W'\sin\Theta_W'^2\sin\Theta_W'\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+ \\
& +2ig_1g_{BY}\sin\Theta_W\sin\Theta_W'^2\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+-8ig_1g_B\sin\Theta_W\sin\Theta_W'^2\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+ \\
& -8ig_{BY}g_{YB}\sin\Theta_W\sin\Theta_W'^2\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^++32ig_Bg_{YB}\sin\Theta_W\sin\Theta_W'^2\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+ \\
& +16ig_B^2\sin2\Theta_W'\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+-16ig_{YB}^2\sin\Theta_W'^2\sin2\Theta_W'\sum_{a=1}^2Z_{i3+a}^+Z_{j3+a}^+
\end{aligned}$$

$$\begin{aligned}
& + \frac{i}{2} g_{BY} g_2 \cos \Theta_W \cos \Theta_W'^2 Z_{i1}^+ Z_{j1}^+ - \frac{i}{2} g_1 g_{BY} \cos \Theta_W'^2 \sin \Theta_W Z_{i1}^+ Z_{j1}^+ \\
& + \frac{i}{2} g_{BY}^2 \cos \Theta_W' \sin \Theta_W' Z_{i1}^+ Z_{j1}^+ - \frac{i}{2} g_2^2 \cos \Theta_W^2 \cos \Theta_W' \sin \Theta_W' Z_{i1}^+ Z_{j1}^+ \\
& - \frac{i}{2} g_1^2 \cos \Theta_W' \sin \Theta_W^2 \sin \Theta_W' Z_{i1}^+ Z_{j1}^+ - \frac{i}{2} g_{BY} g_2 \cos \Theta_W \sin \Theta_W'^2 Z_{i1}^+ Z_{j1}^+ \\
& + \frac{i}{2} g_1 g_{BY} \sin \Theta_W \sin \Theta_W'^2 Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_1 g_2 \cos \Theta_W \sin \Theta_W \sin 2\Theta_W' Z_{i1}^+ Z_{j1}^+ \Big) (g_{\mu\nu})
\end{aligned} \tag{234}$$

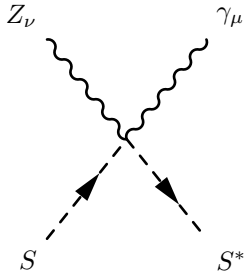


$$\begin{aligned}
& \left(+ 2ig_{BY}^2 \cos \Theta_W'^2 \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 4ig_{BY} g_B \cos \Theta_W'^2 \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \right. \\
& + 2ig_B^2 \cos \Theta_W'^2 \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 4ig_1 g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 4ig_1 g_B \cos \Theta_W' \sin \Theta_W \sin \Theta_W' \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 4ig_{BY} g_{YB} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 4ig_B g_{YB} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 2ig_1^2 \sin \Theta_W^2 \sin \Theta_W'^2 \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 4ig_1 g_{YB} \sin \Theta_W^2 \sin \Theta_W'^2 \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ \\
& + 2ig_{YB}^2 \sin \Theta_W^2 \sin \Theta_W'^2 \sum_{a=1}^2 Z_{i1+a}^+ Z_{j1+a}^+ + 2ig_{BY}^2 \cos \Theta_W'^2 \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& - 16ig_{BY} g_B \cos \Theta_W'^2 \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ + 32ig_B^2 \cos \Theta_W'^2 \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& \left. + 4ig_1 g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \right)
\end{aligned}$$

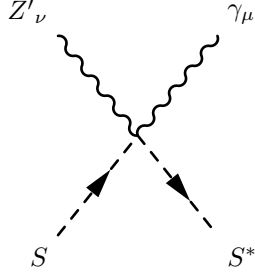
$$\begin{aligned}
& -16ig_1g_B \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& -16ig_{BY}g_{YB} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& +64ig_Bg_{YB} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& +2ig_1^2 \sin \Theta_W^2 \sin \Theta'^2_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ -16ig_1g_{YB} \sin \Theta_W^2 \sin \Theta'^2_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ \\
& +32ig_{YB}^2 \sin \Theta_W^2 \sin \Theta'^2_W \sum_{a=1}^2 Z_{i3+a}^+ Z_{j3+a}^+ + \frac{i}{2}g_{BY}^2 \cos \Theta'^2_W Z_{i1}^+ Z_{j1}^+ \\
& -ig_{BY}g_2 \cos \Theta_W \cos \Theta'_W \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ \\
& +ig_1g_{BY} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2}g_2^2 \cos \Theta_W^2 \sin \Theta'^2_W Z_{i1}^+ Z_{j1}^+ \\
& -ig_1g_2 \cos \Theta_W \sin \Theta_W \sin \Theta'^2_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2}g_1^2 \sin \Theta_W^2 \sin \Theta'^2_W Z_{i1}^+ Z_{j1}^+ \Big) (g_{\mu\nu})
\end{aligned} \tag{235}$$



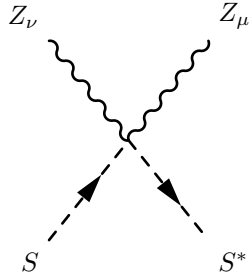
$$50ig_{YB}^2 \cos \Theta_W^2 (g_{\mu\nu}) \tag{236}$$



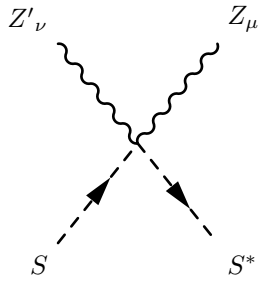
$$\left(50ig_Bg_{YB}\cos\Theta_W\sin\Theta'_W-50ig_{YB}^2\cos\Theta_W\cos\Theta'_W\sin\Theta_W\right)\left(g_{\mu\nu}\right) \quad (237)$$



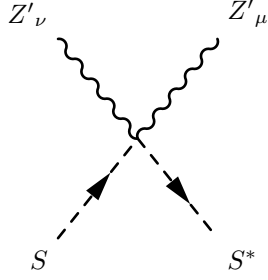
$$\left(50ig_Bg_{YB}\cos\Theta_W\cos\Theta'_W+50ig_{YB}^2\cos\Theta_W\sin\Theta_W\sin\Theta'_W\right)\left(g_{\mu\nu}\right) \quad (238)$$



$$\left(-100ig_Bg_{YB}\cos\Theta'_W\sin\Theta_W\sin\Theta'_W+50ig_B^2\sin\Theta'^2_W+50ig_{YB}^2\cos\Theta'^2_W\sin\Theta_W^2\right)\left(g_{\mu\nu}\right) \quad (239)$$

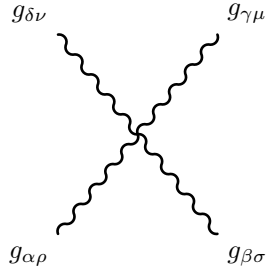


$$\begin{aligned} &\left(-50ig_Bg_{YB}\cos\Theta_W^2\sin\Theta_W+50ig_B^2\cos\Theta'_W\sin\Theta'_W-50ig_{YB}^2\cos\Theta'_W\sin\Theta_W^2\sin\Theta'_W\right. \\ &\left.+50ig_Bg_{YB}\sin\Theta_W\sin\Theta_W^2\right)\left(g_{\mu\nu}\right) \end{aligned} \quad (240)$$



$$\left(100ig_Bg_{YB}\cos\Theta'_W\sin\Theta_W\sin\Theta'_W+50ig_B^2\cos\Theta'^2_W+50ig_{YB}^2\sin\Theta_W^2\sin\Theta'^2_W\right)\left(g_{\mu\nu}\right) \quad (241)$$

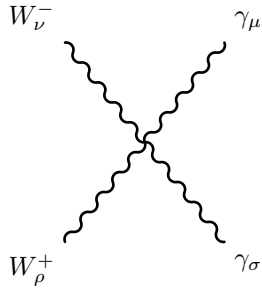
7.9 Four Vector Boson-Interaction



$$ig_3^2\left(-\sum_{a=1}^8f_{\alpha,\delta,a}f_{\beta,\gamma,a}-\sum_{a=1}^8f_{\alpha,\gamma,a}f_{\beta,\delta,a}\right)\left(g_{\rho\sigma}g_{\mu\nu}\right) \quad (242)$$

$$+ig_3^2\left(-\sum_{a=1}^8f_{\alpha,\beta,a}f_{\gamma,\delta,a}+\sum_{a=1}^8f_{\alpha,\delta,a}f_{\beta,\gamma,a}\right)\left(g_{\rho\mu}g_{\sigma\nu}\right) \quad (243)$$

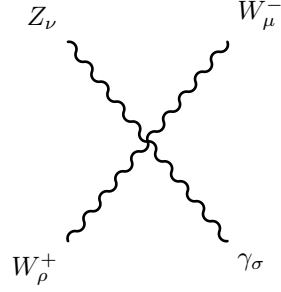
$$+ig_3^2\left(\sum_{a=1}^8f_{\alpha,\gamma,a}f_{\beta,\delta,a}+\sum_{a=1}^8f_{\alpha,\beta,a}f_{\gamma,\delta,a}\right)\left(g_{\rho\nu}g_{\sigma\mu}\right) \quad (244)$$



$$ig_2^2 \sin \Theta_W^2 (g_{\rho\sigma} g_{\mu\nu}) \quad (245)$$

$$+ ig_2^2 \sin \Theta_W^2 (g_{\rho\mu} g_{\sigma\nu}) \quad (246)$$

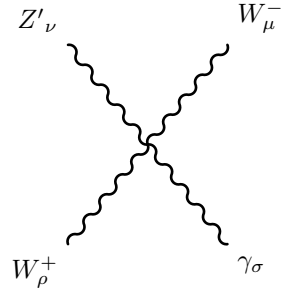
$$+ -2ig_2^2 \sin \Theta_W^2 (g_{\rho\nu} g_{\sigma\mu}) \quad (247)$$



$$\frac{i}{2} g_2^2 \cos \Theta'_W \sin 2\Theta_W (g_{\rho\sigma} g_{\mu\nu}) \quad (248)$$

$$+ -ig_2^2 \cos \Theta'_W \sin 2\Theta_W (g_{\rho\mu} g_{\sigma\nu}) \quad (249)$$

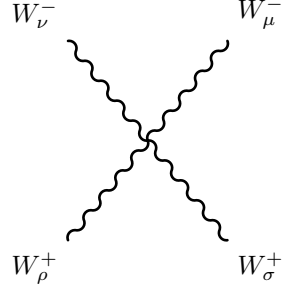
$$+ \frac{i}{2} g_2^2 \cos \Theta'_W \sin 2\Theta_W (g_{\rho\nu} g_{\sigma\mu}) \quad (250)$$



$$- \frac{i}{2} g_2^2 \sin 2\Theta_W \sin \Theta'_W (g_{\rho\sigma} g_{\mu\nu}) \quad (251)$$

$$+ ig_2^2 \sin 2\Theta_W \sin \Theta'_W (g_{\rho\mu} g_{\sigma\nu}) \quad (252)$$

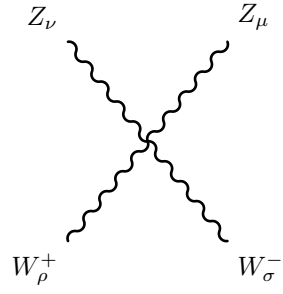
$$+ -\frac{i}{2} g_2^2 \sin 2\Theta_W \sin \Theta'_W (g_{\rho\nu} g_{\sigma\mu}) \quad (253)$$



$$2ig_2^2(g_{\rho\sigma}g_{\mu\nu}) \quad (254)$$

$$+ -ig_2^2(g_{\rho\mu}g_{\sigma\nu}) \quad (255)$$

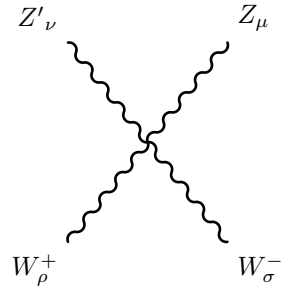
$$+ -ig_2^2(g_{\rho\nu}g_{\sigma\mu}) \quad (256)$$



$$- 2ig_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 (g_{\rho\sigma}g_{\mu\nu}) \quad (257)$$

$$+ ig_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 (g_{\rho\mu}g_{\sigma\nu}) \quad (258)$$

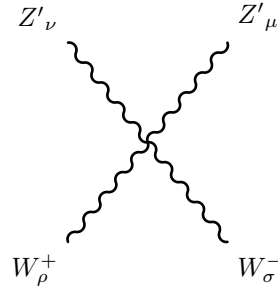
$$+ ig_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 (g_{\rho\nu}g_{\sigma\mu}) \quad (259)$$



$$ig_2^2 \cos \Theta_W^2 \sin 2\Theta'_W \left(g_{\rho\sigma} g_{\mu\nu} \right) \quad (260)$$

$$+ -\frac{i}{2} g_2^2 \cos \Theta_W^2 \sin 2\Theta'_W \left(g_{\rho\mu} g_{\sigma\nu} \right) \quad (261)$$

$$+ -\frac{i}{2} g_2^2 \cos \Theta_W^2 \sin 2\Theta'_W \left(g_{\rho\nu} g_{\sigma\mu} \right) \quad (262)$$

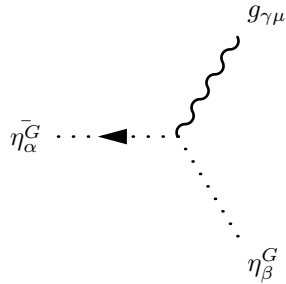


$$- 2ig_2^2 \cos \Theta_W^2 \sin \Theta'^2_W \left(g_{\rho\sigma} g_{\mu\nu} \right) \quad (263)$$

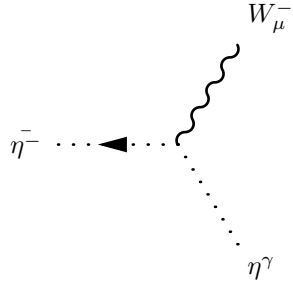
$$+ ig_2^2 \cos \Theta_W^2 \sin \Theta'^2_W \left(g_{\rho\mu} g_{\sigma\nu} \right) \quad (264)$$

$$+ ig_2^2 \cos \Theta_W^2 \sin \Theta'^2_W \left(g_{\rho\nu} g_{\sigma\mu} \right) \quad (265)$$

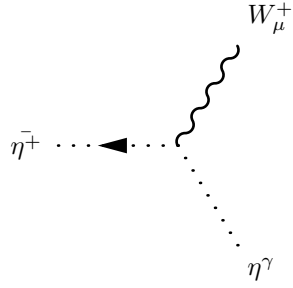
7.10 Two Ghosts-One Vector Boson-Interaction



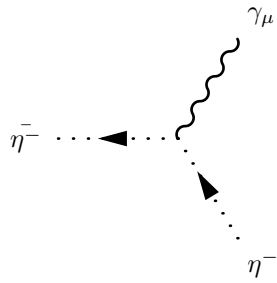
$$g_3 f_{\alpha,\beta,\gamma} \left(p_\mu^{\eta_\beta^G} \right) \quad (266)$$



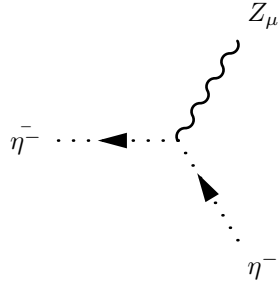
$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^\gamma} \right) \quad (267)$$



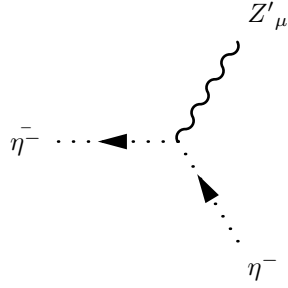
$$- ig_2 \sin \Theta_W \left(p_\mu^{\eta^\gamma} \right) \quad (268)$$



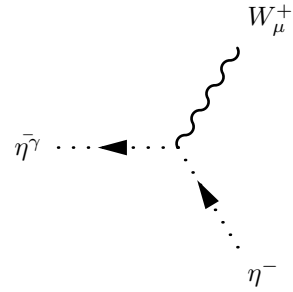
$$- ig_2 \sin \Theta_W \left(p_\mu^{\eta^-} \right) \quad (269)$$



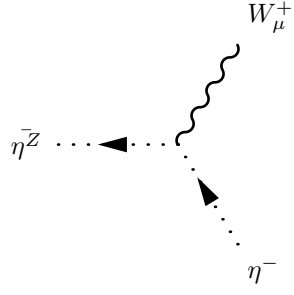
$$-ig_2 \cos \Theta_W \cos \Theta'_W \left(p_\mu^{\eta^-} \right) \quad (270)$$



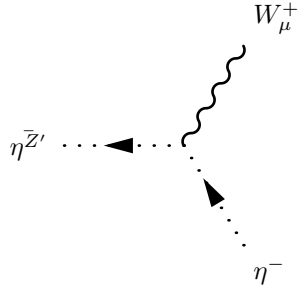
$$ig_2 \cos \Theta_W \sin \Theta'_W \left(p_\mu^{\eta^-} \right) \quad (271)$$



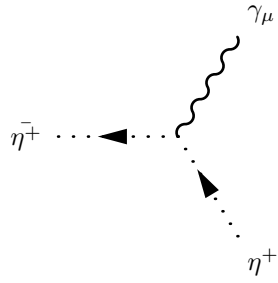
$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^-} \right) \quad (272)$$



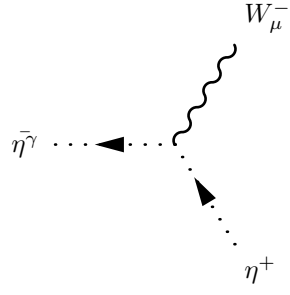
$$ig_2 \cos \Theta_W \cos \Theta'_W \left(p_\mu^{\eta^-} \right) \quad (273)$$



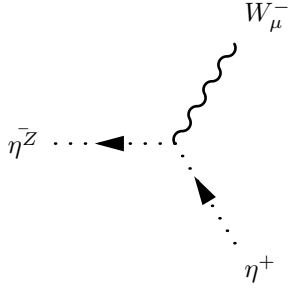
$$-ig_2 \cos \Theta_W \sin \Theta'_W \left(p_\mu^{\eta^-} \right) \quad (274)$$



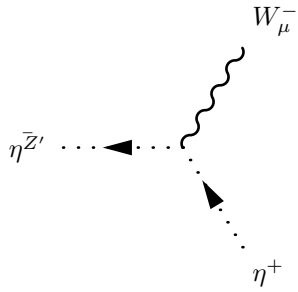
$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^+} \right) \quad (275)$$



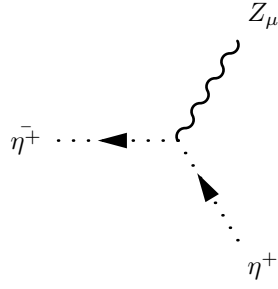
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (276)$$



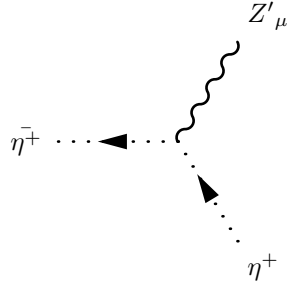
$$-ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^+}) \quad (277)$$



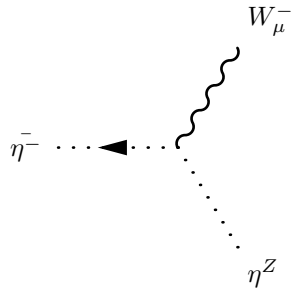
$$ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^+}) \quad (278)$$



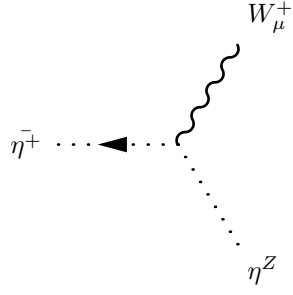
$$ig_2 \cos \Theta_W \cos \Theta'_W \left(p_\mu^{\eta^+} \right) \quad (279)$$



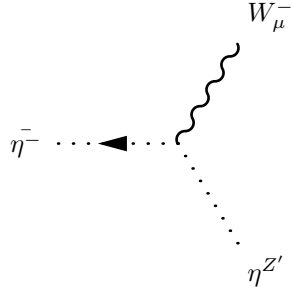
$$-ig_2 \cos \Theta_W \sin \Theta'_W \left(p_\mu^{\eta^+} \right) \quad (280)$$



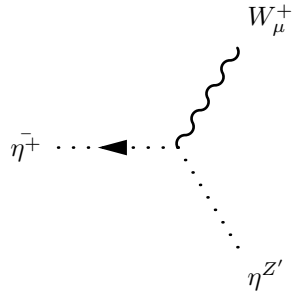
$$ig_2 \cos \Theta_W \cos \Theta'_W \left(p_\mu^{\eta^Z} \right) \quad (281)$$



$$-ig_2 \cos \Theta_W \cos \Theta'_W \left(p_\mu^{\eta^Z} \right) \quad (282)$$

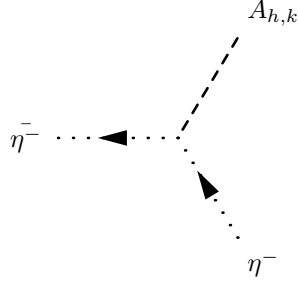


$$-ig_2 \cos \Theta_W \sin \Theta'_W \left(p_\mu^{\eta^{Z'}} \right) \quad (283)$$

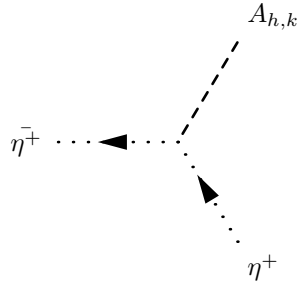


$$ig_2 \cos \Theta_W \sin \Theta'_W \left(p_\mu^{\eta^{Z'}} \right) \quad (284)$$

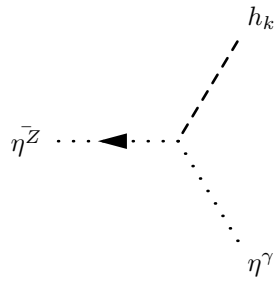
7.11 Two Ghosts-One Scalar-Interaction



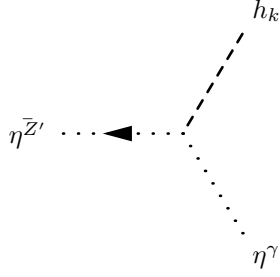
$$-\frac{1}{4}g_2^2 v \xi_{W-} Z_{k1}^A \quad (285)$$



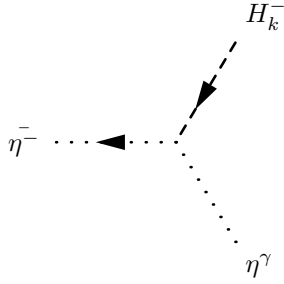
$$\frac{1}{4}g_2^2 v \xi_{W-} Z_{k1}^A \quad (286)$$



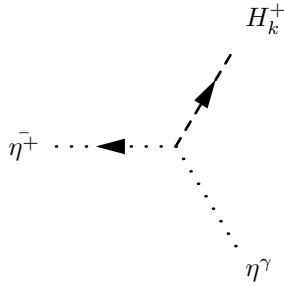
$$\begin{aligned} & \frac{i}{4} \xi_Z \left(v \left(g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \left(g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right) Z_{k1}^H \right. \\ & \left. + 50 g_{YB} v x \left(-2 g_B \cos \Theta_W \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin 2\Theta_W \right) Z_{k2}^H \right) \end{aligned} \quad (287)$$



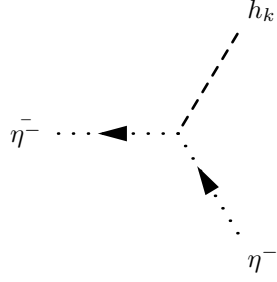
$$\begin{aligned}
& -\frac{i}{4}\xi_{Z'}\left(v\left(g_1\cos\Theta_W-g_2\sin\Theta_W\right)\left(\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)Z_{k1}^H\right. \\
& \left.+50g_{YB}vx\left(2g_B\cos\Theta_W\cos\Theta'_W+g_{YB}\sin2\Theta_W\sin\Theta'_W\right)Z_{k2}^H\right)
\end{aligned} \tag{288}$$



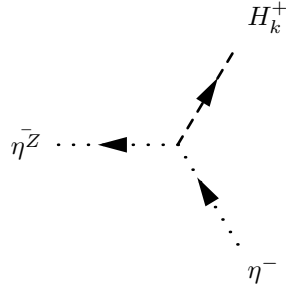
$$-\frac{i}{4}g_2v\xi_{W-}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)Z_{k1}^+ \tag{289}$$



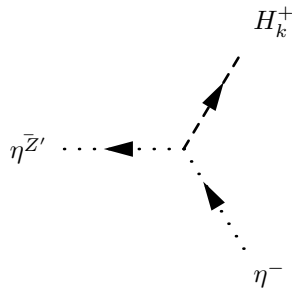
$$-\frac{i}{4}g_2v\xi_{W-}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)Z_{k1}^+ \tag{290}$$



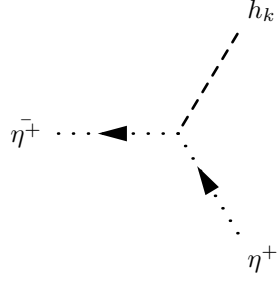
$$-\frac{i}{4}g_2^2v\xi_{W^-}Z_{k1}^H \quad (291)$$



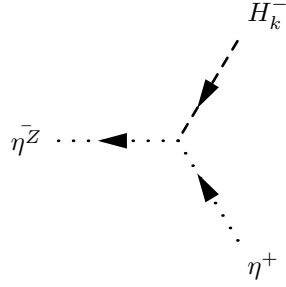
$$\frac{i}{4}g_2v\xi_Z\left(g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W-g_{BY}\sin\Theta'_W\right)Z_{k1}^+ \quad (292)$$



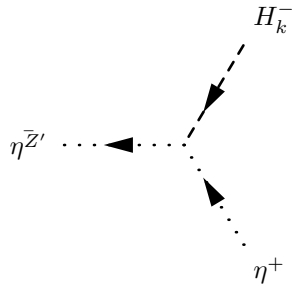
$$-\frac{i}{4}g_2v\xi_{Z'}\left(\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)Z_{k1}^+ \quad (293)$$



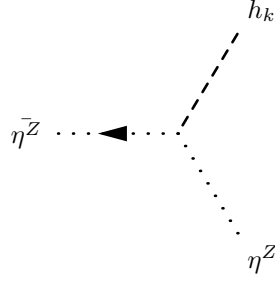
$$-\frac{i}{4}g_2^2v\xi_{W^-}Z_{k1}^H \quad (294)$$



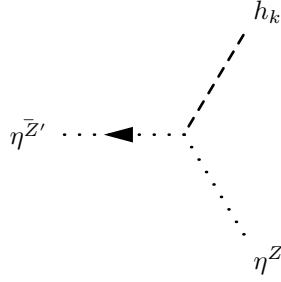
$$\frac{i}{4}g_2v\xi_Z\left(g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W-g_{BY}\sin\Theta'_W\right)Z_{k1}^+ \quad (295)$$



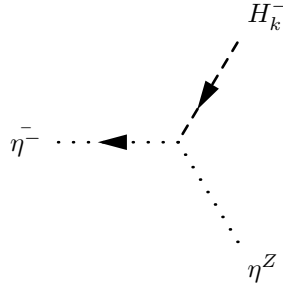
$$-\frac{i}{4}g_2v\xi_{Z'}\left(\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)Z_{k1}^+ \quad (296)$$



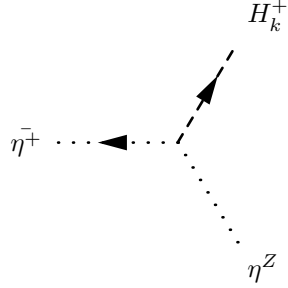
$$\begin{aligned}
& -\frac{i}{4}\xi_Z \left(v \left(g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right)^2 Z_{k1}^H \right. \\
& \left. + 100vx \left(-g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right)^2 Z_{k2}^H \right)
\end{aligned} \tag{297}$$



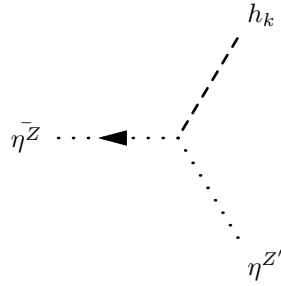
$$\begin{aligned}
& \frac{i}{4}\xi_{Z'} \left(v \left(g_1 g_{BY} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \right. \\
& \left. \left. + \cos \Theta'_W \left(g_1^2 \sin \Theta_W^2 - g_{BY}^2 \right) \sin \Theta'_W - g_1 g_{BY} \sin \Theta_W \sin \Theta'^2_W \right. \right. \\
& \left. \left. + g_2 \cos \Theta_W \left(g_1 \sin \Theta_W \sin 2\Theta'_W + g_{BY} \cos \Theta'^2_W - g_{BY} \sin \Theta'^2_W \right) \right) Z_{k1}^H \right. \\
& \left. - 50vx \left(-2g_B g_{YB} \cos \Theta'^2_W \sin \Theta_W + 2g_B g_{YB} \sin \Theta_W \sin \Theta'^2_W + g_B^2 \sin 2\Theta'_W \right. \right. \\
& \left. \left. - g_{YB}^2 \sin \Theta_W^2 \sin 2\Theta'_W \right) Z_{k2}^H \right)
\end{aligned} \tag{298}$$



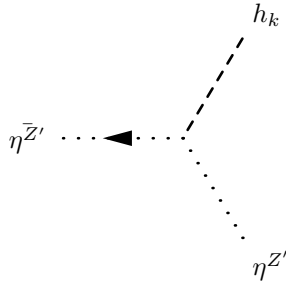
$$-\frac{i}{4}g_2v\xi_{W-}\left(-g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W+g_{BY}\sin\Theta'_W\right)Z_{k1}^+ \quad (299)$$



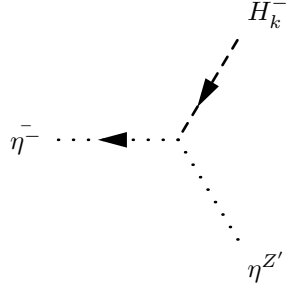
$$-\frac{i}{4}g_2v\xi_{W-}\left(-g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W+g_{BY}\sin\Theta'_W\right)Z_{k1}^+ \quad (300)$$



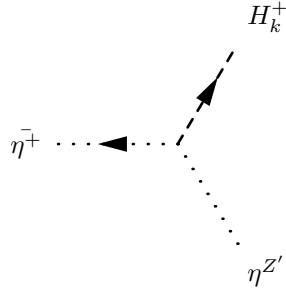
$$\begin{aligned} & \frac{i}{4}\xi_Z\left(v\left(g_1g_{BY}\cos\Theta'^2_W\sin\Theta_W+g_2^2\cos\Theta_W^2\cos\Theta'_W\sin\Theta'_W\right.\right. \\ & +\cos\Theta'_W\left(g_1^2\sin\Theta_W^2-g_{BY}^2\right)\sin\Theta'_W-g_1g_{BY}\sin\Theta_W\sin\Theta'^2_W \\ & +g_2\cos\Theta_W\left(g_1\sin\Theta_W\sin2\Theta'_W+g_{BY}\cos\Theta'^2_W-g_{BY}\sin\Theta'^2_W\right)\left.\right)Z_{k1}^H \\ & -50vx\left(-2g_Bg_{YB}\cos\Theta'^2_W\sin\Theta_W+2g_Bg_{YB}\sin\Theta_W\sin\Theta'^2_W+g_B^2\sin2\Theta'_W\right. \\ & \left.-g_{YB}^2\sin\Theta_W^2\sin2\Theta'_W\right)Z_{k2}^H \end{aligned} \quad (301)$$



$$\begin{aligned}
& -\frac{i}{4}\xi_{Z'}\left(v\left(\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)^2Z_{k1}^H\right. \\
& \left.+100vx\left(g_B\cos\Theta'_W+g_{YB}\sin\Theta_W\sin\Theta'_W\right)^2Z_{k2}^H\right)
\end{aligned} \tag{302}$$



$$\frac{i}{4}g_2v\xi_{W-}\left(\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W-g_{BY}\cos\Theta'_W\right)Z_{k1}^+ \tag{303}$$



$$\frac{i}{4}g_2v\xi_{W-}\left(\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W-g_{BY}\cos\Theta'_W\right)Z_{k1}^+ \tag{304}$$

8 Clebsch-Gordan Coefficients