

U(1)B extension for Baryogenesis  
Lagrangian, Rotations and Interactions for eigenstates 'EWSB'  
including one-loop Self-Energies

SARAH 4.14.4

August 3, 2021

This file was automatically generated by SARAH version 4.14.4.

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**

Package Homepage: [projects.hepforge.org/sarah/](http://projects.hepforge.org/sarah/)  
by **Florian Staub**, [florian.staub@cern.ch](mailto:florian.staub@cern.ch)

# Contents

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>Fields</b>  | <b>3</b>  |
| 1.1      | Gauge Fields . . . . .   | 3         |
| 1.2      | Matter Superfields . . . . .   | 3         |
| <b>2</b> | <b>Lagrangian</b>  | <b>3</b>  |
| 2.1      | Input Lagrangian for Eigenstates GaugeES . . . . .                       | 3         |
| 2.2      | Gauge fixing terms . . . . .   | 4         |
| 2.2.1    | Gauge fixing terms for eigenstates 'GaugeES' . . . . .                   | 4         |
| 2.2.2    | Gauge fixing terms for eigenstates 'EWSB' . . . . .                      | 4         |
| 2.3      | Fields integrated out . . . . .  | 4         |
| <b>3</b> | <b>Field Rotations</b>   | <b>5</b>  |
| 3.1      | Rotations in gauge sector for eigenstates 'EWSB' . . . . .               | 5         |
| 3.2      | Rotations in Mass sector for eigenstates 'EWSB' . . . . .                | 5         |
| 3.2.1    | Mass Matrices for Scalars . . . . .                                      | 5         |
| 3.2.2    | Mass Matrices for Fermions . . . . .                                     | 7         |
| <b>4</b> | <b>Vacuum Expectation Values</b>   | <b>8</b>  |
| <b>5</b> | <b>Tadpole Equations</b>   | <b>8</b>  |
| <b>6</b> | <b>Particle content for eigenstates 'EWSB'</b>                           | <b>8</b>  |
| <b>7</b> | <b>One Loop Self-Energy and One Loop Tadpoles for eigenstates 'EWSB'</b> | <b>9</b>  |
| 7.1      | One Loop Self-Energy . . . . .   | 9         |
| 7.2      | Tadpoles . . . . .   | 25        |
| <b>8</b> | <b>Interactions for eigenstates 'EWSB'</b>                               | <b>26</b> |
| 8.1      | Three Scalar-Interaction . . . . .                                       | 26        |
| 8.2      | Two Scalar-One Vector Boson-Interaction . . . . .                        | 27        |
| 8.3      | One Scalar-Two Vector Boson-Interaction . . . . .                        | 32        |
| 8.4      | Two Fermion-One Vector Boson-Interaction . . . . .                       | 36        |
| 8.5      | Two Fermion-One Scalar Boson-Interaction . . . . .                       | 47        |
| 8.6      | Three Vector Boson-Interaction . . . . .                                 | 57        |
| 8.7      | Four Scalar-Interaction . . . . .  | 58        |
| 8.8      | Two Scalar-Two Vector Boson-Interaction . . . . .                        | 62        |
| 8.9      | Four Vector Boson-Interaction . . . . .                                  | 78        |
| 8.10     | Two Ghosts-One Vector Boson-Interaction . . . . .                        | 81        |
| 8.11     | Two Ghosts-One Scalar-Interaction . . . . .                              | 87        |
| <b>9</b> | <b>Clebsch-Gordan Coefficients</b>                                       | <b>94</b> |

# 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           | $(0, \mathbf{1}, \mathbf{1}, 5)$                            |
| $S$  | 0             | 1           | $(1, \mathbf{1}, \mathbf{1}, 1)$                            |
| Sc   | 0             | 1           | $(1, \mathbf{1}, \mathbf{1}, 6)$                            |
| $q$  | $\frac{1}{2}$ | 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           | $(0, \mathbf{1}, \mathbf{1}, -5)$                           |
| vr3  | $\frac{1}{2}$ | 1           | $(0, \mathbf{1}, \mathbf{1}, 0)$                            |
| 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

$$\begin{aligned}
L = & -\mu' |\text{BiD}|^2 - \mu_2 |H^0|^2 - \mu_2 |H^-|^2 - MP_c^2 |si2|^2 - M_P^2 |si1|^2 + \lambda_2 |\text{BiD}|^4 + \lambda_1 |H^0|^4 + \lambda_1 |H^-|^4 + \lambda_2 3 |si2|^4 \\
& + \lambda_2 2 |si1|^4 + H^0 \lambda_3 |\text{BiD}|^2 H^{0,*} + H^- \lambda_3 |\text{BiD}|^2 H^{-,*} + 2H^- \lambda_1 |H^0|^2 H^{-,*} - \text{BiD} si1 hr_f si2^* + \lambda_3 3 si2 |H^0|^2 si2^*
\end{aligned}$$

$$\begin{aligned}
& + \lambda_3 3si2|H^-|^2 si2^* + \lambda_3 2si1|H^0|^2 si1^* + \lambda_3 2si1|H^-|^2 si1^* - si2hr_f \text{conj}(\text{BiD}) si1^* - 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} - h_c \text{conj}(\text{BiD}) \text{conj}(\text{ep}(2)) \text{ep}(1) - H^0 h_g \text{conj}(\text{x5R}(2)) \text{ep}(1) - h_c \text{conj}(\text{BiD}) \text{conj}(\text{ep}(1)) \text{ep}(2) \\
& - \text{BiD} h_c \text{conj}(\text{ep}(2)) \text{ep}(1) - \text{BiD} h_c \text{conj}(\text{ep}(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} \\
& + H^- d_{L,k\gamma}^* Y_{u,jk}^* \delta_{\beta\gamma} u_{R,j\beta} + H^0 u_{L,k\gamma}^* Y_{u,jk}^* \delta_{\beta\gamma} u_{R,j\beta} - h_c \text{conj}(\text{BiD}) \text{conj}(\text{vpp}(2)) \text{vp}(1) + H^- h_g \text{conj}(\text{x5R}(2)) \text{vp}(1) \\
& - h_c \text{conj}(\text{BiD}) \text{conj}(\text{vpp}(1)) \text{vp}(2) + H^- h_g \text{conj}(\text{x5R}(1)) \text{vp}(2) - \text{BiD} h_c \text{conj}(\text{vp}(2)) \text{vpp}(1) - \text{BiD} h_c \text{conj}(\text{vp}(1)) \text{vpp}(2) \\
& - \text{BiD} h_a \text{conj}(\text{x3L}(2)) \text{x4R}(1) - \text{BiD} h_a \text{conj}(\text{x3L}(1)) \text{x4R}(2) - h_g H^{0,*} \text{conj}(\text{ep}(2)) \text{x5R}(1) + h_g H^{-,*} \text{conj}(\text{vp}(2)) \text{x5R}(1) \\
& - h_g H^{0,*} \text{conj}(\text{ep}(1)) \text{x5R}(2) + h_g H^{-,*} \text{conj}(\text{vp}(1)) \text{x5R}(2) - h_b \text{conj}(\text{BiD}) \text{conj}(\text{x6L}(1)) \text{x5R}(2) - \text{BiD} h_b \text{conj}(\text{x5R}(2)) \text{x6L}(1) \\
& - 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} \\
& + si1^* \text{conj}(\text{vp}(2)) \text{conj}(\text{eL}(\{\text{gt}1\})(1)) h_{d,i} + si1^* \text{conj}(\text{vp}(1)) \text{conj}(\text{eL}(\{\text{gt}1\})(2)) h_{d,i} - si1^* \text{conj}(\text{ep}(2)) \text{conj}(\text{vL}(\{\text{gt}1\})(1)) \\
& - si2 \text{conj}(\text{vvR}(\{\text{gt}3\})(1)) \text{x5R}(2) hr_{e,k} + 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} + si1 \text{vp}(2) h_{d,i} \text{eL}(\{\text{gt}1\})(1) \\
& - si1 \text{ep}(2) h_{d,i} \text{vL}(\{\text{gt}1\})(1) - si1 \text{ep}(1) h_{d,i} \text{vL}(\{\text{gt}1\})(2) - si2^* \text{conj}(\text{x5R}(2)) hr_{e,k} \text{vvR}(\{\text{gt}3\})(1) - si2^* \text{conj}(\text{x5R}(1)) h_{d,i} \text{vL}(\{\text{gt}1\})(1) \\
& \hspace{15em} (1)
\end{aligned}$$

## 2.2 Gauge fixing terms

### 2.2.1 Gauge fixing terms for eigenstates 'GaugeES'

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

### 2.2.2 Gauge fixing terms for eigenstates 'EWSB'

$$\begin{aligned}
L_{GF} = & -\frac{1}{2}|\partial_\mu g|^2 \xi_g^{-1} - \frac{1}{2}|\partial_\mu \gamma|^2 \xi_\gamma^{-1} - \frac{i}{2}g_2 H^- v \xi_{W^-} + \partial_\mu W^-|^2 \xi_{W^-}^{-1} \\
& - \frac{1}{2}|\frac{1}{2}(2\partial_\mu Z + \xi_Z((10g_B \text{sigma} Bx - g_{BY} \text{sigma} Hv) \sin \Theta'_W + (-10g_Y B \text{sigma} Bx + g_1 \text{sigma} Hv) \cos \Theta'_W \sin \Theta_W + g_2 \text{sigma} Bx \\
& - \frac{1}{2}|\xi_{Z'}((10g_B \text{sigma} Bx + g_{BY} \text{sigma} Hv) \cos \Theta'_W + (-10g_Y B \text{sigma} Bx \sin \Theta_W + g_1 \text{sigma} Hv \sin \Theta_W + g_2 \text{sigma} Hv \cos \Theta_W) \\
& \hspace{15em} (3)
\end{aligned}$$

## 2.3 Fields integrated out

None

### 3 Field Rotations

#### 3.1 Rotations in gauge sector for eigenstates 'EWSB'

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

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

$$(6)$$

The mixing matrices are parametrized by

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

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

$$(9)$$

#### 3.2 Rotations in Mass sector for eigenstates 'EWSB'

##### 3.2.1 Mass Matrices for Scalars

- **Mass matrix for Higgs**, Basis:  $(\text{phiH}, \text{phiB}), (\text{phiH}, \text{phiB})$

$$m_h^2 = \begin{pmatrix} -3\lambda_1 v^2 - \frac{1}{2}\lambda_3 x^2 + \mu_2 & -\lambda_3 vx \\ -\lambda_3 vx & -3\lambda_2 x^2 - \frac{1}{2}\lambda_3 v^2 + \mu' \end{pmatrix} \quad (10)$$

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:  $(\text{sigmaH}, \text{sigmaB}), (\text{sigmaH}, \text{sigmaB})$

$$m_{A_h}^2 = \begin{pmatrix} -\frac{1}{2}\lambda_3 x^2 - \lambda_1 v^2 + \mu_2 & 0 \\ 0 & -\frac{1}{2}\lambda_3 v^2 - \lambda_2 x^2 + \mu' \end{pmatrix} + \xi_Z m^2(Z) + \xi_{Z'} m^2(Z') \quad (13)$$

Gauge fixing contributions:

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

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

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

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

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

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

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

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

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 Singlet**, Basis:  $(si1, si2), (si1^*, si2^*)$

$$m_\sigma^2 = \begin{pmatrix} -\frac{1}{2}\lambda_3 2v^2 + M_P^2 & \frac{1}{\sqrt{2}}x h r_f \\ \frac{1}{\sqrt{2}}x h r_f & -\frac{1}{2}\lambda_3 3v^2 + M_{P_c}^2 \end{pmatrix} \quad (24)$$

This matrix is diagonalized by  $VS$ :

$$VS m_\sigma^2 VS^\dagger = m_{2,\sigma}^{dia} \quad (25)$$

with

$$si1 = \sum_j VS_{j1} \sigma_j, \quad si2 = \sum_j VS_{j2} \sigma_j \quad (26)$$

### 3.2.2 Mass Matrices for Fermions

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

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

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

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

with

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

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

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

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

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

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

with

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

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

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

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

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

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

with

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

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

- **Mass matrix for Neutrinos**, Basis:  $(\nu_L), (V v_R^* \text{conj}(\text{vR3}),)$

$$m_\nu = \begin{pmatrix} & \\ 00 & \end{pmatrix} \quad (39)$$

This matrix is diagonalized by  $U^V$  and  $U^{UR}$

$$U^{V,*} m_\nu U^{UR,\dagger} = m_\nu^{dia} \quad (40)$$

with

$$\nu_{L,i} = \sum_{t_2} U_{ji}^{V,*} V_{L,j} \quad (41)$$

$$V v_{R,i} = \sum_{t_2} U_{ij}^{UR} V_{R,j}^*, \quad \text{vR3} = \sum_{t_2} U_{3j}^{UR} V_{R,j}^* \quad (42)$$

## 4 Vacuum Expectation Values

$$H^0 = \frac{1}{\sqrt{2}} \text{phiH} + \frac{1}{\sqrt{2}} v + i \frac{1}{\sqrt{2}} \text{sigmaH} \quad (43)$$

$$\text{BiD} = \frac{1}{\sqrt{2}} \text{phiB} + \frac{1}{\sqrt{2}} x + i \frac{1}{\sqrt{2}} \text{sigmaB} \quad (44)$$

## 5 Tadpole Equations

$$\frac{\partial V}{\partial \text{phiH}} = -\lambda_1 v^3 + v \left( -\frac{1}{2} \lambda_3 x^2 + \mu_2 \right) \quad (45)$$

$$\frac{\partial V}{\partial \text{phiB}} = \left( -\frac{1}{2} \lambda_3 v^2 + \mu' \right) x - \lambda_2 x^3 \quad (46)$$

## 6 Particle content for eigenstates 'EWSB'

| Name     | Type    | complex/real | Generations | Indices       |
|----------|---------|--------------|-------------|---------------|
| $H^-$    | Scalar  | complex      | 1           |               |
| $h$      | Scalar  | real         | 2           | generation, 2 |
| $A_h$    | Scalar  | real         | 2           | generation, 2 |
| $\sigma$ | Scalar  | complex      | 2           | generation, 2 |
| $\chi^0$ | Fermion | Dirac        | 1           |               |
| $e2$     | Fermion | Dirac        | 1           |               |
| $e3$     | Fermion | Dirac        | 1           |               |



|               |         |         |   |                         |
|---------------|---------|---------|---|-------------------------|
| $\nu^d$       | 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           |
| $\nu$         | Fermion | Dirac   | 3 | generation, 3           |
| $g$           | Vector  | real    | 1 | color, 8, lorentz, 4    |
| $\gamma$      | Vector  | real    | 1 | lorentz, 4              |
| $Z$           | Vector  | real    | 1 | lorentz, 4              |
| $Z'$          | Vector  | real    | 1 | lorentz, 4              |
| $W^-$         | Vector  | complex | 1 | lorentz, 4              |
| $\eta^G$      | Ghost   | real    | 1 | color, 8                |
| $\eta^\gamma$ | Ghost   | real    | 1 |                         |
| $\eta^Z$      | Ghost   | real    | 1 |                         |
| $\eta^{Z'}$   | Ghost   | real    | 1 |                         |
| $\eta^-$      | Ghost   | complex | 1 |                         |
| $\eta^+$      | Ghost   | complex | 1 |                         |

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

### 7.1 One Loop Self-Energy

- Self-Energy for Higgs ( $h$ )

$$\begin{aligned}
16\pi^2 \Pi_{i,j}(p^2) = & +4\left(-\frac{1}{2}\text{rMS} + B_0(p^2, 0, m_Z^2)\right)\Gamma_{\tilde{h}_j, Z, \gamma}^* \Gamma_{\tilde{h}_i, Z, \gamma} + 2\left(-\frac{1}{2}\text{rMS} + B_0(p^2, m_Z^2, m_Z^2)\right)\Gamma_{\tilde{h}_j, Z, Z}^* \Gamma_{\tilde{h}_i, Z, Z} + 4\left(-\frac{1}{2}\text{rMS} \right. \\
& + 4\left(-\frac{1}{2}\text{rMS} + B_0(p^2, m_Z^2, m_{Z'}^2)\right)\Gamma_{\tilde{h}_j, Z', Z}^* \Gamma_{\tilde{h}_i, Z', Z} + 2\left(-\frac{1}{2}\text{rMS} + B_0(p^2, m_{Z'}^2, m_{Z'}^2)\right)\Gamma_{\tilde{h}_j, Z', Z'}^* \Gamma_{\tilde{h}_i, Z', Z'} \\
& + B_0(p^2, m_{H^-}^2, m_{H^-}^2)\Gamma_{\tilde{h}_j, H^-, *, H^-}^* \Gamma_{\tilde{h}_i, H^-, *, H^-} + 4\left(-\frac{1}{2}\text{rMS} + B_0(p^2, m_{W^-}^2, m_{W^-}^2)\right)\Gamma_{\tilde{h}_j, W^+, W^-}^* \Gamma_{\tilde{h}_i, W^+, W^-} \\
& - B_0(p^2, m_{\eta^-}^2, m_{\eta^-}^2)\Gamma_{\tilde{h}_i, \eta^-, \eta^-} \Gamma_{\tilde{h}_j, \eta^-, \eta^-} - B_0(p^2, m_{\eta^+}^2, m_{\eta^+}^2)\Gamma_{\tilde{h}_i, \eta^+, \eta^+} \Gamma_{\tilde{h}_j, \eta^+, \eta^+} \\
& - B_0(p^2, m_{\eta^Z}^2, m_{\eta^Z}^2)\Gamma_{\tilde{h}_i, \eta^Z, \eta^Z} \Gamma_{\tilde{h}_j, \eta^Z, \eta^Z} - 2B_0(p^2, m_{\eta^Z}^2, m_{\eta^{Z'}}^2)\Gamma_{\tilde{h}_i, \eta^Z, \eta^{Z'}} \Gamma_{\tilde{h}_j, \eta^Z, \eta^{Z'}} \\
& - B_0(p^2, m_{\eta^{Z'}}^2, m_{\eta^{Z'}}^2)\Gamma_{\tilde{h}_i, \eta^{Z'}, \eta^{Z'}} \Gamma_{\tilde{h}_j, \eta^{Z'}, \eta^{Z'}} - A_0(m_{H^-}^2)\Gamma_{\tilde{h}_i, \tilde{h}_j, H^-, *, H^-} \\
& + 2\Gamma_{\tilde{h}_j, W^+, H^-}^* \Gamma_{\tilde{h}_i, W^+, H^-} - F_0(p^2, m_{H^-}^2, m_{W^-}^2) + 4\Gamma_{\tilde{h}_i, \tilde{h}_j, W^+, W^-} \left(-\frac{1}{2}\text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2)\right)
\end{aligned}$$

$$\begin{aligned}
& + 2\Gamma_{\tilde{h}_i, \tilde{h}_j, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) + 2\Gamma_{\tilde{h}_i, \tilde{h}_j, Z', Z'} \left( -\frac{1}{2} \text{rMS} m_{Z'}^2 + A_0(m_{Z'}^2) \right) - \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_{h,a}}^2) \Gamma_{\tilde{h}_i, \tilde{h}_j, A_{h,a}} \\
& - \sum_{a=1}^2 A_0(m_{\sigma_a}^2) \Gamma_{\tilde{h}_i, \tilde{h}_j, \sigma_a^*, \sigma_a} - \frac{1}{2} \sum_{a=1}^2 A_0(m_{h_a}^2) \Gamma_{\tilde{h}_i, \tilde{h}_j, h_a, h_a} \\
& + \frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{A_{h,a}}^2, m_{A_{h,b}}^2) \Gamma_{\tilde{h}_j, A_{h,a}, A_{h,b}}^* \Gamma_{\tilde{h}_i, A_{h,a}, A_{h,b}} \\
& + \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{\sigma_a}^2, m_{\sigma_b}^2) \Gamma_{\tilde{h}_j, \sigma_a^*, \sigma_b}^* \Gamma_{\tilde{h}_i, \sigma_a^*, \sigma_b} + \frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{h_a}^2, m_{h_b}^2) \Gamma_{\tilde{h}_j, h_a, h_b}^* \Gamma_{\tilde{h}_i, h_a, h_b} \\
& - 6 \sum_{a=1}^3 m_{d_a} \sum_{b=1}^3 B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_b} \left( \Gamma_{\tilde{h}_j, \bar{d}_a, d_b}^{L*} \Gamma_{\tilde{h}_i, \bar{d}_a, d_b}^R + \Gamma_{\tilde{h}_j, \bar{d}_a, d_b}^{R*} \Gamma_{\tilde{h}_i, \bar{d}_a, d_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{d_a}^2, m_{d_b}^2) \left( \Gamma_{\tilde{h}_j, \bar{d}_a, d_b}^{L*} \Gamma_{\tilde{h}_i, \bar{d}_a, d_b}^L + \Gamma_{\tilde{h}_j, \bar{d}_a, d_b}^{R*} \Gamma_{\tilde{h}_i, \bar{d}_a, d_b}^R \right) \\
& - 2 \sum_{a=1}^3 m_{e_a} \sum_{b=1}^3 B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_b} \left( \Gamma_{\tilde{h}_j, \bar{e}_a, e_b}^{L*} \Gamma_{\tilde{h}_i, \bar{e}_a, e_b}^R + \Gamma_{\tilde{h}_j, \bar{e}_a, e_b}^{R*} \Gamma_{\tilde{h}_i, \bar{e}_a, e_b}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{e_a}^2, m_{e_b}^2) \left( \Gamma_{\tilde{h}_j, \bar{e}_a, e_b}^{L*} \Gamma_{\tilde{h}_i, \bar{e}_a, e_b}^L + \Gamma_{\tilde{h}_j, \bar{e}_a, e_b}^{R*} \Gamma_{\tilde{h}_i, \bar{e}_a, e_b}^R \right) \\
& - 6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_b} \left( \Gamma_{\tilde{h}_j, \bar{u}_a, u_b}^{L*} \Gamma_{\tilde{h}_i, \bar{u}_a, u_b}^R + \Gamma_{\tilde{h}_j, \bar{u}_a, u_b}^{R*} \Gamma_{\tilde{h}_i, \bar{u}_a, u_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{u_a}^2, m_{u_b}^2) \left( \Gamma_{\tilde{h}_j, \bar{u}_a, u_b}^{L*} \Gamma_{\tilde{h}_i, \bar{u}_a, u_b}^L + \Gamma_{\tilde{h}_j, \bar{u}_a, u_b}^{R*} \Gamma_{\tilde{h}_i, \bar{u}_a, u_b}^R \right) \\
& + \sum_{b=1}^2 \Gamma_{\tilde{h}_j, \gamma, A_{h,b}}^* \Gamma_{\tilde{h}_i, \gamma, A_{h,b}} F_0(p^2, m_{A_{h,b}}^2, 0) + \sum_{b=1}^2 \Gamma_{\tilde{h}_j, Z, A_{h,b}}^* \Gamma_{\tilde{h}_i, Z, A_{h,b}} F_0(p^2, m_{A_{h,b}}^2, m_Z^2) \\
& + \sum_{b=1}^2 \Gamma_{\tilde{h}_j, Z', A_{h,b}}^* \Gamma_{\tilde{h}_i, Z', A_{h,b}} F_0(p^2, m_{A_{h,b}}^2, m_{Z'}^2) \\
& - 2B_0(p^2, m_{e3}^2, m_{e3}^2) m_{e3}^2 \left( \Gamma_{\tilde{h}_j, \bar{e}3, e3}^{L*} \Gamma_{\tilde{h}_i, \bar{e}3, e3}^R + \Gamma_{\tilde{h}_j, \bar{e}3, e3}^{R*} \Gamma_{\tilde{h}_i, \bar{e}3, e3}^L \right) \\
& + G_0(p^2, m_{e3}^2, m_{e3}^2) \left( \Gamma_{\tilde{h}_j, \bar{e}3, e3}^{L*} \Gamma_{\tilde{h}_i, \bar{e}3, e3}^L + \Gamma_{\tilde{h}_j, \bar{e}3, e3}^{R*} \Gamma_{\tilde{h}_i, \bar{e}3, e3}^R \right) \\
& - 4B_0(p^2, m_{e2}^2, m_{e3}^2) m_{e3} m_{e2} \left( \Gamma_{\tilde{h}_j, \bar{e}2, e3}^{L*} \Gamma_{\tilde{h}_i, \bar{e}2, e3}^R + \Gamma_{\tilde{h}_j, \bar{e}2, e3}^{R*} \Gamma_{\tilde{h}_i, \bar{e}2, e3}^L \right) \\
& + 2G_0(p^2, m_{e2}^2, m_{e3}^2) \left( \Gamma_{\tilde{h}_j, \bar{e}2, e3}^{L*} \Gamma_{\tilde{h}_i, \bar{e}2, e3}^L + \Gamma_{\tilde{h}_j, \bar{e}2, e3}^{R*} \Gamma_{\tilde{h}_i, \bar{e}2, e3}^R \right) \\
& - 2B_0(p^2, m_{e2}^2, m_{e2}^2) m_{e2}^2 \left( \Gamma_{\tilde{h}_j, \bar{e}2, e2}^{L*} \Gamma_{\tilde{h}_i, \bar{e}2, e2}^R + \Gamma_{\tilde{h}_j, \bar{e}2, e2}^{R*} \Gamma_{\tilde{h}_i, \bar{e}2, e2}^L \right) \\
& + G_0(p^2, m_{e2}^2, m_{e2}^2) \left( \Gamma_{\tilde{h}_j, \bar{e}2, e2}^{L*} \Gamma_{\tilde{h}_i, \bar{e}2, e2}^L + \Gamma_{\tilde{h}_j, \bar{e}2, e2}^{R*} \Gamma_{\tilde{h}_i, \bar{e}2, e2}^R \right)
\end{aligned}$$

$$\begin{aligned}
& -2B_0(p^2, m_{\nu^d}^2, m_{\nu^d}^2) m_{\nu^d}^2 \left( \Gamma_{\check{h}_j, \bar{\nu}^d, \nu^d}^{L*} \Gamma_{\check{h}_i, \bar{\nu}^d, \nu^d}^R + \Gamma_{\check{h}_j, \bar{\nu}^d, \nu^d}^{R*} \Gamma_{\check{h}_i, \bar{\nu}^d, \nu^d}^L \right) \\
& + G_0(p^2, m_{\nu^d}^2, m_{\nu^d}^2) \left( \Gamma_{\check{h}_j, \bar{\nu}^d, \nu^d}^{L*} \Gamma_{\check{h}_i, \bar{\nu}^d, \nu^d}^L + \Gamma_{\check{h}_j, \bar{\nu}^d, \nu^d}^{R*} \Gamma_{\check{h}_i, \bar{\nu}^d, \nu^d}^R \right) \\
& -2B_0(p^2, m_{\chi^0}^2, m_{\chi^0}^2) m_{\chi^0}^2 \left( \Gamma_{\check{h}_j, \bar{\chi}^0, \chi^0}^{L*} \Gamma_{\check{h}_i, \bar{\chi}^0, \chi^0}^R + \Gamma_{\check{h}_j, \bar{\chi}^0, \chi^0}^{R*} \Gamma_{\check{h}_i, \bar{\chi}^0, \chi^0}^L \right) \\
& + G_0(p^2, m_{\chi^0}^2, m_{\chi^0}^2) \left( \Gamma_{\check{h}_j, \bar{\chi}^0, \chi^0}^{L*} \Gamma_{\check{h}_i, \bar{\chi}^0, \chi^0}^L + \Gamma_{\check{h}_j, \bar{\chi}^0, \chi^0}^{R*} \Gamma_{\check{h}_i, \bar{\chi}^0, \chi^0}^R \right)
\end{aligned} \tag{47}$$

• **Self-Energy for Pseudo-Scalar Higgs ( $A_h$ )**

$$\begin{aligned}
16\pi^2 \Pi_{i,j}(p^2) = & -B_0(p^2, m_{\eta^-}^2, m_{\eta^-}^2) \Gamma_{\check{A}_{h,i}, \eta^-, \eta^-} \Gamma_{\check{A}_{h,j}, \eta^-, \eta^-} - B_0(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \Gamma_{\check{A}_{h,i}, \eta^+, \eta^+} \Gamma_{\check{A}_{h,j}, \eta^+, \eta^+} \\
& - A_0(m_{H^-}^2) \Gamma_{\check{A}_{h,i}, \check{A}_{h,j}, H^-, * , H^-} + 2\Gamma_{\check{A}_{h,j}, W^+, H^-}^* \Gamma_{\check{A}_{h,i}, W^+, H^-} F_0(p^2, m_{H^-}^2, m_{W^-}^2) \\
& + 4\Gamma_{\check{A}_{h,i}, \check{A}_{h,j}, W^+, W^-} \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\check{A}_{h,i}, \check{A}_{h,j}, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& + 2\Gamma_{\check{A}_{h,i}, \check{A}_{h,j}, Z', Z'} \left( -\frac{1}{2} \text{rMS} m_{Z'}^2 + A_0(m_{Z'}^2) \right) - \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_{h,a}}^2) \Gamma_{\check{A}_{h,i}, \check{A}_{h,j}, A_{h,a}, A_{h,a}} \\
& - \sum_{a=1}^2 A_0(m_{\sigma_a}^2) \Gamma_{\check{A}_{h,i}, \check{A}_{h,j}, \sigma_a^*, \sigma_a} - \frac{1}{2} \sum_{a=1}^2 A_0(m_{h_a}^2) \Gamma_{\check{A}_{h,i}, \check{A}_{h,j}, h_a, h_a} \\
& + \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{\sigma_a}^2, m_{\sigma_b}^2) \Gamma_{\check{A}_{h,j}, \sigma_a^*, \sigma_b}^* \Gamma_{\check{A}_{h,i}, \sigma_a^*, \sigma_b} \\
& + \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{h_a}^2, m_{A_{h,b}}^2) \Gamma_{\check{A}_{h,j}, h_a, A_{h,b}}^* \Gamma_{\check{A}_{h,i}, h_a, A_{h,b}} \\
& - 6 \sum_{a=1}^3 m_{d_a} \sum_{b=1}^3 B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_b} \left( \Gamma_{\check{A}_{h,j}, \bar{d}_a, d_b}^{L*} \Gamma_{\check{A}_{h,i}, \bar{d}_a, d_b}^R + \Gamma_{\check{A}_{h,j}, \bar{d}_a, d_b}^{R*} \Gamma_{\check{A}_{h,i}, \bar{d}_a, d_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{d_a}^2, m_{d_b}^2) \left( \Gamma_{\check{A}_{h,j}, \bar{d}_a, d_b}^{L*} \Gamma_{\check{A}_{h,i}, \bar{d}_a, d_b}^L + \Gamma_{\check{A}_{h,j}, \bar{d}_a, d_b}^{R*} \Gamma_{\check{A}_{h,i}, \bar{d}_a, d_b}^R \right) \\
& - 2 \sum_{a=1}^3 m_{e_a} \sum_{b=1}^3 B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_b} \left( \Gamma_{\check{A}_{h,j}, \bar{e}_a, e_b}^{L*} \Gamma_{\check{A}_{h,i}, \bar{e}_a, e_b}^R + \Gamma_{\check{A}_{h,j}, \bar{e}_a, e_b}^{R*} \Gamma_{\check{A}_{h,i}, \bar{e}_a, e_b}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{e_a}^2, m_{e_b}^2) \left( \Gamma_{\check{A}_{h,j}, \bar{e}_a, e_b}^{L*} \Gamma_{\check{A}_{h,i}, \bar{e}_a, e_b}^L + \Gamma_{\check{A}_{h,j}, \bar{e}_a, e_b}^{R*} \Gamma_{\check{A}_{h,i}, \bar{e}_a, e_b}^R \right) \\
& - 6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_b} \left( \Gamma_{\check{A}_{h,j}, \bar{u}_a, u_b}^{L*} \Gamma_{\check{A}_{h,i}, \bar{u}_a, u_b}^R + \Gamma_{\check{A}_{h,j}, \bar{u}_a, u_b}^{R*} \Gamma_{\check{A}_{h,i}, \bar{u}_a, u_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{u_a}^2, m_{u_b}^2) \left( \Gamma_{\check{A}_{h,j}, \bar{u}_a, u_b}^{L*} \Gamma_{\check{A}_{h,i}, \bar{u}_a, u_b}^L + \Gamma_{\check{A}_{h,j}, \bar{u}_a, u_b}^{R*} \Gamma_{\check{A}_{h,i}, \bar{u}_a, u_b}^R \right)
\end{aligned}$$

$$\begin{aligned}
& + \sum_{b=1}^2 \Gamma_{\check{A}_{h,j},\gamma,h_b}^* \Gamma_{\check{A}_{h,i},\gamma,h_b} F_0(p^2, m_{h_b}^2, 0) + \sum_{b=1}^2 \Gamma_{\check{A}_{h,j},Z,h_b}^* \Gamma_{\check{A}_{h,i},Z,h_b} F_0(p^2, m_{h_b}^2, m_Z^2) \\
& + \sum_{b=1}^2 \Gamma_{\check{A}_{h,j},Z',h_b}^* \Gamma_{\check{A}_{h,i},Z',h_b} F_0(p^2, m_{h_b}^2, m_{Z'}^2) \\
& - 2B_0(p^2, m_{e3}^2, m_{e3}^2) m_{e3}^2 \left( \Gamma_{\check{A}_{h,j},e\bar{3},e3}^{L*} \Gamma_{\check{A}_{h,i},e\bar{3},e3}^R + \Gamma_{\check{A}_{h,j},e\bar{3},e3}^{R*} \Gamma_{\check{A}_{h,i},e\bar{3},e3}^L \right) \\
& + G_0(p^2, m_{e3}^2, m_{e3}^2) \left( \Gamma_{\check{A}_{h,j},e\bar{3},e3}^{L*} \Gamma_{\check{A}_{h,i},e\bar{3},e3}^L + \Gamma_{\check{A}_{h,j},e\bar{3},e3}^{R*} \Gamma_{\check{A}_{h,i},e\bar{3},e3}^R \right) \\
& - 4B_0(p^2, m_{e2}^2, m_{e3}^2) m_{e3} m_{e2} \left( \Gamma_{\check{A}_{h,j},e\bar{2},e3}^{L*} \Gamma_{\check{A}_{h,i},e\bar{2},e3}^R + \Gamma_{\check{A}_{h,j},e\bar{2},e3}^{R*} \Gamma_{\check{A}_{h,i},e\bar{2},e3}^L \right) \\
& + 2G_0(p^2, m_{e2}^2, m_{e3}^2) \left( \Gamma_{\check{A}_{h,j},e\bar{2},e3}^{L*} \Gamma_{\check{A}_{h,i},e\bar{2},e3}^L + \Gamma_{\check{A}_{h,j},e\bar{2},e3}^{R*} \Gamma_{\check{A}_{h,i},e\bar{2},e3}^R \right) \\
& - 2B_0(p^2, m_{e2}^2, m_{e2}^2) m_{e2}^2 \left( \Gamma_{\check{A}_{h,j},e\bar{2},e2}^{L*} \Gamma_{\check{A}_{h,i},e\bar{2},e2}^R + \Gamma_{\check{A}_{h,j},e\bar{2},e2}^{R*} \Gamma_{\check{A}_{h,i},e\bar{2},e2}^L \right) \\
& + G_0(p^2, m_{e2}^2, m_{e2}^2) \left( \Gamma_{\check{A}_{h,j},e\bar{2},e2}^{L*} \Gamma_{\check{A}_{h,i},e\bar{2},e2}^L + \Gamma_{\check{A}_{h,j},e\bar{2},e2}^{R*} \Gamma_{\check{A}_{h,i},e\bar{2},e2}^R \right) \\
& - 2B_0(p^2, m_{\nu^d}^2, m_{\nu^d}^2) m_{\nu^d}^2 \left( \Gamma_{\check{A}_{h,j},\bar{\nu}^d,\nu^d}^{L*} \Gamma_{\check{A}_{h,i},\bar{\nu}^d,\nu^d}^R + \Gamma_{\check{A}_{h,j},\bar{\nu}^d,\nu^d}^{R*} \Gamma_{\check{A}_{h,i},\bar{\nu}^d,\nu^d}^L \right) \\
& + G_0(p^2, m_{\nu^d}^2, m_{\nu^d}^2) \left( \Gamma_{\check{A}_{h,j},\bar{\nu}^d,\nu^d}^{L*} \Gamma_{\check{A}_{h,i},\bar{\nu}^d,\nu^d}^L + \Gamma_{\check{A}_{h,j},\bar{\nu}^d,\nu^d}^{R*} \Gamma_{\check{A}_{h,i},\bar{\nu}^d,\nu^d}^R \right) \\
& - 2B_0(p^2, m_{\chi^0}^2, m_{\chi^0}^2) m_{\chi^0}^2 \left( \Gamma_{\check{A}_{h,j},\bar{\chi}^0,\chi^0}^{L*} \Gamma_{\check{A}_{h,i},\bar{\chi}^0,\chi^0}^R + \Gamma_{\check{A}_{h,j},\bar{\chi}^0,\chi^0}^{R*} \Gamma_{\check{A}_{h,i},\bar{\chi}^0,\chi^0}^L \right) \\
& + G_0(p^2, m_{\chi^0}^2, m_{\chi^0}^2) \left( \Gamma_{\check{A}_{h,j},\bar{\chi}^0,\chi^0}^{L*} \Gamma_{\check{A}_{h,i},\bar{\chi}^0,\chi^0}^L + \Gamma_{\check{A}_{h,j},\bar{\chi}^0,\chi^0}^{R*} \Gamma_{\check{A}_{h,i},\bar{\chi}^0,\chi^0}^R \right)
\end{aligned} \tag{48}$$

• Self-Energy for Down-Quarks ( $d$ )

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

$$-4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{d}_j, Z', d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, Z', d_b}^L \quad (49)$$

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

$$\begin{aligned} 16\pi^2 \Sigma_{i,j}^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\tilde{d}_j, h_a, d_b}^{L*} \Gamma_{\tilde{d}_i, h_a, d_b}^L \\ & -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{d_a}^2, m_{A_{h,b}}^2) \Gamma_{\tilde{d}_j, d_a, A_{h,b}}^{L*} \Gamma_{\tilde{d}_i, d_a, A_{h,b}}^L \\ & -\frac{1}{2} \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{H^-}^2) \Gamma_{\tilde{d}_j, H^-, u_b}^{L*} \Gamma_{\tilde{d}_i, H^-, u_b}^L - \frac{4}{3} \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, g, d_b}^{R*} \Gamma_{\tilde{d}_i, g, d_b}^R \\ & -\sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, \gamma, d_b}^{R*} \Gamma_{\tilde{d}_i, \gamma, d_b}^R - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{d}_j, W^-, u_b}^{R*} \Gamma_{\tilde{d}_i, W^-, u_b}^R \\ & -\sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, m_Z^2) \right) \Gamma_{\tilde{d}_j, Z, d_b}^{R*} \Gamma_{\tilde{d}_i, Z, d_b}^R - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{d}_j, Z', d_b}^{R*} \Gamma_{\tilde{d}_i, Z', d_b}^R \end{aligned} \quad (51)$$

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

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

$$\begin{aligned}
& -4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_Z^2) \right) \Gamma_{\tilde{u}_j, Z, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, Z, u_b}^L \\
& -4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{u}_j, Z', u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, Z', u_b}^L \\
& + \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{H^-}^2) \Gamma_{\tilde{u}_j, H^-, *, d_b}^{L*} m_{d_b} \Gamma_{\tilde{u}_i, H^-, *, d_b}^R \\
& -4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{u}_j, W^+, d_b}^{R*} m_{d_b} \Gamma_{\tilde{u}_i, W^+, d_b}^L
\end{aligned} \tag{52}$$

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

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^L(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{L*} \Gamma_{\tilde{u}_i, h_a, u_b}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{u_a}^2, m_{A_{h,b}}^2) \Gamma_{\tilde{u}_j, u_a, A_{h,b}}^{L*} \Gamma_{\tilde{u}_i, u_a, A_{h,b}}^L - \frac{4}{3} \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, g, u_b}^{R*} \Gamma_{\tilde{u}_i, g, u_b}^R \\
& - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, \gamma, u_b}^{R*} \Gamma_{\tilde{u}_i, \gamma, u_b}^R - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, m_Z^2) \right) \Gamma_{\tilde{u}_j, Z, u_b}^{R*} \Gamma_{\tilde{u}_i, Z, u_b}^R \\
& - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{u_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{u}_j, Z', u_b}^{R*} \Gamma_{\tilde{u}_i, Z', u_b}^R - \frac{1}{2} \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{H^-}^2) \Gamma_{\tilde{u}_j, H^-, *, d_b}^{L*} \Gamma_{\tilde{u}_i, H^-, *, d_b}^L \\
& - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{d_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{u}_j, W^+, d_b}^{R*} \Gamma_{\tilde{u}_i, W^+, d_b}^R
\end{aligned} \tag{54}$$

• Self-Energy for Leptons ( $e$ )

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{L*} m_{e_b} \Gamma_{\tilde{e}_i, h_a, e_b}^R \\
& + m_{\nu^d} \sum_{a=1}^2 B_0(p^2, m_{\nu^d}^2, m_{\sigma_a}^2) \Gamma_{\tilde{e}_j, \sigma_a^*, \bar{\nu}^d}^{L*} \Gamma_{\tilde{e}_i, \sigma_a^*, \bar{\nu}^d}^R \\
& + \sum_{a=1}^3 m_{e_a} \sum_{b=1}^2 B_0(p^2, m_{e_a}^2, m_{A_{h,b}}^2) \Gamma_{\tilde{e}_j, e_a, A_{h,b}}^{L*} \Gamma_{\tilde{e}_i, e_a, A_{h,b}}^R \\
& + \sum_{b=1}^3 B_0(p^2, m_{\nu_b}^2, m_{H^-}^2) \Gamma_{\tilde{e}_j, H^-, \nu_b}^{L*} m_{\nu_b} \Gamma_{\tilde{e}_i, H^-, \nu_b}^R - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, 0) \right) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, \gamma, e_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{e}_i, W^-, \nu_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, m_Z^2) \right) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, Z, e_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{e}_j, Z', e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, Z', e_b}^L \tag{55}
\end{aligned}$$

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

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{L*} \Gamma_{\tilde{e}_i, h_a, e_b}^L \\
& - \frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{\nu^d}^2, m_{\sigma_a}^2) \Gamma_{\tilde{e}_j, \sigma_a^*, \bar{\nu}^d}^{L*} \Gamma_{\tilde{e}_i, \sigma_a^*, \bar{\nu}^d}^L
\end{aligned}$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{e_a}^2, m_{A_{h,b}}^2) \Gamma_{\tilde{e}_j, e_a, A_{h,b}}^{L*} \Gamma_{\tilde{e}_i, e_a, A_{h,b}}^L \\
& -\frac{1}{2} \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{H^-}^2) \Gamma_{\tilde{e}_j, H^-, \nu_b}^{L*} \Gamma_{\tilde{e}_i, H^-, \nu_b}^L - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e_b}^2, 0) \right) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} \Gamma_{\tilde{e}_i, \gamma, e_b}^R \\
& - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} \Gamma_{\tilde{e}_i, W^-, \nu_b}^R - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e_b}^2, m_Z^2) \right) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} \Gamma_{\tilde{e}_i, Z, e_b}^R \\
& - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{e}_j, Z', e_b}^{R*} \Gamma_{\tilde{e}_i, Z', e_b}^R \tag{57}
\end{aligned}$$

• Self-Energy for Neutrinos ( $\nu$ )

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^S(p^2) &= +m_{e3} \sum_{a=1}^2 B_0(p^2, m_{e3}^2, m_{\sigma_a}^2) \Gamma_{\tilde{\nu}_j, \sigma_a^*, e3}^{L*} \Gamma_{\tilde{\nu}_i, \sigma_a^*, e3}^R \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu_b}^2, 0) \right) \Gamma_{\tilde{\nu}_j, \gamma, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{\nu}_i, \gamma, \nu_b}^L - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu_b}^2, m_Z^2) \right) \Gamma_{\tilde{\nu}_j, Z, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{\nu}_i, Z, \nu_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{\nu}_j, Z', \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{\nu}_i, Z', \nu_b}^L \\
& + \sum_{b=1}^3 B_0(p^2, m_{e_b}^2, m_{H^-}^2) \Gamma_{\tilde{\nu}_j, H^-, e_b}^{L*} m_{e_b} \Gamma_{\tilde{\nu}_i, H^-, e_b}^R \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{\nu}_j, W^+, e_b}^{R*} m_{e_b} \Gamma_{\tilde{\nu}_i, W^+, e_b}^L \tag{58}
\end{aligned}$$

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^R(p^2) &= -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e3}^2, m_{\sigma_a}^2) \Gamma_{\tilde{\nu}_j, \sigma_a^*, e3}^{R*} \Gamma_{\tilde{\nu}_i, \sigma_a^*, e3}^R - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu_b}^2, 0) \right) \Gamma_{\tilde{\nu}_j, \gamma, \nu_b}^{L*} \Gamma_{\tilde{\nu}_i, \gamma, \nu_b}^L \\
& - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu_b}^2, m_Z^2) \right) \Gamma_{\tilde{\nu}_j, Z, \nu_b}^{L*} \Gamma_{\tilde{\nu}_i, Z, \nu_b}^L - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{\nu}_j, Z', \nu_b}^{L*} \Gamma_{\tilde{\nu}_i, Z', \nu_b}^L \\
& - \frac{1}{2} \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{H^-}^2) \Gamma_{\tilde{\nu}_j, H^-, e_b}^{R*} \Gamma_{\tilde{\nu}_i, H^-, e_b}^R - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{\nu}_j, W^+, e_b}^{L*} \Gamma_{\tilde{\nu}_i, W^+, e_b}^L \tag{59}
\end{aligned}$$

$$\begin{aligned}
16\pi^2 \Sigma_{i,j}^L(p^2) &= -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e3}^2, m_{\sigma_a}^2) \Gamma_{\tilde{\nu}_j, \sigma_a^*, e3}^{L*} \Gamma_{\tilde{\nu}_i, \sigma_a^*, e3}^L - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu_b}^2, 0) \right) \Gamma_{\tilde{\nu}_j, \gamma, \nu_b}^{R*} \Gamma_{\tilde{\nu}_i, \gamma, \nu_b}^R \\
& - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu_b}^2, m_Z^2) \right) \Gamma_{\tilde{\nu}_j, Z, \nu_b}^{R*} \Gamma_{\tilde{\nu}_i, Z, \nu_b}^R - \sum_{b=1}^3 \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{\nu}_j, Z', \nu_b}^{R*} \Gamma_{\tilde{\nu}_i, Z', \nu_b}^R
\end{aligned}$$



$$-\frac{1}{2}\sum_{b=1}^3 B_1\left(p^2, m_{e_b}^2, m_{H^-}^2\right) \Gamma_{\tilde{\nu}_j, H^-, *, e_b}^{L*} \Gamma_{\tilde{\nu}_i, H^-, *, e_b}^L - \sum_{b=1}^3 \left(\frac{1}{2}\text{rMS} + B_1\left(p^2, m_{e_b}^2, m_{W^-}^2\right)\right) \Gamma_{\tilde{\nu}_j, W^+, e_b}^{R*} \Gamma_{\tilde{\nu}_i, W^+, e_b}^R \quad (60)$$

• **Self-Energy for Singlet ( $\sigma$ )**

$$\begin{aligned} 16\pi^2 \Pi_{i,j}(p^2) = & -A_0\left(m_{H^-}^2\right) \Gamma_{\tilde{\sigma}_i, \tilde{\sigma}_j^*, H^-, *, H^-} + 2\Gamma_{\tilde{\sigma}_i, \tilde{\sigma}_j^*, Z, Z} \left(-\frac{1}{2}\text{rMS}m_Z^2 + A_0\left(m_Z^2\right)\right) + 2\Gamma_{\tilde{\sigma}_i, \tilde{\sigma}_j^*, Z', Z'} \left(-\frac{1}{2}\text{rMS}m_{Z'}^2 + A_0\left(m_{Z'}^2\right)\right) \\ & -\frac{1}{2}\sum_{a=1}^2 A_0\left(m_{A_{h,a}}^2\right) \Gamma_{\tilde{\sigma}_i, \tilde{\sigma}_j^*, A_{h,a}, A_{h,a}} - \sum_{a=1}^2 A_0\left(m_{\sigma_a}^2\right) \Gamma_{\tilde{\sigma}_i, \tilde{\sigma}_j^*, \sigma_a^*, \sigma_a} \\ & -\frac{1}{2}\sum_{a=1}^2 A_0\left(m_{h_a}^2\right) \Gamma_{\tilde{\sigma}_i, \tilde{\sigma}_j^*, h_a, h_a} + \sum_{a=1}^2 \sum_{b=1}^2 B_0\left(p^2, m_{\sigma_a}^2, m_{A_{h,b}}^2\right) \Gamma_{\tilde{\sigma}_j^*, \sigma_a, A_{h,b}}^* \Gamma_{\tilde{\sigma}_i^*, \sigma_a, A_{h,b}} \\ & + \sum_{a=1}^2 \sum_{b=1}^2 B_0\left(p^2, m_{\sigma_a}^2, m_{h_b}^2\right) \Gamma_{\tilde{\sigma}_j^*, \sigma_a, h_b}^* \Gamma_{\tilde{\sigma}_i^*, \sigma_a, h_b} \\ & - 2m_{e3} \sum_{a=1}^3 B_0\left(p^2, m_{\nu_a}^2, m_{e3}^2\right) m_{\nu_a} \left(\Gamma_{\tilde{\sigma}_j^*, \bar{\nu}_a, \bar{e}3}^{L*} \Gamma_{\tilde{\sigma}_i^*, \bar{\nu}_a, \bar{e}3}^R + \Gamma_{\tilde{\sigma}_j^*, \bar{\nu}_a, \bar{e}3}^{R*} \Gamma_{\tilde{\sigma}_i^*, \bar{\nu}_a, \bar{e}3}^L\right) \\ & + \sum_{a=1}^3 G_0\left(p^2, m_{\nu_a}^2, m_{e3}^2\right) \left(\Gamma_{\tilde{\sigma}_j^*, \bar{\nu}_a, \bar{e}3}^{L*} \Gamma_{\tilde{\sigma}_i^*, \bar{\nu}_a, \bar{e}3}^L + \Gamma_{\tilde{\sigma}_j^*, \bar{\nu}_a, \bar{e}3}^{R*} \Gamma_{\tilde{\sigma}_i^*, \bar{\nu}_a, \bar{e}3}^R\right) \\ & + \sum_{b=1}^2 \Gamma_{\tilde{\sigma}_j^*, \gamma, \sigma_b}^* \Gamma_{\tilde{\sigma}_i^*, \gamma, \sigma_b} F_0\left(p^2, m_{\sigma_b}^2, 0\right) + \sum_{b=1}^2 \Gamma_{\tilde{\sigma}_j^*, Z, \sigma_b}^* \Gamma_{\tilde{\sigma}_i^*, Z, \sigma_b} F_0\left(p^2, m_{\sigma_b}^2, m_Z^2\right) \\ & + \sum_{b=1}^2 \Gamma_{\tilde{\sigma}_j^*, Z', \sigma_b}^* \Gamma_{\tilde{\sigma}_i^*, Z', \sigma_b} F_0\left(p^2, m_{\sigma_b}^2, m_{Z'}^2\right) \\ & - 2m_{\nu^d} \sum_{b=1}^3 B_0\left(p^2, m_{\nu^d}^2, m_{e_b}^2\right) m_{e_b} \left(\Gamma_{\tilde{\sigma}_j^*, \bar{\nu}^d, \bar{e}_b}^{L*} \Gamma_{\tilde{\sigma}_i^*, \bar{\nu}^d, \bar{e}_b}^R + \Gamma_{\tilde{\sigma}_j^*, \bar{\nu}^d, \bar{e}_b}^{R*} \Gamma_{\tilde{\sigma}_i^*, \bar{\nu}^d, \bar{e}_b}^L\right) \\ & + \sum_{b=1}^3 G_0\left(p^2, m_{\nu^d}^2, m_{e_b}^2\right) \left(\Gamma_{\tilde{\sigma}_j^*, \bar{\nu}^d, \bar{e}_b}^{L*} \Gamma_{\tilde{\sigma}_i^*, \bar{\nu}^d, \bar{e}_b}^L + \Gamma_{\tilde{\sigma}_j^*, \bar{\nu}^d, \bar{e}_b}^{R*} \Gamma_{\tilde{\sigma}_i^*, \bar{\nu}^d, \bar{e}_b}^R\right) \end{aligned} \quad (61)$$

• **Self-Energy for Fx ( $\chi^0$ )**

$$\begin{aligned} 16\pi^2 \Sigma^S(p^2) = & +m_{\chi^0} \sum_{a=1}^2 B_0\left(p^2, m_{\chi^0}^2, m_{h_a}^2\right) \Gamma_{\tilde{\chi}^0, h_a, \chi^0}^{L*} \Gamma_{\tilde{\chi}^0, h_a, \chi^0}^R \\ & + m_{\chi^0} \sum_{b=1}^2 B_0\left(p^2, m_{\chi^0}^2, m_{A_{h,b}}^2\right) \Gamma_{\tilde{\chi}^0, \chi^0, A_{h,b}}^{L*} \Gamma_{\tilde{\chi}^0, \chi^0, A_{h,b}}^R \\ & - 4\left(-\frac{1}{2}\text{rMS} + B_0\left(p^2, m_{\chi^0}^2, 0\right)\right) \Gamma_{\tilde{\chi}^0, \gamma, \chi^0}^{R*} m_{\chi^0} \Gamma_{\tilde{\chi}^0, \gamma, \chi^0}^L \end{aligned}$$

$$\begin{aligned}
& -4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\chi^0}^2, m_Z^2) \right) \Gamma_{\tilde{\chi}^0, Z, \chi^0}^{R*} m_{\chi^0} \Gamma_{\tilde{\chi}^0, Z, \chi^0}^L \\
& -4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\chi^0}^2, m_{Z'}^2) \right) \Gamma_{\tilde{\chi}^0, Z', \chi^0}^{R*} m_{\chi^0} \Gamma_{\tilde{\chi}^0, Z', \chi^0}^L
\end{aligned} \tag{62}$$

$$\begin{aligned}
16\pi^2 \Sigma^R(p^2) &= -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{\chi^0}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}^0, h_a, \chi^0}^{R*} \Gamma_{\tilde{\chi}^0, h_a, \chi^0}^R \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{\chi^0}^2, m_{A_{h,b}}^2) \Gamma_{\tilde{\chi}^0, \chi^0, A_{h,b}}^{R*} \Gamma_{\tilde{\chi}^0, \chi^0, A_{h,b}}^R \\
& -\left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\chi^0}^2, 0) \right) \Gamma_{\tilde{\chi}^0, \gamma, \chi^0}^{L*} \Gamma_{\tilde{\chi}^0, \gamma, \chi^0}^L - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\chi^0}^2, m_Z^2) \right) \Gamma_{\tilde{\chi}^0, Z, \chi^0}^{L*} \Gamma_{\tilde{\chi}^0, Z, \chi^0}^L \\
& -\left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\chi^0}^2, m_{Z'}^2) \right) \Gamma_{\tilde{\chi}^0, Z', \chi^0}^{L*} \Gamma_{\tilde{\chi}^0, Z', \chi^0}^L
\end{aligned} \tag{63}$$

$$\begin{aligned}
16\pi^2 \Sigma^L(p^2) &= -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{\chi^0}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}^0, h_a, \chi^0}^{L*} \Gamma_{\tilde{\chi}^0, h_a, \chi^0}^L \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{\chi^0}^2, m_{A_{h,b}}^2) \Gamma_{\tilde{\chi}^0, \chi^0, A_{h,b}}^{L*} \Gamma_{\tilde{\chi}^0, \chi^0, A_{h,b}}^L \\
& -\left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\chi^0}^2, 0) \right) \Gamma_{\tilde{\chi}^0, \gamma, \chi^0}^{R*} \Gamma_{\tilde{\chi}^0, \gamma, \chi^0}^R - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\chi^0}^2, m_Z^2) \right) \Gamma_{\tilde{\chi}^0, Z, \chi^0}^{R*} \Gamma_{\tilde{\chi}^0, Z, \chi^0}^R \\
& -\left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\chi^0}^2, m_{Z'}^2) \right) \Gamma_{\tilde{\chi}^0, Z', \chi^0}^{R*} \Gamma_{\tilde{\chi}^0, Z', \chi^0}^R
\end{aligned} \tag{64}$$

• **Self-Energy for Fes** ( $e2$ )

$$\begin{aligned}
16\pi^2 \Sigma^S(p^2) &= +m_{e3} \sum_{a=1}^2 B_0(p^2, m_{e3}^2, m_{h_a}^2) \Gamma_{e2, h_a, e3}^{L*} \Gamma_{e2, h_a, e3}^R \\
& +m_{e2} \sum_{a=1}^2 B_0(p^2, m_{e2}^2, m_{h_a}^2) \Gamma_{e2, h_a, e2}^{L*} \Gamma_{e2, h_a, e2}^R \\
& +m_{e3} \sum_{b=1}^2 B_0(p^2, m_{e3}^2, m_{A_{h,b}}^2) \Gamma_{e2, e3, A_{h,b}}^{L*} \Gamma_{e2, e3, A_{h,b}}^R \\
& +m_{e2} \sum_{b=1}^2 B_0(p^2, m_{e2}^2, m_{A_{h,b}}^2) \Gamma_{e2, e2, A_{h,b}}^{L*} \Gamma_{e2, e2, A_{h,b}}^R \\
& +B_0(p^2, m_{\nu^d}^2, m_{H^-}^2) \Gamma_{e2, H^-, \nu^d}^{L*} m_{\nu^d} \Gamma_{e2, H^-, \nu^d}^R - 4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e2}^2, 0) \right) \Gamma_{e2, \gamma, e2}^{R*} m_{e2} \Gamma_{e2, \gamma, e2}^L \\
& -4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e2}^2, m_Z^2) \right) \Gamma_{e2, Z, e2}^{R*} m_{e2} \Gamma_{e2, Z, e2}^L - 4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e2}^2, m_{Z'}^2) \right) \Gamma_{e2, Z', e2}^{R*} m_{e2} \Gamma_{e2, Z', e2}^L
\end{aligned} \tag{65}$$

$$16\pi^2 \Sigma^R(p^2) = -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e3}^2, m_{h_a}^2) \Gamma_{e2, h_a, e3}^{R*} \Gamma_{e2, h_a, e3}^R$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e2}^2, m_{h_a}^2) \Gamma_{e2, h_a, e2}^{R*} \Gamma_{e2, h_a, e2}^R \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{e3}^2, m_{A_{h,b}}^2) \Gamma_{e2, e3, A_{h,b}}^{R*} \Gamma_{e2, e3, A_{h,b}}^R \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{e2}^2, m_{A_{h,b}}^2) \Gamma_{e2, e2, A_{h,b}}^{R*} \Gamma_{e2, e2, A_{h,b}}^R - \frac{1}{2} B_1(p^2, m_{\nu^d}^2, m_{H^-}^2) \Gamma_{e2, H^-, \nu^d}^{R*} \Gamma_{e2, H^-, \nu^d}^R \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e2}^2, 0) \right) \Gamma_{e2, \gamma, e2}^{L*} \Gamma_{e2, \gamma, e2}^L - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e2}^2, m_Z^2) \right) \Gamma_{e2, Z, e2}^{L*} \Gamma_{e2, Z, e2}^L \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e2}^2, m_{Z'}^2) \right) \Gamma_{e2, Z', e2}^{L*} \Gamma_{e2, Z', e2}^L \tag{66}
\end{aligned}$$

$$\begin{aligned}
16\pi^2 \Sigma^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e3}^2, m_{h_a}^2) \Gamma_{e2, h_a, e3}^{L*} \Gamma_{e2, h_a, e3}^L \\
& -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e2}^2, m_{h_a}^2) \Gamma_{e2, h_a, e2}^{L*} \Gamma_{e2, h_a, e2}^L \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{e3}^2, m_{A_{h,b}}^2) \Gamma_{e2, e3, A_{h,b}}^{L*} \Gamma_{e2, e3, A_{h,b}}^L \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{e2}^2, m_{A_{h,b}}^2) \Gamma_{e2, e2, A_{h,b}}^{L*} \Gamma_{e2, e2, A_{h,b}}^L - \frac{1}{2} B_1(p^2, m_{\nu^d}^2, m_{H^-}^2) \Gamma_{e2, H^-, \nu^d}^{L*} \Gamma_{e2, H^-, \nu^d}^L \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e2}^2, 0) \right) \Gamma_{e2, \gamma, e2}^{R*} \Gamma_{e2, \gamma, e2}^R - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e2}^2, m_Z^2) \right) \Gamma_{e2, Z, e2}^{R*} \Gamma_{e2, Z, e2}^R \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e2}^2, m_{Z'}^2) \right) \Gamma_{e2, Z', e2}^{R*} \Gamma_{e2, Z', e2}^R \tag{67}
\end{aligned}$$

• **Self-Energy for Fed** ( $e3$ )

$$\begin{aligned}
16\pi^2 \Sigma^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{\nu_b}^2, m_{\sigma_a}^2) \Gamma_{e3, \sigma_a^*, \bar{\nu}_b}^{L*} m_{\nu_b} \Gamma_{e3, \sigma_a^*, \bar{\nu}_b}^R \\
& + m_{e3} \sum_{a=1}^2 B_0(p^2, m_{e3}^2, m_{h_a}^2) \Gamma_{e3, h_a, e3}^{L*} \Gamma_{e3, h_a, e3}^R \\
& + m_{e2} \sum_{a=1}^2 B_0(p^2, m_{e2}^2, m_{h_a}^2) \Gamma_{e3, h_a, e2}^{L*} \Gamma_{e3, h_a, e2}^R \\
& + m_{e3} \sum_{b=1}^2 B_0(p^2, m_{e3}^2, m_{A_{h,b}}^2) \Gamma_{e3, e3, A_{h,b}}^{L*} \Gamma_{e3, e3, A_{h,b}}^R \\
& + m_{e2} \sum_{b=1}^2 B_0(p^2, m_{e2}^2, m_{A_{h,b}}^2) \Gamma_{e3, e2, A_{h,b}}^{L*} \Gamma_{e3, e2, A_{h,b}}^R - 4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e3}^2, 0) \right) \Gamma_{e3, \gamma, e3}^{R*} m_{e3} \Gamma_{e3, \gamma, e3}^L
\end{aligned}$$

$$\begin{aligned}
& -4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu^d}^2, m_{W^-}^2) \right) \Gamma_{e3, W^-, \nu^d}^{R*} m_{\nu^d} \Gamma_{e3, W^-, \nu^d}^L \\
& -4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e3}^2, m_Z^2) \right) \Gamma_{e3, Z, e3}^{R*} m_{e3} \Gamma_{e3, Z, e3}^L - 4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e3}^2, m_{Z'}^2) \right) \Gamma_{e3, Z', e3}^{R*} m_{e3} \Gamma_{e3, Z', e3}^L
\end{aligned} \tag{68}$$

$$\begin{aligned}
16\pi^2 \Sigma^R(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{\sigma_a}^2) \Gamma_{e3, \sigma_a^*, \bar{\nu}_b}^{R*} \Gamma_{e3, \sigma_a^*, \bar{\nu}_b}^R \\
& -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e3}^2, m_{h_a}^2) \Gamma_{e3, h_a, e3}^{R*} \Gamma_{e3, h_a, e3}^R \\
& -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e2}^2, m_{h_a}^2) \Gamma_{e3, h_a, e2}^{R*} \Gamma_{e3, h_a, e2}^R \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{e3}^2, m_{A_{h,b}}^2) \Gamma_{e3, e3, A_{h,b}}^{R*} \Gamma_{e3, e3, A_{h,b}}^R \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{e2}^2, m_{A_{h,b}}^2) \Gamma_{e3, e2, A_{h,b}}^{R*} \Gamma_{e3, e2, A_{h,b}}^R - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e3}^2, 0) \right) \Gamma_{e3, \gamma, e3}^{L*} \Gamma_{e3, \gamma, e3}^L \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu^d}^2, m_{W^-}^2) \right) \Gamma_{e3, W^-, \nu^d}^{L*} \Gamma_{e3, W^-, \nu^d}^L - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e3}^2, m_Z^2) \right) \Gamma_{e3, Z, e3}^{L*} \Gamma_{e3, Z, e3}^L \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e3}^2, m_{Z'}^2) \right) \Gamma_{e3, Z', e3}^{L*} \Gamma_{e3, Z', e3}^L
\end{aligned} \tag{69}$$

$$\begin{aligned}
16\pi^2 \Sigma^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{\sigma_a}^2) \Gamma_{e3, \sigma_a^*, \bar{\nu}_b}^{L*} \Gamma_{e3, \sigma_a^*, \bar{\nu}_b}^L \\
& -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e3}^2, m_{h_a}^2) \Gamma_{e3, h_a, e3}^{L*} \Gamma_{e3, h_a, e3}^L \\
& -\frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{e2}^2, m_{h_a}^2) \Gamma_{e3, h_a, e2}^{L*} \Gamma_{e3, h_a, e2}^L \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{e3}^2, m_{A_{h,b}}^2) \Gamma_{e3, e3, A_{h,b}}^{L*} \Gamma_{e3, e3, A_{h,b}}^L \\
& -\frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{e2}^2, m_{A_{h,b}}^2) \Gamma_{e3, e2, A_{h,b}}^{L*} \Gamma_{e3, e2, A_{h,b}}^L - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e3}^2, 0) \right) \Gamma_{e3, \gamma, e3}^{R*} \Gamma_{e3, \gamma, e3}^R \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu^d}^2, m_{W^-}^2) \right) \Gamma_{e3, W^-, \nu^d}^{R*} \Gamma_{e3, W^-, \nu^d}^R - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e3}^2, m_Z^2) \right) \Gamma_{e3, Z, e3}^{R*} \Gamma_{e3, Z, e3}^R \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e3}^2, m_{Z'}^2) \right) \Gamma_{e3, Z', e3}^{R*} \Gamma_{e3, Z', e3}^R
\end{aligned} \tag{70}$$

• Self-Energy for Fvv ( $\nu^d$ )

$$\begin{aligned}
16\pi^2 \Sigma^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{e_b}^2, m_{\sigma_a}^2) \Gamma_{\bar{\nu}^d, \sigma_a^*, \bar{e}_b}^{L*} m_{e_b} \Gamma_{\bar{\nu}^d, \sigma_a^*, \bar{e}_b}^R \\
& + m_{\nu^d} \sum_{a=1}^2 B_0(p^2, m_{\nu^d}^2, m_{h_a}^2) \Gamma_{\bar{\nu}^d, h_a, \nu^d}^{L*} \Gamma_{\bar{\nu}^d, h_a, \nu^d}^R \\
& + m_{\nu^d} \sum_{b=1}^2 B_0(p^2, m_{\nu^d}^2, m_{A_{h,b}}^2) \Gamma_{\bar{\nu}^d, \nu^d, A_{h,b}}^{L*} \Gamma_{\bar{\nu}^d, \nu^d, A_{h,b}}^R \\
& - 4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu^d}^2, 0) \right) \Gamma_{\bar{\nu}^d, \gamma, \nu^d}^{R*} m_{\nu^d} \Gamma_{\bar{\nu}^d, \gamma, \nu^d}^L \\
& - 4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu^d}^2, m_Z^2) \right) \Gamma_{\bar{\nu}^d, Z, \nu^d}^{R*} m_{\nu^d} \Gamma_{\bar{\nu}^d, Z, \nu^d}^L \\
& - 4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu^d}^2, m_{Z'}^2) \right) \Gamma_{\bar{\nu}^d, Z', \nu^d}^{R*} m_{\nu^d} \Gamma_{\bar{\nu}^d, Z', \nu^d}^L \\
& + B_0(p^2, m_{e_2}^2, m_{H^-}^2) \Gamma_{\bar{\nu}^d, H^-, e_2}^{L*} m_{e_2} \Gamma_{\bar{\nu}^d, H^-, e_2}^R \\
& - 4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_3}^2, m_{W^-}^2) \right) \Gamma_{\bar{\nu}^d, W^+, e_3}^{R*} m_{e_3} \Gamma_{\bar{\nu}^d, W^+, e_3}^L
\end{aligned} \tag{71}$$

$$\begin{aligned}
16\pi^2 \Sigma^R(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{\sigma_a}^2) \Gamma_{\bar{\nu}^d, \sigma_a^*, \bar{e}_b}^{R*} \Gamma_{\bar{\nu}^d, \sigma_a^*, \bar{e}_b}^R \\
& - \frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{\nu^d}^2, m_{h_a}^2) \Gamma_{\bar{\nu}^d, h_a, \nu^d}^{R*} \Gamma_{\bar{\nu}^d, h_a, \nu^d}^R \\
& - \frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{\nu^d}^2, m_{A_{h,b}}^2) \Gamma_{\bar{\nu}^d, \nu^d, A_{h,b}}^{R*} \Gamma_{\bar{\nu}^d, \nu^d, A_{h,b}}^R \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu^d}^2, 0) \right) \Gamma_{\bar{\nu}^d, \gamma, \nu^d}^{L*} \Gamma_{\bar{\nu}^d, \gamma, \nu^d}^L - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu^d}^2, m_Z^2) \right) \Gamma_{\bar{\nu}^d, Z, \nu^d}^{L*} \Gamma_{\bar{\nu}^d, Z, \nu^d}^L \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu^d}^2, m_{Z'}^2) \right) \Gamma_{\bar{\nu}^d, Z', \nu^d}^{L*} \Gamma_{\bar{\nu}^d, Z', \nu^d}^L - \frac{1}{2} B_1(p^2, m_{e_2}^2, m_{H^-}^2) \Gamma_{\bar{\nu}^d, H^-, e_2}^{R*} \Gamma_{\bar{\nu}^d, H^-, e_2}^R \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e_3}^2, m_{W^-}^2) \right) \Gamma_{\bar{\nu}^d, W^+, e_3}^{L*} \Gamma_{\bar{\nu}^d, W^+, e_3}^L
\end{aligned} \tag{72}$$

$$\begin{aligned}
16\pi^2 \Sigma^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{\sigma_a}^2) \Gamma_{\bar{\nu}^d, \sigma_a^*, \bar{e}_b}^{L*} \Gamma_{\bar{\nu}^d, \sigma_a^*, \bar{e}_b}^L \\
& - \frac{1}{2} \sum_{a=1}^2 B_1(p^2, m_{\nu^d}^2, m_{h_a}^2) \Gamma_{\bar{\nu}^d, h_a, \nu^d}^{L*} \Gamma_{\bar{\nu}^d, h_a, \nu^d}^L \\
& - \frac{1}{2} \sum_{b=1}^2 B_1(p^2, m_{\nu^d}^2, m_{A_{h,b}}^2) \Gamma_{\bar{\nu}^d, \nu^d, A_{h,b}}^{L*} \Gamma_{\bar{\nu}^d, \nu^d, A_{h,b}}^L \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu^d}^2, 0) \right) \Gamma_{\bar{\nu}^d, \gamma, \nu^d}^{R*} \Gamma_{\bar{\nu}^d, \gamma, \nu^d}^R - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu^d}^2, m_Z^2) \right) \Gamma_{\bar{\nu}^d, Z, \nu^d}^{R*} \Gamma_{\bar{\nu}^d, Z, \nu^d}^R
\end{aligned}$$

$$\begin{aligned}
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{\nu^d}^2, m_{Z'}^2) \right) \Gamma_{\bar{\nu}^d, Z', \nu^d}^{R*} \Gamma_{\bar{\nu}^d, Z', \nu^d}^R - \frac{1}{2} B_1(p^2, m_{e2}^2, m_{H^-}^2) \Gamma_{\bar{\nu}^d, H^-, * , e2}^{L*} \Gamma_{\bar{\nu}^d, H^-, * , e2}^L \\
& - \left( \frac{1}{2} \text{rMS} + B_1(p^2, m_{e3}^2, m_{W^-}^2) \right) \Gamma_{\bar{\nu}^d, W^+, e3}^{R*} \Gamma_{\bar{\nu}^d, W^+, e3}^R
\end{aligned} \tag{73}$$

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

$$\begin{aligned}
16\pi^2 \Pi(p^2) = & 4|\Gamma_{H^-, *, W^-, \gamma}|^2 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, 0, m_{W^-}^2) \right) + 4|\Gamma_{H^-, *, Z, W^-}|^2 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{W^-}^2, m_Z^2) \right) + 4|\Gamma_{H^-, *, Z'}| \\
& - B_0(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \Gamma_{H^-, \eta^+, \eta^+} \Gamma_{H^-, *, \eta^+, \eta^+} - B_0(p^2, m_{\eta^{Z'}}^2, m_{\eta^+}^2) \Gamma_{H^-, \eta^+, \eta^{Z'}} \Gamma_{H^-, *, \eta^+, \eta^{Z'}} \\
& - B_0(p^2, m_{\eta^-}^2, m_{\eta^-}^2) \Gamma_{H^-, \eta^-, \eta^-} \Gamma_{H^-, *, \eta^-, \eta^-} - B_0(p^2, m_{\eta^{Z'}}^2, m_{\eta^-}^2) \Gamma_{H^-, \eta^-, \eta^{Z'}} \Gamma_{H^-, *, \eta^-, \eta^{Z'}} \\
& - A_0(m_{H^-}^2) \Gamma_{H^-, H^-, *, H^-, * , H^-} + |\Gamma_{H^-, *, \gamma, H^-}|^2 F_0(p^2, m_{H^-}^2, 0) + |\Gamma_{H^-, *, Z, H^-}|^2 F_0(p^2, m_{H^-}^2, m_Z^2) \\
& + |\Gamma_{H^-, *, Z', H^-}|^2 F_0(p^2, m_{H^-}^2, m_{Z'}^2) + \left( |\Gamma_{H^-, *, \bar{\nu}^d, e2}^L|^2 + |\Gamma_{H^-, *, \bar{\nu}^d, e2}^R|^2 \right) G_0(p^2, m_{\nu^d}^2, m_{e2}^2) \\
& + 4\Gamma_{H^-, H^-, *, W^+, W^-} \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{H^-, H^-, *, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& + 2\Gamma_{H^-, H^-, *, Z', Z'} \left( -\frac{1}{2} \text{rMS} m_{Z'}^2 + A_0(m_{Z'}^2) \right) - \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_{h,a}}^2) \Gamma_{H^-, H^-, *, A_{h,a}, A_{h,a}} \\
& - \sum_{a=1}^2 A_0(m_{\sigma_a}^2) \Gamma_{H^-, H^-, *, \sigma_a^*, \sigma_a} - \frac{1}{2} \sum_{a=1}^2 A_0(m_{h_a}^2) \Gamma_{H^-, H^-, *, h_a, h_a} \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left( |\Gamma_{H^-, *, \bar{u}_a, d_b}^L|^2 + |\Gamma_{H^-, *, \bar{u}_a, d_b}^R|^2 \right) G_0(p^2, m_{u_a}^2, m_{d_b}^2) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left( |\Gamma_{H^-, *, \bar{\nu}_a, e_b}^L|^2 + |\Gamma_{H^-, *, \bar{\nu}_a, e_b}^R|^2 \right) G_0(p^2, m_{\nu_a}^2, m_{e_b}^2) \\
& - 6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{d_b}^2) m_{d_b} \left( \Gamma_{H^-, *, \bar{u}_a, d_b}^{L*} \Gamma_{H^-, *, \bar{u}_a, d_b}^R + \Gamma_{H^-, *, \bar{u}_a, d_b}^{R*} \Gamma_{H^-, *, \bar{u}_a, d_b}^L \right) \\
& - 2 \sum_{a=1}^3 m_{\nu_a} \sum_{b=1}^3 B_0(p^2, m_{\nu_a}^2, m_{e_b}^2) m_{e_b} \left( \Gamma_{H^-, *, \bar{\nu}_a, e_b}^{L*} \Gamma_{H^-, *, \bar{\nu}_a, e_b}^R + \Gamma_{H^-, *, \bar{\nu}_a, e_b}^{R*} \Gamma_{H^-, *, \bar{\nu}_a, e_b}^L \right) \\
& + \sum_{b=1}^2 |\Gamma_{H^-, *, H^-, h_b}|^2 B_0(p^2, m_{H^-}^2, m_{h_b}^2) + \sum_{b=1}^2 |\Gamma_{H^-, *, W^-, A_{h,b}}|^2 F_0(p^2, m_{A_{h,b}}^2, m_{W^-}^2) \\
& + \sum_{b=1}^2 |\Gamma_{H^-, *, W^-, h_b}|^2 F_0(p^2, m_{h_b}^2, m_{W^-}^2) \\
& - 2B_0(p^2, m_{\nu^d}^2, m_{e2}^2) m_{e2} m_{\nu^d} \left( \Gamma_{H^-, *, \bar{\nu}^d, e2}^{L*} \Gamma_{H^-, *, \bar{\nu}^d, e2}^R + \Gamma_{H^-, *, \bar{\nu}^d, e2}^{R*} \Gamma_{H^-, *, \bar{\nu}^d, e2}^L \right)
\end{aligned} \tag{74}$$

• **Self-Energy for Z-Boson ( $Z$ )**

$$\begin{aligned}
16\pi^2 \Pi(p^2) = & +2|\Gamma_{Z,W^+,H^-}|^2 B_0(p^2, m_{W^-}^2, m_{H^-}^2) + |\Gamma_{Z,\eta^-, \eta^-}|^2 B_{00}(p^2, m_{\eta^-}^2, m_{\eta^-}^2) + |\Gamma_{Z,\eta^+, \eta^+}|^2 B_{00}(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \\
& - 4|\Gamma_{Z,H^-,*,H^-}|^2 B_{00}(p^2, m_{H^-}^2, m_{H^-}^2) + A_0(m_{H^-}^2) \Gamma_{Z,Z,H^-,*,H^-} \\
& + \left(|\Gamma_{Z,e3,e3}^L|^2 + |\Gamma_{Z,e3,e3}^R|^2\right) H_0(p^2, m_{e3}^2, m_{e3}^2) + \left(|\Gamma_{Z,e2,e2}^L|^2 + |\Gamma_{Z,e2,e2}^R|^2\right) H_0(p^2, m_{e2}^2, m_{e2}^2) \\
& + \left(|\Gamma_{Z,\bar{\nu}^d,\nu^d}^L|^2 + |\Gamma_{Z,\bar{\nu}^d,\nu^d}^R|^2\right) H_0(p^2, m_{\nu^d}^2, m_{\nu^d}^2) + \left(|\Gamma_{Z,\bar{\chi}^0,\chi^0}^L|^2 + |\Gamma_{Z,\bar{\chi}^0,\chi^0}^R|^2\right) H_0(p^2, m_{\chi^0}^2, m_{\chi^0}^2) \\
& - |\Gamma_{Z,W^+,W^-}|^2 \left(10B_{00}(p^2, m_{W^-}^2, m_{W^-}^2) + 2A_0(m_{W^-}^2) - 2\text{rMS}(2m_{W^-}^2 - \frac{1}{3}p^2) + B_0(p^2, m_{W^-}^2, m_{W^-}^2) \left(2m_{W^-}^2 + \right.\right. \\
& \left. + 4B_0(p^2, m_{e3}^2, m_{e3}^2) m_{e3}^2 \Re(\Gamma_{Z,e3,e3}^{L*} \Gamma_{Z,e3,e3}^R) + 4B_0(p^2, m_{e2}^2, m_{e2}^2) m_{e2}^2 \Re(\Gamma_{Z,e2,e2}^{L*} \Gamma_{Z,e2,e2}^R) + 4B_0(p^2, m_{\nu^d}^2, m_{\nu^d}^2) m_{\nu^d}^2 \right. \\
& \left. + \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_{h,a}}^2) \Gamma_{Z,Z,A_{h,a},A_{h,a}} + \sum_{a=1}^2 A_0(m_{\sigma_a}^2) \Gamma_{Z,Z,\sigma_a^*,\sigma_a} + \frac{1}{2} \sum_{a=1}^2 A_0(m_{h_a}^2) \Gamma_{Z,Z,h_a,h_a} \right. \\
& \left. - 4 \sum_{a=1}^2 \sum_{b=1}^2 |\Gamma_{Z,h_a,A_{h,b}}|^2 B_{00}(p^2, m_{A_{h,b}}^2, m_{h_a}^2) - 4 \sum_{a=1}^2 \sum_{b=1}^2 |\Gamma_{Z,\sigma_a^*,\sigma_b}|^2 B_{00}(p^2, m_{\sigma_a}^2, m_{\sigma_b}^2) \right. \\
& \left. + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left(|\Gamma_{Z,\bar{d}_a,d_b}^L|^2 + |\Gamma_{Z,\bar{d}_a,d_b}^R|^2\right) H_0(p^2, m_{d_a}^2, m_{d_b}^2) \right. \right. \\
& \left. + 4B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_a} m_{d_b} \Re(\Gamma_{Z,\bar{d}_a,d_b}^{L*} \Gamma_{Z,\bar{d}_a,d_b}^R) \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left(|\Gamma_{Z,\bar{e}_a,e_b}^L|^2 + |\Gamma_{Z,\bar{e}_a,e_b}^R|^2\right) H_0(p^2, m_{e_a}^2, m_{e_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_a} m_{e_b} \Re(\Gamma_{Z,\bar{e}_a,e_b}^{L*} \Gamma_{Z,\bar{e}_a,e_b}^R) \right] \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left(|\Gamma_{Z,\bar{u}_a,u_b}^L|^2 + |\Gamma_{Z,\bar{u}_a,u_b}^R|^2\right) H_0(p^2, m_{u_a}^2, m_{u_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_a} m_{u_b} \Re(\Gamma_{Z,\bar{u}_a,u_b}^{L*} \Gamma_{Z,\bar{u}_a,u_b}^R) \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left(|\Gamma_{Z,\bar{\nu}_a,\nu_b}^L|^2 + |\Gamma_{Z,\bar{\nu}_a,\nu_b}^R|^2\right) H_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) m_{\nu_a} m_{\nu_b} \Re(\Gamma_{Z,\bar{\nu}_a,\nu_b}^{L*} \Gamma_{Z,\bar{\nu}_a,\nu_b}^R) \right] \\
& + \sum_{b=1}^2 |\Gamma_{Z,\gamma,h_b}|^2 B_0(p^2, 0, m_{h_b}^2) + \sum_{b=1}^2 |\Gamma_{Z,Z,h_b}|^2 B_0(p^2, m_Z^2, m_{h_b}^2) + \sum_{b=1}^2 |\Gamma_{Z,Z',h_b}|^2 B_0(p^2, m_{Z'}^2, m_{h_b}^2) \\
& + 2\text{rMS} m_{W^-}^2 \Gamma_{Z,Z,W^+,W^-}^1 - A_0(m_{W^-}^2) \left(4\Gamma_{Z,Z,W^+,W^-}^1 + \Gamma_{Z,Z,W^+,W^-}^2 + \Gamma_{Z,Z,W^+,W^-}^3\right) \quad (75)
\end{aligned}$$

• Self-Energy for Z'-Boson (Z')

$$\begin{aligned}
16\pi^2 \Pi(p^2) = & +2|\Gamma_{Z',W^+,H^-}|^2 B_0(p^2, m_{W^-}^2, m_{H^-}^2) + |\Gamma_{Z',\eta^-, \eta^-}|^2 B_{00}(p^2, m_{\eta^-}^2, m_{\eta^-}^2) + |\Gamma_{Z',\eta^+, \eta^+}|^2 B_{00}(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \\
& - 4|\Gamma_{Z',H^-,*,H^-}|^2 B_{00}(p^2, m_{H^-}^2, m_{H^-}^2) + A_0(m_{H^-}^2) \Gamma_{Z',Z',H^-,*,H^-} \\
& + \left(|\Gamma_{Z',e\bar{3},e3}^L|^2 + |\Gamma_{Z',e\bar{3},e3}^R|^2\right) H_0(p^2, m_{e3}^2, m_{e3}^2) + \left(|\Gamma_{Z',e\bar{2},e2}^L|^2 + |\Gamma_{Z',e\bar{2},e2}^R|^2\right) H_0(p^2, m_{e2}^2, m_{e2}^2) \\
& + \left(|\Gamma_{Z',\bar{\nu}^d,\nu^d}^L|^2 + |\Gamma_{Z',\bar{\nu}^d,\nu^d}^R|^2\right) H_0(p^2, m_{\nu^d}^2, m_{\nu^d}^2) + \left(|\Gamma_{Z',\bar{\chi}^0,\chi^0}^L|^2 + |\Gamma_{Z',\bar{\chi}^0,\chi^0}^R|^2\right) H_0(p^2, m_{\chi^0}^2, m_{\chi^0}^2) \\
& - |\Gamma_{Z',W^+,W^-}|^2 \left(10B_{00}(p^2, m_{W^-}^2, m_{W^-}^2) + 2A_0(m_{W^-}^2) - 2\text{rMS}\left(2m_{W^-}^2 - \frac{1}{3}p^2\right) + B_0(p^2, m_{W^-}^2, m_{W^-}^2)\right) (2m_{W^-}^2 + \\
& + 4B_0(p^2, m_{e3}^2, m_{e3}^2) m_{e3}^2 \Re(\Gamma_{Z',e\bar{3},e3}^{L*} \Gamma_{Z',e\bar{3},e3}^R) + 4B_0(p^2, m_{e2}^2, m_{e2}^2) m_{e2}^2 \Re(\Gamma_{Z',e\bar{2},e2}^{L*} \Gamma_{Z',e\bar{2},e2}^R) + 4B_0(p^2, m_{\nu^d}^2, m_{\nu^d}^2) \\
& + \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_{h,a}}^2) \Gamma_{Z',Z',A_{h,a},A_{h,a}} + \sum_{a=1}^2 A_0(m_{\sigma_a}^2) \Gamma_{Z',Z',\sigma_a^*,\sigma_a} + \frac{1}{2} \sum_{a=1}^2 A_0(m_{h_a}^2) \Gamma_{Z',Z',h_a,h_a} \\
& - 4 \sum_{a=1}^2 \sum_{b=1}^2 |\Gamma_{Z',h_a,A_{h,b}}|^2 B_{00}(p^2, m_{A_{h,b}}^2, m_{h_a}^2) - 4 \sum_{a=1}^2 \sum_{b=1}^2 |\Gamma_{Z',\sigma_a^*,\sigma_b}|^2 B_{00}(p^2, m_{\sigma_a}^2, m_{\sigma_b}^2) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left(|\Gamma_{Z',\bar{d}_a,d_b}^L|^2 + |\Gamma_{Z',\bar{d}_a,d_b}^R|^2\right) H_0(p^2, m_{d_a}^2, m_{d_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_a} m_{d_b} \Re(\Gamma_{Z',\bar{d}_a,d_b}^{L*} \Gamma_{Z',\bar{d}_a,d_b}^R) \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left(|\Gamma_{Z',\bar{e}_a,e_b}^L|^2 + |\Gamma_{Z',\bar{e}_a,e_b}^R|^2\right) H_0(p^2, m_{e_a}^2, m_{e_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_a} m_{e_b} \Re(\Gamma_{Z',\bar{e}_a,e_b}^{L*} \Gamma_{Z',\bar{e}_a,e_b}^R) \right] \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left(|\Gamma_{Z',\bar{u}_a,u_b}^L|^2 + |\Gamma_{Z',\bar{u}_a,u_b}^R|^2\right) H_0(p^2, m_{u_a}^2, m_{u_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_a} m_{u_b} \Re(\Gamma_{Z',\bar{u}_a,u_b}^{L*} \Gamma_{Z',\bar{u}_a,u_b}^R) \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left(|\Gamma_{Z',\bar{\nu}_a,\nu_b}^L|^2 + |\Gamma_{Z',\bar{\nu}_a,\nu_b}^R|^2\right) H_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) m_{\nu_a} m_{\nu_b} \Re(\Gamma_{Z',\bar{\nu}_a,\nu_b}^{L*} \Gamma_{Z',\bar{\nu}_a,\nu_b}^R) \right] \\
& + \sum_{b=1}^2 |\Gamma_{Z',\gamma,h_b}|^2 B_0(p^2, 0, m_{h_b}^2) + \sum_{b=1}^2 |\Gamma_{Z',Z,h_b}|^2 B_0(p^2, m_Z^2, m_{h_b}^2) + \sum_{b=1}^2 |\Gamma_{Z',Z',h_b}|^2 B_0(p^2, m_{Z'}^2, m_{h_b}^2) \\
& + 2\text{rMS} m_{W^-}^2 - \Gamma_{Z',Z',W^+,W^-}^1 - A_0(m_{W^-}^2) \left(4\Gamma_{Z',Z',W^+,W^-}^1 + \Gamma_{Z',Z',W^+,W^-}^2 + \Gamma_{Z',Z',W^+,W^-}^3\right) \quad (76)
\end{aligned}$$

• Self-Energy for W-Boson ( $W^-$ )



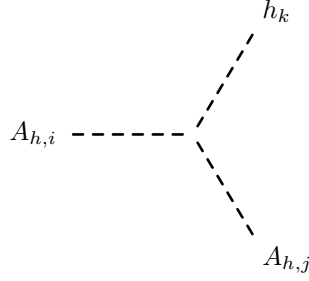
$$\begin{aligned}
16\pi^2 \Pi(p^2) = & 2\text{rMS}m_{W^-}^2 \Gamma_{W^-,W^+,W^+,W^-}^1 + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left( |\Gamma_{W^+,\bar{u}_a,d_b}^L|^2 + |\Gamma_{W^+,\bar{u}_a,d_b}^R|^2 \right) H_0(p^2, m_{u_a}^2, m_{d_b}^2) \right. \\
& + 4B_0(p^2, m_{u_a}^2, m_{d_b}^2) m_{d_b} m_{u_a} \Re \left( \Gamma_{W^+,\bar{u}_a,d_b}^{L*} \Gamma_{W^+,\bar{u}_a,d_b}^R \right) \Big] + 4B_0(p^2, m_{\nu^d}^2, m_{e3}^2) m_{e3} m_{\nu^d} \Re \left( \Gamma_{W^+,\bar{\nu}^d,e3}^{L*} \Gamma_{W^+,\bar{\nu}^d,e3}^R \right) - 4 \\
& + 4B_0(p^2, m_{\nu_a}^2, m_{e_b}^2) m_{e_b} m_{\nu_a} \Re \left( \Gamma_{W^+,\bar{\nu}_a,e_b}^{L*} \Gamma_{W^+,\bar{\nu}_a,e_b}^R \right) \Big] + \sum_{b=1}^2 |\Gamma_{W^+,W^-,h_b}|^2 B_0(p^2, m_{W^-}^2, m_{h_b}^2) \quad (77)
\end{aligned}$$

## 7.2 Tadpoles

$$\begin{aligned}
16\pi^2 \delta t_h^{(1)} = & + A_0(m_{\eta^-}^2) \Gamma_{\check{h}_i, \eta^-, \eta^-} + A_0(m_{\eta^+}^2) \Gamma_{\check{h}_i, \eta^+, \eta^+} + A_0(m_{\eta^Z}^2) \Gamma_{\check{h}_i, \eta^Z, \eta^Z} \\
& + A_0(m_{\eta^{Z'}}^2) \Gamma_{\check{h}_i, \eta^{Z'}, \eta^{Z'}} - A_0(m_{H^-}^2) \Gamma_{\check{h}_i, H^-, * , H^-} + 4\Gamma_{\check{h}_i, W^+, W^-} \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) \\
& + 2\Gamma_{\check{h}_i, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) + 2\Gamma_{\check{h}_i, Z', Z'} \left( -\frac{1}{2} \text{rMS} m_{Z'}^2 + A_0(m_{Z'}^2) \right) - \frac{1}{2} \sum_{a=1}^2 A_0(m_{A_{h,a}}^2) \Gamma_{\check{h}_i, A_{h,a}, A_{h,a}} \\
& - \sum_{a=1}^2 A_0(m_{\sigma_a}^2) \Gamma_{\check{h}_i, \sigma_a^*, \sigma_a} - \frac{1}{2} \sum_{a=1}^2 A_0(m_{h_a}^2) \Gamma_{\check{h}_i, h_a, h_a} \\
& + 6 \sum_{a=1}^3 A_0(m_{d_a}^2) m_{d_a} \left( \Gamma_{\check{h}_i, \bar{d}_a, d_a}^L + \Gamma_{\check{h}_i, \bar{d}_a, d_a}^R \right) \\
& + 2 \sum_{a=1}^3 A_0(m_{e_a}^2) m_{e_a} \left( \Gamma_{\check{h}_i, \bar{e}_a, e_a}^L + \Gamma_{\check{h}_i, \bar{e}_a, e_a}^R \right) \\
& + 6 \sum_{a=1}^3 A_0(m_{u_a}^2) m_{u_a} \left( \Gamma_{\check{h}_i, \bar{u}_a, u_a}^L + \Gamma_{\check{h}_i, \bar{u}_a, u_a}^R \right) + 2A_0(m_{e3}^2) m_{e3} \left( \Gamma_{\check{h}_i, \bar{e}3, e3}^L + \Gamma_{\check{h}_i, \bar{e}3, e3}^R \right) \\
& + 2A_0(m_{e2}^2) m_{e2} \left( \Gamma_{\check{h}_i, \bar{e}2, e2}^L + \Gamma_{\check{h}_i, \bar{e}2, e2}^R \right) + 2A_0(m_{\nu^d}^2) m_{\nu^d} \left( \Gamma_{\check{h}_i, \bar{\nu}^d, \nu^d}^L + \Gamma_{\check{h}_i, \bar{\nu}^d, \nu^d}^R \right) \\
& + 2A_0(m_{\chi^0}^2) m_{\chi^0} \left( \Gamma_{\check{h}_i, \bar{\chi}^0, \chi^0}^L + \Gamma_{\check{h}_i, \bar{\chi}^0, \chi^0}^R \right) \quad (78)
\end{aligned}$$

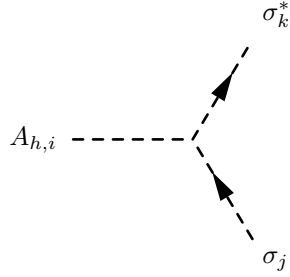
## 8 Interactions for eigenstates 'EWSB'

### 8.1 Three Scalar-Interaction



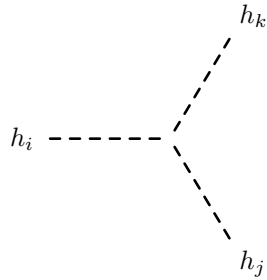
$$i \left( Z_{i1}^A Z_{j1}^A \left( 2\lambda_1 v Z_{k1}^H + \lambda_3 x Z_{k2}^H \right) + Z_{i2}^A Z_{j2}^A \left( 2\lambda_2 x Z_{k2}^H + \lambda_3 v Z_{k1}^H \right) \right) \quad (79)$$


---



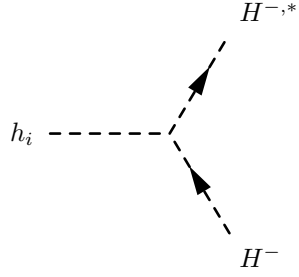
$$- \frac{1}{\sqrt{2}} h r_f \left( - V S_{j1} V S_{k2} + V S_{j2} V S_{k1} \right) Z_{i2}^A \quad (80)$$


---



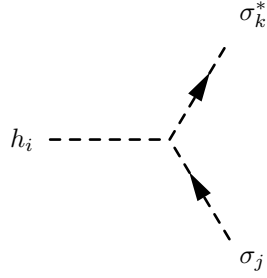
$$\begin{aligned} & i \left( Z_{i2}^H \left( \lambda_3 Z_{j1}^H \left( v Z_{k2}^H + x Z_{k1}^H \right) + Z_{j2}^H \left( 6\lambda_2 x Z_{k2}^H + \lambda_3 v Z_{k1}^H \right) \right) \right. \\ & \left. + Z_{i1}^H \left( \lambda_3 Z_{j2}^H \left( v Z_{k2}^H + x Z_{k1}^H \right) + Z_{j1}^H \left( 6\lambda_1 v Z_{k1}^H + \lambda_3 x Z_{k2}^H \right) \right) \right) \end{aligned} \quad (81)$$


---



$$i\left(2\lambda_1 v Z_{i1}^H + \lambda_3 x Z_{i2}^H\right) \quad (82)$$

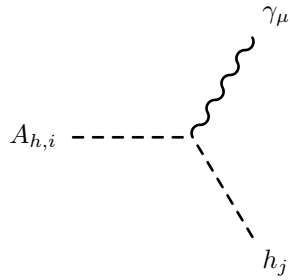

---



$$i\left(V S_{j1}\left(-\frac{1}{\sqrt{2}} h r_f V S_{k2} Z_{i2}^H + \lambda_3 2v V S_{k1} Z_{i1}^H\right) + V S_{j2}\left(-\frac{1}{\sqrt{2}} h r_f V S_{k1} Z_{i2}^H + \lambda_3 3v V S_{k2} Z_{i1}^H\right)\right) \quad (83)$$

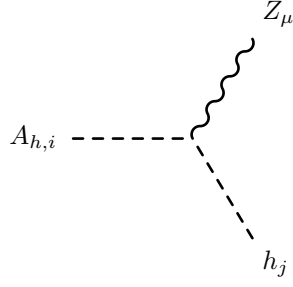

---

## 8.2 Two Scalar-One Vector Boson-Interaction



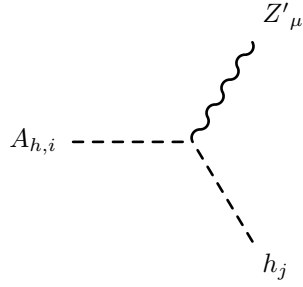
$$\frac{1}{2}\left(10g_{YB} \cos \Theta_W Z_{i2}^A Z_{j2}^H - \left(g_1 \cos \Theta_W - g_2 \sin \Theta_W\right) Z_{i1}^A Z_{j1}^H\right)\left(-p_\mu^{h_j} + p_\mu^{A_{h,i}}\right) \quad (84)$$


---



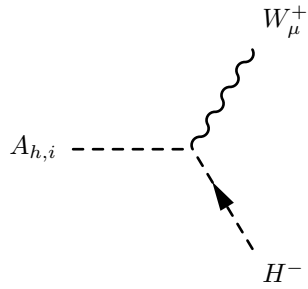
$$\begin{aligned} & \frac{1}{2} \left( \left( g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right) Z_{i1}^A Z_{j1}^H \right. \\ & \left. + 10 \left( g_B \sin \Theta'_W - g_{YB} \cos \Theta'_W \sin \Theta_W \right) Z_{i2}^A Z_{j2}^H \right) \left( -p_\mu^{h_j} + p_\mu^{A_{h,i}} \right) \end{aligned} \quad (85)$$


---



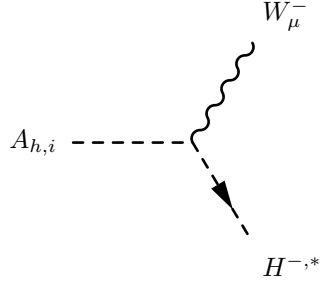
$$\begin{aligned} & \frac{1}{2} \left( - \left( \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) Z_{i1}^A Z_{j1}^H \right. \\ & \left. + 10 \left( g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right) Z_{i2}^A Z_{j2}^H \right) \left( -p_\mu^{h_j} + p_\mu^{A_{h,i}} \right) \end{aligned} \quad (86)$$


---



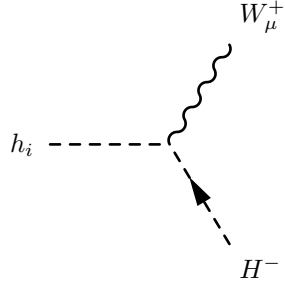
$$\frac{1}{2} g_2 Z_{i1}^A \left( -p_\mu^{H^-} + p_\mu^{A_{h,i}} \right) \quad (87)$$


---



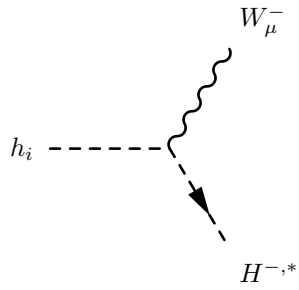
$$\frac{1}{2}g_2 Z_{i1}^A \left( -p_\mu^{H^{-,*}} + p_\mu^{A_{h,i}} \right) \quad (88)$$


---



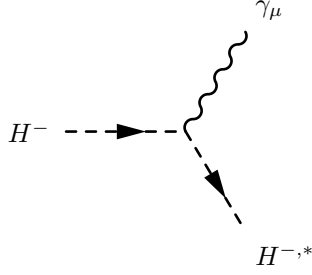
$$\frac{i}{2}g_2 Z_{i1}^H \left( -p_\mu^{H^-} + p_\mu^{h_i} \right) \quad (89)$$


---



$$-\frac{i}{2}g_2 Z_{i1}^H \left( -p_\mu^{H^{-,*}} + p_\mu^{h_i} \right) \quad (90)$$

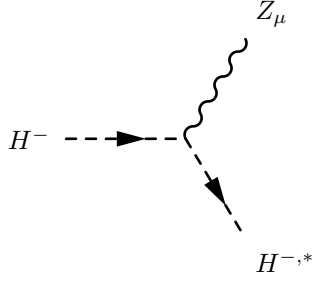

---



---


$$\frac{i}{2} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left( -p_\mu^{H^{-,*}} + p_\mu^{H^-} \right) \quad (91)$$

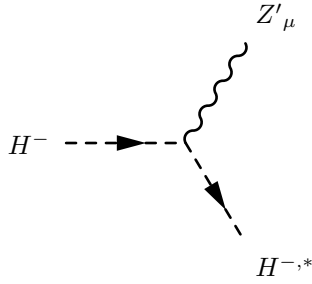

---



---


$$\frac{i}{2} \left( -g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W + g_{BY} \sin \Theta'_W \right) \left( -p_\mu^{H^{-,*}} + p_\mu^{H^-} \right) \quad (92)$$

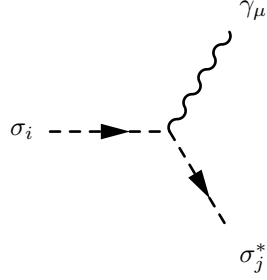

---



---


$$\frac{i}{2} \left( \left( g_1 \sin \Theta_W - g_2 \cos \Theta_W \right) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) \left( -p_\mu^{H^{-,*}} + p_\mu^{H^-} \right) \quad (93)$$

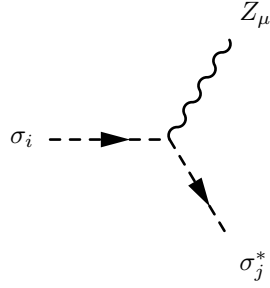

---



---

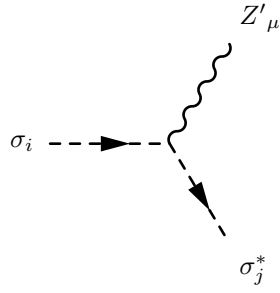

$$-i \cos \Theta_W \left( (6g_{YB} + g_1) V S_{i2} V S_{j2} + (g_1 + g_{YB}) V S_{i1} V S_{j1} \right) \left( -p_\mu^{\sigma_j^*} + p_\mu^{\sigma_i} \right) \quad (94)$$


---



$$i \left( \left( (g_1 + g_{YB}) \cos \Theta'_W \sin \Theta_W - (g_{BY} + g_B) \sin \Theta'_W \right) V S_{i1} V S_{j1} + \left( - (6g_B + g_{BY}) \sin \Theta'_W + (6g_{YB} + g_1) \cos \Theta'_W \sin \Theta_W \right) V S_{i2} V S_{j2} \right) \left( -p_\mu^{\sigma_j^*} + p_\mu^{\sigma_i} \right) \quad (95)$$

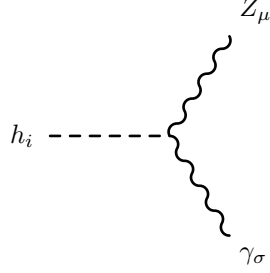

---



$$-i \left( \left( (g_1 + g_{YB}) \sin \Theta_W \sin \Theta'_W + (g_{BY} + g_B) \cos \Theta'_W \right) V S_{i1} V S_{j1} + \left( (6g_B + g_{BY}) \cos \Theta'_W + (6g_{YB} + g_1) \sin \Theta_W \sin \Theta'_W \right) V S_{i2} V S_{j2} \right) \left( -p_\mu^{\sigma_j^*} + p_\mu^{\sigma_i} \right) \quad (96)$$

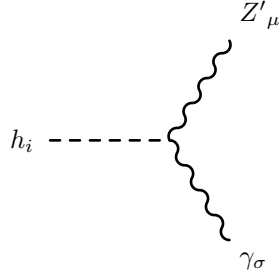

---

### 8.3 One Scalar-Two Vector Boson-Interaction



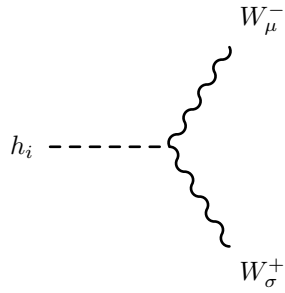
$$\begin{aligned} & \frac{i}{2} \left( -v \left( g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \left( g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right) Z_{i1}^H \right. \\ & \left. - 50 g_{YB} x \left( -2 g_B \cos \Theta_W \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin 2\Theta_W \right) Z_{i2}^H \right) (g_{\sigma\mu}) \end{aligned} \quad (97)$$


---



$$\begin{aligned} & \frac{i}{2} \left( v \left( g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \left( \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) Z_{i1}^H \right. \\ & \left. + 50 g_{YB} x \left( 2 g_B \cos \Theta_W \cos \Theta'_W + g_{YB} \sin 2\Theta_W \sin \Theta'_W \right) Z_{i2}^H \right) (g_{\sigma\mu}) \end{aligned} \quad (98)$$

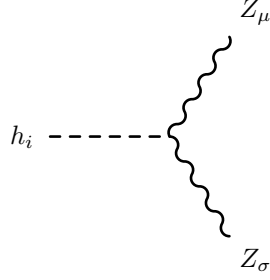

---



$$\frac{i}{2} g_2^2 v Z_{i1}^H (g_{\sigma\mu}) \quad (99)$$

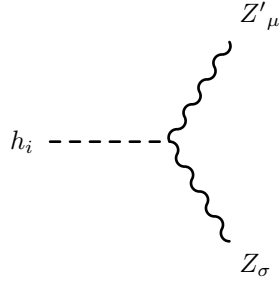

---





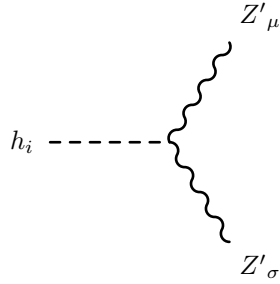
$$\begin{aligned}
& \frac{i}{2} \left( v \left( g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right)^2 Z_{i1}^H \right. \\
& \left. + 100x \left( -g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right)^2 Z_{i2}^H \right) (g_{\sigma\mu})
\end{aligned}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


---



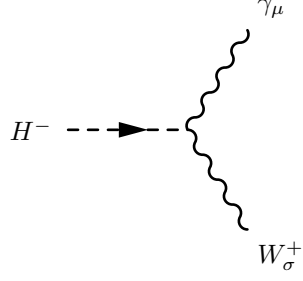
$$\begin{aligned}
& \frac{i}{2} \left( -v \left( g_1 g_{BY} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \right. \\
& \left. \left. + \cos \Theta'_W \left( g_1^2 \sin \Theta_W^2 - g_{BY}^2 \right) \sin \Theta'_W - g_1 g_{BY} \sin \Theta_W \sin \Theta'^2_W \right. \right. \\
& \left. \left. + g_2 \cos \Theta_W \left( g_1 \sin \Theta_W \sin 2\Theta'_W + g_{BY} \cos \Theta'^2_W - g_{BY} \sin \Theta'^2_W \right) \right) Z_{i1}^H \right. \\
& \left. + 50x \left( -2g_B g_{YB} \cos \Theta'^2_W \sin \Theta_W + 2g_B g_{YB} \sin \Theta_W \sin \Theta'^2_W + g_B^2 \sin 2\Theta'_W \right. \right. \\
& \left. \left. - g_{YB}^2 \sin \Theta_W^2 \sin 2\Theta'_W \right) Z_{i2}^H \right) (g_{\sigma\mu})
\end{aligned} \tag{101}$$


---



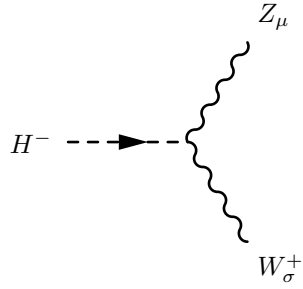
$$\begin{aligned}
& \frac{i}{2} \left( v \left( \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right)^2 Z_{i1}^H \right. \\
& \left. + 100x \left( g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right)^2 Z_{i2}^H \right) (g_{\sigma\mu})
\end{aligned} \tag{102}$$


---



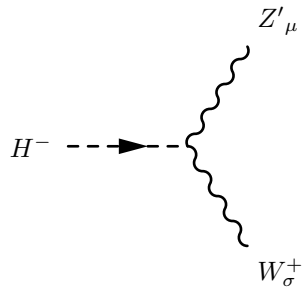
$$-\frac{i}{2} g_1 g_2 v \cos \Theta_W (g_{\sigma\mu}) \tag{103}$$


---



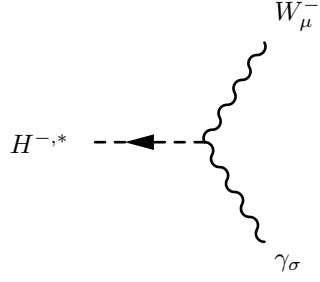
$$\frac{i}{2} g_2 v \left( g_1 \cos \Theta'_W \sin \Theta_W - g_{BY} \sin \Theta'_W \right) (g_{\sigma\mu}) \tag{104}$$


---



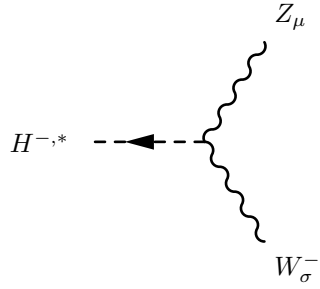
$$-\frac{i}{2}g_2v\left(g_1\sin\Theta_W\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)\left(g_{\sigma\mu}\right) \quad (105)$$


---



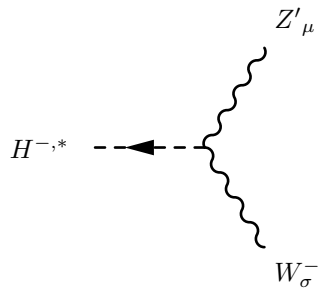
$$-\frac{i}{2}g_1g_2v\cos\Theta_W\left(g_{\sigma\mu}\right) \quad (106)$$


---



$$\frac{i}{2}g_2v\left(g_1\cos\Theta'_W\sin\Theta_W-g_{BY}\sin\Theta'_W\right)\left(g_{\sigma\mu}\right) \quad (107)$$

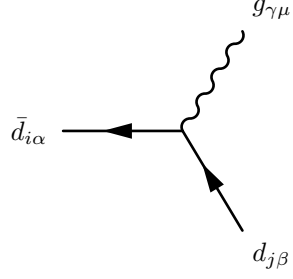

---



$$-\frac{i}{2}g_2v\left(g_1\sin\Theta_W\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)\left(g_{\sigma\mu}\right) \quad (108)$$


---

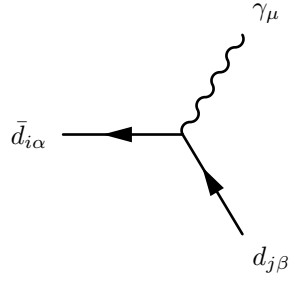
## 8.4 Two Fermion-One Vector Boson-Interaction



$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (109)$$

$$+\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (110)$$

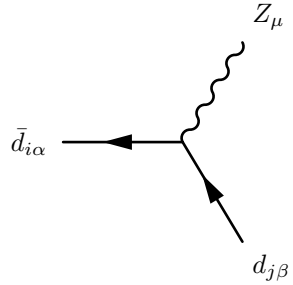

---



$$-\frac{i}{18}\delta_{\alpha\beta}\delta_{ij}\left(\left(-10g_{YB}+3g_1\right)\cos\Theta_W-9g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (111)$$

$$+\frac{i}{9}\left(3g_1+5g_{YB}\right)\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (112)$$

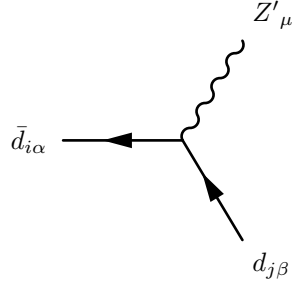

---



$$\frac{i}{18}\delta_{\alpha\beta}\delta_{ij}\left(\left(10g_B - 3g_{BY}\right)\sin\Theta'_W + \left(-10g_{YB} + 3g_1\right)\cos\Theta'_W\sin\Theta_W + 9g_2\cos\Theta_W\cos\Theta'_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (113)$$

$$+ \frac{i}{9}\delta_{\alpha\beta}\delta_{ij}\left(\left(3g_1 + 5g_{YB}\right)\cos\Theta'_W\sin\Theta_W - \left(3g_{BY} + 5g_B\right)\sin\Theta'_W\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (114)$$

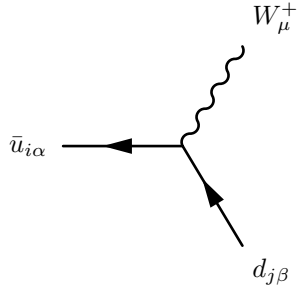

---



$$- \frac{i}{18}\delta_{\alpha\beta}\delta_{ij}\left(\left(-10g_B + 3g_{BY}\right)\cos\Theta'_W + \left(\left(-10g_{YB} + 3g_1\right)\sin\Theta_W + 9g_2\cos\Theta_W\right)\sin\Theta'_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (115)$$

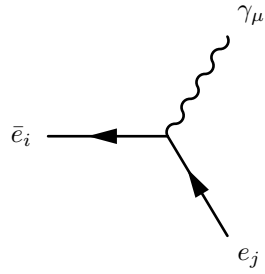
$$+ \frac{i}{9}\delta_{\alpha\beta}\delta_{ij}\left(\left(3g_1 + 5g_{YB}\right)\sin\Theta_W\sin\Theta'_W + \left(3g_{BY} + 5g_B\right)\cos\Theta'_W\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (116)$$


---



$$- i \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^3 U_{L,ja}^{d,*} U_{L,ia}^u \left( \gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (117)$$

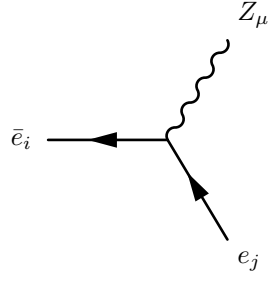

---



$$\frac{i}{2}\delta_{ij}\left(g_1 \cos \Theta_W + g_2 \sin \Theta_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (118)$$

$$+ i g_1 \cos \Theta_W \delta_{ij}\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (119)$$

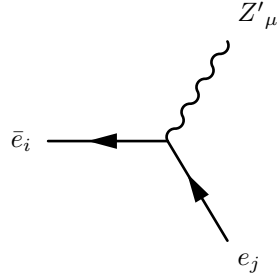

---



$$\frac{i}{2}\delta_{ij}\left(-g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W + g_{BY} \sin \Theta'_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (120)$$

$$+ -i\delta_{ij}\left(g_1 \cos \Theta'_W \sin \Theta_W - g_{BY} \sin \Theta'_W\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (121)$$

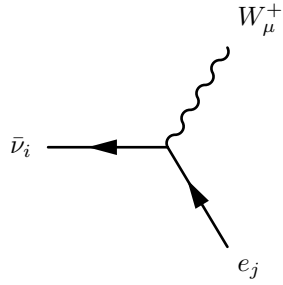

---



$$\frac{i}{2}\delta_{ij}\left(\left(g_1 \sin \Theta_W - g_2 \cos \Theta_W\right) \sin \Theta'_W + g_{BY} \cos \Theta'_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (122)$$

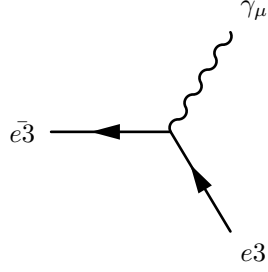
$$+ i\delta_{ij}\left(g_1 \sin \Theta_W \sin \Theta'_W + g_{BY} \cos \Theta'_W\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (123)$$


---



$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 U_{L,ja}^{e,*} U_{ia}^V \left( \gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (124)$$

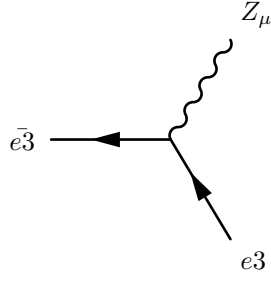

---



$$\frac{i}{2} \left( (2g_{YB} + g_1) \cos \Theta_W + g_2 \sin \Theta_W \right) \left( \gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (125)$$

$$+ \frac{i}{2} \left( (12g_{YB} + g_1) \cos \Theta_W + g_2 \sin \Theta_W \right) \left( \gamma_\mu \cdot \frac{1+\gamma_5}{2} \right) \quad (126)$$

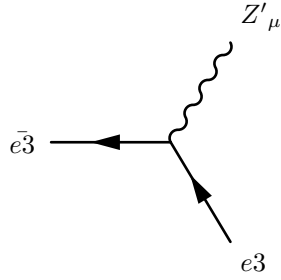

---



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

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

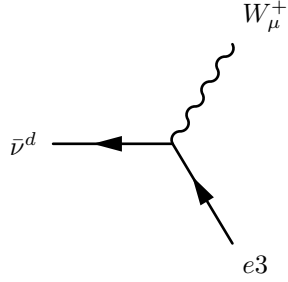

---



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

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

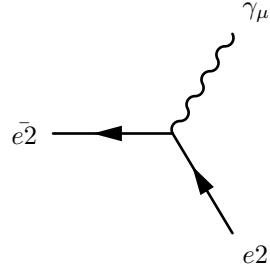

---



$$-i \frac{1}{\sqrt{2}} g_2 \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (131)$$

$$+ -i \frac{1}{\sqrt{2}} g_2 \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (132)$$

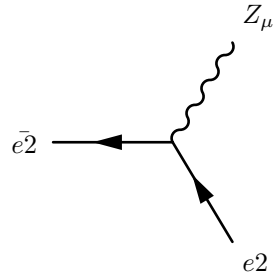

---



$$i \left( 6g_{YB} + g_1 \right) \cos \Theta_W \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (133)$$

$$+ i \left( g_1 + g_{YB} \right) \cos \Theta_W \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (134)$$


---

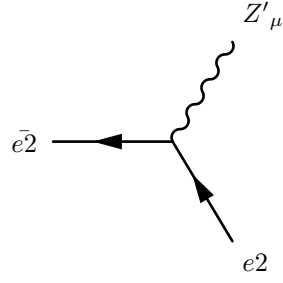




$$-i \left( - \left( 6g_B + g_{BY} \right) \sin \Theta'_W + \left( 6g_{YB} + g_1 \right) \cos \Theta'_W \sin \Theta_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (135)$$

$$+ -i \left( \left( g_1 + g_{YB} \right) \cos \Theta'_W \sin \Theta_W - \left( g_{BY} + g_B \right) \sin \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (136)$$

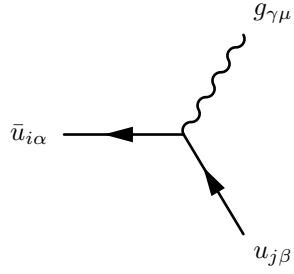

---



$$i \left( \left( 6g_B + g_{BY} \right) \cos \Theta'_W + \left( 6g_{YB} + g_1 \right) \sin \Theta_W \sin \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (137)$$

$$+ i \left( \left( g_1 + g_{YB} \right) \sin \Theta_W \sin \Theta'_W + \left( g_{BY} + g_B \right) \cos \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (138)$$

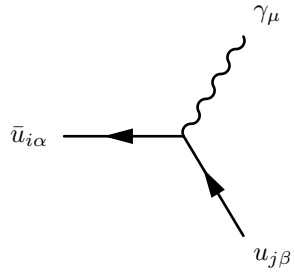

---



$$- \frac{i}{2} g_3 \delta_{ij} \lambda_{\alpha,\beta}^\gamma \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (139)$$

$$+ - \frac{i}{2} g_3 \delta_{ij} \lambda_{\alpha,\beta}^\gamma \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (140)$$

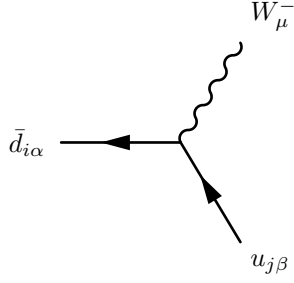

---



$$-\frac{i}{18}\delta_{\alpha\beta}\delta_{ij}\left(\left(-10g_{YB}+3g_1\right)\cos\Theta_W+9g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (141)$$

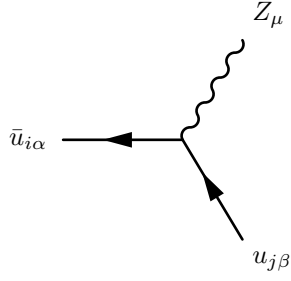
$$+\frac{i}{9}\left(-5g_{YB}+6g_1\right)\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (142)$$


---



$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3U_{L,ja}^{u,*}U_{L,ia}^d\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (143)$$

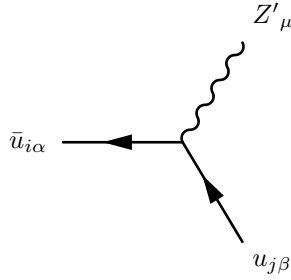

---



$$-\frac{i}{18}\delta_{\alpha\beta}\delta_{ij}\left(\left(-10g_B+3g_{BY}\right)\sin\Theta'_W-\left(-10g_{YB}+3g_1\right)\cos\Theta'_W\sin\Theta_W+9g_2\cos\Theta_W\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (144)$$

$$+\frac{i}{9}\delta_{\alpha\beta}\delta_{ij}\left(\left(5g_B-6g_{BY}\right)\sin\Theta'_W+\left(-5g_{YB}+6g_1\right)\cos\Theta'_W\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (145)$$

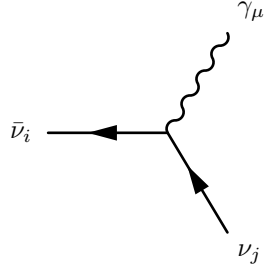

---



$$-\frac{i}{18}\delta_{\alpha\beta}\delta_{ij}\left(\left(-10g_B+3g_{BY}\right)\cos\Theta'_W+\left(\left(-10g_{YB}+3g_1\right)\sin\Theta_W-9g_2\cos\Theta_W\right)\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (146)$$

$$+\frac{i}{9}\delta_{\alpha\beta}\delta_{ij}\left(\left(-5g_B+6g_{BY}\right)\cos\Theta'_W+\left(-5g_{YB}+6g_1\right)\sin\Theta_W\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (147)$$

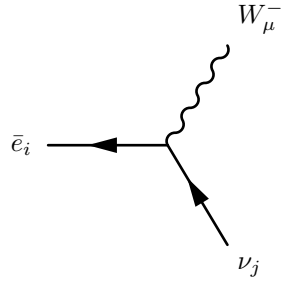

---



$$\frac{i}{2}\delta_{ij}\left(g_1\cos\Theta_W-g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (148)$$

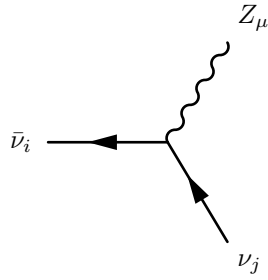
$$+\frac{i}{2}\delta_{ij}\left(g_1\cos\Theta_W-g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (149)$$


---



$$-i\frac{1}{\sqrt{2}}g_2\sum_{a=1}^3U_{ja}^{V,*}U_{L,ia}^e\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (150)$$

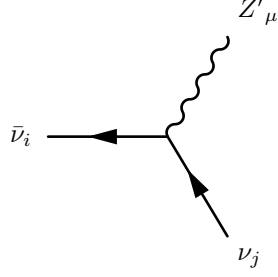

---



$$-\frac{i}{2}\delta_{ij}\left(g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W-g_{BY}\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (151)$$

$$+5i\left(-g_B\sin\Theta'_W+g_{YB}\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^2U_{ia}^{UR,*}U_{ja}^{UR}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (152)$$

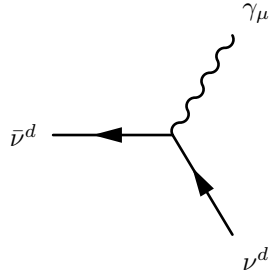

---



$$\frac{i}{2}\delta_{ij}\left(\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (153)$$

$$-5i\left(g_B\cos\Theta'_W+g_{YB}\sin\Theta_W\sin\Theta'_W\right)\sum_{a=1}^2U_{ia}^{UR,*}U_{ja}^{UR}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (154)$$

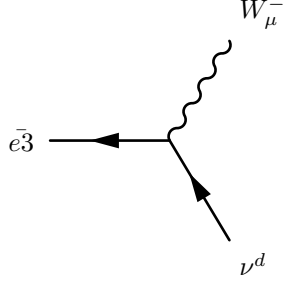

---



$$\frac{i}{2}\left(\left(2g_{YB}+g_1\right)\cos\Theta_W-g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (155)$$

$$+\frac{i}{2}\left(\left(12g_{YB}+g_1\right)\cos\Theta_W-g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (156)$$

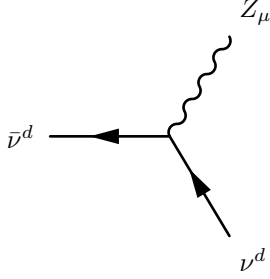

---



$$-i \frac{1}{\sqrt{2}} g_2 \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (157)$$

$$+ -i \frac{1}{\sqrt{2}} g_2 \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (158)$$

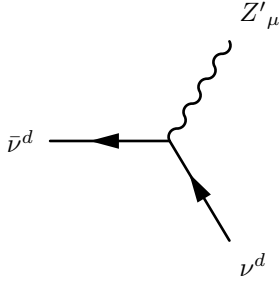

---



$$- \frac{i}{2} \left( - (2g_B + g_{BY}) \sin \Theta'_W + (2g_{YB} + g_1) \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (159)$$

$$+ - \frac{i}{2} \left( - (12g_B + g_{BY}) \sin \Theta'_W + (12g_{YB} + g_1) \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (160)$$

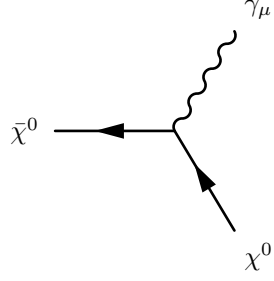

---



$$\frac{i}{2} \left( (2g_B + g_{BY}) \cos \Theta'_W + \left( (2g_{YB} + g_1) \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (161)$$

$$+ \frac{i}{2} \left( (12g_B + g_{BY}) \cos \Theta'_W + \left( (12g_{YB} + g_1) \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (162)$$

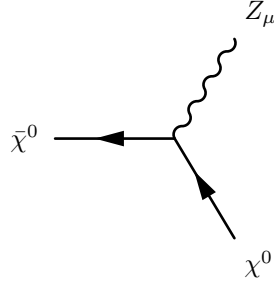

---



$$- 3ig_{YB} \cos \Theta_W \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (163)$$

$$+ 2ig_{YB} \cos \Theta_W \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (164)$$

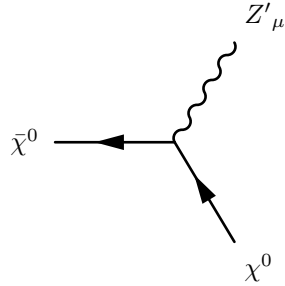

---



$$3i \left( -g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (165)$$

$$+ -2i \left( -g_B \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin \Theta_W \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (166)$$

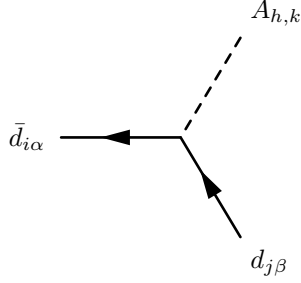

---



$$- 3i \left( g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (167)$$

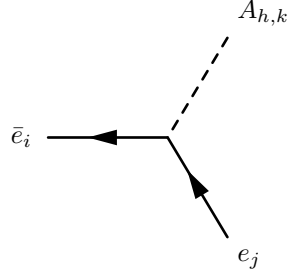
$$+ 2i \left( g_B \cos \Theta'_W + g_{YB} \sin \Theta_W \sin \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (168)$$

## 8.5 Two Fermion-One Scalar Boson-Interaction



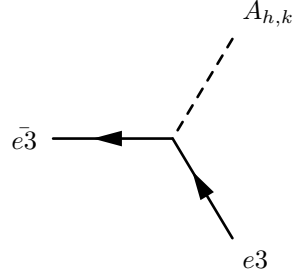
$$\frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^A \left( \frac{1 - \gamma_5}{2} \right) \quad (169)$$

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



$$\frac{1}{\sqrt{2}} \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} Z_{k1}^A \left( \frac{1 - \gamma_5}{2} \right) \quad (171)$$

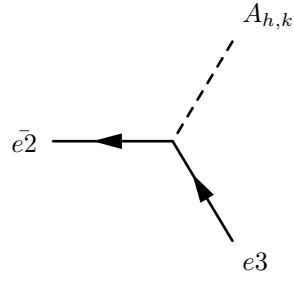
$$+ - \frac{1}{\sqrt{2}} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e Z_{k1}^A \left( \frac{1 + \gamma_5}{2} \right) \quad (172)$$



$$- \frac{1}{\sqrt{2}} h_c Z_{k2}^A \left( \frac{1 - \gamma_5}{2} \right) \quad (173)$$

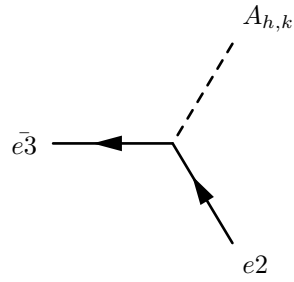
$$+ \frac{1}{\sqrt{2}} h_c Z_{k2}^A \left( \frac{1 + \gamma_5}{2} \right) \quad (174)$$


---



$$\frac{1}{\sqrt{2}} h_g Z_{k1}^A \left( \frac{1 - \gamma_5}{2} \right) \quad (175)$$


---

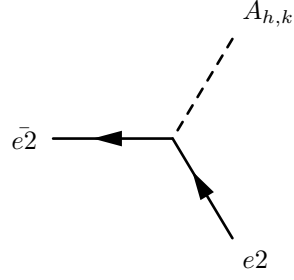


$$(176)$$

$$+ - \frac{1}{\sqrt{2}} h_g Z_{k1}^A \left( \frac{1 + \gamma_5}{2} \right) \quad (177)$$


---

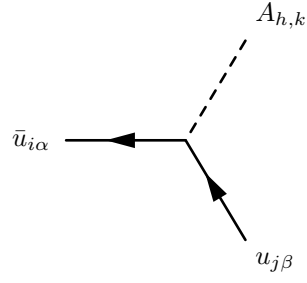




$$\frac{1}{\sqrt{2}} h_b Z_{k2}^A \left( \frac{1 - \gamma_5}{2} \right) \quad (178)$$

$$+ -\frac{1}{\sqrt{2}} h_b Z_{k2}^A \left( \frac{1 + \gamma_5}{2} \right) \quad (179)$$

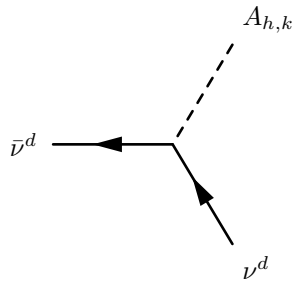

---



$$\frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} Z_{k1}^A \left( \frac{1 - \gamma_5}{2} \right) \quad (180)$$

$$+ -\frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^u Z_{k1}^A \left( \frac{1 + \gamma_5}{2} \right) \quad (181)$$

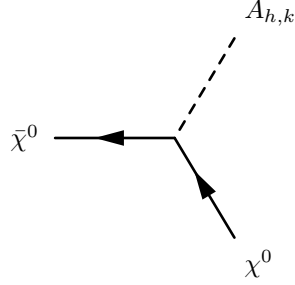

---



$$- \frac{1}{\sqrt{2}} h_c Z_{k2}^A \left( \frac{1 - \gamma_5}{2} \right) \quad (182)$$

$$+ \frac{1}{\sqrt{2}} h_c Z_{k2}^A \left( \frac{1 + \gamma_5}{2} \right) \quad (183)$$

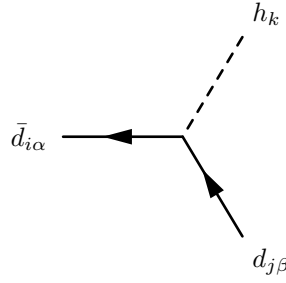

---



$$- \frac{1}{\sqrt{2}} h_a Z_{k2}^A \left( \frac{1 - \gamma_5}{2} \right) \quad (184)$$

$$+ \frac{1}{\sqrt{2}} h_a Z_{k2}^A \left( \frac{1 + \gamma_5}{2} \right) \quad (185)$$

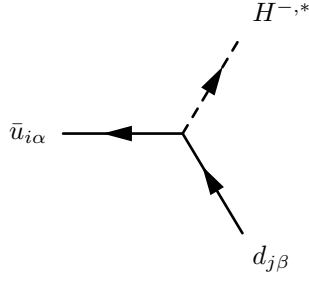

---



$$- i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^H \left( \frac{1 - \gamma_5}{2} \right) \quad (186)$$

$$+ -i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d Z_{k1}^H \left( \frac{1 + \gamma_5}{2} \right) \quad (187)$$

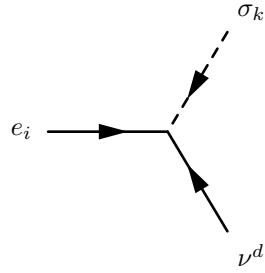

---



$$i\delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (188)$$

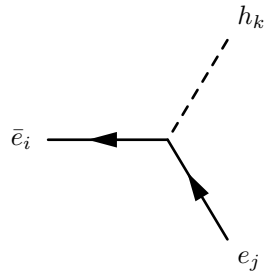
$$+ i\delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^u \left( \frac{1+\gamma_5}{2} \right) \quad (189)$$


---



$$i \sum_{a=1}^3 U_{L,ia}^{e,*} h_{d,a} V S_{k1} \left( \frac{1-\gamma_5}{2} \right) \quad (190)$$

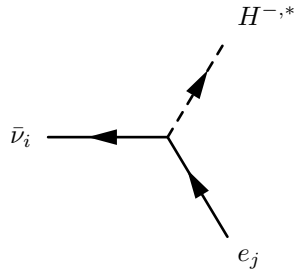

---



$$- i \frac{1}{\sqrt{2}} \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} Z_{k1}^H \left( \frac{1-\gamma_5}{2} \right) \quad (191)$$

$$+ -i \frac{1}{\sqrt{2}} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e Z_{k1}^H \left( \frac{1+\gamma_5}{2} \right) \quad (192)$$

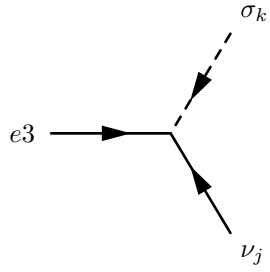

---



(193)

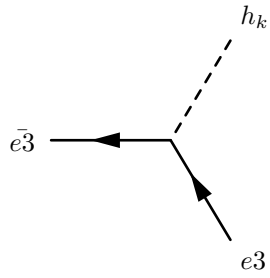
$$+ i \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{ib}^V \left( \frac{1+\gamma_5}{2} \right) \quad (194)$$


---



$$- i \sum_{a=1}^3 U_{ja}^{V,*} h_{d,a} V S_{k1} \left( \frac{1-\gamma_5}{2} \right) \quad (195)$$

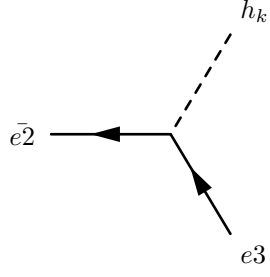

---



$$-i \frac{1}{\sqrt{2}} h_c Z_{k2}^H \left( \frac{1 - \gamma_5}{2} \right) \quad (196)$$

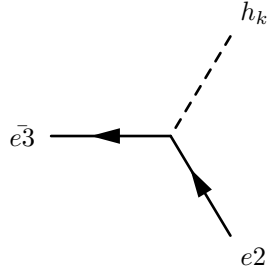
$$+ -i \frac{1}{\sqrt{2}} h_c Z_{k2}^H \left( \frac{1 + \gamma_5}{2} \right) \quad (197)$$


---



$$-i \frac{1}{\sqrt{2}} h_g Z_{k1}^H \left( \frac{1 - \gamma_5}{2} \right) \quad (198)$$

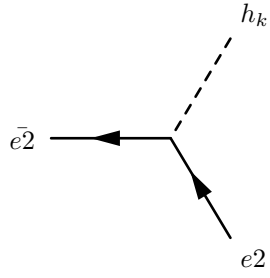

---



$$+ -i \frac{1}{\sqrt{2}} h_g Z_{k1}^H \left( \frac{1 + \gamma_5}{2} \right) \quad (199)$$

$$(200)$$

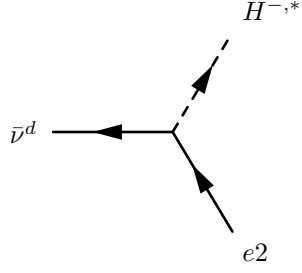

---



$$-i \frac{1}{\sqrt{2}} h_b Z_{k2}^H \left( \frac{1 - \gamma_5}{2} \right) \quad (201)$$

$$+ -i \frac{1}{\sqrt{2}} h_b Z_{k2}^H \left( \frac{1 + \gamma_5}{2} \right) \quad (202)$$

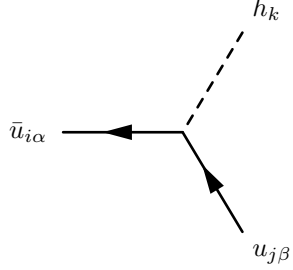

---



(203)

$$+ i h_g \left( \frac{1 + \gamma_5}{2} \right) \quad (204)$$

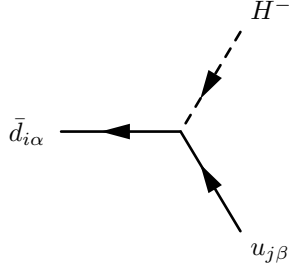

---



$$i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} Z_{k1}^H \left( \frac{1 - \gamma_5}{2} \right) \quad (205)$$

$$+ i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^u Z_{k1}^H \left( \frac{1 + \gamma_5}{2} \right) \quad (206)$$

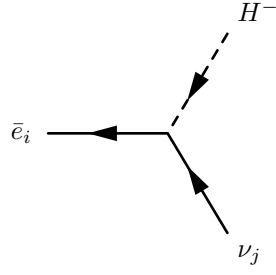

---



$$i\delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (207)$$

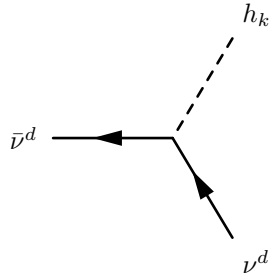
$$+ i\delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^d \left( \frac{1+\gamma_5}{2} \right) \quad (208)$$


---



$$i \sum_{b=1}^3 U_{jb}^{V,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (209)$$

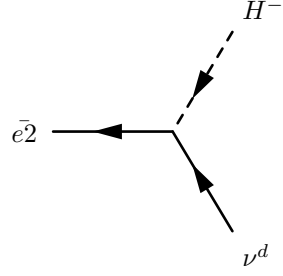

---



$$- i \frac{1}{\sqrt{2}} h_c Z_{k2}^H \left( \frac{1-\gamma_5}{2} \right) \quad (210)$$

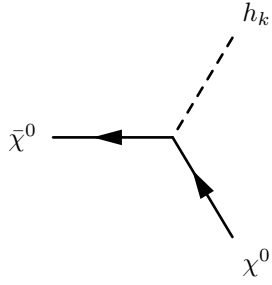
$$+ -i \frac{1}{\sqrt{2}} h_c Z_{k2}^H \left( \frac{1 + \gamma_5}{2} \right) \quad (211)$$


---



$$i h_g \left( \frac{1 - \gamma_5}{2} \right) \quad (212)$$

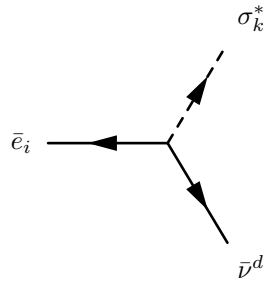

---



$$- i \frac{1}{\sqrt{2}} h_a Z_{k2}^H \left( \frac{1 - \gamma_5}{2} \right) \quad (213)$$

$$+ -i \frac{1}{\sqrt{2}} h_a Z_{k2}^H \left( \frac{1 + \gamma_5}{2} \right) \quad (214)$$


---

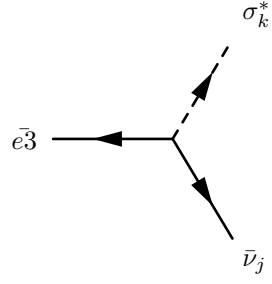




(215)

$$+ i \sum_{a=1}^3 U_{L,ia}^e h_{d,a} V S_{k1} \left( \frac{1 + \gamma_5}{2} \right) \quad (216)$$


---

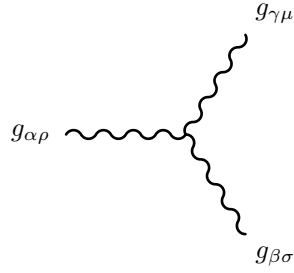


(217)

$$+ -i \sum_{a=1}^3 U_{ja}^V h_{d,a} V S_{k1} \left( \frac{1 + \gamma_5}{2} \right) \quad (218)$$

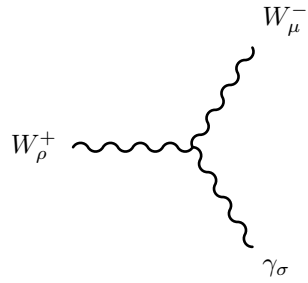

---

## 8.6 Three Vector Boson-Interaction



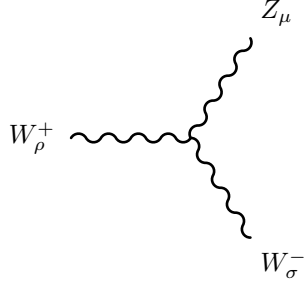
$$g_3 f_{\alpha,\beta,\gamma} \left( g_{\rho\mu} \left( -p_\sigma^{g\gamma\mu} + p_\sigma^{g\alpha\rho} \right) + g_{\rho\sigma} \left( -p_\mu^{g\alpha\rho} + p_\mu^{g\beta\sigma} \right) + g_{\sigma\mu} \left( -p_\rho^{g\beta\sigma} + p_\rho^{g\gamma\mu} \right) \right) \quad (219)$$


---



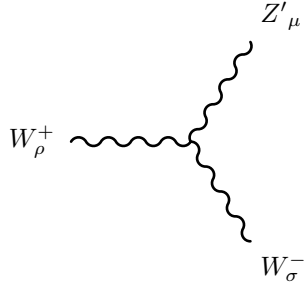
$$ig_2 \sin \Theta_W \left( g_{\rho\mu} \left( -p_\sigma^{W^-} + p_\sigma^{W^+} \right) + g_{\rho\sigma} \left( -p_\mu^{W^+} + p_\mu^{\gamma_\sigma} \right) + g_{\sigma\mu} \left( -p_\rho^{\gamma_\sigma} + p_\rho^{W^-} \right) \right) \quad (220)$$


---



$$-ig_2 \cos \Theta_W \cos \Theta'_W \left( g_{\rho\mu} \left( -p_\sigma^{Z_\mu} + p_\sigma^{W^+} \right) + g_{\rho\sigma} \left( -p_\mu^{W^+} + p_\mu^{W^-} \right) + g_{\sigma\mu} \left( -p_\rho^{W^-} + p_\rho^{Z_\mu} \right) \right) \quad (221)$$

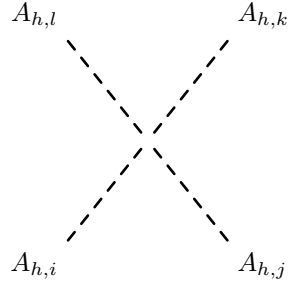

---



$$ig_2 \cos \Theta_W \sin \Theta'_W \left( g_{\rho\mu} \left( -p_\sigma^{Z'_\mu} + p_\sigma^{W^+} \right) + g_{\rho\sigma} \left( -p_\mu^{W^+} + p_\mu^{W^-} \right) + g_{\sigma\mu} \left( -p_\rho^{W^-} + p_\rho^{Z'_\mu} \right) \right) \quad (222)$$

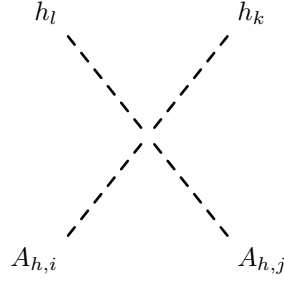

---

## 8.7 Four Scalar-Interaction



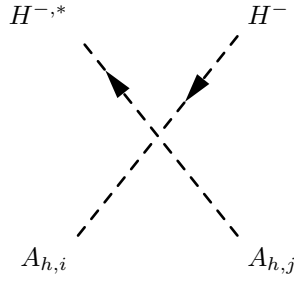
$$\begin{aligned}
& i \left( Z_{i2}^A \left( \lambda_3 Z_{j1}^A \left( Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \right) + Z_{j2}^A \left( 6\lambda_2 Z_{k2}^A Z_{l2}^A + \lambda_3 Z_{k1}^A Z_{l1}^A \right) \right) \right. \\
& \left. + Z_{i1}^A \left( \lambda_3 Z_{j2}^A \left( Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \right) + Z_{j1}^A \left( 6\lambda_1 Z_{k1}^A Z_{l1}^A + \lambda_3 Z_{k2}^A Z_{l2}^A \right) \right) \right)
\end{aligned} \tag{223}$$


---



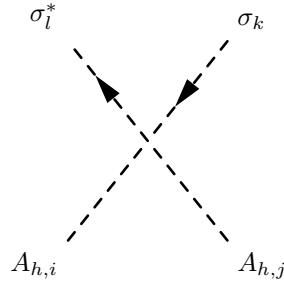
$$i \left( Z_{i1}^A Z_{j1}^A \left( 2\lambda_1 Z_{k1}^H Z_{l1}^H + \lambda_3 Z_{k2}^H Z_{l2}^H \right) + Z_{i2}^A Z_{j2}^A \left( 2\lambda_2 Z_{k2}^H Z_{l2}^H + \lambda_3 Z_{k1}^H Z_{l1}^H \right) \right) \tag{224}$$


---



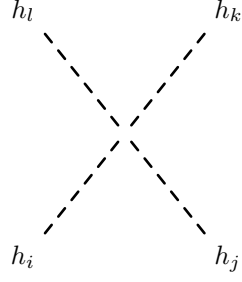
$$i \left( 2\lambda_1 Z_{i1}^A Z_{j1}^A + \lambda_3 Z_{i2}^A Z_{j2}^A \right) \tag{225}$$


---



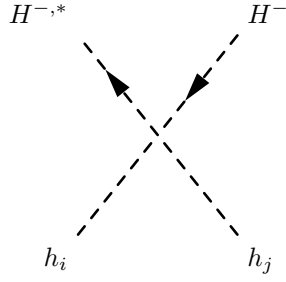
$$i \left( \lambda_3 2V S_{k1} V S_{l1} + \lambda_3 3V S_{k2} V S_{l2} \right) Z_{i1}^A Z_{j1}^A \tag{226}$$


---



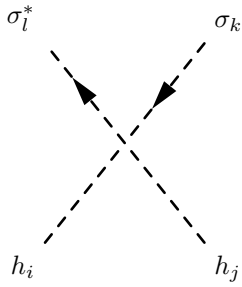
$$\begin{aligned}
& i \left( Z_{i2}^H \left( \lambda_3 Z_{j1}^H \left( Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) + Z_{j2}^H \left( 6\lambda_2 Z_{k2}^H Z_{l2}^H + \lambda_3 Z_{k1}^H Z_{l1}^H \right) \right) \right. \\
& \left. + Z_{i1}^H \left( \lambda_3 Z_{j2}^H \left( Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) + Z_{j1}^H \left( 6\lambda_1 Z_{k1}^H Z_{l1}^H + \lambda_3 Z_{k2}^H Z_{l2}^H \right) \right) \right)
\end{aligned} \tag{227}$$


---



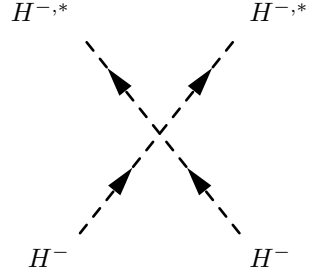
$$i \left( 2\lambda_1 Z_{i1}^H Z_{j1}^H + \lambda_3 Z_{i2}^H Z_{j2}^H \right) \tag{228}$$


---



$$i \left( \lambda_3 2V S_{k1} V S_{l1} + \lambda_3 3V S_{k2} V S_{l2} \right) Z_{i1}^H Z_{j1}^H \tag{229}$$

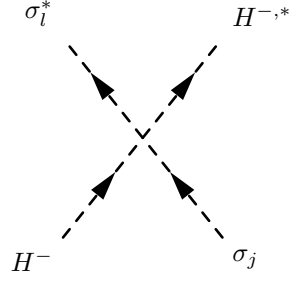

---



$$4i\lambda_1$$

(230)

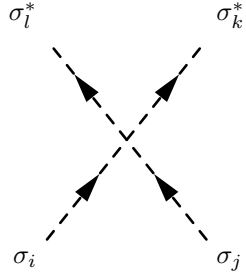
---



$$i\left(\lambda_3 2V S_{j1} V S_{l1} + \lambda_3 3V S_{j2} V S_{l2}\right)$$

(231)

---

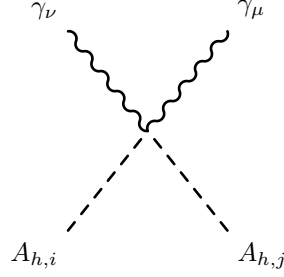


$$4i\left(\lambda_2 2V S_{i1} V S_{j1} V S_{k1} V S_{l1} + \lambda_2 3V S_{i2} V S_{j2} V S_{k2} V S_{l2}\right)$$

(232)

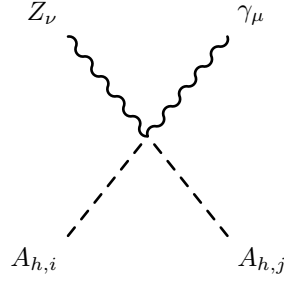
---

## 8.8 Two Scalar-Two Vector Boson-Interaction



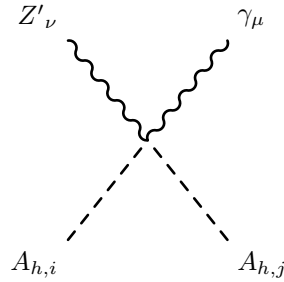
$$\begin{aligned} & \left( + \frac{i}{2} g_1^2 \cos \Theta_W^2 Z_{i1}^A Z_{j1}^A - i g_1 g_2 \cos \Theta_W \sin \Theta_W Z_{i1}^A Z_{j1}^A \right. \\ & \left. + \frac{i}{2} g_2^2 \sin \Theta_W^2 Z_{i1}^A Z_{j1}^A + 50 i g_{YB}^2 \cos \Theta_W^2 Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu}) \end{aligned} \quad (233)$$


---



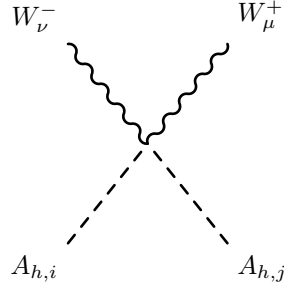
$$\begin{aligned} & \left( - \frac{i}{2} g_1 g_2 \cos \Theta_W^2 \cos \Theta'_W Z_{i1}^A Z_{j1}^A - \frac{i}{2} g_1^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i1}^A Z_{j1}^A \right. \\ & + \frac{i}{2} g_2^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i1}^A Z_{j1}^A + \frac{i}{2} g_1 g_2 \cos \Theta'_W \sin \Theta_W^2 Z_{i1}^A Z_{j1}^A \\ & + \frac{i}{2} g_1 g_{BY} \cos \Theta_W \sin \Theta'_W Z_{i1}^A Z_{j1}^A - \frac{i}{2} g_{BY} g_2 \sin \Theta_W \sin \Theta'_W Z_{i1}^A Z_{j1}^A \\ & \left. - 50 i g_{YB}^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i2}^A Z_{j2}^A + 50 i g_B g_{YB} \cos \Theta_W \sin \Theta'_W Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu}) \end{aligned} \quad (234)$$


---



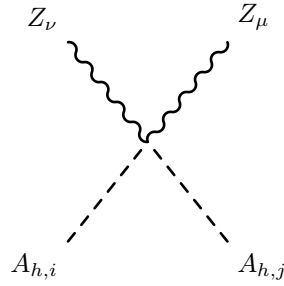
$$\begin{aligned}
& \left( +\frac{i}{2}g_1g_{BY}\cos\Theta_W\cos\Theta'_W Z_{i1}^A Z_{j1}^A -\frac{i}{2}g_{BY}g_2\cos\Theta'_W\sin\Theta_W Z_{i1}^A Z_{j1}^A \right. \\
& +\frac{i}{2}g_1g_2\cos\Theta_W^2\sin\Theta'_W Z_{i1}^A Z_{j1}^A +\frac{i}{2}g_1^2\cos\Theta_W\sin\Theta_W\sin\Theta'_W Z_{i1}^A Z_{j1}^A \\
& -\frac{i}{2}g_2^2\cos\Theta_W\sin\Theta_W\sin\Theta'_W Z_{i1}^A Z_{j1}^A -\frac{i}{2}g_1g_2\sin\Theta_W^2\sin\Theta'_W Z_{i1}^A Z_{j1}^A \\
& \left. +50ig_Bg_{YB}\cos\Theta_W\cos\Theta'_W Z_{i2}^A Z_{j2}^A +25ig_Y^2\sin2\Theta_W\sin\Theta'_W Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu})
\end{aligned} \tag{235}$$


---



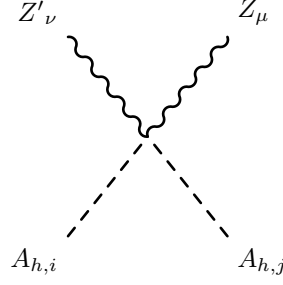
$$\frac{i}{2}g_2^2 Z_{i1}^A Z_{j1}^A (g_{\mu\nu}) \tag{236}$$


---



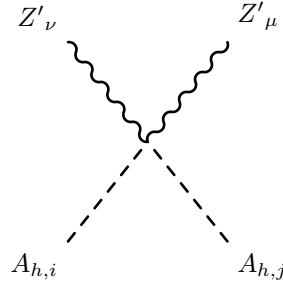
$$\begin{aligned}
& \left( +\frac{i}{2}g_2^2\cos\Theta_W^2\cos\Theta'^2_W Z_{i1}^A Z_{j1}^A +ig_1g_2\cos\Theta_W\cos\Theta'^2_W\sin\Theta_W Z_{i1}^A Z_{j1}^A \right. \\
& +\frac{i}{2}g_1^2\cos\Theta'^2_W\sin\Theta_W^2 Z_{i1}^A Z_{j1}^A -ig_{BY}g_2\cos\Theta_W\cos\Theta'_W\sin\Theta'_W Z_{i1}^A Z_{j1}^A \\
& -ig_1g_{BY}\cos\Theta'_W\sin\Theta_W\sin\Theta'_W Z_{i1}^A Z_{j1}^A +\frac{i}{2}g_{BY}^2\sin\Theta'^2_W Z_{i1}^A Z_{j1}^A \\
& +50ig_Y^2\cos\Theta'^2_W\sin\Theta_W^2 Z_{i2}^A Z_{j2}^A -100ig_Bg_{YB}\cos\Theta'_W\sin\Theta_W\sin\Theta'_W Z_{i2}^A Z_{j2}^A \\
& \left. +50ig_B^2\sin\Theta'^2_W Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu})
\end{aligned} \tag{237}$$


---



$$\begin{aligned}
& \left( -\frac{i}{2} g_{BY} g_2 \cos \Theta_W \cos \Theta_W'^2 Z_{i1}^A Z_{j1}^A - \frac{i}{2} g_1 g_{BY} \cos \Theta_W'^2 \sin \Theta_W Z_{i1}^A Z_{j1}^A \right. \\
& + \frac{i}{2} g_{BY}^2 \cos \Theta_W' \sin \Theta_W' Z_{i1}^A Z_{j1}^A - \frac{i}{2} g_2^2 \cos \Theta_W^2 \cos \Theta_W' \sin \Theta_W' Z_{i1}^A Z_{j1}^A \\
& - \frac{i}{2} g_1^2 \cos \Theta_W' \sin \Theta_W^2 \sin \Theta_W' Z_{i1}^A Z_{j1}^A + \frac{i}{2} g_{BY} g_2 \cos \Theta_W \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A \\
& + \frac{i}{2} g_1 g_{BY} \sin \Theta_W \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A - \frac{i}{2} g_1 g_2 \cos \Theta_W \sin \Theta_W \sin 2\Theta_W' Z_{i1}^A Z_{j1}^A \\
& - 50i g_B g_Y \cos \Theta_W'^2 \sin \Theta_W Z_{i2}^A Z_{j2}^A + 50i g_B g_Y \sin \Theta_W \sin \Theta_W'^2 Z_{i2}^A Z_{j2}^A \\
& \left. + 25i g_B^2 \sin 2\Theta_W' Z_{i2}^A Z_{j2}^A - 25i g_Y^2 \sin \Theta_W^2 \sin 2\Theta_W' Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu})
\end{aligned} \tag{238}$$

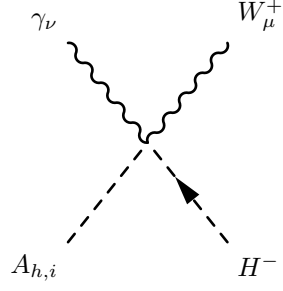

---



$$\begin{aligned}
& \left( +\frac{i}{2} g_{BY}^2 \cos \Theta_W'^2 Z_{i1}^A Z_{j1}^A + i g_{BY} g_2 \cos \Theta_W \cos \Theta_W' \sin \Theta_W' Z_{i1}^A Z_{j1}^A \right. \\
& + i g_1 g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' Z_{i1}^A Z_{j1}^A + \frac{i}{2} g_2^2 \cos \Theta_W^2 \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A \\
& + i g_1 g_2 \cos \Theta_W \sin \Theta_W \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A + \frac{i}{2} g_1^2 \sin \Theta_W^2 \sin \Theta_W'^2 Z_{i1}^A Z_{j1}^A \\
& + 50i g_B^2 \cos \Theta_W'^2 Z_{i2}^A Z_{j2}^A + 100i g_B g_Y \cos \Theta_W' \sin \Theta_W \sin \Theta_W' Z_{i2}^A Z_{j2}^A \\
& \left. + 50i g_Y^2 \sin \Theta_W^2 \sin \Theta_W'^2 Z_{i2}^A Z_{j2}^A \right) (g_{\mu\nu})
\end{aligned} \tag{239}$$

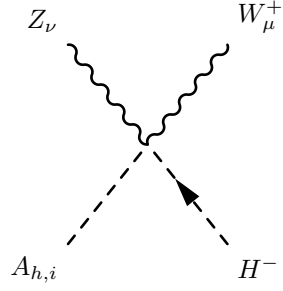

---





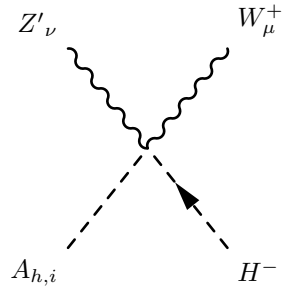
$$-\frac{1}{2}g_1g_2\cos\Theta_W Z_{i1}^A(g_{\mu\nu}) \quad (240)$$


---



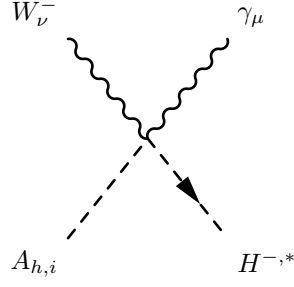
$$\left(\frac{1}{2}g_1g_2\cos\Theta'_W\sin\Theta_W Z_{i1}^A - \frac{1}{2}g_{BY}g_2\sin\Theta'_W Z_{i1}^A\right)(g_{\mu\nu}) \quad (241)$$


---



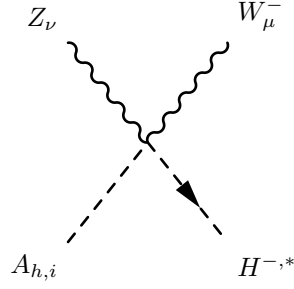
$$\left(-\frac{1}{2}g_1g_2\sin\Theta_W\sin\Theta'_W Z_{i1}^A - \frac{1}{2}g_{BY}g_2\cos\Theta'_W Z_{i1}^A\right)(g_{\mu\nu}) \quad (242)$$


---



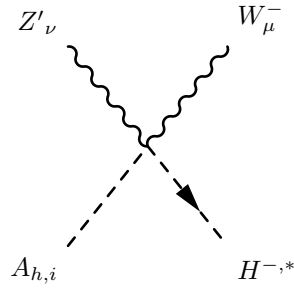
$$\frac{1}{2}g_1g_2\cos\Theta_W Z_{i1}^A(g_{\mu\nu}) \quad (243)$$


---



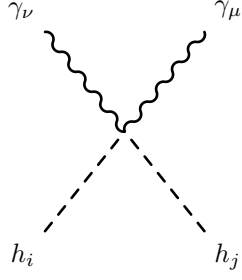
$$\left(-\frac{1}{2}g_1g_2\cos\Theta'_W\sin\Theta_W Z_{i1}^A+\frac{1}{2}g_{BY}g_2\sin\Theta'_W Z_{i1}^A\right)(g_{\mu\nu}) \quad (244)$$


---



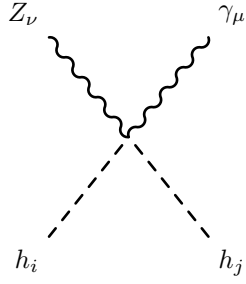
$$\left(\frac{1}{2}g_1g_2\sin\Theta_W\sin\Theta'_W Z_{i1}^A+\frac{1}{2}g_{BY}g_2\cos\Theta'_W Z_{i1}^A\right)(g_{\mu\nu}) \quad (245)$$


---



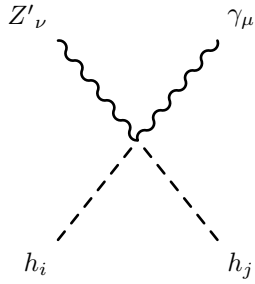
$$\begin{aligned} & \left( +\frac{i}{2}g_1^2 \cos \Theta_W^2 Z_{i1}^H Z_{j1}^H - ig_1 g_2 \cos \Theta_W \sin \Theta_W Z_{i1}^H Z_{j1}^H \right. \\ & \left. +\frac{i}{2}g_2^2 \sin \Theta_W^2 Z_{i1}^H Z_{j1}^H + 50ig_Y^2 \cos \Theta_W^2 Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu}) \end{aligned} \quad (246)$$


---



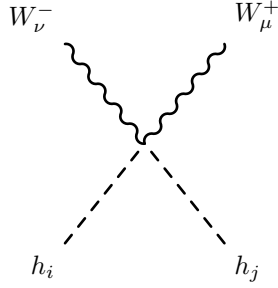
$$\begin{aligned} & \left( -\frac{i}{2}g_1 g_2 \cos \Theta_W^2 \cos \Theta'_W Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_1^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i1}^H Z_{j1}^H \right. \\ & +\frac{i}{2}g_2^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_1 g_2 \cos \Theta'_W \sin \Theta_W^2 Z_{i1}^H Z_{j1}^H \\ & +\frac{i}{2}g_1 g_{BY} \cos \Theta_W \sin \Theta'_W Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_{BY} g_2 \sin \Theta_W \sin \Theta'_W Z_{i1}^H Z_{j1}^H \\ & \left. - 50ig_Y^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W Z_{i2}^H Z_{j2}^H + 50ig_B g_{YB} \cos \Theta_W \sin \Theta'_W Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu}) \end{aligned} \quad (247)$$


---



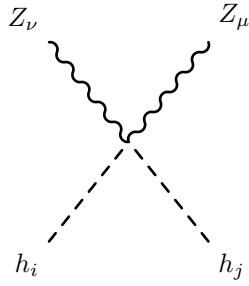
$$\begin{aligned}
& \left( +\frac{i}{2}g_1g_{BY}\cos\Theta_W\cos\Theta'_W Z_{i1}^H Z_{j1}^H -\frac{i}{2}g_{BY}g_2\cos\Theta'_W\sin\Theta_W Z_{i1}^H Z_{j1}^H \right. \\
& +\frac{i}{2}g_1g_2\cos\Theta_W^2\sin\Theta'_W Z_{i1}^H Z_{j1}^H +\frac{i}{2}g_1^2\cos\Theta_W\sin\Theta_W\sin\Theta'_W Z_{i1}^H Z_{j1}^H \\
& -\frac{i}{2}g_2^2\cos\Theta_W\sin\Theta_W\sin\Theta'_W Z_{i1}^H Z_{j1}^H -\frac{i}{2}g_1g_2\sin\Theta_W^2\sin\Theta'_W Z_{i1}^H Z_{j1}^H \\
& \left. +50ig_Bg_{YB}\cos\Theta_W\cos\Theta'_W Z_{i2}^H Z_{j2}^H +25ig_{YB}^2\sin2\Theta_W\sin\Theta'_W Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu})
\end{aligned} \tag{248}$$


---



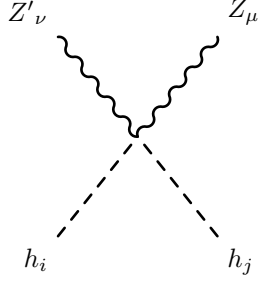
$$\frac{i}{2}g_2^2 Z_{i1}^H Z_{j1}^H (g_{\mu\nu}) \tag{249}$$


---



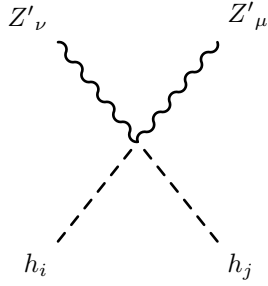
$$\begin{aligned}
& \left( +\frac{i}{2}g_2^2\cos\Theta_W^2\cos\Theta'^2_W Z_{i1}^H Z_{j1}^H +ig_1g_2\cos\Theta_W\cos\Theta'^2_W\sin\Theta_W Z_{i1}^H Z_{j1}^H \right. \\
& +\frac{i}{2}g_1^2\cos\Theta'^2_W\sin\Theta_W^2 Z_{i1}^H Z_{j1}^H -ig_{BY}g_2\cos\Theta_W\cos\Theta'_W\sin\Theta'_W Z_{i1}^H Z_{j1}^H \\
& -ig_1g_{BY}\cos\Theta'_W\sin\Theta_W\sin\Theta'_W Z_{i1}^H Z_{j1}^H +\frac{i}{2}g_{BY}^2\sin\Theta'^2_W Z_{i1}^H Z_{j1}^H \\
& +50ig_{YB}^2\cos\Theta_W^2\sin\Theta_W^2 Z_{i2}^H Z_{j2}^H -100ig_Bg_{YB}\cos\Theta'_W\sin\Theta_W\sin\Theta'_W Z_{i2}^H Z_{j2}^H \\
& \left. +50ig_B^2\sin\Theta'^2_W Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu})
\end{aligned} \tag{250}$$


---



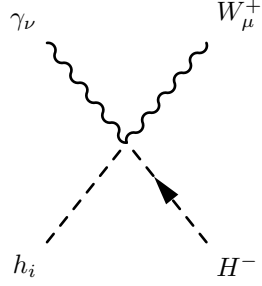
$$\begin{aligned}
& \left( -\frac{i}{2}g_{BY}g_2 \cos \Theta_W \cos \Theta_W'^2 Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_1 g_{BY} \cos \Theta_W'^2 \sin \Theta_W Z_{i1}^H Z_{j1}^H \right. \\
& + \frac{i}{2}g_{BY}^2 \cos \Theta_W' \sin \Theta_W' Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_2^2 \cos \Theta_W^2 \cos \Theta_W' \sin \Theta_W' Z_{i1}^H Z_{j1}^H \\
& - \frac{i}{2}g_1^2 \cos \Theta_W' \sin \Theta_W^2 \sin \Theta_W' Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_{BY}g_2 \cos \Theta_W \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H \\
& + \frac{i}{2}g_1 g_{BY} \sin \Theta_W \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H - \frac{i}{2}g_1 g_2 \cos \Theta_W \sin \Theta_W \sin 2\Theta_W' Z_{i1}^H Z_{j1}^H \\
& - 50i g_B g_{YB} \cos \Theta_W'^2 \sin \Theta_W Z_{i2}^H Z_{j2}^H + 50i g_B g_{YB} \sin \Theta_W \sin \Theta_W'^2 Z_{i2}^H Z_{j2}^H \\
& \left. + 25i g_B^2 \sin 2\Theta_W' Z_{i2}^H Z_{j2}^H - 25i g_{YB}^2 \sin \Theta_W^2 \sin 2\Theta_W' Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu})
\end{aligned} \tag{251}$$


---



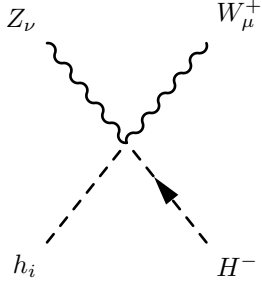
$$\begin{aligned}
& \left( + \frac{i}{2}g_{BY}^2 \cos \Theta_W'^2 Z_{i1}^H Z_{j1}^H + i g_{BY}g_2 \cos \Theta_W \cos \Theta_W' \sin \Theta_W' Z_{i1}^H Z_{j1}^H \right. \\
& + i g_1 g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_2^2 \cos \Theta_W^2 \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H \\
& + i g_1 g_2 \cos \Theta_W \sin \Theta_W \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_1^2 \sin \Theta_W^2 \sin \Theta_W'^2 Z_{i1}^H Z_{j1}^H \\
& + 50i g_B^2 \cos \Theta_W'^2 Z_{i2}^H Z_{j2}^H + 100i g_B g_{YB} \cos \Theta_W' \sin \Theta_W \sin \Theta_W'^2 Z_{i2}^H Z_{j2}^H \\
& \left. + 50i g_{YB}^2 \sin \Theta_W^2 \sin \Theta_W'^2 Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu})
\end{aligned} \tag{252}$$


---



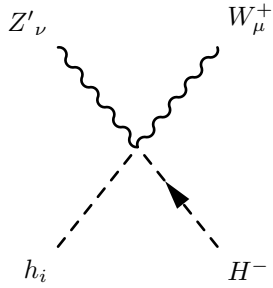
$$-\frac{i}{2}g_1g_2\cos\Theta_W Z_{i1}^H(g_{\mu\nu}) \quad (253)$$


---



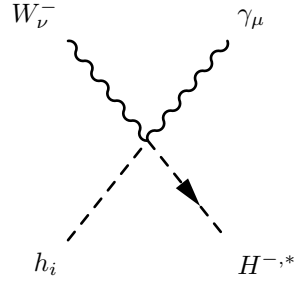
$$\left(\frac{i}{2}g_1g_2\cos\Theta'_W\sin\Theta_W Z_{i1}^H - \frac{i}{2}g_{BY}g_2\sin\Theta'_W Z_{i1}^H\right)(g_{\mu\nu}) \quad (254)$$


---



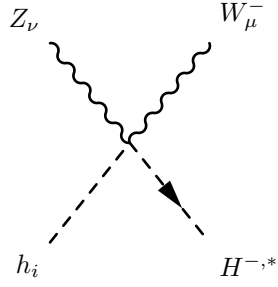
$$\left(-\frac{i}{2}g_1g_2\sin\Theta_W\sin\Theta'_W Z_{i1}^H - \frac{i}{2}g_{BY}g_2\cos\Theta'_W Z_{i1}^H\right)(g_{\mu\nu}) \quad (255)$$


---



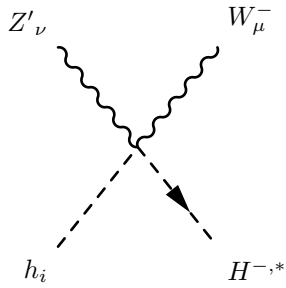
$$-\frac{i}{2}g_1g_2\cos\Theta_W Z_{i1}^H(g_{\mu\nu}) \quad (256)$$


---



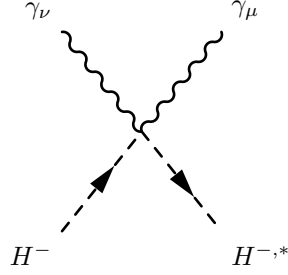
$$\left(\frac{i}{2}g_1g_2\cos\Theta'_W\sin\Theta_W Z_{i1}^H - \frac{i}{2}g_{BY}g_2\sin\Theta'_W Z_{i1}^H\right)(g_{\mu\nu}) \quad (257)$$


---



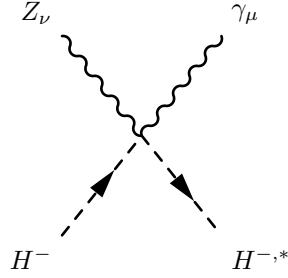
$$\left(-\frac{i}{2}g_1g_2\sin\Theta_W\sin\Theta'_W Z_{i1}^H - \frac{i}{2}g_{BY}g_2\cos\Theta'_W Z_{i1}^H\right)(g_{\mu\nu}) \quad (258)$$


---



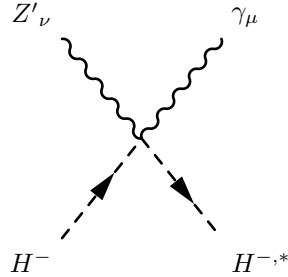
$$\left( \frac{i}{2} g_1^2 \cos \Theta_W^2 + \frac{i}{2} g_2^2 \sin \Theta_W^2 + i g_1 g_2 \cos \Theta_W \sin \Theta_W \right) (g_{\mu\nu}) \quad (259)$$


---



$$\begin{aligned} & \left( + \frac{i}{2} g_1 g_2 \cos \Theta_W^2 \cos \Theta'_W - \frac{i}{2} g_1^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W \right. \\ & + \frac{i}{2} g_2^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W - \frac{i}{2} g_1 g_2 \cos \Theta'_W \sin \Theta_W^2 + \frac{i}{2} g_1 g_{BY} \cos \Theta_W \sin \Theta'_W \\ & \left. + \frac{i}{2} g_{BY} g_2 \sin \Theta_W \sin \Theta'_W \right) (g_{\mu\nu}) \end{aligned} \quad (260)$$


---

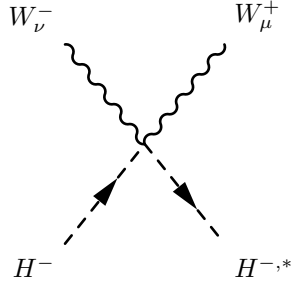


$$\left( + \frac{i}{2} g_1 g_{BY} \cos \Theta_W \cos \Theta'_W + \frac{i}{2} g_{BY} g_2 \cos \Theta'_W \sin \Theta_W - \frac{i}{2} g_1 g_2 \cos \Theta_W^2 \sin \Theta'_W \right)$$



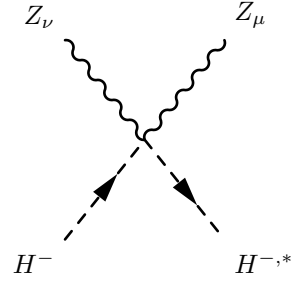
$$\begin{aligned}
& + \frac{i}{2} g_1^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W - \frac{i}{2} g_2^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W \\
& + \frac{i}{2} g_1 g_2 \sin \Theta_W^2 \sin \Theta'_W \Big) (g_{\mu\nu})
\end{aligned} \tag{261}$$


---



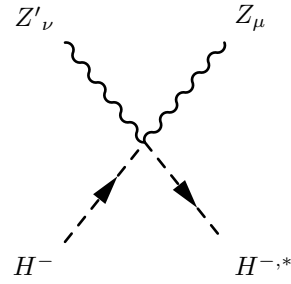
$$\frac{i}{2} g_2^2 (g_{\mu\nu}) \tag{262}$$


---



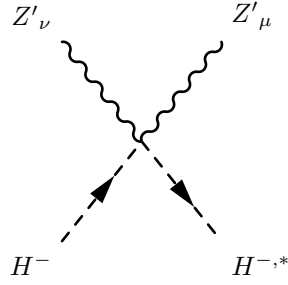
$$\begin{aligned}
& \left( + \frac{i}{2} g_2^2 \cos \Theta_W^2 \cos \Theta'^2_W - i g_1 g_2 \cos \Theta_W \cos \Theta'^2_W \sin \Theta_W \right. \\
& + \frac{i}{2} g_1^2 \cos \Theta'^2_W \sin \Theta_W^2 + i g_{BY} g_2 \cos \Theta_W \cos \Theta'_W \sin \Theta'_W \\
& \left. - i g_1 g_{BY} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + \frac{i}{2} g_{BY}^2 \sin \Theta'^2_W \right) (g_{\mu\nu})
\end{aligned} \tag{263}$$


---



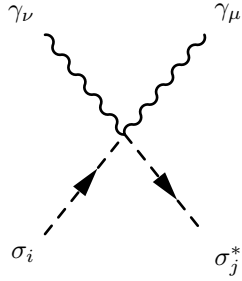
$$\begin{aligned}
& \left( +\frac{i}{2}g_{BY}g_2 \cos \Theta_W \cos \Theta_W'^2 - \frac{i}{2}g_1g_{BY} \cos \Theta_W'^2 \sin \Theta_W + \frac{i}{2}g_{BY}^2 \cos \Theta_W' \sin \Theta_W' \right. \\
& - \frac{i}{2}g_2^2 \cos \Theta_W'^2 \cos \Theta_W' \sin \Theta_W' - \frac{i}{2}g_1^2 \cos \Theta_W' \sin \Theta_W'^2 \sin \Theta_W' \\
& - \frac{i}{2}g_{BY}g_2 \cos \Theta_W \sin \Theta_W'^2 + \frac{i}{2}g_1g_{BY} \sin \Theta_W \sin \Theta_W'^2 \\
& \left. + \frac{i}{2}g_1g_2 \cos \Theta_W \sin \Theta_W \sin 2\Theta_W' \right) (g_{\mu\nu})
\end{aligned} \tag{264}$$


---



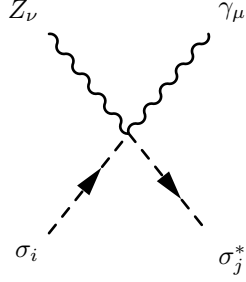
$$\begin{aligned}
& \left( +\frac{i}{2}g_{BY}^2 \cos \Theta_W'^2 - ig_{BY}g_2 \cos \Theta_W \cos \Theta_W' \sin \Theta_W' + ig_1g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' \right. \\
& + \frac{i}{2}g_2^2 \cos \Theta_W'^2 \sin \Theta_W'^2 - ig_1g_2 \cos \Theta_W \sin \Theta_W \sin \Theta_W'^2 \\
& \left. + \frac{i}{2}g_1^2 \sin \Theta_W'^2 \sin \Theta_W'^2 \right) (g_{\mu\nu})
\end{aligned} \tag{265}$$


---



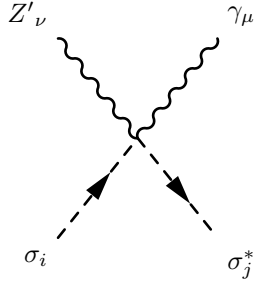
$$\begin{aligned}
& \left( +2ig_1^2 \cos \Theta_W^2 VS_{i1}VS_{j1} + 4ig_1g_{YB} \cos \Theta_W^2 VS_{i1}VS_{j1} + 2ig_{YB}^2 \cos \Theta_W^2 VS_{i1}VS_{j1} \right. \\
& \left. + 2ig_1^2 \cos \Theta_W^2 VS_{i2}VS_{j2} + 24ig_1g_{YB} \cos \Theta_W^2 VS_{i2}VS_{j2} + 72ig_{YB}^2 \cos \Theta_W^2 VS_{i2}VS_{j2} \right) (g_{\mu\nu})
\end{aligned} \tag{266}$$


---



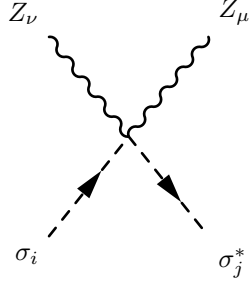
$$\begin{aligned}
& \left( -2ig_1^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W V S_{i1} V S_{j1} - 4ig_1 g_{YB} \cos \Theta_W \cos \Theta'_W \sin \Theta_W V S_{i1} V S_{j1} \right. \\
& - 2ig_{YB}^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W V S_{i1} V S_{j1} + 2ig_1 g_{BY} \cos \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} \\
& + 2ig_1 g_B \cos \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} + 2ig_{BY} g_{YB} \cos \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} \\
& + 2ig_B g_{YB} \cos \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} - 2ig_1^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W V S_{i2} V S_{j2} \\
& - 24ig_1 g_{YB} \cos \Theta_W \cos \Theta'_W \sin \Theta_W V S_{i2} V S_{j2} - 72ig_{YB}^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W V S_{i2} V S_{j2} \\
& + 2ig_1 g_{BY} \cos \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} + 12ig_1 g_B \cos \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} \\
& \left. + 12ig_{BY} g_{YB} \cos \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} + 72ig_B g_{YB} \cos \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} \right) (g_{\mu\nu}) \quad (267)
\end{aligned}$$


---

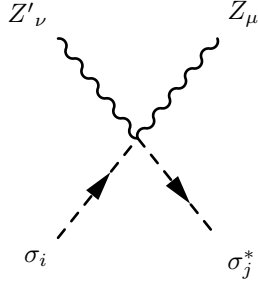


$$\begin{aligned}
& \left( +2ig_1 g_{BY} \cos \Theta_W \cos \Theta'_W V S_{i1} V S_{j1} + 2ig_1 g_B \cos \Theta_W \cos \Theta'_W V S_{i1} V S_{j1} \right. \\
& + 2ig_{BY} g_{YB} \cos \Theta_W \cos \Theta'_W V S_{i1} V S_{j1} + 2ig_B g_{YB} \cos \Theta_W \cos \Theta'_W V S_{i1} V S_{j1} \\
& + 2ig_1^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} + 4ig_1 g_{YB} \cos \Theta_W \sin \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} \\
& + 2ig_{YB}^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} + 2ig_1 g_{BY} \cos \Theta_W \cos \Theta'_W V S_{i2} V S_{j2} \\
& + 12ig_1 g_B \cos \Theta_W \cos \Theta'_W V S_{i2} V S_{j2} + 12ig_{BY} g_{YB} \cos \Theta_W \cos \Theta'_W V S_{i2} V S_{j2} \\
& + 72ig_B g_{YB} \cos \Theta_W \cos \Theta'_W V S_{i2} V S_{j2} + 2ig_1^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} \\
& \left. + 24ig_1 g_{YB} \cos \Theta_W \sin \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} + 72ig_{YB}^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} \right) (g_{\mu\nu}) \quad (268)
\end{aligned}$$


---



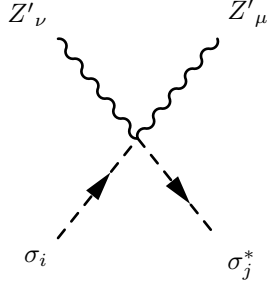
$$\begin{aligned}
& \left( + 2ig_1^2 \cos \Theta_W'^2 \sin \Theta_W^2 VS_{i1}VS_{j1} + 4ig_1g_{YB} \cos \Theta_W'^2 \sin \Theta_W^2 VS_{i1}VS_{j1} \right. \\
& + 2ig_{YB}^2 \cos \Theta_W'^2 \sin \Theta_W^2 VS_{i1}VS_{j1} - 4ig_1g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' VS_{i1}VS_{j1} \\
& - 4ig_1g_B \cos \Theta_W' \sin \Theta_W \sin \Theta_W' VS_{i1}VS_{j1} - 4ig_{BY}g_{YB} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' VS_{i1}VS_{j1} \\
& - 4ig_Bg_{YB} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' VS_{i1}VS_{j1} + 2ig_{BY}^2 \sin \Theta_W'^2 VS_{i1}VS_{j1} \\
& + 4ig_{BY}g_B \sin \Theta_W'^2 VS_{i1}VS_{j1} + 2ig_B^2 \sin \Theta_W'^2 VS_{i1}VS_{j1} + 2ig_1^2 \cos \Theta_W'^2 \sin \Theta_W^2 VS_{i2}VS_{j2} \\
& + 24ig_1g_{YB} \cos \Theta_W'^2 \sin \Theta_W^2 VS_{i2}VS_{j2} + 72ig_{YB}^2 \cos \Theta_W'^2 \sin \Theta_W^2 VS_{i2}VS_{j2} \\
& - 4ig_1g_{BY} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' VS_{i2}VS_{j2} - 24ig_1g_B \cos \Theta_W' \sin \Theta_W \sin \Theta_W' VS_{i2}VS_{j2} \\
& - 24ig_{BY}g_{YB} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' VS_{i2}VS_{j2} - 144ig_Bg_{YB} \cos \Theta_W' \sin \Theta_W \sin \Theta_W' VS_{i2}VS_{j2} \\
& \left. + 2ig_{BY}^2 \sin \Theta_W'^2 VS_{i2}VS_{j2} + 24ig_{BY}g_B \sin \Theta_W'^2 VS_{i2}VS_{j2} + 72ig_B^2 \sin \Theta_W'^2 VS_{i2}VS_{j2} \right) (g_{\mu\nu}) \quad (269)
\end{aligned}$$



$$\begin{aligned}
& \left( - 2ig_1g_{BY} \cos \Theta_W'^2 \sin \Theta_W VS_{i1}VS_{j1} - 2ig_1g_B \cos \Theta_W'^2 \sin \Theta_W VS_{i1}VS_{j1} \right. \\
& - 2ig_{BY}g_{YB} \cos \Theta_W'^2 \sin \Theta_W VS_{i1}VS_{j1} - 2ig_Bg_{YB} \cos \Theta_W'^2 \sin \Theta_W VS_{i1}VS_{j1} \\
& + 2ig_{BY}^2 \cos \Theta_W' \sin \Theta_W' VS_{i1}VS_{j1} + 4ig_{BY}g_B \cos \Theta_W' \sin \Theta_W' VS_{i1}VS_{j1} \\
& + 2ig_B^2 \cos \Theta_W' \sin \Theta_W' VS_{i1}VS_{j1} - 2ig_1^2 \cos \Theta_W' \sin \Theta_W^2 \sin \Theta_W' VS_{i1}VS_{j1} \\
& - 2ig_{YB}^2 \cos \Theta_W' \sin \Theta_W^2 \sin \Theta_W' VS_{i1}VS_{j1} + 2ig_1g_{BY} \sin \Theta_W \sin \Theta_W'^2 VS_{i1}VS_{j1} \\
& \left. + 2ig_1g_B \sin \Theta_W \sin \Theta_W'^2 VS_{i1}VS_{j1} + 2ig_{BY}g_{YB} \sin \Theta_W \sin \Theta_W'^2 VS_{i1}VS_{j1} \right)
\end{aligned}$$

$$\begin{aligned}
& + 2ig_B g_{YB} \sin \Theta_W \sin \Theta_W'^2 V S_{i1} V S_{j1} - 2ig_1 g_{YB} \sin \Theta_W'^2 \sin 2\Theta'_W V S_{i1} V S_{j1} \\
& - 2ig_1 g_{BY} \cos \Theta_W'^2 \sin \Theta_W V S_{i2} V S_{j2} - 12ig_1 g_B \cos \Theta_W'^2 \sin \Theta_W V S_{i2} V S_{j2} \\
& - 12ig_{BY} g_{YB} \cos \Theta_W'^2 \sin \Theta_W V S_{i2} V S_{j2} - 72ig_B g_{YB} \cos \Theta_W'^2 \sin \Theta_W V S_{i2} V S_{j2} \\
& + 2ig_{BY}^2 \cos \Theta'_W \sin \Theta'_W V S_{i2} V S_{j2} + 72ig_B^2 \cos \Theta'_W \sin \Theta'_W V S_{i2} V S_{j2} \\
& - 2ig_1^2 \cos \Theta'_W \sin \Theta_W'^2 \sin \Theta'_W V S_{i2} V S_{j2} - 72ig_{YB}^2 \cos \Theta'_W \sin \Theta_W'^2 \sin \Theta'_W V S_{i2} V S_{j2} \\
& + 2ig_1 g_{BY} \sin \Theta_W \sin \Theta_W'^2 V S_{i2} V S_{j2} + 12ig_1 g_B \sin \Theta_W \sin \Theta_W'^2 V S_{i2} V S_{j2} \\
& + 12ig_{BY} g_{YB} \sin \Theta_W \sin \Theta_W'^2 V S_{i2} V S_{j2} + 72ig_B g_{YB} \sin \Theta_W \sin \Theta_W'^2 V S_{i2} V S_{j2} \\
& + 12ig_{BY} g_B \sin 2\Theta'_W V S_{i2} V S_{j2} - 12ig_1 g_{YB} \sin \Theta_W'^2 \sin 2\Theta'_W V S_{i2} V S_{j2} \Big) (g_{\mu\nu})
\end{aligned} \tag{270}$$

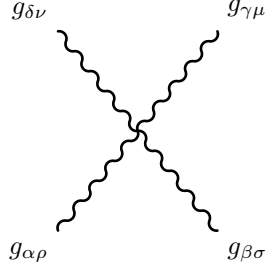

---



$$\begin{aligned}
& \Big( + 2ig_{BY}^2 \cos \Theta_W'^2 V S_{i1} V S_{j1} + 4ig_{BY} g_B \cos \Theta_W'^2 V S_{i1} V S_{j1} + 2ig_B^2 \cos \Theta_W'^2 V S_{i1} V S_{j1} \\
& + 4ig_1 g_{BY} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} + 4ig_1 g_B \cos \Theta'_W \sin \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} \\
& + 4ig_{BY} g_{YB} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} + 4ig_B g_{YB} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W V S_{i1} V S_{j1} \\
& + 2ig_1^2 \sin \Theta_W'^2 \sin \Theta_W'^2 V S_{i1} V S_{j1} + 4ig_1 g_{YB} \sin \Theta_W'^2 \sin \Theta_W'^2 V S_{i1} V S_{j1} \\
& + 2ig_{YB}^2 \sin \Theta_W'^2 \sin \Theta_W'^2 V S_{i1} V S_{j1} + 2ig_{BY}^2 \cos \Theta_W'^2 V S_{i2} V S_{j2} + 24ig_{BY} g_B \cos \Theta_W'^2 V S_{i2} V S_{j2} \\
& + 72ig_B^2 \cos \Theta_W'^2 V S_{i2} V S_{j2} + 4ig_1 g_{BY} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} \\
& + 24ig_1 g_B \cos \Theta'_W \sin \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} + 24ig_{BY} g_{YB} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} \\
& + 144ig_B g_{YB} \cos \Theta'_W \sin \Theta_W \sin \Theta'_W V S_{i2} V S_{j2} + 2ig_1^2 \sin \Theta_W'^2 \sin \Theta_W'^2 V S_{i2} V S_{j2} \\
& + 24ig_1 g_{YB} \sin \Theta_W'^2 \sin \Theta_W'^2 V S_{i2} V S_{j2} + 72ig_{YB}^2 \sin \Theta_W'^2 \sin \Theta_W'^2 V S_{i2} V S_{j2} \Big) (g_{\mu\nu})
\end{aligned} \tag{271}$$


---

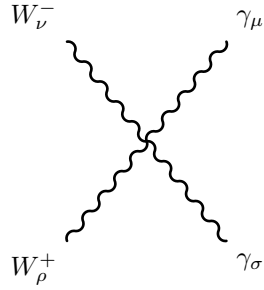
## 8.9 Four Vector Boson-Interaction



$$ig_3^2 \left( - \sum_{a=1}^8 f_{\alpha,\delta,a} f_{\beta,\gamma,a} - \sum_{a=1}^8 f_{\alpha,\gamma,a} f_{\beta,\delta,a} \right) (g_{\rho\sigma} g_{\mu\nu}) \quad (272)$$

$$+ ig_3^2 \left( - \sum_{a=1}^8 f_{\alpha,\beta,a} f_{\gamma,\delta,a} + \sum_{a=1}^8 f_{\alpha,\delta,a} f_{\beta,\gamma,a} \right) (g_{\rho\mu} g_{\sigma\nu}) \quad (273)$$

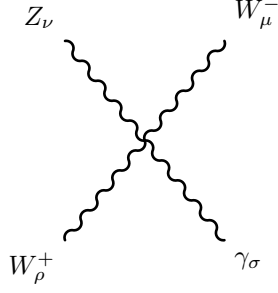
$$+ ig_3^2 \left( \sum_{a=1}^8 f_{\alpha,\gamma,a} f_{\beta,\delta,a} + \sum_{a=1}^8 f_{\alpha,\beta,a} f_{\gamma,\delta,a} \right) (g_{\rho\nu} g_{\sigma\mu}) \quad (274)$$



$$ig_2^2 \sin^2 \Theta_W (g_{\rho\sigma} g_{\mu\nu}) \quad (275)$$

$$+ ig_2^2 \sin^2 \Theta_W (g_{\rho\mu} g_{\sigma\nu}) \quad (276)$$

$$+ -2ig_2^2 \sin^2 \Theta_W (g_{\rho\nu} g_{\sigma\mu}) \quad (277)$$

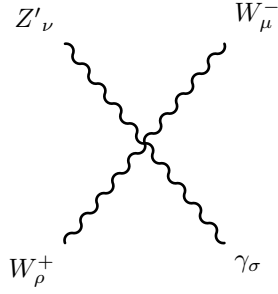


$$\frac{i}{2}g_2^2 \cos \Theta'_W \sin 2\Theta_W \left( g_{\rho\sigma} g_{\mu\nu} \right) \quad (278)$$

$$+ -ig_2^2 \cos \Theta'_W \sin 2\Theta_W \left( g_{\rho\mu} g_{\sigma\nu} \right) \quad (279)$$

$$+ \frac{i}{2}g_2^2 \cos \Theta'_W \sin 2\Theta_W \left( g_{\rho\nu} g_{\sigma\mu} \right) \quad (280)$$


---

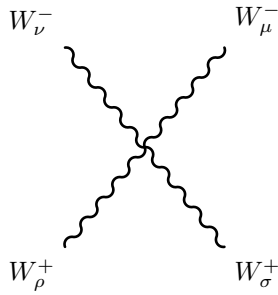


$$- \frac{i}{2}g_2^2 \sin 2\Theta_W \sin \Theta'_W \left( g_{\rho\sigma} g_{\mu\nu} \right) \quad (281)$$

$$+ ig_2^2 \sin 2\Theta_W \sin \Theta'_W \left( g_{\rho\mu} g_{\sigma\nu} \right) \quad (282)$$

$$+ -\frac{i}{2}g_2^2 \sin 2\Theta_W \sin \Theta'_W \left( g_{\rho\nu} g_{\sigma\mu} \right) \quad (283)$$

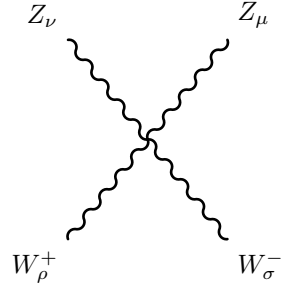

---



$$2ig_2^2(g_{\rho\sigma}g_{\mu\nu}) \quad (284)$$

$$+ -ig_2^2(g_{\rho\mu}g_{\sigma\nu}) \quad (285)$$

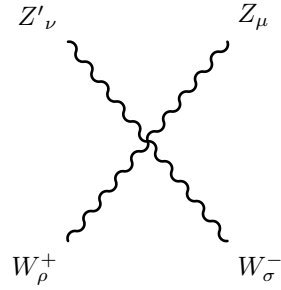
$$+ -ig_2^2(g_{\rho\nu}g_{\sigma\mu}) \quad (286)$$



$$- 2ig_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 (g_{\rho\sigma}g_{\mu\nu}) \quad (287)$$

$$+ ig_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 (g_{\rho\mu}g_{\sigma\nu}) \quad (288)$$

$$+ ig_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 (g_{\rho\nu}g_{\sigma\mu}) \quad (289)$$

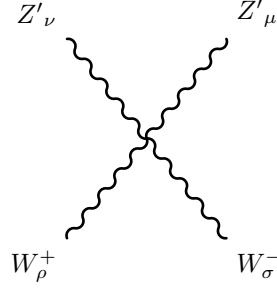


$$ig_2^2 \cos \Theta_W^2 \sin 2\Theta'_W (g_{\rho\sigma}g_{\mu\nu}) \quad (290)$$

$$+ -\frac{i}{2}g_2^2 \cos \Theta_W^2 \sin 2\Theta'_W (g_{\rho\mu}g_{\sigma\nu}) \quad (291)$$

$$+ -\frac{i}{2}g_2^2 \cos \Theta_W^2 \sin 2\Theta'_W (g_{\rho\nu}g_{\sigma\mu}) \quad (292)$$



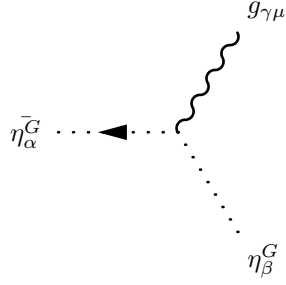


$$- 2ig_2^2 \cos \Theta_W^2 \sin \Theta_W'^2 \left( g_{\rho\sigma} g_{\mu\nu} \right) \quad (293)$$

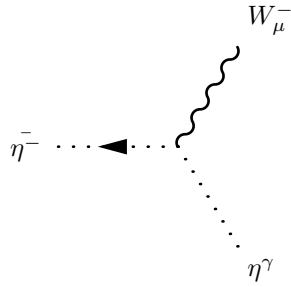
$$+ ig_2^2 \cos \Theta_W^2 \sin \Theta_W'^2 \left( g_{\rho\mu} g_{\sigma\nu} \right) \quad (294)$$

$$+ ig_2^2 \cos \Theta_W^2 \sin \Theta_W'^2 \left( g_{\rho\nu} g_{\sigma\mu} \right) \quad (295)$$

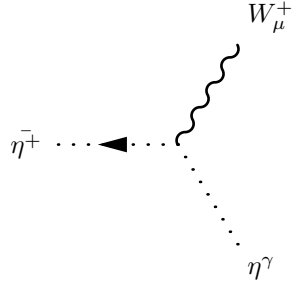
## 8.10 Two Ghosts-One Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma} \left( p_\mu^{\eta_\beta^G} \right) \quad (296)$$

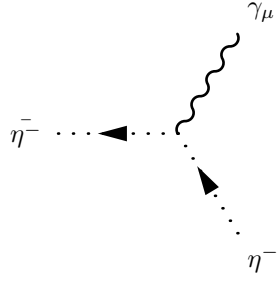


$$ig_2 \sin \Theta_W \left( p_\mu^{\eta^\gamma} \right) \quad (297)$$



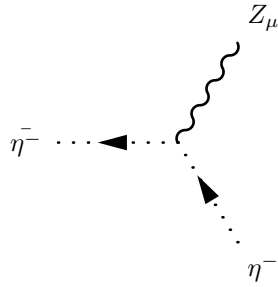
$$-ig_2 \sin \Theta_W \left( p_\mu^{\eta^\gamma} \right) \quad (298)$$


---



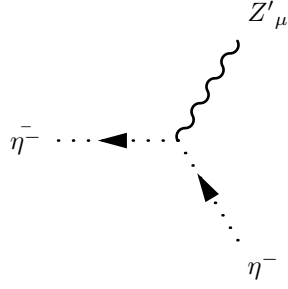
$$-ig_2 \sin \Theta_W \left( p_\mu^{\eta^-} \right) \quad (299)$$


---



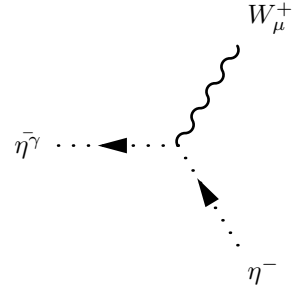
$$-ig_2 \cos \Theta_W \cos \Theta'_W \left( p_\mu^{\eta^-} \right) \quad (300)$$


---



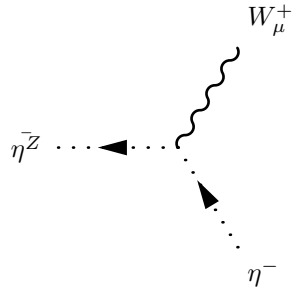
$$ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^-}) \quad (301)$$


---



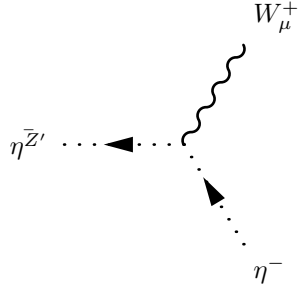
$$ig_2 \sin \Theta_W (p_\mu^{\eta^-}) \quad (302)$$


---



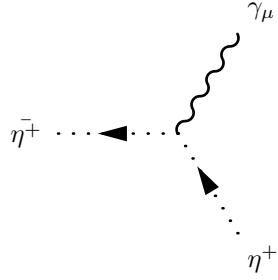
$$ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^-}) \quad (303)$$


---



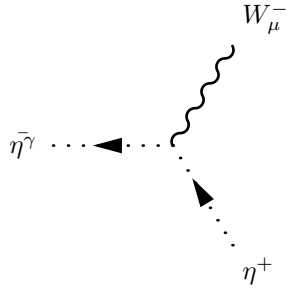
$$-ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^-}) \quad (304)$$


---



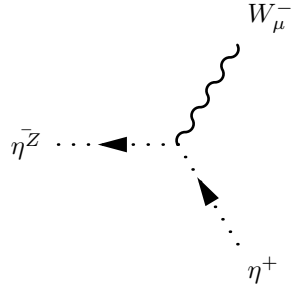
$$ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (305)$$


---



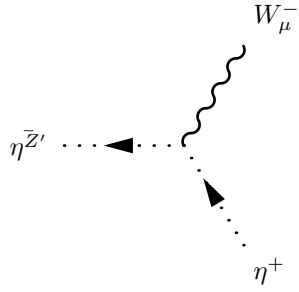
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (306)$$


---



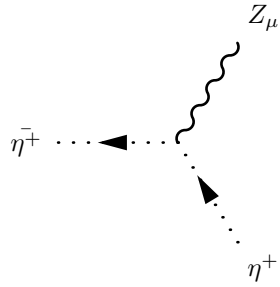
$$-ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^+}) \quad (307)$$


---



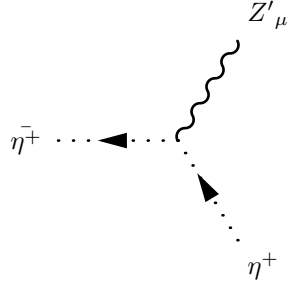
$$ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^+}) \quad (308)$$


---



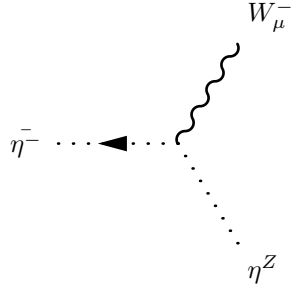
$$ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^+}) \quad (309)$$


---



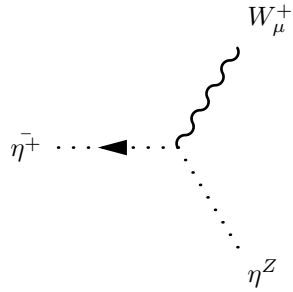
$$-ig_2 \cos \Theta_W \sin \Theta'_W \left( p_\mu^{\eta^+} \right) \quad (310)$$


---



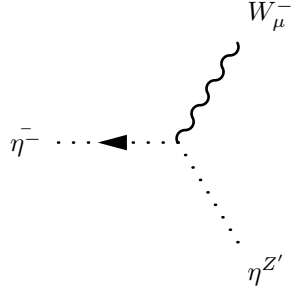
$$ig_2 \cos \Theta_W \cos \Theta'_W \left( p_\mu^{\eta^Z} \right) \quad (311)$$


---



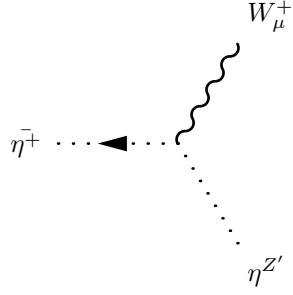
$$-ig_2 \cos \Theta_W \cos \Theta'_W \left( p_\mu^{\eta^Z} \right) \quad (312)$$


---



$$-ig_2 \cos \Theta_W \sin \Theta'_W \left( p_\mu^{\eta^{Z'}} \right) \quad (313)$$

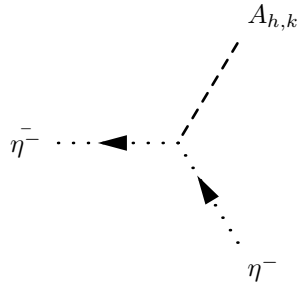

---



$$ig_2 \cos \Theta_W \sin \Theta'_W \left( p_\mu^{\eta^{Z'}} \right) \quad (314)$$

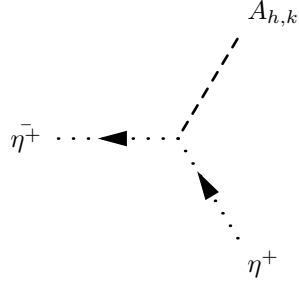

---

### 8.11 Two Ghosts-One Scalar-Interaction



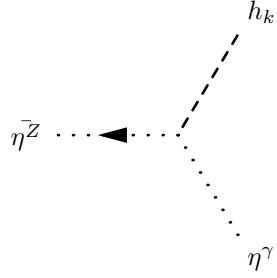
$$\frac{1}{4} g_2^2 v \xi_{W^-} Z_{k1}^A \quad (315)$$


---



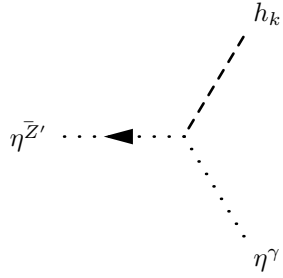
$$-\frac{1}{4}g_2^2 v \xi_{W^-} Z_{k1}^A \quad (316)$$


---



$$\begin{aligned} & \frac{i}{4} \xi_Z \left( v \left( g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \left( g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W - g_{BY} \sin \Theta'_W \right) Z_{k1}^H \right. \\ & \left. + 50 g_{YB} x \left( -2 g_B \cos \Theta_W \sin \Theta'_W + g_{YB} \cos \Theta'_W \sin 2\Theta_W \right) Z_{k2}^H \right) \end{aligned} \quad (317)$$

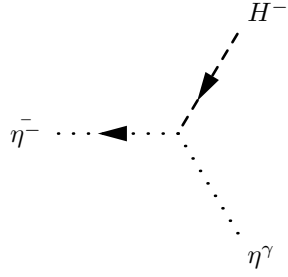

---



$$\begin{aligned} & -\frac{i}{4} \xi_{Z'} \left( v \left( g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \left( \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W + g_{BY} \cos \Theta'_W \right) Z_{k1}^H \right. \\ & \left. + 50 g_{YB} x \left( 2 g_B \cos \Theta_W \cos \Theta'_W + g_{YB} \sin 2\Theta_W \sin \Theta'_W \right) Z_{k2}^H \right) \end{aligned} \quad (318)$$

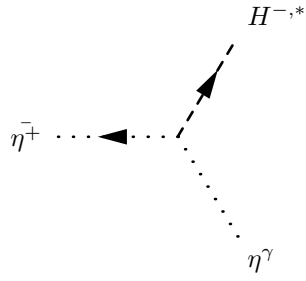

---





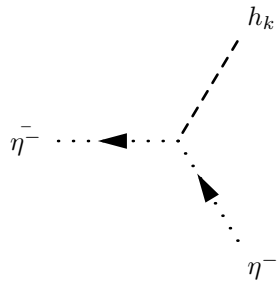
$$\frac{i}{4}g_2v\xi_{W^-}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right) \quad (319)$$


---



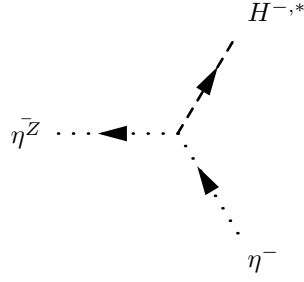
$$\frac{i}{4}g_2v\xi_{W^-}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right) \quad (320)$$


---



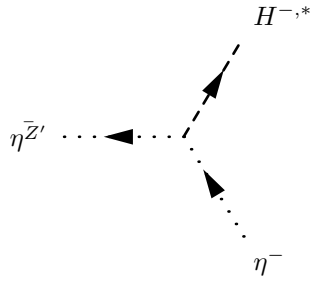
$$-\frac{i}{4}g_2^2v\xi_{W^-}Z_{k1}^H \quad (321)$$


---



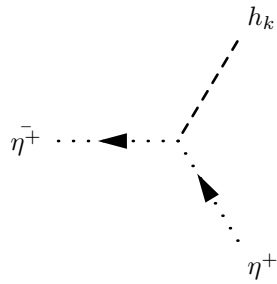
$$-\frac{i}{4}g_2v\xi_Z\left(g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W-g_{BY}\sin\Theta'_W\right) \quad (322)$$


---



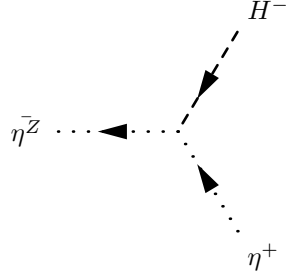
$$\frac{i}{4}g_2v\xi_{Z'}\left(\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right) \quad (323)$$


---



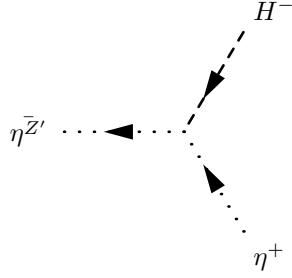
$$-\frac{i}{4}g_2^2v\xi_{W^-}Z_{k1}^H \quad (324)$$


---



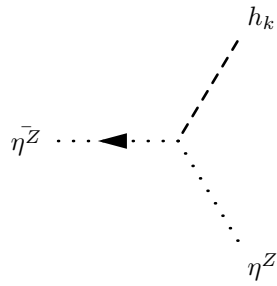
$$-\frac{i}{4}g_2v\xi_Z\left(g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W-g_{BY}\sin\Theta'_W\right) \quad (325)$$


---



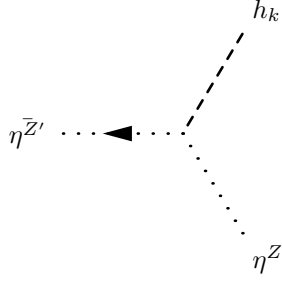
$$\frac{i}{4}g_2v\xi_{Z'}\left(\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right) \quad (326)$$


---



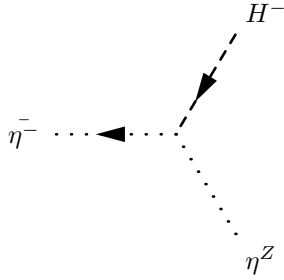
$$\begin{aligned} &-\frac{i}{4}\xi_Z\left(v\left(g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W-g_{BY}\sin\Theta'_W\right)^2Z_{k1}^H\right. \\ &\left.+100x\left(-g_B\sin\Theta'_W+g_{YB}\cos\Theta'_W\sin\Theta_W\right)^2Z_{k2}^H\right) \end{aligned} \quad (327)$$


---



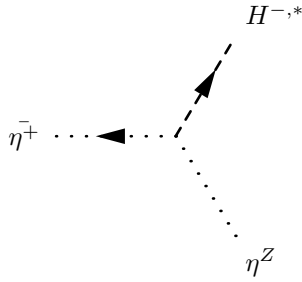
$$\begin{aligned}
& \frac{i}{4} \xi_{Z'} \left( v \left( g_1 g_{BY} \cos \Theta_W'^2 \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta_W' \sin \Theta_W' \right. \right. \\
& + \cos \Theta_W' \left( g_1^2 \sin \Theta_W^2 - g_{BY}^2 \right) \sin \Theta_W' - g_1 g_{BY} \sin \Theta_W \sin \Theta_W'^2 \\
& + g_2 \cos \Theta_W \left( g_1 \sin \Theta_W \sin 2\Theta_W' + g_{BY} \cos \Theta_W'^2 - g_{BY} \sin \Theta_W'^2 \right) \Big) Z_{k1}^H \\
& - 50x \left( -2g_B g_{YB} \cos \Theta_W'^2 \sin \Theta_W + 2g_B g_{YB} \sin \Theta_W \sin \Theta_W'^2 + g_B^2 \sin 2\Theta_W' \right. \\
& \left. \left. - g_{YB}^2 \sin \Theta_W^2 \sin 2\Theta_W' \right) Z_{k2}^H \right) \tag{328}
\end{aligned}$$


---



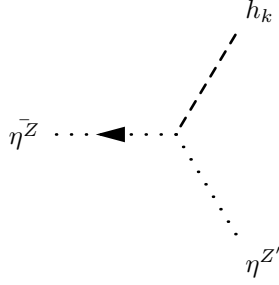
$$\frac{i}{4} g_2 v \xi_{W-} \left( -g_1 \cos \Theta_W' \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta_W' + g_{BY} \sin \Theta_W' \right) \tag{329}$$


---



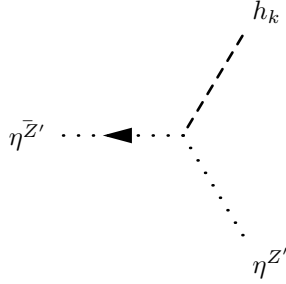
$$\frac{i}{4}g_2v\xi_{W-}\left(-g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W+g_{BY}\sin\Theta'_W\right) \quad (330)$$


---



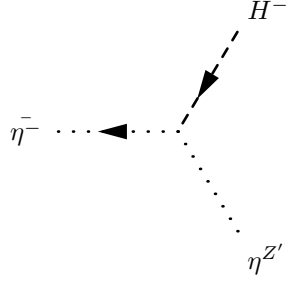
$$\begin{aligned} & \frac{i}{4}\xi_Z\left(v\left(g_1g_{BY}\cos\Theta'^2_W\sin\Theta_W+g_2^2\cos\Theta_W^2\cos\Theta'_W\sin\Theta'_W\right.\right. \\ & +\cos\Theta'_W\left(g_1^2\sin\Theta_W^2-g_{BY}^2\right)\sin\Theta'_W-g_1g_{BY}\sin\Theta_W\sin\Theta'^2_W \\ & \left.\left.+g_2\cos\Theta_W\left(g_1\sin\Theta_W\sin2\Theta'_W+g_{BY}\cos\Theta'^2_W-g_{BY}\sin\Theta'^2_W\right)\right)Z_{k1}^H \right. \\ & -50x\left(-2g_Bg_{YB}\cos\Theta'^2_W\sin\Theta_W+2g_Bg_{YB}\sin\Theta_W\sin\Theta'^2_W+g_B^2\sin2\Theta'_W\right. \\ & \left.-g_{YB}^2\sin\Theta_W^2\sin2\Theta'_W\right)Z_{k2}^H\Big) \quad (331) \end{aligned}$$


---



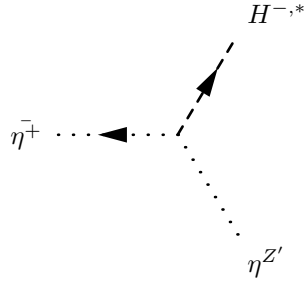
$$\begin{aligned} & -\frac{i}{4}\xi_{Z'}\left(v\left(\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right)^2Z_{k1}^H\right. \\ & \left.+100x\left(g_B\cos\Theta'_W+g_{YB}\sin\Theta_W\sin\Theta'_W\right)^2Z_{k2}^H\right) \quad (332) \end{aligned}$$


---



$$\frac{i}{4}g_2v\xi_{W^-}\left(\left(g_1\sin\Theta_W-g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right) \quad (333)$$


---



$$\frac{i}{4}g_2v\xi_{W^-}\left(\left(g_1\sin\Theta_W-g_2\cos\Theta_W\right)\sin\Theta'_W+g_{BY}\cos\Theta'_W\right) \quad (334)$$


---

## 9 Clebsch-Gordan Coefficients