

MSSM-CPV  
Superpotential, Rotations and Interactions for eigenstates 'EWSB'  
including Renormalization Group Equations  
including one-loop Self-Energies

SARAH 4.6.0

November 18, 2015

This file was automatically generated by SARAH version 4.6.0.

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 Superfields</b>	<b>4</b>
1.1 Vector Superfields . . . . .	4
1.2 Chiral Superfields . . . . .	4
<b>2 Superpotential and Lagrangian</b>	<b>4</b>
2.1 Superpotential . . . . .	4
2.2 Softbreaking terms . . . . .	4
2.3 Gauge fixing terms . . . . .	5
2.3.1 Gauge fixing terms for eigenstates 'GaugeES'	5
2.3.2 Gauge fixing terms for eigenstates 'EWSB'	5
2.4 Fields integrated out . . . . .	5
<b>3 Renormalization Group Equations</b>	<b>5</b>
3.1 Anomalous Dimensions . . . . .	5
3.2 Gauge Couplings . . . . .	6
3.3 Gaugino Mass Parameters . . . . .	6
3.4 Trilinear Superpotential Parameters . . . . .	7
3.5 Bilinear Superpotential Parameters . . . . .	7
3.6 Trilinear Soft-Breaking Parameters . . . . .	8
3.7 Bilinear Soft-Breaking Parameters . . . . .	9
3.8 Soft-Breaking Scalar Masses . . . . .	10
3.9 Vacuum expectation values . . . . .	15
<b>4 Field Rotations</b>	<b>16</b>
4.1 Rotations in gauge sector for eigenstates 'EWSB'	16
4.2 Rotations in Mass sector for eigenstates 'EWSB'	16
4.2.1 Mass Matrices for Scalars . . . . .	16
4.2.2 Mass Matrices for Fermions . . . . .	19
<b>5 Vacuum Expectation Values</b>	<b>21</b>
<b>6 Tadpole Equations</b>	<b>21</b>
<b>7 Particle content for eigenstates 'EWSB'</b>	<b>21</b>
<b>8 One Loop Self-Energy and One Loop Tadpoles for eigenstates 'EWSB'</b>	<b>22</b>
8.1 One Loop Self-Energy . . . . .	22
8.2 Tadpoles . . . . .	38
<b>9 Interactions for eigenstates 'EWSB'</b>	<b>38</b>
9.1 Three Scalar-Interaction . . . . .	38
9.2 Two Scalar-One Vector Boson-Interaction . . . . .	44
9.3 One Scalar-Two Vector Boson-Interaction . . . . .	50
9.4 Two Fermion-One Vector Boson-Interaction . . . . .	52
9.5 Two Fermion-One Scalar Boson-Interaction . . . . .	58

9.6	Three Vector Boson-Interaction . . . . .	71
9.7	Four Scalar-Interaction . . . . .	72
9.8	Two Scalar-Two Vector Boson-Interaction . . . . .	88
9.9	Four Vector Boson-Interaction . . . . .	102
9.10	Two Ghosts-One Vector Boson-Interaction . . . . .	104
9.11	Two Ghosts-One Scalar-Interaction . . . . .	108
<b>10</b>	<b>Clebsch-Gordan Coefficients</b>	<b>111</b>

# 1 Superfields

## 1.1 Vector Superfields

SF	Spin $\frac{1}{2}$	Spin 1	$SU(N)$	Coupling	Name
$\hat{B}$	$\lambda_{\hat{B}}$	$B$	$U(1)$	$g_1$	hypercharge
$\hat{W}$	$\lambda_{\hat{W}}$	$W$	$SU(2)$	$g_2$	left
$\hat{g}$	$\lambda_{\hat{g}}$	$g$	$SU(3)$	$g_3$	color

## 1.2 Chiral Superfields

SF	Spin 0	Spin $\frac{1}{2}$	Generations	$(U(1) \otimes SU(2) \otimes SU(3))$
$\hat{q}$	$\tilde{q}$	$q$	3	$(\frac{1}{6}, \mathbf{2}, \mathbf{3})$
$\hat{l}$	$\tilde{l}$	$l$	3	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1})$
$\hat{H}_d$	$H_d$	$\tilde{H}_d$	1	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1})$
$\hat{H}_u$	$H_u$	$\tilde{H}_u$	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1})$
$\hat{d}$	$\tilde{d}_R^*$	$d_R^*$	3	$(\frac{1}{3}, \mathbf{1}, \bar{\mathbf{3}})$
$\hat{u}$	$\tilde{u}_R^*$	$u_R^*$	3	$(-\frac{2}{3}, \mathbf{1}, \bar{\mathbf{3}})$
$\hat{e}$	$\tilde{e}_R^*$	$e_R^*$	3	$(1, \mathbf{1}, \mathbf{1})$

# 2 Superpotential and Lagrangian

## 2.1 Superpotential

$$W = \mu \hat{H}_u \hat{H}_d - Y_d \hat{d} \hat{q} \hat{H}_d - Y_e \hat{e} \hat{l} \hat{H}_d + Y_u \hat{u} \hat{q} \hat{H}_u \quad (1)$$

## 2.2 Softbreaking terms

$$-L_{SB,W} = -H_d^0 H_u^0 B_\mu + H_d^- H_u^+ B_\mu + H_d^0 \tilde{d}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{d}_{L,j\beta} T_{d,ij} - H_d^- \tilde{d}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{u}_{L,j\beta} T_{d,ij} \\ + H_d^0 \tilde{e}_{R,i}^* \tilde{e}_{L,j} T_{e,ij} - H_d^- \tilde{e}_{R,i}^* \tilde{\nu}_{L,j} T_{e,ij} - H_u^+ \tilde{u}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{d}_{L,j\beta} T_{u,ij} + H_u^0 \tilde{u}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{u}_{L,j\beta} T_{u,ij} + \text{h.c.} \quad (2)$$

$$-L_{SB,\phi} = +m_{H_d}^2 |H_d^0|^2 + m_{H_d}^2 |H_d^-|^2 + m_{H_u}^2 |H_u^0|^2 + m_{H_u}^2 |H_u^+|^2 + \tilde{d}_{L,i\alpha}^* \delta_{\alpha\beta} m_{q,ij}^2 \tilde{d}_{L,j\beta} \\ + \tilde{d}_{R,i\alpha}^* \delta_{\alpha\beta} m_{d,ij}^2 \tilde{d}_{R,j\beta} + \tilde{e}_{L,i}^* m_{l,ij}^2 \tilde{e}_{L,j} + \tilde{e}_{R,i}^* m_{e,ij}^2 \tilde{e}_{R,j} + \tilde{u}_{L,i\alpha}^* \delta_{\alpha\beta} m_{q,ij}^2 \tilde{u}_{L,j\beta} \\ + \tilde{u}_{R,i\alpha}^* \delta_{\alpha\beta} m_{u,ij}^2 \tilde{u}_{R,j\beta} + \tilde{\nu}_{L,i}^* m_{l,ij}^2 \tilde{\nu}_{L,j} \quad (3)$$

$$-L_{SB,\lambda} = \frac{1}{2} \left( \lambda_{\hat{B}}^2 M_1 \delta_{ij} + M_2 \delta_{ij} \lambda_{\hat{W},i} \lambda_{\hat{W},j} + M_3 \delta_{ij} \lambda_{\hat{g},\alpha} \lambda_{\hat{g},\beta} + \text{h.c.} \right) \quad (4)$$

## 2.3 Gauge fixing terms

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

$$L_{GF} = -\frac{1}{2}|\partial_\mu B|^2\xi_B^{-1} - \frac{1}{2}|\partial_\mu g|^2\xi_g^{-1} - \frac{1}{2}|\partial_\mu W|^2\xi_W^{-1} \quad (5)$$

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

$$L_{GF} = -\frac{1}{2}|\partial_\mu g|^2\xi_g^{-1} - \frac{1}{2}|\partial_\mu \gamma|^2\xi_\gamma^{-1} - \frac{i}{2}g_2\left(H_d^- v_d - v_u H_u^{+,*}\right)\xi_{W^-} + \partial_\mu W^-|^2\xi_{W^-}^{-1} \\ - \frac{1}{2}\left|\frac{1}{2}\left(2\partial_\mu Z + \left(\sigma_d v_d - \sigma_u v_u\right)\xi_Z\left(g_1 \sin \Theta_W + g_2 \cos \Theta_W\right)\right)\right|^2\xi_Z^{-1} \quad (6)$$

## 2.4 Fields integrated out

None

# 3 Renormalization Group Equations

## 3.1 Anomalous Dimensions

$$\gamma_{\hat{q}}^{(1)} = -\frac{1}{30}\left(45g_2^2 + 80g_3^2 + g_1^2\right)\mathbf{1} + Y_d^\dagger Y_d + Y_u^\dagger Y_u \quad (7)$$

$$\gamma_{\hat{q}}^{(2)} = +\left(8g_2^2g_3^2 + \frac{15}{4}g_2^4 + \frac{1}{90}g_1^2\left(16g_3^2 + 9g_2^2\right) + \frac{199}{900}g_1^4 - \frac{8}{9}g_3^4\right)\mathbf{1} + \frac{4}{5}g_1^2Y_u^\dagger Y_u - 2Y_d^\dagger Y_d Y_d^\dagger Y_d \\ - 2Y_u^\dagger Y_u Y_u^\dagger Y_u + Y_d^\dagger Y_d\left(-3\text{Tr}\left(Y_d Y_d^\dagger\right) + \frac{2}{5}g_1^2 - \text{Tr}\left(Y_e Y_e^\dagger\right)\right) - 3Y_u^\dagger Y_u \text{Tr}\left(Y_u Y_u^\dagger\right) \quad (8)$$

$$\gamma_{\hat{i}}^{(1)} = -\frac{3}{10}\left(5g_2^2 + g_1^2\right)\mathbf{1} + Y_e^\dagger Y_e \quad (9)$$

$$\gamma_{\hat{i}}^{(2)} = -2Y_e^\dagger Y_e Y_e^\dagger Y_e + \frac{3}{100}\left(125g_2^4 + 30g_1^2g_2^2 + 69g_1^4\right)\mathbf{1} + Y_e^\dagger Y_e\left(-3\text{Tr}\left(Y_d Y_d^\dagger\right) + \frac{6}{5}g_1^2 - \text{Tr}\left(Y_e Y_e^\dagger\right)\right) \quad (10)$$

$$\gamma_{\hat{H}_d}^{(1)} = 3\text{Tr}\left(Y_d Y_d^\dagger\right) - \frac{3}{10}\left(5g_2^2 + g_1^2\right) + \text{Tr}\left(Y_e Y_e^\dagger\right) \quad (11)$$

$$\gamma_{\hat{H}_d}^{(2)} = +\frac{207}{100}g_1^4 + \frac{9}{10}g_1^2g_2^2 + \frac{15}{4}g_2^4 - \frac{2}{5}\left(-40g_3^2 + g_1^2\right)\text{Tr}\left(Y_d Y_d^\dagger\right) + \frac{6}{5}g_1^2\text{Tr}\left(Y_e Y_e^\dagger\right) - 9\text{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right) \\ - 3\text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 3\text{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right) \quad (12)$$

$$\gamma_{\hat{H}_u}^{(1)} = -\frac{3}{10}\left(-10\text{Tr}\left(Y_u Y_u^\dagger\right) + 5g_2^2 + g_1^2\right) \quad (13)$$

$$\gamma_{\hat{H}_u}^{(2)} = -3\text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 9\text{Tr}\left(Y_u Y_u^\dagger Y_u Y_u^\dagger\right) + \frac{15}{4}g_2^4 + \frac{207}{100}g_1^4 + \frac{4}{5}\left(20g_3^2 + g_1^2\right)\text{Tr}\left(Y_u Y_u^\dagger\right) + \frac{9}{10}g_1^2g_2^2 \quad (14)$$

$$\gamma_{\hat{d}}^{(1)} = 2Y_d^* Y_d^T - \frac{2}{15}\left(20g_3^2 + g_1^2\right)\mathbf{1} \quad (15)$$

$$\gamma_{\hat{d}}^{(2)} = +\frac{2}{225}\left(-100g_3^4 + 101g_1^4 + 80g_1^2g_3^2\right)\mathbf{1} - 2\left(Y_d^* Y_d^T Y_d^* Y_d^T + Y_d^* Y_u^T Y_u^* Y_d^T\right)$$

$$+ Y_d^* Y_d^T \left( -2\text{Tr}(Y_e Y_e^\dagger) + 6g_2^2 - 6\text{Tr}(Y_d Y_d^\dagger) + \frac{2}{5}g_1^2 \right) \quad (16)$$

$$\gamma_{\hat{u}}^{(1)} = 2Y_u^* Y_u^T - \frac{8}{15} \left( 5g_3^2 + g_1^2 \right) \mathbf{1} \quad (17)$$

$$\begin{aligned} \gamma_{\hat{u}}^{(2)} = & + \frac{8}{225} \left( 107g_1^4 - 25g_3^4 + 80g_1^2 g_3^2 \right) \mathbf{1} - 2 \left( Y_u^* Y_d^T Y_d^* Y_u^T + Y_u^* Y_u^T Y_u^* Y_u^T \right) \\ & + Y_u^* Y_u^T \left( 6g_2^2 - 6\text{Tr}(Y_u Y_u^\dagger) - \frac{2}{5}g_1^2 \right) \end{aligned} \quad (18)$$

$$\gamma_{\hat{e}}^{(1)} = 2Y_e^* Y_e^T - \frac{6}{5}g_1^2 \mathbf{1} \quad (19)$$

$$\gamma_{\hat{e}}^{(2)} = -2Y_e^* Y_e^T Y_e^* Y_e^T + \frac{234}{25}g_1^4 \mathbf{1} + Y_e^* Y_e^T \left( -2\text{Tr}(Y_e Y_e^\dagger) + 6g_2^2 - 6\text{Tr}(Y_d Y_d^\dagger) - \frac{6}{5}g_1^2 \right) \quad (20)$$

### 3.2 Gauge Couplings

$$\beta_{g_1}^{(1)} = \frac{33}{5}g_1^3 \quad (21)$$

$$\beta_{g_1}^{(2)} = \frac{1}{25}g_1^3 \left( -130\text{Tr}(Y_u Y_u^\dagger) + 135g_2^2 + 199g_1^2 + 440g_3^2 - 70\text{Tr}(Y_d Y_d^\dagger) - 90\text{Tr}(Y_e Y_e^\dagger) \right) \quad (22)$$

$$\beta_{g_2}^{(1)} = g_2^3 \quad (23)$$

$$\beta_{g_2}^{(2)} = \frac{1}{5}g_2^3 \left( -10\text{Tr}(Y_e Y_e^\dagger) + 120g_3^2 + 125g_2^2 - 30\text{Tr}(Y_d Y_d^\dagger) - 30\text{Tr}(Y_u Y_u^\dagger) + 9g_1^2 \right) \quad (24)$$

$$\beta_{g_3}^{(1)} = -3g_3^3 \quad (25)$$

$$\beta_{g_3}^{(2)} = \frac{1}{5}g_3^3 \left( 11g_1^2 - 20\text{Tr}(Y_d Y_d^\dagger) - 20\text{Tr}(Y_u Y_u^\dagger) + 45g_2^2 + 70g_3^2 \right) \quad (26)$$

### 3.3 Gaugino Mass Parameters

$$\beta_{M_1}^{(1)} = \frac{66}{5}g_1^2 M_1 \quad (27)$$

$$\begin{aligned} \beta_{M_1}^{(2)} = & \frac{2}{25}g_1^2 \left( 398g_1^2 M_1 + 135g_2^2 M_1 + 440g_3^2 M_1 + 440g_3^2 M_3 + 135g_2^2 M_2 - 70M_1 \text{Tr}(Y_d Y_d^\dagger) - 90M_1 \text{Tr}(Y_e Y_e^\dagger) \right. \\ & \left. - 130M_1 \text{Tr}(Y_u Y_u^\dagger) + 70\text{Tr}(Y_d^\dagger T_d) + 90\text{Tr}(Y_e^\dagger T_e) + 130\text{Tr}(Y_u^\dagger T_u) \right) \end{aligned} \quad (28)$$

$$\beta_{M_2}^{(1)} = 2g_2^2 M_2 \quad (29)$$

$$\begin{aligned} \beta_{M_2}^{(2)} = & \frac{2}{5}g_2^2 \left( 9g_1^2 M_1 + 120g_3^2 M_3 + 9g_1^2 M_2 + 250g_2^2 M_2 + 120g_3^2 M_2 - 30M_2 \text{Tr}(Y_d Y_d^\dagger) - 10M_2 \text{Tr}(Y_e Y_e^\dagger) \right. \\ & \left. - 30M_2 \text{Tr}(Y_u Y_u^\dagger) + 30\text{Tr}(Y_d^\dagger T_d) + 10\text{Tr}(Y_e^\dagger T_e) + 30\text{Tr}(Y_u^\dagger T_u) \right) \end{aligned} \quad (30)$$

$$\beta_{M_3}^{(1)} = -6g_3^2 M_3 \quad (31)$$

$$\beta_{M_3}^{(2)} = \frac{2}{5}g_3^2 \left( 11g_1^2 M_1 + 11g_1^2 M_3 + 45g_2^2 M_3 + 140g_3^2 M_3 + 45g_2^2 M_2 - 20M_3 \text{Tr}(Y_d Y_d^\dagger) - 20M_3 \text{Tr}(Y_u Y_u^\dagger) \right)$$

$$+ 20\text{Tr}(Y_d^\dagger T_d) + 20\text{Tr}(Y_u^\dagger T_u)) \quad (32)$$

### 3.4 Trilinear Superpotential Parameters

$$\beta_{Y_d}^{(1)} = 3Y_d Y_d^\dagger Y_d + Y_d \left( -3g_2^2 + 3\text{Tr}(Y_d Y_d^\dagger) - \frac{16}{3}g_3^2 - \frac{7}{15}g_1^2 + \text{Tr}(Y_e Y_e^\dagger) \right) + Y_d Y_u^\dagger Y_u \quad (33)$$

$$\begin{aligned} \beta_{Y_d}^{(2)} = & + \frac{4}{5}g_1^2 Y_d Y_u^\dagger Y_u - 4Y_d Y_d^\dagger Y_d Y_d^\dagger Y_d - 2Y_d Y_u^\dagger Y_u Y_d^\dagger Y_d - 2Y_d Y_u^\dagger Y_u Y_u^\dagger Y_u \\ & + Y_d Y_d^\dagger Y_d \left( -3\text{Tr}(Y_e Y_e^\dagger) + 6g_2^2 - 9\text{Tr}(Y_d Y_d^\dagger) + \frac{4}{5}g_1^2 \right) - 3Y_d Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) \\ & + Y_d \left( \frac{287}{90}g_1^4 + g_1^2 g_2^2 + \frac{15}{2}g_2^4 + \frac{8}{9}g_1^2 g_3^2 + 8g_2^2 g_3^2 - \frac{16}{9}g_3^4 - \frac{2}{5}(-40g_3^2 + g_1^2) \text{Tr}(Y_d Y_d^\dagger) \right. \\ & \left. + \frac{6}{5}g_1^2 \text{Tr}(Y_e Y_e^\dagger) - 9\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 3\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 3\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \right) \end{aligned} \quad (34)$$

$$\beta_{Y_e}^{(1)} = 3Y_e Y_e^\dagger Y_e + Y_e \left( -3g_2^2 + 3\text{Tr}(Y_d Y_d^\dagger) - \frac{9}{5}g_1^2 + \text{Tr}(Y_e Y_e^\dagger) \right) \quad (35)$$

$$\begin{aligned} \beta_{Y_e}^{(2)} = & -4Y_e Y_e^\dagger Y_e Y_e^\dagger Y_e + Y_e Y_e^\dagger Y_e \left( -3\text{Tr}(Y_e Y_e^\dagger) + 6g_2^2 - 9\text{Tr}(Y_d Y_d^\dagger) \right) \\ & + \frac{1}{10}Y_e \left( -4(-40g_3^2 + g_1^2) \text{Tr}(Y_d Y_d^\dagger) \right. \\ & \left. + 3(45g_1^4 + 6g_1^2 g_2^2 + 25g_2^4 + 4g_1^2 \text{Tr}(Y_e Y_e^\dagger)) - 30\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 10\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) \right. \\ & \left. - 10\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \right) \end{aligned} \quad (36)$$

$$\beta_{Y_u}^{(1)} = 3Y_u Y_u^\dagger Y_u - \frac{1}{15}Y_u \left( 13g_1^2 + 45g_2^2 - 45\text{Tr}(Y_u Y_u^\dagger) + 80g_3^2 \right) + Y_u Y_d^\dagger Y_d \quad (37)$$

$$\begin{aligned} \beta_{Y_u}^{(2)} = & + \frac{2}{5}g_1^2 Y_u Y_u^\dagger Y_u + 6g_2^2 Y_u Y_u^\dagger Y_u - 2Y_u Y_d^\dagger Y_d Y_d^\dagger Y_d - 2Y_u Y_d^\dagger Y_d Y_u^\dagger Y_u \\ & - 4Y_u Y_u^\dagger Y_u Y_u^\dagger Y_u + Y_u Y_d^\dagger Y_d \left( -3\text{Tr}(Y_d Y_d^\dagger) + \frac{2}{5}g_1^2 - \text{Tr}(Y_e Y_e^\dagger) \right) - 9Y_u Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) \\ & + Y_u \left( \frac{2743}{450}g_1^4 + g_1^2 g_2^2 + \frac{15}{2}g_2^4 + \frac{136}{45}g_1^2 g_3^2 + 8g_2^2 g_3^2 - \frac{16}{9}g_3^4 + \frac{4}{5}(20g_3^2 + g_1^2) \text{Tr}(Y_u Y_u^\dagger) \right. \\ & \left. - 3\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 9\text{Tr}(Y_u Y_u^\dagger Y_u Y_u^\dagger) \right) \end{aligned} \quad (38)$$

### 3.5 Bilinear Superpotential Parameters

$$\beta_\mu^{(1)} = 3\mu \text{Tr}(Y_d Y_d^\dagger) - \frac{3}{5}\mu \left( 5g_2^2 - 5\text{Tr}(Y_u Y_u^\dagger) + g_1^2 \right) + \mu \text{Tr}(Y_e Y_e^\dagger) \quad (39)$$

$$\begin{aligned} \beta_\mu^{(2)} = & \frac{1}{50}\mu \left( 207g_1^4 + 90g_1^2 g_2^2 + 375g_2^4 - 20(-40g_3^2 + g_1^2) \text{Tr}(Y_d Y_d^\dagger) + 60g_1^2 \text{Tr}(Y_e Y_e^\dagger) + 40g_1^2 \text{Tr}(Y_u Y_u^\dagger) \right. \\ & \left. + 800g_3^2 \text{Tr}(Y_u Y_u^\dagger) - 450\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 300\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 150\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \right) \end{aligned}$$

$$-450\text{Tr}\left(Y_u Y_u^\dagger Y_u Y_u^\dagger\right) \quad (40)$$

### 3.6 Trilinear Soft-Breaking Parameters

$$\begin{aligned} \beta_{T_d}^{(1)} = & +4Y_d Y_d^\dagger T_d + 2Y_d Y_u^\dagger T_u + 5T_d Y_d^\dagger Y_d + T_d Y_u^\dagger Y_u - \frac{7}{15}g_1^2 T_d - 3g_2^2 T_d - \frac{16}{3}g_3^2 T_d \\ & + 3T_d \text{Tr}\left(Y_d Y_d^\dagger\right) + T_d \text{Tr}\left(Y_e Y_e^\dagger\right) + Y_d \left(2\text{Tr}\left(Y_e^\dagger T_e\right) + 6g_2^2 M_2 + 6\text{Tr}\left(Y_d^\dagger T_d\right) + \frac{14}{15}g_1^2 M_1 + \frac{32}{3}g_3^2 M_3\right) \end{aligned} \quad (41)$$

$$\begin{aligned} \beta_{T_d}^{(2)} = & +\frac{6}{5}g_1^2 Y_d Y_d^\dagger T_d + 6g_2^2 Y_d Y_d^\dagger T_d - \frac{8}{5}g_1^2 M_1 Y_d Y_u^\dagger Y_u + \frac{8}{5}g_1^2 Y_d Y_u^\dagger T_u \\ & + \frac{6}{5}g_1^2 T_d Y_d^\dagger Y_d + 12g_2^2 T_d Y_d^\dagger Y_d + \frac{4}{5}g_1^2 T_d Y_u^\dagger Y_u - 6Y_d Y_d^\dagger Y_d Y_d^\dagger T_d \\ & - 8Y_d Y_d^\dagger T_d Y_d^\dagger Y_d - 2Y_d Y_u^\dagger Y_u Y_d^\dagger T_d - 4Y_d Y_u^\dagger Y_u Y_u^\dagger T_u - 4Y_d Y_u^\dagger T_u Y_d^\dagger Y_d \\ & - 4Y_d Y_u^\dagger T_u Y_u^\dagger Y_u - 6T_d Y_d^\dagger Y_d Y_d^\dagger Y_d - 4T_d Y_u^\dagger Y_u Y_d^\dagger Y_d - 2T_d Y_u^\dagger Y_u Y_u^\dagger Y_u \\ & + \frac{287}{90}g_1^4 T_d + g_1^2 g_2^2 T_d + \frac{15}{2}g_2^4 T_d + \frac{8}{9}g_1^2 g_3^2 T_d + 8g_2^2 g_3^2 T_d - \frac{16}{9}g_3^4 T_d \\ & - 12Y_d Y_d^\dagger T_d \text{Tr}\left(Y_d Y_d^\dagger\right) - 15T_d Y_d^\dagger Y_d \text{Tr}\left(Y_d Y_d^\dagger\right) - \frac{2}{5}g_1^2 T_d \text{Tr}\left(Y_d Y_d^\dagger\right) \\ & + 16g_3^2 T_d \text{Tr}\left(Y_d Y_d^\dagger\right) - 4Y_d Y_d^\dagger T_d \text{Tr}\left(Y_e Y_e^\dagger\right) - 5T_d Y_d^\dagger Y_d \text{Tr}\left(Y_e Y_e^\dagger\right) \\ & + \frac{6}{5}g_1^2 T_d \text{Tr}\left(Y_e Y_e^\dagger\right) - 6Y_d Y_u^\dagger T_u \text{Tr}\left(Y_u Y_u^\dagger\right) - 3T_d Y_u^\dagger Y_u \text{Tr}\left(Y_u Y_u^\dagger\right) \\ & - \frac{2}{5}Y_d Y_d^\dagger Y_d \left(15\text{Tr}\left(Y_e^\dagger T_e\right) + 30g_2^2 M_2 + 45\text{Tr}\left(Y_d^\dagger T_d\right) + 4g_1^2 M_1\right) - 6Y_d Y_u^\dagger Y_u \text{Tr}\left(Y_u^\dagger T_u\right) \\ & - 9T_d \text{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right) - 3T_d \text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 3T_d \text{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right) \\ & - \frac{2}{45}Y_d \left(287g_1^4 M_1 + 45g_1^2 g_2^2 M_1 + 40g_1^2 g_3^2 M_1 + 40g_1^2 g_3^2 M_3 + 360g_2^2 g_3^2 M_3 - 160g_3^4 M_3\right. \\ & + 45g_1^2 g_2^2 M_2 + 675g_2^4 M_2 + 360g_2^2 g_3^2 M_2 - 18\left(-40g_3^2 M_3 + g_1^2 M_1\right) \text{Tr}\left(Y_d Y_d^\dagger\right) \\ & + 54g_1^2 M_1 \text{Tr}\left(Y_e Y_e^\dagger\right) + 18g_1^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 720g_3^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 54g_1^2 \text{Tr}\left(Y_e^\dagger T_e\right) \\ & \left. + 810\text{Tr}\left(Y_d Y_d^\dagger T_d Y_d^\dagger\right) + 135\text{Tr}\left(Y_d Y_u^\dagger T_u Y_d^\dagger\right) + 270\text{Tr}\left(Y_e Y_e^\dagger T_e Y_e^\dagger\right) + 135\text{Tr}\left(Y_u Y_d^\dagger T_d Y_u^\dagger\right)\right) \end{aligned} \quad (42)$$

$$\begin{aligned} \beta_{T_e}^{(1)} = & +4Y_e Y_e^\dagger T_e + 5T_e Y_e^\dagger Y_e - \frac{9}{5}g_1^2 T_e - 3g_2^2 T_e + 3T_e \text{Tr}\left(Y_d Y_d^\dagger\right) + T_e \text{Tr}\left(Y_e Y_e^\dagger\right) \\ & + Y_e \left(2\text{Tr}\left(Y_e^\dagger T_e\right) + 6g_2^2 M_2 + 6\text{Tr}\left(Y_d^\dagger T_d\right) + \frac{18}{5}g_1^2 M_1\right) \end{aligned} \quad (43)$$

$$\begin{aligned} \beta_{T_e}^{(2)} = & +\frac{6}{5}g_1^2 Y_e Y_e^\dagger T_e + 6g_2^2 Y_e Y_e^\dagger T_e - \frac{6}{5}g_1^2 T_e Y_e^\dagger Y_e + 12g_2^2 T_e Y_e^\dagger Y_e \\ & - 6Y_e Y_e^\dagger Y_e Y_e^\dagger T_e - 8Y_e Y_e^\dagger T_e Y_e^\dagger Y_e - 6T_e Y_e^\dagger Y_e Y_e^\dagger Y_e + \frac{27}{2}g_1^4 T_e + \frac{9}{5}g_1^2 g_2^2 T_e + \frac{15}{2}g_2^4 T_e \\ & - 12Y_e Y_e^\dagger T_e \text{Tr}\left(Y_d Y_d^\dagger\right) - 15T_e Y_e^\dagger Y_e \text{Tr}\left(Y_d Y_d^\dagger\right) - \frac{2}{5}g_1^2 T_e \text{Tr}\left(Y_d Y_d^\dagger\right) \end{aligned}$$



$$\begin{aligned}
& + 16g_3^2 T_e \text{Tr}(Y_d Y_d^\dagger) - 4Y_e Y_e^\dagger T_e \text{Tr}(Y_e Y_e^\dagger) - 5T_e Y_e^\dagger Y_e \text{Tr}(Y_e Y_e^\dagger) \\
& + \frac{6}{5} g_1^2 T_e \text{Tr}(Y_e Y_e^\dagger) - 6Y_e Y_e^\dagger Y_e (2g_2^2 M_2 + 3\text{Tr}(Y_d^\dagger T_d) + \text{Tr}(Y_e^\dagger T_e)) - 9T_e \text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) \\
& - 3T_e \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 3T_e \text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \\
& - \frac{2}{5} Y_e (135g_1^4 M_1 + 9g_1^2 g_2^2 M_1 + 9g_1^2 g_2^2 M_2 + 75g_2^4 M_2 + (-2g_1^2 M_1 + 80g_3^2 M_3) \text{Tr}(Y_d Y_d^\dagger) \\
& + 6g_1^2 M_1 \text{Tr}(Y_e Y_e^\dagger) + 2g_1^2 \text{Tr}(Y_d^\dagger T_d) - 80g_3^2 \text{Tr}(Y_d^\dagger T_d) - 6g_1^2 \text{Tr}(Y_e^\dagger T_e) \\
& + 90\text{Tr}(Y_d Y_d^\dagger T_d Y_d^\dagger) + 15\text{Tr}(Y_d Y_u^\dagger T_u Y_d^\dagger) + 30\text{Tr}(Y_e Y_e^\dagger T_e Y_e^\dagger) + 15\text{Tr}(Y_u Y_d^\dagger T_d Y_u^\dagger)) \tag{44}
\end{aligned}$$

$$\begin{aligned}
\beta_{T_u}^{(1)} & = +2Y_u Y_d^\dagger T_d + 4Y_u Y_u^\dagger T_u + T_u Y_d^\dagger Y_d + 5T_u Y_u^\dagger Y_u - \frac{13}{15} g_1^2 T_u - 3g_2^2 T_u - \frac{16}{3} g_3^2 T_u \\
& + 3T_u \text{Tr}(Y_u Y_u^\dagger) + Y_u (6g_2^2 M_2 + 6\text{Tr}(Y_u^\dagger T_u) + \frac{26}{15} g_1^2 M_1 + \frac{32}{3} g_3^2 M_3) \tag{45}
\end{aligned}$$

$$\begin{aligned}
\beta_{T_u}^{(2)} & = +\frac{4}{5} g_1^2 Y_u Y_d^\dagger T_d - \frac{4}{5} g_1^2 M_1 Y_u Y_u^\dagger Y_u - 12g_2^2 M_2 Y_u Y_u^\dagger Y_u + \frac{6}{5} g_1^2 Y_u Y_u^\dagger T_u \\
& + 6g_2^2 Y_u Y_u^\dagger T_u + \frac{2}{5} g_1^2 T_u Y_d^\dagger Y_d + 12g_2^2 T_u Y_u^\dagger Y_u - 4Y_u Y_d^\dagger Y_d Y_d^\dagger T_d \\
& - 2Y_u Y_d^\dagger Y_d Y_u^\dagger T_u - 4Y_u Y_d^\dagger T_d Y_d^\dagger Y_d - 4Y_u Y_d^\dagger T_d Y_u^\dagger Y_u - 6Y_u Y_u^\dagger Y_u Y_u^\dagger T_u \\
& - 8Y_u Y_u^\dagger T_u Y_u^\dagger Y_u - 2T_u Y_d^\dagger Y_d Y_d^\dagger Y_d - 4T_u Y_d^\dagger Y_d Y_u^\dagger Y_u - 6T_u Y_u^\dagger Y_u Y_u^\dagger Y_u + \frac{2743}{450} g_1^4 T_u \\
& + g_1^2 g_2^2 T_u + \frac{15}{2} g_2^4 T_u + \frac{136}{45} g_1^2 g_3^2 T_u + 8g_2^2 g_3^2 T_u - \frac{16}{9} g_3^4 T_u - 6Y_u Y_d^\dagger T_d \text{Tr}(Y_d Y_d^\dagger) \\
& - 3T_u Y_d^\dagger Y_d \text{Tr}(Y_d Y_d^\dagger) - 2Y_u Y_d^\dagger T_d \text{Tr}(Y_e Y_e^\dagger) - T_u Y_d^\dagger Y_d \text{Tr}(Y_e Y_e^\dagger) \\
& - 12Y_u Y_u^\dagger T_u \text{Tr}(Y_u Y_u^\dagger) - 15T_u Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) + \frac{4}{5} g_1^2 T_u \text{Tr}(Y_u Y_u^\dagger) \\
& + 16g_3^2 T_u \text{Tr}(Y_u Y_u^\dagger) - \frac{2}{5} Y_u Y_d^\dagger Y_d (15\text{Tr}(Y_d^\dagger T_d) + 2g_2^2 M_1 + 5\text{Tr}(Y_e^\dagger T_e)) \\
& - 18Y_u Y_u^\dagger Y_u \text{Tr}(Y_u^\dagger T_u) - 3T_u \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 9T_u \text{Tr}(Y_u Y_u^\dagger Y_u Y_u^\dagger) \\
& - \frac{2}{225} Y_u (2743g_1^4 M_1 + 225g_1^2 g_2^2 M_1 + 680g_1^2 g_3^2 M_1 + 680g_1^2 g_3^2 M_3 + 1800g_2^2 g_3^2 M_3 - 800g_3^4 M_3 \\
& + 225g_1^2 g_2^2 M_2 + 3375g_2^4 M_2 + 1800g_2^2 g_3^2 M_2 + 180(20g_3^2 M_3 + g_1^2 M_1) \text{Tr}(Y_u Y_u^\dagger) \\
& - 180(20g_3^2 + g_1^2) \text{Tr}(Y_u^\dagger T_u) + 675\text{Tr}(Y_d Y_u^\dagger T_u Y_d^\dagger) + 675\text{Tr}(Y_u Y_d^\dagger T_d Y_u^\dagger) \\
& + 4050\text{Tr}(Y_u Y_u^\dagger T_u Y_u^\dagger)) \tag{46}
\end{aligned}$$

### 3.7 Bilinear Soft-Breaking Parameters

$$\beta_{B_\mu}^{(1)} = +\frac{6}{5} g_1^2 M_1 \mu + 6g_2^2 M_2 \mu + B_\mu (-3g_2^2 + 3\text{Tr}(Y_d Y_d^\dagger) + 3\text{Tr}(Y_u Y_u^\dagger) - \frac{3}{5} g_1^2 + \text{Tr}(Y_e Y_e^\dagger))$$

$$+ 6\mu\text{Tr}\left(Y_d^\dagger T_d\right) + 2\mu\text{Tr}\left(Y_e^\dagger T_e\right) + 6\mu\text{Tr}\left(Y_u^\dagger T_u\right) \quad (47)$$

$$\begin{aligned} \beta_{B_\mu}^{(2)} = & +B_\mu\left(\frac{207}{50}g_1^4 + \frac{9}{5}g_1^2g_2^2 + \frac{15}{2}g_2^4 - \frac{2}{5}\left(-40g_3^2 + g_1^2\right)\text{Tr}\left(Y_dY_d^\dagger\right) + \frac{6}{5}g_1^2\text{Tr}\left(Y_eY_e^\dagger\right) + \frac{4}{5}g_1^2\text{Tr}\left(Y_uY_u^\dagger\right)\right. \\ & + 16g_3^2\text{Tr}\left(Y_uY_u^\dagger\right) - 9\text{Tr}\left(Y_dY_d^\dagger Y_dY_d^\dagger\right) - 6\text{Tr}\left(Y_dY_u^\dagger Y_uY_d^\dagger\right) - 3\text{Tr}\left(Y_eY_e^\dagger Y_eY_e^\dagger\right) - 9\text{Tr}\left(Y_uY_u^\dagger Y_uY_u^\dagger\right) \\ & - \frac{2}{25}\mu\left(207g_1^4M_1 + 45g_1^2g_2^2M_1 + 45g_1^2g_2^2M_2 + 375g_2^4M_2 - 10\left(-40g_3^2M_3 + g_1^2M_1\right)\text{Tr}\left(Y_dY_d^\dagger\right)\right. \\ & + 30g_1^2M_1\text{Tr}\left(Y_eY_e^\dagger\right) + 20g_1^2M_1\text{Tr}\left(Y_uY_u^\dagger\right) + 400g_3^2M_3\text{Tr}\left(Y_uY_u^\dagger\right) + 10g_1^2\text{Tr}\left(Y_d^\dagger T_d\right) \\ & - 400g_3^2\text{Tr}\left(Y_d^\dagger T_d\right) - 30g_1^2\text{Tr}\left(Y_e^\dagger T_e\right) - 20g_1^2\text{Tr}\left(Y_u^\dagger T_u\right) - 400g_3^2\text{Tr}\left(Y_u^\dagger T_u\right) \\ & + 450\text{Tr}\left(Y_dY_d^\dagger T_dY_d^\dagger\right) + 150\text{Tr}\left(Y_dY_u^\dagger T_uY_d^\dagger\right) + 150\text{Tr}\left(Y_eY_e^\dagger T_eY_e^\dagger\right) + 150\text{Tr}\left(Y_uY_d^\dagger T_dY_u^\dagger\right) \\ & \left. + 450\text{Tr}\left(Y_uY_u^\dagger T_uY_u^\dagger\right)\right) \end{aligned} \quad (48)$$

### 3.8 Soft-Breaking Scalar Masses

$$\sigma_{1,1} = \sqrt{\frac{3}{5}}g_1\left(-2\text{Tr}\left(m_u^2\right) - \text{Tr}\left(m_l^2\right) - m_{H_d}^2 + m_{H_u}^2 + \text{Tr}\left(m_d^2\right) + \text{Tr}\left(m_e^2\right) + \text{Tr}\left(m_q^2\right)\right) \quad (49)$$

$$\sigma_{2,11} = \frac{1}{10}g_1^2\left(2\text{Tr}\left(m_d^2\right) + 3\text{Tr}\left(m_l^2\right) + 3m_{H_d}^2 + 3m_{H_u}^2 + 6\text{Tr}\left(m_e^2\right) + 8\text{Tr}\left(m_u^2\right) + \text{Tr}\left(m_q^2\right)\right) \quad (50)$$

$$\begin{aligned} \sigma_{3,1} = & \frac{1}{20}\frac{1}{\sqrt{15}}g_1\left(-9g_1^2m_{H_d}^2 - 45g_2^2m_{H_d}^2 + 9g_1^2m_{H_u}^2 + 45g_2^2m_{H_u}^2 + 4\left(20g_3^2 + g_1^2\right)\text{Tr}\left(m_d^2\right) + 36g_1^2\text{Tr}\left(m_e^2\right)\right. \\ & - 9g_1^2\text{Tr}\left(m_l^2\right) - 45g_2^2\text{Tr}\left(m_l^2\right) + g_1^2\text{Tr}\left(m_q^2\right) + 45g_2^2\text{Tr}\left(m_q^2\right) + 80g_3^2\text{Tr}\left(m_q^2\right) - 32g_1^2\text{Tr}\left(m_u^2\right) \\ & - 160g_3^2\text{Tr}\left(m_u^2\right) + 90m_{H_d}^2\text{Tr}\left(Y_dY_d^\dagger\right) + 30m_{H_d}^2\text{Tr}\left(Y_eY_e^\dagger\right) - 90m_{H_u}^2\text{Tr}\left(Y_uY_u^\dagger\right) - 60\text{Tr}\left(Y_dY_d^\dagger m_d^{2*}\right) \\ & - 30\text{Tr}\left(Y_d m_q^{2*} Y_d^\dagger\right) - 60\text{Tr}\left(Y_eY_e^\dagger m_e^{2*}\right) + 30\text{Tr}\left(Y_e m_l^{2*} Y_e^\dagger\right) + 120\text{Tr}\left(Y_uY_u^\dagger m_u^{2*}\right) \\ & \left. - 30\text{Tr}\left(Y_u m_q^{2*} Y_u^\dagger\right)\right) \end{aligned} \quad (51)$$

$$\sigma_{2,2} = \frac{1}{2}\left(3\text{Tr}\left(m_q^2\right) + m_{H_d}^2 + m_{H_u}^2 + \text{Tr}\left(m_l^2\right)\right) \quad (52)$$

$$\sigma_{2,3} = \frac{1}{2}\left(2\text{Tr}\left(m_q^2\right) + \text{Tr}\left(m_d^2\right) + \text{Tr}\left(m_u^2\right)\right) \quad (53)$$

$$\begin{aligned} \beta_{m_q^2}^{(1)} = & -\frac{2}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 - 6g_2^2\mathbf{1}|M_2|^2 + 2m_{H_d}^2Y_d^\dagger Y_d + 2m_{H_u}^2Y_u^\dagger Y_u + 2T_d^\dagger T_d \\ & + 2T_u^\dagger T_u + m_q^2Y_d^\dagger Y_d + m_q^2Y_u^\dagger Y_u + 2Y_d^\dagger m_d^2 Y_d + Y_d^\dagger Y_d m_q^2 + 2Y_u^\dagger m_u^2 Y_u \\ & + Y_u^\dagger Y_u m_q^2 + \frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1} \end{aligned} \quad (54)$$

$$\beta_{m_q^2}^{(2)} = +\frac{2}{5}g_1^2g_2^2\mathbf{1}|M_2|^2 + 33g_2^4\mathbf{1}|M_2|^2 + 32g_2^2g_3^2\mathbf{1}|M_2|^2$$

$$\begin{aligned}
& + \frac{16}{45}g_3^2 \left( 15 \left( 3g_2^2 (2M_3 + M_2) - 8g_3^2 M_3 \right) + g_1^2 (2M_3 + M_1) \right) \mathbf{1}M_3^* + \frac{1}{5}g_1^2 g_2^2 M_1 \mathbf{1}M_2^* + 16g_2^2 g_3^2 M_3 \mathbf{1}M_2^* \\
& + \frac{4}{5}g_1^2 m_{H_d}^2 Y_d^\dagger Y_d + \frac{8}{5}g_1^2 m_{H_u}^2 Y_u^\dagger Y_u \\
& + \frac{1}{225}g_1^2 M_1^* \left( \left( 5 \left( 16g_3^2 (2M_1 + M_3) + 9g_2^2 (2M_1 + M_2) \right) + 597g_1^2 M_1 \right) \mathbf{1} \right. \\
& + 180 \left( 2M_1 Y_d^\dagger Y_d - 2Y_u^\dagger T_u + 4M_1 Y_u^\dagger Y_u - Y_d^\dagger T_d \right) \\
& - \frac{4}{5}g_1^2 M_1 T_d^\dagger Y_d + \frac{4}{5}g_1^2 T_d^\dagger T_d - \frac{8}{5}g_1^2 M_1 T_u^\dagger Y_u + \frac{8}{5}g_1^2 T_u^\dagger T_u \\
& + \frac{2}{5}g_1^2 m_q^2 Y_d^\dagger Y_d + \frac{4}{5}g_1^2 m_q^2 Y_u^\dagger Y_u + \frac{4}{5}g_1^2 Y_d^\dagger m_d^2 Y_d + \frac{2}{5}g_1^2 Y_d^\dagger Y_d m_q^2 \\
& + \frac{8}{5}g_1^2 Y_u^\dagger m_u^2 Y_u + \frac{4}{5}g_1^2 Y_u^\dagger Y_u m_q^2 - 8m_{H_d}^2 Y_d^\dagger Y_d Y_d^\dagger Y_d - 4Y_d^\dagger Y_d T_d^\dagger T_d \\
& - 4Y_d^\dagger T_d T_d^\dagger Y_d - 8m_{H_u}^2 Y_u^\dagger Y_u Y_u^\dagger Y_u - 4Y_u^\dagger Y_u T_u^\dagger T_u - 4Y_u^\dagger T_u T_u^\dagger Y_u \\
& - 4T_d^\dagger Y_d Y_d^\dagger T_d - 4T_d^\dagger T_d Y_d^\dagger Y_d - 4T_u^\dagger Y_u Y_u^\dagger T_u - 4T_u^\dagger T_u Y_u^\dagger Y_u \\
& - 2m_q^2 Y_d^\dagger Y_d Y_d^\dagger Y_d - 2m_q^2 Y_u^\dagger Y_u Y_u^\dagger Y_u - 4Y_d^\dagger m_d^2 Y_d Y_d^\dagger Y_d - 4Y_d^\dagger Y_d m_q^2 Y_d^\dagger Y_d \\
& - 4Y_d^\dagger Y_d Y_d^\dagger m_d^2 Y_d - 2Y_d^\dagger Y_d Y_d^\dagger Y_d m_q^2 - 4Y_u^\dagger m_u^2 Y_u Y_u^\dagger Y_u - 4Y_u^\dagger Y_u m_q^2 Y_u^\dagger Y_u \\
& - 4Y_u^\dagger Y_u Y_u^\dagger m_u^2 Y_u - 2Y_u^\dagger Y_u Y_u^\dagger Y_u m_q^2 + 6g_2^4 \mathbf{1}\sigma_{2,2} + \frac{32}{3}g_3^4 \mathbf{1}\sigma_{2,3} + \frac{2}{15}g_1^2 \mathbf{1}\sigma_{2,11} + 4\frac{1}{\sqrt{15}}g_1 \mathbf{1}\sigma_{3,1} \\
& - 12m_{H_d}^2 Y_d^\dagger Y_d \text{Tr} \left( Y_d Y_d^\dagger \right) - 6T_d^\dagger T_d \text{Tr} \left( Y_d Y_d^\dagger \right) - 3m_q^2 Y_d^\dagger Y_d \text{Tr} \left( Y_d Y_d^\dagger \right) \\
& - 6Y_d^\dagger m_d^2 Y_d \text{Tr} \left( Y_d Y_d^\dagger \right) - 3Y_d^\dagger Y_d m_q^2 \text{Tr} \left( Y_d Y_d^\dagger \right) - 4m_{H_d}^2 Y_d^\dagger Y_d \text{Tr} \left( Y_e Y_e^\dagger \right) \\
& - 2T_d^\dagger T_d \text{Tr} \left( Y_e Y_e^\dagger \right) - m_q^2 Y_d^\dagger Y_d \text{Tr} \left( Y_e Y_e^\dagger \right) - 2Y_d^\dagger m_d^2 Y_d \text{Tr} \left( Y_e Y_e^\dagger \right) \\
& - Y_d^\dagger Y_d m_q^2 \text{Tr} \left( Y_e Y_e^\dagger \right) - 12m_{H_u}^2 Y_u^\dagger Y_u \text{Tr} \left( Y_u Y_u^\dagger \right) - 6T_u^\dagger T_u \text{Tr} \left( Y_u Y_u^\dagger \right) \\
& - 3m_q^2 Y_u^\dagger Y_u \text{Tr} \left( Y_u Y_u^\dagger \right) - 6Y_u^\dagger m_u^2 Y_u \text{Tr} \left( Y_u Y_u^\dagger \right) - 3Y_u^\dagger Y_u m_q^2 \text{Tr} \left( Y_u Y_u^\dagger \right) \\
& - 6T_d^\dagger Y_d \text{Tr} \left( Y_e^\dagger T_e \right) - 2T_d^\dagger Y_d \text{Tr} \left( Y_e^\dagger T_e \right) - 6T_u^\dagger Y_u \text{Tr} \left( Y_u^\dagger T_u \right) \\
& - 6Y_d^\dagger T_d \text{Tr} \left( T_d^* Y_d^T \right) - 6Y_d^\dagger Y_d \text{Tr} \left( T_d^* T_d^T \right) - 2Y_d^\dagger T_d \text{Tr} \left( T_e^* Y_e^T \right) \\
& - 2Y_d^\dagger Y_d \text{Tr} \left( T_e^* T_e^T \right) - 6Y_u^\dagger T_u \text{Tr} \left( T_u^* Y_u^T \right) - 6Y_u^\dagger Y_u \text{Tr} \left( T_u^* T_u^T \right) \\
& - 6Y_d^\dagger Y_d \text{Tr} \left( m_e^2 Y_e Y_e^\dagger \right) - 2Y_d^\dagger Y_d \text{Tr} \left( m_e^2 Y_e Y_e^\dagger \right) - 2Y_d^\dagger Y_d \text{Tr} \left( m_l^2 Y_e^\dagger Y_e \right) \\
& - 6Y_d^\dagger Y_d \text{Tr} \left( m_q^2 Y_d^\dagger Y_d \right) - 6Y_u^\dagger Y_u \text{Tr} \left( m_q^2 Y_u^\dagger Y_u \right) - 6Y_u^\dagger Y_u \text{Tr} \left( m_u^2 Y_u Y_u^\dagger \right)
\end{aligned} \tag{55}$$

$$\beta_{m_l^2}^{(1)} = -\frac{6}{5}g_1^2 \mathbf{1}|M_1|^2 - 6g_2^2 \mathbf{1}|M_2|^2 + 2m_{H_d}^2 Y_e^\dagger Y_e + 2T_e^\dagger T_e + m_l^2 Y_e^\dagger Y_e + 2Y_e^\dagger m_e^2 Y_e$$

$$+ Y_e^\dagger Y_e m_l^2 - \sqrt{\frac{3}{5}}g_1 \mathbf{1}\sigma_{1,1} \tag{56}$$

$$\beta_{m_l^2}^{(2)} = +\frac{3}{5}g_2^2 \left( 3g_1^2 (2M_2 + M_1) + 55g_2^2 M_2 \right) \mathbf{1}M_2^* + \frac{12}{5}g_1^2 m_{H_d}^2 Y_e^\dagger Y_e$$

$$\begin{aligned}
& + \frac{3}{25}g_1^2M_1^* \left( -20Y_e^\dagger T_e + 3 \left( 5g_2^2(2M_1 + M_2) + 69g_1^2M_1 \right) \mathbf{1} + 40M_1Y_e^\dagger Y_e \right) - \frac{12}{5}g_1^2M_1T_e^\dagger Y_e \\
& + \frac{12}{5}g_1^2T_e^\dagger T_e + \frac{6}{5}g_1^2m_l^2Y_e^\dagger Y_e + \frac{12}{5}g_1^2Y_e^\dagger m_e^2Y_e + \frac{6}{5}g_1^2Y_e^\dagger Y_e m_l^2 \\
& - 8m_{H_d}^2Y_e^\dagger Y_e Y_e^\dagger Y_e - 4Y_e^\dagger Y_e T_e^\dagger T_e - 4Y_e^\dagger T_e T_e^\dagger Y_e - 4T_e^\dagger Y_e Y_e^\dagger T_e \\
& - 4T_e^\dagger T_e Y_e^\dagger Y_e - 2m_l^2Y_e^\dagger Y_e Y_e^\dagger Y_e - 4Y_e^\dagger m_e^2Y_e Y_e^\dagger Y_e - 4Y_e^\dagger Y_e m_l^2Y_e^\dagger Y_e \\
& - 4Y_e^\dagger Y_e Y_e^\dagger m_e^2Y_e - 2Y_e^\dagger Y_e Y_e^\dagger Y_e m_l^2 + 6g_2^4\mathbf{1}\sigma_{2,2} + \frac{6}{5}g_1^2\mathbf{1}\sigma_{2,11} - 4\sqrt{\frac{3}{5}}g_1\mathbf{1}\sigma_{3,1} \\
& - 12m_{H_d}^2Y_e^\dagger Y_e \text{Tr}(Y_d Y_d^\dagger) - 6T_e^\dagger T_e \text{Tr}(Y_d Y_d^\dagger) - 3m_l^2Y_e^\dagger Y_e \text{Tr}(Y_d Y_d^\dagger) \\
& - 6Y_e^\dagger m_e^2Y_e \text{Tr}(Y_d Y_d^\dagger) - 3Y_e^\dagger Y_e m_l^2 \text{Tr}(Y_d Y_d^\dagger) - 4m_{H_d}^2Y_e^\dagger Y_e \text{Tr}(Y_e Y_e^\dagger) \\
& - 2T_e^\dagger T_e \text{Tr}(Y_e Y_e^\dagger) - m_l^2Y_e^\dagger Y_e \text{Tr}(Y_e Y_e^\dagger) - 2Y_e^\dagger m_e^2Y_e \text{Tr}(Y_e Y_e^\dagger) \\
& - Y_e^\dagger Y_e m_l^2 \text{Tr}(Y_e Y_e^\dagger) - 6T_e^\dagger Y_e \text{Tr}(Y_d^\dagger T_d) - 2T_e^\dagger Y_e \text{Tr}(Y_e^\dagger T_e) \\
& - 6Y_e^\dagger T_e \text{Tr}(T_d^* Y_d^T) - 6Y_e^\dagger Y_e \text{Tr}(T_d^* T_d^T) - 2Y_e^\dagger T_e \text{Tr}(T_e^* Y_e^T) \\
& - 2Y_e^\dagger Y_e \text{Tr}(T_e^* T_e^T) - 6Y_e^\dagger Y_e \text{Tr}(m_d^2 Y_d Y_d^\dagger) - 2Y_e^\dagger Y_e \text{Tr}(m_e^2 Y_e Y_e^\dagger) \\
& - 2Y_e^\dagger Y_e \text{Tr}(m_l^2 Y_e^\dagger Y_e) - 6Y_e^\dagger Y_e \text{Tr}(m_q^2 Y_d^\dagger Y_d) \tag{57}
\end{aligned}$$

$$\begin{aligned}
\beta_{m_{H_d}^2}^{(1)} & = -\frac{6}{5}g_1^2|M_1|^2 - 6g_2^2|M_2|^2 - \sqrt{\frac{3}{5}}g_1\sigma_{1,1} + 6m_{H_d}^2 \text{Tr}(Y_d Y_d^\dagger) + 2m_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) + 6\text{Tr}(T_d^* T_d^T) \\
& + 2\text{Tr}(T_e^* T_e^T) + 6\text{Tr}(m_d^2 Y_d Y_d^\dagger) + 2\text{Tr}(m_e^2 Y_e Y_e^\dagger) + 2\text{Tr}(m_l^2 Y_e^\dagger Y_e) + 6\text{Tr}(m_q^2 Y_d^\dagger Y_d) \tag{58}
\end{aligned}$$

$$\begin{aligned}
\beta_{m_{H_d}^2}^{(2)} & = \frac{1}{25} \left( 15g_2^2(3g_1^2(2M_2 + M_1) + 55g_2^2M_2)M_2^* \right. \\
& + g_1^2M_1^* \left( 621g_1^2M_1 + 90g_2^2M_1 + 45g_2^2M_2 - 40M_1 \text{Tr}(Y_d Y_d^\dagger) + 120M_1 \text{Tr}(Y_e Y_e^\dagger) + 20\text{Tr}(Y_d^\dagger T_d) \right. \\
& \left. \left. - 60\text{Tr}(Y_e^\dagger T_e) \right) \right) \\
& + 10 \left( 15g_2^4\sigma_{2,2} + 3g_1^2\sigma_{2,11} - 2\sqrt{15}g_1\sigma_{3,1} + \left( 160g_3^2|M_3|^2 - 2g_1^2m_{H_d}^2 + 80g_3^2m_{H_d}^2 \right) \text{Tr}(Y_d Y_d^\dagger) \right. \\
& + 6g_1^2m_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) - 80g_3^2M_3^* \text{Tr}(Y_d^\dagger T_d) + 2g_1^2M_1 \text{Tr}(T_d^* Y_d^T) - 80g_3^2M_3 \text{Tr}(T_d^* Y_d^T) \\
& - 2g_1^2 \text{Tr}(T_d^* T_d^T) + 80g_3^2 \text{Tr}(T_d^* T_d^T) - 6g_1^2M_1 \text{Tr}(T_e^* Y_e^T) + 6g_1^2 \text{Tr}(T_e^* T_e^T) \\
& - 2g_1^2 \text{Tr}(m_d^2 Y_d Y_d^\dagger) + 80g_3^2 \text{Tr}(m_d^2 Y_d Y_d^\dagger) + 6g_1^2 \text{Tr}(m_e^2 Y_e Y_e^\dagger) + 6g_1^2 \text{Tr}(m_l^2 Y_e^\dagger Y_e) \\
& - 2g_1^2 \text{Tr}(m_q^2 Y_d^\dagger Y_d) + 80g_3^2 \text{Tr}(m_q^2 Y_d^\dagger Y_d) - 90m_{H_d}^2 \text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 90\text{Tr}(Y_d Y_d^\dagger T_d T_d^\dagger) \\
& - 15m_{H_d}^2 \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 15m_{H_d}^2 \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 15\text{Tr}(Y_d Y_u^\dagger T_u T_u^\dagger) \\
& \left. \left. - 90\text{Tr}(Y_d T_d^\dagger T_d Y_d^\dagger) - 15\text{Tr}(Y_d T_u^\dagger T_u Y_d^\dagger) - 30m_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) - 30\text{Tr}(Y_e Y_e^\dagger T_e T_e^\dagger) \right) \right)
\end{aligned}$$

$$\begin{aligned}
& -30\text{Tr}\left(Y_e T_e^\dagger T_e Y_e^\dagger\right) - 15\text{Tr}\left(Y_u Y_d^\dagger T_d T_u^\dagger\right) - 15\text{Tr}\left(Y_u T_d^\dagger T_d Y_u^\dagger\right) - 90\text{Tr}\left(m_d^2 Y_d Y_d^\dagger Y_d Y_d^\dagger\right) \\
& - 15\text{Tr}\left(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 30\text{Tr}\left(m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger\right) - 30\text{Tr}\left(m_l^2 Y_e^\dagger Y_e Y_e^\dagger Y_e\right) - 90\text{Tr}\left(m_q^2 Y_d^\dagger Y_d Y_d^\dagger Y_d\right) \\
& - 15\text{Tr}\left(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\right) - 15\text{Tr}\left(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\right) - 15\text{Tr}\left(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\right)
\end{aligned} \tag{59}$$

$$\begin{aligned}
\beta_{m_{H_u}^2}^{(1)} &= -\frac{6}{5}g_1^2|M_1|^2 - 6g_2^2|M_2|^2 + \sqrt{\frac{3}{5}}g_1\sigma_{1,1} + 6m_{H_u}^2\text{Tr}\left(Y_u Y_u^\dagger\right) + 6\text{Tr}\left(T_u^* T_u^T\right) + 6\text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) \\
&+ 6\text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right)
\end{aligned} \tag{60}$$

$$\begin{aligned}
\beta_{m_{H_u}^2}^{(2)} &= +\frac{3}{5}g_2^2\left(3g_1^2\left(2M_2 + M_1\right) + 55g_2^2M_2\right)M_2^* + 6g_2^4\sigma_{2,2} + \frac{6}{5}g_1^2\sigma_{2,11} + 4\sqrt{\frac{3}{5}}g_1\sigma_{3,1} + \frac{8}{5}g_1^2m_{H_u}^2\text{Tr}\left(Y_u Y_u^\dagger\right) \\
&+ 32g_3^2m_{H_u}^2\text{Tr}\left(Y_u Y_u^\dagger\right) + 64g_3^2|M_3|^2\text{Tr}\left(Y_u Y_u^\dagger\right) \\
&+ \frac{1}{25}g_1^2M_1^*\left(-40\text{Tr}\left(Y_u^\dagger T_u\right) + 45g_2^2M_2 + 621g_1^2M_1 + 80M_1\text{Tr}\left(Y_u Y_u^\dagger\right) + 90g_2^2M_1\right) \\
&- 32g_3^2M_3^*\text{Tr}\left(Y_u^\dagger T_u\right) - \frac{8}{5}g_1^2M_1\text{Tr}\left(T_u^* Y_u^T\right) - 32g_3^2M_3\text{Tr}\left(T_u^* Y_u^T\right) + \frac{8}{5}g_1^2\text{Tr}\left(T_u^* T_u^T\right) \\
&+ 32g_3^2\text{Tr}\left(T_u^* T_u^T\right) + \frac{8}{5}g_1^2\text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) + 32g_3^2\text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) + \frac{8}{5}g_1^2\text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right) \\
&+ 32g_3^2\text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right) - 6m_{H_d}^2\text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 6m_{H_u}^2\text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) \\
&- 6\text{Tr}\left(Y_d Y_u^\dagger T_u T_d^\dagger\right) - 6\text{Tr}\left(Y_d T_u^\dagger T_u Y_d^\dagger\right) - 6\text{Tr}\left(Y_u Y_d^\dagger T_d T_u^\dagger\right) - 36m_{H_u}^2\text{Tr}\left(Y_u Y_u^\dagger Y_u Y_u^\dagger\right) \\
&- 36\text{Tr}\left(Y_u Y_u^\dagger T_u T_u^\dagger\right) - 6\text{Tr}\left(Y_u T_d^\dagger T_d Y_u^\dagger\right) - 36\text{Tr}\left(Y_u T_u^\dagger T_u Y_u^\dagger\right) \\
&- 6\text{Tr}\left(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 6\text{Tr}\left(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\right) - 6\text{Tr}\left(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\right) \\
&- 36\text{Tr}\left(m_q^2 Y_u^\dagger Y_u Y_u^\dagger Y_u\right) - 6\text{Tr}\left(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\right) - 36\text{Tr}\left(m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger\right)
\end{aligned} \tag{61}$$

$$\begin{aligned}
\beta_{m_d^2}^{(1)} &= -\frac{8}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 + 4m_{H_d}^2 Y_d Y_d^\dagger + 4T_d T_d^\dagger + 2m_d^2 Y_d Y_d^\dagger + 4Y_d m_q^2 Y_d^\dagger \\
&+ 2Y_d Y_d^\dagger m_d^2 + 2\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1}
\end{aligned} \tag{62}$$

$$\begin{aligned}
\beta_{m_d^2}^{(2)} &= +\frac{64}{45}g_3^2\left(-30g_3^2M_3 + g_1^2\left(2M_3 + M_1\right)\right)\mathbf{1}M_3^* + \frac{4}{5}g_1^2m_{H_d}^2 Y_d Y_d^\dagger + 12g_2^2m_{H_d}^2 Y_d Y_d^\dagger \\
&+ 24g_2^2|M_2|^2 Y_d Y_d^\dagger - \frac{4}{5}g_1^2M_1 Y_d T_d^\dagger - 12g_2^2M_2 Y_d T_d^\dagger \\
&+ \frac{4}{225}g_1^2M_1^*\left(2\left(303g_1^2M_1 + 40g_3^2\left(2M_1 + M_3\right)\right)\mathbf{1} - 45T_d Y_d^\dagger + 90M_1 Y_d Y_d^\dagger\right) - 12g_2^2M_2^* T_d Y_d^\dagger \\
&+ \frac{4}{5}g_1^2 T_d T_d^\dagger + 12g_2^2 T_d T_d^\dagger + \frac{2}{5}g_1^2 m_d^2 Y_d Y_d^\dagger + 6g_2^2 m_d^2 Y_d Y_d^\dagger \\
&+ \frac{4}{5}g_1^2 Y_d m_q^2 Y_d^\dagger + 12g_2^2 Y_d m_q^2 Y_d^\dagger + \frac{2}{5}g_1^2 Y_d Y_d^\dagger m_d^2 + 6g_2^2 Y_d Y_d^\dagger m_d^2 \\
&- 8m_{H_d}^2 Y_d Y_d^\dagger Y_d Y_d^\dagger - 4Y_d Y_d^\dagger T_d T_d^\dagger - 4m_{H_d}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger \\
&- 4m_{H_u}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger - 4Y_d Y_u^\dagger T_u T_d^\dagger - 4Y_d T_d^\dagger T_d Y_d^\dagger - 4Y_d T_u^\dagger T_u Y_d^\dagger
\end{aligned}$$

$$\begin{aligned}
& -4T_d Y_d^\dagger Y_d T_d^\dagger - 4T_d Y_u^\dagger Y_u T_d^\dagger - 4T_d T_d^\dagger Y_d Y_d^\dagger - 4T_d T_d^\dagger Y_u Y_u^\dagger \\
& -2m_d^2 Y_d Y_d^\dagger Y_d Y_d^\dagger - 2m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger - 4Y_d m_q^2 Y_d^\dagger Y_d Y_d^\dagger - 4Y_d m_q^2 Y_u^\dagger Y_u Y_d^\dagger \\
& -4Y_d Y_d^\dagger m_d^2 Y_d Y_d^\dagger - 4Y_d Y_d^\dagger Y_d m_q^2 Y_d^\dagger - 2Y_d Y_d^\dagger Y_d Y_d^\dagger m_d^2 - 4Y_d Y_u^\dagger m_u^2 Y_u Y_d^\dagger \\
& -4Y_d Y_u^\dagger Y_u m_q^2 Y_d^\dagger - 2Y_d Y_u^\dagger Y_u Y_d^\dagger m_d^2 + \frac{32}{3} g_3^4 \mathbf{1}\sigma_{2,3} + \frac{8}{15} g_1^2 \mathbf{1}\sigma_{2,11} + 8 \frac{1}{\sqrt{15}} g_1 \mathbf{1}\sigma_{3,1} \\
& -24m_{H_d}^2 Y_d Y_d^\dagger \text{Tr}(Y_d Y_d^\dagger) - 12T_d T_d^\dagger \text{Tr}(Y_d Y_d^\dagger) - 6m_d^2 Y_d Y_d^\dagger \text{Tr}(Y_d Y_d^\dagger) \\
& -12Y_d m_q^2 Y_d^\dagger \text{Tr}(Y_d Y_d^\dagger) - 6Y_d Y_d^\dagger m_d^2 \text{Tr}(Y_d Y_d^\dagger) - 8m_{H_d}^2 Y_d Y_d^\dagger \text{Tr}(Y_e Y_e^\dagger) \\
& -4T_d T_d^\dagger \text{Tr}(Y_e Y_e^\dagger) - 2m_d^2 Y_d Y_d^\dagger \text{Tr}(Y_e Y_e^\dagger) - 4Y_d m_q^2 Y_d^\dagger \text{Tr}(Y_e Y_e^\dagger) \\
& -2Y_d Y_d^\dagger m_d^2 \text{Tr}(Y_e Y_e^\dagger) - 12Y_d T_d^\dagger \text{Tr}(Y_d^\dagger T_d) - 4Y_d T_d^\dagger \text{Tr}(Y_e^\dagger T_e) \\
& -12T_d Y_d^\dagger \text{Tr}(T_d^* Y_d^T) - 12Y_d Y_d^\dagger \text{Tr}(T_d^* T_d^T) - 4T_d Y_d^\dagger \text{Tr}(T_e^* Y_e^T) \\
& -4Y_d Y_d^\dagger \text{Tr}(T_e^* T_e^T) - 12Y_d Y_d^\dagger \text{Tr}(m_d^2 Y_d Y_d^\dagger) - 4Y_d Y_d^\dagger \text{Tr}(m_e^2 Y_e Y_e^\dagger) \\
& -4Y_d Y_d^\dagger \text{Tr}(m_l^2 Y_e^\dagger Y_e) - 12Y_d Y_d^\dagger \text{Tr}(m_q^2 Y_d^\dagger Y_d)
\end{aligned} \tag{63}$$

$$\begin{aligned}
\beta_{m_u^2}^{(1)} &= -\frac{32}{15} g_1^2 \mathbf{1}|M_1|^2 - \frac{32}{3} g_3^2 \mathbf{1}|M_3|^2 + 4m_{H_u}^2 Y_u Y_u^\dagger + 4T_u T_u^\dagger + 2m_u^2 Y_u Y_u^\dagger + 4Y_u m_q^2 Y_u^\dagger \\
&+ 2Y_u Y_u^\dagger m_u^2 - 4 \frac{1}{\sqrt{15}} g_1 \mathbf{1}\sigma_{1,1}
\end{aligned} \tag{64}$$

$$\begin{aligned}
\beta_{m_u^2}^{(2)} &= -\frac{128}{45} g_3^2 (15g_3^2 M_3 - 2g_1^2 (2M_3 + M_1)) \mathbf{1}M_3^* - \frac{4}{5} g_1^2 m_{H_u}^2 Y_u Y_u^\dagger + 12g_2^2 m_{H_u}^2 Y_u Y_u^\dagger \\
&+ 24g_2^2 |M_2|^2 Y_u Y_u^\dagger + \frac{4}{5} g_1^2 M_1 Y_u T_u^\dagger - 12g_2^2 M_2 Y_u T_u^\dagger - 12g_2^2 M_2^* T_u Y_u^\dagger \\
&+ \frac{4}{225} g_1^2 M_1^* (45(-2M_1 Y_u Y_u^\dagger + T_u Y_u^\dagger) + 8(321g_1^2 M_1 + 40g_3^2 (2M_1 + M_3))) \mathbf{1} - \frac{4}{5} g_1^2 T_u T_u^\dagger \\
&+ 12g_2^2 T_u T_u^\dagger - \frac{2}{5} g_1^2 m_u^2 Y_u Y_u^\dagger + 6g_2^2 m_u^2 Y_u Y_u^\dagger - \frac{4}{5} g_1^2 Y_u m_q^2 Y_u^\dagger \\
&+ 12g_2^2 Y_u m_q^2 Y_u^\dagger - \frac{2}{5} g_1^2 Y_u Y_u^\dagger m_u^2 + 6g_2^2 Y_u Y_u^\dagger m_u^2 - 4m_{H_d}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger \\
&- 4m_{H_u}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger - 4Y_u Y_d^\dagger T_d T_u^\dagger - 8m_{H_u}^2 Y_u Y_u^\dagger Y_u Y_u^\dagger - 4Y_u Y_u^\dagger T_u T_u^\dagger \\
&- 4Y_u T_d^\dagger T_d Y_u^\dagger - 4Y_u T_u^\dagger T_u Y_u^\dagger - 4T_u Y_d^\dagger Y_d T_u^\dagger - 4T_u Y_u^\dagger Y_u T_u^\dagger \\
&- 4T_u T_d^\dagger Y_d Y_u^\dagger - 4T_u T_u^\dagger Y_u Y_u^\dagger - 2m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger - 2m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger \\
&- 4Y_u m_q^2 Y_d^\dagger Y_d Y_u^\dagger - 4Y_u m_q^2 Y_u^\dagger Y_u Y_u^\dagger - 4Y_u Y_d^\dagger m_d^2 Y_d Y_u^\dagger \\
&- 4Y_u Y_d^\dagger Y_d m_q^2 Y_u^\dagger - 2Y_u Y_d^\dagger Y_d Y_u^\dagger m_u^2 - 4Y_u Y_u^\dagger m_u^2 Y_u Y_u^\dagger - 4Y_u Y_u^\dagger Y_u m_q^2 Y_u^\dagger \\
&- 2Y_u Y_u^\dagger Y_u Y_u^\dagger m_u^2 + \frac{32}{3} g_3^4 \mathbf{1}\sigma_{2,3} + \frac{32}{15} g_1^2 \mathbf{1}\sigma_{2,11} - 16 \frac{1}{\sqrt{15}} g_1 \mathbf{1}\sigma_{3,1} - 24m_{H_u}^2 Y_u Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) \\
&- 12T_u T_u^\dagger \text{Tr}(Y_u Y_u^\dagger) - 6m_u^2 Y_u Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) - 12Y_u m_q^2 Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger)
\end{aligned}$$

$$\begin{aligned}
& -6Y_u Y_u^\dagger m_u^2 \text{Tr}(Y_u Y_u^\dagger) - 12Y_u T_u^\dagger \text{Tr}(Y_u^\dagger T_u) - 12T_u Y_u^\dagger \text{Tr}(T_u^* Y_u^T) \\
& - 12Y_u Y_u^\dagger \text{Tr}(T_u^* T_u^T) - 12Y_u Y_u^\dagger \text{Tr}(m_q^2 Y_u^\dagger Y_u) - 12Y_u Y_u^\dagger \text{Tr}(m_u^2 Y_u Y_u^\dagger)
\end{aligned} \tag{65}$$

$$\begin{aligned}
\beta_{m_e^2}^{(1)} &= -\frac{24}{5} g_1^2 \mathbf{1} |M_1|^2 + 2 \left( 2m_{H_d}^2 Y_e Y_e^\dagger + 2T_e T_e^\dagger + 2Y_e m_l^2 Y_e^\dagger + m_e^2 Y_e Y_e^\dagger + Y_e Y_e^\dagger m_e^2 \right) \\
&+ 2\sqrt{\frac{3}{5}} g_1 \mathbf{1} \sigma_{1,1}
\end{aligned} \tag{66}$$

$$\begin{aligned}
\beta_{m_e^2}^{(2)} &= \frac{2}{25} \left( 6g_1^2 M_1^* \left( 234g_1^2 M_1 \mathbf{1} + 5 \left( -2M_1 Y_e Y_e^\dagger + T_e Y_e^\dagger \right) \right) + 20g_1 \mathbf{1} \left( 3g_1 \sigma_{2,11} + \sqrt{15} \sigma_{3,1} \right) \right. \\
&- 5 \left( 30g_2^2 M_2^* T_e Y_e^\dagger + 6g_1^2 T_e T_e^\dagger - 30g_2^2 T_e T_e^\dagger + 3g_1^2 m_e^2 Y_e Y_e^\dagger \right. \\
&- 15g_2^2 m_e^2 Y_e Y_e^\dagger + 6g_1^2 Y_e m_l^2 Y_e^\dagger - 30g_2^2 Y_e m_l^2 Y_e^\dagger + 3g_1^2 Y_e Y_e^\dagger m_e^2 \\
&- 15g_2^2 Y_e Y_e^\dagger m_e^2 + 20m_{H_d}^2 Y_e Y_e^\dagger Y_e Y_e^\dagger + 10Y_e Y_e^\dagger T_e T_e^\dagger + 10Y_e T_e^\dagger T_e Y_e^\dagger \\
&+ 10T_e Y_e^\dagger Y_e T_e^\dagger + 10T_e T_e^\dagger Y_e Y_e^\dagger + 5m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger + 10Y_e m_l^2 Y_e^\dagger Y_e Y_e^\dagger \\
&+ 10Y_e Y_e^\dagger m_e^2 Y_e Y_e^\dagger + 10Y_e Y_e^\dagger Y_e m_l^2 Y_e^\dagger + 5Y_e Y_e^\dagger Y_e Y_e^\dagger m_e^2 + 30T_e T_e^\dagger \text{Tr}(Y_d Y_d^\dagger) \\
&+ 15m_e^2 Y_e Y_e^\dagger \text{Tr}(Y_d Y_d^\dagger) + 30Y_e m_l^2 Y_e^\dagger \text{Tr}(Y_d Y_d^\dagger) + 15Y_e Y_e^\dagger m_e^2 \text{Tr}(Y_d Y_d^\dagger) \\
&+ 10T_e T_e^\dagger \text{Tr}(Y_e Y_e^\dagger) + 5m_e^2 Y_e Y_e^\dagger \text{Tr}(Y_e Y_e^\dagger) + 10Y_e m_l^2 Y_e^\dagger \text{Tr}(Y_e Y_e^\dagger) \\
&+ 5Y_e Y_e^\dagger m_e^2 \text{Tr}(Y_e Y_e^\dagger) + Y_e T_e^\dagger \left( 10\text{Tr}(Y_e^\dagger T_e) + 30g_2^2 M_2 + 30\text{Tr}(Y_d^\dagger T_d) - 6g_1^2 M_1 \right) \\
&+ 30T_e Y_e^\dagger \text{Tr}(T_d^* Y_d^T) + 10T_e Y_e^\dagger \text{Tr}(T_e^* Y_e^T) \\
&+ 2Y_e Y_e^\dagger \left( 3g_1^2 m_{H_d}^2 - 15g_2^2 m_{H_d}^2 - 30g_2^2 |M_2|^2 + 30m_{H_d}^2 \text{Tr}(Y_d Y_d^\dagger) + 10m_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) + 15\text{Tr}(T_d^* T_d^T) \right. \\
&\left. + 5\text{Tr}(T_e^* T_e^T) + 15\text{Tr}(m_d^2 Y_d Y_d^\dagger) + 5\text{Tr}(m_e^2 Y_e Y_e^\dagger) + 5\text{Tr}(m_l^2 Y_e^\dagger Y_e) + 15\text{Tr}(m_q^2 Y_d^\dagger Y_d) \right) \Big)
\end{aligned} \tag{67}$$

### 3.9 Vacuum expectation values

$$\beta_{v_d}^{(1)} = \frac{1}{20} v_d \left( -20\text{Tr}(Y_e Y_e^\dagger) + 3(5g_2^2 + g_1^2)(1 + \text{Xi}) - 60\text{Tr}(Y_d Y_d^\dagger) \right) \tag{68}$$

$$\begin{aligned}
\beta_{v_d}^{(2)} &= \frac{1}{400} v_d \left( -414g_1^4 - 180g_1^2 g_2^2 - 1200g_2^4 - 9g_1^4 \text{Xi} - 90g_1^2 g_2^2 \text{Xi} + 875g_2^4 \text{Xi} + 9g_1^4 \text{Xi}^2 + 90g_1^2 g_2^2 \text{Xi}^2 \right. \\
&- 225g_2^4 \text{Xi}^2 - 40 \left( 5(32g_3^2 + 9g_2^2 \text{Xi}) + g_1^2(9\text{Xi} - 4) \right) \text{Tr}(Y_d Y_d^\dagger) - 120(5g_2^2 \text{Xi} + g_1^2(4 + \text{Xi})) \text{Tr}(Y_e Y_e^\dagger) \\
&\left. + 3600\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) + 1200\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) + 1200\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \right)
\end{aligned} \tag{69}$$

$$\beta_{v_u}^{(1)} = \frac{3}{20} v_u \left( -20\text{Tr}(Y_u Y_u^\dagger) + (5g_2^2 + g_1^2)(1 + \text{Xi}) \right) \tag{70}$$

$$\beta_{v_u}^{(2)} = \frac{1}{400} v_u \left( -414g_1^4 - 180g_1^2 g_2^2 - 1200g_2^4 - 9g_1^4 \text{Xi} - 90g_1^2 g_2^2 \text{Xi} + 875g_2^4 \text{Xi} + 9g_1^4 \text{Xi}^2 + 90g_1^2 g_2^2 \text{Xi}^2 \right)$$

$$-225g_2^4 X_i^2 - 40\left(5\left(32g_3^2 + 9g_2^2 X_i\right) + g_1^2(9X_i + 8)\right)\text{Tr}\left(Y_u Y_u^\dagger\right) + 1200\text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) + 3600\text{Tr}\left(Y_u Y_u^\dagger Y_u Y_u^\dagger\right) \quad (71)$$

## 4 Field Rotations

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

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \end{pmatrix} = Z^{\gamma Z} \begin{pmatrix} \gamma_\rho \\ Z_\rho \end{pmatrix} \quad (72)$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho} \end{pmatrix} = Z^W \begin{pmatrix} W_\rho^- \\ W_\rho^- \end{pmatrix} \quad (73)$$

$$\begin{pmatrix} \lambda_{\tilde{W},1} \\ \lambda_{\tilde{W},2} \\ \lambda_{\tilde{W},3} \end{pmatrix} = Z^{\tilde{W}} \begin{pmatrix} \tilde{W}^- \\ \tilde{W}^+ \\ \tilde{W}^0 \end{pmatrix} \quad (74)$$

$$(75)$$

The mixing matrices are parametrized by

$$Z^{\gamma Z} = \begin{pmatrix} \cos \Theta_W & -\sin \Theta_W \\ \sin \Theta_W & \cos \Theta_W \end{pmatrix} \quad (76)$$

$$Z^W = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} \end{pmatrix} \quad (77)$$

$$Z^{\tilde{W}} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (78)$$

$$(79)$$

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

#### 4.2.1 Mass Matrices for Scalars

- Mass matrix for Down-Squarks, Basis:  $(\tilde{d}_{L,\alpha_1}, \tilde{d}_{R,\alpha_2}), (\tilde{d}_{L,\beta_1}^*, \tilde{d}_{R,\beta_2}^*)$

$$m_{\tilde{d}}^2 = \begin{pmatrix} m_{\tilde{d}_L \tilde{d}_L} & \frac{1}{\sqrt{2}} \left( -e^{i\eta} v_u \mu Y_d^\dagger + v_d T_d^\dagger \right) \delta_{\alpha_1 \beta_2} \\ \frac{1}{\sqrt{2}} e^{-i\eta} \delta_{\alpha_2 \beta_1} \left( e^{i\eta} v_d T_d - v_u Y_d \mu^* \right) & m_{\tilde{d}_R \tilde{d}_R} \end{pmatrix} \quad (80)$$



$$m_{\tilde{d}_L \tilde{d}_L^*} = -\frac{1}{24} (3g_2^2 + g_1^2) \mathbf{1} \left( -v_u^2 + v_d^2 \right) \delta_{\alpha_1 \beta_1} + \frac{1}{2} \delta_{\alpha_1 \beta_1} \left( 2m_q^2 + v_d^2 Y_d^\dagger Y_d \right) \quad (81)$$

$$m_{\tilde{d}_R \tilde{d}_R^*} = \frac{1}{12} g_1^2 \mathbf{1} \left( -v_d^2 + v_u^2 \right) \delta_{\alpha_2 \beta_2} + \frac{1}{2} \delta_{\alpha_2 \beta_2} \left( 2m_d^2 + v_d^2 Y_d Y_d^\dagger \right) \quad (82)$$

This matrix is diagonalized by  $Z^D$ :

$$Z^D m_{\tilde{d}}^2 Z^{D,\dagger} = m_{2,d}^{dia} \quad (83)$$

with

$$\tilde{d}_{L,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha}, \quad \tilde{d}_{R,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha} \quad (84)$$

- **Mass matrix for Up-Squarks**, Basis:  $(\tilde{u}_{L,\alpha_1}, \tilde{u}_{R,\alpha_2}), (\tilde{u}_{L,\beta_1}^*, \tilde{u}_{R,\beta_2}^*)$

$$m_{\tilde{u}}^2 = \begin{pmatrix} m_{\tilde{u}_L \tilde{u}_L^*} & \frac{1}{\sqrt{2}} \left( e^{-in} v_u T_u^\dagger - v_d \mu Y_u^\dagger \right) \delta_{\alpha_1 \beta_2} \\ \frac{1}{\sqrt{2}} \delta_{\alpha_2 \beta_1} \left( e^{in} v_u T_u - v_d Y_u \mu^* \right) & m_{\tilde{u}_R \tilde{u}_R^*} \end{pmatrix} \quad (85)$$

$$m_{\tilde{u}_L \tilde{u}_L^*} = -\frac{1}{24} \left( -3g_2^2 + g_1^2 \right) \mathbf{1} \left( -v_u^2 + v_d^2 \right) \delta_{\alpha_1 \beta_1} + \frac{1}{2} \delta_{\alpha_1 \beta_1} \left( 2m_q^2 + v_u^2 Y_u^\dagger Y_u \right) \quad (86)$$

$$m_{\tilde{u}_R \tilde{u}_R^*} = \frac{1}{2} \delta_{\alpha_2 \beta_2} \left( 2m_u^2 + v_u^2 Y_u Y_u^\dagger \right) + \frac{1}{6} g_1^2 \mathbf{1} \left( -v_u^2 + v_d^2 \right) \delta_{\alpha_2 \beta_2} \quad (87)$$

This matrix is diagonalized by  $Z^U$ :

$$Z^U m_{\tilde{u}}^2 Z^{U,\dagger} = m_{2,u}^{dia} \quad (88)$$

with

$$\tilde{u}_{L,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha}, \quad \tilde{u}_{R,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha} \quad (89)$$

- **Mass matrix for Sleptons**, Basis:  $(\tilde{e}_L, \tilde{e}_R), (\tilde{e}_L^*, \tilde{e}_R^*)$

$$m_{\tilde{e}}^2 = \begin{pmatrix} m_{\tilde{e}_L \tilde{e}_L^*} & \frac{1}{\sqrt{2}} \left( -e^{in} v_u \mu Y_e^\dagger + v_d T_e^\dagger \right) \\ \frac{1}{\sqrt{2}} \left( -e^{-in} v_u Y_e \mu^* + v_d T_e \right) & m_{\tilde{e}_R \tilde{e}_R^*} \end{pmatrix} \quad (90)$$

$$m_{\tilde{e}_L \tilde{e}_L^*} = \frac{1}{2} v_d^2 Y_e^\dagger Y_e + \frac{1}{8} \left( -g_2^2 + g_1^2 \right) \mathbf{1} \left( -v_u^2 + v_d^2 \right) + m_l^2 \quad (91)$$

$$m_{\tilde{e}_R \tilde{e}_R^*} = \frac{1}{2} v_d^2 Y_e Y_e^\dagger + \frac{1}{4} g_1^2 \mathbf{1} \left( -v_d^2 + v_u^2 \right) + m_e^2 \quad (92)$$

This matrix is diagonalized by  $Z^E$ :

$$Z^E m_{\tilde{e}}^2 Z^{E,\dagger} = m_{2,e}^{dia} \quad (93)$$

with

$$\tilde{e}_{L,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j, \quad \tilde{e}_{R,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j \quad (94)$$

- **Mass matrix for Sneutrinos**, Basis:  $(\tilde{\nu}_L), (\tilde{\nu}_L^*)$

$$m_{\tilde{\nu}}^2 = \left( \frac{1}{8} (g_1^2 + g_2^2) \mathbf{1} \left( -v_u^2 + v_d^2 \right) + m_t^2 \right) \quad (95)$$

This matrix is diagonalized by  $Z^V$ :

$$Z^V m_{\tilde{\nu}}^2 Z^{V,\dagger} = m_{2,\tilde{\nu}}^{dia} \quad (96)$$

with

$$\tilde{\nu}_{L,i} = \sum_j Z_{ji}^{V,*} \tilde{\nu}_j \quad (97)$$

- **Mass matrix for Higgs**, Basis:  $(\phi_d, \phi_u, \sigma_d, \sigma_u), (\phi_d, \phi_u, \sigma_d, \sigma_u)$

$$m_h^2 = \begin{pmatrix} m_{\phi_d \phi_d} & m_{\phi_u \phi_d} & 0 & m_{\sigma_u \phi_d} \\ m_{\phi_d \phi_u} & m_{\phi_u \phi_u} & m_{\sigma_d \phi_u} & 0 \\ 0 & m_{\phi_u \sigma_d} & m_{\sigma_d \sigma_d} & m_{\sigma_u \sigma_d} \\ m_{\phi_d \sigma_u} & 0 & m_{\sigma_d \sigma_u} & m_{\sigma_u \sigma_u} \end{pmatrix} + \xi_Z m^2(Z) \quad (98)$$

$$m_{\phi_d \phi_d} = \frac{1}{8} (g_1^2 + g_2^2) (3v_d^2 - v_u^2) + m_{H_d}^2 + |\mu|^2 \quad (99)$$

$$m_{\phi_d \phi_u} = -\frac{1}{2} e^{-i\eta} (e^{2i\eta} B_\mu + B_\mu^*) - \frac{1}{4} (g_1^2 + g_2^2) v_d v_u \quad (100)$$

$$m_{\phi_u \phi_u} = -\frac{1}{8} (g_1^2 + g_2^2) (-3v_u^2 + v_d^2) + m_{H_u}^2 + |\mu|^2 \quad (101)$$

$$m_{\phi_u \sigma_d} = -\frac{i}{2} e^{-i\eta} (-B_\mu^* + e^{2i\eta} B_\mu) \quad (102)$$

$$m_{\sigma_d \sigma_d} = \frac{1}{8} (g_1^2 + g_2^2) (-v_u^2 + v_d^2) + m_{H_d}^2 + |\mu|^2 \quad (103)$$

$$m_{\phi_d \sigma_u} = -\frac{i}{2} e^{-i\eta} (-B_\mu^* + e^{2i\eta} B_\mu) \quad (104)$$

$$m_{\sigma_d \sigma_u} = \frac{1}{2} e^{-i\eta} (e^{2i\eta} B_\mu + B_\mu^*) \quad (105)$$

$$m_{\sigma_u \sigma_u} = -\frac{1}{8} (g_1^2 + g_2^2) (-v_u^2 + v_d^2) + m_{H_u}^2 + |\mu|^2 \quad (106)$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & m_{\sigma_d \sigma_d} & m_{\sigma_u \sigma_d} \\ 0 & 0 & m_{\sigma_d \sigma_u} & m_{\sigma_u \sigma_u} \end{pmatrix} \quad (107)$$

$$m_{\sigma_d \sigma_d} = \frac{1}{4} v_d^2 (g_1 \sin \Theta_W + g_2 \cos \Theta_W)^2 \quad (108)$$

$$m_{\sigma_d \sigma_u} = -\frac{1}{4} v_d v_u \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 \quad (109)$$

$$m_{\sigma_u \sigma_u} = \frac{1}{4} v_u^2 \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 \quad (110)$$

This matrix is diagonalized by  $Z^H$ :

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \quad (111)$$

with

$$\phi_d = \sum_j Z_{j1}^H h_j, \quad \phi_u = \sum_j Z_{j2}^H h_j, \quad \sigma_d = \sum_j Z_{j3}^H h_j \quad (112)$$

$$\sigma_u = \sum_j Z_{j4}^H h_j \quad (113)$$

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

$$m_{H^-}^2 = \begin{pmatrix} m_{H_d^- H_d^{-,*}} & e^{-i\eta} B_\mu^* + \frac{1}{4} g_2^2 v_d v_u \\ e^{i\eta} B_\mu + \frac{1}{4} g_2^2 v_d v_u & m_{H_u^{+,*} H_u^+} \end{pmatrix} + \xi_{W^-} m^2(W^-) \quad (114)$$

$$m_{H_d^- H_d^{-,*}} = \frac{1}{8} \left( g_1^2 (-v_u^2 + v_d^2) + g_2^2 (v_d^2 + v_u^2) \right) + m_{H_d}^2 + |\mu|^2 \quad (115)$$

$$m_{H_u^{+,*} H_u^+} = \frac{1}{8} \left( g_1^2 (-v_d^2 + v_u^2) + g_2^2 (v_d^2 + v_u^2) \right) + m_{H_u}^2 + |\mu|^2 \quad (116)$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4} g_2^2 v_d^2 & -\frac{1}{4} g_2^2 v_d v_u \\ -\frac{1}{4} g_2^2 v_d v_u & \frac{1}{4} g_2^2 v_u^2 \end{pmatrix} \quad (117)$$

This matrix is diagonalized by  $Z^+$ :

$$Z^+ m_{H^-}^2 Z^{+,\dagger} = m_{2,H^-}^{dia} \quad (118)$$

with

$$H_d^- = \sum_j Z_{j1}^{+,*} H_j^-, \quad H_u^+ = \sum_j Z_{j2}^+ H_j^+ \quad (119)$$

#### 4.2.2 Mass Matrices for Fermions

- **Mass matrix for Neutralinos**, Basis:  $(\lambda_{\tilde{B}}, \tilde{W}^0, \tilde{H}_d^0, \tilde{H}_u^0), (\lambda_{\tilde{B}}, \tilde{W}^0, \tilde{H}_d^0, \tilde{H}_u^0)$

$$m_{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & -\frac{1}{2} g_1 v_d & \frac{1}{2} e^{-i\eta} g_1 v_u \\ 0 & M_2 & \frac{1}{2} g_2 v_d & -\frac{1}{2} e^{-i\eta} g_2 v_u \\ -\frac{1}{2} g_1 v_d & \frac{1}{2} g_2 v_d & 0 & -\mu \\ \frac{1}{2} e^{-i\eta} g_1 v_u & -\frac{1}{2} e^{-i\eta} g_2 v_u & -\mu & 0 \end{pmatrix} \quad (120)$$

This matrix is diagonalized by  $N$ :

$$N^* m_{\tilde{\chi}^0} N^\dagger = m_{\tilde{\chi}^0}^{dia} \quad (121)$$

with

$$\lambda_{\tilde{B}} = \sum_j N_{j1}^* \lambda_j^0, \quad \tilde{W}^0 = \sum_j N_{j2}^* \lambda_j^0, \quad \tilde{H}_d^0 = \sum_j N_{j3}^* \lambda_j^0 \quad (122)$$

$$\tilde{H}_u^0 = \sum_j N_{j4}^* \lambda_j^0 \quad (123)$$

- **Mass matrix for Charginos**, Basis:  $(\tilde{W}^-, \tilde{H}_d^-), (\tilde{W}^+, \tilde{H}_u^+)$

$$m_{\tilde{\chi}^-} = \begin{pmatrix} M_2 & \frac{1}{\sqrt{2}} e^{-in} g_2 v_u \\ \frac{1}{\sqrt{2}} g_2 v_d & \mu \end{pmatrix} \quad (124)$$

This matrix is diagonalized by  $U$  and  $V$

$$U^* m_{\tilde{\chi}^-} V^\dagger = m_{\tilde{\chi}^-}^{dia} \quad (125)$$

with

$$\tilde{W}^- = \sum_{t_2} U_{j1}^* \lambda_j^-, \quad \tilde{H}_d^- = \sum_{t_2} U_{j2}^* \lambda_j^- \quad (126)$$

$$\tilde{W}^+ = \sum_{t_2} V_{1j}^* \lambda_j^+, \quad \tilde{H}_u^+ = \sum_{t_2} V_{2j}^* \lambda_j^+ \quad (127)$$

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

$$m_e = \begin{pmatrix} \frac{1}{\sqrt{2}} v_d Y_e^T \end{pmatrix} \quad (128)$$

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

$$U_L^{e,*} m_e U_R^{e,\dagger} = m_e^{dia} \quad (129)$$

with

$$e_{L,i} = \sum_{t_2} U_{L,ji}^{e,*} E_{L,j} \quad (130)$$

$$e_{R,i} = \sum_{t_2} U_{R,ij}^e E_{R,j}^* \quad (131)$$

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

$$m_d = \begin{pmatrix} \frac{1}{\sqrt{2}} v_d \delta_{\alpha_1 \beta_1} Y_d^T \end{pmatrix} \quad (132)$$

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

$$U_L^{d,*} m_d U_R^{d,\dagger} = m_d^{dia} \quad (133)$$

with

$$d_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{d,*} D_{L,j\alpha} \quad (134)$$

$$d_{R,i\alpha} = \sum_{t_2} U_{R,ij}^d D_{R,j\alpha}^* \quad (135)$$

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

$$m_u = \left( \frac{1}{\sqrt{2}} e^{i\eta} v_u \delta_{\alpha_1 \beta_1} Y_u^T \right) \quad (136)$$

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

$$U_L^{u,*} m_u U_R^{u,\dagger} = m_u^{dia} \quad (137)$$

with

$$u_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{u,*} U_{L,j\alpha} \quad (138)$$

$$u_{R,i\alpha} = \sum_{t_2} U_{R,ij}^u U_{R,j\alpha}^* \quad (139)$$

## 5 Vacuum Expectation Values

$$H_d^0 = \frac{1}{\sqrt{2}} \phi_d + \frac{1}{\sqrt{2}} v_d + i \frac{1}{\sqrt{2}} \sigma_d \quad (140)$$

$$H_u^0 = \frac{1}{\sqrt{2}} \phi_u + \frac{1}{\sqrt{2}} v_u + i \frac{1}{\sqrt{2}} \sigma_u \quad (141)$$

## 6 Tadpole Equations

$$\frac{\partial V}{\partial \phi_d} = -\frac{1}{2} e^{-i\eta} v_u \left( e^{2i\eta} B_\mu + B_\mu^* \right) + \frac{1}{8} \left( g_1^2 + g_2^2 \right) v_d \left( -v_u + v_d \right) \left( v_d + v_u \right) + v_d \left( m_{H_d}^2 + |\mu|^2 \right) \quad (142)$$

$$\frac{\partial V}{\partial \phi_u} = -\frac{1}{2} e^{-i\eta} v_d \left( e^{2i\eta} B_\mu + B_\mu^* \right) + \frac{1}{8} \left( g_1^2 + g_2^2 \right) v_u \left( -v_d^2 + v_u^2 \right) + v_u \left( m_{H_u}^2 + |\mu|^2 \right) \quad (143)$$

$$(144)$$

## 7 Particle content for eigenstates 'EWSB'

Name	Type	complex/real	Generations	Indices
------	------	--------------	-------------	---------

$\tilde{d}$	Scalar	complex	6	generation, 6, color, 3
$\tilde{u}$	Scalar	complex	6	generation, 6, color, 3
$\tilde{e}$	Scalar	complex	6	generation, 6
$\tilde{\nu}$	Scalar	complex	3	generation, 3
$h$	Scalar	real	4	generation, 4
$H^-$	Scalar	complex	2	generation, 2
$\tilde{g}$	Fermion	Majorana	1	color, 8
$\nu$	Fermion	Dirac	3	generation, 3
$\tilde{\chi}^0$	Fermion	Majorana	4	generation, 4
$\tilde{\chi}^-$	Fermion	Dirac	2	generation, 2
$e$	Fermion	Dirac	3	generation, 3
$d$	Fermion	Dirac	3	generation, 3, color, 3
$u$	Fermion	Dirac	3	generation, 3, color, 3
$g$	Vector	real	1	color, 8, lorentz, 4
$\gamma$	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	
$\eta^-$	Ghost	complex	1	
$\eta^+$	Ghost	complex	1	

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

### 8.1 One Loop Self-Energy

- Self-Energy for Down-Squarks ( $\tilde{d}$ )

$$\begin{aligned}
\Pi_{i,j}(p^2) = & +4\Gamma_{\tilde{d}_i, \tilde{d}_j^*, W^+, W^-} \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\tilde{d}_i, \tilde{d}_j^*, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, H_a^+, H_a^-} - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a}
\end{aligned}$$

$$\begin{aligned}
& -2 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^2 B_0(p^2, m_{u_a}^2, m_{\tilde{\chi}_b^-}^2) m_{\tilde{\chi}_b^-} \left( \Gamma_{\tilde{d}_j^*, u_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{d}_i^*, u_a, \tilde{\chi}_b^-}^R + \Gamma_{\tilde{d}_j^*, u_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{d}_i^*, u_a, \tilde{\chi}_b^-}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^2 G_0(p^2, m_{u_a}^2, m_{\tilde{\chi}_b^-}^2) \left( \Gamma_{\tilde{d}_j^*, u_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{d}_i^*, u_a, \tilde{\chi}_b^-}^L + \Gamma_{\tilde{d}_j^*, u_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{d}_i^*, u_a, \tilde{\chi}_b^-}^R \right) \\
& -2 \sum_{a=1}^3 m_{d_a} \sum_{b=1}^4 B_0(p^2, m_{d_a}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_b^0} \left( \Gamma_{\tilde{d}_j^*, d_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{d}_i^*, d_a, \tilde{\chi}_b^0}^R + \Gamma_{\tilde{d}_j^*, d_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{d}_i^*, d_a, \tilde{\chi}_b^0}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^4 G_0(p^2, m_{d_a}^2, m_{\tilde{\chi}_b^0}^2) \left( \Gamma_{\tilde{d}_j^*, d_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{d}_i^*, d_a, \tilde{\chi}_b^0}^L + \Gamma_{\tilde{d}_j^*, d_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{d}_i^*, d_a, \tilde{\chi}_b^0}^R \right) \\
& - \frac{1}{2} \sum_{a=1}^4 A_0(m_{h_a}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, h_a, h_a} - C \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, \tilde{d}_a, \tilde{d}_a} \\
& - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, \tilde{e}_a, \tilde{e}_a} - C \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, \tilde{u}_a, \tilde{u}_a} \\
& + \sum_{a=1}^6 \sum_{b=1}^2 B_0(p^2, m_{\tilde{u}_a}^2, m_{H_b^-}^2) \Gamma_{\tilde{d}_j^*, \tilde{u}_a, H_b^-}^* \Gamma_{\tilde{d}_i^*, \tilde{u}_a, H_b^-} + \sum_{a=1}^6 \sum_{b=1}^4 B_0(p^2, m_{\tilde{d}_a}^2, m_{h_b}^2) \Gamma_{\tilde{d}_j^*, \tilde{d}_a, h_b}^* \Gamma_{\tilde{d}_i^*, \tilde{d}_a, h_b} \\
& - \frac{8}{3} m_{\tilde{g}} \sum_{b=1}^3 B_0(p^2, m_{\tilde{g}}^2, m_{d_b}^2) m_{d_b} \left( \Gamma_{\tilde{d}_j^*, \tilde{g}_1, d_b}^{L*} \Gamma_{\tilde{d}_i^*, \tilde{g}_1, d_b}^R + \Gamma_{\tilde{d}_j^*, \tilde{g}_1, d_b}^{R*} \Gamma_{\tilde{d}_i^*, \tilde{g}_1, d_b}^L \right) \\
& + \frac{4}{3} \sum_{b=1}^3 G_0(p^2, m_{\tilde{g}}^2, m_{d_b}^2) \left( \Gamma_{\tilde{d}_j^*, \tilde{g}_1, d_b}^{L*} \Gamma_{\tilde{d}_i^*, \tilde{g}_1, d_b}^L + \Gamma_{\tilde{d}_j^*, \tilde{g}_1, d_b}^{R*} \Gamma_{\tilde{d}_i^*, \tilde{g}_1, d_b}^R \right) \\
& + \frac{4}{3} \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, g, \tilde{d}_b}^* \Gamma_{\tilde{d}_i^*, g, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, 0) + \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, \gamma, \tilde{d}_b}^* \Gamma_{\tilde{d}_i^*, \gamma, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, 0) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, Z, \tilde{d}_b}^* \Gamma_{\tilde{d}_i^*, Z, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, m_Z^2) + \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, W^-, \tilde{u}_b}^* \Gamma_{\tilde{d}_i^*, W^-, \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, m_{W^-}^2) \tag{145}
\end{aligned}$$

• Self-Energy for Up-Squarks ( $\tilde{u}$ )

$$\begin{aligned}
\Pi_{i,j}(p^2) & = +4\Gamma_{\tilde{u}_i, \tilde{u}_j^*, W^+, W^-} \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\tilde{u}_i, \tilde{u}_j^*, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, H_a^+, H_a^-} \\
& - 2 \sum_{a=1}^2 m_{\tilde{\chi}_a^-} \sum_{b=1}^3 B_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{d_b}^2) m_{d_b} \left( \Gamma_{\tilde{u}_j^*, \tilde{\chi}_a^-, d_b}^{L*} \Gamma_{\tilde{u}_i^*, \tilde{\chi}_a^-, d_b}^R + \Gamma_{\tilde{u}_j^*, \tilde{\chi}_a^-, d_b}^{R*} \Gamma_{\tilde{u}_i^*, \tilde{\chi}_a^-, d_b}^L \right) \\
& + \sum_{a=1}^2 \sum_{b=1}^3 G_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{d_b}^2) \left( \Gamma_{\tilde{u}_j^*, \tilde{\chi}_a^-, d_b}^{L*} \Gamma_{\tilde{u}_i^*, \tilde{\chi}_a^-, d_b}^L + \Gamma_{\tilde{u}_j^*, \tilde{\chi}_a^-, d_b}^{R*} \Gamma_{\tilde{u}_i^*, \tilde{\chi}_a^-, d_b}^R \right)
\end{aligned}$$

$$\begin{aligned}
& + \sum_{a=1}^2 \sum_{b=1}^6 B_0(p^2, m_{H_a^-}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{u}_j^*, H_a^+, \tilde{d}_b}^* \Gamma_{\tilde{u}_i^*, H_a^+, \tilde{d}_b} - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a} \\
& - 2 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^4 B_0(p^2, m_{u_a}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_b^0} \left( \Gamma_{\tilde{u}_j^*, u_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{u}_i^*, u_a, \tilde{\chi}_b^0}^R + \Gamma_{\tilde{u}_j^*, u_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{u}_i^*, u_a, \tilde{\chi}_b^0}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^4 G_0(p^2, m_{u_a}^2, m_{\tilde{\chi}_b^0}^2) \left( \Gamma_{\tilde{u}_j^*, u_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{u}_i^*, u_a, \tilde{\chi}_b^0}^L + \Gamma_{\tilde{u}_j^*, u_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{u}_i^*, u_a, \tilde{\chi}_b^0}^R \right) \\
& - \frac{1}{2} \sum_{a=1}^4 A_0(m_{h_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, h_a, h_a} - C \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, \tilde{d}_a^*, \tilde{d}_a} \\
& - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, \tilde{e}_a^*, \tilde{e}_a} - C \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, \tilde{u}_a^*, \tilde{u}_a} \\
& + \sum_{a=1}^6 \sum_{b=1}^4 B_0(p^2, m_{\tilde{u}_a}^2, m_{h_b}^2) \Gamma_{\tilde{u}_j^*, \tilde{u}_a, h_b}^* \Gamma_{\tilde{u}_i^*, \tilde{u}_a, h_b} \\
& - \frac{8}{3} m_{\tilde{g}} \sum_{b=1}^3 B_0(p^2, m_{\tilde{g}}^2, m_{u_b}^2) m_{u_b} \left( \Gamma_{\tilde{u}_j^*, \tilde{g}_1, u_b}^{L*} \Gamma_{\tilde{u}_i^*, \tilde{g}_1, u_b}^R + \Gamma_{\tilde{u}_j^*, \tilde{g}_1, u_b}^{R*} \Gamma_{\tilde{u}_i^*, \tilde{g}_1, u_b}^L \right) \\
& + \frac{4}{3} \sum_{b=1}^3 G_0(p^2, m_{\tilde{g}}^2, m_{u_b}^2) \left( \Gamma_{\tilde{u}_j^*, \tilde{g}_1, u_b}^{L*} \Gamma_{\tilde{u}_i^*, \tilde{g}_1, u_b}^L + \Gamma_{\tilde{u}_j^*, \tilde{g}_1, u_b}^{R*} \Gamma_{\tilde{u}_i^*, \tilde{g}_1, u_b}^R \right) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{u}_j^*, W^+, \tilde{d}_b}^* \Gamma_{\tilde{u}_i^*, W^+, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, m_{W^-}^2) + \frac{4}{3} \sum_{b=1}^6 \Gamma_{\tilde{u}_j^*, g, \tilde{u}_b}^* \Gamma_{\tilde{u}_i^*, g, \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, 0) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{u}_j^*, \gamma, \tilde{u}_b}^* \Gamma_{\tilde{u}_i^*, \gamma, \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, 0) + \sum_{b=1}^6 \Gamma_{\tilde{u}_j^*, Z, \tilde{u}_b}^* \Gamma_{\tilde{u}_i^*, Z, \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, m_Z^2) \tag{146}
\end{aligned}$$

• Self-Energy for Sleptons ( $\tilde{e}$ )

$$\begin{aligned}
\Pi_{i,j}(p^2) & = +4\Gamma_{\tilde{e}_i, \tilde{e}_j^*, W^+, W^-} \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\tilde{e}_i, \tilde{e}_j^*, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{e}_i, \tilde{e}_j^*, H_a^+, H_a^-} - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{e}_i, \tilde{e}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a} \\
& + \sum_{a=1}^3 \sum_{b=1}^2 B_0(p^2, m_{\tilde{\nu}_a}^2, m_{H_b^-}^2) \Gamma_{\tilde{e}_j^*, \tilde{\nu}_a, H_b^-}^* \Gamma_{\tilde{e}_i^*, \tilde{\nu}_a, H_b^-} \\
& - 2 \sum_{a=1}^3 m_{\nu_a} \sum_{b=1}^2 B_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^-}^2) m_{\tilde{\chi}_b^-} \left( \Gamma_{\tilde{e}_j^*, \nu_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{e}_i^*, \nu_a, \tilde{\chi}_b^-}^R + \Gamma_{\tilde{e}_j^*, \nu_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{e}_i^*, \nu_a, \tilde{\chi}_b^-}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^2 G_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^-}^2) \left( \Gamma_{\tilde{e}_j^*, \nu_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{e}_i^*, \nu_a, \tilde{\chi}_b^-}^L + \Gamma_{\tilde{e}_j^*, \nu_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{e}_i^*, \nu_a, \tilde{\chi}_b^-}^R \right)
\end{aligned}$$



$$\begin{aligned}
& -2 \sum_{a=1}^3 m_{e_a} \sum_{b=1}^4 B_0(p^2, m_{e_a}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_b^0} \left( \Gamma_{\tilde{e}_j^*, e_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{e}_i^*, e_a, \tilde{\chi}_b^0}^R + \Gamma_{\tilde{e}_j^*, e_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{e}_i^*, e_a, \tilde{\chi}_b^0}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^4 G_0(p^2, m_{e_a}^2, m_{\tilde{\chi}_b^0}^2) \left( \Gamma_{\tilde{e}_j^*, e_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{e}_i^*, e_a, \tilde{\chi}_b^0}^L + \Gamma_{\tilde{e}_j^*, e_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{e}_i^*, e_a, \tilde{\chi}_b^0}^R \right) \\
& - \frac{1}{2} \sum_{a=1}^4 A_0(m_{h_a}^2) \Gamma_{\tilde{e}_i, \tilde{e}_j^*, h_a, h_a} - 3 \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\tilde{e}_i, \tilde{e}_j^*, \tilde{d}_a^*, \tilde{d}_a} \\
& - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{e}_i, \tilde{e}_j^*, \tilde{e}_a^*, \tilde{e}_a} - 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{e}_i, \tilde{e}_j^*, \tilde{u}_a^*, \tilde{u}_a} \\
& + \sum_{a=1}^6 \sum_{b=1}^4 B_0(p^2, m_{\tilde{e}_a}^2, m_{\tilde{h}_b}^2) \Gamma_{\tilde{e}_j^*, \tilde{e}_a, h_b}^* \Gamma_{\tilde{e}_i^*, \tilde{e}_a, h_b} + \sum_{b=1}^3 \Gamma_{\tilde{e}_j^*, W^-, \tilde{\nu}_b}^* \Gamma_{\tilde{e}_i^*, W^-, \tilde{\nu}_b} F_0(p^2, m_{\tilde{\nu}_b}^2, m_{W^-}^2) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{e}_j^*, \gamma, \tilde{e}_b}^* \Gamma_{\tilde{e}_i^*, \gamma, \tilde{e}_b} F_0(p^2, m_{\tilde{e}_b}^2, 0) + \sum_{b=1}^6 \Gamma_{\tilde{e}_j^*, Z, \tilde{e}_b}^* \Gamma_{\tilde{e}_i^*, Z, \tilde{e}_b} F_0(p^2, m_{\tilde{e}_b}^2, m_Z^2) \tag{147}
\end{aligned}$$

• Self-Energy for Sneutrinos ( $\tilde{\nu}$ )

$$\begin{aligned}
\Pi_{i,j}(p^2) & = +4\Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, W^+, W^-} - \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, Z, Z} - \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, H_a^+, H_a^-} \\
& - 2 \sum_{a=1}^2 m_{\tilde{\chi}_a^-} \sum_{b=1}^3 B_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{e_b}^2) m_{e_b} \left( \Gamma_{\tilde{\nu}_j^*, \tilde{\chi}_a^-, e_b}^{L*} \Gamma_{\tilde{\nu}_i^*, \tilde{\chi}_a^-, e_b}^R + \Gamma_{\tilde{\nu}_j^*, \tilde{\chi}_a^-, e_b}^{R*} \Gamma_{\tilde{\nu}_i^*, \tilde{\chi}_a^-, e_b}^L \right) \\
& + \sum_{a=1}^2 \sum_{b=1}^3 G_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{e_b}^2) \left( \Gamma_{\tilde{\nu}_j^*, \tilde{\chi}_a^-, e_b}^{L*} \Gamma_{\tilde{\nu}_i^*, \tilde{\chi}_a^-, e_b}^L + \Gamma_{\tilde{\nu}_j^*, \tilde{\chi}_a^-, e_b}^{R*} \Gamma_{\tilde{\nu}_i^*, \tilde{\chi}_a^-, e_b}^R \right) \\
& + \sum_{a=1}^2 \sum_{b=1}^6 B_0(p^2, m_{H_a^-}^2, m_{\tilde{e}_b}^2) \Gamma_{\tilde{\nu}_j^*, H_a^+, \tilde{e}_b}^* \Gamma_{\tilde{\nu}_i^*, H_a^+, \tilde{e}_b} - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a} \\
& + \sum_{a=1}^3 \sum_{b=1}^4 B_0(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{h}_b}^2) \Gamma_{\tilde{\nu}_j^*, \tilde{\nu}_a, h_b}^* \Gamma_{\tilde{\nu}_i^*, \tilde{\nu}_a, h_b} \\
& - 2 \sum_{a=1}^3 m_{\nu_a} \sum_{b=1}^4 B_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_b^0} \left( \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^R + \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^4 G_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^0}^2) \left( \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^L + \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^R \right) \\
& - \frac{1}{2} \sum_{a=1}^4 A_0(m_{h_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, h_a, h_a} - 3 \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, \tilde{d}_a^*, \tilde{d}_a}
\end{aligned}$$

$$\begin{aligned}
& - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, \tilde{e}_a^*, \tilde{e}_a} - 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, \tilde{u}_a^*, \tilde{u}_a} \\
& + \sum_{b=1}^3 \Gamma_{\tilde{\nu}_j^*, Z, \tilde{\nu}_b}^* \Gamma_{\tilde{\nu}_i^*, Z, \tilde{\nu}_b} F_0(p^2, m_{\tilde{\nu}_b}^2, m_Z^2) + \sum_{b=1}^6 \Gamma_{\tilde{\nu}_j^*, W^+, \tilde{e}_b}^* \Gamma_{\tilde{\nu}_i^*, W^+, \tilde{e}_b} F_0(p^2, m_{\tilde{e}_b}^2, m_{W^-}^2)
\end{aligned} \tag{148}$$

• **Self-Energy for Higgs ( $h$ )**

$$\begin{aligned}
\Pi_{i,j}(p^2) = & +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} + 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} + 4 \Gamma_{\tilde{h}_i, \tilde{h}_j, W^+, W^-} + \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) \\
& + 2 \Gamma_{\tilde{h}_i, \tilde{h}_j, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{h}_i, \tilde{h}_j, H_a^+, H_a^-} \\
& + \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{H_a^-}^2, m_{H_b^-}^2) \Gamma_{\tilde{h}_j, H_a^+, H_b^-}^* \Gamma_{\tilde{h}_i, H_a^+, H_b^-} \\
& - 2 \sum_{a=1}^2 m_{\tilde{\chi}_a^-} \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2) m_{\tilde{\chi}_b^-} \left( \Gamma_{\tilde{h}_j, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^R + \Gamma_{\tilde{h}_j, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^L \right) \\
& + \sum_{a=1}^2 \sum_{b=1}^2 G_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2) \left( \Gamma_{\tilde{h}_j, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^L + \Gamma_{\tilde{h}_j, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^R \right) \\
& - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{h}_i, \tilde{h}_j, \tilde{\nu}_a^*, \tilde{\nu}_a} + \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2) \Gamma_{\tilde{h}_j, \tilde{\nu}_a^*, \tilde{\nu}_b}^* \Gamma_{\tilde{h}_i, \tilde{\nu}_a^*, \tilde{\nu}_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, \tilde{d}_a, d_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{d}_a, d_b}^R + \Gamma_{\tilde{h}_j, \tilde{d}_a, d_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{d}_a, d_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{d_a}^2, m_{d_b}^2) \left( \Gamma_{\tilde{h}_j, \tilde{d}_a, d_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{d}_a, d_b}^L + \Gamma_{\tilde{h}_j, \tilde{d}_a, d_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{d}_a, d_b}^R \right) \\
& - 2 \sum_{a=1}^3 m_{e_a} \sum_{b=1}^3 B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_b} \left( \Gamma_{\tilde{h}_j, \tilde{e}_a, e_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{e}_a, e_b}^R + \Gamma_{\tilde{h}_j, \tilde{e}_a, e_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{e}_a, e_b}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{e_a}^2, m_{e_b}^2) \left( \Gamma_{\tilde{h}_j, \tilde{e}_a, e_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{e}_a, e_b}^L + \Gamma_{\tilde{h}_j, \tilde{e}_a, e_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{e}_a, e_b}^R \right) \\
& - 6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_b} \left( \Gamma_{\tilde{h}_j, \tilde{u}_a, u_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{u}_a, u_b}^R + \Gamma_{\tilde{h}_j, \tilde{u}_a, u_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{u}_a, u_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{u_a}^2, m_{u_b}^2) \left( \Gamma_{\tilde{h}_j, \tilde{u}_a, u_b}^{L*} \Gamma_{\tilde{h}_i, \tilde{u}_a, u_b}^L + \Gamma_{\tilde{h}_j, \tilde{u}_a, u_b}^{R*} \Gamma_{\tilde{h}_i, \tilde{u}_a, u_b}^R \right)
\end{aligned}$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^4 A_0(m_{h_a}^2) \Gamma_{\check{h}_i, \check{h}_j, h_a, h_a} + \frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^4 B_0(p^2, m_{h_a}^2, m_{h_b}^2) \Gamma_{\check{h}_j, h_a, h_b}^* \Gamma_{\check{h}_i, h_a, h_b} \\
& - \sum_{a=1}^4 m_{\check{\chi}_a^0} \sum_{b=1}^4 B_0(p^2, m_{\check{\chi}_a^0}^2, m_{\check{\chi}_b^0}^2) m_{\check{\chi}_b^0} \left( \Gamma_{\check{h}_j, \check{\chi}_a^0, \check{\chi}_b^0}^{L*} \Gamma_{\check{h}_i, \check{\chi}_a^0, \check{\chi}_b^0}^R + \Gamma_{\check{h}_j, \check{\chi}_a^0, \check{\chi}_b^0}^{R*} \Gamma_{\check{h}_i, \check{\chi}_a^0, \check{\chi}_b^0}^L \right) \\
& + \frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^4 G_0(p^2, m_{\check{\chi}_a^0}^2, m_{\check{\chi}_b^0}^2) \left( \Gamma_{\check{h}_j, \check{\chi}_a^0, \check{\chi}_b^0}^{L*} \Gamma_{\check{h}_i, \check{\chi}_a^0, \check{\chi}_b^0}^L + \Gamma_{\check{h}_j, \check{\chi}_a^0, \check{\chi}_b^0}^{R*} \Gamma_{\check{h}_i, \check{\chi}_a^0, \check{\chi}_b^0}^R \right) \\
& - 3 \sum_{a=1}^6 A_0(m_{\check{d}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \check{d}_a^*, \check{d}_a} - \sum_{a=1}^6 A_0(m_{\check{e}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \check{e}_a^*, \check{e}_a} \\
& - 3 \sum_{a=1}^6 A_0(m_{\check{u}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \check{u}_a^*, \check{u}_a} + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\check{d}_a}^2, m_{\check{d}_b}^2) \Gamma_{\check{h}_j, \check{d}_a^*, \check{d}_b}^* \Gamma_{\check{h}_i, \check{d}_a^*, \check{d}_b} \\
& + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\check{e}_a}^2, m_{\check{e}_b}^2) \Gamma_{\check{h}_j, \check{e}_a^*, \check{e}_b}^* \Gamma_{\check{h}_i, \check{e}_a^*, \check{e}_b} + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\check{u}_a}^2, m_{\check{u}_b}^2) \Gamma_{\check{h}_j, \check{u}_a^*, \check{u}_b}^* \Gamma_{\check{h}_i, \check{u}_a^*, \check{u}_b} \\
& + 2 \sum_{b=1}^2 \Gamma_{\check{h}_j, W^+, H_b^-}^* \Gamma_{\check{h}_i, W^+, H_b^-} F_0(p^2, m_{H_b^-}^2, m_{W^-}^2) + \sum_{b=1}^4 \Gamma_{\check{h}_j, Z, h_b}^* \Gamma_{\check{h}_i, Z, h_b} F_0(p^2, m_{h_b}^2, m_Z^2) \tag{149}
\end{aligned}$$

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

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

$$\begin{aligned}
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{\nu_a}^2, m_{e_b}^2) \left( \Gamma_{\tilde{H}_j^+, \tilde{\nu}_a, e_b}^{L*} \Gamma_{\tilde{H}_i^+, \tilde{\nu}_a, e_b}^L + \Gamma_{\tilde{H}_j^+, \tilde{\nu}_a, e_b}^{R*} \Gamma_{\tilde{H}_i^+, \tilde{\nu}_a, e_b}^R \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^6 B_0(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{e}_b}^2) \Gamma_{\tilde{H}_j^+, \tilde{\nu}_a^*, \tilde{e}_b} \Gamma_{\tilde{H}_i^+, \tilde{\nu}_a^*, \tilde{e}_b} - \frac{1}{2} \sum_{a=1}^4 A_0(m_{h_a}^2) \Gamma_{\tilde{H}_i^-, \tilde{H}_j^+, h_a, h_a} \\
& - 2 \sum_{a=1}^4 m_{\tilde{\chi}_a^0} \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^-}^2) m_{\tilde{\chi}_b^-} \left( \Gamma_{\tilde{H}_j^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{H}_i^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^L + \Gamma_{\tilde{H}_j^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{H}_i^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^R \right) \\
& + \sum_{a=1}^4 \sum_{b=1}^2 G_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^-}^2) \left( \Gamma_{\tilde{H}_j^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{H}_i^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^L + \Gamma_{\tilde{H}_j^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{H}_i^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^R \right) \\
& - 3 \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\tilde{H}_i^-, \tilde{H}_j^+, \tilde{d}_a^*, \tilde{d}_a} - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{H}_i^-, \tilde{H}_j^+, \tilde{e}_a^*, \tilde{e}_a} \\
& - 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{H}_i^-, \tilde{H}_j^+, \tilde{u}_a^*, \tilde{u}_a} + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{u}_a}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{H}_j^+, \tilde{u}_a^*, \tilde{d}_b} \Gamma_{\tilde{H}_i^+, \tilde{u}_a^*, \tilde{d}_b} \\
& + \sum_{b=1}^2 \Gamma_{\tilde{H}_j^+, \gamma, H_b^-}^* \Gamma_{\tilde{H}_i^+, \gamma, H_b^-} F_0(p^2, m_{H_b^-}^2, 0) + \sum_{b=1}^2 \Gamma_{\tilde{H}_j^+, Z, H_b^-}^* \Gamma_{\tilde{H}_i^+, Z, H_b^-} F_0(p^2, m_{H_b^-}^2, m_Z^2) \\
& + \sum_{b=1}^4 \Gamma_{\tilde{H}_j^+, W^-, h_b}^* \Gamma_{\tilde{H}_i^+, W^-, h_b} F_0(p^2, m_{h_b}^2, m_{W^-}^2)
\end{aligned} \tag{150}$$

• Self-Energy for Neutralinos ( $\tilde{\chi}^0$ )

$$\begin{aligned}
\Sigma_{i,j}^S(p^2) & = +2 \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^0, H_a^+, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^0, H_a^+, \tilde{\chi}_b^-}^R \\
& + 2 \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{\nu_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{\nu}_a^*, \nu_b}^{L*} m_{\nu_b} \Gamma_{\tilde{\chi}_i^0, \tilde{\nu}_a^*, \nu_b}^R \\
& + \sum_{a=1}^4 \sum_{b=1}^4 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}_j^0, h_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^0, h_a, \tilde{\chi}_b^0}^R \\
& + 6 \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{d}_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{d}_a^*, \tilde{d}_b}^{L*} m_{\tilde{d}_b} \Gamma_{\tilde{\chi}_i^0, \tilde{d}_a^*, \tilde{d}_b}^R \\
& + 2 \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{e_b}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{e}_a^*, e_b}^{L*} m_{e_b} \Gamma_{\tilde{\chi}_i^0, \tilde{e}_a^*, e_b}^R \\
& + 6 \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{u}_a^*, u_b}^{L*} m_{u_b} \Gamma_{\tilde{\chi}_i^0, \tilde{u}_a^*, u_b}^R
\end{aligned}$$

$$\begin{aligned}
& -8 \sum_{b=1}^2 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2) \right) \Gamma_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-}^L \\
& -4 \sum_{b=1}^4 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2) \right) \Gamma_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0}^{R*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0}^L \tag{151}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^R(p^2) &= - \sum_{a=1}^2 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^0, H_a^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^0, H_a^+, \tilde{\chi}_b^-}^R \\
& - \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{\nu}_a^*, \nu_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{\nu}_a^*, \nu_b}^R \\
& - \frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^4 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}_j^0, h_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, h_a, \tilde{\chi}_b^0}^R \\
& - 3 \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{d}_a^*, d_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{d}_a^*, d_b}^R \\
& - \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{e}_a^*, e_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{e}_a^*, e_b}^R \\
& - 3 \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{u}_a^*, u_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{u}_a^*, u_b}^R \\
& - 2 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2) \Gamma_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-}^L - \sum_{b=1}^4 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2) \Gamma_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0}^L \tag{152}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) &= - \sum_{a=1}^2 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^0, H_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^0, H_a^+, \tilde{\chi}_b^-}^L \\
& - \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{\nu}_a^*, \nu_b}^{L*} \Gamma_{\tilde{\chi}_i^0, \tilde{\nu}_a^*, \nu_b}^L \\
& - \frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^4 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}_j^0, h_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, h_a, \tilde{\chi}_b^0}^L \\
& - 3 \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{d}_a^*, d_b}^{L*} \Gamma_{\tilde{\chi}_i^0, \tilde{d}_a^*, d_b}^L \\
& - \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{e}_a^*, e_b}^{L*} \Gamma_{\tilde{\chi}_i^0, \tilde{e}_a^*, e_b}^L \\
& - 3 \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{u}_a^*, u_b}^{L*} \Gamma_{\tilde{\chi}_i^0, \tilde{u}_a^*, u_b}^L
\end{aligned}$$

$$- 2 \sum_{b=1}^2 B_1 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2 \right) \Gamma_{\tilde{\chi}_j^+, W^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-}^R - \sum_{b=1}^4 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2 \right) \Gamma_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0}^R \quad (153)$$

• Self-Energy for Charginos ( $\tilde{\chi}^-$ )

$$\begin{aligned} \Sigma_{i,j}^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^4 B_0 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{H_a^-}^2 \right) \Gamma_{\tilde{\chi}_j^+, H_a^-, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^+, H_a^-, \tilde{\chi}_b^0}^R \\ & + \sum_{a=1}^3 \sum_{b=1}^3 B_0 \left( p^2, m_{e_b}^2, m_{\tilde{\nu}_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a^*, e_b}^{L*} m_{e_b} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a^*, e_b}^R \\ & + 3 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^6 B_0 \left( p^2, m_{u_a}^2, m_{\tilde{d}_b}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a, \tilde{d}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a, \tilde{d}_b}^R \\ & + \sum_{a=1}^3 m_{\nu_a} \sum_{b=1}^6 B_0 \left( p^2, m_{\nu_a}^2, m_{\tilde{e}_b}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a, \tilde{e}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a, \tilde{e}_b}^R \\ & + \sum_{a=1}^4 \sum_{b=1}^2 B_0 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_{h_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, h_a, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, h_a, \tilde{\chi}_b^-}^R \\ & + 3 \sum_{a=1}^6 \sum_{b=1}^3 B_0 \left( p^2, m_{d_b}^2, m_{\tilde{u}_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a^*, d_b}^{L*} m_{d_b} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a^*, d_b}^R \\ & - 4 \sum_{b=1}^2 \left( -\frac{1}{2} \text{rMS} + B_0 \left( p^2, m_{\tilde{\chi}_b^-}^2, 0 \right) \right) \Gamma_{\tilde{\chi}_j^+, \gamma, \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, \gamma, \tilde{\chi}_b^-}^L \\ & - 4 \sum_{b=1}^2 \left( -\frac{1}{2} \text{rMS} + B_0 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_Z^2 \right) \right) \Gamma_{\tilde{\chi}_j^+, Z, \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, Z, \tilde{\chi}_b^-}^L \\ & - 4 \sum_{b=1}^4 \left( -\frac{1}{2} \text{rMS} + B_0 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2 \right) \right) \Gamma_{\tilde{\chi}_j^+, W^-, \tilde{\chi}_b^0}^{R*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^+, W^-, \tilde{\chi}_b^0}^L \end{aligned} \quad (154)$$

$$\begin{aligned} \Sigma_{i,j}^R(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^4 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{H_a^-}^2 \right) \Gamma_{\tilde{\chi}_j^+, H_a^-, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^+, H_a^-, \tilde{\chi}_b^0}^R \\ & - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1 \left( p^2, m_{e_b}^2, m_{\tilde{\nu}_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a^*, e_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a^*, e_b}^R \\ & - \frac{3}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1 \left( p^2, m_{u_a}^2, m_{\tilde{d}_b}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a, \tilde{d}_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a, \tilde{d}_b}^R \\ & - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1 \left( p^2, m_{\nu_a}^2, m_{\tilde{e}_b}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a, \tilde{e}_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a, \tilde{e}_b}^R \end{aligned}$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^2 B_1 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{h}_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, h_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, h_a, \tilde{\chi}_b^-}^R \\
& -\frac{3}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1 \left( p^2, m_{\tilde{d}_b}^2, m_{\tilde{u}_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a^*, d_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a^*, d_b}^R - \sum_{b=1}^2 B_1 \left( p^2, m_{\tilde{\chi}_b^-}^2, 0 \right) \Gamma_{\tilde{\chi}_j^+, \gamma, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^+, \gamma, \tilde{\chi}_b^-}^L \\
& - \sum_{b=1}^2 B_1 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_Z^2 \right) \Gamma_{\tilde{\chi}_j^+, Z, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^+, Z, \tilde{\chi}_b^-}^L - \sum_{b=1}^4 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2 \right) \Gamma_{\tilde{\chi}_j^+, W^-, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^+, W^-, \tilde{\chi}_b^0}^L \quad (155)
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^4 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{H_a^-}^2 \right) \Gamma_{\tilde{\chi}_j^+, H_a^-, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^+, H_a^-, \tilde{\chi}_b^0}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1 \left( p^2, m_{\tilde{e}_b}^2, m_{\tilde{\nu}_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a^*, e_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a^*, e_b}^L \\
& -\frac{3}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1 \left( p^2, m_{\tilde{u}_a}^2, m_{\tilde{d}_b}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a, \tilde{d}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a, \tilde{d}_b}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1 \left( p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{e}_b}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a, \tilde{e}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a, \tilde{e}_b}^L \\
& -\frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^2 B_1 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{h}_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, h_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^+, h_a, \tilde{\chi}_b^-}^L \\
& -\frac{3}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1 \left( p^2, m_{\tilde{d}_b}^2, m_{\tilde{u}_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a^*, d_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a^*, d_b}^L - \sum_{b=1}^2 B_1 \left( p^2, m_{\tilde{\chi}_b^-}^2, 0 \right) \Gamma_{\tilde{\chi}_j^+, \gamma, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, \gamma, \tilde{\chi}_b^-}^R \\
& - \sum_{b=1}^2 B_1 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_Z^2 \right) \Gamma_{\tilde{\chi}_j^+, Z, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, Z, \tilde{\chi}_b^-}^R - \sum_{b=1}^4 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2 \right) \Gamma_{\tilde{\chi}_j^+, W^-, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^+, W^-, \tilde{\chi}_b^0}^R \quad (156)
\end{aligned}$$

• Self-Energy for Leptons ( $e$ )

$$\begin{aligned}
\Sigma_{i,j}^S(p^2) &= + \sum_{a=1}^2 \sum_{b=1}^3 B_0 \left( p^2, m_{\nu_b}^2, m_{H_a^-}^2 \right) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{L*} m_{\nu_b} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^R \\
& + \sum_{a=1}^3 \sum_{b=1}^2 B_0 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2 \right) \Gamma_{\tilde{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^R \\
& + \sum_{a=1}^4 \sum_{b=1}^3 B_0 \left( p^2, m_{\tilde{e}_b}^2, m_{\tilde{h}_a}^2 \right) \Gamma_{\tilde{e}_j, h_a, e_b}^{L*} m_{e_b} \Gamma_{\tilde{e}_i, h_a, e_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^4 B_0 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2 \right) \Gamma_{\tilde{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^R
\end{aligned}$$

$$\begin{aligned}
& -4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, 0) \right) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, \gamma, e_b}^L \\
& -4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{e}_i, W^-, \nu_b}^L \\
& -4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, m_Z^2) \right) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, Z, e_b}^L \tag{157}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^R(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{R*} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^R \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^R \\
& -\frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{R*} \Gamma_{\tilde{e}_i, h_a, e_b}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^4 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^R - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, 0) \Gamma_{\tilde{e}_j, \gamma, e_b}^{L*} \Gamma_{\tilde{e}_i, \gamma, e_b}^L \\
& -\sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{W^-}^2) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{L*} \Gamma_{\tilde{e}_i, W^-, \nu_b}^L - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_Z^2) \Gamma_{\tilde{e}_j, Z, e_b}^{L*} \Gamma_{\tilde{e}_i, Z, e_b}^L \tag{158}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{L*} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^L \\
& -\frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{L*} \Gamma_{\tilde{e}_i, h_a, e_b}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^4 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^L - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, 0) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} \Gamma_{\tilde{e}_i, \gamma, e_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{W^-}^2) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} \Gamma_{\tilde{e}_i, W^-, \nu_b}^R - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_Z^2) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} \Gamma_{\tilde{e}_i, Z, e_b}^R \tag{159}
\end{aligned}$$

• Self-Energy for Down-Quarks (d)

$$\Sigma_{i,j}^S(p^2) = + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{d}_j, H_a^-, u_b}^{L*} m_{u_b} \Gamma_{\tilde{d}_i, H_a^-, u_b}^R$$



$$\begin{aligned}
& + \sum_{a=1}^4 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\tilde{d}_j, h_a, d_b}^{L*} m_{d_b} \Gamma_{\tilde{d}_i, h_a, d_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^4 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^R \\
& + \frac{4}{3} m_{\tilde{g}} \sum_{a=1}^6 B_0(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{g}_1}^R - \frac{16}{3} \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, g, d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, g, d_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, \gamma, d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, \gamma, d_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{d}_j, W^-, u_b}^{R*} m_{u_b} \Gamma_{\tilde{d}_i, W^-, u_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_Z^2) \right) \Gamma_{\tilde{d}_j, Z, d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, Z, d_b}^L \tag{160}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^R(p^2) & = -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{d}_j, H_a^-, u_b}^{R*} \Gamma_{\tilde{d}_i, H_a^-, u_b}^R \\
& - \frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\tilde{d}_j, h_a, d_b}^{R*} \Gamma_{\tilde{d}_i, h_a, d_b}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^4 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^R \\
& - \frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{g}_1}^{R*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{g}_1}^R - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, 0) \Gamma_{\tilde{d}_j, g, d_b}^{L*} \Gamma_{\tilde{d}_i, g, d_b}^L \\
& - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, 0) \Gamma_{\tilde{d}_j, \gamma, d_b}^{L*} \Gamma_{\tilde{d}_i, \gamma, d_b}^L - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{W^-}^2) \Gamma_{\tilde{d}_j, W^-, u_b}^{L*} \Gamma_{\tilde{d}_i, W^-, u_b}^L \\
& - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_Z^2) \Gamma_{\tilde{d}_j, Z, d_b}^{L*} \Gamma_{\tilde{d}_i, Z, d_b}^L \tag{161}
\end{aligned}$$

$$\Sigma_{i,j}^L(p^2) = -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{d}_j, H_a^-, u_b}^{L*} \Gamma_{\tilde{d}_i, H_a^-, u_b}^L$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_{\tilde{h}_a}^2) \Gamma_{\tilde{d}_j, \tilde{h}_a, \tilde{d}_b}^{L*} \Gamma_{\tilde{d}_i, \tilde{h}_a, \tilde{d}_b}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^4 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^L \\
& -\frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{g}_1}^L - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, 0) \Gamma_{\tilde{d}_j, \tilde{g}, \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i, \tilde{g}, \tilde{d}_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, 0) \Gamma_{\tilde{d}_j, \gamma, \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i, \gamma, \tilde{d}_b}^R - \sum_{b=1}^3 B_1(p^2, m_{\tilde{u}_b}^2, m_{\tilde{W}^-}^2) \Gamma_{\tilde{d}_j, \tilde{W}^-, \tilde{u}_b}^{R*} \Gamma_{\tilde{d}_i, \tilde{W}^-, \tilde{u}_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_Z^2) \Gamma_{\tilde{d}_j, Z, \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i, Z, \tilde{d}_b}^R
\end{aligned} \tag{162}$$

• Self-Energy for Up-Quarks ( $u$ )

$$\begin{aligned}
\Sigma_{i,j}^S(p^2) &= + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{\tilde{d}_b}^2, m_{\tilde{H}_a^-}^2) \Gamma_{\tilde{u}_j, \tilde{H}_a^+, \tilde{d}_b}^{L*} m_{\tilde{d}_b} \Gamma_{\tilde{u}_i, \tilde{H}_a^+, \tilde{d}_b}^R \\
& + \sum_{a=1}^2 m_{\tilde{\chi}_a^-} \sum_{b=1}^6 B_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{u}_j, \tilde{\chi}_a^+, \tilde{d}_b}^{L*} \Gamma_{\tilde{u}_i, \tilde{\chi}_a^+, \tilde{d}_b}^R \\
& + \sum_{a=1}^4 \sum_{b=1}^3 B_0(p^2, m_{\tilde{u}_b}^2, m_{\tilde{h}_a}^2) \Gamma_{\tilde{u}_j, \tilde{h}_a, \tilde{u}_b}^{L*} m_{\tilde{u}_b} \Gamma_{\tilde{u}_i, \tilde{h}_a, \tilde{u}_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^4 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{\chi}_b^0}^R \\
& + \frac{4}{3} m_{\tilde{g}} \sum_{a=1}^6 B_0(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{g}_1}^R - \frac{16}{3} \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{u}_b}^2, 0) \right) \Gamma_{\tilde{u}_j, \tilde{g}, \tilde{u}_b}^{R*} m_{\tilde{u}_b} \Gamma_{\tilde{u}_i, \tilde{g}, \tilde{u}_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{u}_b}^2, 0) \right) \Gamma_{\tilde{u}_j, \gamma, \tilde{u}_b}^{R*} m_{\tilde{u}_b} \Gamma_{\tilde{u}_i, \gamma, \tilde{u}_b}^L - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{u}_b}^2, m_Z^2) \right) \Gamma_{\tilde{u}_j, Z, \tilde{u}_b}^{R*} m_{\tilde{u}_b} \Gamma_{\tilde{u}_i, Z, \tilde{u}_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{d}_b}^2, m_{\tilde{W}^-}^2) \right) \Gamma_{\tilde{u}_j, \tilde{W}^+, \tilde{d}_b}^{R*} m_{\tilde{d}_b} \Gamma_{\tilde{u}_i, \tilde{W}^+, \tilde{d}_b}^L
\end{aligned} \tag{163}$$

$$\Sigma_{i,j}^R(p^2) = -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_{\tilde{H}_a^-}^2) \Gamma_{\tilde{u}_j, \tilde{H}_a^+, \tilde{d}_b}^{R*} \Gamma_{\tilde{u}_i, \tilde{H}_a^+, \tilde{d}_b}^R$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{u}_j, \tilde{\chi}_a^+, \tilde{d}_b}^{R*} \Gamma_{\tilde{u}_i, \tilde{\chi}_a^+, \tilde{d}_b}^R \\
& -\frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{R*} \Gamma_{\tilde{u}_i, h_a, u_b}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^4 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{\chi}_b^0}^R \\
& -\frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{g}_1}^{R*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{g}_1}^R - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, g, u_b}^{L*} \Gamma_{\tilde{u}_i, g, u_b}^L \\
& -\sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, \gamma, u_b}^{L*} \Gamma_{\tilde{u}_i, \gamma, u_b}^L - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_Z^2) \Gamma_{\tilde{u}_j, Z, u_b}^{L*} \Gamma_{\tilde{u}_i, Z, u_b}^L \\
& -\sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{W^-}^2) \Gamma_{\tilde{u}_j, W^+, d_b}^{L*} \Gamma_{\tilde{u}_i, W^+, d_b}^L \tag{164}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{u}_j, H_a^+, d_b}^{L*} \Gamma_{\tilde{u}_i, H_a^+, d_b}^L \\
& -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{u}_j, \tilde{\chi}_a^+, \tilde{d}_b}^{L*} \Gamma_{\tilde{u}_i, \tilde{\chi}_a^+, \tilde{d}_b}^L \\
& -\frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{L*} \Gamma_{\tilde{u}_i, h_a, u_b}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^4 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{\chi}_b^0}^L \\
& -\frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{g}_1}^L - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, g, u_b}^{R*} \Gamma_{\tilde{u}_i, g, u_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, \gamma, u_b}^{R*} \Gamma_{\tilde{u}_i, \gamma, u_b}^R - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_Z^2) \Gamma_{\tilde{u}_j, Z, u_b}^{R*} \Gamma_{\tilde{u}_i, Z, u_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{W^-}^2) \Gamma_{\tilde{u}_j, W^+, d_b}^{R*} \Gamma_{\tilde{u}_i, W^+, d_b}^R \tag{165}
\end{aligned}$$

• Self-Energy for Gluino ( $\tilde{g}$ )

$$\Sigma^S(p^2) = + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{g}_j, \tilde{d}_a^*, d_b}^{L*} m_{d_b} \Gamma_{\tilde{g}_i, \tilde{d}_a^*, d_b}^R$$

$$+ \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{g}_j, \tilde{u}_a^*, u_b}^{L*} m_{u_b} \Gamma_{\tilde{g}_i, \tilde{u}_a^*, u_b}^R - 12 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{g}}^2, 0) \right) \Gamma_{\tilde{g}_j, g, \tilde{g}_1}^{R*} m_{\tilde{g}} \Gamma_{\tilde{g}_i, g, \tilde{g}_1}^L \quad (166)$$

$$\begin{aligned} \Sigma^R(p^2) &= -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{g}_j, \tilde{d}_a^*, d_b}^{R*} \Gamma_{\tilde{g}_i, \tilde{d}_a^*, d_b}^R \\ &\quad - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{g}_j, \tilde{u}_a^*, u_b}^{R*} \Gamma_{\tilde{g}_i, \tilde{u}_a^*, u_b}^R - 3B_1(p^2, m_{\tilde{g}}^2, 0) \Gamma_{\tilde{g}_j, g, \tilde{g}_1}^{L*} \Gamma_{\tilde{g}_i, g, \tilde{g}_1}^L \end{aligned} \quad (167)$$

$$\begin{aligned} \Sigma^L(p^2) &= -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{g}_j, \tilde{d}_a^*, d_b}^{L*} \Gamma_{\tilde{g}_i, \tilde{d}_a^*, d_b}^L \\ &\quad - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{g}_j, \tilde{u}_a^*, u_b}^{L*} \Gamma_{\tilde{g}_i, \tilde{u}_a^*, u_b}^L - 3B_1(p^2, m_{\tilde{g}}^2, 0) \Gamma_{\tilde{g}_j, g, \tilde{g}_1}^{R*} \Gamma_{\tilde{g}_i, g, \tilde{g}_1}^R \end{aligned} \quad (168)$$

• **Self-Energy for Z-Boson** ( $Z$ )

$$\begin{aligned} \Pi(p^2) &= +|\Gamma_{Z, \eta^-, \eta^-}|^2 B_{00}(p^2, m_{\eta^-}^2, m_{\eta^-}^2) + |\Gamma_{Z, \eta^+, \eta^+}|^2 B_{00}(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \\ &\quad - |\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) (2m_{W^-}^2 + 4p^2) \right) \\ &\quad + \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{Z, Z, H_a^+, H_a^-} - 4 \sum_{a=1}^2 \sum_{b=1}^2 |\Gamma_{Z, H_a^+, H_b^-}|^2 B_{00}(p^2, m_{H_a^-}^2, m_{H_b^-}^2) \\ &\quad + \sum_{a=1}^2 \sum_{b=1}^2 \left[ \left( |\Gamma_{Z, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^L|^2 + |\Gamma_{Z, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^R|^2 \right) H_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2) \right. \\ &\quad \left. + 4B_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2) m_{\tilde{\chi}_a^-} m_{\tilde{\chi}_b^-} \Re \left( \Gamma_{Z, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{Z, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^R \right) \right] \\ &\quad + \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{Z, Z, \tilde{\nu}_a^*, \tilde{\nu}_a} - 4 \sum_{a=1}^3 \sum_{b=1}^3 |\Gamma_{Z, \tilde{\nu}_a^*, \tilde{\nu}_b}|^2 B_{00}(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2) \\ &\quad + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left( |\Gamma_{Z, \tilde{d}_a, d_b}^L|^2 + |\Gamma_{Z, \tilde{d}_a, d_b}^R|^2 \right) H_0(p^2, m_{d_a}^2, m_{d_b}^2) \right. \\ &\quad \left. + 4B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_a} m_{d_b} \Re \left( \Gamma_{Z, \tilde{d}_a, d_b}^{L*} \Gamma_{Z, \tilde{d}_a, d_b}^R \right) \right] \\ &\quad + \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left( |\Gamma_{Z, \tilde{e}_a, e_b}^L|^2 + |\Gamma_{Z, \tilde{e}_a, e_b}^R|^2 \right) H_0(p^2, m_{e_a}^2, m_{e_b}^2) \right. \\ &\quad \left. + 4B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_a} m_{e_b} \Re \left( \Gamma_{Z, \tilde{e}_a, e_b}^{L*} \Gamma_{Z, \tilde{e}_a, e_b}^R \right) \right] \\ &\quad + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left( |\Gamma_{Z, \tilde{u}_a, u_b}^L|^2 + |\Gamma_{Z, \tilde{u}_a, u_b}^R|^2 \right) H_0(p^2, m_{u_a}^2, m_{u_b}^2) \right. \end{aligned}$$

$$\begin{aligned}
& + 4B_0\left(p^2, m_{u_a}^2, m_{u_b}^2\right) m_{u_a} m_{u_b} \Re\left(\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\left(p^2, m_{\nu_a}^2, m_{\nu_b}^2\right) \right. \\
& + 4B_0\left(p^2, m_{\nu_a}^2, m_{\nu_b}^2\right) m_{\nu_a} m_{\nu_b} \Re\left(\Gamma_{Z, \bar{\nu}_a, \nu_b}^{L*} \Gamma_{Z, \bar{\nu}_a, \nu_b}^R\right) \\
& + \frac{1}{2} \sum_{a=1}^4 A_0\left(m_{h_a}^2\right) \Gamma_{Z, Z, h_a, h_a} - 2 \sum_{a=1}^4 \sum_{b=1}^4 |\Gamma_{Z, h_a, h_b}|^2 B_{00}\left(p^2, m_{h_a}^2, m_{h_b}^2\right) \\
& + \frac{1}{2} \sum_{a=1}^4 \sum_{b=1}^4 \left[ \left( |\Gamma_{Z, \bar{\chi}_a^0, \bar{\chi}_b^0}^L|^2 + |\Gamma_{Z, \bar{\chi}_a^0, \bar{\chi}_b^0}^R|^2 \right) H_0\left(p^2, m_{\bar{\chi}_a^0}^2, m_{\bar{\chi}_b^0}^2\right) \right. \\
& + 4B_0\left(p^2, m_{\bar{\chi}_a^0}^2, m_{\bar{\chi}_b^0}^2\right) m_{\bar{\chi}_a^0} m_{\bar{\chi}_b^0} \Re\left(\Gamma_{Z, \bar{\chi}_a^0, \bar{\chi}_b^0}^{L*} \Gamma_{Z, \bar{\chi}_a^0, \bar{\chi}_b^0}^R\right) \\
& + 3 \sum_{a=1}^6 A_0\left(m_{\bar{d}_a}^2\right) \Gamma_{Z, Z, \bar{d}_a^*, \bar{d}_a} + \sum_{a=1}^6 A_0\left(m_{\bar{e}_a}^2\right) \Gamma_{Z, Z, \bar{e}_a^*, \bar{e}_a} + 3 \sum_{a=1}^6 A_0\left(m_{\bar{u}_a}^2\right) \Gamma_{Z, Z, \bar{u}_a^*, \bar{u}_a} \\
& - 12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z, \bar{d}_a^*, \bar{d}_b}|^2 B_{00}\left(p^2, m_{\bar{d}_a}^2, m_{\bar{d}_b}^2\right) - 4 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z, \bar{e}_a^*, \bar{e}_b}|^2 B_{00}\left(p^2, m_{\bar{e}_a}^2, m_{\bar{e}_b}^2\right) \\
& - 12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z, \bar{u}_a^*, \bar{u}_b}|^2 B_{00}\left(p^2, m_{\bar{u}_a}^2, m_{\bar{u}_b}^2\right) + 2 \sum_{b=1}^2 |\Gamma_{Z, W^+, H_b^-}|^2 B_0\left(p^2, m_{W^-}^2, m_{H_b^-}^2\right) \\
& + \sum_{b=1}^4 |\Gamma_{Z, Z, h_b}|^2 B_0\left(p^2, m_Z^2, m_{h_b}^2\right) + 2\text{rMS} m_{W^-}^2 \Gamma_{Z, Z, W^+, W^-}^1 - A_0\left(m_{W^-}^2\right) \left( 4\Gamma_{Z, Z, W^+, W^-}^1 + \Gamma_{Z, Z, W^+, W^-}^2 + \Gamma_{Z, Z, W^+, W^-}^3 \right)
\end{aligned} \tag{169}$$

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

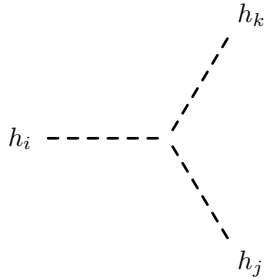
$$\begin{aligned}
\Pi(p^2) & = -12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{W^+, \bar{u}_a^*, \bar{d}_b}|^2 B_{00}\left(p^2, m_{\bar{d}_b}^2, m_{\bar{u}_a}^2\right) + 2\text{rMS} m_{W^-}^2 \Gamma_{W^-, W^+, W^+, W^-}^1 + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left( |\Gamma_{W^+, \bar{u}_a, d_b}^L|^2 + |\Gamma_{W^+, \bar{u}_a, d_b}^R|^2 \right) H_0\left(p^2, m_{\bar{u}_a}^2, m_{d_b}^2\right) \right. \\
& + 4B_0\left(p^2, m_{u_a}^2, m_{d_b}^2\right) m_{d_b} m_{u_a} \Re\left(\Gamma_{W^+, \bar{u}_a, d_b}^{L*} \Gamma_{W^+, \bar{u}_a, d_b}^R\right) + 3 \sum_{a=1}^6 A_0\left(m_{\bar{d}_a}^2\right) \Gamma_{W^-, W^+, \bar{d}_a^*, \bar{d}_a} + 3 \sum_{a=1}^6 A_0\left(m_{\bar{u}_a}^2\right) \Gamma_{W^-, W^+, \bar{u}_a^*, \bar{u}_a} \\
& + 4B_0\left(p^2, m_{\nu_a}^2, m_{e_b}^2\right) m_{e_b} m_{\nu_a} \Re\left(\Gamma_{W^+, \bar{\nu}_a, e_b}^{L*} \Gamma_{W^+, \bar{\nu}_a, e_b}^R\right) + \sum_{a=1}^4 \sum_{b=1}^2 \left[ \left( |\Gamma_{W^+, \bar{\chi}_a^0, \bar{\chi}_b^-}^L|^2 + |\Gamma_{W^+, \bar{\chi}_a^0, \bar{\chi}_b^-}^R|^2 \right) H_0\left(p^2, m_{\bar{\chi}_a^0}^2, m_{\bar{\chi}_b^-}^2\right) \right. \\
& + 4B_0\left(p^2, m_{\bar{\chi}_a^0}^2, m_{\bar{\chi}_b^-}^2\right) m_{\bar{\chi}_b^-} m_{\bar{\chi}_a^0} \Re\left(\Gamma_{W^+, \bar{\chi}_a^0, \bar{\chi}_b^-}^{L*} \Gamma_{W^+, \bar{\chi}_a^0, \bar{\chi}_b^-}^R\right) + \sum_{a=1}^6 A_0\left(m_{\bar{e}_a}^2\right) \Gamma_{W^-, W^+, \bar{e}_a^*, \bar{e}_a} + \sum_{b=1}^2 |\Gamma_{W^+, \gamma, H_b^-}|^2 B_0\left(p^2, 0, m_{H_b^-}^2\right)
\end{aligned} \tag{170}$$

## 8.2 Tadpoles

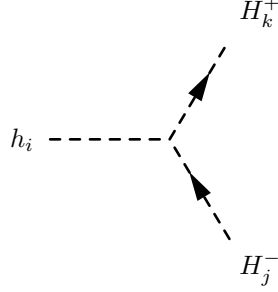
$$\begin{aligned}
\delta t_h^{(1)} = & + A_0(m_{\eta^-}^2) \Gamma_{\tilde{h}_i, \eta^-, \eta^-} + A_0(m_{\eta^+}^2) \Gamma_{\tilde{h}_i, \eta^+, \eta^+} + A_0(m_{\eta^Z}^2) \Gamma_{\tilde{h}_i, \eta^Z, \eta^Z} \\
& + 4\Gamma_{\tilde{h}_i, W^+, W^-} \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\tilde{h}_i, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{h}_i, H_a^+, H_a^-} \\
& + 2 \sum_{a=1}^2 A_0(m_{\tilde{\chi}_a^-}^2) m_{\tilde{\chi}_a^-} \left( \Gamma_{\tilde{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_a^-}^L + \Gamma_{\tilde{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_a^-}^R \right) - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{h}_i, \tilde{\nu}_a^*, \tilde{\nu}_a} \\
& + 6 \sum_{a=1}^3 A_0(m_{\tilde{d}_a}^2) m_{\tilde{d}_a} \left( \Gamma_{\tilde{h}_i, \tilde{d}_a, \tilde{d}_a}^L + \Gamma_{\tilde{h}_i, \tilde{d}_a, \tilde{d}_a}^R \right) \\
& + 2 \sum_{a=1}^3 A_0(m_{\tilde{e}_a}^2) m_{\tilde{e}_a} \left( \Gamma_{\tilde{h}_i, \tilde{e}_a, \tilde{e}_a}^L + \Gamma_{\tilde{h}_i, \tilde{e}_a, \tilde{e}_a}^R \right) \\
& + 6 \sum_{a=1}^3 A_0(m_{\tilde{u}_a}^2) m_{\tilde{u}_a} \left( \Gamma_{\tilde{h}_i, \tilde{u}_a, \tilde{u}_a}^L + \Gamma_{\tilde{h}_i, \tilde{u}_a, \tilde{u}_a}^R \right) - \frac{1}{2} \sum_{a=1}^4 A_0(m_{h_a}^2) \Gamma_{\tilde{h}_i, h_a, h_a} \\
& + \sum_{a=1}^4 A_0(m_{\tilde{\chi}_a^0}^2) m_{\tilde{\chi}_a^0} \left( \Gamma_{\tilde{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_a^0}^L + \Gamma_{\tilde{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_a^0}^R \right) - 3 \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\tilde{h}_i, \tilde{d}_a^*, \tilde{d}_a} \\
& - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{h}_i, \tilde{e}_a^*, \tilde{e}_a} - 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{h}_i, \tilde{u}_a^*, \tilde{u}_a}
\end{aligned} \tag{171}$$

## 9 Interactions for eigenstates 'EWSB'

### 9.1 Three Scalar-Interaction

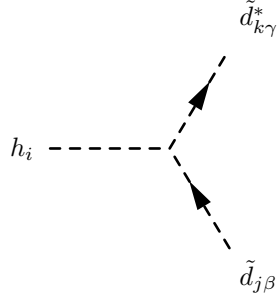


$$\begin{aligned}
& -\frac{i}{4} \left( g_1^2 + g_2^2 \right) \left( v_d Z_{i3}^H Z_{j3}^H Z_{k1}^H - v_d Z_{i4}^H Z_{j4}^H Z_{k1}^H - v_u Z_{i3}^H Z_{j3}^H Z_{k2}^H + v_u Z_{i4}^H Z_{j4}^H Z_{k2}^H \right. \\
& + v_d Z_{i3}^H Z_{j1}^H Z_{k3}^H - v_u Z_{i3}^H Z_{j2}^H Z_{k3}^H - v_d Z_{i4}^H Z_{j1}^H Z_{k4}^H + v_u Z_{i4}^H Z_{j2}^H Z_{k4}^H \\
& - Z_{i1}^H \left( -v_d Z_{j3}^H Z_{k3}^H + v_d Z_{j4}^H Z_{k4}^H + Z_{j1}^H \left( -3v_d Z_{k1}^H + v_u Z_{k2}^H \right) + Z_{j2}^H \left( v_d Z_{k2}^H + v_u Z_{k1}^H \right) \right) \\
& \left. - Z_{i2}^H \left( v_u \left( Z_{j3}^H Z_{k3}^H - Z_{j4}^H Z_{k4}^H \right) + Z_{j1}^H \left( v_d Z_{k2}^H + v_u Z_{k1}^H \right) + Z_{j2}^H \left( -3v_u Z_{k2}^H + v_d Z_{k1}^H \right) \right) \right)
\end{aligned} \tag{172}$$



$$\begin{aligned}
& -\frac{i}{4} \left( Z_{j1}^{+,*} \left( -ig_2^2 (v_d Z_{i4}^H + v_u Z_{i3}^H) Z_{k2}^+ + Z_{i2}^H \left( (-g_1^2 + g_2^2) v_u Z_{k1}^+ + g_2^2 v_d Z_{k2}^+ \right) \right. \right. \\
& + Z_{i1}^H \left( (g_1^2 + g_2^2) v_d Z_{k1}^+ + g_2^2 v_u Z_{k2}^+ \right) \left. \right) \\
& + Z_{j2}^{+,*} \left( ig_2^2 (v_d Z_{i4}^H + v_u Z_{i3}^H) Z_{k1}^+ + Z_{i1}^H \left( (-g_1^2 + g_2^2) v_d Z_{k2}^+ + g_2^2 v_u Z_{k1}^+ \right) \right. \\
& \left. \left. + Z_{i2}^H \left( (g_1^2 + g_2^2) v_u Z_{k2}^+ + g_2^2 v_d Z_{k1}^+ \right) \right) \right) \tag{173}
\end{aligned}$$

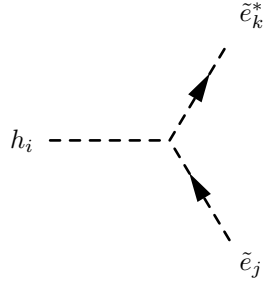

---



$$\begin{aligned}
& \frac{1}{12} e^{-i\eta} \delta_{\beta\gamma} \left( ie^{i\eta} (3g_2^2 + g_1^2) \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D (v_d Z_{i1}^H - v_u Z_{i2}^H) \right. \\
& + 2 \left( ie^{i\eta} g_1^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D (v_d Z_{i1}^H - v_u Z_{i2}^H) \right. \\
& + 3 \left( -2ie^{i\eta} v_d \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{k3+b}^D Z_{i1}^H \right. \\
& - 2ie^{i\eta} v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{kc}^D Z_{i1}^H + i\sqrt{2}\mu^* \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D Z_{i2}^H \\
& \left. \left. + i\sqrt{2}e^{2i\eta}\mu \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{kb}^D Z_{i2}^H \right) \right)
\end{aligned}$$

$$\begin{aligned}
& -i\sqrt{2}e^{i\eta} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{D,*} T_{d,ab}^* Z_{kb}^D \left( -iZ_{i3}^H + Z_{i1}^H \right) \\
& + \sqrt{2}e^{i\eta} \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Z_{k3+a}^D T_{d,ab} \left( -iZ_{i1}^H + Z_{i3}^H \right) + \sqrt{2}\mu^* \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D Z_{i4}^H \\
& - \sqrt{2}e^{2i\eta} \mu \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{kb}^D Z_{i4}^H \Big) \Big) \Big) \tag{174}
\end{aligned}$$

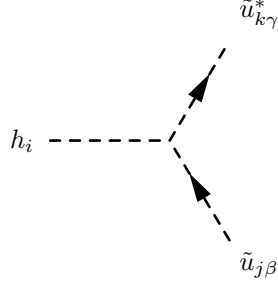

---



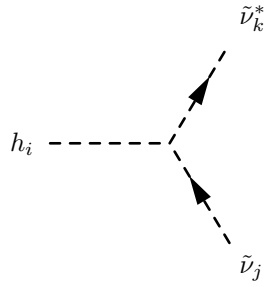
$$\begin{aligned}
& \frac{1}{4} e^{-i\eta} \left( -ie^{i\eta} \left( -g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \left( v_d Z_{i1}^H - v_u Z_{i2}^H \right) \right. \\
& + 2 \left( -i\sqrt{2}e^{i\eta} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{E,*} T_{e,ab}^* Z_{kb}^E Z_{i1}^H \right. \\
& - 2ie^{i\eta} v_d \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{k3+b}^E Z_{i1}^H \\
& - 2ie^{i\eta} v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{kc}^E Z_{i1}^H + i\sqrt{2}\mu^* \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E Z_{i2}^H \\
& + i\sqrt{2}e^{2i\eta} \mu \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{kb}^E Z_{i2}^H \\
& + ie^{i\eta} g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \left( v_d Z_{i1}^H - v_u Z_{i2}^H \right) - \sqrt{2}e^{i\eta} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{E,*} T_{e,ab}^* Z_{kb}^E Z_{i3}^H \\
& + \sqrt{2}e^{i\eta} \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Z_{k3+a}^E T_{e,ab} \left( -iZ_{i1}^H + Z_{i3}^H \right) + \sqrt{2}\mu^* \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E Z_{i4}^H \\
& \left. \left. \left. - \sqrt{2}e^{2i\eta} \mu \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{kb}^E Z_{i4}^H \right) \right) \right) \Big) \tag{175}
\end{aligned}$$


---

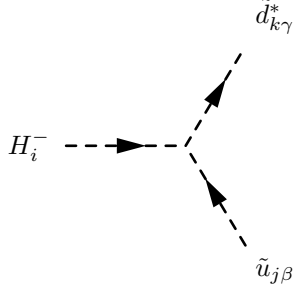




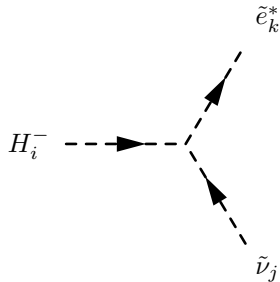
$$\begin{aligned}
& \frac{1}{12} e^{-i\eta} \delta_{\beta\gamma} \left( i e^{i\eta} \left( -3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \left( v_d Z_{i1}^H - v_u Z_{i2}^H \right) \right. \\
& + 2 \left( -2i e^{i\eta} g_1^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \left( v_d Z_{i1}^H - v_u Z_{i2}^H \right) \right. \\
& + 3 \left( -i\sqrt{2} e^{2i\eta} \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Z_{k3+a}^U T_{u,ab} Z_{i2}^H - i\sqrt{2} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{U,*} T_{u,ab}^* Z_{kb}^U Z_{i2}^H \right. \\
& - 2i e^{i\eta} v_u \sum_{c=1}^3 Z_{j3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{k3+b}^U Z_{i2}^H \\
& - 2i e^{i\eta} v_u \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{kc}^U Z_{i2}^H \\
& + i\sqrt{2} e^{i\eta} \mu \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{j3+a}^{U,*} Z_{kb}^U \left( i Z_{i3}^H + Z_{i1}^H \right) \\
& + \sqrt{2} e^{i\eta} \mu^* \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \left( i Z_{i1}^H + Z_{i3}^H \right) + \sqrt{2} e^{2i\eta} \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Z_{k3+a}^U T_{u,ab} Z_{i4}^H \\
& \left. \left. \left. - \sqrt{2} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{U,*} T_{u,ab}^* Z_{kb}^U Z_{i4}^H \right) \right) \right) \tag{176}
\end{aligned}$$



$$-\frac{i}{4}(g_1^2 + g_2^2)\delta_{jk}(v_d Z_{i1}^H - v_u Z_{i2}^H) \quad (177)$$



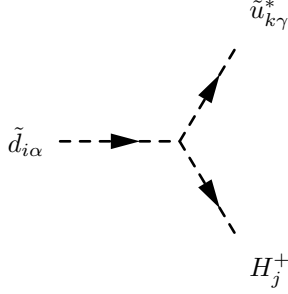
$$\begin{aligned} & -\frac{i}{4}e^{-i\eta}\delta_{\beta\gamma}\left(Z_{i1}^{+,*}\left(\sqrt{2}e^{i\eta}g_2^2v_d\sum_{a=1}^3Z_{ja}^{U,*}Z_{ka}^D\right.\right. \\ & - 2\left(2e^{i\eta}\sum_{b=1}^3Z_{jb}^{U,*}\sum_{a=1}^3Z_{k3+a}^DT_{d,ab}+2e^{i\eta}\mu\sum_{b=1}^3\sum_{a=1}^3Y_{u,ab}^*Z_{j3+a}^{U,*}Z_{kb}^D\right. \\ & \left.\left.+\sqrt{2}\left(e^{i\eta}v_d\sum_{c=1}^3\sum_{b=1}^3Z_{jb}^{U,*}\sum_{a=1}^3Y_{d,ac}^*Y_{d,ab}Z_{kc}^D+v_u\sum_{c=1}^3Z_{j3+c}^{U,*}\sum_{b=1}^3\sum_{a=1}^3Y_{u,ca}^*Y_{d,ba}Z_{k3+b}^D\right)\right)\right) \\ & + Z_{i2}^{+,*}\left(\sqrt{2}e^{i\eta}g_2^2v_u\sum_{a=1}^3Z_{ja}^{U,*}Z_{ka}^D\right. \\ & - 2\left(2\mu^*\sum_{b=1}^3Z_{jb}^{U,*}\sum_{a=1}^3Y_{d,ab}Z_{k3+a}^D+2\sum_{b=1}^3\sum_{a=1}^3Z_{j3+a}^{U,*}T_{u,ab}^*Z_{kb}^D\right. \\ & \left.\left.+\sqrt{2}\left(e^{i\eta}v_u\sum_{c=1}^3\sum_{b=1}^3Z_{jb}^{U,*}\sum_{a=1}^3Y_{u,ac}^*Y_{u,ab}Z_{kc}^D+v_d\sum_{c=1}^3Z_{j3+c}^{U,*}\sum_{b=1}^3\sum_{a=1}^3Y_{u,ca}^*Y_{d,ba}Z_{k3+b}^D\right)\right)\right) \quad (178) \end{aligned}$$



$$-\frac{i}{4}e^{-i\eta}\left(Z_{i2}^{+,*}\left(-4\mu^*\sum_{b=1}^3Z_{jb}^{V,*}\sum_{a=1}^3Y_{e,ab}Z_{k3+a}^E+\sqrt{2}e^{i\eta}g_2^2v_u\sum_{a=1}^3Z_{ja}^{V,*}Z_{ka}^E\right)\right)$$

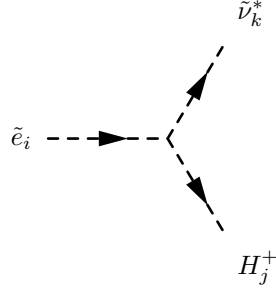
$$\begin{aligned}
& + e^{i\eta} Z_{i1}^{+,*} \left( \sqrt{2} g_2^2 v_d \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^E - 4 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Z_{k3+a}^E T_{e,ab} \right. \\
& \left. - 2\sqrt{2} v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{kc}^E \right) \tag{179}
\end{aligned}$$


---



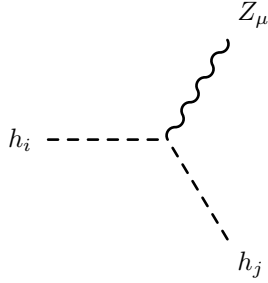
$$\begin{aligned}
& - \frac{i}{4} \delta_{\alpha\gamma} \left( \sqrt{2} g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^U \left( v_d Z_{j1}^+ + v_u Z_{j2}^+ \right) \right. \\
& - 2 \left( 2\mu^* \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U Z_{j1}^+ + 2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{i3+a}^{D,*} T_{d,ab}^* Z_{kb}^U Z_{j1}^+ \right. \\
& + \sqrt{2} e^{i\eta} v_u \sum_{c=1}^3 Z_{i3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{k3+b}^U Z_{j1}^+ \\
& + \sqrt{2} v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{kc}^U Z_{j1}^+ + 2e^{i\eta} \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Z_{k3+a}^U T_{u,ab} Z_{j2}^+ \\
& + 2e^{i\eta} \mu \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{i3+a}^{D,*} Z_{kb}^U Z_{j2}^+ \\
& + \sqrt{2} e^{i\eta} v_d \sum_{c=1}^3 Z_{i3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{k3+b}^U Z_{j2}^+ \\
& \left. \left. + \sqrt{2} v_u \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{kc}^U Z_{j2}^+ \right) \right) \tag{180}
\end{aligned}$$


---

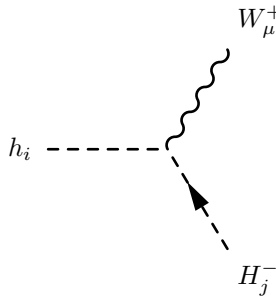


$$\begin{aligned}
& -\frac{i}{4} \left( \sqrt{2} g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^V (v_d Z_{j1}^+ + v_u Z_{j2}^+) \right. \\
& - 2 \left( 2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{i3+a}^{E,*} T_{e,ab}^* Z_{kb}^V Z_{j1}^+ + \sqrt{2} v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{kc}^V Z_{j1}^+ \right. \\
& \left. \left. + 2 \epsilon^{in} \mu \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{i3+a}^{E,*} Z_{kb}^V Z_{j2}^+ \right) \right) \quad (181)
\end{aligned}$$

## 9.2 Two Scalar-One Vector Boson-Interaction

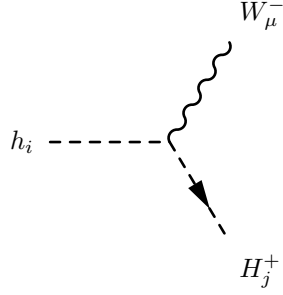


$$\frac{1}{2} (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \left( -Z_{i1}^H Z_{j3}^H + Z_{i2}^H Z_{j4}^H + Z_{i3}^H Z_{j1}^H - Z_{i4}^H Z_{j2}^H \right) \left( -p_\mu^{h_j} + p_\mu^{h_i} \right) \quad (182)$$



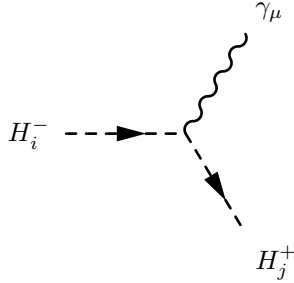
$$\frac{1}{2}g_2 \left( Z_{j1}^{+,*} (iZ_{i1}^H + Z_{i3}^H) + Z_{j2}^{+,*} (-iZ_{i2}^H + Z_{i4}^H) \right) (-p_\mu^{H_j^-} + p_\mu^{h_i}) \quad (183)$$


---



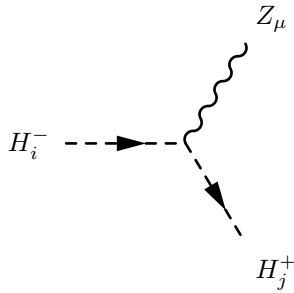
$$\frac{1}{2}g_2 \left( -iZ_{i1}^H Z_{j1}^+ + (iZ_{i2}^H + Z_{i4}^H) Z_{j2}^+ + Z_{i3}^H Z_{j1}^+ \right) (-p_\mu^{H_j^+} + p_\mu^{h_i}) \quad (184)$$


---



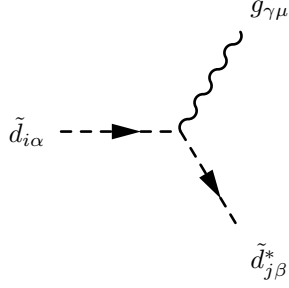
$$\frac{i}{2} (g_1 \cos \Theta_W + g_2 \sin \Theta_W) \left( Z_{i1}^{+,*} Z_{j1}^+ + Z_{i2}^{+,*} Z_{j2}^+ \right) (-p_\mu^{H_j^+} + p_\mu^{H_i^-}) \quad (185)$$


---



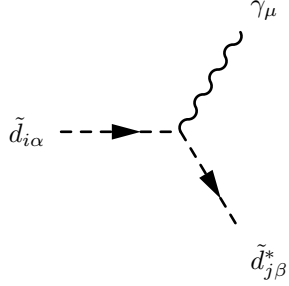
$$\frac{i}{2} (-g_1 \sin \Theta_W + g_2 \cos \Theta_W) \left( Z_{i1}^{+,*} Z_{j1}^+ + Z_{i2}^{+,*} Z_{j2}^+ \right) (-p_\mu^{H_j^+} + p_\mu^{H_i^-}) \quad (186)$$


---



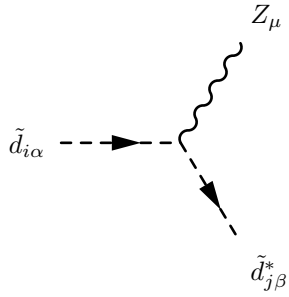
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\beta,\alpha}^\gamma\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (187)$$


---



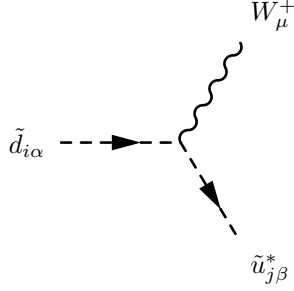
$$-\frac{i}{6}\delta_{\alpha,\beta}\left(-2g_1\cos\Theta_W\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D+\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right)\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (188)$$


---



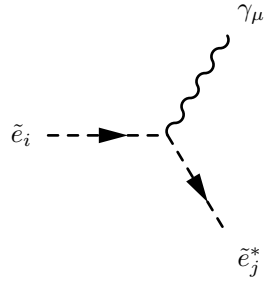
$$\frac{i}{6}\delta_{\alpha,\beta}\left(-2g_1\sin\Theta_W\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D+\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right)\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (189)$$


---



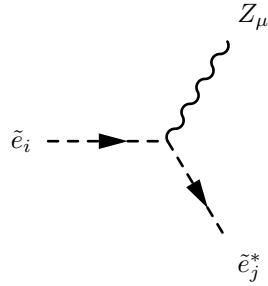
$$-i \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U \left( -p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{d}_{i\alpha}} \right) \quad (190)$$


---



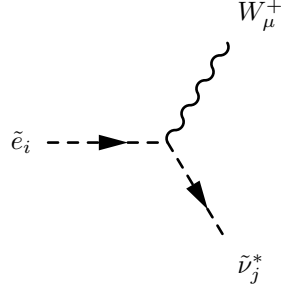
$$\frac{i}{2} \left( 2g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E + \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right) \left( -p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i} \right) \quad (191)$$


---



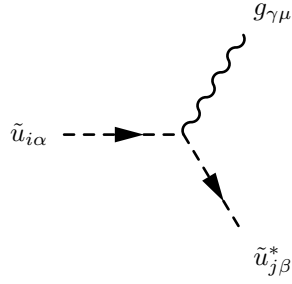
$$\frac{i}{2} \left( -2g_1 \sin \Theta_W \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right) \left( -p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i} \right) \quad (192)$$


---



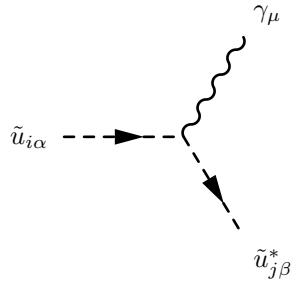
$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V \left( -p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{e}_i} \right) \quad (193)$$


---



$$- \frac{i}{2} g_3 \delta_{ij} \lambda_{\beta,\alpha}^\gamma \left( -p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \quad (194)$$

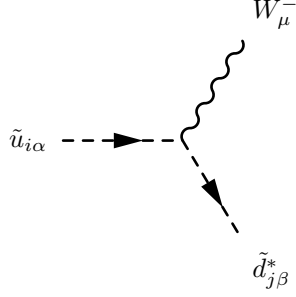

---



$$- \frac{i}{6} \delta_{\alpha,\beta} \left( \left( 3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + 4g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) \left( -p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \quad (195)$$

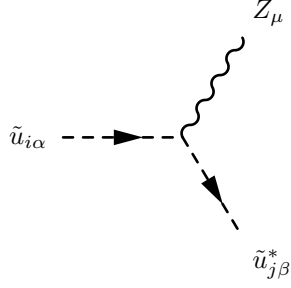

---





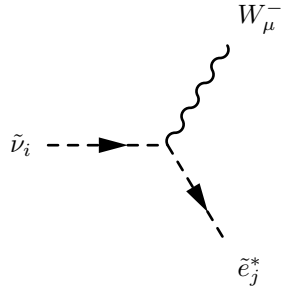
$$-i \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D \left( -p_\mu^{\tilde{d}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \quad (196)$$


---



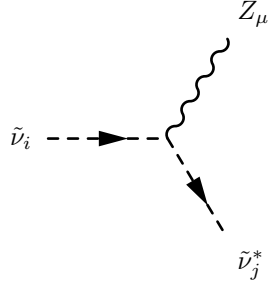
$$-\frac{i}{6} \delta_{\alpha\beta} \left( \left( 3g_2 \cos \Theta_W - g_1 \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U - 4g_1 \sin \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) \left( -p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \quad (197)$$


---



$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E \left( -p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{\nu}_i} \right) \quad (198)$$

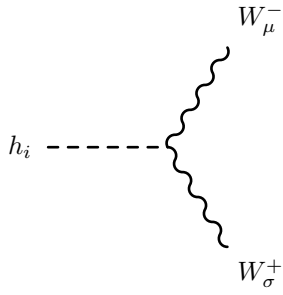

---



$$-\frac{i}{2}\delta_{ij}\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(-p_\mu^{\tilde{\nu}_j^*}+p_\mu^{\tilde{\nu}_i}\right) \quad (199)$$

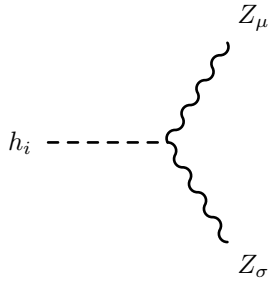

---

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



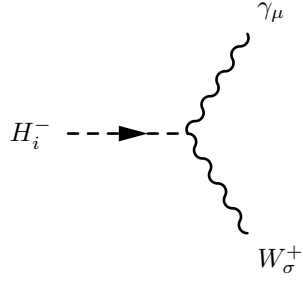
$$\frac{i}{2}g_2^2\left(v_dZ_{i1}^H+v_uZ_{i2}^H\right)\left(g_{\sigma\mu}\right) \quad (200)$$


---



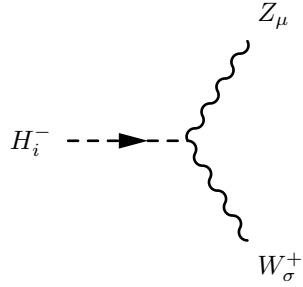
$$\frac{i}{2}\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)^2\left(v_dZ_{i1}^H+v_uZ_{i2}^H\right)\left(g_{\sigma\mu}\right) \quad (201)$$


---



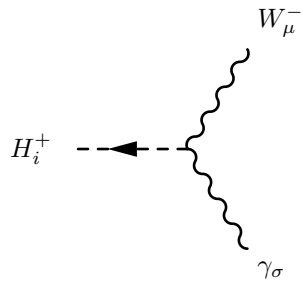
$$-\frac{i}{2}g_1g_2(v_dZ_{i1}^{+,*} - v_uZ_{i2}^{+,*})\cos\Theta_W(g_{\sigma\mu}) \quad (202)$$


---



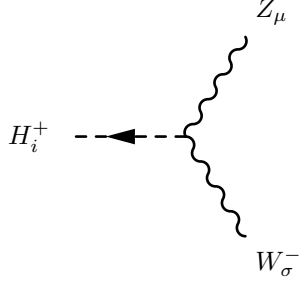
$$\frac{i}{2}g_1g_2(v_dZ_{i1}^{+,*} - v_uZ_{i2}^{+,*})\sin\Theta_W(g_{\sigma\mu}) \quad (203)$$


---



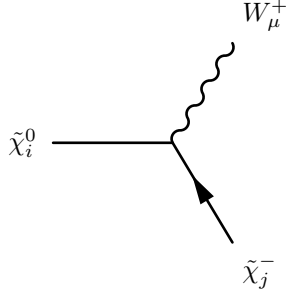
$$-\frac{i}{2}g_1g_2\cos\Theta_W(v_dZ_{i1}^+ - v_uZ_{i2}^+)(g_{\sigma\mu}) \quad (204)$$


---



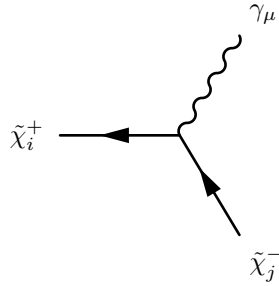
$$\frac{i}{2}g_1g_2\sin\Theta_W\left(v_dZ_{i1}^+ - v_uZ_{i2}^+\right)\left(g_{\sigma\mu}\right) \quad (205)$$

#### 9.4 Two Fermion-One Vector Boson-Interaction



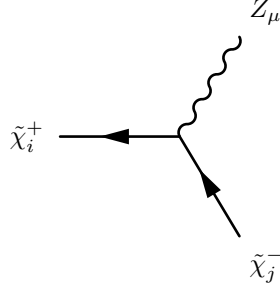
$$-\frac{i}{2}g_2\left(2U_{j1}^*N_{i2} + \sqrt{2}U_{j2}^*N_{i3}\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (206)$$

$$+ \left(i\frac{1}{\sqrt{2}}g_2N_{i4}^*V_{j2} - ig_2N_{i2}^*V_{j1}\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (207)$$



$$\frac{i}{2}\left(2g_2U_{j1}^*\sin\Theta_WU_{i1} + U_{j2}^*\left(g_1\cos\Theta_W + g_2\sin\Theta_W\right)U_{i2}\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (208)$$

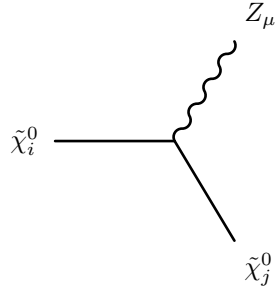
$$+ \frac{i}{2}\left(2g_2V_{i1}^*\sin\Theta_WV_{j1} + V_{i2}^*\left(g_1\cos\Theta_W + g_2\sin\Theta_W\right)V_{j2}\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (209)$$



$$\frac{i}{2} \left( 2g_2 U_{j1}^* \cos \Theta_W U_{i1} + U_{j2}^* \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) U_{i2} \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (210)$$

$$+ \frac{i}{2} \left( 2g_2 V_{i1}^* \cos \Theta_W V_{j1} + V_{i2}^* \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) V_{j2} \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (211)$$

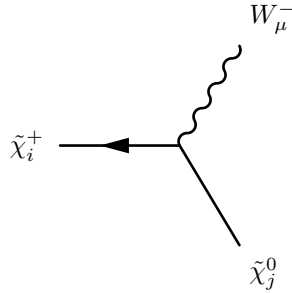

---



$$- \frac{i}{2} \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left( N_{j3}^* N_{i3} - N_{j4}^* N_{i4} \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (212)$$

$$+ \frac{i}{2} \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left( N_{i3}^* N_{j3} - N_{i4}^* N_{j4} \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (213)$$

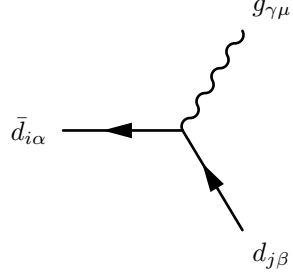

---



$$- \frac{i}{2} g_2 \left( 2N_{j2}^* U_{i1} + \sqrt{2} N_{j3}^* U_{i2} \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (214)$$

$$+ \left( i \frac{1}{\sqrt{2}} g_2 V_{i2}^* N_{j4} - i g_2 V_{i1}^* N_{j2} \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (215)$$

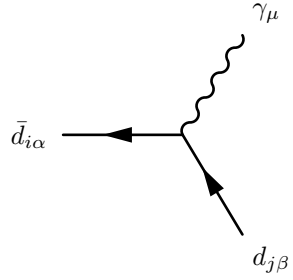

---



$$- \frac{i}{2} g_3 \delta_{ij} \lambda_{\alpha,\beta}^\gamma \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (216)$$

$$+ - \frac{i}{2} g_3 \delta_{ij} \lambda_{\alpha,\beta}^\gamma \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (217)$$

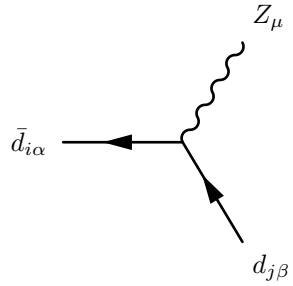

---



$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \left( -3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (218)$$

$$+ \frac{i}{3} g_1 \cos \Theta_W \delta_{\alpha\beta} \delta_{ij} \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (219)$$

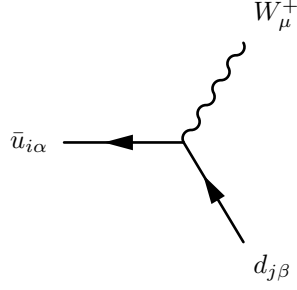

---



$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (220)$$

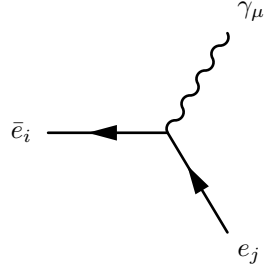
$$+ \frac{i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (221)$$


---



$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3U_{L,ja}^{d,*}U_{L,ia}^u\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (222)$$

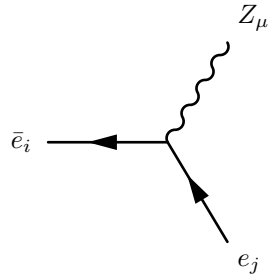

---



$$\frac{i}{2}\delta_{ij}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (223)$$

$$+ ig_1\cos\Theta_W\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (224)$$

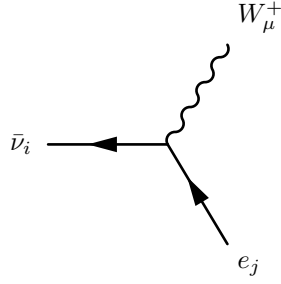

---



$$\frac{i}{2}\delta_{ij}\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (225)$$

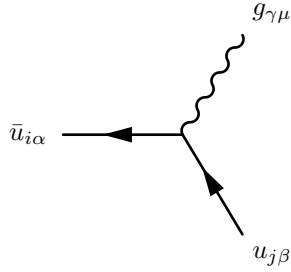
$$+ -ig_1\delta_{ij}\sin\Theta_W\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (226)$$


---



$$-i\frac{1}{\sqrt{2}}g_2U_{L,ji}^{e,*}\Theta_{i,3}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (227)$$

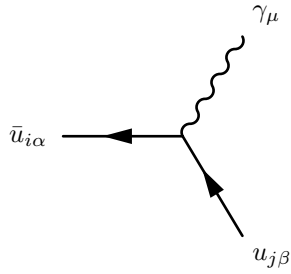

---



$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (228)$$

$$+ -\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (229)$$


---

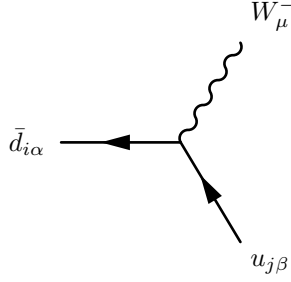




$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (230)$$

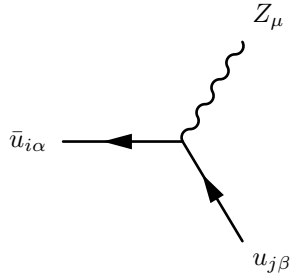
$$+\frac{2i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (231)$$


---



$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3U_{L,ja}^{u,*}U_{L,ia}^d\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (232)$$

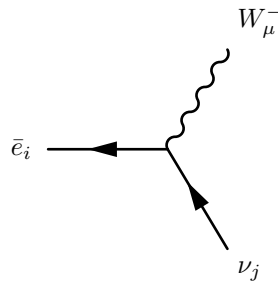

---



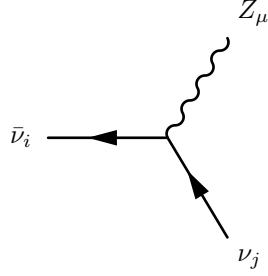
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\cos\Theta_W-g_1\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (233)$$

$$+\frac{2i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (234)$$

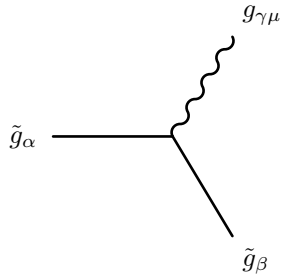

---



$$-i \frac{1}{\sqrt{2}} g_2 \Theta_{j,3} U_{L,ij}^e \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (235)$$



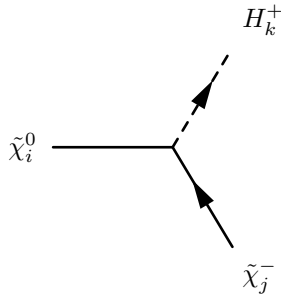
$$-\frac{i}{2} \delta_{ij} \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (236)$$



$$-g_3 |\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma} \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (237)$$

$$+ -g_3 |\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma} \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (238)$$

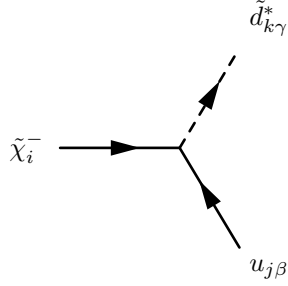
## 9.5 Two Fermion-One Scalar Boson-Interaction



$$\frac{i}{2} \left( -2g_2 U_{j1}^* N_{i3}^* + \sqrt{2} U_{j2}^* (g_1 N_{i1}^* + g_2 N_{i2}^*) \right) Z_{k1}^+ \left( \frac{1-\gamma_5}{2} \right) \quad (239)$$

$$+ -\frac{i}{2} e^{i\eta} \left( 2g_2 V_{j1} N_{i4} + \sqrt{2} V_{j2} (g_1 N_{i1} + g_2 N_{i2}) \right) Z_{k2}^+ \left( \frac{1+\gamma_5}{2} \right) \quad (240)$$

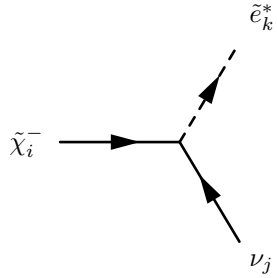

---



$$-i\delta_{\beta\gamma} \left( g_2 U_{i1}^* \sum_{a=1}^3 U_{L,ja}^{u,*} Z_{ka}^D - U_{i2}^* \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \right) \left( \frac{1-\gamma_5}{2} \right) \quad (241)$$

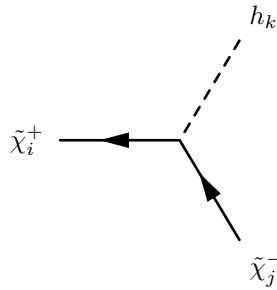
$$+ i\delta_{\beta\gamma} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u Z_{kb}^D V_{i2} \left( \frac{1+\gamma_5}{2} \right) \quad (242)$$


---



$$i \left( -g_2 U_{i1}^* \Theta_{j,3} Z_{kj}^E + U_{i2}^* \sum_{a=1}^3 Y_{e,aj} Z_{k3+a}^E \right) \left( \frac{1-\gamma_5}{2} \right) \quad (243)$$

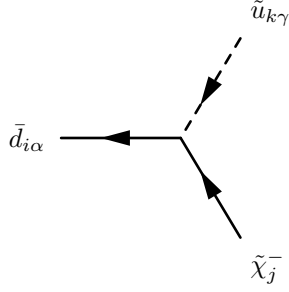

---



$$-i \frac{1}{\sqrt{2}} e^{-i\eta} g_2 \left( e^{i\eta} U_{j2}^* V_{i1}^* \left( -i Z_{k3}^H + Z_{k1}^H \right) + U_{j1}^* V_{i2}^* \left( -i Z_{k4}^H + Z_{k2}^H \right) \right) \left( \frac{1-\gamma_5}{2} \right) \quad (244)$$

$$+ \frac{1}{\sqrt{2}} g_2 \left( e^{i\eta} U_{i1} V_{j2} \left( -i Z_{k2}^H + Z_{k4}^H \right) + U_{i2} V_{j1} \left( -i Z_{k1}^H + Z_{k3}^H \right) \right) \left( \frac{1+\gamma_5}{2} \right) \quad (245)$$

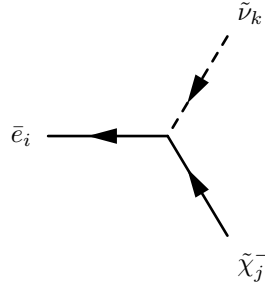

---



$$i U_{j2}^* \delta_{\alpha\gamma} \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (246)$$

$$+ -i \delta_{\alpha\gamma} \left( g_2 \sum_{a=1}^3 Z_{ka}^{U,*} U_{L,ia}^d V_{j1} - \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} U_{L,ib}^d V_{j2} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (247)$$

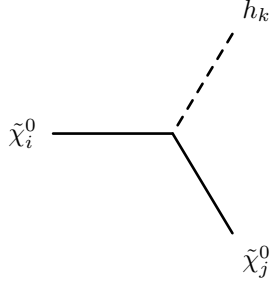

---



$$i U_{j2}^* \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (248)$$

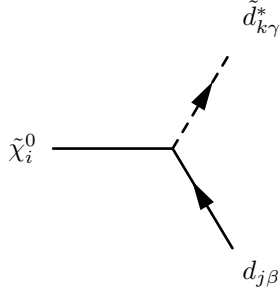
$$+ -i g_2 \sum_{a=1}^3 Z_{ka}^{V,*} U_{L,ia}^e V_{j1} \left( \frac{1+\gamma_5}{2} \right) \quad (249)$$


---



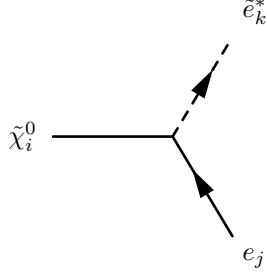
$$\begin{aligned}
& \frac{1}{2}e^{-i\eta} \left( -ie^{i\eta}g_2N_{i2}^*N_{j3}^*Z_{k1}^H - ig_1N_{i4}^*N_{j1}^*Z_{k2}^H + ig_2N_{i4}^*N_{j2}^*Z_{k2}^H + ig_2N_{i2}^*N_{j4}^*Z_{k2}^H \right. \\
& - e^{i\eta}g_2N_{i2}^*N_{j3}^*Z_{k3}^H + e^{i\eta}N_{i3}^*(g_1N_{j1}^* - g_2N_{j2}^*)(iZ_{k1}^H + Z_{k3}^H) \\
& + g_1N_{i1}^*(e^{i\eta}N_{j3}^*(iZ_{k1}^H + Z_{k3}^H) + N_{j4}^*(-iZ_{k2}^H - Z_{k4}^H)) - g_1N_{i4}^*N_{j1}^*Z_{k4}^H \\
& \left. + g_2N_{i4}^*N_{j2}^*Z_{k4}^H + g_2N_{i2}^*N_{j4}^*Z_{k4}^H \right) \left( \frac{1-\gamma_5}{2} \right) \tag{250}
\end{aligned}$$

$$\begin{aligned}
& + \frac{1}{2} \left( iZ_{k1}^H \left( (g_1N_{i1} - g_2N_{i2})N_{j3} + N_{i3}(g_1N_{j1} - g_2N_{j2}) \right) \right. \\
& + Z_{k3}^H \left( (-g_1N_{i1} + g_2N_{i2})N_{j3} + N_{i3}(-g_1N_{j1} + g_2N_{j2}) \right) \\
& \left. + e^{i\eta} \left( -iZ_{k2}^H + Z_{k4}^H \right) \left( (g_1N_{i1} - g_2N_{i2})N_{j4} + N_{i4}(g_1N_{j1} - g_2N_{j2}) \right) \right) \left( \frac{1+\gamma_5}{2} \right) \tag{251}
\end{aligned}$$



$$-\frac{i}{6}\delta_{\beta\gamma} \left( -3\sqrt{2}g_2N_{i2}^* \sum_{a=1}^3 U_{L,ja}^{d,*} Z_{ka}^D + 6N_{i3}^* \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D + \sqrt{2}g_1N_{i1}^* \sum_{a=1}^3 U_{L,ja}^{d,*} Z_{ka}^D \right) \left( \frac{1-\gamma_5}{2} \right) \tag{252}$$

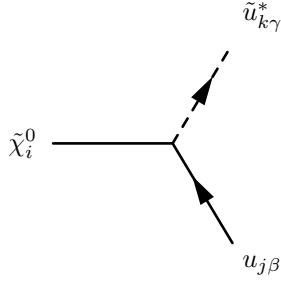
$$+ -\frac{i}{3}\delta_{\beta\gamma} \left( 3 \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d Z_{kb}^D N_{i3} + \sqrt{2}g_1 \sum_{a=1}^3 Z_{k3+a}^D U_{R,ja}^d N_{i1} \right) \left( \frac{1+\gamma_5}{2} \right) \tag{253}$$



$$\frac{i}{2} \left( -2N_{i3}^* \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E + \sqrt{2}g_1 N_{i1}^* \sum_{a=1}^3 U_{L,ja}^{e,*} Z_{ka}^E + \sqrt{2}g_2 N_{i2}^* \sum_{a=1}^3 U_{L,ja}^{e,*} Z_{ka}^E \right) \left( \frac{1-\gamma_5}{2} \right) \quad (254)$$

$$+ -i \left( \sqrt{2}g_1 \sum_{a=1}^3 Z_{k3+a}^E U_{R,ja}^e N_{i1} + \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e Z_{kb}^E N_{i3} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (255)$$

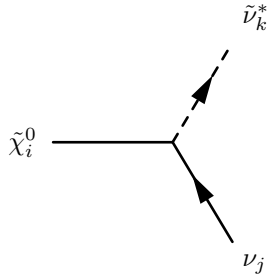

---



$$- \frac{i}{6} \delta_{\beta\gamma} \left( 3\sqrt{2}g_2 N_{i2}^* \sum_{a=1}^3 U_{L,ja}^{u,*} Z_{ka}^U + 6N_{i4}^* \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U + \sqrt{2}g_1 N_{i1}^* \sum_{a=1}^3 U_{L,ja}^{u,*} Z_{ka}^U \right) \left( \frac{1-\gamma_5}{2} \right) \quad (256)$$

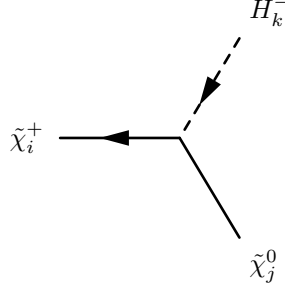
$$+ \frac{i}{3} \delta_{\beta\gamma} \left( 2\sqrt{2}g_1 \sum_{a=1}^3 Z_{k3+a}^U U_{R,ja}^u N_{i1} - 3 \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u Z_{kb}^U N_{i4} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (257)$$


---



$$i \frac{1}{\sqrt{2}} (g_1 N_{i1}^* - g_2 N_{i2}^*) \Theta_{j,3} Z_{kj}^V \left( \frac{1 - \gamma_5}{2} \right) \quad (258)$$

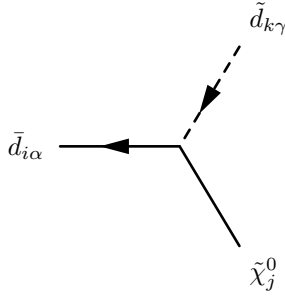

---



$$- \frac{i}{2} e^{-i\eta} \left( 2g_2 V_{i1}^* N_{j4}^* + \sqrt{2} V_{i2}^* (g_1 N_{j1}^* + g_2 N_{j2}^*) \right) Z_{k2}^{+,*} \left( \frac{1 - \gamma_5}{2} \right) \quad (259)$$

$$+ \frac{i}{2} Z_{k1}^{+,*} \left( -2g_2 U_{i1} N_{j3} + \sqrt{2} U_{i2} (g_1 N_{j1} + g_2 N_{j2}) \right) \left( \frac{1 + \gamma_5}{2} \right) \quad (260)$$

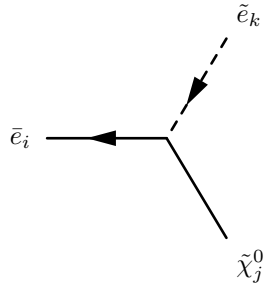

---



$$- \frac{i}{3} \delta_{\alpha\gamma} \left( 3N_{j3}^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} + \sqrt{2} g_1 N_{j1}^* \sum_{a=1}^3 Z_{k3+a}^{D,*} U_{R,ia}^{d,*} \right) \left( \frac{1 - \gamma_5}{2} \right) \quad (261)$$

$$+ - \frac{i}{6} \delta_{\alpha\gamma} \left( 6 \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} U_{L,ib}^d N_{j3} + \sqrt{2} \sum_{a=1}^3 Z_{ka}^{D,*} U_{L,ia}^d (-3g_2 N_{j2} + g_1 N_{j1}) \right) \left( \frac{1 + \gamma_5}{2} \right) \quad (262)$$

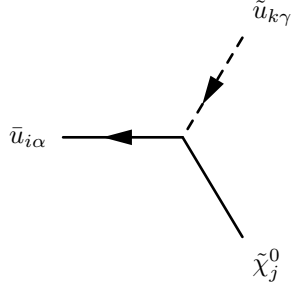

---



$$-i \left( N_{j3}^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} + \sqrt{2} g_1 N_{j1}^* \sum_{a=1}^3 Z_{k3+a}^{E,*} U_{R,ia}^{e,*} \right) \left( \frac{1-\gamma_5}{2} \right) \quad (263)$$

$$+ \frac{i}{2} \left( -2 \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} U_{L,ib}^e N_{j3} + \sqrt{2} \sum_{a=1}^3 Z_{ka}^{E,*} U_{L,ia}^e (g_1 N_{j1} + g_2 N_{j2}) \right) \left( \frac{1+\gamma_5}{2} \right) \quad (264)$$

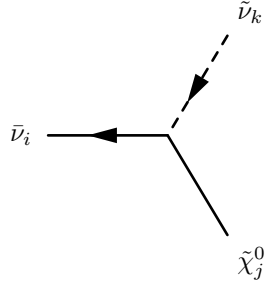

---



$$\frac{i}{3} \delta_{\alpha\gamma} \left( 2\sqrt{2} g_1 N_{j1}^* \sum_{a=1}^3 Z_{k3+a}^{U,*} U_{R,ia}^{u,*} - 3N_{j4}^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} \right) \left( \frac{1-\gamma_5}{2} \right) \quad (265)$$

$$+ \frac{i}{6} \delta_{\alpha\gamma} \left( 6 \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} U_{L,ib}^u N_{j4} + \sqrt{2} \sum_{a=1}^3 Z_{ka}^{U,*} U_{L,ia}^u (3g_2 N_{j2} + g_1 N_{j1}) \right) \left( \frac{1+\gamma_5}{2} \right) \quad (266)$$


---

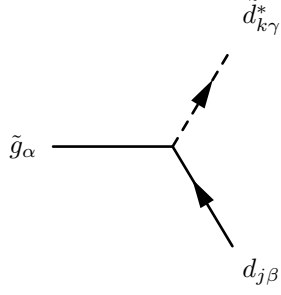


$$(267)$$

$$+ i \frac{1}{\sqrt{2}} Z_{ki}^{V,*} \Theta_{i,3} (g_1 N_{j1} - g_2 N_{j2}) \left( \frac{1+\gamma_5}{2} \right) \quad (268)$$


---

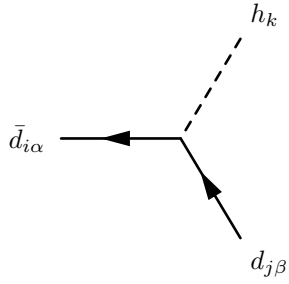




$$-i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\gamma, \beta}^\alpha \sum_{a=1}^3 U_{L,ja}^{d,*} Z_{ka}^D \left( \frac{1-\gamma_5}{2} \right) \quad (269)$$

$$+ i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma, \beta}^\alpha \sum_{a=1}^3 Z_{k3+a}^D U_{R,ja}^d \left( \frac{1+\gamma_5}{2} \right) \quad (270)$$

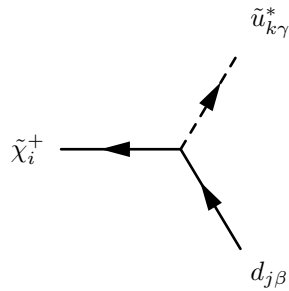

---



$$\frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} \left( -iZ_{k1}^H + Z_{k3}^H \right) \left( \frac{1-\gamma_5}{2} \right) \quad (271)$$

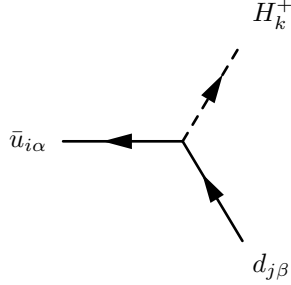
$$+ \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d \left( -iZ_{k1}^H - Z_{k3}^H \right) \left( \frac{1+\gamma_5}{2} \right) \quad (272)$$


---



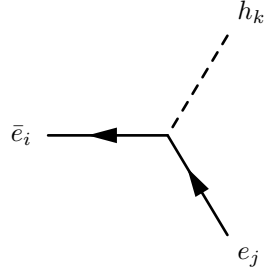
$$-i\delta_{\beta\gamma}\left(g_2V_{i1}^*\sum_{a=1}^3U_{L,ja}^{d,*}Z_{ka}^U - V_{i2}^*\sum_{b=1}^3U_{L,jb}^{d,*}\sum_{a=1}^3Y_{u,ab}Z_{k3+a}^U\right)\left(\frac{1-\gamma_5}{2}\right) \quad (273)$$

$$+i\delta_{\beta\gamma}\sum_{b=1}^3\sum_{a=1}^3Y_{d,ab}^*U_{R,ja}^dZ_{kb}^U U_{i2}\left(\frac{1+\gamma_5}{2}\right) \quad (274)$$



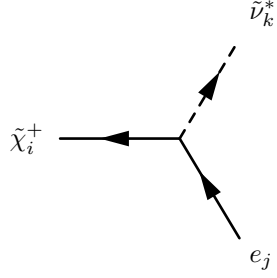
$$ie^{i\eta}\delta_{\alpha\beta}\sum_{b=1}^3U_{L,jb}^{d,*}\sum_{a=1}^3U_{R,ia}^{u,*}Y_{u,ab}Z_{k2}^+\left(\frac{1-\gamma_5}{2}\right) \quad (275)$$

$$+i\delta_{\alpha\beta}\sum_{b=1}^3\sum_{a=1}^3Y_{d,ab}^*U_{R,ja}^dU_{L,ib}^uZ_{k1}^+\left(\frac{1+\gamma_5}{2}\right) \quad (276)$$



$$\frac{1}{\sqrt{2}}\sum_{b=1}^3U_{L,jb}^{e,*}\sum_{a=1}^3U_{R,ia}^{e,*}Y_{e,ab}\left(-iZ_{k1}^H + Z_{k3}^H\right)\left(\frac{1-\gamma_5}{2}\right) \quad (277)$$

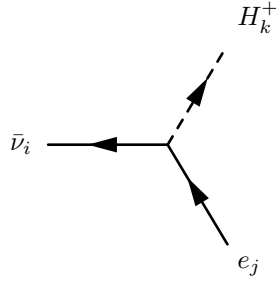
$$+ \frac{1}{\sqrt{2}}\sum_{b=1}^3\sum_{a=1}^3Y_{e,ab}^*U_{R,ja}^eU_{L,ib}^e\left(-iZ_{k1}^H - Z_{k3}^H\right)\left(\frac{1+\gamma_5}{2}\right) \quad (278)$$



$$-ig_2 V_{i1}^* \sum_{a=1}^3 U_{L,ja}^{e,*} Z_{ka}^V \left( \frac{1-\gamma_5}{2} \right) \quad (279)$$

$$+ i \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e Z_{kb}^V U_{i2} \left( \frac{1+\gamma_5}{2} \right) \quad (280)$$

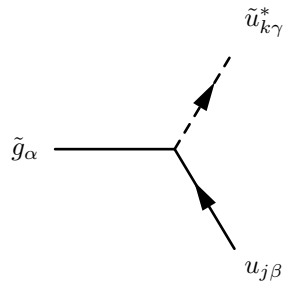

---



$$(281)$$

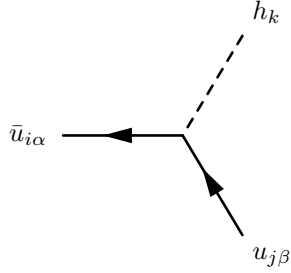
$$+ i \sum_{a=1}^3 Y_{e,ai}^* U_{R,ja}^e Z_{k1}^+ \left( \frac{1+\gamma_5}{2} \right) \quad (282)$$


---



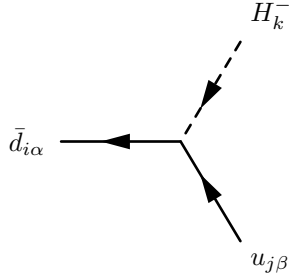
$$-i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\gamma, \beta}^{\alpha} \sum_{a=1}^3 U_{L, ja}^{u, *} Z_{ka}^U \left( \frac{1 - \gamma_5}{2} \right) \quad (283)$$

$$+ i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma, \beta}^{\alpha} \sum_{a=1}^3 Z_{k3+a}^U U_{R, ja}^u \left( \frac{1 + \gamma_5}{2} \right) \quad (284)$$



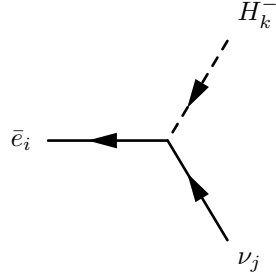
$$\frac{1}{\sqrt{2}} e^{i\eta} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L, jb}^{u, *} \sum_{a=1}^3 U_{R, ia}^{u, *} Y_{u, ab} \left( -iZ_{k2}^H + Z_{k4}^H \right) \left( \frac{1 - \gamma_5}{2} \right) \quad (285)$$

$$+ -i \frac{1}{\sqrt{2}} e^{-i\eta} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u, ab}^* U_{R, ja}^u U_{L, ib}^u \left( -iZ_{k4}^H + Z_{k2}^H \right) \left( \frac{1 + \gamma_5}{2} \right) \quad (286)$$



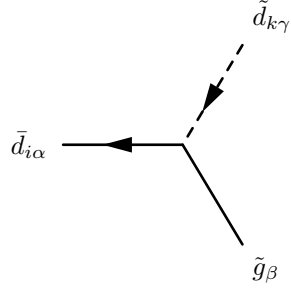
$$iZ_{k1}^{+, *} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L, jb}^{u, *} \sum_{a=1}^3 U_{R, ia}^{d, *} Y_{d, ab} \left( \frac{1 - \gamma_5}{2} \right) \quad (287)$$

$$+ ie^{-i\eta} Z_{k2}^{+, *} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u, ab}^* U_{R, ja}^u U_{L, ib}^d \left( \frac{1 + \gamma_5}{2} \right) \quad (288)$$



$$iZ_{k1}^{+,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,aj} \left( \frac{1-\gamma_5}{2} \right) \quad (289)$$

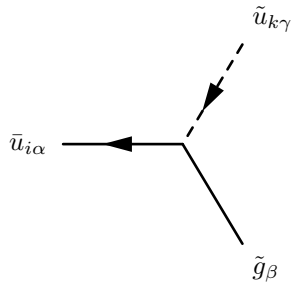

---



$$i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\alpha,\gamma}^\beta \sum_{a=1}^3 Z_{k3+a}^{D,*} U_{R,ia}^{d,*} \left( \frac{1-\gamma_5}{2} \right) \quad (290)$$

$$+ -i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\alpha,\gamma}^\beta \sum_{a=1}^3 Z_{ka}^{D,*} U_{L,ia}^d \left( \frac{1+\gamma_5}{2} \right) \quad (291)$$

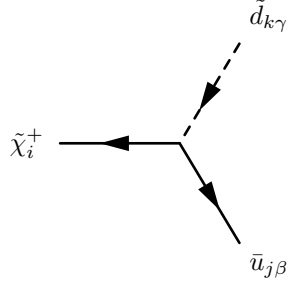

---



$$i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\alpha,\gamma}^\beta \sum_{a=1}^3 Z_{k3+a}^{U,*} U_{R,ia}^{u,*} \left( \frac{1-\gamma_5}{2} \right) \quad (292)$$

$$+ -i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\alpha, \gamma}^\beta \sum_{a=1}^3 Z_{ka}^{U,*} U_{L,ia}^u \left( \frac{1+\gamma_5}{2} \right) \quad (293)$$

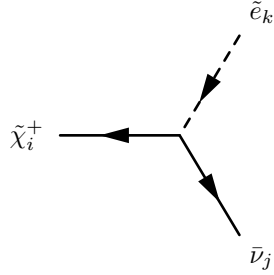

---



$$iV_{i2}^* \delta_{\beta\gamma} \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 U_{R,ja}^{u,*} Y_{u,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (294)$$

$$+ -i \delta_{\beta\gamma} \left( g_2 \sum_{a=1}^3 Z_{ka}^{D,*} U_{L,ja}^u U_{i1} - \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} U_{L,jb}^u U_{i2} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (295)$$


---

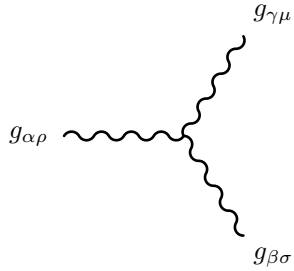


(296)

$$+ -i \left( g_2 Z_{kj}^{E,*} \Theta_{j,3} U_{i1} - \sum_{a=1}^3 Y_{e,aj}^* Z_{k3+a}^{E,*} U_{i2} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (297)$$

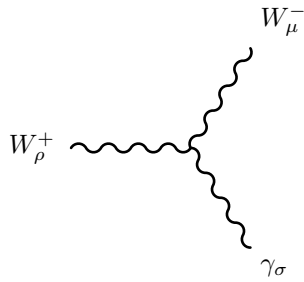

---

## 9.6 Three Vector Boson-Interaction



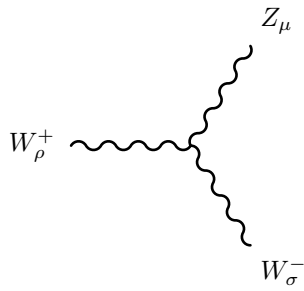
$$g_3 f_{\alpha,\beta,\gamma} \left( g_{\rho\mu} \left( -p_\sigma^{g_{\gamma\mu}} + p_\sigma^{g_{\alpha\rho}} \right) + g_{\rho\sigma} \left( -p_\mu^{g_{\alpha\rho}} + p_\mu^{g_{\beta\sigma}} \right) + g_{\sigma\mu} \left( -p_\rho^{g_{\beta\sigma}} + p_\rho^{g_{\gamma\mu}} \right) \right) \quad (298)$$


---



$$ig_2 \sin \Theta_W \left( g_{\rho\mu} \left( -p_\sigma^{W_\mu^-} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left( -p_\mu^{W_\rho^+} + p_\mu^{\gamma_\sigma} \right) + g_{\sigma\mu} \left( -p_\rho^{\gamma_\sigma} + p_\rho^{W_\mu^-} \right) \right) \quad (299)$$

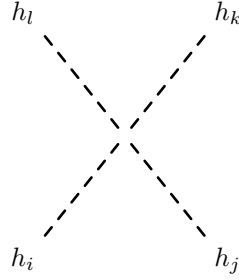

---



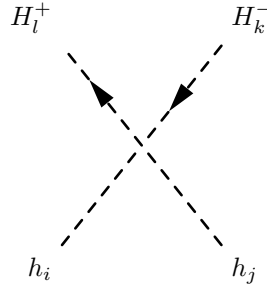
$$-ig_2 \cos \Theta_W \left( g_{\rho\mu} \left( -p_\sigma^{Z_\mu} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left( -p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-} \right) + g_{\sigma\mu} \left( -p_\rho^{W_\sigma^-} + p_\rho^{Z_\mu} \right) \right) \quad (300)$$


---

## 9.7 Four Scalar-Interaction



$$\begin{aligned}
& -\frac{i}{4}(g_1^2 + g_2^2) \left( Z_{i3}^H Z_{j3}^H Z_{k1}^H Z_{l1}^H - Z_{i4}^H Z_{j4}^H Z_{k1}^H Z_{l1}^H + Z_{i3}^H Z_{j1}^H Z_{k3}^H Z_{l1}^H - Z_{i4}^H Z_{j1}^H Z_{k4}^H Z_{l1}^H \right. \\
& - Z_{i3}^H Z_{j3}^H Z_{k2}^H Z_{l2}^H + Z_{i4}^H Z_{j4}^H Z_{k2}^H Z_{l2}^H - Z_{i3}^H Z_{j2}^H Z_{k3}^H Z_{l2}^H + Z_{i4}^H Z_{j2}^H Z_{k4}^H Z_{l2}^H \\
& + Z_{i3}^H Z_{j1}^H Z_{k1}^H Z_{l3}^H - Z_{i3}^H Z_{j2}^H Z_{k2}^H Z_{l3}^H + 3Z_{i3}^H Z_{j3}^H Z_{k3}^H Z_{l3}^H - Z_{i4}^H Z_{j4}^H Z_{k3}^H Z_{l3}^H \\
& - Z_{i4}^H Z_{j3}^H Z_{k4}^H Z_{l3}^H - Z_{i3}^H Z_{j4}^H Z_{k4}^H Z_{l3}^H - Z_{i4}^H Z_{j1}^H Z_{k1}^H Z_{l4}^H + Z_{i4}^H Z_{j2}^H Z_{k2}^H Z_{l4}^H \\
& - Z_{i4}^H Z_{j3}^H Z_{k3}^H Z_{l4}^H - Z_{i3}^H Z_{j4}^H Z_{k3}^H Z_{l4}^H - Z_{i3}^H Z_{j3}^H Z_{k4}^H Z_{l4}^H + 3Z_{i4}^H Z_{j4}^H Z_{k4}^H Z_{l4}^H \\
& - Z_{i2}^H \left( Z_{j3}^H Z_{k3}^H Z_{l2}^H - Z_{j4}^H Z_{k4}^H Z_{l2}^H + Z_{j1}^H \left( Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) + Z_{j3}^H Z_{k2}^H Z_{l3}^H \right. \\
& \left. - Z_{j4}^H Z_{k2}^H Z_{l4}^H + Z_{j2}^H \left( -3Z_{k2}^H Z_{l2}^H + Z_{k1}^H Z_{l1}^H + Z_{k3}^H Z_{l3}^H - Z_{k4}^H Z_{l4}^H \right) \right) \\
& + Z_{i1}^H \left( Z_{j3}^H Z_{k3}^H Z_{l1}^H - Z_{j4}^H Z_{k4}^H Z_{l1}^H - Z_{j2}^H \left( Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) + Z_{j3}^H Z_{k1}^H Z_{l3}^H \right. \\
& \left. - Z_{j4}^H Z_{k1}^H Z_{l4}^H + Z_{j1}^H \left( 3Z_{k1}^H Z_{l1}^H - Z_{k2}^H Z_{l2}^H + Z_{k3}^H Z_{l3}^H - Z_{k4}^H Z_{l4}^H \right) \right) \Big) \tag{301}
\end{aligned}$$

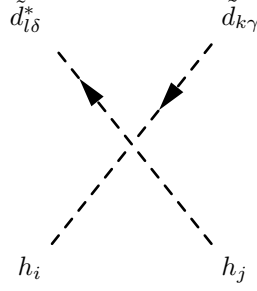


$$\begin{aligned}
& -\frac{i}{4} \left( Z_{k1}^{+,*} \left( g_1^2 Z_{i3}^H Z_{j3}^H Z_{l1}^+ + g_2^2 Z_{i3}^H Z_{j3}^H Z_{l1}^+ - g_1^2 Z_{i4}^H Z_{j4}^H Z_{l1}^+ + g_2^2 Z_{i4}^H Z_{j4}^H Z_{l1}^+ \right. \right. \\
& - i g_2^2 Z_{i4}^H Z_{j1}^H Z_{l2}^+ - i g_2^2 Z_{i3}^H Z_{j2}^H Z_{l2}^+ - g_2^2 Z_{i4}^H Z_{j3}^H Z_{l2}^+ - g_2^2 Z_{i3}^H Z_{j4}^H Z_{l2}^+ \\
& + Z_{i2}^H \left( \left( -g_1^2 + g_2^2 \right) Z_{j2}^H Z_{l1}^+ + g_2^2 \left( -i Z_{j3}^H + Z_{j1}^H \right) Z_{l2}^+ \right) \\
& \left. \left. + Z_{i1}^H \left( \left( g_1^2 + g_2^2 \right) Z_{j1}^H Z_{l1}^+ + g_2^2 \left( -i Z_{j4}^H + Z_{j2}^H \right) Z_{l2}^+ \right) \right) \right)
\end{aligned}$$



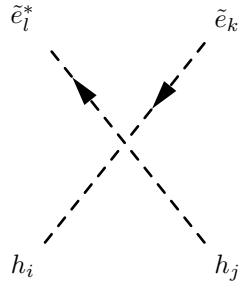
$$\begin{aligned}
& + Z_{k2}^{+,*} \left( g_2^2 Z_{i1}^H Z_{j2}^H Z_{l1}^+ + i g_2^2 Z_{i3}^H Z_{j2}^H Z_{l1}^+ + i g_2^2 Z_{i1}^H Z_{j4}^H Z_{l1}^+ - g_2^2 Z_{i3}^H Z_{j4}^H Z_{l1}^+ \right. \\
& - g_1^2 Z_{i1}^H Z_{j1}^H Z_{l2}^+ + g_2^2 Z_{i1}^H Z_{j1}^H Z_{l2}^+ - g_1^2 Z_{i3}^H Z_{j3}^H Z_{l2}^+ + g_2^2 Z_{i3}^H Z_{j3}^H Z_{l2}^+ \\
& + Z_{i2}^H \left( (g_1^2 + g_2^2) Z_{j2}^H Z_{l2}^+ + g_2^2 Z_{j1}^H Z_{l1}^+ + i g_2^2 Z_{j3}^H Z_{l1}^+ \right) \\
& \left. + Z_{i4}^H \left( (g_1^2 + g_2^2) Z_{j4}^H Z_{l2}^+ - g_2^2 Z_{j3}^H Z_{l1}^+ + i g_2^2 Z_{j1}^H Z_{l1}^+ \right) \right) \tag{302}
\end{aligned}$$


---



$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left( (3g_2^2 + g_1^2) \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \left( Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H + Z_{i3}^H Z_{j3}^H - Z_{i4}^H Z_{j4}^H \right) \right. \\
& + 2 \left( -6 \left( \sum_{c=1}^3 Z_{k3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D \right) \left( Z_{i1}^H Z_{j1}^H + Z_{i3}^H Z_{j3}^H \right) \right. \\
& \left. \left. + g_1^2 \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D \left( Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H + Z_{i3}^H Z_{j3}^H - Z_{i4}^H Z_{j4}^H \right) \right) \right) \tag{303}
\end{aligned}$$

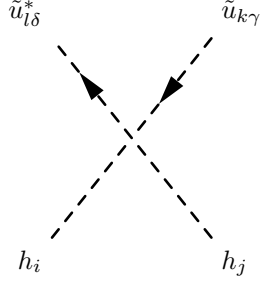

---



$$\begin{aligned}
& - \frac{i}{4} \left( 4 \left( \sum_{c=1}^3 Z_{k3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{l3+b}^E + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^E \right) \left( Z_{i1}^H Z_{j1}^H + Z_{i3}^H Z_{j3}^H \right) \right. \\
& \left. + \left( -g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \left( Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H + Z_{i3}^H Z_{j3}^H - Z_{i4}^H Z_{j4}^H \right) \right)
\end{aligned}$$

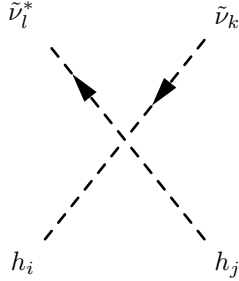
$$-2g_1^2 \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E \left( Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H + Z_{i3}^H Z_{j3}^H - Z_{i4}^H Z_{j4}^H \right) \quad (304)$$


---



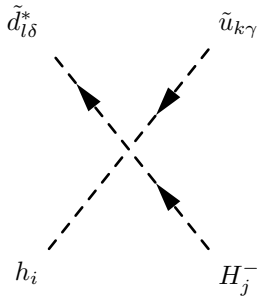
$$\begin{aligned} & \frac{i}{12} \delta_{\gamma\delta} \left( \left( -3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U \left( Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H + Z_{i3}^H Z_{j3}^H - Z_{i4}^H Z_{j4}^H \right) \right. \\ & - 4 \left( g_1^2 \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \left( Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H + Z_{i3}^H Z_{j3}^H - Z_{i4}^H Z_{j4}^H \right) \right. \\ & \left. \left. + 3 \left( \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{l3+b}^U + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^U \right) \left( Z_{i2}^H Z_{j2}^H + Z_{i4}^H Z_{j4}^H \right) \right) \right) \quad (305) \end{aligned}$$


---



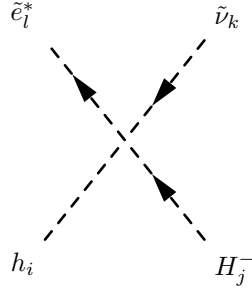
$$-\frac{i}{4} \left( g_1^2 + g_2^2 \right) \delta_{kl} \left( Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H + Z_{i3}^H Z_{j3}^H - Z_{i4}^H Z_{j4}^H \right) \quad (306)$$


---



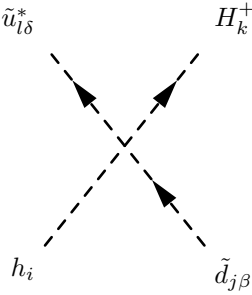
$$\begin{aligned}
& \frac{1}{2} \frac{1}{\sqrt{2}} e^{-i\eta} \delta_{\gamma\delta} \left( Z_{j2}^{+,*} \left( 2i \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D \left( iZ_{i3}^H + Z_{i1}^H \right) \right. \right. \\
& + e^{i\eta} \left( -2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^D + g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D \right) \left( -iZ_{i2}^H + Z_{i4}^H \right) \Big) \\
& + Z_{j1}^{+,*} \left( -ie^{i\eta} g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D \left( -iZ_{i3}^H + Z_{i1}^H \right) \right. \\
& + 2 \left( e^{i\eta} \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D \left( iZ_{i1}^H + Z_{i3}^H \right) \right. \\
& \left. \left. + \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D \left( iZ_{i2}^H + Z_{i4}^H \right) \right) \right) \Big) \tag{307}
\end{aligned}$$


---



$$\begin{aligned}
& \frac{1}{2} \frac{1}{\sqrt{2}} \left( -iZ_{j1}^{+,*} \left( -2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^E + g_2^2 \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E \right) \left( -iZ_{i3}^H + Z_{i1}^H \right) \right. \\
& \left. + g_2^2 Z_{j2}^{+,*} \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E \left( -iZ_{i2}^H + Z_{i4}^H \right) \right) \tag{308}
\end{aligned}$$

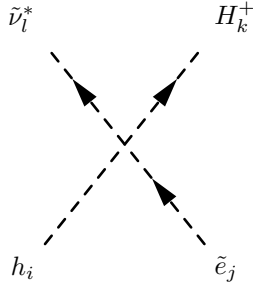

---



$$\frac{1}{2} \frac{1}{\sqrt{2}} \delta_{\beta\delta} \left( g_2^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^U \left( -iZ_{i1}^H Z_{k1}^+ + \left( -iZ_{i2}^H - Z_{i4}^H \right) Z_{k2}^+ + Z_{i3}^H Z_{k1}^+ \right) \right)$$

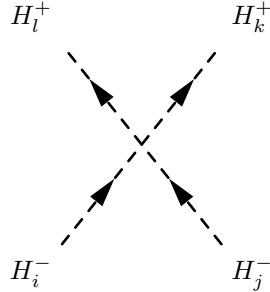
$$\begin{aligned}
& + 2 \left( i \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^U (iZ_{i3}^H + Z_{i1}^H) Z_{k1}^+ \right. \\
& + \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^U (iZ_{i2}^H + Z_{i4}^H) Z_{k2}^+ \\
& \left. + e^{i\eta} \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{l3+b}^U \left( (iZ_{i1}^H + Z_{i3}^H) Z_{k2}^+ + iZ_{i2}^H Z_{k1}^+ - Z_{i4}^H Z_{k1}^+ \right) \right) \quad (309)
\end{aligned}$$


---



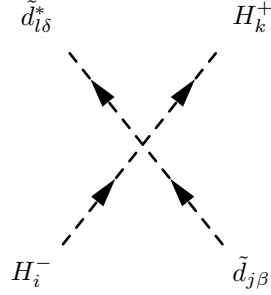
$$\begin{aligned}
& \frac{1}{2} \frac{1}{\sqrt{2}} \left( 2i \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^V (iZ_{i3}^H + Z_{i1}^H) Z_{k1}^+ \right. \\
& \left. + g_2^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^V \left( -iZ_{i1}^H Z_{k1}^+ + \left( -iZ_{i2}^H - Z_{i4}^H \right) Z_{k2}^+ + Z_{i3}^H Z_{k1}^+ \right) \right) \quad (310)
\end{aligned}$$


---



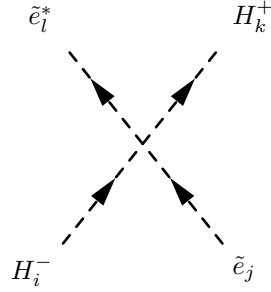
$$\begin{aligned}
& - \frac{i}{4} (g_1^2 + g_2^2) \left( -Z_{i2}^{+,*} \left( -2Z_{j2}^{+,*} Z_{k2}^+ Z_{l2}^+ + Z_{j1}^{+,*} \left( Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right) \right. \\
& \left. + Z_{i1}^{+,*} \left( 2Z_{j1}^{+,*} Z_{k1}^+ Z_{l1}^+ - Z_{j2}^{+,*} \left( Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right) \right) \quad (311)
\end{aligned}$$


---



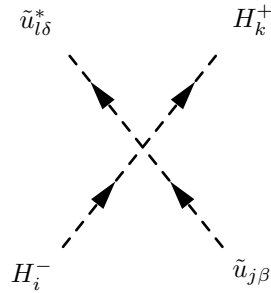
$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\delta} \left( Z_{i1}^{+,*} \left( 2 \left( -6 \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D + g_1^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{l3+a}^D \right) + \left( -3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^D \right) Z_{k1}^+ \right. \\
& \left. - Z_{i2}^{+,*} \left( 2 \left( 6 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^D + g_1^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{l3+a}^D \right) + \left( -3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^D \right) Z_{k2}^+ \right) \quad (312)
\end{aligned}$$


---



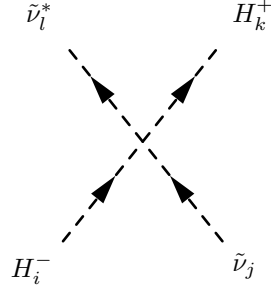
$$\begin{aligned}
& - \frac{i}{4} \left( Z_{i1}^{+,*} \left( -2g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{l3+a}^E + 4 \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{l3+b}^E + \left( g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^E \right) Z_{k1}^+ \right. \\
& \left. - Z_{i2}^{+,*} \left( -2g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{l3+a}^E + \left( g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^E \right) Z_{k2}^+ \right) \quad (313)
\end{aligned}$$


---



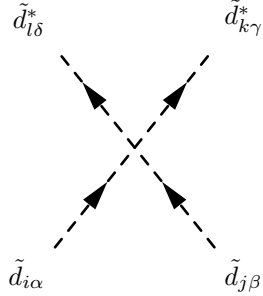
$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\delta} \left( Z_{i1}^{+,*} \left( (3g_2^2 + g_1^2) \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U - 4 \left( 3 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^U + g_1^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \right) \right) Z_{k1}^+ \right. \\
& \left. - Z_{i2}^{+,*} \left( 12 \sum_{c=1}^3 Z_{j3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{l3+b}^U + (3g_2^2 + g_1^2) \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U - 4g_1^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \right) Z_{k2}^+ \right) \quad (314)
\end{aligned}$$


---



$$\begin{aligned}
& - \frac{i}{4} \left( Z_{i1}^{+,*} \left( 4 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^V + (-g_2^2 + g_1^2) \delta_{jl} \right) Z_{k1}^+ \right. \\
& \left. + (-g_1^2 + g_2^2) Z_{i2}^{+,*} \delta_{jl} Z_{k2}^+ \right) \quad (315)
\end{aligned}$$

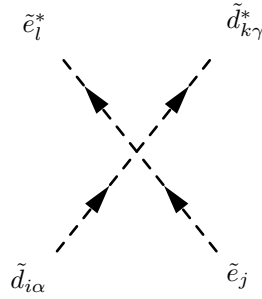

---



$$\begin{aligned}
& - \frac{i}{72} \left( \delta_{\alpha\delta} \delta_{\beta\gamma} \left( g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \right. \right. \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D + 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \\
& + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \\
& \left. \left. + 18g_3^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^D \left( - \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \right) \right)
\end{aligned}$$

$$\begin{aligned}
& -18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{l3+a}^D \left( - \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \\
& + 2g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \\
& + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D - 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \\
& + g_1^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D + 9g_2^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D + 2g_1^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \\
& + 6g_3^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D + 18g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D \\
& - 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D + 2g_1^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D \\
& + 6g_3^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D + 4g_1^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D \\
& - 6g_3^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D - 18g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{l3+b}^D \\
& + 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{l3+b}^D \\
& + 72 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{j3+c}^{D,*} Z_{kd}^D \\
& + 72 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{i3+c}^{D,*} Z_{ld}^D \Big) \\
& + \delta_{\alpha\gamma} \delta_{\beta\delta} \left( 18g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D - 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \right. \\
& + 2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{l3+a}^D \left( (2g_1^2 - 3g_3^2) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + (3g_3^2 + g_1^2) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \\
& \left. + \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^D \left( 2(3g_3^2 + g_1^2) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + (-6g_3^2 + 9g_2^2 + g_1^2) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \right)
\end{aligned}$$

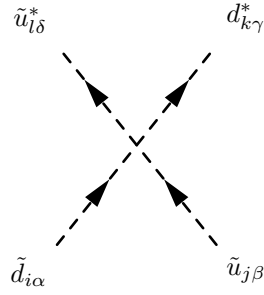
$$\begin{aligned}
& - 18g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D + 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \\
& + 18g_3^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D - 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \\
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D + 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D \\
& + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D - 18g_3^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D \\
& + 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D + 2g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{l3+b}^D \\
& + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{l3+b}^D + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{l3+b}^D \\
& - 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{l3+b}^D \\
& + 72 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{i3+c}^{D,*} Z_{kd}^D \\
& + 72 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{j3+c}^{D,*} Z_{ld}^D \Big)
\end{aligned} \tag{316}$$



$$\begin{aligned}
& \frac{i}{24} \delta_{\alpha\gamma} \left( - 2g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{l3+a}^E \left( 2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \right. \\
& \left. + \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^E \left( 2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \left( - 3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \right)
\end{aligned}$$

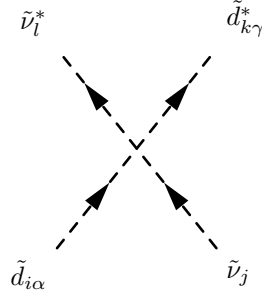


$$\begin{aligned}
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E - 3g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \\
& + 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E - 2g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& - 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& - 24 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{i3+c}^{D,*} Z_{kd}^D \\
& - 24 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{j3+c}^{E,*} Z_{ld}^E \Big) \tag{317}
\end{aligned}$$

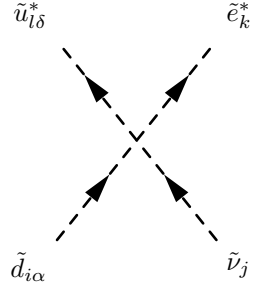


$$\begin{aligned}
& - \frac{i}{72} \left( \delta_{\alpha\gamma} \delta_{\beta\delta} \left( \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( 2(3g_3^2 + g_1^2) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + (-6g_3^2 - 9g_2^2 + g_1^2) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \right. \right. \\
& - 2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( (2g_1^2 - 3g_3^2) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D + (3g_3^2 + 4g_1^2) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \right) \\
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 9g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 4g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U - 8g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& \left. - 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \right)
\end{aligned}$$

$$\begin{aligned}
& + 18\delta_{\alpha\delta}\delta_{\beta\gamma} \left( g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^D + g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( - \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \right. \\
& + g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( - \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D + \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \right) \\
& + g_2^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^U + g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U + 4 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd}^* Z_{j3+c}^{U,*} Z_{kd}^D \\
& \left. + 4 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{i3+c}^{D,*} Z_{ld}^U \right) \tag{318}
\end{aligned}$$

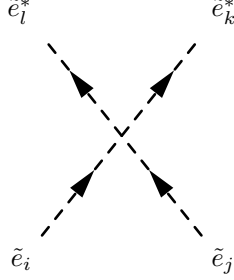


$$\frac{i}{12} \delta_{\alpha\gamma} \delta_{jl} \left( 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D + (3g_2^2 + g_1^2) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \right) \tag{319}$$



$$-\frac{i}{4} \delta_{\alpha\delta} \left( g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^E + g_2^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^E \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^U \right)$$

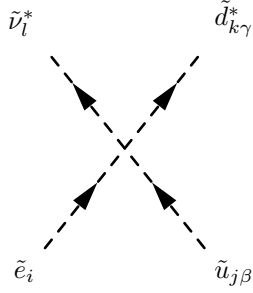
$$+ 4 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{i3+c}^{D,*} Z_{ld}^U \quad (320)$$



$$\begin{aligned}
& - \frac{i}{8} \left( g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E + g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E \right. \\
& - 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{l3+a}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E \\
& - 2g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{l3+a}^E \left( -2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E + \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \right) \\
& + \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^E \left( -2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E + (g_1^2 + g_2^2) \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \right) \\
& - 2g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{k3+b}^E + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{l3+a}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{k3+b}^E \\
& + g_1^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^E + g_2^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^E \\
& - 2g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^E + g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \\
& + g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E - 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \\
& - 2g_1^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E + 4g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E \\
& - 2g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& + 8 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{i3+c}^{E,*} Z_{kd}^E
\end{aligned}$$

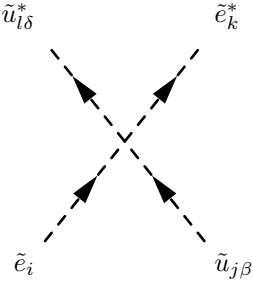
$$\begin{aligned}
& + 8 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd} Z_{j3+c}^{E,*} Z_{kd}^E \\
& + 8 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd} Z_{i3+c}^{E,*} Z_{ld}^E \\
& + 8 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd} Z_{j3+c}^{E,*} Z_{ld}^E
\end{aligned} \tag{321}$$


---



$$\begin{aligned}
& - \frac{i}{4} \delta_{\beta\gamma} \left( g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^V \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^D + g_2^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^D \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^V \right. \\
& \left. + 4 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd} Z_{i3+c}^{E,*} Z_{ld}^V \right)
\end{aligned} \tag{322}$$

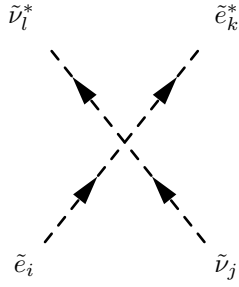

---



$$\begin{aligned}
& \frac{i}{24} \delta_{\beta\delta} \left( -4g_1^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( -2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E + \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \right) \right. \\
& \left. + \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( -2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E + (3g_2^2 + g_1^2) \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \right) \right)
\end{aligned}$$

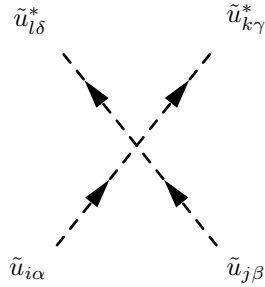
$$\begin{aligned}
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 3g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 4g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 8g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \quad (323)
\end{aligned}$$


---



$$\begin{aligned}
& - \frac{i}{4} \left( \delta_{jl} \left( -2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E + \left( -g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \right) \right. \\
& + g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^E + g_2^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^E \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^V \\
& \left. + 4 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{i3+c}^{E,*} Z_{ld}^V \right) \quad (324)
\end{aligned}$$

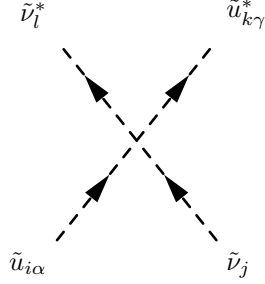

---



$$- \frac{i}{72} \left( \delta_{\alpha\delta} \delta_{\beta\gamma} \left( g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \right) \right)$$

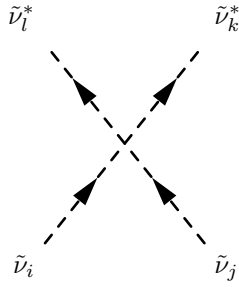
$$\begin{aligned}
& -6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U - 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \\
& + 18g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( - \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U + \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \right) \\
& - 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( - \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U + \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \right) \\
& - 4g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \\
& + 16g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U - 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \\
& + g_1^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U + 9g_2^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U - 4g_1^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U + 18g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 4g_1^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U + 16g_1^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U - 18g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 72 \sum_{b=1}^3 Z_{ib}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd}^* Z_{j3+c}^{U,*} Z_{kd}^U \\
& + 72 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd}^* Z_{i3+c}^{U,*} Z_{ld}^U
\end{aligned}$$

$$\begin{aligned}
& + \delta_{\alpha\gamma}\delta_{\beta\delta} \left( 18g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U - 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \right. \\
& + \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( 2 \left( -3g_3^2 + 8g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U + \left( -4g_1^2 + 6g_3^2 \right) \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \right) \\
& + \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( 2 \left( -2g_1^2 + 3g_3^2 \right) \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U + \left( -6g_3^2 + 9g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \right) \\
& - 18g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U + 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \\
& + 18g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U - 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \\
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 18g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \\
& + 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U - 4g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U + 16g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 72 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd}^* Z_{i3+c}^{U,*} Z_{kd}^U \\
& \left. + 72 \sum_{b=1}^3 Z_{ib}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd}^* Z_{j3+c}^{U,*} Z_{ld}^U \right) \tag{325}
\end{aligned}$$



$$\frac{i}{12} \delta_{\alpha\gamma} \delta_{jl} \left( \left( -3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U - 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \right) \quad (326)$$

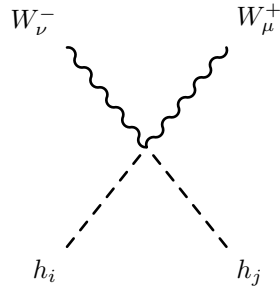

---



$$-\frac{i}{4} (g_1^2 + g_2^2) (\delta_{ik} \delta_{jl} + \delta_{il} \delta_{jk}) \quad (327)$$


---

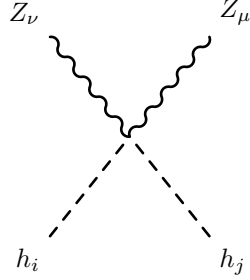
## 9.8 Two Scalar-Two Vector Boson-Interaction



$$\frac{i}{2} g_2^2 \left( Z_{i1}^H Z_{j1}^H + Z_{i2}^H Z_{j2}^H + Z_{i3}^H Z_{j3}^H + Z_{i4}^H Z_{j4}^H \right) (g_{\mu\nu}) \quad (328)$$

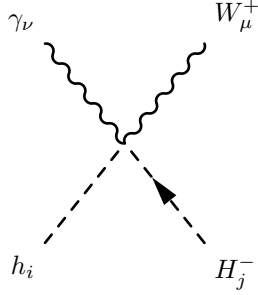

---





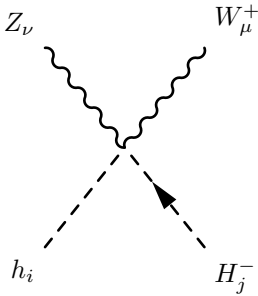
$$\frac{i}{2} (g_1 \sin \Theta_W + g_2 \cos \Theta_W)^2 \left( Z_{i1}^H Z_{j1}^H + Z_{i2}^H Z_{j2}^H + Z_{i3}^H Z_{j3}^H + Z_{i4}^H Z_{j4}^H \right) (g_{\mu\nu}) \quad (329)$$


---



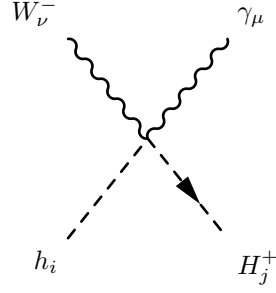
$$-\frac{i}{2} g_1 g_2 \cos \Theta_W \left( Z_{j1}^{+,*} \left( -iZ_{i3}^H + Z_{i1}^H \right) - Z_{j2}^{+,*} \left( iZ_{i4}^H + Z_{i2}^H \right) \right) (g_{\mu\nu}) \quad (330)$$


---



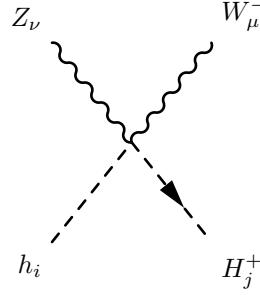
$$\frac{1}{2} g_1 g_2 \sin \Theta_W \left( Z_{j1}^{+,*} \left( iZ_{i1}^H + Z_{i3}^H \right) + Z_{j2}^{+,*} \left( -iZ_{i2}^H + Z_{i4}^H \right) \right) (g_{\mu\nu}) \quad (331)$$


---



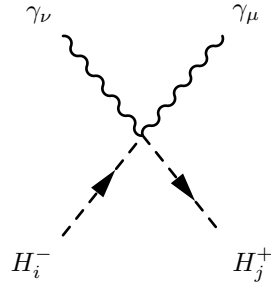
$$\frac{1}{2}g_1g_2 \cos \Theta_W \left( -iZ_{i1}^H Z_{j1}^+ + (iZ_{i2}^H + Z_{i4}^H)Z_{j2}^+ + Z_{i3}^H Z_{j1}^+ \right) (g_{\mu\nu}) \quad (332)$$


---



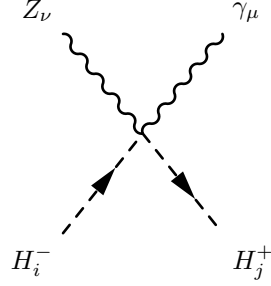
$$\frac{i}{2}g_1g_2 \sin \Theta_W \left( i \left( (iZ_{i2}^H + Z_{i4}^H)Z_{j2}^+ + Z_{i3}^H Z_{j1}^+ \right) + Z_{i1}^H Z_{j1}^+ \right) (g_{\mu\nu}) \quad (333)$$


---



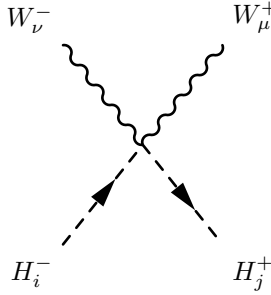
$$\frac{i}{2} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right)^2 \left( Z_{i1}^{+,*} Z_{j1}^+ + Z_{i2}^{+,*} Z_{j2}^+ \right) (g_{\mu\nu}) \quad (334)$$


---



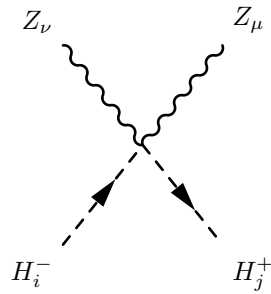
$$-\frac{i}{4} \left( -2g_1g_2 \cos 2\Theta_W + (-g_2^2 + g_1^2) \sin 2\Theta_W \right) \left( Z_{i1}^{+,*} Z_{j1}^+ + Z_{i2}^{+,*} Z_{j2}^+ \right) (g_{\mu\nu}) \quad (335)$$


---



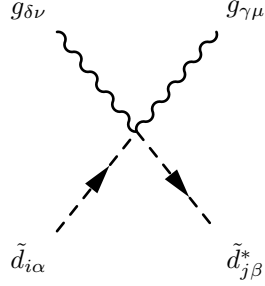
$$\frac{i}{2} g_2^2 \left( Z_{i1}^{+,*} Z_{j1}^+ + Z_{i2}^{+,*} Z_{j2}^+ \right) (g_{\mu\nu}) \quad (336)$$


---



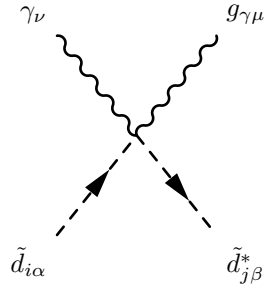
$$\frac{i}{2} \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 \left( Z_{i1}^{+,*} Z_{j1}^+ + Z_{i2}^{+,*} Z_{j2}^+ \right) (g_{\mu\nu}) \quad (337)$$


---



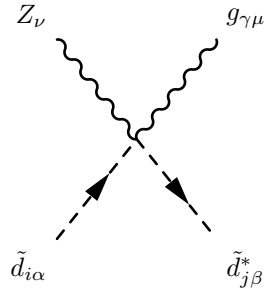
$$\frac{i}{4} g_3^2 \delta_{ij} \left( \sum_{a=1}^3 \lambda_{a,\alpha}^\gamma \lambda_{\beta,a}^\delta + \sum_{a=1}^3 \lambda_{\beta,a}^\gamma \lambda_{a,\alpha}^\delta \right) (g_{\mu\nu}) \quad (338)$$


---



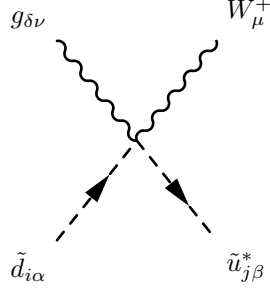
$$\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left( -2g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D + \left( -3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right) (g_{\mu\nu}) \quad (339)$$


---



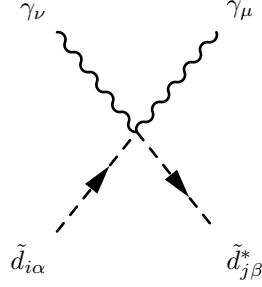
$$-\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left( -2g_1 \sin \Theta_W \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D + \left( 3g_2 \cos \Theta_W + g_1 \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right) (g_{\mu\nu}) \quad (340)$$


---



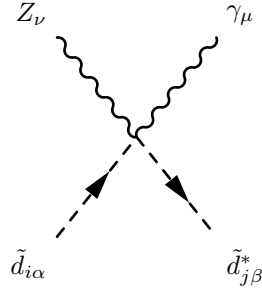
$$i \frac{1}{\sqrt{2}} g_2 g_3 \lambda_{\beta,\alpha}^{\delta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \quad (341)$$


---



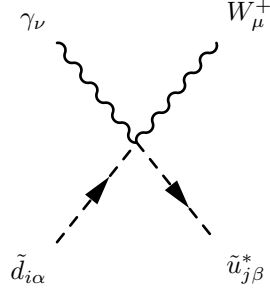
$$\frac{i}{18} \delta_{\alpha\beta} \left( (-3g_2 \sin \Theta_W + g_1 \cos \Theta_W)^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D + 4g_1^2 \cos^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \quad (342)$$


---



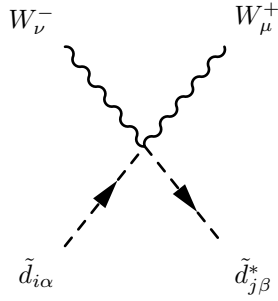
$$-\frac{i}{36} \delta_{\alpha\beta} \left( (6g_1 g_2 \cos 2\Theta_W + (-9g_2^2 + g_1^2) \sin 2\Theta_W) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D + 4g_1^2 \sin 2\Theta_W \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \quad (343)$$


---



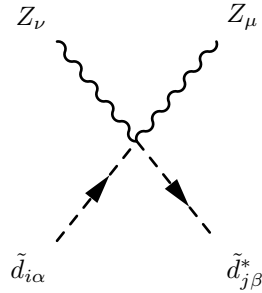
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \quad (344)$$


---



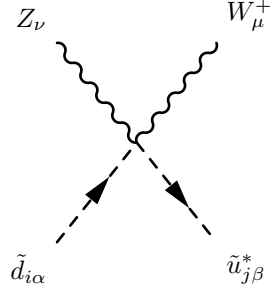
$$\frac{i}{2} g_2^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D (g_{\mu\nu}) \quad (345)$$


---



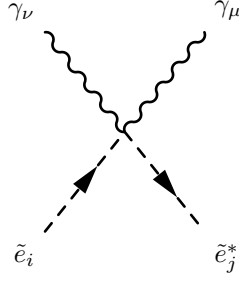
$$\frac{i}{18} \delta_{\alpha\beta} \left( (3g_2 \cos \Theta_W + g_1 \sin \Theta_W)^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D + 4g_1^2 \sin^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \quad (346)$$


---



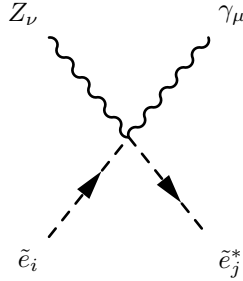
$$-\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \delta_{\alpha\beta} \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \quad (347)$$


---



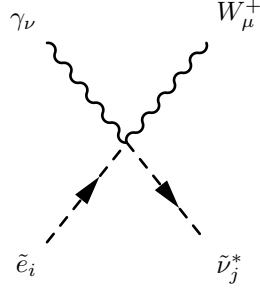
$$\frac{i}{2} \left( 4g_1^2 \cos^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E + (g_1 \cos \Theta_W + g_2 \sin \Theta_W)^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right) (g_{\mu\nu}) \quad (348)$$


---



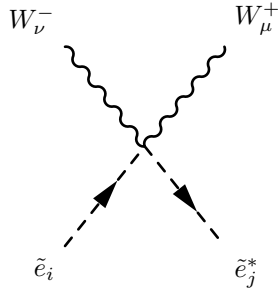
$$-\frac{i}{4} \left( (-2g_1 g_2 \cos 2\Theta_W + (-g_2^2 + g_1^2) \sin 2\Theta_W) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E + 4g_1^2 \sin 2\Theta_W \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu}) \quad (349)$$


---



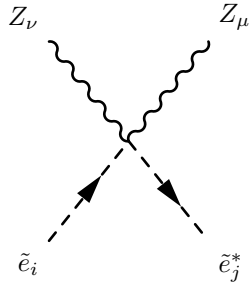
$$-i \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V (g_{\mu\nu}) \quad (350)$$


---



$$\frac{i}{2} g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E (g_{\mu\nu}) \quad (351)$$

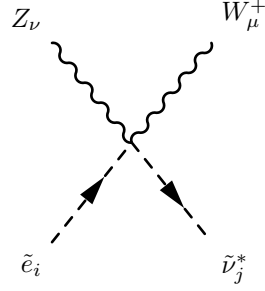

---



$$\frac{i}{2} \left( 4g_1^2 \sin^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right) (g_{\mu\nu}) \quad (352)$$

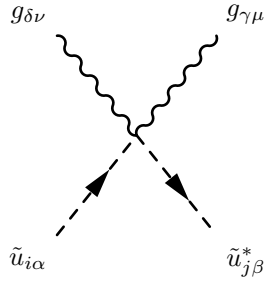

---





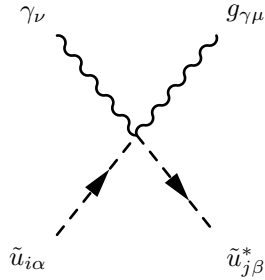
$$i \frac{1}{\sqrt{2}} g_1 g_2 \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V (g_{\mu\nu}) \quad (353)$$


---



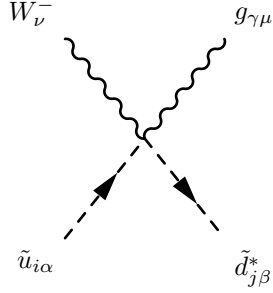
$$\frac{i}{4} g_3^2 \delta_{ij} \left( \sum_{a=1}^3 \lambda_{a,\alpha}^\gamma \lambda_{\beta,a}^\delta + \sum_{a=1}^3 \lambda_{\beta,a}^\gamma \lambda_{a,\alpha}^\delta \right) (g_{\mu\nu}) \quad (354)$$


---



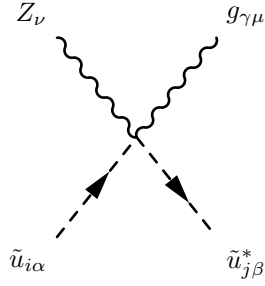
$$\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left( \left( 3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + 4g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu}) \quad (355)$$


---



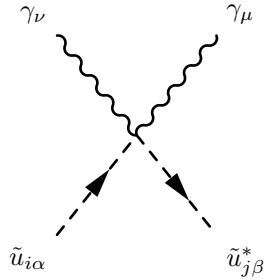
$$i \frac{1}{\sqrt{2}} g_2 g_3 \lambda_{\beta,\alpha}^\gamma \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D (g_{\mu\nu}) \quad (356)$$


---



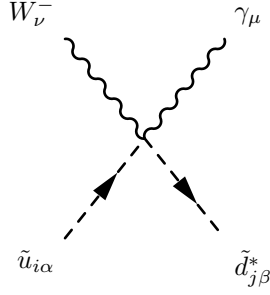
$$\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left( (3g_2 \cos \Theta_W - g_1 \sin \Theta_W) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U - 4g_1 \sin \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu}) \quad (357)$$


---



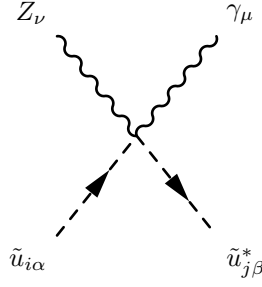
$$\frac{i}{18} \delta_{\alpha\beta} \left( 16g_1^2 \cos^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U + (3g_2 \sin \Theta_W + g_1 \cos \Theta_W)^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right) (g_{\mu\nu}) \quad (358)$$


---



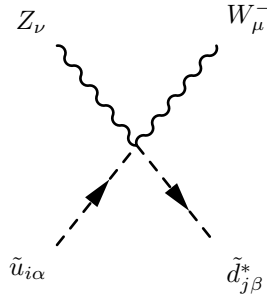
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D (g_{\mu\nu}) \quad (359)$$


---



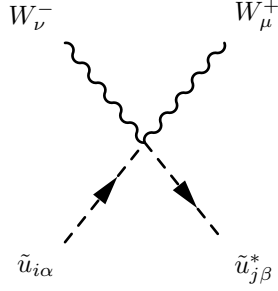
$$\begin{aligned} & - \frac{i}{36} \delta_{\alpha\beta} \left( (-6g_1 g_2 \cos 2\Theta_W + (-9g_2^2 + g_1^2) \sin 2\Theta_W) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\ & \left. + 16g_1^2 \sin 2\Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu}) \quad (360) \end{aligned}$$


---



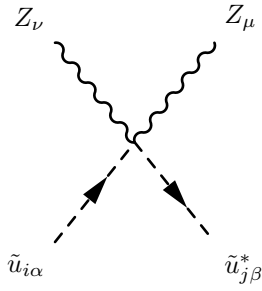
$$- \frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \delta_{\alpha\beta} \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D (g_{\mu\nu}) \quad (361)$$


---



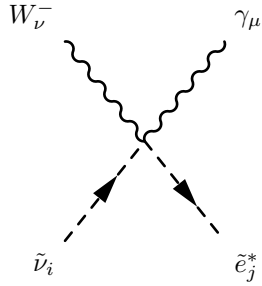
$$\frac{i}{2} g_2^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U (g_{\mu\nu}) \quad (362)$$


---



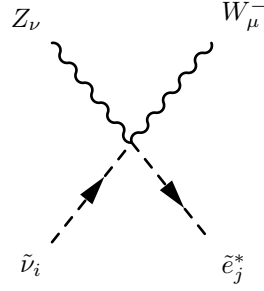
$$\frac{i}{18} \delta_{\alpha\beta} \left( 16g_1^2 \sin^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U + \left( -3g_2 \cos \Theta_W + g_1 \sin \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right) (g_{\mu\nu}) \quad (363)$$


---



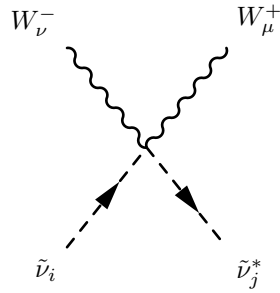
$$-i \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E (g_{\mu\nu}) \quad (364)$$


---



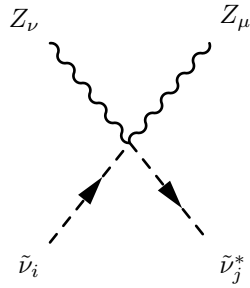
$$i \frac{1}{\sqrt{2}} g_1 g_2 \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E (g_{\mu\nu}) \quad (365)$$


---



$$\frac{i}{2} g_2^2 \delta_{ij} (g_{\mu\nu}) \quad (366)$$

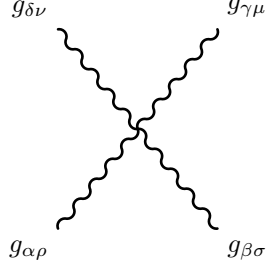

---



$$\frac{i}{2} \delta_{ij} (g_1 \sin \Theta_W + g_2 \cos \Theta_W)^2 (g_{\mu\nu}) \quad (367)$$


---

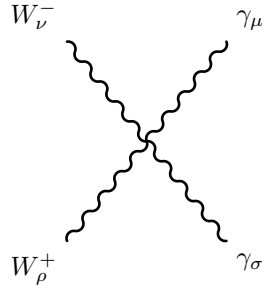
## 9.9 Four Vector Boson-Interaction



$$-ig_3^2 \left( \sum_{a=1}^8 f_{\alpha,\delta,a} f_{\beta,\gamma,a} + \sum_{a=1}^8 f_{\alpha,\gamma,a} f_{\beta,\delta,a} \right) (g_{\rho\sigma} g_{\mu\nu}) \quad (368)$$

$$+ ig_3^2 \left( - \sum_{a=1}^8 f_{\alpha,\beta,a} f_{\gamma,\delta,a} + \sum_{a=1}^8 f_{\alpha,\delta,a} f_{\beta,\gamma,a} \right) (g_{\rho\mu} g_{\sigma\nu}) \quad (369)$$

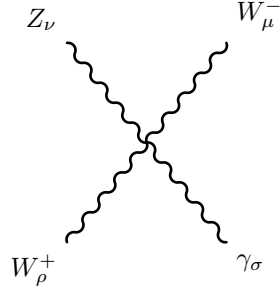
$$+ ig_3^2 \left( \sum_{a=1}^8 f_{\alpha,\gamma,a} f_{\beta,\delta,a} + \sum_{a=1}^8 f_{\alpha,\beta,a} f_{\gamma,\delta,a} \right) (g_{\rho\nu} g_{\sigma\mu}) \quad (370)$$



$$ig_2^2 \sin^2 \Theta_W (g_{\rho\sigma} g_{\mu\nu}) \quad (371)$$

$$+ ig_2^2 \sin^2 \Theta_W (g_{\rho\mu} g_{\sigma\nu}) \quad (372)$$

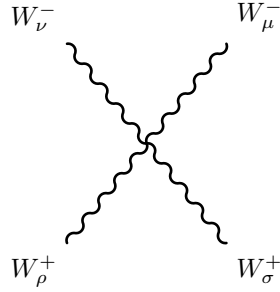
$$+ -2ig_2^2 \sin^2 \Theta_W (g_{\rho\nu} g_{\sigma\mu}) \quad (373)$$



$$ig_2^2 \cos \Theta_W \sin \Theta_W (g_{\rho\sigma} g_{\mu\nu}) \quad (374)$$

$$+ -ig_2^2 \sin 2\Theta_W (g_{\rho\mu} g_{\sigma\nu}) \quad (375)$$

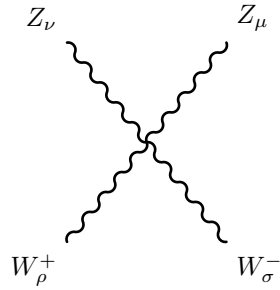
$$+ ig_2^2 \cos \Theta_W \sin \Theta_W (g_{\rho\nu} g_{\sigma\mu}) \quad (376)$$



$$2ig_2^2 (g_{\rho\sigma} g_{\mu\nu}) \quad (377)$$

$$+ -ig_2^2 (g_{\rho\mu} g_{\sigma\nu}) \quad (378)$$

$$+ -ig_2^2 (g_{\rho\nu} g_{\sigma\mu}) \quad (379)$$

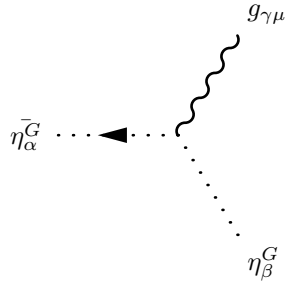


$$- 2ig_2^2 \cos^2 \Theta_W^2 (g_{\rho\sigma} g_{\mu\nu}) \quad (380)$$

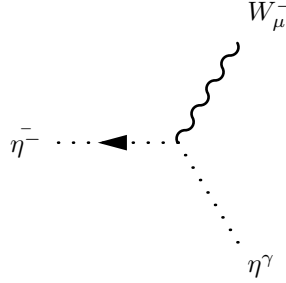
$$+ ig_2^2 \cos^2 \Theta_W^2 (g_{\rho\mu} g_{\sigma\nu}) \quad (381)$$

$$+ ig_2^2 \cos^2 \Theta_W^2 (g_{\rho\nu} g_{\sigma\mu}) \quad (382)$$

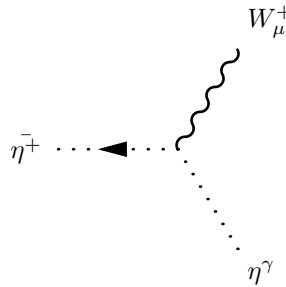
### 9.10 Two Ghosts-One Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma} (p_\mu^{\eta_\beta^G}) \quad (383)$$



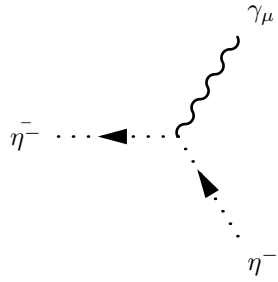
$$ig_2 \sin \Theta_W (p_\mu^{\eta^\gamma}) \quad (384)$$





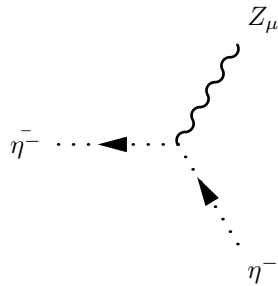
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^\gamma}) \quad (385)$$


---



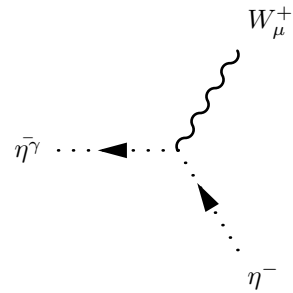
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^-}) \quad (386)$$


---



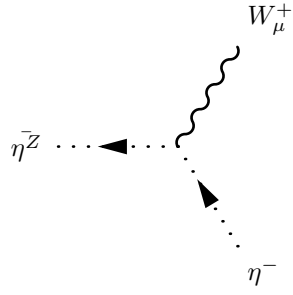
$$-ig_2 \cos \Theta_W (p_\mu^{\eta^-}) \quad (387)$$


---



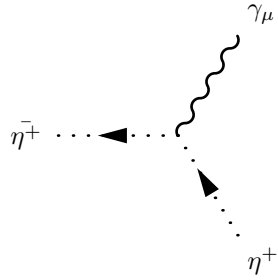
$$ig_2 \sin \Theta_W (p_\mu^{\eta^-}) \quad (388)$$


---



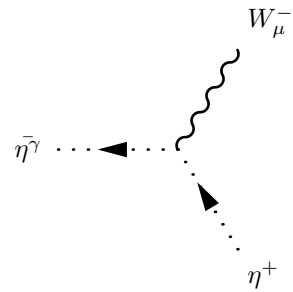
$$ig_2 \cos \Theta_W (p_\mu^{\eta^-}) \quad (389)$$


---



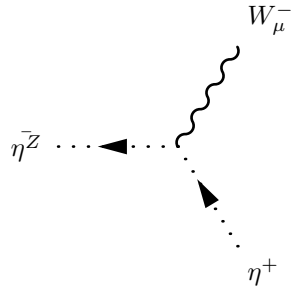
$$ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (390)$$


---



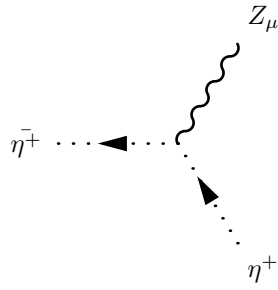
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (391)$$


---



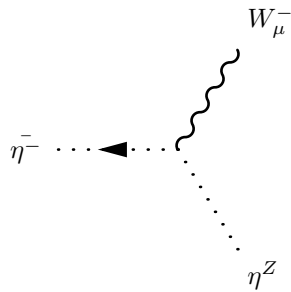
$$-ig_2 \cos \Theta_W (p_\mu^{\eta^+}) \quad (392)$$


---



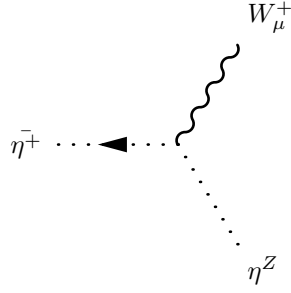
$$ig_2 \cos \Theta_W (p_\mu^{\eta^+}) \quad (393)$$


---



$$ig_2 \cos \Theta_W (p_\mu^{\eta^Z}) \quad (394)$$

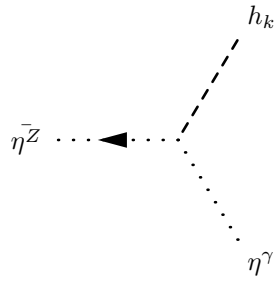

---



$$-ig_2 \cos \Theta_W (p_\mu^{\eta^Z}) \quad (395)$$

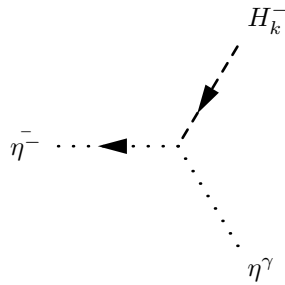

---

### 9.11 Two Ghosts-One Scalar-Interaction



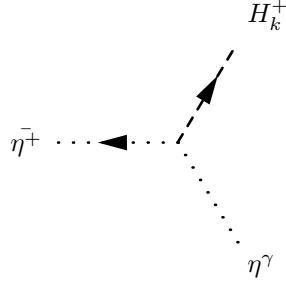
$$\frac{i}{8} \xi_Z (2g_1 g_2 \cos 2\Theta_W + (-g_2^2 + g_1^2) \sin 2\Theta_W) (v_d Z_{k1}^H + v_u Z_{k2}^H) \quad (396)$$


---



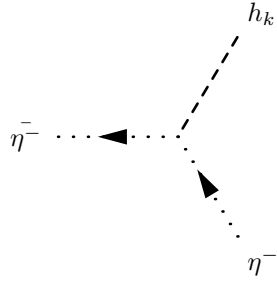
$$\frac{i}{4} g_2 (v_d Z_{k1}^{+,*} - v_u Z_{k2}^{+,*}) \xi_{W^-} (g_1 \cos \Theta_W + g_2 \sin \Theta_W) \quad (397)$$


---



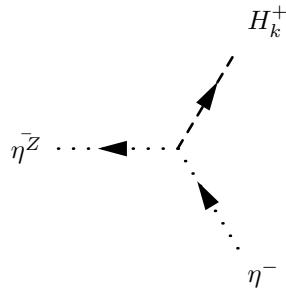
$$\frac{i}{4} g_2 \xi_{W^-} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left( v_d Z_{k1}^+ - v_u Z_{k2}^+ \right) \quad (398)$$


---



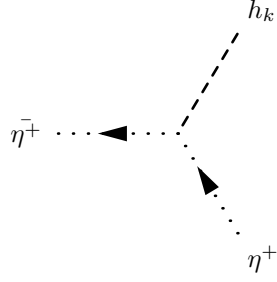
$$\frac{1}{4} g_2^2 \xi_{W^-} \left( -i v_d Z_{k1}^H - i v_u Z_{k2}^H + v_d Z_{k3}^H - v_u Z_{k4}^H \right) \quad (399)$$


---



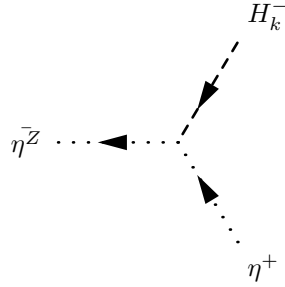
$$-\frac{i}{4} g_2 \xi_Z \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left( v_d Z_{k1}^+ - v_u Z_{k2}^+ \right) \quad (400)$$


---



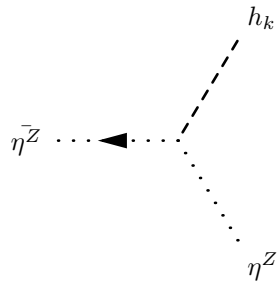
$$\frac{1}{4}g_2^2\xi_{W^-}\left(-iv_dZ_{k1}^H-iv_uZ_{k2}^H-v_dZ_{k3}^H+v_uZ_{k4}^H\right) \quad (401)$$


---



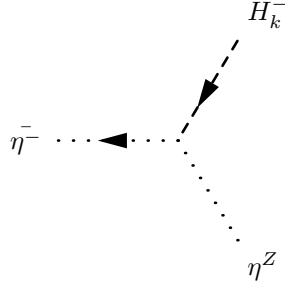
$$-\frac{i}{4}g_2\left(v_dZ_{k1}^{+,*}-v_uZ_{k2}^{+,*}\right)\xi_Z\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right) \quad (402)$$


---



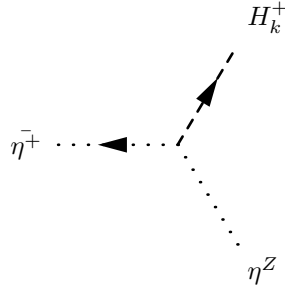
$$-\frac{i}{4}\xi_Z\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)^2\left(v_dZ_{k1}^H+v_uZ_{k2}^H\right) \quad (403)$$


---



$$\frac{i}{4}g_2(v_d Z_{k1}^{+,*} - v_u Z_{k2}^{+,*})\xi_{W^-}(-g_1 \sin \Theta_W + g_2 \cos \Theta_W) \quad (404)$$


---



$$\frac{i}{4}g_2\xi_{W^-}(-g_1 \sin \Theta_W + g_2 \cos \Theta_W)(v_d Z_{k1}^+ - v_u Z_{k2}^+) \quad (405)$$


---

## 10 Clebsch-Gordan Coefficients