

MSSM (CKM)
Superpotential, Rotations and Interactions for eigenstates 'EWSB'
including Renormalization Group Equations

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Package Homepage: projects.hepforge.org/sarah/
by **Florian Staub**, florian.staub@cern.ch

Contents

1	Superfields	3
1.1	Vector Superfields	3
1.2	Chiral Superfields	3
2	Superpotential and Lagrangian	3
2.1	Superpotential	3
2.2	Softbreaking terms	3
2.3	Gauge fixing terms	4
2.3.1	Gauge fixing terms for eigenstates 'GaugeES'	4
2.3.2	Gauge fixing terms for eigenstates 'SCKM'	4
2.3.3	Gauge fixing terms for eigenstates 'EWSB'	4
2.4	Fields integrated out	4
3	Renormalization Group Equations	4
3.1	Anomalous Dimensions	4
3.2	Gauge Couplings	5
3.3	Gaugino Mass Parameters	5
3.4	Trilinear Superpotential Parameters	6
3.5	Bilinear Superpotential Parameters	7
3.6	Trilinear Soft-Breaking Parameters	7
3.7	Bilinear Soft-Breaking Parameters	9
3.8	Soft-Breaking Scalar Masses	9
3.9	Vacuum expectation values	15
4	Field Rotations	15
4.1	Rotations in gauge sector for eigenstates 'SCKM'	15
4.2	Rotations in Mass sector for eigenstates 'SCKM'	16
4.2.1	Mass Matrices for Scalars	16
4.2.2	Mass Matrices for Fermions	19
4.3	Rotations in Mass sector for eigenstates 'EWSB'	21
4.3.1	Mass Matrices for Scalars	21
4.3.2	Mass Matrices for Fermions	22
5	Vacuum Expectation Values	22
5.1	VEVs for eigenstates 'SCKM'	22
6	Tadpole Equations	23
6.1	Tadpole Equations for eigenstates 'SCKM'	23
7	Particle content for eigenstates 'EWSB'	23

8	Interactions for eigenstates 'EWSB'	24
8.1	Three Scalar-Interaction	24
8.2	Two Scalar-One Vector Boson-Interaction	31
8.3	One Scalar-Two Vector Boson-Interaction	38
8.4	Two Fermion-One Vector Boson-Interaction	40
8.5	Two Fermion-One Scalar Boson-Interaction	46
8.6	Three Vector Boson-Interaction	59
8.7	Four Scalar-Interaction	60
8.8	Two Scalar-Two Vector Boson-Interaction	82
8.9	Four Vector Boson-Interaction	98
8.10	Two Ghosts-One Vector Boson-Interaction	100
8.11	Two Ghosts-One Scalar-Interaction	105
9	Clebsch-Gordan Coefficients	108

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}	Sq0	Fq0	3	$(\frac{1}{6}, \mathbf{2}, \mathbf{3})$
$\text{SF}(10)$	Sl0	Fl0	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}	$\tilde{d}_R^{0,*}$	d_R^*	3	$(\frac{1}{3}, \mathbf{1}, \mathbf{\bar{3}})$
\hat{u}	$\tilde{u}_R^{0,*}$	u_R^*	3	$(-\frac{2}{3}, \mathbf{1}, \mathbf{\bar{3}})$
$\text{SF}(e0)$	$\tilde{e}_R^{0,*}$	$\text{conj}(\text{FeR0})$	3	$(1, \mathbf{1}, \mathbf{1})$

2 Superpotential and Lagrangian

2.1 Superpotential

$$W = \mu \hat{H}_u \hat{H}_d - Y_d \hat{d} \hat{q} \hat{H}_d - Y_e \text{SF}(e0) \text{SF}(10) \hat{H}_d + Y_u \hat{u} \hat{q} \hat{H}_u \quad (1)$$

2.2 Softbreaking terms

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

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

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

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 'SCKM'

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

2.3.3 Gauge fixing terms for eigenstates 'EWSB'

$$\begin{aligned} L_{GF} = & -\frac{1}{2}|\partial_\mu g|^2\xi_g^{-1} - \frac{1}{2}|\partial_\mu \gamma|^2\xi_\gamma^{-1} - \left| -ig_2 H_{\text{gen}2}^- \xi_{W^-} \left(v_d Z_{\text{gen}21}^+ - v_u Z_{\text{gen}22}^+\right) + \partial_\mu W^- \right|^2\xi_{W^-}^{-1} \\ & - \frac{1}{2}\left|\frac{1}{2}\left(2A_{\text{gen}2}^0 \xi_Z\left(g_1 \sin \Theta_W + g_2 \cos \Theta_W\right)\left(v_d Z_{\text{gen}21}^A - v_u Z_{\text{gen}22}^A\right) + 2\partial_\mu Z\right)\right|^2\xi_Z^{-1} \end{aligned} \quad (7)$$

2.4 Fields integrated out

None

3 Renormalization Group Equations

3.1 Anomalous Dimensions

$$\gamma_{\hat{q}}^{(1)} = -\frac{1}{30}\left(45g_2^2 + 80g_3^2 + g_1^2\right)\mathbf{1} + Y_d^\dagger Y_d + Y_u^\dagger Y_u \quad (8)$$

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

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

$$\gamma_{\text{SF}(10)}^{(2)} = -2Y_e^\dagger Y_e Y_e^\dagger Y_e + \frac{3}{100}\left(125g_2^4 + 30g_1^2g_2^2 + 69g_1^4\right)\mathbf{1} + Y_e^\dagger Y_e\left(-3\text{Tr}\left(Y_d Y_d^\dagger\right) + \frac{6}{5}g_1^2 - \text{Tr}\left(Y_e Y_e^\dagger\right)\right) \quad (11)$$

$$\gamma_{\hat{H}_d}^{(1)} = 3\text{Tr}\left(Y_d Y_d^\dagger\right) - \frac{3}{10}\left(5g_2^2 + g_1^2\right) + \text{Tr}\left(Y_e Y_e^\dagger\right) \quad (12)$$

$$\begin{aligned} \gamma_{\hat{H}_d}^{(2)} = & +\frac{207}{100}g_1^4 + \frac{9}{10}g_1^2g_2^2 + \frac{15}{4}g_2^4 - \frac{2}{5}\left(-40g_3^2 + g_1^2\right)\text{Tr}\left(Y_d Y_d^\dagger\right) + \frac{6}{5}g_1^2\text{Tr}\left(Y_e Y_e^\dagger\right) - 9\text{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right) \\ & - 3\text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 3\text{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right) \end{aligned} \quad (13)$$

$$\gamma_{\hat{H}_u}^{(1)} = -\frac{3}{10} \left(-10\text{Tr}(Y_u Y_u^\dagger) + 5g_2^2 + g_1^2 \right) \quad (14)$$

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

$$\gamma_{\hat{d}}^{(1)} = 2Y_d^* Y_d^T - \frac{2}{15} (20g_3^2 + g_1^2) \mathbf{1} \quad (16)$$

$$\begin{aligned} \gamma_{\hat{d}}^{(2)} = & +\frac{2}{225} \left(-100g_3^4 + 101g_1^4 + 80g_1^2 g_3^2 \right) \mathbf{1} - 2 \left(Y_d^* Y_d^T Y_d^* Y_d^T + Y_d^* Y_u^T Y_u^* Y_d^T \right) \\ & + Y_d^* Y_d^T \left(-2\text{Tr}(Y_e Y_e^\dagger) + 6g_2^2 - 6\text{Tr}(Y_d Y_d^\dagger) + \frac{2}{5}g_1^2 \right) \end{aligned} \quad (17)$$

$$\gamma_{\hat{u}}^{(1)} = 2Y_u^* Y_u^T - \frac{8}{15} (5g_3^2 + g_1^2) \mathbf{1} \quad (18)$$

$$\begin{aligned} \gamma_{\hat{u}}^{(2)} = & +\frac{8}{225} \left(107g_1^4 - 25g_3^4 + 80g_1^2 g_3^2 \right) \mathbf{1} - 2 \left(Y_u^* Y_d^T Y_d^* Y_u^T + Y_u^* Y_u^T Y_u^* Y_u^T \right) \\ & + Y_u^* Y_u^T \left(6g_2^2 - 6\text{Tr}(Y_u Y_u^\dagger) - \frac{2}{5}g_1^2 \right) \end{aligned} \quad (19)$$

$$\gamma_{\text{SF}(\text{e}0)}^{(1)} = 2Y_e^* Y_e^T - \frac{6}{5}g_1^2 \mathbf{1} \quad (20)$$

$$\gamma_{\text{SF}(\text{e}0)}^{(2)} = -2Y_e^* Y_e^T Y_e^* Y_e^T + \frac{234}{25}g_1^4 \mathbf{1} + Y_e^* Y_e^T \left(-2\text{Tr}(Y_e Y_e^\dagger) + 6g_2^2 - 6\text{Tr}(Y_d Y_d^\dagger) - \frac{6}{5}g_1^2 \right) \quad (21)$$

3.2 Gauge Couplings

$$\beta_{g_1}^{(1)} = \frac{33}{5}g_1^3 \quad (22)$$

$$\beta_{g_1}^{(2)} = \frac{1}{25}g_1^3 \left(-130\text{Tr}(Y_u Y_u^\dagger) + 135g_2^2 + 199g_1^2 + 440g_3^2 - 70\text{Tr}(Y_d Y_d^\dagger) - 90\text{Tr}(Y_e Y_e^\dagger) \right) \quad (23)$$

$$\beta_{g_2}^{(1)} = g_2^3 \quad (24)$$

$$\beta_{g_2}^{(2)} = \frac{1}{5}g_2^3 \left(-10\text{Tr}(Y_e Y_e^\dagger) + 120g_3^2 + 125g_2^2 - 30\text{Tr}(Y_d Y_d^\dagger) - 30\text{Tr}(Y_u Y_u^\dagger) + 9g_1^2 \right) \quad (25)$$

$$\beta_{g_3}^{(1)} = -3g_3^3 \quad (26)$$

$$\beta_{g_3}^{(2)} = \frac{1}{5}g_3^3 \left(11g_1^2 - 20\text{Tr}(Y_d Y_d^\dagger) - 20\text{Tr}(Y_u Y_u^\dagger) + 45g_2^2 + 70g_3^2 \right) \quad (27)$$

3.3 Gaugino Mass Parameters

$$\beta_{M_1}^{(1)} = \frac{66}{5}g_1^2 M_1 \quad (28)$$

$$\beta_{M_1}^{(2)} = \frac{2}{25}g_1^2 \left(398g_1^2 M_1 + 135g_2^2 M_1 + 440g_3^2 M_1 + 440g_3^2 M_3 + 135g_2^2 M_2 - 70M_1 \text{Tr}(Y_d Y_d^\dagger) - 90M_1 \text{Tr}(Y_e Y_e^\dagger) \right)$$

$$-130M_1\text{Tr}(Y_u Y_u^\dagger) + 70\text{Tr}(Y_d^\dagger T_d) + 90\text{Tr}(Y_e^\dagger T_e) + 130\text{Tr}(Y_u^\dagger T_u) \quad (29)$$

$$\beta_{M_2}^{(1)} = 2g_2^2 M_2 \quad (30)$$

$$\begin{aligned} \beta_{M_2}^{(2)} = & \frac{2}{5}g_2^2 \left(9g_1^2 M_1 + 120g_3^2 M_3 + 9g_1^2 M_2 + 250g_2^2 M_2 + 120g_3^2 M_2 - 30M_2\text{Tr}(Y_d Y_d^\dagger) - 10M_2\text{Tr}(Y_e Y_e^\dagger) \right. \\ & \left. - 30M_2\text{Tr}(Y_u Y_u^\dagger) + 30\text{Tr}(Y_d^\dagger T_d) + 10\text{Tr}(Y_e^\dagger T_e) + 30\text{Tr}(Y_u^\dagger T_u) \right) \end{aligned} \quad (31)$$

$$\beta_{M_3}^{(1)} = -6g_3^2 M_3 \quad (32)$$

$$\begin{aligned} \beta_{M_3}^{(2)} = & \frac{2}{5}g_3^2 \left(11g_1^2 M_1 + 11g_1^2 M_3 + 45g_2^2 M_3 + 140g_3^2 M_3 + 45g_2^2 M_2 - 20M_3\text{Tr}(Y_d Y_d^\dagger) - 20M_3\text{Tr}(Y_u Y_u^\dagger) \right. \\ & \left. + 20\text{Tr}(Y_d^\dagger T_d) + 20\text{Tr}(Y_u^\dagger T_u) \right) \end{aligned} \quad (33)$$

3.4 Trilinear Superpotential Parameters

$$\beta_{Y_d}^{(1)} = 3Y_d Y_d^\dagger Y_d + Y_d \left(-3g_2^2 + 3\text{Tr}(Y_d Y_d^\dagger) - \frac{16}{3}g_3^2 - \frac{7}{15}g_1^2 + \text{Tr}(Y_e Y_e^\dagger) \right) + Y_d Y_u^\dagger Y_u \quad (34)$$

$$\begin{aligned} \beta_{Y_d}^{(2)} = & \frac{4}{5}g_1^2 Y_d Y_u^\dagger Y_u - 4Y_d Y_d^\dagger Y_d Y_d^\dagger Y_d - 2Y_d Y_u^\dagger Y_u Y_d^\dagger Y_d - 2Y_d Y_u^\dagger Y_u Y_u^\dagger Y_u \\ & + Y_d Y_d^\dagger Y_d \left(-3\text{Tr}(Y_e Y_e^\dagger) + 6g_2^2 - 9\text{Tr}(Y_d Y_d^\dagger) + \frac{4}{5}g_1^2 \right) - 3Y_d Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) \\ & + Y_d \left(\frac{287}{90}g_1^4 + g_1^2 g_2^2 + \frac{15}{2}g_2^4 + \frac{8}{9}g_1^2 g_3^2 + 8g_2^2 g_3^2 - \frac{16}{9}g_3^4 - \frac{2}{5}(-40g_3^2 + g_1^2) \text{Tr}(Y_d Y_d^\dagger) \right. \\ & \left. + \frac{6}{5}g_1^2 \text{Tr}(Y_e Y_e^\dagger) - 9\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 3\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 3\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \right) \end{aligned} \quad (35)$$

$$\beta_{Y_e}^{(1)} = 3Y_e Y_e^\dagger Y_e + Y_e \left(-3g_2^2 + 3\text{Tr}(Y_d Y_d^\dagger) - \frac{9}{5}g_1^2 + \text{Tr}(Y_e Y_e^\dagger) \right) \quad (36)$$

$$\begin{aligned} \beta_{Y_e}^{(2)} = & -4Y_e Y_e^\dagger Y_e Y_e^\dagger Y_e + Y_e Y_e^\dagger Y_e \left(-3\text{Tr}(Y_e Y_e^\dagger) + 6g_2^2 - 9\text{Tr}(Y_d Y_d^\dagger) \right) \\ & + \frac{1}{10}Y_e \left(-4(-40g_3^2 + g_1^2) \text{Tr}(Y_d Y_d^\dagger) \right. \\ & \left. + 3(45g_1^4 + 6g_1^2 g_2^2 + 25g_2^4 + 4g_1^2 \text{Tr}(Y_e Y_e^\dagger) - 30\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 10\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) \right. \\ & \left. - 10\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \right) \end{aligned} \quad (37)$$

$$\beta_{Y_u}^{(1)} = 3Y_u Y_u^\dagger Y_u - \frac{1}{15}Y_u \left(13g_1^2 + 45g_2^2 - 45\text{Tr}(Y_u Y_u^\dagger) + 80g_3^2 \right) + Y_u Y_d^\dagger Y_d \quad (38)$$

$$\begin{aligned} \beta_{Y_u}^{(2)} = & \frac{2}{5}g_1^2 Y_u Y_u^\dagger Y_u + 6g_2^2 Y_u Y_u^\dagger Y_u - 2Y_u Y_d^\dagger Y_d Y_d^\dagger Y_d - 2Y_u Y_d^\dagger Y_d Y_u^\dagger Y_u \\ & - 4Y_u Y_u^\dagger Y_u Y_u^\dagger Y_u + Y_u Y_d^\dagger Y_d \left(-3\text{Tr}(Y_d Y_d^\dagger) + \frac{2}{5}g_1^2 - \text{Tr}(Y_e Y_e^\dagger) \right) - 9Y_u Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) \\ & + Y_u \left(\frac{2743}{450}g_1^4 + g_1^2 g_2^2 + \frac{15}{2}g_2^4 + \frac{136}{45}g_1^2 g_3^2 + 8g_2^2 g_3^2 - \frac{16}{9}g_3^4 + \frac{4}{5}(20g_3^2 + g_1^2) \text{Tr}(Y_u Y_u^\dagger) \right. \\ & \left. - 3\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 9\text{Tr}(Y_u Y_u^\dagger Y_u Y_u^\dagger) \right) \end{aligned} \quad (39)$$

3.5 Bilinear Superpotential Parameters

$$\beta_\mu^{(1)} = 3\mu \text{Tr}(Y_d Y_d^\dagger) - \frac{3}{5}\mu(5g_2^2 - 5\text{Tr}(Y_u Y_u^\dagger) + g_1^2) + \mu \text{Tr}(Y_e Y_e^\dagger) \quad (40)$$

$$\begin{aligned} \beta_\mu^{(2)} = & \frac{1}{50}\mu(207g_1^4 + 90g_1^2g_2^2 + 375g_2^4 - 20(-40g_3^2 + g_1^2)\text{Tr}(Y_d Y_d^\dagger) + 60g_1^2\text{Tr}(Y_e Y_e^\dagger) + 40g_1^2\text{Tr}(Y_u Y_u^\dagger) \\ & + 800g_3^2\text{Tr}(Y_u Y_u^\dagger) - 450\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 300\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 150\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \\ & - 450\text{Tr}(Y_u Y_u^\dagger Y_u Y_u^\dagger)) \end{aligned} \quad (41)$$

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}(Y_d Y_d^\dagger) + T_d \text{Tr}(Y_e Y_e^\dagger) + Y_d(2\text{Tr}(Y_e^\dagger T_e) + 6g_2^2 M_2 + 6\text{Tr}(Y_d^\dagger T_d) + \frac{14}{15}g_1^2 M_1 + \frac{32}{3}g_3^2 M_3) \\ \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 + \frac{15}{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}(Y_d Y_d^\dagger) - 15T_d Y_d^\dagger Y_d \text{Tr}(Y_d Y_d^\dagger) - \frac{2}{5}g_1^2 T_d \text{Tr}(Y_d Y_d^\dagger) \\ & + 16g_3^2 T_d \text{Tr}(Y_d Y_d^\dagger) - 4Y_d Y_d^\dagger T_d \text{Tr}(Y_e Y_e^\dagger) - 5T_d Y_d^\dagger Y_d \text{Tr}(Y_e Y_e^\dagger) \\ & + \frac{6}{5}g_1^2 T_d \text{Tr}(Y_e Y_e^\dagger) - 6Y_d Y_u^\dagger T_u \text{Tr}(Y_u Y_u^\dagger) - 3T_d Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) \\ & - \frac{2}{5}Y_d Y_d^\dagger Y_d(15\text{Tr}(Y_e^\dagger T_e) + 30g_2^2 M_2 + 45\text{Tr}(Y_d^\dagger T_d) + 4g_1^2 M_1) - 6Y_d Y_u^\dagger Y_u \text{Tr}(Y_u^\dagger T_u) \\ & - 9T_d \text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 3T_d \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 3T_d \text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \\ & - \frac{2}{45}Y_d(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 \\ & + 45g_1^2 g_2^2 M_2 + 675g_2^4 M_2 + 360g_2^2 g_3^2 M_2 - 18(-40g_3^2 M_3 + g_1^2 M_1)\text{Tr}(Y_d Y_d^\dagger) \\ & + 54g_1^2 M_1 \text{Tr}(Y_e Y_e^\dagger) + 18g_1^2 \text{Tr}(Y_d^\dagger T_d) - 720g_3^2 \text{Tr}(Y_d^\dagger T_d) - 54g_1^2 \text{Tr}(Y_e^\dagger T_e) \end{aligned} \quad (42)$$

$$+ 810\text{Tr}\left(Y_d Y_d^\dagger T_d Y_d^\dagger\right) + 135\text{Tr}\left(Y_d Y_u^\dagger T_u Y_d^\dagger\right) + 270\text{Tr}\left(Y_e Y_e^\dagger T_e Y_e^\dagger\right) + 135\text{Tr}\left(Y_u Y_d^\dagger T_d Y_u^\dagger\right) \quad (43)$$

$$\begin{aligned} \beta_{T_e}^{(1)} = & + 4Y_e Y_e^\dagger T_e + 5T_e Y_e^\dagger Y_e - \frac{9}{5}g_1^2 T_e - 3g_2^2 T_e + 3T_e \text{Tr}\left(Y_d Y_d^\dagger\right) + T_e \text{Tr}\left(Y_e Y_e^\dagger\right) \\ & + Y_e \left(2\text{Tr}\left(Y_e^\dagger T_e\right) + 6g_2^2 M_2 + 6\text{Tr}\left(Y_d^\dagger T_d\right) + \frac{18}{5}g_1^2 M_1 \right) \end{aligned} \quad (44)$$

$$\begin{aligned} \beta_{T_e}^{(2)} = & + \frac{6}{5}g_1^2 Y_e Y_e^\dagger T_e + 6g_2^2 Y_e Y_e^\dagger T_e - \frac{6}{5}g_1^2 T_e Y_e^\dagger Y_e + 12g_2^2 T_e Y_e^\dagger Y_e \\ & - 6Y_e Y_e^\dagger Y_e Y_e^\dagger T_e - 8Y_e Y_e^\dagger T_e Y_e^\dagger Y_e - 6T_e Y_e^\dagger Y_e Y_e^\dagger Y_e + \frac{27}{2}g_1^4 T_e + \frac{9}{5}g_1^2 g_2^2 T_e + \frac{15}{2}g_2^4 T_e \\ & - 12Y_e Y_e^\dagger T_e \text{Tr}\left(Y_d Y_d^\dagger\right) - 15T_e Y_e^\dagger Y_e \text{Tr}\left(Y_d Y_d^\dagger\right) - \frac{2}{5}g_1^2 T_e \text{Tr}\left(Y_d Y_d^\dagger\right) \\ & + 16g_3^2 T_e \text{Tr}\left(Y_d Y_d^\dagger\right) - 4Y_e Y_e^\dagger T_e \text{Tr}\left(Y_e Y_e^\dagger\right) - 5T_e Y_e^\dagger Y_e \text{Tr}\left(Y_e Y_e^\dagger\right) \\ & + \frac{6}{5}g_1^2 T_e \text{Tr}\left(Y_e Y_e^\dagger\right) - 6Y_e Y_e^\dagger Y_e \left(2g_2^2 M_2 + 3\text{Tr}\left(Y_d^\dagger T_d\right) + \text{Tr}\left(Y_e^\dagger T_e\right) \right) - 9T_e \text{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right) \\ & - 3T_e \text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 3T_e \text{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right) \\ & - \frac{2}{5}Y_e \left(135g_1^4 M_1 + 9g_1^2 g_2^2 M_1 + 9g_1^2 g_2^2 M_2 + 75g_2^4 M_2 + \left(-2g_1^2 M_1 + 80g_3^2 M_3 \right) \text{Tr}\left(Y_d Y_d^\dagger\right) \right. \\ & + 6g_1^2 M_1 \text{Tr}\left(Y_e Y_e^\dagger\right) + 2g_1^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 80g_3^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 6g_1^2 \text{Tr}\left(Y_e^\dagger T_e\right) \\ & \left. + 90\text{Tr}\left(Y_d Y_d^\dagger T_d Y_d^\dagger\right) + 15\text{Tr}\left(Y_d Y_u^\dagger T_u Y_d^\dagger\right) + 30\text{Tr}\left(Y_e Y_e^\dagger T_e Y_e^\dagger\right) + 15\text{Tr}\left(Y_u Y_d^\dagger T_d Y_u^\dagger\right) \right) \end{aligned} \quad (45)$$

$$\begin{aligned} \beta_{T_u}^{(1)} = & + 2Y_u Y_d^\dagger T_d + 4Y_u Y_u^\dagger T_u + T_u Y_d^\dagger Y_d + 5T_u Y_u^\dagger Y_u - \frac{13}{15}g_1^2 T_u - 3g_2^2 T_u - \frac{16}{3}g_3^2 T_u \\ & + 3T_u \text{Tr}\left(Y_u Y_u^\dagger\right) + Y_u \left(6g_2^2 M_2 + 6\text{Tr}\left(Y_u^\dagger T_u\right) + \frac{26}{15}g_1^2 M_1 + \frac{32}{3}g_3^2 M_3 \right) \end{aligned} \quad (46)$$

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

$$\begin{aligned}
& + 225g_1^2g_2^2M_2 + 3375g_2^4M_2 + 1800g_2^2g_3^2M_2 + 180(20g_3^2M_3 + g_1^2M_1)\text{Tr}(Y_uY_u^\dagger) \\
& - 180(20g_3^2 + g_1^2)\text{Tr}(Y_u^\dagger T_u) + 675\text{Tr}(Y_dY_u^\dagger T_uY_d^\dagger) + 675\text{Tr}(Y_uY_d^\dagger T_dY_u^\dagger) \\
& + 4050\text{Tr}(Y_uY_u^\dagger T_uY_u^\dagger)
\end{aligned} \tag{47}$$

3.7 Bilinear Soft-Breaking Parameters

$$\begin{aligned}
\beta_{B_\mu}^{(1)} &= +\frac{6}{5}g_1^2M_1\mu + 6g_2^2M_2\mu + B_\mu(-3g_2^2 + 3\text{Tr}(Y_dY_d^\dagger) + 3\text{Tr}(Y_uY_u^\dagger) - \frac{3}{5}g_1^2 + \text{Tr}(Y_eY_e^\dagger)) \\
& + 6\mu\text{Tr}(Y_d^\dagger T_d) + 2\mu\text{Tr}(Y_e^\dagger T_e) + 6\mu\text{Tr}(Y_u^\dagger T_u) \\
\beta_{B_\mu}^{(2)} &= +B_\mu\left(\frac{207}{50}g_1^4 + \frac{9}{5}g_1^2g_2^2 + \frac{15}{2}g_2^4 - \frac{2}{5}(-40g_3^2 + g_1^2)\text{Tr}(Y_dY_d^\dagger) + \frac{6}{5}g_1^2\text{Tr}(Y_eY_e^\dagger) + \frac{4}{5}g_1^2\text{Tr}(Y_uY_u^\dagger)\right. \\
& + 16g_3^2\text{Tr}(Y_uY_u^\dagger) - 9\text{Tr}(Y_dY_d^\dagger Y_dY_d^\dagger) - 6\text{Tr}(Y_dY_u^\dagger Y_uY_d^\dagger) - 3\text{Tr}(Y_eY_e^\dagger Y_eY_e^\dagger) - 9\text{Tr}(Y_uY_u^\dagger Y_uY_u^\dagger) \\
& - \frac{2}{25}\mu(207g_1^4M_1 + 45g_1^2g_2^2M_1 + 45g_1^2g_2^2M_2 + 375g_2^4M_2 - 10(-40g_3^2M_3 + g_1^2M_1)\text{Tr}(Y_dY_d^\dagger) \\
& + 30g_1^2M_1\text{Tr}(Y_eY_e^\dagger) + 20g_1^2M_1\text{Tr}(Y_uY_u^\dagger) + 400g_3^2M_3\text{Tr}(Y_uY_u^\dagger) + 10g_1^2\text{Tr}(Y_d^\dagger T_d) \\
& - 400g_3^2\text{Tr}(Y_d^\dagger T_d) - 30g_1^2\text{Tr}(Y_e^\dagger T_e) - 20g_1^2\text{Tr}(Y_u^\dagger T_u) - 400g_3^2\text{Tr}(Y_u^\dagger T_u) \\
& + 450\text{Tr}(Y_dY_d^\dagger T_dY_d^\dagger) + 150\text{Tr}(Y_dY_u^\dagger T_uY_d^\dagger) + 150\text{Tr}(Y_eY_e^\dagger T_eY_e^\dagger) + 150\text{Tr}(Y_uY_d^\dagger T_dY_u^\dagger) \\
& \left. + 450\text{Tr}(Y_uY_u^\dagger T_uY_u^\dagger)\right)
\end{aligned} \tag{48}$$

$$\begin{aligned}
& + 450\text{Tr}(Y_uY_u^\dagger T_uY_u^\dagger)
\end{aligned} \tag{49}$$

3.8 Soft-Breaking Scalar Masses

$$\sigma_{1,1} = \sqrt{\frac{3}{5}}g_1(-2\text{Tr}(m_u^2) - \text{Tr}(m_l^2) - m_{H_d}^2 + m_{H_u}^2 + \text{Tr}(m_d^2) + \text{Tr}(m_e^2) + \text{Tr}(m_q^2)) \tag{50}$$

$$\sigma_{2,11} = \frac{1}{10}g_1^2(2\text{Tr}(m_d^2) + 3\text{Tr}(m_l^2) + 3m_{H_d}^2 + 3m_{H_u}^2 + 6\text{Tr}(m_e^2) + 8\text{Tr}(m_u^2) + \text{Tr}(m_q^2)) \tag{51}$$

$$\begin{aligned}
\sigma_{3,1} &= \frac{1}{20}\frac{1}{\sqrt{15}}g_1(-9g_1^2m_{H_d}^2 - 45g_2^2m_{H_d}^2 + 9g_1^2m_{H_u}^2 + 45g_2^2m_{H_u}^2 + 4(20g_3^2 + g_1^2)\text{Tr}(m_d^2) + 36g_1^2\text{Tr}(m_e^2) \\
& - 9g_1^2\text{Tr}(m_l^2) - 45g_2^2\text{Tr}(m_l^2) + g_1^2\text{Tr}(m_q^2) + 45g_2^2\text{Tr}(m_q^2) + 80g_3^2\text{Tr}(m_q^2) - 32g_1^2\text{Tr}(m_u^2) \\
& - 160g_3^2\text{Tr}(m_u^2) + 90m_{H_d}^2\text{Tr}(Y_dY_d^\dagger) + 30m_{H_d}^2\text{Tr}(Y_eY_e^\dagger) - 90m_{H_u}^2\text{Tr}(Y_uY_u^\dagger) - 60\text{Tr}(Y_dY_d^\dagger m_d^{2*}) \\
& - 30\text{Tr}(Y_dY_q^{2*}Y_d^\dagger) - 60\text{Tr}(Y_eY_e^\dagger m_e^{2*}) + 30\text{Tr}(Y_eY_l^{2*}Y_e^\dagger) + 120\text{Tr}(Y_uY_u^\dagger m_u^{2*}) \\
& - 30\text{Tr}(Y_um_q^{2*}Y_u^\dagger)
\end{aligned} \tag{52}$$

$$\sigma_{2,2} = \frac{1}{2} \left(3\text{Tr}(m_q^2) + m_{H_d}^2 + m_{H_u}^2 + \text{Tr}(m_t^2) \right) \quad (53)$$

$$\sigma_{2,3} = \frac{1}{2} \left(2\text{Tr}(m_q^2) + \text{Tr}(m_d^2) + \text{Tr}(m_u^2) \right) \quad (54)$$

$$\begin{aligned} \beta_{m_q^2}^{(1)} = & -\frac{2}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 - 6g_2^2\mathbf{1}|M_2|^2 + 2m_{H_d}^2Y_d^\dagger Y_d + 2m_{H_u}^2Y_u^\dagger Y_u + 2T_d^\dagger T_d \\ & + 2T_u^\dagger T_u + m_q^2Y_d^\dagger Y_d + m_q^2Y_u^\dagger Y_u + 2Y_d^\dagger m_d^2 Y_d + Y_d^\dagger Y_d m_q^2 + 2Y_u^\dagger m_u^2 Y_u \\ & + Y_u^\dagger Y_u m_q^2 + \frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1} \end{aligned} \quad (55)$$

$$\begin{aligned} \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 \\ & + \frac{16}{45}g_3^2 \left(15 \left(3g_2^2(2M_3 + M_2) - 8g_3^2M_3 \right) + g_1^2(2M_3 + M_1) \right) \mathbf{1}M_3^* + \frac{1}{5}g_1^2g_2^2M_1\mathbf{1}M_2^* + 16g_2^2g_3^2M_3\mathbf{1}M_2^* \\ & + \frac{4}{5}g_1^2m_{H_d}^2Y_d^\dagger Y_d + \frac{8}{5}g_1^2m_{H_u}^2Y_u^\dagger Y_u \\ & + \frac{1}{225}g_1^2M_1^* \left(\left(5 \left(16g_3^2(2M_1 + M_3) + 9g_2^2(2M_1 + M_2) \right) + 597g_1^2M_1 \right) \mathbf{1} \right. \\ & \left. + 180 \left(2M_1Y_d^\dagger Y_d - 2Y_u^\dagger T_u + 4M_1Y_u^\dagger Y_u - Y_d^\dagger T_d \right) \right) \\ & - \frac{4}{5}g_1^2M_1T_d^\dagger Y_d + \frac{4}{5}g_1^2T_d^\dagger T_d - \frac{8}{5}g_1^2M_1T_u^\dagger Y_u + \frac{8}{5}g_1^2T_u^\dagger T_u \\ & + \frac{2}{5}g_1^2m_q^2Y_d^\dagger Y_d + \frac{4}{5}g_1^2m_q^2Y_u^\dagger Y_u + \frac{4}{5}g_1^2Y_d^\dagger m_d^2 Y_d + \frac{2}{5}g_1^2Y_d^\dagger Y_d m_q^2 \\ & + \frac{8}{5}g_1^2Y_u^\dagger m_u^2 Y_u + \frac{4}{5}g_1^2Y_u^\dagger Y_u m_q^2 - 8m_{H_d}^2Y_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}^2Y_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^2Y_d^\dagger Y_d Y_d^\dagger Y_d - 2m_q^2Y_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}^2Y_d^\dagger Y_d \text{Tr}(Y_d Y_d^\dagger) - 6T_d^\dagger T_d \text{Tr}(Y_d Y_d^\dagger) - 3m_q^2Y_d^\dagger Y_d \text{Tr}(Y_d Y_d^\dagger) \\ & - 6Y_d^\dagger m_d^2 Y_d \text{Tr}(Y_d Y_d^\dagger) - 3Y_d^\dagger Y_d m_q^2 \text{Tr}(Y_d Y_d^\dagger) - 4m_{H_d}^2Y_d^\dagger Y_d \text{Tr}(Y_e Y_e^\dagger) \\ & - 2T_d^\dagger T_d \text{Tr}(Y_e Y_e^\dagger) - m_q^2Y_d^\dagger Y_d \text{Tr}(Y_e Y_e^\dagger) - 2Y_d^\dagger m_d^2 Y_d \text{Tr}(Y_e Y_e^\dagger) \\ & - Y_d^\dagger Y_d m_q^2 \text{Tr}(Y_e Y_e^\dagger) - 12m_{H_u}^2Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) - 6T_u^\dagger T_u \text{Tr}(Y_u Y_u^\dagger) \\ & - 3m_q^2Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) - 6Y_u^\dagger m_u^2 Y_u \text{Tr}(Y_u Y_u^\dagger) - 3Y_u^\dagger Y_u m_q^2 \text{Tr}(Y_u Y_u^\dagger) \\ & - 6T_d^\dagger Y_d \text{Tr}(Y_e^\dagger T_d) - 2T_d^\dagger Y_d \text{Tr}(Y_e^\dagger T_e) - 6T_u^\dagger Y_u \text{Tr}(Y_u^\dagger T_u) \end{aligned}$$

$$\begin{aligned}
& -6Y_d^\dagger T_d \text{Tr}(T_d^* Y_d^T) - 6Y_d^\dagger Y_d \text{Tr}(T_d^* T_d^T) - 2Y_d^\dagger T_d \text{Tr}(T_e^* Y_e^T) \\
& -2Y_d^\dagger Y_d \text{Tr}(T_e^* T_e^T) - 6Y_u^\dagger T_u \text{Tr}(T_u^* Y_u^T) - 6Y_u^\dagger Y_u \text{Tr}(T_u^* T_u^T) \\
& -6Y_d^\dagger Y_d \text{Tr}(m_d^2 Y_d Y_d^\dagger) - 2Y_d^\dagger Y_d \text{Tr}(m_e^2 Y_e Y_e^\dagger) - 2Y_d^\dagger Y_d \text{Tr}(m_l^2 Y_e^\dagger Y_e) \\
& -6Y_d^\dagger Y_d \text{Tr}(m_q^2 Y_d^\dagger Y_d) - 6Y_u^\dagger Y_u \text{Tr}(m_q^2 Y_u^\dagger Y_u) - 6Y_u^\dagger Y_u \text{Tr}(m_u^2 Y_u Y_u^\dagger)
\end{aligned} \tag{56}$$

$$\begin{aligned}
\beta_{m_l^2}^{(1)} = & -\frac{6}{5}g_1^2 \mathbf{1} |M_1|^2 - 6g_2^2 \mathbf{1} |M_2|^2 + 2m_{H_d}^2 Y_e^\dagger Y_e + 2T_e^\dagger T_e + m_l^2 Y_e^\dagger Y_e + 2Y_e^\dagger m_e^2 Y_e \\
& + Y_e^\dagger Y_e m_l^2 - \sqrt{\frac{3}{5}}g_1 \mathbf{1} \sigma_{1,1}
\end{aligned} \tag{57}$$

$$\begin{aligned}
\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 \\
& + \frac{3}{25}g_1^2 M_1^* \left(-20Y_e^\dagger T_e + 3\left(5g_2^2 (2M_1 + M_2) + 69g_1^2 M_1\right) \mathbf{1} + 40M_1 Y_e^\dagger Y_e\right) - \frac{12}{5}g_1^2 M_1 T_e^\dagger Y_e \\
& + \frac{12}{5}g_1^2 T_e^\dagger T_e + \frac{6}{5}g_1^2 m_l^2 Y_e^\dagger Y_e + \frac{12}{5}g_1^2 Y_e^\dagger m_e^2 Y_e + \frac{6}{5}g_1^2 Y_e^\dagger Y_e m_l^2 \\
& - 8m_{H_d}^2 Y_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^2 Y_e^\dagger Y_e Y_e^\dagger Y_e - 4Y_e^\dagger m_e^2 Y_e Y_e^\dagger Y_e - 4Y_e^\dagger Y_e m_l^2 Y_e^\dagger Y_e \\
& - 4Y_e^\dagger Y_e Y_e^\dagger m_e^2 Y_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}^2 Y_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^2 Y_e^\dagger Y_e \text{Tr}(Y_d Y_d^\dagger) \\
& - 6Y_e^\dagger m_e^2 Y_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}^2 Y_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^2 Y_e^\dagger Y_e \text{Tr}(Y_e Y_e^\dagger) - 2Y_e^\dagger m_e^2 Y_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)
\end{aligned} \tag{58}$$

$$\begin{aligned}
\beta_{m_{H_d}^2}^{(1)} = & -\frac{6}{5}g_1^2 |M_1|^2 - 6g_2^2 |M_2|^2 - \sqrt{\frac{3}{5}}g_1 \sigma_{1,1} + 6m_{H_d}^2 \text{Tr}(Y_d Y_d^\dagger) + 2m_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) + 6\text{Tr}(T_d^* T_d^T) \\
& + 2\text{Tr}(T_e^* T_e^T) + 6\text{Tr}(m_d^2 Y_d Y_d^\dagger) + 2\text{Tr}(m_e^2 Y_e Y_e^\dagger) + 2\text{Tr}(m_l^2 Y_e^\dagger Y_e) + 6\text{Tr}(m_q^2 Y_d^\dagger Y_d)
\end{aligned} \tag{59}$$

$$\begin{aligned}
\beta_{m_{H_d}^2}^{(2)} = & \frac{1}{25} \left(15g_2^2 \left(3g_1^2 (2M_2 + M_1) + 55g_2^2 M_2\right) M_2^* \right. \\
& + g_1^2 M_1^* \left(621g_1^2 M_1 + 90g_2^2 M_1 + 45g_2^2 M_2 - 40M_1 \text{Tr}(Y_d Y_d^\dagger) + 120M_1 \text{Tr}(Y_e Y_e^\dagger) + 20\text{Tr}(Y_d^\dagger T_d) \right. \\
& \left. \left. - 60\text{Tr}(Y_e^\dagger T_e)\right) \right)
\end{aligned}$$

$$\begin{aligned}
& + 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_1^2 m_{H_d}^2 + 80g_3^2 m_{H_d}^2 \right) \text{Tr} \left(Y_d Y_d^\dagger \right) \right. \\
& + 6g_1^2 m_{H_d}^2 \text{Tr} \left(Y_e Y_e^\dagger \right) - 80g_3^2 M_3^* \text{Tr} \left(Y_d^\dagger T_d \right) + 2g_1^2 M_1 \text{Tr} \left(T_d^* Y_d^T \right) - 80g_3^2 M_3 \text{Tr} \left(T_d^* Y_d^T \right) \\
& - 2g_1^2 \text{Tr} \left(T_d^* T_d^T \right) + 80g_3^2 \text{Tr} \left(T_d^* T_d^T \right) - 6g_1^2 M_1 \text{Tr} \left(T_e^* Y_e^T \right) + 6g_1^2 \text{Tr} \left(T_e^* T_e^T \right) \\
& - 2g_1^2 \text{Tr} \left(m_d^2 Y_d Y_d^\dagger \right) + 80g_3^2 \text{Tr} \left(m_d^2 Y_d Y_d^\dagger \right) + 6g_1^2 \text{Tr} \left(m_e^2 Y_e Y_e^\dagger \right) + 6g_1^2 \text{Tr} \left(m_l^2 Y_e^\dagger Y_e \right) \\
& - 2g_1^2 \text{Tr} \left(m_q^2 Y_d^\dagger Y_d \right) + 80g_3^2 \text{Tr} \left(m_q^2 Y_d^\dagger Y_d \right) - 90m_{H_d}^2 \text{Tr} \left(Y_d Y_d^\dagger Y_d Y_d^\dagger \right) - 90 \text{Tr} \left(Y_d Y_d^\dagger T_d T_d^\dagger \right) \\
& - 15m_{H_d}^2 \text{Tr} \left(Y_d Y_u^\dagger Y_u Y_d^\dagger \right) - 15m_{H_u}^2 \text{Tr} \left(Y_d Y_u^\dagger Y_u Y_d^\dagger \right) - 15 \text{Tr} \left(Y_d Y_u^\dagger T_u T_d^\dagger \right) \\
& - 90 \text{Tr} \left(Y_d T_d^\dagger T_d Y_d^\dagger \right) - 15 \text{Tr} \left(Y_d T_u^\dagger T_u Y_d^\dagger \right) - 30m_{H_d}^2 \text{Tr} \left(Y_e Y_e^\dagger Y_e Y_e^\dagger \right) - 30 \text{Tr} \left(Y_e Y_e^\dagger T_e T_e^\dagger \right) \\
& - 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) \\
& \left. - 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) \right) \quad (60)
\end{aligned}$$

$$\begin{aligned}
\beta_{m_{H_u}^2}^{(1)} &= -\frac{6}{5}g_1^2 |M_1|^2 - 6g_2^2 |M_2|^2 + \sqrt{\frac{3}{5}}g_1 \sigma_{1,1} + 6m_{H_u}^2 \text{Tr} \left(Y_u Y_u^\dagger \right) + 6 \text{Tr} \left(T_u^* T_u^T \right) + 6 \text{Tr} \left(m_q^2 Y_u^\dagger Y_u \right) \\
&+ 6 \text{Tr} \left(m_u^2 Y_u Y_u^\dagger \right) \quad (61)
\end{aligned}$$

$$\begin{aligned}
\beta_{m_{H_u}^2}^{(2)} &= +\frac{3}{5}g_2^2 \left(3g_1^2 (2M_2 + M_1) + 55g_2^2 M_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_1^2 m_{H_u}^2 \text{Tr} \left(Y_u Y_u^\dagger \right) \\
&+ 32g_3^2 m_{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_1^2 M_1^* \left(-40 \text{Tr} \left(Y_u^\dagger T_u \right) + 45g_2^2 M_2 + 621g_1^2 M_1 + 80M_1 \text{Tr} \left(Y_u Y_u^\dagger \right) + 90g_2^2 M_1 \right) \\
&- 32g_3^2 M_3^* \text{Tr} \left(Y_u^\dagger T_u \right) - \frac{8}{5}g_1^2 M_1 \text{Tr} \left(T_u^* Y_u^T \right) - 32g_3^2 M_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) \quad (62)
\end{aligned}$$

$$\begin{aligned}
\beta_{m_d^2}^{(1)} &= -\frac{8}{15}g_1^2 \mathbf{1} |M_1|^2 - \frac{32}{3}g_3^2 \mathbf{1} |M_3|^2 + 4m_{H_d}^2 Y_d Y_d^\dagger + 4T_d T_d^\dagger + 2m_d^2 Y_d Y_d^\dagger + 4Y_d m_q^2 Y_d^\dagger \\
&+ 2Y_d Y_d^\dagger m_d^2 + 2\frac{1}{\sqrt{15}}g_1 \mathbf{1} \sigma_{1,1} \quad (63)
\end{aligned}$$

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

$$\begin{aligned}
\beta_{m_u^2}^{(1)} = & - \frac{32}{15} g_1^2 \mathbf{1} |M_1|^2 - \frac{32}{3} g_3^2 \mathbf{1} |M_3|^2 + 4 m_{H_u}^2 Y_u Y_u^\dagger + 4 T_u T_u^\dagger + 2 m_u^2 Y_u Y_u^\dagger + 4 Y_u m_q^2 Y_u^\dagger \\
& + 2 Y_u Y_u^\dagger m_u^2 - 4 \frac{1}{\sqrt{15}} g_1 \mathbf{1} \sigma_{1,1}
\end{aligned} \tag{65}$$

$$\begin{aligned}
\beta_{m_u^2}^{(2)} = & - \frac{128}{45} g_3^2 \left(15 g_3^2 M_3 - 2 g_1^2 (2M_3 + M_1) \right) \mathbf{1} M_3^* - \frac{4}{5} g_1^2 m_{H_u}^2 Y_u Y_u^\dagger + 12 g_2^2 m_{H_u}^2 Y_u Y_u^\dagger \\
& + 24 g_2^2 |M_2|^2 Y_u Y_u^\dagger + \frac{4}{5} g_1^2 M_1 Y_u T_u^\dagger - 12 g_2^2 M_2 Y_u T_u^\dagger - 12 g_2^2 M_2^* T_u Y_u^\dagger \\
& + \frac{4}{225} g_1^2 M_1^* \left(45 \left(-2 M_1 Y_u Y_u^\dagger + T_u Y_u^\dagger \right) + 8 \left(321 g_1^2 M_1 + 40 g_3^2 (2M_1 + M_3) \right) \mathbf{1} \right) - \frac{4}{5} g_1^2 T_u T_u^\dagger \\
& + 12 g_2^2 T_u T_u^\dagger - \frac{2}{5} g_1^2 m_u^2 Y_u Y_u^\dagger + 6 g_2^2 m_u^2 Y_u Y_u^\dagger - \frac{4}{5} g_1^2 Y_u m_q^2 Y_u^\dagger \\
& + 12 g_2^2 Y_u m_q^2 Y_u^\dagger - \frac{2}{5} g_1^2 Y_u Y_u^\dagger m_u^2 + 6 g_2^2 Y_u Y_u^\dagger m_u^2 - 4 m_{H_d}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger
\end{aligned}$$

$$\begin{aligned}
& -4m_{H_u}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger - 4Y_u Y_d^\dagger T_d T_u^\dagger - 8m_{H_u}^2 Y_u Y_u^\dagger Y_u Y_u^\dagger - 4Y_u Y_u^\dagger T_u T_u^\dagger \\
& - 4Y_u T_d^\dagger T_d Y_u^\dagger - 4Y_u T_u^\dagger T_u Y_u^\dagger - 4T_u Y_d^\dagger Y_d T_u^\dagger - 4T_u Y_u^\dagger Y_u T_u^\dagger \\
& - 4T_u T_d^\dagger Y_d Y_u^\dagger - 4T_u T_u^\dagger Y_u Y_u^\dagger - 2m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger - 2m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger \\
& - 4Y_u m_q^2 Y_d^\dagger Y_d Y_u^\dagger - 4Y_u m_q^2 Y_u^\dagger Y_u Y_u^\dagger - 4Y_u Y_d^\dagger m_d^2 Y_d Y_u^\dagger \\
& - 4Y_u Y_d^\dagger Y_d m_q^2 Y_u^\dagger - 2Y_u Y_d^\dagger Y_d Y_u^\dagger m_u^2 - 4Y_u Y_u^\dagger m_u^2 Y_u Y_u^\dagger - 4Y_u Y_u^\dagger Y_u m_q^2 Y_u^\dagger \\
& - 2Y_u Y_u^\dagger Y_u Y_u^\dagger m_u^2 + \frac{32}{3} g_3^4 \mathbf{1} \sigma_{2,3} + \frac{32}{15} g_1^2 \mathbf{1} \sigma_{2,11} - 16 \frac{1}{\sqrt{15}} g_1 \mathbf{1} \sigma_{3,1} - 24m_{H_u}^2 Y_u Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) \\
& - 12T_u T_u^\dagger \text{Tr}(Y_u Y_u^\dagger) - 6m_u^2 Y_u Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) - 12Y_u m_q^2 Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) \\
& - 6Y_u Y_u^\dagger m_u^2 \text{Tr}(Y_u Y_u^\dagger) - 12Y_u T_u^\dagger \text{Tr}(Y_u^\dagger T_u) - 12T_u Y_u^\dagger \text{Tr}(T_u^* Y_u^T) \\
& - 12Y_u Y_u^\dagger \text{Tr}(T_u^* T_u^T) - 12Y_u Y_u^\dagger \text{Tr}(m_q^2 Y_u^\dagger Y_u) - 12Y_u Y_u^\dagger \text{Tr}(m_u^2 Y_u Y_u^\dagger)
\end{aligned} \tag{66}$$

$$\begin{aligned}
\beta_{m_e^2}^{(1)} &= -\frac{24}{5} g_1^2 \mathbf{1} |M_1|^2 + 2 \left(2m_{H_d}^2 Y_e Y_e^\dagger + 2T_e T_e^\dagger + 2Y_e m_l^2 Y_e^\dagger + m_e^2 Y_e Y_e^\dagger + Y_e Y_e^\dagger m_e^2 \right) \\
&+ 2\sqrt{\frac{3}{5}} g_1 \mathbf{1} \sigma_{1,1}
\end{aligned} \tag{67}$$

$$\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. \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) \right)
\end{aligned} \tag{68}$$

3.9 Vacuum expectation values

$$\beta_{v_d}^{(1)} = \frac{1}{20} v_d \left(-20 \text{Tr} \left(Y_e Y_e^\dagger \right) + 3 \left(5g_2^2 + g_1^2 \right) (1 + \text{Xi}) - 60 \text{Tr} \left(Y_d Y_d^\dagger \right) \right) \quad (69)$$

$$\begin{aligned} \beta_{v_d}^{(2)} = \frac{1}{400} v_d \left(-414g_1^4 - 180g_1^2g_2^2 - 1200g_2^4 - 9g_1^4\text{Xi} - 90g_1^2g_2^2\text{Xi} + 875g_2^4\text{Xi} + 9g_1^4\text{Xi}^2 + 90g_1^2g_2^2\text{Xi}^2 \right. \\ \left. - 225g_2^4\text{Xi}^2 - 40 \left(5 \left(32g_3^2 + 9g_2^2\text{Xi} \right) + g_1^2 \left(9\text{Xi} - 4 \right) \right) \text{Tr} \left(Y_d Y_d^\dagger \right) - 120 \left(5g_2^2\text{Xi} + g_1^2 \left(4 + \text{Xi} \right) \right) \text{Tr} \left(Y_e Y_e^\dagger \right) \right. \\ \left. + 3600 \text{Tr} \left(Y_d Y_d^\dagger Y_d Y_d^\dagger \right) + 1200 \text{Tr} \left(Y_d Y_u^\dagger Y_u Y_d^\dagger \right) + 1200 \text{Tr} \left(Y_e Y_e^\dagger Y_e Y_e^\dagger \right) \right) \end{aligned} \quad (70)$$

$$\beta_{v_u}^{(1)} = \frac{3}{20} v_u \left(-20 \text{Tr} \left(Y_u Y_u^\dagger \right) + \left(5g_2^2 + g_1^2 \right) (1 + \text{Xi}) \right) \quad (71)$$

$$\begin{aligned} \beta_{v_u}^{(2)} = \frac{1}{400} v_u \left(-414g_1^4 - 180g_1^2g_2^2 - 1200g_2^4 - 9g_1^4\text{Xi} - 90g_1^2g_2^2\text{Xi} + 875g_2^4\text{Xi} + 9g_1^4\text{Xi}^2 + 90g_1^2g_2^2\text{Xi}^2 \right. \\ \left. - 225g_2^4\text{Xi}^2 - 40 \left(5 \left(32g_3^2 + 9g_2^2\text{Xi} \right) + g_1^2 \left(9\text{Xi} + 8 \right) \right) \text{Tr} \left(Y_u Y_u^\dagger \right) + 1200 \text{Tr} \left(Y_d Y_u^\dagger Y_u Y_d^\dagger \right) + 3600 \text{Tr} \left(Y_u Y_u^\dagger Y_u Y_u^\dagger \right) \right) \end{aligned} \quad (72)$$

4 Field Rotations

4.1 Rotations in gauge sector for eigenstates 'SCKM'

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \end{pmatrix} = Z^{\gamma Z} \begin{pmatrix} \gamma_\rho \\ Z_\rho \end{pmatrix} \quad (73)$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho} \end{pmatrix} = Z^W \begin{pmatrix} W_\rho^- \\ W_\rho^- \end{pmatrix} \quad (74)$$

$$\begin{pmatrix} \lambda_{\tilde{W},1} \\ \lambda_{\tilde{W},2} \\ \lambda_{\tilde{W},3} \end{pmatrix} = Z^{\tilde{W}} \begin{pmatrix} \tilde{W}^- \\ \tilde{W}^+ \\ \tilde{W}^0 \end{pmatrix} \quad (75)$$

$$(76)$$

The mixing matrices are parametrized by

$$Z^{\gamma Z} = \begin{pmatrix} \cos \Theta_W & -\sin \Theta_W \\ \sin \Theta_W & \cos \Theta_W \end{pmatrix} \quad (77)$$

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

$$Z^{\bar{W}} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (79)$$

$$(80)$$

4.2 Rotations in Mass sector for eigenstates 'SCKM'

4.2.1 Mass Matrices for Scalars

- Mass matrix for Left Selectron, Basis: $(\tilde{e}_L^0), (\tilde{e}_L^{0,*})$

$$m_{\tilde{e}_L}^2 = \begin{pmatrix} m_{\tilde{e}_L^0 \tilde{e}_L^{0,*}} \end{pmatrix} \quad (81)$$

$$m_{\tilde{e}_L^0 \tilde{e}_L^{0,*}} = \frac{1}{2} v_d^2 \sum_{a=1}^3 |\hat{Y}_{e,aa}^0|^2 U_{L,ao_1}^{e,*} U_{L,ap_1}^e + \frac{1}{8} (-g_2^2 + g_1^2) \mathbf{1} (-v_u^2 + v_d^2) + \sum_{a=1}^3 U_{L,ao_1}^{e,*} \hat{m}_{l,aa}^2 U_{L,ap_1}^e \quad (82)$$

This matrix is diagonalized by U_L^e :

$$U_L^e m_{\tilde{e}_L}^2 U_L^{e,\dagger} = m_{2,\tilde{e}_L}^{dia} \quad (83)$$

with

$$\tilde{e}_{L,i}^0 = \sum_j U_{L,ji}^{e,*} \tilde{e}_{L,j} \quad (84)$$

- Mass matrix for Left Down-Squarks, Basis: $(\tilde{d}_{L,\alpha_1}^0), (\tilde{d}_{L,\beta_1}^{0,*})$

$$m_{\tilde{d}_L}^2 = \begin{pmatrix} m_{\tilde{d}_L^0 \tilde{d}_L^{0,*}} \end{pmatrix} \quad (85)$$

$$m_{\tilde{d}_L^0 \tilde{d}_L^{0,*}} = -\frac{1}{24} (3g_2^2 + g_1^2) \mathbf{1} (-v_u^2 + v_d^2) \delta_{\alpha_1\beta_1} + \frac{1}{2} \delta_{\alpha_1\beta_1} \left(2 \sum_{a=1}^3 U_{L,ap_1}^{d,*} \hat{m}_{q,aa}^2 U_{L,ao_1}^d + v_d^2 \sum_{a=1}^3 |\hat{Y}_{d,aa}^0|^2 U_{L,ao_1}^{d,*} U_{L,ap_1}^d \right) \quad (86)$$

This matrix is diagonalized by U_L^d :

$$U_L^d m_{\tilde{d}_L}^2 U_L^{d,\dagger} = m_{2,\tilde{d}_L}^{dia} \quad (87)$$

with

$$\tilde{d}_{L,i\alpha}^0 = \sum_j U_{L,ji}^{d,*} \tilde{d}_{L,j\alpha} \quad (88)$$

- Mass matrix for Left Up-Squarks, Basis: $(\tilde{u}_{L,\alpha_1}^0), (\tilde{u}_{L,\beta_1}^{0,*})$

$$m_{\tilde{u}_L}^2 = \begin{pmatrix} m_{\tilde{u}_L^0 \tilde{u}_L^{0,*}} \end{pmatrix} \quad (89)$$

$$m_{\tilde{u}_L^0 \tilde{u}_L^{0,*}} = -\frac{1}{24} \left(-3g_2^2 + g_1^2 \right) \mathbf{1} \left(-v_u^2 + v_d^2 \right) \delta_{\alpha_1 \beta_1} + \frac{1}{2} \delta_{\alpha_1 \beta_1} \left(2 \sum_{a=1}^3 U_{L,ap_1}^{d,*} \hat{m}_{\tilde{q},aa}^2 U_{L,ao_1}^d + v_u^2 \sum_{a=1}^3 |\hat{Y}_{u,aa}^0|^2 U_{L,ao_1}^{u,*} U_{L,ap_1}^u \right) \quad (90)$$

This matrix is diagonalized by U_L^u :

$$U_L^u m_{\tilde{u}_L}^2 U_L^{u,\dagger} = m_{2,\tilde{u}_L}^{dia} \quad (91)$$

with

$$\tilde{u}_{L,i\alpha}^0 = \sum_j U_{L,ji}^{u,*} \tilde{u}_{L,j\alpha} \quad (92)$$

- **Mass matrix for Right Selectron**, Basis: $(\tilde{e}_R^{0,*}), (\tilde{e}_R^0)$

$$m_{\tilde{e}_R}^2 = \left(\frac{1}{2} v_d^2 \sum_{a=1}^3 |\hat{Y}_{e,aa}^0|^2 U_{R,ao_1}^{e,*} U_{R,ap_1}^e + \frac{1}{4} g_1^2 \mathbf{1} \left(-v_d^2 + v_u^2 \right) + \sum_{a=1}^3 U_{R,ao_1}^{e,*} \hat{m}_{\tilde{e},aa}^2 U_{R,ap_1}^e \right) \quad (93)$$

This matrix is diagonalized by \tilde{e} :

$$\tilde{e} m_{\tilde{e}_R}^2 \tilde{e}^\dagger = m_{2,\tilde{e}_R}^{dia} \quad (94)$$

with

$$\tilde{e}_{R,i}^0 = \sum_j U_{R,ji}^e \tilde{e}_{R,j} \quad (95)$$

- **Mass matrix for Right Down-Squarks**, Basis: $(\tilde{d}_{R,\alpha_1}^{0,*}), (\tilde{d}_{R,\beta_1}^0)$

$$m_{\tilde{d}_R}^2 = \left(m_{\tilde{d}_R^{0,*} \tilde{d}_R^0} \right) \quad (96)$$

$$m_{\tilde{d}_R^{0,*} \tilde{d}_R^0} = \frac{1}{12} g_1^2 \mathbf{1} \left(-v_d^2 + v_u^2 \right) \delta_{\alpha_1 \beta_1} + \frac{1}{2} \delta_{\alpha_1 \beta_1} \left(2 \sum_{a=1}^3 U_{R,ao_1}^{d,*} \hat{m}_{\tilde{d},aa}^2 U_{R,ap_1}^d + v_d^2 \sum_{a=1}^3 |\hat{Y}_{d,aa}^0|^2 U_{R,ao_1}^{d,*} U_{R,ap_1}^d \right) \quad (97)$$

This matrix is diagonalized by U_R^d :

$$U_R^d m_{\tilde{d}_R}^2 U_R^{d,\dagger} = m_{2,\tilde{d}_R}^{dia} \quad (98)$$

with

$$\tilde{d}_{R,i\alpha}^0 = \sum_j U_{R,ji}^d \tilde{d}_{R,j\alpha} \quad (99)$$

- **Mass matrix for Right Up-Squarks**, Basis: $(\tilde{u}_{R,\alpha_1}^{0,*}), (\tilde{u}_{R,\beta_1}^0)$

$$m_{\tilde{u}_R}^2 = \left(m_{\tilde{u}_R^{0,*} \tilde{u}_R^0} \right) \quad (100)$$

$$m_{\tilde{u}_R^{0,*} \tilde{u}_R^0} = \frac{1}{2} \delta_{\alpha_1 \beta_1} \left(2 \sum_{a=1}^3 U_{R,ao_1}^{u,*} \hat{m}_{\tilde{u},aa}^2 U_{R,ap_1}^u + v_u^2 \sum_{a=1}^3 |\hat{Y}_{u,aa}^0|^2 U_{R,ao_1}^{u,*} U_{R,ap_1}^u \right) + \frac{1}{6} g_1^2 \mathbf{1} \left(-v_u^2 + v_d^2 \right) \delta_{\alpha_1 \beta_1} \quad (101)$$

This matrix is diagonalized by U_R^u :

$$U_R^u m_{\tilde{u}_R}^2 U_R^{u,\dagger} = m_{2,\tilde{u}_R}^{dia} \quad (102)$$

with

$$\tilde{u}_{R,i\alpha}^0 = \sum_j U_{R,ji}^u \tilde{u}_{R,j\alpha} \quad (103)$$

- **Mass matrix for Sneutrinos**, Basis: $(\tilde{u}_L^0), (\tilde{u}_L^{0,*})$

$$m_{\tilde{\nu}}^2 = \left(\frac{1}{8}(g_1^2 + g_2^2) \mathbf{1} \begin{pmatrix} -v_u^2 + v_d^2 \end{pmatrix} + \sum_{a=1}^3 U_{L,a\alpha_1}^{e,*} \hat{m}_{\tilde{l},aa}^2 U_{L,ap_1}^e \right) \quad (104)$$

This matrix is diagonalized by Z^V :

$$Z^V m_{\tilde{\nu}}^2 Z^{V,\dagger} = m_{2,\tilde{\nu}}^{dia} \quad (105)$$

with

$$\tilde{u}_{L,i}^0 = \sum_j Z_{ji}^{V,*} \tilde{\nu}_j \quad (106)$$

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

$$m_h^2 = \begin{pmatrix} \frac{1}{8}(g_1^2 + g_2^2) \begin{pmatrix} 3v_d^2 - v_u^2 \end{pmatrix} + m_{H_d}^2 + |\mu|^2 & -\frac{1}{4}(g_1^2 + g_2^2) v_d v_u - \Re(B_\mu) \\ -\frac{1}{4}(g_1^2 + g_2^2) v_d v_u - \Re(B_\mu) & -\frac{1}{8}(g_1^2 + g_2^2) \begin{pmatrix} -3v_u^2 + v_d^2 \end{pmatrix} + m_{H_u}^2 + |\mu|^2 \end{pmatrix} \quad (107)$$

This matrix is diagonalized by Z^H :

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \quad (108)$$

with

$$\phi_d = \sum_j Z_{j1}^H h_j, \quad \phi_u = \sum_j Z_{j2}^H h_j \quad (109)$$

- **Mass matrix for Pseudo-Scalar Higgs**, Basis: $(\sigma_d, \sigma_u), (\sigma_d, \sigma_u)$

$$m_{A^0}^2 = \begin{pmatrix} \frac{1}{8}(g_1^2 + g_2^2) \begin{pmatrix} -v_u^2 + v_d^2 \end{pmatrix} + m_{H_d}^2 + |\mu|^2 & \Re(B_\mu) \\ \Re(B_\mu) & -\frac{1}{8}(g_1^2 + g_2^2) \begin{pmatrix} -v_u^2 + v_d^2 \end{pmatrix} + m_{H_u}^2 + |\mu|^2 \end{pmatrix} + \xi_Z m^2(Z) \quad (110)$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} \frac{1}{4} v_d^2 (g_1 \sin \Theta_W + g_2 \cos \Theta_W)^2 & -\frac{1}{4} v_d v_u (g_1 \sin \Theta_W + g_2 \cos \Theta_W)^2 \\ -\frac{1}{4} v_d v_u (g_1 \sin \Theta_W + g_2 \cos \Theta_W)^2 & \frac{1}{4} v_u^2 (g_1 \sin \Theta_W + g_2 \cos \Theta_W)^2 \end{pmatrix} \quad (111)$$

This matrix is diagonalized by Z^A :

$$Z^A m_{A^0}^2 Z^{A,\dagger} = m_{2,A^0}^{dia} \quad (112)$$

with

$$\sigma_d = \sum_j Z_{j1}^A A_j^0, \quad \sigma_u = \sum_j Z_{j2}^A A_j^0 \quad (113)$$

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

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

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

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

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

$$m_d = \left(\frac{1}{\sqrt{2}} v_d \delta_{\alpha_1 \beta_1} \sum_{a=1}^3 U_{R,ap_1}^d U_{L,ao_1}^d \hat{Y}_{d,aa}^0 \right) \quad (120)$$

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

$$U_L^{d,*} m_d U_R^{d,\dagger} = m_d^{dia} \quad (121)$$

with

$$d_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{d,*} D_{L,j\alpha} \quad (122)$$

$$d_{R,i\alpha} = \sum_{t_2} U_{R,ij}^d D_{R,j\alpha}^* \quad (123)$$

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

$$m_u = \left(\frac{1}{\sqrt{2}} v_u \delta_{\alpha_1 \beta_1} \sum_{a=1}^3 U_{R,ap_1}^u U_{L,a\alpha_1}^u \hat{Y}_{u,aa}^0 \right) \quad (124)$$

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

$$U_L^{u,*} m_u U_R^{u,\dagger} = m_u^{dia} \quad (125)$$

with

$$u_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{u,*} U_{L,j\alpha} \quad (126)$$

$$u_{R,i\alpha} = \sum_{t_2} U_{R,ij}^u U_{R,j\alpha}^* \quad (127)$$

- **Mass matrix for Leptons**, Basis: $(\text{FeL0}), (\text{conj}(\text{FeR0}))$

$$m_e = \left(\frac{1}{\sqrt{2}} v_d \sum_{a=1}^3 U_{R,ap_1}^e U_{L,a\alpha_1}^e \hat{Y}_{e,aa}^0 \right) \quad (128)$$

This matrix is diagonalized by U_L^e and \tilde{e}

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

with

$$\text{FeL0}(\{\text{gt1}\}) = \sum_{t_2} U_{L,ji}^{e,*} e_{L,j} \quad (130)$$

$$\text{FeR0}(\{\text{gt1}\}) = \sum_{t_2} U_{R,ij}^e e_{R,j}^* \quad (131)$$

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

$$m_{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & -\frac{1}{2}g_1 v_d & \frac{1}{2}g_1 v_u \\ 0 & M_2 & \frac{1}{2}g_2 v_d & -\frac{1}{2}g_2 v_u \\ -\frac{1}{2}g_1 v_d & \frac{1}{2}g_2 v_d & 0 & -\mu \\ \frac{1}{2}g_1 v_u & -\frac{1}{2}g_2 v_u & -\mu & 0 \end{pmatrix} \quad (132)$$

This matrix is diagonalized by N :

$$N^* m_{\tilde{\chi}^0} N^\dagger = m_{\tilde{\chi}^0}^{dia} \quad (133)$$

with

$$\lambda_{\tilde{B}} = \sum_j N_{j1}^* \lambda_j^0, \quad \tilde{W}^0 = \sum_j N_{j2}^* \lambda_j^0, \quad \tilde{H}_d^0 = \sum_j N_{j3}^* \lambda_j^0 \quad (134)$$

$$\tilde{H}_u^0 = \sum_j N_{j4}^* \lambda_j^0 \quad (135)$$

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

$$m_{\tilde{\chi}^-} = \begin{pmatrix} M_2 & \frac{1}{\sqrt{2}}g_2v_u \\ \frac{1}{\sqrt{2}}g_2v_d & \mu \end{pmatrix} \quad (136)$$

This matrix is diagonalized by U and V

$$U^* m_{\tilde{\chi}^-} V^\dagger = m_{\tilde{\chi}^-}^{dia} \quad (137)$$

with

$$\tilde{W}^- = \sum_{t_2} U_{j1}^* \lambda_j^-, \quad \tilde{H}_d^- = \sum_{t_2} U_{j2}^* \lambda_j^- \quad (138)$$

$$\tilde{W}^+ = \sum_{t_2} V_{1j}^* \lambda_j^+, \quad \tilde{H}_u^+ = \sum_{t_2} V_{2j}^* \lambda_j^+ \quad (139)$$

4.3 Rotations in Mass sector for eigenstates 'EWSB'

4.3.1 Mass Matrices for Scalars

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

$$m_{\tilde{d}}^2 = \begin{pmatrix} m_{\tilde{d}_L \tilde{d}_L^*} & \frac{1}{\sqrt{2}} \left(-\text{Delta} v_u \mu \hat{Y}_{d,o_1 o_1}^{0,*} + v_d \hat{T}_d^{0,\dagger} \right) \delta_{\alpha_1 \beta_2} \\ \frac{1}{\sqrt{2}} \delta_{\alpha_2 \beta_1} \left(-\text{Delta} v_u \mu^* \hat{Y}_{d,o_2 o_2}^0 + v_d \hat{T}_d^0 \right) & m_{\tilde{d}_R \tilde{d}_R^*} \end{pmatrix} \quad (140)$$

$$m_{\tilde{d}_L \tilde{d}_L^*} = -\frac{1}{24} (3g_2^2 + g_1^2) \mathbf{1} \left(-v_u^2 + v_d^2 \right) \delta_{\alpha_1 \beta_1} + \frac{1}{2} \delta_{\alpha_1 \beta_1} \left(2 \sum_{c=1}^3 U_{L,p_1 c}^{d,*} \sum_{b=1}^3 \sum_{a=1}^3 U_{L,ac}^{d,*} \hat{m}_{\tilde{q},aa}^2 U_{L,ab}^d U_{L,o_1 b}^d + \mathbf{1} v_d^2 |\hat{Y}_{d,o_1 o_1}^0|^2 \right) \quad (141)$$

$$m_{\tilde{d}_R \tilde{d}_R^*} = \frac{1}{12} g_1^2 \mathbf{1} \left(-v_d^2 + v_u^2 \right) \delta_{\alpha_2 \beta_2} + \frac{1}{2} \mathbf{1} \delta_{\alpha_2 \beta_2} \left(2 \hat{m}_{\tilde{d},o_2 o_2}^2 + v_d^2 |\hat{Y}_{d,o_2 o_2}^0|^2 \right) \quad (142)$$

This matrix is diagonalized by Z^D :

$$Z^D m_{\tilde{d}}^2 Z^{D,\dagger} = m_{2,\tilde{d}}^{dia} \quad (143)$$

with

$$\tilde{d}_{L,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha}, \quad \tilde{d}_{R,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha} \quad (144)$$

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

$$m_{\tilde{u}}^2 = \begin{pmatrix} m_{\tilde{u}_L \tilde{u}_L^*} & \frac{1}{\sqrt{2}} \left(-\text{Delta} v_d \mu \hat{Y}_{u,o_1 o_1}^{0,*} + v_u \hat{T}_u^{0,\dagger} \right) \delta_{\alpha_1 \beta_2} \\ \frac{1}{\sqrt{2}} \delta_{\alpha_2 \beta_1} \left(-\text{Delta} v_d \mu^* \hat{Y}_{u,o_2 o_2}^0 + v_u \hat{T}_u^0 \right) & m_{\tilde{u}_R \tilde{u}_R^*} \end{pmatrix} \quad (145)$$

$$m_{\tilde{u}_L \tilde{u}_L^*} = -\frac{1}{24} \left(-3g_2^2 + g_1^2 \right) \mathbf{1} \left(-v_u^2 + v_d^2 \right) \delta_{\alpha_1 \beta_1} + \frac{1}{2} \delta_{\alpha_1 \beta_1} \left(2 \sum_{c=1}^3 U_{L,p_1 c}^{u,*} \sum_{b=1}^3 \sum_{a=1}^3 U_{L,ac}^{d,*} \hat{m}_{\tilde{q},aa}^2 U_{L,ab}^d U_{L,o_1 b}^u + \mathbf{1} v_u^2 |\hat{Y}_{u,o_1 o_1}^0|^2 \right) \quad (146)$$

$$m_{\tilde{u}_R \tilde{u}_R^*} = \frac{1}{2} \mathbf{1} \delta_{\alpha_2 \beta_2} \left(2 \hat{m}_{\tilde{u},o_2 o_2}^2 + v_u^2 |\hat{Y}_{u,o_2 o_2}^0|^2 \right) + \frac{1}{6} g_1^2 \mathbf{1} \left(-v_u^2 + v_d^2 \right) \delta_{\alpha_2 \beta_2} \quad (147)$$

This matrix is diagonalized by Z^U :

$$Z^U m_{\tilde{u}}^2 Z^{U,\dagger} = m_{2,\tilde{u}}^{dia} \quad (148)$$

with

$$\tilde{u}_{L,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha}, \quad \tilde{u}_{R,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha} \quad (149)$$

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

$$m_{\tilde{e}}^2 = \begin{pmatrix} m_{\tilde{e}_L \tilde{e}_L^*} & \frac{1}{\sqrt{2}} \text{Delta} \left(v_d \hat{T}_{e,o_1 o_1}^{0,*} - v_u \mu \hat{Y}_{e,o_1 o_1}^{0,*} \right) \\ \frac{1}{\sqrt{2}} \text{Delta} \left(v_d \hat{T}_{e,o_2 o_2}^0 - v_u \mu^* \hat{Y}_{e,o_2 o_2}^0 \right) & m_{\tilde{e}_R \tilde{e}_R^*} \end{pmatrix} \quad (150)$$

$$m_{\tilde{e}_L \tilde{e}_L^*} = \frac{1}{2} \mathbf{1} \left(2 \hat{m}_{\tilde{l},o_1 o_1}^2 + v_d^2 |\hat{Y}_{e,o_1 o_1}^0|^2 \right) + \frac{1}{8} \left(-g_2^2 + g_1^2 \right) \mathbf{1} \left(-v_u^2 + v_d^2 \right) \quad (151)$$

$$m_{\tilde{e}_R \tilde{e}_R^*} = \frac{1}{2} \mathbf{1} \left(2 \hat{m}_{\tilde{e},o_2 o_2}^2 + v_d^2 |\hat{Y}_{e,o_2 o_2}^0|^2 \right) + \frac{1}{4} g_1^2 \mathbf{1} \left(-v_d^2 + v_u^2 \right) \quad (152)$$

This matrix is diagonalized by Z^E :

$$Z^E m_{\tilde{e}}^2 Z^{E,\dagger} = m_{2,\tilde{e}}^{dia} \quad (153)$$

with

$$\tilde{e}_{L,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j, \quad \tilde{e}_{R,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j \quad (154)$$

4.3.2 Mass Matrices for Fermions

- No Fermion Mixings

5 Vacuum Expectation Values

5.1 VEVs for eigenstates 'SCKM'

$$H_d^0 = \frac{1}{\sqrt{2}} \phi_d + \frac{1}{\sqrt{2}} v_d + i \frac{1}{\sqrt{2}} \sigma_d \quad (155)$$

$$H_u^0 = \frac{1}{\sqrt{2}} \phi_u + \frac{1}{\sqrt{2}} v_u + i \frac{1}{\sqrt{2}} \sigma_u \quad (156)$$

6 Tadpole Equations

6.1 Tadpole Equations for eigenstates 'SCKM'

$$\frac{\partial V}{\partial \phi_d} = -\frac{1}{2}v_u(B_\mu + B_\mu^*) + \frac{1}{8}(g_1^2 + g_2^2)v_d(-v_u + v_d)(v_d + v_u) + v_d(m_{H_d}^2 + |\mu|^2) \quad (157)$$

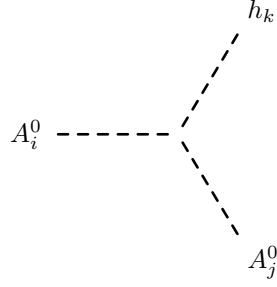
$$\frac{\partial V}{\partial \phi_u} = \frac{1}{8}(g_1^2 + g_2^2)v_u(-v_d^2 + v_u^2) - v_d\Re(B_\mu) + v_u(m_{H_u}^2 + |\mu|^2) \quad (158)$$

7 Particle content for eigenstates 'EWSB'

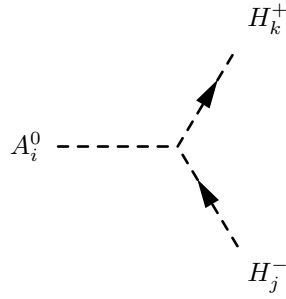
Name	Type	complex/real	Generations	Indices
$\tilde{\nu}$	Scalar	complex	3	generation, 3
h	Scalar	real	2	generation, 2
A^0	Scalar	real	2	generation, 2
H^-	Scalar	complex	2	generation, 2
\tilde{d}	Scalar	complex	6	generation, 6, color, 3
\tilde{u}	Scalar	complex	6	generation, 6, color, 3
\tilde{e}	Scalar	complex	6	generation, 6
\tilde{g}	Fermion	Majorana	1	color, 8
ν	Fermion	Dirac	3	generation, 3
d	Fermion	Dirac	3	generation, 3, color, 3
u	Fermion	Dirac	3	generation, 3, color, 3
e	Fermion	Dirac	3	generation, 3
$\tilde{\chi}^0$	Fermion	Majorana	4	generation, 4
$\tilde{\chi}^-$	Fermion	Dirac	2	generation, 2
g	Vector	real	1	color, 8, lorentz, 4
γ	Vector	real	1	lorentz, 4
Z	Vector	real	1	lorentz, 4
W^-	Vector	complex	1	lorentz, 4
η^G	Ghost	real	1	color, 8
η^γ	Ghost	real	1	
η^Z	Ghost	real	1	
η^-	Ghost	complex	1	
η^+	Ghost	complex	1	

8 Interactions for eigenstates 'EWSB'

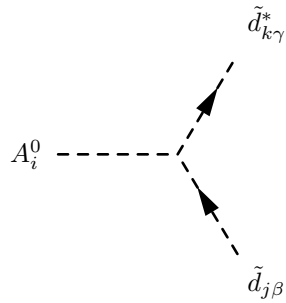
8.1 Three Scalar-Interaction



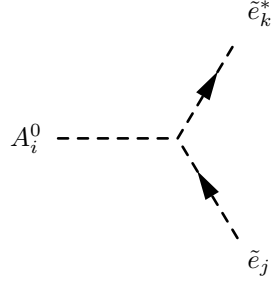
$$-\frac{i}{4}\left(g_1^2+g_2^2\right)\left(Z_{i1}^AZ_{j1}^A-Z_{i2}^AZ_{j2}^A\right)\left(v_dZ_{k1}^H-v_uZ_{k2}^H\right) \quad (159)$$



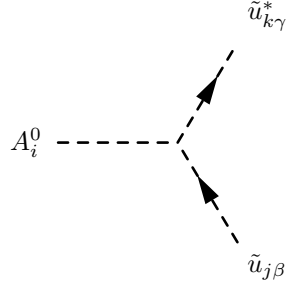
$$\frac{1}{4}g_2^2\left(v_dZ_{i2}^A+v_uZ_{i1}^A\right)\left(-Z_{j1}^+Z_{k2}^++Z_{j2}^+Z_{k1}^+\right) \quad (160)$$



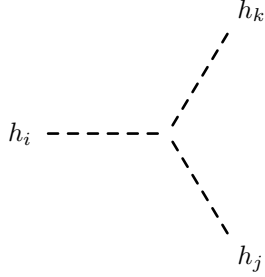
$$\begin{aligned}
& \frac{1}{\sqrt{2}} \delta_{\beta\gamma} \left(\sum_{d=1}^3 Z_{jd}^{D,*} \sum_{c=1}^3 Z_{k3+c}^D \hat{T}_{d,cd}^0 Z_{i1}^A - \sum_{d=1}^3 \sum_{c=1}^3 Z_{j3+c}^{D,*} \hat{T}_{d,cd}^{0,*} Z_{kd}^D Z_{i1}^A \right. \\
& \left. + \left(-\mu \sum_{c=1}^3 \hat{Y}_{d,cc}^{0,*} Z_{j3+c}^{D,*} Z_{kc}^D + \mu^* \sum_{c=1}^3 Z_{jc}^{D,*} \hat{Y}_{d,cc}^0 Z_{k3+c}^D \right) Z_{i2}^A \right)
\end{aligned} \tag{161}$$



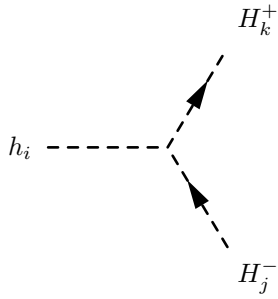
$$\begin{aligned}
& -\frac{1}{\sqrt{2}} \left(\sum_{c=1}^3 Z_{j3+c}^{E,*} \hat{T}_{e,cc}^{0,*} Z_{kc}^E Z_{i1}^A - \sum_{c=1}^3 Z_{jc}^{E,*} Z_{k3+c}^E \hat{T}_{e,cc}^0 Z_{i1}^A \right. \\
& \left. + \left(\mu \sum_{c=1}^3 \hat{Y}_{e,cc}^{0,*} Z_{j3+c}^{E,*} Z_{kc}^E - \mu^* \sum_{c=1}^3 Z_{jc}^{E,*} \hat{Y}_{e,cc}^0 Z_{k3+c}^E \right) Z_{i2}^A \right)
\end{aligned} \tag{162}$$



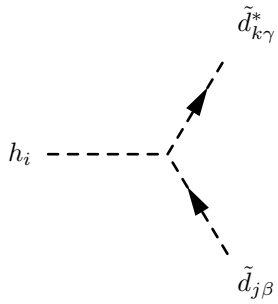
$$\begin{aligned}
& -\frac{1}{\sqrt{2}} \delta_{\beta\gamma} \left(\mu \sum_{c=1}^3 \hat{Y}_{u,cc}^{0,*} Z_{j3+c}^{U,*} Z_{kc}^U Z_{i1}^A - \mu^* \sum_{c=1}^3 Z_{jc}^{U,*} \hat{Y}_{u,cc}^0 Z_{k3+c}^U Z_{i1}^A \right. \\
& \left. + \left(-\sum_{d=1}^3 Z_{jd}^{U,*} \sum_{c=1}^3 Z_{k3+c}^U \hat{T}_{u,cd}^0 + \sum_{d=1}^3 \sum_{c=1}^3 Z_{j3+c}^{U,*} \hat{T}_{u,cd}^{0,*} Z_{kd}^U \right) Z_{i2}^A \right)
\end{aligned} \tag{163}$$



$$\begin{aligned} & \frac{i}{4} \left(g_1^2 + g_2^2 \right) \left(Z_{i2}^H \left(Z_{j1}^H \left(v_d Z_{k2}^H + v_u Z_{k1}^H \right) + Z_{j2}^H \left(-3v_u Z_{k2}^H + v_d Z_{k1}^H \right) \right) \right. \\ & \left. + Z_{i1}^H \left(Z_{j1}^H \left(-3v_d Z_{k1}^H + v_u Z_{k2}^H \right) + Z_{j2}^H \left(v_d Z_{k2}^H + v_u Z_{k1}^H \right) \right) \right) \end{aligned} \quad (164)$$

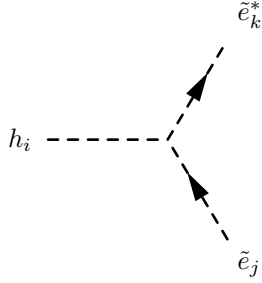


$$\begin{aligned} & \frac{i}{4} \left(-Z_{i1}^H \left(Z_{j1}^+ \left(\left(g_1^2 + g_2^2 \right) v_d Z_{k1}^+ + g_2^2 v_u Z_{k2}^+ \right) + Z_{j2}^+ \left(\left(-g_1^2 + g_2^2 \right) v_d Z_{k2}^+ + g_2^2 v_u Z_{k1}^+ \right) \right) \right. \\ & \left. + Z_{i2}^H \left(Z_{j1}^+ \left(\left(-g_2^2 + g_1^2 \right) v_u Z_{k1}^+ - g_2^2 v_d Z_{k2}^+ \right) - Z_{j2}^+ \left(\left(g_1^2 + g_2^2 \right) v_u Z_{k2}^+ + g_2^2 v_d Z_{k1}^+ \right) \right) \right) \end{aligned} \quad (165)$$

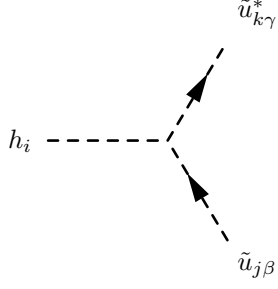


$$\frac{i}{12} \delta_{\beta\gamma} \left(\left(3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \left(v_d Z_{i1}^H - v_u Z_{i2}^H \right) \right)$$

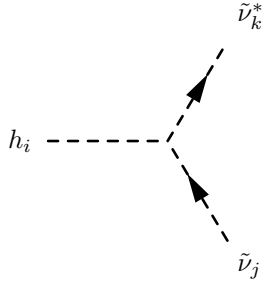
$$\begin{aligned}
& + 2 \left(g_1^2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \left(v_d Z_{i1}^H - v_u Z_{i2}^H \right) \right. \\
& - 3 \left(2v_d \sum_{c=1}^3 |\hat{Y}_{d,cc}^0|^2 Z_{jc}^{D,*} Z_{kc}^D Z_{i1}^H + 2v_d \sum_{c=1}^3 |\hat{Y}_{d,cc}^0|^2 Z_{j3+c}^{D,*} Z_{k3+c}^D Z_{i1}^H \right. \\
& + \sqrt{2} \left(\sum_{d=1}^3 Z_{jd}^{D,*} \sum_{c=1}^3 Z_{k3+c}^D \hat{T}_{d,cd}^0 Z_{i1}^H + \sum_{d=1}^3 \sum_{c=1}^3 Z_{j3+c}^{D,*} \hat{T}_{d,cd}^{0,*} Z_{kd}^D Z_{i1}^H \right. \\
& \left. \left. - \left(\mu \sum_{c=1}^3 \hat{Y}_{d,cc}^{0,*} Z_{j3+c}^{D,*} Z_{kc}^D + \mu^* \sum_{c=1}^3 Z_{jc}^{D,*} \hat{Y}_{d,cc}^0 Z_{k3+c}^D \right) Z_{i2}^H \right) \right) \Big) \Big) \quad (166)
\end{aligned}$$



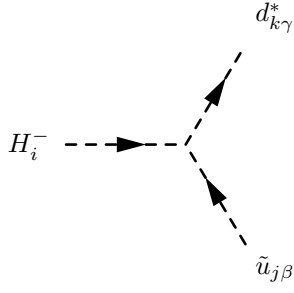
$$\begin{aligned}
& \frac{i}{4} \left(- \left(-g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E \left(v_d Z_{i1}^H - v_u Z_{i2}^H \right) \right. \\
& + 2 \left(-2v_d \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{jc}^{E,*} Z_{kc}^E Z_{i1}^H - \sqrt{2} \sum_{c=1}^3 Z_{j3+c}^{E,*} \hat{T}_{e,cc}^{0,*} Z_{kc}^E Z_{i1}^H \right. \\
& - 2v_d \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{j3+c}^{E,*} Z_{k3+c}^E Z_{i1}^H - \sqrt{2} \sum_{c=1}^3 Z_{jc}^{E,*} Z_{k3+c}^E \hat{T}_{e,cc}^0 Z_{i1}^H \\
& + \sqrt{2} \mu \sum_{c=1}^3 \hat{Y}_{e,cc}^{0,*} Z_{j3+c}^{E,*} Z_{kc}^E Z_{i2}^H + \sqrt{2} \mu^* \sum_{c=1}^3 Z_{jc}^{E,*} \hat{Y}_{e,cc}^0 Z_{k3+c}^E Z_{i2}^H \\
& \left. \left. + g_1^2 \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{k3+b}^E \left(v_d Z_{i1}^H - v_u Z_{i2}^H \right) \right) \right) \Big) \quad (167)
\end{aligned}$$



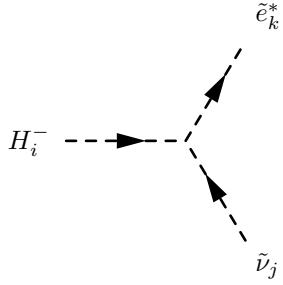
$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\gamma} \left(\left(-3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \left(v_d Z_{i1}^H - v_u Z_{i2}^H \right) \right. \\
& - 2 \left(-3\sqrt{2}\mu \sum_{c=1}^3 \hat{Y}_{u,cc}^{0,*} Z_{j3+c}^{U,*} Z_{kc}^U Z_{i1}^H - 3\sqrt{2}\mu^* \sum_{c=1}^3 Z_{jc}^{U,*} \hat{Y}_{u,cc}^0 Z_{k3+c}^U Z_{i1}^H \right. \\
& + 6v_u \sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 Z_{jc}^{U,*} Z_{kc}^U Z_{i2}^H + 6v_u \sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 Z_{j3+c}^{U,*} Z_{k3+c}^U Z_{i2}^H \\
& + 3\sqrt{2} \sum_{d=1}^3 Z_{jd}^{U,*} \sum_{c=1}^3 Z_{k3+c}^U \hat{T}_{u,cd}^0 Z_{i2}^H + 3\sqrt{2} \sum_{d=1}^3 \sum_{c=1}^3 Z_{j3+c}^{U,*} \hat{T}_{u,cd}^{0,*} Z_{kd}^U Z_{i2}^H \\
& \left. \left. + 2g_1^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \left(v_d Z_{i1}^H - v_u Z_{i2}^H \right) \right) \right) \quad (168)
\end{aligned}$$



$$- \frac{i}{4} \left(g_1^2 + g_2^2 \right) \delta_{jk} \left(v_d Z_{i1}^H - v_u Z_{i2}^H \right) \quad (169)$$

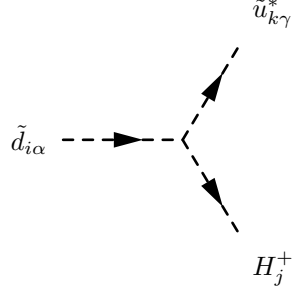


$$\begin{aligned}
& -\frac{i}{4}\delta_{\beta\gamma}\left(\sqrt{2}g_2^2\sum_{b=1}^3Z_{jb}^{U,*}\sum_{a=1}^3V_{ba}^{CKM}Z_{ka}^D\left(v_dZ_{i1}^++v_uZ_{i2}^+\right)\right. \\
& -2\left(\sqrt{2}v_d\sum_{c=1}^3|\hat{Y}_{d,cc}^0|^2\sum_{b=1}^3V_{bc}^{CKM}Z_{jb}^{U,*}Z_{kc}^DZ_{i1}^++2\mu\sum_{c=1}^3\sum_{b=1}^3V_{bc}^{CKM}\hat{Y}_{u,bb}^{0,*}Z_{j3+b}^{U,*}Z_{kc}^DZ_{i1}^+ \right. \\
& +2\sum_{d=1}^3Z_{jd}^{U,*}\sum_{c=1}^3\sum_{b=1}^3V_{db}^{CKM}\hat{T}_{d,cb}^0Z_{k3+c}^DZ_{i1}^+ \\
& +\sqrt{2}v_u\sum_{d=1}^3\hat{Y}_{u,dd}^{0,*}Z_{j3+d}^{U,*}\sum_{c=1}^3V_{dc}^{CKM}\hat{Y}_{d,cc}^0Z_{k3+c}^DZ_{i1}^+ \\
& +2\mu^*\sum_{c=1}^3Z_{jc}^{U,*}\sum_{b=1}^3V_{cb}^{CKM}\hat{Y}_{d,bb}^0Z_{k3+b}^DZ_{i2}^++\sqrt{2}v_u\sum_{c=1}^3\sum_{b=1}^3|\hat{Y}_{u,bb}^0|^2V_{bc}^{CKM}Z_{jb}^{U,*}Z_{kc}^DZ_{i2}^+ \\
& +\sqrt{2}v_d\sum_{d=1}^3\hat{Y}_{u,dd}^{0,*}Z_{j3+d}^{U,*}\sum_{c=1}^3V_{dc}^{CKM}\hat{Y}_{d,cc}^0Z_{k3+c}^DZ_{i2}^+ \\
& \left. +2\sum_{d=1}^3\sum_{c=1}^3Z_{j3+c}^{U,*}\sum_{b=1}^3V_{bd}^{CKM}\hat{T}_{u,cb}^{0,*}Z_{kd}^DZ_{i2}^+\right)\Bigg) \tag{170}
\end{aligned}$$

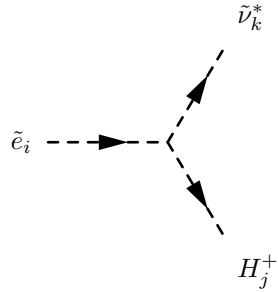


$$\frac{i}{4}\left(2\sqrt{2}v_d\sum_{c=1}^3|\hat{Y}_{e,cc}^0|^2\sum_{b=1}^3Z_{jb}^{V,*}U_{L,cb}^eZ_{kc}^EZ_{i1}^++4\sum_{c=1}^3\sum_{b=1}^3Z_{jb}^{V,*}U_{L,cb}^eZ_{k3+c}^E\hat{T}_{e,cc}^0Z_{i1}^+ \right.$$

$$\begin{aligned}
& + 4\mu^* \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} U_{L,cb}^e \hat{Y}_{e,cc}^0 Z_{k3+c}^E Z_{i2}^+ \\
& - \sqrt{2}g_2^2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} U_{L,ba}^e Z_{kb}^E \left(v_d Z_{i1}^+ + v_u Z_{i2}^+ \right)
\end{aligned} \tag{171}$$

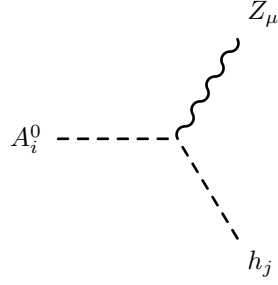


$$\begin{aligned}
& - \frac{i}{4} \delta_{\alpha\gamma} \left(\sqrt{2}g_2^2 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 V_{ab}^{CKM,*} Z_{ka}^U \left(v_d Z_{j1}^+ + v_u Z_{j2}^+ \right) \right. \\
& - 2 \left(2\mu^* \sum_{c=1}^3 Z_{ic}^{D,*} \sum_{b=1}^3 V_{bc}^{CKM,*} \hat{Y}_{u,bb}^0 Z_{k3+b}^U Z_{j1}^+ + \sqrt{2}v_d \sum_{c=1}^3 \sum_{b=1}^3 |\hat{Y}_{d,bb}^0|^2 V_{cb}^{CKM,*} Z_{ib}^{D,*} Z_{kc}^U Z_{j1}^+ \right. \\
& + \sqrt{2}v_u \sum_{d=1}^3 \hat{Y}_{d,dd}^0 Z_{i3+d}^{D,*} \sum_{c=1}^3 V_{cd}^{CKM,*} \hat{Y}_{u,cc}^0 Z_{k3+c}^U Z_{j1}^+ \\
& + 2 \sum_{d=1}^3 \sum_{c=1}^3 Z_{i3+c}^{D,*} \sum_{b=1}^3 V_{db}^{CKM,*} \hat{T}_{d,cb}^0 Z_{kd}^U Z_{j1}^+ + \sqrt{2}v_u \sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 \sum_{b=1}^3 V_{cb}^{CKM,*} Z_{ib}^{D,*} Z_{kc}^U Z_{j2}^+ \\
& + 2\mu \sum_{c=1}^3 \sum_{b=1}^3 V_{cb}^{CKM,*} \hat{Y}_{d,bb}^0 Z_{i3+b}^{D,*} Z_{kc}^U Z_{j2}^+ + 2 \sum_{d=1}^3 Z_{id}^{D,*} \sum_{c=1}^3 \sum_{b=1}^3 V_{bd}^{CKM,*} \hat{T}_{u,cb}^0 Z_{k3+c}^U Z_{j2}^+ \\
& \left. \left. + \sqrt{2}v_d \sum_{d=1}^3 \hat{Y}_{d,dd}^0 Z_{i3+d}^{D,*} \sum_{c=1}^3 V_{cd}^{CKM,*} \hat{Y}_{u,cc}^0 Z_{k3+c}^U Z_{j2}^+ \right) \right)
\end{aligned} \tag{172}$$

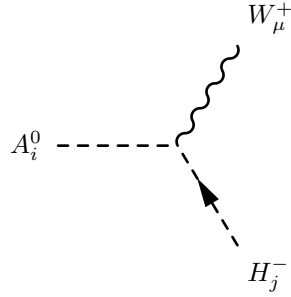


$$\begin{aligned}
& \frac{i}{4} \left(2\sqrt{2}v_d \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{ic}^{E,*} \sum_{b=1}^3 U_{L,cb}^{e,*} Z_{kb}^V Z_{j1}^+ + 4 \sum_{c=1}^3 Z_{i3+c}^{E,*} \hat{T}_{e,cc}^{0,*} \sum_{b=1}^3 U_{L,cb}^{e,*} Z_{kb}^V Z_{j1}^+ \right. \\
& + 4\mu \sum_{c=1}^3 \hat{Y}_{e,cc}^{0,*} Z_{i3+c}^{E,*} \sum_{b=1}^3 U_{L,cb}^{e,*} Z_{kb}^V Z_{j2}^+ \\
& \left. - \sqrt{2}g_2^2 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 U_{L,ba}^{e,*} Z_{ka}^V (v_d Z_{j1}^+ + v_u Z_{j2}^+) \right) \quad (173)
\end{aligned}$$

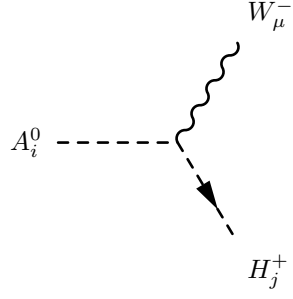
8.2 Two Scalar-One Vector Boson-Interaction



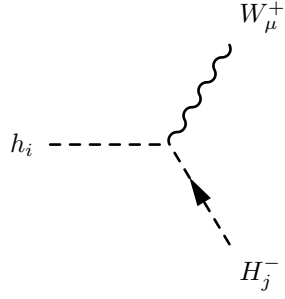
$$\frac{1}{2} \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left(Z_{i1}^A Z_{j1}^H - Z_{i2}^A Z_{j2}^H \right) \left(-p_\mu^{h_j} + p_\mu^{A_i^0} \right) \quad (174)$$



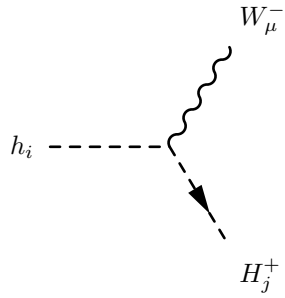
$$\frac{1}{2} g_2 \left(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+ \right) \left(-p_\mu^{H_j^-} + p_\mu^{A_i^0} \right) \quad (175)$$



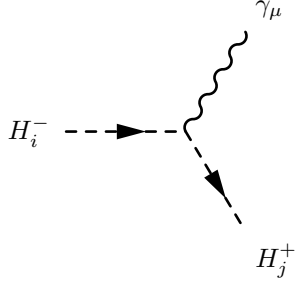
$$\frac{1}{2}g_2\left(Z_{i1}^AZ_{j1}^++Z_{i2}^AZ_{j2}^+\right)\left(-p_\mu^{H_j^+}+p_\mu^{A_i^0}\right) \quad (176)$$



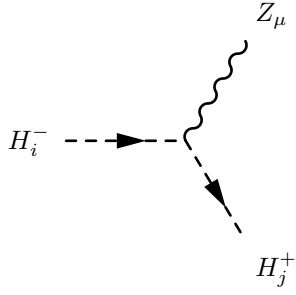
$$\frac{i}{2}g_2\left(Z_{i1}^HZ_{j1}^+-Z_{i2}^HZ_{j2}^+\right)\left(-p_\mu^{H_j^-}+p_\mu^{h_i}\right) \quad (177)$$



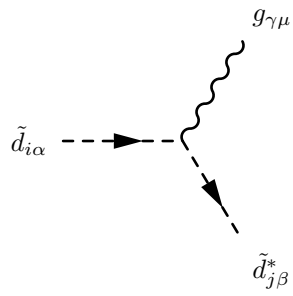
$$-\frac{i}{2}g_2\left(Z_{i1}^HZ_{j1}^+-Z_{i2}^HZ_{j2}^+\right)\left(-p_\mu^{H_j^+}+p_\mu^{h_i}\right) \quad (178)$$



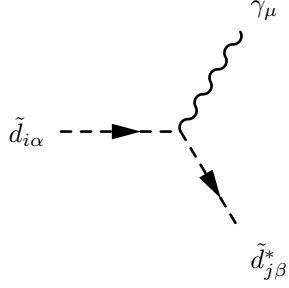
$$\frac{i}{2}\delta_{ij}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)\left(-p_\mu^{H_j^+}+p_\mu^{H_i^-}\right) \quad (179)$$



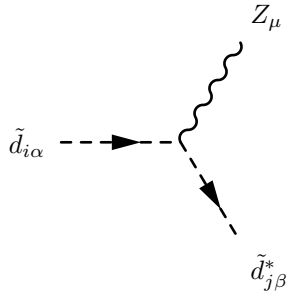
$$\frac{i}{2}\delta_{ij}\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(-p_\mu^{H_j^+}+p_\mu^{H_i^-}\right) \quad (180)$$



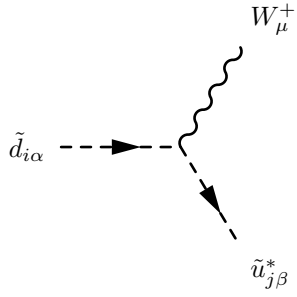
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\beta,\alpha}^\gamma\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (181)$$



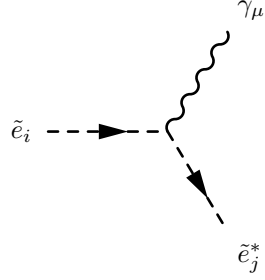
$$-\frac{i}{6}\delta_{\alpha\beta}\left(-2g_1\cos\Theta_W\sum_{b=1}^3Z_{i3+b}^{D,*}Z_{j3+b}^D+\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\sum_{b=1}^3Z_{ib}^{D,*}Z_{jb}^D\right)\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (182)$$



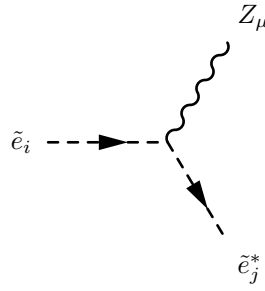
$$\frac{i}{6}\delta_{\alpha\beta}\left(-2g_1\sin\Theta_W\sum_{b=1}^3Z_{i3+b}^{D,*}Z_{j3+b}^D+\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sum_{b=1}^3Z_{ib}^{D,*}Z_{jb}^D\right)\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (183)$$



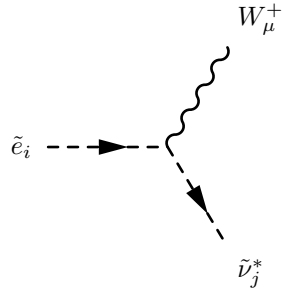
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{b=1}^3\sum_{a=1}^3V_{ba}^{CKM,*}Z_{ia}^{D,*}Z_{jb}^U\left(-p_\mu^{\tilde{u}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (184)$$



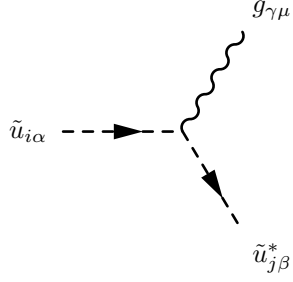
$$\frac{i}{2} \left(2g_1 \cos \Theta_W \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{j3+b}^E + \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \sum_{b=1}^3 Z_{ib}^{E,*} Z_{jb}^E \right) \left(-p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i} \right) \quad (185)$$



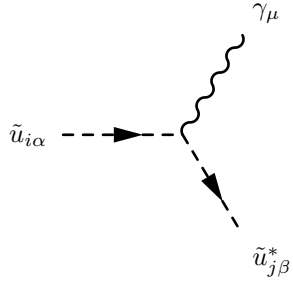
$$\frac{i}{2} \left(-2g_1 \sin \Theta_W \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{j3+b}^E + \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sum_{b=1}^3 Z_{ib}^{E,*} Z_{jb}^E \right) \left(-p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i} \right) \quad (186)$$



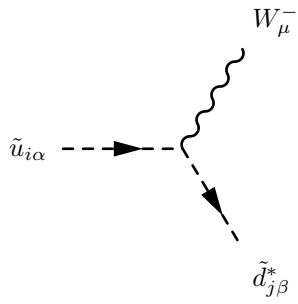
$$-i \frac{1}{\sqrt{2}} g_2 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 U_{L,ba}^{e,*} Z_{ja}^V \left(-p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{e}_i} \right) \quad (187)$$



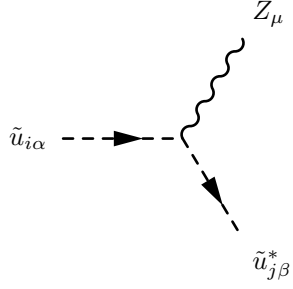
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\beta,\alpha}^{\gamma}\left(-p_{\mu}^{\tilde{u}_{j\beta}^*}+p_{\mu}^{\tilde{u}_{i\alpha}}\right) \quad (188)$$



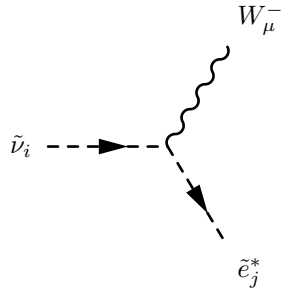
$$-\frac{i}{6}\delta_{\alpha\beta}\left(\left(3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\sum_{b=1}^3Z_{ib}^{U,*}Z_{jb}^U+4g_1\cos\Theta_W\sum_{b=1}^3Z_{i3+b}^{U,*}Z_{j3+b}^U\right)\left(-p_{\mu}^{\tilde{u}_{j\beta}^*}+p_{\mu}^{\tilde{u}_{i\alpha}}\right) \quad (189)$$



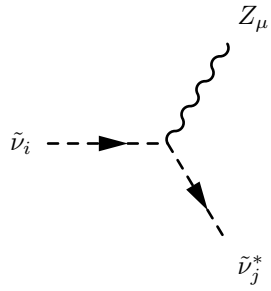
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{b=1}^3\sum_{a=1}^3V_{ab}^{CKM}Z_{ia}^{U,*}Z_{jb}^D\left(-p_{\mu}^{\tilde{d}_{j\beta}^*}+p_{\mu}^{\tilde{u}_{i\alpha}}\right) \quad (190)$$



$$-\frac{i}{6}\delta_{\alpha\beta}\left(\left(3g_2\cos\Theta_W-g_1\sin\Theta_W\right)\sum_{b=1}^3Z_{ib}^{U,*}Z_{jb}^U-4g_1\sin\Theta_W\sum_{b=1}^3Z_{i3+b}^{U,*}Z_{j3+b}^U\right)\left(-p_\mu^{\tilde{u}_{j\beta}^*}+p_\mu^{\tilde{u}_{i\alpha}}\right) \quad (191)$$

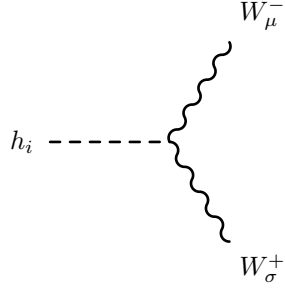


$$-i\frac{1}{\sqrt{2}}g_2\sum_{b=1}^3\sum_{a=1}^3Z_{ia}^{V,*}U_{L,ba}^eZ_{jb}^E\left(-p_\mu^{\tilde{e}_j^*}+p_\mu^{\tilde{\nu}_i}\right) \quad (192)$$

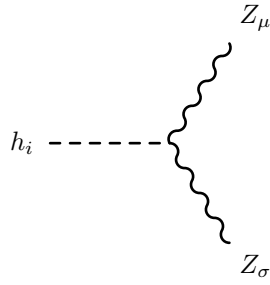


$$-\frac{i}{2}\delta_{ij}\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(-p_\mu^{\tilde{\nu}_j^*}+p_\mu^{\tilde{\nu}_i}\right) \quad (193)$$

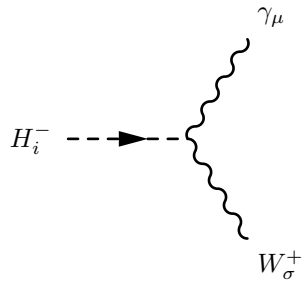
8.3 One Scalar-Two Vector Boson-Interaction



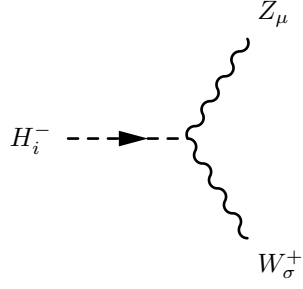
$$\frac{i}{2}g_2^2\left(v_dZ_{i1}^H+v_uZ_{i2}^H\right)\left(g_{\sigma\mu}\right) \quad (194)$$



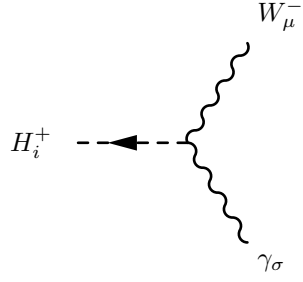
$$\frac{i}{2}\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)^2\left(v_dZ_{i1}^H+v_uZ_{i2}^H\right)\left(g_{\sigma\mu}\right) \quad (195)$$



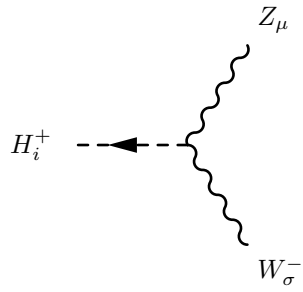
$$-\frac{i}{2}g_1g_2\cos\Theta_W\left(v_dZ_{i1}^+-v_uZ_{i2}^+\right)\left(g_{\sigma\mu}\right) \quad (196)$$



$$\frac{i}{2} g_1 g_2 \sin \Theta_W \left(v_d Z_{i1}^+ - v_u Z_{i2}^+ \right) \left(g_{\sigma\mu} \right) \quad (197)$$

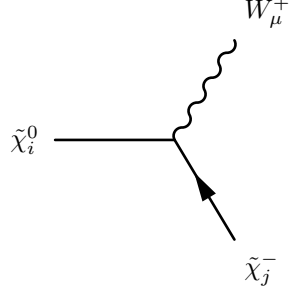


$$-\frac{i}{2} g_1 g_2 \cos \Theta_W \left(v_d Z_{i1}^+ - v_u Z_{i2}^+ \right) \left(g_{\sigma\mu} \right) \quad (198)$$



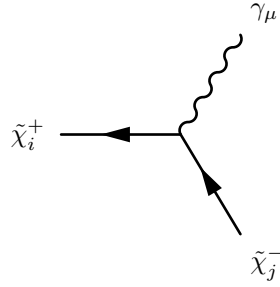
$$\frac{i}{2} g_1 g_2 \sin \Theta_W \left(v_d Z_{i1}^+ - v_u Z_{i2}^+ \right) \left(g_{\sigma\mu} \right) \quad (199)$$

8.4 Two Fermion-One Vector Boson-Interaction



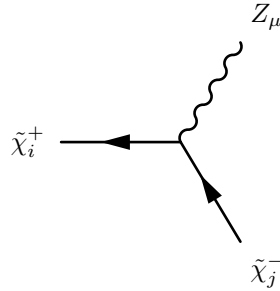
$$-\frac{i}{2}g_2\left(2U_{j1}^*N_{i2}+\sqrt{2}U_{j2}^*N_{i3}\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (200)$$

$$+\frac{i}{2}g_2\left(2N_{i2}^*V_{j1}-\sqrt{2}N_{i4}^*V_{j2}\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (201)$$



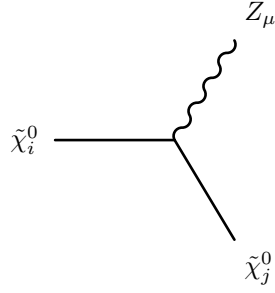
$$\frac{i}{2}\left(2g_2U_{j1}^*\sin\Theta_W U_{i1}+U_{j2}^*\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)U_{i2}\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (202)$$

$$+\frac{i}{2}\left(2g_2V_{i1}^*\sin\Theta_W V_{j1}+V_{i2}^*\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)V_{j2}\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (203)$$



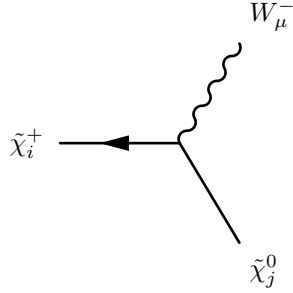
$$\frac{i}{2} \left(2g_2 U_{j1}^* \cos \Theta_W U_{i1} + U_{j2}^* \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) U_{i2} \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (204)$$

$$+ \frac{i}{2} \left(2g_2 V_{i1}^* \cos \Theta_W V_{j1} + V_{i2}^* \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) V_{j2} \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (205)$$



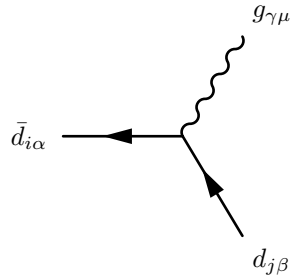
$$- \frac{i}{2} \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left(N_{j3}^* N_{i3} - N_{j4}^* N_{i4} \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (206)$$

$$+ \frac{i}{2} \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left(N_{i3}^* N_{j3} - N_{i4}^* N_{j4} \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (207)$$



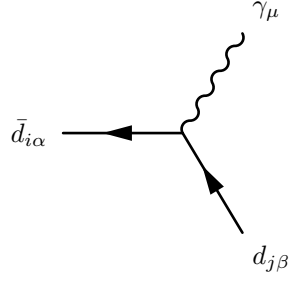
$$- \frac{i}{2} g_2 \left(2N_{j2}^* U_{i1} + \sqrt{2} N_{j3}^* U_{i2} \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (208)$$

$$+ - \frac{i}{2} g_2 \left(2V_{i1}^* N_{j2} - \sqrt{2} V_{i2}^* N_{j4} \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (209)$$



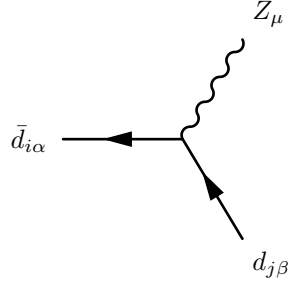
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (210)$$

$$+\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (211)$$



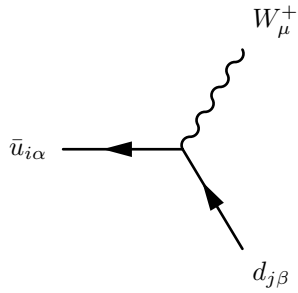
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (212)$$

$$+\frac{i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (213)$$

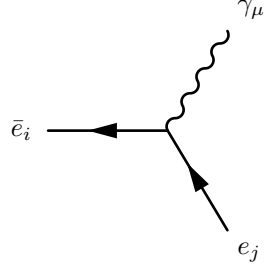


$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (214)$$

$$+\frac{i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (215)$$

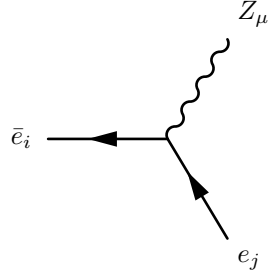


$$-i \frac{1}{\sqrt{2}} g_2 V_{ij}^{CKM,*} \delta_{\alpha\beta} \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (216)$$



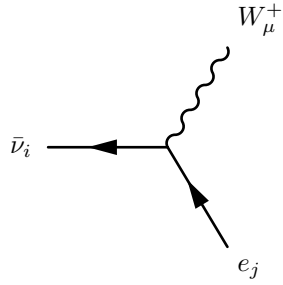
$$\frac{i}{2} \delta_{ij} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (217)$$

$$+ i g_1 \cos \Theta_W \delta_{ij} \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (218)$$

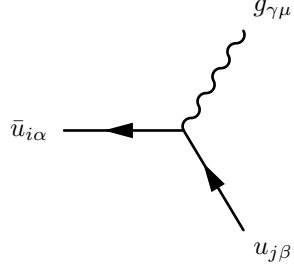


$$\frac{i}{2} \delta_{ij} \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (219)$$

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

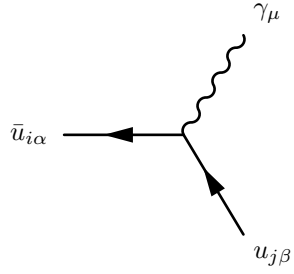


$$-i \frac{1}{\sqrt{2}} g_2 U_{L,ji}^{e,*} \Theta_{i,3} \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (221)$$



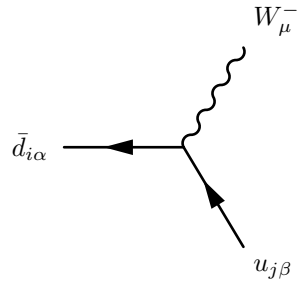
$$- \frac{i}{2} g_3 \delta_{ij} \lambda_{\alpha,\beta}^\gamma \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (222)$$

$$+ - \frac{i}{2} g_3 \delta_{ij} \lambda_{\alpha,\beta}^\gamma \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (223)$$

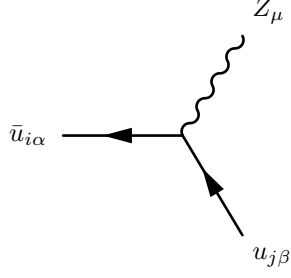


$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \left(3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (224)$$

$$+ - \frac{2i}{3} g_1 \cos \Theta_W \delta_{\alpha\beta} \delta_{ij} \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (225)$$

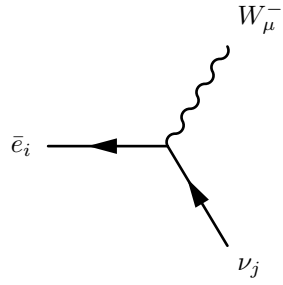


$$-i \frac{1}{\sqrt{2}} g_2 V_{ji}^{CKM} \delta_{\alpha\beta} \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (226)$$

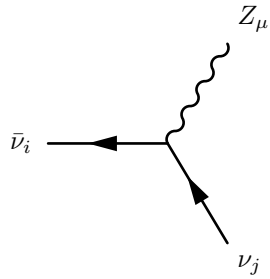


$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \left(3g_2 \cos \Theta_W - g_1 \sin \Theta_W \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (227)$$

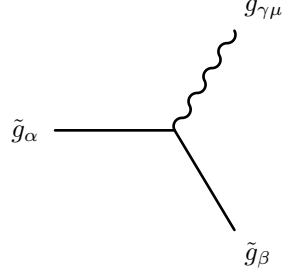
$$+ \frac{2i}{3} g_1 \delta_{\alpha\beta} \delta_{ij} \sin \Theta_W \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (228)$$



$$-i \frac{1}{\sqrt{2}} g_2 \Theta_{j,3} U_{L,ij}^e \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (229)$$



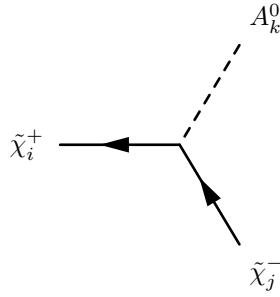
$$-\frac{i}{2}\delta_{ij}\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (230)$$



$$-g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (231)$$

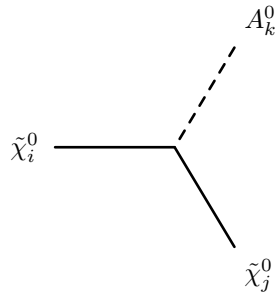
$$+ -g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (232)$$

8.5 Two Fermion-One Scalar Boson-Interaction



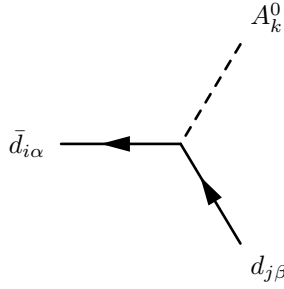
$$-\frac{1}{\sqrt{2}}g_2\left(U_{j1}^*V_{i2}^*Z_{k2}^A+U_{j2}^*V_{i1}^*Z_{k1}^A\right)\left(\frac{1-\gamma_5}{2}\right) \quad (233)$$

$$+\frac{1}{\sqrt{2}}g_2\left(U_{i1}V_{j2}Z_{k2}^A+U_{i2}V_{j1}Z_{k1}^A\right)\left(\frac{1+\gamma_5}{2}\right) \quad (234)$$



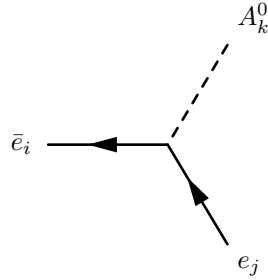
$$\begin{aligned} & \frac{1}{2} \left(N_{i3}^* \left(g_1 N_{j1}^* - g_2 N_{j2}^* \right) Z_{k1}^A - g_2 N_{i2}^* N_{j3}^* Z_{k1}^A - g_1 N_{i4}^* N_{j1}^* Z_{k2}^A + g_2 N_{i4}^* N_{j2}^* Z_{k2}^A \right. \\ & \left. + g_2 N_{i2}^* N_{j4}^* Z_{k2}^A + g_1 N_{i1}^* \left(N_{j3}^* Z_{k1}^A - N_{j4}^* Z_{k2}^A \right) \right) \left(\frac{1 - \gamma_5}{2} \right) \end{aligned} \quad (235)$$

$$\begin{aligned} & + \frac{1}{2} \left(- Z_{k1}^A \left(\left(g_1 N_{i1} - g_2 N_{i2} \right) N_{j3} + N_{i3} \left(g_1 N_{j1} - g_2 N_{j2} \right) \right) \right. \\ & \left. - Z_{k2}^A \left(\left(-g_1 N_{i1} + g_2 N_{i2} \right) N_{j4} + N_{i4} \left(-g_1 N_{j1} + g_2 N_{j2} \right) \right) \right) \left(\frac{1 + \gamma_5}{2} \right) \end{aligned} \quad (236)$$



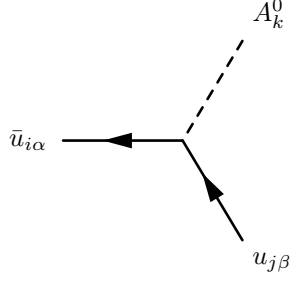
$$\frac{1}{\sqrt{2}} \delta_{\alpha\beta} \delta_{ij} \Theta_{i,3} \hat{Y}_{d,ii}^0 Z_{k1}^A \left(\frac{1 - \gamma_5}{2} \right) \quad (237)$$

$$+ - \frac{1}{\sqrt{2}} \hat{Y}_{d,ii}^{0,*} \delta_{\alpha\beta} \delta_{ij} \Theta_{i,3} Z_{k1}^A \left(\frac{1 + \gamma_5}{2} \right) \quad (238)$$



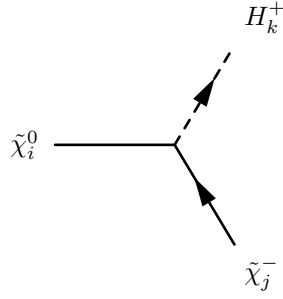
$$\frac{1}{\sqrt{2}} \delta_{ij} \Theta_{i,3} \hat{Y}_{e,ii}^0 Z_{k1}^A \left(\frac{1 - \gamma_5}{2} \right) \quad (239)$$

$$+ - \frac{1}{\sqrt{2}} \hat{Y}_{e,ii}^{0,*} \delta_{ij} \Theta_{i,3} Z_{k1}^A \left(\frac{1 + \gamma_5}{2} \right) \quad (240)$$



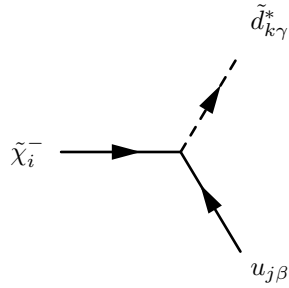
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\delta_{ij}\Theta_{i,3}\hat{Y}_{u,ii}^0Z_{k2}^A\left(\frac{1-\gamma_5}{2}\right) \quad (241)$$

$$+ -\frac{1}{\sqrt{2}}\hat{Y}_{u,ii}^{0,*}\delta_{\alpha\beta}\delta_{ij}\Theta_{i,3}Z_{k2}^A\left(\frac{1+\gamma_5}{2}\right) \quad (242)$$



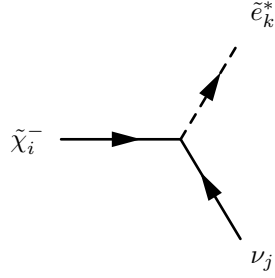
$$\frac{i}{2}\left(-2g_2U_{j1}^*N_{i3}^*+\sqrt{2}U_{j2}^*\left(g_1N_{i1}^*+g_2N_{i2}^*\right)\right)Z_{k1}^+\left(\frac{1-\gamma_5}{2}\right) \quad (243)$$

$$+ -\frac{i}{2}\left(2g_2V_{j1}N_{i4}+\sqrt{2}V_{j2}\left(g_1N_{i1}+g_2N_{i2}\right)\right)Z_{k2}^+\left(\frac{1+\gamma_5}{2}\right) \quad (244)$$

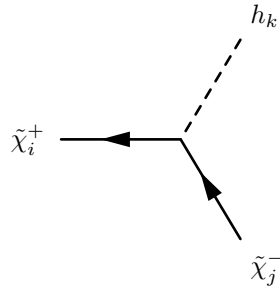


$$i\delta_{\beta\gamma}\left(-g_2U_{i1}^*\sum_{a=1}^3V_{ja}^{CKM}Z_{ka}^D+U_{i2}^*\sum_{b=1}^3V_{jb}^{CKM}\hat{Y}_{d,bb}^0Z_{k3+b}^D\right)\left(\frac{1-\gamma_5}{2}\right) \quad (245)$$

$$+ i\hat{Y}_{u,jj}^{0,*}\delta_{\beta\gamma}\sum_{b=1}^3V_{jb}^{CKM}Z_{kb}^D\Theta_{j,3}V_{i2}\left(\frac{1+\gamma_5}{2}\right) \quad (246)$$

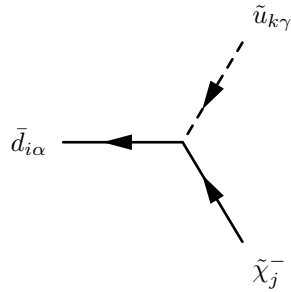


$$i\left(-g_2U_{i1}^*\sum_{b=1}^3U_{L,bj}^eZ_{kb}^E\Theta_{j,3}+U_{i2}^*\sum_{b=1}^3U_{L,bj}^e\hat{Y}_{e,bb}^0Z_{k3+b}^E\right)\left(\frac{1-\gamma_5}{2}\right) \quad (247)$$



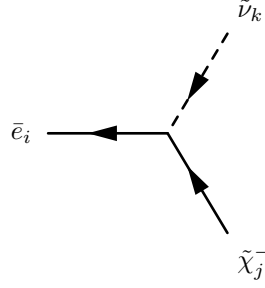
$$-i\frac{1}{\sqrt{2}}g_2\left(U_{j1}^*V_{i2}^*Z_{k2}^H+U_{j2}^*V_{i1}^*Z_{k1}^H\right)\left(\frac{1-\gamma_5}{2}\right) \quad (248)$$

$$+ -i\frac{1}{\sqrt{2}}g_2\left(U_{i1}V_{j2}Z_{k2}^H+U_{i2}V_{j1}Z_{k1}^H\right)\left(\frac{1+\gamma_5}{2}\right) \quad (249)$$



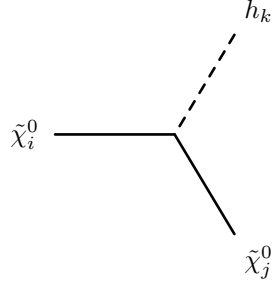
$$iU_{j2}^* \delta_{\alpha\gamma} \sum_{b=1}^3 V_{bi}^{CKM} Z_{kb}^{U,*} \Theta_{i,3} \hat{Y}_{d,ii}^0 \left(\frac{1-\gamma_5}{2} \right) \quad (250)$$

$$+ i\delta_{\alpha\gamma} \left(-g_2 \sum_{a=1}^3 V_{ai}^{CKM} Z_{ka}^{U,*} V_{j1} + \sum_{b=1}^3 V_{bi}^{CKM} \hat{Y}_{u,bb}^{0,*} Z_{k3+b}^{U,*} V_{j2} \right) \left(\frac{1+\gamma_5}{2} \right) \quad (251)$$



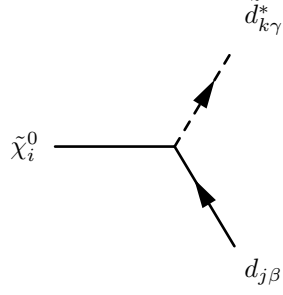
$$iU_{j2}^* \sum_{b=1}^3 Z_{kb}^{V,*} U_{L,ib}^e \Theta_{i,3} \hat{Y}_{e,ii}^0 \left(\frac{1-\gamma_5}{2} \right) \quad (252)$$

$$+ -ig_2 \sum_{a=1}^3 Z_{ka}^{V,*} U_{L,ia}^e V_{j1} \left(\frac{1+\gamma_5}{2} \right) \quad (253)$$



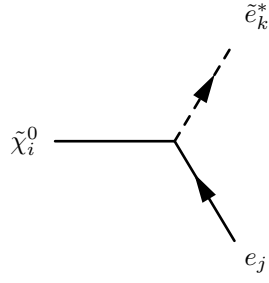
$$\begin{aligned} & \frac{i}{2} \left(N_{i3}^* \left(g_1 N_{j1}^* - g_2 N_{j2}^* \right) Z_{k1}^H - g_2 N_{i2}^* N_{j3}^* Z_{k1}^H - g_1 N_{i4}^* N_{j1}^* Z_{k2}^H + g_2 N_{i4}^* N_{j2}^* Z_{k2}^H \right. \\ & \left. + g_2 N_{i2}^* N_{j4}^* Z_{k2}^H + g_1 N_{i1}^* \left(N_{j3}^* Z_{k1}^H - N_{j4}^* Z_{k2}^H \right) \right) \left(\frac{1-\gamma_5}{2} \right) \end{aligned} \quad (254)$$

$$\begin{aligned} & + \frac{i}{2} \left(Z_{k1}^H \left(\left(g_1 N_{i1} - g_2 N_{i2} \right) N_{j3} + N_{i3} \left(g_1 N_{j1} - g_2 N_{j2} \right) \right) \right. \\ & \left. + Z_{k2}^H \left(\left(-g_1 N_{i1} + g_2 N_{i2} \right) N_{j4} + N_{i4} \left(-g_1 N_{j1} + g_2 N_{j2} \right) \right) \right) \left(\frac{1+\gamma_5}{2} \right) \end{aligned} \quad (255)$$



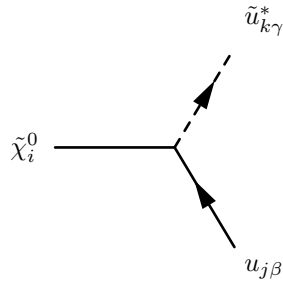
$$-\frac{i}{6}\delta_{\beta\gamma}\Theta_{j,3}\left(-3\sqrt{2}g_2N_{i2}^*Z_{kj}^D+6N_{i3}^*\hat{Y}_{d,jj}^0Z_{k3+j}^D+\sqrt{2}g_1N_{i1}^*Z_{kj}^D\right)\left(\frac{1-\gamma_5}{2}\right) \quad (256)$$

$$+\frac{i}{3}\delta_{\beta\gamma}\Theta_{j,3}\left(3\hat{Y}_{d,jj}^{0,*}Z_{kj}^DN_{i3}+\sqrt{2}g_1Z_{k3+j}^DN_{i1}\right)\left(\frac{1+\gamma_5}{2}\right) \quad (257)$$



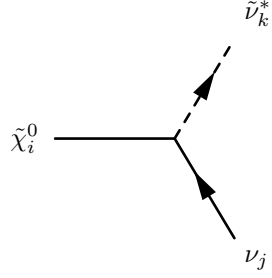
$$\frac{i}{2}\Theta_{j,3}\left(-2N_{i3}^*\hat{Y}_{e,jj}^0Z_{k3+j}^E+\sqrt{2}g_1N_{i1}^*Z_{kj}^E+\sqrt{2}g_2N_{i2}^*Z_{kj}^E\right)\left(\frac{1-\gamma_5}{2}\right) \quad (258)$$

$$+i\Theta_{j,3}\left(\hat{Y}_{e,jj}^{0,*}Z_{kj}^EN_{i3}+\sqrt{2}g_1Z_{k3+j}^EN_{i1}\right)\left(\frac{1+\gamma_5}{2}\right) \quad (259)$$

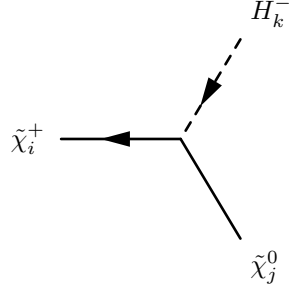


$$-\frac{i}{6}\delta_{\beta\gamma}\Theta_{j,3}\left(3\sqrt{2}g_2N_{i2}^*Z_{kj}^U+6N_{i4}^*\hat{Y}_{u,jj}^0Z_{k3+j}^U+\sqrt{2}g_1N_{i1}^*Z_{kj}^U\right)\left(\frac{1-\gamma_5}{2}\right) \quad (260)$$

$$+\frac{i}{3}\delta_{\beta\gamma}\Theta_{j,3}\left(2\sqrt{2}g_1N_{i1}Z_{k3+j}^U-3\hat{Y}_{u,jj}^{0,*}N_{i4}Z_{kj}^U\right)\left(\frac{1+\gamma_5}{2}\right) \quad (261)$$

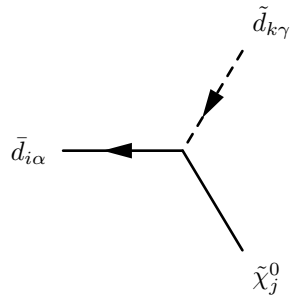


$$i \frac{1}{\sqrt{2}} \left(g_1 N_{i1}^* - g_2 N_{i2}^* \right) \Theta_{j,3} Z_{kj}^V \left(\frac{1 - \gamma_5}{2} \right) \quad (262)$$



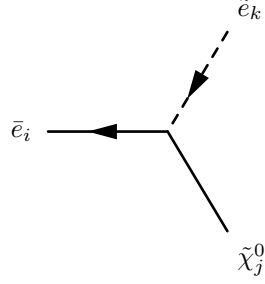
$$- \frac{i}{2} \left(2g_2 V_{i1}^* N_{j4}^* + \sqrt{2} V_{i2}^* \left(g_1 N_{j1}^* + g_2 N_{j2}^* \right) \right) Z_{k2}^+ \left(\frac{1 - \gamma_5}{2} \right) \quad (263)$$

$$+ \frac{i}{2} \left(-2g_2 U_{i1} N_{j3} + \sqrt{2} U_{i2} \left(g_1 N_{j1} + g_2 N_{j2} \right) \right) Z_{k1}^+ \left(\frac{1 + \gamma_5}{2} \right) \quad (264)$$



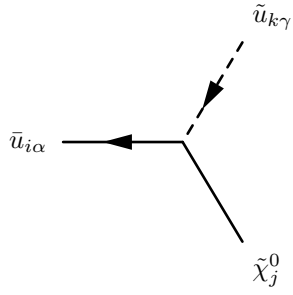
$$- \frac{i}{3} \delta_{\alpha\gamma} \Theta_{i,3} \left(3Z_{ki}^{D,*} N_{j3}^* \hat{Y}_{d,ii}^0 + \sqrt{2} g_1 Z_{k3+i}^{D,*} N_{j1}^* \right) \left(\frac{1 - \gamma_5}{2} \right) \quad (265)$$

$$+ - \frac{i}{6} \delta_{\alpha\gamma} \Theta_{i,3} \left(6\hat{Y}_{d,ii}^{0,*} Z_{k3+i}^{D,*} N_{j3} + \sqrt{2} Z_{ki}^{D,*} \left(-3g_2 N_{j2} + g_1 N_{j1} \right) \right) \left(\frac{1 + \gamma_5}{2} \right) \quad (266)$$



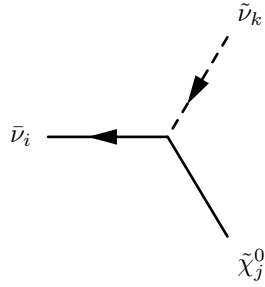
$$-i\Theta_{i,3}\left(\sqrt{2}g_1Z_{k3+i}^{E,*}N_{j1}^*+Z_{ki}^{E,*}N_{j3}^*\hat{Y}_{e,ii}^0\right)\left(\frac{1-\gamma_5}{2}\right) \quad (267)$$

$$+\frac{i}{2}\Theta_{i,3}\left(-2\hat{Y}_{e,ii}^{0,*}Z_{k3+i}^{E,*}N_{j3}+\sqrt{2}Z_{ki}^{E,*}\left(g_1N_{j1}+g_2N_{j2}\right)\right)\left(\frac{1+\gamma_5}{2}\right) \quad (268)$$



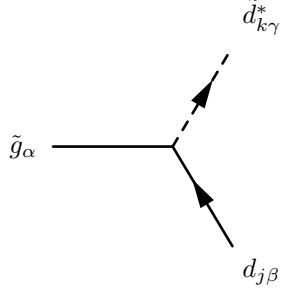
$$\frac{i}{3}\delta_{\alpha\gamma}\Theta_{i,3}\left(2\sqrt{2}g_1N_{j1}^*Z_{k3+i}^{U,*}-3N_{j4}^*Z_{ki}^{U,*}\hat{Y}_{u,ii}^0\right)\left(\frac{1-\gamma_5}{2}\right) \quad (269)$$

$$+-\frac{i}{6}\delta_{\alpha\gamma}\Theta_{i,3}\left(6\hat{Y}_{u,ii}^{0,*}Z_{k3+i}^{U,*}N_{j4}+\sqrt{2}Z_{ki}^{U,*}\left(3g_2N_{j2}+g_1N_{j1}\right)\right)\left(\frac{1+\gamma_5}{2}\right) \quad (270)$$



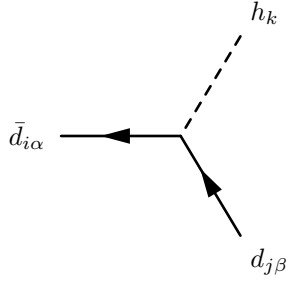
$$(271)$$

$$+i\frac{1}{\sqrt{2}}Z_{ki}^{V,*}\Theta_{i,3}\left(g_1N_{j1}-g_2N_{j2}\right)\left(\frac{1+\gamma_5}{2}\right) \quad (272)$$



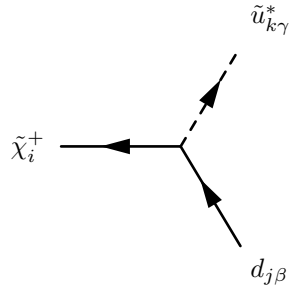
$$-i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\gamma,\beta}^\alpha \Theta_{j,3} Z_{kj}^D \left(\frac{1-\gamma_5}{2} \right) \quad (273)$$

$$+ i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^\alpha \Theta_{j,3} Z_{k3+j}^D \left(\frac{1+\gamma_5}{2} \right) \quad (274)$$



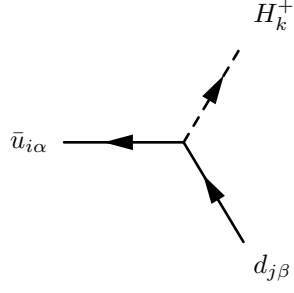
$$-i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \delta_{ij} \Theta_{i,3} \hat{Y}_{d,ii}^0 Z_{k1}^H \left(\frac{1-\gamma_5}{2} \right) \quad (275)$$

$$+ -i \frac{1}{\sqrt{2}} \hat{Y}_{d,ii}^{0,*} \delta_{\alpha\beta} \delta_{ij} \Theta_{i,3} Z_{k1}^H \left(\frac{1+\gamma_5}{2} \right) \quad (276)$$



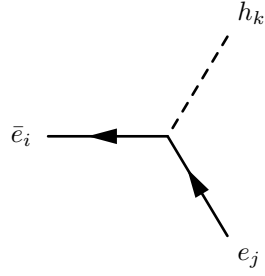
$$i\delta_{\beta\gamma} \left(-g_2 V_{i1}^* \sum_{a=1}^3 V_{aj}^{CKM,*} Z_{ka}^U + V_{i2}^* \sum_{b=1}^3 V_{bj}^{CKM,*} \hat{Y}_{u,bb}^0 Z_{k3+b}^U \right) \left(\frac{1-\gamma_5}{2} \right) \quad (277)$$

$$+ i\hat{Y}_{d,jj}^{0,*}\delta_{\beta\gamma}\sum_{b=1}^3 V_{bj}^{CKM,*}Z_{kb}^U\Theta_{j,3}U_{i2}\left(\frac{1+\gamma_5}{2}\right) \quad (278)$$



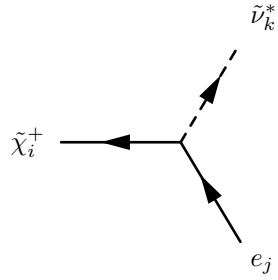
$$iV_{ij}^{CKM,*}\delta_{\alpha\beta}\Theta_{i,3}\hat{Y}_{u,ii}^0Z_{k2}^+\left(\frac{1-\gamma_5}{2}\right) \quad (279)$$

$$+ iV_{ij}^{CKM,*}\hat{Y}_{d,jj}^{0,*}\delta_{\alpha\beta}\Theta_{j,3}Z_{k1}^+\left(\frac{1+\gamma_5}{2}\right) \quad (280)$$



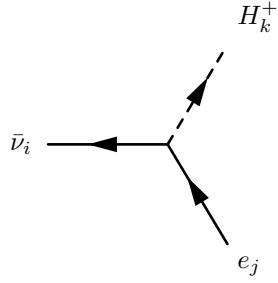
$$-i\frac{1}{\sqrt{2}}\delta_{ij}\Theta_{i,3}\hat{Y}_{e,ii}^0Z_{k1}^H\left(\frac{1-\gamma_5}{2}\right) \quad (281)$$

$$+ -i\frac{1}{\sqrt{2}}\hat{Y}_{e,ii}^{0,*}\delta_{ij}\Theta_{i,3}Z_{k1}^H\left(\frac{1+\gamma_5}{2}\right) \quad (282)$$



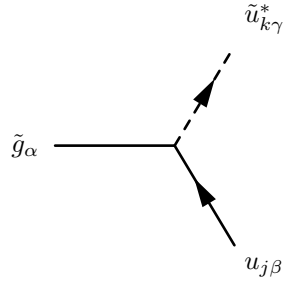
$$-ig_2 V_{i1}^* \sum_{a=1}^3 U_{L,ja}^{e,*} Z_{ka}^V \left(\frac{1-\gamma_5}{2} \right) \quad (283)$$

$$+ i\hat{Y}_{e,jj}^{0,*} \sum_{b=1}^3 U_{L,jb}^{e,*} Z_{kb}^V \Theta_{j,3} U_{i2} \left(\frac{1+\gamma_5}{2} \right) \quad (284)$$



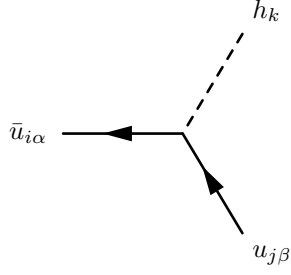
(285)

$$+ iU_{L,ji}^{e,*} \hat{Y}_{e,jj}^{0,*} \Theta_{j,3} Z_{k1}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (286)$$



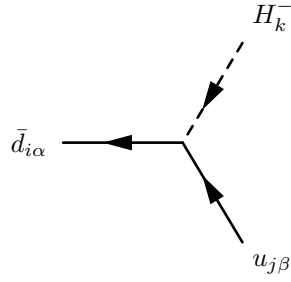
$$-i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^\alpha \Theta_{j,3} Z_{kj}^U \left(\frac{1-\gamma_5}{2} \right) \quad (287)$$

$$+ i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^\alpha \Theta_{j,3} Z_{k3+j}^U \left(\frac{1+\gamma_5}{2} \right) \quad (288)$$



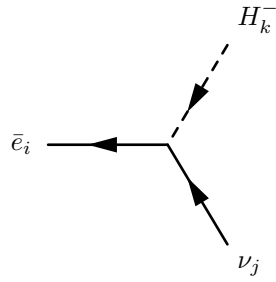
$$-i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \delta_{ij} \Theta_{i,3} \hat{Y}_{u,ii}^0 Z_{k2}^H \left(\frac{1-\gamma_5}{2} \right) \quad (289)$$

$$+ -i \frac{1}{\sqrt{2}} \hat{Y}_{u,ii}^{0,*} \delta_{\alpha\beta} \delta_{ij} \Theta_{i,3} Z_{k2}^H \left(\frac{1+\gamma_5}{2} \right) \quad (290)$$

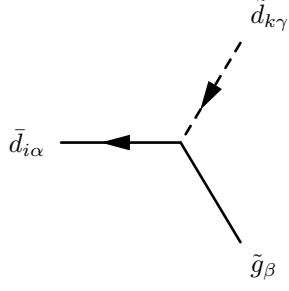


$$i V_{ji}^{CKM} \delta_{\alpha\beta} \Theta_{i,3} \hat{Y}_{d,ii}^0 Z_{k1}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (291)$$

$$+ i V_{ji}^{CKM} \hat{Y}_{u,jj}^{0,*} \delta_{\alpha\beta} \Theta_{j,3} Z_{k2}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (292)$$

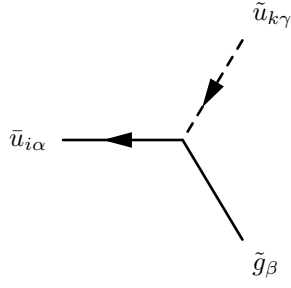


$$i \Theta_{i,3} U_{L,ij}^e \hat{Y}_{e,ii}^0 Z_{k1}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (293)$$



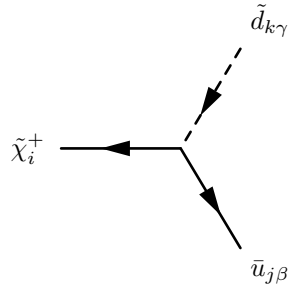
$$i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} Z_{k3+i}^{D,*} \lambda_{\alpha,\gamma}^\beta \Theta_{i,3} \left(\frac{1-\gamma_5}{2} \right) \quad (294)$$

$$+ -i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* Z_{ki}^{D,*} \lambda_{\alpha,\gamma}^\beta \Theta_{i,3} \left(\frac{1+\gamma_5}{2} \right) \quad (295)$$



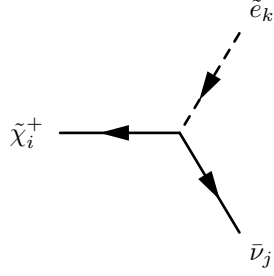
$$i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} Z_{k3+i}^{U,*} \lambda_{\alpha,\gamma}^\beta \Theta_{i,3} \left(\frac{1-\gamma_5}{2} \right) \quad (296)$$

$$+ -i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* Z_{ki}^{U,*} \lambda_{\alpha,\gamma}^\beta \Theta_{i,3} \left(\frac{1+\gamma_5}{2} \right) \quad (297)$$



$$i V_{i2}^* \delta_{\beta\gamma} \sum_{b=1}^3 V_{jb}^{CKM,*} Z_{kb}^{D,*} \Theta_{j,3} \hat{Y}_{u,jj}^0 \left(\frac{1-\gamma_5}{2} \right) \quad (298)$$

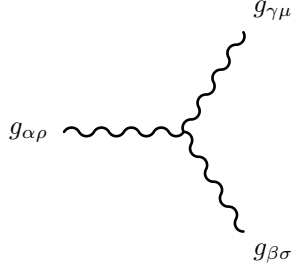
$$+ i\delta_{\beta\gamma}\left(-g_2\sum_{a=1}^3V_{ja}^{CKM,*}Z_{ka}^{D,*}U_{i1}+\sum_{b=1}^3V_{jb}^{CKM,*}\hat{Y}_{d,bb}^{0,*}Z_{k3+b}^{D,*}U_{i2}\right)\left(\frac{1+\gamma_5}{2}\right) \quad (299)$$



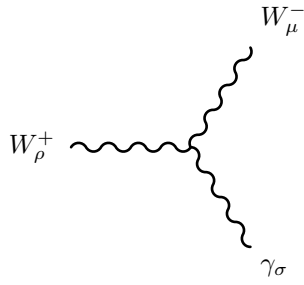
(300)

$$+ i\left(-g_2\sum_{b=1}^3U_{L,bj}^{e,*}Z_{kb}^{E,*}\Theta_{j,3}U_{i1}+\sum_{b=1}^3U_{L,bj}^{e,*}\hat{Y}_{e,bb}^{0,*}Z_{k3+b}^{E,*}U_{i2}\right)\left(\frac{1+\gamma_5}{2}\right) \quad (301)$$

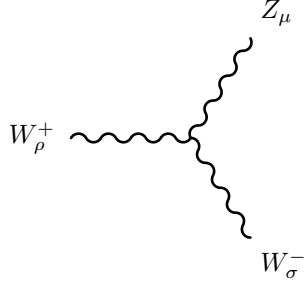
8.6 Three Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma}\left(g_{\rho\mu}\left(-p_{\sigma}^{g_{\gamma\mu}}+p_{\sigma}^{g_{\alpha\rho}}\right)+g_{\rho\sigma}\left(-p_{\mu}^{g_{\alpha\rho}}+p_{\mu}^{g_{\beta\sigma}}\right)+g_{\sigma\mu}\left(-p_{\rho}^{g_{\beta\sigma}}+p_{\rho}^{g_{\gamma\mu}}\right)\right) \quad (302)$$

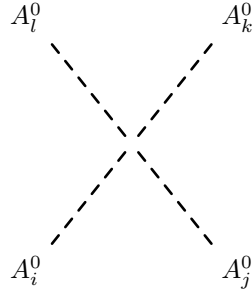


$$ig_2 \sin \Theta_W \left(g_{\rho\mu} \left(-p_\sigma^{W^-} + p_\sigma^{W^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W^+} + p_\mu^{\gamma_\sigma} \right) + g_{\sigma\mu} \left(-p_\rho^{\gamma_\sigma} + p_\rho^{W^-} \right) \right) \quad (303)$$

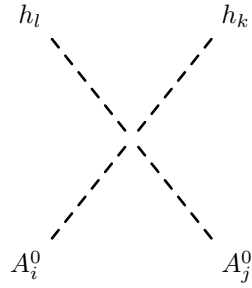


$$-ig_2 \cos \Theta_W \left(g_{\rho\mu} \left(-p_\sigma^{Z_\mu} + p_\sigma^{W^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W^+} + p_\mu^{W^-} \right) + g_{\sigma\mu} \left(-p_\rho^{W^-} + p_\rho^{Z_\mu} \right) \right) \quad (304)$$

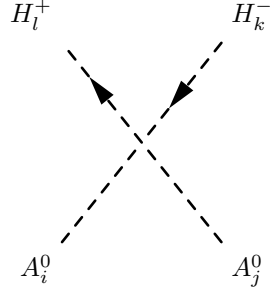
8.7 Four Scalar-Interaction



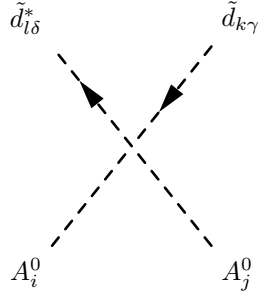
$$\begin{aligned} & \frac{i}{4} \left(g_1^2 + g_2^2 \right) \left(Z_{i2}^A \left(Z_{j1}^A \left(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \right) + Z_{j2}^A \left(-3Z_{k2}^A Z_{l2}^A + Z_{k1}^A Z_{l1}^A \right) \right) \right. \\ & \left. + Z_{i1}^A \left(Z_{j1}^A \left(-3Z_{k1}^A Z_{l1}^A + Z_{k2}^A Z_{l2}^A \right) + Z_{j2}^A \left(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \right) \right) \right) \end{aligned} \quad (305)$$



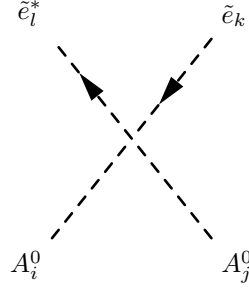
$$-\frac{i}{4}(g_1^2 + g_2^2)(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A)(Z_{k1}^H Z_{l1}^H - Z_{k2}^H Z_{l2}^H) \quad (306)$$



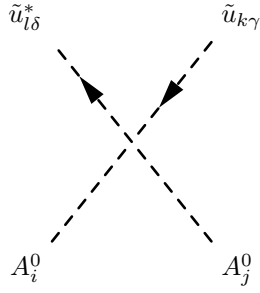
$$\begin{aligned} & \frac{i}{4} \left(Z_{i1}^A \left(g_2^2 Z_{j2}^A (Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+) \right) - Z_{j1}^A \left((g_1^2 + g_2^2) Z_{k1}^+ Z_{l1}^+ + (-g_1^2 + g_2^2) Z_{k2}^+ Z_{l2}^+ \right) \right) \\ & + Z_{i2}^A \left(g_2^2 Z_{j1}^A (Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+) \right) + Z_{j2}^A \left(-(g_1^2 + g_2^2) Z_{k2}^+ Z_{l2}^+ + (-g_2^2 + g_1^2) Z_{k1}^+ Z_{l1}^+ \right) \end{aligned} \quad (307)$$



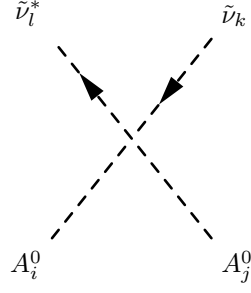
$$\begin{aligned} & \frac{i}{12} \delta_{\gamma\delta} \left((3g_2^2 + g_1^2) \sum_{b=1}^3 Z_{kb}^{D,*} Z_{lb}^D (Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A) \right. \\ & + 2 \left(-6 \left(\sum_{c=1}^3 |\hat{Y}_{d,cc}^0|^2 Z_{kc}^{D,*} Z_{lc}^D + \sum_{c=1}^3 |\hat{Y}_{d,cc}^0|^2 Z_{k3+c}^{D,*} Z_{l3+c}^D \right) Z_{i1}^A Z_{j1}^A \right. \\ & \left. \left. + g_1^2 \sum_{b=1}^3 Z_{k3+b}^{D,*} Z_{l3+b}^D (Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A) \right) \right) \end{aligned} \quad (308)$$



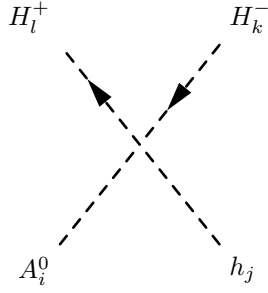
$$\begin{aligned}
& \frac{i}{4} \left(-4 \left(\sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{kc}^{E,*} Z_{lc}^E + \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{k3+c}^{E,*} Z_{l3+c}^E \right) Z_{i1}^A Z_{j1}^A \right. \\
& - \left(-g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{kb}^{E,*} Z_{lb}^E \left(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A \right) \\
& \left. + 2g_1^2 \sum_{b=1}^3 Z_{k3+b}^{E,*} Z_{l3+b}^E \left(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A \right) \right) \quad (309)
\end{aligned}$$



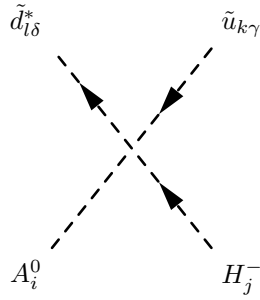
$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left(\left(-3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{kb}^{U,*} Z_{lb}^U \left(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A \right) \right. \\
& - 4 \left(3 \left(\sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 Z_{kc}^{U,*} Z_{lc}^U + \sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 Z_{k3+c}^{U,*} Z_{l3+c}^U \right) Z_{i2}^A Z_{j2}^A \right. \\
& \left. \left. + g_1^2 \sum_{b=1}^3 Z_{k3+b}^{U,*} Z_{l3+b}^U \left(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A \right) \right) \right) \quad (310)
\end{aligned}$$



$$-\frac{i}{4}(g_1^2 + g_2^2)\delta_{kl}\left(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\right) \quad (311)$$

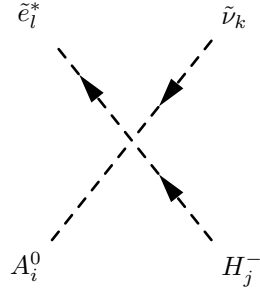


$$\frac{1}{4}g_2^2\left(Z_{i1}^A Z_{j2}^H + Z_{i2}^A Z_{j1}^H\right)\left(-Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\right) \quad (312)$$

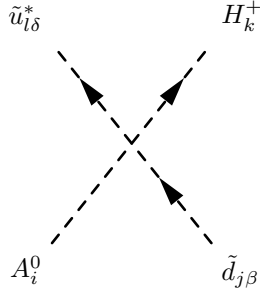


$$\begin{aligned} & -\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\left(-2\sum_{c=1}^3|\hat{Y}_{d,cc}^0|^2\sum_{b=1}^3V_{bc}^{CKM}Z_{kb}^{U,*}Z_{lc}^D Z_{i1}^A Z_{j1}^+\right. \\ & \left.-2\sum_{d=1}^3\hat{Y}_{u,dd}^{0,*}Z_{k3+d}^{U,*}\sum_{c=1}^3V_{dc}^{CKM}\hat{Y}_{d,cc}^0 Z_{l3+c}^D Z_{i2}^A Z_{j1}^+\right) \end{aligned}$$

$$\begin{aligned}
& + 2 \sum_{d=1}^3 \hat{Y}_{u,dd}^{0,*} Z_{k3+d}^{U,*} \sum_{c=1}^3 V_{dc}^{CKM} \hat{Y}_{d,cc}^0 Z_{l3+c}^D Z_{i1}^A Z_{j2}^+ \\
& + 2 \sum_{c=1}^3 \sum_{b=1}^3 |\hat{Y}_{u,bb}^0|^2 V_{bc}^{CKM} Z_{kb}^{U,*} Z_{lc}^D Z_{i2}^A Z_{j2}^+ \\
& + g_2^2 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 V_{ba}^{CKM} Z_{la}^D \left(Z_{i1}^A Z_{j1}^+ - Z_{i2}^A Z_{j2}^+ \right)
\end{aligned} \tag{313}$$

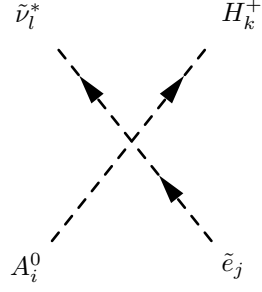


$$\begin{aligned}
& - \frac{1}{2} \frac{1}{\sqrt{2}} \left(- 2 \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 \sum_{b=1}^3 Z_{kb}^{V,*} U_{L,cb}^e Z_{lc}^E Z_{i1}^A Z_{j1}^+ \right. \\
& \left. + g_2^2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ka}^{V,*} U_{L,ba}^e Z_{lb}^E \left(Z_{i1}^A Z_{j1}^+ - Z_{i2}^A Z_{j2}^+ \right) \right)
\end{aligned} \tag{314}$$

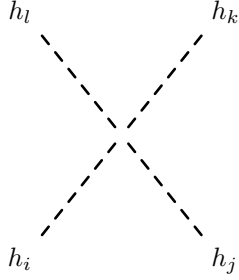


$$\begin{aligned}
& - \frac{1}{2} \frac{1}{\sqrt{2}} \delta_{\beta\delta} \left(g_2^2 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 V_{ab}^{CKM,*} Z_{la}^U \left(- Z_{i1}^A Z_{k1}^+ + Z_{i2}^A Z_{k2}^+ \right) \right. \\
& \left. + 2 \left(\sum_{c=1}^3 \sum_{b=1}^3 |\hat{Y}_{d,bb}^0|^2 V_{cb}^{CKM,*} Z_{jb}^{D,*} Z_{lc}^U Z_{i1}^A Z_{k1}^+ \right) \right)
\end{aligned}$$

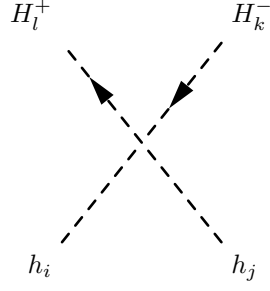
$$\begin{aligned}
& - \sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 \sum_{b=1}^3 V_{cb}^{CKM,*} Z_{jb}^{D,*} Z_{lc}^U Z_{i2}^A Z_{k2}^+ \\
& + \sum_{d=1}^3 \hat{Y}_{d,dd}^{0,*} Z_{j3+d}^{D,*} \sum_{c=1}^3 V_{cd}^{CKM,*} \hat{Y}_{u,cc}^0 Z_{l3+c}^U \left(-Z_{i1}^A Z_{k2}^+ + Z_{i2}^A Z_{k1}^+ \right) \Big) \Big) \quad (315)
\end{aligned}$$



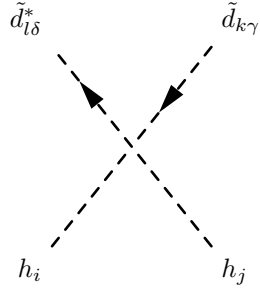
$$\begin{aligned}
& - \frac{1}{2} \frac{1}{\sqrt{2}} \left(2 \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{jc}^{E,*} \sum_{b=1}^3 U_{L,cb}^{e,*} Z_{lb}^V Z_{i1}^A Z_{k1}^+ \right. \\
& \left. + g_2^2 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 U_{L,ba}^{e,*} Z_{la}^V \left(-Z_{i1}^A Z_{k1}^+ + Z_{i2}^A Z_{k2}^+ \right) \right) \quad (316)
\end{aligned}$$



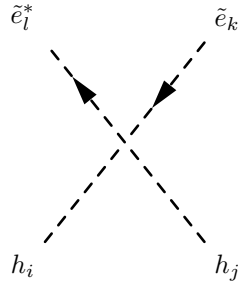
$$\begin{aligned}
& \frac{i}{4} \left(g_1^2 + g_2^2 \right) \left(Z_{i2}^H \left(Z_{j1}^H \left(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) + Z_{j2}^H \left(-3Z_{k2}^H Z_{l2}^H + Z_{k1}^H Z_{l1}^H \right) \right) \right. \\
& \left. + Z_{i1}^H \left(Z_{j1}^H \left(-3Z_{k1}^H Z_{l1}^H + Z_{k2}^H Z_{l2}^H \right) + Z_{j2}^H \left(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H \right) \right) \right) \quad (317)
\end{aligned}$$



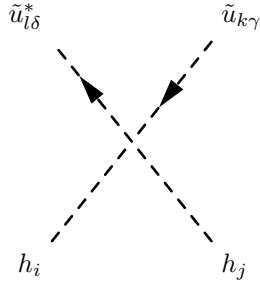
$$\begin{aligned}
& \frac{i}{4} \left(-Z_{i1}^H \left(g_2^2 Z_{j2}^H \left(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) + Z_{j1}^H \left(\left(g_1^2 + g_2^2 \right) Z_{k1}^+ Z_{l1}^+ + \left(-g_1^2 + g_2^2 \right) Z_{k2}^+ Z_{l2}^+ \right) \right) \right. \\
& \left. + Z_{i2}^H \left(-g_2^2 Z_{j1}^H \left(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) + Z_{j2}^H \left(- \left(g_1^2 + g_2^2 \right) Z_{k2}^+ Z_{l2}^+ + \left(-g_2^2 + g_1^2 \right) Z_{k1}^+ Z_{l1}^+ \right) \right) \right) \quad (318)
\end{aligned}$$



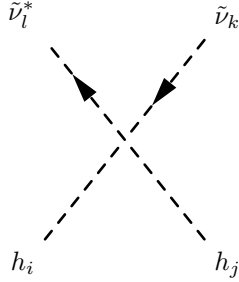
$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left(\left(3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{kb}^{D,*} Z_{lb}^D \left(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H \right) \right. \\
& + 2 \left(-6 \left(\sum_{c=1}^3 |\hat{Y}_{d,cc}^0|^2 Z_{kc}^{D,*} Z_{lc}^D + \sum_{c=1}^3 |\hat{Y}_{d,cc}^0|^2 Z_{k3+c}^{D,*} Z_{l3+c}^D \right) Z_{i1}^H Z_{j1}^H \right. \\
& \left. \left. + g_1^2 \sum_{b=1}^3 Z_{k3+b}^{D,*} Z_{l3+b}^D \left(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H \right) \right) \right) \quad (319)
\end{aligned}$$



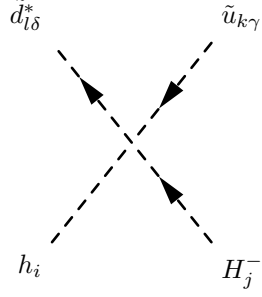
$$\begin{aligned}
& \frac{i}{4} \left(-4 \left(\sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{kc}^{E,*} Z_{lc}^E + \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{k3+c}^{E,*} Z_{l3+c}^E \right) Z_{i1}^H Z_{j1}^H \right. \\
& - \left(-g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{kb}^{E,*} Z_{lb}^E \left(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H \right) \\
& \left. + 2g_1^2 \sum_{b=1}^3 Z_{k3+b}^{E,*} Z_{l3+b}^E \left(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H \right) \right) \quad (320)
\end{aligned}$$



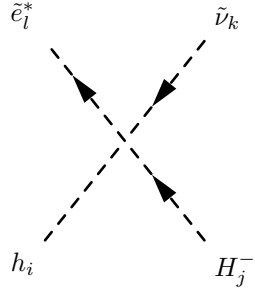
$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left(\left(-3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{kb}^{U,*} Z_{lb}^U \left(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H \right) \right. \\
& - 4 \left(3 \left(\sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 Z_{kc}^{U,*} Z_{lc}^U + \sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 Z_{k3+c}^{U,*} Z_{l3+c}^U \right) Z_{i2}^H Z_{j2}^H \right. \\
& \left. \left. + g_1^2 \sum_{b=1}^3 Z_{k3+b}^{U,*} Z_{l3+b}^U \left(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H \right) \right) \right) \quad (321)
\end{aligned}$$



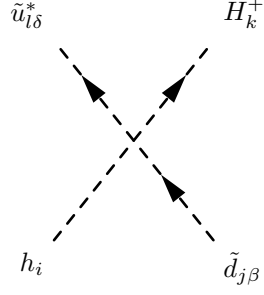
$$- \frac{i}{4} \left(g_1^2 + g_2^2 \right) \delta_{kl} \left(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H \right) \quad (322)$$



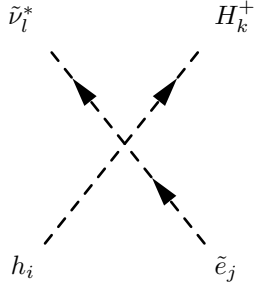
$$\begin{aligned}
& \frac{i}{2} \frac{1}{\sqrt{2}} \delta_{\gamma\delta} \left(-g_2^2 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 V_{ba}^{CKM} Z_{la}^D \left(Z_{i1}^H Z_{j1}^+ + Z_{i2}^H Z_{j2}^+ \right) \right. \\
& + 2 \left(\sum_{c=1}^3 |\hat{Y}_{d,cc}^0|^2 \sum_{b=1}^3 V_{bc}^{CKM} Z_{kb}^{U,*} Z_{lc}^D Z_{i1}^H Z_{j1}^+ + \sum_{c=1}^3 \sum_{b=1}^3 |\hat{Y}_{u,bb}^0|^2 V_{bc}^{CKM} Z_{kb}^{U,*} Z_{lc}^D Z_{i2}^H Z_{j2}^+ \right. \\
& \left. \left. + \sum_{d=1}^3 \hat{Y}_{u,dd}^{0,*} Z_{k3+d}^{U,*} \sum_{c=1}^3 V_{dc}^{CKM} \hat{Y}_{d,cc}^0 Z_{l3+c}^D \left(Z_{i1}^H Z_{j2}^+ + Z_{i2}^H Z_{j1}^+ \right) \right) \right) \quad (323)
\end{aligned}$$



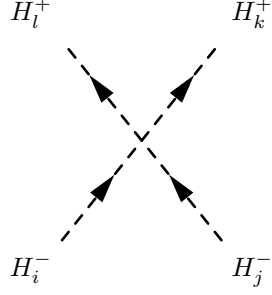
$$\begin{aligned}
& \frac{i}{2} \frac{1}{\sqrt{2}} \left(2 \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 \sum_{b=1}^3 Z_{kb}^{V,*} U_{L,cb}^e Z_{lc}^E Z_{i1}^H Z_{j1}^+ \right. \\
& \left. - g_2^2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ka}^{V,*} U_{L,ba}^e Z_{lb}^E \left(Z_{i1}^H Z_{j1}^+ + Z_{i2}^H Z_{j2}^+ \right) \right) \quad (324)
\end{aligned}$$



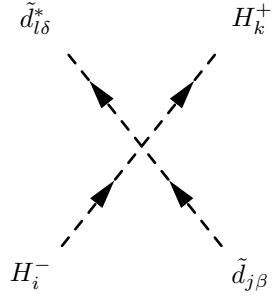
$$\begin{aligned}
& \frac{i}{2} \frac{1}{\sqrt{2}} \delta_{\beta\delta} \left(-g_2^2 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 V_{ab}^{CKM,*} Z_{la}^U \left(Z_{i1}^H Z_{k1}^+ + Z_{i2}^H Z_{k2}^+ \right) \right. \\
& + 2 \left(\sum_{c=1}^3 \sum_{b=1}^3 |\hat{Y}_{d,bb}^0|^2 V_{cb}^{CKM,*} Z_{jb}^{D,*} Z_{lc}^U Z_{i1}^H Z_{k1}^+ \right. \\
& + \sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 \sum_{b=1}^3 V_{cb}^{CKM,*} Z_{jb}^{D,*} Z_{lc}^U Z_{i2}^H Z_{k2}^+ \\
& \left. \left. + \sum_{d=1}^3 \hat{Y}_{d,dd}^{0,*} Z_{j3+d}^{D,*} \sum_{c=1}^3 V_{cd}^{CKM,*} \hat{Y}_{u,cc}^0 Z_{l3+c}^U \left(Z_{i1}^H Z_{k2}^+ + Z_{i2}^H Z_{k1}^+ \right) \right) \right) \quad (325)
\end{aligned}$$



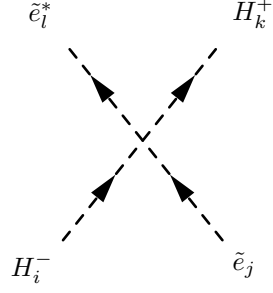
$$\begin{aligned}
& \frac{i}{2} \frac{1}{\sqrt{2}} \left(2 \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{jc}^{E,*} \sum_{b=1}^3 U_{L,bc}^{e,*} Z_{lb}^V Z_{i1}^H Z_{k1}^+ \right. \\
& \left. - g_2^2 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 U_{L,ba}^{e,*} Z_{la}^V \left(Z_{i1}^H Z_{k1}^+ + Z_{i2}^H Z_{k2}^+ \right) \right) \quad (326)
\end{aligned}$$



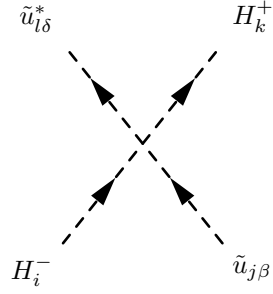
$$\begin{aligned}
& -\frac{i}{4}(g_1^2 + g_2^2) \left(-Z_{i2}^+ \left(-2Z_{j2}^+ Z_{k2}^+ Z_{l2}^+ + Z_{j1}^+ (Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+) \right) \right. \\
& \left. + Z_{i1}^+ (2Z_{j1}^+ Z_{k1}^+ Z_{l1}^+ - Z_{j2}^+ (Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+)) \right)
\end{aligned} \tag{327}$$



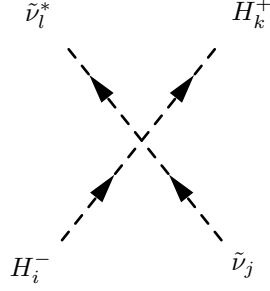
$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\delta} \left(\left(-3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D (Z_{i1}^+ Z_{k1}^+ - Z_{i2}^+ Z_{k2}^+) \right. \\
& + 2 \left(g_1^2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{l3+b}^D (Z_{i1}^+ Z_{k1}^+ - Z_{i2}^+ Z_{k2}^+) \right. \\
& - 6 \left(\sum_{c=1}^3 |\hat{Y}_{d,cc}^0|^2 Z_{j3+c}^{D,*} Z_{l3+c}^D Z_{i1}^+ Z_{k1}^+ \right. \\
& \left. \left. + \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 |\hat{Y}_{u,aa}^0|^2 V_{ac}^{CKM} V_{ab}^{CKM,*} Z_{lc}^D Z_{i2}^+ Z_{k2}^+ \right) \right)
\end{aligned} \tag{328}$$



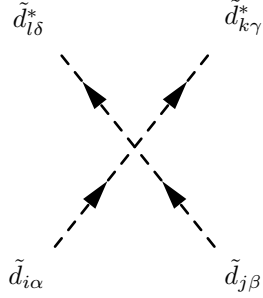
$$\begin{aligned}
& \frac{i}{4} \left(-4 \sum_{c=1}^3 |\hat{Y}_{e,cc}^0|^2 Z_{j3+c}^{E,*} Z_{l3+c}^E Z_{i1}^+ Z_{k1}^+ - (g_1^2 + g_2^2) \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E (Z_{i1}^+ Z_{k1}^+ - Z_{i2}^+ Z_{k2}^+) \right. \\
& \left. + 2g_1^2 \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E (Z_{i1}^+ Z_{k1}^+ - Z_{i2}^+ Z_{k2}^+) \right) \quad (329)
\end{aligned}$$



$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\delta} \left((3g_2^2 + g_1^2) \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U (Z_{i1}^+ Z_{k1}^+ - Z_{i2}^+ Z_{k2}^+) \right. \\
& - 4 \left(g_1^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U (Z_{i1}^+ Z_{k1}^+ - Z_{i2}^+ Z_{k2}^+) \right. \\
& + 3 \left(\sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 |\hat{Y}_{d,aa}^0|^2 V_{ba}^{CKM} V_{ca}^{CKM,*} Z_{lc}^U Z_{i1}^+ Z_{k1}^+ \right. \\
& \left. \left. + \sum_{c=1}^3 |\hat{Y}_{u,cc}^0|^2 Z_{j3+c}^{U,*} Z_{l3+c}^U Z_{i2}^+ Z_{k2}^+ \right) \right) \quad (330)
\end{aligned}$$



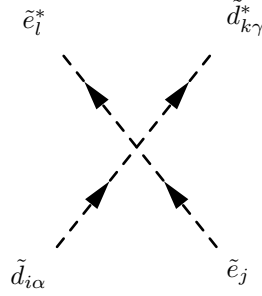
$$\begin{aligned}
& \frac{i}{4} \left(-4 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 |\hat{Y}_{e,aa}^0|^2 U_{L,ac}^{e,*} U_{L,ab}^e Z_{lc}^V Z_{i1}^+ Z_{k1}^+ \right. \\
& \left. - \left(-g_2^2 + g_1^2 \right) \delta_{jl} \left(Z_{i1}^+ Z_{k1}^+ - Z_{i2}^+ Z_{k2}^+ \right) \right) \quad (331)
\end{aligned}$$



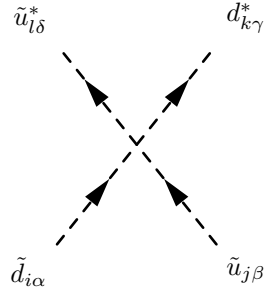
$$\begin{aligned}
& \frac{i}{72} \left(-\delta_{\alpha\gamma} \delta_{\beta\delta} \left(18g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{kd}^D - 18g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{kd}^D \right. \right. \\
& + 2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{l3+b}^D \left((2g_1^2 - 3g_3^2) \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D + (3g_3^2 + g_1^2) \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D \right) \\
& + \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D \left(2(3g_3^2 + g_1^2) \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D + (-6g_3^2 + 9g_2^2 + g_1^2) \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D \right) \\
& - 18g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{k3+d}^D + 18g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{k3+d}^D \\
& + 18g_3^2 \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{id}^{D,*} Z_{ld}^D - 18g_3^2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{id}^{D,*} Z_{ld}^D \\
& \left. \left. + g_1^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{ld}^D + 9g_2^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{ld}^D \right) \right)
\end{aligned}$$

$$\begin{aligned}
& -6g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{ld}^D + 2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{ld}^D \\
& + 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{ld}^D - 18g_3^2 \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{l3+d}^D \\
& + 18g_3^2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{l3+d}^D + 2g_1^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{l3+d}^D \\
& + 6g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{l3+d}^D + 4g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{l3+d}^D \\
& - 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{l3+d}^D + 72 \sum_{e=1}^3 |\hat{Y}_{d,ee}^0|^2 Z_{ie}^{D,*} Z_{j3+e}^{D,*} Z_{k3+e}^D Z_{le}^D \\
& + 72 \sum_{e=1}^3 |\hat{Y}_{d,ee}^0|^2 Z_{i3+e}^{D,*} Z_{je}^{D,*} Z_{ke}^D Z_{l3+e}^D \Big) \\
& - \delta_{\alpha\delta} \delta_{\beta\gamma} \Big(g_1^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{kd}^D + 9g_2^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{kd}^D \\
& - 6g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{kd}^D + 2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{kd}^D \\
& + 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{kd}^D \\
& + 18g_3^2 \sum_{b=1}^3 Z_{jb}^{D,*} Z_{lb}^D \Big(- \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D + \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D \Big) \\
& - 18g_3^2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{l3+b}^D \Big(- \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D + \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D \Big) \\
& + 2g_1^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{k3+d}^D + 6g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{k3+d}^D \\
& + 4g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{k3+d}^D - 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{l3+b}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{k3+d}^D \\
& + g_1^2 \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{id}^{D,*} Z_{ld}^D + 9g_2^2 \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{id}^{D,*} Z_{ld}^D \\
& - 6g_3^2 \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{id}^{D,*} Z_{ld}^D + 2g_1^2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{id}^{D,*} Z_{ld}^D
\end{aligned}$$

$$\begin{aligned}
& + 6g_3^2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{id}^{D,*} Z_{ld}^D + 18g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{ld}^D \\
& - 18g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{jd}^{D,*} Z_{ld}^D + 2g_1^2 \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{l3+d}^D \\
& + 6g_3^2 \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{l3+d}^D + 4g_1^2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{l3+d}^D \\
& - 6g_3^2 \sum_{b=1}^3 Z_{j3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{l3+d}^D - 18g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{l3+d}^D \\
& + 18g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{j3+d}^{D,*} Z_{l3+d}^D + 72 \sum_{e=1}^3 |\hat{Y}_{d,ee}^0|^2 Z_{i3+e}^{D,*} Z_{je}^{D,*} Z_{k3+e}^D Z_{le}^D \\
& + 72 \sum_{e=1}^3 |\hat{Y}_{d,ee}^0|^2 Z_{ie}^{D,*} Z_{j3+e}^{D,*} Z_{ke}^D Z_{l3+e}^D \Big) \Big) \tag{332}
\end{aligned}$$

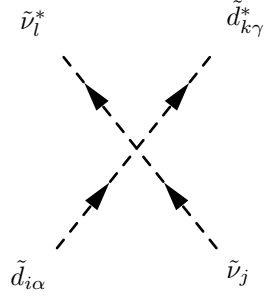


$$\begin{aligned}
& \frac{i}{24} \delta_{\alpha\gamma} \Big(- 2g_1^2 \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \Big(2 \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D + \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D \Big) \\
& + \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \Big(2g_1^2 \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D + \Big(- 3g_2^2 + g_1^2 \Big) \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D \Big) \\
& + g_1^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{E,*} Z_{ld}^E - 3g_2^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{E,*} Z_{ld}^E \\
& + 2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{jd}^{E,*} Z_{ld}^E - 2g_1^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{j3+d}^{E,*} Z_{l3+d}^E \\
& - 4g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{j3+d}^{E,*} Z_{l3+d}^E - 24 \sum_{e=1}^3 \hat{Y}_{e,ee}^{0,*} Z_{ie}^{D,*} Z_{j3+e}^{E,*} \hat{Y}_{d,ee}^0 Z_{k3+e}^D Z_{le}^E \\
& - 24 \sum_{e=1}^3 \hat{Y}_{d,ee}^{0,*} Z_{i3+e}^{D,*} Z_{je}^{E,*} \hat{Y}_{e,ee}^0 Z_{ke}^D Z_{l3+e}^E \Big) \tag{333}
\end{aligned}$$

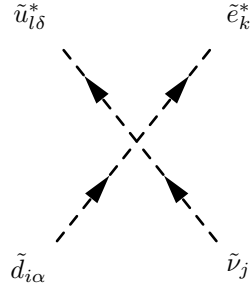


$$\begin{aligned}
& \frac{i}{72} \left(\delta_{\alpha\gamma} \delta_{\beta\delta} \left(- \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \left(2(3g_3^2 + g_1^2) \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D + (-6g_3^2 - 9g_2^2 + g_1^2) \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D \right) \right. \right. \\
& + \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \left(2(3g_3^2 + 4g_1^2) \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D + (4g_1^2 - 6g_3^2) \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D \right) \\
& - g_1^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U + 9g_2^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U \\
& + 6g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U - 2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U \\
& - 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U + 4g_1^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \\
& - 6g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U + 8g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \\
& \left. + 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \right) \\
& - 18\delta_{\alpha\delta} \delta_{\beta\gamma} \left(g_2^2 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 V_{ab}^{CKM,*} Z_{la}^U \sum_{d=1}^3 Z_{jd}^{U,*} \sum_{c=1}^3 V_{dc}^{CKM} Z_{kc}^D \right. \\
& + g_2^2 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 V_{ba}^{CKM} Z_{ka}^D \sum_{d=1}^3 Z_{id}^{D,*} \sum_{c=1}^3 V_{cd}^{CKM,*} Z_{lc}^U + g_3^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D \\
& - g_3^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \sum_{d=1}^3 Z_{id}^{D,*} Z_{kd}^D - g_3^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D \\
& \left. + g_3^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \sum_{d=1}^3 Z_{i3+d}^{D,*} Z_{k3+d}^D + g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U \right)
\end{aligned}$$

$$\begin{aligned}
& -g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U - g_3^2 \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \\
& + g_3^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \\
& + 4 \sum_{e=1}^3 \sum_{d=1}^3 |\hat{Y}_{u,dd}^0|^2 V_{de}^{CKM} Z_{j3+d}^{U,*} \sum_{c=1}^3 V_{dc}^{CKM,*} Z_{ic}^{D,*} Z_{l3+d}^U Z_{ke}^D \\
& + 4 \sum_{e=1}^3 \sum_{d=1}^3 |\hat{Y}_{d,dd}^0|^2 V_{ed}^{CKM,*} Z_{i3+d}^{D,*} \sum_{c=1}^3 V_{cd}^{CKM} Z_{jc}^{U,*} Z_{k3+d}^D Z_{le}^U \Big) \tag{334}
\end{aligned}$$

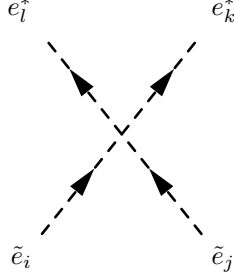


$$\frac{i}{12} \delta_{\alpha\gamma} \delta_{jl} \left(2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \left(3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \tag{335}$$



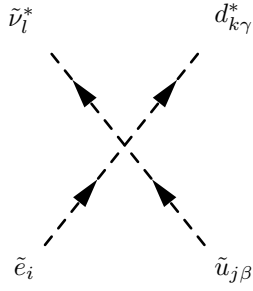
$$\begin{aligned}
& -\frac{i}{4} \delta_{\alpha\delta} \left(g_2^2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} U_{L,ba}^e Z_{kb}^E \sum_{d=1}^3 Z_{id}^{D,*} \sum_{c=1}^3 V_{cd}^{CKM,*} Z_{lc}^U \right. \\
& \left. + g_2^2 \sum_{c=1}^3 Z_{ic}^{D,*} \sum_{b=1}^3 V_{bc}^{CKM,*} Z_{lb}^U \sum_{d=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} U_{L,da}^e Z_{kd}^E \right)
\end{aligned}$$

$$+ 4 \sum_{e=1}^3 \sum_{d=1}^3 V_{ed}^{CKM,*} \hat{Y}_{d,dd}^{0,*} Z_{i3+d}^{D,*} \sum_{b=1}^3 Z_{jb}^{V,*} U_{L,db}^e \hat{Y}_{e,dd}^0 Z_{k3+d}^E Z_{le}^U \quad (336)$$

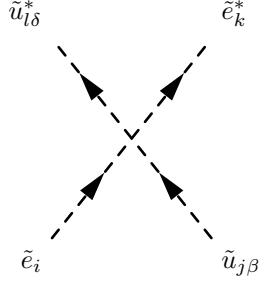


$$\begin{aligned} & \frac{i}{8} \left(-g_1^2 \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^E \sum_{d=1}^3 Z_{jd}^{E,*} Z_{kd}^E - g_2^2 \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^E \sum_{d=1}^3 Z_{jd}^{E,*} Z_{kd}^E \right. \\ & + 2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E \sum_{d=1}^3 Z_{jd}^{E,*} Z_{kd}^E \\ & + 2g_1^2 \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \left(-2 \sum_{d=1}^3 Z_{i3+d}^{E,*} Z_{k3+d}^E + \sum_{d=1}^3 Z_{id}^{E,*} Z_{kd}^E \right) \\ & - \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \left(-2g_1^2 \sum_{d=1}^3 Z_{i3+d}^{E,*} Z_{k3+d}^E + (g_1^2 + g_2^2) \sum_{d=1}^3 Z_{id}^{E,*} Z_{kd}^E \right) \\ & + 2g_1^2 \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^E \sum_{d=1}^3 Z_{j3+d}^{E,*} Z_{k3+d}^E - 4g_1^2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E \sum_{d=1}^3 Z_{j3+d}^{E,*} Z_{k3+d}^E \\ & - g_1^2 \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E \sum_{d=1}^3 Z_{id}^{E,*} Z_{ld}^E - g_2^2 \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E \sum_{d=1}^3 Z_{id}^{E,*} Z_{ld}^E \\ & + 2g_1^2 \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{k3+b}^E \sum_{d=1}^3 Z_{id}^{E,*} Z_{ld}^E - g_1^2 \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \sum_{d=1}^3 Z_{jd}^{E,*} Z_{ld}^E \\ & - g_2^2 \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \sum_{d=1}^3 Z_{jd}^{E,*} Z_{ld}^E + 2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E \sum_{d=1}^3 Z_{jd}^{E,*} Z_{ld}^E \\ & + 2g_1^2 \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E \sum_{d=1}^3 Z_{i3+d}^{E,*} Z_{l3+d}^E - 4g_1^2 \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{k3+b}^E \sum_{d=1}^3 Z_{i3+d}^{E,*} Z_{l3+d}^E \\ & + 2g_1^2 \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \sum_{d=1}^3 Z_{j3+d}^{E,*} Z_{l3+d}^E - 4g_1^2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E \sum_{d=1}^3 Z_{j3+d}^{E,*} Z_{l3+d}^E \\ & \left. - 8 \sum_{e=1}^3 |\hat{Y}_{e,ee}^0|^2 Z_{i3+e}^{E,*} Z_{je}^{E,*} Z_{k3+e}^E Z_{le}^E - 8 \sum_{e=1}^3 |\hat{Y}_{e,ee}^0|^2 Z_{ie}^{E,*} Z_{j3+e}^{E,*} Z_{k3+e}^E Z_{le}^E \right) \end{aligned}$$

$$- 8 \sum_{e=1}^3 |\hat{Y}_{e,ee}^0|^2 Z_{i3+e}^{E,*} Z_{je}^{E,*} Z_{ke}^E Z_{l3+e}^E - 8 \sum_{e=1}^3 |\hat{Y}_{e,ee}^0|^2 Z_{ie}^{E,*} Z_{j3+e}^{E,*} Z_{ke}^E Z_{l3+e}^E \quad (337)$$

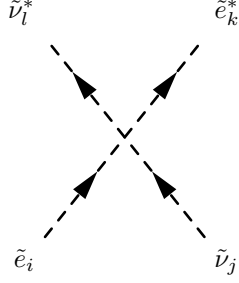


$$\begin{aligned} & - \frac{i}{4} \delta_{\beta\gamma} \left(g_2^2 \sum_{c=1}^3 Z_{jc}^{U,*} \sum_{b=1}^3 V_{cb}^{CKM} Z_{kb}^D \sum_{d=1}^3 Z_{id}^{E,*} \sum_{a=1}^3 U_{L,da}^{e,*} Z_{la}^V \right. \\ & + g_2^2 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 U_{L,ba}^{e,*} Z_{la}^V \sum_{d=1}^3 Z_{jd}^{U,*} \sum_{c=1}^3 V_{dc}^{CKM} Z_{kc}^D \\ & \left. + 4 \sum_{e=1}^3 \hat{Y}_{e,ee}^{0,*} Z_{i3+e}^{E,*} \sum_{b=1}^3 U_{L,eb}^{e,*} Z_{lb}^V \sum_{d=1}^3 V_{de}^{CKM} Z_{jd}^{U,*} \hat{Y}_{d,ee}^0 Z_{k3+e}^D \right) \quad (338) \end{aligned}$$

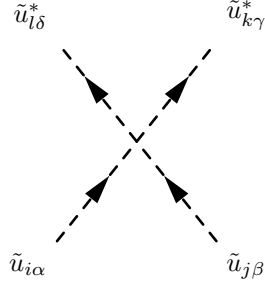


$$\begin{aligned} & \frac{i}{24} \delta_{\beta\delta} \left(-4g_1^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \left(-2 \sum_{d=1}^3 Z_{i3+d}^{E,*} Z_{k3+d}^E + \sum_{d=1}^3 Z_{id}^{E,*} Z_{kd}^E \right) \right. \\ & + \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \left(-2g_1^2 \sum_{d=1}^3 Z_{i3+d}^{E,*} Z_{k3+d}^E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

$$\begin{aligned}
& -2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U - 4g_1^2 \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \\
& + 8g_1^2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \Big) \tag{339}
\end{aligned}$$



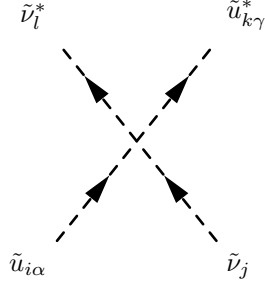
$$\begin{aligned}
& \frac{i}{4} \Big(\delta_{jl} \Big(2g_1^2 \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E + \Big(-g_1^2 + g_2^2 \Big) \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \Big) \\
& - g_2^2 \sum_{c=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} U_{L,ca}^e Z_{kc}^E \sum_{d=1}^3 Z_{id}^{E,*} \sum_{b=1}^3 U_{L,db}^{e,*} Z_{lb}^V \\
& - g_2^2 \sum_{c=1}^3 Z_{ic}^{E,*} \sum_{a=1}^3 U_{L,ca}^{e,*} Z_{la}^V \sum_{d=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} U_{L,db}^e Z_{kd}^E \\
& - 4 \sum_{e=1}^3 |\hat{Y}_{e,ee}^0|^2 Z_{i3+e}^{E,*} \sum_{b=1}^3 Z_{jb}^{V,*} U_{L,eb}^e \sum_{c=1}^3 U_{L,ec}^{e,*} Z_{lc}^V Z_{k3+e}^E \Big) \tag{340}
\end{aligned}$$



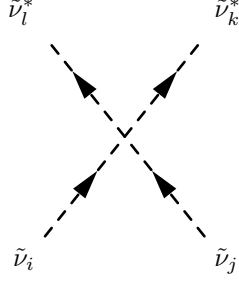
$$\frac{i}{72} \Big(-\delta_{\alpha\gamma} \delta_{\beta\delta} \Big(18g_3^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{kd}^U - 18g_3^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{kd}^U$$

$$\begin{aligned}
& + \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \left(2 \left(-3g_3^2 + 8g_1^2 \right) \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{k3+d}^U + \left(-4g_1^2 + 6g_3^2 \right) \sum_{d=1}^3 Z_{id}^{U,*} Z_{kd}^U \right) \\
& + \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \left(2 \left(-2g_1^2 + 3g_3^2 \right) \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{k3+d}^U + \left(-6g_3^2 + 9g_2^2 + g_1^2 \right) \sum_{d=1}^3 Z_{id}^{U,*} Z_{kd}^U \right) \\
& - 18g_3^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{k3+d}^U + 18g_3^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{k3+d}^U \\
& + 18g_3^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{id}^{U,*} Z_{ld}^U - 18g_3^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{id}^{U,*} Z_{ld}^U \\
& + g_1^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U + 9g_2^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U \\
& - 6g_3^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U - 4g_1^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U \\
& + 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U - 18g_3^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{l3+d}^U \\
& + 18g_3^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{l3+d}^U - 4g_1^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \\
& + 6g_3^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U + 16g_1^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \\
& - 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U + 72 \sum_{e=1}^3 |\hat{Y}_{u,ee}^0|^2 Z_{ie}^{U,*} Z_{j3+e}^{U,*} Z_{k3+e}^U Z_{le}^U \\
& + 72 \sum_{e=1}^3 |\hat{Y}_{u,ee}^0|^2 Z_{i3+e}^{U,*} Z_{je}^{U,*} Z_{ke}^U Z_{l3+e}^U \Big) \\
& - \delta_{\alpha\delta} \delta_{\beta\gamma} \left(g_1^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{kd}^U + 9g_2^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{kd}^U \right. \\
& - 6g_3^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{kd}^U - 4g_1^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{kd}^U \\
& + 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{kd}^U \\
& \left. + 18g_3^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \left(- \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{k3+d}^U + \sum_{d=1}^3 Z_{id}^{U,*} Z_{kd}^U \right) \right)
\end{aligned}$$

$$\begin{aligned}
& -18g_3^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \left(- \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{k3+d}^U + \sum_{d=1}^3 Z_{id}^{U,*} Z_{kd}^U \right) \\
& -4g_1^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{k3+d}^U + 6g_3^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{k3+d}^U \\
& +16g_1^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{k3+d}^U - 6g_3^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{k3+d}^U \\
& +g_1^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{id}^{U,*} Z_{ld}^U + 9g_2^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{id}^{U,*} Z_{ld}^U \\
& -6g_3^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{id}^{U,*} Z_{ld}^U - 4g_1^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{id}^{U,*} Z_{ld}^U \\
& +6g_3^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{id}^{U,*} Z_{ld}^U + 18g_3^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U \\
& -18g_3^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{jd}^{U,*} Z_{ld}^U - 4g_1^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{l3+d}^U \\
& +6g_3^2 \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{l3+d}^U + 16g_1^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{l3+d}^U \\
& -6g_3^2 \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{i3+d}^{U,*} Z_{l3+d}^U - 18g_3^2 \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U \\
& +18g_3^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U \sum_{d=1}^3 Z_{j3+d}^{U,*} Z_{l3+d}^U + 72 \sum_{e=1}^3 |\hat{Y}_{u,ee}^0|^2 Z_{i3+e}^{U,*} Z_{je}^{U,*} Z_{k3+e}^U Z_{le}^U \\
& +72 \sum_{e=1}^3 |\hat{Y}_{u,ee}^0|^2 Z_{ie}^{U,*} Z_{j3+e}^{U,*} Z_{ke}^U Z_{l3+e}^U \Big) \tag{341}
\end{aligned}$$

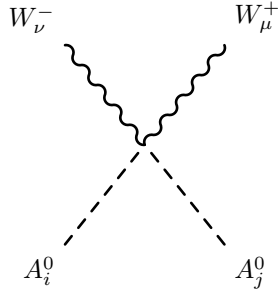


$$\frac{i}{12} \delta_{\alpha\gamma} \delta_{jl} \left(\left(-3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U - 4g_1^2 \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U \right) \tag{342}$$

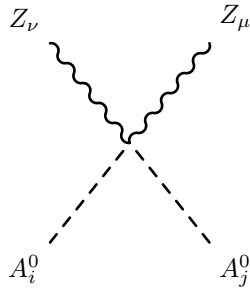


$$-\frac{i}{4}(g_1^2 + g_2^2)(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk}) \quad (343)$$

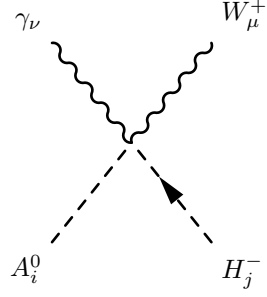
8.8 Two Scalar-Two Vector Boson-Interaction



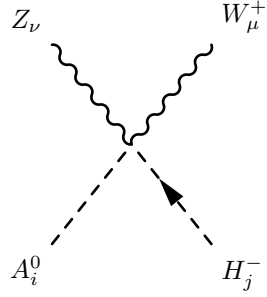
$$\left(\frac{i}{2}g_2^2 Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_2^2 Z_{i2}^A Z_{j2}^A\right)(g_{\mu\nu}) \quad (344)$$



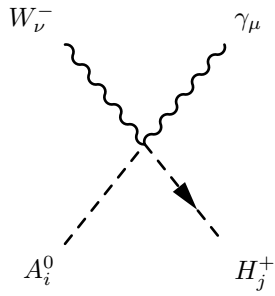
$$\begin{aligned} &\left(+\frac{i}{2}g_2^2 \cos \Theta_W^2 Z_{i1}^A Z_{j1}^A + ig_1 g_2 \cos \Theta_W \sin \Theta_W Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_1^2 \sin \Theta_W^2 Z_{i1}^A Z_{j1}^A \right. \\ &\left. + \frac{i}{2}g_2^2 \cos \Theta_W^2 Z_{i2}^A Z_{j2}^A + ig_1 g_2 \cos \Theta_W \sin \Theta_W Z_{i2}^A Z_{j2}^A + \frac{i}{2}g_1^2 \sin \Theta_W^2 Z_{i2}^A Z_{j2}^A \right)(g_{\mu\nu}) \end{aligned} \quad (345)$$



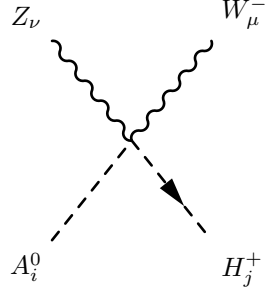
$$\left(-\frac{1}{2}g_1g_2 \cos \Theta_W Z_{i1}^A Z_{j1}^+ - \frac{1}{2}g_1g_2 \cos \Theta_W Z_{i2}^A Z_{j2}^+ \right) \left(g_{\mu\nu} \right) \quad (346)$$



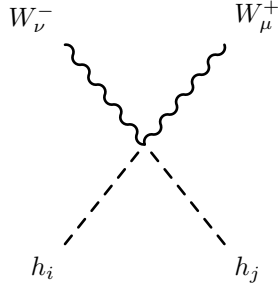
$$\left(\frac{1}{2}g_1g_2 \sin \Theta_W Z_{i1}^A Z_{j1}^+ + \frac{1}{2}g_1g_2 \sin \Theta_W Z_{i2}^A Z_{j2}^+ \right) \left(g_{\mu\nu} \right) \quad (347)$$



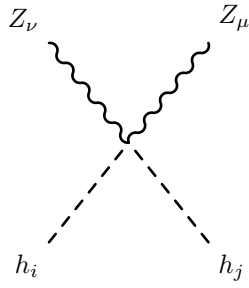
$$\left(\frac{1}{2}g_1g_2 \cos \Theta_W Z_{i1}^A Z_{j1}^+ + \frac{1}{2}g_1g_2 \cos \Theta_W Z_{i2}^A Z_{j2}^+ \right) \left(g_{\mu\nu} \right) \quad (348)$$



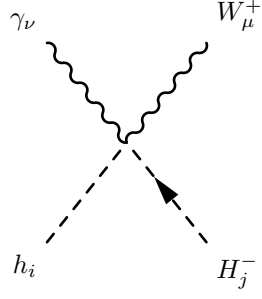
$$\left(-\frac{1}{2}g_1g_2\sin\Theta_W Z_{i1}^A Z_{j1}^+ - \frac{1}{2}g_1g_2\sin\Theta_W Z_{i2}^A Z_{j2}^+ \right) (g_{\mu\nu}) \quad (349)$$



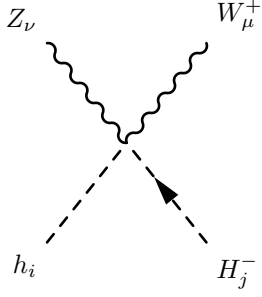
$$\left(\frac{i}{2}g_2^2 Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_2^2 Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu}) \quad (350)$$



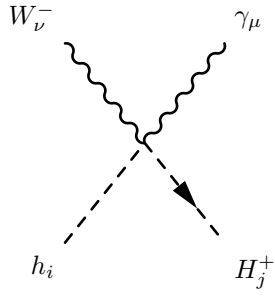
$$\begin{aligned} & \left(+\frac{i}{2}g_2^2\cos\Theta_W^2 Z_{i1}^H Z_{j1}^H + ig_1g_2\cos\Theta_W\sin\Theta_W Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_1^2\sin\Theta_W^2 Z_{i1}^H Z_{j1}^H \right. \\ & \left. + \frac{i}{2}g_2^2\cos\Theta_W^2 Z_{i2}^H Z_{j2}^H + ig_1g_2\cos\Theta_W\sin\Theta_W Z_{i2}^H Z_{j2}^H + \frac{i}{2}g_1^2\sin\Theta_W^2 Z_{i2}^H Z_{j2}^H \right) (g_{\mu\nu}) \end{aligned} \quad (351)$$



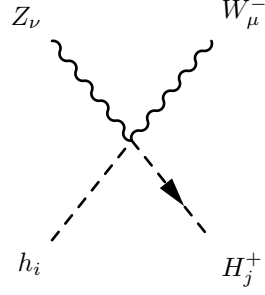
$$\left(-\frac{i}{2}g_1g_2\cos\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2}g_1g_2\cos\Theta_W Z_{i2}^H Z_{j2}^+ \right) (g_{\mu\nu}) \quad (352)$$



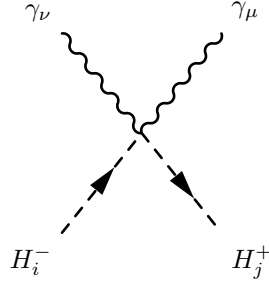
$$\left(\frac{i}{2}g_1g_2\sin\Theta_W Z_{i1}^H Z_{j1}^+ - \frac{i}{2}g_1g_2\sin\Theta_W Z_{i2}^H Z_{j2}^+ \right) (g_{\mu\nu}) \quad (353)$$



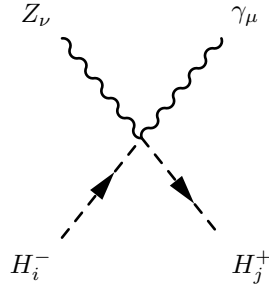
$$\left(-\frac{i}{2}g_1g_2\cos\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2}g_1g_2\cos\Theta_W Z_{i2}^H Z_{j2}^+ \right) (g_{\mu\nu}) \quad (354)$$



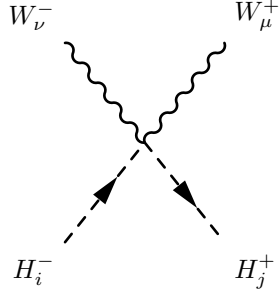
$$\left(\frac{i}{2} g_1 g_2 \sin \Theta_W Z_{i1}^H Z_{j1}^+ - \frac{i}{2} g_1 g_2 \sin \Theta_W Z_{i2}^H Z_{j2}^+ \right) (g_{\mu\nu}) \quad (355)$$



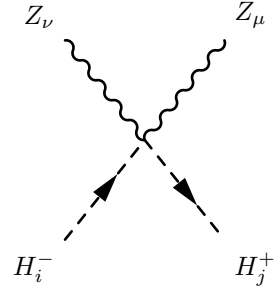
$$\begin{aligned} & \left(+ \frac{i}{2} g_1^2 \cos \Theta_W^2 Z_{i1}^+ Z_{j1}^+ + i g_1 g_2 \cos \Theta_W \sin \Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_2^2 \sin \Theta_W^2 Z_{i1}^+ Z_{j1}^+ \right. \\ & \left. + \frac{i}{2} g_1^2 \cos \Theta_W^2 Z_{i2}^+ Z_{j2}^+ + i g_1 g_2 \cos \Theta_W \sin \Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{2} g_2^2 \sin \Theta_W^2 Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (356)$$



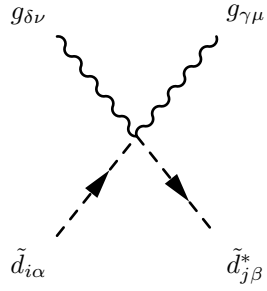
$$\begin{aligned} & \left(+ \frac{i}{2} g_1 g_2 \cos 2\Theta_W Z_{i1}^+ Z_{j1}^+ - \frac{i}{4} g_1^2 \sin 2\Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{4} g_2^2 \sin 2\Theta_W Z_{i1}^+ Z_{j1}^+ \right. \\ & \left. + \frac{i}{2} g_1 g_2 \cos 2\Theta_W Z_{i2}^+ Z_{j2}^+ - \frac{i}{4} g_1^2 \sin 2\Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{4} g_2^2 \sin 2\Theta_W Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (357)$$



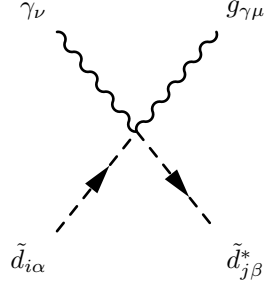
$$\left(\frac{i}{2} g_2^2 Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_2^2 Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (358)$$



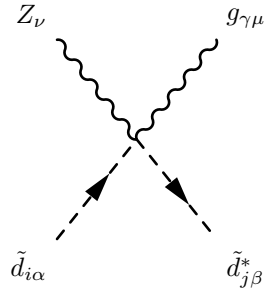
$$\begin{aligned} & \left(+ \frac{i}{2} g_2^2 \cos^2 \Theta_W Z_{i1}^+ Z_{j1}^+ - i g_1 g_2 \cos \Theta_W \sin \Theta_W Z_{i1}^+ Z_{j1}^+ \right. \\ & + \frac{i}{2} g_1^2 \sin^2 \Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_2^2 \cos^2 \Theta_W Z_{i2}^+ Z_{j2}^+ \\ & \left. - i g_1 g_2 \cos \Theta_W \sin \Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{2} g_1^2 \sin^2 \Theta_W Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (359)$$



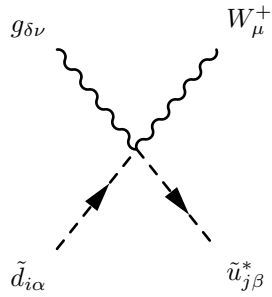
$$\left(\frac{i}{4} g_3^2 \delta_{ij} \sum_{a=1}^3 \lambda_{a,\alpha}^\gamma \lambda_{\beta,a}^\delta + \frac{i}{4} g_3^2 \delta_{ij} \sum_{a=1}^3 \lambda_{\beta,a}^\gamma \lambda_{a,\alpha}^\delta \right) (g_{\mu\nu}) \quad (360)$$



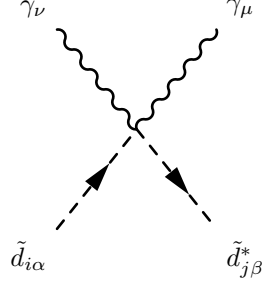
$$\begin{aligned}
& \left(+\frac{i}{6}g_1g_3\cos\Theta_W\lambda_{\beta,\alpha}^\gamma\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D -\frac{i}{2}g_2g_3\lambda_{\beta,\alpha}^\gamma\sin\Theta_W\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D \right. \\
& \left. -\frac{i}{3}g_1g_3\cos\Theta_W\lambda_{\beta,\alpha}^\gamma\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D \right) \left(g_{\mu\nu} \right)
\end{aligned} \tag{361}$$



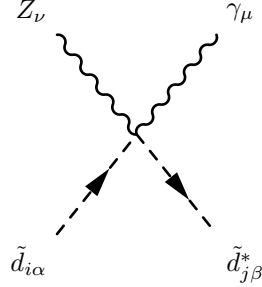
$$\begin{aligned}
& \left(-\frac{i}{2}g_2g_3\cos\Theta_W\lambda_{\beta,\alpha}^\gamma\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D -\frac{i}{6}g_1g_3\lambda_{\beta,\alpha}^\gamma\sin\Theta_W\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D \right. \\
& \left. +\frac{i}{3}g_1g_3\lambda_{\beta,\alpha}^\gamma\sin\Theta_W\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D \right) \left(g_{\mu\nu} \right)
\end{aligned} \tag{362}$$



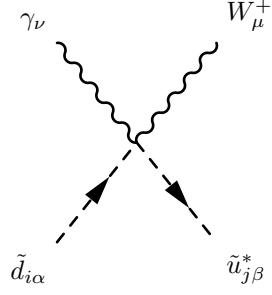
$$i \frac{1}{\sqrt{2}} g_2 g_3 \lambda_{\beta, \alpha}^\delta \sum_{b=1}^3 \sum_{a=1}^3 V_{ba}^{CKM, *} Z_{ia}^{D, *} Z_{jb}^U (g_{\mu\nu}) \quad (363)$$



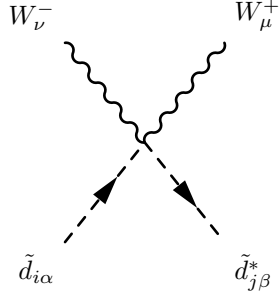
$$\begin{aligned} & \left(+ \frac{i}{18} g_1^2 \cos \Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D, *} Z_{ja}^D - \frac{i}{3} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{D, *} Z_{ja}^D \right. \\ & \left. + \frac{i}{2} g_2^2 \delta_{\alpha\beta} \sin \Theta_W^2 \sum_{a=1}^3 Z_{ia}^{D, *} Z_{ja}^D + \frac{2i}{9} g_1^2 \cos \Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{i3+a}^{D, *} Z_{j3+a}^D \right) (g_{\mu\nu}) \end{aligned} \quad (364)$$



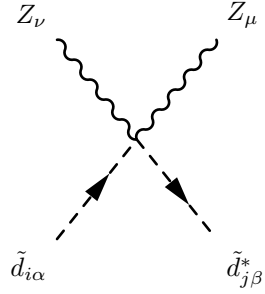
$$\begin{aligned} & \left(- \frac{i}{6} g_1 g_2 \cos 2\Theta_W \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D, *} Z_{ja}^D - \frac{i}{36} g_1^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^3 Z_{ia}^{D, *} Z_{ja}^D \right. \\ & \left. + \frac{i}{4} g_2^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^3 Z_{ia}^{D, *} Z_{ja}^D - \frac{i}{9} g_1^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^3 Z_{i3+a}^{D, *} Z_{j3+a}^D \right) (g_{\mu\nu}) \end{aligned} \quad (365)$$



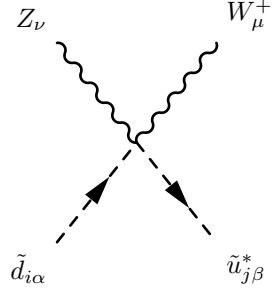
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 V_{ba}^{CKM,*} Z_{ia}^{D,*} Z_{jb}^U (g_{\mu\nu}) \quad (366)$$



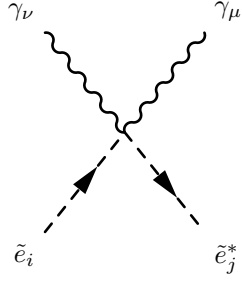
$$\frac{i}{2} g_2^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D (g_{\mu\nu}) \quad (367)$$



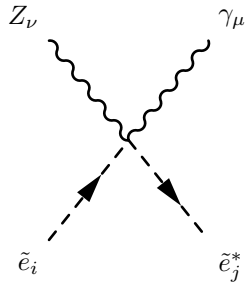
$$\begin{aligned} & \left(+ \frac{i}{2} g_2^2 \cos \Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D + \frac{i}{3} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right. \\ & \left. + \frac{i}{18} g_1^2 \delta_{\alpha\beta} \sin \Theta_W^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D + \frac{2i}{9} g_1^2 \delta_{\alpha\beta} \sin \Theta_W^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \end{aligned} \quad (368)$$



$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1g_2\delta_{\alpha\beta}\sin\Theta_W\sum_{b=1}^3\sum_{a=1}^3V_{ba}^{CKM,*}Z_{ia}^{D,*}Z_{jb}^U(g_{\mu\nu}) \quad (369)$$

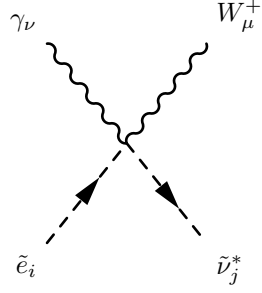


$$\begin{aligned} & \left(+\frac{i}{2}g_1^2\cos\Theta_W^2\sum_{a=1}^3Z_{ia}^{E,*}Z_{ja}^E + ig_1g_2\cos\Theta_W\sin\Theta_W\sum_{a=1}^3Z_{ia}^{E,*}Z_{ja}^E \right. \\ & \left. +\frac{i}{2}g_2^2\sin\Theta_W^2\sum_{a=1}^3Z_{ia}^{E,*}Z_{ja}^E + 2ig_1^2\cos\Theta_W^2\sum_{a=1}^3Z_{i3+a}^{E,*}Z_{j3+a}^E \right)(g_{\mu\nu}) \end{aligned} \quad (370)$$

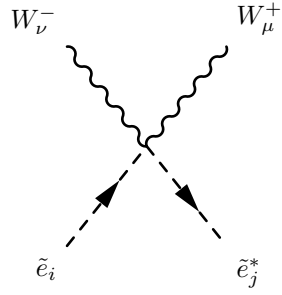


$$\left(+\frac{i}{2}g_1g_2\cos 2\Theta_W\sum_{a=1}^3Z_{ia}^{E,*}Z_{ja}^E - \frac{i}{4}g_1^2\sin 2\Theta_W\sum_{a=1}^3Z_{ia}^{E,*}Z_{ja}^E \right)$$

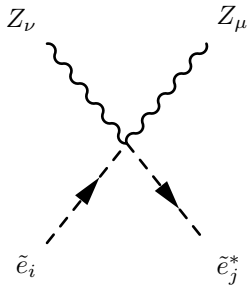
$$+ \frac{i}{4} g_2^2 \sin 2\Theta_W \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E - i g_1^2 \sin 2\Theta_W \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \Big(g_{\mu\nu} \Big) \quad (371)$$



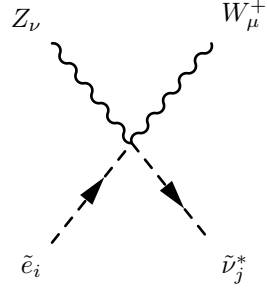
$$- i \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 U_{L,ba}^{e,*} Z_{ja}^V \Big(g_{\mu\nu} \Big) \quad (372)$$



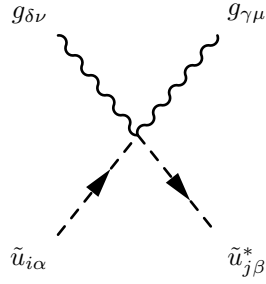
$$\frac{i}{2} g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \Big(g_{\mu\nu} \Big) \quad (373)$$



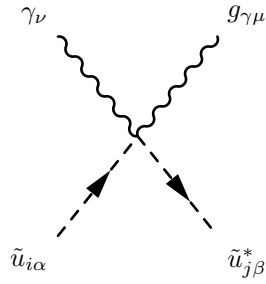
$$\begin{aligned}
& \left(+\frac{i}{2}g_2^2 \cos \Theta_W^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E - ig_1 g_2 \cos \Theta_W \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. + \frac{i}{2}g_1^2 \sin \Theta_W^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E + 2ig_1^2 \sin \Theta_W^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu})
\end{aligned} \tag{374}$$



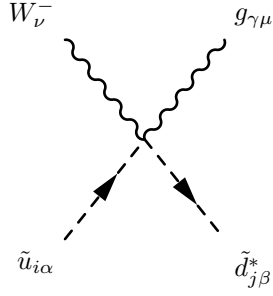
$$i \frac{1}{\sqrt{2}} g_1 g_2 \sin \Theta_W \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 U_{L,ba}^{e,*} Z_{ja}^V (g_{\mu\nu}) \tag{375}$$



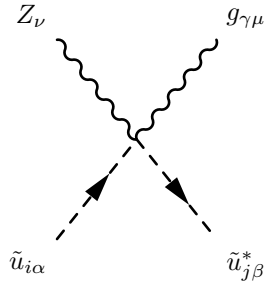
$$\left(\frac{i}{4} g_3^2 \delta_{ij} \sum_{a=1}^3 \lambda_{a,\alpha}^\gamma \lambda_{\beta,a}^\delta + \frac{i}{4} g_3^2 \delta_{ij} \sum_{a=1}^3 \lambda_{\beta,a}^\gamma \lambda_{a,\alpha}^\delta \right) (g_{\mu\nu}) \tag{376}$$



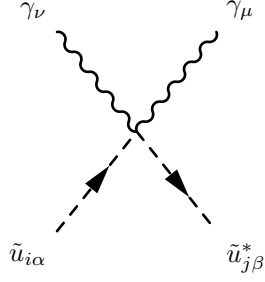
$$\begin{aligned}
& \left(+ \frac{i}{6} g_1 g_3 \cos \Theta_W \lambda_{\beta, \alpha}^\gamma \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + \frac{i}{2} g_2 g_3 \lambda_{\beta, \alpha}^\gamma \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\
& \left. + \frac{2i}{3} g_1 g_3 \cos \Theta_W \lambda_{\beta, \alpha}^\gamma \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu})
\end{aligned} \tag{377}$$



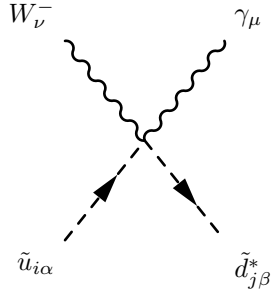
$$i \frac{1}{\sqrt{2}} g_2 g_3 \lambda_{\beta, \alpha}^\gamma \sum_{b=1}^3 \sum_{a=1}^3 V_{ab}^{CKM} Z_{ia}^{U,*} Z_{jb}^D (g_{\mu\nu}) \tag{378}$$



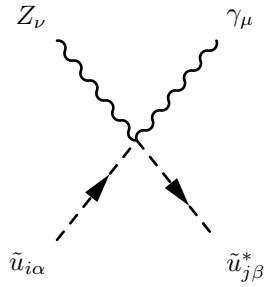
$$\begin{aligned}
& \left(+ \frac{i}{2} g_2 g_3 \cos \Theta_W \lambda_{\beta, \alpha}^\gamma \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U - \frac{i}{6} g_1 g_3 \lambda_{\beta, \alpha}^\gamma \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\
& \left. - \frac{2i}{3} g_1 g_3 \lambda_{\beta, \alpha}^\gamma \sin \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu})
\end{aligned} \tag{379}$$



$$\begin{aligned}
& \left(+ \frac{i}{18} g_1^2 \cos \Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + \frac{i}{3} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\
& \left. + \frac{i}{2} g_2^2 \delta_{\alpha\beta} \sin \Theta_W^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + \frac{8i}{9} g_1^2 \cos \Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu})
\end{aligned} \tag{380}$$

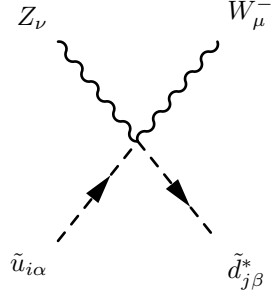


$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 V_{ab}^{CKM} Z_{ia}^{U,*} Z_{jb}^D (g_{\mu\nu}) \tag{381}$$

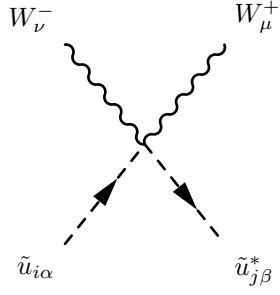


$$\left(+ \frac{i}{6} g_1 g_2 \cos 2\Theta_W \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U - \frac{i}{36} g_1^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right)$$

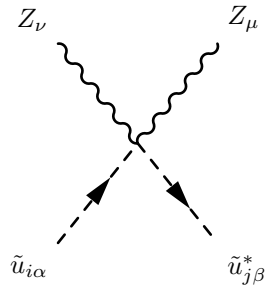
$$+ \frac{i}{4} g_2^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U - \frac{4i}{9} g_1^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \Big) (g_{\mu\nu}) \quad (382)$$



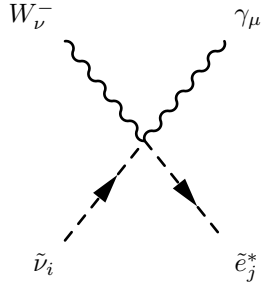
$$- \frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \delta_{\alpha\beta} \sin \Theta_W \sum_{b=1}^3 \sum_{a=1}^3 V_{ab}^{CKM} Z_{ia}^{U,*} Z_{jb}^D \Big) (g_{\mu\nu}) \quad (383)$$



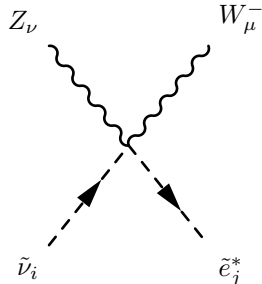
$$\frac{i}{2} g_2^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \Big) (g_{\mu\nu}) \quad (384)$$



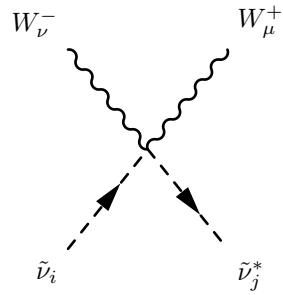
$$\begin{aligned}
& \left(+ \frac{i}{2} g_2^2 \cos \Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U - \frac{i}{3} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sin \Theta_W \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\
& \left. + \frac{i}{18} g_1^2 \delta_{\alpha\beta} \sin \Theta_W^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + \frac{8i}{9} g_1^2 \delta_{\alpha\beta} \sin \Theta_W^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu})
\end{aligned} \tag{385}$$



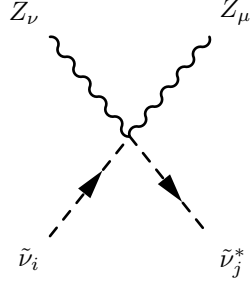
$$- i \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \sum_{b=1}^3 \sum_{a=1}^3 Z_{ia}^{V,*} U_{L,ba}^e Z_{jb}^E (g_{\mu\nu}) \tag{386}$$



$$i \frac{1}{\sqrt{2}} g_1 g_2 \sin \Theta_W \sum_{b=1}^3 \sum_{a=1}^3 Z_{ia}^{V,*} U_{L,ba}^e Z_{jb}^E (g_{\mu\nu}) \tag{387}$$

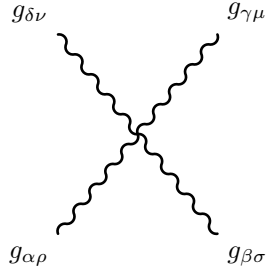


$$\frac{i}{2}g_2^2\delta_{ij}\left(g_{\mu\nu}\right) \quad (388)$$



$$\left(\frac{i}{2}g_1^2\delta_{ij}\sin\Theta_W^2 + \frac{i}{2}g_2^2\cos\Theta_W^2\delta_{ij} + ig_1g_2\cos\Theta_W\delta_{ij}\sin\Theta_W\right)\left(g_{\mu\nu}\right) \quad (389)$$

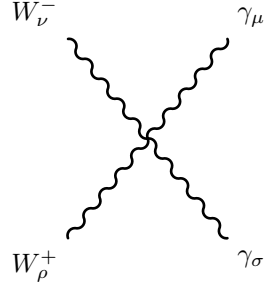
8.9 Four Vector Boson-Interaction



$$ig_3^2\left(-\sum_{a=1}^8f_{\alpha,\delta,a}f_{\beta,\gamma,a}-\sum_{a=1}^8f_{\alpha,\gamma,a}f_{\beta,\delta,a}\right)\left(g_{\rho\sigma}g_{\mu\nu}\right) \quad (390)$$

$$+ig_3^2\left(-\sum_{a=1}^8f_{\alpha,\beta,a}f_{\gamma,\delta,a}+\sum_{a=1}^8f_{\alpha,\delta,a}f_{\beta,\gamma,a}\right)\left(g_{\rho\mu}g_{\sigma\nu}\right) \quad (391)$$

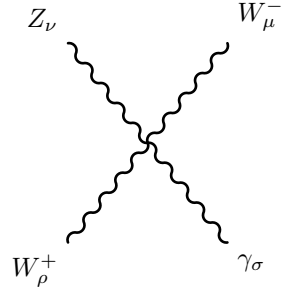
$$+ig_3^2\left(\sum_{a=1}^8f_{\alpha,\gamma,a}f_{\beta,\delta,a}+\sum_{a=1}^8f_{\alpha,\beta,a}f_{\gamma,\delta,a}\right)\left(g_{\rho\nu}g_{\sigma\mu}\right) \quad (392)$$



$$ig_2^2 \sin \Theta_W^2 (g_{\rho\sigma} g_{\mu\nu}) \quad (393)$$

$$+ ig_2^2 \sin \Theta_W^2 (g_{\rho\mu} g_{\sigma\nu}) \quad (394)$$

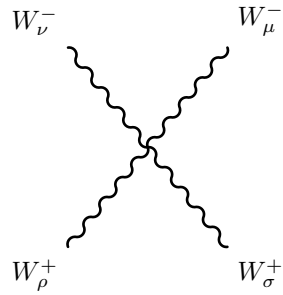
$$+ -2ig_2^2 \sin \Theta_W^2 (g_{\rho\nu} g_{\sigma\mu}) \quad (395)$$



$$\frac{i}{2} g_2^2 \sin 2\Theta_W (g_{\rho\sigma} g_{\mu\nu}) \quad (396)$$

$$+ -ig_2^2 \sin 2\Theta_W (g_{\rho\mu} g_{\sigma\nu}) \quad (397)$$

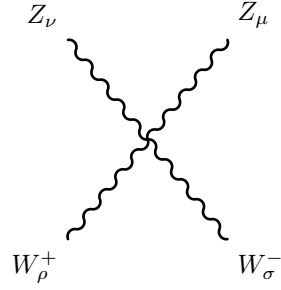
$$+ \frac{i}{2} g_2^2 \sin 2\Theta_W (g_{\rho\nu} g_{\sigma\mu}) \quad (398)$$



$$2ig_2^2(g_{\rho\sigma}g_{\mu\nu}) \quad (399)$$

$$+ -ig_2^2(g_{\rho\mu}g_{\sigma\nu}) \quad (400)$$

$$+ -ig_2^2(g_{\rho\nu}g_{\sigma\mu}) \quad (401)$$

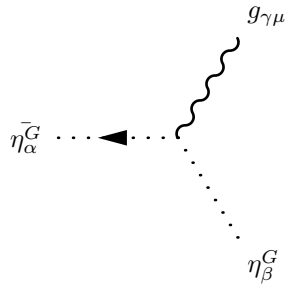


$$- 2ig_2^2 \cos \Theta_W^2 (g_{\rho\sigma}g_{\mu\nu}) \quad (402)$$

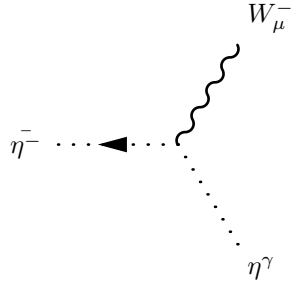
$$+ ig_2^2 \cos \Theta_W^2 (g_{\rho\mu}g_{\sigma\nu}) \quad (403)$$

$$+ ig_2^2 \cos \Theta_W^2 (g_{\rho\nu}g_{\sigma\mu}) \quad (404)$$

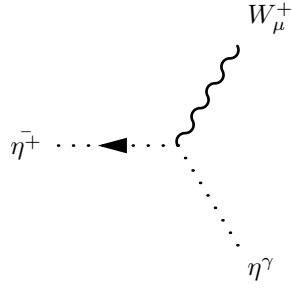
8.10 Two Ghosts-One Vector Boson-Interaction



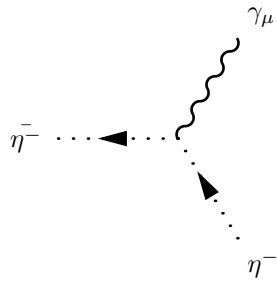
$$g_3 f_{\alpha,\beta,\gamma} (p_\mu^{\eta_\beta^G}) \quad (405)$$



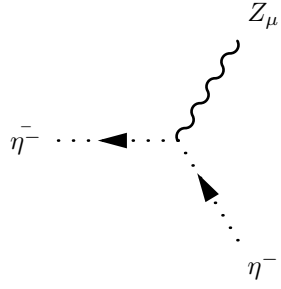
$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^\gamma} \right) \quad (406)$$



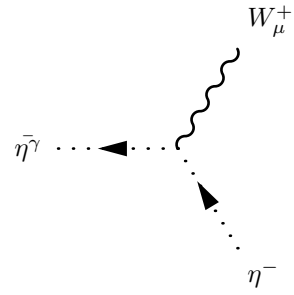
$$- ig_2 \sin \Theta_W \left(p_\mu^{\eta^\gamma} \right) \quad (407)$$



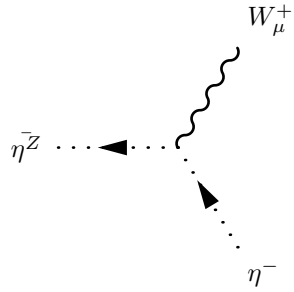
$$- ig_2 \sin \Theta_W \left(p_\mu^{\eta^-} \right) \quad (408)$$



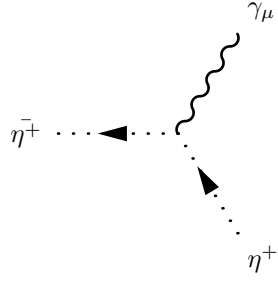
$$-ig_2 \cos \Theta_W (p_\mu^{\eta^-}) \quad (409)$$



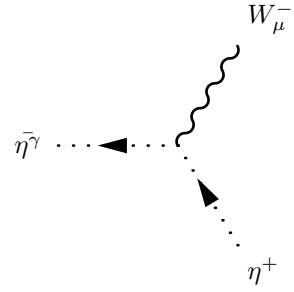
$$ig_2 \sin \Theta_W (p_\mu^{\eta^-}) \quad (410)$$



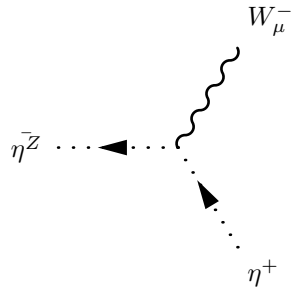
$$ig_2 \cos \Theta_W (p_\mu^{\eta^-}) \quad (411)$$



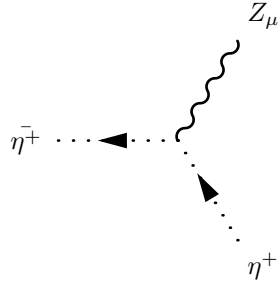
$$ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (412)$$



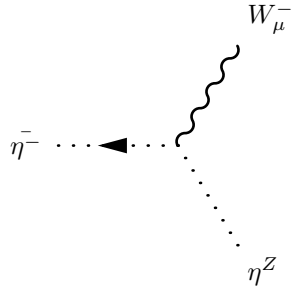
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (413)$$



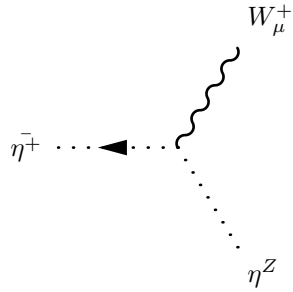
$$-ig_2 \cos \Theta_W (p_\mu^{\eta^+}) \quad (414)$$



$$ig_2 \cos \Theta_W (p_\mu^{\eta^+}) \quad (415)$$

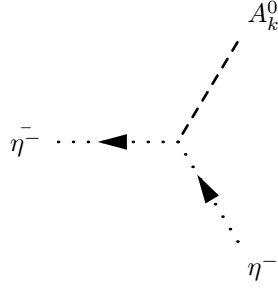


$$ig_2 \cos \Theta_W (p_\mu^{\eta^Z}) \quad (416)$$

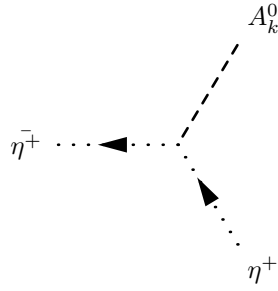


$$-ig_2 \cos \Theta_W (p_\mu^{\eta^Z}) \quad (417)$$

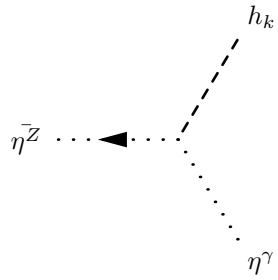
8.11 Two Ghosts-One Scalar-Interaction



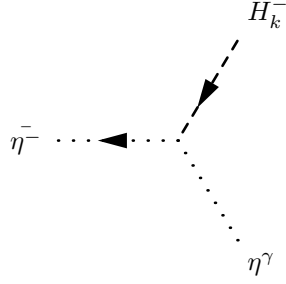
$$\frac{1}{4}g_2^2\xi_{W^-}\left(v_dZ_{k1}^A-v_uZ_{k2}^A\right) \quad (418)$$



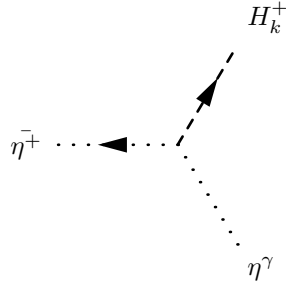
$$-\frac{1}{4}g_2^2\xi_{W^-}\left(v_dZ_{k1}^A-v_uZ_{k2}^A\right) \quad (419)$$



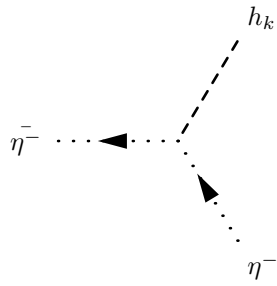
$$\frac{i}{8}\xi_Z\left(2g_1g_2\cos 2\Theta_W+\left(-g_2^2+g_1^2\right)\sin 2\Theta_W\right)\left(v_dZ_{k1}^H+v_uZ_{k2}^H\right) \quad (420)$$



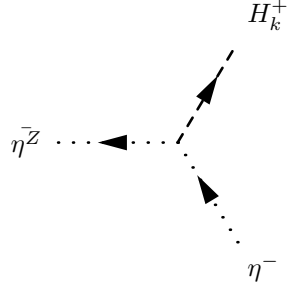
$$\frac{i}{4} g_2 \xi_{W^-} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left(v_d Z_{k1}^+ - v_u Z_{k2}^+ \right) \quad (421)$$



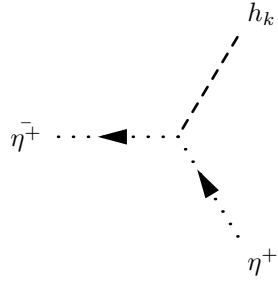
$$\frac{i}{4} g_2 \xi_{W^-} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left(v_d Z_{k1}^+ - v_u Z_{k2}^+ \right) \quad (422)$$



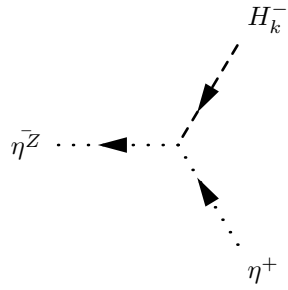
$$-\frac{i}{4} g_2^2 \xi_{W^-} \left(v_d Z_{k1}^H + v_u Z_{k2}^H \right) \quad (423)$$



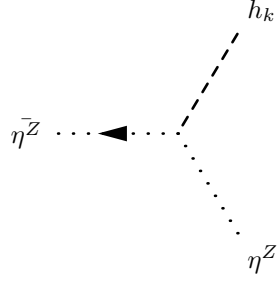
$$-\frac{i}{4}g_2\xi_Z\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(v_dZ_{k1}^+-v_uZ_{k2}^+\right) \quad (424)$$



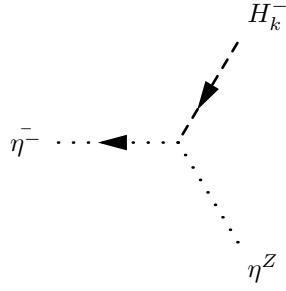
$$-\frac{i}{4}g_2^2\xi_{W^-}\left(v_dZ_{k1}^H+v_uZ_{k2}^H\right) \quad (425)$$



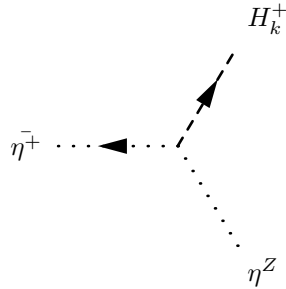
$$-\frac{i}{4}g_2\xi_Z\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(v_dZ_{k1}^+-v_uZ_{k2}^+\right) \quad (426)$$



$$-\frac{i}{4}\xi_Z\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)^2\left(v_dZ_{k1}^H+v_uZ_{k2}^H\right) \quad (427)$$



$$\frac{i}{4}g_2\xi_{W-}\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(v_dZ_{k1}^+-v_uZ_{k2}^+\right) \quad (428)$$



$$\frac{i}{4}g_2\xi_{W-}\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(v_dZ_{k1}^+-v_uZ_{k2}^+\right) \quad (429)$$

9 Clebsch-Gordan Coefficients