MSSM with color sextets
Superpotential, Rotations and Interactions for eigenstates 'EWSB' including Renormalization Group Equations

SARAH 4.6.0

November 19, 2015

References: **arXiv: 1309.7223** , **Comput.Phys.Commun.184:1792-1809,2011 (1207.0906)** , **Comput.Phys.Commun.182:833,2011 (1002.0840)** , **Comput.Phys.Commun.181:1077-1086,2010 (0909.2863)** , **arXiv: 0806.0538**
Package Homepage: projects.hepforge.org/sarah/
by **Florian Staub, florian.staub@cern.ch**

Contents

1 Superfields

1.1 Vector Superfields

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

1.2 Chiral Superfields

SF	Spin 0	Spin $\frac{1}{2}$	Generations	$(U(1) \otimes \mathrm{SU}(2) \otimes \mathrm{SU}(3))$
$\hat{q}$	$\tilde{q}$	q	3	$(\frac{1}{6}, \mathbf{2}, \mathbf{3})$
$\hat{l}$	$\tilde{l}$	l	3	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1})$
$\hat{H}_d$	H_d	$\tilde{H}_d$	1	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1})$
$\hat{H}_u$	H_u	$\tilde{H}_u$	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1})$
$\hat{d}$	$\tilde{d}^*_R$	d^*_R	3	$(\frac{1}{3}, \mathbf{1}, \overline{\mathbf{3}})$
$\hat{u}$	$\tilde{u}^*_R$	u^*_R	3	$(-\frac{2}{3}, \mathbf{1}, \overline{\mathbf{3}})$
$\hat{e}$	$\tilde{e}^*_R$	e^*_R	3	$(1, \mathbf{1}, \mathbf{1})$
$\mathrm{SF}\Big(\mathrm{six1}\Big)$	$\tilde{\Psi}$	FS1	1	$(\frac{1}{3}, \mathbf{1}, \mathbf{6})$
$\mathrm{SF}\Big(\mathrm{six2}\Big)$	$\tilde{\bar{\Psi}}$	FS2	1	$(-\frac{1}{3}, \mathbf{1}, \overline{\mathbf{6}})$

2 Superpotential and Lagrangian

2.1 Superpotential

$$W = \mu\, \hat{H}_u\, \hat{H}_d + M_S\, \mathrm{SF}\Big(\mathrm{six1}\Big)\, \mathrm{SF}\Big(\mathrm{six2}\Big) - Y_d\, \hat{d}\, \hat{q}\, \hat{H}_d - Y_e\, \hat{e}\, \hat{l}\, \hat{H}_d + Y_H\, \mathrm{SF}\Big(\mathrm{six1}\Big)\, \hat{u}\, \hat{d} + Y_{\bar{H}}\, \mathrm{SF}\Big(\mathrm{six2}\Big)\, \hat{q}\, \hat{q} + Y_u\, \hat{u}\, \hat{q}\, \hat{H}_u \tag{1}$$

2.2 Softbreaking terms

$$\begin{aligned}
-L_{SB,W} = &- H_d^0 H_u^0 B_\mu + H_d^- H_u^+ B_\mu + B_S \delta_{\alpha\beta} \tilde{\Psi}_\alpha \tilde{\bar{\Psi}}_\beta + \tilde{d}^*_{R,k\gamma} \tilde{u}^*_{R,j\beta} \tilde{\Psi}_\alpha K^{SU[3],6\times\bar{3}\times\bar{3}}_{\alpha,\beta,\gamma} T_{H,jk} + \tilde{d}_{L,k\gamma} \tilde{\bar{\Psi}}_\alpha \tilde{u}_{L,j\beta} K^{SU[3],\bar{6}\times 3\times 3}_{\alpha,\beta,\gamma} T_{\bar{H},jk} \\
&- \tilde{d}_{L,j\beta} \tilde{\bar{\Psi}}_\alpha \tilde{u}_{L,k\gamma} K^{SU[3],\bar{6}\times 3\times 3}_{\alpha,\beta,\gamma} T_{\bar{H},jk} + H_d^0 \tilde{d}^*_{R,i\alpha} \delta_{\alpha\beta} \tilde{d}_{L,j\beta} T_{d,ij} - H_d^- \tilde{d}^*_{R,i\alpha} \delta_{\alpha\beta} \tilde{u}_{L,j\beta} T_{d,ij} \\
&+ H_d^0 \tilde{e}^*_{R,i} \tilde{e}_{L,j} T_{e,ij} - H_d^- \tilde{e}^*_{R,i} \tilde{\nu}_{L,j} T_{e,ij} - H_u^+ \tilde{u}^*_{R,i\alpha} \delta_{\alpha\beta} \tilde{d}_{L,j\beta} T_{u,ij} + H_u^0 \tilde{u}^*_{R,i\alpha} \delta_{\alpha\beta} \tilde{u}_{L,j\beta} T_{u,ij} + \mathrm{h.c.} \qquad (2) \\
-L_{SB,\phi} = &+ m^2_{H_d} |H_d^0|^2 + m^2_{H_d} |H_d^-|^2 + m^2_{H_u} |H_u^0|^2 + m^2_{H_u} |H_u^+|^2 + \tilde{d}^*_{L,i\alpha} \delta_{\alpha\beta} m^2_{q,ij} \tilde{d}_{L,j\beta} \\
&+ \tilde{d}^*_{R,i\alpha} \delta_{\alpha\beta} m^2_{d,ij} \tilde{d}_{R,j\beta} + \tilde{e}^*_{L,i} m^2_{l,ij} \tilde{e}_{L,j} + \tilde{e}^*_{R,i} m^2_{e,ij} \tilde{e}_{R,j} + m^2_S \tilde{\Psi}^*_\alpha \delta_{\alpha\beta} \tilde{\Psi}_\beta + m^2_{\bar{S}} \tilde{\bar{\Psi}}^*_\alpha \delta_{\alpha\beta} \tilde{\bar{\Psi}}_\beta \\
&+ \tilde{u}^*_{L,i\alpha} \delta_{\alpha\beta} m^2_{q,ij} \tilde{u}_{L,j\beta} + \tilde{u}^*_{R,i\alpha} \delta_{\alpha\beta} m^2_{u,ij} \tilde{u}_{R,j\beta} + \tilde{\nu}^*_{L,i} m^2_{l,ij} \tilde{\nu}_{L,j} \qquad (3)
\end{aligned}$$

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

2.3 Gauge fixing terms

2.3.1 Gauge fixing terms for eigenstates 'GaugeES'

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

2.3.2 Gauge fixing terms for eigenstates 'EWSB'

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

2.4 Fields integrated out

None

3 Renormalization Group Equations

3.1 Anomalous Dimensions

$$\gamma_{\hat{q}}^{(1)} = -8 Y_{\bar{H}}^* Y_{\bar{H}} - \frac{1}{30}\Big(45 g_2^2 + 80 g_3^2 + g_1^2\Big)\mathbf{1} + Y_d^\dagger Y_d + Y_u^\dagger Y_u \tag{7}$$

$$\begin{aligned} \gamma_{\hat{q}}^{(2)} = &+\Big(8 g_2^2 g_3^2 + \frac{112}{9} g_3^4 + \frac{15}{4} g_2^4 + \frac{1}{90} g_1^2 \Big(16 g_3^2 + 9 g_2^2\Big) + \frac{223}{900} g_1^4\Big)\mathbf{1} + \frac{4}{5} g_1^2 Y_u^\dagger Y_u - \frac{16}{15} g_1^2 Y_{\bar{H}}^* Y_{\bar{H}} \\ &- \frac{160}{3} g_3^2 Y_{\bar{H}}^* Y_{\bar{H}} - 2 Y_d^\dagger Y_d Y_d^\dagger Y_d - 2 Y_d^\dagger Y_H^T Y_H^* Y_d - 2 Y_u^\dagger Y_H Y_H^\dagger Y_u - 2 Y_u^\dagger Y_u Y_u^\dagger Y_u \\ &- 64 Y_{\bar{H}}^* Y_{\bar{H}} Y_{\bar{H}}^* Y_{\bar{H}} + 8 Y_{\bar{H}}^* Y_d^T Y_d^* Y_{\bar{H}} + 8 Y_{\bar{H}}^* Y_u^T Y_u^* Y_{\bar{H}} - 32 Y_{\bar{H}}^* Y_{\bar{H}} \text{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big) \\ &+ Y_d^\dagger Y_d \Big(-3\text{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{2}{5} g_1^2 - \text{Tr}\Big(Y_e Y_e^\dagger\Big)\Big) - 3 Y_u^\dagger Y_u \text{Tr}\Big(Y_u Y_u^\dagger\Big) \end{aligned} \tag{8}$$

$$\gamma_{\hat{l}}^{(1)} = -\frac{3}{10}\Big(5 g_2^2 + g_1^2\Big)\mathbf{1} + Y_e^\dagger Y_e \tag{9}$$

$$\gamma_{\hat{l}}^{(2)} = -2 Y_e^\dagger Y_e Y_e^\dagger Y_e + \frac{3}{100}\Big(125 g_2^4 + 30 g_1^2 g_2^2 + 77 g_1^4\Big)\mathbf{1} + Y_e^\dagger Y_e \Big(-3\text{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{6}{5} g_1^2 - \text{Tr}\Big(Y_e Y_e^\dagger\Big)\Big) \tag{10}$$

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

$$\begin{aligned} \gamma_{\hat{H}_d}^{(2)} = &+\frac{231}{100} g_1^4 + \frac{9}{10} g_1^2 g_2^2 + \frac{15}{4} g_2^4 - \frac{2}{5}\Big(-40 g_3^2 + g_1^2\Big)\text{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{6}{5} g_1^2 \text{Tr}\Big(Y_e Y_e^\dagger\Big) + 24\text{Tr}\Big(Y_{\bar{H}} Y_d^\dagger Y_d Y_{\bar{H}}^*\Big) \\ &- 9\text{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 6\text{Tr}\Big(Y_d Y_d^\dagger Y_H^T Y_H^*\Big) - 3\text{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 3\text{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) \end{aligned} \tag{12}$$

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

$$\gamma^{(2)}_{\hat{H}_u} = +\frac{231}{100}g_1^4 + \frac{9}{10}g_1^2g_2^2 + \frac{15}{4}g_2^4 + \frac{4}{5}\Big(20g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 6\mathrm{Tr}\Big(Y_HY_H^\dagger Y_uY_u^\dagger\Big)$$
$$+ 24\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*\Big) - 3\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 9\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big) \tag{14}$$

$$\gamma^{(1)}_{\hat{d}} = 2\Big(Y_H^\dagger Y_H + Y_d^*Y_d^T\Big) - \frac{2}{15}\Big(20g_3^2 + g_1^2\Big)\mathbf{1} \tag{15}$$

$$\gamma^{(2)}_{\hat{d}} = +\frac{2}{225}\Big(113g_1^4 + 1400g_3^4 + 80g_1^2g_3^2\Big)\mathbf{1} + \frac{2}{5}g_1^2Y_d^*Y_d^T + 6g_2^2Y_d^*Y_d^T - 4Y_H^\dagger Y_HY_H^\dagger Y_H$$
$$- 4Y_H^\dagger Y_uY_u^\dagger Y_H + 16Y_d^*Y_{\bar{H}}Y_{\bar{H}}^*Y_d^T - 2Y_d^*Y_d^TY_d^*Y_d^T - 2Y_d^*Y_u^TY_u^*Y_d^T$$
$$+ \frac{2}{15}Y_H^\dagger Y_H\Big(100g_3^2 - 15\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) + 8g_1^2\Big) - 6Y_d^*Y_d^T\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 2Y_d^*Y_d^T\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) \tag{16}$$

$$\gamma^{(1)}_{\hat{u}} = 2\Big(Y_H^*Y_H^T + Y_u^*Y_u^T\Big) - \frac{8}{15}\Big(5g_3^2 + g_1^2\Big)\mathbf{1} \tag{17}$$

$$\gamma^{(2)}_{\hat{u}} = +\frac{8}{225}\Big(119g_1^4 + 350g_3^4 + 80g_1^2g_3^2\Big)\mathbf{1} - \frac{2}{5}g_1^2Y_u^*Y_u^T + 6g_2^2Y_u^*Y_u^T - 4Y_H^*Y_dY_d^\dagger Y_H^T$$
$$- 4Y_H^*Y_H^TY_H^*Y_H^T + 16Y_u^*Y_{\bar{H}}Y_{\bar{H}}^*Y_u^T - 2Y_u^*Y_d^TY_d^*Y_u^T - 2Y_u^*Y_u^TY_u^*Y_u^T$$
$$+ Y_H^*Y_H^T\Big(- 2\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) + \frac{40}{3}g_3^2 - \frac{8}{15}g_1^2\Big) - 6Y_u^*Y_u^T\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \tag{18}$$

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

$$\gamma^{(2)}_{\hat{e}} = -2Y_e^*Y_e^TY_e^*Y_e^T + \frac{258}{25}g_1^4\mathbf{1} + Y_e^*Y_e^T\Big(- 2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 6g_2^2 - 6\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - \frac{6}{5}g_1^2\Big) \tag{20}$$

$$\gamma^{(1)}_{\mathrm{SF}\left(\mathrm{six1}\right)} = -\frac{2}{15}\Big(50g_3^2 + g_1^2\Big) + \mathrm{Tr}\Big(Y_HY_H^\dagger\Big) \tag{21}$$

$$\gamma^{(2)}_{\mathrm{SF}\left(\mathrm{six1}\right)} = +\frac{226}{225}g_1^4 + \frac{16}{9}g_1^2g_3^2 + \frac{520}{9}g_3^4 + \frac{4}{15}\Big(2g_1^2 - 5g_3^2\Big)\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) - 4\mathrm{Tr}\Big(Y_HY_H^\dagger Y_HY_H^\dagger\Big) - 2\mathrm{Tr}\Big(Y_HY_H^\dagger Y_uY_u^\dagger\Big)$$
$$- 2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_H^TY_H^*\Big) \tag{22}$$

$$\gamma^{(1)}_{\mathrm{SF}\left(\mathrm{six2}\right)} = -\frac{2}{15}\Big(30\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big) + 50g_3^2 + g_1^2\Big) \tag{23}$$

$$\gamma^{(2)}_{\mathrm{SF}\left(\mathrm{six2}\right)} = +\frac{226}{225}g_1^4 + \frac{16}{9}g_1^2g_3^2 + \frac{520}{9}g_3^4 + \frac{4}{15}\Big(20g_3^2 - 45g_2^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big) + 8\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big)$$
$$+ 8\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*\Big) - 64\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*\Big) \tag{24}$$

3.2 Gauge Couplings

$$\beta^{(1)}_{g_1} = \frac{37}{5}g_1^3 \tag{25}$$

$$\beta^{(2)}_{g_1} = \frac{1}{75}g_1^3\Big(613g_1^2 + 405g_2^2 + 2120g_3^2 - 360\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) + 360\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big) - 210\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 270\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)$$

$$- 390\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\Big) \tag{26}$$

$$\beta_{g_2}^{(1)} = g_2^3 \tag{27}$$

$$\beta_{g_2}^{(2)} = \frac{1}{5}g_2^3\Big(- 10\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 120g_3^2 + 120\mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big) + 125g_2^2 - 30\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 30\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 9g_1^2\Big) \tag{28}$$

$$\beta_{g_3}^{(1)} = 2g_3^3 \tag{29}$$

$$\beta_{g_3}^{(2)} = \frac{1}{15}g_3^3\Big(135g_2^2 - 135\mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) + 1660g_3^2 + 53g_1^2 + 540\mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big) - 60\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 60\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)\Big) \tag{30}$$

3.3 Gaugino Mass Parameters

$$\beta_{M_1}^{(1)} = \frac{74}{5}g_1^2 M_1 \tag{31}$$

$$\begin{aligned}\beta_{M_1}^{(2)} = \frac{2}{75}g_1^2\Big(&1226g_1^2M_1 + 405g_2^2M_1 + 2120g_3^2M_1 + 2120g_3^2M_3 + 405g_2^2M_2 - 360M_1\mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) + 360M_1\mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big)\\ &- 210M_1\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 270M_1\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 390M_1\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 360\mathrm{Tr}\Big(Y_H^\dagger T_H\Big) + 210\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)\\ &+ 270\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 390\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - 360\mathrm{Tr}\Big(Y_{\bar{H}}^* T_{\bar{H}}\Big)\Big)\end{aligned} \tag{32}$$

$$\beta_{M_2}^{(1)} = 2g_2^2 M_2 \tag{33}$$

$$\begin{aligned}\beta_{M_2}^{(2)} = \frac{2}{5}g_2^2\Big(&9g_1^2M_1 + 120g_3^2M_3 + 9g_1^2M_2 + 250g_2^2M_2 + 120g_3^2M_2 + 120M_2\mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big) - 30M_2\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big)\\ &- 10M_2\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 30M_2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 30\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + 10\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 30\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - 120\mathrm{Tr}\Big(Y_{\bar{H}}^* T_{\bar{H}}\Big)\Big)\end{aligned} \tag{34}$$

$$\beta_{M_3}^{(1)} = 4g_3^2 M_3 \tag{35}$$

$$\begin{aligned}\beta_{M_3}^{(2)} = \frac{2}{15}g_3^2\Big(&53g_1^2M_1 + 53g_1^2M_3 + 135g_2^2M_3 + 3320g_3^2M_3 + 135g_2^2M_2 - 135M_3\mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) + 540M_3\mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big)\\ &- 60M_3\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 60M_3\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 135\mathrm{Tr}\Big(Y_H^\dagger T_H\Big) + 60\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + 60\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - 540\mathrm{Tr}\Big(Y_{\bar{H}}^* T_{\bar{H}}\Big)\Big)\end{aligned} \tag{36}$$

3.4 Trilinear Superpotential Parameters

$$\begin{aligned}\beta_{Y_d}^{(1)} = &+3Y_d Y_d^\dagger Y_d + Y_d Y_u^\dagger Y_u - 8Y_d Y_{\bar{H}}^* Y_{\bar{H}} + 2Y_H^T Y_H^* Y_d\\ &+ Y_d\Big(- 3g_2^2 + 3\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - \frac{16}{3}g_3^2 - \frac{7}{15}g_1^2 + \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)\Big)\end{aligned} \tag{37}$$

$$\begin{aligned}\beta_{Y_d}^{(2)} = &+\frac{4}{5}g_1^2 Y_d Y_u^\dagger Y_u - \frac{16}{15}g_1^2 Y_d Y_{\bar{H}}^* Y_{\bar{H}} - \frac{160}{3}g_3^2 Y_d Y_{\bar{H}}^* Y_{\bar{H}} + \frac{16}{15}g_1^2 Y_H^T Y_H^* Y_d\\ &+ \frac{40}{3}g_3^2 Y_H^T Y_H^* Y_d - 4Y_d Y_d^\dagger Y_d Y_d^\dagger Y_d - 2Y_d Y_d^\dagger Y_H^T Y_H^* Y_d - 2Y_d Y_u^\dagger Y_H Y_H^\dagger Y_u\\ &- 2Y_d Y_u^\dagger Y_u Y_d^\dagger Y_d - 2Y_d Y_u^\dagger Y_u Y_u^\dagger Y_u + 16Y_d Y_{\bar{H}}^* Y_{\bar{H}} Y_d^\dagger Y_d - 64Y_d Y_{\bar{H}}^* Y_{\bar{H}} Y_{\bar{H}}^* Y_{\bar{H}}\end{aligned}$$

$$
\begin{aligned}
&+8Y_dY_{\bar{H}}^*Y_d^TY_d^*Y_{\bar{H}}+8Y_dY_{\bar{H}}^*Y_u^TY_u^*Y_{\bar{H}}-4Y_H^TY_H^*Y_H^TY_H^*Y_d-4Y_H^TY_u^*Y_u^TY_H^*Y_d\\
&-2Y_H^TY_H^*Y_dTr\Big(Y_HY_H^\dagger\Big)-32Y_dY_{\bar{H}}^*Y_{\bar{H}}Tr\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)\\
&+Y_dY_d^\dagger Y_d\Big(-3Tr\Big(Y_eY_e^\dagger\Big)+6g_2^2-9Tr\Big(Y_dY_d^\dagger\Big)+\frac{4}{5}g_1^2\Big)-3Y_dY_u^\dagger Y_uTr\Big(Y_uY_u^\dagger\Big)\\
&+Y_d\Big(\frac{1603}{450}g_1^4+g_1^2g_2^2+\frac{15}{2}g_2^4+\frac{8}{9}g_1^2g_3^2+8g_2^2g_3^2+\frac{224}{9}g_3^4-\frac{2}{5}\Big(-40g_3^2+g_1^2\Big)Tr\Big(Y_dY_d^\dagger\Big)\\
&+\frac{6}{5}g_1^2Tr\Big(Y_eY_e^\dagger\Big)+24Tr\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big)-9Tr\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)-6Tr\Big(Y_dY_d^\dagger Y_H^TY_H^*\Big)\\
&-3Tr\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)-3Tr\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\Big) \qquad (38)
\end{aligned}
$$

$$
\beta_{Y_e}^{(1)}=3Y_eY_e^\dagger Y_e+Y_e\Big(-3g_2^2+3Tr\Big(Y_dY_d^\dagger\Big)-\frac{9}{5}g_1^2+Tr\Big(Y_eY_e^\dagger\Big)\Big) \qquad (39)
$$

$$
\begin{aligned}
\beta_{Y_e}^{(2)}=&-4Y_eY_e^\dagger Y_eY_e^\dagger Y_e+Y_eY_e^\dagger Y_e\Big(-3Tr\Big(Y_eY_e^\dagger\Big)+6g_2^2-9Tr\Big(Y_dY_d^\dagger\Big)\Big)\\
&+Y_e\Big(\frac{747}{50}g_1^4+\frac{9}{5}g_1^2g_2^2+\frac{15}{2}g_2^4-\frac{2}{5}\Big(-40g_3^2+g_1^2\Big)Tr\Big(Y_dY_d^\dagger\Big)+\frac{6}{5}g_1^2Tr\Big(Y_eY_e^\dagger\Big)+24Tr\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big)\\
&-9Tr\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)-6Tr\Big(Y_dY_d^\dagger Y_H^TY_H^*\Big)-3Tr\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)-3Tr\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\Big) \qquad (40)
\end{aligned}
$$

$$
\beta_{Y_H}^{(1)}=2\Big(2Y_HY_H^\dagger Y_H+Y_HY_d^*Y_d^T+Y_uY_u^\dagger Y_H\Big)+Y_H\Big(-\frac{4}{5}\Big(15g_3^2+g_1^2\Big)+Tr\Big(Y_HY_H^\dagger\Big)\Big) \qquad (41)
$$

$$
\begin{aligned}
\beta_{Y_H}^{(2)}=&+\frac{2}{5}g_1^2Y_HY_d^*Y_d^T+6g_2^2Y_HY_d^*Y_d^T-\frac{2}{5}g_1^2Y_uY_u^\dagger Y_H+6g_2^2Y_uY_u^\dagger Y_H\\
&-8Y_HY_H^\dagger Y_HY_H^\dagger Y_H-4Y_HY_H^\dagger Y_uY_u^\dagger Y_H+16Y_HY_d^*Y_{\bar{H}}Y_{\bar{H}}^*Y_d^T-4Y_HY_d^*Y_d^TY_H^\dagger Y_H\\
&-2Y_HY_d^*Y_d^TY_d^*Y_d^T-2Y_HY_d^*Y_u^TY_u^*Y_d^T-2Y_uY_d^\dagger Y_dY_u^\dagger Y_H-2Y_uY_u^\dagger Y_uY_u^\dagger Y_H\\
&+16Y_uY_{\bar{H}}^*Y_{\bar{H}}Y_u^\dagger Y_H+Y_HY_H^\dagger Y_H\Big(-4Tr\Big(Y_HY_H^\dagger\Big)+\frac{8}{15}\Big(50g_3^2+g_1^2\Big)\Big)-6Y_HY_d^*Y_d^TTr\Big(Y_dY_d^\dagger\Big)\\
&-2Y_HY_d^*Y_d^TTr\Big(Y_eY_e^\dagger\Big)-6Y_uY_u^\dagger Y_HTr\Big(Y_uY_u^\dagger\Big)\\
&+\frac{2}{75}Y_H\Big(234g_1^4+200g_1^2g_3^2+3100g_3^4+10\Big(2g_1^2-5g_3^2\Big)Tr\Big(Y_HY_H^\dagger\Big)-150Tr\Big(Y_HY_H^\dagger Y_HY_H^\dagger\Big)\\
&-75Tr\Big(Y_HY_H^\dagger Y_uY_u^\dagger\Big)-75Tr\Big(Y_dY_d^\dagger Y_H^TY_H^*\Big)\Big) \qquad (42)
\end{aligned}
$$

$$
\begin{aligned}
\beta_{Y_{\bar{H}}}^{(1)}=&+Y_{\bar{H}}Y_d^\dagger Y_d+Y_{\bar{H}}Y_u^\dagger Y_u-16Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}+Y_d^TY_d^*Y_{\bar{H}}+Y_u^TY_u^*Y_{\bar{H}}\\
&-\frac{1}{5}Y_{\bar{H}}\Big(15g_2^2+20Tr\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)+60g_3^2+g_1^2\Big) \qquad (43)
\end{aligned}
$$

$$
\begin{aligned}
\beta_{Y_{\bar{H}}}^{(2)}=&+\frac{4}{5}g_1^2Y_{\bar{H}}Y_u^\dagger Y_u-\frac{32}{15}g_1^2Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}-\frac{320}{3}g_3^2Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}+\frac{2}{5}g_1^2Y_d^TY_d^*Y_{\bar{H}}\\
&+\frac{4}{5}g_1^2Y_u^TY_u^*Y_{\bar{H}}-2Y_{\bar{H}}Y_d^\dagger Y_dY_d^\dagger Y_d+8Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*Y_{\bar{H}}-2Y_{\bar{H}}Y_d^\dagger Y_H^TY_H^*Y_d\\
&-2Y_{\bar{H}}Y_u^\dagger Y_HY_H^\dagger Y_u-2Y_{\bar{H}}Y_u^\dagger Y_uY_u^\dagger Y_u+8Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*Y_{\bar{H}}-128Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}\\
&+8Y_{\bar{H}}Y_{\bar{H}}^*Y_d^TY_d^*Y_{\bar{H}}+8Y_{\bar{H}}Y_{\bar{H}}^*Y_u^TY_u^*Y_{\bar{H}}-2Y_d^TY_H^\dagger Y_HY_d^*Y_{\bar{H}}-2Y_d^TY_d^*Y_d^TY_d^*Y_{\bar{H}}\\
&-2Y_u^TY_H^*Y_H^TY_u^*Y_{\bar{H}}-2Y_u^TY_u^*Y_u^TY_u^*Y_{\bar{H}}-64Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}Tr\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)
\end{aligned}
$$

$$
\begin{aligned}
&- 3Y_d^T Y_d^* Y_{\bar{H}} \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + Y_{\bar{H}} Y_d^\dagger Y_d \Big(- 3\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{2}{5} g_1^2 - \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)\Big) \\
&- Y_d^T Y_d^* Y_{\bar{H}} \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 3 Y_{\bar{H}} Y_u^\dagger Y_u \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 3 Y_u^T Y_u^* Y_{\bar{H}} \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ \frac{1}{30} Y_{\bar{H}} \Big(45 g_1^4 + 6 g_1^2 g_2^2 + 225 g_2^4 + 64 g_1^2 g_3^2 + 480 g_2^2 g_3^2 + 2480 g_3^4 + 8\Big(20 g_3^2 - 45 g_2^2 + g_1^2\Big) \mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big) \\
&+ 240 \mathrm{Tr}\Big(Y_{\bar{H}} Y_d^\dagger Y_d Y_{\bar{H}}^*\Big) + 240 \mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger Y_u Y_{\bar{H}}^*\Big) - 1920 \mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^* Y_{\bar{H}} Y_{\bar{H}}^*\Big)\Big)
\end{aligned} \tag{44}
$$

$$
\begin{aligned}
\beta_{Y_u}^{(1)} &= +2 Y_H Y_H^\dagger Y_u + Y_u Y_d^\dagger Y_d + 3 Y_u Y_u^\dagger Y_u - 8 Y_u Y_{\bar{H}}^* Y_{\bar{H}} \\
&- \frac{1}{15} Y_u \Big(13 g_1^2 + 45 g_2^2 - 45 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 80 g_3^2\Big)
\end{aligned} \tag{45}
$$

$$
\begin{aligned}
\beta_{Y_u}^{(2)} &= + \frac{2}{5} g_1^2 Y_u Y_d^\dagger Y_d + \frac{2}{5} g_1^2 Y_u Y_u^\dagger Y_u + 6 g_2^2 Y_u Y_u^\dagger Y_u - \frac{16}{15} g_1^2 Y_u Y_{\bar{H}}^* Y_{\bar{H}} \\
&- \frac{160}{3} g_3^2 Y_u Y_{\bar{H}}^* Y_{\bar{H}} - 4 Y_H Y_H^\dagger Y_H Y_H^\dagger Y_u - 4 Y_H Y_d^* Y_d^T Y_H^\dagger Y_u - 2 Y_u Y_d^\dagger Y_d Y_d^\dagger Y_d \\
&- 2 Y_u Y_d^\dagger Y_d Y_u^\dagger Y_u - 2 Y_u Y_d^\dagger Y_H^T Y_H^* Y_d - 2 Y_u Y_u^\dagger Y_H Y_H^\dagger Y_u - 4 Y_u Y_u^\dagger Y_u Y_u^\dagger Y_u \\
&+ 16 Y_u Y_{\bar{H}}^* Y_{\bar{H}} Y_u^\dagger Y_u - 64 Y_u Y_{\bar{H}}^* Y_{\bar{H}} Y_{\bar{H}}^* Y_{\bar{H}} + 8 Y_u Y_{\bar{H}}^* Y_d^T Y_d^* Y_{\bar{H}} + 8 Y_u Y_{\bar{H}}^* Y_u^T Y_u^* Y_{\bar{H}} \\
&+ Y_H Y_H^\dagger Y_u \Big(- 2 \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) + \frac{40}{3} g_3^2 - \frac{8}{15} g_1^2\Big) - 32 Y_u Y_{\bar{H}}^* Y_{\bar{H}} \mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big) \\
&- 3 Y_u Y_d^\dagger Y_d \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - Y_u Y_d^\dagger Y_d \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 9 Y_u Y_u^\dagger Y_u \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ Y_u \Big(\frac{611}{90} g_1^4 + g_1^2 g_2^2 + \frac{15}{2} g_2^4 + \frac{136}{45} g_1^2 g_3^2 + 8 g_2^2 g_3^2 + \frac{224}{9} g_3^4 + \frac{4}{5}\Big(20 g_3^2 + g_1^2\Big) \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&- 6 \mathrm{Tr}\Big(Y_H Y_H^\dagger Y_u Y_u^\dagger\Big) + 24 \mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger Y_u Y_{\bar{H}}^*\Big) - 3 \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 9 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big)
\end{aligned} \tag{46}
$$

3.5 Bilinear Superpotential Parameters

$$
\beta_\mu^{(1)} = 3\mu \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - \frac{3}{5}\mu\Big(5 g_2^2 - 5 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + g_1^2\Big) + \mu \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) \tag{47}
$$

$$
\begin{aligned}
\beta_\mu^{(2)} &= \frac{1}{50}\mu\Big(231 g_1^4 + 90 g_1^2 g_2^2 + 375 g_2^4 - 20\Big(- 40 g_3^2 + g_1^2\Big) \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 60 g_1^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 40 g_1^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ 800 g_3^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 300 \mathrm{Tr}\Big(Y_H Y_H^\dagger Y_u Y_u^\dagger\Big) + 1200 \mathrm{Tr}\Big(Y_{\bar{H}} Y_d^\dagger Y_d Y_{\bar{H}}^*\Big) + 1200 \mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger Y_u Y_{\bar{H}}^*\Big) \\
&- 450 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 300 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_H^T Y_H^*\Big) - 300 \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 150 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) \\
&- 450 \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big)
\end{aligned} \tag{48}
$$

$$
\beta_{M_S}^{(1)} = \frac{1}{15} M_S \Big(15 \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) - 4\Big(15 \mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big) + 50 g_3^2 + g_1^2\Big)\Big) \tag{49}
$$

$$
\begin{aligned}
\beta_{M_S}^{(2)} &= \frac{2}{225} M_S \Big(226 g_1^4 + 400 g_1^2 g_3^2 + 13000 g_3^4 + 30\Big(2 g_1^2 - 5 g_3^2\Big) \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) + 30\Big(20 g_3^2 - 45 g_2^2 + g_1^2\Big) \mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big) \\
&- 450 \mathrm{Tr}\Big(Y_H Y_H^\dagger Y_H Y_H^\dagger\Big) - 225 \mathrm{Tr}\Big(Y_H Y_H^\dagger Y_u Y_u^\dagger\Big) + 900 \mathrm{Tr}\Big(Y_{\bar{H}} Y_d^\dagger Y_d Y_{\bar{H}}^*\Big) + 900 \mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger Y_u Y_{\bar{H}}^*\Big)
\end{aligned}
$$

$$- 7200\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) - 225\mathrm{Tr}\Big(Y_dY_d^{\dagger}Y_H^{T}Y_H^{*}\Big)\Big) \tag{50}$$

3.6 Trilinear Soft-Breaking Parameters

$$\begin{aligned}
\beta_{T_d}^{(1)} &= +4Y_dY_d^{\dagger}T_d + 2Y_dY_u^{\dagger}T_u - 16Y_dY_{\bar{H}}^{*}T_{\bar{H}} + 5T_dY_d^{\dagger}Y_d + T_dY_u^{\dagger}Y_u - 8T_dY_{\bar{H}}^{*}Y_{\bar{H}} \\
&\quad + 2Y_H^{T}Y_H^{*}T_d + 4T_H^{T}Y_H^{*}Y_d - \frac{7}{15}g_1^2T_d - 3g_2^2T_d - \frac{16}{3}g_3^2T_d + 3T_d\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) + T_d\mathrm{Tr}\Big(Y_eY_e^{\dagger}\Big) \\
&\quad + Y_d\Big(2\mathrm{Tr}\Big(Y_e^{\dagger}T_e\Big) + 6g_2^2M_2 + 6\mathrm{Tr}\Big(Y_d^{\dagger}T_d\Big) + \frac{14}{15}g_1^2M_1 + \frac{32}{3}g_3^2M_3\Big) \qquad (51) \\
\beta_{T_d}^{(2)} &= +\frac{6}{5}g_1^2Y_dY_d^{\dagger}T_d + 6g_2^2Y_dY_d^{\dagger}T_d - \frac{8}{5}g_1^2M_1Y_dY_u^{\dagger}Y_u + \frac{8}{5}g_1^2Y_dY_u^{\dagger}T_u \\
&\quad + \frac{32}{15}g_1^2M_1Y_dY_{\bar{H}}^{*}Y_{\bar{H}} + \frac{320}{3}g_3^2M_3Y_dY_{\bar{H}}^{*}Y_{\bar{H}} - \frac{32}{15}g_1^2Y_dY_{\bar{H}}^{*}T_{\bar{H}} - \frac{320}{3}g_3^2Y_dY_{\bar{H}}^{*}T_{\bar{H}} \\
&\quad + \frac{6}{5}g_1^2T_dY_d^{\dagger}Y_d + 12g_2^2T_dY_d^{\dagger}Y_d + \frac{4}{5}g_1^2T_dY_u^{\dagger}Y_u - \frac{16}{15}g_1^2T_dY_{\bar{H}}^{*}Y_{\bar{H}} \\
&\quad - \frac{160}{3}g_3^2T_dY_{\bar{H}}^{*}Y_{\bar{H}} - \frac{32}{15}g_1^2M_1Y_H^{T}Y_H^{*}Y_d - \frac{80}{3}g_3^2M_3Y_H^{T}Y_H^{*}Y_d + \frac{16}{15}g_1^2Y_H^{T}Y_H^{*}T_d \\
&\quad + \frac{40}{3}g_3^2Y_H^{T}Y_H^{*}T_d + \frac{32}{15}g_1^2T_H^{T}Y_H^{*}Y_d + \frac{80}{3}g_3^2T_H^{T}Y_H^{*}Y_d - 6Y_dY_d^{\dagger}Y_dY_d^{\dagger}T_d \\
&\quad - 8Y_dY_d^{\dagger}T_dY_d^{\dagger}Y_d - 4Y_dY_d^{\dagger}Y_H^{T}Y_H^{*}T_d - 4Y_dY_d^{\dagger}T_H^{T}Y_H^{*}Y_d - 4Y_dY_u^{\dagger}Y_HY_H^{\dagger}T_u \\
&\quad - 2Y_dY_u^{\dagger}Y_uY_d^{\dagger}T_d - 4Y_dY_u^{\dagger}Y_uY_u^{\dagger}T_u - 4Y_dY_u^{\dagger}T_HY_H^{\dagger}Y_u \\
&\quad - 4Y_dY_u^{\dagger}T_uY_d^{\dagger}Y_d - 4Y_dY_u^{\dagger}T_uY_u^{\dagger}Y_u + 16Y_dY_{\bar{H}}^{*}Y_{\bar{H}}Y_d^{\dagger}T_d - 128Y_dY_{\bar{H}}^{*}Y_{\bar{H}}Y_{\bar{H}}^{*}T_{\bar{H}} \\
&\quad + 32Y_dY_{\bar{H}}^{*}T_{\bar{H}}Y_d^{\dagger}Y_d - 128Y_dY_{\bar{H}}^{*}T_{\bar{H}}Y_{\bar{H}}^{*}Y_{\bar{H}} + 16Y_dY_{\bar{H}}^{*}Y_d^{T}Y_d^{*}T_{\bar{H}} + 16Y_dY_{\bar{H}}^{*}Y_u^{T}Y_u^{*}T_{\bar{H}} \\
&\quad + 16Y_dY_{\bar{H}}^{*}T_d^{T}Y_d^{*}Y_{\bar{H}} + 16Y_dY_{\bar{H}}^{*}T_u^{T}Y_u^{*}Y_{\bar{H}} - 6T_dY_d^{\dagger}Y_dY_d^{\dagger}Y_d - 2T_dY_d^{\dagger}Y_H^{T}Y_H^{*}Y_d \\
&\quad - 2T_dY_u^{\dagger}Y_HY_H^{\dagger}Y_u - 4T_dY_u^{\dagger}Y_uY_d^{\dagger}Y_d - 2T_dY_u^{\dagger}Y_uY_u^{\dagger}Y_u + 32T_dY_{\bar{H}}^{*}Y_{\bar{H}}Y_d^{\dagger}Y_d \\
&\quad - 64T_dY_{\bar{H}}^{*}Y_{\bar{H}}Y_{\bar{H}}^{*}Y_{\bar{H}} + 8T_dY_{\bar{H}}^{*}Y_d^{T}Y_d^{*}Y_{\bar{H}} + 8T_dY_{\bar{H}}^{*}Y_u^{T}Y_u^{*}Y_{\bar{H}} - 4Y_H^{T}Y_H^{*}Y_H^{T}Y_H^{*}T_d \\
&\quad - 8Y_H^{T}Y_H^{*}T_H^{T}Y_H^{*}Y_d - 4Y_H^{T}Y_u^{*}Y_u^{T}Y_H^{*}T_d - 8Y_H^{T}Y_u^{*}T_u^{T}Y_H^{*}Y_d \\
&\quad - 8T_H^{T}Y_H^{*}Y_H^{T}Y_H^{*}Y_d - 8T_H^{T}Y_u^{*}Y_u^{T}Y_H^{*}Y_d + \frac{1603}{450}g_1^4T_d + g_1^2g_2^2T_d + \frac{15}{2}g_2^4T_d \\
&\quad + \frac{8}{9}g_1^2g_3^2T_d + 8g_2^2g_3^2T_d + \frac{224}{9}g_3^4T_d - 2Y_H^{T}Y_H^{*}T_d\mathrm{Tr}\Big(Y_HY_H^{\dagger}\Big) \\
&\quad - 4T_H^{T}Y_H^{*}Y_d\mathrm{Tr}\Big(Y_HY_H^{\dagger}\Big) - 64Y_dY_{\bar{H}}^{*}T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) - 32T_dY_{\bar{H}}^{*}Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) \\
&\quad - 12Y_dY_d^{\dagger}T_d\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) - 15T_dY_d^{\dagger}Y_d\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) - \frac{2}{5}g_1^2T_d\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) \\
&\quad + 16g_3^2T_d\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) - 4Y_dY_d^{\dagger}T_d\mathrm{Tr}\Big(Y_eY_e^{\dagger}\Big) - 5T_dY_d^{\dagger}Y_d\mathrm{Tr}\Big(Y_eY_e^{\dagger}\Big) \\
&\quad + \frac{6}{5}g_1^2T_d\mathrm{Tr}\Big(Y_eY_e^{\dagger}\Big) - 6Y_dY_u^{\dagger}T_u\mathrm{Tr}\Big(Y_uY_u^{\dagger}\Big) - 3T_dY_u^{\dagger}Y_u\mathrm{Tr}\Big(Y_uY_u^{\dagger}\Big) \\
&\quad - 4Y_H^{T}Y_H^{*}Y_d\mathrm{Tr}\Big(Y_H^{\dagger}T_H\Big) - \frac{2}{5}Y_dY_d^{\dagger}Y_d\Big(15\mathrm{Tr}\Big(Y_e^{\dagger}T_e\Big) + 30g_2^2M_2 + 45\mathrm{Tr}\Big(Y_d^{\dagger}T_d\Big) + 4g_1^2M_1\Big)
\end{aligned}$$

$$
\begin{aligned}
&- 6Y_dY_u^\dagger Y_u\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - 64Y_dY_{\bar{H}}^* Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}^* T_{\bar{H}}\Big) + 24T_d\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big)\\
&- 9T_d\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 6T_d\mathrm{Tr}\Big(Y_dY_d^\dagger Y_H^T Y_H^*\Big) - 3T_d\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 3T_d\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\\
&+ Y_d\Big(-\frac{3206}{225}g_1^4M_1 - 2g_1^2g_2^2M_1 - \frac{16}{9}g_1^2g_3^2M_1 - \frac{16}{9}g_1^2g_3^2M_3 - 16g_2^2g_3^2M_3 - \frac{896}{9}g_3^4M_3\\
&- 2g_1^2g_2^2M_2 - 30g_2^4M_2 - 16g_2^2g_3^2M_2 + \frac{4}{5}\Big(-40g_3^2M_3 + g_1^2M_1\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&- \frac{12}{5}g_1^2M_1\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - \frac{4}{5}g_1^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + 32g_3^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + \frac{12}{5}g_1^2\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\\
&+ 48\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger T_dY_{\bar{H}}^*\Big) - 36\mathrm{Tr}\Big(Y_dY_d^\dagger T_dY_d^\dagger\Big) - 6\mathrm{Tr}\Big(Y_dY_u^\dagger T_uY_d^\dagger\Big) + 48\mathrm{Tr}\Big(Y_dY_{\bar{H}}^* T_{\bar{H}}Y_d^\dagger\Big)\\
&- 12\mathrm{Tr}\Big(Y_eY_e^\dagger T_eY_e^\dagger\Big) - 6\mathrm{Tr}\Big(Y_uY_d^\dagger T_dY_u^\dagger\Big) - 12\mathrm{Tr}\Big(Y_H^\dagger T_HY_d^*Y_d^T\Big) - 12\mathrm{Tr}\Big(Y_d^\dagger Y_H^TY_H^*T_d\Big)\Big)
\end{aligned}
\tag{52}
$$

$$
\begin{aligned}
\beta_{T_e}^{(1)} &= +4Y_eY_e^\dagger T_e + 5T_eY_e^\dagger Y_e - \frac{9}{5}g_1^2T_e - 3g_2^2T_e + 3T_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + T_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&+ Y_e\Big(2\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 6g_2^2M_2 + 6\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + \frac{18}{5}g_1^2M_1\Big)
\end{aligned}
\tag{53}
$$

$$
\begin{aligned}
\beta_{T_e}^{(2)} &= +\frac{6}{5}g_1^2Y_eY_e^\dagger T_e + 6g_2^2Y_eY_e^\dagger T_e - \frac{6}{5}g_1^2T_eY_e^\dagger Y_e + 12g_2^2T_eY_e^\dagger Y_e\\
&- 6Y_eY_e^\dagger Y_eY_e^\dagger T_e - 8Y_eY_e^\dagger T_eY_e^\dagger Y_e - 6T_eY_e^\dagger Y_eY_e^\dagger Y_e + \frac{747}{50}g_1^4T_e + \frac{9}{5}g_1^2g_2^2T_e + \frac{15}{2}g_2^4T_e\\
&- 12Y_eY_e^\dagger T_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 15T_eY_e^\dagger Y_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - \frac{2}{5}g_1^2T_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&+ 16g_3^2T_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 4Y_eY_e^\dagger T_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 5T_eY_e^\dagger Y_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&+ \frac{6}{5}g_1^2T_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 6Y_eY_e^\dagger Y_e\Big(2g_2^2M_2 + 3\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + \mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\Big)\\
&+ 24T_e\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big) - 9T_e\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 6T_e\mathrm{Tr}\Big(Y_dY_d^\dagger Y_H^TY_H^*\Big)\\
&- 3T_e\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 3T_e\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\\
&- \frac{2}{25}Y_e\Big(747g_1^4M_1 + 45g_1^2g_2^2M_1 + 45g_1^2g_2^2M_2 + 375g_2^4M_2 - 10\Big(-40g_3^2M_3 + g_1^2M_1\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&+ 30g_1^2M_1\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 10g_1^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 400g_3^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 30g_1^2\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\\
&- 600\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger T_dY_{\bar{H}}^*\Big) + 450\mathrm{Tr}\Big(Y_dY_d^\dagger T_dY_d^\dagger\Big) + 75\mathrm{Tr}\Big(Y_dY_u^\dagger T_uY_d^\dagger\Big) - 600\mathrm{Tr}\Big(Y_dY_{\bar{H}}^* T_{\bar{H}}Y_d^\dagger\Big)\\
&+ 150\mathrm{Tr}\Big(Y_eY_e^\dagger T_eY_e^\dagger\Big) + 75\mathrm{Tr}\Big(Y_uY_d^\dagger T_dY_u^\dagger\Big) + 150\mathrm{Tr}\Big(Y_H^\dagger T_HY_d^*Y_d^T\Big) + 150\mathrm{Tr}\Big(Y_d^\dagger Y_H^TY_H^*T_d\Big)\Big)
\end{aligned}
\tag{54}
$$

$$
\begin{aligned}
\beta_{T_H}^{(1)} &= +6Y_HY_H^\dagger T_H + 4Y_HY_d^*T_d^T + 2Y_uY_u^\dagger T_H + 6T_HY_H^\dagger Y_H + 2T_HY_d^*Y_d^T + 4T_uY_u^\dagger Y_H\\
&- \frac{4}{5}g_1^2T_H - 12g_3^2T_H + T_H\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) + Y_H\Big(24g_3^2M_3 + 2\mathrm{Tr}\Big(Y_H^\dagger T_H\Big) + \frac{8}{5}g_1^2M_1\Big)
\end{aligned}
\tag{55}
$$

$$
\begin{aligned}
\beta_{T_H}^{(2)} &= +\frac{8}{5}g_1^2Y_HY_H^\dagger T_H + 40g_3^2Y_HY_H^\dagger T_H - \frac{4}{5}g_1^2M_1Y_HY_d^*Y_d^T - 12g_2^2M_2Y_HY_d^*Y_d^T\\
&+ \frac{4}{5}g_1^2Y_HY_d^*T_d^T + 12g_2^2Y_HY_d^*T_d^T + \frac{4}{5}g_1^2M_1Y_uY_u^\dagger Y_H - 12g_2^2M_2Y_uY_u^\dagger Y_H
\end{aligned}
$$

$$
\begin{aligned}
&- \frac{2}{5}g_1^2 Y_u Y_u^\dagger T_H + 6g_2^2 Y_u Y_u^\dagger T_H + 40 g_3^2 T_H Y_H^\dagger Y_H + \frac{2}{5}g_1^2 T_H Y_d^* Y_d^T \\
&+ 6g_2^2 T_H Y_d^* Y_d^T - \frac{4}{5}g_1^2 T_u Y_u^\dagger Y_H + 12 g_2^2 T_u Y_u^\dagger Y_H - 12 Y_H Y_H^\dagger Y_H Y_H^\dagger T_H \\
&- 8 Y_H Y_H^\dagger Y_u Y_u^\dagger T_H - 16 Y_H Y_H^\dagger T_H Y_H^\dagger Y_H - 8 Y_H Y_H^\dagger T_u Y_u^\dagger Y_H + 32 Y_H Y_d^* Y_{\bar{H}} Y_{\bar{H}}^* T_d^T \\
&+ 32 Y_H Y_d^* T_{\bar{H}} Y_{\bar{H}}^* Y_d^T - 4 Y_H Y_d^* Y_d^T Y_H^\dagger T_H - 4 Y_H Y_d^* Y_d^T Y_d^* T_d^T \\
&- 4 Y_H Y_d^* Y_u^T Y_u^* T_d^T - 8 Y_H Y_d^* T_d^T Y_H^\dagger Y_H - 4 Y_H Y_d^* T_d^T Y_d^* Y_d^T \\
&- 4 Y_H Y_d^* T_u^T Y_u^* Y_d^T - 2 Y_u Y_d^\dagger Y_d Y_u^\dagger T_H - 4 Y_u Y_d^\dagger T_d Y_u^\dagger Y_H \\
&- 2 Y_u Y_u^\dagger Y_u Y_u^\dagger T_H - 4 Y_u Y_u^\dagger T_u Y_u^\dagger Y_H + 16 Y_u Y_{\bar{H}}^* Y_{\bar{H}} Y_u^\dagger T_H + 32 Y_u Y_{\bar{H}}^* T_{\bar{H}} Y_u^\dagger Y_H \\
&- 12 T_H Y_H^\dagger Y_H Y_H^\dagger Y_H - 4 T_H Y_H^\dagger Y_u Y_u^\dagger Y_H + 16 T_H Y_d^* Y_{\bar{H}} Y_{\bar{H}}^* Y_d^T - 8 T_H Y_d^* Y_d^T Y_H^\dagger Y_H \\
&- 2 T_H Y_d^* Y_d^T Y_d^* Y_d^T - 2 T_H Y_d^* Y_u^T Y_u^* Y_d^T - 4 T_u Y_d^\dagger Y_d Y_u^\dagger Y_H - 4 T_u Y_u^\dagger Y_u Y_u^\dagger Y_H \\
&+ 32 T_u Y_{\bar{H}}^* Y_{\bar{H}} Y_u^\dagger Y_H + \frac{156}{25}g_1^4 T_H + \frac{16}{3}g_1^2 g_3^2 T_H + \frac{248}{3}g_3^4 T_H - 6 Y_H Y_H^\dagger T_H \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) \\
&- 6 T_H Y_H^\dagger Y_H \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) + \frac{8}{15}g_1^2 T_H \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) - \frac{4}{3}g_3^2 T_H \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) \\
&- 12 Y_H Y_d^* T_d^T \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 6 T_H Y_d^* Y_d^T \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 4 Y_H Y_d^* T_d^T \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) \\
&- 2 T_H Y_d^* Y_d^T \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 6 Y_u Y_u^\dagger T_H \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 12 T_u Y_u^\dagger Y_H \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&- \frac{8}{15}Y_H Y_H^\dagger Y_H \Big(100 g_3^2 M_3 + 15 \mathrm{Tr}\Big(Y_H^\dagger T_H\Big) + 2 g_1^2 M_1\Big) - 12 Y_H Y_d^* Y_d^T \mathrm{Tr}\Big(Y_d^\dagger T_d\Big) \\
&- 4 Y_H Y_d^* Y_d^T \mathrm{Tr}\Big(Y_e^\dagger T_e\Big) - 12 Y_u Y_u^\dagger Y_H \mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - 4 T_H \mathrm{Tr}\Big(Y_H Y_H^\dagger Y_H Y_H^\dagger\Big) \\
&- 2 T_H \mathrm{Tr}\Big(Y_H Y_H^\dagger Y_u Y_u^\dagger\Big) - 2 T_H \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_H^T Y_H^*\Big) \\
&- \frac{4}{75}Y_H \Big(468 g_1^4 M_1 + 200 g_1^2 g_3^2 M_1 + 200 g_1^2 g_3^2 M_3 + 6200 g_3^4 M_3 + 10\Big(2 g_1^2 M_1 - 5 g_3^2 M_3\Big)\mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) \\
&+ \Big(-20 g_1^2 + 50 g_3^2\Big)\mathrm{Tr}\Big(Y_H^\dagger T_H\Big) + 300 \mathrm{Tr}\Big(Y_H Y_H^\dagger T_H Y_H^\dagger\Big) + 75 \mathrm{Tr}\Big(Y_H Y_H^\dagger T_u Y_u^\dagger\Big) + 75 \mathrm{Tr}\Big(Y_u Y_u^\dagger T_H Y_H^\dagger\Big) \\
&+ 75 \mathrm{Tr}\Big(Y_H^\dagger T_H Y_d^* Y_d^T\Big) + 75 \mathrm{Tr}\Big(Y_d^\dagger Y_H^T Y_H^* T_d\Big)\Big)
\end{aligned} \tag{56}
$$

$$
\begin{aligned}
\beta^{(1)}_{T_{\bar{H}}} = &+ 2 Y_{\bar{H}} Y_d^\dagger T_d + 2 Y_{\bar{H}} Y_u^\dagger T_u - 24 Y_{\bar{H}} Y_{\bar{H}}^* T_{\bar{H}} + T_{\bar{H}} Y_d^\dagger Y_d + T_{\bar{H}} Y_u^\dagger Y_u - 24 T_{\bar{H}} Y_{\bar{H}}^* Y_{\bar{H}} \\
&+ Y_d^T Y_d^* T_{\bar{H}} + Y_u^T Y_u^* T_{\bar{H}} + 2 T_d^T Y_d^* Y_{\bar{H}} + 2 T_u^T Y_u^* Y_{\bar{H}} - \frac{1}{5}g_1^2 T_{\bar{H}} - 3 g_2^2 T_{\bar{H}} - 12 g_3^2 T_{\bar{H}} \\
&- 4 T_{\bar{H}} \mathrm{Tr}\Big(Y_{\bar{H}} Y_{\bar{H}}^*\Big) + Y_{\bar{H}} \Big(24 g_3^2 M_3 + 6 g_2^2 M_2 - 8 \mathrm{Tr}\Big(Y_{\bar{H}}^* T_{\bar{H}}\Big) + \frac{2}{5}g_1^2 M_1\Big)
\end{aligned} \tag{57}
$$

$$
\begin{aligned}
\beta^{(2)}_{T_{\bar{H}}} = &+ \frac{4}{5}g_1^2 Y_{\bar{H}} Y_d^\dagger T_d - \frac{8}{5}g_1^2 M_1 Y_{\bar{H}} Y_u^\dagger Y_u + \frac{8}{5}g_1^2 Y_{\bar{H}} Y_u^\dagger T_u + \frac{64}{15}g_1^2 M_1 Y_{\bar{H}} Y_{\bar{H}}^* Y_{\bar{H}} \\
&+ \frac{640}{3}g_3^2 M_3 Y_{\bar{H}} Y_{\bar{H}}^* Y_{\bar{H}} - \frac{16}{5}g_1^2 Y_{\bar{H}} Y_{\bar{H}}^* T_{\bar{H}} - 160 g_3^2 Y_{\bar{H}} Y_{\bar{H}}^* T_{\bar{H}} + \frac{2}{5}g_1^2 T_{\bar{H}} Y_d^\dagger Y_d \\
&+ \frac{4}{5}g_1^2 T_{\bar{H}} Y_u^\dagger Y_u - \frac{16}{5}g_1^2 T_{\bar{H}} Y_{\bar{H}}^* Y_{\bar{H}} - 160 g_3^2 T_{\bar{H}} Y_{\bar{H}}^* Y_{\bar{H}} - \frac{4}{5}g_1^2 M_1 Y_d^T Y_d^* Y_{\bar{H}}
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{2}{5}g_1^2Y_d^TY_d^*T_{\bar{H}}-\frac{8}{5}g_1^2M_1Y_u^TY_u^*Y_{\bar{H}}+\frac{4}{5}g_1^2Y_u^TY_u^*T_{\bar{H}}+\frac{4}{5}g_1^2T_d^TY_d^*Y_{\bar{H}}\\
&+\frac{8}{5}g_1^2T_u^TY_u^*Y_{\bar{H}}-4Y_{\bar{H}}Y_d^\dagger Y_dY_d^\dagger T_d+8Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*T_{\bar{H}}-4Y_{\bar{H}}Y_d^\dagger T_dY_d^\dagger Y_d\\
&+16Y_{\bar{H}}Y_d^\dagger T_dY_{\bar{H}}^*Y_{\bar{H}}-4Y_{\bar{H}}Y_d^\dagger Y_H^TY_H^*T_d-4Y_{\bar{H}}Y_d^\dagger T_H^TY_H^*Y_d\\
&-4Y_{\bar{H}}Y_u^\dagger Y_HY_H^\dagger T_u-4Y_{\bar{H}}Y_u^\dagger Y_uY_u^\dagger T_u+8Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*T_{\bar{H}}-4Y_{\bar{H}}Y_u^\dagger T_HY_H^\dagger Y_u\\
&-4Y_{\bar{H}}Y_u^\dagger T_uY_u^\dagger Y_u+16Y_{\bar{H}}Y_u^\dagger T_uY_{\bar{H}}^*Y_{\bar{H}}-192Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*T_{\bar{H}}-256Y_{\bar{H}}Y_{\bar{H}}^*T_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}\\
&+16Y_{\bar{H}}Y_{\bar{H}}^*Y_d^TY_d^*T_{\bar{H}}+16Y_{\bar{H}}Y_{\bar{H}}^*Y_u^TY_u^*T_{\bar{H}}+16Y_{\bar{H}}Y_{\bar{H}}^*T_d^TY_d^*Y_{\bar{H}}+16Y_{\bar{H}}Y_{\bar{H}}^*T_u^TY_u^*Y_{\bar{H}}\\
&-2T_{\bar{H}}Y_d^\dagger Y_dY_d^\dagger Y_d+16T_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*Y_{\bar{H}}-2T_{\bar{H}}Y_d^\dagger Y_H^TY_H^*Y_d-2T_{\bar{H}}Y_u^\dagger Y_HY_H^\dagger Y_u\\
&-2T_{\bar{H}}Y_u^\dagger Y_uY_u^\dagger Y_u+16T_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*Y_{\bar{H}}-192T_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}+8T_{\bar{H}}Y_{\bar{H}}^*Y_d^TY_d^*Y_{\bar{H}}\\
&+8T_{\bar{H}}Y_{\bar{H}}^*Y_u^TY_u^*Y_{\bar{H}}-2Y_d^TY_H^\dagger Y_HY_d^*T_{\bar{H}}-4Y_d^TY_H^\dagger T_HY_d^*Y_{\bar{H}}-2Y_d^TY_d^*Y_d^TY_d^*T_{\bar{H}}\\
&-4Y_d^TY_d^*T_d^TY_d^*Y_{\bar{H}}-2Y_u^TY_H^*Y_H^TY_u^*T_{\bar{H}}-4Y_u^TY_H^*T_H^TY_u^*Y_{\bar{H}}-2Y_u^TY_u^*Y_u^TY_u^*T_{\bar{H}}\\
&-4Y_u^TY_u^*T_u^TY_u^*Y_{\bar{H}}-4T_d^TY_H^\dagger Y_HY_d^*Y_{\bar{H}}-4T_d^TY_d^*Y_d^TY_d^*Y_{\bar{H}}\\
&-4T_u^TY_H^*Y_H^TY_u^*Y_{\bar{H}}-4T_u^TY_u^*Y_u^TY_u^*Y_{\bar{H}}+\frac{3}{2}g_1^4T_{\bar{H}}+\frac{1}{5}g_1^2g_2^2T_{\bar{H}}+\frac{15}{2}g_2^4T_{\bar{H}}\\
&+\frac{32}{15}g_1^2g_3^2T_{\bar{H}}+16g_2^2g_3^2T_{\bar{H}}+\frac{248}{3}g_3^4T_{\bar{H}}-96Y_{\bar{H}}Y_{\bar{H}}^*T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)-96T_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)\\
&+\frac{4}{15}g_1^2T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)-12g_2^2T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)+\frac{16}{3}g_3^2T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)-6Y_{\bar{H}}Y_d^\dagger T_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&-3T_{\bar{H}}Y_d^\dagger Y_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-3Y_d^TY_d^*T_{\bar{H}}\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-6T_d^TY_d^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&-2Y_{\bar{H}}Y_d^\dagger T_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-T_{\bar{H}}Y_d^\dagger Y_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-Y_d^TY_d^*T_{\bar{H}}\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&-2T_d^TY_d^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-6Y_{\bar{H}}Y_u^\dagger T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-3T_{\bar{H}}Y_u^\dagger Y_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)\\
&-3Y_u^TY_u^*T_{\bar{H}}\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-6T_u^TY_u^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-6Y_d^TY_d^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)\\
&-2Y_d^TY_d^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)-\frac{2}{5}Y_{\bar{H}}Y_d^\dagger Y_d\Big(15\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)+2g_1^2M_1+5\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\Big)\\
&-6Y_{\bar{H}}Y_u^\dagger Y_u\mathrm{Tr}\Big(Y_u^\dagger T_u\Big)-6Y_u^TY_u^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_u^\dagger T_u\Big)-128Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}^*T_{\bar{H}}\Big)\\
&+8T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big)+8T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*\Big)-64T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*\Big)\\
&-\frac{2}{15}Y_{\bar{H}}\Big(45g_1^4M_1+3g_1^2g_2^2M_1+32g_1^2g_3^2M_1+32g_1^2g_3^2M_3+240g_2^2g_3^2M_3+2480g_3^4M_3\\
&+3g_1^2g_2^2M_2+225g_2^4M_2+240g_2^2g_3^2M_2+4\Big(20g_3^2M_3-45g_2^2M_2+g_1^2M_1\Big)\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)\\
&-4\Big(20g_3^2-45g_2^2+g_1^2\Big)\mathrm{Tr}\Big(Y_{\bar{H}}^*T_{\bar{H}}\Big)-120\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger T_dY_{\bar{H}}^*\Big)-120\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger T_uY_{\bar{H}}^*\Big)\\
&+1920\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*T_{\bar{H}}Y_{\bar{H}}^*\Big)-120\mathrm{Tr}\Big(Y_dY_{\bar{H}}^*T_{\bar{H}}Y_d^\dagger\Big)-120\mathrm{Tr}\Big(Y_uY_{\bar{H}}^*T_{\bar{H}}Y_u^\dagger\Big)\Big)
\end{aligned}
\tag{58}
$$

$$
\beta_{T_u}^{(1)}=+2Y_HY_H^\dagger T_u+2Y_uY_d^\dagger T_d+4Y_uY_u^\dagger T_u-16Y_uY_{\bar{H}}^*T_{\bar{H}}+4T_HY_H^\dagger Y_u+T_uY_d^\dagger Y_d
$$

$$
\begin{aligned}
&+ 5T_uY_u^\dagger Y_u - 8T_uY_{\bar{H}}^* Y_{\bar{H}} - \frac{13}{15}g_1^2T_u - 3g_2^2T_u - \frac{16}{3}g_3^2T_u + 3T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)\\
&+ Y_u\Big(6g_2^2M_2 + 6\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) + \frac{26}{15}g_1^2M_1 + \frac{32}{3}g_3^2M_3\Big) \qquad (59)\\
\beta_{T_u}^{(2)} &= -\frac{8}{15}g_1^2Y_HY_H^\dagger T_u + \frac{40}{3}g_3^2Y_HY_H^\dagger T_u - \frac{4}{5}g_1^2M_1Y_uY_d^\dagger Y_d + \frac{4}{5}g_1^2Y_uY_d^\dagger T_d\\
&- \frac{4}{5}g_1^2M_1Y_uY_u^\dagger Y_u - 12g_2^2M_2Y_uY_u^\dagger Y_u + \frac{6}{5}g_1^2Y_uY_u^\dagger T_u + 6g_2^2Y_uY_u^\dagger T_u\\
&+ \frac{32}{15}g_1^2M_1Y_uY_{\bar{H}}^*Y_{\bar{H}} + \frac{320}{3}g_3^2M_3Y_uY_{\bar{H}}^*Y_{\bar{H}} - \frac{32}{15}g_1^2Y_uY_{\bar{H}}^*T_{\bar{H}} - \frac{320}{3}g_3^2Y_uY_{\bar{H}}^*T_{\bar{H}}\\
&- \frac{16}{15}g_1^2T_HY_H^\dagger Y_u + \frac{80}{3}g_3^2T_HY_H^\dagger Y_u + \frac{2}{5}g_1^2T_uY_d^\dagger Y_d + 12g_2^2T_uY_u^\dagger Y_u\\
&- \frac{16}{15}g_1^2T_uY_{\bar{H}}^*Y_{\bar{H}} - \frac{160}{3}g_3^2T_uY_{\bar{H}}^*Y_{\bar{H}} - 4Y_HY_H^\dagger Y_HY_H^\dagger T_u - 8Y_HY_H^\dagger T_HY_H^\dagger Y_u\\
&- 4Y_HY_d^*Y_d^TY_H^\dagger T_u - 8Y_HY_d^*T_d^TY_H^\dagger Y_u - 4Y_uY_d^\dagger Y_dY_d^\dagger T_d\\
&- 2Y_uY_d^\dagger Y_dY_u^\dagger T_u - 4Y_uY_d^\dagger T_dY_d^\dagger Y_d - 4Y_uY_d^\dagger T_dY_u^\dagger Y_u\\
&- 4Y_uY_d^\dagger Y_H^TY_H^*T_d - 4Y_uY_d^\dagger T_H^TY_H^*Y_d - 4Y_uY_u^\dagger Y_HY_H^\dagger T_u\\
&- 6Y_uY_u^\dagger Y_uY_u^\dagger T_u - 4Y_uY_u^\dagger T_HY_H^\dagger Y_u - 8Y_uY_u^\dagger T_uY_u^\dagger Y_u + 16Y_uY_{\bar{H}}^*Y_{\bar{H}}Y_u^\dagger T_u
\end{aligned}
$$

$$
\begin{aligned}
&- 128Y_uY_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*T_{\bar{H}} + 32Y_uY_{\bar{H}}^*T_{\bar{H}}Y_u^\dagger Y_u - 128Y_uY_{\bar{H}}^*T_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}} + 16Y_uY_{\bar{H}}^*Y_d^TY_d^*T_{\bar{H}}\\
&+ 16Y_uY_{\bar{H}}^*Y_u^TY_u^*T_{\bar{H}} + 16Y_uY_{\bar{H}}^*T_d^TY_d^*Y_{\bar{H}} + 16Y_uY_{\bar{H}}^*T_u^TY_u^*Y_{\bar{H}} - 8T_HY_H^\dagger Y_HY_H^\dagger Y_u\\
&- 8T_HY_d^*Y_d^TY_H^\dagger Y_u - 2T_uY_d^\dagger Y_dY_d^\dagger Y_d - 4T_uY_d^\dagger Y_dY_u^\dagger Y_u\\
&- 2T_uY_d^\dagger Y_H^TY_H^*Y_d - 2T_uY_u^\dagger Y_HY_H^\dagger Y_u - 6T_uY_u^\dagger Y_uY_u^\dagger Y_u + 32T_uY_{\bar{H}}^*Y_{\bar{H}}Y_u^\dagger Y_u\\
&- 64T_uY_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}} + 8T_uY_{\bar{H}}^*Y_d^TY_d^*Y_{\bar{H}} + 8T_uY_{\bar{H}}^*Y_u^TY_u^*Y_{\bar{H}} + \frac{611}{90}g_1^4T_u + g_1^2g_2^2T_u\\
&+ \frac{15}{2}g_2^4T_u + \frac{136}{45}g_1^2g_3^2T_u + 8g_2^2g_3^2T_u + \frac{224}{9}g_3^4T_u - 2Y_HY_H^\dagger T_u\mathrm{Tr}\Big(Y_HY_H^\dagger\Big)\\
&- 4T_HY_H^\dagger Y_u\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) - 64Y_uY_{\bar{H}}^*T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big) - 32T_uY_{\bar{H}}^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)\\
&- 6Y_uY_d^\dagger T_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 3T_uY_d^\dagger Y_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 2Y_uY_d^\dagger T_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&- T_uY_d^\dagger Y_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 12Y_uY_u^\dagger T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 15T_uY_u^\dagger Y_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)\\
&+ \frac{4}{5}g_1^2T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + 16g_3^2T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)\\
&+ \frac{4}{15}Y_HY_H^\dagger Y_u\Big(-100g_3^2M_3 - 15\mathrm{Tr}\Big(Y_H^\dagger T_H\Big) + 4g_1^2M_1\Big) - 6Y_uY_d^\dagger Y_d\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)\\
&- 2Y_uY_d^\dagger Y_d\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) - 18Y_uY_u^\dagger Y_u\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - 64Y_uY_{\bar{H}}^*Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}^*T_{\bar{H}}\Big)\\
&- 6T_u\mathrm{Tr}\Big(Y_HY_H^\dagger Y_uY_u^\dagger\Big) + 24T_u\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*\Big) - 3T_u\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)\\
&- 9T_u\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)
\end{aligned}
$$

$$
\begin{aligned}
&- \frac{2}{45}Y_u\Big(611g_1^4M_1 + 45g_1^2g_2^2M_1 + 136g_1^2g_3^2M_1 + 136g_1^2g_3^2M_3 + 360g_2^2g_3^2M_3 + 2240g_3^4M_3 \\
&+ 45g_1^2g_2^2M_2 + 675g_2^4M_2 + 360g_2^2g_3^2M_2 + 36\Big(20g_3^2M_3 + g_1^2M_1\Big)\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\
&- 36\Big(20g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) + 270\mathrm{Tr}\Big(Y_HY_H^\dagger T_uY_u^\dagger\Big) - 1080\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger T_uY_{\bar{H}}^*\Big) \\
&+ 135\mathrm{Tr}\Big(Y_dY_u^\dagger T_uY_d^\dagger\Big) + 135\mathrm{Tr}\Big(Y_uY_d^\dagger T_dY_u^\dagger\Big) + 270\mathrm{Tr}\Big(Y_uY_u^\dagger T_HY_H^\dagger\Big) + 810\mathrm{Tr}\Big(Y_uY_u^\dagger T_uY_u^\dagger\Big) \\
&- 1080\mathrm{Tr}\Big(Y_uY_{\bar{H}}^*T_{\bar{H}}Y_u^\dagger\Big)\Big)
\end{aligned} \tag{60}
$$

3.7 Bilinear Soft-Breaking Parameters

$$
\begin{aligned}
\beta_{B_\mu}^{(1)} &= +\frac{6}{5}g_1^2M_1\mu + 6g_2^2M_2\mu + B_\mu\Big(-3g_2^2 + 3\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 3\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - \frac{3}{5}g_1^2 + \mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\Big) \\
&\quad + 6\mu\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + 2\mu\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 6\mu\mathrm{Tr}\Big(Y_u^\dagger T_u\Big)
\end{aligned} \tag{61}
$$

$$
\begin{aligned}
\beta_{B_\mu}^{(2)} &= +B_\mu\Big(\frac{231}{50}g_1^4 + \frac{9}{5}g_1^2g_2^2 + \frac{15}{2}g_2^4 - \frac{2}{5}\Big(-40g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + \frac{6}{5}g_1^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + \frac{4}{5}g_1^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\
&\quad + 16g_3^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 6\mathrm{Tr}\Big(Y_HY_H^\dagger Y_uY_u^\dagger\Big) + 24\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big) + 24\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*\Big) \\
&\quad - 9\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 6\mathrm{Tr}\Big(Y_dY_d^\dagger Y_H^TY_H^*\Big) - 6\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 3\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) \\
&\quad - 9\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)\Big) \\
&\quad - \frac{2}{25}\mu\Big(231g_1^4M_1 + 45g_1^2g_2^2M_1 + 45g_1^2g_2^2M_2 + 375g_2^4M_2 - 10\Big(-40g_3^2M_3 + g_1^2M_1\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) \\
&\quad + 30g_1^2M_1\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 20g_1^2M_1\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + 400g_3^2M_3\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + 10g_1^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) \\
&\quad - 400g_3^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 30g_1^2\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) - 20g_1^2\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - 400g_3^2\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) \\
&\quad + 150\mathrm{Tr}\Big(Y_HY_H^\dagger T_uY_u^\dagger\Big) - 600\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger T_dY_{\bar{H}}^*\Big) - 600\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger T_uY_{\bar{H}}^*\Big) + 450\mathrm{Tr}\Big(Y_dY_d^\dagger T_dY_d^\dagger\Big) \\
&\quad + 150\mathrm{Tr}\Big(Y_dY_u^\dagger T_uY_d^\dagger\Big) - 600\mathrm{Tr}\Big(Y_dY_{\bar{H}}^*T_{\bar{H}}Y_d^\dagger\Big) + 150\mathrm{Tr}\Big(Y_eY_e^\dagger T_eY_e^\dagger\Big) + 150\mathrm{Tr}\Big(Y_uY_d^\dagger T_dY_u^\dagger\Big) \\
&\quad + 150\mathrm{Tr}\Big(Y_uY_u^\dagger T_HY_H^\dagger\Big) + 450\mathrm{Tr}\Big(Y_uY_u^\dagger T_uY_u^\dagger\Big) - 600\mathrm{Tr}\Big(Y_uY_{\bar{H}}^*T_{\bar{H}}Y_u^\dagger\Big) + 150\mathrm{Tr}\Big(Y_H^\dagger T_HY_d^*Y_d^T\Big) \\
&\quad + 150\mathrm{Tr}\Big(Y_d^\dagger Y_H^TY_H^*T_d\Big)\Big)
\end{aligned} \tag{62}
$$

$$
\begin{aligned}
\beta_{B_S}^{(1)} &= +B_S\Big(-\frac{4}{15}\Big(15\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big) + 50g_3^2 + g_1^2\Big) + \mathrm{Tr}\Big(Y_HY_H^\dagger\Big)\Big) \\
&\quad + \frac{2}{15}M_S\Big(15\mathrm{Tr}\Big(Y_H^\dagger T_H\Big) + 200g_3^2M_3 + 4g_1^2M_1 - 60\mathrm{Tr}\Big(Y_{\bar{H}}^*T_{\bar{H}}\Big)\Big)
\end{aligned} \tag{63}
$$

$$
\begin{aligned}
\beta_{B_S}^{(2)} &= \frac{2}{225}\Big(B_S\Big(226g_1^4 + 400g_1^2g_3^2 + 13000g_3^4 + 30\Big(2g_1^2 - 5g_3^2\Big)\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) + 30\Big(20g_3^2 - 45g_2^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big) \\
&\quad - 450\mathrm{Tr}\Big(Y_HY_H^\dagger Y_HY_H^\dagger\Big) - 225\mathrm{Tr}\Big(Y_HY_H^\dagger Y_uY_u^\dagger\Big) + 900\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big) + 900\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*\Big)
\end{aligned}
$$

$$
\begin{aligned}
&- 7200\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) - 225\mathrm{Tr}\Big(Y_d Y_d^{\dagger}Y_H^{T}Y_H^{*}\Big)\Big)\\
&- 2M_S\Big(452g_1^4M_1 + 400g_1^2g_3^2M_1 + 400g_1^2g_3^2M_3 + 26000g_3^4M_3 + 30\Big(2g_1^2M_1 - 5g_3^2M_3\Big)\mathrm{Tr}\Big(Y_H Y_H^{\dagger}\Big)\\
&+ 30\Big(20g_3^2M_3 - 45g_2^2M_2 + g_1^2M_1\Big)\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) - 60g_1^2\mathrm{Tr}\Big(Y_H^{\dagger}T_H\Big) + 150g_3^2\mathrm{Tr}\Big(Y_H^{\dagger}T_H\Big)\\
&- 30g_1^2\mathrm{Tr}\Big(Y_{\bar{H}}^{*}T_{\bar{H}}\Big) + 1350g_2^2\mathrm{Tr}\Big(Y_{\bar{H}}^{*}T_{\bar{H}}\Big) - 600g_3^2\mathrm{Tr}\Big(Y_{\bar{H}}^{*}T_{\bar{H}}\Big) + 900\mathrm{Tr}\Big(Y_H Y_H^{\dagger}T_H Y_H^{\dagger}\Big)\\
&+ 225\mathrm{Tr}\Big(Y_H Y_H^{\dagger}T_u Y_u^{\dagger}\Big) - 900\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^{\dagger}T_d Y_{\bar{H}}^{*}\Big) - 900\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^{\dagger}T_u Y_{\bar{H}}^{*}\Big) + 14400\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}T_{\bar{H}}Y_{\bar{H}}^{*}\Big)\\
&- 900\mathrm{Tr}\Big(Y_d Y_{\bar{H}}^{*}T_{\bar{H}}Y_d^{\dagger}\Big) + 225\mathrm{Tr}\Big(Y_u Y_u^{\dagger}T_H Y_H^{\dagger}\Big) - 900\mathrm{Tr}\Big(Y_u Y_{\bar{H}}^{*}T_{\bar{H}}Y_u^{\dagger}\Big) + 225\mathrm{Tr}\Big(Y_H^{\dagger}T_H Y_d^{*}Y_d^{T}\Big)\\
&+ 225\mathrm{Tr}\Big(Y_d^{\dagger}Y_H^{T}Y_H^{*}T_d\Big)\Big)\Big) \qquad (64)
\end{aligned}
$$

3.8 Soft-Breaking Scalar Masses

$$
\sigma_{1,1} = \sqrt{\frac{3}{5}}g_1\Big(-2m_{\bar{S}}^2 - 2\mathrm{Tr}\Big(m_u^2\Big) + 2m_S^2 - \mathrm{Tr}\Big(m_l^2\Big) - m_{H_d}^2 + m_{H_u}^2 + \mathrm{Tr}\Big(m_d^2\Big) + \mathrm{Tr}\Big(m_e^2\Big) + \mathrm{Tr}\Big(m_q^2\Big)\Big) \qquad (65)
$$

$$
\sigma_{2,11} = \frac{1}{10}g_1^2\Big(2\mathrm{Tr}\Big(m_d^2\Big) + 3\mathrm{Tr}\Big(m_l^2\Big) + 3m_{H_d}^2 + 3m_{H_u}^2 + 4m_{\bar{S}}^2 + 4m_S^2 + 6\mathrm{Tr}\Big(m_e^2\Big) + 8\mathrm{Tr}\Big(m_u^2\Big) + \mathrm{Tr}\Big(m_q^2\Big)\Big) \qquad (66)
$$

$$
\begin{aligned}
\sigma_{3,1} = {}& \frac{1}{20}\frac{1}{\sqrt{15}}g_1\Big(-9g_1^2m_{H_d}^2 - 45g_2^2m_{H_d}^2 + 9g_1^2m_{H_u}^2 + 45g_2^2m_{H_u}^2 + 8g_1^2m_S^2 + 400g_3^2m_S^2 - 8g_1^2m_{\bar{S}}^2 - 400g_3^2m_{\bar{S}}^2\\
&+ 4\Big(20g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(m_d^2\Big) + 36g_1^2\mathrm{Tr}\Big(m_e^2\Big) - 9g_1^2\mathrm{Tr}\Big(m_l^2\Big) - 45g_2^2\mathrm{Tr}\Big(m_l^2\Big) + g_1^2\mathrm{Tr}\Big(m_q^2\Big) + 45g_2^2\mathrm{Tr}\Big(m_q^2\Big)\\
&+ 80g_3^2\mathrm{Tr}\Big(m_q^2\Big) - 32g_1^2\mathrm{Tr}\Big(m_u^2\Big) - 160g_3^2\mathrm{Tr}\Big(m_u^2\Big) - 60m_S^2\mathrm{Tr}\Big(Y_H Y_H^{\dagger}\Big) - 240m_{\bar{S}}^2\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}\Big)\\
&+ 90m_{H_d}^2\mathrm{Tr}\Big(Y_d Y_d^{\dagger}\Big) + 30m_{H_d}^2\mathrm{Tr}\Big(Y_e Y_e^{\dagger}\Big) - 90m_{H_u}^2\mathrm{Tr}\Big(Y_u Y_u^{\dagger}\Big) - 60\mathrm{Tr}\Big(Y_H m_d^2 Y_H^{\dagger}\Big)\\
&+ 120\mathrm{Tr}\Big(Y_H Y_H^{\dagger}m_u^{2*}\Big) + 240\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}m_q^2\Big) - 60\mathrm{Tr}\Big(Y_d Y_d^{\dagger}m_d^{2*}\Big) - 30\mathrm{Tr}\Big(Y_d m_q^{2*}Y_d^{\dagger}\Big)\\
&- 60\mathrm{Tr}\Big(Y_e Y_e^{\dagger}m_e^{2*}\Big) + 30\mathrm{Tr}\Big(Y_e m_l^{2*}Y_e^{\dagger}\Big) + 120\mathrm{Tr}\Big(Y_u Y_u^{\dagger}m_u^{2*}\Big) - 30\mathrm{Tr}\Big(Y_u m_q^{2*}Y_u^{\dagger}\Big)\Big) \qquad (67)
\end{aligned}
$$

$$
\sigma_{2,2} = \frac{1}{2}\Big(3\mathrm{Tr}\Big(m_q^2\Big) + m_{H_d}^2 + m_{H_u}^2 + \mathrm{Tr}\Big(m_l^2\Big)\Big) \qquad (68)
$$

$$
\sigma_{2,3} = \frac{1}{2}\Big(2\mathrm{Tr}\Big(m_q^2\Big) + 5m_{\bar{S}}^2 + 5m_S^2 + \mathrm{Tr}\Big(m_d^2\Big) + \mathrm{Tr}\Big(m_u^2\Big)\Big) \qquad (69)
$$

$$
\begin{aligned}
\beta_{m_q^2}^{(1)} = {}& -\frac{2}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 - 6g_2^2\mathbf{1}|M_2|^2 + 2m_{H_d}^2Y_d^{\dagger}Y_d + 2m_{H_u}^2Y_u^{\dagger}Y_u + 2T_d^{\dagger}T_d\\
&+ 2T_u^{\dagger}T_u - 16m_{\bar{S}}^2Y_{\bar{H}}^{*}Y_{\bar{H}} - 16T_{\bar{H}}^{*}T_{\bar{H}} + m_q^2Y_d^{\dagger}Y_d + m_q^2Y_u^{\dagger}Y_u - 8m_q^2Y_{\bar{H}}^{*}Y_{\bar{H}}\\
&+ 2Y_d^{\dagger}m_d^2Y_d + Y_d^{\dagger}Y_d m_q^2 + 2Y_u^{\dagger}m_u^2Y_u + Y_u^{\dagger}Y_u m_q^2 - 8Y_{\bar{H}}^{*}Y_{\bar{H}}m_q^2\\
&- 16Y_{\bar{H}}^{*}m_q^{2*}Y_{\bar{H}} + \frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1} \qquad (70)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(2)}_{m_q^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{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{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{32}{15}g_1^2m_{\bar{S}}^2Y_{\bar{H}}^*Y_{\bar{H}} - \frac{320}{3}g_3^2m_{\bar{S}}^2Y_{\bar{H}}^*Y_{\bar{H}} \\
&+ \frac{16}{45}g_3^2M_3^*\Big(\Big(15\Big(22g_3^2M_3 + 3g_2^2\Big(2M_3 + M_2\Big)\Big) + g_1^2\Big(2M_3 + M_1\Big)\Big)\mathbf{1} + 300\Big(- 2M_3Y_{\bar{H}}^*Y_{\bar{H}} + Y_{\bar{H}}^*T_{\bar{H}}\Big)\Big) \\
&+ \frac{1}{225}g_1^2M_1^*\Big(\Big(5\Big(16g_3^2\Big(2M_1 + M_3\Big) + 9g_2^2\Big(2M_1 + M_2\Big)\Big) + 669g_1^2M_1\Big)\mathbf{1} \\
&+ 60\Big(12M_1Y_u^\dagger Y_u - 16M_1Y_{\bar{H}}^*Y_{\bar{H}} - 3Y_d^\dagger T_d + 6M_1Y_d^\dagger Y_d - 6Y_u^\dagger T_u + 8Y_{\bar{H}}^*T_{\bar{H}}\Big)\Big) \\
&+ \frac{32}{15}g_1^2M_1T_{\bar{H}}^*Y_{\bar{H}} + \frac{320}{3}g_3^2M_3T_{\bar{H}}^*Y_{\bar{H}} - \frac{32}{15}g_1^2T_{\bar{H}}^*T_{\bar{H}} - \frac{320}{3}g_3^2T_{\bar{H}}^*T_{\bar{H}} + \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{16}{15}g_1^2m_q^2Y_{\bar{H}}^*Y_{\bar{H}} - \frac{160}{3}g_3^2m_q^2Y_{\bar{H}}^*Y_{\bar{H}} + \frac{4}{5}g_1^2Y_d^\dagger m_d^2Y_d \\
&+ \frac{2}{5}g_1^2Y_d^\dagger Y_dm_q^2 + \frac{8}{5}g_1^2Y_u^\dagger m_u^2Y_u + \frac{4}{5}g_1^2Y_u^\dagger Y_um_q^2 - \frac{16}{15}g_1^2Y_{\bar{H}}^*Y_{\bar{H}}m_q^2 \\
&- \frac{160}{3}g_3^2Y_{\bar{H}}^*Y_{\bar{H}}m_q^2 - \frac{32}{15}g_1^2Y_{\bar{H}}^*m_q^{2*}Y_{\bar{H}} - \frac{320}{3}g_3^2Y_{\bar{H}}^*m_q^{2*}Y_{\bar{H}} - 8m_{H_d}^2Y_d^\dagger Y_dY_d^\dagger Y_d \\
&- 4Y_d^\dagger Y_dT_d^\dagger T_d - 4Y_d^\dagger T_dT_d^\dagger Y_d - 4m_{H_d}^2Y_d^\dagger Y_H^TY_H^*Y_d \\
&- 4m_S^2Y_d^\dagger Y_H^TY_H^*Y_d - 4Y_d^\dagger Y_H^TT_H^*T_d - 4Y_d^\dagger T_H^TT_H^*Y_d \\
&- 4m_{H_u}^2Y_u^\dagger Y_HY_H^\dagger Y_u - 4m_S^2Y_u^\dagger Y_HY_H^\dagger Y_u - 4Y_u^\dagger Y_HT_H^\dagger T_u \\
&- 8m_{H_u}^2Y_u^\dagger Y_uY_u^\dagger Y_u - 4Y_u^\dagger Y_uT_u^\dagger T_u - 4Y_u^\dagger T_HT_H^\dagger Y_u - 4Y_u^\dagger T_uT_u^\dagger Y_u \\
&- 4T_d^\dagger Y_dY_d^\dagger T_d - 4T_d^\dagger T_dY_d^\dagger Y_d - 4T_d^\dagger Y_H^TY_H^*T_d - 4T_d^\dagger T_H^TY_H^*Y_d \\
&- 4T_u^\dagger Y_HY_H^\dagger T_u - 4T_u^\dagger Y_uY_u^\dagger T_u - 4T_u^\dagger T_HY_H^\dagger Y_u - 4T_u^\dagger T_uY_u^\dagger Y_u \\
&- 256m_{\bar{S}}^2Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}} - 128Y_{\bar{H}}^*Y_{\bar{H}}T_{\bar{H}}^*T_{\bar{H}} - 128Y_{\bar{H}}^*T_{\bar{H}}T_{\bar{H}}^*Y_{\bar{H}} + 16m_{H_d}^2Y_{\bar{H}}^*Y_d^TY_d^*Y_{\bar{H}} \\
&+ 16m_{\bar{S}}^2Y_{\bar{H}}^*Y_d^TY_d^*Y_{\bar{H}} + 16Y_{\bar{H}}^*Y_d^TT_d^*T_{\bar{H}} + 16m_{H_u}^2Y_{\bar{H}}^*Y_u^TY_u^*Y_{\bar{H}} + 16m_{\bar{S}}^2Y_{\bar{H}}^*Y_u^TY_u^*Y_{\bar{H}} \\
&+ 16Y_{\bar{H}}^*Y_u^TT_u^*T_{\bar{H}} + 16Y_{\bar{H}}^*T_d^TT_d^*Y_{\bar{H}} + 16Y_{\bar{H}}^*T_u^TT_u^*Y_{\bar{H}} - 128T_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*T_{\bar{H}} \\
&- 128T_{\bar{H}}^*T_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}} + 16T_{\bar{H}}^*Y_d^TY_d^*T_{\bar{H}} + 16T_{\bar{H}}^*Y_u^TY_u^*T_{\bar{H}} + 16T_{\bar{H}}^*T_d^TY_d^*Y_{\bar{H}} \\
&+ 16T_{\bar{H}}^*T_u^TY_u^*Y_{\bar{H}} - 2m_q^2Y_d^\dagger Y_dY_d^\dagger Y_d - 2m_q^2Y_d^\dagger Y_H^TY_H^*Y_d - 2m_q^2Y_u^\dagger Y_HY_H^\dagger Y_u \\
&- 2m_q^2Y_u^\dagger Y_uY_u^\dagger Y_u - 64m_q^2Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}} + 8m_q^2Y_{\bar{H}}^*Y_d^TY_d^*Y_{\bar{H}} + 8m_q^2Y_{\bar{H}}^*Y_u^TY_u^*Y_{\bar{H}} \\
&- 4Y_d^\dagger m_d^2Y_dY_d^\dagger Y_d - 4Y_d^\dagger m_d^2Y_H^TY_H^*Y_d - 4Y_d^\dagger Y_dm_q^2Y_d^\dagger Y_d - 4Y_d^\dagger Y_dY_d^\dagger m_d^2Y_d \\
&- 2Y_d^\dagger Y_dY_d^\dagger Y_dm_q^2 - 4Y_d^\dagger Y_H^TY_H^*Y_H^*m_d^2Y_d - 2Y_d^\dagger Y_H^TY_H^*Y_dm_q^2 \\
&- 4Y_d^\dagger Y_H^Tm_u^{2*}Y_H^*Y_d - 4Y_u^\dagger Y_HY_H^\dagger m_u^2Y_u - 2Y_u^\dagger Y_HY_H^\dagger Y_um_q^2 \\
&- 4Y_u^\dagger Y_Hm_d^{2*}Y_H^\dagger Y_u - 4Y_u^\dagger m_u^2Y_HY_H^\dagger Y_u - 4Y_u^\dagger m_u^2Y_uY_u^\dagger Y_u - 4Y_u^\dagger Y_um_q^2Y_u^\dagger Y_u \\
&- 4Y_u^\dagger Y_uY_u^\dagger m_u^2Y_u - 2Y_u^\dagger Y_uY_u^\dagger Y_um_q^2 - 128Y_{\bar{H}}^*Y_{\bar{H}}m_q^2Y_{\bar{H}}^*Y_{\bar{H}} - 64Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}m_q^2 \\
&- 128Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*m_q^{2*}Y_{\bar{H}} - 128Y_{\bar{H}}^*m_q^{2*}Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}} + 16Y_{\bar{H}}^*m_q^{2*}Y_d^TY_d^*Y_{\bar{H}} + 16Y_{\bar{H}}^*m_q^{2*}Y_u^TY_u^*Y_{\bar{H}}
\end{aligned}
$$

$$
\begin{aligned}
&+ 16Y_{\bar{H}}^{*}Y_d^{T}m_d^{2*}Y_d^{*}Y_{\bar{H}} + 8Y_{\bar{H}}^{*}Y_d^{T}Y_d^{*}Y_{\bar{H}}m_q^2 + 16Y_{\bar{H}}^{*}Y_d^{T}Y_d^{*}m_q^{2*}Y_{\bar{H}} \\
&+ 16Y_{\bar{H}}^{*}Y_u^{T}m_u^{2*}Y_u^{*}Y_{\bar{H}} + 8Y_{\bar{H}}^{*}Y_u^{T}Y_u^{*}Y_{\bar{H}}m_q^2 + 16Y_{\bar{H}}^{*}Y_u^{T}Y_u^{*}m_q^{2*}Y_{\bar{H}} + 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} - 128m_S^2Y_{\bar{H}}^{*}Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) - 64T_{\bar{H}}^{*}T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) \\
&- 32m_q^2Y_{\bar{H}}^{*}Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) - 32Y_{\bar{H}}^{*}Y_{\bar{H}}m_q^2\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) - 64Y_{\bar{H}}^{*}m_q^{2*}Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^{*}\Big) \\
&- 64Y_{\bar{H}}^{*}T_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}T_{\bar{H}}^{*}\Big) - 12m_{H_d}^2Y_d^{\dagger}Y_d\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) - 6T_d^{\dagger}T_d\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) \\
&- 3m_q^2Y_d^{\dagger}Y_d\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) - 6Y_d^{\dagger}m_d^2Y_d\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) - 3Y_d^{\dagger}Y_dm_q^2\mathrm{Tr}\Big(Y_dY_d^{\dagger}\Big) \\
&- 4m_{H_d}^2Y_d^{\dagger}Y_d\mathrm{Tr}\Big(Y_eY_e^{\dagger}\Big) - 2T_d^{\dagger}T_d\mathrm{Tr}\Big(Y_eY_e^{\dagger}\Big) - m_q^2Y_d^{\dagger}Y_d\mathrm{Tr}\Big(Y_eY_e^{\dagger}\Big) \\
&- 2Y_d^{\dagger}m_d^2Y_d\mathrm{Tr}\Big(Y_eY_e^{\dagger}\Big) - Y_d^{\dagger}Y_dm_q^2\mathrm{Tr}\Big(Y_eY_e^{\dagger}\Big) - 12m_{H_u}^2Y_u^{\dagger}Y_u\mathrm{Tr}\Big(Y_uY_u^{\dagger}\Big) \\
&- 6T_u^{\dagger}T_u\mathrm{Tr}\Big(Y_uY_u^{\dagger}\Big) - 3m_q^2Y_u^{\dagger}Y_u\mathrm{Tr}\Big(Y_uY_u^{\dagger}\Big) - 6Y_u^{\dagger}m_u^2Y_u\mathrm{Tr}\Big(Y_uY_u^{\dagger}\Big) \\
&- 3Y_u^{\dagger}Y_um_q^2\mathrm{Tr}\Big(Y_uY_u^{\dagger}\Big) - 6T_d^{\dagger}Y_d\mathrm{Tr}\Big(Y_d^{\dagger}T_d\Big) - 2T_d^{\dagger}Y_d\mathrm{Tr}\Big(Y_e^{\dagger}T_e\Big) \\
&- 6T_u^{\dagger}Y_u\mathrm{Tr}\Big(Y_u^{\dagger}T_u\Big) - 64T_{\bar{H}}^{*}Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}^{*}T_{\bar{H}}\Big) - 64Y_{\bar{H}}^{*}Y_{\bar{H}}\mathrm{Tr}\Big(T_{\bar{H}}^{*}T_{\bar{H}}\Big) \\
&- 6Y_d^{\dagger}T_d\mathrm{Tr}\Big(T_d^{*}Y_d^{T}\Big) - 6Y_d^{\dagger}Y_d\mathrm{Tr}\Big(T_d^{*}T_d^{T}\Big) - 2Y_d^{\dagger}T_d\mathrm{Tr}\Big(T_e^{*}Y_e^{T}\Big) \\
&- 2Y_d^{\dagger}Y_d\mathrm{Tr}\Big(T_e^{*}T_e^{T}\Big) - 6Y_u^{\dagger}T_u\mathrm{Tr}\Big(T_u^{*}Y_u^{T}\Big) - 6Y_u^{\dagger}Y_u\mathrm{Tr}\Big(T_u^{*}T_u^{T}\Big) \\
&- 128Y_{\bar{H}}^{*}Y_{\bar{H}}\mathrm{Tr}\Big(Y_{\bar{H}}m_q^2Y_{\bar{H}}^{*}\Big) - 6Y_d^{\dagger}Y_d\mathrm{Tr}\Big(m_d^2Y_dY_d^{\dagger}\Big) - 2Y_d^{\dagger}Y_d\mathrm{Tr}\Big(m_e^2Y_eY_e^{\dagger}\Big) \\
&- 2Y_d^{\dagger}Y_d\mathrm{Tr}\Big(m_l^2Y_e^{\dagger}Y_e\Big) - 6Y_d^{\dagger}Y_d\mathrm{Tr}\Big(m_q^2Y_d^{\dagger}Y_d\Big) - 6Y_u^{\dagger}Y_u\mathrm{Tr}\Big(m_q^2Y_u^{\dagger}Y_u\Big) \\
&- 6Y_u^{\dagger}Y_u\mathrm{Tr}\Big(m_u^2Y_uY_u^{\dagger}\Big)
\end{aligned} \tag{71}
$$

$$
\begin{aligned}
\beta_{m_l^2}^{(1)} &= -\frac{6}{5}g_1^2\mathbf{1}|M_1|^2 - 6g_2^2\mathbf{1}|M_2|^2 + 2m_{H_d}^2Y_e^{\dagger}Y_e + 2T_e^{\dagger}T_e + m_l^2Y_e^{\dagger}Y_e + 2Y_e^{\dagger}m_e^2Y_e \\
&+ Y_e^{\dagger}Y_em_l^2 - \sqrt{\frac{3}{5}}g_1\mathbf{1}\sigma_{1,1}
\end{aligned} \tag{72}
$$

$$
\begin{aligned}
\beta_{m_l^2}^{(2)} &= +\frac{3}{5}g_2^2\Big(3g_1^2\Big(2M_2 + M_1\Big) + 55g_2^2M_2\Big)\mathbf{1}M_2^{*} + \frac{12}{5}g_1^2m_{H_d}^2Y_e^{\dagger}Y_e \\
&+ \frac{3}{25}g_1^2M_1^{*}\Big(- 20Y_e^{\dagger}T_e + 3\Big(5g_2^2\Big(2M_1 + M_2\Big) + 77g_1^2M_1\Big)\mathbf{1} + 40M_1Y_e^{\dagger}Y_e\Big) - \frac{12}{5}g_1^2M_1T_e^{\dagger}Y_e \\
&+ \frac{12}{5}g_1^2T_e^{\dagger}T_e + \frac{6}{5}g_1^2m_l^2Y_e^{\dagger}Y_e + \frac{12}{5}g_1^2Y_e^{\dagger}m_e^2Y_e + \frac{6}{5}g_1^2Y_e^{\dagger}Y_em_l^2 \\
&- 8m_{H_d}^2Y_e^{\dagger}Y_eY_e^{\dagger}Y_e - 4Y_e^{\dagger}Y_eT_e^{\dagger}T_e - 4Y_e^{\dagger}T_eT_e^{\dagger}Y_e - 4T_e^{\dagger}Y_eY_e^{\dagger}T_e \\
&- 4T_e^{\dagger}T_eY_e^{\dagger}Y_e - 2m_l^2Y_e^{\dagger}Y_eY_e^{\dagger}Y_e - 4Y_e^{\dagger}m_e^2Y_eY_e^{\dagger}Y_e - 4Y_e^{\dagger}Y_em_l^2Y_e^{\dagger}Y_e \\
&- 4Y_e^{\dagger}Y_eY_e^{\dagger}m_e^2Y_e - 2Y_e^{\dagger}Y_eY_e^{\dagger}Y_em_l^2 + 6g_2^4\mathbf{1}\sigma_{2,2} + \frac{6}{5}g_1^2\mathbf{1}\sigma_{2,11} - 4\sqrt{\frac{3}{5}}g_1\mathbf{1}\sigma_{3,1}
\end{aligned}
$$

$$
\begin{aligned}
&- 12m_{H_d}^2 Y_e^\dagger Y_e \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 6T_e^\dagger T_e \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 3m_l^2 Y_e^\dagger Y_e \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\
&- 6Y_e^\dagger m_e^2 Y_e \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 3Y_e^\dagger Y_e m_l^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 4m_{H_d}^2 Y_e^\dagger Y_e \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) \\
&- 2T_e^\dagger T_e \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - m_l^2 Y_e^\dagger Y_e \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 2Y_e^\dagger m_e^2 Y_e \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) \\
&- Y_e^\dagger Y_e m_l^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 6T_e^\dagger Y_e \mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 2T_e^\dagger Y_e \mathrm{Tr}\Big(Y_e^\dagger T_e\Big) \\
&- 6Y_e^\dagger T_e \mathrm{Tr}\Big(T_d^* Y_d^T\Big) - 6Y_e^\dagger Y_e \mathrm{Tr}\Big(T_d^* T_d^T\Big) - 2Y_e^\dagger T_e \mathrm{Tr}\Big(T_e^* Y_e^T\Big) \\
&- 2Y_e^\dagger Y_e \mathrm{Tr}\Big(T_e^* T_e^T\Big) - 6Y_e^\dagger Y_e \mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger\Big) - 2Y_e^\dagger Y_e \mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger\Big) \\
&- 2Y_e^\dagger Y_e \mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e\Big) - 6Y_e^\dagger Y_e \mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d\Big)
\end{aligned} \tag{73}
$$

$$
\begin{aligned}
\beta^{(1)}_{m_{H_d}^2} &= -\frac{6}{5} g_1^2 |M_1|^2 - 6g_2^2 |M_2|^2 - \sqrt{\frac{3}{5}} g_1 \sigma_{1,1} + 6m_{H_d}^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 2m_{H_d}^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 6\mathrm{Tr}\Big(T_d^* T_d^T\Big) \\
&+ 2\mathrm{Tr}\Big(T_e^* T_e^T\Big) + 6\mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger\Big) + 2\mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger\Big) + 2\mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e\Big) + 6\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d\Big)
\end{aligned} \tag{74}
$$

$$
\begin{aligned}
\beta^{(2)}_{m_{H_d}^2} &= \frac{1}{25}\Big(15g_2^2\Big(3g_1^2\Big(2M_2 + M_1\Big) + 55g_2^2 M_2\Big) M_2^* \\
&+ g_1^2 M_1^* \Big(693g_1^2 M_1 + 90g_2^2 M_1 + 45g_2^2 M_2 - 40M_1 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + 120M_1 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 20\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) \\
&- 60\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\Big) \\
&+ 10\Big(15g_2^4 \sigma_{2,2} + 3g_1^2 \sigma_{2,11} - 2\sqrt{15} g_1 \sigma_{3,1} + \Big(160g_3^2 |M_3|^2 - 2g_1^2 m_{H_d}^2 + 80g_3^2 m_{H_d}^2\Big) \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\
&+ 6g_1^2 m_{H_d}^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 80g_3^2 M_3^* \mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + 2g_1^2 M_1 \mathrm{Tr}\Big(T_d^* Y_d^T\Big) - 80g_3^2 M_3 \mathrm{Tr}\Big(T_d^* Y_d^T\Big) \\
&- 2g_1^2 \mathrm{Tr}\Big(T_d^* T_d^T\Big) + 80g_3^2 \mathrm{Tr}\Big(T_d^* T_d^T\Big) - 6g_1^2 M_1 \mathrm{Tr}\Big(T_e^* Y_e^T\Big) + 6g_1^2 \mathrm{Tr}\Big(T_e^* T_e^T\Big) \\
&- 2g_1^2 \mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger\Big) + 80g_3^2 \mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger\Big) + 6g_1^2 \mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger\Big) + 6g_1^2 \mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e\Big) \\
&- 2g_1^2 \mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d\Big) + 80g_3^2 \mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d\Big) - 30\mathrm{Tr}\Big(Y_H T_d^* T_d^T Y_H^\dagger\Big) \\
&+ 120m_{H_d}^2 \mathrm{Tr}\Big(Y_{\bar{H}} Y_d^\dagger Y_d Y_{\bar{H}}^*\Big) + 120m_S^2 \mathrm{Tr}\Big(Y_{\bar{H}} Y_d^\dagger Y_d Y_{\bar{H}}^*\Big) + 120\mathrm{Tr}\Big(Y_{\bar{H}} Y_d^\dagger T_d T_{\bar{H}}^*\Big) \\
&+ 120\mathrm{Tr}\Big(Y_{\bar{H}} T_d^\dagger T_d Y_{\bar{H}}^*\Big) - 90m_{H_d}^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 90\mathrm{Tr}\Big(Y_d Y_d^\dagger T_d T_d^\dagger\Big) \\
&- 30m_{H_d}^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_H^T Y_H^*\Big) - 30m_S^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_H^T Y_H^*\Big) - 30\mathrm{Tr}\Big(Y_d Y_d^\dagger T_H^T T_H^*\Big) \\
&- 15m_{H_d}^2 \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 15m_{H_u}^2 \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 15\mathrm{Tr}\Big(Y_d Y_u^\dagger T_u T_d^\dagger\Big) \\
&- 90\mathrm{Tr}\Big(Y_d T_d^\dagger T_d Y_d^\dagger\Big) - 15\mathrm{Tr}\Big(Y_d T_u^\dagger T_u Y_d^\dagger\Big) + 120\mathrm{Tr}\Big(Y_d T_{\bar{H}}^* T_{\bar{H}} Y_d^\dagger\Big) - 30m_{H_d}^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) \\
&- 30\mathrm{Tr}\Big(Y_e Y_e^\dagger T_e T_e^\dagger\Big) - 30\mathrm{Tr}\Big(Y_e T_e^\dagger T_e Y_e^\dagger\Big) - 15\mathrm{Tr}\Big(Y_u Y_d^\dagger T_d T_u^\dagger\Big) - 15\mathrm{Tr}\Big(Y_u T_d^\dagger T_d Y_u^\dagger\Big) \\
&- 30\mathrm{Tr}\Big(Y_H^\dagger T_H T_d^* Y_d^T\Big) - 30\mathrm{Tr}\Big(Y_d^\dagger Y_H^T T_H^* T_d\Big) + 120\mathrm{Tr}\Big(Y_{\bar{H}}^* Y_d^T T_d^* T_{\bar{H}}\Big)
\end{aligned}
$$

$$
\begin{aligned}
&+ 120\mathrm{Tr}\Big(Y_{\bar{H}} m_q^2 Y_d^\dagger Y_d Y_{\bar{H}}^*\Big) + 120\mathrm{Tr}\Big(Y_{\bar{H}} Y_d^\dagger m_d^2 Y_d Y_{\bar{H}}^*\Big) + 120\mathrm{Tr}\Big(Y_{\bar{H}} Y_d^\dagger Y_d m_q^2 Y_{\bar{H}}^*\Big) \\
&+ 120\mathrm{Tr}\Big(Y_{\bar{H}} Y_d^\dagger Y_d Y_H^* m_q^{2*}\Big) - 90\mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) - 30\mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger Y_H^T Y_H^*\Big) \\
&- 15\mathrm{Tr}\Big(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 30\mathrm{Tr}\Big(m_d^2 Y_H^T Y_H^* Y_d Y_d^\dagger\Big) - 30\mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) \\
&- 30\mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e Y_e^\dagger Y_e\Big) - 90\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d Y_d^\dagger Y_d\Big) - 15\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\Big) \\
&- 30\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_H^T Y_H^* Y_d\Big) - 15\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\Big) - 15\mathrm{Tr}\Big(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\Big) \\
&- 30\mathrm{Tr}\Big(Y_d Y_d^\dagger Y_H^T m_u^{2*} Y_H^*\Big)\Big)\Big) \qquad (75)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(1)}_{m^2_{H_u}} &= -\frac{6}{5} g_1^2 |M_1|^2 - 6 g_2^2 |M_2|^2 + \sqrt{\frac{3}{5}} g_1 \sigma_{1,1} + 6 m^2_{H_u} \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 6\mathrm{Tr}\Big(T_u^* T_u^T\Big) + 6\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) \\
&+ 6\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big) \qquad (76)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(2)}_{m^2_{H_u}} &= +\frac{3}{5} g_2^2 \Big(3 g_1^2 \Big(2M_2 + M_1\Big) + 55 g_2^2 M_2\Big) M_2^* + 6 g_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^2_{H_u} \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ 32 g_3^2 m^2_{H_u} \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 64 g_3^2 |M_3|^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ \frac{1}{25} g_1^2 M_1^* \Big(- 40\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) + 45 g_2^2 M_2 + 693 g_1^2 M_1 + 80 M_1 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 90 g_2^2 M_1\Big) \\
&- 32 g_3^2 M_3^* \mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - \frac{8}{5} g_1^2 M_1 \mathrm{Tr}\Big(T_u^* Y_u^T\Big) - 32 g_3^2 M_3 \mathrm{Tr}\Big(T_u^* Y_u^T\Big) + \frac{8}{5} g_1^2 \mathrm{Tr}\Big(T_u^* T_u^T\Big) \\
&+ 32 g_3^2 \mathrm{Tr}\Big(T_u^* T_u^T\Big) + \frac{8}{5} g_1^2 \mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) + 32 g_3^2 \mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) + \frac{8}{5} g_1^2 \mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big) \\
&+ 32 g_3^2 \mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big) - 12 m^2_{H_u} \mathrm{Tr}\Big(Y_H Y_H^\dagger Y_u Y_u^\dagger\Big) - 12 m_S^2 \mathrm{Tr}\Big(Y_H Y_H^\dagger Y_u Y_u^\dagger\Big) \\
&- 12\mathrm{Tr}\Big(Y_H Y_H^\dagger T_u T_u^\dagger\Big) - 12\mathrm{Tr}\Big(Y_H T_H^\dagger T_u Y_u^\dagger\Big) + 48 m^2_{H_u} \mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger Y_u Y_{\bar{H}}^*\Big) \\
&+ 48 m_S^2 \mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger Y_u Y_{\bar{H}}^*\Big) + 48\mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger T_u T_{\bar{H}}^*\Big) + 48\mathrm{Tr}\Big(Y_{\bar{H}} T_u^\dagger T_u Y_{\bar{H}}^*\Big) \\
&- 6 m^2_{H_d} \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 6 m^2_{H_u} \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 6\mathrm{Tr}\Big(Y_d Y_u^\dagger T_u T_d^\dagger\Big) \\
&- 6\mathrm{Tr}\Big(Y_d T_u^\dagger T_u Y_d^\dagger\Big) - 6\mathrm{Tr}\Big(Y_u Y_d^\dagger T_d T_u^\dagger\Big) - 36 m^2_{H_u} \mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) - 12\mathrm{Tr}\Big(Y_u Y_u^\dagger T_H T_H^\dagger\Big) \\
&- 36\mathrm{Tr}\Big(Y_u Y_u^\dagger T_u T_u^\dagger\Big) - 6\mathrm{Tr}\Big(Y_u T_d^\dagger T_d Y_u^\dagger\Big) - 12\mathrm{Tr}\Big(Y_u T_u^\dagger T_H Y_H^\dagger\Big) - 36\mathrm{Tr}\Big(Y_u T_u^\dagger T_u Y_u^\dagger\Big) \\
&+ 48\mathrm{Tr}\Big(Y_u T_{\bar{H}}^* T_{\bar{H}} Y_u^\dagger\Big) + 48\mathrm{Tr}\Big(Y_{\bar{H}}^* Y_u^T T_u^* T_{\bar{H}}\Big) - 12\mathrm{Tr}\Big(Y_H Y_H^\dagger m_u^2 Y_u Y_u^\dagger\Big) \\
&- 12\mathrm{Tr}\Big(Y_H Y_H^\dagger Y_u m_q^2 Y_u^\dagger\Big) - 12\mathrm{Tr}\Big(Y_H Y_H^\dagger Y_u Y_u^\dagger m_u^2\Big) - 12\mathrm{Tr}\Big(Y_H m_d^{2*} Y_H^\dagger Y_u Y_u^\dagger\Big) \\
&+ 48\mathrm{Tr}\Big(Y_{\bar{H}} m_q^2 Y_u^\dagger Y_u Y_{\bar{H}}^*\Big) + 48\mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger m_u^2 Y_u Y_{\bar{H}}^*\Big) + 48\mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger Y_u m_q^2 Y_{\bar{H}}^*\Big) \\
&+ 48\mathrm{Tr}\Big(Y_{\bar{H}} Y_u^\dagger Y_u Y_H^* m_q^{2*}\Big) - 6\mathrm{Tr}\Big(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 6\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\Big) \\
&- 6\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\Big) - 36\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u Y_u^\dagger Y_u\Big) - 6\mathrm{Tr}\Big(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\Big)
\end{aligned}
$$

$$- 36\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) \tag{77}$$

$$\begin{aligned}\beta^{(1)}_{m_d^2} =& -\frac{8}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 + 4m_{H_d}^2 Y_d Y_d^\dagger + 4T_d T_d^\dagger + 4m_S^2 Y_H^T Y_H^* + 4T_H^T T_H^* \\ &+ 2m_d^2 Y_d Y_d^\dagger + 2m_d^2 Y_H^T Y_H^* + 4Y_d m_q^2 Y_d^\dagger + 2Y_d Y_d^\dagger m_d^2 + 2Y_H^T Y_H^* m_d^2 \\ &+ 4Y_H^T m_u^{2*} Y_H^* + 2\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1}\end{aligned} \tag{78}$$

$$\begin{aligned}\beta^{(2)}_{m_d^2} =& +\frac{4}{5}g_1^2 m_{H_d}^2 Y_d Y_d^\dagger + 12g_2^2 m_{H_d}^2 Y_d Y_d^\dagger + 24g_2^2|M_2|^2 Y_d Y_d^\dagger - \frac{4}{5}g_1^2 M_1 Y_d T_d^\dagger \\ &- 12g_2^2 M_2 Y_d T_d^\dagger - 12g_2^2 M_2^* T_d Y_d^\dagger + \frac{4}{5}g_1^2 T_d T_d^\dagger + 12g_2^2 T_d T_d^\dagger \\ &+ \frac{32}{15}g_1^2 m_S^2 Y_H^T Y_H^* + \frac{80}{3}g_3^2 m_S^2 Y_H^T Y_H^* - \frac{32}{15}g_1^2 M_1 Y_H^T T_H^* - \frac{80}{3}g_3^2 M_3 Y_H^T T_H^* \\ &+ \frac{4}{225}g_1^2 M_1^*\Big(15\Big(16M_1 Y_H^T Y_H^* - 3T_d Y_d^\dagger + 6M_1 Y_d Y_d^\dagger - 8T_H^T Y_H^*\Big) + 2\Big(339g_1^2 M_1 + 40g_3^2\Big(2M_1 + M_3\Big)\Big)\mathbf{1}\Big) \\ &+ \frac{16}{45}g_3^2 M_3^*\Big(\Big(330g_3^2 M_3 + 4g_1^2\Big(2M_3 + M_1\Big)\Big)\mathbf{1} + 75\Big(2M_3 Y_H^T Y_H^* - T_H^T Y_H^*\Big)\Big) + \frac{32}{15}g_1^2 T_H^T T_H^* \\ &+ \frac{80}{3}g_3^2 T_H^T T_H^* + \frac{2}{5}g_1^2 m_d^2 Y_d Y_d^\dagger + 6g_2^2 m_d^2 Y_d Y_d^\dagger + \frac{16}{15}g_1^2 m_d^2 Y_H^T Y_H^* \\ &+ \frac{40}{3}g_3^2 m_d^2 Y_H^T Y_H^* + \frac{4}{5}g_1^2 Y_d m_q^2 Y_d^\dagger + 12g_2^2 Y_d m_q^2 Y_d^\dagger + \frac{2}{5}g_1^2 Y_d Y_d^\dagger m_d^2 \\ &+ 6g_2^2 Y_d Y_d^\dagger m_d^2 + \frac{16}{15}g_1^2 Y_H^T Y_H^* m_d^2 + \frac{40}{3}g_3^2 Y_H^T Y_H^* m_d^2 + \frac{32}{15}g_1^2 Y_H^T m_u^{2*} Y_H^* \\ &+ \frac{80}{3}g_3^2 Y_H^T m_u^{2*} Y_H^* - 8m_{H_d}^2 Y_d Y_d^\dagger Y_d Y_d^\dagger - 4Y_d Y_d^\dagger T_d T_d^\dagger - 4m_{H_d}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger \\ &- 4m_{H_u}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger - 4Y_d Y_u^\dagger T_u T_d^\dagger - 4Y_d T_d^\dagger T_d Y_d^\dagger - 4Y_d T_u^\dagger T_u Y_d^\dagger \\ &+ 32m_{H_d}^2 Y_d Y_{\bar{H}}^* Y_{\bar{H}} Y_d^\dagger + 32m_{\bar{S}}^2 Y_d Y_{\bar{H}}^* Y_{\bar{H}} Y_d^\dagger + 32Y_d Y_{\bar{H}}^* T_{\bar{H}} T_d^\dagger + 32Y_d T_{\bar{H}}^* T_{\bar{H}} Y_d^\dagger \\ &- 4T_d Y_d^\dagger Y_d T_d^\dagger - 4T_d Y_u^\dagger Y_u T_d^\dagger - 4T_d T_d^\dagger Y_d Y_d^\dagger - 4T_d T_u^\dagger Y_u Y_d^\dagger \\ &+ 32T_d Y_{\bar{H}}^* Y_{\bar{H}} T_d^\dagger + 32T_d T_{\bar{H}}^* Y_{\bar{H}} Y_d^\dagger - 16m_S^2 Y_H^T Y_H^* Y_H^T Y_H^* - 8Y_H^T Y_H^* T_H^T T_H^* \\ &- 8m_{H_u}^2 Y_H^T Y_u^* Y_u^T Y_H^* - 8m_S^2 Y_H^T Y_u^* Y_u^T Y_H^* - 8Y_H^T Y_u^* T_u^T T_H^* \\ &- 8Y_H^T T_H^* T_H^T Y_H^* - 8Y_H^T T_u^* T_u^T Y_H^* - 8T_H^T Y_H^* Y_H^T T_H^* - 8T_H^T Y_u^* Y_u^T T_H^* \\ &- 8T_H^T T_H^* Y_H^T Y_H^* - 8T_H^T T_u^* Y_u^T Y_H^* - 2m_d^2 Y_d Y_d^\dagger Y_d Y_d^\dagger - 2m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger \\ &+ 16m_d^2 Y_d Y_{\bar{H}}^* Y_{\bar{H}} Y_d^\dagger - 4m_d^2 Y_H^T Y_H^* Y_H^T Y_H^* - 4m_d^2 Y_H^T Y_u^* Y_u^T Y_H^* - 4Y_d m_q^2 Y_d^\dagger Y_d Y_d^\dagger \\ &- 4Y_d m_q^2 Y_u^\dagger Y_u Y_d^\dagger + 32Y_d m_q^2 Y_{\bar{H}}^* Y_{\bar{H}} Y_d^\dagger - 4Y_d Y_d^\dagger m_d^2 Y_d Y_d^\dagger - 4Y_d Y_d^\dagger Y_d m_q^2 Y_d^\dagger \\ &- 2Y_d Y_d^\dagger Y_d Y_d^\dagger m_d^2 - 4Y_d Y_u^\dagger m_u^2 Y_u Y_d^\dagger - 4Y_d Y_u^\dagger Y_u m_q^2 Y_d^\dagger \\ &- 2Y_d Y_u^\dagger Y_u Y_d^\dagger m_d^2 + 32Y_d Y_{\bar{H}}^* Y_{\bar{H}} m_q^2 Y_d^\dagger + 16Y_d Y_{\bar{H}}^* Y_{\bar{H}} Y_d^\dagger m_d^2 \\ &+ 32Y_d Y_{\bar{H}}^* m_q^{2*} Y_{\bar{H}} Y_d^\dagger - 8Y_H^T Y_H^* m_d^2 Y_H^T Y_H^* - 4Y_H^T Y_H^* Y_H^T Y_H^* m_d^2 - 8Y_H^T Y_H^* Y_H^T m_u^{2*} Y_H^* \\ &- 8Y_H^T m_u^{2*} Y_H^* Y_H^T Y_H^* - 8Y_H^T m_u^{2*} Y_u^* Y_u^T Y_H^* - 8Y_H^T Y_u^* m_q^{2*} Y_u^T Y_H^*\end{aligned}$$

$$
\begin{aligned}
&- 4Y_H^T Y_u^* Y_u^T Y_H^* m_d^2 - 8Y_H^T Y_u^* Y_u^T m_u^{2*} Y_H^* + \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} \\
&- 8m_S^2 Y_H^T Y_H^* \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) - 4T_H^T T_H^* \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) - 2m_d^2 Y_H^T Y_H^* \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) \\
&- 2Y_H^T Y_H^* m_d^2 \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) - 4Y_H^T m_u^{2*} Y_H^* \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) - 24 m_{H_d}^2 Y_d Y_d^\dagger \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\
&- 12T_d T_d^\dagger \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 6m_d^2 Y_d Y_d^\dagger \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 12 Y_d m_q^2 Y_d^\dagger \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) \\
&- 6Y_d Y_d^\dagger m_d^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 8m_{H_d}^2 Y_d Y_d^\dagger \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 4T_d T_d^\dagger \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) \\
&- 2m_d^2 Y_d Y_d^\dagger \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 4Y_d m_q^2 Y_d^\dagger \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 2Y_d Y_d^\dagger m_d^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) \\
&- 4Y_H^T T_H^* \mathrm{Tr}\Big(Y_H^\dagger T_H\Big) - 12 Y_d T_d^\dagger \mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 4 Y_d T_d^\dagger \mathrm{Tr}\Big(Y_e^\dagger T_e\Big) \\
&- 4T_H^T Y_H^* \mathrm{Tr}\Big(T_H^* Y_H^T\Big) - 4Y_H^T Y_H^* \mathrm{Tr}\Big(T_H^* T_H^T\Big) - 12 T_d Y_d^\dagger \mathrm{Tr}\Big(T_d^* Y_d^T\Big) \\
&- 12Y_d Y_d^\dagger \mathrm{Tr}\Big(T_d^* T_d^T\Big) - 4T_d Y_d^\dagger \mathrm{Tr}\Big(T_e^* Y_e^T\Big) - 4Y_d Y_d^\dagger \mathrm{Tr}\Big(T_e^* T_e^T\Big) \\
&- 4Y_H^T Y_H^* \mathrm{Tr}\Big(Y_H Y_H^\dagger m_u^2\Big) - 4Y_H^T Y_H^* \mathrm{Tr}\Big(Y_H m_d^{2*} Y_H^\dagger\Big) - 12 Y_d Y_d^\dagger \mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger\Big) \\
&- 4Y_d Y_d^\dagger \mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger\Big) - 4Y_d Y_d^\dagger \mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e\Big) - 12 Y_d Y_d^\dagger \mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d\Big)
\end{aligned} \tag{79}
$$

$$
\begin{aligned}
\beta_{m_u^2}^{(1)} =& -\frac{32}{15} g_1^2 \mathbf{1}|M_1|^2 - \frac{32}{3} g_3^2 \mathbf{1}|M_3|^2 + 4m_S^2 Y_H Y_H^\dagger + 4m_{H_u}^2 Y_u Y_u^\dagger + 4T_H T_H^\dagger + 4T_u T_u^\dagger \\
&+ 2Y_H Y_H^\dagger m_u^2 + 4Y_H m_d^{2*} Y_H^\dagger + 2m_u^2 Y_H Y_H^\dagger + 2m_u^2 Y_u Y_u^\dagger + 4Y_u m_q^2 Y_u^\dagger \\
&+ 2Y_u Y_u^\dagger m_u^2 - 4\frac{1}{\sqrt{15}} g_1 \mathbf{1}\sigma_{1,1}
\end{aligned} \tag{80}
$$

$$
\begin{aligned}
\beta_{m_u^2}^{(2)} =& -\frac{16}{15} g_1^2 m_S^2 Y_H Y_H^\dagger + \frac{80}{3} g_3^2 m_S^2 Y_H Y_H^\dagger + \frac{16}{15} g_1^2 M_1 Y_H T_H^\dagger - \frac{80}{3} g_3^2 M_3 Y_H T_H^\dagger \\
&- \frac{4}{5} g_1^2 m_{H_u}^2 Y_u Y_u^\dagger + 12 g_2^2 m_{H_u}^2 Y_u Y_u^\dagger + 24 g_2^2 |M_2|^2 Y_u Y_u^\dagger + \frac{4}{5} g_1^2 M_1 Y_u T_u^\dagger \\
&- 12 g_2^2 M_2 Y_u T_u^\dagger + \frac{16}{45} g_3^2 M_3^* \Big(2\Big(165 g_3^2 M_3 + 8 g_1^2 \Big(2M_3 + M_1\Big)\Big)\mathbf{1} + 75\Big(2M_3 Y_H Y_H^\dagger - T_H Y_H^\dagger\Big)\Big) \\
&- \frac{16}{15} g_1^2 T_H T_H^\dagger + \frac{80}{3} g_3^2 T_H T_H^\dagger \\
&+ \frac{4}{225} g_1^2 M_1^* \Big(- 15\Big(- 3T_u Y_u^\dagger - 4T_H Y_H^\dagger + 6M_1 Y_u Y_u^\dagger + 8 M_1 Y_H Y_H^\dagger\Big) + 8\Big(357 g_1^2 M_1 + 40 g_3^2 \Big(2M_1 + M_3\Big)\Big)\mathbf{1}\Big) \\
&- 12 g_2^2 M_2^* T_u Y_u^\dagger - \frac{4}{5} g_1^2 T_u T_u^\dagger + 12 g_2^2 T_u T_u^\dagger - \frac{8}{15} g_1^2 Y_H Y_H^\dagger m_u^2 \\
&+ \frac{40}{3} g_3^2 Y_H Y_H^\dagger m_u^2 - \frac{16}{15} g_1^2 Y_H m_d^{2*} Y_H^\dagger + \frac{80}{3} g_3^2 Y_H m_d^{2*} Y_H^\dagger - \frac{8}{15} g_1^2 m_u^2 Y_H Y_H^\dagger \\
&+ \frac{40}{3} g_3^2 m_u^2 Y_H Y_H^\dagger - \frac{2}{5} g_1^2 m_u^2 Y_u Y_u^\dagger + 6 g_2^2 m_u^2 Y_u Y_u^\dagger - \frac{4}{5} g_1^2 Y_u m_q^2 Y_u^\dagger \\
&+ 12 g_2^2 Y_u m_q^2 Y_u^\dagger - \frac{2}{5} g_1^2 Y_u Y_u^\dagger m_u^2 + 6 g_2^2 Y_u Y_u^\dagger m_u^2 - 16 m_S^2 Y_H Y_H^\dagger Y_H Y_H^\dagger \\
&- 8 Y_H Y_H^\dagger T_H T_H^\dagger - 8 Y_H T_H^\dagger T_H Y_H^\dagger - 8 m_{H_d}^2 Y_H Y_d^* Y_d^T Y_H^\dagger
\end{aligned}
$$

$$
\begin{aligned}
&- 8m_S^2 Y_H Y_d^* Y_d^T Y_H^\dagger - 8Y_H Y_d^* T_d^T T_H^\dagger - 8Y_H T_d^* T_d^T Y_H^\dagger \\
&- 4m_{H_d}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger - 4m_{H_u}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger - 4Y_u Y_d^\dagger T_d T_u^\dagger \\
&- 8m_{H_u}^2 Y_u Y_u^\dagger Y_u Y_u^\dagger - 4Y_u Y_u^\dagger T_u T_u^\dagger - 4Y_u T_d^\dagger T_d Y_u^\dagger - 4Y_u T_u^\dagger T_u Y_u^\dagger \\
&+ 32m_{H_u}^2 Y_u Y_{\bar{H}}^* Y_{\bar{H}} Y_u^\dagger + 32m_{\bar{S}}^2 Y_u Y_{\bar{H}}^* Y_{\bar{H}} Y_u^\dagger + 32Y_u Y_{\bar{H}}^* T_{\bar{H}} T_u^\dagger + 32Y_u T_{\bar{H}}^* T_{\bar{H}} Y_u^\dagger \\
&- 8T_H Y_H^\dagger Y_H T_H^\dagger - 8T_H T_H^\dagger Y_H Y_H^\dagger - 8T_H Y_d^* Y_d^T T_H^\dagger - 8T_H T_d^* Y_d^T Y_H^\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 \\
&+ 32T_u Y_{\bar{H}}^* Y_{\bar{H}} T_u^\dagger + 32T_u T_{\bar{H}}^* Y_{\bar{H}} Y_u^\dagger - 4Y_H Y_H^\dagger Y_H Y_H^\dagger m_u^2 - 8Y_H Y_H^\dagger Y_H m_d^{2*} Y_H^\dagger \\
&- 8Y_H Y_H^\dagger m_u^2 Y_H Y_H^\dagger - 8Y_H m_d^{2*} Y_H^\dagger Y_H Y_H^\dagger - 8Y_H m_d^{2*} Y_d^* Y_d^T Y_H^\dagger \\
&- 8Y_H Y_d^* m_q^{2*} Y_d^T Y_H^\dagger - 4Y_H Y_d^* Y_d^T Y_H^\dagger m_u^2 - 8Y_H Y_d^* Y_d^T m_d^{2*} Y_H^\dagger \\
&- 4m_u^2 Y_H Y_H^\dagger Y_H Y_H^\dagger - 4m_u^2 Y_H Y_d^* Y_d^T Y_H^\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 \\
&+ 16m_u^2 Y_u Y_{\bar{H}}^* Y_{\bar{H}} 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 \\
&+ 32Y_u m_q^2 Y_{\bar{H}}^* Y_{\bar{H}} 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 \\
&+ 32Y_u Y_{\bar{H}}^* Y_{\bar{H}} m_q^2 Y_u^\dagger + 16Y_u Y_{\bar{H}}^* Y_{\bar{H}} Y_u^\dagger m_u^2 + 32Y_u Y_{\bar{H}}^* m_q^{2*} Y_{\bar{H}} Y_u^\dagger + \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} - 8m_S^2 Y_H Y_H^\dagger \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) - 4T_H T_H^\dagger \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) \\
&- 2Y_H Y_H^\dagger m_u^2 \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) - 4Y_H m_d^{2*} Y_H^\dagger \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) - 2m_u^2 Y_H Y_H^\dagger \mathrm{Tr}\Big(Y_H Y_H^\dagger\Big) \\
&- 24m_{H_u}^2 Y_u Y_u^\dagger \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 12T_u T_u^\dagger \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 6m_u^2 Y_u Y_u^\dagger \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&- 12Y_u m_q^2 Y_u^\dagger \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 6Y_u Y_u^\dagger m_u^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 4Y_H T_H^\dagger \mathrm{Tr}\Big(Y_H^\dagger T_H\Big) \\
&- 12Y_u T_u^\dagger \mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - 4T_H Y_H^\dagger \mathrm{Tr}\Big(T_H^* Y_H^T\Big) - 4Y_H Y_H^\dagger \mathrm{Tr}\Big(T_H^* T_H^T\Big) \\
&- 12T_u Y_u^\dagger \mathrm{Tr}\Big(T_u^* Y_u^T\Big) - 12Y_u Y_u^\dagger \mathrm{Tr}\Big(T_u^* T_u^T\Big) - 4Y_H Y_H^\dagger \mathrm{Tr}\Big(Y_H Y_H^\dagger m_u^2\Big) \\
&- 4Y_H Y_H^\dagger \mathrm{Tr}\Big(Y_H m_d^{2*} Y_H^\dagger\Big) - 12Y_u Y_u^\dagger \mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) - 12Y_u Y_u^\dagger \mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big)
\end{aligned} \tag{81}
$$

$$
\begin{aligned}
\beta_{m_e^2}^{(1)} = &- \frac{24}{5} g_1^2 \mathbf{1} |M_1|^2 + 2\Big(2m_{H_d}^2 Y_e Y_e^\dagger + 2T_e T_e^\dagger + 2Y_e m_l^2 Y_e^\dagger + m_e^2 Y_e Y_e^\dagger + Y_e Y_e^\dagger m_e^2\Big) \\
&+ 2\sqrt{\frac{3}{5}} g_1 \mathbf{1} \sigma_{1,1}
\end{aligned} \tag{82}
$$

$$
\begin{aligned}
\beta_{m_e^2}^{(2)} = &\frac{2}{25}\Big(6g_1^2 M_1^* \Big(258 g_1^2 M_1 \mathbf{1} + 5\Big(-2M_1 Y_e Y_e^\dagger + T_e Y_e^\dagger\Big)\Big) + 20 g_1 \mathbf{1}\Big(3g_1 \sigma_{2,11} + \sqrt{15}\sigma_{3,1}\Big) \\
&- 5\Big(30 g_2^2 M_2^* T_e Y_e^\dagger + 6g_1^2 T_e T_e^\dagger - 30 g_2^2 T_e T_e^\dagger + 3g_1^2 m_e^2 Y_e Y_e^\dagger \\
&- 15 g_2^2 m_e^2 Y_e Y_e^\dagger + 6g_1^2 Y_e m_l^2 Y_e^\dagger - 30 g_2^2 Y_e m_l^2 Y_e^\dagger + 3g_1^2 Y_e Y_e^\dagger m_e^2 \\
&- 15 g_2^2 Y_e Y_e^\dagger m_e^2 + 20 m_{H_d}^2 Y_e Y_e^\dagger Y_e Y_e^\dagger + 10 Y_e Y_e^\dagger T_e T_e^\dagger + 10 Y_e T_e^\dagger T_e Y_e^\dagger \\
&+ 10 T_e Y_e^\dagger Y_e T_e^\dagger + 10 T_e T_e^\dagger Y_e Y_e^\dagger + 5 m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger + 10 Y_e m_l^2 Y_e^\dagger Y_e Y_e^\dagger
\end{aligned}
$$

$$
\begin{aligned}
&+ 10Y_eY_e^\dagger m_e^2 Y_eY_e^\dagger + 10Y_eY_e^\dagger Y_e m_l^2 Y_e^\dagger + 5Y_eY_e^\dagger Y_eY_e^\dagger m_e^2 + 30T_eT_e^\dagger \mathrm{Tr}\Big(Y_dY_d^\dagger\Big) \\
&+ 15m_e^2 Y_eY_e^\dagger \mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 30Y_e m_l^2 Y_e^\dagger \mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 15Y_eY_e^\dagger m_e^2 \mathrm{Tr}\Big(Y_dY_d^\dagger\Big) \\
&+ 10T_eT_e^\dagger \mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 5m_e^2 Y_eY_e^\dagger \mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 10Y_e m_l^2 Y_e^\dagger \mathrm{Tr}\Big(Y_eY_e^\dagger\Big) \\
&+ 5Y_eY_e^\dagger m_e^2 \mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + Y_eT_e^\dagger\Big(10\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 30g_2^2 M_2 + 30\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 6g_1^2 M_1\Big) \\
&+ 30T_eY_e^\dagger \mathrm{Tr}\Big(T_d^* Y_d^T\Big) + 10T_eY_e^\dagger \mathrm{Tr}\Big(T_e^* Y_e^T\Big) \\
&+ 2Y_eY_e^\dagger\Big(3g_1^2 m_{H_d}^2 - 15g_2^2 m_{H_d}^2 - 30g_2^2|M_2|^2 + 30m_{H_d}^2 \mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 10m_{H_d}^2 \mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 15\mathrm{Tr}\Big(T_d^* T_d^T\Big) \\
&+ 5\mathrm{Tr}\Big(T_e^* T_e^T\Big) + 15\mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger\Big) + 5\mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger\Big) + 5\mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e\Big) + 15\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d\Big)\Big)\Big)\Big) \qquad (83)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(1)}_{m_S^2} &= -\frac{8}{15}g_1^2|M_1|^2 - \frac{80}{3}g_3^2|M_3|^2 + 2\frac{1}{\sqrt{15}}g_1\sigma_{1,1} + 2m_S^2\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) + 2\mathrm{Tr}\Big(T_H^*T_H^T\Big) \\
&+ 2\mathrm{Tr}\Big(Y_HY_H^\dagger m_u^2\Big) + 2\mathrm{Tr}\Big(Y_H m_d^{2*} Y_H^\dagger\Big) \qquad (84)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(2)}_{m_S^2} &= \frac{4}{225}\Big(2g_1^2M_1^*\Big(100g_3^2M_3 + 200g_3^2M_1 - 30\mathrm{Tr}\Big(Y_H^\dagger T_H\Big) + 339g_1^2M_1 + 60M_1\mathrm{Tr}\Big(Y_HY_H^\dagger\Big)\Big) \\
&+ 5\Big(10g_3^2M_3^*\Big(3\mathrm{Tr}\Big(Y_H^\dagger T_H\Big) + 4g_1^2M_1 + 690g_3^2M_3 - 6M_3\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) + 8g_1^2M_3\Big) \\
&+ 3\Big(100g_3^4\sigma_{2,3} + 2g_1^2\sigma_{2,11} + 2\sqrt{15}g_1\sigma_{3,1} + 2\Big(2g_1^2 - 5g_3^2\Big)m_S^2\mathrm{Tr}\Big(Y_HY_H^\dagger\Big) \\
&+ \Big(10g_3^2M_3 - 4g_1^2M_1\Big)\mathrm{Tr}\Big(T_H^*Y_H^T\Big) + 4g_1^2\mathrm{Tr}\Big(T_H^*T_H^T\Big) - 10g_3^2\mathrm{Tr}\Big(T_H^*T_H^T\Big) + 4g_1^2\mathrm{Tr}\Big(Y_HY_H^\dagger m_u^2\Big) \\
&- 10g_3^2\mathrm{Tr}\Big(Y_HY_H^\dagger m_u^2\Big) + 4g_1^2\mathrm{Tr}\Big(Y_H m_d^{2*}Y_H^\dagger\Big) - 10g_3^2\mathrm{Tr}\Big(Y_H m_d^{2*}Y_H^\dagger\Big) - 60m_S^2\mathrm{Tr}\Big(Y_HY_H^\dagger Y_HY_H^\dagger\Big) \\
&- 15m_{H_u}^2\mathrm{Tr}\Big(Y_HY_H^\dagger Y_uY_u^\dagger\Big) - 15m_S^2\mathrm{Tr}\Big(Y_HY_H^\dagger Y_uY_u^\dagger\Big) - 60\mathrm{Tr}\Big(Y_HY_H^\dagger T_HT_H^\dagger\Big) \\
&- 15\mathrm{Tr}\Big(Y_HY_H^\dagger T_uT_u^\dagger\Big) - 60\mathrm{Tr}\Big(Y_HT_H^\dagger T_HY_H^\dagger\Big) - 15\mathrm{Tr}\Big(Y_HT_H^\dagger T_uY_u^\dagger\Big) - 15\mathrm{Tr}\Big(Y_HT_d^*T_d^TY_H^\dagger\Big) \\
&- 15m_{H_d}^2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_H^TY_H^*\Big) - 15m_S^2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_H^TY_H^*\Big) - 15\mathrm{Tr}\Big(Y_dY_d^\dagger T_H^TT_H^*\Big) \\
&- 15\mathrm{Tr}\Big(Y_uY_u^\dagger T_HT_H^\dagger\Big) - 15\mathrm{Tr}\Big(Y_uT_u^\dagger T_HY_H^\dagger\Big) - 15\mathrm{Tr}\Big(Y_H^\dagger T_HT_d^*Y_d^T\Big) - 15\mathrm{Tr}\Big(Y_d^\dagger Y_H^TT_H^*T_d\Big) \\
&- 30\mathrm{Tr}\Big(Y_HY_H^\dagger Y_HY_H^\dagger m_u^2\Big) - 30\mathrm{Tr}\Big(Y_HY_H^\dagger Y_Hm_d^{2*}Y_H^\dagger\Big) - 30\mathrm{Tr}\Big(Y_HY_H^\dagger m_u^2Y_HY_H^\dagger\Big) - 15\mathrm{Tr}\Big(Y_HY_H^\dagger m_u^2Y_uY_u^\dagger\Big) \\
&- 15\mathrm{Tr}\Big(Y_HY_H^\dagger Y_um_q^2Y_u^\dagger\Big) - 15\mathrm{Tr}\Big(Y_HY_H^\dagger Y_uY_u^\dagger m_u^2\Big) - 30\mathrm{Tr}\Big(Y_Hm_d^{2*}Y_H^\dagger Y_HY_H^\dagger\Big) \\
&- 15\mathrm{Tr}\Big(Y_Hm_d^{2*}Y_H^\dagger Y_uY_u^\dagger\Big) - 15\mathrm{Tr}\Big(m_d^2Y_dY_d^\dagger Y_H^TY_H^*\Big) - 15\mathrm{Tr}\Big(m_d^2Y_H^TY_H^*Y_dY_d^\dagger\Big) \\
&- 15\mathrm{Tr}\Big(m_q^2Y_d^\dagger Y_H^TY_H^*Y_d\Big) - 15\mathrm{Tr}\Big(Y_dY_d^\dagger Y_H^Tm_u^{2*}Y_H^*\Big)\Big)\Big)\Big) \qquad (85)
\end{aligned}
$$

$$
\beta^{(1)}_{m_{\bar S}^2} = -\frac{2}{15}\Big(120\mathrm{Tr}\Big(Y_{\bar H}m_q^2Y_{\bar H}^*\Big) + 200g_3^2|M_3|^2 + 4g_1^2|M_1|^2 + 60m_{\bar S}^2\mathrm{Tr}\Big(Y_{\bar H}Y_{\bar H}^*\Big) + 60\mathrm{Tr}\Big(T_{\bar H}^*T_{\bar H}\Big) + \sqrt{15}g_1\sigma_{1,1}\Big) \qquad (86)
$$

$$
\beta^{(2)}_{m_{\bar S}^2} = \frac{8}{225}\Big(g_1^2M_1^*\Big(100g_3^2M_3 - 15\mathrm{Tr}\Big(Y_{\bar H}^*T_{\bar H}\Big) + 200g_3^2M_1 + 30M_1\mathrm{Tr}\Big(Y_{\bar H}Y_{\bar H}^*\Big) + 339g_1^2M_1\Big)
$$

$$
\begin{aligned}
&+5\Big(10g_3^2M_3^*\Big(12M_3\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)+2g_1^2M_1+345g_3^2M_3+4g_1^2M_3-6\mathrm{Tr}\Big(Y_{\bar{H}}^*T_{\bar{H}}\Big)\Big)\\
&+3\Big(50g_3^4\sigma_{2,3}+g_1^2\sigma_{2,11}-\sqrt{15}g_1\sigma_{3,1}+\Big(\Big(20g_3^2-45g_2^2+g_1^2\Big)m_{\bar{S}}^2-90g_2^2|M_2|^2\Big)\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*\Big)\\
&-\Big(20g_3^2M_3-45g_2^2M_2+g_1^2M_1\Big)\mathrm{Tr}\Big(Y_{\bar{H}}T_{\bar{H}}^*\Big)+45g_2^2M_2^*\mathrm{Tr}\Big(Y_{\bar{H}}^*T_{\bar{H}}\Big)+g_1^2\mathrm{Tr}\Big(T_{\bar{H}}^*T_{\bar{H}}\Big)\\
&-45g_2^2\mathrm{Tr}\Big(T_{\bar{H}}^*T_{\bar{H}}\Big)+20g_3^2\mathrm{Tr}\Big(T_{\bar{H}}^*T_{\bar{H}}\Big)+2g_1^2\mathrm{Tr}\Big(Y_{\bar{H}}m_q^2Y_{\bar{H}}^*\Big)-90g_2^2\mathrm{Tr}\Big(Y_{\bar{H}}m_q^2Y_{\bar{H}}^*\Big)\\
&+40g_3^2\mathrm{Tr}\Big(Y_{\bar{H}}m_q^2Y_{\bar{H}}^*\Big)+30m_{H_d}^2\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big)+30m_{\bar{S}}^2\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger T_dT_{\bar{H}}^*\Big)\\
&+30m_{H_u}^2\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*\Big)+30m_{\bar{S}}^2\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger T_uT_{\bar{H}}^*\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}T_d^\dagger T_dY_{\bar{H}}^*\Big)\\
&+30\mathrm{Tr}\Big(Y_{\bar{H}}T_u^\dagger T_uY_{\bar{H}}^*\Big)-480m_{\bar{S}}^2\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*\Big)-480\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*T_{\bar{H}}T_{\bar{H}}^*\Big)-480\mathrm{Tr}\Big(Y_{\bar{H}}T_{\bar{H}}^*T_{\bar{H}}Y_{\bar{H}}^*\Big)\\
&+30\mathrm{Tr}\Big(Y_dT_{\bar{H}}^*T_{\bar{H}}Y_d^\dagger\Big)+30\mathrm{Tr}\Big(Y_uT_{\bar{H}}^*T_{\bar{H}}Y_u^\dagger\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}^*Y_d^TT_d^*T_{\bar{H}}\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}^*Y_u^TT_u^*T_{\bar{H}}\Big)\\
&+30\mathrm{Tr}\Big(Y_{\bar{H}}m_q^2Y_d^\dagger Y_dY_{\bar{H}}^*\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}m_q^2Y_u^\dagger Y_uY_{\bar{H}}^*\Big)-480\mathrm{Tr}\Big(Y_{\bar{H}}m_q^2Y_{\bar{H}}^*Y_{\bar{H}}Y_{\bar{H}}^*\Big)\\
&+30\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger m_d^2Y_dY_{\bar{H}}^*\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dm_q^2Y_{\bar{H}}^*\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*m_q^{2*}\Big)\\
&+30\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger m_u^2Y_uY_{\bar{H}}^*\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_um_q^2Y_{\bar{H}}^*\Big)+30\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*m_q^{2*}\Big)\\
&-480\mathrm{Tr}\Big(Y_{\bar{H}}Y_{\bar{H}}^*Y_{\bar{H}}m_q^2Y_{\bar{H}}^*\Big)\Big)\Big)\Big)
\end{aligned}
\tag{87}
$$

3.9 Vacuum expectation values

$$
\beta_{v_d}^{(1)}=\frac{1}{20}v_d\Big(-20\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)+3\Big(5g_2^2+g_1^2\Big)\Big(1+\mathrm{Xi}\Big)-60\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\Big) \tag{88}
$$

$$
\begin{aligned}
\beta_{v_d}^{(2)}=&\frac{1}{400}v_d\Big(-462g_1^4-180g_1^2g_2^2-1200g_2^4-9g_1^4\mathrm{Xi}-90g_1^2g_2^2\mathrm{Xi}+875g_2^4\mathrm{Xi}+9g_1^4\mathrm{Xi}^2+90g_1^2g_2^2\mathrm{Xi}^2\\
&-225g_2^4\mathrm{Xi}^2-40\Big(5\Big(32g_3^2+9g_2^2\mathrm{Xi}\Big)+g_1^2\Big(9\mathrm{Xi}-4\Big)\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-120\Big(5g_2^2\mathrm{Xi}+g_1^2\Big(4+\mathrm{Xi}\Big)\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&-9600\mathrm{Tr}\Big(Y_{\bar{H}}Y_d^\dagger Y_dY_{\bar{H}}^*\Big)+3600\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)+2400\mathrm{Tr}\Big(Y_dY_d^\dagger Y_H^TY_H^*\Big)+1200\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)\\
&+1200\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\Big)
\end{aligned}
\tag{89}
$$

$$
\beta_{v_u}^{(1)}=\frac{3}{20}v_u\Big(-20\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+\Big(5g_2^2+g_1^2\Big)\Big(1+\mathrm{Xi}\Big)\Big) \tag{90}
$$

$$
\begin{aligned}
\beta_{v_u}^{(2)}=&\frac{1}{400}v_u\Big(-462g_1^4-180g_1^2g_2^2-1200g_2^4-9g_1^4\mathrm{Xi}-90g_1^2g_2^2\mathrm{Xi}+875g_2^4\mathrm{Xi}+9g_1^4\mathrm{Xi}^2+90g_1^2g_2^2\mathrm{Xi}^2\\
&-225g_2^4\mathrm{Xi}^2-40\Big(5\Big(32g_3^2+9g_2^2\mathrm{Xi}\Big)+g_1^2\Big(9\mathrm{Xi}+8\Big)\Big)\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+2400\mathrm{Tr}\Big(Y_HY_H^\dagger Y_uY_u^\dagger\Big)\\
&-9600\mathrm{Tr}\Big(Y_{\bar{H}}Y_u^\dagger Y_uY_{\bar{H}}^*\Big)+1200\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)+3600\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)\Big)
\end{aligned}
\tag{91}
$$

4 Field Rotations

4.1 Rotations in gauge sector for eigenstates 'EWSB'

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \end{pmatrix} = Z^{\gamma Z} \begin{pmatrix} \gamma_\rho \\ Z_\rho \end{pmatrix} \tag{92}$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho} \end{pmatrix} = Z^{W} \begin{pmatrix} W_\rho^- \\ W_\rho^- \end{pmatrix} \tag{93}$$

$$\begin{pmatrix} \lambda_{\tilde{W},1} \\ \lambda_{\tilde{W},2} \\ \lambda_{\tilde{W},3} \end{pmatrix} = Z^{\tilde{W}} \begin{pmatrix} \tilde{W}^- \\ \tilde{W}^+ \\ \tilde{W}^0 \end{pmatrix} \tag{94}$$

$$\tag{95}$$

The mixing matrices are parametrized by

$$Z^{\gamma Z} = \begin{pmatrix} \cos\Theta_W & -\sin\Theta_W \\ \sin\Theta_W & \cos\Theta_W \end{pmatrix} \tag{96}$$

$$Z^{W} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} \end{pmatrix} \tag{97}$$

$$Z^{\tilde{W}} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{98}$$

$$\tag{99}$$

4.2 Rotations in Mass sector for eigenstates 'EWSB'

4.2.1 Mass Matrices for Scalars

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

$$m^2_{\tilde{d}} = \begin{pmatrix} m_{\tilde{d}_L \tilde{d}^*_L} & \frac{1}{\sqrt{2}}\Big(v_d T_d^\dagger - v_u \mu Y_d^\dagger\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\delta_{\alpha_2\beta_1}\Big(v_d T_d - v_u Y_d \mu^*\Big) & m_{\tilde{d}_R \tilde{d}^*_R} \end{pmatrix} \tag{100}$$

$$m_{\tilde{d}_L \tilde{d}^*_L} = -\frac{1}{24}\Big(3g_2^2 + g_1^2\Big)\mathbf{1}\Big(-v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m_q^2 + v_d^2 Y_d^\dagger Y_d\Big) \tag{101}$$

$$m_{\tilde{d}_R \tilde{d}^*_R} = \frac{1}{12}g_1^2\mathbf{1}\Big(-v_d^2 + v_u^2\Big)\delta_{\alpha_2\beta_2} + \frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m_d^2 + v_d^2 Y_d Y_d^\dagger\Big) \tag{102}$$

This matrix is diagonalized by Z^D:

$$Z^D m^2_{\tilde{d}} Z^{D,\dagger} = m^{dia}_{2,\tilde{d}} \tag{103}$$

with

$$\tilde{d}_{L,i\alpha} = \sum_j Z^{D,*}_{ji} \tilde{d}_{j\alpha}\,, \qquad \tilde{d}_{R,i\alpha} = \sum_j Z^{D,*}_{ji} \tilde{d}_{j\alpha} \tag{104}$$

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

$$m^2_{\tilde{\nu}} = \Big(\ \tfrac{1}{8}\Big(g_1^2 + g_2^2\Big)\mathbf{1}\Big(- v_u^2 + v_d^2\Big) + m_l^2 \ \Big) \tag{105}$$

This matrix is diagonalized by Z^V:

$$Z^V m^2_{\tilde{\nu}} Z^{V,\dagger} = m^{dia}_{2,\tilde{\nu}} \tag{106}$$

with

$$\tilde{\nu}_{L,i} = \sum_j Z^{V,*}_{ji} \tilde{\nu}_j \tag{107}$$

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

$$m^2_{\tilde{u}} = \begin{pmatrix} m_{\tilde{u}_L \tilde{u}^*_L} & \frac{1}{\sqrt{2}}\Big(- v_d \mu Y_u^\dagger + v_u T_u^\dagger\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\delta_{\alpha_2\beta_1}\Big(- v_d Y_u \mu^* + v_u T_u\Big) & m_{\tilde{u}_R \tilde{u}^*_R} \end{pmatrix} \tag{108}$$

$$m_{\tilde{u}_L \tilde{u}^*_L} = -\frac{1}{24}\Big(- 3g_2^2 + g_1^2\Big)\mathbf{1}\Big(- v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m_q^2 + v_u^2 Y_u^\dagger Y_u\Big) \tag{109}$$

$$m_{\tilde{u}_R \tilde{u}^*_R} = \frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m_u^2 + v_u^2 Y_u Y_u^\dagger\Big) + \frac{1}{6}g_1^2\mathbf{1}\Big(- v_u^2 + v_d^2\Big)\delta_{\alpha_2\beta_2} \tag{110}$$

This matrix is diagonalized by Z^U:

$$Z^U m^2_{\tilde{u}} Z^{U,\dagger} = m^{dia}_{2,\tilde{u}} \tag{111}$$

with

$$\tilde{u}_{L,i\alpha} = \sum_j Z^{U,*}_{ji} \tilde{u}_{j\alpha}\,, \qquad \tilde{u}_{R,i\alpha} = \sum_j Z^{U,*}_{ji} \tilde{u}_{j\alpha} \tag{112}$$

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

$$m^2_{\tilde{e}} = \begin{pmatrix} m_{\tilde{e}_L \tilde{e}^*_L} & \frac{1}{\sqrt{2}}\Big(v_d T_e^\dagger - v_u \mu Y_e^\dagger\Big) \\ \frac{1}{\sqrt{2}}\Big(v_d T_e - v_u Y_e \mu^*\Big) & m_{\tilde{e}_R \tilde{e}^*_R} \end{pmatrix} \tag{113}$$

$$m_{\tilde{e}_L \tilde{e}^*_L} = \frac{1}{2}v_d^2 Y_e^\dagger Y_e + \frac{1}{8}\Big(- g_2^2 + g_1^2\Big)\mathbf{1}\Big(- v_u^2 + v_d^2\Big) + m_l^2 \tag{114}$$

$$m_{\tilde{e}_R\tilde{e}_R^*} = \frac{1}{2}v_d^2 Y_e Y_e^\dagger + \frac{1}{4}g_1^2\mathbf{1}\Big(-v_d^2+v_u^2\Big) + m_e^2 \tag{115}$$

This matrix is diagonalized by Z^E:

$$Z^E m_{\tilde{e}}^2 Z^{E,\dagger} = m_{2,\tilde{e}}^{dia} \tag{116}$$

with

$$\tilde{e}_{L,i} = \sum_j Z_{ji}^{E,*}\tilde{e}_j\,, \qquad \tilde{e}_{R,i} = \sum_j Z_{ji}^{E,*}\tilde{e}_j \tag{117}$$

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

$$m_h^2 = \begin{pmatrix} \frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(3v_d^2-v_u^2\Big)+m_{H_d}^2+|\mu|^2 & -\frac{1}{4}\Big(g_1^2+g_2^2\Big)v_dv_u - \Re\Big(B_\mu\Big) \\ -\frac{1}{4}\Big(g_1^2+g_2^2\Big)v_dv_u - \Re\Big(B_\mu\Big) & -\frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(-3v_u^2+v_d^2\Big)+m_{H_u}^2+|\mu|^2 \end{pmatrix} \tag{118}$$

This matrix is diagonalized by Z^H:

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \tag{119}$$

with

$$\phi_d = \sum_j Z_{j1}^H h_j\,, \qquad \phi_u = \sum_j Z_{j2}^H h_j \tag{120}$$

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

$$m_{A^0}^2 = \begin{pmatrix} \frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(-v_u^2+v_d^2\Big)+m_{H_d}^2+|\mu|^2 & \Re\Big(B_\mu\Big) \\ \Re\Big(B_\mu\Big) & -\frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(-v_u^2+v_d^2\Big)+m_{H_u}^2+|\mu|^2 \end{pmatrix} + \xi_Z m^2(Z) \tag{121}$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} \frac{1}{4}v_d^2\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 & -\frac{1}{4}v_dv_u\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 \\ -\frac{1}{4}v_dv_u\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 & \frac{1}{4}v_u^2\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 \end{pmatrix} \tag{122}$$

This matrix is diagonalized by Z^A:

$$Z^A m_{A^0}^2 Z^{A,\dagger} = m_{2,A^0}^{dia} \tag{123}$$

with

$$\sigma_d = \sum_j Z_{j1}^A A_j^0\,, \qquad \sigma_u = \sum_j Z_{j2}^A A_j^0 \tag{124}$$

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

$$m^2_{H^-} = \begin{pmatrix} m_{H_d^- H_d^{-,*}} & \frac{1}{4}g_2^2 v_d v_u + B_\mu^* \\ \frac{1}{4}g_2^2 v_d v_u + B_\mu & m_{H_u^{+,*} H_u^+} \end{pmatrix} + \xi_{W^-} m^2(W^-) \tag{125}$$

$$m_{H_d^- H_d^{-,*}} = \frac{1}{8}\Big(g_1^2\Big(-v_u^2 + v_d^2\Big) + g_2^2\Big(v_d^2 + v_u^2\Big)\Big) + m^2_{H_d} + |\mu|^2 \tag{126}$$

$$m_{H_u^{+,*} H_u^+} = \frac{1}{8}\Big(g_1^2\Big(-v_d^2 + v_u^2\Big) + g_2^2\Big(v_d^2 + v_u^2\Big)\Big) + m^2_{H_u} + |\mu|^2 \tag{127}$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4}g_2^2 v_d^2 & -\frac{1}{4}g_2^2 v_d v_u \\ -\frac{1}{4}g_2^2 v_d v_u & \frac{1}{4}g_2^2 v_u^2 \end{pmatrix} \tag{128}$$

This matrix is diagonalized by Z^+:

$$Z^+ m^2_{H^-} Z^{+,\dagger} = m^{dia}_{2,H^-} \tag{129}$$

with

$$H_d^- = \sum_j Z^+_{j1} H_j^- \,, \qquad H_u^+ = \sum_j Z^+_{j2} H_j^+ \tag{130}$$

4.2.2 Mass Matrices for Fermions

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

$$m_{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & -\frac{1}{2}g_1 v_d & \frac{1}{2}g_1 v_u \\ 0 & M_2 & \frac{1}{2}g_2 v_d & -\frac{1}{2}g_2 v_u \\ -\frac{1}{2}g_1 v_d & \frac{1}{2}g_2 v_d & 0 & -\mu \\ \frac{1}{2}g_1 v_u & -\frac{1}{2}g_2 v_u & -\mu & 0 \end{pmatrix} \tag{131}$$

This matrix is diagonalized by N:

$$N^* m_{\tilde{\chi}^0} N^\dagger = m^{dia}_{\tilde{\chi}^0} \tag{132}$$

with

$$\lambda_{\tilde{B}} = \sum_j N^*_{j1} \lambda_j^0 \,, \qquad \tilde{W}^0 = \sum_j N^*_{j2} \lambda_j^0 \,, \qquad \tilde{H}_d^0 = \sum_j N^*_{j3} \lambda_j^0 \tag{133}$$

$$\tilde{H}_u^0 = \sum_j N^*_{j4} \lambda_j^0 \tag{134}$$

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

$$m_{\tilde{\chi}^-} = \begin{pmatrix} M_2 & \frac{1}{\sqrt{2}}g_2 v_u \\ \frac{1}{\sqrt{2}}g_2 v_d & \mu \end{pmatrix} \tag{135}$$

This matrix is diagonalized by U and V

$$U^* m_{\tilde{\chi}^-} V^\dagger = m_{\tilde{\chi}^-}^{dia} \tag{136}$$

with

$$\tilde{W}^- = \sum_{t_2} U_{j1}^* \lambda_j^- \,, \qquad \tilde{H}_d^- = \sum_{t_2} U_{j2}^* \lambda_j^- \tag{137}$$

$$\tilde{W}^+ = \sum_{t_2} V_{1j}^* \lambda_j^+ \,, \qquad \tilde{H}_u^+ = \sum_{t_2} V_{2j}^* \lambda_j^+ \tag{138}$$

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

$$m_e = \left(\begin{array}{c} \frac{1}{\sqrt{2}} v_d Y_e^T \end{array} \right) \tag{139}$$

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

$$U_L^{e,*} m_e U_R^{e,\dagger} = m_e^{dia} \tag{140}$$

with

$$e_{L,i} = \sum_{t_2} U_{L,ji}^{e,*} E_{L,j} \tag{141}$$

$$e_{R,i} = \sum_{t_2} U_{R,ij}^{e} E_{R,j}^* \tag{142}$$

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

$$m_d = \left(\begin{array}{c} \frac{1}{\sqrt{2}} v_d \delta_{\alpha_1\beta_1} Y_d^T \end{array} \right) \tag{143}$$

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

$$U_L^{d,*} m_d U_R^{d,\dagger} = m_d^{dia} \tag{144}$$

with

$$d_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{d,*} D_{L,j\alpha} \tag{145}$$

$$d_{R,i\alpha} = \sum_{t_2} U_{R,ij}^{d} D_{R,j\alpha}^* \tag{146}$$

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

$$m_u = \left(\begin{array}{c} \frac{1}{\sqrt{2}} v_u \delta_{\alpha_1\beta_1} Y_u^T \end{array} \right) \tag{147}$$

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

$$U_L^{u,*} m_u U_R^{u,\dagger} = m_u^{dia} \tag{148}$$

with

$$u_{L,i\alpha} = \sum_{t_2} U^{u,*}_{L,ji} U_{L,j\alpha} \tag{149}$$

$$u_{R,i\alpha} = \sum_{t_2} U^{u}_{R,ij} U^{*}_{R,j\alpha} \tag{150}$$

5 Vacuum Expectation Values

$$H^0_d = \frac{1}{\sqrt{2}}\phi_d + \frac{1}{\sqrt{2}}v_d + i\frac{1}{\sqrt{2}}\sigma_d \tag{151}$$

$$H^0_u = \frac{1}{\sqrt{2}}\phi_u + \frac{1}{\sqrt{2}}v_u + i\frac{1}{\sqrt{2}}\sigma_u \tag{152}$$

6 Tadpole Equations

$$\frac{\partial V}{\partial \phi_d} = -\frac{1}{2}v_u\Big(B_\mu + B^*_\mu\Big) + \frac{1}{8}\Big(g_1^2 + g_2^2\Big)v_d\Big(-v_u + v_d\Big)\Big(v_d + v_u\Big) + v_d\Big(m^2_{H_d} + |\mu|^2\Big) \tag{153}$$

$$\frac{\partial V}{\partial \phi_u} = \frac{1}{8}\Big(g_1^2 + g_2^2\Big)v_u\Big(-v_d^2 + v_u^2\Big) - v_d\Re\Big(B_\mu\Big) + v_u\Big(m^2_{H_u} + |\mu|^2\Big) \tag{154}$$

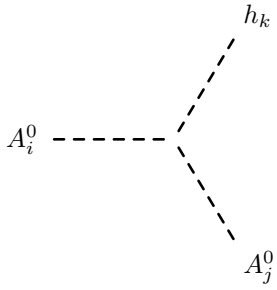
7 Particle content for eigenstates 'EWSB'

Name	Type	complex/real	Generations	Indices
$\tilde{\Psi}$	Scalar	complex	1	color, 6
$\tilde{\bar{\Psi}}$	Scalar	complex	1	color, 6
$\tilde{d}$	Scalar	complex	6	generation, 6, color, 3
$\tilde{\nu}$	Scalar	complex	3	generation, 3
$\tilde{u}$	Scalar	complex	6	generation, 6, color, 3
$\tilde{e}$	Scalar	complex	6	generation, 6
h	Scalar	real	2	generation, 2
A^0	Scalar	real	2	generation, 2
H^-	Scalar	complex	2	generation, 2
$\tilde{g}$	Fermion	Majorana	1	color, 8
ν	Fermion	Dirac	3	generation, 3
Ψ	Fermion	Dirac	1	color, 6
$\tilde{\chi}^0$	Fermion	Majorana	4	generation, 4

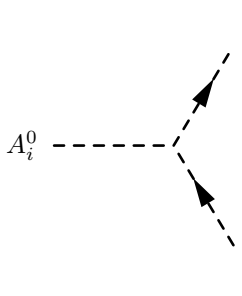
$\tilde{\chi}^-$	Fermion	Dirac	2	generation, 2
e	Fermion	Dirac	3	generation, 3
d	Fermion	Dirac	3	generation, 3, color, 3
u	Fermion	Dirac	3	generation, 3, color, 3
g	Vector	real	1	color, 8, lorentz, 4
γ	Vector	real	1	lorentz, 4
Z	Vector	real	1	lorentz, 4
W^-	Vector	complex	1	lorentz, 4
η^G	Ghost	real	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'

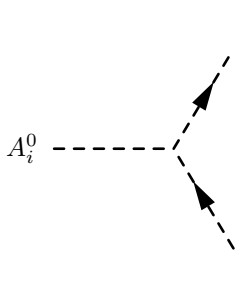
8.1 Three Scalar-Interaction



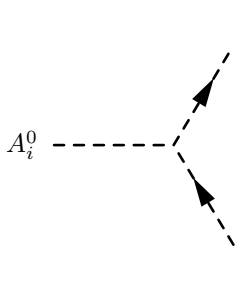
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\Big)\Big(v_d Z_{k1}^H - v_u Z_{k2}^H\Big) \tag{155}$$



$$\frac{1}{4}g_2^2\Big(v_d Z_{i2}^A + v_u Z_{i1}^A\Big)\Big(- Z_{j1}^+ Z_{k2}^+ + Z_{j2}^+ Z_{k1}^+\Big) \tag{156}$$

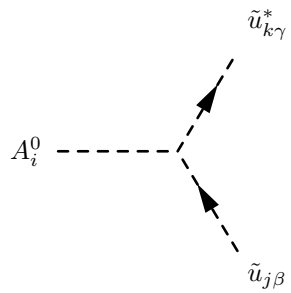


$$\begin{aligned}&\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\Big(\sum_{b=1}^{3} Z_{jb}^{D,*}\sum_{a=1}^{3} Z_{k3+a}^{D} T_{d,ab} Z_{i1}^{A} - \sum_{b=1}^{3}\sum_{a=1}^{3} Z_{j3+a}^{D,*} T_{d,ab}^{*} Z_{kb}^{D} Z_{i1}^{A}\\ &+ \Big(- \mu \sum_{b=1}^{3}\sum_{a=1}^{3} Y_{d,ab}^{*} Z_{j3+a}^{D,*} Z_{kb}^{D} + \mu^{*}\sum_{b=1}^{3} Z_{jb}^{D,*}\sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D}\Big) Z_{i2}^{A}\Big)\end{aligned} \tag{157}$$

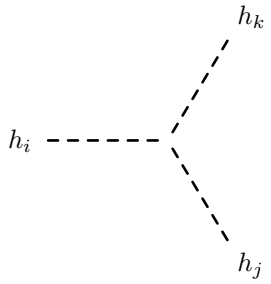


$$\frac{1}{\sqrt{2}}\Big(\sum_{b=1}^{3} Z_{jb}^{E,*}\sum_{a=1}^{3} Z_{k3+a}^{E} T_{e,ab} Z_{i1}^{A} - \sum_{b=1}^{3}\sum_{a=1}^{3} Z_{j3+a}^{E,*} T_{e,ab}^{*} Z_{kb}^{E} Z_{i1}^{A}$$

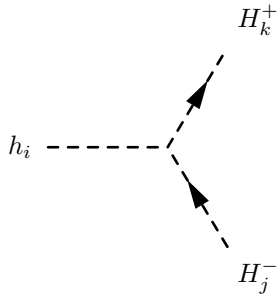
$$+\Big(-\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{e,ab}Z^{E,*}_{j3+a}Z^{E}_{kb}+\mu^{*}\sum_{b=1}^{3}Z^{E,*}_{jb}\sum_{a=1}^{3}Y_{e,ab}Z^{E}_{k3+a}\Big)Z^{A}_{i2}\Big) \tag{158}$$



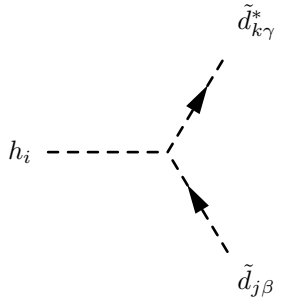
$$\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\Big(\mu^{*}\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Y_{u,ab}Z^{U}_{k3+a}Z^{A}_{i1}-\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{u,ab}Z^{U,*}_{j3+a}Z^{U}_{kb}Z^{A}_{i1}$$
$$+\Big(-\sum_{b=1}^{3}\sum_{a=1}^{3}Z^{U,*}_{j3+a}T^{*}_{u,ab}Z^{U}_{kb}+\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Z^{U}_{k3+a}T_{u,ab}\Big)Z^{A}_{i2}\Big) \tag{159}$$



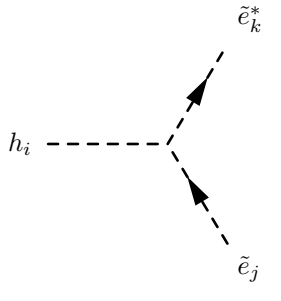
$$\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z^{H}_{i2}\Big(Z^{H}_{j1}\Big(v_dZ^{H}_{k2}+v_uZ^{H}_{k1}\Big)+Z^{H}_{j2}\Big(-3v_uZ^{H}_{k2}+v_dZ^{H}_{k1}\Big)\Big)$$
$$+Z^{H}_{i1}\Big(Z^{H}_{j1}\Big(-3v_dZ^{H}_{k1}+v_uZ^{H}_{k2}\Big)+Z^{H}_{j2}\Big(v_dZ^{H}_{k2}+v_uZ^{H}_{k1}\Big)\Big)\Big) \tag{160}$$



$$\frac{i}{4}\Big(- Z_{i1}^{H}\Big(Z_{j1}^{+}\Big(\Big(g_1^2+g_2^2\Big)v_d Z_{k1}^{+} + g_2^2 v_u Z_{k2}^{+}\Big) + Z_{j2}^{+}\Big(\Big(-g_1^2+g_2^2\Big)v_d Z_{k2}^{+} + g_2^2 v_u Z_{k1}^{+}\Big)\Big)$$
$$+ Z_{i2}^{H}\Big(Z_{j1}^{+}\Big(\Big(-g_2^2+g_1^2\Big)v_u Z_{k1}^{+} - g_2^2 v_d Z_{k2}^{+}\Big) - Z_{j2}^{+}\Big(\Big(g_1^2+g_2^2\Big)v_u Z_{k2}^{+} + g_2^2 v_d Z_{k1}^{+}\Big)\Big)\Big) \tag{161}$$

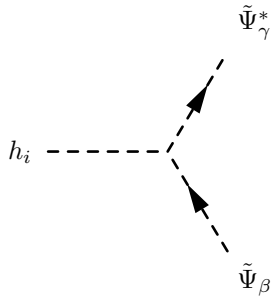


$$\frac{i}{12}\delta_{\beta\gamma}\Big(\Big(3g_2^2+g_1^2\Big)\sum_{a=1}^{3} Z_{ja}^{D,*} Z_{ka}^{D}\Big(v_d Z_{i1}^{H} - v_u Z_{i2}^{H}\Big)$$
$$+ 2\Big(g_1^2\sum_{a=1}^{3} Z_{j3+a}^{D,*} Z_{k3+a}^{D}\Big(v_d Z_{i1}^{H} - v_u Z_{i2}^{H}\Big)$$
$$- 3\Big(\sqrt{2}\sum_{b=1}^{3} Z_{jb}^{D,*}\sum_{a=1}^{3} Z_{k3+a}^{D} T_{d,ab} Z_{i1}^{H} + \sqrt{2}\sum_{b=1}^{3}\sum_{a=1}^{3} Z_{j3+a}^{D,*} T_{d,ab}^{*} Z_{kb}^{D} Z_{i1}^{H}$$
$$+ 2v_d\sum_{c=1}^{3} Z_{j3+c}^{D,*}\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{d,ca}^{*} Y_{d,ba} Z_{k3+b}^{D} Z_{i1}^{H} + 2v_d\sum_{c=1}^{3}\sum_{b=1}^{3} Z_{jb}^{D,*}\sum_{a=1}^{3} Y_{d,ac}^{*} Y_{d,ab} Z_{kc}^{D} Z_{i1}^{H}$$
$$- \sqrt{2}\mu^{*}\sum_{b=1}^{3} Z_{jb}^{D,*}\sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} Z_{i2}^{H} - \sqrt{2}\mu\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{d,ab}^{*} Z_{j3+a}^{D,*} Z_{kb}^{D} Z_{i2}^{H}\Big)\Big)\Big) \tag{162}$$

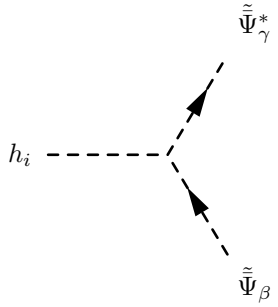


$$\frac{i}{4}\Big(- \Big(- g_2^2+g_1^2\Big)\sum_{a=1}^{3} Z_{ja}^{E,*} Z_{ka}^{E}\Big(v_d Z_{i1}^{H} - v_u Z_{i2}^{H}\Big)$$

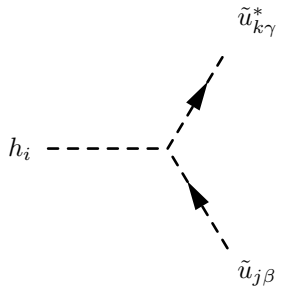
$$+2\Big(-\sqrt{2}\sum_{b=1}^{3}Z_{jb}^{E,*}\sum_{a=1}^{3}Z_{k3+a}^{E}T_{e,ab}Z_{i1}^{H}-\sqrt{2}\sum_{b=1}^{3}\sum_{a=1}^{3}Z_{j3+a}^{E,*}T_{e,ab}^{*}Z_{kb}^{E}Z_{i1}^{H}$$
$$-2v_d\sum_{c=1}^{3}Z_{j3+c}^{E,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ca}^{*}Y_{e,ba}Z_{k3+b}^{E}Z_{i1}^{H}-2v_d\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{E,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{kc}^{E}Z_{i1}^{H}$$
$$+\sqrt{2}\mu^{*}\sum_{b=1}^{3}Z_{jb}^{E,*}\sum_{a=1}^{3}Y_{e,ab}Z_{k3+a}^{E}Z_{i2}^{H}+\sqrt{2}\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^{*}Z_{j3+a}^{E,*}Z_{kb}^{E}Z_{i2}^{H}$$
$$+g_1^2\sum_{a=1}^{3}Z_{j3+a}^{E,*}Z_{k3+a}^{E}\Big(v_dZ_{i1}^{H}-v_uZ_{i2}^{H}\Big)\Big)\Big) \tag{163}$$



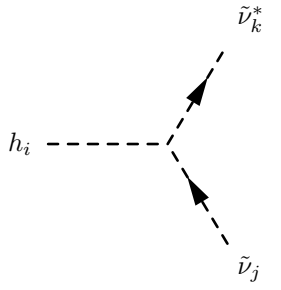
$$\frac{i}{6}g_1^2\delta_{\beta\gamma}\Big(v_dZ_{i1}^{H}-v_uZ_{i2}^{H}\Big) \tag{164}$$



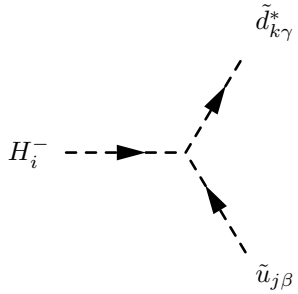
$$\frac{i}{6}g_1^2\delta_{\beta\gamma}\Big(-v_dZ_{i1}^{H}+v_uZ_{i2}^{H}\Big) \tag{165}$$



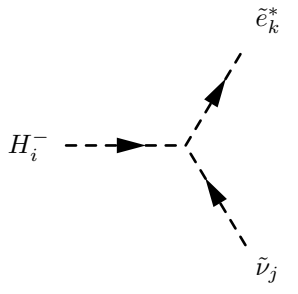
$$\frac{i}{12}\delta_{\beta\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z^{U,*}_{ja}Z^{U}_{ka}\Big(v_dZ^H_{i1}-v_uZ^H_{i2}\Big)$$
$$-2\Big(-3\sqrt{2}\mu^*\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Y_{u,ab}Z^U_{k3+a}Z^H_{i1}-3\sqrt{2}\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{u,ab}Z^{U,*}_{j3+a}Z^U_{kb}Z^H_{i1}$$
$$+3\sqrt{2}\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Z^U_{k3+a}T_{u,ab}Z^H_{i2}+3\sqrt{2}\sum_{b=1}^{3}\sum_{a=1}^{3}Z^{U,*}_{j3+a}T^*_{u,ab}Z^U_{kb}Z^H_{i2}$$
$$+6v_u\sum_{c=1}^{3}Z^{U,*}_{j3+c}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{u,ca}Y_{u,ba}Z^U_{k3+b}Z^H_{i2}+6v_u\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Y^*_{u,ac}Y_{u,ab}Z^U_{kc}Z^H_{i2}$$
$$+2g_1^2\sum_{a=1}^{3}Z^{U,*}_{j3+a}Z^U_{k3+a}\Big(v_dZ^H_{i1}-v_uZ^H_{i2}\Big)\Big)\Big) \tag{166}$$



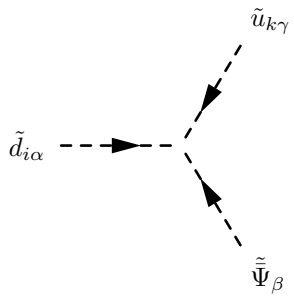
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\delta_{jk}\Big(v_dZ^H_{i1}-v_uZ^H_{i2}\Big) \tag{167}$$



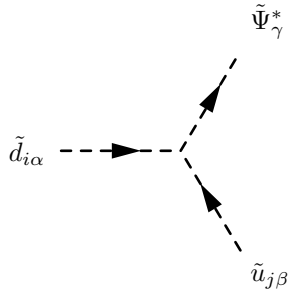
$$
\begin{aligned}
&-\frac{i}{4}\delta_{\beta\gamma}\Big(\sqrt{2}g_2^2\sum_{a=1}^{3}Z^{U,*}_{ja}Z^{D}_{ka}\Big(v_dZ^+_{i1}+v_uZ^+_{i2}\Big)\\
&-2\Big(2\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Z^{D}_{k3+a}T_{d,ab}Z^+_{i1}+2\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{u,ab}Z^{U,*}_{j3+a}Z^{D}_{kb}Z^+_{i1}\\
&+\sqrt{2}v_u\sum_{c=1}^{3}Z^{U,*}_{j3+c}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{u,ca}Y_{d,ba}Z^{D}_{k3+b}Z^+_{i1}\\
&+\sqrt{2}v_d\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Y^*_{d,ac}Y_{d,ab}Z^{D}_{kc}Z^+_{i1}+2\mu^*\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Y_{d,ab}Z^{D}_{k3+a}Z^+_{i2}\\
&+2\sum_{b=1}^{3}\sum_{a=1}^{3}Z^{U,*}_{j3+a}T^*_{u,ab}Z^{D}_{kb}Z^+_{i2}+\sqrt{2}v_d\sum_{c=1}^{3}Z^{U,*}_{j3+c}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{u,ca}Y_{d,ba}Z^{D}_{k3+b}Z^+_{i2}\\
&+\sqrt{2}v_u\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Y^*_{u,ac}Y_{u,ab}Z^{D}_{kc}Z^+_{i2}\Big)\Big)
\end{aligned}
\tag{168}
$$



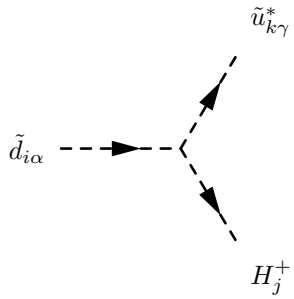
$$
\begin{aligned}
&\frac{i}{4}\Big(4\sum_{b=1}^{3}Z^{V,*}_{jb}\sum_{a=1}^{3}Z^{E}_{k3+a}T_{e,ab}Z^+_{i1}+2\sqrt{2}v_d\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{V,*}_{jb}\sum_{a=1}^{3}Y^*_{e,ac}Y_{e,ab}Z^{E}_{kc}Z^+_{i1}\\
&+4\mu^*\sum_{b=1}^{3}Z^{V,*}_{jb}\sum_{a=1}^{3}Y_{e,ab}Z^{E}_{k3+a}Z^+_{i2}-\sqrt{2}g_2^2\sum_{a=1}^{3}Z^{V,*}_{ja}Z^{E}_{ka}\Big(v_dZ^+_{i1}+v_uZ^+_{i2}\Big)\Big)
\end{aligned}
\tag{169}
$$



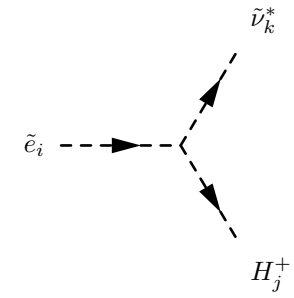
$$
\begin{aligned}
&i\Big(- M_S\Big(K^{SU[3],6\times\bar{3}\times\bar{3}}_{\beta,\alpha,\gamma}\Big)^* \sum_{b=1}^{3} Z^{U,*}_{k3+b} \sum_{a=1}^{3} Y^*_{H,ba} Z^{D,*}_{i3+a} \\
&+ \frac{1}{2}\Big(2\sum_{b=1}^{3} Z^{U,*}_{kb} \sum_{a=1}^{3} Z^{D,*}_{ia} T_{\bar{H},ab} - 2\sum_{b=1}^{3} Z^{D,*}_{ib} \sum_{a=1}^{3} Z^{U,*}_{ka} T_{\bar{H},ab} \\
&+ \sqrt{2}\Big(v_d \sum_{c=1}^{3} Z^{D,*}_{i3+c} \sum_{b=1}^{3} Z^{U,*}_{kb} \sum_{a=1}^{3} Y^*_{d,ca} Y_{\bar{H},ab} - v_u \sum_{c=1}^{3} Z^{U,*}_{k3+c} \sum_{b=1}^{3} Z^{D,*}_{ib} \sum_{a=1}^{3} Y^*_{u,ca} Y_{\bar{H},ab} \\
&- v_d \sum_{c=1}^{3} Z^{D,*}_{i3+c} \sum_{b=1}^{3} Z^{U,*}_{kb} \sum_{a=1}^{3} Y^*_{d,ca} Y_{\bar{H},ba} + v_u \sum_{c=1}^{3} Z^{U,*}_{k3+c} \sum_{b=1}^{3} Z^{D,*}_{ib} \sum_{a=1}^{3} Y^*_{u,ca} Y_{\bar{H},ba}\Big)\Big) K^{SU[3],\bar{6}\times3\times3}_{\beta,\alpha,\gamma}\Big)
\end{aligned}
\tag{170}
$$



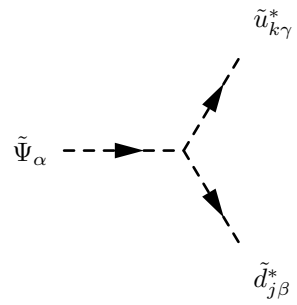
$$
\begin{aligned}
&i\Big(- \frac{1}{2}\Big(K^{SU[3],6\times\bar{3}\times\bar{3}}_{\gamma,\alpha,\beta}\Big)^* \Big(2\sum_{b=1}^{3} Z^{D,*}_{i3+b} \sum_{a=1}^{3} Z^{U,*}_{j3+a} T^*_{H,ab} \\
&+ \sqrt{2}\Big(v_d \sum_{c=1}^{3} Z^{U,*}_{j3+c} \sum_{b=1}^{3} Z^{D,*}_{ib} \sum_{a=1}^{3} Y^*_{H,ca} Y_{d,ab} + v_u \sum_{c=1}^{3} Z^{D,*}_{i3+c} \sum_{b=1}^{3} Z^{U,*}_{jb} \sum_{a=1}^{3} Y^*_{H,ac} Y_{u,ab}\Big)\Big) \\
&+ M^*_S\Big(- \sum_{b=1}^{3} Z^{U,*}_{jb} \sum_{a=1}^{3} Z^{D,*}_{ia} Y_{\bar{H},ba} + \sum_{b=1}^{3} Z^{D,*}_{ib} \sum_{a=1}^{3} Z^{U,*}_{ja} Y_{\bar{H},ba}\Big) K^{SU[3],\bar{6}\times3\times3}_{\gamma,\alpha,\beta}\Big)
\end{aligned}
\tag{171}
$$



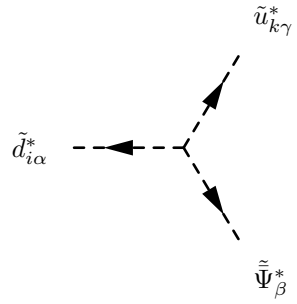
$$
\begin{aligned}
&-\frac{i}{4}\delta_{\alpha\gamma}\Big(\sqrt{2}g_2^2\sum_{a=1}^{3}Z^{D,*}_{ia}Z^{U}_{ka}\Big(v_dZ^+_{j1}+v_uZ^+_{j2}\Big)\\
&-2\Big(2\mu^*\sum_{b=1}^{3}Z^{D,*}_{ib}\sum_{a=1}^{3}Y_{u,ab}Z^U_{k3+a}Z^+_{j1}+2\sum_{b=1}^{3}\sum_{a=1}^{3}Z^{D,*}_{i3+a}T^*_{d,ab}Z^U_{kb}Z^+_{j1}\\
&+\sqrt{2}v_u\sum_{c=1}^{3}Z^{D,*}_{i3+c}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ca}Y_{u,ba}Z^U_{k3+b}Z^+_{j1}\\
&+\sqrt{2}v_d\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{D,*}_{ib}\sum_{a=1}^{3}Y^*_{d,ac}Y_{d,ab}Z^U_{kc}Z^+_{j1}+2\sum_{b=1}^{3}Z^{D,*}_{ib}\sum_{a=1}^{3}Z^U_{k3+a}T_{u,ab}Z^+_{j2}\\
&+2\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ab}Z^{D,*}_{i3+a}Z^U_{kb}Z^+_{j2}+\sqrt{2}v_d\sum_{c=1}^{3}Z^{D,*}_{i3+c}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ca}Y_{u,ba}Z^U_{k3+b}Z^+_{j2}\\
&+\sqrt{2}v_u\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{D,*}_{ib}\sum_{a=1}^{3}Y^*_{u,ac}Y_{u,ab}Z^U_{kc}Z^+_{j2}\Big)\Big)
\end{aligned}
\tag{172}
$$



$$
\begin{aligned}
&\frac{i}{4}\Big(4\sum_{b=1}^{3}\sum_{a=1}^{3}Z^{E,*}_{i3+a}T^*_{e,ab}Z^V_{kb}Z^+_{j1}+2\sqrt{2}v_d\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{E,*}_{ib}\sum_{a=1}^{3}Y^*_{e,ac}Y_{e,ab}Z^V_{kc}Z^+_{j1}\\
&+4\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{e,ab}Z^{E,*}_{i3+a}Z^V_{kb}Z^+_{j2}-\sqrt{2}g_2^2\sum_{a=1}^{3}Z^{E,*}_{ia}Z^V_{ka}\Big(v_dZ^+_{j1}+v_uZ^+_{j2}\Big)\Big)
\end{aligned}
\tag{173}
$$

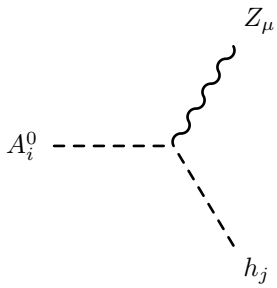


$$
\begin{aligned}
&i\Big(M_S\Big(K^{SU[3],\bar{6}\times 3\times 3}_{\alpha,\beta,\gamma}\Big)^*\Big(-\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{\bar{H},ba}Z^D_{ja}Z^U_{kb}+\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{\bar{H},ba}Z^U_{ka}Z^D_{jb}\Big)\\
&-\frac{1}{2}\Big(2\sum_{b=1}^{3}\sum_{a=1}^{3}Z^U_{k3+a}T_{H,ab}Z^D_{j3+b}\\
&+\sqrt{2}\Big(v_d\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ac}Y_{H,ba}Z^U_{k3+b}Z^D_{jc}+v_u\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{u,ac}Y_{H,ab}Z^D_{j3+b}Z^U_{kc}\Big)\Big)K^{SU[3],6\times\bar{3}\times\bar{3}}_{\alpha,\beta,\gamma}\Big)
\end{aligned}
\tag{174}
$$

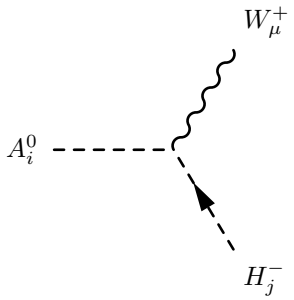


$$
\begin{aligned}
&i\Big(-\frac{1}{2}\Big(K^{SU[3],\bar{6}\times 3\times 3}_{\beta,\alpha,\gamma}\Big)^*\Big(2\sum_{b=1}^{3}\sum_{a=1}^{3}T^*_{\bar{H},ab}Z^U_{ka}Z^D_{ib}-2\sum_{b=1}^{3}\sum_{a=1}^{3}T^*_{\bar{H},ab}Z^D_{ia}Z^U_{kb}\\
&+\sqrt{2}\Big(v_u\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{\bar{H},ac}Y_{u,ba}Z^U_{k3+b}Z^D_{ic}-v_u\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{\bar{H},ca}Y_{u,ba}Z^U_{k3+b}Z^D_{ic}\\
&-v_d\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{\bar{H},ac}Y_{d,ba}Z^D_{i3+b}Z^U_{kc}+v_d\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{\bar{H},ca}Y_{d,ba}Z^D_{i3+b}Z^U_{kc}\Big)\Big)\\
&-M^*_S\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{H,ba}Z^D_{i3+a}Z^U_{k3+b}K^{SU[3],6\times\bar{3}\times\bar{3}}_{\beta,\alpha,\gamma}\Big)
\end{aligned}
\tag{175}
$$

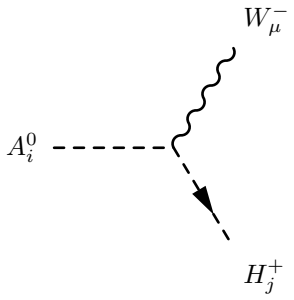
8.2 Two Scalar-One Vector Boson-Interaction



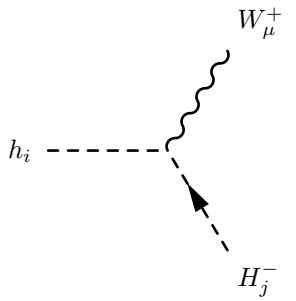
$$\frac{1}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big(Z_{i1}^A Z_{j1}^H - Z_{i2}^A Z_{j2}^H\Big)\Big(-p_\mu^{h_j} + p_\mu^{A_i^0}\Big) \tag{176}$$



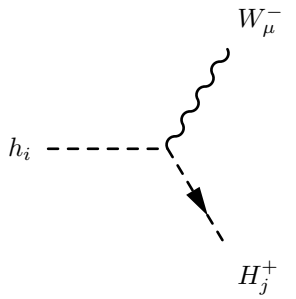
$$\frac{1}{2}g_2\Big(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+\Big)\Big(-p_\mu^{H_j^-} + p_\mu^{A_i^0}\Big) \tag{177}$$



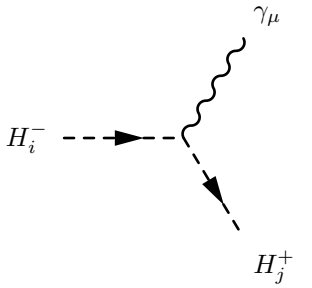
$$\frac{1}{2}g_2\Big(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{A_i^0}\Big) \tag{178}$$



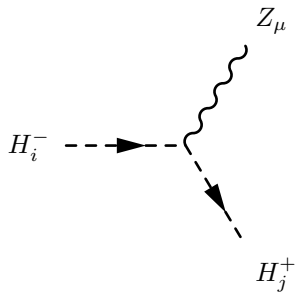
$$\frac{i}{2}g_2\Big(Z_{i1}^H Z_{j1}^+ - Z_{i2}^H Z_{j2}^+\Big)\Big(-p_\mu^{H_j^-} + p_\mu^{h_i}\Big) \tag{179}$$



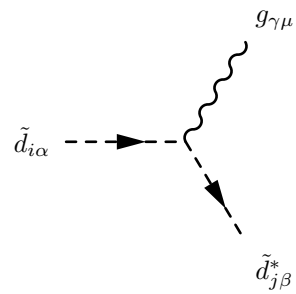
$$-\frac{i}{2}g_2\Big(Z_{i1}^H Z_{j1}^+ - Z_{i2}^H Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{h_i}\Big) \tag{180}$$



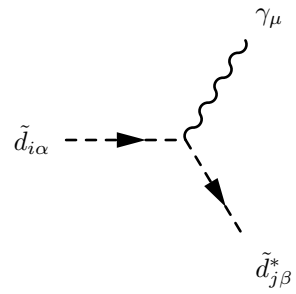
$$\frac{i}{2}\delta_{ij}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{181}$$



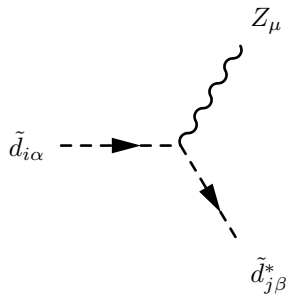
$$\frac{i}{2}\delta_{ij}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(-p_\mu^{H_j^+}+p_\mu^{H_i^-}\Big) \tag{182}$$



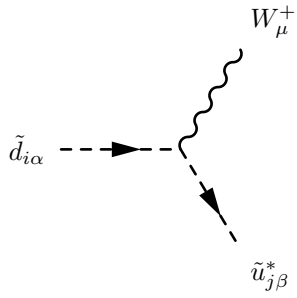
$$-\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\beta,\alpha}\Big(-p_\mu^{\tilde{d}^*_{j\beta}}+p_\mu^{\tilde{d}_{i\alpha}}\Big) \tag{183}$$



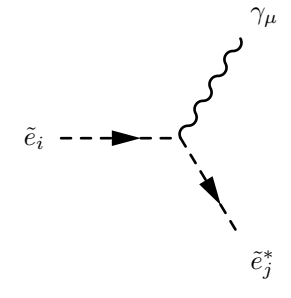
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1\cos\Theta_W\sum_{a=1}^{3}Z^{D,*}_{i3+a}Z^D_{j3+a}+\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\sum_{a=1}^{3}Z^{D,*}_{ia}Z^D_{ja}\Big)\Big(-p_\mu^{\tilde{d}^*_{j\beta}}+p_\mu^{\tilde{d}_{i\alpha}}\Big) \tag{184}$$



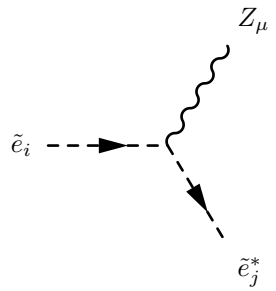
$$\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1\sin\Theta_W\sum_{a=1}^{3}Z^{D,*}_{i3+a}Z^{D}_{j3+a}+\Big(3g_2\cos\Theta_W+g_1\sin\Theta_W\Big)\sum_{a=1}^{3}Z^{D,*}_{ia}Z^{D}_{ja}\Big)\Big(-p_\mu^{\tilde{d}^*_{j\beta}}+p_\mu^{\tilde{d}_{i\alpha}}\Big) \tag{185}$$



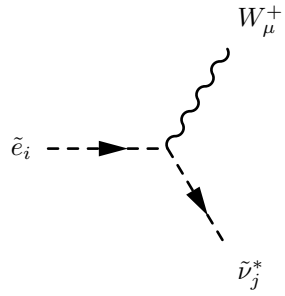
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}Z^{D,*}_{ia}Z^{U}_{ja}\Big(-p_\mu^{\tilde{u}^*_{j\beta}}+p_\mu^{\tilde{d}_{i\alpha}}\Big) \tag{186}$$



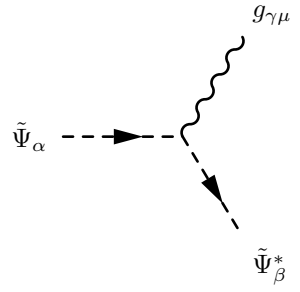
$$\frac{i}{2}\Big(2g_1\cos\Theta_W\sum_{a=1}^{3}Z^{E,*}_{i3+a}Z^{E}_{j3+a}+\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)\sum_{a=1}^{3}Z^{E,*}_{ia}Z^{E}_{ja}\Big)\Big(-p_\mu^{\tilde{e}^*_j}+p_\mu^{\tilde{e}_i}\Big) \tag{187}$$



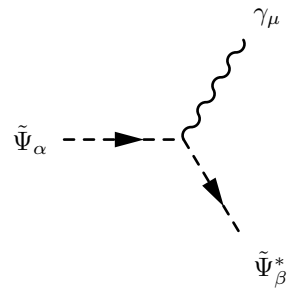
$$\frac{i}{2}\Big(- 2g_1 \sin\Theta_W \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{j3+a}^{E} + \Big(- g_1 \sin\Theta_W + g_2 \cos\Theta_W \Big) \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} \Big) \Big(- p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i} \Big) \tag{188}$$



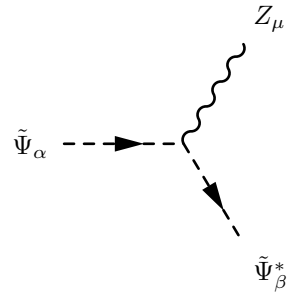
$$- i\frac{1}{\sqrt{2}} g_2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{V} \Big(- p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{e}_i} \Big) \tag{189}$$



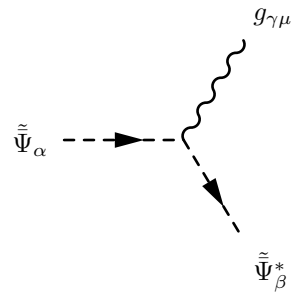
$$- ig_3 T_{\gamma\beta\alpha}^{\mathrm{SU}\left(3\right),6} \Big(- p_\mu^{\tilde{\Psi}_\beta^*} + p_\mu^{\tilde{\Psi}_\alpha} \Big) \tag{190}$$



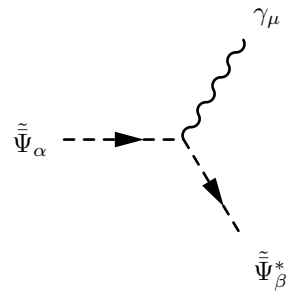
$$-\frac{i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\Big(-p_\mu^{\tilde{\Psi}^*_\beta}+p_\mu^{\tilde{\Psi}_\alpha}\Big) \tag{191}$$



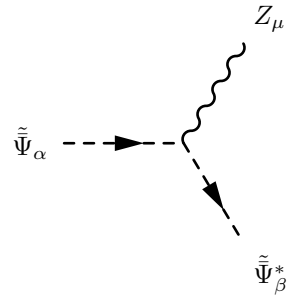
$$\frac{i}{3}g_1\delta_{\alpha\beta}\sin\Theta_W\Big(-p_\mu^{\tilde{\Psi}^*_\beta}+p_\mu^{\tilde{\Psi}_\alpha}\Big) \tag{192}$$



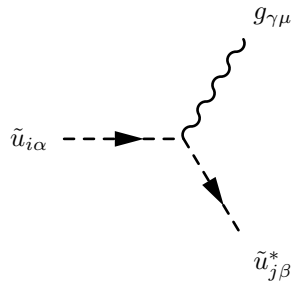
$$ig_3T_{\gamma\alpha\beta}^{\mathrm{SU}\left(3\right),6}\Big(-p_\mu^{\tilde{\tilde{\Psi}}^*_\beta}+p_\mu^{\tilde{\tilde{\Psi}}_\alpha}\Big) \tag{193}$$



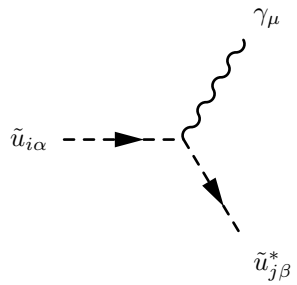
$$\frac{i}{3}g_1 \cos\Theta_W \delta_{\alpha\beta}\Big(- p_\mu^{\tilde{\bar{\Psi}}^*_\beta} + p_\mu^{\tilde{\bar{\Psi}}_\alpha}\Big) \tag{194}$$



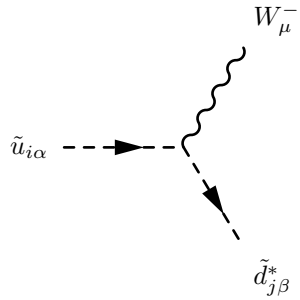
$$-\frac{i}{3}g_1 \delta_{\alpha\beta} \sin\Theta_W \Big(- p_\mu^{\tilde{\bar{\Psi}}^*_\beta} + p_\mu^{\tilde{\bar{\Psi}}_\alpha}\Big) \tag{195}$$



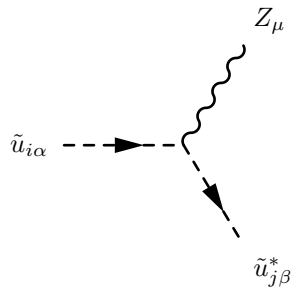
$$-\frac{i}{2}g_3 \delta_{ij} \lambda^\gamma_{\beta,\alpha}\Big(- p_\mu^{\tilde{u}^*_{j\beta}} + p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{196}$$



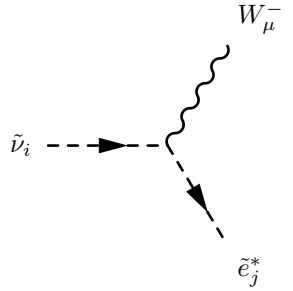
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(\Big(3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{U}_{ja}+4g_1\cos\Theta_W\sum_{a=1}^{3}Z^{U,*}_{i3+a}Z^{U}_{j3+a}\Big)\Big(-p_\mu^{\tilde{u}^*_{j\beta}}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{197}$$



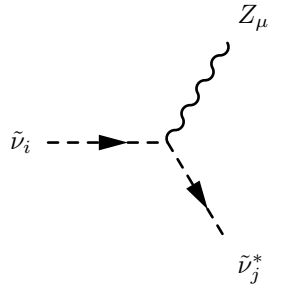
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{D}_{ja}\Big(-p_\mu^{\tilde{d}^*_{j\beta}}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{198}$$



$$-\frac{i}{6}\delta_{\alpha\beta}\Big(\Big(3g_2\cos\Theta_W-g_1\sin\Theta_W\Big)\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{U}_{ja}-4g_1\sin\Theta_W\sum_{a=1}^{3}Z^{U,*}_{i3+a}Z^{U}_{j3+a}\Big)\Big(-p_\mu^{\tilde{u}^*_{j\beta}}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{199}$$

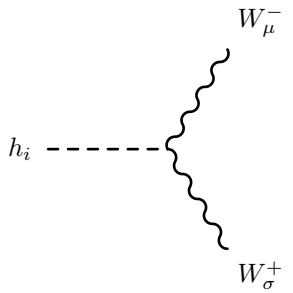


$$-i\frac{1}{\sqrt{2}}g_2\sum_{a=1}^{3}Z_{ia}^{V,*}Z_{ja}^{E}\Big(-p_\mu^{\tilde{e}_j^*}+p_\mu^{\tilde{\nu}_i}\Big) \tag{200}$$

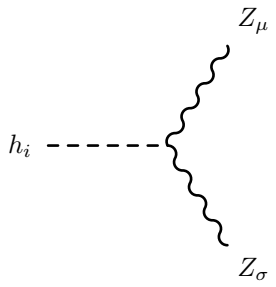


$$-\frac{i}{2}\delta_{ij}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(-p_\mu^{\tilde{\nu}_j^*}+p_\mu^{\tilde{\nu}_i}\Big) \tag{201}$$

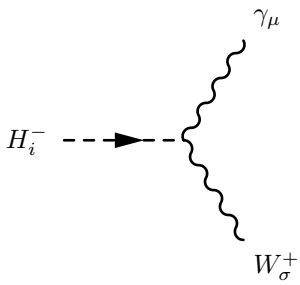
8.3 One Scalar-Two Vector Boson-Interaction



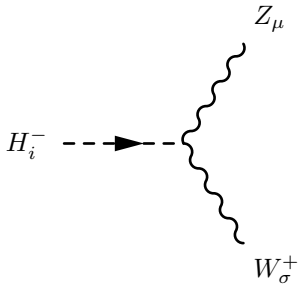
$$\frac{i}{2}g_2^2\Big(v_dZ_{i1}^H+v_uZ_{i2}^H\Big)\Big(g_{\sigma\mu}\Big) \tag{202}$$



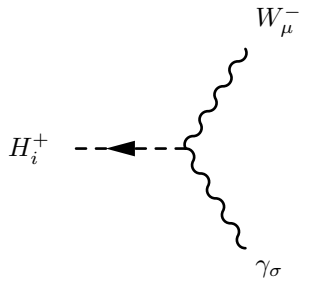
$$\frac{i}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 \Big(v_d Z^H_{i1} + v_u Z^H_{i2}\Big)\Big(g_{\sigma\mu}\Big) \tag{203}$$



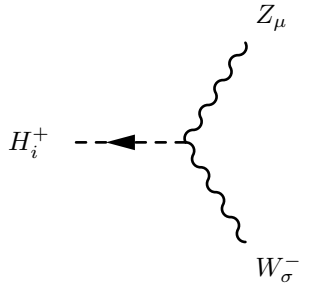
$$-\frac{i}{2} g_1 g_2 \cos\Theta_W \Big(v_d Z^+_{i1} - v_u Z^+_{i2}\Big)\Big(g_{\sigma\mu}\Big) \tag{204}$$



$$\frac{i}{2} g_1 g_2 \sin\Theta_W \Big(v_d Z^+_{i1} - v_u Z^+_{i2}\Big)\Big(g_{\sigma\mu}\Big) \tag{205}$$

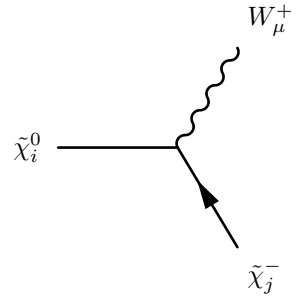


$$-\frac{i}{2}g_1 g_2 \cos\Theta_W \Big(v_d Z_{i1}^+ - v_u Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{206}$$



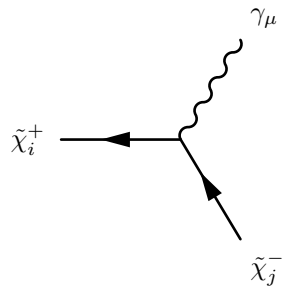
$$\frac{i}{2}g_1 g_2 \sin\Theta_W \Big(v_d Z_{i1}^+ - v_u Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{207}$$

8.4 Two Fermion-One Vector Boson-Interaction



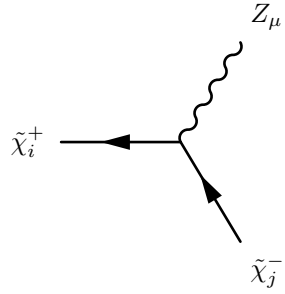
$$-\frac{i}{2}g_2\Big(2U_{j1}^* N_{i2} + \sqrt{2}U_{j2}^* N_{i3}\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{208}$$

$$+\ -\frac{i}{2}g_2\Big(2N_{i2}^* V_{j1} - \sqrt{2}N_{i4}^* V_{j2}\Big)\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{209}$$



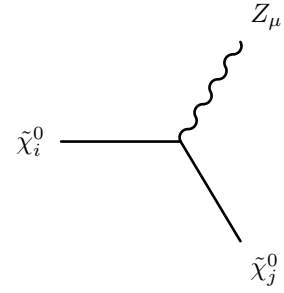
$$\frac{i}{2}\Big(2g_2U^*_{j1}\sin\Theta_W U_{i1} + U^*_{j2}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)U_{i2}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{210}$$

$$+\ \frac{i}{2}\Big(2g_2V^*_{i1}\sin\Theta_W V_{j1} + V^*_{i2}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)V_{j2}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{211}$$



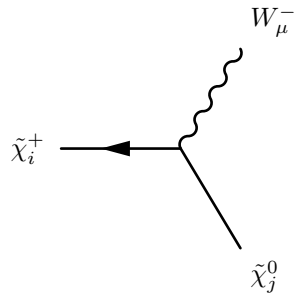
$$\frac{i}{2}\Big(2g_2U^*_{j1}\cos\Theta_W U_{i1} + U^*_{j2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)U_{i2}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{212}$$

$$+\ \frac{i}{2}\Big(2g_2V^*_{i1}\cos\Theta_W V_{j1} + V^*_{i2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)V_{j2}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{213}$$



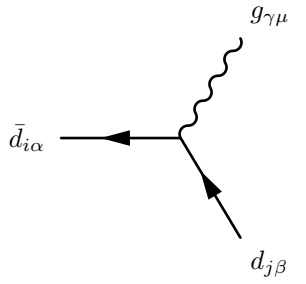
$$-\ \frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(N^*_{j3}N_{i3} - N^*_{j4}N_{i4}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{214}$$

$$+\ \frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(N^*_{i3}N_{j3} - N^*_{i4}N_{j4}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{215}$$



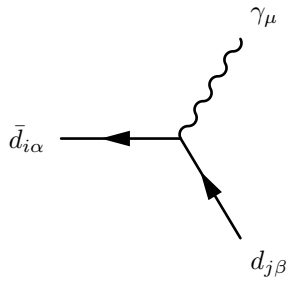
$$- \frac{i}{2} g_2 \Big(2 N_{j2}^* U_{i1} + \sqrt{2} N_{j3}^* U_{i2} \Big) \Big(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \Big) \tag{216}$$

$$+ \; - \frac{i}{2} g_2 \Big(2 V_{i1}^* N_{j2} - \sqrt{2} V_{i2}^* N_{j4} \Big) \Big(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \Big) \tag{217}$$



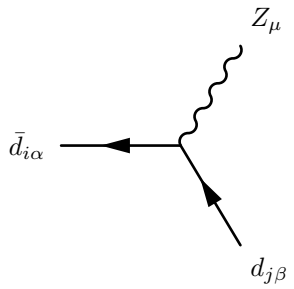
$$- \frac{i}{2} g_3 \delta_{ij} \lambda^\gamma_{\alpha,\beta} \Big(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \Big) \tag{218}$$

$$+ \; - \frac{i}{2} g_3 \delta_{ij} \lambda^\gamma_{\alpha,\beta} \Big(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \Big) \tag{219}$$



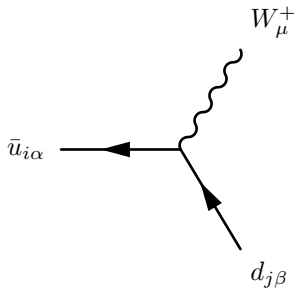
$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \Big(- 3 g_2 \sin\Theta_W + g_1 \cos\Theta_W \Big) \Big(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \Big) \tag{220}$$

$$+ \; \frac{i}{3} g_1 \cos\Theta_W \delta_{\alpha\beta} \delta_{ij} \Big(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \Big) \tag{221}$$

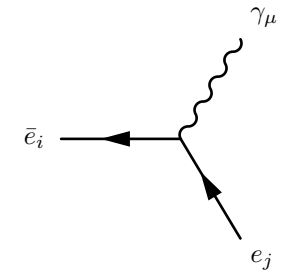


$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2\cos\Theta_W + g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{222}$$

$$+\ -\frac{i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{223}$$

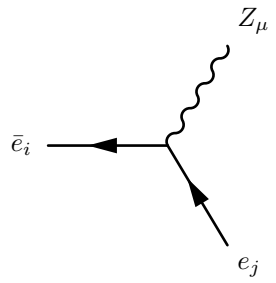


$$-\,i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}U^{d,*}_{L,ja}U^{u}_{L,ia}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{224}$$



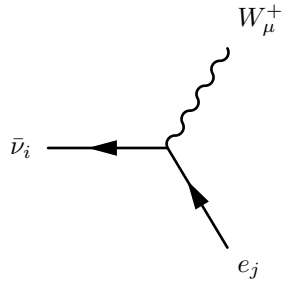
$$\frac{i}{2}\delta_{ij}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{225}$$

$$+\ ig_1\cos\Theta_W\delta_{ij}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{226}$$

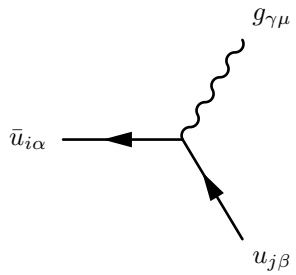


$$\frac{i}{2}\delta_{ij}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{227}$$

$$+\ -ig_1\delta_{ij}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{228}$$

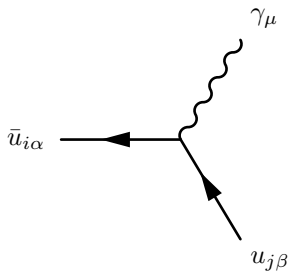


$$-\,i\frac{1}{\sqrt{2}}g_2U^{e,*}_{L,ji}\Theta_{i,3}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{229}$$



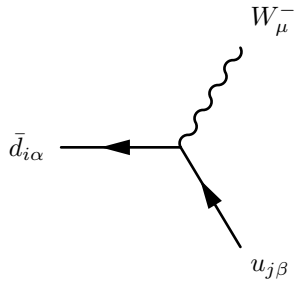
$$-\,\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{230}$$

$$+\ -\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{231}$$

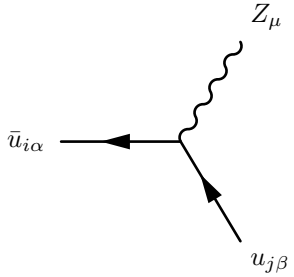


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{232}$$

$$+\ -\frac{2i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{233}$$

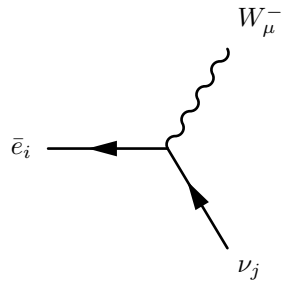


$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}U_{L,ja}^{u,*}U_{L,ia}^{d}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{234}$$

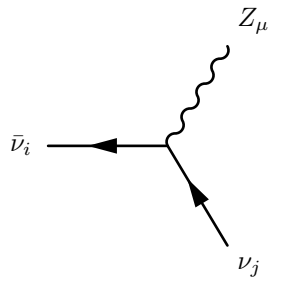


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2\cos\Theta_W-g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{235}$$

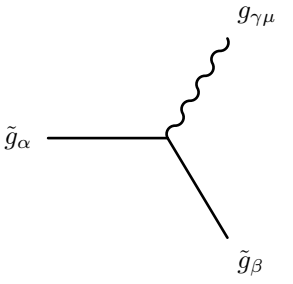
$$+\ \frac{2i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{236}$$



$$-i\frac{1}{\sqrt{2}}g_2\Theta_{j,3}U^e_{L,ij}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{237}$$

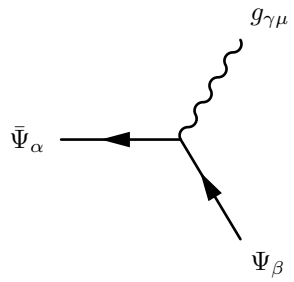


$$-\frac{i}{2}\delta_{ij}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{238}$$



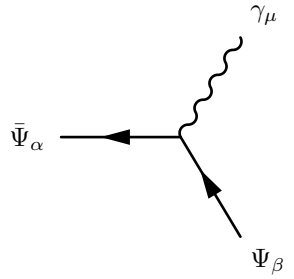
$$-g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{239}$$

$$+\ -g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{240}$$



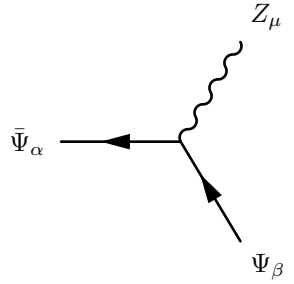
$$- ig_3 T^{\mathrm{SU}\left(3\right),6}_{\gamma\alpha\beta}\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \tag{241}$$

$$+ \; -ig_3 T^{\mathrm{SU}\left(3\right),6\,*}_{\gamma\beta\alpha}\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \tag{242}$$



$$- \frac{i}{3} g_1 \cos\Theta_W \delta_{\alpha\beta}\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \tag{243}$$

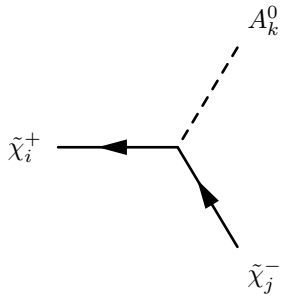
$$+ \; -\frac{i}{3} g_1 \cos\Theta_W \delta_{\alpha\beta}\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \tag{244}$$



$$\frac{i}{3}g_1\delta_{\alpha\beta}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{245}$$

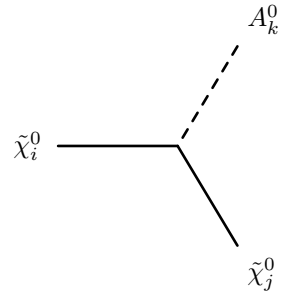
$$+\ \frac{i}{3}g_1\delta_{\alpha\beta}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{246}$$

8.5 Two Fermion-One Scalar Boson-Interaction



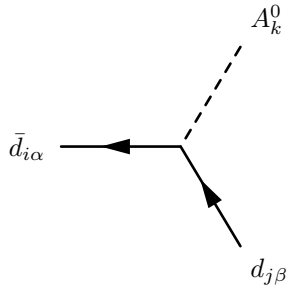
$$-\frac{1}{\sqrt{2}}g_2\Big(U_{j1}^*V_{i2}^*Z_{k2}^A+U_{j2}^*V_{i1}^*Z_{k1}^A\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{247}$$

$$+\ \frac{1}{\sqrt{2}}g_2\Big(U_{i1}V_{j2}Z_{k2}^A+U_{i2}V_{j1}Z_{k1}^A\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{248}$$



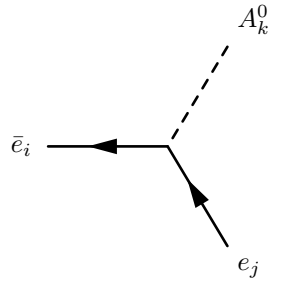
$$\begin{aligned}&\frac{1}{2}\Big(N_{i3}^*\Big(g_1N_{j1}^*-g_2N_{j2}^*\Big)Z_{k1}^A-g_2N_{i2}^*N_{j3}^*Z_{k1}^A-g_1N_{i4}^*N_{j1}^*Z_{k2}^A+g_2N_{i4}^*N_{j2}^*Z_{k2}^A\\&+g_2N_{i2}^*N_{j4}^*Z_{k2}^A+g_1N_{i1}^*\Big(N_{j3}^*Z_{k1}^A-N_{j4}^*Z_{k2}^A\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big)\end{aligned} \tag{249}$$

$$\begin{aligned}&+\ \frac{1}{2}\Big(-Z_{k1}^A\Big(\Big(g_1N_{i1}-g_2N_{i2}\Big)N_{j3}+N_{i3}\Big(g_1N_{j1}-g_2N_{j2}\Big)\Big)\\&-Z_{k2}^A\Big(\Big(-g_1N_{i1}+g_2N_{i2}\Big)N_{j4}+N_{i4}\Big(-g_1N_{j1}+g_2N_{j2}\Big)\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big)\end{aligned} \tag{250}$$



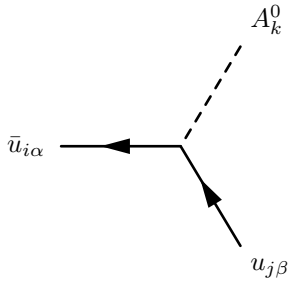
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U^{d,*}_{L,jb}\sum_{a=1}^{3}U^{d,*}_{R,ia}Y_{d,ab}Z^{A}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{251}$$

$$+\ -\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{d,ab}U^{d}_{R,ja}U^{d}_{L,ib}Z^{A}_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{252}$$



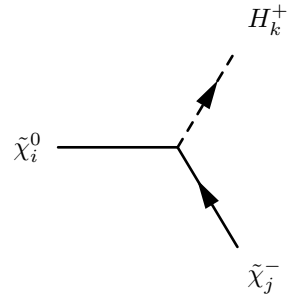
$$\frac{1}{\sqrt{2}}\sum_{b=1}^{3}U^{e,*}_{L,jb}\sum_{a=1}^{3}U^{e,*}_{R,ia}Y_{e,ab}Z^{A}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{253}$$

$$+\ -\frac{1}{\sqrt{2}}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{e,ab}U^{e}_{R,ja}U^{e}_{L,ib}Z^{A}_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{254}$$



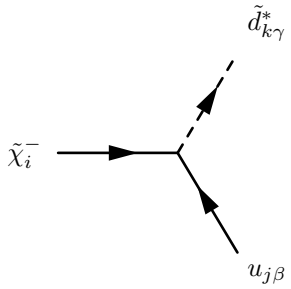
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{u,*}\sum_{a=1}^{3}U_{R,ia}^{u,*}Y_{u,ab}Z_{k2}^{A}\Big(\frac{1-\gamma_5}{2}\Big) \tag{255}$$

$$+\ -\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^{*}U_{R,ja}^{u}U_{L,ib}^{u}Z_{k2}^{A}\Big(\frac{1+\gamma_5}{2}\Big) \tag{256}$$



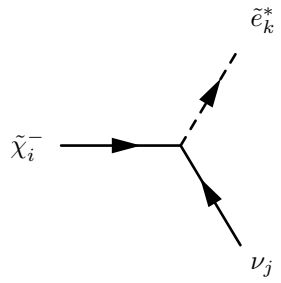
$$\frac{i}{2}\Big(-2g_2U_{j1}^{*}N_{i3}^{*}+\sqrt{2}U_{j2}^{*}\Big(g_1N_{i1}^{*}+g_2N_{i2}^{*}\Big)\Big)Z_{k1}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{257}$$

$$+\ -\frac{i}{2}\Big(2g_2V_{j1}N_{i4}+\sqrt{2}V_{j2}\Big(g_1N_{i1}+g_2N_{i2}\Big)\Big)Z_{k2}^{+}\Big(\frac{1+\gamma_5}{2}\Big) \tag{258}$$

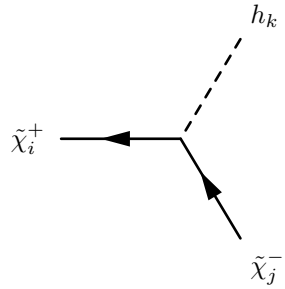


$$i\delta_{\beta\gamma}\Big(-g_2U_{i1}^{*}\sum_{a=1}^{3}U_{L,ja}^{u,*}Z_{ka}^{D}+U_{i2}^{*}\sum_{b=1}^{3}U_{L,jb}^{u,*}\sum_{a=1}^{3}Y_{d,ab}Z_{k3+a}^{D}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{259}$$

$$+\ i\delta_{\beta\gamma}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^{*}U_{R,ja}^{u}Z_{kb}^{D}V_{i2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{260}$$

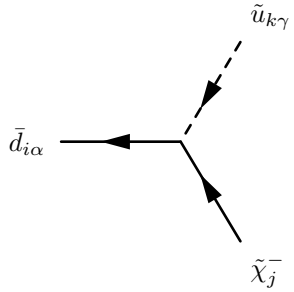


$$i\Big(- g_2 U_{i1}^* \Theta_{j,3} Z_{kj}^E + U_{i2}^* \sum_{a=1}^{3} Y_{e,aj} Z_{k3+a}^E \Big) \Big(\frac{1-\gamma_5}{2} \Big) \tag{261}$$



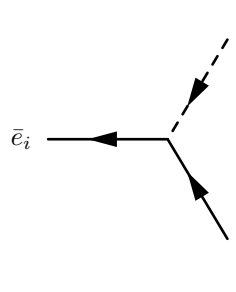
$$- i \frac{1}{\sqrt{2}} g_2 \Big(U_{j1}^* V_{i2}^* Z_{k2}^H + U_{j2}^* V_{i1}^* Z_{k1}^H \Big) \Big(\frac{1-\gamma_5}{2} \Big) \tag{262}$$

$$+ \; -i \frac{1}{\sqrt{2}} g_2 \Big(U_{i1} V_{j2} Z_{k2}^H + U_{i2} V_{j1} Z_{k1}^H \Big) \Big(\frac{1+\gamma_5}{2} \Big) \tag{263}$$



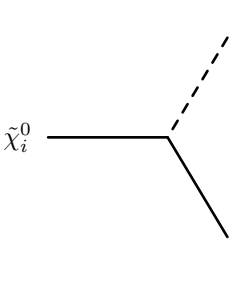
$$i U_{j2}^* \delta_{\alpha\gamma} \sum_{b=1}^{3} Z_{kb}^{U,*} \sum_{a=1}^{3} U_{R,ia}^{d,*} Y_{d,ab} \Big(\frac{1-\gamma_5}{2} \Big) \tag{264}$$

$$+\ i\delta_{\alpha\gamma}\Big(-g_2\sum_{a=1}^{3}Z^{U,*}_{ka}U^{d}_{L,ia}V_{j1}+\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{u,ab}Z^{U,*}_{k3+a}U^{d}_{L,ib}V_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{265}$$



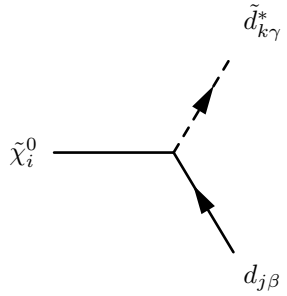
$$iU^{*}_{j2}\sum_{b=1}^{3}Z^{V,*}_{kb}\sum_{a=1}^{3}U^{e,*}_{R,ia}Y_{e,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{266}$$

$$+\ -ig_2\sum_{a=1}^{3}Z^{V,*}_{ka}U^{e}_{L,ia}V_{j1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{267}$$



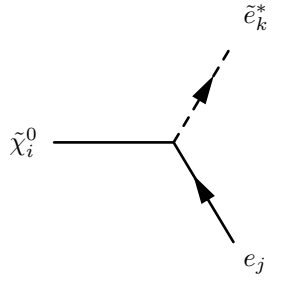
$$\begin{aligned}&\frac{i}{2}\Big(N^{*}_{i3}\Big(g_1N^{*}_{j1}-g_2N^{*}_{j2}\Big)Z^{H}_{k1}-g_2N^{*}_{i2}N^{*}_{j3}Z^{H}_{k1}-g_1N^{*}_{i4}N^{*}_{j1}Z^{H}_{k2}+g_2N^{*}_{i4}N^{*}_{j2}Z^{H}_{k2}\\&+g_2N^{*}_{i2}N^{*}_{j4}Z^{H}_{k2}+g_1N^{*}_{i1}\Big(N^{*}_{j3}Z^{H}_{k1}-N^{*}_{j4}Z^{H}_{k2}\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big)\end{aligned} \tag{268}$$

$$\begin{aligned}&+\ \frac{i}{2}\Big(Z^{H}_{k1}\Big(\Big(g_1N_{i1}-g_2N_{i2}\Big)N_{j3}+N_{i3}\Big(g_1N_{j1}-g_2N_{j2}\Big)\Big)\\&+Z^{H}_{k2}\Big(\Big(-g_1N_{i1}+g_2N_{i2}\Big)N_{j4}+N_{i4}\Big(-g_1N_{j1}+g_2N_{j2}\Big)\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big)\end{aligned} \tag{269}$$



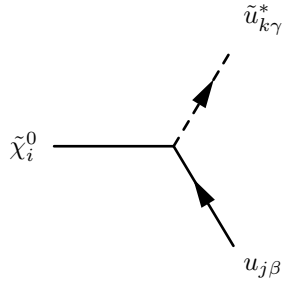
$$-\frac{i}{6}\delta_{\beta\gamma}\Big(-3\sqrt{2}g_2N^*_{i2}\sum_{a=1}^{3}U^{d,*}_{L,ja}Z^D_{ka}+6N^*_{i3}\sum_{b=1}^{3}U^{d,*}_{L,jb}\sum_{a=1}^{3}Y_{d,ab}Z^D_{k3+a}+\sqrt{2}g_1N^*_{i1}\sum_{a=1}^{3}U^{d,*}_{L,ja}Z^D_{ka}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{270}$$

$$+\ -\frac{i}{3}\delta_{\beta\gamma}\Big(3\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ab}U^d_{R,ja}Z^D_{kb}N_{i3}+\sqrt{2}g_1\sum_{a=1}^{3}Z^D_{k3+a}U^d_{R,ja}N_{i1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{271}$$



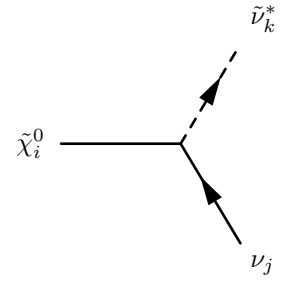
$$i\Big(\frac{1}{\sqrt{2}}g_1N^*_{i1}\sum_{a=1}^{3}U^{e,*}_{L,ja}Z^E_{ka}+\frac{1}{\sqrt{2}}g_2N^*_{i2}\sum_{a=1}^{3}U^{e,*}_{L,ja}Z^E_{ka}-N^*_{i3}\sum_{b=1}^{3}U^{e,*}_{L,jb}\sum_{a=1}^{3}Y_{e,ab}Z^E_{k3+a}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{272}$$

$$+\ i\Big(-\sqrt{2}g_1\sum_{a=1}^{3}Z^E_{k3+a}U^e_{R,ja}N_{i1}-\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{e,ab}U^e_{R,ja}Z^E_{kb}N_{i3}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{273}$$

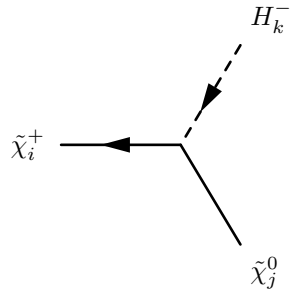


$$-\frac{i}{6}\delta_{\beta\gamma}\Big(3\sqrt{2}g_2N_{i2}^*\sum_{a=1}^{3}U_{L,ja}^{u,*}Z_{ka}^U+6N_{i4}^*\sum_{b=1}^{3}U_{L,jb}^{u,*}\sum_{a=1}^{3}Y_{u,ab}Z_{k3+a}^U+\sqrt{2}g_1N_{i1}^*\sum_{a=1}^{3}U_{L,ja}^{u,*}Z_{ka}^U\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{274}$$

$$+\frac{i}{3}\delta_{\beta\gamma}\Big(2\sqrt{2}g_1\sum_{a=1}^{3}Z_{k3+a}^UU_{R,ja}^uN_{i1}-3\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^*U_{R,ja}^uZ_{kb}^UN_{i4}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{275}$$

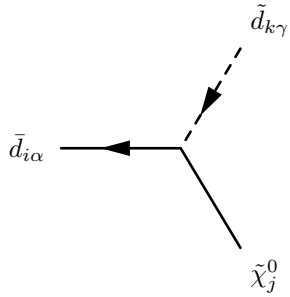


$$i\frac{1}{\sqrt{2}}\Big(g_1N_{i1}^*-g_2N_{i2}^*\Big)\Theta_{j,3}Z_{kj}^V\Big(\frac{1-\gamma_5}{2}\Big) \tag{276}$$



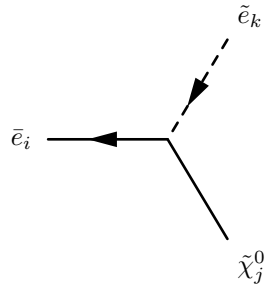
$$-\frac{i}{2}\Big(2g_2V_{i1}^*N_{j4}^*+\sqrt{2}V_{i2}^*\Big(g_1N_{j1}^*+g_2N_{j2}^*\Big)\Big)Z_{k2}^+\Big(\frac{1-\gamma_5}{2}\Big) \tag{277}$$

$$+\frac{i}{2}\Big(-2g_2U_{i1}N_{j3}+\sqrt{2}U_{i2}\Big(g_1N_{j1}+g_2N_{j2}\Big)\Big)Z_{k1}^+\Big(\frac{1+\gamma_5}{2}\Big) \tag{278}$$



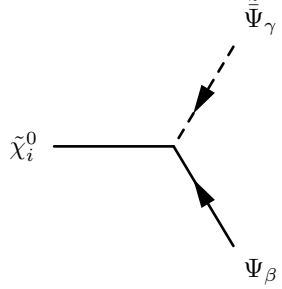
$$-\frac{i}{3}\delta_{\alpha\gamma}\Big(3N_{j3}^{*}\sum_{b=1}^{3}Z_{kb}^{D,*}\sum_{a=1}^{3}U_{R,ia}^{d,*}Y_{d,ab}+\sqrt{2}g_1N_{j1}^{*}\sum_{a=1}^{3}Z_{k3+a}^{D,*}U_{R,ia}^{d,*}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{279}$$

$$+\ -\frac{i}{6}\delta_{\alpha\gamma}\Big(6\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}Z_{k3+a}^{D,*}U_{L,ib}^{d}N_{j3}+\sqrt{2}\sum_{a=1}^{3}Z_{ka}^{D,*}U_{L,ia}^{d}\Big(-3g_2N_{j2}+g_1N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{280}$$



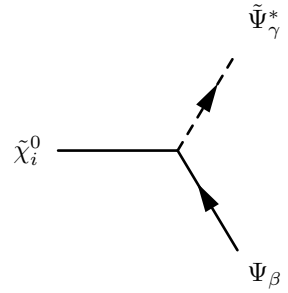
$$i\Big(-N_{j3}^{*}\sum_{b=1}^{3}Z_{kb}^{E,*}\sum_{a=1}^{3}U_{R,ia}^{e,*}Y_{e,ab}-\sqrt{2}g_1N_{j1}^{*}\sum_{a=1}^{3}Z_{k3+a}^{E,*}U_{R,ia}^{e,*}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{281}$$

$$+\ i\Big(\frac{1}{\sqrt{2}}\sum_{a=1}^{3}Z_{ka}^{E,*}U_{L,ia}^{e}\Big(g_1N_{j1}+g_2N_{j2}\Big)-\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^{*}Z_{k3+a}^{E,*}U_{L,ib}^{e}N_{j3}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{282}$$

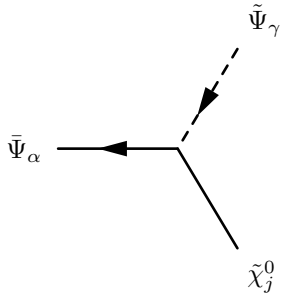


$$\tag{283}$$

$$+\ \frac{i}{3}\sqrt{2}g_1\delta_{\beta\gamma}N_{i1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{284}$$

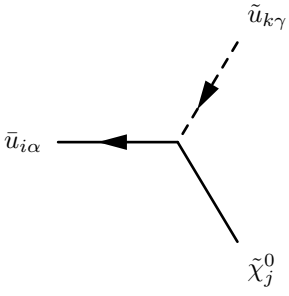


$$-\frac{i}{3}\sqrt{2}g_1 N^*_{i1}\delta_{\beta\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{285}$$



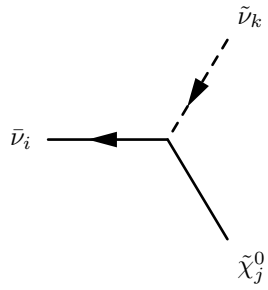
(286)

$$+\ -\frac{i}{3}\sqrt{2}g_1\delta_{\alpha\gamma}N_{j1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{287}$$



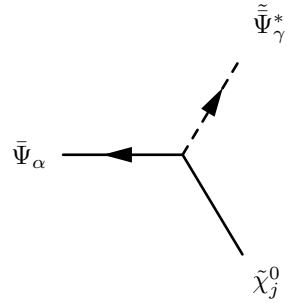
$$\frac{i}{3}\delta_{\alpha\gamma}\Big(2\sqrt{2}g_1 N^*_{j1}\sum_{a=1}^{3}Z^{U,*}_{k3+a}U^{u,*}_{R,ia} - 3N^*_{j4}\sum_{b=1}^{3}Z^{U,*}_{kb}\sum_{a=1}^{3}U^{u,*}_{R,ia}Y_{u,ab}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{288}$$

$$+\ -\frac{i}{6}\delta_{\alpha\gamma}\Big(6\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{u,ab}Z^{U,*}_{k3+a}U^{u}_{L,ib}N_{j4} + \sqrt{2}\sum_{a=1}^{3}Z^{U,*}_{ka}U^{u}_{L,ia}\Big(3g_2 N_{j2} + g_1 N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{289}$$

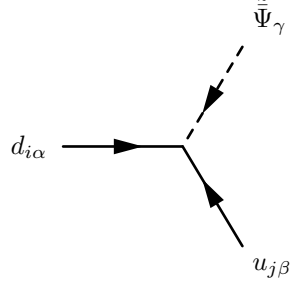


$$+ \; i\frac{1}{\sqrt{2}} Z_{ki}^{V,*} \Theta_{i,3} \Big(g_1 N_{j1} - g_2 N_{j2} \Big) \Big(\frac{1+\gamma_5}{2} \Big) \tag{290}$$

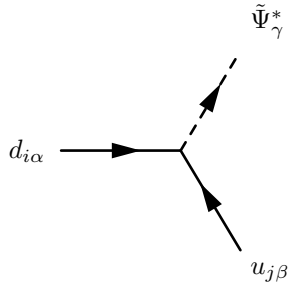
$$+ \; i\frac{1}{\sqrt{2}} Z_{ki}^{V,*} \Theta_{i,3} \Big(g_1 N_{j1} - g_2 N_{j2} \Big) \Big(\frac{1+\gamma_5}{2} \Big) \tag{291}$$



$$\frac{i}{3}\sqrt{2} g_1 N_{j1}^* \delta_{\alpha\gamma} \Big(\frac{1-\gamma_5}{2} \Big) \tag{292}$$

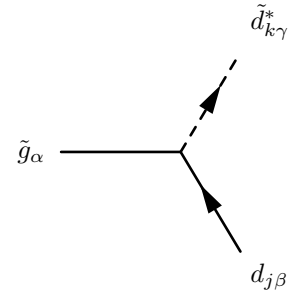


$$i\Big(-\sum_{b=1}^{3} U_{L,ib}^{d,*} \sum_{a=1}^{3} U_{L,ja}^{u,*} Y_{\bar{H},ab} + \sum_{b=1}^{3} U_{L,jb}^{u,*} \sum_{a=1}^{3} U_{L,ia}^{d,*} Y_{\bar{H},ab} \Big) K_{\gamma,\alpha,\beta}^{SU[3],\bar{6}\times 3\times 3} \Big(\frac{1-\gamma_5}{2} \Big) \tag{293}$$



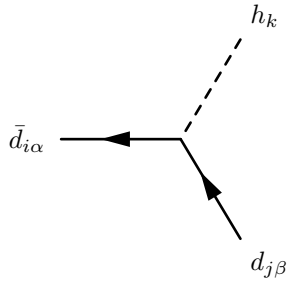
(294)

$$+\ -i\Big(K^{SU[3],6\times\bar{3}\times\bar{3}}_{\gamma,\alpha,\beta}\Big)^* \sum_{b=1}^{3}\sum_{a=1}^{3} Y^*_{H,ab} U^u_{R,ja} U^d_{R,ib} \Big(\frac{1+\gamma_5}{2}\Big) \tag{295}$$



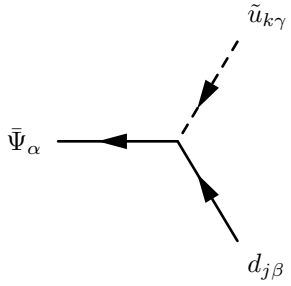
$$-\ i\frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda^\alpha_{\gamma,\beta} \sum_{a=1}^{3} U^{d,*}_{L,ja} Z^D_{ka} \Big(\frac{1-\gamma_5}{2}\Big) \tag{296}$$

$$+\ i\frac{1}{\sqrt{2}} g_3 \phi^*_{\tilde{g}} \lambda^\alpha_{\gamma,\beta} \sum_{a=1}^{3} Z^D_{k3+a} U^d_{R,ja} \Big(\frac{1+\gamma_5}{2}\Big) \tag{297}$$



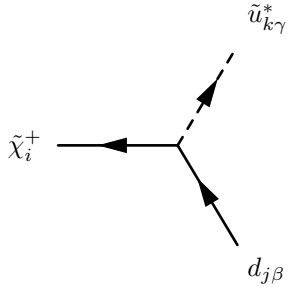
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}U_{R,ia}^{d,*}Y_{d,ab}Z_{k1}^{H}\Big(\frac{1-\gamma_5}{2}\Big) \tag{298}$$

$$+\ -i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{R,ja}^{d}U_{L,ib}^{d}Z_{k1}^{H}\Big(\frac{1+\gamma_5}{2}\Big) \tag{299}$$



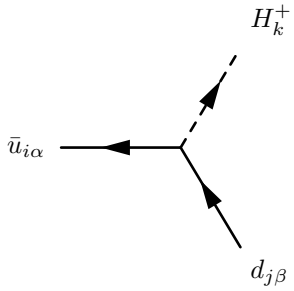
$$i\Big(-\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}Z_{ka}^{U,*}Y_{\bar{H},ab}+\sum_{b=1}^{3}Z_{kb}^{U,*}\sum_{a=1}^{3}U_{L,ja}^{d,*}Y_{\bar{H},ab}\Big)K_{\alpha,\beta,\gamma}^{SU[3],\bar{6}\times3\times3}\Big(\frac{1-\gamma_5}{2}\Big) \tag{300}$$

$$+\ -i\Big(K_{\alpha,\beta,\gamma}^{SU[3],6\times\bar{3}\times\bar{3}}\Big)^{*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{H,ab}^{*}Z_{k3+a}^{U,*}U_{R,jb}^{d}\Big(\frac{1+\gamma_5}{2}\Big) \tag{301}$$



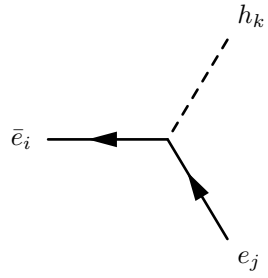
$$i\delta_{\beta\gamma}\Big(-g_2V_{i1}^{*}\sum_{a=1}^{3}U_{L,ja}^{d,*}Z_{ka}^{U}+V_{i2}^{*}\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}Y_{u,ab}Z_{k3+a}^{U}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{302}$$

$$+\ i\delta_{\beta\gamma}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{R,ja}^{d}Z_{kb}^{U}U_{i2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{303}$$



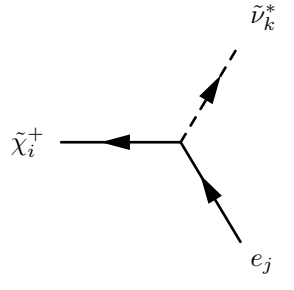
$$i\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}U_{R,ia}^{u,*}Y_{u,ab}Z_{k2}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{304}$$

$$+\ i\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{R,ja}^{d}U_{L,ib}^{u}Z_{k1}^{+}\Big(\frac{1+\gamma_5}{2}\Big) \tag{305}$$



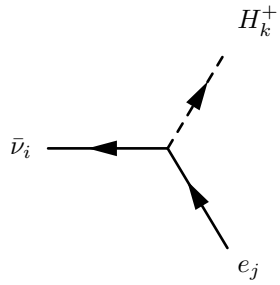
$$-\,i\frac{1}{\sqrt{2}}\sum_{b=1}^{3}U_{L,jb}^{e,*}\sum_{a=1}^{3}U_{R,ia}^{e,*}Y_{e,ab}Z_{k1}^{H}\Big(\frac{1-\gamma_5}{2}\Big) \tag{306}$$

$$+\ -i\frac{1}{\sqrt{2}}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^{*}U_{R,ja}^{e}U_{L,ib}^{e}Z_{k1}^{H}\Big(\frac{1+\gamma_5}{2}\Big) \tag{307}$$



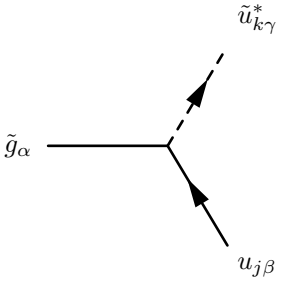
$$- ig_2 V_{i1}^* \sum_{a=1}^{3} U_{L,ja}^{e,*} Z_{ka}^V \Big(\frac{1-\gamma_5}{2}\Big) \tag{308}$$

$$+ i \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{e,ab}^* U_{R,ja}^e Z_{kb}^V U_{i2} \Big(\frac{1+\gamma_5}{2}\Big) \tag{309}$$



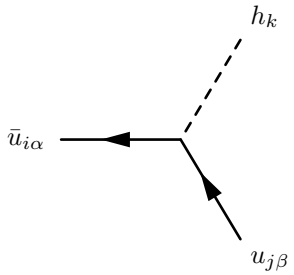
(310)

$$+ i \sum_{a=1}^{3} Y_{e,ai}^* U_{R,ja}^e Z_{k1}^+ \Big(\frac{1+\gamma_5}{2}\Big) \tag{311}$$



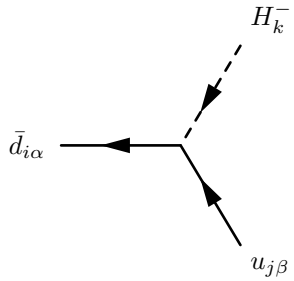
$$- i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\gamma,\beta}^{\alpha} \sum_{a=1}^{3} U_{L,ja}^{u,*} Z_{ka}^U \Big(\frac{1-\gamma_5}{2}\Big) \tag{312}$$

$$+ i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^{\alpha} \sum_{a=1}^{3} Z_{k3+a}^U U_{R,ja}^u \Big(\frac{1+\gamma_5}{2}\Big) \tag{313}$$



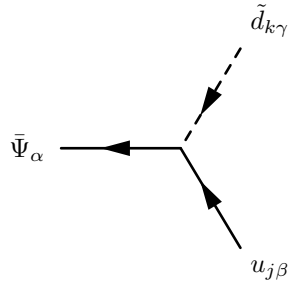
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{u,*}\sum_{a=1}^{3}U_{R,ia}^{u,*}Y_{u,ab}Z_{k2}^{H}\Big(\frac{1-\gamma_5}{2}\Big) \tag{314}$$

$$+ -i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^{*}U_{R,ja}^{u}U_{L,ib}^{u}Z_{k2}^{H}\Big(\frac{1+\gamma_5}{2}\Big) \tag{315}$$



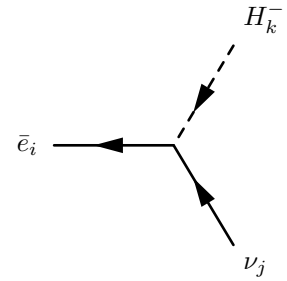
$$i\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{u,*}\sum_{a=1}^{3}U_{R,ia}^{d,*}Y_{d,ab}Z_{k1}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{316}$$

$$+ i\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^{*}U_{R,ja}^{u}U_{L,ib}^{d}Z_{k2}^{+}\Big(\frac{1+\gamma_5}{2}\Big) \tag{317}$$

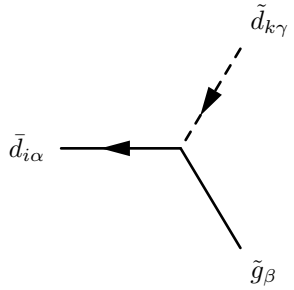


$$i\Big(-\sum_{b=1}^{3} Z^{D,*}_{kb}\sum_{a=1}^{3} U^{u,*}_{L,ja}Y_{\bar{H},ab}+\sum_{b=1}^{3} U^{u,*}_{L,jb}\sum_{a=1}^{3} Z^{D,*}_{ka}Y_{\bar{H},ab}\Big)K^{SU[3],\bar{6}\times 3\times 3}_{\alpha,\beta,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{318}$$

$$+\ -i\Big(K^{SU[3],6\times\bar{3}\times\bar{3}}_{\alpha,\beta,\gamma}\Big)^{*}\sum_{b=1}^{3} Z^{D,*}_{k3+b}\sum_{a=1}^{3} Y^{*}_{H,ab}U^{u}_{R,ja}\Big(\frac{1+\gamma_5}{2}\Big) \tag{319}$$

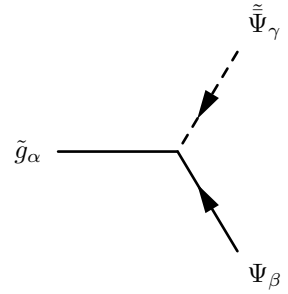


$$i\sum_{a=1}^{3} U^{e,*}_{R,ia}Y_{e,aj}Z^{+}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{320}$$



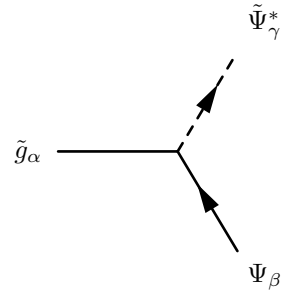
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\lambda^{\beta}_{\alpha,\gamma}\sum_{a=1}^{3} Z^{D,*}_{k3+a}U^{d,*}_{R,ia}\Big(\frac{1-\gamma_5}{2}\Big) \tag{321}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^{*}_{\tilde{g}}\lambda^{\beta}_{\alpha,\gamma}\sum_{a=1}^{3} Z^{D,*}_{ka}U^{d}_{L,ia}\Big(\frac{1+\gamma_5}{2}\Big) \tag{322}$$

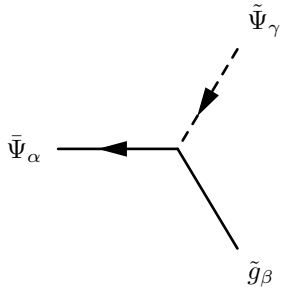


(323)

$$+\ i\sqrt{2}g_3\phi^*_{\tilde{g}}T^{\mathrm{SU}\left(3\right),6}_{\alpha\gamma\beta}\left(\frac{1+\gamma_5}{2}\right) \tag{324}$$

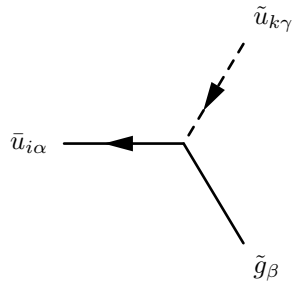


$$-\ i\sqrt{2}g_3\phi_{\tilde{g}}T^{\mathrm{SU}\left(3\right),6}_{\alpha\gamma\beta}\left(\frac{1-\gamma_5}{2}\right) \tag{325}$$



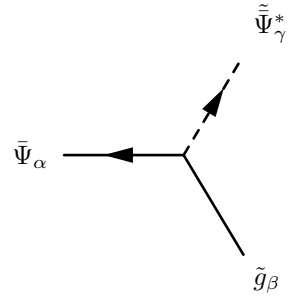
(326)

$$+\ -i\sqrt{2}g_3\phi^*_{\tilde{g}}T^{\mathrm{SU}\left(3\right),6}_{\beta\alpha\gamma}\left(\frac{1+\gamma_5}{2}\right) \tag{327}$$

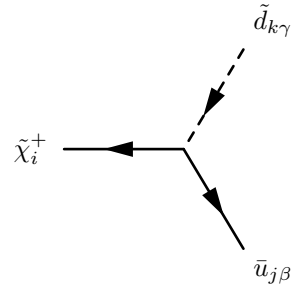


$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\lambda^{\beta}_{\alpha,\gamma}\sum_{a=1}^{3}Z^{U,*}_{k3+a}U^{u,*}_{R,ia}\Big(\frac{1-\gamma_5}{2}\Big) \tag{328}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^{*}_{\tilde{g}}\lambda^{\beta}_{\alpha,\gamma}\sum_{a=1}^{3}Z^{U,*}_{ka}U^{u}_{L,ia}\Big(\frac{1+\gamma_5}{2}\Big) \tag{329}$$

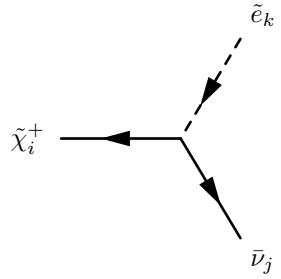


$$i\sqrt{2}g_3\phi_{\tilde{g}}T^{\mathrm{SU}\left(3\right),6}_{\beta\alpha\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{330}$$



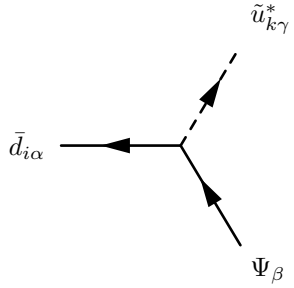
$$iV^{*}_{i2}\delta_{\beta\gamma}\sum_{b=1}^{3}Z^{D,*}_{kb}\sum_{a=1}^{3}U^{u,*}_{R,ja}Y_{u,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{331}$$

$$+\ i\delta_{\beta\gamma}\Big(-g_2\sum_{a=1}^{3}Z^{D,*}_{ka}U^{u}_{L,ja}U_{i1}+\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{d,ab}Z^{D,*}_{k3+a}U^{u}_{L,jb}U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{332}$$



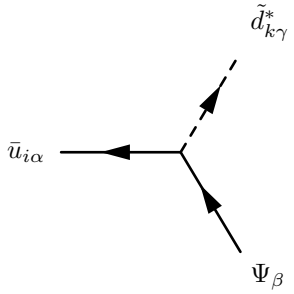
(333)

$$+\ i\Big(-g_2Z^{E,*}_{kj}\Theta_{j,3}U_{i1}+\sum_{a=1}^{3}Y^{*}_{e,aj}Z^{E,*}_{k3+a}U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{334}$$



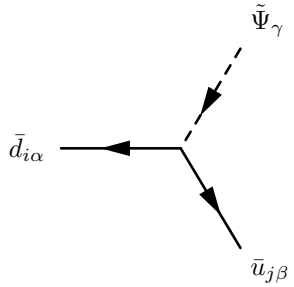
$$-\ i\sum_{b=1}^{3}U^{d,*}_{R,ib}\sum_{a=1}^{3}Y_{H,ab}Z^{U}_{k3+a}K^{SU[3],6\times\bar{3}\times\bar{3}}_{\beta,\alpha,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{335}$$

$$+\ i\Big(K^{SU[3],\bar{6}\times3\times3}_{\beta,\alpha,\gamma}\Big)^{*}\Big(-\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{\bar{H},ab}Z^{U}_{ka}U^{d}_{L,ib}+\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{\bar{H},ab}U^{d}_{L,ia}Z^{U}_{kb}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{336}$$

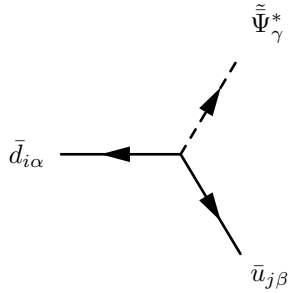


$$- i \sum_{b=1}^{3} \sum_{a=1}^{3} U^{u,*}_{R,ia} Y_{H,ab} Z^{D}_{k3+b} K^{SU[3],6\times\bar{3}\times\bar{3}}_{\beta,\alpha,\gamma} \Big(\frac{1-\gamma_5}{2} \Big) \tag{337}$$

$$+ i \Big(K^{SU[3],\bar{6}\times 3\times 3}_{\beta,\alpha,\gamma} \Big)^{*} \Big(- \sum_{b=1}^{3} \sum_{a=1}^{3} Y^{*}_{\tilde{H},ab} U^{u}_{L,ia} Z^{D}_{kb} + \sum_{b=1}^{3} \sum_{a=1}^{3} Y^{*}_{\tilde{H},ab} Z^{D}_{ka} U^{u}_{L,ib} \Big) \Big(\frac{1+\gamma_5}{2} \Big) \tag{338}$$



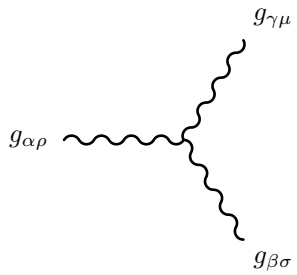
$$- i \sum_{b=1}^{3} U^{d,*}_{R,ib} \sum_{a=1}^{3} U^{u,*}_{R,ja} Y_{H,ab} K^{SU[3],6\times\bar{3}\times\bar{3}}_{\gamma,\alpha,\beta} \Big(\frac{1-\gamma_5}{2} \Big) \tag{339}$$



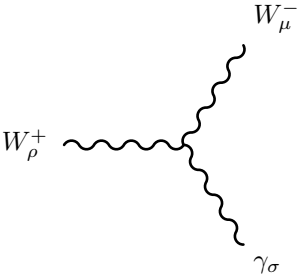
(340)

$$+ i \Big(K^{SU[3],\bar{6}\times 3\times 3}_{\gamma,\alpha,\beta} \Big)^{*} \Big(- \sum_{b=1}^{3} \sum_{a=1}^{3} Y^{*}_{\tilde{H},ab} U^{u}_{L,ja} U^{d}_{L,ib} + \sum_{b=1}^{3} \sum_{a=1}^{3} Y^{*}_{\tilde{H},ab} U^{d}_{L,ia} U^{u}_{L,jb} \Big) \Big(\frac{1+\gamma_5}{2} \Big) \tag{341}$$

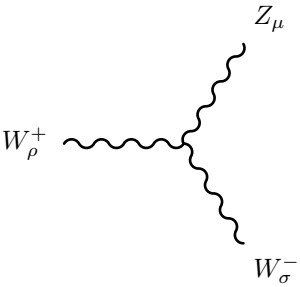
8.6 Three Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma}\Big(g_{\rho\mu}\Big(-p_\sigma^{g_{\gamma\mu}}+p_\sigma^{g_{\alpha\rho}}\Big)+g_{\rho\sigma}\Big(-p_\mu^{g_{\alpha\rho}}+p_\mu^{g_{\beta\sigma}}\Big)+g_{\sigma\mu}\Big(-p_\rho^{g_{\beta\sigma}}+p_\rho^{g_{\gamma\mu}}\Big)\Big) \tag{342}$$

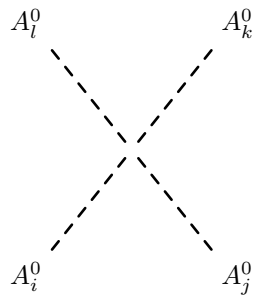


$$ig_2 \sin\Theta_W\Big(g_{\rho\mu}\Big(-p_\sigma^{W_\mu^-}+p_\sigma^{W_\rho^+}\Big)+g_{\rho\sigma}\Big(-p_\mu^{W_\rho^+}+p_\mu^{\gamma_\sigma}\Big)+g_{\sigma\mu}\Big(-p_\rho^{\gamma_\sigma}+p_\rho^{W_\mu^-}\Big)\Big) \tag{343}$$

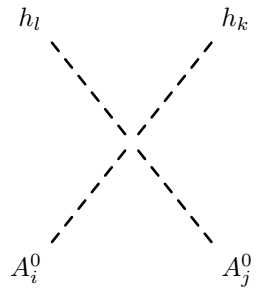


$$-ig_2 \cos\Theta_W\Big(g_{\rho\mu}\Big(-p_\sigma^{Z_\mu}+p_\sigma^{W_\rho^+}\Big)+g_{\rho\sigma}\Big(-p_\mu^{W_\rho^+}+p_\mu^{W_\sigma^-}\Big)+g_{\sigma\mu}\Big(-p_\rho^{W_\sigma^-}+p_\rho^{Z_\mu}\Big)\Big) \tag{344}$$

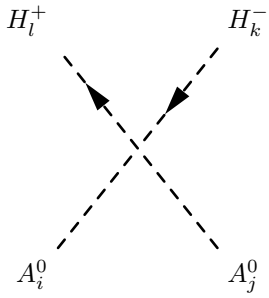
8.7 Four Scalar-Interaction



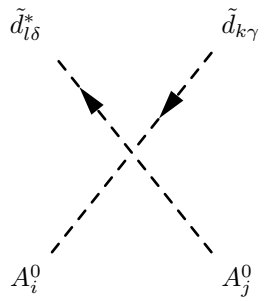
$$\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i2}^A\Big(Z_{j1}^A\Big(Z_{k1}^AZ_{l2}^A+Z_{k2}^AZ_{l1}^A\Big)+Z_{j2}^A\Big(-3Z_{k2}^AZ_{l2}^A+Z_{k1}^AZ_{l1}^A\Big)\Big)$$
$$+Z_{i1}^A\Big(Z_{j1}^A\Big(-3Z_{k1}^AZ_{l1}^A+Z_{k2}^AZ_{l2}^A\Big)+Z_{j2}^A\Big(Z_{k1}^AZ_{l2}^A+Z_{k2}^AZ_{l1}^A\Big)\Big)\Big) \tag{345}$$



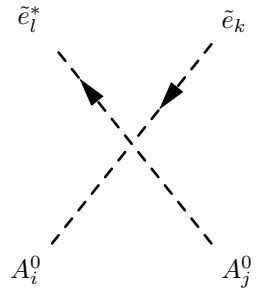
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i1}^AZ_{j1}^A-Z_{i2}^AZ_{j2}^A\Big)\Big(Z_{k1}^HZ_{l1}^H-Z_{k2}^HZ_{l2}^H\Big) \tag{346}$$



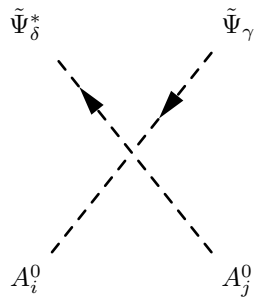
$$\frac{i}{4}\Big(Z_{i1}^A\Big(g_2^2Z_{j2}^A\Big(Z_{k1}^+Z_{l2}^++Z_{k2}^+Z_{l1}^+\Big)-Z_{j1}^A\Big(\Big(g_1^2+g_2^2\Big)Z_{k1}^+Z_{l1}^++\Big(-g_1^2+g_2^2\Big)Z_{k2}^+Z_{l2}^+\Big)\Big)$$
$$+Z_{i2}^A\Big(g_2^2Z_{j1}^A\Big(Z_{k1}^+Z_{l2}^++Z_{k2}^+Z_{l1}^+\Big)+Z_{j2}^A\Big(-\Big(g_1^2+g_2^2\Big)Z_{k2}^+Z_{l2}^++\Big(-g_2^2+g_1^2\Big)Z_{k1}^+Z_{l1}^+\Big)\Big)\Big) \tag{347}$$



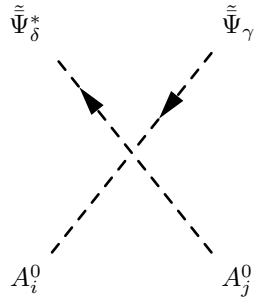
$$\frac{i}{12}\delta_{\gamma\delta}\Big(\Big(3g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z^{D,*}_{ka}Z^{D}_{la}\Big(Z^{A}_{i1}Z^{A}_{j1}-Z^{A}_{i2}Z^{A}_{j2}\Big)$$
$$+2\Big(-6\Big(\sum_{c=1}^{3}Z^{D,*}_{k3+c}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{d,ca}Y_{d,ba}Z^{D}_{l3+b}+\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{D,*}_{kb}\sum_{a=1}^{3}Y^{*}_{d,ac}Y_{d,ab}Z^{D}_{lc}\Big)Z^{A}_{i1}Z^{A}_{j1}$$
$$+g_1^2\sum_{a=1}^{3}Z^{D,*}_{k3+a}Z^{D}_{l3+a}\Big(Z^{A}_{i1}Z^{A}_{j1}-Z^{A}_{i2}Z^{A}_{j2}\Big)\Big)\Big) \tag{348}$$



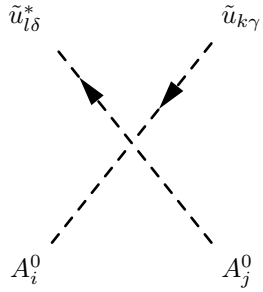
$$\frac{i}{4}\Big(-4\Big(\sum_{c=1}^{3}Z^{E,*}_{k3+c}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^{*}_{e,ca}Y_{e,ba}Z^{E}_{l3+b}+\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{E,*}_{kb}\sum_{a=1}^{3}Y^{*}_{e,ac}Y_{e,ab}Z^{E}_{lc}\Big)Z^{A}_{i1}Z^{A}_{j1}$$
$$-\Big(-g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z^{E,*}_{ka}Z^{E}_{la}\Big(Z^{A}_{i1}Z^{A}_{j1}-Z^{A}_{i2}Z^{A}_{j2}\Big)$$
$$+2g_1^2\sum_{a=1}^{3}Z^{E,*}_{k3+a}Z^{E}_{l3+a}\Big(Z^{A}_{i1}Z^{A}_{j1}-Z^{A}_{i2}Z^{A}_{j2}\Big)\Big) \tag{349}$$



$$\frac{i}{6}g_1^2\delta_{\gamma\delta}\Big(Z^A_{i1}Z^A_{j1} - Z^A_{i2}Z^A_{j2}\Big) \tag{350}$$

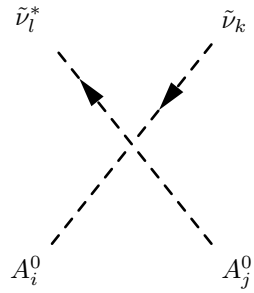


$$\frac{i}{6}g_1^2\delta_{\gamma\delta}\Big(- Z^A_{i1}Z^A_{j1} + Z^A_{i2}Z^A_{j2}\Big) \tag{351}$$

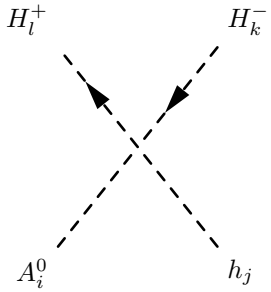


$$\frac{i}{12}\delta_{\gamma\delta}\Big(\Big(- 3g_2^2 + g_1^2\Big)\sum_{a=1}^{3} Z^{U,*}_{ka}Z^U_{la}\Big(Z^A_{i1}Z^A_{j1} - Z^A_{i2}Z^A_{j2}\Big)$$
$$- 4\Big(3\Big(\sum_{c=1}^{3} Z^{U,*}_{k3+c}\sum_{b=1}^{3}\sum_{a=1}^{3} Y^*_{u,ca}Y_{u,ba}Z^U_{l3+b} + \sum_{c=1}^{3}\sum_{b=1}^{3} Z^{U,*}_{kb}\sum_{a=1}^{3} Y^*_{u,ac}Y_{u,ab}Z^U_{lc}\Big)Z^A_{i2}Z^A_{j2}$$

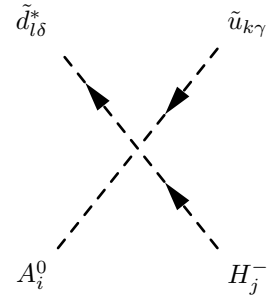
$$+ g_1^2 \sum_{a=1}^{3} Z^{U,*}_{k3+a} Z^{U}_{l3+a} \Big(Z^A_{i1} Z^A_{j1} - Z^A_{i2} Z^A_{j2} \Big) \Big) \Big) \tag{352}$$



$$- \frac{i}{4} \Big(g_1^2 + g_2^2 \Big) \delta_{kl} \Big(Z^A_{i1} Z^A_{j1} - Z^A_{i2} Z^A_{j2} \Big) \tag{353}$$

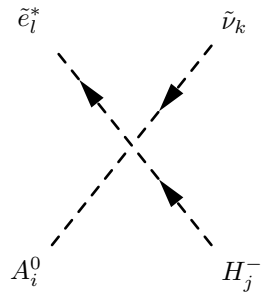


$$\frac{1}{4} g_2^2 \Big(Z^A_{i1} Z^H_{j2} + Z^A_{i2} Z^H_{j1} \Big) \Big(- Z^+_{k1} Z^+_{l2} + Z^+_{k2} Z^+_{l1} \Big) \tag{354}$$

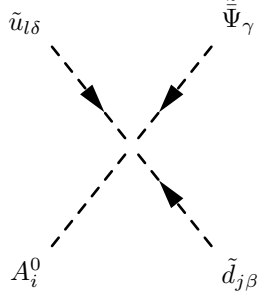


$$- \frac{1}{2} \frac{1}{\sqrt{2}} \delta_{\gamma\delta} \Big(- 2 \sum_{c=1}^{3} \sum_{b=1}^{3} Z^{U,*}_{kb} \sum_{a=1}^{3} Y^*_{d,ac} Y_{d,ab} Z^D_{lc} Z^A_{i1} Z^+_{j1}$$

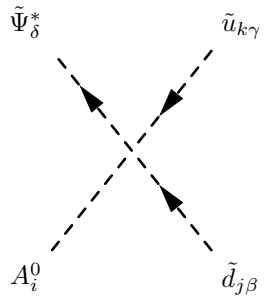
$$
\begin{aligned}
&- 2\sum_{c=1}^{3} Z^{U,*}_{k3+c} \sum_{b=1}^{3}\sum_{a=1}^{3} Y^{*}_{u,ca} Y_{d,ba} Z^{D}_{l3+b} Z^{A}_{i2} Z^{+}_{j1} \\
&+ 2\sum_{c=1}^{3} Z^{U,*}_{k3+c} \sum_{b=1}^{3}\sum_{a=1}^{3} Y^{*}_{u,ca} Y_{d,ba} Z^{D}_{l3+b} Z^{A}_{i1} Z^{+}_{j2} \\
&+ 2\sum_{c=1}^{3}\sum_{b=1}^{3} Z^{U,*}_{kb} \sum_{a=1}^{3} Y^{*}_{u,ac} Y_{u,ab} Z^{D}_{lc} Z^{A}_{i2} Z^{+}_{j2} + g_2^2 \sum_{a=1}^{3} Z^{U,*}_{ka} Z^{D}_{la} \Big(Z^{A}_{i1} Z^{+}_{j1} - Z^{A}_{i2} Z^{+}_{j2} \Big) \Big)
\end{aligned} \tag{355}
$$



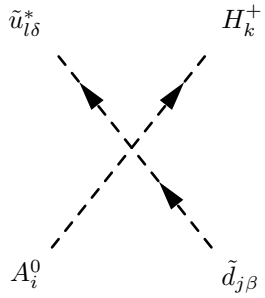
$$
- \frac{1}{2}\frac{1}{\sqrt{2}} \Big(- 2\sum_{c=1}^{3}\sum_{b=1}^{3} Z^{V,*}_{kb} \sum_{a=1}^{3} Y^{*}_{e,ac} Y_{e,ab} Z^{E}_{lc} Z^{A}_{i1} Z^{+}_{j1} + g_2^2 \sum_{a=1}^{3} Z^{V,*}_{ka} Z^{E}_{la} \Big(Z^{A}_{i1} Z^{+}_{j1} - Z^{A}_{i2} Z^{+}_{j2} \Big) \Big) \tag{356}
$$



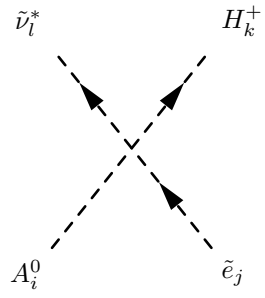
$$
\begin{aligned}
&\frac{1}{\sqrt{2}} \Big(\sum_{c=1}^{3} Z^{D,*}_{j3+c} \sum_{b=1}^{3} Z^{U,*}_{lb} \sum_{a=1}^{3} Y^{*}_{d,ca} Y_{\bar{H},ab} Z^{A}_{i1} - \sum_{c=1}^{3} Z^{D,*}_{j3+c} \sum_{b=1}^{3} Z^{U,*}_{lb} \sum_{a=1}^{3} Y^{*}_{d,ca} Y_{\bar{H},ba} Z^{A}_{i1} \\
&+ \Big(- \sum_{c=1}^{3} Z^{U,*}_{l3+c} \sum_{b=1}^{3} Z^{D,*}_{jb} \sum_{a=1}^{3} Y^{*}_{u,ca} Y_{\bar{H},ab} + \sum_{c=1}^{3} Z^{U,*}_{l3+c} \sum_{b=1}^{3} Z^{D,*}_{jb} \sum_{a=1}^{3} Y^{*}_{u,ca} Y_{\bar{H},ba} \Big) Z^{A}_{i2} \Big) K^{SU[3],\bar{6}\times 3\times 3}_{\gamma,\beta,\delta}
\end{aligned} \tag{357}
$$



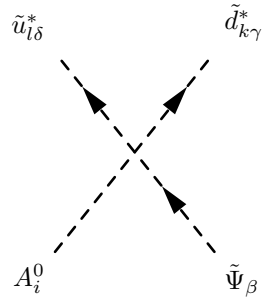
$$\frac{1}{\sqrt{2}}\Big(K^{SU[3],6\times\bar{3}\times\bar{3}}_{\delta,\beta,\gamma}\Big)^*\Big(\sum_{c=1}^{3}Z^{D,*}_{j3+c}\sum_{b=1}^{3}Z^{U,*}_{kb}\sum_{a=1}^{3}Y^*_{H,ac}Y_{u,ab}Z^A_{i2}+\sum_{c=1}^{3}Z^{U,*}_{k3+c}\sum_{b=1}^{3}Z^{D,*}_{jb}\sum_{a=1}^{3}Y^*_{H,ca}Y_{d,ab}Z^A_{i1}\Big) \tag{358}$$



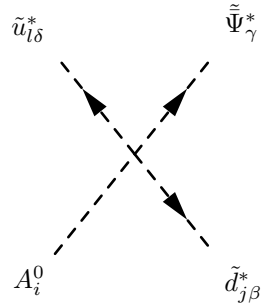
$$\begin{aligned}
&-\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(g_2^2\sum_{a=1}^{3}Z^{D,*}_{ja}Z^U_{la}\Big(-Z^A_{i1}Z^+_{k1}+Z^A_{i2}Z^+_{k2}\Big)\\
&+2\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{D,*}_{jb}\sum_{a=1}^{3}Y^*_{d,ac}Y_{d,ab}Z^U_{lc}Z^A_{i1}Z^+_{k1}-\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{D,*}_{jb}\sum_{a=1}^{3}Y^*_{u,ac}Y_{u,ab}Z^U_{lc}Z^A_{i2}Z^+_{k2}\\
&+\sum_{c=1}^{3}Z^{D,*}_{j3+c}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ca}Y_{u,ba}Z^U_{l3+b}\Big(-Z^A_{i1}Z^+_{k2}+Z^A_{i2}Z^+_{k1}\Big)\Big)\Big)
\end{aligned} \tag{359}$$



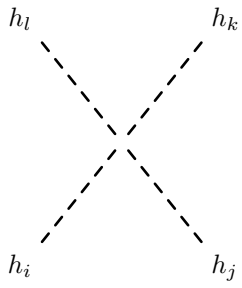
$$-\frac{1}{2}\frac{1}{\sqrt{2}}\Big(2\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{E,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{V}Z_{i1}^{A}Z_{k1}^{+}+g_2^2\sum_{a=1}^{3}Z_{ja}^{E,*}Z_{la}^{V}\Big(-Z_{i1}^{A}Z_{k1}^{+}+Z_{i2}^{A}Z_{k2}^{+}\Big)\Big) \tag{360}$$



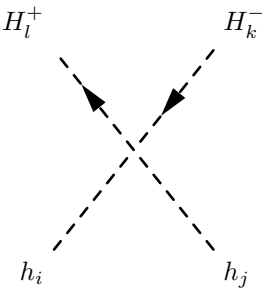
$$-\frac{1}{\sqrt{2}}\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ac}^{*}Y_{H,ba}Z_{l3+b}^{U}Z_{kc}^{D}Z_{i1}^{A}+\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ac}^{*}Y_{H,ab}Z_{k3+b}^{D}Z_{lc}^{U}Z_{i2}^{A}\Big)K_{\beta,\gamma,\delta}^{SU[3],6\times\bar{3}\times\bar{3}} \tag{361}$$



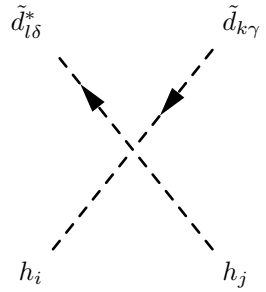
$$-\frac{1}{\sqrt{2}}\Big(K_{\gamma,\beta,\delta}^{SU[3],\bar{6}\times3\times3}\Big)^{*}\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ac}^{*}Y_{d,ba}Z_{j3+b}^{D}Z_{lc}^{U}Z_{i1}^{A}-\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ca}^{*}Y_{d,ba}Z_{j3+b}^{D}Z_{lc}^{U}Z_{i1}^{A}$$
$$+\Big(-\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ac}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{jc}^{D}+\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ca}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{jc}^{D}\Big)Z_{i2}^{A}\Big) \tag{362}$$



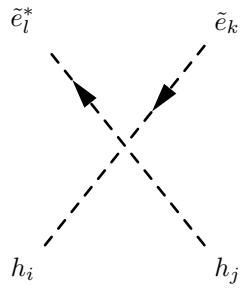
$$\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i2}^H\Big(Z_{j1}^H\Big(Z_{k1}^H Z_{l2}^H+Z_{k2}^H Z_{l1}^H\Big)+Z_{j2}^H\Big(-3Z_{k2}^H Z_{l2}^H+Z_{k1}^H Z_{l1}^H\Big)\Big)$$
$$+Z_{i1}^H\Big(Z_{j1}^H\Big(-3Z_{k1}^H Z_{l1}^H+Z_{k2}^H Z_{l2}^H\Big)+Z_{j2}^H\Big(Z_{k1}^H Z_{l2}^H+Z_{k2}^H Z_{l1}^H\Big)\Big)\Big) \tag{363}$$



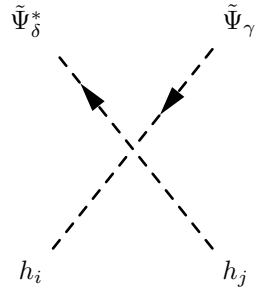
$$\frac{i}{4}\Big(-Z_{i1}^H\Big(g_2^2 Z_{j2}^H\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big)+Z_{j1}^H\Big(\Big(g_1^2+g_2^2\Big)Z_{k1}^+ Z_{l1}^+ + \Big(-g_1^2+g_2^2\Big)Z_{k2}^+ Z_{l2}^+\Big)\Big)$$
$$+Z_{i2}^H\Big(-g_2^2 Z_{j1}^H\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big)+Z_{j2}^H\Big(-\Big(g_1^2+g_2^2\Big)Z_{k2}^+ Z_{l2}^+ + \Big(-g_2^2+g_1^2\Big)Z_{k1}^+ Z_{l1}^+\Big)\Big)\Big) \tag{364}$$



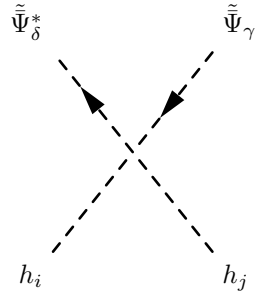
$$\frac{i}{12}\delta_{\gamma\delta}\Big(\Big(3g_2^2+g_1^2\Big)\sum_{a=1}^{3} Z_{ka}^{D,*} Z_{la}^D\Big(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H\Big)$$
$$+2\Big(-6\Big(\sum_{c=1}^{3} Z_{k3+c}^{D,*}\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D + \sum_{c=1}^{3}\sum_{b=1}^{3} Z_{kb}^{D,*}\sum_{a=1}^{3} Y_{d,ac}^* Y_{d,ab} Z_{lc}^D\Big)Z_{i1}^H Z_{j1}^H$$
$$+g_1^2\sum_{a=1}^{3} Z_{k3+a}^{D,*} Z_{l3+a}^D\Big(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H\Big)\Big)\Big) \tag{365}$$



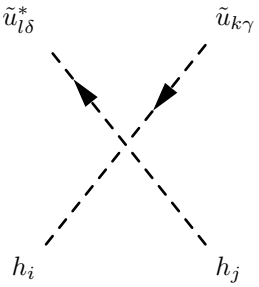
$$\frac{i}{4}\Big(-4\Big(\sum_{c=1}^{3} Z^{E,*}_{k3+c}\sum_{b=1}^{3}\sum_{a=1}^{3} Y^*_{e,ca}Y_{e,ba}Z^E_{l3+b}+\sum_{c=1}^{3}\sum_{b=1}^{3} Z^{E,*}_{kb}\sum_{a=1}^{3} Y^*_{e,ac}Y_{e,ab}Z^E_{lc}\Big)Z^H_{i1}Z^H_{j1}$$
$$-\Big(-g_2^2+g_1^2\Big)\sum_{a=1}^{3} Z^{E,*}_{ka}Z^E_{la}\Big(Z^H_{i1}Z^H_{j1}-Z^H_{i2}Z^H_{j2}\Big)$$
$$+2g_1^2\sum_{a=1}^{3} Z^{E,*}_{k3+a}Z^E_{l3+a}\Big(Z^H_{i1}Z^H_{j1}-Z^H_{i2}Z^H_{j2}\Big)\Big) \tag{366}$$



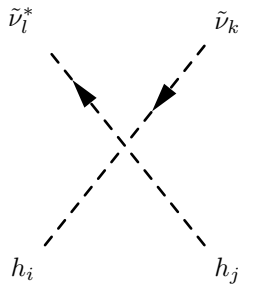
$$\frac{i}{6}g_1^2\delta_{\gamma\delta}\Big(Z^H_{i1}Z^H_{j1}-Z^H_{i2}Z^H_{j2}\Big) \tag{367}$$



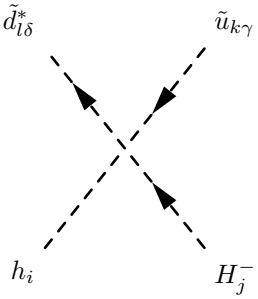
$$\frac{i}{6}g_1^2\delta_{\gamma\delta}\Big(- Z_{i1}^H Z_{j1}^H + Z_{i2}^H Z_{j2}^H\Big) \tag{368}$$



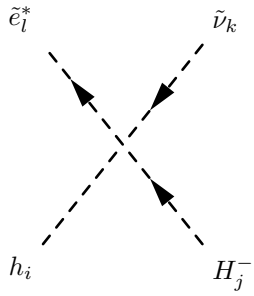
$$\begin{aligned}
&\frac{i}{12}\delta_{\gamma\delta}\Big(\Big(- 3g_2^2 + g_1^2\Big)\sum_{a=1}^{3} Z_{ka}^{U,*} Z_{la}^{U}\Big(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H\Big)\\
&- 4\Big(3\Big(\sum_{c=1}^{3} Z_{k3+c}^{U,*}\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{u,ca}^* Y_{u,ba} Z_{l3+b}^{U} + \sum_{c=1}^{3}\sum_{b=1}^{3} Z_{kb}^{U,*}\sum_{a=1}^{3} Y_{u,ac}^* Y_{u,ab} Z_{lc}^{U}\Big) Z_{i2}^H Z_{j2}^H\\
&+ g_1^2\sum_{a=1}^{3} Z_{k3+a}^{U,*} Z_{l3+a}^{U}\Big(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H\Big)\Big)\Big)
\end{aligned} \tag{369}$$



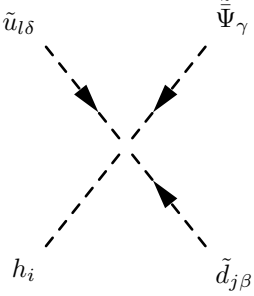
$$- \frac{i}{4}\Big(g_1^2 + g_2^2\Big)\delta_{kl}\Big(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H\Big) \tag{370}$$



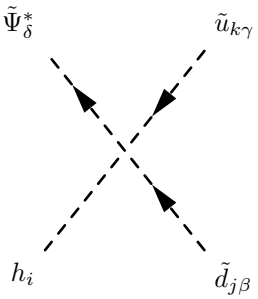
$$\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\Big(-g_2^2\sum_{a=1}^{3}Z_{ka}^{U,*}Z_{la}^{D}\Big(Z_{i1}^{H}Z_{j1}^{+}+Z_{i2}^{H}Z_{j2}^{+}\Big)$$
$$+2\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{kb}^{U,*}\sum_{a=1}^{3}Y_{d,ac}^{*}Y_{d,ab}Z_{lc}^{D}Z_{i1}^{H}Z_{j1}^{+}+\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{kb}^{U,*}\sum_{a=1}^{3}Y_{u,ac}^{*}Y_{u,ab}Z_{lc}^{D}Z_{i2}^{H}Z_{j2}^{+}$$
$$+\sum_{c=1}^{3}Z_{k3+c}^{U,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ca}^{*}Y_{d,ba}Z_{l3+b}^{D}\Big(Z_{i1}^{H}Z_{j2}^{+}+Z_{i2}^{H}Z_{j1}^{+}\Big)\Big)\Big) \tag{371}$$



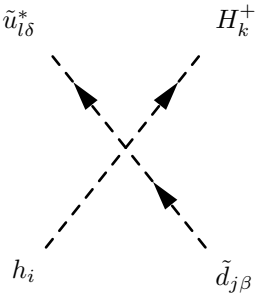
$$\frac{i}{2}\frac{1}{\sqrt{2}}\Big(2\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{kb}^{V,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{E}Z_{i1}^{H}Z_{j1}^{+}-g_2^2\sum_{a=1}^{3}Z_{ka}^{V,*}Z_{la}^{E}\Big(Z_{i1}^{H}Z_{j1}^{+}+Z_{i2}^{H}Z_{j2}^{+}\Big)\Big) \tag{372}$$



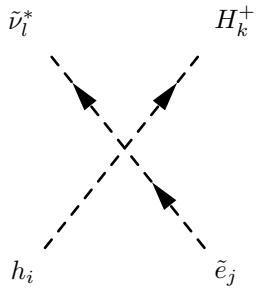
$$i\frac{1}{\sqrt{2}}\Big(\sum_{c=1}^{3}Z_{j3+c}^{D,*}\sum_{b=1}^{3}Z_{lb}^{U,*}\sum_{a=1}^{3}Y_{d,ca}^{*}Y_{\bar{H},ab}Z_{i1}^{H}-\sum_{c=1}^{3}Z_{j3+c}^{D,*}\sum_{b=1}^{3}Z_{lb}^{U,*}\sum_{a=1}^{3}Y_{d,ca}^{*}Y_{\bar{H},ba}Z_{i1}^{H}$$
$$+\Big(-\sum_{c=1}^{3}Z_{l3+c}^{U,*}\sum_{b=1}^{3}Z_{jb}^{D,*}\sum_{a=1}^{3}Y_{u,ca}^{*}Y_{\bar{H},ab}+\sum_{c=1}^{3}Z_{l3+c}^{U,*}\sum_{b=1}^{3}Z_{jb}^{D,*}\sum_{a=1}^{3}Y_{u,ca}^{*}Y_{\bar{H},ba}\Big)Z_{i2}^{H}\Big)K_{\gamma,\beta,\delta}^{SU[3],\bar{6}\times3\times3} \tag{373}$$



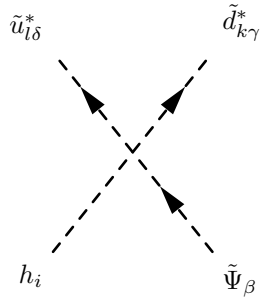
$$-i\frac{1}{\sqrt{2}}\Big(K^{SU[3],6\times\bar{3}\times\bar{3}}_{\delta,\beta,\gamma}\Big)^*\Big(\sum_{c=1}^{3}Z^{D,*}_{j3+c}\sum_{b=1}^{3}Z^{U,*}_{kb}\sum_{a=1}^{3}Y^*_{H,ac}Y_{u,ab}Z^H_{i2}+\sum_{c=1}^{3}Z^{U,*}_{k3+c}\sum_{b=1}^{3}Z^{D,*}_{jb}\sum_{a=1}^{3}Y^*_{H,ca}Y_{d,ab}Z^H_{i1}\Big) \tag{374}$$



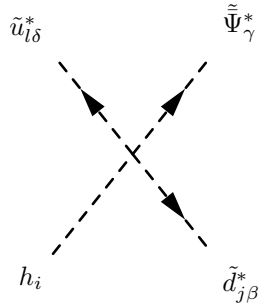
$$\begin{aligned}&\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(-g_2^2\sum_{a=1}^{3}Z^{D,*}_{ja}Z^U_{la}\Big(Z^H_{i1}Z^+_{k1}+Z^H_{i2}Z^+_{k2}\Big)\\&+2\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{D,*}_{jb}\sum_{a=1}^{3}Y^*_{d,ac}Y_{d,ab}Z^U_{lc}Z^H_{i1}Z^+_{k1}+\sum_{c=1}^{3}\sum_{b=1}^{3}Z^{D,*}_{jb}\sum_{a=1}^{3}Y^*_{u,ac}Y_{u,ab}Z^U_{lc}Z^H_{i2}Z^+_{k2}\\&+\sum_{c=1}^{3}Z^{D,*}_{j3+c}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ca}Y_{u,ba}Z^U_{l3+b}\Big(Z^H_{i1}Z^+_{k2}+Z^H_{i2}Z^+_{k1}\Big)\Big)\Big)\end{aligned} \tag{375}$$



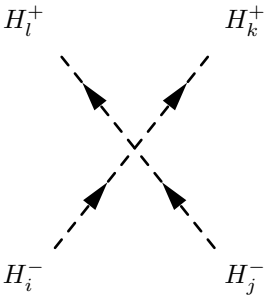
$$\frac{i}{2}\frac{1}{\sqrt{2}}\Big(2\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{E,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{V}Z_{i1}^{H}Z_{k1}^{+}-g_2^2\sum_{a=1}^{3}Z_{ja}^{E,*}Z_{la}^{V}\Big(Z_{i1}^{H}Z_{k1}^{+}+Z_{i2}^{H}Z_{k2}^{+}\Big)\Big) \tag{376}$$



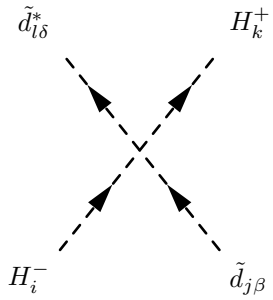
$$-i\frac{1}{\sqrt{2}}\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ac}^{*}Y_{H,ba}Z_{l3+b}^{U}Z_{kc}^{D}Z_{i1}^{H}+\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ac}^{*}Y_{H,ab}Z_{k3+b}^{D}Z_{lc}^{U}Z_{i2}^{H}\Big)K_{\beta,\gamma,\delta}^{SU[3],6\times\bar{3}\times\bar{3}} \tag{377}$$



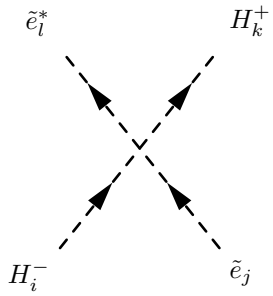
$$i\frac{1}{\sqrt{2}}\Big(K_{\gamma,\beta,\delta}^{SU[3],\bar{6}\times3\times3}\Big)^{*}\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ac}^{*}Y_{d,ba}Z_{j3+b}^{D}Z_{lc}^{U}Z_{i1}^{H}-\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ca}^{*}Y_{d,ba}Z_{j3+b}^{D}Z_{lc}^{U}Z_{i1}^{H}$$
$$+\Big(-\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ac}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{jc}^{D}+\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ca}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{jc}^{D}\Big)Z_{i2}^{H}\Big) \tag{378}$$



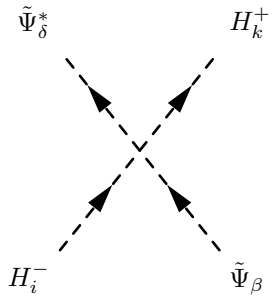
$$
\begin{aligned}
&-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(-Z_{i2}^{+}\Big(-2Z_{j2}^{+}Z_{k2}^{+}Z_{l2}^{+}+Z_{j1}^{+}\Big(Z_{k1}^{+}Z_{l2}^{+}+Z_{k2}^{+}Z_{l1}^{+}\Big)\Big)\\
&+Z_{i1}^{+}\Big(2Z_{j1}^{+}Z_{k1}^{+}Z_{l1}^{+}-Z_{j2}^{+}\Big(Z_{k1}^{+}Z_{l2}^{+}+Z_{k2}^{+}Z_{l1}^{+}\Big)\Big)\Big)
\end{aligned}
\tag{379}
$$



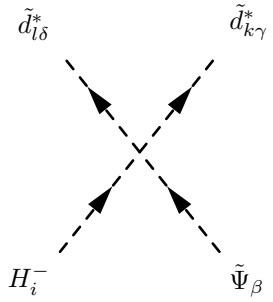
$$
\begin{aligned}
&\frac{i}{12}\delta_{\beta\delta}\Big(\Big(-3g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{la}^{D}\Big(Z_{i1}^{+}Z_{k1}^{+}-Z_{i2}^{+}Z_{k2}^{+}\Big)\\
&+2\Big(g_1^2\sum_{a=1}^{3}Z_{j3+a}^{D,*}Z_{l3+a}^{D}\Big(Z_{i1}^{+}Z_{k1}^{+}-Z_{i2}^{+}Z_{k2}^{+}\Big)\\
&-6\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{D,*}\sum_{a=1}^{3}Y_{u,ac}^{*}Y_{u,ab}Z_{lc}^{D}Z_{i2}^{+}Z_{k2}^{+}+\sum_{c=1}^{3}Z_{j3+c}^{D,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ca}^{*}Y_{d,ba}Z_{l3+b}^{D}Z_{i1}^{+}Z_{k1}^{+}\Big)\Big)\Big)
\end{aligned}
\tag{380}
$$



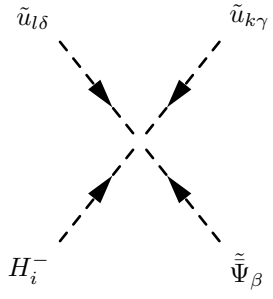
$$
\begin{aligned}
&\frac{i}{4}\Big(-4\sum_{c=1}^{3}Z_{j3+c}^{E,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ca}^{*}Y_{e,ba}Z_{l3+b}^{E}Z_{i1}^{+}Z_{k1}^{+}\\
&-\Big(g_1^2+g_2^2\Big)\sum_{a=1}^{3}Z_{ja}^{E,*}Z_{la}^{E}\Big(Z_{i1}^{+}Z_{k1}^{+}-Z_{i2}^{+}Z_{k2}^{+}\Big)\\
&+2g_1^2\sum_{a=1}^{3}Z_{j3+a}^{E,*}Z_{l3+a}^{E}\Big(Z_{i1}^{+}Z_{k1}^{+}-Z_{i2}^{+}Z_{k2}^{+}\Big)\Big)
\end{aligned}
\tag{381}
$$



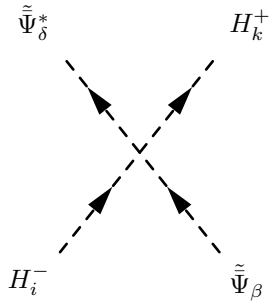
$$\frac{i}{6}g_1^2\delta_{\beta\delta}\Big(Z^+_{i1}Z^+_{k1} - Z^+_{i2}Z^+_{k2}\Big) \tag{382}$$



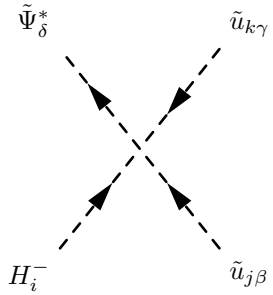
$$i\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{u,ac}Y_{H,ab}Z^D_{l3+b}Z^D_{kc} + \sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{u,ac}Y_{H,ab}Z^D_{k3+b}Z^D_{lc}\Big)Z^+_{i2}K^{SU[3],6\times\bar{3}\times\bar{3}}_{\beta,\gamma,\delta} \tag{383}$$



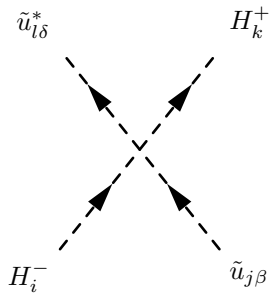
$$\begin{aligned} i\Big(&-\sum_{c=1}^{3}Z^{U,*}_{l3+c}\sum_{b=1}^{3}Z^{U,*}_{kb}\sum_{a=1}^{3}Y^*_{u,ca}Y_{\bar{H},ab} - \sum_{c=1}^{3}Z^{U,*}_{k3+c}\sum_{b=1}^{3}Z^{U,*}_{lb}\sum_{a=1}^{3}Y^*_{u,ca}Y_{\bar{H},ab} \\ &+\sum_{c=1}^{3}Z^{U,*}_{l3+c}\sum_{b=1}^{3}Z^{U,*}_{kb}\sum_{a=1}^{3}Y^*_{u,ca}Y_{\bar{H},ba} + \sum_{c=1}^{3}Z^{U,*}_{k3+c}\sum_{b=1}^{3}Z^{U,*}_{lb}\sum_{a=1}^{3}Y^*_{u,ca}Y_{\bar{H},ba}\Big)Z^+_{i2}K^{SU[3],\bar{6}\times3\times3}_{\beta,\gamma,\delta} \end{aligned} \tag{384}$$



$$\frac{i}{6}g_1^2\delta_{\beta\delta}\Big(-Z_{i1}^+Z_{k1}^+ + Z_{i2}^+Z_{k2}^+\Big) \tag{385}$$

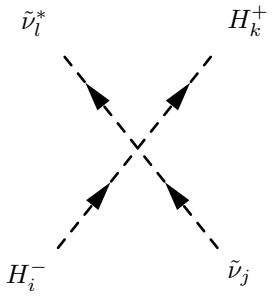


$$i\Big(K^{SU[3],6\times\bar{3}\times\bar{3}}_{\delta,\beta,\gamma}\Big)^*\Big(\sum_{c=1}^{3}Z^{U,*}_{k3+c}\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Y^*_{H,ca}Y_{d,ab}+\sum_{c=1}^{3}Z^{U,*}_{j3+c}\sum_{b=1}^{3}Z^{U,*}_{kb}\sum_{a=1}^{3}Y^*_{H,ca}Y_{d,ab}\Big)Z^+_{i1} \tag{386}$$

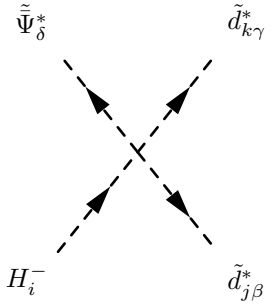


$$\frac{i}{12}\delta_{\beta\delta}\Big(\Big(3g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z^{U,*}_{ja}Z^U_{la}\Big(Z^+_{i1}Z^+_{k1}-Z^+_{i2}Z^+_{k2}\Big)$$
$$-4\Big(g_1^2\sum_{a=1}^{3}Z^{U,*}_{j3+a}Z^U_{l3+a}\Big(Z^+_{i1}Z^+_{k1}-Z^+_{i2}Z^+_{k2}\Big)$$

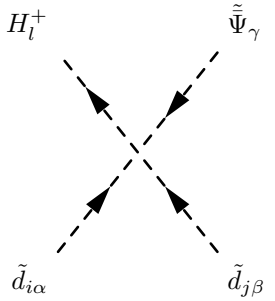
$$+ 3\Big(\sum_{c=1}^{3}\sum_{b=1}^{3} Z_{jb}^{U,*}\sum_{a=1}^{3} Y_{d,ac}^{*}Y_{d,ab}Z_{lc}^{U}Z_{i1}^{+}Z_{k1}^{+} + \sum_{c=1}^{3} Z_{j3+c}^{U,*}\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{u,ca}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{i2}^{+}Z_{k2}^{+}\Big)\Big)\Big) \tag{387}$$



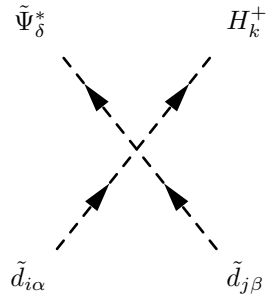
$$\frac{i}{4}\Big(-4\sum_{c=1}^{3}\sum_{b=1}^{3} Z_{jb}^{V,*}\sum_{a=1}^{3} Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{V}Z_{i1}^{+}Z_{k1}^{+} - \Big(-g_2^2+g_1^2\Big)\delta_{jl}\Big(Z_{i1}^{+}Z_{k1}^{+} - Z_{i2}^{+}Z_{k2}^{+}\Big)\Big) \tag{388}$$



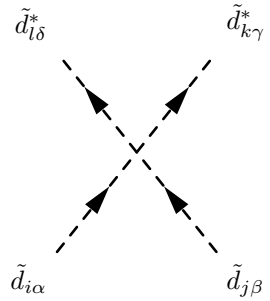
$$\begin{aligned} &i\Big(K_{\delta,\beta,\gamma}^{SU[3],\bar{6}\times 3\times 3}\Big)^{*}\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{\bar{H},ac}^{*}Y_{d,ba}Z_{k3+b}^{D}Z_{jc}^{D} - \sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{\bar{H},ca}^{*}Y_{d,ba}Z_{k3+b}^{D}Z_{jc}^{D} \\ &+\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{\bar{H},ac}^{*}Y_{d,ba}Z_{j3+b}^{D}Z_{kc}^{D} - \sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{\bar{H},ca}^{*}Y_{d,ba}Z_{j3+b}^{D}Z_{kc}^{D}\Big)Z_{i1}^{+} \end{aligned} \tag{389}$$



$$i\Big(\sum_{c=1}^{3} Z^{D,*}_{j3+c}\sum_{b=1}^{3} Z^{D,*}_{ib}\sum_{a=1}^{3} Y^{*}_{d,ca}Y_{\bar{H},ab}+\sum_{c=1}^{3} Z^{D,*}_{i3+c}\sum_{b=1}^{3} Z^{D,*}_{jb}\sum_{a=1}^{3} Y^{*}_{d,ca}Y_{\bar{H},ab}$$
$$-\sum_{c=1}^{3} Z^{D,*}_{j3+c}\sum_{b=1}^{3} Z^{D,*}_{ib}\sum_{a=1}^{3} Y^{*}_{d,ca}Y_{\bar{H},ba}-\sum_{c=1}^{3} Z^{D,*}_{i3+c}\sum_{b=1}^{3} Z^{D,*}_{jb}\sum_{a=1}^{3} Y^{*}_{d,ca}Y_{\bar{H},ba}\Big)Z^{+}_{l1}K^{SU[3],\bar{6}\times 3\times 3}_{\gamma,\alpha,\beta} \tag{390}$$



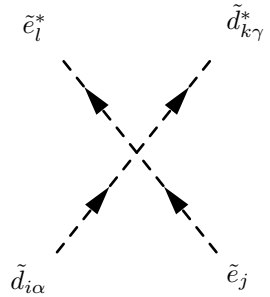
$$i\Big(K^{SU[3],6\times\bar{3}\times\bar{3}}_{\delta,\alpha,\beta}\Big)^{*}\Big(\sum_{c=1}^{3} Z^{D,*}_{j3+c}\sum_{b=1}^{3} Z^{D,*}_{ib}\sum_{a=1}^{3} Y^{*}_{H,ac}Y_{u,ab}+\sum_{c=1}^{3} Z^{D,*}_{i3+c}\sum_{b=1}^{3} Z^{D,*}_{jb}\sum_{a=1}^{3} Y^{*}_{H,ac}Y_{u,ab}\Big)Z^{+}_{k2} \tag{391}$$



$$\frac{i}{72}\Big(-\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(g_1^2\sum_{a=1}^{3} Z^{D,*}_{ia}Z^{D}_{la}\sum_{b=1}^{3} Z^{D,*}_{jb}Z^{D}_{kb}+9g_2^2\sum_{a=1}^{3} Z^{D,*}_{ia}Z^{D}_{la}\sum_{b=1}^{3} Z^{D,*}_{jb}Z^{D}_{kb}$$
$$-6g_3^2\sum_{a=1}^{3} Z^{D,*}_{ia}Z^{D}_{la}\sum_{b=1}^{3} Z^{D,*}_{jb}Z^{D}_{kb}+2g_1^2\sum_{a=1}^{3} Z^{D,*}_{i3+a}Z^{D}_{l3+a}\sum_{b=1}^{3} Z^{D,*}_{jb}Z^{D}_{kb}$$
$$+6g_3^2\sum_{a=1}^{3} Z^{D,*}_{i3+a}Z^{D}_{l3+a}\sum_{b=1}^{3} Z^{D,*}_{jb}Z^{D}_{kb}$$
$$+18g_3^2\sum_{a=1}^{3} Z^{D,*}_{ja}Z^{D}_{la}\Big(-\sum_{b=1}^{3} Z^{D,*}_{i3+b}Z^{D}_{k3+b}+\sum_{b=1}^{3} Z^{D,*}_{ib}Z^{D}_{kb}\Big)$$

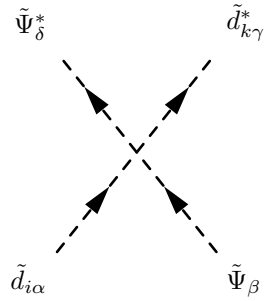
$$
\begin{aligned}
&- 18g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{D,*} Z_{l3+a}^{D} \Big(- \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{k3+b}^{D} + \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{kb}^{D} \Big) \\
&+ 2g_1^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{la}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{k3+b}^{D} + 6g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*}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

$$
\begin{aligned}
&- 18g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{la}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{k3+b}^{D} + 18g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{l3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{k3+b}^{D} \\
&+ 18g_3^2 \sum_{a=1}^{3} Z_{ja}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{lb}^{D} - 18g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{lb}^{D} \\
&+ g_1^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D} + 9g_2^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D} \\
&- 6g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D} + 2g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D} \\
&+ 6g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D} - 18g_3^2 \sum_{a=1}^{3} Z_{ja}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{l3+b}^{D} \\
&+ 18g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{l3+b}^{D} + 2g_1^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D} \\
&+ 6g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D} + 4g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D} \\
&- 6g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D} \\
&+ 72 \sum_{b=1}^{3} Z_{jb}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{l3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{i3+c}^{D,*} Z_{kd}^{D} \\
&+ 72 \sum_{b=1}^{3} Z_{ib}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{j3+c}^{D,*} Z_{ld}^{D} \Big) \Big)
\end{aligned}
\tag{392}
$$

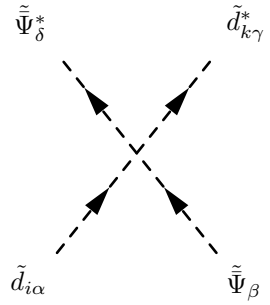


$$
\begin{aligned}
&\frac{i}{24}\delta_{\alpha\gamma}\Big(- 2g_1^2 \sum_{a=1}^{3} Z_{j3+a}^{E,*} Z_{l3+a}^{E} \Big(2 \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{k3+b}^{D} + \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{kb}^{D} \Big) \\
&+ \sum_{a=1}^{3} Z_{ja}^{E,*} Z_{la}^{E} \Big(2g_1^2 \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{k3+b}^{D}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

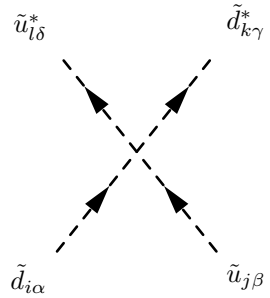
$$
\begin{aligned}
&+ g_1^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{lb}^{E} - 3 g_2^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{lb}^{E} \\
&+ 2 g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{lb}^{E} - 2 g_1^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{j3+b}^{E,*} Z_{l3+b}^{E} \\
&- 4 g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{E,*} Z_{l3+b}^{E} \\
&- 24 \sum_{b=1}^{3} Z_{jb}^{E,*} \sum_{a=1}^{3} Y_{e,ab} Z_{l3+a}^{E} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{i3+c}^{D,*} Z_{kd}^{D} \\
&- 24 \sum_{b=1}^{3} Z_{ib}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{e,cd}^{*} Z_{j3+c}^{E,*} Z_{ld}^{E} \Big)
\end{aligned} \tag{393}
$$



$$
\begin{aligned}
&\frac{i}{18} \Big(- g_1^2 \delta_{\alpha\gamma} \delta_{\beta\delta} \Big(2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} + \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \Big) \\
&- 9 \Big(g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{8} \lambda_{\gamma,\alpha}^{b} T_{b\delta\beta}^{\mathrm{SU}\left(3\right),6} - g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{8} \lambda_{\gamma,\alpha}^{b} T_{b\delta\beta}^{\mathrm{SU}\left(3\right),6} \\
&+ 2 \sum_{a=1}^{3} \Big(K_{\delta,\alpha,a}^{SU[3],6\times\bar{3}\times\bar{3}} \Big)^{*} K_{\beta,\gamma,a}^{SU[3],6\times\bar{3}\times\bar{3}} \sum_{d=1}^{3} Z_{i3+d}^{D,*} \sum_{c=1}^{3} \sum_{b=1}^{3} Y_{H,bd}^{*} Y_{H,bc} Z_{k3+c}^{D} \Big) \Big)
\end{aligned} \tag{394}
$$



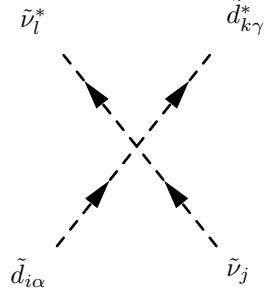
$$
\begin{aligned}
&i\Big(\frac{1}{18}g_1^2\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(2\sum_{a=1}^{3}Z^{D,*}_{i3+a}Z^{D}_{k3+a}+\sum_{a=1}^{3}Z^{D,*}_{ia}Z^{D}_{ka}\Big)+\frac{1}{2}g_3^2\sum_{a=1}^{3}Z^{D,*}_{ia}Z^{D}_{ka}\sum_{b=1}^{8}\lambda^{b}_{\gamma,\alpha}T^{\mathrm{SU}\left(3\right),6}_{b\beta\delta}\\
&-\frac{1}{2}g_3^2\sum_{a=1}^{3}Z^{D,*}_{i3+a}Z^{D}_{k3+a}\sum_{b=1}^{8}\lambda^{b}_{\gamma,\alpha}T^{\mathrm{SU}\left(3\right),6}_{b\beta\delta}-\sum_{a=1}^{3}\Big(K^{SU[3],\bar{6}\times3\times3}_{\delta,\gamma,a}\Big)^{*}K^{SU[3],\bar{6}\times3\times3}_{\beta,\alpha,a}\sum_{d=1}^{3}\sum_{c=1}^{3}Z^{D,*}_{ic}\sum_{b=1}^{3}Y^{*}_{\bar{H},bd}Y_{\bar{H},bc}Z^{D}_{kd}\\
&+\sum_{a=1}^{3}\Big(K^{SU[3],\bar{6}\times3\times3}_{\delta,\gamma,a}\Big)^{*}K^{SU[3],\bar{6}\times3\times3}_{\beta,\alpha,a}\sum_{d=1}^{3}\sum_{c=1}^{3}Z^{D,*}_{ic}\sum_{b=1}^{3}Y^{*}_{\bar{H},db}Y_{\bar{H},bc}Z^{D}_{kd}\\
&+\sum_{a=1}^{3}\Big(K^{SU[3],\bar{6}\times3\times3}_{\delta,\gamma,a}\Big)^{*}K^{SU[3],\bar{6}\times3\times3}_{\beta,\alpha,a}\sum_{d=1}^{3}\sum_{c=1}^{3}Z^{D,*}_{ic}\sum_{b=1}^{3}Y^{*}_{\bar{H},bd}Y_{\bar{H},cb}Z^{D}_{kd}\\
&-\sum_{a=1}^{3}\Big(K^{SU[3],\bar{6}\times3\times3}_{\delta,\gamma,a}\Big)^{*}K^{SU[3],\bar{6}\times3\times3}_{\beta,\alpha,a}\sum_{d=1}^{3}\sum_{c=1}^{3}Z^{D,*}_{ic}\sum_{b=1}^{3}Y^{*}_{\bar{H},db}Y_{\bar{H},cb}Z^{D}_{kd}\Big)
\end{aligned}
\tag{395}
$$



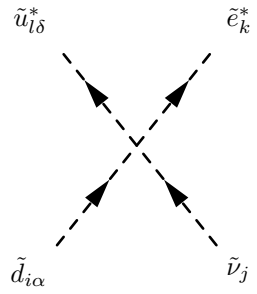
$$
\begin{aligned}
&\frac{i}{72}\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(-\sum_{a=1}^{3}Z^{U,*}_{ja}Z^{U}_{la}\Big(2\Big(3g_3^2+g_1^2\Big)\sum_{b=1}^{3}Z^{D,*}_{i3+b}Z^{D}_{k3+b}+\Big(-6g_3^2-9g_2^2+g_1^2\Big)\sum_{b=1}^{3}Z^{D,*}_{ib}Z^{D}_{kb}\Big)\\
&+\sum_{a=1}^{3}Z^{U,*}_{j3+a}Z^{U}_{l3+a}\Big(2\Big(3g_3^2+4g_1^2\Big)\sum_{b=1}^{3}Z^{D,*}_{i3+b}Z^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

$$+ 6g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U} \Big)$$
$$- 18\delta_{\alpha\delta}\delta_{\beta\gamma} \Big(g_2^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{la}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{kb}^{D} + g_3^2 \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{la}^{U} \Big(- \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{k3+b}^{D} + \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{kb}^{D} \Big)$$
$$+ g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{U,*} Z_{l3+a}^{U} \Big(- \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{kb}^{D} + \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{k3+b}^{D} \Big)$$
$$+ g_2^2 \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{lb}^{U} + g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U}$$
$$- g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U} - g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U}$$
$$+ g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U} + 4 \sum_{b=1}^{3} Z_{ib}^{D,*} \sum_{a=1}^{3} Y_{u,ab} Z_{l3+a}^{U} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{u,cd}^{*} Z_{j3+c}^{U,*} Z_{kd}^{D}$$
$$+ 4 \sum_{b=1}^{3} Z_{jb}^{U,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{i3+c}^{D,*} Z_{ld}^{U} \Big)$$
$$- 72 \Big(\sum_{a=1}^{6} \Big(K_{a,\alpha,\beta}^{SU[3],6\times\bar{3}\times\bar{3}} \Big)^{*} K_{a,\gamma,\delta}^{SU[3],6\times\bar{3}\times\bar{3}} \sum_{c=1}^{3} \sum_{b=1}^{3} Y_{H,cb} Z_{k3+b}^{D} Z_{l3+c}^{U} \sum_{e=1}^{3} Z_{j3+e}^{U,*} \sum_{d=1}^{3} Y_{H,ed}^{*} Z_{i3+d}^{D,*}$$
$$- \sum_{a=1}^{6} \Big(K_{a,\gamma,\delta}^{SU[3],\bar{6}\times 3\times 3} \Big)^{*} K_{a,\alpha,\beta}^{SU[3],\bar{6}\times 3\times 3} \Big(- \sum_{c=1}^{3} Z_{ic}^{D,*} \sum_{b=1}^{3} Z_{jb}^{U,*} Y_{\bar{H},cb} + \sum_{c=1}^{3} Z_{jc}^{U,*} \sum_{b=1}^{3} Z_{ib}^{D,*} Y_{\bar{H},cb} \Big) \Big(- \sum_{e=1}^{3} \sum_{d=1}^{3} Y_{\bar{H},ed}^{*} Z_{kd}^{D} Z_{le}^{U} + \sum_{e=1}^{3} \sum_{d=1}^{3} Y_{\bar{H},ed}^{*} Z_{l}$$

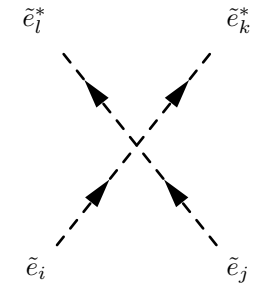
(396)



$$\frac{i}{12}\delta_{\alpha\gamma}\delta_{jl} \Big(2g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} + \Big(3g_2^2 + g_1^2 \Big) \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \Big) \tag{397}$$

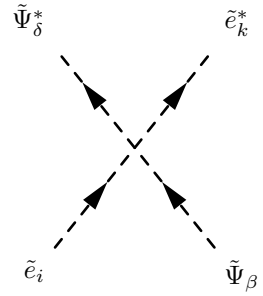


$$
\begin{aligned}
&-\frac{i}{4}\delta_{\alpha\delta}\Big(g_2^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{la}^{U}\sum_{b=1}^{3}Z_{jb}^{V,*}Z_{kb}^{E}+g_2^2\sum_{a=1}^{3}Z_{ja}^{V,*}Z_{ka}^{E}\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{lb}^{U}\\
&+4\sum_{b=1}^{3}Z_{jb}^{V,*}\sum_{a=1}^{3}Y_{e,ab}Z_{k3+a}^{E}\sum_{d=1}^{3}\sum_{c=1}^{3}Y_{d,cd}^{*}Z_{i3+c}^{D,*}Z_{ld}^{U}\Big)
\end{aligned}
\tag{398}
$$

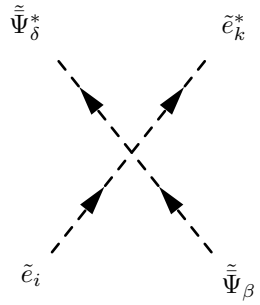


$$
\begin{aligned}
&\frac{i}{8}\Big(-g_1^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{la}^{E}\sum_{b=1}^{3}Z_{jb}^{E,*}Z_{kb}^{E}-g_2^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{la}^{E}\sum_{b=1}^{3}Z_{jb}^{E,*}Z_{kb}^{E}\\
&+2g_1^2\sum_{a=1}^{3}Z_{i3+a}^{E,*}Z_{l3+a}^{E}\sum_{b=1}^{3}Z_{jb}^{E,*}Z_{kb}^{E}\\
&+2g_1^2\sum_{a=1}^{3}Z_{j3+a}^{E,*}Z_{l3+a}^{E}\Big(-2\sum_{b=1}^{3}Z_{i3+b}^{E,*}Z_{k3+b}^{E}+\sum_{b=1}^{3}Z_{ib}^{E,*}Z_{kb}^{E}\Big)\\
&-\sum_{a=1}^{3}Z_{ja}^{E,*}Z_{la}^{E}\Big(-2g_1^2\sum_{b=1}^{3}Z_{i3+b}^{E,*}Z_{k3+b}^{E}+\Big(g_1^2+g_2^2\Big)\sum_{b=1}^{3}Z_{ib}^{E,*}Z_{kb}^{E}\Big)\\
&+2g_1^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{la}^{E}\sum_{b=1}^{3}Z_{j3+b}^{E,*}Z_{k3+b}^{E}-4g_1^2\sum_{a=1}^{3}Z_{i3+a}^{E,*}Z_{l3+a}^{E}\sum_{b=1}^{3}Z_{j3+b}^{E,*}Z_{k3+b}^{E}\\
&-g_1^2\sum_{a=1}^{3}Z_{ja}^{E,*}Z_{ka}^{E}\sum_{b=1}^{3}Z_{ib}^{E,*}Z_{lb}^{E}-g_2^2\sum_{a=1}^{3}Z_{ja}^{E,*}Z_{ka}^{E}\sum_{b=1}^{3}Z_{ib}^{E,*}Z_{lb}^{E}
\end{aligned}
$$

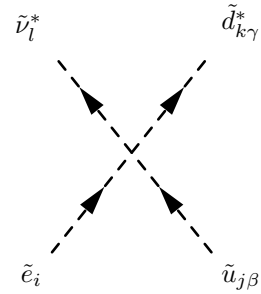
$$
\begin{aligned}
&+ 2g_1^2 \sum_{a=1}^{3} Z^{E,*}_{j3+a} Z^{E}_{k3+a} \sum_{b=1}^{3} Z^{E,*}_{ib} Z^{E}_{lb} - g_1^2 \sum_{a=1}^{3} Z^{E,*}_{ia} Z^{E}_{ka} \sum_{b=1}^{3} Z^{E,*}_{jb} Z^{E}_{lb} \\
&- g_2^2 \sum_{a=1}^{3} Z^{E,*}_{ia} Z^{E}_{ka} \sum_{b=1}^{3} Z^{E,*}_{jb} Z^{E}_{lb} + 2g_1^2 \sum_{a=1}^{3} Z^{E,*}_{i3+a} Z^{E}_{k3+a} \sum_{b=1}^{3} Z^{E,*}_{jb} Z^{E}_{lb} \\
&+ 2g_1^2 \sum_{a=1}^{3} Z^{E,*}_{ja} Z^{E}_{ka} \sum_{b=1}^{3} Z^{E,*}_{i3+b} Z^{E}_{l3+b} - 4g_1^2 \sum_{a=1}^{3} Z^{E,*}_{j3+a} Z^{E}_{k3+a} \sum_{b=1}^{3} Z^{E,*}_{i3+b} Z^{E}_{l3+b} \\
&+ 2g_1^2 \sum_{a=1}^{3} Z^{E,*}_{ia} Z^{E}_{ka} \sum_{b=1}^{3} Z^{E,*}_{j3+b} Z^{E}_{l3+b} - 4g_1^2 \sum_{a=1}^{3} Z^{E,*}_{i3+a} Z^{E}_{k3+a} \sum_{b=1}^{3} Z^{E,*}_{j3+b} Z^{E}_{l3+b} \\
&- 8 \sum_{b=1}^{3} Z^{E,*}_{jb} \sum_{a=1}^{3} Y_{e,ab} Z^{E}_{l3+a} \sum_{d=1}^{3} \sum_{c=1}^{3} Y^{*}_{e,cd} Z^{E,*}_{i3+c} Z^{E}_{kd} \\
&- 8 \sum_{b=1}^{3} Z^{E,*}_{ib} \sum_{a=1}^{3} Y_{e,ab} Z^{E}_{l3+a} \sum_{d=1}^{3} \sum_{c=1}^{3} Y^{*}_{e,cd} Z^{E,*}_{j3+c} Z^{E}_{kd} \\
&- 8 \sum_{b=1}^{3} Z^{E,*}_{jb} \sum_{a=1}^{3} Y_{e,ab} Z^{E}_{k3+a} \sum_{d=1}^{3} \sum_{c=1}^{3} Y^{*}_{e,cd} Z^{E,*}_{i3+c} Z^{E}_{ld} \\
&- 8 \sum_{b=1}^{3} Z^{E,*}_{ib} \sum_{a=1}^{3} Y_{e,ab} Z^{E}_{k3+a} \sum_{d=1}^{3} \sum_{c=1}^{3} Y^{*}_{e,cd} Z^{E,*}_{j3+c} Z^{E}_{ld} \Big)
\end{aligned}
\tag{399}
$$



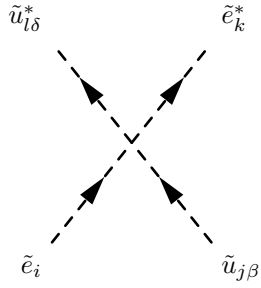
$$
\frac{i}{6} g_1^2 \delta_{\beta\delta} \Big(- 2 \sum_{a=1}^{3} Z^{E,*}_{i3+a} Z^{E}_{k3+a} + \sum_{a=1}^{3} Z^{E,*}_{ia} Z^{E}_{ka} \Big)
\tag{400}
$$



$$-\frac{i}{6}g_1^2\delta_{\beta\delta}\Big(-2\sum_{a=1}^{3}Z^{E,*}_{i3+a}Z^{E}_{k3+a}+\sum_{a=1}^{3}Z^{E,*}_{ia}Z^{E}_{ka}\Big) \tag{401}$$

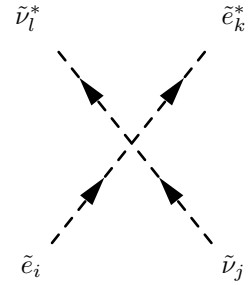


$$\begin{aligned}&-\frac{i}{4}\delta_{\beta\gamma}\Big(g_2^2\sum_{a=1}^{3}Z^{E,*}_{ia}Z^{V}_{la}\sum_{b=1}^{3}Z^{U,*}_{jb}Z^{D}_{kb}+g_2^2\sum_{a=1}^{3}Z^{U,*}_{ja}Z^{D}_{ka}\sum_{b=1}^{3}Z^{E,*}_{ib}Z^{V}_{lb}\\&+4\sum_{b=1}^{3}Z^{U,*}_{jb}\sum_{a=1}^{3}Y_{d,ab}Z^{D}_{k3+a}\sum_{d=1}^{3}\sum_{c=1}^{3}Y^*_{e,cd}Z^{E,*}_{i3+c}Z^{V}_{ld}\Big)\end{aligned} \tag{402}$$

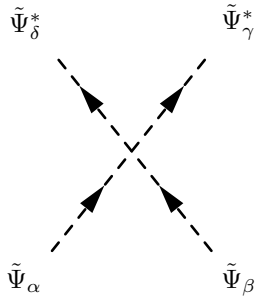


$$\frac{i}{24}\delta_{\beta\delta}\Big(-4g_1^2\sum_{a=1}^{3}Z^{U,*}_{j3+a}Z^{U}_{l3+a}\Big(-2\sum_{b=1}^{3}Z^{E,*}_{i3+b}Z^{E}_{k3+b}+\sum_{b=1}^{3}Z^{E,*}_{ib}Z^{E}_{kb}\Big)$$

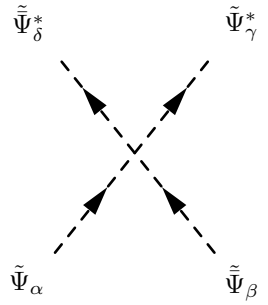
$$+\sum_{a=1}^{3} Z_{ja}^{U,*} Z_{la}^{U}\Big(-2g_1^2 \sum_{b=1}^{3} Z_{i3+b}^{E,*} Z_{k3+b}^{E} + \Big(3g_2^2 + g_1^2\Big) \sum_{b=1}^{3} Z_{ib}^{E,*} Z_{kb}^{E}\Big)$$
$$+ g_1^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U} + 3g_2^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U}$$
$$- 2g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{k3+a}^{E} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U} - 4g_1^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U}$$
$$+ 8g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{k3+a}^{E} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U}\Big) \tag{403}$$



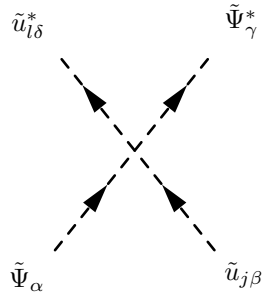
$$\frac{i}{4}\Big(\delta_{jl}\Big(2g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{k3+a}^{E} + \Big(-g_1^2 + g_2^2\Big) \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ka}^{E}\Big)$$
$$- g_2^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{la}^{V} \sum_{b=1}^{3} Z_{jb}^{V,*} Z_{kb}^{E} - g_2^2 \sum_{a=1}^{3} Z_{ja}^{V,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{ib}^{E,*} Z_{lb}^{V}$$
$$- 4 \sum_{b=1}^{3} Z_{jb}^{V,*} \sum_{a=1}^{3} Y_{e,ab} Z_{k3+a}^{E} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{e,cd}^{*} Z_{i3+c}^{E,*} Z_{ld}^{V}\Big) \tag{404}$$



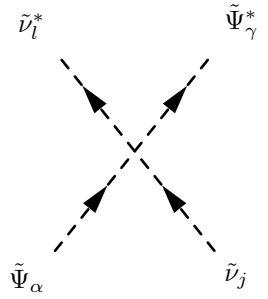
$$\frac{i}{9}\Big(-9g_3^2\Big(\sum_{a=1}^{8} T_{a\gamma\beta}^{\mathrm{SU}\left(3\right),6} T_{a\delta\alpha}^{\mathrm{SU}\left(3\right),6} + \sum_{a=1}^{8} T_{a\gamma\alpha}^{\mathrm{SU}\left(3\right),6} T_{a\delta\beta}^{\mathrm{SU}\left(3\right),6}\Big) - g_1^2 \delta_{\alpha\delta}\delta_{\beta\gamma} - g_1^2 \delta_{\alpha\gamma}\delta_{\beta\delta}\Big) \tag{405}$$



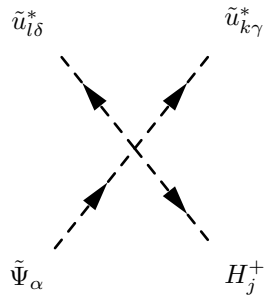
$$i\Big(\frac{1}{9}g_1^2\delta_{\alpha\gamma}\delta_{\beta\delta}+g_3^2\sum_{a=1}^{8}T_{a\beta\delta}^{\mathrm{SU}\left(3\right),6}\,T_{a\gamma\alpha}^{\mathrm{SU}\left(3\right),6}\Big) \tag{406}$$



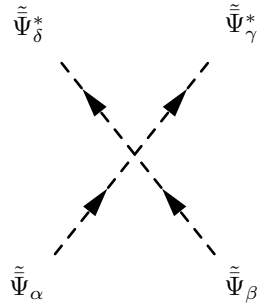
$$\begin{aligned}&\frac{i}{18}\Big(-g_1^2\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(-4\sum_{a=1}^{3}Z^{U,*}_{j3+a}Z^{U}_{l3+a}+\sum_{a=1}^{3}Z^{U,*}_{ja}Z^{U}_{la}\Big)\\&-9\Big(g_3^2\sum_{a=1}^{3}Z^{U,*}_{ja}Z^{U}_{la}\sum_{b=1}^{8}\lambda^{b}_{\delta,\beta}T_{b\gamma\alpha}^{\mathrm{SU}\left(3\right),6}-g_3^2\sum_{a=1}^{3}Z^{U,*}_{j3+a}Z^{U}_{l3+a}\sum_{b=1}^{8}\lambda^{b}_{\delta,\beta}T_{b\gamma\alpha}^{\mathrm{SU}\left(3\right),6}\\&+2\sum_{a=1}^{3}\Big(K^{SU[3],6\times\bar{3}\times\bar{3}}_{\gamma,\beta,a}\Big)^{*}K^{SU[3],6\times\bar{3}\times\bar{3}}_{\alpha,\delta,a}\sum_{d=1}^{3}Z^{U,*}_{j3+d}\sum_{c=1}^{3}\sum_{b=1}^{3}Y^{*}_{H,db}Y_{H,cb}Z^{U}_{l3+c}\Big)\Big)\end{aligned} \tag{407}$$



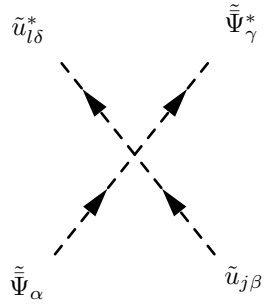
$$\frac{i}{6}g_1^2\delta_{\alpha\gamma}\delta_{jl} \tag{408}$$



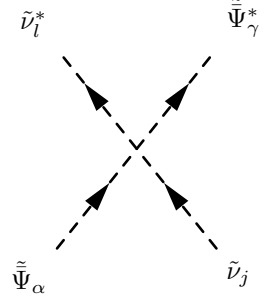
$$i\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ac}Y_{H,ba}Z^U_{l3+b}Z^U_{kc}+\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y^*_{d,ac}Y_{H,ba}Z^U_{k3+b}Z^U_{lc}\Big)Z^+_{j1}K^{SU[3],6\times\bar{3}\times\bar{3}}_{\alpha,\gamma,\delta} \tag{409}$$



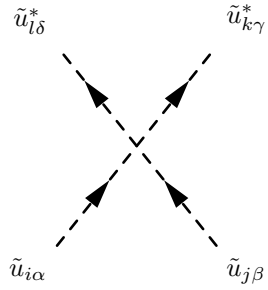
$$\frac{i}{9}\Big(-9g_3^2\Big(\sum_{a=1}^{8}T^{\mathrm{SU}\left(3\right),6}_{a\alpha\delta}T^{\mathrm{SU}\left(3\right),6}_{a\beta\gamma}+\sum_{a=1}^{8}T^{\mathrm{SU}\left(3\right),6}_{a\alpha\gamma}T^{\mathrm{SU}\left(3\right),6}_{a\beta\delta}\Big)-g_1^2\delta_{\alpha\delta}\delta_{\beta\gamma}-g_1^2\delta_{\alpha\gamma}\delta_{\beta\delta}\Big) \tag{410}$$



$$
\begin{aligned}
&i\Big(\frac{1}{18}g_1^2\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(-4\sum_{a=1}^{3}Z^{U,*}_{j3+a}Z^{U}_{l3+a}+\sum_{a=1}^{3}Z^{U,*}_{ja}Z^{U}_{la}\Big)+\frac{1}{2}g_3^2\sum_{a=1}^{3}Z^{U,*}_{ja}Z^{U}_{la}\sum_{b=1}^{8}\lambda^{b}_{\delta,\beta}T^{\mathrm{SU}\left(3\right),6}_{b\alpha\gamma}\\
&-\frac{1}{2}g_3^2\sum_{a=1}^{3}Z^{U,*}_{j3+a}Z^{U}_{l3+a}\sum_{b=1}^{8}\lambda^{b}_{\delta,\beta}T^{\mathrm{SU}\left(3\right),6}_{b\alpha\gamma}-\sum_{a=1}^{3}\Big(K^{SU[3],\bar{6}\times3\times3}_{\gamma,\delta,a}\Big)^{*}K^{SU[3],\bar{6}\times3\times3}_{\alpha,\beta,a}\sum_{d=1}^{3}\sum_{c=1}^{3}Z^{U,*}_{jc}\sum_{b=1}^{3}Y^{*}_{\bar{H},bd}Y_{\bar{H},bc}Z^{U}_{ld}\\
&+\sum_{a=1}^{3}\Big(K^{SU[3],\bar{6}\times3\times3}_{\gamma,\delta,a}\Big)^{*}K^{SU[3],\bar{6}\times3\times3}_{\alpha,\beta,a}\sum_{d=1}^{3}\sum_{c=1}^{3}Z^{U,*}_{jc}\sum_{b=1}^{3}Y^{*}_{\bar{H},db}Y_{\bar{H},bc}Z^{U}_{ld}\\
&+\sum_{a=1}^{3}\Big(K^{SU[3],\bar{6}\times3\times3}_{\gamma,\delta,a}\Big)^{*}K^{SU[3],\bar{6}\times3\times3}_{\alpha,\beta,a}\sum_{d=1}^{3}\sum_{c=1}^{3}Z^{U,*}_{jc}\sum_{b=1}^{3}Y^{*}_{\bar{H},bd}Y_{\bar{H},cb}Z^{U}_{ld}\\
&-\sum_{a=1}^{3}\Big(K^{SU[3],\bar{6}\times3\times3}_{\gamma,\delta,a}\Big)^{*}K^{SU[3],\bar{6}\times3\times3}_{\alpha,\beta,a}\sum_{d=1}^{3}\sum_{c=1}^{3}Z^{U,*}_{jc}\sum_{b=1}^{3}Y^{*}_{\bar{H},db}Y_{\bar{H},cb}Z^{U}_{ld}\Big)
\end{aligned}
\tag{411}
$$



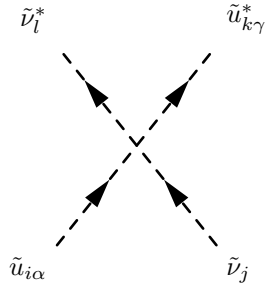
$$
-\frac{i}{6}g_1^2\delta_{\alpha\gamma}\delta_{jl}
\tag{412}
$$



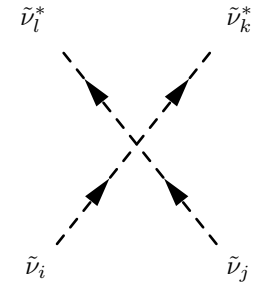
$$
\begin{aligned}
&\frac{i}{72}\Big(-\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(g_1^2\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{U}_{la}\sum_{b=1}^{3}Z^{U,*}_{jb}Z^{U}_{kb}+9g_2^2\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{U}_{la}\sum_{b=1}^{3}Z^{U,*}_{jb}Z^{U}_{kb}
\end{aligned}
$$

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

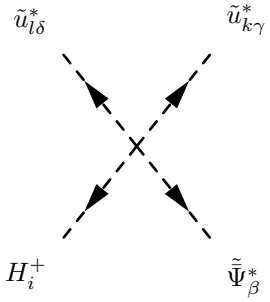
$$
\begin{aligned}
&- \delta_{\alpha\gamma}\delta_{\beta\delta}\Big(18g_3^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{la}^{U}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{kb}^{U} - 18g_3^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{l3+a}^{U}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{kb}^{U} \\
&+ \sum_{a=1}^{3}Z_{j3+a}^{U,*}Z_{l3+a}^{U}\Big(2\Big(-3g_3^2+8g_1^2\Big)\sum_{b=1}^{3}Z_{i3+b}^{U,*}Z_{k3+b}^{U} + \Big(-4g_1^2+6g_3^2\Big)\sum_{b=1}^{3}Z_{ib}^{U,*}Z_{kb}^{U}\Big) \\
&+ \sum_{a=1}^{3}Z_{ja}^{U,*}Z_{la}^{U}\Big(2\Big(-2g_1^2+3g_3^2\Big)\sum_{b=1}^{3}Z_{i3+b}^{U,*}Z_{k3+b}^{U} + \Big(-6g_3^2+9g_2^2+g_1^2\Big)\sum_{b=1}^{3}Z_{ib}^{U,*}Z_{kb}^{U}\Big) \\
&- 18g_3^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{la}^{U}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{k3+b}^{U} + 18g_3^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{l3+a}^{U}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{k3+b}^{U} \\
&+ 18g_3^2\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{ka}^{U}\sum_{b=1}^{3}Z_{ib}^{U,*}Z_{lb}^{U} - 18g_3^2\sum_{a=1}^{3}Z_{j3+a}^{U,*}Z_{k3+a}^{U}\sum_{b=1}^{3}Z_{ib}^{U,*}Z_{lb}^{U} \\
&+ g_1^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ka}^{U}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U} + 9g_2^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ka}^{U}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U} \\
&- 6g_3^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ka}^{U}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U} - 4g_1^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{k3+a}^{U}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U} \\
&+ 6g_3^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{k3+a}^{U}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U} - 18g_3^2\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{ka}^{U}\sum_{b=1}^{3}Z_{i3+b}^{U,*}Z_{l3+b}^{U} \\
&+ 18g_3^2\sum_{a=1}^{3}Z_{j3+a}^{U,*}Z_{k3+a}^{U}\sum_{b=1}^{3}Z_{i3+b}^{U,*}Z_{l3+b}^{U} - 4g_1^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ka}^{U}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U} \\
&+ 6g_3^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ka}^{U}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U} + 16g_1^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{k3+a}^{U}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U} \\
&- 6g_3^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{k3+a}^{U}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U} \\
&+ 72\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Y_{u,ab}Z_{l3+a}^{U}\sum_{d=1}^{3}\sum_{c=1}^{3}Y_{u,cd}^{*}Z_{i3+c}^{U,*}Z_{kd}^{U} \\
&+ 72\sum_{b=1}^{3}Z_{ib}^{U,*}\sum_{a=1}^{3}Y_{u,ab}Z_{k3+a}^{U}\sum_{d=1}^{3}\sum_{c=1}^{3}Y_{u,cd}^{*}Z_{j3+c}^{U,*}Z_{ld}^{U}\Big)\Big)
\end{aligned}
\tag{413}
$$



$$\frac{i}{12}\delta_{\alpha\gamma}\delta_{jl}\Big(\Big(-3g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ka}^{U}-4g_1^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{k3+a}^{U}\Big) \tag{414}$$

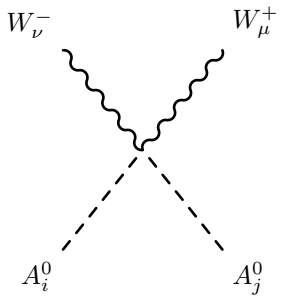


$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(\delta_{ik}\delta_{jl}+\delta_{il}\delta_{jk}\Big) \tag{415}$$

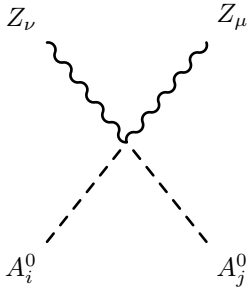


$$\begin{aligned}&i\Big(K_{\beta,\gamma,\delta}^{SU[3],\bar{6}\times3\times3}\Big)^*\Big(-\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ac}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{kc}^{U}+\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ca}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{kc}^{U}\\&-\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ac}^{*}Y_{u,ba}Z_{k3+b}^{U}Z_{lc}^{U}+\sum_{c=1}^{3}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{\bar{H},ca}^{*}Y_{u,ba}Z_{k3+b}^{U}Z_{lc}^{U}\Big)Z_{i2}^{+}\end{aligned} \tag{416}$$

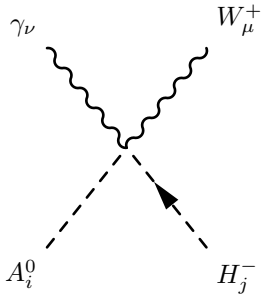
8.8 Two Scalar-Two Vector Boson-Interaction



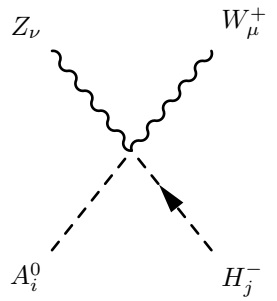
$$\Big(\frac{i}{2}g_2^2 Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_2^2 Z_{i2}^A Z_{j2}^A\Big)\Big(g_{\mu\nu}\Big) \tag{417}$$



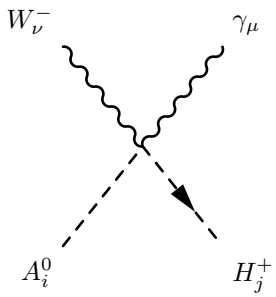
$$\begin{aligned}\Big(&+ \frac{i}{2}g_2^2 \cos\Theta_W^2 Z_{i1}^A Z_{j1}^A + ig_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_1^2 \sin\Theta_W^2 Z_{i1}^A Z_{j1}^A \\ &+ \frac{i}{2}g_2^2 \cos\Theta_W^2 Z_{i2}^A Z_{j2}^A + ig_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i2}^A Z_{j2}^A + \frac{i}{2}g_1^2 \sin\Theta_W^2 Z_{i2}^A Z_{j2}^A\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{418}$$



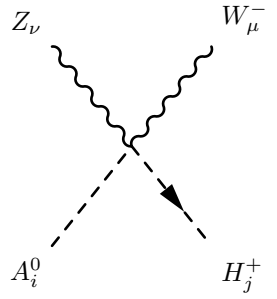
$$\Big(-\frac{1}{2}g_1 g_2 \cos\Theta_W Z_{i1}^A Z_{j1}^+ - \frac{1}{2}g_1 g_2 \cos\Theta_W Z_{i2}^A Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{419}$$



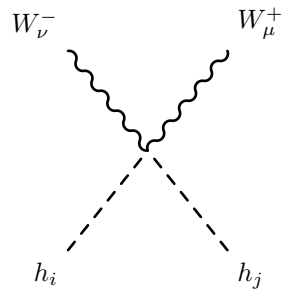
$$\Big(\frac{1}{2}g_1 g_2 \sin\Theta_W Z_{i1}^A Z_{j1}^+ + \frac{1}{2}g_1 g_2 \sin\Theta_W Z_{i2}^A Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{420}$$



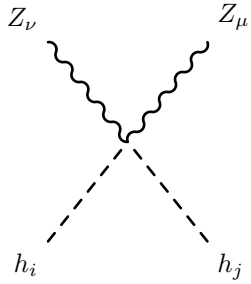
$$\Big(\frac{1}{2}g_1 g_2 \cos\Theta_W Z_{i1}^A Z_{j1}^+ + \frac{1}{2}g_1 g_2 \cos\Theta_W Z_{i2}^A Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{421}$$



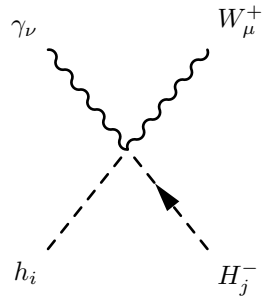
$$\Big(-\frac{1}{2}g_1 g_2 \sin\Theta_W Z_{i1}^A Z_{j1}^+ - \frac{1}{2}g_1 g_2 \sin\Theta_W Z_{i2}^A Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{422}$$



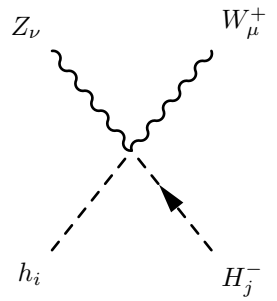
$$\Big(\frac{i}{2}g_2^2 Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_2^2 Z_{i2}^H Z_{j2}^H\Big)\Big(g_{\mu\nu}\Big) \tag{423}$$



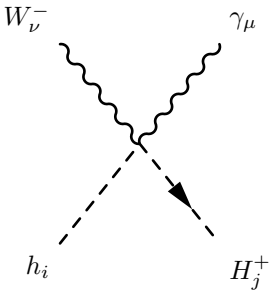
$$\begin{aligned}\Big(&+ \frac{i}{2}g_2^2 \cos\Theta_W^2 Z_{i1}^H Z_{j1}^H + ig_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_1^2 \sin\Theta_W^2 Z_{i1}^H Z_{j1}^H \\ &+ \frac{i}{2}g_2^2 \cos\Theta_W^2 Z_{i2}^H Z_{j2}^H + ig_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i2}^H Z_{j2}^H + \frac{i}{2}g_1^2 \sin\Theta_W^2 Z_{i2}^H Z_{j2}^H\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{424}$$



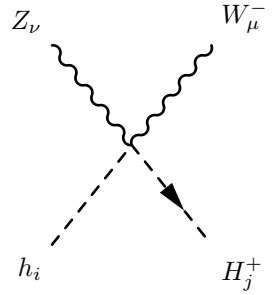
$$\Big(-\frac{i}{2}g_1 g_2 \cos\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2}g_1 g_2 \cos\Theta_W Z_{i2}^H Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{425}$$



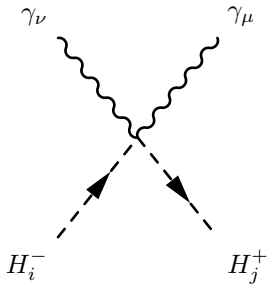
$$\Big(\frac{i}{2}g_1 g_2 \sin\Theta_W Z_{i1}^H Z_{j1}^+ - \frac{i}{2}g_1 g_2 \sin\Theta_W Z_{i2}^H Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{426}$$



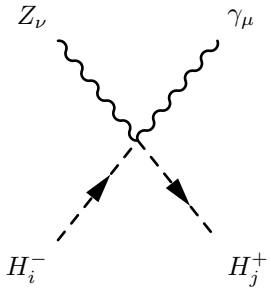
$$\Big(-\frac{i}{2}g_1 g_2 \cos\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2}g_1 g_2 \cos\Theta_W Z_{i2}^H Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{427}$$



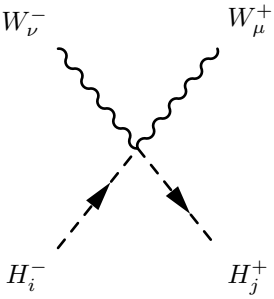
$$\Big(\frac{i}{2}g_1 g_2 \sin\Theta_W Z_{i1}^H Z_{j1}^+ - \frac{i}{2}g_1 g_2 \sin\Theta_W Z_{i2}^H Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{428}$$



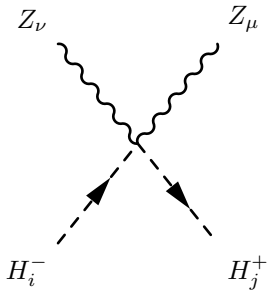
$$\Big(+ \frac{i}{2} g_1^2 \cos\Theta_W^2 Z_{i1}^+ Z_{j1}^+ + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_2^2 \sin\Theta_W^2 Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_1^2 \cos\Theta_W^2 Z_{i2}^+ Z_{j2}^+ + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{2} g_2^2 \sin\Theta_W^2 Z_{i2}^+ Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{429}$$



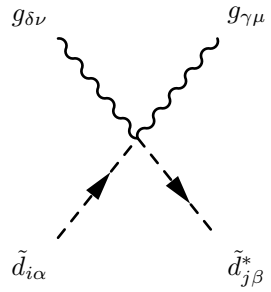
$$\Big(+ \frac{i}{2} g_1 g_2 \cos 2\Theta_W Z_{i1}^+ Z_{j1}^+ - \frac{i}{4} g_1^2 \sin 2\Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{4} g_2^2 \sin 2\Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_1 g_2 \cos 2\Theta_W Z_{i2}^+ Z_{j2}^+ - \frac{i}{4} g_1^2 \sin 2\Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{4} g_2^2 \sin 2\Theta_W Z_{i2}^+ Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{430}$$



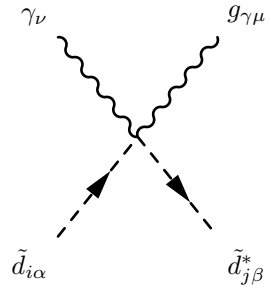
$$\Big(\frac{i}{2} g_2^2 Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_2^2 Z_{i2}^+ Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{431}$$



$$\Big(+ \frac{i}{2} g_2^2 \cos\Theta_W^2 Z_{i1}^+ Z_{j1}^+ - i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_2^2 \cos\Theta_W^2 Z_{i2}^+ Z_{j2}^+ - i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z_{i2}^+ Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{432}$$

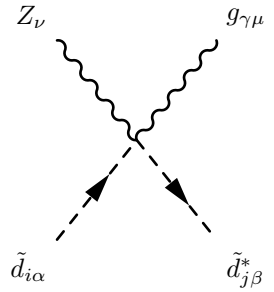


$$\Big(\frac{i}{4} g_3^2 \delta_{ij} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} + \frac{i}{4} g_3^2 \delta_{ij} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} \Big) \Big(g_{\mu\nu} \Big) \tag{433}$$

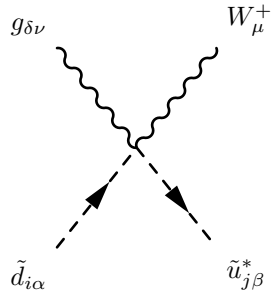


$$\Big(+ \frac{i}{6} g_1 g_3 \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ja}^{D} - \frac{i}{2} g_2 g_3 \lambda_{\beta,\alpha}^{\gamma} \sin\Theta_W \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ja}^{D}$$

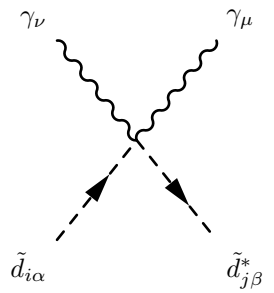
$$- \frac{i}{3} g_1 g_3 \cos\Theta_W \lambda^{\gamma}_{\beta,\alpha} \sum_{a=1}^{3} Z^{D,*}_{i3+a} Z^{D}_{j3+a} \Big) \Big(g_{\mu\nu} \Big) \tag{434}$$



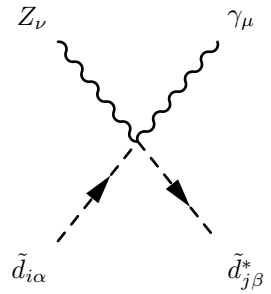
$$\Big(- \frac{i}{2} g_2 g_3 \cos\Theta_W \lambda^{\gamma}_{\beta,\alpha} \sum_{a=1}^{3} Z^{D,*}_{ia} Z^{D}_{ja} - \frac{i}{6} g_1 g_3 \lambda^{\gamma}_{\beta,\alpha} \sin\Theta_W \sum_{a=1}^{3} Z^{D,*}_{ia} Z^{D}_{ja}$$
$$+ \frac{i}{3} g_1 g_3 \lambda^{\gamma}_{\beta,\alpha} \sin\Theta_W \sum_{a=1}^{3} Z^{D,*}_{i3+a} Z^{D}_{j3+a} \Big) \Big(g_{\mu\nu} \Big) \tag{435}$$



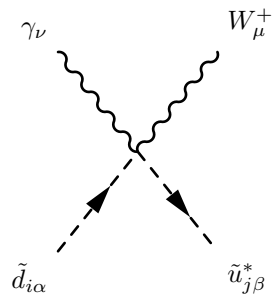
$$i \frac{1}{\sqrt{2}} g_2 g_3 \lambda^{\delta}_{\beta,\alpha} \sum_{a=1}^{3} Z^{D,*}_{ia} Z^{U}_{ja} \Big(g_{\mu\nu} \Big) \tag{436}$$



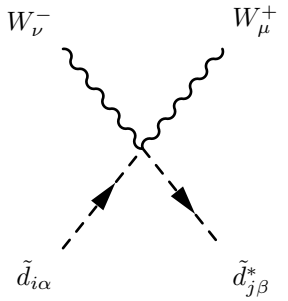
$$\Big(+ \frac{i}{18} g_1^2 \cos\Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ja}^{D} - \frac{i}{3} g_1 g_2 \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ja}^{D}$$
$$+ \frac{i}{2} g_2^2 \delta_{\alpha\beta} \sin\Theta_W^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ja}^{D} + \frac{2i}{9} g_1^2 \cos\Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{j3+a}^{D} \Big) \Big(g_{\mu\nu} \Big) \tag{437}$$



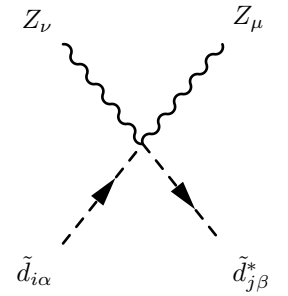
$$\Big(- \frac{i}{6} g_1 g_2 \cos 2\Theta_W \delta_{\alpha\beta} \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ja}^{D} - \frac{i}{36} g_1^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ja}^{D}$$
$$+ \frac{i}{4} g_2^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ja}^{D} - \frac{i}{9} g_1^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{j3+a}^{D} \Big) \Big(g_{\mu\nu} \Big) \tag{438}$$



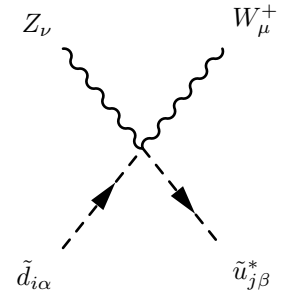
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos\Theta_W \delta_{\alpha\beta} \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ja}^{U} \Big(g_{\mu\nu} \Big) \tag{439}$$



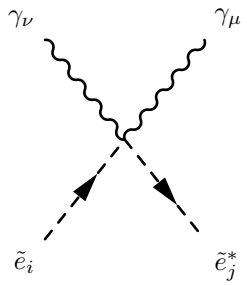
$$\frac{i}{2}g_2^2\delta_{\alpha\beta}\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{D}\Big(g_{\mu\nu}\Big) \tag{440}$$



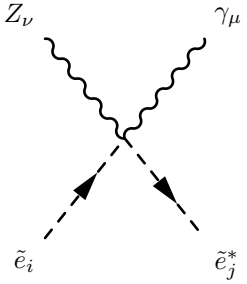
$$\begin{aligned}\Big(&+\frac{i}{2}g_2^2\cos\Theta_W^2\delta_{\alpha\beta}\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{D}+\frac{i}{3}g_1g_2\cos\Theta_W\delta_{\alpha\beta}\sin\Theta_W\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{D}\\ &+\frac{i}{18}g_1^2\delta_{\alpha\beta}\sin\Theta_W^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{D}+\frac{2i}{9}g_1^2\delta_{\alpha\beta}\sin\Theta_W^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{j3+a}^{D}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{441}$$



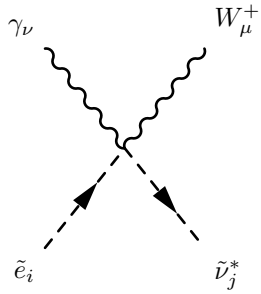
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1g_2\delta_{\alpha\beta}\sin\Theta_W\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{U}\Big(g_{\mu\nu}\Big) \tag{442}$$



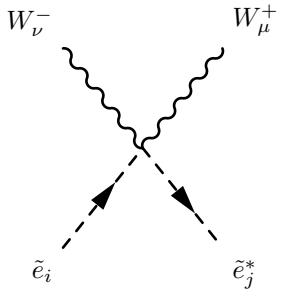
$$\Big(+ \frac{i}{2} g_1^2 \cos\Theta_W^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} + i g_1 g_2 \cos\Theta_W \sin\Theta_W \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} + \frac{i}{2} g_2^2 \sin\Theta_W^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} + 2 i g_1^2 \cos\Theta_W^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{j3+a}^{E} \Big) \Big(g_{\mu\nu} \Big) \tag{443}$$



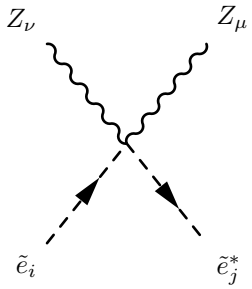
$$\Big(+ \frac{i}{2} g_1 g_2 \cos 2\Theta_W \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} - \frac{i}{4} g_1^2 \sin 2\Theta_W \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} + \frac{i}{4} g_2^2 \sin 2\Theta_W \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} - i g_1^2 \sin 2\Theta_W \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{j3+a}^{E} \Big) \Big(g_{\mu\nu} \Big) \tag{444}$$



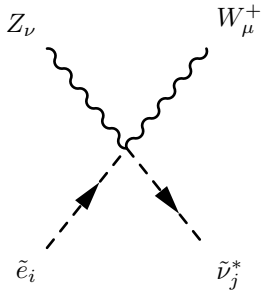
$$- i\frac{1}{\sqrt{2}} g_1 g_2 \cos\Theta_W \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{V} \Big(g_{\mu\nu} \Big) \tag{445}$$



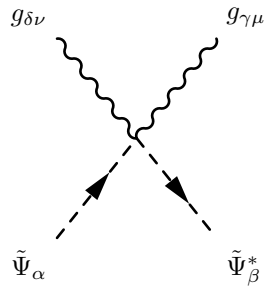
$$\frac{i}{2} g_2^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} \Big(g_{\mu\nu} \Big) \tag{446}$$



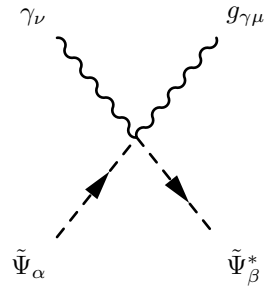
$$\begin{aligned} \Big(&+ \frac{i}{2} g_2^2 \cos\Theta_W^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} - i g_1 g_2 \cos\Theta_W \sin\Theta_W \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} \\ &+ \frac{i}{2} g_1^2 \sin\Theta_W^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} + 2 i g_1^2 \sin\Theta_W^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{j3+a}^{E} \Big) \Big(g_{\mu\nu} \Big) \end{aligned} \tag{447}$$



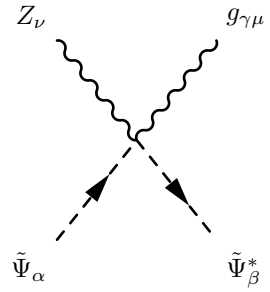
$$i\frac{1}{\sqrt{2}}g_1 g_2 \sin\Theta_W \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{V}\Big(g_{\mu\nu}\Big) \tag{448}$$



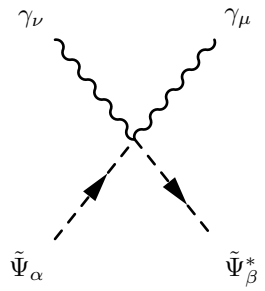
$$\Big(ig_3^2 \sum_{a=1}^{6} T_\alpha^{\mathrm{SU}\left(3\right),6}\, T_\delta^{\mathrm{SU}\left(3\right),6} + ig_3^2 \sum_{a=1}^{6} T_\gamma^{\mathrm{SU}\left(3\right),6}\, T_\alpha^{\mathrm{SU}\left(3\right),6}\Big)\Big(g_{\mu\nu}\Big) \tag{449}$$



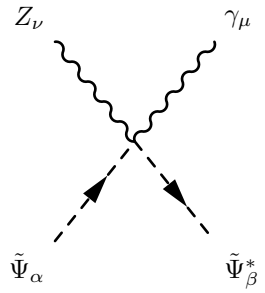
$$\frac{2i}{3}g_1 g_3 \cos\Theta_W T_{\gamma\beta\alpha}^{\mathrm{SU}\left(3\right),6}\Big(g_{\mu\nu}\Big) \tag{450}$$



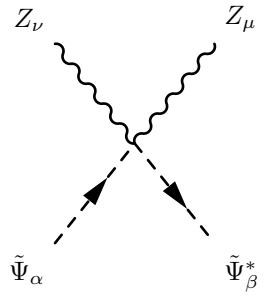
$$-\frac{2i}{3}g_1 g_3 \sin\Theta_W T^{\mathrm{SU}\left(3\right),6}_{\gamma\beta\alpha}\left(g_{\mu\nu}\right) \tag{451}$$



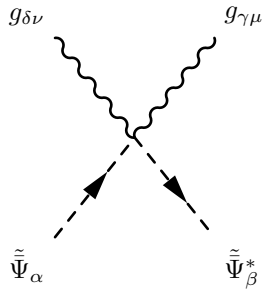
$$\frac{2i}{9}g_1^2 \cos\Theta_W^2 \delta_{\alpha\beta}\left(g_{\mu\nu}\right) \tag{452}$$



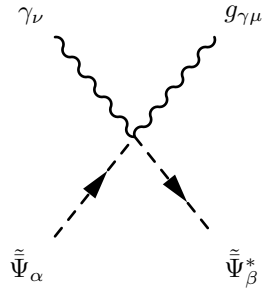
$$-\frac{2i}{9}g_1^2 \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W\left(g_{\mu\nu}\right) \tag{453}$$



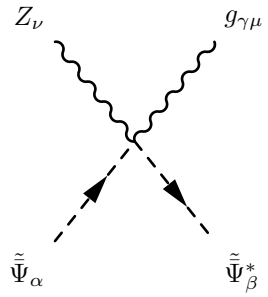
$$\frac{2i}{9}g_1^2 \delta_{\alpha\beta} \sin\Theta_W^2\left(g_{\mu\nu}\right) \tag{454}$$



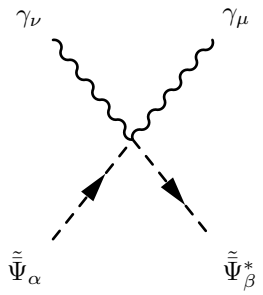
$$\left(ig_3^2\sum_{a=1}^{6}T_{\beta}^{\mathrm{SU}\left(3\right),6}T_{\delta}^{\mathrm{SU}\left(3\right),6}+ig_3^2\sum_{a=1}^{6}T_{\gamma}^{\mathrm{SU}\left(3\right),6}T_{\beta}^{\mathrm{SU}\left(3\right),6}\right)\left(g_{\mu\nu}\right) \tag{455}$$



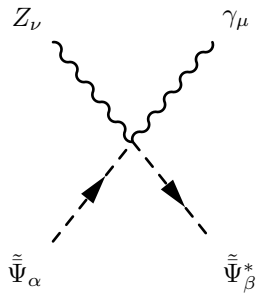
$$\frac{2i}{3}g_1g_3\cos\Theta_W T_{\gamma\alpha\beta}^{\mathrm{SU}\left(3\right),6}\left(g_{\mu\nu}\right) \tag{456}$$



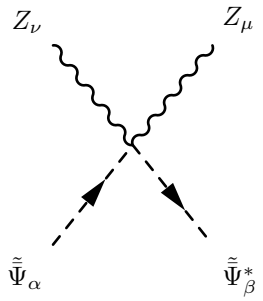
$$-\frac{2i}{3}g_1g_3\sin\Theta_W T_{\gamma\alpha\beta}^{\mathrm{SU}\left(3\right),6}\left(g_{\mu\nu}\right) \tag{457}$$



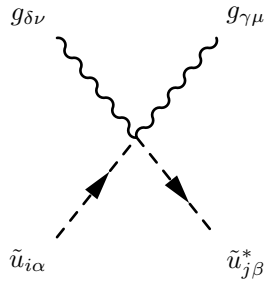
$$\frac{2i}{9} g_1^2 \cos\Theta_W^2 \delta_{\alpha\beta} \Big(g_{\mu\nu} \Big) \tag{458}$$



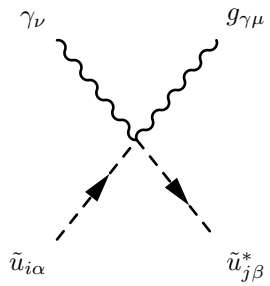
$$-\frac{2i}{9} g_1^2 \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W \Big(g_{\mu\nu} \Big) \tag{459}$$



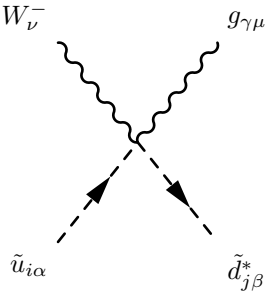
$$\frac{2i}{9} g_1^2 \delta_{\alpha\beta} \sin\Theta_W^2 \Big(g_{\mu\nu} \Big) \tag{460}$$



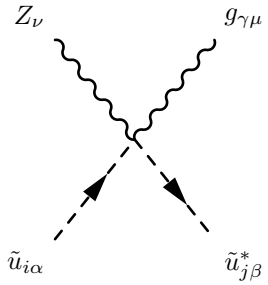
$$\Big(\frac{i}{4}g_3^2\delta_{ij}\sum_{a=1}^{3}\lambda^{\gamma}_{a,\alpha}\lambda^{\delta}_{\beta,a}+\frac{i}{4}g_3^2\delta_{ij}\sum_{a=1}^{3}\lambda^{\gamma}_{\beta,a}\lambda^{\delta}_{a,\alpha}\Big)\Big(g_{\mu\nu}\Big) \tag{461}$$



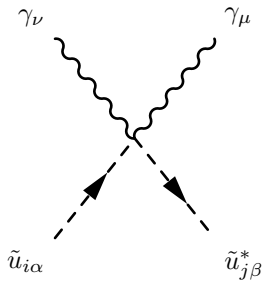
$$\begin{aligned}&\Big(+\frac{i}{6}g_1g_3\cos\Theta_W\lambda^{\gamma}_{\beta,\alpha}\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{U}_{ja}+\frac{i}{2}g_2g_3\lambda^{\gamma}_{\beta,\alpha}\sin\Theta_W\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{U}_{ja}\\&+\frac{2i}{3}g_1g_3\cos\Theta_W\lambda^{\gamma}_{\beta,\alpha}\sum_{a=1}^{3}Z^{U,*}_{i3+a}Z^{U}_{j3+a}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{462}$$



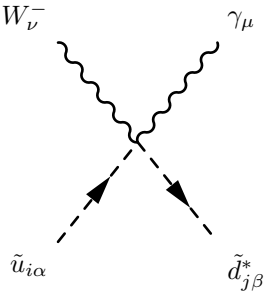
$$i\frac{1}{\sqrt{2}}g_2g_3\lambda^{\gamma}_{\beta,\alpha}\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{D}_{ja}\Big(g_{\mu\nu}\Big) \tag{463}$$



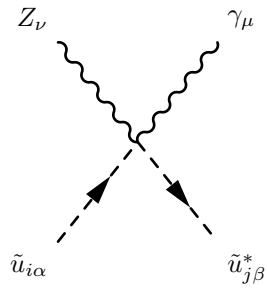
$$\Big(+ \frac{i}{2} g_2 g_3 \cos\Theta_W \lambda^\gamma_{\beta,\alpha} \sum_{a=1}^{3} Z^{U,*}_{ia} Z^U_{ja} - \frac{i}{6} g_1 g_3 \lambda^\gamma_{\beta,\alpha} \sin\Theta_W \sum_{a=1}^{3} Z^{U,*}_{ia} Z^U_{ja} - \frac{2i}{3} g_1 g_3 \lambda^\gamma_{\beta,\alpha} \sin\Theta_W \sum_{a=1}^{3} Z^{U,*}_{i3+a} Z^U_{j3+a} \Big) \Big(g_{\mu\nu} \Big) \tag{464}$$



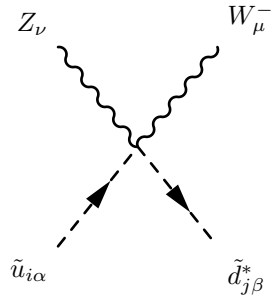
$$\Big(+ \frac{i}{18} g_1^2 \cos\Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^{3} Z^{U,*}_{ia} Z^U_{ja} + \frac{i}{3} g_1 g_2 \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W \sum_{a=1}^{3} Z^{U,*}_{ia} Z^U_{ja} + \frac{i}{2} g_2^2 \delta_{\alpha\beta} \sin\Theta_W^2 \sum_{a=1}^{3} Z^{U,*}_{ia} Z^U_{ja} + \frac{8i}{9} g_1^2 \cos\Theta_W^2 \delta_{\alpha\beta} \sum_{a=1}^{3} Z^{U,*}_{i3+a} Z^U_{j3+a} \Big) \Big(g_{\mu\nu} \Big) \tag{465}$$



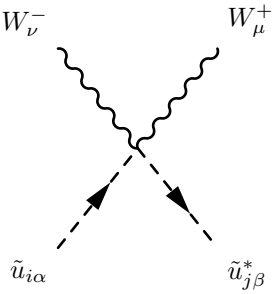
$$\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 \cos\Theta_W \delta_{\alpha\beta} \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ja}^{D} \Big(g_{\mu\nu} \Big) \tag{466}$$



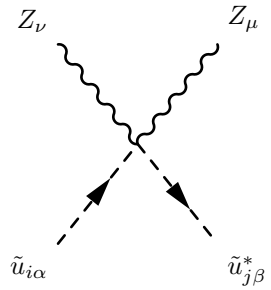
$$\Big(+ \frac{i}{6} g_1 g_2 \cos 2\Theta_W \delta_{\alpha\beta} \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ja}^{U} - \frac{i}{36} g_1^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ja}^{U}$$
$$+ \frac{i}{4} g_2^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ja}^{U} - \frac{4i}{9} g_1^2 \delta_{\alpha\beta} \sin 2\Theta_W \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{j3+a}^{U} \Big) \Big(g_{\mu\nu} \Big) \tag{467}$$



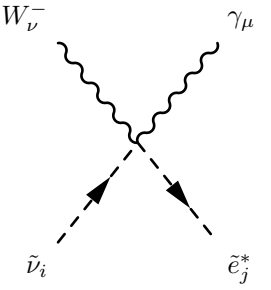
$$- \frac{i}{3}\frac{1}{\sqrt{2}} g_1 g_2 \delta_{\alpha\beta} \sin\Theta_W \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ja}^{D} \Big(g_{\mu\nu} \Big) \tag{468}$$



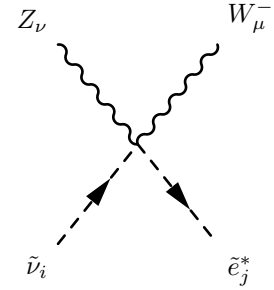
$$\frac{i}{2}g_2^2\delta_{\alpha\beta}\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ja}^{U}\Big(g_{\mu\nu}\Big) \tag{469}$$



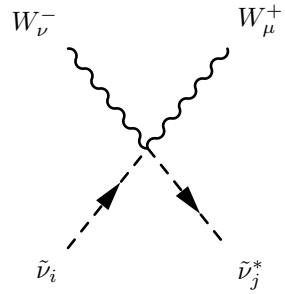
$$\Big(+\frac{i}{2}g_2^2\cos\Theta_W^2\delta_{\alpha\beta}\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ja}^{U}-\frac{i}{3}g_1g_2\cos\Theta_W\delta_{\alpha\beta}\sin\Theta_W\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ja}^{U}$$
$$+\frac{i}{18}g_1^2\delta_{\alpha\beta}\sin\Theta_W^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ja}^{U}+\frac{8i}{9}g_1^2\delta_{\alpha\beta}\sin\Theta_W^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{j3+a}^{U}\Big)\Big(g_{\mu\nu}\Big) \tag{470}$$



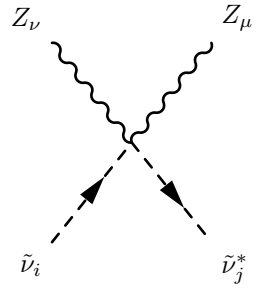
$$-i\frac{1}{\sqrt{2}}g_1g_2\cos\Theta_W\sum_{a=1}^{3}Z_{ia}^{V,*}Z_{ja}^{E}\Big(g_{\mu\nu}\Big) \tag{471}$$



$$i\frac{1}{\sqrt{2}}g_1 g_2 \sin\Theta_W \sum_{a=1}^{3} Z_{ia}^{V,*} Z_{ja}^{E}\Big(g_{\mu\nu}\Big) \tag{472}$$

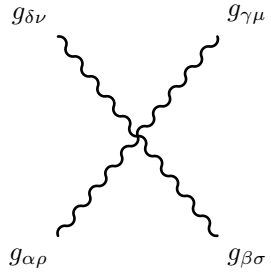


$$\frac{i}{2}g_2^2\delta_{ij}\Big(g_{\mu\nu}\Big) \tag{473}$$



$$\Big(\frac{i}{2}g_1^2\delta_{ij}\sin\Theta_W^2 + \frac{i}{2}g_2^2\cos\Theta_W^2\delta_{ij} + ig_1g_2\cos\Theta_W\delta_{ij}\sin\Theta_W\Big)\Big(g_{\mu\nu}\Big) \tag{474}$$

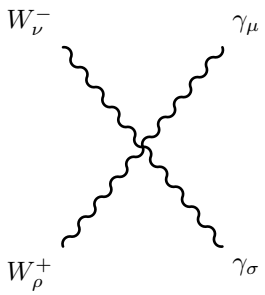
8.9 Four Vector Boson-Interaction



$$ig_3^2\Big(-\sum_{a=1}^{8} f_{\alpha,\delta,a}f_{\beta,\gamma,a} - \sum_{a=1}^{8} f_{\alpha,\gamma,a}f_{\beta,\delta,a}\Big)\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{475}$$

$$+\ ig_3^2\Big(-\sum_{a=1}^{8} f_{\alpha,\beta,a}f_{\gamma,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\delta,a}f_{\beta,\gamma,a}\Big)\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{476}$$

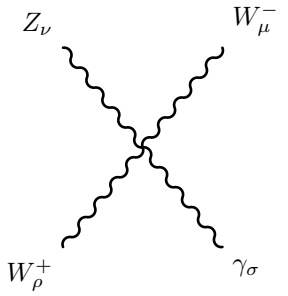
$$+\ ig_3^2\Big(\sum_{a=1}^{8} f_{\alpha,\gamma,a}f_{\beta,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\beta,a}f_{\gamma,\delta,a}\Big)\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{477}$$



$$ig_2^2 \sin\Theta_W^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{478}$$

$$+\ ig_2^2 \sin\Theta_W^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{479}$$

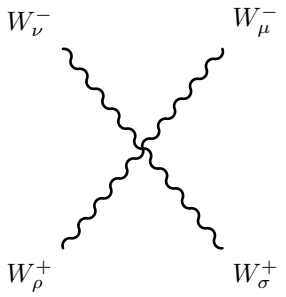
$$+\ -2ig_2^2 \sin\Theta_W^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{480}$$



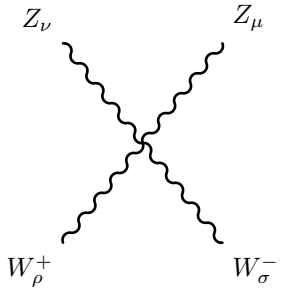
$$\frac{i}{2}g_2^2 \sin 2\Theta_W\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{481}$$

$$+\ -ig_2^2 \sin 2\Theta_W\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{482}$$

$$+\ \frac{i}{2}g_2^2 \sin 2\Theta_W\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{483}$$

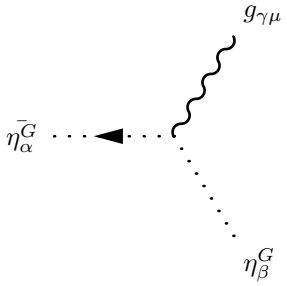


$$2ig_2^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{484}$$
$$+\ -ig_2^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{485}$$
$$+\ -ig_2^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{486}$$

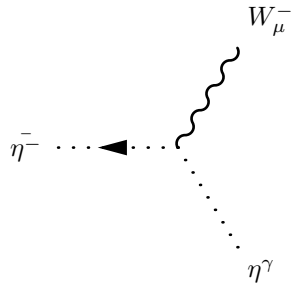


$$-\ 2ig_2^2\cos\Theta_W^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{487}$$
$$+\ ig_2^2\cos\Theta_W^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{488}$$
$$+\ ig_2^2\cos\Theta_W^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{489}$$

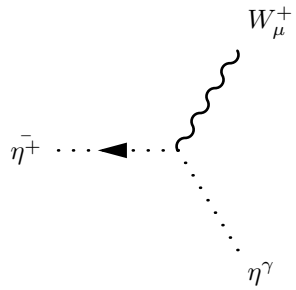
8.10 Two Ghosts-One Vector Boson-Interaction



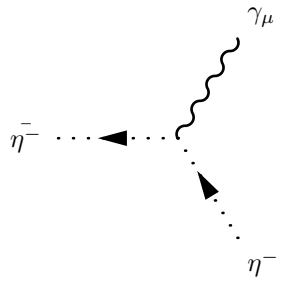
$$g_3 f_{\alpha,\beta,\gamma}\left(p_\mu^{\eta_\beta^G}\right) \tag{490}$$



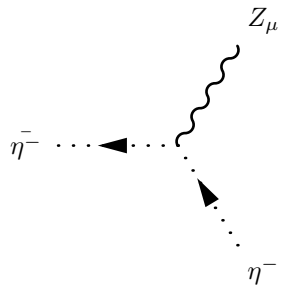
$$ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{491}$$



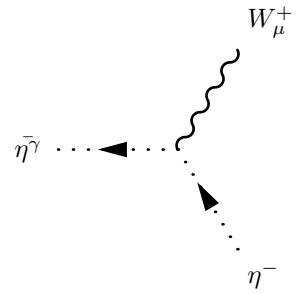
$$-ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{492}$$



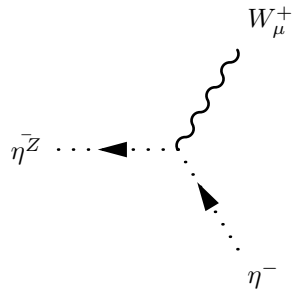
$$-ig_2 \sin\Theta_W\left(p_\mu^{\eta^-}\right) \tag{493}$$



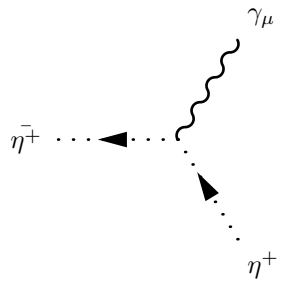
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{494}$$



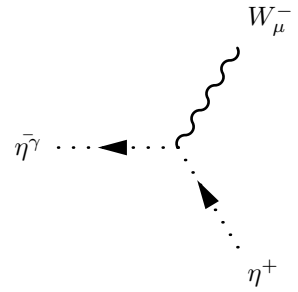
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^-}\right) \tag{495}$$



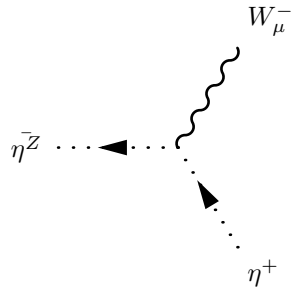
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{496}$$



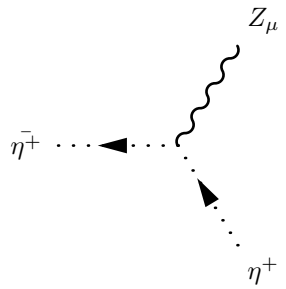
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{497}$$



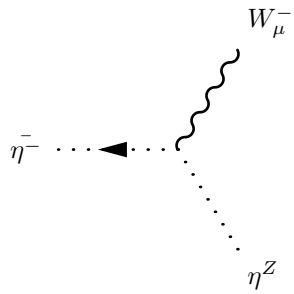
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{498}$$



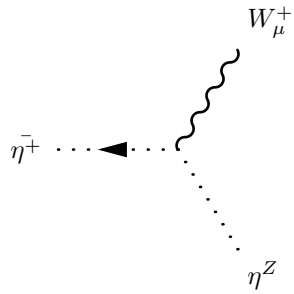
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{499}$$



$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{500}$$

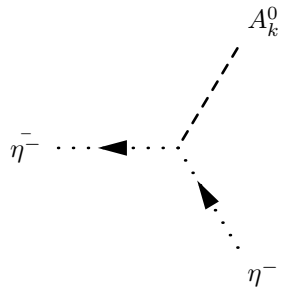


$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{501}$$

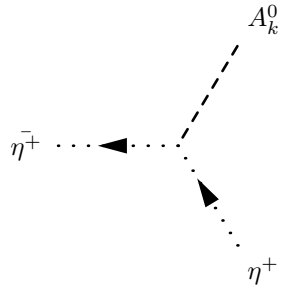


$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{502}$$

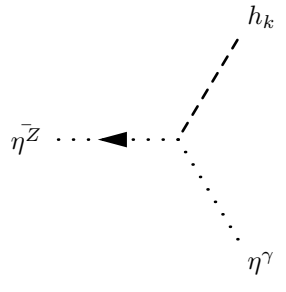
8.11 Two Ghosts-One Scalar-Interaction



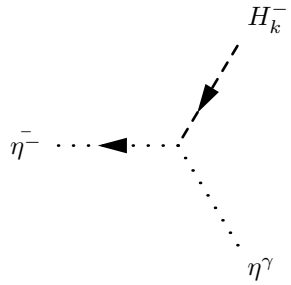
$$\frac{1}{4}g_2^2\xi_{W^-}\Big(v_d Z_{k1}^A - v_u Z_{k2}^A\Big) \tag{503}$$



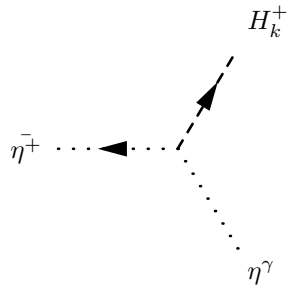
$$-\frac{1}{4}g_2^2\xi_{W^-}\Big(v_d Z_{k1}^A - v_u Z_{k2}^A\Big) \tag{504}$$



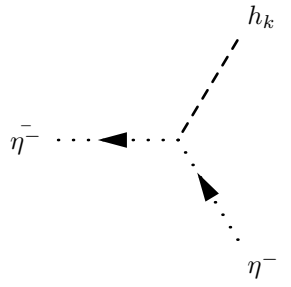
$$\frac{i}{8}\xi_Z\Big(2g_1g_2\cos 2\Theta_W + \Big(-g_2^2+g_1^2\Big)\sin 2\Theta_W\Big)\Big(v_d Z_{k1}^H + v_u Z_{k2}^H\Big) \tag{505}$$



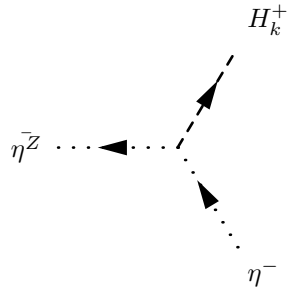
$$\frac{i}{4}g_2\xi_{W^-}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(v_d Z_{k1}^+ - v_u Z_{k2}^+\Big) \tag{506}$$



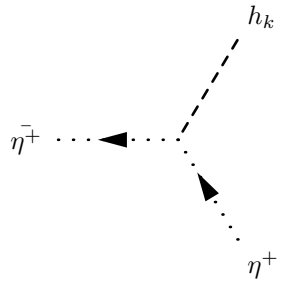
$$\frac{i}{4}g_2\xi_{W^-}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(v_d Z_{k1}^+ - v_u Z_{k2}^+\Big) \tag{507}$$



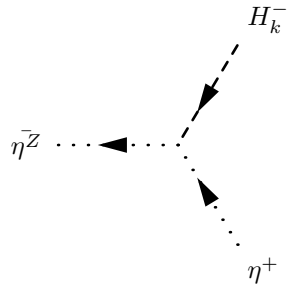
$$-\frac{i}{4}g_2^2\xi_{W^-}\Big(v_d Z_{k1}^H + v_u Z_{k2}^H\Big) \tag{508}$$



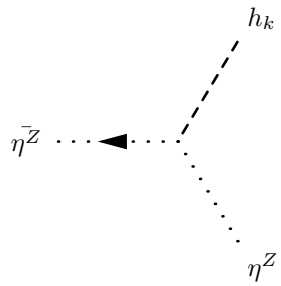
$$-\frac{i}{4}g_2\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ_{k1}^+-v_uZ_{k2}^+\Big) \tag{509}$$



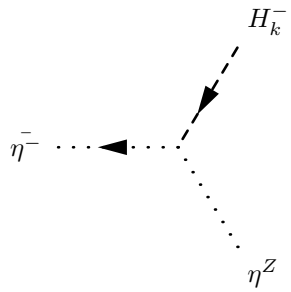
$$-\frac{i}{4}g_2^2\xi_{W^-}\Big(v_dZ_{k1}^H+v_uZ_{k2}^H\Big) \tag{510}$$



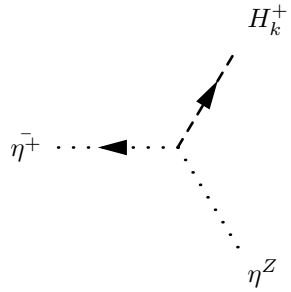
$$-\frac{i}{4}g_2\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ_{k1}^+-v_uZ_{k2}^+\Big) \tag{511}$$



$$-\frac{i}{4}\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2\Big(v_dZ^H_{k1}+v_uZ^H_{k2}\Big) \tag{512}$$



$$\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ^+_{k1}-v_uZ^+_{k2}\Big) \tag{513}$$



$$\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ^+_{k1}-v_uZ^+_{k2}\Big) \tag{514}$$

---

9 Clebsch-Gordan Coefficients

- : Gauge group:SU[3], Dynkin labels: (0 2),(1 0),(1 0)

$$K_{1,a,b}^{SU[3],\bar{6}\times 3\times 3} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}_{ab} \tag{515}$$

$$K_{2,a,b}^{SU[3],\bar{6}\times 3\times 3} = \begin{pmatrix} 0 & \frac{1}{\sqrt{2}} & 0 \\ \frac{1}{\sqrt{2}} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}_{ab} \tag{516}$$

$$K_{3,a,b}^{SU[3],\bar{6}\times 3\times 3} = \begin{pmatrix} 0 & 0 & \frac{1}{\sqrt{2}} \\ 0 & 0 & 0 \\ \frac{1}{\sqrt{2}} & 0 & 0 \end{pmatrix}_{ab} \tag{517}$$

$$K_{4,a,b}^{SU[3],\bar{6}\times 3\times 3} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}_{ab} \tag{518}$$

$$K_{5,a,b}^{SU[3],\bar{6}\times 3\times 3} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} \\ 0 & \frac{1}{\sqrt{2}} & 0 \end{pmatrix}_{ab} \tag{519}$$

$$K_{6,a,b}^{SU[3],\bar{6}\times 3\times 3} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}_{ab} \tag{520}$$

$$\tag{521}$$

- : Gauge group:SU[3], Dynkin labels: (2 0),(0 1),(0 1)

$$K_{1,a,b}^{SU[3],6\times\bar{3}\times\bar{3}} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}_{ab} \tag{522}$$

$$K_{2,a,b}^{SU[3],6\times\bar{3}\times\bar{3}} = \begin{pmatrix} 0 & \frac{1}{\sqrt{2}} & 0 \\ \frac{1}{\sqrt{2}} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}_{ab} \tag{523}$$

$$K_{3,a,b}^{SU[3],6\times\bar{3}\times\bar{3}} = \begin{pmatrix} 0 & 0 & \frac{1}{\sqrt{2}} \\ 0 & 0 & 0 \\ \frac{1}{\sqrt{2}} & 0 & 0 \end{pmatrix}_{ab} \tag{524}$$

$$K^{SU[3],6\times\bar{3}\times\bar{3}}_{4,a,b} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}_{ab} \tag{525}$$

$$K^{SU[3],6\times\bar{3}\times\bar{3}}_{5,a,b} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} \\ 0 & \frac{1}{\sqrt{2}} & 0 \end{pmatrix}_{ab} \tag{526}$$

$$K^{SU[3],6\times\bar{3}\times\bar{3}}_{6,a,b} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}_{ab} \tag{527}$$

$$\tag{528}$$