

$U(1)$  extended MSSM  
Superpotential, Rotations and Interactions for eigenstates 'EWSB'  
including Renormalization Group Equations  
including one-loop Self-Energies

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

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# 1 Superfields

## 1.1 Vector Superfields

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

## 1.2 Chiral Superfields

SF	Spin 0	Spin $\frac{1}{2}$	Generations	$(U(1) \otimes SU(2) \otimes SU(3) \otimes U(1))$
$\hat{q}$	$\tilde{q}$	$q$	3	$(\frac{1}{6}, \mathbf{2}, \mathbf{3}, Q_q)$
$\hat{l}$	$\tilde{l}$	$l$	3	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1}, Q_q)$
$\hat{H}_d$	$H_d$	$\tilde{H}_d$	1	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1}, Q_{H_d})$
$\hat{H}_u$	$H_u$	$\tilde{H}_u$	1	$(\frac{1}{2}, \mathbf{2}, \mathbf{1}, Q_{H_u})$
$\hat{d}$	$\tilde{d}_R^*$	$d_R^*$	3	$(\frac{1}{3}, \mathbf{1}, \bar{\mathbf{3}}, Q_d)$
$\hat{u}$	$\tilde{u}_R^*$	$u_R^*$	3	$(-\frac{2}{3}, \mathbf{1}, \bar{\mathbf{3}}, Q_u)$
$\hat{e}$	$\tilde{e}_R^*$	$e_R^*$	3	$(1, \mathbf{1}, \mathbf{1}, Q_e)$
SF(vR)	conj(SvR)	conj(FvR)	3	$(1, \mathbf{1}, \mathbf{1}, Q_v)$
$\hat{s}$	$S$	$\tilde{S}$	1	$(0, \mathbf{1}, \mathbf{1}, Q_s)$

# 2 Superpotential and Lagrangian

## 2.1 Superpotential

$$W = -Y_d \hat{d} \hat{q} \hat{H}_d - Y_e \hat{e} \hat{l} \hat{H}_d + \lambda \hat{H}_u \hat{H}_d \hat{s} + Y_\nu \hat{l} \hat{H}_u \text{SF(vR)} + Y_u \hat{u} \hat{q} \hat{H}_u \quad (1)$$

## 2.2 Softbreaking terms

$$\begin{aligned}
-L_{SB,W} = & -H_d^0 H_u^0 \tilde{S} T_\lambda + H_d^- H_u^+ \tilde{S} T_\lambda + H_d^0 \tilde{d}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{d}_{L,j\beta} T_{d,ij} - H_d^- \tilde{d}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{u}_{L,j\beta} T_{d,ij} \\
& + H_d^0 \tilde{e}_{R,i}^* \tilde{e}_{L,j} T_{e,ij} - H_d^- \tilde{e}_{R,i}^* \tilde{\nu}_{L,j} T_{e,ij} - H_u^+ \tilde{u}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{d}_{L,j\beta} T_{u,ij} + H_u^0 \tilde{u}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{u}_{L,j\beta} T_{u,ij} \\
& - H_u^+ \text{conj(SvR}(\{\text{gt3}\})) \tilde{e}_{L,i} T_{\nu,ik} + H_u^0 \text{conj(SvR}(\{\text{gt3}\})) \tilde{\nu}_{L,i} T_{\nu,ik} + \text{h.c.} \quad (2)
\end{aligned}$$

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

$$+ \tilde{u}_{R,i\alpha}^* \delta_{\alpha\beta} m_{u,ij}^2 \tilde{u}_{R,j\beta} + \tilde{\nu}_{L,i}^* m_{l,ij}^2 \tilde{\nu}_{L,j} + \text{conj}\left(\text{SvR}\left(\{\text{gt}1\}\right)\right) m_{\nu,ij}^2 \text{SvR}\left(\{\text{gt}2\}\right) \quad (3)$$

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

## 2.3 Gauge fixing terms

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

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

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

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

## 2.4 Fields integrated out

None

## 3 Renormalization Group Equations

### 3.1 Anomalous Dimensions

$$\gamma_{\hat{q}}^{(1)} = -\frac{1}{30} \left( 45g_2^2 + 60g_p^2 Q_q^2 + 80g_3^2 + g_1^2 \right) \mathbf{1} + Y_d^\dagger Y_d + Y_u^\dagger Y_u \quad (7)$$

$$\begin{aligned} \gamma_{\hat{q}}^{(2)} = & +\frac{1}{900} \left( 253g_1^4 + 10g_1^2 \left( 4 \left( 3g_p^2 Q_q \left( 10Q_q - 18Q_u - 3Q_{H_d} + 3Q_{H_u} + 9Q_d + 9Q_e - 9Q_q + 9Q_v \right) + 4g_3^2 \right) + 9g_2^2 \right) \right. \\ & + 25 \left( 135g_2^4 + 72g_2^2 \left( 3g_p^2 Q_q^2 + 4g_3^2 \right) \right. \\ & \left. \left. + 8 \left( 48g_3^2 g_p^2 Q_q^2 - 4g_3^4 + 9g_p^4 Q_q^2 \left( 20Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_v^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \right) \right) \right) \right) \mathbf{1} \\ & + \frac{4}{5} g_1^2 Y_u^\dagger Y_u + 2g_p^2 Q_{H_u}^2 Y_u^\dagger Y_u - 2g_p^2 Q_q^2 Y_u^\dagger Y_u + 2g_p^2 Q_u^2 Y_u^\dagger Y_u \end{aligned}$$

$$\begin{aligned}
& -|\lambda|^2 Y_u^\dagger Y_u - 2Y_d^\dagger Y_d Y_d^\dagger Y_d - 2Y_u^\dagger Y_u Y_u^\dagger Y_u \\
& + Y_d^\dagger Y_d \left( 2g_p^2 Q_d^2 + 2g_p^2 Q_{H_d}^2 - 2g_p^2 Q_q^2 - 3\text{Tr}(Y_d Y_d^\dagger) + \frac{2}{5}g_1^2 - |\lambda|^2 - \text{Tr}(Y_e Y_e^\dagger) \right) \\
& - 3Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) - Y_u^\dagger Y_u \text{Tr}(Y_\nu Y_\nu^\dagger)
\end{aligned} \tag{8}$$

$$\gamma_i^{(1)} = -\frac{1}{10} \left( 15g_2^2 + 20g_p^2 Q_q^2 + 3g_1^2 \right) \mathbf{1} + Y_e^\dagger Y_e + Y_\nu^* Y_\nu^T \tag{9}$$

$$\begin{aligned}
\gamma_i^{(2)} = & +\frac{1}{100} \left( 261g_1^4 + 30g_1^2 \left( 3g_2^2 - 4g_p^2 Q_q \left( 3Q_d + 3Q_e + 3Q_q + 3Q_\nu - 4Q_q - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right) \right. \\
& + 25 \left( 15g_2^4 + 24g_2^2 g_p^2 Q_q^2 + 8g_p^4 Q_q^2 \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_\nu^2 + 8Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \right) \right) \mathbf{1} \\
& + \frac{6}{5}g_1^2 Y_\nu^* Y_\nu^T + 2g_p^2 Q_{H_u}^2 Y_\nu^* Y_\nu^T - 2g_p^2 Q_q^2 Y_\nu^* Y_\nu^T + 2g_p^2 Q_\nu^2 Y_\nu^* Y_\nu^T \\
& - |\lambda|^2 Y_\nu^* Y_\nu^T - 2Y_e^\dagger Y_e Y_e^\dagger Y_e - 2Y_\nu^* Y_\nu^T Y_\nu^* Y_\nu^T \\
& + Y_e^\dagger Y_e \left( 2g_p^2 Q_e^2 + 2g_p^2 Q_{H_d}^2 - 2g_p^2 Q_q^2 - 3\text{Tr}(Y_d Y_d^\dagger) + \frac{6}{5}g_1^2 - |\lambda|^2 - \text{Tr}(Y_e Y_e^\dagger) \right) \\
& \left. - 3Y_\nu^* Y_\nu^T \text{Tr}(Y_u Y_u^\dagger) - Y_\nu^* Y_\nu^T \text{Tr}(Y_\nu Y_\nu^\dagger) \right) \mathbf{1}
\end{aligned} \tag{10}$$

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

$$\begin{aligned}
\gamma_{\hat{H}_d}^{(2)} = & +\frac{261}{100}g_1^4 + \frac{9}{10}g_1^2 g_2^2 + \frac{15}{4}g_2^4 - \frac{18}{5}g_1^2 g_p^2 Q_d Q_{H_d} - \frac{18}{5}g_1^2 g_p^2 Q_e Q_{H_d} + \frac{12}{5}g_1^2 g_p^2 Q_{H_d}^2 \\
& + 6g_2^2 g_p^2 Q_{H_d}^2 + 18g_p^4 Q_d^2 Q_{H_d}^2 + 6g_p^4 Q_e^2 Q_{H_d}^2 + 8g_p^4 Q_{H_d}^4 - \frac{6}{5}g_1^2 g_p^2 Q_{H_d} Q_{H_u} \\
& + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 + \frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_q + 12g_p^4 Q_{H_d}^2 Q_q^2 - \frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_q + 36g_p^4 Q_{H_d}^2 Q_q^2 \\
& + 2g_p^4 Q_{H_d}^2 Q_s^2 + \frac{36}{5}g_1^2 g_p^2 Q_{H_d} Q_u + 18g_p^4 Q_{H_d}^2 Q_u^2 - \frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_\nu + 6g_p^4 Q_{H_d}^2 Q_\nu^2 \\
& - 3\lambda^2 \lambda^{*,2} - \frac{2}{5} \left( -5 \left( 3g_p^2 \left( -Q_{H_d}^2 + Q_d^2 + Q_q^2 \right) + 8g_3^2 \right) + g_1^2 \right) \text{Tr}(Y_d Y_d^\dagger) + \frac{6}{5}g_1^2 \text{Tr}(Y_e Y_e^\dagger) \\
& + 2g_p^2 Q_e^2 \text{Tr}(Y_e Y_e^\dagger) - 2g_p^2 Q_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) + 2g_p^2 Q_q^2 \text{Tr}(Y_e Y_e^\dagger) \\
& - |\lambda|^2 \left( 2g_p^2 \left( -Q_{H_u}^2 - Q_s^2 + Q_{H_d}^2 \right) + 3\text{Tr}(Y_u Y_u^\dagger) + \text{Tr}(Y_\nu Y_\nu^\dagger) \right) - 9\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) \\
& - 3\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 3\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) - \text{Tr}(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*)
\end{aligned} \tag{12}$$

$$\gamma_{\hat{H}_u}^{(1)} = -2g_p^2 Q_{H_u}^2 + 3\text{Tr}(Y_u Y_u^\dagger) - \frac{3}{10}g_1^2 - \frac{3}{2}g_2^2 + |\lambda|^2 + \text{Tr}(Y_\nu Y_\nu^\dagger) \tag{13}$$

$$\begin{aligned}
\gamma_{\hat{H}_u}^{(2)} = & +\frac{261}{100}g_1^4 + \frac{9}{10}g_1^2 g_2^2 + \frac{15}{4}g_2^4 + \frac{18}{5}g_1^2 g_p^2 Q_d Q_{H_u} + \frac{18}{5}g_1^2 g_p^2 Q_e Q_{H_u} - \frac{6}{5}g_1^2 g_p^2 Q_{H_d} Q_{H_u} \\
& + \frac{12}{5}g_1^2 g_p^2 Q_{H_u}^2 + 6g_2^2 g_p^2 Q_{H_u}^2 + 18g_p^4 Q_d^2 Q_{H_u}^2 + 6g_p^4 Q_e^2 Q_{H_u}^2 + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 \\
& + 8g_p^4 Q_{H_u}^4 - \frac{18}{5}g_1^2 g_p^2 Q_{H_u} Q_q + 12g_p^4 Q_{H_u}^2 Q_q^2 + \frac{18}{5}g_1^2 g_p^2 Q_{H_u} Q_q + 36g_p^4 Q_{H_u}^2 Q_q^2 \\
& + 2g_p^4 Q_{H_u}^2 Q_s^2 - \frac{36}{5}g_1^2 g_p^2 Q_{H_u} Q_u + 18g_p^4 Q_{H_u}^2 Q_u^2 + \frac{18}{5}g_1^2 g_p^2 Q_{H_u} Q_\nu + 6g_p^4 Q_{H_u}^2 Q_\nu^2
\end{aligned}$$

$$\begin{aligned}
& -3\lambda^2\lambda^{*,2} + |\lambda|^2 \left( 2g_p^2 \left( -Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2 \right) - 3\text{Tr} \left( Y_d Y_d^\dagger \right) - \text{Tr} \left( Y_e Y_e^\dagger \right) \right) \\
& + \frac{2}{5} \left( 2g_1^2 + 5 \left( 3g_p^2 \left( -Q_{H_u}^2 + Q_q^2 + Q_u^2 \right) + 8g_3^2 \right) \right) \text{Tr} \left( Y_u Y_u^\dagger \right) + \frac{6}{5} g_1^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \\
& - 2g_p^2 Q_{H_u}^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) + 2g_p^2 Q_q^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) + 2g_p^2 Q_v^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 3\text{Tr} \left( Y_d Y_u^\dagger Y_u Y_d^\dagger \right) \\
& - 9\text{Tr} \left( Y_u Y_u^\dagger Y_u Y_u^\dagger \right) - 3\text{Tr} \left( Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger \right) - \text{Tr} \left( Y_\nu Y_\nu^\dagger Y_e^T Y_e^* \right)
\end{aligned} \tag{14}$$

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

$$\begin{aligned}
\gamma_{\hat{d}}^{(2)} & = + \frac{2}{225} \left( 128g_1^4 + 10g_1^2 \left( 3g_p^2 Q_d \left( 11Q_d - 18Q_u - 3Q_{H_d} + 3Q_{H_u} + 9Q_e - 9Q_q + 9Q_q + 9Q_v \right) + 8g_3^2 \right) \right. \\
& - 25 \left( -48g_3^2 g_p^2 Q_d^2 + 4g_3^4 - 9g_p^4 Q_d^2 \left( 11Q_d^2 + 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_v^2 + 6Q_q^2 + 9Q_u^2 + Q_s^2 \right) \right) \mathbf{1} \\
& - 2 \left( Y_d^* Y_d^T Y_d^* Y_d^T + Y_d^* Y_u^T Y_u^* Y_d^T \right) \\
& + Y_d^* Y_d^T \left( -2|\lambda|^2 - 2\text{Tr} \left( Y_e Y_e^\dagger \right) - 4g_p^2 Q_d^2 + 4g_p^2 Q_{H_d}^2 + 4g_p^2 Q_q^2 + 6g_2^2 - 6\text{Tr} \left( Y_d Y_d^\dagger \right) + \frac{2}{5} g_1^2 \right)
\end{aligned} \tag{16}$$

$$\gamma_{\hat{u}}^{(1)} = 2Y_u^* Y_u^T - \frac{2}{15} \left( 15g_p^2 Q_u^2 + 20g_3^2 + 4g_1^2 \right) \mathbf{1} \tag{17}$$

$$\begin{aligned}
\gamma_{\hat{u}}^{(2)} & = + \frac{2}{225} \left( 536g_1^4 + 20g_1^2 \left( 16g_3^2 - 3g_p^2 Q_u \left( -22Q_u - 3Q_{H_d} + 3Q_{H_u} + 9Q_d + 9Q_e - 9Q_q + 9Q_q + 9Q_v \right) \right) \right. \\
& - 25 \left( -48g_3^2 g_p^2 Q_u^2 + 4g_3^4 - 9g_p^4 Q_u^2 \left( 11Q_u^2 + 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_v^2 + 6Q_q^2 + 9Q_d^2 + Q_s^2 \right) \right) \mathbf{1} \\
& - 2 \left( Y_u^* Y_d^T Y_d^* Y_u^T + Y_u^* Y_u^T Y_u^* Y_u^T \right) \\
& + Y_u^* Y_u^T \left( -2|\lambda|^2 - 2\text{Tr} \left( Y_\nu Y_\nu^\dagger \right) + 4g_p^2 Q_{H_u}^2 + 4g_p^2 Q_q^2 - 4g_p^2 Q_u^2 + 6g_2^2 - 6\text{Tr} \left( Y_u Y_u^\dagger \right) - \frac{2}{5} g_1^2 \right)
\end{aligned} \tag{18}$$

$$\gamma_{\hat{e}}^{(1)} = 2Y_e^* Y_e^T - \frac{2}{5} \left( 3g_1^2 + 5g_p^2 Q_e^2 \right) \mathbf{1} \tag{19}$$

$$\begin{aligned}
\gamma_{\hat{e}}^{(2)} & = + \frac{2}{25} \left( 144g_1^4 + 30g_1^2 g_p^2 Q_e \left( 3Q_d - 3Q_q + 3Q_q + 3Q_v + 5Q_e - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right. \\
& + 25g_p^4 Q_e^2 \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_v^2 + 5Q_e^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \right) \mathbf{1} \\
& - 2 \left( Y_e^* Y_\nu Y_\nu^\dagger Y_e^T + Y_e^* Y_e^T Y_e^* Y_e^T \right) \\
& + Y_e^* Y_e^T \left( -2|\lambda|^2 - 2\text{Tr} \left( Y_e Y_e^\dagger \right) - 4g_p^2 Q_e^2 + 4g_p^2 Q_{H_d}^2 + 4g_p^2 Q_q^2 + 6g_2^2 - 6\text{Tr} \left( Y_d Y_d^\dagger \right) - \frac{6}{5} g_1^2 \right)
\end{aligned} \tag{20}$$

$$\gamma_{\text{SF}(\nu\text{R})}^{(1)} = 2Y_\nu^\dagger Y_\nu - \frac{2}{5} \left( 3g_1^2 + 5g_p^2 Q_v^2 \right) \mathbf{1} \tag{21}$$

$$\begin{aligned}
\gamma_{\text{SF}(\nu\text{R})}^{(2)} & = + \frac{2}{25} \left( 144g_1^4 + 30g_1^2 g_p^2 Q_v \left( 3Q_d + 3Q_e - 3Q_q + 3Q_q + 5Q_v - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right. \\
& + 25g_p^4 Q_v^2 \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 5Q_v^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \right) \mathbf{1} \\
& - 2 \left( Y_\nu^\dagger Y_\nu Y_\nu^\dagger Y_\nu + Y_\nu^\dagger Y_e^T Y_e^* Y_\nu \right)
\end{aligned}$$

$$+ Y_\nu^\dagger Y_\nu \left( -2|\lambda|^2 - 2\text{Tr}(Y_\nu Y_\nu^\dagger) + 4g_p^2 Q_{H_u}^2 + 4g_p^2 Q_q^2 - 4g_p^2 Q_v^2 + 6g_2^2 - 6\text{Tr}(Y_u Y_u^\dagger) - \frac{6}{5}g_1^2 \right) \quad (22)$$

$$\gamma_s^{(1)} = -2g_p^2 Q_s^2 + 2|\lambda|^2 \quad (23)$$

$$\begin{aligned} \gamma_s^{(2)} = & +2g_p^4 Q_s^2 \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_s^2 + 3Q_v^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 \right) - 4\lambda^2 \lambda^{*,2} \\ & + \frac{2}{5}|\lambda|^2 \left( 3g_1^2 + 15g_2^2 + 10g_p^2 Q_{H_d}^2 + 10g_p^2 Q_{H_u}^2 - 10g_p^2 Q_s^2 - 15\text{Tr}(Y_d Y_d^\dagger) - 5\text{Tr}(Y_e Y_e^\dagger) \right. \\ & \left. - 15\text{Tr}(Y_u Y_u^\dagger) - 5\text{Tr}(Y_\nu Y_\nu^\dagger) \right) \end{aligned} \quad (24)$$

### 3.2 Gauge Couplings

$$\beta_{g_1}^{(1)} = \frac{42}{5}g_1^3 \quad (25)$$

$$\begin{aligned} \beta_{g_1}^{(2)} = & \frac{1}{25}g_1^3 \left( 307g_1^2 + 135g_2^2 + 440g_3^2 + 60g_p^2 Q_d^2 + 180g_p^2 Q_e^2 + 30g_p^2 Q_{H_d}^2 + 30g_p^2 Q_{H_u}^2 + 90g_p^2 Q_q^2 \right. \\ & + 30g_p^2 Q_v^2 + 240g_p^2 Q_u^2 + 180g_p^2 Q_s^2 - 30|\lambda|^2 - 70\text{Tr}(Y_d Y_d^\dagger) - 90\text{Tr}(Y_e Y_e^\dagger) - 130\text{Tr}(Y_u Y_u^\dagger) \\ & \left. - 90\text{Tr}(Y_\nu Y_\nu^\dagger) \right) \end{aligned} \quad (26)$$

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

$$\begin{aligned} \beta_{g_2}^{(2)} = & \frac{1}{5}g_2^3 \left( 9g_1^2 + 125g_2^2 + 120g_3^2 + 10g_p^2 Q_{H_d}^2 + 10g_p^2 Q_{H_u}^2 + 30g_p^2 Q_q^2 + 90g_p^2 Q_v^2 - 10|\lambda|^2 \right. \\ & \left. - 30\text{Tr}(Y_d Y_d^\dagger) - 10\text{Tr}(Y_e Y_e^\dagger) - 30\text{Tr}(Y_u Y_u^\dagger) - 10\text{Tr}(Y_\nu Y_\nu^\dagger) \right) \end{aligned} \quad (28)$$

$$\beta_{g_3}^{(1)} = -3g_3^3 \quad (29)$$

$$\beta_{g_3}^{(2)} = \frac{1}{5}g_3^3 \left( 11g_1^2 - 20\text{Tr}(Y_d Y_d^\dagger) - 20\text{Tr}(Y_u Y_u^\dagger) + 30g_p^2 Q_d^2 + 30g_p^2 Q_u^2 + 45g_2^2 + 60g_p^2 Q_q^2 + 70g_3^2 \right) \quad (30)$$

$$\beta_{g_p}^{(1)} = g_p^3 \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_v^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \right) \quad (31)$$

$$\begin{aligned} \beta_{g_p}^{(2)} = & \frac{2}{5}g_p^3 \left( 6g_1^2 Q_d^2 + 120g_3^2 Q_d^2 + 90g_p^2 Q_d^4 + 18g_1^2 Q_e^2 + 30g_p^2 Q_e^4 + 3g_1^2 Q_{H_d}^2 + 15g_2^2 Q_{H_d}^2 \right. \\ & + 20g_p^2 Q_{H_d}^4 + 3g_1^2 Q_{H_u}^2 + 15g_2^2 Q_{H_u}^2 + 20g_p^2 Q_{H_u}^4 + 9g_1^2 Q_q^2 + 45g_2^2 Q_q^2 + 60g_p^2 Q_q^4 \\ & + 3g_1^2 Q_v^2 + 135g_2^2 Q_v^2 + 240g_3^2 Q_v^2 + 180g_p^2 Q_v^4 + 10g_p^2 Q_s^4 + 24g_1^2 Q_u^2 + 120g_3^2 Q_u^2 \\ & + 90g_p^2 Q_u^4 + 18g_1^2 Q_v^2 + 30g_p^2 Q_v^4 - 10(Q_{H_d}^2 + Q_{H_u}^2 + Q_s^2)|\lambda|^2 - 30(Q_d^2 + Q_{H_d}^2 + Q_q^2)\text{Tr}(Y_d Y_d^\dagger) \\ & - 10Q_e^2\text{Tr}(Y_e Y_e^\dagger) - 10Q_{H_d}^2\text{Tr}(Y_e Y_e^\dagger) - 10Q_q^2\text{Tr}(Y_e Y_e^\dagger) - 30Q_{H_u}^2\text{Tr}(Y_u Y_u^\dagger) \\ & - 30Q_q^2\text{Tr}(Y_u Y_u^\dagger) - 30Q_u^2\text{Tr}(Y_u Y_u^\dagger) - 10Q_{H_u}^2\text{Tr}(Y_\nu Y_\nu^\dagger) - 10Q_q^2\text{Tr}(Y_\nu Y_\nu^\dagger) \\ & \left. - 10Q_v^2\text{Tr}(Y_\nu Y_\nu^\dagger) \right) \end{aligned} \quad (32)$$



### 3.3 Gaugino Mass Parameters

$$\beta_{M_1}^{(1)} = \frac{84}{5}g_1^2 M_1 \quad (33)$$

$$\begin{aligned} \beta_{M_1}^{(2)} = & \frac{2}{25}g_1^2 \left( 614g_1^2 M_1 + 135g_2^2 M_1 + 440g_3^2 M_1 + 440g_3^2 M_3 + 135g_2^2 M_2 + 60g_p^2 M_1 Q_d^2 + 60g_p^2 M_Z Q_d^2 \right. \\ & + 180g_p^2 M_1 Q_e^2 + 180g_p^2 M_Z Q_e^2 + 30g_p^2 M_1 Q_{H_d}^2 + 30g_p^2 M_Z Q_{H_d}^2 + 30g_p^2 M_1 Q_{H_u}^2 + 30g_p^2 M_Z Q_{H_u}^2 \\ & + 90g_p^2 M_1 Q_q^2 + 90g_p^2 M_Z Q_q^2 + 30g_p^2 M_1 Q_u^2 + 30g_p^2 M_Z Q_u^2 + 240g_p^2 M_1 Q_v^2 + 240g_p^2 M_Z Q_v^2 \\ & \left. + 180g_p^2 M_1 Q_v^2 + 180g_p^2 M_Z Q_v^2 - 30\lambda^* (M_1 \lambda - T_\lambda) - 70M_1 \text{Tr}(Y_d Y_d^\dagger) - 90M_1 \text{Tr}(Y_e Y_e^\dagger) \right. \\ & \left. - 130M_1 \text{Tr}(Y_u Y_u^\dagger) - 90M_1 \text{Tr}(Y_\nu Y_\nu^\dagger) + 70\text{Tr}(Y_d^\dagger T_d) + 90\text{Tr}(Y_e^\dagger T_e) + 130\text{Tr}(Y_u^\dagger T_u) + 90\text{Tr}(Y_\nu^\dagger T_\nu) \right) \quad (34) \end{aligned}$$

$$\beta_{M_2}^{(1)} = 2g_2^2 M_2 \quad (35)$$

$$\begin{aligned} \beta_{M_2}^{(2)} = & \frac{2}{5}g_2^2 \left( 9g_1^2 M_1 + 120g_3^2 M_3 + 9g_1^2 M_2 + 250g_2^2 M_2 + 120g_3^2 M_2 + 10g_p^2 M_Z Q_{H_d}^2 + 10g_p^2 M_2 Q_{H_d}^2 \right. \\ & + 10g_p^2 M_Z Q_{H_u}^2 + 10g_p^2 M_2 Q_{H_u}^2 + 30g_p^2 M_Z Q_q^2 + 30g_p^2 M_2 Q_q^2 + 90g_p^2 M_Z Q_q^2 + 90g_p^2 M_2 Q_q^2 \\ & \left. - 10\lambda^* (M_2 \lambda - T_\lambda) - 30M_2 \text{Tr}(Y_d Y_d^\dagger) - 10M_2 \text{Tr}(Y_e Y_e^\dagger) - 30M_2 \text{Tr}(Y_u Y_u^\dagger) - 10M_2 \text{Tr}(Y_\nu Y_\nu^\dagger) \right. \\ & \left. + 30\text{Tr}(Y_d^\dagger T_d) + 10\text{Tr}(Y_e^\dagger T_e) + 30\text{Tr}(Y_u^\dagger T_u) + 10\text{Tr}(Y_\nu^\dagger T_\nu) \right) \quad (36) \end{aligned}$$

$$\beta_{M_3}^{(1)} = -6g_3^2 M_3 \quad (37)$$

$$\begin{aligned} \beta_{M_3}^{(2)} = & \frac{2}{5}g_3^2 \left( 11g_1^2 M_1 + 11g_1^2 M_3 + 45g_2^2 M_3 + 140g_3^2 M_3 + 45g_2^2 M_2 + 30g_p^2 M_3 Q_d^2 + 30g_p^2 M_Z Q_d^2 \right. \\ & + 60g_p^2 M_3 Q_q^2 + 60g_p^2 M_Z Q_q^2 + 30g_p^2 M_3 Q_u^2 + 30g_p^2 M_Z Q_u^2 - 20M_3 \text{Tr}(Y_d Y_d^\dagger) \\ & \left. - 20M_3 \text{Tr}(Y_u Y_u^\dagger) + 20\text{Tr}(Y_d^\dagger T_d) + 20\text{Tr}(Y_u^\dagger T_u) \right) \quad (38) \end{aligned}$$

$$\beta_{M_Z}^{(1)} = 2g_p^2 M_Z \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_v^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \right) \quad (39)$$

$$\begin{aligned} \beta_{M_Z}^{(2)} = & \frac{4}{5}g_p^2 \left( 6g_1^2 M_1 Q_d^2 + 120g_3^2 M_3 Q_d^2 + 6g_1^2 M_Z Q_d^2 + 120g_3^2 M_Z Q_d^2 + 180g_p^2 M_Z Q_d^4 + 18g_1^2 M_1 Q_e^2 \right. \\ & + 18g_1^2 M_Z Q_e^2 + 60g_p^2 M_Z Q_e^4 + 3g_1^2 M_1 Q_{H_d}^2 + 3g_1^2 M_Z Q_{H_d}^2 + 15g_2^2 M_Z Q_{H_d}^2 + 15g_2^2 M_2 Q_{H_d}^2 \\ & + 40g_p^2 M_Z Q_{H_d}^4 + 3g_1^2 M_1 Q_{H_u}^2 + 3g_1^2 M_Z Q_{H_u}^2 + 15g_2^2 M_Z Q_{H_u}^2 + 15g_2^2 M_2 Q_{H_u}^2 + 40g_p^2 M_Z Q_{H_u}^4 \\ & + 9g_1^2 M_1 Q_q^2 + 9g_1^2 M_Z Q_q^2 + 45g_2^2 M_Z Q_q^2 + 45g_2^2 M_2 Q_q^2 + 120g_p^2 M_Z Q_q^4 + 3g_1^2 M_1 Q_q^2 \\ & + 240g_3^2 M_3 Q_q^2 + 3g_1^2 M_Z Q_q^2 + 135g_2^2 M_Z Q_q^2 + 240g_3^2 M_Z Q_q^2 + 135g_2^2 M_2 Q_q^2 + 360g_p^2 M_Z Q_q^4 \\ & + 20g_p^2 M_Z Q_s^4 + 24g_1^2 M_1 Q_u^2 + 120g_3^2 M_3 Q_u^2 + 24g_1^2 M_Z Q_u^2 + 120g_3^2 M_Z Q_u^2 + 180g_p^2 M_Z Q_u^4 \\ & + 18g_1^2 M_1 Q_v^2 + 18g_1^2 M_Z Q_v^2 + 60g_p^2 M_Z Q_v^4 - 10(Q_{H_d}^2 + Q_{H_u}^2 + Q_s^2)\lambda^* (M_Z \lambda - T_\lambda) \\ & - 30M_Z (Q_d^2 + Q_{H_d}^2 + Q_q^2) \text{Tr}(Y_d Y_d^\dagger) - 10M_Z Q_e^2 \text{Tr}(Y_e Y_e^\dagger) - 10M_Z Q_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) \\ & - 10M_Z Q_q^2 \text{Tr}(Y_e Y_e^\dagger) - 30M_Z Q_{H_u}^2 \text{Tr}(Y_u Y_u^\dagger) - 30M_Z Q_q^2 \text{Tr}(Y_u Y_u^\dagger) - 30M_Z Q_u^2 \text{Tr}(Y_u Y_u^\dagger) \\ & - 10M_Z Q_{H_u}^2 \text{Tr}(Y_\nu Y_\nu^\dagger) - 10M_Z Q_q^2 \text{Tr}(Y_\nu Y_\nu^\dagger) - 10M_Z Q_v^2 \text{Tr}(Y_\nu Y_\nu^\dagger) + 30Q_d^2 \text{Tr}(Y_d^\dagger T_d) \end{aligned}$$

$$\begin{aligned}
& + 30Q_{H_d}^2 \text{Tr}(Y_d^\dagger T_d) + 30Q_q^2 \text{Tr}(Y_d^\dagger T_d) + 10Q_e^2 \text{Tr}(Y_e^\dagger T_e) + 10Q_{H_d}^2 \text{Tr}(Y_e^\dagger T_e) \\
& + 10Q_q^2 \text{Tr}(Y_e^\dagger T_e) + 30Q_{H_u}^2 \text{Tr}(Y_u^\dagger T_u) + 30Q_q^2 \text{Tr}(Y_u^\dagger T_u) + 30Q_u^2 \text{Tr}(Y_u^\dagger T_u) \\
& + 10Q_{H_u}^2 \text{Tr}(Y_\nu^\dagger T_\nu) + 10Q_q^2 \text{Tr}(Y_\nu^\dagger T_\nu) + 10Q_\nu^2 \text{Tr}(Y_\nu^\dagger T_\nu)
\end{aligned} \tag{40}$$

### 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 \\
& + Y_d \left( -2g_p^2 Q_d^2 - 2g_p^2 Q_{H_d}^2 - 2g_p^2 Q_q^2 - 3g_2^2 + 3\text{Tr}(Y_d Y_d^\dagger) - \frac{16}{3}g_3^2 - \frac{7}{15}g_1^2 + |\lambda|^2 + \text{Tr}(Y_e Y_e^\dagger) \right) \\
\beta_{Y_d}^{(2)} & = +\frac{4}{5}g_1^2 Y_d Y_u^\dagger Y_u + 2g_p^2 Q_{H_u}^2 Y_d Y_u^\dagger Y_u - 2g_p^2 Q_q^2 Y_d Y_u^\dagger Y_u \\
& + 2g_p^2 Q_u^2 Y_d Y_u^\dagger Y_u - |\lambda|^2 Y_d Y_u^\dagger Y_u - 4Y_d Y_d^\dagger Y_d Y_d^\dagger Y_d - 2Y_d Y_u^\dagger Y_u Y_d^\dagger Y_d \\
& - 2Y_d Y_u^\dagger Y_u Y_u^\dagger Y_u \\
& + Y_d Y_d^\dagger Y_d \left( -2g_p^2 Q_d^2 + 2g_p^2 Q_q^2 - 3|\lambda|^2 - 3\text{Tr}(Y_e Y_e^\dagger) + 6g_2^2 + 6g_p^2 Q_{H_d}^2 - 9\text{Tr}(Y_d Y_d^\dagger) + \frac{4}{5}g_1^2 \right) \\
& - 3Y_d Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) - Y_d Y_u^\dagger Y_u \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& + Y_d \left( \frac{1813}{450}g_1^4 + g_1^2 g_2^2 + \frac{15}{2}g_2^4 + \frac{8}{9}g_1^2 g_3^2 + 8g_2^2 g_3^2 - \frac{16}{9}g_3^4 + \frac{44}{15}g_1^2 g_p^2 Q_d^2 + \frac{32}{3}g_3^2 g_p^2 Q_d^2 \right. \\
& + 22g_p^4 Q_d^4 + \frac{12}{5}g_1^2 g_p^2 Q_d Q_e + 6g_p^4 Q_d^2 Q_e^2 - \frac{22}{5}g_1^2 g_p^2 Q_d Q_{H_d} - \frac{18}{5}g_1^2 g_p^2 Q_e Q_{H_d} \\
& + \frac{12}{5}g_1^2 g_p^2 Q_{H_d}^2 + 6g_2^2 g_p^2 Q_{H_d}^2 + 22g_p^4 Q_d^2 Q_{H_d}^2 + 6g_p^4 Q_e^2 Q_{H_d}^2 + 8g_p^4 Q_{H_d}^4 \\
& + \frac{4}{5}g_1^2 g_p^2 Q_d Q_{H_u} - \frac{6}{5}g_1^2 g_p^2 Q_{H_d} Q_{H_u} + 4g_p^4 Q_d^2 Q_{H_u}^2 + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 - \frac{12}{5}g_1^2 g_p^2 Q_d Q_q \\
& + \frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_q + 12g_p^4 Q_d^2 Q_q^2 + 12g_p^4 Q_{H_d}^2 Q_q^2 + \frac{18}{5}g_1^2 g_p^2 Q_d Q_q + \frac{6}{5}g_1^2 g_p^2 Q_e Q_q \\
& - 4g_1^2 g_p^2 Q_{H_d} Q_q + \frac{2}{5}g_1^2 g_p^2 Q_{H_u} Q_q - \frac{6}{5}g_1^2 g_p^2 Q_q Q_q + \frac{4}{3}g_1^2 g_p^2 Q_q^2 + 6g_2^2 g_p^2 Q_q^2 \\
& + \frac{32}{3}g_3^2 g_p^2 Q_q^2 + 54g_p^4 Q_d^2 Q_q^2 + 6g_p^4 Q_e^2 Q_q^2 + 40g_p^4 Q_{H_d}^2 Q_q^2 + 4g_p^4 Q_{H_u}^2 Q_q^2 \\
& + 12g_p^4 Q_q^2 Q_q^2 + 40g_p^4 Q_q^4 + 2g_p^4 Q_d^2 Q_s^2 + 2g_p^4 Q_{H_d}^2 Q_s^2 + 2g_p^4 Q_q^2 Q_s^2 - \frac{24}{5}g_1^2 g_p^2 Q_d Q_u \\
& + \frac{36}{5}g_1^2 g_p^2 Q_{H_d} Q_u - \frac{12}{5}g_1^2 g_p^2 Q_q Q_u + 18g_p^4 Q_d^2 Q_u^2 + 18g_p^4 Q_{H_d}^2 Q_u^2 + 18g_p^4 Q_q^2 Q_u^2 \\
& + \frac{12}{5}g_1^2 g_p^2 Q_d Q_v - \frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_v + \frac{6}{5}g_1^2 g_p^2 Q_q Q_v + 6g_p^4 Q_d^2 Q_v^2 + 6g_p^4 Q_{H_d}^2 Q_v^2 \\
& + 6g_p^4 Q_q^2 Q_v^2 - 3\lambda^2 \lambda^{*2} - \frac{2}{5} \left( -5 \left( 3g_p^2 \left( -Q_{H_d}^2 + Q_d^2 + Q_q^2 \right) + 8g_3^2 \right) + g_1^2 \right) \text{Tr}(Y_d Y_d^\dagger) \\
& + \frac{6}{5}g_1^2 \text{Tr}(Y_e Y_e^\dagger) + 2g_p^2 Q_e^2 \text{Tr}(Y_e Y_e^\dagger) - 2g_p^2 Q_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) + 2g_p^2 Q_q^2 \text{Tr}(Y_e Y_e^\dagger)
\end{aligned} \tag{41}$$

$$\begin{aligned}
& -|\lambda|^2 \left( 2g_p^2 \left( -Q_{H_u}^2 - Q_s^2 + Q_{H_d}^2 \right) + 3\text{Tr} \left( Y_u Y_u^\dagger \right) + \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \right) - 9\text{Tr} \left( Y_d Y_d^\dagger Y_d Y_d^\dagger \right) \\
& - 3\text{Tr} \left( Y_d Y_u^\dagger Y_u Y_d^\dagger \right) - 3\text{Tr} \left( Y_e Y_e^\dagger Y_e Y_e^\dagger \right) - \text{Tr} \left( Y_\nu Y_\nu^\dagger Y_e^T Y_e^* \right)
\end{aligned} \tag{42}$$

$$\begin{aligned}
\beta_{Y_e}^{(1)} & = +3Y_e Y_e^\dagger Y_e + Y_e Y_\nu^* Y_\nu^T \\
& + Y_e \left( -2g_p^2 Q_e^2 - 2g_p^2 Q_{H_d}^2 - 2g_p^2 Q_q^2 - 3g_2^2 + 3\text{Tr} \left( Y_d Y_d^\dagger \right) - \frac{9}{5}g_1^2 + |\lambda|^2 + \text{Tr} \left( Y_e Y_e^\dagger \right) \right)
\end{aligned} \tag{43}$$

$$\begin{aligned}
\beta_{Y_e}^{(2)} & = +\frac{6}{5}g_1^2 Y_e Y_\nu^* Y_\nu^T + 2g_p^2 Q_{H_u}^2 Y_e Y_\nu^* Y_\nu^T - 2g_p^2 Q_q^2 Y_e Y_\nu^* Y_\nu^T \\
& + 2g_p^2 Q_e^2 Y_e Y_\nu^* Y_\nu^T - |\lambda|^2 Y_e Y_\nu^* Y_\nu^T - 4Y_e Y_e^\dagger Y_e Y_e^\dagger Y_e - 2Y_e Y_\nu^* Y_\nu^T Y_e^\dagger Y_e \\
& - 2Y_e Y_\nu^* Y_\nu^T Y_\nu^* Y_\nu^T \\
& + Y_e Y_e^\dagger Y_e \left( -2g_p^2 Q_e^2 + 2g_p^2 Q_q^2 - 3|\lambda|^2 - 3\text{Tr} \left( Y_e Y_e^\dagger \right) + 6g_2^2 + 6g_p^2 Q_{H_d}^2 - 9\text{Tr} \left( Y_d Y_d^\dagger \right) \right) \\
& - 3Y_e Y_\nu^* Y_\nu^T \text{Tr} \left( Y_u Y_u^\dagger \right) - Y_e Y_\nu^* Y_\nu^T \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \\
& + Y_e \left( \frac{837}{50}g_1^4 + \frac{9}{5}g_1^2 g_2^2 + \frac{15}{2}g_2^4 + \frac{36}{5}g_1^2 g_p^2 Q_d Q_e + 12g_1^2 g_p^2 Q_e^2 + 18g_p^4 Q_d^2 Q_e^2 + 10g_p^4 Q_e^4 \right. \\
& - \frac{18}{5}g_1^2 g_p^2 Q_d Q_{H_d} - 6g_1^2 g_p^2 Q_e Q_{H_d} + \frac{12}{5}g_1^2 g_p^2 Q_{H_d}^2 + 6g_2^2 g_p^2 Q_{H_d}^2 + 18g_p^4 Q_d^2 Q_{H_d}^2 \\
& + 10g_p^4 Q_e^2 Q_{H_d}^2 + 8g_p^4 Q_{H_d}^4 + \frac{12}{5}g_1^2 g_p^2 Q_e Q_{H_u} - \frac{6}{5}g_1^2 g_p^2 Q_{H_d} Q_{H_u} + 4g_p^4 Q_e^2 Q_{H_u}^2 \\
& + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 - \frac{18}{5}g_1^2 g_p^2 Q_d Q_q - \frac{54}{5}g_1^2 g_p^2 Q_e Q_q + \frac{24}{5}g_1^2 g_p^2 Q_{H_d} Q_q - \frac{6}{5}g_1^2 g_p^2 Q_{H_u} Q_q \\
& + \frac{24}{5}g_1^2 g_p^2 Q_q^2 + 6g_2^2 g_p^2 Q_q^2 + 18g_p^4 Q_d^2 Q_q^2 + 18g_p^4 Q_e^2 Q_q^2 + 16g_p^4 Q_{H_d}^2 Q_q^2 \\
& + 4g_p^4 Q_{H_u}^2 Q_q^2 + 16g_p^4 Q_q^4 + \frac{36}{5}g_1^2 g_p^2 Q_e Q_q - \frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_q - \frac{18}{5}g_1^2 g_p^2 Q_q Q_q \\
& + 36g_p^4 Q_e^2 Q_q^2 + 36g_p^4 Q_{H_d}^2 Q_q^2 + 36g_p^4 Q_q^2 Q_q^2 + 2g_p^4 Q_e^2 Q_s^2 + 2g_p^4 Q_{H_d}^2 Q_s^2 \\
& + 2g_p^4 Q_q^2 Q_s^2 - \frac{72}{5}g_1^2 g_p^2 Q_e Q_u + \frac{36}{5}g_1^2 g_p^2 Q_{H_d} Q_u + \frac{36}{5}g_1^2 g_p^2 Q_q Q_u + 18g_p^4 Q_e^2 Q_u^2 \\
& + 18g_p^4 Q_{H_d}^2 Q_u^2 + 18g_p^4 Q_q^2 Q_u^2 + \frac{36}{5}g_1^2 g_p^2 Q_e Q_v - \frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_v - \frac{18}{5}g_1^2 g_p^2 Q_q Q_v \\
& + 6g_p^4 Q_e^2 Q_v^2 + 6g_p^4 Q_{H_d}^2 Q_v^2 + 6g_p^4 Q_q^2 Q_v^2 - 3\lambda^2 \lambda^{*,2} \\
& - \frac{2}{5} \left( -5 \left( 3g_p^2 \left( -Q_{H_d}^2 + Q_d^2 + Q_q^2 \right) + 8g_3^2 \right) + g_1^2 \right) \text{Tr} \left( Y_d Y_d^\dagger \right) + \frac{6}{5}g_1^2 \text{Tr} \left( Y_e Y_e^\dagger \right) + 2g_p^2 Q_e^2 \text{Tr} \left( Y_e Y_e^\dagger \right) \\
& - 2g_p^2 Q_{H_d}^2 \text{Tr} \left( Y_e Y_e^\dagger \right) + 2g_p^2 Q_q^2 \text{Tr} \left( Y_e Y_e^\dagger \right) \\
& - |\lambda|^2 \left( 2g_p^2 \left( -Q_{H_u}^2 - Q_s^2 + Q_{H_d}^2 \right) + 3\text{Tr} \left( Y_u Y_u^\dagger \right) + \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \right) - 9\text{Tr} \left( Y_d Y_d^\dagger Y_d Y_d^\dagger \right) \\
& - 3\text{Tr} \left( Y_d Y_u^\dagger Y_u Y_d^\dagger \right) - 3\text{Tr} \left( Y_e Y_e^\dagger Y_e Y_e^\dagger \right) - \text{Tr} \left( Y_\nu Y_\nu^\dagger Y_e^T Y_e^* \right)
\end{aligned} \tag{44}$$

$$\begin{aligned}
\beta_\lambda^{(1)} & = -\frac{3}{5}g_1^2 \lambda - 3g_2^2 \lambda - 2g_p^2 Q_{H_d}^2 \lambda - 2g_p^2 Q_{H_u}^2 \lambda - 2g_p^2 Q_s^2 \lambda + 4\lambda^2 \lambda^* + 3\lambda \text{Tr} \left( Y_d Y_d^\dagger \right) \\
& + \lambda \text{Tr} \left( Y_e Y_e^\dagger \right) + 3\lambda \text{Tr} \left( Y_u Y_u^\dagger \right) + \lambda \text{Tr} \left( Y_\nu Y_\nu^\dagger \right)
\end{aligned} \tag{45}$$

$$\begin{aligned}
\beta_\lambda^{(2)} = & -\frac{1}{50}\lambda\left(-261g_1^4 - 90g_1^2g_2^2 - 375g_2^4 + 180g_1^2g_p^2Q_dQ_{H_d} + 180g_1^2g_p^2Q_eQ_{H_d} - 120g_1^2g_p^2Q_{H_d}^2\right. \\
& - 300g_2^2g_p^2Q_{H_d}^2 - 900g_p^4Q_d^2Q_{H_d}^2 - 300g_p^4Q_e^2Q_{H_d}^2 - 400g_p^4Q_{H_d}^4 - 180g_1^2g_p^2Q_dQ_{H_u} \\
& - 180g_1^2g_p^2Q_eQ_{H_u} + 120g_1^2g_p^2Q_{H_d}Q_{H_u} - 120g_1^2g_p^2Q_{H_u}^2 - 300g_2^2g_p^2Q_{H_u}^2 \\
& - 900g_p^4Q_d^2Q_{H_u}^2 - 300g_p^4Q_e^2Q_{H_u}^2 - 400g_p^4Q_{H_d}^2Q_{H_u}^2 - 400g_p^4Q_{H_u}^4 - 180g_1^2g_p^2Q_{H_d}Q_q \\
& + 180g_1^2g_p^2Q_{H_u}Q_q - 600g_p^4Q_{H_d}^2Q_q^2 - 600g_p^4Q_{H_u}^2Q_q^2 + 180g_1^2g_p^2Q_{H_d}Q_q \\
& - 180g_1^2g_p^2Q_{H_u}Q_q - 1800g_p^4Q_{H_d}^2Q_q^2 - 1800g_p^4Q_{H_u}^2Q_q^2 - 900g_p^4Q_d^2Q_s^2 \\
& - 300g_p^4Q_e^2Q_s^2 - 300g_p^4Q_{H_d}^2Q_s^2 - 300g_p^4Q_{H_u}^2Q_s^2 - 600g_p^4Q_q^2Q_s^2 - 1800g_p^4Q_q^2Q_s^2 \\
& - 300g_p^4Q_s^4 - 360g_1^2g_p^2Q_{H_d}Q_u + 360g_1^2g_p^2Q_{H_u}Q_u - 900g_p^4Q_{H_d}^2Q_u^2 - 900g_p^4Q_{H_u}^2Q_u^2 \\
& - 900g_p^4Q_s^2Q_u^2 + 180g_1^2g_p^2Q_{H_d}Q_v - 180g_1^2g_p^2Q_{H_u}Q_v - 300g_p^4Q_{H_d}^2Q_v^2 \\
& - 300g_p^4Q_{H_u}^2Q_v^2 - 300g_p^4Q_s^2Q_v^2 + 500\lambda^2\lambda^{*,2} \\
& + 20\left(-5\left(3g_p^2\left(-Q_{H_d}^2 + Q_d^2 + Q_q^2\right) + 8g_3^2\right) + g_1^2\right)\text{Tr}\left(Y_dY_d^\dagger\right) - 60g_1^2\text{Tr}\left(Y_eY_e^\dagger\right) \\
& - 100g_p^2Q_e^2\text{Tr}\left(Y_eY_e^\dagger\right) + 100g_p^2Q_{H_d}^2\text{Tr}\left(Y_eY_e^\dagger\right) - 100g_p^2Q_q^2\text{Tr}\left(Y_eY_e^\dagger\right) \\
& - 40g_1^2\text{Tr}\left(Y_uY_u^\dagger\right) - 800g_3^2\text{Tr}\left(Y_uY_u^\dagger\right) + 300g_p^2Q_{H_u}^2\text{Tr}\left(Y_uY_u^\dagger\right) - 300g_p^2Q_q^2\text{Tr}\left(Y_uY_u^\dagger\right) \\
& - 300g_p^2Q_u^2\text{Tr}\left(Y_uY_u^\dagger\right) \\
& - 10|\lambda|^2\left(6g_1^2 + 30g_2^2 + 20g_p^2Q_{H_d}^2 + 20g_p^2Q_{H_u}^2 - 45\text{Tr}\left(Y_dY_d^\dagger\right) - 15\text{Tr}\left(Y_eY_e^\dagger\right) - 45\text{Tr}\left(Y_uY_u^\dagger\right)\right. \\
& \left. - 15\text{Tr}\left(Y_\nu Y_\nu^\dagger\right)\right) \\
& - 60g_1^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 100g_p^2Q_{H_u}^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) - 100g_p^2Q_q^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) \\
& - 100g_p^2Q_v^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 450\text{Tr}\left(Y_dY_d^\dagger Y_dY_d^\dagger\right) + 300\text{Tr}\left(Y_dY_u^\dagger Y_uY_d^\dagger\right) + 150\text{Tr}\left(Y_eY_e^\dagger Y_eY_e^\dagger\right) \\
& + 450\text{Tr}\left(Y_uY_u^\dagger Y_uY_u^\dagger\right) + 150\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger\right) + 100\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*\right) \Big) \tag{46}
\end{aligned}$$

$$\begin{aligned}
\beta_{Y_\nu}^{(1)} = & +3Y_\nu Y_\nu^\dagger Y_\nu + Y_e^T Y_e^* Y_\nu \\
& + Y_\nu\left(-2g_p^2Q_{H_u}^2 - 2g_p^2Q_q^2 - 2g_p^2Q_v^2 - 3g_2^2 + 3\text{Tr}\left(Y_uY_u^\dagger\right) - \frac{9}{5}g_1^2 + |\lambda|^2 + \text{Tr}\left(Y_\nu Y_\nu^\dagger\right)\right) \tag{47}
\end{aligned}$$

$$\begin{aligned}
\beta_{Y_\nu}^{(2)} = & +\frac{6}{5}g_1^2Y_e^T Y_e^* Y_\nu + 2g_p^2Q_e^2Y_e^T Y_e^* Y_\nu + 2g_p^2Q_{H_d}^2Y_e^T Y_e^* Y_\nu \\
& - 2g_p^2Q_q^2Y_e^T Y_e^* Y_\nu - |\lambda|^2Y_e^T Y_e^* Y_\nu - 4Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger Y_\nu - 2Y_\nu Y_\nu^\dagger Y_e^T Y_e^* Y_\nu \\
& - 2Y_e^T Y_e^* Y_e^T Y_e^* Y_\nu - 3Y_e^T Y_e^* Y_\nu \text{Tr}\left(Y_dY_d^\dagger\right) - Y_e^T Y_e^* Y_\nu \text{Tr}\left(Y_eY_e^\dagger\right) \\
& + Y_\nu Y_\nu^\dagger Y_\nu\left(2g_p^2Q_q^2 - 2g_p^2Q_v^2 - 3|\lambda|^2 - 3\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 6g_2^2 + 6g_p^2Q_{H_u}^2 - 9\text{Tr}\left(Y_uY_u^\dagger\right)\right) \\
& + Y_\nu\left(\frac{837}{50}g_1^4 + \frac{9}{5}g_1^2g_2^2 + \frac{15}{2}g_2^4 + \frac{18}{5}g_1^2g_p^2Q_dQ_{H_u} + \frac{18}{5}g_1^2g_p^2Q_eQ_{H_u} - \frac{6}{5}g_1^2g_p^2Q_{H_d}Q_{H_u}\right. \\
& \left.+ \frac{12}{5}g_1^2g_p^2Q_{H_u}^2 + 6g_2^2g_p^2Q_{H_u}^2 + 18g_p^4Q_d^2Q_{H_u}^2 + 6g_p^4Q_e^2Q_{H_u}^2 + 4g_p^4Q_{H_d}^2Q_{H_u}^2\right)
\end{aligned}$$

$$\begin{aligned}
& + 8g_p^4 Q_{H_u}^4 - \frac{18}{5} g_1^2 g_p^2 Q_d Q_q - \frac{18}{5} g_1^2 g_p^2 Q_e Q_q + \frac{6}{5} g_1^2 g_p^2 Q_{H_d} Q_q - \frac{24}{5} g_1^2 g_p^2 Q_{H_u} Q_q \\
& + \frac{24}{5} g_1^2 g_p^2 Q_q^2 + 6g_2^2 g_p^2 Q_q^2 + 18g_p^4 Q_d^2 Q_q^2 + 6g_p^4 Q_e^2 Q_q^2 + 4g_p^4 Q_{H_d}^2 Q_q^2 \\
& + 16g_p^4 Q_{H_u}^2 Q_q^2 + 16g_p^4 Q_q^4 + \frac{18}{5} g_1^2 g_p^2 Q_{H_u} Q_q - \frac{18}{5} g_1^2 g_p^2 Q_q Q_q + 36g_p^4 Q_{H_u}^2 Q_q^2 \\
& + 36g_p^4 Q_q^2 Q_q^2 + 2g_p^4 Q_{H_u}^2 Q_s^2 + 2g_p^4 Q_q^2 Q_s^2 - \frac{36}{5} g_1^2 g_p^2 Q_{H_u} Q_u + \frac{36}{5} g_1^2 g_p^2 Q_q Q_u \\
& + 18g_p^4 Q_{H_u}^2 Q_u^2 + 18g_p^4 Q_q^2 Q_u^2 + \frac{36}{5} g_1^2 g_p^2 Q_d Q_v + \frac{36}{5} g_1^2 g_p^2 Q_e Q_v - \frac{12}{5} g_1^2 g_p^2 Q_{H_d} Q_v \\
& + 6g_1^2 g_p^2 Q_{H_u} Q_v - \frac{54}{5} g_1^2 g_p^2 Q_q Q_v + \frac{36}{5} g_1^2 g_p^2 Q_q Q_v - \frac{72}{5} g_1^2 g_p^2 Q_u Q_v + 12g_1^2 g_p^2 Q_v^2 \\
& + 18g_p^4 Q_d^2 Q_v^2 + 6g_p^4 Q_e^2 Q_v^2 + 4g_p^4 Q_{H_d}^2 Q_v^2 + 10g_p^4 Q_{H_u}^2 Q_v^2 + 18g_p^4 Q_q^2 Q_v^2 \\
& + 36g_p^4 Q_q^2 Q_v^2 + 2g_p^4 Q_s^2 Q_v^2 + 18g_p^4 Q_u^2 Q_v^2 + 10g_p^4 Q_v^4 - 3\lambda^2 \lambda^{*,2} \\
& + |\lambda|^2 \left( 2g_p^2 \left( -Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2 \right) - 3\text{Tr} \left( Y_d Y_d^\dagger \right) - \text{Tr} \left( Y_e Y_e^\dagger \right) \right) \\
& + \frac{2}{5} \left( 2g_1^2 + 5 \left( 3g_p^2 \left( -Q_{H_u}^2 + Q_q^2 + Q_u^2 \right) + 8g_3^2 \right) \right) \text{Tr} \left( Y_u Y_u^\dagger \right) + \frac{6}{5} g_1^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \\
& - 2g_p^2 Q_{H_u}^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) + 2g_p^2 Q_q^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) + 2g_p^2 Q_v^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 3\text{Tr} \left( Y_d Y_u^\dagger Y_u Y_d^\dagger \right) \\
& - 9\text{Tr} \left( Y_u Y_u^\dagger Y_u Y_u^\dagger \right) - 3\text{Tr} \left( Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger \right) - \text{Tr} \left( Y_\nu Y_\nu^\dagger Y_e^T Y_e^* \right)
\end{aligned} \tag{48}$$

$$\begin{aligned}
\beta_{Y_u}^{(1)} & = +Y_u Y_d^\dagger Y_d + 3Y_u Y_u^\dagger Y_u \\
& + Y_u \left( -2g_p^2 Q_{H_u}^2 - 2g_p^2 Q_q^2 - 2g_p^2 Q_u^2 - 3g_2^2 + 3\text{Tr} \left( Y_u Y_u^\dagger \right) - \frac{13}{15} g_1^2 - \frac{16}{3} g_3^2 + |\lambda|^2 + \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \right)
\end{aligned} \tag{49}$$

$$\begin{aligned}
\beta_{Y_u}^{(2)} & = +\frac{2}{5} g_1^2 Y_u Y_u^\dagger Y_u + 6g_2^2 Y_u Y_u^\dagger Y_u + 6g_p^2 Q_{H_u}^2 Y_u Y_u^\dagger Y_u + 2g_p^2 Q_q^2 Y_u Y_u^\dagger Y_u \\
& - 2g_p^2 Q_u^2 Y_u Y_u^\dagger Y_u - 3|\lambda|^2 Y_u Y_u^\dagger Y_u - 2Y_u Y_d^\dagger Y_d Y_d^\dagger Y_d - 2Y_u Y_d^\dagger Y_d Y_u^\dagger Y_u \\
& - 4Y_u Y_u^\dagger Y_u Y_u^\dagger Y_u \\
& + Y_u Y_d^\dagger Y_d \left( 2g_p^2 Q_d^2 + 2g_p^2 Q_{H_d}^2 - 2g_p^2 Q_q^2 - 3\text{Tr} \left( Y_d Y_d^\dagger \right) + \frac{2}{5} g_1^2 - |\lambda|^2 - \text{Tr} \left( Y_e Y_e^\dagger \right) \right) \\
& - 9Y_u Y_u^\dagger Y_u \text{Tr} \left( Y_u Y_u^\dagger \right) - 3Y_u Y_u^\dagger Y_u \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \\
& + Y_u \left( \frac{689}{90} g_1^4 + g_1^2 g_2^2 + \frac{15}{2} g_2^4 + \frac{136}{45} g_1^2 g_3^2 + 8g_2^2 g_3^2 - \frac{16}{9} g_3^4 + \frac{18}{5} g_1^2 g_p^2 Q_d Q_{H_u} + \frac{18}{5} g_1^2 g_p^2 Q_e Q_{H_u} \right. \\
& - \frac{6}{5} g_1^2 g_p^2 Q_{H_d} Q_{H_u} + \frac{12}{5} g_1^2 g_p^2 Q_{H_u}^2 + 6g_2^2 g_p^2 Q_{H_u}^2 + 18g_p^4 Q_d^2 Q_{H_u}^2 + 6g_p^4 Q_e^2 Q_{H_u}^2 \\
& + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 + 8g_p^4 Q_{H_u}^4 - \frac{18}{5} g_1^2 g_p^2 Q_{H_u} Q_q + 12g_p^4 Q_{H_u}^2 Q_q^2 + \frac{6}{5} g_1^2 g_p^2 Q_d Q_q \\
& + \frac{6}{5} g_1^2 g_p^2 Q_e Q_q - \frac{2}{5} g_1^2 g_p^2 Q_{H_d} Q_q + 4g_1^2 g_p^2 Q_{H_u} Q_q - \frac{6}{5} g_1^2 g_p^2 Q_q Q_q + \frac{4}{3} g_1^2 g_p^2 Q_q^2 \\
& + 6g_2^2 g_p^2 Q_q^2 + \frac{32}{3} g_3^2 g_p^2 Q_q^2 + 18g_p^4 Q_d^2 Q_q^2 + 6g_p^4 Q_e^2 Q_q^2 + 4g_p^4 Q_{H_d}^2 Q_q^2 \\
& \left. + 40g_p^4 Q_{H_u}^2 Q_q^2 + 12g_p^4 Q_q^2 Q_q^2 + 40g_p^4 Q_q^4 + 2g_p^4 Q_{H_u}^2 Q_s^2 + 2g_p^4 Q_q^2 Q_s^2 \right)
\end{aligned}$$

$$\begin{aligned}
& -\frac{24}{5}g_1^2g_p^2Q_dQ_u - \frac{24}{5}g_1^2g_p^2Q_eQ_u + \frac{8}{5}g_1^2g_p^2Q_{H_d}Q_u - \frac{44}{5}g_1^2g_p^2Q_{H_u}Q_u + \frac{24}{5}g_1^2g_p^2Q_qQ_u \\
& -\frac{36}{5}g_1^2g_p^2Q_qQ_u + \frac{176}{15}g_1^2g_p^2Q_u^2 + \frac{32}{3}g_3^2g_p^2Q_u^2 + 18g_p^4Q_d^2Q_u^2 + 6g_p^4Q_e^2Q_u^2 \\
& + 4g_p^4Q_{H_d}^2Q_u^2 + 22g_p^4Q_{H_u}^2Q_u^2 + 12g_p^4Q_q^2Q_u^2 + 54g_p^4Q_q^2Q_u^2 + 2g_p^4Q_s^2Q_u^2 + 22g_p^4Q_u^4 \\
& + \frac{18}{5}g_1^2g_p^2Q_{H_u}Q_v + \frac{6}{5}g_1^2g_p^2Q_qQ_v - \frac{24}{5}g_1^2g_p^2Q_uQ_v + 6g_p^4Q_{H_u}^2Q_v^2 + 6g_p^4Q_q^2Q_v^2 \\
& + 6g_p^4Q_u^2Q_v^2 - 3\lambda^2\lambda^{*,2} + |\lambda|^2\left(2g_p^2\left(-Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2\right) - 3\text{Tr}\left(Y_dY_d^\dagger\right) - \text{Tr}\left(Y_eY_e^\dagger\right)\right) \\
& + \frac{2}{5}\left(2g_1^2 + 5\left(3g_p^2\left(-Q_{H_u}^2 + Q_q^2 + Q_u^2\right) + 8g_3^2\right)\right)\text{Tr}\left(Y_uY_u^\dagger\right) + \frac{6}{5}g_1^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) \\
& - 2g_p^2Q_{H_u}^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 2g_p^2Q_q^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 2g_p^2Q_v^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) - 3\text{Tr}\left(Y_dY_u^\dagger Y_uY_d^\dagger\right) \\
& - 9\text{Tr}\left(Y_uY_u^\dagger Y_uY_u^\dagger\right) - 3\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger\right) - \text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*\right)
\end{aligned} \tag{50}$$

### 3.5 Trilinear Soft-Breaking Parameters

$$\begin{aligned}
\beta_{T_d}^{(1)} & = +4Y_dY_d^\dagger T_d + 2Y_dY_u^\dagger T_u + 5T_dY_d^\dagger Y_d + T_dY_u^\dagger Y_u - \frac{7}{15}g_1^2T_d - 3g_2^2T_d - \frac{16}{3}g_3^2T_d \\
& - 2g_p^2Q_d^2T_d - 2g_p^2Q_{H_d}^2T_d - 2g_p^2Q_q^2T_d + |\lambda|^2T_d + 3T_d\text{Tr}\left(Y_dY_d^\dagger\right) + T_d\text{Tr}\left(Y_eY_e^\dagger\right) \\
& + Y_d\left(\frac{14}{15}g_1^2M_1 + \frac{32}{3}g_3^2M_3 + 6g_2^2M_2 + 4g_p^2M_ZQ_d^2 + 4g_p^2M_ZQ_{H_d}^2 + 4g_p^2M_ZQ_q^2 + 2\lambda^*T_\lambda + 6\text{Tr}\left(Y_d^\dagger T_d\right)\right) \\
& + 2\text{Tr}\left(Y_e^\dagger T_e\right)
\end{aligned} \tag{51}$$

$$\begin{aligned}
\beta_{T_d}^{(2)} & = +\frac{6}{5}g_1^2Y_dY_d^\dagger T_d + 6g_2^2Y_dY_d^\dagger T_d + 8g_p^2Q_{H_d}^2Y_dY_d^\dagger T_d - 4|\lambda|^2Y_dY_d^\dagger T_d \\
& - \frac{8}{5}g_1^2M_1Y_dY_u^\dagger Y_u - 4g_p^2M_ZQ_{H_u}^2Y_dY_u^\dagger Y_u + 4g_p^2M_ZQ_q^2Y_dY_u^\dagger Y_u \\
& - 4g_p^2M_ZQ_u^2Y_dY_u^\dagger Y_u + \frac{8}{5}g_1^2Y_dY_u^\dagger T_u + 4g_p^2Q_{H_u}^2Y_dY_u^\dagger T_u \\
& - 4g_p^2Q_q^2Y_dY_u^\dagger T_u + 4g_p^2Q_u^2Y_dY_u^\dagger T_u - 2|\lambda|^2Y_dY_u^\dagger T_u \\
& + \frac{6}{5}g_1^2T_dY_d^\dagger Y_d + 12g_2^2T_dY_d^\dagger Y_d - 6g_p^2Q_d^2T_dY_d^\dagger Y_d \\
& + 10g_p^2Q_{H_d}^2T_dY_d^\dagger Y_d + 6g_p^2Q_q^2T_dY_d^\dagger Y_d - 5|\lambda|^2T_dY_d^\dagger Y_d \\
& + \frac{4}{5}g_1^2T_dY_u^\dagger Y_u + 2g_p^2Q_{H_u}^2T_dY_u^\dagger Y_u - 2g_p^2Q_q^2T_dY_u^\dagger Y_u \\
& + 2g_p^2Q_u^2T_dY_u^\dagger Y_u - |\lambda|^2T_dY_u^\dagger Y_u - 6Y_dY_d^\dagger Y_dY_d^\dagger T_d - 8Y_dY_d^\dagger T_dY_d^\dagger Y_d \\
& - 2Y_dY_u^\dagger Y_uY_d^\dagger T_d - 4Y_dY_u^\dagger Y_uY_u^\dagger T_u - 4Y_dY_u^\dagger T_uY_d^\dagger Y_d - 4Y_dY_u^\dagger T_uY_u^\dagger Y_u \\
& - 6T_dY_d^\dagger Y_dY_d^\dagger Y_d - 4T_dY_u^\dagger Y_uY_d^\dagger Y_d - 2T_dY_u^\dagger Y_uY_u^\dagger Y_u + \frac{1813}{450}g_1^4T_d + g_1^2g_2^2T_d \\
& + \frac{15}{2}g_2^4T_d + \frac{8}{9}g_1^2g_3^2T_d + 8g_2^2g_3^2T_d - \frac{16}{9}g_3^4T_d + \frac{44}{15}g_1^2g_p^2Q_d^2T_d + \frac{32}{3}g_3^2g_p^2Q_d^2T_d
\end{aligned}$$

$$\begin{aligned}
& + 22g_p^4 Q_d^4 T_d + \frac{12}{5} g_1^2 g_p^2 Q_d Q_e T_d + 6g_p^4 Q_d^2 Q_e^2 T_d - \frac{22}{5} g_1^2 g_p^2 Q_d Q_{H_d} T_d \\
& - \frac{18}{5} g_1^2 g_p^2 Q_e Q_{H_d} T_d + \frac{12}{5} g_1^2 g_p^2 Q_{H_d}^2 T_d + 6g_2^2 g_p^2 Q_{H_d}^2 T_d + 22g_p^4 Q_d^2 Q_{H_d}^2 T_d \\
& + 6g_p^4 Q_e^2 Q_{H_d}^2 T_d + 8g_p^4 Q_{H_d}^4 T_d + \frac{4}{5} g_1^2 g_p^2 Q_d Q_{H_u} T_d - \frac{6}{5} g_1^2 g_p^2 Q_{H_d} Q_{H_u} T_d \\
& + 4g_p^4 Q_d^2 Q_{H_u}^2 T_d + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 T_d - \frac{12}{5} g_1^2 g_p^2 Q_d Q_q T_d + \frac{18}{5} g_1^2 g_p^2 Q_{H_d} Q_q T_d \\
& + 12g_p^4 Q_d^2 Q_q^2 T_d + 12g_p^4 Q_{H_d}^2 Q_q^2 T_d + \frac{18}{5} g_1^2 g_p^2 Q_d Q_q T_d + \frac{6}{5} g_1^2 g_p^2 Q_e Q_q T_d \\
& - 4g_1^2 g_p^2 Q_{H_d} Q_q T_d + \frac{2}{5} g_1^2 g_p^2 Q_{H_u} Q_q T_d - \frac{6}{5} g_1^2 g_p^2 Q_q Q_q T_d + \frac{4}{3} g_1^2 g_p^2 Q_q^2 T_d \\
& + 6g_2^2 g_p^2 Q_q^2 T_d + \frac{32}{3} g_3^2 g_p^2 Q_q^2 T_d + 54g_p^4 Q_d^2 Q_q^2 T_d + 6g_p^4 Q_e^2 Q_q^2 T_d \\
& + 40g_p^4 Q_{H_d}^2 Q_q^2 T_d + 4g_p^4 Q_{H_u}^2 Q_q^2 T_d + 12g_p^4 Q_q^2 Q_q^2 T_d + 40g_p^4 Q_q^4 T_d + 2g_p^4 Q_d^2 Q_s^2 T_d \\
& + 2g_p^4 Q_{H_d}^2 Q_s^2 T_d + 2g_p^4 Q_q^2 Q_s^2 T_d - \frac{24}{5} g_1^2 g_p^2 Q_d Q_u T_d + \frac{36}{5} g_1^2 g_p^2 Q_{H_d} Q_u T_d \\
& - \frac{12}{5} g_1^2 g_p^2 Q_q Q_u T_d + 18g_p^4 Q_d^2 Q_u^2 T_d + 18g_p^4 Q_{H_d}^2 Q_u^2 T_d + 18g_p^4 Q_q^2 Q_u^2 T_d \\
& + \frac{12}{5} g_1^2 g_p^2 Q_d Q_v T_d - \frac{18}{5} g_1^2 g_p^2 Q_{H_d} Q_v T_d + \frac{6}{5} g_1^2 g_p^2 Q_q Q_v T_d + 6g_p^4 Q_d^2 Q_v^2 T_d \\
& + 6g_p^4 Q_{H_d}^2 Q_v^2 T_d + 6g_p^4 Q_q^2 Q_v^2 T_d - 2g_p^2 Q_{H_d}^2 |\lambda|^2 T_d + 2g_p^2 Q_{H_u}^2 |\lambda|^2 T_d \\
& + 2g_p^2 Q_s^2 |\lambda|^2 T_d - 3\lambda^* \lambda^{*2} T_d - 2\lambda^* Y_d Y_u^\dagger Y_u T_\lambda - 12Y_d Y_d^\dagger T_d \text{Tr}(Y_d Y_d^\dagger) \\
& - 15T_d Y_d^\dagger Y_d \text{Tr}(Y_d Y_d^\dagger) - \frac{2}{5} g_1^2 T_d \text{Tr}(Y_d Y_d^\dagger) + 16g_3^2 T_d \text{Tr}(Y_d Y_d^\dagger) \\
& + 6g_p^2 Q_d^2 T_d \text{Tr}(Y_d Y_d^\dagger) - 6g_p^2 Q_{H_d}^2 T_d \text{Tr}(Y_d Y_d^\dagger) + 6g_p^2 Q_q^2 T_d \text{Tr}(Y_d Y_d^\dagger) \\
& - 4Y_d Y_d^\dagger T_d \text{Tr}(Y_e Y_e^\dagger) - 5T_d Y_d^\dagger Y_d \text{Tr}(Y_e Y_e^\dagger) + \frac{6}{5} g_1^2 T_d \text{Tr}(Y_e Y_e^\dagger) \\
& + 2g_p^2 Q_e^2 T_d \text{Tr}(Y_e Y_e^\dagger) - 2g_p^2 Q_{H_d}^2 T_d \text{Tr}(Y_e Y_e^\dagger) + 2g_p^2 Q_q^2 T_d \text{Tr}(Y_e Y_e^\dagger) \\
& - 6Y_d Y_u^\dagger T_u \text{Tr}(Y_u Y_u^\dagger) - 3T_d Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) - 3|\lambda|^2 T_d \text{Tr}(Y_u Y_u^\dagger) \\
& - 2Y_d Y_u^\dagger T_u \text{Tr}(Y_\nu Y_\nu^\dagger) - T_d Y_u^\dagger Y_u \text{Tr}(Y_\nu Y_\nu^\dagger) - |\lambda|^2 T_d \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& - \frac{2}{5} Y_d Y_d^\dagger Y_d (4g_1^2 M_1 + 30g_2^2 M_2 - 10g_p^2 M_Z Q_d^2 + 30g_p^2 M_Z Q_{H_d}^2 + 10g_p^2 M_Z Q_q^2 + 15\lambda^* T_\lambda + 45\text{Tr}(Y_d^\dagger T_d) \\
& + 15\text{Tr}(Y_e^\dagger T_e)) \\
& - 6Y_d Y_u^\dagger Y_u \text{Tr}(Y_u^\dagger T_u) - 2Y_d Y_u^\dagger Y_u \text{Tr}(Y_\nu^\dagger T_\nu) - 9T_d \text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) \\
& - 3T_d \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 3T_d \text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) - T_d \text{Tr}(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*) \\
& - \frac{2}{225} Y_d (1813g_1^4 M_1 + 225g_1^2 g_2^2 M_1 + 200g_1^2 g_3^2 M_1 + 200g_1^2 g_3^2 M_3 + 1800g_2^2 g_3^2 M_3 - 800g_3^4 M_3
\end{aligned}$$

$$\begin{aligned}
& + 225g_1^2g_2^2M_2 + 3375g_2^4M_2 + 1800g_2^2g_3^2M_2 + 660g_1^2g_p^2M_1Q_d^2 + 2400g_3^2g_p^2M_3Q_d^2 \\
& + 660g_1^2g_p^2M_ZQ_d^2 + 2400g_3^2g_p^2M_ZQ_d^2 + 9900g_p^4M_ZQ_d^4 + 540g_1^2g_p^2M_1Q_dQ_e \\
& + 540g_1^2g_p^2M_ZQ_dQ_e + 2700g_p^4M_ZQ_d^2Q_e^2 - 990g_1^2g_p^2M_1Q_dQ_{H_d} - 990g_1^2g_p^2M_ZQ_dQ_{H_d} \\
& - 810g_1^2g_p^2M_1Q_eQ_{H_d} - 810g_1^2g_p^2M_ZQ_eQ_{H_d} + 540g_1^2g_p^2M_1Q_{H_d}^2 + 540g_1^2g_p^2M_ZQ_{H_d}^2 \\
& + 1350g_2^2g_p^2M_ZQ_{H_d}^2 + 1350g_2^2g_p^2M_2Q_{H_d}^2 + 9900g_p^4M_ZQ_d^2Q_{H_d}^2 + 2700g_p^4M_ZQ_e^2Q_{H_d}^2 \\
& + 3600g_p^4M_ZQ_{H_d}^4 + 180g_1^2g_p^2M_1Q_dQ_{H_u} + 180g_1^2g_p^2M_ZQ_dQ_{H_u} - 270g_1^2g_p^2M_1Q_{H_d}Q_{H_u} \\
& - 270g_1^2g_p^2M_ZQ_{H_d}Q_{H_u} + 1800g_p^4M_ZQ_d^2Q_{H_u}^2 + 1800g_p^4M_ZQ_{H_d}^2Q_{H_u}^2 - 540g_1^2g_p^2M_1Q_dQ_q \\
& - 540g_1^2g_p^2M_ZQ_dQ_q + 810g_1^2g_p^2M_1Q_{H_d}Q_q + 810g_1^2g_p^2M_ZQ_{H_d}Q_q + 5400g_p^4M_ZQ_d^2Q_q^2 \\
& + 5400g_p^4M_ZQ_{H_d}^2Q_q^2 + 810g_1^2g_p^2M_1Q_dQ_q + 810g_1^2g_p^2M_ZQ_dQ_q + 270g_1^2g_p^2M_1Q_eQ_q \\
& + 270g_1^2g_p^2M_ZQ_eQ_q - 900g_1^2g_p^2M_1Q_{H_d}Q_q - 900g_1^2g_p^2M_ZQ_{H_d}Q_q + 90g_1^2g_p^2M_1Q_{H_u}Q_q \\
& + 90g_1^2g_p^2M_ZQ_{H_u}Q_q - 270g_1^2g_p^2M_1Q_qQ_q - 270g_1^2g_p^2M_ZQ_qQ_q + 300g_1^2g_p^2M_1Q_q^2 \\
& + 2400g_3^2g_p^2M_3Q_q^2 + 300g_1^2g_p^2M_ZQ_q^2 + 1350g_2^2g_p^2M_ZQ_q^2 + 2400g_3^2g_p^2M_ZQ_q^2 \\
& + 1350g_2^2g_p^2M_2Q_q^2 + 24300g_p^4M_ZQ_d^2Q_q^2 + 2700g_p^4M_ZQ_e^2Q_q^2 + 18000g_p^4M_ZQ_{H_d}^2Q_q^2 \\
& + 1800g_p^4M_ZQ_{H_u}^2Q_q^2 + 5400g_p^4M_ZQ_q^2Q_q^2 + 18000g_p^4M_ZQ_q^4 + 900g_p^4M_ZQ_d^2Q_s^2 \\
& + 900g_p^4M_ZQ_{H_d}^2Q_s^2 + 900g_p^4M_ZQ_q^2Q_s^2 - 1080g_1^2g_p^2M_1Q_dQ_u - 1080g_1^2g_p^2M_ZQ_dQ_u \\
& + 1620g_1^2g_p^2M_1Q_{H_d}Q_u + 1620g_1^2g_p^2M_ZQ_{H_d}Q_u - 540g_1^2g_p^2M_1Q_qQ_u - 540g_1^2g_p^2M_ZQ_qQ_u \\
& + 8100g_p^4M_ZQ_d^2Q_u^2 + 8100g_p^4M_ZQ_{H_d}^2Q_u^2 + 8100g_p^4M_ZQ_q^2Q_u^2 + 540g_1^2g_p^2M_1Q_dQ_v \\
& + 540g_1^2g_p^2M_ZQ_dQ_v - 810g_1^2g_p^2M_1Q_{H_d}Q_v - 810g_1^2g_p^2M_ZQ_{H_d}Q_v + 270g_1^2g_p^2M_1Q_qQ_v \\
& + 270g_1^2g_p^2M_ZQ_qQ_v + 2700g_p^4M_ZQ_d^2Q_v^2 + 2700g_p^4M_ZQ_{H_d}^2Q_v^2 + 2700g_p^4M_ZQ_q^2Q_v^2 \\
& + 1350\lambda\lambda^{*2}T_\lambda - 90\left(-5\left(3g_p^2M_Z\left(-Q_{H_d}^2+Q_d^2+Q_q^2\right)+8g_3^2M_3\right)+g_1^2M_1\right)\text{Tr}\left(Y_dY_d^\dagger\right) \\
& + 270g_1^2M_1\text{Tr}\left(Y_eY_e^\dagger\right)+450g_p^2M_ZQ_e^2\text{Tr}\left(Y_eY_e^\dagger\right)-450g_p^2M_ZQ_{H_d}^2\text{Tr}\left(Y_eY_e^\dagger\right) \\
& + 450g_p^2M_ZQ_q^2\text{Tr}\left(Y_eY_e^\dagger\right)+90g_1^2\text{Tr}\left(Y_d^\dagger T_d\right)-3600g_3^2\text{Tr}\left(Y_d^\dagger T_d\right)-1350g_p^2Q_d^2\text{Tr}\left(Y_d^\dagger T_d\right) \\
& + 1350g_p^2Q_{H_d}^2\text{Tr}\left(Y_d^\dagger T_d\right)-1350g_p^2Q_q^2\text{Tr}\left(Y_d^\dagger T_d\right)-270g_1^2\text{Tr}\left(Y_e^\dagger T_e\right) \\
& - 450g_p^2Q_e^2\text{Tr}\left(Y_e^\dagger T_e\right)+450g_p^2Q_{H_d}^2\text{Tr}\left(Y_e^\dagger T_e\right)-450g_p^2Q_q^2\text{Tr}\left(Y_e^\dagger T_e\right) \\
& - 225\lambda^*\left(-T_\lambda\left(2g_p^2\left(-Q_{H_u}^2-Q_s^2+Q_{H_d}^2\right)+3\text{Tr}\left(Y_uY_u^\dagger\right)+\text{Tr}\left(Y_\nu Y_\nu^\dagger\right)\right)\right. \\
& \left.+\lambda\left(2g_p^2M_Z\left(-Q_{H_u}^2-Q_s^2+Q_{H_d}^2\right)-3\text{Tr}\left(Y_u^\dagger T_u\right)-\text{Tr}\left(Y_\nu^\dagger T_\nu\right)\right)\right) \\
& + 4050\text{Tr}\left(Y_dY_d^\dagger T_dY_d^\dagger\right)+675\text{Tr}\left(Y_dY_u^\dagger T_uY_d^\dagger\right)+1350\text{Tr}\left(Y_eY_e^\dagger T_eY_e^\dagger\right)+675\text{Tr}\left(Y_uY_d^\dagger T_dY_u^\dagger\right) \\
& + 225\text{Tr}\left(Y_e^\dagger T_eY_\nu^*Y_\nu^T\right)+225\text{Tr}\left(Y_\nu^\dagger Y_e^TY_e^*T_\nu\right)
\end{aligned} \tag{52}$$

$$\begin{aligned}
\beta_{T_e}^{(1)} & = +4Y_eY_e^\dagger T_e + 2Y_eY_\nu^*T_\nu^T + 5T_eY_e^\dagger Y_e + T_eY_\nu^*Y_\nu^T - \frac{9}{5}g_1^2T_e - 3g_2^2T_e \\
& - 2g_p^2Q_e^2T_e - 2g_p^2Q_{H_d}^2T_e - 2g_p^2Q_q^2T_e + |\lambda|^2T_e + 3T_e\text{Tr}\left(Y_dY_d^\dagger\right) + T_e\text{Tr}\left(Y_eY_e^\dagger\right)
\end{aligned}$$



$$\begin{aligned}
& + Y_e \left( \frac{18}{5} g_1^2 M_1 + 6g_2^2 M_2 + 4g_p^2 M_Z Q_e^2 + 4g_p^2 M_Z Q_{H_d}^2 + 4g_p^2 M_Z Q_q^2 + 2\lambda^* T_\lambda + 6\text{Tr} \left( Y_d^\dagger T_d \right) \right. \\
& \left. + 2\text{Tr} \left( Y_e^\dagger T_e \right) \right) \\
\beta_{T_e}^{(2)} = & + \frac{6}{5} g_1^2 Y_e Y_e^\dagger T_e + 6g_2^2 Y_e Y_e^\dagger T_e + 8g_p^2 Q_{H_d}^2 Y_e Y_e^\dagger T_e - 4|\lambda|^2 Y_e Y_e^\dagger T_e \\
& - \frac{12}{5} g_1^2 M_1 Y_e Y_\nu^* Y_\nu^T - 4g_p^2 M_Z Q_{H_u}^2 Y_e Y_\nu^* Y_\nu^T + 4g_p^2 M_Z Q_q^2 Y_e Y_\nu^* Y_\nu^T \\
& - 4g_p^2 M_Z Q_v^2 Y_e Y_\nu^* Y_\nu^T + \frac{12}{5} g_1^2 Y_e Y_\nu^* T_\nu^T + 4g_p^2 Q_{H_u}^2 Y_e Y_\nu^* T_\nu^T \\
& - 4g_p^2 Q_q^2 Y_e Y_\nu^* T_\nu^T + 4g_p^2 Q_v^2 Y_e Y_\nu^* T_\nu^T - 2|\lambda|^2 Y_e Y_\nu^* T_\nu^T \\
& - \frac{6}{5} g_1^2 T_e Y_e^\dagger Y_e + 12g_2^2 T_e Y_e^\dagger Y_e - 6g_p^2 Q_e^2 T_e Y_e^\dagger Y_e \\
& + 10g_p^2 Q_{H_d}^2 T_e Y_e^\dagger Y_e + 6g_p^2 Q_q^2 T_e Y_e^\dagger Y_e - 5|\lambda|^2 T_e Y_e^\dagger Y_e \\
& + \frac{6}{5} g_1^2 T_e Y_\nu^* Y_\nu^T + 2g_p^2 Q_{H_u}^2 T_e Y_\nu^* Y_\nu^T - 2g_p^2 Q_q^2 T_e Y_\nu^* Y_\nu^T \\
& + 2g_p^2 Q_v^2 T_e Y_\nu^* Y_\nu^T - |\lambda|^2 T_e Y_\nu^* Y_\nu^T - 6Y_e Y_e^\dagger Y_e Y_e^\dagger T_e - 8Y_e Y_e^\dagger T_e Y_e^\dagger Y_e \\
& - 2Y_e Y_\nu^* Y_\nu^T Y_e^\dagger T_e - 4Y_e Y_\nu^* Y_\nu^T Y_\nu^* T_\nu^T - 4Y_e Y_\nu^* T_\nu^T Y_e^\dagger Y_e - 4Y_e Y_\nu^* T_\nu^T Y_\nu^* Y_\nu^T \\
& - 6T_e Y_e^\dagger Y_e Y_e^\dagger Y_e - 4T_e Y_\nu^* Y_\nu^T Y_e^\dagger Y_e - 2T_e Y_\nu^* Y_\nu^T Y_\nu^* Y_\nu^T + \frac{837}{50} g_1^4 T_e + \frac{9}{5} g_1^2 g_2^2 T_e \\
& + \frac{15}{2} g_2^4 T_e + \frac{36}{5} g_1^2 g_p^2 Q_d Q_e T_e + 12g_1^2 g_p^2 Q_e^2 T_e + 18g_p^4 Q_d^2 Q_e^2 T_e + 10g_p^4 Q_e^4 T_e \\
& - \frac{18}{5} g_1^2 g_p^2 Q_d Q_{H_d} T_e - 6g_1^2 g_p^2 Q_e Q_{H_d} T_e + \frac{12}{5} g_1^2 g_p^2 Q_{H_d}^2 T_e + 6g_2^2 g_p^2 Q_{H_d}^2 T_e \\
& + 18g_p^4 Q_d^2 Q_{H_d}^2 T_e + 10g_p^4 Q_e^2 Q_{H_d}^2 T_e + 8g_p^4 Q_{H_d}^4 T_e + \frac{12}{5} g_1^2 g_p^2 Q_e Q_{H_u} T_e \\
& - \frac{6}{5} g_1^2 g_p^2 Q_{H_d} Q_{H_u} T_e + 4g_p^4 Q_e^2 Q_{H_u}^2 T_e + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 T_e - \frac{18}{5} g_1^2 g_p^2 Q_d Q_q T_e \\
& - \frac{54}{5} g_1^2 g_p^2 Q_e Q_q T_e + \frac{24}{5} g_1^2 g_p^2 Q_{H_d} Q_q T_e - \frac{6}{5} g_1^2 g_p^2 Q_{H_u} Q_q T_e + \frac{24}{5} g_1^2 g_p^2 Q_q^2 T_e \\
& + 6g_2^2 g_p^2 Q_q^2 T_e + 18g_p^4 Q_d^2 Q_q^2 T_e + 18g_p^4 Q_e^2 Q_q^2 T_e + 16g_p^4 Q_{H_d}^2 Q_q^2 T_e \\
& + 4g_p^4 Q_{H_u}^2 Q_q^2 T_e + 16g_p^4 Q_q^4 T_e + \frac{36}{5} g_1^2 g_p^2 Q_e Q_q T_e - \frac{18}{5} g_1^2 g_p^2 Q_{H_d} Q_q T_e \\
& - \frac{18}{5} g_1^2 g_p^2 Q_q Q_q T_e + 36g_p^4 Q_e^2 Q_q^2 T_e + 36g_p^4 Q_{H_d}^2 Q_q^2 T_e + 36g_p^4 Q_q^2 Q_q^2 T_e \\
& + 2g_p^4 Q_e^2 Q_s^2 T_e + 2g_p^4 Q_{H_d}^2 Q_s^2 T_e + 2g_p^4 Q_q^2 Q_s^2 T_e - \frac{72}{5} g_1^2 g_p^2 Q_e Q_u T_e \\
& + \frac{36}{5} g_1^2 g_p^2 Q_{H_d} Q_u T_e + \frac{36}{5} g_1^2 g_p^2 Q_q Q_u T_e + 18g_p^4 Q_e^2 Q_u^2 T_e + 18g_p^4 Q_{H_d}^2 Q_u^2 T_e \\
& + 18g_p^4 Q_q^2 Q_u^2 T_e + \frac{36}{5} g_1^2 g_p^2 Q_e Q_v T_e - \frac{18}{5} g_1^2 g_p^2 Q_{H_d} Q_v T_e - \frac{18}{5} g_1^2 g_p^2 Q_q Q_v T_e \\
& + 6g_p^4 Q_e^2 Q_v^2 T_e + 6g_p^4 Q_{H_d}^2 Q_v^2 T_e + 6g_p^4 Q_q^2 Q_v^2 T_e - 2g_p^2 Q_{H_d}^2 |\lambda|^2 T_e \\
& + 2g_p^2 Q_{H_u}^2 |\lambda|^2 T_e + 2g_p^2 Q_s^2 |\lambda|^2 T_e - 3\lambda^2 \lambda^{*2} T_e - 2\lambda^* Y_e Y_\nu^* Y_\nu^T T_\lambda
\end{aligned} \tag{53}$$

$$\begin{aligned}
& -12Y_e Y_e^\dagger T_e \text{Tr}(Y_d Y_d^\dagger) - 15T_e Y_e^\dagger Y_e \text{Tr}(Y_d Y_d^\dagger) - \frac{2}{5}g_1^2 T_e \text{Tr}(Y_d Y_d^\dagger) \\
& + 16g_3^2 T_e \text{Tr}(Y_d Y_d^\dagger) + 6g_p^2 Q_d^2 T_e \text{Tr}(Y_d Y_d^\dagger) - 6g_p^2 Q_{H_d}^2 T_e \text{Tr}(Y_d Y_d^\dagger) \\
& + 6g_p^2 Q_q^2 T_e \text{Tr}(Y_d Y_d^\dagger) - 4Y_e Y_e^\dagger T_e \text{Tr}(Y_e Y_e^\dagger) - 5T_e Y_e^\dagger Y_e \text{Tr}(Y_e Y_e^\dagger) \\
& + \frac{6}{5}g_1^2 T_e \text{Tr}(Y_e Y_e^\dagger) + 2g_p^2 Q_e^2 T_e \text{Tr}(Y_e Y_e^\dagger) - 2g_p^2 Q_{H_d}^2 T_e \text{Tr}(Y_e Y_e^\dagger) \\
& + 2g_p^2 Q_q^2 T_e \text{Tr}(Y_e Y_e^\dagger) - 6Y_e Y_\nu^* T_\nu^T \text{Tr}(Y_u Y_u^\dagger) - 3T_e Y_\nu^* Y_\nu^T \text{Tr}(Y_u Y_u^\dagger) \\
& - 3|\lambda|^2 T_e \text{Tr}(Y_u Y_u^\dagger) - 2Y_e Y_\nu^* T_\nu^T \text{Tr}(Y_\nu Y_\nu^\dagger) - T_e Y_\nu^* Y_\nu^T \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& - |\lambda|^2 T_e \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& - 2Y_e Y_e^\dagger Y_e \left( -2g_p^2 M_Z Q_e^2 + 2g_p^2 M_Z Q_q^2 + 3\lambda^* T_\lambda + 3\text{Tr}(Y_e^\dagger T_e) + 6g_2^2 M_2 + 6g_p^2 M_Z Q_{H_d}^2 + 9\text{Tr}(Y_d^\dagger T_d) \right) \\
& - 6Y_e Y_\nu^* Y_\nu^T \text{Tr}(Y_u^\dagger T_u) - 2Y_e Y_\nu^* Y_\nu^T \text{Tr}(Y_\nu^\dagger T_\nu) - 9T_e \text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) \\
& - 3T_e \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 3T_e \text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) - T_e \text{Tr}(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*) \\
& - \frac{2}{25}Y_e \left( 837g_1^4 M_1 + 45g_1^2 g_2^2 M_1 + 45g_1^2 g_2^2 M_2 + 375g_2^4 M_2 + 180g_1^2 g_p^2 M_1 Q_d Q_e \right. \\
& + 180g_1^2 g_p^2 M_Z Q_d Q_e + 300g_1^2 g_p^2 M_1 Q_e^2 + 300g_1^2 g_p^2 M_Z Q_e^2 + 900g_1^4 M_Z Q_d^2 Q_e^2 \\
& + 500g_p^4 M_Z Q_e^4 - 90g_1^2 g_p^2 M_1 Q_d Q_{H_d} - 90g_1^2 g_p^2 M_Z Q_d Q_{H_d} - 150g_1^2 g_p^2 M_1 Q_e Q_{H_d} \\
& - 150g_1^2 g_p^2 M_Z Q_e Q_{H_d} + 60g_1^2 g_p^2 M_1 Q_{H_d}^2 + 60g_1^2 g_p^2 M_Z Q_{H_d}^2 + 150g_2^2 g_p^2 M_Z Q_{H_d}^2 \\
& + 150g_2^2 g_p^2 M_2 Q_{H_d}^2 + 900g_p^4 M_Z Q_d^2 Q_{H_d}^2 + 500g_p^4 M_Z Q_e^2 Q_{H_d}^2 + 400g_p^4 M_Z Q_{H_d}^4 \\
& + 60g_1^2 g_p^2 M_1 Q_e Q_{H_u} + 60g_1^2 g_p^2 M_Z Q_e Q_{H_u} - 30g_1^2 g_p^2 M_1 Q_{H_d} Q_{H_u} - 30g_1^2 g_p^2 M_Z Q_{H_d} Q_{H_u} \\
& + 200g_p^4 M_Z Q_e^2 Q_{H_u}^2 + 200g_p^4 M_Z Q_{H_d}^2 Q_{H_u}^2 - 90g_1^2 g_p^2 M_1 Q_d Q_q - 90g_1^2 g_p^2 M_Z Q_d Q_q \\
& - 270g_1^2 g_p^2 M_1 Q_e Q_q - 270g_1^2 g_p^2 M_Z Q_e Q_q + 120g_1^2 g_p^2 M_1 Q_{H_d} Q_q + 120g_1^2 g_p^2 M_Z Q_{H_d} Q_q \\
& - 30g_1^2 g_p^2 M_1 Q_{H_u} Q_q - 30g_1^2 g_p^2 M_Z Q_{H_u} Q_q + 120g_1^2 g_p^2 M_1 Q_q^2 + 120g_1^2 g_p^2 M_Z Q_q^2 \\
& + 150g_2^2 g_p^2 M_Z Q_q^2 + 150g_2^2 g_p^2 M_2 Q_q^2 + 900g_p^4 M_Z Q_d^2 Q_q^2 + 900g_p^4 M_Z Q_e^2 Q_q^2 \\
& + 800g_p^4 M_Z Q_{H_d}^2 Q_q^2 + 200g_p^4 M_Z Q_{H_u}^2 Q_q^2 + 800g_p^4 M_Z Q_q^4 + 180g_1^2 g_p^2 M_1 Q_e Q_q \\
& + 180g_1^2 g_p^2 M_Z Q_e Q_q - 90g_1^2 g_p^2 M_1 Q_{H_d} Q_q - 90g_1^2 g_p^2 M_Z Q_{H_d} Q_q - 90g_1^2 g_p^2 M_1 Q_q Q_q \\
& - 90g_1^2 g_p^2 M_Z Q_q Q_q + 1800g_p^4 M_Z Q_e^2 Q_q^2 + 1800g_p^4 M_Z Q_{H_d}^2 Q_q^2 + 1800g_p^4 M_Z Q_q^2 Q_q^2 \\
& + 100g_p^4 M_Z Q_e^2 Q_s^2 + 100g_p^4 M_Z Q_{H_d}^2 Q_s^2 + 100g_p^4 M_Z Q_q^2 Q_s^2 - 360g_1^2 g_p^2 M_1 Q_e Q_u \\
& - 360g_1^2 g_p^2 M_Z Q_e Q_u + 180g_1^2 g_p^2 M_1 Q_{H_d} Q_u + 180g_1^2 g_p^2 M_Z Q_{H_d} Q_u + 180g_1^2 g_p^2 M_1 Q_q Q_u \\
& + 180g_1^2 g_p^2 M_Z Q_q Q_u + 900g_p^4 M_Z Q_e^2 Q_u^2 + 900g_p^4 M_Z Q_{H_d}^2 Q_u^2 + 900g_p^4 M_Z Q_q^2 Q_u^2 \\
& + 180g_1^2 g_p^2 M_1 Q_e Q_v + 180g_1^2 g_p^2 M_Z Q_e Q_v - 90g_1^2 g_p^2 M_1 Q_{H_d} Q_v - 90g_1^2 g_p^2 M_Z Q_{H_d} Q_v \\
& - 90g_1^2 g_p^2 M_1 Q_q Q_v - 90g_1^2 g_p^2 M_Z Q_q Q_v + 300g_p^4 M_Z Q_e^2 Q_v^2 + 300g_p^4 M_Z Q_{H_d}^2 Q_v^2 \\
& \left. + 300g_p^4 M_Z Q_q^2 Q_v^2 + 150\lambda\lambda^* T_\lambda \right)
\end{aligned}$$

$$\begin{aligned}
& -10\left(-5\left(3g_p^2 M_Z\left(-Q_{H_d}^2+Q_d^2+Q_q^2\right)+8g_3^2 M_3\right)+g_1^2 M_1\right) \operatorname{Tr}\left(Y_d Y_d^\dagger\right)+30g_1^2 M_1 \operatorname{Tr}\left(Y_e Y_e^\dagger\right) \\
& +50g_p^2 M_Z Q_e^2 \operatorname{Tr}\left(Y_e Y_e^\dagger\right)-50g_p^2 M_Z Q_{H_d}^2 \operatorname{Tr}\left(Y_e Y_e^\dagger\right)+50g_p^2 M_Z Q_q^2 \operatorname{Tr}\left(Y_e Y_e^\dagger\right) \\
& +10g_1^2 \operatorname{Tr}\left(Y_d^\dagger T_d\right)-400g_3^2 \operatorname{Tr}\left(Y_d^\dagger T_d\right)-150g_p^2 Q_d^2 \operatorname{Tr}\left(Y_d^\dagger T_d\right)+150g_p^2 Q_{H_d}^2 \operatorname{Tr}\left(Y_d^\dagger T_d\right) \\
& -150g_p^2 Q_q^2 \operatorname{Tr}\left(Y_d^\dagger T_d\right)-30g_1^2 \operatorname{Tr}\left(Y_e^\dagger T_e\right)-50g_p^2 Q_e^2 \operatorname{Tr}\left(Y_e^\dagger T_e\right)+50g_p^2 Q_{H_d}^2 \operatorname{Tr}\left(Y_e^\dagger T_e\right) \\
& -50g_p^2 Q_q^2 \operatorname{Tr}\left(Y_e^\dagger T_e\right) \\
& -25\lambda^*\left(-T_\lambda\left(2g_p^2\left(-Q_{H_u}^2-Q_s^2+Q_{H_d}^2\right)+3\operatorname{Tr}\left(Y_u Y_u^\dagger\right)+\operatorname{Tr}\left(Y_\nu Y_\nu^\dagger\right)\right)\right. \\
& \left.+\lambda\left(2g_p^2 M_Z\left(-Q_{H_u}^2-Q_s^2+Q_{H_d}^2\right)-3\operatorname{Tr}\left(Y_u^\dagger T_u\right)-\operatorname{Tr}\left(Y_\nu^\dagger T_\nu\right)\right)\right) \\
& +450\operatorname{Tr}\left(Y_d Y_d^\dagger T_d Y_d^\dagger\right)+75\operatorname{Tr}\left(Y_d Y_u^\dagger T_u Y_d^\dagger\right)+150\operatorname{Tr}\left(Y_e Y_e^\dagger T_e Y_e^\dagger\right)+75\operatorname{Tr}\left(Y_u Y_d^\dagger T_d Y_u^\dagger\right) \\
& +25\operatorname{Tr}\left(Y_e^\dagger T_e Y_\nu^* Y_\nu^T\right)+25\operatorname{Tr}\left(Y_\nu^\dagger Y_e^T Y_e^* T_\nu\right)
\end{aligned} \tag{54}$$

$$\begin{aligned}
\beta_{T_\lambda}^{(1)} & =+T_\lambda\left(-\frac{3}{5}g_1^2-3g_2^2-2g_p^2 Q_{H_d}^2-2g_p^2 Q_{H_u}^2-2g_p^2 Q_s^2+12|\lambda|^2+3\operatorname{Tr}\left(Y_d Y_d^\dagger\right)+\operatorname{Tr}\left(Y_e Y_e^\dagger\right)\right. \\
& \left.+3\operatorname{Tr}\left(Y_u Y_u^\dagger\right)+\operatorname{Tr}\left(Y_\nu Y_\nu^\dagger\right)\right) \\
& +\frac{2}{5}\lambda\left(3g_1^2 M_1+15g_2^2 M_2+10g_p^2 M_Z Q_{H_d}^2+10g_p^2 M_Z Q_{H_u}^2+10g_p^2 M_Z Q_s^2+15\operatorname{Tr}\left(Y_d^\dagger T_d\right)+5\operatorname{Tr}\left(Y_e^\dagger T_e\right)\right. \\
& \left.+15\operatorname{Tr}\left(Y_u^\dagger T_u\right)+5\operatorname{Tr}\left(Y_\nu^\dagger T_\nu\right)\right)
\end{aligned} \tag{55}$$

$$\begin{aligned}
\beta_{T_\lambda}^{(2)} & =-50\lambda^2\lambda^{*2}T_\lambda \\
& -\frac{1}{5}|\lambda|^2\left(-3T_\lambda\left(6g_1^2+30g_2^2+20g_p^2 Q_{H_d}^2+20g_p^2 Q_{H_u}^2-45\operatorname{Tr}\left(Y_d Y_d^\dagger\right)-15\operatorname{Tr}\left(Y_e Y_e^\dagger\right)-45\operatorname{Tr}\left(Y_u Y_u^\dagger\right)\right.\right. \\
& \left.-15\operatorname{Tr}\left(Y_\nu Y_\nu^\dagger\right)\right) \\
& +2\lambda\left(6g_1^2 M_1+30g_2^2 M_2+20g_p^2 M_Z Q_{H_d}^2+20g_p^2 M_Z Q_{H_u}^2+45\operatorname{Tr}\left(Y_d^\dagger T_d\right)+15\operatorname{Tr}\left(Y_e^\dagger T_e\right)+45\operatorname{Tr}\left(Y_u^\dagger T_u\right)\right. \\
& \left.+15\operatorname{Tr}\left(Y_\nu^\dagger T_\nu\right)\right) \\
& +T_\lambda\left(\frac{261}{50}g_1^4+\frac{9}{5}g_1^2 g_2^2+\frac{15}{2}g_2^4-\frac{18}{5}g_1^2 g_p^2 Q_d Q_{H_d}-\frac{18}{5}g_1^2 g_p^2 Q_e Q_{H_d}+\frac{12}{5}g_1^2 g_p^2 Q_{H_d}^2\right. \\
& +6g_2^2 g_p^2 Q_{H_d}^2+18g_p^4 Q_d^2 Q_{H_d}^2+6g_p^4 Q_e^2 Q_{H_d}^2+8g_p^4 Q_{H_d}^4+\frac{18}{5}g_1^2 g_p^2 Q_d Q_{H_u} \\
& +\frac{18}{5}g_1^2 g_p^2 Q_e Q_{H_u}-\frac{12}{5}g_1^2 g_p^2 Q_{H_d} Q_{H_u}+\frac{12}{5}g_1^2 g_p^2 Q_{H_u}^2+6g_2^2 g_p^2 Q_{H_u}^2+18g_p^4 Q_d^2 Q_{H_u}^2 \\
& +6g_p^4 Q_e^2 Q_{H_u}^2+8g_p^4 Q_{H_d}^2 Q_{H_u}^2+8g_p^4 Q_{H_u}^4+\frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_q-\frac{18}{5}g_1^2 g_p^2 Q_{H_u} Q_q \\
& +12g_p^4 Q_{H_d}^2 Q_q^2+12g_p^4 Q_{H_u}^2 Q_q^2-\frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_q+\frac{18}{5}g_1^2 g_p^2 Q_{H_u} Q_q+36g_p^4 Q_{H_d}^2 Q_q^2 \\
& \left.+36g_p^4 Q_{H_u}^2 Q_q^2+18g_p^4 Q_d^2 Q_s^2+6g_p^4 Q_e^2 Q_s^2+6g_p^4 Q_{H_d}^2 Q_s^2+6g_p^4 Q_{H_u}^2 Q_s^2\right)
\end{aligned}$$

$$\begin{aligned}
& + 12g_p^4 Q_q^2 Q_s^2 + 36g_p^4 Q_q^2 Q_s^2 + 6g_p^4 Q_s^4 + \frac{36}{5} g_1^2 g_p^2 Q_{H_d} Q_u - \frac{36}{5} g_1^2 g_p^2 Q_{H_u} Q_u \\
& + 18g_p^4 Q_{H_d}^2 Q_u^2 + 18g_p^4 Q_{H_u}^2 Q_u^2 + 18g_p^4 Q_s^2 Q_u^2 - \frac{18}{5} g_1^2 g_p^2 Q_{H_d} Q_v + \frac{18}{5} g_1^2 g_p^2 Q_{H_u} Q_v \\
& + 6g_p^4 Q_{H_d}^2 Q_v^2 + 6g_p^4 Q_{H_u}^2 Q_v^2 + 6g_p^4 Q_s^2 Q_v^2 \\
& - \frac{2}{5} \left( -5 \left( 3g_p^2 \left( -Q_{H_d}^2 + Q_d^2 + Q_q^2 \right) + 8g_3^2 \right) + g_1^2 \right) \text{Tr} \left( Y_d Y_d^\dagger \right) \\
& + \frac{2}{5} \left( 3g_1^2 + 5g_p^2 \left( -Q_{H_d}^2 + Q_e^2 + Q_q^2 \right) \right) \text{Tr} \left( Y_e Y_e^\dagger \right) + \frac{4}{5} g_1^2 \text{Tr} \left( Y_u Y_u^\dagger \right) + 16g_3^2 \text{Tr} \left( Y_u Y_u^\dagger \right) \\
& - 6g_p^2 Q_{H_u}^2 \text{Tr} \left( Y_u Y_u^\dagger \right) + 6g_p^2 Q_q^2 \text{Tr} \left( Y_u Y_u^\dagger \right) + 6g_p^2 Q_u^2 \text{Tr} \left( Y_u Y_u^\dagger \right) + \frac{6}{5} g_1^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \\
& - 2g_p^2 Q_{H_u}^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) + 2g_p^2 Q_q^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) + 2g_p^2 Q_v^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 9\text{Tr} \left( Y_d Y_d^\dagger Y_d Y_d^\dagger \right) \\
& - 6\text{Tr} \left( Y_d Y_u^\dagger Y_u Y_d^\dagger \right) - 3\text{Tr} \left( Y_e Y_e^\dagger Y_e Y_e^\dagger \right) - 9\text{Tr} \left( Y_u Y_u^\dagger Y_u Y_u^\dagger \right) - 3\text{Tr} \left( Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger \right) \\
& - 2\text{Tr} \left( Y_\nu Y_\nu^\dagger Y_e^T Y_e^* \right) \\
& - \frac{2}{25} \lambda \left( 261g_1^4 M_1 + 45g_1^2 g_2^2 M_1 + 45g_1^2 g_2^2 M_2 + 375g_2^4 M_2 - 90g_1^2 g_p^2 M_1 Q_d Q_{H_d} \right. \\
& - 90g_1^2 g_p^2 M_Z Q_d Q_{H_d} - 90g_1^2 g_p^2 M_1 Q_e Q_{H_d} - 90g_1^2 g_p^2 M_Z Q_e Q_{H_d} + 60g_1^2 g_p^2 M_1 Q_{H_d}^2 \\
& + 60g_1^2 g_p^2 M_Z Q_{H_d}^2 + 150g_2^2 g_p^2 M_Z Q_{H_d}^2 + 150g_2^2 g_p^2 M_2 Q_{H_d}^2 + 900g_p^4 M_Z Q_d^2 Q_{H_d}^2 \\
& + 300g_p^4 M_Z Q_e^2 Q_{H_d}^2 + 400g_p^4 M_Z Q_{H_d}^4 + 90g_1^2 g_p^2 M_1 Q_d Q_{H_u} + 90g_1^2 g_p^2 M_Z Q_d Q_{H_u} \\
& + 90g_1^2 g_p^2 M_1 Q_e Q_{H_u} + 90g_1^2 g_p^2 M_Z Q_e Q_{H_u} - 60g_1^2 g_p^2 M_1 Q_{H_d} Q_{H_u} - 60g_1^2 g_p^2 M_Z Q_{H_d} Q_{H_u} \\
& + 60g_1^2 g_p^2 M_1 Q_{H_u}^2 + 60g_1^2 g_p^2 M_Z Q_{H_u}^2 + 150g_2^2 g_p^2 M_Z Q_{H_u}^2 + 150g_2^2 g_p^2 M_2 Q_{H_u}^2 \\
& + 900g_p^4 M_Z Q_d^2 Q_{H_u}^2 + 300g_p^4 M_Z Q_e^2 Q_{H_u}^2 + 400g_p^4 M_Z Q_{H_d}^2 Q_{H_u}^2 + 400g_p^4 M_Z Q_{H_u}^4 \\
& + 90g_1^2 g_p^2 M_1 Q_{H_d} Q_q + 90g_1^2 g_p^2 M_Z Q_{H_d} Q_q - 90g_1^2 g_p^2 M_1 Q_{H_u} Q_q - 90g_1^2 g_p^2 M_Z Q_{H_u} Q_q \\
& + 600g_p^4 M_Z Q_{H_d}^2 Q_q^2 + 600g_p^4 M_Z Q_{H_u}^2 Q_q^2 - 90g_1^2 g_p^2 M_1 Q_{H_d} Q_q - 90g_1^2 g_p^2 M_Z Q_{H_d} Q_q \\
& + 90g_1^2 g_p^2 M_1 Q_{H_u} Q_q + 90g_1^2 g_p^2 M_Z Q_{H_u} Q_q + 1800g_p^4 M_Z Q_{H_d}^2 Q_q^2 + 1800g_p^4 M_Z Q_{H_u}^2 Q_q^2 \\
& + 900g_p^4 M_Z Q_d^2 Q_s^2 + 300g_p^4 M_Z Q_e^2 Q_s^2 + 300g_p^4 M_Z Q_{H_d}^2 Q_s^2 + 300g_p^4 M_Z Q_{H_u}^2 Q_s^2 \\
& + 600g_p^4 M_Z Q_q^2 Q_s^2 + 1800g_p^4 M_Z Q_q^2 Q_s^2 + 300g_p^4 M_Z Q_s^4 + 180g_1^2 g_p^2 M_1 Q_{H_d} Q_u \\
& + 180g_1^2 g_p^2 M_Z Q_{H_d} Q_u - 180g_1^2 g_p^2 M_1 Q_{H_u} Q_u - 180g_1^2 g_p^2 M_Z Q_{H_u} Q_u + 900g_p^4 M_Z Q_{H_d}^2 Q_u^2 \\
& + 900g_p^4 M_Z Q_{H_u}^2 Q_u^2 + 900g_p^4 M_Z Q_s^2 Q_u^2 - 90g_1^2 g_p^2 M_1 Q_{H_d} Q_v - 90g_1^2 g_p^2 M_Z Q_{H_d} Q_v \\
& + 90g_1^2 g_p^2 M_1 Q_{H_u} Q_v + 90g_1^2 g_p^2 M_Z Q_{H_u} Q_v + 300g_p^4 M_Z Q_{H_d}^2 Q_v^2 + 300g_p^4 M_Z Q_{H_u}^2 Q_v^2 \\
& + 300g_p^4 M_Z Q_s^2 Q_v^2 - 10 \left( -5 \left( 3g_p^2 M_Z \left( -Q_{H_d}^2 + Q_d^2 + Q_q^2 \right) + 8g_3^2 M_3 \right) + g_1^2 M_1 \right) \text{Tr} \left( Y_d Y_d^\dagger \right) \\
& + 10 \left( 3g_1^2 M_1 + 5g_p^2 M_Z \left( -Q_{H_d}^2 + Q_e^2 + Q_q^2 \right) \right) \text{Tr} \left( Y_e Y_e^\dagger \right) + 20g_1^2 M_1 \text{Tr} \left( Y_u Y_u^\dagger \right) \\
& + 400g_3^2 M_3 \text{Tr} \left( Y_u Y_u^\dagger \right) - 150g_p^2 M_Z Q_{H_u}^2 \text{Tr} \left( Y_u Y_u^\dagger \right) + 150g_p^2 M_Z Q_q^2 \text{Tr} \left( Y_u Y_u^\dagger \right) \\
& + 150g_p^2 M_Z Q_u^2 \text{Tr} \left( Y_u Y_u^\dagger \right) + 30g_1^2 M_1 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 50g_p^2 M_Z Q_{H_u}^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right)
\end{aligned}$$

$$\begin{aligned}
& + 50g_p^2 M_Z Q_q^2 \text{Tr}(Y_\nu Y_\nu^\dagger) + 50g_p^2 M_Z Q_v^2 \text{Tr}(Y_\nu Y_\nu^\dagger) + 10g_1^2 \text{Tr}(Y_d^\dagger T_d) - 400g_3^2 \text{Tr}(Y_d^\dagger T_d) \\
& - 150g_p^2 Q_d^2 \text{Tr}(Y_d^\dagger T_d) + 150g_p^2 Q_{H_d}^2 \text{Tr}(Y_d^\dagger T_d) - 150g_p^2 Q_q^2 \text{Tr}(Y_d^\dagger T_d) \\
& - 30g_1^2 \text{Tr}(Y_e^\dagger T_e) - 50g_p^2 Q_e^2 \text{Tr}(Y_e^\dagger T_e) + 50g_p^2 Q_{H_d}^2 \text{Tr}(Y_e^\dagger T_e) - 50g_p^2 Q_q^2 \text{Tr}(Y_e^\dagger T_e) \\
& - 20g_1^2 \text{Tr}(Y_u^\dagger T_u) - 400g_3^2 \text{Tr}(Y_u^\dagger T_u) + 150g_p^2 Q_{H_u}^2 \text{Tr}(Y_u^\dagger T_u) - 150g_p^2 Q_q^2 \text{Tr}(Y_u^\dagger T_u) \\
& - 150g_p^2 Q_u^2 \text{Tr}(Y_u^\dagger T_u) - 30g_1^2 \text{Tr}(Y_\nu^\dagger T_\nu) + 50g_p^2 Q_{H_u}^2 \text{Tr}(Y_\nu^\dagger T_\nu) - 50g_p^2 Q_q^2 \text{Tr}(Y_\nu^\dagger T_\nu) \\
& - 50g_p^2 Q_v^2 \text{Tr}(Y_\nu^\dagger T_\nu) + 450 \text{Tr}(Y_d Y_d^\dagger T_d Y_d^\dagger) + 150 \text{Tr}(Y_d Y_u^\dagger T_u Y_d^\dagger) + 150 \text{Tr}(Y_e Y_e^\dagger T_e Y_e^\dagger) \\
& + 150 \text{Tr}(Y_u Y_d^\dagger T_d Y_u^\dagger) + 450 \text{Tr}(Y_u Y_u^\dagger T_u Y_u^\dagger) + 150 \text{Tr}(Y_\nu Y_\nu^\dagger T_\nu Y_\nu^\dagger) + 50 \text{Tr}(Y_e^\dagger T_e Y_\nu^* Y_\nu^T) \\
& + 50 \text{Tr}(Y_\nu^\dagger Y_e^T Y_e^* T_\nu)
\end{aligned} \tag{56}$$

$$\begin{aligned}
\beta_{T_\nu}^{(1)} & = +5Y_\nu Y_\nu^\dagger T_\nu + 4T_\nu Y_\nu^\dagger Y_\nu + Y_e^T Y_e^* T_\nu + 2T_e^T Y_e^* Y_\nu - \frac{9}{5}g_1^2 T_\nu - 3g_2^2 T_\nu \\
& - 2g_p^2 Q_{H_u}^2 T_\nu - 2g_p^2 Q_q^2 T_\nu - 2g_p^2 Q_v^2 T_\nu + |\lambda|^2 T_\nu + 3T_\nu \text{Tr}(Y_u Y_u^\dagger) + T_\nu \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& + Y_\nu \left( \frac{18}{5}g_1^2 M_1 + 6g_2^2 M_2 + 4g_p^2 M_Z Q_{H_u}^2 + 4g_p^2 M_Z Q_q^2 + 4g_p^2 M_Z Q_v^2 + 2\lambda^* T_\lambda + 6 \text{Tr}(Y_u^\dagger T_u) \right) \\
& + 2 \text{Tr}(Y_\nu^\dagger T_\nu)
\end{aligned} \tag{57}$$

$$\begin{aligned}
\beta_{T_\nu}^{(2)} & = -\frac{6}{5}g_1^2 Y_\nu Y_\nu^\dagger T_\nu + 12g_2^2 Y_\nu Y_\nu^\dagger T_\nu + 10g_p^2 Q_{H_u}^2 Y_\nu Y_\nu^\dagger T_\nu + 6g_p^2 Q_q^2 Y_\nu Y_\nu^\dagger T_\nu \\
& - 6g_p^2 Q_v^2 Y_\nu Y_\nu^\dagger T_\nu - 5|\lambda|^2 Y_\nu Y_\nu^\dagger T_\nu + \frac{6}{5}g_1^2 T_\nu Y_\nu^\dagger Y_\nu + 6g_2^2 T_\nu Y_\nu^\dagger Y_\nu \\
& + 8g_p^2 Q_{H_u}^2 T_\nu Y_\nu^\dagger Y_\nu - 4|\lambda|^2 T_\nu Y_\nu^\dagger Y_\nu - \frac{12}{5}g_1^2 M_1 Y_e^T Y_e^* Y_\nu \\
& - 4g_p^2 M_Z Q_e^2 Y_e^T Y_e^* Y_\nu - 4g_p^2 M_Z Q_{H_d}^2 Y_e^T Y_e^* Y_\nu + 4g_p^2 M_Z Q_q^2 Y_e^T Y_e^* Y_\nu \\
& + \frac{6}{5}g_1^2 Y_e^T Y_e^* T_\nu + 2g_p^2 Q_e^2 Y_e^T Y_e^* T_\nu + 2g_p^2 Q_{H_d}^2 Y_e^T Y_e^* T_\nu \\
& - 2g_p^2 Q_q^2 Y_e^T Y_e^* T_\nu - |\lambda|^2 Y_e^T Y_e^* T_\nu + \frac{12}{5}g_1^2 T_e^T Y_e^* Y_\nu \\
& + 4g_p^2 Q_e^2 T_e^T Y_e^* Y_\nu + 4g_p^2 Q_{H_d}^2 T_e^T Y_e^* Y_\nu - 4g_p^2 Q_q^2 T_e^T Y_e^* Y_\nu \\
& - 2|\lambda|^2 T_e^T Y_e^* Y_\nu - 6Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger T_\nu - 8Y_\nu Y_\nu^\dagger T_\nu Y_\nu^\dagger Y_\nu - 4Y_\nu Y_\nu^\dagger Y_e^T Y_e^* T_\nu \\
& - 4Y_\nu Y_\nu^\dagger T_e^T Y_e^* Y_\nu - 6T_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger Y_\nu - 2T_\nu Y_\nu^\dagger Y_e^T Y_e^* Y_\nu - 2Y_e^T Y_e^* Y_e^T Y_e^* T_\nu \\
& - 4Y_e^T Y_e^* T_e^T Y_e^* Y_\nu - 4T_e^T Y_e^* Y_e^T Y_e^* Y_\nu + \frac{837}{50}g_1^4 T_\nu + \frac{9}{5}g_1^2 g_2^2 T_\nu + \frac{15}{2}g_2^4 T_\nu \\
& + \frac{18}{5}g_1^2 g_p^2 Q_d Q_{H_u} T_\nu + \frac{18}{5}g_1^2 g_p^2 Q_e Q_{H_u} T_\nu - \frac{6}{5}g_1^2 g_p^2 Q_{H_d} Q_{H_u} T_\nu + \frac{12}{5}g_1^2 g_p^2 Q_{H_u}^2 T_\nu \\
& + 6g_2^2 g_p^2 Q_{H_u}^2 T_\nu + 18g_p^4 Q_d^2 Q_{H_u}^2 T_\nu + 6g_p^4 Q_e^2 Q_{H_u}^2 T_\nu + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 T_\nu \\
& + 8g_p^4 Q_{H_u}^4 T_\nu - \frac{18}{5}g_1^2 g_p^2 Q_d Q_q T_\nu - \frac{18}{5}g_1^2 g_p^2 Q_e Q_q T_\nu + \frac{6}{5}g_1^2 g_p^2 Q_{H_d} Q_q T_\nu
\end{aligned}$$

$$\begin{aligned}
& -\frac{24}{5}g_1^2g_p^2Q_{H_u}Q_qT_\nu + \frac{24}{5}g_1^2g_p^2Q_q^2T_\nu + 6g_2^2g_p^2Q_q^2T_\nu + 18g_p^4Q_d^2Q_q^2T_\nu \\
& + 6g_p^4Q_e^2Q_q^2T_\nu + 4g_p^4Q_{H_d}^2Q_q^2T_\nu + 16g_p^4Q_{H_u}^2Q_q^2T_\nu + 16g_p^4Q_q^4T_\nu \\
& + \frac{18}{5}g_1^2g_p^2Q_{H_u}Q_qT_\nu - \frac{18}{5}g_1^2g_p^2Q_qQ_qT_\nu + 36g_p^4Q_{H_u}^2Q_q^2T_\nu + 36g_p^4Q_q^2Q_q^2T_\nu \\
& + 2g_p^4Q_{H_u}^2Q_s^2T_\nu + 2g_p^4Q_q^2Q_s^2T_\nu - \frac{36}{5}g_1^2g_p^2Q_{H_u}Q_uT_\nu + \frac{36}{5}g_1^2g_p^2Q_qQ_uT_\nu \\
& + 18g_p^4Q_{H_u}^2Q_u^2T_\nu + 18g_p^4Q_q^2Q_u^2T_\nu + \frac{36}{5}g_1^2g_p^2Q_dQ_vT_\nu + \frac{36}{5}g_1^2g_p^2Q_eQ_vT_\nu \\
& - \frac{12}{5}g_1^2g_p^2Q_{H_d}Q_vT_\nu + 6g_1^2g_p^2Q_{H_u}Q_vT_\nu - \frac{54}{5}g_1^2g_p^2Q_qQ_vT_\nu + \frac{36}{5}g_1^2g_p^2Q_qQ_vT_\nu \\
& - \frac{72}{5}g_1^2g_p^2Q_uQ_vT_\nu + 12g_1^2g_p^2Q_v^2T_\nu + 18g_p^4Q_d^2Q_v^2T_\nu + 6g_p^4Q_e^2Q_v^2T_\nu \\
& + 4g_p^4Q_{H_d}^2Q_v^2T_\nu + 10g_p^4Q_{H_u}^2Q_v^2T_\nu + 18g_p^4Q_q^2Q_v^2T_\nu + 36g_p^4Q_q^2Q_v^2T_\nu \\
& + 2g_p^4Q_s^2Q_v^2T_\nu + 18g_p^4Q_u^2Q_v^2T_\nu + 10g_p^4Q_v^4T_\nu + 2g_p^2Q_{H_d}^2|\lambda|^2T_\nu \\
& - 2g_p^2Q_{H_u}^2|\lambda|^2T_\nu + 2g_p^2Q_s^2|\lambda|^2T_\nu - 3\lambda^2\lambda^{*,2}T_\nu - 2\lambda^*Y_e^TY_e^*Y_\nu T_\lambda \\
& - 3Y_e^TY_e^*T_\nu \text{Tr}(Y_dY_d^\dagger) - 6T_e^TY_e^*Y_\nu \text{Tr}(Y_dY_d^\dagger) - 3|\lambda|^2T_\nu \text{Tr}(Y_dY_d^\dagger) \\
& - Y_e^TY_e^*T_\nu \text{Tr}(Y_eY_e^\dagger) - 2T_e^TY_e^*Y_\nu \text{Tr}(Y_eY_e^\dagger) - |\lambda|^2T_\nu \text{Tr}(Y_eY_e^\dagger) \\
& - 15Y_\nu Y_\nu^\dagger T_\nu \text{Tr}(Y_uY_u^\dagger) - 12T_\nu Y_\nu^\dagger Y_\nu \text{Tr}(Y_uY_u^\dagger) + \frac{4}{5}g_1^2T_\nu \text{Tr}(Y_uY_u^\dagger) \\
& + 16g_3^2T_\nu \text{Tr}(Y_uY_u^\dagger) - 6g_p^2Q_{H_u}^2T_\nu \text{Tr}(Y_uY_u^\dagger) + 6g_p^2Q_q^2T_\nu \text{Tr}(Y_uY_u^\dagger) \\
& + 6g_p^2Q_u^2T_\nu \text{Tr}(Y_uY_u^\dagger) - 5Y_\nu Y_\nu^\dagger T_\nu \text{Tr}(Y_\nu Y_\nu^\dagger) - 4T_\nu Y_\nu^\dagger Y_\nu \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& + \frac{6}{5}g_1^2T_\nu \text{Tr}(Y_\nu Y_\nu^\dagger) - 2g_p^2Q_{H_u}^2T_\nu \text{Tr}(Y_\nu Y_\nu^\dagger) + 2g_p^2Q_q^2T_\nu \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& + 2g_p^2Q_v^2T_\nu \text{Tr}(Y_\nu Y_\nu^\dagger) - 6Y_e^TY_e^*Y_\nu \text{Tr}(Y_d^\dagger T_d) - 2Y_e^TY_e^*Y_\nu \text{Tr}(Y_e^\dagger T_e) \\
& - 2Y_\nu Y_\nu^\dagger Y_\nu (2g_p^2M_ZQ_q^2 - 2g_p^2M_ZQ_v^2 + 3\lambda^*T_\lambda + 3\text{Tr}(Y_\nu^\dagger T_\nu) + 6g_2^2M_2 + 6g_p^2M_ZQ_{H_u}^2 + 9\text{Tr}(Y_u^\dagger T_u)) \\
& - 3T_\nu \text{Tr}(Y_dY_u^\dagger Y_uY_d^\dagger) - 9T_\nu \text{Tr}(Y_uY_u^\dagger Y_uY_u^\dagger) - 3T_\nu \text{Tr}(Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger) - T_\nu \text{Tr}(Y_\nu Y_\nu^\dagger Y_e^TY_e^*) \\
& - \frac{2}{25}Y_\nu (837g_1^4M_1 + 45g_1^2g_2^2M_1 + 45g_1^2g_2^2M_2 + 375g_2^4M_2 + 90g_1^2g_p^2M_1Q_dQ_{H_u} \\
& + 90g_1^2g_p^2M_ZQ_dQ_{H_u} + 90g_1^2g_p^2M_1Q_eQ_{H_u} + 90g_1^2g_p^2M_ZQ_eQ_{H_u} - 30g_1^2g_p^2M_1Q_{H_d}Q_{H_u} \\
& - 30g_1^2g_p^2M_ZQ_{H_d}Q_{H_u} + 60g_1^2g_p^2M_1Q_{H_u}^2 + 60g_1^2g_p^2M_ZQ_{H_u}^2 + 150g_2^2g_p^2M_ZQ_{H_u}^2 \\
& + 150g_2^2g_p^2M_2Q_{H_u}^2 + 900g_p^4M_ZQ_d^2Q_{H_u}^2 + 300g_p^4M_ZQ_e^2Q_{H_u}^2 + 200g_p^4M_ZQ_{H_d}^2Q_{H_u}^2 \\
& + 400g_p^4M_ZQ_{H_u}^4 - 90g_1^2g_p^2M_1Q_dQ_q - 90g_1^2g_p^2M_ZQ_dQ_q - 90g_1^2g_p^2M_1Q_eQ_q \\
& - 90g_1^2g_p^2M_ZQ_eQ_q + 30g_1^2g_p^2M_1Q_{H_d}Q_q + 30g_1^2g_p^2M_ZQ_{H_d}Q_q - 120g_1^2g_p^2M_1Q_{H_u}Q_q \\
& - 120g_1^2g_p^2M_ZQ_{H_u}Q_q + 120g_1^2g_p^2M_1Q_q^2 + 120g_1^2g_p^2M_ZQ_q^2 + 150g_2^2g_p^2M_ZQ_q^2
\end{aligned}$$

$$\begin{aligned}
& + 150g_2^2g_p^2M_2Q_q^2 + 900g_p^4M_ZQ_d^2Q_q^2 + 300g_p^4M_ZQ_e^2Q_q^2 + 200g_p^4M_ZQ_{H_d}^2Q_q^2 \\
& + 800g_p^4M_ZQ_{H_u}^2Q_q^2 + 800g_p^4M_ZQ_q^4 + 90g_1^2g_p^2M_1Q_{H_u}Q_q + 90g_1^2g_p^2M_ZQ_{H_u}Q_q \\
& - 90g_1^2g_p^2M_1Q_qQ_q - 90g_1^2g_p^2M_ZQ_qQ_q + 1800g_p^4M_ZQ_{H_u}^2Q_q^2 + 1800g_p^4M_ZQ_q^2Q_q^2 \\
& + 100g_p^4M_ZQ_{H_u}^2Q_s^2 + 100g_p^4M_ZQ_q^2Q_s^2 - 180g_1^2g_p^2M_1Q_{H_u}Q_u - 180g_1^2g_p^2M_ZQ_{H_u}Q_u \\
& + 180g_1^2g_p^2M_1Q_qQ_u + 180g_1^2g_p^2M_ZQ_qQ_u + 900g_p^4M_ZQ_{H_u}^2Q_u^2 + 900g_p^4M_ZQ_q^2Q_u^2 \\
& + 180g_1^2g_p^2M_1Q_dQ_v + 180g_1^2g_p^2M_ZQ_dQ_v + 180g_1^2g_p^2M_1Q_eQ_v + 180g_1^2g_p^2M_ZQ_eQ_v \\
& - 60g_1^2g_p^2M_1Q_{H_d}Q_v - 60g_1^2g_p^2M_ZQ_{H_d}Q_v + 150g_1^2g_p^2M_1Q_{H_u}Q_v + 150g_1^2g_p^2M_ZQ_{H_u}Q_v \\
& - 270g_1^2g_p^2M_1Q_qQ_v - 270g_1^2g_p^2M_ZQ_qQ_v + 180g_1^2g_p^2M_1Q_qQ_v + 180g_1^2g_p^2M_ZQ_qQ_v \\
& - 360g_1^2g_p^2M_1Q_uQ_v - 360g_1^2g_p^2M_ZQ_uQ_v + 300g_1^2g_p^2M_1Q_v^2 + 300g_1^2g_p^2M_ZQ_v^2 \\
& + 900g_p^4M_ZQ_d^2Q_v^2 + 300g_p^4M_ZQ_e^2Q_v^2 + 200g_p^4M_ZQ_{H_d}^2Q_v^2 + 500g_p^4M_ZQ_{H_u}^2Q_v^2 \\
& + 900g_p^4M_ZQ_q^2Q_v^2 + 1800g_p^4M_ZQ_q^2Q_v^2 + 100g_p^4M_ZQ_s^2Q_v^2 + 900g_p^4M_ZQ_u^2Q_v^2 \\
& + 500g_p^4M_ZQ_v^4 + 150\lambda\lambda^{*2}T_\lambda + 10\left(2g_1^2M_1 + 5\left(3g_p^2M_Z\left(-Q_{H_u}^2 + Q_q^2 + Q_u^2\right) + 8g_3^2M_3\right)\right)\text{Tr}\left(Y_uY_u^\dagger\right) \\
& + 30g_1^2M_1\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) - 50g_p^2M_ZQ_{H_u}^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 50g_p^2M_ZQ_q^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) \\
& + 50g_p^2M_ZQ_v^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) \\
& + 25\lambda^*\left(T_\lambda\left(-2g_p^2\left(-Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2\right) + 3\text{Tr}\left(Y_dY_d^\dagger\right) + \text{Tr}\left(Y_eY_e^\dagger\right)\right)\right. \\
& \left. + \lambda\left(2g_p^2M_Z\left(-Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2\right) + 3\text{Tr}\left(Y_d^\dagger T_d\right) + \text{Tr}\left(Y_e^\dagger T_e\right)\right)\right) \\
& - 20g_1^2\text{Tr}\left(Y_u^\dagger T_u\right) - 400g_3^2\text{Tr}\left(Y_u^\dagger T_u\right) + 150g_p^2Q_{H_u}^2\text{Tr}\left(Y_u^\dagger T_u\right) - 150g_p^2Q_q^2\text{Tr}\left(Y_u^\dagger T_u\right) \\
& - 150g_p^2Q_u^2\text{Tr}\left(Y_u^\dagger T_u\right) - 30g_1^2\text{Tr}\left(Y_\nu^\dagger T_\nu\right) + 50g_p^2Q_{H_u}^2\text{Tr}\left(Y_\nu^\dagger T_\nu\right) - 50g_p^2Q_q^2\text{Tr}\left(Y_\nu^\dagger T_\nu\right) \\
& - 50g_p^2Q_v^2\text{Tr}\left(Y_\nu^\dagger T_\nu\right) + 75\text{Tr}\left(Y_dY_u^\dagger T_uY_d^\dagger\right) + 75\text{Tr}\left(Y_uY_d^\dagger T_dY_u^\dagger\right) + 450\text{Tr}\left(Y_uY_u^\dagger T_uY_u^\dagger\right) \\
& + 150\text{Tr}\left(Y_\nu Y_\nu^\dagger T_\nu Y_\nu^\dagger\right) + 25\text{Tr}\left(Y_e^\dagger T_e Y_\nu^* Y_\nu^T\right) + 25\text{Tr}\left(Y_\nu^\dagger Y_e^T Y_e^* T_\nu\right)
\end{aligned} \tag{58}$$

$$\begin{aligned}
\beta_{T_u}^{(1)} & = +2Y_uY_d^\dagger T_d + 4Y_uY_u^\dagger T_u + T_uY_d^\dagger Y_d + 5T_uY_u^\dagger Y_u - \frac{13}{15}g_1^2T_u - 3g_2^2T_u - \frac{16}{3}g_3^2T_u \\
& - 2g_p^2Q_{H_u}^2T_u - 2g_p^2Q_q^2T_u - 2g_p^2Q_u^2T_u + |\lambda|^2T_u + 3T_u\text{Tr}\left(Y_uY_u^\dagger\right) + T_u\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) \\
& + Y_u\left(\frac{26}{15}g_1^2M_1 + \frac{32}{3}g_3^2M_3 + 6g_2^2M_2 + 4g_p^2M_ZQ_{H_u}^2 + 4g_p^2M_ZQ_q^2 + 4g_p^2M_ZQ_u^2 + 2\lambda^*T_\lambda + 6\text{Tr}\left(Y_u^\dagger T_u\right)\right. \\
& \left. + 2\text{Tr}\left(Y_\nu^\dagger T_\nu\right)\right)
\end{aligned} \tag{59}$$

$$\begin{aligned}
\beta_{T_u}^{(2)} & = +\frac{4}{5}g_1^2Y_uY_d^\dagger T_d + 4g_p^2Q_d^2Y_uY_d^\dagger T_d + 4g_p^2Q_{H_d}^2Y_uY_d^\dagger T_d \\
& - 4g_p^2Q_q^2Y_uY_d^\dagger T_d - 2|\lambda|^2Y_uY_d^\dagger T_d - \frac{4}{5}g_1^2M_1Y_uY_u^\dagger Y_u \\
& - 12g_2^2M_2Y_uY_u^\dagger Y_u - 12g_p^2M_ZQ_{H_u}^2Y_uY_u^\dagger Y_u - 4g_p^2M_ZQ_q^2Y_uY_u^\dagger Y_u
\end{aligned}$$

$$\begin{aligned}
& + 4g_p^2 M_Z Q_u^2 Y_u Y_u^\dagger Y_u + \frac{6}{5} g_1^2 Y_u Y_u^\dagger T_u + 6g_2^2 Y_u Y_u^\dagger T_u + 8g_p^2 Q_{H_u}^2 Y_u Y_u^\dagger T_u \\
& - 4|\lambda|^2 Y_u Y_u^\dagger T_u + \frac{2}{5} g_1^2 T_u Y_d^\dagger Y_d + 2g_p^2 Q_d^2 T_u Y_d^\dagger Y_d \\
& + 2g_p^2 Q_{H_d}^2 T_u Y_d^\dagger Y_d - 2g_p^2 Q_q^2 T_u Y_d^\dagger Y_d - |\lambda|^2 T_u Y_d^\dagger Y_d \\
& + 12g_2^2 T_u Y_u^\dagger Y_u + 10g_p^2 Q_{H_u}^2 T_u Y_u^\dagger Y_u + 6g_p^2 Q_q^2 T_u Y_u^\dagger Y_u \\
& - 6g_p^2 Q_u^2 T_u Y_u^\dagger Y_u - 5|\lambda|^2 T_u Y_u^\dagger Y_u - 4Y_u Y_d^\dagger Y_d Y_d^\dagger T_d \\
& - 2Y_u Y_d^\dagger Y_d Y_u^\dagger T_u - 4Y_u Y_d^\dagger T_d Y_d^\dagger Y_d - 4Y_u Y_d^\dagger T_d Y_u^\dagger Y_u - 6Y_u Y_u^\dagger Y_u Y_u^\dagger T_u \\
& - 8Y_u Y_u^\dagger T_u Y_u^\dagger Y_u - 2T_u Y_d^\dagger Y_d Y_d^\dagger Y_d - 4T_u Y_d^\dagger Y_d Y_u^\dagger Y_u - 6T_u Y_u^\dagger Y_u Y_u^\dagger Y_u + \frac{689}{90} g_1^4 T_u \\
& + g_1^2 g_2^2 T_u + \frac{15}{2} g_2^4 T_u + \frac{136}{45} g_1^2 g_3^2 T_u + 8g_2^2 g_3^2 T_u - \frac{16}{9} g_3^4 T_u + \frac{18}{5} g_1^2 g_p^2 Q_d Q_{H_u} T_u \\
& + \frac{18}{5} g_1^2 g_p^2 Q_e Q_{H_u} T_u - \frac{6}{5} g_1^2 g_p^2 Q_{H_d} Q_{H_u} T_u + \frac{12}{5} g_1^2 g_p^2 Q_{H_u}^2 T_u + 6g_2^2 g_p^2 Q_{H_u}^2 T_u \\
& + 18g_p^4 Q_d^2 Q_{H_u}^2 T_u + 6g_p^4 Q_e^2 Q_{H_u}^2 T_u + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 T_u + 8g_p^4 Q_{H_u}^4 T_u \\
& - \frac{18}{5} g_1^2 g_p^2 Q_{H_u} Q_q T_u + 12g_p^4 Q_{H_u}^2 Q_q^2 T_u + \frac{6}{5} g_1^2 g_p^2 Q_d Q_q T_u + \frac{6}{5} g_1^2 g_p^2 Q_e Q_q T_u \\
& - \frac{2}{5} g_1^2 g_p^2 Q_{H_d} Q_q T_u + 4g_1^2 g_p^2 Q_{H_u} Q_q T_u - \frac{6}{5} g_1^2 g_p^2 Q_q Q_q T_u + \frac{4}{3} g_1^2 g_p^2 Q_q^2 T_u \\
& + 6g_2^2 g_p^2 Q_q^2 T_u + \frac{32}{3} g_3^2 g_p^2 Q_q^2 T_u + 18g_p^4 Q_d^2 Q_q^2 T_u + 6g_p^4 Q_e^2 Q_q^2 T_u \\
& + 4g_p^4 Q_{H_d}^2 Q_q^2 T_u + 40g_p^4 Q_{H_u}^2 Q_q^2 T_u + 12g_p^4 Q_q^2 Q_q^2 T_u + 40g_p^4 Q_q^4 T_u + 2g_p^4 Q_{H_u}^2 Q_s^2 T_u \\
& + 2g_p^4 Q_q^2 Q_s^2 T_u - \frac{24}{5} g_1^2 g_p^2 Q_d Q_u T_u - \frac{24}{5} g_1^2 g_p^2 Q_e Q_u T_u + \frac{8}{5} g_1^2 g_p^2 Q_{H_d} Q_u T_u \\
& - \frac{44}{5} g_1^2 g_p^2 Q_{H_u} Q_u T_u + \frac{24}{5} g_1^2 g_p^2 Q_q Q_u T_u - \frac{36}{5} g_1^2 g_p^2 Q_q Q_u T_u + \frac{176}{15} g_1^2 g_p^2 Q_u^2 T_u \\
& + \frac{32}{3} g_3^2 g_p^2 Q_u^2 T_u + 18g_p^4 Q_d^2 Q_u^2 T_u + 6g_p^4 Q_e^2 Q_u^2 T_u + 4g_p^4 Q_{H_d}^2 Q_u^2 T_u \\
& + 22g_p^4 Q_{H_u}^2 Q_u^2 T_u + 12g_p^4 Q_q^2 Q_u^2 T_u + 54g_p^4 Q_q Q_u^2 T_u + 2g_p^4 Q_s^2 Q_u^2 T_u + 22g_p^4 Q_u^4 T_u \\
& + \frac{18}{5} g_1^2 g_p^2 Q_{H_u} Q_v T_u + \frac{6}{5} g_1^2 g_p^2 Q_q Q_v T_u - \frac{24}{5} g_1^2 g_p^2 Q_u Q_v T_u + 6g_p^4 Q_{H_u}^2 Q_v^2 T_u \\
& + 6g_p^4 Q_q^2 Q_v^2 T_u + 6g_p^4 Q_u^2 Q_v^2 T_u + 2g_p^2 Q_{H_d}^2 |\lambda|^2 T_u - 2g_p^2 Q_{H_u}^2 |\lambda|^2 T_u \\
& + 2g_p^2 Q_s^2 |\lambda|^2 T_u - 3\lambda^2 \lambda^{*2} T_u - 6\lambda^* Y_u Y_u^\dagger Y_u T_\lambda - 6Y_u Y_d^\dagger T_d \text{Tr}(Y_d Y_d^\dagger) \\
& - 3T_u Y_d^\dagger Y_d \text{Tr}(Y_d Y_d^\dagger) - 3|\lambda|^2 T_u \text{Tr}(Y_d Y_d^\dagger) - 2Y_u Y_d^\dagger T_d \text{Tr}(Y_e Y_e^\dagger) \\
& - T_u Y_d^\dagger Y_d \text{Tr}(Y_e Y_e^\dagger) - |\lambda|^2 T_u \text{Tr}(Y_e Y_e^\dagger) - 12Y_u Y_u^\dagger T_u \text{Tr}(Y_u Y_u^\dagger) \\
& - 15T_u Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) + \frac{4}{5} g_1^2 T_u \text{Tr}(Y_u Y_u^\dagger) + 16g_3^2 T_u \text{Tr}(Y_u Y_u^\dagger) \\
& - 6g_p^2 Q_{H_u}^2 T_u \text{Tr}(Y_u Y_u^\dagger) + 6g_p^2 Q_q^2 T_u \text{Tr}(Y_u Y_u^\dagger) + 6g_p^2 Q_u^2 T_u \text{Tr}(Y_u Y_u^\dagger)
\end{aligned}$$



$$\begin{aligned}
& -4Y_u Y_u^\dagger T_u \text{Tr}(Y_\nu Y_\nu^\dagger) - 5T_u Y_u^\dagger Y_u \text{Tr}(Y_\nu Y_\nu^\dagger) + \frac{6}{5}g_1^2 T_u \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& -2g_p^2 Q_{H_u}^2 T_u \text{Tr}(Y_\nu Y_\nu^\dagger) + 2g_p^2 Q_q^2 T_u \text{Tr}(Y_\nu Y_\nu^\dagger) + 2g_p^2 Q_v^2 T_u \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& + Y_u Y_d^\dagger Y_d \left( -2\lambda^* T_\lambda - 2\text{Tr}(Y_e^\dagger T_e) - 4g_p^2 M_Z Q_d^2 - 4g_p^2 M_Z Q_{H_d}^2 + 4g_p^2 M_Z Q_q^2 - 6\text{Tr}(Y_d^\dagger T_d) - \frac{4}{5}g_1^2 M_1 \right) \\
& -18Y_u Y_u^\dagger Y_u \text{Tr}(Y_u^\dagger T_u) - 6Y_u Y_u^\dagger Y_u \text{Tr}(Y_\nu^\dagger T_\nu) - 3T_u \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) \\
& -9T_u \text{Tr}(Y_u Y_u^\dagger Y_u Y_u^\dagger) - 3T_u \text{Tr}(Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger) - T_u \text{Tr}(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*) \\
& -\frac{2}{45}Y_u \left( 689g_1^4 M_1 + 45g_1^2 g_2^2 M_1 + 136g_1^2 g_3^2 M_1 + 136g_1^2 g_3^2 M_3 + 360g_2^2 g_3^2 M_3 - 160g_3^4 M_3 \right. \\
& + 45g_1^2 g_2^2 M_2 + 675g_2^4 M_2 + 360g_2^2 g_3^2 M_2 + 162g_1^2 g_p^2 M_1 Q_d Q_{H_u} + 162g_1^2 g_p^2 M_Z Q_d Q_{H_u} \\
& + 162g_1^2 g_p^2 M_1 Q_e Q_{H_u} + 162g_1^2 g_p^2 M_Z Q_e Q_{H_u} - 54g_1^2 g_p^2 M_1 Q_{H_d} Q_{H_u} - 54g_1^2 g_p^2 M_Z Q_{H_d} Q_{H_u} \\
& + 108g_1^2 g_p^2 M_1 Q_{H_u}^2 + 108g_1^2 g_p^2 M_Z Q_{H_u}^2 + 270g_2^2 g_p^2 M_Z Q_{H_u}^2 + 270g_2^2 g_p^2 M_2 Q_{H_u}^2 \\
& + 1620g_p^4 M_Z Q_d^2 Q_{H_u}^2 + 540g_p^4 M_Z Q_e^2 Q_{H_u}^2 + 360g_p^4 M_Z Q_{H_d}^2 Q_{H_u}^2 + 720g_p^4 M_Z Q_{H_u}^4 \\
& -162g_1^2 g_p^2 M_1 Q_{H_u} Q_q - 162g_1^2 g_p^2 M_Z Q_{H_u} Q_q + 1080g_p^4 M_Z Q_{H_u}^2 Q_q^2 + 54g_1^2 g_p^2 M_1 Q_d Q_q \\
& + 54g_1^2 g_p^2 M_Z Q_d Q_q + 54g_1^2 g_p^2 M_1 Q_e Q_q + 54g_1^2 g_p^2 M_Z Q_e Q_q - 18g_1^2 g_p^2 M_1 Q_{H_d} Q_q \\
& -18g_1^2 g_p^2 M_Z Q_{H_d} Q_q + 180g_1^2 g_p^2 M_1 Q_{H_u} Q_q + 180g_1^2 g_p^2 M_Z Q_{H_u} Q_q - 54g_1^2 g_p^2 M_1 Q_q Q_q \\
& -54g_1^2 g_p^2 M_Z Q_q Q_q + 60g_1^2 g_p^2 M_1 Q_q^2 + 480g_3^2 g_p^2 M_3 Q_q^2 + 60g_1^2 g_p^2 M_Z Q_q^2 \\
& + 270g_2^2 g_p^2 M_Z Q_q^2 + 480g_3^2 g_p^2 M_Z Q_q^2 + 270g_2^2 g_p^2 M_2 Q_q^2 + 1620g_p^4 M_Z Q_d^2 Q_q^2 \\
& + 540g_p^4 M_Z Q_e^2 Q_q^2 + 360g_p^4 M_Z Q_{H_d}^2 Q_q^2 + 3600g_p^4 M_Z Q_{H_u}^2 Q_q^2 + 1080g_p^4 M_Z Q_q^2 Q_q^2 \\
& + 3600g_p^4 M_Z Q_q^4 + 180g_p^4 M_Z Q_{H_u}^2 Q_s^2 + 180g_p^4 M_Z Q_q^2 Q_s^2 - 216g_1^2 g_p^2 M_1 Q_d Q_u \\
& -216g_1^2 g_p^2 M_Z Q_d Q_u - 216g_1^2 g_p^2 M_1 Q_e Q_u - 216g_1^2 g_p^2 M_Z Q_e Q_u + 72g_1^2 g_p^2 M_1 Q_{H_d} Q_u \\
& + 72g_1^2 g_p^2 M_Z Q_{H_d} Q_u - 396g_1^2 g_p^2 M_1 Q_{H_u} Q_u - 396g_1^2 g_p^2 M_Z Q_{H_u} Q_u + 216g_1^2 g_p^2 M_1 Q_q Q_u \\
& + 216g_1^2 g_p^2 M_Z Q_q Q_u - 324g_1^2 g_p^2 M_1 Q_q Q_u - 324g_1^2 g_p^2 M_Z Q_q Q_u + 528g_1^2 g_p^2 M_1 Q_u^2 \\
& + 480g_3^2 g_p^2 M_3 Q_u^2 + 528g_1^2 g_p^2 M_Z Q_u^2 + 480g_3^2 g_p^2 M_Z Q_u^2 + 1620g_p^4 M_Z Q_d^2 Q_u^2 \\
& + 540g_p^4 M_Z Q_e^2 Q_u^2 + 360g_p^4 M_Z Q_{H_d}^2 Q_u^2 + 1980g_p^4 M_Z Q_{H_u}^2 Q_u^2 + 1080g_p^4 M_Z Q_q^2 Q_u^2 \\
& + 4860g_p^4 M_Z Q_q^2 Q_u^2 + 180g_p^4 M_Z Q_s^2 Q_u^2 + 1980g_p^4 M_Z Q_u^4 + 162g_1^2 g_p^2 M_1 Q_{H_u} Q_v \\
& + 162g_1^2 g_p^2 M_Z Q_{H_u} Q_v + 54g_1^2 g_p^2 M_1 Q_q Q_v + 54g_1^2 g_p^2 M_Z Q_q Q_v - 216g_1^2 g_p^2 M_1 Q_u Q_v \\
& -216g_1^2 g_p^2 M_Z Q_u Q_v + 540g_p^4 M_Z Q_{H_u}^2 Q_v^2 + 540g_p^4 M_Z Q_q^2 Q_v^2 + 540g_p^4 M_Z Q_u^2 Q_v^2 \\
& + 270\lambda\lambda^{*2} T_\lambda + 18 \left( 2g_1^2 M_1 + 5 \left( 3g_p^2 M_Z \left( -Q_{H_u}^2 + Q_q^2 + Q_u^2 \right) + 8g_3^2 M_3 \right) \right) \text{Tr}(Y_u Y_u^\dagger) \\
& + 54g_1^2 M_1 \text{Tr}(Y_\nu Y_\nu^\dagger) - 90g_p^2 M_Z Q_{H_u}^2 \text{Tr}(Y_\nu Y_\nu^\dagger) + 90g_p^2 M_Z Q_q^2 \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& + 90g_p^2 M_Z Q_v^2 \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& + 45\lambda^* \left( T_\lambda \left( -2g_p^2 \left( -Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2 \right) + 3\text{Tr}(Y_d Y_d^\dagger) + \text{Tr}(Y_e Y_e^\dagger) \right) \right)
\end{aligned}$$

$$\begin{aligned}
& + \lambda \left( 2g_p^2 M_Z \left( -Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2 \right) + 3\text{Tr} \left( Y_d^\dagger T_d \right) + \text{Tr} \left( Y_e^\dagger T_e \right) \right) \\
& - 36g_1^2 \text{Tr} \left( Y_u^\dagger T_u \right) - 720g_3^2 \text{Tr} \left( Y_u^\dagger T_u \right) + 270g_p^2 Q_{H_u}^2 \text{Tr} \left( Y_u^\dagger T_u \right) - 270g_p^2 Q_q^2 \text{Tr} \left( Y_u^\dagger T_u \right) \\
& - 270g_p^2 Q_u^2 \text{Tr} \left( Y_u^\dagger T_u \right) - 54g_1^2 \text{Tr} \left( Y_\nu^\dagger T_\nu \right) + 90g_p^2 Q_{H_u}^2 \text{Tr} \left( Y_\nu^\dagger T_\nu \right) - 90g_p^2 Q_q^2 \text{Tr} \left( Y_\nu^\dagger T_\nu \right) \\
& - 90g_p^2 Q_v^2 \text{Tr} \left( Y_\nu^\dagger T_\nu \right) + 135\text{Tr} \left( Y_d Y_u^\dagger T_u Y_d^\dagger \right) + 135\text{Tr} \left( Y_u Y_d^\dagger T_d Y_u^\dagger \right) + 810\text{Tr} \left( Y_u Y_u^\dagger T_u Y_u^\dagger \right) \\
& + 270\text{Tr} \left( Y_\nu Y_\nu^\dagger T_\nu Y_\nu^\dagger \right) + 45\text{Tr} \left( Y_e^\dagger T_e Y_\nu^* Y_\nu^T \right) + 45\text{Tr} \left( Y_\nu^\dagger Y_e^T Y_e^* T_\nu \right)
\end{aligned} \tag{60}$$

### 3.6 Soft-Breaking Scalar Masses

$$\sigma_{1,1} = \sqrt{\frac{3}{5}} g_1 \left( -2\text{Tr} \left( m_u^2 \right) - \text{Tr} \left( m_l^2 \right) - m_{H_d}^2 + m_{H_u}^2 + \text{Tr} \left( m_d^2 \right) + \text{Tr} \left( m_e^2 \right) + \text{Tr} \left( m_q^2 \right) + \text{Tr} \left( m_\nu^2 \right) \right) \tag{61}$$

$$\begin{aligned}
\sigma_{1,4} = & g_p \left( 2m_{H_d}^2 Q_{H_d} + 2m_{H_u}^2 Q_{H_u} + m_S^2 Q_s + 3Q_d \text{Tr} \left( m_d^2 \right) + Q_e \text{Tr} \left( m_e^2 \right) + 2Q_q \text{Tr} \left( m_l^2 \right) + 6Q_q \text{Tr} \left( m_q^2 \right) + 3Q_u \text{Tr} \left( m_u^2 \right) \right. \\
& \left. + Q_v \text{Tr} \left( m_\nu^2 \right) \right)
\end{aligned} \tag{62}$$

$$\sigma_{2,11} = \frac{1}{10} g_1^2 \left( 2\text{Tr} \left( m_d^2 \right) + 3\text{Tr} \left( m_l^2 \right) + 3m_{H_d}^2 + 3m_{H_u}^2 + 6\text{Tr} \left( m_e^2 \right) + 6\text{Tr} \left( m_\nu^2 \right) + 8\text{Tr} \left( m_u^2 \right) + \text{Tr} \left( m_q^2 \right) \right) \tag{63}$$

$$\sigma_{2,14} = \sqrt{\frac{3}{5}} g_1 g_p \left( -2Q_u \text{Tr} \left( m_u^2 \right) - m_{H_d}^2 Q_{H_d} + m_{H_u}^2 Q_{H_u} + Q_d \text{Tr} \left( m_d^2 \right) + Q_e \text{Tr} \left( m_e^2 \right) - Q_q \text{Tr} \left( m_l^2 \right) + Q_q \text{Tr} \left( m_q^2 \right) + Q_v \text{Tr} \left( m_\nu^2 \right) \right) \tag{64}$$

$$\begin{aligned}
\sigma_{3,1} = & \frac{1}{20} \frac{1}{\sqrt{15}} g_1 \left( -9g_1^2 m_{H_d}^2 - 45g_2^2 m_{H_d}^2 + 9g_1^2 m_{H_u}^2 + 45g_2^2 m_{H_u}^2 - 60g_p^2 m_{H_d}^2 Q_{H_d}^2 + 60g_p^2 m_{H_u}^2 Q_{H_u}^2 \right. \\
& + 30 \left( -m_{H_u}^2 + m_{H_d}^2 \right) |\lambda|^2 + 4 \left( 15g_p^2 Q_d^2 + 20g_3^2 + g_1^2 \right) \text{Tr} \left( m_d^2 \right) + 36g_1^2 \text{Tr} \left( m_e^2 \right) + 60g_p^2 Q_e^2 \text{Tr} \left( m_e^2 \right) \\
& - 9g_1^2 \text{Tr} \left( m_l^2 \right) - 45g_2^2 \text{Tr} \left( m_l^2 \right) - 60g_p^2 Q_q^2 \text{Tr} \left( m_l^2 \right) + g_1^2 \text{Tr} \left( m_q^2 \right) + 45g_2^2 \text{Tr} \left( m_q^2 \right) + 80g_3^2 \text{Tr} \left( m_q^2 \right) \\
& + 60g_p^2 Q_q^2 \text{Tr} \left( m_q^2 \right) - 32g_1^2 \text{Tr} \left( m_u^2 \right) - 160g_3^2 \text{Tr} \left( m_u^2 \right) - 120g_p^2 Q_u^2 \text{Tr} \left( m_u^2 \right) + 36g_1^2 \text{Tr} \left( m_\nu^2 \right) \\
& + 60g_p^2 Q_v^2 \text{Tr} \left( m_\nu^2 \right) + 90m_{H_d}^2 \text{Tr} \left( Y_d Y_d^\dagger \right) + 30m_{H_d}^2 \text{Tr} \left( Y_e Y_e^\dagger \right) - 90m_{H_u}^2 \text{Tr} \left( Y_u Y_u^\dagger \right) \\
& - 30m_{H_u}^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) + 30\text{Tr} \left( m_l^2 Y_\nu Y_\nu^\dagger \right) - 60\text{Tr} \left( m_\nu^2 Y_\nu^\dagger Y_\nu \right) - 60\text{Tr} \left( Y_d Y_d^\dagger m_d^{2*} \right) \\
& - 30\text{Tr} \left( Y_d m_q^{2*} Y_d^\dagger \right) - 60\text{Tr} \left( Y_e Y_e^\dagger m_e^{2*} \right) + 30\text{Tr} \left( Y_e m_l^{2*} Y_e^\dagger \right) + 120\text{Tr} \left( Y_u Y_u^\dagger m_u^{2*} \right) \\
& \left. - 30\text{Tr} \left( Y_u m_q^{2*} Y_u^\dagger \right) \right)
\end{aligned} \tag{65}$$

$$\sigma_{2,2} = \frac{1}{2} \left( 3\text{Tr} \left( m_q^2 \right) + m_{H_d}^2 + m_{H_u}^2 + \text{Tr} \left( m_l^2 \right) \right) \tag{66}$$

$$\sigma_{2,3} = \frac{1}{2} \left( 2\text{Tr} \left( m_q^2 \right) + \text{Tr} \left( m_d^2 \right) + \text{Tr} \left( m_u^2 \right) \right) \tag{67}$$

$$\sigma_{2,41} = \sqrt{\frac{3}{5}} g_1 g_p \left( -2Q_u \text{Tr}(m_u^2) - m_{H_d}^2 Q_{H_d} + m_{H_u}^2 Q_{H_u} + Q_d \text{Tr}(m_d^2) + Q_e \text{Tr}(m_e^2) - Q_q \text{Tr}(m_l^2) + Q_q \text{Tr}(m_q^2) + Q_v \text{Tr}(m_\nu^2) \right) \quad (68)$$

$$\sigma_{2,44} = g_p^2 \left( 2m_{H_d}^2 Q_{H_d}^2 + 2m_{H_u}^2 Q_{H_u}^2 + m_S^2 Q_s^2 + 3Q_d^2 \text{Tr}(m_d^2) + Q_e^2 \text{Tr}(m_e^2) + 2Q_q^2 \text{Tr}(m_l^2) + 6Q_q^2 \text{Tr}(m_q^2) + 3Q_u^2 \text{Tr}(m_u^2) + Q_v^2 \text{Tr}(m_\nu^2) \right) \quad (69)$$

$$\begin{aligned} \sigma_{3,4} = & \frac{1}{10} g_p \left( 3g_1^2 m_{H_d}^2 Q_{H_d} + 15g_2^2 m_{H_d}^2 Q_{H_d} + 20g_p^2 m_{H_d}^2 Q_{H_d}^3 + 3g_1^2 m_{H_u}^2 Q_{H_u} + 15g_2^2 m_{H_u}^2 Q_{H_u} \right. \\ & + 20g_p^2 m_{H_u}^2 Q_{H_u}^3 + 10g_p^2 m_S^2 Q_s^3 - 10 \left( m_{H_d}^2 Q_{H_d} + m_{H_u}^2 Q_{H_u} + m_S^2 Q_s \right) |\lambda|^2 \\ & + 2Q_d \left( 15g_p^2 Q_d^2 + 20g_3^2 + g_1^2 \right) \text{Tr}(m_d^2) + 6g_1^2 Q_e \text{Tr}(m_e^2) + 10g_p^2 Q_e^3 \text{Tr}(m_e^2) + 3g_1^2 Q_q \text{Tr}(m_l^2) \\ & + 15g_2^2 Q_q \text{Tr}(m_l^2) + 20g_p^2 Q_q^3 \text{Tr}(m_l^2) + g_1^2 Q_q \text{Tr}(m_q^2) + 45g_2^2 Q_q \text{Tr}(m_q^2) + 80g_3^2 Q_q \text{Tr}(m_q^2) \\ & + 60g_p^2 Q_q^3 \text{Tr}(m_q^2) + 8g_1^2 Q_u \text{Tr}(m_u^2) + 40g_3^2 Q_u \text{Tr}(m_u^2) + 30g_p^2 Q_u^3 \text{Tr}(m_u^2) + 6g_1^2 Q_v \text{Tr}(m_\nu^2) \\ & + 10g_p^2 Q_v^3 \text{Tr}(m_\nu^2) - 30m_{H_d}^2 Q_{H_d} \text{Tr}(Y_d Y_d^\dagger) - 10m_{H_d}^2 Q_{H_d} \text{Tr}(Y_e Y_e^\dagger) - 30m_{H_u}^2 Q_{H_u} \text{Tr}(Y_u Y_u^\dagger) \\ & - 10m_{H_u}^2 Q_{H_u} \text{Tr}(Y_\nu Y_\nu^\dagger) - 10Q_q \text{Tr}(m_l^2 Y_\nu Y_\nu^\dagger) - 10Q_v \text{Tr}(m_\nu^2 Y_\nu^\dagger Y_\nu) - 30Q_d \text{Tr}(Y_d Y_d^\dagger m_d^{2*}) \\ & - 30Q_q \text{Tr}(Y_d m_q^{2*} Y_d^\dagger) - 10Q_e \text{Tr}(Y_e Y_e^\dagger m_e^{2*}) - 10Q_q \text{Tr}(Y_e m_l^{2*} Y_e^\dagger) - 30Q_u \text{Tr}(Y_u Y_u^\dagger m_u^{2*}) \\ & \left. - 30Q_q \text{Tr}(Y_u m_q^{2*} Y_u^\dagger) \right) \quad (70) \end{aligned}$$

$$\begin{aligned} \beta_{m_q^2}^{(1)} = & -\frac{2}{15} g_1^2 \mathbf{1} |M_1|^2 - \frac{32}{3} g_3^2 \mathbf{1} |M_3|^2 - 8g_p^2 Q_q^2 \mathbf{1} |M_Z|^2 - 6g_2^2 \mathbf{1} |M_2|^2 + 2m_{H_d}^2 Y_d^\dagger Y_d \\ & + 2m_{H_u}^2 Y_u^\dagger Y_u + 2T_d^\dagger T_d + 2T_u^\dagger T_u + m_q^2 Y_d^\dagger Y_d + m_q^2 Y_u^\dagger Y_u + 2Y_d^\dagger m_d^2 Y_d \\ & + Y_d^\dagger Y_d m_q^2 + 2Y_u^\dagger m_u^2 Y_u + Y_u^\dagger Y_u m_q^2 + \frac{1}{\sqrt{15}} g_1 \mathbf{1} \sigma_{1,1} + 2g_p Q_q \mathbf{1} \sigma_{1,4} \quad (71) \end{aligned}$$

$$\begin{aligned} \beta_{m_q^2}^{(2)} = & +\frac{24}{5} g_1^2 g_p^2 Q_d Q_q \mathbf{1} |M_Z|^2 + \frac{24}{5} g_1^2 g_p^2 Q_e Q_q \mathbf{1} |M_Z|^2 - \frac{8}{5} g_1^2 g_p^2 Q_{H_d} Q_q \mathbf{1} |M_Z|^2 \\ & + \frac{8}{5} g_1^2 g_p^2 Q_{H_u} Q_q \mathbf{1} |M_Z|^2 - \frac{24}{5} g_1^2 g_p^2 Q_q Q_q \mathbf{1} |M_Z|^2 + \frac{16}{3} g_1^2 g_p^2 Q_q^2 \mathbf{1} |M_Z|^2 \\ & + 24g_2^2 g_p^2 Q_q^2 \mathbf{1} |M_Z|^2 + \frac{128}{3} g_3^2 g_p^2 Q_q^2 \mathbf{1} |M_Z|^2 + 216g_p^4 Q_d^2 Q_q^2 \mathbf{1} |M_Z|^2 \\ & + 72g_p^4 Q_e^2 Q_q^2 \mathbf{1} |M_Z|^2 + 48g_p^4 Q_{H_d}^2 Q_q^2 \mathbf{1} |M_Z|^2 + 48g_p^4 Q_{H_u}^2 Q_q^2 \mathbf{1} |M_Z|^2 \\ & + 144g_p^4 Q_q^2 Q_q^2 \mathbf{1} |M_Z|^2 + 480g_p^4 Q_q^4 \mathbf{1} |M_Z|^2 + 24g_p^4 Q_q^2 Q_s^2 \mathbf{1} |M_Z|^2 \\ & - \frac{48}{5} g_1^2 g_p^2 Q_q Q_u \mathbf{1} |M_Z|^2 + 216g_p^4 Q_q^2 Q_u^2 \mathbf{1} |M_Z|^2 + \frac{24}{5} g_1^2 g_p^2 Q_q Q_v \mathbf{1} |M_Z|^2 \\ & + 72g_p^4 Q_q^2 Q_v^2 \mathbf{1} |M_Z|^2 + \frac{2}{5} g_1^2 g_2^2 \mathbf{1} |M_2|^2 + 33g_2^4 \mathbf{1} |M_2|^2 + 32g_2^2 g_3^2 \mathbf{1} |M_2|^2 \\ & + 24g_2^2 g_p^2 Q_q^2 \mathbf{1} |M_2|^2 \\ & - \frac{16}{45} g_3^2 \left( -15 \left( 3g_2^2 (2M_3 + M_2) + 4g_p^2 (2M_3 + M_Z) \right) Q_q^2 - 8g_3^2 M_3 \right) - g_1^2 (2M_3 + M_1) \mathbf{1} M_3^* \end{aligned}$$

$$\begin{aligned}
& + \frac{12}{5} g_1^2 g_p^2 M_1 Q_d Q_q \mathbf{1} M_Z^* + \frac{12}{5} g_1^2 g_p^2 M_1 Q_e Q_q \mathbf{1} M_Z^* - \frac{4}{5} g_1^2 g_p^2 M_1 Q_{H_d} Q_q \mathbf{1} M_Z^* \\
& + \frac{4}{5} g_1^2 g_p^2 M_1 Q_{H_u} Q_q \mathbf{1} M_Z^* - \frac{12}{5} g_1^2 g_p^2 M_1 Q_q Q_q \mathbf{1} M_Z^* + \frac{8}{3} g_1^2 g_p^2 M_1 Q_q^2 \mathbf{1} M_Z^* \\
& + \frac{64}{3} g_3^2 g_p^2 M_3 Q_q^2 \mathbf{1} M_Z^* + 12 g_2^2 g_p^2 M_2 Q_q^2 \mathbf{1} M_Z^* - \frac{24}{5} g_1^2 g_p^2 M_1 Q_q Q_u \mathbf{1} M_Z^* \\
& + \frac{12}{5} g_1^2 g_p^2 M_1 Q_q Q_v \mathbf{1} M_Z^* + \frac{1}{5} g_1^2 g_2^2 M_1 \mathbf{1} M_2^* + 16 g_2^2 g_3^2 M_3 \mathbf{1} M_2^* + 12 g_2^2 g_p^2 M_Z Q_q^2 \mathbf{1} M_2^* \\
& + \frac{4}{5} g_1^2 m_{H_d}^2 Y_d^\dagger Y_d + 4 g_p^2 m_{H_d}^2 Q_d^2 Y_d^\dagger Y_d + 4 g_p^2 m_{H_d}^2 Q_{H_d}^2 Y_d^\dagger Y_d \\
& - 4 g_p^2 m_{H_d}^2 Q_q^2 Y_d^\dagger Y_d + 8 g_p^2 Q_d^2 |M_Z|^2 Y_d^\dagger Y_d + 8 g_p^2 Q_{H_d}^2 |M_Z|^2 Y_d^\dagger Y_d \\
& - 8 g_p^2 Q_q^2 |M_Z|^2 Y_d^\dagger Y_d - 4 m_{H_d}^2 |\lambda|^2 Y_d^\dagger Y_d - 2 m_{H_u}^2 |\lambda|^2 Y_d^\dagger Y_d \\
& - 2 m_S^2 |\lambda|^2 Y_d^\dagger Y_d - 2 |T_\lambda|^2 Y_d^\dagger Y_d - 4 g_p^2 Q_d^2 M_Z^* Y_d^\dagger T_d \\
& - 4 g_p^2 Q_{H_d}^2 M_Z^* Y_d^\dagger T_d + 4 g_p^2 Q_q^2 M_Z^* Y_d^\dagger T_d - 2 \lambda T_\lambda^* Y_d^\dagger T_d \\
& + \frac{8}{5} g_1^2 m_{H_u}^2 Y_u^\dagger Y_u + 4 g_p^2 m_{H_u}^2 Q_{H_u}^2 Y_u^\dagger Y_u - 4 g_p^2 m_{H_u}^2 Q_q^2 Y_u^\dagger Y_u \\
& + 4 g_p^2 m_{H_u}^2 Q_u^2 Y_u^\dagger Y_u + 8 g_p^2 Q_{H_u}^2 |M_Z|^2 Y_u^\dagger Y_u - 8 g_p^2 Q_q^2 |M_Z|^2 Y_u^\dagger Y_u \\
& + 8 g_p^2 Q_u^2 |M_Z|^2 Y_u^\dagger Y_u - 2 m_{H_d}^2 |\lambda|^2 Y_u^\dagger Y_u - 4 m_{H_u}^2 |\lambda|^2 Y_u^\dagger Y_u \\
& - 2 m_S^2 |\lambda|^2 Y_u^\dagger Y_u - 2 |T_\lambda|^2 Y_u^\dagger Y_u \\
& + \frac{1}{225} g_1^2 M_1^* \left( (759 g_1^2 M_1 \right. \\
& + 5 \left( 4 \left( 3 g_p^2 (2 M_1 + M_Z) Q_q (10 Q_q - 18 Q_u - 3 Q_{H_d} + 3 Q_{H_u} + 9 Q_d + 9 Q_e - 9 Q_q + 9 Q_v) + 4 g_3^2 (2 M_1 + M_3) \right) + 9 g_2^2 (2 M_1 + M_2) \right. \\
& \left. \left. + 180 (2 M_1 Y_d^\dagger Y_d - 2 Y_u^\dagger T_u + 4 M_1 Y_u^\dagger Y_u - Y_d^\dagger T_d) \right) \right) \\
& - 4 g_p^2 Q_{H_u}^2 M_Z^* Y_u^\dagger T_u + 4 g_p^2 Q_q^2 M_Z^* Y_u^\dagger T_u - 4 g_p^2 Q_u^2 M_Z^* Y_u^\dagger T_u \\
& - 2 \lambda T_\lambda^* Y_u^\dagger T_u - \frac{4}{5} g_1^2 M_1 T_d^\dagger Y_d - 4 g_p^2 M_Z Q_d^2 T_d^\dagger Y_d - 4 g_p^2 M_Z Q_{H_d}^2 T_d^\dagger Y_d \\
& + 4 g_p^2 M_Z Q_q^2 T_d^\dagger Y_d + \frac{4}{5} g_1^2 T_d^\dagger T_d + 4 g_p^2 Q_d^2 T_d^\dagger T_d + 4 g_p^2 Q_{H_d}^2 T_d^\dagger T_d \\
& - 4 g_p^2 Q_q^2 T_d^\dagger T_d - 2 |\lambda|^2 T_d^\dagger T_d - \frac{8}{5} g_1^2 M_1 T_u^\dagger Y_u - 4 g_p^2 M_Z Q_{H_u}^2 T_u^\dagger Y_u \\
& + 4 g_p^2 M_Z Q_q^2 T_u^\dagger Y_u - 4 g_p^2 M_Z Q_u^2 T_u^\dagger Y_u + \frac{8}{5} g_1^2 T_u^\dagger T_u + 4 g_p^2 Q_{H_u}^2 T_u^\dagger T_u \\
& - 4 g_p^2 Q_q^2 T_u^\dagger T_u + 4 g_p^2 Q_u^2 T_u^\dagger T_u - 2 |\lambda|^2 T_u^\dagger T_u + \frac{2}{5} g_1^2 m_q^2 Y_d^\dagger Y_d \\
& + 2 g_p^2 Q_d^2 m_q^2 Y_d^\dagger Y_d + 2 g_p^2 Q_{H_d}^2 m_q^2 Y_d^\dagger Y_d - 2 g_p^2 Q_q^2 m_q^2 Y_d^\dagger Y_d \\
& - |\lambda|^2 m_q^2 Y_d^\dagger Y_d + \frac{4}{5} g_1^2 m_q^2 Y_u^\dagger Y_u + 2 g_p^2 Q_{H_u}^2 m_q^2 Y_u^\dagger Y_u \\
& - 2 g_p^2 Q_q^2 m_q^2 Y_u^\dagger Y_u + 2 g_p^2 Q_u^2 m_q^2 Y_u^\dagger Y_u - |\lambda|^2 m_q^2 Y_u^\dagger Y_u \\
& + \frac{4}{5} g_1^2 Y_d^\dagger m_d^2 Y_d + 4 g_p^2 Q_d^2 Y_d^\dagger m_d^2 Y_d + 4 g_p^2 Q_{H_d}^2 Y_d^\dagger m_d^2 Y_d
\end{aligned}$$

$$\begin{aligned}
& -4g_p^2 Q_q^2 Y_d^\dagger m_d^2 Y_d - 2|\lambda|^2 Y_d^\dagger m_d^2 Y_d + \frac{2}{5} g_1^2 Y_d^\dagger Y_d m_q^2 \\
& + 2g_p^2 Q_d^2 Y_d^\dagger Y_d m_q^2 + 2g_p^2 Q_{H_d}^2 Y_d^\dagger Y_d m_q^2 - 2g_p^2 Q_q^2 Y_d^\dagger Y_d m_q^2 \\
& - |\lambda|^2 Y_d^\dagger Y_d m_q^2 + \frac{8}{5} g_1^2 Y_u^\dagger m_u^2 Y_u + 4g_p^2 Q_{H_u}^2 Y_u^\dagger m_u^2 Y_u \\
& - 4g_p^2 Q_q^2 Y_u^\dagger m_u^2 Y_u + 4g_p^2 Q_u^2 Y_u^\dagger m_u^2 Y_u - 2|\lambda|^2 Y_u^\dagger m_u^2 Y_u \\
& + \frac{4}{5} g_1^2 Y_u^\dagger Y_u m_q^2 + 2g_p^2 Q_{H_u}^2 Y_u^\dagger Y_u m_q^2 - 2g_p^2 Q_q^2 Y_u^\dagger Y_u m_q^2 \\
& + 2g_p^2 Q_u^2 Y_u^\dagger Y_u m_q^2 - |\lambda|^2 Y_u^\dagger Y_u m_q^2 - 8m_{H_d}^2 Y_d^\dagger Y_d Y_d^\dagger Y_d - 4Y_d^\dagger Y_d T_d^\dagger T_d \\
& - 4Y_d^\dagger T_d T_d^\dagger Y_d - 8m_{H_u}^2 Y_u^\dagger Y_u Y_u^\dagger Y_u - 4Y_u^\dagger Y_u T_u^\dagger T_u - 4Y_u^\dagger T_u T_u^\dagger Y_u \\
& - 4T_d^\dagger Y_d Y_d^\dagger T_d - 4T_d^\dagger T_d Y_d^\dagger Y_d - 4T_u^\dagger Y_u Y_u^\dagger T_u - 4T_u^\dagger T_u Y_u^\dagger Y_u \\
& - 2m_q^2 Y_d^\dagger Y_d Y_d^\dagger Y_d - 2m_q^2 Y_u^\dagger Y_u Y_u^\dagger Y_u - 4Y_d^\dagger m_d^2 Y_d Y_d^\dagger Y_d - 4Y_d^\dagger Y_d m_q^2 Y_d^\dagger Y_d \\
& - 4Y_d^\dagger Y_d Y_d^\dagger m_d^2 Y_d - 2Y_d^\dagger Y_d Y_d^\dagger Y_d m_q^2 - 4Y_u^\dagger m_u^2 Y_u Y_u^\dagger Y_u - 4Y_u^\dagger Y_u m_q^2 Y_u^\dagger Y_u \\
& - 4Y_u^\dagger Y_u Y_u^\dagger m_u^2 Y_u - 2Y_u^\dagger Y_u Y_u^\dagger Y_u m_q^2 - 2\lambda^* T_d^\dagger Y_d T_\lambda - 2\lambda^* T_u^\dagger Y_u T_\lambda + 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 g_p Q_q \mathbf{1}_{\sigma_{2,14}} + 4 \frac{1}{\sqrt{15}} g_1 g_p Q_q \mathbf{1}_{\sigma_{2,41}} + 8g_p^2 Q_q^2 \mathbf{1}_{\sigma_{2,44}} \\
& + 4 \frac{1}{\sqrt{15}} g_1 \mathbf{1}_{\sigma_{3,1}} + 8g_p Q_q \mathbf{1}_{\sigma_{3,4}} - 12m_{H_d}^2 Y_d^\dagger Y_d \text{Tr}(Y_d Y_d^\dagger) - 6T_d^\dagger T_d \text{Tr}(Y_d Y_d^\dagger) \\
& - 3m_q^2 Y_d^\dagger Y_d \text{Tr}(Y_d Y_d^\dagger) - 6Y_d^\dagger m_d^2 Y_d \text{Tr}(Y_d Y_d^\dagger) - 3Y_d^\dagger Y_d m_q^2 \text{Tr}(Y_d Y_d^\dagger) \\
& - 4m_{H_d}^2 Y_d^\dagger Y_d \text{Tr}(Y_e Y_e^\dagger) - 2T_d^\dagger T_d \text{Tr}(Y_e Y_e^\dagger) - m_q^2 Y_d^\dagger Y_d \text{Tr}(Y_e Y_e^\dagger) \\
& - 2Y_d^\dagger m_d^2 Y_d \text{Tr}(Y_e Y_e^\dagger) - Y_d^\dagger Y_d m_q^2 \text{Tr}(Y_e Y_e^\dagger) - 12m_{H_u}^2 Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) \\
& - 6T_u^\dagger T_u \text{Tr}(Y_u Y_u^\dagger) - 3m_q^2 Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger) - 6Y_u^\dagger m_u^2 Y_u \text{Tr}(Y_u Y_u^\dagger) \\
& - 3Y_u^\dagger Y_u m_q^2 \text{Tr}(Y_u Y_u^\dagger) - 4m_{H_u}^2 Y_u^\dagger Y_u \text{Tr}(Y_\nu Y_\nu^\dagger) - 2T_u^\dagger T_u \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& - m_q^2 Y_u^\dagger Y_u \text{Tr}(Y_\nu Y_\nu^\dagger) - 2Y_u^\dagger m_u^2 Y_u \text{Tr}(Y_\nu Y_\nu^\dagger) - Y_u^\dagger Y_u m_q^2 \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& - 6T_d^\dagger Y_d \text{Tr}(Y_d^\dagger T_d) - 2T_d^\dagger Y_d \text{Tr}(Y_e^\dagger T_e) - 6T_u^\dagger Y_u \text{Tr}(Y_u^\dagger T_u) \\
& - 2T_u^\dagger Y_u \text{Tr}(Y_\nu^\dagger T_\nu) - 6Y_d^\dagger T_d \text{Tr}(T_d^* Y_d^T) - 6Y_d^\dagger Y_d \text{Tr}(T_d^* T_d^T) \\
& - 2Y_d^\dagger T_d \text{Tr}(T_e^* Y_e^T) - 2Y_d^\dagger Y_d \text{Tr}(T_e^* T_e^T) - 6Y_u^\dagger T_u \text{Tr}(T_u^* Y_u^T) \\
& - 6Y_u^\dagger Y_u \text{Tr}(T_u^* T_u^T) - 2Y_u^\dagger T_u \text{Tr}(T_\nu^* Y_\nu^T) - 2Y_u^\dagger Y_u \text{Tr}(T_\nu^* T_\nu^T) \\
& - 6Y_d^\dagger Y_d \text{Tr}(m_d^2 Y_d Y_d^\dagger) - 2Y_d^\dagger Y_d \text{Tr}(m_e^2 Y_e Y_e^\dagger) - 2Y_d^\dagger Y_d \text{Tr}(m_i^2 Y_e^\dagger Y_e) \\
& - 6Y_d^\dagger Y_d \text{Tr}(m_q^2 Y_d^\dagger Y_d) - 6Y_u^\dagger Y_u \text{Tr}(m_q^2 Y_u^\dagger Y_u) - 6Y_u^\dagger Y_u \text{Tr}(m_u^2 Y_u Y_u^\dagger) \\
& - 2Y_u^\dagger Y_u \text{Tr}(Y_\nu Y_\nu^\dagger m_l^{2*}) - 2Y_u^\dagger Y_u \text{Tr}(Y_\nu m_\nu^{2*} Y_\nu^\dagger)
\end{aligned} \tag{72}$$

$$\begin{aligned}
\beta_{m_l^2}^{(1)} = & -\frac{6}{5}g_1^2\mathbf{1}|M_1|^2 - 8g_p^2Q_q^2\mathbf{1}|M_Z|^2 - 6g_2^2\mathbf{1}|M_2|^2 + 2m_{H_d}^2Y_e^\dagger Y_e + 2T_e^\dagger T_e \\
& + 2m_{H_u}^2Y_\nu^* Y_\nu^T + 2T_\nu^* T_\nu^T + m_l^2Y_e^\dagger Y_e + m_l^2Y_\nu^* Y_\nu^T + 2Y_e^\dagger m_e^2 Y_e + Y_e^\dagger Y_e m_l^2 \\
& + 2Y_\nu^* m_\nu^2 Y_\nu^T + Y_\nu^* Y_\nu^T m_l^2 - \sqrt{\frac{3}{5}}g_1\mathbf{1}\sigma_{1,1} + 2g_pQ_q\mathbf{1}\sigma_{1,4}
\end{aligned} \tag{73}$$

$$\begin{aligned}
\beta_{m_l^2}^{(2)} = & +\frac{18}{5}g_1^2g_2^2\mathbf{1}|M_2|^2 + 33g_2^4\mathbf{1}|M_2|^2 + 24g_2^2g_p^2Q_q^2\mathbf{1}|M_2|^2 + \frac{9}{5}g_1^2g_2^2M_1\mathbf{1}M_2^* \\
& + 12g_2^2g_p^2M_ZQ_q^2\mathbf{1}M_2^* + \frac{12}{5}g_1^2m_{H_d}^2Y_e^\dagger Y_e + 4g_p^2m_{H_d}^2Q_e^2Y_e^\dagger Y_e \\
& + 4g_p^2m_{H_d}^2Q_{H_d}^2Y_e^\dagger Y_e - 4g_p^2m_{H_d}^2Q_q^2Y_e^\dagger Y_e - 4m_{H_d}^2|\lambda|^2Y_e^\dagger Y_e \\
& - 2m_{H_u}^2|\lambda|^2Y_e^\dagger Y_e - 2m_S^2|\lambda|^2Y_e^\dagger Y_e - 2|T_\lambda|^2Y_e^\dagger Y_e - 2\lambda T_\lambda^* Y_e^\dagger T_e \\
& - \frac{12}{5}g_1^2M_1T_e^\dagger Y_e - 4g_p^2M_ZQ_e^2T_e^\dagger Y_e - 4g_p^2M_ZQ_{H_d}^2T_e^\dagger Y_e \\
& + 4g_p^2M_ZQ_q^2T_e^\dagger Y_e + \frac{12}{5}g_1^2T_e^\dagger T_e + 4g_p^2Q_e^2T_e^\dagger T_e + 4g_p^2Q_{H_d}^2T_e^\dagger T_e \\
& - 4g_p^2Q_q^2T_e^\dagger T_e - 2|\lambda|^2T_e^\dagger T_e + \frac{12}{5}g_1^2m_{H_u}^2Y_\nu^* Y_\nu^T + 4g_p^2m_{H_u}^2Q_{H_u}^2Y_\nu^* Y_\nu^T \\
& - 4g_p^2m_{H_u}^2Q_q^2Y_\nu^* Y_\nu^T + 4g_p^2m_{H_u}^2Q_v^2Y_\nu^* Y_\nu^T - 2m_{H_d}^2|\lambda|^2Y_\nu^* Y_\nu^T \\
& - 4m_{H_u}^2|\lambda|^2Y_\nu^* Y_\nu^T - 2m_S^2|\lambda|^2Y_\nu^* Y_\nu^T - 2|T_\lambda|^2Y_\nu^* Y_\nu^T \\
& + \frac{4}{5}g_p^2M_Z^* \left( 3Q_q \left( -g_1^2 \left( 2M_Z + M_1 \right) \left( 3Q_d + 3Q_e + 3Q_q + 3Q_v - 4Q_q - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right. \right. \\
& \left. \left. + 5Q_q \left( 2g_p^2M_Z \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_v^2 + 8Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \right) + g_2^2 \left( 2M_Z + M_2 \right) \right) \right) \mathbf{1} \\
& + 5 \left( 2M_Z \left( -Q_q^2 + Q_e^2 + Q_{H_d}^2 \right) Y_e^\dagger Y_e - \left( -Q_q^2 + Q_e^2 + Q_{H_d}^2 \right) Y_e^\dagger T_e \right. \\
& \left. + \left( -Q_q^2 + Q_{H_u}^2 + Q_v^2 \right) \left( 2M_Z Y_\nu^* Y_\nu^T - Y_\nu^* T_\nu^T \right) \right) \\
& + \frac{3}{25}g_1^2M_1^* \left( \left( 261g_1^2M_1 + 5 \left( 3g_2^2 \left( 2M_1 + M_2 \right) - 4g_p^2 \left( 2M_1 + M_Z \right) \right) Q_q \left( 3Q_d + 3Q_e + 3Q_q + 3Q_v - 4Q_q - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right) \right) \mathbf{1} \\
& + 20 \left( 2M_1 Y_e^\dagger Y_e + 2M_1 Y_\nu^* Y_\nu^T - Y_e^\dagger T_e - Y_\nu^* T_\nu^T \right) \\
& - 2\lambda T_\lambda^* Y_\nu^* T_\nu^T - \frac{12}{5}g_1^2M_1T_\nu^* Y_\nu^T - 4g_p^2M_ZQ_{H_u}^2T_\nu^* Y_\nu^T + 4g_p^2M_ZQ_q^2T_\nu^* Y_\nu^T \\
& - 4g_p^2M_ZQ_v^2T_\nu^* Y_\nu^T + \frac{12}{5}g_1^2T_\nu^* T_\nu^T + 4g_p^2Q_{H_u}^2T_\nu^* T_\nu^T - 4g_p^2Q_q^2T_\nu^* T_\nu^T \\
& + 4g_p^2Q_v^2T_\nu^* T_\nu^T - 2|\lambda|^2T_\nu^* T_\nu^T + \frac{6}{5}g_1^2m_l^2Y_e^\dagger Y_e + 2g_p^2Q_e^2m_l^2Y_e^\dagger Y_e \\
& + 2g_p^2Q_{H_d}^2m_l^2Y_e^\dagger Y_e - 2g_p^2Q_q^2m_l^2Y_e^\dagger Y_e - |\lambda|^2m_l^2Y_e^\dagger Y_e \\
& + \frac{6}{5}g_1^2m_l^2Y_\nu^* Y_\nu^T + 2g_p^2Q_{H_u}^2m_l^2Y_\nu^* Y_\nu^T - 2g_p^2Q_q^2m_l^2Y_\nu^* Y_\nu^T \\
& + 2g_p^2Q_v^2m_l^2Y_\nu^* Y_\nu^T - |\lambda|^2m_l^2Y_\nu^* Y_\nu^T + \frac{12}{5}g_1^2Y_e^\dagger m_e^2 Y_e \\
& + 4g_p^2Q_e^2Y_e^\dagger m_e^2 Y_e + 4g_p^2Q_{H_d}^2Y_e^\dagger m_e^2 Y_e - 4g_p^2Q_q^2Y_e^\dagger m_e^2 Y_e
\end{aligned}$$

$$\begin{aligned}
& -2|\lambda|^2 Y_e^\dagger m_e^2 Y_e + \frac{6}{5} g_1^2 Y_e^\dagger Y_e m_l^2 + 2g_p^2 Q_e^2 Y_e^\dagger Y_e m_l^2 \\
& + 2g_p^2 Q_{H_d}^2 Y_e^\dagger Y_e m_l^2 - 2g_p^2 Q_q^2 Y_e^\dagger Y_e m_l^2 - |\lambda|^2 Y_e^\dagger Y_e m_l^2 \\
& + \frac{12}{5} g_1^2 Y_\nu^* m_\nu^2 Y_\nu^T + 4g_p^2 Q_{H_u}^2 Y_\nu^* m_\nu^2 Y_\nu^T - 4g_p^2 Q_q^2 Y_\nu^* m_\nu^2 Y_\nu^T \\
& + 4g_p^2 Q_\nu^2 Y_\nu^* m_\nu^2 Y_\nu^T - 2|\lambda|^2 Y_\nu^* m_\nu^2 Y_\nu^T + \frac{6}{5} g_1^2 Y_\nu^* Y_\nu^T m_l^2 \\
& + 2g_p^2 Q_{H_u}^2 Y_\nu^* Y_\nu^T m_l^2 - 2g_p^2 Q_q^2 Y_\nu^* Y_\nu^T m_l^2 + 2g_p^2 Q_\nu^2 Y_\nu^* Y_\nu^T m_l^2 \\
& - |\lambda|^2 Y_\nu^* Y_\nu^T m_l^2 - 8m_{H_d}^2 Y_e^\dagger Y_e Y_e^\dagger Y_e - 4Y_e^\dagger Y_e T_e^\dagger T_e - 4Y_e^\dagger T_e T_e^\dagger Y_e \\
& - 4T_e^\dagger Y_e Y_e^\dagger T_e - 4T_e^\dagger T_e Y_e^\dagger Y_e - 8m_{H_u}^2 Y_\nu^* Y_\nu^T Y_\nu^* Y_\nu^T - 4Y_\nu^* Y_\nu^T T_\nu^* T_\nu^T \\
& - 4Y_\nu^* T_\nu^* T_\nu^* Y_\nu^T - 4T_\nu^* Y_\nu^T Y_\nu^* T_\nu^T - 4T_\nu^* T_\nu^* Y_\nu^* Y_\nu^T - 2m_l^2 Y_e^\dagger Y_e Y_e^\dagger Y_e \\
& - 2m_l^2 Y_\nu^* Y_\nu^T Y_\nu^* Y_\nu^T - 4Y_e^\dagger m_e^2 Y_e Y_e^\dagger Y_e - 4Y_e^\dagger Y_e m_l^2 Y_e^\dagger Y_e - 4Y_e^\dagger Y_e Y_e^\dagger m_e^2 Y_e \\
& - 2Y_e^\dagger Y_e Y_e^\dagger Y_e m_l^2 - 4Y_\nu^* m_\nu^2 Y_\nu^T Y_\nu^* Y_\nu^T - 4Y_\nu^* Y_\nu^T m_l^2 Y_\nu^* Y_\nu^T - 4Y_\nu^* Y_\nu^T Y_\nu^* m_\nu^2 Y_\nu^T \\
& - 2Y_\nu^* Y_\nu^T Y_\nu^* Y_\nu^T m_l^2 - 2\lambda^* T_e^\dagger Y_e T_\lambda - 2\lambda^* T_\nu^* Y_\nu^T T_\lambda + 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 g_p Q_q \mathbf{1}_{\sigma_{2,14}} - 4\sqrt{\frac{3}{5}} g_1 g_p Q_q \mathbf{1}_{\sigma_{2,41}} + 8g_p^2 Q_q^2 \mathbf{1}_{\sigma_{2,44}} - 4\sqrt{\frac{3}{5}} g_1 \mathbf{1}_{\sigma_{3,1}} + 8g_p Q_q \mathbf{1}_{\sigma_{3,4}} \\
& - 12m_{H_d}^2 Y_e^\dagger Y_e \text{Tr}(Y_d Y_d^\dagger) - 6T_e^\dagger T_e \text{Tr}(Y_d Y_d^\dagger) - 3m_l^2 Y_e^\dagger Y_e \text{Tr}(Y_d Y_d^\dagger) \\
& - 6Y_e^\dagger m_e^2 Y_e \text{Tr}(Y_d Y_d^\dagger) - 3Y_e^\dagger Y_e m_l^2 \text{Tr}(Y_d Y_d^\dagger) - 4m_{H_d}^2 Y_e^\dagger Y_e \text{Tr}(Y_e Y_e^\dagger) \\
& \quad - 2T_e^\dagger T_e \text{Tr}(Y_e Y_e^\dagger) - m_l^2 Y_e^\dagger Y_e \text{Tr}(Y_e Y_e^\dagger) - 2Y_e^\dagger m_e^2 Y_e \text{Tr}(Y_e Y_e^\dagger) \\
& \quad - Y_e^\dagger Y_e m_l^2 \text{Tr}(Y_e Y_e^\dagger) - 12m_{H_u}^2 Y_\nu^* Y_\nu^T \text{Tr}(Y_u Y_u^\dagger) - 6T_\nu^* T_\nu^* \text{Tr}(Y_u Y_u^\dagger) \\
& \quad - 3m_l^2 Y_\nu^* Y_\nu^T \text{Tr}(Y_u Y_u^\dagger) - 6Y_\nu^* m_\nu^2 Y_\nu^T \text{Tr}(Y_u Y_u^\dagger) - 3Y_\nu^* Y_\nu^T m_l^2 \text{Tr}(Y_u Y_u^\dagger) \\
& \quad - 4m_{H_u}^2 Y_\nu^* Y_\nu^T \text{Tr}(Y_\nu Y_\nu^\dagger) - 2T_\nu^* T_\nu^* \text{Tr}(Y_\nu Y_\nu^\dagger) - m_l^2 Y_\nu^* Y_\nu^T \text{Tr}(Y_\nu Y_\nu^\dagger) \\
& \quad - 2Y_\nu^* m_\nu^2 Y_\nu^T \text{Tr}(Y_\nu Y_\nu^\dagger) - Y_\nu^* Y_\nu^T m_l^2 \text{Tr}(Y_\nu Y_\nu^\dagger) - 6T_e^\dagger Y_e \text{Tr}(Y_d^\dagger T_d) \\
& \quad - 2T_e^\dagger Y_e \text{Tr}(Y_e^\dagger T_e) - 6T_\nu^* Y_\nu^T \text{Tr}(Y_u^\dagger T_u) - 2T_\nu^* Y_\nu^T \text{Tr}(Y_\nu^\dagger T_\nu) \\
& \quad - 6Y_e^\dagger T_e \text{Tr}(T_d^* Y_d^T) - 6Y_e^\dagger Y_e \text{Tr}(T_d^* T_d^T) - 2Y_e^\dagger T_e \text{Tr}(T_e^* Y_e^T) \\
& \quad - 2Y_e^\dagger Y_e \text{Tr}(T_e^* T_e^T) - 6Y_\nu^* T_\nu^* \text{Tr}(T_u^* Y_u^T) - 6Y_\nu^* Y_\nu^T \text{Tr}(T_u^* T_u^T) \\
& \quad - 2Y_\nu^* T_\nu^* \text{Tr}(T_\nu^* Y_\nu^T) - 2Y_\nu^* Y_\nu^T \text{Tr}(T_\nu^* T_\nu^T) - 6Y_e^\dagger Y_e \text{Tr}(m_d^2 Y_d Y_d^\dagger) \\
& \quad - 2Y_e^\dagger Y_e \text{Tr}(m_e^2 Y_e Y_e^\dagger) - 2Y_e^\dagger Y_e \text{Tr}(m_l^2 Y_e^\dagger Y_e) - 6Y_e^\dagger Y_e \text{Tr}(m_q^2 Y_d^\dagger Y_d) \\
& \quad - 6Y_\nu^* Y_\nu^T \text{Tr}(m_q^2 Y_u^\dagger Y_u) - 6Y_\nu^* Y_\nu^T \text{Tr}(m_u^2 Y_u Y_u^\dagger) - 2Y_\nu^* Y_\nu^T \text{Tr}(Y_\nu Y_\nu^\dagger m_l^{2*}) \\
& \quad - 2Y_\nu^* Y_\nu^T \text{Tr}(Y_\nu m_\nu^{2*} Y_\nu^\dagger)
\end{aligned} \tag{74}$$

$$\begin{aligned}
\beta_{m_{H_d}^2}^{(1)} &= -\frac{6}{5}g_1^2|M_1|^2 - 8g_p^2Q_{H_d}^2|M_Z|^2 - 6g_2^2|M_2|^2 + 2m_{H_d}^2|\lambda|^2 + 2m_{H_u}^2|\lambda|^2 + 2m_S^2|\lambda|^2 + 2|T_\lambda|^2 \\
&\quad - \sqrt{\frac{3}{5}}g_1\sigma_{1,1} + 2g_pQ_{H_d}\sigma_{1,4} + 6m_{H_d}^2\text{Tr}(Y_dY_d^\dagger) + 2m_{H_d}^2\text{Tr}(Y_eY_e^\dagger) + 6\text{Tr}(T_d^*T_d^T) + 2\text{Tr}(T_e^*T_e^T) \\
&\quad + 6\text{Tr}(m_d^2Y_dY_d^\dagger) + 2\text{Tr}(m_e^2Y_eY_e^\dagger) + 2\text{Tr}(m_l^2Y_e^\dagger Y_e) + 6\text{Tr}(m_q^2Y_d^\dagger Y_d) \tag{75} \\
\beta_{m_{H_d}^2}^{(2)} &= +\frac{18}{5}g_1^2g_2^2|M_2|^2 + 33g_2^4|M_2|^2 + 24g_2^2g_p^2Q_{H_d}^2|M_2|^2 - 4g_p^2m_{H_d}^2Q_{H_d}^2|\lambda|^2 \\
&\quad - 4g_p^2m_{H_u}^2Q_{H_d}^2|\lambda|^2 - 4g_p^2m_S^2Q_{H_d}^2|\lambda|^2 + 4g_p^2m_{H_d}^2Q_{H_u}^2|\lambda|^2 + 4g_p^2m_{H_u}^2Q_{H_u}^2|\lambda|^2 \\
&\quad + 4g_p^2m_S^2Q_{H_u}^2|\lambda|^2 + 4g_p^2m_{H_d}^2Q_s^2|\lambda|^2 + 4g_p^2m_{H_u}^2Q_s^2|\lambda|^2 + 4g_p^2m_S^2Q_s^2|\lambda|^2 \\
&\quad - 4g_p^2Q_{H_d}^2|T_\lambda|^2 + 4g_p^2Q_{H_u}^2|T_\lambda|^2 + 4g_p^2Q_s^2|T_\lambda|^2 + \frac{9}{5}g_1^2g_2^2M_1M_2^* \\
&\quad + 12g_2^2g_p^2M_ZQ_{H_d}^2M_2^* - 12m_{H_d}^2\lambda^2\lambda^{*,2} - 12m_{H_u}^2\lambda^2\lambda^{*,2} - 12m_S^2\lambda^2\lambda^{*,2} + 4g_p^2M_ZQ_{H_d}^2\lambda T_\lambda^* \\
&\quad - 4g_p^2M_ZQ_{H_u}^2\lambda T_\lambda^* - 4g_p^2M_ZQ_s^2\lambda T_\lambda^* - 24|\lambda|^2T_\lambda^*T_\lambda + 6g_2^4\sigma_{2,2} + \frac{6}{5}g_1^2\sigma_{2,11} - 4\sqrt{\frac{3}{5}}g_1g_pQ_{H_d}\sigma_{2,14} \\
&\quad - 4\sqrt{\frac{3}{5}}g_1g_pQ_{H_d}\sigma_{2,41} + 8g_p^2Q_{H_d}^2\sigma_{2,44} - 4\sqrt{\frac{3}{5}}g_1\sigma_{3,1} + 8g_pQ_{H_d}\sigma_{3,4} - \frac{4}{5}g_1^2m_{H_d}^2\text{Tr}(Y_dY_d^\dagger) \\
&\quad + 32g_3^2m_{H_d}^2\text{Tr}(Y_dY_d^\dagger) + 12g_p^2m_{H_d}^2Q_d^2\text{Tr}(Y_dY_d^\dagger) - 12g_p^2m_{H_d}^2Q_{H_d}^2\text{Tr}(Y_dY_d^\dagger) \\
&\quad + 12g_p^2m_{H_d}^2Q_q^2\text{Tr}(Y_dY_d^\dagger) + 64g_3^2|M_3|^2\text{Tr}(Y_dY_d^\dagger) + \frac{12}{5}g_1^2m_{H_d}^2\text{Tr}(Y_eY_e^\dagger) \\
&\quad + 4g_p^2m_{H_d}^2Q_e^2\text{Tr}(Y_eY_e^\dagger) - 4g_p^2m_{H_d}^2Q_{H_d}^2\text{Tr}(Y_eY_e^\dagger) + 4g_p^2m_{H_d}^2Q_q^2\text{Tr}(Y_eY_e^\dagger) \\
&\quad - 6m_{H_d}^2|\lambda|^2\text{Tr}(Y_uY_u^\dagger) - 12m_{H_u}^2|\lambda|^2\text{Tr}(Y_uY_u^\dagger) - 6m_S^2|\lambda|^2\text{Tr}(Y_uY_u^\dagger) \\
&\quad - 6|T_\lambda|^2\text{Tr}(Y_uY_u^\dagger) - 2m_{H_d}^2|\lambda|^2\text{Tr}(Y_\nu Y_\nu^\dagger) - 4m_{H_u}^2|\lambda|^2\text{Tr}(Y_\nu Y_\nu^\dagger) \\
&\quad - 2m_S^2|\lambda|^2\text{Tr}(Y_\nu Y_\nu^\dagger) - 2|T_\lambda|^2\text{Tr}(Y_\nu Y_\nu^\dagger) - 32g_3^2M_3^*\text{Tr}(Y_d^\dagger T_d) \\
&\quad + \frac{1}{25}g_1^2M_1^* \left( 783g_1^2M_1 + 90g_2^2M_1 + 45g_2^2M_2 - 360g_p^2M_1Q_dQ_{H_d} - 180g_p^2M_ZQ_dQ_{H_d} - 360g_p^2M_1Q_eQ_{H_d} \right. \\
&\quad - 180g_p^2M_ZQ_eQ_{H_d} + 240g_p^2M_1Q_{H_d}^2 + 120g_p^2M_ZQ_{H_d}^2 - 120g_p^2M_1Q_{H_d}Q_{H_u} - 60g_p^2M_ZQ_{H_d}Q_{H_u} \\
&\quad + 360g_p^2M_1Q_{H_d}Q_q + 180g_p^2M_ZQ_{H_d}Q_q - 360g_p^2M_1Q_{H_d}Q_q - 180g_p^2M_ZQ_{H_d}Q_q + 720g_p^2M_1Q_{H_d}Q_u \\
&\quad + 360g_p^2M_ZQ_{H_d}Q_u - 360g_p^2M_1Q_{H_d}Q_v - 180g_p^2M_ZQ_{H_d}Q_v - 40M_1\text{Tr}(Y_dY_d^\dagger) + 120M_1\text{Tr}(Y_eY_e^\dagger) \\
&\quad \left. + 20\text{Tr}(Y_d^\dagger T_d) - 60\text{Tr}(Y_e^\dagger T_e) \right) \\
&\quad + \frac{4}{5}g_p^2M_Z^* \left( -9g_1^2M_1Q_dQ_{H_d} - 18g_1^2M_ZQ_dQ_{H_d} - 9g_1^2M_1Q_eQ_{H_d} - 18g_1^2M_ZQ_eQ_{H_d} + 6g_1^2M_1Q_{H_d}^2 \right. \\
&\quad + 12g_1^2M_ZQ_{H_d}^2 + 30g_2^2M_ZQ_{H_d}^2 + 15g_2^2M_2Q_{H_d}^2 + 270g_p^2M_ZQ_d^2Q_{H_d}^2 + 90g_p^2M_ZQ_e^2Q_{H_d}^2 \\
&\quad + 120g_p^2M_ZQ_{H_d}^4 - 3g_1^2M_1Q_{H_d}Q_{H_u} - 6g_1^2M_ZQ_{H_d}Q_{H_u} + 60g_p^2M_ZQ_{H_d}^2Q_{H_u}^2 + 9g_1^2M_1Q_{H_d}Q_q \\
&\quad + 18g_1^2M_ZQ_{H_d}Q_q + 180g_p^2M_ZQ_{H_d}^2Q_q^2 - 9g_1^2M_1Q_{H_d}Q_q - 18g_1^2M_ZQ_{H_d}Q_q \\
&\quad \left. + 540g_p^2M_ZQ_{H_d}^2Q_q^2 + 30g_p^2M_ZQ_{H_d}^2Q_s^2 + 18g_1^2M_1Q_{H_d}Q_u + 36g_1^2M_ZQ_{H_d}Q_u \right)
\end{aligned}$$



$$\begin{aligned}
& + 270g_p^2 M_Z Q_{H_d}^2 Q_u^2 - 9g_1^2 M_1 Q_{H_d} Q_v - 18g_1^2 M_Z Q_{H_d} Q_v + 90g_p^2 M_Z Q_{H_d}^2 Q_v^2 \\
& - 5\left(-Q_{H_u}^2 - Q_s^2 + Q_{H_d}^2\right)\lambda^*\left(2M_Z\lambda - T_\lambda\right) + 30M_Z\left(-Q_{H_d}^2 + Q_d^2 + Q_q^2\right)\text{Tr}\left(Y_d Y_d^\dagger\right) \\
& + 10M_Z Q_e^2 \text{Tr}\left(Y_e Y_e^\dagger\right) - 10M_Z Q_{H_d}^2 \text{Tr}\left(Y_e Y_e^\dagger\right) + 10M_Z Q_q^2 \text{Tr}\left(Y_e Y_e^\dagger\right) - 15Q_d^2 \text{Tr}\left(Y_d^\dagger T_d\right) \\
& + 15Q_{H_d}^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 15Q_q^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 5Q_e^2 \text{Tr}\left(Y_e^\dagger T_e\right) + 5Q_{H_d}^2 \text{Tr}\left(Y_e^\dagger T_e\right) \\
& - 5Q_q^2 \text{Tr}\left(Y_e^\dagger T_e\right) \\
& - 6\lambda T_\lambda^* \text{Tr}\left(Y_u^\dagger T_u\right) - 2\lambda T_\lambda^* \text{Tr}\left(Y_\nu^\dagger T_\nu\right) + \frac{4}{5}g_1^2 M_1 \text{Tr}\left(T_d^* Y_d^T\right) - 32g_3^2 M_3 \text{Tr}\left(T_d^* Y_d^T\right) \\
& - 12g_p^2 M_Z Q_d^2 \text{Tr}\left(T_d^* Y_d^T\right) + 12g_p^2 M_Z Q_{H_d}^2 \text{Tr}\left(T_d^* Y_d^T\right) - 12g_p^2 M_Z Q_q^2 \text{Tr}\left(T_d^* Y_d^T\right) \\
& - \frac{4}{5}g_1^2 \text{Tr}\left(T_d^* T_d^T\right) + 32g_3^2 \text{Tr}\left(T_d^* T_d^T\right) + 12g_p^2 Q_d^2 \text{Tr}\left(T_d^* T_d^T\right) - 12g_p^2 Q_{H_d}^2 \text{Tr}\left(T_d^* T_d^T\right) \\
& + 12g_p^2 Q_q^2 \text{Tr}\left(T_d^* T_d^T\right) - \frac{12}{5}g_1^2 M_1 \text{Tr}\left(T_e^* Y_e^T\right) - 4g_p^2 M_Z Q_e^2 \text{Tr}\left(T_e^* Y_e^T\right) \\
& + 4g_p^2 M_Z Q_{H_d}^2 \text{Tr}\left(T_e^* Y_e^T\right) - 4g_p^2 M_Z Q_q^2 \text{Tr}\left(T_e^* Y_e^T\right) + \frac{12}{5}g_1^2 \text{Tr}\left(T_e^* T_e^T\right) \\
& + 4g_p^2 Q_e^2 \text{Tr}\left(T_e^* T_e^T\right) - 4g_p^2 Q_{H_d}^2 \text{Tr}\left(T_e^* T_e^T\right) + 4g_p^2 Q_q^2 \text{Tr}\left(T_e^* T_e^T\right) - 6\lambda^* T_\lambda \text{Tr}\left(T_u^* Y_u^T\right) \\
& - 6|\lambda|^2 \text{Tr}\left(T_u^* T_u^T\right) - 2\lambda^* T_\lambda \text{Tr}\left(T_\nu^* Y_\nu^T\right) - 2|\lambda|^2 \text{Tr}\left(T_\nu^* T_\nu^T\right) - \frac{4}{5}g_1^2 \text{Tr}\left(m_d^2 Y_d Y_d^\dagger\right) \\
& + 32g_3^2 \text{Tr}\left(m_d^2 Y_d Y_d^\dagger\right) + 12g_p^2 Q_d^2 \text{Tr}\left(m_d^2 Y_d Y_d^\dagger\right) - 12g_p^2 Q_{H_d}^2 \text{Tr}\left(m_d^2 Y_d Y_d^\dagger\right) \\
& + 12g_p^2 Q_q^2 \text{Tr}\left(m_d^2 Y_d Y_d^\dagger\right) + \frac{12}{5}g_1^2 \text{Tr}\left(m_e^2 Y_e Y_e^\dagger\right) + 4g_p^2 Q_e^2 \text{Tr}\left(m_e^2 Y_e Y_e^\dagger\right) \\
& - 4g_p^2 Q_{H_d}^2 \text{Tr}\left(m_e^2 Y_e Y_e^\dagger\right) + 4g_p^2 Q_q^2 \text{Tr}\left(m_e^2 Y_e Y_e^\dagger\right) + \frac{12}{5}g_1^2 \text{Tr}\left(m_l^2 Y_e^\dagger Y_e\right) \\
& + 4g_p^2 Q_e^2 \text{Tr}\left(m_l^2 Y_e^\dagger Y_e\right) - 4g_p^2 Q_{H_d}^2 \text{Tr}\left(m_l^2 Y_e^\dagger Y_e\right) + 4g_p^2 Q_q^2 \text{Tr}\left(m_l^2 Y_e^\dagger Y_e\right) \\
& - \frac{4}{5}g_1^2 \text{Tr}\left(m_q^2 Y_d^\dagger Y_d\right) + 32g_3^2 \text{Tr}\left(m_q^2 Y_d^\dagger Y_d\right) + 12g_p^2 Q_d^2 \text{Tr}\left(m_q^2 Y_d^\dagger Y_d\right) \\
& - 12g_p^2 Q_{H_d}^2 \text{Tr}\left(m_q^2 Y_d^\dagger Y_d\right) + 12g_p^2 Q_q^2 \text{Tr}\left(m_q^2 Y_d^\dagger Y_d\right) - 6|\lambda|^2 \text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) \\
& - 6|\lambda|^2 \text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right) - 2|\lambda|^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger m_l^{2*}\right) - 2|\lambda|^2 \text{Tr}\left(Y_\nu m_\nu^{2*} Y_\nu^\dagger\right) \\
& - 36m_{H_d}^2 \text{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right) - 36\text{Tr}\left(Y_d Y_d^\dagger T_d T_d^\dagger\right) - 6m_{H_d}^2 \text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) \\
& - 6m_{H_u}^2 \text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 6\text{Tr}\left(Y_d Y_u^\dagger T_u T_u^\dagger\right) - 36\text{Tr}\left(Y_d T_d^\dagger T_d Y_d^\dagger\right) \\
& - 6\text{Tr}\left(Y_d T_u^\dagger T_u Y_d^\dagger\right) - 12m_{H_d}^2 \text{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right) - 12\text{Tr}\left(Y_e Y_e^\dagger T_e T_e^\dagger\right) - 12\text{Tr}\left(Y_e T_e^\dagger T_e Y_e^\dagger\right) \\
& - 2\text{Tr}\left(Y_e T_\nu^* T_\nu^T Y_e^\dagger\right) - 6\text{Tr}\left(Y_u Y_d^\dagger T_d T_u^\dagger\right) - 6\text{Tr}\left(Y_u T_d^\dagger T_d Y_u^\dagger\right) \\
& - 2m_{H_d}^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*\right) - 2m_{H_u}^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*\right) - 2\text{Tr}\left(Y_\nu Y_\nu^\dagger T_e^T T_e^*\right)
\end{aligned}$$

$$\begin{aligned}
& -2\text{Tr}\left(Y_e^\dagger T_e T_\nu^* Y_\nu^T\right) - 2\text{Tr}\left(Y_\nu^\dagger Y_e^T T_e^* T_\nu\right) - 36\text{Tr}\left(m_d^2 Y_d Y_d^\dagger Y_d Y_d^\dagger\right) - 6\text{Tr}\left(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\right) \\
& - 12\text{Tr}\left(m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger\right) - 12\text{Tr}\left(m_l^2 Y_e^\dagger Y_e Y_e^\dagger Y_e\right) - 36\text{Tr}\left(m_q^2 Y_d^\dagger Y_d Y_d^\dagger Y_d\right) - 6\text{Tr}\left(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\right) \\
& - 6\text{Tr}\left(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\right) - 6\text{Tr}\left(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\right) - 2\text{Tr}\left(Y_\nu Y_\nu^\dagger m_l^{2*} Y_e^T Y_e^*\right) \\
& - 2\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T m_e^{2*} Y_e^*\right) - 2\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^* m_l^{2*}\right) - 2\text{Tr}\left(Y_\nu m_\nu^{2*} Y_\nu^\dagger Y_e^T Y_e^*\right)
\end{aligned} \tag{76}$$

$$\begin{aligned}
\beta_{m_{H_u}^2}^{(1)} &= -\frac{6}{5}g_1^2|M_1|^2 - 8g_p^2Q_{H_u}^2|M_Z|^2 - 6g_2^2|M_2|^2 + 2m_{H_d}^2|\lambda|^2 + 2m_{H_u}^2|\lambda|^2 + 2m_S^2|\lambda|^2 + 2|T_\lambda|^2 \\
&+ \sqrt{\frac{3}{5}}g_1\sigma_{1,1} + 2g_pQ_{H_u}\sigma_{1,4} + 6m_{H_u}^2\text{Tr}\left(Y_u Y_u^\dagger\right) + 2m_{H_u}^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 6\text{Tr}\left(T_u^* T_u^T\right) + 2\text{Tr}\left(T_\nu^* T_\nu^T\right) \\
&+ 6\text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) + 6\text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right) + 2\text{Tr}\left(Y_\nu Y_\nu^\dagger m_l^{2*}\right) + 2\text{Tr}\left(Y_\nu m_\nu^{2*} Y_\nu^\dagger\right)
\end{aligned} \tag{77}$$

$$\begin{aligned}
\beta_{m_{H_u}^2}^{(2)} &= +\frac{18}{5}g_1^2g_2^2|M_2|^2 + 33g_2^4|M_2|^2 + 24g_2^2g_p^2Q_{H_u}^2|M_2|^2 + 4g_p^2m_{H_d}^2Q_{H_d}^2|\lambda|^2 \\
&+ 4g_p^2m_{H_u}^2Q_{H_d}^2|\lambda|^2 + 4g_p^2m_S^2Q_{H_d}^2|\lambda|^2 - 4g_p^2m_{H_d}^2Q_{H_u}^2|\lambda|^2 - 4g_p^2m_{H_u}^2Q_{H_u}^2|\lambda|^2 \\
&- 4g_p^2m_S^2Q_{H_u}^2|\lambda|^2 + 4g_p^2m_{H_d}^2Q_s^2|\lambda|^2 + 4g_p^2m_{H_u}^2Q_s^2|\lambda|^2 + 4g_p^2m_S^2Q_s^2|\lambda|^2 \\
&+ 4g_p^2Q_{H_d}^2|T_\lambda|^2 - 4g_p^2Q_{H_u}^2|T_\lambda|^2 + 4g_p^2Q_s^2|T_\lambda|^2 + \frac{9}{5}g_1^2g_2^2M_1M_2^* \\
&+ 12g_2^2g_p^2M_ZQ_{H_u}^2M_2^* - 12m_{H_d}^2\lambda^2\lambda^{*,2} - 12m_{H_u}^2\lambda^2\lambda^{*,2} - 12m_S^2\lambda^2\lambda^{*,2} \\
&- 4g_p^2M_ZQ_{H_d}^2\lambda T_\lambda^* + 4g_p^2M_ZQ_{H_u}^2\lambda T_\lambda^* - 4g_p^2M_ZQ_s^2\lambda T_\lambda^* - 24|\lambda|^2T_\lambda^*T_\lambda + 6g_2^4\sigma_{2,2} \\
&+ \frac{6}{5}g_1^2\sigma_{2,11} + 4\sqrt{\frac{3}{5}}g_1g_pQ_{H_u}\sigma_{2,14} + 4\sqrt{\frac{3}{5}}g_1g_pQ_{H_u}\sigma_{2,41} + 8g_p^2Q_{H_u}^2\sigma_{2,44} + 4\sqrt{\frac{3}{5}}g_1\sigma_{3,1} + 8g_pQ_{H_u}\sigma_{3,4} \\
&- 12m_{H_d}^2|\lambda|^2\text{Tr}\left(Y_d Y_d^\dagger\right) - 6m_{H_u}^2|\lambda|^2\text{Tr}\left(Y_d Y_d^\dagger\right) - 6m_S^2|\lambda|^2\text{Tr}\left(Y_d Y_d^\dagger\right) \\
&- 6|T_\lambda|^2\text{Tr}\left(Y_d Y_d^\dagger\right) - 4m_{H_d}^2|\lambda|^2\text{Tr}\left(Y_e Y_e^\dagger\right) - 2m_{H_u}^2|\lambda|^2\text{Tr}\left(Y_e Y_e^\dagger\right) \\
&- 2m_S^2|\lambda|^2\text{Tr}\left(Y_e Y_e^\dagger\right) - 2|T_\lambda|^2\text{Tr}\left(Y_e Y_e^\dagger\right) + \frac{8}{5}g_1^2m_{H_u}^2\text{Tr}\left(Y_u Y_u^\dagger\right) + 32g_3^2m_{H_u}^2\text{Tr}\left(Y_u Y_u^\dagger\right) \\
&- 12g_p^2m_{H_u}^2Q_{H_u}^2\text{Tr}\left(Y_u Y_u^\dagger\right) + 12g_p^2m_{H_u}^2Q_q^2\text{Tr}\left(Y_u Y_u^\dagger\right) + 12g_p^2m_{H_u}^2Q_u^2\text{Tr}\left(Y_u Y_u^\dagger\right) \\
&+ 64g_3^2|M_3|^2\text{Tr}\left(Y_u Y_u^\dagger\right) + \frac{12}{5}g_1^2m_{H_u}^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) - 4g_p^2m_{H_u}^2Q_{H_u}^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) \\
&+ 4g_p^2m_{H_u}^2Q_q^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 4g_p^2m_{H_u}^2Q_v^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) - 6\lambda T_\lambda^*\text{Tr}\left(Y_d^\dagger T_d\right) \\
&- 2\lambda T_\lambda^*\text{Tr}\left(Y_e^\dagger T_e\right) - 32g_3^2M_3^*\text{Tr}\left(Y_u^\dagger T_u\right) \\
&+ \frac{1}{25}g_1^2M_1^*\left(783g_1^2M_1 + 90g_2^2M_1 + 45g_2^2M_2 + 360g_p^2M_1Q_dQ_{H_u} + 180g_p^2M_ZQ_dQ_{H_u} + 360g_p^2M_1Q_eQ_{H_u}\right. \\
&+ 180g_p^2M_ZQ_eQ_{H_u} - 120g_p^2M_1Q_{H_d}Q_{H_u} - 60g_p^2M_ZQ_{H_d}Q_{H_u} + 240g_p^2M_1Q_{H_u}^2 + 120g_p^2M_ZQ_{H_u}^2 \\
&- 360g_p^2M_1Q_{H_u}Q_q - 180g_p^2M_ZQ_{H_u}Q_q + 360g_p^2M_1Q_{H_u}Q_q + 180g_p^2M_ZQ_{H_u}Q_q - 720g_p^2M_1Q_{H_u}Q_u \\
&\left. - 360g_p^2M_ZQ_{H_u}Q_u + 360g_p^2M_1Q_{H_u}Q_v + 180g_p^2M_ZQ_{H_u}Q_v + 80M_1\text{Tr}\left(Y_u Y_u^\dagger\right) + 120M_1\text{Tr}\left(Y_\nu Y_\nu^\dagger\right)\right)
\end{aligned}$$

$$\begin{aligned}
& -40\text{Tr}\left(Y_u^\dagger T_u\right) - 60\text{Tr}\left(Y_\nu^\dagger T_\nu\right) \\
& + \frac{4}{5}g_p^2 M_Z^* \left(9g_1^2 M_1 Q_d Q_{H_u} + 18g_1^2 M_Z Q_d Q_{H_u} + 9g_1^2 M_1 Q_e Q_{H_u} + 18g_1^2 M_Z Q_e Q_{H_u} - 3g_1^2 M_1 Q_{H_d} Q_{H_u}\right. \\
& - 6g_1^2 M_Z Q_{H_d} Q_{H_u} + 6g_1^2 M_1 Q_{H_u}^2 + 12g_1^2 M_Z Q_{H_u}^2 + 30g_2^2 M_Z Q_{H_u}^2 + 15g_2^2 M_2 Q_{H_u}^2 \\
& + 270g_p^2 M_Z Q_d^2 Q_{H_u}^2 + 90g_p^2 M_Z Q_e^2 Q_{H_u}^2 + 60g_p^2 M_Z Q_{H_d}^2 Q_{H_u}^2 + 120g_p^2 M_Z Q_{H_u}^4 \\
& - 9g_1^2 M_1 Q_{H_u} Q_q - 18g_1^2 M_Z Q_{H_u} Q_q + 180g_p^2 M_Z Q_{H_u}^2 Q_q^2 + 9g_1^2 M_1 Q_{H_u} Q_q + 18g_1^2 M_Z Q_{H_u} Q_q \\
& + 540g_p^2 M_Z Q_{H_u}^2 Q_q^2 + 30g_p^2 M_Z Q_{H_u}^2 Q_s^2 - 18g_1^2 M_1 Q_{H_u} Q_u - 36g_1^2 M_Z Q_{H_u} Q_u \\
& + 270g_p^2 M_Z Q_{H_u}^2 Q_u^2 + 9g_1^2 M_1 Q_{H_u} Q_v + 18g_1^2 M_Z Q_{H_u} Q_v + 90g_p^2 M_Z Q_{H_u}^2 Q_v^2 \\
& + 5\left(-Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2\right)\lambda^* \left(2M_Z \lambda - T_\lambda\right) - 30M_Z \left(-Q_q^2 - Q_u^2 + Q_{H_u}^2\right)\text{Tr}\left(Y_u Y_u^\dagger\right) \\
& - 10M_Z Q_{H_u}^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 10M_Z Q_q^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 10M_Z Q_v^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 15Q_{H_u}^2 \text{Tr}\left(Y_u^\dagger T_u\right) \\
& - 15Q_q^2 \text{Tr}\left(Y_u^\dagger T_u\right) - 15Q_u^2 \text{Tr}\left(Y_u^\dagger T_u\right) + 5Q_{H_u}^2 \text{Tr}\left(Y_\nu^\dagger T_\nu\right) - 5Q_q^2 \text{Tr}\left(Y_\nu^\dagger T_\nu\right) \\
& - 5Q_v^2 \text{Tr}\left(Y_\nu^\dagger T_\nu\right) \\
& - 6\lambda^* T_\lambda \text{Tr}\left(T_d^* Y_d^T\right) - 6|\lambda|^2 \text{Tr}\left(T_d^* T_d^T\right) - 2\lambda^* T_\lambda \text{Tr}\left(T_e^* Y_e^T\right) - 2|\lambda|^2 \text{Tr}\left(T_e^* T_e^T\right) \\
& - \frac{8}{5}g_1^2 M_1 \text{Tr}\left(T_u^* Y_u^T\right) - 32g_3^2 M_3 \text{Tr}\left(T_u^* Y_u^T\right) + 12g_p^2 M_Z Q_{H_u}^2 \text{Tr}\left(T_u^* Y_u^T\right) \\
& - 12g_p^2 M_Z Q_q^2 \text{Tr}\left(T_u^* Y_u^T\right) - 12g_p^2 M_Z Q_u^2 \text{Tr}\left(T_u^* Y_u^T\right) + \frac{8}{5}g_1^2 \text{Tr}\left(T_u^* T_u^T\right) + 32g_3^2 \text{Tr}\left(T_u^* T_u^T\right) \\
& - 12g_p^2 Q_{H_u}^2 \text{Tr}\left(T_u^* T_u^T\right) + 12g_p^2 Q_q^2 \text{Tr}\left(T_u^* T_u^T\right) + 12g_p^2 Q_u^2 \text{Tr}\left(T_u^* T_u^T\right) - \frac{12}{5}g_1^2 M_1 \text{Tr}\left(T_\nu^* Y_\nu^T\right) \\
& + 4g_p^2 M_Z Q_{H_u}^2 \text{Tr}\left(T_\nu^* Y_\nu^T\right) - 4g_p^2 M_Z Q_q^2 \text{Tr}\left(T_\nu^* Y_\nu^T\right) - 4g_p^2 M_Z Q_v^2 \text{Tr}\left(T_\nu^* Y_\nu^T\right) \\
& + \frac{12}{5}g_1^2 \text{Tr}\left(T_\nu^* T_\nu^T\right) - 4g_p^2 Q_{H_u}^2 \text{Tr}\left(T_\nu^* T_\nu^T\right) + 4g_p^2 Q_q^2 \text{Tr}\left(T_\nu^* T_\nu^T\right) + 4g_p^2 Q_v^2 \text{Tr}\left(T_\nu^* T_\nu^T\right) \\
& - 6|\lambda|^2 \text{Tr}\left(m_d^2 Y_d Y_d^\dagger\right) - 2|\lambda|^2 \text{Tr}\left(m_e^2 Y_e Y_e^\dagger\right) - 2|\lambda|^2 \text{Tr}\left(m_l^2 Y_e^\dagger Y_e\right)
\end{aligned}$$

$$\begin{aligned}
& -6|\lambda|^2 \text{Tr}\left(m_q^2 Y_d^\dagger Y_d\right) + \frac{8}{5}g_1^2 \text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) + 32g_3^2 \text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) \\
& - 12g_p^2 Q_{H_u}^2 \text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) + 12g_p^2 Q_q^2 \text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) + 12g_p^2 Q_u^2 \text{Tr}\left(m_q^2 Y_u^\dagger Y_u\right) \\
& + \frac{8}{5}g_1^2 \text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right) + 32g_3^2 \text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right) - 12g_p^2 Q_{H_u}^2 \text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right) \\
& + 12g_p^2 Q_q^2 \text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right) + 12g_p^2 Q_u^2 \text{Tr}\left(m_u^2 Y_u Y_u^\dagger\right) + \frac{12}{5}g_1^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger m_l^{2*}\right) \\
& - 4g_p^2 Q_{H_u}^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger m_l^{2*}\right) + 4g_p^2 Q_q^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger m_l^{2*}\right) + 4g_p^2 Q_v^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger m_l^{2*}\right) \\
& + \frac{12}{5}g_1^2 \text{Tr}\left(Y_\nu m_\nu^{2*} Y_\nu^\dagger\right) - 4g_p^2 Q_{H_u}^2 \text{Tr}\left(Y_\nu m_\nu^{2*} Y_\nu^\dagger\right) + 4g_p^2 Q_q^2 \text{Tr}\left(Y_\nu m_\nu^{2*} Y_\nu^\dagger\right) \\
& + 4g_p^2 Q_v^2 \text{Tr}\left(Y_\nu m_\nu^{2*} Y_\nu^\dagger\right) - 6m_{H_d}^2 \text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 6m_{H_u}^2 \text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right)
\end{aligned}$$

$$\begin{aligned}
& -6\text{Tr}\left(Y_d Y_u^\dagger T_u T_d^\dagger\right) - 6\text{Tr}\left(Y_d T_u^\dagger T_u Y_d^\dagger\right) - 2\text{Tr}\left(Y_e T_\nu^* T_\nu^T Y_e^\dagger\right) - 6\text{Tr}\left(Y_u Y_d^\dagger T_d T_u^\dagger\right) \\
& - 36m_{H_u}^2 \text{Tr}\left(Y_u Y_u^\dagger Y_u Y_u^\dagger\right) - 36\text{Tr}\left(Y_u Y_u^\dagger T_u T_u^\dagger\right) - 6\text{Tr}\left(Y_u T_d^\dagger T_d Y_u^\dagger\right) - 36\text{Tr}\left(Y_u T_u^\dagger T_u Y_u^\dagger\right) \\
& - 12m_{H_u}^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger\right) - 12\text{Tr}\left(Y_\nu Y_\nu^\dagger T_\nu T_\nu^\dagger\right) - 2m_{H_d}^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*\right) \\
& - 2m_{H_u}^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*\right) - 2\text{Tr}\left(Y_\nu Y_\nu^\dagger T_e^T T_e^*\right) - 12\text{Tr}\left(Y_\nu T_\nu^\dagger T_\nu Y_\nu^\dagger\right) \\
& - 2\text{Tr}\left(Y_e^\dagger T_e T_\nu^* Y_\nu^T\right) - 2\text{Tr}\left(Y_\nu^\dagger Y_e^T T_e^* T_\nu\right) - 6\text{Tr}\left(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\right) \\
& - 6\text{Tr}\left(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\right) - 6\text{Tr}\left(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\right) - 36\text{Tr}\left(m_q^2 Y_u^\dagger Y_u Y_u^\dagger Y_u\right) \\
& - 6\text{Tr}\left(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\right) - 36\text{Tr}\left(m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger\right) - 6\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger m_l^{2*}\right) - 6\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_\nu m_\nu^{2*} Y_\nu^\dagger\right) \\
& - 6\text{Tr}\left(Y_\nu Y_\nu^\dagger m_l^{2*} Y_\nu Y_\nu^\dagger\right) - 2\text{Tr}\left(Y_\nu Y_\nu^\dagger m_l^{2*} Y_e^T Y_e^*\right) - 2\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T m_e^{2*} Y_e^*\right) \\
& - 2\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^* m_l^{2*}\right) - 6\text{Tr}\left(Y_\nu m_\nu^{2*} Y_\nu^\dagger Y_\nu Y_\nu^\dagger\right) - 2\text{Tr}\left(Y_\nu m_\nu^{2*} Y_\nu^\dagger Y_e^T Y_e^*\right)
\end{aligned} \tag{78}$$

$$\begin{aligned}
\beta_{m_a^2}^{(1)} &= -\frac{8}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 - 8g_p^2Q_d^2\mathbf{1}|M_Z|^2 + 4m_{H_d}^2Y_dY_d^\dagger + 4T_dT_d^\dagger \\
& + 2m_d^2Y_dY_d^\dagger + 4Y_d m_q^2 Y_d^\dagger + 2Y_d Y_d^\dagger m_d^2 + 2\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1} + 2g_p Q_d \mathbf{1}\sigma_{1,4}
\end{aligned} \tag{79}$$

$$\begin{aligned}
\beta_{m_a^2}^{(2)} &= +\frac{176}{15}g_1^2g_p^2Q_d^2\mathbf{1}|M_Z|^2 + \frac{128}{3}g_3^2g_p^2Q_d^2\mathbf{1}|M_Z|^2 + 264g_p^4Q_d^4\mathbf{1}|M_Z|^2 \\
& + \frac{48}{5}g_1^2g_p^2Q_dQ_e\mathbf{1}|M_Z|^2 + 72g_p^4Q_d^2Q_e^2\mathbf{1}|M_Z|^2 - \frac{16}{5}g_1^2g_p^2Q_dQ_{H_d}\mathbf{1}|M_Z|^2 \\
& + 48g_p^4Q_d^2Q_{H_d}^2\mathbf{1}|M_Z|^2 + \frac{16}{5}g_1^2g_p^2Q_dQ_{H_u}\mathbf{1}|M_Z|^2 + 48g_p^4Q_d^2Q_{H_u}^2\mathbf{1}|M_Z|^2 \\
& - \frac{48}{5}g_1^2g_p^2Q_dQ_q\mathbf{1}|M_Z|^2 + 144g_p^4Q_d^2Q_q^2\mathbf{1}|M_Z|^2 + \frac{48}{5}g_1^2g_p^2Q_dQ_q\mathbf{1}|M_Z|^2 \\
& + 432g_p^4Q_d^2Q_q^2\mathbf{1}|M_Z|^2 + 24g_p^4Q_d^2Q_s^2\mathbf{1}|M_Z|^2 - \frac{96}{5}g_1^2g_p^2Q_dQ_u\mathbf{1}|M_Z|^2 \\
& + 216g_p^4Q_d^2Q_u^2\mathbf{1}|M_Z|^2 + \frac{48}{5}g_1^2g_p^2Q_dQ_v\mathbf{1}|M_Z|^2 + 72g_p^4Q_d^2Q_v^2\mathbf{1}|M_Z|^2 \\
& - \frac{64}{45}g_3^2\left(15\left(2g_3^2M_3 - g_p^2\left(2M_3 + M_Z\right)Q_d^2\right) - g_1^2\left(2M_3 + M_1\right)\right)\mathbf{1}M_3^* + \frac{88}{15}g_1^2g_p^2M_1Q_d^2\mathbf{1}M_Z^* \\
& + \frac{64}{3}g_3^2g_p^2M_3Q_d^2\mathbf{1}M_Z^* + \frac{24}{5}g_1^2g_p^2M_1Q_dQ_e\mathbf{1}M_Z^* - \frac{8}{5}g_1^2g_p^2M_1Q_dQ_{H_d}\mathbf{1}M_Z^* \\
& + \frac{8}{5}g_1^2g_p^2M_1Q_dQ_{H_u}\mathbf{1}M_Z^* - \frac{24}{5}g_1^2g_p^2M_1Q_dQ_q\mathbf{1}M_Z^* + \frac{24}{5}g_1^2g_p^2M_1Q_dQ_q\mathbf{1}M_Z^* \\
& - \frac{48}{5}g_1^2g_p^2M_1Q_dQ_u\mathbf{1}M_Z^* + \frac{24}{5}g_1^2g_p^2M_1Q_dQ_v\mathbf{1}M_Z^* + \frac{4}{5}g_1^2m_{H_d}^2Y_dY_d^\dagger \\
& + 12g_p^2m_{H_d}^2Y_dY_d^\dagger - 8g_p^2m_{H_d}^2Q_d^2Y_dY_d^\dagger + 8g_p^2m_{H_d}^2Q_{H_d}^2Y_dY_d^\dagger \\
& + 8g_p^2m_{H_d}^2Q_q^2Y_dY_d^\dagger - 16g_p^2Q_d^2|M_Z|^2Y_dY_d^\dagger + 16g_p^2Q_{H_d}^2|M_Z|^2Y_dY_d^\dagger \\
& + 16g_p^2Q_q^2|M_Z|^2Y_dY_d^\dagger + 24g_2^2|M_2|^2Y_dY_d^\dagger - 8m_{H_d}^2|\lambda|^2Y_dY_d^\dagger
\end{aligned}$$

$$\begin{aligned}
& -4m_{H_u}^2|\lambda|^2Y_dY_d^\dagger - 4m_S^2|\lambda|^2Y_dY_d^\dagger - 4|T_\lambda|^2Y_dY_d^\dagger - \frac{4}{5}g_1^2M_1Y_dT_d^\dagger \\
& -12g_2^2M_2Y_dT_d^\dagger + 8g_p^2M_ZQ_d^2Y_dT_d^\dagger - 8g_p^2M_ZQ_{H_d}^2Y_dT_d^\dagger \\
& -8g_p^2M_ZQ_q^2Y_dT_d^\dagger \\
& + \frac{4}{225}g_1^2M_1^* \left( 2 \left( 384g_1^2M_1 + 5 \left( 3g_p^2 \left( 2M_1 + M_Z \right) Q_d \left( 11Q_d + 3 \left( 3Q_e - 3Q_q + 3Q_q + 3Q_v - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right) \right) + 8g_3^2 \left( 2M_1 + M_2 \right) \right. \right. \\
& \left. \left. + 90M_1Y_dY_d^\dagger - 45T_dY_d^\dagger \right) \right. \\
& + 8g_p^2Q_d^2M_Z^*T_dY_d^\dagger - 8g_p^2Q_{H_d}^2M_Z^*T_dY_d^\dagger - 8g_p^2Q_q^2M_Z^*T_dY_d^\dagger \\
& - 12g_2^2M_2^*T_dY_d^\dagger - 4\lambda T_\lambda^*T_dY_d^\dagger + \frac{4}{5}g_1^2T_dT_d^\dagger + 12g_2^2T_dT_d^\dagger \\
& - 8g_p^2Q_d^2T_dT_d^\dagger + 8g_p^2Q_{H_d}^2T_dT_d^\dagger + 8g_p^2Q_q^2T_dT_d^\dagger - 4|\lambda|^2T_dT_d^\dagger \\
& + \frac{2}{5}g_1^2m_d^2Y_dY_d^\dagger + 6g_2^2m_d^2Y_dY_d^\dagger - 4g_p^2Q_d^2m_d^2Y_dY_d^\dagger \\
& + 4g_p^2Q_{H_d}^2m_d^2Y_dY_d^\dagger + 4g_p^2Q_q^2m_d^2Y_dY_d^\dagger - 2|\lambda|^2m_d^2Y_dY_d^\dagger \\
& + \frac{4}{5}g_1^2Y_dm_q^2Y_d^\dagger + 12g_2^2Y_dm_q^2Y_d^\dagger - 8g_p^2Q_d^2Y_dm_q^2Y_d^\dagger \\
& + 8g_p^2Q_{H_d}^2Y_dm_q^2Y_d^\dagger + 8g_p^2Q_q^2Y_dm_q^2Y_d^\dagger - 4|\lambda|^2Y_dm_q^2Y_d^\dagger \\
& + \frac{2}{5}g_1^2Y_dY_d^\dagger m_d^2 + 6g_2^2Y_dY_d^\dagger m_d^2 - 4g_p^2Q_d^2Y_dY_d^\dagger m_d^2 \\
& + 4g_p^2Q_{H_d}^2Y_dY_d^\dagger m_d^2 + 4g_p^2Q_q^2Y_dY_d^\dagger m_d^2 - 2|\lambda|^2Y_dY_d^\dagger m_d^2 \\
& - 8m_{H_d}^2Y_dY_d^\dagger Y_dY_d^\dagger - 4Y_dY_d^\dagger T_dT_d^\dagger - 4m_{H_d}^2Y_dY_u^\dagger Y_uY_d^\dagger \\
& - 4m_{H_u}^2Y_dY_u^\dagger Y_uY_d^\dagger - 4Y_dY_u^\dagger T_uT_d^\dagger - 4Y_dT_d^\dagger T_dY_d^\dagger - 4Y_dT_u^\dagger T_uY_d^\dagger \\
& - 4T_dY_d^\dagger Y_dT_d^\dagger - 4T_dY_u^\dagger Y_uT_d^\dagger - 4T_dT_d^\dagger Y_dY_d^\dagger - 4T_dT_u^\dagger Y_uY_d^\dagger \\
& - 2m_d^2Y_dY_d^\dagger Y_dY_d^\dagger - 2m_d^2Y_dY_u^\dagger Y_uY_d^\dagger - 4Y_dm_q^2Y_d^\dagger Y_dY_d^\dagger - 4Y_dm_q^2Y_u^\dagger Y_uY_d^\dagger \\
& - 4Y_dY_d^\dagger m_d^2Y_dY_d^\dagger - 4Y_dY_d^\dagger Y_dm_q^2Y_d^\dagger - 2Y_dY_d^\dagger Y_dY_d^\dagger m_d^2 - 4Y_dY_u^\dagger m_u^2Y_uY_d^\dagger \\
& - 4Y_dY_u^\dagger Y_u m_q^2Y_d^\dagger - 2Y_dY_u^\dagger Y_uY_d^\dagger m_d^2 - 4\lambda^*Y_dT_d^\dagger T_\lambda + \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_1g_pQ_d\mathbf{1}\sigma_{2,14} + 8\frac{1}{\sqrt{15}}g_1g_pQ_d\mathbf{1}\sigma_{2,41} + 8g_p^2Q_d^2\mathbf{1}\sigma_{2,44} + 8\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{3,1} \\
& + 8g_pQ_d\mathbf{1}\sigma_{3,4} - 24m_{H_d}^2Y_dY_d^\dagger \text{Tr}(Y_dY_d^\dagger) - 12T_dT_d^\dagger \text{Tr}(Y_dY_d^\dagger) \\
& - 6m_d^2Y_dY_d^\dagger \text{Tr}(Y_dY_d^\dagger) - 12Y_dm_q^2Y_d^\dagger \text{Tr}(Y_dY_d^\dagger) - 6Y_dY_d^\dagger m_d^2 \text{Tr}(Y_dY_d^\dagger) \\
& - 8m_{H_d}^2Y_dY_d^\dagger \text{Tr}(Y_eY_e^\dagger) - 4T_dT_d^\dagger \text{Tr}(Y_eY_e^\dagger) - 2m_d^2Y_dY_d^\dagger \text{Tr}(Y_eY_e^\dagger) \\
& - 4Y_dm_q^2Y_d^\dagger \text{Tr}(Y_eY_e^\dagger) - 2Y_dY_d^\dagger m_d^2 \text{Tr}(Y_eY_e^\dagger) - 12Y_dT_d^\dagger \text{Tr}(Y_d^\dagger T_d) \\
& - 4Y_dT_d^\dagger \text{Tr}(Y_e^\dagger T_e) - 12T_dY_d^\dagger \text{Tr}(T_d^*Y_d^T) - 12Y_dY_d^\dagger \text{Tr}(T_d^*T_d^T) \\
& - 4T_dY_d^\dagger \text{Tr}(T_e^*Y_e^T) - 4Y_dY_d^\dagger \text{Tr}(T_e^*T_e^T) - 12Y_dY_d^\dagger \text{Tr}(m_d^2Y_dY_d^\dagger)
\end{aligned}$$

$$-4Y_d Y_d^\dagger \text{Tr}(m_e^2 Y_e Y_e^\dagger) - 4Y_d Y_d^\dagger \text{Tr}(m_l^2 Y_e^\dagger Y_e) - 12Y_d Y_d^\dagger \text{Tr}(m_q^2 Y_d^\dagger Y_d) \quad (80)$$

$$\begin{aligned} \beta_{m_u^2}^{(1)} = & -\frac{32}{15}g_1^2 \mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2 \mathbf{1}|M_3|^2 - 8g_p^2 Q_u^2 \mathbf{1}|M_Z|^2 + 4m_{H_u}^2 Y_u Y_u^\dagger + 4T_u T_u^\dagger \\ & + 2m_u^2 Y_u Y_u^\dagger + 4Y_u m_q^2 Y_u^\dagger + 2Y_u Y_u^\dagger m_u^2 - 4\frac{1}{\sqrt{15}}g_1 \mathbf{1}\sigma_{1,1} + 2g_p Q_u \mathbf{1}\sigma_{1,4} \end{aligned} \quad (81)$$

$$\begin{aligned} \beta_{m_u^2}^{(2)} = & \frac{2}{225} \left( 2g_1^2 M_1^* \left( 4 \left( 5 \left( 16g_3^2 (2M_1 + M_3) \right) - 3g_p^2 (2M_1 + M_Z) \right) Q_u \left( -22Q_u - 3Q_{H_d} + 3Q_{H_u} + 9Q_d + 9Q_e - 9Q_q + 9Q_q + 9Q_v \right) \right) \right. \\ & \left. + 45 \left( -2M_1 Y_u Y_u^\dagger + T_u Y_u^\dagger \right) \right) \\ & + 5 \left( 32g_3^2 \left( 15 \left( -2g_3^2 M_3 + g_p^2 (2M_3 + M_Z) \right) Q_u^2 \right) + 4g_1^2 (2M_3 + M_1) \right) \mathbf{1}M_3^* \\ & - 3 \left( -4g_p^2 M_Z^* \left( Q_u \left( -2g_1^2 (2M_Z + M_1) \right) \left( -22Q_u - 3Q_{H_d} + 3Q_{H_u} + 9Q_d + 9Q_e - 9Q_q + 9Q_q + 9Q_v \right) \right) \right. \\ & \left. + 5Q_u \left( 8g_3^2 (2M_Z + M_3) + 9g_p^2 M_Z \left( 11Q_u^2 + 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_v^2 + 6Q_q^2 + 9Q_d^2 + Q_s^2 \right) \right) \right) \mathbf{1} \\ & + 15 \left( -Q_u^2 + Q_{H_u}^2 + Q_q^2 \right) \left( 2M_Z Y_u Y_u^\dagger - T_u Y_u^\dagger \right) \\ & - 41 \left( 15g_p Q_u \left( g_p Q_u \sigma_{2,44} + \sigma_{3,4} \right) + 20g_3^4 \sigma_{2,3} - 2\sqrt{15}g_1 \left( g_p Q_u \left( \sigma_{2,14} + \sigma_{2,41} \right) + \sigma_{3,1} \right) + 4g_1^2 \sigma_{2,11} \right) \\ & + 3 \left( 30g_2^2 M_2^* T_u Y_u^\dagger + 10\lambda T_\lambda^* T_u Y_u^\dagger + 2g_1^2 T_u T_u^\dagger - 30g_2^2 T_u T_u^\dagger \right. \\ & - 20g_p^2 Q_{H_u}^2 T_u T_u^\dagger - 20g_p^2 Q_q^2 T_u T_u^\dagger + 20g_p^2 Q_u^2 T_u T_u^\dagger + 10|\lambda|^2 T_u T_u^\dagger \\ & + g_1^2 m_u^2 Y_u Y_u^\dagger - 15g_2^2 m_u^2 Y_u Y_u^\dagger - 10g_p^2 Q_{H_u}^2 m_u^2 Y_u Y_u^\dagger \\ & - 10g_p^2 Q_q^2 m_u^2 Y_u Y_u^\dagger + 10g_p^2 Q_u^2 m_u^2 Y_u Y_u^\dagger + 5|\lambda|^2 m_u^2 Y_u Y_u^\dagger \\ & + 2g_1^2 Y_u m_q^2 Y_u^\dagger - 30g_2^2 Y_u m_q^2 Y_u^\dagger - 20g_p^2 Q_{H_u}^2 Y_u m_q^2 Y_u^\dagger \\ & - 20g_p^2 Q_q^2 Y_u m_q^2 Y_u^\dagger + 20g_p^2 Q_u^2 Y_u m_q^2 Y_u^\dagger + 10|\lambda|^2 Y_u m_q^2 Y_u^\dagger \\ & + g_1^2 Y_u Y_u^\dagger m_u^2 - 15g_2^2 Y_u Y_u^\dagger m_u^2 - 10g_p^2 Q_{H_u}^2 Y_u Y_u^\dagger m_u^2 \\ & - 10g_p^2 Q_q^2 Y_u Y_u^\dagger m_u^2 + 10g_p^2 Q_u^2 Y_u Y_u^\dagger m_u^2 + 5|\lambda|^2 Y_u Y_u^\dagger m_u^2 \\ & + 10m_{H_d}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger + 10m_{H_u}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger + 10Y_u Y_d^\dagger T_d T_u^\dagger \\ & + 20m_{H_u}^2 Y_u Y_u^\dagger Y_u Y_u^\dagger + 10Y_u Y_u^\dagger T_u T_u^\dagger + 10Y_u T_d^\dagger T_d Y_u^\dagger + 10Y_u T_u^\dagger T_u Y_u^\dagger \\ & + 10T_u Y_d^\dagger Y_d T_u^\dagger + 10T_u Y_u^\dagger Y_u T_u^\dagger + 10T_u T_d^\dagger Y_d Y_u^\dagger + 10T_u T_u^\dagger Y_u Y_u^\dagger \\ & + 5m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger + 5m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger + 10Y_u m_q^2 Y_d^\dagger Y_d Y_u^\dagger + 10Y_u m_q^2 Y_u^\dagger Y_u Y_u^\dagger \\ & + 10Y_u Y_d^\dagger m_d^2 Y_d Y_u^\dagger + 10Y_u Y_d^\dagger Y_d m_q^2 Y_u^\dagger + 5Y_u Y_d^\dagger Y_d Y_u^\dagger m_u^2 \\ & + 10Y_u Y_u^\dagger m_u^2 Y_u Y_u^\dagger + 10Y_u Y_u^\dagger Y_u m_q^2 Y_u^\dagger + 5Y_u Y_u^\dagger Y_u Y_u^\dagger m_u^2 + 30T_u T_u^\dagger \text{Tr}(Y_u Y_u^\dagger) \\ & + 15m_u^2 Y_u Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) + 30Y_u m_q^2 Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) + 15Y_u Y_u^\dagger m_u^2 \text{Tr}(Y_u Y_u^\dagger) \\ & + 10T_u T_u^\dagger \text{Tr}(Y_\nu Y_\nu^\dagger) + 5m_u^2 Y_u Y_u^\dagger \text{Tr}(Y_\nu Y_\nu^\dagger) + 10Y_u m_q^2 Y_u^\dagger \text{Tr}(Y_\nu Y_\nu^\dagger) \\ & \left. + 5Y_u Y_u^\dagger m_u^2 \text{Tr}(Y_\nu Y_\nu^\dagger) \right) \end{aligned}$$

$$\begin{aligned}
& + Y_u T_u^\dagger \left( -2g_1^2 M_1 + 30g_2^2 M_2 + 20g_p^2 M_Z Q_{H_u}^2 + 20g_p^2 M_Z Q_q^2 - 20g_p^2 M_Z Q_u^2 + 10\lambda^* T_\lambda + 30\text{Tr}(Y_u^\dagger T_u) \right. \\
& \left. + 10\text{Tr}(Y_\nu^\dagger T_\nu) \right) \\
& + 30T_u Y_u^\dagger \text{Tr}(T_u^* Y_u^T) + 10T_u Y_u^\dagger \text{Tr}(T_\nu^* Y_\nu^T) \\
& + 2Y_u Y_u^\dagger \left( g_1^2 m_{H_u}^2 - 15g_2^2 m_{H_u}^2 - 10g_p^2 m_{H_u}^2 Q_{H_u}^2 - 10g_p^2 m_{H_u}^2 Q_q^2 + 10g_p^2 m_{H_u}^2 Q_u^2 - 30g_2^2 |M_2|^2 \right. \\
& + 5(2m_{H_u}^2 + m_{H_d}^2 + m_S^2) |\lambda|^2 + 5|T_\lambda|^2 + 30m_{H_u}^2 \text{Tr}(Y_u Y_u^\dagger) + 10m_{H_u}^2 \text{Tr}(Y_\nu Y_\nu^\dagger) + 15\text{Tr}(T_u^* T_u^T) \\
& \left. + 5\text{Tr}(T_\nu^* T_\nu^T) + 15\text{Tr}(m_q^2 Y_u^\dagger Y_u) + 15\text{Tr}(m_u^2 Y_u Y_u^\dagger) + 5\text{Tr}(Y_\nu Y_\nu^\dagger m_l^{2*}) + 5\text{Tr}(Y_\nu m_\nu^{2*} Y_\nu^\dagger) \right) \Big) \Big) \Big) \Big) \Big) \quad (82)
\end{aligned}$$

$$\begin{aligned}
\beta_{m_e^2}^{(1)} = & -\frac{24}{5} g_1^2 \mathbf{1} |M_1|^2 - 8g_p^2 Q_e^2 \mathbf{1} |M_Z|^2 + 4m_{H_d}^2 Y_e Y_e^\dagger + 4T_e T_e^\dagger + 2m_e^2 Y_e Y_e^\dagger \\
& + 4Y_e m_l^2 Y_e^\dagger + 2Y_e Y_e^\dagger m_e^2 + 2\sqrt{\frac{3}{5}} g_1 \mathbf{1} \sigma_{1,1} + 2g_p Q_e \mathbf{1} \sigma_{1,4} \quad (83)
\end{aligned}$$

$$\begin{aligned}
\beta_{m_e^2}^{(2)} = & -\frac{12}{5} g_1^2 m_{H_d}^2 Y_e Y_e^\dagger + 12g_2^2 m_{H_d}^2 Y_e Y_e^\dagger - 8g_p^2 m_{H_d}^2 Q_e^2 Y_e Y_e^\dagger \\
& + 8g_p^2 m_{H_d}^2 Q_{H_d}^2 Y_e Y_e^\dagger + 8g_p^2 m_{H_d}^2 Q_q^2 Y_e Y_e^\dagger + 24g_2^2 |M_2|^2 Y_e Y_e^\dagger \\
& - 8m_{H_d}^2 |\lambda|^2 Y_e Y_e^\dagger - 4m_{H_u}^2 |\lambda|^2 Y_e Y_e^\dagger - 4m_S^2 |\lambda|^2 Y_e Y_e^\dagger - 4|T_\lambda|^2 Y_e Y_e^\dagger \\
& + \frac{12}{5} g_1^2 M_1 Y_e T_e^\dagger - 12g_2^2 M_2 Y_e T_e^\dagger + 8g_p^2 M_Z Q_e^2 Y_e T_e^\dagger \\
& - 8g_p^2 M_Z Q_{H_d}^2 Y_e T_e^\dagger - 8g_p^2 M_Z Q_q^2 Y_e T_e^\dagger \\
& + \frac{8}{5} g_p^2 M_Z^* \left( 3Q_e \left( g_1^2 (2M_Z + M_1) \right) (3Q_d - 3Q_q + 3Q_q + 3Q_v + 5Q_e - 6Q_u - Q_{H_d} + Q_{H_u}) \right) \\
& + 5g_p^2 M_Z Q_e \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_v^2 + 5Q_e^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \right) \mathbf{1} \\
& - 5 \left( -Q_{H_d}^2 - Q_q^2 + Q_e^2 \right) \left( 2M_Z Y_e Y_e^\dagger - T_e Y_e^\dagger \right) \\
& - 12g_2^2 M_2^* T_e Y_e^\dagger - 4\lambda T_\lambda^* T_e Y_e^\dagger \\
& + \frac{12}{25} g_1^2 M_1^* \left( 2 \left( 144g_1^2 M_1 + 5g_p^2 (2M_1 + M_Z) \right) Q_e \left( 3Q_d - 3Q_q + 3Q_q + 3Q_v + 5Q_e - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right) \mathbf{1} \\
& + 5 \left( -2M_1 Y_e Y_e^\dagger + T_e Y_e^\dagger \right) \\
& - \frac{12}{5} g_1^2 T_e T_e^\dagger + 12g_2^2 T_e T_e^\dagger - 8g_p^2 Q_e^2 T_e T_e^\dagger + 8g_p^2 Q_{H_d}^2 T_e T_e^\dagger \\
& + 8g_p^2 Q_q^2 T_e T_e^\dagger - 4|\lambda|^2 T_e T_e^\dagger - \frac{6}{5} g_1^2 m_e^2 Y_e Y_e^\dagger + 6g_2^2 m_e^2 Y_e Y_e^\dagger \\
& - 4g_p^2 Q_e^2 m_e^2 Y_e Y_e^\dagger + 4g_p^2 Q_{H_d}^2 m_e^2 Y_e Y_e^\dagger + 4g_p^2 Q_q^2 m_e^2 Y_e Y_e^\dagger \\
& - 2|\lambda|^2 m_e^2 Y_e Y_e^\dagger - \frac{12}{5} g_1^2 Y_e m_l^2 Y_e^\dagger + 12g_2^2 Y_e m_l^2 Y_e^\dagger - 8g_p^2 Q_e^2 Y_e m_l^2 Y_e^\dagger \\
& + 8g_p^2 Q_{H_d}^2 Y_e m_l^2 Y_e^\dagger + 8g_p^2 Q_q^2 Y_e m_l^2 Y_e^\dagger - 4|\lambda|^2 Y_e m_l^2 Y_e^\dagger \\
& - \frac{6}{5} g_1^2 Y_e Y_e^\dagger m_e^2 + 6g_2^2 Y_e Y_e^\dagger m_e^2 - 4g_p^2 Q_e^2 Y_e Y_e^\dagger m_e^2
\end{aligned}$$

$$\begin{aligned}
& + 4g_p^2 Q_{H_d}^2 Y_e Y_e^\dagger m_e^2 + 4g_p^2 Q_q^2 Y_e Y_e^\dagger m_e^2 - 2|\lambda|^2 Y_e Y_e^\dagger m_e^2 \\
& - 8m_{H_d}^2 Y_e Y_e^\dagger Y_e Y_e^\dagger - 4Y_e Y_e^\dagger T_e T_e^\dagger - 4Y_e T_e^\dagger T_e Y_e^\dagger - 4m_{H_d}^2 Y_e Y_\nu^* Y_\nu^T Y_e^\dagger \\
& - 4m_{H_u}^2 Y_e Y_\nu^* Y_\nu^T Y_e^\dagger - 4Y_e Y_\nu^* T_\nu^T T_e^\dagger - 4Y_e T_\nu^* T_\nu^T Y_e^\dagger - 4T_e Y_e^\dagger Y_e T_e^\dagger \\
& - 4T_e T_e^\dagger Y_e Y_e^\dagger - 4T_e Y_\nu^* Y_\nu^T T_e^\dagger - 4T_e T_\nu^* Y_\nu^T Y_e^\dagger - 2m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger \\
& - 2m_e^2 Y_e Y_\nu^* Y_\nu^T Y_e^\dagger - 4Y_e m_l^2 Y_e^\dagger Y_e Y_e^\dagger - 4Y_e m_l^2 Y_\nu^* Y_\nu^T Y_e^\dagger - 4Y_e Y_e^\dagger m_e^2 Y_e Y_e^\dagger \\
& - 4Y_e Y_e^\dagger Y_e m_l^2 Y_e^\dagger - 2Y_e Y_e^\dagger Y_e Y_e^\dagger m_e^2 - 4Y_e Y_\nu^* m_\nu^2 Y_\nu^T Y_e^\dagger - 4Y_e Y_\nu^* Y_\nu^T m_l^2 Y_e^\dagger \\
& - 2Y_e Y_\nu^* Y_\nu^T Y_e^\dagger m_e^2 - 4\lambda^* Y_e T_e^\dagger T_\lambda + \frac{24}{5} g_1^2 \mathbf{1}\sigma_{2,11} + 8\sqrt{\frac{3}{5}} g_1 g_p Q_e \mathbf{1}\sigma_{2,14} + 8\sqrt{\frac{3}{5}} g_1 g_p Q_e \mathbf{1}\sigma_{2,41} \\
& + 8g_p^2 Q_e^2 \mathbf{1}\sigma_{2,44} + 8\sqrt{\frac{3}{5}} g_1 \mathbf{1}\sigma_{3,1} + 8g_p Q_e \mathbf{1}\sigma_{3,4} - 24m_{H_d}^2 Y_e Y_e^\dagger \text{Tr}(Y_d Y_d^\dagger) - 12T_e T_e^\dagger \text{Tr}(Y_d Y_d^\dagger) \\
& - 6m_e^2 Y_e Y_e^\dagger \text{Tr}(Y_d Y_d^\dagger) - 12Y_e m_l^2 Y_e^\dagger \text{Tr}(Y_d Y_d^\dagger) - 6Y_e Y_e^\dagger m_e^2 \text{Tr}(Y_d Y_d^\dagger) \\
& - 8m_{H_d}^2 Y_e Y_e^\dagger \text{Tr}(Y_e Y_e^\dagger) - 4T_e T_e^\dagger \text{Tr}(Y_e Y_e^\dagger) - 2m_e^2 Y_e Y_e^\dagger \text{Tr}(Y_e Y_e^\dagger) \\
& - 4Y_e m_l^2 Y_e^\dagger \text{Tr}(Y_e Y_e^\dagger) - 2Y_e Y_e^\dagger m_e^2 \text{Tr}(Y_e Y_e^\dagger) - 12Y_e T_e^\dagger \text{Tr}(Y_d^\dagger T_d) \\
& - 4Y_e T_e^\dagger \text{Tr}(Y_e^\dagger T_e) - 12T_e Y_e^\dagger \text{Tr}(T_d^* Y_d^T) - 12Y_e Y_e^\dagger \text{Tr}(T_d^* T_d^T) \\
& - 4T_e Y_e^\dagger \text{Tr}(T_e^* Y_e^T) - 4Y_e Y_e^\dagger \text{Tr}(T_e^* T_e^T) - 12Y_e Y_e^\dagger \text{Tr}(m_d^2 Y_d Y_d^\dagger) \\
& - 4Y_e Y_e^\dagger \text{Tr}(m_e^2 Y_e Y_e^\dagger) - 4Y_e Y_e^\dagger \text{Tr}(m_l^2 Y_e^\dagger Y_e) - 12Y_e Y_e^\dagger \text{Tr}(m_q^2 Y_d^\dagger Y_d)
\end{aligned} \tag{84}$$

$$\begin{aligned}
\beta_{m_e^2}^{(1)} & = -\frac{24}{5} g_1^2 \mathbf{1}|M_1|^2 - 8g_p^2 Q_v^2 \mathbf{1}|M_Z|^2 + 4m_{H_u}^2 Y_\nu^T Y_\nu^* + 4T_\nu^T T_\nu^* + 2m_\nu^2 Y_\nu^T Y_\nu^* \\
& + 4Y_\nu^T m_l^2 Y_\nu^* + 2Y_\nu^T Y_\nu^* m_\nu^2 + 2\sqrt{\frac{3}{5}} g_1 \mathbf{1}\sigma_{1,1} + 2g_p Q_v \mathbf{1}\sigma_{1,4}
\end{aligned} \tag{85}$$

$$\begin{aligned}
\beta_{m_e^2}^{(2)} & = -\frac{12}{5} g_1^2 m_{H_u}^2 Y_\nu^T Y_\nu^* + 12g_2^2 m_{H_u}^2 Y_\nu^T Y_\nu^* + 8g_p^2 m_{H_u}^2 Q_{H_u}^2 Y_\nu^T Y_\nu^* \\
& + 8g_p^2 m_{H_u}^2 Q_q^2 Y_\nu^T Y_\nu^* - 8g_p^2 m_{H_u}^2 Q_v^2 Y_\nu^T Y_\nu^* + 24g_2^2 |M_2|^2 Y_\nu^T Y_\nu^* \\
& - 4m_{H_d}^2 |\lambda|^2 Y_\nu^T Y_\nu^* - 8m_{H_u}^2 |\lambda|^2 Y_\nu^T Y_\nu^* - 4m_\nu^2 |\lambda|^2 Y_\nu^T Y_\nu^* - 4|T_\lambda|^2 Y_\nu^T Y_\nu^* \\
& + \frac{12}{5} g_1^2 M_1 Y_\nu^T T_\nu^* - 12g_2^2 M_2 Y_\nu^T T_\nu^* - 8g_p^2 M_Z Q_{H_u}^2 Y_\nu^T T_\nu^* \\
& - 8g_p^2 M_Z Q_q^2 Y_\nu^T T_\nu^* + 8g_p^2 M_Z Q_v^2 Y_\nu^T T_\nu^* \\
& + \frac{8}{5} g_p^2 M_Z^* \left( 3Q_v \left( g_1^2 \left( 2M_Z + M_1 \right) \left( 3Q_d + 3Q_e - 3Q_q + 3Q_q + 5Q_v - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right. \right. \\
& \left. \left. + 5g_p^2 M_Z Q_v \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 5Q_v^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \right) \right) \mathbf{1} \right. \\
& \left. + 5 \left( -Q_v^2 + Q_{H_u}^2 + Q_q^2 \right) \left( 2M_Z Y_\nu^T Y_\nu^* - T_\nu^T Y_\nu^* \right) \right) \\
& - 12g_2^2 M_2^* T_\nu^T Y_\nu^* - 4\lambda T_\lambda^* T_\nu^T Y_\nu^* \\
& + \frac{12}{25} g_1^2 M_1^* \left( 2 \left( 144g_1^2 M_1 + 5g_p^2 \left( 2M_1 + M_Z \right) \right) Q_v \left( 3Q_d + 3Q_e - 3Q_q + 3Q_q + 5Q_v - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right) \mathbf{1}
\end{aligned}$$



$$\begin{aligned}
& + 5 \left( -2M_1 Y_\nu^T Y_\nu^* + T_\nu^T Y_\nu^* \right) \\
& - \frac{12}{5} g_1^2 T_\nu^T T_\nu^* + 12g_2^2 T_\nu^T T_\nu^* + 8g_p^2 Q_{H_u}^2 T_\nu^T T_\nu^* + 8g_p^2 Q_q^2 T_\nu^T T_\nu^* \\
& - 8g_p^2 Q_v^2 T_\nu^T T_\nu^* - 4|\lambda|^2 T_\nu^T T_\nu^* - \frac{6}{5} g_1^2 m_\nu^2 Y_\nu^T Y_\nu^* + 6g_2^2 m_\nu^2 Y_\nu^T Y_\nu^* \\
& + 4g_p^2 Q_{H_u}^2 m_\nu^2 Y_\nu^T Y_\nu^* + 4g_p^2 Q_q^2 m_\nu^2 Y_\nu^T Y_\nu^* - 4g_p^2 Q_v^2 m_\nu^2 Y_\nu^T Y_\nu^* \\
& - 2|\lambda|^2 m_\nu^2 Y_\nu^T Y_\nu^* - \frac{12}{5} g_1^2 Y_\nu^T m_l^2 Y_\nu^* + 12g_2^2 Y_\nu^T m_l^2 Y_\nu^* + 8g_p^2 Q_{H_u}^2 Y_\nu^T m_l^2 Y_\nu^* \\
& + 8g_p^2 Q_q^2 Y_\nu^T m_l^2 Y_\nu^* - 8g_p^2 Q_v^2 Y_\nu^T m_l^2 Y_\nu^* - 4|\lambda|^2 Y_\nu^T m_l^2 Y_\nu^* \\
& - \frac{6}{5} g_1^2 Y_\nu^T Y_\nu^* m_\nu^2 + 6g_2^2 Y_\nu^T Y_\nu^* m_\nu^2 + 4g_p^2 Q_{H_u}^2 Y_\nu^T Y_\nu^* m_\nu^2 \\
& + 4g_p^2 Q_q^2 Y_\nu^T Y_\nu^* m_\nu^2 - 4g_p^2 Q_v^2 Y_\nu^T Y_\nu^* m_\nu^2 - 2|\lambda|^2 Y_\nu^T Y_\nu^* m_\nu^2 \\
& - 4m_{H_d}^2 Y_\nu^T Y_e^\dagger Y_e Y_\nu^* - 4m_{H_u}^2 Y_\nu^T Y_e^\dagger Y_e Y_\nu^* - 4Y_\nu^T Y_e^\dagger T_e T_\nu^* \\
& - 4Y_\nu^T T_e^\dagger T_e Y_\nu^* - 8m_{H_u}^2 Y_\nu^T Y_\nu^* Y_\nu^T Y_\nu^* - 4Y_\nu^T Y_\nu^* T_\nu^T T_\nu^* - 4Y_\nu^T T_\nu^* T_\nu^T Y_\nu^* \\
& - 4T_\nu^T Y_e^\dagger Y_e T_\nu^* - 4T_\nu^T T_e^\dagger Y_e Y_\nu^* - 4T_\nu^T Y_\nu^* Y_\nu^T T_\nu^* - 4T_\nu^T T_\nu^* Y_\nu^T Y_\nu^* \\
& - 2m_\nu^2 Y_\nu^T Y_e^\dagger Y_e Y_\nu^* - 2m_\nu^2 Y_\nu^T Y_\nu^* Y_\nu^T Y_\nu^* - 4Y_\nu^T m_l^2 Y_e^\dagger Y_e Y_\nu^* - 4Y_\nu^T m_l^2 Y_\nu^* Y_\nu^T Y_\nu^* \\
& - 4Y_\nu^T Y_e^\dagger m_e^2 Y_e Y_\nu^* - 4Y_\nu^T Y_e^\dagger Y_e m_l^2 Y_\nu^* - 2Y_\nu^T Y_e^\dagger Y_e Y_\nu^* m_\nu^2 \\
& - 4Y_\nu^T Y_\nu^* m_\nu^2 Y_\nu^T Y_\nu^* - 4Y_\nu^T Y_\nu^* Y_\nu^T m_l^2 Y_\nu^* - 2Y_\nu^T Y_\nu^* Y_\nu^T Y_\nu^* m_\nu^2 - 4\lambda^* Y_\nu^T T_\nu^* T_\lambda + \frac{24}{5} g_1^2 \mathbf{1}\sigma_{2,11} \\
& + 8\sqrt{\frac{3}{5}} g_1 g_p Q_v \mathbf{1}\sigma_{2,14} + 8\sqrt{\frac{3}{5}} g_1 g_p Q_v \mathbf{1}\sigma_{2,41} + 8g_p^2 Q_v^2 \mathbf{1}\sigma_{2,44} + 8\sqrt{\frac{3}{5}} g_1 \mathbf{1}\sigma_{3,1} + 8g_p Q_v \mathbf{1}\sigma_{3,4} \\
& - 24m_{H_u}^2 Y_\nu^T Y_\nu^* \text{Tr} \left( Y_u Y_u^\dagger \right) - 12T_\nu^T T_\nu^* \text{Tr} \left( Y_u Y_u^\dagger \right) - 6m_\nu^2 Y_\nu^T Y_\nu^* \text{Tr} \left( Y_u Y_u^\dagger \right) \\
& - 12Y_\nu^T m_l^2 Y_\nu^* \text{Tr} \left( Y_u Y_u^\dagger \right) - 6Y_\nu^T Y_\nu^* m_\nu^2 \text{Tr} \left( Y_u Y_u^\dagger \right) - 8m_{H_u}^2 Y_\nu^T Y_\nu^* \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \\
& - 4T_\nu^T T_\nu^* \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 2m_\nu^2 Y_\nu^T Y_\nu^* \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 4Y_\nu^T m_l^2 Y_\nu^* \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \\
& - 2Y_\nu^T Y_\nu^* m_\nu^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 12Y_\nu^T T_\nu^* \text{Tr} \left( Y_u^\dagger T_u \right) - 4Y_\nu^T T_\nu^* \text{Tr} \left( Y_\nu^\dagger T_\nu \right) \\
& - 12T_\nu^T Y_\nu^* \text{Tr} \left( T_u^* Y_u^T \right) - 12Y_\nu^T Y_\nu^* \text{Tr} \left( T_u^* T_u^T \right) - 4T_\nu^T Y_\nu^* \text{Tr} \left( T_\nu^* Y_\nu^T \right) \\
& - 4Y_\nu^T Y_\nu^* \text{Tr} \left( T_\nu^* T_\nu^T \right) - 12Y_\nu^T Y_\nu^* \text{Tr} \left( m_q^2 Y_u^\dagger Y_u \right) - 12Y_\nu^T Y_\nu^* \text{Tr} \left( m_u^2 Y_u Y_u^\dagger \right) \\
& - 4Y_\nu^T Y_\nu^* \text{Tr} \left( Y_\nu Y_\nu^\dagger m_l^{2*} \right) - 4Y_\nu^T Y_\nu^* \text{Tr} \left( Y_\nu m_\nu^{2*} Y_\nu^\dagger \right) \tag{86}
\end{aligned}$$

$$\beta_{m_S^2}^{(1)} = 2g_p Q_s \sigma_{1,4} + 4 \left( m_{H_d}^2 + m_{H_u}^2 + m_S^2 \right) |\lambda|^2 + 4|T_\lambda|^2 - 8g_p^2 Q_s^2 |M_Z|^2 \tag{87}$$

$$\begin{aligned}
\beta_{m_S^2}^{(2)} & = + \frac{12}{5} g_1^2 |T_\lambda|^2 + 12g_2^2 |T_\lambda|^2 + 8g_p^2 Q_{H_d}^2 |T_\lambda|^2 + 8g_p^2 Q_{H_u}^2 |T_\lambda|^2 - 8g_p^2 Q_s^2 |T_\lambda|^2 \\
& - 16 \left( m_{H_d}^2 + m_{H_u}^2 + m_S^2 \right) \lambda^2 \lambda^{*,2} - \frac{12}{5} g_1^2 M_1 \lambda T_\lambda^* - 12g_2^2 M_2 \lambda T_\lambda^* - 8g_p^2 M_Z Q_{H_d}^2 \lambda T_\lambda^* \\
& - 8g_p^2 M_Z Q_{H_u}^2 \lambda T_\lambda^* + 8g_p^2 M_Z Q_s^2 \lambda T_\lambda^*
\end{aligned}$$

$$\begin{aligned}
& + 8g_p^2 M_Z^* \left( 3g_p^2 M_Z Q_s^2 \left( 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_s^2 + 3Q_v^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 \right) \right. \\
& + \left. \left( -Q_s^2 + Q_{H_d}^2 + Q_{H_u}^2 \right) \lambda^* \left( 2M_Z \lambda - T_\lambda \right) \right) \\
& + 8g_p^2 Q_s^2 \sigma_{2,44} + 8g_p Q_s \sigma_{3,4} - 12|T_\lambda|^2 \text{Tr} \left( Y_d Y_d^\dagger \right) - 4|T_\lambda|^2 \text{Tr} \left( Y_e Y_e^\dagger \right) - 12|T_\lambda|^2 \text{Tr} \left( Y_u Y_u^\dagger \right) \\
& - 4|T_\lambda|^2 \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 12\lambda T_\lambda^* \text{Tr} \left( Y_d^\dagger T_d \right) - 4\lambda T_\lambda^* \text{Tr} \left( Y_e^\dagger T_e \right) - 12\lambda T_\lambda^* \text{Tr} \left( Y_u^\dagger T_u \right) \\
& - 4\lambda T_\lambda^* \text{Tr} \left( Y_\nu^\dagger T_\nu \right) \\
& + \frac{4}{5} \lambda^* \left( 3g_1^2 m_{H_d}^2 \lambda + 15g_2^2 m_{H_d}^2 \lambda + 3g_1^2 m_{H_u}^2 \lambda + 15g_2^2 m_{H_u}^2 \lambda + 3g_1^2 m_S^2 \lambda + 15g_2^2 m_S^2 \lambda \right. \\
& + 10g_p^2 m_{H_d}^2 Q_{H_d}^2 \lambda + 10g_p^2 m_{H_u}^2 Q_{H_d}^2 \lambda + 10g_p^2 m_S^2 Q_{H_d}^2 \lambda + 10g_p^2 m_{H_d}^2 Q_{H_u}^2 \lambda \\
& + 10g_p^2 m_{H_u}^2 Q_{H_u}^2 \lambda + 10g_p^2 m_S^2 Q_{H_u}^2 \lambda - 10g_p^2 m_{H_d}^2 Q_s^2 \lambda - 10g_p^2 m_{H_u}^2 Q_s^2 \lambda \\
& - 10g_p^2 m_S^2 Q_s^2 \lambda - 40\lambda |T_\lambda|^2 + 3g_1^2 M_1^* \left( 2M_1 \lambda - T_\lambda \right) + 15g_2^2 M_2^* \left( 2M_2 \lambda - T_\lambda \right) \\
& - 30m_{H_d}^2 \lambda \text{Tr} \left( Y_d Y_d^\dagger \right) - 15m_{H_u}^2 \lambda \text{Tr} \left( Y_d Y_d^\dagger \right) - 15m_S^2 \lambda \text{Tr} \left( Y_d Y_d^\dagger \right) - 10m_{H_d}^2 \lambda \text{Tr} \left( Y_e Y_e^\dagger \right) \\
& - 5m_{H_u}^2 \lambda \text{Tr} \left( Y_e Y_e^\dagger \right) - 5m_S^2 \lambda \text{Tr} \left( Y_e Y_e^\dagger \right) - 15m_{H_d}^2 \lambda \text{Tr} \left( Y_u Y_u^\dagger \right) - 30m_{H_u}^2 \lambda \text{Tr} \left( Y_u Y_u^\dagger \right) \\
& - 15m_S^2 \lambda \text{Tr} \left( Y_u Y_u^\dagger \right) - 5m_{H_d}^2 \lambda \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 10m_{H_u}^2 \lambda \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) - 5m_S^2 \lambda \text{Tr} \left( Y_\nu Y_\nu^\dagger \right) \\
& - 15T_\lambda \text{Tr} \left( T_d^* Y_d^T \right) - 15\lambda \text{Tr} \left( T_d^* T_d^T \right) - 5T_\lambda \text{Tr} \left( T_e^* Y_e^T \right) - 5\lambda \text{Tr} \left( T_e^* T_e^T \right) - 15T_\lambda \text{Tr} \left( T_u^* Y_u^T \right) \\
& - 15\lambda \text{Tr} \left( T_u^* T_u^T \right) - 5T_\lambda \text{Tr} \left( T_\nu^* Y_\nu^T \right) - 5\lambda \text{Tr} \left( T_\nu^* T_\nu^T \right) - 15\lambda \text{Tr} \left( m_d^2 Y_d Y_d^\dagger \right) - 5\lambda \text{Tr} \left( m_e^2 Y_e Y_e^\dagger \right) \\
& - 5\lambda \text{Tr} \left( m_l^2 Y_e^\dagger Y_e \right) - 15\lambda \text{Tr} \left( m_q^2 Y_d^\dagger Y_d \right) - 15\lambda \text{Tr} \left( m_q^2 Y_u^\dagger Y_u \right) - 15\lambda \text{Tr} \left( m_u^2 Y_u Y_u^\dagger \right) \\
& - 5\lambda \text{Tr} \left( Y_\nu Y_\nu^\dagger m_l^{2*} \right) - 5\lambda \text{Tr} \left( Y_\nu m_\nu^{2*} Y_\nu^\dagger \right) \tag{88}
\end{aligned}$$

### 3.7 Vacuum expectation values

$$\begin{aligned}
\beta_{v_d}^{(1)} &= \frac{1}{20} v_d \left( 15g_2^2 + 15g_2^2 \text{Xi} + 20g_p^2 Q_{H_d}^2 + 20g_p^2 Q_{H_d}^2 \text{Xi} - 20|\lambda|^2 - 20\text{Tr} \left( Y_e Y_e^\dagger \right) + 3g_1^2 + 3g_1^2 \text{Xi} - 60\text{Tr} \left( Y_d Y_d^\dagger \right) \right) \tag{89} \\
\beta_{v_d}^{(2)} &= \frac{1}{400} v_d \left( -522g_1^4 - 180g_1^2 g_2^2 - 1200g_2^4 + 720g_1^2 g_p^2 Q_d Q_{H_d} + 720g_1^2 g_p^2 Q_e Q_{H_d} - 480g_1^2 g_p^2 Q_{H_d}^2 \right. \\
& - 1200g_2^2 g_p^2 Q_{H_d}^2 - 3600g_p^4 Q_d^2 Q_{H_d}^2 - 1200g_p^4 Q_e^2 Q_{H_d}^2 - 1600g_p^4 Q_{H_d}^4 + 240g_1^2 g_p^2 Q_{H_d} Q_{H_u} \\
& - 800g_p^4 Q_{H_d}^2 Q_{H_u}^2 - 720g_1^2 g_p^2 Q_{H_d} Q_q - 2400g_p^4 Q_{H_d}^2 Q_q^2 + 720g_1^2 g_p^2 Q_{H_d} Q_q \\
& - 7200g_p^4 Q_{H_d}^2 Q_q^2 - 400g_p^4 Q_{H_d}^2 Q_s^2 - 1440g_1^2 g_p^2 Q_{H_d} Q_u - 3600g_p^4 Q_{H_d}^2 Q_u^2 \\
& + 720g_1^2 g_p^2 Q_{H_d} Q_v - 1200g_p^4 Q_{H_d}^2 Q_v^2 - 9g_1^4 \text{Xi} - 90g_1^2 g_2^2 \text{Xi} + 875g_2^4 \text{Xi} - 120g_1^2 g_p^2 Q_{H_d}^2 \text{Xi} \\
& - 600g_2^2 g_p^2 Q_{H_d}^2 \text{Xi} - 400g_p^4 Q_{H_d}^4 \text{Xi} + 9g_1^4 \text{Xi}^2 + 90g_1^2 g_2^2 \text{Xi}^2 - 225g_2^4 \text{Xi}^2 + 120g_1^2 g_p^2 Q_{H_d}^2 \text{Xi}^2 \\
& \left. + 600g_2^2 g_p^2 Q_{H_d}^2 \text{Xi}^2 + 400g_p^4 Q_{H_d}^4 \text{Xi}^2 + 1200\lambda^2 \lambda^{*,2} \right)
\end{aligned}$$

$$\begin{aligned}
& -40\left(5\left(32g_3^2 + 3\left(3g_2^2\text{Xi} + 4g_p^2\left(Q_{H_d}^2(-1 + \text{Xi}) + Q_d^2 + Q_q^2\right)\right)\right) + g_1^2(9\text{Xi} - 4)\right)\text{Tr}\left(Y_d Y_d^\dagger\right) - 480g_1^2\text{Tr}\left(Y_e Y_e^\dagger\right) \\
& - 800g_p^2 Q_e^2 \text{Tr}\left(Y_e Y_e^\dagger\right) + 800g_p^2 Q_{H_d}^2 \text{Tr}\left(Y_e Y_e^\dagger\right) - 800g_p^2 Q_q^2 \text{Tr}\left(Y_e Y_e^\dagger\right) \\
& - 120g_1^2 \text{Xi} \text{Tr}\left(Y_e Y_e^\dagger\right) - 600g_2^2 \text{Xi} \text{Tr}\left(Y_e Y_e^\dagger\right) - 800g_p^2 Q_{H_d}^2 \text{Xi} \text{Tr}\left(Y_e Y_e^\dagger\right) \\
& - 40|\lambda|^2\left(-20g_p^2 Q_{H_d}^2 + 20g_p^2 Q_{H_u}^2 + 20g_p^2 Q_s^2 + 3g_1^2 \text{Xi} + 15g_2^2 \text{Xi} + 20g_p^2 Q_{H_d}^2 \text{Xi} - 30\text{Tr}\left(Y_u Y_u^\dagger\right)\right) \\
& - 10\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) \\
& + 3600\text{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right) + 1200\text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) + 1200\text{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right) + 400\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*\right) \tag{90}
\end{aligned}$$

$$\beta_{v_u}^{(1)} = \frac{1}{20} v_u \left(15g_2^2 + 15g_2^2 \text{Xi} + 20g_p^2 Q_{H_u}^2 + 20g_p^2 Q_{H_u}^2 \text{Xi} - 20|\lambda|^2 - 20\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 3g_1^2 + 3g_1^2 \text{Xi} - 60\text{Tr}\left(Y_u Y_u^\dagger\right)\right) \tag{91}$$

$$\begin{aligned}
\beta_{v_u}^{(2)} = & \frac{1}{400} v_u \left(-522g_1^4 - 180g_1^2 g_2^2 - 1200g_2^4 - 720g_1^2 g_p^2 Q_d Q_{H_u} - 720g_1^2 g_p^2 Q_e Q_{H_u} + 240g_1^2 g_p^2 Q_{H_d} Q_{H_u}\right. \\
& - 480g_1^2 g_p^2 Q_{H_u}^2 - 1200g_2^2 g_p^2 Q_{H_u}^2 - 3600g_p^4 Q_d^2 Q_{H_u}^2 - 1200g_p^4 Q_e^2 Q_{H_u}^2 \\
& - 800g_p^4 Q_{H_d}^2 Q_{H_u}^2 - 1600g_p^4 Q_{H_u}^4 + 720g_1^2 g_p^2 Q_{H_u} Q_q - 2400g_p^4 Q_{H_u}^2 Q_q^2 - 720g_1^2 g_p^2 Q_{H_u} Q_q \\
& - 7200g_p^4 Q_{H_u}^2 Q_q^2 - 400g_p^4 Q_{H_u}^2 Q_s^2 + 1440g_1^2 g_p^2 Q_{H_u} Q_u - 3600g_p^4 Q_{H_u}^2 Q_u^2 \\
& - 720g_1^2 g_p^2 Q_{H_u} Q_v - 1200g_p^4 Q_{H_u}^2 Q_v^2 - 9g_1^4 \text{Xi} - 90g_1^2 g_2^2 \text{Xi} + 875g_2^4 \text{Xi} - 120g_1^2 g_p^2 Q_{H_u}^2 \text{Xi} \\
& - 600g_2^2 g_p^2 Q_{H_u}^2 \text{Xi} - 400g_p^4 Q_{H_u}^4 \text{Xi} + 9g_1^4 \text{Xi}^2 + 90g_1^2 g_2^2 \text{Xi}^2 - 225g_2^4 \text{Xi}^2 + 120g_1^2 g_p^2 Q_{H_u}^2 \text{Xi}^2 \\
& + 600g_2^2 g_p^2 Q_{H_u}^2 \text{Xi}^2 + 400g_p^4 Q_{H_u}^4 \text{Xi}^2 + 1200\lambda^2 \lambda^{*,2} \\
& \left. - 40|\lambda|^2\left(20g_p^2 Q_{H_d}^2 - 20g_p^2 Q_{H_u}^2 + 20g_p^2 Q_s^2 + 3g_1^2 \text{Xi} + 15g_2^2 \text{Xi} + 20g_p^2 Q_{H_u}^2 \text{Xi} - 30\text{Tr}\left(Y_d Y_d^\dagger\right)\right)\right. \\
& \left. - 10\text{Tr}\left(Y_e Y_e^\dagger\right)\right) \\
& - 40\left(5\left(32g_3^2 + 3\left(3g_2^2\text{Xi} + 4g_p^2\left(Q_{H_u}^2(-1 + \text{Xi}) + Q_q^2 + Q_u^2\right)\right)\right) + g_1^2(9\text{Xi} + 8)\right)\text{Tr}\left(Y_u Y_u^\dagger\right) - 480g_1^2\text{Tr}\left(Y_\nu Y_\nu^\dagger\right) \\
& + 800g_p^2 Q_{H_u}^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger\right) - 800g_p^2 Q_q^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger\right) - 800g_p^2 Q_v^2 \text{Tr}\left(Y_\nu Y_\nu^\dagger\right) \\
& - 120g_1^2 \text{Xi} \text{Tr}\left(Y_\nu Y_\nu^\dagger\right) - 600g_2^2 \text{Xi} \text{Tr}\left(Y_\nu Y_\nu^\dagger\right) - 800g_p^2 Q_{H_u}^2 \text{Xi} \text{Tr}\left(Y_\nu Y_\nu^\dagger\right) + 1200\text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) \\
& + 3600\text{Tr}\left(Y_u Y_u^\dagger Y_u Y_u^\dagger\right) + 1200\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_\nu Y_\nu^\dagger\right) + 400\text{Tr}\left(Y_\nu Y_\nu^\dagger Y_e^T Y_e^*\right) \tag{92}
\end{aligned}$$

$$\beta_{v_s}^{(1)} = v_s \left(-2|\lambda|^2 + g_p^2 Q_s^2 (1 + \text{Xi})\right) \tag{93}$$

$$\begin{aligned}
\beta_{v_s}^{(2)} = & -\frac{1}{5} v_s \left(5g_p^4 Q_s^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_s^2 + 3Q_v^2 + 6Q_q^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \text{Xi} - Q_s^2 \text{Xi}^2\right) - 20\lambda^2 \lambda^{*,2}\right. \\
& \left. + 2|\lambda|^2\left(3g_1^2 + 15g_2^2 + 10g_p^2 Q_{H_d}^2 + 10g_p^2 Q_{H_u}^2 - 10g_p^2 Q_s^2 + 10g_p^2 Q_s^2 \text{Xi} - 15\text{Tr}\left(Y_d Y_d^\dagger\right) - 5\text{Tr}\left(Y_e Y_e^\dagger\right)\right)\right. \\
& \left. - 15\text{Tr}\left(Y_u Y_u^\dagger\right) - 5\text{Tr}\left(Y_\nu Y_\nu^\dagger\right)\right) \tag{94}
\end{aligned}$$

## 4 Field Rotations

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

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \\ U_\rho \end{pmatrix} = Z^{\gamma ZZ'} \begin{pmatrix} \gamma_\rho \\ Z_\rho \\ Z'_\rho \end{pmatrix} \quad (95)$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho} \end{pmatrix} = Z^W \begin{pmatrix} W_\rho^- \\ W_\rho^- \end{pmatrix} \quad (96)$$

$$\begin{pmatrix} \lambda_{\tilde{W},1} \\ \lambda_{\tilde{W},2} \\ \lambda_{\tilde{W},3} \end{pmatrix} = Z^{\tilde{W}} \begin{pmatrix} \tilde{W}^- \\ \tilde{W}^+ \\ \tilde{W}^0 \end{pmatrix} \quad (97)$$

$$(98)$$

The mixing matrices are parametrized by

$$Z^{\gamma ZZ'} = \begin{pmatrix} \cos \Theta_W & -\cos \Theta'_W \sin \Theta_W & \sin \Theta_W \sin \Theta'_W \\ \sin \Theta_W & \cos \Theta_W \cos \Theta'_W & -\cos \Theta_W \sin \Theta'_W \\ 0 & \sin \Theta'_W & \cos \Theta'_W \end{pmatrix} \quad (99)$$

$$Z^W = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} \end{pmatrix} \quad (100)$$

$$Z^{\tilde{W}} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (101)$$

$$(102)$$

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

#### 4.2.1 Mass Matrices for Scalars

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

$$m_{\tilde{d}}^2 = \begin{pmatrix} m_{\tilde{d}_L \tilde{d}_L^*} & \frac{1}{2} (\sqrt{2} v_d T_d^\dagger - v_s v_u \lambda Y_d^\dagger) \delta_{\alpha_1 \beta_2} \\ \frac{1}{2} \delta_{\alpha_2 \beta_1} (\sqrt{2} v_d T_d - v_s v_u Y_d \lambda^*) & m_{\tilde{d}_R \tilde{d}_R^*} \end{pmatrix} \quad (103)$$

$$m_{\tilde{d}_L \tilde{d}_L^*} = +\frac{1}{24} \mathbf{1} \left( 3(4g_p^2 Q_q (Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + g_2^2 (-v_d^2 + v_u^2)) + g_1^2 (-v_d^2 + v_u^2) \right) \delta_{\alpha_1 \beta_1}$$

$$+ \frac{1}{2} \delta_{\alpha_1 \beta_1} \left( 2m_q^2 + v_d^2 Y_d^\dagger Y_d \right) \quad (104)$$

$$m_{\tilde{d}_R \tilde{d}_R^*} = \frac{1}{12} \mathbf{1} \left( 6g_p^2 Q_d \left( Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + g_1^2 \left( -v_d^2 + v_u^2 \right) \right) \delta_{\alpha_2 \beta_2} + \frac{1}{2} \delta_{\alpha_2 \beta_2} \left( 2m_d^2 + v_d^2 Y_d Y_d^\dagger \right) \quad (105)$$

This matrix is diagonalized by  $Z^D$ :

$$Z^D m_{\tilde{d}}^2 Z^{D,\dagger} = m_{2,\tilde{d}}^{dia} \quad (106)$$

with

$$\tilde{d}_{L,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha}, \quad \tilde{d}_{R,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha} \quad (107)$$

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

$$m_{\tilde{\nu}}^2 = \begin{pmatrix} m_{\tilde{\nu}_L \tilde{\nu}_L^*} & -\frac{1}{2} v_d v_s \lambda Y_\nu^* + \frac{1}{\sqrt{2}} v_u T_\nu^* \\ -\frac{1}{2} v_d v_s \lambda^* Y_\nu^T + \frac{1}{\sqrt{2}} v_u T_\nu^T & m_{\text{SvRconj}(\text{SvR})} \end{pmatrix} \quad (108)$$

$$m_{\tilde{\nu}_L \tilde{\nu}_L^*} = \frac{1}{2} v_u^2 Y_\nu^* Y_\nu^T + \frac{1}{8} \mathbf{1} \left( 4g_p^2 Q_q \left( Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + (g_1^2 + g_2^2) \left( -v_u^2 + v_d^2 \right) \right) + m_l^2 \quad (109)$$

$$m_{\text{SvRconj}(\text{SvR})} = \frac{1}{2} v_u^2 Y_\nu^T Y_\nu^* + \frac{1}{4} \mathbf{1} \left( 2g_p^2 Q_v \left( Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + g_1^2 \left( -v_d^2 + v_u^2 \right) \right) + m_\nu^2 \quad (110)$$

This matrix is diagonalized by  $Z^V$ :

$$Z^V m_{\tilde{\nu}}^2 Z^{V,\dagger} = m_{2,\tilde{\nu}}^{dia} \quad (111)$$

with

$$\tilde{\nu}_{L,i} = \sum_j Z_{ji}^{V,*} \tilde{\nu}_j, \quad \text{SvR}(\{\text{gt}1\}) = \sum_j Z_{ji}^{V,*} \tilde{\nu}_j \quad (112)$$

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

$$m_{\tilde{u}}^2 = \begin{pmatrix} m_{\tilde{u}_L \tilde{u}_L^*} & \frac{1}{2} \left( \sqrt{2} v_u T_u^\dagger - v_d v_s \lambda Y_u^\dagger \right) \delta_{\alpha_1 \beta_2} \\ \frac{1}{2} \delta_{\alpha_2 \beta_1} \left( \sqrt{2} v_u T_u - v_d v_s Y_u \lambda^* \right) & m_{\tilde{u}_R \tilde{u}_R^*} \end{pmatrix} \quad (113)$$

$$m_{\tilde{u}_L \tilde{u}_L^*} = + \frac{1}{24} \mathbf{1} \left( 3 \left( 4g_p^2 Q_q \left( Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + g_2^2 \left( -v_u^2 + v_d^2 \right) \right) + g_1^2 \left( -v_d^2 + v_u^2 \right) \right) \delta_{\alpha_1 \beta_1} \\ + \frac{1}{2} \delta_{\alpha_1 \beta_1} \left( 2m_q^2 + v_u^2 Y_u^\dagger Y_u \right) \quad (114)$$

$$m_{\tilde{u}_R \tilde{u}_R^*} = \frac{1}{2} \delta_{\alpha_2 \beta_2} \left( 2m_u^2 + v_u^2 Y_u Y_u^\dagger \right) + \frac{1}{6} \mathbf{1} \left( 3g_p^2 Q_u \left( Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + g_1^2 \left( -v_u^2 + v_d^2 \right) \right) \delta_{\alpha_2 \beta_2} \quad (115)$$

This matrix is diagonalized by  $Z^U$ :

$$Z^U m_{\tilde{u}}^2 Z^{U,\dagger} = m_{2,\tilde{u}}^{dia} \quad (116)$$

with

$$\tilde{u}_{L,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha}, \quad \tilde{u}_{R,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha} \quad (117)$$

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

$$m_{\tilde{e}}^2 = \begin{pmatrix} m_{\tilde{e}_L \tilde{e}_L^*} & -\frac{1}{2} v_s v_u \lambda Y_e^\dagger + \frac{1}{\sqrt{2}} v_d T_e^\dagger \\ -\frac{1}{2} v_s v_u Y_e \lambda^* + \frac{1}{\sqrt{2}} v_d T_e & m_{\tilde{e}_R \tilde{e}_R^*} \end{pmatrix} \quad (118)$$

$$m_{\tilde{e}_L \tilde{e}_L^*} = +m_l^2 + \frac{1}{8} \mathbf{1} \left( 4g_p^2 Q_q (Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + g_1^2 (-v_u^2 + v_d^2) + g_2^2 (-v_d^2 + v_u^2) \right) + \frac{1}{2} v_d^2 Y_e^\dagger Y_e \quad (119)$$

$$m_{\tilde{e}_R \tilde{e}_R^*} = \frac{1}{2} v_d^2 Y_e Y_e^\dagger + \frac{1}{4} \mathbf{1} \left( 2g_p^2 Q_e (Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + g_1^2 (-v_d^2 + v_u^2) \right) + m_e^2 \quad (120)$$

This matrix is diagonalized by  $Z^E$ :

$$Z^E m_{\tilde{e}}^2 Z^{E,\dagger} = m_{2,\tilde{e}}^{dia} \quad (121)$$

with

$$\tilde{e}_{L,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j, \quad \tilde{e}_{R,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j \quad (122)$$

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

$$m_h^2 = \begin{pmatrix} m_{\phi_d \phi_d} & m_{\phi_u \phi_d} & m_{\phi_s \phi_d} \\ m_{\phi_d \phi_u} & m_{\phi_u \phi_u} & m_{\phi_s \phi_u} \\ m_{\phi_d \phi_s} & m_{\phi_u \phi_s} & m_{\phi_s \phi_s} \end{pmatrix} \quad (123)$$

$$m_{\phi_d \phi_d} = \frac{1}{2} (v_s^2 + v_u^2) |\lambda|^2 + \frac{1}{8} \left( 4g_p^2 Q_{H_d} (3Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + (g_1^2 + g_2^2) (3v_d^2 - v_u^2) \right) + m_{H_d}^2 \quad (124)$$

$$m_{\phi_d \phi_u} = -\frac{1}{4} \left( -4g_p^2 Q_{H_d} Q_{H_u} + g_1^2 + g_2^2 \right) v_d v_u - \frac{1}{\sqrt{2}} v_s \Re(T_\lambda) + v_d v_u |\lambda|^2 \quad (125)$$

$$m_{\phi_u \phi_u} = \frac{1}{2} (v_d^2 + v_s^2) |\lambda|^2 + \frac{1}{8} \left( 4g_p^2 Q_{H_u} (3Q_{H_u} v_u^2 + Q_{H_d} v_d^2 + Q_s v_s^2) + (-g_1^2 - g_2^2) (-3v_u^2 + v_d^2) \right) + m_{H_u}^2 \quad (126)$$

$$m_{\phi_d \phi_s} = -\frac{1}{\sqrt{2}} v_u \Re(T_\lambda) + g_p^2 Q_{H_d} Q_s v_d v_s + v_d v_s |\lambda|^2 \quad (127)$$

$$m_{\phi_u \phi_s} = -\frac{1}{\sqrt{2}} v_d \Re(T_\lambda) + g_p^2 Q_{H_u} Q_s v_s v_u + v_s v_u |\lambda|^2 \quad (128)$$

$$m_{\phi_s \phi_s} = \frac{1}{2} g_p^2 Q_s (3Q_s v_s^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2) + \frac{1}{2} (v_d^2 + v_u^2) |\lambda|^2 + m_S^2 \quad (129)$$

This matrix is diagonalized by  $Z^H$ :

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \quad (130)$$

with

$$\phi_d = \sum_j Z_{j1}^{H,*} h_j, \quad \phi_u = \sum_j Z_{j2}^{H,*} h_j, \quad \phi_s = \sum_j Z_{j3}^{H,*} h_j \quad (131)$$

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

$$m_{A^0}^2 = \begin{pmatrix} m_{\sigma_d \sigma_d} & \frac{1}{\sqrt{2}} v_s \Re(T_\lambda) & \frac{1}{\sqrt{2}} v_u \Re(T_\lambda) \\ \frac{1}{\sqrt{2}} v_s \Re(T_\lambda) & m_{\sigma_u \sigma_u} & \frac{1}{\sqrt{2}} v_d \Re(T_\lambda) \\ \frac{1}{\sqrt{2}} v_u \Re(T_\lambda) & \frac{1}{\sqrt{2}} v_d \Re(T_\lambda) & m_{\sigma_s \sigma_s} \end{pmatrix} + \xi_Z m^2(Z) + \xi_{Z'} m^2(Z') \quad (132)$$

$$m_{\sigma_d \sigma_d} = \frac{1}{2} (v_s^2 + v_u^2) |\lambda|^2 + \frac{1}{8} (4g_p^2 Q_{H_d} (Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + (g_1^2 + g_2^2) (-v_u^2 + v_d^2)) + m_{H_d}^2 \quad (133)$$

$$m_{\sigma_u \sigma_u} = \frac{1}{2} (v_d^2 + v_s^2) |\lambda|^2 + \frac{1}{8} (4g_p^2 Q_{H_u} (Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + (g_1^2 + g_2^2) (-v_d^2 + v_u^2)) + m_{H_u}^2 \quad (134)$$

$$m_{\sigma_s \sigma_s} = \frac{1}{2} g_p^2 Q_s (Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + \frac{1}{2} (v_d^2 + v_u^2) |\lambda|^2 + m_S^2 \quad (135)$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} m_{\sigma_d \sigma_d} & m_{\sigma_u \sigma_d} & m_{\sigma_s \sigma_d} \\ m_{\sigma_d \sigma_u} & m_{\sigma_u \sigma_u} & m_{\sigma_s \sigma_u} \\ m_{\sigma_d \sigma_s} & m_{\sigma_u \sigma_s} & g_p^2 Q_s^2 v_s^2 \sin^2 \Theta'_W \end{pmatrix} \quad (136)$$

$$m_{\sigma_d \sigma_d} = \frac{1}{4} v_d^2 (2g_p Q_{H_d} \sin \Theta'_W + \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W))^2 \quad (137)$$

$$m_{\sigma_d \sigma_u} = -\frac{1}{4} v_d v_u (2g_p Q_{H_d} \sin \Theta'_W + \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W)) (-2g_p Q_{H_u} \sin \Theta'_W + \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W)) \quad (138)$$

$$m_{\sigma_u \sigma_u} = \frac{1}{4} v_u^2 (-2g_p Q_{H_u} \sin \Theta'_W + \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W))^2 \quad (139)$$

$$m_{\sigma_d \sigma_s} = \frac{1}{2} g_p Q_s v_d v_s \sin \Theta'_W (2g_p Q_{H_d} \sin \Theta'_W + \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W)) \quad (140)$$

$$m_{\sigma_u \sigma_s} = \frac{1}{2} g_p Q_s v_s v_u \sin \Theta'_W (2g_p Q_{H_u} \sin \Theta'_W - \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W)) \quad (141)$$

$$m^2(\xi_{Z'}) = \begin{pmatrix} m_{\sigma_d \sigma_d} & m_{\sigma_u \sigma_d} & m_{\sigma_s \sigma_d} \\ m_{\sigma_d \sigma_u} & m_{\sigma_u \sigma_u} & m_{\sigma_s \sigma_u} \\ m_{\sigma_d \sigma_s} & m_{\sigma_u \sigma_s} & g_p^2 Q_s^2 v_s^2 \cos^2 \Theta'_W \end{pmatrix} \quad (142)$$

$$m_{\sigma_d \sigma_d} = \frac{1}{4} v_d^2 \left( -2g_p Q_{H_d} \cos \Theta'_W + (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W \right)^2 \quad (143)$$

$$m_{\sigma_d \sigma_u} = \frac{1}{8} v_d v_u \left( -2(g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W + 4g_p Q_{H_d} \cos \Theta'_W \right) \left( 2g_p Q_{H_u} \cos \Theta'_W + (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W \right) \sin \Theta \quad (144)$$

$$m_{\sigma_u \sigma_u} = \frac{1}{4} v_u^2 \left( 2g_p Q_{H_u} \cos \Theta'_W + (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W \right)^2 \quad (145)$$

$$m_{\sigma_d \sigma_s} = \frac{1}{2} g_p Q_s v_d v_s \cos \Theta'_W \left( 2g_p Q_{H_d} \cos \Theta'_W - (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W \right) \quad (146)$$

$$m_{\sigma_u \sigma_s} = \frac{1}{2} g_p Q_s v_s v_u \cos \Theta'_W \left( 2g_p Q_{H_u} \cos \Theta'_W + (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W \right) \quad (147)$$

This matrix is diagonalized by  $Z^A$ :

$$Z^A m_{A^0}^2 Z^{A,\dagger} = m_{2,A^0}^{dia} \quad (148)$$

with

$$\sigma_d = \sum_j Z_{j1}^{A,*} A_j^0, \quad \sigma_u = \sum_j Z_{j2}^{A,*} A_j^0, \quad \sigma_s = \sum_j Z_{j3}^{A,*} A_j^0 \quad (149)$$

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

$$m_{H^-}^2 = \begin{pmatrix} m_{H_d^- H_d^{-,*}} & -\frac{1}{2} v_d v_u |\lambda|^2 + \frac{1}{4} g_2^2 v_d v_u + \frac{1}{\sqrt{2}} v_s T_\lambda^* \\ -\frac{1}{2} v_d v_u |\lambda|^2 + \frac{1}{4} g_2^2 v_d v_u + \frac{1}{\sqrt{2}} v_s T_\lambda & m_{H_u^{+,*} H_u^+} \end{pmatrix} + \xi_{W^-} m^2(W^-) \quad (150)$$

$$m_{H_d^- H_d^{-,*}} = \frac{1}{2} v_s^2 |\lambda|^2 + \frac{1}{8} \left( 4g_p^2 Q_{H_d} (Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + g_1^2 (-v_u^2 + v_d^2) + g_2^2 (v_d^2 + v_u^2) \right) + m_{H_d}^2 \quad (151)$$

$$m_{H_u^{+,*} H_u^+} = \frac{1}{2} v_s^2 |\lambda|^2 + \frac{1}{8} \left( 4g_p^2 Q_{H_u} (Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + g_1^2 (-v_d^2 + v_u^2) + g_2^2 (v_d^2 + v_u^2) \right) + m_{H_u}^2 \quad (152)$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4} g_2^2 v_d^2 & -\frac{1}{4} g_2^2 v_d v_u \\ -\frac{1}{4} g_2^2 v_d v_u & \frac{1}{4} g_2^2 v_u^2 \end{pmatrix} \quad (153)$$

This matrix is diagonalized by  $Z^+$ :

$$Z^+ m_{H^-}^2 Z^{+,\dagger} = m_{2,H^-}^{dia} \quad (154)$$

with

$$H_d^- = \sum_j Z_{j1}^+ H_j^-, \quad H_u^+ = \sum_j Z_{j2}^+ H_j^+ \quad (155)$$

#### 4.2.2 Mass Matrices for Fermions

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



$$m_{\tilde{\chi}^0} = \begin{pmatrix} M_Z & 0 & 0 & g_p Q_{H_d} v_d & g_p Q_{H_u} v_u & g_p Q_s v_s \\ 0 & M_1 & 0 & -\frac{1}{2} g_1 v_d & \frac{1}{2} g_1 v_u & 0 \\ 0 & 0 & M_2 & \frac{1}{2} g_2 v_d & -\frac{1}{2} g_2 v_u & 0 \\ g_p Q_{H_d} v_d & -\frac{1}{2} g_1 v_d & \frac{1}{2} g_2 v_d & 0 & -\frac{1}{\sqrt{2}} v_s \lambda & -\frac{1}{\sqrt{2}} v_u \lambda \\ g_p Q_{H_u} v_u & \frac{1}{2} g_1 v_u & -\frac{1}{2} g_2 v_u & -\frac{1}{\sqrt{2}} v_s \lambda & 0 & -\frac{1}{\sqrt{2}} v_d \lambda \\ g_p Q_s v_s & 0 & 0 & -\frac{1}{\sqrt{2}} v_u \lambda & -\frac{1}{\sqrt{2}} v_d \lambda & 0 \end{pmatrix} \quad (156)$$

This matrix is diagonalized by  $N$ :

$$N^* m_{\tilde{\chi}^0} N^\dagger = m_{\tilde{\chi}^0}^{dia} \quad (157)$$

with

$$\lambda_U = \sum_j N_{j1}^* \lambda_j^0, \quad \lambda_{\tilde{B}} = \sum_j N_{j2}^* \lambda_j^0, \quad \tilde{W}^0 = \sum_j N_{j3}^* \lambda_j^0 \quad (158)$$

$$\tilde{H}_d^0 = \sum_j N_{j4}^* \lambda_j^0, \quad \tilde{H}_u^0 = \sum_j N_{j5}^* \lambda_j^0, \quad \tilde{S} = \sum_j N_{j6}^* \lambda_j^0 \quad (159)$$

- **Mass matrix for Neutrinos**, Basis:  $(\nu_L, \text{conj}(\text{FvR})), (\nu_L, \text{conj}(\text{FvR}))$

$$m_\nu = \begin{pmatrix} 0 & \frac{1}{\sqrt{2}} v_u Y_\nu \\ \frac{1}{\sqrt{2}} v_u Y_\nu^T & 0 \end{pmatrix} \quad (160)$$

This matrix is diagonalized by  $U^V$ :

$$U^{V,*} m_\nu U^{V,\dagger} = m_\nu^{dia} \quad (161)$$

with

$$\nu_{L,i} = \sum_j U_{ji}^{V,*} \text{Fvm}(\{\text{gt}2\}), \quad \text{FvR}(\{\text{gt}1\}) = \sum_j U_{ji}^V \text{conj}(\text{Fvm}(\{\text{gt}2\})) \quad (162)$$

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

$$m_{\tilde{\chi}^-} = \begin{pmatrix} M_2 & \frac{1}{\sqrt{2}} g_2 v_u \\ \frac{1}{\sqrt{2}} g_2 v_d & \frac{1}{\sqrt{2}} v_s \lambda \end{pmatrix} \quad (163)$$

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

$$U^* m_{\tilde{\chi}^-} V^\dagger = m_{\tilde{\chi}^-}^{dia} \quad (164)$$

with

$$\tilde{W}^- = \sum_{t_2} U_{j1}^* \lambda_j^-, \quad \tilde{H}_d^- = \sum_{t_2} U_{j2}^* \lambda_j^- \quad (165)$$

$$\tilde{W}^+ = \sum_{t_2} V_{1j}^* \lambda_j^+, \quad \tilde{H}_u^+ = \sum_{t_2} V_{2j}^* \lambda_j^+ \quad (166)$$

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

$$m_e = \left( \frac{1}{\sqrt{2}} v_d Y_e^T \right) \quad (167)$$

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

$$U_L^{e,*} m_e U_R^{e,\dagger} = m_e^{dia} \quad (168)$$

with

$$e_{L,i} = \sum_{t_2} U_{L,ji}^{e,*} E_{L,j} \quad (169)$$

$$e_{R,i} = \sum_{t_2} U_{R,ij}^e E_{R,j}^* \quad (170)$$

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

$$m_d = \left( \frac{1}{\sqrt{2}} v_d \delta_{\alpha_1 \beta_1} Y_d^T \right) \quad (171)$$

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

$$U_L^{d,*} m_d U_R^{d,\dagger} = m_d^{dia} \quad (172)$$

with

$$d_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{d,*} D_{L,j\alpha} \quad (173)$$

$$d_{R,i\alpha} = \sum_{t_2} U_{R,ij}^d D_{R,j\alpha}^* \quad (174)$$

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

$$m_u = \left( \frac{1}{\sqrt{2}} v_u \delta_{\alpha_1 \beta_1} Y_u^T \right) \quad (175)$$

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

$$U_L^{u,*} m_u U_R^{u,\dagger} = m_u^{dia} \quad (176)$$

with

$$u_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{u,*} U_{L,j\alpha} \quad (177)$$

$$u_{R,i\alpha} = \sum_{t_2} U_{R,ij}^u U_{R,j\alpha}^* \quad (178)$$

## 5 Vacuum Expectation Values

$$H_d^0 = \frac{1}{\sqrt{2}}\phi_d + \frac{1}{\sqrt{2}}v_d + i\frac{1}{\sqrt{2}}\sigma_d \quad (179)$$

$$H_u^0 = \frac{1}{\sqrt{2}}\phi_u + \frac{1}{\sqrt{2}}v_u + i\frac{1}{\sqrt{2}}\sigma_u \quad (180)$$

$$S = \frac{1}{\sqrt{2}}\phi_s + \frac{1}{\sqrt{2}}v_s + i\frac{1}{\sqrt{2}}\sigma_s \quad (181)$$

## 6 Tadpole Equations

$$\begin{aligned} \frac{\partial V}{\partial \phi_d} = & +\frac{1}{8}v_d\left(4g_p^2Q_{H_d}\left(Q_{H_d}v_d^2 + Q_{H_u}v_u^2 + Q_s v_s^2\right) + \left(g_1^2 + g_2^2\right)\left(-v_u + v_d\right)\left(v_d + v_u\right)\right) \\ & + \frac{1}{4}\left(-\sqrt{2}v_s v_u\left(T_\lambda^* + T_\lambda\right) + v_d\left(2\left(v_s^2 + v_u^2\right)|\lambda|^2 + 4m_{H_d}^2\right)\right) \end{aligned} \quad (182)$$

$$\begin{aligned} \frac{\partial V}{\partial \phi_u} = & +\frac{1}{8}v_u\left(4g_p^2Q_{H_u}\left(Q_{H_d}v_d^2 + Q_{H_u}v_u^2 + Q_s v_s^2\right) + \left(g_1^2 + g_2^2\right)\left(-v_d^2 + v_u^2\right)\right) \\ & + \frac{1}{2}\left(-\sqrt{2}v_d v_s \Re\left(T_\lambda\right) + v_u\left(2m_{H_u}^2 + \left(v_d^2 + v_s^2\right)|\lambda|^2\right)\right) \end{aligned} \quad (183)$$

$$\frac{\partial V}{\partial \phi_s} = \frac{1}{2}g_p^2Q_s v_s\left(Q_{H_d}v_d^2 + Q_{H_u}v_u^2 + Q_s v_s^2\right) + \frac{1}{4}\left(-\sqrt{2}v_d v_u\left(T_\lambda^* + T_\lambda\right) + v_s\left(2\left(v_d^2 + v_u^2\right)|\lambda|^2 + 4m_S^2\right)\right) \quad (184)$$

## 7 Particle content for eigenstates 'EWSB'

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

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

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

### 8.1 One Loop Self-Energy

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

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

$$\begin{aligned}
& -C \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, \tilde{d}_a^*, \tilde{d}_a} - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, \tilde{e}_a^*, \tilde{e}_a} \\
& -C \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, \tilde{u}_a^*, \tilde{u}_a} - \sum_{a=1}^6 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{d}_i, \tilde{d}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a} \\
& + \sum_{a=1}^6 \sum_{b=1}^2 B_0(p^2, m_{\tilde{u}_a}^2, m_{H_b^-}^2) \Gamma_{\tilde{d}_j^*, \tilde{u}_a, H_b^-}^* \Gamma_{\tilde{d}_i^*, \tilde{u}_a, H_b^-} \\
& + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{d}_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{d}_j^*, \tilde{d}_a, A_b^0}^* \Gamma_{\tilde{d}_i^*, \tilde{d}_a, A_b^0} + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{d}_a}^2, m_{h_b}^2) \Gamma_{\tilde{d}_j^*, \tilde{d}_a, h_b}^* \Gamma_{\tilde{d}_i^*, \tilde{d}_a, h_b} \\
& - \frac{8}{3} m_{\tilde{g}} \sum_{b=1}^3 B_0(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_b}^2) m_{\tilde{d}_b} \left( \Gamma_{\tilde{d}_j^*, \tilde{g}_1, \tilde{d}_b}^{L*} \Gamma_{\tilde{d}_i^*, \tilde{g}_1, \tilde{d}_b}^R + \Gamma_{\tilde{d}_j^*, \tilde{g}_1, \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i^*, \tilde{g}_1, \tilde{d}_b}^L \right) \\
& + \frac{4}{3} \sum_{b=1}^3 G_0(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_b}^2) \left( \Gamma_{\tilde{d}_j^*, \tilde{g}_1, \tilde{d}_b}^{L*} \Gamma_{\tilde{d}_i^*, \tilde{g}_1, \tilde{d}_b}^L + \Gamma_{\tilde{d}_j^*, \tilde{g}_1, \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i^*, \tilde{g}_1, \tilde{d}_b}^R \right) \\
& + \frac{4}{3} \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, \tilde{g}, \tilde{d}_b}^* \Gamma_{\tilde{d}_i^*, \tilde{g}, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, 0) + \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, \gamma, \tilde{d}_b}^* \Gamma_{\tilde{d}_i^*, \gamma, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, 0) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, Z, \tilde{d}_b}^* \Gamma_{\tilde{d}_i^*, Z, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, m_Z^2) + \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, Z', \tilde{d}_b}^* \Gamma_{\tilde{d}_i^*, Z', \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, m_{Z'}^2) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, W^-, \tilde{u}_b}^* \Gamma_{\tilde{d}_i^*, W^-, \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, m_{W^-}^2) \tag{185}
\end{aligned}$$

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

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

$$\begin{aligned}
& - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, \tilde{e}_a^*, \tilde{e}_a} - 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, \tilde{u}_a^*, \tilde{u}_a} \\
& - \sum_{a=1}^6 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a} + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{\nu}_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{\nu}_j^*, \tilde{\nu}_a, A_b^0}^* \Gamma_{\tilde{\nu}_i^*, \tilde{\nu}_a, A_b^0} \\
& + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{\nu}_a}^2, m_{h_b}^2) \Gamma_{\tilde{\nu}_j^*, \tilde{\nu}_a, h_b}^* \Gamma_{\tilde{\nu}_i^*, \tilde{\nu}_a, h_b} \\
& - \sum_{a=1}^6 m_{\nu_a} \sum_{b=1}^6 B_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_b^0} \left( \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^R + \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^L \right) \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 G_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^0}^2) \left( \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^L + \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^R \right) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{\nu}_j^*, W^+, \tilde{e}_b}^* \Gamma_{\tilde{\nu}_i^*, W^+, \tilde{e}_b} F_0(p^2, m_{\tilde{e}_b}^2, m_{W^-}^2) + \sum_{b=1}^6 \Gamma_{\tilde{\nu}_j^*, \gamma, \tilde{\nu}_b}^* \Gamma_{\tilde{\nu}_i^*, \gamma, \tilde{\nu}_b} F_0(p^2, m_{\tilde{\nu}_b}^2, 0) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{\nu}_j^*, Z, \tilde{\nu}_b}^* \Gamma_{\tilde{\nu}_i^*, Z, \tilde{\nu}_b} F_0(p^2, m_{\tilde{\nu}_b}^2, m_Z^2) + \sum_{b=1}^6 \Gamma_{\tilde{\nu}_j^*, Z', \tilde{\nu}_b}^* \Gamma_{\tilde{\nu}_i^*, Z', \tilde{\nu}_b} F_0(p^2, m_{\tilde{\nu}_b}^2, m_{Z'}^2) \tag{186}
\end{aligned}$$

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

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

$$\begin{aligned}
& -C \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, \tilde{d}_a^*, \tilde{d}_a} - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, \tilde{e}_a^*, \tilde{e}_a} \\
& -C \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, \tilde{u}_a^*, \tilde{u}_a} - \sum_{a=1}^6 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a} \\
& + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{u}_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{u}_j^*, \tilde{u}_a, A_b^0}^* \Gamma_{\tilde{u}_i^*, \tilde{u}_a, A_b^0} + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{u}_a}^2, m_{h_b}^2) \Gamma_{\tilde{u}_j^*, \tilde{u}_a, h_b}^* \Gamma_{\tilde{u}_i^*, \tilde{u}_a, h_b} \\
& - \frac{8}{3} m_{\tilde{g}} \sum_{b=1}^3 B_0(p^2, m_{\tilde{g}}^2, m_{u_b}^2) m_{u_b} \left( \Gamma_{\tilde{u}_j^*, \tilde{g}_1, u_b}^{L*} \Gamma_{\tilde{u}_i^*, \tilde{g}_1, u_b}^R + \Gamma_{\tilde{u}_j^*, \tilde{g}_1, u_b}^{R*} \Gamma_{\tilde{u}_i^*, \tilde{g}_1, u_b}^L \right) \\
& + \frac{4}{3} \sum_{b=1}^3 G_0(p^2, m_{\tilde{g}}^2, m_{u_b}^2) \left( \Gamma_{\tilde{u}_j^*, \tilde{g}_1, u_b}^{L*} \Gamma_{\tilde{u}_i^*, \tilde{g}_1, u_b}^L + \Gamma_{\tilde{u}_j^*, \tilde{g}_1, u_b}^{R*} \Gamma_{\tilde{u}_i^*, \tilde{g}_1, u_b}^R \right) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{u}_j^*, W^+, \tilde{d}_b}^* \Gamma_{\tilde{u}_i^*, W^+, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, m_{W^-}^2) + \frac{4}{3} \sum_{b=1}^6 \Gamma_{\tilde{u}_j^*, g, \tilde{u}_b}^* \Gamma_{\tilde{u}_i^*, g, \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, 0) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{u}_j^*, \gamma, \tilde{u}_b}^* \Gamma_{\tilde{u}_i^*, \gamma, \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, 0) + \sum_{b=1}^6 \Gamma_{\tilde{u}_j^*, Z, \tilde{u}_b}^* \Gamma_{\tilde{u}_i^*, Z, \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, m_Z^2) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{u}_j^*, Z', \tilde{u}_b}^* \Gamma_{\tilde{u}_i^*, Z', \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, m_{Z'}^2) \tag{187}
\end{aligned}$$

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

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

$$\begin{aligned}
& + \sum_{a=1}^6 \sum_{b=1}^2 B_0(p^2, m_{\tilde{\nu}_a}^2, m_{H_b^-}^2) \Gamma_{\tilde{e}_j^*, \tilde{\nu}_a, H_b^-}^* \Gamma_{\tilde{e}_i^*, \tilde{\nu}_a, H_b^-}^* \\
& - 2 \sum_{a=1}^6 m_{\nu_a} \sum_{b=1}^2 B_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^-}^2) m_{\tilde{\chi}_b^-} \left( \Gamma_{\tilde{e}_j^*, \nu_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{e}_i^*, \nu_a, \tilde{\chi}_b^-}^R + \Gamma_{\tilde{e}_j^*, \nu_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{e}_i^*, \nu_a, \tilde{\chi}_b^-}^L \right) \\
& + \sum_{a=1}^6 \sum_{b=1}^2 G_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^-}^2) \left( \Gamma_{\tilde{e}_j^*, \nu_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{e}_i^*, \nu_a, \tilde{\chi}_b^-}^L + \Gamma_{\tilde{e}_j^*, \nu_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{e}_i^*, \nu_a, \tilde{\chi}_b^-}^R \right) \\
& + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{e}_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{e}_j^*, \tilde{e}_a, A_b^0}^* \Gamma_{\tilde{e}_i^*, \tilde{e}_a, A_b^0}^* + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{e}_a}^2, m_{h_b}^2) \Gamma_{\tilde{e}_j^*, \tilde{e}_a, h_b}^* \Gamma_{\tilde{e}_i^*, \tilde{e}_a, h_b}^* \\
& + \sum_{b=1}^6 \Gamma_{\tilde{e}_j^*, \gamma, \tilde{e}_b}^* \Gamma_{\tilde{e}_i^*, \gamma, \tilde{e}_b}^* F_0(p^2, m_{\tilde{e}_b}^2, 0) + \sum_{b=1}^6 \Gamma_{\tilde{e}_j^*, Z, \tilde{e}_b}^* \Gamma_{\tilde{e}_i^*, Z, \tilde{e}_b}^* F_0(p^2, m_{\tilde{e}_b}^2, m_Z^2) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{e}_j^*, Z', \tilde{e}_b}^* \Gamma_{\tilde{e}_i^*, Z', \tilde{e}_b}^* F_0(p^2, m_{\tilde{e}_b}^2, m_{Z'}^2) + \sum_{b=1}^6 \Gamma_{\tilde{e}_j^*, W^-, \tilde{\nu}_b}^* \Gamma_{\tilde{e}_i^*, W^-, \tilde{\nu}_b}^* F_0(p^2, m_{\tilde{\nu}_b}^2, m_{W^-}^2) \quad (188)
\end{aligned}$$

• Self-Energy for Higgs ( $h$ )

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



$$\begin{aligned}
& + \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{h_a}^2, m_{A_b^0}^2) \Gamma_{\check{h}_j, h_a, A_b^0}^* \Gamma_{\check{h}_i, h_a, A_b^0} + \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{h_a}^2, m_{h_b}^2) \Gamma_{\check{h}_j, h_a, h_b}^* \Gamma_{\check{h}_i, h_a, h_b} \\
& - 6 \sum_{a=1}^3 m_{d_a} \sum_{b=1}^3 B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_b} \left( \Gamma_{\check{h}_j, \bar{d}_a, d_b}^{L*} \Gamma_{\check{h}_i, \bar{d}_a, d_b}^R + \Gamma_{\check{h}_j, \bar{d}_a, d_b}^{R*} \Gamma_{\check{h}_i, \bar{d}_a, d_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{d_a}^2, m_{d_b}^2) \left( \Gamma_{\check{h}_j, \bar{d}_a, d_b}^{L*} \Gamma_{\check{h}_i, \bar{d}_a, d_b}^L + \Gamma_{\check{h}_j, \bar{d}_a, d_b}^{R*} \Gamma_{\check{h}_i, \bar{d}_a, d_b}^R \right) \\
& - 2 \sum_{a=1}^3 m_{e_a} \sum_{b=1}^3 B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_b} \left( \Gamma_{\check{h}_j, \bar{e}_a, e_b}^{L*} \Gamma_{\check{h}_i, \bar{e}_a, e_b}^R + \Gamma_{\check{h}_j, \bar{e}_a, e_b}^{R*} \Gamma_{\check{h}_i, \bar{e}_a, e_b}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{e_a}^2, m_{e_b}^2) \left( \Gamma_{\check{h}_j, \bar{e}_a, e_b}^{L*} \Gamma_{\check{h}_i, \bar{e}_a, e_b}^L + \Gamma_{\check{h}_j, \bar{e}_a, e_b}^{R*} \Gamma_{\check{h}_i, \bar{e}_a, e_b}^R \right) \\
& - 6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_b} \left( \Gamma_{\check{h}_j, \bar{u}_a, u_b}^{L*} \Gamma_{\check{h}_i, \bar{u}_a, u_b}^R + \Gamma_{\check{h}_j, \bar{u}_a, u_b}^{R*} \Gamma_{\check{h}_i, \bar{u}_a, u_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{u_a}^2, m_{u_b}^2) \left( \Gamma_{\check{h}_j, \bar{u}_a, u_b}^{L*} \Gamma_{\check{h}_i, \bar{u}_a, u_b}^L + \Gamma_{\check{h}_j, \bar{u}_a, u_b}^{R*} \Gamma_{\check{h}_i, \bar{u}_a, u_b}^R \right) \\
& - 3 \sum_{a=1}^6 A_0(m_{\bar{d}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \bar{d}_a^*, \bar{d}_a} - \sum_{a=1}^6 A_0(m_{\bar{e}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \bar{e}_a^*, \bar{e}_a} \\
& - 3 \sum_{a=1}^6 A_0(m_{\bar{u}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \bar{u}_a^*, \bar{u}_a} - \sum_{a=1}^6 A_0(m_{\bar{\nu}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \bar{\nu}_a^*, \bar{\nu}_a} \\
& + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\bar{d}_a}^2, m_{\bar{d}_b}^2) \Gamma_{\check{h}_j, \bar{d}_a^*, \bar{d}_b} \Gamma_{\check{h}_i, \bar{d}_a^*, \bar{d}_b} + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\bar{e}_a}^2, m_{\bar{e}_b}^2) \Gamma_{\check{h}_j, \bar{e}_a^*, \bar{e}_b} \Gamma_{\check{h}_i, \bar{e}_a^*, \bar{e}_b} \\
& + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\bar{u}_a}^2, m_{\bar{u}_b}^2) \Gamma_{\check{h}_j, \bar{u}_a^*, \bar{u}_b} \Gamma_{\check{h}_i, \bar{u}_a^*, \bar{u}_b} + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\bar{\nu}_a}^2, m_{\bar{\nu}_b}^2) \Gamma_{\check{h}_j, \bar{\nu}_a^*, \bar{\nu}_b} \Gamma_{\check{h}_i, \bar{\nu}_a^*, \bar{\nu}_b} \\
& - \sum_{a=1}^6 m_{\bar{\chi}_a^0} \sum_{b=1}^6 B_0(p^2, m_{\bar{\chi}_a^0}^2, m_{\bar{\chi}_b^0}^2) m_{\bar{\chi}_b^0} \left( \Gamma_{\check{h}_j, \bar{\chi}_a^0, \bar{\chi}_b^0}^{L*} \Gamma_{\check{h}_i, \bar{\chi}_a^0, \bar{\chi}_b^0}^R + \Gamma_{\check{h}_j, \bar{\chi}_a^0, \bar{\chi}_b^0}^{R*} \Gamma_{\check{h}_i, \bar{\chi}_a^0, \bar{\chi}_b^0}^L \right) \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 G_0(p^2, m_{\bar{\chi}_a^0}^2, m_{\bar{\chi}_b^0}^2) \left( \Gamma_{\check{h}_j, \bar{\chi}_a^0, \bar{\chi}_b^0}^{L*} \Gamma_{\check{h}_i, \bar{\chi}_a^0, \bar{\chi}_b^0}^L + \Gamma_{\check{h}_j, \bar{\chi}_a^0, \bar{\chi}_b^0}^{R*} \Gamma_{\check{h}_i, \bar{\chi}_a^0, \bar{\chi}_b^0}^R \right) \\
& - \sum_{a=1}^6 m_{\nu_a} \sum_{b=1}^6 B_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) m_{\nu_b} \left( \Gamma_{\check{h}_j, \nu_a, \nu_b}^{L*} \Gamma_{\check{h}_i, \nu_a, \nu_b}^R + \Gamma_{\check{h}_j, \nu_a, \nu_b}^{R*} \Gamma_{\check{h}_i, \nu_a, \nu_b}^L \right) \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 G_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) \left( \Gamma_{\check{h}_j, \nu_a, \nu_b}^{L*} \Gamma_{\check{h}_i, \nu_a, \nu_b}^L + \Gamma_{\check{h}_j, \nu_a, \nu_b}^{R*} \Gamma_{\check{h}_i, \nu_a, \nu_b}^R \right)
\end{aligned}$$

$$\begin{aligned}
& + 2 \sum_{b=1}^2 \Gamma_{\tilde{h}_j, W^+, H_b^-}^* \Gamma_{\tilde{h}_i, W^+, H_b^-} F_0(p^2, m_{H_b^-}^2, m_{W^-}^2) + \sum_{b=1}^3 \Gamma_{\tilde{h}_j, Z, A_b^0}^* \Gamma_{\tilde{h}_i, Z, A_b^0} F_0(p^2, m_{A_b^0}^2, m_Z^2) \\
& + \sum_{b=1}^3 \Gamma_{\tilde{h}_j, Z', A_b^0}^* \Gamma_{\tilde{h}_i, Z', A_b^0} F_0(p^2, m_{A_b^0}^2, m_{Z'}^2)
\end{aligned} \tag{189}$$

• Self-Energy for Pseudo-Scalar Higgs ( $A^0$ )

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

$$\begin{aligned}
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{e_a}^2, m_{e_b}^2) \left( \Gamma_{\check{A}_j^0, \bar{e}_a, e_b}^{L*} \Gamma_{\check{A}_i^0, \bar{e}_a, e_b}^L + \Gamma_{\check{A}_j^0, \bar{e}_a, e_b}^{R*} \Gamma_{\check{A}_i^0, \bar{e}_a, e_b}^R \right) \\
& - 6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_b} \left( \Gamma_{\check{A}_j^0, \bar{u}_a, u_b}^{L*} \Gamma_{\check{A}_i^0, \bar{u}_a, u_b}^R + \Gamma_{\check{A}_j^0, \bar{u}_a, u_b}^{R*} \Gamma_{\check{A}_i^0, \bar{u}_a, u_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{u_a}^2, m_{u_b}^2) \left( \Gamma_{\check{A}_j^0, \bar{u}_a, u_b}^{L*} \Gamma_{\check{A}_i^0, \bar{u}_a, u_b}^L + \Gamma_{\check{A}_j^0, \bar{u}_a, u_b}^{R*} \Gamma_{\check{A}_i^0, \bar{u}_a, u_b}^R \right) \\
& - 3 \sum_{a=1}^6 A_0(m_{\check{d}_a}^2) \Gamma_{\check{A}_i^0, \check{A}_j^0, \check{d}_a^*, \bar{d}_a} - \sum_{a=1}^6 A_0(m_{\check{e}_a}^2) \Gamma_{\check{A}_i^0, \check{A}_j^0, \check{e}_a^*, \bar{e}_a} \\
& - 3 \sum_{a=1}^6 A_0(m_{\check{u}_a}^2) \Gamma_{\check{A}_i^0, \check{A}_j^0, \check{u}_a^*, \bar{u}_a} - \sum_{a=1}^6 A_0(m_{\check{\nu}_a}^2) \Gamma_{\check{A}_i^0, \check{A}_j^0, \check{\nu}_a^*, \bar{\nu}_a} \\
& + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\check{d}_a}^2, m_{\check{d}_b}^2) \Gamma_{\check{A}_j^0, \check{d}_a^*, \bar{d}_b}^* \Gamma_{\check{A}_i^0, \check{d}_a^*, \bar{d}_b} \\
& + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\check{e}_a}^2, m_{\check{e}_b}^2) \Gamma_{\check{A}_j^0, \check{e}_a^*, \bar{e}_b}^* \Gamma_{\check{A}_i^0, \check{e}_a^*, \bar{e}_b} \\
& + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\check{u}_a}^2, m_{\check{u}_b}^2) \Gamma_{\check{A}_j^0, \check{u}_a^*, \bar{u}_b}^* \Gamma_{\check{A}_i^0, \check{u}_a^*, \bar{u}_b} \\
& + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\check{\nu}_a}^2, m_{\check{\nu}_b}^2) \Gamma_{\check{A}_j^0, \check{\nu}_a^*, \bar{\nu}_b}^* \Gamma_{\check{A}_i^0, \check{\nu}_a^*, \bar{\nu}_b} \\
& - \sum_{a=1}^6 m_{\check{\chi}_a^0} \sum_{b=1}^6 B_0(p^2, m_{\check{\chi}_a^0}^2, m_{\check{\chi}_b^0}^2) m_{\check{\chi}_b^0} \left( \Gamma_{\check{A}_j^0, \check{\chi}_a^0, \check{\chi}_b^0}^{L*} \Gamma_{\check{A}_i^0, \check{\chi}_a^0, \check{\chi}_b^0}^R + \Gamma_{\check{A}_j^0, \check{\chi}_a^0, \check{\chi}_b^0}^{R*} \Gamma_{\check{A}_i^0, \check{\chi}_a^0, \check{\chi}_b^0}^L \right) \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 G_0(p^2, m_{\check{\chi}_a^0}^2, m_{\check{\chi}_b^0}^2) \left( \Gamma_{\check{A}_j^0, \check{\chi}_a^0, \check{\chi}_b^0}^{L*} \Gamma_{\check{A}_i^0, \check{\chi}_a^0, \check{\chi}_b^0}^L + \Gamma_{\check{A}_j^0, \check{\chi}_a^0, \check{\chi}_b^0}^{R*} \Gamma_{\check{A}_i^0, \check{\chi}_a^0, \check{\chi}_b^0}^R \right) \\
& - \sum_{a=1}^6 m_{\nu_a} \sum_{b=1}^6 B_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) m_{\nu_b} \left( \Gamma_{\check{A}_j^0, \nu_a, \nu_b}^{L*} \Gamma_{\check{A}_i^0, \nu_a, \nu_b}^R + \Gamma_{\check{A}_j^0, \nu_a, \nu_b}^{R*} \Gamma_{\check{A}_i^0, \nu_a, \nu_b}^L \right) \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 G_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) \left( \Gamma_{\check{A}_j^0, \nu_a, \nu_b}^{L*} \Gamma_{\check{A}_i^0, \nu_a, \nu_b}^L + \Gamma_{\check{A}_j^0, \nu_a, \nu_b}^{R*} \Gamma_{\check{A}_i^0, \nu_a, \nu_b}^R \right) \\
& + 2 \sum_{b=1}^2 \Gamma_{\check{A}_j^0, W^+, H_b^-}^* \Gamma_{\check{A}_i^0, W^+, H_b^-} F_0(p^2, m_{H_b^-}^2, m_{W^-}^2) + \sum_{b=1}^3 \Gamma_{\check{A}_j^0, Z, h_b}^* \Gamma_{\check{A}_i^0, Z, h_b} F_0(p^2, m_{h_b}^2, m_Z^2) \\
& + \sum_{b=1}^3 \Gamma_{\check{A}_j^0, Z', h_b}^* \Gamma_{\check{A}_i^0, Z', h_b} F_0(p^2, m_{h_b}^2, m_{Z'}^2) \tag{190}
\end{aligned}$$

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

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

$$\begin{aligned}
& + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{e}_b}^2) \Gamma_{\tilde{H}_j^+, \tilde{\nu}_a^*, \tilde{e}_b}^* \Gamma_{\tilde{H}_i^+, \tilde{\nu}_a^*, \tilde{e}_b} + \sum_{b=1}^2 \Gamma_{\tilde{H}_j^+, \gamma, H_b^-}^* \Gamma_{\tilde{H}_i^+, \gamma, H_b^-} F_0(p^2, m_{H_b^-}^2, 0) \\
& + \sum_{b=1}^2 \Gamma_{\tilde{H}_j^+, Z, H_b^-}^* \Gamma_{\tilde{H}_i^+, Z, H_b^-} F_0(p^2, m_{H_b^-}^2, m_Z^2) + \sum_{b=1}^2 \Gamma_{\tilde{H}_j^+, Z', H_b^-}^* \Gamma_{\tilde{H}_i^+, Z', H_b^-} F_0(p^2, m_{H_b^-}^2, m_{Z'}^2) \\
& + \sum_{b=1}^3 \Gamma_{\tilde{H}_j^+, W^-, A_b^0}^* \Gamma_{\tilde{H}_i^+, W^-, A_b^0} F_0(p^2, m_{A_b^0}^2, m_{W^-}^2) + \sum_{b=1}^3 \Gamma_{\tilde{H}_j^+, W^-, h_b}^* \Gamma_{\tilde{H}_i^+, W^-, h_b} F_0(p^2, m_{h_b}^2, m_{W^-}^2) \quad (191)
\end{aligned}$$

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

$$\begin{aligned}
\Sigma_{i,j}^S(p^2) = & +2 \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^0, H_a^+, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^0, H_a^+, \tilde{\chi}_b^-}^R \\
& + \sum_{a=1}^3 \sum_{b=1}^6 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}_j^0, h_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^0, h_a, \tilde{\chi}_b^0}^R \\
& + \sum_{a=1}^6 m_{\tilde{\chi}_a^0} \sum_{b=1}^3 B_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{A_b^0}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{\chi}_a^0, A_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, \tilde{\chi}_a^0, A_b^0}^R \\
& + 6 \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{d}_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{d}_a^*, \tilde{d}_b}^{L*} m_{\tilde{d}_b} \Gamma_{\tilde{\chi}_i^0, \tilde{d}_a^*, \tilde{d}_b}^R \\
& + 2 \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{e}_b}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{e}_a^*, \tilde{e}_b}^{L*} m_{\tilde{e}_b} \Gamma_{\tilde{\chi}_i^0, \tilde{e}_a^*, \tilde{e}_b}^R \\
& + 6 \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{\tilde{u}_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{u}_a^*, \tilde{u}_b}^{L*} m_{\tilde{u}_b} \Gamma_{\tilde{\chi}_i^0, \tilde{u}_a^*, \tilde{u}_b}^R \\
& + 2 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{\nu}_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{\nu}_a^*, \tilde{\nu}_b}^{L*} m_{\tilde{\nu}_b} \Gamma_{\tilde{\chi}_i^0, \tilde{\nu}_a^*, \tilde{\nu}_b}^R \\
& - 8 \sum_{b=1}^2 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2) \right) \Gamma_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-}^L \\
& - 4 \sum_{b=1}^6 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2) \right) \Gamma_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0}^{R*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0}^L \\
& - 4 \sum_{b=1}^6 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{Z'}^2) \right) \Gamma_{\tilde{\chi}_j^0, Z', \tilde{\chi}_b^0}^{R*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^0, Z', \tilde{\chi}_b^0}^L \quad (192) \\
\Sigma_{i,j}^R(p^2) = & - \sum_{a=1}^2 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^0, H_a^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^0, H_a^+, \tilde{\chi}_b^-}^R
\end{aligned}$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{h_a}^2 \right) \Gamma_{\tilde{\chi}_j^0, h_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, h_a, \tilde{\chi}_b^0}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1 \left( p^2, m_{\tilde{\chi}_a^0}^2, m_{A_b^0}^2 \right) \Gamma_{\tilde{\chi}_j^0, \tilde{\chi}_a^0, A_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{\chi}_a^0, A_b^0}^R \\
& -3 \sum_{a=1}^6 \sum_{b=1}^3 B_1 \left( p^2, m_{d_b}^2, m_{\tilde{d}_a}^2 \right) \Gamma_{\tilde{\chi}_j^0, \tilde{d}_a^*, d_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{d}_a^*, d_b}^R \\
& -\sum_{a=1}^6 \sum_{b=1}^3 B_1 \left( p^2, m_{e_b}^2, m_{\tilde{e}_a}^2 \right) \Gamma_{\tilde{\chi}_j^0, \tilde{e}_a^*, e_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{e}_a^*, e_b}^R \\
& -3 \sum_{a=1}^6 \sum_{b=1}^3 B_1 \left( p^2, m_{u_b}^2, m_{\tilde{u}_a}^2 \right) \Gamma_{\tilde{\chi}_j^0, \tilde{u}_a^*, u_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{u}_a^*, u_b}^R \\
& -\sum_{a=1}^6 \sum_{b=1}^6 B_1 \left( p^2, m_{\nu_b}^2, m_{\tilde{\nu}_a}^2 \right) \Gamma_{\tilde{\chi}_j^0, \tilde{\nu}_a^*, \nu_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{\nu}_a^*, \nu_b}^R \\
& -2 \sum_{b=1}^2 B_1 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2 \right) \Gamma_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-}^L - \sum_{b=1}^6 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2 \right) \Gamma_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0}^L \\
& -\sum_{b=1}^6 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{Z'}^2 \right) \Gamma_{\tilde{\chi}_j^0, Z', \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, Z', \tilde{\chi}_b^0}^L \tag{193}
\end{aligned}$$

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

$$\begin{aligned}
& -2 \sum_{b=1}^2 B_1 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2 \right) \Gamma_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-}^R - \sum_{b=1}^6 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2 \right) \Gamma_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0}^R \\
& - \sum_{b=1}^6 B_1 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{Z'}^2 \right) \Gamma_{\tilde{\chi}_j^0, Z', \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, Z', \tilde{\chi}_b^0}^R
\end{aligned} \tag{194}$$

• Self-Energy for Neutrinos ( $\nu$ )

$$\begin{aligned}
\Sigma_{i,j}^S(p^2) &= +2 \sum_{a=1}^2 \sum_{b=1}^3 B_0 \left( p^2, m_{e_b}^2, m_{H_a^-}^2 \right) \Gamma_{\tilde{\nu}_j, H_a^+, e_b}^{L*} m_{e_b} \Gamma_{\tilde{\nu}_i, H_a^+, e_b}^R \\
&+ \sum_{a=1}^3 \sum_{b=1}^6 B_0 \left( p^2, m_{\nu_b}^2, m_{h_a}^2 \right) \Gamma_{\tilde{\nu}_j, h_a, \nu_b}^{L*} m_{\nu_b} \Gamma_{\tilde{\nu}_i, h_a, \nu_b}^R \\
&+ 2 \sum_{a=1}^6 \sum_{b=1}^2 B_0 \left( p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{e}_a}^2 \right) \Gamma_{\tilde{\nu}_j, \tilde{e}_a^*, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\nu}_i, \tilde{e}_a^*, \tilde{\chi}_b^-}^R \\
&+ \sum_{a=1}^6 m_{\nu_a} \sum_{b=1}^3 B_0 \left( p^2, m_{\nu_a}^2, m_{A_b^0}^2 \right) \Gamma_{\tilde{\nu}_j, \nu_a, A_b^0}^{L*} \Gamma_{\tilde{\nu}_i, \nu_a, A_b^0}^R \\
&+ 2 \sum_{a=1}^6 \sum_{b=1}^6 B_0 \left( p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{\nu}_a}^2 \right) \Gamma_{\tilde{\nu}_j, \tilde{\nu}_a^*, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\nu}_i, \tilde{\nu}_a^*, \tilde{\chi}_b^0}^R \\
&- 8 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0 \left( p^2, m_{e_b}^2, m_{W^-}^2 \right) \right) \Gamma_{\tilde{\nu}_j, W^+, e_b}^{R*} m_{e_b} \Gamma_{\tilde{\nu}_i, W^+, e_b}^L - 4 \sum_{b=1}^6 \left( -\frac{1}{2} \text{rMS} + B_0 \left( p^2, m_{\nu_b}^2, 0 \right) \right) \Gamma_{\tilde{\nu}_j, \gamma, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{\nu}_i, \gamma}^L \\
&- 4 \sum_{b=1}^6 \left( -\frac{1}{2} \text{rMS} + B_0 \left( p^2, m_{\nu_b}^2, m_Z^2 \right) \right) \Gamma_{\tilde{\nu}_j, Z, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{\nu}_i, Z, \nu_b}^L - 4 \sum_{b=1}^6 \left( -\frac{1}{2} \text{rMS} + B_0 \left( p^2, m_{\nu_b}^2, m_{Z'}^2 \right) \right) \Gamma_{\tilde{\nu}_j, Z', \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{\nu}_i, Z'}^L
\end{aligned} \tag{195}$$

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

$$\begin{aligned}
& - \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, 0) \Gamma_{\tilde{\nu}_j, \gamma, \nu_b}^{L*} \Gamma_{\tilde{\nu}_i, \gamma, \nu_b}^L - \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_Z^2) \Gamma_{\tilde{\nu}_j, Z, \nu_b}^{L*} \Gamma_{\tilde{\nu}_i, Z, \nu_b}^L \\
& - \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_{Z'}^2) \Gamma_{\tilde{\nu}_j, Z', \nu_b}^{L*} \Gamma_{\tilde{\nu}_i, Z', \nu_b}^L
\end{aligned} \tag{196}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) = & - \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{\nu}_j, H_a^+, e_b}^{L*} \Gamma_{\tilde{\nu}_i, H_a^+, e_b}^L \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_{h_a}^2) \Gamma_{\tilde{\nu}_j, h_a, \nu_b}^{L*} \Gamma_{\tilde{\nu}_i, h_a, \nu_b}^L \\
& - \sum_{a=1}^6 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\nu}_j, \tilde{e}_a^*, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\nu}_i, \tilde{e}_a^*, \tilde{\chi}_b^-}^L \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{\nu_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{\nu}_j, \nu_a, A_b^0}^{L*} \Gamma_{\tilde{\nu}_i, \nu_a, A_b^0}^L \\
& - \sum_{a=1}^6 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\nu}_j, \tilde{\nu}_a^*, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\nu}_i, \tilde{\nu}_a^*, \tilde{\chi}_b^0}^L - 2 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{W^-}^2) \Gamma_{\tilde{\nu}_j, W^+, e_b}^{R*} \Gamma_{\tilde{\nu}_i, W^+, e_b}^R \\
& - \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, 0) \Gamma_{\tilde{\nu}_j, \gamma, \nu_b}^{R*} \Gamma_{\tilde{\nu}_i, \gamma, \nu_b}^R - \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_Z^2) \Gamma_{\tilde{\nu}_j, Z, \nu_b}^{R*} \Gamma_{\tilde{\nu}_i, Z, \nu_b}^R \\
& - \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_{Z'}^2) \Gamma_{\tilde{\nu}_j, Z', \nu_b}^{R*} \Gamma_{\tilde{\nu}_i, Z', \nu_b}^R
\end{aligned} \tag{197}$$

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

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



$$\begin{aligned}
& + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{e_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a^*, e_b}^{L*} m_{e_b} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a^*, e_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\nu_b}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{e}_a, \nu_b}^{L*} m_{\nu_b} \Gamma_{\tilde{\chi}_i^+, \tilde{e}_a, \nu_b}^R \\
& - 4 \sum_{b=1}^2 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^-}^2, 0) \right) \Gamma_{\tilde{\chi}_j^+, \gamma, \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, \gamma, \tilde{\chi}_b^-}^L \\
& - 4 \sum_{b=1}^2 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_Z^2) \right) \Gamma_{\tilde{\chi}_j^+, Z, \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, Z, \tilde{\chi}_b^-}^L \\
& - 4 \sum_{b=1}^2 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{Z'}^2) \right) \Gamma_{\tilde{\chi}_j^+, Z', \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, Z', \tilde{\chi}_b^-}^L \\
& - 4 \sum_{b=1}^6 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2) \right) \Gamma_{\tilde{\chi}_j^+, W^-, \tilde{\chi}_b^0}^{R*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^+, W^-, \tilde{\chi}_b^0}^L \tag{198}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^R(p^2) & = -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\tilde{\chi}_a^-}^2, m_{A_b^0}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{\chi}_a^-, A_b^0}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{\chi}_a^-, A_b^0}^R \\
& - \frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^+, H_a^-, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^+, H_a^-, \tilde{\chi}_b^0}^R \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}_j^+, h_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, h_a, \tilde{\chi}_b^-}^R \\
& - \frac{3}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{u_a}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a, \tilde{d}_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a, \tilde{d}_b}^R \\
& - \frac{3}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a, \tilde{d}_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a, \tilde{d}_b}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a^*, e_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a^*, e_b}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{e}_a, \nu_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{e}_a, \nu_b}^R - \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, 0) \Gamma_{\tilde{\chi}_j^+, \gamma, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^+, \gamma, \tilde{\chi}_b^-}^L \\
& - \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_Z^2) \Gamma_{\tilde{\chi}_j^+, Z, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^+, Z, \tilde{\chi}_b^-}^L - \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{Z'}^2) \Gamma_{\tilde{\chi}_j^+, Z', \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^+, Z', \tilde{\chi}_b^-}^L \\
& - \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2) \Gamma_{\tilde{\chi}_j^+, W^-, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^+, W^-, \tilde{\chi}_b^0}^L \tag{199}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\tilde{\chi}_a^-}^2, m_{A_b^0}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{\chi}_a^-, A_b^0}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\chi}_a^-, A_b^0}^L \\
& -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^+, H_a^-, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^+, H_a^-, \tilde{\chi}_b^0}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}_j^+, h_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^+, h_a, \tilde{\chi}_b^-}^L \\
& -\frac{3}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{\tilde{u}_a}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a, \tilde{d}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a, \tilde{d}_b}^L \\
& -\frac{3}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a, \tilde{d}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a, \tilde{d}_b}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{\tilde{e}_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a, \tilde{e}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a, \tilde{e}_b}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{e}_a, \nu_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{e}_a, \nu_b}^L - \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, 0) \Gamma_{\tilde{\chi}_j^+, \gamma, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, \gamma, \tilde{\chi}_b^-}^R \\
& - \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_Z^2) \Gamma_{\tilde{\chi}_j^+, Z, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, Z, \tilde{\chi}_b^-}^R - \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{Z'}^2) \Gamma_{\tilde{\chi}_j^+, Z', \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, Z', \tilde{\chi}_b^-}^R \\
& - \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2) \Gamma_{\tilde{\chi}_j^+, W^-, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^+, W^-, \tilde{\chi}_b^0}^R
\end{aligned} \tag{200}$$

• Self-Energy for Leptons ( $e$ )

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

$$\begin{aligned}
& -4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, 0) \right) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, \gamma, e_b}^L - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, m_Z^2) \right) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, Z, e_b}^L \\
& -4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{e}_j, Z', e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, Z', e_b}^L \\
& -4 \sum_{b=1}^6 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{e}_i, W^-, \nu_b}^L \tag{201}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^R(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{R*} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^R \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{e_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{e}_j, e_a, A_b^0}^{R*} \Gamma_{\tilde{e}_i, e_a, A_b^0}^R \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{R*} \Gamma_{\tilde{e}_i, h_a, e_b}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^R - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, 0) \Gamma_{\tilde{e}_j, \gamma, e_b}^{L*} \Gamma_{\tilde{e}_i, \gamma, e_b}^L \\
& -\sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_Z^2) \Gamma_{\tilde{e}_j, Z, e_b}^{L*} \Gamma_{\tilde{e}_i, Z, e_b}^L - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{Z'}^2) \Gamma_{\tilde{e}_j, Z', e_b}^{L*} \Gamma_{\tilde{e}_i, Z', e_b}^L \\
& -\sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_{W^-}^2) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{L*} \Gamma_{\tilde{e}_i, W^-, \nu_b}^L \tag{202}
\end{aligned}$$

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

$$\begin{aligned}
& - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_Z^2) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} \Gamma_{\tilde{e}_i, Z, e_b}^R - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{Z'}^2) \Gamma_{\tilde{e}_j, Z', e_b}^{R*} \Gamma_{\tilde{e}_i, Z', e_b}^R \\
& - \sum_{b=1}^6 B_1(p^2, m_{\nu_b}^2, m_{W^-}^2) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} \Gamma_{\tilde{e}_i, W^-, \nu_b}^R
\end{aligned} \tag{203}$$

• **Self-Energy for Down-Quarks** (*d*)

$$\begin{aligned}
\Sigma_{i,j}^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{d}_j, H_a^-, u_b}^{L*} m_{u_b} \Gamma_{\tilde{d}_i, H_a^-, u_b}^R \\
& + \sum_{a=1}^3 m_{d_a} \sum_{b=1}^3 B_0(p^2, m_{d_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{d}_j, d_a, A_b^0}^{L*} \Gamma_{\tilde{d}_i, d_a, A_b^0}^R \\
& + \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\tilde{d}_j, h_a, d_b}^{L*} m_{d_b} \Gamma_{\tilde{d}_i, h_a, d_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^R \\
& + \frac{4}{3} m_{\tilde{g}} \sum_{a=1}^6 B_0(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{g}_1}^R - \frac{16}{3} \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, g, d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, g, d_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, \gamma, d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, \gamma, d_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{d}_j, W^-, u_b}^{R*} m_{u_b} \Gamma_{\tilde{d}_i, W^-, u_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_Z^2) \right) \Gamma_{\tilde{d}_j, Z, d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, Z, d_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{d}_j, Z', d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, Z', d_b}^L
\end{aligned} \tag{204}$$

$$\begin{aligned}
\Sigma_{i,j}^R(p^2) = & - \frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{d}_j, H_a^-, u_b}^{R*} \Gamma_{\tilde{d}_i, H_a^-, u_b}^R \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{d_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{d}_j, d_a, A_b^0}^{R*} \Gamma_{\tilde{d}_i, d_a, A_b^0}^R
\end{aligned}$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_{\tilde{h}_a}^2) \Gamma_{\tilde{d}_j, \tilde{h}_a, \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i, \tilde{h}_a, \tilde{d}_b}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^R \\
& -\frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{g}_1}^{R*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{g}_1}^R - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, 0) \Gamma_{\tilde{d}_j, g, \tilde{d}_b}^{L*} \Gamma_{\tilde{d}_i, g, \tilde{d}_b}^L \\
& -\sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, 0) \Gamma_{\tilde{d}_j, \gamma, \tilde{d}_b}^{L*} \Gamma_{\tilde{d}_i, \gamma, \tilde{d}_b}^L - \sum_{b=1}^3 B_1(p^2, m_{\tilde{u}_b}^2, m_{W^-}^2) \Gamma_{\tilde{d}_j, W^-, \tilde{u}_b}^{L*} \Gamma_{\tilde{d}_i, W^-, \tilde{u}_b}^L \\
& -\sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_Z^2) \Gamma_{\tilde{d}_j, Z, \tilde{d}_b}^{L*} \Gamma_{\tilde{d}_i, Z, \tilde{d}_b}^L - \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_{Z'}^2) \Gamma_{\tilde{d}_j, Z', \tilde{d}_b}^{L*} \Gamma_{\tilde{d}_i, Z', \tilde{d}_b}^L \tag{205}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\tilde{u}_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{d}_j, H_a^-, \tilde{u}_b}^{L*} \Gamma_{\tilde{d}_i, H_a^-, \tilde{u}_b}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, A_b^0}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, A_b^0}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_{\tilde{h}_a}^2) \Gamma_{\tilde{d}_j, \tilde{h}_a, \tilde{d}_b}^{L*} \Gamma_{\tilde{d}_i, \tilde{h}_a, \tilde{d}_b}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^L \\
& -\frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{g}_1}^L - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, 0) \Gamma_{\tilde{d}_j, g, \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i, g, \tilde{d}_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, 0) \Gamma_{\tilde{d}_j, \gamma, \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i, \gamma, \tilde{d}_b}^R - \sum_{b=1}^3 B_1(p^2, m_{\tilde{u}_b}^2, m_{W^-}^2) \Gamma_{\tilde{d}_j, W^-, \tilde{u}_b}^{R*} \Gamma_{\tilde{d}_i, W^-, \tilde{u}_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_Z^2) \Gamma_{\tilde{d}_j, Z, \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i, Z, \tilde{d}_b}^R - \sum_{b=1}^3 B_1(p^2, m_{\tilde{d}_b}^2, m_{Z'}^2) \Gamma_{\tilde{d}_j, Z', \tilde{d}_b}^{R*} \Gamma_{\tilde{d}_i, Z', \tilde{d}_b}^R \tag{206}
\end{aligned}$$

• Self-Energy for Up-Quarks ( $u$ )

$$\begin{aligned}
\Sigma_{i,j}^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{u}_j, H_a^+, d_b}^{L*} m_{d_b} \Gamma_{\tilde{u}_i, H_a^+, d_b}^R \\
& + \sum_{a=1}^2 m_{\tilde{\chi}_a^-} \sum_{b=1}^6 B_0(p^2, m_{\tilde{\chi}_a^-}^2, m_{d_b}^2) \Gamma_{\tilde{u}_j, \tilde{\chi}_a^+, \bar{d}_b}^{L*} \Gamma_{\tilde{u}_i, \tilde{\chi}_a^+, \bar{d}_b}^R \\
& + \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{u}_j, u_a, A_b^0}^{L*} \Gamma_{\tilde{u}_i, u_a, A_b^0}^R \\
& + \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{L*} m_{u_b} \Gamma_{\tilde{u}_i, h_a, u_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{\chi}_b^0}^R \\
& + \frac{4}{3} m_{\tilde{g}} \sum_{a=1}^6 B_0(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{g}_1}^R - \frac{16}{3} \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, g, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, g, u_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, \gamma, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, \gamma, u_b}^L - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_Z^2) \right) \Gamma_{\tilde{u}_j, Z, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, Z, u_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{u}_j, Z', u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, Z', u_b}^L \\
& - 4 \sum_{b=1}^3 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{u}_j, W^+, d_b}^{R*} m_{d_b} \Gamma_{\tilde{u}_i, W^+, d_b}^L \tag{207}
\end{aligned}$$

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

$$\begin{aligned}
& - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, \gamma, u_b}^{L*} \Gamma_{\tilde{u}_i, \gamma, u_b}^L - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_Z^2) \Gamma_{\tilde{u}_j, Z, u_b}^{L*} \Gamma_{\tilde{u}_i, Z, u_b}^L \\
& - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{Z'}^2) \Gamma_{\tilde{u}_j, Z', u_b}^{L*} \Gamma_{\tilde{u}_i, Z', u_b}^L - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{W^-}^2) \Gamma_{\tilde{u}_j, W^+, d_b}^{L*} \Gamma_{\tilde{u}_i, W^+, d_b}^L
\end{aligned} \tag{208}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{u}_j, H_a^+, d_b}^{L*} \Gamma_{\tilde{u}_i, H_a^+, d_b}^L \\
& - \frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_a^-}^2, m_{d_b}^2) \Gamma_{\tilde{u}_j, \tilde{\chi}_a^+, \bar{d}_b}^{L*} \Gamma_{\tilde{u}_i, \tilde{\chi}_a^+, \bar{d}_b}^L \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{u_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{u}_j, u_a, A_b^0}^{L*} \Gamma_{\tilde{u}_i, u_a, A_b^0}^L \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{L*} \Gamma_{\tilde{u}_i, h_a, u_b}^L \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{\chi}_b^0}^L \\
& - \frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{g}_1}^L - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, g, u_b}^{R*} \Gamma_{\tilde{u}_i, g, u_b}^R \\
& - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, \gamma, u_b}^{R*} \Gamma_{\tilde{u}_i, \gamma, u_b}^R - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_Z^2) \Gamma_{\tilde{u}_j, Z, u_b}^{R*} \Gamma_{\tilde{u}_i, Z, u_b}^R \\
& - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{Z'}^2) \Gamma_{\tilde{u}_j, Z', u_b}^{R*} \Gamma_{\tilde{u}_i, Z', u_b}^R - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{W^-}^2) \Gamma_{\tilde{u}_j, W^+, d_b}^{R*} \Gamma_{\tilde{u}_i, W^+, d_b}^R
\end{aligned} \tag{209}$$

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

$$\begin{aligned}
\Sigma^S(p^2) &= + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{g}_j, \tilde{d}_a^*, d_b}^{L*} m_{d_b} \Gamma_{\tilde{g}_i, \tilde{d}_a^*, d_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{g}_j, \tilde{u}_a^*, u_b}^{L*} m_{u_b} \Gamma_{\tilde{g}_i, \tilde{u}_a^*, u_b}^R - 12 \left( -\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{g}}^2, 0) \right) \Gamma_{\tilde{g}_j, g, \tilde{g}_1}^{R*} m_{\tilde{g}} \Gamma_{\tilde{g}_i, g, \tilde{g}_1}^L
\end{aligned} \tag{210}$$

$$\begin{aligned}
\Sigma^R(p^2) &= -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{g}_j, \tilde{d}_a^*, d_b}^{L*} \Gamma_{\tilde{g}_i, \tilde{d}_a^*, d_b}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{g}_j, \tilde{u}_a^*, u_b}^{L*} \Gamma_{\tilde{g}_i, \tilde{u}_a^*, u_b}^R - 3 B_1(p^2, m_{\tilde{g}}^2, 0) \Gamma_{\tilde{g}_j, g, \tilde{g}_1}^{L*} \Gamma_{\tilde{g}_i, g, \tilde{g}_1}^L
\end{aligned} \tag{211}$$

$$\begin{aligned}
\Sigma^L(p^2) = & -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\bar{d}_a}^2) \Gamma_{\bar{g}_j, \bar{d}_a^*, d_b}^{L*} \Gamma_{\bar{g}_i, \bar{d}_a^*, d_b}^L \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{\bar{u}_a}^2) \Gamma_{\bar{g}_j, \bar{u}_a^*, u_b}^{L*} \Gamma_{\bar{g}_i, \bar{u}_a^*, u_b}^L - 3B_1(p^2, m_{\bar{g}}^2, 0) \Gamma_{\bar{g}_j, g, \bar{g}_1}^{R*} \Gamma_{\bar{g}_i, g, \bar{g}_1}^R
\end{aligned} \tag{212}$$

• Self-Energy for Z-Boson ( $Z$ )

$$\begin{aligned}
\Pi(p^2) = & + |\Gamma_{Z, \eta^-, \eta^-}|^2 B_{00}(p^2, m_{\eta^-}^2, m_{\eta^-}^2) + |\Gamma_{Z, \eta^+, \eta^+}|^2 B_{00}(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \\
& - |\Gamma_{Z, W^+, W^-}|^2 \left( 10B_{00}(p^2, m_{W^-}^2, m_{W^-}^2) + 2A_0(m_{W^-}^2) - 2\text{rMS}(2m_{W^-}^2 - \frac{1}{3}p^2) + B_0(p^2, m_{W^-}^2, m_{W^-}^2) (2m_{W^-}^2 + 4p^2) \right) \\
& + \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{Z, Z, H_a^+, H_a^-} - 4 \sum_{a=1}^2 \sum_{b=1}^2 |\Gamma_{Z, H_a^+, H_b^-}|^2 B_{00}(p^2, m_{H_a^-}^2, m_{H_b^-}^2) \\
& + \sum_{a=1}^2 \sum_{b=1}^2 \left[ (|\Gamma_{Z, \bar{\chi}_a^+, \bar{\chi}_b^-}^L|^2 + |\Gamma_{Z, \bar{\chi}_a^+, \bar{\chi}_b^-}^R|^2) H_0(p^2, m_{\bar{\chi}_a^-}^2, m_{\bar{\chi}_b^-}^2) \right. \\
& \left. + 4B_0(p^2, m_{\bar{\chi}_a^-}^2, m_{\bar{\chi}_b^-}^2) m_{\bar{\chi}_a^-} m_{\bar{\chi}_b^-} \Re(\Gamma_{Z, \bar{\chi}_a^+, \bar{\chi}_b^-}^{L*} \Gamma_{Z, \bar{\chi}_a^+, \bar{\chi}_b^-}^R) \right] \\
& + \frac{1}{2} \sum_{a=1}^3 A_0(m_{A_a^0}^2) \Gamma_{Z, Z, A_a^0, A_a^0} + \frac{1}{2} \sum_{a=1}^3 A_0(m_{h_a}^2) \Gamma_{Z, Z, h_a, h_a} \\
& - 4 \sum_{a=1}^3 \sum_{b=1}^3 |\Gamma_{Z, h_a, A_b^0}|^2 B_{00}(p^2, m_{A_b^0}^2, m_{h_a}^2) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ (|\Gamma_{Z, \bar{d}_a, d_b}^L|^2 + |\Gamma_{Z, \bar{d}_a, d_b}^R|^2) H_0(p^2, m_{d_a}^2, m_{d_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_a} m_{d_b} \Re(\Gamma_{Z, \bar{d}_a, d_b}^{L*} \Gamma_{Z, \bar{d}_a, d_b}^R) \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[ (|\Gamma_{Z, \bar{e}_a, e_b}^L|^2 + |\Gamma_{Z, \bar{e}_a, e_b}^R|^2) H_0(p^2, m_{e_a}^2, m_{e_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{e_a}^2, m_{e_b}^2) m_{e_a} m_{e_b} \Re(\Gamma_{Z, \bar{e}_a, e_b}^{L*} \Gamma_{Z, \bar{e}_a, e_b}^R) \right] \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ (|\Gamma_{Z, \bar{u}_a, u_b}^L|^2 + |\Gamma_{Z, \bar{u}_a, u_b}^R|^2) H_0(p^2, m_{u_a}^2, m_{u_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_a} m_{u_b} \Re(\Gamma_{Z, \bar{u}_a, u_b}^{L*} \Gamma_{Z, \bar{u}_a, u_b}^R) \right] \\
& + 3 \sum_{a=1}^6 A_0(m_{\bar{d}_a}^2) \Gamma_{Z, Z, \bar{d}_a^*, \bar{d}_a} + \sum_{a=1}^6 A_0(m_{\bar{e}_a}^2) \Gamma_{Z, Z, \bar{e}_a^*, \bar{e}_a} + 3 \sum_{a=1}^6 A_0(m_{\bar{u}_a}^2) \Gamma_{Z, Z, \bar{u}_a^*, \bar{u}_a} \\
& + \sum_{a=1}^6 A_0(m_{\bar{\nu}_a}^2) \Gamma_{Z, Z, \bar{\nu}_a^*, \bar{\nu}_a} - 12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z, \bar{d}_a^*, \bar{d}_b}|^2 B_{00}(p^2, m_{d_a}^2, m_{d_b}^2)
\end{aligned}$$



$$\begin{aligned}
& -4 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z, \tilde{e}_a^*, \tilde{e}_b}|^2 B_{00}(p^2, m_{\tilde{e}_a}^2, m_{\tilde{e}_b}^2) - 12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z, \tilde{u}_a^*, \tilde{u}_b}|^2 B_{00}(p^2, m_{\tilde{u}_a}^2, m_{\tilde{u}_b}^2) \\
& -4 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z, \tilde{\nu}_a^*, \tilde{\nu}_b}|^2 B_{00}(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2) \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 \left[ \left( |\Gamma_{Z, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^L|^2 + |\Gamma_{Z, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^R|^2 \right) H_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_a^0} m_{\tilde{\chi}_b^0} \Re(\Gamma_{Z, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L*} \Gamma_{Z, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^R) \right] \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 \left[ \left( |\Gamma_{Z, \nu_a, \nu_b}^L|^2 + |\Gamma_{Z, \nu_a, \nu_b}^R|^2 \right) H_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\nu_a}^2, m_{\nu_b}^2) m_{\nu_a} m_{\nu_b} \Re(\Gamma_{Z, \nu_a, \nu_b}^{L*} \Gamma_{Z, \nu_a, \nu_b}^R) \right] \\
& + 2 \sum_{b=1}^2 |\Gamma_{Z, W^+, H_b^-}|^2 B_0(p^2, m_{W^-}^2, m_{H_b^-}^2) + \sum_{b=1}^3 |\Gamma_{Z, Z, h_b}|^2 B_0(p^2, m_Z^2, m_{h_b}^2) \\
& + \sum_{b=1}^3 |\Gamma_{Z, Z', h_b}|^2 B_0(p^2, m_{Z'}^2, m_{h_b}^2) + 2\text{rMS} m_{W^-}^2 \Gamma_{Z, Z, W^+, W^-}^1 - A_0(m_{W^-}^2) \left( 4\Gamma_{Z, Z, W^+, W^-}^1 + \Gamma_{Z, Z, W^+, W^-}^2 + \Gamma_{Z, Z, W^+, W^-}^3 \right)
\end{aligned} \tag{213}$$

• **Self-Energy for Z'-Boson** ( $Z'$ )

$$\begin{aligned}
\Pi(p^2) & = +|\Gamma_{Z', \eta^-, \eta^-}|^2 B_{00}(p^2, m_{\eta^-}^2, m_{\eta^-}^2) + |\Gamma_{Z', \eta^+, \eta^+}|^2 B_{00}(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \\
& - |\Gamma_{Z', W^+, W^-}|^2 \left( 10B_{00}(p^2, m_{W^-}^2, m_{W^-}^2) + 2A_0(m_{W^-}^2) - 2\text{rMS} \left( 2m_{W^-}^2 - \frac{1}{3}p^2 \right) + B_0(p^2, m_{W^-}^2, m_{W^-}^2) \right) (2m_{W^-}^2 + 4p^2) \\
& + \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{Z', Z', H_a^+, H_a^-} - 4 \sum_{a=1}^2 \sum_{b=1}^2 |\Gamma_{Z', H_a^+, H_b^-}|^2 B_{00}(p^2, m_{H_a^-}^2, m_{H_b^-}^2) \\
& + \sum_{a=1}^2 \sum_{b=1}^2 \left[ \left( |\Gamma_{Z', \tilde{\chi}_a^+, \tilde{\chi}_b^-}^L|^2 + |\Gamma_{Z', \tilde{\chi}_a^+, \tilde{\chi}_b^-}^R|^2 \right) H_0(p^2, m_{\tilde{\chi}_a^+}^2, m_{\tilde{\chi}_b^-}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{\chi}_a^+}^2, m_{\tilde{\chi}_b^-}^2) m_{\tilde{\chi}_a^+} m_{\tilde{\chi}_b^-} \Re(\Gamma_{Z', \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{Z', \tilde{\chi}_a^+, \tilde{\chi}_b^-}^R) \right] \\
& + \frac{1}{2} \sum_{a=1}^3 A_0(m_{A_a^0}^2) \Gamma_{Z', Z', A_a^0, A_a^0} + \frac{1}{2} \sum_{a=1}^3 A_0(m_{h_a}^2) \Gamma_{Z', Z', h_a, h_a} \\
& - 4 \sum_{a=1}^3 \sum_{b=1}^3 |\Gamma_{Z', h_a, A_b^0}|^2 B_{00}(p^2, m_{A_b^0}^2, m_{h_a}^2) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left( |\Gamma_{Z', \tilde{d}_a, \tilde{d}_b}^L|^2 + |\Gamma_{Z', \tilde{d}_a, \tilde{d}_b}^R|^2 \right) H_0(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2) \right]
\end{aligned}$$

$$\begin{aligned}
& + 4B_0 \left( p^2, m_{d_a}^2, m_{d_b}^2 \right) m_{d_a} m_{d_b} \Re \left( \Gamma_{Z', \bar{d}_a, d_b}^{L*} \Gamma_{Z', \bar{d}_a, d_b}^R \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left( |\Gamma_{Z', \bar{e}_a, e_b}^L|^2 + |\Gamma_{Z', \bar{e}_a, e_b}^R|^2 \right) H_0 \left( p^2, m_{e_a}^2, m_{e_b}^2 \right) \right. \\
& + 4B_0 \left( p^2, m_{e_a}^2, m_{e_b}^2 \right) m_{e_a} m_{e_b} \Re \left( \Gamma_{Z', \bar{e}_a, e_b}^{L*} \Gamma_{Z', \bar{e}_a, e_b}^R \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left( |\Gamma_{Z', \bar{u}_a, u_b}^L|^2 + |\Gamma_{Z', \bar{u}_a, u_b}^R|^2 \right) H_0 \left( p^2, m_{u_a}^2, m_{u_b}^2 \right) \right. \\
& + 4B_0 \left( p^2, m_{u_a}^2, m_{u_b}^2 \right) m_{u_a} m_{u_b} \Re \left( \Gamma_{Z', \bar{u}_a, u_b}^{L*} \Gamma_{Z', \bar{u}_a, u_b}^R \right) \\
& + 3 \sum_{a=1}^6 A_0 \left( m_{d_a}^2 \right) \Gamma_{Z', Z', \bar{d}_a, \bar{d}_a} + \sum_{a=1}^6 A_0 \left( m_{e_a}^2 \right) \Gamma_{Z', Z', \bar{e}_a, \bar{e}_a} + 3 \sum_{a=1}^6 A_0 \left( m_{u_a}^2 \right) \Gamma_{Z', Z', \bar{u}_a, \bar{u}_a} \\
& + \sum_{a=1}^6 A_0 \left( m_{\bar{\nu}_a}^2 \right) \Gamma_{Z', Z', \bar{\nu}_a, \bar{\nu}_a} - 12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z', \bar{d}_a, \bar{d}_b}|^2 B_{00} \left( p^2, m_{d_a}^2, m_{d_b}^2 \right) \\
& - 4 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z', \bar{e}_a, \bar{e}_b}|^2 B_{00} \left( p^2, m_{e_a}^2, m_{e_b}^2 \right) - 12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z', \bar{u}_a, \bar{u}_b}|^2 B_{00} \left( p^2, m_{u_a}^2, m_{u_b}^2 \right) \\
& - 4 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z', \bar{\nu}_a, \bar{\nu}_b}|^2 B_{00} \left( p^2, m_{\bar{\nu}_a}^2, m_{\bar{\nu}_b}^2 \right) \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 \left[ \left( |\Gamma_{Z', \bar{\chi}_a^0, \bar{\chi}_b^0}^L|^2 + |\Gamma_{Z', \bar{\chi}_a^0, \bar{\chi}_b^0}^R|^2 \right) H_0 \left( p^2, m_{\bar{\chi}_a^0}^2, m_{\bar{\chi}_b^0}^2 \right) \right. \\
& + 4B_0 \left( p^2, m_{\bar{\chi}_a^0}^2, m_{\bar{\chi}_b^0}^2 \right) m_{\bar{\chi}_a^0} m_{\bar{\chi}_b^0} \Re \left( \Gamma_{Z', \bar{\chi}_a^0, \bar{\chi}_b^0}^{L*} \Gamma_{Z', \bar{\chi}_a^0, \bar{\chi}_b^0}^R \right) \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 \left[ \left( |\Gamma_{Z', \nu_a, \nu_b}^L|^2 + |\Gamma_{Z', \nu_a, \nu_b}^R|^2 \right) H_0 \left( p^2, m_{\nu_a}^2, m_{\nu_b}^2 \right) \right. \\
& + 4B_0 \left( p^2, m_{\nu_a}^2, m_{\nu_b}^2 \right) m_{\nu_a} m_{\nu_b} \Re \left( \Gamma_{Z', \nu_a, \nu_b}^{L*} \Gamma_{Z', \nu_a, \nu_b}^R \right) \\
& + 2 \sum_{b=1}^2 |\Gamma_{Z', W^+, H_b^-}|^2 B_0 \left( p^2, m_{W^-}^2, m_{H_b^-}^2 \right) + \sum_{b=1}^3 |\Gamma_{Z', Z, h_b}|^2 B_0 \left( p^2, m_Z^2, m_{h_b}^2 \right) \\
& + \sum_{b=1}^3 |\Gamma_{Z', Z', h_b}|^2 B_0 \left( p^2, m_{Z'}^2, m_{h_b}^2 \right) + 2\text{rMS} m_{W^-}^2 \Gamma_{Z', Z', W^+, W^-}^1 - A_0 \left( m_{W^-}^2 \right) \left( 4\Gamma_{Z', Z', W^+, W^-}^1 + \Gamma_{Z', Z', W^+, W^-}^2 + \Gamma_{Z', Z', W^+, W^-}^3 \right)
\end{aligned} \tag{214}$$

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

$$\Pi(p^2) = -12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{W^+, \bar{u}_a, \bar{d}_b}|^2 B_{00} \left( p^2, m_{d_b}^2, m_{u_a}^2 \right) + 2\text{rMS} m_{W^-}^2 \Gamma_{W^-, W^+, W^+, W^-}^1 + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[ \left( |\Gamma_{W^+, \bar{u}_a, d_b}^L|^2 + |\Gamma_{W^+, \bar{u}_a, d_b}^R|^2 \right) H_0 \left( p^2, m_{d_b}^2, m_{u_a}^2 \right) \right.$$

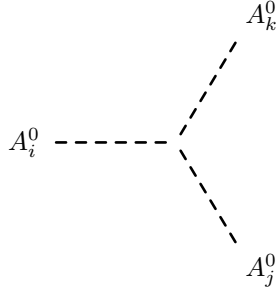
$$\begin{aligned}
& + 4B_0\left(p^2, m_{u_a}^2, m_{d_b}^2\right) m_{d_b} m_{u_a} \Re\left(\Gamma_{W^+, \bar{u}_a, d_b}^{L*} \Gamma_{W^+, \bar{u}_a, d_b}^R\right) + 3 \sum_{a=1}^6 A_0\left(m_{\bar{d}_a}^2\right) \Gamma_{W^-, W^+, \bar{d}_a^*, \bar{d}_a} + 3 \sum_{a=1}^6 A_0\left(m_{\bar{u}_a}^2\right) \Gamma_{W^-, W^+, \bar{u}_a^*, \bar{u}_a} \\
& + 4B_0\left(p^2, m_{\bar{\chi}_a^0}^2, m_{\bar{\chi}_b^0}^2\right) m_{\bar{\chi}_b^0} m_{\bar{\chi}_a^0} \Re\left(\Gamma_{W^+, \bar{\chi}_a^0, \bar{\chi}_b^0}^{L*} \Gamma_{W^+, \bar{\chi}_a^0, \bar{\chi}_b^0}^R\right) + \sum_{a=1}^6 \sum_{b=1}^3 \left[ \left( |\Gamma_{W^+, \nu_a, e_b}^L|^2 + |\Gamma_{W^+, \nu_a, e_b}^R|^2 \right) H_0\left(p^2, m_{\nu_a}^2, m_{e_b}^2\right) \right. \\
& \left. + 4B_0\left(p^2, m_{\nu_a}^2, m_{e_b}^2\right) m_{e_b} m_{\nu_a} \Re\left(\Gamma_{W^+, \nu_a, e_b}^{L*} \Gamma_{W^+, \nu_a, e_b}^R\right) \right] + \sum_{b=1}^2 |\Gamma_{W^+, \gamma, H_b^-}|^2 B_0\left(p^2, 0, m_{H_b^-}^2\right) + \sum_{b=1}^2 |\Gamma_{W^+, Z, H_b^-}|^2 B_0\left(p^2, m_Z^2, \right. \\
& \left. \right) \tag{215}
\end{aligned}$$

## 8.2 Tadpoles

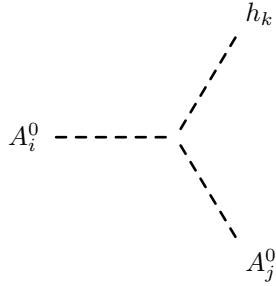
$$\begin{aligned}
\delta t_h^{(1)} = & + A_0\left(m_{\eta^-}^2\right) \Gamma_{\tilde{h}_i, \eta^-, \eta^-} + A_0\left(m_{\eta^+}^2\right) \Gamma_{\tilde{h}_i, \eta^+, \eta^+} + A_0\left(m_{\eta^Z}^2\right) \Gamma_{\tilde{h}_i, \eta^Z, \eta^Z} \\
& + A_0\left(m_{\eta^{Z'}}^2\right) \Gamma_{\tilde{h}_i, \eta^{Z'}, \eta^{Z'}} + 4\Gamma_{\tilde{h}_i, W^+, W^-} \left( -\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0\left(m_{W^-}^2\right) \right) + 2\Gamma_{\tilde{h}_i, Z, Z} \left( -\frac{1}{2} \text{rMS} m_Z^2 + A_0\left(m_Z^2\right) \right) \\
& + 2\Gamma_{\tilde{h}_i, Z', Z'} \left( -\frac{1}{2} \text{rMS} m_{Z'}^2 + A_0\left(m_{Z'}^2\right) \right) - \sum_{a=1}^2 A_0\left(m_{H_a^-}^2\right) \Gamma_{\tilde{h}_i, H_a^+, H_a^-} \\
& + 2 \sum_{a=1}^2 A_0\left(m_{\bar{\chi}_a^-}^2\right) m_{\bar{\chi}_a^-} \left( \Gamma_{\tilde{h}_i, \bar{\chi}_a^+, \bar{\chi}_a^-}^L + \Gamma_{\tilde{h}_i, \bar{\chi}_a^+, \bar{\chi}_a^-}^R \right) - \frac{1}{2} \sum_{a=1}^3 A_0\left(m_{A_a^0}^2\right) \Gamma_{\tilde{h}_i, A_a^0, A_a^0} \\
& - \frac{1}{2} \sum_{a=1}^3 A_0\left(m_{h_a}^2\right) \Gamma_{\tilde{h}_i, h_a, h_a} + 6 \sum_{a=1}^3 A_0\left(m_{d_a}^2\right) m_{d_a} \left( \Gamma_{\tilde{h}_i, \bar{d}_a, d_a}^L + \Gamma_{\tilde{h}_i, \bar{d}_a, d_a}^R \right) \\
& + 2 \sum_{a=1}^3 A_0\left(m_{e_a}^2\right) m_{e_a} \left( \Gamma_{\tilde{h}_i, \bar{e}_a, e_a}^L + \Gamma_{\tilde{h}_i, \bar{e}_a, e_a}^R \right) \\
& + 6 \sum_{a=1}^3 A_0\left(m_{u_a}^2\right) m_{u_a} \left( \Gamma_{\tilde{h}_i, \bar{u}_a, u_a}^L + \Gamma_{\tilde{h}_i, \bar{u}_a, u_a}^R \right) - 3 \sum_{a=1}^6 A_0\left(m_{\bar{d}_a}^2\right) \Gamma_{\tilde{h}_i, \bar{d}_a^*, \bar{d}_a} \\
& - \sum_{a=1}^6 A_0\left(m_{\bar{e}_a}^2\right) \Gamma_{\tilde{h}_i, \bar{e}_a^*, \bar{e}_a} - 3 \sum_{a=1}^6 A_0\left(m_{\bar{u}_a}^2\right) \Gamma_{\tilde{h}_i, \bar{u}_a^*, \bar{u}_a} - \sum_{a=1}^6 A_0\left(m_{\bar{\nu}_a}^2\right) \Gamma_{\tilde{h}_i, \bar{\nu}_a^*, \bar{\nu}_a} \\
& + \sum_{a=1}^6 A_0\left(m_{\bar{\chi}_a^0}^2\right) m_{\bar{\chi}_a^0} \left( \Gamma_{\tilde{h}_i, \bar{\chi}_a^0, \bar{\chi}_a^0}^L + \Gamma_{\tilde{h}_i, \bar{\chi}_a^0, \bar{\chi}_a^0}^R \right) + \sum_{a=1}^6 A_0\left(m_{\nu_a}^2\right) m_{\nu_a} \left( \Gamma_{\tilde{h}_i, \nu_a, \nu_a}^L + \Gamma_{\tilde{h}_i, \nu_a, \nu_a}^R \right) \tag{216}
\end{aligned}$$

## 9 Interactions for eigenstates 'EWSB'

### 9.1 Three Scalar-Interaction



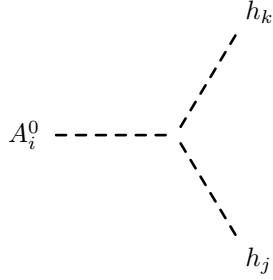
$$\begin{aligned}
& -\frac{1}{2} \frac{1}{\sqrt{2}} \left( Z_{i3}^{A,*} \left( Z_{j1}^{A,*} Z_{k2}^{A,*} + Z_{j2}^{A,*} Z_{k1}^{A,*} \right) + Z_{i2}^{A,*} \left( Z_{j1}^{A,*} Z_{k3}^{A,*} + Z_{j3}^{A,*} Z_{k1}^{A,*} \right) \right. \\
& \left. + Z_{i1}^{A,*} \left( Z_{j2}^{A,*} Z_{k3}^{A,*} + Z_{j3}^{A,*} Z_{k2}^{A,*} \right) \right) \left( -T_\lambda + T_\lambda^* \right)
\end{aligned} \tag{217}$$



$$\begin{aligned}
& -\frac{i}{4} \left( Z_{i3}^{A,*} \left( \sqrt{2} T_\lambda^* \left( Z_{j1}^{A,*} Z_{k2}^{H,*} + Z_{j2}^{A,*} Z_{k1}^{H,*} \right) \right. \right. \\
& + 4 Z_{j3}^{A,*} \left( g_p^2 Q_s^2 v_s Z_{k3}^{H,*} + v_d \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k1}^{H,*} + v_u \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k2}^{H,*} \right) \\
& \left. + \sqrt{2} \left( Z_{j1}^{A,*} Z_{k2}^{H,*} + Z_{j2}^{A,*} Z_{k1}^{H,*} \right) T_\lambda \right) \\
& + Z_{i2}^{A,*} \left( Z_{j2}^{A,*} \left( -v_d \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k1}^{H,*} + \left( 4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) v_u Z_{k2}^{H,*} \right. \right. \\
& \left. \left. + 4v_s \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} \right) \right. \\
& \left. + \sqrt{2} \left( Z_{j1}^{A,*} Z_{k3}^{H,*} + Z_{j3}^{A,*} Z_{k1}^{H,*} \right) \left( T_\lambda^* + T_\lambda \right) \right) \\
& + Z_{i1}^{A,*} \left( Z_{j1}^{A,*} \left( \left( 4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) v_d Z_{k1}^{H,*} - v_u \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k2}^{H,*} \right. \right. \\
& \left. \left. + 4v_s \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} \right) \right)
\end{aligned}$$

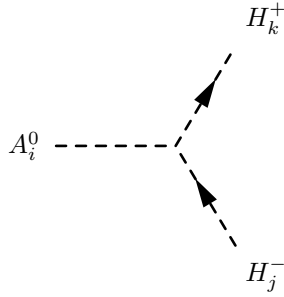
$$+ \sqrt{2} \left( Z_{j_2}^{A,*} Z_{k_3}^{H,*} + Z_{j_3}^{A,*} Z_{k_2}^{H,*} \right) \left( T_\lambda^* + T_\lambda \right) \quad (218)$$


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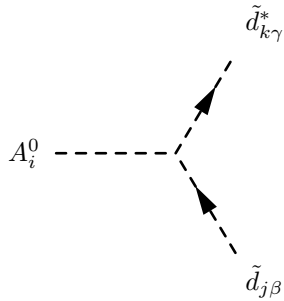
$$\begin{aligned} & \frac{1}{2} \frac{1}{\sqrt{2}} \left( Z_{i_3}^{A,*} \left( Z_{j_1}^{H,*} Z_{k_2}^{H,*} + Z_{j_2}^{H,*} Z_{k_1}^{H,*} \right) + Z_{i_2}^{A,*} \left( Z_{j_1}^{H,*} Z_{k_3}^{H,*} + Z_{j_3}^{H,*} Z_{k_1}^{H,*} \right) \right. \\ & \left. + Z_{i_1}^{A,*} \left( Z_{j_2}^{H,*} Z_{k_3}^{H,*} + Z_{j_3}^{H,*} Z_{k_2}^{H,*} \right) \right) \left( -T_\lambda + T_\lambda^* \right) \end{aligned} \quad (219)$$


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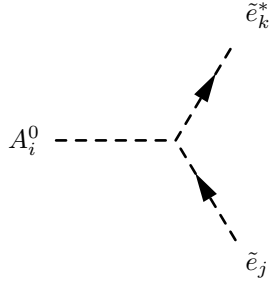
$$\begin{aligned} & \frac{1}{4} \left( v_u \left( -2|\lambda|^2 + g_2^2 \right) Z_{i_1}^{A,*} \left( -Z_{j_1}^+ Z_{k_2}^+ + Z_{j_2}^+ Z_{k_1}^+ \right) \right. \\ & \left. + v_d \left( -2|\lambda|^2 + g_2^2 \right) Z_{i_2}^{A,*} \left( -Z_{j_1}^+ Z_{k_2}^+ + Z_{j_2}^+ Z_{k_1}^+ \right) + 2\sqrt{2} Z_{i_3}^{A,*} \left( T_\lambda Z_{j_1}^+ Z_{k_2}^+ - T_\lambda^* Z_{j_2}^+ Z_{k_1}^+ \right) \right) \end{aligned} \quad (220)$$


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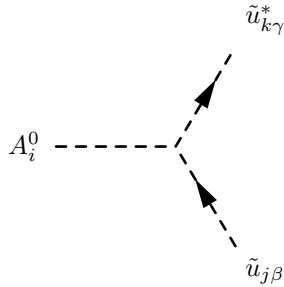
$$\begin{aligned}
& \frac{1}{2} \delta_{\beta\gamma} \left( \lambda^* \left( v_s Z_{i2}^{A,*} + v_u Z_{i3}^{A,*} \right) \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \right. \\
& - \lambda \left( v_s Z_{i2}^{A,*} + v_u Z_{i3}^{A,*} \right) \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{kb}^D \\
& \left. + \sqrt{2} Z_{i1}^{A,*} \left( - \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{D,*} T_{d,ab}^* Z_{kb}^D + \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Z_{k3+a}^D T_{d,ab} \right) \right) \quad (221)
\end{aligned}$$


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$$\begin{aligned}
& \frac{1}{2} \left( \lambda^* \left( v_s Z_{i2}^{A,*} + v_u Z_{i3}^{A,*} \right) \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \right. \\
& - \lambda \left( v_s Z_{i2}^{A,*} + v_u Z_{i3}^{A,*} \right) \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{kb}^E \\
& \left. + \sqrt{2} Z_{i1}^{A,*} \left( - \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{E,*} T_{e,ab}^* Z_{kb}^E + \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Z_{k3+a}^E T_{e,ab} \right) \right) \quad (222)
\end{aligned}$$

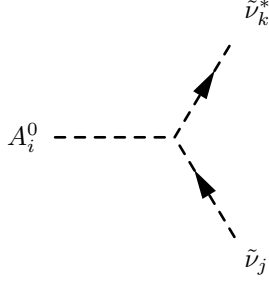

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$$\frac{1}{2} \delta_{\beta\gamma} \left( \lambda^* \left( v_d Z_{i3}^{A,*} + v_s Z_{i1}^{A,*} \right) \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \right)$$

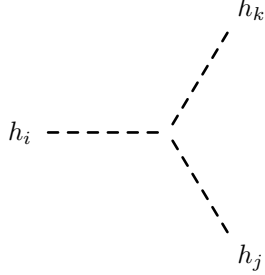
$$\begin{aligned}
& -\lambda \left( v_d Z_{i3}^{A,*} + v_s Z_{i1}^{A,*} \right) \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{j3+a}^{U,*} Z_{kb}^U \\
& + \sqrt{2} Z_{i2}^{A,*} \left( - \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{U,*} T_{u,ab}^* Z_{kb}^U + \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Z_{k3+a}^U T_{u,ab} \right)
\end{aligned} \tag{223}$$


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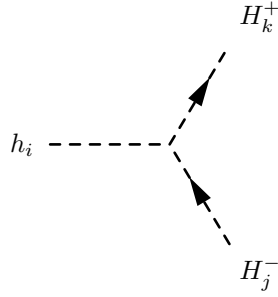
$$\begin{aligned}
& \frac{1}{2} \left( Z_{i3}^{A,*} \left( v_d \lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} Y_{\nu,ab} Z_{k3+b}^V - v_d \lambda \sum_{b=1}^3 Z_{j3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{ka}^V \right) \right. \\
& + Z_{i1}^{A,*} \left( v_s \lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} Y_{\nu,ab} Z_{k3+b}^V - v_s \lambda \sum_{b=1}^3 Z_{j3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{ka}^V \right) \\
& \left. + \sqrt{2} Z_{i2}^{A,*} \left( - \sum_{b=1}^3 Z_{j3+b}^{V,*} \sum_{a=1}^3 T_{\nu,ab}^* Z_{ka}^V + \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} T_{\nu,ab} Z_{k3+b}^V \right) \right)
\end{aligned} \tag{224}$$


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$$\begin{aligned}
& \frac{i}{4} \left( - Z_{i3}^{H,*} \left( - \sqrt{2} T_\lambda^* Z_{j2}^{H,*} Z_{k1}^{H,*} + 4g_p^2 Q_{H_u} Q_s v_d Z_{j3}^{H,*} Z_{k1}^{H,*} + 4v_d |\lambda|^2 Z_{j3}^{H,*} Z_{k1}^{H,*} \right. \right. \\
& + 4g_p^2 Q_{H_u} Q_s v_s Z_{j2}^{H,*} Z_{k2}^{H,*} + 4v_s |\lambda|^2 Z_{j2}^{H,*} Z_{k2}^{H,*} + 4g_p^2 Q_{H_u} Q_s v_u Z_{j3}^{H,*} Z_{k2}^{H,*} \\
& + 4v_u |\lambda|^2 Z_{j3}^{H,*} Z_{k2}^{H,*} + 4g_p^2 Q_{H_u} Q_s v_u Z_{j2}^{H,*} Z_{k3}^{H,*} + 4v_u |\lambda|^2 Z_{j2}^{H,*} Z_{k3}^{H,*} \\
& \left. \left. + 12g_p^2 Q_s^2 v_s Z_{j3}^{H,*} Z_{k3}^{H,*} - \sqrt{2} Z_{j2}^{H,*} Z_{k1}^{H,*} T_\lambda \right) \right)
\end{aligned}$$

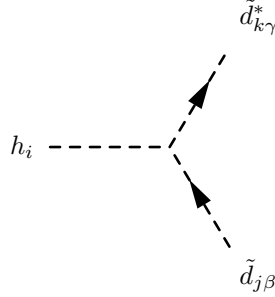
$$\begin{aligned}
& + Z_{j_1}^{H,*} \left( 4v_s \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k_1}^{H,*} - \sqrt{2} T_\lambda^* Z_{k_2}^{H,*} + 4g_p^2 Q_{H_d} Q_s v_d Z_{k_3}^{H,*} + 4v_d |\lambda|^2 Z_{k_3}^{H,*} \right. \\
& \left. - \sqrt{2} Z_{k_2}^{H,*} T_\lambda \right) \\
& + Z_{i_2}^{H,*} \left( Z_{j_2}^{H,*} \left( v_d \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k_1}^{H,*} - 3 \left( 4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) v_u Z_{k_2}^{H,*} \right. \right. \\
& \left. \left. - 4v_s \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k_3}^{H,*} \right) \right) \\
& + Z_{j_3}^{H,*} \left( \sqrt{2} T_\lambda^* Z_{k_1}^{H,*} - 4v_s \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k_2}^{H,*} - 4g_p^2 Q_{H_u} Q_s v_u Z_{k_3}^{H,*} - 4v_u |\lambda|^2 Z_{k_3}^{H,*} \right. \\
& \left. + \sqrt{2} Z_{k_1}^{H,*} T_\lambda \right) \\
& + Z_{j_1}^{H,*} \left( v_u \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k_1}^{H,*} + v_d \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k_2}^{H,*} \right. \\
& \left. + \sqrt{2} Z_{k_3}^{H,*} \left( T_\lambda^* + T_\lambda \right) \right) \\
& + Z_{i_1}^{H,*} \left( -Z_{j_1}^{H,*} \left( 3 \left( 4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) v_d Z_{k_1}^{H,*} - v_u \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k_2}^{H,*} \right. \right. \\
& \left. \left. + 4v_s \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k_3}^{H,*} \right) \right) \\
& + Z_{j_3}^{H,*} \left( -4v_s \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k_1}^{H,*} + \sqrt{2} T_\lambda^* Z_{k_2}^{H,*} - 4g_p^2 Q_{H_d} Q_s v_d Z_{k_3}^{H,*} - 4v_d |\lambda|^2 Z_{k_3}^{H,*} \right. \\
& \left. + \sqrt{2} Z_{k_2}^{H,*} T_\lambda \right) \\
& + Z_{j_2}^{H,*} \left( v_u \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k_1}^{H,*} + v_d \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k_2}^{H,*} \right. \\
& \left. + \sqrt{2} Z_{k_3}^{H,*} \left( T_\lambda^* + T_\lambda \right) \right) \Big) \Big) \tag{225}
\end{aligned}$$



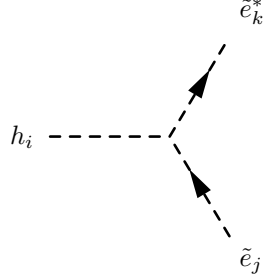
$$\begin{aligned}
& - \frac{i}{4} \left( Z_{i_2}^{H,*} \left( Z_{j_2}^+ \left( \left( 4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) v_u Z_{k_2}^+ + v_d \left( -2|\lambda|^2 + g_2^2 \right) Z_{k_1}^+ \right) \right. \right. \\
& \left. \left. + Z_{j_1}^+ \left( \left( 4g_p^2 Q_{H_d} Q_{H_u} - g_1^2 + g_2^2 \right) v_u Z_{k_1}^+ + v_d \left( -2|\lambda|^2 + g_2^2 \right) Z_{k_2}^+ \right) \right) \right) \\
& + Z_{i_1}^{H,*} \left( Z_{j_2}^+ \left( \left( 4g_p^2 Q_{H_d} Q_{H_u} - g_1^2 + g_2^2 \right) v_d Z_{k_2}^+ + v_u \left( -2|\lambda|^2 + g_2^2 \right) Z_{k_1}^+ \right) \right. \\
& \left. + Z_{j_1}^+ \left( \left( 4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) v_d Z_{k_1}^+ + v_u \left( -2|\lambda|^2 + g_2^2 \right) Z_{k_2}^+ \right) \right)
\end{aligned}$$



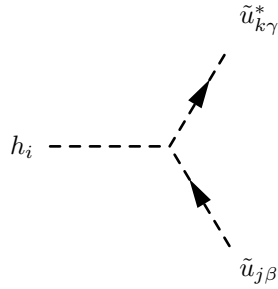
$$\begin{aligned}
& + 2Z_{i3}^{H,*} \left( Z_{j2}^+ \left( 2v_s \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k2}^+ + \sqrt{2} T_\lambda^* Z_{k1}^+ \right) \right. \\
& \left. + Z_{j1}^+ \left( 2v_s \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k1}^+ + \sqrt{2} T_\lambda Z_{k2}^+ \right) \right) \tag{226}
\end{aligned}$$



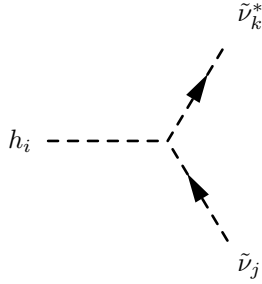
$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\gamma} \left( 6Z_{i3}^{H,*} \left( -2g_p^2 Q_q Q_s v_s \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D - 2g_p^2 Q_d Q_s v_s \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \right. \right. \\
& \left. \left. + v_u \lambda^* \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D + v_u \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{kb}^D \right) \right. \\
& \left. - Z_{i2}^{H,*} \left( \left( 3 \left( 4g_p^2 Q_{H_u} Q_q + g_2^2 \right) + g_1^2 \right) v_u \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \right. \right. \\
& \left. \left. + 2 \left( \left( 6g_p^2 Q_d Q_{H_u} + g_1^2 \right) v_u \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \right. \right. \right. \\
& \left. \left. \left. - 3v_s \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{kb}^D + \lambda^* \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \right) \right) \right) \right. \\
& \left. + Z_{i1}^{H,*} \left( \left( 3 \left( -4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) v_d \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \right. \right. \\
& \left. \left. + 2 \left( \left( -6g_p^2 Q_d Q_{H_d} + g_1^2 \right) v_d \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \right. \right. \right. \\
& \left. \left. \left. - 3 \left( \sqrt{2} \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Z_{k3+a}^D T_{d,ab} + \sqrt{2} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{D,*} T_{d,ab}^* Z_{kb}^D \right. \right. \right. \\
& \left. \left. \left. + 2v_d \left( \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{k3+b}^D + \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{kc}^D \right) \right) \right) \right) \tag{227}
\end{aligned}$$



$$\begin{aligned}
& -\frac{i}{4} \left( Z_{i2}^{H,*} \left( (4g_p^2 Q_{H_u} Q_q - g_1^2 + g_2^2) v_u \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E + 2(2g_p^2 Q_e Q_{H_u} + g_1^2) v_u \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \right. \right. \\
& - 2v_s \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{kb}^E + \lambda^* \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \right) \left. \right) \\
& + 2Z_{i3}^{H,*} \left( 2g_p^2 Q_q Q_s v_s \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E + 2g_p^2 Q_e Q_s v_s \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \right. \\
& - v_u \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{kb}^E + \lambda^* \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \right) \left. \right) \\
& + Z_{i1}^{H,*} \left( (4g_p^2 Q_{H_d} Q_q - g_2^2 + g_1^2) v_d \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \right. \\
& + 2 \left( - \left( -2g_p^2 Q_e Q_{H_d} + g_1^2 \right) v_d \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E + \sqrt{2} \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Z_{k3+a}^E T_{e,ab} \right. \\
& + \sqrt{2} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{E,*} T_{e,ab}^* Z_{kb}^E + 2v_d \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{k3+b}^E \\
& \left. \left. \left. + 2v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{kc}^E \right) \right) \right) \tag{228}
\end{aligned}$$

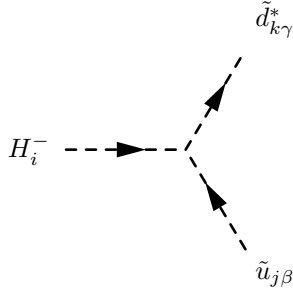


$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\gamma} \left( 6Z_{i3}^{H,*} \left( -2g_p^2 Q_q Q_s v_s \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U - 2g_p^2 Q_s Q_u v_s \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \right. \right. \\
& + v_d \lambda^* \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U + v_d \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{j3+a}^{U,*} Z_{kb}^U \left. \right) \\
& + Z_{i1}^{H,*} \left( \left( -3 \left( 4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) v_d \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U - 4 \left( 3g_p^2 Q_{H_d} Q_u + g_1^2 \right) v_d \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \right. \\
& + 6v_s \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{j3+a}^{U,*} Z_{kb}^U + \lambda^* \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \right) \\
& - Z_{i2}^{H,*} \left( \left( 12g_p^2 Q_{H_u} Q_q - 3g_2^2 + g_1^2 \right) v_u \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \right. \\
& + 2 \left( -2 \left( -3g_p^2 Q_{H_u} Q_u + g_1^2 \right) v_u \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \right. \\
& + 3 \left( \sqrt{2} \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Z_{k3+a}^U T_{u,ab} + \sqrt{2} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{U,*} T_{u,ab}^* Z_{kb}^U \right. \\
& \left. \left. \left. + 2v_u \left( \sum_{c=1}^3 Z_{j3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{k3+b}^U + \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{kc}^U \right) \right) \right) \right) \right) \quad (229)
\end{aligned}$$

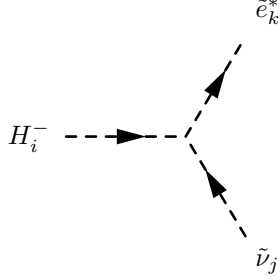


$$\begin{aligned}
& - \frac{i}{4} \left( 2Z_{i3}^{H,*} \left( 2g_p^2 Q_q Q_s v_s \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^V + 2g_p^2 Q_s Q_v v_s \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{k3+a}^V \right. \right. \\
& - v_d \left( \lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} Y_{\nu,ab} Z_{k3+b}^V + \lambda \sum_{b=1}^3 Z_{j3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{ka}^V \right) \left. \right) \\
& + Z_{i1}^{H,*} \left( \left( 4g_p^2 Q_{H_d} Q_q + g_1^2 + g_2^2 \right) v_d \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^V \right. \\
& \left. - 2 \left( \left( -2g_p^2 Q_{H_d} Q_v + g_1^2 \right) v_d \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{k3+a}^V \right) \right)
\end{aligned}$$

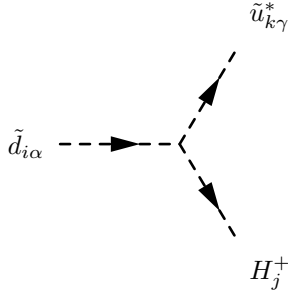
$$\begin{aligned}
& + v_s \left( \lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} Y_{\nu,ab} Z_{k3+b}^V + \lambda \sum_{b=1}^3 Z_{j3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab} Z_{ka}^V \right) \\
& + Z_{i2}^{H,*} \left( - \left( -4g_p^2 Q_{H_u} Q_q + g_1^2 + g_2^2 \right) v_u \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^V \right. \\
& + 2 \left( \left( 2g_p^2 Q_{H_u} Q_v + g_1^2 \right) v_u \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{k3+a}^V + \sqrt{2} \sum_{b=1}^3 Z_{j3+b}^{V,*} \sum_{a=1}^3 T_{\nu,ab}^* Z_{ka}^V \right. \\
& + \sqrt{2} \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} T_{\nu,ab} Z_{k3+b}^V + 2v_u \sum_{c=1}^3 Z_{j3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{\nu,ab} Z_{k3+b}^V \\
& \left. \left. + 2v_u \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{kc}^V \right) \right) \tag{230}
\end{aligned}$$



$$\begin{aligned}
& - \frac{i}{4} \delta_{\beta\gamma} \left( \sqrt{2} g_2^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^D \left( v_d Z_{i1}^+ + v_u Z_{i2}^+ \right) \right. \\
& - 2 \left( 2 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Z_{k3+a}^D T_{d,ab} Z_{i1}^+ + \sqrt{2} v_s \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{j3+a}^{U,*} Z_{kb}^D Z_{i1}^+ \right. \\
& + \sqrt{2} v_u \sum_{c=1}^3 Z_{j3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{k3+b}^D Z_{i1}^+ \\
& + \sqrt{2} v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{kc}^D Z_{i1}^+ + \sqrt{2} v_s \lambda^* \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D Z_{i2}^+ \\
& + 2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{U,*} T_{u,ab}^* Z_{kb}^D Z_{i2}^+ + \sqrt{2} v_d \sum_{c=1}^3 Z_{j3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{k3+b}^D Z_{i2}^+ \\
& \left. \left. + \sqrt{2} v_u \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{kc}^D Z_{i2}^+ \right) \right) \tag{231}
\end{aligned}$$

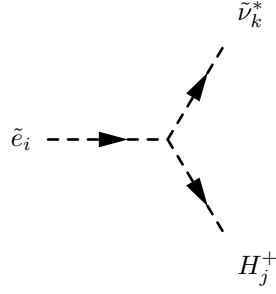


$$\begin{aligned}
& -\frac{i}{4} \left( \sqrt{2} g_2^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^E (v_d Z_{i1}^+ + v_u Z_{i2}^+) \right. \\
& - 2 \left( \sqrt{2} v_s \lambda \sum_{b=1}^3 Z_{j3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{ka}^E Z_{i1}^+ + 2 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Z_{k3+a}^E T_{e,ab} Z_{i1}^+ \right. \\
& + \sqrt{2} v_u \sum_{c=1}^3 Z_{j3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{e,ba} Z_{k3+b}^E Z_{i1}^+ \\
& + \sqrt{2} v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{kc}^E Z_{i1}^+ + 2 \sum_{b=1}^3 Z_{j3+b}^{V,*} \sum_{a=1}^3 T_{\nu,ab}^* Z_{ka}^E Z_{i2}^+ \\
& + \sqrt{2} v_s \lambda^* \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E Z_{i2}^+ + \sqrt{2} v_d \sum_{c=1}^3 Z_{j3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{e,ba} Z_{k3+b}^E Z_{i2}^+ \\
& \left. \left. + \sqrt{2} v_u \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{kc}^E Z_{i2}^+ \right) \right) \tag{232}
\end{aligned}$$



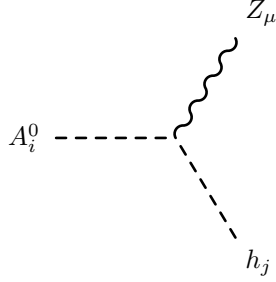
$$\begin{aligned}
& -\frac{i}{4} \delta_{\alpha\gamma} \left( \sqrt{2} g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^U (v_d Z_{j1}^+ + v_u Z_{j2}^+) \right. \\
& - 2 \left( \sqrt{2} v_s \lambda^* \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U Z_{j1}^+ + 2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{i3+a}^{D,*}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

$$\begin{aligned}
& + \sqrt{2}v_u \sum_{c=1}^3 Z_{i3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{k3+b}^U Z_{j1}^+ \\
& + \sqrt{2}v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{kc}^U Z_{j1}^+ + 2 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Z_{k3+a}^U T_{u,ab} Z_{j2}^+ \\
& + \sqrt{2}v_s \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{i3+a}^{D,*} Z_{kb}^U Z_{j2}^+ + \sqrt{2}v_d \sum_{c=1}^3 Z_{i3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{k3+b}^U Z_{j2}^+ \\
& + \sqrt{2}v_u \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{kc}^U Z_{j2}^+ \Big) \Big) \tag{233}
\end{aligned}$$



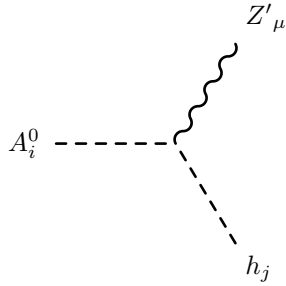
$$\begin{aligned}
& - \frac{i}{4} \left( \sqrt{2}g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^V \left( v_d Z_{j1}^+ + v_u Z_{j2}^+ \right) \right. \\
& - 2 \left( 2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{i3+a}^{E,*} T_{e,ab}^* Z_{kb}^V Z_{j1}^+ + \sqrt{2}v_s \lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ia}^{E,*} Y_{\nu,ab} Z_{k3+b}^V Z_{j1}^+ \right. \\
& + \sqrt{2}v_u \sum_{c=1}^3 Z_{i3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{\nu,ab} Z_{k3+b}^V Z_{j1}^+ \\
& + \sqrt{2}v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{kc}^V Z_{j1}^+ + \sqrt{2}v_s \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{i3+a}^{E,*} Z_{kb}^V Z_{j2}^+ \\
& + 2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ia}^{E,*} T_{\nu,ab} Z_{k3+b}^V Z_{j2}^+ + \sqrt{2}v_d \sum_{c=1}^3 Z_{i3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{\nu,ab} Z_{k3+b}^V Z_{j2}^+ \\
& \left. \left. + \sqrt{2}v_u \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{kc}^V Z_{j2}^+ \right) \right) \Big) \tag{234}
\end{aligned}$$

## 9.2 Two Scalar-One Vector Boson-Interaction



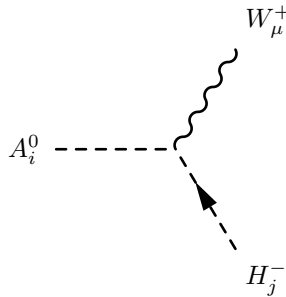
$$\begin{aligned}
 & \frac{1}{2} \left( 2g_p Q_s Z_{i3}^{A,*} Z_{j3}^{H,*} \sin \Theta'_W \right. \\
 & + Z_{i1}^{A,*} Z_{j1}^{H,*} \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \\
 & \left. - Z_{i2}^{A,*} Z_{j2}^{H,*} \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \right) \left( -p_\mu^{h_j} + p_\mu^{A_i^0} \right) \quad (235)
 \end{aligned}$$


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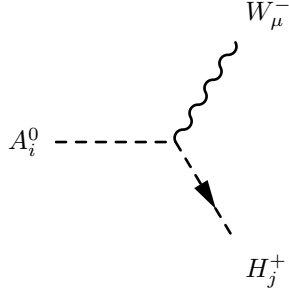
$$\begin{aligned}
 & \frac{1}{2} \left( 2g_p Q_s Z_{i3}^{A,*} Z_{j3}^{H,*} \cos \Theta'_W \right. \\
 & + Z_{i2}^{A,*} Z_{j2}^{H,*} \left( 2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W + g_2 \cos \Theta_W \sin \Theta'_W \right) \\
 & \left. + Z_{i1}^{A,*} Z_{j1}^{H,*} \left( 2g_p Q_{H_d} \cos \Theta'_W - \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \right) \left( -p_\mu^{h_j} + p_\mu^{A_i^0} \right) \quad (236)
 \end{aligned}$$


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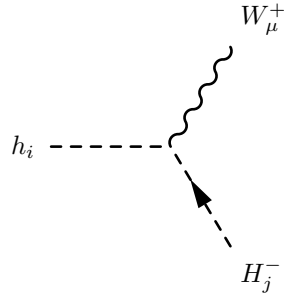
$$\frac{1}{2}g_2 \left( Z_{i1}^{A,*} Z_{j1}^+ + Z_{i2}^{A,*} Z_{j2}^+ \right) \left( -p_\mu^{H_j^-} + p_\mu^{A_i^0} \right) \quad (237)$$


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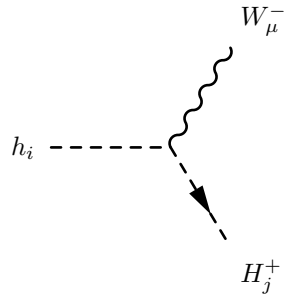
$$\frac{1}{2}g_2 \left( Z_{i1}^{A,*} Z_{j1}^+ + Z_{i2}^{A,*} Z_{j2}^+ \right) \left( -p_\mu^{H_j^+} + p_\mu^{A_i^0} \right) \quad (238)$$


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$$\frac{i}{2}g_2 \left( Z_{i1}^{H,*} Z_{j1}^+ - Z_{i2}^{H,*} Z_{j2}^+ \right) \left( -p_\mu^{H_j^-} + p_\mu^{h_i} \right) \quad (239)$$

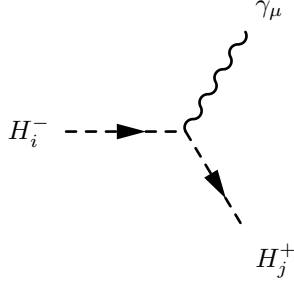

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$$-\frac{i}{2}g_2 \left( Z_{i1}^{H,*} Z_{j1}^+ - Z_{i2}^{H,*} Z_{j2}^+ \right) \left( -p_\mu^{H_j^+} + p_\mu^{h_i} \right) \quad (240)$$

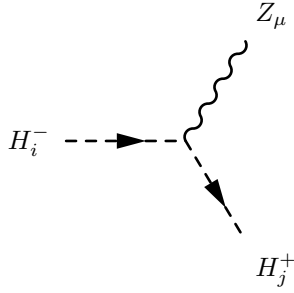

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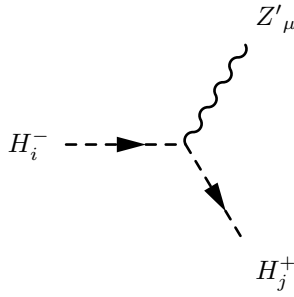
$$\frac{i}{2} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left( Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) \left( -p_\mu^{H_j^+} + p_\mu^{H_i^-} \right) \quad (241)$$


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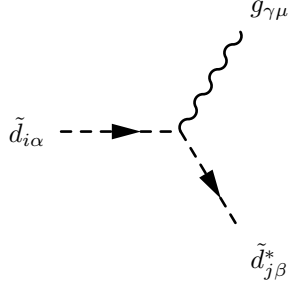
$$\begin{aligned} & \frac{i}{2} \left( \left( -2g_p Q_{H_d} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right. \\ & \left. + \left( 2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{i2}^+ Z_{j2}^+ \right) \left( -p_\mu^{H_j^+} + p_\mu^{H_i^-} \right) \end{aligned} \quad (242)$$


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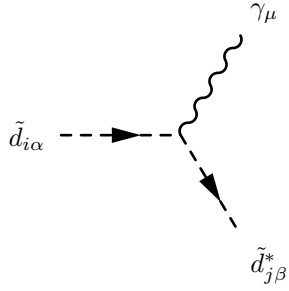
$$\begin{aligned} & -\frac{i}{2} \left( \left( 2g_p Q_{H_d} \cos \Theta'_W + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right. \\ & \left. + \left( -2g_p Q_{H_u} \cos \Theta'_W + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{i2}^+ Z_{j2}^+ \right) \left( -p_\mu^{H_j^+} + p_\mu^{H_i^-} \right) \end{aligned} \quad (243)$$


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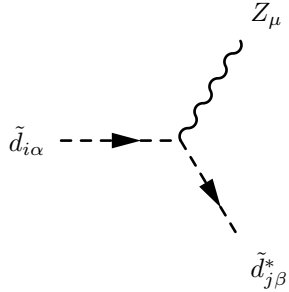
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\beta,\alpha}^\gamma\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (244)$$


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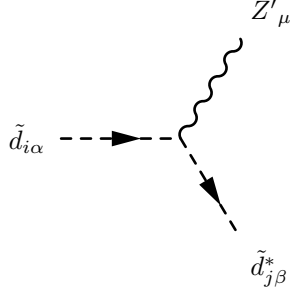
$$-\frac{i}{6}\delta_{\alpha\beta}\left(-2g_1\cos\Theta_W\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D+\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right)\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (245)$$


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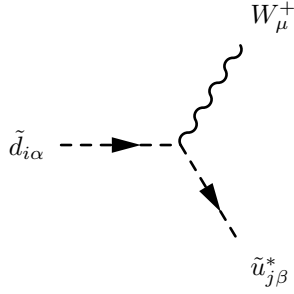
$$\begin{aligned} &\frac{i}{6}\delta_{\alpha\beta}\left(\left(3g_2\cos\Theta_W\cos\Theta'_W-6g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right. \\ &\left.-2\left(-3g_pQ_d\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\right)\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{d}_{i\alpha}}\right) \quad (246) \end{aligned}$$


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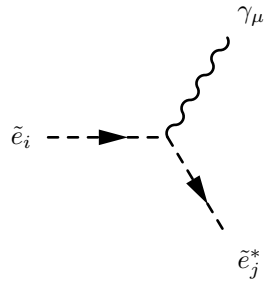
$$\begin{aligned}
& -\frac{i}{6}\delta_{\alpha\beta}\left(\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D \\
& -2\left(3g_pQ_d\cos\Theta'_W+g_1\sin\Theta_W\sin\Theta'_W\right)\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\left(-p_{\mu}^{\tilde{d}^*_{j\beta}}+p_{\mu}^{\tilde{d}_{i\alpha}}\right)
\end{aligned} \tag{247}$$


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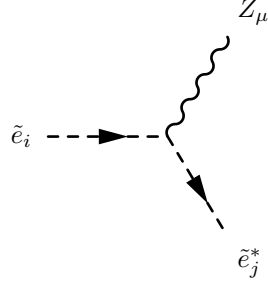
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^U\left(-p_{\mu}^{\tilde{u}^*_{j\beta}}+p_{\mu}^{\tilde{d}_{i\alpha}}\right) \tag{248}$$


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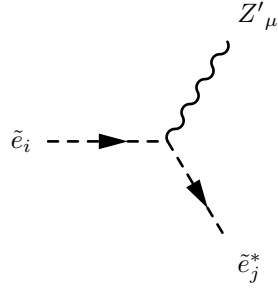
$$\frac{i}{2}\left(2g_1\cos\Theta_W\sum_{a=1}^3Z_{i3+a}^{E,*}Z_{j3+a}^E+\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{E,*}Z_{ja}^E\right)\left(-p_{\mu}^{\tilde{e}^*_j}+p_{\mu}^{\tilde{e}_i}\right) \tag{249}$$


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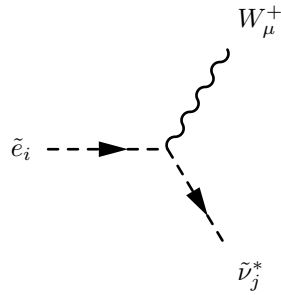
$$\begin{aligned}
& \frac{i}{2} \left( \left( -2g_p Q_q \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. + 2 \left( -g_1 \cos \Theta'_W \sin \Theta_W + g_p Q_e \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) \left( -p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i} \right)
\end{aligned} \tag{250}$$


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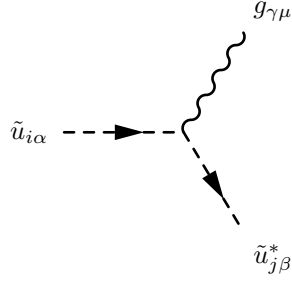
$$\begin{aligned}
& -\frac{i}{2} \left( \left( 2g_p Q_q \cos \Theta'_W + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. - 2 \left( g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_e \cos \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) \left( -p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i} \right)
\end{aligned} \tag{251}$$


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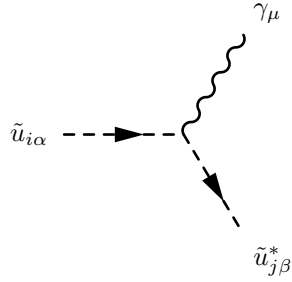
$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V \left( -p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{e}_i} \right) \quad (252)$$


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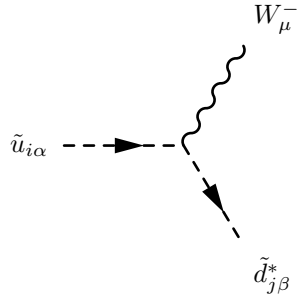
$$- \frac{i}{2} g_3 \delta_{ij} \lambda_{\beta,\alpha}^\gamma \left( -p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \quad (253)$$


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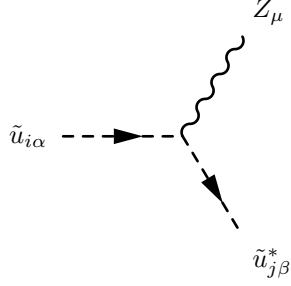
$$- \frac{i}{6} \delta_{\alpha\beta} \left( (3g_2 \sin \Theta_W + g_1 \cos \Theta_W) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + 4g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) \left( -p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \quad (254)$$


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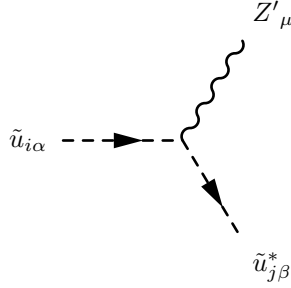
$$-i \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D \left( -p_\mu^{\tilde{d}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \quad (255)$$


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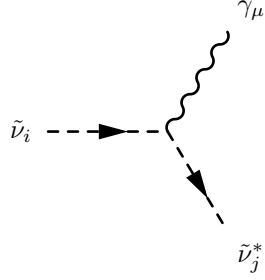
$$\begin{aligned} & -\frac{i}{6} \delta_{\alpha\beta} \left( \left( 3g_2 \cos \Theta_W \cos \Theta'_W + 6g_p Q_q \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\ & \left. - 2 \left( 2g_1 \cos \Theta'_W \sin \Theta_W + 3g_p Q_u \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) \left( -p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \end{aligned} \quad (256)$$


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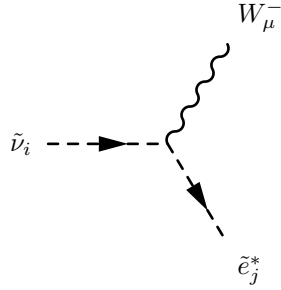
$$\begin{aligned} & -\frac{i}{6} \delta_{\alpha\beta} \left( \left( \left( -3g_2 \cos \Theta_W + g_1 \sin \Theta_W \right) \sin \Theta'_W + 6g_p Q_q \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\ & \left. + 2 \left( 2g_1 \sin \Theta_W \sin \Theta'_W - 3g_p Q_u \cos \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) \left( -p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \end{aligned} \quad (257)$$


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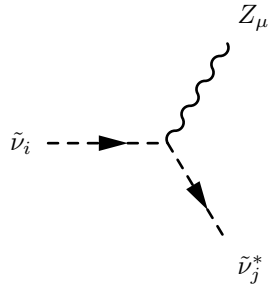
$$\frac{i}{2} \left( 2g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{j3+a}^V + \left( g_1 \cos \Theta_W - g_2 \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V \right) \left( -p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{\nu}_i} \right) \quad (258)$$


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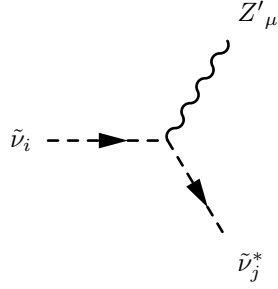
$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E \left( -p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{\nu}_i} \right) \quad (259)$$


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$$\begin{aligned} & -\frac{i}{2} \left( \left( 2g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V \right. \\ & \left. + 2 \left( g_1 \cos \Theta'_W \sin \Theta_W - g_p Q_v \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{j3+a}^V \right) \left( -p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{\nu}_i} \right) \quad (260) \end{aligned}$$

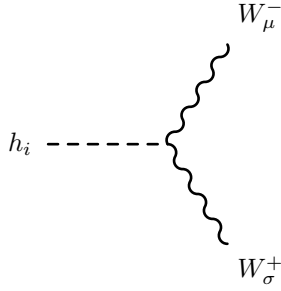

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$$\begin{aligned}
& -\frac{i}{2} \left( 2g_p Q_q \cos \Theta'_W - (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V \\
& - 2 \left( g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_v \cos \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{j3+a}^V \left( -p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{\nu}_i} \right)
\end{aligned} \tag{261}$$

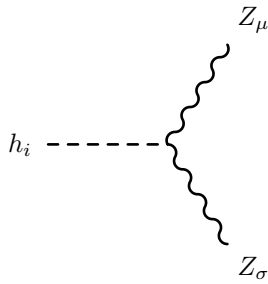

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### 9.3 One Scalar-Two Vector Boson-Interaction



$$\frac{i}{2} g_2^2 \left( v_d Z_{i1}^{H,*} + v_u Z_{i2}^{H,*} \right) \left( g_{\sigma\mu} \right) \tag{262}$$

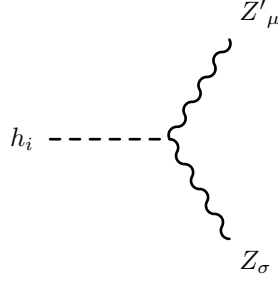

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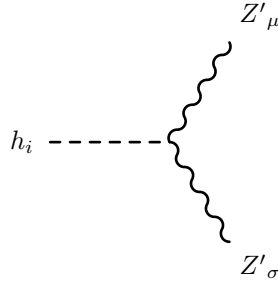
$$\begin{aligned}
& \frac{i}{2} \left( 4g_p^2 Q_s^2 v_s Z_{i3}^{H,*} \sin^2 \Theta'_W \right. \\
& + v_d Z_{i1}^{H,*} \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \\
& \left. + v_u Z_{i2}^{H,*} \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \right) (g_{\sigma\mu})
\end{aligned} \tag{263}$$


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$$\begin{aligned}
& -\frac{i}{2} \left( -4g_p^2 Q_s^2 v_s Z_{i3}^{H,*} \cos \Theta'_W \sin \Theta'_W \right. \\
& + v_d Z_{i1}^{H,*} \left( -2g_1 g_p Q_{H_d} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos^2 \Theta'^2_W \cos \Theta'_W \sin \Theta'_W \right. \\
& + \left. \cos \Theta'_W \left( -4g_p^2 Q_{H_d}^2 + g_1^2 \sin^2 \Theta'^2_W \right) \sin \Theta'_W + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta'^2_W \right. \\
& \left. + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W - g_p Q_{H_d} \cos \Theta'^2_W + g_p Q_{H_d} \sin \Theta'^2_W \right) \right) \\
& + v_u Z_{i2}^{H,*} \left( 2g_1 g_p Q_{H_u} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos^2 \Theta'^2_W \cos \Theta'_W \sin \Theta'_W \right. \\
& + \left. \cos \Theta'_W \left( -4g_p^2 Q_{H_u}^2 + g_1^2 \sin^2 \Theta'^2_W \right) \sin \Theta'_W - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta'^2_W \right. \\
& \left. + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_u} \cos \Theta'^2_W - g_p Q_{H_u} \sin \Theta'^2_W \right) \right) (g_{\sigma\mu})
\end{aligned} \tag{264}$$

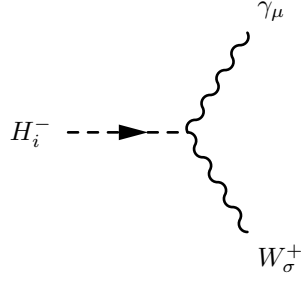

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$$\frac{i}{2} \left( 4g_p^2 Q_s^2 v_s Z_{i3}^{H,*} \cos^2 \Theta'_W \right)$$

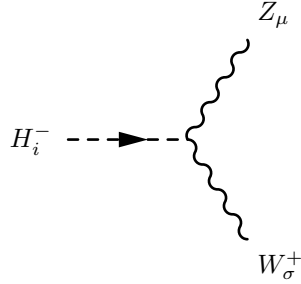
$$\begin{aligned}
& + v_d Z_{i1}^{H,*} \left( -2g_p Q_{H_d} \cos \Theta'_W + (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W \right)^2 \\
& + v_u Z_{i2}^{H,*} \left( 2g_p Q_{H_u} \cos \Theta'_W + (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W \right)^2 (g_{\sigma\mu})
\end{aligned} \tag{265}$$


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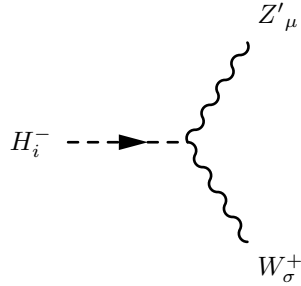
$$-\frac{i}{2} g_1 g_2 \cos \Theta_W (v_d Z_{i1}^+ - v_u Z_{i2}^+) (g_{\sigma\mu}) \tag{266}$$


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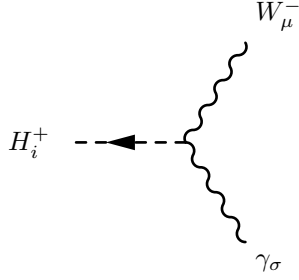
$$\begin{aligned}
& \frac{i}{2} g_2 \left( v_d (2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W) Z_{i1}^+ \right. \\
& \left. + v_u (2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W) Z_{i2}^+ \right) (g_{\sigma\mu})
\end{aligned} \tag{267}$$


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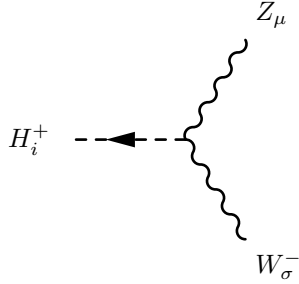
$$\begin{aligned}
& \frac{i}{2}g_2 \left( v_d \left( 2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{i1}^+ \right. \\
& \left. + v_u \left( 2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{i2}^+ \right) (g_{\sigma\mu})
\end{aligned} \tag{268}$$


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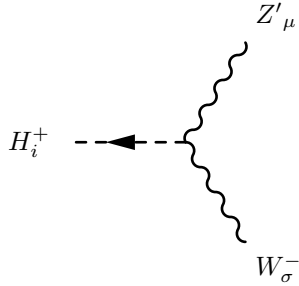
$$- \frac{i}{2}g_1 g_2 \cos \Theta_W \left( v_d Z_{i1}^+ - v_u Z_{i2}^+ \right) (g_{\sigma\mu}) \tag{269}$$


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$$\begin{aligned}
& \frac{i}{2}g_2 \left( v_d \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{i1}^+ \right. \\
& \left. + v_u \left( 2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{i2}^+ \right) (g_{\sigma\mu})
\end{aligned} \tag{270}$$

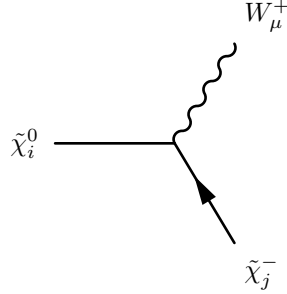

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$$\begin{aligned} & \frac{i}{2}g_2 \left( v_d \left( 2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{i1}^+ \right. \\ & \left. + v_u \left( 2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{i2}^+ \right) (g_{\sigma\mu}) \end{aligned} \quad (271)$$


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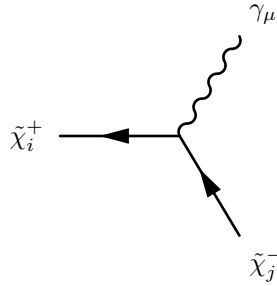
#### 9.4 Two Fermion-One Vector Boson-Interaction



$$- \frac{i}{2}g_2 \left( 2U_{j1}^* N_{i3} + \sqrt{2}U_{j2}^* N_{i4} \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (272)$$

$$+ \left( i \frac{1}{\sqrt{2}} g_2 N_{i5}^* V_{j2} - i g_2 N_{i3}^* V_{j1} \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (273)$$

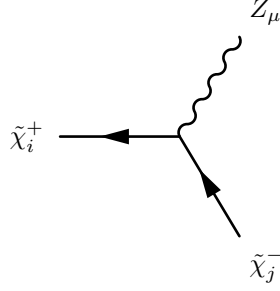

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$$\frac{i}{2} \left( 2g_2 U_{j1}^* \sin \Theta_W U_{i1} + U_{j2}^* \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) U_{i2} \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (274)$$

$$+ \frac{i}{2} \left( 2g_2 V_{i1}^* \sin \Theta_W V_{j1} + V_{i2}^* \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) V_{j2} \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (275)$$

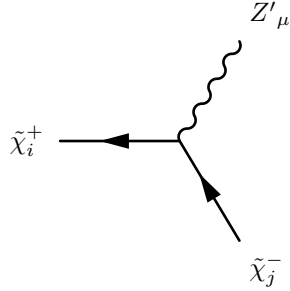

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$$\begin{aligned} & \frac{i}{2} \left( 2g_2 U_{j1}^* \cos \Theta_W \cos \Theta'_W U_{i1} \right. \\ & \left. + U_{j2}^* \left( -2g_p Q_{H_d} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) U_{i2} \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \end{aligned} \quad (276)$$

$$\begin{aligned} & + \frac{i}{2} \left( 2g_2 V_{i1}^* \cos \Theta_W \cos \Theta'_W V_{j1} \right. \\ & \left. + V_{i2}^* \left( 2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) V_{j2} \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \end{aligned} \quad (277)$$

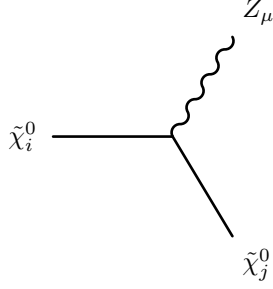

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$$\begin{aligned} & - \frac{i}{2} \left( 2g_2 U_{j1}^* \cos \Theta_W \sin \Theta'_W U_{i1} \right. \\ & \left. + U_{j2}^* \left( 2g_p Q_{H_d} \cos \Theta'_W + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) U_{i2} \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \end{aligned} \quad (278)$$

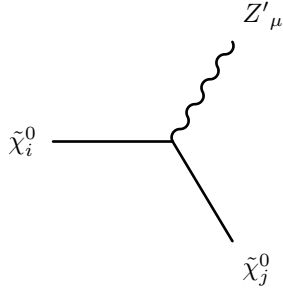
$$\begin{aligned} & + - \frac{i}{2} \left( 2g_2 V_{i1}^* \cos \Theta_W \sin \Theta'_W V_{j1} \right. \\ & \left. + V_{i2}^* \left( -2g_p Q_{H_u} \cos \Theta'_W + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) V_{j2} \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \end{aligned} \quad (279)$$


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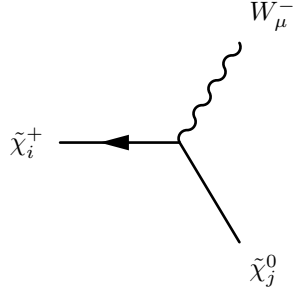
$$\begin{aligned}
& -\frac{i}{2} \left( N_{j4}^* \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) N_{i4} \right. \\
& - N_{j5}^* \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) N_{i5} \\
& \left. + 2g_p Q_s N_{j6}^* \sin \Theta'_W N_{i6} \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \tag{280}
\end{aligned}$$

$$\begin{aligned}
& +\frac{i}{2} \left( N_{i4}^* \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) N_{j4} \right. \\
& - N_{i5}^* \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) N_{j5} \\
& \left. + 2g_p Q_s N_{i6}^* \sin \Theta'_W N_{j6} \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \tag{281}
\end{aligned}$$



$$\begin{aligned}
& -\frac{i}{2} \left( N_{j4}^* \left( 2g_p Q_{H_d} \cos \Theta'_W - \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) N_{i4} \right. \\
& + N_{j5}^* \left( 2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W + g_2 \cos \Theta_W \sin \Theta'_W \right) N_{i5} \\
& \left. + 2g_p Q_s N_{j6}^* \cos \Theta'_W N_{i6} \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \tag{282}
\end{aligned}$$

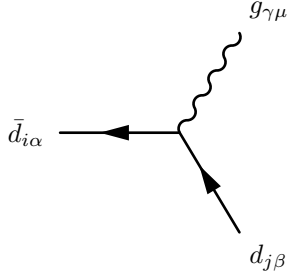
$$\begin{aligned}
& +\frac{i}{2} \left( N_{i4}^* \left( 2g_p Q_{H_d} \cos \Theta'_W - \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) N_{j4} \right. \\
& + N_{i5}^* \left( 2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W + g_2 \cos \Theta_W \sin \Theta'_W \right) N_{j5} \\
& \left. + 2g_p Q_s N_{i6}^* \cos \Theta'_W N_{j6} \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \tag{283}
\end{aligned}$$



$$-\frac{i}{2}g_2\left(2N_{j3}^*U_{i1} + \sqrt{2}N_{j4}^*U_{i2}\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (284)$$

$$+ \left(i\frac{1}{\sqrt{2}}g_2V_{i2}^*N_{j5} - ig_2V_{i1}^*N_{j3}\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (285)$$

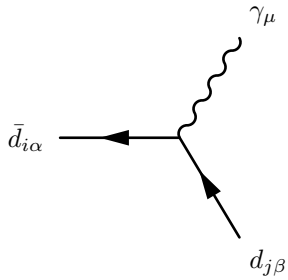

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$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (286)$$

$$+ -\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (287)$$

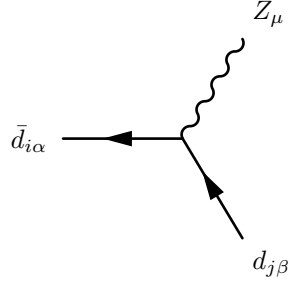

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$$-\frac{i}{6}\delta_{\alpha,\beta}\delta_{ij}\left(-3g_2\sin\Theta_W + g_1\cos\Theta_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (288)$$

$$+ \frac{i}{3} g_1 \cos \Theta_W \delta_{\alpha\beta} \delta_{ij} \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (289)$$

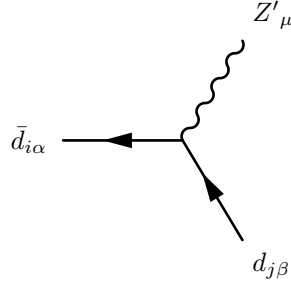

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$$\frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \left( 3g_2 \cos \Theta_W \cos \Theta'_W - 6g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (290)$$

$$+ -\frac{i}{3} \delta_{\alpha\beta} \delta_{ij} \left( -3g_p Q_d \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (291)$$

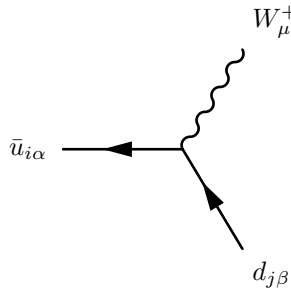

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$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \left( \left( 3g_2 \cos \Theta_W + g_1 \sin \Theta_W \right) \sin \Theta'_W + 6g_p Q_q \cos \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (292)$$

$$+ \frac{i}{3} \delta_{\alpha\beta} \delta_{ij} \left( 3g_p Q_d \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (293)$$

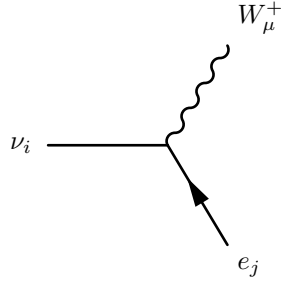

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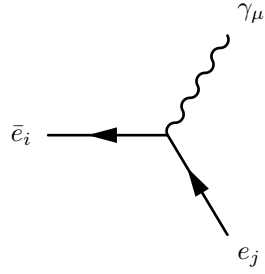
$$-i \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \sum_{a=1}^3 U_{L,ja}^{d,*} U_{L,ia}^u \left( \gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (294)$$


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$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 U_{L,ja}^{e,*} U_{ia}^V \left( \gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (295)$$

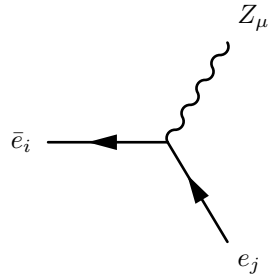

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$$\frac{i}{2} \delta_{ij} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left( \gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (296)$$

$$+ i g_1 \cos \Theta_W \delta_{ij} \left( \gamma_\mu \cdot \frac{1+\gamma_5}{2} \right) \quad (297)$$

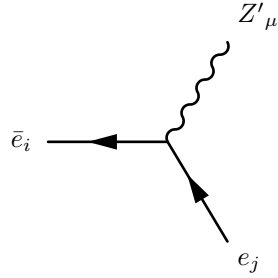

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$$\frac{i}{2}\delta_{ij}\left(-2g_p Q_q \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (298)$$

$$+ -i\delta_{ij}\left(g_1 \cos \Theta'_W \sin \Theta_W - g_p Q_e \sin \Theta'_W\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (299)$$

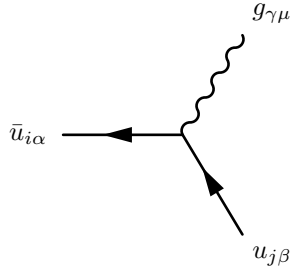

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$$- \frac{i}{2}\delta_{ij}\left(2g_p Q_q \cos \Theta'_W + \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W\right) \sin \Theta'_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (300)$$

$$+ i\delta_{ij}\left(g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_e \cos \Theta'_W\right)\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (301)$$

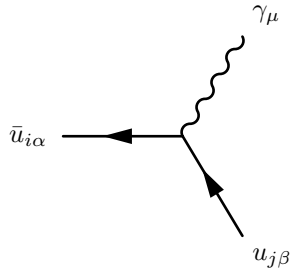

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$$- \frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (302)$$

$$+ -\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (303)$$

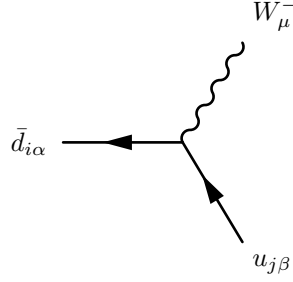

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$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (304)$$

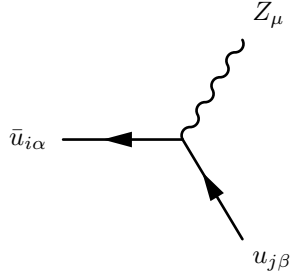
$$+\frac{2i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (305)$$


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$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3U_{L,ja}^{u,*}U_{L,ia}^d\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (306)$$

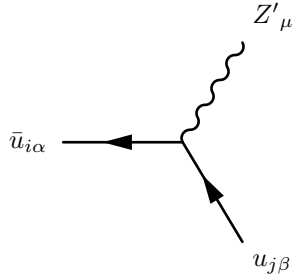

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$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\cos\Theta_W\cos\Theta'_W+6g_pQ_q\sin\Theta'_W-g_1\cos\Theta'_W\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (307)$$

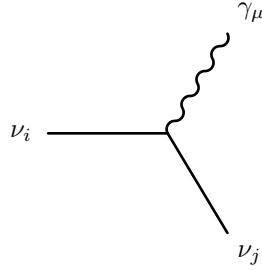
$$+\frac{i}{3}\delta_{\alpha\beta}\delta_{ij}\left(2g_1\cos\Theta'_W\sin\Theta_W+3g_pQ_u\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (308)$$


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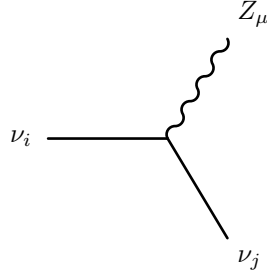
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(\left(-3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (309)$$

$$+\frac{i}{3}\delta_{\alpha\beta}\delta_{ij}\left(-2g_1\sin\Theta_W\sin\Theta'_W+3g_pQ_u\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (310)$$



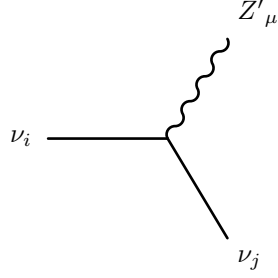
$$\frac{i}{2}\left(-2g_1\cos\Theta_W\sum_{a=1}^3U_{j3+a}^{V,*}U_{i3+a}^V+(g_1\cos\Theta_W-g_2\sin\Theta_W)\sum_{a=1}^3U_{ja}^{V,*}U_{ia}^V\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (311)$$

$$+\frac{i}{2}\left(-2g_1\cos\Theta_W\sum_{a=1}^3U_{i3+a}^{V,*}U_{j3+a}^V+(g_1\cos\Theta_W-g_2\sin\Theta_W)\sum_{a=1}^3U_{ia}^{V,*}U_{ja}^V\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (312)$$



$$-\frac{i}{2}\left(\left(2g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W\right)\sum_{a=1}^3U_{ja}^{V,*}U_{ia}^V\right. \\ \left.+2\left(-g_1\cos\Theta'_W\sin\Theta_W+g_pQ_v\sin\Theta'_W\right)\sum_{a=1}^3U_{j3+a}^{V,*}U_{i3+a}^V\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (313)$$

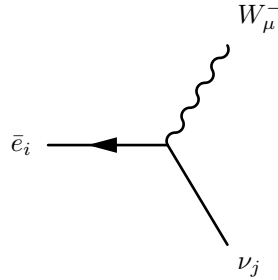
$$+\frac{i}{2}\left(\left(2g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W\right)\sum_{a=1}^3U_{ia}^{V,*}U_{ja}^V\right. \\ \left.+2\left(-g_1\cos\Theta'_W\sin\Theta_W+g_pQ_v\sin\Theta'_W\right)\sum_{a=1}^3U_{i3+a}^{V,*}U_{j3+a}^V\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (314)$$



$$\begin{aligned}
& -\frac{i}{2} \left( (2g_p Q_q \cos \Theta'_W - (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W) \sum_{a=1}^3 U_{ja}^{V,*} U_{ia}^V \right. \\
& \left. + 2 \left( g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_v \cos \Theta'_W \right) \sum_{a=1}^3 U_{j3+a}^{V,*} U_{i3+a}^V \right) \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (315)
\end{aligned}$$

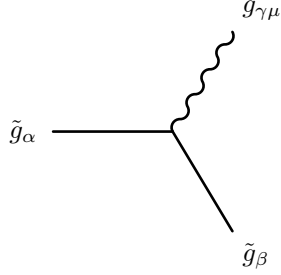
$$\begin{aligned}
& +\frac{i}{2} \left( (2g_p Q_q \cos \Theta'_W - (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W) \sum_{a=1}^3 U_{ia}^{V,*} U_{ja}^V \right. \\
& \left. + 2 \left( g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_v \cos \Theta'_W \right) \sum_{a=1}^3 U_{i3+a}^{V,*} U_{j3+a}^V \right) \left( \gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (316)
\end{aligned}$$


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$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 U_{ja}^{V,*} U_{L,ia}^e \left( \gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (317)$$

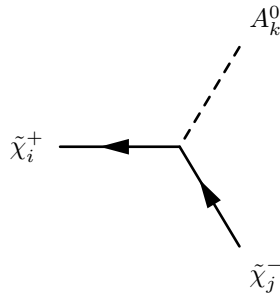

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$$-g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \quad (318)$$

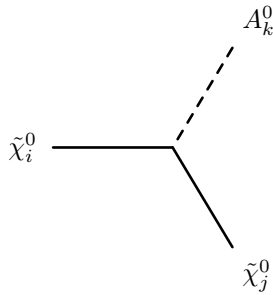
$$+ -g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \quad (319)$$

## 9.5 Two Fermion-One Scalar Boson-Interaction

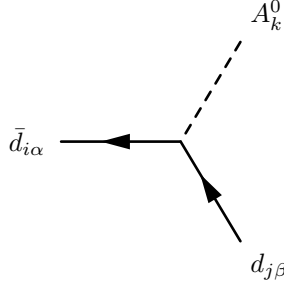


$$\frac{1}{\sqrt{2}}\left(-g_2 U_{j1}^* V_{i2}^* Z_{k2}^{A,*} + U_{j2}^*\left(-g_2 V_{i1}^* Z_{k1}^{A,*} + \lambda V_{i2}^* Z_{k3}^{A,*}\right)\right)\left(\frac{1-\gamma_5}{2}\right) \quad (320)$$

$$+ \frac{1}{\sqrt{2}}\left(g_2 Z_{k1}^{A,*} U_{i2} V_{j1} + \left(g_2 Z_{k2}^{A,*} U_{i1} - \lambda^* Z_{k3}^{A,*} U_{i2}\right) V_{j2}\right)\left(\frac{1+\gamma_5}{2}\right) \quad (321)$$

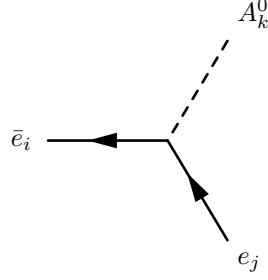


$$\begin{aligned}
& \frac{1}{2} \left( -Z_{k3}^{A,*} \left( 2g_p Q_s N_{i1}^* N_{j6}^* + 2g_p Q_s N_{i6}^* N_{j1}^* + \sqrt{2}\lambda N_{i4}^* N_{j5}^* + \sqrt{2}\lambda N_{i5}^* N_{j4}^* \right) \right. \\
& - Z_{k2}^{A,*} \left( N_{i5}^* \left( 2g_p Q_{H_u} N_{j1}^* + g_1 N_{j2}^* - g_2 N_{j3}^* \right) + \sqrt{2}\lambda N_{i6}^* N_{j4}^* + 2g_p Q_{H_u} N_{i1}^* N_{j5}^* + g_1 N_{i2}^* N_{j5}^* \right. \\
& \left. \left. - g_2 N_{i3}^* N_{j5}^* + \sqrt{2}\lambda N_{i4}^* N_{j6}^* \right) \right. \\
& - Z_{k1}^{A,*} \left( N_{i4}^* \left( 2g_p Q_{H_d} N_{j1}^* - g_1 N_{j2}^* + g_2 N_{j3}^* \right) + 2g_p Q_{H_d} N_{i1}^* N_{j4}^* - g_1 N_{i2}^* N_{j4}^* + g_2 N_{i3}^* N_{j4}^* \right. \\
& \left. \left. + \sqrt{2}\lambda N_{i6}^* N_{j5}^* + \sqrt{2}\lambda N_{i5}^* N_{j6}^* \right) \right) \left( \frac{1-\gamma_5}{2} \right) \tag{322} \\
& + \frac{1}{2} \left( Z_{k3}^{A,*} \left( 2g_p Q_s N_{i1} N_{j6} + 2g_p Q_s N_{i6} N_{j1} + \sqrt{2}\lambda^* \left( N_{i4} N_{j5} + N_{i5} N_{j4} \right) \right) \right. \\
& + Z_{k1}^{A,*} \left( N_{i4} \left( 2g_p Q_{H_d} N_{j1} - g_1 N_{j2} + g_2 N_{j3} \right) + 2g_p Q_{H_d} N_{i1} N_{j4} - g_1 N_{i2} N_{j4} + g_2 N_{i3} N_{j4} \right. \\
& \left. \left. + \sqrt{2}\lambda^* N_{i6} N_{j5} + \sqrt{2}\lambda^* N_{i5} N_{j6} \right) \right. \\
& + Z_{k2}^{A,*} \left( N_{i5} \left( 2g_p Q_{H_u} N_{j1} + g_1 N_{j2} - g_2 N_{j3} \right) + \left( 2g_p Q_{H_u} N_{i1} + g_1 N_{i2} - g_2 N_{i3} \right) N_{j5} \right. \\
& \left. \left. + \sqrt{2}\lambda^* \left( N_{i4} N_{j6} + N_{i6} N_{j4} \right) \right) \right) \left( \frac{1+\gamma_5}{2} \right) \tag{323}
\end{aligned}$$



$$\frac{1}{\sqrt{2}} Z_{k1}^{A,*} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} \left( \frac{1-\gamma_5}{2} \right) \tag{324}$$

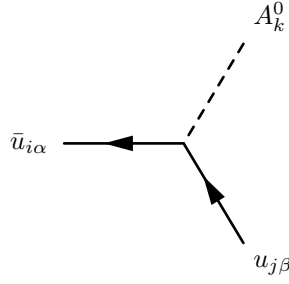
$$+ -\frac{1}{\sqrt{2}} Z_{k1}^{A,*} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d \left( \frac{1+\gamma_5}{2} \right) \tag{325}$$



$$\frac{1}{\sqrt{2}} Z_{k1}^{A,*} \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (326)$$

$$+ -\frac{1}{\sqrt{2}} Z_{k1}^{A,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e \left( \frac{1+\gamma_5}{2} \right) \quad (327)$$

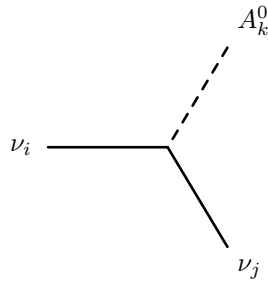

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$$\frac{1}{\sqrt{2}} Z_{k2}^{A,*} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (328)$$

$$+ -\frac{1}{\sqrt{2}} Z_{k2}^{A,*} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^u \left( \frac{1+\gamma_5}{2} \right) \quad (329)$$

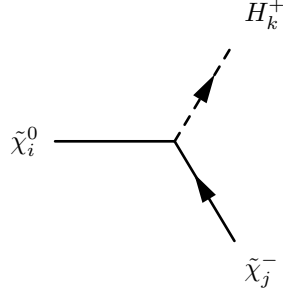

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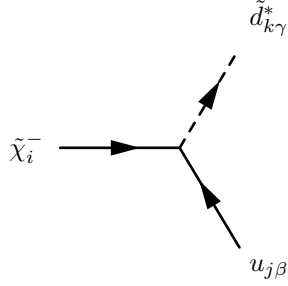
$$\frac{1}{\sqrt{2}}Z_{k2}^{A,*} \left( \sum_{b=1}^3 U_{j3+b}^{V,*} \sum_{a=1}^3 U_{ia}^{V,*} Y_{\nu,ab} + \sum_{b=1}^3 U_{i3+b}^{V,*} \sum_{a=1}^3 U_{ja}^{V,*} Y_{\nu,ab} \right) \left( \frac{1-\gamma_5}{2} \right) \quad (330)$$

$$+ -\frac{1}{\sqrt{2}}Z_{k2}^{A,*} \left( \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ab}^* U_{ja}^V U_{i3+b}^V + \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ab}^* U_{ia}^V U_{j3+b}^V \right) \left( \frac{1+\gamma_5}{2} \right) \quad (331)$$



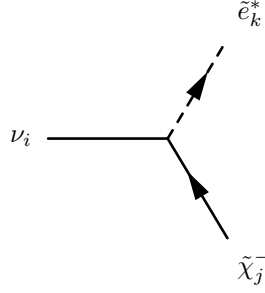
$$- \frac{i}{2} \left( 2g_2 U_{j1}^* N_{i4}^* Z_{k1}^+ + U_{j2}^* \left( 2\lambda N_{i6}^* Z_{k2}^+ + 2\sqrt{2}g_p Q_{H_d} N_{i1}^* Z_{k1}^+ - \sqrt{2}g_1 N_{i2}^* Z_{k1}^+ - \sqrt{2}g_2 N_{i3}^* Z_{k1}^+ \right) \right) \left( \frac{1-\gamma_5}{2} \right) \quad (332)$$

$$+ -\frac{i}{2} \left( \left( 2g_2 V_{j1} N_{i5} + \sqrt{2}V_{j2} \left( 2g_p Q_{H_u} N_{i1} + g_1 N_{i2} + g_2 N_{i3} \right) \right) Z_{k2}^+ + 2\lambda^* V_{j2} N_{i6} Z_{k1}^+ \right) \left( \frac{1+\gamma_5}{2} \right) \quad (333)$$



$$- i\delta_{\beta\gamma} \left( g_2 U_{i1}^* \sum_{a=1}^3 U_{L,ja}^{u,*} Z_{ka}^D - U_{i2}^* \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \right) \left( \frac{1-\gamma_5}{2} \right) \quad (334)$$

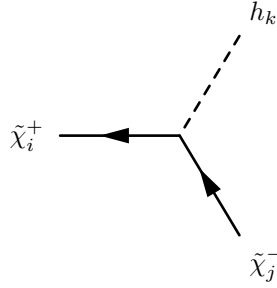
$$+ i\delta_{\beta\gamma} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u Z_{kb}^D V_{i2} \left( \frac{1+\gamma_5}{2} \right) \quad (335)$$



$$-i \left( g_2 U_{j1}^* \sum_{a=1}^3 U_{ia}^{V,*} Z_{ka}^E - U_{j2}^* \sum_{b=1}^3 U_{ib}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \right) \left( \frac{1-\gamma_5}{2} \right) \quad (336)$$

$$+ i \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ab}^* Z_{ka}^E U_{i3+b}^V V_{j2} \left( \frac{1+\gamma_5}{2} \right) \quad (337)$$

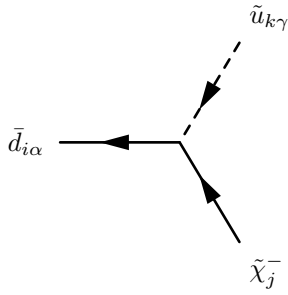

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$$-i \frac{1}{\sqrt{2}} \left( g_2 U_{j1}^* V_{i2}^* Z_{k2}^{H,*} + U_{j2}^* \left( g_2 V_{i1}^* Z_{k1}^{H,*} + \lambda V_{i2}^* Z_{k3}^{H,*} \right) \right) \left( \frac{1-\gamma_5}{2} \right) \quad (338)$$

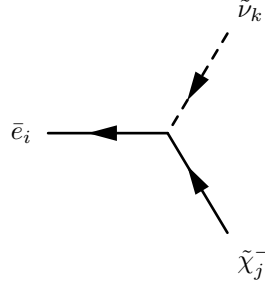
$$+ -i \frac{1}{\sqrt{2}} \left( g_2 Z_{k1}^{H,*} U_{i2} V_{j1} + \left( g_2 Z_{k2}^{H,*} U_{i1} + \lambda^* Z_{k3}^{H,*} U_{i2} \right) V_{j2} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (339)$$


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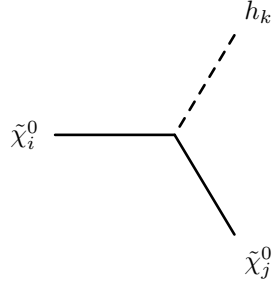
$$iU_{j2}^* \delta_{\alpha\gamma} \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (340)$$

$$+ -i\delta_{\alpha\gamma} \left( g_2 \sum_{a=1}^3 Z_{ka}^{U,*} U_{L,ia}^d V_{j1} - \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} U_{L,ib}^d V_{j2} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (341)$$



$$iU_{j2}^* \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (342)$$

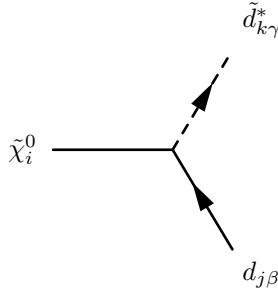
$$+ -i \left( g_2 \sum_{a=1}^3 Z_{ka}^{V,*} U_{L,ia}^e V_{j1} - \sum_{b=1}^3 Z_{k3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* U_{L,ia}^e V_{j2} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (343)$$



$$\begin{aligned} & -\frac{i}{2} \left( Z_{k3}^{H,*} \left( 2g_p Q_s N_{i1}^* N_{j6}^* + 2g_p Q_s N_{i6}^* N_{j1}^* - \sqrt{2}\lambda N_{i4}^* N_{j5}^* - \sqrt{2}\lambda N_{i5}^* N_{j4}^* \right) \right. \\ & + Z_{k2}^{H,*} \left( N_{i5}^* \left( 2g_p Q_{H_u} N_{j1}^* + g_1 N_{j2}^* - g_2 N_{j3}^* \right) - \sqrt{2}\lambda N_{i6}^* N_{j4}^* + 2g_p Q_{H_u} N_{i1}^* N_{j5}^* + g_1 N_{i2}^* N_{j5}^* \right. \\ & \left. \left. - g_2 N_{i3}^* N_{j5}^* - \sqrt{2}\lambda N_{i4}^* N_{j6}^* \right) \right. \\ & + Z_{k1}^{H,*} \left( N_{i4}^* \left( 2g_p Q_{H_d} N_{j1}^* - g_1 N_{j2}^* + g_2 N_{j3}^* \right) + 2g_p Q_{H_d} N_{i1}^* N_{j4}^* - g_1 N_{i2}^* N_{j4}^* + g_2 N_{i3}^* N_{j4}^* \right. \\ & \left. \left. - \sqrt{2}\lambda N_{i6}^* N_{j5}^* - \sqrt{2}\lambda N_{i5}^* N_{j6}^* \right) \right) \left( \frac{1-\gamma_5}{2} \right) \quad (344) \end{aligned}$$

$$\begin{aligned}
& + \frac{i}{2} \left( Z_{k3}^{H,*} \left( 2g_p Q_s N_{i1} N_{j6} + 2g_p Q_s N_{i6} N_{j1} - \sqrt{2} \lambda^* \left( N_{i4} N_{j5} + N_{i5} N_{j4} \right) \right) \right. \\
& + Z_{k1}^{H,*} \left( N_{i4} \left( 2g_p Q_{H_d} N_{j1} - g_1 N_{j2} + g_2 N_{j3} \right) + 2g_p Q_{H_d} N_{i1} N_{j4} - g_1 N_{i2} N_{j4} + g_2 N_{i3} N_{j4} \right. \\
& \left. \left. - \sqrt{2} \lambda^* N_{i6} N_{j5} - \sqrt{2} \lambda^* N_{i5} N_{j6} \right) \right. \\
& + Z_{k2}^{H,*} \left( N_{i5} \left( 2g_p Q_{H_u} N_{j1} + g_1 N_{j2} - g_2 N_{j3} \right) + \left( 2g_p Q_{H_u} N_{i1} + g_1 N_{i2} - g_2 N_{i3} \right) N_{j5} \right. \\
& \left. \left. - \sqrt{2} \lambda^* \left( N_{i4} N_{j6} + N_{i6} N_{j4} \right) \right) \right) \left( \frac{1 + \gamma_5}{2} \right) \tag{345}
\end{aligned}$$

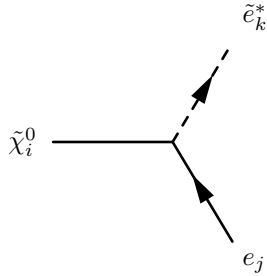

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$$\begin{aligned}
& - \frac{i}{6} \delta_{\beta\gamma} \left( 6\sqrt{2} g_p Q_q N_{i1}^* \sum_{a=1}^3 U_{L,ja}^{d,*} Z_{ka}^D + \sqrt{2} g_1 N_{i2}^* \sum_{a=1}^3 U_{L,ja}^{d,*} Z_{ka}^D - 3\sqrt{2} g_2 N_{i3}^* \sum_{a=1}^3 U_{L,ja}^{d,*} Z_{ka}^D \right. \\
& \left. + 6N_{i4}^* \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \right) \left( \frac{1 - \gamma_5}{2} \right) \tag{346}
\end{aligned}$$

$$\begin{aligned}
& + \frac{i}{3} \delta_{\beta\gamma} \left( 3 \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d Z_{kb}^D N_{i4} + \sqrt{2} \sum_{a=1}^3 Z_{k3+a}^D U_{R,ja}^d \left( 3g_p Q_d N_{i1} + g_1 N_{i2} \right) \right) \left( \frac{1 + \gamma_5}{2} \right) \tag{347}
\end{aligned}$$

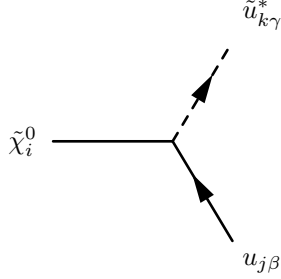

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$$\begin{aligned}
& - \frac{i}{2} \left( 2\sqrt{2} g_p Q_q N_{i1}^* \sum_{a=1}^3 U_{L,ja}^{e,*} Z_{ka}^E - \sqrt{2} g_1 N_{i2}^* \sum_{a=1}^3 U_{L,ja}^{e,*} Z_{ka}^E - \sqrt{2} g_2 N_{i3}^* \sum_{a=1}^3 U_{L,ja}^{e,*} Z_{ka}^E \right.
\end{aligned}$$

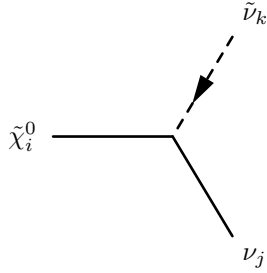
$$+ 2N_{i4}^* \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \left( \frac{1-\gamma_5}{2} \right) \quad (348)$$

$$+ -i \left( \sqrt{2} \sum_{a=1}^3 Z_{k3+a}^E U_{R,ja}^e (g_1 N_{i2} + g_p Q_e N_{i1}) + \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e Z_{kb}^E N_{i4} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (349)$$



$$- \frac{i}{6} \delta_{\beta\gamma} \left( 6\sqrt{2} g_p Q_q N_{i1}^* \sum_{a=1}^3 U_{L,ja}^{u,*} Z_{ka}^U + \sqrt{2} g_1 N_{i2}^* \sum_{a=1}^3 U_{L,ja}^{u,*} Z_{ka}^U + 3\sqrt{2} g_2 N_{i3}^* \sum_{a=1}^3 U_{L,ja}^{u,*} Z_{ka}^U \right. \\ \left. + 6N_{i5}^* \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \right) \left( \frac{1-\gamma_5}{2} \right) \quad (350)$$

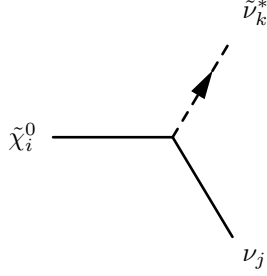
$$+ -\frac{i}{3} \delta_{\beta\gamma} \left( 3 \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u Z_{kb}^U N_{i5} + \sqrt{2} \sum_{a=1}^3 Z_{k3+a}^U U_{R,ja}^u (-2g_1 N_{i2} + 3g_p Q_u N_{i1}) \right) \left( \frac{1+\gamma_5}{2} \right) \quad (351)$$



$$- i \left( \sqrt{2} g_p Q_v N_{i1}^* \sum_{a=1}^3 U_{j3+a}^{V,*} Z_{k3+a}^{V,*} + \sqrt{2} g_1 N_{i2}^* \sum_{a=1}^3 U_{j3+a}^{V,*} Z_{k3+a}^{V,*} \right. \\ \left. + N_{i5}^* \sum_{b=1}^3 U_{j3+b}^{V,*} \sum_{a=1}^3 Z_{ka}^{V,*} Y_{\nu,ab} \right) \left( \frac{1-\gamma_5}{2} \right) \quad (352)$$

$$+ -\frac{i}{2} \left( 2 \sum_{b=1}^3 Z_{k3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* U_{ja}^V N_{i5} + \sqrt{2} \sum_{a=1}^3 Z_{ka}^{V,*} U_{ja}^V (2g_p Q_q N_{i1} - g_1 N_{i2} + g_2 N_{i3}) \right) \left( \frac{1+\gamma_5}{2} \right) \quad (353)$$

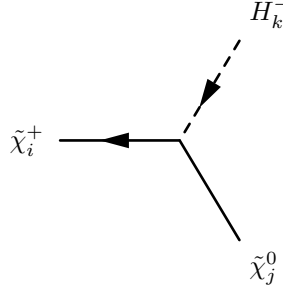

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$$-\frac{i}{2} \left( 2\sqrt{2}g_p Q_q N_{i1}^* \sum_{a=1}^3 U_{ja}^{V,*} Z_{ka}^V - \sqrt{2}g_1 N_{i2}^* \sum_{a=1}^3 U_{ja}^{V,*} Z_{ka}^V + \sqrt{2}g_2 N_{i3}^* \sum_{a=1}^3 U_{ja}^{V,*} Z_{ka}^V + 2N_{i5}^* \sum_{b=1}^3 \sum_{a=1}^3 U_{ja}^{V,*} Y_{\nu,ab} Z_{k3+b}^V \right) \left( \frac{1-\gamma_5}{2} \right) \quad (354)$$

$$+ -i \left( \sqrt{2} \sum_{a=1}^3 U_{j3+a}^V Z_{k3+a}^V (g_1 N_{i2} + g_p Q_v N_{i1}) + \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ab}^* Z_{ka}^V U_{j3+b}^V N_{i5} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (355)$$

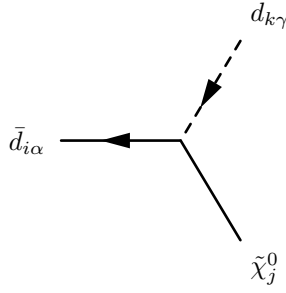

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$$-\frac{i}{2} \left( 2g_2 V_{i1}^* N_{j5}^* Z_{k2}^+ + V_{i2}^* \left( 2\lambda N_{j6}^* Z_{k1}^+ + \sqrt{2} \left( 2g_p Q_{H_u} N_{j1}^* + g_1 N_{j2}^* + g_2 N_{j3}^* \right) Z_{k2}^+ \right) \right) \left( \frac{1-\gamma_5}{2} \right) \quad (356)$$

$$+ -\frac{i}{2} \left( 2g_2 U_{i1} N_{j4} Z_{k1}^+ + U_{i2} \left( 2\lambda^* N_{j6} Z_{k2}^+ + 2\sqrt{2}g_p Q_{H_d} N_{j1} Z_{k1}^+ - \sqrt{2}g_1 N_{j2} Z_{k1}^+ - \sqrt{2}g_2 N_{j3} Z_{k1}^+ \right) \right) \left( \frac{1+\gamma_5}{2} \right) \quad (357)$$

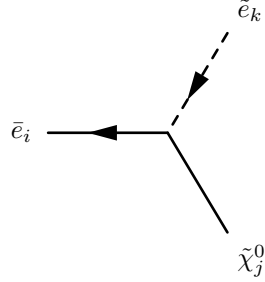

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$$\begin{aligned}
& -\frac{i}{3}\delta_{\alpha\gamma}\left(3\sqrt{2}g_pQ_dN_{j1}^*\sum_{a=1}^3Z_{k3+a}^{D,*}U_{R,ia}^{d,*}+\sqrt{2}g_1N_{j2}^*\sum_{a=1}^3Z_{k3+a}^{D,*}U_{R,ia}^{d,*}\right. \\
& \left.+3N_{j4}^*\sum_{b=1}^3Z_{kb}^{D,*}\sum_{a=1}^3U_{R,ia}^{d,*}Y_{d,ab}\right)\left(\frac{1-\gamma_5}{2}\right) \tag{358}
\end{aligned}$$

$$\begin{aligned}
& +\frac{i}{6}\delta_{\alpha\gamma}\left(6\sum_{b=1}^3\sum_{a=1}^3Y_{d,ab}^*Z_{k3+a}^{D,*}U_{L,ib}^dN_{j4}+\sqrt{2}\sum_{a=1}^3Z_{ka}^{D,*}U_{L,ia}^d\left(-3g_2N_{j3}+6g_pQ_qN_{j1}+g_1N_{j2}\right)\right)\left(\frac{1+\gamma_5}{2}\right) \tag{359}
\end{aligned}$$

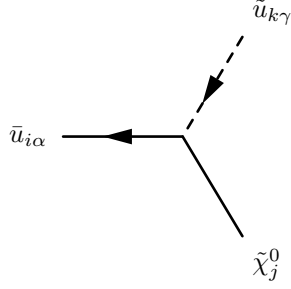

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$$\begin{aligned}
& -i\left(\sqrt{2}g_pQ_eN_{j1}^*\sum_{a=1}^3Z_{k3+a}^{E,*}U_{R,ia}^{e,*}+\sqrt{2}g_1N_{j2}^*\sum_{a=1}^3Z_{k3+a}^{E,*}U_{R,ia}^{e,*}\right. \\
& \left.+N_{j4}^*\sum_{b=1}^3Z_{kb}^{E,*}\sum_{a=1}^3U_{R,ia}^{e,*}Y_{e,ab}\right)\left(\frac{1-\gamma_5}{2}\right) \tag{360}
\end{aligned}$$

$$\begin{aligned}
& +\frac{i}{2}\left(2\sum_{b=1}^3\sum_{a=1}^3Y_{e,ab}^*Z_{k3+a}^{E,*}U_{L,ib}^eN_{j4}+\sqrt{2}\sum_{a=1}^3Z_{ka}^{E,*}U_{L,ia}^e\left(2g_pQ_qN_{j1}-g_1N_{j2}-g_2N_{j3}\right)\right)\left(\frac{1+\gamma_5}{2}\right) \tag{361}
\end{aligned}$$

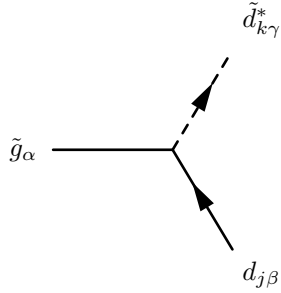

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$$\begin{aligned}
& -\frac{i}{3}\delta_{\alpha\gamma}\left(3\sqrt{2}g_p Q_u N_{j1}^* \sum_{a=1}^3 Z_{k3+a}^{U,*} U_{R,ia}^{u,*} - 2\sqrt{2}g_1 N_{j2}^* \sum_{a=1}^3 Z_{k3+a}^{U,*} U_{R,ia}^{u,*}\right. \\
& \left. + 3N_{j5}^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab}\right)\left(\frac{1-\gamma_5}{2}\right) \tag{362}
\end{aligned}$$

$$\begin{aligned}
& + -\frac{i}{6}\delta_{\alpha\gamma}\left(6 \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} U_{L,ib}^u N_{j5} + \sqrt{2} \sum_{a=1}^3 Z_{ka}^{U,*} U_{L,ia}^u \left(3g_2 N_{j3} + 6g_p Q_q N_{j1} + g_1 N_{j2}\right)\right)\left(\frac{1+\gamma_5}{2}\right) \tag{363}
\end{aligned}$$


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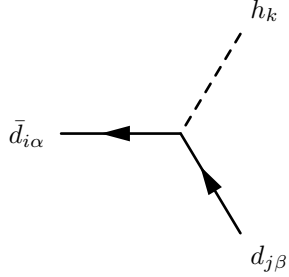


$$\begin{aligned}
& -i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\lambda_{\gamma,\beta}^\alpha \sum_{a=1}^3 U_{L,ja}^{d,*} Z_{ka}^D \left(\frac{1-\gamma_5}{2}\right) \tag{364}
\end{aligned}$$

$$\begin{aligned}
& + i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}^*\lambda_{\gamma,\beta}^\alpha \sum_{a=1}^3 Z_{k3+a}^D U_{R,ja}^d \left(\frac{1+\gamma_5}{2}\right) \tag{365}
\end{aligned}$$

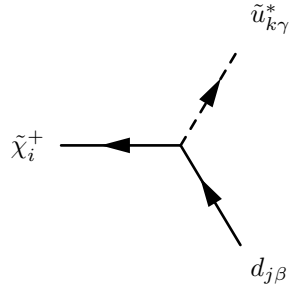

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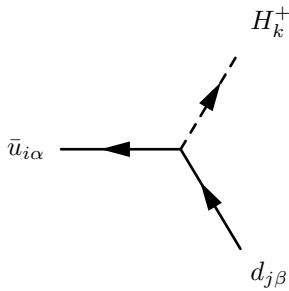
$$-i \frac{1}{\sqrt{2}} Z_{k1}^{H,*} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (366)$$

$$+ -i \frac{1}{\sqrt{2}} Z_{k1}^{H,*} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d \left( \frac{1+\gamma_5}{2} \right) \quad (367)$$



$$-i \delta_{\beta\gamma} \left( g_2 V_{i1}^* \sum_{a=1}^3 U_{L,ja}^{d,*} Z_{ka}^U - V_{i2}^* \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \right) \left( \frac{1-\gamma_5}{2} \right) \quad (368)$$

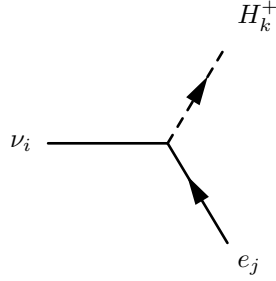
$$+ i \delta_{\beta\gamma} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d Z_{kb}^U U_{i2} \left( \frac{1+\gamma_5}{2} \right) \quad (369)$$



$$i\delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} Z_{k2}^+ \left( \frac{1-\gamma_5}{2} \right) \quad (370)$$

$$+ i\delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^u Z_{k1}^+ \left( \frac{1+\gamma_5}{2} \right) \quad (371)$$

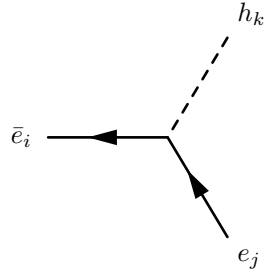

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$$i \sum_{b=1}^3 U_{i3+b}^{V,*} \sum_{a=1}^3 U_{L,ja}^{e,*} Y_{\nu,ab} Z_{k2}^+ \left( \frac{1-\gamma_5}{2} \right) \quad (372)$$

$$+ i \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{ib}^V Z_{k1}^+ \left( \frac{1+\gamma_5}{2} \right) \quad (373)$$

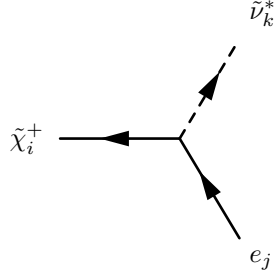

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$$-i \frac{1}{\sqrt{2}} Z_{k1}^{H,*} \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (374)$$

$$+ -i \frac{1}{\sqrt{2}} Z_{k1}^{H,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e \left( \frac{1+\gamma_5}{2} \right) \quad (375)$$

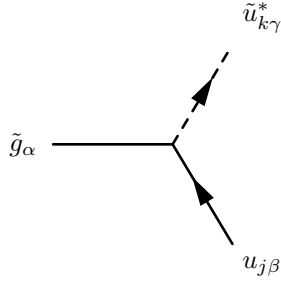

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$$-i \left( g_2 V_{i1}^* \sum_{a=1}^3 U_{L,ja}^{e,*} Z_{ka}^V - V_{i2}^* \sum_{b=1}^3 \sum_{a=1}^3 U_{L,ja}^{e,*} Y_{\nu,ab} Z_{k3+b}^V \right) \left( \frac{1-\gamma_5}{2} \right) \quad (376)$$

$$+ i \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e Z_{kb}^V U_{i2} \left( \frac{1+\gamma_5}{2} \right) \quad (377)$$

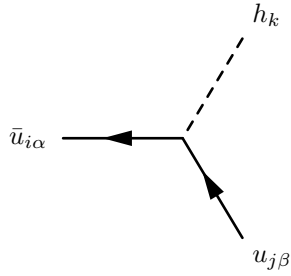

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$$-i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^\alpha \sum_{a=1}^3 U_{L,ja}^{u,*} Z_{ka}^U \left( \frac{1-\gamma_5}{2} \right) \quad (378)$$

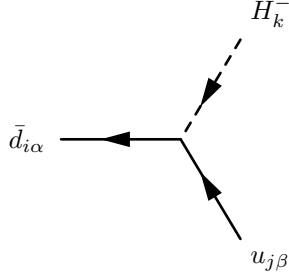
$$+ i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^\alpha \sum_{a=1}^3 Z_{k3+a}^U U_{R,ja}^u \left( \frac{1+\gamma_5}{2} \right) \quad (379)$$


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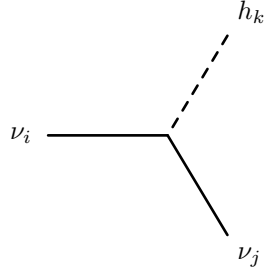
$$-i \frac{1}{\sqrt{2}} Z_{k2}^{H,*} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (380)$$

$$+ -i \frac{1}{\sqrt{2}} Z_{k2}^{H,*} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^u \left( \frac{1+\gamma_5}{2} \right) \quad (381)$$



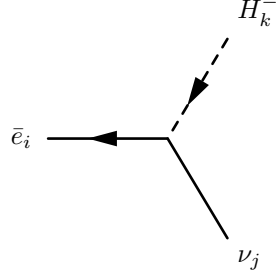
$$i \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^+ \left( \frac{1-\gamma_5}{2} \right) \quad (382)$$

$$+ i \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^d Z_{k2}^+ \left( \frac{1+\gamma_5}{2} \right) \quad (383)$$



$$-i \frac{1}{\sqrt{2}} Z_{k2}^{H,*} \left( \sum_{b=1}^3 U_{j3+b}^{V,*} \sum_{a=1}^3 U_{ia}^{V,*} Y_{\nu,ab} + \sum_{b=1}^3 U_{i3+b}^{V,*} \sum_{a=1}^3 U_{ja}^{V,*} Y_{\nu,ab} \right) \left( \frac{1-\gamma_5}{2} \right) \quad (384)$$

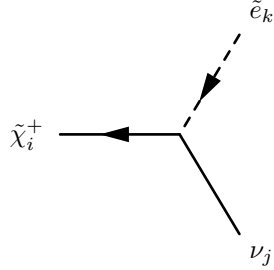
$$+ -i \frac{1}{\sqrt{2}} Z_{k2}^{H,*} \left( \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ab}^* U_{ja}^V U_{i3+b}^V + \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ab}^* U_{ia}^V U_{j3+b}^V \right) \left( \frac{1+\gamma_5}{2} \right) \quad (385)$$



$$i \sum_{b=1}^3 U_{jb}^{V,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} Z_{k1}^+ \left( \frac{1-\gamma_5}{2} \right) \quad (386)$$

$$+ i \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ab}^* U_{L,ia}^e U_{j3+b}^V Z_{k2}^+ \left( \frac{1+\gamma_5}{2} \right) \quad (387)$$

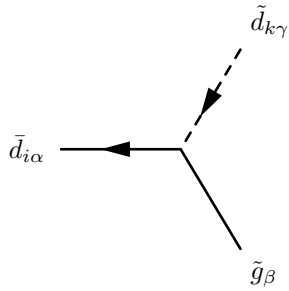

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$$i V_{i2}^* \sum_{b=1}^3 U_{j3+b}^{V,*} \sum_{a=1}^3 Z_{ka}^{E,*} Y_{\nu,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (388)$$

$$+ -i \left( g_2 \sum_{a=1}^3 Z_{ka}^{E,*} U_{ja}^V U_{i1} - \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} U_{jb}^V U_{i2} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (389)$$

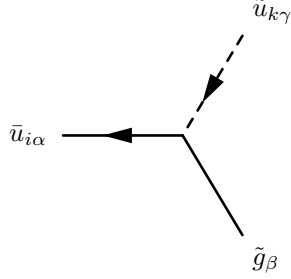

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$$i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\alpha, \gamma}^{\beta} \sum_{a=1}^3 Z_{k3+a}^{D,*} U_{R,ia}^{d,*} \left( \frac{1-\gamma_5}{2} \right) \quad (390)$$

$$+ -i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\alpha, \gamma}^{\beta} \sum_{a=1}^3 Z_{ka}^{D,*} U_{L,ia}^d \left( \frac{1+\gamma_5}{2} \right) \quad (391)$$

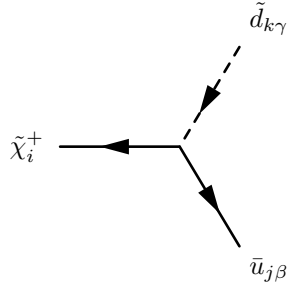

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$$i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\alpha, \gamma}^{\beta} \sum_{a=1}^3 Z_{k3+a}^{U,*} U_{R,ia}^{u,*} \left( \frac{1-\gamma_5}{2} \right) \quad (392)$$

$$+ -i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\alpha, \gamma}^{\beta} \sum_{a=1}^3 Z_{ka}^{U,*} U_{L,ia}^u \left( \frac{1+\gamma_5}{2} \right) \quad (393)$$


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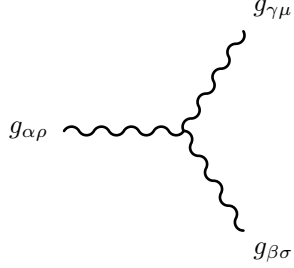


$$i V_{i2}^* \delta_{\beta\gamma} \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 U_{R,ja}^{u,*} Y_{u,ab} \left( \frac{1-\gamma_5}{2} \right) \quad (394)$$

$$+ -i \delta_{\beta\gamma} \left( g_2 \sum_{a=1}^3 Z_{ka}^{D,*} U_{L,ja}^u U_{i1} - \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} U_{L,jb}^u U_{i2} \right) \left( \frac{1+\gamma_5}{2} \right) \quad (395)$$

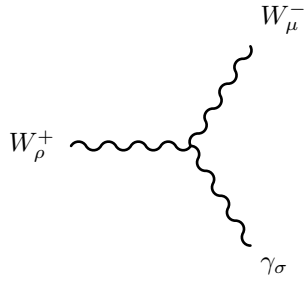

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## 9.6 Three Vector Boson-Interaction



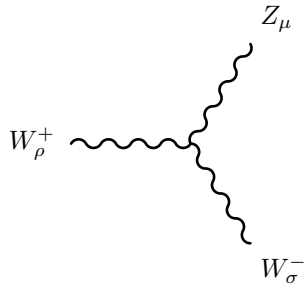
$$g_3 f_{\alpha,\beta,\gamma} \left( g_{\rho\mu} \left( -p_\sigma^{g_{\gamma\mu}} + p_\sigma^{g_{\alpha\rho}} \right) + g_{\rho\sigma} \left( -p_\mu^{g_{\alpha\rho}} + p_\mu^{g_{\beta\sigma}} \right) + g_{\sigma\mu} \left( -p_\rho^{g_{\beta\sigma}} + p_\rho^{g_{\gamma\mu}} \right) \right) \quad (396)$$


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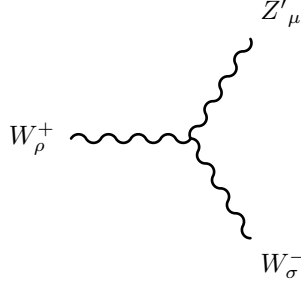
$$ig_2 \sin \Theta_W \left( g_{\rho\mu} \left( -p_\sigma^{W_\mu^-} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left( -p_\mu^{W_\rho^+} + p_\mu^{\gamma_\sigma} \right) + g_{\sigma\mu} \left( -p_\rho^{\gamma_\sigma} + p_\rho^{W_\mu^-} \right) \right) \quad (397)$$


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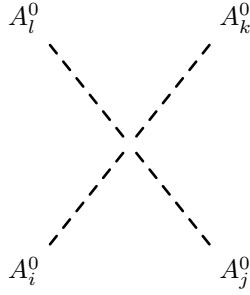
$$-ig_2 \cos \Theta_W \cos \Theta'_W \left( g_{\rho\mu} \left( -p_\sigma^{Z_\mu} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left( -p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-} \right) + g_{\sigma\mu} \left( -p_\rho^{W_\sigma^-} + p_\rho^{Z_\mu} \right) \right) \quad (398)$$


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$$ig_2 \cos \Theta_W \sin \Theta'_W \left( g_{\rho\mu} \left( -p_\sigma^{Z'\mu} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left( -p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-} \right) + g_{\sigma\mu} \left( -p_\rho^{W_\sigma^-} + p_\rho^{Z'\mu} \right) \right) \quad (399)$$

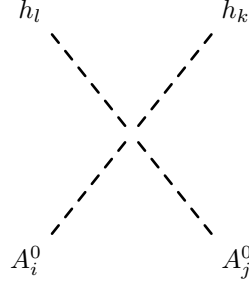
## 9.7 Four Scalar-Interaction



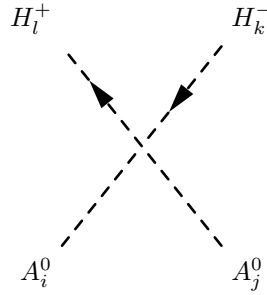
$$\begin{aligned} & -\frac{i}{4} \left( 4Z_{i3}^{A,*} \left( \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{j1}^{A,*} \left( Z_{k1}^{A,*} Z_{l3}^{A,*} + Z_{k3}^{A,*} Z_{l1}^{A,*} \right) \right. \right. \\ & + \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{j2}^{A,*} \left( Z_{k2}^{A,*} Z_{l3}^{A,*} + Z_{k3}^{A,*} Z_{l2}^{A,*} \right) \\ & + Z_{j3}^{A,*} \left( 3g_p^2 Q_s^2 Z_{k3}^{A,*} Z_{l3}^{A,*} + \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k1}^{A,*} Z_{l1}^{A,*} + \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k2}^{A,*} Z_{l2}^{A,*} \right) \\ & + Z_{i1}^{A,*} \left( - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j2}^{A,*} \left( Z_{k1}^{A,*} Z_{l2}^{A,*} + Z_{k2}^{A,*} Z_{l1}^{A,*} \right) \right. \\ & + 4 \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{j3}^{A,*} \left( Z_{k1}^{A,*} Z_{l3}^{A,*} + Z_{k3}^{A,*} Z_{l1}^{A,*} \right) \\ & + Z_{j1}^{A,*} \left( 3 \left( 4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) Z_{k1}^{A,*} Z_{l1}^{A,*} - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k2}^{A,*} Z_{l2}^{A,*} \right. \\ & + \left. \left. 4 \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k3}^{A,*} Z_{l3}^{A,*} \right) \right) \\ & + Z_{i2}^{A,*} \left( - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j1}^{A,*} \left( Z_{k1}^{A,*} Z_{l2}^{A,*} + Z_{k2}^{A,*} Z_{l1}^{A,*} \right) \right. \\ & + 4 \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{j3}^{A,*} \left( Z_{k2}^{A,*} Z_{l3}^{A,*} + Z_{k3}^{A,*} Z_{l2}^{A,*} \right) \\ & + Z_{j2}^{A,*} \left( - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k1}^{A,*} Z_{l1}^{A,*} + 3 \left( 4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{k2}^{A,*} Z_{l2}^{A,*} \right) \end{aligned}$$



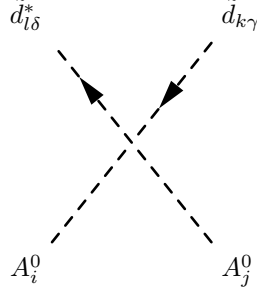
$$+ 4(g_p^2 Q_{H_u} Q_s + |\lambda|^2) Z_{k3}^{A,*} Z_{l3}^{A,*}))) \quad (400)$$



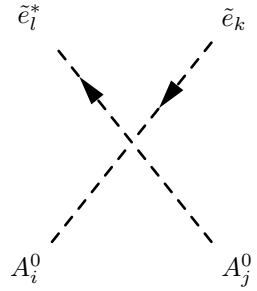
$$\begin{aligned}
& -\frac{i}{4} \left( 4Z_{i3}^{A,*} Z_{j3}^{A,*} \left( (g_p^2 Q_{H_d} Q_s + |\lambda|^2) Z_{k1}^{H,*} Z_{l1}^{H,*} + (g_p^2 Q_{H_u} Q_s + |\lambda|^2) Z_{k2}^{H,*} Z_{l2}^{H,*} + g_p^2 Q_s^2 Z_{k3}^{H,*} Z_{l3}^{H,*} \right) \right. \\
& + Z_{i1}^{A,*} Z_{j1}^{A,*} \left( (4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2) Z_{k1}^{H,*} Z_{l1}^{H,*} - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k2}^{H,*} Z_{l2}^{H,*} \right. \\
& + 4(g_p^2 Q_{H_d} Q_s + |\lambda|^2) Z_{k3}^{H,*} Z_{l3}^{H,*} \left. \right) \\
& + Z_{i2}^{A,*} Z_{j2}^{A,*} \left( - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k1}^{H,*} Z_{l1}^{H,*} + \left( 4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{k2}^{H,*} Z_{l2}^{H,*} \right. \\
& \left. \left. + 4(g_p^2 Q_{H_u} Q_s + |\lambda|^2) Z_{k3}^{H,*} Z_{l3}^{H,*} \right) \right) \quad (401)
\end{aligned}$$



$$\begin{aligned}
& -\frac{i}{4} \left( 4Z_{i3}^{A,*} Z_{j3}^{A,*} \left( (g_p^2 Q_{H_d} Q_s + |\lambda|^2) Z_{k1}^+ Z_{l1}^+ + (g_p^2 Q_{H_u} Q_s + |\lambda|^2) Z_{k2}^+ Z_{l2}^+ \right) \right. \\
& + Z_{i1}^{A,*} \left( - \left( -2|\lambda|^2 + g_2^2 \right) Z_{j2}^{A,*} \left( Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right. \\
& + Z_{j1}^{A,*} \left( (4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2) Z_{k1}^+ Z_{l1}^+ + \left( 4g_p^2 Q_{H_d} Q_{H_u} - g_1^2 + g_2^2 \right) Z_{k2}^+ Z_{l2}^+ \right) \\
& + Z_{i2}^{A,*} \left( - \left( -2|\lambda|^2 + g_2^2 \right) Z_{j1}^{A,*} \left( Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right. \\
& \left. \left. + Z_{j2}^{A,*} \left( (4g_p^2 Q_{H_d} Q_{H_u} - g_1^2 + g_2^2) Z_{k1}^+ Z_{l1}^+ + \left( 4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{k2}^+ Z_{l2}^+ \right) \right) \right) \quad (402)
\end{aligned}$$

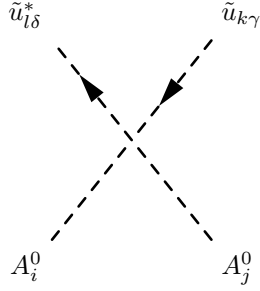


$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left( -6 Z_{i3}^{A,*} \left( 2g_p^2 Q_s Z_{j3}^{A,*} \left( Q_d \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D + Q_q \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right) \right. \right. \\
& + Z_{j2}^{A,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \left. \right) \\
& - Z_{i2}^{A,*} \left( Z_{j2}^{A,*} \left( (12g_p^2 Q_{H_u} Q_q + 3g_2^2 + g_1^2) \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D + 2(6g_p^2 Q_d Q_{H_u} + g_1^2) \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D \right) \right. \\
& + 6Z_{j3}^{A,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \left. \right) \\
& + Z_{i1}^{A,*} Z_{j1}^{A,*} \left( \left( 3(-4g_p^2 Q_{H_d} Q_q + g_2^2) + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right. \\
& + 2 \left( (-6g_p^2 Q_d Q_{H_d} + g_1^2) \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D \right. \\
& \left. \left. - 6 \left( \sum_{c=1}^3 Z_{k3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D \right) \right) \right) \right) \quad (403)
\end{aligned}$$

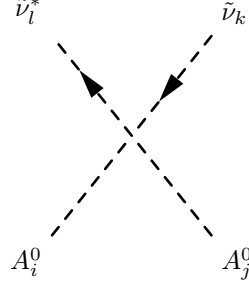


$$- \frac{i}{4} \left( 2Z_{i3}^{A,*} \left( 2g_p^2 Q_s Z_{j3}^{A,*} \left( Q_e \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E + Q_q \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \right) \right) \right)$$

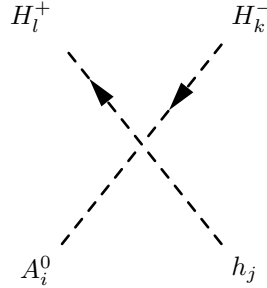
$$\begin{aligned}
& + Z_{j2}^{A,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} Z_{lb}^E + \lambda^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \right) \\
& + Z_{i2}^{A,*} \left( Z_{j2}^{A,*} \left( 2 \left( 2g_p^2 Q_e Q_{H_u} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E + \left( 4g_p^2 Q_{H_u} Q_q - g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \right) \right. \\
& + 2Z_{j3}^{A,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} Z_{lb}^E + \lambda^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \right) \\
& + Z_{i1}^{A,*} Z_{j1}^{A,*} \left( \left( 4g_p^2 Q_{H_d} Q_q - g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E - 2 \left( -2g_p^2 Q_e Q_{H_d} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E \right. \\
& \left. + 4 \left( \sum_{c=1}^3 Z_{k3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{l3+b}^E + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^E \right) \right) \tag{404}
\end{aligned}$$



$$\begin{aligned}
& - \frac{i}{12} \delta_{\gamma\delta} \left( 6Z_{i3}^{A,*} \left( 2g_p^2 Q_s Z_{j3}^{A,*} \left( Q_q \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U + Q_u \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right) \right. \right. \\
& + Z_{j1}^{A,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \right) \left. \right) \\
& + Z_{i1}^{A,*} \left( Z_{j1}^{A,*} \left( \left( 12g_p^2 Q_{H_d} Q_q + 3g_2^2 - g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U + 4 \left( 3g_p^2 Q_{H_d} Q_u + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right) \right. \\
& + 6Z_{j3}^{A,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \right) \\
& + Z_{i2}^{A,*} Z_{j2}^{A,*} \left( \left( 12g_p^2 Q_{H_u} Q_q - 3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U \right. \\
& + 4 \left( - \left( -3g_p^2 Q_{H_u} Q_u + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right. \\
& \left. \left. + 3 \left( \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{l3+b}^U + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^U \right) \right) \right) \tag{405}
\end{aligned}$$

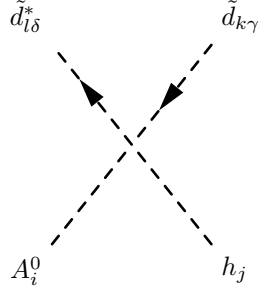


$$\begin{aligned}
& -\frac{i}{4} \left( 2Z_{i3}^{A,*} \left( 2g_p^2 Q_s Z_{j3}^{A,*} \left( Q_q \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^V + Q_v \sum_{a=1}^3 Z_{k3+a}^{V,*} Z_{l3+a}^V \right) \right. \right. \\
& + Z_{j1}^{A,*} \left( \lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ka}^{V,*} Y_{\nu,ab} Z_{l3+b}^V + \lambda \sum_{b=1}^3 Z_{k3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{la}^V \right) \left. \right) \\
& + Z_{i1}^{A,*} \left( Z_{j1}^{A,*} \left( -2 \left( -2g_p^2 Q_{H_d} Q_v + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{V,*} Z_{l3+a}^V + \left( 4g_p^2 Q_{H_d} Q_q + g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^V \right) \right. \\
& + 2Z_{j3}^{A,*} \left( \lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ka}^{V,*} Y_{\nu,ab} Z_{l3+b}^V + \lambda \sum_{b=1}^3 Z_{k3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{la}^V \right) \\
& + Z_{i2}^{A,*} Z_{j2}^{A,*} \left( - \left( -4g_p^2 Q_{H_u} Q_q + g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^V + 2 \left( 2g_p^2 Q_{H_u} Q_v + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{V,*} Z_{l3+a}^V \right. \\
& \left. \left. + 4 \left( \sum_{c=1}^3 Z_{k3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{\nu,ab} Z_{l3+b}^V + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{lc}^V \right) \right) \right) \quad (406)
\end{aligned}$$



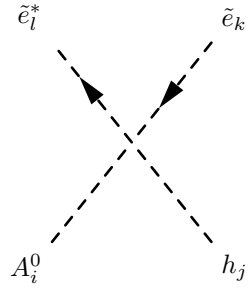
$$\frac{1}{4} \left( -2|\lambda|^2 + g_2^2 \right) \left( Z_{i1}^{A,*} Z_{j2}^{H,*} + Z_{i2}^{A,*} Z_{j1}^{H,*} \right) \left( -Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \quad (407)$$


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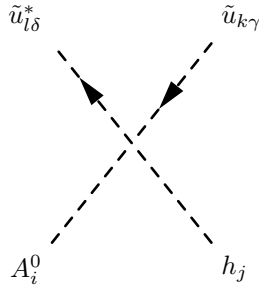
$$\frac{1}{2} \left( Z_{i2}^{A,*} Z_{j3}^{H,*} + Z_{i3}^{A,*} Z_{j2}^{H,*} \right) \delta_{\gamma\delta} \left( -\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \quad (408)$$


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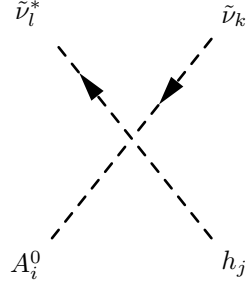
$$\frac{1}{2} \left( Z_{i2}^{A,*} Z_{j3}^{H,*} + Z_{i3}^{A,*} Z_{j2}^{H,*} \right) \left( -\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} Z_{lb}^E + \lambda^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \right) \quad (409)$$


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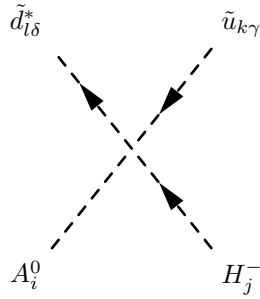
$$\frac{1}{2} \left( Z_{i1}^{A,*} Z_{j3}^{H,*} + Z_{i3}^{A,*} Z_{j1}^{H,*} \right) \delta_{\gamma\delta} \left( -\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \right) \quad (410)$$


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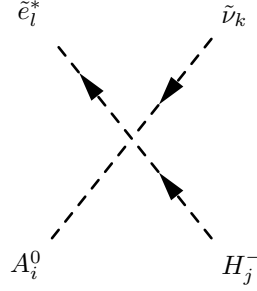
$$-\frac{1}{2} \left( Z_{i1}^{A,*} Z_{j3}^{H,*} + Z_{i3}^{A,*} Z_{j1}^{H,*} \right) \left( -\lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ka}^{V,*} Y_{\nu,ab} Z_{l3+b}^V + \lambda \sum_{b=1}^3 Z_{k3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab} Z_{la}^V \right) \quad (411)$$


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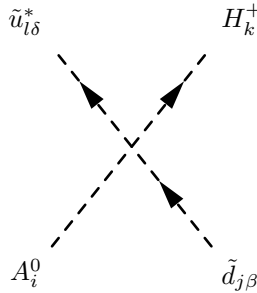


$$\begin{aligned} & \frac{1}{2} \frac{1}{\sqrt{2}} \delta_{\gamma\delta} \left( Z_{i3}^{A,*} \left( -2\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^D Z_{j1}^+ + 2\lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D Z_{j2}^+ \right) \right. \\ & - Z_{i1}^{A,*} \left( g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D Z_{j1}^+ - 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D Z_{j1}^+ \right. \\ & + 2 \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{j2}^+ \left. \right) \\ & + Z_{i2}^{A,*} \left( 2 \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{j1}^+ \right. \\ & \left. + \left( -2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^D + g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D \right) Z_{j2}^+ \right) \end{aligned} \quad (412)$$


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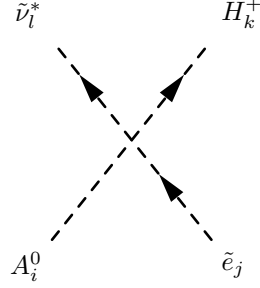
$$\begin{aligned}
& \frac{1}{2} \frac{1}{\sqrt{2}} \left( Z_{i3}^{A,*} \left( -2\lambda \sum_{b=1}^3 Z_{k3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{la}^E Z_{j1}^+ + 2\lambda^* \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E Z_{j2}^+ \right) \right. \\
& - Z_{i1}^{A,*} \left( g_2^2 \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E Z_{j1}^+ - 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^E Z_{j1}^+ \right. \\
& + 2 \sum_{c=1}^3 Z_{k3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{e,ba} Z_{l3+b}^E Z_{j2}^+ \left. \right) \\
& + Z_{i2}^{A,*} \left( 2 \sum_{c=1}^3 Z_{k3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{e,ba} Z_{l3+b}^E Z_{j1}^+ \right. \\
& \left. \left. + \left( -2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{lc}^E + g_2^2 \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E \right) Z_{j2}^+ \right) \right) \quad (413)
\end{aligned}$$



$$\begin{aligned}
& \frac{1}{2} \frac{1}{\sqrt{2}} \delta_{\beta\delta} \left( 2\lambda^* Z_{i3}^{A,*} \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U Z_{k1}^+ - 2Z_{i2}^{A,*} \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{k1}^+ \right. \\
& - g_2^2 Z_{i2}^{A,*} \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^U Z_{k2}^+ - 2\lambda Z_{i3}^{A,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{lb}^U Z_{k2}^+ \\
& \left. + 2Z_{i2}^{A,*} \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^U Z_{k2}^+ \right)
\end{aligned}$$

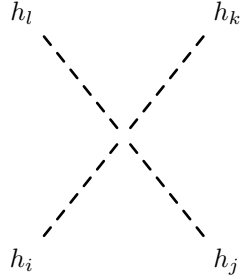
$$\begin{aligned}
& + Z_{i1}^{A,*} \left( g_2^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^U Z_{k1}^+ - 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^U Z_{k1}^+ \right. \\
& \left. + 2 \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{k2}^+ \right) \tag{414}
\end{aligned}$$


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$$\begin{aligned}
& \frac{1}{2} \frac{1}{\sqrt{2}} \left( 2\lambda^* Z_{i3}^{A,*} \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{E,*} Y_{\nu,ab} Z_{l3+b}^V Z_{k1}^+ - 2Z_{i2}^{A,*} \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{\nu,ab} Z_{l3+b}^V Z_{k1}^+ \right. \\
& - g_2^2 Z_{i2}^{A,*} \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^V Z_{k2}^+ - 2\lambda Z_{i3}^{A,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{lb}^V Z_{k2}^+ \\
& + 2Z_{i2}^{A,*} \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{lc}^V Z_{k2}^+ \\
& + Z_{i1}^{A,*} \left( g_2^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^V Z_{k1}^+ - 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^V Z_{k1}^+ \right. \\
& \left. + 2 \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{\nu,ab} Z_{l3+b}^V Z_{k2}^+ \right) \tag{415}
\end{aligned}$$

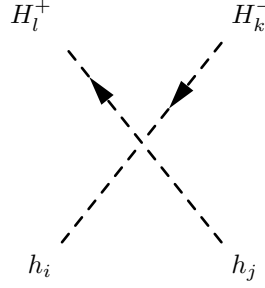

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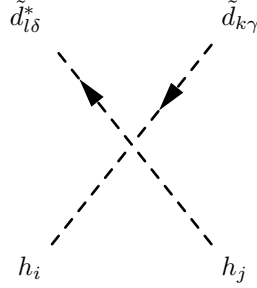
$$-\frac{i}{4} \left( 4Z_{i3}^{H,*} \left( (g_p^2 Q_{H_d} Q_s + |\lambda|^2) Z_{j1}^{H,*} \left( Z_{k1}^{H,*} Z_{l3}^{H,*} + Z_{k3}^{H,*} Z_{l1}^{H,*} \right) \right. \right.$$



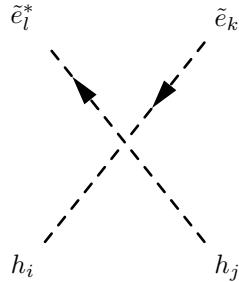
$$\begin{aligned}
& + \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{j2}^{H,*} \left( Z_{k2}^{H,*} Z_{l3}^{H,*} + Z_{k3}^{H,*} Z_{l2}^{H,*} \right) \\
& + Z_{j3}^{H,*} \left( 3g_p^2 Q_s^2 Z_{k3}^{H,*} Z_{l3}^{H,*} + \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k1}^{H,*} Z_{l1}^{H,*} + \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k2}^{H,*} Z_{l2}^{H,*} \right) \\
& + Z_{i1}^{H,*} \left( - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j2}^{H,*} \left( Z_{k1}^{H,*} Z_{l2}^{H,*} + Z_{k2}^{H,*} Z_{l1}^{H,*} \right) \right. \\
& + 4 \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{j3}^{H,*} \left( Z_{k1}^{H,*} Z_{l3}^{H,*} + Z_{k3}^{H,*} Z_{l1}^{H,*} \right) \\
& + Z_{j1}^{H,*} \left( 3 \left( 4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) Z_{k1}^{H,*} Z_{l1}^{H,*} - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k2}^{H,*} Z_{l2}^{H,*} \right. \\
& + 4 \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} Z_{l3}^{H,*} \left. \right) \\
& + Z_{i2}^{H,*} \left( - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j1}^{H,*} \left( Z_{k1}^{H,*} Z_{l2}^{H,*} + Z_{k2}^{H,*} Z_{l1}^{H,*} \right) \right. \\
& + 4 \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{j3}^{H,*} \left( Z_{k2}^{H,*} Z_{l3}^{H,*} + Z_{k3}^{H,*} Z_{l2}^{H,*} \right) \\
& + Z_{j2}^{H,*} \left( - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k1}^{H,*} Z_{l1}^{H,*} + 3 \left( 4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{k2}^{H,*} Z_{l2}^{H,*} \right. \\
& + 4 \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} Z_{l3}^{H,*} \left. \right) \left. \right) \left. \right) \tag{416}
\end{aligned}$$



$$\begin{aligned}
& - \frac{i}{4} \left( 4Z_{i3}^{H,*} Z_{j3}^{H,*} \left( \left( g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k1}^+ Z_{l1}^+ + \left( g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k2}^+ Z_{l2}^+ \right) \right. \\
& + Z_{i1}^{H,*} \left( \left( -2|\lambda|^2 + g_2^2 \right) Z_{j2}^{H,*} \left( Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right. \\
& + Z_{j1}^{H,*} \left( \left( 4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) Z_{k1}^+ Z_{l1}^+ + \left( 4g_p^2 Q_{H_d} Q_{H_u} - g_1^2 + g_2^2 \right) Z_{k2}^+ Z_{l2}^+ \right) \\
& + Z_{i2}^{H,*} \left( \left( -2|\lambda|^2 + g_2^2 \right) Z_{j1}^{H,*} \left( Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right. \\
& + Z_{j2}^{H,*} \left( \left( 4g_p^2 Q_{H_d} Q_{H_u} - g_1^2 + g_2^2 \right) Z_{k1}^+ Z_{l1}^+ + \left( 4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{k2}^+ Z_{l2}^+ \right) \left. \right) \left. \right) \tag{417}
\end{aligned}$$

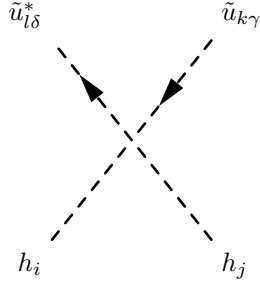


$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left( 6Z_{i3}^{H,*} \left( -2g_p^2 Q_s Z_{j3}^{H,*} \left( Q_d \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D + Q_q \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right) \right. \right. \\
& + Z_{j2}^{H,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \left. \right) \\
& - Z_{i2}^{H,*} \left( Z_{j2}^{H,*} \left( (12g_p^2 Q_{H_u} Q_q + 3g_2^2 + g_1^2) \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D + 2(6g_p^2 Q_d Q_{H_u} + g_1^2) \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D \right) \right. \\
& - 6Z_{j3}^{H,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \left. \right) \\
& + Z_{i1}^{H,*} Z_{j1}^{H,*} \left( (3(-4g_p^2 Q_{H_d} Q_q + g_2^2) + g_1^2) \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right. \\
& + 2 \left( (-6g_p^2 Q_d Q_{H_d} + g_1^2) \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D \right. \\
& \left. \left. - 6 \left( \sum_{c=1}^3 Z_{k3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D \right) \right) \right) \right) \quad (418)
\end{aligned}$$

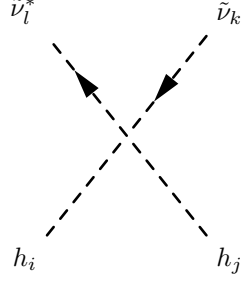


$$- \frac{i}{4} \left( 2Z_{i3}^{H,*} \left( 2g_p^2 Q_s Z_{j3}^{H,*} \left( Q_e \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E + Q_q \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \right) \right) \right.$$

$$\begin{aligned}
& - Z_{j_2}^{H,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k_{3+a}}^{E,*} Z_{lb}^E + \lambda^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l_{3+a}}^E \right) \\
& + Z_{i_2}^{H,*} \left( Z_{j_2}^{H,*} \left( 2 \left( 2g_p^2 Q_e Q_{H_u} + g_1^2 \right) \sum_{a=1}^3 Z_{k_{3+a}}^{E,*} Z_{l_{3+a}}^E + \left( 4g_p^2 Q_{H_u} Q_q - g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \right) \right. \\
& - 2 Z_{j_3}^{H,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k_{3+a}}^{E,*} Z_{lb}^E + \lambda^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l_{3+a}}^E \right) \\
& + Z_{i_1}^{H,*} Z_{j_1}^{H,*} \left( \left( 4g_p^2 Q_{H_d} Q_q - g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E - 2 \left( -2g_p^2 Q_e Q_{H_d} + g_1^2 \right) \sum_{a=1}^3 Z_{k_{3+a}}^{E,*} Z_{l_{3+a}}^E \right. \\
& \left. + 4 \left( \sum_{c=1}^3 Z_{k_{3+c}}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{l_{3+b}}^E + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{l_c}^E \right) \right) \tag{419}
\end{aligned}$$

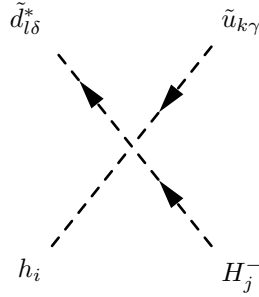


$$\begin{aligned}
& \frac{i}{12} \delta_\gamma \delta_\delta \left( 6 Z_{i_3}^{H,*} \left( -2g_p^2 Q_s Z_{j_3}^{H,*} \left( Q_q \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U + Q_u \sum_{a=1}^3 Z_{k_{3+a}}^{U,*} Z_{l_{3+a}}^U \right) \right. \right. \\
& + Z_{j_1}^{H,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k_{3+a}}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l_{3+a}}^U \right) \\
& + Z_{i_1}^{H,*} \left( Z_{j_1}^{H,*} \left( \left( -3 \left( 4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U - 4 \left( 3g_p^2 Q_{H_d} Q_u + g_1^2 \right) \sum_{a=1}^3 Z_{k_{3+a}}^{U,*} Z_{l_{3+a}}^U \right) \right. \\
& + 6 Z_{j_3}^{H,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k_{3+a}}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l_{3+a}}^U \right) \\
& - Z_{i_2}^{H,*} Z_{j_2}^{H,*} \left( \left( 12g_p^2 Q_{H_u} Q_q - 3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U \right. \\
& \left. + 4 \left( - \left( -3g_p^2 Q_{H_u} Q_u + g_1^2 \right) \sum_{a=1}^3 Z_{k_{3+a}}^{U,*} Z_{l_{3+a}}^U \right. \right. \\
& \left. \left. + 3 \left( \sum_{c=1}^3 Z_{k_{3+c}}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{l_{3+b}}^U + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{l_c}^U \right) \right) \right) \tag{420}
\end{aligned}$$



$$\begin{aligned}
& -\frac{i}{4} \left( 2Z_{i3}^{H,*} \left( 2g_p^2 Q_s Z_{j3}^{H,*} \left( Q_q \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^V + Q_v \sum_{a=1}^3 Z_{k3+a}^{V,*} Z_{l3+a}^V \right) \right. \right. \\
& - Z_{j1}^{H,*} \left( \lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ka}^{V,*} Y_{\nu,ab} Z_{l3+b}^V + \lambda \sum_{b=1}^3 Z_{k3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{la}^V \right) \left. \right) \\
& + Z_{i1}^{H,*} \left( Z_{j1}^{H,*} \left( -2 \left( -2g_p^2 Q_{H_d} Q_v + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{V,*} Z_{l3+a}^V + \left( 4g_p^2 Q_{H_d} Q_q + g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^V \right) \right. \\
& - 2Z_{j3}^{H,*} \left( \lambda^* \sum_{b=1}^3 \sum_{a=1}^3 Z_{ka}^{V,*} Y_{\nu,ab} Z_{l3+b}^V + \lambda \sum_{b=1}^3 Z_{k3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{la}^V \right) \left. \right) \\
& + Z_{i2}^{H,*} Z_{j2}^{H,*} \left( - \left( -4g_p^2 Q_{H_u} Q_q + g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^V + 2 \left( 2g_p^2 Q_{H_u} Q_v + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{V,*} Z_{l3+a}^V \right. \\
& \left. \left. + 4 \left( \sum_{c=1}^3 Z_{k3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{\nu,ab} Z_{l3+b}^V + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{lc}^V \right) \right) \right) \quad (421)
\end{aligned}$$

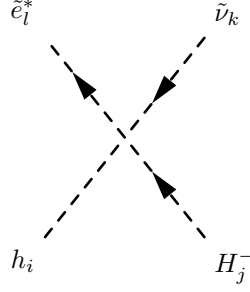

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$$\frac{i}{2} \frac{1}{\sqrt{2}} \delta_{\gamma\delta} \left( 2Z_{i3}^{H,*} \left( \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^D Z_{j1}^+ + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D Z_{j2}^+ \right) \right)$$

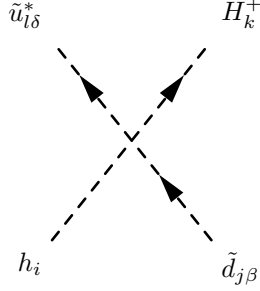
$$\begin{aligned}
& + Z_{i1}^{H,*} \left( -g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D Z_{j1}^+ + 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D Z_{j1}^+ \right. \\
& \left. + 2 \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{j2}^+ \right) \\
& + Z_{i2}^{H,*} \left( 2 \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{j1}^+ \right. \\
& \left. + \left( 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^D - g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D \right) Z_{j2}^+ \right) \tag{422}
\end{aligned}$$


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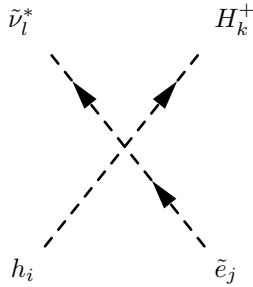


$$\begin{aligned}
& \frac{i}{2} \frac{1}{\sqrt{2}} \left( 2Z_{i3}^{H,*} \left( \lambda \sum_{b=1}^3 Z_{k3+b}^{V,*} \sum_{a=1}^3 Y_{\nu,ab}^* Z_{la}^E Z_{j1}^+ + \lambda^* \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E Z_{j2}^+ \right) \right. \\
& + Z_{i1}^{H,*} \left( -g_2^2 \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E Z_{j1}^+ + 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^E Z_{j1}^+ \right. \\
& \left. + 2 \sum_{c=1}^3 Z_{k3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{e,ba} Z_{l3+b}^E Z_{j2}^+ \right) \\
& + Z_{i2}^{H,*} \left( 2 \sum_{c=1}^3 Z_{k3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{e,ba} Z_{l3+b}^E Z_{j1}^+ \right. \\
& \left. + \left( 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{lc}^E - g_2^2 \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E \right) Z_{j2}^+ \right) \tag{423}
\end{aligned}$$


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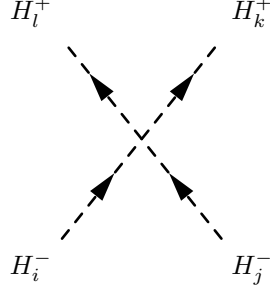
$$\begin{aligned}
& \frac{i}{2} \frac{1}{\sqrt{2}} \delta_{\beta\delta} \left( 2\lambda^* Z_{i3}^{H,*} \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U Z_{k1}^+ + 2Z_{i2}^{H,*} \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{k1}^+ \right. \\
& - g_2^2 Z_{i2}^{H,*} \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^U Z_{k2}^+ + 2\lambda Z_{i3}^{H,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{lb}^U Z_{k2}^+ \\
& + 2Z_{i2}^{H,*} \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^U Z_{k2}^+ \\
& + Z_{i1}^{H,*} \left( -g_2^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^U Z_{k1}^+ + 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^U Z_{k1}^+ \right. \\
& \left. \left. + 2 \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{k2}^+ \right) \right) \tag{424}
\end{aligned}$$



$$\begin{aligned}
& \frac{i}{2} \frac{1}{\sqrt{2}} \left( 2\lambda^* Z_{i3}^{H,*} \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{E,*} Y_{\nu,ab} Z_{l3+b}^V Z_{k1}^+ + 2Z_{i2}^{H,*} \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{\nu,ab} Z_{l3+b}^V Z_{k1}^+ \right. \\
& - g_2^2 Z_{i2}^{H,*} \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^V Z_{k2}^+ + 2\lambda Z_{i3}^{H,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{lb}^V Z_{k2}^+ \\
& \left. + 2Z_{i2}^{H,*} \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{lc}^V Z_{k2}^+ \right)
\end{aligned}$$

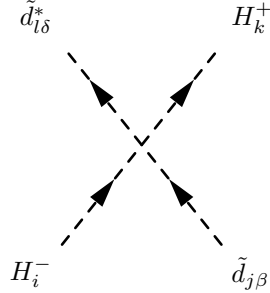
$$\begin{aligned}
& + Z_{i1}^{H,*} \left( -g_2^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^V Z_{k1}^+ + 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^V Z_{k1}^+ \right. \\
& \left. + 2 \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{\nu,ab} Z_{l3+b}^V Z_{k2}^+ \right) \tag{425}
\end{aligned}$$


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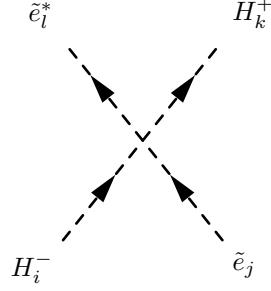
$$\begin{aligned}
& - \frac{i}{4} \left( Z_{i2}^+ \left( 2 \left( 4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{j2}^+ Z_{k2}^+ Z_{l2}^+ \right. \right. \\
& - \left. \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j1}^+ \left( Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right) \\
& + Z_{i1}^+ \left( 2 \left( 4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) Z_{j1}^+ Z_{k1}^+ Z_{l1}^+ \right. \\
& \left. \left. - \left( -4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j2}^+ \left( Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right) \right) \tag{426}
\end{aligned}$$


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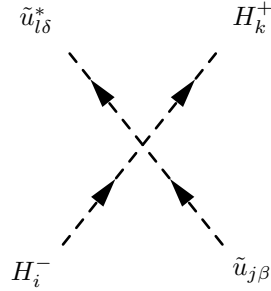


$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\delta} \left( \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^D \left( - \left( 12g_p^2 Q_{H_u} Q_q - 3g_2^2 + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ + \left( -3 \left( 4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ \right) \right. \\
& + 2 \left( \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{l3+a}^D \left( \left( -6g_p^2 Q_d Q_{H_d} + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ - \left( 6g_p^2 Q_d Q_{H_u} + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \right. \\
& \left. \left. - 6 \left( \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^D Z_{i2}^+ Z_{k2}^+ + \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{i1}^+ Z_{k1}^+ \right) \right) \right) \tag{427}
\end{aligned}$$


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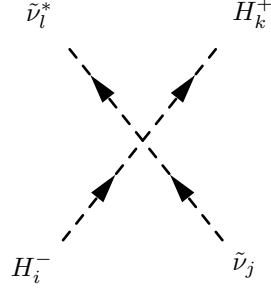


$$\begin{aligned}
& -\frac{i}{4} \left( \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{l3+a}^E \left( -2 \left( -2g_p^2 Q_e Q_{H_d} + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ + 2 \left( 2g_p^2 Q_e Q_{H_u} + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \right. \\
& + \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^E \left( \left( 4g_p^2 Q_{H_d} Q_q + g_1^2 + g_2^2 \right) Z_{i1}^+ Z_{k1}^+ - \left( -4g_p^2 Q_{H_u} Q_q + g_1^2 + g_2^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \\
& \left. + 4 \left( \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{\nu,ca}^* Y_{\nu,ba} Z_{lc}^E Z_{i2}^+ Z_{k2}^+ + \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{l3+b}^E Z_{i1}^+ Z_{k1}^+ \right) \right) \quad (428)
\end{aligned}$$

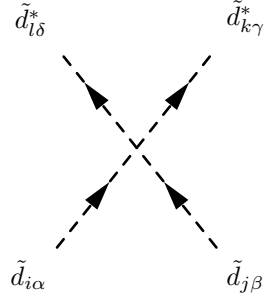


$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\delta} \left( \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( \left( -12g_p^2 Q_{H_d} Q_q + 3g_2^2 + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ - \left( 12g_p^2 Q_{H_u} Q_q + 3g_2^2 + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \right. \\
& - 4 \left( \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( \left( 3g_p^2 Q_{H_d} Q_u + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ - \left( -3g_p^2 Q_{H_u} Q_u + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \right. \\
& \left. \left. + 3 \left( \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^U Z_{i1}^+ Z_{k1}^+ + \sum_{c=1}^3 Z_{j3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{i2}^+ Z_{k2}^+ \right) \right) \right) \quad (429)
\end{aligned}$$





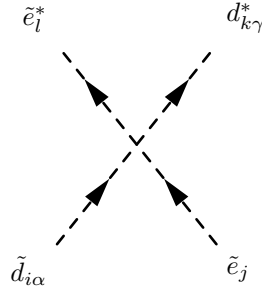
$$\begin{aligned}
& -\frac{i}{4} \left( \sum_{a=1}^3 Z_{ja}^{V,*} Z_{la}^V \left( (4g_p^2 Q_{H_d} Q_q - g_2^2 + g_1^2) Z_{i1}^+ Z_{k1}^+ + (4g_p^2 Q_{H_u} Q_q - g_1^2 + g_2^2) Z_{i2}^+ Z_{k2}^+ \right) \right. \\
& + \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{l3+a}^V \left( -2 \left( -2g_p^2 Q_{H_d} Q_v + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ + 2 \left( 2g_p^2 Q_{H_u} Q_v + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \\
& \left. + 4 \left( \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^V Z_{i1}^+ Z_{k1}^+ + \sum_{c=1}^3 Z_{j3+c}^{V,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{\nu,ac}^* Y_{\nu,ab} Z_{l3+b}^V Z_{i2}^+ Z_{k2}^+ \right) \right) \quad (430)
\end{aligned}$$



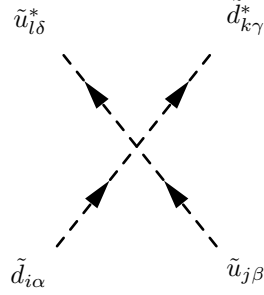
$$\begin{aligned}
& -\frac{i}{72} \left( \delta_{\alpha\delta} \delta_{\beta\gamma} \left( g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \right. \right. \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D + 36g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \\
& + 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \\
& + 36g_p^2 Q_d Q_q \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \\
& \left. + 18g_3^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^D \left( -\sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \right)
\end{aligned}$$

$$\begin{aligned}
& - 18g_3^2 \sum_{a=1}^3 Z_{j_{3+a}}^{D,*} Z_{l_{3+a}}^D \left( - \sum_{b=1}^3 Z_{i_{3+b}}^{D,*} Z_{k_{3+b}}^D + \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \\
& + 2g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{j_{3+b}}^{D,*} Z_{k_{3+b}}^D + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{j_{3+b}}^{D,*} Z_{k_{3+b}}^D \\
& + 36g_p^2 Q_d Q_q \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{j_{3+b}}^{D,*} Z_{k_{3+b}}^D + 4g_1^2 \sum_{a=1}^3 Z_{i_{3+a}}^{D,*} Z_{l_{3+a}}^D \sum_{b=1}^3 Z_{j_{3+b}}^{D,*} Z_{k_{3+b}}^D \\
& - 6g_3^2 \sum_{a=1}^3 Z_{i_{3+a}}^{D,*} Z_{l_{3+a}}^D \sum_{b=1}^3 Z_{j_{3+b}}^{D,*} Z_{k_{3+b}}^D + 36g_p^2 Q_d^2 \sum_{a=1}^3 Z_{i_{3+a}}^{D,*} Z_{l_{3+a}}^D \sum_{b=1}^3 Z_{j_{3+b}}^{D,*} Z_{k_{3+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 + 36g_p^2 Q_q^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_{j_{3+a}}^{D,*} Z_{k_{3+a}}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D + 6g_3^2 \sum_{a=1}^3 Z_{j_{3+a}}^{D,*} Z_{k_{3+a}}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^D \\
& + 36g_p^2 Q_d Q_q \sum_{a=1}^3 Z_{j_{3+a}}^{D,*} Z_{k_{3+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_{i_{3+a}}^{D,*} Z_{k_{3+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_{i_{3+b}}^{D,*} Z_{l_{3+b}}^D \\
& + 6g_3^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{i_{3+b}}^{D,*} Z_{l_{3+b}}^D + 36g_p^2 Q_d Q_q \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{i_{3+b}}^{D,*} Z_{l_{3+b}}^D \\
& + 4g_1^2 \sum_{a=1}^3 Z_{j_{3+a}}^{D,*} Z_{k_{3+a}}^D \sum_{b=1}^3 Z_{i_{3+b}}^{D,*} Z_{l_{3+b}}^D - 6g_3^2 \sum_{a=1}^3 Z_{j_{3+a}}^{D,*} Z_{k_{3+a}}^D \sum_{b=1}^3 Z_{i_{3+b}}^{D,*} Z_{l_{3+b}}^D \\
& + 36g_p^2 Q_d^2 \sum_{a=1}^3 Z_{j_{3+a}}^{D,*} Z_{k_{3+a}}^D \sum_{b=1}^3 Z_{i_{3+b}}^{D,*} Z_{l_{3+b}}^D - 18g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j_{3+b}}^{D,*} Z_{l_{3+b}}^D \\
& + 18g_3^2 \sum_{a=1}^3 Z_{i_{3+a}}^{D,*} Z_{k_{3+a}}^D \sum_{b=1}^3 Z_{j_{3+b}}^{D,*} Z_{l_{3+b}}^D \\
& + 72 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l_{3+a}}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{j_{3+c}}^{D,*} Z_{kd}^D \\
& + 72 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k_{3+a}}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{i_{3+c}}^{D,*} Z_{ld}^D
\end{aligned}$$

$$\begin{aligned}
& + \delta_{\alpha\gamma}\delta_{\beta\delta} \left( 18g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D - 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{l3+a}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \right. \\
& + 2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{l3+a}^D \left( (18g_p^2 Q_d^2 + 2g_1^2 - 3g_3^2) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + (18g_p^2 Q_d Q_q + 3g_3^2 + g_1^2) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \\
& + \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^D \left( 2(18g_p^2 Q_d Q_q + 3g_3^2 + g_1^2) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + (36g_p^2 Q_q^2 - 6g_3^2 + 9g_2^2 + g_1^2) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \\
& - 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 + 36g_p^2 Q_q^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 \\
& + 36g_p^2 Q_d Q_q \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 + 36g_p^2 Q_d Q_q \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 \\
& + 36g_p^2 Q_d^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 \\
& \left. + 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 \right) \tag{431}
\end{aligned}$$

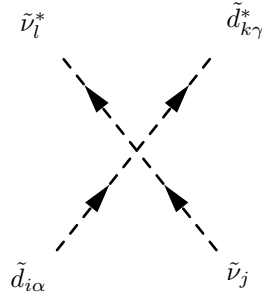


$$\begin{aligned}
& -\frac{i}{24}\delta_{\alpha\gamma}\left(2\sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{l3+a}^E \left(2\left(3g_p^2 Q_d Q_e + g_1^2\right)\sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \left(6g_p^2 Q_e Q_q + g_1^2\right)\sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D\right)\right. \\
& + \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^E \left(\left(12g_p^2 Q_q Q_q + 3g_2^2 - g_1^2\right)\sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D - 2\left(-6g_p^2 Q_d Q_q + g_1^2\right)\sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D\right) \\
& - g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E + 3g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \\
& + 12g_p^2 Q_q Q_q \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E - 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \\
& + 12g_p^2 Q_d Q_q \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E + 2g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& + 12g_p^2 Q_e Q_q \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& + 12g_p^2 Q_d Q_e \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& + 24 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd} Z_{i3+c}^{D,*} Z_{kd}^D \\
& \left. + 24 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd} Z_{j3+c}^{E,*} Z_{ld}^E\right) \tag{432}
\end{aligned}$$

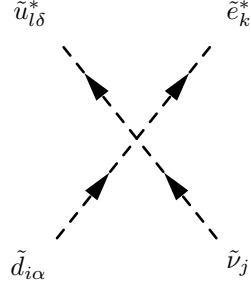


$$\begin{aligned}
& -\frac{i}{72} \left( \delta_{\alpha\gamma} \delta_{\beta\delta} \left( \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( (36g_p^2 Q_q^2 - 6g_3^2 - 9g_2^2 + g_1^2) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right. \right. \right. \\
& + 2 \left( 18g_p^2 Q_d Q_q + 3g_3^2 + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \left. \left. \left. \right) \right) \right. \\
& + \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( -2 \left( -18g_p^2 Q_d Q_u + 3g_3^2 + 4g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \left( 36g_p^2 Q_q Q_u - 4g_1^2 + 6g_3^2 \right) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \\
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 9g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 36g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& + 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& + 36g_p^2 Q_d Q_q \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 4g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U + 36g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& - 8g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U - 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 \\
& + 36g_p^2 Q_d Q_u \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \left. \right) \\
& + 18\delta_{\alpha\delta} \delta_{\beta\gamma} \left( g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^D + g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( - \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \right. \\
& \left. + g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( - \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D + \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \right) \right)
\end{aligned}$$

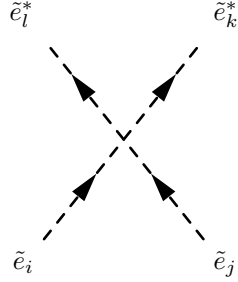
$$\begin{aligned}
& + g_2^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^U + g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U + 4 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd}^* Z_{j3+c}^{U,*} Z_{kd}^D \\
& + 4 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{i3+c}^{D,*} Z_{ld}^U \Big) \tag{433}
\end{aligned}$$



$$\begin{aligned}
& \frac{i}{24} \delta_{\alpha\gamma} \left( \sum_{a=1}^3 Z_{ja}^{V,*} Z_{la}^V \left( \left( -12g_p^2 Q_q Q_q + 3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D + 2 \left( -6g_p^2 Q_d Q_d + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D \right) \right. \\
& - 2 \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{l3+a}^V \left( 2 \left( 3g_p^2 Q_d Q_v + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \left( 6g_p^2 Q_q Q_v + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \\
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V + 3g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& - 12g_p^2 Q_q Q_q \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V + 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& - 12g_p^2 Q_d Q_q \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V - 2g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \\
& - 12g_p^2 Q_q Q_v \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V - 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \\
& \left. - 12g_p^2 Q_d Q_v \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \right) \tag{434}
\end{aligned}$$



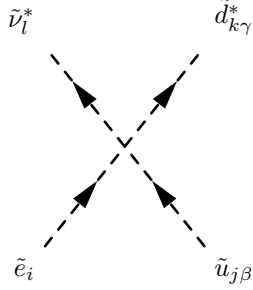
$$\begin{aligned}
& -\frac{i}{4}\delta_{\alpha\delta}\left(g_2^2\sum_{a=1}^3Z_{ia}^{D,*}Z_{la}^U\sum_{b=1}^3Z_{jb}^{V,*}Z_{kb}^E+g_2^2\sum_{a=1}^3Z_{ja}^{V,*}Z_{ka}^E\sum_{b=1}^3Z_{ib}^{D,*}Z_{lb}^U\right. \\
& +4\sum_{b=1}^3Z_{ib}^{D,*}\sum_{a=1}^3Y_{u,ab}Z_{l3+a}^U\sum_{d=1}^3Z_{j3+d}^{V,*}\sum_{c=1}^3Y_{\nu,cd}Z_{kc}^E \\
& \left.+4\sum_{b=1}^3Z_{jb}^{V,*}\sum_{a=1}^3Y_{e,ab}Z_{k3+a}^E\sum_{d=1}^3\sum_{c=1}^3Y_{d,cd}^*Z_{i3+c}^{D,*}Z_{ld}^U\right) \tag{435}
\end{aligned}$$



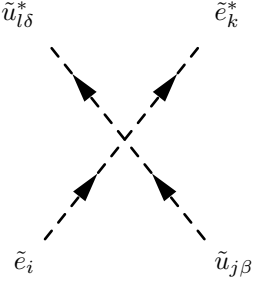
$$\begin{aligned}
& -\frac{i}{8}\left(g_1^2\sum_{a=1}^3Z_{ia}^{E,*}Z_{la}^E\sum_{b=1}^3Z_{jb}^{E,*}Z_{kb}^E+g_2^2\sum_{a=1}^3Z_{ia}^{E,*}Z_{la}^E\sum_{b=1}^3Z_{jb}^{E,*}Z_{kb}^E\right. \\
& +4g_p^2Q_q^2\sum_{a=1}^3Z_{ia}^{E,*}Z_{la}^E\sum_{b=1}^3Z_{jb}^{E,*}Z_{kb}^E-2g_1^2\sum_{a=1}^3Z_{i3+a}^{E,*}Z_{l3+a}^E\sum_{b=1}^3Z_{jb}^{E,*}Z_{kb}^E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

$$\begin{aligned}
& -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_p^2 Q_e Q_q \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 + 4g_p^2 Q_e^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 \\
& + 4g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^E - 2g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^E \\
& + 4g_p^2 Q_e Q_q \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^E + g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \\
& + g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E + 4g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \\
& - 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E + 4g_p^2 Q_e Q_q \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{lb}^E \\
& - 2g_1^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E + 4g_p^2 Q_e Q_q \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E \\
& + 4g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E + 4g_p^2 Q_e^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E \\
& - 2g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E + 4g_p^2 Q_e Q_q \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E + 4g_p^2 Q_e^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& + 8 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd} Z_{i3+c}^{E,*} Z_{kd}^E \\
& + 8 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd} Z_{j3+c}^{E,*} Z_{kd}^E \\
& + 8 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd} Z_{i3+c}^{E,*} Z_{ld}^E \\
& + 8 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd} Z_{j3+c}^{E,*} Z_{ld}^E
\end{aligned} \tag{436}$$



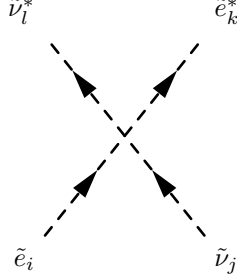


$$\begin{aligned}
& -\frac{i}{4}\delta_{\beta\gamma}\left(g_2^2\sum_{a=1}^3Z_{ia}^{E,*}Z_{la}^V\sum_{b=1}^3Z_{jb}^{U,*}Z_{kb}^D+g_2^2\sum_{a=1}^3Z_{ja}^{U,*}Z_{ka}^D\sum_{b=1}^3Z_{ib}^{E,*}Z_{lb}^V\right. \\
& +4\sum_{b=1}^3\sum_{a=1}^3Z_{ia}^{E,*}Y_{\nu,ab}Z_{l3+b}^V\sum_{d=1}^3\sum_{c=1}^3Y_{u,cd}^*Z_{j3+c}^{U,*}Z_{kd}^D \\
& \left.+4\sum_{b=1}^3Z_{jb}^{U,*}\sum_{a=1}^3Y_{d,ab}Z_{k3+a}^D\sum_{d=1}^3\sum_{c=1}^3Y_{e,cd}^*Z_{i3+c}^{E,*}Z_{ld}^V\right) \tag{437}
\end{aligned}$$

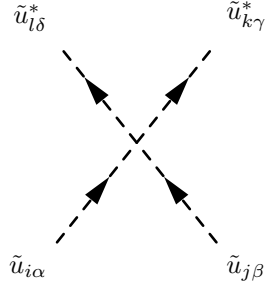


$$\begin{aligned}
& \frac{i}{24}\delta_{\beta\delta}\left(\sum_{a=1}^3Z_{ja}^{U,*}Z_{la}^U\left(\left(-12g_p^2Q_qQ_q+3g_2^2+g_1^2\right)\sum_{b=1}^3Z_{ib}^{E,*}Z_{kb}^E-2\left(6g_p^2Q_eQ_q+g_1^2\right)\sum_{b=1}^3Z_{i3+b}^{E,*}Z_{k3+b}^E\right)\right. \\
& -4\sum_{a=1}^3Z_{j3+a}^{U,*}Z_{l3+a}^U\left(\left(-2g_1^2+3g_p^2Q_eQ_u\right)\sum_{b=1}^3Z_{i3+b}^{E,*}Z_{k3+b}^E+\left(3g_p^2Q_qQ_u+g_1^2\right)\sum_{b=1}^3Z_{ib}^{E,*}Z_{kb}^E\right) \\
& +g_1^2\sum_{a=1}^3Z_{ia}^{E,*}Z_{ka}^E\sum_{b=1}^3Z_{jb}^{U,*}Z_{lb}^U+3g_2^2\sum_{a=1}^3Z_{ia}^{E,*}Z_{ka}^E\sum_{b=1}^3Z_{jb}^{U,*}Z_{lb}^U \\
& -12g_p^2Q_qQ_q\sum_{a=1}^3Z_{ia}^{E,*}Z_{ka}^E\sum_{b=1}^3Z_{jb}^{U,*}Z_{lb}^U-2g_1^2\sum_{a=1}^3Z_{i3+a}^{E,*}Z_{k3+a}^E\sum_{b=1}^3Z_{jb}^{U,*}Z_{lb}^U \\
& \left.-12g_p^2Q_eQ_q\sum_{a=1}^3Z_{i3+a}^{E,*}Z_{k3+a}^E\sum_{b=1}^3Z_{jb}^{U,*}Z_{lb}^U-4g_1^2\sum_{a=1}^3Z_{ia}^{E,*}Z_{ka}^E\sum_{b=1}^3Z_{j3+b}^{U,*}Z_{l3+b}^U\right)
\end{aligned}$$

$$\begin{aligned}
& -12g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U + 8g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& -12g_p^2 Q_e Q_u \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \Big) \tag{438}
\end{aligned}$$



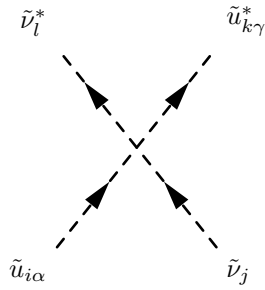
$$\begin{aligned}
& -\frac{i}{8} \left( 2g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^E \right. \\
& + \sum_{a=1}^3 Z_{ja}^{V,*} Z_{la}^V \left( -2 \left( -2g_p^2 Q_e Q_q + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E + \left( 4g_p^2 Q_q^2 - g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \right) \\
& + \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{l3+a}^V \left( -2 \left( -2g_p^2 Q_q Q_v + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E + 4 \left( g_p^2 Q_e Q_v + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E \right) \\
& + 2g_2^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^E \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^V + g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& - g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V + 4g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& - 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V + 4g_p^2 Q_e Q_q \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& - 2g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V + 4g_p^2 Q_q Q_v \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \\
& + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V + 4g_p^2 Q_e Q_v \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \\
& + 8 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ia}^{E,*} Y_{\nu,ab} Z_{l3+b}^V \sum_{d=1}^3 Z_{j3+d}^{V,*} \sum_{c=1}^3 Y_{\nu,cd}^* Z_{kc}^E \\
& \left. + 8 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{i3+c}^{E,*} Z_{ld}^V \right) \tag{439}
\end{aligned}$$



$$\begin{aligned}
& -\frac{i}{72} \left( \delta_{\alpha\delta} \delta_{\beta\gamma} \left( g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \right. \right. \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U + 36g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \\
& - 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \\
& + 36g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \\
& + 18g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( - \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U + \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \right) \\
& - 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( - \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U + \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \right) \\
& - 4g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \\
& + 36g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U + 16g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U + 36g_p^2 Q_u^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \\
& + g_1^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U + 9g_2^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U + 36g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U
\end{aligned}$$

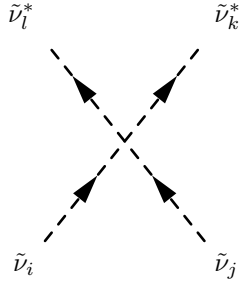
$$\begin{aligned}
& -4g_1^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U + 6g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \\
& + 36g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U + 18g_3^2 \sum_{a=1}^3 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 + 36g_p^2 Q_q Q_u \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 \\
& + 36g_p^2 Q_u^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 \\
& + \delta_{\alpha\gamma} \delta_{\beta\delta} \left( 18g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U - 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \right. \\
& + \sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left( (36g_p^2 Q_q^2 - 6g_3^2 + 9g_2^2 + g_1^2) \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \right. \\
& \left. + 2 \left( 18g_p^2 Q_q Q_u - 2g_1^2 + 3g_3^2 \right) \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U \right) \\
& + \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left( 2 \left( 18g_p^2 Q_u^2 - 3g_3^2 + 8g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U + \left( 36g_p^2 Q_q Q_u - 4g_1^2 + 6g_3^2 \right) \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \right) \\
& - 18g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U + 18g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{l3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{k3+b}^U \\
& + 18g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U - 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U
\end{aligned}$$

$$\begin{aligned}
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 36g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& + 36g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 18g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \\
& + 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U - 4g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U + 36g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 16g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U - 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 36g_p^2 Q_u^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 72 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd} Z_{i3+c}^{U,*} Z_{kd}^U \\
& + 72 \sum_{b=1}^3 Z_{ib}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd} Z_{j3+c}^{U,*} Z_{ld}^U \Big) \tag{440}
\end{aligned}$$



$$\begin{aligned}
& \frac{i}{24} \delta_{\alpha\gamma} \left( \sum_{a=1}^3 Z_{ja}^{V,*} Z_{la}^V \left( \left( -3 \left( 4g_p^2 Q_q Q_u + g_2^2 \right) + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U - 4 \left( 3g_p^2 Q_q Q_u + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U \right) \right. \\
& \left. - 2 \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{l3+a}^V \left( 2 \left( -2g_1^2 + 3g_p^2 Q_u Q_v \right) \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{k3+b}^U + \left( 6g_p^2 Q_q Q_v + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{U,*} Z_{kb}^U \right) \right)
\end{aligned}$$

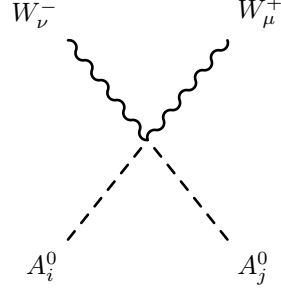
$$\begin{aligned}
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V - 3g_2^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& - 12g_p^2 Q_q Q_q \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V - 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& - 12g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V - 2g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \\
& - 12g_p^2 Q_q Q_v \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V + 8g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \\
& - 12g_p^2 Q_u Q_v \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \\
& - 24 \sum_{b=1}^3 Z_{ib}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \sum_{d=1}^3 Z_{j3+d}^{V,*} \sum_{c=1}^3 Y_{v,cd} Z_{lc}^V \\
& - 24 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} Y_{v,ab} Z_{l3+b}^V \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd} Z_{i3+c}^U Z_{kd}^U
\end{aligned} \tag{441}$$



$$\begin{aligned}
& - \frac{i}{8} \left( g_1^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{la}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^V + g_2^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{la}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^V \right) \\
& + 4g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{la}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^V - 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{l3+a}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^V \\
& + 4g_p^2 Q_q Q_v \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{l3+a}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^V \\
& + \sum_{a=1}^3 Z_{ja}^{V,*} Z_{la}^V \left( -2 \left( -2g_p^2 Q_q Q_v + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{V,*} Z_{k3+b}^V + \left( 4g_p^2 Q_q^2 + g_1^2 + g_2^2 \right) \sum_{b=1}^3 Z_{ib}^{V,*} Z_{kb}^V \right) \\
& + \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{l3+a}^V \left( -2 \left( -2g_p^2 Q_q Q_v + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{V,*} Z_{kb}^V + 4 \left( g_p^2 Q_v^2 + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{V,*} Z_{k3+b}^V \right)
\end{aligned}$$

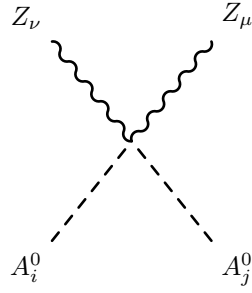
$$\begin{aligned}
& -2g_1^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{la}^V \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{k3+b}^V + 4g_p^2 Q_q Q_v \sum_{a=1}^3 Z_{ia}^{V,*} Z_{la}^V \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{k3+b}^V \\
& + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{l3+a}^V \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{k3+b}^V + 4g_p^2 Q_v^2 \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{l3+a}^V \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{k3+b}^V \\
& + g_1^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{ib}^{V,*} Z_{lb}^V + g_2^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{ib}^{V,*} Z_{lb}^V \\
& + 4g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{ib}^{V,*} Z_{lb}^V - 2g_1^2 \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{k3+a}^V \sum_{b=1}^3 Z_{ib}^{V,*} Z_{lb}^V \\
& + 4g_p^2 Q_q Q_v \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{k3+a}^V \sum_{b=1}^3 Z_{ib}^{V,*} Z_{lb}^V + g_1^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& + g_2^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V + 4g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& - 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{k3+a}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V + 4g_p^2 Q_q Q_v \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{k3+a}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{lb}^V \\
& - 2g_1^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{i3+b}^{V,*} Z_{l3+b}^V + 4g_p^2 Q_q Q_v \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{i3+b}^{V,*} Z_{l3+b}^V \\
& + 4g_1^2 \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{k3+a}^V \sum_{b=1}^3 Z_{i3+b}^{V,*} Z_{l3+b}^V + 4g_p^2 Q_v^2 \sum_{a=1}^3 Z_{j3+a}^{V,*} Z_{k3+a}^V \sum_{b=1}^3 Z_{i3+b}^{V,*} Z_{l3+b}^V \\
& - 2g_1^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V + 4g_p^2 Q_q Q_v \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ka}^V \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \\
& + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{k3+a}^V \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V + 4g_p^2 Q_v^2 \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{k3+a}^V \sum_{b=1}^3 Z_{j3+b}^{V,*} Z_{l3+b}^V \\
& + 8 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} Y_{\nu,ab} Z_{l3+b}^V \sum_{d=1}^3 Z_{i3+d}^{V,*} \sum_{c=1}^3 Y_{\nu,cd} Z_{kc}^V \\
& + 8 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ia}^{V,*} Y_{\nu,ab} Z_{l3+b}^V \sum_{d=1}^3 Z_{j3+d}^{V,*} \sum_{c=1}^3 Y_{\nu,cd} Z_{kc}^V \\
& + 8 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ja}^{V,*} Y_{\nu,ab} Z_{k3+b}^V \sum_{d=1}^3 Z_{i3+d}^{V,*} \sum_{c=1}^3 Y_{\nu,cd} Z_{lc}^V \\
& + 8 \sum_{b=1}^3 \sum_{a=1}^3 Z_{ia}^{V,*} Y_{\nu,ab} Z_{k3+b}^V \sum_{d=1}^3 Z_{j3+d}^{V,*} \sum_{c=1}^3 Y_{\nu,cd} Z_{lc}^V
\end{aligned} \tag{442}$$

## 9.8 Two Scalar-Two Vector Boson-Interaction



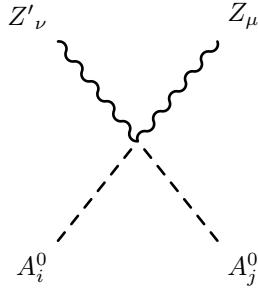
$$\frac{i}{2} g_2^2 \left( Z_{i1}^{A,*} Z_{j1}^{A,*} + Z_{i2}^{A,*} Z_{j2}^{A,*} \right) (g_{\mu\nu}) \quad (443)$$


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$$\begin{aligned} & \frac{i}{2} \left( 4g_p^2 Q_s^2 Z_{i3}^{A,*} Z_{j3}^{A,*} \sin^2 \Theta'_W \right. \\ & + Z_{i1}^{A,*} Z_{j1}^{A,*} \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \\ & \left. + Z_{i2}^{A,*} Z_{j2}^{A,*} \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \right) (g_{\mu\nu}) \quad (444) \end{aligned}$$

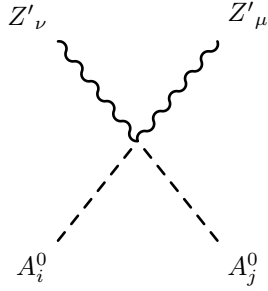

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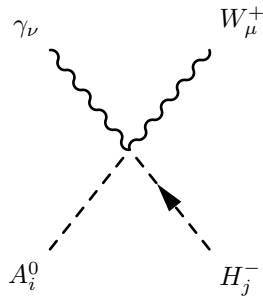
$$\begin{aligned}
& -\frac{i}{2} \left( -4g_p^2 Q_s^2 Z_{i3}^{A,*} Z_{j3}^{A,*} \cos \Theta'_W \sin \Theta'_W \right. \\
& + Z_{i1}^{A,*} Z_{j1}^{A,*} \left( -2g_1 g_p Q_{H_d} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left( -4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta'^2_W \\
& + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W - g_p Q_{H_d} \cos \Theta'^2_W + g_p Q_{H_d} \sin \Theta'^2_W \right) \left. \right) \\
& + Z_{i2}^{A,*} Z_{j2}^{A,*} \left( 2g_1 g_p Q_{H_u} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left( -4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta'^2_W \\
& + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_u} \cos \Theta'^2_W - g_p Q_{H_u} \sin \Theta'^2_W \right) \left. \right) \left( g_{\mu\nu} \right) \quad (445)
\end{aligned}$$


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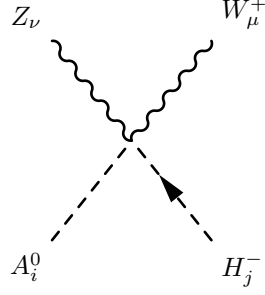
$$\begin{aligned}
& \frac{i}{2} \left( 4g_p^2 Q_s^2 Z_{i3}^{A,*} Z_{j3}^{A,*} \cos \Theta'_W \right. \\
& + Z_{i1}^{A,*} Z_{j1}^{A,*} \left( -2g_p Q_{H_d} \cos \Theta'_W + \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \\
& + Z_{i2}^{A,*} Z_{j2}^{A,*} \left( 2g_p Q_{H_u} \cos \Theta'_W + \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \left. \right) \left( g_{\mu\nu} \right) \quad (446)
\end{aligned}$$


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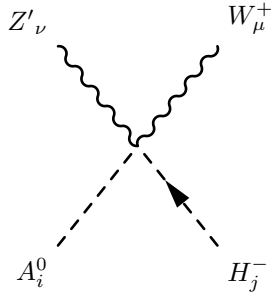
$$-\frac{1}{2} g_1 g_2 \cos \Theta_W \left( Z_{i1}^{A,*} Z_{j1}^+ + Z_{i2}^{A,*} Z_{j2}^+ \right) \left( g_{\mu\nu} \right) \quad (447)$$


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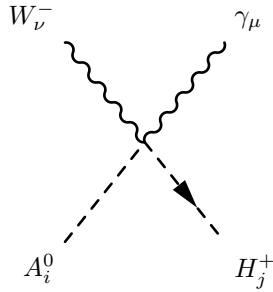
$$\begin{aligned} & \frac{1}{2}g_2 \left( Z_{i1}^{A,*} \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j1}^+ \right. \\ & \left. + Z_{i2}^{A,*} \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (448)$$


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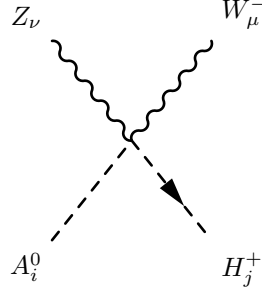
$$\begin{aligned} & \frac{1}{2}g_2 \left( Z_{i1}^{A,*} \left( 2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j1}^+ \right. \\ & \left. - Z_{i2}^{A,*} \left( 2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (449)$$


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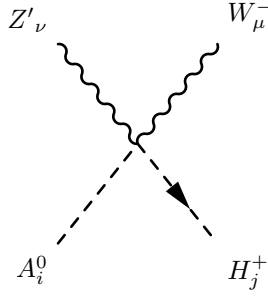
$$\frac{1}{2}g_1 g_2 \cos \Theta_W \left( Z_{i1}^{A,*} Z_{j1}^+ + Z_{i2}^{A,*} Z_{j2}^+ \right) (g_{\mu\nu}) \quad (450)$$


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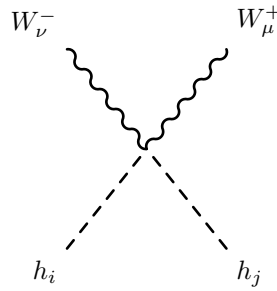
$$\begin{aligned}
& -\frac{1}{2}g_2 \left( Z_{i1}^{A,*} \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j1}^+ \right. \\
& \left. + Z_{i2}^{A,*} \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j2}^+ \right) (g_{\mu\nu})
\end{aligned} \tag{451}$$


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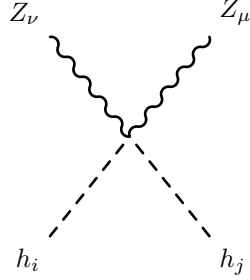
$$\begin{aligned}
& \frac{1}{2}g_2 \left( Z_{i1}^{A,*} \left( -2g_p Q_{H_d} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j1}^+ \right. \\
& \left. + Z_{i2}^{A,*} \left( 2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j2}^+ \right) (g_{\mu\nu})
\end{aligned} \tag{452}$$


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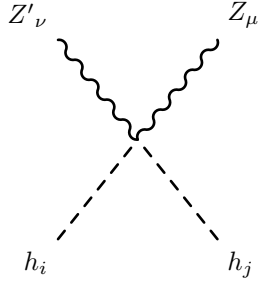
$$\frac{i}{2}g_2^2 \left( Z_{i1}^{H,*} Z_{j1}^{H,*} + Z_{i2}^{H,*} Z_{j2}^{H,*} \right) (g_{\mu\nu}) \tag{453}$$


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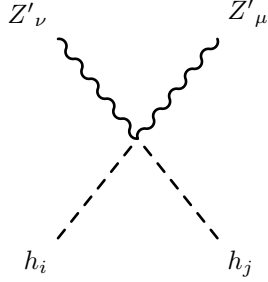
$$\begin{aligned}
& \frac{i}{2} \left( 4g_p^2 Q_s^2 Z_{i3}^{H,*} Z_{j3}^{H,*} \sin^2 \Theta'_W \right. \\
& + Z_{i1}^{H,*} Z_{j1}^{H,*} \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \\
& \left. + Z_{i2}^{H,*} Z_{j2}^{H,*} \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \right) (g_{\mu\nu}) \quad (454)
\end{aligned}$$


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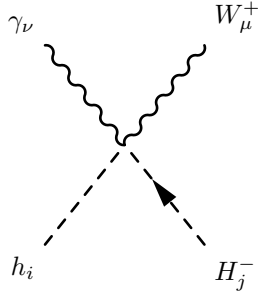
$$\begin{aligned}
& -\frac{i}{2} \left( -4g_p^2 Q_s^2 Z_{i3}^{H,*} Z_{j3}^{H,*} \cos \Theta'_W \sin \Theta'_W \right. \\
& + Z_{i1}^{H,*} Z_{j1}^{H,*} \left( -2g_1 g_p Q_{H_d} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos^2 \Theta'_W \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left( -4g_p^2 Q_{H_d}^2 + g_1^2 \sin^2 \Theta_W \right) \sin \Theta'_W + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta'^2_W \\
& \left. + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W - g_p Q_{H_d} \cos \Theta'^2_W + g_p Q_{H_d} \sin \Theta'^2_W \right) \right) \\
& + Z_{i2}^{H,*} Z_{j2}^{H,*} \left( 2g_1 g_p Q_{H_u} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos^2 \Theta'_W \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left( -4g_p^2 Q_{H_u}^2 + g_1^2 \sin^2 \Theta_W \right) \sin \Theta'_W - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta'^2_W \\
& \left. + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_u} \cos \Theta'^2_W - g_p Q_{H_u} \sin \Theta'^2_W \right) \right) \right) (g_{\mu\nu}) \quad (455)
\end{aligned}$$


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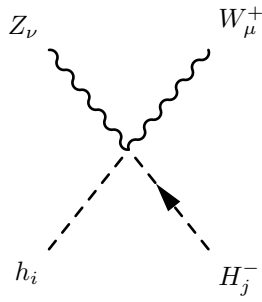
$$\begin{aligned}
& \frac{i}{2} \left( 4g_p^2 Q_s^2 Z_{i3}^{H,*} Z_{j3}^{H,*} \cos \Theta'_W \right. \\
& + Z_{i1}^{H,*} Z_{j1}^{H,*} \left( -2g_p Q_{H_d} \cos \Theta'_W + \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \\
& \left. + Z_{i2}^{H,*} Z_{j2}^{H,*} \left( 2g_p Q_{H_u} \cos \Theta'_W + \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \right) (g_{\mu\nu})
\end{aligned} \tag{456}$$


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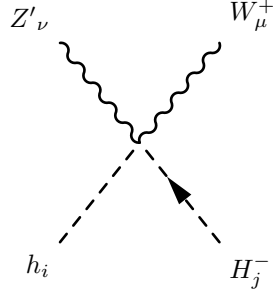
$$-\frac{i}{2} g_1 g_2 \cos \Theta_W \left( Z_{i1}^{H,*} Z_{j1}^+ - Z_{i2}^{H,*} Z_{j2}^+ \right) (g_{\mu\nu}) \tag{457}$$


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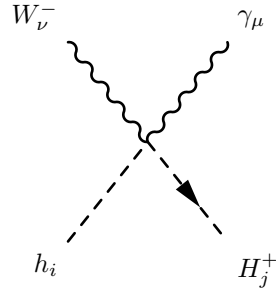
$$\begin{aligned}
& \frac{i}{2} g_2 \left( Z_{i1}^{H,*} \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j1}^+ \right. \\
& \left. + Z_{i2}^{H,*} \left( 2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j2}^+ \right) (g_{\mu\nu})
\end{aligned} \tag{458}$$


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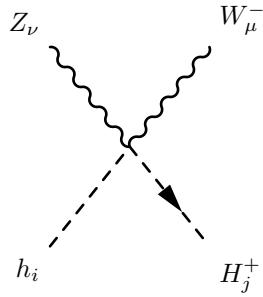
$$\begin{aligned} & \frac{i}{2} g_2 \left( Z_{i1}^{H,*} \left( 2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j1}^+ \right. \\ & \left. + Z_{i2}^{H,*} \left( 2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (459)$$


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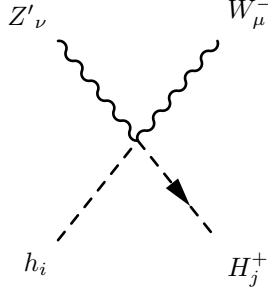
$$- \frac{i}{2} g_1 g_2 \cos \Theta_W \left( Z_{i1}^{H,*} Z_{j1}^+ - Z_{i2}^{H,*} Z_{j2}^+ \right) (g_{\mu\nu}) \quad (460)$$


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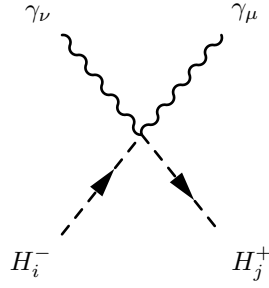
$$\begin{aligned} & \frac{i}{2} g_2 \left( Z_{i1}^{H,*} \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j1}^+ \right. \\ & \left. + Z_{i2}^{H,*} \left( 2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (461)$$


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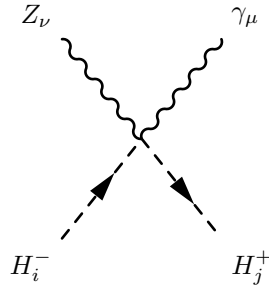
$$\begin{aligned} & \frac{i}{2} g_2 \left( Z_{i1}^{H,*} \left( 2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j1}^+ \right. \\ & \left. + Z_{i2}^{H,*} \left( 2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (462)$$


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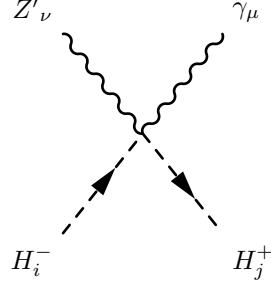
$$\frac{i}{2} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right)^2 \left( Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (463)$$


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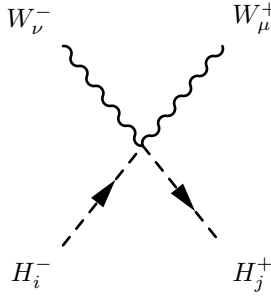
$$\begin{aligned} & - \frac{i}{2} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left( \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right. \\ & \left. + \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (464)$$


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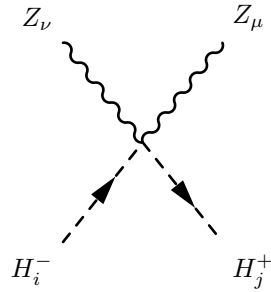
$$\frac{i}{2} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left( \left( -2g_p Q_{H_d} \cos \Theta'_W + \left( g_1 \sin \Theta_W - g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right. \\ \left. + \left( 2g_p Q_{H_u} \cos \Theta'_W + \left( g_1 \sin \Theta_W - g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (465)$$


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$$\frac{i}{2} g_2^2 \left( Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (466)$$

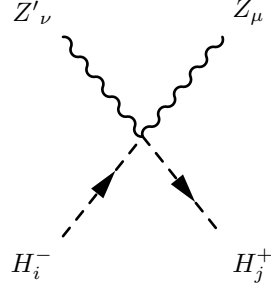

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$$\frac{i}{2} \left( \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right)^2 Z_{i1}^+ Z_{j1}^+ \right. \\ \left. + \left( 2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (467)$$

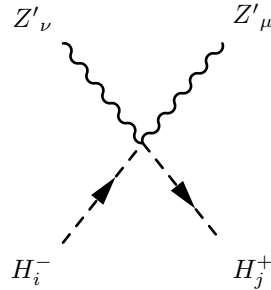

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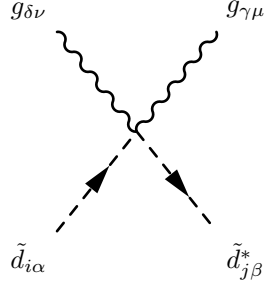
$$\begin{aligned}
& -\frac{i}{2} \left( \left( -2g_1 g_p Q_{H_d} \cos \Theta'_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \right. \\
& + \cos \Theta'_W \left( -4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta'^2_W \\
& + 2g_2 \cos \Theta_W \left( -g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_d} \cos \Theta'^2_W - g_p Q_{H_d} \sin \Theta'^2_W \right) \left. \right) Z_{i1}^+ Z_{j1}^+ \\
& + \left( 2g_1 g_p Q_{H_u} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left( -4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta'^2_W \\
& \left. - 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_u} \cos \Theta'^2_W - g_p Q_{H_u} \sin \Theta'^2_W \right) \right) Z_{i2}^+ Z_{j2}^+ \left( g_{\mu\nu} \right) \quad (468)
\end{aligned}$$


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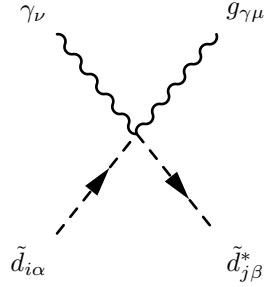
$$\begin{aligned}
& \frac{i}{2} \left( \left( 2g_p Q_{H_d} \cos \Theta'_W + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 Z_{i1}^+ Z_{j1}^+ \right. \\
& \left. + \left( 2g_p Q_{H_u} \cos \Theta'_W + \left( g_1 \sin \Theta_W - g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 Z_{i2}^+ Z_{j2}^+ \right) \left( g_{\mu\nu} \right) \quad (469)
\end{aligned}$$


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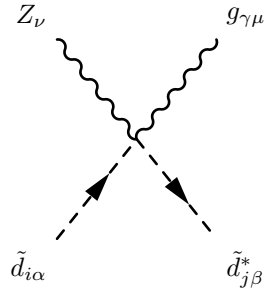
$$\frac{i}{4} g_3^2 \delta_{ij} \left( \sum_{a=1}^3 \lambda_{a,\alpha}^\gamma \lambda_{\beta,a}^\delta + \sum_{a=1}^3 \lambda_{\beta,a}^\gamma \lambda_{a,\alpha}^\delta \right) (g_{\mu\nu}) \quad (470)$$


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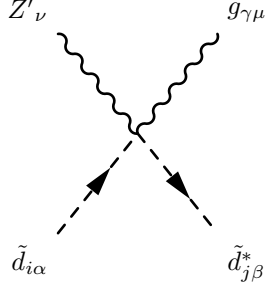
$$\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left( -2g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D + \left( -3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right) (g_{\mu\nu}) \quad (471)$$


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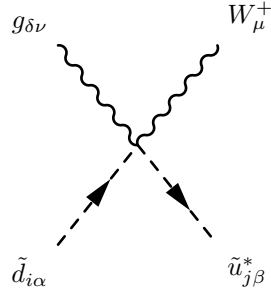
$$\begin{aligned} & -\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left( \left( 3g_2 \cos \Theta_W \cos \Theta'_W - 6g_p Q_d \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right. \\ & \left. - 2 \left( -3g_p Q_d \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \quad (472) \end{aligned}$$


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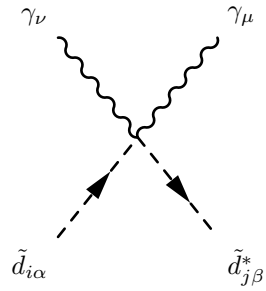
$$\begin{aligned} & \frac{i}{6} g_3 \lambda_{\beta, \alpha}^{\gamma} \left( \left( (3g_2 \cos \Theta_W + g_1 \sin \Theta_W) \sin \Theta'_W + 6g_p Q_q \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right. \\ & \left. - 2 \left( 3g_p Q_d \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \end{aligned} \quad (473)$$


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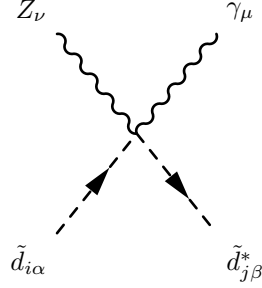
$$i \frac{1}{\sqrt{2}} g_2 g_3 \lambda_{\beta, \alpha}^{\delta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \quad (474)$$


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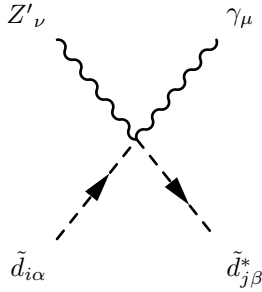
$$\frac{i}{18} \delta_{\alpha\beta} \left( \left( -3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D + 4g_1^2 \cos^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \quad (475)$$


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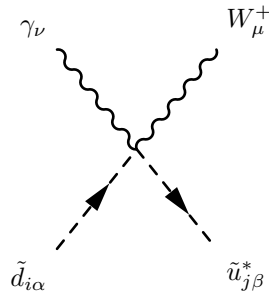
$$\begin{aligned}
& -\frac{i}{18}\delta_{\alpha\beta}\left(\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(3g_2\cos\Theta_W\cos\Theta'_W-6g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right. \\
& \left.+4g_1\cos\Theta_W\left(-3g_pQ_d\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\right)(g_{\mu\nu})
\end{aligned} \tag{476}$$


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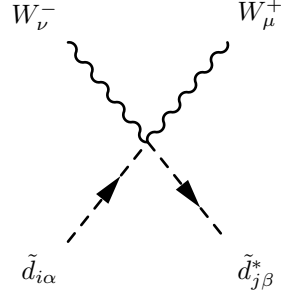
$$\begin{aligned}
& \frac{i}{18}\delta_{\alpha\beta}\left(\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right. \\
& \left.+4g_1\cos\Theta_W\left(3g_pQ_d\cos\Theta'_W+g_1\sin\Theta_W\sin\Theta'_W\right)\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\right)(g_{\mu\nu})
\end{aligned} \tag{477}$$


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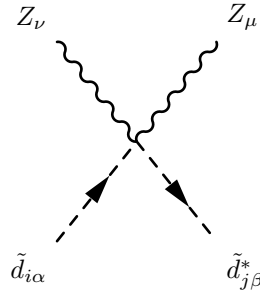
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \quad (478)$$


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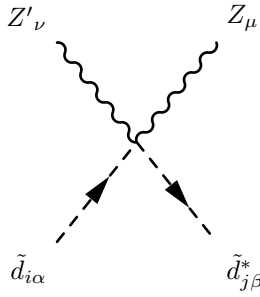
$$\frac{i}{2} g_2^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D (g_{\mu\nu}) \quad (479)$$


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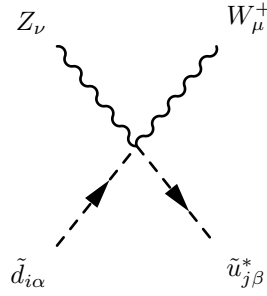
$$\begin{aligned} & \frac{i}{18} \delta_{\alpha\beta} \left( \left( 3g_2 \cos \Theta_W \cos \Theta'_W - 6g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right. \\ & \left. + 4 \left( -3g_p Q_d \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right)^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \quad (480) \end{aligned}$$


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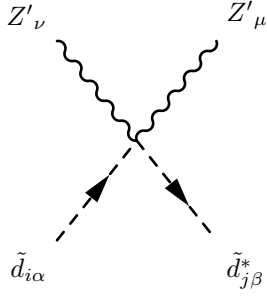
$$\begin{aligned}
& -\frac{i}{18}\delta_{\alpha\beta}\left(\left(6g_1g_pQ_q\cos\Theta'_W\sin\Theta_W+9g_2^2\cos\Theta_W^2\cos\Theta'_W\sin\Theta'_W\right.\right. \\
& \left.\left.+\cos\Theta'_W\left(-36g_p^2Q_q^2+g_1^2\sin\Theta_W^2\right)\sin\Theta'_W-6g_1g_pQ_q\sin\Theta_W\sin\Theta'^2_W\right.\right. \\
& \left.\left.+6g_2\cos\Theta_W\left(3g_pQ_q\cos\Theta'^2_W-3g_pQ_q\sin\Theta'^2_W+g_1\cos\Theta'_W\sin\Theta_W\sin\Theta'_W\right)\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right. \\
& \left.+2\left(6g_1g_pQ_d\cos\Theta'^2_W\sin\Theta_W+g_1^2\sin\Theta_W^2\sin2\Theta'_W\right.\right. \\
& \left.\left.-3g_pQ_d\left(2g_1\sin\Theta_W\sin\Theta'^2_W+3g_pQ_d\sin2\Theta'_W\right)\right)\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\right)(g_{\mu\nu})
\end{aligned} \tag{481}$$


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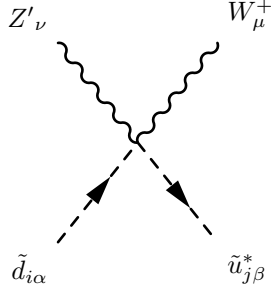
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\left(-6g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^U(g_{\mu\nu}) \tag{482}$$


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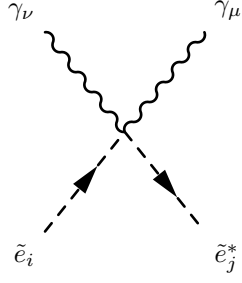
$$\begin{aligned}
& \frac{i}{18}\delta_{\alpha\beta}\left(\left(\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)^2\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right. \\
& \left.+4\left(3g_pQ_d\cos\Theta'_W+g_1\sin\Theta_W\sin\Theta'_W\right)^2\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\right)(g_{\mu\nu})
\end{aligned} \tag{483}$$


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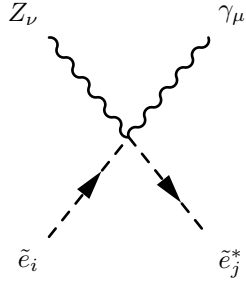
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \left( 6g_p Q_q \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \quad (484)$$


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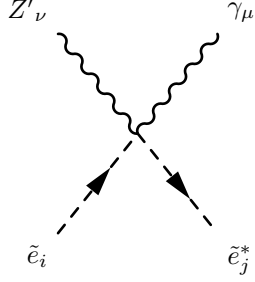
$$\frac{i}{2} \left( 4g_1^2 \cos^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E + \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right) (g_{\mu\nu}) \quad (485)$$


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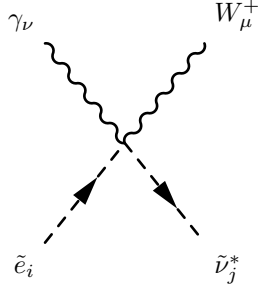
$$\begin{aligned} & - \frac{i}{2} \left( \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left( 2g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\ & \left. + 4g_1 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W - g_p Q_e \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu}) \quad (486) \end{aligned}$$


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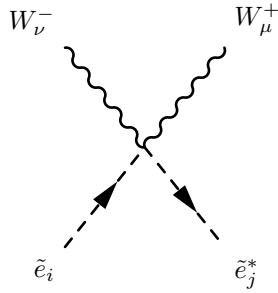
$$\frac{i}{2} \left( (g_1 \cos \Theta_W + g_2 \sin \Theta_W) \left( -2g_p Q_q \cos \Theta'_W + (g_1 \sin \Theta_W - g_2 \cos \Theta_W) \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\ \left. + 4g_1 \cos \Theta_W (g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_e \cos \Theta'_W) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu}) \quad (487)$$


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$$-i \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V (g_{\mu\nu}) \quad (488)$$

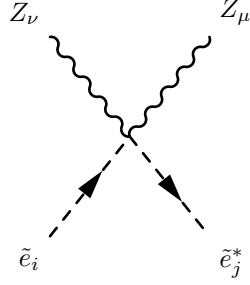

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$$\frac{i}{2} g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E (g_{\mu\nu}) \quad (489)$$

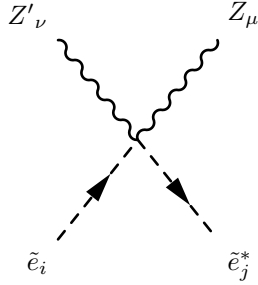

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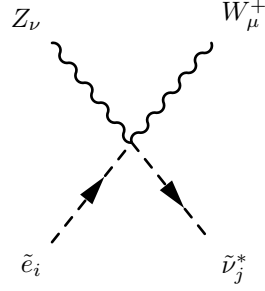
$$\begin{aligned}
& \frac{i}{2} \left( \left( 2g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. + 4 \left( g_1 \cos \Theta'_W \sin \Theta_W - g_p Q_e \sin \Theta'_W \right)^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu}) \quad (490)
\end{aligned}$$


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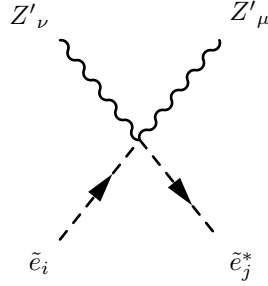
$$\begin{aligned}
& - \frac{i}{2} \left( \left( -2g_1 g_p Q_q \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \right. \\
& \left. \left. + \cos \Theta'_W \left( -4g_p^2 Q_q^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W + 2g_1 g_p Q_q \sin \Theta_W \sin \Theta'^2_W \right. \right. \\
& \left. \left. + 2g_2 \cos \Theta_W \left( -g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_q \cos \Theta'^2_W - g_p Q_q \sin \Theta'^2_W \right) \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. + 4 \left( g_1 g_p Q_e \cos \Theta'^2_W \sin \Theta_W + \cos \Theta'_W \left( g_1^2 \sin \Theta_W^2 - g_p^2 Q_e^2 \right) \sin \Theta'_W \right. \right. \\
& \left. \left. - g_1 g_p Q_e \sin \Theta_W \sin \Theta'^2_W \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu}) \quad (491)
\end{aligned}$$


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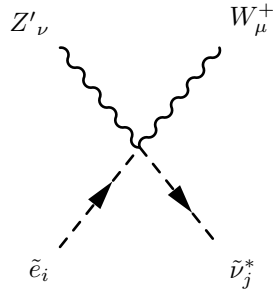
$$i \frac{1}{\sqrt{2}} g_2 \left( 2g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V (g_{\mu\nu}) \quad (492)$$


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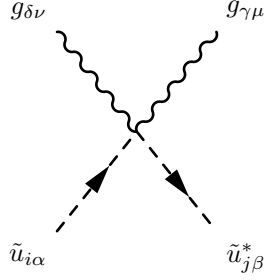
$$\begin{aligned} & \frac{i}{2} \left( \left( 2g_p Q_q \cos \Theta'_W + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\ & \left. + 4 \left( g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_e \cos \Theta'_W \right)^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu}) \quad (493) \end{aligned}$$


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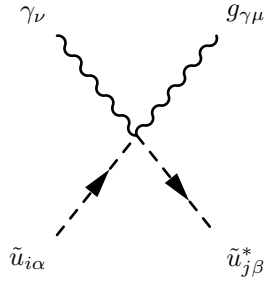
$$i \frac{1}{\sqrt{2}} g_2 \left( 2g_p Q_q \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V (g_{\mu\nu}) \quad (494)$$


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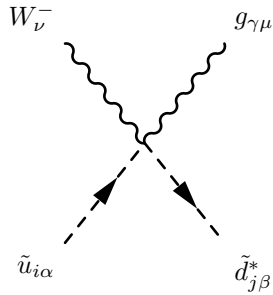
$$\frac{i}{4} g_3^2 \delta_{ij} \left( \sum_{a=1}^3 \lambda_{a,\alpha}^\gamma \lambda_{\beta,a}^\delta + \sum_{a=1}^3 \lambda_{\beta,a}^\gamma \lambda_{a,\alpha}^\delta \right) (g_{\mu\nu}) \quad (495)$$


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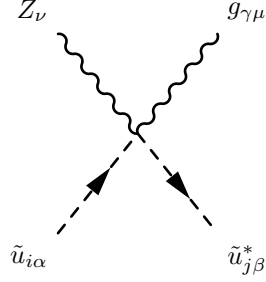
$$\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left( (3g_2 \sin \Theta_W + g_1 \cos \Theta_W) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + 4g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu}) \quad (496)$$


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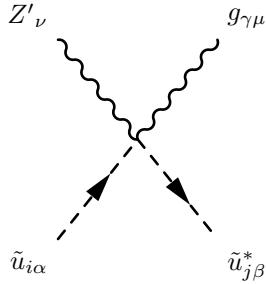
$$i \frac{1}{\sqrt{2}} g_2 g_3 \lambda_{\beta,\alpha}^\gamma \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D (g_{\mu\nu}) \quad (497)$$


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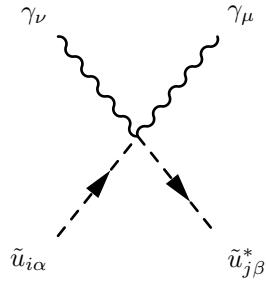
$$\frac{i}{6}g_3\lambda_{\beta,\alpha}^\gamma\left(\left(3g_2\cos\Theta_W\cos\Theta'_W+6g_pQ_q\sin\Theta'_W-g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U\right. \\ \left.-2\left(2g_1\cos\Theta'_W\sin\Theta_W+3g_pQ_u\sin\Theta'_W\right)\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U\right)(g_{\mu\nu}) \quad (498)$$


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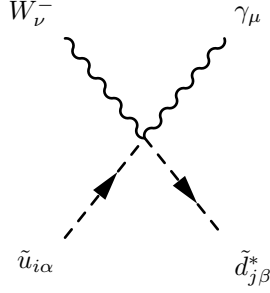
$$\frac{i}{6}g_3\lambda_{\beta,\alpha}^\gamma\left(\left(\left(-3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U\right. \\ \left.+2\left(2g_1\sin\Theta_W\sin\Theta'_W-3g_pQ_u\cos\Theta'_W\right)\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U\right)(g_{\mu\nu}) \quad (499)$$


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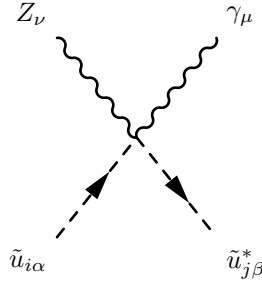
$$\frac{i}{18} \delta_{\alpha\beta} \left( 16g_1^2 \cos^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U + \left( 3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right) (g_{\mu\nu}) \quad (500)$$


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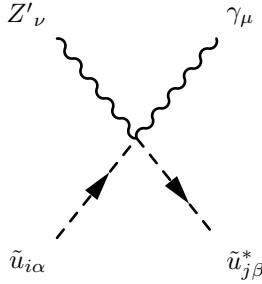
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D (g_{\mu\nu}) \quad (501)$$


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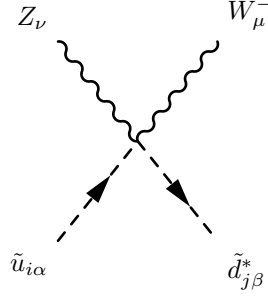
$$\begin{aligned} & -\frac{i}{18} \delta_{\alpha\beta} \left( \left( 3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \left( -3g_2 \cos \Theta_W \cos \Theta'_W - 6g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\ & \left. + 8g_1 \left( 3g_p Q_u \cos \Theta_W \sin \Theta'_W + g_1 \cos \Theta'_W \sin 2\Theta_W \right) \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu}) \quad (502) \end{aligned}$$


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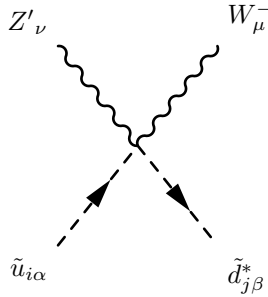
$$\begin{aligned}
& \frac{i}{18} \delta_{\alpha\beta} \left( (3g_2 \sin \Theta_W + g_1 \cos \Theta_W) \left( (-3g_2 \cos \Theta_W + g_1 \sin \Theta_W) \sin \Theta'_W + 6g_p Q_q \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\
& \left. + 8g_1 \left( -3g_p Q_u \cos \Theta_W \cos \Theta'_W + g_1 \sin 2\Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu})
\end{aligned} \tag{503}$$


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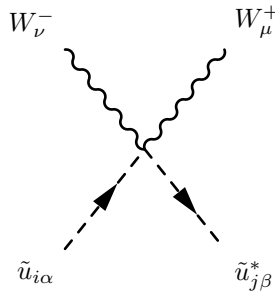
$$-\frac{i}{3} \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \left( -6g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D (g_{\mu\nu}) \tag{504}$$


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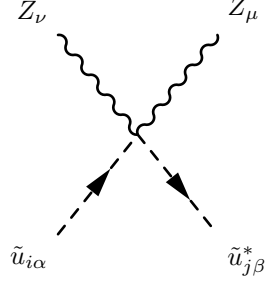
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \left( 6g_p Q_q \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D (g_{\mu\nu}) \tag{505}$$


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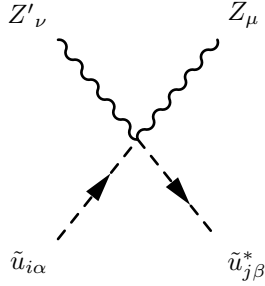
$$\frac{i}{2}g_2^2\delta_{\alpha\beta}\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U(g_{\mu\nu}) \quad (506)$$


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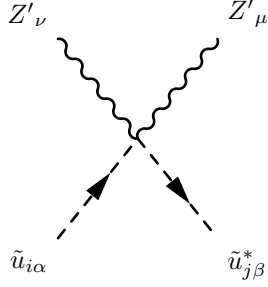
$$\begin{aligned} & \frac{i}{18}\delta_{\alpha\beta}\left(\left(3g_2\cos\Theta_W\cos\Theta'_W+6g_pQ_q\sin\Theta'_W-g_1\cos\Theta'_W\sin\Theta_W\right)^2\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U\right. \\ & \left.+4\left(2g_1\cos\Theta'_W\sin\Theta_W+3g_pQ_u\sin\Theta'_W\right)^2\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U\right)(g_{\mu\nu}) \quad (507) \end{aligned}$$


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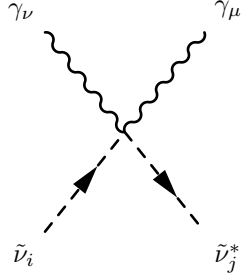
$$\begin{aligned} & -\frac{i}{18}\delta_{\alpha\beta}\left(\left(6g_1g_pQ_q\cos\Theta'^2_W\sin\Theta_W+9g_2^2\cos\Theta_W^2\cos\Theta'_W\sin\Theta'_W\right.\right. \\ & \left.+\cos\Theta'_W\left(-36g_p^2Q_q^2+g_1^2\sin\Theta_W^2\right)\sin\Theta'_W-6g_1g_pQ_q\sin\Theta_W\sin\Theta'^2_W\right. \\ & \left.-6g_2\cos\Theta_W\left(3g_pQ_q\cos\Theta'^2_W-3g_pQ_q\sin\Theta'^2_W+g_1\cos\Theta'_W\sin\Theta_W\sin\Theta'_W\right)\right)\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U \\ & -2\left(6g_1g_pQ_u\sin-2\Theta'_W+\Theta_W-g_1^2\sin 2\left(-\Theta'_W+\Theta_W\right)-2g_1^2\sin 2\Theta'_W+9g_p^2Q_u^2\sin 2\Theta'_W\right. \\ & \left.+g_1^2\sin 2\left(\Theta_W+\Theta'_W\right)+6g_1g_pQ_u\sin 2\Theta'_W+\Theta_W\right)\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U)(g_{\mu\nu}) \quad (508) \end{aligned}$$


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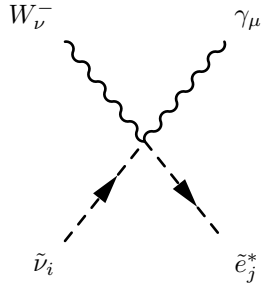
$$\frac{i}{18} \delta_{\alpha\beta} \left( \left( -3g_2 \cos \Theta_W + g_1 \sin \Theta_W \right) \sin \Theta'_W + 6g_p Q_q \cos \Theta'_W \right)^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + 4 \left( -2g_1 \sin \Theta_W \sin \Theta'_W + 3g_p Q_u \cos \Theta'_W \right)^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U (g_{\mu\nu}) \quad (509)$$


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$$\frac{i}{2} \left( 4g_1^2 \cos^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{j3+a}^V + \left( g_1 \cos \Theta_W - g_2 \sin \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V \right) (g_{\mu\nu}) \quad (510)$$

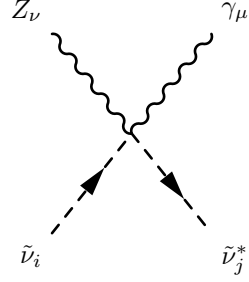

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$$-i \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E (g_{\mu\nu}) \quad (511)$$

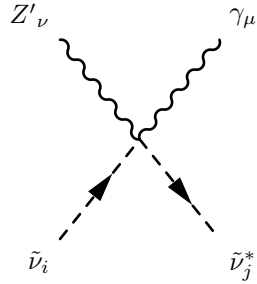

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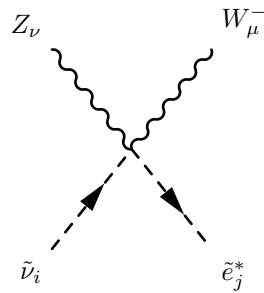
$$\begin{aligned}
& -\frac{i}{2} \left( (g_1 \cos \Theta_W - g_2 \sin \Theta_W) \left( 2g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V \right. \\
& \left. + 4g_1 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W - g_p Q_v \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{j3+a}^V \right) (g_{\mu\nu})
\end{aligned} \tag{512}$$


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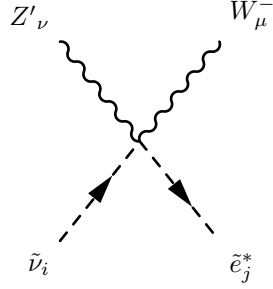
$$\begin{aligned}
& \frac{i}{2} \left( (g_1 \cos \Theta_W - g_2 \sin \Theta_W) \left( -2g_p Q_q \cos \Theta'_W + (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V \right. \\
& \left. + 4g_1 \cos \Theta_W \left( g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_v \cos \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{j3+a}^V \right) (g_{\mu\nu})
\end{aligned} \tag{513}$$


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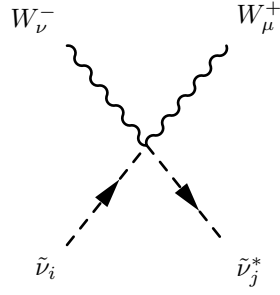
$$i \frac{1}{\sqrt{2}} g_2 \left( 2g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E (g_{\mu\nu}) \quad (514)$$


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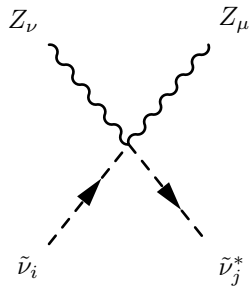
$$i \frac{1}{\sqrt{2}} g_2 \left( 2g_p Q_q \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E (g_{\mu\nu}) \quad (515)$$


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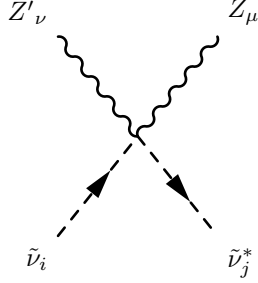
$$\frac{i}{2} g_2^2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V (g_{\mu\nu}) \quad (516)$$


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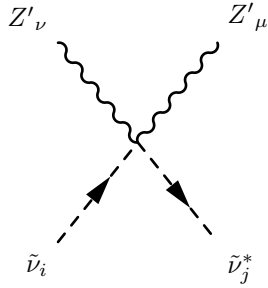
$$\begin{aligned}
& \frac{i}{2} \left( (2g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V \right. \\
& \left. + 4 \left( g_1 \cos \Theta'_W \sin \Theta_W - g_p Q_v \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{j3+a}^V \right) (g_{\mu\nu})
\end{aligned} \tag{517}$$


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$$\begin{aligned}
& - \frac{i}{2} \left( \left( -2g_1 g_p Q_q \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta'^2_W \cos \Theta'_W \sin \Theta'_W \right. \right. \\
& \left. \left. + \cos \Theta'_W \left( -4g_p^2 Q_q^2 + g_1^2 \sin \Theta'^2_W \right) \sin \Theta'_W + 2g_1 g_p Q_q \sin \Theta_W \sin \Theta'^2_W \right. \right. \\
& \left. \left. + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W - g_p Q_q \cos \Theta'^2_W + g_p Q_q \sin \Theta'^2_W \right) \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V \right. \\
& \left. + 4 \left( g_1 g_p Q_v \cos \Theta'^2_W \sin \Theta_W + \cos \Theta'_W \left( g_1^2 \sin \Theta'^2_W - g_p^2 Q_v^2 \right) \sin \Theta'_W \right. \right. \\
& \left. \left. - g_1 g_p Q_v \sin \Theta_W \sin \Theta'^2_W \right) \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{j3+a}^V \right) (g_{\mu\nu})
\end{aligned} \tag{518}$$

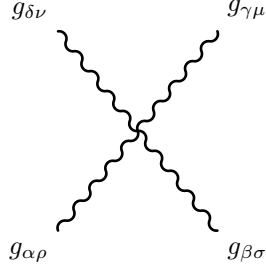

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$$\begin{aligned}
& \frac{i}{2} \left( \left( -2g_p Q_q \cos \Theta'_W + \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^V \right. \\
& \left. + 4 \left( g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_v \cos \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{V,*} Z_{j3+a}^V \right) (g_{\mu\nu})
\end{aligned} \tag{519}$$


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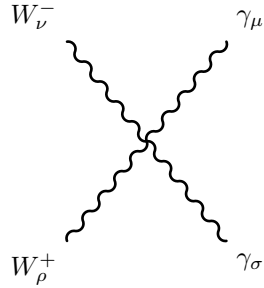
### 9.9 Four Vector Boson-Interaction



$$-ig_3^2 \left( \sum_{a=1}^8 f_{\alpha,\delta,a} f_{\beta,\gamma,a} + \sum_{a=1}^8 f_{\alpha,\gamma,a} f_{\beta,\delta,a} \right) (g_{\rho\sigma} g_{\mu\nu}) \quad (520)$$

$$+ ig_3^2 \left( - \sum_{a=1}^8 f_{\alpha,\beta,a} f_{\gamma,\delta,a} + \sum_{a=1}^8 f_{\alpha,\delta,a} f_{\beta,\gamma,a} \right) (g_{\rho\mu} g_{\sigma\nu}) \quad (521)$$

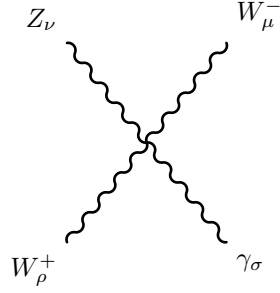
$$+ ig_3^2 \left( \sum_{a=1}^8 f_{\alpha,\gamma,a} f_{\beta,\delta,a} + \sum_{a=1}^8 f_{\alpha,\beta,a} f_{\gamma,\delta,a} \right) (g_{\rho\nu} g_{\sigma\mu}) \quad (522)$$



$$ig_2^2 \sin^2 \Theta_W (g_{\rho\sigma} g_{\mu\nu}) \quad (523)$$

$$+ ig_2^2 \sin^2 \Theta_W (g_{\rho\mu} g_{\sigma\nu}) \quad (524)$$

$$+ -2ig_2^2 \sin^2 \Theta_W (g_{\rho\nu} g_{\sigma\mu}) \quad (525)$$

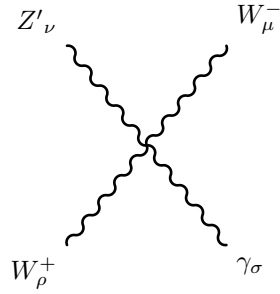


$$ig_2^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W (g_{\rho\sigma} g_{\mu\nu}) \quad (526)$$

$$+ -ig_2^2 \cos \Theta'_W \sin 2\Theta_W (g_{\rho\mu} g_{\sigma\nu}) \quad (527)$$

$$+ ig_2^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W (g_{\rho\nu} g_{\sigma\mu}) \quad (528)$$


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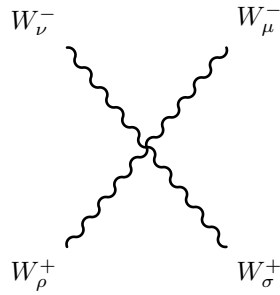


$$- ig_2^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W (g_{\rho\sigma} g_{\mu\nu}) \quad (529)$$

$$+ ig_2^2 \sin 2\Theta_W \sin \Theta'_W (g_{\rho\mu} g_{\sigma\nu}) \quad (530)$$

$$+ -ig_2^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W (g_{\rho\nu} g_{\sigma\mu}) \quad (531)$$


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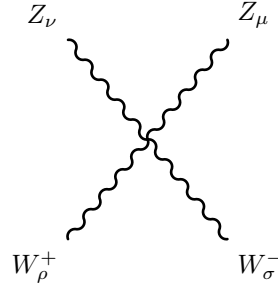


$$2ig_2^2(g_{\rho\sigma}g_{\mu\nu}) \quad (532)$$

$$+ -ig_2^2(g_{\rho\mu}g_{\sigma\nu}) \quad (533)$$

$$+ -ig_2^2(g_{\rho\nu}g_{\sigma\mu}) \quad (534)$$


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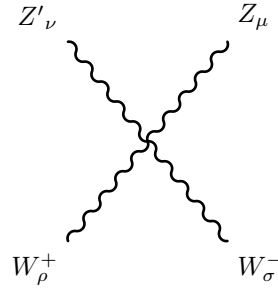


$$- 2ig_2^2 \cos^2 \Theta_W \cos^2 \Theta'_W (g_{\rho\sigma}g_{\mu\nu}) \quad (535)$$

$$+ ig_2^2 \cos^2 \Theta_W \cos^2 \Theta'_W (g_{\rho\mu}g_{\sigma\nu}) \quad (536)$$

$$+ ig_2^2 \cos^2 \Theta_W \cos^2 \Theta'_W (g_{\rho\nu}g_{\sigma\mu}) \quad (537)$$


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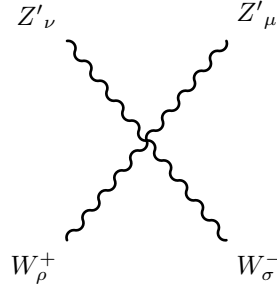


$$ig_2^2 \cos^2 \Theta_W \sin 2\Theta'_W (g_{\rho\sigma}g_{\mu\nu}) \quad (538)$$

$$+ -ig_2^2 \cos^2 \Theta_W \cos \Theta'_W \sin \Theta'_W (g_{\rho\mu}g_{\sigma\nu}) \quad (539)$$

$$+ -ig_2^2 \cos^2 \Theta_W \cos \Theta'_W \sin \Theta'_W (g_{\rho\nu}g_{\sigma\mu}) \quad (540)$$


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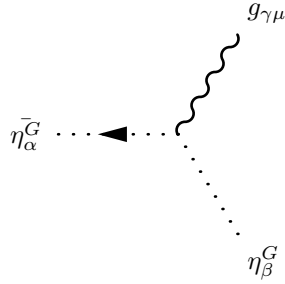


$$- 2ig_2^2 \cos \Theta_W^2 \sin \Theta_W'^2 (g_{\rho\sigma} g_{\mu\nu}) \quad (541)$$

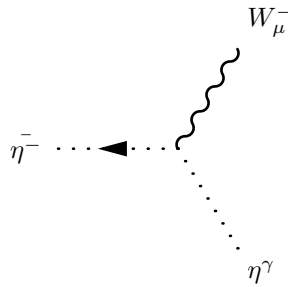
$$+ ig_2^2 \cos \Theta_W^2 \sin \Theta_W'^2 (g_{\rho\mu} g_{\sigma\nu}) \quad (542)$$

$$+ ig_2^2 \cos \Theta_W^2 \sin \Theta_W'^2 (g_{\rho\nu} g_{\sigma\mu}) \quad (543)$$

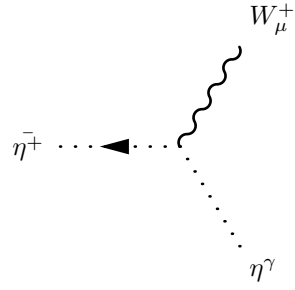
### 9.10 Two Ghosts-One Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma} (p_\mu^{\eta_\beta^G}) \quad (544)$$

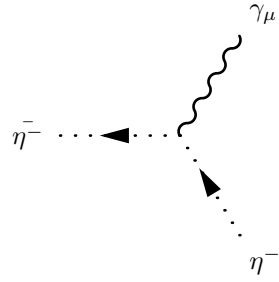


$$ig_2 \sin \Theta_W (p_\mu^{\eta^\gamma}) \quad (545)$$



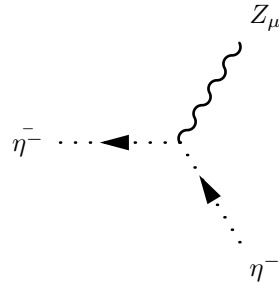
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^\gamma}) \quad (546)$$


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$$-ig_2 \sin \Theta_W (p_\mu^{\eta^-}) \quad (547)$$

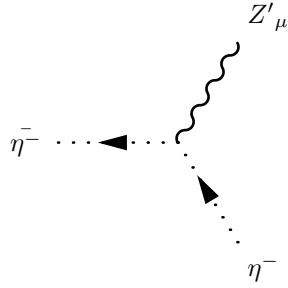

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$$-ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^-}) \quad (548)$$

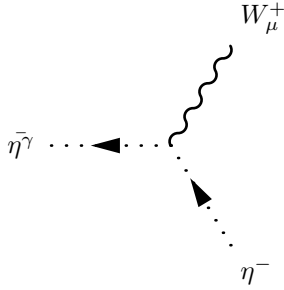

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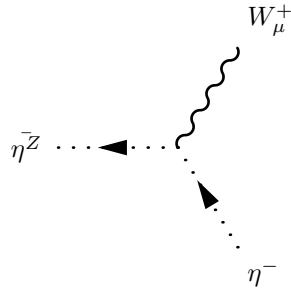
$$ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^-}) \quad (549)$$


---



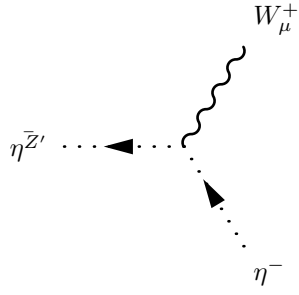
$$ig_2 \sin \Theta_W (p_\mu^{\eta^-}) \quad (550)$$


---



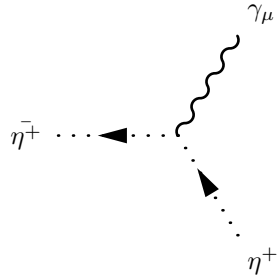
$$ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^-}) \quad (551)$$


---



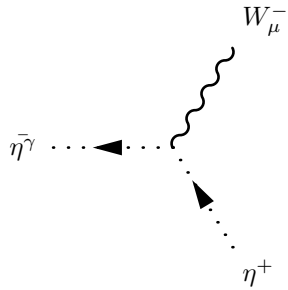
$$-ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^-}) \quad (552)$$


---



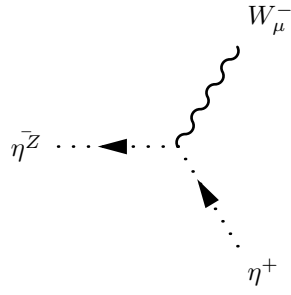
$$ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (553)$$


---



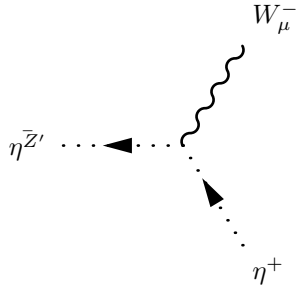
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (554)$$


---



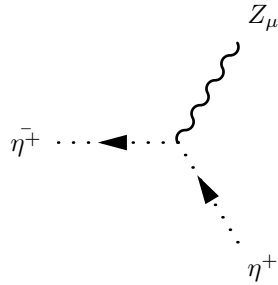
$$-ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^+}) \tag{555}$$


---



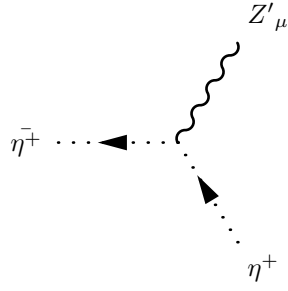
$$ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^+}) \tag{556}$$


---



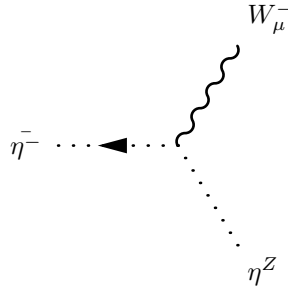
$$ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^+}) \tag{557}$$


---



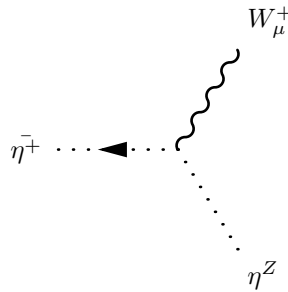
$$-ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^+}) \quad (558)$$


---



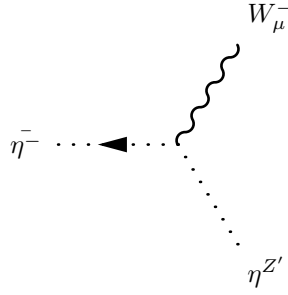
$$ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^Z}) \quad (559)$$


---



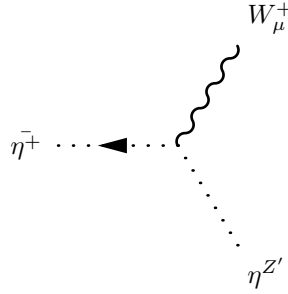
$$-ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^Z}) \quad (560)$$


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$$-ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^{Z'}}) \quad (561)$$

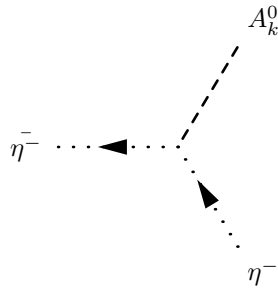

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$$ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^{Z'}}) \quad (562)$$

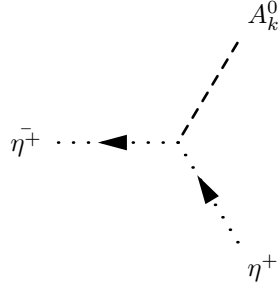

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### 9.11 Two Ghosts-One Scalar-Interaction



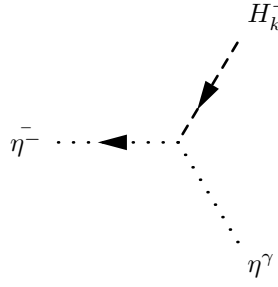
$$\frac{1}{4} g_2^2 (v_d Z_{k1}^{A,*} - v_u Z_{k2}^{A,*}) \xi_{W^-} \quad (563)$$


---



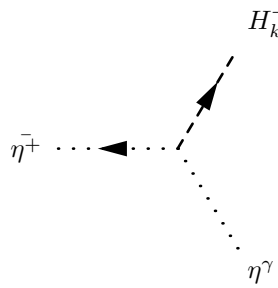
$$\frac{1}{4}g_2^2 \left( -v_d Z_{k1}^{A,*} + v_u Z_{k2}^{A,*} \right) \xi_{W^-} \quad (564)$$


---



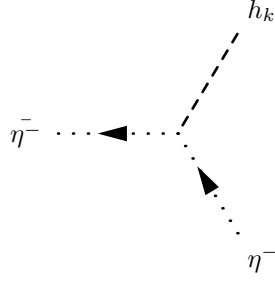
$$\frac{i}{4}g_2 \xi_{W^-} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left( v_d Z_{k1}^+ - v_u Z_{k2}^+ \right) \quad (565)$$


---



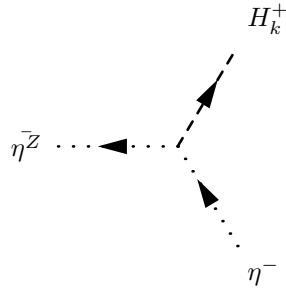
$$\frac{i}{4}g_2 \xi_{W^-} \left( g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left( v_d Z_{k1}^+ - v_u Z_{k2}^+ \right) \quad (566)$$


---



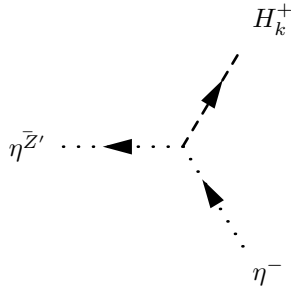
$$-\frac{i}{4}g_2^2(v_d Z_{k1}^{H,*} + v_u Z_{k2}^{H,*})\xi_{W^-} \quad (567)$$


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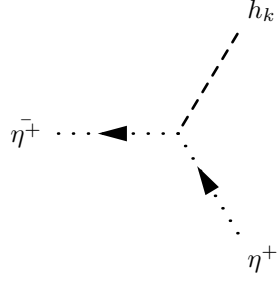
$$\begin{aligned} &-\frac{i}{4}g_2\xi_Z(v_d(2g_p Q_{H_d}\sin\Theta'_W + g_1\cos\Theta'_W\sin\Theta_W + g_2\cos\Theta_W\cos\Theta'_W)Z_{k1}^+ \\ &-v_u(-2g_p Q_{H_u}\sin\Theta'_W + g_1\cos\Theta'_W\sin\Theta_W + g_2\cos\Theta_W\cos\Theta'_W)Z_{k2}^+) \end{aligned} \quad (568)$$


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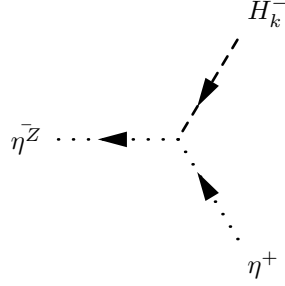
$$\begin{aligned} &\frac{i}{4}g_2\xi_{Z'}(v_d(-2g_p Q_{H_d}\cos\Theta'_W + (g_1\sin\Theta_W + g_2\cos\Theta_W)\sin\Theta'_W)Z_{k1}^+ \\ &-v_u(2g_p Q_{H_u}\cos\Theta'_W + (g_1\sin\Theta_W + g_2\cos\Theta_W)\sin\Theta'_W)Z_{k2}^+) \end{aligned} \quad (569)$$


---



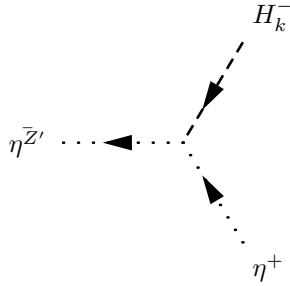
$$-\frac{i}{4}g_2^2(v_d Z_{k1}^{H,*} + v_u Z_{k2}^{H,*})\xi_{W^-} \quad (570)$$


---



$$\begin{aligned} &-\frac{i}{4}g_2\xi_Z\left(v_d\left(2g_p Q_{H_d}\sin\Theta'_W + g_1\cos\Theta'_W\sin\Theta_W + g_2\cos\Theta_W\cos\Theta'_W\right)Z_{k1}^+ \right. \\ &\left. - v_u\left(-2g_p Q_{H_u}\sin\Theta'_W + g_1\cos\Theta'_W\sin\Theta_W + g_2\cos\Theta_W\cos\Theta'_W\right)Z_{k2}^+\right) \end{aligned} \quad (571)$$

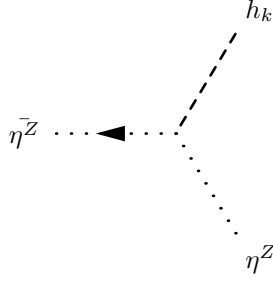

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$$\begin{aligned} &\frac{i}{4}g_2\xi_{Z'}\left(v_d\left(-2g_p Q_{H_d}\cos\Theta'_W + \left(g_1\sin\Theta_W + g_2\cos\Theta_W\right)\sin\Theta'_W\right)Z_{k1}^+ \right. \\ &\left. - v_u\left(2g_p Q_{H_u}\cos\Theta'_W + \left(g_1\sin\Theta_W + g_2\cos\Theta_W\right)\sin\Theta'_W\right)Z_{k2}^+\right) \end{aligned} \quad (572)$$

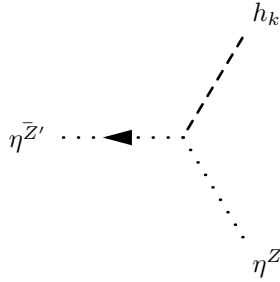

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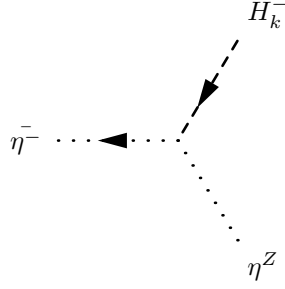
$$\begin{aligned}
& -\frac{i}{4}\xi_Z \left( 4g_p^2 Q_s^2 v_s Z_{k3}^{H,*} \sin \Theta'_W \right. \\
& + v_d Z_{k1}^{H,*} \left( 2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \\
& \left. + v_u Z_{k2}^{H,*} \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \right) \quad (573)
\end{aligned}$$


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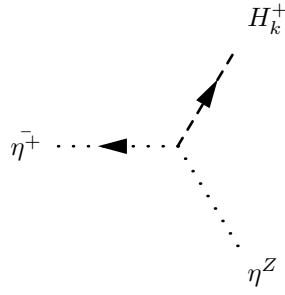
$$\begin{aligned}
& \frac{i}{4}\xi_{Z'} \left( -4g_p^2 Q_s^2 v_s Z_{k3}^{H,*} \cos \Theta'_W \sin \Theta'_W \right. \\
& + v_d Z_{k1}^{H,*} \left( -2g_1 g_p Q_{H_d} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \left. \cos \Theta'_W \left( -4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta'^2_W \right. \\
& \left. + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W - g_p Q_{H_d} \cos \Theta'^2_W + g_p Q_{H_d} \sin \Theta'^2_W \right) \right) \\
& + v_u Z_{k2}^{H,*} \left( 2g_1 g_p Q_{H_u} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \left. \cos \Theta'_W \left( -4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta'^2_W \right. \\
& \left. + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_u} \cos \Theta'^2_W - g_p Q_{H_u} \sin \Theta'^2_W \right) \right) \quad (574)
\end{aligned}$$


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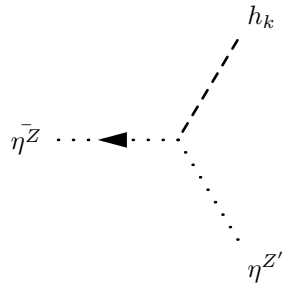
$$\begin{aligned} & \frac{i}{4} g_2 \xi_{W^-} \left( v_d \left( -2g_p Q_{H_d} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{k1}^+ \right. \\ & \left. + v_u \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{k2}^+ \right) \end{aligned} \quad (575)$$


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$$\begin{aligned} & \frac{i}{4} g_2 \xi_{W^-} \left( v_d \left( -2g_p Q_{H_d} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{k1}^+ \right. \\ & \left. + v_u \left( -2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{k2}^+ \right) \end{aligned} \quad (576)$$

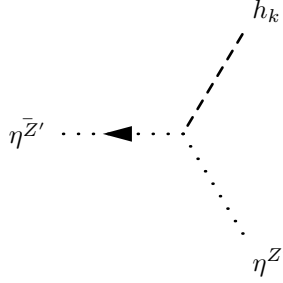

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$$\frac{i}{4} \xi_Z \left( -4g_p^2 Q_s^2 v_s Z_{k3}^{H,*} \cos \Theta'_W \sin \Theta'_W \right)$$

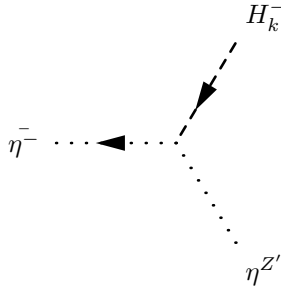
$$\begin{aligned}
& + v_d Z_{k1}^{H,*} \left( -2g_1 g_p Q_{H_d} \cos \Theta'_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left( -4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta'^2_W \\
& \left. + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W - g_p Q_{H_d} \cos \Theta'^2_W + g_p Q_{H_d} \sin \Theta'^2_W \right) \right) \\
& + v_u Z_{k2}^{H,*} \left( 2g_1 g_p Q_{H_u} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left( -4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta'^2_W \\
& \left. + 2g_2 \cos \Theta_W \left( g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_u} \cos \Theta'^2_W - g_p Q_{H_u} \sin \Theta'^2_W \right) \right) \quad (577)
\end{aligned}$$


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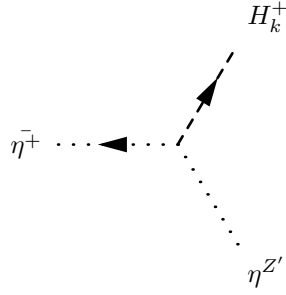
$$\begin{aligned}
& - \frac{i}{4} \xi_{Z'} \left( 4g_p^2 Q_s^2 v_s Z_{k3}^{H,*} \cos \Theta'^2_W \right. \\
& + v_d Z_{k1}^{H,*} \left( -2g_p Q_{H_d} \cos \Theta'_W + \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \\
& \left. + v_u Z_{k2}^{H,*} \left( 2g_p Q_{H_u} \cos \Theta'_W + \left( g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \right) \quad (578)
\end{aligned}$$


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$$\begin{aligned}
& - \frac{i}{4} g_2 \xi_{W^-} \left( v_d \left( 2g_p Q_{H_d} \cos \Theta'_W + \left( -g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{k1}^+ \right. \\
& \left. + v_u \left( 2g_p Q_{H_u} \cos \Theta'_W + \left( g_1 \sin \Theta_W - g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{k2}^+ \right) \quad (579)
\end{aligned}$$


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$$\begin{aligned}
& -\frac{i}{4}g_2\xi_{W-}\left(v_d\left(2g_pQ_{H_d}\cos\Theta'_W+\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W\right)Z_{k1}^+ \right. \\
& \left. +v_u\left(2g_pQ_{H_u}\cos\Theta'_W+\left(g_1\sin\Theta_W-g_2\cos\Theta_W\right)\sin\Theta'_W\right)Z_{k2}^+\right)
\end{aligned} \tag{580}$$

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## 10 Clebsch-Gordan Coefficients