

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

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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}	\tilde{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	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1}, Q_l)$
\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	$(1, \mathbf{1}, \mathbf{1}, Q_e)$
\hat{s}	S	\tilde{S}	1	$(0, \mathbf{1}, \mathbf{1}, Q_s)$
\hat{s}_1	S_1	\tilde{s}_1	1	$(0, \mathbf{1}, \mathbf{1}, Q_1)$
\hat{s}_2	S_2	\tilde{s}_2	1	$(0, \mathbf{1}, \mathbf{1}, Q_2)$
\hat{s}_3	S_3	\tilde{s}_3	1	$(0, \mathbf{1}, \mathbf{1}, Q_3)$

2 Superpotential and Lagrangian

2.1 Superpotential

$$W = -Y_d \hat{d} \hat{q} \hat{H}_d - Y_e \hat{e} \hat{l} \hat{H}_d + \lambda \hat{H}_u \hat{H}_d \hat{s} + \frac{1}{3} \kappa \hat{s}_1 \hat{s}_2 \hat{s}_3 + Y_u \hat{u} \hat{q} \hat{H}_u \quad (1)$$

2.2 Softbreaking terms

$$\begin{aligned}
-L_{SB,W} = & + \frac{1}{3} S_1 S_2 S_3 T_\kappa - H_d^0 H_u^0 S T_\lambda + H_d^- H_u^+ S T_\lambda + H_d^0 \tilde{d}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{d}_{L,j\beta} T_{d,ij} \\
& - H_d^- \tilde{d}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{u}_{L,j\beta} T_{d,ij} + H_d^0 \tilde{e}_{R,i}^* \tilde{e}_{L,j} T_{e,ij} - H_d^- \tilde{e}_{R,i}^* \tilde{\nu}_{L,j} T_{e,ij} - H_u^+ \tilde{u}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{d}_{L,j\beta} T_{u,ij} \\
& + H_u^0 \tilde{u}_{R,i\alpha}^* \delta_{\alpha\beta} \tilde{u}_{L,j\beta} T_{u,ij} + \text{h.c.} \\
-L_{SB,\phi} = & + m_{H_d}^2 |H_d^0|^2 + m_{H_d}^2 |H_d^-|^2 + m_{H_u}^2 |H_u^0|^2 + m_{H_u}^2 |H_u^+|^2 + m_{s_1}^2 |S_1|^2 + m_{s_2}^2 |S_2|^2 + m_{s_3}^2 |S_3|^2
\end{aligned} \quad (2)$$

$$\begin{aligned}
& + m_S^2 |S|^2 + \tilde{d}_{L,i\alpha}^* \delta_{\alpha\beta} m_{q,ij}^2 \tilde{d}_{L,j\beta} + \tilde{d}_{R,i\alpha}^* \delta_{\alpha\beta} m_{d,ij}^2 \tilde{d}_{R,j\beta} + \tilde{e}_{L,i}^* m_{l,ij}^2 \tilde{e}_{L,j} + \tilde{e}_{R,i}^* m_{e,ij}^2 \tilde{e}_{R,j} \\
& + \tilde{u}_{L,i\alpha}^* \delta_{\alpha\beta} m_{q,ij}^2 \tilde{u}_{L,j\beta} + \tilde{u}_{R,i\alpha}^* \delta_{\alpha\beta} m_{u,ij}^2 \tilde{u}_{R,j\beta} + \tilde{\nu}_{L,i}^* m_{l,ij}^2 \tilde{\nu}_{L,j}
\end{aligned} \tag{3}$$

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

2.3 Gauge fixing terms

2.3.1 Gauge fixing terms for eigenstates 'GaugeES'

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

2.3.2 Gauge fixing terms for eigenstates 'EWSB'

$$\begin{aligned}
L_{GF} = & -\frac{1}{2} |\partial_\mu g|^2 \xi_g^{-1} - \frac{1}{2} |\partial_\mu \gamma|^2 \xi_\gamma^{-1} - \frac{i}{2} g_2 \left(H_d^- v_d - v_u H_u^{+,*} \right) \xi_{W^-} + |\partial_\mu W^-|^2 \xi_{W^-}^{-1} \\
& - \frac{1}{2} |\partial_\mu Z|^2 \\
& + \frac{1}{2} \xi_Z \left(g_2 \left(\sigma_d v_d - \sigma_u v_u \right) \cos \Theta_W \cos \Theta'_W + g_1 \left(\sigma_d v_d - \sigma_u v_u \right) \cos \Theta'_W \sin \Theta_W \right. \\
& + 2g_p \left(Q_1 \sigma_1 v_1 + Q_2 \sigma_2 v_2 + Q_3 \sigma_3 v_3 + Q_{H_d} \sigma_d v_d + Q_{H_u} \sigma_u v_u + Q_s \sigma_s v_s \right) \sin \Theta'_W \Big) \xi_Z^{-1} \\
& - \frac{1}{2} |\partial_\mu Z'|^2 \\
& + \frac{1}{2} \xi_{Z'} \left(2g_p \left(Q_1 \sigma_1 v_1 + Q_2 \sigma_2 v_2 + Q_3 \sigma_3 v_3 + Q_{H_d} \sigma_d v_d + Q_{H_u} \sigma_u v_u + Q_s \sigma_s v_s \right) \cos \Theta'_W \right. \\
& \left. - \left(\sigma_d v_d - \sigma_u v_u \right) \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \xi_{Z'}^{-1}
\end{aligned} \tag{6}$$

2.4 Fields integrated out

None

3 Renormalization Group Equations

3.1 Anomalous Dimensions

$$\begin{aligned}
\gamma_{\hat{q}}^{(1)} = & -\frac{1}{30} \left(45g_2^2 + 60g_p^2 Q_q^2 + 80g_3^2 + g_1^2 \right) \mathbf{1} + Y_d^\dagger Y_d + Y_u^\dagger Y_u \\
\gamma_{\hat{q}}^{(2)} = & +\frac{1}{900} \left(199g_1^4 + 10g_1^2 \left(4 \left(3g_p^2 Q_q \left(10Q_q - 18Q_u - 3Q_{H_d} + 3Q_{H_u} + 9Q_d + 9Q_e - 9Q_l \right) + 4g_3^2 \right) + 9g_2^2 \right) \right. \\
& + 25 \left(135g_2^4 + 72g_2^2 \left(3g_p^2 Q_q^2 + 4g_3^2 \right) \right. \\
& \left. \left. + 8 \left(-4g_3^4 + 48g_3^2 g_p^2 Q_q^2 \right) \right) \right)
\end{aligned} \tag{7}$$

$$\begin{aligned}
& + 9g_p^4 Q_q^2 \left(20Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) \Big) \Big) \mathbf{1} \\
& + \frac{4}{5} g_1^2 Y_u^\dagger Y_u + 2g_p^2 Q_{H_u}^2 Y_u^\dagger Y_u - 2g_p^2 Q_q^2 Y_u^\dagger Y_u + 2g_p^2 Q_u^2 Y_u^\dagger Y_u \\
& - |\lambda|^2 Y_u^\dagger Y_u - 2Y_d^\dagger Y_d Y_d^\dagger Y_d - 2Y_u^\dagger Y_u Y_u^\dagger Y_u \\
& + Y_d^\dagger Y_d \left(2g_p^2 Q_d^2 + 2g_p^2 Q_{H_d}^2 - 2g_p^2 Q_q^2 - 3\text{Tr}(Y_d Y_d^\dagger) \right) + \frac{2}{5} g_1^2 - |\lambda|^2 - \text{Tr}(Y_e Y_e^\dagger) \\
& - 3Y_u^\dagger Y_u \text{Tr}(Y_u Y_u^\dagger)
\end{aligned} \tag{8}$$

$$\gamma_l^{(1)} = -\frac{1}{10} \left(15g_2^2 + 20g_p^2 Q_l^2 + 3g_1^2 \right) \mathbf{1} + Y_e^\dagger Y_e \tag{9}$$

$$\begin{aligned}
\gamma_l^{(2)} = & + \frac{1}{100} \left(207g_1^4 + 30g_1^2 \left(3g_2^2 + 4g_p^2 Q_l \left(-3Q_d - 3Q_e - 3Q_q + 4Q_l + 6Q_u - Q_{H_u} + Q_{H_d} \right) \right) \right. \\
& + 25 \left(15g_2^4 + 24g_2^2 g_p^2 Q_l^2 \right. \\
& + 8g_p^4 Q_l^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 8Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) \Big) \Big) \mathbf{1} \\
& - 2Y_e^\dagger Y_e Y_e^\dagger Y_e \\
& + Y_e^\dagger Y_e \left(2g_p^2 Q_e^2 + 2g_p^2 Q_{H_d}^2 - 2g_p^2 Q_l^2 - 3\text{Tr}(Y_d Y_d^\dagger) \right) + \frac{6}{5} g_1^2 - |\lambda|^2 - \text{Tr}(Y_e Y_e^\dagger)
\end{aligned} \tag{10}$$

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

$$\begin{aligned}
\gamma_{H_d}^{(2)} = & + \frac{207}{100} g_1^4 + \frac{9}{10} g_1^2 g_2^2 + \frac{15}{4} g_2^4 - \frac{18}{5} g_1^2 g_p^2 Q_d Q_{H_d} - \frac{18}{5} g_1^2 g_p^2 Q_e Q_{H_d} + \frac{12}{5} g_1^2 g_p^2 Q_{H_d}^2 \\
& + 6g_2^2 g_p^2 Q_{H_d}^2 + 18g_p^4 Q_d^2 Q_{H_d}^2 + 6g_p^4 Q_e^2 Q_{H_d}^2 + 8g_p^4 Q_{H_d}^4 - \frac{6}{5} g_1^2 g_p^2 Q_{H_d} Q_{H_u} \\
& + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 + \frac{18}{5} g_1^2 g_p^2 Q_{H_d} Q_l + 12g_p^4 Q_{H_d}^2 Q_l^2 - \frac{18}{5} g_1^2 g_p^2 Q_{H_d} Q_q + 36g_p^4 Q_{H_d}^2 Q_q^2 \\
& + 2g_p^4 Q_{H_d}^2 Q_s^2 + 2g_p^4 Q_{H_d}^2 Q_1^2 + 2g_p^4 Q_{H_d}^2 Q_2^2 + 2g_p^4 Q_{H_d}^2 Q_3^2 + \frac{36}{5} g_1^2 g_p^2 Q_{H_d} Q_u \\
& + 18g_p^4 Q_{H_d}^2 Q_u^2 - 3\lambda^2 \lambda^{*,2} - \frac{2}{5} \left(-5 \left(3g_p^2 \left(-Q_{H_d}^2 + Q_d^2 + Q_q^2 \right) + 8g_3^2 \right) + g_1^2 \right) \text{Tr}(Y_d Y_d^\dagger) \\
& + \frac{6}{5} g_1^2 \text{Tr}(Y_e Y_e^\dagger) + 2g_p^2 Q_e^2 \text{Tr}(Y_e Y_e^\dagger) - 2g_p^2 Q_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) + 2g_p^2 Q_l^2 \text{Tr}(Y_e Y_e^\dagger) \\
& + |\lambda|^2 \left(2g_p^2 \left(-Q_{H_d}^2 + Q_{H_u}^2 + Q_s^2 \right) - 3\text{Tr}(Y_u Y_u^\dagger) \right) - 9\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 3\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) \\
& - 3\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger)
\end{aligned} \tag{12}$$

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

$$\begin{aligned}
\gamma_{H_u}^{(2)} = & + \frac{207}{100} g_1^4 + \frac{9}{10} g_1^2 g_2^2 + \frac{15}{4} g_2^4 + \frac{18}{5} g_1^2 g_p^2 Q_d Q_{H_u} + \frac{18}{5} g_1^2 g_p^2 Q_e Q_{H_u} - \frac{6}{5} g_1^2 g_p^2 Q_{H_d} Q_{H_u} \\
& + \frac{12}{5} g_1^2 g_p^2 Q_{H_u}^2 + 6g_2^2 g_p^2 Q_{H_u}^2 + 18g_p^4 Q_d^2 Q_{H_u}^2 + 6g_p^4 Q_e^2 Q_{H_u}^2 + 4g_p^4 Q_{H_d}^2 Q_{H_u}^2 \\
& + 8g_p^4 Q_{H_u}^4 - \frac{18}{5} g_1^2 g_p^2 Q_{H_u} Q_l + 12g_p^4 Q_{H_u}^2 Q_l^2 + \frac{18}{5} g_1^2 g_p^2 Q_{H_u} Q_q + 36g_p^4 Q_{H_u}^2 Q_q^2
\end{aligned}$$

$$\begin{aligned}
& + 2g_p^4 Q_{H_u}^2 Q_s^2 + 2g_p^4 Q_{H_u}^2 Q_1^2 + 2g_p^4 Q_{H_u}^2 Q_2^2 + 2g_p^4 Q_{H_u}^2 Q_3^2 - \frac{36}{5} g_1^2 g_p^2 Q_{H_u} Q_u \\
& + 18g_p^4 Q_{H_u}^2 Q_u^2 - 3\lambda^2 \lambda^{*,2} + |\lambda|^2 \left(2g_p^2 \left(-Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2 \right) - 3\text{Tr}(Y_d Y_d^\dagger) - \text{Tr}(Y_e Y_e^\dagger) \right) \\
& + \frac{2}{5} \left(2g_1^2 + 5 \left(3g_p^2 \left(-Q_{H_u}^2 + Q_q^2 + Q_u^2 \right) + 8g_3^2 \right) \right) \text{Tr}(Y_u Y_u^\dagger) - 3\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 9\text{Tr}(Y_u Y_u^\dagger Y_u Y_u^\dagger)
\end{aligned} \tag{14}$$

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

$$\begin{aligned}
\gamma_d^{(2)} = & + \frac{2}{225} \left(101g_1^4 + 10g_1^2 \left(3g_p^2 Q_d \left(11Q_d - 18Q_u - 3Q_{H_d} + 3Q_{H_u} + 9Q_e - 9Q_l + 9Q_q \right) + 8g_3^2 \right) \right. \\
& - 25 \left(4g_3^4 - 48g_3^2 g_p^2 Q_d^2 \right. \\
& - 9g_p^4 Q_d^2 \left(11Q_d^2 + 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 6Q_l^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) \left. \right) \mathbf{1} \\
& - 2 \left(Y_d^* Y_d^T Y_d^* Y_d^T + Y_d^* Y_u^T Y_u^* Y_d^T \right) \\
& + Y_d^* Y_d^T \left(-2|\lambda|^2 - 2\text{Tr}(Y_e Y_e^\dagger) - 4g_p^2 Q_d^2 + 4g_p^2 Q_{H_d}^2 + 4g_p^2 Q_q^2 + 6g_2^2 - 6\text{Tr}(Y_d Y_d^\dagger) + \frac{2}{5} g_1^2 \right)
\end{aligned} \tag{16}$$

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

$$\begin{aligned}
\gamma_u^{(2)} = & + \frac{2}{225} \left(428g_1^4 + 20g_1^2 \left(16g_3^2 - 3g_p^2 \left(-22Q_u - 3Q_{H_d} + 3Q_{H_u} + 9Q_d + 9Q_e - 9Q_l + 9Q_q \right) Q_u \right) \right. \\
& - 25 \left(4g_3^4 - 48g_3^2 g_p^2 Q_u^2 \right. \\
& - 9g_p^4 Q_u^2 \left(11Q_u^2 + 18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) \left. \right) \mathbf{1} \\
& - 2 \left(Y_u^* Y_d^T Y_d^* Y_u^T + Y_u^* Y_u^T Y_u^* Y_u^T \right) \\
& + Y_u^* Y_u^T \left(-2|\lambda|^2 + 4g_p^2 Q_{H_u}^2 + 4g_p^2 Q_q^2 - 4g_p^2 Q_u^2 + 6g_2^2 - 6\text{Tr}(Y_u Y_u^\dagger) - \frac{2}{5} g_1^2 \right)
\end{aligned} \tag{18}$$

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

$$\begin{aligned}
\gamma_e^{(2)} = & + \frac{2}{25} \left(117g_1^4 + 30g_1^2 g_p^2 Q_e \left(3Q_d - 3Q_l + 3Q_q + 5Q_e - 6Q_u - Q_{H_d} + Q_{H_u} \right) \right. \\
& + 25g_p^4 Q_e^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 5Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) \left. \right) \mathbf{1} \\
& - 2Y_e^* Y_e^T Y_e^* Y_e^T \\
& + Y_e^* Y_e^T \left(-2|\lambda|^2 - 2\text{Tr}(Y_e Y_e^\dagger) - 4g_p^2 Q_e^2 + 4g_p^2 Q_{H_d}^2 + 4g_p^2 Q_l^2 + 6g_2^2 - 6\text{Tr}(Y_d Y_d^\dagger) - \frac{6}{5} g_1^2 \right)
\end{aligned} \tag{20}$$

$$\gamma_s^{(1)} = -2g_p^2 Q_s^2 + 2|\lambda|^2 \tag{21}$$

$$\begin{aligned}
\gamma_s^{(2)} = & + 2g_p^4 Q_s^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_s^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) - 4\lambda^2 \lambda^{*,2} \\
& + \lambda^* \left(\frac{6}{5} g_1^2 \lambda + 6g_2^2 \lambda + 4g_p^2 Q_{H_d}^2 \lambda + 4g_p^2 Q_{H_u}^2 \lambda - 4g_p^2 Q_s^2 \lambda - 6\lambda \text{Tr}(Y_d Y_d^\dagger) - 2\lambda \text{Tr}(Y_e Y_e^\dagger) \right. \\
& \left. - 6\lambda \text{Tr}(Y_u Y_u^\dagger) \right)
\end{aligned} \tag{22}$$

$$\gamma_{\hat{s}_1}^{(1)} = -2g_p^2 Q_1^2 + \frac{1}{9}|\kappa|^2 \quad (23)$$

$$\begin{aligned} \gamma_{\hat{s}_1}^{(2)} = & +2g_p^4 Q_1^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_1^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_2^2 + Q_3^2 \right) \\ & - \frac{2}{9}g_p^2 \left(-Q_2^2 - Q_3^2 + Q_1^2 \right) |\kappa|^2 - \frac{2}{81}\kappa^2 \kappa^{*,2} \end{aligned} \quad (24)$$

$$\gamma_{\hat{s}_2}^{(1)} = -2g_p^2 Q_2^2 + \frac{1}{9}|\kappa|^2 \quad (25)$$

$$\begin{aligned} \gamma_{\hat{s}_2}^{(2)} = & +2g_p^4 Q_2^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_2^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_3^2 \right) \\ & + \frac{2}{9}g_p^2 \left(-Q_2^2 + Q_1^2 + Q_3^2 \right) |\kappa|^2 - \frac{2}{81}\kappa^2 \kappa^{*,2} \end{aligned} \quad (26)$$

$$\gamma_{\hat{s}_3}^{(1)} = -2g_p^2 Q_3^2 + \frac{1}{9}|\kappa|^2 \quad (27)$$

$$\begin{aligned} \gamma_{\hat{s}_3}^{(2)} = & +2g_p^4 Q_3^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_3^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 \right) \\ & + \frac{2}{9}g_p^2 \left(-Q_3^2 + Q_1^2 + Q_2^2 \right) |\kappa|^2 - \frac{2}{81}\kappa^2 \kappa^{*,2} \end{aligned} \quad (28)$$

3.2 Gauge Couplings

$$\beta_{g_1}^{(1)} = \frac{33}{5}g_1^3 \quad (29)$$

$$\begin{aligned} \beta_{g_1}^{(2)} = & \frac{1}{25}g_1^3 \left(199g_1^2 + 135g_2^2 + 440g_3^2 + 60g_p^2 Q_d^2 + 180g_p^2 Q_e^2 + 30g_p^2 Q_{H_d}^2 + 30g_p^2 Q_{H_u}^2 + 90g_p^2 Q_l^2 \right. \\ & \left. + 30g_p^2 Q_q^2 + 240g_p^2 Q_u^2 - 30|\lambda|^2 - 70\text{Tr}\left(Y_d Y_d^\dagger\right) - 90\text{Tr}\left(Y_e Y_e^\dagger\right) - 130\text{Tr}\left(Y_u Y_u^\dagger\right) \right) \end{aligned} \quad (30)$$

$$\beta_{g_2}^{(1)} = g_2^3 \quad (31)$$

$$\begin{aligned} \beta_{g_2}^{(2)} = & \frac{1}{5}g_2^3 \left(9g_1^2 + 125g_2^2 + 120g_3^2 + 10g_p^2 Q_{H_d}^2 + 10g_p^2 Q_{H_u}^2 + 30g_p^2 Q_l^2 + 90g_p^2 Q_q^2 - 10|\lambda|^2 \right. \\ & \left. - 30\text{Tr}\left(Y_d Y_d^\dagger\right) - 10\text{Tr}\left(Y_e Y_e^\dagger\right) - 30\text{Tr}\left(Y_u Y_u^\dagger\right) \right) \end{aligned} \quad (32)$$

$$\beta_{g_3}^{(1)} = -3g_3^3 \quad (33)$$

$$\beta_{g_3}^{(2)} = \frac{1}{5}g_3^3 \left(11g_1^2 - 20\text{Tr}\left(Y_d Y_d^\dagger\right) - 20\text{Tr}\left(Y_u Y_u^\dagger\right) + 30g_p^2 Q_d^2 + 30g_p^2 Q_u^2 + 45g_2^2 + 60g_p^2 Q_q^2 + 70g_3^2 \right) \quad (34)$$

$$\beta_{g_p}^{(1)} = g_p^3 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) \quad (35)$$

$$\begin{aligned} \beta_{g_p}^{(2)} = & \frac{2}{45}g_p^3 \left(-5 \left(Q_1^2 + Q_2^2 + Q_3^2 \right) |\kappa|^2 \right. \\ & + 9 \left(6g_1^2 Q_d^2 + 120g_3^2 Q_d^2 + 90g_p^2 Q_d^4 + 18g_1^2 Q_e^2 + 30g_p^2 Q_e^4 + 3g_1^2 Q_{H_d}^2 + 15g_2^2 Q_{H_d}^2 \right. \\ & + 20g_p^2 Q_{H_d}^4 + 3g_1^2 Q_{H_u}^2 + 15g_2^2 Q_{H_u}^2 + 20g_p^2 Q_{H_u}^4 + 9g_1^2 Q_l^2 + 45g_2^2 Q_l^2 + 60g_p^2 Q_l^4 \\ & + 3g_1^2 Q_q^2 + 135g_2^2 Q_q^2 + 240g_3^2 Q_q^2 + 180g_p^2 Q_q^4 + 10g_p^2 Q_s^4 + 10g_p^2 Q_1^4 + 10g_p^2 Q_2^4 \\ & \left. \left. + 10g_p^2 Q_3^4 + 24g_1^2 Q_u^2 + 120g_3^2 Q_u^2 + 90g_p^2 Q_u^4 - 10 \left(Q_{H_d}^2 + Q_{H_u}^2 + Q_s^2 \right) |\lambda|^2 \right) \right) \end{aligned}$$

$$\begin{aligned}
& -30(Q_d^2 + Q_{H_d}^2 + Q_q^2)\text{Tr}(Y_d Y_d^\dagger) - 10Q_e^2\text{Tr}(Y_e Y_e^\dagger) - 10Q_{H_d}^2\text{Tr}(Y_e Y_e^\dagger) - 10Q_l^2\text{Tr}(Y_e Y_e^\dagger) \\
& -30Q_{H_u}^2\text{Tr}(Y_u Y_u^\dagger) - 30Q_q^2\text{Tr}(Y_u Y_u^\dagger) - 30Q_u^2\text{Tr}(Y_u Y_u^\dagger)
\end{aligned} \tag{36}$$

3.3 Gaugino Mass Parameters

$$\beta_{M_1}^{(1)} = \frac{66}{5}g_1^2 M_1 \tag{37}$$

$$\begin{aligned}
\beta_{M_1}^{(2)} = & \frac{2}{25}g_1^2 \left(398g_1^2 M_1 + 135g_2^2 M_1 + 440g_3^2 M_1 + 440g_3^2 M_3 + 135g_2^2 M_2 + 60g_p^2 M_1 Q_d^2 + 60g_p^2 M_U Q_d^2 \right. \\
& + 180g_p^2 M_1 Q_e^2 + 180g_p^2 M_U Q_e^2 + 30g_p^2 M_1 Q_{H_d}^2 + 30g_p^2 M_U Q_{H_d}^2 + 30g_p^2 M_1 Q_{H_u}^2 + 30g_p^2 M_U Q_{H_u}^2 \\
& + 90g_p^2 M_1 Q_l^2 + 90g_p^2 M_U Q_l^2 + 30g_p^2 M_1 Q_q^2 + 30g_p^2 M_U Q_q^2 + 240g_p^2 M_1 Q_u^2 + 240g_p^2 M_U Q_u^2 \\
& - 30\lambda^* (M_1 \lambda - T_\lambda) - 70M_1 \text{Tr}(Y_d Y_d^\dagger) - 90M_1 \text{Tr}(Y_e Y_e^\dagger) - 130M_1 \text{Tr}(Y_u Y_u^\dagger) + 70\text{Tr}(Y_d^\dagger T_d) \\
& \left. + 90\text{Tr}(Y_e^\dagger T_e) + 130\text{Tr}(Y_u^\dagger T_u) \right)
\end{aligned} \tag{38}$$

$$\beta_{M_2}^{(1)} = 2g_2^2 M_2 \tag{39}$$

$$\begin{aligned}
\beta_{M_2}^{(2)} = & \frac{2}{5}g_2^2 \left(9g_1^2 M_1 + 120g_3^2 M_3 + 9g_1^2 M_2 + 250g_2^2 M_2 + 120g_3^2 M_2 + 10g_p^2 M_U Q_{H_d}^2 + 10g_p^2 M_2 Q_{H_d}^2 \right. \\
& + 10g_p^2 M_U Q_{H_u}^2 + 10g_p^2 M_2 Q_{H_u}^2 + 30g_p^2 M_U Q_l^2 + 30g_p^2 M_2 Q_l^2 + 90g_p^2 M_U Q_q^2 + 90g_p^2 M_2 Q_q^2 \\
& - 10\lambda^* (M_2 \lambda - T_\lambda) - 30M_2 \text{Tr}(Y_d Y_d^\dagger) - 10M_2 \text{Tr}(Y_e Y_e^\dagger) - 30M_2 \text{Tr}(Y_u Y_u^\dagger) + 30\text{Tr}(Y_d^\dagger T_d) \\
& \left. + 10\text{Tr}(Y_e^\dagger T_e) + 30\text{Tr}(Y_u^\dagger T_u) \right)
\end{aligned} \tag{40}$$

$$\beta_{M_3}^{(1)} = -6g_3^2 M_3 \tag{41}$$

$$\begin{aligned}
\beta_{M_3}^{(2)} = & \frac{2}{5}g_3^2 \left(11g_1^2 M_1 + 11g_1^2 M_3 + 45g_2^2 M_3 + 140g_3^2 M_3 + 45g_2^2 M_2 + 30g_p^2 M_3 Q_d^2 + 30g_p^2 M_U Q_d^2 \right. \\
& + 60g_p^2 M_3 Q_q^2 + 60g_p^2 M_U Q_q^2 + 30g_p^2 M_3 Q_u^2 + 30g_p^2 M_U Q_u^2 - 20M_3 \text{Tr}(Y_d Y_d^\dagger) \\
& \left. - 20M_3 \text{Tr}(Y_u Y_u^\dagger) + 20\text{Tr}(Y_d^\dagger T_d) + 20\text{Tr}(Y_u^\dagger T_u) \right)
\end{aligned} \tag{42}$$

$$\beta_{M_U}^{(1)} = 2g_p^2 M_U \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) \tag{43}$$

$$\begin{aligned}
\beta_{M_U}^{(2)} = & \frac{4}{45}g_p^2 \left(-5(Q_1^2 + Q_2^2 + Q_3^2)\kappa^* (M_U \kappa - T_\kappa) \right. \\
& + 9(6g_1^2 M_1 Q_d^2 + 120g_3^2 M_3 Q_d^2 + 6g_1^2 M_U Q_d^2 + 120g_3^2 M_U Q_d^2 + 180g_p^2 M_U Q_d^4 + 18g_1^2 M_1 Q_e^2 \\
& + 18g_1^2 M_U Q_e^2 + 60g_p^2 M_U Q_e^4 + 3g_1^2 M_1 Q_{H_d}^2 + 3g_1^2 M_U Q_{H_d}^2 + 15g_2^2 M_U Q_{H_d}^2 + 15g_2^2 M_2 Q_{H_d}^2 \\
& + 40g_p^2 M_U Q_{H_d}^4 + 3g_1^2 M_1 Q_{H_u}^2 + 3g_1^2 M_U Q_{H_u}^2 + 15g_2^2 M_U Q_{H_u}^2 + 15g_2^2 M_2 Q_{H_u}^2 + 40g_p^2 M_U Q_{H_u}^4 \\
& + 9g_1^2 M_1 Q_l^2 + 9g_1^2 M_U Q_l^2 + 45g_2^2 M_U Q_l^2 + 45g_2^2 M_2 Q_l^2 + 120g_p^2 M_U Q_l^4 + 3g_1^2 M_1 Q_q^2 \\
& \left. + 240g_3^2 M_3 Q_q^2 + 3g_1^2 M_U Q_q^2 + 135g_2^2 M_U Q_q^2 + 240g_3^2 M_U Q_q^2 + 135g_2^2 M_2 Q_q^2 + 360g_p^2 M_U Q_q^4 \right)
\end{aligned}$$

$$\begin{aligned}
& + 20g_p^2 M_U Q_s^4 + 20g_p^2 M_U Q_1^4 + 20g_p^2 M_U Q_2^4 + 20g_p^2 M_U Q_3^4 + 24g_1^2 M_1 Q_u^2 + 120g_3^2 M_3 Q_u^2 \\
& + 24g_1^2 M_U Q_u^2 + 120g_3^2 M_U Q_u^2 + 180g_p^2 M_U Q_u^4 - 10 \left(Q_{H_d}^2 + Q_{H_u}^2 + Q_s^2 \right) \lambda^* \left(M_U \lambda - T_\lambda \right) \\
& - 30M_U \left(Q_d^2 + Q_{H_d}^2 + Q_q^2 \right) \text{Tr} \left(Y_d Y_d^\dagger \right) - 10M_U Q_e^2 \text{Tr} \left(Y_e Y_e^\dagger \right) - 10M_U Q_{H_d}^2 \text{Tr} \left(Y_e Y_e^\dagger \right) \\
& - 10M_U Q_l^2 \text{Tr} \left(Y_e Y_e^\dagger \right) - 30M_U Q_{H_u}^2 \text{Tr} \left(Y_u Y_u^\dagger \right) - 30M_U Q_q^2 \text{Tr} \left(Y_u Y_u^\dagger \right) - 30M_U Q_u^2 \text{Tr} \left(Y_u Y_u^\dagger \right) \\
& + 30Q_d^2 \text{Tr} \left(Y_d^\dagger T_d \right) + 30Q_{H_d}^2 \text{Tr} \left(Y_d^\dagger T_d \right) + 30Q_q^2 \text{Tr} \left(Y_d^\dagger T_d \right) + 10Q_e^2 \text{Tr} \left(Y_e^\dagger T_e \right) \\
& + 10Q_{H_d}^2 \text{Tr} \left(Y_e^\dagger T_e \right) + 10Q_l^2 \text{Tr} \left(Y_e^\dagger T_e \right) + 30Q_{H_u}^2 \text{Tr} \left(Y_u^\dagger T_u \right) + 30Q_q^2 \text{Tr} \left(Y_u^\dagger T_u \right) \\
& + 30Q_u^2 \text{Tr} \left(Y_u^\dagger T_u \right) \Big) \Big) \tag{44}
\end{aligned}$$

$$\begin{aligned}
& + 2g_p^4 Q_d^2 Q_3^2 + 2g_p^4 Q_{H_d}^2 Q_3^2 + 2g_p^4 Q_q^2 Q_3^2 - \frac{24}{5} g_1^2 g_p^2 Q_d Q_u + \frac{36}{5} g_1^2 g_p^2 Q_{H_d} Q_u \\
& - \frac{12}{5} g_1^2 g_p^2 Q_q Q_u + 18g_p^4 Q_d^2 Q_u^2 + 18g_p^4 Q_{H_d}^2 Q_u^2 + 18g_p^4 Q_q^2 Q_u^2 - 3\lambda^2 \lambda^{*,2} \\
& - \frac{2}{5} \left(-5 \left(3g_p^2 \left(-Q_{H_d}^2 + Q_d^2 + Q_q^2 \right) + 8g_3^2 \right) + g_1^2 \right) \text{Tr} \left(Y_d Y_d^\dagger \right) + \frac{6}{5} g_1^2 \text{Tr} \left(Y_e Y_e^\dagger \right) + 2g_p^2 Q_e^2 \text{Tr} \left(Y_e Y_e^\dagger \right) \\
& - 2g_p^2 Q_{H_d}^2 \text{Tr} \left(Y_e Y_e^\dagger \right) + 2g_p^2 Q_l^2 \text{Tr} \left(Y_e Y_e^\dagger \right) + |\lambda|^2 \left(2g_p^2 \left(-Q_{H_d}^2 + Q_{H_u}^2 + Q_s^2 \right) - 3 \text{Tr} \left(Y_u Y_u^\dagger \right) \right) \\
& - 9 \text{Tr} \left(Y_d Y_d^\dagger Y_d Y_d^\dagger \right) - 3 \text{Tr} \left(Y_d Y_u^\dagger Y_u Y_d^\dagger \right) - 3 \text{Tr} \left(Y_e Y_e^\dagger Y_e Y_e^\dagger \right)
\end{aligned} \tag{46}$$

$$\begin{aligned}
\beta_{Y_e}^{(1)} & = +3Y_e Y_e^\dagger Y_e \\
& + Y_e \left(-2g_p^2 Q_e^2 - 2g_p^2 Q_{H_d}^2 - 2g_p^2 Q_l^2 - 3g_2^2 + 3 \text{Tr} \left(Y_d Y_d^\dagger \right) - \frac{9}{5} g_1^2 + |\lambda|^2 + \text{Tr} \left(Y_e Y_e^\dagger \right) \right)
\end{aligned} \tag{47}$$

$$\begin{aligned}
\beta_{Y_e}^{(2)} & = -4Y_e Y_e^\dagger Y_e Y_e^\dagger Y_e \\
& + Y_e Y_e^\dagger Y_e \left(-2g_p^2 Q_e^2 + 2g_p^2 Q_l^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) \\
& + \frac{1}{10} Y_e \left(135g_1^4 + 18g_1^2 g_2^2 + 75g_2^4 + 72g_1^2 g_p^2 Q_d Q_e + 120g_1^2 g_p^2 Q_e^2 + 180g_p^4 Q_d^2 Q_e^2 + 100g_p^4 Q_e^4 \right. \\
& - 36g_1^2 g_p^2 Q_d Q_{H_d} - 60g_1^2 g_p^2 Q_e Q_{H_d} + 24g_1^2 g_p^2 Q_{H_d}^2 + 60g_2^2 g_p^2 Q_{H_d}^2 + 180g_p^4 Q_d^2 Q_{H_d}^2 \\
& + 100g_p^4 Q_e^2 Q_{H_d}^2 + 80g_p^4 Q_{H_d}^4 + 24g_1^2 g_p^2 Q_e Q_{H_u} - 12g_1^2 g_p^2 Q_{H_d} Q_{H_u} + 40g_p^4 Q_e^2 Q_{H_u}^2 \\
& + 40g_p^4 Q_{H_d}^2 Q_{H_u}^2 - 36g_1^2 g_p^2 Q_d Q_l - 108g_1^2 g_p^2 Q_e Q_l + 48g_1^2 g_p^2 Q_{H_d} Q_l \\
& - 12g_1^2 g_p^2 Q_{H_u} Q_l + 48g_1^2 g_p^2 Q_l^2 + 60g_2^2 g_p^2 Q_l^2 + 180g_p^4 Q_d^2 Q_l^2 + 180g_p^4 Q_e^2 Q_l^2 \\
& + 160g_p^4 Q_{H_d}^2 Q_l^2 + 40g_p^4 Q_{H_u}^2 Q_l^2 + 160g_p^4 Q_l^4 + 72g_1^2 g_p^2 Q_e Q_q - 36g_1^2 g_p^2 Q_{H_d} Q_q \\
& - 36g_1^2 g_p^2 Q_l Q_q + 360g_p^4 Q_e^2 Q_q^2 + 360g_p^4 Q_{H_d}^2 Q_q^2 + 360g_p^4 Q_l^2 Q_q^2 + 20g_p^4 Q_e^2 Q_s^2 \\
& + 20g_p^4 Q_{H_d}^2 Q_s^2 + 20g_p^4 Q_l^2 Q_s^2 + 20g_p^4 Q_e^2 Q_1^2 + 20g_p^4 Q_{H_d}^2 Q_1^2 + 20g_p^4 Q_l^2 Q_1^2 \\
& + 20g_p^4 Q_e^2 Q_2^2 + 20g_p^4 Q_{H_d}^2 Q_2^2 + 20g_p^4 Q_l^2 Q_2^2 + 20g_p^4 Q_e^2 Q_3^2 + 20g_p^4 Q_{H_d}^2 Q_3^2 \\
& + 20g_p^4 Q_l^2 Q_3^2 - 144g_1^2 g_p^2 Q_e Q_u + 72g_1^2 g_p^2 Q_{H_d} Q_u + 72g_1^2 g_p^2 Q_l Q_u + 180g_p^4 Q_e^2 Q_u^2 \\
& + 180g_p^4 Q_{H_d}^2 Q_u^2 + 180g_p^4 Q_l^2 Q_u^2 - 30\lambda^2 \lambda^{*,2} \\
& - 4 \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) + 12g_1^2 \text{Tr} \left(Y_e Y_e^\dagger \right) + 20g_p^2 Q_e^2 \text{Tr} \left(Y_e Y_e^\dagger \right) \\
& - 20g_p^2 Q_{H_d}^2 \text{Tr} \left(Y_e Y_e^\dagger \right) + 20g_p^2 Q_l^2 \text{Tr} \left(Y_e Y_e^\dagger \right) \\
& - 10|\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) \right) - 90 \text{Tr} \left(Y_d Y_d^\dagger Y_d Y_d^\dagger \right) - 30 \text{Tr} \left(Y_d Y_u^\dagger Y_u Y_d^\dagger \right) \\
& - 30 \text{Tr} \left(Y_e Y_e^\dagger Y_e Y_e^\dagger \right)
\end{aligned} \tag{48}$$

$$\begin{aligned}
\beta_\lambda^{(1)} & = -\frac{3}{5} g_1^2 \lambda - 3g_2^2 \lambda - 2g_p^2 Q_{H_d}^2 \lambda - 2g_p^2 Q_{H_u}^2 \lambda - 2g_p^2 Q_s^2 \lambda + 4\lambda^2 \lambda^* + 3\lambda \text{Tr} \left(Y_d Y_d^\dagger \right) \\
& + \lambda \text{Tr} \left(Y_e Y_e^\dagger \right) + 3\lambda \text{Tr} \left(Y_u Y_u^\dagger \right)
\end{aligned} \tag{49}$$

$$\beta_\lambda^{(2)} = \frac{1}{50} \lambda \left(207g_1^4 + 90g_1^2 g_2^2 + 375g_2^4 - 180g_1^2 g_p^2 Q_d Q_{H_d} - 180g_1^2 g_p^2 Q_e Q_{H_d} + 120g_1^2 g_p^2 Q_{H_d}^2 \right)$$

$$\begin{aligned}
& + 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_l \\
& - 180g_1^2g_p^2Q_{H_u}Q_l + 600g_p^4Q_{H_d}^2Q_l^2 + 600g_p^4Q_{H_u}^2Q_l^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_l^2Q_s^2 + 1800g_p^4Q_q^2Q_s^2 + 300g_p^4Q_s^4 \\
& + 100g_p^4Q_{H_d}^2Q_1^2 + 100g_p^4Q_{H_u}^2Q_1^2 + 100g_p^4Q_s^2Q_1^2 + 100g_p^4Q_{H_d}^2Q_2^2 + 100g_p^4Q_{H_u}^2Q_2^2 \\
& + 100g_p^4Q_s^2Q_2^2 + 100g_p^4Q_{H_d}^2Q_3^2 + 100g_p^4Q_{H_u}^2Q_3^2 + 100g_p^4Q_s^2Q_3^2 + 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 - 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^\dagger\text{Tr}\left(Y_eY_e^\dagger\right) - 100g_p^2Q_{H_d}^\dagger\text{Tr}\left(Y_eY_e^\dagger\right) + 100g_p^2Q_l^\dagger\text{Tr}\left(Y_eY_e^\dagger\right) \\
& + 10|\lambda|^2\left(-15\text{Tr}\left(Y_eY_e^\dagger\right) + 20g_p^2Q_{H_d}^2 + 20g_p^2Q_{H_u}^2 + 30g_2^2 - 45\text{Tr}\left(Y_dY_d^\dagger\right) - 45\text{Tr}\left(Y_uY_u^\dagger\right) + 6g_1^2\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) - 450\text{Tr}\left(Y_dY_d^\dagger Y_dY_d^\dagger\right) - 300\text{Tr}\left(Y_uY_u^\dagger Y_uY_u^\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)
\end{aligned} \tag{50}$$

$$\beta_\kappa^{(1)} = \frac{1}{3}\kappa\left(-6g_p^2\left(Q_1^2 + Q_2^2 + Q_3^2\right) + |\kappa|^2\right) \tag{51}$$

$$\begin{aligned}
\beta_\kappa^{(2)} = & -\frac{2}{27}\kappa\left(-27g_p^4\left(2Q_{H_d}^2Q_1^2 + 2Q_{H_u}^2Q_1^2 + 6Q_l^2Q_1^2 + 18Q_q^2Q_1^2 + Q_s^2Q_1^2 + 3Q_1^4 + 2Q_{H_d}^2Q_2^2 + 2Q_{H_u}^2Q_2^2\right.\right. \\
& + 6Q_l^2Q_2^2 + 18Q_q^2Q_2^2 + Q_s^2Q_2^2 + 2Q_1^2Q_2^2 + 3Q_2^4 + 2Q_{H_d}^2Q_3^2 + 2Q_{H_u}^2Q_3^2 + 6Q_l^2Q_3^2 \\
& + 18Q_q^2Q_3^2 + Q_s^2Q_3^2 + 2Q_1^2Q_3^2 + 2Q_2^2Q_3^2 + 3Q_3^4 + 9Q_d^2\left(Q_1^2 + Q_2^2 + Q_3^2\right) + 3Q_e^2\left(Q_1^2 + Q_2^2 + Q_3^2\right) \\
& + 9Q_1^2Q_u^2 + 9Q_2^2Q_u^2 + 9Q_3^2Q_u^2\left.\right) \\
& - 3g_p^2\left(Q_1^2 + Q_2^2 + Q_3^2\right)|\kappa|^2 + \kappa^2\kappa^{*,2}\left.\right)
\end{aligned} \tag{52}$$

$$\begin{aligned}
\beta_{Y_u}^{(1)} = & +Y_uY_d^\dagger Y_d + 3Y_uY_u^\dagger Y_u \\
& + Y_u\left(-2g_p^2Q_{H_u}^2 - 2g_p^2Q_q^2 - 2g_p^2Q_u^2 - 3g_2^2 + 3\text{Tr}\left(Y_uY_u^\dagger\right) - \frac{13}{15}g_1^2 - \frac{16}{3}g_3^2 + |\lambda|^2\right)
\end{aligned} \tag{53}$$

$$\begin{aligned}
\beta_{Y_u}^{(2)} = & +\frac{2}{5}g_1^2Y_uY_u^\dagger Y_u + 6g_2^2Y_uY_u^\dagger Y_u + 6g_p^2Q_{H_u}^2Y_uY_u^\dagger Y_u + 2g_p^2Q_q^2Y_uY_u^\dagger Y_u \\
& - 2g_p^2Q_u^2Y_uY_u^\dagger Y_u - 3|\lambda|^2Y_uY_u^\dagger Y_u - 2Y_uY_d^\dagger Y_dY_d^\dagger Y_d - 2Y_uY_d^\dagger Y_dY_u^\dagger Y_u \\
& - 4Y_uY_u^\dagger Y_uY_u^\dagger Y_u \\
& + Y_uY_d^\dagger Y_d\left(2g_p^2Q_d^2 + 2g_p^2Q_{H_d}^2 - 2g_p^2Q_q^2 - 3\text{Tr}\left(Y_dY_d^\dagger\right) + \frac{2}{5}g_1^2 - |\lambda|^2 - \text{Tr}\left(Y_eY_e^\dagger\right)\right) \\
& - 9Y_uY_u^\dagger Y_u\text{Tr}\left(Y_uY_u^\dagger\right)
\end{aligned}$$

$$\begin{aligned}
& + Y_u \left(\frac{2743}{450} g_1^4 + g_1^2 g_2^2 + \frac{15}{2} g_2^4 + \frac{136}{45} g_1^2 g_3^2 + 8 g_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 + 6 g_2^2 g_p^2 Q_{H_u}^2 + 18 g_p^4 Q_d^2 Q_{H_u}^2 + 6 g_p^4 Q_e^2 Q_{H_u}^2 \\
& + 4 g_p^4 Q_{H_d}^2 Q_{H_u}^2 + 8 g_p^4 Q_{H_u}^4 - \frac{18}{5} g_1^2 g_p^2 Q_{H_u} Q_l + 12 g_p^4 Q_{H_u}^2 Q_l^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 + 4 g_1^2 g_p^2 Q_{H_u} Q_q - \frac{6}{5} g_1^2 g_p^2 Q_l Q_q + \frac{4}{3} g_1^2 g_p^2 Q_q^2 \\
& + 6 g_2^2 g_p^2 Q_q^2 + \frac{32}{3} g_3^2 g_p^2 Q_q^2 + 18 g_p^4 Q_d^2 Q_q^2 + 6 g_p^4 Q_e^2 Q_q^2 + 4 g_p^4 Q_{H_d}^2 Q_q^2 \\
& + 40 g_p^4 Q_{H_u}^2 Q_q^2 + 12 g_p^4 Q_l^2 Q_q^2 + 40 g_p^4 Q_q^4 + 2 g_p^4 Q_{H_u}^2 Q_s^2 + 2 g_p^4 Q_q^2 Q_s^2 + 2 g_p^4 Q_{H_u}^2 Q_1^2 \\
& + 2 g_p^4 Q_q^2 Q_1^2 + 2 g_p^4 Q_{H_u}^2 Q_2^2 + 2 g_p^4 Q_q^2 Q_2^2 + 2 g_p^4 Q_{H_u}^2 Q_3^2 + 2 g_p^4 Q_q^2 Q_3^2 \\
& - \frac{24}{5} g_1^2 g_p^2 Q_d Q_u - \frac{24}{5} g_1^2 g_p^2 Q_e Q_u + \frac{8}{5} g_1^2 g_p^2 Q_{H_d} Q_u - \frac{44}{5} g_1^2 g_p^2 Q_{H_u} Q_u + \frac{24}{5} g_1^2 g_p^2 Q_l Q_u \\
& - \frac{36}{5} g_1^2 g_p^2 Q_q Q_u + \frac{176}{15} g_1^2 g_p^2 Q_u^2 + \frac{32}{3} g_3^2 g_p^2 Q_u^2 + 18 g_p^4 Q_d^2 Q_u^2 + 6 g_p^4 Q_e^2 Q_u^2 \\
& + 4 g_p^4 Q_{H_d}^2 Q_u^2 + 22 g_p^4 Q_{H_u}^2 Q_u^2 + 12 g_p^4 Q_l^2 Q_u^2 + 54 g_p^4 Q_q^2 Q_u^2 + 2 g_p^4 Q_s^2 Q_u^2 \\
& + 2 g_p^4 Q_1^2 Q_u^2 + 2 g_p^4 Q_2^2 Q_u^2 + 2 g_p^4 Q_3^2 Q_u^2 + 22 g_p^4 Q_u^4 - 3 \lambda^2 \lambda^{*,2} \\
& + |\lambda|^2 \left(2 g_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(2 g_1^2 + 5 \left(3 g_p^2 \left(-Q_{H_u}^2 + Q_q^2 + Q_u^2 \right) + 8 g_3^2 \right) \right) \text{Tr} \left(Y_u Y_u^\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) \quad (54)
\end{aligned}$$

3.5 Trilinear Soft-Breaking Parameters

$$\begin{aligned}
\beta_{T_d}^{(1)} &= +4 Y_d Y_d^\dagger T_d + 2 Y_d Y_u^\dagger T_u + 5 T_d Y_d^\dagger Y_d + T_d Y_u^\dagger Y_u - \frac{7}{15} g_1^2 T_d - 3 g_2^2 T_d - \frac{16}{3} g_3^2 T_d \\
& - 2 g_p^2 Q_d^2 T_d - 2 g_p^2 Q_{H_d}^2 T_d - 2 g_p^2 Q_q^2 T_d + |\lambda|^2 T_d + 3 T_d \text{Tr} \left(Y_d Y_d^\dagger \right) + T_d \text{Tr} \left(Y_e Y_e^\dagger \right) \\
& + Y_d \left(\frac{14}{15} g_1^2 M_1 + \frac{32}{3} g_3^2 M_3 + 6 g_2^2 M_2 + 4 g_p^2 M_U Q_d^2 + 4 g_p^2 M_U Q_{H_d}^2 + 4 g_p^2 M_U Q_q^2 + 2 \lambda^* T_\lambda + 6 \text{Tr} \left(Y_d^\dagger T_d \right) \right. \\
& \left. + 2 \text{Tr} \left(Y_e^\dagger T_e \right) \right) \quad (55) \\
\beta_{T_d}^{(2)} &= + \frac{6}{5} g_1^2 Y_d Y_d^\dagger T_d + 6 g_2^2 Y_d Y_d^\dagger T_d + 8 g_p^2 Q_{H_d}^2 Y_d Y_d^\dagger T_d - 4 |\lambda|^2 Y_d Y_d^\dagger T_d \\
& - \frac{8}{5} g_1^2 M_1 Y_d Y_u^\dagger Y_u - 4 g_p^2 M_U Q_{H_u}^2 Y_d Y_u^\dagger Y_u + 4 g_p^2 M_U Q_q^2 Y_d Y_u^\dagger Y_u \\
& - 4 g_p^2 M_U Q_u^2 Y_d Y_u^\dagger Y_u + \frac{8}{5} g_1^2 Y_d Y_u^\dagger T_u + 4 g_p^2 Q_{H_u}^2 Y_d Y_u^\dagger T_u \\
& - 4 g_p^2 Q_q^2 Y_d Y_u^\dagger T_u + 4 g_p^2 Q_u^2 Y_d Y_u^\dagger T_u - 2 |\lambda|^2 Y_d Y_u^\dagger T_u \\
& + \frac{6}{5} g_1^2 T_d Y_d^\dagger Y_d + 12 g_2^2 T_d Y_d^\dagger Y_d - 6 g_p^2 Q_d^2 T_d Y_d^\dagger Y_d \\
& + 10 g_p^2 Q_{H_d}^2 T_d Y_d^\dagger Y_d + 6 g_p^2 Q_q^2 T_d Y_d^\dagger Y_d - 5 |\lambda|^2 T_d Y_d^\dagger Y_d
\end{aligned}$$

$$\begin{aligned}
& + \frac{4}{5}g_1^2 T_d Y_u^\dagger Y_u + 2g_p^2 Q_{H_u}^2 T_d Y_u^\dagger Y_u - 2g_p^2 Q_q^2 T_d Y_u^\dagger Y_u \\
& + 2g_p^2 Q_u^2 T_d Y_u^\dagger Y_u - |\lambda|^2 T_d Y_u^\dagger Y_u - 6Y_d Y_d^\dagger Y_d Y_d^\dagger T_d - 8Y_d Y_d^\dagger T_d Y_d^\dagger Y_d \\
& - 2Y_d Y_u^\dagger Y_u Y_d^\dagger T_d - 4Y_d Y_u^\dagger Y_u Y_u^\dagger T_u - 4Y_d Y_u^\dagger T_u Y_d^\dagger Y_d - 4Y_d Y_u^\dagger T_u Y_u^\dagger Y_u \\
& - 6T_d Y_d^\dagger Y_d Y_d^\dagger Y_d - 4T_d Y_u^\dagger Y_u Y_d^\dagger Y_d - 2T_d Y_u^\dagger Y_u Y_u^\dagger Y_u + \frac{287}{90}g_1^4 T_d + g_1^2 g_2^2 T_d \\
& + \frac{15}{2}g_2^4 T_d + \frac{8}{9}g_1^2 g_3^2 T_d + 8g_2^2 g_3^2 T_d - \frac{16}{9}g_3^4 T_d + \frac{44}{15}g_1^2 g_p^2 Q_d^2 T_d + \frac{32}{3}g_3^2 g_p^2 Q_d^2 T_d \\
& + 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_l T_d + \frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_l T_d \\
& + 12g_p^4 Q_d^2 Q_l^2 T_d + 12g_p^4 Q_{H_d}^2 Q_l^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_l 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_l^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 + 2g_p^4 Q_d^2 Q_1^2 T_d + 2g_p^4 Q_{H_d}^2 Q_1^2 T_d \\
& + 2g_p^4 Q_q^2 Q_1^2 T_d + 2g_p^4 Q_d^2 Q_2^2 T_d + 2g_p^4 Q_{H_d}^2 Q_2^2 T_d + 2g_p^4 Q_q^2 Q_2^2 T_d \\
& + 2g_p^4 Q_d^2 Q_3^2 T_d + 2g_p^4 Q_{H_d}^2 Q_3^2 T_d + 2g_p^4 Q_q^2 Q_3^2 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 - 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^2 \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_l^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) \\
& - \frac{2}{5}Y_d Y_d^\dagger Y_d \left(4g_1^2 M_1 + 30g_2^2 M_2 - 10g_p^2 M_U Q_d^2 + 30g_p^2 M_U Q_{H_d}^2 + 10g_p^2 M_U Q_q^2 + 15\lambda^* T_\lambda + 45\text{Tr}(Y_d^\dagger T_d) \right)
\end{aligned}$$

$$\begin{aligned}
& + 15\text{Tr}\left(Y_e^\dagger T_e\right) \\
& - 6Y_d Y_u^\dagger Y_u \text{Tr}\left(Y_u^\dagger T_u\right) - 9T_d \text{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right) - 3T_d \text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) \\
& - 3T_d \text{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right) \\
& - \frac{2}{45}Y_d \left(287g_1^4 M_1 + 45g_1^2 g_2^2 M_1 + 40g_1^2 g_3^2 M_1 + 40g_1^2 g_3^2 M_3 + 360g_2^2 g_3^2 M_3 - 160g_3^4 M_3 \right. \\
& + 45g_1^2 g_2^2 M_2 + 675g_2^4 M_2 + 360g_2^2 g_3^2 M_2 + 132g_1^2 g_p^2 M_1 Q_d^2 + 480g_3^2 g_p^2 M_3 Q_d^2 \\
& + 132g_1^2 g_p^2 M_U Q_d^2 + 480g_3^2 g_p^2 M_U Q_d^2 + 1980g_p^4 M_U Q_d^4 + 108g_1^2 g_p^2 M_1 Q_d Q_e \\
& + 108g_1^2 g_p^2 M_U Q_d Q_e + 540g_p^4 M_U Q_d^2 Q_e^2 - 198g_1^2 g_p^2 M_1 Q_d Q_{H_d} - 198g_1^2 g_p^2 M_U Q_d Q_{H_d} \\
& - 162g_1^2 g_p^2 M_1 Q_e Q_{H_d} - 162g_1^2 g_p^2 M_U Q_e Q_{H_d} + 108g_1^2 g_p^2 M_1 Q_{H_d}^2 + 108g_1^2 g_p^2 M_U Q_{H_d}^2 \\
& + 270g_2^2 g_p^2 M_U Q_{H_d}^2 + 270g_2^2 g_p^2 M_2 Q_{H_d}^2 + 1980g_p^4 M_U Q_d^2 Q_{H_d}^2 + 540g_p^4 M_U Q_e^2 Q_{H_d}^2 \\
& + 720g_p^4 M_U Q_{H_d}^4 + 36g_1^2 g_p^2 M_1 Q_d Q_{H_u} + 36g_1^2 g_p^2 M_U Q_d Q_{H_u} - 54g_1^2 g_p^2 M_1 Q_{H_d} Q_{H_u} \\
& - 54g_1^2 g_p^2 M_U Q_{H_d} Q_{H_u} + 360g_p^4 M_U Q_d^2 Q_{H_u}^2 + 360g_p^4 M_U Q_{H_d}^2 Q_{H_u}^2 - 108g_1^2 g_p^2 M_1 Q_d Q_l \\
& - 108g_1^2 g_p^2 M_U Q_d Q_l + 162g_1^2 g_p^2 M_1 Q_{H_d} Q_l + 162g_1^2 g_p^2 M_U Q_{H_d} Q_l + 1080g_p^4 M_U Q_d^2 Q_l^2 \\
& + 1080g_p^4 M_U Q_{H_d}^2 Q_l^2 + 162g_1^2 g_p^2 M_1 Q_d Q_q + 162g_1^2 g_p^2 M_U Q_d Q_q + 54g_1^2 g_p^2 M_1 Q_e Q_q \\
& + 54g_1^2 g_p^2 M_U Q_e Q_q - 180g_1^2 g_p^2 M_1 Q_{H_d} Q_q - 180g_1^2 g_p^2 M_U Q_{H_d} Q_q + 18g_1^2 g_p^2 M_1 Q_{H_u} Q_q \\
& + 18g_1^2 g_p^2 M_U Q_{H_u} Q_q - 54g_1^2 g_p^2 M_1 Q_l Q_q - 54g_1^2 g_p^2 M_U Q_l 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_U Q_q^2 + 270g_2^2 g_p^2 M_U Q_q^2 + 480g_3^2 g_p^2 M_U Q_q^2 \\
& + 270g_2^2 g_p^2 M_2 Q_q^2 + 4860g_p^4 M_U Q_d^2 Q_q^2 + 540g_p^4 M_U Q_e^2 Q_q^2 + 3600g_p^4 M_U Q_{H_d}^2 Q_q^2 \\
& + 360g_p^4 M_U Q_{H_u}^2 Q_q^2 + 1080g_p^4 M_U Q_l^2 Q_q^2 + 3600g_p^4 M_U Q_q^4 + 180g_p^4 M_U Q_d^2 Q_s^2 \\
& + 180g_p^4 M_U Q_{H_d}^2 Q_s^2 + 180g_p^4 M_U Q_q^2 Q_s^2 + 180g_p^4 M_U Q_d^2 Q_1^2 + 180g_p^4 M_U Q_{H_d}^2 Q_1^2 \\
& + 180g_p^4 M_U Q_q^2 Q_1^2 + 180g_p^4 M_U Q_d^2 Q_2^2 + 180g_p^4 M_U Q_{H_d}^2 Q_2^2 + 180g_p^4 M_U Q_q^2 Q_2^2 \\
& + 180g_p^4 M_U Q_d^2 Q_3^2 + 180g_p^4 M_U Q_{H_d}^2 Q_3^2 + 180g_p^4 M_U Q_q^2 Q_3^2 - 216g_1^2 g_p^2 M_1 Q_d Q_u \\
& - 216g_1^2 g_p^2 M_U Q_d Q_u + 324g_1^2 g_p^2 M_1 Q_{H_d} Q_u + 324g_1^2 g_p^2 M_U Q_{H_d} Q_u - 108g_1^2 g_p^2 M_1 Q_q Q_u \\
& - 108g_1^2 g_p^2 M_U Q_q Q_u + 1620g_p^4 M_U Q_d^2 Q_u^2 + 1620g_p^4 M_U Q_{H_d}^2 Q_u^2 + 1620g_p^4 M_U Q_q^2 Q_u^2 \\
& + 270\lambda\lambda^{*,2}T_\lambda - 18\left(-5\left(3g_p^2 M_U\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) \\
& + 54g_1^2 M_1 \text{Tr}\left(Y_e Y_e^\dagger\right) + 90g_p^2 M_U Q_e^2 \text{Tr}\left(Y_e Y_e^\dagger\right) - 90g_p^2 M_U Q_{H_d}^2 \text{Tr}\left(Y_e Y_e^\dagger\right) \\
& + 90g_p^2 M_U Q_l^2 \text{Tr}\left(Y_e Y_e^\dagger\right) + 18g_1^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 720g_3^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 270g_p^2 Q_d^2 \text{Tr}\left(Y_d^\dagger T_d\right) \\
& + 270g_p^2 Q_{H_d}^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 270g_p^2 Q_q^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 54g_1^2 \text{Tr}\left(Y_e^\dagger T_e\right) - 90g_p^2 Q_e^2 \text{Tr}\left(Y_e^\dagger T_e\right) \\
& + 90g_p^2 Q_{H_d}^2 \text{Tr}\left(Y_e^\dagger T_e\right) - 90g_p^2 Q_l^2 \text{Tr}\left(Y_e^\dagger T_e\right) \\
& - 45\lambda^*\left(\lambda\left(2g_p^2 M_U\left(-Q_{H_u}^2 - Q_s^2 + Q_{H_d}^2\right) - 3\text{Tr}\left(Y_u^\dagger T_u\right)\right) + T_\lambda\left(2g_p^2\left(-Q_{H_d}^2 + Q_{H_u}^2 + Q_s^2\right) - 3\text{Tr}\left(Y_u Y_u^\dagger\right)\right)\right) \\
& + 810\text{Tr}\left(Y_d Y_d^\dagger T_d Y_d^\dagger\right) + 135\text{Tr}\left(Y_d Y_u^\dagger T_u Y_d^\dagger\right) + 270\text{Tr}\left(Y_e Y_e^\dagger T_e Y_e^\dagger\right) + 135\text{Tr}\left(Y_u Y_d^\dagger T_d Y_u^\dagger\right) \tag{56}
\end{aligned}$$

$$\begin{aligned}
\beta_{T_e}^{(1)} = & +4Y_e Y_e^\dagger T_e + 5T_e Y_e^\dagger Y_e - \frac{9}{5}g_1^2 T_e - 3g_2^2 T_e - 2g_p^2 Q_e^2 T_e - 2g_p^2 Q_{H_d}^2 T_e \\
& - 2g_p^2 Q_l^2 T_e + |\lambda|^2 T_e + 3T_e \text{Tr}(Y_d Y_d^\dagger) + T_e \text{Tr}(Y_e Y_e^\dagger) \\
& + Y_e \left(\frac{18}{5}g_1^2 M_1 + 6g_2^2 M_2 + 4g_p^2 M_U Q_e^2 + 4g_p^2 M_U Q_{H_d}^2 + 4g_p^2 M_U Q_l^2 + 2\lambda^* T_\lambda + 6\text{Tr}(Y_d^\dagger T_d) \right. \\
& \left. + 2\text{Tr}(Y_e^\dagger T_e) \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{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_l^2 T_e Y_e^\dagger Y_e - 5|\lambda|^2 T_e Y_e^\dagger Y_e - 6Y_e Y_e^\dagger Y_e Y_e^\dagger T_e \\
& - 8Y_e Y_e^\dagger T_e Y_e^\dagger Y_e - 6T_e Y_e^\dagger Y_e Y_e^\dagger Y_e + \frac{27}{2}g_1^4 T_e + \frac{9}{5}g_1^2 g_2^2 T_e + \frac{15}{2}g_2^4 T_e \\
& + \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_l T_e \\
& - \frac{54}{5}g_1^2 g_p^2 Q_e Q_l T_e + \frac{24}{5}g_1^2 g_p^2 Q_{H_d} Q_l T_e - \frac{6}{5}g_1^2 g_p^2 Q_{H_u} Q_l T_e + \frac{24}{5}g_1^2 g_p^2 Q_l^2 T_e \\
& + 6g_2^2 g_p^2 Q_l^2 T_e + 18g_p^4 Q_d^2 Q_l^2 T_e + 18g_p^4 Q_e^2 Q_l^2 T_e + 16g_p^4 Q_{H_d}^2 Q_l^2 T_e \\
& + 4g_p^4 Q_{H_u}^2 Q_l^2 T_e + 16g_p^4 Q_l^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_l 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_l^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_l^2 Q_s^2 T_e + 2g_p^4 Q_e^2 Q_1^2 T_e \\
& + 2g_p^4 Q_{H_d}^2 Q_1^2 T_e + 2g_p^4 Q_l^2 Q_1^2 T_e + 2g_p^4 Q_e^2 Q_2^2 T_e + 2g_p^4 Q_{H_d}^2 Q_2^2 T_e \\
& + 2g_p^4 Q_l^2 Q_2^2 T_e + 2g_p^4 Q_e^2 Q_3^2 T_e + 2g_p^4 Q_{H_d}^2 Q_3^2 T_e + 2g_p^4 Q_l^2 Q_3^2 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_l 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_l^2 Q_u^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 - 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_2^2 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)
\end{aligned} \tag{57}$$

$$\begin{aligned}
& -2g_p^2 Q_{H_d}^2 T_e \text{Tr}(Y_e Y_e^\dagger) + 2g_p^2 Q_l^2 T_e \text{Tr}(Y_e Y_e^\dagger) - 3|\lambda|^2 T_e \text{Tr}(Y_u Y_u^\dagger) \\
& -2Y_e Y_e^\dagger Y_e \left(-2g_p^2 M_U Q_e^2 + 2g_p^2 M_U Q_l^2 + 3\lambda^* T_\lambda + 3\text{Tr}(Y_e^\dagger T_e) + 6g_2^2 M_2 + 6g_p^2 M_U Q_{H_d}^2 + 9\text{Tr}(Y_d^\dagger T_d) \right) \\
& -9T_e \text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 3T_e \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 3T_e \text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \\
& -\frac{2}{5} Y_e \left(135g_1^4 M_1 + 9g_1^2 g_2^2 M_1 + 9g_2^2 g_2^2 M_2 + 75g_2^4 M_2 + 36g_1^2 g_p^2 M_1 Q_d Q_e + 36g_1^2 g_p^2 M_U Q_d Q_e \right. \\
& + 60g_1^2 g_p^2 M_1 Q_e^2 + 60g_1^2 g_p^2 M_U Q_e^2 + 180g_p^4 M_U Q_d^2 Q_e^2 + 100g_p^4 M_U Q_e^4 \\
& - 18g_1^2 g_p^2 M_1 Q_d Q_{H_d} - 18g_1^2 g_p^2 M_U Q_d Q_{H_d} - 30g_1^2 g_p^2 M_1 Q_e Q_{H_d} - 30g_1^2 g_p^2 M_U Q_e Q_{H_d} \\
& + 12g_1^2 g_p^2 M_1 Q_{H_d}^2 + 12g_1^2 g_p^2 M_U Q_{H_d}^2 + 30g_2^2 g_p^2 M_U Q_{H_d}^2 + 30g_2^2 g_p^2 M_2 Q_{H_d}^2 \\
& + 180g_p^4 M_U Q_d^2 Q_{H_d} + 100g_p^4 M_U Q_e^2 Q_{H_d} + 80g_p^4 M_U Q_{H_d}^4 + 12g_1^2 g_p^2 M_1 Q_e Q_{H_u} \\
& + 12g_1^2 g_p^2 M_U Q_e Q_{H_u} - 6g_1^2 g_p^2 M_1 Q_{H_d} Q_{H_u} - 6g_1^2 g_p^2 M_U Q_{H_d} Q_{H_u} + 40g_p^4 M_U Q_e^2 Q_{H_u}^2 \\
& + 40g_p^4 M_U Q_{H_d}^2 Q_{H_u} - 18g_1^2 g_p^2 M_1 Q_d Q_l - 18g_1^2 g_p^2 M_U Q_d Q_l - 54g_1^2 g_p^2 M_1 Q_e Q_l \\
& - 54g_1^2 g_p^2 M_U Q_e Q_l + 24g_1^2 g_p^2 M_1 Q_{H_d} Q_l + 24g_1^2 g_p^2 M_U Q_{H_d} Q_l - 6g_1^2 g_p^2 M_1 Q_{H_u} Q_l \\
& - 6g_1^2 g_p^2 M_U Q_{H_u} Q_l + 24g_1^2 g_p^2 M_1 Q_l^2 + 24g_1^2 g_p^2 M_U Q_l^2 + 30g_2^2 g_p^2 M_U Q_l^2 \\
& + 30g_2^2 g_p^2 M_2 Q_l^2 + 180g_p^4 M_U Q_d^2 Q_l^2 + 180g_p^4 M_U Q_e^2 Q_l^2 + 160g_p^4 M_U Q_{H_d}^2 Q_l^2 \\
& + 40g_p^4 M_U Q_{H_u}^2 Q_l^2 + 160g_p^4 M_U Q_l^4 + 36g_1^2 g_p^2 M_1 Q_e Q_q + 36g_1^2 g_p^2 M_U Q_e Q_q \\
& - 18g_1^2 g_p^2 M_1 Q_{H_d} Q_q - 18g_1^2 g_p^2 M_U Q_{H_d} Q_q - 18g_1^2 g_p^2 M_1 Q_l Q_q - 18g_1^2 g_p^2 M_U Q_l Q_q \\
& + 360g_p^4 M_U Q_e^2 Q_q^2 + 360g_p^4 M_U Q_{H_d}^2 Q_q^2 + 360g_p^4 M_U Q_l^2 Q_q^2 + 20g_p^4 M_U Q_e^2 Q_s^2 \\
& + 20g_p^4 M_U Q_{H_d}^2 Q_s^2 + 20g_p^4 M_U Q_l^2 Q_s^2 + 20g_p^4 M_U Q_e^2 Q_1^2 + 20g_p^4 M_U Q_{H_d}^2 Q_1^2 \\
& + 20g_p^4 M_U Q_l^2 Q_1^2 + 20g_p^4 M_U Q_e^2 Q_2^2 + 20g_p^4 M_U Q_{H_d}^2 Q_2^2 + 20g_p^4 M_U Q_l^2 Q_2^2 \\
& + 20g_p^4 M_U Q_e^2 Q_3^2 + 20g_p^4 M_U Q_{H_d}^2 Q_3^2 + 20g_p^4 M_U Q_l^2 Q_3^2 - 72g_1^2 g_p^2 M_1 Q_e Q_u \\
& - 72g_1^2 g_p^2 M_U Q_e Q_u + 36g_1^2 g_p^2 M_1 Q_{H_d} Q_u + 36g_1^2 g_p^2 M_U Q_{H_d} Q_u + 36g_1^2 g_p^2 M_1 Q_l Q_u \\
& + 36g_1^2 g_p^2 M_U Q_l Q_u + 180g_p^4 M_U Q_e^2 Q_u^2 + 180g_p^4 M_U Q_{H_d}^2 Q_u^2 + 180g_p^4 M_U Q_l^2 Q_u^2 \\
& + 30\lambda\lambda^{*,2} T_\lambda + \left(10(3g_p^2 M_U (-Q_{H_d}^2 + Q_d^2 + Q_q^2) + 8g_3^2 M_3) - 2g_1^2 M_1 \right) \text{Tr}(Y_d Y_d^\dagger) \\
& + 6g_1^2 M_1 \text{Tr}(Y_e Y_e^\dagger) + 10g_p^2 M_U Q_e^2 \text{Tr}(Y_e Y_e^\dagger) - 10g_p^2 M_U Q_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) \\
& + 10g_p^2 M_U Q_l^2 \text{Tr}(Y_e Y_e^\dagger) + 2g_1^2 \text{Tr}(Y_d^\dagger T_d) - 80g_3^2 \text{Tr}(Y_d^\dagger T_d) - 30g_p^2 Q_d^2 \text{Tr}(Y_d^\dagger T_d) \\
& + 30g_p^2 Q_{H_d}^2 \text{Tr}(Y_d^\dagger T_d) - 30g_p^2 Q_q^2 \text{Tr}(Y_d^\dagger T_d) - 6g_1^2 \text{Tr}(Y_e^\dagger T_e) - 10g_p^2 Q_e^2 \text{Tr}(Y_e^\dagger T_e) \\
& + 10g_p^2 Q_{H_d}^2 \text{Tr}(Y_e^\dagger T_e) - 10g_p^2 Q_l^2 \text{Tr}(Y_e^\dagger T_e) \\
& - 5\lambda^* \left(\lambda(2g_p^2 M_U (-Q_{H_u}^2 - Q_s^2 + Q_{H_d}^2) - 3\text{Tr}(Y_u^\dagger T_u)) + T_\lambda(2g_p^2 (-Q_{H_d}^2 + Q_{H_u}^2 + Q_s^2) - 3\text{Tr}(Y_u Y_u^\dagger)) \right) \\
& + 90\text{Tr}(Y_d Y_d^\dagger T_d Y_d^\dagger) + 15\text{Tr}(Y_d Y_u^\dagger T_u Y_d^\dagger) + 30\text{Tr}(Y_e Y_e^\dagger T_e Y_e^\dagger) + 15\text{Tr}(Y_u Y_d^\dagger T_d Y_u^\dagger) \quad (58)
\end{aligned}$$

$$\beta_{T_\lambda}^{(1)} = +\frac{6}{5}g_1^2 M_1 \lambda + 6g_2^2 M_2 \lambda + 4g_p^2 M_U Q_{H_d}^2 \lambda + 4g_p^2 M_U Q_{H_u}^2 \lambda + 4g_p^2 M_U Q_s^2 \lambda$$

$$\begin{aligned}
& + T_\lambda \left(-\frac{3}{5}g_1^2 - 3g_2^2 - 2g_p^2 Q_{H_d}^2 - 2g_p^2 Q_{H_u}^2 - 2g_p^2 Q_s^2 + 12|\lambda|^2 + 3\text{Tr}(Y_d Y_d^\dagger) + \text{Tr}(Y_e Y_e^\dagger) \right. \\
& + 3\text{Tr}(Y_u Y_u^\dagger) \Big) \\
& + 6\lambda \text{Tr}(Y_d^\dagger T_d) + 2\lambda \text{Tr}(Y_e^\dagger T_e) + 6\lambda \text{Tr}(Y_u^\dagger T_u) \Big) \tag{59}
\end{aligned}$$

$$\begin{aligned}
\beta_{T_\lambda}^{(2)} = & -50\lambda^2 \lambda^{*,2} T_\lambda \\
& - \frac{1}{5}|\lambda|^2 \left(-3T_\lambda \left(-15\text{Tr}(Y_e Y_e^\dagger) + 20g_p^2 Q_{H_d}^2 + 20g_p^2 Q_{H_u}^2 + 30g_2^2 - 45\text{Tr}(Y_d Y_d^\dagger) - 45\text{Tr}(Y_u Y_u^\dagger) + 6g_1^2 \right) \right. \\
& + 2\lambda \left(15\text{Tr}(Y_e^\dagger T_e) + 20g_p^2 M_U Q_{H_d}^2 + 20g_p^2 M_U Q_{H_u}^2 + 30g_2^2 M_2 + 45\text{Tr}(Y_d^\dagger T_d) + 45\text{Tr}(Y_u^\dagger T_u) + 6g_1^2 M_1 \right) \Big) \\
& + T_\lambda \left(\frac{207}{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} + 6g_p^4 Q_e^2 Q_{H_d} + 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} \\
& + 6g_p^4 Q_e^2 Q_{H_u} + 8g_p^4 Q_{H_d}^2 Q_{H_u} + 8g_p^4 Q_{H_u}^4 + \frac{18}{5}g_1^2 g_p^2 Q_{H_d} Q_l - \frac{18}{5}g_1^2 g_p^2 Q_{H_u} Q_l \\
& + 12g_p^4 Q_{H_d}^2 Q_l^2 + 12g_p^4 Q_{H_u}^2 Q_l^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 \\
& + 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 \\
& + 12g_p^4 Q_l^2 Q_s^2 + 36g_p^4 Q_q^2 Q_s^2 + 6g_p^4 Q_s^4 + 2g_p^4 Q_{H_d}^2 Q_1^2 + 2g_p^4 Q_{H_u}^2 Q_1^2 + 2g_p^4 Q_s^2 Q_1^2 \\
& + 2g_p^4 Q_{H_d}^2 Q_2^2 + 2g_p^4 Q_{H_u}^2 Q_2^2 + 2g_p^4 Q_s^2 Q_2^2 + 2g_p^4 Q_{H_d}^2 Q_3^2 + 2g_p^4 Q_{H_u}^2 Q_3^2 \\
& + 2g_p^4 Q_s^2 Q_3^2 + \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{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{2}{5} \left(3g_1^2 + 5g_p^2 \left(-Q_{H_d}^2 + Q_e^2 + Q_l^2 \right) \right) \text{Tr}(Y_e Y_e^\dagger) + \frac{4}{5}g_1^2 \text{Tr}(Y_u Y_u^\dagger) + 16g_3^2 \text{Tr}(Y_u Y_u^\dagger) \\
& - 6g_p^2 Q_{H_u}^2 \text{Tr}(Y_u Y_u^\dagger) + 6g_p^2 Q_q^2 \text{Tr}(Y_u Y_u^\dagger) + 6g_p^2 Q_u^2 \text{Tr}(Y_u Y_u^\dagger) - 9\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) \\
& - 6\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) - 9\text{Tr}(Y_u Y_u^\dagger Y_u Y_u^\dagger) \Big) \\
& - \frac{2}{25} \lambda \left(207g_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_U 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_U Q_e Q_{H_d} + 60g_1^2 g_p^2 M_1 Q_{H_d}^2 \\
& + 60g_1^2 g_p^2 M_U Q_{H_d}^2 + 150g_2^2 g_p^2 M_U Q_{H_d}^2 + 150g_2^2 g_p^2 M_2 Q_{H_d}^2 + 900g_p^4 M_U Q_d^2 Q_{H_d}^2 \\
& + 300g_p^4 M_U Q_e^2 Q_{H_d}^2 + 400g_p^4 M_U Q_{H_d}^4 + 90g_1^2 g_p^2 M_1 Q_d Q_{H_u} + 90g_1^2 g_p^2 M_U 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_U 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_U 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_U Q_{H_u}^2 + 150g_2^2 g_p^2 M_U Q_{H_u}^2 + 150g_2^2 g_p^2 M_2 Q_{H_u}^2 \\
& + 900g_p^4 M_U Q_d^2 Q_{H_u}^2 + 300g_p^4 M_U Q_e^2 Q_{H_u}^2 + 400g_p^4 M_U Q_{H_d}^2 Q_{H_u}^2 + 400g_p^4 M_U Q_{H_u}^4 \Big)
\end{aligned}$$

$$\begin{aligned}
& + 90g_1^2g_p^2M_1Q_{H_d}Q_l + 90g_1^2g_p^2M_UQ_{H_d}Q_l - 90g_1^2g_p^2M_1Q_{H_u}Q_l - 90g_1^2g_p^2M_UQ_{H_u}Q_l \\
& + 600g_p^4M_UQ_{H_d}^2Q_l^2 + 600g_p^4M_UQ_{H_u}^2Q_l^2 - 90g_1^2g_p^2M_1Q_{H_d}Q_q - 90g_1^2g_p^2M_UQ_{H_d}Q_q \\
& + 90g_1^2g_p^2M_1Q_{H_u}Q_q + 90g_1^2g_p^2M_UQ_{H_u}Q_q + 1800g_p^4M_UQ_{H_d}^2Q_q^2 + 1800g_p^4M_UQ_{H_u}^2Q_q^2 \\
& + 900g_p^4M_UQ_d^2Q_s^2 + 300g_p^4M_UQ_e^2Q_s^2 + 300g_p^4M_UQ_{H_d}^2Q_s^2 + 300g_p^4M_UQ_{H_u}^2Q_s^2 \\
& + 600g_p^4M_UQ_l^2Q_s^2 + 1800g_p^4M_UQ_q^2Q_s^2 + 300g_p^4M_UQ_s^4 + 100g_p^4M_UQ_{H_d}^2Q_1^2 \\
& + 100g_p^4M_UQ_{H_u}^2Q_1^2 + 100g_p^4M_UQ_s^2Q_1^2 + 100g_p^4M_UQ_{H_d}^2Q_2^2 + 100g_p^4M_UQ_{H_u}^2Q_2^2 \\
& + 100g_p^4M_UQ_s^2Q_2^2 + 100g_p^4M_UQ_{H_d}^2Q_3^2 + 100g_p^4M_UQ_{H_u}^2Q_3^2 + 100g_p^4M_UQ_s^2Q_3^2 \\
& + 180g_1^2g_p^2M_1Q_{H_d}Q_u + 180g_1^2g_p^2M_UQ_{H_d}Q_u - 180g_1^2g_p^2M_1Q_{H_u}Q_u - 180g_1^2g_p^2M_UQ_{H_u}Q_u \\
& + 900g_p^4M_UQ_{H_d}^2Q_u^2 + 900g_p^4M_UQ_{H_u}^2Q_u^2 + 900g_p^4M_UQ_s^2Q_u^2 \\
& - 10\left(-5\left(3g_p^2M_U\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) \\
& + 10\left(3g_1^2M_1 + 5g_p^2M_U\left(-Q_{H_d}^2 + Q_e^2 + Q_l^2\right)\right)\text{Tr}\left(Y_eY_e^\dagger\right) + 20g_1^2M_1\text{Tr}\left(Y_uY_u^\dagger\right) \\
& + 400g_3^2M_3\text{Tr}\left(Y_uY_u^\dagger\right) - 150g_p^2M_UQ_{H_u}^2\text{Tr}\left(Y_uY_u^\dagger\right) + 150g_p^2M_UQ_q^2\text{Tr}\left(Y_uY_u^\dagger\right) \\
& + 150g_p^2M_UQ_u^2\text{Tr}\left(Y_uY_u^\dagger\right) + 10g_1^2\text{Tr}\left(Y_d^\dagger T_d\right) - 400g_3^2\text{Tr}\left(Y_d^\dagger T_d\right) - 150g_p^2Q_d^2\text{Tr}\left(Y_d^\dagger T_d\right) \\
& + 150g_p^2Q_{H_d}^2\text{Tr}\left(Y_d^\dagger T_d\right) - 150g_p^2Q_q^2\text{Tr}\left(Y_d^\dagger T_d\right) - 30g_1^2\text{Tr}\left(Y_e^\dagger T_e\right) - 50g_p^2Q_e^2\text{Tr}\left(Y_e^\dagger T_e\right) \\
& + 50g_p^2Q_{H_d}^2\text{Tr}\left(Y_e^\dagger T_e\right) - 50g_p^2Q_l^2\text{Tr}\left(Y_e^\dagger T_e\right) - 20g_1^2\text{Tr}\left(Y_u^\dagger T_u\right) - 400g_3^2\text{Tr}\left(Y_u^\dagger T_u\right) \\
& + 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) \\
& + 450\text{Tr}\left(Y_dY_d^\dagger T_dY_d^\dagger\right) + 150\text{Tr}\left(Y_dY_u^\dagger T_uY_d^\dagger\right) + 150\text{Tr}\left(Y_eY_e^\dagger T_eY_e^\dagger\right) + 150\text{Tr}\left(Y_uY_d^\dagger T_dY_u^\dagger\right) \\
& + 450\text{Tr}\left(Y_uY_u^\dagger T_uY_u^\dagger\right)
\end{aligned} \tag{60}$$

$$\beta_{T_\kappa}^{(1)} = \left(-2g_p^2\left(Q_1^2 + Q_2^2 + Q_3^2\right) + |\kappa|^2\right)T_\kappa + 4g_p^2M_U\left(Q_1^2 + Q_2^2 + Q_3^2\right)\kappa \tag{61}$$

$$\begin{aligned}
\beta_{T_\kappa}^{(2)} = & -\frac{2}{9}g_p^2\left(Q_1^2 + Q_2^2 + Q_3^2\right)|\kappa|^2\left(2M_U\kappa - 3T_\kappa\right) \\
& - 2g_p^4\left(2Q_{H_d}^2Q_1^2 + 2Q_{H_u}^2Q_1^2 + 6Q_l^2Q_1^2 + 18Q_q^2Q_1^2 + Q_s^2Q_1^2 + 3Q_1^4 + 2Q_{H_d}^2Q_2^2 + 2Q_{H_u}^2Q_2^2\right. \\
& + 6Q_l^2Q_2^2 + 18Q_q^2Q_2^2 + Q_s^2Q_2^2 + 2Q_1^2Q_2^2 + 3Q_2^4 + 2Q_{H_d}^2Q_3^2 + 2Q_{H_u}^2Q_3^2 + 6Q_l^2Q_3^2 \\
& + 18Q_q^2Q_3^2 + Q_s^2Q_3^2 + 2Q_1^2Q_3^2 + 2Q_2^2Q_3^2 + 3Q_3^4 + 9Q_d^2\left(Q_1^2 + Q_2^2 + Q_3^2\right) + 3Q_e^2\left(Q_1^2 + Q_2^2 + Q_3^2\right) \\
& + 9Q_1^2Q_u^2 + 9Q_2^2Q_u^2 + 9Q_3^2Q_u^2\left.\right)\left(4M_U\kappa - T_\kappa\right) \\
& - \frac{10}{27}\kappa^2\kappa^{*,2}T_\kappa
\end{aligned} \tag{62}$$

$$\begin{aligned}
\beta_{T_u}^{(1)} = & + 2Y_uY_d^\dagger T_d + 4Y_uY_u^\dagger T_u + T_uY_d^\dagger Y_d + 5T_uY_u^\dagger Y_u - \frac{13}{15}g_1^2T_u - 3g_2^2T_u - \frac{16}{3}g_3^2T_u \\
& - 2g_p^2Q_{H_u}^2T_u - 2g_p^2Q_q^2T_u - 2g_p^2Q_u^2T_u + |\lambda|^2T_u + 3T_u\text{Tr}\left(Y_uY_u^\dagger\right)
\end{aligned}$$

$$\begin{aligned}
& + Y_u \left(2\lambda^* T_\lambda + 4g_p^2 M_U Q_{H_u}^2 + 4g_p^2 M_U Q_q^2 + 4g_p^2 M_U Q_u^2 + 6g_2^2 M_2 + 6\text{Tr}(Y_u^\dagger T_u) + \frac{26}{15} g_1^2 M_1 + \frac{32}{3} g_3^2 M_3 \right) \quad (63) \\
\beta_{T_u}^{(2)} = & + \frac{4}{5} g_1^2 Y_u Y_d^\dagger T_d + 4g_p^2 Q_d^2 Y_u Y_d^\dagger T_d + 4g_p^2 Q_{H_d}^2 Y_u Y_d^\dagger T_d \\
& - 4g_p^2 Q_q^2 Y_u Y_d^\dagger T_d - 2|\lambda|^2 Y_u Y_d^\dagger T_d - \frac{4}{5} g_1^2 M_1 Y_u Y_u^\dagger Y_u \\
& - 12g_2^2 M_2 Y_u Y_u^\dagger Y_u - 12g_p^2 M_U Q_{H_u}^2 Y_u Y_u^\dagger Y_u - 4g_p^2 M_U Q_q^2 Y_u Y_u^\dagger Y_u \\
& + 4g_p^2 M_U 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{2743}{450} g_1^4 T_u \\
& + g_1^2 g_2^2 T_u + \frac{15}{2} g_2^4 T_u + \frac{136}{45} g_1^2 g_3^2 T_u + 8g_2^2 g_3^2 T_u - \frac{16}{9} g_3^4 T_u + \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_l T_u + 12g_p^4 Q_{H_u}^2 Q_l^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_l 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_l^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 + 2g_p^4 Q_{H_u}^2 Q_1^2 T_u + 2g_p^4 Q_q^2 Q_1^2 T_u + 2g_p^4 Q_{H_u}^2 Q_2^2 T_u \\
& + 2g_p^4 Q_q^2 Q_2^2 T_u + 2g_p^4 Q_{H_u}^2 Q_3^2 T_u + 2g_p^4 Q_q^2 Q_3^2 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_l 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_l^2 Q_u^2 T_u \\
& + 54g_p^4 Q_q^2 Q_u^2 T_u + 2g_p^4 Q_s^2 Q_u^2 T_u + 2g_p^4 Q_1^2 Q_u^2 T_u + 2g_p^4 Q_2^2 Q_u^2 T_u \\
& + 2g_p^4 Q_3^2 Q_u^2 T_u + 22g_p^4 Q_u^4 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)
\end{aligned}$$

$$\begin{aligned}
& -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) \\
& + Y_u Y_d^\dagger Y_d \left(-2\lambda^* T_\lambda - 2\text{Tr}(Y_e^\dagger T_e) - 4g_p^2 M_U Q_d^2 - 4g_p^2 M_U Q_{H_d}^2 + 4g_p^2 M_U 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) - 3T_u \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 9T_u \text{Tr}(Y_u Y_u^\dagger Y_u Y_u^\dagger) \\
& - \frac{2}{225} Y_u \left(2743g_1^4 M_1 + 225g_1^2 g_2^2 M_1 + 680g_1^2 g_3^2 M_1 + 680g_1^2 g_3^2 M_3 + 1800g_2^2 g_3^2 M_3 - 800g_3^4 M_3 \right. \\
& + 225g_1^2 g_2^2 M_2 + 3375g_2^4 M_2 + 1800g_2^2 g_3^2 M_2 + 810g_1^2 g_p^2 M_1 Q_d Q_{H_u} + 810g_1^2 g_p^2 M_U Q_d Q_{H_u} \\
& + 810g_1^2 g_p^2 M_1 Q_e Q_{H_u} + 810g_1^2 g_p^2 M_U Q_e Q_{H_u} - 270g_1^2 g_p^2 M_1 Q_{H_d} Q_{H_u} - 270g_1^2 g_p^2 M_U Q_{H_d} Q_{H_u} \\
& + 540g_1^2 g_p^2 M_1 Q_{H_u}^2 + 540g_1^2 g_p^2 M_U Q_{H_u}^2 + 1350g_2^2 g_p^2 M_U Q_{H_u}^2 + 1350g_2^2 g_p^2 M_2 Q_{H_u}^2 \\
& + 8100g_p^4 M_U Q_d^2 Q_{H_u}^2 + 2700g_p^4 M_U Q_e^2 Q_{H_u}^2 + 1800g_p^4 M_U Q_{H_d}^2 Q_{H_u}^2 + 3600g_p^4 M_U Q_{H_u}^4 \\
& \left. - 810g_1^2 g_p^2 M_1 Q_{H_u} Q_l - 810g_1^2 g_p^2 M_U Q_{H_u} Q_l + 5400g_p^4 M_U Q_{H_u}^2 Q_l^2 + 270g_1^2 g_p^2 M_1 Q_d Q_q \right. \\
& + 270g_1^2 g_p^2 M_U Q_d Q_q + 270g_1^2 g_p^2 M_1 Q_e Q_q + 270g_1^2 g_p^2 M_U Q_e Q_q - 90g_1^2 g_p^2 M_1 Q_{H_d} Q_q \\
& - 90g_1^2 g_p^2 M_U Q_{H_d} Q_q + 900g_1^2 g_p^2 M_1 Q_{H_u} Q_q + 900g_1^2 g_p^2 M_U Q_{H_u} Q_q - 270g_1^2 g_p^2 M_1 Q_l Q_q \\
& - 270g_1^2 g_p^2 M_U Q_l Q_q + 300g_1^2 g_p^2 M_1 Q_q^2 + 2400g_3^2 g_p^2 M_3 Q_q^2 + 300g_1^2 g_p^2 M_U Q_q^2 \\
& + 1350g_2^2 g_p^2 M_U Q_q^2 + 2400g_3^2 g_p^2 M_U Q_q^2 + 1350g_2^2 g_p^2 M_2 Q_q^2 + 8100g_p^4 M_U Q_d^2 Q_q^2 \\
& + 2700g_p^4 M_U Q_e^2 Q_q^2 + 1800g_p^4 M_U Q_{H_d}^2 Q_q^2 + 18000g_p^4 M_U Q_{H_u}^2 Q_q^2 + 5400g_p^4 M_U Q_l^2 Q_q^2 \\
& + 18000g_p^4 M_U Q_q^4 + 900g_p^4 M_U Q_{H_u}^2 Q_s^2 + 900g_p^4 M_U Q_q^2 Q_s^2 + 900g_p^4 M_U Q_{H_u}^2 Q_1^2 \\
& + 900g_p^4 M_U Q_q^2 Q_1^2 + 900g_p^4 M_U Q_{H_u}^2 Q_2^2 + 900g_p^4 M_U Q_q^2 Q_2^2 + 900g_p^4 M_U Q_{H_u}^2 Q_3^2 \\
& + 900g_p^4 M_U Q_q^2 Q_3^2 - 1080g_1^2 g_p^2 M_1 Q_d Q_u - 1080g_1^2 g_p^2 M_U Q_d Q_u - 1080g_1^2 g_p^2 M_1 Q_e Q_u \\
& - 1080g_1^2 g_p^2 M_U Q_e Q_u + 360g_1^2 g_p^2 M_1 Q_{H_d} Q_u + 360g_1^2 g_p^2 M_U Q_{H_d} Q_u - 1980g_1^2 g_p^2 M_1 Q_{H_u} Q_u \\
& - 1980g_1^2 g_p^2 M_U Q_{H_u} Q_u + 1080g_1^2 g_p^2 M_1 Q_l Q_u + 1080g_1^2 g_p^2 M_U Q_l Q_u - 1620g_1^2 g_p^2 M_1 Q_q Q_u \\
& - 1620g_1^2 g_p^2 M_U Q_q Q_u + 2640g_1^2 g_p^2 M_1 Q_u^2 + 2400g_3^2 g_p^2 M_3 Q_u^2 + 2640g_1^2 g_p^2 M_U Q_u^2 \\
& + 2400g_3^2 g_p^2 M_U Q_u^2 + 8100g_p^4 M_U Q_d^2 Q_u^2 + 2700g_p^4 M_U Q_e^2 Q_u^2 + 1800g_p^4 M_U Q_{H_d}^2 Q_u^2 \\
& + 9900g_p^4 M_U Q_{H_u}^2 Q_u^2 + 5400g_p^4 M_U Q_l^2 Q_u^2 + 24300g_p^4 M_U Q_q^2 Q_u^2 + 900g_p^4 M_U Q_s^2 Q_u^2 \\
& + 900g_p^4 M_U Q_1^2 Q_u^2 + 900g_p^4 M_U Q_2^2 Q_u^2 + 900g_p^4 M_U Q_3^2 Q_u^2 + 9900g_p^4 M_U Q_u^4 + 1350\lambda\lambda^{*,2} T_\lambda \\
& + 90 \left(2g_1^2 M_1 + 5 \left(3g_p^2 M_U \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) \\
& + 225\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. \\
& \left. + \lambda \left(2g_p^2 M_U \left(-Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2 \right) + 3\text{Tr}(Y_d^\dagger T_d) + \text{Tr}(Y_e^\dagger T_e) \right) \right)
\end{aligned}$$

$$\begin{aligned}
& -180g_1^2\text{Tr}\left(Y_u^\dagger T_u\right) - 3600g_3^2\text{Tr}\left(Y_u^\dagger T_u\right) + 1350g_p^2Q_{H_u}^2\text{Tr}\left(Y_u^\dagger T_u\right) - 1350g_p^2Q_q^2\text{Tr}\left(Y_u^\dagger T_u\right) \\
& - 1350g_p^2Q_u^2\text{Tr}\left(Y_u^\dagger T_u\right) + 675\text{Tr}\left(Y_dY_u^\dagger T_uY_d^\dagger\right) + 675\text{Tr}\left(Y_uY_d^\dagger T_dY_u^\dagger\right) + 4050\text{Tr}\left(Y_uY_u^\dagger T_uY_u^\dagger\right)
\end{aligned} \tag{64}$$

3.6 Soft-Breaking Scalar Masses

$$\sigma_{1,1} = \sqrt{\frac{3}{5}}g_1\left(-2\text{Tr}\left(m_u^2\right) - \text{Tr}\left(m_l^2\right) - m_{H_d}^2 + m_{H_u}^2 + \text{Tr}\left(m_d^2\right) + \text{Tr}\left(m_e^2\right) + \text{Tr}\left(m_q^2\right)\right) \tag{65}$$

$$\begin{aligned}
\sigma_{1,4} = & g_p\left(2m_{H_d}^2Q_{H_d} + 2m_{H_u}^2Q_{H_u} + m_S^2Q_s + m_{s_1}^2Q_1 + m_{s_2}^2Q_2 + m_{s_3}^2Q_3 + 3Q_d\text{Tr}\left(m_d^2\right) + Q_e\text{Tr}\left(m_e^2\right) + 2Q_l\text{Tr}\left(m_l^2\right) \right. \\
& \left. + 6Q_q\text{Tr}\left(m_q^2\right) + 3Q_u\text{Tr}\left(m_u^2\right)\right)
\end{aligned} \tag{66}$$

$$\sigma_{2,11} = \frac{1}{10}g_1^2\left(2\text{Tr}\left(m_d^2\right) + 3\text{Tr}\left(m_l^2\right) + 3m_{H_d}^2 + 3m_{H_u}^2 + 6\text{Tr}\left(m_e^2\right) + 8\text{Tr}\left(m_u^2\right) + \text{Tr}\left(m_q^2\right)\right) \tag{67}$$

$$\sigma_{2,14} = \sqrt{\frac{3}{5}}g_1g_p\left(-2Q_u\text{Tr}\left(m_u^2\right) - m_{H_d}^2Q_{H_d} + m_{H_u}^2Q_{H_u} + Q_d\text{Tr}\left(m_d^2\right) + Q_e\text{Tr}\left(m_e^2\right) - Q_l\text{Tr}\left(m_l^2\right) + Q_q\text{Tr}\left(m_q^2\right)\right) \tag{68}$$

$$\begin{aligned}
\sigma_{3,1} = & \frac{1}{20}\frac{1}{\sqrt{15}}g_1\left(-9g_1^2m_{H_d}^2 - 45g_2^2m_{H_d}^2 + 9g_1^2m_{H_u}^2 + 45g_2^2m_{H_u}^2 - 60g_p^2m_{H_d}^2Q_{H_d}^2 + 60g_p^2m_{H_u}^2Q_{H_u}^2 \right. \\
& + 30\left(-m_{H_u}^2 + m_{H_d}^2\right)|\lambda|^2 + 4\left(15g_p^2Q_d^2 + 20g_3^2 + g_1^2\right)\text{Tr}\left(m_d^2\right) + 36g_1^2\text{Tr}\left(m_e^2\right) + 60g_p^2Q_e^2\text{Tr}\left(m_e^2\right) \\
& - 9g_1^2\text{Tr}\left(m_l^2\right) - 45g_2^2\text{Tr}\left(m_l^2\right) - 60g_p^2Q_l^2\text{Tr}\left(m_l^2\right) + g_1^2\text{Tr}\left(m_q^2\right) + 45g_2^2\text{Tr}\left(m_q^2\right) + 80g_3^2\text{Tr}\left(m_q^2\right) \\
& + 60g_p^2Q_q^2\text{Tr}\left(m_q^2\right) - 32g_1^2\text{Tr}\left(m_u^2\right) - 160g_3^2\text{Tr}\left(m_u^2\right) - 120g_p^2Q_u^2\text{Tr}\left(m_u^2\right) + 90m_{H_d}^2\text{Tr}\left(Y_dY_d^\dagger\right) \\
& + 30m_{H_d}^2\text{Tr}\left(Y_eY_e^\dagger\right) - 90m_{H_u}^2\text{Tr}\left(Y_uY_u^\dagger\right) - 60\text{Tr}\left(Y_dY_d^\dagger m_d^{2*}\right) - 30\text{Tr}\left(Y_d m_q^{2*} Y_d^\dagger\right) \\
& - 60\text{Tr}\left(Y_eY_e^\dagger m_e^{2*}\right) + 30\text{Tr}\left(Y_e m_l^{2*} Y_e^\dagger\right) + 120\text{Tr}\left(Y_uY_u^\dagger m_u^{2*}\right) - 30\text{Tr}\left(Y_u m_q^{2*} Y_u^\dagger\right)
\end{aligned} \tag{69}$$

$$\sigma_{2,2} = \frac{1}{2}\left(3\text{Tr}\left(m_q^2\right) + m_{H_d}^2 + m_{H_u}^2 + \text{Tr}\left(m_l^2\right)\right) \tag{70}$$

$$\sigma_{2,3} = \frac{1}{2}\left(2\text{Tr}\left(m_q^2\right) + \text{Tr}\left(m_d^2\right) + \text{Tr}\left(m_u^2\right)\right) \tag{71}$$

$$\sigma_{2,41} = \sqrt{\frac{3}{5}}g_1g_p\left(-2Q_u\text{Tr}\left(m_u^2\right) - m_{H_d}^2Q_{H_d} + m_{H_u}^2Q_{H_u} + Q_d\text{Tr}\left(m_d^2\right) + Q_e\text{Tr}\left(m_e^2\right) - Q_l\text{Tr}\left(m_l^2\right) + Q_q\text{Tr}\left(m_q^2\right)\right) \tag{72}$$

$$\begin{aligned}
\sigma_{2,44} = & g_p^2\left(2m_{H_d}^2Q_{H_d}^2 + 2m_{H_u}^2Q_{H_u}^2 + m_S^2Q_s^2 + m_{s_1}^2Q_1^2 + m_{s_2}^2Q_2^2 + m_{s_3}^2Q_3^2 + 3Q_d^2\text{Tr}\left(m_d^2\right) + Q_e^2\text{Tr}\left(m_e^2\right) \right. \\
& \left. + 2Q_l^2\text{Tr}\left(m_l^2\right) + 6Q_q^2\text{Tr}\left(m_q^2\right) + 3Q_u^2\text{Tr}\left(m_u^2\right)\right)
\end{aligned} \tag{73}$$

$$\begin{aligned}
\sigma_{3,4} = & \frac{1}{90}g_p\left(-5\left(m_{s_1}^2Q_1 + m_{s_2}^2Q_2 + m_{s_3}^2Q_3\right)|\kappa|^2 \right. \\
& \left. + 9\left(3g_1^2m_{H_d}^2Q_{H_d} + 15g_2^2m_{H_d}^2Q_{H_d} + 20g_p^2m_{H_d}^2Q_{H_d}^3 + 3g_1^2m_{H_u}^2Q_{H_u} + 15g_2^2m_{H_u}^2Q_{H_u}\right) \right.
\end{aligned}$$

$$\begin{aligned}
& + 20g_p^2 m_{H_u}^2 Q_{H_u}^3 + 10g_p^2 m_S^2 Q_s^3 + 10g_p^2 m_{s_1}^2 Q_1^3 + 10g_p^2 m_{s_2}^2 Q_2^3 + 10g_p^2 m_{s_3}^2 Q_3^3 \\
& - 10 \left(m_{H_d}^2 Q_{H_d} + m_{H_u}^2 Q_{H_u} + m_S^2 Q_s \right) |\lambda|^2 + 2Q_d \left(15g_p^2 Q_d^2 + 20g_3^2 + g_1^2 \right) \text{Tr} \left(m_d^2 \right) + 6g_1^2 Q_e \text{Tr} \left(m_e^2 \right) \\
& + 10g_p^2 Q_e^3 \text{Tr} \left(m_e^2 \right) + 3g_1^2 Q_l \text{Tr} \left(m_l^2 \right) + 15g_2^2 Q_l \text{Tr} \left(m_l^2 \right) + 20g_p^2 Q_l^3 \text{Tr} \left(m_l^2 \right) + g_1^2 Q_q \text{Tr} \left(m_q^2 \right) \\
& + 45g_2^2 Q_q \text{Tr} \left(m_q^2 \right) + 80g_3^2 Q_q \text{Tr} \left(m_q^2 \right) + 60g_p^2 Q_q^3 \text{Tr} \left(m_q^2 \right) + 8g_1^2 Q_u \text{Tr} \left(m_u^2 \right) + 40g_3^2 Q_u \text{Tr} \left(m_u^2 \right) \\
& + 30g_p^2 Q_u^3 \text{Tr} \left(m_u^2 \right) - 30m_{H_d}^2 Q_{H_d} \text{Tr} \left(Y_d Y_d^\dagger \right) - 10m_{H_d}^2 Q_{H_d} \text{Tr} \left(Y_e Y_e^\dagger \right) - 30m_{H_u}^2 Q_{H_u} \text{Tr} \left(Y_u Y_u^\dagger \right) \\
& - 30Q_d \text{Tr} \left(Y_d Y_d^\dagger m_d^{2*} \right) - 30Q_q \text{Tr} \left(Y_d m_q^{2*} Y_d^\dagger \right) - 10Q_e \text{Tr} \left(Y_e Y_e^\dagger m_e^{2*} \right) - 10Q_l \text{Tr} \left(Y_e m_l^{2*} Y_e^\dagger \right) \\
& - 30Q_u \text{Tr} \left(Y_u Y_u^\dagger m_u^{2*} \right) - 30Q_q \text{Tr} \left(Y_u m_q^{2*} Y_u^\dagger \right) \Big) \tag{74}
\end{aligned}$$

$$\begin{aligned}
\beta_{m_q^2}^{(1)} = & -\frac{2}{15} g_1^2 \mathbf{1} |M_1|^2 - \frac{32}{3} g_3^2 \mathbf{1} |M_3|^2 - 8g_p^2 Q_q^2 \mathbf{1} |M_U|^2 - 6g_2^2 \mathbf{1} |M_2|^2 + 2m_{H_d}^2 Y_d^\dagger Y_d \\
& + 2m_{H_u}^2 Y_u^\dagger Y_u + 2T_d^\dagger T_d + 2T_u^\dagger T_u + m_q^2 Y_d^\dagger Y_d + m_q^2 Y_u^\dagger Y_u + 2Y_d^\dagger m_d^2 Y_d \\
& + Y_d^\dagger Y_d m_q^2 + 2Y_u^\dagger m_u^2 Y_u + Y_u^\dagger Y_u m_q^2 + \frac{1}{\sqrt{15}} g_1 \mathbf{1} \sigma_{1,1} + 2g_p Q_q \mathbf{1} \sigma_{1,4} \tag{75}
\end{aligned}$$

$$\begin{aligned}
\beta_{m_q^2}^{(2)} = & + \frac{24}{5} g_1^2 g_p^2 Q_d Q_q \mathbf{1} |M_U|^2 + \frac{24}{5} g_1^2 g_p^2 Q_e Q_q \mathbf{1} |M_U|^2 - \frac{8}{5} g_1^2 g_p^2 Q_{H_d} Q_q \mathbf{1} |M_U|^2 \\
& + \frac{8}{5} g_1^2 g_p^2 Q_{H_u} Q_q \mathbf{1} |M_U|^2 - \frac{24}{5} g_1^2 g_p^2 Q_l Q_q \mathbf{1} |M_U|^2 + \frac{16}{3} g_1^2 g_p^2 Q_q^2 \mathbf{1} |M_U|^2 \\
& + 24g_2^2 g_p^2 Q_q^2 \mathbf{1} |M_U|^2 + \frac{128}{3} g_3^2 g_p^2 Q_q^2 \mathbf{1} |M_U|^2 + 216g_p^4 Q_d^2 Q_q^2 \mathbf{1} |M_U|^2 \\
& + 72g_p^4 Q_e^2 Q_q^2 \mathbf{1} |M_U|^2 + 48g_p^4 Q_{H_d}^2 Q_q^2 \mathbf{1} |M_U|^2 + 48g_p^4 Q_{H_u}^2 Q_q^2 \mathbf{1} |M_U|^2 \\
& + 144g_p^4 Q_l^2 Q_q^2 \mathbf{1} |M_U|^2 + 480g_p^4 Q_q^4 \mathbf{1} |M_U|^2 + 24g_p^4 Q_q^2 Q_s^2 \mathbf{1} |M_U|^2 + 24g_p^4 Q_q^2 Q_1^2 \mathbf{1} |M_U|^2 \\
& + 24g_p^4 Q_q^2 Q_2^2 \mathbf{1} |M_U|^2 + 24g_p^4 Q_q^2 Q_3^2 \mathbf{1} |M_U|^2 - \frac{48}{5} g_1^2 g_p^2 Q_q Q_u \mathbf{1} |M_U|^2 \\
& + 216g_p^4 Q_q^2 Q_u^2 \mathbf{1} |M_U|^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) \right) + 4g_p^2 (2M_3 + M_U) Q_q^2 - 8g_3^2 M_3 \right) - g_1^2 (2M_3 + M_1) \Big) \mathbf{1} M_3^* \\
& + \frac{12}{5} g_1^2 g_p^2 M_1 Q_d Q_q \mathbf{1} M_U^* + \frac{12}{5} g_1^2 g_p^2 M_1 Q_e Q_q \mathbf{1} M_U^* - \frac{4}{5} g_1^2 g_p^2 M_1 Q_{H_d} Q_q \mathbf{1} M_U^* \\
& + \frac{4}{5} g_1^2 g_p^2 M_1 Q_{H_u} Q_q \mathbf{1} M_U^* - \frac{12}{5} g_1^2 g_p^2 M_1 Q_l Q_q \mathbf{1} M_U^* + \frac{8}{3} g_1^2 g_p^2 M_1 Q_q^2 \mathbf{1} M_U^* \\
& + \frac{64}{3} g_3^2 g_p^2 M_3 Q_q^2 \mathbf{1} M_U^* + 12g_2^2 g_p^2 M_2 Q_q^2 \mathbf{1} M_U^* - \frac{24}{5} g_1^2 g_p^2 M_1 Q_q Q_u \mathbf{1} M_U^* + \frac{1}{5} g_1^2 g_2^2 M_1 \mathbf{1} M_2^* \\
& + 16g_2^2 g_3^2 M_3 \mathbf{1} M_2^* + 12g_2^2 g_p^2 M_U Q_q^2 \mathbf{1} M_2^* + \frac{4}{5} g_1^2 m_{H_d}^2 Y_d^\dagger Y_d + 4g_p^2 m_{H_d}^2 Q_d^2 Y_d^\dagger Y_d \\
& + 4g_p^2 m_{H_d}^2 Q_{H_d}^2 Y_d^\dagger Y_d - 4g_p^2 m_{H_d}^2 Q_q^2 Y_d^\dagger Y_d + 8g_p^2 Q_d^2 |M_U|^2 Y_d^\dagger Y_d \\
& + 8g_p^2 Q_{H_d}^2 |M_U|^2 Y_d^\dagger Y_d - 8g_p^2 Q_q^2 |M_U|^2 Y_d^\dagger Y_d - 4m_{H_d}^2 |\lambda|^2 Y_d^\dagger Y_d
\end{aligned}$$

$$\begin{aligned}
& -2m_{H_u}^2|\lambda|^2Y_d^\dagger Y_d - 2m_S^2|\lambda|^2Y_d^\dagger Y_d - 2|T_\lambda|^2Y_d^\dagger Y_d \\
& -4g_p^2Q_d^2M_U^*Y_d^\dagger T_d - 4g_p^2Q_{H_d}^2M_U^*Y_d^\dagger T_d + 4g_p^2Q_q^2M_U^*Y_d^\dagger T_d \\
& -2\lambda T_\lambda^*Y_d^\dagger T_d + \frac{8}{5}g_1^2m_{H_u}^2Y_u^\dagger Y_u + 4g_p^2m_{H_u}^2Q_{H_u}^2Y_u^\dagger Y_u \\
& -4g_p^2m_{H_u}^2Q_q^2Y_u^\dagger Y_u + 4g_p^2m_{H_u}^2Q_u^2Y_u^\dagger Y_u + 8g_p^2Q_{H_u}^2|M_U|^2Y_u^\dagger Y_u \\
& -8g_p^2Q_q^2|M_U|^2Y_u^\dagger Y_u + 8g_p^2Q_u^2|M_U|^2Y_u^\dagger Y_u - 2m_{H_d}^2|\lambda|^2Y_u^\dagger Y_u \\
& -4m_{H_u}^2|\lambda|^2Y_u^\dagger Y_u - 2m_S^2|\lambda|^2Y_u^\dagger Y_u - 2|T_\lambda|^2Y_u^\dagger Y_u \\
& + \frac{1}{225}g_1^2M_1^*\left(\left(597g_1^2M_1\right.\right. \\
& + 5\left(4\left(3g_p^2\left(2M_1 + M_U\right)Q_q\left(10Q_q - 18Q_u - 3Q_{H_d} + 3Q_{H_u} + 9Q_d + 9Q_e - 9Q_l\right) + 4g_3^2\left(2M_1 + M_3\right)\right) + 9g_2^2\left(2M_1 + M_2\right)\right)\right)1 \\
& + 180\left(2M_1Y_d^\dagger Y_d - 2Y_u^\dagger T_u + 4M_1Y_u^\dagger Y_u - Y_d^\dagger T_d\right)\left.\right) \\
& -4g_p^2Q_{H_u}^2M_U^*Y_u^\dagger T_u + 4g_p^2Q_q^2M_U^*Y_u^\dagger T_u - 4g_p^2Q_u^2M_U^*Y_u^\dagger T_u \\
& -2\lambda T_\lambda^*Y_u^\dagger T_u - \frac{4}{5}g_1^2M_1T_d^\dagger Y_d - 4g_p^2M_UQ_d^2T_d^\dagger Y_d - 4g_p^2M_UQ_{H_d}^2T_d^\dagger Y_d \\
& + 4g_p^2M_UQ_q^2T_d^\dagger Y_d + \frac{4}{5}g_1^2T_d^\dagger T_d + 4g_p^2Q_d^2T_d^\dagger T_d + 4g_p^2Q_{H_d}^2T_d^\dagger T_d \\
& -4g_p^2Q_q^2T_d^\dagger T_d - 2|\lambda|^2T_d^\dagger T_d - \frac{8}{5}g_1^2M_1T_u^\dagger Y_u - 4g_p^2M_UQ_{H_u}^2T_u^\dagger Y_u \\
& + 4g_p^2M_UQ_q^2T_u^\dagger Y_u - 4g_p^2M_UQ_u^2T_u^\dagger Y_u + \frac{8}{5}g_1^2T_u^\dagger T_u + 4g_p^2Q_{H_u}^2T_u^\dagger T_u \\
& -4g_p^2Q_q^2T_u^\dagger T_u + 4g_p^2Q_u^2T_u^\dagger T_u - 2|\lambda|^2T_u^\dagger T_u + \frac{2}{5}g_1^2m_q^2Y_d^\dagger Y_d \\
& + 2g_p^2Q_d^2m_q^2Y_d^\dagger Y_d + 2g_p^2Q_{H_d}^2m_q^2Y_d^\dagger Y_d - 2g_p^2Q_q^2m_q^2Y_d^\dagger Y_d \\
& -|\lambda|^2m_q^2Y_d^\dagger Y_d + \frac{4}{5}g_1^2m_q^2Y_u^\dagger Y_u + 2g_p^2Q_{H_u}^2m_q^2Y_u^\dagger Y_u \\
& -2g_p^2Q_q^2m_q^2Y_u^\dagger Y_u + 2g_p^2Q_u^2m_q^2Y_u^\dagger Y_u - |\lambda|^2m_q^2Y_u^\dagger Y_u \\
& + \frac{4}{5}g_1^2Y_d^\dagger m_d^2Y_d + 4g_p^2Q_d^2Y_d^\dagger m_d^2Y_d + 4g_p^2Q_{H_d}^2Y_d^\dagger m_d^2Y_d \\
& -4g_p^2Q_q^2Y_d^\dagger m_d^2Y_d - 2|\lambda|^2Y_d^\dagger m_d^2Y_d + \frac{2}{5}g_1^2Y_d^\dagger Y_d m_q^2 \\
& + 2g_p^2Q_d^2Y_d^\dagger Y_d m_q^2 + 2g_p^2Q_{H_d}^2Y_d^\dagger Y_d m_q^2 - 2g_p^2Q_q^2Y_d^\dagger Y_d m_q^2 \\
& -|\lambda|^2Y_d^\dagger Y_d m_q^2 + \frac{8}{5}g_1^2Y_u^\dagger m_u^2Y_u + 4g_p^2Q_{H_u}^2Y_u^\dagger m_u^2Y_u \\
& -4g_p^2Q_q^2Y_u^\dagger m_u^2Y_u + 4g_p^2Q_u^2Y_u^\dagger m_u^2Y_u - 2|\lambda|^2Y_u^\dagger m_u^2Y_u \\
& + \frac{4}{5}g_1^2Y_u^\dagger Y_u m_q^2 + 2g_p^2Q_{H_u}^2Y_u^\dagger Y_u m_q^2 - 2g_p^2Q_q^2Y_u^\dagger Y_u m_q^2 \\
& + 2g_p^2Q_u^2Y_u^\dagger Y_u m_q^2 - |\lambda|^2Y_u^\dagger Y_u m_q^2 - 8m_{H_d}^2Y_d^\dagger Y_d Y_d^\dagger Y_d - 4Y_d^\dagger Y_d T_d^\dagger T_d \\
& -4Y_d^\dagger T_d T_d^\dagger Y_d - 8m_{H_u}^2Y_u^\dagger Y_u Y_u^\dagger Y_u - 4Y_u^\dagger Y_u T_u^\dagger T_u - 4Y_u^\dagger T_u T_u^\dagger Y_u \\
& -4T_d^\dagger Y_d Y_d^\dagger T_d - 4T_d^\dagger T_d Y_d^\dagger Y_d - 4T_u^\dagger Y_u Y_u^\dagger T_u - 4T_u^\dagger T_u Y_u^\dagger Y_u
\end{aligned}$$

$$\begin{aligned}
& -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) - 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) - 6Y_d^\dagger T_d \text{Tr}(T_d^* Y_d^T) - 6Y_d^\dagger Y_d \text{Tr}(T_d^* T_d^T) \\
& - 2Y_d^\dagger T_d \text{Tr}(T_e^* Y_e^T) - 2Y_d^\dagger Y_d \text{Tr}(T_e^* T_e^T) - 6Y_u^\dagger T_u \text{Tr}(T_u^* Y_u^T) \\
& - 6Y_u^\dagger Y_u \text{Tr}(T_u^* T_u^T) - 6Y_d^\dagger Y_d \text{Tr}(m_d^2 Y_d Y_d^\dagger) - 2Y_d^\dagger Y_d \text{Tr}(m_e^2 Y_e Y_e^\dagger) \\
& - 2Y_d^\dagger Y_d \text{Tr}(m_l^2 Y_e^\dagger Y_e) - 6Y_d^\dagger Y_d \text{Tr}(m_q^2 Y_d^\dagger Y_d) - 6Y_u^\dagger Y_u \text{Tr}(m_q^2 Y_u^\dagger Y_u) \\
& - 6Y_u^\dagger Y_u \text{Tr}(m_u^2 Y_u Y_u^\dagger)
\end{aligned} \tag{76}$$

$$\begin{aligned}
\beta_{m_l^2}^{(1)} &= -\frac{6}{5} g_1^2 \mathbf{1}_{|M_1|^2} - 8g_p^2 Q_l^2 \mathbf{1}_{|M_U|^2} - 6g_2^2 \mathbf{1}_{|M_2|^2} + 2m_{H_d}^2 Y_e^\dagger Y_e + 2T_e^\dagger T_e + m_l^2 Y_e^\dagger Y_e \\
&+ 2Y_e^\dagger m_e^2 Y_e + Y_e^\dagger Y_e m_l^2 - \sqrt{\frac{3}{5}} g_1 \mathbf{1}_{\sigma_{1,1}} + 2g_p Q_l \mathbf{1}_{\sigma_{1,4}}
\end{aligned} \tag{77}$$

$$\begin{aligned}
\beta_{m_l^2}^{(2)} &= +\frac{18}{5} g_1^2 g_2^2 \mathbf{1}_{|M_2|^2} + 33g_2^4 \mathbf{1}_{|M_2|^2} + 24g_2^2 g_p^2 Q_l^2 \mathbf{1}_{|M_2|^2} + \frac{9}{5} g_1^2 g_2^2 M_1 \mathbf{1}_{M_2^*} \\
&+ 12g_2^2 g_p^2 M_U Q_l^2 \mathbf{1}_{M_2^*} + \frac{12}{5} g_1^2 m_{H_d}^2 Y_e^\dagger Y_e + 4g_p^2 m_{H_d}^2 Q_e^2 Y_e^\dagger Y_e \\
&+ 4g_p^2 m_{H_d}^2 Q_{H_d}^2 Y_e^\dagger Y_e - 4g_p^2 m_{H_d}^2 Q_l^2 Y_e^\dagger Y_e - 4m_{H_d}^2 |\lambda|^2 Y_e^\dagger Y_e \\
&- 2m_{H_u}^2 |\lambda|^2 Y_e^\dagger Y_e - 2m_S^2 |\lambda|^2 Y_e^\dagger Y_e - 2|T_\lambda|^2 Y_e^\dagger Y_e \\
&+ \frac{4}{5} g_p^2 M_U^* \left(3Q_l \left(-g_1^2 (2M_U + M_1) \right) (3Q_d + 3Q_e + 3Q_q - 4Q_l - 6Q_u - Q_{H_d} + Q_{H_u}) \right. \\
&+ 5Q_l \left(2g_p^2 M_U (18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 8Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2) + g_2^2 (2M_U + M_2) \right) \Big) \mathbf{1} \\
&+ 5 \left(-Q_l^2 + Q_e^2 + Q_{H_d}^2 \right) \left(2M_U Y_e^\dagger Y_e - Y_e^\dagger T_e \right) \Big) \\
&+ \frac{3}{25} g_1^2 M_1^* \left(\left(207g_1^2 M_1 + 5 \left(3g_2^2 (2M_1 + M_2) + 4g_p^2 (2M_1 + M_U) Q_l \left(-3Q_d - 3Q_e - 3Q_q + 4Q_l + 6Q_u - Q_{H_u} + Q_{H_d} \right) \right) \right) \right) \mathbf{1}
\end{aligned}$$

$$\begin{aligned}
& + 40M_1Y_e^\dagger Y_e - 20Y_e^\dagger T_e) \\
& - 2\lambda T_\lambda^* Y_e^\dagger T_e - \frac{12}{5}g_1^2 M_1 T_e^\dagger Y_e - 4g_p^2 M_U Q_e^2 T_e^\dagger Y_e - 4g_p^2 M_U Q_{H_d}^2 T_e^\dagger Y_e \\
& + 4g_p^2 M_U Q_l^2 T_e^\dagger Y_e + \frac{12}{5}g_1^2 T_e^\dagger T_e + 4g_p^2 Q_e^2 T_e^\dagger T_e + 4g_p^2 Q_{H_d}^2 T_e^\dagger T_e \\
& - 4g_p^2 Q_l^2 T_e^\dagger T_e - 2|\lambda|^2 T_e^\dagger T_e + \frac{6}{5}g_1^2 m_l^2 Y_e^\dagger Y_e + 2g_p^2 Q_e^2 m_l^2 Y_e^\dagger Y_e \\
& + 2g_p^2 Q_{H_d}^2 m_l^2 Y_e^\dagger Y_e - 2g_p^2 Q_l^2 m_l^2 Y_e^\dagger Y_e - |\lambda|^2 m_l^2 Y_e^\dagger Y_e \\
& + \frac{12}{5}g_1^2 Y_e^\dagger m_e^2 Y_e + 4g_p^2 Q_e^2 Y_e^\dagger m_e^2 Y_e + 4g_p^2 Q_{H_d}^2 Y_e^\dagger m_e^2 Y_e \\
& - 4g_p^2 Q_l^2 Y_e^\dagger m_e^2 Y_e - 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_l^2 Y_e^\dagger Y_e m_l^2 \\
& - |\lambda|^2 Y_e^\dagger Y_e m_l^2 - 8m_{H_d}^2 Y_e^\dagger Y_e Y_e^\dagger Y_e - 4Y_e^\dagger Y_e T_e^\dagger T_e - 4Y_e^\dagger T_e T_e^\dagger Y_e \\
& - 4T_e^\dagger Y_e Y_e^\dagger T_e - 4T_e^\dagger T_e Y_e^\dagger Y_e - 2m_l^2 Y_e^\dagger Y_e Y_e^\dagger Y_e - 4Y_e^\dagger m_e^2 Y_e Y_e^\dagger Y_e \\
& - 4Y_e^\dagger Y_e m_l^2 Y_e^\dagger Y_e - 4Y_e^\dagger Y_e Y_e^\dagger m_e^2 Y_e - 2Y_e^\dagger Y_e Y_e^\dagger Y_e m_l^2 - 2\lambda^* T_e^\dagger Y_e 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_l \mathbf{1}_{\sigma_{2,14}} - 4\sqrt{\frac{3}{5}}g_1 g_p Q_l \mathbf{1}_{\sigma_{2,41}} + 8g_p^2 Q_l^2 \mathbf{1}_{\sigma_{2,44}} - 4\sqrt{\frac{3}{5}}g_1 \mathbf{1}_{\sigma_{3,1}} + 8g_p Q_l \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) \\
& - 2T_e^\dagger T_e \text{Tr}(Y_e Y_e^\dagger) - m_l^2 Y_e^\dagger Y_e \text{Tr}(Y_e Y_e^\dagger) - 2Y_e^\dagger m_e^2 Y_e \text{Tr}(Y_e Y_e^\dagger) \\
& - Y_e^\dagger Y_e m_l^2 \text{Tr}(Y_e Y_e^\dagger) - 6T_e^\dagger Y_e \text{Tr}(Y_d^\dagger T_d) - 2T_e^\dagger Y_e \text{Tr}(Y_e^\dagger T_e) \\
& - 6Y_e^\dagger T_e \text{Tr}(T_d^* Y_d^T) - 6Y_e^\dagger Y_e \text{Tr}(T_d^* T_d^T) - 2Y_e^\dagger T_e \text{Tr}(T_e^* Y_e^T) \\
& - 2Y_e^\dagger Y_e \text{Tr}(T_e^* T_e^T) - 6Y_e^\dagger Y_e \text{Tr}(m_d^2 Y_d Y_d^\dagger) - 2Y_e^\dagger Y_e \text{Tr}(m_e^2 Y_e Y_e^\dagger) \\
& - 2Y_e^\dagger Y_e \text{Tr}(m_l^2 Y_e^\dagger Y_e) - 6Y_e^\dagger Y_e \text{Tr}(m_q^2 Y_d^\dagger Y_d)
\end{aligned} \tag{78}$$

$$\begin{aligned}
\beta_{m_{H_d}^2}^{(1)} &= -\frac{6}{5}g_1^2 |M_1|^2 - 8g_p^2 Q_{H_d}^2 |M_U|^2 - 6g_2^2 |M_2|^2 + 2m_{H_d}^2 |\lambda|^2 + 2m_{H_u}^2 |\lambda|^2 + 2m_S^2 |\lambda|^2 + 2|T_\lambda|^2 \\
& - \sqrt{\frac{3}{5}}g_1 \sigma_{1,1} + 2g_p Q_{H_d} \sigma_{1,4} + 6m_{H_d}^2 \text{Tr}(Y_d Y_d^\dagger) + 2m_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) + 6\text{Tr}(T_d^* T_d^T) + 2\text{Tr}(T_e^* T_e^T) \\
& + 6\text{Tr}(m_d^2 Y_d Y_d^\dagger) + 2\text{Tr}(m_e^2 Y_e Y_e^\dagger) + 2\text{Tr}(m_l^2 Y_e^\dagger Y_e) + 6\text{Tr}(m_q^2 Y_d^\dagger Y_d)
\end{aligned} \tag{79}$$

$$\begin{aligned}
\beta_{m_{H_d}^2}^{(2)} &= +\frac{18}{5}g_1^2 g_2^2 |M_2|^2 + 33g_2^4 |M_2|^2 + 24g_2^2 g_p^2 Q_{H_d}^2 |M_2|^2 - 4g_p^2 m_{H_d}^2 Q_{H_d}^2 |\lambda|^2 \\
& - 4g_p^2 m_{H_u}^2 Q_{H_d}^2 |\lambda|^2 - 4g_p^2 m_S^2 Q_{H_d}^2 |\lambda|^2 + 4g_p^2 m_{H_d}^2 Q_{H_u}^2 |\lambda|^2 + 4g_p^2 m_{H_u}^2 Q_{H_u}^2 |\lambda|^2 \\
& + 4g_p^2 m_S^2 Q_{H_u}^2 |\lambda|^2 + 4g_p^2 m_{H_d}^2 Q_s^2 |\lambda|^2 + 4g_p^2 m_{H_u}^2 Q_s^2 |\lambda|^2 + 4g_p^2 m_S^2 Q_s^2 |\lambda|^2
\end{aligned}$$

$$\begin{aligned}
& -4g_p^2 Q_{H_d}^2 |T_\lambda|^2 + 4g_p^2 Q_{H_u}^2 |T_\lambda|^2 + 4g_p^2 Q_s^2 |T_\lambda|^2 + \frac{9}{5} g_1^2 g_2^2 M_1 M_2^* \\
& + 12g_2^2 g_p^2 M_U Q_{H_d}^2 M_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^2 M_U Q_{H_d}^2 \lambda T_\lambda^* \\
& - 4g_p^2 M_U Q_{H_u}^2 \lambda T_\lambda^* - 4g_p^2 M_U Q_s^2 \lambda T_\lambda^* - 24|\lambda|^2 T_\lambda^* T_\lambda + 6g_2^4 \sigma_{2,2} + \frac{6}{5} g_1^2 \sigma_{2,11} - 4\sqrt{\frac{3}{5}} g_1 g_p Q_{H_d} \sigma_{2,14} \\
& - 4\sqrt{\frac{3}{5}} g_1 g_p Q_{H_d} \sigma_{2,41} + 8g_p^2 Q_{H_d}^2 \sigma_{2,44} - 4\sqrt{\frac{3}{5}} g_1 \sigma_{3,1} + 8g_p Q_{H_d} \sigma_{3,4} - \frac{4}{5} g_1^2 m_{H_d}^2 \text{Tr}(Y_d Y_d^\dagger) \\
& + 32g_3^2 m_{H_d}^2 \text{Tr}(Y_d Y_d^\dagger) + 12g_p^2 m_{H_d}^2 Q_d^2 \text{Tr}(Y_d Y_d^\dagger) - 12g_p^2 m_{H_d}^2 Q_{H_d}^2 \text{Tr}(Y_d Y_d^\dagger) \\
& + 12g_p^2 m_{H_d}^2 Q_q^2 \text{Tr}(Y_d Y_d^\dagger) + 64g_3^2 |M_3|^2 \text{Tr}(Y_d Y_d^\dagger) + \frac{12}{5} g_1^2 m_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) \\
& + 4g_p^2 m_{H_d}^2 Q_e^2 \text{Tr}(Y_e Y_e^\dagger) - 4g_p^2 m_{H_d}^2 Q_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) + 4g_p^2 m_{H_d}^2 Q_l^2 \text{Tr}(Y_e Y_e^\dagger) \\
& - 6m_{H_d}^2 |\lambda|^2 \text{Tr}(Y_u Y_u^\dagger) - 12m_{H_u}^2 |\lambda|^2 \text{Tr}(Y_u Y_u^\dagger) - 6m_S^2 |\lambda|^2 \text{Tr}(Y_u Y_u^\dagger) \\
& - 6|T_\lambda|^2 \text{Tr}(Y_u Y_u^\dagger) - 32g_3^2 M_3^* \text{Tr}(Y_d^\dagger T_d) \\
& + \frac{1}{25} g_1^2 M_1^* \left(621g_1^2 M_1 + 90g_2^2 M_1 + 45g_2^2 M_2 - 360g_p^2 M_1 Q_d Q_{H_d} - 180g_p^2 M_U Q_d Q_{H_d} - 360g_p^2 M_1 Q_e Q_{H_d} \right. \\
& - 180g_p^2 M_U Q_e Q_{H_d} + 240g_p^2 M_1 Q_{H_d}^2 + 120g_p^2 M_U Q_{H_d}^2 - 120g_p^2 M_1 Q_{H_d} Q_{H_u} - 60g_p^2 M_U Q_{H_d} Q_{H_u} \\
& + 360g_p^2 M_1 Q_{H_d} Q_l + 180g_p^2 M_U Q_{H_d} Q_l - 360g_p^2 M_1 Q_{H_d} Q_q - 180g_p^2 M_U Q_{H_d} Q_q + 720g_p^2 M_1 Q_{H_d} Q_u \\
& + 360g_p^2 M_U Q_{H_d} Q_u - 40M_1 \text{Tr}(Y_d Y_d^\dagger) + 120M_1 \text{Tr}(Y_e Y_e^\dagger) + 20\text{Tr}(Y_d^\dagger T_d) - 60\text{Tr}(Y_e^\dagger T_e) \Big) \\
& + \frac{4}{5} g_p^2 M_U^* \left(-9g_1^2 M_1 Q_d Q_{H_d} - 18g_1^2 M_U Q_d Q_{H_d} - 9g_1^2 M_1 Q_e Q_{H_d} - 18g_1^2 M_U Q_e Q_{H_d} + 6g_1^2 M_1 Q_{H_d}^2 \right. \\
& + 12g_1^2 M_U Q_{H_d}^2 + 30g_2^2 M_U Q_{H_d}^2 + 15g_2^2 M_2 Q_{H_d}^2 + 270g_p^2 M_U Q_d^2 Q_{H_d}^2 + 90g_p^2 M_U Q_e^2 Q_{H_d}^2 \\
& + 120g_p^2 M_U Q_{H_d}^4 - 3g_1^2 M_1 Q_{H_d} Q_{H_u} - 6g_1^2 M_U Q_{H_d} Q_{H_u} + 60g_p^2 M_U Q_{H_d}^2 Q_{H_u}^2 + 9g_1^2 M_1 Q_{H_d} Q_l \\
& + 18g_1^2 M_U Q_{H_d} Q_l + 180g_p^2 M_U Q_{H_d}^2 Q_l^2 - 9g_1^2 M_1 Q_{H_d} Q_q - 18g_1^2 M_U Q_{H_d} Q_q \\
& + 540g_p^2 M_U Q_{H_d}^2 Q_q^2 + 30g_p^2 M_U Q_{H_d}^2 Q_s^2 + 30g_p^2 M_U Q_{H_d}^2 Q_1^2 + 30g_p^2 M_U Q_{H_d}^2 Q_2^2 \\
& + 30g_p^2 M_U Q_{H_d}^2 Q_3^2 + 18g_1^2 M_1 Q_{H_d} Q_u + 36g_1^2 M_U Q_{H_d} Q_u + 270g_p^2 M_U Q_{H_d}^2 Q_u^2 \\
& - 5 \left(-Q_{H_u}^2 - Q_s^2 + Q_{H_d}^2 \right) \lambda^* \left(2M_U \lambda - T_\lambda \right) + 30M_U \left(-Q_{H_d}^2 + Q_d^2 + Q_q^2 \right) \text{Tr}(Y_d Y_d^\dagger) \\
& + 10M_U Q_e^2 \text{Tr}(Y_e Y_e^\dagger) - 10M_U Q_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) + 10M_U Q_l^2 \text{Tr}(Y_e Y_e^\dagger) - 15Q_d^2 \text{Tr}(Y_d^\dagger T_d) \\
& + 15Q_{H_d}^2 \text{Tr}(Y_d^\dagger T_d) - 15Q_q^2 \text{Tr}(Y_d^\dagger T_d) - 5Q_e^2 \text{Tr}(Y_e^\dagger T_e) + 5Q_{H_d}^2 \text{Tr}(Y_e^\dagger T_e) \\
& - 5Q_l^2 \text{Tr}(Y_e^\dagger T_e) \Big) \\
& - 6\lambda T_\lambda^* \text{Tr}(Y_u^\dagger T_u) + \frac{4}{5} g_1^2 M_1 \text{Tr}(T_d^* Y_d^T) - 32g_3^2 M_3 \text{Tr}(T_d^* Y_d^T) - 12g_p^2 M_U Q_d^2 \text{Tr}(T_d^* Y_d^T) \\
& + 12g_p^2 M_U Q_{H_d}^2 \text{Tr}(T_d^* Y_d^T) - 12g_p^2 M_U Q_q^2 \text{Tr}(T_d^* Y_d^T) - \frac{4}{5} g_1^2 \text{Tr}(T_d^* T_d^T) + 32g_3^2 \text{Tr}(T_d^* T_d^T)
\end{aligned}$$

$$\begin{aligned}
& + 12g_p^2 Q_d^2 \text{Tr}(T_d^* T_d^T) - 12g_p^2 Q_{H_d}^2 \text{Tr}(T_d^* T_d^T) + 12g_p^2 Q_q^2 \text{Tr}(T_d^* T_d^T) - \frac{12}{5} g_1^2 M_1 \text{Tr}(T_e^* Y_e^T) \\
& - 4g_p^2 M_U Q_e^2 \text{Tr}(T_e^* Y_e^T) + 4g_p^2 M_U Q_{H_d}^2 \text{Tr}(T_e^* Y_e^T) - 4g_p^2 M_U Q_l^2 \text{Tr}(T_e^* Y_e^T) \\
& + \frac{12}{5} g_1^2 \text{Tr}(T_e^* T_e^T) + 4g_p^2 Q_e^2 \text{Tr}(T_e^* T_e^T) - 4g_p^2 Q_{H_d}^2 \text{Tr}(T_e^* T_e^T) + 4g_p^2 Q_l^2 \text{Tr}(T_e^* T_e^T) \\
& - 6\lambda^* T_\lambda \text{Tr}(T_u^* Y_u^T) - 6|\lambda|^2 \text{Tr}(T_u^* T_u^T) - \frac{4}{5} g_1^2 \text{Tr}(m_d^2 Y_d Y_d^\dagger) + 32g_3^2 \text{Tr}(m_d^2 Y_d Y_d^\dagger) \\
& + 12g_p^2 Q_d^2 \text{Tr}(m_d^2 Y_d Y_d^\dagger) - 12g_p^2 Q_{H_d}^2 \text{Tr}(m_d^2 Y_d Y_d^\dagger) + 12g_p^2 Q_q^2 \text{Tr}(m_d^2 Y_d Y_d^\dagger) \\
& + \frac{12}{5} g_1^2 \text{Tr}(m_e^2 Y_e Y_e^\dagger) + 4g_p^2 Q_e^2 \text{Tr}(m_e^2 Y_e Y_e^\dagger) - 4g_p^2 Q_{H_d}^2 \text{Tr}(m_e^2 Y_e Y_e^\dagger) \\
& + 4g_p^2 Q_l^2 \text{Tr}(m_e^2 Y_e Y_e^\dagger) + \frac{12}{5} g_1^2 \text{Tr}(m_l^2 Y_e^\dagger Y_e) + 4g_p^2 Q_e^2 \text{Tr}(m_l^2 Y_e^\dagger Y_e) \\
& - 4g_p^2 Q_{H_d}^2 \text{Tr}(m_l^2 Y_e^\dagger Y_e) + 4g_p^2 Q_l^2 \text{Tr}(m_l^2 Y_e^\dagger Y_e) - \frac{4}{5} g_1^2 \text{Tr}(m_q^2 Y_d^\dagger Y_d) \\
& + 32g_3^2 \text{Tr}(m_q^2 Y_d^\dagger Y_d) + 12g_p^2 Q_d^2 \text{Tr}(m_q^2 Y_d^\dagger Y_d) - 12g_p^2 Q_{H_d}^2 \text{Tr}(m_q^2 Y_d^\dagger Y_d) \\
& + 12g_p^2 Q_q^2 \text{Tr}(m_q^2 Y_d^\dagger Y_d) - 6|\lambda|^2 \text{Tr}(m_q^2 Y_u^\dagger Y_u) - 6|\lambda|^2 \text{Tr}(m_u^2 Y_u Y_u^\dagger) \\
& - 36m_{H_d}^2 \text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) - 36\text{Tr}(Y_d Y_d^\dagger T_d T_d^\dagger) - 6m_{H_d}^2 \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) \\
& - 6m_{H_u}^2 \text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) - 6\text{Tr}(Y_d Y_u^\dagger T_u T_u^\dagger) - 36\text{Tr}(Y_d T_d^\dagger T_d Y_d^\dagger) \\
& - 6\text{Tr}(Y_d T_u^\dagger T_u Y_d^\dagger) - 12m_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) - 12\text{Tr}(Y_e Y_e^\dagger T_e T_e^\dagger) - 12\text{Tr}(Y_e T_e^\dagger T_e Y_e^\dagger) \\
& - 6\text{Tr}(Y_u Y_d^\dagger T_d T_d^\dagger) - 6\text{Tr}(Y_u T_d^\dagger T_d Y_u^\dagger) - 36\text{Tr}(m_d^2 Y_d Y_d^\dagger Y_d Y_d^\dagger) - 6\text{Tr}(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger) \\
& - 12\text{Tr}(m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger) - 12\text{Tr}(m_l^2 Y_e^\dagger Y_e Y_e^\dagger Y_e) - 36\text{Tr}(m_q^2 Y_d^\dagger Y_d Y_d^\dagger Y_d) - 6\text{Tr}(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u) \\
& - 6\text{Tr}(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d) - 6\text{Tr}(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger)
\end{aligned} \tag{80}$$

$$\begin{aligned}
\beta_{m_{H_u}^2}^{(1)} &= -\frac{6}{5} g_1^2 |M_1|^2 - 8g_p^2 Q_{H_u}^2 |M_U|^2 - 6g_2^2 |M_2|^2 + 2m_{H_d}^2 |\lambda|^2 + 2m_{H_u}^2 |\lambda|^2 + 2m_S^2 |\lambda|^2 + 2|T_\lambda|^2 \\
&+ \sqrt{\frac{3}{5}} g_1 \sigma_{1,1} + 2g_p Q_{H_u} \sigma_{1,4} + 6m_{H_u}^2 \text{Tr}(Y_u Y_u^\dagger) + 6\text{Tr}(T_u^* T_u^T) + 6\text{Tr}(m_q^2 Y_u^\dagger Y_u) + 6\text{Tr}(m_u^2 Y_u Y_u^\dagger)
\end{aligned} \tag{81}$$

$$\begin{aligned}
\beta_{m_{H_u}^2}^{(2)} &= +\frac{18}{5} g_1^2 g_2^2 |M_2|^2 + 33g_2^4 |M_2|^2 + 24g_2^2 g_p^2 Q_{H_u}^2 |M_2|^2 + 4g_p^2 m_{H_d}^2 Q_{H_d}^2 |\lambda|^2 \\
&+ 4g_p^2 m_{H_u}^2 Q_{H_d}^2 |\lambda|^2 + 4g_p^2 m_S^2 Q_{H_d}^2 |\lambda|^2 - 4g_p^2 m_{H_d}^2 Q_{H_u}^2 |\lambda|^2 - 4g_p^2 m_{H_u}^2 Q_{H_u}^2 |\lambda|^2 \\
&- 4g_p^2 m_S^2 Q_{H_u}^2 |\lambda|^2 + 4g_p^2 m_{H_d}^2 Q_s^2 |\lambda|^2 + 4g_p^2 m_{H_u}^2 Q_s^2 |\lambda|^2 + 4g_p^2 m_S^2 Q_s^2 |\lambda|^2 \\
&+ 4g_p^2 Q_{H_d}^2 |T_\lambda|^2 - 4g_p^2 Q_{H_u}^2 |T_\lambda|^2 + 4g_p^2 Q_s^2 |T_\lambda|^2 + \frac{9}{5} g_1^2 g_2^2 M_1 M_2^* \\
&+ 12g_2^2 g_p^2 M_U Q_{H_u}^2 M_2^* - 12m_{H_d}^2 \lambda^2 \lambda^{*,2} - 12m_{H_u}^2 \lambda^2 \lambda^{*,2} - 12m_S^2 \lambda^2 \lambda^{*,2} \\
&- 4g_p^2 M_U Q_{H_d}^2 \lambda T_\lambda^* + 4g_p^2 M_U Q_{H_u}^2 \lambda T_\lambda^* - 4g_p^2 M_U Q_s^2 \lambda T_\lambda^* - 24|\lambda|^2 T_\lambda^* T_\lambda + 6g_2^4 \sigma_{2,2}
\end{aligned}$$

$$\begin{aligned}
& + \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}(Y_dY_d^\dagger) - 6m_{H_u}^2|\lambda|^2\text{Tr}(Y_dY_d^\dagger) - 6m_S^2|\lambda|^2\text{Tr}(Y_dY_d^\dagger) \\
& - 6|T_\lambda|^2\text{Tr}(Y_dY_d^\dagger) - 4m_{H_d}^2|\lambda|^2\text{Tr}(Y_eY_e^\dagger) - 2m_{H_u}^2|\lambda|^2\text{Tr}(Y_eY_e^\dagger) \\
& - 2m_S^2|\lambda|^2\text{Tr}(Y_eY_e^\dagger) - 2|T_\lambda|^2\text{Tr}(Y_eY_e^\dagger) + \frac{8}{5}g_1^2m_{H_u}^2\text{Tr}(Y_uY_u^\dagger) + 32g_3^2m_{H_u}^2\text{Tr}(Y_uY_u^\dagger) \\
& - 12g_p^2m_{H_u}^2Q_{H_u}^2\text{Tr}(Y_uY_u^\dagger) + 12g_p^2m_{H_u}^2Q_q^2\text{Tr}(Y_uY_u^\dagger) + 12g_p^2m_{H_u}^2Q_u^2\text{Tr}(Y_uY_u^\dagger) \\
& + 64g_3^2|M_3|^2\text{Tr}(Y_uY_u^\dagger) - 6\lambda T_\lambda^*\text{Tr}(Y_d^\dagger T_d) - 2\lambda T_\lambda^*\text{Tr}(Y_e^\dagger T_e) \\
& + \frac{1}{25}g_1^2M_1^*\left(3\left(207g_1^2M_1 + 5\left(3g_2^2(2M_1 + M_2) + 4g_p^2(2M_1 + M_U)\right)Q_{H_u}\left(2Q_{H_u} + 3Q_d + 3Q_e - 3Q_l + 3Q_q - 6Q_u - Q_{H_d}\right)\right)\right) \\
& + 80M_1\text{Tr}(Y_uY_u^\dagger) - 40\text{Tr}(Y_u^\dagger T_u) \\
& - 32g_3^2M_3^*\text{Tr}(Y_u^\dagger T_u) \\
& + \frac{4}{5}g_p^2M_U^*\left(5\left(-Q_{H_u}^2 + Q_{H_d}^2 + Q_s^2\right)\lambda^*\left(2M_U\lambda - T_\lambda\right)\right. \\
& + 3\left(Q_{H_u}\left(g_1^2(2M_U + M_1)\right)\left(2Q_{H_u} + 3Q_d + 3Q_e - 3Q_l + 3Q_q - 6Q_u - Q_{H_d}\right)\right. \\
& + 5Q_{H_u}\left(2g_p^2M_U\left(18Q_q^2 + 2Q_{H_d}^2 + 3Q_e^2 + 4Q_{H_u}^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2\right) + g_2^2(2M_U + M_2)\right)\left.\right) \\
& - 10M_U\left(-Q_q^2 - Q_u^2 + Q_{H_u}^2\right)\text{Tr}(Y_uY_u^\dagger) + 5\left(-Q_q^2 - Q_u^2 + Q_{H_u}^2\right)\text{Tr}(Y_u^\dagger T_u)\left.\right) \\
& - 6\lambda^*T_\lambda\text{Tr}(T_d^*Y_d^T) - 6|\lambda|^2\text{Tr}(T_d^*T_d^T) - 2\lambda^*T_\lambda\text{Tr}(T_e^*Y_e^T) - 2|\lambda|^2\text{Tr}(T_e^*T_e^T) \\
& - \frac{8}{5}g_1^2M_1\text{Tr}(T_u^*Y_u^T) - 32g_3^2M_3\text{Tr}(T_u^*Y_u^T) + 12g_p^2M_UQ_{H_u}^2\text{Tr}(T_u^*Y_u^T) \\
& - 12g_p^2M_UQ_q^2\text{Tr}(T_u^*Y_u^T) - 12g_p^2M_UQ_u^2\text{Tr}(T_u^*Y_u^T) + \frac{8}{5}g_1^2\text{Tr}(T_u^*T_u^T) + 32g_3^2\text{Tr}(T_u^*T_u^T) \\
& - 12g_p^2Q_{H_u}^2\text{Tr}(T_u^*T_u^T) + 12g_p^2Q_q^2\text{Tr}(T_u^*T_u^T) + 12g_p^2Q_u^2\text{Tr}(T_u^*T_u^T) \\
& - 6|\lambda|^2\text{Tr}(m_d^2Y_dY_d^\dagger) - 2|\lambda|^2\text{Tr}(m_e^2Y_eY_e^\dagger) - 2|\lambda|^2\text{Tr}(m_l^2Y_e^\dagger Y_e) \\
& - 6|\lambda|^2\text{Tr}(m_q^2Y_u^\dagger Y_d) + \frac{8}{5}g_1^2\text{Tr}(m_q^2Y_u^\dagger Y_u) + 32g_3^2\text{Tr}(m_q^2Y_u^\dagger Y_u) \\
& - 12g_p^2Q_{H_u}^2\text{Tr}(m_q^2Y_u^\dagger Y_u) + 12g_p^2Q_q^2\text{Tr}(m_q^2Y_u^\dagger Y_u) + 12g_p^2Q_u^2\text{Tr}(m_q^2Y_u^\dagger Y_u) \\
& + \frac{8}{5}g_1^2\text{Tr}(m_u^2Y_uY_u^\dagger) + 32g_3^2\text{Tr}(m_u^2Y_uY_u^\dagger) - 12g_p^2Q_{H_u}^2\text{Tr}(m_u^2Y_uY_u^\dagger) \\
& + 12g_p^2Q_q^2\text{Tr}(m_u^2Y_uY_u^\dagger) + 12g_p^2Q_u^2\text{Tr}(m_u^2Y_uY_u^\dagger) - 6m_{H_d}^2\text{Tr}(Y_dY_u^\dagger Y_uY_d^\dagger) \\
& - 6m_{H_u}^2\text{Tr}(Y_dY_u^\dagger Y_uY_d^\dagger) - 6\text{Tr}(Y_dY_u^\dagger T_uT_d^\dagger) - 6\text{Tr}(Y_dT_u^\dagger T_uY_d^\dagger) \\
& - 6\text{Tr}(Y_uY_d^\dagger T_dT_u^\dagger) - 36m_{H_u}^2\text{Tr}(Y_uY_u^\dagger Y_uY_u^\dagger) - 36\text{Tr}(Y_uY_u^\dagger T_uT_u^\dagger) - 6\text{Tr}(Y_uT_d^\dagger T_dY_u^\dagger)
\end{aligned}$$

$$\begin{aligned}
& -36\text{Tr}\left(Y_u T_u^\dagger T_u Y_u^\dagger\right) - 6\text{Tr}\left(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 6\text{Tr}\left(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\right) \\
& - 6\text{Tr}\left(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\right) - 36\text{Tr}\left(m_q^2 Y_u^\dagger Y_u Y_u^\dagger Y_u\right) - 6\text{Tr}\left(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\right) \\
& - 36\text{Tr}\left(m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger\right)
\end{aligned} \tag{82}$$

$$\begin{aligned}
\beta_{m_d^2}^{(1)} = & -\frac{8}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 - 8g_p^2Q_d^2\mathbf{1}|M_U|^2 + 4m_{H_d}^2Y_dY_d^\dagger + 4T_dT_d^\dagger \\
& + 2m_d^2Y_dY_d^\dagger + 4Y_dm_q^2Y_d^\dagger + 2Y_dY_d^\dagger m_d^2 + 2\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1} + 2g_pQ_d\mathbf{1}\sigma_{1,4}
\end{aligned} \tag{83}$$

$$\begin{aligned}
\beta_{m_d^2}^{(2)} = & +\frac{176}{15}g_1^2g_p^2Q_d^2\mathbf{1}|M_U|^2 + \frac{128}{3}g_3^2g_p^2Q_d^2\mathbf{1}|M_U|^2 + 264g_p^4Q_d^4\mathbf{1}|M_U|^2 \\
& + \frac{48}{5}g_1^2g_p^2Q_dQ_e\mathbf{1}|M_U|^2 + 72g_p^4Q_d^2Q_e^2\mathbf{1}|M_U|^2 - \frac{16}{5}g_1^2g_p^2Q_dQ_{H_d}\mathbf{1}|M_U|^2 \\
& + 48g_p^4Q_d^2Q_{H_d}^2\mathbf{1}|M_U|^2 + \frac{16}{5}g_1^2g_p^2Q_dQ_{H_u}\mathbf{1}|M_U|^2 + 48g_p^4Q_d^2Q_{H_u}^2\mathbf{1}|M_U|^2 \\
& - \frac{48}{5}g_1^2g_p^2Q_dQ_l\mathbf{1}|M_U|^2 + 144g_p^4Q_d^2Q_l^2\mathbf{1}|M_U|^2 + \frac{48}{5}g_1^2g_p^2Q_dQ_q\mathbf{1}|M_U|^2 \\
& + 432g_p^4Q_d^2Q_q^2\mathbf{1}|M_U|^2 + 24g_p^4Q_d^2Q_s^2\mathbf{1}|M_U|^2 + 24g_p^4Q_d^2Q_1^2\mathbf{1}|M_U|^2 \\
& + 24g_p^4Q_d^2Q_2^2\mathbf{1}|M_U|^2 + 24g_p^4Q_d^2Q_3^2\mathbf{1}|M_U|^2 - \frac{96}{5}g_1^2g_p^2Q_dQ_u\mathbf{1}|M_U|^2 \\
& + 216g_p^4Q_d^2Q_u^2\mathbf{1}|M_U|^2 - \frac{64}{45}g_3^2\left(15\left(2g_3^2M_3 - g_p^2\left(2M_3 + M_U\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_U^* + \frac{64}{3}g_3^2g_p^2M_3Q_d^2\mathbf{1}M_U^* + \frac{24}{5}g_1^2g_p^2M_1Q_dQ_e\mathbf{1}M_U^* \\
& - \frac{8}{5}g_1^2g_p^2M_1Q_dQ_{H_d}\mathbf{1}M_U^* + \frac{8}{5}g_1^2g_p^2M_1Q_dQ_{H_u}\mathbf{1}M_U^* - \frac{24}{5}g_1^2g_p^2M_1Q_dQ_l\mathbf{1}M_U^* \\
& + \frac{24}{5}g_1^2g_p^2M_1Q_dQ_q\mathbf{1}M_U^* - \frac{48}{5}g_1^2g_p^2M_1Q_dQ_u\mathbf{1}M_U^* + \frac{4}{5}g_1^2m_{H_d}^2Y_dY_d^\dagger \\
& + 12g_2^2m_{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_U|^2Y_dY_d^\dagger + 16g_p^2Q_{H_d}^2|M_U|^2Y_dY_d^\dagger \\
& + 16g_p^2Q_q^2|M_U|^2Y_dY_d^\dagger + 24g_2^2|M_2|^2Y_dY_d^\dagger - 8m_{H_d}^2|\lambda|^2Y_dY_d^\dagger \\
& - 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_UQ_d^2Y_dT_d^\dagger - 8g_p^2M_UQ_{H_d}^2Y_dT_d^\dagger \\
& - 8g_p^2M_UQ_q^2Y_dT_d^\dagger \\
& + \frac{4}{225}g_1^2M_1^*\left(2\left(303g_1^2M_1 + 5\left(3g_p^2\left(2M_1 + M_U\right)Q_d\left(11Q_d + 3\left(3Q_e - 3Q_l + 3Q_q - 6Q_u - Q_{H_d} + Q_{H_u}\right)\right) + 8g_3^2\left(2M_1 + M_3\right)\right)\right)\right. \\
& \left.+ 90M_1Y_dY_d^\dagger - 45T_dY_d^\dagger\right) \\
& + 8g_p^2Q_d^2M_U^*T_dY_d^\dagger - 8g_p^2Q_{H_d}^2M_U^*T_dY_d^\dagger - 8g_p^2Q_q^2M_U^*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
\end{aligned}$$

$$\begin{aligned}
& -8g_p^2 Q_d^2 T_d T_d^\dagger + 8g_p^2 Q_{H_d}^2 T_d T_d^\dagger + 8g_p^2 Q_q^2 T_d T_d^\dagger - 4|\lambda|^2 T_d T_d^\dagger \\
& + \frac{2}{5} g_1^2 m_d^2 Y_d Y_d^\dagger + 6g_2^2 m_d^2 Y_d Y_d^\dagger - 4g_p^2 Q_d^2 m_d^2 Y_d Y_d^\dagger \\
& + 4g_p^2 Q_{H_d}^2 m_d^2 Y_d Y_d^\dagger + 4g_p^2 Q_q^2 m_d^2 Y_d Y_d^\dagger - 2|\lambda|^2 m_d^2 Y_d Y_d^\dagger \\
& + \frac{4}{5} g_1^2 Y_d m_q^2 Y_d^\dagger + 12g_2^2 Y_d m_q^2 Y_d^\dagger - 8g_p^2 Q_d^2 Y_d m_q^2 Y_d^\dagger \\
& + 8g_p^2 Q_{H_d}^2 Y_d m_q^2 Y_d^\dagger + 8g_p^2 Q_q^2 Y_d m_q^2 Y_d^\dagger - 4|\lambda|^2 Y_d m_q^2 Y_d^\dagger \\
& + \frac{2}{5} g_1^2 Y_d Y_d^\dagger m_d^2 + 6g_2^2 Y_d Y_d^\dagger m_d^2 - 4g_p^2 Q_d^2 Y_d Y_d^\dagger m_d^2 \\
& + 4g_p^2 Q_{H_d}^2 Y_d Y_d^\dagger m_d^2 + 4g_p^2 Q_q^2 Y_d Y_d^\dagger m_d^2 - 2|\lambda|^2 Y_d Y_d^\dagger m_d^2 \\
& - 8m_{H_d}^2 Y_d Y_d^\dagger Y_d Y_d^\dagger - 4Y_d Y_d^\dagger T_d T_d^\dagger - 4m_{H_d}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger \\
& - 4m_{H_u}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger - 4Y_d Y_u^\dagger T_u T_u^\dagger - 4Y_d T_d^\dagger T_d Y_d^\dagger - 4Y_d T_u^\dagger T_u Y_d^\dagger \\
& - 4T_d Y_d^\dagger Y_d T_d^\dagger - 4T_d Y_u^\dagger Y_u T_d^\dagger - 4T_d T_d^\dagger Y_d Y_d^\dagger - 4T_d T_u^\dagger Y_u Y_d^\dagger \\
& - 2m_d^2 Y_d Y_d^\dagger Y_d Y_d^\dagger - 2m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger - 4Y_d m_q^2 Y_d^\dagger Y_d Y_d^\dagger - 4Y_d m_q^2 Y_u^\dagger Y_u Y_d^\dagger \\
& - 4Y_d Y_d^\dagger m_d^2 Y_d Y_d^\dagger - 4Y_d Y_d^\dagger Y_d m_q^2 Y_d^\dagger - 2Y_d Y_d^\dagger Y_d Y_d^\dagger m_d^2 - 4Y_d Y_u^\dagger m_u^2 Y_u Y_d^\dagger \\
& - 4Y_d Y_u^\dagger Y_u m_q^2 Y_d^\dagger - 2Y_d Y_u^\dagger Y_u Y_d^\dagger m_d^2 - 4\lambda^* Y_d T_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_1 g_p Q_d \mathbf{1}_{\sigma_{2,14}} + 8\frac{1}{\sqrt{15}} g_1 g_p Q_d \mathbf{1}_{\sigma_{2,41}} + 8g_p^2 Q_d^2 \mathbf{1}_{\sigma_{2,44}} + 8\frac{1}{\sqrt{15}} g_1 \mathbf{1}_{\sigma_{3,1}} \\
& + 8g_p Q_d \mathbf{1}_{\sigma_{3,4}} - 24m_{H_d}^2 Y_d Y_d^\dagger \text{Tr}(Y_d Y_d^\dagger) - 12T_d T_d^\dagger \text{Tr}(Y_d Y_d^\dagger) \\
& - 6m_d^2 Y_d Y_d^\dagger \text{Tr}(Y_d Y_d^\dagger) - 12Y_d m_q^2 Y_d^\dagger \text{Tr}(Y_d Y_d^\dagger) - 6Y_d Y_d^\dagger m_d^2 \text{Tr}(Y_d Y_d^\dagger) \\
& - 8m_{H_d}^2 Y_d Y_d^\dagger \text{Tr}(Y_e Y_e^\dagger) - 4T_d T_d^\dagger \text{Tr}(Y_e Y_e^\dagger) - 2m_d^2 Y_d Y_d^\dagger \text{Tr}(Y_e Y_e^\dagger) \\
& - 4Y_d m_q^2 Y_d^\dagger \text{Tr}(Y_e Y_e^\dagger) - 2Y_d Y_d^\dagger m_d^2 \text{Tr}(Y_e Y_e^\dagger) - 12Y_d T_d^\dagger \text{Tr}(Y_d^\dagger T_d) \\
& - 4Y_d T_d^\dagger \text{Tr}(Y_e^\dagger T_e) - 12T_d Y_d^\dagger \text{Tr}(T_d^* Y_d^T) - 12Y_d Y_d^\dagger \text{Tr}(T_d^* T_d^T) \\
& - 4T_d Y_d^\dagger \text{Tr}(T_e^* Y_e^T) - 4Y_d Y_d^\dagger \text{Tr}(T_e^* T_e^T) - 12Y_d Y_d^\dagger \text{Tr}(m_d^2 Y_d Y_d^\dagger) \\
& - 4Y_d Y_d^\dagger \text{Tr}(m_e^2 Y_e Y_e^\dagger) - 4Y_d Y_d^\dagger \text{Tr}(m_l^2 Y_e^\dagger Y_e) - 12Y_d Y_d^\dagger \text{Tr}(m_q^2 Y_d^\dagger Y_d)
\end{aligned} \tag{84}$$

$$\begin{aligned}
\beta_{m_u^2}^{(1)} &= -\frac{32}{15} g_1^2 \mathbf{1}|M_1|^2 - \frac{32}{3} g_3^2 \mathbf{1}|M_3|^2 - 8g_p^2 Q_u^2 \mathbf{1}|M_U|^2 + 4m_{H_u}^2 Y_u Y_u^\dagger + 4T_u T_u^\dagger \\
& + 2m_u^2 Y_u Y_u^\dagger + 4Y_u m_q^2 Y_u^\dagger + 2Y_u Y_u^\dagger m_u^2 - 4\frac{1}{\sqrt{15}} g_1 \mathbf{1}_{\sigma_{1,1}} + 2g_p Q_u \mathbf{1}_{\sigma_{1,4}}
\end{aligned} \tag{85}$$

$$\begin{aligned}
\beta_{m_u^2}^{(2)} &= -\frac{96}{5} g_1^2 g_p^2 Q_d Q_u \mathbf{1}|M_U|^2 - \frac{96}{5} g_1^2 g_p^2 Q_e Q_u \mathbf{1}|M_U|^2 + \frac{32}{5} g_1^2 g_p^2 Q_{H_d} Q_u \mathbf{1}|M_U|^2 \\
& - \frac{32}{5} g_1^2 g_p^2 Q_{H_u} Q_u \mathbf{1}|M_U|^2 + \frac{96}{5} g_1^2 g_p^2 Q_l Q_u \mathbf{1}|M_U|^2 - \frac{96}{5} g_1^2 g_p^2 Q_q Q_u \mathbf{1}|M_U|^2
\end{aligned}$$

$$\begin{aligned}
& + \frac{704}{15} g_1^2 g_p^2 Q_u^2 \mathbf{1} |M_U|^2 + \frac{128}{3} g_3^2 g_p^2 Q_u^2 \mathbf{1} |M_U|^2 + 216 g_p^4 Q_d^2 Q_u^2 \mathbf{1} |M_U|^2 \\
& + 72 g_p^4 Q_e^2 Q_u^2 \mathbf{1} |M_U|^2 + 48 g_p^4 Q_{H_d}^2 Q_u^2 \mathbf{1} |M_U|^2 + 48 g_p^4 Q_{H_u}^2 Q_u^2 \mathbf{1} |M_U|^2 \\
& + 144 g_p^4 Q_l^2 Q_u^2 \mathbf{1} |M_U|^2 + 432 g_p^4 Q_q^2 Q_u^2 \mathbf{1} |M_U|^2 + 24 g_p^4 Q_s^2 Q_u^2 \mathbf{1} |M_U|^2 \\
& + 24 g_p^4 Q_1^2 Q_u^2 \mathbf{1} |M_U|^2 + 24 g_p^4 Q_2^2 Q_u^2 \mathbf{1} |M_U|^2 + 24 g_p^4 Q_3^2 Q_u^2 \mathbf{1} |M_U|^2 + 264 g_p^4 Q_u^4 \mathbf{1} |M_U|^2 \\
& - \frac{64}{45} g_3^2 \left(15 \left(2g_3^2 M_3 - g_p^2 (2M_3 + M_U) Q_u^2 \right) - 4g_1^2 (2M_3 + M_1) \right) \mathbf{1} M_3^* - \frac{48}{5} g_1^2 g_p^2 M_1 Q_d Q_u \mathbf{1} M_U^* \\
& - \frac{48}{5} g_1^2 g_p^2 M_1 Q_e Q_u \mathbf{1} M_U^* + \frac{16}{5} g_1^2 g_p^2 M_1 Q_{H_d} Q_u \mathbf{1} M_U^* - \frac{16}{5} g_1^2 g_p^2 M_1 Q_{H_u} Q_u \mathbf{1} M_U^* \\
& + \frac{48}{5} g_1^2 g_p^2 M_1 Q_l Q_u \mathbf{1} M_U^* - \frac{48}{5} g_1^2 g_p^2 M_1 Q_q Q_u \mathbf{1} M_U^* + \frac{352}{15} g_1^2 g_p^2 M_1 Q_u^2 \mathbf{1} M_U^* \\
& + \frac{64}{3} g_3^2 g_p^2 M_3 Q_u^2 \mathbf{1} M_U^* - \frac{4}{5} g_1^2 m_{H_u}^2 Y_u Y_u^\dagger + 12 g_2^2 m_{H_u}^2 Y_u Y_u^\dagger \\
& + 8 g_p^2 m_{H_u}^2 Q_{H_u}^2 Y_u Y_u^\dagger + 8 g_p^2 m_{H_u}^2 Q_q^2 Y_u Y_u^\dagger - 8 g_p^2 m_{H_u}^2 Q_u^2 Y_u Y_u^\dagger \\
& + 16 g_p^2 Q_{H_u}^2 |M_U|^2 Y_u Y_u^\dagger + 16 g_p^2 Q_q^2 |M_U|^2 Y_u Y_u^\dagger - 16 g_p^2 Q_u^2 |M_U|^2 Y_u Y_u^\dagger \\
& + 24 g_2^2 |M_2|^2 Y_u Y_u^\dagger - 4 m_{H_d}^2 |\lambda|^2 Y_u Y_u^\dagger - 8 m_{H_u}^2 |\lambda|^2 Y_u Y_u^\dagger \\
& - 4 m_S^2 |\lambda|^2 Y_u Y_u^\dagger - 4 |T_\lambda|^2 Y_u Y_u^\dagger + \frac{4}{5} g_1^2 M_1 Y_u T_u^\dagger - 12 g_2^2 M_2 Y_u T_u^\dagger \\
& - 8 g_p^2 M_U Q_{H_u}^2 Y_u T_u^\dagger - 8 g_p^2 M_U Q_q^2 Y_u T_u^\dagger + 8 g_p^2 M_U Q_u^2 Y_u T_u^\dagger \\
& - 8 g_p^2 Q_{H_u}^2 M_U^* T_u Y_u^\dagger - 8 g_p^2 Q_q^2 M_U^* T_u Y_u^\dagger + 8 g_p^2 Q_u^2 M_U^* T_u Y_u^\dagger \\
& - 12 g_2^2 M_2^* T_u Y_u^\dagger - 4 \lambda T_\lambda^* T_u Y_u^\dagger \\
& + \frac{4}{225} g_1^2 M_1^* \left(4 \left(5 \left(16 g_3^2 (2M_1 + M_3) - 3 g_p^2 (2M_1 + M_U) \right) \left(-22 Q_u - 3 Q_{H_d} + 3 Q_{H_u} + 9 Q_d + 9 Q_e - 9 Q_l + 9 Q_q \right) Q_u \right) + 642 g_1^2 M \right. \\
& \left. + 45 \left(-2 M_1 Y_u Y_u^\dagger + T_u Y_u^\dagger \right) \right) \\
& - \frac{4}{5} g_1^2 T_u T_u^\dagger + 12 g_2^2 T_u T_u^\dagger + 8 g_p^2 Q_{H_u}^2 T_u T_u^\dagger + 8 g_p^2 Q_q^2 T_u T_u^\dagger \\
& - 8 g_p^2 Q_u^2 T_u T_u^\dagger - 4 |\lambda|^2 T_u T_u^\dagger - \frac{2}{5} g_1^2 m_u^2 Y_u Y_u^\dagger + 6 g_2^2 m_u^2 Y_u Y_u^\dagger \\
& + 4 g_p^2 Q_{H_u}^2 m_u^2 Y_u Y_u^\dagger + 4 g_p^2 Q_q^2 m_u^2 Y_u Y_u^\dagger - 4 g_p^2 Q_u^2 m_u^2 Y_u Y_u^\dagger \\
& - 2 |\lambda|^2 m_u^2 Y_u Y_u^\dagger - \frac{4}{5} g_1^2 Y_u m_q^2 Y_u^\dagger + 12 g_2^2 Y_u m_q^2 Y_u^\dagger + 8 g_p^2 Q_{H_u}^2 Y_u m_q^2 Y_u^\dagger \\
& + 8 g_p^2 Q_q^2 Y_u m_q^2 Y_u^\dagger - 8 g_p^2 Q_u^2 Y_u m_q^2 Y_u^\dagger - 4 |\lambda|^2 Y_u m_q^2 Y_u^\dagger \\
& - \frac{2}{5} g_1^2 Y_u Y_u^\dagger m_u^2 + 6 g_2^2 Y_u Y_u^\dagger m_u^2 + 4 g_p^2 Q_{H_u}^2 Y_u Y_u^\dagger m_u^2 \\
& + 4 g_p^2 Q_q^2 Y_u Y_u^\dagger m_u^2 - 4 g_p^2 Q_u^2 Y_u Y_u^\dagger m_u^2 - 2 |\lambda|^2 Y_u Y_u^\dagger m_u^2 \\
& - 4 m_{H_d}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger - 4 m_{H_u}^2 Y_u Y_d^\dagger Y_d Y_u^\dagger - 4 Y_u Y_d^\dagger T_d T_u^\dagger \\
& - 8 m_{H_u}^2 Y_u Y_u^\dagger Y_u Y_u^\dagger - 4 Y_u Y_u^\dagger T_u T_u^\dagger - 4 Y_u T_d^\dagger T_d Y_u^\dagger - 4 Y_u T_u^\dagger T_u Y_u^\dagger \\
& - 4 T_u Y_d^\dagger Y_d T_u^\dagger - 4 T_u Y_u^\dagger Y_u T_u^\dagger - 4 T_u T_d^\dagger Y_d Y_u^\dagger - 4 T_u T_u^\dagger Y_u Y_u^\dagger \\
& - 2 m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger - 2 m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger - 4 Y_u m_q^2 Y_d^\dagger Y_d Y_u^\dagger - 4 Y_u m_q^2 Y_u^\dagger Y_u Y_u^\dagger
\end{aligned}$$

$$\begin{aligned}
& -4Y_u Y_d^\dagger m_d^2 Y_d Y_u^\dagger - 4Y_u Y_d^\dagger Y_d m_q^2 Y_u^\dagger - 2Y_u Y_d^\dagger Y_d Y_u^\dagger m_u^2 \\
& -4Y_u Y_u^\dagger m_u^2 Y_u Y_u^\dagger - 4Y_u Y_u^\dagger Y_u m_q^2 Y_u^\dagger - 2Y_u Y_u^\dagger Y_u Y_u^\dagger m_u^2 - 4\lambda^* Y_u T_u^\dagger T_\lambda + \frac{32}{3} g_3^4 \mathbf{1}_{\sigma_{2,3}} \\
& + \frac{32}{15} g_1^2 \mathbf{1}_{\sigma_{2,11}} - 16 \frac{1}{\sqrt{15}} g_1 g_p Q_u \mathbf{1}_{\sigma_{2,14}} - 16 \frac{1}{\sqrt{15}} g_1 g_p Q_u \mathbf{1}_{\sigma_{2,41}} + 8g_p^2 Q_u^2 \mathbf{1}_{\sigma_{2,44}} \\
& - 16 \frac{1}{\sqrt{15}} g_1 \mathbf{1}_{\sigma_{3,1}} + 8g_p Q_u \mathbf{1}_{\sigma_{3,4}} - 24m_{H_u}^2 Y_u Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) - 12T_u T_u^\dagger \text{Tr}(Y_u Y_u^\dagger) \\
& - 6m_u^2 Y_u Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) - 12Y_u m_q^2 Y_u^\dagger \text{Tr}(Y_u Y_u^\dagger) - 6Y_u Y_u^\dagger m_u^2 \text{Tr}(Y_u Y_u^\dagger) \\
& - 12Y_u T_u^\dagger \text{Tr}(Y_u^\dagger T_u) - 12T_u Y_u^\dagger \text{Tr}(T_u^* Y_u^T) - 12Y_u Y_u^\dagger \text{Tr}(T_u^* T_u^T) \\
& - 12Y_u Y_u^\dagger \text{Tr}(m_q^2 Y_u^\dagger Y_u) - 12Y_u Y_u^\dagger \text{Tr}(m_u^2 Y_u Y_u^\dagger)
\end{aligned} \tag{86}$$

$$\begin{aligned}
\beta_{m_e^2}^{(1)} = & -\frac{24}{5} g_1^2 \mathbf{1} |M_1|^2 - 8g_p^2 Q_e^2 \mathbf{1} |M_U|^2 + 4m_{H_d}^2 Y_e Y_e^\dagger + 4T_e T_e^\dagger + 2m_e^2 Y_e Y_e^\dagger \\
& + 4Y_e m_l^2 Y_e^\dagger + 2Y_e Y_e^\dagger m_e^2 + 2\sqrt{\frac{3}{5}} g_1 \mathbf{1}_{\sigma_{1,1}} + 2g_p Q_e \mathbf{1}_{\sigma_{1,4}}
\end{aligned} \tag{87}$$

$$\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_l^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_U Q_e^2 Y_e T_e^\dagger \\
& - 8g_p^2 M_U Q_{H_d}^2 Y_e T_e^\dagger - 8g_p^2 M_U Q_l^2 Y_e T_e^\dagger \\
& + \frac{8}{5} g_p^2 M_U^* \left(3Q_e \left(g_1^2 (2M_U + M_1) \right) (3Q_d - 3Q_l + 3Q_q + 5Q_e - 6Q_u - Q_{H_d} + Q_{H_u}) \right. \\
& + 5g_p^2 M_U Q_e \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 5Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) \mathbf{1} \\
& \left. - 5 \left(-Q_{H_d}^2 - Q_l^2 + Q_e^2 \right) (2M_U 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(117g_1^2 M_1 + 5g_p^2 (2M_1 + M_U) \right) Q_e \left(3Q_d - 3Q_l + 3Q_q + 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_l^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_l^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_l^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}$$

$$\begin{aligned}
& + 4g_p^2 Q_{H_d}^2 Y_e Y_e^\dagger m_e^2 + 4g_p^2 Q_l^2 Y_e Y_e^\dagger m_e^2 - 2|\lambda|^2 Y_e Y_e^\dagger m_e^2 \\
& - 8m_{H_d}^2 Y_e Y_e^\dagger Y_e Y_e^\dagger - 4Y_e Y_e^\dagger T_e T_e^\dagger - 4Y_e T_e^\dagger T_e Y_e^\dagger - 4T_e Y_e^\dagger Y_e T_e^\dagger \\
& - 4T_e T_e^\dagger Y_e Y_e^\dagger - 2m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger - 4Y_e m_l^2 Y_e^\dagger Y_e Y_e^\dagger - 4Y_e Y_e^\dagger m_e^2 Y_e Y_e^\dagger \\
& - 4Y_e Y_e^\dagger Y_e m_l^2 Y_e^\dagger - 2Y_e Y_e^\dagger Y_e Y_e^\dagger m_e^2 - 4\lambda^* Y_e T_e^\dagger T_\lambda + \frac{24}{5} g_1^2 \mathbf{1}_{\sigma_{2,11}} + 8\sqrt{\frac{3}{5}} g_1 g_p Q_e \mathbf{1}_{\sigma_{2,14}} \\
& + 8\sqrt{\frac{3}{5}} g_1 g_p Q_e \mathbf{1}_{\sigma_{2,41}} + 8g_p^2 Q_e^2 \mathbf{1}_{\sigma_{2,44}} + 8\sqrt{\frac{3}{5}} g_1 \mathbf{1}_{\sigma_{3,1}} + 8g_p Q_e \mathbf{1}_{\sigma_{3,4}} - 24m_{H_d}^2 Y_e Y_e^\dagger \text{Tr}(Y_d Y_d^\dagger) \\
& - 12T_e T_e^\dagger \text{Tr}(Y_d Y_d^\dagger) - 6m_e^2 Y_e Y_e^\dagger \text{Tr}(Y_d Y_d^\dagger) - 12Y_e m_l^2 Y_e^\dagger \text{Tr}(Y_d Y_d^\dagger) \\
& - 6Y_e Y_e^\dagger m_e^2 \text{Tr}(Y_d Y_d^\dagger) - 8m_{H_d}^2 Y_e Y_e^\dagger \text{Tr}(Y_e Y_e^\dagger) - 4T_e T_e^\dagger \text{Tr}(Y_e Y_e^\dagger) \\
& - 2m_e^2 Y_e Y_e^\dagger \text{Tr}(Y_e Y_e^\dagger) - 4Y_e m_l^2 Y_e^\dagger \text{Tr}(Y_e Y_e^\dagger) - 2Y_e Y_e^\dagger m_e^2 \text{Tr}(Y_e Y_e^\dagger) \\
& - 12Y_e T_e^\dagger \text{Tr}(Y_d^\dagger T_d) - 4Y_e T_e^\dagger \text{Tr}(Y_e^\dagger T_e) - 12T_e Y_e^\dagger \text{Tr}(T_d^* Y_d^T) \\
& - 12Y_e Y_e^\dagger \text{Tr}(T_d^* T_d^T) - 4T_e Y_e^\dagger \text{Tr}(T_e^* Y_e^T) - 4Y_e Y_e^\dagger \text{Tr}(T_e^* T_e^T) \\
& - 12Y_e Y_e^\dagger \text{Tr}(m_d^2 Y_d Y_d^\dagger) - 4Y_e Y_e^\dagger \text{Tr}(m_e^2 Y_e Y_e^\dagger) - 4Y_e Y_e^\dagger \text{Tr}(m_l^2 Y_e^\dagger Y_e) \\
& - 12Y_e Y_e^\dagger \text{Tr}(m_q^2 Y_d^\dagger Y_d) \tag{88}
\end{aligned}$$

$$\beta_{m_S^2}^{(1)} = 2g_p Q_s \sigma_{1,4} + 4(m_{H_d}^2 + m_{H_u}^2 + m_S^2)|\lambda|^2 + 4|T_\lambda|^2 - 8g_p^2 Q_s^2 |M_U|^2 \tag{89}$$

$$\begin{aligned}
\beta_{m_S^2}^{(2)} = & + \frac{12}{5} g_1^2 |T_\lambda|^2 + 12g_2^2 |T_\lambda|^2 + 8g_p^2 Q_{H_d}^2 |T_\lambda|^2 + 8g_p^2 Q_{H_u}^2 |T_\lambda|^2 - 8g_p^2 Q_s^2 |T_\lambda|^2 \\
& - 16(m_{H_d}^2 + m_{H_u}^2 + m_S^2)\lambda^2 \lambda^{*,2} - \frac{12}{5} g_1^2 M_1 \lambda T_\lambda^* - 12g_2^2 M_2 \lambda T_\lambda^* - 8g_p^2 M_U Q_{H_d}^2 \lambda T_\lambda^* \\
& - 8g_p^2 M_U Q_{H_u}^2 \lambda T_\lambda^* + 8g_p^2 M_U Q_s^2 \lambda T_\lambda^* \\
& + 8g_p^2 M_U^* \left(3g_p^2 M_U Q_s^2 (18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_s^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_1^2 + Q_2^2 + Q_3^2) \right. \\
& \left. + (-Q_s^2 + Q_{H_d}^2 + Q_{H_u}^2)\lambda^* (2M_U \lambda - T_\lambda) \right) \\
& + 8g_p^2 Q_s^2 \sigma_{2,44} + 8g_p Q_s \sigma_{3,4} - 12|T_\lambda|^2 \text{Tr}(Y_d Y_d^\dagger) - 4|T_\lambda|^2 \text{Tr}(Y_e Y_e^\dagger) - 12|T_\lambda|^2 \text{Tr}(Y_u Y_u^\dagger) \\
& - 12\lambda T_\lambda^* \text{Tr}(Y_d^\dagger T_d) - 4\lambda T_\lambda^* \text{Tr}(Y_e^\dagger T_e) - 12\lambda T_\lambda^* \text{Tr}(Y_u^\dagger T_u) \\
& + \frac{4}{5} \lambda^* \left(3g_1^2 m_{H_d}^2 \lambda + 15g_2^2 m_{H_d}^2 \lambda + 3g_1^2 m_{H_u}^2 \lambda + 15g_2^2 m_{H_u}^2 \lambda + 3g_1^2 m_S^2 \lambda + 15g_2^2 m_S^2 \lambda \right. \\
& + 10g_p^2 m_{H_d}^2 Q_{H_d}^2 \lambda + 10g_p^2 m_{H_u}^2 Q_{H_d}^2 \lambda + 10g_p^2 m_S^2 Q_{H_d}^2 \lambda + 10g_p^2 m_{H_d}^2 Q_{H_u}^2 \lambda \\
& + 10g_p^2 m_{H_u}^2 Q_{H_u}^2 \lambda + 10g_p^2 m_S^2 Q_{H_u}^2 \lambda - 10g_p^2 m_{H_d}^2 Q_s^2 \lambda - 10g_p^2 m_{H_u}^2 Q_s^2 \lambda \\
& - 10g_p^2 m_S^2 Q_s^2 \lambda - 40\lambda |T_\lambda|^2 + 3g_1^2 M_1^* (2M_1 \lambda - T_\lambda) + 15g_2^2 M_2^* (2M_2 \lambda - T_\lambda) \\
& \left. - 30m_{H_d}^2 \lambda \text{Tr}(Y_d Y_d^\dagger) - 15m_{H_u}^2 \lambda \text{Tr}(Y_d Y_d^\dagger) - 15m_S^2 \lambda \text{Tr}(Y_d Y_d^\dagger) - 10m_{H_d}^2 \lambda \text{Tr}(Y_e Y_e^\dagger) \right)
\end{aligned}$$

$$\begin{aligned}
& -5m_{H_u}^2 \lambda \text{Tr}(Y_e Y_e^\dagger) - 5m_S^2 \lambda \text{Tr}(Y_e Y_e^\dagger) - 15m_{H_d}^2 \lambda \text{Tr}(Y_u Y_u^\dagger) - 30m_{H_u}^2 \lambda \text{Tr}(Y_u Y_u^\dagger) \\
& -15m_S^2 \lambda \text{Tr}(Y_u Y_u^\dagger) - 15T_\lambda \text{Tr}(T_d^* Y_d^T) - 15\lambda \text{Tr}(T_d^* T_d^T) - 5T_\lambda \text{Tr}(T_e^* Y_e^T) - 5\lambda \text{Tr}(T_e^* T_e^T) \\
& -15T_\lambda \text{Tr}(T_u^* Y_u^T) - 15\lambda \text{Tr}(T_u^* T_u^T) - 15\lambda \text{Tr}(m_d^2 Y_d Y_d^\dagger) - 5\lambda \text{Tr}(m_e^2 Y_e Y_e^\dagger) \\
& -5\lambda \text{Tr}(m_l^2 Y_e^\dagger Y_e) - 15\lambda \text{Tr}(m_q^2 Y_d^\dagger Y_d) - 15\lambda \text{Tr}(m_q^2 Y_u^\dagger Y_u) - 15\lambda \text{Tr}(m_u^2 Y_u Y_u^\dagger)
\end{aligned} \tag{90}$$

$$\beta_{m_{s_1}}^{(1)} = \frac{2}{9} \left(-36g_p^2 Q_1^2 |M_U|^2 + 9g_p Q_1 \sigma_{1,4} + (m_{s_1}^2 + m_{s_2}^2 + m_{s_3}^2) |\kappa|^2 + |T_\kappa|^2 \right) \tag{91}$$

$$\begin{aligned}
\beta_{m_{s_1}}^{(2)} &= \frac{4}{81} \left(-2(m_{s_1}^2 + m_{s_2}^2 + m_{s_3}^2) \kappa^2 \kappa^{*,2} \right. \\
&+ 9g_p^2 M_U^* \left(54g_p^2 M_U Q_1^2 (18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_1^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_2^2 + Q_3^2) \right. \\
&- \left. \left(-Q_2^2 - Q_3^2 + Q_1^2 \right) \kappa^* (2M_U \kappa - T_\kappa) \right) \\
&+ |\kappa|^2 \left(-4T_\kappa^* T_\kappa - 9g_p^2 (m_{s_1}^2 + m_{s_2}^2 + m_{s_3}^2) (-Q_2^2 - Q_3^2 + Q_1^2) \right) \\
&+ 9g_p \left(18Q_1 (g_p Q_1 \sigma_{2,44} + \sigma_{3,4}) + g_p (-Q_2^2 - Q_3^2 + Q_1^2) T_\kappa^* (M_U \kappa - T_\kappa) \right) \Big)
\end{aligned} \tag{92}$$

$$\beta_{m_{s_2}}^{(1)} = \frac{2}{9} \left(-36g_p^2 Q_2^2 |M_U|^2 + 9g_p Q_2 \sigma_{1,4} + (m_{s_1}^2 + m_{s_2}^2 + m_{s_3}^2) |\kappa|^2 + |T_\kappa|^2 \right) \tag{93}$$

$$\begin{aligned}
\beta_{m_{s_2}}^{(2)} &= \frac{4}{81} \left(-2(m_{s_1}^2 + m_{s_2}^2 + m_{s_3}^2) \kappa^2 \kappa^{*,2} \right. \\
&+ 9g_p^2 M_U^* \left(54g_p^2 M_U Q_2^2 (18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_2^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_3^2) \right. \\
&+ \left. \left(-Q_2^2 + Q_1^2 + Q_3^2 \right) \kappa^* (2M_U \kappa - T_\kappa) \right) \\
&+ |\kappa|^2 \left(-4T_\kappa^* T_\kappa + 9g_p^2 (m_{s_1}^2 + m_{s_2}^2 + m_{s_3}^2) (-Q_2^2 + Q_1^2 + Q_3^2) \right) \\
&+ 9g_p \left(18Q_2 (g_p Q_2 \sigma_{2,44} + \sigma_{3,4}) - g_p (-Q_2^2 + Q_1^2 + Q_3^2) T_\kappa^* (M_U \kappa - T_\kappa) \right) \Big)
\end{aligned} \tag{94}$$

$$\beta_{m_{s_3}}^{(1)} = \frac{2}{9} \left(-36g_p^2 Q_3^2 |M_U|^2 + 9g_p Q_3 \sigma_{1,4} + (m_{s_1}^2 + m_{s_2}^2 + m_{s_3}^2) |\kappa|^2 + |T_\kappa|^2 \right) \tag{95}$$

$$\begin{aligned}
\beta_{m_{s_3}}^{(2)} &= \frac{4}{81} \left(-2(m_{s_1}^2 + m_{s_2}^2 + m_{s_3}^2) \kappa^2 \kappa^{*,2} \right. \\
&+ 9g_p^2 M_U^* \left(54g_p^2 M_U Q_3^2 (18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_3^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 + Q_1^2 + Q_2^2) \right. \\
&+ \left. \left(-Q_3^2 + Q_1^2 + Q_2^2 \right) \kappa^* (2M_U \kappa - T_\kappa) \right) \\
&+ |\kappa|^2 \left(-4T_\kappa^* T_\kappa + 9g_p^2 (m_{s_1}^2 + m_{s_2}^2 + m_{s_3}^2) (-Q_3^2 + Q_1^2 + Q_2^2) \right) \\
&+ 9g_p \left(18Q_3 (g_p Q_3 \sigma_{2,44} + \sigma_{3,4}) - g_p (-Q_3^2 + Q_1^2 + Q_2^2) T_\kappa^* (M_U \kappa - T_\kappa) \right) \Big)
\end{aligned} \tag{96}$$

3.7 Vacuum expectation values

$$\beta_{v_d}^{(1)} = \frac{1}{20} v_d \left(15g_2^2 + 15g_2^2 \text{Xi} + 20g_p^2 Q_{H_d}^2 + 20g_p^2 Q_{H_d}^2 \text{Xi} - 20|\lambda|^2 - 20\text{Tr}(Y_e Y_e^\dagger) + 3g_1^2 + 3g_1^2 \text{Xi} - 60\text{Tr}(Y_d Y_d^\dagger) \right) \quad (97)$$

$$\begin{aligned} \beta_{v_d}^{(2)} = \frac{1}{400} v_d \bigg(& -414g_1^4 - 180g_1^2 g_2^2 - 1200g_2^4 + 720g_1^2 g_p^2 Q_d Q_{H_d} + 720g_1^2 g_p^2 Q_e Q_{H_d} - 480g_1^2 g_p^2 Q_{H_d}^2 \\ & - 1200g_2^2 g_p^2 Q_{H_d}^2 - 3600g_p^4 Q_d^2 Q_{H_d}^2 - 1200g_p^4 Q_e^2 Q_{H_d}^2 - 1600g_p^4 Q_{H_d}^4 + 240g_1^2 g_p^2 Q_{H_d} Q_{H_u} \\ & - 800g_p^4 Q_{H_d}^2 Q_{H_u}^2 - 720g_1^2 g_p^2 Q_{H_d} Q_l - 2400g_p^4 Q_{H_d}^2 Q_l^2 + 720g_1^2 g_p^2 Q_{H_d} Q_q \\ & - 7200g_p^4 Q_{H_d}^2 Q_q^2 - 400g_p^4 Q_{H_d}^2 Q_s^2 - 400g_p^4 Q_{H_d}^2 Q_1^2 - 400g_p^4 Q_{H_d}^2 Q_2^2 \\ & - 400g_p^4 Q_{H_d}^2 Q_3^2 - 1440g_1^2 g_p^2 Q_{H_d} Q_u - 3600g_p^4 Q_{H_d}^2 Q_u^2 - 9g_1^4 \text{Xi} - 90g_1^2 g_2^2 \text{Xi} + 875g_2^4 \text{Xi} \\ & - 120g_1^2 g_p^2 Q_{H_d}^2 \text{Xi} - 600g_2^2 g_p^2 Q_{H_d}^2 \text{Xi} - 400g_p^4 Q_{H_d}^4 \text{Xi} + 9g_1^4 \text{Xi}^2 + 90g_1^2 g_2^2 \text{Xi}^2 - 225g_2^4 \text{Xi}^2 \\ & + 120g_1^2 g_p^2 Q_{H_d}^2 \text{Xi}^2 + 600g_2^2 g_p^2 Q_{H_d}^2 \text{Xi}^2 + 400g_p^4 Q_{H_d}^4 \text{Xi}^2 + 1200\lambda^2 \lambda^{*,2} \\ & - 40 \left(5 \left(32g_3^2 + 3 \left(3g_2^2 \text{Xi} + 4g_p^2 \left(Q_{H_d}^2 \left(-1 + \text{Xi} \right) + Q_d^2 + Q_q^2 \right) \right) \right) + g_1^2 \left(9\text{Xi} - 4 \right) \right) \text{Tr}(Y_d Y_d^\dagger) - 480g_1^2 \text{Tr}(Y_e Y_e^\dagger) \\ & - 800g_p^2 Q_e^2 \text{Tr}(Y_e Y_e^\dagger) + 800g_p^2 Q_{H_d}^2 \text{Tr}(Y_e Y_e^\dagger) - 800g_p^2 Q_l^2 \text{Tr}(Y_e Y_e^\dagger) \\ & - 120g_1^2 \text{Xi} \text{Tr}(Y_e Y_e^\dagger) - 600g_2^2 \text{Xi} \text{Tr}(Y_e Y_e^\dagger) - 800g_p^2 Q_{H_d}^2 \text{Xi} \text{Tr}(Y_e Y_e^\dagger) \\ & - 40|\lambda|^2 \left(20g_p^2 \left(Q_{H_d}^2 \left(-1 + \text{Xi} \right) + Q_{H_u}^2 + Q_s^2 \right) - 30\text{Tr}(Y_u Y_u^\dagger) + 3 \left(5g_2^2 + g_1^2 \right) \text{Xi} \right) + 3600\text{Tr}(Y_d Y_d^\dagger Y_d Y_d^\dagger) \\ & + 1200\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) + 1200\text{Tr}(Y_e Y_e^\dagger Y_e Y_e^\dagger) \bigg) \quad (98) \end{aligned}$$

$$\beta_{v_u}^{(1)} = \frac{1}{20} v_u \left(\left(15g_2^2 + 20g_p^2 Q_{H_u}^2 + 3g_1^2 \right) \left(1 + \text{Xi} \right) - 20|\lambda|^2 - 60\text{Tr}(Y_u Y_u^\dagger) \right) \quad (99)$$

$$\begin{aligned} \beta_{v_u}^{(2)} = \frac{1}{400} v_u \bigg(& -414g_1^4 - 180g_1^2 g_2^2 - 1200g_2^4 - 720g_1^2 g_p^2 Q_d Q_{H_u} - 720g_1^2 g_p^2 Q_e Q_{H_u} + 240g_1^2 g_p^2 Q_{H_d} Q_{H_u} \\ & - 480g_1^2 g_p^2 Q_{H_u}^2 - 1200g_2^2 g_p^2 Q_{H_u}^2 - 3600g_p^4 Q_d^2 Q_{H_u}^2 - 1200g_p^4 Q_e^2 Q_{H_u}^2 \\ & - 800g_p^4 Q_{H_d}^2 Q_{H_u}^2 - 1600g_p^4 Q_{H_u}^4 + 720g_1^2 g_p^2 Q_{H_u} Q_l - 2400g_p^4 Q_{H_u}^2 Q_l^2 - 720g_1^2 g_p^2 Q_{H_u} Q_q \\ & - 7200g_p^4 Q_{H_u}^2 Q_q^2 - 400g_p^4 Q_{H_u}^2 Q_s^2 - 400g_p^4 Q_{H_u}^2 Q_1^2 - 400g_p^4 Q_{H_u}^2 Q_2^2 \\ & - 400g_p^4 Q_{H_u}^2 Q_3^2 + 1440g_1^2 g_p^2 Q_{H_u} Q_u - 3600g_p^4 Q_{H_u}^2 Q_u^2 - 9g_1^4 \text{Xi} - 90g_1^2 g_2^2 \text{Xi} + 875g_2^4 \text{Xi} \\ & - 120g_1^2 g_p^2 Q_{H_u}^2 \text{Xi} - 600g_2^2 g_p^2 Q_{H_u}^2 \text{Xi} - 400g_p^4 Q_{H_u}^4 \text{Xi} + 9g_1^4 \text{Xi}^2 + 90g_1^2 g_2^2 \text{Xi}^2 - 225g_2^4 \text{Xi}^2 \\ & + 120g_1^2 g_p^2 Q_{H_u}^2 \text{Xi}^2 + 600g_2^2 g_p^2 Q_{H_u}^2 \text{Xi}^2 + 400g_p^4 Q_{H_u}^4 \text{Xi}^2 + 1200\lambda^2 \lambda^{*,2} \\ & - 40|\lambda|^2 \left(20g_p^2 Q_{H_d}^2 - 20g_p^2 Q_{H_u}^2 + 20g_p^2 Q_s^2 + 3g_1^2 \text{Xi} + 15g_2^2 \text{Xi} + 20g_p^2 Q_{H_u}^2 \text{Xi} - 30\text{Tr}(Y_d Y_d^\dagger) \right. \\ & \left. - 10\text{Tr}(Y_e Y_e^\dagger) \right) \\ & - 40 \left(5 \left(32g_3^2 + 3 \left(3g_2^2 \text{Xi} + 4g_p^2 \left(Q_{H_u}^2 \left(-1 + \text{Xi} \right) + Q_q^2 + Q_u^2 \right) \right) \right) + g_1^2 \left(9\text{Xi} + 8 \right) \right) \text{Tr}(Y_u Y_u^\dagger) + 1200\text{Tr}(Y_d Y_u^\dagger Y_u Y_d^\dagger) \\ & + 3600\text{Tr}(Y_u Y_u^\dagger Y_u Y_u^\dagger) \bigg) \quad (100) \end{aligned}$$

$$\beta_{v_s}^{(1)} = v_s \left(-2|\lambda|^2 + g_p^2 Q_s^2 \left(1 + \text{Xi} \right) \right) \quad (101)$$

$$\begin{aligned}
\beta_{v_s}^{(2)} = & -\frac{1}{5}v_s \left(5g_p^4 Q_s^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_e^2 + 3Q_s^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_s^2 \text{Xi} - Q_s^2 \text{Xi}^2 + Q_1^2 + Q_2^2 + Q_3^2 \right) \right. \\
& - 20\lambda^2 \lambda^{*,2} \\
& + 2|\lambda|^2 \left(3g_1^2 + 15g_2^2 + 10g_p^2 Q_{H_d}^2 + 10g_p^2 Q_{H_u}^2 - 10g_p^2 Q_s^2 + 10g_p^2 Q_s^2 \text{Xi} - 15\text{Tr}(Y_d Y_d^\dagger) - 5\text{Tr}(Y_e Y_e^\dagger) \right. \\
& \left. \left. - 15\text{Tr}(Y_u Y_u^\dagger) \right) \right) \quad (102)
\end{aligned}$$

$$\beta_{v_1}^{(1)} = -\frac{1}{9}v_1 |\kappa|^2 + g_p^2 Q_1^2 v_1 (1 + \text{Xi}) \quad (103)$$

$$\begin{aligned}
\beta_{v_1}^{(2)} = & -\frac{1}{81}v_1 \left(81g_p^4 Q_1^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_1^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_1^2 \text{Xi} - Q_1^2 \text{Xi}^2 + Q_s^2 + Q_2^2 + Q_3^2 \right) \right. \\
& + 18g_p^2 \left(Q_1^2 (-1 + \text{Xi}) + Q_2^2 + Q_3^2 \right) |\kappa|^2 - 2\kappa^2 \kappa^{*,2} \Big) \quad (104)
\end{aligned}$$

$$\beta_{v_2}^{(1)} = -\frac{1}{9}v_2 |\kappa|^2 + g_p^2 Q_2^2 v_2 (1 + \text{Xi}) \quad (105)$$

$$\begin{aligned}
\beta_{v_2}^{(2)} = & -\frac{1}{81}v_2 \left(81g_p^4 Q_2^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_2^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_2^2 \text{Xi} - Q_2^2 \text{Xi}^2 + Q_s^2 + Q_1^2 + Q_3^2 \right) \right. \\
& + 18g_p^2 \left(Q_2^2 (-1 + \text{Xi}) + Q_1^2 + Q_3^2 \right) |\kappa|^2 - 2\kappa^2 \kappa^{*,2} \Big) \quad (106)
\end{aligned}$$

$$\beta_{v_3}^{(1)} = -\frac{1}{9}v_3 |\kappa|^2 + g_p^2 Q_3^2 v_3 (1 + \text{Xi}) \quad (107)$$

$$\begin{aligned}
\beta_{v_3}^{(2)} = & -\frac{1}{81}v_3 \left(81g_p^4 Q_3^2 \left(18Q_q^2 + 2Q_{H_d}^2 + 2Q_{H_u}^2 + 3Q_3^2 + 3Q_e^2 + 6Q_l^2 + 9Q_d^2 + 9Q_u^2 + Q_3^2 \text{Xi} - Q_3^2 \text{Xi}^2 + Q_s^2 + Q_1^2 + Q_2^2 \right) \right. \\
& + 18g_p^2 \left(Q_3^2 (-1 + \text{Xi}) + Q_1^2 + Q_2^2 \right) |\kappa|^2 - 2\kappa^2 \kappa^{*,2} \Big) \quad (108)
\end{aligned}$$

4 Field Rotations

4.1 Rotations in gauge sector for eigenstates 'EWSB'

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \\ U_\rho \end{pmatrix} = Z^{\gamma Z Z'} \begin{pmatrix} \gamma_\rho \\ Z_\rho \\ Z'_\rho \end{pmatrix} \quad (109)$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho} \end{pmatrix} = Z^W \begin{pmatrix} W_\rho^- \\ W_\rho^- \end{pmatrix} \quad (110)$$

$$\begin{pmatrix} \lambda_{\tilde{W},1} \\ \lambda_{\tilde{W},2} \\ \lambda_{\tilde{W},3} \end{pmatrix} = Z^{\tilde{W}} \begin{pmatrix} \tilde{W}^- \\ \tilde{W}^+ \\ \tilde{W}^0 \end{pmatrix} \quad (111)$$

$$(112)$$

The mixing matrices are parametrized by

$$Z^{\gamma ZZ'} = \begin{pmatrix} \cos \Theta_W & -\cos \Theta'_W \sin \Theta_W & \sin \Theta_W \sin \Theta'_W \\ \sin \Theta_W & \cos \Theta_W \cos \Theta'_W & -\cos \Theta_W \sin \Theta'_W \\ 0 & \sin \Theta'_W & \cos \Theta'_W \end{pmatrix} \quad (113)$$

$$Z^W = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} \end{pmatrix} \quad (114)$$

$$Z^{\tilde{W}} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (115)$$

$$(116)$$

4.2 Rotations in Mass sector for eigenstates 'EWSB'

4.2.1 Mass Matrices for Scalars

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

$$m_d^2 = \begin{pmatrix} m_{\tilde{d}_L \tilde{d}_L^*} & \frac{1}{2}(\sqrt{2}v_d T_d^\dagger - v_s v_u \lambda Y_d^\dagger)\delta_{\alpha_1 \beta_2} \\ \frac{1}{2}\delta_{\alpha_2 \beta_1}(\sqrt{2}v_d T_d - v_s v_u Y_d \lambda^*) & m_{\tilde{d}_R \tilde{d}_R^*} \end{pmatrix} \quad (117)$$

$$\begin{aligned} m_{\tilde{d}_L \tilde{d}_L^*} = & \frac{1}{24} \mathbf{1} \left(g_1^2 (-v_d^2 + v_u^2) \right. \\ & + 3 \left(4g_p^2 Q_q (Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + g_2^2 (-v_d^2 + v_u^2) \right) \Big) \delta_{\alpha_1 \beta_1} \\ & + \frac{1}{2} \delta_{\alpha_1 \beta_1} (2m_q^2 + v_d^2 Y_d^\dagger Y_d) \end{aligned} \quad (118)$$

$$\begin{aligned} m_{\tilde{d}_R \tilde{d}_R^*} = & \frac{1}{12} \mathbf{1} \left(6g_p^2 Q_d (Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + g_1^2 (-v_d^2 + v_u^2) \right) \delta_{\alpha_2 \beta_2} \\ & + \frac{1}{2} \delta_{\alpha_2 \beta_2} (2m_d^2 + v_d^2 Y_d Y_d^\dagger) \end{aligned} \quad (119)$$

This matrix is diagonalized by Z^D :

$$Z^D m_d^2 Z^{D,\dagger} = m_{2,\tilde{d}}^{dia} \quad (120)$$

with

$$\tilde{d}_{L,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha}, \quad \tilde{d}_{R,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha} \quad (121)$$

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

$$m_{\tilde{\nu}}^2 = \begin{pmatrix} m_{\tilde{\nu}_L \tilde{\nu}_L^*} \end{pmatrix} \quad (122)$$

$$m_{\tilde{\nu}_L \tilde{\nu}_L^*} = \frac{1}{8} \mathbf{1} \left(4g_p^2 Q_l \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + (g_1^2 + g_2^2) (-v_u^2 + v_d^2) \right) + m_l^2 \quad (123)$$

This matrix is diagonalized by Z^V :

$$Z^V m_{\tilde{\nu}}^2 Z^{V,\dagger} = m_{2,\tilde{\nu}}^{dia} \quad (124)$$

with

$$\tilde{\nu}_{L,i} = \sum_j Z_{ji}^{V,*} \tilde{\nu}_j \quad (125)$$

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

$$m_{\tilde{u}}^2 = \begin{pmatrix} m_{\tilde{u}_L \tilde{u}_L^*} & \frac{1}{2} (\sqrt{2} v_u T_u^\dagger - v_d v_s \lambda Y_u^\dagger) \delta_{\alpha_1 \beta_2} \\ \frac{1}{2} \delta_{\alpha_2 \beta_1} (\sqrt{2} v_u T_u - v_d v_s Y_u \lambda^*) & m_{\tilde{u}_R \tilde{u}_R^*} \end{pmatrix} \quad (126)$$

$$\begin{aligned} m_{\tilde{u}_L \tilde{u}_L^*} = & + \frac{1}{24} \mathbf{1} \left(g_1^2 (-v_d^2 + v_u^2) \right. \\ & + 3 \left(4g_p^2 Q_q \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + g_2^2 (-v_u^2 + v_d^2) \right) \left. \right) \delta_{\alpha_1 \beta_1} \\ & + \frac{1}{2} \delta_{\alpha_1 \beta_1} (2m_q^2 + v_u^2 Y_u^\dagger Y_u) \end{aligned} \quad (127)$$

$$\begin{aligned} m_{\tilde{u}_R \tilde{u}_R^*} = & + \frac{1}{6} \mathbf{1} \left(3g_p^2 Q_u \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + g_1^2 (-v_u^2 + v_d^2) \right) \delta_{\alpha_2 \beta_2} \\ & + \frac{1}{2} \delta_{\alpha_2 \beta_2} (2m_u^2 + v_u^2 Y_u Y_u^\dagger) \end{aligned} \quad (128)$$

This matrix is diagonalized by Z^U :

$$Z^U m_{\tilde{u}}^2 Z^{U,\dagger} = m_{2,\tilde{u}}^{dia} \quad (129)$$

with

$$\tilde{u}_{L,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha}, \quad \tilde{u}_{R,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha} \quad (130)$$

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

$$m_{\tilde{e}}^2 = \begin{pmatrix} m_{\tilde{e}_L \tilde{e}_L^*} & -\frac{1}{2} v_s v_u \lambda Y_e^\dagger + \frac{1}{\sqrt{2}} v_d T_e^\dagger \\ -\frac{1}{2} v_s v_u Y_e \lambda^* + \frac{1}{\sqrt{2}} v_d T_e & m_{\tilde{e}_R \tilde{e}_R^*} \end{pmatrix} \quad (131)$$

$$m_{\tilde{e}_L \tilde{e}_L^*} = +m_l^2$$

$$\begin{aligned}
& + \frac{1}{8} \mathbf{1} \left(g_1^2 \left(-v_u^2 + v_d^2 \right) + g_2^2 \left(-v_d^2 + v_u^2 \right) \right. \\
& + 4g_p^2 Q_l \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) \Big) \\
& + \frac{1}{2} v_d^2 Y_e^\dagger Y_e
\end{aligned} \tag{132}$$

$$\begin{aligned}
m_{\tilde{e}_R \tilde{e}_R^*} & = +m_e^2 + \frac{1}{4} \mathbf{1} \left(2g_p^2 Q_e \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + g_1^2 \left(-v_d^2 + v_u^2 \right) \right) \\
& + \frac{1}{2} v_d^2 Y_e Y_e^\dagger
\end{aligned} \tag{133}$$

This matrix is diagonalized by Z^E :

$$Z^E m_{\tilde{e}}^2 Z^{E,\dagger} = m_{2,\tilde{e}}^{dia} \tag{134}$$

with

$$\tilde{e}_{L,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j, \quad \tilde{e}_{R,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j \tag{135}$$

- **Mass matrix for Higgs, Basis:** $(\phi_d, \phi_u, \phi_s, \phi_1, \phi_2, \phi_3), (\phi_d, \phi_u, \phi_s, \phi_1, \phi_2, \phi_3)$

$$m_h^2 = \begin{pmatrix} m_{\phi_d \phi_d} & m_{\phi_u \phi_d} & m_{\phi_s \phi_d} & m_{\phi_1 \phi_d} & m_{\phi_2 \phi_d} & m_{\phi_3 \phi_d} \\ m_{\phi_d \phi_u} & m_{\phi_u \phi_u} & m_{\phi_s \phi_u} & m_{\phi_1 \phi_u} & m_{\phi_2 \phi_u} & m_{\phi_3 \phi_u} \\ m_{\phi_d \phi_s} & m_{\phi_u \phi_s} & m_{\phi_s \phi_s} & m_{\phi_1 \phi_s} & m_{\phi_2 \phi_s} & m_{\phi_3 \phi_s} \\ m_{\phi_d \phi_1} & m_{\phi_u \phi_1} & m_{\phi_s \phi_1} & m_{\phi_1 \phi_1} & m_{\phi_2 \phi_1} & m_{\phi_3 \phi_1} \\ m_{\phi_d \phi_2} & m_{\phi_u \phi_2} & m_{\phi_s \phi_2} & m_{\phi_1 \phi_2} & m_{\phi_2 \phi_2} & m_{\phi_3 \phi_2} \\ m_{\phi_d \phi_3} & m_{\phi_u \phi_3} & m_{\phi_s \phi_3} & m_{\phi_1 \phi_3} & m_{\phi_2 \phi_3} & m_{\phi_3 \phi_3} \end{pmatrix} \tag{136}$$

$$\begin{aligned}
m_{\phi_d \phi_d} & = +m_{H_d}^2 \\
& + \frac{1}{8} \left(4g_p^2 Q_{H_d} \left(3Q_{H_d} v_d^2 + Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + \left(g_1^2 + g_2^2 \right) \left(3v_d^2 - v_u^2 \right) \right) \\
& + \frac{1}{2} \left(v_s^2 + v_u^2 \right) |\lambda|^2
\end{aligned} \tag{137}$$

$$m_{\phi_d \phi_u} = -\frac{1}{4} \left(-4g_p^2 Q_{H_d} Q_{H_u} + g_1^2 + g_2^2 \right) v_d v_u - \frac{1}{\sqrt{2}} v_s \Re(T_\lambda) + v_d v_u |\lambda|^2 \tag{138}$$

$$\begin{aligned}
m_{\phi_u \phi_u} & = +m_{H_u}^2 \\
& + \frac{1}{8} \left(4g_p^2 Q_{H_u} \left(3Q_{H_u} v_u^2 + Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_s v_s^2 \right) + \left(-g_1^2 - g_2^2 \right) \left(-3v_u^2 + v_d^2 \right) \right) \\
& + \frac{1}{2} \left(v_d^2 + v_s^2 \right) |\lambda|^2
\end{aligned} \tag{139}$$

$$m_{\phi_d \phi_s} = -\frac{1}{\sqrt{2}} v_u \Re(T_\lambda) + g_p^2 Q_{H_d} Q_s v_d v_s + v_d v_s |\lambda|^2 \tag{140}$$

$$m_{\phi_u \phi_s} = -\frac{1}{\sqrt{2}} v_d \Re(T_\lambda) + g_p^2 Q_{H_u} Q_s v_s v_u + v_s v_u |\lambda|^2 \tag{141}$$

$$m_{\phi_s \phi_s} = \frac{1}{2} g_p^2 Q_s \left(3Q_s v_s^2 + Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 \right) + \frac{1}{2} (v_d^2 + v_u^2) |\lambda|^2 + m_S^2 \quad (142)$$

$$m_{\phi_d \phi_1} = g_p^2 Q_{H_d} Q_1 v_d v_1 \quad (143)$$

$$m_{\phi_u \phi_1} = g_p^2 Q_{H_u} Q_1 v_1 v_u \quad (144)$$

$$m_{\phi_s \phi_1} = g_p^2 Q_s Q_1 v_s v_1 \quad (145)$$

$$m_{\phi_1 \phi_1} = \frac{1}{18} (v_2^2 + v_3^2) |\kappa|^2 + \frac{1}{2} g_p^2 Q_1 \left(3Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + m_{s_1}^2 \quad (146)$$

$$m_{\phi_d \phi_2} = g_p^2 Q_{H_d} Q_2 v_d v_2 \quad (147)$$

$$m_{\phi_u \phi_2} = g_p^2 Q_{H_u} Q_2 v_2 v_u \quad (148)$$

$$m_{\phi_s \phi_2} = g_p^2 Q_s Q_2 v_s v_2 \quad (149)$$

$$m_{\phi_1 \phi_2} = \frac{1}{18} \left(2v_1 v_2 |\kappa|^2 + 3\sqrt{2} v_3 \Re(T_\kappa) \right) + g_p^2 Q_1 Q_2 v_1 v_2 \quad (150)$$

$$m_{\phi_2 \phi_2} = \frac{1}{18} (v_1^2 + v_3^2) |\kappa|^2 + \frac{1}{2} g_p^2 Q_2 \left(3Q_2 v_2^2 + Q_1 v_1^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + m_{s_2}^2 \quad (151)$$

$$m_{\phi_d \phi_3} = g_p^2 Q_{H_d} Q_3 v_d v_3 \quad (152)$$

$$m_{\phi_u \phi_3} = g_p^2 Q_{H_u} Q_3 v_3 v_u \quad (153)$$

$$m_{\phi_s \phi_3} = g_p^2 Q_s Q_3 v_s v_3 \quad (154)$$

$$m_{\phi_1 \phi_3} = \frac{1}{18} \left(2v_1 v_3 |\kappa|^2 + 3\sqrt{2} v_2 \Re(T_\kappa) \right) + g_p^2 Q_1 Q_3 v_1 v_3 \quad (155)$$

$$m_{\phi_2 \phi_3} = \frac{1}{18} \left(2v_2 v_3 |\kappa|^2 + 3\sqrt{2} v_1 \Re(T_\kappa) \right) + g_p^2 Q_2 Q_3 v_2 v_3 \quad (156)$$

$$m_{\phi_3 \phi_3} = \frac{1}{18} (v_1^2 + v_2^2) |\kappa|^2 + \frac{1}{2} g_p^2 Q_3 \left(3Q_3 v_3^2 + Q_1 v_1^2 + Q_2 v_2^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + m_{s_3}^2 \quad (157)$$

This matrix is diagonalized by Z^H :

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \quad (158)$$

with

$$\phi_d = \sum_j Z_{j1}^{H,*} h_j, \quad \phi_u = \sum_j Z_{j2}^{H,*} h_j, \quad \phi_s = \sum_j Z_{j3}^{H,*} h_j \quad (159)$$

$$\phi_1 = \sum_j Z_{j4}^{H,*} h_j, \quad \phi_2 = \sum_j Z_{j5}^{H,*} h_j, \quad \phi_3 = \sum_j Z_{j6}^{H,*} h_j \quad (160)$$

- **Mass matrix for Pseudo-Scalar Higgs, Basis:** $(\sigma_d, \sigma_u, \sigma_s, \sigma_1, \sigma_2, \sigma_3), (\sigma_d, \sigma_u, \sigma_s, \sigma_1, \sigma_2, \sigma_3)$

$$m_{A^0}^2 = \begin{pmatrix} m_{\sigma_d \sigma_d} & \frac{1}{\sqrt{2}} v_s \Re(T_\lambda) & \frac{1}{\sqrt{2}} v_u \Re(T_\lambda) & 0 & 0 & 0 \\ \frac{1}{\sqrt{2}} v_s \Re(T_\lambda) & m_{\sigma_u \sigma_u} & \frac{1}{\sqrt{2}} v_d \Re(T_\lambda) & 0 & 0 & 0 \\ \frac{1}{\sqrt{2}} v_u \Re(T_\lambda) & \frac{1}{\sqrt{2}} v_d \Re(T_\lambda) & m_{\sigma_s \sigma_s} & 0 & 0 & 0 \\ 0 & 0 & 0 & m_{\sigma_1 \sigma_1} & -\frac{1}{3} \frac{1}{\sqrt{2}} v_3 \Re(T_\kappa) & -\frac{1}{3} \frac{1}{\sqrt{2}} v_2 \Re(T_\kappa) \\ 0 & 0 & 0 & -\frac{1}{3} \frac{1}{\sqrt{2}} v_3 \Re(T_\kappa) & m_{\sigma_2 \sigma_2} & -\frac{1}{3} \frac{1}{\sqrt{2}} v_1 \Re(T_\kappa) \\ 0 & 0 & 0 & -\frac{1}{3} \frac{1}{\sqrt{2}} v_2 \Re(T_\kappa) & -\frac{1}{3} \frac{1}{\sqrt{2}} v_1 \Re(T_\kappa) & m_{\sigma_3 \sigma_3} \end{pmatrix} + \xi_Z m^2(Z) + \xi_{Z'} m^2(Z') \quad (161)$$

$$m_{\sigma_d \sigma_d} = +m_{H_d}^2 + \frac{1}{8} \left(4g_p^2 Q_{H_d} (Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + (g_1^2 + g_2^2) (-v_u^2 + v_d^2) \right) + \frac{1}{2} (v_s^2 + v_u^2) |\lambda|^2 \quad (162)$$

$$m_{\sigma_u \sigma_u} = +m_{H_u}^2 + \frac{1}{8} \left(4g_p^2 Q_{H_u} (Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + (g_1^2 + g_2^2) (-v_d^2 + v_u^2) \right) + \frac{1}{2} (v_d^2 + v_s^2) |\lambda|^2 \quad (163)$$

$$m_{\sigma_s \sigma_s} = \frac{1}{2} g_p^2 Q_s (Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + \frac{1}{2} (v_d^2 + v_u^2) |\lambda|^2 + m_S^2 \quad (164)$$

$$m_{\sigma_1 \sigma_1} = \frac{1}{18} (v_2^2 + v_3^2) |\kappa|^2 + \frac{1}{2} g_p^2 Q_1 (Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + m_{s_1}^2 \quad (165)$$

$$m_{\sigma_2 \sigma_2} = \frac{1}{18} (v_1^2 + v_3^2) |\kappa|^2 + \frac{1}{2} g_p^2 Q_2 (Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + m_{s_2}^2 \quad (166)$$

$$m_{\sigma_3 \sigma_3} = \frac{1}{18} (v_1^2 + v_2^2) |\kappa|^2 + \frac{1}{2} g_p^2 Q_3 (Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2) + m_{s_3}^2 \quad (167)$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} m_{\sigma_d \sigma_d} & m_{\sigma_u \sigma_d} & m_{\sigma_s \sigma_d} & m_{\sigma_1 \sigma_d} & m_{\sigma_2 \sigma_d} & m_{\sigma_3 \sigma_d} \\ m_{\sigma_d \sigma_u} & m_{\sigma_u \sigma_u} & m_{\sigma_s \sigma_u} & m_{\sigma_1 \sigma_u} & m_{\sigma_2 \sigma_u} & m_{\sigma_3 \sigma_u} \\ m_{\sigma_d \sigma_s} & m_{\sigma_u \sigma_s} & m_{\sigma_s \sigma_s} & m_{\sigma_1 \sigma_s} & m_{\sigma_2 \sigma_s} & m_{\sigma_3 \sigma_s} \\ m_{\sigma_d \sigma_1} & m_{\sigma_u \sigma_1} & m_{\sigma_s \sigma_1} & m_{\sigma_1 \sigma_1} & m_{\sigma_2 \sigma_1} & m_{\sigma_3 \sigma_1} \\ m_{\sigma_d \sigma_2} & m_{\sigma_u \sigma_2} & m_{\sigma_s \sigma_2} & m_{\sigma_1 \sigma_2} & m_{\sigma_2 \sigma_2} & m_{\sigma_3 \sigma_2} \\ m_{\sigma_d \sigma_3} & m_{\sigma_u \sigma_3} & m_{\sigma_s \sigma_3} & m_{\sigma_1 \sigma_3} & m_{\sigma_2 \sigma_3} & m_{\sigma_3 \sigma_3} \end{pmatrix} \quad (168)$$

$$m_{\sigma_d \sigma_d} = \frac{1}{4} v_d^2 \left(2g_p Q_{H_d} \sin \Theta'_W + \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \right)^2 \quad (169)$$

$$m_{\sigma_d \sigma_u} = -\frac{1}{4} v_d v_u \left(2g_p Q_{H_d} \sin \Theta'_W + \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \right) \left(-2g_p Q_{H_u} \sin \Theta'_W + \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \right) \quad (170)$$

$$m_{\sigma_u \sigma_u} = \frac{1}{4} v_u^2 \left(-2g_p Q_{H_u} \sin \Theta'_W + \cos \Theta'_W (g_1 \sin \Theta_W + g_2 \cos \Theta_W) \right)^2 \quad (171)$$

$$m_{\sigma_d \sigma_s} = \frac{1}{2} g_p Q_s v_d v_s \sin \Theta'_W \left(2g_p Q_{H_d} \sin \Theta'_W + \cos \Theta'_W \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \right) \quad (172)$$

$$m_{\sigma_u \sigma_s} = \frac{1}{2} g_p Q_s v_s v_u \sin \Theta'_W \left(2g_p Q_{H_u} \sin \Theta'_W - \cos \Theta'_W \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \right) \quad (173)$$

$$m_{\sigma_s \sigma_s} = g_p^2 Q_s^2 v_s^2 \sin \Theta'^2_W \quad (174)$$

$$m_{\sigma_d \sigma_1} = \frac{1}{2} g_p Q_1 v_d v_1 \sin \Theta'_W \left(2g_p Q_{H_d} \sin \Theta'_W + \cos \Theta'_W \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \right) \quad (175)$$

$$m_{\sigma_u \sigma_1} = \frac{1}{2} g_p Q_1 v_1 v_u \sin \Theta'_W \left(2g_p Q_{H_u} \sin \Theta'_W - \cos \Theta'_W \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \right) \quad (176)$$

$$m_{\sigma_s \sigma_1} = g_p^2 Q_s Q_1 v_s v_1 \sin \Theta'^2_W \quad (177)$$

$$m_{\sigma_1 \sigma_1} = g_p^2 Q_1^2 v_1^2 \sin \Theta'^2_W \quad (178)$$

$$m_{\sigma_d \sigma_2} = \frac{1}{2} g_p Q_2 v_d v_2 \sin \Theta'_W \left(2g_p Q_{H_d} \sin \Theta'_W + \cos \Theta'_W \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \right) \quad (179)$$

$$m_{\sigma_u \sigma_2} = \frac{1}{2} g_p Q_2 v_2 v_u \sin \Theta'_W \left(2g_p Q_{H_u} \sin \Theta'_W - \cos \Theta'_W \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \right) \quad (180)$$

$$m_{\sigma_s \sigma_2} = g_p^2 Q_s Q_2 v_s v_2 \sin \Theta'^2_W \quad (181)$$

$$m_{\sigma_1 \sigma_2} = g_p^2 Q_1 Q_2 v_1 v_2 \sin \Theta'^2_W \quad (182)$$

$$m_{\sigma_2 \sigma_2} = g_p^2 Q_2^2 v_2^2 \sin \Theta'^2_W \quad (183)$$

$$m_{\sigma_d \sigma_3} = \frac{1}{2} g_p Q_3 v_d v_3 \sin \Theta'_W \left(2g_p Q_{H_d} \sin \Theta'_W + \cos \Theta'_W \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \right) \quad (184)$$

$$m_{\sigma_u \sigma_3} = \frac{1}{2} g_p Q_3 v_3 v_u \sin \Theta'_W \left(2g_p Q_{H_u} \sin \Theta'_W - \cos \Theta'_W \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \right) \quad (185)$$

$$m_{\sigma_s \sigma_3} = g_p^2 Q_s Q_3 v_s v_3 \sin \Theta'^2_W \quad (186)$$

$$m_{\sigma_1 \sigma_3} = g_p^2 Q_1 Q_3 v_1 v_3 \sin \Theta'^2_W \quad (187)$$

$$m_{\sigma_2 \sigma_3} = g_p^2 Q_2 Q_3 v_2 v_3 \sin \Theta'^2_W \quad (188)$$

$$m_{\sigma_3 \sigma_3} = g_p^2 Q_3^2 v_3^2 \sin \Theta'^2_W \quad (189)$$

$$m^2(\xi_{Z'}) = \begin{pmatrix} m_{\sigma_d \sigma_d} & m_{\sigma_u \sigma_d} & m_{\sigma_s \sigma_d} & m_{\sigma_1 \sigma_d} & m_{\sigma_2 \sigma_d} & m_{\sigma_3 \sigma_d} \\ m_{\sigma_d \sigma_u} & m_{\sigma_u \sigma_u} & m_{\sigma_s \sigma_u} & m_{\sigma_1 \sigma_u} & m_{\sigma_2 \sigma_u} & m_{\sigma_3 \sigma_u} \\ m_{\sigma_d \sigma_s} & m_{\sigma_u \sigma_s} & m_{\sigma_s \sigma_s} & m_{\sigma_1 \sigma_s} & m_{\sigma_2 \sigma_s} & m_{\sigma_3 \sigma_s} \\ m_{\sigma_d \sigma_1} & m_{\sigma_u \sigma_1} & m_{\sigma_s \sigma_1} & m_{\sigma_1 \sigma_1} & m_{\sigma_2 \sigma_1} & m_{\sigma_3 \sigma_1} \\ m_{\sigma_d \sigma_2} & m_{\sigma_u \sigma_2} & m_{\sigma_s \sigma_2} & m_{\sigma_1 \sigma_2} & m_{\sigma_2 \sigma_2} & m_{\sigma_3 \sigma_2} \\ m_{\sigma_d \sigma_3} & m_{\sigma_u \sigma_3} & m_{\sigma_s \sigma_3} & m_{\sigma_1 \sigma_3} & m_{\sigma_2 \sigma_3} & m_{\sigma_3 \sigma_3} \end{pmatrix} \quad (190)$$

$$m_{\sigma_d \sigma_d} = \frac{1}{4} v_d^2 \left(-2g_p Q_{H_d} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \quad (191)$$

$$m_{\sigma_d \sigma_u} = \frac{1}{8} v_d v_u \left(-2 \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W + 4g_p Q_{H_d} \cos \Theta'_W \right) \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \quad (192)$$

$$m_{\sigma_u \sigma_u} = \frac{1}{4} v_u^2 \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \quad (193)$$

$$m_{\sigma_d \sigma_s} = \frac{1}{2} g_p Q_s v_d v_s \cos \Theta'_W \left(2g_p Q_{H_d} \cos \Theta'_W - \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \quad (194)$$

$$m_{\sigma_u \sigma_s} = \frac{1}{2} g_p Q_s v_s v_u \cos \Theta'_W \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \quad (195)$$

$$m_{\sigma_s \sigma_s} = g_p^2 Q_s^2 v_s^2 \cos \Theta'^2_W \quad (196)$$

$$m_{\sigma_d \sigma_1} = \frac{1}{2} g_p Q_1 v_d v_1 \cos \Theta'_W \left(2g_p Q_{H_d} \cos \Theta'_W - \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \quad (197)$$

$$m_{\sigma_u \sigma_1} = \frac{1}{2} g_p Q_1 v_1 v_u \cos \Theta'_W \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \quad (198)$$

$$m_{\sigma_s \sigma_1} = g_p^2 Q_s Q_1 v_s v_1 \cos \Theta'^2_W \quad (199)$$

$$m_{\sigma_1 \sigma_1} = g_p^2 Q_1^2 v_1^2 \cos \Theta'^2_W \quad (200)$$

$$m_{\sigma_d \sigma_2} = \frac{1}{2} g_p Q_2 v_d v_2 \cos \Theta'_W \left(2g_p Q_{H_d} \cos \Theta'_W - \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \quad (201)$$

$$m_{\sigma_u \sigma_2} = \frac{1}{2} g_p Q_2 v_2 v_u \cos \Theta'_W \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \quad (202)$$

$$m_{\sigma_s \sigma_2} = g_p^2 Q_s Q_2 v_s v_2 \cos \Theta'^2_W \quad (203)$$

$$m_{\sigma_1 \sigma_2} = g_p^2 Q_1 Q_2 v_1 v_2 \cos \Theta'^2_W \quad (204)$$

$$m_{\sigma_2 \sigma_2} = g_p^2 Q_2^2 v_2^2 \cos \Theta'^2_W \quad (205)$$

$$m_{\sigma_d \sigma_3} = \frac{1}{2} g_p Q_3 v_d v_3 \cos \Theta'_W \left(2g_p Q_{H_d} \cos \Theta'_W - \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \quad (206)$$

$$m_{\sigma_u \sigma_3} = \frac{1}{2} g_p Q_3 v_3 v_u \cos \Theta'_W \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \quad (207)$$

$$m_{\sigma_s \sigma_3} = g_p^2 Q_s Q_3 v_s v_3 \cos \Theta'^2_W \quad (208)$$

$$m_{\sigma_1 \sigma_3} = g_p^2 Q_1 Q_3 v_1 v_3 \cos \Theta'^2_W \quad (209)$$

$$m_{\sigma_2 \sigma_3} = g_p^2 Q_2 Q_3 v_2 v_3 \cos \Theta'^2_W \quad (210)$$

$$m_{\sigma_3 \sigma_3} = g_p^2 Q_3^2 v_3^2 \cos \Theta'^2_W \quad (211)$$

This matrix is diagonalized by Z^A :

$$Z^A m_{A0}^2 Z^{A,\dagger} = m_{2,A0}^{dia} \quad (212)$$

with

$$\sigma_d = \sum_j Z_{j1}^{A,*} A_j^0, \quad \sigma_u = \sum_j Z_{j2}^{A,*} A_j^0, \quad \sigma_s = \sum_j Z_{j3}^{A,*} A_j^0 \quad (213)$$

$$\sigma_1 = \sum_j Z_{j4}^{A,*} A_j^0, \quad \sigma_2 = \sum_j Z_{j5}^{A,*} A_j^0, \quad \sigma_3 = \sum_j Z_{j6}^{A,*} A_j^0 \quad (214)$$

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

$$m_{H^-}^2 = \begin{pmatrix} m_{H_d^- H_d^-,*} & -\frac{1}{2}v_d v_u |\lambda|^2 + \frac{1}{4}g_2^2 v_d v_u + \frac{1}{\sqrt{2}}v_s T_\lambda^* \\ -\frac{1}{2}v_d v_u |\lambda|^2 + \frac{1}{4}g_2^2 v_d v_u + \frac{1}{\sqrt{2}}v_s T_\lambda & m_{H_u^+,*} H_u^+ \end{pmatrix} + \xi_{W^-} m^2(W^-) \quad (215)$$

$$\begin{aligned} m_{H_d^- H_d^-,*} &= +m_{H_d}^2 \\ &+ \frac{1}{8} \left(g_1^2 (-v_u^2 + v_d^2) + g_2^2 (v_d^2 + v_u^2) \right) \\ &+ 4g_p^2 Q_{H_d} \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) \\ &+ \frac{1}{2} v_s^2 |\lambda|^2 \end{aligned} \quad (216)$$

$$\begin{aligned} m_{H_u^+,*} H_u^+ &= +m_{H_u}^2 \\ &+ \frac{1}{8} \left(g_1^2 (-v_d^2 + v_u^2) + g_2^2 (v_d^2 + v_u^2) \right) \\ &+ 4g_p^2 Q_{H_u} \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) \\ &+ \frac{1}{2} v_s^2 |\lambda|^2 \end{aligned} \quad (217)$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4}g_2^2 v_d^2 & -\frac{1}{4}g_2^2 v_d v_u \\ -\frac{1}{4}g_2^2 v_d v_u & \frac{1}{4}g_2^2 v_u^2 \end{pmatrix} \quad (218)$$

This matrix is diagonalized by Z^+ :

$$Z^+ m_{H^-}^2 Z^{+,\dagger} = m_{2,H^-}^{dia} \quad (219)$$

with

$$H_d^- = \sum_j Z_{j1}^+ H_j^-, \quad H_u^+ = \sum_j Z_{j2}^+ H_j^+ \quad (220)$$

4.2.2 Mass Matrices for Fermions

- **Mass matrix for Neutralinos**, Basis: $(\tilde{U}, \lambda_{\tilde{B}}, \tilde{W}^0, \tilde{H}_d^0, \tilde{H}_u^0, \tilde{S}, \tilde{s}_1, \tilde{s}_2, \tilde{s}_3)$, $(\tilde{U}, \lambda_{\tilde{B}}, \tilde{W}^0, \tilde{H}_d^0, \tilde{H}_u^0, \tilde{S}, \tilde{s}_1, \tilde{s}_2, \tilde{s}_3)$

$$m_{\tilde{\chi}^0} = \begin{pmatrix} M_U & 0 & 0 & m_{\tilde{H}_d^0 \tilde{U}} & m_{\tilde{H}_u^0 \tilde{U}} & m_{\tilde{S} \tilde{U}} & m_{\tilde{s}_1 \tilde{U}} & m_{\tilde{s}_2 \tilde{U}} & m_{\tilde{s}_3 \tilde{U}} \\ 0 & M_1 & 0 & -\frac{1}{2}g_1 v_d & \frac{1}{2}g_1 v_u & 0 & 0 & 0 & 0 \\ 0 & 0 & M_2 & \frac{1}{2}g_2 v_d & -\frac{1}{2}g_2 v_u & 0 & 0 & 0 & 0 \\ m_{\tilde{U} \tilde{H}_d^0} & -\frac{1}{2}g_1 v_d & \frac{1}{2}g_2 v_d & 0 & m_{\tilde{H}_u^0 \tilde{H}_d^0} & m_{\tilde{S} \tilde{H}_d^0} & 0 & 0 & 0 \\ m_{\tilde{U} \tilde{H}_u^0} & \frac{1}{2}g_1 v_u & -\frac{1}{2}g_2 v_u & m_{\tilde{H}_d^0 \tilde{H}_u^0} & 0 & m_{\tilde{S} \tilde{H}_u^0} & 0 & 0 & 0 \\ m_{\tilde{U} \tilde{S}} & 0 & 0 & m_{\tilde{H}_d^0 \tilde{S}} & m_{\tilde{H}_u^0 \tilde{S}} & 0 & 0 & 0 & 0 \\ m_{\tilde{U} \tilde{s}_1} & 0 & 0 & 0 & 0 & 0 & 0 & m_{\tilde{s}_2 \tilde{s}_1} & m_{\tilde{s}_3 \tilde{s}_1} \\ m_{\tilde{U} \tilde{s}_2} & 0 & 0 & 0 & 0 & 0 & m_{\tilde{s}_1 \tilde{s}_2} & 0 & m_{\tilde{s}_3 \tilde{s}_2} \\ m_{\tilde{U} \tilde{s}_3} & 0 & 0 & 0 & 0 & 0 & m_{\tilde{s}_1 \tilde{s}_3} & m_{\tilde{s}_2 \tilde{s}_3} & 0 \end{pmatrix} \quad (221)$$

$$m_{\tilde{U}\tilde{H}_d^0} = g_p Q_{H_d} v_d \quad (222)$$

$$m_{\tilde{U}\tilde{H}_u^0} = g_p Q_{H_u} v_u \quad (223)$$

$$m_{\tilde{H}_d^0\tilde{H}_u^0} = -\frac{1}{\sqrt{2}} v_s \lambda \quad (224)$$

$$m_{\tilde{U}\tilde{S}} = g_p Q_s v_s \quad (225)$$

$$m_{\tilde{H}_d^0\tilde{S}} = -\frac{1}{\sqrt{2}} v_u \lambda \quad (226)$$

$$m_{\tilde{H}_u^0\tilde{S}} = -\frac{1}{\sqrt{2}} v_d \lambda \quad (227)$$

$$m_{\tilde{U}\tilde{s}_1} = g_p Q_1 v_1 \quad (228)$$

$$m_{\tilde{U}\tilde{s}_2} = g_p Q_2 v_2 \quad (229)$$

$$m_{\tilde{s}_1\tilde{s}_2} = \frac{1}{3} \frac{1}{\sqrt{2}} v_3 \kappa \quad (230)$$

$$m_{\tilde{U}\tilde{s}_3} = g_p Q_3 v_3 \quad (231)$$

$$m_{\tilde{s}_1\tilde{s}_3} = \frac{1}{3} \frac{1}{\sqrt{2}} v_2 \kappa \quad (232)$$

$$m_{\tilde{s}_2\tilde{s}_3} = \frac{1}{3} \frac{1}{\sqrt{2}} v_1 \kappa \quad (233)$$

This matrix is diagonalized by N :

$$N^* m_{\tilde{\chi}^0} N^\dagger = m_{\tilde{\chi}^0}^{dia} \quad (234)$$

with

$$\tilde{U} = \sum_j N_{j1}^* \lambda_j^0, \quad \lambda_{\tilde{B}} = \sum_j N_{j2}^* \lambda_j^0, \quad \tilde{W}^0 = \sum_j N_{j3}^* \lambda_j^0 \quad (235)$$

$$\tilde{H}_d^0 = \sum_j N_{j4}^* \lambda_j^0, \quad \tilde{H}_u^0 = \sum_j N_{j5}^* \lambda_j^0, \quad \tilde{S} = \sum_j N_{j6}^* \lambda_j^0 \quad (236)$$

$$\tilde{s}_1 = \sum_j N_{j7}^* \lambda_j^0, \quad \tilde{s}_2 = \sum_j N_{j8}^* \lambda_j^0, \quad \tilde{s}_3 = \sum_j N_{j9}^* \lambda_j^0 \quad (237)$$

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

$$m_{\tilde{\chi}^-} = \begin{pmatrix} M_2 & \frac{1}{\sqrt{2}} g_2 v_u \\ \frac{1}{\sqrt{2}} g_2 v_d & \frac{1}{\sqrt{2}} v_s \lambda \end{pmatrix} \quad (238)$$

This matrix is diagonalized by U and V

$$U^* m_{\tilde{\chi}^-} V^\dagger = m_{\tilde{\chi}^-}^{dia} \quad (239)$$

with

$$\tilde{W}^- = \sum_{t_2} U_{j1}^* \lambda_j^-, \quad \tilde{H}_d^- = \sum_{t_2} U_{j2}^* \lambda_j^- \quad (240)$$

$$\tilde{W}^+ = \sum_{t_2} V_{1j}^* \lambda_j^+, \quad \tilde{H}_u^+ = \sum_{t_2} V_{2j}^* \lambda_j^+ \quad (241)$$

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

$$m_e = \left(\frac{1}{\sqrt{2}} v_d Y_e^T \right) \quad (242)$$

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

$$U_L^{e,*} m_e U_R^{e,\dagger} = m_e^{dia} \quad (243)$$

with

$$e_{L,i} = \sum_{t_2} U_{L,ji}^{e,*} E_{L,j} \quad (244)$$

$$e_{R,i} = \sum_{t_2} U_{R,ij}^e E_{R,j}^* \quad (245)$$

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

$$m_d = \left(\frac{1}{\sqrt{2}} v_d \delta_{\alpha_1 \beta_1} Y_d^T \right) \quad (246)$$

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

$$U_L^{d,*} m_d U_R^{d,\dagger} = m_d^{dia} \quad (247)$$

with

$$d_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{d,*} D_{L,j\alpha} \quad (248)$$

$$d_{R,i\alpha} = \sum_{t_2} U_{R,ij}^d D_{R,j\alpha}^* \quad (249)$$

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

$$m_u = \left(\frac{1}{\sqrt{2}} v_u \delta_{\alpha_1 \beta_1} Y_u^T \right) \quad (250)$$

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

$$U_L^{u,*} m_u U_R^{u,\dagger} = m_u^{dia} \quad (251)$$

with

$$u_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{u,*} U_{L,j\alpha} \quad (252)$$

$$u_{R,i\alpha} = \sum_{t_2} U_{R,ij}^u U_{R,j\alpha}^* \quad (253)$$

5 Vacuum Expectation Values

$$H_d^0 = \frac{1}{\sqrt{2}}\phi_d + \frac{1}{\sqrt{2}}v_d + i\frac{1}{\sqrt{2}}\sigma_d \quad (254)$$

$$H_u^0 = \frac{1}{\sqrt{2}}\phi_u + \frac{1}{\sqrt{2}}v_u + i\frac{1}{\sqrt{2}}\sigma_u \quad (255)$$

$$S = \frac{1}{\sqrt{2}}\phi_s + \frac{1}{\sqrt{2}}v_s + i\frac{1}{\sqrt{2}}\sigma_s \quad (256)$$

$$S_1 = \frac{1}{\sqrt{2}}\phi_1 + \frac{1}{\sqrt{2}}v_1 + i\frac{1}{\sqrt{2}}\sigma_1 \quad (257)$$

$$S_2 = \frac{1}{\sqrt{2}}\phi_2 + \frac{1}{\sqrt{2}}v_2 + i\frac{1}{\sqrt{2}}\sigma_2 \quad (258)$$

$$S_3 = \frac{1}{\sqrt{2}}\phi_3 + \frac{1}{\sqrt{2}}v_3 + i\frac{1}{\sqrt{2}}\sigma_3 \quad (259)$$

6 Tadpole Equations

$$\begin{aligned} \frac{\partial V}{\partial \phi_d} = & +\frac{1}{8}v_d \left(4g_p^2 Q_{H_d} \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + (g_1^2 + g_2^2) \left(-v_u + v_d \right) \left(v_d + v_u \right) \right) \\ & + \frac{1}{4} \left(-\sqrt{2} v_s v_u (T_\lambda^* + T_\lambda) + v_d \left(2(v_s^2 + v_u^2) |\lambda|^2 + 4m_{H_d}^2 \right) \right) \end{aligned} \quad (260)$$

$$\begin{aligned} \frac{\partial V}{\partial \phi_u} = & +\frac{1}{8}v_u \left(4g_p^2 Q_{H_u} \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) + (g_1^2 + g_2^2) \left(-v_d^2 + v_u^2 \right) \right) \\ & + \frac{1}{2} \left(-\sqrt{2} v_d v_s \Re(T_\lambda) + v_u \left(2m_{H_u}^2 + (v_d^2 + v_s^2) |\lambda|^2 \right) \right) \end{aligned} \quad (261)$$

$$\begin{aligned} \frac{\partial V}{\partial \phi_s} = & +\frac{1}{2}g_p^2 Q_s \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) \\ & + \frac{1}{4} \left(-\sqrt{2} v_d v_u (T_\lambda^* + T_\lambda) + v_s \left(2(v_d^2 + v_u^2) |\lambda|^2 + 4m_S^2 \right) \right) \end{aligned} \quad (262)$$

$$\begin{aligned} \frac{\partial V}{\partial \phi_1} = & +\frac{1}{2}g_p^2 Q_1 v_1 \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) \\ & + \frac{1}{36} \left(3\sqrt{2} v_2 v_3 (T_\kappa^* + T_\kappa) + v_1 \left(2(v_2^2 + v_3^2) |\kappa|^2 + 36m_{s_1}^2 \right) \right) \end{aligned} \quad (263)$$

$$\begin{aligned} \frac{\partial V}{\partial \phi_2} = & +\frac{1}{2}g_p^2 Q_2 v_2 \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) \\ & + \frac{1}{36} \left(3\sqrt{2} v_1 v_3 (T_\kappa^* + T_\kappa) + v_2 \left(2(v_1^2 + v_3^2) |\kappa|^2 + 36m_{s_2}^2 \right) \right) \end{aligned} \quad (264)$$

$$\begin{aligned} \frac{\partial V}{\partial \phi_3} = & +\frac{1}{2}g_p^2 Q_3 v_3 \left(Q_1 v_1^2 + Q_2 v_2^2 + Q_3 v_3^2 + Q_{H_d} v_d^2 + Q_{H_u} v_u^2 + Q_s v_s^2 \right) \\ & + \frac{1}{18} \left(3\sqrt{2} v_1 v_2 \Re(T_\kappa) + v_3 \left(18m_{s_3}^2 + (v_1^2 + v_2^2) |\kappa|^2 \right) \right) \end{aligned} \quad (265)$$

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	3	generation, 3
\tilde{u}	Scalar	complex	6	generation, 6, color, 3
\tilde{e}	Scalar	complex	6	generation, 6
h	Scalar	real	6	generation, 6
A^0	Scalar	real	6	generation, 6
H^-	Scalar	complex	2	generation, 2
\tilde{g}	Fermion	Majorana	1	color, 8
ν	Fermion	Dirac	3	generation, 3
$\tilde{\chi}^0$	Fermion	Majorana	9	generation, 9
$\tilde{\chi}^-$	Fermion	Dirac	2	generation, 2
e	Fermion	Dirac	3	generation, 3
d	Fermion	Dirac	3	generation, 3, color, 3
u	Fermion	Dirac	3	generation, 3, color, 3
g	Vector	real	1	color, 8, lorentz, 4
γ	Vector	real	1	lorentz, 4
Z	Vector	real	1	lorentz, 4
Z'	Vector	real	1	lorentz, 4
W^-	Vector	complex	1	lorentz, 4
η^G	Ghost	real	1	color, 8
η^γ	Ghost	real	1	
η^Z	Ghost	real	1	
$\eta^{Z'}$	Ghost	real	1	
η^-	Ghost	complex	1	
η^+	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_{\check{d}_i, \check{d}_j^*, W^+, W^-} \left(-\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\check{d}_i, \check{d}_j^*, Z, Z} \left(-\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& + 2\Gamma_{\check{d}_i, \check{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_{\check{d}_i, \check{d}_j^*, H_a^+, H_a^-} \\
& - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\check{d}_i, \check{d}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_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_{\check{d}_j^*, u_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\check{d}_i^*, u_a, \tilde{\chi}_b^-}^R + \Gamma_{\check{d}_j^*, u_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\check{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_{\check{d}_j^*, u_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\check{d}_i^*, u_a, \tilde{\chi}_b^-}^L + \Gamma_{\check{d}_j^*, u_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\check{d}_i^*, u_a, \tilde{\chi}_b^-}^R \right) \\
& - 2 \sum_{a=1}^3 m_{d_a} \sum_{b=1}^9 B_0(p^2, m_{d_a}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_b^0} \left(\Gamma_{\check{d}_j^*, d_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\check{d}_i^*, d_a, \tilde{\chi}_b^0}^R + \Gamma_{\check{d}_j^*, d_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\check{d}_i^*, d_a, \tilde{\chi}_b^0}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^9 G_0(p^2, m_{d_a}^2, m_{\tilde{\chi}_b^0}^2) \left(\Gamma_{\check{d}_j^*, d_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\check{d}_i^*, d_a, \tilde{\chi}_b^0}^L + \Gamma_{\check{d}_j^*, d_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\check{d}_i^*, d_a, \tilde{\chi}_b^0}^R \right) \\
& - \frac{1}{2} \sum_{a=1}^6 A_0(m_{A_a^0}^2) \Gamma_{\check{d}_i, \check{d}_j^*, A_a^0, A_a^0} - C \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\check{d}_i, \check{d}_j^*, \tilde{d}_a^*, \tilde{d}_a} \\
& - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\check{d}_i, \check{d}_j^*, \tilde{e}_a^*, \tilde{e}_a} - C \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\check{d}_i, \check{d}_j^*, \tilde{u}_a^*, \tilde{u}_a} \\
& - \frac{1}{2} \sum_{a=1}^6 A_0(m_{h_a}^2) \Gamma_{\check{d}_i, \check{d}_j^*, h_a, h_a} + \sum_{a=1}^6 \sum_{b=1}^2 B_0(p^2, m_{\tilde{u}_a}^2, m_{H_b^-}^2) \Gamma_{\check{d}_j^*, \tilde{u}_a, H_b^-}^* \Gamma_{\check{d}_i^*, \tilde{u}_a, H_b^-} \\
& + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{d}_a}^2, m_{A_b^0}^2) \Gamma_{\check{d}_j^*, \tilde{d}_a, A_b^0}^* \Gamma_{\check{d}_i^*, \tilde{d}_a, A_b^0} + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{d}_a}^2, m_{h_b}^2) \Gamma_{\check{d}_j^*, \tilde{d}_a, h_b}^* \Gamma_{\check{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_{\check{d}_j^*, \tilde{g}_1, \tilde{d}_b}^{L*} \Gamma_{\check{d}_i^*, \tilde{g}_1, \tilde{d}_b}^R + \Gamma_{\check{d}_j^*, \tilde{g}_1, \tilde{d}_b}^{R*} \Gamma_{\check{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_{\check{d}_j^*, \tilde{g}_1, \tilde{d}_b}^{L*} \Gamma_{\check{d}_i^*, \tilde{g}_1, \tilde{d}_b}^L + \Gamma_{\check{d}_j^*, \tilde{g}_1, \tilde{d}_b}^{R*} \Gamma_{\check{d}_i^*, \tilde{g}_1, \tilde{d}_b}^R \right) \\
& + \frac{4}{3} \sum_{b=1}^6 \Gamma_{\check{d}_j^*, g, \tilde{d}_b}^* \Gamma_{\check{d}_i^*, g, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, 0) + \sum_{b=1}^6 \Gamma_{\check{d}_j^*, \gamma, \tilde{d}_b}^* \Gamma_{\check{d}_i^*, \gamma, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, 0) \\
& + \sum_{b=1}^6 \Gamma_{\check{d}_j^*, Z, \tilde{d}_b}^* \Gamma_{\check{d}_i^*, Z, \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, m_Z^2) + \sum_{b=1}^6 \Gamma_{\check{d}_j^*, Z', \tilde{d}_b}^* \Gamma_{\check{d}_i^*, Z', \tilde{d}_b} F_0(p^2, m_{\tilde{d}_b}^2, m_{Z'}^2)
\end{aligned}$$

$$+ \sum_{b=1}^6 \Gamma_{\tilde{d}_j^*, W^-, \tilde{u}_b}^* \Gamma_{\tilde{d}_i^*, W^-, \tilde{u}_b} F_0(p^2, m_{\tilde{u}_b}^2, m_{W^-}^2) \quad (266)$$

• **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} - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a} \\ & + \sum_{a=1}^3 \sum_{b=1}^6 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} \\ & - 2 \sum_{a=1}^3 m_{\nu_a} \sum_{b=1}^9 B_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_b^0} \left(\Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^R + \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^L \right) \\ & + \sum_{a=1}^3 \sum_{b=1}^9 G_0(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^0}^2) \left(\Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^L + \Gamma_{\tilde{\nu}_j^*, \nu_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\nu}_i^*, \nu_a, \tilde{\chi}_b^0}^R \right) \\ & - \frac{1}{2} \sum_{a=1}^6 A_0(m_{A_a^0}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, A_a^0, A_a^0} - 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} \\ & - \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} \\ & - \frac{1}{2} \sum_{a=1}^6 A_0(m_{h_a}^2) \Gamma_{\tilde{\nu}_i, \tilde{\nu}_j^*, h_a, h_a} + \sum_{b=1}^3 \Gamma_{\tilde{\nu}_j^*, Z, \tilde{\nu}_b}^* \Gamma_{\tilde{\nu}_i^*, Z, \tilde{\nu}_b} F_0(p^2, m_{\tilde{\nu}_b}^2, m_Z^2) \\ & + \sum_{b=1}^3 \Gamma_{\tilde{\nu}_j^*, Z', \tilde{\nu}_b}^* \Gamma_{\tilde{\nu}_i^*, Z', \tilde{\nu}_b} F_0(p^2, m_{\tilde{\nu}_b}^2, m_{Z'}^2) + \sum_{b=1}^6 \Gamma_{\tilde{\nu}_j^*, W^+, \tilde{e}_b}^* \Gamma_{\tilde{\nu}_i^*, W^+, \tilde{e}_b} F_0(p^2, m_{\tilde{e}_b}^2, m_{W^-}^2) \end{aligned} \quad (267)$$

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

$$\Pi_{i,j}(p^2) = +4\Gamma_{\tilde{u}_i, \tilde{u}_j^*, W^+, W^-} \left(-\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\tilde{u}_i, \tilde{u}_j^*, Z, Z} \left(-\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right)$$

$$\begin{aligned}
& + 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_{\tilde{d}_b}^2) \Gamma_{\tilde{u}_j^*, H_a^+, \tilde{d}_b}^* \Gamma_{\tilde{u}_i^*, H_a^+, \tilde{d}_b} - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a} \\
& - 2 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^9 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}^9 G_0(p^2, m_{u_a}^2, m_{\tilde{\chi}_b^0}^2) \left(\Gamma_{\tilde{u}_j^*, u_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{u}_i^*, u_a, \tilde{\chi}_b^0}^L + \Gamma_{\tilde{u}_j^*, u_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{u}_i^*, u_a, \tilde{\chi}_b^0}^R \right) \\
& - \frac{1}{2} \sum_{a=1}^6 A_0(m_{A_a^0}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, A_a^0, A_a^0} - 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} \\
& - \frac{1}{2} \sum_{a=1}^6 A_0(m_{h_a}^2) \Gamma_{\tilde{u}_i, \tilde{u}_j^*, h_a, h_a} + \sum_{a=1}^6 \sum_{b=1}^6 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}^6 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)
\end{aligned} \tag{268}$$

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

$$\begin{aligned}
\Pi_{i,j}(p^2) = & +4\Gamma_{\check{e}_i,\check{e}_j^*,W^+,W^-}\left(-\frac{1}{2}\text{rMS}m_{W^-}^2+A_0\left(m_{W^-}^2\right)\right)+2\Gamma_{\check{e}_i,\check{e}_j^*,Z,Z}\left(-\frac{1}{2}\text{rMS}m_Z^2+A_0\left(m_Z^2\right)\right) \\
& +2\Gamma_{\check{e}_i,\check{e}_j^*,Z',Z'}\left(-\frac{1}{2}\text{rMS}m_{Z'}^2+A_0\left(m_{Z'}^2\right)\right)-\sum_{a=1}^2A_0\left(m_{H_a^-}^2\right)\Gamma_{\check{e}_i,\check{e}_j^*,H_a^+,H_a^-} \\
& -\sum_{a=1}^3A_0\left(m_{\nu_a}^2\right)\Gamma_{\check{e}_i,\check{e}_j^*,\tilde{\nu}_a^*,\tilde{\nu}_a}+\sum_{a=1}^3\sum_{b=1}^2B_0\left(p^2,m_{\nu_a}^2,m_{H_b^-}^2\right)\Gamma_{\check{e}_j^*,\tilde{\nu}_a,H_b^-}^*\Gamma_{\check{e}_i^*,\tilde{\nu}_a,H_b^-} \\
& -2\sum_{a=1}^3m_{\nu_a}\sum_{b=1}^2B_0\left(p^2,m_{\nu_a}^2,m_{\tilde{\chi}_b^-}^2\right)m_{\tilde{\chi}_b^-}\left(\Gamma_{\check{e}_j^*,\nu_a,\tilde{\chi}_b^-}^{L*}\Gamma_{\check{e}_i^*,\nu_a,\tilde{\chi}_b^-}^R+\Gamma_{\check{e}_j^*,\nu_a,\tilde{\chi}_b^-}^{R*}\Gamma_{\check{e}_i^*,\nu_a,\tilde{\chi}_b^-}^L\right) \\
& +\sum_{a=1}^3\sum_{b=1}^2G_0\left(p^2,m_{\nu_a}^2,m_{\tilde{\chi}_b^-}^2\right)\left(\Gamma_{\check{e}_j^*,\nu_a,\tilde{\chi}_b^-}^{L*}\Gamma_{\check{e}_i^*,\nu_a,\tilde{\chi}_b^-}^L+\Gamma_{\check{e}_j^*,\nu_a,\tilde{\chi}_b^-}^{R*}\Gamma_{\check{e}_i^*,\nu_a,\tilde{\chi}_b^-}^R\right) \\
& -2\sum_{a=1}^3m_{e_a}\sum_{b=1}^9B_0\left(p^2,m_{e_a}^2,m_{\tilde{\chi}_b^0}^2\right)m_{\tilde{\chi}_b^0}\left(\Gamma_{\check{e}_j^*,e_a,\tilde{\chi}_b^0}^{L*}\Gamma_{\check{e}_i^*,e_a,\tilde{\chi}_b^0}^R+\Gamma_{\check{e}_j^*,e_a,\tilde{\chi}_b^0}^{R*}\Gamma_{\check{e}_i^*,e_a,\tilde{\chi}_b^0}^L\right) \\
& +\sum_{a=1}^3\sum_{b=1}^9G_0\left(p^2,m_{e_a}^2,m_{\tilde{\chi}_b^0}^2\right)\left(\Gamma_{\check{e}_j^*,e_a,\tilde{\chi}_b^0}^{L*}\Gamma_{\check{e}_i^*,e_a,\tilde{\chi}_b^0}^L+\Gamma_{\check{e}_j^*,e_a,\tilde{\chi}_b^0}^{R*}\Gamma_{\check{e}_i^*,e_a,\tilde{\chi}_b^0}^R\right) \\
& -\frac{1}{2}\sum_{a=1}^6A_0\left(m_{A_a^0}^2\right)\Gamma_{\check{e}_i,\check{e}_j^*,A_a^0,A_a^0}-3\sum_{a=1}^6A_0\left(m_{\tilde{d}_a}^2\right)\Gamma_{\check{e}_i,\check{e}_j^*,\tilde{d}_a^*,\tilde{d}_a} \\
& -\sum_{a=1}^6A_0\left(m_{\tilde{e}_a}^2\right)\Gamma_{\check{e}_i,\check{e}_j^*,\tilde{e}_a^*,\tilde{e}_a}-3\sum_{a=1}^6A_0\left(m_{\tilde{u}_a}^2\right)\Gamma_{\check{e}_i,\check{e}_j^*,\tilde{u}_a^*,\tilde{u}_a} \\
& -\frac{1}{2}\sum_{a=1}^6A_0\left(m_{h_a}^2\right)\Gamma_{\check{e}_i,\check{e}_j^*,h_a,h_a}+\sum_{a=1}^6\sum_{b=1}^6B_0\left(p^2,m_{\tilde{e}_a}^2,m_{A_b^0}^2\right)\Gamma_{\check{e}_j^*,\tilde{e}_a,A_b^0}^*\Gamma_{\check{e}_i^*,\tilde{e}_a,A_b^0} \\
& +\sum_{a=1}^6\sum_{b=1}^6B_0\left(p^2,m_{\tilde{e}_a}^2,m_{h_b}^2\right)\Gamma_{\check{e}_j^*,\tilde{e}_a,h_b}^*\Gamma_{\check{e}_i^*,\tilde{e}_a,h_b}+\sum_{b=1}^3\Gamma_{\check{e}_j^*,W^-, \tilde{\nu}_b}^*\Gamma_{\check{e}_i^*,W^-, \tilde{\nu}_b}F_0\left(p^2,m_{\tilde{\nu}_b}^2,m_{W^-}^2\right) \\
& +\sum_{b=1}^6\Gamma_{\check{e}_j^*,\gamma,\tilde{e}_b}^*\Gamma_{\check{e}_i^*,\gamma,\tilde{e}_b}F_0\left(p^2,m_{\tilde{e}_b}^2,0\right)+\sum_{b=1}^6\Gamma_{\check{e}_j^*,Z,\tilde{e}_b}^*\Gamma_{\check{e}_i^*,Z,\tilde{e}_b}F_0\left(p^2,m_{\tilde{e}_b}^2,m_Z^2\right) \\
& +\sum_{b=1}^6\Gamma_{\check{e}_j^*,Z',\tilde{e}_b}^*\Gamma_{\check{e}_i^*,Z',\tilde{e}_b}F_0\left(p^2,m_{\tilde{e}_b}^2,m_{Z'}^2\right)
\end{aligned} \tag{269}$$

• Self-Energy for Higgs (h)

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

$$\begin{aligned}
& -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^z}^2, m_{\eta^z}^2) \Gamma_{\check{h}_i, \eta^z, \eta^z} \Gamma_{\check{h}_j, \eta^z, \eta^z} \\
& - 2B_0(p^2, m_{\eta^z}^2, m_{\eta^{z'}}^2) \Gamma_{\check{h}_i, \eta^z, \eta^z} \Gamma_{\check{h}_j, \eta^z, \eta^z} - B_0(p^2, m_{\eta^{z'}}^2, m_{\eta^{z'}}^2) \Gamma_{\check{h}_i, \eta^{z'}, \eta^{z'}} \Gamma_{\check{h}_j, \eta^{z'}, \eta^{z'}} \\
& + 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 \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}^2 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^-} \\
& - 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_{\check{h}_j, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\check{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^R + \Gamma_{\check{h}_j, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\check{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_{\check{h}_j, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\check{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^L + \Gamma_{\check{h}_j, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\check{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^R \right) \\
& - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \tilde{\nu}_a^*, \tilde{\nu}_a} + \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2) \Gamma_{\check{h}_j, \tilde{\nu}_a^*, \tilde{\nu}_b}^* \Gamma_{\check{h}_i, \tilde{\nu}_a^*, \tilde{\nu}_b} \\
& - 6 \sum_{a=1}^3 m_{d_a} \sum_{b=1}^3 B_0(p^2, m_{d_a}^2, m_{d_b}^2) m_{d_b} \left(\Gamma_{\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) \\
& - \frac{1}{2} \sum_{a=1}^6 A_0(m_{A_a^0}^2) \Gamma_{\check{h}_i, \check{h}_j, A_a^0, A_a^0} - 3 \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \tilde{d}_a^*, \tilde{d}_a} \\
& - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \tilde{e}_a^*, \tilde{e}_a} - 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\check{h}_i, \check{h}_j, \tilde{u}_a^*, \tilde{u}_a} \\
& - \frac{1}{2} \sum_{a=1}^6 A_0(m_{h_a}^2) \Gamma_{\check{h}_i, \check{h}_j, h_a, h_a} + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{A_a^0}^2, m_{A_b^0}^2) \Gamma_{\check{h}_j, A_a^0, A_b^0}^* \Gamma_{\check{h}_i, A_a^0, A_b^0} \\
& + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2) \Gamma_{\check{h}_j, \tilde{d}_a^*, \tilde{d}_b}^* \Gamma_{\check{h}_i, \tilde{d}_a^*, \tilde{d}_b} + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{e}_a}^2, m_{\tilde{e}_b}^2) \Gamma_{\check{h}_j, \tilde{e}_a^*, \tilde{e}_b}^* \Gamma_{\check{h}_i, \tilde{e}_a^*, \tilde{e}_b}
\end{aligned}$$

$$\begin{aligned}
& + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{u}_a}^2, m_{\tilde{u}_b}^2) \Gamma_{\tilde{h}_j, \tilde{u}_a^*, \tilde{u}_b}^* \Gamma_{\tilde{h}_i, \tilde{u}_a^*, \tilde{u}_b} + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{h_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{h}_j, h_a, A_b^0}^* \Gamma_{\tilde{h}_i, h_a, A_b^0} \\
& + \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{h_a}^2, m_{h_b}^2) \Gamma_{\tilde{h}_j, h_a, h_b}^* \Gamma_{\tilde{h}_i, h_a, h_b} \\
& - \sum_{a=1}^9 m_{\tilde{\chi}_a^0} \sum_{b=1}^9 B_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_b^0} \left(\Gamma_{\tilde{h}_j, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^R + \Gamma_{\tilde{h}_j, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^L \right) \\
& + \frac{1}{2} \sum_{a=1}^9 \sum_{b=1}^9 G_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2) \left(\Gamma_{\tilde{h}_j, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^L + \Gamma_{\tilde{h}_j, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^R \right) \\
& + 2 \sum_{b=1}^2 \Gamma_{\tilde{h}_j, W^+, H_b^-}^* \Gamma_{\tilde{h}_i, W^+, H_b^-} F_0(p^2, m_{H_b^-}^2, m_{W^-}^2) + \sum_{b=1}^6 \Gamma_{\tilde{h}_j, Z, A_b^0}^* \Gamma_{\tilde{h}_i, Z, A_b^0} F_0(p^2, m_{A_b^0}^2, m_Z^2) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{h}_j, Z', A_b^0}^* \Gamma_{\tilde{h}_i, Z', A_b^0} F_0(p^2, m_{A_b^0}^2, m_{Z'}^2) \tag{270}
\end{aligned}$$

• **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) \\
& - \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, \tilde{\nu}_a^*, \tilde{\nu}_a} \\
& - 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)
\end{aligned}$$

$$\begin{aligned}
& -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, \tilde{e}_a, e_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{e}_a, e_b}^R + \Gamma_{\tilde{A}_j^0, \tilde{e}_a, e_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{e}_a, e_b}^L \right) \\
& + \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{e_a}^2, m_{e_b}^2) \left(\Gamma_{\tilde{A}_j^0, \tilde{e}_a, e_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{e}_a, e_b}^L + \Gamma_{\tilde{A}_j^0, \tilde{e}_a, e_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{e}_a, e_b}^R \right) \\
& -6 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^3 B_0(p^2, m_{u_a}^2, m_{u_b}^2) m_{u_b} \left(\Gamma_{\tilde{A}_j^0, \tilde{u}_a, u_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{u}_a, u_b}^R + \Gamma_{\tilde{A}_j^0, \tilde{u}_a, u_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{u}_a, u_b}^L \right) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 G_0(p^2, m_{u_a}^2, m_{u_b}^2) \left(\Gamma_{\tilde{A}_j^0, \tilde{u}_a, u_b}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{u}_a, u_b}^L + \Gamma_{\tilde{A}_j^0, \tilde{u}_a, u_b}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{u}_a, u_b}^R \right) \\
& - \frac{1}{2} \sum_{a=1}^6 A_0(m_{A_a^0}^2) \Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, A_a^0, A_a^0} - 3 \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, \tilde{d}_a^*, \tilde{d}_a} \\
& - \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, \tilde{e}_a^*, \tilde{e}_a} - 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{\tilde{A}_i^0, \tilde{A}_j^0, \tilde{u}_a^*, \tilde{u}_a} \\
& - \frac{1}{2} \sum_{a=1}^6 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}^6 \sum_{b=1}^6 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} \\
& + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{A}_j^0, \tilde{d}_a^*, \tilde{d}_b}^* \Gamma_{\tilde{A}_i^0, \tilde{d}_a^*, \tilde{d}_b} \\
& + \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{e}_a}^2, m_{\tilde{e}_b}^2) \Gamma_{\tilde{A}_j^0, \tilde{e}_a^*, \tilde{e}_b}^* \Gamma_{\tilde{A}_i^0, \tilde{e}_a^*, \tilde{e}_b} \\
& + 3 \sum_{a=1}^6 \sum_{b=1}^6 B_0(p^2, m_{\tilde{u}_a}^2, m_{\tilde{u}_b}^2) \Gamma_{\tilde{A}_j^0, \tilde{u}_a^*, \tilde{u}_b}^* \Gamma_{\tilde{A}_i^0, \tilde{u}_a^*, \tilde{u}_b} \\
& + \sum_{a=1}^6 \sum_{b=1}^6 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}^6 \sum_{b=1}^6 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} \\
& - \sum_{a=1}^9 m_{\tilde{\chi}_a^0} \sum_{b=1}^9 B_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_b^0} \left(\Gamma_{\tilde{A}_j^0, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^R + \Gamma_{\tilde{A}_j^0, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^L \right) \\
& + \frac{1}{2} \sum_{a=1}^9 \sum_{b=1}^9 G_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2) \left(\Gamma_{\tilde{A}_j^0, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{A}_i^0, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^L + \Gamma_{\tilde{A}_j^0, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{A}_i^0, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^R \right) \\
& + 2 \sum_{b=1}^2 \Gamma_{\tilde{A}_j^0, W^+, H_b^-}^* \Gamma_{\tilde{A}_i^0, W^+, H_b^-} F_0(p^2, m_{H_b^-}^2, m_{W^-}^2) + \sum_{b=1}^6 \Gamma_{\tilde{A}_j^0, Z, h_b}^* \Gamma_{\tilde{A}_i^0, Z, h_b} F_0(p^2, m_{h_b}^2, m_Z^2)
\end{aligned}$$

$$+ \sum_{b=1}^6 \Gamma_{\tilde{A}_j^0, Z', h_b}^* \Gamma_{\tilde{A}_i^0, Z', h_b} F_0(p^2, m_{h_b}^2, m_{Z'}^2) \quad (271)$$

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

$$\begin{aligned}
& -2 \sum_{a=1}^9 m_{\tilde{\chi}_a^0} \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^-}^2) m_{\tilde{\chi}_b^-} \left(\Gamma_{\tilde{H}_j^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{H}_i^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^R + \Gamma_{\tilde{H}_j^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{H}_i^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^L \right) \\
& + \sum_{a=1}^9 \sum_{b=1}^2 G_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^-}^2) \left(\Gamma_{\tilde{H}_j^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{H}_i^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^L + \Gamma_{\tilde{H}_j^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{H}_i^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^R \right) \\
& + \sum_{b=1}^2 \Gamma_{\tilde{H}_j^+, \gamma, H_b^-}^* \Gamma_{\tilde{H}_i^+, \gamma, H_b^-} F_0(p^2, m_{H_b^-}^2, 0) + \sum_{b=1}^2 \Gamma_{\tilde{H}_j^+, Z, H_b^-}^* \Gamma_{\tilde{H}_i^+, Z, H_b^-} F_0(p^2, m_{H_b^-}^2, m_Z^2) \\
& + \sum_{b=1}^2 \Gamma_{\tilde{H}_j^+, Z', H_b^-}^* \Gamma_{\tilde{H}_i^+, Z', H_b^-} F_0(p^2, m_{H_b^-}^2, m_{Z'}^2) + \sum_{b=1}^6 \Gamma_{\tilde{H}_j^+, W^-, A_b^0}^* \Gamma_{\tilde{H}_i^+, W^-, A_b^0} F_0(p^2, m_{A_b^0}^2, m_{W^-}^2) \\
& + \sum_{b=1}^6 \Gamma_{\tilde{H}_j^+, W^-, h_b}^* \Gamma_{\tilde{H}_i^+, W^-, h_b} F_0(p^2, m_{h_b}^2, m_{W^-}^2) \tag{272}
\end{aligned}$$

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

$$\begin{aligned}
\Sigma_{i,j}^S(p^2) = & +2 \sum_{a=1}^2 \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^0, H_a^+, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^0, H_a^+, \tilde{\chi}_b^-}^R \\
& + 2 \sum_{a=1}^3 \sum_{b=1}^3 B_0(p^2, m_{\nu_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{\nu}_a^*, \nu_b}^{L*} m_{\nu_b} \Gamma_{\tilde{\chi}_i^0, \tilde{\nu}_a^*, \nu_b}^R \\
& + 6 \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{d}_a^*, d_b}^{L*} m_{d_b} \Gamma_{\tilde{\chi}_i^0, \tilde{d}_a^*, d_b}^R \\
& + 2 \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{e_b}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{e}_a^*, e_b}^{L*} m_{e_b} \Gamma_{\tilde{\chi}_i^0, \tilde{e}_a^*, e_b}^R \\
& + 6 \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{u}_a^*, u_b}^{L*} m_{u_b} \Gamma_{\tilde{\chi}_i^0, \tilde{u}_a^*, u_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^9 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}_j^0, h_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^0, h_a, \tilde{\chi}_b^0}^R \\
& + \sum_{a=1}^9 m_{\tilde{\chi}_a^0} \sum_{b=1}^6 B_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{A_b^0}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{\chi}_a^0, A_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, \tilde{\chi}_a^0, A_b^0}^R \\
& - 8 \sum_{b=1}^2 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2) \right) \Gamma_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-}^L \\
& - 4 \sum_{b=1}^9 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2) \right) \Gamma_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0}^{R*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0}^L
\end{aligned}$$

$$-4 \sum_{b=1}^9 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{Z'}^2) \right) \Gamma_{\tilde{\chi}_j^0, Z', \tilde{\chi}_b^0}^{R*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^0, Z', \tilde{\chi}_b^0}^L \quad (273)$$

$$\begin{aligned} \Sigma_{i,j}^R(p^2) = & - \sum_{a=1}^2 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^0, H_a^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^0, H_a^+, \tilde{\chi}_b^-}^R \\ & - \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{\nu}_a^*, \nu_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{\nu}_a^*, \nu_b}^R \\ & - 3 \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{d}_a^*, d_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{d}_a^*, d_b}^R \\ & - \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{e}_a^*, e_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{e}_a^*, e_b}^R \\ & - 3 \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{u}_a^*, u_b}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{u}_a^*, u_b}^R \\ & - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}_j^0, h_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, h_a, \tilde{\chi}_b^0}^R \\ & - \frac{1}{2} \sum_{a=1}^9 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_a^0}^2, m_{A_b^0}^2) \Gamma_{\tilde{\chi}_j^0, \tilde{\chi}_a^0, A_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, \tilde{\chi}_a^0, A_b^0}^R \\ & - 2 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2) \Gamma_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-}^L - \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2) \Gamma_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0}^L \\ & - \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{Z'}^2) \Gamma_{\tilde{\chi}_j^0, Z', \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, Z', \tilde{\chi}_b^0}^L \quad (274) \end{aligned}$$

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

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^9 B_1 \left(p^2, m_{\tilde{\chi}_b^0}^2, m_{h_a}^2 \right) \Gamma_{\tilde{\chi}_j^0, h_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, h_a, \tilde{\chi}_b^0}^L \\
& -\frac{1}{2} \sum_{a=1}^9 \sum_{b=1}^6 B_1 \left(p^2, m_{\tilde{\chi}_a^0}^2, m_{A_b^0}^2 \right) \Gamma_{\tilde{\chi}_j^0, \tilde{\chi}_a^0, A_b^0}^{L*} \Gamma_{\tilde{\chi}_i^0, \tilde{\chi}_a^0, A_b^0}^L \\
& -2 \sum_{b=1}^2 B_1 \left(p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2 \right) \Gamma_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-}^R - \sum_{b=1}^9 B_1 \left(p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2 \right) \Gamma_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0}^R \\
& - \sum_{b=1}^9 B_1 \left(p^2, m_{\tilde{\chi}_b^0}^2, m_{Z'}^2 \right) \Gamma_{\tilde{\chi}_j^0, Z', \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^0, Z', \tilde{\chi}_b^0}^R
\end{aligned} \tag{275}$$

• 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}^6 B_0 \left(p^2, m_{\tilde{\chi}_a^-}^2, m_{A_b^0}^2 \right) \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}^9 B_0 \left(p^2, m_{\tilde{\chi}_b^0}^2, m_{H_a^-}^2 \right) \Gamma_{\tilde{\chi}_j^+, H_a^-, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^+, H_a^-, \tilde{\chi}_b^0}^R \\
& + \sum_{a=1}^3 \sum_{b=1}^3 B_0 \left(p^2, m_{e_b}^2, m_{\tilde{\nu}_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a^*, e_b}^{L*} m_{e_b} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a^*, e_b}^R \\
& + 3 \sum_{a=1}^3 m_{u_a} \sum_{b=1}^6 B_0 \left(p^2, m_{u_a}^2, m_{\tilde{d}_b}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a, \tilde{d}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a, \tilde{d}_b}^R \\
& + \sum_{a=1}^3 m_{\nu_a} \sum_{b=1}^6 B_0 \left(p^2, m_{\nu_a}^2, m_{\tilde{e}_b}^2 \right) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a, \tilde{e}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a, \tilde{e}_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^2 B_0 \left(p^2, m_{\tilde{\chi}_b^-}^2, m_{h_a}^2 \right) \Gamma_{\tilde{\chi}_j^+, h_a, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, h_a, \tilde{\chi}_b^-}^R \\
& + 3 \sum_{a=1}^6 \sum_{b=1}^3 B_0 \left(p^2, m_{\tilde{d}_b}^2, m_{\tilde{u}_a}^2 \right) \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 \\
& - 4 \sum_{b=1}^2 \left(-\frac{1}{2} \text{rMS} + B_0 \left(p^2, m_{\tilde{\chi}_b^-}^2, 0 \right) \right) \Gamma_{\tilde{\chi}_j^+, \gamma, \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, \gamma, \tilde{\chi}_b^-}^L \\
& - 4 \sum_{b=1}^2 \left(-\frac{1}{2} \text{rMS} + B_0 \left(p^2, m_{\tilde{\chi}_b^-}^2, m_Z^2 \right) \right) \Gamma_{\tilde{\chi}_j^+, Z, \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, Z, \tilde{\chi}_b^-}^L \\
& - 4 \sum_{b=1}^2 \left(-\frac{1}{2} \text{rMS} + B_0 \left(p^2, m_{\tilde{\chi}_b^-}^2, m_{Z'}^2 \right) \right) \Gamma_{\tilde{\chi}_j^+, Z', \tilde{\chi}_b^-}^{R*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{\chi}_i^+, Z', \tilde{\chi}_b^-}^L
\end{aligned}$$

$$-4 \sum_{b=1}^9 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2) \right) \Gamma_{\tilde{\chi}_j^+, W^-, \tilde{\chi}_b^0}^{R*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{\chi}_i^+, W^-, \tilde{\chi}_b^0}^L \quad (276)$$

$$\begin{aligned} \Sigma_{i,j}^R(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^6 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}^9 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}^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{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{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{\nu_a}^2, m_{\tilde{e}_b}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a, \tilde{e}_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a, \tilde{e}_b}^R \\ & -\frac{1}{2} \sum_{a=1}^6 \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}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a^*, d_b}^{R*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a^*, d_b}^R - \sum_{b=1}^2 B_1(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}^9 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 \quad (277) \end{aligned}$$

$$\begin{aligned} \Sigma_{i,j}^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_a^-}^2, m_{A_b^0}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{\chi}_a^-, A_b^0}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\chi}_a^-, A_b^0}^L \\ & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{H_a^-}^2) \Gamma_{\tilde{\chi}_j^+, H_a^-, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^+, H_a^-, \tilde{\chi}_b^0}^L \\ & -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a^*, e_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a^*, e_b}^L \\ & -\frac{3}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{u_a}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a, \tilde{d}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a, \tilde{d}_b}^L \\ & -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{\nu_a}^2, m_{\tilde{e}_b}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a, \tilde{e}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a, \tilde{e}_b}^L \end{aligned}$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{h_a}^2) \Gamma_{\tilde{\chi}_j^+, h_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^+, h_a, \tilde{\chi}_b^-}^L \\
& -\frac{3}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a^*, d_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a^*, d_b}^L - \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, 0) \Gamma_{\tilde{\chi}_j^+, \gamma, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, \gamma, \tilde{\chi}_b^-}^R \\
& -\sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_Z^2) \Gamma_{\tilde{\chi}_j^+, Z, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, Z, \tilde{\chi}_b^-}^R - \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{Z'}^2) \Gamma_{\tilde{\chi}_j^+, Z', \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, Z', \tilde{\chi}_b^-}^R \\
& -\sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2) \Gamma_{\tilde{\chi}_j^+, W^-, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^+, W^-, \tilde{\chi}_b^0}^R
\end{aligned} \tag{278}$$

• Self-Energy for Leptons (e)

$$\begin{aligned}
\Sigma_{i,j}^S(p^2) = & + \sum_{a=1}^2 \sum_{b=1}^3 B_0(p^2, m_{\nu_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{L*} m_{\nu_b} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^R \\
& + \sum_{a=1}^3 \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^R \\
& + \sum_{a=1}^3 m_{e_a} \sum_{b=1}^6 B_0(p^2, m_{e_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{e}_j, e_a, A_b^0}^{L*} \Gamma_{\tilde{e}_i, e_a, A_b^0}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{L*} m_{e_b} \Gamma_{\tilde{e}_i, h_a, e_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^9 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^R \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, 0) \right) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, \gamma, e_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{\nu_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{e}_i, W^-, \nu_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, m_Z^2) \right) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, Z, e_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{e_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{e}_j, Z', e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, Z', e_b}^L \\
\Sigma_{i,j}^R(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{R*} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^R
\end{aligned} \tag{279}$$

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^R \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{e_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{e}_j, e_a, A_b^0}^{R*} \Gamma_{\tilde{e}_i, e_a, A_b^0}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{R*} \Gamma_{\tilde{e}_i, h_a, e_b}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^R - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, 0) \Gamma_{\tilde{e}_j, \gamma, e_b}^{L*} \Gamma_{\tilde{e}_i, \gamma, e_b}^L \\
& -\sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{W^-}^2) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{L*} \Gamma_{\tilde{e}_i, W^-, \nu_b}^L - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_Z^2) \Gamma_{\tilde{e}_j, Z, e_b}^{L*} \Gamma_{\tilde{e}_i, Z, e_b}^L \\
& -\sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{Z'}^2) \Gamma_{\tilde{e}_j, Z', e_b}^{L*} \Gamma_{\tilde{e}_i, Z', e_b}^L \tag{280}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) = & -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{L*} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2) \Gamma_{\tilde{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^L \\
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{e_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{e}_j, e_a, A_b^0}^{L*} \Gamma_{\tilde{e}_i, e_a, A_b^0}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{h_a}^2) \Gamma_{\tilde{e}_j, h_a, e_b}^{L*} \Gamma_{\tilde{e}_i, h_a, e_b}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2) \Gamma_{\tilde{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^L - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, 0) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} \Gamma_{\tilde{e}_i, \gamma, e_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{\nu_b}^2, m_{W^-}^2) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} \Gamma_{\tilde{e}_i, W^-, \nu_b}^R - \sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_Z^2) \Gamma_{\tilde{e}_j, Z, e_b}^{R*} \Gamma_{\tilde{e}_i, Z, e_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{e_b}^2, m_{Z'}^2) \Gamma_{\tilde{e}_j, Z', e_b}^{R*} \Gamma_{\tilde{e}_i, Z', e_b}^R \tag{281}
\end{aligned}$$

• Self-Energy for Down-Quarks (d)

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

$$\begin{aligned}
& + \sum_{a=1}^3 m_{d_a} \sum_{b=1}^6 B_0(p^2, m_{d_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{d}_j, d_a, A_b^0}^{L*} \Gamma_{\tilde{d}_i, d_a, A_b^0}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^2 B_0(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\tilde{d}_j, h_a, d_b}^{L*} m_{d_b} \Gamma_{\tilde{d}_i, h_a, d_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^9 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^R \\
& + \frac{4}{3} m_{\tilde{g}} \sum_{a=1}^6 B_0(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{g}_1}^R - \frac{16}{3} \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, g, d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, g, d_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, 0) \right) \Gamma_{\tilde{d}_j, \gamma, d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, \gamma, d_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{d}_j, W^-, u_b}^{R*} m_{u_b} \Gamma_{\tilde{d}_i, W^-, u_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_Z^2) \right) \Gamma_{\tilde{d}_j, Z, d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, Z, d_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{d}_j, Z', d_b}^{R*} m_{d_b} \Gamma_{\tilde{d}_i, Z', d_b}^L \tag{282}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^R(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{d}_j, H_a^-, u_b}^{R*} \Gamma_{\tilde{d}_i, H_a^-, u_b}^R \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{d_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{d}_j, d_a, A_b^0}^{R*} \Gamma_{\tilde{d}_i, d_a, A_b^0}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\tilde{d}_j, h_a, d_b}^{R*} \Gamma_{\tilde{d}_i, h_a, d_b}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^R \\
& - \frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{g}_1}^{R*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{g}_1}^R - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, 0) \Gamma_{\tilde{d}_j, g, d_b}^{L*} \Gamma_{\tilde{d}_i, g, d_b}^L
\end{aligned}$$

$$\begin{aligned}
& - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, 0) \Gamma_{\tilde{d}_j, \gamma, d_b}^{L*} \Gamma_{\tilde{d}_i, \gamma, d_b}^L - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{W^-}^2) \Gamma_{\tilde{d}_j, W^-, u_b}^{L*} \Gamma_{\tilde{d}_i, W^-, u_b}^L \\
& - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_Z^2) \Gamma_{\tilde{d}_j, Z, d_b}^{L*} \Gamma_{\tilde{d}_i, Z, d_b}^L - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{Z'}^2) \Gamma_{\tilde{d}_j, Z', d_b}^{L*} \Gamma_{\tilde{d}_i, Z', d_b}^L
\end{aligned} \tag{283}$$

$$\begin{aligned}
\Sigma_{i,j}^L(p^2) = & - \frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{d}_j, H_a^-, u_b}^{L*} \Gamma_{\tilde{d}_i, H_a^-, u_b}^L \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{d_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{d}_j, d_a, A_b^0}^{L*} \Gamma_{\tilde{d}_i, d_a, A_b^0}^L \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^2 B_1(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^L \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{h_a}^2) \Gamma_{\tilde{d}_j, h_a, d_b}^{L*} \Gamma_{\tilde{d}_i, h_a, d_b}^L \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^L \\
& - \frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{d}_j, \tilde{d}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{d}_i, \tilde{d}_a, \tilde{g}_1}^L - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, 0) \Gamma_{\tilde{d}_j, g, d_b}^{R*} \Gamma_{\tilde{d}_i, g, d_b}^R \\
& - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, 0) \Gamma_{\tilde{d}_j, \gamma, d_b}^{R*} \Gamma_{\tilde{d}_i, \gamma, d_b}^R - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{W^-}^2) \Gamma_{\tilde{d}_j, W^-, u_b}^{R*} \Gamma_{\tilde{d}_i, W^-, u_b}^R \\
& - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_Z^2) \Gamma_{\tilde{d}_j, Z, d_b}^{R*} \Gamma_{\tilde{d}_i, Z, d_b}^R - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{Z'}^2) \Gamma_{\tilde{d}_j, Z', d_b}^{R*} \Gamma_{\tilde{d}_i, Z', d_b}^R
\end{aligned} \tag{284}$$

• **Self-Energy for Up-Quarks (u)**

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

$$\begin{aligned}
& + \sum_{a=1}^6 \sum_{b=1}^9 B_0(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{\chi}_b^0}^R \\
& + \frac{4}{3} m_{\tilde{g}} \sum_{a=1}^6 B_0(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{g}_1}^R - \frac{16}{3} \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, g, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, g, u_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, 0) \right) \Gamma_{\tilde{u}_j, \gamma, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, \gamma, u_b}^L - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_Z^2) \right) \Gamma_{\tilde{u}_j, Z, u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, Z, u_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{u_b}^2, m_{Z'}^2) \right) \Gamma_{\tilde{u}_j, Z', u_b}^{R*} m_{u_b} \Gamma_{\tilde{u}_i, Z', u_b}^L \\
& - 4 \sum_{b=1}^3 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{d_b}^2, m_{W^-}^2) \right) \Gamma_{\tilde{u}_j, W^+, d_b}^{R*} m_{d_b} \Gamma_{\tilde{u}_i, W^+, d_b}^L \tag{285}
\end{aligned}$$

$$\begin{aligned}
\Sigma_{i,j}^R(p^2) &= -\frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{H_a^-}^2) \Gamma_{\tilde{u}_j, H_a^+, d_b}^{R*} \Gamma_{\tilde{u}_i, H_a^+, d_b}^R \\
& - \frac{1}{2} \sum_{a=1}^2 \sum_{b=1}^6 B_1(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{d}_b}^2) \Gamma_{\tilde{u}_j, \tilde{\chi}_a^+, \tilde{d}_b}^{R*} \Gamma_{\tilde{u}_i, \tilde{\chi}_a^+, \tilde{d}_b}^R \\
& - \frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{u_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{u}_j, u_a, A_b^0}^{R*} \Gamma_{\tilde{u}_i, u_a, A_b^0}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{R*} \Gamma_{\tilde{u}_i, h_a, u_b}^R \\
& - \frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{\chi}_b^0}^R \\
& - \frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{g}_1}^{R*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{g}_1}^R - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, g, u_b}^{L*} \Gamma_{\tilde{u}_i, g, u_b}^L \\
& - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, \gamma, u_b}^{L*} \Gamma_{\tilde{u}_i, \gamma, u_b}^L - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_Z^2) \Gamma_{\tilde{u}_j, Z, u_b}^{L*} \Gamma_{\tilde{u}_i, Z, u_b}^L \\
& - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{Z'}^2) \Gamma_{\tilde{u}_j, Z', u_b}^{L*} \Gamma_{\tilde{u}_i, Z', u_b}^L - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{W^-}^2) \Gamma_{\tilde{u}_j, W^+, d_b}^{L*} \Gamma_{\tilde{u}_i, W^+, d_b}^L \tag{286}
\end{aligned}$$

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

$$\begin{aligned}
& -\frac{1}{2} \sum_{a=1}^3 \sum_{b=1}^6 B_1(p^2, m_{u_a}^2, m_{A_b^0}^2) \Gamma_{\tilde{u}_j, u_a, A_b^0}^{L*} \Gamma_{\tilde{u}_i, u_a, A_b^0}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{h_a}^2) \Gamma_{\tilde{u}_j, h_a, u_b}^{L*} \Gamma_{\tilde{u}_i, h_a, u_b}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^9 B_1(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{\chi}_b^0}^L \\
& -\frac{2}{3} \sum_{a=1}^6 B_1(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{u}_j, \tilde{u}_a, \tilde{g}_1}^{L*} \Gamma_{\tilde{u}_i, \tilde{u}_a, \tilde{g}_1}^L - \frac{4}{3} \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, g, u_b}^{R*} \Gamma_{\tilde{u}_i, g, u_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{u_b}^2, 0) \Gamma_{\tilde{u}_j, \gamma, u_b}^{R*} \Gamma_{\tilde{u}_i, \gamma, u_b}^R - \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_Z^2) \Gamma_{\tilde{u}_j, Z, u_b}^{R*} \Gamma_{\tilde{u}_i, Z, u_b}^R \\
& -\sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{Z'}^2) \Gamma_{\tilde{u}_j, Z', u_b}^{R*} \Gamma_{\tilde{u}_i, Z', u_b}^R - \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{W^-}^2) \Gamma_{\tilde{u}_j, W^+, d_b}^{R*} \Gamma_{\tilde{u}_i, W^+, d_b}^R
\end{aligned} \tag{287}$$

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

$$\begin{aligned}
\Sigma^S(p^2) = & + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{g}_j, \tilde{d}_a^*, d_b}^{L*} m_{d_b} \Gamma_{\tilde{g}_i, \tilde{d}_a^*, d_b}^R \\
& + \sum_{a=1}^6 \sum_{b=1}^3 B_0(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{g}_j, \tilde{u}_a^*, u_b}^{L*} m_{u_b} \Gamma_{\tilde{g}_i, \tilde{u}_a^*, u_b}^R - 12 \left(-\frac{1}{2} \text{rMS} + B_0(p^2, m_{\tilde{g}}^2, 0) \right) \Gamma_{\tilde{g}_j, g, \tilde{g}_1}^{R*} m_{\tilde{g}} \Gamma_{\tilde{g}_i, g, \tilde{g}_1}^L
\end{aligned} \tag{288}$$

$$\begin{aligned}
\Sigma^R(p^2) = & -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{g}_j, \tilde{d}_a^*, d_b}^{R*} \Gamma_{\tilde{g}_i, \tilde{d}_a^*, d_b}^R \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{g}_j, \tilde{u}_a^*, u_b}^{R*} \Gamma_{\tilde{g}_i, \tilde{u}_a^*, u_b}^R - 3B_1(p^2, m_{\tilde{g}}^2, 0) \Gamma_{\tilde{g}_j, g, \tilde{g}_1}^{L*} \Gamma_{\tilde{g}_i, g, \tilde{g}_1}^L
\end{aligned} \tag{289}$$

$$\begin{aligned}
\Sigma^L(p^2) = & -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2) \Gamma_{\tilde{g}_j, \tilde{d}_a^*, d_b}^{L*} \Gamma_{\tilde{g}_i, \tilde{d}_a^*, d_b}^L \\
& -\frac{1}{2} \sum_{a=1}^6 \sum_{b=1}^3 B_1(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2) \Gamma_{\tilde{g}_j, \tilde{u}_a^*, u_b}^{L*} \Gamma_{\tilde{g}_i, \tilde{u}_a^*, u_b}^L - 3B_1(p^2, m_{\tilde{g}}^2, 0) \Gamma_{\tilde{g}_j, g, \tilde{g}_1}^{R*} \Gamma_{\tilde{g}_i, g, \tilde{g}_1}^R
\end{aligned} \tag{290}$$

• **Self-Energy for Z-Boson (Z)**

$$\begin{aligned}
\Pi(p^2) = & + |\Gamma_{Z, \eta^-, \eta^-}|^2 B_{00}(p^2, m_{\eta^-}^2, m_{\eta^-}^2) + |\Gamma_{Z, \eta^+, \eta^+}|^2 B_{00}(p^2, m_{\eta^+}^2, m_{\eta^+}^2) \\
& - |\Gamma_{Z, W^+, W^-}|^2 \left(10B_{00}(p^2, m_{W^-}^2, m_{W^-}^2) + 2A_0(m_{W^-}^2) - 2\text{rMS} \left(2m_{W^-}^2 - \frac{1}{3}p^2 \right) + B_0(p^2, m_{W^-}^2, m_{W^-}^2) (2m_{W^-}^2 + 4p^2) \right)
\end{aligned}$$

$$\begin{aligned}
& + \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] \\
& + \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{Z,Z,\tilde{\nu}_a^*,\tilde{\nu}_a} - 4 \sum_{a=1}^3 \sum_{b=1}^3 |\Gamma_{Z,\tilde{\nu}_a^*,\tilde{\nu}_b}|^2 B_{00}(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z,\tilde{d}_a,d_b}^L|^2 + |\Gamma_{Z,\tilde{d}_a,d_b}^R|^2 \right) H_0(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2) m_{\tilde{d}_a} m_{\tilde{d}_b} \Re(\Gamma_{Z,\tilde{d}_a,d_b}^{L*} \Gamma_{Z,\tilde{d}_a,d_b}^R) \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z,\tilde{e}_a,e_b}^L|^2 + |\Gamma_{Z,\tilde{e}_a,e_b}^R|^2 \right) H_0(p^2, m_{\tilde{e}_a}^2, m_{\tilde{e}_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{e}_a}^2, m_{\tilde{e}_b}^2) m_{\tilde{e}_a} m_{\tilde{e}_b} \Re(\Gamma_{Z,\tilde{e}_a,e_b}^{L*} \Gamma_{Z,\tilde{e}_a,e_b}^R) \right] \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z,\tilde{u}_a,u_b}^L|^2 + |\Gamma_{Z,\tilde{u}_a,u_b}^R|^2 \right) H_0(p^2, m_{\tilde{u}_a}^2, m_{\tilde{u}_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{u}_a}^2, m_{\tilde{u}_b}^2) m_{\tilde{u}_a} m_{\tilde{u}_b} \Re(\Gamma_{Z,\tilde{u}_a,u_b}^{L*} \Gamma_{Z,\tilde{u}_a,u_b}^R) \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z,\tilde{\nu}_a,\nu_b}^L|^2 + |\Gamma_{Z,\tilde{\nu}_a,\nu_b}^R|^2 \right) H_0(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2) m_{\tilde{\nu}_a} m_{\tilde{\nu}_b} \Re(\Gamma_{Z,\tilde{\nu}_a,\nu_b}^{L*} \Gamma_{Z,\tilde{\nu}_a,\nu_b}^R) \right] \\
& + \frac{1}{2} \sum_{a=1}^6 A_0(m_{A_a^0}^2) \Gamma_{Z,Z,A_a^0,A_a^0} + 3 \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{Z,Z,\tilde{d}_a^*,\tilde{d}_a} + \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{Z,Z,\tilde{e}_a^*,\tilde{e}_a} \\
& + 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{Z,Z,\tilde{u}_a^*,\tilde{u}_a} + \frac{1}{2} \sum_{a=1}^6 A_0(m_{h_a}^2) \Gamma_{Z,Z,h_a,h_a} \\
& - 4 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z,h_a,A_b^0}|^2 B_{00}(p^2, m_{A_b^0}^2, m_{h_a}^2) - 12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z,\tilde{d}_a^*,\tilde{d}_b}|^2 B_{00}(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2) \\
& - 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) \\
& + \frac{1}{2} \sum_{a=1}^9 \sum_{b=1}^9 \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]
\end{aligned}$$

$$\begin{aligned}
& + 2 \sum_{b=1}^2 |\Gamma_{Z,W^+,H_b^-}|^2 B_0(p^2, m_{W^-}^2, m_{H_b^-}^2) + \sum_{b=1}^6 |\Gamma_{Z,Z,h_b}|^2 B_0(p^2, m_Z^2, m_{h_b}^2) \\
& + \sum_{b=1}^6 |\Gamma_{Z,Z',h_b}|^2 B_0(p^2, m_{Z'}^2, m_{h_b}^2) + 2\text{rMS} m_{W^-}^2 \Gamma_{Z,Z,W^+,W^-}^1 - A_0(m_{W^-}^2) \left(4\Gamma_{Z,Z,W^+,W^-}^1 + \Gamma_{Z,Z,W^+,W^-}^2 + \Gamma_{Z,Z,W^+,W^-}^3 \right)
\end{aligned} \tag{291}$$

• **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 \left(\Gamma_{Z',\tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{Z',\tilde{\chi}_a^+, \tilde{\chi}_b^-}^R \right) \right] \\
& + \sum_{a=1}^3 A_0(m_{\tilde{\nu}_a}^2) \Gamma_{Z',Z',\tilde{\nu}_a^*, \tilde{\nu}_a} - 4 \sum_{a=1}^3 \sum_{b=1}^3 |\Gamma_{Z',\tilde{\nu}_a^*, \tilde{\nu}_b}|^2 B_{00}(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2) \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z',\tilde{d}_a, d_b}^L|^2 + |\Gamma_{Z',\tilde{d}_a, d_b}^R|^2 \right) H_0(p^2, m_{\tilde{d}_a}^2, m_{d_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{d}_a}^2, m_{d_b}^2) m_{\tilde{d}_a} m_{d_b} \Re \left(\Gamma_{Z',\tilde{d}_a, d_b}^{L*} \Gamma_{Z',\tilde{d}_a, d_b}^R \right) \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z',\tilde{e}_a, e_b}^L|^2 + |\Gamma_{Z',\tilde{e}_a, e_b}^R|^2 \right) H_0(p^2, m_{\tilde{e}_a}^2, m_{e_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{e}_a}^2, m_{e_b}^2) m_{\tilde{e}_a} m_{e_b} \Re \left(\Gamma_{Z',\tilde{e}_a, e_b}^{L*} \Gamma_{Z',\tilde{e}_a, e_b}^R \right) \right] \\
& + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z',\tilde{u}_a, u_b}^L|^2 + |\Gamma_{Z',\tilde{u}_a, u_b}^R|^2 \right) H_0(p^2, m_{\tilde{u}_a}^2, m_{u_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{u}_a}^2, m_{u_b}^2) m_{\tilde{u}_a} m_{u_b} \Re \left(\Gamma_{Z',\tilde{u}_a, u_b}^{L*} \Gamma_{Z',\tilde{u}_a, u_b}^R \right) \right] \\
& + \sum_{a=1}^3 \sum_{b=1}^3 \left[\left(|\Gamma_{Z',\tilde{\nu}_a, \nu_b}^L|^2 + |\Gamma_{Z',\tilde{\nu}_a, \nu_b}^R|^2 \right) H_0(p^2, m_{\tilde{\nu}_a}^2, m_{\nu_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{\nu}_a}^2, m_{\nu_b}^2) m_{\tilde{\nu}_a} m_{\nu_b} \Re \left(\Gamma_{Z',\tilde{\nu}_a, \nu_b}^{L*} \Gamma_{Z',\tilde{\nu}_a, \nu_b}^R \right) \right] \\
& + \frac{1}{2} \sum_{a=1}^6 A_0(m_{A_a^0}^2) \Gamma_{Z',Z',A_a^0,A_a^0} + 3 \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{Z',Z',\tilde{d}_a^*, \tilde{d}_a} + \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{Z',Z',\tilde{e}_a^*, \tilde{e}_a}
\end{aligned}$$

$$\begin{aligned}
& + 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{Z', Z', \tilde{u}_a^*, \tilde{u}_a} + \frac{1}{2} \sum_{a=1}^6 A_0(m_{h_a}^2) \Gamma_{Z', Z', h_a, h_a} \\
& - 4 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z', h_a, A_b^0}|^2 B_{00}(p^2, m_{A_b^0}^2, m_{h_a}^2) - 12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z', \tilde{d}_a^*, \tilde{d}_b}|^2 B_{00}(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2) \\
& - 4 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z', \tilde{e}_a^*, \tilde{e}_b}|^2 B_{00}(p^2, m_{\tilde{e}_a}^2, m_{\tilde{e}_b}^2) - 12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{Z', \tilde{u}_a^*, \tilde{u}_b}|^2 B_{00}(p^2, m_{\tilde{u}_a}^2, m_{\tilde{u}_b}^2) \\
& + \frac{1}{2} \sum_{a=1}^9 \sum_{b=1}^9 \left[(|\Gamma_{Z', \tilde{\chi}_a^0, \tilde{\chi}_b^0}^L|^2 + |\Gamma_{Z', \tilde{\chi}_a^0, \tilde{\chi}_b^0}^R|^2) H_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2) m_{\tilde{\chi}_a^0} m_{\tilde{\chi}_b^0} \Re(\Gamma_{Z', \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L*} \Gamma_{Z', \tilde{\chi}_a^0, \tilde{\chi}_b^0}^R) \right] \\
& + 2 \sum_{b=1}^2 |\Gamma_{Z', W^+, H_b^-}|^2 B_0(p^2, m_{W^-}^2, m_{H_b^-}^2) + \sum_{b=1}^6 |\Gamma_{Z', Z, h_b}|^2 B_0(p^2, m_Z^2, m_{h_b}^2) \\
& + \sum_{b=1}^6 |\Gamma_{Z', Z', h_b}|^2 B_0(p^2, m_{Z'}^2, m_{h_b}^2) + 2\text{rMS} m_{W^-}^2 \Gamma_{Z', Z', W^+, W^-}^1 - A_0(m_{W^-}^2) (4\Gamma_{Z', Z', W^+, W^-}^1 + \Gamma_{Z', Z', W^+, W^-}^2 + \Gamma_{Z', Z', W^+, W^-}^3)
\end{aligned} \tag{292}$$

• **Self-Energy for W-Boson (W^-)**

$$\begin{aligned}
\Pi(p^2) = & -12 \sum_{a=1}^6 \sum_{b=1}^6 |\Gamma_{W^+, \tilde{u}_a^*, \tilde{d}_b}|^2 B_{00}(p^2, m_{\tilde{d}_b}^2, m_{\tilde{u}_a}^2) + 2\text{rMS} m_{W^-}^2 \Gamma_{W^-, W^+, W^+, W^-}^1 + 3 \sum_{a=1}^3 \sum_{b=1}^3 \left[(|\Gamma_{W^+, \tilde{u}_a, d_b}^L|^2 + |\Gamma_{W^+, \tilde{u}_a, d_b}^R|^2) H_0(p^2, m_{\tilde{u}_a}^2, m_{d_b}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{u}_a}^2, m_{d_b}^2) m_{d_b} m_{\tilde{u}_a} \Re(\Gamma_{W^+, \tilde{u}_a, d_b}^{L*} \Gamma_{W^+, \tilde{u}_a, d_b}^R) \right] + 3 \sum_{a=1}^6 A_0(m_{\tilde{d}_a}^2) \Gamma_{W^-, W^+, \tilde{d}_a^*, \tilde{d}_a} + 3 \sum_{a=1}^6 A_0(m_{\tilde{u}_a}^2) \Gamma_{W^-, W^+, \tilde{u}_a^*, \tilde{u}_a} \\
& + 4B_0(p^2, m_{\nu_a}^2, m_{e_b}^2) m_{e_b} m_{\nu_a} \Re(\Gamma_{W^+, \tilde{\nu}_a, e_b}^{L*} \Gamma_{W^+, \tilde{\nu}_a, e_b}^R) + \sum_{a=1}^6 A_0(m_{\tilde{e}_a}^2) \Gamma_{W^-, W^+, \tilde{e}_a^*, \tilde{e}_a} + \sum_{a=1}^9 \sum_{b=1}^2 \left[(|\Gamma_{W^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^L|^2 + |\Gamma_{W^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^R|^2) H_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^-}^2) \right. \\
& \left. + 4B_0(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^-}^2) m_{\tilde{\chi}_b^-} m_{\tilde{\chi}_a^0} \Re(\Gamma_{W^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^{L*} \Gamma_{W^+, \tilde{\chi}_a^0, \tilde{\chi}_b^-}^R) \right] + \sum_{b=1}^2 |\Gamma_{W^+, \gamma, H_b^-}|^2 B_0(p^2, 0, m_{H_b^-}^2) + \sum_{b=1}^2 |\Gamma_{W^+, Z, H_b^-}|^2 B_0(p^2, m_Z^2, m_{H_b^-}^2)
\end{aligned} \tag{293}$$

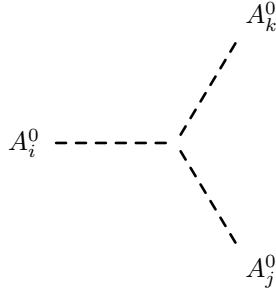
8.2 Tadpoles

$$\begin{aligned}
\delta t_h^{(1)} = & + A_0(m_{\eta^-}^2) \Gamma_{\tilde{h}_i, \eta^-, \eta^-} + A_0(m_{\eta^+}^2) \Gamma_{\tilde{h}_i, \eta^+, \eta^+} + A_0(m_{\eta^Z}^2) \Gamma_{\tilde{h}_i, \eta^Z, \eta^Z} \\
& + A_0(m_{\eta^{Z'}}^2) \Gamma_{\tilde{h}_i, \eta^{Z'}, \eta^{Z'}} + 4\Gamma_{\tilde{h}_i, W^+, W^-} \left(-\frac{1}{2} \text{rMS} m_{W^-}^2 + A_0(m_{W^-}^2) \right) + 2\Gamma_{\tilde{h}_i, Z, Z} \left(-\frac{1}{2} \text{rMS} m_Z^2 + A_0(m_Z^2) \right) \\
& + 2\Gamma_{\tilde{h}_i, Z', Z'} \left(-\frac{1}{2} \text{rMS} m_{Z'}^2 + A_0(m_{Z'}^2) \right) - \sum_{a=1}^2 A_0(m_{H_a^-}^2) \Gamma_{\tilde{h}_i, H_a^+, H_a^-}
\end{aligned}$$

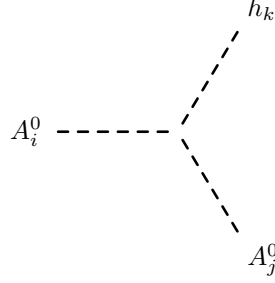
$$\begin{aligned}
& + 2 \sum_{a=1}^2 A_0 \left(m_{\tilde{\chi}_a^-}^2 \right) m_{\tilde{\chi}_a^-} \left(\Gamma_{\tilde{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_a^-}^L + \Gamma_{\tilde{h}_i, \tilde{\chi}_a^+, \tilde{\chi}_a^-}^R \right) - \sum_{a=1}^3 A_0 \left(m_{\tilde{\nu}_a}^2 \right) \Gamma_{\tilde{h}_i, \tilde{\nu}_a^*, \tilde{\nu}_a} \\
& + 6 \sum_{a=1}^3 A_0 \left(m_{d_a}^2 \right) m_{d_a} \left(\Gamma_{\tilde{h}_i, \bar{d}_a, d_a}^L + \Gamma_{\tilde{h}_i, \bar{d}_a, d_a}^R \right) \\
& + 2 \sum_{a=1}^3 A_0 \left(m_{e_a}^2 \right) m_{e_a} \left(\Gamma_{\tilde{h}_i, \bar{e}_a, e_a}^L + \Gamma_{\tilde{h}_i, \bar{e}_a, e_a}^R \right) \\
& + 6 \sum_{a=1}^3 A_0 \left(m_{u_a}^2 \right) m_{u_a} \left(\Gamma_{\tilde{h}_i, \bar{u}_a, u_a}^L + \Gamma_{\tilde{h}_i, \bar{u}_a, u_a}^R \right) - \frac{1}{2} \sum_{a=1}^6 A_0 \left(m_{A_a^0}^2 \right) \Gamma_{\tilde{h}_i, A_a^0, A_a^0} \\
& - 3 \sum_{a=1}^6 A_0 \left(m_{\tilde{d}_a}^2 \right) \Gamma_{\tilde{h}_i, \tilde{d}_a^*, \tilde{d}_a} - \sum_{a=1}^6 A_0 \left(m_{\tilde{e}_a}^2 \right) \Gamma_{\tilde{h}_i, \tilde{e}_a^*, \tilde{e}_a} - 3 \sum_{a=1}^6 A_0 \left(m_{\tilde{u}_a}^2 \right) \Gamma_{\tilde{h}_i, \tilde{u}_a^*, \tilde{u}_a} \\
& - \frac{1}{2} \sum_{a=1}^6 A_0 \left(m_{h_a}^2 \right) \Gamma_{\tilde{h}_i, h_a, h_a} + \sum_{a=1}^9 A_0 \left(m_{\tilde{\chi}_a^0}^2 \right) m_{\tilde{\chi}_a^0} \left(\Gamma_{\tilde{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_a^0}^L + \Gamma_{\tilde{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_a^0}^R \right)
\end{aligned} \tag{294}$$

9 Interactions for eigenstates 'EWSB'

9.1 Three Scalar-Interaction

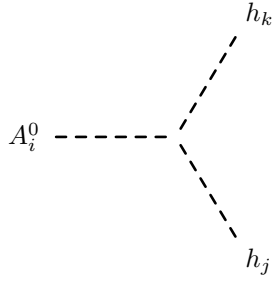


$$\begin{aligned}
& \frac{1}{6} \frac{1}{\sqrt{2}} \left(-3T_\lambda^* \left(Z_{i3}^{A,*} \left(Z_{j1}^{A,*} Z_{k2}^{A,*} + Z_{j2}^{A,*} Z_{k1}^{A,*} \right) + Z_{i2}^{A,*} \left(Z_{j1}^{A,*} Z_{k3}^{A,*} + Z_{j3}^{A,*} Z_{k1}^{A,*} \right) \right. \right. \\
& \quad \left. \left. + Z_{i1}^{A,*} \left(Z_{j2}^{A,*} Z_{k3}^{A,*} + Z_{j3}^{A,*} Z_{k2}^{A,*} \right) \right) \right. \\
& \quad \left. + T_\kappa^* \left(Z_{i6}^{A,*} \left(Z_{j4}^{A,*} Z_{k5}^{A,*} + Z_{j5}^{A,*} Z_{k4}^{A,*} \right) + Z_{i5}^{A,*} \left(Z_{j4}^{A,*} Z_{k6}^{A,*} + Z_{j6}^{A,*} Z_{k4}^{A,*} \right) \right. \right. \\
& \quad \left. \left. + Z_{i4}^{A,*} \left(Z_{j5}^{A,*} Z_{k6}^{A,*} + Z_{j6}^{A,*} Z_{k5}^{A,*} \right) \right) \right. \\
& \quad \left. - Z_{i6}^{A,*} Z_{j5}^{A,*} Z_{k4}^{A,*} T_\kappa - Z_{i5}^{A,*} Z_{j6}^{A,*} Z_{k4}^{A,*} T_\kappa - Z_{i6}^{A,*} Z_{j4}^{A,*} Z_{k5}^{A,*} T_\kappa \right. \\
& \quad \left. - Z_{i4}^{A,*} Z_{j6}^{A,*} Z_{k5}^{A,*} T_\kappa - Z_{i5}^{A,*} Z_{j4}^{A,*} Z_{k6}^{A,*} T_\kappa - Z_{i4}^{A,*} Z_{j5}^{A,*} Z_{k6}^{A,*} T_\kappa \right. \\
& \quad \left. + 3Z_{i3}^{A,*} Z_{j2}^{A,*} Z_{k1}^{A,*} T_\lambda + 3Z_{i2}^{A,*} Z_{j3}^{A,*} Z_{k1}^{A,*} T_\lambda + 3Z_{i3}^{A,*} Z_{j1}^{A,*} Z_{k2}^{A,*} T_\lambda + 3Z_{i1}^{A,*} Z_{j3}^{A,*} Z_{k2}^{A,*} T_\lambda \right. \\
& \quad \left. + 3Z_{i2}^{A,*} Z_{j1}^{A,*} Z_{k3}^{A,*} T_\lambda + 3Z_{i1}^{A,*} Z_{j2}^{A,*} Z_{k3}^{A,*} T_\lambda \right)
\end{aligned} \tag{295}$$

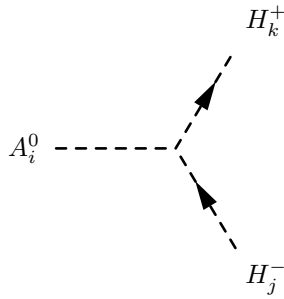


$$\begin{aligned}
& -\frac{i}{36} \left(9\sqrt{2}T_\lambda^* Z_{i3}^{A,*} Z_{j2}^{A,*} Z_{k1}^{H,*} + 36g_p^2 Q_{H_d} Q_s v_d Z_{i3}^{A,*} Z_{j3}^{A,*} Z_{k1}^{H,*} \right. \\
& + 36v_d |\lambda|^2 Z_{i3}^{A,*} Z_{j3}^{A,*} Z_{k1}^{H,*} + 36g_p^2 Q_{H_d} Q_1 v_d Z_{i4}^{A,*} Z_{j4}^{A,*} Z_{k1}^{H,*} \\
& + 36g_p^2 Q_{H_d} Q_2 v_d Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k1}^{H,*} + 36g_p^2 Q_{H_d} Q_3 v_d Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k1}^{H,*} \\
& + 9\sqrt{2}T_\lambda^* Z_{i3}^{A,*} Z_{j1}^{A,*} Z_{k2}^{H,*} + 36g_p^2 Q_{H_u} Q_s v_u Z_{i3}^{A,*} Z_{j3}^{A,*} Z_{k2}^{H,*} \\
& + 36v_u |\lambda|^2 Z_{i3}^{A,*} Z_{j3}^{A,*} Z_{k2}^{H,*} + 36g_p^2 Q_{H_u} Q_1 v_u Z_{i4}^{A,*} Z_{j4}^{A,*} Z_{k2}^{H,*} \\
& + 36g_p^2 Q_{H_u} Q_2 v_u Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k2}^{H,*} + 36g_p^2 Q_{H_u} Q_3 v_u Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k2}^{H,*} \\
& + 36g_p^2 Q_s^2 v_s Z_{i3}^{A,*} Z_{j3}^{A,*} Z_{k3}^{H,*} + 36g_p^2 Q_s Q_1 v_s Z_{i4}^{A,*} Z_{j4}^{A,*} Z_{k3}^{H,*} \\
& + 36g_p^2 Q_s Q_2 v_s Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k3}^{H,*} + 36g_p^2 Q_s Q_3 v_s Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k3}^{H,*} \\
& + 36g_p^2 Q_s Q_1 v_1 Z_{i3}^{A,*} Z_{j3}^{A,*} Z_{k4}^{H,*} + 36g_p^2 Q_1^2 v_1 Z_{i4}^{A,*} Z_{j4}^{A,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_1 Q_2 v_1 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k4}^{H,*} + 4v_1 |\kappa|^2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k4}^{H,*} - 3\sqrt{2}T_\kappa^* Z_{i6}^{A,*} Z_{j5}^{A,*} Z_{k4}^{H,*} \\
& - 3\sqrt{2}T_\kappa^* Z_{i5}^{A,*} Z_{j6}^{A,*} Z_{k4}^{H,*} + 36g_p^2 Q_1 Q_3 v_1 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k4}^{H,*} + 4v_1 |\kappa|^2 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_s Q_2 v_2 Z_{i3}^{A,*} Z_{j3}^{A,*} Z_{k5}^{H,*} + 36g_p^2 Q_1 Q_2 v_2 Z_{i4}^{A,*} Z_{j4}^{A,*} Z_{k5}^{H,*} \\
& + 4v_2 |\kappa|^2 Z_{i4}^{A,*} Z_{j4}^{A,*} Z_{k5}^{H,*} - 3\sqrt{2}T_\kappa^* Z_{i6}^{A,*} Z_{j4}^{A,*} Z_{k5}^{H,*} + 36g_p^2 Q_2^2 v_2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k5}^{H,*} \\
& - 3\sqrt{2}T_\kappa^* Z_{i4}^{A,*} Z_{j6}^{A,*} Z_{k5}^{H,*} + 36g_p^2 Q_2 Q_3 v_2 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k5}^{H,*} + 4v_2 |\kappa|^2 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k5}^{H,*} \\
& + 36g_p^2 Q_s Q_3 v_3 Z_{i3}^{A,*} Z_{j3}^{A,*} Z_{k6}^{H,*} + 36g_p^2 Q_1 Q_3 v_3 Z_{i4}^{A,*} Z_{j4}^{A,*} Z_{k6}^{H,*} \\
& + 4v_3 |\kappa|^2 Z_{i4}^{A,*} Z_{j4}^{A,*} Z_{k6}^{H,*} - 3\sqrt{2}T_\kappa^* Z_{i5}^{A,*} Z_{j4}^{A,*} Z_{k6}^{H,*} - 3\sqrt{2}T_\kappa^* Z_{i4}^{A,*} Z_{j5}^{A,*} Z_{k6}^{H,*} \\
& + 36g_p^2 Q_2 Q_3 v_3 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k6}^{H,*} + 4v_3 |\kappa|^2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k6}^{H,*} \\
& + 36g_p^2 Q_3^2 v_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k6}^{H,*} - 3\sqrt{2}Z_{i6}^{A,*} Z_{j5}^{A,*} Z_{k4}^{H,*} T_\kappa - 3\sqrt{2}Z_{i5}^{A,*} Z_{j6}^{A,*} Z_{k4}^{H,*} T_\kappa \\
& - 3\sqrt{2}Z_{i6}^{A,*} Z_{j4}^{A,*} Z_{k5}^{H,*} T_\kappa - 3\sqrt{2}Z_{i4}^{A,*} Z_{j6}^{A,*} Z_{k5}^{H,*} T_\kappa - 3\sqrt{2}Z_{i5}^{A,*} Z_{j4}^{A,*} Z_{k6}^{H,*} T_\kappa \\
& - 3\sqrt{2}Z_{i4}^{A,*} Z_{j5}^{A,*} Z_{k6}^{H,*} T_\kappa + 9\sqrt{2}Z_{i3}^{A,*} Z_{j2}^{A,*} Z_{k1}^{H,*} T_\lambda + 9\sqrt{2}Z_{i3}^{A,*} Z_{j1}^{A,*} Z_{k2}^{H,*} T_\lambda \\
& + 9Z_{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. + 4 \left(g_p^2 Q_{H_u} \left(Q_1 v_1 Z_{k4}^{H,*} + Q_2 v_2 Z_{k5}^{H,*} + Q_3 v_3 Z_{k6}^{H,*} \right) + v_s \left(g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} \right) \right) \right)
\end{aligned}$$

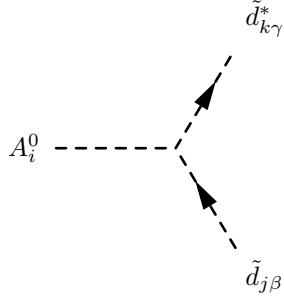
$$\begin{aligned}
& + \sqrt{2} \left(Z_{j1}^{A,*} Z_{k3}^{H,*} + Z_{j3}^{A,*} Z_{k1}^{H,*} \right) (T_\lambda^* + T_\lambda) \\
& + 9 Z_{i1}^{A,*} \left(Z_{j1}^{A,*} \left((4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2) v_d Z_{k1}^{H,*} - v_u \left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k2}^{H,*} \right. \right. \\
& + 4 \left(g_p^2 Q_{H_d} \left(Q_1 v_1 Z_{k4}^{H,*} + Q_2 v_2 Z_{k5}^{H,*} + Q_3 v_3 Z_{k6}^{H,*} \right) + v_s \left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} \right) \\
& \left. \left. + \sqrt{2} \left(Z_{j2}^{A,*} Z_{k3}^{H,*} + Z_{j3}^{A,*} Z_{k2}^{H,*} \right) (T_\lambda^* + T_\lambda) \right) \right) \quad (296)
\end{aligned}$$



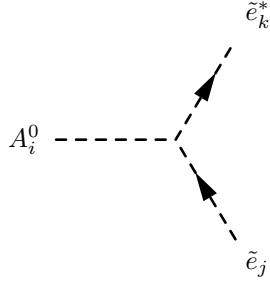
$$\begin{aligned}
& \frac{1}{6} \frac{1}{\sqrt{2}} \left(3 T_\lambda^* \left(Z_{i3}^{A,*} \left(Z_{j1}^{H,*} Z_{k2}^{H,*} + Z_{j2}^{H,*} Z_{k1}^{H,*} \right) + Z_{i2}^{A,*} \left(Z_{j1}^{H,*} Z_{k3}^{H,*} + Z_{j3}^{H,*} Z_{k1}^{H,*} \right) \right. \right. \\
& + Z_{i1}^{A,*} \left(Z_{j2}^{H,*} Z_{k3}^{H,*} + Z_{j3}^{H,*} Z_{k2}^{H,*} \right) \left. \right) \\
& - T_\kappa^* \left(Z_{i6}^{A,*} \left(Z_{j4}^{H,*} Z_{k5}^{H,*} + Z_{j5}^{H,*} Z_{k4}^{H,*} \right) + Z_{i5}^{A,*} \left(Z_{j4}^{H,*} Z_{k6}^{H,*} + Z_{j6}^{H,*} Z_{k4}^{H,*} \right) \right. \\
& + Z_{i4}^{A,*} \left(Z_{j5}^{H,*} Z_{k6}^{H,*} + Z_{j6}^{H,*} Z_{k5}^{H,*} \right) \left. \right) \\
& + Z_{i6}^{A,*} Z_{j5}^{H,*} Z_{k4}^{H,*} T_\kappa + Z_{i5}^{A,*} Z_{j6}^{H,*} Z_{k4}^{H,*} T_\kappa + Z_{i6}^{A,*} Z_{j4}^{H,*} Z_{k5}^{H,*} T_\kappa + Z_{i4}^{A,*} Z_{j6}^{H,*} Z_{k5}^{H,*} T_\kappa \\
& + Z_{i5}^{A,*} Z_{j4}^{H,*} Z_{k6}^{H,*} T_\kappa + Z_{i4}^{A,*} Z_{j5}^{H,*} Z_{k6}^{H,*} T_\kappa - 3 Z_{i3}^{A,*} Z_{j2}^{H,*} Z_{k1}^{H,*} T_\lambda - 3 Z_{i2}^{A,*} Z_{j3}^{H,*} Z_{k1}^{H,*} T_\lambda \\
& - 3 Z_{i3}^{A,*} Z_{j1}^{H,*} Z_{k2}^{H,*} T_\lambda - 3 Z_{i1}^{A,*} Z_{j3}^{H,*} Z_{k2}^{H,*} T_\lambda - 3 Z_{i2}^{A,*} Z_{j1}^{H,*} Z_{k3}^{H,*} T_\lambda \\
& - 3 Z_{i1}^{A,*} Z_{j2}^{H,*} Z_{k3}^{H,*} T_\lambda \left. \right) \quad (297)
\end{aligned}$$



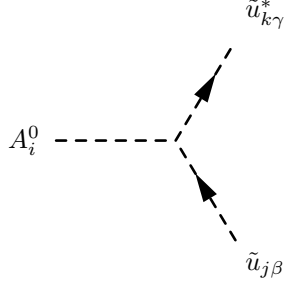
$$\begin{aligned}
& \frac{1}{4} \left(v_u \left(-2|\lambda|^2 + g_2^2 \right) Z_{i1}^{A,*} \left(-Z_{j1}^+ Z_{k2}^+ + Z_{j2}^+ Z_{k1}^+ \right) \right. \\
& \left. + v_d \left(-2|\lambda|^2 + g_2^2 \right) Z_{i2}^{A,*} \left(-Z_{j1}^+ Z_{k2}^+ + Z_{j2}^+ Z_{k1}^+ \right) + 2\sqrt{2} Z_{i3}^{A,*} \left(T_\lambda Z_{j1}^+ Z_{k2}^+ - T_\lambda^* Z_{j2}^+ Z_{k1}^+ \right) \right)
\end{aligned} \tag{298}$$



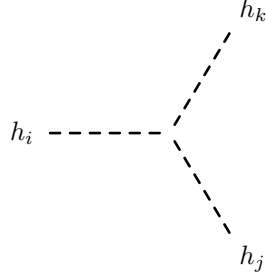
$$\begin{aligned}
& \frac{1}{2} \delta_{\beta\gamma} \left(\lambda^* \left(v_s Z_{i2}^{A,*} + v_u Z_{i3}^{A,*} \right) \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \right. \\
& - \lambda \left(v_s Z_{i2}^{A,*} + v_u Z_{i3}^{A,*} \right) \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{kb}^D \\
& \left. + \sqrt{2} Z_{i1}^{A,*} \left(- \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{D,*} T_{d,ab}^* Z_{kb}^D + \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Z_{k3+a}^D T_{d,ab} \right) \right)
\end{aligned} \tag{299}$$



$$\begin{aligned}
& \frac{1}{2} \left(\lambda^* \left(v_s Z_{i2}^{A,*} + v_u Z_{i3}^{A,*} \right) \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \right. \\
& - \lambda \left(v_s Z_{i2}^{A,*} + v_u Z_{i3}^{A,*} \right) \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{kb}^E \\
& \left. + \sqrt{2} Z_{i1}^{A,*} \left(- \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{E,*} T_{e,ab}^* Z_{kb}^E + \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Z_{k3+a}^E T_{e,ab} \right) \right)
\end{aligned} \tag{300}$$



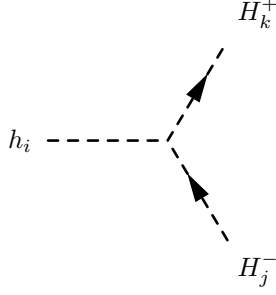
$$\begin{aligned}
& \frac{1}{2} \delta_{\beta\gamma} \left(\lambda^* \left(v_d Z_{i3}^{A,*} + v_s Z_{i1}^{A,*} \right) \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \right. \\
& - \lambda \left(v_d Z_{i3}^{A,*} + v_s Z_{i1}^{A,*} \right) \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{j3+a}^{U,*} Z_{kb}^U \\
& \left. + \sqrt{2} Z_{i2}^{A,*} \left(- \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{U,*} T_{u,ab}^* Z_{kb}^U + \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Z_{k3+a}^U T_{u,ab} \right) \right) \quad (301)
\end{aligned}$$



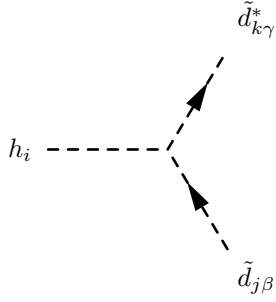
$$\begin{aligned}
& - \frac{i}{36} \left(36g_p^2 Q_{H_d} Q_s v_s Z_{i3}^{H,*} Z_{j1}^{H,*} Z_{k1}^{H,*} + 36v_s |\lambda|^2 Z_{i3}^{H,*} Z_{j1}^{H,*} Z_{k1}^{H,*} \right. \\
& + 36g_p^2 Q_{H_d} Q_1 v_1 Z_{i4}^{H,*} Z_{j1}^{H,*} Z_{k1}^{H,*} + 36g_p^2 Q_{H_d} Q_2 v_2 Z_{i5}^{H,*} Z_{j1}^{H,*} Z_{k1}^{H,*} \\
& + 36g_p^2 Q_{H_d} Q_3 v_3 Z_{i6}^{H,*} Z_{j1}^{H,*} Z_{k1}^{H,*} - 9\sqrt{2} T_\lambda^* Z_{i3}^{H,*} Z_{j2}^{H,*} Z_{k1}^{H,*} \\
& + 36g_p^2 Q_{H_d} Q_s v_d Z_{i3}^{H,*} Z_{j3}^{H,*} Z_{k1}^{H,*} + 36v_d |\lambda|^2 Z_{i3}^{H,*} Z_{j3}^{H,*} Z_{k1}^{H,*} \\
& + 36g_p^2 Q_{H_d} Q_1 v_d Z_{i4}^{H,*} Z_{j4}^{H,*} Z_{k1}^{H,*} + 36g_p^2 Q_{H_d} Q_2 v_d Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k1}^{H,*} \\
& + 36g_p^2 Q_{H_d} Q_3 v_d Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k1}^{H,*} - 9\sqrt{2} T_\lambda^* Z_{i3}^{H,*} Z_{j1}^{H,*} Z_{k2}^{H,*} \\
& + 36g_p^2 Q_{H_u} Q_s v_s Z_{i3}^{H,*} Z_{j2}^{H,*} Z_{k2}^{H,*} + 36v_s |\lambda|^2 Z_{i3}^{H,*} Z_{j2}^{H,*} Z_{k2}^{H,*} \\
& + 36g_p^2 Q_{H_u} Q_1 v_1 Z_{i4}^{H,*} Z_{j2}^{H,*} Z_{k2}^{H,*} + 36g_p^2 Q_{H_u} Q_2 v_2 Z_{i5}^{H,*} Z_{j2}^{H,*} Z_{k2}^{H,*} \\
& \left. + 36g_p^2 Q_{H_u} Q_3 v_3 Z_{i6}^{H,*} Z_{j2}^{H,*} Z_{k2}^{H,*} + 36g_p^2 Q_{H_u} Q_s v_u Z_{i3}^{H,*} Z_{j3}^{H,*} Z_{k2}^{H,*} \right)
\end{aligned}$$

$$\begin{aligned}
& + 36v_u|\lambda|^2 Z_{i3}^{H,*} Z_{j3}^{H,*} Z_{k2}^{H,*} + 36g_p^2 Q_{H_u} Q_1 v_u Z_{i4}^{H,*} Z_{j4}^{H,*} Z_{k2}^{H,*} \\
& + 36g_p^2 Q_{H_u} Q_2 v_u Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k2}^{H,*} + 36g_p^2 Q_{H_u} Q_3 v_u Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k2}^{H,*} \\
& + 36g_p^2 Q_{H_d} Q_s v_d Z_{i3}^{H,*} Z_{j1}^{H,*} Z_{k3}^{H,*} + 36v_d|\lambda|^2 Z_{i3}^{H,*} Z_{j1}^{H,*} Z_{k3}^{H,*} \\
& + 36g_p^2 Q_{H_u} Q_s v_u Z_{i3}^{H,*} Z_{j2}^{H,*} Z_{k3}^{H,*} + 36v_u|\lambda|^2 Z_{i3}^{H,*} Z_{j2}^{H,*} Z_{k3}^{H,*} \\
& + 108g_p^2 Q_s^2 v_s Z_{i3}^{H,*} Z_{j3}^{H,*} Z_{k3}^{H,*} + 36g_p^2 Q_s Q_1 v_1 Z_{i4}^{H,*} Z_{j3}^{H,*} Z_{k3}^{H,*} \\
& + 36g_p^2 Q_s Q_2 v_2 Z_{i5}^{H,*} Z_{j3}^{H,*} Z_{k3}^{H,*} + 36g_p^2 Q_s Q_3 v_3 Z_{i6}^{H,*} Z_{j3}^{H,*} Z_{k3}^{H,*} \\
& + 36g_p^2 Q_s Q_1 v_1 Z_{i3}^{H,*} Z_{j4}^{H,*} Z_{k3}^{H,*} + 36g_p^2 Q_s Q_1 v_s Z_{i4}^{H,*} Z_{j4}^{H,*} Z_{k3}^{H,*} \\
& + 36g_p^2 Q_s Q_2 v_2 Z_{i3}^{H,*} Z_{j5}^{H,*} Z_{k3}^{H,*} + 36g_p^2 Q_s Q_2 v_s Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k3}^{H,*} \\
& + 36g_p^2 Q_s Q_3 v_3 Z_{i3}^{H,*} Z_{j6}^{H,*} Z_{k3}^{H,*} + 36g_p^2 Q_s Q_3 v_s Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k3}^{H,*} \\
& + 36g_p^2 Q_{H_d} Q_1 v_d Z_{i4}^{H,*} Z_{j1}^{H,*} Z_{k4}^{H,*} + 36g_p^2 Q_{H_u} Q_1 v_u Z_{i4}^{H,*} Z_{j2}^{H,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_s Q_1 v_1 Z_{i3}^{H,*} Z_{j3}^{H,*} Z_{k4}^{H,*} + 36g_p^2 Q_s Q_1 v_s Z_{i4}^{H,*} Z_{j3}^{H,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_s Q_1 v_s Z_{i3}^{H,*} Z_{j4}^{H,*} Z_{k4}^{H,*} + 108g_p^2 Q_1^2 v_1 Z_{i4}^{H,*} Z_{j4}^{H,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_1 Q_2 v_2 Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k4}^{H,*} + 4v_2|\kappa|^2 Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_1 Q_3 v_3 Z_{i6}^{H,*} Z_{j4}^{H,*} Z_{k4}^{H,*} + 4v_3|\kappa|^2 Z_{i6}^{H,*} Z_{j4}^{H,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_1 Q_2 v_2 Z_{i4}^{H,*} Z_{j5}^{H,*} Z_{k4}^{H,*} + 4v_2|\kappa|^2 Z_{i4}^{H,*} Z_{j5}^{H,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_1 Q_2 v_1 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k4}^{H,*} + 4v_1|\kappa|^2 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k4}^{H,*} + 3\sqrt{2}T_\kappa^* Z_{i6}^{H,*} Z_{j5}^{H,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_1 Q_3 v_3 Z_{i4}^{H,*} Z_{j6}^{H,*} Z_{k4}^{H,*} + 4v_3|\kappa|^2 Z_{i4}^{H,*} Z_{j6}^{H,*} Z_{k4}^{H,*} + 3\sqrt{2}T_\kappa^* Z_{i5}^{H,*} Z_{j6}^{H,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_1 Q_3 v_1 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k4}^{H,*} + 4v_1|\kappa|^2 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k4}^{H,*} \\
& + 36g_p^2 Q_{H_d} Q_2 v_d Z_{i5}^{H,*} Z_{j1}^{H,*} Z_{k5}^{H,*} + 36g_p^2 Q_{H_u} Q_2 v_u Z_{i5}^{H,*} Z_{j2}^{H,*} Z_{k5}^{H,*} \\
& + 36g_p^2 Q_s Q_2 v_2 Z_{i3}^{H,*} Z_{j3}^{H,*} Z_{k5}^{H,*} + 36g_p^2 Q_s Q_2 v_s Z_{i5}^{H,*} Z_{j3}^{H,*} Z_{k5}^{H,*} \\
& + 36g_p^2 Q_1 Q_2 v_2 Z_{i4}^{H,*} Z_{j4}^{H,*} Z_{k5}^{H,*} + 4v_2|\kappa|^2 Z_{i4}^{H,*} Z_{j4}^{H,*} Z_{k5}^{H,*} \\
& + 36g_p^2 Q_1 Q_2 v_1 Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k5}^{H,*} + 4v_1|\kappa|^2 Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k5}^{H,*} + 3\sqrt{2}T_\kappa^* Z_{i6}^{H,*} Z_{j4}^{H,*} Z_{k5}^{H,*} \\
& + 36g_p^2 Q_s Q_2 v_s Z_{i3}^{H,*} Z_{j5}^{H,*} Z_{k5}^{H,*} + 36g_p^2 Q_1 Q_2 v_1 Z_{i4}^{H,*} Z_{j5}^{H,*} Z_{k5}^{H,*} \\
& + 4v_1|\kappa|^2 Z_{i4}^{H,*} Z_{j5}^{H,*} Z_{k5}^{H,*} + 108g_p^2 Q_2^2 v_2 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k5}^{H,*} \\
& + 36g_p^2 Q_2 Q_3 v_3 Z_{i6}^{H,*} Z_{j5}^{H,*} Z_{k5}^{H,*} + 4v_3|\kappa|^2 Z_{i6}^{H,*} Z_{j5}^{H,*} Z_{k5}^{H,*} + 3\sqrt{2}T_\kappa^* Z_{i4}^{H,*} Z_{j6}^{H,*} Z_{k5}^{H,*} \\
& + 36g_p^2 Q_2 Q_3 v_3 Z_{i5}^{H,*} Z_{j6}^{H,*} Z_{k5}^{H,*} + 4v_3|\kappa|^2 Z_{i5}^{H,*} Z_{j6}^{H,*} Z_{k5}^{H,*} \\
& + 36g_p^2 Q_2 Q_3 v_2 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k5}^{H,*} + 4v_2|\kappa|^2 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k5}^{H,*} \\
& + 36g_p^2 Q_{H_d} Q_3 v_d Z_{i6}^{H,*} Z_{j1}^{H,*} Z_{k6}^{H,*} + 36g_p^2 Q_{H_u} Q_3 v_u Z_{i6}^{H,*} Z_{j2}^{H,*} Z_{k6}^{H,*} \\
& + 36g_p^2 Q_s Q_3 v_3 Z_{i3}^{H,*} Z_{j3}^{H,*} Z_{k6}^{H,*} + 36g_p^2 Q_s Q_3 v_s Z_{i6}^{H,*} Z_{j3}^{H,*} Z_{k6}^{H,*} \\
& + 36g_p^2 Q_1 Q_3 v_3 Z_{i4}^{H,*} Z_{j4}^{H,*} Z_{k6}^{H,*} + 4v_3|\kappa|^2 Z_{i4}^{H,*} Z_{j4}^{H,*} Z_{k6}^{H,*} + 3\sqrt{2}T_\kappa^* Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k6}^{H,*} \\
& + 36g_p^2 Q_1 Q_3 v_1 Z_{i6}^{H,*} Z_{j4}^{H,*} Z_{k6}^{H,*} + 4v_1|\kappa|^2 Z_{i6}^{H,*} Z_{j4}^{H,*} Z_{k6}^{H,*} + 3\sqrt{2}T_\kappa^* Z_{i4}^{H,*} Z_{j5}^{H,*} Z_{k6}^{H,*}
\end{aligned}$$

$$\begin{aligned}
& + 36g_p^2 Q_2 Q_3 v_3 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k6}^{H,*} + 4v_3 |\kappa|^2 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k6}^{H,*} \\
& + 36g_p^2 Q_2 Q_3 v_2 Z_{i6}^{H,*} Z_{j5}^{H,*} Z_{k6}^{H,*} + 4v_2 |\kappa|^2 Z_{i6}^{H,*} Z_{j5}^{H,*} Z_{k6}^{H,*} \\
& + 36g_p^2 Q_s Q_3 v_3 Z_{i3}^{H,*} Z_{j6}^{H,*} Z_{k6}^{H,*} + 36g_p^2 Q_1 Q_3 v_1 Z_{i4}^{H,*} Z_{j6}^{H,*} Z_{k6}^{H,*} \\
& + 4v_1 |\kappa|^2 Z_{i4}^{H,*} Z_{j6}^{H,*} Z_{k6}^{H,*} + 36g_p^2 Q_2 Q_3 v_2 Z_{i5}^{H,*} Z_{j6}^{H,*} Z_{k6}^{H,*} \\
& + 4v_2 |\kappa|^2 Z_{i5}^{H,*} Z_{j6}^{H,*} Z_{k6}^{H,*} + 108g_p^2 Q_3^2 v_3 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k6}^{H,*} + 3\sqrt{2} Z_{i6}^{H,*} Z_{j5}^{H,*} Z_{k4}^{H,*} T_\kappa \\
& + 3\sqrt{2} Z_{i5}^{H,*} Z_{j6}^{H,*} Z_{k4}^{H,*} T_\kappa + 3\sqrt{2} Z_{i6}^{H,*} Z_{j4}^{H,*} Z_{k5}^{H,*} T_\kappa + 3\sqrt{2} Z_{i4}^{H,*} Z_{j6}^{H,*} Z_{k5}^{H,*} T_\kappa \\
& + 3\sqrt{2} Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k6}^{H,*} T_\kappa + 3\sqrt{2} Z_{i4}^{H,*} Z_{j5}^{H,*} Z_{k6}^{H,*} T_\kappa - 9\sqrt{2} Z_{i3}^{H,*} Z_{j2}^{H,*} Z_{k1}^{H,*} T_\lambda \\
& - 9\sqrt{2} Z_{i3}^{H,*} Z_{j1}^{H,*} Z_{k2}^{H,*} T_\lambda \\
& - 9Z_{i2}^{H,*} \left(\sqrt{2} T_\lambda^* Z_{j3}^{H,*} Z_{k1}^{H,*} - 4g_p^2 Q_{Hu} Q_s v_s Z_{j3}^{H,*} Z_{k2}^{H,*} - 4v_s |\lambda|^2 Z_{j3}^{H,*} Z_{k2}^{H,*} \right. \\
& - 4g_p^2 Q_{Hu} Q_1 v_1 Z_{j4}^{H,*} Z_{k2}^{H,*} - 4g_p^2 Q_{Hu} Q_2 v_2 Z_{j5}^{H,*} Z_{k2}^{H,*} - 4g_p^2 Q_{Hu} Q_3 v_3 Z_{j6}^{H,*} Z_{k2}^{H,*} \\
& - 4g_p^2 Q_{Hu} Q_s v_u Z_{j3}^{H,*} Z_{k3}^{H,*} - 4v_u |\lambda|^2 Z_{j3}^{H,*} Z_{k3}^{H,*} - 4g_p^2 Q_{Hu} Q_1 v_u Z_{j4}^{H,*} Z_{k4}^{H,*} \\
& \left. - 4g_p^2 Q_{Hu} Q_2 v_u Z_{j5}^{H,*} Z_{k5}^{H,*} - 4g_p^2 Q_{Hu} Q_3 v_u Z_{j6}^{H,*} Z_{k6}^{H,*} \right) \\
& + Z_{j2}^{H,*} \left(v_d (-4g_p^2 Q_{ Hd } Q_{ Hu } - 4|\lambda|^2 + g_1^2 + g_2^2) Z_{k1}^{H,*} - 3(4g_p^2 Q_{ Hu }^2 + g_1^2 + g_2^2) v_u Z_{k2}^{H,*} \right. \\
& \left. - 4(g_p^2 Q_{ Hu } (Q_1 v_1 Z_{k4}^{H,*} + Q_2 v_2 Z_{k5}^{H,*} + Q_3 v_3 Z_{k6}^{H,*}) + v_s (g_p^2 Q_{ Hu } Q_s + |\lambda|^2) Z_{k3}^{H,*}) \right) \\
& + \sqrt{2} Z_{j3}^{H,*} Z_{k1}^{H,*} T_\lambda \\
& + Z_{j1}^{H,*} \left(v_u (-4g_p^2 Q_{ Hd } Q_{ Hu } - 4|\lambda|^2 + g_1^2 + g_2^2) Z_{k1}^{H,*} + v_d (-4g_p^2 Q_{ Hd } Q_{ Hu } - 4|\lambda|^2 + g_1^2 + g_2^2) Z_{k2}^{H,*} \right. \\
& \left. + \sqrt{2} Z_{k3}^{H,*} (T_\lambda^* + T_\lambda) \right)) \\
& + 9Z_{i1}^{H,*} \left(4g_p^2 Q_{ Hd } Q_s v_s Z_{j3}^{H,*} Z_{k1}^{H,*} + 4v_s |\lambda|^2 Z_{j3}^{H,*} Z_{k1}^{H,*} + 4g_p^2 Q_{ Hd } Q_1 v_1 Z_{j4}^{H,*} Z_{k1}^{H,*} \right. \\
& + 4g_p^2 Q_{ Hd } Q_2 v_2 Z_{j5}^{H,*} Z_{k1}^{H,*} + 4g_p^2 Q_{ Hd } Q_3 v_3 Z_{j6}^{H,*} Z_{k1}^{H,*} - \sqrt{2} T_\lambda^* Z_{j3}^{H,*} Z_{k2}^{H,*} \\
& + 4g_p^2 Q_{ Hd } Q_s v_d Z_{j3}^{H,*} Z_{k3}^{H,*} + 4v_d |\lambda|^2 Z_{j3}^{H,*} Z_{k3}^{H,*} + 4g_p^2 Q_{ Hd } Q_1 v_d Z_{j4}^{H,*} Z_{k4}^{H,*} \\
& + 4g_p^2 Q_{ Hd } Q_2 v_d Z_{j5}^{H,*} Z_{k5}^{H,*} + 4g_p^2 Q_{ Hd } Q_3 v_d Z_{j6}^{H,*} Z_{k6}^{H,*} \\
& + Z_{j1}^{H,*} \left(3(4g_p^2 Q_{ Hd }^2 + g_1^2 + g_2^2) v_d Z_{k1}^{H,*} - v_u (-4g_p^2 Q_{ Hd } Q_{ Hu } - 4|\lambda|^2 + g_1^2 + g_2^2) Z_{k2}^{H,*} \right. \\
& \left. + 4(g_p^2 Q_{ Hd } (Q_1 v_1 Z_{k4}^{H,*} + Q_2 v_2 Z_{k5}^{H,*} + Q_3 v_3 Z_{k6}^{H,*}) + v_s (g_p^2 Q_{ Hd } Q_s + |\lambda|^2) Z_{k3}^{H,*}) \right) \\
& - \sqrt{2} Z_{j3}^{H,*} Z_{k2}^{H,*} T_\lambda \\
& - Z_{j2}^{H,*} \left(v_u (-4g_p^2 Q_{ Hd } Q_{ Hu } - 4|\lambda|^2 + g_1^2 + g_2^2) Z_{k1}^{H,*} + v_d (-4g_p^2 Q_{ Hd } Q_{ Hu } - 4|\lambda|^2 + g_1^2 + g_2^2) Z_{k2}^{H,*} \right. \\
& \left. + \sqrt{2} Z_{k3}^{H,*} (T_\lambda^* + T_\lambda) \right)))
\end{aligned} \tag{302}$$

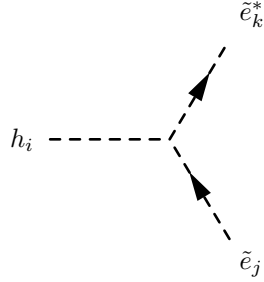


$$\begin{aligned}
& -\frac{i}{4} \left(Z_{i2}^{H,*} \left(Z_{j2}^+ \left(\left(4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) v_u Z_{k2}^+ + v_d \left(-2|\lambda|^2 + g_2^2 \right) Z_{k1}^+ \right) \right. \right. \\
& + Z_{j1}^+ \left(\left(4g_p^2 Q_{H_d} Q_{H_u} - g_1^2 + g_2^2 \right) v_u Z_{k1}^+ + v_d \left(-2|\lambda|^2 + g_2^2 \right) Z_{k2}^+ \right) \Big) \\
& + Z_{i1}^{H,*} \left(Z_{j2}^+ \left(\left(4g_p^2 Q_{H_d} Q_{H_u} - g_1^2 + g_2^2 \right) v_d Z_{k2}^+ + v_u \left(-2|\lambda|^2 + g_2^2 \right) Z_{k1}^+ \right) \right. \\
& + Z_{j1}^+ \left(\left(4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) v_d Z_{k1}^+ + v_u \left(-2|\lambda|^2 + g_2^2 \right) Z_{k2}^+ \right) \Big) \\
& + 2 \left(2g_p^2 \left(Q_1 v_1 Z_{i4}^{H,*} + Q_2 v_2 Z_{i5}^{H,*} + Q_3 v_3 Z_{i6}^{H,*} \right) \left(Q_{H_d} Z_{j1}^+ Z_{k1}^+ + Q_{H_u} Z_{j2}^+ Z_{k2}^+ \right) \right. \\
& + Z_{i3}^{H,*} \left(Z_{j2}^+ \left(2v_s \left(g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k2}^+ + \sqrt{2} T_\lambda^* Z_{k1}^+ \right) \right. \\
& \left. \left. + Z_{j1}^+ \left(2v_s \left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k1}^+ + \sqrt{2} T_\lambda Z_{k2}^+ \right) \right) \right) \Big) \Big) \quad (303)
\end{aligned}$$



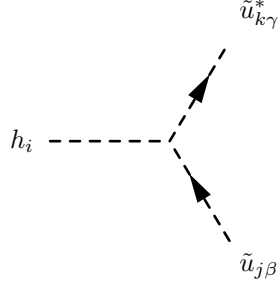
$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\gamma} \left(-Z_{i2}^{H,*} \left(\left(3 \left(4g_p^2 Q_{H_u} Q_q + g_2^2 \right) + g_1^2 \right) v_u \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \right. \right. \\
& + 2 \left(\left(6g_p^2 Q_d Q_{H_u} + g_1^2 \right) v_u \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \right. \\
& \left. \left. - 3v_s \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{kb}^D + \lambda^* \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \right) \right) \right) \Big)
\end{aligned}$$

$$\begin{aligned}
& -6 \left(2g_p^2 \left(Q_1 v_1 Z_{i4}^{H,*} + Q_2 v_2 Z_{i5}^{H,*} + Q_3 v_3 Z_{i6}^{H,*} \right) \left(Q_d \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D + Q_q \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \right) \right. \\
& + Z_{i3}^{H,*} \left(2g_p^2 Q_q Q_s v_s \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D + 2g_p^2 Q_d Q_s v_s \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \right. \\
& \left. \left. - v_u \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{kb}^D + \lambda^* \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \right) \right) \right) \\
& + Z_{i1}^{H,*} \left(\left(3 \left(-4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) v_d \sum_{a=1}^3 Z_{ja}^{D,*} Z_{ka}^D \right. \\
& + 2 \left(\left(-6g_p^2 Q_d Q_{H_d} + g_1^2 \right) v_d \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{k3+a}^D \right. \\
& - 3 \left(\sqrt{2} \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Z_{k3+a}^D T_{d,ab} + \sqrt{2} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{D,*} T_{d,ab}^* Z_{kb}^D \right. \\
& \left. \left. \left. + 2v_d \left(\sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{k3+b}^D + \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{kc}^D \right) \right) \right) \right) \right) \quad (304)
\end{aligned}$$



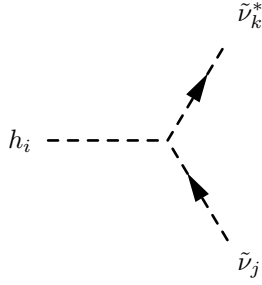
$$\begin{aligned}
& -\frac{i}{4} \left(4g_p^2 Q_l Q_s v_s Z_{i3}^{H,*} \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E + 4g_p^2 Q_l Q_1 v_1 Z_{i4}^{H,*} \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \right. \\
& + 4g_p^2 Q_l Q_2 v_2 Z_{i5}^{H,*} \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E + 4g_p^2 Q_l Q_3 v_3 Z_{i6}^{H,*} \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \\
& + 4g_p^2 Q_e Q_s v_s Z_{i3}^{H,*} \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E + 4g_p^2 Q_e Q_1 v_1 Z_{i4}^{H,*} \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \\
& + 4g_p^2 Q_e Q_2 v_2 Z_{i5}^{H,*} \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E + 4g_p^2 Q_e Q_3 v_3 Z_{i6}^{H,*} \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \\
& \left. - 2v_u \lambda^* Z_{i3}^{H,*} \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E - 2v_u \lambda Z_{i3}^{H,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{kb}^E \right)
\end{aligned}$$

$$\begin{aligned}
& + Z_{i2}^{H,*} \left(\left(4g_p^2 Q_{H_u} Q_l - g_1^2 + g_2^2 \right) v_u \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E + 2 \left(2g_p^2 Q_e Q_{H_u} + g_1^2 \right) v_u \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \right. \\
& - 2v_s \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{kb}^E + \lambda^* \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \right) \Big) \\
& + Z_{i1}^{H,*} \left(\left(4g_p^2 Q_{H_d} Q_l - g_2^2 + g_1^2 \right) v_d \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \right. \\
& + 2 \left(- \left(- 2g_p^2 Q_e Q_{H_d} + g_1^2 \right) v_d \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E + \sqrt{2} \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Z_{k3+a}^E T_{e,ab} \right. \\
& + \sqrt{2} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{E,*} T_{e,ab}^* Z_{kb}^E + 2v_d \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{k3+b}^E \\
& \left. \left. \left. + 2v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{kc}^E \right) \right) \right) \Big) \tag{305}
\end{aligned}$$

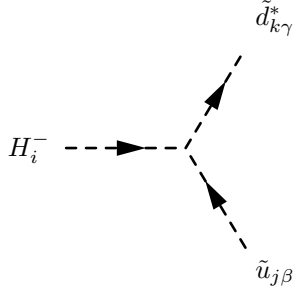


$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\gamma} \left(Z_{i1}^{H,*} \left(\left(- 3 \left(4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) v_d \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U - 4 \left(3g_p^2 Q_{H_d} Q_u + g_1^2 \right) v_d \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \right. \right. \\
& + 6v_s \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{j3+a}^{U,*} Z_{kb}^U + \lambda^* \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \right) \Big) \\
& - 6 \left(2g_p^2 \left(Q_1 v_1 Z_{i4}^{H,*} + Q_2 v_2 Z_{i5}^{H,*} + Q_3 v_3 Z_{i6}^{H,*} \right) \left(Q_q \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U + Q_u \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \right) \right. \\
& + Z_{i3}^{H,*} \left(2g_p^2 Q_q Q_s v_s \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U + 2g_p^2 Q_s Q_u v_s \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \right. \\
& - v_d \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{j3+a}^{U,*} Z_{kb}^U + \lambda^* \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \right) \Big) \\
& \left. \left. \left. - Z_{i2}^{H,*} \left(\left(12g_p^2 Q_{H_u} Q_q - 3g_2^2 + g_1^2 \right) v_u \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \right. \right. \right) \right)
\end{aligned}$$

$$\begin{aligned}
& + 2 \left(- 2 \left(- 3g_p^2 Q_{H_u} Q_u + g_1^2 \right) v_u \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \right. \\
& + 3 \left(\sqrt{2} \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Z_{k3+a}^U T_{u,ab} + \sqrt{2} \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{U,*} T_{u,ab}^* Z_{kb}^U \right. \\
& \left. \left. + 2v_u \left(\sum_{c=1}^3 Z_{j3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{k3+b}^U + \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{kc}^U \right) \right) \right) \quad (306)
\end{aligned}$$

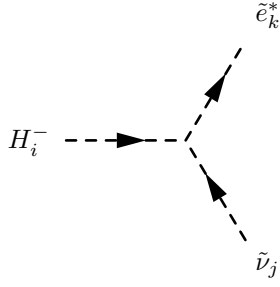


$$\begin{aligned}
& - \frac{i}{4} \left(\left(4g_p^2 Q_{H_d} Q_l + g_1^2 + g_2^2 \right) v_d Z_{i1}^{H,*} - \left(- 4g_p^2 Q_{H_u} Q_l + g_1^2 + g_2^2 \right) v_u Z_{i2}^{H,*} \right. \\
& \left. + 4g_p^2 Q_l \left(Q_1 v_1 Z_{i4}^{H,*} + Q_2 v_2 Z_{i5}^{H,*} + Q_3 v_3 Z_{i6}^{H,*} + Q_s v_s Z_{i3}^{H,*} \right) \right) \delta_{jk} \quad (307)
\end{aligned}$$

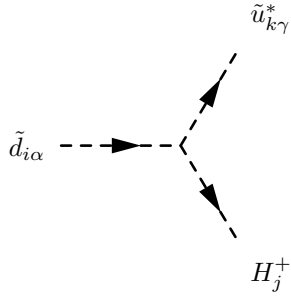


$$\begin{aligned}
& - \frac{i}{4} \delta_{\beta\gamma} \left(\sqrt{2} g_2^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^D \left(v_d Z_{i1}^+ + v_u Z_{i2}^+ \right) \right. \\
& - 2 \left(2 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Z_{k3+a}^D T_{d,ab} Z_{i1}^+ + \sqrt{2} v_s \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^*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

$$\begin{aligned}
& + \sqrt{2}v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{kc}^D Z_{i1}^+ + \sqrt{2}v_s \lambda^* \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D Z_{i2}^+ \\
& + 2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{j3+a}^{U,*} T_{u,ab}^* Z_{kb}^D Z_{i2}^+ + \sqrt{2}v_d \sum_{c=1}^3 Z_{j3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{k3+b}^D Z_{i2}^+ \\
& + \sqrt{2}v_u \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{kc}^D Z_{i2}^+ \Big) \Big) \tag{308}
\end{aligned}$$

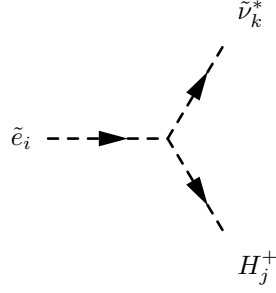


$$\begin{aligned}
& - \frac{i}{4} \left(\sqrt{2}g_2^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^E (v_d Z_{i1}^+ + v_u Z_{i2}^+) \right. \\
& - 2 \left(2 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Z_{k3+a}^E T_{e,ab} Z_{i1}^+ \right. \\
& \left. \left. + \sqrt{2} \left(v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{kc}^E Z_{i1}^+ + v_s \lambda^* \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E Z_{i2}^+ \right) \right) \right) \tag{309}
\end{aligned}$$



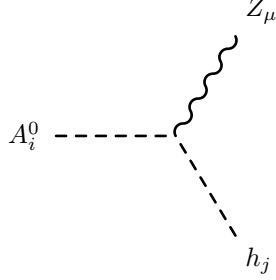
$$- \frac{i}{4} \delta_{\alpha\gamma} \left(\sqrt{2}g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^U (v_d Z_{j1}^+ + v_u Z_{j2}^+) \right)$$

$$\begin{aligned}
& -2 \left(\sqrt{2} v_s \lambda^* \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U Z_{j1}^+ + 2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{i3+a}^{D,*} T_{d,ab}^* Z_{kb}^U Z_{j1}^+ \right. \\
& + \sqrt{2} v_u \sum_{c=1}^3 Z_{i3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{k3+b}^U Z_{j1}^+ \\
& + \sqrt{2} v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{kc}^U Z_{j1}^+ + 2 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Z_{k3+a}^U T_{u,ab} Z_{j2}^+ \\
& + \sqrt{2} v_s \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{i3+a}^{D,*} Z_{kb}^U Z_{j2}^+ + \sqrt{2} v_d \sum_{c=1}^3 Z_{i3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{k3+b}^U Z_{j2}^+ \\
& \left. + \sqrt{2} v_u \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{kc}^U Z_{j2}^+ \right) \quad (310)
\end{aligned}$$

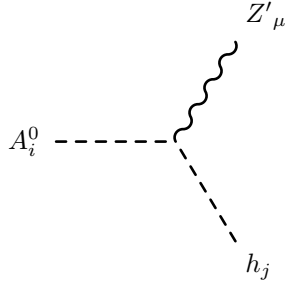


$$\begin{aligned}
& -\frac{i}{4} \left(\sqrt{2} g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^V \left(v_d Z_{j1}^+ + v_u Z_{j2}^+ \right) \right. \\
& - 2 \left(2 \sum_{b=1}^3 \sum_{a=1}^3 Z_{i3+a}^{E,*} T_{e,ab}^* Z_{kb}^V Z_{j1}^+ \right. \\
& \left. \left. + \sqrt{2} \left(v_d \sum_{c=1}^3 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{kc}^V Z_{j1}^+ + v_s \lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{i3+a}^{E,*} Z_{kb}^V Z_{j2}^+ \right) \right) \right) \quad (311)
\end{aligned}$$

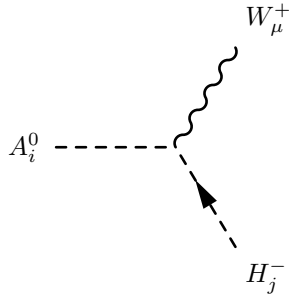
9.2 Two Scalar-One Vector Boson-Interaction



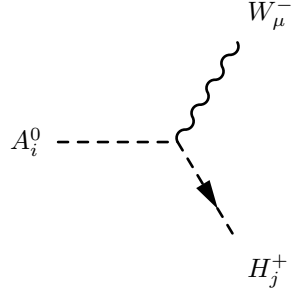
$$\begin{aligned}
& \frac{1}{2} \left(2g_p \left(Q_1 Z_{i4}^{A,*} Z_{j4}^{H,*} + Q_2 Z_{i5}^{A,*} Z_{j5}^{H,*} + Q_3 Z_{i6}^{A,*} Z_{j6}^{H,*} + Q_s Z_{i3}^{A,*} Z_{j3}^{H,*} \right) \sin \Theta'_W \right. \\
& + Z_{i1}^{A,*} Z_{j1}^{H,*} \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \\
& \left. - Z_{i2}^{A,*} Z_{j2}^{H,*} \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \right) \left(-p_\mu^{h_j} + p_\mu^{A_i^0} \right) \quad (312)
\end{aligned}$$



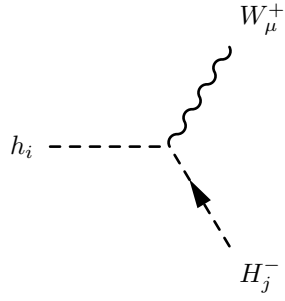
$$\begin{aligned}
& \frac{1}{2} \left(2g_p \left(Q_1 Z_{i4}^{A,*} Z_{j4}^{H,*} + Q_2 Z_{i5}^{A,*} Z_{j5}^{H,*} + Q_3 Z_{i6}^{A,*} Z_{j6}^{H,*} + Q_s Z_{i3}^{A,*} Z_{j3}^{H,*} \right) \cos \Theta'_W \right. \\
& + Z_{i2}^{A,*} Z_{j2}^{H,*} \left(2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W + g_2 \cos \Theta_W \sin \Theta'_W \right) \\
& \left. + Z_{i1}^{A,*} Z_{j1}^{H,*} \left(2g_p Q_{H_d} \cos \Theta'_W - \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \right) \left(-p_\mu^{h_j} + p_\mu^{A_i^0} \right) \quad (313)
\end{aligned}$$



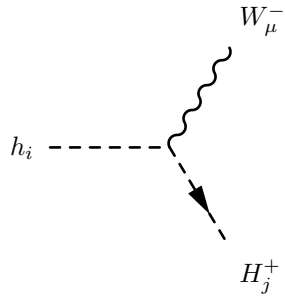
$$\frac{1}{2}g_2\left(Z_{i1}^{A,*}Z_{j1}^+ + Z_{i2}^{A,*}Z_{j2}^+\right)\left(-p_\mu^{H_j^-} + p_\mu^{A_i^0}\right) \quad (314)$$



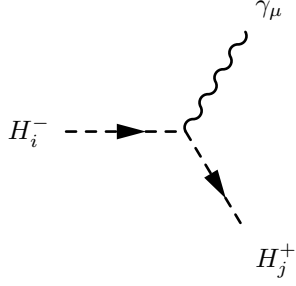
$$\frac{1}{2}g_2\left(Z_{i1}^{A,*}Z_{j1}^+ + Z_{i2}^{A,*}Z_{j2}^+\right)\left(-p_\mu^{H_j^+} + p_\mu^{A_i^0}\right) \quad (315)$$



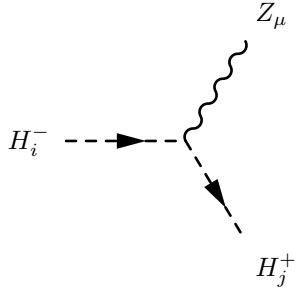
$$\frac{i}{2}g_2\left(Z_{i1}^{H,*}Z_{j1}^+ - Z_{i2}^{H,*}Z_{j2}^+\right)\left(-p_\mu^{H_j^-} + p_\mu^{h_i}\right) \quad (316)$$



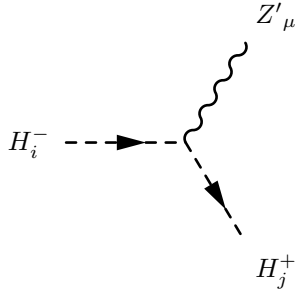
$$-\frac{i}{2}g_2\left(Z_{i1}^{H,*}Z_{j1}^+ - Z_{i2}^{H,*}Z_{j2}^+\right)\left(-p_\mu^{H_j^+} + p_\mu^{h_i}\right) \quad (317)$$



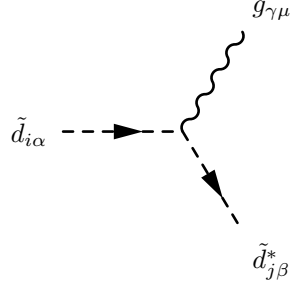
$$\frac{i}{2} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) \left(-p_\mu^{H_j^+} + p_\mu^{H_i^-} \right) \quad (318)$$



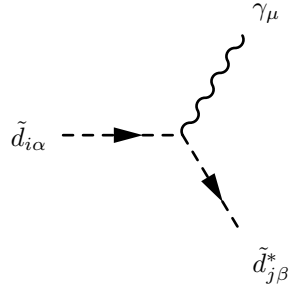
$$\begin{aligned} & \frac{i}{2} \left(\left(-2g_p Q_{H_d} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right. \\ & \left. + \left(2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{i2}^+ Z_{j2}^+ \right) \left(-p_\mu^{H_j^+} + p_\mu^{H_i^-} \right) \end{aligned} \quad (319)$$



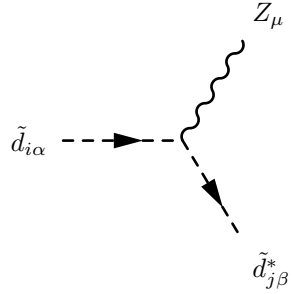
$$\begin{aligned} & -\frac{i}{2} \left(\left(2g_p Q_{H_d} \cos \Theta'_W + \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right. \\ & \left. + \left(-2g_p Q_{H_u} \cos \Theta'_W + \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{i2}^+ Z_{j2}^+ \right) \left(-p_\mu^{H_j^+} + p_\mu^{H_i^-} \right) \end{aligned} \quad (320)$$



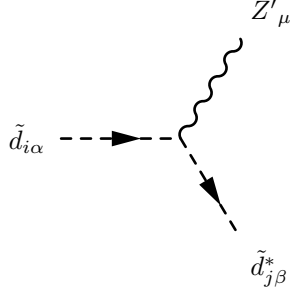
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\beta,\alpha}^{\gamma}\left(-p_{\mu}^{\tilde{d}_{j\beta}^*}+p_{\mu}^{\tilde{d}_{i\alpha}}\right) \quad (321)$$



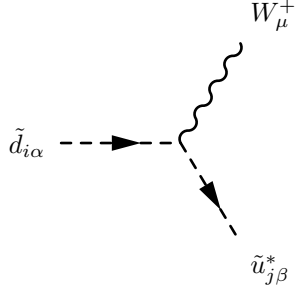
$$-\frac{i}{6}\delta_{\alpha\beta}\left(-2g_1\cos\Theta_W\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D+\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right)\left(-p_{\mu}^{\tilde{d}_{j\beta}^*}+p_{\mu}^{\tilde{d}_{i\alpha}}\right) \quad (322)$$



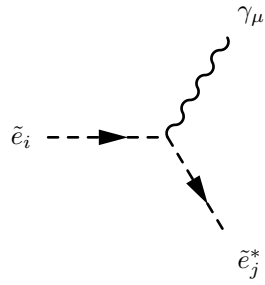
$$\begin{aligned} &\frac{i}{6}\delta_{\alpha\beta}\left(\left(3g_2\cos\Theta_W\cos\Theta'_W-6g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right. \\ &\quad \left.-2\left(-3g_pQ_d\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\right)\left(-p_{\mu}^{\tilde{d}_{j\beta}^*}+p_{\mu}^{\tilde{d}_{i\alpha}}\right) \end{aligned} \quad (323)$$



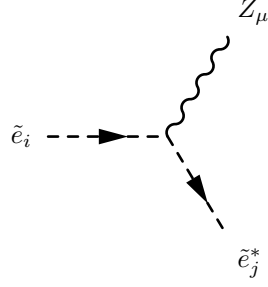
$$\begin{aligned}
& -\frac{i}{6}\delta_{\alpha\beta}\left(\left((3g_2\cos\Theta_W+g_1\sin\Theta_W)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right. \\
& \left.-2\left(3g_pQ_d\cos\Theta'_W+g_1\sin\Theta_W\sin\Theta'_W\right)\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\right)\left(-p_{\mu}^{\tilde{d}_{j\beta}^*}+p_{\mu}^{\tilde{d}_{i\alpha}}\right)
\end{aligned} \tag{324}$$



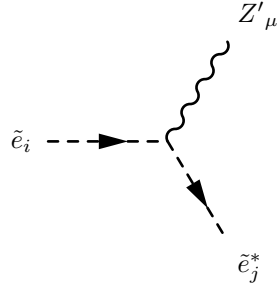
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^U\left(-p_{\mu}^{\tilde{u}_{j\beta}^*}+p_{\mu}^{\tilde{d}_{i\alpha}}\right) \tag{325}$$



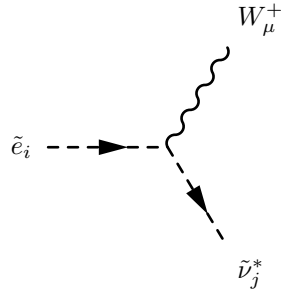
$$\frac{i}{2}\left(2g_1\cos\Theta_W\sum_{a=1}^3Z_{i3+a}^{E,*}Z_{j3+a}^E+\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{E,*}Z_{ja}^E\right)\left(-p_{\mu}^{\tilde{e}_j^*}+p_{\mu}^{\tilde{e}_i}\right) \tag{326}$$



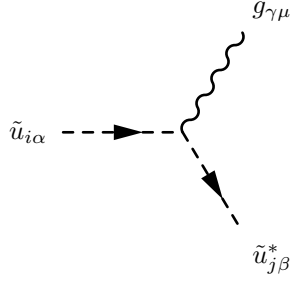
$$\begin{aligned}
& \frac{i}{2} \left(\left(-2g_p Q_l \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. + 2 \left(-g_1 \cos \Theta'_W \sin \Theta_W + g_p Q_e \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) \left(-p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i} \right)
\end{aligned} \tag{327}$$



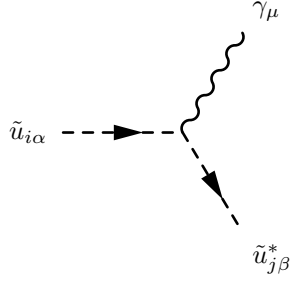
$$\begin{aligned}
& -\frac{i}{2} \left(\left(2g_p Q_l \cos \Theta'_W + \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. - 2 \left(g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_e \cos \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) \left(-p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i} \right)
\end{aligned} \tag{328}$$



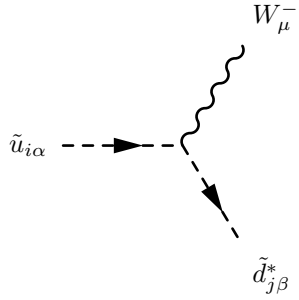
$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V \left(-p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{e}_i} \right) \quad (329)$$



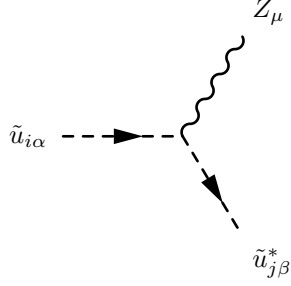
$$- \frac{i}{2} g_3 \delta_{ij} \lambda_{\beta,\alpha}^\gamma \left(-p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \quad (330)$$



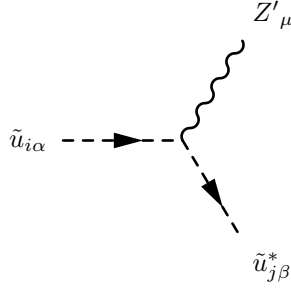
$$- \frac{i}{6} \delta_{\alpha\beta} \left(\left(3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + 4g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) \left(-p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}} \right) \quad (331)$$



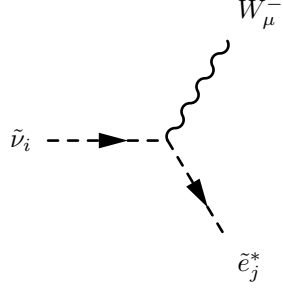
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^D\left(-p_\mu^{\tilde{d}_{j\beta}^*}+p_\mu^{\tilde{u}_{i\alpha}}\right) \quad (332)$$



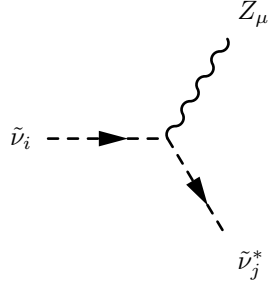
$$\begin{aligned} & -\frac{i}{6}\delta_{\alpha\beta}\left(\left(3g_2\cos\Theta_W\cos\Theta'_W+6g_pQ_q\sin\Theta'_W-g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U\right. \\ & \left.-2\left(2g_1\cos\Theta'_W\sin\Theta_W+3g_pQ_u\sin\Theta'_W\right)\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U\right)\left(-p_\mu^{\tilde{u}_{j\beta}^*}+p_\mu^{\tilde{u}_{i\alpha}}\right) \end{aligned} \quad (333)$$



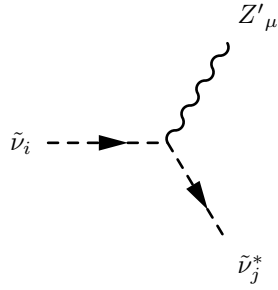
$$\begin{aligned} & -\frac{i}{6}\delta_{\alpha\beta}\left(\left(\left(-3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U\right. \\ & \left.+2\left(2g_1\sin\Theta_W\sin\Theta'_W-3g_pQ_u\cos\Theta'_W\right)\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U\right)\left(-p_\mu^{\tilde{u}_{j\beta}^*}+p_\mu^{\tilde{u}_{i\alpha}}\right) \end{aligned} \quad (334)$$



$$-i \frac{1}{\sqrt{2}} g_2 \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E \left(-p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{\nu}_i} \right) \quad (335)$$

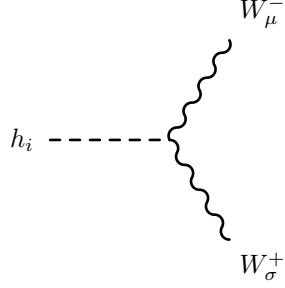


$$-\frac{i}{2} \delta_{ij} \left(2g_p Q_l \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) \left(-p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{\nu}_i} \right) \quad (336)$$

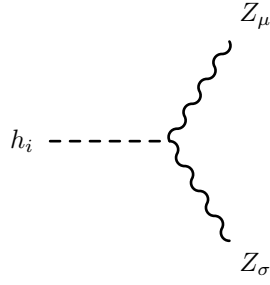


$$-\frac{i}{2} \delta_{ij} \left(2g_p Q_l \cos \Theta'_W - \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) \left(-p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{\nu}_i} \right) \quad (337)$$

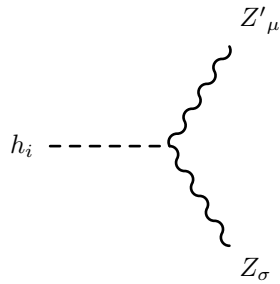
9.3 One Scalar-Two Vector Boson-Interaction



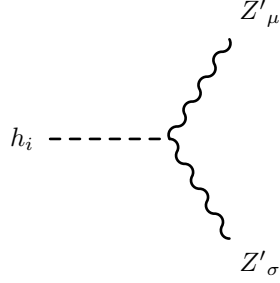
$$\frac{i}{2}g_2^2\left(v_dZ_{i1}^{H,*}+v_uZ_{i2}^{H,*}\right)\left(g_{\sigma\mu}\right) \quad (338)$$



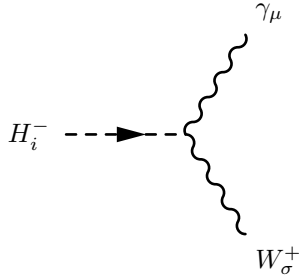
$$\begin{aligned} & \frac{i}{2}\left(4g_p^2\left(Q_1^2v_1Z_{i4}^{H,*}+Q_2^2v_2Z_{i5}^{H,*}+Q_3^2v_3Z_{i6}^{H,*}+Q_s^2v_sZ_{i3}^{H,*}\right)\sin\Theta_W'^2\right. \\ & +v_dZ_{i1}^{H,*}\left(2g_pQ_{H_d}\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W\right)^2 \\ & \left.+v_uZ_{i2}^{H,*}\left(-2g_pQ_{H_u}\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W\right)^2\right)\left(g_{\sigma\mu}\right) \end{aligned} \quad (339)$$



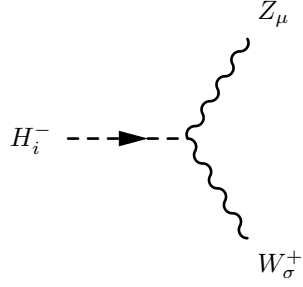
$$\begin{aligned}
& -\frac{i}{2} \left(v_d Z_{i1}^{H,*} \left(-2g_1 g_p Q_{H_d} \cos \Theta'_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \right. \\
& + \cos \Theta'_W \left(-4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta'^2_W \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W - g_p Q_{H_d} \cos \Theta'^2_W + g_p Q_{H_d} \sin \Theta'^2_W \right) \Big) \\
& + v_u Z_{i2}^{H,*} \left(2g_1 g_p Q_{H_u} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left(-4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta'^2_W \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_u} \cos \Theta'^2_W - g_p Q_{H_u} \sin \Theta'^2_W \right) \Big) \\
& - 2g_p^2 \left(Q_1^2 v_1 Z_{i4}^{H,*} + Q_2^2 v_2 Z_{i5}^{H,*} + Q_3^2 v_3 Z_{i6}^{H,*} + Q_s^2 v_s Z_{i3}^{H,*} \right) \sin 2\Theta'_W \Big) (g_{\sigma\mu})
\end{aligned} \tag{340}$$



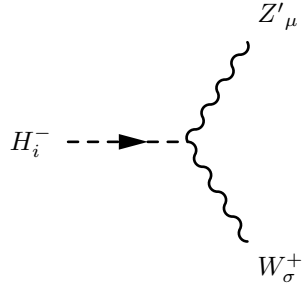
$$\begin{aligned}
& \frac{i}{2} \left(4g_p^2 \left(Q_1^2 v_1 Z_{i4}^{H,*} + Q_2^2 v_2 Z_{i5}^{H,*} + Q_3^2 v_3 Z_{i6}^{H,*} + Q_s^2 v_s Z_{i3}^{H,*} \right) \cos \Theta'^2_W \right. \\
& + v_d Z_{i1}^{H,*} \left(-2g_p Q_{H_d} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \\
& + v_u Z_{i2}^{H,*} \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \Big) (g_{\sigma\mu})
\end{aligned} \tag{341}$$



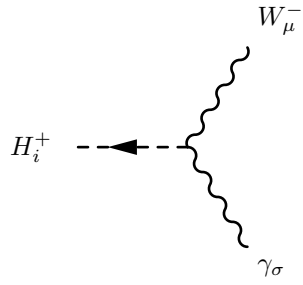
$$-\frac{i}{2} g_1 g_2 \cos \Theta_W \left(v_d Z_{i1}^+ - v_u Z_{i2}^+ \right) (g_{\sigma\mu}) \tag{342}$$



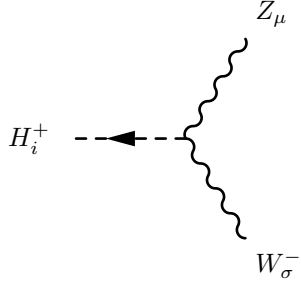
$$\begin{aligned} & \frac{i}{2} g_2 \left(v_d \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{i1}^+ \right. \\ & \left. + v_u \left(2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{i2}^+ \right) (g_{\sigma\mu}) \end{aligned} \quad (343)$$



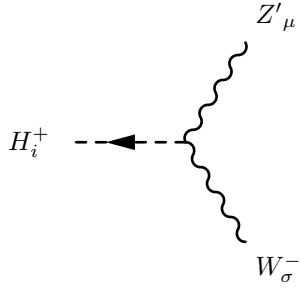
$$\begin{aligned} & \frac{i}{2} g_2 \left(v_d \left(2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{i1}^+ \right. \\ & \left. + v_u \left(2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{i2}^+ \right) (g_{\sigma\mu}) \end{aligned} \quad (344)$$



$$- \frac{i}{2} g_1 g_2 \cos \Theta_W \left(v_d Z_{i1}^+ - v_u Z_{i2}^+ \right) (g_{\sigma\mu}) \quad (345)$$

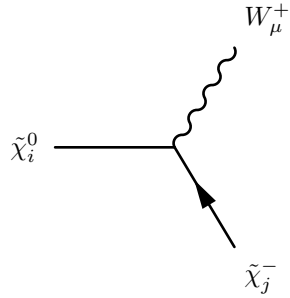


$$\begin{aligned} & \frac{i}{2} g_2 \left(v_d \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{i1}^+ \right. \\ & \left. + v_u \left(2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{i2}^+ \right) (g_{\sigma\mu}) \end{aligned} \quad (346)$$



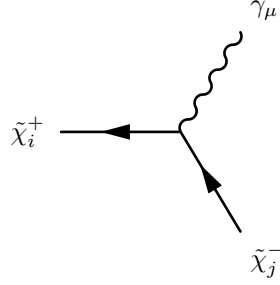
$$\begin{aligned} & \frac{i}{2} g_2 \left(v_d \left(2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{i1}^+ \right. \\ & \left. + v_u \left(2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{i2}^+ \right) (g_{\sigma\mu}) \end{aligned} \quad (347)$$

9.4 Two Fermion-One Vector Boson-Interaction



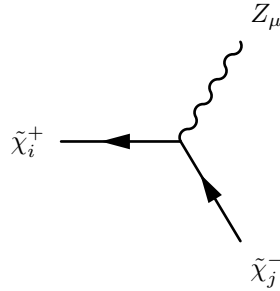
$$-\frac{i}{2}g_2\left(2U_{j1}^*N_{i3}+\sqrt{2}U_{j2}^*N_{i4}\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (348)$$

$$+\left(i\frac{1}{\sqrt{2}}g_2N_{i5}^*V_{j2}-ig_2N_{i3}^*V_{j1}\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (349)$$



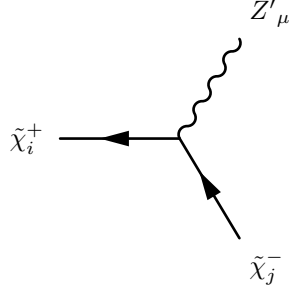
$$\frac{i}{2}\left(2g_2U_{j1}^*\sin\Theta_WU_{i1}+U_{j2}^*\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)U_{i2}\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (350)$$

$$+\frac{i}{2}\left(2g_2V_{i1}^*\sin\Theta_WV_{j1}+V_{i2}^*\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)V_{j2}\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (351)$$



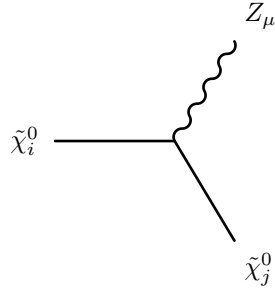
$$\begin{aligned} &\frac{i}{2}\left(2g_2U_{j1}^*\cos\Theta_W\cos\Theta'_WU_{i1}\right. \\ &\left.+U_{j2}^*\left(-2g_pQ_{H_d}\sin\Theta'_W-g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W\right)U_{i2}\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \end{aligned} \quad (352)$$

$$\begin{aligned} &+\frac{i}{2}\left(2g_2V_{i1}^*\cos\Theta_W\cos\Theta'_WV_{j1}\right. \\ &\left.+V_{i2}^*\left(2g_pQ_{H_u}\sin\Theta'_W-g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W\right)V_{j2}\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \end{aligned} \quad (353)$$



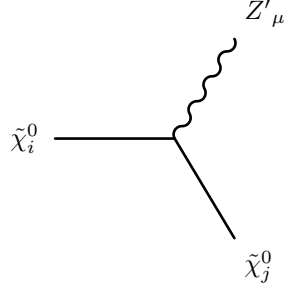
$$\begin{aligned}
& -\frac{i}{2} \left(2g_2 U_{j1}^* \cos \Theta_W \sin \Theta'_W U_{i1} \right. \\
& \left. + U_{j2}^* \left(2g_p Q_{H_d} \cos \Theta'_W + \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) U_{i2} \right) \left(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (354)
\end{aligned}$$

$$\begin{aligned}
& + -\frac{i}{2} \left(2g_2 V_{i1}^* \cos \Theta_W \sin \Theta'_W V_{j1} \right. \\
& \left. + V_{i2}^* \left(-2g_p Q_{H_u} \cos \Theta'_W + \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) V_{j2} \right) \left(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \right) \quad (355)
\end{aligned}$$



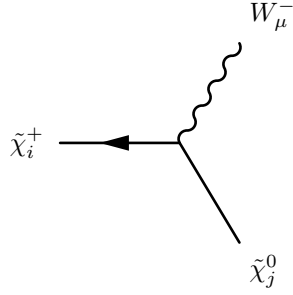
$$\begin{aligned}
& -\frac{i}{2} \left(N_{j4}^* \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) N_{i4} \right. \\
& - N_{j5}^* \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) N_{i5} \\
& \left. + 2g_p \sin \Theta'_W \left(Q_1 N_{j7}^* N_{i7} + Q_2 N_{j8}^* N_{i8} + Q_3 N_{j9}^* N_{i9} + Q_s N_{j6}^* N_{i6} \right) \right) \left(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \right) \quad (356)
\end{aligned}$$

$$\begin{aligned}
& + \frac{i}{2} \left(N_{i4}^* \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) N_{j4} \right. \\
& - N_{i5}^* \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) N_{j5} \\
& \left. + 2g_p \sin \Theta'_W \left(Q_1 N_{i7}^* N_{j7} + Q_2 N_{i8}^* N_{j8} + Q_3 N_{i9}^* N_{j9} + Q_s N_{i6}^* N_{j6} \right) \right) \left(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \right) \quad (357)
\end{aligned}$$



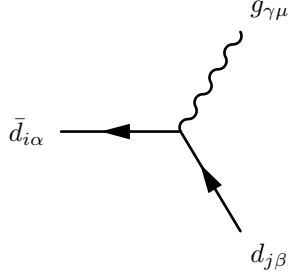
$$\begin{aligned}
& -\frac{i}{2} \left(N_{j4}^* \left(2g_p Q_{H_d} \cos \Theta'_W - \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) N_{i4} \right. \\
& + N_{j5}^* \left(2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W + g_2 \cos \Theta_W \sin \Theta'_W \right) N_{i5} \\
& \left. + 2g_p \cos \Theta'_W \left(Q_1 N_{j7}^* N_{i7} + Q_2 N_{j8}^* N_{i8} + Q_3 N_{j9}^* N_{i9} + Q_s N_{j6}^* N_{i6} \right) \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (358)
\end{aligned}$$

$$\begin{aligned}
& +\frac{i}{2} \left(N_{i4}^* \left(2g_p Q_{H_d} \cos \Theta'_W - \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) N_{j4} \right. \\
& + N_{i5}^* \left(2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W + g_2 \cos \Theta_W \sin \Theta'_W \right) N_{j5} \\
& \left. + 2g_p \cos \Theta'_W \left(Q_1 N_{i7}^* N_{j7} + Q_2 N_{i8}^* N_{j8} + Q_3 N_{i9}^* N_{j9} + Q_s N_{i6}^* N_{j6} \right) \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (359)
\end{aligned}$$



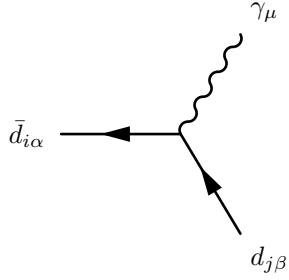
$$-\frac{i}{2} g_2 \left(2N_{j3}^* U_{i1} + \sqrt{2} N_{j4}^* U_{i2} \right) \left(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \right) \quad (360)$$

$$+ \left(i \frac{1}{\sqrt{2}} g_2 V_{i2}^* N_{j5} - i g_2 V_{i1}^* N_{j3} \right) \left(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \right) \quad (361)$$



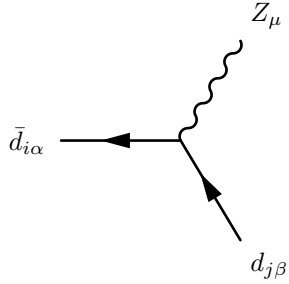
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (362)$$

$$+\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (363)$$



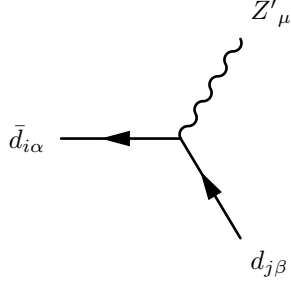
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (364)$$

$$+\frac{i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (365)$$



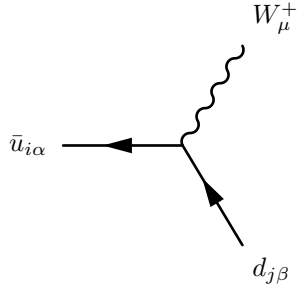
$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\cos\Theta_W\cos\Theta'_W-6g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (366)$$

$$+\frac{i}{3}\delta_{\alpha\beta}\delta_{ij}\left(-3g_pQ_d\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (367)$$

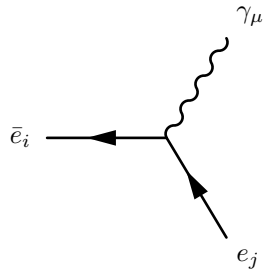


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (368)$$

$$+\frac{i}{3}\delta_{\alpha\beta}\delta_{ij}\left(3g_pQ_d\cos\Theta'_W+g_1\sin\Theta_W\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (369)$$

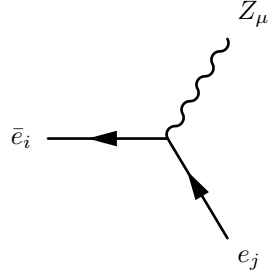


$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3U_{L,ja}^{d,*}U_{L,ia}^u\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (370)$$



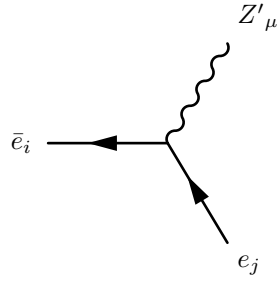
$$\frac{i}{2}\delta_{ij}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (371)$$

$$+ig_1\cos\Theta_W\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (372)$$



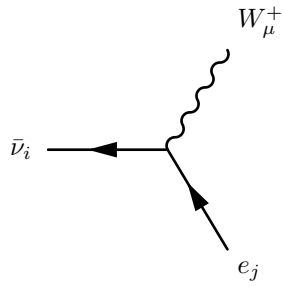
$$\frac{i}{2}\delta_{ij}\left(-2g_pQ_l\sin\Theta'_W - g_1\cos\Theta'_W\sin\Theta_W + g_2\cos\Theta_W\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (373)$$

$$+ -i\delta_{ij}\left(g_1\cos\Theta'_W\sin\Theta_W - g_pQ_e\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (374)$$

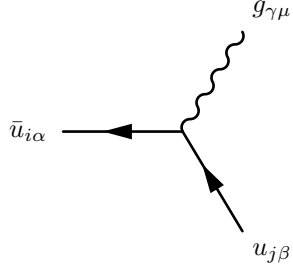


$$- \frac{i}{2}\delta_{ij}\left(2g_pQ_l\cos\Theta'_W + \left(-g_1\sin\Theta_W + g_2\cos\Theta_W\right)\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (375)$$

$$+ i\delta_{ij}\left(g_1\sin\Theta_W\sin\Theta'_W + g_pQ_e\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (376)$$

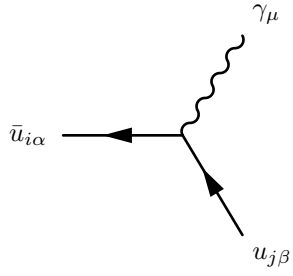


$$- i\frac{1}{\sqrt{2}}g_2U_{L,ji}^{e,*}\Theta_{i,3}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (377)$$



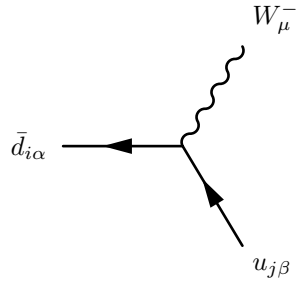
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (378)$$

$$+\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^\gamma\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (379)$$

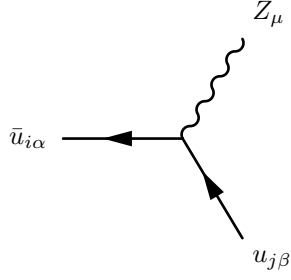


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (380)$$

$$+\frac{2i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (381)$$

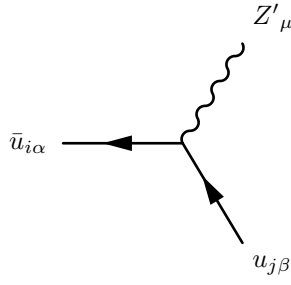


$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^3U_{L,ja}^{u,*}U_{L,ia}^d\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (382)$$



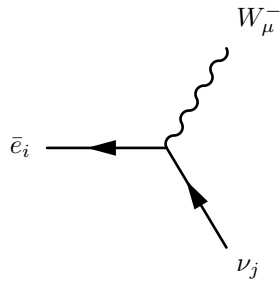
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\cos\Theta_W\cos\Theta'_W+6g_pQ_q\sin\Theta'_W-g_1\cos\Theta'_W\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (383)$$

$$+\frac{i}{3}\delta_{\alpha\beta}\delta_{ij}\left(2g_1\cos\Theta'_W\sin\Theta_W+3g_pQ_u\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (384)$$

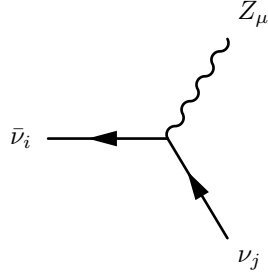


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(\left(-3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (385)$$

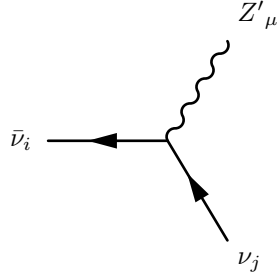
$$+\frac{i}{3}\delta_{\alpha\beta}\delta_{ij}\left(-2g_1\sin\Theta_W\sin\Theta'_W+3g_pQ_u\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (386)$$



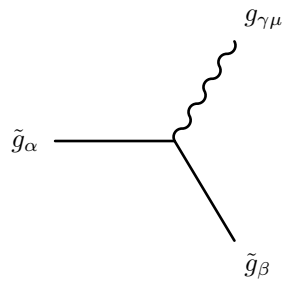
$$-i\frac{1}{\sqrt{2}}g_2\Theta_{j,3}U_{L,ij}^e\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (387)$$



$$-\frac{i}{2}\delta_{ij}\left(2g_pQ_l\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (388)$$



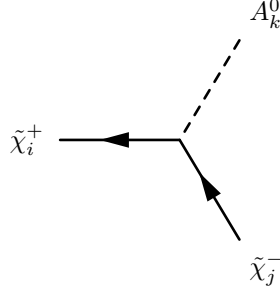
$$-\frac{i}{2}\delta_{ij}\left(2g_pQ_l\cos\Theta'_W-\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (389)$$



$$-g_3|\phi_{\tilde{g}}|^2f_{\alpha,\beta,\gamma}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \quad (390)$$

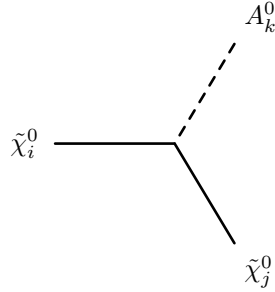
$$+ -g_3|\phi_{\tilde{g}}|^2f_{\alpha,\beta,\gamma}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \quad (391)$$

9.5 Two Fermion-One Scalar Boson-Interaction



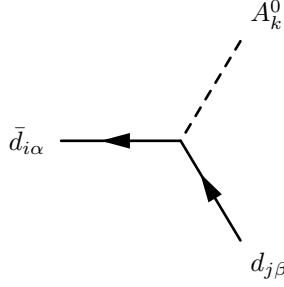
$$\frac{1}{\sqrt{2}} \left(-g_2 U_{j1}^* V_{i2}^* Z_{k2}^{A,*} + U_{j2}^* \left(-g_2 V_{i1}^* Z_{k1}^{A,*} + \lambda V_{i2}^* Z_{k3}^{A,*} \right) \right) \left(\frac{1-\gamma_5}{2} \right) \quad (392)$$

$$+ \frac{1}{\sqrt{2}} \left(g_2 Z_{k1}^{A,*} U_{i2} V_{j1} + \left(g_2 Z_{k2}^{A,*} U_{i1} - \lambda^* Z_{k3}^{A,*} U_{i2} \right) V_{j2} \right) \left(\frac{1+\gamma_5}{2} \right) \quad (393)$$



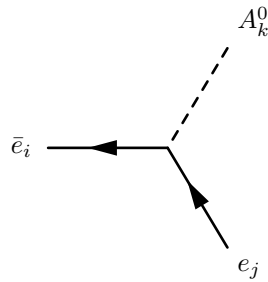
$$\begin{aligned} & \frac{1}{6} \left(-6g_p Q_s Z_{k3}^{A,*} N_{i6}^* N_{j1}^* - 6g_p Q_1 Z_{k4}^{A,*} N_{i7}^* N_{j1}^* - 6g_p Q_2 Z_{k5}^{A,*} N_{i8}^* N_{j1}^* \right. \\ & - 6g_p Q_3 Z_{k6}^{A,*} N_{i9}^* N_{j1}^* - 3\sqrt{2}\lambda Z_{k3}^{A,*} N_{i5}^* N_{j4}^* - 3\sqrt{2}\lambda Z_{k3}^{A,*} N_{i4}^* N_{j5}^* \\ & - 6g_p Q_s Z_{k3}^{A,*} N_{i1}^* N_{j6}^* \\ & - 3Z_{k2}^{A,*} \left(N_{i5}^* \left(2g_p Q_{H_u} N_{j1}^* + g_1 N_{j2}^* - g_2 N_{j3}^* \right) + \sqrt{2}\lambda N_{i6}^* N_{j4}^* + 2g_p Q_{H_u} N_{i1}^* N_{j5}^* + g_1 N_{i2}^* N_{j5}^* \right. \\ & \left. - g_2 N_{i3}^* N_{j5}^* + \sqrt{2}\lambda N_{i4}^* N_{j6}^* \right) \\ & - 3Z_{k1}^{A,*} \left(N_{i4}^* \left(2g_p Q_{H_d} N_{j1}^* - g_1 N_{j2}^* + g_2 N_{j3}^* \right) + 2g_p Q_{H_d} N_{i1}^* N_{j4}^* - g_1 N_{i2}^* N_{j4}^* + g_2 N_{i3}^* N_{j4}^* \right. \\ & \left. + \sqrt{2}\lambda N_{i6}^* N_{j5}^* + \sqrt{2}\lambda N_{i5}^* N_{j6}^* \right) \\ & - 6g_p Q_1 Z_{k4}^{A,*} N_{i1}^* N_{j7}^* + \sqrt{2}\kappa Z_{k6}^{A,*} N_{i8}^* N_{j7}^* + \sqrt{2}\kappa Z_{k5}^{A,*} N_{i9}^* N_{j7}^* \\ & - 6g_p Q_2 Z_{k5}^{A,*} N_{i1}^* N_{j8}^* + \sqrt{2}\kappa Z_{k6}^{A,*} N_{i7}^* N_{j8}^* + \sqrt{2}\kappa Z_{k4}^{A,*} N_{i9}^* N_{j8}^* \\ & \left. - 6g_p Q_3 Z_{k6}^{A,*} N_{i1}^* N_{j9}^* + \sqrt{2}\kappa Z_{k5}^{A,*} N_{i7}^* N_{j9}^* + \sqrt{2}\kappa Z_{k4}^{A,*} N_{i8}^* N_{j9}^* \right) \left(\frac{1-\gamma_5}{2} \right) \quad (394) \end{aligned}$$

$$\begin{aligned}
& + \frac{1}{6} \left(6g_p Q_s Z_{k3}^{A,*} N_{i6} N_{j1} + 6g_p Q_1 Z_{k4}^{A,*} N_{i7} N_{j1} + 6g_p Q_2 Z_{k5}^{A,*} N_{i8} N_{j1} + 6g_p Q_3 Z_{k6}^{A,*} N_{i9} N_{j1} \right. \\
& + 3\sqrt{2}\lambda^* Z_{k3}^{A,*} N_{i5} N_{j4} + 3\sqrt{2}\lambda^* Z_{k3}^{A,*} N_{i4} N_{j5} + 6g_p Q_s Z_{k3}^{A,*} N_{i1} N_{j6} \\
& + 3Z_{k1}^{A,*} \left(N_{i4} \left(2g_p Q_{H_d} N_{j1} - g_1 N_{j2} + g_2 N_{j3} \right) + 2g_p Q_{H_d} N_{i1} N_{j4} - g_1 N_{i2} N_{j4} + g_2 N_{i3} N_{j4} \right. \\
& + \sqrt{2}\lambda^* N_{i6} N_{j5} + \sqrt{2}\lambda^* N_{i5} N_{j6} \left. \right) \\
& + 3Z_{k2}^{A,*} \left(N_{i5} \left(2g_p Q_{H_u} N_{j1} + g_1 N_{j2} - g_2 N_{j3} \right) + \left(2g_p Q_{H_u} N_{i1} + g_1 N_{i2} - g_2 N_{i3} \right) N_{j5} \right. \\
& + \sqrt{2}\lambda^* \left(N_{i4} N_{j6} + N_{i6} N_{j4} \right) \left. \right) \\
& + 6g_p Q_1 Z_{k4}^{A,*} N_{i1} N_{j7} - \sqrt{2}\kappa^* Z_{k6}^{A,*} N_{i8} N_{j7} - \sqrt{2}\kappa^* Z_{k5}^{A,*} N_{i9} N_{j7} + 6g_p Q_2 Z_{k5}^{A,*} N_{i1} N_{j8} \\
& - \sqrt{2}\kappa^* Z_{k6}^{A,*} N_{i7} N_{j8} - \sqrt{2}\kappa^* Z_{k4}^{A,*} N_{i9} N_{j8} + 6g_p Q_3 Z_{k6}^{A,*} N_{i1} N_{j9} - \sqrt{2}\kappa^* Z_{k5}^{A,*} N_{i7} N_{j9} \\
& - \sqrt{2}\kappa^* Z_{k4}^{A,*} N_{i8} N_{j9} \left. \right) \left(\frac{1+\gamma_5}{2} \right)
\end{aligned} \tag{395}$$



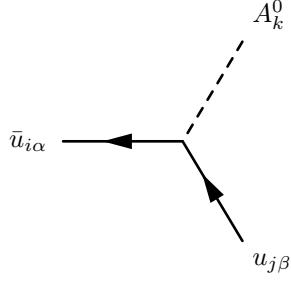
$$\frac{1}{\sqrt{2}} Z_{k1}^{A,*} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} \left(\frac{1-\gamma_5}{2} \right) \tag{396}$$

$$+ -\frac{1}{\sqrt{2}} Z_{k1}^{A,*} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d \left(\frac{1+\gamma_5}{2} \right) \tag{397}$$



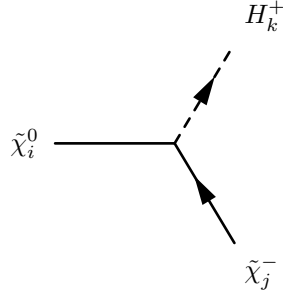
$$\frac{1}{\sqrt{2}} Z_{k1}^{A,*} \sum_{b=1}^3 U_{L,jb}^{e,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} \left(\frac{1-\gamma_5}{2} \right) \quad (398)$$

$$+ -\frac{1}{\sqrt{2}} Z_{k1}^{A,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e \left(\frac{1+\gamma_5}{2} \right) \quad (399)$$



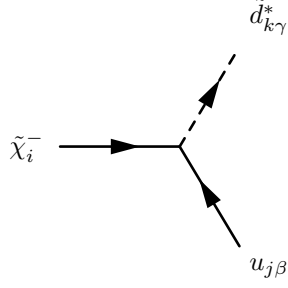
$$\frac{1}{\sqrt{2}} Z_{k2}^{A,*} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} \left(\frac{1-\gamma_5}{2} \right) \quad (400)$$

$$+ -\frac{1}{\sqrt{2}} Z_{k2}^{A,*} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^u \left(\frac{1+\gamma_5}{2} \right) \quad (401)$$



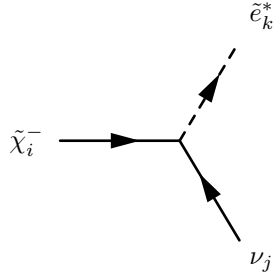
$$- \frac{i}{2} \left(2g_2 U_{j1}^* N_{i4}^* Z_{k1}^+ \right. \\ \left. + U_{j2}^* \left(2\lambda N_{i6}^* Z_{k2}^+ + 2\sqrt{2} g_p Q_{H_d} N_{i1}^* Z_{k1}^+ - \sqrt{2} g_1 N_{i2}^* Z_{k1}^+ - \sqrt{2} g_2 N_{i3}^* Z_{k1}^+ \right) \right) \left(\frac{1-\gamma_5}{2} \right) \quad (402)$$

$$+ -\frac{i}{2} \left(\left(2g_2 V_{j1} N_{i5} + \sqrt{2} V_{j2} \left(2g_p Q_{H_u} N_{i1} + g_1 N_{i2} + g_2 N_{i3} \right) \right) Z_{k2}^+ + 2\lambda^* V_{j2} N_{i6} Z_{k1}^+ \right) \left(\frac{1+\gamma_5}{2} \right) \quad (403)$$

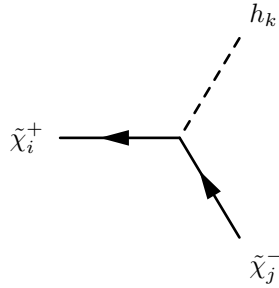


$$-i\delta_{\beta\gamma}\left(g_2U_{i1}^*\sum_{a=1}^3U_{L,ja}^{u,*}Z_{ka}^D-U_{i2}^*\sum_{b=1}^3U_{L,jb}^{u,*}\sum_{a=1}^3Y_{d,ab}Z_{k3+a}^D\right)\left(\frac{1-\gamma_5}{2}\right) \quad (404)$$

$$+i\delta_{\beta\gamma}\sum_{b=1}^3\sum_{a=1}^3Y_{u,ab}^*U_{R,ja}^uZ_{kb}^DV_{i2}\left(\frac{1+\gamma_5}{2}\right) \quad (405)$$

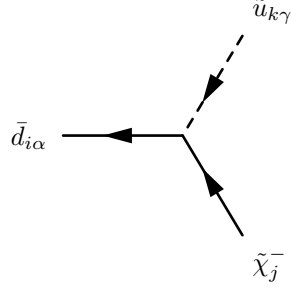


$$i\left(-g_2U_{i1}^*\Theta_{j,3}Z_{kj}^E+U_{i2}^*\sum_{a=1}^3Y_{e,aj}Z_{k3+a}^E\right)\left(\frac{1-\gamma_5}{2}\right) \quad (406)$$



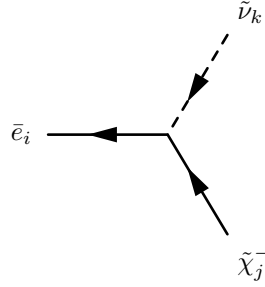
$$-i\frac{1}{\sqrt{2}}\left(g_2U_{j1}^*V_{i2}^*Z_{k2}^{H,*}+U_{j2}^*\left(g_2V_{i1}^*Z_{k1}^{H,*}+\lambda V_{i2}^*Z_{k3}^{H,*}\right)\right)\left(\frac{1-\gamma_5}{2}\right) \quad (407)$$

$$+ -i \frac{1}{\sqrt{2}} \left(g_2 Z_{k1}^{H,*} U_{i2} V_{j1} + \left(g_2 Z_{k2}^{H,*} U_{i1} + \lambda^* Z_{k3}^{H,*} U_{i2} \right) V_{j2} \right) \left(\frac{1+\gamma_5}{2} \right) \quad (408)$$



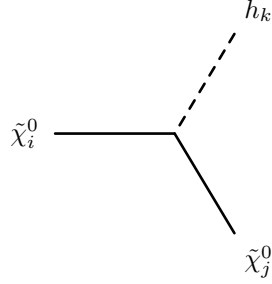
$$i U_{j2}^* \delta_{\alpha\gamma} \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} \left(\frac{1-\gamma_5}{2} \right) \quad (409)$$

$$+ -i \delta_{\alpha\gamma} \left(g_2 \sum_{a=1}^3 Z_{ka}^{U,*} U_{L,ia}^d V_{j1} - \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} U_{L,ib}^d V_{j2} \right) \left(\frac{1+\gamma_5}{2} \right) \quad (410)$$



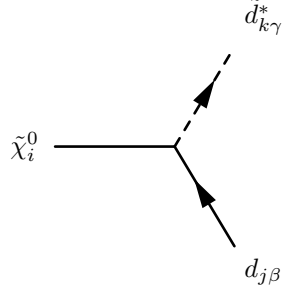
$$i U_{j2}^* \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,ab} \left(\frac{1-\gamma_5}{2} \right) \quad (411)$$

$$+ -i g_2 \sum_{a=1}^3 Z_{ka}^{V,*} U_{L,ia}^e V_{j1} \left(\frac{1+\gamma_5}{2} \right) \quad (412)$$



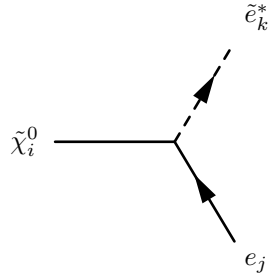
$$\begin{aligned}
& -\frac{i}{6} \left(6g_p Q_s Z_{k3}^{H,*} N_{i6}^* N_{j1}^* + 6g_p Q_1 Z_{k4}^{H,*} N_{i7}^* N_{j1}^* + 6g_p Q_2 Z_{k5}^{H,*} N_{i8}^* N_{j1}^* \right. \\
& + 6g_p Q_3 Z_{k6}^{H,*} N_{i9}^* N_{j1}^* - 3\sqrt{2}\lambda Z_{k3}^{H,*} N_{i5}^* N_{j4}^* - 3\sqrt{2}\lambda Z_{k3}^{H,*} N_{i4}^* N_{j5}^* \\
& + 6g_p Q_s Z_{k3}^{H,*} N_{i1}^* N_{j6}^* \\
& + 3Z_{k2}^{H,*} \left(N_{i5}^* \left(2g_p Q_{H_u} N_{j1}^* + g_1 N_{j2}^* - g_2 N_{j3}^* \right) - \sqrt{2}\lambda N_{i6}^* N_{j4}^* + 2g_p Q_{H_u} N_{i1}^* N_{j5}^* + g_1 N_{i2}^* N_{j5}^* \right. \\
& \left. - g_2 N_{i3}^* N_{j5}^* - \sqrt{2}\lambda N_{i4}^* N_{j6}^* \right) \\
& + 3Z_{k1}^{H,*} \left(N_{i4}^* \left(2g_p Q_{H_d} N_{j1}^* - g_1 N_{j2}^* + g_2 N_{j3}^* \right) + 2g_p Q_{H_d} N_{i1}^* N_{j4}^* - g_1 N_{i2}^* N_{j4}^* + g_2 N_{i3}^* N_{j4}^* \right. \\
& \left. - \sqrt{2}\lambda N_{i6}^* N_{j5}^* - \sqrt{2}\lambda N_{i5}^* N_{j6}^* \right) \\
& + 6g_p Q_1 Z_{k4}^{H,*} N_{i1}^* N_{j7}^* + \sqrt{2}\kappa Z_{k6}^{H,*} N_{i8}^* N_{j7}^* + \sqrt{2}\kappa Z_{k5}^{H,*} N_{i9}^* N_{j7}^* \\
& + 6g_p Q_2 Z_{k5}^{H,*} N_{i1}^* N_{j8}^* + \sqrt{2}\kappa Z_{k6}^{H,*} N_{i7}^* N_{j8}^* + \sqrt{2}\kappa Z_{k4}^{H,*} N_{i9}^* N_{j8}^* \\
& + 6g_p Q_3 Z_{k6}^{H,*} N_{i1}^* N_{j9}^* + \sqrt{2}\kappa Z_{k5}^{H,*} N_{i7}^* N_{j9}^* + \sqrt{2}\kappa Z_{k4}^{H,*} N_{i8}^* N_{j9}^* \left(\frac{1-\gamma_5}{2} \right) \tag{413}
\end{aligned}$$

$$\begin{aligned}
& + -\frac{i}{6} \left(6g_p Q_s Z_{k3}^{H,*} N_{i6} N_{j1} + 6g_p Q_1 Z_{k4}^{H,*} N_{i7} N_{j1} + 6g_p Q_2 Z_{k5}^{H,*} N_{i8} N_{j1} + 6g_p Q_3 Z_{k6}^{H,*} N_{i9} N_{j1} \right. \\
& - 3\sqrt{2}\lambda^* Z_{k3}^{H,*} N_{i5} N_{j4} - 3\sqrt{2}\lambda^* Z_{k3}^{H,*} N_{i4} N_{j5} + 6g_p Q_s Z_{k3}^{H,*} N_{i1} N_{j6} \\
& + 3Z_{k2}^{H,*} \left(N_{i4} \left(2g_p Q_{H_d} N_{j1} - g_1 N_{j2} + g_2 N_{j3} \right) + 2g_p Q_{H_d} N_{i1} N_{j4} - g_1 N_{i2} N_{j4} + g_2 N_{i3} N_{j4} \right. \\
& \left. - \sqrt{2}\lambda^* N_{i6} N_{j5} - \sqrt{2}\lambda^* N_{i5} N_{j6} \right) \\
& + 3Z_{k1}^{H,*} \left(N_{i5} \left(2g_p Q_{H_u} N_{j1} + g_1 N_{j2} - g_2 N_{j3} \right) + \left(2g_p Q_{H_u} N_{i1} + g_1 N_{i2} - g_2 N_{i3} \right) N_{j5} \right. \\
& \left. - \sqrt{2}\lambda^* \left(N_{i4} N_{j6} + N_{i6} N_{j4} \right) \right) \\
& + 6g_p Q_1 Z_{k4}^{H,*} N_{i1} N_{j7} + \sqrt{2}\kappa^* Z_{k6}^{H,*} N_{i8} N_{j7} + \sqrt{2}\kappa^* Z_{k5}^{H,*} N_{i9} N_{j7} + 6g_p Q_2 Z_{k5}^{H,*} N_{i1} N_{j8} \\
& + \sqrt{2}\kappa^* Z_{k6}^{H,*} N_{i7} N_{j8} + \sqrt{2}\kappa^* Z_{k4}^{H,*} N_{i9} N_{j8} + 6g_p Q_3 Z_{k6}^{H,*} N_{i1} N_{j9} + \sqrt{2}\kappa^* Z_{k5}^{H,*} N_{i7} N_{j9} \\
& + \sqrt{2}\kappa^* Z_{k4}^{H,*} N_{i8} N_{j9} \left(\frac{1+\gamma_5}{2} \right) \tag{414}
\end{aligned}$$



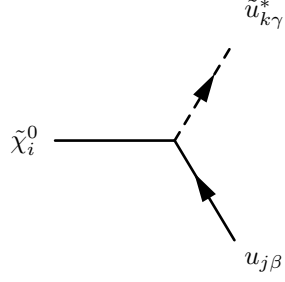
$$\begin{aligned}
& -\frac{i}{6}\delta_{\beta\gamma}\left(6\sqrt{2}g_pQ_qN_{i1}^*\sum_{a=1}^3U_{L,ja}^{d,*}Z_{ka}^D+\sqrt{2}g_1N_{i2}^*\sum_{a=1}^3U_{L,ja}^{d,*}Z_{ka}^D-3\sqrt{2}g_2N_{i3}^*\sum_{a=1}^3U_{L,ja}^{d,*}Z_{ka}^D\right. \\
& \left.+6N_{i4}^*\sum_{b=1}^3U_{L,jb}^{d,*}\sum_{a=1}^3Y_{d,ab}Z_{k3+a}^D\right)\left(\frac{1-\gamma_5}{2}\right) \tag{415}
\end{aligned}$$

$$\begin{aligned}
& +\frac{i}{3}\delta_{\beta\gamma}\left(3\sum_{b=1}^3\sum_{a=1}^3Y_{d,ab}^*U_{R,ja}^dZ_{kb}^DN_{i4}+\sqrt{2}\sum_{a=1}^3Z_{k3+a}^DU_{R,ja}^d\left(3g_pQ_dN_{i1}+g_1N_{i2}\right)\right)\left(\frac{1+\gamma_5}{2}\right) \tag{416}
\end{aligned}$$



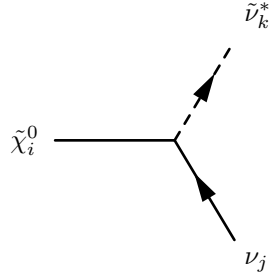
$$\begin{aligned}
& -\frac{i}{2}\left(2\sqrt{2}g_pQ_lN_{i1}^*\sum_{a=1}^3U_{L,ja}^{e,*}Z_{ka}^E-\sqrt{2}g_1N_{i2}^*\sum_{a=1}^3U_{L,ja}^{e,*}Z_{ka}^E-\sqrt{2}g_2N_{i3}^*\sum_{a=1}^3U_{L,ja}^{e,*}Z_{ka}^E\right. \\
& \left.+2N_{i4}^*\sum_{b=1}^3U_{L,jb}^{e,*}\sum_{a=1}^3Y_{e,ab}Z_{k3+a}^E\right)\left(\frac{1-\gamma_5}{2}\right) \tag{417}
\end{aligned}$$

$$\begin{aligned}
& +\frac{i}{2}\left(\sqrt{2}\sum_{a=1}^3Z_{k3+a}^EU_{R,ja}^e\left(g_1N_{i2}+g_pQ_eN_{i1}\right)+\sum_{b=1}^3\sum_{a=1}^3Y_{e,ab}^*U_{R,ja}^eZ_{kb}^EN_{i4}\right)\left(\frac{1+\gamma_5}{2}\right) \tag{418}
\end{aligned}$$

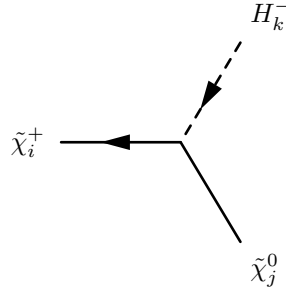


$$\begin{aligned}
& -\frac{i}{6}\delta_{\beta\gamma}\left(6\sqrt{2}g_pQ_qN_{i1}^*\sum_{a=1}^3U_{L,ja}^{u,*}Z_{ka}^U+\sqrt{2}g_1N_{i2}^*\sum_{a=1}^3U_{L,ja}^{u,*}Z_{ka}^U+3\sqrt{2}g_2N_{i3}^*\sum_{a=1}^3U_{L,ja}^{u,*}Z_{ka}^U\right. \\
& \left.+6N_{i5}^*\sum_{b=1}^3U_{L,jb}^{u,*}\sum_{a=1}^3Y_{u,ab}Z_{k3+a}^U\right)\left(\frac{1-\gamma_5}{2}\right) \tag{419}
\end{aligned}$$

$$\begin{aligned}
& +-\frac{i}{3}\delta_{\beta\gamma}\left(3\sum_{b=1}^3\sum_{a=1}^3Y_{u,ab}^*U_{R,ja}^uZ_{kb}^UN_{i5}+\sqrt{2}\sum_{a=1}^3Z_{k3+a}^U U_{R,ja}^u\left(-2g_1N_{i2}+3g_pQ_uN_{i1}\right)\right)\left(\frac{1+\gamma_5}{2}\right) \tag{420}
\end{aligned}$$

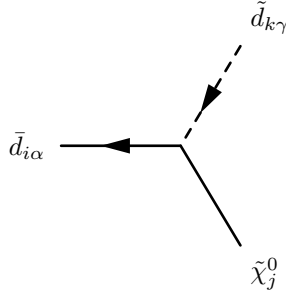


$$-i\frac{1}{\sqrt{2}}\left(2g_pQ_lN_{i1}^*-g_1N_{i2}^*+g_2N_{i3}^*\right)\Theta_{j,3}Z_{kj}^V\left(\frac{1-\gamma_5}{2}\right) \tag{421}$$



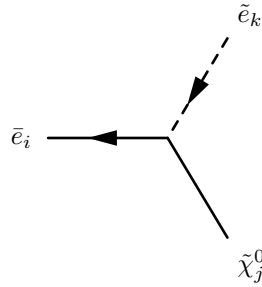
$$-\frac{i}{2}\left(2g_2V_{i1}^*N_{j5}^*Z_{k2}^+ + V_{i2}^*\left(2\lambda N_{j6}^*Z_{k1}^+ + \sqrt{2}\left(2g_pQ_{Hu}N_{j1}^* + g_1N_{j2}^* + g_2N_{j3}^*\right)Z_{k2}^+\right)\right)\left(\frac{1-\gamma_5}{2}\right) \quad (422)$$

$$+ -\frac{i}{2}\left(2g_2U_{i1}N_{j4}Z_{k1}^+ + U_{i2}\left(2\lambda^*N_{j6}Z_{k2}^+ + 2\sqrt{2}g_pQ_{Hd}N_{j1}Z_{k1}^+ - \sqrt{2}g_1N_{j2}Z_{k1}^+ - \sqrt{2}g_2N_{j3}Z_{k1}^+\right)\right)\left(\frac{1+\gamma_5}{2}\right) \quad (423)$$



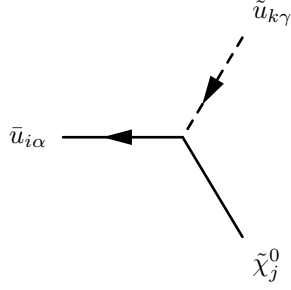
$$-\frac{i}{3}\delta_{\alpha\gamma}\left(3\sqrt{2}g_pQ_dN_{j1}^*\sum_{a=1}^3Z_{k3+a}^{D,*}U_{R,ia}^{d,*} + \sqrt{2}g_1N_{j2}^*\sum_{a=1}^3Z_{k3+a}^{D,*}U_{R,ia}^{d,*}\right. \\ \left.+ 3N_{j4}^*\sum_{b=1}^3Z_{kb}^{D,*}\sum_{a=1}^3U_{R,ia}^{d,*}Y_{d,ab}\right)\left(\frac{1-\gamma_5}{2}\right) \quad (424)$$

$$+ -\frac{i}{6}\delta_{\alpha\gamma}\left(6\sum_{b=1}^3\sum_{a=1}^3Y_{d,ab}^*Z_{k3+a}^{D,*}U_{L,ib}^dN_{j4} + \sqrt{2}\sum_{a=1}^3Z_{ka}^{D,*}U_{L,ia}^d\left(-3g_2N_{j3} + 6g_pQ_qN_{j1} + g_1N_{j2}\right)\right)\left(\frac{1+\gamma_5}{2}\right) \quad (425)$$



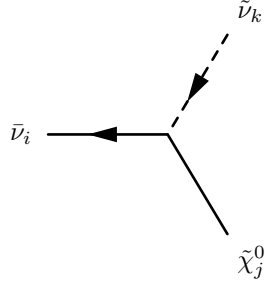
$$-i\left(\sqrt{2}g_pQ_eN_{j1}^*\sum_{a=1}^3Z_{k3+a}^{E,*}U_{R,ia}^{e,*} + \sqrt{2}g_1N_{j2}^*\sum_{a=1}^3Z_{k3+a}^{E,*}U_{R,ia}^{e,*}\right. \\ \left.+ N_{j4}^*\sum_{b=1}^3Z_{kb}^{E,*}\sum_{a=1}^3U_{R,ia}^{e,*}Y_{e,ab}\right)\left(\frac{1-\gamma_5}{2}\right) \quad (426)$$

$$+ -\frac{i}{2} \left(2 \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} U_{L,ib}^e N_{j4} + \sqrt{2} \sum_{a=1}^3 Z_{ka}^{E,*} U_{L,ia}^e \left(2g_p Q_l N_{j1} - g_1 N_{j2} - g_2 N_{j3} \right) \right) \left(\frac{1+\gamma_5}{2} \right) \quad (427)$$



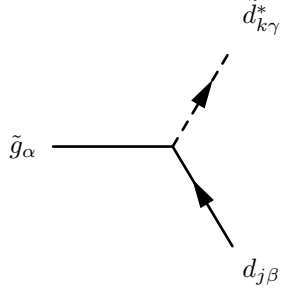
$$- \frac{i}{3} \delta_{\alpha\gamma} \left(3\sqrt{2} g_p Q_u N_{j1}^* \sum_{a=1}^3 Z_{k3+a}^{U,*} U_{R,ia}^{u,*} - 2\sqrt{2} g_1 N_{j2}^* \sum_{a=1}^3 Z_{k3+a}^{U,*} U_{R,ia}^{u,*} \right. \\ \left. + 3N_{j5}^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} \right) \left(\frac{1-\gamma_5}{2} \right) \quad (428)$$

$$+ -\frac{i}{6} \delta_{\alpha\gamma} \left(6 \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} U_{L,ib}^u N_{j5} + \sqrt{2} \sum_{a=1}^3 Z_{ka}^{U,*} U_{L,ia}^u \left(3g_2 N_{j3} + 6g_p Q_q N_{j1} + g_1 N_{j2} \right) \right) \left(\frac{1+\gamma_5}{2} \right) \quad (429)$$



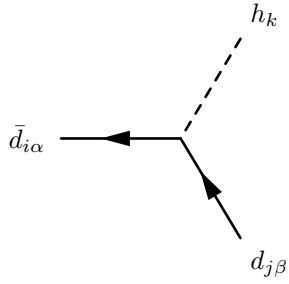
$$(430)$$

$$+ -i \frac{1}{\sqrt{2}} Z_{ki}^{V,*} \Theta_{i,3} \left(2g_p Q_l N_{j1} - g_1 N_{j2} + g_2 N_{j3} \right) \left(\frac{1+\gamma_5}{2} \right) \quad (431)$$



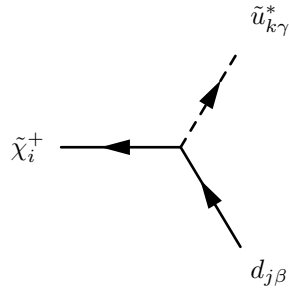
$$-i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma, \beta}^\alpha \sum_{a=1}^3 U_{L,ja}^{d,*} Z_{ka}^D \left(\frac{1-\gamma_5}{2} \right) \quad (432)$$

$$+ i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma, \beta}^\alpha \sum_{a=1}^3 Z_{k3+a}^D U_{R,ja}^d \left(\frac{1+\gamma_5}{2} \right) \quad (433)$$



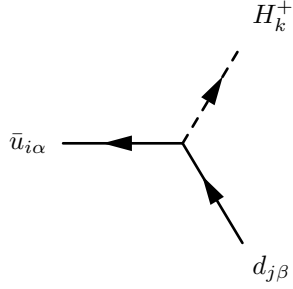
$$-i \frac{1}{\sqrt{2}} Z_{k1}^{H,*} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{d,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} \left(\frac{1-\gamma_5}{2} \right) \quad (434)$$

$$+ -i \frac{1}{\sqrt{2}} Z_{k1}^{H,*} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d \left(\frac{1+\gamma_5}{2} \right) \quad (435)$$



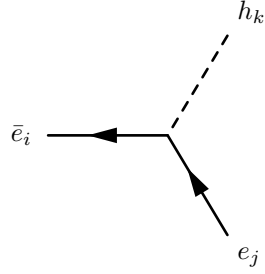
$$-i\delta_{\beta\gamma}\left(g_2V_{i1}^*\sum_{a=1}^3U_{L,ja}^{d,*}Z_{ka}^U-V_{i2}^*\sum_{b=1}^3U_{L,jb}^{d,*}\sum_{a=1}^3Y_{u,ab}Z_{k3+a}^U\right)\left(\frac{1-\gamma_5}{2}\right) \quad (436)$$

$$+i\delta_{\beta\gamma}\sum_{b=1}^3\sum_{a=1}^3Y_{d,ab}^*U_{R,ja}^dZ_{kb}^U U_{i2}\left(\frac{1+\gamma_5}{2}\right) \quad (437)$$



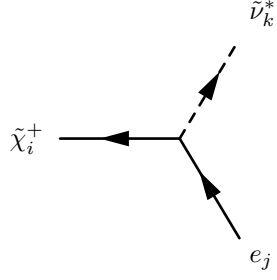
$$i\delta_{\alpha\beta}\sum_{b=1}^3U_{L,jb}^{d,*}\sum_{a=1}^3U_{R,ia}^{u,*}Y_{u,ab}Z_{k2}^+\left(\frac{1-\gamma_5}{2}\right) \quad (438)$$

$$+i\delta_{\alpha\beta}\sum_{b=1}^3\sum_{a=1}^3Y_{d,ab}^*U_{R,ja}^dU_{L,ib}^uZ_{k1}^+\left(\frac{1+\gamma_5}{2}\right) \quad (439)$$



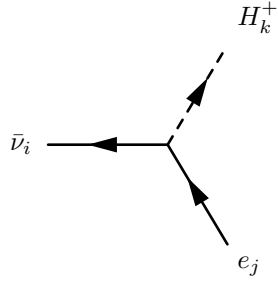
$$-i\frac{1}{\sqrt{2}}Z_{k1}^{H,*}\sum_{b=1}^3U_{L,jb}^{e,*}\sum_{a=1}^3U_{R,ia}^{e,*}Y_{e,ab}\left(\frac{1-\gamma_5}{2}\right) \quad (440)$$

$$+i\frac{1}{\sqrt{2}}Z_{k1}^{H,*}\sum_{b=1}^3\sum_{a=1}^3Y_{e,ab}^*U_{R,ja}^eU_{L,ib}^e\left(\frac{1+\gamma_5}{2}\right) \quad (441)$$



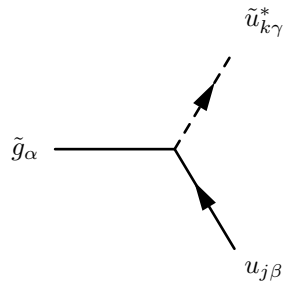
$$-ig_2 V_{i1}^* \sum_{a=1}^3 U_{L,ja}^{e,*} Z_{ka}^V \left(\frac{1-\gamma_5}{2} \right) \quad (442)$$

$$+ i \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* U_{R,ja}^e Z_{kb}^V U_{i2} \left(\frac{1+\gamma_5}{2} \right) \quad (443)$$



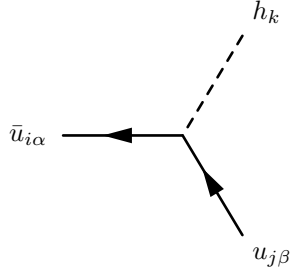
$$(444)$$

$$+ i \sum_{a=1}^3 Y_{e,ai}^* U_{R,ja}^e Z_{k1}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (445)$$



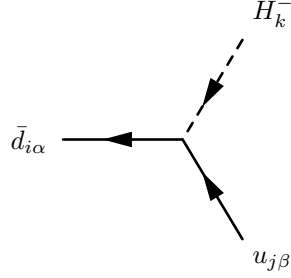
$$-i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^\alpha \sum_{a=1}^3 U_{L,ja}^{u,*} Z_{ka}^U \left(\frac{1-\gamma_5}{2} \right) \quad (446)$$

$$+ i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^\alpha \sum_{a=1}^3 Z_{k3+a}^U U_{R,ja}^u \left(\frac{1+\gamma_5}{2} \right) \quad (447)$$



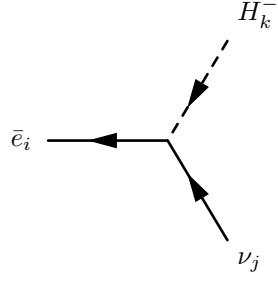
$$-i \frac{1}{\sqrt{2}} Z_{k2}^{H,*} \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{u,*} Y_{u,ab} \left(\frac{1-\gamma_5}{2} \right) \quad (448)$$

$$+ -i \frac{1}{\sqrt{2}} Z_{k2}^{H,*} \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^u \left(\frac{1+\gamma_5}{2} \right) \quad (449)$$

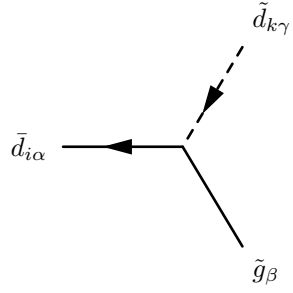


$$i \delta_{\alpha\beta} \sum_{b=1}^3 U_{L,jb}^{u,*} \sum_{a=1}^3 U_{R,ia}^{d,*} Y_{d,ab} Z_{k1}^+ \left(\frac{1-\gamma_5}{2} \right) \quad (450)$$

$$+ i \delta_{\alpha\beta} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* U_{R,ja}^u U_{L,ib}^d Z_{k2}^+ \left(\frac{1+\gamma_5}{2} \right) \quad (451)$$

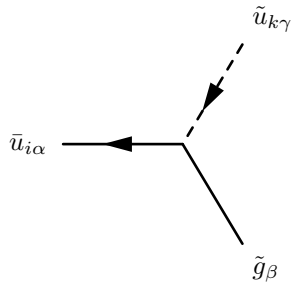


$$i \sum_{a=1}^3 U_{R,ia}^{e,*} Y_{e,a} Z_{k1}^+ \left(\frac{1 - \gamma_5}{2} \right) \quad (452)$$



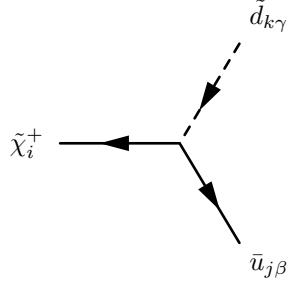
$$i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\alpha,\gamma}^\beta \sum_{a=1}^3 Z_{k3+a}^{D,*} U_{R,ia}^{d,*} \left(\frac{1 - \gamma_5}{2} \right) \quad (453)$$

$$+ -i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\alpha,\gamma}^\beta \sum_{a=1}^3 Z_{ka}^{D,*} U_{L,ia}^d \left(\frac{1 + \gamma_5}{2} \right) \quad (454)$$



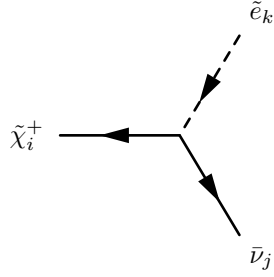
$$i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\alpha,\gamma}^\beta \sum_{a=1}^3 Z_{k3+a}^{U,*} U_{R,ia}^{u,*} \left(\frac{1 - \gamma_5}{2} \right) \quad (455)$$

$$+ -i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\alpha, \gamma}^\beta \sum_{a=1}^3 Z_{ka}^{U, *} U_{L, ia}^u \left(\frac{1 + \gamma_5}{2} \right) \quad (456)$$



$$i V_{i2}^* \delta_{\beta\gamma} \sum_{b=1}^3 Z_{kb}^{D, *} \sum_{a=1}^3 U_{R, ja}^{u, *} Y_{u, ab} \left(\frac{1 - \gamma_5}{2} \right) \quad (457)$$

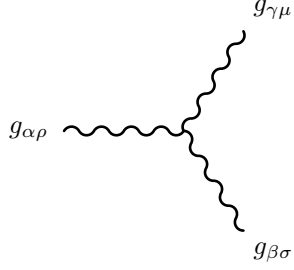
$$+ -i \delta_{\beta\gamma} \left(g_2 \sum_{a=1}^3 Z_{ka}^{D, *} U_{L, ja}^u U_{i1} - \sum_{b=1}^3 \sum_{a=1}^3 Y_{d, ab}^* Z_{k3+a}^{D, *} U_{L, jb}^u U_{i2} \right) \left(\frac{1 + \gamma_5}{2} \right) \quad (458)$$



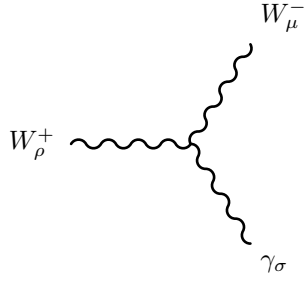
(459)

$$+ -i \left(g_2 Z_{kj}^{E, *} \Theta_{j, 3} U_{i1} - \sum_{a=1}^3 Y_{e, aj}^* Z_{k3+a}^{E, *} U_{i2} \right) \left(\frac{1 + \gamma_5}{2} \right) \quad (460)$$

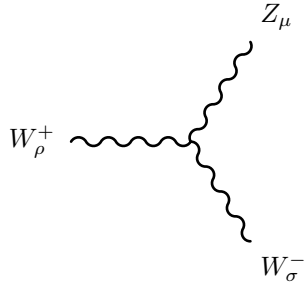
9.6 Three Vector Boson-Interaction



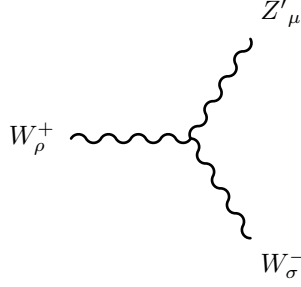
$$g_3 f_{\alpha,\beta,\gamma} \left(g_{\rho\mu} \left(-p_\sigma^{g_{\gamma\mu}} + p_\sigma^{g_{\alpha\rho}} \right) + g_{\rho\sigma} \left(-p_\mu^{g_{\alpha\rho}} + p_\mu^{g_{\beta\sigma}} \right) + g_{\sigma\mu} \left(-p_\rho^{g_{\beta\sigma}} + p_\rho^{g_{\gamma\mu}} \right) \right) \quad (461)$$



$$ig_2 \sin \Theta_W \left(g_{\rho\mu} \left(-p_\sigma^{W_\mu^-} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W_\rho^+} + p_\mu^{\gamma_\sigma} \right) + g_{\sigma\mu} \left(-p_\rho^{\gamma_\sigma} + p_\rho^{W_\mu^-} \right) \right) \quad (462)$$

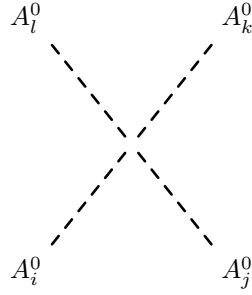


$$-ig_2 \cos \Theta_W \cos \Theta'_W \left(g_{\rho\mu} \left(-p_\sigma^{Z_\mu} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-} \right) + g_{\sigma\mu} \left(-p_\rho^{W_\sigma^-} + p_\rho^{Z_\mu} \right) \right) \quad (463)$$



$$ig_2 \cos \Theta_W \sin \Theta'_W \left(g_{\rho\mu} \left(-p_\sigma^{Z'\mu} + p_\sigma^{W_\rho^+} \right) + g_{\rho\sigma} \left(-p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-} \right) + g_{\sigma\mu} \left(-p_\rho^{W_\sigma^-} + p_\rho^{Z'\mu} \right) \right) \quad (464)$$

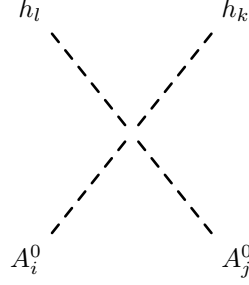
9.7 Four Scalar-Interaction



$$\begin{aligned} & -\frac{i}{36} \left(9Z_{i1}^{A,*} \left(- \left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j2}^{A,*} \left(Z_{k1}^{A,*} Z_{l2}^{A,*} + Z_{k2}^{A,*} Z_{l1}^{A,*} \right) \right. \right. \\ & + 4 \left(\left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{j3}^{A,*} \left(Z_{k1}^{A,*} Z_{l3}^{A,*} + Z_{k3}^{A,*} Z_{l1}^{A,*} \right) \right. \\ & + g_p^2 Q_{H_d} \left(Q_1 Z_{j4}^{A,*} \left(Z_{k1}^{A,*} Z_{l4}^{A,*} + Z_{k4}^{A,*} Z_{l1}^{A,*} \right) + Q_2 Z_{j5}^{A,*} \left(Z_{k1}^{A,*} Z_{l5}^{A,*} + Z_{k5}^{A,*} Z_{l1}^{A,*} \right) \right. \\ & \left. \left. + Q_3 Z_{j6}^{A,*} \left(Z_{k1}^{A,*} Z_{l6}^{A,*} + Z_{k6}^{A,*} Z_{l1}^{A,*} \right) \right) \right) \\ & + Z_{j1}^{A,*} \left(3 \left(4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) Z_{k1}^{A,*} Z_{l1}^{A,*} - \left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k2}^{A,*} Z_{l2}^{A,*} \right. \\ & + 4 \left(g_p^2 Q_{H_d} \left(Q_1 Z_{k4}^{A,*} Z_{l4}^{A,*} + Q_2 Z_{k5}^{A,*} Z_{l5}^{A,*} + Q_3 Z_{k6}^{A,*} Z_{l6}^{A,*} \right) + \left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k3}^{A,*} Z_{l3}^{A,*} \right) \left. \right) \\ & - 9Z_{i2}^{A,*} \left(\left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j1}^{A,*} \left(Z_{k1}^{A,*} Z_{l2}^{A,*} + Z_{k2}^{A,*} Z_{l1}^{A,*} \right) \right. \\ & - 4 \left(\left(g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{j3}^{A,*} \left(Z_{k2}^{A,*} Z_{l3}^{A,*} + Z_{k3}^{A,*} Z_{l2}^{A,*} \right) \right. \\ & + g_p^2 Q_{H_u} \left(Q_1 Z_{j4}^{A,*} \left(Z_{k2}^{A,*} Z_{l4}^{A,*} + Z_{k4}^{A,*} Z_{l2}^{A,*} \right) + Q_2 Z_{j5}^{A,*} \left(Z_{k2}^{A,*} Z_{l5}^{A,*} + Z_{k5}^{A,*} Z_{l2}^{A,*} \right) \right. \\ & \left. \left. + Q_3 Z_{j6}^{A,*} \left(Z_{k2}^{A,*} Z_{l6}^{A,*} + Z_{k6}^{A,*} Z_{l2}^{A,*} \right) \right) \right) \end{aligned}$$

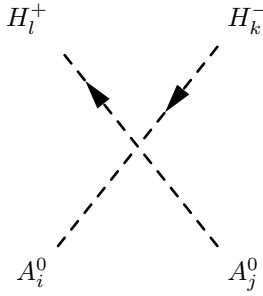
$$\begin{aligned}
& + Z_{j2}^{A,*} \left(\left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k1}^{A,*} Z_{l1}^{A,*} - 3 \left(4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{k2}^{A,*} Z_{l2}^{A,*} \right. \\
& - 4 \left(g_p^2 Q_{H_u} \left(Q_1 Z_{k4}^{A,*} Z_{l4}^{A,*} + Q_2 Z_{k5}^{A,*} Z_{l5}^{A,*} + Q_3 Z_{k6}^{A,*} Z_{l6}^{A,*} \right) + \left(g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k3}^{A,*} Z_{l3}^{A,*} \right) \Big) \\
& + 4 \left(9g_p^2 Q_{H_d} Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k1}^{A,*} Z_{l1}^{A,*} + 9g_p^2 Q_{H_d} Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k1}^{A,*} Z_{l1}^{A,*} \right. \\
& + 9g_p^2 Q_{H_d} Q_2 Z_{i5}^{A,*} Z_{j1}^{A,*} Z_{k5}^{A,*} Z_{l1}^{A,*} + 9g_p^2 Q_{H_d} Q_3 Z_{i6}^{A,*} Z_{j1}^{A,*} Z_{k6}^{A,*} Z_{l1}^{A,*} \\
& + 9g_p^2 Q_{H_u} Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k2}^{A,*} Z_{l2}^{A,*} + 9g_p^2 Q_{H_u} Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k2}^{A,*} Z_{l2}^{A,*} \\
& + 9g_p^2 Q_{H_u} Q_2 Z_{i5}^{A,*} Z_{j2}^{A,*} Z_{k5}^{A,*} Z_{l2}^{A,*} + 9g_p^2 Q_{H_u} Q_3 Z_{i6}^{A,*} Z_{j2}^{A,*} Z_{k6}^{A,*} Z_{l2}^{A,*} \\
& + 9g_p^2 Q_s Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k3}^{A,*} Z_{l3}^{A,*} + 9g_p^2 Q_s Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k3}^{A,*} Z_{l3}^{A,*} \\
& + 9g_p^2 Q_s Q_2 Z_{i5}^{A,*} Z_{j3}^{A,*} Z_{k5}^{A,*} Z_{l3}^{A,*} + 9g_p^2 Q_s Q_3 Z_{i6}^{A,*} Z_{j3}^{A,*} Z_{k6}^{A,*} Z_{l3}^{A,*} \\
& + 9g_p^2 Q_1 Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k4}^{A,*} Z_{l4}^{A,*} + |\kappa|^2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k4}^{A,*} Z_{l4}^{A,*} \\
& + 9g_p^2 Q_1 Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k4}^{A,*} Z_{l4}^{A,*} + |\kappa|^2 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k4}^{A,*} Z_{l4}^{A,*} \\
& + 9g_p^2 Q_1 Q_2 Z_{i5}^{A,*} Z_{j4}^{A,*} Z_{k5}^{A,*} Z_{l4}^{A,*} + |\kappa|^2 Z_{i5}^{A,*} Z_{j4}^{A,*} Z_{k5}^{A,*} Z_{l4}^{A,*} \\
& + 9g_p^2 Q_1 Q_3 Z_{i6}^{A,*} Z_{j4}^{A,*} Z_{k6}^{A,*} Z_{l4}^{A,*} + |\kappa|^2 Z_{i6}^{A,*} Z_{j4}^{A,*} Z_{k6}^{A,*} Z_{l4}^{A,*} \\
& + 9g_p^2 Q_{H_d} Q_2 Z_{i5}^{A,*} Z_{j1}^{A,*} Z_{k1}^{A,*} Z_{l5}^{A,*} + 9g_p^2 Q_{H_u} Q_2 Z_{i5}^{A,*} Z_{j2}^{A,*} Z_{k2}^{A,*} Z_{l5}^{A,*} \\
& + 9g_p^2 Q_s Q_2 Z_{i5}^{A,*} Z_{j3}^{A,*} Z_{k3}^{A,*} Z_{l5}^{A,*} + 9g_p^2 Q_1 Q_2 Z_{i5}^{A,*} Z_{j4}^{A,*} Z_{k4}^{A,*} Z_{l5}^{A,*} \\
& + |\kappa|^2 Z_{i5}^{A,*} Z_{j4}^{A,*} Z_{k4}^{A,*} Z_{l5}^{A,*} + 27g_p^2 Q_2^2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k5}^{A,*} Z_{l5}^{A,*} \\
& + 9g_p^2 Q_2 Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k5}^{A,*} Z_{l5}^{A,*} + |\kappa|^2 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k5}^{A,*} Z_{l5}^{A,*} \\
& + 9g_p^2 Q_2 Q_3 Z_{i6}^{A,*} Z_{j5}^{A,*} Z_{k6}^{A,*} Z_{l5}^{A,*} + |\kappa|^2 Z_{i6}^{A,*} Z_{j5}^{A,*} Z_{k6}^{A,*} Z_{l5}^{A,*} \\
& + 9g_p^2 Q_2 Q_3 Z_{i5}^{A,*} Z_{j6}^{A,*} Z_{k6}^{A,*} Z_{l5}^{A,*} + |\kappa|^2 Z_{i5}^{A,*} Z_{j6}^{A,*} Z_{k6}^{A,*} Z_{l5}^{A,*} \\
& + 9g_p^2 Q_{H_d} Q_3 Z_{i6}^{A,*} Z_{j1}^{A,*} Z_{k1}^{A,*} Z_{l6}^{A,*} + 9g_p^2 Q_{H_u} Q_3 Z_{i6}^{A,*} Z_{j2}^{A,*} Z_{k2}^{A,*} Z_{l6}^{A,*} \\
& + 9g_p^2 Q_s Q_3 Z_{i6}^{A,*} Z_{j3}^{A,*} Z_{k3}^{A,*} Z_{l6}^{A,*} + 9g_p^2 Q_1 Q_3 Z_{i6}^{A,*} Z_{j4}^{A,*} Z_{k4}^{A,*} Z_{l6}^{A,*} \\
& + |\kappa|^2 Z_{i6}^{A,*} Z_{j4}^{A,*} Z_{k4}^{A,*} Z_{l6}^{A,*} + 9g_p^2 Q_2 Q_3 Z_{i6}^{A,*} Z_{j5}^{A,*} Z_{k5}^{A,*} Z_{l6}^{A,*} \\
& + |\kappa|^2 Z_{i6}^{A,*} Z_{j5}^{A,*} Z_{k5}^{A,*} Z_{l6}^{A,*} + 9g_p^2 Q_2 Q_3 Z_{i5}^{A,*} Z_{j6}^{A,*} Z_{k5}^{A,*} Z_{l6}^{A,*} \\
& + |\kappa|^2 Z_{i5}^{A,*} Z_{j6}^{A,*} Z_{k5}^{A,*} Z_{l6}^{A,*} + 9g_p^2 Q_2 Q_3 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k6}^{A,*} Z_{l6}^{A,*} \\
& + |\kappa|^2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k6}^{A,*} Z_{l6}^{A,*} + 27g_p^2 Q_3^2 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k6}^{A,*} Z_{l6}^{A,*} \\
& + Z_{i4}^{A,*} \left(9g_p^2 Q_{H_u} Q_1 Z_{j2}^{A,*} Z_{k4}^{A,*} Z_{l2}^{A,*} + 9g_p^2 Q_s Q_1 Z_{j3}^{A,*} Z_{k4}^{A,*} Z_{l3}^{A,*} \right. \\
& + 9g_p^2 Q_{H_u} Q_1 Z_{j2}^{A,*} Z_{k2}^{A,*} Z_{l4}^{A,*} + 9g_p^2 Q_s Q_1 Z_{j3}^{A,*} Z_{k3}^{A,*} Z_{l4}^{A,*} \\
& + 9g_p^2 Q_1 Q_2 Z_{j5}^{A,*} Z_{k5}^{A,*} Z_{l4}^{A,*} + |\kappa|^2 Z_{j5}^{A,*} Z_{k5}^{A,*} Z_{l4}^{A,*} + 9g_p^2 Q_1 Q_3 Z_{j6}^{A,*} Z_{k6}^{A,*} Z_{l4}^{A,*} \\
& + |\kappa|^2 Z_{j6}^{A,*} Z_{k6}^{A,*} Z_{l4}^{A,*} + 9g_p^2 Q_{H_d} Q_1 Z_{j1}^{A,*} \left(Z_{k1}^{A,*} Z_{l4}^{A,*} + Z_{k4}^{A,*} Z_{l1}^{A,*} \right) \\
& + 9g_p^2 Q_1 Q_2 Z_{j5}^{A,*} Z_{k4}^{A,*} Z_{l5}^{A,*} + |\kappa|^2 Z_{j5}^{A,*} Z_{k4}^{A,*} Z_{l5}^{A,*} + 9g_p^2 Q_1 Q_3 Z_{j6}^{A,*} Z_{k4}^{A,*} Z_{l6}^{A,*} \\
& + |\kappa|^2 Z_{j6}^{A,*} Z_{k4}^{A,*} Z_{l6}^{A,*}
\end{aligned}$$

$$\begin{aligned}
& + Z_{j4}^{A,*} \left(9g_p^2 Q_{H_d} Q_1 Z_{k1}^{A,*} Z_{l1}^{A,*} + 9g_p^2 Q_{H_u} Q_1 Z_{k2}^{A,*} Z_{l2}^{A,*} + 9g_p^2 Q_s Q_1 Z_{k3}^{A,*} Z_{l3}^{A,*} \right. \\
& + 27g_p^2 Q_1^2 Z_{k4}^{A,*} Z_{l4}^{A,*} + 9g_p^2 Q_1 Q_2 Z_{k5}^{A,*} Z_{l5}^{A,*} + |\kappa|^2 Z_{k5}^{A,*} Z_{l5}^{A,*} \\
& \left. + 9g_p^2 Q_1 Q_3 Z_{k6}^{A,*} Z_{l6}^{A,*} + |\kappa|^2 Z_{k6}^{A,*} Z_{l6}^{A,*} \right) \\
& + 9Z_{i3}^{A,*} \left(g_p^2 Q_{H_u} Q_s Z_{j2}^{A,*} Z_{k3}^{A,*} Z_{l2}^{A,*} + |\lambda|^2 Z_{j2}^{A,*} Z_{k3}^{A,*} Z_{l2}^{A,*} + g_p^2 Q_{H_u} Q_s Z_{j2}^{A,*} Z_{k2}^{A,*} Z_{l3}^{A,*} \right. \\
& + |\lambda|^2 Z_{j2}^{A,*} Z_{k2}^{A,*} Z_{l3}^{A,*} + g_p^2 Q_s Q_1 Z_{j4}^{A,*} Z_{k4}^{A,*} Z_{l3}^{A,*} + g_p^2 Q_s Q_2 Z_{j5}^{A,*} Z_{k5}^{A,*} Z_{l3}^{A,*} \\
& + g_p^2 Q_s Q_3 Z_{j6}^{A,*} Z_{k6}^{A,*} Z_{l3}^{A,*} + \left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{j1}^{A,*} \left(Z_{k1}^{A,*} Z_{l3}^{A,*} + Z_{k3}^{A,*} Z_{l1}^{A,*} \right) \\
& + g_p^2 Q_s Q_1 Z_{j4}^{A,*} Z_{k3}^{A,*} Z_{l4}^{A,*} + g_p^2 Q_s Q_2 Z_{j5}^{A,*} Z_{k3}^{A,*} Z_{l5}^{A,*} + g_p^2 Q_s Q_3 Z_{j6}^{A,*} Z_{k3}^{A,*} Z_{l6}^{A,*} \\
& + Z_{j3}^{A,*} \left(\left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k1}^{A,*} Z_{l1}^{A,*} + \left(g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k2}^{A,*} Z_{l2}^{A,*} \right. \\
& \left. \left. + g_p^2 Q_s \left(3Q_s Z_{k3}^{A,*} Z_{l3}^{A,*} + Q_1 Z_{k4}^{A,*} Z_{l4}^{A,*} + Q_2 Z_{k5}^{A,*} Z_{l5}^{A,*} + Q_3 Z_{k6}^{A,*} Z_{l6}^{A,*} \right) \right) \right) \right) \quad (465)
\end{aligned}$$

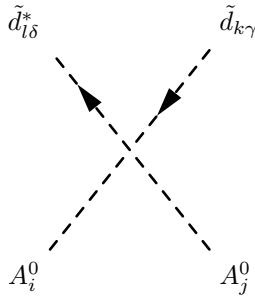


$$\begin{aligned}
& - \frac{i}{36} \left(9Z_{i1}^{A,*} Z_{j1}^{A,*} \left(\left(4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) Z_{k1}^{H,*} Z_{l1}^{H,*} - \left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k2}^{H,*} Z_{l2}^{H,*} \right. \right. \\
& + 4 \left(g_p^2 Q_{H_d} \left(Q_1 Z_{k4}^{H,*} Z_{l4}^{H,*} + Q_2 Z_{k5}^{H,*} Z_{l5}^{H,*} + Q_3 Z_{k6}^{H,*} Z_{l6}^{H,*} \right) + \left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} Z_{l3}^{H,*} \right) \\
& - 9Z_{i2}^{A,*} Z_{j2}^{A,*} \left(\left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{k1}^{H,*} Z_{l1}^{H,*} - \left(4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{k2}^{H,*} Z_{l2}^{H,*} \right. \\
& - 4 \left(g_p^2 Q_{H_u} \left(Q_1 Z_{k4}^{H,*} Z_{l4}^{H,*} + Q_2 Z_{k5}^{H,*} Z_{l5}^{H,*} + Q_3 Z_{k6}^{H,*} Z_{l6}^{H,*} \right) + \left(g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} Z_{l3}^{H,*} \right) \\
& + 4 \left(9g_p^2 Q_{H_d} Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k1}^{H,*} Z_{l1}^{H,*} + 9g_p^2 Q_{H_d} Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k1}^{H,*} Z_{l1}^{H,*} \right. \\
& + 9g_p^2 Q_{H_u} Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k2}^{H,*} Z_{l2}^{H,*} + 9g_p^2 Q_{H_u} Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k2}^{H,*} Z_{l2}^{H,*} \\
& + 9g_p^2 Q_s Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k3}^{H,*} Z_{l3}^{H,*} + 9g_p^2 Q_s Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k3}^{H,*} Z_{l3}^{H,*} \\
& + 9g_p^2 Q_1 Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k4}^{H,*} Z_{l4}^{H,*} + |\kappa|^2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k4}^{H,*} Z_{l4}^{H,*} \\
& + 9g_p^2 Q_1 Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k4}^{H,*} Z_{l4}^{H,*} + |\kappa|^2 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k4}^{H,*} Z_{l4}^{H,*} \\
& + 9g_p^2 Q_2^2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k5}^{H,*} Z_{l5}^{H,*} + 9g_p^2 Q_2 Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k5}^{H,*} Z_{l5}^{H,*} \\
& \left. + |\kappa|^2 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k5}^{H,*} Z_{l5}^{H,*} + 9g_p^2 Q_2 Q_3 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k6}^{H,*} Z_{l6}^{H,*} \right)
\end{aligned}$$

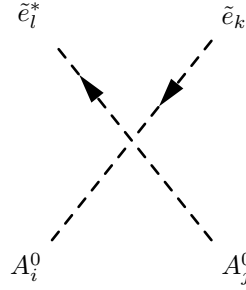
$$\begin{aligned}
& + |\kappa|^2 Z_{i5}^{A,*} Z_{j5}^{A,*} Z_{k6}^{H,*} Z_{l6}^{H,*} + 9g_p^2 Q_3^2 Z_{i6}^{A,*} Z_{j6}^{A,*} Z_{k6}^{H,*} Z_{l6}^{H,*} \\
& + Z_{i4}^{A,*} Z_{j4}^{A,*} \left(9g_p^2 Q_{H_d} Q_1 Z_{k1}^{H,*} Z_{l1}^{H,*} + 9g_p^2 Q_{H_u} Q_1 Z_{k2}^{H,*} Z_{l2}^{H,*} + 9g_p^2 Q_s Q_1 Z_{k3}^{H,*} Z_{l3}^{H,*} \right. \\
& + 9g_p^2 Q_1^2 Z_{k4}^{H,*} Z_{l4}^{H,*} + 9g_p^2 Q_1 Q_2 Z_{k5}^{H,*} Z_{l5}^{H,*} + |\kappa|^2 Z_{k5}^{H,*} Z_{l5}^{H,*} \\
& \left. + 9g_p^2 Q_1 Q_3 Z_{k6}^{H,*} Z_{l6}^{H,*} + |\kappa|^2 Z_{k6}^{H,*} Z_{l6}^{H,*} \right) \\
& + 9Z_{i3}^{A,*} Z_{j3}^{A,*} \left(\left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k1}^{H,*} Z_{l1}^{H,*} + \left(g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k2}^{H,*} Z_{l2}^{H,*} \right. \\
& \left. + g_p^2 Q_s \left(Q_1 Z_{k4}^{H,*} Z_{l4}^{H,*} + Q_2 Z_{k5}^{H,*} Z_{l5}^{H,*} + Q_3 Z_{k6}^{H,*} Z_{l6}^{H,*} + Q_s Z_{k3}^{H,*} Z_{l3}^{H,*} \right) \right) \Big) \Big) \quad (466)
\end{aligned}$$



$$\begin{aligned}
& -\frac{i}{4}\left(Z_{i1}^{A,*}\left(-\left(-2|\lambda|^2+g_2^2\right)Z_{j2}^{A,*}\left(Z_{k1}^+Z_{l2}^++Z_{k2}^+Z_{l1}^+\right)\right.\right. \\
& +Z_{j1}^{A,*}\left(\left(4g_p^2Q_{H_d}^2+g_1^2+g_2^2\right)Z_{k1}^+Z_{l1}^++\left(4g_p^2Q_{H_d}Q_{H_u}-g_1^2+g_2^2\right)Z_{k2}^+Z_{l2}^+\right) \\
& +Z_{i2}^{A,*}\left(-\left(-2|\lambda|^2+g_2^2\right)Z_{j1}^{A,*}\left(Z_{k1}^+Z_{l2}^++Z_{k2}^+Z_{l1}^+\right)\right. \\
& +Z_{j2}^{A,*}\left(\left(4g_p^2Q_{H_d}Q_{H_u}-g_1^2+g_2^2\right)Z_{k1}^+Z_{l1}^++\left(4g_p^2Q_{H_u}^2+g_1^2+g_2^2\right)Z_{k2}^+Z_{l2}^+\right) \\
& +4\left(g_p^2\left(Q_1Z_{i4}^{A,*}Z_{j4}^{A,*}+Q_2Z_{i5}^{A,*}Z_{j5}^{A,*}+Q_3Z_{i6}^{A,*}Z_{j6}^{A,*}\right)\left(Q_{H_d}Z_{k1}^+Z_{l1}^++Q_{H_u}Z_{k2}^+Z_{l2}^+\right)\right. \\
& \left.\left.+Z_{i3}^{A,*}Z_{j3}^{A,*}\left(\left(g_p^2Q_{H_d}Q_s+|\lambda|^2\right)Z_{k1}^+Z_{l1}^++\left(g_p^2Q_{H_u}Q_s+|\lambda|^2\right)Z_{k2}^+Z_{l2}^+\right)\right)\right) \quad (467)
\end{aligned}$$

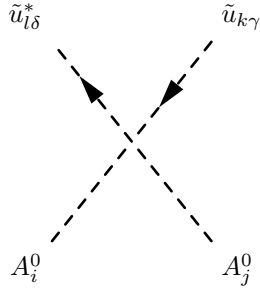


$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left(-Z_{i2}^{A,*} \left(Z_{j2}^{A,*} \left(\left(12g_p^2 Q_{H_u} Q_q + 3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D + 2 \left(6g_p^2 Q_d Q_{H_u} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D \right) \right. \right. \\
& + 6Z_{j3}^{A,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \Big) \\
& - 6 \left(2g_p^2 \left(Q_1 Z_{i4}^{A,*} Z_{j4}^{A,*} + Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} + Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} \right) \left(Q_d \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D + Q_q \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right) \right. \\
& + Z_{i3}^{A,*} \left(2g_p^2 Q_s Z_{j3}^{A,*} \left(Q_d \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D + Q_q \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right) \right. \\
& + Z_{j2}^{A,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \Big) \Big) \\
& + Z_{i1}^{A,*} Z_{j1}^{A,*} \left(\left(3 \left(-4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right. \\
& + 2 \left(\left(-6g_p^2 Q_d Q_{H_d} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D \right. \\
& \left. \left. - 6 \left(\sum_{c=1}^3 Z_{k3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D \right) \right) \right) \Big) \Big) \quad (468)
\end{aligned}$$

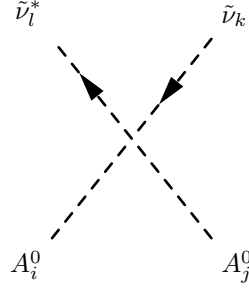


$$\begin{aligned}
& -\frac{i}{4} \left(Z_{i2}^{A,*} \left(Z_{j2}^{A,*} \left(2 \left(2g_p^2 Q_e Q_{H_u} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E + \left(4g_p^2 Q_{H_u} Q_l - g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \right) \right. \right. \\
& + 2Z_{j3}^{A,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} Z_{lb}^E + \lambda^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \right) \Big) \\
& + 2 \left(2g_p^2 \left(Q_1 Z_{i4}^{A,*} Z_{j4}^{A,*} + Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} + Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} \right) \left(Q_e \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E + Q_l \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \right) \right. \\
& + Z_{i3}^{A,*} \left(2g_p^2 Q_s Z_{j3}^{A,*} \left(Q_e \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E + Q_l \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \right) \right.
\end{aligned}$$

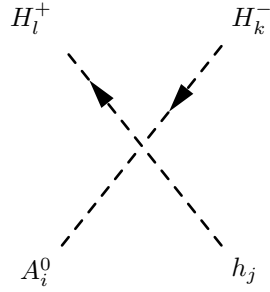
$$\begin{aligned}
& + Z_{j2}^{A,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} Z_{lb}^E + \lambda^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \right) \Big) \\
& + Z_{i1}^{A,*} Z_{j1}^{A,*} \left(\left(4g_p^2 Q_{H_d} Q_l - g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E - 2 \left(-2g_p^2 Q_e Q_{H_d} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E \right. \\
& \left. + 4 \left(\sum_{c=1}^3 Z_{k3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{l3+b}^E + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^E \right) \right) \Big) \tag{469}
\end{aligned}$$



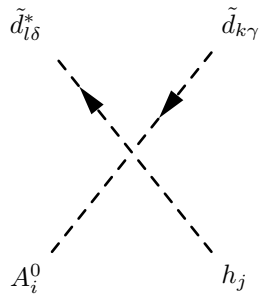
$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left(Z_{i1}^{A,*} \left(Z_{j1}^{A,*} \left(\left(-3 \left(4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U - 4 \left(3g_p^2 Q_{H_d} Q_u + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right) \right. \right. \\
& - 6 Z_{j3}^{A,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \right) \Big) \\
& - 6 \left(2g_p^2 \left(Q_1 Z_{i4}^{A,*} Z_{j4}^{A,*} + Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} + Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} \right) \left(Q_q \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U + Q_u \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right) \right. \\
& + Z_{i3}^{A,*} \left(2g_p^2 Q_s Z_{j3}^{A,*} \left(Q_q \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U + Q_u \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right) \right. \\
& \left. \left. + Z_{j1}^{A,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \right) \right) \right) \\
& - Z_{i2}^{A,*} Z_{j2}^{A,*} \left(\left(12g_p^2 Q_{H_u} Q_q - 3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U \right. \\
& \left. + 4 \left(- \left(-3g_p^2 Q_{H_u} Q_u + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right) \right. \\
& \left. + 3 \left(\sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{l3+b}^U + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^U \right) \right) \Big) \tag{470}
\end{aligned}$$



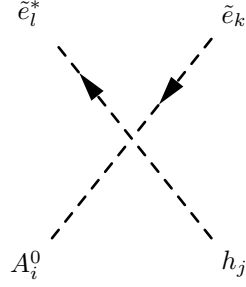
$$\begin{aligned}
& -\frac{i}{4} \left(\left(4g_p^2 Q_{H_d} Q_l + g_1^2 + g_2^2 \right) Z_{i1}^{A,*} Z_{j1}^{A,*} - \left(-4g_p^2 Q_{H_u} Q_l + g_1^2 + g_2^2 \right) Z_{i2}^{A,*} Z_{j2}^{A,*} \right. \\
& \left. + 4g_p^2 Q_l \left(Q_1 Z_{i4}^{A,*} Z_{j4}^{A,*} + Q_2 Z_{i5}^{A,*} Z_{j5}^{A,*} + Q_3 Z_{i6}^{A,*} Z_{j6}^{A,*} + Q_s Z_{i3}^{A,*} Z_{j3}^{A,*} \right) \right) \delta_{kl}
\end{aligned} \tag{471}$$



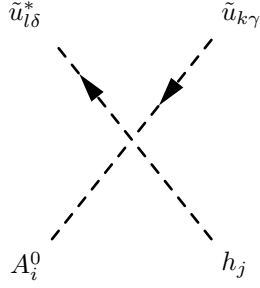
$$\frac{1}{4} \left(-2|\lambda|^2 + g_2^2 \right) \left(Z_{i1}^{A,*} Z_{j2}^{H,*} + Z_{i2}^{A,*} Z_{j1}^{H,*} \right) \left(-Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \tag{472}$$



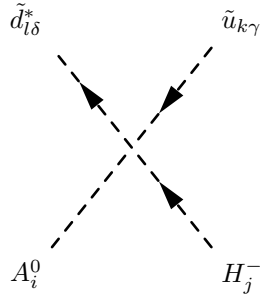
$$\frac{1}{2} \left(Z_{i2}^{A,*} Z_{j3}^{H,*} + Z_{i3}^{A,*} Z_{j2}^{H,*} \right) \delta_{\gamma\delta} \left(-\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \tag{473}$$



$$\frac{1}{2} \left(Z_{i2}^{A,*} Z_{j3}^{H,*} + Z_{i3}^{A,*} Z_{j2}^{H,*} \right) \left(-\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} Z_{lb}^E + \lambda^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \right) \quad (474)$$

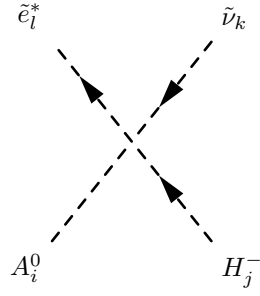


$$\frac{1}{2} \left(Z_{i1}^{A,*} Z_{j3}^{H,*} + Z_{i3}^{A,*} Z_{j1}^{H,*} \right) \delta_{\gamma\delta} \left(-\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \right) \quad (475)$$

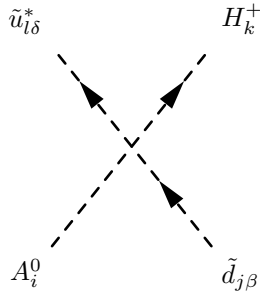


$$\frac{1}{2} \frac{1}{\sqrt{2}} \delta_{\gamma\delta} \left(Z_{i3}^{A,*} \left(-2\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^D Z_{j1}^+ + 2\lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D Z_{j2}^+ \right) \right)$$

$$\begin{aligned}
& -Z_{i1}^{A,*} \left(g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D Z_{j1}^+ - 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D Z_{j1}^+ \right. \\
& + 2 \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{j2}^+ \left. \right) \\
& + Z_{i2}^{A,*} \left(2 \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{j1}^+ \right. \\
& + \left. \left(-2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^D + g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D \right) Z_{j2}^+ \right) \Big) \quad (476)
\end{aligned}$$

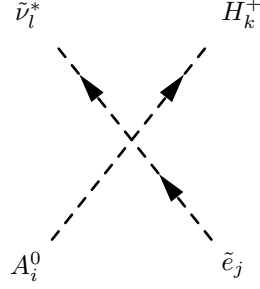


$$\begin{aligned}
& \frac{1}{2} \frac{1}{\sqrt{2}} \left(Z_{i1}^{A,*} \left(2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^E - g_2^2 \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E \right) Z_{j1}^+ \right. \\
& + \left. \left(2 \lambda^* Z_{i3}^{A,*} \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E + g_2^2 Z_{i2}^{A,*} \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E \right) Z_{j2}^+ \right) \quad (477)
\end{aligned}$$

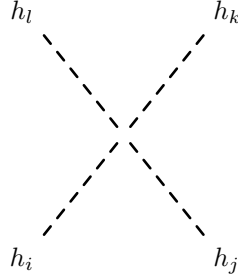


$$\frac{1}{2} \frac{1}{\sqrt{2}} \delta_{\beta\delta} \left(2 \lambda^* Z_{i3}^{A,*} \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U Z_{k1}^+ - 2 Z_{i2}^{A,*} \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{k1}^+ \right)$$

$$\begin{aligned}
& -g_2^2 Z_{i2}^{A,*} \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^U Z_{k2}^+ - 2\lambda Z_{i3}^{A,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{lb}^U Z_{k2}^+ \\
& + 2Z_{i2}^{A,*} \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^U Z_{k2}^+ \\
& + Z_{i1}^{A,*} \left(g_2^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^U Z_{k1}^+ - 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^U Z_{k1}^+ \right. \\
& \left. + 2 \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{k2}^+ \right) \quad (478)
\end{aligned}$$



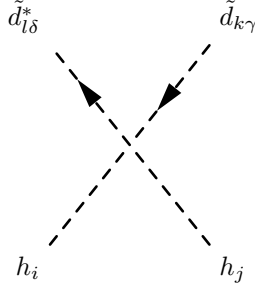
$$\begin{aligned}
& \frac{1}{2} \frac{1}{\sqrt{2}} \left(Z_{i1}^{A,*} \left(-2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^V + g_2^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^V \right) Z_{k1}^+ \right. \\
& \left. - \left(2\lambda Z_{i3}^{A,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{lb}^V + g_2^2 Z_{i2}^{A,*} \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^V \right) Z_{k2}^+ \right) \quad (479)
\end{aligned}$$



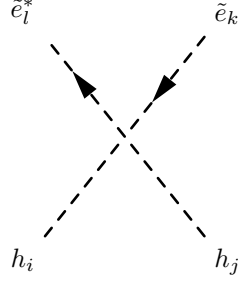
$$\begin{aligned}
& -\frac{i}{36} \left(9Z_{i1}^{H,*} \left(- \left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j2}^{H,*} \left(Z_{k1}^{H,*} Z_{l2}^{H,*} + Z_{k2}^{H,*} Z_{l1}^{H,*} \right) \right. \right. \\
& \left. \left. + 4 \left(\left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{j3}^{H,*} \left(Z_{k1}^{H,*} Z_{l3}^{H,*} + Z_{k3}^{H,*} Z_{l1}^{H,*} \right) \right) \right) \right)
\end{aligned}$$

$$\begin{aligned}
& + g_p^2 Q_{H_d} \left(Q_1 Z_{j4}^{H,*} \left(Z_{k1}^{H,*} Z_{l4}^{H,*} + Z_{k4}^{H,*} Z_{l1}^{H,*} \right) + Q_2 Z_{j5}^{H,*} \left(Z_{k1}^{H,*} Z_{l5}^{H,*} + Z_{k5}^{H,*} Z_{l1}^{H,*} \right) \right. \\
& + Q_3 Z_{j6}^{H,*} \left(Z_{k1}^{H,*} Z_{l6}^{H,*} + Z_{k6}^{H,*} Z_{l1}^{H,*} \right) \left. \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} \left(Q_1 Z_{k4}^{H,*} Z_{l4}^{H,*} + Q_2 Z_{k5}^{H,*} Z_{l5}^{H,*} + Q_3 Z_{k6}^{H,*} Z_{l6}^{H,*} \right) + \left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} Z_{l3}^{H,*} \left. \right) \left. \right) \\
& - 9Z_{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(\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) \right. \\
& + g_p^2 Q_{H_u} \left(Q_1 Z_{j4}^{H,*} \left(Z_{k2}^{H,*} Z_{l4}^{H,*} + Z_{k4}^{H,*} Z_{l2}^{H,*} \right) + Q_2 Z_{j5}^{H,*} \left(Z_{k2}^{H,*} Z_{l5}^{H,*} + Z_{k5}^{H,*} Z_{l2}^{H,*} \right) \right. \\
& + Q_3 Z_{j6}^{H,*} \left(Z_{k2}^{H,*} Z_{l6}^{H,*} + Z_{k6}^{H,*} Z_{l2}^{H,*} \right) \left. \right) \left. \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} \left(Q_1 Z_{k4}^{H,*} Z_{l4}^{H,*} + Q_2 Z_{k5}^{H,*} Z_{l5}^{H,*} + Q_3 Z_{k6}^{H,*} Z_{l6}^{H,*} \right) + \left(g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k3}^{H,*} Z_{l3}^{H,*} \left. \right) \left. \right) \\
& + 4 \left(9g_p^2 Q_{H_d} Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k1}^{H,*} Z_{l1}^{H,*} + 9g_p^2 Q_{H_d} Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k1}^{H,*} Z_{l1}^{H,*} \right. \\
& + 9g_p^2 Q_{H_d} Q_2 Z_{i5}^{H,*} Z_{j1}^{H,*} Z_{k5}^{H,*} Z_{l1}^{H,*} + 9g_p^2 Q_{H_d} Q_3 Z_{i6}^{H,*} Z_{j1}^{H,*} Z_{k6}^{H,*} Z_{l1}^{H,*} \\
& + 9g_p^2 Q_{H_u} Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k2}^{H,*} Z_{l2}^{H,*} + 9g_p^2 Q_{H_u} Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k2}^{H,*} Z_{l2}^{H,*} \\
& + 9g_p^2 Q_{H_u} Q_2 Z_{i5}^{H,*} Z_{j2}^{H,*} Z_{k5}^{H,*} Z_{l2}^{H,*} + 9g_p^2 Q_{H_u} Q_3 Z_{i6}^{H,*} Z_{j2}^{H,*} Z_{k6}^{H,*} Z_{l2}^{H,*} \\
& + 9g_p^2 Q_s Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k3}^{H,*} Z_{l3}^{H,*} + 9g_p^2 Q_s Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k3}^{H,*} Z_{l3}^{H,*} \\
& + 9g_p^2 Q_s Q_2 Z_{i5}^{H,*} Z_{j3}^{H,*} Z_{k5}^{H,*} Z_{l3}^{H,*} + 9g_p^2 Q_s Q_3 Z_{i6}^{H,*} Z_{j3}^{H,*} Z_{k6}^{H,*} Z_{l3}^{H,*} \\
& + 9g_p^2 Q_1 Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k4}^{H,*} Z_{l4}^{H,*} + |\kappa|^2 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k4}^{H,*} Z_{l4}^{H,*} \\
& + 9g_p^2 Q_1 Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k4}^{H,*} Z_{l4}^{H,*} + |\kappa|^2 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k4}^{H,*} Z_{l4}^{H,*} \\
& + 9g_p^2 Q_1 Q_2 Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k5}^{H,*} Z_{l4}^{H,*} + |\kappa|^2 Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k5}^{H,*} Z_{l4}^{H,*} \\
& + 9g_p^2 Q_1 Q_3 Z_{i6}^{H,*} Z_{j4}^{H,*} Z_{k6}^{H,*} Z_{l4}^{H,*} + |\kappa|^2 Z_{i6}^{H,*} Z_{j4}^{H,*} Z_{k6}^{H,*} Z_{l4}^{H,*} \\
& + 9g_p^2 Q_{H_d} Q_2 Z_{i5}^{H,*} Z_{j1}^{H,*} Z_{k1}^{H,*} Z_{l5}^{H,*} + 9g_p^2 Q_{H_u} Q_2 Z_{i5}^{H,*} Z_{j2}^{H,*} Z_{k2}^{H,*} Z_{l5}^{H,*} \\
& + 9g_p^2 Q_s Q_2 Z_{i5}^{H,*} Z_{j3}^{H,*} Z_{k3}^{H,*} Z_{l5}^{H,*} + 9g_p^2 Q_1 Q_2 Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k4}^{H,*} Z_{l5}^{H,*} \\
& + |\kappa|^2 Z_{i5}^{H,*} Z_{j4}^{H,*} Z_{k4}^{H,*} Z_{l5}^{H,*} + 27g_p^2 Q_2^2 Z_{i5}^{H,*} Z_{j5}^{H,*} Z_{k5}^{H,*} Z_{l5}^{H,*} \\
& + 9g_p^2 Q_2 Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k5}^{H,*} Z_{l5}^{H,*} + |\kappa|^2 Z_{i6}^{H,*} Z_{j6}^{H,*} Z_{k5}^{H,*} Z_{l5}^{H,*} \\
& + 9g_p^2 Q_2 Q_3 Z_{i6}^{H,*} Z_{j5}^{H,*} Z_{k6}^{H,*} Z_{l5}^{H,*} + |\kappa|^2 Z_{i6}^{H,*} Z_{j5}^{H,*} Z_{k6}^{H,*} Z_{l5}^{H,*} \\
& + 9g_p^2 Q_2 Q_3 Z_{i5}^{H,*} Z_{j6}^{H,*} Z_{k6}^{H,*} Z_{l5}^{H,*} + |\kappa|^2 Z_{i5}^{H,*} Z_{j6}^{H,*} Z_{k6}^{H,*} Z_{l5}^{H,*} \\
& + 9g_p^2 Q_{H_d} Q_3 Z_{i6}^{H,*} Z_{j1}^{H,*} Z_{k1}^{H,*} Z_{l6}^{H,*} + 9g_p^2 Q_{H_u} Q_3 Z_{i6}^{H,*} Z_{j2}^{H,*} Z_{k2}^{H,*} Z_{l6}^{H,*} \\
& + 9g_p^2 Q_s Q_3 Z_{i6}^{H,*} Z_{j3}^{H,*} Z_{k3}^{H,*} Z_{l6}^{H,*} + 9g_p^2 Q_1 Q_3 Z_{i6}^{H,*} Z_{j4}^{H,*} Z_{k4}^{H,*} Z_{l6}^{H,*}
\end{aligned}$$

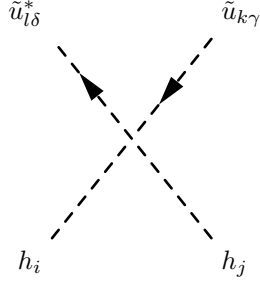
$$\begin{aligned}
& + Z_{i2}^{H,*} \left(\left(-2|\lambda|^2 + g_2^2 \right) Z_{j1}^{H,*} \left(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right. \\
& + Z_{j2}^{H,*} \left(\left(4g_p^2 Q_{H_d} Q_{H_u} - g_1^2 + g_2^2 \right) Z_{k1}^+ Z_{l1}^+ + \left(4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{k2}^+ Z_{l2}^+ \right) \\
& + 4 \left(g_p^2 \left(Q_1 Z_{i4}^{H,*} Z_{j4}^{H,*} + Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} + Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} \right) \left(Q_{H_d} Z_{k1}^+ Z_{l1}^+ + Q_{H_u} Z_{k2}^+ Z_{l2}^+ \right) \right. \\
& \left. \left. + Z_{i3}^{H,*} Z_{j3}^{H,*} \left(\left(g_p^2 Q_{H_d} Q_s + |\lambda|^2 \right) Z_{k1}^+ Z_{l1}^+ + \left(g_p^2 Q_{H_u} Q_s + |\lambda|^2 \right) Z_{k2}^+ Z_{l2}^+ \right) \right) \right) \quad (481)
\end{aligned}$$



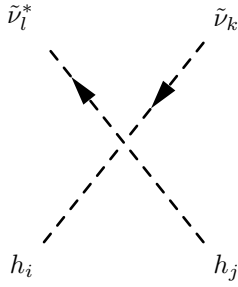
$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left(- Z_{i2}^{H,*} \left(Z_{j2}^{H,*} \left(\left(12g_p^2 Q_{H_u} Q_q + 3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D + 2 \left(6g_p^2 Q_d Q_{H_u} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D \right) \right. \right. \\
& - 6 Z_{j3}^{H,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \Bigg) \\
& - 6 \left(2g_p^2 \left(Q_1 Z_{i4}^{H,*} Z_{j4}^{H,*} + Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} + Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} \right) \left(Q_d \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D + Q_q \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right) \right. \\
& + Z_{i3}^{H,*} \left(2g_p^2 Q_s Z_{j3}^{H,*} \left(Q_d \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D + Q_q \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right) \right. \\
& \left. \left. - Z_{j2}^{H,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{k3+a}^{D,*} Z_{lb}^D + \lambda^* \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D \right) \right) \right) \\
& + Z_{i1}^{H,*} Z_{j1}^{H,*} \left(\left(3 \left(-4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{D,*} Z_{la}^D \right. \\
& + 2 \left(\left(-6g_p^2 Q_d Q_{H_d} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{D,*} Z_{l3+a}^D \right. \\
& \left. \left. - 6 \left(\sum_{c=1}^3 Z_{k3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D \right) \right) \right) \quad (482)
\end{aligned}$$



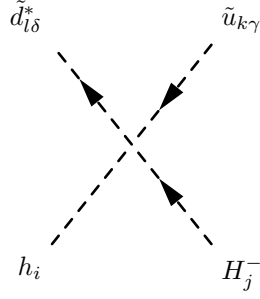
$$\begin{aligned}
& -\frac{i}{4} \left(4g_p^2 Q_l Q_s Z_{i3}^{H,*} Z_{j3}^{H,*} \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E + 4g_p^2 Q_l Q_1 Z_{i4}^{H,*} Z_{j4}^{H,*} \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \right. \\
& + 4g_p^2 Q_l Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E + 4g_p^2 Q_l Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \\
& + 4g_p^2 Q_e Q_s Z_{i3}^{H,*} Z_{j3}^{H,*} \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E + 4g_p^2 Q_e Q_1 Z_{i4}^{H,*} Z_{j4}^{H,*} \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E \\
& + 4g_p^2 Q_e Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E + 4g_p^2 Q_e Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E \\
& - 2\lambda^* Z_{i3}^{H,*} Z_{j2}^{H,*} \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E - 2\lambda Z_{i3}^{H,*} Z_{j2}^{H,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} Z_{lb}^E \\
& + Z_{i2}^{H,*} \left(Z_{j2}^{H,*} \left(2 \left(2g_p^2 Q_e Q_{H_u} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E + \left(4g_p^2 Q_{H_u} Q_l - g_1^2 + g_2^2 \right) \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E \right) \right. \\
& \left. - 2Z_{j3}^{H,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{k3+a}^{E,*} Z_{lb}^E + \lambda^* \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \right) \right) \\
& + Z_{i1}^{H,*} Z_{j1}^{H,*} \left(\left(4g_p^2 Q_{H_d} Q_l - g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{E,*} Z_{la}^E - 2 \left(-2g_p^2 Q_e Q_{H_d} + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{E,*} Z_{l3+a}^E \right. \\
& \left. + 4 \left(\sum_{c=1}^3 Z_{k3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{l3+b}^E + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^E \right) \right) \Big) \quad (483)
\end{aligned}$$



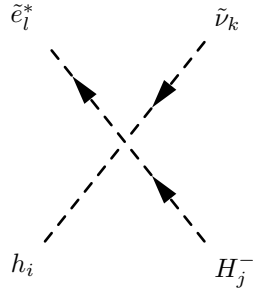
$$\begin{aligned}
& \frac{i}{12} \delta_{\gamma\delta} \left(Z_{i1}^{H,*} \left(Z_{j1}^{H,*} \left(\left(-3 \left(4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U - 4 \left(3g_p^2 Q_{H_d} Q_u + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right) \right. \right. \\
& + 6 Z_{j3}^{H,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \right) \Big) \\
& - 6 \left(2g_p^2 \left(Q_1 Z_{i4}^{H,*} Z_{j4}^{H,*} + Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} + Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} \right) \left(Q_q \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U + Q_u \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right) \right. \\
& + Z_{i3}^{H,*} \left(2g_p^2 Q_s Z_{j3}^{H,*} \left(Q_q \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U + Q_u \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right) \right. \\
& \left. \left. - Z_{j1}^{H,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^U + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \right) \right) \right) \\
& - Z_{i2}^{H,*} Z_{j2}^{H,*} \left(\left(12g_p^2 Q_{H_u} Q_q - 3g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^U \right. \\
& + 4 \left(- \left(-3g_p^2 Q_{H_u} Q_u + g_1^2 \right) \sum_{a=1}^3 Z_{k3+a}^{U,*} Z_{l3+a}^U \right. \\
& \left. \left. + 3 \left(\sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{l3+b}^U + \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^U \right) \right) \right) \Big) \Big) \quad (484)
\end{aligned}$$



$$\begin{aligned}
& -\frac{i}{4} \left((4g_p^2 Q_{H_d} Q_l + g_1^2 + g_2^2) Z_{i1}^{H,*} Z_{j1}^{H,*} - (-4g_p^2 Q_{H_u} Q_l + g_1^2 + g_2^2) Z_{i2}^{H,*} Z_{j2}^{H,*} \right. \\
& \left. + 4g_p^2 Q_l (Q_1 Z_{i4}^{H,*} Z_{j4}^{H,*} + Q_2 Z_{i5}^{H,*} Z_{j5}^{H,*} + Q_3 Z_{i6}^{H,*} Z_{j6}^{H,*} + Q_s Z_{i3}^{H,*} Z_{j3}^{H,*}) \right) \delta_{kl}
\end{aligned} \tag{485}$$

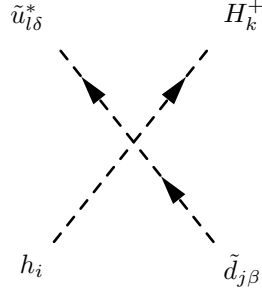


$$\begin{aligned}
& \frac{i}{2} \frac{1}{\sqrt{2}} \delta_{\gamma\delta} \left(2Z_{i3}^{H,*} \left(\lambda \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ab}^* Z_{k3+a}^{U,*} Z_{lb}^D Z_{j1}^+ + \lambda^* \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{l3+a}^D Z_{j2}^+ \right) \right. \\
& + Z_{i1}^{H,*} \left(-g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D Z_{j1}^+ + 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^D Z_{j1}^+ \right. \\
& + 2 \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{j2}^+ \left. \right) \\
& + Z_{i2}^{H,*} \left(2 \sum_{c=1}^3 Z_{k3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{j1}^+ \right. \\
& \left. \left. + \left(2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{U,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^D - g_2^2 \sum_{a=1}^3 Z_{ka}^{U,*} Z_{la}^D \right) Z_{j2}^+ \right) \right)
\end{aligned} \tag{486}$$

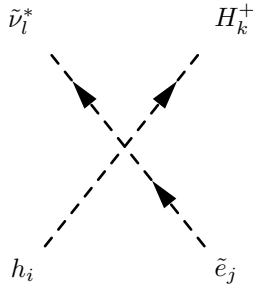


$$-\frac{i}{2} \frac{1}{\sqrt{2}} \left(Z_{i1}^{H,*} \left(-2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^E + g_2^2 \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E \right) Z_{j1}^+ \right.$$

$$+ \left(-2\lambda^* Z_{i3}^{H,*} \sum_{b=1}^3 Z_{kb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E + g_2^2 Z_{i2}^{H,*} \sum_{a=1}^3 Z_{ka}^{V,*} Z_{la}^E \right) Z_{j2}^+ \quad (487)$$

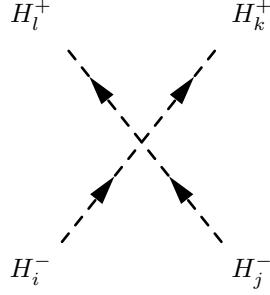


$$\begin{aligned} & \frac{i}{2} \frac{1}{\sqrt{2}} \delta_{\beta\delta} \left(2\lambda^* Z_{i3}^{H,*} \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U Z_{k1}^+ + 2Z_{i2}^{H,*} \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{k1}^+ \right. \\ & - g_2^2 Z_{i2}^{H,*} \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^U Z_{k2}^+ + 2\lambda Z_{i3}^{H,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ab}^* Z_{j3+a}^{D,*} Z_{lb}^U Z_{k2}^+ \\ & + 2Z_{i2}^{H,*} \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^U Z_{k2}^+ \\ & + Z_{i1}^{H,*} \left(-g_2^2 \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^U Z_{k1}^+ + 2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^U Z_{k1}^+ \right. \\ & \left. \left. + 2 \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{k2}^+ \right) \right) \quad (488) \end{aligned}$$

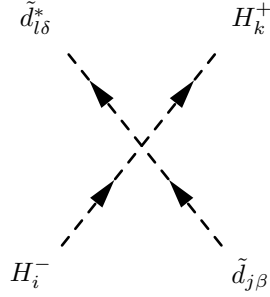


$$- \frac{i}{2} \frac{1}{\sqrt{2}} \left(Z_{i1}^{H,*} \left(-2 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^V + g_2^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^V \right) Z_{k1}^+ \right.$$

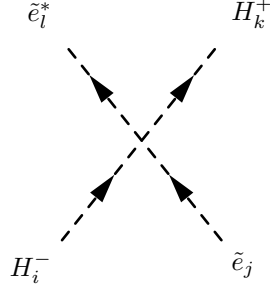
$$+ \left(-2\lambda Z_{i3}^{H,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ab}^* Z_{j3+a}^{E,*} Z_{lb}^V + g_2^2 Z_{i2}^{H,*} \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^V \right) Z_{k2}^+ \quad (489)$$



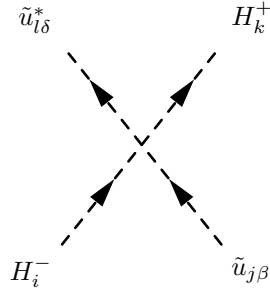
$$\begin{aligned} & -\frac{i}{4} \left(Z_{i2}^+ \left(2 \left(4g_p^2 Q_{H_u}^2 + g_1^2 + g_2^2 \right) Z_{j2}^+ Z_{k2}^+ Z_{l2}^+ \right. \right. \\ & - \left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j1}^+ \left(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \\ & + Z_{i1}^+ \left(2 \left(4g_p^2 Q_{H_d}^2 + g_1^2 + g_2^2 \right) Z_{j1}^+ Z_{k1}^+ Z_{l1}^+ \right. \\ & \left. \left. - \left(-4g_p^2 Q_{H_d} Q_{H_u} - 4|\lambda|^2 + g_1^2 + g_2^2 \right) Z_{j2}^+ \left(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \right) \right) \right) \quad (490) \end{aligned}$$



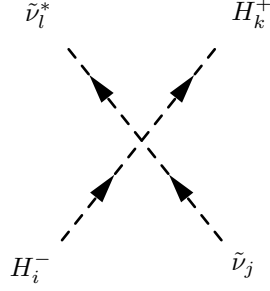
$$\begin{aligned} & \frac{i}{12} \delta_{\beta\delta} \left(\sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^D \left(- \left(12g_p^2 Q_{H_u} Q_q - 3g_2^2 + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ + \left(-3 \left(4g_p^2 Q_{H_d} Q_q + g_2^2 \right) + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ \right) \right. \\ & + 2 \left(\sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{l3+a}^D \left(\left(-6g_p^2 Q_d Q_{H_d} + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ - \left(6g_p^2 Q_d Q_{H_u} + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \right. \\ & \left. \left. - 6 \left(\sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{D,*} \sum_{a=1}^3 Y_{u,ac}^* Y_{u,ab} Z_{lc}^D Z_{i2}^+ Z_{k2}^+ + \sum_{c=1}^3 Z_{j3+c}^{D,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D Z_{i1}^+ Z_{k1}^+ \right) \right) \right) \quad (491) \end{aligned}$$



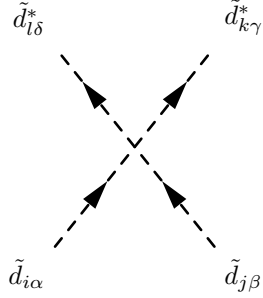
$$\begin{aligned}
& -\frac{i}{4} \left(4 \sum_{c=1}^3 Z_{j3+c}^{E,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{e,ca}^* Y_{e,ba} Z_{l3+b}^E Z_{i1}^+ Z_{k1}^+ \right. \\
& + \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{l3+a}^E \left(-2 \left(-2g_p^2 Q_e Q_{H_d} + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ + 2 \left(2g_p^2 Q_e Q_{H_u} + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \\
& \left. + \sum_{a=1}^3 Z_{ja}^{E,*} Z_{la}^E \left(\left(4g_p^2 Q_{H_d} Q_l + g_1^2 + g_2^2 \right) Z_{i1}^+ Z_{k1}^+ - \left(-4g_p^2 Q_{H_u} Q_l + g_1^2 + g_2^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \right) \quad (492)
\end{aligned}$$



$$\begin{aligned}
& \frac{i}{12} \delta_{\beta\delta} \left(\sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left(\left(-12g_p^2 Q_{H_d} Q_q + 3g_2^2 + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ - \left(12g_p^2 Q_{H_u} Q_q + 3g_2^2 + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \right. \\
& - 4 \left(\sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left(\left(3g_p^2 Q_{H_d} Q_u + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ - \left(-3g_p^2 Q_{H_u} Q_u + g_1^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \right. \\
& \left. \left. + 3 \left(\sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ac}^* Y_{d,ab} Z_{lc}^U Z_{i1}^+ Z_{k1}^+ + \sum_{c=1}^3 Z_{j3+c}^{U,*} \sum_{b=1}^3 \sum_{a=1}^3 Y_{u,ca}^* Y_{u,ba} Z_{l3+b}^U Z_{i2}^+ Z_{k2}^+ \right) \right) \right) \quad (493)
\end{aligned}$$



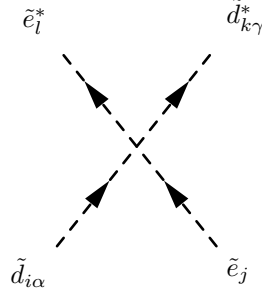
$$\begin{aligned}
& -\frac{i}{4} \left(4 \sum_{c=1}^3 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ac}^* Y_{e,ab} Z_{lc}^V Z_{i1}^+ Z_{k1}^+ \right. \\
& \left. + \delta_{jl} \left(\left(4g_p^2 Q_{H_d} Q_l - g_2^2 + g_1^2 \right) Z_{i1}^+ Z_{k1}^+ + \left(4g_p^2 Q_{H_u} Q_l - g_1^2 + g_2^2 \right) Z_{i2}^+ Z_{k2}^+ \right) \right) \quad (494)
\end{aligned}$$



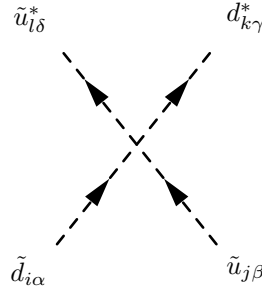
$$\begin{aligned}
& -\frac{i}{72} \left(\delta_{\alpha\delta} \delta_{\beta\gamma} \left(g_1^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D \sum_{b=1}^3 Z_{jb}^{D,*} Z_{kb}^D \right. \right. \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^D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

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

$$\begin{aligned}
& + 2 \sum_{a=1}^3 Z_{j3+a}^{D,*} Z_{l3+a}^D \left(\left(18g_p^2 Q_d^2 + 2g_1^2 - 3g_3^2 \right) \sum_{b=1}^3 Z_{i3+b}^{D,*} Z_{k3+b}^D + \left(18g_p^2 Q_d Q_q + 3g_3^2 + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right) \\
& + \sum_{a=1}^3 Z_{ja}^{D,*} Z_{la}^D \left(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(36g_p^2 Q_q^2 - 6g_3^2 + 9g_2^2 + g_1^2 \right) \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 \\
& + 72 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{j3+c}^{D,*} Z_{ld}^D \Big) \tag{495}
\end{aligned}$$

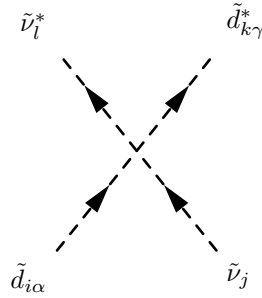


$$\begin{aligned}
& -\frac{i}{24}\delta_{\alpha\gamma}\left(2\sum_{a=1}^3Z_{j3+a}^{E,*}Z_{l3+a}^E\left(2\left(3g_p^2Q_dQ_e+g_1^2\right)\sum_{b=1}^3Z_{i3+b}^{D,*}Z_{k3+b}^D+\left(6g_p^2Q_eQ_q+g_1^2\right)\sum_{b=1}^3Z_{ib}^{D,*}Z_{kb}^D\right)\right. \\
& +\sum_{a=1}^3Z_{ja}^{E,*}Z_{la}^E\left(\left(12g_p^2Q_lQ_q+3g_2^2-g_1^2\right)\sum_{b=1}^3Z_{ib}^{D,*}Z_{kb}^D-2\left(-6g_p^2Q_dQ_l+g_1^2\right)\sum_{b=1}^3Z_{i3+b}^{D,*}Z_{k3+b}^D\right) \\
& -g_1^2\sum_{a=1}^3Z_{ia}^{D,*}Z_{ka}^D\sum_{b=1}^3Z_{jb}^{E,*}Z_{lb}^E+3g_2^2\sum_{a=1}^3Z_{ia}^{D,*}Z_{ka}^D\sum_{b=1}^3Z_{jb}^{E,*}Z_{lb}^E \\
& +12g_p^2Q_lQ_q\sum_{a=1}^3Z_{ia}^{D,*}Z_{ka}^D\sum_{b=1}^3Z_{jb}^{E,*}Z_{lb}^E-2g_1^2\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{k3+a}^D\sum_{b=1}^3Z_{jb}^{E,*}Z_{lb}^E \\
& +12g_p^2Q_dQ_l\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{k3+a}^D\sum_{b=1}^3Z_{jb}^{E,*}Z_{lb}^E+2g_1^2\sum_{a=1}^3Z_{ia}^{D,*}Z_{ka}^D\sum_{b=1}^3Z_{j3+b}^{E,*}Z_{l3+b}^E \\
& +12g_p^2Q_eQ_q\sum_{a=1}^3Z_{ia}^{D,*}Z_{ka}^D\sum_{b=1}^3Z_{j3+b}^{E,*}Z_{l3+b}^E+4g_1^2\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{k3+a}^D\sum_{b=1}^3Z_{j3+b}^{E,*}Z_{l3+b}^E \\
& +12g_p^2Q_dQ_e\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{k3+a}^D\sum_{b=1}^3Z_{j3+b}^{E,*}Z_{l3+b}^E \\
& +24\sum_{b=1}^3Z_{jb}^{E,*}\sum_{a=1}^3Y_{e,ab}Z_{l3+a}^E\sum_{d=1}^3\sum_{c=1}^3Y_{d,cd}Z_{i3+c}^{D,*}Z_{kd}^D \\
& \left.+24\sum_{b=1}^3Z_{ib}^{D,*}\sum_{a=1}^3Y_{d,ab}Z_{k3+a}^D\sum_{d=1}^3\sum_{c=1}^3Y_{e,cd}Z_{j3+c}^{E,*}Z_{ld}^E\right) \tag{496}
\end{aligned}$$

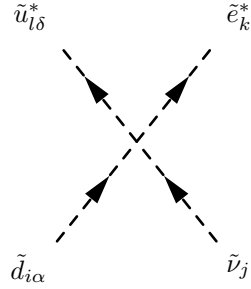


$$\begin{aligned}
& -\frac{i}{72} \left(\delta_{\alpha\gamma} \delta_{\beta\delta} \left(\sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left((36g_p^2 Q_q^2 - 6g_3^2 - 9g_2^2 + g_1^2) \sum_{b=1}^3 Z_{ib}^{D,*} Z_{kb}^D \right. \right. \right. \\
& + 2 \left(18g_p^2 Q_d Q_q + 3g_3^2 + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{D,*}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

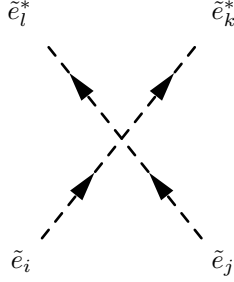
$$\begin{aligned}
& + g_2^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^D \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^U + g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - g_3^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + g_3^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U + 4 \sum_{b=1}^3 Z_{ib}^{D,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd}^* Z_{j3+c}^{U,*} Z_{kd}^D \\
& + 4 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{i3+c}^{D,*} Z_{ld}^U \Big) \Big) \tag{497}
\end{aligned}$$



$$\frac{i}{12} \delta_{\alpha\gamma} \delta_{jl} \left(2 \left(-6g_p^2 Q_d Q_l + g_1^2 \right) \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{k3+a}^D + \left(3 \left(-4g_p^2 Q_l Q_q + g_2^2 \right) + g_1^2 \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ka}^D \right) \tag{498}$$

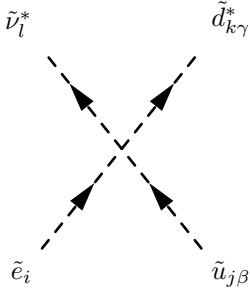


$$\begin{aligned}
& - \frac{i}{4} \delta_{\alpha\delta} \left(g_2^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^E + g_2^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^E \sum_{b=1}^3 Z_{ib}^{D,*} Z_{lb}^U \right. \\
& \left. + 4 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{d,cd}^* Z_{i3+c}^{D,*} Z_{ld}^U \right) \tag{499}
\end{aligned}$$

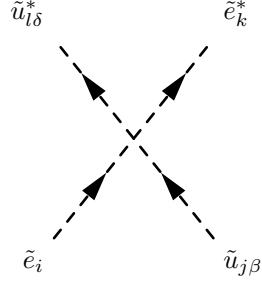


$$\begin{aligned}
& -\frac{i}{8} \left(g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E + g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E \right. \\
& + 4g_p^2 Q_l^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^E \sum_{b=1}^3 Z_{jb}^{E,*} Z_{kb}^E - 2g_1^2 \sum_{a=1}^3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

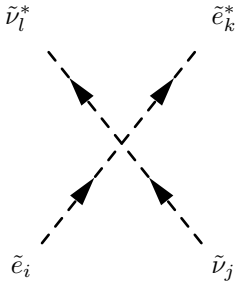
$$\begin{aligned}
& -2g_1^2 \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E + 4g_p^2 Q_e Q_l \sum_{a=1}^3 Z_{ja}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E \\
& + 4g_1^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E + 4g_p^2 Q_e^2 \sum_{a=1}^3 Z_{j3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{l3+b}^E \\
& - 2g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E + 4g_p^2 Q_e Q_l \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& + 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E + 4g_p^2 Q_e^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{E,*} Z_{l3+b}^E \\
& + 8 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{i3+c}^{E,*} Z_{kd}^E \\
& + 8 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{l3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{j3+c}^{E,*} Z_{kd}^E \\
& + 8 \sum_{b=1}^3 Z_{jb}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{i3+c}^{E,*} Z_{ld}^E \\
& + 8 \sum_{b=1}^3 Z_{ib}^{E,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{j3+c}^{E,*} Z_{ld}^E \Big) \tag{500}
\end{aligned}$$



$$\begin{aligned}
& -\frac{i}{4} \delta_{\beta\gamma} \left(g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^V \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^D + g_2^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^D \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^V \right. \\
& \left. + 4 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{d,ab} Z_{k3+a}^D \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{i3+c}^{E,*} Z_{ld}^V \right) \tag{501}
\end{aligned}$$

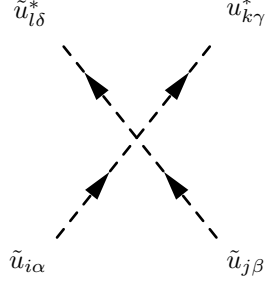


$$\begin{aligned}
& \frac{i}{24} \delta_{\beta\delta} \left(\sum_{a=1}^3 Z_{ja}^{U,*} Z_{la}^U \left(\left(-12g_p^2 Q_l Q_q + 3g_2^2 + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E - 2 \left(6g_p^2 Q_e Q_q + g_1^2 \right) \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E \right) \right. \\
& - 4 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{l3+a}^U \left(\left(-2g_1^2 + 3g_p^2 Q_e Q_u \right) \sum_{b=1}^3 Z_{i3+b}^{E,*} Z_{k3+b}^E + \left(3g_p^2 Q_l Q_u + g_1^2 \right) \sum_{b=1}^3 Z_{ib}^{E,*} Z_{kb}^E \right) \\
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 3g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 12g_p^2 Q_l Q_q \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 2g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 12g_p^2 Q_e Q_q \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 4g_1^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& - 12g_p^2 Q_l Q_u \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U + 8g_1^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& \left. - 12g_p^2 Q_e Q_u \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \right) \tag{502}
\end{aligned}$$



$$- \frac{i}{4} \left(\delta_{jl} \left(-2 \left(-2g_p^2 Q_e Q_l + g_1^2 \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{k3+a}^E + \left(4g_p^2 Q_l^2 - g_2^2 + g_1^2 \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ka}^E \right) \right.$$

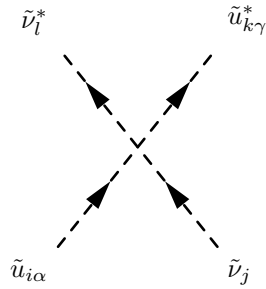
$$\begin{aligned}
& + g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{la}^V \sum_{b=1}^3 Z_{jb}^{V,*} Z_{kb}^E + g_2^2 \sum_{a=1}^3 Z_{ja}^{V,*} Z_{ka}^E \sum_{b=1}^3 Z_{ib}^{E,*} Z_{lb}^V \\
& + 4 \sum_{b=1}^3 Z_{jb}^{V,*} \sum_{a=1}^3 Y_{e,ab} Z_{k3+a}^E \sum_{d=1}^3 \sum_{c=1}^3 Y_{e,cd}^* Z_{i3+c}^{E,*} Z_{ld}^V \Big) \tag{503}
\end{aligned}$$



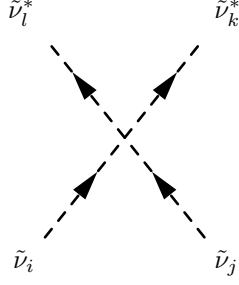
$$\begin{aligned}
& - \frac{i}{72} \left(\delta_{\alpha\delta} \delta_{\beta\gamma} \left(g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{la}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{kb}^U \right. \right. \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*}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

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

$$\begin{aligned}
& + 18g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U - 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{ib}^{U,*} Z_{lb}^U \\
& + g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 9g_2^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 36g_p^2 Q_q^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& - 4g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U + 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U \\
& + 36g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{jb}^{U,*} Z_{lb}^U - 18g_3^2 \sum_{a=1}^3 Z_{ja}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U \\
& + 18g_3^2 \sum_{a=1}^3 Z_{j3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{i3+b}^{U,*} Z_{l3+b}^U - 4g_1^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 6g_3^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U + 36g_p^2 Q_q Q_u \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 16g_1^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U - 6g_3^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 36g_p^2 Q_u^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \sum_{b=1}^3 Z_{j3+b}^{U,*} Z_{l3+b}^U \\
& + 72 \sum_{b=1}^3 Z_{jb}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{l3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd}^* Z_{i3+c}^{U,*} Z_{kd}^U \\
& + 72 \sum_{b=1}^3 Z_{ib}^{U,*} \sum_{a=1}^3 Y_{u,ab} Z_{k3+a}^U \sum_{d=1}^3 \sum_{c=1}^3 Y_{u,cd}^* Z_{j3+c}^{U,*} Z_{ld}^U \Big) \tag{504}
\end{aligned}$$

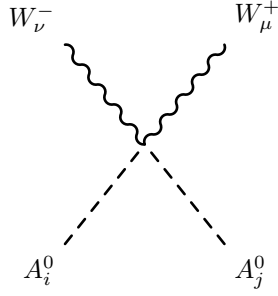


$$\frac{i}{12} \delta_{\alpha\gamma} \delta_{jl} \left(\left(-3 \left(4g_p^2 Q_l Q_q + g_2^2 \right) + g_1^2 \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ka}^U - 4 \left(3g_p^2 Q_l Q_u + g_1^2 \right) \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{k3+a}^U \right) \tag{505}$$

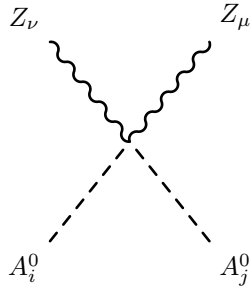


$$-\frac{i}{4} \left(4g_p^2 Q_l^2 + g_1^2 + g_2^2 \right) \left(\delta_{ik} \delta_{jl} + \delta_{il} \delta_{jk} \right) \quad (506)$$

9.8 Two Scalar-Two Vector Boson-Interaction

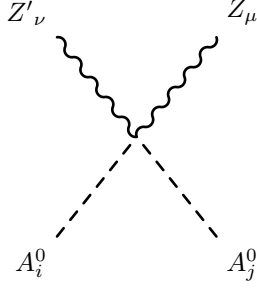


$$\frac{i}{2} g_2^2 \left(Z_{i1}^{A,*} Z_{j1}^{A,*} + Z_{i2}^{A,*} Z_{j2}^{A,*} \right) (g_{\mu\nu}) \quad (507)$$

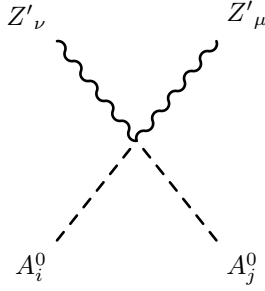


$$\frac{i}{2} \left(4g_p^2 \left(Q_1^2 Z_{i4}^{A,*} Z_{j4}^{A,*} + Q_2^2 Z_{i5}^{A,*} Z_{j5}^{A,*} + Q_3^2 Z_{i6}^{A,*} Z_{j6}^{A,*} + Q_s^2 Z_{i3}^{A,*} Z_{j3}^{A,*} \right) \sin \Theta'_W \right)$$

$$\begin{aligned}
& + Z_{i1}^{A,*} Z_{j1}^{A,*} \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \\
& + Z_{i2}^{A,*} Z_{j2}^{A,*} \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \Big) (g_{\mu\nu})
\end{aligned} \tag{508}$$

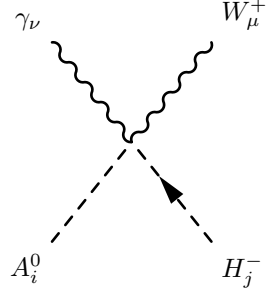


$$\begin{aligned}
& - \frac{i}{2} \left(Z_{i1}^{A,*} Z_{j1}^{A,*} \left(-2g_1 g_p Q_{H_d} \cos \Theta_W'^2 \sin \Theta_W + g_2^2 \cos \Theta_W'^2 \cos \Theta'_W \sin \Theta'_W \right. \right. \\
& + \cos \Theta'_W \left(-4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W'^2 \right) \sin \Theta'_W + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta_W'^2 \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W - g_p Q_{H_d} \cos \Theta_W'^2 + g_p Q_{H_d} \sin \Theta_W'^2 \right) \Big) \\
& + Z_{i2}^{A,*} Z_{j2}^{A,*} \left(2g_1 g_p Q_{H_u} \cos \Theta_W'^2 \sin \Theta_W + g_2^2 \cos \Theta_W'^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left(-4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W'^2 \right) \sin \Theta'_W - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta_W'^2 \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_u} \cos \Theta_W'^2 - g_p Q_{H_u} \sin \Theta_W'^2 \right) \Big) \\
& \left. - 2g_p^2 \left(Q_1^2 Z_{i4}^{A,*} Z_{j4}^{A,*} + Q_2^2 Z_{i5}^{A,*} Z_{j5}^{A,*} + Q_3^2 Z_{i6}^{A,*} Z_{j6}^{A,*} + Q_s^2 Z_{i3}^{A,*} Z_{j3}^{A,*} \right) \sin 2\Theta'_W \right) (g_{\mu\nu})
\end{aligned} \tag{509}$$

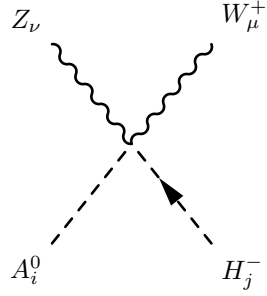


$$\begin{aligned}
& \frac{i}{2} \left(4g_p^2 \left(Q_1^2 Z_{i4}^{A,*} Z_{j4}^{A,*} + Q_2^2 Z_{i5}^{A,*} Z_{j5}^{A,*} + Q_3^2 Z_{i6}^{A,*} Z_{j6}^{A,*} + Q_s^2 Z_{i3}^{A,*} Z_{j3}^{A,*} \right) \cos \Theta_W'^2 \right. \\
& \left. + Z_{i1}^{A,*} Z_{j1}^{A,*} \left(-2g_p Q_{H_d} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \right)
\end{aligned}$$

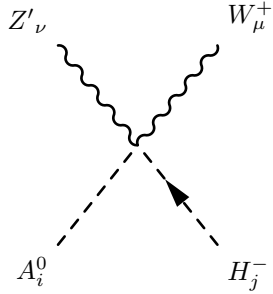
$$+ Z_{i2}^{A,*} Z_{j2}^{A,*} \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 \left(g_{\mu\nu} \right) \quad (510)$$



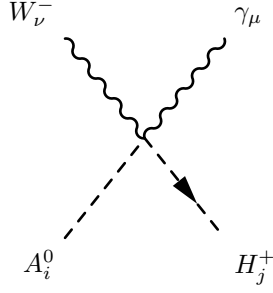
$$- \frac{1}{2} g_1 g_2 \cos \Theta_W \left(Z_{i1}^{A,*} Z_{j1}^+ + Z_{i2}^{A,*} Z_{j2}^+ \right) \left(g_{\mu\nu} \right) \quad (511)$$



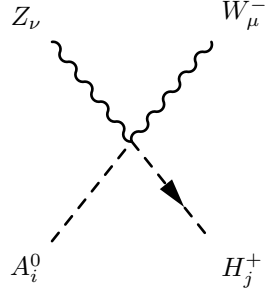
$$\begin{aligned} & \frac{1}{2} g_2 \left(Z_{i1}^{A,*} \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j1}^+ \right. \\ & \left. + Z_{i2}^{A,*} \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j2}^+ \right) \left(g_{\mu\nu} \right) \end{aligned} \quad (512)$$



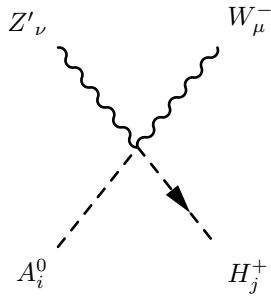
$$\begin{aligned}
& \frac{1}{2}g_2 \left(Z_{i1}^{A,*} \left(2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j1}^+ \right. \\
& \left. - Z_{i2}^{A,*} \left(2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j2}^+ \right) (g_{\mu\nu})
\end{aligned} \tag{513}$$



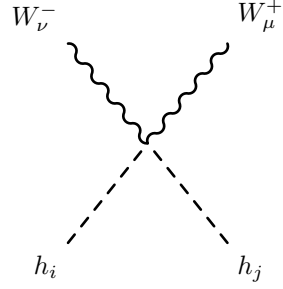
$$\frac{1}{2}g_1 g_2 \cos \Theta_W \left(Z_{i1}^{A,*} Z_{j1}^+ + Z_{i2}^{A,*} Z_{j2}^+ \right) (g_{\mu\nu}) \tag{514}$$



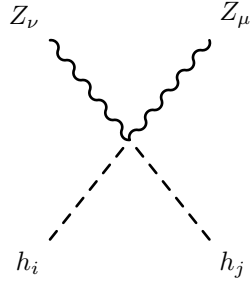
$$\begin{aligned}
& -\frac{1}{2}g_2 \left(Z_{i1}^{A,*} \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j1}^+ \right. \\
& \left. + Z_{i2}^{A,*} \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j2}^+ \right) (g_{\mu\nu})
\end{aligned} \tag{515}$$



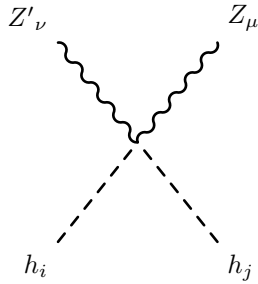
$$\begin{aligned}
& \frac{1}{2}g_2 \left(Z_{i1}^{A,*} \left(-2g_p Q_{H_d} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j1}^+ \right. \\
& \left. + Z_{i2}^{A,*} \left(2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j2}^+ \right) (g_{\mu\nu})
\end{aligned} \tag{516}$$



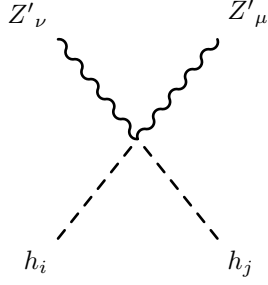
$$\frac{i}{2}g_2^2 \left(Z_{i1}^{H,*} Z_{j1}^{H,*} + Z_{i2}^{H,*} Z_{j2}^{H,*} \right) (g_{\mu\nu}) \tag{517}$$



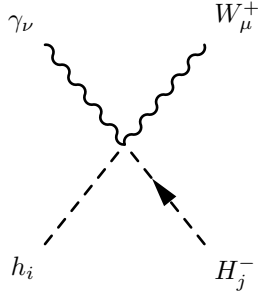
$$\begin{aligned}
& \frac{i}{2} \left(4g_p^2 \left(Q_1^2 Z_{i4}^{H,*} Z_{j4}^{H,*} + Q_2^2 Z_{i5}^{H,*} Z_{j5}^{H,*} + Q_3^2 Z_{i6}^{H,*} Z_{j6}^{H,*} + Q_s^2 Z_{i3}^{H,*} Z_{j3}^{H,*} \right) \sin^2 \Theta'_W \right. \\
& + Z_{i1}^{H,*} Z_{j1}^{H,*} \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \\
& \left. + Z_{i2}^{H,*} Z_{j2}^{H,*} \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \right) (g_{\mu\nu})
\end{aligned} \tag{518}$$



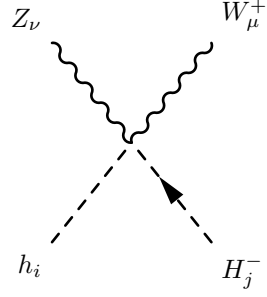
$$\begin{aligned}
& -\frac{i}{2} \left(Z_{i1}^{H,*} Z_{j1}^{H,*} \left(-2g_1 g_p Q_{H_d} \cos \Theta_W' \sin \Theta_W + g_2^2 \cos \Theta_W'^2 \cos \Theta_W' \sin \Theta_W' \right. \right. \\
& + \cos \Theta_W' \left(-4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W'^2 \right) \sin \Theta_W' + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta_W'^2 \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta_W' \sin \Theta_W \sin \Theta_W' - g_p Q_{H_d} \cos \Theta_W'^2 + g_p Q_{H_d} \sin \Theta_W'^2 \right) \Big) \\
& + Z_{i2}^{H,*} Z_{j2}^{H,*} \left(2g_1 g_p Q_{H_u} \cos \Theta_W' \sin \Theta_W + g_2^2 \cos \Theta_W'^2 \cos \Theta_W' \sin \Theta_W' \right. \\
& + \cos \Theta_W' \left(-4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W'^2 \right) \sin \Theta_W' - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta_W'^2 \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta_W' \sin \Theta_W \sin \Theta_W' + g_p Q_{H_u} \cos \Theta_W'^2 - g_p Q_{H_u} \sin \Theta_W'^2 \right) \Big) \\
& - 2g_p^2 \left(Q_1^2 Z_{i4}^{H,*} Z_{j4}^{H,*} + Q_2^2 Z_{i5}^{H,*} Z_{j5}^{H,*} + Q_3^2 Z_{i6}^{H,*} Z_{j6}^{H,*} + Q_s^2 Z_{i3}^{H,*} Z_{j3}^{H,*} \right) \sin 2\Theta_W' \Big) (g_{\mu\nu})
\end{aligned} \tag{519}$$



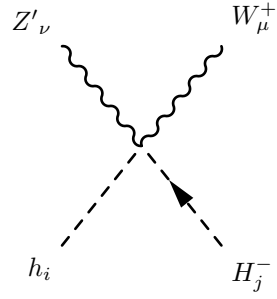
$$\begin{aligned}
& \frac{i}{2} \left(4g_p^2 \left(Q_1^2 Z_{i4}^{H,*} Z_{j4}^{H,*} + Q_2^2 Z_{i5}^{H,*} Z_{j5}^{H,*} + Q_3^2 Z_{i6}^{H,*} Z_{j6}^{H,*} + Q_s^2 Z_{i3}^{H,*} Z_{j3}^{H,*} \right) \cos \Theta_W'^2 \right. \\
& + Z_{i1}^{H,*} Z_{j1}^{H,*} \left(-2g_p Q_{H_d} \cos \Theta_W' + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta_W' \right)^2 \\
& + Z_{i2}^{H,*} Z_{j2}^{H,*} \left(2g_p Q_{H_u} \cos \Theta_W' + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta_W' \right)^2 \Big) (g_{\mu\nu})
\end{aligned} \tag{520}$$



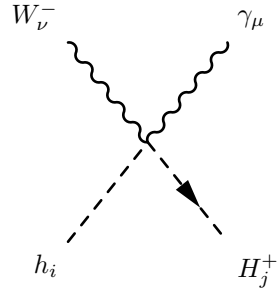
$$-\frac{i}{2} g_1 g_2 \cos \Theta_W \left(Z_{i1}^{H,*} Z_{j1}^+ - Z_{i2}^{H,*} Z_{j2}^+ \right) (g_{\mu\nu}) \tag{521}$$



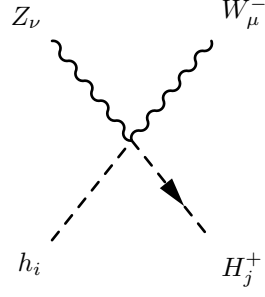
$$\begin{aligned} & \frac{i}{2} g_2 \left(Z_{i1}^{H,*} \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j1}^+ \right. \\ & \left. + Z_{i2}^{H,*} \left(2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (522)$$



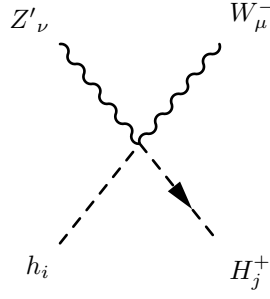
$$\begin{aligned} & \frac{i}{2} g_2 \left(Z_{i1}^{H,*} \left(2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j1}^+ \right. \\ & \left. + Z_{i2}^{H,*} \left(2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (523)$$



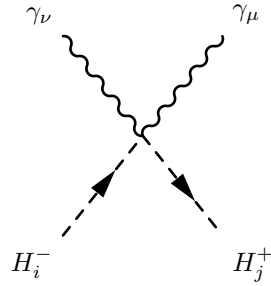
$$- \frac{i}{2} g_1 g_2 \cos \Theta_W \left(Z_{i1}^{H,*} Z_{j1}^+ - Z_{i2}^{H,*} Z_{j2}^+ \right) (g_{\mu\nu}) \quad (524)$$



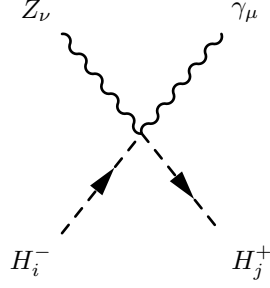
$$\begin{aligned} & \frac{i}{2} g_2 \left(Z_{i1}^{H,*} \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j1}^+ \right. \\ & \left. + Z_{i2}^{H,*} \left(2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right) Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (525)$$



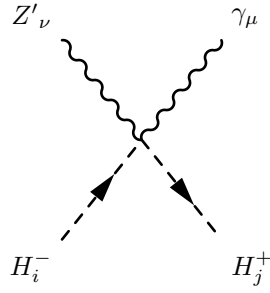
$$\begin{aligned} & \frac{i}{2} g_2 \left(Z_{i1}^{H,*} \left(2g_p Q_{H_d} \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j1}^+ \right. \\ & \left. + Z_{i2}^{H,*} \left(2g_p Q_{H_u} \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (526)$$



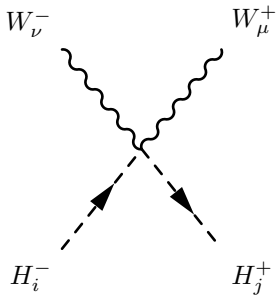
$$\frac{i}{2} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right)^2 \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \quad (527)$$



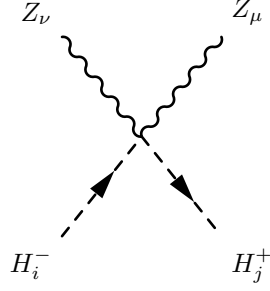
$$\begin{aligned}
& -\frac{i}{2} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left(\left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right. \\
& \left. + \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu})
\end{aligned} \tag{528}$$



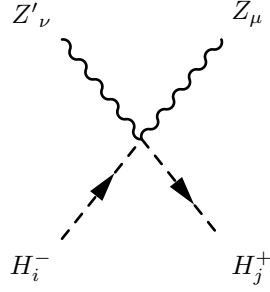
$$\begin{aligned}
& \frac{i}{2} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left(\left(-2g_p Q_{H_d} \cos \Theta'_W + \left(g_1 \sin \Theta_W - g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{i1}^+ Z_{j1}^+ \right. \\
& \left. + \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W - g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu})
\end{aligned} \tag{529}$$



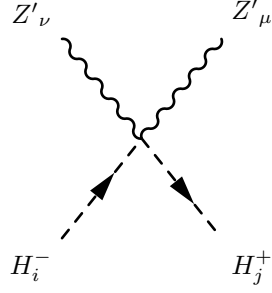
$$\frac{i}{2} g_2^2 \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \tag{530}$$



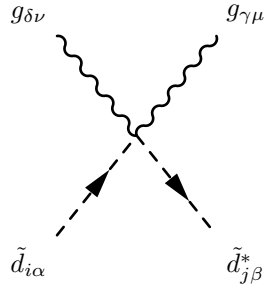
$$\begin{aligned}
& \frac{i}{2} \left(\left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right)^2 Z_{i1}^+ Z_{j1}^+ \right. \\
& \left. + \left(2g_p Q_{H_u} \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu})
\end{aligned} \tag{531}$$



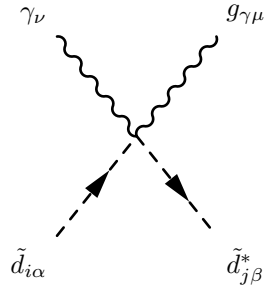
$$\begin{aligned}
& -\frac{i}{2} \left(\left(-2g_1 g_p Q_{H_d} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \right. \\
& + \cos \Theta'_W \left(-4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta'^2_W \\
& + 2g_2 \cos \Theta_W \left(-g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_d} \cos \Theta'^2_W - g_p Q_{H_d} \sin \Theta'^2_W \right) \left. \right) Z_{i1}^+ Z_{j1}^+ \\
& + \left(2g_1 g_p Q_{H_u} \cos \Theta'^2_W \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \right. \\
& + \cos \Theta'_W \left(-4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta'_W - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta'^2_W \\
& \left. - 2g_2 \cos \Theta_W \left(g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W + g_p Q_{H_u} \cos \Theta'^2_W - g_p Q_{H_u} \sin \Theta'^2_W \right) \right) Z_{i2}^+ Z_{j2}^+ \Big) (g_{\mu\nu})
\end{aligned} \tag{532}$$



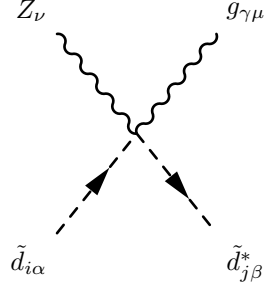
$$\begin{aligned} & \frac{i}{2} \left(\left(2g_p Q_{H_d} \cos \Theta'_W + \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 Z_{i1}^+ Z_{j1}^+ \right. \\ & \left. + \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W - g_2 \cos \Theta_W \right) \sin \Theta'_W \right)^2 Z_{i2}^+ Z_{j2}^+ \right) (g_{\mu\nu}) \end{aligned} \quad (533)$$



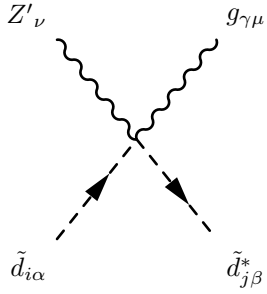
$$\frac{i}{4} g_3^2 \delta_{ij} \left(\sum_{a=1}^3 \lambda_{a,\alpha}^\gamma \lambda_{\beta,a}^\delta + \sum_{a=1}^3 \lambda_{\beta,a}^\gamma \lambda_{a,\alpha}^\delta \right) (g_{\mu\nu}) \quad (534)$$



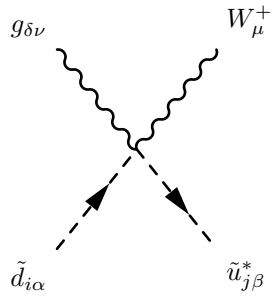
$$\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left(-2g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D + \left(-3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right) (g_{\mu\nu}) \quad (535)$$



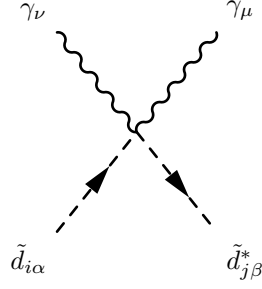
$$\begin{aligned}
& -\frac{i}{6}g_3\lambda_{\beta,\alpha}^\gamma\left(\left(3g_2\cos\Theta_W\cos\Theta'_W-6g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right. \\
& \left.-2\left(-3g_pQ_d\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\right)(g_{\mu\nu})
\end{aligned} \tag{536}$$



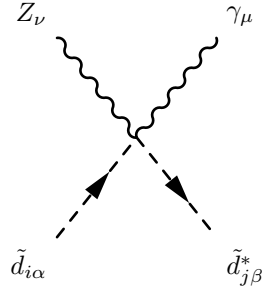
$$\begin{aligned}
& \frac{i}{6}g_3\lambda_{\beta,\alpha}^\gamma\left(\left(\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\sum_{a=1}^3Z_{ia}^{D,*}Z_{ja}^D\right. \\
& \left.-2\left(3g_pQ_d\cos\Theta'_W+g_1\sin\Theta_W\sin\Theta'_W\right)\sum_{a=1}^3Z_{i3+a}^{D,*}Z_{j3+a}^D\right)(g_{\mu\nu})
\end{aligned} \tag{537}$$



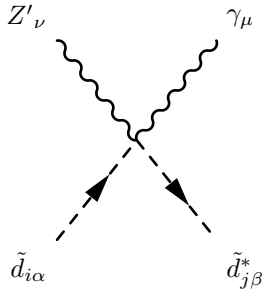
$$i \frac{1}{\sqrt{2}} g_2 g_3 \lambda_{\beta, \alpha}^\delta \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \quad (538)$$



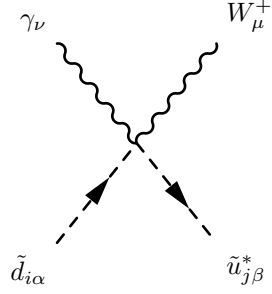
$$\frac{i}{18} \delta_{\alpha\beta} \left(\left(-3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D + 4g_1^2 \cos^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \quad (539)$$



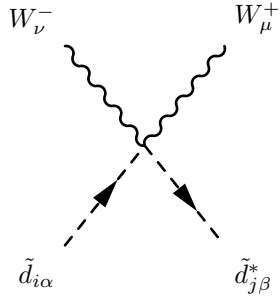
$$\begin{aligned} & - \frac{i}{18} \delta_{\alpha\beta} \left(\left(-3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \left(3g_2 \cos \Theta_W \cos \Theta'_W - 6g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right. \\ & \left. + 4g_1 \cos \Theta_W \left(-3g_p Q_d \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \end{aligned} \quad (540)$$



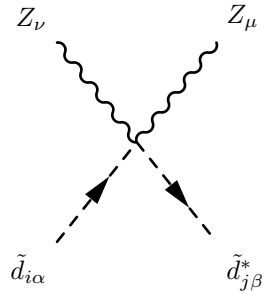
$$\begin{aligned}
& \frac{i}{18} \delta_{\alpha\beta} \left(\left(-3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \left(\left(3g_2 \cos \Theta_W + g_1 \sin \Theta_W \right) \sin \Theta'_W + 6g_p Q_q \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right. \\
& \left. + 4g_1 \cos \Theta_W \left(3g_p Q_d \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu})
\end{aligned} \tag{541}$$



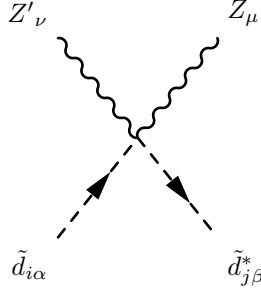
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \tag{542}$$



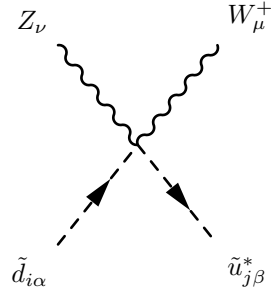
$$\frac{i}{2} g_2^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D (g_{\mu\nu}) \tag{543}$$



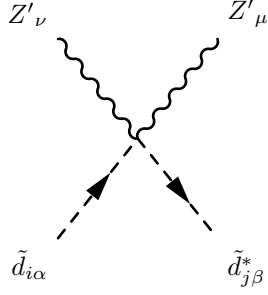
$$\begin{aligned}
& \frac{i}{18} \delta_{\alpha\beta} \left(\left(3g_2 \cos \Theta_W \cos \Theta'_W - 6g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right. \\
& \left. + 4 \left(-3g_p Q_d \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right)^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu})
\end{aligned} \tag{544}$$



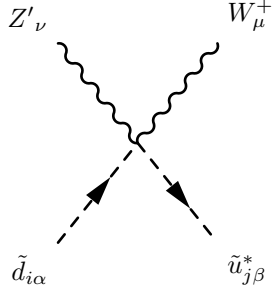
$$\begin{aligned}
& -\frac{i}{18} \delta_{\alpha\beta} \left(\left(6g_1 g_p Q_q \cos \Theta_W'^2 \sin \Theta_W + 9g_2^2 \cos \Theta_W'^2 \cos \Theta'_W \sin \Theta'_W \right. \right. \\
& \left. \left. + \cos \Theta'_W \left(-36g_p^2 Q_q^2 + g_1^2 \sin^2 \Theta_W'^2 \right) \sin \Theta'_W - 6g_1 g_p Q_q \sin \Theta_W \sin \Theta_W'^2 \right. \right. \\
& \left. \left. + 6g_2 \cos \Theta_W \left(3g_p Q_q \cos \Theta_W'^2 - 3g_p Q_q \sin \Theta_W'^2 + g_1 \cos \Theta'_W \sin \Theta_W \sin \Theta'_W \right) \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right. \\
& \left. + 2 \left(6g_1 g_p Q_d \cos \Theta_W'^2 \sin \Theta_W + g_1^2 \sin^2 \Theta_W'^2 \sin 2\Theta'_W \right. \right. \\
& \left. \left. - 3g_p Q_d \left(2g_1 \sin \Theta_W \sin \Theta_W'^2 + 3g_p Q_d \sin 2\Theta'_W \right) \right) \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu})
\end{aligned} \tag{545}$$



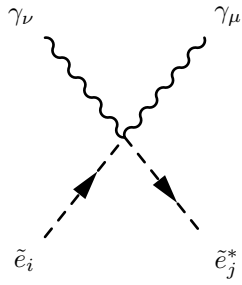
$$-\frac{i}{3} \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \left(-6g_p Q_q \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \tag{546}$$



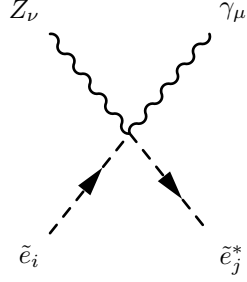
$$\begin{aligned} & \frac{i}{18} \delta_{\alpha\beta} \left(\left(\left(3g_2 \cos \Theta_W + g_1 \sin \Theta_W \right) \sin \Theta'_W + 6g_p Q_q \cos \Theta'_W \right)^2 \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^D \right. \\ & \left. + 4 \left(3g_p Q_d \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right)^2 \sum_{a=1}^3 Z_{i3+a}^{D,*} Z_{j3+a}^D \right) (g_{\mu\nu}) \end{aligned} \quad (547)$$



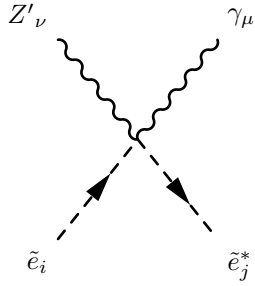
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \left(6g_p Q_q \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{D,*} Z_{ja}^U (g_{\mu\nu}) \quad (548)$$



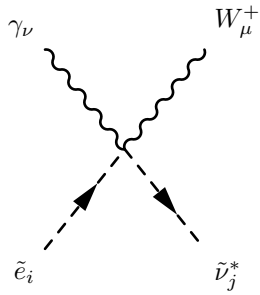
$$\frac{i}{2} \left(4g_1^2 \cos^2 \Theta_W \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E + \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right) (g_{\mu\nu}) \quad (549)$$



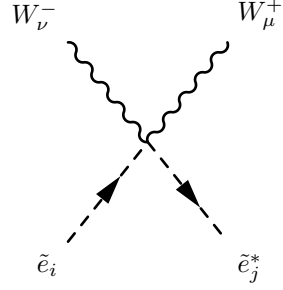
$$\begin{aligned}
& -\frac{i}{2} \left((g_1 \cos \Theta_W + g_2 \sin \Theta_W) \left(2g_p Q_l \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. + 4g_1 \cos \Theta_W \left(g_1 \cos \Theta'_W \sin \Theta_W - g_p Q_e \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu})
\end{aligned} \tag{550}$$



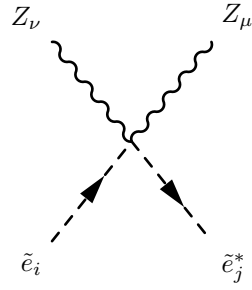
$$\begin{aligned}
& \frac{i}{2} \left((g_1 \cos \Theta_W + g_2 \sin \Theta_W) \left(-2g_p Q_l \cos \Theta'_W + (g_1 \sin \Theta_W - g_2 \cos \Theta_W) \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. + 4g_1 \cos \Theta_W \left(g_1 \sin \Theta_W \sin \Theta'_W + g_p Q_e \cos \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu})
\end{aligned} \tag{551}$$



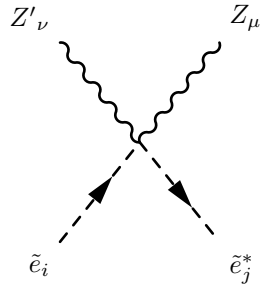
$$-i \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V (g_{\mu\nu}) \quad (552)$$



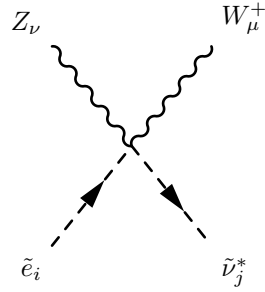
$$\frac{i}{2} g_2^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E (g_{\mu\nu}) \quad (553)$$



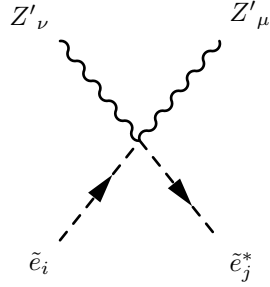
$$\begin{aligned} & \frac{i}{2} \left(\left(2g_p Q_l \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\ & \left. + 4 \left(g_1 \cos \Theta'_W \sin \Theta_W - g_p Q_e \sin \Theta'_W \right)^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu}) \end{aligned} \quad (554)$$



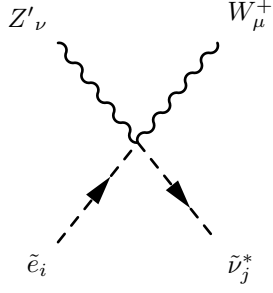
$$\begin{aligned}
& -\frac{i}{2} \left(\left(-2g_1 g_p Q_l \cos \Theta_W'^2 \sin \Theta_W + g_2^2 \cos \Theta_W'^2 \cos \Theta_W' \sin \Theta_W' \right. \right. \\
& + \cos \Theta_W' \left(-4g_p^2 Q_l^2 + g_1^2 \sin \Theta_W'^2 \right) \sin \Theta_W' + 2g_1 g_p Q_l \sin \Theta_W \sin \Theta_W'^2 \\
& + 2g_2 \cos \Theta_W \left(-g_1 \cos \Theta_W' \sin \Theta_W \sin \Theta_W' + g_p Q_l \cos \Theta_W'^2 - g_p Q_l \sin \Theta_W'^2 \right) \Big) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \\
& + 4 \left(g_1 g_p Q_e \cos \Theta_W'^2 \sin \Theta_W + \cos \Theta_W' \left(g_1^2 \sin \Theta_W'^2 - g_p^2 Q_e^2 \right) \sin \Theta_W' \right. \\
& \left. \left. - g_1 g_p Q_e \sin \Theta_W \sin \Theta_W'^2 \right) \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu})
\end{aligned} \tag{555}$$



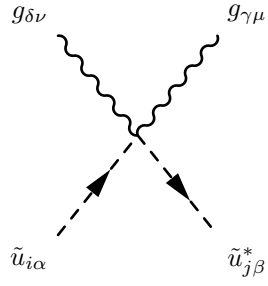
$$i \frac{1}{\sqrt{2}} g_2 \left(2g_p Q_l \sin \Theta_W' + g_1 \cos \Theta_W' \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V (g_{\mu\nu}) \tag{556}$$



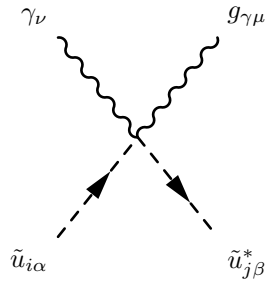
$$\begin{aligned}
& \frac{i}{2} \left(\left(2g_p Q_l \cos \Theta_W' + \left(-g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta_W' \right)^2 \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^E \right. \\
& \left. + 4 \left(g_1 \sin \Theta_W \sin \Theta_W' + g_p Q_e \cos \Theta_W' \right)^2 \sum_{a=1}^3 Z_{i3+a}^{E,*} Z_{j3+a}^E \right) (g_{\mu\nu})
\end{aligned} \tag{557}$$



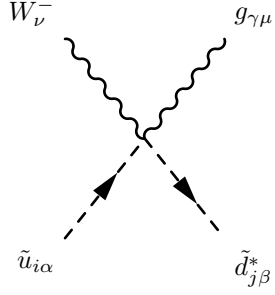
$$i \frac{1}{\sqrt{2}} g_2 \left(2g_p Q_l \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{E,*} Z_{ja}^V (g_{\mu\nu}) \quad (558)$$



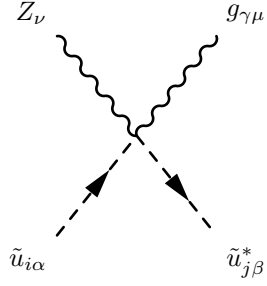
$$\frac{i}{4} g_3^2 \delta_{ij} \left(\sum_{a=1}^3 \lambda_{a,\alpha}^\gamma \lambda_{\beta,a}^\delta + \sum_{a=1}^3 \lambda_{\beta,a}^\gamma \lambda_{a,\alpha}^\delta \right) (g_{\mu\nu}) \quad (559)$$



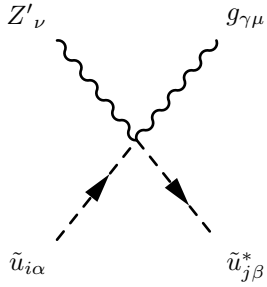
$$\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left(\left(3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U + 4g_1 \cos \Theta_W \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu}) \quad (560)$$



$$i \frac{1}{\sqrt{2}} g_2 g_3 \lambda_{\beta,\alpha}^\gamma \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D (g_{\mu\nu}) \quad (561)$$

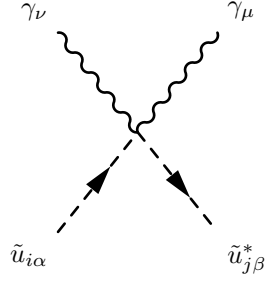


$$\begin{aligned} & \frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left(\left(3g_2 \cos \Theta_W \cos \Theta'_W + 6g_p Q_q \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\ & \left. - 2 \left(2g_1 \cos \Theta'_W \sin \Theta_W + 3g_p Q_u \sin \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu}) \end{aligned} \quad (562)$$

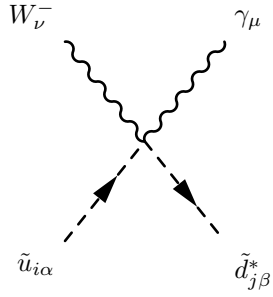


$$\frac{i}{6} g_3 \lambda_{\beta,\alpha}^\gamma \left(\left(\left(-3g_2 \cos \Theta_W + g_1 \sin \Theta_W \right) \sin \Theta'_W + 6g_p Q_q \cos \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right)$$

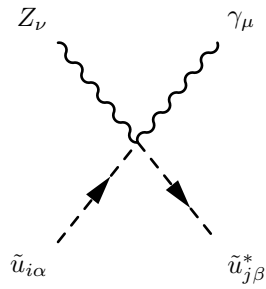
$$+ 2 \left(2g_1 \sin \Theta_W \sin \Theta'_W - 3g_p Q_u \cos \Theta'_W \right) \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \left(g_{\mu\nu} \right) \quad (563)$$



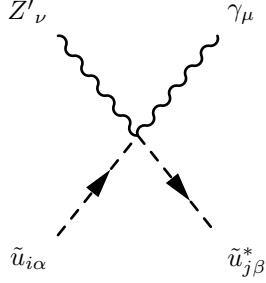
$$\frac{i}{18} \delta_{\alpha\beta} \left(16g_1^2 \cos \Theta_W^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U + \left(3g_2 \sin \Theta_W + g_1 \cos \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right) \left(g_{\mu\nu} \right) \quad (564)$$



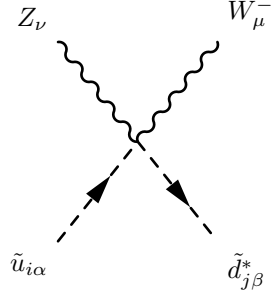
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D \left(g_{\mu\nu} \right) \quad (565)$$



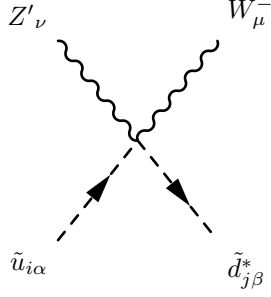
$$\begin{aligned}
& -\frac{i}{18}\delta_{\alpha\beta}\left(\left(3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(-3g_2\cos\Theta_W\cos\Theta'_W-6g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U\right. \\
& \left.+8g_1\left(3g_pQ_u\cos\Theta_W\sin\Theta'_W+g_1\cos\Theta'_W\sin2\Theta_W\right)\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U\right)(g_{\mu\nu})
\end{aligned} \tag{566}$$



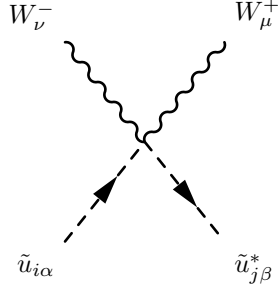
$$\begin{aligned}
& \frac{i}{18}\delta_{\alpha\beta}\left(\left(3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(\left(-3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U\right. \\
& \left.+8g_1\left(-3g_pQ_u\cos\Theta_W\cos\Theta'_W+g_1\sin2\Theta_W\sin\Theta'_W\right)\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U\right)(g_{\mu\nu})
\end{aligned} \tag{567}$$



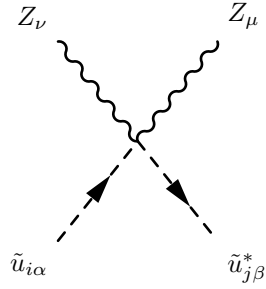
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\left(-6g_pQ_q\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W\right)\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^D(g_{\mu\nu}) \tag{568}$$



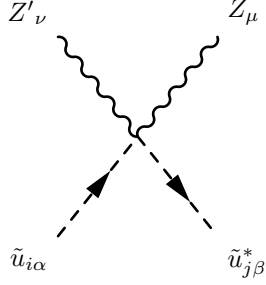
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \left(6g_p Q_q \cos \Theta'_W + g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^D (g_{\mu\nu}) \quad (569)$$



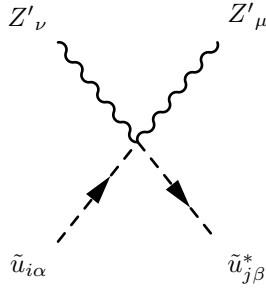
$$\frac{i}{2} g_2^2 \delta_{\alpha\beta} \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U (g_{\mu\nu}) \quad (570)$$



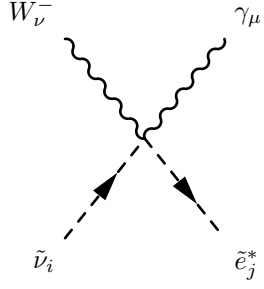
$$\begin{aligned} & \frac{i}{18} \delta_{\alpha\beta} \left(\left(3g_2 \cos \Theta_W \cos \Theta'_W + 6g_p Q_q \sin \Theta'_W - g_1 \cos \Theta'_W \sin \Theta_W \right)^2 \sum_{a=1}^3 Z_{ia}^{U,*} Z_{ja}^U \right. \\ & \left. + 4 \left(2g_1 \cos \Theta'_W \sin \Theta_W + 3g_p Q_u \sin \Theta'_W \right)^2 \sum_{a=1}^3 Z_{i3+a}^{U,*} Z_{j3+a}^U \right) (g_{\mu\nu}) \end{aligned} \quad (571)$$



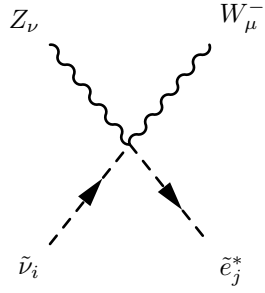
$$\begin{aligned}
& -\frac{i}{18}\delta_{\alpha\beta}\left(\left(6g_1g_pQ_q\cos\Theta'_W\sin\Theta_W+9g_2^2\cos\Theta_W^2\cos\Theta'_W\sin\Theta'_W\right.\right. \\
& \left.+\cos\Theta'_W\left(-36g_p^2Q_q^2+g_1^2\sin\Theta_W^2\right)\sin\Theta'_W-6g_1g_pQ_q\sin\Theta_W\sin\Theta'^2_W\right. \\
& \left.-6g_2\cos\Theta_W\left(3g_pQ_q\cos\Theta'^2_W-3g_pQ_q\sin\Theta'^2_W+g_1\cos\Theta'_W\sin\Theta_W\sin\Theta'_W\right)\right)\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U \\
& -2\left(6g_1g_pQ_u\sin-2\Theta'_W+\Theta_W-g_1^2\sin2\left(-\Theta'_W+\Theta_W\right)-2g_1^2\sin2\Theta'_W+9g_p^2Q_u^2\sin2\Theta'_W\right. \\
& \left.+g_1^2\sin2\left(\Theta_W+\Theta'_W\right)+6g_1g_pQ_u\sin2\Theta'_W+\Theta_W\right)\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U\Big)(g_{\mu\nu})
\end{aligned} \tag{572}$$



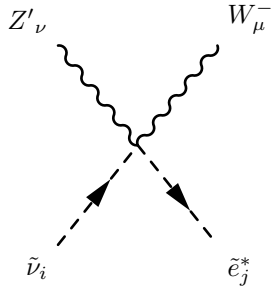
$$\begin{aligned}
& \frac{i}{18}\delta_{\alpha\beta}\left(\left(\left(-3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\sin\Theta'_W+6g_pQ_q\cos\Theta'_W\right)^2\sum_{a=1}^3Z_{ia}^{U,*}Z_{ja}^U\right. \\
& \left.+4\left(-2g_1\sin\Theta_W\sin\Theta'_W+3g_pQ_u\cos\Theta'_W\right)^2\sum_{a=1}^3Z_{i3+a}^{U,*}Z_{j3+a}^U\right)\Big)(g_{\mu\nu})
\end{aligned} \tag{573}$$



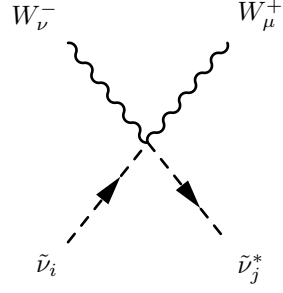
$$-i \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E (g_{\mu\nu}) \quad (574)$$



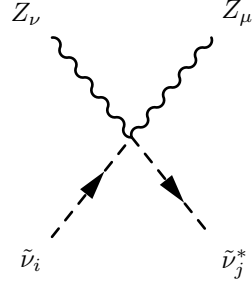
$$i \frac{1}{\sqrt{2}} g_2 \left(2g_p Q_l \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E (g_{\mu\nu}) \quad (575)$$



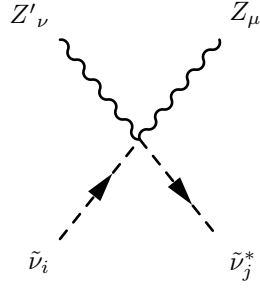
$$i \frac{1}{\sqrt{2}} g_2 \left(2g_p Q_l \cos \Theta'_W - g_1 \sin \Theta_W \sin \Theta'_W \right) \sum_{a=1}^3 Z_{ia}^{V,*} Z_{ja}^E (g_{\mu\nu}) \quad (576)$$



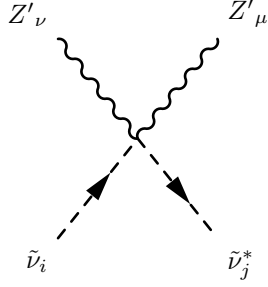
$$\frac{i}{2}g_2^2\delta_{ij}\left(g_{\mu\nu}\right) \quad (577)$$



$$\frac{i}{2}\delta_{ij}\left(2g_pQ_l\sin\Theta'_W+g_1\cos\Theta'_W\sin\Theta_W+g_2\cos\Theta_W\cos\Theta'_W\right)^2\left(g_{\mu\nu}\right) \quad (578)$$

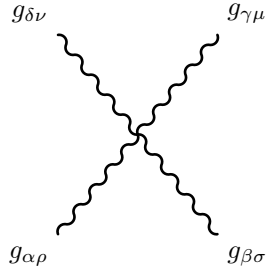


$$\begin{aligned} & -\frac{i}{2}\delta_{ij}\left(-2g_1g_pQ_l\cos\Theta'^2_W\sin\Theta_W+g_2^2\cos\Theta_W^2\cos\Theta'_W\sin\Theta'_W\right. \\ & +\cos\Theta'_W\left(-4g_p^2Q_l^2+g_1^2\sin\Theta_W^2\right)\sin\Theta'_W+2g_1g_pQ_l\sin\Theta_W\sin\Theta'^2_W \\ & \left.+2g_2\cos\Theta_W\left(g_1\cos\Theta'_W\sin\Theta_W\sin\Theta'_W-g_pQ_l\cos\Theta'^2_W+g_pQ_l\sin\Theta'^2_W\right)\right)\left(g_{\mu\nu}\right) \end{aligned} \quad (579)$$



$$\frac{i}{2}\delta_{ij}\left(-2g_p Q_l \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W\right) \sin \Theta'_W\right)^2 (g_{\mu\nu}) \quad (580)$$

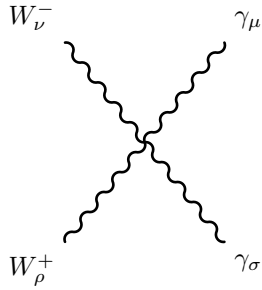
9.9 Four Vector Boson-Interaction



$$-ig_3^2\left(\sum_{a=1}^8 f_{\alpha,\delta,a}f_{\beta,\gamma,a} + \sum_{a=1}^8 f_{\alpha,\gamma,a}f_{\beta,\delta,a}\right)(g_{\rho\sigma}g_{\mu\nu}) \quad (581)$$

$$+ ig_3^2\left(-\sum_{a=1}^8 f_{\alpha,\beta,a}f_{\gamma,\delta,a} + \sum_{a=1}^8 f_{\alpha,\delta,a}f_{\beta,\gamma,a}\right)(g_{\rho\mu}g_{\sigma\nu}) \quad (582)$$

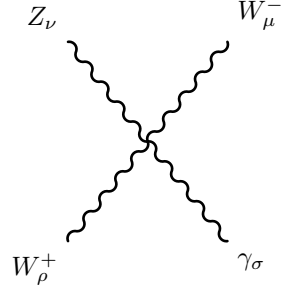
$$+ ig_3^2\left(\sum_{a=1}^8 f_{\alpha,\gamma,a}f_{\beta,\delta,a} + \sum_{a=1}^8 f_{\alpha,\beta,a}f_{\gamma,\delta,a}\right)(g_{\rho\nu}g_{\sigma\mu}) \quad (583)$$



$$ig_2^2 \sin \Theta_W^2 (g_{\rho\sigma} g_{\mu\nu}) \quad (584)$$

$$+ ig_2^2 \sin \Theta_W^2 (g_{\rho\mu} g_{\sigma\nu}) \quad (585)$$

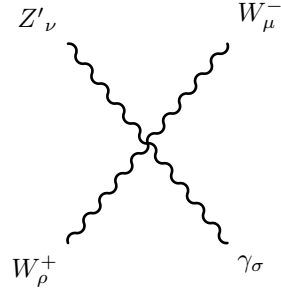
$$+ -2ig_2^2 \sin \Theta_W^2 (g_{\rho\nu} g_{\sigma\mu}) \quad (586)$$



$$ig_2^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W (g_{\rho\sigma} g_{\mu\nu}) \quad (587)$$

$$+ -ig_2^2 \cos \Theta'_W \sin 2\Theta_W (g_{\rho\mu} g_{\sigma\nu}) \quad (588)$$

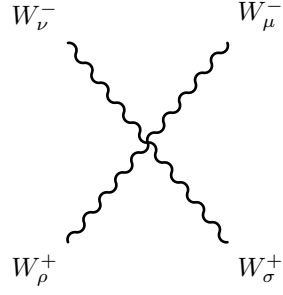
$$+ ig_2^2 \cos \Theta_W \cos \Theta'_W \sin \Theta_W (g_{\rho\nu} g_{\sigma\mu}) \quad (589)$$



$$- ig_2^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W (g_{\rho\sigma} g_{\mu\nu}) \quad (590)$$

$$+ ig_2^2 \sin 2\Theta_W \sin \Theta'_W (g_{\rho\mu} g_{\sigma\nu}) \quad (591)$$

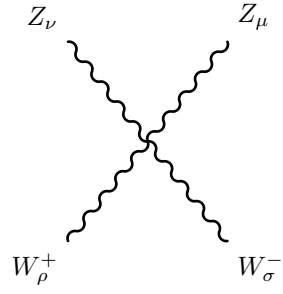
$$+ -ig_2^2 \cos \Theta_W \sin \Theta_W \sin \Theta'_W (g_{\rho\nu} g_{\sigma\mu}) \quad (592)$$



$$2ig_2^2(g_{\rho\sigma}g_{\mu\nu}) \quad (593)$$

$$+ -ig_2^2(g_{\rho\mu}g_{\sigma\nu}) \quad (594)$$

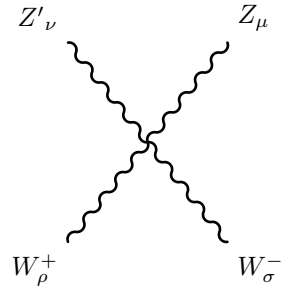
$$+ -ig_2^2(g_{\rho\nu}g_{\sigma\mu}) \quad (595)$$



$$- 2ig_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 (g_{\rho\sigma}g_{\mu\nu}) \quad (596)$$

$$+ ig_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 (g_{\rho\mu}g_{\sigma\nu}) \quad (597)$$

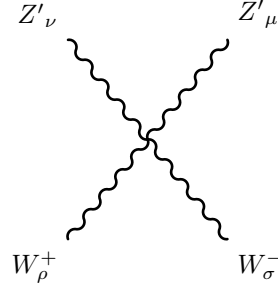
$$+ ig_2^2 \cos \Theta_W^2 \cos \Theta_W'^2 (g_{\rho\nu}g_{\sigma\mu}) \quad (598)$$



$$ig_2^2 \cos \Theta_W^2 \sin 2\Theta'_W \left(g_{\rho\sigma} g_{\mu\nu} \right) \quad (599)$$

$$+ -ig_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \left(g_{\rho\mu} g_{\sigma\nu} \right) \quad (600)$$

$$+ -ig_2^2 \cos \Theta_W^2 \cos \Theta'_W \sin \Theta'_W \left(g_{\rho\nu} g_{\sigma\mu} \right) \quad (601)$$

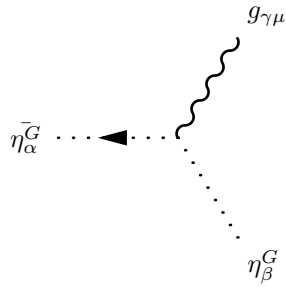


$$- 2ig_2^2 \cos \Theta_W^2 \sin \Theta'^2_W \left(g_{\rho\sigma} g_{\mu\nu} \right) \quad (602)$$

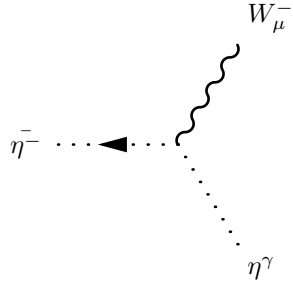
$$+ ig_2^2 \cos \Theta_W^2 \sin \Theta'^2_W \left(g_{\rho\mu} g_{\sigma\nu} \right) \quad (603)$$

$$+ ig_2^2 \cos \Theta_W^2 \sin \Theta'^2_W \left(g_{\rho\nu} g_{\sigma\mu} \right) \quad (604)$$

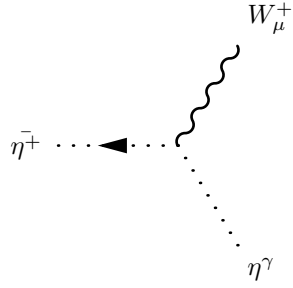
9.10 Two Ghosts-One Vector Boson-Interaction



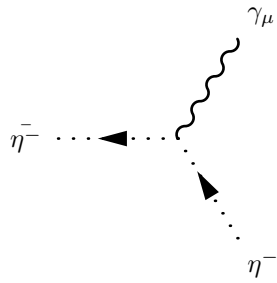
$$g_3 f_{\alpha,\beta,\gamma} \left(p_\mu^{\eta_\beta^G} \right) \quad (605)$$



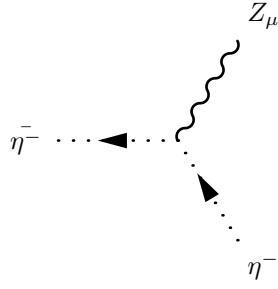
$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^\gamma} \right) \quad (606)$$



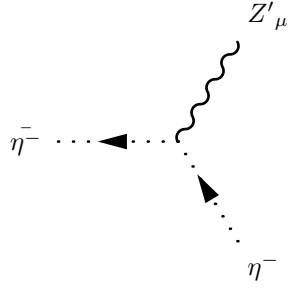
$$- ig_2 \sin \Theta_W \left(p_\mu^{\eta^\gamma} \right) \quad (607)$$



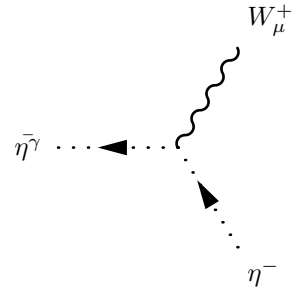
$$- ig_2 \sin \Theta_W \left(p_\mu^{\eta^-} \right) \quad (608)$$



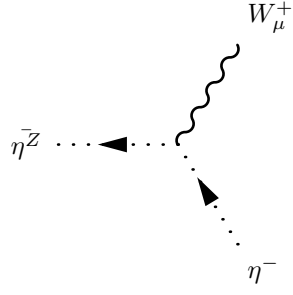
$$-ig_2 \cos \Theta_W \cos \Theta'_W \left(p_\mu^{\eta^-} \right) \quad (609)$$



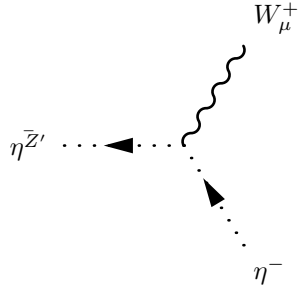
$$ig_2 \cos \Theta_W \sin \Theta'_W \left(p_\mu^{\eta^-} \right) \quad (610)$$



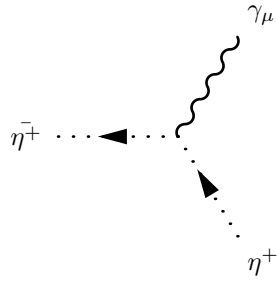
$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^-} \right) \quad (611)$$



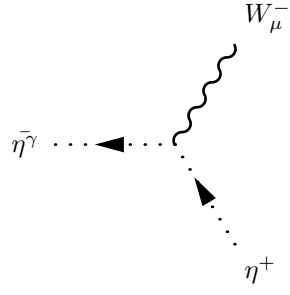
$$ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^-}) \quad (612)$$



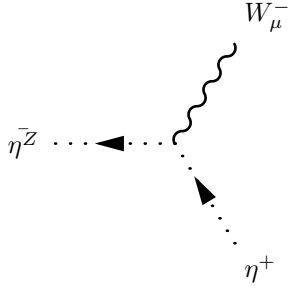
$$-ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^-}) \quad (613)$$



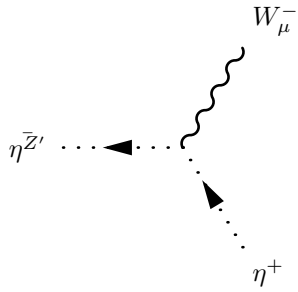
$$ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (614)$$



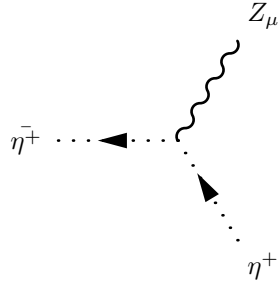
$$-ig_2 \sin \Theta_W (p_\mu^{\eta^+}) \quad (615)$$



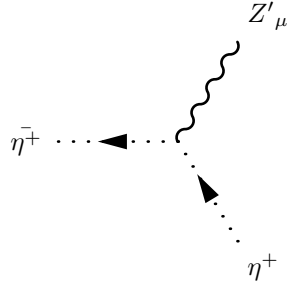
$$-ig_2 \cos \Theta_W \cos \Theta'_W (p_\mu^{\eta^+}) \quad (616)$$



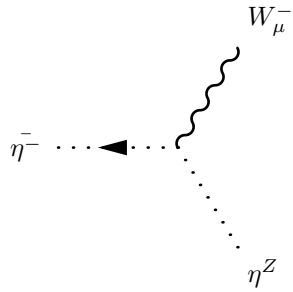
$$ig_2 \cos \Theta_W \sin \Theta'_W (p_\mu^{\eta^+}) \quad (617)$$



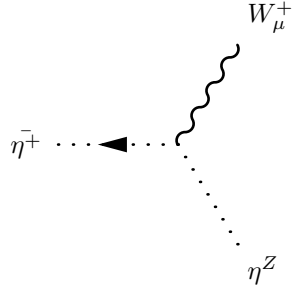
$$ig_2 \cos \Theta_W \cos \Theta'_W \left(p_\mu^{\eta^+} \right) \quad (618)$$



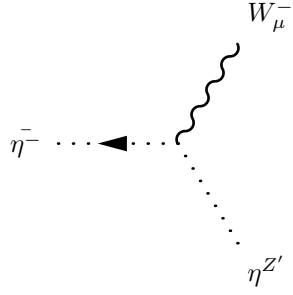
$$-ig_2 \cos \Theta_W \sin \Theta'_W \left(p_\mu^{\eta^+} \right) \quad (619)$$



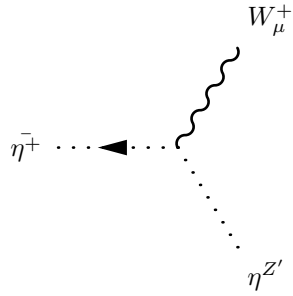
$$ig_2 \cos \Theta_W \cos \Theta'_W \left(p_\mu^{\eta^Z} \right) \quad (620)$$



$$-ig_2 \cos \Theta_W \cos \Theta'_W \left(p_\mu^{\eta^Z} \right) \quad (621)$$

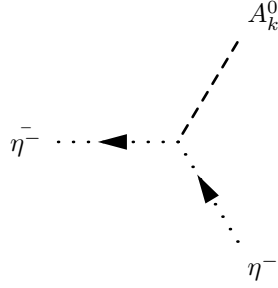


$$-ig_2 \cos \Theta_W \sin \Theta'_W \left(p_\mu^{\eta^{Z'}} \right) \quad (622)$$

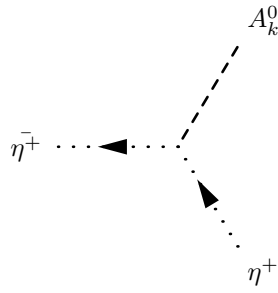


$$ig_2 \cos \Theta_W \sin \Theta'_W \left(p_\mu^{\eta^{Z'}} \right) \quad (623)$$

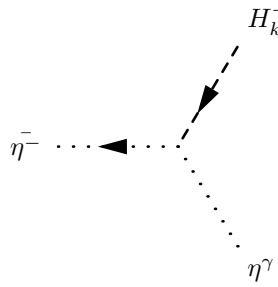
9.11 Two Ghosts-One Scalar-Interaction



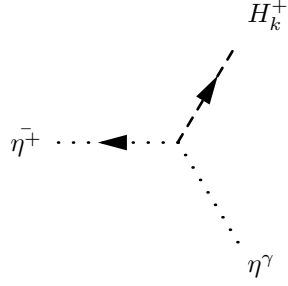
$$\frac{1}{4}g_2^2\left(v_d Z_{k1}^{A,*} - v_u Z_{k2}^{A,*}\right)\xi_{W^-} \quad (624)$$



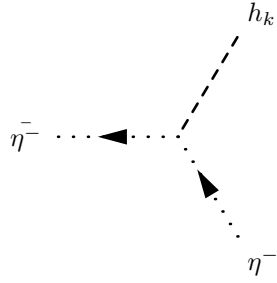
$$\frac{1}{4}g_2^2\left(-v_d Z_{k1}^{A,*} + v_u Z_{k2}^{A,*}\right)\xi_{W^-} \quad (625)$$



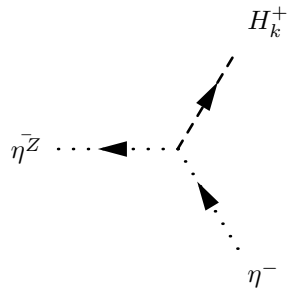
$$\frac{i}{4}g_2\xi_{W^-}\left(g_1\cos\Theta_W + g_2\sin\Theta_W\right)\left(v_d Z_{k1}^+ - v_u Z_{k2}^+\right) \quad (626)$$



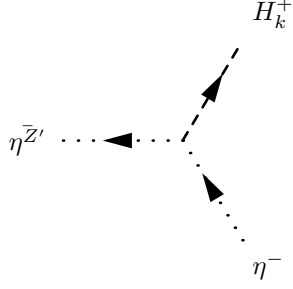
$$\frac{i}{4} g_2 \xi_{W-} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right) \left(v_d Z_{k1}^+ - v_u Z_{k2}^+ \right) \quad (627)$$



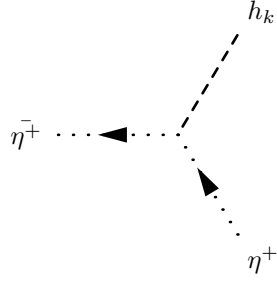
$$-\frac{i}{4} g_2^2 \left(v_d Z_{k1}^{H,*} + v_u Z_{k2}^{H,*} \right) \xi_{W-} \quad (628)$$



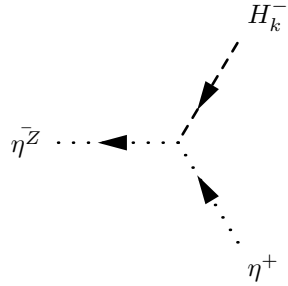
$$\begin{aligned} & -\frac{i}{4} g_2 \xi_Z \left(v_d \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{k1}^+ \right. \\ & \left. - v_u \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{k2}^+ \right) \end{aligned} \quad (629)$$



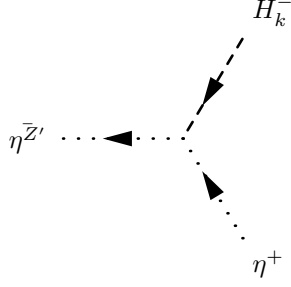
$$\begin{aligned}
& \frac{i}{4} g_2 \xi_{Z'} \left(v_d \left(-2g_p Q_{H_d} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{k1}^+ \right. \\
& \left. - v_u \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{k2}^+ \right)
\end{aligned} \tag{630}$$



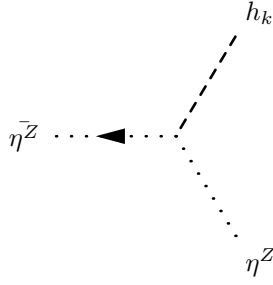
$$-\frac{i}{4} g_2^2 \left(v_d Z_{k1}^{H,*} + v_u Z_{k2}^{H,*} \right) \xi_{W-} \tag{631}$$



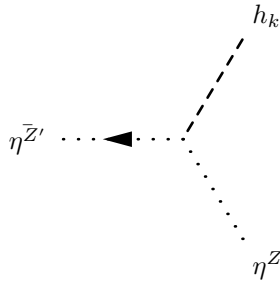
$$\begin{aligned}
& -\frac{i}{4} g_2 \xi_Z \left(v_d \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{k1}^+ \right. \\
& \left. - v_u \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right) Z_{k2}^+ \right)
\end{aligned} \tag{632}$$



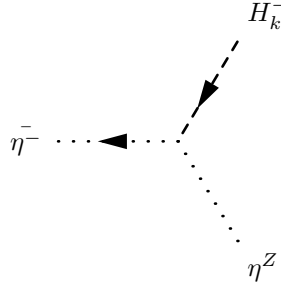
$$\begin{aligned}
& \frac{i}{4} g_2 \xi_{Z'} \left(v_d \left(-2g_p Q_{H_d} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{k1}^+ \right. \\
& \left. - v_u \left(2g_p Q_{H_u} \cos \Theta'_W + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta'_W \right) Z_{k2}^+ \right)
\end{aligned} \tag{633}$$



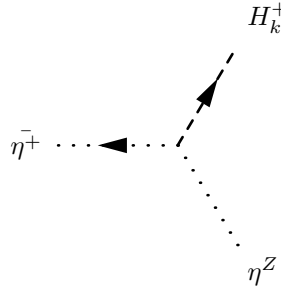
$$\begin{aligned}
& -\frac{i}{4} \xi_Z \left(4g_p^2 \left(Q_1^2 v_1 Z_{k4}^{H,*} + Q_2^2 v_2 Z_{k5}^{H,*} + Q_3^2 v_3 Z_{k6}^{H,*} + Q_s^2 v_s Z_{k3}^{H,*} \right) \sin \Theta'^2_W \right. \\
& + v_d Z_{k1}^{H,*} \left(2g_p Q_{H_d} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \\
& \left. + v_u Z_{k2}^{H,*} \left(-2g_p Q_{H_u} \sin \Theta'_W + g_1 \cos \Theta'_W \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta'_W \right)^2 \right)
\end{aligned} \tag{634}$$



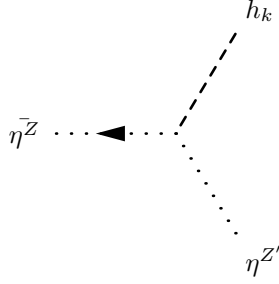
$$\begin{aligned}
& \frac{i}{4} \xi_{Z'} \left(v_d Z_{k1}^{H,*} \left(-2g_1 g_p Q_{H_d} \cos \Theta_W' \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta_W' \sin \Theta_W' \right. \right. \\
& + \cos \Theta_W' \left(-4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta_W' + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta_W'^2 \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta_W' \sin \Theta_W \sin \Theta_W' - g_p Q_{H_d} \cos \Theta_W'^2 + g_p Q_{H_d} \sin \Theta_W'^2 \right) \Big) \\
& + v_u Z_{k2}^{H,*} \left(2g_1 g_p Q_{H_u} \cos \Theta_W' \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta_W' \sin \Theta_W' \right. \\
& + \cos \Theta_W' \left(-4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta_W' - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta_W'^2 \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta_W' \sin \Theta_W \sin \Theta_W' + g_p Q_{H_u} \cos \Theta_W'^2 - g_p Q_{H_u} \sin \Theta_W'^2 \right) \Big) \\
& - 2g_p^2 \left(Q_1^2 v_1 Z_{k4}^{H,*} + Q_2^2 v_2 Z_{k5}^{H,*} + Q_3^2 v_3 Z_{k6}^{H,*} + Q_s^2 v_s Z_{k3}^{H,*} \right) \sin 2\Theta_W' \Big) \quad (635)
\end{aligned}$$



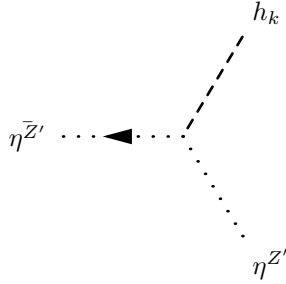
$$\begin{aligned}
& \frac{i}{4} g_2 \xi_{W-} \left(v_d \left(-2g_p Q_{H_d} \sin \Theta_W' - g_1 \cos \Theta_W' \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta_W' \right) Z_{k1}^+ \right. \\
& + v_u \left(-2g_p Q_{H_u} \sin \Theta_W' + g_1 \cos \Theta_W' \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta_W' \right) Z_{k2}^+ \Big) \quad (636)
\end{aligned}$$



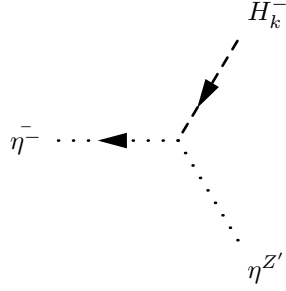
$$\begin{aligned}
& \frac{i}{4} g_2 \xi_{W-} \left(v_d \left(-2g_p Q_{H_d} \sin \Theta_W' - g_1 \cos \Theta_W' \sin \Theta_W + g_2 \cos \Theta_W \cos \Theta_W' \right) Z_{k1}^+ \right. \\
& + v_u \left(-2g_p Q_{H_u} \sin \Theta_W' + g_1 \cos \Theta_W' \sin \Theta_W - g_2 \cos \Theta_W \cos \Theta_W' \right) Z_{k2}^+ \Big) \quad (637)
\end{aligned}$$



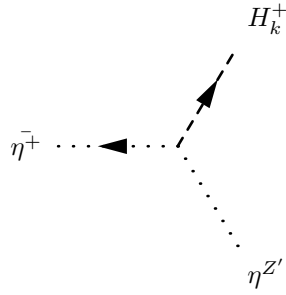
$$\begin{aligned}
& \frac{i}{4} \xi_Z \left(v_d Z_{k1}^{H,*} \left(-2g_1 g_p Q_{H_d} \cos \Theta_W' \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta_W' \sin \Theta_W' \right. \right. \\
& + \cos \Theta_W' \left(-4g_p^2 Q_{H_d}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta_W' + 2g_1 g_p Q_{H_d} \sin \Theta_W \sin \Theta_W' \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta_W' \sin \Theta_W \sin \Theta_W' - g_p Q_{H_d} \cos \Theta_W'^2 + g_p Q_{H_d} \sin \Theta_W'^2 \right) \Big) \\
& + v_u Z_{k2}^{H,*} \left(2g_1 g_p Q_{H_u} \cos \Theta_W' \sin \Theta_W + g_2^2 \cos \Theta_W^2 \cos \Theta_W' \sin \Theta_W' \right. \\
& + \cos \Theta_W' \left(-4g_p^2 Q_{H_u}^2 + g_1^2 \sin \Theta_W^2 \right) \sin \Theta_W' - 2g_1 g_p Q_{H_u} \sin \Theta_W \sin \Theta_W' \\
& + 2g_2 \cos \Theta_W \left(g_1 \cos \Theta_W' \sin \Theta_W \sin \Theta_W' + g_p Q_{H_u} \cos \Theta_W'^2 - g_p Q_{H_u} \sin \Theta_W'^2 \right) \Big) \\
& - 2g_p^2 \left(Q_1^2 v_1 Z_{k4}^{H,*} + Q_2^2 v_2 Z_{k5}^{H,*} + Q_3^2 v_3 Z_{k6}^{H,*} + Q_s^2 v_s Z_{k3}^{H,*} \right) \sin 2\Theta_W' \Big) \quad (638)
\end{aligned}$$



$$\begin{aligned}
& - \frac{i}{4} \xi_{Z'} \left(4g_p^2 \left(Q_1^2 v_1 Z_{k4}^{H,*} + Q_2^2 v_2 Z_{k5}^{H,*} + Q_3^2 v_3 Z_{k6}^{H,*} + Q_s^2 v_s Z_{k3}^{H,*} \right) \cos \Theta_W'^2 \right. \\
& + v_d Z_{k1}^{H,*} \left(-2g_p Q_{H_d} \cos \Theta_W' + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta_W' \right)^2 \\
& + v_u Z_{k2}^{H,*} \left(2g_p Q_{H_u} \cos \Theta_W' + \left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right) \sin \Theta_W' \right)^2 \Big) \quad (639)
\end{aligned}$$



$$\begin{aligned}
& -\frac{i}{4}g_2\xi_{W-}\left(v_d\left(2g_pQ_{H_d}\cos\Theta'_W+\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W\right)Z_{k1}^+\right. \\
& \left.+v_u\left(2g_pQ_{H_u}\cos\Theta'_W+\left(g_1\sin\Theta_W-g_2\cos\Theta_W\right)\sin\Theta'_W\right)Z_{k2}^+\right)
\end{aligned} \tag{640}$$



$$\begin{aligned}
& -\frac{i}{4}g_2\xi_{W-}\left(v_d\left(2g_pQ_{H_d}\cos\Theta'_W+\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sin\Theta'_W\right)Z_{k1}^+\right. \\
& \left.+v_u\left(2g_pQ_{H_u}\cos\Theta'_W+\left(g_1\sin\Theta_W-g_2\cos\Theta_W\right)\sin\Theta'_W\right)Z_{k2}^+\right)
\end{aligned} \tag{641}$$

10 Clebsch-Gordan Coefficients