NHSSM

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

SARAH 4.6.0

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Contents

1 Superfields

1.1 Vector Superfields

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

1.2 Chiral Superfields

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

2 Superpotential and Lagrangian

2.1 Superpotential

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

2.2 Softbreaking terms

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

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

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

2.3 Input Lagrangian for Eigenstates GaugeES

$$L = 0 \tag{5}$$

2.4 Gauge fixing terms

2.4.1 Gauge fixing terms for eigenstates 'GaugeES'

$$L_{GF} = -\frac{1}{2}|\partial_\mu B|^2 \xi_B^{-1} - \frac{1}{2}|\partial_\mu g|^2 \xi_g^{-1} - \frac{1}{2}|\partial_\mu W|^2 \xi_W^{-1} \tag{6}$$

2.4.2 Gauge fixing terms for eigenstates 'EWSB'

$$
\begin{aligned}
L_{GF} = & -\frac{1}{2}|\partial_\mu g|^2 \xi_g^{-1} - \frac{1}{2}|\partial_\mu \gamma|^2 \xi_\gamma^{-1} - |-\frac{i}{2}g_2\Big(H_d^- v_d - v_u H_u^{+,*}\Big)\xi_{W^-} + \partial_\mu W^-|^2 \xi_{W^-}^{-1} \\
& -\frac{1}{2}|\frac{1}{2}\Big(2\partial_\mu Z + \Big(\sigma_d v_d - \sigma_u v_u\Big)\xi_Z\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big)|^2 \xi_Z^{-1}
\end{aligned} \tag{7}
$$

2.5 Fields integrated out

None

3 Renormalization Group Equations

3.1 Anomalous Dimensions

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

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

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

$$\gamma_{\hat{l}}^{(2)} = -2Y_e^\dagger Y_e Y_e^\dagger Y_e + \frac{3}{100}\Big(125g_2^4 + 30g_1^2 g_2^2 + 69g_1^4\Big)\mathbf{1} + Y_e^\dagger Y_e\Big(-3\text{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{6}{5}g_1^2 - \text{Tr}\Big(Y_e Y_e^\dagger\Big)\Big) \tag{11}$$

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

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

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

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

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

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

$$+ Y_d^* Y_d^T \left(- 2\mathrm{Tr}\left(Y_e Y_e^\dagger\right) + 6g_2^2 - 6\mathrm{Tr}\left(Y_d Y_d^\dagger\right) + \frac{2}{5}g_1^2 \right) \tag{17}$$

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

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

$$\gamma_{\hat{e}}^{(1)} = 2Y_e^* Y_e^T - \frac{6}{5}g_1^2 \mathbf{1} \tag{20}$$

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

3.2 Gauge Couplings

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

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

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

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

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

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

3.3 Gaugino Mass Parameters

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

$$\beta_{M_1}^{(2)} = \frac{2}{25}g_1^2 \Big(398g_1^2 M_1 + 135g_2^2 M_1 + 440g_3^2 M_1 + 440g_3^2 M_3 + 135g_2^2 M_2 - 70M_1\mathrm{Tr}\left(Y_d Y_d^\dagger\right) - 90M_1\mathrm{Tr}\left(Y_e Y_e^\dagger\right)$$
$$- 130M_1\mathrm{Tr}\left(Y_u Y_u^\dagger\right) + 70\mathrm{Tr}\left(Y_d^\dagger T_d\right) + 90\mathrm{Tr}\left(Y_e^\dagger T_e\right) + 130\mathrm{Tr}\left(Y_u^\dagger T_u\right) \Big) \tag{29}$$

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

$$\beta_{M_2}^{(2)} = \frac{2}{5}g_2^2 \Big(9g_1^2 M_1 + 120g_3^2 M_3 + 9g_1^2 M_2 + 250g_2^2 M_2 + 120g_3^2 M_2 - 30M_2\mathrm{Tr}\left(Y_d Y_d^\dagger\right) - 10M_2\mathrm{Tr}\left(Y_e Y_e^\dagger\right)$$
$$- 30M_2\mathrm{Tr}\left(Y_u Y_u^\dagger\right) + 30\mathrm{Tr}\left(Y_d^\dagger T_d\right) + 10\mathrm{Tr}\left(Y_e^\dagger T_e\right) + 30\mathrm{Tr}\left(Y_u^\dagger T_u\right) \Big) \tag{31}$$

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

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

$$+ 20\text{Tr}\left(Y_d^\dagger T_d\right) + 20\text{Tr}\left(Y_u^\dagger T_u\right)\Big) \tag{33}$$

3.4 Trilinear Superpotential Parameters

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

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

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

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

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

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

3.5 Bilinear Superpotential Parameters

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

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

$$-450\text{Tr}\left(Y_u Y_u^\dagger Y_u Y_u^\dagger\right)\Big) \tag{41}$$

3.6 Trilinear Soft-Breaking Parameters

$$\beta_{T_d}^{(1)} = +4Y_d Y_d^\dagger T_d + 2Y_d Y_u^\dagger T_u + 5T_d Y_d^\dagger Y_d + T_d Y_u^\dagger Y_u - \frac{7}{15}g_1^2 T_d - 3g_2^2 T_d - \frac{16}{3}g_3^2 T_d$$
$$+ 3T_d \text{Tr}\left(Y_d Y_d^\dagger\right) + T_d \text{Tr}\left(Y_e Y_e^\dagger\right) + Y_d\left(2\text{Tr}\left(Y_e^\dagger T_e\right) + 6g_2^2 M_2 + 6\text{Tr}\left(Y_d^\dagger T_d\right) + \frac{14}{15}g_1^2 M_1 + \frac{32}{3}g_3^2 M_3\right) \tag{42}$$

$$\beta_{T_d}^{(2)} = +\frac{6}{5}g_1^2 Y_d Y_d^\dagger T_d + 6g_2^2 Y_d Y_d^\dagger T_d - \frac{8}{5}g_1^2 M_1 Y_d Y_u^\dagger Y_u + \frac{8}{5}g_1^2 Y_d Y_u^\dagger T_u$$
$$+ \frac{6}{5}g_1^2 T_d Y_d^\dagger Y_d + 12g_2^2 T_d Y_d^\dagger Y_d + \frac{4}{5}g_1^2 T_d Y_u^\dagger Y_u - 6Y_d Y_d^\dagger Y_d Y_d^\dagger T_d$$
$$- 8Y_d Y_d^\dagger T_d Y_d^\dagger Y_d - 2Y_d Y_u^\dagger Y_u Y_d^\dagger T_d - 4Y_d Y_u^\dagger Y_u Y_u^\dagger T_u - 4Y_d Y_u^\dagger T_u Y_d^\dagger Y_d$$
$$- 4Y_d Y_u^\dagger T_u Y_u^\dagger Y_u - 6T_d Y_d^\dagger Y_d Y_d^\dagger Y_d - 4T_d Y_u^\dagger Y_u Y_d^\dagger Y_d - 2T_d Y_u^\dagger Y_u Y_u^\dagger Y_u$$
$$+ \frac{287}{90}g_1^4 T_d + g_1^2 g_2^2 T_d + \frac{15}{2}g_2^4 T_d + \frac{8}{9}g_1^2 g_3^2 T_d + 8g_2^2 g_3^2 T_d - \frac{16}{9}g_3^4 T_d$$
$$- 12Y_d Y_d^\dagger T_d \text{Tr}\left(Y_d Y_d^\dagger\right) - 15T_d Y_d^\dagger Y_d \text{Tr}\left(Y_d Y_d^\dagger\right) - \frac{2}{5}g_1^2 T_d Y_d^\dagger \text{Tr}\left(Y_d Y_d^\dagger\right)$$
$$+ 16g_3^2 T_d \text{Tr}\left(Y_d Y_d^\dagger\right) - 4Y_d Y_d^\dagger T_d \text{Tr}\left(Y_e Y_e^\dagger\right) - 5T_d Y_d^\dagger Y_d \text{Tr}\left(Y_e Y_e^\dagger\right)$$
$$+ \frac{6}{5}g_1^2 T_d \text{Tr}\left(Y_e Y_e^\dagger\right) - 6Y_d Y_u^\dagger T_u \text{Tr}\left(Y_u Y_u^\dagger\right) - 3T_d Y_u^\dagger Y_u \text{Tr}\left(Y_u Y_u^\dagger\right)$$
$$- \frac{2}{5}Y_d Y_d^\dagger Y_d\left(15\text{Tr}\left(Y_e^\dagger T_e\right) + 30g_2^2 M_2 + 45\text{Tr}\left(Y_d^\dagger T_d\right) + 4g_1^2 M_1\right) - 6Y_d Y_u^\dagger Y_u \text{Tr}\left(Y_u^\dagger T_u\right)$$
$$- 9T_d \text{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right) - 3T_d \text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 3T_d \text{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right)$$
$$- \frac{2}{45}Y_d\Big(287g_1^4 M_1 + 45g_1^2 g_2^2 M_1 + 40g_1^2 g_3^2 M_1 + 40g_1^2 g_3^2 M_3 + 360g_2^2 g_3^2 M_3 - 160g_3^4 M_3$$
$$+ 45g_1^2 g_2^2 M_2 + 675g_2^4 M_2 + 360g_2^2 g_3^2 M_2 - 18\left(-40g_3^2 M_3 + g_1^2 M_1\right)\text{Tr}\left(Y_d Y_d^\dagger\right)$$
$$+ 54g_1^2 M_1 \text{Tr}\left(Y_e Y_e^\dagger\right) + 18g_1^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 720g_3^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 54g_1^2 \text{Tr}\left(Y_e^\dagger T_e\right)$$
$$+ 810\text{Tr}\left(Y_d Y_d^\dagger T_d Y_d^\dagger\right) + 135\text{Tr}\left(Y_d Y_u^\dagger T_u Y_d^\dagger\right) + 270\text{Tr}\left(Y_e Y_e^\dagger T_e Y_e^\dagger\right) + 135\text{Tr}\left(Y_u Y_d^\dagger T_d Y_u^\dagger\right)\Big) \tag{43}$$

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

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

$$+ 16g_3^2 T_e \mathrm{Tr}\left(Y_d Y_d^\dagger\right) - 4Y_e Y_e^\dagger T_e \mathrm{Tr}\left(Y_e Y_e^\dagger\right) - 5T_e Y_e^\dagger Y_e \mathrm{Tr}\left(Y_e Y_e^\dagger\right)$$

$$+ \frac{6}{5}g_1^2 T_e \mathrm{Tr}\left(Y_e Y_e^\dagger\right) - 6Y_e Y_e^\dagger Y_e \left(2g_2^2 M_2 + 3\mathrm{Tr}\left(Y_d^\dagger T_d\right) + \mathrm{Tr}\left(Y_e^\dagger T_e\right)\right) - 9T_e \mathrm{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right)$$

$$- 3T_e \mathrm{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 3T_e \mathrm{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right)$$

$$- \frac{2}{5}Y_e \Big(135g_1^4 M_1 + 9g_1^2 g_2^2 M_1 + 9g_1^2 g_2^2 M_2 + 75g_2^4 M_2 + \left(-2g_1^2 M_1 + 80g_3^2 M_3\right)\mathrm{Tr}\left(Y_d Y_d^\dagger\right)$$

$$+ 6g_1^2 M_1 \mathrm{Tr}\left(Y_e Y_e^\dagger\right) + 2g_1^2 \mathrm{Tr}\left(Y_d^\dagger T_d\right) - 80g_3^2 \mathrm{Tr}\left(Y_d^\dagger T_d\right) - 6g_1^2 \mathrm{Tr}\left(Y_e^\dagger T_e\right)$$

$$+ 90\mathrm{Tr}\left(Y_d Y_d^\dagger T_d Y_d^\dagger\right) + 15\mathrm{Tr}\left(Y_d Y_u^\dagger T_u Y_d^\dagger\right) + 30\mathrm{Tr}\left(Y_e Y_e^\dagger T_e Y_e^\dagger\right) + 15\mathrm{Tr}\left(Y_u Y_d^\dagger T_d Y_u^\dagger\right)\Big) \tag{45}$$

$$\beta_{T_u}^{(1)} = +2Y_u Y_d^\dagger T_d + 4Y_u Y_u^\dagger T_u + T_u Y_d^\dagger Y_d + 5T_u Y_u^\dagger Y_u - \frac{13}{15}g_1^2 T_u - 3g_2^2 T_u - \frac{16}{3}g_3^2 T_u$$

$$+ 3T_u \mathrm{Tr}\left(Y_u Y_u^\dagger\right) + Y_u \left(6g_2^2 M_2 + 6\mathrm{Tr}\left(Y_u^\dagger T_u\right) + \frac{26}{15}g_1^2 M_1 + \frac{32}{3}g_3^2 M_3\right) \tag{46}$$

$$\beta_{T_u}^{(2)} = +\frac{4}{5}g_1^2 Y_u Y_d^\dagger T_d - \frac{4}{5}g_1^2 M_1 Y_u Y_u^\dagger Y_u - 12g_2^2 M_2 Y_u Y_u^\dagger Y_u + \frac{6}{5}g_1^2 Y_u Y_u^\dagger T_u$$

$$+ 6g_2^2 Y_u Y_u^\dagger T_u + \frac{2}{5}g_1^2 T_u Y_d^\dagger Y_d + 12g_2^2 T_u Y_u^\dagger Y_u - 4Y_u Y_d^\dagger Y_d Y_d^\dagger T_d$$

$$- 2Y_u Y_d^\dagger Y_d Y_u^\dagger T_u - 4Y_u Y_d^\dagger T_d Y_d^\dagger Y_d - 4Y_u Y_d^\dagger T_d Y_u^\dagger Y_u - 6Y_u Y_u^\dagger Y_u Y_u^\dagger T_u$$

$$- 8Y_u Y_u^\dagger T_u Y_u^\dagger Y_u - 2T_u Y_d^\dagger Y_d Y_d^\dagger Y_d - 4T_u Y_d^\dagger Y_d Y_u^\dagger Y_u - 6T_u Y_u^\dagger Y_u Y_u^\dagger Y_u + \frac{2743}{450}g_1^4 T_u$$

$$+ g_1^2 g_2^2 T_u + \frac{15}{2}g_2^4 T_u + \frac{136}{45}g_1^2 g_3^2 T_u + 8g_2^2 g_3^2 T_u - \frac{16}{9}g_3^4 T_u - 6Y_u Y_d^\dagger T_d \mathrm{Tr}\left(Y_d Y_d^\dagger\right)$$

$$- 3T_u Y_d^\dagger Y_d \mathrm{Tr}\left(Y_d Y_d^\dagger\right) - 2Y_u Y_d^\dagger T_d \mathrm{Tr}\left(Y_e Y_e^\dagger\right) - T_u Y_d^\dagger Y_d \mathrm{Tr}\left(Y_e Y_e^\dagger\right)$$

$$- 12Y_u Y_u^\dagger T_u \mathrm{Tr}\left(Y_u Y_u^\dagger\right) - 15T_u Y_u^\dagger Y_u \mathrm{Tr}\left(Y_u Y_u^\dagger\right) + \frac{4}{5}g_1^2 T_u \mathrm{Tr}\left(Y_u Y_u^\dagger\right)$$

$$+ 16g_3^2 T_u \mathrm{Tr}\left(Y_u Y_u^\dagger\right) - \frac{2}{5}Y_u Y_d^\dagger Y_d \left(15\mathrm{Tr}\left(Y_d^\dagger T_d\right) + 2g_1^2 M_1 + 5\mathrm{Tr}\left(Y_e^\dagger T_e\right)\right)$$

$$- 18Y_u Y_u^\dagger Y_u \mathrm{Tr}\left(Y_u^\dagger T_u\right) - 3T_u \mathrm{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 9T_u \mathrm{Tr}\left(Y_u Y_u^\dagger Y_u Y_u^\dagger\right)$$

$$- \frac{2}{225}Y_u \Big(2743g_1^4 M_1 + 225g_1^2 g_2^2 M_1 + 680g_1^2 g_3^2 M_1 + 680g_1^2 g_3^2 M_3 + 1800g_2^2 g_3^2 M_3 - 800g_3^4 M_3$$

$$+ 225g_1^2 g_2^2 M_2 + 3375g_2^4 M_2 + 1800g_2^2 g_3^2 M_2 + 180\left(20g_3^2 M_3 + g_1^2 M_1\right)\mathrm{Tr}\left(Y_u Y_u^\dagger\right)$$

$$- 180\left(20g_3^2 + g_1^2\right)\mathrm{Tr}\left(Y_u^\dagger T_u\right) + 675\mathrm{Tr}\left(Y_d Y_u^\dagger T_u Y_d^\dagger\right) + 675\mathrm{Tr}\left(Y_u Y_d^\dagger T_d Y_u^\dagger\right)$$

$$+ 4050\mathrm{Tr}\left(Y_u Y_u^\dagger T_u Y_u^\dagger\right)\Big) \tag{47}$$

3.7 Bilinear Soft-Breaking Parameters

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

$$+ 6\mu \text{Tr}\left(Y_d^\dagger T_d\right) + 2\mu \text{Tr}\left(Y_e^\dagger T_e\right) + 6\mu \text{Tr}\left(Y_u^\dagger T_u\right) \tag{48}$$

$$\beta_{B_\mu}^{(2)} = +B_\mu \Big(\frac{207}{50} g_1^4 + \frac{9}{5} g_1^2 g_2^2 + \frac{15}{2} g_2^4 - \frac{2}{5}\left(-40 g_3^2 + g_1^2\right) \text{Tr}\left(Y_d Y_d^\dagger\right) + \frac{6}{5} g_1^2 \text{Tr}\left(Y_e Y_e^\dagger\right) + \frac{4}{5} g_1^2 \text{Tr}\left(Y_u Y_u^\dagger\right)$$
$$+ 16 g_3^2 \text{Tr}\left(Y_u Y_u^\dagger\right) - 9\text{Tr}\left(Y_d Y_d^\dagger Y_d Y_d^\dagger\right) - 6\text{Tr}\left(Y_d Y_u^\dagger Y_u Y_d^\dagger\right) - 3\text{Tr}\left(Y_e Y_e^\dagger Y_e Y_e^\dagger\right) - 9\text{Tr}\left(Y_u Y_u^\dagger Y_u Y_u^\dagger\right) \Big)$$
$$- \frac{2}{25} \mu \Big(207 g_1^4 M_1 + 45 g_1^2 g_2^2 M_1 + 45 g_1^2 g_2^2 M_2 + 375 g_2^4 M_2 - 10\left(-40 g_3^2 M_3 + g_1^2 M_1\right) \text{Tr}\left(Y_d Y_d^\dagger\right)$$
$$+ 30 g_1^2 M_1 \text{Tr}\left(Y_e Y_e^\dagger\right) + 20 g_1^2 M_1 \text{Tr}\left(Y_u Y_u^\dagger\right) + 400 g_3^2 M_3 \text{Tr}\left(Y_u Y_u^\dagger\right) + 10 g_1^2 \text{Tr}\left(Y_d^\dagger T_d\right)$$
$$- 400 g_3^2 \text{Tr}\left(Y_d^\dagger T_d\right) - 30 g_1^2 \text{Tr}\left(Y_e^\dagger T_e\right) - 20 g_1^2 \text{Tr}\left(Y_u^\dagger T_u\right) - 400 g_3^2 \text{Tr}\left(Y_u^\dagger T_u\right)$$
$$+ 450 \text{Tr}\left(Y_d Y_d^\dagger T_d Y_d^\dagger\right) + 150 \text{Tr}\left(Y_d Y_u^\dagger T_u Y_d^\dagger\right) + 150 \text{Tr}\left(Y_e Y_e^\dagger T_e Y_e^\dagger\right) + 150 \text{Tr}\left(Y_u Y_d^\dagger T_d Y_u^\dagger\right)$$
$$+ 450 \text{Tr}\left(Y_u Y_u^\dagger T_u Y_u^\dagger\right) \Big) \tag{49}$$

3.8 Soft-Breaking Scalar Masses

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

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

$$\sigma_{3,1} = \frac{1}{20} \frac{1}{\sqrt{15}} g_1 \Big(-9 g_1^2 m_{H_d}^2 - 45 g_2^2 m_{H_d}^2 + 9 g_1^2 m_{H_u}^2 + 45 g_2^2 m_{H_u}^2 + 4\left(20 g_3^2 + g_1^2\right) \text{Tr}\left(m_d^2\right) + 36 g_1^2 \text{Tr}\left(m_e^2\right)$$
$$- 9 g_1^2 \text{Tr}\left(m_l^2\right) - 45 g_2^2 \text{Tr}\left(m_l^2\right) + g_1^2 \text{Tr}\left(m_q^2\right) + 45 g_2^2 \text{Tr}\left(m_q^2\right) + 80 g_3^2 \text{Tr}\left(m_q^2\right) - 32 g_1^2 \text{Tr}\left(m_u^2\right)$$
$$- 160 g_3^2 \text{Tr}\left(m_u^2\right) + 90 m_{H_d}^2 \text{Tr}\left(Y_d Y_d^\dagger\right) + 30 m_{H_d}^2 \text{Tr}\left(Y_e Y_e^\dagger\right) - 90 m_{H_u}^2 \text{Tr}\left(Y_u Y_u^\dagger\right) - 60\text{Tr}\left(Y_d Y_d^\dagger m_d^{2*}\right)$$
$$- 30\text{Tr}\left(Y_d m_q^{2*} Y_d^\dagger\right) - 60\text{Tr}\left(Y_e Y_e^\dagger m_e^{2*}\right) + 30\text{Tr}\left(Y_e m_l^{2*} Y_e^\dagger\right) + 120\text{Tr}\left(Y_u Y_u^\dagger m_u^{2*}\right)$$
$$- 30\text{Tr}\left(Y_u m_q^{2*} Y_u^\dagger\right) \Big) \tag{52}$$

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

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

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

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

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$$+ \frac{16}{45}g_3^2\Big(15\Big(3g_2^2\Big(2M_3 + M_2\Big) - 8g_3^2 M_3\Big) + g_1^2\Big(2M_3 + M_1\Big)\Big)\mathbf{1}M_3^* + \frac{1}{5}g_1^2 g_2^2 M_1 \mathbf{1}M_2^* + 16g_2^2 g_3^2 M_3 \mathbf{1}M_2^*$$

$$+ \frac{4}{5}g_1^2 m_{H_d}^2 Y_d^\dagger Y_d + \frac{8}{5}g_1^2 m_{H_u}^2 Y_u^\dagger Y_u$$

$$+ \frac{1}{225}g_1^2 M_1^*\Big(\Big(5\Big(16g_3^2\Big(2M_1 + M_3\Big) + 9g_2^2\Big(2M_1 + M_2\Big)\Big) + 597g_1^2 M_1\Big)\mathbf{1}$$

$$+ 180\Big(2M_1 Y_d^\dagger Y_d - 2Y_u^\dagger T_u + 4M_1 Y_u^\dagger Y_u - Y_d^\dagger T_d\Big)\Big)$$

$$- \frac{4}{5}g_1^2 M_1 T_d^\dagger Y_d + \frac{4}{5}g_1^2 T_d^\dagger T_d - \frac{8}{5}g_1^2 M_1 T_u^\dagger Y_u + \frac{8}{5}g_1^2 T_u^\dagger T_u$$

$$+ \frac{2}{5}g_1^2 m_q^2 Y_d^\dagger Y_d + \frac{4}{5}g_1^2 m_q^2 Y_u^\dagger Y_u + \frac{4}{5}g_1^2 Y_d^\dagger m_d^2 Y_d + \frac{2}{5}g_1^2 Y_d^\dagger Y_d m_q^2$$

$$+ \frac{8}{5}g_1^2 Y_u^\dagger m_u^2 Y_u + \frac{4}{5}g_1^2 Y_u^\dagger Y_u m_q^2 - 8m_{H_d}^2 Y_d^\dagger Y_d Y_d^\dagger Y_d - 4Y_d^\dagger Y_d T_d^\dagger T_d$$

$$- 4Y_d^\dagger T_d T_d^\dagger Y_d - 8m_{H_u}^2 Y_u^\dagger Y_u Y_u^\dagger Y_u - 4Y_u^\dagger Y_u T_u^\dagger T_u - 4Y_u^\dagger T_u T_u^\dagger Y_u$$

$$- 4T_d^\dagger Y_d Y_d^\dagger T_d - 4T_d^\dagger T_d Y_d^\dagger Y_d - 4T_u^\dagger Y_u Y_u^\dagger T_u - 4T_u^\dagger T_u Y_u^\dagger Y_u$$

$$- 2m_q^2 Y_d^\dagger Y_d Y_d^\dagger Y_d - 2m_q^2 Y_u^\dagger Y_u Y_u^\dagger Y_u - 4Y_d^\dagger m_d^2 Y_d Y_d^\dagger Y_d - 4Y_d^\dagger Y_d m_q^2 Y_d^\dagger Y_d$$

$$- 4Y_d^\dagger Y_d Y_d^\dagger m_d^2 Y_d - 2Y_d^\dagger Y_d Y_d^\dagger Y_d m_q^2 - 4Y_u^\dagger m_u^2 Y_u Y_u^\dagger Y_u - 4Y_u^\dagger Y_u m_q^2 Y_u^\dagger Y_u$$

$$- 4Y_u^\dagger Y_u Y_u^\dagger m_u^2 Y_u - 2Y_u^\dagger Y_u Y_u^\dagger Y_u m_q^2 + 6g_2^4 \mathbf{1}\sigma_{2,2} + \frac{32}{3}g_3^4 \mathbf{1}\sigma_{2,3} + \frac{2}{15}g_1^2 \mathbf{1}\sigma_{2,11} + 4\frac{1}{\sqrt{15}}g_1 \mathbf{1}\sigma_{3,1}$$

$$- 12m_{H_d}^2 Y_d^\dagger Y_d \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 6T_d^\dagger T_d \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 3m_q^2 Y_d^\dagger Y_d \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big)$$

$$- 6Y_d^\dagger m_d^2 Y_d \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 3Y_d^\dagger Y_d m_q^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 4m_{H_d}^2 Y_d^\dagger Y_d \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)$$

$$- 2T_d^\dagger T_d \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - m_q^2 Y_d^\dagger Y_d \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 2Y_d^\dagger m_d^2 Y_d \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)$$

$$- Y_d^\dagger Y_d m_q^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) - 12m_{H_u}^2 Y_u^\dagger Y_u \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 6T_u^\dagger T_u \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)$$

$$- 3m_q^2 Y_u^\dagger Y_u \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 6Y_u^\dagger m_u^2 Y_u \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - 3Y_u^\dagger Y_u m_q^2 \mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)$$

$$- 6T_d^\dagger Y_d \mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 2T_d^\dagger Y_d \mathrm{Tr}\Big(Y_e^\dagger T_e\Big) - 6T_u^\dagger Y_u \mathrm{Tr}\Big(Y_u^\dagger T_u\Big)$$

$$- 6Y_d^\dagger T_d \mathrm{Tr}\Big(T_d^* Y_d^T\Big) - 6Y_d^\dagger Y_d \mathrm{Tr}\Big(T_d^* T_d^T\Big) - 2Y_d^\dagger T_d \mathrm{Tr}\Big(T_e^* Y_e^T\Big)$$

$$- 2Y_d^\dagger Y_d \mathrm{Tr}\Big(T_e^* T_e^T\Big) - 6Y_u^\dagger T_u \mathrm{Tr}\Big(T_u^* Y_u^T\Big) - 6Y_u^\dagger Y_u \mathrm{Tr}\Big(T_u^* T_u^T\Big)$$

$$- 6Y_d^\dagger Y_d \mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger\Big) - 2Y_d^\dagger Y_d \mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger\Big) - 2Y_d^\dagger Y_d \mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e\Big)$$

$$- 6Y_d^\dagger Y_d \mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d\Big) - 6Y_u^\dagger Y_u \mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) - 6Y_u^\dagger Y_u \mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big) \tag{56}$$

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

$$+ Y_e^\dagger Y_e m_l^2 - \sqrt{\frac{3}{5}}g_1 \mathbf{1}\sigma_{1,1} \tag{57}$$

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

$$
+ \frac{3}{25}g_1^2 M_1^* \Big(-20 Y_e^\dagger T_e + 3\big(5g_2^2 \big(2M_1 + M_2 \big) + 69 g_1^2 M_1 \big) \mathbf{1} + 40 M_1 Y_e^\dagger Y_e \Big) - \frac{12}{5} g_1^2 M_1 T_e^\dagger Y_e
$$

$$
+ \frac{12}{5} g_1^2 T_e^\dagger T_e + \frac{6}{5} g_1^2 m_l^2 Y_e^\dagger Y_e + \frac{12}{5} g_1^2 Y_e^\dagger m_e^2 Y_e + \frac{6}{5} g_1^2 Y_e^\dagger Y_e m_l^2
$$

$$
- 8 m_{H_d}^2 Y_e^\dagger Y_e Y_e^\dagger Y_e - 4 Y_e^\dagger Y_e T_e^\dagger T_e - 4 Y_e^\dagger T_e T_e^\dagger Y_e - 4 T_e^\dagger Y_e Y_e^\dagger T_e
$$

$$
- 4 T_e^\dagger T_e Y_e^\dagger Y_e - 2 m_l^2 Y_e^\dagger Y_e Y_e^\dagger Y_e - 4 Y_e^\dagger m_e^2 Y_e Y_e^\dagger Y_e - 4 Y_e^\dagger Y_e m_l^2 Y_e^\dagger Y_e
$$

$$
- 4 Y_e^\dagger Y_e Y_e^\dagger m_e^2 Y_e - 2 Y_e^\dagger Y_e Y_e^\dagger Y_e m_l^2 + 6 g_2^4 \mathbf{1}\sigma_{2,2} + \frac{6}{5} g_1^2 \mathbf{1}\sigma_{2,11} - 4\sqrt{\frac{3}{5}} g_1 \mathbf{1}\sigma_{3,1}
$$

$$
- 12 m_{H_d}^2 Y_e^\dagger Y_e \mathrm{Tr}\Big(Y_d Y_d^\dagger \Big) - 6 T_e^\dagger T_e \mathrm{Tr}\Big(Y_d Y_d^\dagger \Big) - 3 m_l^2 Y_e^\dagger Y_e \mathrm{Tr}\Big(Y_d Y_d^\dagger \Big)
$$

$$
- 6 Y_e^\dagger m_e^2 Y_e \mathrm{Tr}\Big(Y_d Y_d^\dagger \Big) - 3 Y_e^\dagger Y_e m_l^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger \Big) - 4 m_{H_d}^2 Y_e^\dagger Y_e \mathrm{Tr}\Big(Y_e Y_e^\dagger \Big)
$$

$$
- 2 T_e^\dagger T_e \mathrm{Tr}\Big(Y_e Y_e^\dagger \Big) - m_l^2 Y_e^\dagger Y_e \mathrm{Tr}\Big(Y_e Y_e^\dagger \Big) - 2 Y_e^\dagger m_e^2 Y_e \mathrm{Tr}\Big(Y_e Y_e^\dagger \Big)
$$

$$
- Y_e^\dagger Y_e m_l^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger \Big) - 6 T_e^\dagger Y_e \mathrm{Tr}\Big(Y_d^\dagger T_d \Big) - 2 T_e^\dagger Y_e \mathrm{Tr}\Big(Y_e^\dagger T_e \Big)
$$

$$
- 6 Y_e^\dagger T_e \mathrm{Tr}\Big(T_d^* Y_d^T \Big) - 6 Y_e^\dagger Y_e \mathrm{Tr}\Big(T_d^* T_d^T \Big) - 2 Y_e^\dagger T_e \mathrm{Tr}\Big(T_e^* Y_e^T \Big)
$$

$$
- 2 Y_e^\dagger Y_e \mathrm{Tr}\Big(T_e^* T_e^T \Big) - 6 Y_e^\dagger Y_e \mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger \Big) - 2 Y_e^\dagger Y_e \mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger \Big)
$$

$$
- 2 Y_e^\dagger Y_e \mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e \Big) - 6 Y_e^\dagger Y_e \mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d \Big) \tag{58}
$$

$$
\beta_{m_{H_d}^2}^{(1)} = -\frac{6}{5} g_1^2 |M_1|^2 - 6 g_2^2 |M_2|^2 - \sqrt{\frac{3}{5}} g_1 \sigma_{1,1} + 6 m_{H_d}^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger \Big) + 2 m_{H_d}^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger \Big) + 6 \mathrm{Tr}\Big(T_d^* T_d^T \Big)
$$

$$
+ 2 \mathrm{Tr}\Big(T_e^* T_e^T \Big) + 6 \mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger \Big) + 2 \mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger \Big) + 2 \mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e \Big) + 6 \mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d \Big) \tag{59}
$$

$$
\beta_{m_{H_d}^2}^{(2)} = \frac{1}{25} \Big(15 g_2^2 \big(3 g_1^2 \big(2M_2 + M_1 \big) + 55 g_2^2 M_2 \big) M_2^*
$$

$$
+ g_1^2 M_1^* \Big(621 g_1^2 M_1 + 90 g_2^2 M_1 + 45 g_2^2 M_2 - 40 M_1 \mathrm{Tr}\Big(Y_d Y_d^\dagger \Big) + 120 M_1 \mathrm{Tr}\Big(Y_e Y_e^\dagger \Big) + 20 \mathrm{Tr}\Big(Y_d^\dagger T_d \Big)
$$

$$
- 60 \mathrm{Tr}\Big(Y_e^\dagger T_e \Big) \Big)
$$

$$
+ 10 \Big(15 g_2^4 \sigma_{2,2} + 3 g_1^2 \sigma_{2,11} - 2\sqrt{15} g_1 \sigma_{3,1} + \Big(160 g_3^2 |M_3|^2 - 2 g_1^2 m_{H_d}^2 + 80 g_3^2 m_{H_d}^2 \Big) \mathrm{Tr}\Big(Y_d Y_d^\dagger \Big)
$$

$$
+ 6 g_1^2 m_{H_d}^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger \Big) - 80 g_3^2 M_3^* \mathrm{Tr}\Big(Y_d^\dagger T_d \Big) + 2 g_1^2 M_1 \mathrm{Tr}\Big(T_d^* Y_d^T \Big) - 80 g_3^2 M_3 \mathrm{Tr}\Big(T_d^* Y_d^T \Big)
$$

$$
- 2 g_1^2 \mathrm{Tr}\Big(T_d^* T_d^T \Big) + 80 g_3^2 \mathrm{Tr}\Big(T_d^* T_d^T \Big) - 6 g_1^2 M_1 \mathrm{Tr}\Big(T_e^* Y_e^T \Big) + 6 g_1^2 \mathrm{Tr}\Big(T_e^* T_e^T \Big)
$$

$$
- 2 g_1^2 \mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger \Big) + 80 g_3^2 \mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger \Big) + 6 g_1^2 \mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger \Big) + 6 g_1^2 \mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e \Big)
$$

$$
- 2 g_1^2 \mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d \Big) + 80 g_3^2 \mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d \Big) - 90 m_{H_d}^2 \mathrm{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger \Big) - 90 \mathrm{Tr}\Big(Y_d Y_d^\dagger T_d T_d^\dagger \Big)
$$

$$
- 15 m_{H_d}^2 \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger \Big) - 15 m_{H_u}^2 \mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger \Big) - 15 \mathrm{Tr}\Big(Y_d Y_u^\dagger T_u T_d^\dagger \Big)
$$

$$
- 90 \mathrm{Tr}\Big(Y_d T_d^\dagger T_d Y_d^\dagger \Big) - 15 \mathrm{Tr}\Big(Y_d T_u^\dagger T_u Y_d^\dagger \Big) - 30 m_{H_d}^2 \mathrm{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger \Big) - 30 \mathrm{Tr}\Big(Y_e Y_e^\dagger T_e T_e^\dagger \Big)
$$

$$-30\mathrm{Tr}\Big(Y_e T_e^\dagger T_e Y_e^\dagger\Big) - 15\mathrm{Tr}\Big(Y_u Y_d^\dagger T_d T_u^\dagger\Big) - 15\mathrm{Tr}\Big(Y_u T_d^\dagger T_d Y_u^\dagger\Big) - 90\mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger Y_d Y_d^\dagger\Big)$$

$$-15\mathrm{Tr}\Big(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 30\mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - 30\mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e Y_e^\dagger Y_e\Big) - 90\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d Y_d^\dagger Y_d\Big)$$

$$-15\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\Big) - 15\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\Big) - 15\mathrm{Tr}\Big(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\Big)\Big)\Big) \tag{60}$$

$$\beta_{m_{H_u}^2}^{(1)} = -\frac{6}{5}g_1^2|M_1|^2 - 6g_2^2|M_2|^2 + \sqrt{\frac{3}{5}}g_1\sigma_{1,1} + 6m_{H_u}^2\,\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 6\mathrm{Tr}\Big(T_u^* T_u^T\Big) + 6\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big)$$

$$+ 6\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big) \tag{61}$$

$$\beta_{m_{H_u}^2}^{(2)} = +\frac{3}{5}g_2^2\Big(3g_1^2\big(2M_2 + M_1\big) + 55g_2^2 M_2\Big)M_2^* + 6g_2^4\sigma_{2,2} + \frac{6}{5}g_1^2\sigma_{2,11} + 4\sqrt{\frac{3}{5}}g_1\sigma_{3,1} + \frac{8}{5}g_1^2 m_{H_u}^2\,\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)$$

$$+ 32g_3^2 m_{H_u}^2\,\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 64g_3^2|M_3|^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big)$$

$$+ \frac{1}{25}g_1^2 M_1^*\Big(-40\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) + 45g_2^2 M_2 + 621g_1^2 M_1 + 80M_1\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 90g_2^2 M_1\Big)$$

$$- 32g_3^2 M_3^*\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - \frac{8}{5}g_1^2 M_1\mathrm{Tr}\Big(T_u^* Y_u^T\Big) - 32g_3^2 M_3\mathrm{Tr}\Big(T_u^* Y_u^T\Big) + \frac{8}{5}g_1^2\mathrm{Tr}\Big(T_u^* T_u^T\Big)$$

$$+ 32g_3^2\mathrm{Tr}\Big(T_u^* T_u^T\Big) + \frac{8}{5}g_1^2\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) + 32g_3^2\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) + \frac{8}{5}g_1^2\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big)$$

$$+ 32g_3^2\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big) - 6m_{H_d}^2\,\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 6m_{H_u}^2\,\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big)$$

$$- 6\mathrm{Tr}\Big(Y_d Y_u^\dagger T_u T_d^\dagger\Big) - 6\mathrm{Tr}\Big(Y_d T_u^\dagger T_u Y_d^\dagger\Big) - 6\mathrm{Tr}\Big(Y_u Y_d^\dagger T_d T_u^\dagger\Big) - 36m_{H_u}^2\,\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)$$

$$- 36\mathrm{Tr}\Big(Y_u Y_u^\dagger T_u T_u^\dagger\Big) - 6\mathrm{Tr}\Big(Y_u T_d^\dagger T_d Y_u^\dagger\Big) - 36\mathrm{Tr}\Big(Y_u T_u^\dagger T_u Y_u^\dagger\Big)$$

$$- 6\mathrm{Tr}\Big(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 6\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\Big) - 6\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\Big)$$

$$- 36\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u Y_u^\dagger Y_u\Big) - 6\mathrm{Tr}\Big(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\Big) - 36\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) \tag{62}$$

$$\beta_{m_d^2}^{(1)} = -\frac{8}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 + 4m_{H_d}^2 Y_d Y_d^\dagger + 4T_d T_d^\dagger + 2m_d^2 Y_d Y_d^\dagger + 4Y_d m_q^2 Y_d^\dagger$$

$$+ 2Y_d Y_d^\dagger m_d^2 + 2\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1} \tag{63}$$

$$\beta_{m_d^2}^{(2)} = +\frac{64}{45}g_3^2\Big(-30g_3^2 M_3 + g_1^2\big(2M_3 + M_1\big)\Big)\mathbf{1}M_3^* + \frac{4}{5}g_1^2 m_{H_d}^2 Y_d Y_d^\dagger + 12g_2^2 m_{H_d}^2 Y_d Y_d^\dagger$$

$$+ 24g_2^2|M_2|^2 Y_d Y_d^\dagger - \frac{4}{5}g_1^2 M_1 Y_d T_d^\dagger - 12g_2^2 M_2 Y_d T_d^\dagger$$

$$+ \frac{4}{225}g_1^2 M_1^*\Big(2\big(303g_1^2 M_1 + 40g_3^2\big(2M_1 + M_3\big)\big)\mathbf{1} - 45T_d Y_d^\dagger + 90M_1 Y_d Y_d^\dagger\Big) - 12g_2^2 M_2^* T_d Y_d^\dagger$$

$$+ \frac{4}{5}g_1^2 T_d T_d^\dagger + 12g_2^2 T_d T_d^\dagger + \frac{2}{5}g_1^2 m_d^2 Y_d Y_d^\dagger + 6g_2^2 m_d^2 Y_d Y_d^\dagger$$

$$+ \frac{4}{5}g_1^2 Y_d m_q^2 Y_d^\dagger + 12g_2^2 Y_d m_q^2 Y_d^\dagger + \frac{2}{5}g_1^2 Y_d Y_d^\dagger m_d^2 + 6g_2^2 Y_d Y_d^\dagger m_d^2$$

$$- 8m_{H_d}^2 Y_d Y_d^\dagger Y_d Y_d^\dagger - 4Y_d Y_d^\dagger T_d T_d^\dagger - 4m_{H_d}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger$$

$$- 4m_{H_u}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger - 4Y_d Y_u^\dagger T_u T_d^\dagger - 4Y_d T_d^\dagger T_d Y_d^\dagger - 4Y_d T_u^\dagger T_u Y_d^\dagger$$

$$- 4T_dY_d^\dagger Y_dT_d^\dagger - 4T_dY_u^\dagger Y_uT_d^\dagger - 4T_dT_d^\dagger Y_dY_d^\dagger - 4T_dT_u^\dagger Y_uY_d^\dagger$$

$$- 2m_d^2Y_dY_d^\dagger Y_dY_d^\dagger - 2m_d^2Y_dY_u^\dagger Y_uY_d^\dagger - 4Y_dm_q^2Y_d^\dagger Y_dY_d^\dagger - 4Y_dm_q^2Y_u^\dagger Y_uY_d^\dagger$$

$$- 4Y_dY_d^\dagger m_d^2Y_dY_d^\dagger - 4Y_dY_d^\dagger Y_dm_q^2Y_d^\dagger - 2Y_dY_d^\dagger Y_dY_d^\dagger m_d^2 - 4Y_dY_u^\dagger m_u^2Y_uY_d^\dagger$$

$$- 4Y_dY_u^\dagger Y_um_q^2Y_d^\dagger - 2Y_dY_u^\dagger Y_uY_d^\dagger m_d^2 + \frac{32}{3}g_3^4\mathbf{1}\sigma_{2,3} + \frac{8}{15}g_1^2\mathbf{1}\sigma_{2,11} + 8\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{3,1}$$

$$- 24m_{H_d}^2Y_dY_d^\dagger\mathrm{Tr}\left(Y_dY_d^\dagger\right) - 12T_dT_d^\dagger\mathrm{Tr}\left(Y_dY_d^\dagger\right) - 6m_d^2Y_dY_d^\dagger\mathrm{Tr}\left(Y_dY_d^\dagger\right)$$

$$- 12Y_dm_q^2Y_d^\dagger\mathrm{Tr}\left(Y_dY_d^\dagger\right) - 6Y_dY_d^\dagger m_d^2\mathrm{Tr}\left(Y_dY_d^\dagger\right) - 8m_{H_d}^2Y_dY_d^\dagger\mathrm{Tr}\left(Y_eY_e^\dagger\right)$$

$$- 4T_dT_d^\dagger\mathrm{Tr}\left(Y_eY_e^\dagger\right) - 2m_d^2Y_dY_d^\dagger\mathrm{Tr}\left(Y_eY_e^\dagger\right) - 4Y_dm_q^2Y_d^\dagger\mathrm{Tr}\left(Y_eY_e^\dagger\right)$$

$$- 2Y_dY_d^\dagger m_d^2\mathrm{Tr}\left(Y_eY_e^\dagger\right) - 12Y_dT_d^\dagger\mathrm{Tr}\left(Y_d^\dagger T_d\right) - 4Y_dT_d^\dagger\mathrm{Tr}\left(Y_e^\dagger T_e\right)$$

$$- 12T_dY_d^\dagger\mathrm{Tr}\left(T_d^*Y_d^T\right) - 12Y_dY_d^\dagger\mathrm{Tr}\left(T_d^*T_d^T\right) - 4T_dY_d^\dagger\mathrm{Tr}\left(T_e^*Y_e^T\right)$$

$$- 4Y_dY_d^\dagger\mathrm{Tr}\left(T_e^*T_e^T\right) - 12Y_dY_d^\dagger\mathrm{Tr}\left(m_d^2Y_dY_d^\dagger\right) - 4Y_dY_d^\dagger\mathrm{Tr}\left(m_e^2Y_eY_e^\dagger\right)$$

$$- 4Y_dY_d^\dagger\mathrm{Tr}\left(m_l^2Y_e^\dagger Y_e\right) - 12Y_dY_d^\dagger\mathrm{Tr}\left(m_q^2Y_d^\dagger Y_d\right) \tag{64}$$

$$\beta_{m_u^2}^{(1)} = -\frac{32}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 + 4m_{H_u}^2Y_uY_u^\dagger + 4T_uT_u^\dagger + 2m_u^2Y_uY_u^\dagger + 4Y_um_q^2Y_u^\dagger$$

$$+ 2Y_uY_u^\dagger m_u^2 - 4\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1} \tag{65}$$

$$\beta_{m_u^2}^{(2)} = -\frac{128}{45}g_3^2\left(15g_3^2M_3 - 2g_1^2\left(2M_3 + M_1\right)\right)\mathbf{1}M_3^* - \frac{4}{5}g_1^2m_{H_u}^2Y_uY_u^\dagger + 12g_2^2m_{H_u}^2Y_uY_u^\dagger$$

$$+ 24g_2^2|M_2|^2Y_uY_u^\dagger + \frac{4}{5}g_1^2M_1Y_uT_u^\dagger - 12g_2^2M_2Y_uT_u^\dagger - 12g_2^2M_2^*T_uY_u^\dagger$$

$$+ \frac{4}{225}g_1^2M_1^*\left(45\left(-2M_1Y_uY_u^\dagger + T_uY_u^\dagger\right) + 8\left(321g_1^2M_1 + 40g_3^2\left(2M_1 + M_3\right)\right)\mathbf{1}\right) - \frac{4}{5}g_1^2T_uT_u^\dagger$$

$$+ 12g_2^2T_uT_u^\dagger - \frac{2}{5}g_1^2m_u^2Y_uY_u^\dagger + 6g_2^2m_u^2Y_uY_u^\dagger - \frac{4}{5}g_1^2Y_um_q^2Y_u^\dagger$$

$$+ 12g_2^2Y_um_q^2Y_u^\dagger - \frac{2}{5}g_1^2Y_uY_u^\dagger m_u^2 + 6g_2^2Y_uY_u^\dagger m_u^2 - 4m_{H_d}^2Y_uY_d^\dagger Y_dY_u^\dagger$$

$$- 4m_{H_u}^2Y_uY_d^\dagger Y_dY_u^\dagger - 4Y_uY_d^\dagger T_dT_u^\dagger - 8m_{H_u}^2Y_uY_u^\dagger Y_uY_u^\dagger - 4Y_uY_u^\dagger T_uT_u^\dagger$$

$$- 4Y_uT_d^\dagger T_dY_u^\dagger - 4Y_uT_u^\dagger T_uY_u^\dagger - 4T_uY_d^\dagger Y_dT_u^\dagger - 4T_uY_u^\dagger Y_uT_u^\dagger$$

$$- 4T_uT_d^\dagger Y_dY_u^\dagger - 4T_uT_u^\dagger Y_uY_u^\dagger - 2m_u^2Y_uY_d^\dagger Y_dY_u^\dagger - 2m_u^2Y_uY_u^\dagger Y_uY_u^\dagger$$

$$- 4Y_um_q^2Y_d^\dagger Y_dY_u^\dagger - 4Y_um_q^2Y_u^\dagger Y_uY_u^\dagger - 4Y_uY_d^\dagger m_d^2Y_dY_u^\dagger$$

$$- 4Y_uY_d^\dagger Y_dm_q^2Y_u^\dagger - 2Y_uY_d^\dagger Y_dY_u^\dagger m_u^2 - 4Y_uY_u^\dagger m_u^2Y_uY_u^\dagger - 4Y_uY_u^\dagger Y_um_q^2Y_u^\dagger$$

$$- 2Y_uY_u^\dagger Y_uY_u^\dagger m_u^2 + \frac{32}{3}g_3^4\mathbf{1}\sigma_{2,3} + \frac{32}{15}g_1^2\mathbf{1}\sigma_{2,11} - 16\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{3,1} - 24m_{H_u}^2Y_uY_u^\dagger\mathrm{Tr}\left(Y_uY_u^\dagger\right)$$

$$- 12T_uT_u^\dagger\mathrm{Tr}\left(Y_uY_u^\dagger\right) - 6m_u^2Y_uY_u^\dagger\mathrm{Tr}\left(Y_uY_u^\dagger\right) - 12Y_um_q^2Y_u^\dagger\mathrm{Tr}\left(Y_uY_u^\dagger\right)$$

$$- 6Y_uY_u^\dagger m_u^2 \text{Tr}\left(Y_uY_u^\dagger\right) - 12Y_uT_u^\dagger \text{Tr}\left(Y_u^\dagger T_u\right) - 12T_uY_u^\dagger \text{Tr}\left(T_u^*Y_u^T\right)$$

$$- 12Y_uY_u^\dagger \text{Tr}\left(T_u^*T_u^T\right) - 12Y_uY_u^\dagger \text{Tr}\left(m_q^2Y_u^\dagger Y_u\right) - 12Y_uY_u^\dagger \text{Tr}\left(m_u^2Y_uY_u^\dagger\right) \tag{66}$$

$$\beta_{m_e^2}^{(1)} = -\frac{24}{5}g_1^2\mathbf{1}|M_1|^2 + 2\left(2m_{H_d}^2 Y_eY_e^\dagger + 2T_eT_e^\dagger + 2Y_em_l^2Y_e^\dagger + m_e^2Y_eY_e^\dagger + Y_eY_e^\dagger m_e^2\right)$$

$$+ 2\sqrt{\frac{3}{5}}g_1\mathbf{1}\sigma_{1,1} \tag{67}$$

$$\beta_{m_e^2}^{(2)} = \frac{2}{25}\left(6g_1^2M_1^*\left(234g_1^2M_1\mathbf{1} + 5\left(-2M_1Y_eY_e^\dagger + T_eY_e^\dagger\right)\right) + 20g_1\mathbf{1}\left(3g_1\sigma_{2,11} + \sqrt{15}\sigma_{3,1}\right)\right.$$

$$- 5\left(30g_2^2M_2^*T_eY_e^\dagger + 6g_1^2T_eT_e^\dagger - 30g_2^2T_eT_e^\dagger + 3g_1^2m_e^2Y_eY_e^\dagger\right.$$

$$- 15g_2^2m_e^2Y_eY_e^\dagger + 6g_1^2Y_em_l^2Y_e^\dagger - 30g_2^2Y_em_l^2Y_e^\dagger + 3g_1^2Y_eY_e^\dagger m_e^2$$

$$- 15g_2^2Y_eY_e^\dagger m_e^2 + 20m_{H_d}^2Y_eY_e^\dagger Y_eY_e^\dagger + 10Y_eY_e^\dagger T_eT_e^\dagger + 10Y_eT_e^\dagger T_eY_e^\dagger$$

$$+ 10T_eY_e^\dagger Y_eT_e^\dagger + 10T_eT_e^\dagger Y_eY_e^\dagger + 5m_e^2Y_eY_e^\dagger Y_eY_e^\dagger + 10Y_em_l^2Y_e^\dagger Y_eY_e^\dagger$$

$$+ 10Y_eY_e^\dagger m_e^2Y_eY_e^\dagger + 10Y_eY_e^\dagger Y_em_l^2Y_e^\dagger + 5Y_eY_e^\dagger Y_eY_e^\dagger m_e^2 + 30T_eT_e^\dagger \text{Tr}\left(Y_dY_d^\dagger\right)$$

$$+ 15m_e^2Y_eY_e^\dagger \text{Tr}\left(Y_dY_d^\dagger\right) + 30Y_em_l^2Y_e^\dagger \text{Tr}\left(Y_dY_d^\dagger\right) + 15Y_eY_e^\dagger m_e^2\text{Tr}\left(Y_dY_d^\dagger\right)$$

$$+ 10T_eT_e^\dagger \text{Tr}\left(Y_eY_e^\dagger\right) + 5m_e^2Y_eY_e^\dagger \text{Tr}\left(Y_eY_e^\dagger\right) + 10Y_em_l^2Y_e^\dagger \text{Tr}\left(Y_eY_e^\dagger\right)$$

$$+ 5Y_eY_e^\dagger m_e^2\text{Tr}\left(Y_eY_e^\dagger\right) + Y_eT_e^\dagger \left(10\text{Tr}\left(Y_e^\dagger T_e\right) + 30g_2^2M_2 + 30\text{Tr}\left(Y_d^\dagger T_d\right) - 6g_1^2M_1\right)$$

$$+ 30T_eY_e^\dagger \text{Tr}\left(T_d^*Y_d^T\right) + 10T_eY_e^\dagger \text{Tr}\left(T_e^*Y_e^T\right)$$

$$+ 2Y_eY_e^\dagger \left(3g_1^2m_{H_d}^2 - 15g_2^2m_{H_d}^2 - 30g_2^2|M_2|^2 + 30m_{H_d}^2\text{Tr}\left(Y_dY_d^\dagger\right) + 10m_{H_d}^2\text{Tr}\left(Y_eY_e^\dagger\right) + 15\text{Tr}\left(T_d^*T_d^T\right)\right.$$

$$\left.\left.\left.+ 5\text{Tr}\left(T_e^*T_e^T\right) + 15\text{Tr}\left(m_d^2Y_dY_d^\dagger\right) + 5\text{Tr}\left(m_e^2Y_eY_e^\dagger\right) + 5\text{Tr}\left(m_l^2Y_e^\dagger Y_e\right) + 15\text{Tr}\left(m_q^2Y_d^\dagger Y_d\right)\right)\right)\right) \tag{68}$$

3.9 Vacuum expectation values

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

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

$$- 225g_2^4\text{Xi}^2 - 40\left(5\left(32g_3^2 + 9g_2^2\text{Xi}\right) + g_1^2\left(9\text{Xi} - 4\right)\right)\text{Tr}\left(Y_dY_d^\dagger\right) - 120\left(5g_2^2\text{Xi} + g_1^2\left(4 + \text{Xi}\right)\right)\text{Tr}\left(Y_eY_e^\dagger\right)$$

$$+ 3600\text{Tr}\left(Y_dY_d^\dagger Y_dY_d^\dagger\right) + 1200\text{Tr}\left(Y_dY_u^\dagger Y_uY_d^\dagger\right) + 1200\text{Tr}\left(Y_eY_e^\dagger Y_eY_e^\dagger\right)\right) \tag{70}$$

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

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

$$- 225 g_2^4 \text{Xi}^2 - 40 \Big(5 \Big(32 g_3^2 + 9 g_2^2 \text{Xi} \Big) + g_1^2 \Big(9 \text{Xi} + 8 \Big) \Big) \text{Tr} \Big(Y_u Y_u^\dagger \Big) + 1200 \text{Tr} \Big(Y_d Y_u^\dagger Y_u Y_d^\dagger \Big) + 3600 \text{Tr} \Big(Y_u Y_u^\dagger Y_u Y_u^\dagger \Big) \Big)$$

$$(72)$$

4 Field Rotations

4.1 Rotations in gauge sector for eigenstates 'EWSB'

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

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

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

$$(76)$$

The mixing matrices are parametrized by

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

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

$$Z^{\tilde{W}} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -i \frac{1}{\sqrt{2}} & i \frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{79}$$

$$(80)$$

4.2 Rotations in Mass sector for eigenstates 'EWSB'

4.2.1 Mass Matrices for Scalars

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

$$m_{\tilde{d}}^2 = \begin{pmatrix} m_{\tilde{d}_L \tilde{d}_L^*} & -\frac{1}{\sqrt{2}} \Big(- v_d T_d^\dagger + v_u \Big(\mu Y_d^\dagger + T'_d^\dagger \Big) \Big) \delta_{\alpha_1 \beta_2} \\ -\frac{1}{\sqrt{2}} \delta_{\alpha_2 \beta_1} \Big(- v_d T_d + v_u \Big(Y_d \mu^* + T'_d \Big) \Big) & m_{\tilde{d}_R \tilde{d}_R^*} \end{pmatrix} \tag{81}$$

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$$m_{\tilde{d}_L \tilde{d}_L^*} = -\frac{1}{24}\Big(3g_2^2 + g_1^2\Big)\mathbf{1}\Big(-v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m_q^2 + v_d^2 Y_d^\dagger Y_d\Big) \tag{82}$$

$$m_{\tilde{d}_R \tilde{d}_R^*} = \frac{1}{12}g_1^2\mathbf{1}\Big(-v_d^2 + v_u^2\Big)\delta_{\alpha_2\beta_2} + \frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m_d^2 + v_d^2 Y_d Y_d^\dagger\Big) \tag{83}$$

This matrix is diagonalized by Z^D:

$$Z^D m_{\tilde{d}}^2 Z^{D,\dagger} = m_{2,\tilde{d}}^{dia} \tag{84}$$

with

$$\tilde{d}_{L,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha}\,, \qquad \tilde{d}_{R,i\alpha} = \sum_j Z_{ji}^{D,*} \tilde{d}_{j\alpha} \tag{85}$$

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

$$m_{\tilde{\nu}}^2 = \Big(\ \tfrac{1}{8}\Big(g_1^2 + g_2^2\Big)\mathbf{1}\Big(-v_u^2 + v_d^2\Big) + m_l^2\ \Big) \tag{86}$$

This matrix is diagonalized by Z^V:

$$Z^V m_{\tilde{\nu}}^2 Z^{V,\dagger} = m_{2,\tilde{\nu}}^{dia} \tag{87}$$

with

$$\tilde{\nu}_{L,i} = \sum_j Z_{ji}^{V,*} \tilde{\nu}_j \tag{88}$$

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

$$m_{\tilde{u}}^2 = \begin{pmatrix} m_{\tilde{u}_L \tilde{u}_L^*} & -\frac{1}{\sqrt{2}}\Big(v_d\Big(\mu Y_u^\dagger + T'^\dagger_u\Big) - v_u T_u^\dagger\Big)\delta_{\alpha_1\beta_2} \\ -\frac{1}{\sqrt{2}}\delta_{\alpha_2\beta_1}\Big(v_d\Big(Y_u\mu^* + T'_u\Big) - v_u T_u\Big) & m_{\tilde{u}_R \tilde{u}_R^*} \end{pmatrix} \tag{89}$$

$$m_{\tilde{u}_L \tilde{u}_L^*} = -\frac{1}{24}\Big(-3g_2^2 + g_1^2\Big)\mathbf{1}\Big(-v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m_q^2 + v_u^2 Y_u^\dagger Y_u\Big) \tag{90}$$

$$m_{\tilde{u}_R \tilde{u}_R^*} = \frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m_u^2 + v_u^2 Y_u Y_u^\dagger\Big) + \frac{1}{6}g_1^2\mathbf{1}\Big(-v_u^2 + v_d^2\Big)\delta_{\alpha_2\beta_2} \tag{91}$$

This matrix is diagonalized by Z^U:

$$Z^U m_{\tilde{u}}^2 Z^{U,\dagger} = m_{2,\tilde{u}}^{dia} \tag{92}$$

with

$$\tilde{u}_{L,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha}\,, \qquad \tilde{u}_{R,i\alpha} = \sum_j Z_{ji}^{U,*} \tilde{u}_{j\alpha} \tag{93}$$

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

$$m_{\tilde{e}}^2 = \begin{pmatrix} m_{\tilde{e}_L \tilde{e}_L^*} & \frac{1}{\sqrt{2}}\Big(v_d T_e^\dagger - v_u\Big(\mu Y_e^\dagger + T'^\dagger_e\Big)\Big) \\ \frac{1}{\sqrt{2}}\Big(v_d T_e - v_u\Big(Y_e\mu^* + T'_e\Big)\Big) & m_{\tilde{e}_R \tilde{e}_R^*} \end{pmatrix} \tag{94}$$

$$m_{\tilde{e}_L \tilde{e}_L^*} = \frac{1}{2} v_d^2 Y_e^\dagger Y_e + \frac{1}{8}\Big(-g_2^2 + g_1^2\Big)\mathbf{1}\Big(-v_u^2 + v_d^2\Big) + m_l^2 \tag{95}$$

$$m_{\tilde{e}_R \tilde{e}_R^*} = \frac{1}{2} v_d^2 Y_e Y_e^\dagger + \frac{1}{4} g_1^2 \mathbf{1}\Big(-v_d^2 + v_u^2\Big) + m_e^2 \tag{96}$$

This matrix is diagonalized by Z^E:

$$Z^E m_{\tilde{e}}^2 Z^{E,\dagger} = m_{2,\tilde{e}}^{dia} \tag{97}$$

with

$$\tilde{e}_{L,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j \,, \qquad \tilde{e}_{R,i} = \sum_j Z_{ji}^{E,*} \tilde{e}_j \tag{98}$$

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

$$m_h^2 = \begin{pmatrix} \frac{1}{8}\Big(g_1^2 + g_2^2\Big)\Big(3v_d^2 - v_u^2\Big) + m_{H_d}^2 + |\mu|^2 & -\frac{1}{4}\Big(g_1^2 + g_2^2\Big)v_d v_u - \Re\Big(B_\mu\Big) \\ -\frac{1}{4}\Big(g_1^2 + g_2^2\Big)v_d v_u - \Re\Big(B_\mu\Big) & -\frac{1}{8}\Big(g_1^2 + g_2^2\Big)\Big(-3v_u^2 + v_d^2\Big) + m_{H_u}^2 + |\mu|^2 \end{pmatrix} \tag{99}$$

This matrix is diagonalized by Z^H:

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \tag{100}$$

with

$$\phi_d = \sum_j Z_{j1}^H h_j \,, \qquad \phi_u = \sum_j Z_{j2}^H h_j \tag{101}$$

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

$$m_{A^0}^2 = \begin{pmatrix} \frac{1}{8}\Big(g_1^2 + g_2^2\Big)\Big(-v_u^2 + v_d^2\Big) + m_{H_d}^2 + |\mu|^2 & \Re\Big(B_\mu\Big) \\ \Re\Big(B_\mu\Big) & -\frac{1}{8}\Big(g_1^2 + g_2^2\Big)\Big(-v_u^2 + v_d^2\Big) + m_{H_u}^2 + |\mu|^2 \end{pmatrix} + \xi_Z m^2(Z) \tag{102}$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} \frac{1}{4}v_d^2\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 & -\frac{1}{4}v_d v_u\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 \\ -\frac{1}{4}v_d v_u\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 & \frac{1}{4}v_u^2\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 \end{pmatrix} \tag{103}$$

This matrix is diagonalized by Z^A:

$$Z^A m_{A^0}^2 Z^{A,\dagger} = m_{2,A^0}^{dia} \tag{104}$$

with

$$\sigma_d = \sum_j Z_{j1}^A A_j^0 \,, \qquad \sigma_u = \sum_j Z_{j2}^A A_j^0 \tag{105}$$

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

$$m_{H^-}^2 = \begin{pmatrix} m_{H_d^- H_d^{-,*}} & \frac{1}{4}g_2^2 v_d v_u + B_\mu^* \\ \frac{1}{4}g_2^2 v_d v_u + B_\mu & m_{H_u^{+,*} H_u^+} \end{pmatrix} + \xi_{W^-} m^2(W^-) \tag{106}$$

$$m_{H_d^- H_d^{-,*}} = \frac{1}{8}\left(g_1^2\left(-v_u^2 + v_d^2\right) + g_2^2\left(v_d^2 + v_u^2\right)\right) + m_{H_d}^2 + |\mu|^2 \tag{107}$$

$$m_{H_u^{+,*} H_u^+} = \frac{1}{8}\left(g_1^2\left(-v_d^2 + v_u^2\right) + g_2^2\left(v_d^2 + v_u^2\right)\right) + m_{H_u}^2 + |\mu|^2 \tag{108}$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4}g_2^2 v_d^2 & -\frac{1}{4}g_2^2 v_d v_u \\ -\frac{1}{4}g_2^2 v_d v_u & \frac{1}{4}g_2^2 v_u^2 \end{pmatrix} \tag{109}$$

This matrix is diagonalized by Z^+:

$$Z^+ m_{H^-}^2 Z^{+,\dagger} = m_{2,H^-}^{dia} \tag{110}$$

with

$$H_d^- = \sum_j Z_{j1}^+ H_j^-, \qquad H_u^+ = \sum_j Z_{j2}^+ H_j^+ \tag{111}$$

4.2.2 Mass Matrices for Fermions

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

$$m_{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & -\frac{1}{2}g_1 v_d & \frac{1}{2}g_1 v_u \\ 0 & M_2 & \frac{1}{2}g_2 v_d & -\frac{1}{2}g_2 v_u \\ -\frac{1}{2}g_1 v_d & \frac{1}{2}g_2 v_d & 0 & -\mu + \mu' \\ \frac{1}{2}g_1 v_u & -\frac{1}{2}g_2 v_u & -\mu + \mu' & 0 \end{pmatrix} \tag{112}$$

This matrix is diagonalized by N:

$$N^* m_{\tilde{\chi}^0} N^\dagger = m_{\tilde{\chi}^0}^{dia} \tag{113}$$

with

$$\lambda_{\tilde{B}} = \sum_j N_{j1}^* \lambda_j^0, \qquad \tilde{W}^0 = \sum_j N_{j2}^* \lambda_j^0, \qquad \tilde{H}_d^0 = \sum_j N_{j3}^* \lambda_j^0 \tag{114}$$

$$\tilde{H}_u^0 = \sum_j N_{j4}^* \lambda_j^0 \tag{115}$$

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

$$m_{\tilde{\chi}^-} = \begin{pmatrix} M_2 & \frac{1}{\sqrt{2}}g_2 v_u \\ \frac{1}{\sqrt{2}}g_2 v_d & -\mu' + \mu \end{pmatrix} \tag{116}$$

This matrix is diagonalized by U and V

$$U^* m_{\tilde{\chi}^-} V^\dagger = m_{\tilde{\chi}^-}^{dia} \tag{117}$$

with

$$\tilde{W}^- = \sum_{t_2} U_{j1}^* \lambda_j^- , \qquad \tilde{H}_d^- = \sum_{t_2} U_{j2}^* \lambda_j^- \tag{118}$$

$$\tilde{W}^+ = \sum_{t_2} V_{1j}^* \lambda_j^+ , \qquad \tilde{H}_u^+ = \sum_{t_2} V_{2j}^* \lambda_j^+ \tag{119}$$

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

$$m_e = \left(\quad \frac{1}{\sqrt{2}} v_d Y_e^T \quad \right) \tag{120}$$

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

$$U_L^{e,*} m_e U_R^{e,\dagger} = m_e^{dia} \tag{121}$$

with

$$e_{L,i} = \sum_{t_2} U_{L,ji}^{e,*} E_{L,j} \tag{122}$$

$$e_{R,i} = \sum_{t_2} U_{R,ij}^e E_{R,j}^* \tag{123}$$

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

$$m_d = \left(\quad \frac{1}{\sqrt{2}} v_d \delta_{\alpha_1 \beta_1} Y_d^T \quad \right) \tag{124}$$

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

$$U_L^{d,*} m_d U_R^{d,\dagger} = m_d^{dia} \tag{125}$$

with

$$d_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{d,*} D_{L,j\alpha} \tag{126}$$

$$d_{R,i\alpha} = \sum_{t_2} U_{R,ij}^d D_{R,j\alpha}^* \tag{127}$$

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

$$m_u = \left(\quad \frac{1}{\sqrt{2}} v_u \delta_{\alpha_1 \beta_1} Y_u^T \quad \right) \tag{128}$$

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

$$U_L^{u,*} m_u U_R^{u,\dagger} = m_u^{dia} \tag{129}$$

with

$$u_{L,i\alpha} = \sum_{t_2} U_{L,ji}^{u,*} U_{L,j\alpha} \tag{130}$$

$$u_{R,i\alpha} = \sum_{t_2} U_{R,ij}^{u} U_{R,j\alpha}^{*} \tag{131}$$

5 Vacuum Expectation Values

$$H_d^0 = \frac{1}{\sqrt{2}}\phi_d + \frac{1}{\sqrt{2}}v_d + i\frac{1}{\sqrt{2}}\sigma_d \tag{132}$$

$$H_u^0 = \frac{1}{\sqrt{2}}\phi_u + \frac{1}{\sqrt{2}}v_u + i\frac{1}{\sqrt{2}}\sigma_u \tag{133}$$

6 Tadpole Equations

$$\frac{\partial V}{\partial \phi_d} = -\frac{1}{2}v_u\Big(B_\mu + B_\mu^*\Big) + \frac{1}{8}\Big(g_1^2 + g_2^2\Big)v_d\Big(-v_u + v_d\Big)\Big(v_d + v_u\Big) + v_d\Big(m_{H_d}^2 + |\mu|^2\Big) \tag{134}$$

$$\frac{\partial V}{\partial \phi_u} = \frac{1}{8}\Big(g_1^2 + g_2^2\Big)v_u\Big(-v_d^2 + v_u^2\Big) - v_d\Re\Big(B_\mu\Big) + v_u\Big(m_{H_u}^2 + |\mu|^2\Big) \tag{135}$$

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	2	generation, 2
A^0	Scalar	real	2	generation, 2
H^-	Scalar	complex	2	generation, 2
$\tilde{g}$	Fermion	Majorana	1	color, 8
ν	Fermion	Dirac	3	generation, 3
$\tilde{\chi}^0$	Fermion	Majorana	4	generation, 4
$\tilde{\chi}^-$	Fermion	Dirac	2	generation, 2
e	Fermion	Dirac	3	generation, 3
d	Fermion	Dirac	3	generation, 3, color, 3
u	Fermion	Dirac	3	generation, 3, color, 3

g	Vector	real	1	color, 8, lorentz, 4
γ	Vector	real	1	lorentz, 4
Z	Vector	real	1	lorentz, 4
W^-	Vector	complex	1	lorentz, 4
η^G	Ghost	real	1	color, 8
η^γ	Ghost	real	1	
η^Z	Ghost	real	1	
η^-	Ghost	complex	1	
η^+	Ghost	complex	1	

8   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{\tilde{d}}_i,\check{\tilde{d}}_j^*,W^+,W^-}\left(-\frac{1}{2}\mathrm{rMS}m_{W^-}^2 + A_0\left(m_{W^-}^2\right)\right) + 2\Gamma_{\check{\tilde{d}}_i,\check{\tilde{d}}_j^*,Z,Z}\left(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\left(m_Z^2\right)\right) \\
& -\frac{1}{2}\sum_{a=1}^{2}A_0\left(m_{A_a^0}^2\right)\Gamma_{\check{\tilde{d}}_i,\check{\tilde{d}}_j^*,A_a^0,A_a^0} - \sum_{a=1}^{2}A_0\left(m_{H_a^-}^2\right)\Gamma_{\check{\tilde{d}}_i,\check{\tilde{d}}_j^*,H_a^+,H_a^-} \\
& -\frac{1}{2}\sum_{a=1}^{2}A_0\left(m_{h_a}^2\right)\Gamma_{\check{\tilde{d}}_i,\check{\tilde{d}}_j^*,h_a,h_a} - \sum_{a=1}^{3}A_0\left(m_{\tilde{\nu}_a}^2\right)\Gamma_{\check{\tilde{d}}_i,\check{\tilde{d}}_j^*,\tilde{\nu}_a^*,\tilde{\nu}_a} \\
& -2\sum_{a=1}^{3}m_{u_a}\sum_{b=1}^{2}B_0\left(p^2,m_{u_a}^2,m_{\tilde{\chi}_b^-}^2\right)m_{\tilde{\chi}_b^-}\left(\Gamma^{L*}_{\check{\tilde{d}}_j^*,u_a,\tilde{\chi}_b^-}\Gamma^{R}_{\check{\tilde{d}}_i^*,u_a,\tilde{\chi}_b^-} + \Gamma^{R*}_{\check{\tilde{d}}_j^*,u_a,\tilde{\chi}_b^-}\Gamma^{L}_{\check{\tilde{d}}_i^*,u_a,\tilde{\chi}_b^-}\right) \\
& +\sum_{a=1}^{3}\sum_{b=1}^{2}G_0\left(p^2,m_{u_a}^2,m_{\tilde{\chi}_b^-}^2\right)\left(\Gamma^{L*}_{\check{\tilde{d}}_j^*,u_a,\tilde{\chi}_b^-}\Gamma^{L}_{\check{\tilde{d}}_i^*,u_a,\tilde{\chi}_b^-} + \Gamma^{R*}_{\check{\tilde{d}}_j^*,u_a,\tilde{\chi}_b^-}\Gamma^{R}_{\check{\tilde{d}}_i^*,u_a,\tilde{\chi}_b^-}\right) \\
& -2\sum_{a=1}^{3}m_{d_a}\sum_{b=1}^{4}B_0\left(p^2,m_{d_a}^2,m_{\tilde{\chi}_b^0}^2\right)m_{\tilde{\chi}_b^0}\left(\Gamma^{L*}_{\check{\tilde{d}}_j^*,d_a,\tilde{\chi}_b^0}\Gamma^{R}_{\check{\tilde{d}}_i^*,d_a,\tilde{\chi}_b^0} + \Gamma^{R*}_{\check{\tilde{d}}_j^*,d_a,\tilde{\chi}_b^0}\Gamma^{L}_{\check{\tilde{d}}_i^*,d_a,\tilde{\chi}_b^0}\right) \\
& +\sum_{a=1}^{3}\sum_{b=1}^{4}G_0\left(p^2,m_{d_a}^2,m_{\tilde{\chi}_b^0}^2\right)\left(\Gamma^{L*}_{\check{\tilde{d}}_j^*,d_a,\tilde{\chi}_b^0}\Gamma^{L}_{\check{\tilde{d}}_i^*,d_a,\tilde{\chi}_b^0} + \Gamma^{R*}_{\check{\tilde{d}}_j^*,d_a,\tilde{\chi}_b^0}\Gamma^{R}_{\check{\tilde{d}}_i^*,d_a,\tilde{\chi}_b^0}\right) \\
& -C\sum_{a=1}^{6}A_0\left(m_{\tilde{d}_a}^2\right)\Gamma_{\check{\tilde{d}}_i,\check{\tilde{d}}_j^*,\tilde{d}_a^*,\tilde{d}_a} - \sum_{a=1}^{6}A_0\left(m_{\tilde{e}_a}^2\right)\Gamma_{\check{\tilde{d}}_i,\check{\tilde{d}}_j^*,\tilde{e}_a^*,\tilde{e}_a}
\end{aligned}
$$

$$- C \sum_{a=1}^{6} A_0\Big(m_{\tilde{u}_a}^2\Big)\Gamma_{\check{\tilde{d}}_i,\check{\tilde{d}}_j^*,\tilde{u}_a^*,\tilde{u}_a} + \sum_{a=1}^{6}\sum_{b=1}^{2} B_0\Big(p^2,m_{\tilde{d}_a}^2,m_{A_b^0}^2\Big)\Gamma^*_{\check{\tilde{d}}_j^*,\tilde{d}_a,A_b^0}\Gamma_{\check{\tilde{d}}_i^*,\tilde{d}_a,A_b^0}$$

$$+ \sum_{a=1}^{6}\sum_{b=1}^{2} B_0\Big(p^2,m_{\tilde{d}_a}^2,m_{h_b}^2\Big)\Gamma^*_{\check{\tilde{d}}_j^*,\tilde{d}_a,h_b}\Gamma_{\check{\tilde{d}}_i^*,\tilde{d}_a,h_b} + \sum_{a=1}^{6}\sum_{b=1}^{2} B_0\Big(p^2,m_{\tilde{u}_a}^2,m_{H_b^-}^2\Big)\Gamma^*_{\check{\tilde{d}}_j^*,\tilde{u}_a,H_b^-}\Gamma_{\check{\tilde{d}}_i^*,\tilde{u}_a,H_b^-}$$

$$- \frac{8}{3}m_{\tilde{g}} \sum_{b=1}^{3} B_0\Big(p^2,m_{\tilde{g}}^2,m_{d_b}^2\Big)m_{d_b}\Big(\Gamma^{L*}_{\check{\tilde{d}}_j^*,\tilde{g}_1,d_b}\Gamma^{R}_{\check{\tilde{d}}_i^*,\tilde{g}_1,d_b} + \Gamma^{R*}_{\check{\tilde{d}}_j^*,\tilde{g}_1,d_b}\Gamma^{L}_{\check{\tilde{d}}_i^*,\tilde{g}_1,d_b}\Big)$$

$$+ \frac{4}{3} \sum_{b=1}^{3} G_0\Big(p^2,m_{\tilde{g}}^2,m_{d_b}^2\Big)\Big(\Gamma^{L*}_{\check{\tilde{d}}_j^*,\tilde{g}_1,d_b}\Gamma^{L}_{\check{\tilde{d}}_i^*,\tilde{g}_1,d_b} + \Gamma^{R*}_{\check{\tilde{d}}_j^*,\tilde{g}_1,d_b}\Gamma^{R}_{\check{\tilde{d}}_i^*,\tilde{g}_1,d_b}\Big)$$

$$+ \frac{4}{3} \sum_{b=1}^{6} \Gamma^*_{\check{\tilde{d}}_j^*,g,\tilde{d}_b}\Gamma_{\check{\tilde{d}}_i^*,g,\tilde{d}_b} F_0\Big(p^2,m_{\tilde{d}_b}^2,0\Big) + \sum_{b=1}^{6} \Gamma^*_{\check{\tilde{d}}_j^*,\gamma,\tilde{d}_b}\Gamma_{\check{\tilde{d}}_i^*,\gamma,\tilde{d}_b} F_0\Big(p^2,m_{\tilde{d}_b}^2,0\Big)$$

$$+ \sum_{b=1}^{6} \Gamma^*_{\check{\tilde{d}}_j^*,Z,\tilde{d}_b}\Gamma_{\check{\tilde{d}}_i^*,Z,\tilde{d}_b} F_0\Big(p^2,m_{\tilde{d}_b}^2,m_Z^2\Big) + \sum_{b=1}^{6} \Gamma^*_{\check{\tilde{d}}_j^*,W^-,\tilde{u}_b}\Gamma_{\check{\tilde{d}}_i^*,W^-,\tilde{u}_b} F_0\Big(p^2,m_{\tilde{u}_b}^2,m_{W^-}^2\Big) \qquad (136)$$

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

$$\Pi_{i,j}(p^2) = +4\Gamma_{\check{\tilde{\nu}}_i,\check{\tilde{\nu}}_j^*,W^+,W^-}\Big(-\frac{1}{2}\mathrm{rMS}m_{W^-}^2 + A_0\Big(m_{W^-}^2\Big)\Big) + 2\Gamma_{\check{\tilde{\nu}}_i,\check{\tilde{\nu}}_j^*,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\Big(m_Z^2\Big)\Big)$$

$$- \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{A_a^0}^2\Big)\Gamma_{\check{\tilde{\nu}}_i,\check{\tilde{\nu}}_j^*,A_a^0,A_a^0} - \sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big)\Gamma_{\check{\tilde{\nu}}_i,\check{\tilde{\nu}}_j^*,H_a^+,H_a^-}$$

$$- \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{h_a}^2\Big)\Gamma_{\check{\tilde{\nu}}_i,\check{\tilde{\nu}}_j^*,h_a,h_a}$$

$$- 2\sum_{a=1}^{2} m_{\tilde{\chi}_a^-} \sum_{b=1}^{3} B_0\Big(p^2,m_{\tilde{\chi}_a^-}^2,m_{e_b}^2\Big)m_{e_b}\Big(\Gamma^{L*}_{\check{\tilde{\nu}}_j^*,\tilde{\chi}_a^+,e_b}\Gamma^{R}_{\check{\tilde{\nu}}_i^*,\tilde{\chi}_a^+,e_b} + \Gamma^{R*}_{\check{\tilde{\nu}}_j^*,\tilde{\chi}_a^+,e_b}\Gamma^{L}_{\check{\tilde{\nu}}_i^*,\tilde{\chi}_a^+,e_b}\Big)$$

$$+ \sum_{a=1}^{2}\sum_{b=1}^{3} G_0\Big(p^2,m_{\tilde{\chi}_a^-}^2,m_{e_b}^2\Big)\Big(\Gamma^{L*}_{\check{\tilde{\nu}}_j^*,\tilde{\chi}_a^+,e_b}\Gamma^{L}_{\check{\tilde{\nu}}_i^*,\tilde{\chi}_a^+,e_b} + \Gamma^{R*}_{\check{\tilde{\nu}}_j^*,\tilde{\chi}_a^+,e_b}\Gamma^{R}_{\check{\tilde{\nu}}_i^*,\tilde{\chi}_a^+,e_b}\Big)$$

$$+ \sum_{a=1}^{2}\sum_{b=1}^{6} B_0\Big(p^2,m_{H_a^-}^2,m_{\tilde{e}_b}^2\Big)\Gamma^*_{\check{\tilde{\nu}}_j^*,H_a^+,\tilde{e}_b}\Gamma_{\check{\tilde{\nu}}_i^*,H_a^+,\tilde{e}_b} - \sum_{a=1}^{3} A_0\Big(m_{\tilde{\nu}_a}^2\Big)\Gamma_{\check{\tilde{\nu}}_i,\check{\tilde{\nu}}_j^*,\tilde{\nu}_a^*,\tilde{\nu}_a}$$

$$+ \sum_{a=1}^{3}\sum_{b=1}^{2} B_0\Big(p^2,m_{\tilde{\nu}_a}^2,m_{h_b}^2\Big)\Gamma^*_{\check{\tilde{\nu}}_j^*,\tilde{\nu}_a,h_b}\Gamma_{\check{\tilde{\nu}}_i^*,\tilde{\nu}_a,h_b}$$

$$- 2\sum_{a=1}^{3} m_{\nu_a} \sum_{b=1}^{4} B_0\Big(p^2,m_{\nu_a}^2,m_{\tilde{\chi}_b^0}^2\Big)m_{\tilde{\chi}_b^0}\Big(\Gamma^{L*}_{\check{\tilde{\nu}}_j^*,\nu_a,\tilde{\chi}_b^0}\Gamma^{R}_{\check{\tilde{\nu}}_i^*,\nu_a,\tilde{\chi}_b^0} + \Gamma^{R*}_{\check{\tilde{\nu}}_j^*,\nu_a,\tilde{\chi}_b^0}\Gamma^{L}_{\check{\tilde{\nu}}_i^*,\nu_a,\tilde{\chi}_b^0}\Big)$$

$$+ \sum_{a=1}^{3}\sum_{b=1}^{4} G_0\Big(p^2,m_{\nu_a}^2,m_{\tilde{\chi}_b^0}^2\Big)\Big(\Gamma^{L*}_{\check{\tilde{\nu}}_j^*,\nu_a,\tilde{\chi}_b^0}\Gamma^{L}_{\check{\tilde{\nu}}_i^*,\nu_a,\tilde{\chi}_b^0} + \Gamma^{R*}_{\check{\tilde{\nu}}_j^*,\nu_a,\tilde{\chi}_b^0}\Gamma^{R}_{\check{\tilde{\nu}}_i^*,\nu_a,\tilde{\chi}_b^0}\Big)$$

$$
- 3 \sum_{a=1}^{6} A_0\Big(m_{\tilde{d}_a}^2\Big) \Gamma_{\breve{\nu}_i, \breve{\nu}_j^*, \tilde{d}_a^*, \tilde{d}_a} - \sum_{a=1}^{6} A_0\Big(m_{\tilde{e}_a}^2\Big) \Gamma_{\breve{\nu}_i, \breve{\nu}_j^*, \tilde{e}_a^*, \tilde{e}_a}
$$

$$
- 3 \sum_{a=1}^{6} A_0\Big(m_{\tilde{u}_a}^2\Big) \Gamma_{\breve{\nu}_i, \breve{\nu}_j^*, \tilde{u}_a^*, \tilde{u}_a} + \sum_{b=1}^{3} \Gamma_{\breve{\nu}_j^*, Z, \tilde{\nu}_b}^* \Gamma_{\breve{\nu}_i^*, Z, \tilde{\nu}_b} F_0\Big(p^2, m_{\tilde{\nu}_b}^2, m_Z^2\Big)
$$

$$
+ \sum_{b=1}^{6} \Gamma_{\breve{\nu}_j^*, W^+, \tilde{e}_b}^* \Gamma_{\breve{\nu}_i^*, W^+, \tilde{e}_b} F_0\Big(p^2, m_{\tilde{e}_b}^2, m_{W^-}^2\Big) \tag{137}
$$

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

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

$$
- \frac{1}{2} \sum_{a=1}^{2} A_0\Big(m_{A_a^0}^2\Big) \Gamma_{\breve{u}_i, \breve{u}_j^*, A_a^0, A_a^0} - \sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big) \Gamma_{\breve{u}_i, \breve{u}_j^*, H_a^+, H_a^-}
$$

$$
- \frac{1}{2} \sum_{a=1}^{2} A_0\Big(m_{h_a}^2\Big) \Gamma_{\breve{u}_i, \breve{u}_j^*, h_a, h_a}
$$

$$
- 2 \sum_{a=1}^{2} m_{\tilde{\chi}_a^-} \sum_{b=1}^{3} B_0\Big(p^2, m_{\tilde{\chi}_a^-}^2, m_{d_b}^2\Big) m_{d_b} \Big(\Gamma_{\breve{u}_j^*, \tilde{\chi}_a^+, d_b}^{L*} \Gamma_{\breve{u}_i^*, \tilde{\chi}_a^+, d_b}^{R} + \Gamma_{\breve{u}_j^*, \tilde{\chi}_a^+, d_b}^{R*} \Gamma_{\breve{u}_i^*, \tilde{\chi}_a^+, d_b}^{L}\Big)
$$

$$
+ \sum_{a=1}^{2} \sum_{b=1}^{3} G_0\Big(p^2, m_{\tilde{\chi}_a^-}^2, m_{d_b}^2\Big) \Big(\Gamma_{\breve{u}_j^*, \tilde{\chi}_a^+, d_b}^{L*} \Gamma_{\breve{u}_i^*, \tilde{\chi}_a^+, d_b}^{L} + \Gamma_{\breve{u}_j^*, \tilde{\chi}_a^+, d_b}^{R*} \Gamma_{\breve{u}_i^*, \tilde{\chi}_a^+, d_b}^{R}\Big)
$$

$$
+ \sum_{a=1}^{2} \sum_{b=1}^{6} B_0\Big(p^2, m_{H_a^-}^2, m_{\tilde{d}_b}^2\Big) \Gamma_{\breve{u}_j^*, H_a^+, \tilde{d}_b}^* \Gamma_{\breve{u}_i^*, H_a^+, \tilde{d}_b} - \sum_{a=1}^{3} A_0\Big(m_{\tilde{\nu}_a}^2\Big) \Gamma_{\breve{u}_i, \breve{u}_j^*, \tilde{\nu}_a^*, \tilde{\nu}_a}
$$

$$
- 2 \sum_{a=1}^{3} m_{u_a} \sum_{b=1}^{4} B_0\Big(p^2, m_{u_a}^2, m_{\tilde{\chi}_b^0}^2\Big) m_{\tilde{\chi}_b^0} \Big(\Gamma_{\breve{u}_j^*, u_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\breve{u}_i^*, u_a, \tilde{\chi}_b^0}^{R} + \Gamma_{\breve{u}_j^*, u_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\breve{u}_i^*, u_a, \tilde{\chi}_b^0}^{L}\Big)
$$

$$
+ \sum_{a=1}^{3} \sum_{b=1}^{4} G_0\Big(p^2, m_{u_a}^2, m_{\tilde{\chi}_b^0}^2\Big) \Big(\Gamma_{\breve{u}_j^*, u_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\breve{u}_i^*, u_a, \tilde{\chi}_b^0}^{L} + \Gamma_{\breve{u}_j^*, u_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\breve{u}_i^*, u_a, \tilde{\chi}_b^0}^{R}\Big)
$$

$$
- C \sum_{a=1}^{6} A_0\Big(m_{\tilde{d}_a}^2\Big) \Gamma_{\breve{u}_i, \breve{u}_j^*, \tilde{d}_a^*, \tilde{d}_a} - \sum_{a=1}^{6} A_0\Big(m_{\tilde{e}_a}^2\Big) \Gamma_{\breve{u}_i, \breve{u}_j^*, \tilde{e}_a^*, \tilde{e}_a}
$$

$$
- C \sum_{a=1}^{6} A_0\Big(m_{\tilde{u}_a}^2\Big) \Gamma_{\breve{u}_i, \breve{u}_j^*, \tilde{u}_a^*, \tilde{u}_a} + \sum_{a=1}^{6} \sum_{b=1}^{2} B_0\Big(p^2, m_{\tilde{u}_a}^2, m_{A_b^0}^2\Big) \Gamma_{\breve{u}_j^*, \tilde{u}_a, A_b^0}^* \Gamma_{\breve{u}_i^*, \tilde{u}_a, A_b^0}
$$

$$
+ \sum_{a=1}^{6} \sum_{b=1}^{2} B_0\Big(p^2, m_{\tilde{u}_a}^2, m_{h_b}^2\Big) \Gamma_{\breve{u}_j^*, \tilde{u}_a, h_b}^* \Gamma_{\breve{u}_i^*, \tilde{u}_a, h_b}
$$

$$
- \frac{8}{3} m_{\tilde{g}} \sum_{b=1}^{3} B_0\Big(p^2, m_{\tilde{g}}^2, m_{u_b}^2\Big) m_{u_b} \Big(\Gamma_{\breve{u}_j^*, \tilde{g}_1, u_b}^{L*} \Gamma_{\breve{u}_i^*, \tilde{g}_1, u_b}^{R} + \Gamma_{\breve{u}_j^*, \tilde{g}_1, u_b}^{R*} \Gamma_{\breve{u}_i^*, \tilde{g}_1, u_b}^{L}\Big)
$$

$$+ \frac{4}{3} \sum_{b=1}^{3} G_0\Big(p^2, m_{\tilde{g}}^2, m_{u_b}^2\Big)\Big(\Gamma^{L*}_{\breve{u}_j^*,\tilde{g}_1,u_b}\,\Gamma^{L}_{\breve{u}_i^*,\tilde{g}_1,u_b} + \Gamma^{R*}_{\breve{u}_j^*,\tilde{g}_1,u_b}\,\Gamma^{R}_{\breve{u}_i^*,\tilde{g}_1,u_b}\Big)$$

$$+ \sum_{b=1}^{6} \Gamma^{*}_{\breve{u}_j^*,W^+,\tilde{d}_b}\,\Gamma_{\breve{u}_i^*,W^+,\tilde{d}_b}\,F_0\Big(p^2, m_{\tilde{d}_b}^2, m_{W^-}^2\Big) + \frac{4}{3} \sum_{b=1}^{6} \Gamma^{*}_{\breve{u}_j^*,g,\tilde{u}_b}\,\Gamma_{\breve{u}_i^*,g,\tilde{u}_b}\,F_0\Big(p^2, m_{\tilde{u}_b}^2, 0\Big)$$

$$+ \sum_{b=1}^{6} \Gamma^{*}_{\breve{u}_j^*,\gamma,\tilde{u}_b}\,\Gamma_{\breve{u}_i^*,\gamma,\tilde{u}_b}\,F_0\Big(p^2, m_{\tilde{u}_b}^2, 0\Big) + \sum_{b=1}^{6} \Gamma^{*}_{\breve{u}_j^*,Z,\tilde{u}_b}\,\Gamma_{\breve{u}_i^*,Z,\tilde{u}_b}\,F_0\Big(p^2, m_{\tilde{u}_b}^2, m_Z^2\Big) \tag{138}$$

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

$$\Pi_{i,j}(p^2) = +4\Gamma_{\breve{e}_i,\breve{e}_j^*,W^+,W^-}\Big(-\frac{1}{2}\mathrm{rMS}m_{W^-}^2 + A_0\Big(m_{W^-}^2\Big)\Big) + 2\Gamma_{\breve{e}_i,\breve{e}_j^*,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\Big(m_Z^2\Big)\Big)$$

$$- \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{A_a^0}^2\Big)\Gamma_{\breve{e}_i,\breve{e}_j^*,A_a^0,A_a^0} - \sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big)\Gamma_{\breve{e}_i,\breve{e}_j^*,H_a^+,H_a^-}$$

$$- \frac{1}{2}\sum_{a=1}^{2} A_0\Big(m_{h_a}^2\Big)\Gamma_{\breve{e}_i,\breve{e}_j^*,h_a,h_a} - \sum_{a=1}^{3} A_0\Big(m_{\tilde{\nu}_a}^2\Big)\Gamma_{\breve{e}_i,\breve{e}_j^*,\tilde{\nu}_a^*,\tilde{\nu}_a}$$

$$+ \sum_{a=1}^{3}\sum_{b=1}^{2} B_0\Big(p^2, m_{\tilde{\nu}_a}^2, m_{H_b^-}^2\Big)\Gamma^{*}_{\breve{e}_j^*,\tilde{\nu}_a,H_b^-}\,\Gamma_{\breve{e}_i^*,\tilde{\nu}_a,H_b^-}$$

$$- 2\sum_{a=1}^{3} m_{\nu_a} \sum_{b=1}^{2} B_0\Big(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^-}^2\Big) m_{\tilde{\chi}_b^-}\Big(\Gamma^{L*}_{\breve{e}_j^*,\nu_a,\tilde{\chi}_b^-}\,\Gamma^{R}_{\breve{e}_i^*,\nu_a,\tilde{\chi}_b^-} + \Gamma^{R*}_{\breve{e}_j^*,\nu_a,\tilde{\chi}_b^-}\,\Gamma^{L}_{\breve{e}_i^*,\nu_a,\tilde{\chi}_b^-}\Big)$$

$$+ \sum_{a=1}^{3}\sum_{b=1}^{2} G_0\Big(p^2, m_{\nu_a}^2, m_{\tilde{\chi}_b^-}^2\Big)\Big(\Gamma^{L*}_{\breve{e}_j^*,\nu_a,\tilde{\chi}_b^-}\,\Gamma^{L}_{\breve{e}_i^*,\nu_a,\tilde{\chi}_b^-} + \Gamma^{R*}_{\breve{e}_j^*,\nu_a,\tilde{\chi}_b^-}\,\Gamma^{R}_{\breve{e}_i^*,\nu_a,\tilde{\chi}_b^-}\Big)$$

$$- 2\sum_{a=1}^{3} m_{e_a} \sum_{b=1}^{4} B_0\Big(p^2, m_{e_a}^2, m_{\tilde{\chi}_b^0}^2\Big) m_{\tilde{\chi}_b^0}\Big(\Gamma^{L*}_{\breve{e}_j^*,e_a,\tilde{\chi}_b^0}\,\Gamma^{R}_{\breve{e}_i^*,e_a,\tilde{\chi}_b^0} + \Gamma^{R*}_{\breve{e}_j^*,e_a,\tilde{\chi}_b^0}\,\Gamma^{L}_{\breve{e}_i^*,e_a,\tilde{\chi}_b^0}\Big)$$

$$+ \sum_{a=1}^{3}\sum_{b=1}^{4} G_0\Big(p^2, m_{e_a}^2, m_{\tilde{\chi}_b^0}^2\Big)\Big(\Gamma^{L*}_{\breve{e}_j^*,e_a,\tilde{\chi}_b^0}\,\Gamma^{L}_{\breve{e}_i^*,e_a,\tilde{\chi}_b^0} + \Gamma^{R*}_{\breve{e}_j^*,e_a,\tilde{\chi}_b^0}\,\Gamma^{R}_{\breve{e}_i^*,e_a,\tilde{\chi}_b^0}\Big)$$

$$- 3\sum_{a=1}^{6} A_0\Big(m_{\tilde{d}_a}^2\Big)\Gamma_{\breve{e}_i,\breve{e}_j^*,\tilde{d}_a^*,\tilde{d}_a} - \sum_{a=1}^{6} A_0\Big(m_{\tilde{e}_a}^2\Big)\Gamma_{\breve{e}_i,\breve{e}_j^*,\tilde{e}_a^*,\tilde{e}_a}$$

$$- 3\sum_{a=1}^{6} A_0\Big(m_{\tilde{u}_a}^2\Big)\Gamma_{\breve{e}_i,\breve{e}_j^*,\tilde{u}_a^*,\tilde{u}_a} + \sum_{a=1}^{6}\sum_{b=1}^{2} B_0\Big(p^2, m_{\tilde{e}_a}^2, m_{A_b^0}^2\Big)\Gamma^{*}_{\breve{e}_j^*,\tilde{e}_a,A_b^0}\,\Gamma_{\breve{e}_i^*,\tilde{e}_a,A_b^0}$$

$$+ \sum_{a=1}^{6}\sum_{b=1}^{2} B_0\Big(p^2, m_{\tilde{e}_a}^2, m_{h_b}^2\Big)\Gamma^{*}_{\breve{e}_j^*,\tilde{e}_a,h_b}\,\Gamma_{\breve{e}_i^*,\tilde{e}_a,h_b} + \sum_{b=1}^{3} \Gamma^{*}_{\breve{e}_j^*,W^-,\tilde{\nu}_b}\,\Gamma_{\breve{e}_i^*,W^-,\tilde{\nu}_b}\,F_0\Big(p^2, m_{\tilde{\nu}_b}^2, m_{W^-}^2\Big)$$

$$+ \sum_{b=1}^{6} \Gamma^{*}_{\breve{e}_j^*,\gamma,\tilde{e}_b}\,\Gamma_{\breve{e}_i^*,\gamma,\tilde{e}_b}\,F_0\Big(p^2, m_{\tilde{e}_b}^2, 0\Big) + \sum_{b=1}^{6} \Gamma^{*}_{\breve{e}_j^*,Z,\tilde{e}_b}\,\Gamma_{\breve{e}_i^*,Z,\tilde{e}_b}\,F_0\Big(p^2, m_{\tilde{e}_b}^2, m_Z^2\Big) \tag{139}$$

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- **Self-Energy for Higgs** (h)

$$
\begin{aligned}
\Pi_{i,j}(p^2) = {} & +2\Big(-\tfrac{1}{2}\mathrm{rMS} + B_0\big(p^2, m_Z^2, m_Z^2\big)\Big)\Gamma^*_{\check{h}_j,Z,Z}\Gamma_{\check{h}_i,Z,Z} + 4\Big(-\tfrac{1}{2}\mathrm{rMS} + B_0\big(p^2, m_{W^-}^2, m_{W^-}^2\big)\Big)\Gamma^*_{\check{h}_j,W^+,W^-}\Gamma_{\check{h}_i,W^+,W^-} \\
& - B_0\big(p^2, m_{\eta^-}^2, m_{\eta^-}^2\big)\Gamma_{\check{h}_i,\eta^-,\eta^-}\Gamma_{\check{h}_j,\eta^-,\eta^-} - B_0\big(p^2, m_{\eta^+}^2, m_{\eta^+}^2\big)\Gamma_{\check{h}_i,\eta^+,\eta^+}\Gamma_{\check{h}_j,\eta^+,\eta^+} \\
& - B_0\big(p^2, m_{\eta^Z}^2, m_{\eta^Z}^2\big)\Gamma_{\check{h}_i,\bar{\eta}^Z,\eta^Z}\Gamma_{\check{h}_j,\bar{\eta}^Z,\eta^Z} + 4\Gamma_{\check{h}_i,\check{h}_j,W^+,W^-}\Big(-\tfrac{1}{2}\mathrm{rMS}\,m_{W^-}^2 + A_0\big(m_{W^-}^2\big)\Big) \\
& + 2\Gamma_{\check{h}_i,\check{h}_j,Z,Z}\Big(-\tfrac{1}{2}\mathrm{rMS}\,m_Z^2 + A_0\big(m_Z^2\big)\Big) - \tfrac{1}{2}\sum_{a=1}^{2} A_0\big(m_{A_a^0}^2\big)\Gamma_{\check{h}_i,\check{h}_j,A_a^0,A_a^0} \\
& - \sum_{a=1}^{2} A_0\big(m_{H_a^-}^2\big)\Gamma_{\check{h}_i,\check{h}_j,H_a^+,H_a^-} - \tfrac{1}{2}\sum_{a=1}^{2} A_0\big(m_{h_a}^2\big)\Gamma_{\check{h}_i,\check{h}_j,h_a,h_a} \\
& + \tfrac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{2} B_0\big(p^2, m_{A_a^0}^2, m_{A_b^0}^2\big)\Gamma^*_{\check{h}_j,A_a^0,A_b^0}\Gamma_{\check{h}_i,A_a^0,A_b^0} \\
& + \sum_{a=1}^{2}\sum_{b=1}^{2} B_0\big(p^2, m_{H_a^-}^2, m_{H_b^-}^2\big)\Gamma^*_{\check{h}_j,H_a^+,H_b^-}\Gamma_{\check{h}_i,H_a^+,H_b^-} \\
& + \tfrac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{2} B_0\big(p^2, m_{h_a}^2, m_{h_b}^2\big)\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\big(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2\big) m_{\tilde{\chi}_b^-}\Big(\Gamma^{L*}_{\check{h}_j,\tilde{\chi}_a^+,\tilde{\chi}_b^-}\Gamma^{R}_{\check{h}_i,\tilde{\chi}_a^+,\tilde{\chi}_b^-} + \Gamma^{R*}_{\check{h}_j,\tilde{\chi}_a^+,\tilde{\chi}_b^-}\Gamma^{L}_{\check{h}_i,\tilde{\chi}_a^+,\tilde{\chi}_b^-}\Big) \\
& + \sum_{a=1}^{2}\sum_{b=1}^{2} G_0\big(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2\big)\Big(\Gamma^{L*}_{\check{h}_j,\tilde{\chi}_a^+,\tilde{\chi}_b^-}\Gamma^{L}_{\check{h}_i,\tilde{\chi}_a^+,\tilde{\chi}_b^-} + \Gamma^{R*}_{\check{h}_j,\tilde{\chi}_a^+,\tilde{\chi}_b^-}\Gamma^{R}_{\check{h}_i,\tilde{\chi}_a^+,\tilde{\chi}_b^-}\Big) \\
& - \sum_{a=1}^{3} A_0\big(m_{\tilde{\nu}_a}^2\big)\Gamma_{\check{h}_i,\check{h}_j,\tilde{\nu}_a^*,\tilde{\nu}_a} + \sum_{a=1}^{3}\sum_{b=1}^{3} B_0\big(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2\big)\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\big(p^2, m_{d_a}^2, m_{d_b}^2\big) m_{d_b}\Big(\Gamma^{L*}_{\check{h}_j,\bar{d}_a,d_b}\Gamma^{R}_{\check{h}_i,\bar{d}_a,d_b} + \Gamma^{R*}_{\check{h}_j,\bar{d}_a,d_b}\Gamma^{L}_{\check{h}_i,\bar{d}_a,d_b}\Big) \\
& + 3\sum_{a=1}^{3}\sum_{b=1}^{3} G_0\big(p^2, m_{d_a}^2, m_{d_b}^2\big)\Big(\Gamma^{L*}_{\check{h}_j,\bar{d}_a,d_b}\Gamma^{L}_{\check{h}_i,\bar{d}_a,d_b} + \Gamma^{R*}_{\check{h}_j,\bar{d}_a,d_b}\Gamma^{R}_{\check{h}_i,\bar{d}_a,d_b}\Big) \\
& - 2\sum_{a=1}^{3} m_{e_a} \sum_{b=1}^{3} B_0\big(p^2, m_{e_a}^2, m_{e_b}^2\big) m_{e_b}\Big(\Gamma^{L*}_{\check{h}_j,\bar{e}_a,e_b}\Gamma^{R}_{\check{h}_i,\bar{e}_a,e_b} + \Gamma^{R*}_{\check{h}_j,\bar{e}_a,e_b}\Gamma^{L}_{\check{h}_i,\bar{e}_a,e_b}\Big) \\
& + \sum_{a=1}^{3}\sum_{b=1}^{3} G_0\big(p^2, m_{e_a}^2, m_{e_b}^2\big)\Big(\Gamma^{L*}_{\check{h}_j,\bar{e}_a,e_b}\Gamma^{L}_{\check{h}_i,\bar{e}_a,e_b} + \Gamma^{R*}_{\check{h}_j,\bar{e}_a,e_b}\Gamma^{R}_{\check{h}_i,\bar{e}_a,e_b}\Big) \\
& - 6\sum_{a=1}^{3} m_{u_a} \sum_{b=1}^{3} B_0\big(p^2, m_{u_a}^2, m_{u_b}^2\big) m_{u_b}\Big(\Gamma^{L*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{R}_{\check{h}_i,\bar{u}_a,u_b} + \Gamma^{R*}_{\check{h}_j,\bar{u}_a,u_b}\Gamma^{L}_{\check{h}_i,\bar{u}_a,u_b}\Big)
\end{aligned}
$$

$$
+ 3 \sum_{a=1}^{3} \sum_{b=1}^{3} G_0\Big(p^2, m_{u_a}^2, m_{u_b}^2\Big) \Big(\Gamma_{\check{h}_j, \bar{u}_a, u_b}^{L*} \Gamma_{\check{h}_i, \bar{u}_a, u_b}^{L} + \Gamma_{\check{h}_j, \bar{u}_a, u_b}^{R*} \Gamma_{\check{h}_i, \bar{u}_a, u_b}^{R} \Big)
$$

$$
- \sum_{a=1}^{4} m_{\tilde{\chi}_a^0} \sum_{b=1}^{4} B_0\Big(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2\Big) m_{\tilde{\chi}_b^0} \Big(\Gamma_{\check{h}_j, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L*} \Gamma_{\check{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{R} + \Gamma_{\check{h}_j, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{R*} \Gamma_{\check{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L} \Big)
$$

$$
+ \frac{1}{2} \sum_{a=1}^{4} \sum_{b=1}^{4} G_0\Big(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2\Big) \Big(\Gamma_{\check{h}_j, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L*} \Gamma_{\check{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{L} + \Gamma_{\check{h}_j, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{R*} \Gamma_{\check{h}_i, \tilde{\chi}_a^0, \tilde{\chi}_b^0}^{R} \Big)
$$

$$
- 3 \sum_{a=1}^{6} A_0\Big(m_{\tilde{d}_a}^2\Big) \Gamma_{\check{h}_i, \check{h}_j, \tilde{d}_a^*, \tilde{d}_a} - \sum_{a=1}^{6} A_0\Big(m_{\tilde{e}_a}^2\Big) \Gamma_{\check{h}_i, \check{h}_j, \tilde{e}_a^*, \tilde{e}_a}
$$

$$
- 3 \sum_{a=1}^{6} A_0\Big(m_{\tilde{u}_a}^2\Big) \Gamma_{\check{h}_i, \check{h}_j, \tilde{u}_a^*, \tilde{u}_a} + 3 \sum_{a=1}^{6} \sum_{b=1}^{6} B_0\Big(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2\Big) \Gamma_{\check{h}_j, \tilde{d}_a^*, \tilde{d}_b}^{*} \Gamma_{\check{h}_i, \tilde{d}_a^*, \tilde{d}_b}
$$

$$
+ \sum_{a=1}^{6} \sum_{b=1}^{6} B_0\Big(p^2, m_{\tilde{e}_a}^2, m_{\tilde{e}_b}^2\Big) \Gamma_{\check{h}_j, \tilde{e}_a^*, \tilde{e}_b}^{*} \Gamma_{\check{h}_i, \tilde{e}_a^*, \tilde{e}_b} + 3 \sum_{a=1}^{6} \sum_{b=1}^{6} B_0\Big(p^2, m_{\tilde{u}_a}^2, m_{\tilde{u}_b}^2\Big) \Gamma_{\check{h}_j, \tilde{u}_a^*, \tilde{u}_b}^{*} \Gamma_{\check{h}_i, \tilde{u}_a^*, \tilde{u}_b}
$$

$$
+ \sum_{b=1}^{2} \Gamma_{\check{h}_j, Z, A_b^0}^{*} \Gamma_{\check{h}_i, Z, A_b^0} F_0\Big(p^2, m_{A_b^0}^2, m_Z^2\Big) + 2 \sum_{b=1}^{2} \Gamma_{\check{h}_j, W^+, H_b^-}^{*} \Gamma_{\check{h}_i, W^+, H_b^-} F_0\Big(p^2, m_{H_b^-}^2, m_{W^-}^2\Big) \tag{140}
$$

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

$$
\Pi_{i,j}(p^2) = -B_0\Big(p^2, m_{\eta^-}^2, m_{\eta^-}^2\Big) \Gamma_{\check{A}_i^0, \eta^-, \eta^-} \Gamma_{\check{A}_j^0, \eta^-, \eta^-} - B_0\Big(p^2, m_{\eta^+}^2, m_{\eta^+}^2\Big) \Gamma_{\check{A}_i^0, \eta^+, \eta^+} \Gamma_{\check{A}_j^0, \eta^+, \eta^+}
$$

$$
+ 4 \Gamma_{\check{A}_i^0, \check{A}_j^0, W^+, W^-} \Big(-\frac{1}{2} \mathrm{rMS} m_{W^-}^2 + A_0\Big(m_{W^-}^2\Big) \Big) + 2 \Gamma_{\check{A}_i^0, \check{A}_j^0, Z, Z} \Big(-\frac{1}{2} \mathrm{rMS} m_Z^2 + A_0\Big(m_Z^2\Big) \Big)
$$

$$
- \frac{1}{2} \sum_{a=1}^{2} A_0\Big(m_{A_a^0}^2\Big) \Gamma_{\check{A}_i^0, \check{A}_j^0, A_a^0, A_a^0} - \sum_{a=1}^{2} A_0\Big(m_{H_a^-}^2\Big) \Gamma_{\check{A}_i^0, \check{A}_j^0, H_a^+, H_a^-}
$$

$$
- \frac{1}{2} \sum_{a=1}^{2} A_0\Big(m_{h_a}^2\Big) \Gamma_{\check{A}_i^0, \check{A}_j^0, h_a, h_a} + \sum_{a=1}^{2} \sum_{b=1}^{2} B_0\Big(p^2, m_{H_a^-}^2, m_{H_b^-}^2\Big) \Gamma_{\check{A}_j^0, H_a^+, H_b^-}^{*} \Gamma_{\check{A}_i^0, H_a^+, H_b^-}
$$

$$
+ \sum_{a=1}^{2} \sum_{b=1}^{2} B_0\Big(p^2, m_{h_a}^2, m_{A_b^0}^2\Big) \Gamma_{\check{A}_j^0, h_a, A_b^0}^{*} \Gamma_{\check{A}_i^0, h_a, A_b^0}
$$

$$
- 2 \sum_{a=1}^{2} m_{\tilde{\chi}_a^-} \sum_{b=1}^{2} B_0\Big(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2\Big) m_{\tilde{\chi}_b^-} \Big(\Gamma_{\check{A}_j^0, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\check{A}_i^0, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{R} + \Gamma_{\check{A}_j^0, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\check{A}_i^0, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L} \Big)
$$

$$
+ \sum_{a=1}^{2} \sum_{b=1}^{2} G_0\Big(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2\Big) \Big(\Gamma_{\check{A}_j^0, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L*} \Gamma_{\check{A}_i^0, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{L} + \Gamma_{\check{A}_j^0, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{R*} \Gamma_{\check{A}_i^0, \tilde{\chi}_a^+, \tilde{\chi}_b^-}^{R} \Big)
$$

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

$$
-6\sum_{a=1}^{3} m_{d_a} \sum_{b=1}^{3} B_0\Big(p^2, m_{d_a}^2, m_{d_b}^2\Big) m_{d_b}\Big(\Gamma^{L*}_{\breve{A}^0_j,\bar{d}_a,d_b}\Gamma^{R}_{\breve{A}^0_i,\bar{d}_a,d_b} + \Gamma^{R*}_{\breve{A}^0_j,\bar{d}_a,d_b}\Gamma^{L}_{\breve{A}^0_i,\bar{d}_a,d_b}\Big)
$$

$$
+3\sum_{a=1}^{3}\sum_{b=1}^{3} G_0\Big(p^2, m_{d_a}^2, m_{d_b}^2\Big)\Big(\Gamma^{L*}_{\breve{A}^0_j,\bar{d}_a,d_b}\Gamma^{L}_{\breve{A}^0_i,\bar{d}_a,d_b} + \Gamma^{R*}_{\breve{A}^0_j,\bar{d}_a,d_b}\Gamma^{R}_{\breve{A}^0_i,\bar{d}_a,d_b}\Big)
$$

$$
-2\sum_{a=1}^{3} m_{e_a} \sum_{b=1}^{3} B_0\Big(p^2, m_{e_a}^2, m_{e_b}^2\Big) m_{e_b}\Big(\Gamma^{L*}_{\breve{A}^0_j,\bar{e}_a,e_b}\Gamma^{R}_{\breve{A}^0_i,\bar{e}_a,e_b} + \Gamma^{R*}_{\breve{A}^0_j,\bar{e}_a,e_b}\Gamma^{L}_{\breve{A}^0_i,\bar{e}_a,e_b}\Big)
$$

$$
+\sum_{a=1}^{3}\sum_{b=1}^{3} G_0\Big(p^2, m_{e_a}^2, m_{e_b}^2\Big)\Big(\Gamma^{L*}_{\breve{A}^0_j,\bar{e}_a,e_b}\Gamma^{L}_{\breve{A}^0_i,\bar{e}_a,e_b} + \Gamma^{R*}_{\breve{A}^0_j,\bar{e}_a,e_b}\Gamma^{R}_{\breve{A}^0_i,\bar{e}_a,e_b}\Big)
$$

$$
-6\sum_{a=1}^{3} m_{u_a} \sum_{b=1}^{3} B_0\Big(p^2, m_{u_a}^2, m_{u_b}^2\Big) m_{u_b}\Big(\Gamma^{L*}_{\breve{A}^0_j,\bar{u}_a,u_b}\Gamma^{R}_{\breve{A}^0_i,\bar{u}_a,u_b} + \Gamma^{R*}_{\breve{A}^0_j,\bar{u}_a,u_b}\Gamma^{L}_{\breve{A}^0_i,\bar{u}_a,u_b}\Big)
$$

$$
+3\sum_{a=1}^{3}\sum_{b=1}^{3} G_0\Big(p^2, m_{u_a}^2, m_{u_b}^2\Big)\Big(\Gamma^{L*}_{\breve{A}^0_j,\bar{u}_a,u_b}\Gamma^{L}_{\breve{A}^0_i,\bar{u}_a,u_b} + \Gamma^{R*}_{\breve{A}^0_j,\bar{u}_a,u_b}\Gamma^{R}_{\breve{A}^0_i,\bar{u}_a,u_b}\Big)
$$

$$
-\sum_{a=1}^{4} m_{\tilde{\chi}^0_a} \sum_{b=1}^{4} B_0\Big(p^2, m_{\tilde{\chi}^0_a}^2, m_{\tilde{\chi}^0_b}^2\Big) m_{\tilde{\chi}^0_b}\Big(\Gamma^{L*}_{\breve{A}^0_j,\tilde{\chi}^0_a,\tilde{\chi}^0_b}\Gamma^{R}_{\breve{A}^0_i,\tilde{\chi}^0_a,\tilde{\chi}^0_b} + \Gamma^{R*}_{\breve{A}^0_j,\tilde{\chi}^0_a,\tilde{\chi}^0_b}\Gamma^{L}_{\breve{A}^0_i,\tilde{\chi}^0_a,\tilde{\chi}^0_b}\Big)
$$

$$
+\frac{1}{2}\sum_{a=1}^{4}\sum_{b=1}^{4} G_0\Big(p^2, m_{\tilde{\chi}^0_a}^2, m_{\tilde{\chi}^0_b}^2\Big)\Big(\Gamma^{L*}_{\breve{A}^0_j,\tilde{\chi}^0_a,\tilde{\chi}^0_b}\Gamma^{L}_{\breve{A}^0_i,\tilde{\chi}^0_a,\tilde{\chi}^0_b} + \Gamma^{R*}_{\breve{A}^0_j,\tilde{\chi}^0_a,\tilde{\chi}^0_b}\Gamma^{R}_{\breve{A}^0_i,\tilde{\chi}^0_a,\tilde{\chi}^0_b}\Big)
$$

$$
-3\sum_{a=1}^{6} A_0\Big(m_{\tilde{d}_a}^2\Big)\Gamma_{\breve{A}^0_i,\breve{A}^0_j,\tilde{d}^*_a,\tilde{d}_a} - \sum_{a=1}^{6} A_0\Big(m_{\tilde{e}_a}^2\Big)\Gamma_{\breve{A}^0_i,\breve{A}^0_j,\tilde{e}^*_a,\tilde{e}_a}
$$

$$
-3\sum_{a=1}^{6} A_0\Big(m_{\tilde{u}_a}^2\Big)\Gamma_{\breve{A}^0_i,\breve{A}^0_j,\tilde{u}^*_a,\tilde{u}_a} + 3\sum_{a=1}^{6}\sum_{b=1}^{6} B_0\Big(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2\Big)\Gamma^*_{\breve{A}^0_j,\tilde{d}^*_a,\tilde{d}_b}\Gamma_{\breve{A}^0_i,\tilde{d}^*_a,\tilde{d}_b}
$$

$$
+\sum_{a=1}^{6}\sum_{b=1}^{6} B_0\Big(p^2, m_{\tilde{e}_a}^2, m_{\tilde{e}_b}^2\Big)\Gamma^*_{\breve{A}^0_j,\tilde{e}^*_a,\tilde{e}_b}\Gamma_{\breve{A}^0_i,\tilde{e}^*_a,\tilde{e}_b}
$$

$$
+3\sum_{a=1}^{6}\sum_{b=1}^{6} B_0\Big(p^2, m_{\tilde{u}_a}^2, m_{\tilde{u}_b}^2\Big)\Gamma^*_{\breve{A}^0_j,\tilde{u}^*_a,\tilde{u}_b}\Gamma_{\breve{A}^0_i,\tilde{u}^*_a,\tilde{u}_b} + \sum_{b=1}^{2}\Gamma^*_{\breve{A}^0_j,Z,h_b}\Gamma_{\breve{A}^0_i,Z,h_b}F_0\Big(p^2, m_{h_b}^2, m_Z^2\Big)
$$

$$
+2\sum_{b=1}^{2}\Gamma^*_{\breve{A}^0_j,W^+,H^-_b}\Gamma_{\breve{A}^0_i,W^+,H^-_b}F_0\Big(p^2, m_{H^-_b}^2, m_{W^-}^2\Big) \tag{141}
$$

- **Self-Energy for Charged Higgs** (H^-)

$$
\Pi_{i,j}(p^2) = +4\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, 0, m_{W^-}^2\Big)\Big)\Gamma^*_{\breve{H}^+_j,W^-,\gamma}\Gamma_{\breve{H}^+_i,W^-,\gamma} + 4\Big(-\frac{1}{2}\mathrm{rMS} + B_0\Big(p^2, m_{W^-}^2, m_Z^2\Big)\Big)\Gamma^*_{\breve{H}^+_j,Z,W^-}\Gamma_{\breve{H}^+_i,Z,W^-}
$$

$$
- B_0\Big(p^2, m_{\eta^Z}^2, m_{\eta^+}^2\Big)\Gamma_{\breve{H}^+_i,\bar{\eta}^+,\eta^Z}\Gamma_{\breve{H}^-_j,\eta^+,\bar{\eta}^Z} - B_0\Big(p^2, m_{\eta^-}^2, m_{\eta^Z}^2\Big)\Gamma_{\breve{H}^+_i,\bar{\eta}^Z,\eta^-}\Gamma_{\breve{H}^-_j,\eta^Z,\bar{\eta}^-}
$$

$$+ 4\Gamma_{\breve{H}_i^-,\breve{H}_j^+,W^+,W^-}\left(-\frac{1}{2}\mathrm{rMS}m_{W^-}^2 + A_0\left(m_{W^-}^2\right)\right) + 2\Gamma_{\breve{H}_i^-,\breve{H}_j^+,Z,Z}\left(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\left(m_Z^2\right)\right)$$

$$- \frac{1}{2}\sum_{a=1}^{2} A_0\left(m_{A_a^0}^2\right)\Gamma_{\breve{H}_i^-,\breve{H}_j^+,A_a^0,A_a^0} - \sum_{a=1}^{2} A_0\left(m_{H_a^-}^2\right)\Gamma_{\breve{H}_i^-,\breve{H}_j^+,H_a^+,H_a^-}$$

$$- \frac{1}{2}\sum_{a=1}^{2} A_0\left(m_{h_a}^2\right)\Gamma_{\breve{H}_i^-,\breve{H}_j^+,h_a,h_a} + \sum_{a=1}^{2}\sum_{b=1}^{2} B_0\left(p^2,m_{H_a^-}^2,m_{A_b^0}^2\right)\Gamma_{\breve{H}_j^+,H_a^-,A_b^0}^{*}\Gamma_{\breve{H}_i^+,H_a^-,A_b^0}$$

$$+ \sum_{a=1}^{2}\sum_{b=1}^{2} B_0\left(p^2,m_{H_a^-}^2,m_{h_b}^2\right)\Gamma_{\breve{H}_j^+,H_a^-,h_b}^{*}\Gamma_{\breve{H}_i^+,H_a^-,h_b} - \sum_{a=1}^{3} A_0\left(m_{\tilde{\nu}_a}^2\right)\Gamma_{\breve{H}_i^-,\breve{H}_j^+,\tilde{\nu}_a^*,\tilde{\nu}_a}$$

$$- 6\sum_{a=1}^{3} m_{u_a}\sum_{b=1}^{3} B_0\left(p^2,m_{u_a}^2,m_{d_b}^2\right)m_{d_b}\left(\Gamma_{\breve{H}_j^+,\bar{u}_a,d_b}^{L*}\Gamma_{\breve{H}_i^+,\bar{u}_a,d_b}^{R} + \Gamma_{\breve{H}_j^+,\bar{u}_a,d_b}^{R*}\Gamma_{\breve{H}_i^+,\bar{u}_a,d_b}^{L}\right)$$

$$+ 3\sum_{a=1}^{3}\sum_{b=1}^{3} G_0\left(p^2,m_{u_a}^2,m_{d_b}^2\right)\left(\Gamma_{\breve{H}_j^+,\bar{u}_a,d_b}^{L*}\Gamma_{\breve{H}_i^+,\bar{u}_a,d_b}^{L} + \Gamma_{\breve{H}_j^+,\bar{u}_a,d_b}^{R*}\Gamma_{\breve{H}_i^+,\bar{u}_a,d_b}^{R}\right)$$

$$- 2\sum_{a=1}^{3} m_{\nu_a}\sum_{b=1}^{3} B_0\left(p^2,m_{\nu_a}^2,m_{e_b}^2\right)m_{e_b}\left(\Gamma_{\breve{H}_j^+,\bar{\nu}_a,e_b}^{L*}\Gamma_{\breve{H}_i^+,\bar{\nu}_a,e_b}^{R} + \Gamma_{\breve{H}_j^+,\bar{\nu}_a,e_b}^{R*}\Gamma_{\breve{H}_i^+,\bar{\nu}_a,e_b}^{L}\right)$$

$$+ \sum_{a=1}^{3}\sum_{b=1}^{3} G_0\left(p^2,m_{\nu_a}^2,m_{e_b}^2\right)\left(\Gamma_{\breve{H}_j^+,\bar{\nu}_a,e_b}^{L*}\Gamma_{\breve{H}_i^+,\bar{\nu}_a,e_b}^{L} + \Gamma_{\breve{H}_j^+,\bar{\nu}_a,e_b}^{R*}\Gamma_{\breve{H}_i^+,\bar{\nu}_a,e_b}^{R}\right)$$

$$+ \sum_{a=1}^{3}\sum_{b=1}^{6} B_0\left(p^2,m_{\tilde{\nu}_a}^2,m_{\tilde{e}_b}^2\right)\Gamma_{\breve{H}_j^+,\tilde{\nu}_a^*,\tilde{e}_b}^{*}\Gamma_{\breve{H}_i^+,\tilde{\nu}_a^*,\tilde{e}_b}$$

$$- 2\sum_{a=1}^{4} m_{\tilde{\chi}_a^0}\sum_{b=1}^{2} B_0\left(p^2,m_{\tilde{\chi}_a^0}^2,m_{\tilde{\chi}_b^-}^2\right)m_{\tilde{\chi}_b^-}\left(\Gamma_{\breve{H}_j^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^{L*}\Gamma_{\breve{H}_i^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^{R} + \Gamma_{\breve{H}_j^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^{R*}\Gamma_{\breve{H}_i^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^{L}\right)$$

$$+ \sum_{a=1}^{4}\sum_{b=1}^{2} G_0\left(p^2,m_{\tilde{\chi}_a^0}^2,m_{\tilde{\chi}_b^-}^2\right)\left(\Gamma_{\breve{H}_j^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^{L*}\Gamma_{\breve{H}_i^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^{L} + \Gamma_{\breve{H}_j^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^{R*}\Gamma_{\breve{H}_i^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^{R}\right)$$

$$- 3\sum_{a=1}^{6} A_0\left(m_{\tilde{d}_a}^2\right)\Gamma_{\breve{H}_i^-,\breve{H}_j^+,\tilde{d}_a^*,\tilde{d}_a} - \sum_{a=1}^{6} A_0\left(m_{\tilde{e}_a}^2\right)\Gamma_{\breve{H}_i^-,\breve{H}_j^+,\tilde{e}_a^*,\tilde{e}_a}$$

$$- 3\sum_{a=1}^{6} A_0\left(m_{\tilde{u}_a}^2\right)\Gamma_{\breve{H}_i^-,\breve{H}_j^+,\tilde{u}_a^*,\tilde{u}_a} + 3\sum_{a=1}^{6}\sum_{b=1}^{6} B_0\left(p^2,m_{\tilde{u}_a}^2,m_{\tilde{d}_b}^2\right)\Gamma_{\breve{H}_j^+,\tilde{u}_a^*,\tilde{d}_b}^{*}\Gamma_{\breve{H}_i^+,\tilde{u}_a^*,\tilde{d}_b}$$

$$+ \sum_{b=1}^{2}\Gamma_{\breve{H}_j^+,W^-,A_b^0}^{*}\Gamma_{\breve{H}_i^+,W^-,A_b^0} F_0\left(p^2,m_{A_b^0}^2,m_{W^-}^2\right) + \sum_{b=1}^{2}\Gamma_{\breve{H}_j^+,W^-,h_b}^{*}\Gamma_{\breve{H}_i^+,W^-,h_b} F_0\left(p^2,m_{h_b}^2,m_{W^-}^2\right)$$

$$+ \sum_{b=1}^{2}\Gamma_{\breve{H}_j^+,\gamma,H_b^-}^{*}\Gamma_{\breve{H}_i^+,\gamma,H_b^-} F_0\left(p^2,m_{H_b^-}^2,0\right) + \sum_{b=1}^{2}\Gamma_{\breve{H}_j^+,Z,H_b^-}^{*}\Gamma_{\breve{H}_i^+,Z,H_b^-} F_0\left(p^2,m_{H_b^-}^2,m_Z^2\right) \qquad (142)$$

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

$$\Sigma_{i,j}^{S}(p^2) = +2\sum_{a=1}^{2}\sum_{b=1}^{2}B_0\Big(p^2,m_{\tilde{\chi}_b^-}^2,m_{H_a^-}^2\Big)\Gamma_{\tilde{\chi}_j^0,H_a^+,\tilde{\chi}_b^-}^{L*}m_{\tilde{\chi}_b^-}\Gamma_{\tilde{\chi}_i^0,H_a^+,\tilde{\chi}_b^-}^{R}$$

$$+\sum_{a=1}^{2}\sum_{b=1}^{4}B_0\Big(p^2,m_{\tilde{\chi}_b^0}^2,m_{h_a}^2\Big)\Gamma_{\tilde{\chi}_j^0,h_a,\tilde{\chi}_b^0}^{L*}m_{\tilde{\chi}_b^0}\Gamma_{\tilde{\chi}_i^0,h_a,\tilde{\chi}_b^0}^{R}$$

$$+2\sum_{a=1}^{3}\sum_{b=1}^{3}B_0\Big(p^2,m_{\nu_b}^2,m_{\tilde{\nu}_a}^2\Big)\Gamma_{\tilde{\chi}_j^0,\tilde{\nu}_a^*,\nu_b}^{L*}m_{\nu_b}\Gamma_{\tilde{\chi}_i^0,\tilde{\nu}_a^*,\nu_b}^{R}$$

$$+\sum_{a=1}^{4}m_{\tilde{\chi}_a^0}\sum_{b=1}^{2}B_0\Big(p^2,m_{\tilde{\chi}_a^0}^2,m_{A_b^0}^2\Big)\Gamma_{\tilde{\chi}_j^0,\tilde{\chi}_a^0,A_b^0}^{L*}\Gamma_{\tilde{\chi}_i^0,\tilde{\chi}_a^0,A_b^0}^{R}$$

$$+6\sum_{a=1}^{6}\sum_{b=1}^{3}B_0\Big(p^2,m_{d_b}^2,m_{\tilde{d}_a}^2\Big)\Gamma_{\tilde{\chi}_j^0,\tilde{d}_a^*,d_b}^{L*}m_{d_b}\Gamma_{\tilde{\chi}_i^0,\tilde{d}_a^*,d_b}^{R}$$

$$+2\sum_{a=1}^{6}\sum_{b=1}^{3}B_0\Big(p^2,m_{e_b}^2,m_{\tilde{e}_a}^2\Big)\Gamma_{\tilde{\chi}_j^0,\tilde{e}_a^*,e_b}^{L*}m_{e_b}\Gamma_{\tilde{\chi}_i^0,\tilde{e}_a^*,e_b}^{R}$$

$$+6\sum_{a=1}^{6}\sum_{b=1}^{3}B_0\Big(p^2,m_{u_b}^2,m_{\tilde{u}_a}^2\Big)\Gamma_{\tilde{\chi}_j^0,\tilde{u}_a^*,u_b}^{L*}m_{u_b}\Gamma_{\tilde{\chi}_i^0,\tilde{u}_a^*,u_b}^{R}$$

$$-8\sum_{b=1}^{2}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{\tilde{\chi}_b^-}^2,m_{W^-}^2\Big)\Big)\Gamma_{\tilde{\chi}_j^0,W^+,\tilde{\chi}_b^-}^{R*}m_{\tilde{\chi}_b^-}\Gamma_{\tilde{\chi}_i^0,W^+,\tilde{\chi}_b^-}^{L}$$

$$-4\sum_{b=1}^{4}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{\tilde{\chi}_b^0}^2,m_Z^2\Big)\Big)\Gamma_{\tilde{\chi}_j^0,Z,\tilde{\chi}_b^0}^{R*}m_{\tilde{\chi}_b^0}\Gamma_{\tilde{\chi}_i^0,Z,\tilde{\chi}_b^0}^{L} \tag{143}$$

$$\Sigma_{i,j}^{R}(p^2) = -\sum_{a=1}^{2}\sum_{b=1}^{2}B_1\Big(p^2,m_{\tilde{\chi}_b^-}^2,m_{H_a^-}^2\Big)\Gamma_{\tilde{\chi}_j^0,H_a^+,\tilde{\chi}_b^-}^{R*}\Gamma_{\tilde{\chi}_i^0,H_a^+,\tilde{\chi}_b^-}^{R}$$

$$-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{4}B_1\Big(p^2,m_{\tilde{\chi}_b^0}^2,m_{h_a}^2\Big)\Gamma_{\tilde{\chi}_j^0,h_a,\tilde{\chi}_b^0}^{R*}\Gamma_{\tilde{\chi}_i^0,h_a,\tilde{\chi}_b^0}^{R}$$

$$-\sum_{a=1}^{3}\sum_{b=1}^{3}B_1\Big(p^2,m_{\nu_b}^2,m_{\tilde{\nu}_a}^2\Big)\Gamma_{\tilde{\chi}_j^0,\tilde{\nu}_a^*,\nu_b}^{R*}\Gamma_{\tilde{\chi}_i^0,\tilde{\nu}_a^*,\nu_b}^{R}$$

$$-\frac{1}{2}\sum_{a=1}^{4}\sum_{b=1}^{2}B_1\Big(p^2,m_{\tilde{\chi}_a^0}^2,m_{A_b^0}^2\Big)\Gamma_{\tilde{\chi}_j^0,\tilde{\chi}_a^0,A_b^0}^{R*}\Gamma_{\tilde{\chi}_i^0,\tilde{\chi}_a^0,A_b^0}^{R}$$

$$-3\sum_{a=1}^{6}\sum_{b=1}^{3}B_1\Big(p^2,m_{d_b}^2,m_{\tilde{d}_a}^2\Big)\Gamma_{\tilde{\chi}_j^0,\tilde{d}_a^*,d_b}^{R*}\Gamma_{\tilde{\chi}_i^0,\tilde{d}_a^*,d_b}^{R}$$

$$-\sum_{a=1}^{6}\sum_{b=1}^{3}B_1\Big(p^2,m_{e_b}^2,m_{\tilde{e}_a}^2\Big)\Gamma_{\tilde{\chi}_j^0,\tilde{e}_a^*,e_b}^{R*}\Gamma_{\tilde{\chi}_i^0,\tilde{e}_a^*,e_b}^{R}$$

$$- 3 \sum_{a=1}^{6} \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2\Big) \Gamma^{R*}_{\tilde{\chi}_j^0, \tilde{u}_a^*, u_b} \Gamma^{R}_{\tilde{\chi}_i^0, \tilde{u}_a^*, u_b}$$

$$- 2 \sum_{b=1}^{2} B_1\Big(p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-} \Gamma^{L}_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-} - \sum_{b=1}^{4} B_1\Big(p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0} \Gamma^{L}_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0} \qquad (144)$$

$$\Sigma^L_{i,j}(p^2) = - \sum_{a=1}^{2} \sum_{b=1}^{2} B_1\Big(p^2, m_{\tilde{\chi}_b^-}^2, m_{H_a^-}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^0, H_a^+, \tilde{\chi}_b^-} \Gamma^{L}_{\tilde{\chi}_i^0, H_a^+, \tilde{\chi}_b^-}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{4} B_1\Big(p^2, m_{\tilde{\chi}_b^0}^2, m_{h_a}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^0, h_a, \tilde{\chi}_b^0} \Gamma^{L}_{\tilde{\chi}_i^0, h_a, \tilde{\chi}_b^0}$$

$$- \sum_{a=1}^{3} \sum_{b=1}^{3} B_1\Big(p^2, m_{\nu_b}^2, m_{\tilde{\nu}_a}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^0, \tilde{\nu}_a^*, \nu_b} \Gamma^{L}_{\tilde{\chi}_i^0, \tilde{\nu}_a^*, \nu_b}$$

$$- \frac{1}{2} \sum_{a=1}^{4} \sum_{b=1}^{2} B_1\Big(p^2, m_{\tilde{\chi}_a^0}^2, m_{A_b^0}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^0, \tilde{\chi}_a^0, A_b^0} \Gamma^{L}_{\tilde{\chi}_i^0, \tilde{\chi}_a^0, A_b^0}$$

$$- 3 \sum_{a=1}^{6} \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{\tilde{d}_a}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^0, \tilde{d}_a^*, d_b} \Gamma^{L}_{\tilde{\chi}_i^0, \tilde{d}_a^*, d_b}$$

$$- \sum_{a=1}^{6} \sum_{b=1}^{3} B_1\Big(p^2, m_{e_b}^2, m_{\tilde{e}_a}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^0, \tilde{e}_a^*, e_b} \Gamma^{L}_{\tilde{\chi}_i^0, \tilde{e}_a^*, e_b}$$

$$- 3 \sum_{a=1}^{6} \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{\tilde{u}_a}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^0, \tilde{u}_a^*, u_b} \Gamma^{L}_{\tilde{\chi}_i^0, \tilde{u}_a^*, u_b}$$

$$- 2 \sum_{b=1}^{2} B_1\Big(p^2, m_{\tilde{\chi}_b^-}^2, m_{W^-}^2\Big) \Gamma^{R*}_{\tilde{\chi}_j^0, W^+, \tilde{\chi}_b^-} \Gamma^{R}_{\tilde{\chi}_i^0, W^+, \tilde{\chi}_b^-} - \sum_{b=1}^{4} B_1\Big(p^2, m_{\tilde{\chi}_b^0}^2, m_Z^2\Big) \Gamma^{R*}_{\tilde{\chi}_j^0, Z, \tilde{\chi}_b^0} \Gamma^{R}_{\tilde{\chi}_i^0, Z, \tilde{\chi}_b^0} \qquad (145)$$

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

$$\Sigma^S_{i,j}(p^2) = + \sum_{a=1}^{2} m_{\tilde{\chi}_a^-} \sum_{b=1}^{2} B_0\Big(p^2, m_{\tilde{\chi}_a^-}^2, m_{A_b^0}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^+, \tilde{\chi}_a^-, A_b^0} \Gamma^{R}_{\tilde{\chi}_i^+, \tilde{\chi}_a^-, A_b^0}$$

$$+ \sum_{a=1}^{2} \sum_{b=1}^{2} B_0\Big(p^2, m_{\tilde{\chi}_b^-}^2, m_{h_a}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^+, h_a, \tilde{\chi}_b^-} m_{\tilde{\chi}_b^-} \Gamma^{R}_{\tilde{\chi}_i^+, h_a, \tilde{\chi}_b^-}$$

$$+ \sum_{a=1}^{2} \sum_{b=1}^{4} B_0\Big(p^2, m_{\tilde{\chi}_b^0}^2, m_{H_a^-}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^+, H_a^-, \tilde{\chi}_b^0} m_{\tilde{\chi}_b^0} \Gamma^{R}_{\tilde{\chi}_i^+, H_a^-, \tilde{\chi}_b^0}$$

$$+ \sum_{a=1}^{3} \sum_{b=1}^{3} B_0\Big(p^2, m_{e_b}^2, m_{\tilde{\nu}_a}^2\Big) \Gamma^{L*}_{\tilde{\chi}_j^+, \tilde{\nu}_a^*, e_b} m_{e_b} \Gamma^{R}_{\tilde{\chi}_i^+, \tilde{\nu}_a^*, e_b}$$

$$+\,3\sum_{a=1}^{3}m_{u_a}\sum_{b=1}^{6}B_0\Big(p^2,m_{u_a}^2,m_{\tilde{d}_b}^2\Big)\Gamma^{L*}_{\tilde{\chi}_j^+,\bar{u}_a,\tilde{d}_b}\Gamma^{R}_{\tilde{\chi}_i^+,\bar{u}_a,\tilde{d}_b}$$

$$+\sum_{a=1}^{3}m_{\nu_a}\sum_{b=1}^{6}B_0\Big(p^2,m_{\nu_a}^2,m_{\tilde{e}_b}^2\Big)\Gamma^{L*}_{\tilde{\chi}_j^+,\bar{\nu}_a,\tilde{e}_b}\Gamma^{R}_{\tilde{\chi}_i^+,\bar{\nu}_a,\tilde{e}_b}$$

$$+\,3\sum_{a=1}^{6}\sum_{b=1}^{3}B_0\Big(p^2,m_{d_b}^2,m_{\tilde{u}_a}^2\Big)\Gamma^{L*}_{\tilde{\chi}_j^+,\tilde{u}_a^*,d_b}m_{d_b}\Gamma^{R}_{\tilde{\chi}_i^+,\tilde{u}_a^*,d_b}$$

$$-\,4\sum_{b=1}^{2}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{\tilde{\chi}_b^-}^2,0\Big)\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,\gamma,\tilde{\chi}_b^-}m_{\tilde{\chi}_b^-}\Gamma^{L}_{\tilde{\chi}_i^+,\gamma,\tilde{\chi}_b^-}$$

$$-\,4\sum_{b=1}^{2}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{\tilde{\chi}_b^-}^2,m_Z^2\Big)\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,Z,\tilde{\chi}_b^-}m_{\tilde{\chi}_b^-}\Gamma^{L}_{\tilde{\chi}_i^+,Z,\tilde{\chi}_b^-}$$

$$-\,4\sum_{b=1}^{4}\Big(-\frac{1}{2}\mathrm{rMS}+B_0\Big(p^2,m_{\tilde{\chi}_b^0}^2,m_{W^-}^2\Big)\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,W^-,\tilde{\chi}_b^0}m_{\tilde{\chi}_b^0}\Gamma^{L}_{\tilde{\chi}_i^+,W^-,\tilde{\chi}_b^0} \tag{146}$$

$$\Sigma^R_{i,j}(p^2)=-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{2}B_1\Big(p^2,m_{\tilde{\chi}_a^-}^2,m_{A_b^0}^2\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,\tilde{\chi}_a^-,A_b^0}\Gamma^{R}_{\tilde{\chi}_i^+,\tilde{\chi}_a^-,A_b^0}$$

$$-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{2}B_1\Big(p^2,m_{\tilde{\chi}_b^-}^2,m_{h_a}^2\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,h_a,\tilde{\chi}_b^-}\Gamma^{R}_{\tilde{\chi}_i^+,h_a,\tilde{\chi}_b^-}$$

$$-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{4}B_1\Big(p^2,m_{\tilde{\chi}_b^0}^2,m_{H_a^-}^2\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,H_a^-,\tilde{\chi}_b^0}\Gamma^{R}_{\tilde{\chi}_i^+,H_a^-,\tilde{\chi}_b^0}$$

$$-\frac{1}{2}\sum_{a=1}^{3}\sum_{b=1}^{3}B_1\Big(p^2,m_{e_b}^2,m_{\nu_a}^2\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,\tilde{\nu}_a^*,e_b}\Gamma^{R}_{\tilde{\chi}_i^+,\tilde{\nu}_a^*,e_b}$$

$$-\frac{3}{2}\sum_{a=1}^{3}\sum_{b=1}^{6}B_1\Big(p^2,m_{u_a}^2,m_{\tilde{d}_b}^2\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,\bar{u}_a,\tilde{d}_b}\Gamma^{R}_{\tilde{\chi}_i^+,\bar{u}_a,\tilde{d}_b}$$

$$-\frac{1}{2}\sum_{a=1}^{3}\sum_{b=1}^{6}B_1\Big(p^2,m_{\nu_a}^2,m_{\tilde{e}_b}^2\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,\bar{\nu}_a,\tilde{e}_b}\Gamma^{R}_{\tilde{\chi}_i^+,\bar{\nu}_a,\tilde{e}_b}$$

$$-\frac{3}{2}\sum_{a=1}^{6}\sum_{b=1}^{3}B_1\Big(p^2,m_{d_b}^2,m_{\tilde{u}_a}^2\Big)\Gamma^{R*}_{\tilde{\chi}_j^+,\tilde{u}_a^*,d_b}\Gamma^{R}_{\tilde{\chi}_i^+,\tilde{u}_a^*,d_b}-\sum_{b=1}^{2}B_1\Big(p^2,m_{\tilde{\chi}_b^-}^2,0\Big)\Gamma^{L*}_{\tilde{\chi}_j^+,\gamma,\tilde{\chi}_b^-}\Gamma^{L}_{\tilde{\chi}_i^+,\gamma,\tilde{\chi}_b^-}$$

$$-\sum_{b=1}^{2}B_1\Big(p^2,m_{\tilde{\chi}_b^-}^2,m_Z^2\Big)\Gamma^{L*}_{\tilde{\chi}_j^+,Z,\tilde{\chi}_b^-}\Gamma^{L}_{\tilde{\chi}_i^+,Z,\tilde{\chi}_b^-}-\sum_{b=1}^{4}B_1\Big(p^2,m_{\tilde{\chi}_b^0}^2,m_{W^-}^2\Big)\Gamma^{L*}_{\tilde{\chi}_j^+,W^-,\tilde{\chi}_b^0}\Gamma^{L}_{\tilde{\chi}_i^+,W^-,\tilde{\chi}_b^0} \tag{147}$$

$$\Sigma^L_{i,j}(p^2)=-\frac{1}{2}\sum_{a=1}^{2}\sum_{b=1}^{2}B_1\Big(p^2,m_{\tilde{\chi}_a^-}^2,m_{A_b^0}^2\Big)\Gamma^{L*}_{\tilde{\chi}_j^+,\tilde{\chi}_a^-,A_b^0}\Gamma^{L}_{\tilde{\chi}_i^+,\tilde{\chi}_a^-,A_b^0}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{2} B_1\left(p^2, m_{\tilde{\chi}_b^-}^2, m_{h_a}^2\right) \Gamma_{\tilde{\chi}_j^+, h_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\tilde{\chi}_i^+, h_a, \tilde{\chi}_b^-}^{L}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{4} B_1\left(p^2, m_{\tilde{\chi}_b^0}^2, m_{H_a^-}^2\right) \Gamma_{\tilde{\chi}_j^+, H_a^-, \tilde{\chi}_b^0}^{L*} \Gamma_{\tilde{\chi}_i^+, H_a^-, \tilde{\chi}_b^0}^{L}$$

$$- \frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{3} B_1\left(p^2, m_{e_b}^2, m_{\tilde{\nu}_a}^2\right) \Gamma_{\tilde{\chi}_j^+, \tilde{\nu}_a^*, e_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{\nu}_a^*, e_b}^{L}$$

$$- \frac{3}{2} \sum_{a=1}^{3} \sum_{b=1}^{6} B_1\left(p^2, m_{u_a}^2, m_{\tilde{d}_b}^2\right) \Gamma_{\tilde{\chi}_j^+, \bar{u}_a, \tilde{d}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \bar{u}_a, \tilde{d}_b}^{L}$$

$$- \frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{6} B_1\left(p^2, m_{\nu_a}^2, m_{\tilde{e}_b}^2\right) \Gamma_{\tilde{\chi}_j^+, \bar{\nu}_a, \tilde{e}_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \bar{\nu}_a, \tilde{e}_b}^{L}$$

$$- \frac{3}{2} \sum_{a=1}^{6} \sum_{b=1}^{3} B_1\left(p^2, m_{d_b}^2, m_{\tilde{u}_a}^2\right) \Gamma_{\tilde{\chi}_j^+, \tilde{u}_a^*, d_b}^{L*} \Gamma_{\tilde{\chi}_i^+, \tilde{u}_a^*, d_b}^{L} - \sum_{b=1}^{2} B_1\left(p^2, m_{\tilde{\chi}_b^-}^2, 0\right) \Gamma_{\tilde{\chi}_j^+, \gamma, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, \gamma, \tilde{\chi}_b^-}^{R}$$

$$- \sum_{b=1}^{2} B_1\left(p^2, m_{\tilde{\chi}_b^-}^2, m_Z^2\right) \Gamma_{\tilde{\chi}_j^+, Z, \tilde{\chi}_b^-}^{R*} \Gamma_{\tilde{\chi}_i^+, Z, \tilde{\chi}_b^-}^{R} - \sum_{b=1}^{4} B_1\left(p^2, m_{\tilde{\chi}_b^0}^2, m_{W^-}^2\right) \Gamma_{\tilde{\chi}_j^+, W^-, \tilde{\chi}_b^0}^{R*} \Gamma_{\tilde{\chi}_i^+, W^-, \tilde{\chi}_b^0}^{R} \tag{148}$$

- **Self-Energy for Leptons** (e)

$$\Sigma_{i,j}^{S}(p^2) = + \sum_{a=1}^{2} \sum_{b=1}^{3} B_0\left(p^2, m_{e_b}^2, m_{h_a}^2\right) \Gamma_{\tilde{e}_j, h_a, e_b}^{L*} m_{e_b} \Gamma_{\tilde{e}_i, h_a, e_b}^{R}$$

$$+ \sum_{a=1}^{2} \sum_{b=1}^{3} B_0\left(p^2, m_{\nu_b}^2, m_{H_a^-}^2\right) \Gamma_{\tilde{e}_j, H_a^-, \nu_b}^{L*} m_{\nu_b} \Gamma_{\tilde{e}_i, H_a^-, \nu_b}^{R}$$

$$+ \sum_{a=1}^{3} m_{e_a} \sum_{b=1}^{2} B_0\left(p^2, m_{e_a}^2, m_{A_b^0}^2\right) \Gamma_{\tilde{e}_j, e_a, A_b^0}^{L*} \Gamma_{\tilde{e}_i, e_a, A_b^0}^{R}$$

$$+ \sum_{a=1}^{3} \sum_{b=1}^{2} B_0\left(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2\right) \Gamma_{\tilde{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\tilde{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^{R}$$

$$+ \sum_{a=1}^{6} \sum_{b=1}^{4} B_0\left(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2\right) \Gamma_{\tilde{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\tilde{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^{R}$$

$$- 4 \sum_{b=1}^{3} \left(- \frac{1}{2} \text{rMS} + B_0\left(p^2, m_{e_b}^2, 0\right)\right) \Gamma_{\tilde{e}_j, \gamma, e_b}^{R*} m_{e_b} \Gamma_{\tilde{e}_i, \gamma, e_b}^{L}$$

$$- 4 \sum_{b=1}^{3} \left(- \frac{1}{2} \text{rMS} + B_0\left(p^2, m_{\nu_b}^2, m_{W^-}^2\right)\right) \Gamma_{\tilde{e}_j, W^-, \nu_b}^{R*} m_{\nu_b} \Gamma_{\tilde{e}_i, W^-, \nu_b}^{L}$$

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$$- 4 \sum_{b=1}^{3} \Big(- \frac{1}{2} \mathrm{rMS} + B_0 \Big(p^2, m_{e_b}^2, m_Z^2 \Big) \Big) \Gamma_{\breve{e}_j, Z, e_b}^{R*} m_{e_b} \Gamma_{\breve{e}_i, Z, e_b}^{L} \tag{149}$$

$$\Sigma_{i,j}^{R}(p^2) = -\frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1 \Big(p^2, m_{e_b}^2, m_{h_a}^2 \Big) \Gamma_{\breve{e}_j, h_a, e_b}^{R*} \Gamma_{\breve{e}_i, h_a, e_b}^{R}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1 \Big(p^2, m_{\nu_b}^2, m_{H_a^-}^2 \Big) \Gamma_{\breve{e}_j, H_a^-, \nu_b}^{R*} \Gamma_{\breve{e}_i, H_a^-, \nu_b}^{R}$$

$$- \frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{2} B_1 \Big(p^2, m_{e_a}^2, m_{A_b^0}^2 \Big) \Gamma_{\breve{e}_j, e_a, A_b^0}^{R*} \Gamma_{\breve{e}_i, e_a, A_b^0}^{R}$$

$$- \frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{2} B_1 \Big(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2 \Big) \Gamma_{\breve{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\breve{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^{R}$$

$$- \frac{1}{2} \sum_{a=1}^{6} \sum_{b=1}^{4} B_1 \Big(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2 \Big) \Gamma_{\breve{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\breve{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^{R} - \sum_{b=1}^{3} B_1 \Big(p^2, m_{e_b}^2, 0 \Big) \Gamma_{\breve{e}_j, \gamma, e_b}^{L*} \Gamma_{\breve{e}_i, \gamma, e_b}^{L}$$

$$- \sum_{b=1}^{3} B_1 \Big(p^2, m_{\nu_b}^2, m_{W^-}^2 \Big) \Gamma_{\breve{e}_j, W^-, \nu_b}^{L*} \Gamma_{\breve{e}_i, W^-, \nu_b}^{L} - \sum_{b=1}^{3} B_1 \Big(p^2, m_{e_b}^2, m_Z^2 \Big) \Gamma_{\breve{e}_j, Z, e_b}^{L*} \Gamma_{\breve{e}_i, Z, e_b}^{L} \tag{150}$$

$$\Sigma_{i,j}^{L}(p^2) = -\frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1 \Big(p^2, m_{e_b}^2, m_{h_a}^2 \Big) \Gamma_{\breve{e}_j, h_a, e_b}^{L*} \Gamma_{\breve{e}_i, h_a, e_b}^{L}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1 \Big(p^2, m_{\nu_b}^2, m_{H_a^-}^2 \Big) \Gamma_{\breve{e}_j, H_a^-, \nu_b}^{L*} \Gamma_{\breve{e}_i, H_a^-, \nu_b}^{L}$$

$$- \frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{2} B_1 \Big(p^2, m_{e_a}^2, m_{A_b^0}^2 \Big) \Gamma_{\breve{e}_j, e_a, A_b^0}^{L*} \Gamma_{\breve{e}_i, e_a, A_b^0}^{L}$$

$$- \frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{2} B_1 \Big(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{\nu}_a}^2 \Big) \Gamma_{\breve{e}_j, \tilde{\nu}_a, \tilde{\chi}_b^-}^{L*} \Gamma_{\breve{e}_i, \tilde{\nu}_a, \tilde{\chi}_b^-}^{L}$$

$$- \frac{1}{2} \sum_{a=1}^{6} \sum_{b=1}^{4} B_1 \Big(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{e}_a}^2 \Big) \Gamma_{\breve{e}_j, \tilde{e}_a, \tilde{\chi}_b^0}^{L*} \Gamma_{\breve{e}_i, \tilde{e}_a, \tilde{\chi}_b^0}^{L} - \sum_{b=1}^{3} B_1 \Big(p^2, m_{e_b}^2, 0 \Big) \Gamma_{\breve{e}_j, \gamma, e_b}^{R*} \Gamma_{\breve{e}_i, \gamma, e_b}^{R}$$

$$- \sum_{b=1}^{3} B_1 \Big(p^2, m_{\nu_b}^2, m_{W^-}^2 \Big) \Gamma_{\breve{e}_j, W^-, \nu_b}^{R*} \Gamma_{\breve{e}_i, W^-, \nu_b}^{R} - \sum_{b=1}^{3} B_1 \Big(p^2, m_{e_b}^2, m_Z^2 \Big) \Gamma_{\breve{e}_j, Z, e_b}^{R*} \Gamma_{\breve{e}_i, Z, e_b}^{R} \tag{151}$$

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

$$\Sigma_{i,j}^{S}(p^2) = + \sum_{a=1}^{2} \sum_{b=1}^{3} B_0 \Big(p^2, m_{d_b}^2, m_{h_a}^2 \Big) \Gamma_{\breve{d}_j, h_a, d_b}^{L*} m_{d_b} \Gamma_{\breve{d}_i, h_a, d_b}^{R}$$

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

$$+ \sum_{a=1}^{3} m_{d_a} \sum_{b=1}^{2} B_0\Big(p^2, m_{d_a}^2, m_{A_b^0}^2\Big) \Gamma_{\breve{d}_j, d_a, A_b^0}^{L*} \Gamma_{\breve{d}_i, d_a, A_b^0}^{R}$$

$$+ \sum_{a=1}^{6} \sum_{b=1}^{2} B_0\Big(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2\Big) \Gamma_{\breve{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{L*} m_{\tilde{\chi}_b^-} \Gamma_{\breve{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^{R}$$

$$+ \sum_{a=1}^{6} \sum_{b=1}^{4} B_0\Big(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2\Big) \Gamma_{\breve{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{L*} m_{\tilde{\chi}_b^0} \Gamma_{\breve{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^{R}$$

$$+ \frac{4}{3} m_{\tilde{g}} \sum_{a=1}^{6} B_0\Big(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2\Big) \Gamma_{\breve{d}_j, \tilde{d}_a, \tilde{g}_1}^{L*} \Gamma_{\breve{d}_i, \tilde{d}_a, \tilde{g}_1}^{R} - \frac{16}{3} \sum_{b=1}^{3} \Big(-\frac{1}{2} \text{rMS} + B_0\Big(p^2, m_{d_b}^2, 0\Big)\Big) \Gamma_{\breve{d}_j, g, d_b}^{R*} m_{d_b} \Gamma_{\breve{d}_i, g, d_b}^{L}$$

$$- 4 \sum_{b=1}^{3} \Big(-\frac{1}{2} \text{rMS} + B_0\Big(p^2, m_{d_b}^2, 0\Big)\Big) \Gamma_{\breve{d}_j, \gamma, d_b}^{R*} m_{d_b} \Gamma_{\breve{d}_i, \gamma, d_b}^{L}$$

$$- 4 \sum_{b=1}^{3} \Big(-\frac{1}{2} \text{rMS} + B_0\Big(p^2, m_{u_b}^2, m_{W^-}^2\Big)\Big) \Gamma_{\breve{d}_j, W^-, u_b}^{R*} m_{u_b} \Gamma_{\breve{d}_i, W^-, u_b}^{L}$$

$$- 4 \sum_{b=1}^{3} \Big(-\frac{1}{2} \text{rMS} + B_0\Big(p^2, m_{d_b}^2, m_Z^2\Big)\Big) \Gamma_{\breve{d}_j, Z, d_b}^{R*} m_{d_b} \Gamma_{\breve{d}_i, Z, d_b}^{L} \tag{152}$$

$$\Sigma_{i,j}^{R}(p^2) = -\frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{h_a}^2\Big) \Gamma_{\breve{d}_j, h_a, d_b}^{R*} \Gamma_{\breve{d}_i, h_a, d_b}^{R}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{H_a^-}^2\Big) \Gamma_{\breve{d}_j, H_a^-, u_b}^{R*} \Gamma_{\breve{d}_i, H_a^-, u_b}^{R}$$

$$- \frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{2} B_1\Big(p^2, m_{d_a}^2, m_{A_b^0}^2\Big) \Gamma_{\breve{d}_j, d_a, A_b^0}^{R*} \Gamma_{\breve{d}_i, d_a, A_b^0}^{R}$$

$$- \frac{1}{2} \sum_{a=1}^{6} \sum_{b=1}^{2} B_1\Big(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2\Big) \Gamma_{\breve{d}_j, \tilde{u}_a, \tilde{\chi}_b^-}^{R*} \Gamma_{\breve{d}_i, \tilde{u}_a, \tilde{\chi}_b^-}^{R}$$

$$- \frac{1}{2} \sum_{a=1}^{6} \sum_{b=1}^{4} B_1\Big(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2\Big) \Gamma_{\breve{d}_j, \tilde{d}_a, \tilde{\chi}_b^0}^{R*} \Gamma_{\breve{d}_i, \tilde{d}_a, \tilde{\chi}_b^0}^{R}$$

$$- \frac{2}{3} \sum_{a=1}^{6} B_1\Big(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2\Big) \Gamma_{\breve{d}_j, \tilde{d}_a, \tilde{g}_1}^{R*} \Gamma_{\breve{d}_i, \tilde{d}_a, \tilde{g}_1}^{R} - \frac{4}{3} \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big) \Gamma_{\breve{d}_j, g, d_b}^{L*} \Gamma_{\breve{d}_i, g, d_b}^{L}$$

$$- \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, 0\Big) \Gamma_{\breve{d}_j, \gamma, d_b}^{L*} \Gamma_{\breve{d}_i, \gamma, d_b}^{L} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{W^-}^2\Big) \Gamma_{\breve{d}_j, W^-, u_b}^{L*} \Gamma_{\breve{d}_i, W^-, u_b}^{L}$$

$$-\sum_{b=1}^{3} B_1\left(p^2, m_{d_b}^2, m_Z^2\right) \Gamma^{L*}_{\breve{d}_j, Z, d_b} \Gamma^{L}_{\breve{d}_i, Z, d_b} \tag{153}$$

$$\begin{aligned}
\Sigma^{L}_{i,j}(p^2) = &-\frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1\left(p^2, m_{d_b}^2, m_{h_a}^2\right) \Gamma^{L*}_{\breve{d}_j, h_a, d_b} \Gamma^{L}_{\breve{d}_i, h_a, d_b} \\
&-\frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1\left(p^2, m_{u_b}^2, m_{H_a^-}^2\right) \Gamma^{L*}_{\breve{d}_j, H_a^-, u_b} \Gamma^{L}_{\breve{d}_i, H_a^-, u_b} \\
&-\frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{2} B_1\left(p^2, m_{d_a}^2, m_{A_b^0}^2\right) \Gamma^{L*}_{\breve{d}_j, d_a, A_b^0} \Gamma^{L}_{\breve{d}_i, d_a, A_b^0} \\
&-\frac{1}{2} \sum_{a=1}^{6} \sum_{b=1}^{2} B_1\left(p^2, m_{\tilde{\chi}_b^-}^2, m_{\tilde{u}_a}^2\right) \Gamma^{L*}_{\breve{d}_j, \tilde{u}_a, \tilde{\chi}_b^-} \Gamma^{L}_{\breve{d}_i, \tilde{u}_a, \tilde{\chi}_b^-} \\
&-\frac{1}{2} \sum_{a=1}^{6} \sum_{b=1}^{4} B_1\left(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{d}_a}^2\right) \Gamma^{L*}_{\breve{d}_j, \tilde{d}_a, \tilde{\chi}_b^0} \Gamma^{L}_{\breve{d}_i, \tilde{d}_a, \tilde{\chi}_b^0} \\
&-\frac{2}{3} \sum_{a=1}^{6} B_1\left(p^2, m_{\tilde{g}}^2, m_{\tilde{d}_a}^2\right) \Gamma^{L*}_{\breve{d}_j, \tilde{d}_a, \tilde{g}_1} \Gamma^{L}_{\breve{d}_i, \tilde{d}_a, \tilde{g}_1} - \frac{4}{3} \sum_{b=1}^{3} B_1\left(p^2, m_{d_b}^2, 0\right) \Gamma^{R*}_{\breve{d}_j, g, d_b} \Gamma^{R}_{\breve{d}_i, g, d_b} \\
&-\sum_{b=1}^{3} B_1\left(p^2, m_{d_b}^2, 0\right) \Gamma^{R*}_{\breve{d}_j, \gamma, d_b} \Gamma^{R}_{\breve{d}_i, \gamma, d_b} - \sum_{b=1}^{3} B_1\left(p^2, m_{u_b}^2, m_{W^-}^2\right) \Gamma^{R*}_{\breve{d}_j, W^-, u_b} \Gamma^{R}_{\breve{d}_i, W^-, u_b} \\
&-\sum_{b=1}^{3} B_1\left(p^2, m_{d_b}^2, m_Z^2\right) \Gamma^{R*}_{\breve{d}_j, Z, d_b} \Gamma^{R}_{\breve{d}_i, Z, d_b} \tag{154}
\end{aligned}$$

- **Self-Energy for Up-Quarks** (u)

$$\begin{aligned}
\Sigma^{S}_{i,j}(p^2) = &+\sum_{a=1}^{2} \sum_{b=1}^{3} B_0\left(p^2, m_{d_b}^2, m_{H_a^-}^2\right) \Gamma^{L*}_{\breve{u}_j, H_a^+, d_b} m_{d_b} \Gamma^{R}_{\breve{u}_i, H_a^+, d_b} \\
&+\sum_{a=1}^{2} \sum_{b=1}^{3} B_0\left(p^2, m_{u_b}^2, m_{h_a}^2\right) \Gamma^{L*}_{\breve{u}_j, h_a, u_b} m_{u_b} \Gamma^{R}_{\breve{u}_i, h_a, u_b} \\
&+\sum_{a=1}^{2} m_{\tilde{\chi}_a^-} \sum_{b=1}^{6} B_0\left(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{d}_b}^2\right) \Gamma^{L*}_{\breve{u}_j, \tilde{\chi}_a^+, \tilde{d}_b} \Gamma^{R}_{\breve{u}_i, \tilde{\chi}_a^+, \tilde{d}_b} \\
&+\sum_{a=1}^{3} m_{u_a} \sum_{b=1}^{2} B_0\left(p^2, m_{u_a}^2, m_{A_b^0}^2\right) \Gamma^{L*}_{\breve{u}_j, u_a, A_b^0} \Gamma^{R}_{\breve{u}_i, u_a, A_b^0} \\
&+\sum_{a=1}^{6} \sum_{b=1}^{4} B_0\left(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2\right) \Gamma^{L*}_{\breve{u}_j, \tilde{u}_a, \tilde{\chi}_b^0} m_{\tilde{\chi}_b^0} \Gamma^{R}_{\breve{u}_i, \tilde{u}_a, \tilde{\chi}_b^0}
\end{aligned}$$

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$$+ \frac{4}{3} m_{\tilde{g}} \sum_{a=1}^{6} B_0\Big(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2\Big) \Gamma^{L*}_{\breve{\tilde{u}}_j, \tilde{u}_a, \tilde{g}_1} \Gamma^{R}_{\breve{\tilde{u}}_i, \tilde{u}_a, \tilde{g}_1} - \frac{16}{3} \sum_{b=1}^{3} \Big(-\frac{1}{2}\text{rMS} + B_0\Big(p^2, m_{u_b}^2, 0\Big) \Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, g, u_b} m_{u_b} \Gamma^{L}_{\breve{\tilde{u}}_i, g, u_b}$$

$$- 4 \sum_{b=1}^{3} \Big(-\frac{1}{2}\text{rMS} + B_0\Big(p^2, m_{u_b}^2, 0\Big) \Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, \gamma, u_b} m_{u_b} \Gamma^{L}_{\breve{\tilde{u}}_i, \gamma, u_b} - 4 \sum_{b=1}^{3} \Big(-\frac{1}{2}\text{rMS} + B_0\Big(p^2, m_{u_b}^2, m_Z^2\Big) \Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, Z, u_b} m_{u_b} \Gamma^{L}_{\breve{\tilde{u}}_i, Z, u_b}$$

$$- 4 \sum_{b=1}^{3} \Big(-\frac{1}{2}\text{rMS} + B_0\Big(p^2, m_{d_b}^2, m_{W^-}^2\Big) \Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, W^+, d_b} m_{d_b} \Gamma^{L}_{\breve{\tilde{u}}_i, W^+, d_b} \tag{155}$$

$$\Sigma^{R}_{i,j}(p^2) = -\frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{H_a^-}^2\Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, H_a^+, d_b} \Gamma^{R}_{\breve{\tilde{u}}_i, H_a^+, d_b}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{h_a}^2\Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, h_a, u_b} \Gamma^{R}_{\breve{\tilde{u}}_i, h_a, u_b}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{6} B_1\Big(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{d}_b}^2\Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, \tilde{\chi}_a^+, \tilde{d}_b} \Gamma^{R}_{\breve{\tilde{u}}_i, \tilde{\chi}_a^+, \tilde{d}_b}$$

$$- \frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{2} B_1\Big(p^2, m_{u_a}^2, m_{A_b^0}^2\Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, u_a, A_b^0} \Gamma^{R}_{\breve{\tilde{u}}_i, u_a, A_b^0}$$

$$- \frac{1}{2} \sum_{a=1}^{6} \sum_{b=1}^{4} B_1\Big(p^2, m_{\tilde{\chi}_b^0}^2, m_{\tilde{u}_a}^2\Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, \tilde{u}_a, \tilde{\chi}_b^0} \Gamma^{R}_{\breve{\tilde{u}}_i, \tilde{u}_a, \tilde{\chi}_b^0}$$

$$- \frac{2}{3} \sum_{a=1}^{6} B_1\Big(p^2, m_{\tilde{g}}^2, m_{\tilde{u}_a}^2\Big) \Gamma^{R*}_{\breve{\tilde{u}}_j, \tilde{u}_a, \tilde{g}_1} \Gamma^{R}_{\breve{\tilde{u}}_i, \tilde{u}_a, \tilde{g}_1} - \frac{4}{3} \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big) \Gamma^{L*}_{\breve{\tilde{u}}_j, g, u_b} \Gamma^{L}_{\breve{\tilde{u}}_i, g, u_b}$$

$$- \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, 0\Big) \Gamma^{L*}_{\breve{\tilde{u}}_j, \gamma, u_b} \Gamma^{L}_{\breve{\tilde{u}}_i, \gamma, u_b} - \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_Z^2\Big) \Gamma^{L*}_{\breve{\tilde{u}}_j, Z, u_b} \Gamma^{L}_{\breve{\tilde{u}}_i, Z, u_b}$$

$$- \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{W^-}^2\Big) \Gamma^{L*}_{\breve{\tilde{u}}_j, W^+, d_b} \Gamma^{L}_{\breve{\tilde{u}}_i, W^+, d_b} \tag{156}$$

$$\Sigma^{L}_{i,j}(p^2) = -\frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1\Big(p^2, m_{d_b}^2, m_{H_a^-}^2\Big) \Gamma^{L*}_{\breve{\tilde{u}}_j, H_a^+, d_b} \Gamma^{L}_{\breve{\tilde{u}}_i, H_a^+, d_b}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{3} B_1\Big(p^2, m_{u_b}^2, m_{h_a}^2\Big) \Gamma^{L*}_{\breve{\tilde{u}}_j, h_a, u_b} \Gamma^{L}_{\breve{\tilde{u}}_i, h_a, u_b}$$

$$- \frac{1}{2} \sum_{a=1}^{2} \sum_{b=1}^{6} B_1\Big(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{d}_b}^2\Big) \Gamma^{L*}_{\breve{\tilde{u}}_j, \tilde{\chi}_a^+, \tilde{d}_b} \Gamma^{L}_{\breve{\tilde{u}}_i, \tilde{\chi}_a^+, \tilde{d}_b}$$

$$- \frac{1}{2} \sum_{a=1}^{3} \sum_{b=1}^{2} B_1\Big(p^2, m_{u_a}^2, m_{A_b^0}^2\Big) \Gamma^{L*}_{\breve{\tilde{u}}_j, u_a, A_b^0} \Gamma^{L}_{\breve{\tilde{u}}_i, u_a, A_b^0}$$

$$
-\frac{1}{2}\sum_{a=1}^{6}\sum_{b=1}^{4}B_1\Big(p^2,m_{\tilde\chi_b^0}^2,m_{\tilde u_a}^2\Big)\Gamma^{L*}_{\breve{\tilde u}_j,\tilde u_a,\tilde\chi_b^0}\Gamma^L_{\breve{\tilde u}_i,\tilde u_a,\tilde\chi_b^0}
$$

$$
-\frac{2}{3}\sum_{a=1}^{6}B_1\Big(p^2,m_{\tilde g}^2,m_{\tilde u_a}^2\Big)\Gamma^{L*}_{\breve{\tilde u}_j,\tilde u_a,\tilde g_1}\Gamma^L_{\breve{\tilde u}_i,\tilde u_a,\tilde g_1}-\frac{4}{3}\sum_{b=1}^{3}B_1\Big(p^2,m_{u_b}^2,0\Big)\Gamma^{R*}_{\breve{\tilde u}_j,g,u_b}\Gamma^R_{\breve{\tilde u}_i,g,u_b}
$$

$$
-\sum_{b=1}^{3}B_1\Big(p^2,m_{u_b}^2,0\Big)\Gamma^{R*}_{\breve{\tilde u}_j,\gamma,u_b}\Gamma^R_{\breve{\tilde u}_i,\gamma,u_b}-\sum_{b=1}^{3}B_1\Big(p^2,m_{u_b}^2,m_Z^2\Big)\Gamma^{R*}_{\breve{\tilde u}_j,Z,u_b}\Gamma^R_{\breve{\tilde u}_i,Z,u_b}
$$

$$
-\sum_{b=1}^{3}B_1\Big(p^2,m_{d_b}^2,m_{W^-}^2\Big)\Gamma^{R*}_{\breve{\tilde u}_j,W^+,d_b}\Gamma^R_{\breve{\tilde u}_i,W^+,d_b}\tag{157}
$$

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

$$
\Sigma^S(p^2)=+\sum_{a=1}^{6}\sum_{b=1}^{3}B_0\Big(p^2,m_{d_b}^2,m_{\tilde d_a}^2\Big)\Gamma^{L*}_{\tilde g_j,\tilde d_a^*,d_b}m_{d_b}\Gamma^R_{\tilde g_i,\tilde d_a^*,d_b}
$$

$$
+\sum_{a=1}^{6}\sum_{b=1}^{3}B_0\Big(p^2,m_{u_b}^2,m_{\tilde u_a}^2\Big)\Gamma^{L*}_{\tilde g_j,\tilde u_a^*,u_b}m_{u_b}\Gamma^R_{\tilde g_i,\tilde u_a^*,u_b}-12\Big(-\frac{1}{2}\text{rMS}+B_0\Big(p^2,m_{\tilde g}^2,0\Big)\Big)\Gamma^{R*}_{\tilde g_j,g,\tilde g_1}m_{\tilde g}\Gamma^L_{\tilde g_i,g,\tilde g_1}
$$
$$\tag{158}$$

$$
\Sigma^R(p^2)=-\frac{1}{2}\sum_{a=1}^{6}\sum_{b=1}^{3}B_1\Big(p^2,m_{d_b}^2,m_{\tilde d_a}^2\Big)\Gamma^{R*}_{\tilde g_j,\tilde d_a^*,d_b}\Gamma^R_{\tilde g_i,\tilde d_a^*,d_b}
$$

$$
-\frac{1}{2}\sum_{a=1}^{6}\sum_{b=1}^{3}B_1\Big(p^2,m_{u_b}^2,m_{\tilde u_a}^2\Big)\Gamma^{R*}_{\tilde g_j,\tilde u_a^*,u_b}\Gamma^R_{\tilde g_i,\tilde u_a^*,u_b}-3B_1\Big(p^2,m_{\tilde g}^2,0\Big)\Gamma^{L*}_{\tilde g_j,g,\tilde g_1}\Gamma^L_{\tilde g_i,g,\tilde g_1}\tag{159}
$$

$$
\Sigma^L(p^2)=-\frac{1}{2}\sum_{a=1}^{6}\sum_{b=1}^{3}B_1\Big(p^2,m_{d_b}^2,m_{\tilde d_a}^2\Big)\Gamma^{L*}_{\tilde g_j,\tilde d_a^*,d_b}\Gamma^L_{\tilde g_i,\tilde d_a^*,d_b}
$$

$$
-\frac{1}{2}\sum_{a=1}^{6}\sum_{b=1}^{3}B_1\Big(p^2,m_{u_b}^2,m_{\tilde u_a}^2\Big)\Gamma^{L*}_{\tilde g_j,\tilde u_a^*,u_b}\Gamma^L_{\tilde g_i,\tilde u_a^*,u_b}-3B_1\Big(p^2,m_{\tilde g}^2,0\Big)\Gamma^{R*}_{\tilde g_j,g,\tilde g_1}\Gamma^R_{\tilde g_i,g,\tilde g_1}\tag{160}
$$

- **Self-Energy for Z-Boson** (Z)

$$
\Pi(p^2)=+|\Gamma_{Z,\eta^-,\eta^-}|^2B_{00}\Big(p^2,m_{\eta^-}^2,m_{\eta^-}^2\Big)+|\Gamma_{Z,\eta^+,\eta^+}|^2B_{00}\Big(p^2,m_{\eta^+}^2,m_{\eta^+}^2\Big)
$$

$$
-|\Gamma_{Z,W^+,W^-}|^2\Big(10B_{00}\Big(p^2,m_{W^-}^2,m_{W^-}^2\Big)+2A_0\Big(m_{W^-}^2\Big)-2\text{rMS}\Big(2m_{W^-}^2-\frac{1}{3}p^2\Big)+B_0\Big(p^2,m_{W^-}^2,m_{W^-}^2\Big)\Big(2m_{W^-}^2+4p^2\Big)\Big)
$$

$$
+\frac{1}{2}\sum_{a=1}^{2}A_0\Big(m_{A_a^0}^2\Big)\Gamma_{Z,Z,A_a^0,A_a^0}+\sum_{a=1}^{2}A_0\Big(m_{H_a^-}^2\Big)\Gamma_{Z,Z,H_a^+,H_a^-}+\frac{1}{2}\sum_{a=1}^{2}A_0\Big(m_{h_a}^2\Big)\Gamma_{Z,Z,h_a,h_a}
$$

$$
-4\sum_{a=1}^{2}\sum_{b=1}^{2}|\Gamma_{Z,h_a,A_b^0}|^2B_{00}\Big(p^2,m_{A_b^0}^2,m_{h_a}^2\Big)-4\sum_{a=1}^{2}\sum_{b=1}^{2}|\Gamma_{Z,H_a^+,H_b^-}|^2B_{00}\Big(p^2,m_{H_a^-}^2,m_{H_b^-}^2\Big)
$$

$$+ \sum_{a=1}^{2} \sum_{b=1}^{2} \left[\left(|\Gamma_{Z,\tilde{\chi}_a^+,\tilde{\chi}_b^-}^{L}|^2 + |\Gamma_{Z,\tilde{\chi}_a^+,\tilde{\chi}_b^-}^{R}|^2 \right) H_0\left(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2 \right) \right.$$

$$\left. + 4 B_0\left(p^2, m_{\tilde{\chi}_a^-}^2, m_{\tilde{\chi}_b^-}^2 \right) m_{\tilde{\chi}_a^-} m_{\tilde{\chi}_b^-} \Re\left(\Gamma_{Z,\tilde{\chi}_a^+,\tilde{\chi}_b^-}^{L*} \Gamma_{Z,\tilde{\chi}_a^+,\tilde{\chi}_b^-}^{R} \right) \right]$$

$$+ \sum_{a=1}^{3} A_0\left(m_{\tilde{\nu}_a}^2 \right) \Gamma_{Z,Z,\tilde{\nu}_a^*,\tilde{\nu}_a} - 4 \sum_{a=1}^{3} \sum_{b=1}^{3} |\Gamma_{Z,\tilde{\nu}_a^*,\tilde{\nu}_b}|^2 B_{00}\left(p^2, m_{\tilde{\nu}_a}^2, m_{\tilde{\nu}_b}^2 \right)$$

$$+ 3 \sum_{a=1}^{3} \sum_{b=1}^{3} \left[\left(|\Gamma_{Z,\bar{d}_a,d_b}^{L}|^2 + |\Gamma_{Z,\bar{d}_a,d_b}^{R}|^2 \right) H_0\left(p^2, m_{d_a}^2, m_{d_b}^2 \right) \right.$$

$$\left. + 4 B_0\left(p^2, m_{d_a}^2, m_{d_b}^2 \right) m_{d_a} m_{d_b} \Re\left(\Gamma_{Z,\bar{d}_a,d_b}^{L*} \Gamma_{Z,\bar{d}_a,d_b}^{R} \right) \right]$$

$$+ \sum_{a=1}^{3} \sum_{b=1}^{3} \left[\left(|\Gamma_{Z,\bar{e}_a,e_b}^{L}|^2 + |\Gamma_{Z,\bar{e}_a,e_b}^{R}|^2 \right) H_0\left(p^2, m_{e_a}^2, m_{e_b}^2 \right) \right.$$

$$\left. + 4 B_0\left(p^2, m_{e_a}^2, m_{e_b}^2 \right) m_{e_a} m_{e_b} \Re\left(\Gamma_{Z,\bar{e}_a,e_b}^{L*} \Gamma_{Z,\bar{e}_a,e_b}^{R} \right) \right]$$

$$+ 3 \sum_{a=1}^{3} \sum_{b=1}^{3} \left[\left(|\Gamma_{Z,\bar{u}_a,u_b}^{L}|^2 + |\Gamma_{Z,\bar{u}_a,u_b}^{R}|^2 \right) H_0\left(p^2, m_{u_a}^2, m_{u_b}^2 \right) \right.$$

$$\left. + 4 B_0\left(p^2, m_{u_a}^2, m_{u_b}^2 \right) m_{u_a} m_{u_b} \Re\left(\Gamma_{Z,\bar{u}_a,u_b}^{L*} \Gamma_{Z,\bar{u}_a,u_b}^{R} \right) \right]$$

$$+ \sum_{a=1}^{3} \sum_{b=1}^{3} \left[\left(|\Gamma_{Z,\bar{\nu}_a,\nu_b}^{L}|^2 + |\Gamma_{Z,\bar{\nu}_a,\nu_b}^{R}|^2 \right) H_0\left(p^2, m_{\nu_a}^2, m_{\nu_b}^2 \right) \right.$$

$$\left. + 4 B_0\left(p^2, m_{\nu_a}^2, m_{\nu_b}^2 \right) m_{\nu_a} m_{\nu_b} \Re\left(\Gamma_{Z,\bar{\nu}_a,\nu_b}^{L*} \Gamma_{Z,\bar{\nu}_a,\nu_b}^{R} \right) \right]$$

$$+ \frac{1}{2} \sum_{a=1}^{4} \sum_{b=1}^{4} \left[\left(|\Gamma_{Z,\tilde{\chi}_a^0,\tilde{\chi}_b^0}^{L}|^2 + |\Gamma_{Z,\tilde{\chi}_a^0,\tilde{\chi}_b^0}^{R}|^2 \right) H_0\left(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2 \right) \right.$$

$$\left. + 4 B_0\left(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^0}^2 \right) m_{\tilde{\chi}_a^0} m_{\tilde{\chi}_b^0} \Re\left(\Gamma_{Z,\tilde{\chi}_a^0,\tilde{\chi}_b^0}^{L*} \Gamma_{Z,\tilde{\chi}_a^0,\tilde{\chi}_b^0}^{R} \right) \right]$$

$$+ 3 \sum_{a=1}^{6} A_0\left(m_{\tilde{d}_a}^2 \right) \Gamma_{Z,Z,\tilde{d}_a^*,\tilde{d}_a} + \sum_{a=1}^{6} A_0\left(m_{\tilde{e}_a}^2 \right) \Gamma_{Z,Z,\tilde{e}_a^*,\tilde{e}_a} + 3 \sum_{a=1}^{6} A_0\left(m_{\tilde{u}_a}^2 \right) \Gamma_{Z,Z,\tilde{u}_a^*,\tilde{u}_a}$$

$$- 12 \sum_{a=1}^{6} \sum_{b=1}^{6} |\Gamma_{Z,\tilde{d}_a^*,\tilde{d}_b}|^2 B_{00}\left(p^2, m_{\tilde{d}_a}^2, m_{\tilde{d}_b}^2 \right) - 4 \sum_{a=1}^{6} \sum_{b=1}^{6} |\Gamma_{Z,\tilde{e}_a^*,\tilde{e}_b}|^2 B_{00}\left(p^2, m_{\tilde{e}_a}^2, m_{\tilde{e}_b}^2 \right)$$

$$- 12 \sum_{a=1}^{6} \sum_{b=1}^{6} |\Gamma_{Z,\tilde{u}_a^*,\tilde{u}_b}|^2 B_{00}\left(p^2, m_{\tilde{u}_a}^2, m_{\tilde{u}_b}^2 \right) + 2 \sum_{b=1}^{2} |\Gamma_{Z,W^+,H_b^-}|^2 B_0\left(p^2, m_{W^-}^2, m_{H_b^-}^2 \right)$$

$$+ \sum_{b=1}^{2} |\Gamma_{Z,Z,h_b}|^2 B_0\left(p^2, m_Z^2, m_{h_b}^2 \right) + 2 \mathrm{rMS} m_{W^-}^2 \Gamma_{Z,Z,W^+,W^-}^1 - A_0\left(m_{W^-}^2 \right) \left(4 \Gamma_{Z,Z,W^+,W^-}^1 + \Gamma_{Z,Z,W^+,W^-}^2 + \Gamma_{Z,Z,W^+,W^-}^3 \right)$$

$$(161)$$

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

$$\Pi(p^2) = -12 \sum_{a=1}^{6} \sum_{b=1}^{6} |\Gamma_{W^+,\tilde{u}_a^*,\tilde{d}_b}|^2 B_{00}\Big(p^2, m_{\tilde{d}_b}^2, m_{\tilde{u}_a}^2\Big) + 2\mathrm{rMS}m_{W^-}^2 \Gamma_{W^-,W^+,W^+,W^-}^1 + 3\sum_{a=1}^{3}\sum_{b=1}^{3}\Big[\Big(|\Gamma_{W^+,\bar{u}_a,d_b}^L|^2 + |\Gamma_{W^+,\bar{u}_a,d_b}^R|^2\Big)H$$

$$+ 4B_0\Big(p^2, m_{u_a}^2, m_{d_b}^2\Big)m_{d_b}m_{u_a}\Re\Big(\Gamma_{W^+,\bar{u}_a,d_b}^{L*}\Gamma_{W^+,\bar{u}_a,d_b}^R\Big)\Big] + 3\sum_{a=1}^{6}A_0\Big(m_{\tilde{d}_a}^2\Big)\Gamma_{W^-,W^+,\tilde{d}_a^*,\tilde{d}_a} + 3\sum_{a=1}^{6}A_0\Big(m_{\tilde{u}_a}^2\Big)\Gamma_{W^-,W^+,\tilde{u}_a^*,\tilde{u}_a}$$

$$+ 4B_0\Big(p^2, m_{\nu_a}^2, m_{e_b}^2\Big)m_{e_b}m_{\nu_a}\Re\Big(\Gamma_{W^+,\bar{\nu}_a,e_b}^{L*}\Gamma_{W^+,\bar{\nu}_a,e_b}^R\Big)\Big] + \sum_{a=1}^{4}\sum_{b=1}^{2}\Big[\Big(|\Gamma_{W^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^L|^2 + |\Gamma_{W^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^R|^2\Big)H_0\Big(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^-}^2\Big)$$

$$+ 4B_0\Big(p^2, m_{\tilde{\chi}_a^0}^2, m_{\tilde{\chi}_b^-}^2\Big)m_{\tilde{\chi}_b^-}m_{\tilde{\chi}_a^0}\Re\Big(\Gamma_{W^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^{L*}\Gamma_{W^+,\tilde{\chi}_a^0,\tilde{\chi}_b^-}^R\Big)\Big] + \sum_{a=1}^{6}A_0\Big(m_{\tilde{e}_a}^2\Big)\Gamma_{W^-,W^+,\tilde{e}_a^*,\tilde{e}_a} + \sum_{b=1}^{2}|\Gamma_{W^+,\gamma,H_b^-}|^2 B_0\Big(p^2, 0, m_H^2$$

$$(162)$$

8.2   Tadpoles

$$\delta t_h^{(1)} = + A_0\Big(m_{\eta^-}^2\Big)\Gamma_{\breve{h}_i,\eta^-,\eta^-} + A_0\Big(m_{\eta^+}^2\Big)\Gamma_{\breve{h}_i,\eta^+,\eta^+} + A_0\Big(m_{\eta^Z}^2\Big)\Gamma_{\breve{h}_i,\eta^Z,\eta^Z}$$

$$+ 4\Gamma_{\breve{h}_i,W^+,W^-}\Big(-\frac{1}{2}\mathrm{rMS}m_{W^-}^2 + A_0\Big(m_{W^-}^2\Big)\Big) + 2\Gamma_{\breve{h}_i,Z,Z}\Big(-\frac{1}{2}\mathrm{rMS}m_Z^2 + A_0\Big(m_Z^2\Big)\Big) - \frac{1}{2}\sum_{a=1}^{2}A_0\Big(m_{A_a^0}^2\Big)\Gamma_{\breve{h}_i,A_a^0,A_a^0}$$

$$- \sum_{a=1}^{2}A_0\Big(m_{H_a^-}^2\Big)\Gamma_{\breve{h}_i,H_a^+,H_a^-} - \frac{1}{2}\sum_{a=1}^{2}A_0\Big(m_{h_a}^2\Big)\Gamma_{\breve{h}_i,h_a,h_a}$$

$$+ 2\sum_{a=1}^{2}A_0\Big(m_{\tilde{\chi}_a^-}^2\Big)m_{\tilde{\chi}_a^-}\Big(\Gamma_{\breve{h}_i,\tilde{\chi}_a^+,\tilde{\chi}_a^-}^L + \Gamma_{\breve{h}_i,\tilde{\chi}_a^+,\tilde{\chi}_a^-}^R\Big) - \sum_{a=1}^{3}A_0\Big(m_{\tilde{\nu}_a}^2\Big)\Gamma_{\breve{h}_i,\tilde{\nu}_a^*,\tilde{\nu}_a}$$

$$+ 6\sum_{a=1}^{3}A_0\Big(m_{d_a}^2\Big)m_{d_a}\Big(\Gamma_{\breve{h}_i,\bar{d}_a,d_a}^L + \Gamma_{\breve{h}_i,\bar{d}_a,d_a}^R\Big)$$

$$+ 2\sum_{a=1}^{3}A_0\Big(m_{e_a}^2\Big)m_{e_a}\Big(\Gamma_{\breve{h}_i,\bar{e}_a,e_a}^L + \Gamma_{\breve{h}_i,\bar{e}_a,e_a}^R\Big)$$

$$+ 6\sum_{a=1}^{3}A_0\Big(m_{u_a}^2\Big)m_{u_a}\Big(\Gamma_{\breve{h}_i,\bar{u}_a,u_a}^L + \Gamma_{\breve{h}_i,\bar{u}_a,u_a}^R\Big) + \sum_{a=1}^{4}A_0\Big(m_{\tilde{\chi}_a^0}^2\Big)m_{\tilde{\chi}_a^0}\Big(\Gamma_{\breve{h}_i,\tilde{\chi}_a^0,\tilde{\chi}_a^0}^L + \Gamma_{\breve{h}_i,\tilde{\chi}_a^0,\tilde{\chi}_a^0}^R\Big)$$

$$- 3\sum_{a=1}^{6}A_0\Big(m_{\tilde{d}_a}^2\Big)\Gamma_{\breve{h}_i,\tilde{d}_a^*,\tilde{d}_a} - \sum_{a=1}^{6}A_0\Big(m_{\tilde{e}_a}^2\Big)\Gamma_{\breve{h}_i,\tilde{e}_a^*,\tilde{e}_a} - 3\sum_{a=1}^{6}A_0\Big(m_{\tilde{u}_a}^2\Big)\Gamma_{\breve{h}_i,\tilde{u}_a^*,\tilde{u}_a} \qquad (163)$$

9 Interactions for eigenstates 'EWSB'

9.1 Three Scalar-Interaction
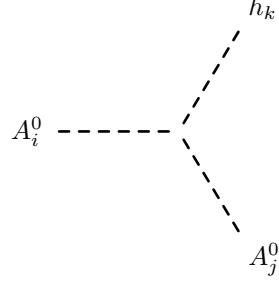
$$-\frac{i}{4}\left(g_1^2 + g_2^2\right)\left(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\right)\left(v_d Z_{k1}^H - v_u Z_{k2}^H\right)$$ (164)
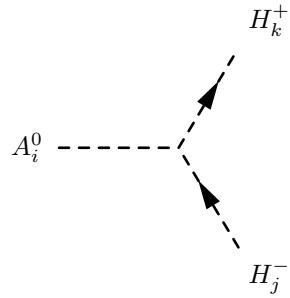
$$\frac{1}{4}g_2^2\left(v_d Z_{i2}^A + v_u Z_{i1}^A\right)\left(-Z_{j1}^+ Z_{k2}^+ + Z_{j2}^+ Z_{k1}^+\right)$$ (165)
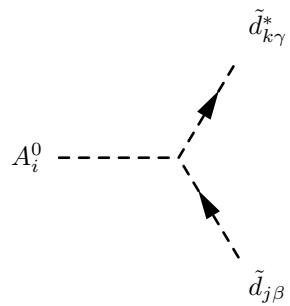
$$\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\Big(\sum_{b=1}^{3} Z_{jb}^{D,*}\sum_{a=1}^{3} Z_{k3+a}^{D}T_{d,ab}Z_{i1}^A - \sum_{b=1}^{3}\sum_{a=1}^{3} Z_{j3+a}^{D,*}T_{d,ab}^{*}Z_{kb}^{D}Z_{i1}^A$$

$$+ \left(\sum_{b=1}^{3} Z_{jb}^{D,*} \sum_{a=1}^{3} T'_{d,ab} Z_{k3+a}^{D} + \mu^* \sum_{b=1}^{3} Z_{jb}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} - \sum_{b=1}^{3} \sum_{a=1}^{3} T'^{*}_{d,ab} Z_{j3+a}^{D,*} Z_{kb}^{D} \right.$$

$$\left. - \mu \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{d,ab}^{*} Z_{j3+a}^{D,*} Z_{kb}^{D} \right) Z_{i2}^{A} \right) \tag{166}$$
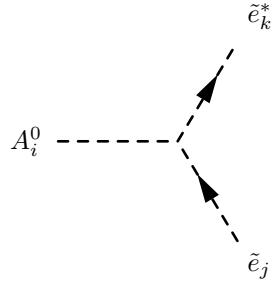
$$\frac{1}{\sqrt{2}} \left(\sum_{b=1}^{3} Z_{jb}^{E,*} \sum_{a=1}^{3} Z_{k3+a}^{E} T_{e,ab} Z_{i1}^{A} - \sum_{b=1}^{3} \sum_{a=1}^{3} Z_{j3+a}^{E,*} T_{e,ab}^{*} Z_{kb}^{E} Z_{i1}^{A} \right.$$

$$+ \left(\sum_{b=1}^{3} Z_{jb}^{E,*} \sum_{a=1}^{3} T'_{e,ab} Z_{k3+a}^{E} + \mu^* \sum_{b=1}^{3} Z_{jb}^{E,*} \sum_{a=1}^{3} Y_{e,ab} Z_{k3+a}^{E} - \sum_{b=1}^{3} \sum_{a=1}^{3} T'^{*}_{e,ab} Z_{j3+a}^{E,*} Z_{kb}^{E} \right.$$

$$\left. \left. - \mu \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{e,ab}^{*} Z_{j3+a}^{E,*} Z_{kb}^{E} \right) Z_{i2}^{A} \right) \tag{167}$$
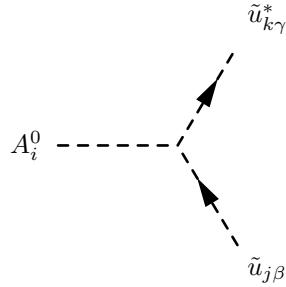
$$\frac{1}{\sqrt{2}} \delta_{\beta\gamma} \left(\sum_{b=1}^{3} Z_{jb}^{U,*} \sum_{a=1}^{3} T'_{u,ab} Z_{k3+a}^{U} Z_{i1}^{A} + \mu^* \sum_{b=1}^{3} Z_{jb}^{U,*} \sum_{a=1}^{3} Y_{u,ab} Z_{k3+a}^{U} Z_{i1}^{A} \right.$$

$$\left. - \sum_{b=1}^{3} \sum_{a=1}^{3} T'^{*}_{u,ab} Z_{j3+a}^{U,*} Z_{kb}^{U} Z_{i1}^{A} - \mu \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{u,ab}^{*} Z_{j3+a}^{U,*} Z_{kb}^{U} Z_{i1}^{A} \right.$$

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$$
+ \sum_{b=1}^{3} Z_{jb}^{U,*} \sum_{a=1}^{3} Z_{k3+a}^{U} T_{u,ab} Z_{i2}^{A} - \sum_{b=1}^{3} \sum_{a=1}^{3} Z_{j3+a}^{U,*} T_{u,ab}^{*} Z_{kb}^{U} Z_{i2}^{A} \Big) \tag{168}
$$
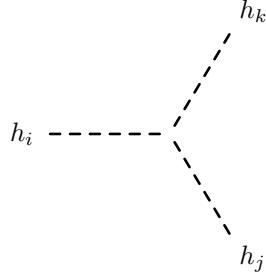
$$
\frac{i}{4} \Big(g_1^2 + g_2^2 \Big) \Big(Z_{i2}^{H} \Big(Z_{j1}^{H} \Big(v_d Z_{k2}^{H} + v_u Z_{k1}^{H} \Big) + Z_{j2}^{H} \Big(- 3 v_u Z_{k2}^{H} + v_d Z_{k1}^{H} \Big) \Big)
$$
$$
+ Z_{i1}^{H} \Big(Z_{j1}^{H} \Big(- 3 v_d Z_{k1}^{H} + v_u Z_{k2}^{H} \Big) + Z_{j2}^{H} \Big(v_d Z_{k2}^{H} + v_u Z_{k1}^{H} \Big) \Big) \Big) \tag{169}
$$
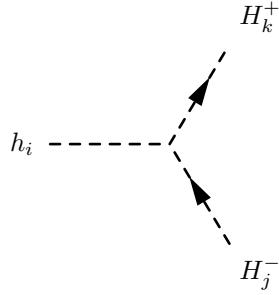
$$
-\frac{i}{4} \Big(Z_{i1}^{H} \Big(Z_{j1}^{+} \Big(\big(g_1^2 + g_2^2 \big) v_d Z_{k1}^{+} + g_2^2 v_u Z_{k2}^{+} \big) + Z_{j2}^{+} \Big(\big(- g_1^2 + g_2^2 \big) v_d Z_{k2}^{+} + g_2^2 v_u Z_{k1}^{+} \big) \Big)
$$
$$
+ Z_{i2}^{H} \Big(Z_{j1}^{+} \Big(\big(- g_1^2 + g_2^2 \big) v_u Z_{k1}^{+} + g_2^2 v_d Z_{k2}^{+} \big) + Z_{j2}^{+} \Big(\big(g_1^2 + g_2^2 \big) v_u Z_{k2}^{+} + g_2^2 v_d Z_{k1}^{+} \big) \Big) \Big) \tag{170}
$$

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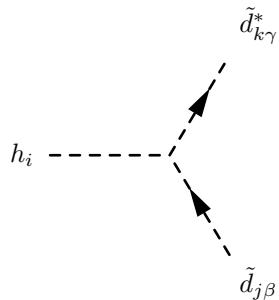
$$
\frac{i}{12}\delta_{\beta\gamma}\Big(\big(3g_2^2 + g_1^2\big)\sum_{a=1}^{3} Z_{ja}^{D,*} Z_{ka}^{D}\big(v_d Z_{i1}^{H} - v_u Z_{i2}^{H}\big)
$$

$$
+ 2\Big(g_1^2 \sum_{a=1}^{3} Z_{j3+a}^{D,*} Z_{k3+a}^{D}\big(v_d Z_{i1}^{H} - v_u Z_{i2}^{H}\big)
$$

$$
+ 3\Big(-\sqrt{2}\sum_{b=1}^{3} Z_{jb}^{D,*}\sum_{a=1}^{3} Z_{k3+a}^{D} T_{d,ab} Z_{i1}^{H} - \sqrt{2}\sum_{b=1}^{3}\sum_{a=1}^{3} Z_{j3+a}^{D,*} T_{d,ab}^{*} Z_{kb}^{D} Z_{i1}^{H}
$$

$$
- 2v_d \sum_{c=1}^{3} Z_{j3+c}^{D,*} \sum_{b=1}^{3}\sum_{a=1}^{3} Y_{d,ca}^{*} Y_{d,ba} Z_{k3+b}^{D} Z_{i1}^{H} - 2v_d \sum_{c=1}^{3}\sum_{b=1}^{3} Z_{jb}^{D,*} \sum_{a=1}^{3} Y_{d,ac}^{*} Y_{d,ab} Z_{kc}^{D} Z_{i1}^{H}
$$

$$
+ \sqrt{2}\sum_{b=1}^{3} Z_{jb}^{D,*} \sum_{a=1}^{3} T'_{d,ab} Z_{k3+a}^{D} Z_{i2}^{H} + \sqrt{2}\mu^{*} \sum_{b=1}^{3} Z_{jb}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} Z_{i2}^{H}
$$

$$
+ \sqrt{2}\sum_{b=1}^{3}\sum_{a=1}^{3} T'^{*}_{d,ab} Z_{j3+a}^{D,*} Z_{kb}^{D} Z_{i2}^{H} + \sqrt{2}\mu \sum_{b=1}^{3}\sum_{a=1}^{3} Y_{d,ab}^{*} Z_{j3+a}^{D,*} Z_{kb}^{D} Z_{i2}^{H}\Big)\Big)\Big) \tag{171}
$$
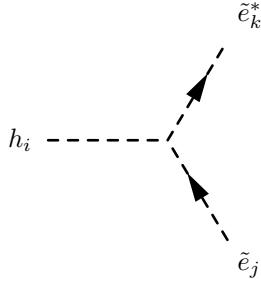
$$
-\frac{i}{4}\Big(\big(-g_2^2 + g_1^2\big)\sum_{a=1}^{3} Z_{ja}^{E,*} Z_{ka}^{E}\big(v_d Z_{i1}^{H} - v_u Z_{i2}^{H}\big)
$$

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

$$
- 2v_d \sum_{c=1}^{3} Z_{j3+c}^{E,*} \sum_{b=1}^{3}\sum_{a=1}^{3} Y_{e,ca}^{*} Y_{e,ba} Z_{k3+b}^{E} Z_{i1}^{H} - 2v_d \sum_{c=1}^{3}\sum_{b=1}^{3} Z_{jb}^{E,*} \sum_{a=1}^{3} Y_{e,ac}^{*} Y_{e,ab} Z_{kc}^{E} Z_{i1}^{H}
$$

$$
+ \sqrt{2}\sum_{b=1}^{3} Z_{jb}^{E,*} \sum_{a=1}^{3} T'_{e,ab} Z_{k3+a}^{E} Z_{i2}^{H} + \sqrt{2}\mu^{*} \sum_{b=1}^{3} Z_{jb}^{E,*} \sum_{a=1}^{3} Y_{e,ab} Z_{k3+a}^{E} Z_{i2}^{H}
$$

$$
+ \sqrt{2}\sum_{b=1}^{3}\sum_{a=1}^{3} T'^{*}_{e,ab} Z_{j3+a}^{E,*} Z_{kb}^{E} Z_{i2}^{H} + \sqrt{2}\mu \sum_{b=1}^{3}\sum_{a=1}^{3} Y_{e,ab}^{*} Z_{j3+a}^{E,*} Z_{kb}^{E} Z_{i2}^{H}
$$

$$
+ g_1^2 \sum_{a=1}^{3} Z_{j3+a}^{E,*} Z_{k3+a}^{E}\big(v_d Z_{i1}^{H} - v_u Z_{i2}^{H}\big)\Big)\Big) \tag{172}
$$
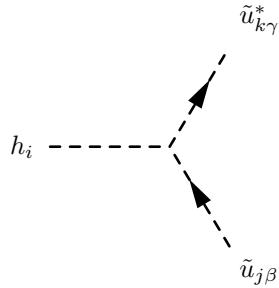
$$\frac{i}{12}\delta_{\beta\gamma}\Bigg(\Big(-3g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{ka}^{U}\Big(v_dZ_{i1}^{H}-v_uZ_{i2}^{H}\Big)+4g_1^2\sum_{a=1}^{3}Z_{j3+a}^{U,*}Z_{k3+a}^{U}\Big(-v_dZ_{i1}^{H}+v_uZ_{i2}^{H}\Big)$$

$$+6\Big(\sqrt{2}\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}T'_{u,ab}Z_{k3+a}^{U}Z_{i1}^{H}+\sqrt{2}\mu^*\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Y_{u,ab}Z_{k3+a}^{U}Z_{i1}^{H}$$

$$+\sqrt{2}\sum_{b=1}^{3}\sum_{a=1}^{3}T'^*_{u,ab}Z_{j3+a}^{U,*}Z_{kb}^{U}Z_{i1}^{H}+\sqrt{2}\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^*Z_{j3+a}^{U,*}Z_{kb}^{U}Z_{i1}^{H}$$

$$-\sqrt{2}\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Z_{k3+a}^{U}T_{u,ab}Z_{i2}^{H}-\sqrt{2}\sum_{b=1}^{3}\sum_{a=1}^{3}Z_{j3+a}^{U,*}T_{u,ab}^*Z_{kb}^{U}Z_{i2}^{H}$$

$$-2v_u\sum_{c=1}^{3}Z_{j3+c}^{U,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ca}^*Y_{u,ba}Z_{k3+b}^{U}Z_{i2}^{H}-2v_u\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Y_{u,ac}^*Y_{u,ab}Z_{kc}^{U}Z_{i2}^{H}\Big)\Bigg)\tag{173}$$
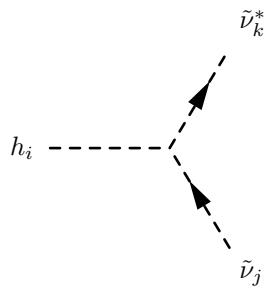
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\delta_{jk}\Big(v_dZ_{i1}^{H}-v_uZ_{i2}^{H}\Big)\tag{174}$$
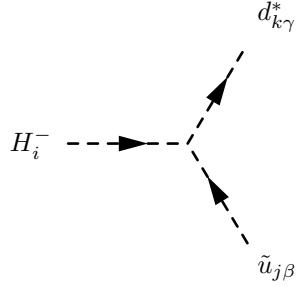
$$-\frac{i}{4}\delta_{\beta\gamma}\Big(\sqrt{2}g_2^2\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{ka}^D\Big(v_dZ_{i1}^{+}+v_uZ_{i2}^{+}\Big)$$

$$-2\Big(2\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Z_{k3+a}^D T_{d,ab}Z_{i1}^{+}+2\sum_{b=1}^{3}\sum_{a=1}^{3}T'^{*}_{u,ab}Z_{j3+a}^{U,*}Z_{kb}^D Z_{i1}^{+}$$

$$+2\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^{*}Z_{j3+a}^{U,*}Z_{kb}^D Z_{i1}^{+}+\sqrt{2}v_u\sum_{c=1}^{3}Z_{j3+c}^{U,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ca}^{*}Y_{d,ba}Z_{k3+b}^D Z_{i1}^{+}$$

$$+\sqrt{2}v_d\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Y_{d,ac}^{*}Y_{d,ab}Z_{kc}^D Z_{i1}^{+}+2\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}T'_{d,ab}Z_{k3+a}^D Z_{i2}^{+}$$

$$+2\mu^{*}\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Y_{d,ab}Z_{k3+a}^D Z_{i2}^{+}+2\sum_{b=1}^{3}\sum_{a=1}^{3}Z_{j3+a}^{U,*}T_{u,ab}^{*}Z_{kb}^D Z_{i2}^{+}$$

$$+\sqrt{2}v_d\sum_{c=1}^{3}Z_{j3+c}^{U,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ca}^{*}Y_{d,ba}Z_{k3+b}^D Z_{i2}^{+}$$

$$+\sqrt{2}v_u\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Y_{u,ac}^{*}Y_{u,ab}Z_{kc}^D Z_{i2}^{+}\Big)\Big) \tag{175}$$
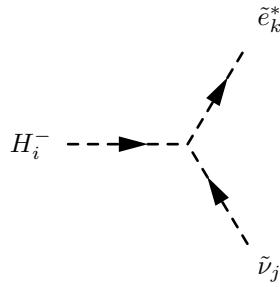
$$-\frac{i}{4}\Big(\sqrt{2}g_2^2\sum_{a=1}^{3}Z_{ja}^{V,*}Z_{ka}^E\Big(v_dZ_{i1}^{+}+v_uZ_{i2}^{+}\Big)$$

$$-2\Big(2\sum_{b=1}^{3}Z_{jb}^{V,*}\sum_{a=1}^{3}Z_{k3+a}^{E}T_{e,ab}Z_{i1}^{+}+\sqrt{2}v_{d}\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{V,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{kc}^{E}Z_{i1}^{+}$$

$$+2\Big(\mu^{*}\sum_{b=1}^{3}Z_{jb}^{V,*}\sum_{a=1}^{3}Y_{e,ab}Z_{k3+a}^{E}+\sum_{b=1}^{3}Z_{jb}^{V,*}\sum_{a=1}^{3}T'_{e,ab}Z_{k3+a}^{E}\Big)Z_{i2}^{+}\Big)\Big)\qquad(176)$$
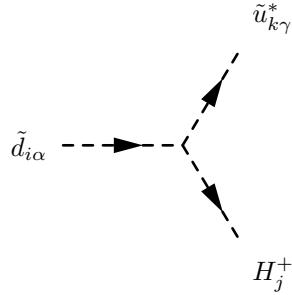
$$-\frac{i}{4}\delta_{\alpha\gamma}\Big(\sqrt{2}g_{2}^{2}\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ka}^{U}\Big(v_{d}Z_{j1}^{+}+v_{u}Z_{j2}^{+}\Big)$$

$$-2\Big(2\sum_{b=1}^{3}Z_{ib}^{D,*}\sum_{a=1}^{3}T'_{u,ab}Z_{k3+a}^{U}Z_{j1}^{+}+2\mu^{*}\sum_{b=1}^{3}Z_{ib}^{D,*}\sum_{a=1}^{3}Y_{u,ab}Z_{k3+a}^{U}Z_{j1}^{+}$$

$$+2\sum_{b=1}^{3}\sum_{a=1}^{3}Z_{i3+a}^{D,*}T_{d,ab}^{*}Z_{kb}^{U}Z_{j1}^{+}+\sqrt{2}v_{u}\sum_{c=1}^{3}Z_{i3+c}^{D,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ca}^{*}Y_{u,ba}Z_{k3+b}^{U}Z_{j1}^{+}$$

$$+\sqrt{2}v_{d}\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{ib}^{D,*}\sum_{a=1}^{3}Y_{d,ac}^{*}Y_{d,ab}Z_{kc}^{U}Z_{j1}^{+}+2\sum_{b=1}^{3}Z_{ib}^{D,*}\sum_{a=1}^{3}Z_{k3+a}^{U}T_{u,ab}Z_{j2}^{+}$$

$$+2\sum_{b=1}^{3}\sum_{a=1}^{3}T'^{*}_{d,ab}Z_{i3+a}^{D,*}Z_{kb}^{U}Z_{j2}^{+}+2\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}Z_{i3+a}^{D,*}Z_{kb}^{U}Z_{j2}^{+}$$

$$+\sqrt{2}v_{d}\sum_{c=1}^{3}Z_{i3+c}^{D,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ca}^{*}Y_{u,ba}Z_{k3+b}^{U}Z_{j2}^{+}$$

$$+\sqrt{2}v_{u}\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{ib}^{D,*}\sum_{a=1}^{3}Y_{u,ac}^{*}Y_{u,ab}Z_{kc}^{U}Z_{j2}^{+}\Big)\Big)\qquad(177)$$
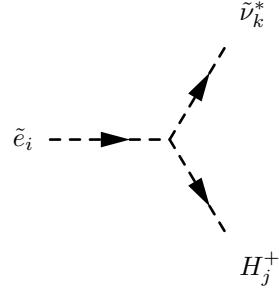
$$
-\frac{i}{4}\bigg(\sqrt{2}g_2^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ka}^{V}\Big(v_dZ_{j1}^{+}+v_uZ_{j2}^{+}\Big)
$$

$$
-2\Big(2\sum_{b=1}^{3}\sum_{a=1}^{3}Z_{i3+a}^{E,*}T_{e,ab}^{*}Z_{kb}^{V}Z_{j1}^{+}+\sqrt{2}v_d\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{ib}^{E,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{kc}^{V}Z_{j1}^{+}
$$

$$
+2\Big(\mu\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^{*}Z_{i3+a}^{E,*}Z_{kb}^{V}+\sum_{b=1}^{3}\sum_{a=1}^{3}T'^{*}_{e,ab}Z_{i3+a}^{E,*}Z_{kb}^{V}\Big)Z_{j2}^{+}\Big)\bigg) \tag{178}
$$

9.2 Two Scalar-One Vector Boson-Interaction
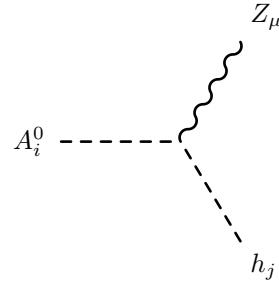
$$
\frac{1}{2}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(Z_{i1}^{A}Z_{j1}^{H}-Z_{i2}^{A}Z_{j2}^{H}\Big)\Big(-p_\mu^{h_j}+p_\mu^{A_i^0}\Big) \tag{179}
$$

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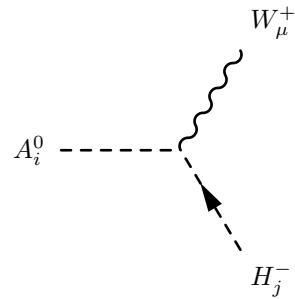
$$\frac{1}{2}g_2\Big(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+\Big)\Big(-p_\mu^{H_j^-} + p_\mu^{A_i^0}\Big) \tag{180}$$
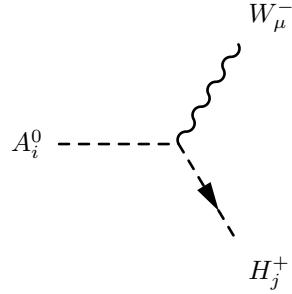
$$\frac{1}{2}g_2\Big(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{A_i^0}\Big) \tag{181}$$
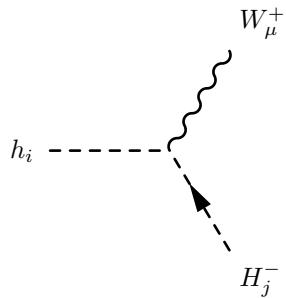
$$\frac{i}{2}g_2\Big(Z_{i1}^H Z_{j1}^+ - Z_{i2}^H Z_{j2}^+\Big)\Big(-p_\mu^{H_j^-} + p_\mu^{h_i}\Big) \tag{182}$$
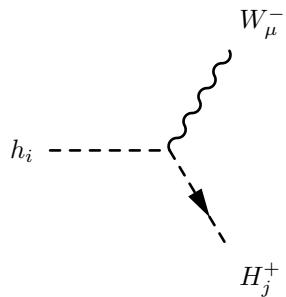
$$-\frac{i}{2}g_2\Big(Z_{i1}^H Z_{j1}^+ - Z_{i2}^H Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{h_i}\Big) \tag{183}$$
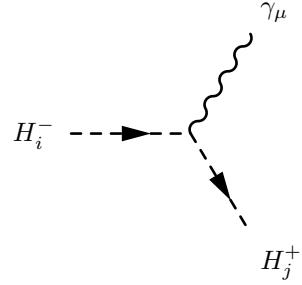
$$\frac{i}{2}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{184}$$
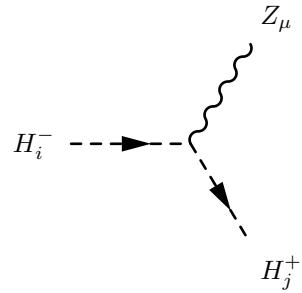
$$\frac{i}{2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{185}$$
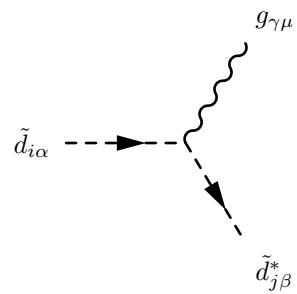
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\beta,\alpha}^\gamma\Big(-p_\mu^{\tilde{d}_{j\beta}^*} + p_\mu^{\tilde{d}_{i\alpha}}\Big) \tag{186}$$
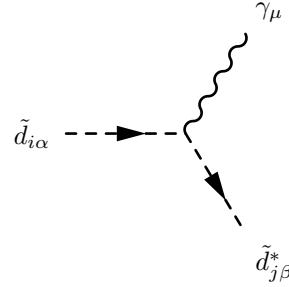
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1\cos\Theta_W\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{j3+a}^{D}+\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{D}\Big)\Big(-p_{\mu}^{\tilde{d}_{j\beta}^{*}}+p_{\mu}^{\tilde{d}_{i\alpha}}\Big) \qquad (187)$$
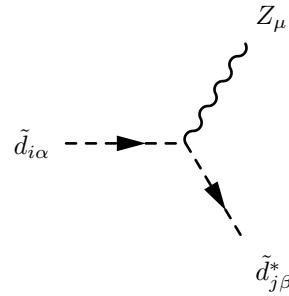
$$\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1\sin\Theta_W\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{j3+a}^{D}+\Big(3g_2\cos\Theta_W+g_1\sin\Theta_W\Big)\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{D}\Big)\Big(-p_{\mu}^{\tilde{d}_{j\beta}^{*}}+p_{\mu}^{\tilde{d}_{i\alpha}}\Big) \qquad (188)$$
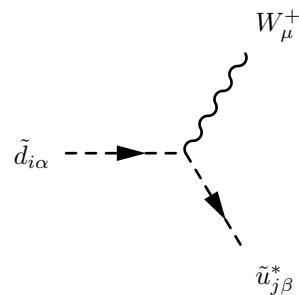
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{U}\Big(-p_{\mu}^{\tilde{u}_{j\beta}^{*}}+p_{\mu}^{\tilde{d}_{i\alpha}}\Big) \qquad (189)$$

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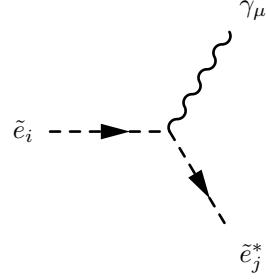
$$\frac{i}{2}\left(2g_1\cos\Theta_W\sum_{a=1}^{3}Z_{i3+a}^{E,*}Z_{j3+a}^{E}+\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ja}^{E}\right)\left(-p_\mu^{\tilde{e}_j^*}+p_\mu^{\tilde{e}_i}\right) \tag{190}$$
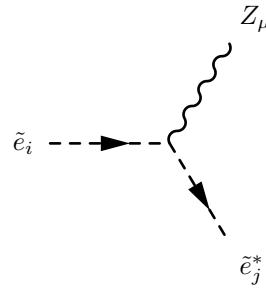
$$\frac{i}{2}\left(-2g_1\sin\Theta_W\sum_{a=1}^{3}Z_{i3+a}^{E,*}Z_{j3+a}^{E}+\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ja}^{E}\right)\left(-p_\mu^{\tilde{e}_j^*}+p_\mu^{\tilde{e}_i}\right) \tag{191}$$
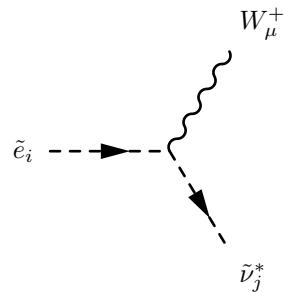
$$-i\frac{1}{\sqrt{2}}g_2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ja}^{V}\left(-p_\mu^{\tilde{\nu}_j^*}+p_\mu^{\tilde{e}_i}\right) \tag{192}$$
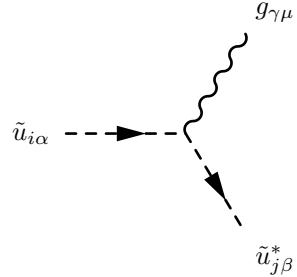
$$-\frac{i}{2}g_3\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\Big(-p_\mu^{\tilde{u}^*_{j\beta}}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{193}$$

$$-\frac{i}{6}\delta_{\alpha\beta}\Big(\big(3g_2\sin\Theta_W+g_1\cos\Theta_W\big)\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{U}_{ja}+4g_1\cos\Theta_W\sum_{a=1}^{3}Z^{U,*}_{i3+a}Z^{U}_{j3+a}\Big)\Big(-p_\mu^{\tilde{u}^*_{j\beta}}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{194}$$

$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{D}_{ja}\Big(-p_\mu^{\tilde{d}^*_{j\beta}}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{195}$$

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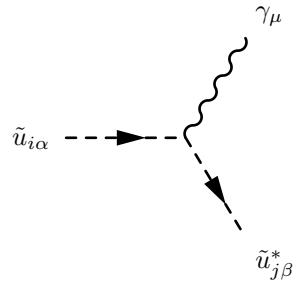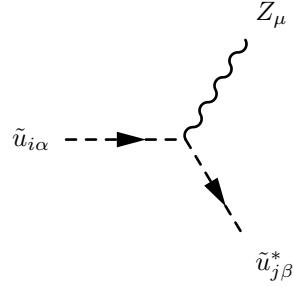
$$-\frac{i}{6}\delta_{\alpha\beta}\left(\left(3g_2\cos\Theta_W - g_1\sin\Theta_W\right)\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ja}^{U} - 4g_1\sin\Theta_W\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{j3+a}^{U}\right)\left(-p_\mu^{\tilde{u}_{j\beta}^*} + p_\mu^{\tilde{u}_{i\alpha}}\right) \qquad (196)$$
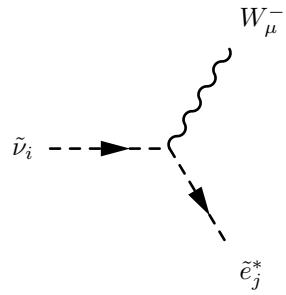
$$-i\frac{1}{\sqrt{2}}g_2\sum_{a=1}^{3}Z_{ia}^{V,*}Z_{ja}^{E}\left(-p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{\nu}_i}\right) \qquad (197)$$
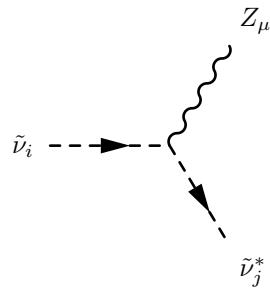
$$-\frac{i}{2}\delta_{ij}\left(g_1\sin\Theta_W + g_2\cos\Theta_W\right)\left(-p_\mu^{\tilde{\nu}_j^*} + p_\mu^{\tilde{\nu}_i}\right) \qquad (198)$$

9.3 One Scalar-Two Vector Boson-Interaction
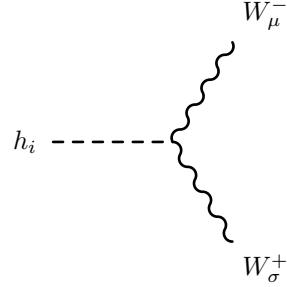
$$\frac{i}{2}g_2^2\left(v_d Z_{i1}^H + v_u Z_{i2}^H\right)\left(g_{\sigma\mu}\right) \tag{199}$$
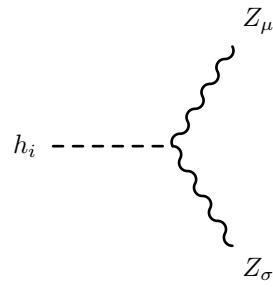
$$\frac{i}{2}\left(g_1 \sin\Theta_W + g_2 \cos\Theta_W\right)^2\left(v_d Z_{i1}^H + v_u Z_{i2}^H\right)\left(g_{\sigma\mu}\right) \tag{200}$$
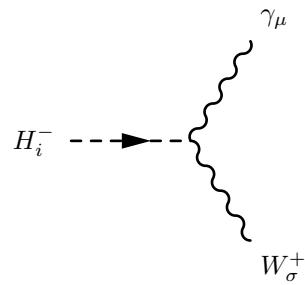
$$-\frac{i}{2}g_1 g_2 \cos\Theta_W\left(v_d Z_{i1}^+ - v_u Z_{i2}^+\right)\left(g_{\sigma\mu}\right) \tag{201}$$
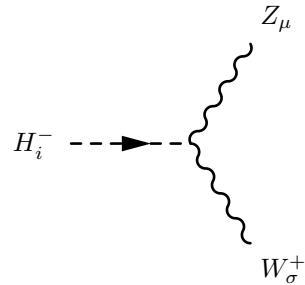
$$\frac{i}{2} g_1 g_2 \sin \Theta_W \left(v_d Z_{i1}^+ - v_u Z_{i2}^+ \right) \left(g_{\sigma\mu} \right) \tag{202}$$
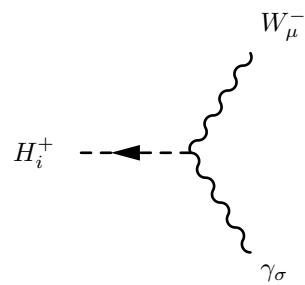
$$-\frac{i}{2} g_1 g_2 \cos \Theta_W \left(v_d Z_{i1}^+ - v_u Z_{i2}^+ \right) \left(g_{\sigma\mu} \right) \tag{203}$$
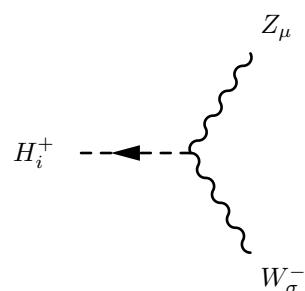
$$\frac{i}{2} g_1 g_2 \sin \Theta_W \left(v_d Z_{i1}^+ - v_u Z_{i2}^+ \right) \left(g_{\sigma\mu} \right) \tag{204}$$

9.4 Two Fermion-One Vector Boson-Interaction
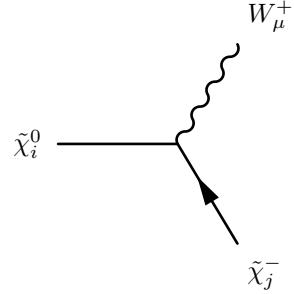
$$-\frac{i}{2}g_2\Big(2U_{j1}^*N_{i2}+\sqrt{2}U_{j2}^*N_{i3}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{205}$$

$$+\Big(i\frac{1}{\sqrt{2}}g_2N_{i4}^*V_{j2}-ig_2N_{i2}^*V_{j1}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{206}$$
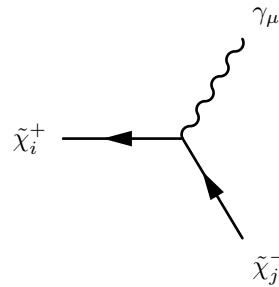
$$\frac{i}{2}\Big(2g_2U_{j1}^*\sin\Theta_W U_{i1}+U_{j2}^*\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)U_{i2}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{207}$$

$$+\frac{i}{2}\Big(2g_2V_{i1}^*\sin\Theta_W V_{j1}+V_{i2}^*\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)V_{j2}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{208}$$
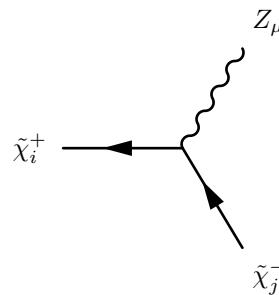
$$\frac{i}{2}\Big(2g_2 U_{j1}^* \cos\Theta_W U_{i1} + U_{j2}^*\big(-g_1\sin\Theta_W + g_2\cos\Theta_W\big)U_{i2}\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \qquad (209)$$

$$+\ \frac{i}{2}\Big(2g_2 V_{i1}^* \cos\Theta_W V_{j1} + V_{i2}^*\big(-g_1\sin\Theta_W + g_2\cos\Theta_W\big)V_{j2}\Big)\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \qquad (210)$$
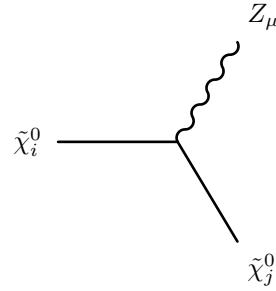
$$-\frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(N_{j3}^* N_{i3} - N_{j4}^* N_{i4}\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \qquad (211)$$

$$+\frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(N_{i3}^* N_{j3} - N_{i4}^* N_{j4}\Big)\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \qquad (212)$$
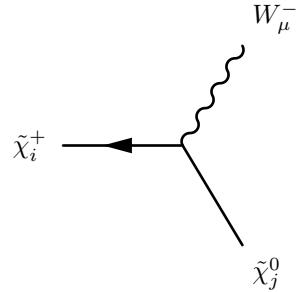
$$-\frac{i}{2}g_2\Big(2N_{j2}^* U_{i1} + \sqrt{2}N_{j3}^* U_{i2}\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \qquad (213)$$

$$+\Big(i\frac{1}{\sqrt{2}}g_2 V_{i2}^* N_{j4} - ig_2 V_{i1}^* N_{j2}\Big)\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \qquad (214)$$
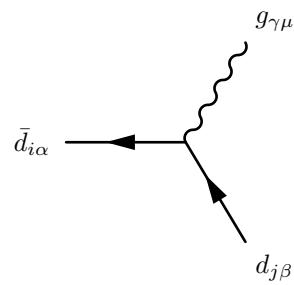
$$-\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right)\tag{215}$$

$$+-\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right)\tag{216}$$
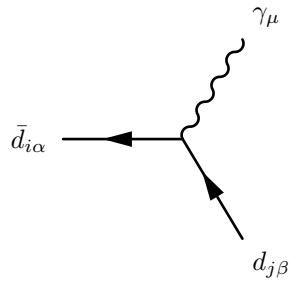
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right)\tag{217}$$

$$+\frac{i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right)\tag{218}$$
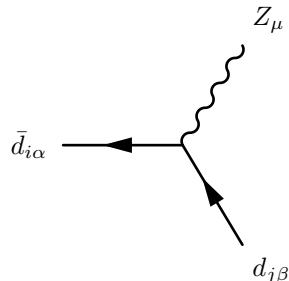
$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\cos\Theta_W+g_1\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right)\tag{219}$$

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

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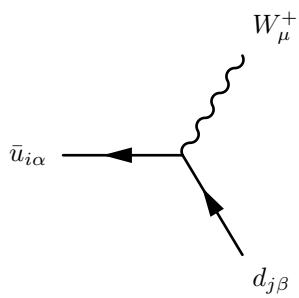
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}U_{L,ja}^{d,*}U_{L,ia}^{u}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \tag{221}$$
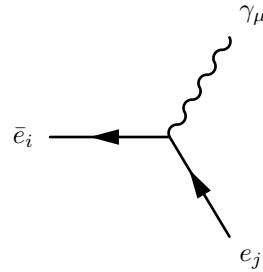
$$\frac{i}{2}\delta_{ij}\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \tag{222}$$

$$+\ ig_1\cos\Theta_W\delta_{ij}\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \tag{223}$$
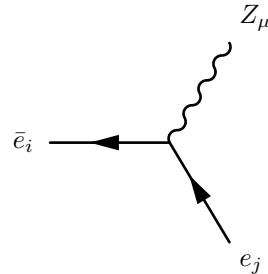
$$\frac{i}{2}\delta_{ij}\left(-g_1\sin\Theta_W+g_2\cos\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \tag{224}$$

$$+\ -ig_1\delta_{ij}\sin\Theta_W\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \tag{225}$$
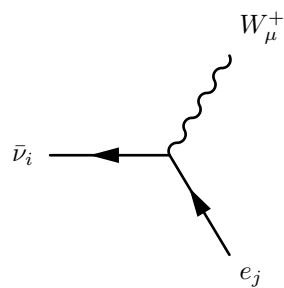
$$- i\frac{1}{\sqrt{2}}g_2 U_{L,ji}^{e,*}\Theta_{i,3}\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \tag{226}$$
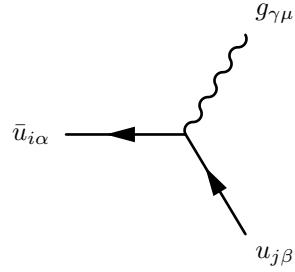
$$- \frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^{\gamma}\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \tag{227}$$

$$+ -\frac{i}{2}g_3\delta_{ij}\lambda_{\alpha,\beta}^{\gamma}\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \tag{228}$$
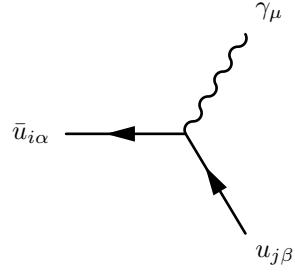
$$- \frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\sin\Theta_W + g_1\cos\Theta_W\right)\left(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\right) \tag{229}$$

$$+ -\frac{2i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\right) \tag{230}$$
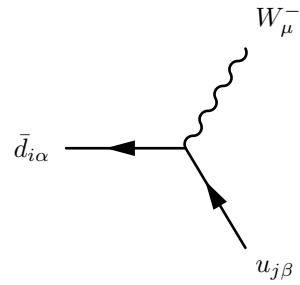
$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\sum_{a=1}^{3}U_{L,ja}^{u,*}U_{L,ia}^{d}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \tag{231}$$
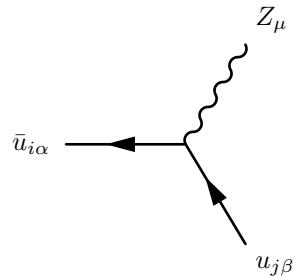
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\left(3g_2\cos\Theta_W-g_1\sin\Theta_W\right)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \tag{232}$$

$$+\frac{2i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \tag{233}$$
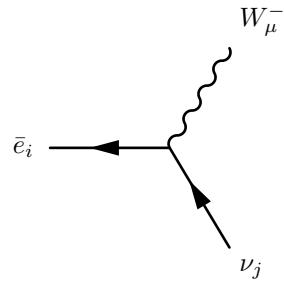
$$-i\frac{1}{\sqrt{2}}g_2\Theta_{j,3}U_{L,ij}^{e}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \tag{234}$$
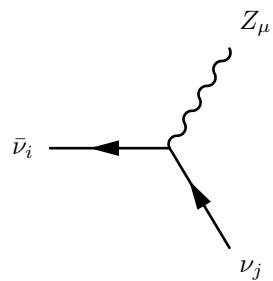
$$-\frac{i}{2}\delta_{ij}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{235}$$
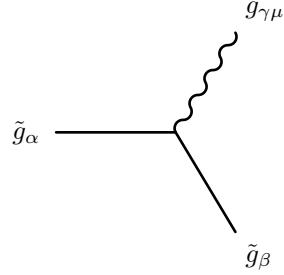
$$-g_3|\phi_{\tilde g}|^2 f_{\alpha,\beta,\gamma}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{236}$$

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

9.5   Two Fermion-One Scalar Boson-Interaction
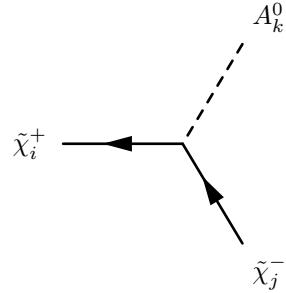
$$-\frac{1}{\sqrt{2}}g_2\Big(U_{j1}^*V_{i2}^*Z_{k2}^A+U_{j2}^*V_{i1}^*Z_{k1}^A\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{238}$$

$$+\frac{1}{\sqrt{2}}g_2\Big(U_{i1}V_{j2}Z_{k2}^A+U_{i2}V_{j1}Z_{k1}^A\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{239}$$
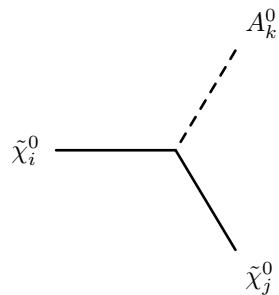
$$\frac{1}{2}\Big(N_{i3}^*\big(g_1 N_{j1}^* - g_2 N_{j2}^*\big)Z_{k1}^A - g_2 N_{i2}^* N_{j3}^* Z_{k1}^A - g_1 N_{i4}^* N_{j1}^* Z_{k2}^A + g_2 N_{i4}^* N_{j2}^* Z_{k2}^A$$

$$+ g_2 N_{i2}^* N_{j4}^* Z_{k2}^A + g_1 N_{i1}^* \big(N_{j3}^* Z_{k1}^A - N_{j4}^* Z_{k2}^A\big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{240}$$

$$+ \frac{1}{2}\Big(Z_{k1}^A\big(\big(-g_1 N_{i1} + g_2 N_{i2}\big)N_{j3} + N_{i3}\big(-g_1 N_{j1} + g_2 N_{j2}\big)\big)$$

$$+ Z_{k2}^A\big(\big(g_1 N_{i1} - g_2 N_{i2}\big)N_{j4} + N_{i4}\big(g_1 N_{j1} - g_2 N_{j2}\big)\big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{241}$$
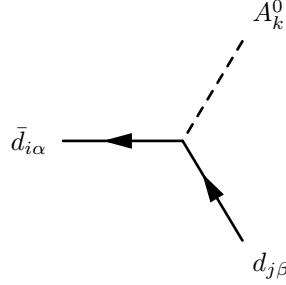
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}U_{R,ia}^{d,*}Y_{d,ab}Z_{k1}^A\Big(\frac{1-\gamma_5}{2}\Big) \tag{242}$$

$$+ -\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^* U_{R,ja}^d U_{L,ib}^d Z_{k1}^A\Big(\frac{1+\gamma_5}{2}\Big) \tag{243}$$
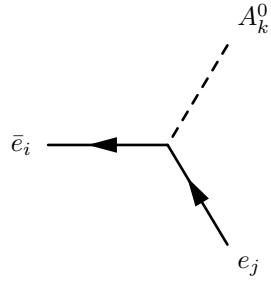
$$\frac{1}{\sqrt{2}}\sum_{b=1}^{3}U_{L,jb}^{e,*}\sum_{a=1}^{3}U_{R,ia}^{e,*}Y_{e,ab}Z_{k1}^A\Big(\frac{1-\gamma_5}{2}\Big) \tag{244}$$

$$+ -\frac{1}{\sqrt{2}}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^* U_{R,ja}^e U_{L,ib}^e Z_{k1}^A\Big(\frac{1+\gamma_5}{2}\Big) \tag{245}$$

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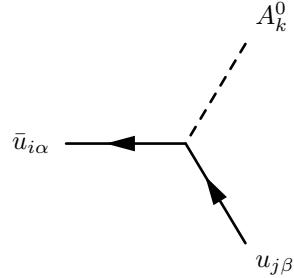
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{u,*}\sum_{a=1}^{3}U_{R,ia}^{u,*}Y_{u,ab}Z_{k2}^{A}\Big(\frac{1-\gamma_5}{2}\Big) \tag{246}$$

$$+ -\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^{*}U_{R,ja}^{u}U_{L,ib}^{u}Z_{k2}^{A}\Big(\frac{1+\gamma_5}{2}\Big) \tag{247}$$
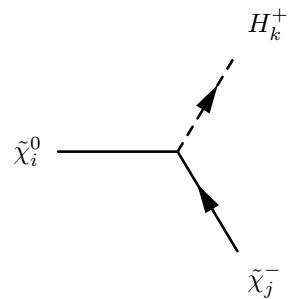
$$\frac{i}{2}\Big(-2g_2U_{j1}^{*}N_{i3}^{*}+\sqrt{2}U_{j2}^{*}\big(g_1N_{i1}^{*}+g_2N_{i2}^{*}\big)\Big)Z_{k1}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{248}$$

$$+ -\frac{i}{2}\Big(2g_2V_{j1}N_{i4}+\sqrt{2}V_{j2}\big(g_1N_{i1}+g_2N_{i2}\big)\Big)Z_{k2}^{+}\Big(\frac{1+\gamma_5}{2}\Big) \tag{249}$$
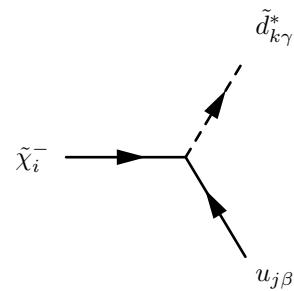
$$- i\delta_{\beta\gamma}\Big(g_2 U_{i1}^* \sum_{a=1}^{3} U_{L,ja}^{u,*} Z_{ka}^{D} - U_{i2}^* \sum_{b=1}^{3} U_{L,jb}^{u,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{250}$$

$$+ i\delta_{\beta\gamma} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{u,ab}^* U_{R,ja}^{u} Z_{kb}^{D} V_{i2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{251}$$
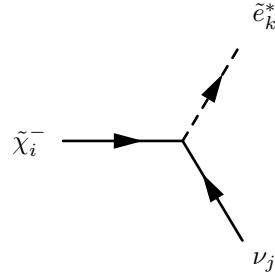
$$i\Big(-g_2 U_{i1}^* \Theta_{j,3} Z_{kj}^{E} + U_{i2}^* \sum_{a=1}^{3} Y_{e,aj} Z_{k3+a}^{E}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{252}$$
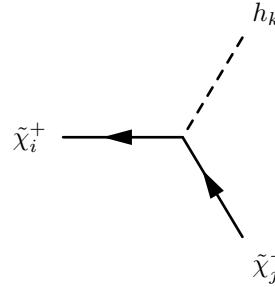
$$-i\frac{1}{\sqrt{2}} g_2\Big(U_{j1}^* V_{i2}^* Z_{k2}^{H} + U_{j2}^* V_{i1}^* Z_{k1}^{H}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{253}$$

$$+ -i\frac{1}{\sqrt{2}} g_2\Big(U_{i1} V_{j2} Z_{k2}^{H} + U_{i2} V_{j1} Z_{k1}^{H}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{254}$$

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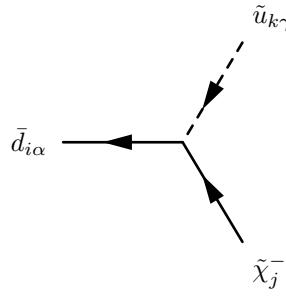
$$iU_{j2}^* \delta_{\alpha\gamma} \sum_{b=1}^{3} Z_{kb}^{U,*} \sum_{a=1}^{3} U_{R,ia}^{d,*} Y_{d,ab} \Big(\frac{1-\gamma_5}{2} \Big) \tag{255}$$

$$+ -i\delta_{\alpha\gamma} \Big(g_2 \sum_{a=1}^{3} Z_{ka}^{U,*} U_{L,ia}^d V_{j1} - \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{u,ab}^* Z_{k3+a}^{U,*} U_{L,ib}^d V_{j2} \Big) \Big(\frac{1+\gamma_5}{2} \Big) \tag{256}$$
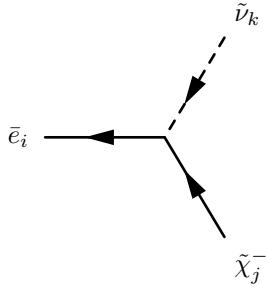
$$iU_{j2}^* \sum_{b=1}^{3} Z_{kb}^{V,*} \sum_{a=1}^{3} U_{R,ia}^{e,*} Y_{e,ab} \Big(\frac{1-\gamma_5}{2} \Big) \tag{257}$$

$$+ -ig_2 \sum_{a=1}^{3} Z_{ka}^{V,*} U_{L,ia}^e V_{j1} \Big(\frac{1+\gamma_5}{2} \Big) \tag{258}$$
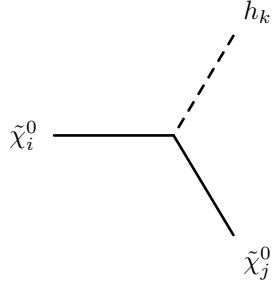
$$\frac{i}{2} \Big(N_{i3}^* \big(g_1 N_{j1}^* - g_2 N_{j2}^* \big) Z_{k1}^H - g_2 N_{i2}^* N_{j3}^* Z_{k1}^H - g_1 N_{i4}^* N_{j1}^* Z_{k2}^H + g_2 N_{i4}^* N_{j2}^* Z_{k2}^H$$
$$+ g_2 N_{i2}^* N_{j4}^* Z_{k2}^H + g_1 N_{i1}^* \big(N_{j3}^* Z_{k1}^H - N_{j4}^* Z_{k2}^H \big) \Big) \Big(\frac{1-\gamma_5}{2} \Big) \tag{259}$$
$$+ \frac{i}{2} \Big(Z_{k1}^H \big(\big(g_1 N_{i1} - g_2 N_{i2} \big) N_{j3} + N_{i3} \big(g_1 N_{j1} - g_2 N_{j2} \big) \big)$$
$$+ Z_{k2}^H \big(\big(-g_1 N_{i1} + g_2 N_{i2} \big) N_{j4} + N_{i4} \big(-g_1 N_{j1} + g_2 N_{j2} \big) \big) \Big) \Big(\frac{1+\gamma_5}{2} \Big) \tag{260}$$
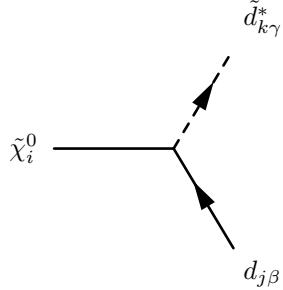
$$-\frac{i}{6}\delta_{\beta\gamma}\Big(-3\sqrt{2}g_2N_{i2}^*\sum_{a=1}^{3}U_{L,ja}^{d,*}Z_{ka}^D+6N_{i3}^*\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}Y_{d,ab}Z_{k3+a}^D+\sqrt{2}g_1N_{i1}^*\sum_{a=1}^{3}U_{L,ja}^{d,*}Z_{ka}^D\Big)\Big(\frac{1-\gamma_5}{2}\Big) \qquad (261)$$

$$+-\frac{i}{3}\delta_{\beta\gamma}\Big(3\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^*U_{R,ja}^dZ_{kb}^DN_{i3}+\sqrt{2}g_1\sum_{a=1}^{3}Z_{k3+a}^DU_{R,ja}^dN_{i1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \qquad (262)$$
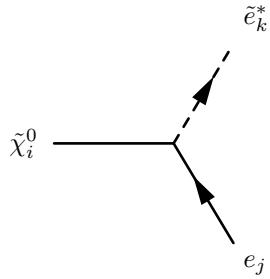
$$\frac{i}{2}\Big(-2N_{i3}^*\sum_{b=1}^{3}U_{L,jb}^{e,*}\sum_{a=1}^{3}Y_{e,ab}Z_{k3+a}^E+\sqrt{2}g_1N_{i1}^*\sum_{a=1}^{3}U_{L,ja}^{e,*}Z_{ka}^E+\sqrt{2}g_2N_{i2}^*\sum_{a=1}^{3}U_{L,ja}^{e,*}Z_{ka}^E\Big)\Big(\frac{1-\gamma_5}{2}\Big) \qquad (263)$$

$$+-i\Big(\sqrt{2}g_1\sum_{a=1}^{3}Z_{k3+a}^EU_{R,ja}^eN_{i1}+\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^*U_{R,ja}^eZ_{kb}^EN_{i3}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \qquad (264)$$

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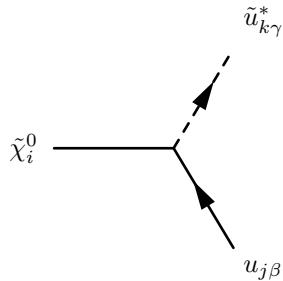
$$-\frac{i}{6}\delta_{\beta\gamma}\Big(3\sqrt{2}g_2 N_{i2}^* \sum_{a=1}^{3} U_{L,ja}^{u,*} Z_{ka}^U + 6N_{i4}^* \sum_{b=1}^{3} U_{L,jb}^{u,*} \sum_{a=1}^{3} Y_{u,ab} Z_{k3+a}^U + \sqrt{2}g_1 N_{i1}^* \sum_{a=1}^{3} U_{L,ja}^{u,*} Z_{ka}^U\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{265}$$

$$+\frac{i}{3}\delta_{\beta\gamma}\Big(2\sqrt{2}g_1 \sum_{a=1}^{3} Z_{k3+a}^U U_{R,ja}^u N_{i1} - 3\sum_{b=1}^{3}\sum_{a=1}^{3} Y_{u,ab}^* U_{R,ja}^u Z_{kb}^U N_{i4}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{266}$$
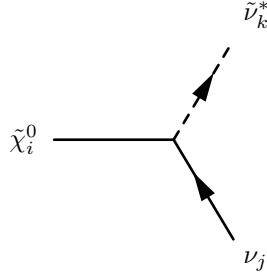
$$i\frac{1}{\sqrt{2}}\Big(g_1 N_{i1}^* - g_2 N_{i2}^*\Big)\Theta_{j,3} Z_{kj}^V \Big(\frac{1-\gamma_5}{2}\Big) \tag{267}$$
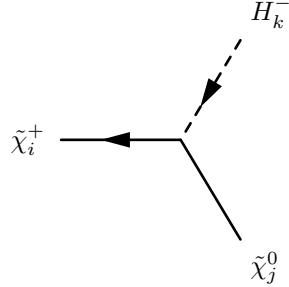
$$-\frac{i}{2}\Big(2g_2 V_{i1}^* N_{j4}^* + \sqrt{2}V_{i2}^*\big(g_1 N_{j1}^* + g_2 N_{j2}^*\big)\Big)Z_{k2}^+\Big(\frac{1-\gamma_5}{2}\Big) \tag{268}$$

$$+\frac{i}{2}\Big(-2g_2 U_{i1} N_{j3} + \sqrt{2}U_{i2}\big(g_1 N_{j1} + g_2 N_{j2}\big)\Big)Z_{k1}^+\Big(\frac{1+\gamma_5}{2}\Big) \tag{269}$$
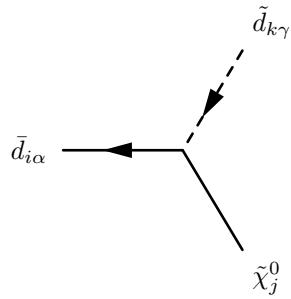
$$-\frac{i}{3}\delta_{\alpha\gamma}\Big(3N_{j3}^*\sum_{b=1}^{3}Z_{kb}^{D,*}\sum_{a=1}^{3}U_{R,ia}^{d,*}Y_{d,ab}+\sqrt{2}g_1 N_{j1}^*\sum_{a=1}^{3}Z_{k3+a}^{D,*}U_{R,ia}^{d,*}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{270}$$

$$+-\frac{i}{6}\delta_{\alpha\gamma}\Big(6\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^* Z_{k3+a}^{D,*}U_{L,ib}^d N_{j3}+\sqrt{2}\sum_{a=1}^{3}Z_{ka}^{D,*}U_{L,ia}^d\Big(-3g_2 N_{j2}+g_1 N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{271}$$
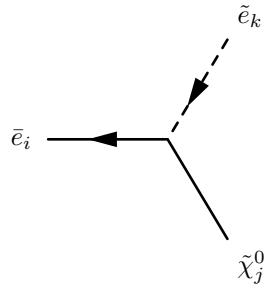
$$-i\Big(N_{j3}^*\sum_{b=1}^{3}Z_{kb}^{E,*}\sum_{a=1}^{3}U_{R,ia}^{e,*}Y_{e,ab}+\sqrt{2}g_1 N_{j1}^*\sum_{a=1}^{3}Z_{k3+a}^{E,*}U_{R,ia}^{e,*}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{272}$$

$$+\frac{i}{2}\Big(-2\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^* Z_{k3+a}^{E,*}U_{L,ib}^e N_{j3}+\sqrt{2}\sum_{a=1}^{3}Z_{ka}^{E,*}U_{L,ia}^e\Big(g_1 N_{j1}+g_2 N_{j2}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{273}$$
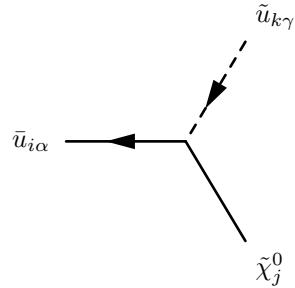
$$\frac{i}{3}\delta_{\alpha\gamma}\Big(2\sqrt{2}g_1 N_{j1}^*\sum_{a=1}^{3}Z_{k3+a}^{U,*}U_{R,ia}^{u,*}-3N_{j4}^*\sum_{b=1}^{3}Z_{kb}^{U,*}\sum_{a=1}^{3}U_{R,ia}^{u,*}Y_{u,ab}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{274}$$

$$+-\frac{i}{6}\delta_{\alpha\gamma}\Big(6\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^* Z_{k3+a}^{U,*}U_{L,ib}^u N_{j4}+\sqrt{2}\sum_{a=1}^{3}Z_{ka}^{U,*}U_{L,ia}^u\Big(3g_2 N_{j2}+g_1 N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{275}$$

$$\tag{276}$$
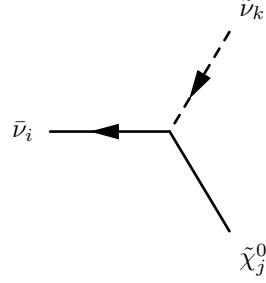
$$+ \, i\frac{1}{\sqrt{2}} Z^{V,*}_{ki} \Theta_{i,3} \Big(g_1 N_{j1} - g_2 N_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{277}$$

$$- \, i\frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda^\alpha_{\gamma,\beta} \sum_{a=1}^{3} U^{d,*}_{L,ja} Z^D_{ka}\Big(\frac{1-\gamma_5}{2}\Big) \tag{278}$$
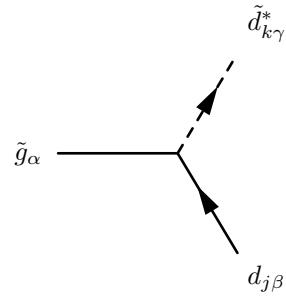
$$+ \, i\frac{1}{\sqrt{2}} g_3 \phi^*_{\tilde{g}} \lambda^\alpha_{\gamma,\beta} \sum_{a=1}^{3} Z^D_{k3+a} U^d_{R,ja}\Big(\frac{1+\gamma_5}{2}\Big) \tag{279}$$
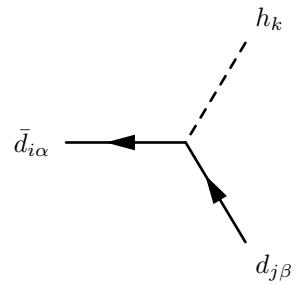
$$-i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}U_{R,ia}^{d,*}Y_{d,ab}Z_{k1}^{H}\Big(\frac{1-\gamma_5}{2}\Big) \tag{280}$$

$$+-i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{R,ja}^{d}U_{L,ib}^{d}Z_{k1}^{H}\Big(\frac{1+\gamma_5}{2}\Big) \tag{281}$$
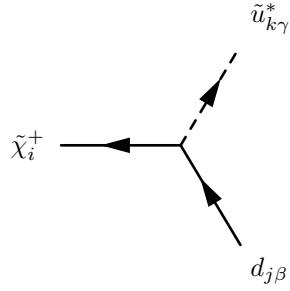
$$-i\delta_{\beta\gamma}\Big(g_2 V_{i1}^{*}\sum_{a=1}^{3}U_{L,ja}^{d,*}Z_{ka}^{U}-V_{i2}^{*}\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}Y_{u,ab}Z_{k3+a}^{U}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{282}$$

$$+i\delta_{\beta\gamma}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{R,ja}^{d}Z_{kb}^{U}U_{i2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{283}$$
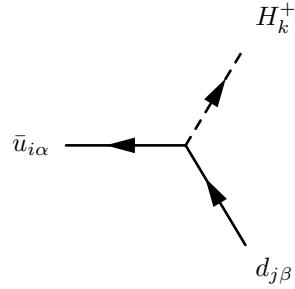
$$i\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{d,*}\sum_{a=1}^{3}U_{R,ia}^{u,*}Y_{u,ab}Z_{k2}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{284}$$

$$+i\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^{*}U_{R,ja}^{d}U_{L,ib}^{u}Z_{k1}^{+}\Big(\frac{1+\gamma_5}{2}\Big) \tag{285}$$
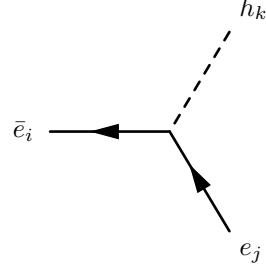
$$-i\frac{1}{\sqrt{2}}\sum_{b=1}^{3}U_{L,jb}^{e,*}\sum_{a=1}^{3}U_{R,ia}^{e,*}Y_{e,ab}Z_{k1}^{H}\left(\frac{1-\gamma_{5}}{2}\right) \tag{286}$$

$$+ -i\frac{1}{\sqrt{2}}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^{*}U_{R,ja}^{e}U_{L,ib}^{e}Z_{k1}^{H}\left(\frac{1+\gamma_{5}}{2}\right) \tag{287}$$
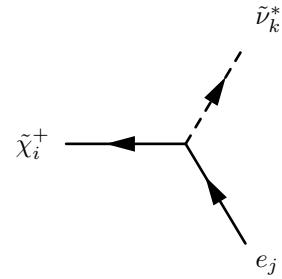
$$-ig_{2}V_{i1}^{*}\sum_{a=1}^{3}U_{L,ja}^{e,*}Z_{ka}^{V}\left(\frac{1-\gamma_{5}}{2}\right) \tag{288}$$

$$+i\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ab}^{*}U_{R,ja}^{e}Z_{kb}^{V}U_{i2}^{V}\left(\frac{1+\gamma_{5}}{2}\right) \tag{289}$$
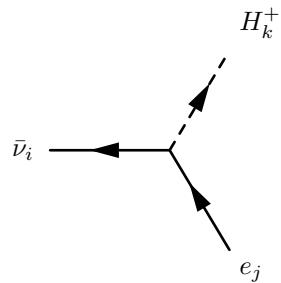
$$+ i \sum_{a=1}^{3} Y_{e,ai}^{*} U_{R,ja}^{e} Z_{k1}^{+} \left(\frac{1+\gamma_5}{2} \right) \tag{291}$$
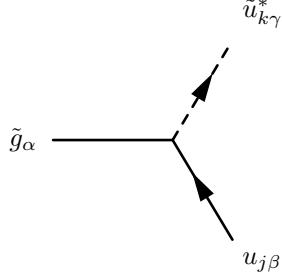
$$- i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\gamma,\beta}^{\alpha} \sum_{a=1}^{3} U_{L,ja}^{u,*} Z_{ka}^{U} \left(\frac{1-\gamma_5}{2} \right) \tag{292}$$

$$+ i \frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^{*} \lambda_{\gamma,\beta}^{\alpha} \sum_{a=1}^{3} Z_{k3+a}^{U} U_{R,ja}^{u} \left(\frac{1+\gamma_5}{2} \right) \tag{293}$$
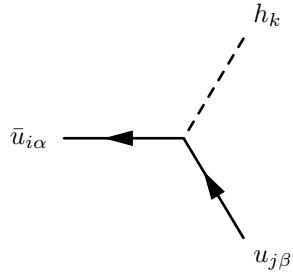
$$- i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} U_{L,jb}^{u,*} \sum_{a=1}^{3} U_{R,ia}^{u,*} Y_{u,ab} Z_{k2}^{H} \left(\frac{1-\gamma_5}{2} \right) \tag{294}$$

$$+ -i \frac{1}{\sqrt{2}} \delta_{\alpha\beta} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{u,ab}^{*} U_{R,ja}^{u} U_{L,ib}^{u} Z_{k2}^{H} \left(\frac{1+\gamma_5}{2} \right) \tag{295}$$
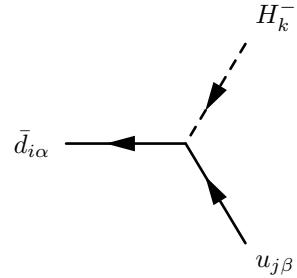
$$i\delta_{\alpha\beta}\sum_{b=1}^{3}U_{L,jb}^{u,*}\sum_{a=1}^{3}U_{R,ia}^{d,*}Y_{d,ab}Z_{k1}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{296}$$

$$+\ i\delta_{\alpha\beta}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ab}^{*}U_{R,ja}^{u}U_{L,ib}^{d}Z_{k2}^{+}\Big(\frac{1+\gamma_5}{2}\Big) \tag{297}$$
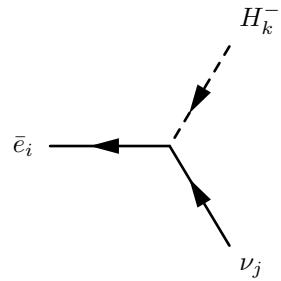
$$i\sum_{a=1}^{3}U_{R,ia}^{e,*}Y_{e,aj}Z_{k1}^{+}\Big(\frac{1-\gamma_5}{2}\Big) \tag{298}$$
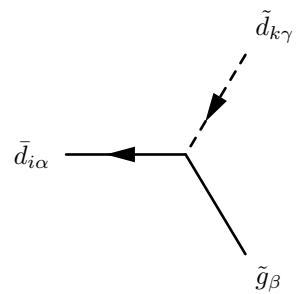
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\lambda_{\alpha,\gamma}^{\beta}\sum_{a=1}^{3}Z_{k3+a}^{D,*}U_{R,ia}^{d,*}\Big(\frac{1-\gamma_5}{2}\Big) \tag{299}$$

$$+ -i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}^*\lambda_{\alpha,\gamma}^\beta\sum_{a=1}^{3}Z_{ka}^{D,*}U_{L,ia}^d\Big(\frac{1+\gamma_5}{2}\Big) \tag{300}$$
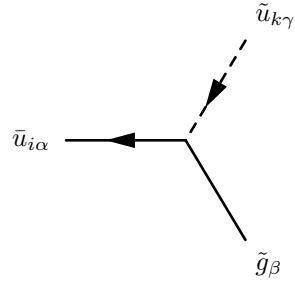
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\lambda_{\alpha,\gamma}^\beta\sum_{a=1}^{3}Z_{k3+a}^{U,*}U_{R,ia}^{u,*}\Big(\frac{1-\gamma_5}{2}\Big) \tag{301}$$

$$+ -i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}^*\lambda_{\alpha,\gamma}^\beta\sum_{a=1}^{3}Z_{ka}^{U,*}U_{L,ia}^u\Big(\frac{1+\gamma_5}{2}\Big) \tag{302}$$
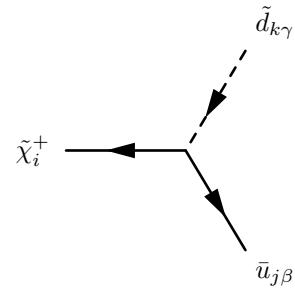
$$iV_{i2}^*\delta_{\beta\gamma}\sum_{b=1}^{3}Z_{kb}^{D,*}\sum_{a=1}^{3}U_{R,ja}^{u,*}Y_{u,ab}\Big(\frac{1-\gamma_5}{2}\Big) \tag{303}$$

$$+ -i\delta_{\beta\gamma}\Big(g_2\sum_{a=1}^{3}Z_{ka}^{D,*}U_{L,ja}^uU_{i1} - \sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ab}^*Z_{k3+a}^{D,*}U_{L,jb}^uU_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{304}$$
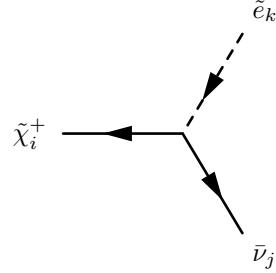
$$(305)$$

$$+ \ -i\Big(g_2 Z_{kj}^{E,*}\Theta_{j,3}U_{i1} - \sum_{a=1}^{3} Y_{e,aj}^* Z_{k3+a}^{E,*}U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \qquad (306)$$

9.6   Three Vector Boson-Interaction
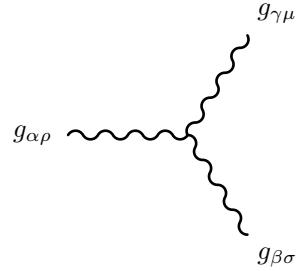
$$g_3 f_{\alpha,\beta,\gamma}\Big(g_{\rho\mu}\Big(-p_\sigma^{g_{\gamma\mu}} + p_\sigma^{g_{\alpha\rho}}\Big) + g_{\rho\sigma}\Big(-p_\mu^{g_{\alpha\rho}} + p_\mu^{g_{\beta\sigma}}\Big) + g_{\sigma\mu}\Big(-p_\rho^{g_{\beta\sigma}} + p_\rho^{g_{\gamma\mu}}\Big)\Big) \qquad (307)$$
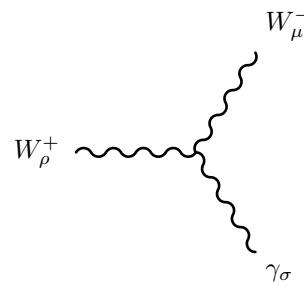
$$ig_2 \sin\Theta_W\Big(g_{\rho\mu}\Big(-p_\sigma^{W_\mu^-} + p_\sigma^{W_\rho^+}\Big) + g_{\rho\sigma}\Big(-p_\mu^{W_\rho^+} + p_\mu^{\gamma_\sigma}\Big) + g_{\sigma\mu}\Big(-p_\rho^{\gamma_\sigma} + p_\rho^{W_\mu^-}\Big)\Big) \qquad (308)$$
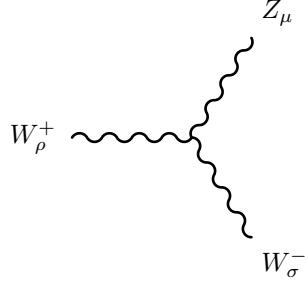
$$-ig_2 \cos\Theta_W \left(g_{\rho\mu}\left(-p_\sigma^{Z_\mu} + p_\sigma^{W_\rho^+}\right) + g_{\rho\sigma}\left(-p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-}\right) + g_{\sigma\mu}\left(-p_\rho^{W_\sigma^-} + p_\rho^{Z_\mu}\right) \right) \qquad (309)$$

9.7 Four Scalar-Interaction
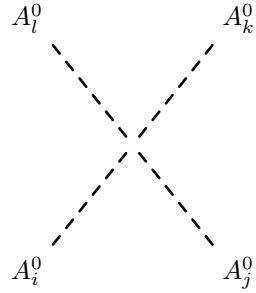
$$\frac{i}{4}\left(g_1^2 + g_2^2\right)\left(Z_{i2}^A\left(Z_{j1}^A\left(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A\right) + Z_{j2}^A\left(-3Z_{k2}^A Z_{l2}^A + Z_{k1}^A Z_{l1}^A\right)\right)\right.$$
$$\left. + Z_{i1}^A\left(Z_{j1}^A\left(-3Z_{k1}^A Z_{l1}^A + Z_{k2}^A Z_{l2}^A\right) + Z_{j2}^A\left(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A\right)\right)\right) \qquad (310)$$
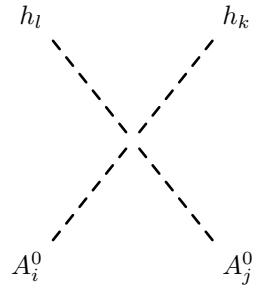
$$-\frac{i}{4}\left(g_1^2 + g_2^2\right)\left(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\right)\left(Z_{k1}^H Z_{l1}^H - Z_{k2}^H Z_{l2}^H\right) \qquad (311)$$
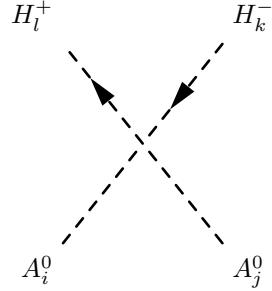
$$\frac{i}{4}\Big(Z_{i1}^A \Big(g_2^2 Z_{j2}^A \Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \Big) - Z_{j1}^A \Big(\Big(g_1^2 + g_2^2 \Big) Z_{k1}^+ Z_{l1}^+ + \Big(-g_1^2 + g_2^2 \Big) Z_{k2}^+ Z_{l2}^+ \Big) \Big)$$
$$+ Z_{i2}^A \Big(g_2^2 Z_{j1}^A \Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \Big) + Z_{j2}^A \Big(-\Big(g_1^2 + g_2^2 \Big) Z_{k2}^+ Z_{l2}^+ + \Big(-g_2^2 + g_1^2 \Big) Z_{k1}^+ Z_{l1}^+ \Big) \Big) \Big) \tag{312}$$
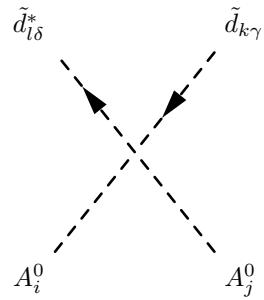
$$\frac{i}{12}\delta_{\gamma\delta}\Big(\Big(3g_2^2 + g_1^2 \Big) \sum_{a=1}^{3} Z_{ka}^{D,*} Z_{la}^D \Big(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A \Big)$$
$$+ 2\Big(-6\Big(\sum_{c=1}^{3} Z_{k3+c}^{D,*} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{d,ca}^* Y_{d,ba} Z_{l3+b}^D + \sum_{c=1}^{3} \sum_{b=1}^{3} Z_{kb}^{D,*} \sum_{a=1}^{3} Y_{d,ac}^* Y_{d,ab} Z_{lc}^D \Big) Z_{i1}^A Z_{j1}^A$$
$$+ g_1^2 \sum_{a=1}^{3} Z_{k3+a}^{D,*} Z_{l3+a}^D \Big(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A \Big) \Big) \Big) \tag{313}$$
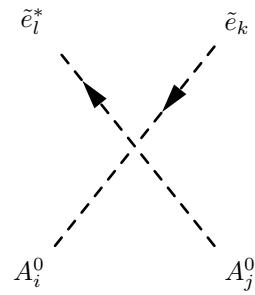
$$-\frac{i}{4}\Big(4\Big(\sum_{c=1}^{3}Z_{k3+c}^{E,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ca}^{*}Y_{e,ba}Z_{l3+b}^{E}+\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{kb}^{E,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{E}\Big)Z_{i1}^{A}Z_{j1}^{A}$$

$$+\Big(-g_{2}^{2}+g_{1}^{2}\Big)\sum_{a=1}^{3}Z_{ka}^{E,*}Z_{la}^{E}\Big(Z_{i1}^{A}Z_{j1}^{A}-Z_{i2}^{A}Z_{j2}^{A}\Big)$$

$$+2g_{1}^{2}\sum_{a=1}^{3}Z_{k3+a}^{E,*}Z_{l3+a}^{E}\Big(-Z_{i1}^{A}Z_{j1}^{A}+Z_{i2}^{A}Z_{j2}^{A}\Big)\Big) \tag{314}$$
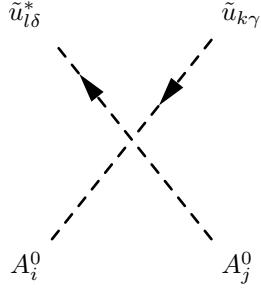
$$\frac{i}{12}\delta_{\gamma\delta}\Big(\Big(-3g_{2}^{2}+g_{1}^{2}\Big)\sum_{a=1}^{3}Z_{ka}^{U,*}Z_{la}^{U}\Big(Z_{i1}^{A}Z_{j1}^{A}-Z_{i2}^{A}Z_{j2}^{A}\Big)$$

$$-4\Big(3\Big(\sum_{c=1}^{3}Z_{k3+c}^{U,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ca}^{*}Y_{u,ba}Z_{l3+b}^{U}+\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{kb}^{U,*}\sum_{a=1}^{3}Y_{u,ac}^{*}Y_{u,ab}Z_{lc}^{U}\Big)Z_{i2}^{A}Z_{j2}^{A}$$

$$+g_{1}^{2}\sum_{a=1}^{3}Z_{k3+a}^{U,*}Z_{l3+a}^{U}\Big(Z_{i1}^{A}Z_{j1}^{A}-Z_{i2}^{A}Z_{j2}^{A}\Big)\Big)\Big) \tag{315}$$
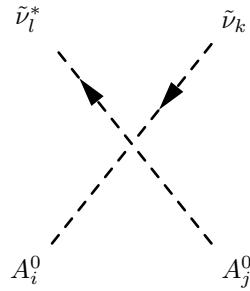
$$-\frac{i}{4}\Big(g_{1}^{2}+g_{2}^{2}\Big)\delta_{kl}\Big(Z_{i1}^{A}Z_{j1}^{A}-Z_{i2}^{A}Z_{j2}^{A}\Big) \tag{316}$$

H_l^+ H_k^-

A_i^0 h_j
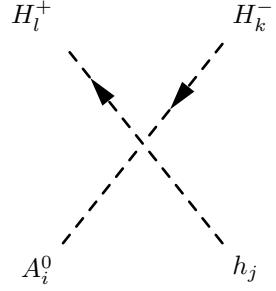
$$\frac{1}{4} g_2^2 \Big(Z_{i1}^A Z_{j2}^H + Z_{i2}^A Z_{j1}^H \Big) \Big(-Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+ \Big) \tag{317}$$

$\tilde{d}_{l\delta}^*$ $\tilde{u}_{k\gamma}$

A_i^0 H_j^-
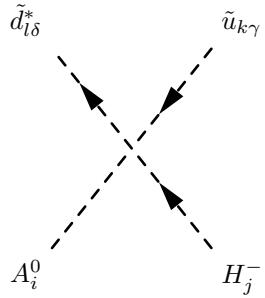
$$\frac{1}{2} \frac{1}{\sqrt{2}} \delta_{\gamma\delta} \Big(g_2^2 \sum_{a=1}^{3} Z_{ka}^{U,*} Z_{la}^D \Big(-Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+ \Big)$$

$$+ 2 \Big(\sum_{c=1}^{3} \sum_{b=1}^{3} Z_{kb}^{U,*} \sum_{a=1}^{3} Y_{d,ac}^* Y_{d,ab} Z_{lc}^D Z_{i1}^A Z_{j1}^+ - \sum_{c=1}^{3} \sum_{b=1}^{3} Z_{kb}^{U,*} \sum_{a=1}^{3} Y_{u,ac}^* Y_{u,ab} Z_{lc}^D Z_{i2}^A Z_{j2}^+$$

$$+ \sum_{c=1}^{3} Z_{k3+c}^{U,*} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^D \Big(-Z_{i1}^A Z_{j2}^+ + Z_{i2}^A Z_{j1}^+ \Big) \Big) \Big) \tag{318}$$

$\tilde{e}_l^*$ $\tilde{\nu}_k$

A_i^0 H_j^-

81
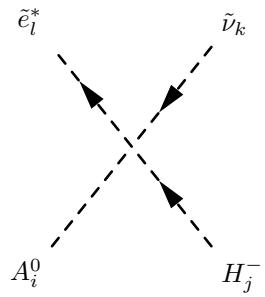
$$\frac{1}{2}\frac{1}{\sqrt{2}}\Big(2\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{kb}^{V,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{E}Z_{i1}^{A}Z_{j1}^{+}+g_{2}^{2}\sum_{a=1}^{3}Z_{ka}^{V,*}Z_{la}^{E}\Big(-Z_{i1}^{A}Z_{j1}^{+}+Z_{i2}^{A}Z_{j2}^{+}\Big)\Big) \tag{319}$$
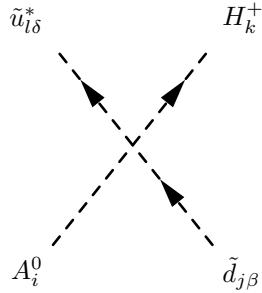
$$\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(-2\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{D,*}\sum_{a=1}^{3}Y_{d,ac}^{*}Y_{d,ab}Z_{lc}^{U}Z_{i1}^{A}Z_{k1}^{+}$$
$$-2\sum_{c=1}^{3}Z_{j3+c}^{D,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ca}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{i2}^{A}Z_{k1}^{+}$$
$$+2\sum_{c=1}^{3}Z_{j3+c}^{D,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ca}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{i1}^{A}Z_{k2}^{+}$$
$$+2\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{D,*}\sum_{a=1}^{3}Y_{u,ac}^{*}Y_{u,ab}Z_{lc}^{U}Z_{i2}^{A}Z_{k2}^{+}+g_{2}^{2}\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{la}^{U}\Big(Z_{i1}^{A}Z_{k1}^{+}-Z_{i2}^{A}Z_{k2}^{+}\Big)\Big) \tag{320}$$
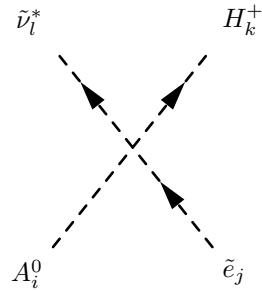
$$\frac{1}{2}\frac{1}{\sqrt{2}}\Big(-2\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{E,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{V}Z_{i1}^{A}Z_{k1}^{+}+g_{2}^{2}\sum_{a=1}^{3}Z_{ja}^{E,*}Z_{la}^{V}\Big(Z_{i1}^{A}Z_{k1}^{+}-Z_{i2}^{A}Z_{k2}^{+}\Big)\Big) \tag{321}$$

Diagram with h_l (top left), h_k (top right), h_i (bottom left), h_j (bottom right), four-point vertex.
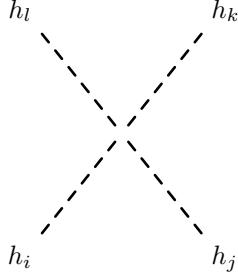
$$\frac{i}{4}\Big(g_1^2 + g_2^2\Big)\Big(Z_{i2}^H\Big(Z_{j1}^H\Big(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H\Big) + Z_{j2}^H\Big(-3Z_{k2}^H Z_{l2}^H + Z_{k1}^H Z_{l1}^H\Big)\Big)$$
$$+ Z_{i1}^H\Big(Z_{j1}^H\Big(-3Z_{k1}^H Z_{l1}^H + Z_{k2}^H Z_{l2}^H\Big) + Z_{j2}^H\Big(Z_{k1}^H Z_{l2}^H + Z_{k2}^H Z_{l1}^H\Big)\Big)\Big) \tag{322}$$

Diagram with H_l^+ (top left), H_k^- (top right), h_i (bottom left), h_j (bottom right), four-point vertex.
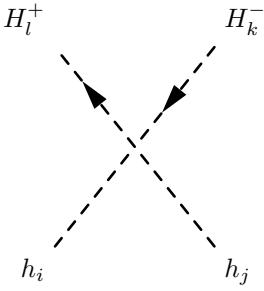
$$-\frac{i}{4}\Big(Z_{i1}^H\Big(g_2^2 Z_{j2}^H\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) + Z_{j1}^H\Big(\big(g_1^2 + g_2^2\big)Z_{k1}^+ Z_{l1}^+ + \big(-g_1^2 + g_2^2\big)Z_{k2}^+ Z_{l2}^+\Big)\Big)$$
$$+ Z_{i2}^H\Big(g_2^2 Z_{j1}^H\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) + Z_{j2}^H\Big(\big(-g_1^2 + g_2^2\big)Z_{k1}^+ Z_{l1}^+ + \big(g_1^2 + g_2^2\big)Z_{k2}^+ Z_{l2}^+\Big)\Big)\Big) \tag{323}$$

Diagram with $\tilde{d}_{l\delta}^*$ (top left), $\tilde{d}_{k\gamma}$ (top right), h_i (bottom left), h_j (bottom right), four-point vertex.
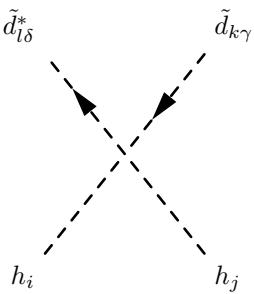
$$\frac{i}{12}\delta_{\gamma\delta}\Big(\big(3g_2^2 + g_1^2\big)\sum_{a=1}^{3} Z_{ka}^{D,*} Z_{la}^D\Big(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H\Big)$$

$$+ 2\Big(-6\Big(\sum_{c=1}^{3} Z_{k3+c}^{D,*} \sum_{b=1}^{3}\sum_{a=1}^{3} Y_{d,ca}^{*} Y_{d,ba} Z_{l3+b}^{D} + \sum_{c=1}^{3}\sum_{b=1}^{3} Z_{kb}^{D,*} \sum_{a=1}^{3} Y_{d,ac}^{*} Y_{d,ab} Z_{lc}^{D}\Big) Z_{i1}^{H} Z_{j1}^{H}$$

$$+ g_1^2 \sum_{a=1}^{3} Z_{k3+a}^{D,*} Z_{l3+a}^{D} \Big(Z_{i1}^{H} Z_{j1}^{H} - Z_{i2}^{H} Z_{j2}^{H}\Big)\Big)\Big)$$

$$\tag{324}$$
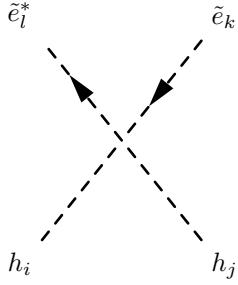
$$-\frac{i}{4}\Big(4\Big(\sum_{c=1}^{3} Z_{k3+c}^{E,*} \sum_{b=1}^{3}\sum_{a=1}^{3} Y_{e,ca}^{*} Y_{e,ba} Z_{l3+b}^{E} + \sum_{c=1}^{3}\sum_{b=1}^{3} Z_{kb}^{E,*} \sum_{a=1}^{3} Y_{e,ac}^{*} Y_{e,ab} Z_{lc}^{E}\Big) Z_{i1}^{H} Z_{j1}^{H}$$

$$+ \Big(-g_2^2 + g_1^2\Big) \sum_{a=1}^{3} Z_{ka}^{E,*} Z_{la}^{E} \Big(Z_{i1}^{H} Z_{j1}^{H} - Z_{i2}^{H} Z_{j2}^{H}\Big)$$

$$+ 2g_1^2 \sum_{a=1}^{3} Z_{k3+a}^{E,*} Z_{l3+a}^{E} \Big(-Z_{i1}^{H} Z_{j1}^{H} + Z_{i2}^{H} Z_{j2}^{H}\Big)\Big)$$

$$\tag{325}$$
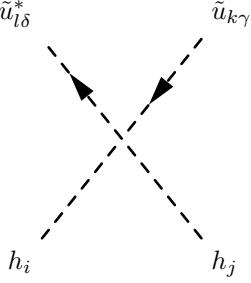
$$\frac{i}{12}\delta_{\gamma\delta}\Big(\Big(-3g_2^2 + g_1^2\Big) \sum_{a=1}^{3} Z_{ka}^{U,*} Z_{la}^{U} \Big(Z_{i1}^{H} Z_{j1}^{H} - Z_{i2}^{H} Z_{j2}^{H}\Big)$$

$$- 4\Big(3\Big(\sum_{c=1}^{3} Z_{k3+c}^{U,*} \sum_{b=1}^{3}\sum_{a=1}^{3} Y_{u,ca}^{*} Y_{u,ba} Z_{l3+b}^{U} + \sum_{c=1}^{3}\sum_{b=1}^{3} Z_{kb}^{U,*} \sum_{a=1}^{3} Y_{u,ac}^{*} Y_{u,ab} Z_{lc}^{U}\Big) Z_{i2}^{H} Z_{j2}^{H}$$

$$+ g_1^2 \sum_{a=1}^{3} Z_{k3+a}^{U,*} Z_{l3+a}^{U} \Big(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H \Big) \Big) \Big) \tag{326}$$
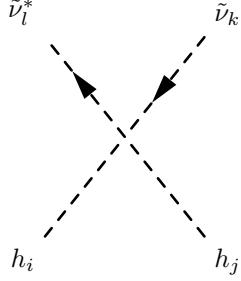
$$- \frac{i}{4} \Big(g_1^2 + g_2^2 \Big) \delta_{kl} \Big(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H \Big) \tag{327}$$
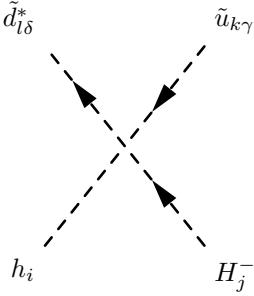
$$- \frac{i}{2} \frac{1}{\sqrt{2}} \delta_{\gamma\delta} \Big(g_2^2 \sum_{a=1}^{3} Z_{ka}^{U,*} Z_{la}^{D} \Big(Z_{i1}^H Z_{j1}^+ + Z_{i2}^H Z_{j2}^+ \Big)$$
$$- 2 \Big(\sum_{c=1}^{3} \sum_{b=1}^{3} Z_{kb}^{U,*} \sum_{a=1}^{3} Y_{d,ac}^* Y_{d,ab} Z_{lc}^{D} Z_{i1}^H Z_{j1}^+ + \sum_{c=1}^{3} \sum_{b=1}^{3} Z_{kb}^{U,*} \sum_{a=1}^{3} Y_{u,ac}^* Y_{u,ab} Z_{lc}^{D} Z_{i2}^H Z_{j2}^+$$
$$+ \sum_{c=1}^{3} Z_{k3+c}^{U,*} \sum_{b=1}^{3} \sum_{a=1}^{3} Y_{u,ca}^* Y_{d,ba} Z_{l3+b}^{D} \Big(Z_{i1}^H Z_{j2}^+ + Z_{i2}^H Z_{j1}^+ \Big) \Big) \Big) \tag{328}$$
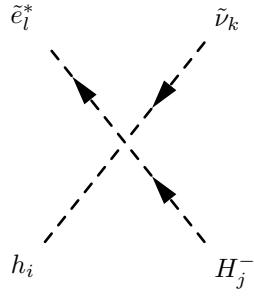
$$-\frac{i}{2}\frac{1}{\sqrt{2}}\Big(-2\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{kb}^{V,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{E}Z_{i1}^{H}Z_{j1}^{+}+g_{2}^{2}\sum_{a=1}^{3}Z_{ka}^{V,*}Z_{la}^{E}\Big(Z_{i1}^{H}Z_{j1}^{+}+Z_{i2}^{H}Z_{j2}^{+}\Big)\Big)\qquad(329)$$

$\tilde{u}_{l\delta}^{*}$ $\qquad$ H_{k}^{+}

h_{i} $\qquad$ $\tilde{d}_{j\beta}$
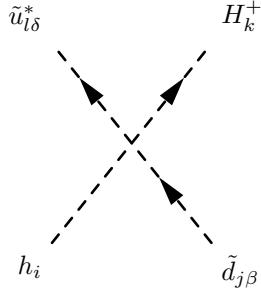
$$-\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(g_{2}^{2}\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{la}^{U}\Big(Z_{i1}^{H}Z_{k1}^{+}+Z_{i2}^{H}Z_{k2}^{+}\Big)$$
$$-2\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{D,*}\sum_{a=1}^{3}Y_{d,ac}^{*}Y_{d,ab}Z_{lc}^{U}Z_{i1}^{H}Z_{k1}^{+}+\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{D,*}\sum_{a=1}^{3}Y_{u,ac}^{*}Y_{u,ab}Z_{lc}^{U}Z_{i2}^{H}Z_{k2}^{+}$$
$$+\sum_{c=1}^{3}Z_{j3+c}^{D,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ca}^{*}Y_{u,ba}Z_{l3+b}^{U}\Big(Z_{i1}^{H}Z_{k2}^{+}+Z_{i2}^{H}Z_{k1}^{+}\Big)\Big)\Big)\qquad(330)$$

$\tilde{\nu}_{l}^{*}$ $\qquad$ H_{k}^{+}

h_{i} $\qquad$ $\tilde{e}_{j}$
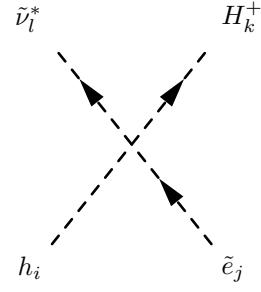
$$-\frac{i}{2}\frac{1}{\sqrt{2}}\Big(-2\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{E,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{V}Z_{i1}^{H}Z_{k1}^{+}+g_{2}^{2}\sum_{a=1}^{3}Z_{ja}^{E,*}Z_{la}^{V}\Big(Z_{i1}^{H}Z_{k1}^{+}+Z_{i2}^{H}Z_{k2}^{+}\Big)\Big)\qquad(331)$$
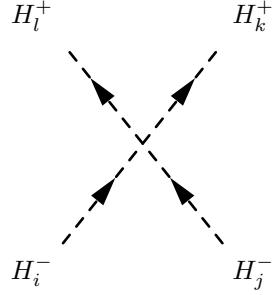
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(-Z_{i2}^+\Big(-2Z_{j2}^+Z_{k2}^+Z_{l2}^+ + Z_{j1}^+\Big(Z_{k1}^+Z_{l2}^+ + Z_{k2}^+Z_{l1}^+\Big)\Big)$$
$$+ Z_{i1}^+\Big(2Z_{j1}^+Z_{k1}^+Z_{l1}^+ - Z_{j2}^+\Big(Z_{k1}^+Z_{l2}^+ + Z_{k2}^+Z_{l1}^+\Big)\Big)\Big) \tag{332}$$
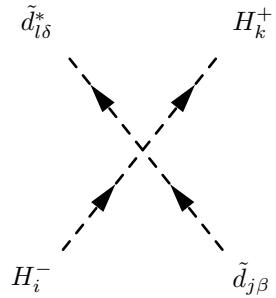
$$\frac{i}{12}\delta_{\beta\delta}\Big(\Big(-3g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{la}^{D}\Big(Z_{i1}^+Z_{k1}^+ - Z_{i2}^+Z_{k2}^+\Big)$$

$$+2\Big(g_1^2\sum_{a=1}^{3}Z_{j3+a}^{D,*}Z_{l3+a}^{D}\Big(Z_{i1}^+Z_{k1}^+ - Z_{i2}^+Z_{k2}^+\Big)$$

$$-6\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{D,*}\sum_{a=1}^{3}Y_{u,ac}^*Y_{u,ab}Z_{lc}^{D}Z_{i2}^+Z_{k2}^+ + \sum_{c=1}^{3}Z_{j3+c}^{D,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{d,ca}^*Y_{d,ba}Z_{l3+b}^{D}Z_{i1}^+Z_{k1}^+\Big)\Big)\Big) \tag{333}$$
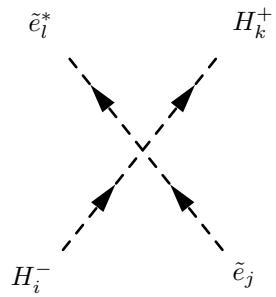
$$-\frac{i}{4}\Big(4\sum_{c=1}^{3}Z_{j3+c}^{E,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{e,ca}^{*}Y_{e,ba}Z_{l3+b}^{E}Z_{i1}^{+}Z_{k1}^{+}$$

$$+\Big(g_1^2+g_2^2\Big)\sum_{a=1}^{3}Z_{ja}^{E,*}Z_{la}^{E}\Big(Z_{i1}^{+}Z_{k1}^{+}-Z_{i2}^{+}Z_{k2}^{+}\Big)$$

$$+2g_1^2\sum_{a=1}^{3}Z_{j3+a}^{E,*}Z_{l3+a}^{E}\Big(-Z_{i1}^{+}Z_{k1}^{+}+Z_{i2}^{+}Z_{k2}^{+}\Big)\Big) \tag{334}$$

$$\tilde{u}_{l\delta}^{*} \qquad H_k^{+}$$

$$H_i^{-} \qquad \tilde{u}_{j\beta}$$
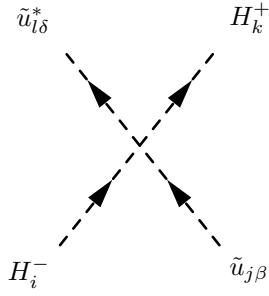
$$\frac{i}{12}\delta_{\beta\delta}\Big(\Big(3g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{la}^{U}\Big(Z_{i1}^{+}Z_{k1}^{+}-Z_{i2}^{+}Z_{k2}^{+}\Big)$$

$$-4\Big(g_1^2\sum_{a=1}^{3}Z_{j3+a}^{U,*}Z_{l3+a}^{U}\Big(Z_{i1}^{+}Z_{k1}^{+}-Z_{i2}^{+}Z_{k2}^{+}\Big)$$

$$+3\Big(\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Y_{d,ac}^{*}Y_{d,ab}Z_{lc}^{U}Z_{i1}^{+}Z_{k1}^{+}+\sum_{c=1}^{3}Z_{j3+c}^{U,*}\sum_{b=1}^{3}\sum_{a=1}^{3}Y_{u,ca}^{*}Y_{u,ba}Z_{l3+b}^{U}Z_{i2}^{+}Z_{k2}^{+}\Big)\Big)\Big) \tag{335}$$

$$\tilde{\nu}_{l}^{*} \qquad H_k^{+}$$

$$H_i^{-} \qquad \tilde{\nu}_{j}$$
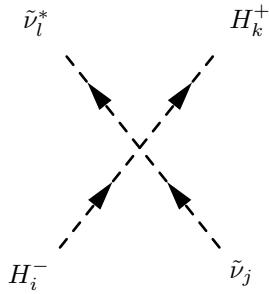
$$-\frac{i}{4}\Big(4\sum_{c=1}^{3}\sum_{b=1}^{3}Z_{jb}^{V,*}\sum_{a=1}^{3}Y_{e,ac}^{*}Y_{e,ab}Z_{lc}^{V}Z_{i1}^{+}Z_{k1}^{+}+\Big(-g_2^2+g_1^2\Big)\delta_{jl}\Big(Z_{i1}^{+}Z_{k1}^{+}-Z_{i2}^{+}Z_{k2}^{+}\Big)\Big) \tag{336}$$

The diagram shows external legs labeled $\tilde{d}_{l\delta}^*$, $\tilde{d}_{k\gamma}^*$ (top), and $\tilde{d}_{i\alpha}$, $\tilde{d}_{j\beta}$ (bottom).
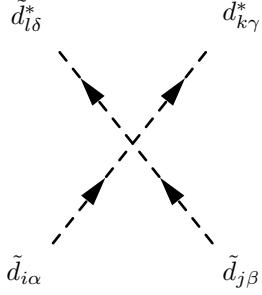
$$-\frac{i}{72}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(g_1^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{la}^{D}\sum_{b=1}^{3}Z_{jb}^{D,*}Z_{kb}^{D} + 9g_2^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{la}^{D}\sum_{b=1}^{3}Z_{jb}^{D,*}Z_{kb}^{D}$$

$$-6g_3^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{la}^{D}\sum_{b=1}^{3}Z_{jb}^{D,*}Z_{kb}^{D} + 2g_1^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{l3+a}^{D}\sum_{b=1}^{3}Z_{jb}^{D,*}Z_{kb}^{D}$$

$$+6g_3^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{l3+a}^{D}\sum_{b=1}^{3}Z_{jb}^{D,*}Z_{kb}^{D}$$

$$+18g_3^2\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{la}^{D}\Big(-\sum_{b=1}^{3}Z_{i3+b}^{D,*}Z_{k3+b}^{D} + \sum_{b=1}^{3}Z_{ib}^{D,*}Z_{kb}^{D}\Big)$$

$$-18g_3^2\sum_{a=1}^{3}Z_{j3+a}^{D,*}Z_{l3+a}^{D}\Big(-\sum_{b=1}^{3}Z_{i3+b}^{D,*}Z_{k3+b}^{D} + \sum_{b=1}^{3}Z_{ib}^{D,*}Z_{kb}^{D}\Big)$$

$$+2g_1^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{la}^{D}\sum_{b=1}^{3}Z_{j3+b}^{D,*}Z_{k3+b}^{D} + 6g_3^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{la}^{D}\sum_{b=1}^{3}Z_{j3+b}^{D,*}Z_{k3+b}^{D}$$

$$+4g_1^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{l3+a}^{D}\sum_{b=1}^{3}Z_{j3+b}^{D,*}Z_{k3+b}^{D} - 6g_3^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{l3+a}^{D}\sum_{b=1}^{3}Z_{j3+b}^{D,*}Z_{k3+b}^{D}$$

$$+g_1^2\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{lb}^{D} + 9g_2^2\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{lb}^{D}$$

$$-6g_3^2\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{lb}^{D} + 2g_1^2\sum_{a=1}^{3}Z_{j3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{lb}^{D}$$

$$+6g_3^2\sum_{a=1}^{3}Z_{j3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{lb}^{D} + 18g_3^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{jb}^{D,*}Z_{lb}^{D}$$

$$-18g_3^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{jb}^{D,*}Z_{lb}^{D} + 2g_1^2\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{i3+b}^{D,*}Z_{l3+b}^{D}$$

$$+6g_3^2\sum_{a=1}^{3}Z_{ja}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{i3+b}^{D,*}Z_{l3+b}^{D} + 4g_1^2\sum_{a=1}^{3}Z_{j3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{i3+b}^{D,*}Z_{l3+b}^{D}$$

$$- 6g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{l3+b}^{D} - 18g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D}$$

$$+ 18g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D}$$

$$+ 72 \sum_{b=1}^{3} Z_{ib}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{l3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{j3+c}^{D,*} Z_{kd}^{D}$$

$$+ 72 \sum_{b=1}^{3} Z_{jb}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{i3+c}^{D,*} Z_{ld}^{D} \Big)$$

$$+ \delta_{\alpha\gamma} \delta_{\beta\delta} \Big(18g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{la}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{kb}^{D} - 18g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{l3+a}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{kb}^{D}$$

$$+ 2 \sum_{a=1}^{3} Z_{j3+a}^{D,*} Z_{l3+a}^{D} \Big(\big(2g_1^2 - 3g_3^2\big) \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{k3+b}^{D} + \big(3g_3^2 + g_1^2\big) \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{kb}^{D} \Big)$$

$$+ \sum_{a=1}^{3} Z_{ja}^{D,*} Z_{la}^{D} \Big(2\big(3g_3^2 + g_1^2\big) \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{k3+b}^{D} + \big(-6g_3^2 + 9g_2^2 + g_1^2\big) \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{kb}^{D} \Big)$$

$$- 18g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{la}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{k3+b}^{D} + 18g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{l3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{k3+b}^{D}$$

$$+ 18g_3^2 \sum_{a=1}^{3} Z_{ja}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{lb}^{D} - 18g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{lb}^{D}$$

$$+ g_1^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D} + 9g_2^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D}$$

$$- 6g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D} + 2g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D}$$

$$+ 6g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{jb}^{D,*} Z_{lb}^{D} - 18g_3^2 \sum_{a=1}^{3} Z_{ja}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{l3+b}^{D}$$

$$+ 18g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{l3+b}^{D} + 2g_1^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D}$$

$$+ 6g_3^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D} + 4g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D}$$

$$- 6g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{D,*} Z_{l3+b}^{D}$$

$$+ 72 \sum_{b=1}^{3} Z_{jb}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{l3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{i3+c}^{D,*} Z_{kd}^{D}$$

$$+ 72 \sum_{b=1}^{3} Z_{ib}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{j3+c}^{D,*} Z_{ld}^{D} \Big) \Big) \tag{337}$$


$$\tilde{e}_l^* \qquad \tilde{d}_{k\gamma}^*$$

$$\tilde{d}_{i\alpha} \qquad \tilde{e}_j$$
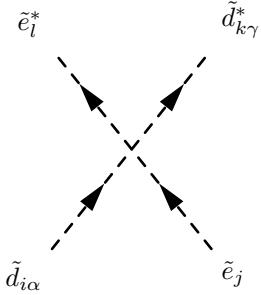
$$\frac{i}{24} \delta_{\alpha\gamma} \Big(- 2 g_1^2 \sum_{a=1}^{3} Z_{j3+a}^{E,*} Z_{l3+a}^{E} \Big(2 \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{k3+b}^{D} + \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{kb}^{D} \Big)$$

$$+ \sum_{a=1}^{3} Z_{ja}^{E,*} Z_{la}^{E} \Big(2 g_1^2 \sum_{b=1}^{3} Z_{i3+b}^{D,*} Z_{k3+b}^{D} + \big(- 3 g_2^2 + g_1^2 \big) \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{kb}^{D} \Big)$$

$$+ g_1^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{lb}^{E} - 3 g_2^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{lb}^{E}$$

$$+ 2 g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{lb}^{E} - 2 g_1^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \sum_{b=1}^{3} Z_{j3+b}^{E,*} Z_{l3+b}^{E}$$

$$- 4 g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} \sum_{b=1}^{3} Z_{j3+b}^{E,*} Z_{l3+b}^{E}$$

$$- 24 \sum_{b=1}^{3} Z_{jb}^{E,*} \sum_{a=1}^{3} Y_{e,ab} Z_{l3+a}^{E} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{i3+c}^{D,*} Z_{kd}^{D}$$

$$- 24 \sum_{b=1}^{3} Z_{ib}^{D,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{e,cd}^{*} Z_{j3+c}^{E,*} Z_{ld}^{E} \Big) \tag{338}$$
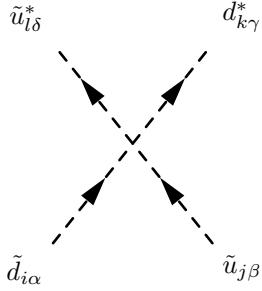
$$-\frac{i}{72}\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{la}^{U}\Big(2\Big(3g_3^2+g_1^2\Big)\sum_{b=1}^{3}Z_{i3+b}^{D,*}Z_{k3+b}^{D}+\Big(-6g_3^2-9g_2^2+g_1^2\Big)\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{kb}^{D}\Big)$$

$$-2\sum_{a=1}^{3}Z_{j3+a}^{U,*}Z_{l3+a}^{U}\Big(\Big(2g_1^2-3g_3^2\Big)\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{kb}^{D}+\Big(3g_3^2+4g_1^2\Big)\sum_{b=1}^{3}Z_{i3+b}^{D,*}Z_{k3+b}^{D}\Big)$$

$$+g_1^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}-9g_2^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}$$

$$-6g_3^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}+2g_1^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}$$

$$+6g_3^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}-4g_1^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U}$$

$$+6g_3^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U}-8g_1^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U}$$

$$-6g_3^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U}\Big)$$

$$+18\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(g_2^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{la}^{U}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{kb}^{D}+g_3^2\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{la}^{U}\Big(-\sum_{b=1}^{3}Z_{i3+b}^{D,*}Z_{k3+b}^{D}+\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{kb}^{D}\Big)$$

$$+g_3^2\sum_{a=1}^{3}Z_{j3+a}^{U,*}Z_{l3+a}^{U}\Big(-\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{kb}^{D}+\sum_{b=1}^{3}Z_{i3+b}^{D,*}Z_{k3+b}^{D}\Big)$$

$$+g_2^2\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{ib}^{D,*}Z_{lb}^{U}+g_3^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}$$

$$-g_3^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}-g_3^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U}$$

$$+g_3^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{k3+a}^{D}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U}+4\sum_{b=1}^{3}Z_{ib}^{D,*}\sum_{a=1}^{3}Y_{u,ab}Z_{l3+a}^{U}\sum_{d=1}^{3}\sum_{c=1}^{3}Y_{u,cd}^{*}Z_{j3+c}^{U,*}Z_{kd}^{D}$$

$$+ 4 \sum_{b=1}^{3} Z_{jb}^{U,*} \sum_{a=1}^{3} Y_{d,ab} Z_{k3+a}^{D} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{i3+c}^{D,*} Z_{ld}^{U} \bigg) \bigg) \tag{339}$$
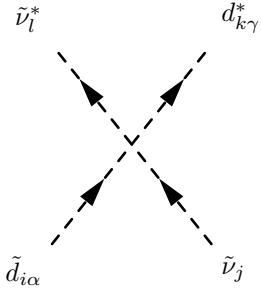
$$\frac{i}{12} \delta_{\alpha\gamma} \delta_{jl} \bigg(2 g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{D,*} Z_{k3+a}^{D} + \left(3 g_2^2 + g_1^2 \right) \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{ka}^{D} \bigg) \tag{340}$$
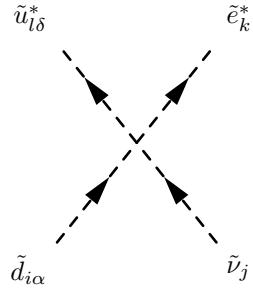
$$-\frac{i}{4} \delta_{\alpha\delta} \bigg(g_2^2 \sum_{a=1}^{3} Z_{ia}^{D,*} Z_{la}^{U} \sum_{b=1}^{3} Z_{jb}^{V,*} Z_{kb}^{E} + g_2^2 \sum_{a=1}^{3} Z_{ja}^{V,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{ib}^{D,*} Z_{lb}^{U}$$

$$+ 4 \sum_{b=1}^{3} Z_{jb}^{V,*} \sum_{a=1}^{3} Y_{e,ab} Z_{k3+a}^{E} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{d,cd}^{*} Z_{i3+c}^{D,*} Z_{ld}^{U} \bigg) \tag{341}$$
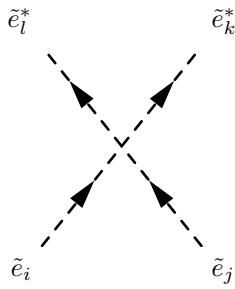
$$
\begin{aligned}
-\frac{i}{8}\Big(& g_1^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{la}^{E} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{kb}^{E} + g_2^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{la}^{E} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{kb}^{E} \\
& - 2g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{l3+a}^{E} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{kb}^{E} \\
& - 2g_1^2 \sum_{a=1}^{3} Z_{j3+a}^{E,*} Z_{l3+a}^{E} \Big(-2 \sum_{b=1}^{3} Z_{i3+b}^{E,*} Z_{k3+b}^{E} + \sum_{b=1}^{3} Z_{ib}^{E,*} Z_{kb}^{E} \Big) \\
& + \sum_{a=1}^{3} Z_{ja}^{E,*} Z_{la}^{E} \Big(-2g_1^2 \sum_{b=1}^{3} Z_{i3+b}^{E,*} Z_{k3+b}^{E} + \big(g_1^2 + g_2^2 \big) \sum_{b=1}^{3} Z_{ib}^{E,*} Z_{kb}^{E} \Big) \\
& - 2g_1^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{la}^{E} \sum_{b=1}^{3} Z_{j3+b}^{E,*} Z_{k3+b}^{E} + 4g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{l3+a}^{E} \sum_{b=1}^{3} Z_{j3+b}^{E,*} Z_{k3+b}^{E} \\
& + g_1^2 \sum_{a=1}^{3} Z_{ja}^{E,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{ib}^{E,*} Z_{lb}^{E} + g_2^2 \sum_{a=1}^{3} Z_{ja}^{E,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{ib}^{E,*} Z_{lb}^{E} \\
& - 2g_1^2 \sum_{a=1}^{3} Z_{j3+a}^{E,*} Z_{k3+a}^{E} \sum_{b=1}^{3} Z_{ib}^{E,*} Z_{lb}^{E} + g_1^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{lb}^{E} \\
& + g_2^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{lb}^{E} - 2g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{k3+a}^{E} \sum_{b=1}^{3} Z_{jb}^{E,*} Z_{lb}^{E} \\
& - 2g_1^2 \sum_{a=1}^{3} Z_{ja}^{E,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{i3+b}^{E,*} Z_{l3+b}^{E} + 4g_1^2 \sum_{a=1}^{3} Z_{j3+a}^{E,*} Z_{k3+a}^{E} \sum_{b=1}^{3} Z_{i3+b}^{E,*} Z_{l3+b}^{E} \\
& - 2g_1^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ka}^{E} \sum_{b=1}^{3} Z_{j3+b}^{E,*} Z_{l3+b}^{E} + 4g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{k3+a}^{E} \sum_{b=1}^{3} Z_{j3+b}^{E,*} Z_{l3+b}^{E} \\
& + 8 \sum_{b=1}^{3} Z_{jb}^{E,*} \sum_{a=1}^{3} Y_{e,ab} Z_{l3+a}^{E} \sum_{d=1}^{3}\sum_{c=1}^{3} Y_{e,cd}^{*} Z_{i3+c}^{E,*} Z_{kd}^{E} \\
& + 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)
\end{aligned}
\tag{342}
$$
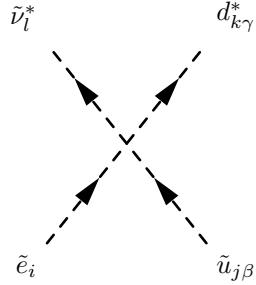
$$-\frac{i}{4}\delta_{\beta\gamma}\Big(g_2^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{la}^{V}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{kb}^{D}+g_2^2\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{ka}^{D}\sum_{b=1}^{3}Z_{ib}^{E,*}Z_{lb}^{V}$$

$$+4\sum_{b=1}^{3}Z_{jb}^{U,*}\sum_{a=1}^{3}Y_{d,ab}Z_{k3+a}^{D}\sum_{d=1}^{3}\sum_{c=1}^{3}Y_{e,cd}^{*}Z_{i3+c}^{E,*}Z_{ld}^{V}\Big)\tag{343}$$
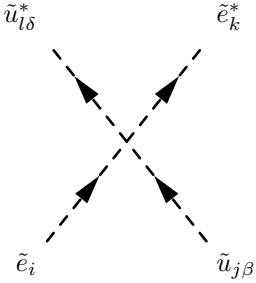
$$\frac{i}{24}\delta_{\beta\delta}\Big(-4g_1^2\sum_{a=1}^{3}Z_{j3+a}^{U,*}Z_{l3+a}^{U}\Big(-2\sum_{b=1}^{3}Z_{i3+b}^{E,*}Z_{k3+b}^{E}+\sum_{b=1}^{3}Z_{ib}^{E,*}Z_{kb}^{E}\Big)$$

$$+\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{la}^{U}\Big(-2g_1^2\sum_{b=1}^{3}Z_{i3+b}^{E,*}Z_{k3+b}^{E}+\Big(3g_2^2+g_1^2\Big)\sum_{b=1}^{3}Z_{ib}^{E,*}Z_{kb}^{E}\Big)$$

$$+g_1^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ka}^{E}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}+3g_2^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ka}^{E}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}$$

$$-2g_1^2\sum_{a=1}^{3}Z_{i3+a}^{E,*}Z_{k3+a}^{E}\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{lb}^{U}-4g_1^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ka}^{E}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U}$$

$$+8g_1^2\sum_{a=1}^{3}Z_{i3+a}^{E,*}Z_{k3+a}^{E}\sum_{b=1}^{3}Z_{j3+b}^{U,*}Z_{l3+b}^{U}\Big)\tag{344}$$

$$\tilde{\nu}_l^* \qquad \tilde{e}_k^*$$

$$\tilde{e}_i \qquad \tilde{\nu}_j$$
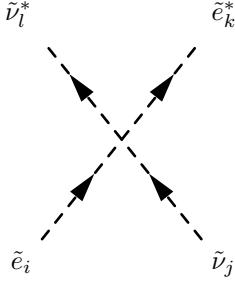
$$-\frac{i}{4}\Big(\delta_{jl}\Big(-2g_1^2\sum_{a=1}^{3}Z_{i3+a}^{E,*}Z_{k3+a}^E+\Big(-g_2^2+g_1^2\Big)\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ka}^E\Big)$$
$$+g_2^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{la}^V\sum_{b=1}^{3}Z_{jb}^{V,*}Z_{kb}^E+g_2^2\sum_{a=1}^{3}Z_{ja}^{V,*}Z_{ka}^E\sum_{b=1}^{3}Z_{ib}^{E,*}Z_{lb}^V$$
$$+4\sum_{b=1}^{3}Z_{jb}^{V,*}\sum_{a=1}^{3}Y_{e,ab}Z_{k3+a}^E\sum_{d=1}^{3}\sum_{c=1}^{3}Y_{e,cd}^*Z_{i3+c}^{E,*}Z_{ld}^V\Big) \tag{345}$$

$$\tilde{u}_{l\delta}^* \qquad \tilde{u}_{k\gamma}^*$$

$$\tilde{u}_{i\alpha} \qquad \tilde{u}_{j\beta}$$
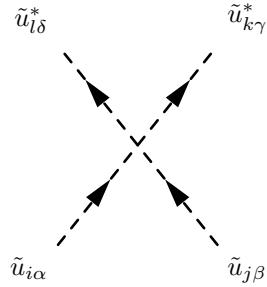
$$-\frac{i}{72}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(g_1^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{la}^U\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{kb}^U+9g_2^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{la}^U\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{kb}^U$$
$$-6g_3^2\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{la}^U\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{kb}^U-4g_1^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{l3+a}^U\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{kb}^U$$
$$+6g_3^2\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{l3+a}^U\sum_{b=1}^{3}Z_{jb}^{U,*}Z_{kb}^U$$
$$+18g_3^2\sum_{a=1}^{3}Z_{ja}^{U,*}Z_{la}^U\Big(-\sum_{b=1}^{3}Z_{i3+b}^{U,*}Z_{k3+b}^U+\sum_{b=1}^{3}Z_{ib}^{U,*}Z_{kb}^U\Big)$$
$$-18g_3^2\sum_{a=1}^{3}Z_{j3+a}^{U,*}Z_{l3+a}^U\Big(-\sum_{b=1}^{3}Z_{i3+b}^{U,*}Z_{k3+b}^U+\sum_{b=1}^{3}Z_{ib}^{U,*}Z_{kb}^U\Big)$$

$$- 4g_1^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{la}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{k3+b}^{U} + 6g_3^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{la}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{k3+b}^{U}$$

$$+ 16g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{l3+a}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{k3+b}^{U} - 6g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{l3+a}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{k3+b}^{U}$$

$$+ g_1^2 \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{ib}^{U,*} Z_{lb}^{U} + 9g_2^2 \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{ib}^{U,*} Z_{lb}^{U}$$

$$- 6g_3^2 \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{ib}^{U,*} Z_{lb}^{U} - 4g_1^2 \sum_{a=1}^{3} Z_{j3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{ib}^{U,*} Z_{lb}^{U}$$

$$+ 6g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{ib}^{U,*} Z_{lb}^{U} + 18g_3^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U}$$

$$- 18g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U} - 4g_1^2 \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{i3+b}^{U,*} Z_{l3+b}^{U}$$

$$+ 6g_3^2 \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{i3+b}^{U,*} Z_{l3+b}^{U} + 16g_1^2 \sum_{a=1}^{3} Z_{j3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{i3+b}^{U,*} Z_{l3+b}^{U}$$

$$- 6g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{i3+b}^{U,*} Z_{l3+b}^{U} - 18g_3^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U}$$

$$+ 18g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U}$$

$$+ 72 \sum_{b=1}^{3} Z_{ib}^{U,*} \sum_{a=1}^{3} Y_{u,ab} Z_{l3+a}^{U} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{u,cd}^{*} Z_{j3+c}^{U,*} Z_{kd}^{U}$$

$$+ 72 \sum_{b=1}^{3} Z_{jb}^{U,*} \sum_{a=1}^{3} Y_{u,ab} Z_{k3+a}^{U} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{u,cd}^{*} Z_{i3+c}^{U,*} Z_{ld}^{U} \Big)$$

$$+ \delta_{\alpha\gamma}\delta_{\beta\delta} \Big(18g_3^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{la}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{kb}^{U} - 18g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{l3+a}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{kb}^{U}$$

$$+ \sum_{a=1}^{3} Z_{j3+a}^{U,*} Z_{l3+a}^{U} \Big(2\big(-3g_3^2 + 8g_1^2 \big) \sum_{b=1}^{3} Z_{i3+b}^{U,*} Z_{k3+b}^{U} + \big(-4g_1^2 + 6g_3^2 \big) \sum_{b=1}^{3} Z_{ib}^{U,*} Z_{kb}^{U} \Big)$$

$$+ \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{la}^{U} \Big(2\big(-2g_1^2 + 3g_3^2 \big) \sum_{b=1}^{3} Z_{i3+b}^{U,*} Z_{k3+b}^{U} + \big(-6g_3^2 + 9g_2^2 + g_1^2 \big) \sum_{b=1}^{3} Z_{ib}^{U,*} Z_{kb}^{U} \Big)$$

$$- 18g_3^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{la}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{k3+b}^{U} + 18g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{l3+a}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{k3+b}^{U}$$

$$
+ 18g_3^2 \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{ib}^{U,*} Z_{lb}^{U} - 18g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{ib}^{U,*} Z_{lb}^{U}
$$

$$
+ g_1^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U} + 9g_2^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U}
$$

$$
- 6g_3^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U} - 4g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U}
$$

$$
+ 6g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{jb}^{U,*} Z_{lb}^{U} - 18g_3^2 \sum_{a=1}^{3} Z_{ja}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{i3+b}^{U,*} Z_{l3+b}^{U}
$$

$$
+ 18g_3^2 \sum_{a=1}^{3} Z_{j3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{i3+b}^{U,*} Z_{l3+b}^{U} - 4g_1^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U}
$$

$$
+ 6g_3^2 \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ka}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U} + 16g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U}
$$

$$
- 6g_3^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{k3+a}^{U} \sum_{b=1}^{3} Z_{j3+b}^{U,*} Z_{l3+b}^{U}
$$

$$
+ 72 \sum_{b=1}^{3} Z_{jb}^{U,*} \sum_{a=1}^{3} Y_{u,ab} Z_{l3+a}^{U} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{u,cd}^{*} Z_{i3+c}^{U,*} Z_{kd}^{U}
$$

$$
+ 72 \sum_{b=1}^{3} Z_{ib}^{U,*} \sum_{a=1}^{3} Y_{u,ab} Z_{k3+a}^{U} \sum_{d=1}^{3} \sum_{c=1}^{3} Y_{u,cd}^{*} Z_{j3+c}^{U,*} Z_{ld}^{U} \Big) \Big)
\tag{346}
$$
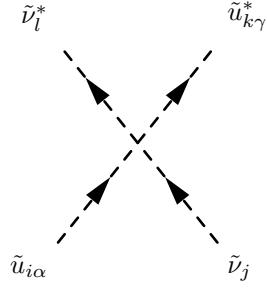
$$
\frac{i}{12} \delta_{\alpha\gamma} \delta_{jl} \Big(\big(-3g_2^2 + g_1^2 \big) \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ka}^{U} - 4g_1^2 \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{k3+a}^{U} \Big)
\tag{347}
$$
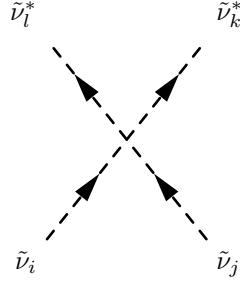
$$-\frac{i}{4}\left(g_1^2+g_2^2\right)\left(\delta_{ik}\delta_{jl}+\delta_{il}\delta_{jk}\right) \tag{348}$$

9.8 Two Scalar-Two Vector Boson-Interaction
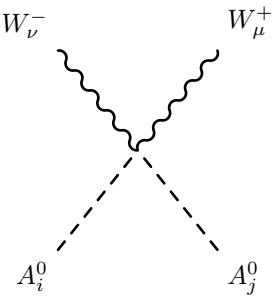
$$\frac{i}{2}g_2^2\left(Z_{i1}^A Z_{j1}^A+Z_{i2}^A Z_{j2}^A\right)\left(g_{\mu\nu}\right) \tag{349}$$
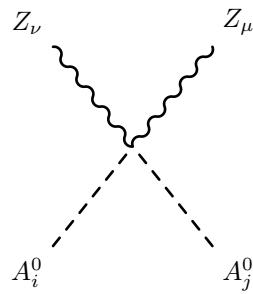
$$\frac{i}{2}\left(g_1\sin\Theta_W+g_2\cos\Theta_W\right)^2\left(Z_{i1}^A Z_{j1}^A+Z_{i2}^A Z_{j2}^A\right)\left(g_{\mu\nu}\right) \tag{350}$$
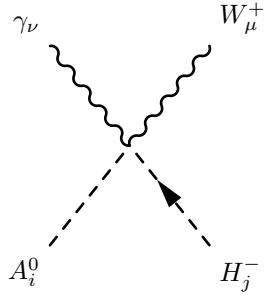
$$-\frac{1}{2}g_1 g_2 \cos\Theta_W \left(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+ \right)\left(g_{\mu\nu} \right) \qquad (351)$$
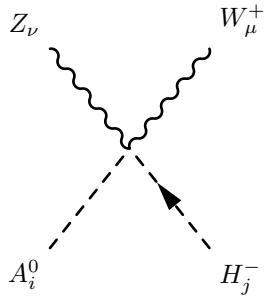
$$\frac{1}{2}g_1 g_2 \sin\Theta_W \left(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+ \right)\left(g_{\mu\nu} \right) \qquad (352)$$
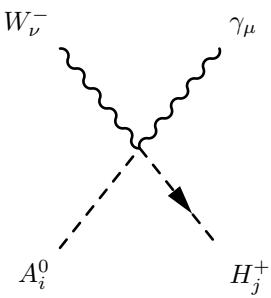
$$\frac{1}{2}g_1 g_2 \cos\Theta_W \left(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+ \right)\left(g_{\mu\nu} \right) \qquad (353)$$
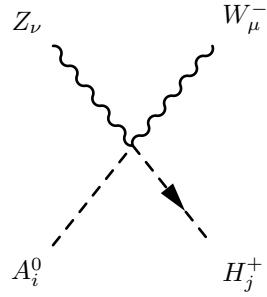
$$-\frac{1}{2}g_1 g_2 \sin \Theta_W \left(Z_{i1}^A Z_{j1}^+ + Z_{i2}^A Z_{j2}^+ \right) \left(g_{\mu\nu} \right) \tag{354}$$
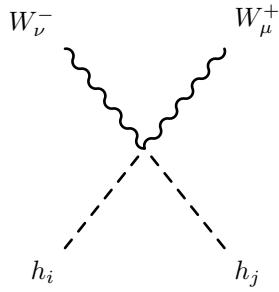
$$\frac{i}{2}g_2^2 \left(Z_{i1}^H Z_{j1}^H + Z_{i2}^H Z_{j2}^H \right) \left(g_{\mu\nu} \right) \tag{355}$$
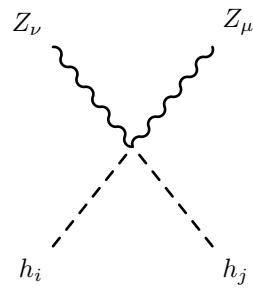
$$\frac{i}{2}\left(g_1 \sin \Theta_W + g_2 \cos \Theta_W \right)^2 \left(Z_{i1}^H Z_{j1}^H + Z_{i2}^H Z_{j2}^H \right) \left(g_{\mu\nu} \right) \tag{356}$$
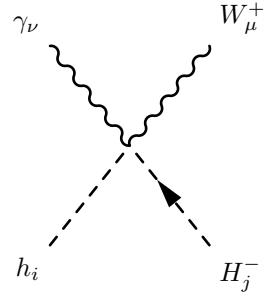
$$-\frac{i}{2}g_1 g_2 \cos\Theta_W \left(Z_{i1}^H Z_{j1}^+ - Z_{i2}^H Z_{j2}^+ \right)\left(g_{\mu\nu} \right) \tag{357}$$
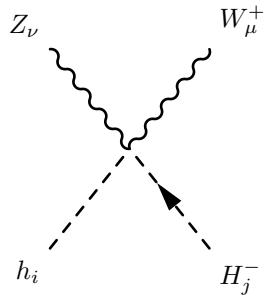
$$\frac{i}{2}g_1 g_2 \sin\Theta_W \left(Z_{i1}^H Z_{j1}^+ - Z_{i2}^H Z_{j2}^+ \right)\left(g_{\mu\nu} \right) \tag{358}$$
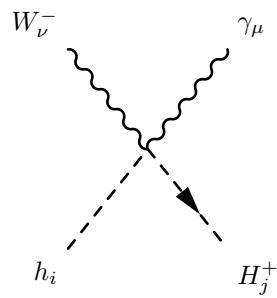
$$-\frac{i}{2}g_1 g_2 \cos\Theta_W \left(Z_{i1}^H Z_{j1}^+ - Z_{i2}^H Z_{j2}^+ \right)\left(g_{\mu\nu} \right) \tag{359}$$
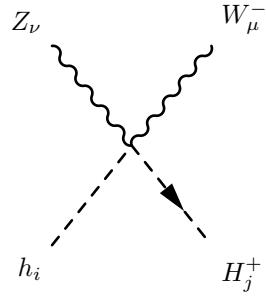
$$\frac{i}{2} g_1 g_2 \sin \Theta_W \left(Z_{i1}^H Z_{j1}^+ - Z_{i2}^H Z_{j2}^+ \right) \left(g_{\mu\nu} \right) \tag{360}$$
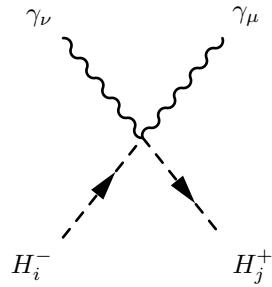
$$\frac{i}{2} \left(g_1 \cos \Theta_W + g_2 \sin \Theta_W \right)^2 \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) \left(g_{\mu\nu} \right) \tag{361}$$
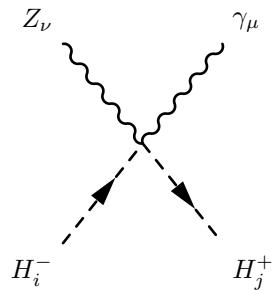
$$-\frac{i}{4} \left(-2 g_1 g_2 \cos 2\Theta_W + \left(-g_2^2 + g_1^2 \right) \sin 2\Theta_W \right) \left(Z_{i1}^+ Z_{j1}^+ + Z_{i2}^+ Z_{j2}^+ \right) \left(g_{\mu\nu} \right) \tag{362}$$
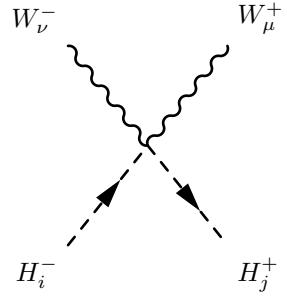
$$\frac{i}{2}g_2^2\Big(Z_{i1}^+Z_{j1}^+ + Z_{i2}^+Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{363}$$
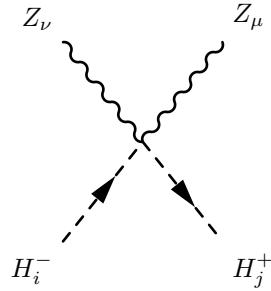
$$\frac{i}{2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(Z_{i1}^+Z_{j1}^+ + Z_{i2}^+Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{364}$$
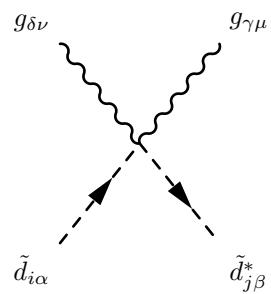
$$\frac{i}{4}g_3^2\delta_{ij}\Big(\sum_{a=1}^{3}\lambda_{a,\alpha}^{\gamma}\lambda_{\beta,a}^{\delta} + \sum_{a=1}^{3}\lambda_{\beta,a}^{\gamma}\lambda_{a,\alpha}^{\delta}\Big)\Big(g_{\mu\nu}\Big) \tag{365}$$

$$\frac{i}{6}g_3\lambda^{\gamma}_{\beta,\alpha}\Big(-2g_1\cos\Theta_W\sum_{a=1}^{3}Z^{D,*}_{i3+a}Z^{D}_{j3+a}+\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\sum_{a=1}^{3}Z^{D,*}_{ia}Z^{D}_{ja}\Big)\Big(g_{\mu\nu}\Big) \qquad (366)$$
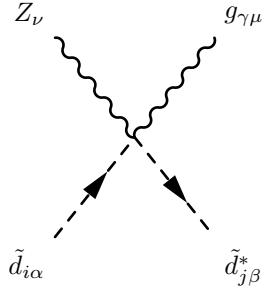
$$-\frac{i}{6}g_3\lambda^{\gamma}_{\beta,\alpha}\Big(-2g_1\sin\Theta_W\sum_{a=1}^{3}Z^{D,*}_{i3+a}Z^{D}_{j3+a}+\Big(3g_2\cos\Theta_W+g_1\sin\Theta_W\Big)\sum_{a=1}^{3}Z^{D,*}_{ia}Z^{D}_{ja}\Big)\Big(g_{\mu\nu}\Big) \qquad (367)$$
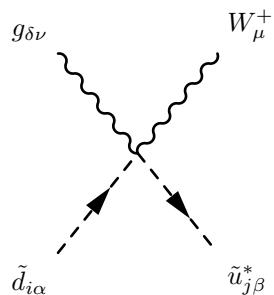
$$i\frac{1}{\sqrt{2}}g_2g_3\lambda^{\delta}_{\beta,\alpha}\sum_{a=1}^{3}Z^{D,*}_{ia}Z^{U}_{ja}\Big(g_{\mu\nu}\Big) \qquad (368)$$

$$\frac{i}{18}\delta_{\alpha\beta}\left(\left(-3g_2\sin\Theta_W+g_1\cos\Theta_W\right)^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^D+4g_1^2\cos\Theta_W^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{j3+a}^D\right)\left(g_{\mu\nu}\right) \qquad (369)$$
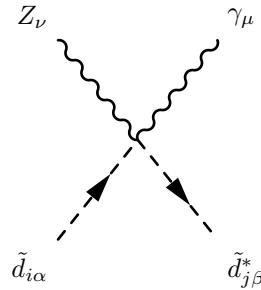
$$-\frac{i}{36}\delta_{\alpha\beta}\left(\left(6g_1g_2\cos 2\Theta_W+\left(-9g_2^2+g_1^2\right)\sin 2\Theta_W\right)\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^D\right.$$
$$\left.+4g_1^2\sin 2\Theta_W\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{j3+a}^D\right)\left(g_{\mu\nu}\right) \qquad (370)$$
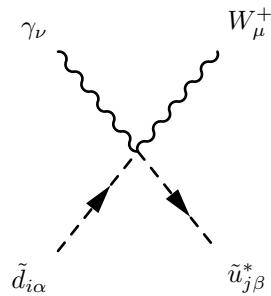
$$\frac{i}{3}\frac{1}{\sqrt{2}}g_1g_2\cos\Theta_W\delta_{\alpha\beta}\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^U\left(g_{\mu\nu}\right) \qquad (371)$$

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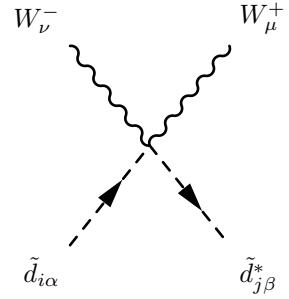
$$\frac{i}{2}g_2^2\delta_{\alpha\beta}\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{D}\Big(g_{\mu\nu}\Big) \tag{372}$$
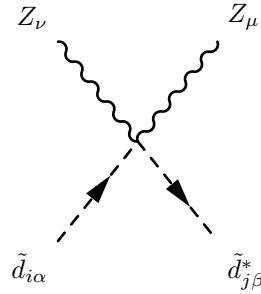
$$\frac{i}{18}\delta_{\alpha\beta}\Big(\Big(3g_2\cos\Theta_W+g_1\sin\Theta_W\Big)^2\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{D}+4g_1^2\sin\Theta_W^2\sum_{a=1}^{3}Z_{i3+a}^{D,*}Z_{j3+a}^{D}\Big)\Big(g_{\mu\nu}\Big) \tag{373}$$
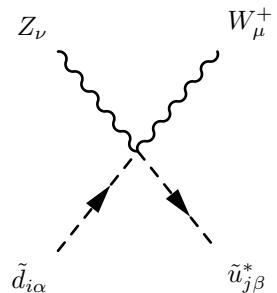
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1g_2\delta_{\alpha\beta}\sin\Theta_W\sum_{a=1}^{3}Z_{ia}^{D,*}Z_{ja}^{U}\Big(g_{\mu\nu}\Big) \tag{374}$$
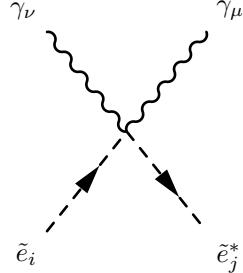
$$\frac{i}{2}\left(4g_1^2\cos\Theta_W^2\sum_{a=1}^{3}Z_{i3+a}^{E,*}Z_{j3+a}^{E}+\left(g_1\cos\Theta_W+g_2\sin\Theta_W\right)^2\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ja}^{E}\right)\left(g_{\mu\nu}\right) \tag{375}$$
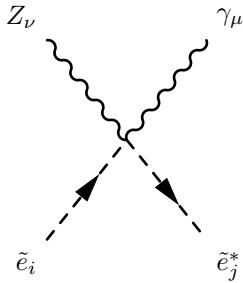
$$-\frac{i}{4}\left(\left(-2g_1g_2\cos2\Theta_W+\left(-g_2^2+g_1^2\right)\sin2\Theta_W\right)\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ja}^{E}\right.$$
$$\left.+4g_1^2\sin2\Theta_W\sum_{a=1}^{3}Z_{i3+a}^{E,*}Z_{j3+a}^{E}\right)\left(g_{\mu\nu}\right) \tag{376}$$
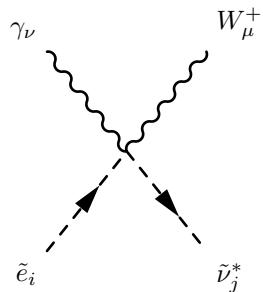
$$-i\frac{1}{\sqrt{2}}g_1g_2\cos\Theta_W\sum_{a=1}^{3}Z_{ia}^{E,*}Z_{ja}^{V}\left(g_{\mu\nu}\right) \tag{377}$$
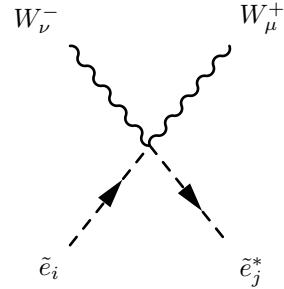
$$\frac{i}{2}g_2^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E} \Big(g_{\mu\nu}\Big) \tag{378}$$
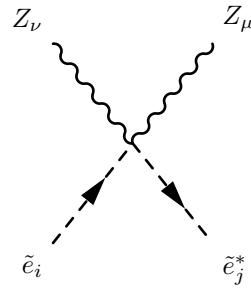
$$\frac{i}{2}\left(4g_1^2 \sin\Theta_W^2 \sum_{a=1}^{3} Z_{i3+a}^{E,*} Z_{j3+a}^{E} + \Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2 \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{E}\right)\Big(g_{\mu\nu}\Big) \tag{379}$$
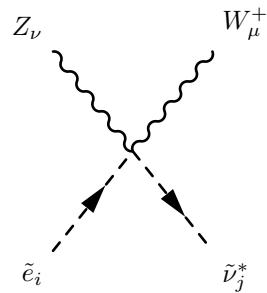
$$i\frac{1}{\sqrt{2}}g_1 g_2 \sin\Theta_W \sum_{a=1}^{3} Z_{ia}^{E,*} Z_{ja}^{V} \Big(g_{\mu\nu}\Big) \tag{380}$$
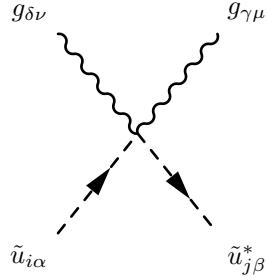
$$\frac{i}{4}g_3^2\delta_{ij}\left(\sum_{a=1}^{3}\lambda_{a,\alpha}^{\gamma}\lambda_{\beta,a}^{\delta} + \sum_{a=1}^{3}\lambda_{\beta,a}^{\gamma}\lambda_{a,\alpha}^{\delta}\right)\left(g_{\mu\nu}\right) \tag{381}$$
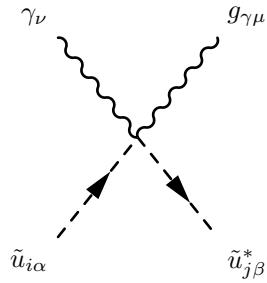
$$\frac{i}{6}g_3\lambda_{\beta,\alpha}^{\gamma}\left(\left(3g_2\sin\Theta_W + g_1\cos\Theta_W\right)\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ja}^{U} + 4g_1\cos\Theta_W\sum_{a=1}^{3}Z_{i3+a}^{U,*}Z_{j3+a}^{U}\right)\left(g_{\mu\nu}\right) \tag{382}$$
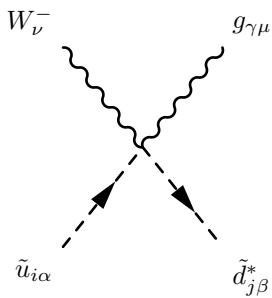
$$i\frac{1}{\sqrt{2}}g_2g_3\lambda_{\beta,\alpha}^{\gamma}\sum_{a=1}^{3}Z_{ia}^{U,*}Z_{ja}^{D}\left(g_{\mu\nu}\right) \tag{383}$$
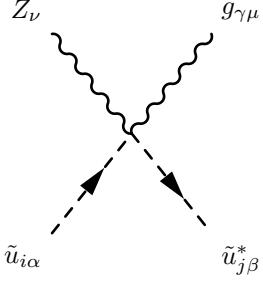
$$\frac{i}{6} g_3 \lambda^\gamma_{\beta,\alpha} \left(\left(3 g_2 \cos \Theta_W - g_1 \sin \Theta_W \right) \sum_{a=1}^3 Z^{U,*}_{ia} Z^U_{ja} - 4 g_1 \sin \Theta_W \sum_{a=1}^3 Z^{U,*}_{i3+a} Z^U_{j3+a} \right) \left(g_{\mu\nu} \right) \tag{384}$$
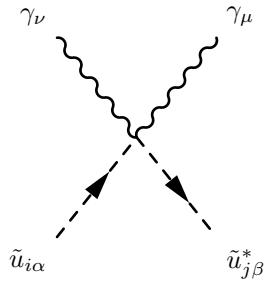
$$\frac{i}{18} \delta_{\alpha\beta} \left(16 g_1^2 \cos \Theta_W^2 \sum_{a=1}^3 Z^{U,*}_{i3+a} Z^U_{j3+a} + \left(3 g_2 \sin \Theta_W + g_1 \cos \Theta_W \right)^2 \sum_{a=1}^3 Z^{U,*}_{ia} Z^U_{ja} \right) \left(g_{\mu\nu} \right) \tag{385}$$

$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 \cos \Theta_W \delta_{\alpha\beta} \sum_{a=1}^3 Z^{U,*}_{ia} Z^D_{ja} \left(g_{\mu\nu} \right) \tag{386}$$

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Z_ν γ_μ

$\tilde{u}_{i\alpha}$ $\tilde{u}_{j\beta}^*$

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

$$+\, 16 g_1^2 \sin 2\Theta_W \sum_{a=1}^{3} Z_{i3+a}^{U,*} Z_{j3+a}^{U}\Big)\Big(g_{\mu\nu}\Big) \tag{387}$$

Z_ν W_μ^-

$\tilde{u}_{i\alpha}$ $\tilde{d}_{j\beta}^*$
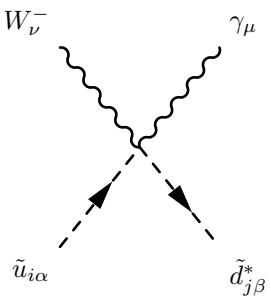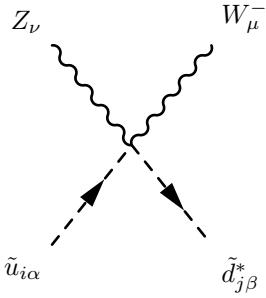
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 \delta_{\alpha\beta}\sin\Theta_W \sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ja}^{D}\Big(g_{\mu\nu}\Big) \tag{388}$$
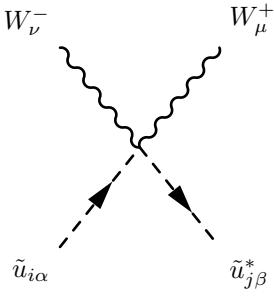
W_ν^- W_μ^+

$\tilde{u}_{i\alpha}$ $\tilde{u}_{j\beta}^*$

$$\frac{i}{2}g_2^2 \delta_{\alpha\beta}\sum_{a=1}^{3} Z_{ia}^{U,*} Z_{ja}^{U}\Big(g_{\mu\nu}\Big) \tag{389}$$
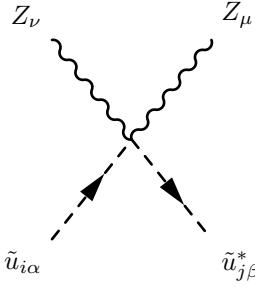
Diagram with Z_ν, Z_μ (wavy lines) and $\tilde{u}_{i\alpha}$, $\tilde{u}^*_{j\beta}$ (dashed lines).

$$\frac{i}{18}\delta_{\alpha\beta}\left(16g_1^2\sin\Theta_W^2\sum_{a=1}^{3}Z^{U,*}_{i3+a}Z^{U}_{j3+a}+\left(-3g_2\cos\Theta_W+g_1\sin\Theta_W\right)^2\sum_{a=1}^{3}Z^{U,*}_{ia}Z^{U}_{ja}\right)\left(g_{\mu\nu}\right) \tag{390}$$

Diagram with W^-_ν, γ_μ (wavy lines) and $\tilde{\nu}_i$, $\tilde{e}^*_j$ (dashed lines).

$$-i\frac{1}{\sqrt{2}}g_1g_2\cos\Theta_W\sum_{a=1}^{3}Z^{V,*}_{ia}Z^{E}_{ja}\left(g_{\mu\nu}\right) \tag{391}$$

Diagram with Z_ν, W^-_μ (wavy lines) and $\tilde{\nu}_i$, $\tilde{e}^*_j$ (dashed lines).
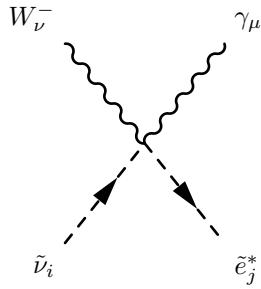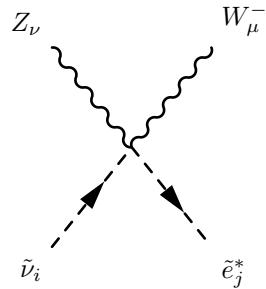
$$i\frac{1}{\sqrt{2}}g_1g_2\sin\Theta_W\sum_{a=1}^{3}Z^{V,*}_{ia}Z^{E}_{ja}\left(g_{\mu\nu}\right) \tag{392}$$
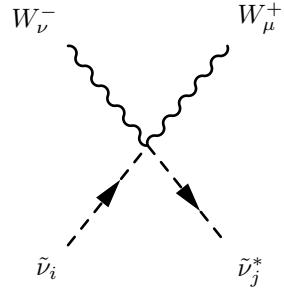
$$\frac{i}{2}g_2^2\delta_{ij}\Big(g_{\mu\nu}\Big) \tag{393}$$

$$\frac{i}{2}\delta_{ij}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2\Big(g_{\mu\nu}\Big) \tag{394}$$

9.9   Four Vector Boson-Interaction
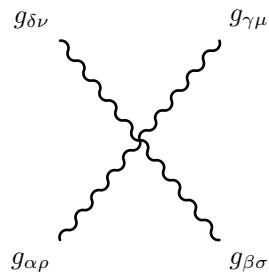
$$-ig_3^2\Big(\sum_{a=1}^{8}f_{\alpha,\delta,a}f_{\beta,\gamma,a}+\sum_{a=1}^{8}f_{\alpha,\gamma,a}f_{\beta,\delta,a}\Big)\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{395}$$

$$+ig_3^2\Big(-\sum_{a=1}^{8}f_{\alpha,\beta,a}f_{\gamma,\delta,a}+\sum_{a=1}^{8}f_{\alpha,\delta,a}f_{\beta,\gamma,a}\Big)\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{396}$$

$$+ ig_3^2 \Big(\sum_{a=1}^{8} f_{\alpha,\gamma,a} f_{\beta,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\beta,a} f_{\gamma,\delta,a} \Big) \Big(g_{\rho\nu} g_{\sigma\mu} \Big) \tag{397}$$
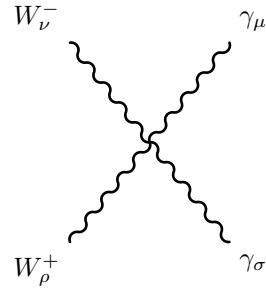
$$ig_2^2 \sin \Theta_W^2 \Big(g_{\rho\sigma} g_{\mu\nu} \Big) \tag{398}$$
$$+ ig_2^2 \sin \Theta_W^2 \Big(g_{\rho\mu} g_{\sigma\nu} \Big) \tag{399}$$
$$+ -2ig_2^2 \sin \Theta_W^2 \Big(g_{\rho\nu} g_{\sigma\mu} \Big) \tag{400}$$
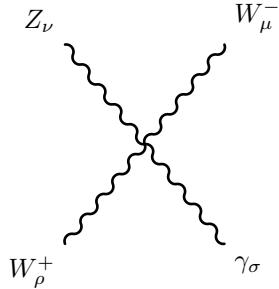
$$ig_2^2 \cos \Theta_W \sin \Theta_W \Big(g_{\rho\sigma} g_{\mu\nu} \Big) \tag{401}$$
$$+ -ig_2^2 \sin 2\Theta_W \Big(g_{\rho\mu} g_{\sigma\nu} \Big) \tag{402}$$
$$+ ig_2^2 \cos \Theta_W \sin \Theta_W \Big(g_{\rho\nu} g_{\sigma\mu} \Big) \tag{403}$$
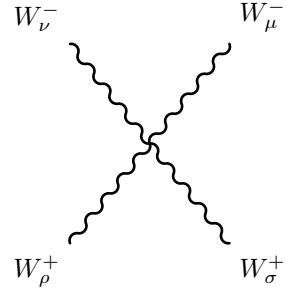
$$2ig_2^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{404}$$

$$+ -ig_2^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{405}$$

$$+ -ig_2^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{406}$$
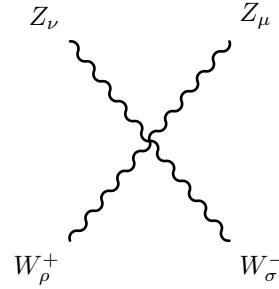
$$- 2ig_2^2\cos\Theta_W^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{407}$$

$$+ ig_2^2\cos\Theta_W^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{408}$$

$$+ ig_2^2\cos\Theta_W^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{409}$$

9.10   Two Ghosts-One Vector Boson-Interaction
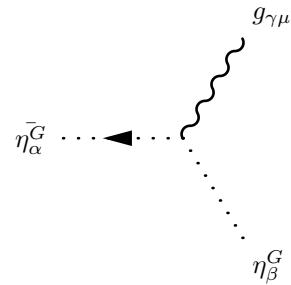
$$g_3 f_{\alpha,\beta,\gamma}\left(p_\mu^{\eta_\beta^G}\right) \tag{410}$$
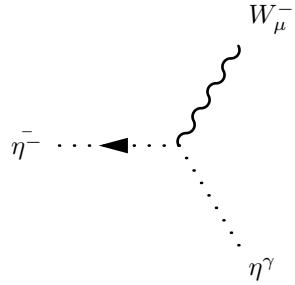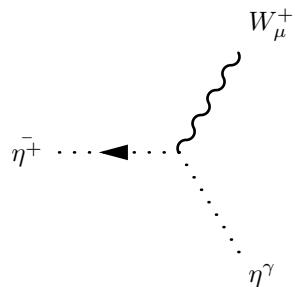
$$ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{411}$$

$$-ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{412}$$

$$-ig_2 \sin\Theta_W\left(p_\mu^{\eta^-}\right) \tag{413}$$

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$$Z_\mu$$

$$\bar{\eta}^- \quad \cdots\blacktriangleleft\cdots \quad \eta^-$$

$$-ig_2\cos\Theta_W\left(p_\mu^{\eta^-}\right) \tag{414}$$

$$W_\mu^+$$

$$\bar{\eta}^\gamma \quad \cdots\blacktriangleleft\cdots \quad \eta^-$$

$$ig_2\sin\Theta_W\left(p_\mu^{\eta^-}\right) \tag{415}$$

$$W_\mu^+$$

$$\bar{\eta}^Z \quad \cdots\blacktriangleleft\cdots \quad \eta^-$$
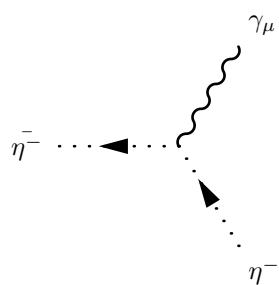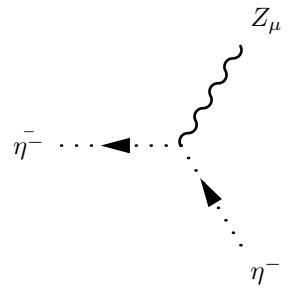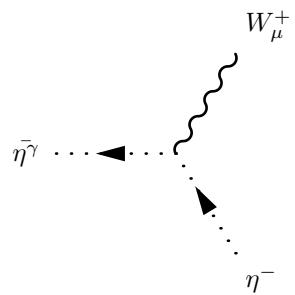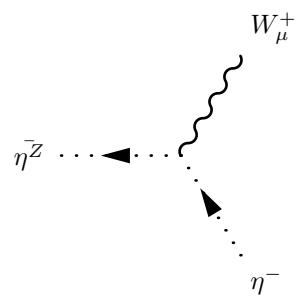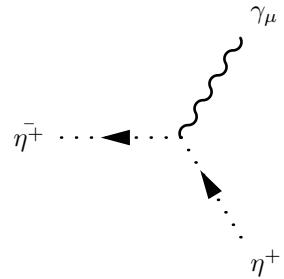
$$ig_2\cos\Theta_W\left(p_\mu^{\eta^-}\right) \tag{416}$$

$$ig_2 \sin \Theta_W \left(p_\mu^{\eta^+} \right) \qquad (417)$$
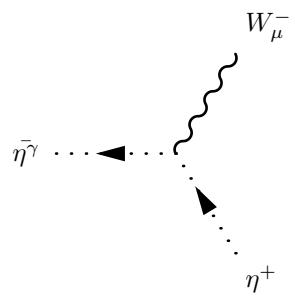
$$-ig_2 \sin \Theta_W \left(p_\mu^{\eta^+} \right) \qquad (418)$$
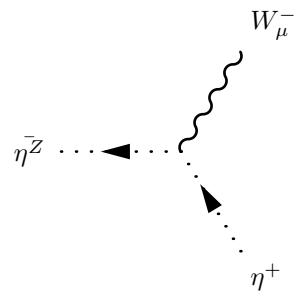
$$-ig_2 \cos \Theta_W \left(p_\mu^{\eta^+} \right) \qquad (419)$$
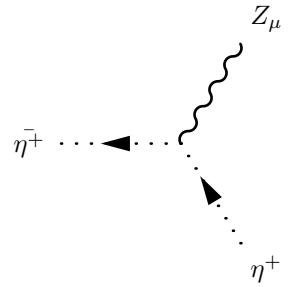
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^+} \right) \tag{420}$$
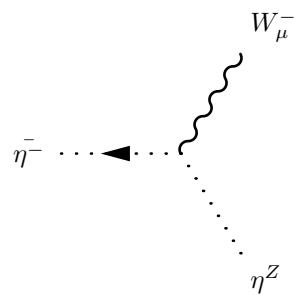
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z} \right) \tag{421}$$
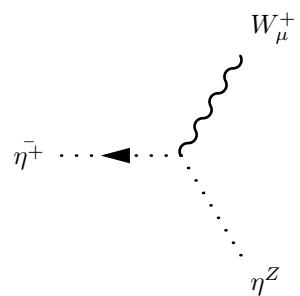
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z} \right) \tag{422}$$

9.11 Two Ghosts-One Scalar-Interaction
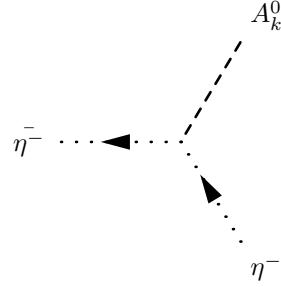
$$\frac{1}{4}g_2^2\xi_{W^-}\left(v_d Z_{k1}^A - v_u Z_{k2}^A\right) \tag{423}$$
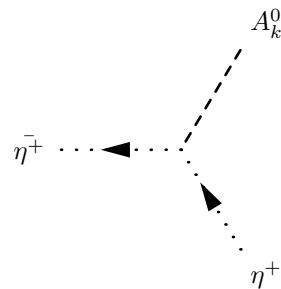
$$\frac{1}{4}g_2^2\xi_{W^-}\left(-v_d Z_{k1}^A + v_u Z_{k2}^A\right) \tag{424}$$
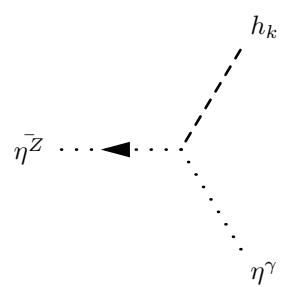
$$\frac{i}{8}\xi_Z\left(2g_1 g_2 \cos 2\Theta_W + \left(-g_2^2 + g_1^2\right)\sin 2\Theta_W\right)\left(v_d Z_{k1}^H + v_u Z_{k2}^H\right) \tag{425}$$

$$H_k^-$$

$$\eta^- \cdots\!\blacktriangleleft\!\cdots$$

$$\eta^\gamma$$
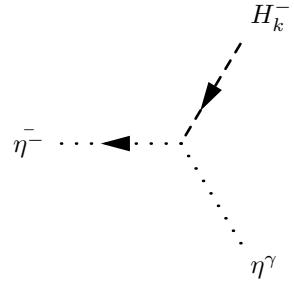
$$\frac{i}{4} g_2 \xi_{W^-} \Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W \Big) \Big(v_d Z_{k1}^+ - v_u Z_{k2}^+ \Big) \tag{426}$$

$$H_k^+$$

$$\bar\eta^+ \cdots\!\blacktriangleleft\!\cdots$$

$$\eta^\gamma$$
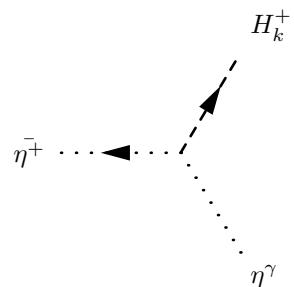
$$\frac{i}{4} g_2 \xi_{W^-} \Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W \Big) \Big(v_d Z_{k1}^+ - v_u Z_{k2}^+ \Big) \tag{427}$$

$$h_k$$

$$\eta^- \cdots\!\blacktriangleleft\!\cdots$$

$$\eta^-$$
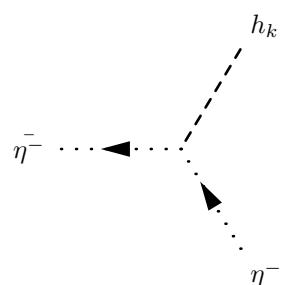
$$-\frac{i}{4} g_2^2 \xi_{W^-} \Big(v_d Z_{k1}^H + v_u Z_{k2}^H \Big) \tag{428}$$
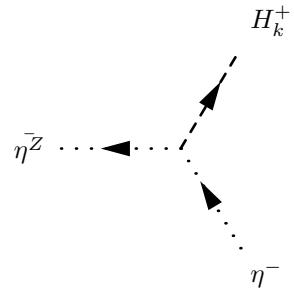
$$-\frac{i}{4}g_2\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ^+_{k1}-v_uZ^+_{k2}\Big) \qquad (429)$$
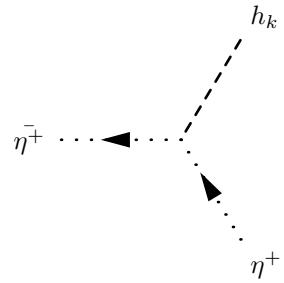

$$-\frac{i}{4}g_2^2\xi_{W^-}\Big(v_dZ^H_{k1}+v_uZ^H_{k2}\Big) \qquad (430)$$
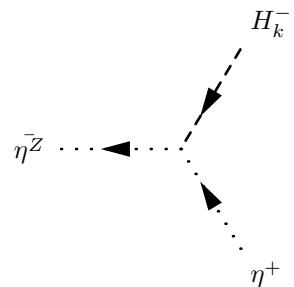
$$-\frac{i}{4}g_2\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ^+_{k1}-v_uZ^+_{k2}\Big) \qquad (431)$$

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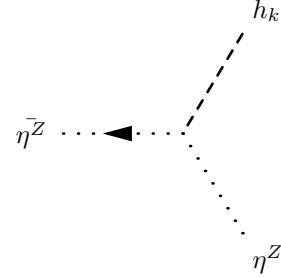
$$-\frac{i}{4}\xi_Z\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(v_d Z^H_{k1} + v_u Z^H_{k2}\Big) \tag{432}$$
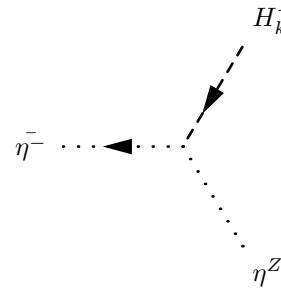
$$\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(v_d Z^+_{k1} - v_u Z^+_{k2}\Big) \tag{433}$$
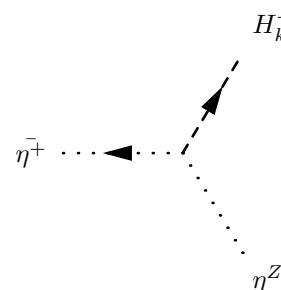
$$\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(v_d Z^+_{k1} - v_u Z^+_{k2}\Big) \tag{434}$$

10 Clebsch-Gordan Coefficients