MSSM without flavor violation
Superpotential, Rotations and Interactions for eigenstates 'EWSB' including Renormalization Group Equations

SARAH 4.6.0

November 19, 2015

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

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1 Superfields

1.1 Vector Superfields

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

1.2 Chiral Superfields

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

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

$$\begin{aligned}
-L_{SB,W} = & - H_d^0 H_u^0 B_\mu + H_d^- H_u^+ B_\mu + H_d^0 \tilde{d}^*_{R,i\alpha} \delta_{\alpha\beta} \delta_{ij} \tilde{d}_{L,j\beta} T_{d,ij} - H_d^- \tilde{d}^*_{R,i\alpha} \delta_{\alpha\beta} \delta_{ij} \tilde{u}_{L,j\beta} T_{d,ij} \\
& + H_d^0 \tilde{e}^*_{R,i} \delta_{ij} \tilde{e}_{L,j} T_{e,ij} - H_d^- \tilde{e}^*_{R,i} \delta_{ij} \tilde{\nu}_j T_{e,ij} - H_u^+ \tilde{u}^*_{R,i\alpha} \delta_{\alpha\beta} \delta_{ij} \tilde{d}_{L,j\beta} T_{u,ij} \\
& + H_u^0 \tilde{u}^*_{R,i\alpha} \delta_{\alpha\beta} \delta_{ij} \tilde{u}_{L,j\beta} T_{u,ij} + \text{h.c.} \qquad (2) \\
-L_{SB,\phi} = & + m_{H_d}^2 |H_d^0|^2 + m_{H_d}^2 |H_d^-|^2 + m_{H_u}^2 |H_u^0|^2 + m_{H_u}^2 |H_u^+|^2 + \tilde{d}^*_{L,i\alpha} \delta_{\alpha\beta} \delta_{ij} m^2_{q,ij} \tilde{d}_{L,j\beta} \\
& + \tilde{d}^*_{R,i\alpha} \delta_{\alpha\beta} \delta_{ij} m^2_{d,ij} \tilde{d}_{R,j\beta} + \tilde{e}^*_{L,i} \delta_{ij} m^2_{l,ij} \tilde{e}_{L,j} + \tilde{e}^*_{R,i} \delta_{ij} m^2_{e,ij} \tilde{e}_{R,j} + \tilde{u}^*_{L,i\alpha} \delta_{\alpha\beta} \delta_{ij} m^2_{q,ij} \tilde{u}_{L,j\beta} \\
& + \tilde{u}^*_{R,i\alpha} \delta_{\alpha\beta} \delta_{ij} m^2_{u,ij} \tilde{u}_{R,j\beta} + \tilde{\nu}^*_i \delta_{ij} m^2_{l,ij} \tilde{\nu}_j \qquad (3) \\
-L_{SB,\lambda} = & \frac{1}{2} \left(\lambda_{\tilde{B}}^2 M_1 \delta_{ij} + M_2 \delta_{ij} \lambda_{\tilde{W},i} \lambda_{\tilde{W},j} + M_3 \delta_{ij} \lambda_{\tilde{g},\alpha} \lambda_{\tilde{g},\beta} + \text{h.c.} \right) \qquad (4)
\end{aligned}$$

2.3 Gauge fixing terms

2.3.1 Gauge fixing terms for eigenstates 'GaugeES'

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

2.3.2 Gauge fixing terms for eigenstates 'EWSB'

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

2.4 Fields integrated out

None

3 Renormalization Group Equations

3.1 Anomalous Dimensions

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

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

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

$$\gamma_{\hat{l}}^{(2)} = -2Y_e^\dagger Y_e Y_e^\dagger Y_e + \frac{3}{100}\Big(125g_2^4 + 30g_1^2g_2^2 + 69g_1^4\Big)\mathbf{1} + Y_e^\dagger Y_e\Big(-3\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + \frac{6}{5}g_1^2 - \mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\Big) \tag{10}$$

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

$$\begin{aligned} \gamma_{\hat{H}_d}^{(2)} = &+\frac{207}{100}g_1^4 + \frac{9}{10}g_1^2g_2^2 + \frac{15}{4}g_2^4 - \frac{2}{5}\Big(-40g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + \frac{6}{5}g_1^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 9\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) \\ &- 3\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 3\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) \end{aligned} \tag{12}$$

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

$$\gamma_{\hat{H}_u}^{(2)} = -3\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 9\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big) + \frac{15}{4}g_2^4 + \frac{207}{100}g_1^4 + \frac{4}{5}\Big(20g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + \frac{9}{10}g_1^2g_2^2 \tag{14}$$

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

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

$$+ Y_d^* Y_d^T \Big(-2\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 6g_2^2 - 6\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{2}{5}g_1^2\Big) \tag{16}$$

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

$$\gamma_{\hat{u}}^{(2)} = +\frac{8}{225}\Big(107g_1^4 - 25g_3^4 + 80g_1^2 g_3^2\Big)\mathbf{1} - 2\Big(Y_u^* Y_d^T Y_d^* Y_u^T + Y_u^* Y_u^T Y_u^* Y_u^T\Big)$$
$$+ Y_u^* Y_u^T \Big(6g_2^2 - 6\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{2}{5}g_1^2\Big) \tag{18}$$

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

$$\gamma_{\hat{e}}^{(2)} = -2Y_e^* Y_e^T Y_e^* Y_e^T + \frac{234}{25}g_1^4\mathbf{1} + Y_e^* Y_e^T \Big(-2\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 6g_2^2 - 6\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - \frac{6}{5}g_1^2\Big) \tag{20}$$

3.2 Gauge Couplings

$$\beta_{g_1}^{(1)} = \frac{33}{5}g_1^3 \tag{21}$$

$$\beta_{g_1}^{(2)} = \frac{1}{25}g_1^3\Big(-130\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 135g_2^2 + 199g_1^2 + 440g_3^2 - 70\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 90\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)\Big) \tag{22}$$

$$\beta_{g_2}^{(1)} = g_2^3 \tag{23}$$

$$\beta_{g_2}^{(2)} = \frac{1}{5}g_2^3\Big(-10\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big) + 120g_3^2 + 125g_2^2 - 30\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 30\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 9g_1^2\Big) \tag{24}$$

$$\beta_{g_3}^{(1)} = -3g_3^3 \tag{25}$$

$$\beta_{g_3}^{(2)} = \frac{1}{5}g_3^3\Big(11g_1^2 - 20\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 20\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 45g_2^2 + 70g_3^2\Big) \tag{26}$$

3.3 Gaugino Mass Parameters

$$\beta_{M_1}^{(1)} = \frac{66}{5}g_1^2 M_1 \tag{27}$$

$$\beta_{M_1}^{(2)} = \frac{2}{25}g_1^2\Big(398g_1^2 M_1 + 135g_2^2 M_1 + 440g_3^2 M_1 + 440g_3^2 M_3 + 135g_2^2 M_2 - 70M_1\mathrm{Tr}\Big(Y_d Y_d^\dagger\Big) - 90M_1\mathrm{Tr}\Big(Y_e Y_e^\dagger\Big)$$
$$- 130M_1\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 70\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + 90\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 130\mathrm{Tr}\Big(Y_u^\dagger T_u\Big)\Big) \tag{28}$$

$$\beta_{M_2}^{(1)} = 2g_2^2 M_2 \tag{29}$$

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

$$\beta_{M_3}^{(1)} = -6g_3^2 M_3 \tag{31}$$

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

$$+ 20\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + 20\mathrm{Tr}\Big(Y_u^\dagger T_u\Big)\Big) \tag{32}$$

3.4 Trilinear Superpotential Parameters

$$\beta_{Y_d}^{(1)} = 3Y_dY_d^\dagger Y_d + Y_d\Big(-3g_2^2 + 3\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - \frac{16}{3}g_3^2 - \frac{7}{15}g_1^2 + \mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\Big) + Y_dY_u^\dagger Y_u \tag{33}$$

$$\begin{aligned}\beta_{Y_d}^{(2)} = {}& +\frac{4}{5}g_1^2Y_dY_u^\dagger Y_u - 4Y_dY_d^\dagger Y_dY_d^\dagger Y_d - 2Y_dY_u^\dagger Y_uY_d^\dagger Y_d - 2Y_dY_u^\dagger Y_uY_u^\dagger Y_u \\ & + Y_dY_d^\dagger Y_d\Big(-3\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 6g_2^2 - 9\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + \frac{4}{5}g_1^2\Big) - 3Y_dY_u^\dagger Y_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\ & + Y_d\Big(\frac{287}{90}g_1^4 + g_1^2g_2^2 + \frac{15}{2}g_2^4 + \frac{8}{9}g_1^2g_3^2 + 8g_2^2g_3^2 - \frac{16}{9}g_3^4 - \frac{2}{5}\Big(-40g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) \\ & + \frac{6}{5}g_1^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 9\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 3\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 3\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\Big)\end{aligned} \tag{34}$$

$$\beta_{Y_e}^{(1)} = 3Y_eY_e^\dagger Y_e + Y_e\Big(-3g_2^2 + 3\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - \frac{9}{5}g_1^2 + \mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\Big) \tag{35}$$

$$\begin{aligned}\beta_{Y_e}^{(2)} = {}& -4Y_eY_e^\dagger Y_eY_e^\dagger Y_e + Y_eY_e^\dagger Y_e\Big(-3\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 6g_2^2 - 9\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\Big) \\ & + \frac{1}{10}Y_e\Big(-4\Big(-40g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) \\ & + 3\Big(45g_1^4 + 6g_1^2g_2^2 + 25g_2^4 + 4g_1^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 30\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 10\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) \\ & - 10\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\Big)\Big)\end{aligned} \tag{36}$$

$$\beta_{Y_u}^{(1)} = 3Y_uY_u^\dagger Y_u - \frac{1}{15}Y_u\Big(13g_1^2 + 45g_2^2 - 45\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + 80g_3^2\Big) + Y_uY_d^\dagger Y_d \tag{37}$$

$$\begin{aligned}\beta_{Y_u}^{(2)} = {}& +\frac{2}{5}g_1^2Y_uY_u^\dagger Y_u + 6g_2^2Y_uY_u^\dagger Y_u - 2Y_uY_d^\dagger Y_dY_d^\dagger Y_d - 2Y_uY_d^\dagger Y_dY_u^\dagger Y_u \\ & - 4Y_uY_u^\dagger Y_uY_u^\dagger Y_u + Y_uY_d^\dagger Y_d\Big(-3\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + \frac{2}{5}g_1^2 - \mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\Big) - 9Y_uY_u^\dagger Y_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\ & + Y_u\Big(\frac{2743}{450}g_1^4 + g_1^2g_2^2 + \frac{15}{2}g_2^4 + \frac{136}{45}g_1^2g_3^2 + 8g_2^2g_3^2 - \frac{16}{9}g_3^4 + \frac{4}{5}\Big(20g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\ & - 3\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 9\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)\Big)\end{aligned} \tag{38}$$

3.5 Bilinear Superpotential Parameters

$$\beta_\mu^{(1)} = 3\mu\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - \frac{3}{5}\mu\Big(5g_2^2 - 5\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + g_1^2\Big) + \mu\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) \tag{39}$$

$$\begin{aligned}\beta_\mu^{(2)} = {}& \frac{1}{50}\mu\Big(207g_1^4 + 90g_1^2g_2^2 + 375g_2^4 - 20\Big(-40g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 60g_1^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 40g_1^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\ & + 800g_3^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 450\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 300\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 150\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\end{aligned}$$

$$- 450\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big) \tag{40}$$

3.6 Trilinear Soft-Breaking Parameters

$$\begin{aligned}
\beta_{T_d}^{(1)} &= +4Y_dY_d^\dagger T_d + 2Y_dY_u^\dagger T_u + 5T_dY_d^\dagger Y_d + T_dY_u^\dagger Y_u - \frac{7}{15}g_1^2T_d - 3g_2^2T_d - \frac{16}{3}g_3^2T_d \\
&\quad + 3T_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + T_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + Y_d\Big(2\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 6g_2^2M_2 + 6\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + \frac{14}{15}g_1^2M_1 + \frac{32}{3}g_3^2M_3\Big) \qquad (41)\\
\beta_{T_d}^{(2)} &= +\frac{6}{5}g_1^2Y_dY_d^\dagger T_d + 6g_2^2Y_dY_d^\dagger T_d - \frac{8}{5}g_1^2M_1Y_dY_u^\dagger Y_u + \frac{8}{5}g_1^2Y_dY_u^\dagger T_u \\
&\quad + \frac{6}{5}g_1^2T_dY_d^\dagger Y_d + 12g_2^2T_dY_d^\dagger Y_d + \frac{4}{5}g_1^2T_dY_u^\dagger Y_u - 6Y_dY_d^\dagger Y_dY_d^\dagger T_d \\
&\quad - 8Y_dY_d^\dagger T_dY_d^\dagger Y_d - 2Y_dY_u^\dagger Y_uY_d^\dagger T_d - 4Y_dY_u^\dagger Y_uY_u^\dagger T_u - 4Y_dY_u^\dagger T_uY_d^\dagger Y_d \\
&\quad - 4Y_dY_u^\dagger T_uY_u^\dagger Y_u - 6T_dY_d^\dagger Y_dY_d^\dagger Y_d - 4T_dY_u^\dagger Y_uY_d^\dagger Y_d - 2T_dY_u^\dagger Y_uY_u^\dagger Y_u \\
&\quad + \frac{287}{90}g_1^4T_d + g_1^2g_2^2T_d + \frac{15}{2}g_2^4T_d + \frac{8}{9}g_1^2g_3^2T_d + 8g_2^2g_3^2T_d - \frac{16}{9}g_3^4T_d \\
&\quad - 12Y_dY_d^\dagger T_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 15T_dY_d^\dagger Y_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - \frac{2}{5}g_1^2T_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) \\
&\quad + 16g_3^2T_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 4Y_dY_d^\dagger T_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 5T_dY_d^\dagger Y_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) \\
&\quad + \frac{6}{5}g_1^2T_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 6Y_dY_u^\dagger T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 3T_dY_u^\dagger Y_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\
&\quad - \frac{2}{5}Y_dY_d^\dagger Y_d\Big(15\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 30g_2^2M_2 + 45\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + 4g_1^2M_1\Big) - 6Y_dY_u^\dagger Y_u\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) \\
&\quad - 9T_d\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) - 3T_d\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) - 3T_d\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big) \\
&\quad - \frac{2}{45}Y_d\Big(287g_1^4M_1 + 45g_1^2g_2^2M_1 + 40g_1^2g_3^2M_1 + 40g_1^2g_3^2M_3 + 360g_2^2g_3^2M_3 - 160g_3^4M_3 \\
&\quad + 45g_1^2g_2^2M_2 + 675g_2^4M_2 + 360g_2^2g_3^2M_2 - 18\Big(-40g_3^2M_3 + g_1^2M_1\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) \\
&\quad + 54g_1^2M_1\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 18g_1^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 720g_3^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 54g_1^2\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) \\
&\quad + 810\mathrm{Tr}\Big(Y_dY_d^\dagger T_dY_d^\dagger\Big) + 135\mathrm{Tr}\Big(Y_dY_u^\dagger T_uY_d^\dagger\Big) + 270\mathrm{Tr}\Big(Y_eY_e^\dagger T_eY_e^\dagger\Big) + 135\mathrm{Tr}\Big(Y_uY_d^\dagger T_dY_u^\dagger\Big)\Big) \qquad (42)\\
\beta_{T_e}^{(1)} &= +4Y_eY_e^\dagger T_e + 5T_eY_e^\dagger Y_e - \frac{9}{5}g_1^2T_e - 3g_2^2T_e + 3T_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + T_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) \\
&\quad + Y_e\Big(2\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 6g_2^2M_2 + 6\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + \frac{18}{5}g_1^2M_1\Big) \qquad (43)\\
\beta_{T_e}^{(2)} &= +\frac{6}{5}g_1^2Y_eY_e^\dagger T_e + 6g_2^2Y_eY_e^\dagger T_e - \frac{6}{5}g_1^2T_eY_e^\dagger Y_e + 12g_2^2T_eY_e^\dagger Y_e \\
&\quad - 6Y_eY_e^\dagger Y_eY_e^\dagger T_e - 8Y_eY_e^\dagger T_eY_e^\dagger Y_e - 6T_eY_e^\dagger Y_eY_e^\dagger Y_e + \frac{27}{2}g_1^4T_e + \frac{9}{5}g_1^2g_2^2T_e + \frac{15}{2}g_2^4T_e \\
&\quad - 12Y_eY_e^\dagger T_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 15T_eY_e^\dagger Y_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - \frac{2}{5}g_1^2T_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)
\end{aligned}$$

$$
\begin{aligned}
&+16g_3^2T_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-4Y_eY_e^\dagger T_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-5T_eY_e^\dagger Y_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&+\frac{6}{5}g_1^2T_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-6Y_eY_e^\dagger Y_e\Big(2g_2^2M_2+3\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)+\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\Big)-9T_e\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)\\
&-3T_e\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)-3T_e\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\\
&-\frac{2}{5}Y_e\Big(135g_1^4M_1+9g_1^2g_2^2M_1+9g_1^2g_2^2M_2+75g_2^4M_2+\Big(-2g_1^2M_1+80g_3^2M_3\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&+6g_1^2M_1\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)+2g_1^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)-80g_3^2\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)-6g_1^2\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\\
&+90\mathrm{Tr}\Big(Y_dY_d^\dagger T_dY_d^\dagger\Big)+15\mathrm{Tr}\Big(Y_dY_u^\dagger T_uY_d^\dagger\Big)+30\mathrm{Tr}\Big(Y_eY_e^\dagger T_eY_e^\dagger\Big)+15\mathrm{Tr}\Big(Y_uY_d^\dagger T_dY_u^\dagger\Big)\Big)
\end{aligned}
\tag{44}
$$

$$
\begin{aligned}
\beta_{T_u}^{(1)}=&+2Y_uY_d^\dagger T_d+4Y_uY_u^\dagger T_u+T_uY_d^\dagger Y_d+5T_uY_u^\dagger Y_u-\frac{13}{15}g_1^2T_u-3g_2^2T_u-\frac{16}{3}g_3^2T_u\\
&+3T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+Y_u\Big(6g_2^2M_2+6\mathrm{Tr}\Big(Y_u^\dagger T_u\Big)+\frac{26}{15}g_1^2M_1+\frac{32}{3}g_3^2M_3\Big)
\end{aligned}
\tag{45}
$$

$$
\begin{aligned}
\beta_{T_u}^{(2)}=&+\frac{4}{5}g_1^2Y_uY_d^\dagger T_d-\frac{4}{5}g_1^2M_1Y_uY_u^\dagger Y_u-12g_2^2M_2Y_uY_u^\dagger Y_u+\frac{6}{5}g_1^2Y_uY_u^\dagger T_u\\
&+6g_2^2Y_uY_u^\dagger T_u+\frac{2}{5}g_1^2T_uY_d^\dagger Y_d+12g_2^2T_uY_u^\dagger Y_u-4Y_uY_d^\dagger Y_dY_d^\dagger T_d\\
&-2Y_uY_d^\dagger Y_dY_u^\dagger T_u-4Y_uY_d^\dagger T_dY_d^\dagger Y_d-4Y_uY_d^\dagger T_dY_u^\dagger Y_u-6Y_uY_u^\dagger Y_uY_u^\dagger T_u\\
&-8Y_uY_u^\dagger T_uY_u^\dagger Y_u-2T_uY_d^\dagger Y_dY_d^\dagger Y_d-4T_uY_d^\dagger Y_dY_u^\dagger Y_u-6T_uY_u^\dagger Y_uY_u^\dagger Y_u+\frac{2743}{450}g_1^4T_u\\
&+g_1^2g_2^2T_u+\frac{15}{2}g_2^4T_u+\frac{136}{45}g_1^2g_3^2T_u+8g_2^2g_3^2T_u-\frac{16}{9}g_3^4T_u-6Y_uY_d^\dagger T_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&-3T_uY_d^\dagger Y_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-2Y_uY_d^\dagger T_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-T_uY_d^\dagger Y_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&-12Y_uY_u^\dagger T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-15T_uY_u^\dagger Y_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)+\frac{4}{5}g_1^2T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)\\
&+16g_3^2T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-\frac{2}{5}Y_uY_d^\dagger Y_d\Big(15\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)+2g_1^2M_1+5\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\Big)\\
&-18Y_uY_u^\dagger Y_u\mathrm{Tr}\Big(Y_u^\dagger T_u\Big)-3T_u\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)-9T_u\mathrm{Tr}\Big(Y_uY_u^\dagger Y_uY_u^\dagger\Big)\\
&-\frac{2}{225}Y_u\Big(2743g_1^4M_1+225g_1^2g_2^2M_1+680g_1^2g_3^2M_1+680g_1^2g_3^2M_3+1800g_2^2g_3^2M_3-800g_3^4M_3\\
&+225g_1^2g_2^2M_2+3375g_2^4M_2+1800g_2^2g_3^2M_2+180\Big(20g_3^2M_3+g_1^2M_1\Big)\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)\\
&-180\Big(20g_3^2+g_1^2\Big)\mathrm{Tr}\Big(Y_u^\dagger T_u\Big)+675\mathrm{Tr}\Big(Y_dY_u^\dagger T_uY_d^\dagger\Big)+675\mathrm{Tr}\Big(Y_uY_d^\dagger T_dY_u^\dagger\Big)\\
&+4050\mathrm{Tr}\Big(Y_uY_u^\dagger T_uY_u^\dagger\Big)\Big)
\end{aligned}
\tag{46}
$$

3.7 Bilinear Soft-Breaking Parameters

$$
\beta_{B_\mu}^{(1)}=+\frac{6}{5}g_1^2M_1\mu+6g_2^2M_2\mu+B_\mu\Big(-3g_2^2+3\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)+3\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-\frac{3}{5}g_1^2+\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\Big)
$$

$$+ 6\mu\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) + 2\mu\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 6\mu\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) \tag{47}$$

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

3.8 Soft-Breaking Scalar Masses

$$\sigma_{1,1} = \sqrt{\frac{3}{5}}g_1\Big(-2\mathrm{Tr}\Big(m_u^2\Big) - \mathrm{Tr}\Big(m_l^2\Big) - m_{H_d}^2 + m_{H_u}^2 + \mathrm{Tr}\Big(m_d^2\Big) + \mathrm{Tr}\Big(m_e^2\Big) + \mathrm{Tr}\Big(m_q^2\Big)\Big) \tag{49}$$

$$\sigma_{2,11} = \frac{1}{10}g_1^2\Big(2\mathrm{Tr}\Big(m_d^2\Big) + 3\mathrm{Tr}\Big(m_l^2\Big) + 3m_{H_d}^2 + 3m_{H_u}^2 + 6\mathrm{Tr}\Big(m_e^2\Big) + 8\mathrm{Tr}\Big(m_u^2\Big) + \mathrm{Tr}\Big(m_q^2\Big)\Big) \tag{50}$$

$$\begin{aligned}\sigma_{3,1} = &\frac{1}{20}\frac{1}{\sqrt{15}}g_1\Big(-9g_1^2m_{H_d}^2 - 45g_2^2m_{H_d}^2 + 9g_1^2m_{H_u}^2 + 45g_2^2m_{H_u}^2 + 4\Big(20g_3^2 + g_1^2\Big)\mathrm{Tr}\Big(m_d^2\Big) + 36g_1^2\mathrm{Tr}\Big(m_e^2\Big)\\ &- 9g_1^2\mathrm{Tr}\Big(m_l^2\Big) - 45g_2^2\mathrm{Tr}\Big(m_l^2\Big) + g_1^2\mathrm{Tr}\Big(m_q^2\Big) + 45g_2^2\mathrm{Tr}\Big(m_q^2\Big) + 80g_3^2\mathrm{Tr}\Big(m_q^2\Big) - 32g_1^2\mathrm{Tr}\Big(m_u^2\Big)\\ &- 160g_3^2\mathrm{Tr}\Big(m_u^2\Big) + 90m_{H_d}^2\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 30m_{H_d}^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 90m_{H_u}^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 60\mathrm{Tr}\Big(Y_dY_d^\dagger m_d^{2*}\Big)\\ &- 30\mathrm{Tr}\Big(Y_dm_q^{2*}Y_d^\dagger\Big) - 60\mathrm{Tr}\Big(Y_eY_e^\dagger m_e^{2*}\Big) + 30\mathrm{Tr}\Big(Y_em_l^{2*}Y_e^\dagger\Big) + 120\mathrm{Tr}\Big(Y_uY_u^\dagger m_u^{2*}\Big)\\ &- 30\mathrm{Tr}\Big(Y_um_q^{2*}Y_u^\dagger\Big)\Big)\end{aligned} \tag{51}$$

$$\sigma_{2,2} = \frac{1}{2}\Big(3\mathrm{Tr}\Big(m_q^2\Big) + m_{H_d}^2 + m_{H_u}^2 + \mathrm{Tr}\Big(m_l^2\Big)\Big) \tag{52}$$

$$\sigma_{2,3} = \frac{1}{2}\Big(2\mathrm{Tr}\Big(m_q^2\Big) + \mathrm{Tr}\Big(m_d^2\Big) + \mathrm{Tr}\Big(m_u^2\Big)\Big) \tag{53}$$

$$\begin{aligned}\beta_{m_q^2}^{(1)} = &-\frac{2}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 - 6g_2^2\mathbf{1}|M_2|^2 + 2m_{H_d}^2Y_d^\dagger Y_d + 2m_{H_u}^2Y_u^\dagger Y_u + 2T_d^\dagger T_d\\ &+ 2T_u^\dagger T_u + m_q^2Y_d^\dagger Y_d + m_q^2Y_u^\dagger Y_u + 2Y_d^\dagger m_d^2Y_d + Y_d^\dagger Y_dm_q^2 + 2Y_u^\dagger m_u^2Y_u\\ &+ Y_u^\dagger Y_um_q^2 + \frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1}\end{aligned} \tag{54}$$

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

$$
\begin{aligned}
&+\frac{16}{45}g_3^2\Big(15\Big(3g_2^2\Big(2M_3+M_2\Big)-8g_3^2M_3\Big)+g_1^2\Big(2M_3+M_1\Big)\Big)\mathbf{1}M_3^*+\frac{1}{5}g_1^2g_2^2M_1\mathbf{1}M_2^*+16g_2^2g_3^2M_3\mathbf{1}M_2^*\\
&+\frac{4}{5}g_1^2m_{H_d}^2Y_d^\dagger Y_d+\frac{8}{5}g_1^2m_{H_u}^2Y_u^\dagger Y_u\\
&+\frac{1}{225}g_1^2M_1^*\Big(\Big(5\Big(16g_3^2\Big(2M_1+M_3\Big)+9g_2^2\Big(2M_1+M_2\Big)\Big)+597g_1^2M_1\Big)\mathbf{1}\\
&+180\Big(2M_1Y_d^\dagger Y_d-2Y_u^\dagger T_u+4M_1Y_u^\dagger Y_u-Y_d^\dagger T_d\Big)\Big)\\
&-\frac{4}{5}g_1^2M_1T_d^\dagger Y_d+\frac{4}{5}g_1^2T_d^\dagger T_d-\frac{8}{5}g_1^2M_1T_u^\dagger Y_u+\frac{8}{5}g_1^2T_u^\dagger T_u\\
&+\frac{2}{5}g_1^2m_q^2Y_d^\dagger Y_d+\frac{4}{5}g_1^2m_q^2Y_u^\dagger Y_u+\frac{4}{5}g_1^2Y_d^\dagger m_d^2Y_d+\frac{2}{5}g_1^2Y_d^\dagger Y_dm_q^2\\
&+\frac{8}{5}g_1^2Y_u^\dagger m_u^2Y_u+\frac{4}{5}g_1^2Y_u^\dagger Y_um_q^2-8m_{H_d}^2Y_d^\dagger Y_dY_d^\dagger Y_d-4Y_d^\dagger Y_dT_d^\dagger T_d\\
&-4Y_d^\dagger T_dT_d^\dagger Y_d-8m_{H_u}^2Y_u^\dagger Y_uY_u^\dagger Y_u-4Y_u^\dagger Y_uT_u^\dagger T_u-4Y_u^\dagger T_uT_u^\dagger Y_u\\
&-4T_d^\dagger Y_dY_d^\dagger T_d-4T_d^\dagger T_dY_d^\dagger Y_d-4T_u^\dagger Y_uY_u^\dagger T_u-4T_u^\dagger T_uY_u^\dagger Y_u\\
&-2m_q^2Y_d^\dagger Y_dY_d^\dagger Y_d-2m_q^2Y_u^\dagger Y_uY_u^\dagger Y_u-4Y_d^\dagger m_d^2Y_dY_d^\dagger Y_d-4Y_d^\dagger Y_dm_q^2Y_d^\dagger Y_d\\
&-4Y_d^\dagger Y_dY_d^\dagger m_d^2Y_d-2Y_d^\dagger Y_dY_d^\dagger Y_dm_q^2-4Y_u^\dagger m_u^2Y_uY_u^\dagger Y_u-4Y_u^\dagger Y_um_q^2Y_u^\dagger Y_u\\
&-4Y_u^\dagger Y_uY_u^\dagger m_u^2Y_u-2Y_u^\dagger Y_uY_u^\dagger Y_um_q^2+6g_2^4\mathbf{1}\sigma_{2,2}+\frac{32}{3}g_3^4\mathbf{1}\sigma_{2,3}+\frac{2}{15}g_1^2\mathbf{1}\sigma_{2,11}+4\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{3,1}\\
&-12m_{H_d}^2Y_d^\dagger Y_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-6T_d^\dagger T_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-3m_q^2Y_d^\dagger Y_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&-6Y_d^\dagger m_d^2Y_d\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-3Y_d^\dagger Y_dm_q^2\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-4m_{H_d}^2Y_d^\dagger Y_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&-2T_d^\dagger T_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-m_q^2Y_d^\dagger Y_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-2Y_d^\dagger m_d^2Y_d\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&-Y_d^\dagger Y_dm_q^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-12m_{H_u}^2Y_u^\dagger Y_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-6T_u^\dagger T_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)\\
&-3m_q^2Y_u^\dagger Y_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-6Y_u^\dagger m_u^2Y_u\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)-3Y_u^\dagger Y_um_q^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big)\\
&-6T_d^\dagger Y_d\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)-2T_d^\dagger Y_d\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)-6T_u^\dagger Y_u\mathrm{Tr}\Big(Y_u^\dagger T_u\Big)\\
&-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^2Y_dY_d^\dagger\Big)-2Y_d^\dagger Y_d\mathrm{Tr}\Big(m_e^2Y_eY_e^\dagger\Big)-2Y_d^\dagger Y_d\mathrm{Tr}\Big(m_l^2Y_e^\dagger Y_e\Big)\\
&-6Y_d^\dagger Y_d\mathrm{Tr}\Big(m_q^2Y_d^\dagger Y_d\Big)-6Y_u^\dagger Y_u\mathrm{Tr}\Big(m_q^2Y_u^\dagger Y_u\Big)-6Y_u^\dagger Y_u\mathrm{Tr}\Big(m_u^2Y_uY_u^\dagger\Big)
\end{aligned}
\tag{55}
$$

$$
\begin{aligned}
\beta_{m_l^2}^{(1)}=&-\frac{6}{5}g_1^2\mathbf{1}|M_1|^2-6g_2^2\mathbf{1}|M_2|^2+2m_{H_d}^2Y_e^\dagger Y_e+2T_e^\dagger T_e+m_l^2Y_e^\dagger Y_e+2Y_e^\dagger m_e^2Y_e\\
&+Y_e^\dagger Y_em_l^2-\sqrt{\frac{3}{5}}g_1\mathbf{1}\sigma_{1,1}
\end{aligned}
\tag{56}
$$

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

$$
\begin{aligned}
&+\frac{3}{25}g_1^2M_1^*\Big(-20Y_e^\dagger T_e+3\Big(5g_2^2\Big(2M_1+M_2\Big)+69g_1^2M_1\Big)\mathbf{1}+40M_1Y_e^\dagger Y_e\Big)-\frac{12}{5}g_1^2M_1T_e^\dagger Y_e\\
&+\frac{12}{5}g_1^2T_e^\dagger T_e+\frac{6}{5}g_1^2m_l^2Y_e^\dagger Y_e+\frac{12}{5}g_1^2Y_e^\dagger m_e^2Y_e+\frac{6}{5}g_1^2Y_e^\dagger Y_em_l^2\\
&-8m_{H_d}^2Y_e^\dagger Y_eY_e^\dagger Y_e-4Y_e^\dagger Y_eT_e^\dagger T_e-4Y_e^\dagger T_eT_e^\dagger Y_e-4T_e^\dagger Y_eY_e^\dagger T_e\\
&-4T_e^\dagger T_eY_e^\dagger Y_e-2m_l^2Y_e^\dagger Y_eY_e^\dagger Y_e-4Y_e^\dagger m_e^2Y_eY_e^\dagger Y_e-4Y_e^\dagger Y_em_l^2Y_e^\dagger Y_e\\
&-4Y_e^\dagger Y_eY_e^\dagger m_e^2Y_e-2Y_e^\dagger Y_eY_e^\dagger Y_em_l^2+6g_2^4\mathbf{1}\sigma_{2,2}+\frac{6}{5}g_1^2\mathbf{1}\sigma_{2,11}-4\sqrt{\frac{3}{5}}g_1\mathbf{1}\sigma_{3,1}\\
&-12m_{H_d}^2Y_e^\dagger Y_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-6T_e^\dagger T_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-3m_l^2Y_e^\dagger Y_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&-6Y_e^\dagger m_e^2Y_e\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-3Y_e^\dagger Y_em_l^2\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)-4m_{H_d}^2Y_e^\dagger Y_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&-2T_e^\dagger T_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-m_l^2Y_e^\dagger Y_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-2Y_e^\dagger m_e^2Y_e\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&-Y_e^\dagger Y_em_l^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-6T_e^\dagger Y_e\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)-2T_e^\dagger Y_e\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\\
&-6Y_e^\dagger T_e\mathrm{Tr}\Big(T_d^*Y_d^T\Big)-6Y_e^\dagger Y_e\mathrm{Tr}\Big(T_d^*T_d^T\Big)-2Y_e^\dagger T_e\mathrm{Tr}\Big(T_e^*Y_e^T\Big)\\
&-2Y_e^\dagger Y_e\mathrm{Tr}\Big(T_e^*T_e^T\Big)-6Y_e^\dagger Y_e\mathrm{Tr}\Big(m_d^2Y_dY_d^\dagger\Big)-2Y_e^\dagger Y_e\mathrm{Tr}\Big(m_e^2Y_eY_e^\dagger\Big)\\
&-2Y_e^\dagger Y_e\mathrm{Tr}\Big(m_l^2Y_e^\dagger Y_e\Big)-6Y_e^\dagger Y_e\mathrm{Tr}\Big(m_q^2Y_d^\dagger Y_d\Big)
\end{aligned}
\tag{57}
$$

$$
\begin{aligned}
\beta^{(1)}_{m_{H_d}^2}=&-\frac{6}{5}g_1^2|M_1|^2-6g_2^2|M_2|^2-\sqrt{\frac{3}{5}}g_1\sigma_{1,1}+6m_{H_d}^2\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)+2m_{H_d}^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)+6\mathrm{Tr}\Big(T_d^*T_d^T\Big)\\
&+2\mathrm{Tr}\Big(T_e^*T_e^T\Big)+6\mathrm{Tr}\Big(m_d^2Y_dY_d^\dagger\Big)+2\mathrm{Tr}\Big(m_e^2Y_eY_e^\dagger\Big)+2\mathrm{Tr}\Big(m_l^2Y_e^\dagger Y_e\Big)+6\mathrm{Tr}\Big(m_q^2Y_d^\dagger Y_d\Big)
\end{aligned}
\tag{58}
$$

$$
\begin{aligned}
\beta^{(2)}_{m_{H_d}^2}=&\frac{1}{25}\Big(15g_2^2\Big(3g_1^2\Big(2M_2+M_1\Big)+55g_2^2M_2\Big)M_2^*\\
&+g_1^2M_1^*\Big(621g_1^2M_1+90g_2^2M_1+45g_2^2M_2-40M_1\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)+120M_1\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)+20\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)\\
&-60\mathrm{Tr}\Big(Y_e^\dagger T_e\Big)\Big)\\
&+10\Big(15g_2^4\sigma_{2,2}+3g_1^2\sigma_{2,11}-2\sqrt{15}g_1\sigma_{3,1}+\Big(160g_3^2|M_3|^2-2g_1^2m_{H_d}^2+80g_3^2m_{H_d}^2\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&+6g_1^2m_{H_d}^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)-80g_3^2M_3^*\mathrm{Tr}\Big(Y_d^\dagger T_d\Big)+2g_1^2M_1\mathrm{Tr}\Big(T_d^*Y_d^T\Big)-80g_3^2M_3\mathrm{Tr}\Big(T_d^*Y_d^T\Big)\\
&-2g_1^2\mathrm{Tr}\Big(T_d^*T_d^T\Big)+80g_3^2\mathrm{Tr}\Big(T_d^*T_d^T\Big)-6g_1^2M_1\mathrm{Tr}\Big(T_e^*Y_e^T\Big)+6g_1^2\mathrm{Tr}\Big(T_e^*T_e^T\Big)\\
&-2g_1^2\mathrm{Tr}\Big(m_d^2Y_dY_d^\dagger\Big)+80g_3^2\mathrm{Tr}\Big(m_d^2Y_dY_d^\dagger\Big)+6g_1^2\mathrm{Tr}\Big(m_e^2Y_eY_e^\dagger\Big)+6g_1^2\mathrm{Tr}\Big(m_l^2Y_e^\dagger Y_e\Big)\\
&-2g_1^2\mathrm{Tr}\Big(m_q^2Y_d^\dagger Y_d\Big)+80g_3^2\mathrm{Tr}\Big(m_q^2Y_d^\dagger Y_d\Big)-90m_{H_d}^2\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big)-90\mathrm{Tr}\Big(Y_dY_d^\dagger T_dT_d^\dagger\Big)\\
&-15m_{H_d}^2\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)-15m_{H_u}^2\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big)-15\mathrm{Tr}\Big(Y_dY_u^\dagger T_uT_d^\dagger\Big)\\
&-90\mathrm{Tr}\Big(Y_dT_d^\dagger T_dY_d^\dagger\Big)-15\mathrm{Tr}\Big(Y_dT_u^\dagger T_uY_d^\dagger\Big)-30m_{H_d}^2\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)-30\mathrm{Tr}\Big(Y_eY_e^\dagger T_eT_e^\dagger\Big)
\end{aligned}
$$

$$
\begin{aligned}
&- 30\mathrm{Tr}\Big(Y_e T_e^\dagger T_e Y_e^\dagger\Big) - 15\mathrm{Tr}\Big(Y_u Y_d^\dagger T_d T_u^\dagger\Big) - 15\mathrm{Tr}\Big(Y_u T_d^\dagger T_d Y_u^\dagger\Big) - 90\mathrm{Tr}\Big(m_d^2 Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) \\
&- 15\mathrm{Tr}\Big(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 30\mathrm{Tr}\Big(m_e^2 Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) - 30\mathrm{Tr}\Big(m_l^2 Y_e^\dagger Y_e Y_e^\dagger Y_e\Big) - 90\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d Y_d^\dagger Y_d\Big) \\
&- 15\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\Big) - 15\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\Big) - 15\mathrm{Tr}\Big(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\Big)\Big)\Big) \qquad (59)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(1)}_{m_{H_u}^2} &= -\frac{6}{5}g_1^2|M_1|^2 - 6g_2^2|M_2|^2 + \sqrt{\frac{3}{5}}g_1\sigma_{1,1} + 6m_{H_u}^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 6\mathrm{Tr}\Big(T_u^* T_u^T\Big) + 6\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) \\
&+ 6\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big) \qquad (60)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(2)}_{m_{H_u}^2} &= +\frac{3}{5}g_2^2\Big(3g_1^2\Big(2M_2 + M_1\Big) + 55g_2^2 M_2\Big)M_2^* + 6g_2^4\sigma_{2,2} + \frac{6}{5}g_1^2\sigma_{2,11} + 4\sqrt{\frac{3}{5}}g_1\sigma_{3,1} + \frac{8}{5}g_1^2 m_{H_u}^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ 32g_3^2 m_{H_u}^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 64g_3^2|M_3|^2\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) \\
&+ \frac{1}{25}g_1^2 M_1^*\Big(-40\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) + 45g_2^2 M_2 + 621g_1^2 M_1 + 80M_1\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 90g_2^2 M_1\Big) \\
&- 32g_3^2 M_3^*\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - \frac{8}{5}g_1^2 M_1\mathrm{Tr}\Big(T_u^* Y_u^T\Big) - 32g_3^2 M_3\mathrm{Tr}\Big(T_u^* Y_u^T\Big) + \frac{8}{5}g_1^2\mathrm{Tr}\Big(T_u^* T_u^T\Big) \\
&+ 32g_3^2\mathrm{Tr}\Big(T_u^* T_u^T\Big) + \frac{8}{5}g_1^2\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) + 32g_3^2\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u\Big) + \frac{8}{5}g_1^2\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big) \\
&+ 32g_3^2\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger\Big) - 6m_{H_d}^2\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 6m_{H_u}^2\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) \\
&- 6\mathrm{Tr}\Big(Y_d Y_u^\dagger T_u T_d^\dagger\Big) - 6\mathrm{Tr}\Big(Y_d T_u^\dagger T_u Y_d^\dagger\Big) - 6\mathrm{Tr}\Big(Y_u Y_d^\dagger T_d T_u^\dagger\Big) - 36m_{H_u}^2\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) \\
&- 36\mathrm{Tr}\Big(Y_u Y_u^\dagger T_u T_u^\dagger\Big) - 6\mathrm{Tr}\Big(Y_u T_d^\dagger T_d Y_u^\dagger\Big) - 36\mathrm{Tr}\Big(Y_u T_u^\dagger T_u Y_u^\dagger\Big) \\
&- 6\mathrm{Tr}\Big(m_d^2 Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) - 6\mathrm{Tr}\Big(m_q^2 Y_d^\dagger Y_d Y_u^\dagger Y_u\Big) - 6\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u Y_d^\dagger Y_d\Big) \\
&- 36\mathrm{Tr}\Big(m_q^2 Y_u^\dagger Y_u Y_u^\dagger Y_u\Big) - 6\mathrm{Tr}\Big(m_u^2 Y_u Y_d^\dagger Y_d Y_u^\dagger\Big) - 36\mathrm{Tr}\Big(m_u^2 Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) \qquad (61)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(1)}_{m_d^2} &= -\frac{8}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 + 4m_{H_d}^2 Y_d Y_d^\dagger + 4T_d T_d^\dagger + 2m_d^2 Y_d Y_d^\dagger + 4Y_d m_q^2 Y_d^\dagger \\
&+ 2Y_d Y_d^\dagger m_d^2 + 2\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1} \qquad (62)
\end{aligned}
$$

$$
\begin{aligned}
\beta^{(2)}_{m_d^2} &= +\frac{64}{45}g_3^2\Big(-30g_3^2 M_3 + g_1^2\Big(2M_3 + M_1\Big)\Big)\mathbf{1}M_3^* + \frac{4}{5}g_1^2 m_{H_d}^2 Y_d Y_d^\dagger + 12g_2^2 m_{H_d}^2 Y_d Y_d^\dagger \\
&+ 24g_2^2|M_2|^2 Y_d Y_d^\dagger - \frac{4}{5}g_1^2 M_1 Y_d T_d^\dagger - 12g_2^2 M_2 Y_d T_d^\dagger \\
&+ \frac{4}{225}g_1^2 M_1^*\Big(2\Big(303g_1^2 M_1 + 40g_3^2\Big(2M_1 + M_3\Big)\Big)\mathbf{1} - 45T_d Y_d^\dagger + 90M_1 Y_d Y_d^\dagger\Big) - 12g_2^2 M_2^* T_d Y_d^\dagger \\
&+ \frac{4}{5}g_1^2 T_d T_d^\dagger + 12g_2^2 T_d T_d^\dagger + \frac{2}{5}g_1^2 m_d^2 Y_d Y_d^\dagger + 6g_2^2 m_d^2 Y_d Y_d^\dagger \\
&+ \frac{4}{5}g_1^2 Y_d m_q^2 Y_d^\dagger + 12g_2^2 Y_d m_q^2 Y_d^\dagger + \frac{2}{5}g_1^2 Y_d Y_d^\dagger m_d^2 + 6g_2^2 Y_d Y_d^\dagger m_d^2 \\
&- 8m_{H_d}^2 Y_d Y_d^\dagger Y_d Y_d^\dagger - 4Y_d Y_d^\dagger T_d T_d^\dagger - 4m_{H_d}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger \\
&- 4m_{H_u}^2 Y_d Y_u^\dagger Y_u Y_d^\dagger - 4Y_d Y_u^\dagger T_u T_d^\dagger - 4Y_d T_d^\dagger T_d Y_d^\dagger - 4Y_d T_u^\dagger T_u Y_d^\dagger
\end{aligned}
$$

$$
\begin{aligned}
&- 4T_dY_d^\dagger Y_dT_d^\dagger - 4T_dY_u^\dagger Y_uT_d^\dagger - 4T_dT_d^\dagger Y_dY_d^\dagger - 4T_dT_u^\dagger Y_uY_d^\dagger \\
&- 2m_d^2Y_dY_d^\dagger Y_dY_d^\dagger - 2m_d^2Y_dY_u^\dagger Y_uY_d^\dagger - 4Y_dm_q^2Y_d^\dagger Y_dY_d^\dagger - 4Y_dm_q^2Y_u^\dagger Y_uY_d^\dagger \\
&- 4Y_dY_d^\dagger m_d^2Y_dY_d^\dagger - 4Y_dY_d^\dagger Y_dm_q^2Y_d^\dagger - 2Y_dY_d^\dagger Y_dY_d^\dagger m_d^2 - 4Y_dY_u^\dagger m_u^2Y_uY_d^\dagger \\
&- 4Y_dY_u^\dagger Y_um_q^2Y_d^\dagger - 2Y_dY_u^\dagger Y_uY_d^\dagger m_d^2 + \frac{32}{3}g_3^4\mathbf{1}\sigma_{2,3} + \frac{8}{15}g_1^2\mathbf{1}\sigma_{2,11} + 8\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{3,1} \\
&- 24m_{H_d}^2Y_dY_d^\dagger \mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 12T_dT_d^\dagger \mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 6m_d^2Y_dY_d^\dagger \mathrm{Tr}\Big(Y_dY_d^\dagger\Big) \\
&- 12Y_dm_q^2Y_d^\dagger \mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 6Y_dY_d^\dagger m_d^2\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 8m_{H_d}^2Y_dY_d^\dagger \mathrm{Tr}\Big(Y_eY_e^\dagger\Big) \\
&- 4T_dT_d^\dagger \mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 2m_d^2Y_dY_d^\dagger \mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 4Y_dm_q^2Y_d^\dagger \mathrm{Tr}\Big(Y_eY_e^\dagger\Big) \\
&- 2Y_dY_d^\dagger m_d^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) - 12Y_dT_d^\dagger \mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 4Y_dT_d^\dagger \mathrm{Tr}\Big(Y_e^\dagger T_e\Big) \\
&- 12T_dY_d^\dagger \mathrm{Tr}\Big(T_d^*Y_d^T\Big) - 12Y_dY_d^\dagger \mathrm{Tr}\Big(T_d^*T_d^T\Big) - 4T_dY_d^\dagger \mathrm{Tr}\Big(T_e^*Y_e^T\Big) \\
&- 4Y_dY_d^\dagger \mathrm{Tr}\Big(T_e^*T_e^T\Big) - 12Y_dY_d^\dagger \mathrm{Tr}\Big(m_d^2Y_dY_d^\dagger\Big) - 4Y_dY_d^\dagger \mathrm{Tr}\Big(m_e^2Y_eY_e^\dagger\Big) \\
&- 4Y_dY_d^\dagger \mathrm{Tr}\Big(m_l^2Y_e^\dagger Y_e\Big) - 12Y_dY_d^\dagger \mathrm{Tr}\Big(m_q^2Y_d^\dagger Y_d\Big)
\end{aligned} \tag{63}
$$

$$
\begin{aligned}
\beta_{m_u^2}^{(1)} =& -\frac{32}{15}g_1^2\mathbf{1}|M_1|^2 - \frac{32}{3}g_3^2\mathbf{1}|M_3|^2 + 4m_{H_u}^2Y_uY_u^\dagger + 4T_uT_u^\dagger + 2m_u^2Y_uY_u^\dagger + 4Y_um_q^2Y_u^\dagger \\
&+ 2Y_uY_u^\dagger m_u^2 - 4\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{1,1}
\end{aligned} \tag{64}
$$

$$
\begin{aligned}
\beta_{m_u^2}^{(2)} =& -\frac{128}{45}g_3^2\Big(15g_3^2M_3 - 2g_1^2\Big(2M_3 + M_1\Big)\Big)\mathbf{1}M_3^* - \frac{4}{5}g_1^2m_{H_u}^2Y_uY_u^\dagger + 12g_2^2m_{H_u}^2Y_uY_u^\dagger \\
&+ 24g_2^2|M_2|^2Y_uY_u^\dagger + \frac{4}{5}g_1^2M_1Y_uT_u^\dagger - 12g_2^2M_2Y_uT_u^\dagger - 12g_2^2M_2^*T_uY_u^\dagger \\
&+ \frac{4}{225}g_1^2M_1^*\Big(45\Big(-2M_1Y_uY_u^\dagger + T_uY_u^\dagger\Big) + 8\Big(321g_1^2M_1 + 40g_3^2\Big(2M_1 + M_3\Big)\Big)\mathbf{1}\Big) - \frac{4}{5}g_1^2T_uT_u^\dagger \\
&+ 12g_2^2T_uT_u^\dagger - \frac{2}{5}g_1^2m_u^2Y_uY_u^\dagger + 6g_2^2m_u^2Y_uY_u^\dagger - \frac{4}{5}g_1^2Y_um_q^2Y_u^\dagger \\
&+ 12g_2^2Y_um_q^2Y_u^\dagger - \frac{2}{5}g_1^2Y_uY_u^\dagger m_u^2 + 6g_2^2Y_uY_u^\dagger m_u^2 - 4m_{H_d}^2Y_uY_d^\dagger Y_dY_u^\dagger \\
&- 4m_{H_u}^2Y_uY_d^\dagger Y_dY_u^\dagger - 4Y_uY_d^\dagger T_dT_u^\dagger - 8m_{H_u}^2Y_uY_u^\dagger Y_uY_u^\dagger - 4Y_uY_u^\dagger T_uT_u^\dagger \\
&- 4Y_uT_d^\dagger T_dY_u^\dagger - 4Y_uT_u^\dagger T_uY_u^\dagger - 4T_uY_d^\dagger Y_dT_u^\dagger - 4T_uY_u^\dagger Y_uT_u^\dagger \\
&- 4T_uT_d^\dagger Y_dY_u^\dagger - 4T_uT_u^\dagger Y_uY_u^\dagger - 2m_u^2Y_uY_d^\dagger Y_dY_u^\dagger - 2m_u^2Y_uY_u^\dagger Y_uY_u^\dagger \\
&- 4Y_um_q^2Y_d^\dagger Y_dY_u^\dagger - 4Y_um_q^2Y_u^\dagger Y_uY_u^\dagger - 4Y_uY_d^\dagger m_d^2Y_dY_u^\dagger \\
&- 4Y_uY_d^\dagger Y_dm_q^2Y_u^\dagger - 2Y_uY_d^\dagger Y_dY_u^\dagger m_u^2 - 4Y_uY_u^\dagger m_u^2Y_uY_u^\dagger - 4Y_uY_u^\dagger Y_um_q^2Y_u^\dagger \\
&- 2Y_uY_u^\dagger Y_uY_u^\dagger m_u^2 + \frac{32}{3}g_3^4\mathbf{1}\sigma_{2,3} + \frac{32}{15}g_1^2\mathbf{1}\sigma_{2,11} - 16\frac{1}{\sqrt{15}}g_1\mathbf{1}\sigma_{3,1} - 24m_{H_u}^2Y_uY_u^\dagger \mathrm{Tr}\Big(Y_uY_u^\dagger\Big) \\
&- 12T_uT_u^\dagger \mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 6m_u^2Y_uY_u^\dagger \mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 12Y_um_q^2Y_u^\dagger \mathrm{Tr}\Big(Y_uY_u^\dagger\Big)
\end{aligned}
$$

$$
\begin{aligned}
&- 6Y_uY_u^\dagger m_u^2\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) - 12Y_uT_u^\dagger\mathrm{Tr}\Big(Y_u^\dagger T_u\Big) - 12T_uY_u^\dagger\mathrm{Tr}\Big(T_u^*Y_u^T\Big)\\
&- 12Y_uY_u^\dagger\mathrm{Tr}\Big(T_u^*T_u^T\Big) - 12Y_uY_u^\dagger\mathrm{Tr}\Big(m_q^2Y_u^\dagger Y_u\Big) - 12Y_uY_u^\dagger\mathrm{Tr}\Big(m_u^2Y_uY_u^\dagger\Big) \qquad (65)\\
\beta_{m_e^2}^{(1)} &= -\frac{24}{5}g_1^2\mathbf{1}|M_1|^2 + 2\Big(2m_{H_d}^2Y_eY_e^\dagger + 2T_eT_e^\dagger + 2Y_em_l^2Y_e^\dagger + m_e^2Y_eY_e^\dagger + Y_eY_e^\dagger m_e^2\Big)\\
&+ 2\sqrt{\frac{3}{5}}g_1\mathbf{1}\sigma_{1,1} \qquad (66)\\
\beta_{m_e^2}^{(2)} &= \frac{2}{25}\Big(6g_1^2M_1^*\Big(234g_1^2M_1\mathbf{1} + 5\Big(-2M_1Y_eY_e^\dagger + T_eY_e^\dagger\Big)\Big) + 20g_1\mathbf{1}\Big(3g_1\sigma_{2,11} + \sqrt{15}\sigma_{3,1}\Big)\\
&- 5\Big(30g_2^2M_2^*T_eY_e^\dagger + 6g_1^2T_eT_e^\dagger - 30g_2^2T_eT_e^\dagger + 3g_1^2m_e^2Y_eY_e^\dagger\\
&- 15g_2^2m_e^2Y_eY_e^\dagger + 6g_1^2Y_em_l^2Y_e^\dagger - 30g_2^2Y_em_l^2Y_e^\dagger + 3g_1^2Y_eY_e^\dagger m_e^2\\
&- 15g_2^2Y_eY_e^\dagger m_e^2 + 20m_{H_d}^2Y_eY_e^\dagger Y_eY_e^\dagger + 10Y_eY_e^\dagger T_eT_e^\dagger + 10Y_eT_e^\dagger T_eY_e^\dagger\\
&+ 10T_eY_e^\dagger Y_eT_e^\dagger + 10T_eT_e^\dagger Y_eY_e^\dagger + 5m_e^2Y_eY_e^\dagger Y_eY_e^\dagger + 10Y_em_l^2Y_e^\dagger Y_eY_e^\dagger\\
&+ 10Y_eY_e^\dagger m_e^2Y_eY_e^\dagger + 10Y_eY_e^\dagger Y_em_l^2Y_e^\dagger + 5Y_eY_e^\dagger Y_eY_e^\dagger m_e^2 + 30T_eT_e^\dagger\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\\
&+ 15m_e^2Y_eY_e^\dagger\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 30Y_em_l^2Y_e^\dagger\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 15Y_eY_e^\dagger m_e^2\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)
\end{aligned}
$$

$$
\begin{aligned}
&+ 10T_eT_e^\dagger\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 5m_e^2Y_eY_e^\dagger\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 10Y_em_l^2Y_e^\dagger\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&+ 5Y_eY_e^\dagger m_e^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + Y_eT_e^\dagger\Big(10\mathrm{Tr}\Big(Y_e^\dagger T_e\Big) + 30g_2^2M_2 + 30\mathrm{Tr}\Big(Y_d^\dagger T_d\Big) - 6g_1^2M_1\Big)\\
&+ 30T_eY_e^\dagger\mathrm{Tr}\Big(T_d^*Y_d^T\Big) + 10T_eY_e^\dagger\mathrm{Tr}\Big(T_e^*Y_e^T\Big)\\
&+ 2Y_eY_e^\dagger\Big(3g_1^2m_{H_d}^2 - 15g_2^2m_{H_d}^2 - 30g_2^2|M_2|^2 + 30m_{H_d}^2\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) + 10m_{H_d}^2\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 15\mathrm{Tr}\Big(T_d^*T_d^T\Big)\\
&+ 5\mathrm{Tr}\Big(T_e^*T_e^T\Big) + 15\mathrm{Tr}\Big(m_d^2Y_dY_d^\dagger\Big) + 5\mathrm{Tr}\Big(m_e^2Y_eY_e^\dagger\Big) + 5\mathrm{Tr}\Big(m_l^2Y_e^\dagger Y_e\Big) + 15\mathrm{Tr}\Big(m_q^2Y_d^\dagger Y_d\Big)\Big)\Big)\Big) \qquad (67)
\end{aligned}
$$

3.9 Vacuum expectation values

$$
\begin{aligned}
\beta_{v_d}^{(1)} &= \frac{1}{20}v_d\Big(-20\mathrm{Tr}\Big(Y_eY_e^\dagger\Big) + 3\Big(5g_2^2 + g_1^2\Big)\Big(1 + \mathrm{Xi}\Big) - 60\mathrm{Tr}\Big(Y_dY_d^\dagger\Big)\Big) \qquad (68)\\
\beta_{v_d}^{(2)} &= \frac{1}{400}v_d\Big(-414g_1^4 - 180g_1^2g_2^2 - 1200g_2^4 - 9g_1^4\mathrm{Xi} - 90g_1^2g_2^2\mathrm{Xi} + 875g_2^4\mathrm{Xi} + 9g_1^4\mathrm{Xi}^2 + 90g_1^2g_2^2\mathrm{Xi}^2\\
&- 225g_2^4\mathrm{Xi}^2 - 40\Big(5\Big(32g_3^2 + 9g_2^2\mathrm{Xi}\Big) + g_1^2\Big(9\mathrm{Xi} - 4\Big)\Big)\mathrm{Tr}\Big(Y_dY_d^\dagger\Big) - 120\Big(5g_2^2\mathrm{Xi} + g_1^2\Big(4 + \mathrm{Xi}\Big)\Big)\mathrm{Tr}\Big(Y_eY_e^\dagger\Big)\\
&+ 3600\mathrm{Tr}\Big(Y_dY_d^\dagger Y_dY_d^\dagger\Big) + 1200\mathrm{Tr}\Big(Y_dY_u^\dagger Y_uY_d^\dagger\Big) + 1200\mathrm{Tr}\Big(Y_eY_e^\dagger Y_eY_e^\dagger\Big)\Big) \qquad (69)\\
\beta_{v_u}^{(1)} &= \frac{3}{20}v_u\Big(-20\mathrm{Tr}\Big(Y_uY_u^\dagger\Big) + \Big(5g_2^2 + g_1^2\Big)\Big(1 + \mathrm{Xi}\Big)\Big) \qquad (70)\\
\beta_{v_u}^{(2)} &= \frac{1}{400}v_u\Big(-414g_1^4 - 180g_1^2g_2^2 - 1200g_2^4 - 9g_1^4\mathrm{Xi} - 90g_1^2g_2^2\mathrm{Xi} + 875g_2^4\mathrm{Xi} + 9g_1^4\mathrm{Xi}^2 + 90g_1^2g_2^2\mathrm{Xi}^2
\end{aligned}
$$

$$- 225 g_2^4 \mathrm{Xi}^2 - 40\Big(5\Big(32 g_3^2 + 9 g_2^2 \mathrm{Xi}\Big) + g_1^2\Big(9\mathrm{Xi} + 8\Big)\Big)\mathrm{Tr}\Big(Y_u Y_u^\dagger\Big) + 1200\mathrm{Tr}\Big(Y_d Y_u^\dagger Y_u Y_d^\dagger\Big) + 3600\mathrm{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big)\Big) \tag{71}$$

4 Field Rotations

4.1 Rotations in gauge sector for eigenstates 'EWSB'

$$\begin{pmatrix} B_\rho \\ W_{3\rho} \end{pmatrix} = Z^{\gamma Z} \begin{pmatrix} \gamma_\rho \\ Z_\rho \end{pmatrix} \tag{72}$$

$$\begin{pmatrix} W_{1\rho} \\ W_{2\rho} \end{pmatrix} = Z^{W} \begin{pmatrix} W_\rho^- \\ W_\rho^- \end{pmatrix} \tag{73}$$

$$\begin{pmatrix} \lambda_{\tilde{W},1} \\ \lambda_{\tilde{W},2} \\ \lambda_{\tilde{W},3} \end{pmatrix} = Z^{\tilde{W}} \begin{pmatrix} \tilde{W}^- \\ \tilde{W}^+ \\ \tilde{W}^0 \end{pmatrix} \tag{74}$$

$$\tag{75}$$

The mixing matrices are parametrized by

$$Z^{\gamma Z} = \begin{pmatrix} \cos\Theta_W & -\sin\Theta_W \\ \sin\Theta_W & \cos\Theta_W \end{pmatrix} \tag{76}$$

$$Z^{W} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} \end{pmatrix} \tag{77}$$

$$Z^{\tilde{W}} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -i\frac{1}{\sqrt{2}} & i\frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{78}$$

$$\tag{79}$$

4.2 Rotations in Mass sector for eigenstates 'EWSB'

4.2.1 Mass Matrices for Scalars

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

$$m_h^2 = \begin{pmatrix} \frac{1}{8}\Big(g_1^2 + g_2^2\Big)\Big(3v_d^2 - v_u^2\Big) + m_{H_d}^2 + |\mu|^2 & -\frac{1}{4}\Big(g_1^2 + g_2^2\Big)v_d v_u - \Re\Big(B_\mu\Big) \\ -\frac{1}{4}\Big(g_1^2 + g_2^2\Big)v_d v_u - \Re\Big(B_\mu\Big) & -\frac{1}{8}\Big(g_1^2 + g_2^2\Big)\Big(-3v_u^2 + v_d^2\Big) + m_{H_u}^2 + |\mu|^2 \end{pmatrix} \tag{80}$$

This matrix is diagonalized by Z^H:

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \tag{81}$$

with

$$\phi_d = \sum_j Z_{j1}^H h_j\,, \qquad \phi_u = \sum_j Z_{j2}^H h_j \tag{82}$$

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

$$m_{A^0}^2 = \begin{pmatrix} \frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(-v_u^2+v_d^2\Big)+m_{H_d}^2+|\mu|^2 & \Re\Big(B_\mu\Big) \\ \Re\Big(B_\mu\Big) & -\frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(-v_u^2+v_d^2\Big)+m_{H_u}^2+|\mu|^2 \end{pmatrix} + \xi_Z m^2(Z) \tag{83}$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} \frac{1}{4}v_d^2\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 & -\frac{1}{4}v_d v_u\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 \\ -\frac{1}{4}v_d v_u\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 & \frac{1}{4}v_u^2\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2 \end{pmatrix} \tag{84}$$

This matrix is diagonalized by Z^A:

$$Z^A m_{A^0}^2 Z^{A,\dagger} = m_{2,A^0}^{dia} \tag{85}$$

with

$$\sigma_d = \sum_j Z_{j1}^A A_j^0\,, \qquad \sigma_u = \sum_j Z_{j2}^A A_j^0 \tag{86}$$

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

$$m_{H^-}^2 = \begin{pmatrix} m_{H_d^- H_d^{-,*}} & \frac{1}{4}g_2^2 v_d v_u + B_\mu^* \\ \frac{1}{4}g_2^2 v_d v_u + B_\mu & m_{H_u^{+,*}H_u^+} \end{pmatrix} + \xi_{W^-} m^2(W^-) \tag{87}$$

$$m_{H_d^- H_d^{-,*}} = \frac{1}{8}\Big(g_1^2\Big(-v_u^2+v_d^2\Big)+g_2^2\Big(v_d^2+v_u^2\Big)\Big)+m_{H_d}^2+|\mu|^2 \tag{88}$$

$$m_{H_u^{+,*}H_u^+} = \frac{1}{8}\Big(g_1^2\Big(-v_d^2+v_u^2\Big)+g_2^2\Big(v_d^2+v_u^2\Big)\Big)+m_{H_u}^2+|\mu|^2 \tag{89}$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4}g_2^2 v_d^2 & -\frac{1}{4}g_2^2 v_d v_u \\ -\frac{1}{4}g_2^2 v_d v_u & \frac{1}{4}g_2^2 v_u^2 \end{pmatrix} \tag{90}$$

This matrix is diagonalized by Z^+:

$$Z^+ m_{H^-}^2 Z^{+,\dagger} = m_{2,H^-}^{dia} \tag{91}$$

with

$$H_d^- = \sum_j Z_{j1}^+ H_j^-\,, \qquad H_u^+ = \sum_j Z_{j2}^+ H_j^+ \tag{92}$$

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

$$m^2_{\tilde{d}} = \begin{pmatrix} m_{\tilde{d}_L \tilde{d}^*_L} & \frac{1}{\sqrt{2}}\text{Delta}\Big(v_d T_d^\dagger - v_u \mu Y_d^\dagger\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\text{Delta}\delta_{\alpha_2\beta_1}\Big(v_d T_d - v_u Y_d \mu^*\Big) & m_{\tilde{d}_R \tilde{d}^*_R} \end{pmatrix} \tag{93}$$

$$m_{\tilde{d}_L \tilde{d}^*_L} = -\frac{1}{24}\Big(3g_2^2 + g_1^2\Big)\mathbf{1}\Big(-v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\mathbf{1}\Big(2m_q^2 + v_d^2 Y_d Y^*_{d,o_1o_1}\Big)\delta_{\alpha_1\beta_1} \tag{94}$$

$$m_{\tilde{d}_R \tilde{d}^*_R} = \frac{1}{12}g_1^2\mathbf{1}\Big(-v_d^2 + v_u^2\Big)\delta_{\alpha_2\beta_2} + \frac{1}{2}\mathbf{1}\delta_{\alpha_2\beta_2}\Big(2m_d^2 + v_d^2 Y_d^\dagger Y_{d,o_2o_2}\Big) \tag{95}$$

This matrix is diagonalized by Z^D:

$$Z^D m^2_{\tilde{d}} Z^{D,\dagger} = m^{dia}_{2,\tilde{d}} \tag{96}$$

with

$$\tilde{d}_{L,i\alpha} = \sum_j Z^{D,*}_{ji}\tilde{d}_{j\text{ft}1\alpha}\,, \qquad \tilde{d}_{R,i\alpha} = \sum_j Z^{D,*}_{ji}\tilde{d}_{j\text{ft}1\alpha} \tag{97}$$

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

$$m^2_{\tilde{u}} = \begin{pmatrix} m_{\tilde{u}_L \tilde{u}^*_L} & \frac{1}{\sqrt{2}}\text{Delta}\Big(-v_d \mu Y_u^\dagger + v_u T_u^\dagger\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\text{Delta}\delta_{\alpha_2\beta_1}\Big(-v_d Y_u \mu^* + v_u T_u\Big) & m_{\tilde{u}_R \tilde{u}^*_R} \end{pmatrix} \tag{98}$$

$$m_{\tilde{u}_L \tilde{u}^*_L} = -\frac{1}{24}\Big(-3g_2^2 + g_1^2\Big)\mathbf{1}\Big(-v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\mathbf{1}\Big(2m_q^2 + v_u^2 Y_u Y^*_{u,o_1o_1}\Big)\delta_{\alpha_1\beta_1} \tag{99}$$

$$m_{\tilde{u}_R \tilde{u}^*_R} = \frac{1}{2}\mathbf{1}\delta_{\alpha_2\beta_2}\Big(2m_u^2 + v_u^2 Y_u^\dagger Y_{u,o_2o_2}\Big) + \frac{1}{6}g_1^2\mathbf{1}\Big(-v_u^2 + v_d^2\Big)\delta_{\alpha_2\beta_2} \tag{100}$$

This matrix is diagonalized by Z^U:

$$Z^U m^2_{\tilde{u}} Z^{U,\dagger} = m^{dia}_{2,\tilde{u}} \tag{101}$$

with

$$\tilde{u}_{L,i\alpha} = \sum_j Z^{U,*}_{ji}\tilde{u}_{j\text{ft}1\alpha}\,, \qquad \tilde{u}_{R,i\alpha} = \sum_j Z^{U,*}_{ji}\tilde{u}_{j\text{ft}1\alpha} \tag{102}$$

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

$$m^2_{\tilde{e}} = \begin{pmatrix} m_{\tilde{e}_L \tilde{e}^*_L} & \frac{1}{\sqrt{2}}\text{Delta}\Big(v_d T_e^\dagger - v_u \mu Y_e^\dagger\Big) \\ \frac{1}{\sqrt{2}}\text{Delta}\Big(v_d T_e - v_u Y_e \mu^*\Big) & m_{\tilde{e}_R \tilde{e}^*_R} \end{pmatrix} \tag{103}$$

$$m_{\tilde{e}_L \tilde{e}^*_L} = \frac{1}{2}\mathbf{1}\Big(2m_l^2 + v_d^2 Y_e Y^*_{e,o_1o_1}\Big) + \frac{1}{8}\Big(-g_2^2 + g_1^2\Big)\mathbf{1}\Big(-v_u^2 + v_d^2\Big) \tag{104}$$

$$m_{\tilde{e}_R \tilde{e}_R^*} = \frac{1}{2}\mathbf{1}\Big(2m_e^2 + v_d^2 Y_e^\dagger Y_{e,o_2 o_2}\Big) + \frac{1}{4}g_1^2\mathbf{1}\Big(-v_d^2 + v_u^2\Big) \tag{105}$$

This matrix is diagonalized by Z^E:

$$Z^E m_{\tilde{e}}^2 Z^{E,\dagger} = m_{2,\tilde{e}}^{dia} \tag{106}$$

with

$$\tilde{e}_{L,i} = \sum_j Z_{ji}^{E,*}\tilde{e}_{j\mathrm{ft}1}\,, \qquad \tilde{e}_{R,i} = \sum_j Z_{ji}^{E,*}\tilde{e}_{j\mathrm{ft}1} \tag{107}$$

4.2.2 Mass Matrices for Fermions

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

$$m_{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & -\frac{1}{2}g_1 v_d & \frac{1}{2}g_1 v_u \\ 0 & M_2 & \frac{1}{2}g_2 v_d & -\frac{1}{2}g_2 v_u \\ -\frac{1}{2}g_1 v_d & \frac{1}{2}g_2 v_d & 0 & -\mu \\ \frac{1}{2}g_1 v_u & -\frac{1}{2}g_2 v_u & -\mu & 0 \end{pmatrix} \tag{108}$$

This matrix is diagonalized by N:

$$N^* m_{\tilde{\chi}^0} N^\dagger = m_{\tilde{\chi}^0}^{dia} \tag{109}$$

with

$$\lambda_{\tilde{B}} = \sum_j N_{j1}^*\lambda_j^0\,, \qquad \tilde{W}^0 = \sum_j N_{j2}^*\lambda_j^0\,, \qquad \tilde{H}_d^0 = \sum_j N_{j3}^*\lambda_j^0 \tag{110}$$

$$\tilde{H}_u^0 = \sum_j N_{j4}^*\lambda_j^0 \tag{111}$$

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

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

This matrix is diagonalized by U and V

$$U^* m_{\tilde{\chi}^-} V^\dagger = m_{\tilde{\chi}^-}^{dia} \tag{113}$$

with

$$\tilde{W}^- = \sum_{t_2} U_{j1}^*\lambda_j^-\,, \qquad \tilde{H}_d^- = \sum_{t_2} U_{j2}^*\lambda_j^- \tag{114}$$

$$\tilde{W}^+ = \sum_{t_2} V_{1j}^*\lambda_j^+\,, \qquad \tilde{H}_u^+ = \sum_{t_2} V_{2j}^*\lambda_j^+ \tag{115}$$

5 Vacuum Expectation Values

$$H_d^0 = \frac{1}{\sqrt{2}}\phi_d + \frac{1}{\sqrt{2}}v_d + i\frac{1}{\sqrt{2}}\sigma_d \tag{116}$$

$$H_u^0 = \frac{1}{\sqrt{2}}\phi_u + \frac{1}{\sqrt{2}}v_u + i\frac{1}{\sqrt{2}}\sigma_u \tag{117}$$

6 Tadpole Equations

$$\frac{\partial V}{\partial \phi_d} = -\frac{1}{2}v_u\Big(B_\mu + B_\mu^*\Big) + \frac{1}{8}\Big(g_1^2 + g_2^2\Big)v_d\Big(-v_u + v_d\Big)\Big(v_d + v_u\Big) + v_d\Big(m_{H_d}^2 + |\mu|^2\Big) \tag{118}$$

$$\frac{\partial V}{\partial \phi_u} = \frac{1}{8}\Big(g_1^2 + g_2^2\Big)v_u\Big(-v_d^2 + v_u^2\Big) - v_d\Re\Big(B_\mu\Big) + v_u\Big(m_{H_u}^2 + |\mu|^2\Big) \tag{119}$$

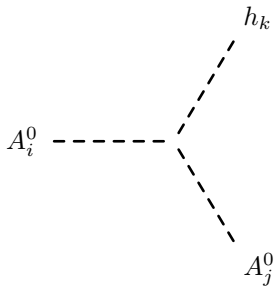
7 Particle content for eigenstates 'EWSB'

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

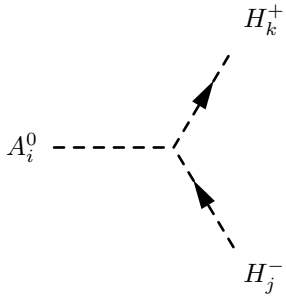
η^γ	Ghost	real	1
η^Z	Ghost	real	1
η^-	Ghost	complex	1
η^+	Ghost	complex	1

8 Interactions for eigenstates 'EWSB'

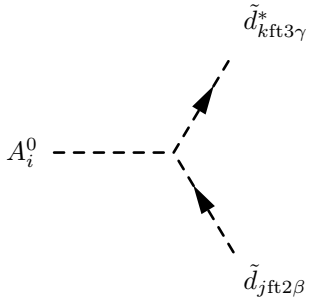
8.1 Three Scalar-Interaction



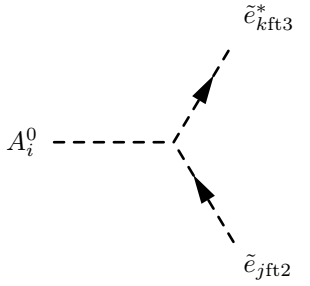
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\Big)\Big(v_d Z_{k1}^H - v_u Z_{k2}^H\Big) \tag{120}$$



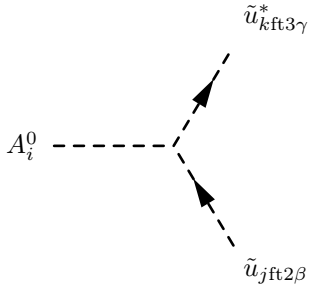
$$\frac{1}{4}g_2^2\Big(v_d Z_{i2}^A + v_u Z_{i1}^A\Big)\Big(-Z_{j1}^+ Z_{k2}^+ + Z_{j2}^+ Z_{k1}^+\Big) \tag{121}$$



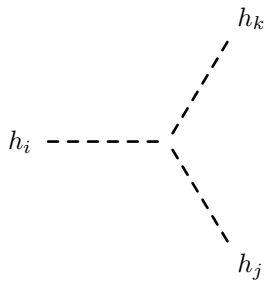
$$-\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\delta_{jk}\Big(\mu Y^*_{d,jk}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)Z^A_{i2}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+T^*_{d,jk}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)Z^A_{i1}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)-\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}$$
(122)



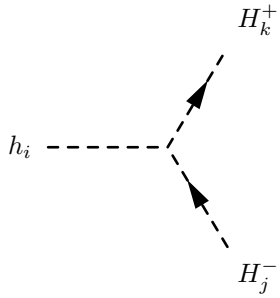
$$-\frac{1}{\sqrt{2}}\delta_{jk}\Big(\mu Y^*_{e,jk}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)Z^A_{i2}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+T^*_{e,jk}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)Z^A_{i1}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)-\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft}$$
(123)



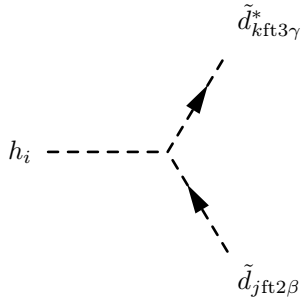
$$-\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\delta_{jk}\Big(\mu Y^*_{u,jk}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)Z^A_{i1}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)-\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\mu^* Y_{u,kj}Z^A_{i1}+Z^A_{i2}T_{u,kj}\Big)\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)$$
(124)



$$\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i2}^H\Big(Z_{j1}^H\Big(v_dZ_{k2}^H+v_uZ_{k1}^H\Big)+Z_{j2}^H\Big(-3v_uZ_{k2}^H+v_dZ_{k1}^H\Big)\Big)$$
$$+Z_{i1}^H\Big(Z_{j1}^H\Big(-3v_dZ_{k1}^H+v_uZ_{k2}^H\Big)+Z_{j2}^H\Big(v_dZ_{k2}^H+v_uZ_{k1}^H\Big)\Big)\Big) \tag{125}$$

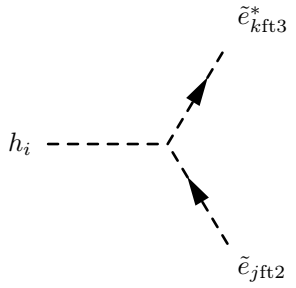


$$\frac{i}{4}\Big(-Z_{i1}^H\Big(Z_{j1}^+\Big(\Big(g_1^2+g_2^2\Big)v_dZ_{k1}^++g_2^2v_uZ_{k2}^+\Big)+Z_{j2}^+\Big(\Big(-g_1^2+g_2^2\Big)v_dZ_{k2}^++g_2^2v_uZ_{k1}^+\Big)\Big)$$
$$+Z_{i2}^H\Big(Z_{j1}^+\Big(\Big(-g_2^2+g_1^2\Big)v_uZ_{k1}^+-g_2^2v_dZ_{k2}^+\Big)-Z_{j2}^+\Big(\Big(g_1^2+g_2^2\Big)v_uZ_{k2}^++g_2^2v_dZ_{k1}^+\Big)\Big)\Big) \tag{126}$$

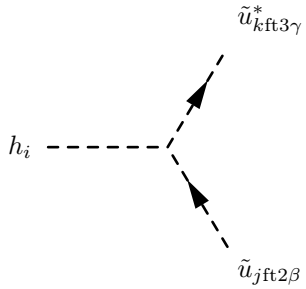


$$\frac{i}{12}\delta_{\beta\gamma}\delta_{jk}\Big(-2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(-3\sqrt{2}\mu Y^*_{d,jk}Z^H_{i2}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+3\sqrt{2}T^*_{d,jk}Z^H_{i1}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+\Big(g_1^2v_uZ^H_{i2}-v_d\Big(-6Y^*_{d,j}$$

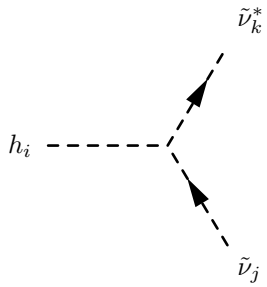
$$+ \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(-Z_{i2}^{H}\Big(\Big(3g_2^2+g_1^2\Big)v_u\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)-6\sqrt{2}\mu^{*}Y_{d,kj}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)$$
$$+ Z_{i1}^{H}\Big(-6\sqrt{2}T_{d,kj}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+v_d\Big(-12Y_{d,jk}^{*}Y_{d,jj}+3g_2^2+g_1^2\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big)\Big) \tag{127}$$



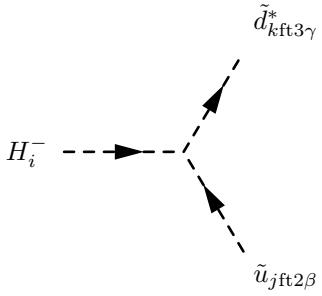
$$-\frac{i}{4}\delta_{jk}\Big(2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\Big(g_1^2v_uZ_{i2}^{H}-v_d\Big(-2Y_{e,jj}^{*}Y_{e,kj}+g_1^2\Big)Z_{i1}^{H}\Big)\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)-\sqrt{2}\mu Y_{e,jk}^{*}Z_{i2}^{H}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+\sqrt{2}T_{}$$
$$+ \mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(Z_{i2}^{H}\Big(-2\sqrt{2}\mu^{*}Y_{e,kj}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+\Big(-g_1^2+g_2^2\Big)v_u\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)$$
$$+ Z_{i1}^{H}\Big(2\sqrt{2}T_{e,kj}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+v_d\Big(4Y_{e,jk}^{*}Y_{e,jj}-g_2^2+g_1^2\Big)\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big)\Big) \tag{128}$$



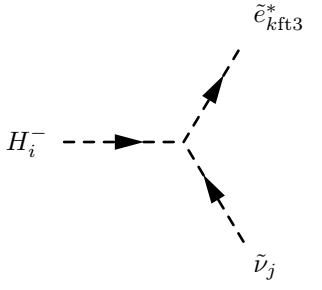
$$\frac{i}{12}\delta_{\beta\gamma}\delta_{jk}\Big(2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(-2\Big(g_1^2v_dZ_{i1}^{H}-v_u\Big(-3Y_{u,jj}^{*}Y_{u,kj}+g_1^2\Big)Z_{i2}^{H}\Big)\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+3\sqrt{2}\mu Y_{u,jk}^{*}Z_{i1}^{H}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)$$
$$+ \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(Z_{i1}^{H}\Big(\Big(-3g_2^2+g_1^2\Big)v_d\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+6\sqrt{2}\mu^{*}Y_{u,kj}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)$$
$$- Z_{i2}^{H}\Big(6\sqrt{2}T_{u,kj}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+v_u\Big(12Y_{u,jk}^{*}Y_{u,jj}-3g_2^2+g_1^2\Big)\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big)\Big) \tag{129}$$



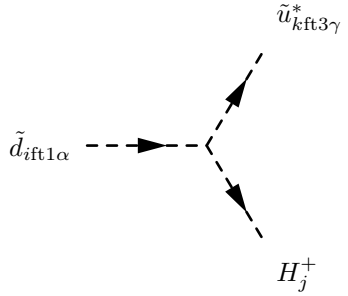
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\delta_{jk}\Big(v_d Z_{i1}^H - v_u Z_{i2}^H\Big) \tag{130}$$



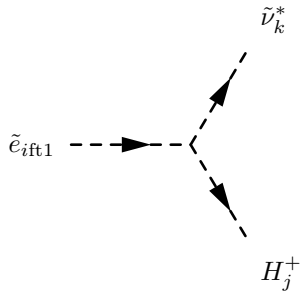
$$\begin{aligned}
&-\frac{i}{4}\delta_{\beta\gamma}\delta_{jk}\Big(-2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(2\mu Y^*_{u,jk}Z^+_{i1}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+2T^*_{u,jk}Z^+_{i2}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+\sqrt{2}Y^*_{u,jj}Y_{d,kj}\Big(v_d Z^+_{i2}+v_u Z^+_{i1}\Big)\mathrm{Z}\\
&+\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(Z^+_{i2}\Big(-4\mu^* Y_{d,kj}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+\sqrt{2}v_u\Big(-2Y^*_{u,jk}Y_{u,jj}+g_2^2\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\\
&+Z^+_{i1}\Big(-4T_{d,kj}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+\sqrt{2}v_d\Big(-2Y^*_{d,jk}Y_{d,jj}+g_2^2\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big)\Big)
\end{aligned} \tag{131}$$



$$-\frac{i}{4}\delta_{jk}\Big(Z^+_{i1}\Big(-4T_{e,kj}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+\sqrt{2}v_d\Big(-2Y^*_{e,jk}Y_{e,jj}+g_2^2\Big)\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)+Z^+_{i2}\Big(-4\mu^* Y_{e,kj}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+\sqrt{2}g_2^2 v_u \tag{132}$$

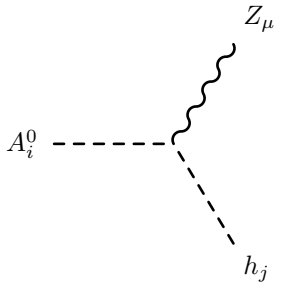


$$-\frac{i}{4}\delta_{\alpha\gamma}\delta_{ik}\Big(-2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\Big(2\mu Y^*_{d,ik}Z^+_{j2}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+2T^*_{d,ik}Z^+_{j1}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+\sqrt{2}Y^*_{d,ii}Y_{u,ki}\Big(v_dZ^+_{j2}+v_uZ^+_{j1}\Big)\mathrm{ZU}$$
$$+\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(Z^+_{j1}\Big(-4\mu^*Y_{u,ki}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+\sqrt{2}v_d\Big(-2Y^*_{d,ik}Y_{d,ii}+g_2^2\Big)\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)$$
$$+Z^+_{j2}\Big(-4T_{u,ki}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+\sqrt{2}v_u\Big(-2Y^*_{u,ik}Y_{u,ii}+g_2^2\Big)\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big)\Big) \tag{133}$$

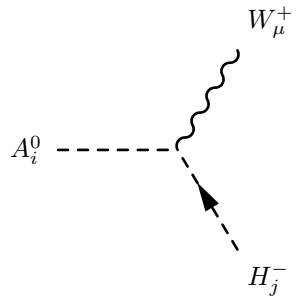


$$-\frac{i}{4}\delta_{ik}\Big(-4\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\Big(\mu Y^*_{e,ik}Z^+_{j2}+T^*_{e,ik}Z^+_{j1}\Big)+\sqrt{2}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(g_2^2v_uZ^+_{j2}+v_d\Big(-2Y^*_{e,ik}Y_{e,ii}+g_2^2\Big)Z^+_{j1}\Big)\Big) \tag{134}$$

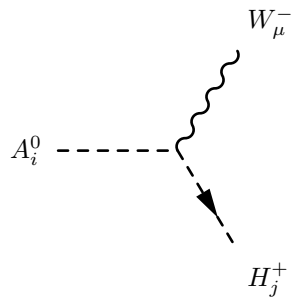
8.2 Two Scalar-One Vector Boson-Interaction



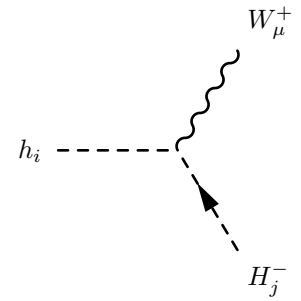
$$\frac{1}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big(Z^A_{i1}Z^H_{j1} - Z^A_{i2}Z^H_{j2}\Big)\Big(- p_\mu^{h_j} + p_\mu^{A^0_i}\Big) \tag{135}$$



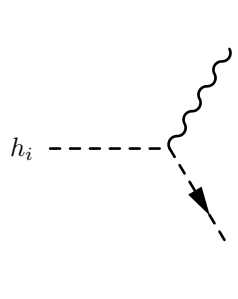
$$\frac{1}{2}g_2\Big(Z^A_{i1}Z^+_{j1} + Z^A_{i2}Z^+_{j2}\Big)\Big(- p_\mu^{H^-_j} + p_\mu^{A^0_i}\Big) \tag{136}$$



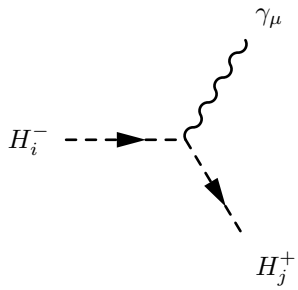
$$\frac{1}{2}g_2\Big(Z^A_{i1}Z^+_{j1} + Z^A_{i2}Z^+_{j2}\Big)\Big(- p_\mu^{H^+_j} + p_\mu^{A^0_i}\Big) \tag{137}$$



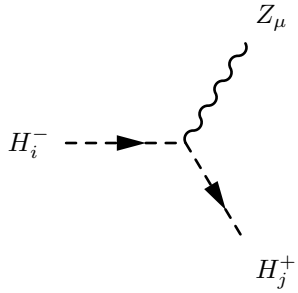
$$\frac{i}{2}g_2\Big(Z^H_{i1}Z^+_{j1} - Z^H_{i2}Z^+_{j2}\Big)\Big(- p_\mu^{H^-_j} + p_\mu^{h_i}\Big) \tag{138}$$



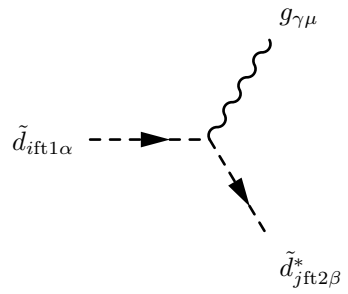
$$-\frac{i}{2}g_2\Big(Z_{i1}^H Z_{j1}^+ - Z_{i2}^H Z_{j2}^+\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{h_i}\Big) \tag{139}$$



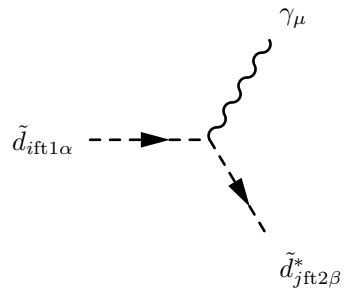
$$\frac{i}{2}\delta_{ij}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{140}$$



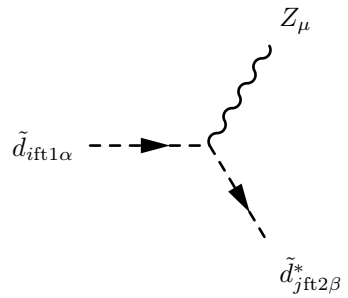
$$\frac{i}{2}\delta_{ij}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{141}$$



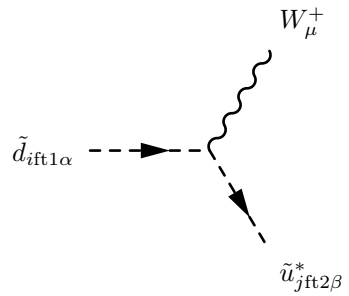
$$-\frac{i}{2}g_3\delta_{\mathrm{ft}1\mathrm{ft}2}\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\Big(-p_{\mu}^{\tilde{d}^{*}_{j\mathrm{ft}2\beta}}+p_{\mu}^{\tilde{d}_{i\mathrm{ft}1\alpha}}\Big) \tag{142}$$



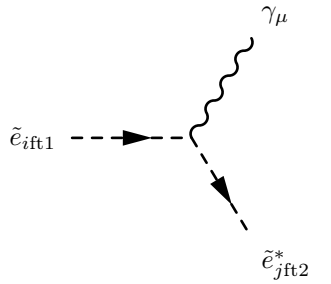
$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(-2g_1\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt}1\Big)\Big(\mathrm{ft}1,2\Big)\Big)\cos\Theta_W\mathrm{ZD}\Big(\mathrm{gt}2\Big)\Big(\mathrm{ft}2,2\Big)+\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt}1\Big)\Big(\mathrm{ft}1,1\Big)\Big)\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\mathrm{ZD}\Big(\mathrm{gt}2\Big) \tag{143}$$



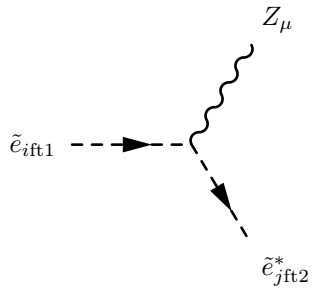
$$\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(-2g_1\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt}1\Big)\Big(\mathrm{ft}1,2\Big)\Big)\sin\Theta_W\mathrm{ZD}\Big(\mathrm{gt}2\Big)\Big(\mathrm{ft}2,2\Big)+\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt}1\Big)\Big(\mathrm{ft}1,1\Big)\Big)\Big(3g_2\cos\Theta_W+g_1\sin\Theta_W\Big)\mathrm{ZD}\Big(\mathrm{gt}2\Big)\Big(\mathrm{ft}2,1 \tag{144}$$



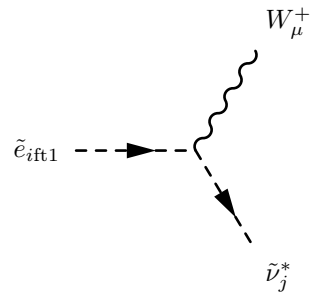
$$-i\frac{1}{\sqrt{2}}g_2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(-p_\mu^{\tilde{u}^*_{j\mathrm{ft}2\beta}}+p_\mu^{\tilde{d}_{i\mathrm{ft}1\alpha}}\Big) \tag{145}$$



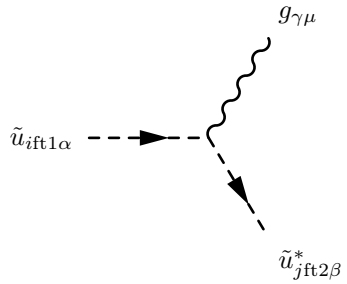
$$\frac{i}{2}\delta_{ij}\Big(2g_1\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\cos\Theta_W\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)+\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(-p \tag{146}$$



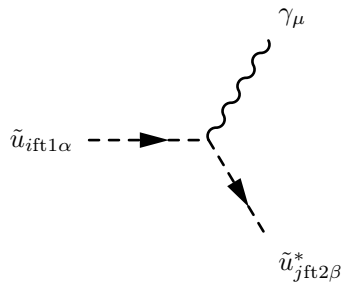
$$\frac{i}{2}\delta_{ij}\Big(-2g_1\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\sin\Theta_W\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)+\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big) \tag{147}$$



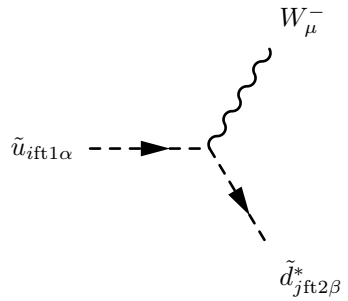
$$-i\frac{1}{\sqrt{2}}g_2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt}1\Big)\Big(\mathrm{ft}1,1\Big)\Big)\delta_{ij}\Big(-p_\mu^{\tilde{\nu}_j^*}+p_\mu^{\tilde{e}_{i\mathrm{ft}1}}\Big) \tag{148}$$



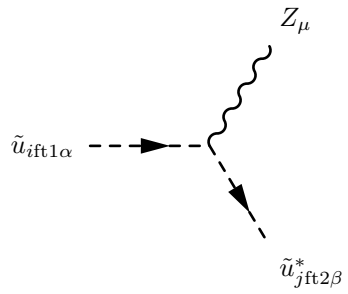
$$-\frac{i}{2}g_3\delta_{\mathrm{ft}1\mathrm{ft}2}\delta_{ij}\lambda_{\beta,\alpha}^{\gamma}\Big(-p_\mu^{\tilde{u}_{j\mathrm{ft}2\beta}^*}+p_\mu^{\tilde{u}_{i\mathrm{ft}1\alpha}}\Big) \tag{149}$$



$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(4g_1\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt}1\Big)\Big(\mathrm{ft}1,2\Big)\Big)\cos\Theta_W\mathrm{ZU}\Big(\mathrm{gt}2\Big)\Big(\mathrm{ft}2,2\Big)+\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt}1\Big)\Big(\mathrm{ft}1,1\Big)\Big)\Big(3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\mathrm{ZU}\Big(\mathrm{gt}2\Big)\Big(\mathrm{ft}2,1 \tag{150}$$

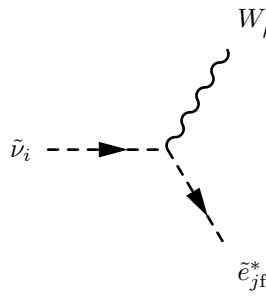


$$-i\frac{1}{\sqrt{2}}g_2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(-p_\mu^{\tilde{d}^*_{j\mathrm{ft}2\beta}}+p_\mu^{\tilde{u}_{i\mathrm{ft}1\alpha}}\Big) \tag{151}$$

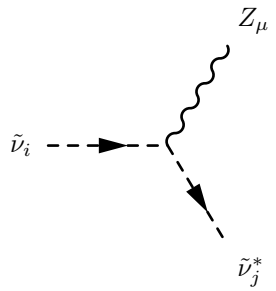


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(-4g_1\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\sin\Theta_W\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)+\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(3g_2\cos\Theta_W-g_1\sin\Theta_W\Big)\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2}$$

(152)

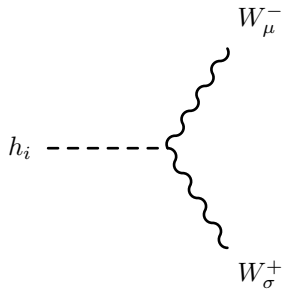


$$-i\frac{1}{\sqrt{2}}g_2\delta_{ij}\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(-p_\mu^{\tilde{e}^*_{j\mathrm{ft}2}}+p_\mu^{\tilde{\nu}_i}\Big) \tag{153}$$

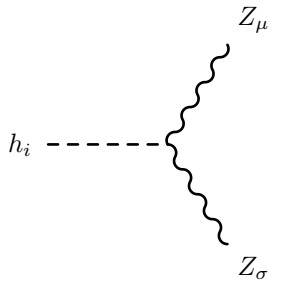


$$-\frac{i}{2}\delta_{ij}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(-p_\mu^{\tilde{\nu}_j^*}+p_\mu^{\tilde{\nu}_i}\Big) \tag{154}$$

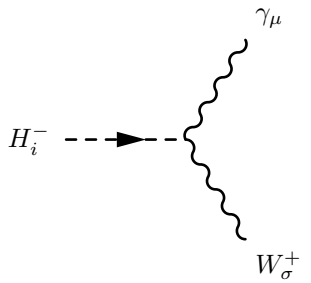
8.3 One Scalar-Two Vector Boson-Interaction



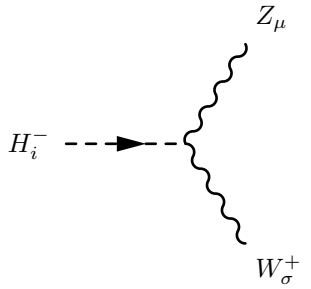
$$\frac{i}{2}g_2^2\Big(v_dZ_{i1}^H+v_uZ_{i2}^H\Big)\Big(g_{\sigma\mu}\Big) \tag{155}$$



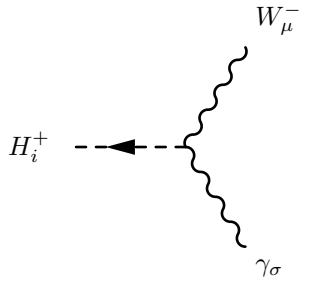
$$\frac{i}{2}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2\Big(v_dZ_{i1}^H+v_uZ_{i2}^H\Big)\Big(g_{\sigma\mu}\Big) \tag{156}$$



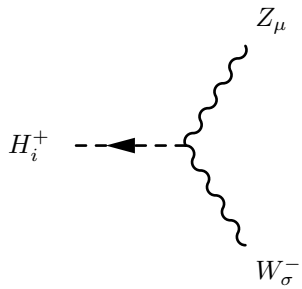
$$-\frac{i}{2}g_1 g_2 \cos\Theta_W \Big(v_d Z_{i1}^+ - v_u Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{157}$$



$$\frac{i}{2}g_1 g_2 \sin\Theta_W \Big(v_d Z_{i1}^+ - v_u Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{158}$$

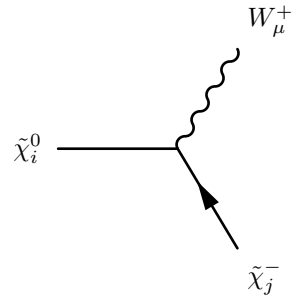


$$-\frac{i}{2}g_1 g_2 \cos\Theta_W \Big(v_d Z_{i1}^+ - v_u Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{159}$$



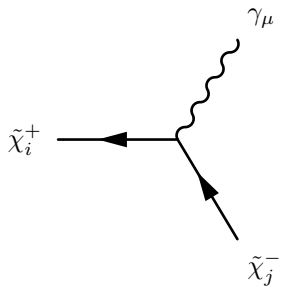
$$\frac{i}{2} g_1 g_2 \sin\Theta_W \Big(v_d Z_{i1}^+ - v_u Z_{i2}^+ \Big) \Big(g_{\sigma\mu} \Big) \tag{160}$$

8.4 Two Fermion-One Vector Boson-Interaction



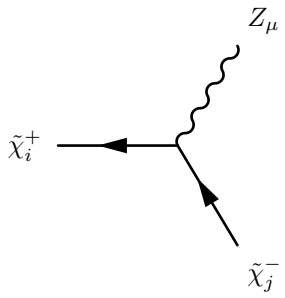
$$-\frac{i}{2} g_2 \Big(2 U_{j1}^* N_{i2} + \sqrt{2} U_{j2}^* N_{i3} \Big) \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{161}$$

$$+ \; -\frac{i}{2} g_2 \Big(2 N_{i2}^* V_{j1} - \sqrt{2} N_{i4}^* V_{j2} \Big) \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \Big) \tag{162}$$



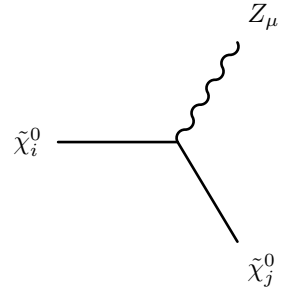
$$\frac{i}{2} \Big(2 g_2 U_{j1}^* \sin\Theta_W U_{i1} + U_{j2}^* \Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W \Big) U_{i2} \Big) \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{163}$$

$$+ \; \frac{i}{2} \Big(2 g_2 V_{i1}^* \sin\Theta_W V_{j1} + V_{i2}^* \Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W \Big) V_{j2} \Big) \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \Big) \tag{164}$$



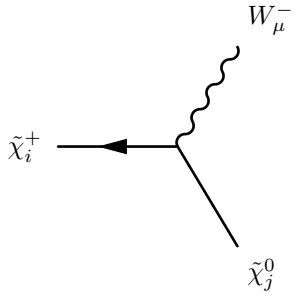
$$\frac{i}{2}\Big(2g_2 U^*_{j1}\cos\Theta_W U_{i1} + U^*_{j2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)U_{i2}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{165}$$

$$+\ \frac{i}{2}\Big(2g_2 V^*_{i1}\cos\Theta_W V_{j1} + V^*_{i2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)V_{j2}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{166}$$



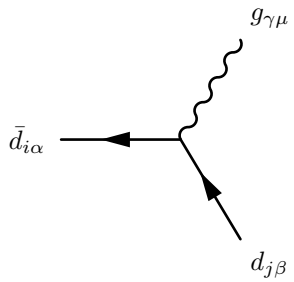
$$-\frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(N^*_{j3}N_{i3} - N^*_{j4}N_{i4}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{167}$$

$$+\ \frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(N^*_{i3}N_{j3} - N^*_{i4}N_{j4}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{168}$$



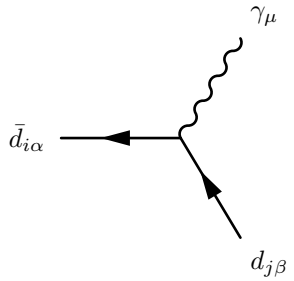
$$-\frac{i}{2}g_2\Big(2N^*_{j2}U_{i1} + \sqrt{2}N^*_{j3}U_{i2}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{169}$$

$$+\ -\frac{i}{2}g_2\Big(2V^*_{i1}N_{j2} - \sqrt{2}V^*_{i2}N_{j4}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{170}$$



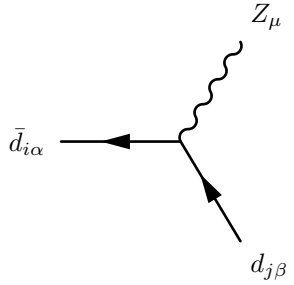
$$- \frac{i}{2} g_3 \delta_{ij} \lambda^{\gamma}_{\alpha,\beta} \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{171}$$

$$+ \; - \frac{i}{2} g_3 \delta_{ij} \lambda^{\gamma}_{\alpha,\beta} \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \Big) \tag{172}$$



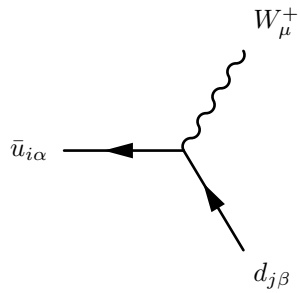
$$- \frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \Big(- 3 g_2 \sin\Theta_W + g_1 \cos\Theta_W \Big) \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{173}$$

$$+ \; \frac{i}{3} g_1 \cos\Theta_W \delta_{\alpha\beta} \delta_{ij} \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \Big) \tag{174}$$

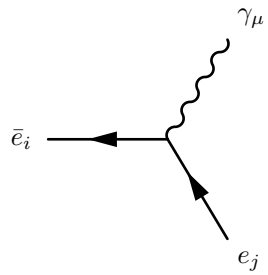


$$\frac{i}{6} \delta_{\alpha\beta} \delta_{ij} \Big(3 g_2 \cos\Theta_W + g_1 \sin\Theta_W \Big) \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{175}$$

$$+ \; - \frac{i}{3} g_1 \delta_{\alpha\beta} \delta_{ij} \sin\Theta_W \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \Big) \tag{176}$$

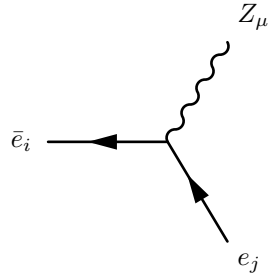


$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\delta_{ij}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{177}$$



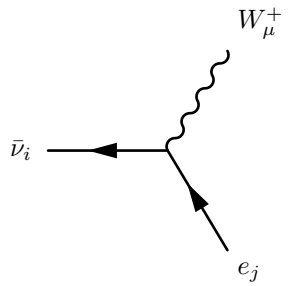
$$\frac{i}{2}\delta_{ij}\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{178}$$

$$+\ ig_1\cos\Theta_W\delta_{ij}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{179}$$

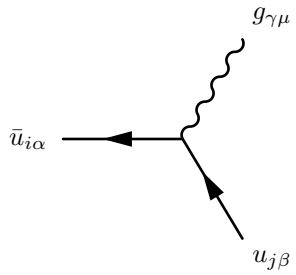


$$\frac{i}{2}\delta_{ij}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{180}$$

$$+\ -ig_1\delta_{ij}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{181}$$

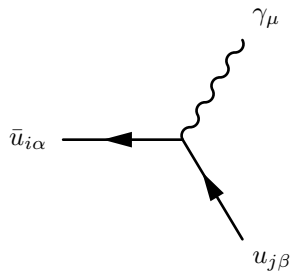


$$-i\frac{1}{\sqrt{2}}g_2\delta_{ij}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{182}$$



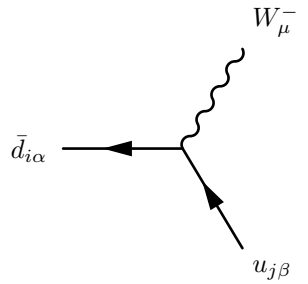
$$-\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{183}$$

$$+\ -\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{184}$$

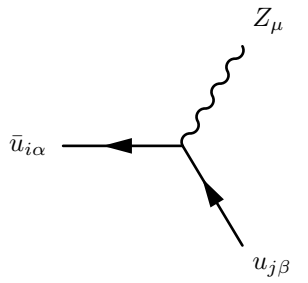


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{185}$$

$$+\ -\frac{2i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{186}$$

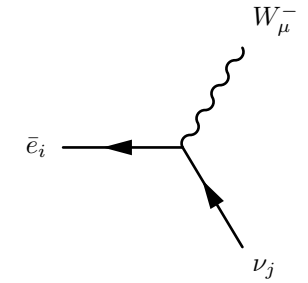


$$-i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\delta_{ij}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \tag{187}$$

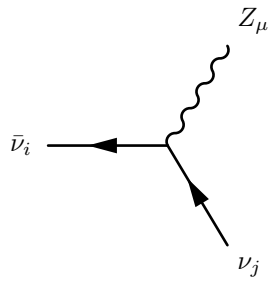


$$-\frac{i}{6}\delta_{\alpha\beta}\delta_{ij}\Big(3g_2\cos\Theta_W-g_1\sin\Theta_W\Big)\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \tag{188}$$

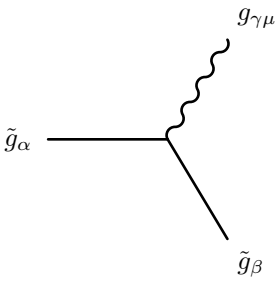
$$+\frac{2i}{3}g_1\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\left(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\right) \tag{189}$$



$$-i\frac{1}{\sqrt{2}}g_2\delta_{ij}\left(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\right) \tag{190}$$



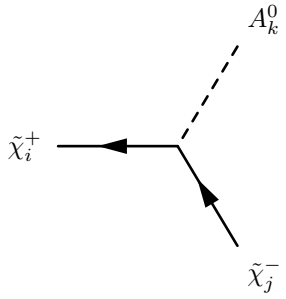
$$-\frac{i}{2}\delta_{ij}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{191}$$



$$-g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{192}$$

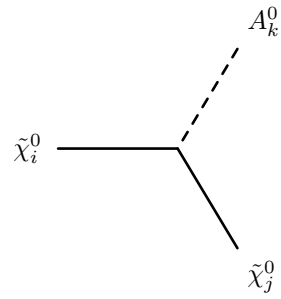
$$+\ -g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{193}$$

8.5 Two Fermion-One Scalar Boson-Interaction

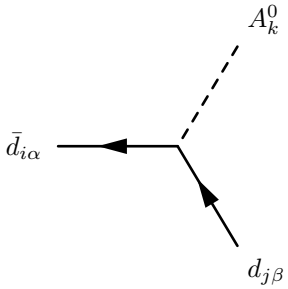


$$-\frac{1}{\sqrt{2}}g_2\Big(U_{j1}^* V_{i2}^* Z_{k2}^A + U_{j2}^* V_{i1}^* Z_{k1}^A\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{194}$$

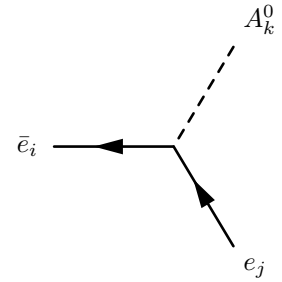
$$+\ \frac{1}{\sqrt{2}}g_2\Big(U_{i1}V_{j2}Z^A_{k2}+U_{i2}V_{j1}Z^A_{k1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{195}$$



$$\frac{1}{2}\Big(N^*_{i3}\Big(g_1N^*_{j1}-g_2N^*_{j2}\Big)Z^A_{k1}-g_2N^*_{i2}N^*_{j3}Z^A_{k1}-g_1N^*_{i4}N^*_{j1}Z^A_{k2}+g_2N^*_{i4}N^*_{j2}Z^A_{k2}$$
$$+\,g_2N^*_{i2}N^*_{j4}Z^A_{k2}+g_1N^*_{i1}\Big(N^*_{j3}Z^A_{k1}-N^*_{j4}Z^A_{k2}\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{196}$$
$$+\ \frac{1}{2}\Big(-Z^A_{k1}\Big(\Big(g_1N_{i1}-g_2N_{i2}\Big)N_{j3}+N_{i3}\Big(g_1N_{j1}-g_2N_{j2}\Big)\Big)$$
$$-\,Z^A_{k2}\Big(\Big(-g_1N_{i1}+g_2N_{i2}\Big)N_{j4}+N_{i4}\Big(-g_1N_{j1}+g_2N_{j2}\Big)\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{197}$$

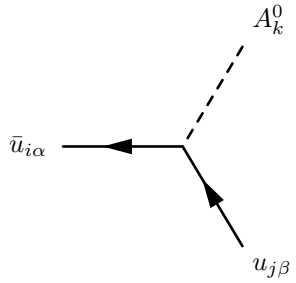


$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\delta_{ij}Y_{d,ij}Z^A_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{198}$$
$$+\ -\frac{1}{\sqrt{2}}Y^*_{d,ji}\delta_{\alpha\beta}\delta_{ij}Z^A_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{199}$$



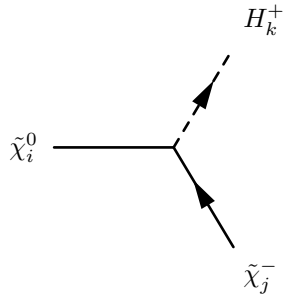
$$\frac{1}{\sqrt{2}}\delta_{ij}Y_{e,ij}Z^A_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{200}$$

$$+\ -\frac{1}{\sqrt{2}}Y^*_{e,ji}\delta_{ij}Z^A_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{201}$$



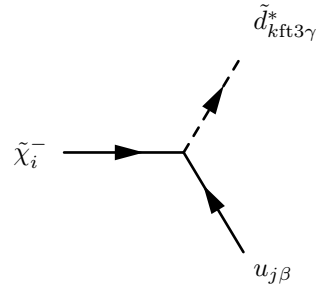
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\delta_{ij}Y_{u,ij}Z^A_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{202}$$

$$+\ -\frac{1}{\sqrt{2}}Y^*_{u,ji}\delta_{\alpha\beta}\delta_{ij}Z^A_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{203}$$



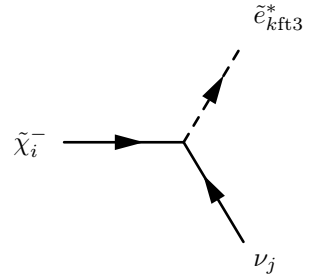
$$\frac{i}{2}\Big(-2g_2U^*_{j1}N^*_{i3}+\sqrt{2}U^*_{j2}\Big(g_1N^*_{i1}+g_2N^*_{i2}\Big)\Big)Z^+_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{204}$$

$$+ \; -\frac{i}{2}\Big(2g_2V_{j1}N_{i4} + \sqrt{2}V_{j2}\Big(g_1N_{i1} + g_2N_{i2}\Big)\Big)Z^+_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{205}$$

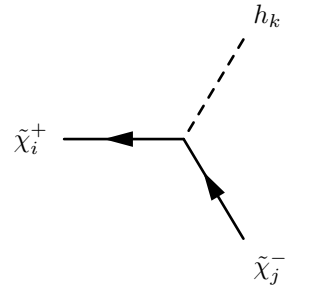


$$i\delta_{\beta\gamma}\delta_{jk}\Big(-g_2U^*_{i1}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big) + U^*_{i2}Y_{d,kj}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{206}$$

$$+ \; iY^*_{u,jk}\delta_{\beta\gamma}\delta_{jk}V_{i2}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{207}$$

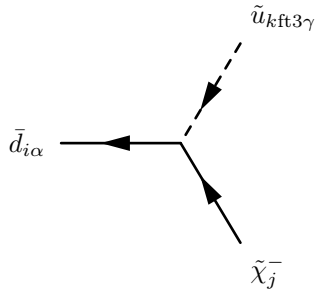


$$i\delta_{jk}\Big(-g_2U^*_{i1}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big) + U^*_{i2}Y_{e,kj}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{208}$$



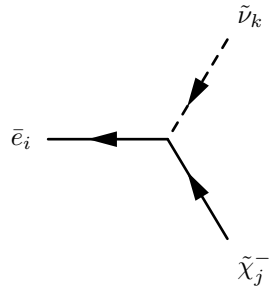
$$- i\frac{1}{\sqrt{2}}g_2\Big(U^*_{j1}V^*_{i2}Z^H_{k2} + U^*_{j2}V^*_{i1}Z^H_{k1}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{209}$$

$$+ -i\frac{1}{\sqrt{2}}g_2\Big(U_{i1}V_{j2}Z^H_{k2} + U_{i2}V_{j1}Z^H_{k1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{210}$$



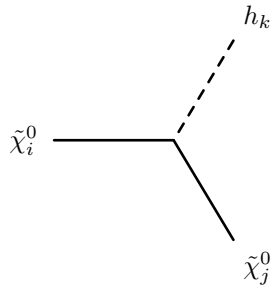
$$iU^*_{j2}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\delta_{\alpha\gamma}\delta_{ik}Y_{d,ik}\Big(\frac{1-\gamma_5}{2}\Big) \tag{211}$$

$$+\ i\delta_{\alpha\gamma}\delta_{ik}\Big(-g_2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)V_{j1} + Y^*_{u,ki}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)V_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{212}$$

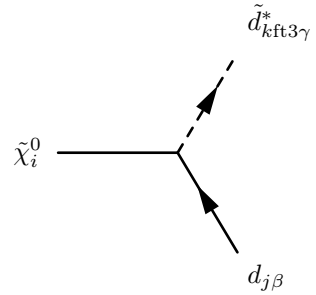


$$iU^*_{j2}\delta_{ik}Y_{e,ik}\Big(\frac{1-\gamma_5}{2}\Big) \tag{213}$$

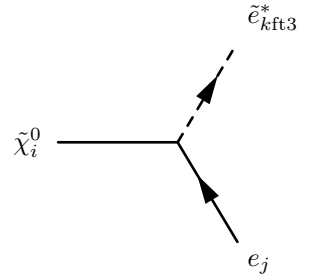
$$+ -ig_2\delta_{ik}V_{j1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{214}$$



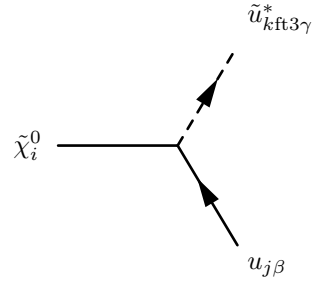
$$\frac{i}{2}\Big(N_{i3}^{*}\Big(g_1 N_{j1}^{*} - g_2 N_{j2}^{*}\Big)Z_{k1}^{H} - g_2 N_{i2}^{*} N_{j3}^{*} Z_{k1}^{H} - g_1 N_{i4}^{*} N_{j1}^{*} Z_{k2}^{H} + g_2 N_{i4}^{*} N_{j2}^{*} Z_{k2}^{H}$$
$$+ g_2 N_{i2}^{*} N_{j4}^{*} Z_{k2}^{H} + g_1 N_{i1}^{*}\Big(N_{j3}^{*} Z_{k1}^{H} - N_{j4}^{*} Z_{k2}^{H}\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{215}$$
$$+ \frac{i}{2}\Big(Z_{k1}^{H}\Big(\Big(g_1 N_{i1} - g_2 N_{i2}\Big)N_{j3} + N_{i3}\Big(g_1 N_{j1} - g_2 N_{j2}\Big)\Big)$$
$$+ Z_{k2}^{H}\Big(\Big(-g_1 N_{i1} + g_2 N_{i2}\Big)N_{j4} + N_{i4}\Big(-g_1 N_{j1} + g_2 N_{j2}\Big)\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{216}$$



$$-\frac{i}{6}\delta_{\beta\gamma}\delta_{jk}\Big(-3\sqrt{2}g_2 N_{i2}^{*}\mathrm{ZD}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big) + 6N_{i3}^{*}Y_{d,kj}\mathrm{ZD}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,2\Big) + \sqrt{2}g_1 N_{i1}^{*}\mathrm{ZD}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{217}$$
$$+ -\frac{i}{3}\delta_{\beta\gamma}\delta_{jk}\Big(3Y_{d,jk}^{*}N_{i3}\mathrm{ZD}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big) + \sqrt{2}g_1 N_{i1}\mathrm{ZD}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,2\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{218}$$

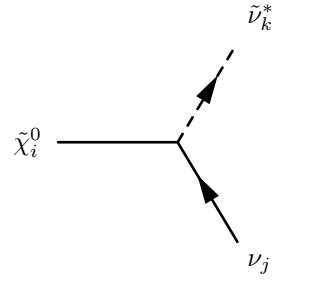


$$\frac{i}{2}\delta_{jk}\Big(-2N_{i3}^{*}Y_{e,kj}\mathrm{ZE}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,2\Big) + \sqrt{2}g_1 N_{i1}^{*}\mathrm{ZE}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big) + \sqrt{2}g_2 N_{i2}^{*}\mathrm{ZE}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{219}$$
$$+ -i\delta_{jk}\Big(\sqrt{2}g_1 N_{i1}\mathrm{ZE}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,2\Big) + Y_{e,jk}^{*}N_{i3}\mathrm{ZE}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{220}$$

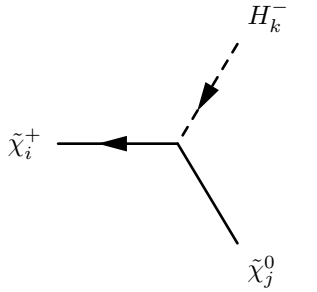


$$-\frac{i}{6}\delta_{\beta\gamma}\delta_{jk}\Big(3\sqrt{2}g_2N^*_{i2}\mathrm{ZU}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big)+6N^*_{i4}Y_{u,kj}\mathrm{ZU}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,2\Big)+\sqrt{2}g_1N^*_{i1}\mathrm{ZU}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \quad (221)$$

$$+\frac{i}{3}\delta_{\beta\gamma}\delta_{jk}\Big(2\sqrt{2}g_1N_{i1}\mathrm{ZU}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,2\Big)-3Y^*_{u,jk}N_{i4}\mathrm{ZU}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \quad (222)$$

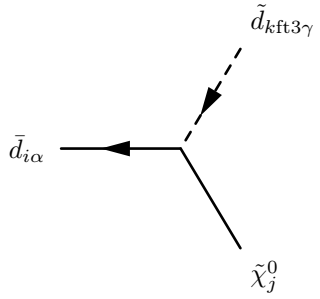


$$i\frac{1}{\sqrt{2}}\Big(g_1N^*_{i1}-g_2N^*_{i2}\Big)\delta_{jk}\Big(\frac{1-\gamma_5}{2}\Big) \quad (223)$$



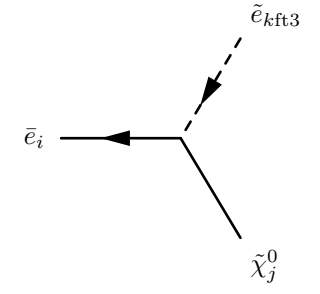
$$-\frac{i}{2}\Big(2g_2V^*_{i1}N^*_{j4}+\sqrt{2}V^*_{i2}\Big(g_1N^*_{j1}+g_2N^*_{j2}\Big)\Big)Z^+_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \quad (224)$$

$$+\frac{i}{2}\Big(-2g_2U_{i1}N_{j3}+\sqrt{2}U_{i2}\Big(g_1N_{j1}+g_2N_{j2}\Big)\Big)Z^+_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \quad (225)$$



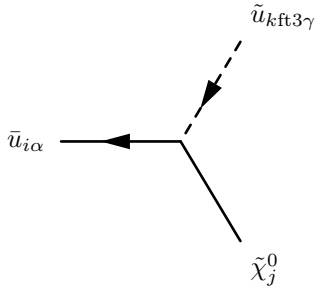
$$-\frac{i}{3}\delta_{\alpha\gamma}\delta_{ik}\Big(3N_{j3}^{*}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)Y_{d,ik}+\sqrt{2}g_1N_{j1}^{*}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{226}$$

$$+\ -\frac{i}{6}\delta_{\alpha\gamma}\delta_{ik}\Big(6Y_{d,ki}^{*}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)N_{j3}+\sqrt{2}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(-3g_2N_{j2}+g_1N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{227}$$



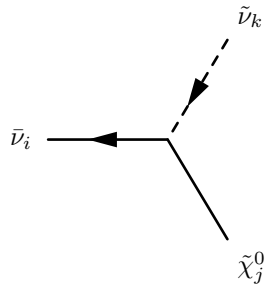
$$-i\delta_{ik}\Big(N_{j3}^{*}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)Y_{e,ik}+\sqrt{2}g_1N_{j1}^{*}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{228}$$

$$+\ \frac{i}{2}\delta_{ik}\Big(-2Y_{e,ki}^{*}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)N_{j3}+\sqrt{2}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(g_1N_{j1}+g_2N_{j2}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{229}$$



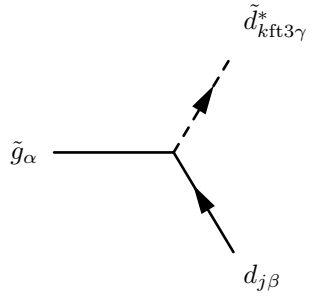
$$\frac{i}{3}\delta_{\alpha\gamma}\delta_{ik}\Big(2\sqrt{2}g_1N_{j1}^{*}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)-3N_{j4}^{*}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)Y_{u,ik}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{230}$$

$$+\ -\frac{i}{6}\delta_{\alpha\gamma}\delta_{ik}\Big(6Y_{u,ki}^{*}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)N_{j4}+\sqrt{2}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(3g_2N_{j2}+g_1N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{231}$$



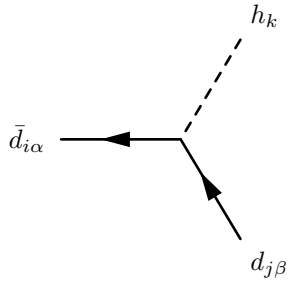
$$+ i\frac{1}{\sqrt{2}}\delta_{ik}\Big(g_1 N_{j1} - g_2 N_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{232}$$

$$+ i\frac{1}{\sqrt{2}}\delta_{ik}\Big(g_1 N_{j1} - g_2 N_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{233}$$



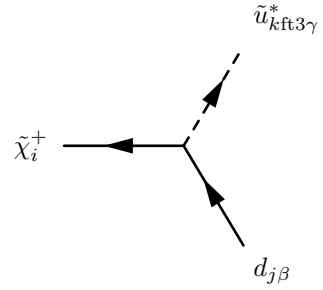
$$- i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\delta_{jk}\lambda^{\alpha}_{\gamma,\beta}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{234}$$

$$+ i\frac{1}{\sqrt{2}}g_3\phi^*_{\tilde{g}}\delta_{jk}\lambda^{\alpha}_{\gamma,\beta}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{235}$$



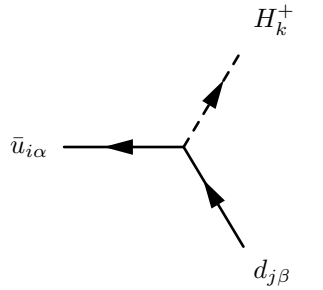
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\delta_{ij}Y_{d,ij}Z^H_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{236}$$

$$+\ -i\frac{1}{\sqrt{2}}Y^*_{d,ji}\delta_{\alpha\beta}\delta_{ij}Z^H_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{237}$$



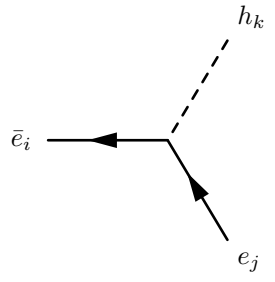
$$i\delta_{\beta\gamma}\delta_{jk}\Big(-g_2V^*_{i1}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)+V^*_{i2}Y_{u,kj}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{238}$$

$$+\ iY^*_{d,jk}\delta_{\beta\gamma}\delta_{jk}U_{i2}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{239}$$



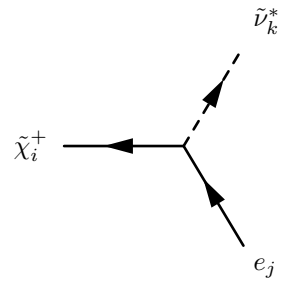
$$i\delta_{\alpha\beta}\delta_{ij}Y_{u,ij}Z^+_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{240}$$

$$+\ iY^*_{d,ji}\delta_{\alpha\beta}\delta_{ij}Z^+_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{241}$$



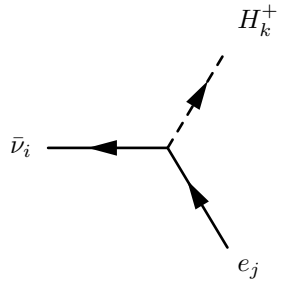
$$- i\frac{1}{\sqrt{2}}\delta_{ij}Y_{e,ij}Z^H_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{242}$$

$$+\ -i\frac{1}{\sqrt{2}}Y^*_{e,ji}\delta_{ij}Z^H_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{243}$$



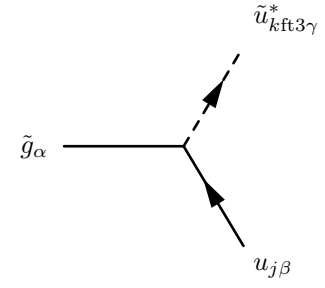
$$- ig_2V^*_{i1}\delta_{jk}\Big(\frac{1-\gamma_5}{2}\Big) \tag{244}$$

$$+\ iY^*_{e,jk}\delta_{jk}U_{i2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{245}$$



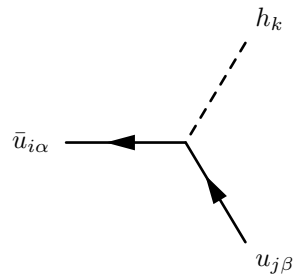
(246)

$$+\ iY^*_{e,ji}\delta_{ij}Z^+_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{247}$$



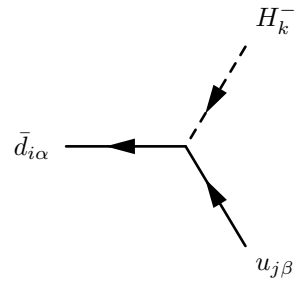
$$- i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\delta_{jk}\lambda^{\alpha}_{\gamma,\beta}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{248}$$

$$+ i\frac{1}{\sqrt{2}}g_3\phi^*_{\tilde{g}}\delta_{jk}\lambda^{\alpha}_{\gamma,\beta}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{249}$$



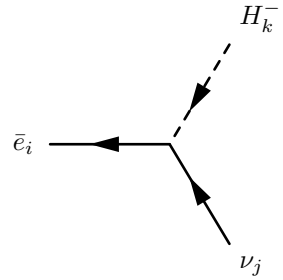
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}\delta_{ij}Y_{u,ij}Z^H_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{250}$$

$$+ -i\frac{1}{\sqrt{2}}Y^*_{u,ji}\delta_{\alpha\beta}\delta_{ij}Z^H_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{251}$$

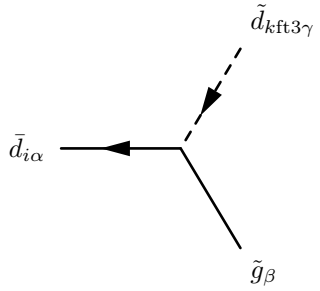


$$i\delta_{\alpha\beta}\delta_{ij}Y_{d,ij}Z^+_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{252}$$

$$+ iY^*_{u,ji}\delta_{\alpha\beta}\delta_{ij}Z^+_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{253}$$

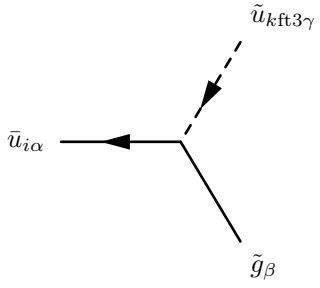


$$i\delta_{ij}Y_{e,ij}Z^{+}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{254}$$



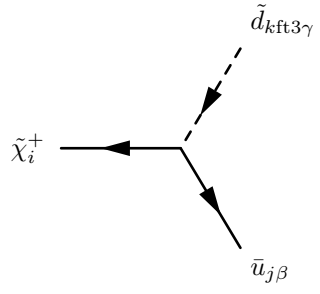
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\delta_{ik}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{255}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^{*}_{\tilde{g}}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\delta_{ik}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1+\gamma_5}{2}\Big) \tag{256}$$



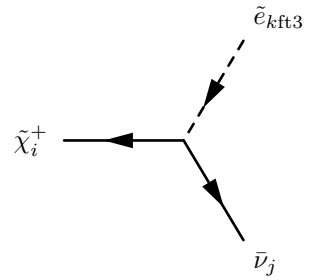
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\delta_{ik}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{257}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^{*}_{\tilde{g}}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\delta_{ik}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1+\gamma_5}{2}\Big) \tag{258}$$



$$iV_{i2}^{*}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\delta_{\beta\gamma}\delta_{jk}Y_{u,jk}\Big(\frac{1-\gamma_5}{2}\Big) \tag{259}$$

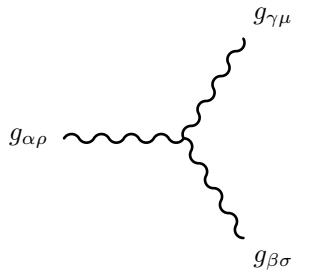
$$+\ i\delta_{\beta\gamma}\delta_{jk}\Big(-g_2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)U_{i1}+Y_{d,kj}^{*}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{260}$$



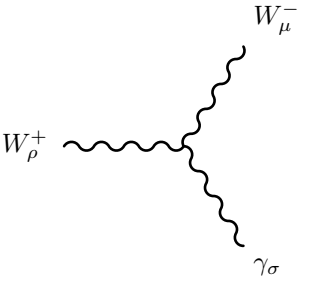
(261)

$$+\ i\delta_{jk}\Big(-g_2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)U_{i1}+Y_{e,kj}^{*}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{262}$$

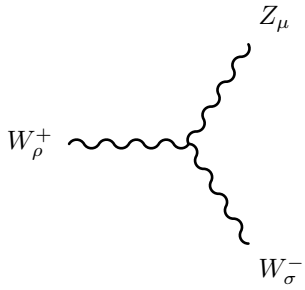
8.6 Three Vector Boson-Interaction



$$g_3 f_{\alpha,\beta,\gamma}\Big(g_{\rho\mu}\Big(-p_\sigma^{g_{\gamma\mu}}+p_\sigma^{g_{\alpha\rho}}\Big)+g_{\rho\sigma}\Big(-p_\mu^{g_{\alpha\rho}}+p_\mu^{g_{\beta\sigma}}\Big)+g_{\sigma\mu}\Big(-p_\rho^{g_{\beta\sigma}}+p_\rho^{g_{\gamma\mu}}\Big)\Big) \tag{263}$$

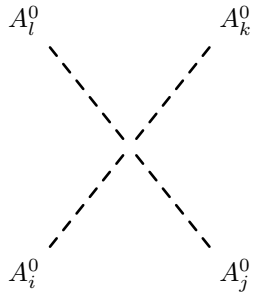


$$ig_2 \sin\Theta_W \Big(g_{\rho\mu} \Big(- p_\sigma^{W_\mu^-} + p_\sigma^{W_\rho^+} \Big) + g_{\rho\sigma} \Big(- p_\mu^{W_\rho^+} + p_\mu^{\gamma_\sigma} \Big) + g_{\sigma\mu} \Big(- p_\rho^{\gamma_\sigma} + p_\rho^{W_\mu^-} \Big) \Big) \tag{264}$$

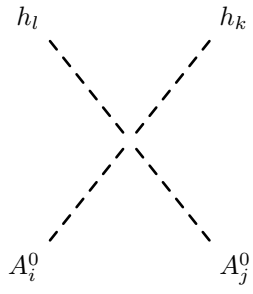


$$- ig_2 \cos\Theta_W \Big(g_{\rho\mu} \Big(- p_\sigma^{Z_\mu} + p_\sigma^{W_\rho^+} \Big) + g_{\rho\sigma} \Big(- p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-} \Big) + g_{\sigma\mu} \Big(- p_\rho^{W_\sigma^-} + p_\rho^{Z_\mu} \Big) \Big) \tag{265}$$

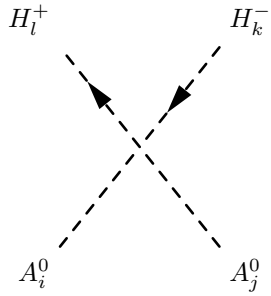
8.7 Four Scalar-Interaction



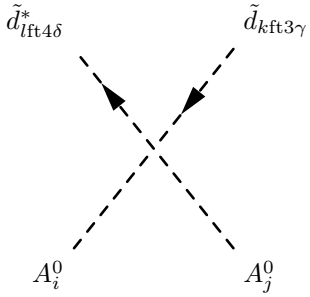
$$\begin{aligned} &\frac{i}{4} \Big(g_1^2 + g_2^2 \Big) \Big(Z_{i2}^A \Big(Z_{j1}^A \Big(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \Big) + Z_{j2}^A \Big(- 3 Z_{k2}^A Z_{l2}^A + Z_{k1}^A Z_{l1}^A \Big) \Big) \\ &+ Z_{i1}^A \Big(Z_{j1}^A \Big(- 3 Z_{k1}^A Z_{l1}^A + Z_{k2}^A Z_{l2}^A \Big) + Z_{j2}^A \Big(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \Big) \Big) \Big) \end{aligned} \tag{266}$$



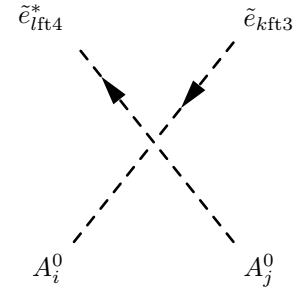
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\Big)\Big(Z_{k1}^H Z_{l1}^H - Z_{k2}^H Z_{l2}^H\Big) \tag{267}$$



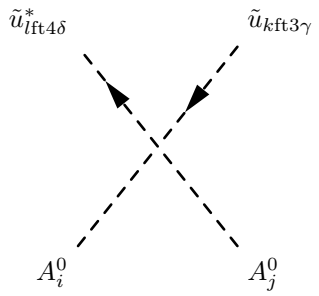
$$\begin{aligned}&\frac{i}{4}\Big(Z_{i1}^A\Big(g_2^2 Z_{j2}^A\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) - Z_{j1}^A\Big(\Big(g_1^2+g_2^2\Big)Z_{k1}^+ Z_{l1}^+ + \Big(-g_1^2+g_2^2\Big)Z_{k2}^+ Z_{l2}^+\Big)\Big)\\ &+ Z_{i2}^A\Big(g_2^2 Z_{j1}^A\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) + Z_{j2}^A\Big(-\Big(g_1^2+g_2^2\Big)Z_{k2}^+ Z_{l2}^+ + \Big(-g_2^2+g_1^2\Big)Z_{k1}^+ Z_{l1}^+\Big)\Big)\Big)\end{aligned} \tag{268}$$



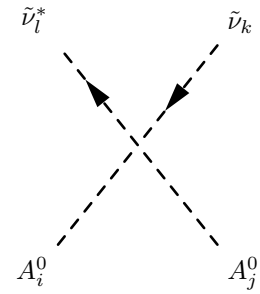
$$\begin{aligned}&\frac{i}{12}\delta_{\gamma\delta}\delta_{kl}\Big(\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,1\Big)\Big)\Big(\Big(-12Y^*_{d,kl}Y_{d,kk}+3g_2^2+g_1^2\Big)Z_{i1}^A Z_{j1}^A - \Big(3g_2^2+g_1^2\Big)Z_{i2}^A Z_{j2}^A\Big)\mathrm{ZD}\Big(\mathrm{gt}4\Big)\Big(\mathrm{ft}4,1\Big)\\ &+ 2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt}3\Big)\Big(\mathrm{ft}3,2\Big)\Big)\Big(\Big(-6Y^*_{d,kk}Y_{d,lk}+g_1^2\Big)Z_{i1}^A Z_{j1}^A - g_1^2 Z_{i2}^A Z_{j2}^A\Big)\mathrm{ZD}\Big(\mathrm{gt}4\Big)\Big(\mathrm{ft}4,2\Big)\Big)\end{aligned} \tag{269}$$



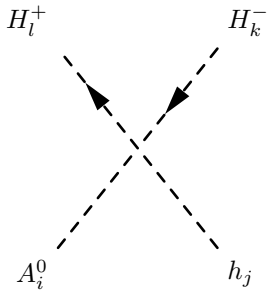
$$-\frac{i}{4}\delta_{kl}\Big(\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(\Big(4Y^*_{e,kl}Y_{e,kk}-g_2^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}+\Big(-g_1^2+g_2^2\Big)Z^A_{i2}Z^A_{j2}\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$+2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big(-\Big(-2Y^*_{e,kk}Y_{e,lk}+g_1^2\Big)Z^A_{i1}Z^A_{j1}+g_1^2Z^A_{i2}Z^A_{j2}\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{270}$$



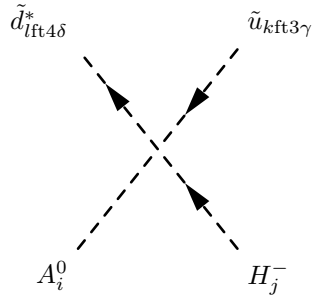
$$\frac{i}{12}\delta_{\gamma\delta}\delta_{kl}\Big(\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(-\Big(12Y^*_{u,kl}Y_{u,kk}-3g_2^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}+\Big(-3g_2^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$-4\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big(-\Big(-3Y^*_{u,kk}Y_{u,lk}+g_1^2\Big)Z^A_{i2}Z^A_{j2}+g_1^2Z^A_{i1}Z^A_{j1}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{271}$$



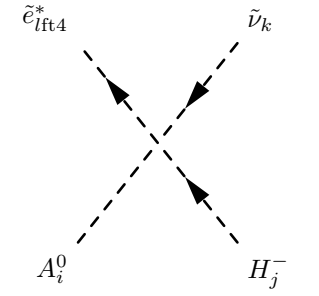
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\delta_{kl}\Big(Z^A_{i1}Z^A_{j1}-Z^A_{i2}Z^A_{j2}\Big) \tag{272}$$



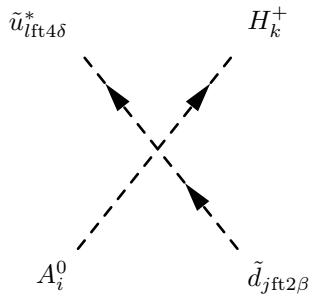
$$\frac{1}{4}g_2^2\Big(Z_{i1}^A Z_{j2}^H + Z_{i2}^A Z_{j1}^H\Big)\Big(- Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) \tag{273}$$



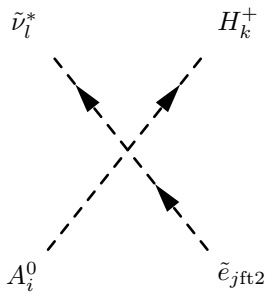
$$-\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\delta_{kl}\Big(\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(\Big(- 2Y_{d,kl}^* Y_{d,kk} + g_2^2\Big)Z_{i1}^A Z_{j1}^+ - \Big(- 2Y_{u,kl}^* Y_{u,kk} + g_2^2\Big)Z_{i2}^A Z_{j2}^+\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$+ 2Y_{u,kk}^*\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)Y_{d,lk}\Big(Z_{i1}^A Z_{j2}^+ - Z_{i2}^A Z_{j1}^+\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{274}$$



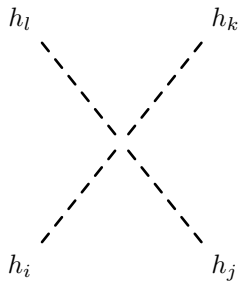
$$-\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{kl}\Big(\Big(- 2Y_{e,kl}^* Y_{e,kk} + g_2^2\Big)Z_{i1}^A Z_{j1}^+ - g_2^2 Z_{i2}^A Z_{j2}^+\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big) \tag{275}$$



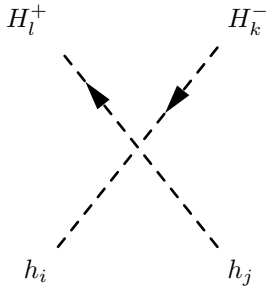
$$\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\delta_{jl}\Big(\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\Big(-2Y^*_{d,jl}Y_{d,jj}+g_2^2\Big)Z^A_{i1}Z^+_{k1}-\Big(-2Y^*_{u,jl}Y_{u,jj}+g_2^2\Big)Z^A_{i2}Z^+_{k2}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$+2Y^*_{d,jj}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)Y_{u,lj}\Big(Z^A_{i1}Z^+_{k2}-Z^A_{i2}Z^+_{k1}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{276}$$



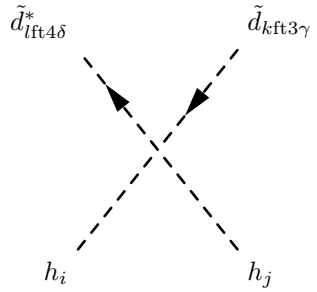
$$\frac{1}{2}\frac{1}{\sqrt{2}}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\delta_{jl}\Big(\Big(-2Y^*_{e,jl}Y_{e,jj}+g_2^2\Big)Z^A_{i1}Z^+_{k1}-g_2^2Z^A_{i2}Z^+_{k2}\Big) \tag{277}$$



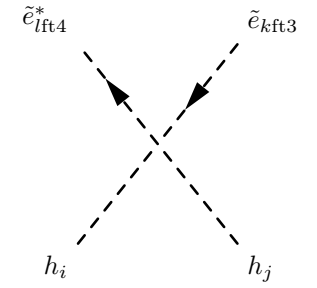
$$\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z^H_{i2}\Big(Z^H_{j1}\Big(Z^H_{k1}Z^H_{l2}+Z^H_{k2}Z^H_{l1}\Big)+Z^H_{j2}\Big(-3Z^H_{k2}Z^H_{l2}+Z^H_{k1}Z^H_{l1}\Big)\Big)$$
$$+Z^H_{i1}\Big(Z^H_{j1}\Big(-3Z^H_{k1}Z^H_{l1}+Z^H_{k2}Z^H_{l2}\Big)+Z^H_{j2}\Big(Z^H_{k1}Z^H_{l2}+Z^H_{k2}Z^H_{l1}\Big)\Big)\Big) \tag{278}$$



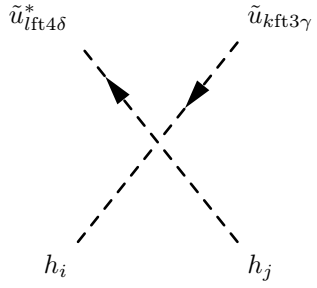
$$\frac{i}{4}\Big(- Z_{i1}^{H}\Big(g_2^2 Z_{j2}^{H}\Big(Z_{k1}^{+}Z_{l2}^{+} + Z_{k2}^{+}Z_{l1}^{+}\Big) + Z_{j1}^{H}\Big(\Big(g_1^2 + g_2^2\Big)Z_{k1}^{+}Z_{l1}^{+} + \Big(- g_1^2 + g_2^2\Big)Z_{k2}^{+}Z_{l2}^{+}\Big)\Big)$$
$$+ Z_{i2}^{H}\Big(- g_2^2 Z_{j1}^{H}\Big(Z_{k1}^{+}Z_{l2}^{+} + Z_{k2}^{+}Z_{l1}^{+}\Big) + Z_{j2}^{H}\Big(- \Big(g_1^2 + g_2^2\Big)Z_{k2}^{+}Z_{l2}^{+} + \Big(- g_2^2 + g_1^2\Big)Z_{k1}^{+}Z_{l1}^{+}\Big)\Big)\Big) \tag{279}$$



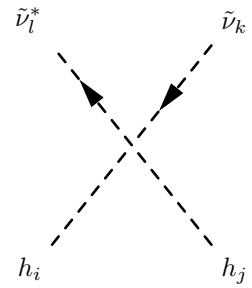
$$\frac{i}{12}\delta_{\gamma\delta}\delta_{kl}\Big(\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(\Big(- 12Y_{d,kl}^{*}Y_{d,kk} + 3g_2^2 + g_1^2\Big)Z_{i1}^{H}Z_{j1}^{H} - \Big(3g_2^2 + g_1^2\Big)Z_{i2}^{H}Z_{j2}^{H}\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$+ 2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big(\Big(- 6Y_{d,kk}^{*}Y_{d,lk} + g_1^2\Big)Z_{i1}^{H}Z_{j1}^{H} - g_1^2 Z_{i2}^{H}Z_{j2}^{H}\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{280}$$



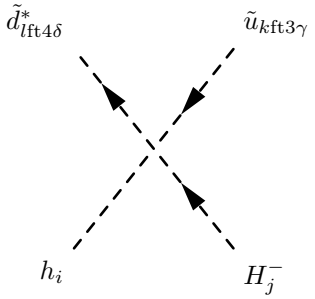
$$- \frac{i}{4}\delta_{kl}\Big(\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(\Big(4Y_{e,kl}^{*}Y_{e,kk} - g_2^2 + g_1^2\Big)Z_{i1}^{H}Z_{j1}^{H} + \Big(- g_1^2 + g_2^2\Big)Z_{i2}^{H}Z_{j2}^{H}\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$+ 2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big(- \Big(- 2Y_{e,kk}^{*}Y_{e,lk} + g_1^2\Big)Z_{i1}^{H}Z_{j1}^{H} + g_1^2 Z_{i2}^{H}Z_{j2}^{H}\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{281}$$



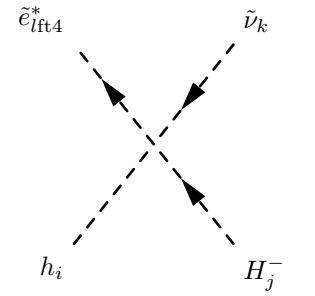
$$\frac{i}{12}\delta_{\gamma\delta}\delta_{kl}\Big(\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(-\Big(12Y^*_{u,kl}Y_{u,kk}-3g_2^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}+\Big(-3g_2^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$-4\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)\Big(-\Big(-3Y^*_{u,kk}Y_{u,lk}+g_1^2\Big)Z^H_{i2}Z^H_{j2}+g_1^2Z^H_{i1}Z^H_{j1}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{282}$$



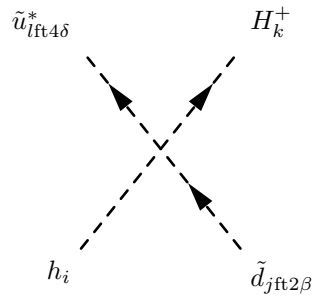
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\delta_{kl}\Big(Z^H_{i1}Z^H_{j1}-Z^H_{i2}Z^H_{j2}\Big) \tag{283}$$



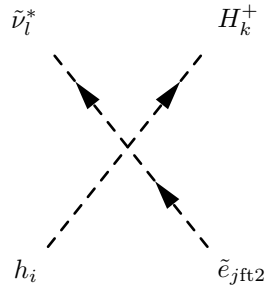
$$\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\delta_{kl}\Big(-\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\Big(\Big(-2Y^*_{d,kl}Y_{d,kk}+g_2^2\Big)Z^H_{i1}Z^+_{j1}+\Big(-2Y^*_{u,kl}Y_{u,kk}+g_2^2\Big)Z^H_{i2}Z^+_{j2}\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$+2Y^*_{u,kk}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)Y_{d,lk}\Big(Z^H_{i1}Z^+_{j2}+Z^H_{i2}Z^+_{j1}\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{284}$$



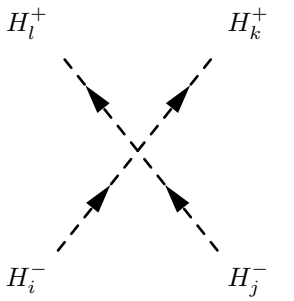
$$-\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{kl}\Big(\Big(-2Y^*_{e,kl}Y_{e,kk}+g_2^2\Big)Z^H_{i1}Z^+_{j1}+g_2^2Z^H_{i2}Z^+_{j2}\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big) \tag{285}$$



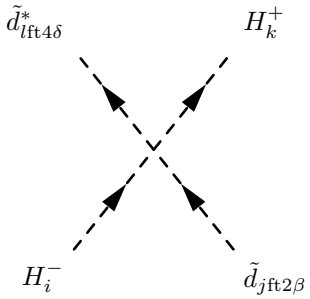
$$\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\delta_{jl}\Big(-\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\Big(-2Y^*_{d,jl}Y_{d,jj}+g_2^2\Big)Z^H_{i1}Z^+_{k1}+\Big(-2Y^*_{u,jl}Y_{u,jj}+g_2^2\Big)Z^H_{i2}Z^+_{k2}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$+2Y^*_{d,jj}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)Y_{u,lj}\Big(Z^H_{i1}Z^+_{k2}+Z^H_{i2}Z^+_{k1}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{286}$$



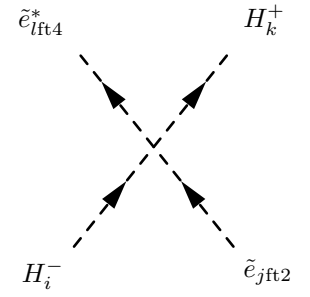
$$-\frac{i}{2}\frac{1}{\sqrt{2}}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\delta_{jl}\Big(\Big(-2Y^*_{e,jl}Y_{e,jj}+g_2^2\Big)Z^H_{i1}Z^+_{k1}+g_2^2Z^H_{i2}Z^+_{k2}\Big) \tag{287}$$



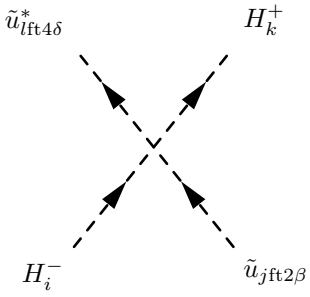
$$- \frac{i}{4}\Big(g_1^2 + g_2^2\Big)\Big(- Z_{i2}^+\Big(- 2Z_{j2}^+ Z_{k2}^+ Z_{l2}^+ + Z_{j1}^+\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big)\Big) + Z_{i1}^+\Big(2Z_{j1}^+ Z_{k1}^+ Z_{l1}^+ - Z_{j2}^+\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big)\Big)\Big) \tag{288}$$



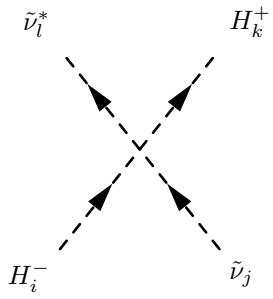
$$\frac{i}{12}\delta_{\beta\delta}\delta_{jl}\Big(\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(- \Big(12Y_{u,jl}^* Y_{u,jj} - 3g_2^2 + g_1^2\Big)Z_{i2}^+ Z_{k2}^+ + \Big(- 3g_2^2 + g_1^2\Big)Z_{i1}^+ Z_{k1}^+\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big) + 2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\Big(- 6Y_{d,jj}^* Y_{d,lj} + g_1^2\Big)Z_{i1}^+ Z_{k1}^+ - g_1^2 Z_{i2}^+ Z_{k2}^+\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{289}$$



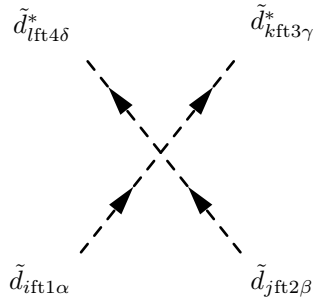
$$- \frac{i}{4}\delta_{jl}\Big(\Big(g_1^2 + g_2^2\Big)\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(Z_{i1}^+ Z_{k1}^+ - Z_{i2}^+ Z_{k2}^+\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big) + 2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(- \Big(- 2Y_{e,jj}^* Y_{e,lj} + g_1^2\Big)Z_{i1}^+ Z_{k1}^+ + g_1^2 Z_{i2}^+ Z_{k2}^+\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{290}$$



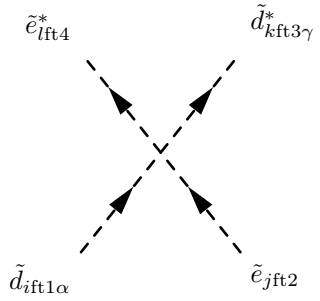
$$\frac{i}{12}\delta_{\beta\delta}\delta_{jl}\Big(\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\Big(-12Y^*_{d,jl}Y_{d,jj}+3g_2^2+g_1^2\Big)Z^+_{i1}Z^+_{k1}-\Big(3g_2^2+g_1^2\Big)Z^+_{i2}Z^+_{k2}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$-4\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(-\Big(-3Y^*_{u,jj}Y_{u,lj}+g_1^2\Big)Z^+_{i2}Z^+_{k2}+g_1^2Z^+_{i1}Z^+_{k1}\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big) \tag{291}$$



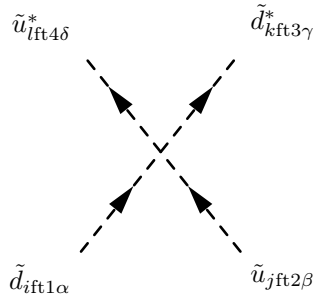
$$\frac{i}{4}\delta_{jl}\Big(\Big(-4Y^*_{e,jl}Y_{e,jj}-g_1^2+g_2^2\Big)Z^+_{i1}Z^+_{k1}+\Big(-g_2^2+g_1^2\Big)Z^+_{i2}Z^+_{k2}\Big) \tag{292}$$



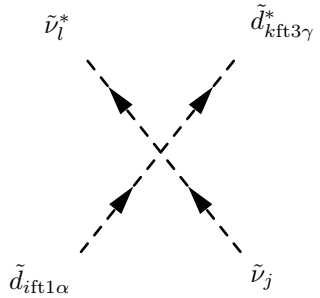
$$\frac{i}{36}\Big(-\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(18g_3^2\delta_{ik}\delta_{jl}+\Big(-6g_3^2+9g_2^2+g_1^2\Big)\delta_{il}\delta_{jk}\Big)$$
$$+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(18g_3^2\delta_{il}\delta_{jk}+\Big(-6g_3^2+9g_2^2+g_1^2\Big)\delta_{ik}\delta_{jl}\Big)\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$+2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(-9g_3^2\delta_{il}\delta_{jk}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)+\delta_{ik}\delta_{jl}\Big(18Y^*_{d,jl}Y_{d,ki}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft}$$
$$+\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(-9g_3^2\delta_{ik}\delta_{jl}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\delta_{il}\delta_{jk}\Big(18Y^*_{d,jk}Y_{d,li}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\Big(3g_3^2+g_1^2\Big)\mathrm{ZD}\Big(\mathrm{gt}$$
$$+2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\Big(-\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(2g_1^2-3g_3^2\Big)\delta_{il}\delta_{jk}+9g_3^2\delta_{ik}\delta_{jl}\Big)$$
$$+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(2g_1^2-3g_3^2\Big)\delta_{ik}\delta_{jl}+9g_3^2\delta_{il}\delta_{jk}\Big)\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)$$
$$+\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(9g_3^2\delta_{ik}\delta_{jl}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)-\delta_{il}\delta_{jk}\Big(18Y^*_{d,il}Y_{d,kj}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1$$
$$-\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(-9g_3^2\delta_{il}\delta_{jk}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\delta_{ik}\delta_{jl}\Big(18Y^*_{d,ik}Y_{d,lj}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZD}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\Big(3g_3^2+g_1^2\Big)\mathrm{ZD}\Big(\mathrm{gt}$$
(293)



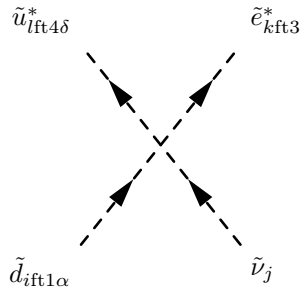
$$\frac{i}{12}\delta_{\alpha\gamma}\delta_{ik}\delta_{jl}\Big(\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(-2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(6Y^*_{e,jl}Y_{d,ki}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)+g_1^2\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)$$
$$+2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\Big(-2g_1^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(-6Y^*_{d,ik}Y_{e,}$$
(294)



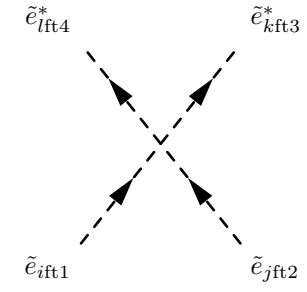
$$\frac{i}{36}\Big(2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big(\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(-\Big(3g_3^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\delta_{ik}\delta_{jl}+9\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(-2Y^*_{d,il}\delta_{il}\delta_{jk}Y_{d,kj}+$$
$$+\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\Big(3g_3^2+4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)\delta_{ik}\delta_{jl}\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big)$$
$$-\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big(\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(18\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(g_2^2\delta_{il}\delta_{jk}+g_3^2\delta_{ik}\delta_{jl}\Big)+\Big(-6g_3^2-9g_2^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\delta_{ik}$$
$$+2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\Big(-2g_1^2+3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\delta_{ik}\delta_{jl}-9\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(-2Y^*_{u,jk}\delta_{il}\delta_{jk}Y_{u,li}+g_3^2\delta_{ik}\delta_{jl}\Big)\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big)\Big)$$
(295)



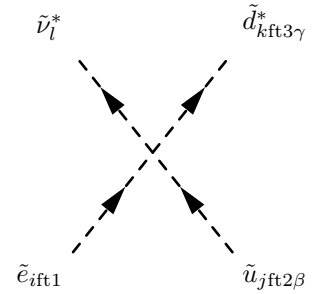
$$\frac{i}{12}\delta_{\alpha\gamma}\delta_{ik}\delta_{jl}\Big(2g_1^2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+\Big(3g_2^2+g_1^2\Big)\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big) \tag{296}$$



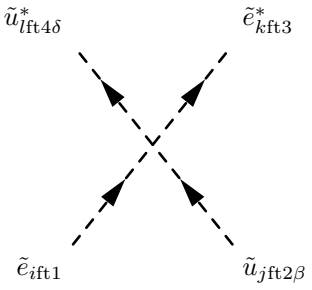
$$-\frac{i}{2}\delta_{\alpha\delta}\delta_{il}\delta_{jk}\Big(2Y^*_{d,il}\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)Y_{e,kj}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+g_2^2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big) \tag{297}$$



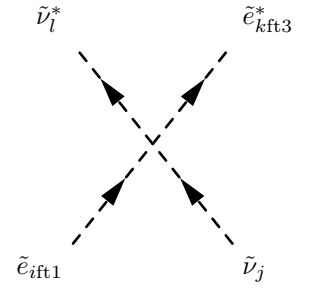
$$\begin{aligned}
&\frac{i}{4}\Big(-\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(\Big(g_1^2+g_2^2\Big)\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\delta_{ik}\delta_{jl}+\delta_{il}\delta_{jk}\Big)\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)\\
&-2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\delta_{ik}\delta_{jl}\Big(-2Y^*_{e,jl}Y_{e,ki}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)+g_1^2\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\Big)+\delta_{il}\delta_{jk}\Big(\\
&+2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\Big(-2g_1^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\delta_{ik}\delta_{jl}+\delta_{il}\delta_{jk}\Big)\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)\\
&+\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\delta_{ik}\delta_{jl}\Big(-2Y^*_{e,ik}Y_{e,lj}\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+g_1^2\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZE}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)\Big)+\delta_{il}\delta_{jk}\Big(-
\end{aligned} \tag{298}$$



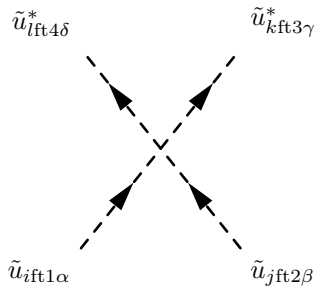
$$-\frac{i}{2}\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\delta_{\beta\gamma}\delta_{il}\delta_{jk}\Big(2Y^*_{e,il}\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)Y_{d,kj}\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+g_2^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\mathrm{ZD}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},\tag{299}$$



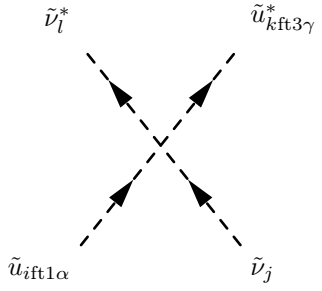
$$\frac{i}{12}\delta_{\beta\delta}\delta_{ik}\delta_{jl}\Big(-2g_1^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big(-4\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big)\tag{300}$$



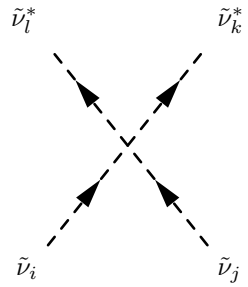
$$\frac{i}{4}\Big(2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\Big(-2Y^*_{e,il}\delta_{il}\delta_{jk}Y_{e,kj}+g_1^2\delta_{ik}\delta_{jl}\Big)\mathrm{ZE}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)+\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(-2g_2^2\delta_{il}\delta_{jk}+\Big(-g_1^2+g_2^2\Big)\delta$$
(301)



$$\frac{i}{36}\Big(-\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\Big(\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(18g_3^2\delta_{ik}\delta_{jl}+\Big(-6g_3^2+9g_2^2+g_1^2\Big)\delta_{il}\delta_{jk}\Big)$$
$$+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(18g_3^2\delta_{il}\delta_{jk}+\Big(-6g_3^2+9g_2^2+g_1^2\Big)\delta_{ik}\delta_{jl}\Big)\Big)\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)$$
$$+2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(-9g_3^2\delta_{il}\delta_{jk}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)+\delta_{ik}\delta_{jl}\Big(18Y^*_{u,jl}Y_{u,ki}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{f}$$
$$+\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(-9g_3^2\delta_{ik}\delta_{jl}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\delta_{il}\delta_{jk}\Big(18Y^*_{u,jk}Y_{u,li}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\Big(-2g_1^2+3g_3^2\Big)\mathrm{ZU}$$
$$+2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\Big(-\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(-3g_3^2+8g_1^2\Big)\delta_{il}\delta_{jk}+9g_3^2\delta_{ik}\delta_{jl}\Big)$$
$$+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(-3g_3^2+8g_1^2\Big)\delta_{ik}\delta_{jl}+9g_3^2\delta_{il}\delta_{jk}\Big)\Big)\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)$$
$$+\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big)\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(9g_3^2\delta_{ik}\delta_{jl}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},1\Big)+\delta_{il}\delta_{jk}\Big(-18Y^*_{u,il}Y_{u,kj}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4}$$
$$+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(9g_3^2\delta_{il}\delta_{jk}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\delta_{ik}\delta_{jl}\Big(-18Y^*_{u,ik}Y_{u,lj}\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)\mathrm{ZU}\Big(\mathrm{gt4}\Big)\Big(\mathrm{ft4},2\Big)+\Big(2g_1^2-3g_3^2\Big)\mathrm{ZU}\Big(\mathrm{g}$$
(302)

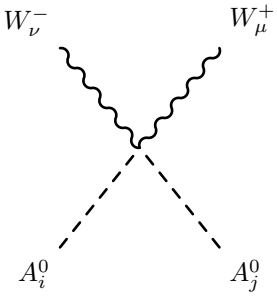


$$\frac{i}{12}\delta_{\alpha\gamma}\delta_{ik}\delta_{jl}\Big(\Big(-3g_2^2+g_1^2\Big)\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},1\Big)-4g_1^2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\mathrm{ZU}\Big(\mathrm{gt3}\Big)\Big(\mathrm{ft3},2\Big)\Big)$$
(303)

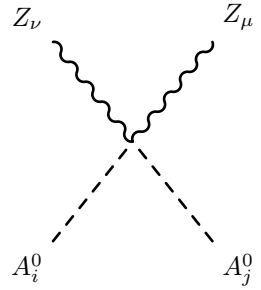


$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(\delta_{ik}\delta_{jl}+\delta_{il}\delta_{jk}\Big) \tag{304}$$

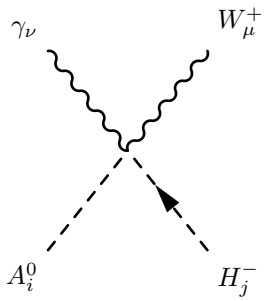
8.8 Two Scalar-Two Vector Boson-Interaction



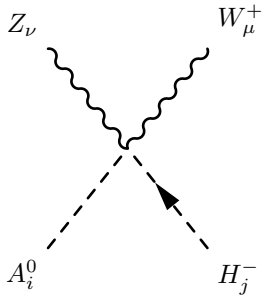
$$\Big(\frac{i}{2}g_2^2 Z_{i1}^A Z_{j1}^A+\frac{i}{2}g_2^2 Z_{i2}^A Z_{j2}^A\Big)\Big(g_{\mu\nu}\Big) \tag{305}$$



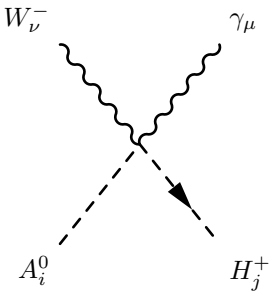
$$\begin{aligned}\Big(&+\frac{i}{2}g_2^2\cos\Theta_W^2 Z_{i1}^A Z_{j1}^A+ig_1g_2\cos\Theta_W\sin\Theta_W Z_{i1}^A Z_{j1}^A+\frac{i}{2}g_1^2\sin\Theta_W^2 Z_{i1}^A Z_{j1}^A\\&+\frac{i}{2}g_2^2\cos\Theta_W^2 Z_{i2}^A Z_{j2}^A+ig_1g_2\cos\Theta_W\sin\Theta_W Z_{i2}^A Z_{j2}^A+\frac{i}{2}g_1^2\sin\Theta_W^2 Z_{i2}^A Z_{j2}^A\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{306}$$



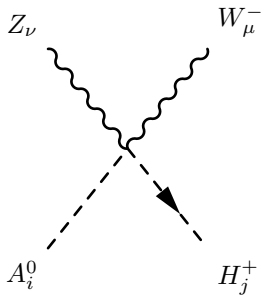
$$\Big(-\frac{1}{2} g_1 g_2 \cos\Theta_W Z^A_{i1} Z^+_{j1} - \frac{1}{2} g_1 g_2 \cos\Theta_W Z^A_{i2} Z^+_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{307}$$



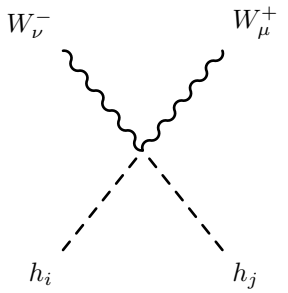
$$\Big(\frac{1}{2} g_1 g_2 \sin\Theta_W Z^A_{i1} Z^+_{j1} + \frac{1}{2} g_1 g_2 \sin\Theta_W Z^A_{i2} Z^+_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{308}$$



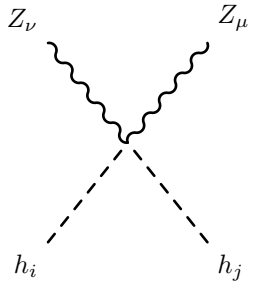
$$\Big(\frac{1}{2} g_1 g_2 \cos\Theta_W Z^A_{i1} Z^+_{j1} + \frac{1}{2} g_1 g_2 \cos\Theta_W Z^A_{i2} Z^+_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{309}$$



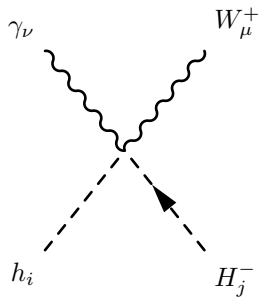
$$\Big(-\frac{1}{2} g_1 g_2 \sin\Theta_W Z^A_{i1} Z^+_{j1} - \frac{1}{2} g_1 g_2 \sin\Theta_W Z^A_{i2} Z^+_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{310}$$



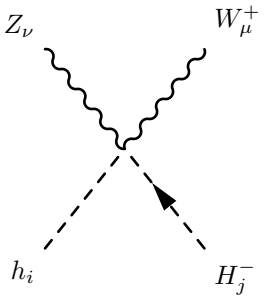
$$\Big(\frac{i}{2} g_2^2 Z^H_{i1} Z^H_{j1} + \frac{i}{2} g_2^2 Z^H_{i2} Z^H_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{311}$$



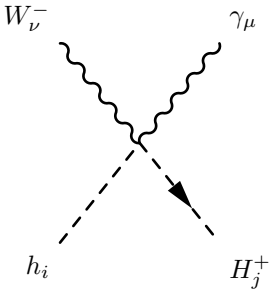
$$\begin{aligned} &\Big(+ \frac{i}{2} g_2^2 \cos\Theta_W^2 Z^H_{i1} Z^H_{j1} + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z^H_{i1} Z^H_{j1} + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z^H_{i1} Z^H_{j1} \\ &+ \frac{i}{2} g_2^2 \cos\Theta_W^2 Z^H_{i2} Z^H_{j2} + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z^H_{i2} Z^H_{j2} + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z^H_{i2} Z^H_{j2} \Big) \Big(g_{\mu\nu} \Big) \end{aligned} \tag{312}$$



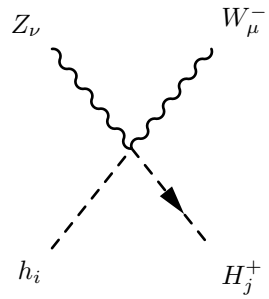
$$\Big(-\frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i2}^H Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{313}$$



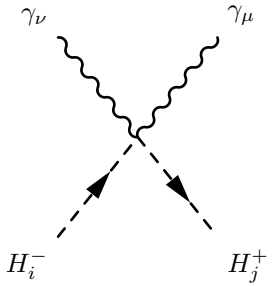
$$\Big(\frac{i}{2} g_1 g_2 \sin\Theta_W Z_{i1}^H Z_{j1}^+ - \frac{i}{2} g_1 g_2 \sin\Theta_W Z_{i2}^H Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{314}$$



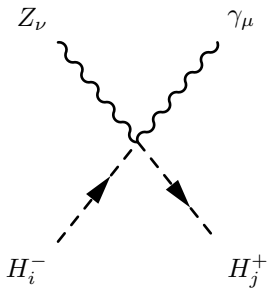
$$\Big(-\frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i2}^H Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{315}$$



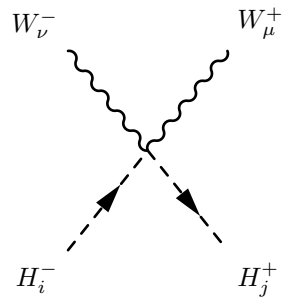
$$\Big(\frac{i}{2}g_1g_2\sin\Theta_W Z_{i1}^H Z_{j1}^+ - \frac{i}{2}g_1g_2\sin\Theta_W Z_{i2}^H Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{316}$$



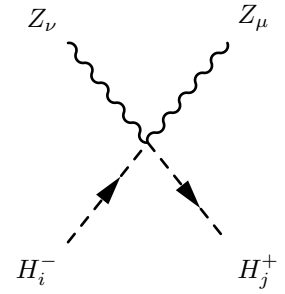
$$\begin{aligned}&\Big(+\frac{i}{2}g_1^2\cos\Theta_W^2 Z_{i1}^+Z_{j1}^+ + ig_1g_2\cos\Theta_W\sin\Theta_W Z_{i1}^+Z_{j1}^+ + \frac{i}{2}g_2^2\sin\Theta_W^2 Z_{i1}^+Z_{j1}^+\\&+\frac{i}{2}g_1^2\cos\Theta_W^2 Z_{i2}^+Z_{j2}^+ + ig_1g_2\cos\Theta_W\sin\Theta_W Z_{i2}^+Z_{j2}^+ + \frac{i}{2}g_2^2\sin\Theta_W^2 Z_{i2}^+Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{317}$$



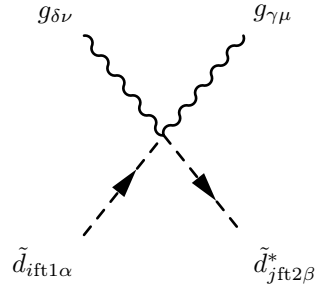
$$\begin{aligned}&\Big(+\frac{i}{2}g_1g_2\cos 2\Theta_W Z_{i1}^+Z_{j1}^+ - \frac{i}{4}g_1^2\sin 2\Theta_W Z_{i1}^+Z_{j1}^+ + \frac{i}{4}g_2^2\sin 2\Theta_W Z_{i1}^+Z_{j1}^+\\&+\frac{i}{2}g_1g_2\cos 2\Theta_W Z_{i2}^+Z_{j2}^+ - \frac{i}{4}g_1^2\sin 2\Theta_W Z_{i2}^+Z_{j2}^+ + \frac{i}{4}g_2^2\sin 2\Theta_W Z_{i2}^+Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{318}$$



$$\Big(\frac{i}{2}g_2^2 Z_{i1}^+ Z_{j1}^+ + \frac{i}{2}g_2^2 Z_{i2}^+ Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{319}$$

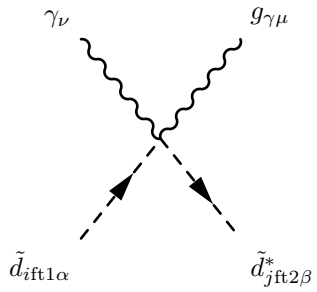


$$\begin{aligned}&\Big(+ \frac{i}{2}g_2^2 \cos\Theta_W^2 Z_{i1}^+ Z_{j1}^+ - ig_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i1}^+ Z_{j1}^+ \\ &+ \frac{i}{2}g_1^2 \sin\Theta_W^2 Z_{i1}^+ Z_{j1}^+ + \frac{i}{2}g_2^2 \cos\Theta_W^2 Z_{i2}^+ Z_{j2}^+ \\ &- ig_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{2}g_1^2 \sin\Theta_W^2 Z_{i2}^+ Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{320}$$

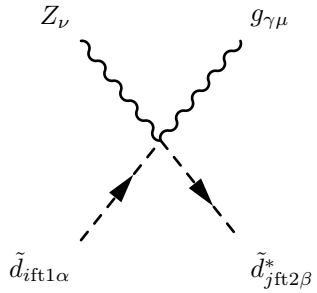


$$\Big(+ \frac{i}{4}g_3^2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\sum_{a=1}^{3}\lambda_{a,\alpha}^{\gamma}\lambda_{\beta,a}^{\delta}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) + \frac{i}{4}g_3^2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\sum_{a=1}^{3}\lambda_{\beta,a}^{\gamma}\lambda_{a,\alpha}^{\delta}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) + \frac{i}{4}g$$

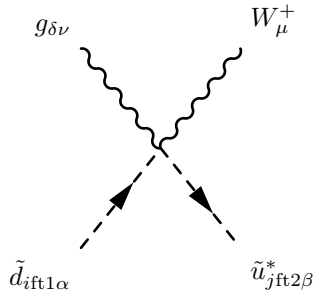
$$+ \frac{i}{4} g_3^2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1}, 2\Big)\Big)\delta_{ij} \sum_{a=1}^{3} \lambda^{\gamma}_{\beta,a}\lambda^{\delta}_{a,\alpha}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2}, 2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{321}$$



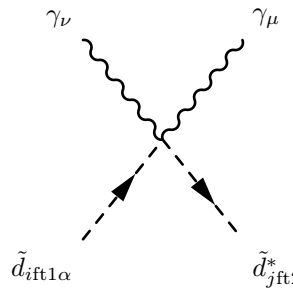
$$\Big(+ \frac{i}{6} g_1 g_3 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1}, 1\Big)\Big)\cos\Theta_W \delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2}, 1\Big) - \frac{i}{2} g_2 g_3 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1}, 1\Big)\Big)\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\sin\Theta_W \mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2}, 1\Big)$$
$$- \frac{i}{3} g_1 g_3 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1}, 2\Big)\Big)\cos\Theta_W \delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2}, 2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{322}$$



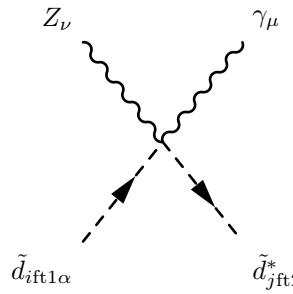
$$\Big(- \frac{i}{2} g_2 g_3 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1}, 1\Big)\Big)\cos\Theta_W \delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2}, 1\Big) - \frac{i}{6} g_1 g_3 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1}, 1\Big)\Big)\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\sin\Theta_W \mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2}, 1\Big)$$
$$+ \frac{i}{3} g_1 g_3 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1}, 2\Big)\Big)\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\sin\Theta_W \mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2}, 2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{323}$$



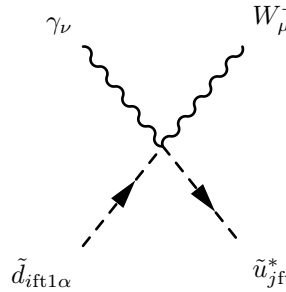
$$i\frac{1}{\sqrt{2}}g_2 g_3 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\lambda^{\delta}_{\beta,\alpha}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{324}$$



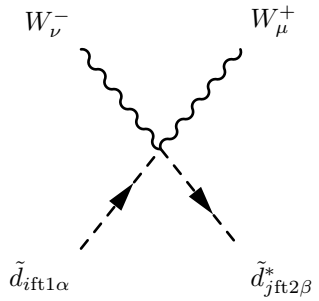
$$\Big(+\frac{i}{18}g_1^2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W^2\delta_{\alpha\beta}\delta_{ij}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) - \frac{i}{3}g_1 g_2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},$$
$$+\frac{i}{2}g_2^2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W^2\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) + \frac{2i}{9}g_1^2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\cos\Theta_W^2\delta_{\alpha\beta}\delta_{ij}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{325}$$



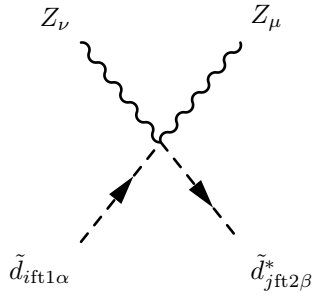
$$\Big(-\frac{i}{6}g_1 g_2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos 2\Theta_W\delta_{\alpha\beta}\delta_{ij}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) - \frac{i}{36}g_1^2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin 2\Theta_W\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)$$
$$+\frac{i}{4}g_2^2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin 2\Theta_W\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) - \frac{i}{9}g_1^2\mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin 2\Theta_W\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{326}$$



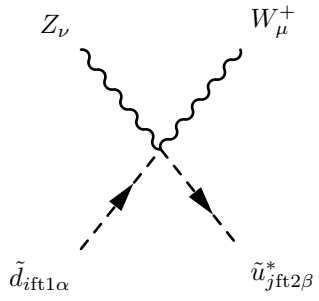
$$\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W \delta_{\alpha\beta}\delta_{ij}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{327}$$



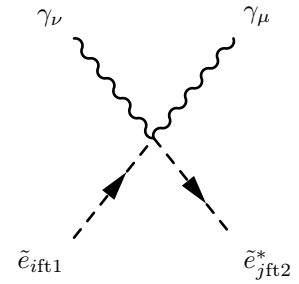
$$\frac{i}{2}g_2^2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{328}$$



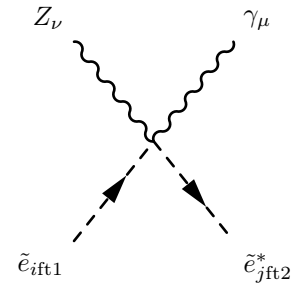
$$\Big(+\frac{i}{2}g_2^2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W^2\delta_{\alpha\beta}\delta_{ij}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)+\frac{i}{3}g_1 g_2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1$$
$$+\frac{i}{18}g_1^2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W^2\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)+\frac{2i}{9}g_1^2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W^2\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{329}$$



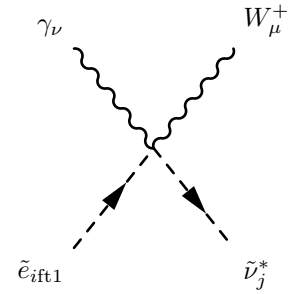
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 \mathrm{conj}\Big(\mathrm{ZD}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W \mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{330}$$



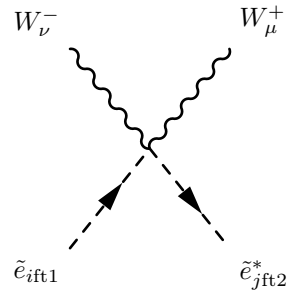
$$\Big(+\frac{i}{2}g_1^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W^2\delta_{ij}\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)+ig_1g_2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W\delta_{ij}\sin\Theta_W\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)$$
$$+\frac{i}{2}g_2^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\sin\Theta_W^2\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)+2ig_1^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\cos\Theta_W^2\delta_{ij}\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{331}$$



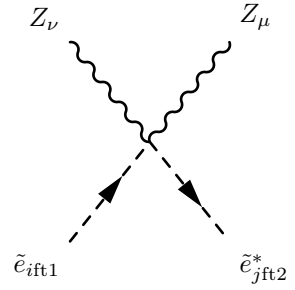
$$\Big(+\frac{i}{2}g_1g_2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos 2\Theta_W\delta_{ij}\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)-\frac{i}{4}g_1^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\sin 2\Theta_W\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)+\frac{i}{4}g_2^2\mathrm{conj}($$
$$-ig_1^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\delta_{ij}\sin 2\Theta_W\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{332}$$



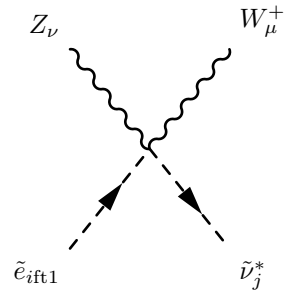
$$-i\frac{1}{\sqrt{2}}g_1 g_2 \mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W\delta_{ij}\Big(g_{\mu\nu}\Big) \tag{333}$$



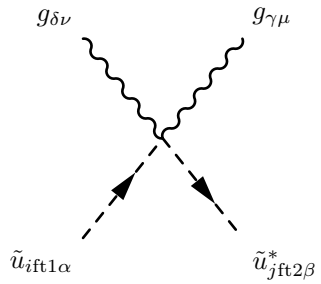
$$\frac{i}{2}g_2^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{334}$$



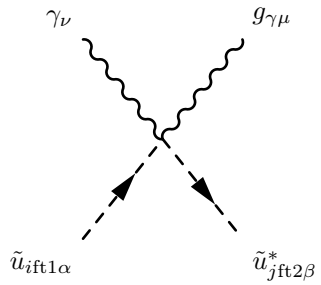
$$\Big(+\frac{i}{2}g_2^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W^2\delta_{ij}\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) - ig_1 g_2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W\delta_{ij}\sin\Theta_W\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)$$
$$+\frac{i}{2}g_1^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\sin\Theta_W^2\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) + 2ig_1^2\mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\delta_{ij}\sin\Theta_W^2\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{335}$$



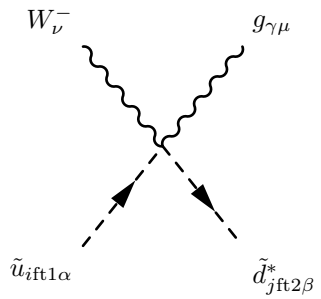
$$i\frac{1}{\sqrt{2}}g_1 g_2 \mathrm{conj}\Big(\mathrm{ZE}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\sin\Theta_W\Big(g_{\mu\nu}\Big) \tag{336}$$



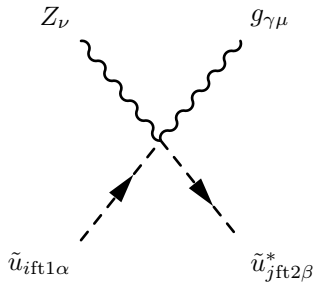
$$\Big(+\frac{i}{4}g_3^2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\sum_{a=1}^{3}\lambda^{\gamma}_{a,\alpha}\lambda^{\delta}_{\beta,a}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)+\frac{i}{4}g_3^2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\sum_{a=1}^{3}\lambda^{\gamma}_{\beta,a}\lambda^{\delta}_{a,\alpha}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)+\frac{i}{4}g$$
$$+\frac{i}{4}g_3^2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\delta_{ij}\sum_{a=1}^{3}\lambda^{\gamma}_{\beta,a}\lambda^{\delta}_{a,\alpha}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{337}$$



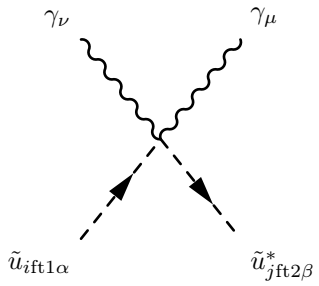
$$\Big(+\frac{i}{6}g_1 g_3\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)+\frac{i}{2}g_2 g_3\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\sin\Theta_W\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)$$
$$+\frac{2i}{3}g_1 g_3\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\cos\Theta_W\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{338}$$



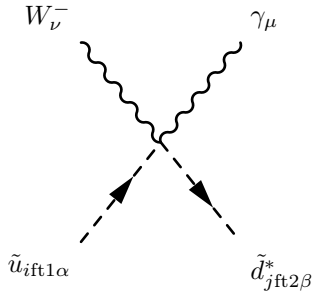
$$i\frac{1}{\sqrt{2}}g_2 g_3 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{339}$$



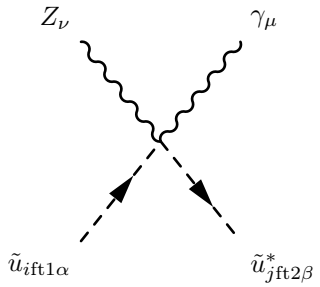
$$\Big(+\frac{i}{2}g_2 g_3 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) - \frac{i}{6}g_1 g_3 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\sin\Theta_W\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)$$
$$-\frac{2i}{3}g_1 g_3 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\sin\Theta_W\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{340}$$



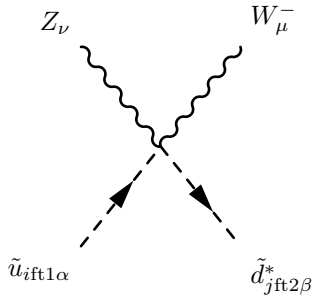
$$\Big(+\frac{i}{18}g_1^2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W^2\delta_{\alpha\beta}\delta_{ij}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) + \frac{i}{3}g_1 g_2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},$$
$$+\frac{i}{2}g_2^2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W^2\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) + \frac{8i}{9}g_1^2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\cos\Theta_W^2\delta_{\alpha\beta}\delta_{ij}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{341}$$



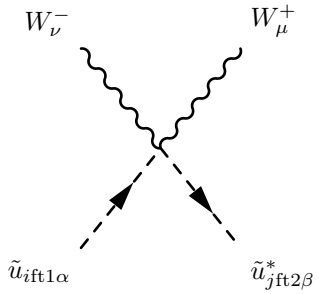
$$\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W \delta_{\alpha\beta}\delta_{ij}\mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{342}$$



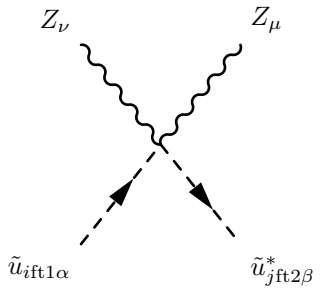
$$\Big(+\frac{i}{6}g_1 g_2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos 2\Theta_W \delta_{\alpha\beta}\delta_{ij}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) - \frac{i}{36}g_1^2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin 2\Theta_W \mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)$$
$$+\frac{i}{4}g_2^2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin 2\Theta_W \mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big) - \frac{4i}{9}g_1^2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin 2\Theta_W \mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{343}$$



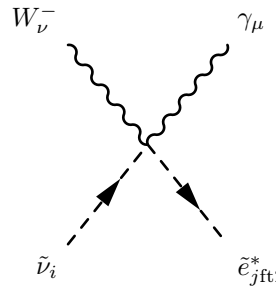
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 \mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W \mathrm{ZD}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{344}$$



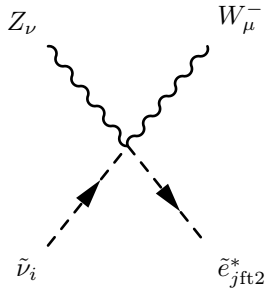
$$\frac{i}{2}g_2^2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{345}$$



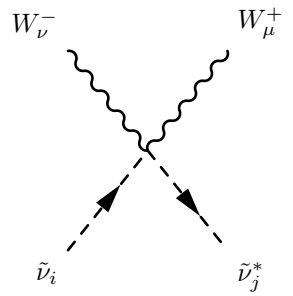
$$\Big(+\frac{i}{2}g_2^2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W^2\delta_{\alpha\beta}\delta_{ij}\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)-\frac{i}{3}g_1g_2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\cos\Theta_W\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1$$
$$+\frac{i}{18}g_1^2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},1\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W^2\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)+\frac{8i}{9}g_1^2\mathrm{conj}\Big(\mathrm{ZU}\Big(\mathrm{gt1}\Big)\Big(\mathrm{ft1},2\Big)\Big)\delta_{\alpha\beta}\delta_{ij}\sin\Theta_W^2\mathrm{ZU}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},2\Big)\Big)\Big(g_{\mu\nu}\Big) \tag{346}$$



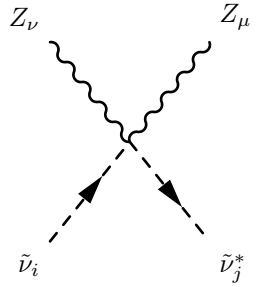
$$-i\frac{1}{\sqrt{2}}g_1g_2\cos\Theta_W\delta_{ij}\mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{347}$$



$$i\frac{1}{\sqrt{2}}g_1 g_2 \delta_{ij} \sin\Theta_W \mathrm{ZE}\Big(\mathrm{gt2}\Big)\Big(\mathrm{ft2},1\Big)\Big(g_{\mu\nu}\Big) \tag{348}$$

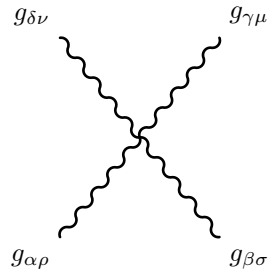


$$\frac{i}{2}g_2^2 \delta_{ij}\Big(g_{\mu\nu}\Big) \tag{349}$$



$$\Big(\frac{i}{2}g_1^2 \delta_{ij}\sin\Theta_W^2 + \frac{i}{2}g_2^2 \cos\Theta_W^2 \delta_{ij} + i g_1 g_2 \cos\Theta_W \delta_{ij}\sin\Theta_W\Big)\Big(g_{\mu\nu}\Big) \tag{350}$$

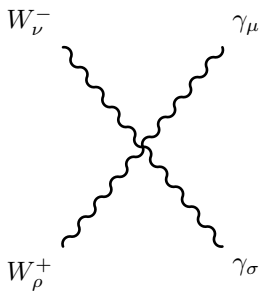
8.9 Four Vector Boson-Interaction



$$ig_3^2\Big(-\sum_{a=1}^{8} f_{\alpha,\delta,a}f_{\beta,\gamma,a} - \sum_{a=1}^{8} f_{\alpha,\gamma,a}f_{\beta,\delta,a}\Big)\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{351}$$

$$+\ ig_3^2\Big(-\sum_{a=1}^{8} f_{\alpha,\beta,a}f_{\gamma,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\delta,a}f_{\beta,\gamma,a}\Big)\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{352}$$

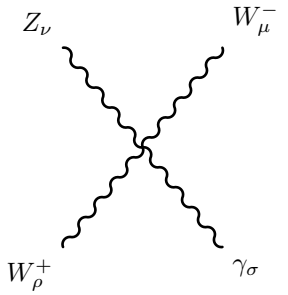
$$+\ ig_3^2\Big(\sum_{a=1}^{8} f_{\alpha,\gamma,a}f_{\beta,\delta,a} + \sum_{a=1}^{8} f_{\alpha,\beta,a}f_{\gamma,\delta,a}\Big)\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{353}$$



$$ig_2^2 \sin\Theta_W^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{354}$$

$$+\ ig_2^2 \sin\Theta_W^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{355}$$

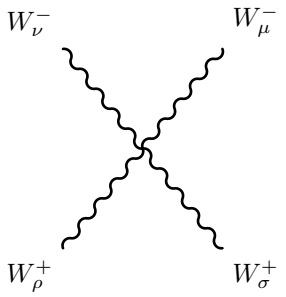
$$+\ -2ig_2^2 \sin\Theta_W^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{356}$$



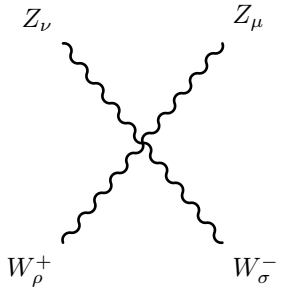
$$\frac{i}{2}g_2^2 \sin 2\Theta_W\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{357}$$

$$+\ -ig_2^2 \sin 2\Theta_W\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{358}$$

$$+\ \frac{i}{2}g_2^2 \sin 2\Theta_W\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{359}$$

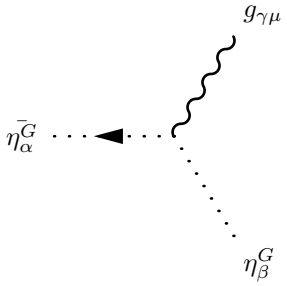


$$2ig_2^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{360}$$
$$+\ -ig_2^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{361}$$
$$+\ -ig_2^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{362}$$

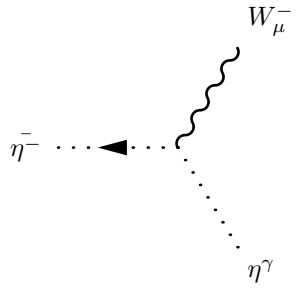


$$-\ 2ig_2^2\cos\Theta_W^2\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{363}$$
$$+\ ig_2^2\cos\Theta_W^2\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{364}$$
$$+\ ig_2^2\cos\Theta_W^2\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{365}$$

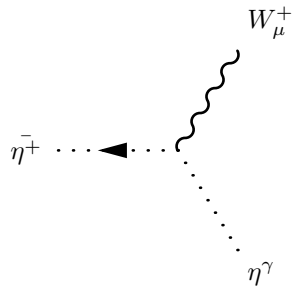
8.10 Two Ghosts-One Vector Boson-Interaction



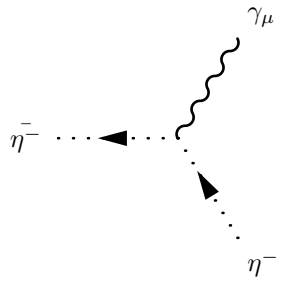
$$g_3 f_{\alpha,\beta,\gamma}\left(p_\mu^{\eta_\beta^G}\right) \tag{366}$$



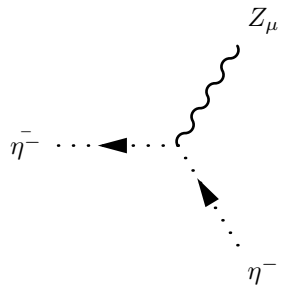
$$ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{367}$$



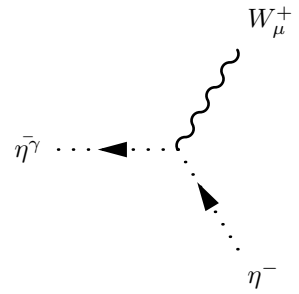
$$-ig_2 \sin\Theta_W\left(p_\mu^{\eta^\gamma}\right) \tag{368}$$



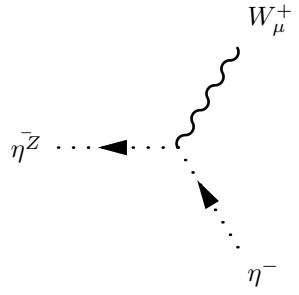
$$-ig_2 \sin\Theta_W\left(p_\mu^{\eta^-}\right) \tag{369}$$



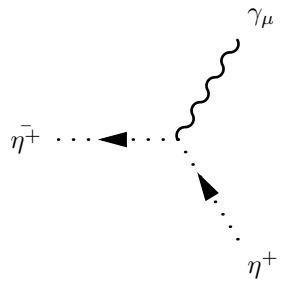
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{370}$$



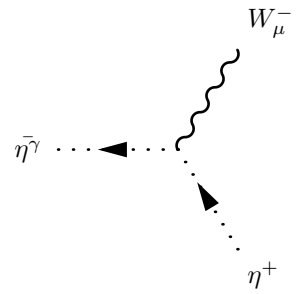
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^-}\right) \tag{371}$$



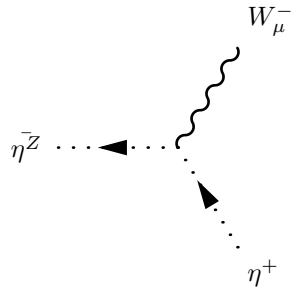
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{372}$$



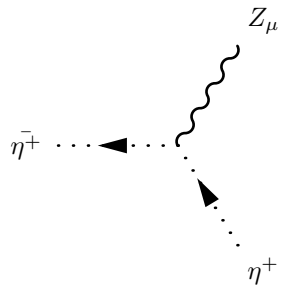
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{373}$$



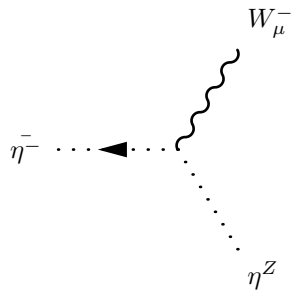
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{374}$$



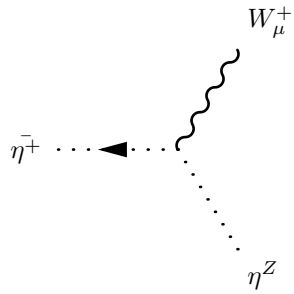
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{375}$$



$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{376}$$

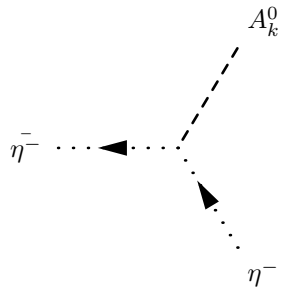


$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{377}$$

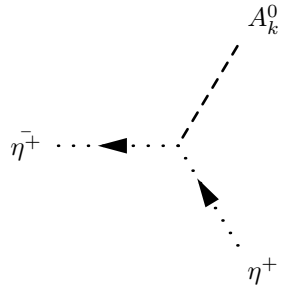


$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{378}$$

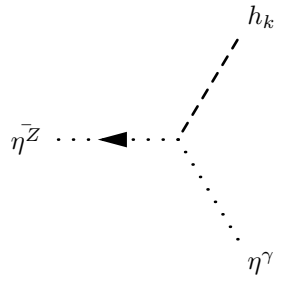
8.11 Two Ghosts-One Scalar-Interaction



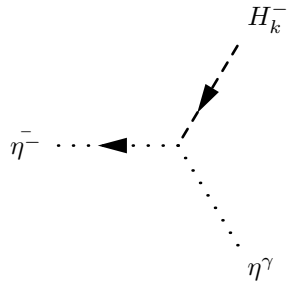
$$\frac{1}{4}g_2^2\xi_{W^-}\Big(v_d Z_{k1}^A - v_u Z_{k2}^A\Big) \tag{379}$$



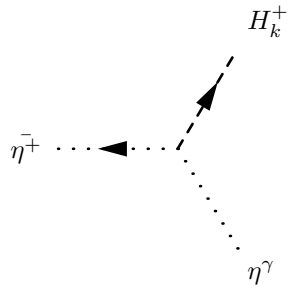
$$-\frac{1}{4}g_2^2\xi_{W^-}\Big(v_d Z_{k1}^A - v_u Z_{k2}^A\Big) \tag{380}$$



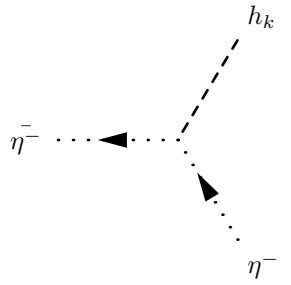
$$\frac{i}{8}\xi_Z\Big(2g_1g_2\cos 2\Theta_W + \Big(-g_2^2+g_1^2\Big)\sin 2\Theta_W\Big)\Big(v_d Z_{k1}^H + v_u Z_{k2}^H\Big) \tag{381}$$



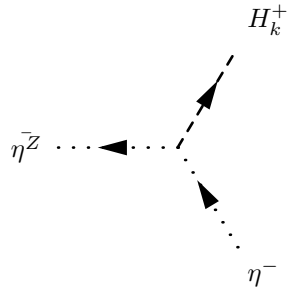
$$\frac{i}{4}g_2\xi_{W^-}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(v_d Z_{k1}^+ - v_u Z_{k2}^+\Big) \tag{382}$$



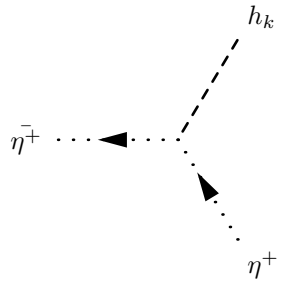
$$\frac{i}{4}g_2\xi_{W^-}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(v_d Z_{k1}^+ - v_u Z_{k2}^+\Big) \tag{383}$$



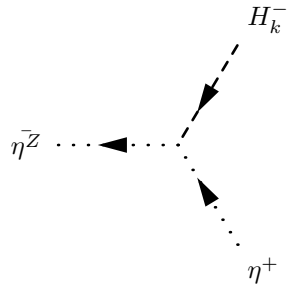
$$-\frac{i}{4}g_2^2\xi_{W^-}\Big(v_d Z_{k1}^H + v_u Z_{k2}^H\Big) \tag{384}$$



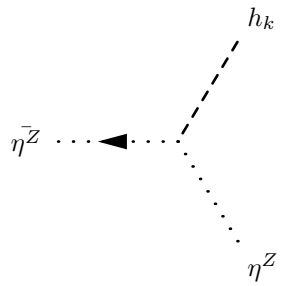
$$-\frac{i}{4}g_2\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ_{k1}^+-v_uZ_{k2}^+\Big) \tag{385}$$



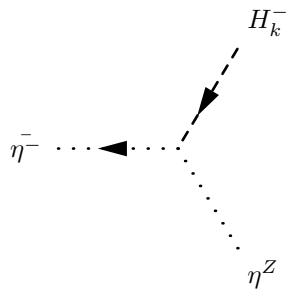
$$-\frac{i}{4}g_2^2\xi_{W^-}\Big(v_dZ_{k1}^H+v_uZ_{k2}^H\Big) \tag{386}$$



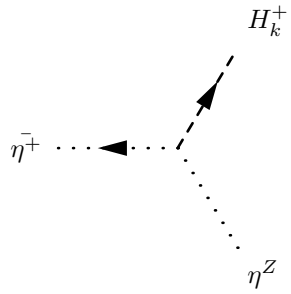
$$-\frac{i}{4}g_2\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ_{k1}^+-v_uZ_{k2}^+\Big) \tag{387}$$



$$-\frac{i}{4}\xi_Z\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)^2\Big(v_dZ^H_{k1}+v_uZ^H_{k2}\Big) \tag{388}$$



$$\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ^+_{k1}-v_uZ^+_{k2}\Big) \tag{389}$$



$$\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ^+_{k1}-v_uZ^+_{k2}\Big) \tag{390}$$

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9 Clebsch-Gordan Coefficients