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

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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

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

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

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

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

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 Down Squark**, Basis: $\left(\tilde{d}_{L,\alpha_1},\tilde{d}_{R,\alpha_2}\right),\left(\tilde{d}^*_{L,\beta_1},\tilde{d}^*_{R,\beta_2}\right)$

$$m^2_{\tilde{d}} = \begin{pmatrix} m_{\tilde{d}_L\tilde{d}_L^*} & \frac{1}{\sqrt{2}}\Big(v_dT^*_{d,11}-v_u\mu Y^*_{d,11}\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\delta_{\alpha_2\beta_1}\Big(v_dT_{d,11}-v_u\mu^*Y_{d,11}\Big) & m_{\tilde{d}_R\tilde{d}_R^*} \end{pmatrix} \tag{80}$$

$$m_{\tilde{d}_L\tilde{d}_L^*} = -\frac{1}{24}\Big(3g_2^2+g_1^2\Big)\Big(-v_u^2+v_d^2\Big)\delta_{\alpha_1\beta_1}+\frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m_{q,11}^2+v_d^2|Y_{d,11}|^2\Big) \tag{81}$$

$$m_{\tilde{d}_R\tilde{d}_R^*} = \frac{1}{12}g_1^2\Big(-v_d^2+v_u^2\Big)\delta_{\alpha_2\beta_2}+\frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m_{d,11}^2+v_d^2|Y_{d,11}|^2\Big) \tag{82}$$

This matrix is diagonalized by Z^D:

$$Z^D m_{\tilde{d}}^2 Z^{D,\dagger} = m_{2,\tilde{d}}^{dia} \tag{83}$$

with

$$\tilde{d}_{L,\alpha} = \sum_j Z_{j1}^{D,*}\tilde{d}_{j\alpha}\,, \qquad \tilde{d}_{R,\alpha} = \sum_j Z_{j2}^{D,*}\tilde{d}_{j\alpha} \tag{84}$$

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

$$m_{\tilde{u}}^2 = \begin{pmatrix} m_{\tilde{u}_L\tilde{u}_L^*} & \frac{1}{\sqrt{2}}\Big(-v_d\mu Y_{u,11}^*+v_uT_{u,11}^*\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\delta_{\alpha_2\beta_1}\Big(-v_d\mu^*Y_{u,11}+v_uT_{u,11}\Big) & m_{\tilde{u}_R\tilde{u}_R^*} \end{pmatrix} \tag{85}$$

$$m_{\tilde{u}_L\tilde{u}_L^*} = -\frac{1}{24}\Big(-3g_2^2+g_1^2\Big)\Big(-v_u^2+v_d^2\Big)\delta_{\alpha_1\beta_1}+\frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m_{q,11}^2+v_u^2|Y_{u,11}|^2\Big) \tag{86}$$

$$m_{\tilde{u}_R\tilde{u}_R^*} = \frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m_{u,11}^2+v_u^2|Y_{u,11}|^2\Big)+\frac{1}{6}g_1^2\Big(-v_u^2+v_d^2\Big)\delta_{\alpha_2\beta_2} \tag{87}$$

This matrix is diagonalized by Z^U:

$$Z^U m_{\tilde{u}}^2 Z^{U,\dagger} = m_{2,\tilde{u}}^{dia} \tag{88}$$

with

$$\tilde{u}_{L,\alpha} = \sum_j Z_{j1}^{U,*}\tilde{u}_{j\alpha}\,, \qquad \tilde{u}_{R,\alpha} = \sum_j Z_{j2}^{U,*}\tilde{u}_{j\alpha} \tag{89}$$

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

$$m_{\tilde{e}}^2 = \begin{pmatrix} m_{\tilde{e}_L\tilde{e}_L^*} & \frac{1}{\sqrt{2}}\Big(v_dT_{e,11}^*-v_u\mu Y_{e,11}^*\Big) \\ \frac{1}{\sqrt{2}}\Big(v_dT_{e,11}-v_u\mu^*Y_{e,11}\Big) & \frac{1}{2}v_d^2|Y_{e,11}|^2+\frac{1}{4}g_1^2\Big(-v_d^2+v_u^2\Big)+m_{e,11}^2 \end{pmatrix} \tag{90}$$

$$m_{\tilde{e}_L\tilde{e}_L^*} = \frac{1}{2}v_d^2|Y_{e,11}|^2+\frac{1}{8}\Big(-g_2^2+g_1^2\Big)\Big(-v_u^2+v_d^2\Big)+m_{l,11}^2 \tag{91}$$

This matrix is diagonalized by Z^E:

$$Z^E m_{\tilde{e}}^2 Z^{E,\dagger} = m_{2,\tilde{e}}^{dia} \tag{92}$$

with

$$\tilde{e}_L = \sum_j Z_{j1}^{E,*}\tilde{e}_j\,, \qquad \tilde{e}_R = \sum_j Z_{j2}^{E,*}\tilde{e}_j \tag{93}$$

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

$$m^2_{\tilde{\mu}} = \begin{pmatrix} m_{\tilde{\mu}_L\tilde{\mu}_L^*} & \frac{1}{\sqrt{2}}\Big(v_d T^*_{e,22} - v_u \mu Y^*_{e,22}\Big) \\ \frac{1}{\sqrt{2}}\Big(v_d T_{e,22} - v_u \mu^* Y_{e,22}\Big) & \frac{1}{2}v_d^2|Y_{e,22}|^2 + \frac{1}{4}g_1^2\Big(-v_d^2 + v_u^2\Big) + m^2_{e,22} \end{pmatrix} \tag{94}$$

$$m_{\tilde{\mu}_L\tilde{\mu}_L^*} = \frac{1}{2}v_d^2|Y_{e,22}|^2 + \frac{1}{8}\Big(-g_2^2 + g_1^2\Big)\Big(-v_u^2 + v_d^2\Big) + m^2_{l,22} \tag{95}$$

This matrix is diagonalized by Z^μ:

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

with

$$\tilde{\mu}_L = \sum_j Z^{\mu,*}_{j1}\tilde{\mu}_j\,, \qquad \tilde{\mu}_R = \sum_j Z^{\mu,*}_{j2}\tilde{\mu}_j \tag{97}$$

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

$$m^2_{\tilde{\tau}} = \begin{pmatrix} m_{\tilde{\tau}_L\tilde{\tau}_L^*} & \frac{1}{\sqrt{2}}\Big(v_d T^*_{e,33} - v_u \mu Y^*_{e,33}\Big) \\ \frac{1}{\sqrt{2}}\Big(v_d T_{e,33} - v_u \mu^* Y_{e,33}\Big) & \frac{1}{2}v_d^2|Y_{e,33}|^2 + \frac{1}{4}g_1^2\Big(-v_d^2 + v_u^2\Big) + m^2_{e,33} \end{pmatrix} \tag{98}$$

$$m_{\tilde{\tau}_L\tilde{\tau}_L^*} = \frac{1}{2}v_d^2|Y_{e,33}|^2 + \frac{1}{8}\Big(-g_2^2 + g_1^2\Big)\Big(-v_u^2 + v_d^2\Big) + m^2_{l,33} \tag{99}$$

This matrix is diagonalized by Z^τ:

$$Z^\tau m^2_{\tilde{\tau}} Z^{\tau,\dagger} = m^{dia}_{2,\tilde{\tau}} \tag{100}$$

with

$$\tilde{\tau}_L = \sum_j Z^{\tau,*}_{j1}\tilde{\tau}_j\,, \qquad \tilde{\tau}_R = \sum_j Z^{\tau,*}_{j2}\tilde{\tau}_j \tag{101}$$

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

$$m^2_{\tilde{s}} = \begin{pmatrix} m_{\tilde{s}_L\tilde{s}_L^*} & \frac{1}{\sqrt{2}}\Big(v_d T^*_{d,22} - v_u \mu Y^*_{d,22}\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\delta_{\alpha_2\beta_1}\Big(v_d T_{d,22} - v_u \mu^* Y_{d,22}\Big) & m_{\tilde{s}_R\tilde{s}_R^*} \end{pmatrix} \tag{102}$$

$$m_{\tilde{s}_L\tilde{s}_L^*} = -\frac{1}{24}\Big(3g_2^2 + g_1^2\Big)\Big(-v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m^2_{q,22} + v_d^2|Y_{d,22}|^2\Big) \tag{103}$$

$$m_{\tilde{s}_R\tilde{s}_R^*} = \frac{1}{12}g_1^2\Big(-v_d^2 + v_u^2\Big)\delta_{\alpha_2\beta_2} + \frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m^2_{d,22} + v_d^2|Y_{d,22}|^2\Big) \tag{104}$$

This matrix is diagonalized by Z^S:

$$Z^S m^2_{\tilde{s}} Z^{S,\dagger} = m^{dia}_{2,\tilde{s}} \tag{105}$$

with

$$\tilde{s}_{L,\alpha} = \sum_j Z^{S,*}_{j1}\tilde{s}_{j\alpha}\,, \qquad \tilde{s}_{R,\alpha} = \sum_j Z^{S,*}_{j2}\tilde{s}_{j\alpha} \tag{106}$$

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

$$m^2_{\tilde{c}} = \begin{pmatrix} m_{\tilde{c}_L\tilde{c}^*_L} & \frac{1}{\sqrt{2}}\Big(- v_d\mu Y^*_{u,22} + v_u T^*_{u,22}\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\delta_{\alpha_2\beta_1}\Big(- v_d\mu^* Y_{u,22} + v_u T_{u,22}\Big) & m_{\tilde{c}_R\tilde{c}^*_R} \end{pmatrix} \tag{107}$$

$$m_{\tilde{c}_L\tilde{c}^*_L} = -\frac{1}{24}\Big(- 3g_2^2 + g_1^2\Big)\Big(- v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m^2_{q,22} + v_u^2|Y_{u,22}|^2\Big) \tag{108}$$

$$m_{\tilde{c}_R\tilde{c}^*_R} = \frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m^2_{u,22} + v_u^2|Y_{u,22}|^2\Big) + \frac{1}{6}g_1^2\Big(- v_u^2 + v_d^2\Big)\delta_{\alpha_2\beta_2} \tag{109}$$

This matrix is diagonalized by Z^C:

$$Z^C m^2_{\tilde{c}} Z^{C,\dagger} = m^{dia}_{2,\tilde{c}} \tag{110}$$

with

$$\tilde{c}_{L,\alpha} = \sum_j Z^{C,*}_{j1}\tilde{c}_{j\alpha}\,, \qquad \tilde{c}_{R,\alpha} = \sum_j Z^{C,*}_{j2}\tilde{c}_{j\alpha} \tag{111}$$

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

$$m^2_{\tilde{b}} = \begin{pmatrix} m_{\tilde{b}_L\tilde{b}^*_L} & \frac{1}{\sqrt{2}}\Big(v_d T^*_{d,33} - v_u\mu Y^*_{d,33}\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\delta_{\alpha_2\beta_1}\Big(v_d T_{d,33} - v_u\mu^* Y_{d,33}\Big) & m_{\tilde{b}_R\tilde{b}^*_R} \end{pmatrix} \tag{112}$$

$$m_{\tilde{b}_L\tilde{b}^*_L} = -\frac{1}{24}\Big(3g_2^2 + g_1^2\Big)\Big(- v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m^2_{q,33} + v_d^2|Y_{d,33}|^2\Big) \tag{113}$$

$$m_{\tilde{b}_R\tilde{b}^*_R} = \frac{1}{12}g_1^2\Big(- v_d^2 + v_u^2\Big)\delta_{\alpha_2\beta_2} + \frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m^2_{d,33} + v_d^2|Y_{d,33}|^2\Big) \tag{114}$$

This matrix is diagonalized by Z^B:

$$Z^B m^2_{\tilde{b}} Z^{B,\dagger} = m^{dia}_{2,\tilde{b}} \tag{115}$$

with

$$\tilde{b}_{L,\alpha} = \sum_j Z^{B,*}_{j1}\tilde{b}_{j\alpha}\,, \qquad \tilde{b}_{R,\alpha} = \sum_j Z^{B,*}_{j2}\tilde{b}_{j\alpha} \tag{116}$$

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

$$m^2_{\tilde{t}} = \begin{pmatrix} m_{\tilde{t}_L\tilde{t}^*_L} & \frac{1}{\sqrt{2}}\Big(- v_d\mu Y^*_{u,33} + v_u T^*_{u,33}\Big)\delta_{\alpha_1\beta_2} \\ \frac{1}{\sqrt{2}}\delta_{\alpha_2\beta_1}\Big(- v_d\mu^* Y_{u,33} + v_u T_{u,33}\Big) & m_{\tilde{t}_R\tilde{t}^*_R} \end{pmatrix} \tag{117}$$

$$m_{\tilde{t}_L\tilde{t}^*_L} = -\frac{1}{24}\Big(- 3g_2^2 + g_1^2\Big)\Big(- v_u^2 + v_d^2\Big)\delta_{\alpha_1\beta_1} + \frac{1}{2}\delta_{\alpha_1\beta_1}\Big(2m^2_{q,33} + v_u^2|Y_{u,33}|^2\Big) \tag{118}$$

$$m_{\tilde{t}_R\tilde{t}_R^*} = \frac{1}{2}\delta_{\alpha_2\beta_2}\Big(2m_{u,33}^2 + v_u^2|Y_{u,33}|^2\Big) + \frac{1}{6}g_1^2\Big(-v_u^2 + v_d^2\Big)\delta_{\alpha_2\beta_2} \tag{119}$$

This matrix is diagonalized by Z^T:

$$Z^T m_{\tilde{t}}^2 Z^{T,\dagger} = m_{2,\tilde{t}}^{dia} \tag{120}$$

with

$$\tilde{t}_{L,\alpha} = \sum_j Z_{j1}^{T,*}\tilde{t}_{j\alpha}\,, \qquad \tilde{t}_{R,\alpha} = \sum_j Z_{j2}^{T,*}\tilde{t}_{j\alpha} \tag{121}$$

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

$$m_h^2 = \begin{pmatrix} \frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(3v_d^2 - v_u^2\Big) + m_{H_d}^2 + |\mu|^2 & -\frac{1}{4}\Big(g_1^2+g_2^2\Big)v_d v_u - \Re\Big(B_\mu\Big) \\ -\frac{1}{4}\Big(g_1^2+g_2^2\Big)v_d v_u - \Re\Big(B_\mu\Big) & -\frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(-3v_u^2 + v_d^2\Big) + m_{H_u}^2 + |\mu|^2 \end{pmatrix} \tag{122}$$

This matrix is diagonalized by Z^H:

$$Z^H m_h^2 Z^{H,\dagger} = m_{2,h}^{dia} \tag{123}$$

with

$$\phi_d = \sum_j Z_{j1}^H h_j\,, \qquad \phi_u = \sum_j Z_{j2}^H h_j \tag{124}$$

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

$$m_{A^0}^2 = \begin{pmatrix} \frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(-v_u^2 + v_d^2\Big) + m_{H_d}^2 + |\mu|^2 & \Re\Big(B_\mu\Big) \\ \Re\Big(B_\mu\Big) & -\frac{1}{8}\Big(g_1^2+g_2^2\Big)\Big(-v_u^2 + v_d^2\Big) + m_{H_u}^2 + |\mu|^2 \end{pmatrix} + \xi_Z m^2(Z) \tag{125}$$

Gauge fixing contributions:

$$m^2(\xi_Z) = \begin{pmatrix} \frac{1}{4}v_d^2\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2 & -\frac{1}{4}v_d v_u\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2 \\ -\frac{1}{4}v_d v_u\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2 & \frac{1}{4}v_u^2\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2 \end{pmatrix} \tag{126}$$

This matrix is diagonalized by Z^A:

$$Z^A m_{A^0}^2 Z^{A,\dagger} = m_{2,A^0}^{dia} \tag{127}$$

with

$$\sigma_d = \sum_j Z_{j1}^A A_j^0\,, \qquad \sigma_u = \sum_j Z_{j2}^A A_j^0 \tag{128}$$

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

$$m^2_{H^-} = \begin{pmatrix} m_{H_d^- H_d^{-,*}} & \frac{1}{4}g_2^2 v_d v_u + B_\mu^* \\ \frac{1}{4}g_2^2 v_d v_u + B_\mu & m_{H_u^{+,*} H_u^+} \end{pmatrix} + \xi_{W^-} m^2(W^-) \tag{129}$$

$$m_{H_d^- H_d^{-,*}} = \frac{1}{8}\Big(g_1^2\Big(-v_u^2 + v_d^2\Big) + g_2^2\Big(v_d^2 + v_u^2\Big)\Big) + m_{H_d}^2 + |\mu|^2 \tag{130}$$

$$m_{H_u^{+,*} H_u^+} = \frac{1}{8}\Big(g_1^2\Big(-v_d^2 + v_u^2\Big) + g_2^2\Big(v_d^2 + v_u^2\Big)\Big) + m_{H_u}^2 + |\mu|^2 \tag{131}$$

Gauge fixing contributions:

$$m^2(\xi_{W^-}) = \begin{pmatrix} \frac{1}{4}g_2^2 v_d^2 & -\frac{1}{4}g_2^2 v_d v_u \\ -\frac{1}{4}g_2^2 v_d v_u & \frac{1}{4}g_2^2 v_u^2 \end{pmatrix} \tag{132}$$

This matrix is diagonalized by Z^+:

$$Z^+ m^2_{H^-} Z^{+,\dagger} = m^{dia}_{2,H^-} \tag{133}$$

with

$$H_d^- = \sum_j Z^+_{j1} H_j^- \,, \qquad H_u^+ = \sum_j Z^+_{j2} H_j^+ \tag{134}$$

4.2.2 Mass Matrices for Fermions

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

$$m_{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & -\frac{1}{2}g_1 v_d & \frac{1}{2}g_1 v_u \\ 0 & M_2 & \frac{1}{2}g_2 v_d & -\frac{1}{2}g_2 v_u \\ -\frac{1}{2}g_1 v_d & \frac{1}{2}g_2 v_d & 0 & -\mu \\ \frac{1}{2}g_1 v_u & -\frac{1}{2}g_2 v_u & -\mu & 0 \end{pmatrix} \tag{135}$$

This matrix is diagonalized by N:

$$N^* m_{\tilde{\chi}^0} N^\dagger = m^{dia}_{\tilde{\chi}^0} \tag{136}$$

with

$$\lambda_{\tilde{B}} = \sum_j N^*_{j1} \lambda_j^0 \,, \qquad \tilde{W}^0 = \sum_j N^*_{j2} \lambda_j^0 \,, \qquad \tilde{H}_d^0 = \sum_j N^*_{j3} \lambda_j^0 \tag{137}$$

$$\tilde{H}_u^0 = \sum_j N^*_{j4} \lambda_j^0 \tag{138}$$

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

$$m_{\tilde{\chi}^-} = \begin{pmatrix} M_2 & \frac{1}{\sqrt{2}}g_2 v_u \\ \frac{1}{\sqrt{2}}g_2 v_d & \mu \end{pmatrix} \tag{139}$$

This matrix is diagonalized by U and V

$$U^* m_{\tilde{\chi}^-} V^\dagger = m^{dia}_{\tilde{\chi}^-} \tag{140}$$

with

$$\tilde{W}^- = \sum_{t_2} U^*_{j1} \lambda^-_j \,, \qquad \tilde{H}^-_d = \sum_{t_2} U^*_{j2} \lambda^-_j \tag{141}$$

$$\tilde{W}^+ = \sum_{t_2} V^*_{1j} \lambda^+_j \,, \qquad \tilde{H}^+_u = \sum_{t_2} V^*_{2j} \lambda^+_j \tag{142}$$

5 Vacuum Expectation Values

$$H^0_d = \frac{1}{\sqrt{2}}\phi_d + \frac{1}{\sqrt{2}} v_d + i \frac{1}{\sqrt{2}} \sigma_d \tag{143}$$

$$H^0_u = \frac{1}{\sqrt{2}}\phi_u + \frac{1}{\sqrt{2}} v_u + i \frac{1}{\sqrt{2}} \sigma_u \tag{144}$$

6 Flavor decomposition

$$d_R \to d_R, s_R, b_R \tag{145}$$

$$d_L \to d_L, s_L, b_L \tag{146}$$

$$u_L \to u_L, c_L, t_L \tag{147}$$

$$u_R \to u_R, c_R, t_R \tag{148}$$

$$\nu \to \nu_e, \nu_\mu, \nu_\tau \tag{149}$$

$$\tilde{d}_R \to \tilde{d}_R, \tilde{s}_R, \tilde{b}_R \tag{150}$$

$$\tilde{d}_L \to \tilde{d}_L, \tilde{s}_L, \tilde{b}_L \tag{151}$$

$$\tilde{u}_L \to \tilde{u}_L, \tilde{c}_L, \tilde{t}_L \tag{152}$$

$$\tilde{u}_R \to \tilde{u}_R, \tilde{c}_R, \tilde{t}_R \tag{153}$$

$$e_L \to e_L, \mu_L, \tau_L \tag{154}$$

$$e_R \to e_R, \mu_R, \tau_R \tag{155}$$

$$\tilde{e}_R \to \tilde{e}_R, \tilde{\mu}_R, \tilde{\tau}_R \tag{156}$$

$$\tilde{e}_L \to \tilde{e}_L, \tilde{\mu}_L, \tilde{\tau}_L \tag{157}$$

$$\tilde{\nu}_L \to \tilde{\nu}_e, \tilde{\nu}_\mu, \tilde{\nu}_\tau \tag{158}$$

7 Tadpole Equations

$$\frac{\partial V}{\partial \phi_d} = -\frac{1}{2} v_u \Big(B_\mu + B^*_\mu \Big) + \frac{1}{8} \Big(g_1^2 + g_2^2 \Big) v_d \Big(-v_u + v_d \Big) \Big(v_d + v_u \Big) + v_d \Big(m^2_{H_d} + |\mu|^2 \Big) \tag{159}$$

$$\frac{\partial V}{\partial \phi_u} = \frac{1}{8} \Big(g_1^2 + g_2^2 \Big) v_u \Big(-v_d^2 + v_u^2 \Big) - v_d \Re \Big(B_\mu \Big) + v_u \Big(m^2_{H_u} + |\mu|^2 \Big) \tag{160}$$

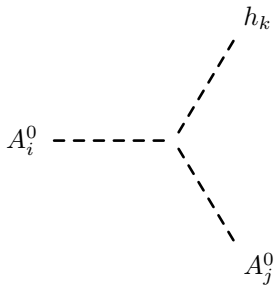
8 Particle content for eigenstates 'EWSB'

Name	Type	complex/real	Generations	Indices
$\tilde{\nu}_e$	Scalar	complex	1	
$\tilde{\nu}_\mu$	Scalar	complex	1	
$\tilde{\nu}_\tau$	Scalar	complex	1	
$\tilde{d}$	Scalar	complex	2	generation, 2, color, 3
$\tilde{u}$	Scalar	complex	2	generation, 2, color, 3
$\tilde{e}$	Scalar	complex	2	generation, 2
$\tilde{\mu}$	Scalar	complex	2	generation, 2
$\tilde{\tau}$	Scalar	complex	2	generation, 2
$\tilde{s}$	Scalar	complex	2	generation, 2, color, 3
$\tilde{c}$	Scalar	complex	2	generation, 2, color, 3
$\tilde{b}$	Scalar	complex	2	generation, 2, color, 3
$\tilde{t}$	Scalar	complex	2	generation, 2, color, 3
h	Scalar	real	2	generation, 2
A^0	Scalar	real	2	generation, 2
H^-	Scalar	complex	2	generation, 2
$\tilde{g}$	Fermion	Majorana	1	color, 8
d	Fermion	Dirac	1	color, 3
s	Fermion	Dirac	1	color, 3
b	Fermion	Dirac	1	color, 3
u	Fermion	Dirac	1	color, 3
c	Fermion	Dirac	1	color, 3
t	Fermion	Dirac	1	color, 3
ν_e	Fermion	Dirac	1	
ν_μ	Fermion	Dirac	1	
ν_τ	Fermion	Dirac	1	
e	Fermion	Dirac	1	
m	Fermion	Dirac	1	
τ	Fermion	Dirac	1	
$\tilde{\chi}^0$	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

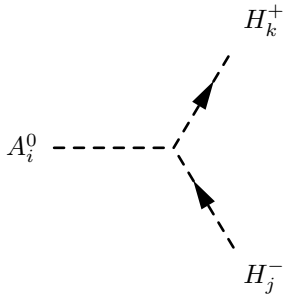
Z	Vector	real	1	lorentz, 4
W^-	Vector	complex	1	lorentz, 4
η^G	Ghost	real	1	color, 8
η^γ	Ghost	real	1	
η^Z	Ghost	real	1	
η^-	Ghost	complex	1	
η^+	Ghost	complex	1	

9 Interactions for eigenstates 'EWSB'

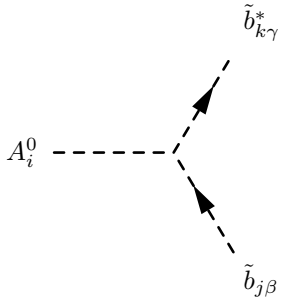
9.1 Three Scalar-Interaction



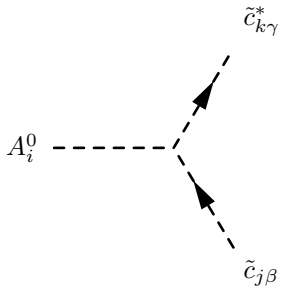
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\Big)\Big(v_d Z_{k1}^H - v_u Z_{k2}^H\Big) \tag{161}$$



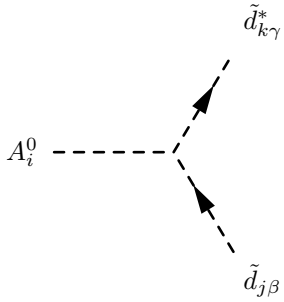
$$\frac{1}{4}g_2^2\Big(v_d Z_{i2}^A + v_u Z_{i1}^A\Big)\Big(-Z_{j1}^+ Z_{k2}^+ + Z_{j2}^+ Z_{k1}^+\Big) \tag{162}$$



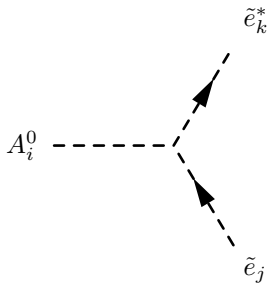
$$-\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\Big(-Z^{B,*}_{j1}Z^{B}_{k2}\Big(\mu^* Y_{d,33}Z^{A}_{i2}+Z^{A}_{i1}T_{d,33}\Big)+Z^{B,*}_{j2}\Big(\mu Y^*_{d,33}Z^{A}_{i2}+T^*_{d,33}Z^{A}_{i1}\Big)Z^{B}_{k1}\Big) \tag{163}$$



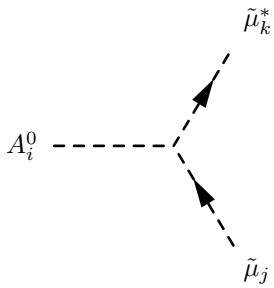
$$-\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\Big(\mu Y^*_{u,22}Z^{C,*}_{j2}Z^{A}_{i1}Z^{C}_{k1}-Z^{C,*}_{j1}Z^{C}_{k2}\Big(\mu^* Y_{u,22}Z^{A}_{i1}+Z^{A}_{i2}T_{u,22}\Big)+Z^{C,*}_{j2}T^*_{u,22}Z^{A}_{i2}Z^{C}_{k1}\Big) \tag{164}$$



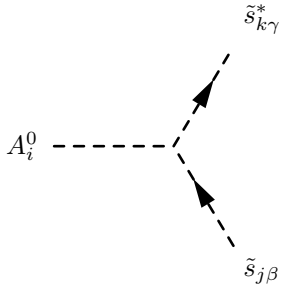
$$-\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\Big(-Z^{D,*}_{j1}Z^{D}_{k2}\Big(\mu^* Y_{d,11}Z^{A}_{i2}+Z^{A}_{i1}T_{d,11}\Big)+Z^{D,*}_{j2}\Big(\mu Y^*_{d,11}Z^{A}_{i2}+T^*_{d,11}Z^{A}_{i1}\Big)Z^{D}_{k1}\Big) \tag{165}$$



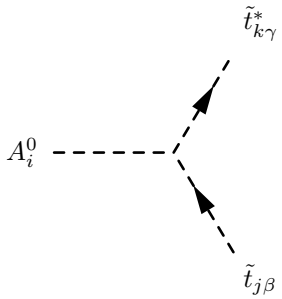
$$-\frac{1}{\sqrt{2}}\Big(-Z_{j1}^{E,*}Z_{k2}^{E}\Big(\mu^* Y_{e,11}Z_{i2}^{A}+Z_{i1}^{A}T_{e,11}\Big)+Z_{j2}^{E,*}\Big(\mu Y_{e,11}^{*}Z_{i2}^{A}+T_{e,11}^{*}Z_{i1}^{A}\Big)Z_{k1}^{E}\Big) \tag{166}$$



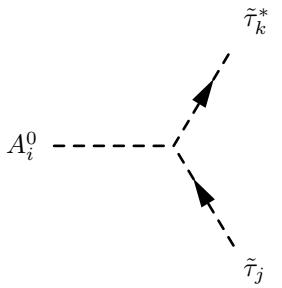
$$-\frac{1}{\sqrt{2}}\Big(-Z_{j1}^{\mu,*}Z_{k2}^{\mu}\Big(\mu^* Y_{e,22}Z_{i2}^{A}+Z_{i1}^{A}T_{e,22}\Big)+Z_{j2}^{\mu,*}\Big(\mu Y_{e,22}^{*}Z_{i2}^{A}+T_{e,22}^{*}Z_{i1}^{A}\Big)Z_{k1}^{\mu}\Big) \tag{167}$$



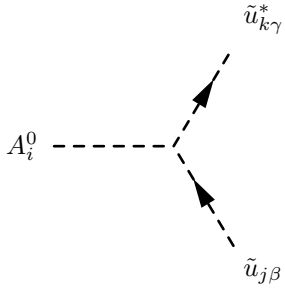
$$-\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\Big(-Z_{j1}^{S,*}Z_{k2}^{S}\Big(\mu^* Y_{d,22}Z_{i2}^{A}+Z_{i1}^{A}T_{d,22}\Big)+Z_{j2}^{S,*}\Big(\mu Y_{d,22}^{*}Z_{i2}^{A}+T_{d,22}^{*}Z_{i1}^{A}\Big)Z_{k1}^{S}\Big) \tag{168}$$



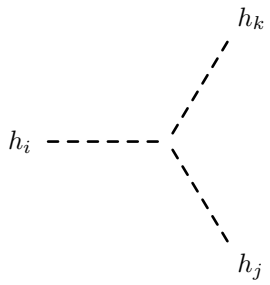
$$-\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\Big(\mu Y^*_{u,33}Z^{T,*}_{j2}Z^A_{i1}Z^T_{k1} - Z^{T,*}_{j1}Z^T_{k2}\Big(\mu^* Y_{u,33}Z^A_{i1} + Z^A_{i2}T_{u,33}\Big) + Z^{T,*}_{j2}T^*_{u,33}Z^A_{i2}Z^T_{k1}\Big) \tag{169}$$



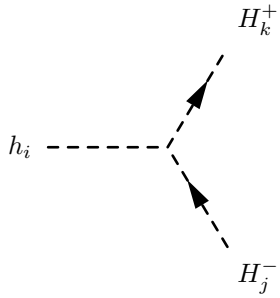
$$-\frac{1}{\sqrt{2}}\Big(-Z^{\tau,*}_{j1}Z^\tau_{k2}\Big(\mu^* Y_{e,33}Z^A_{i2} + Z^A_{i1}T_{e,33}\Big) + Z^{\tau,*}_{j2}\Big(\mu Y^*_{e,33}Z^A_{i2} + T^*_{e,33}Z^A_{i1}\Big)Z^\tau_{k1}\Big) \tag{170}$$



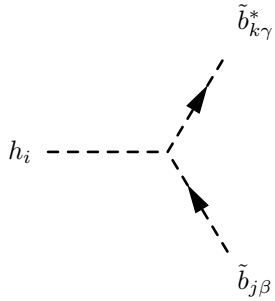
$$-\frac{1}{\sqrt{2}}\delta_{\beta\gamma}\Big(\mu Y^*_{u,11}Z^{U,*}_{j2}Z^A_{i1}Z^U_{k1} - Z^{U,*}_{j1}Z^U_{k2}\Big(\mu^* Y_{u,11}Z^A_{i1} + Z^A_{i2}T_{u,11}\Big) + Z^{U,*}_{j2}T^*_{u,11}Z^A_{i2}Z^U_{k1}\Big) \tag{171}$$



$$\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i2}^H\Big(Z_{j1}^H\Big(v_dZ_{k2}^H+v_uZ_{k1}^H\Big)+Z_{j2}^H\Big(-3v_uZ_{k2}^H+v_dZ_{k1}^H\Big)\Big)$$
$$+Z_{i1}^H\Big(Z_{j1}^H\Big(-3v_dZ_{k1}^H+v_uZ_{k2}^H\Big)+Z_{j2}^H\Big(v_dZ_{k2}^H+v_uZ_{k1}^H\Big)\Big)\Big) \tag{172}$$

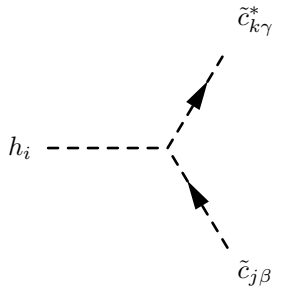


$$\frac{i}{4}\Big(-Z_{i1}^H\Big(Z_{j1}^+\Big(\Big(g_1^2+g_2^2\Big)v_dZ_{k1}^++g_2^2v_uZ_{k2}^+\Big)+Z_{j2}^+\Big(\Big(-g_1^2+g_2^2\Big)v_dZ_{k2}^++g_2^2v_uZ_{k1}^+\Big)\Big)$$
$$+Z_{i2}^H\Big(Z_{j1}^+\Big(\Big(-g_2^2+g_1^2\Big)v_uZ_{k1}^+-g_2^2v_dZ_{k2}^+\Big)-Z_{j2}^+\Big(\Big(g_1^2+g_2^2\Big)v_uZ_{k2}^++g_2^2v_dZ_{k1}^+\Big)\Big)\Big) \tag{173}$$

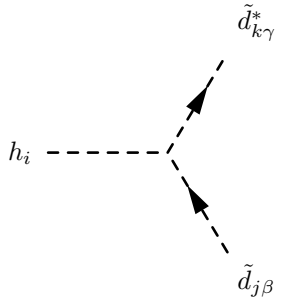


$$\frac{i}{12}\delta_{\beta\gamma}\Big(-2Z_{j2}^{B,*}\Big(-3\sqrt{2}\mu Y_{d,33}^*Z_{k1}^BZ_{i2}^H+3\sqrt{2}T_{d,33}^*Z_{k1}^BZ_{i1}^H+Z_{k2}^B\Big(g_1^2v_uZ_{i2}^H-v_d\Big(-6|Y_{d,33}|^2+g_1^2\Big)Z_{i1}^H\Big)\Big)$$

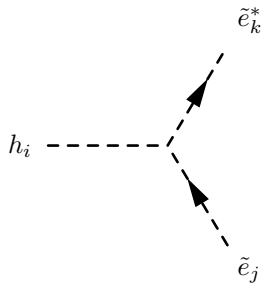
$$+ Z_{j1}^{B,*}\Big(Z_{k1}^{B}\Big(-\Big(3g_2^2+g_1^2\Big)v_u Z_{i2}^{H}+v_d\Big(-12|Y_{d,33}|^2+3g_2^2+g_1^2\Big)Z_{i1}^{H}\Big)$$
$$+ 6\sqrt{2}Z_{k2}^{B}\Big(\mu^* Y_{d,33}Z_{i2}^{H}-Z_{i1}^{H}T_{d,33}\Big)\Big)\Big) \tag{174}$$



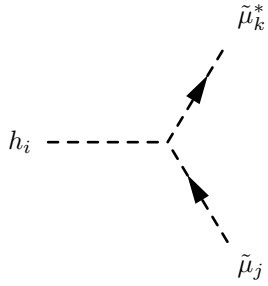
$$\frac{i}{12}\delta_{\beta\gamma}\Big(2Z_{j2}^{C,*}\Big(-3\sqrt{2}T_{u,22}^{*}Z_{k1}^{C}Z_{i2}^{H}+2g_1^2Z_{k2}^{C}\Big(-v_d Z_{i1}^{H}+v_u Z_{i2}^{H}\Big)$$
$$+ 3Y_{u,22}^{*}\Big(-2v_u Y_{u,22}Z_{k2}^{C}Z_{i2}^{H}+\sqrt{2}\mu Z_{k1}^{C}Z_{i1}^{H}\Big)\Big)$$
$$+ Z_{j1}^{C,*}\Big(Z_{k1}^{C}\Big(\Big(-3g_2^2+g_1^2\Big)v_d Z_{i1}^{H}-v_u\Big(12|Y_{u,22}|^2-3g_2^2+g_1^2\Big)Z_{i2}^{H}\Big)$$
$$+ 6\sqrt{2}Z_{k2}^{C}\Big(\mu^* Y_{u,22}Z_{i1}^{H}-Z_{i2}^{H}T_{u,22}\Big)\Big)\Big) \tag{175}$$



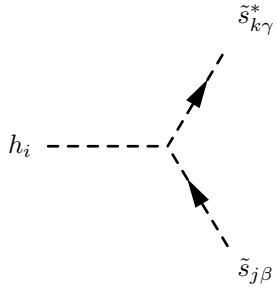
$$\frac{i}{12}\delta_{\beta\gamma}\Big(-2Z_{j2}^{D,*}\Big(-3\sqrt{2}\mu Y_{d,11}^{*}Z_{k1}^{D}Z_{i2}^{H}+3\sqrt{2}T_{d,11}^{*}Z_{k1}^{D}Z_{i1}^{H}+Z_{k2}^{D}\Big(g_1^2v_u Z_{i2}^{H}-v_d\Big(-6|Y_{d,11}|^2+g_1^2\Big)Z_{i1}^{H}\Big)\Big)$$
$$+ Z_{j1}^{D,*}\Big(Z_{k1}^{D}\Big(-\Big(3g_2^2+g_1^2\Big)v_u Z_{i2}^{H}+v_d\Big(-12|Y_{d,11}|^2+3g_2^2+g_1^2\Big)Z_{i1}^{H}\Big)$$
$$+ 6\sqrt{2}Z_{k2}^{D}\Big(\mu^* Y_{d,11}Z_{i2}^{H}-Z_{i1}^{H}T_{d,11}\Big)\Big)\Big) \tag{176}$$



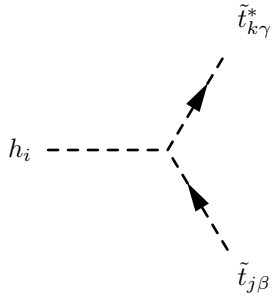
$$\frac{i}{4}\Big(- 2Z_{j2}^{E,*}\Big(- \sqrt{2}\mu Y_{e,11}^* Z_{k1}^E Z_{i2}^H + \sqrt{2}T_{e,11}^* Z_{k1}^E Z_{i1}^H + Z_{k2}^E\Big(g_1^2 v_u Z_{i2}^H - v_d\Big(- 2|Y_{e,11}|^2 + g_1^2\Big)Z_{i1}^H\Big)\Big)$$
$$+ Z_{j1}^{E,*}\Big(Z_{k1}^E\Big(\Big(- g_2^2 + g_1^2\Big)v_u Z_{i2}^H + v_d\Big(- 4|Y_{e,11}|^2 - g_1^2 + g_2^2\Big)Z_{i1}^H\Big)$$
$$+ 2\sqrt{2}Z_{k2}^E\Big(\mu^* Y_{e,11} Z_{i2}^H - Z_{i1}^H T_{e,11}\Big)\Big)\Big) \tag{177}$$



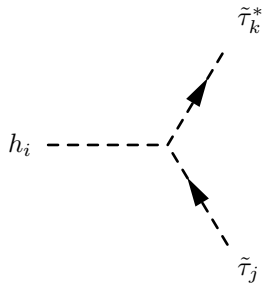
$$\frac{i}{4}\Big(- 2Z_{j2}^{\mu,*}\Big(\sqrt{2}T_{e,22}^* Z_{i1}^H Z_{k1}^\mu + g_1^2\Big(- v_d Z_{i1}^H + v_u Z_{i2}^H\Big)Z_{k2}^\mu$$
$$+ Y_{e,22}^*\Big(2v_d Y_{e,22} Z_{i1}^H Z_{k2}^\mu - \sqrt{2}\mu Z_{i2}^H Z_{k1}^\mu\Big)\Big)$$
$$+ Z_{j1}^{\mu,*}\Big(Z_{i2}^H\Big(2\sqrt{2}\mu^* Y_{e,22} Z_{k2}^\mu + \Big(- g_2^2 + g_1^2\Big)v_u Z_{k1}^\mu\Big)$$
$$- Z_{i1}^H\Big(2\sqrt{2}Z_{k2}^\mu T_{e,22} + v_d\Big(4|Y_{e,22}|^2 - g_2^2 + g_1^2\Big)Z_{k1}^\mu\Big)\Big)\Big) \tag{178}$$



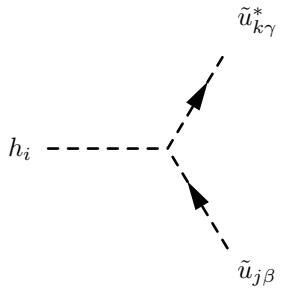
$$\frac{i}{12}\delta_{\beta\gamma}\Big(-2Z_{j2}^{S,*}\Big(3\sqrt{2}T_{d,22}^{*}Z_{i1}^{H}Z_{k1}^{S}+g_1^2\Big(-v_dZ_{i1}^{H}+v_uZ_{i2}^{H}\Big)Z_{k2}^{S}$$
$$+Y_{d,22}^{*}\Big(-3\sqrt{2}\mu Z_{i2}^{H}Z_{k1}^{S}+6v_dY_{d,22}Z_{i1}^{H}Z_{k2}^{S}\Big)\Big)$$
$$+Z_{j1}^{S,*}\Big(-Z_{i2}^{H}\Big(\Big(3g_2^2+g_1^2\Big)v_uZ_{k1}^{S}-6\sqrt{2}\mu^{*}Y_{d,22}Z_{k2}^{S}\Big)$$
$$+Z_{i1}^{H}\Big(-6\sqrt{2}Z_{k2}^{S}T_{d,22}+v_d\Big(-12|Y_{d,22}|^2+3g_2^2+g_1^2\Big)Z_{k1}^{S}\Big)\Big)\Big) \tag{179}$$



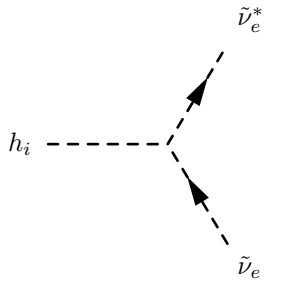
$$\frac{i}{12}\delta_{\beta\gamma}\Big(2Z_{j2}^{T,*}\Big(-3\sqrt{2}T_{u,33}^{*}Z_{i2}^{H}Z_{k1}^{T}+2g_1^2\Big(-v_dZ_{i1}^{H}+v_uZ_{i2}^{H}\Big)Z_{k2}^{T}$$
$$+3Y_{u,33}^{*}\Big(-2v_uY_{u,33}Z_{i2}^{H}Z_{k2}^{T}+\sqrt{2}\mu Z_{i1}^{H}Z_{k1}^{T}\Big)\Big)$$
$$+Z_{j1}^{T,*}\Big(Z_{i1}^{H}\Big(\Big(-3g_2^2+g_1^2\Big)v_dZ_{k1}^{T}+6\sqrt{2}\mu^{*}Y_{u,33}Z_{k2}^{T}\Big)$$
$$-Z_{i2}^{H}\Big(6\sqrt{2}Z_{k2}^{T}T_{u,33}+v_u\Big(12|Y_{u,33}|^2-3g_2^2+g_1^2\Big)Z_{k1}^{T}\Big)\Big)\Big) \tag{180}$$



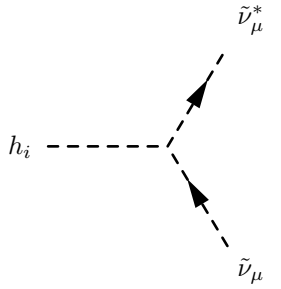
$$\frac{i}{4}\Big(-2Z_{j2}^{\tau,*}\Big(\sqrt{2}T_{e,33}^{*}Z_{i1}^{H}Z_{k1}^{\tau}+g_1^2\Big(-v_dZ_{i1}^{H}+v_uZ_{i2}^{H}\Big)Z_{k2}^{\tau}$$
$$+Y_{e,33}^{*}\Big(2v_dY_{e,33}Z_{i1}^{H}Z_{k2}^{\tau}-\sqrt{2}\mu Z_{i2}^{H}Z_{k1}^{\tau}\Big)\Big)$$
$$+Z_{j1}^{\tau,*}\Big(Z_{i2}^{H}\Big(2\sqrt{2}\mu^{*}Y_{e,33}Z_{k2}^{\tau}+\Big(-g_2^2+g_1^2\Big)v_uZ_{k1}^{\tau}\Big)$$
$$-Z_{i1}^{H}\Big(2\sqrt{2}Z_{k2}^{\tau}T_{e,33}+v_d\Big(4|Y_{e,33}|^2-g_2^2+g_1^2\Big)Z_{k1}^{\tau}\Big)\Big)\Big) \tag{181}$$



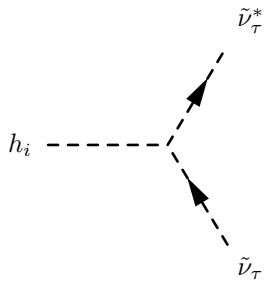
$$\begin{aligned}
&\frac{i}{12}\delta_{\beta\gamma}\Big(2Z^{U,*}_{j2}\Big(-3\sqrt{2}T^*_{u,11}Z^H_{i2}Z^U_{k1}+2g_1^2\Big(-v_dZ^H_{i1}+v_uZ^H_{i2}\Big)Z^U_{k2}\\
&+3Y^*_{u,11}\Big(-2v_uY_{u,11}Z^H_{i2}Z^U_{k2}+\sqrt{2}\mu Z^H_{i1}Z^U_{k1}\Big)\Big)\\
&+Z^{U,*}_{j1}\Big(Z^H_{i1}\Big(\Big(-3g_2^2+g_1^2\Big)v_dZ^U_{k1}+6\sqrt{2}\mu^*Y_{u,11}Z^U_{k2}\Big)\\
&-Z^H_{i2}\Big(6\sqrt{2}Z^U_{k2}T_{u,11}+v_u\Big(12|Y_{u,11}|^2-3g_2^2+g_1^2\Big)Z^U_{k1}\Big)\Big)\Big)
\end{aligned} \tag{182}$$



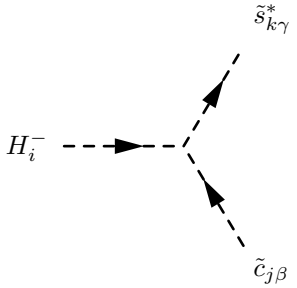
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(v_dZ^H_{i1}-v_uZ^H_{i2}\Big) \tag{183}$$



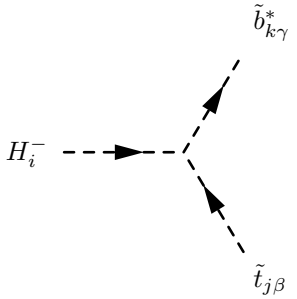
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(v_d Z_{i1}^H - v_u Z_{i2}^H\Big) \tag{184}$$



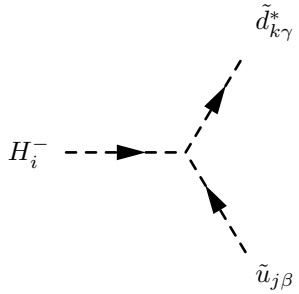
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(v_d Z_{i1}^H - v_u Z_{i2}^H\Big) \tag{185}$$



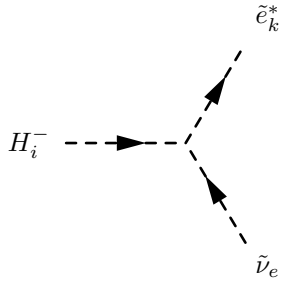
$$\begin{aligned}
&-\frac{i}{4}\delta_{\beta\gamma}\Big(-2Z_{j2}^{C,*}\Big(2T_{u,22}^* Z_{i2}^+ Z_{k1}^S + Y_{u,22}^*\Big(\sqrt{2}v_d Y_{d,22} Z_{i2}^+ Z_{k2}^S + Z_{i1}^+\Big(2\mu Z_{k1}^S + \sqrt{2}v_u Y_{d,22} Z_{k2}^S\Big)\Big)\Big)\\
&+ Z_{j1}^{C,*}\Big(Z_{i2}^+\Big(-4\mu^* Y_{d,22} Z_{k2}^S + \sqrt{2}v_u\Big(-2|Y_{u,22}|^2 + g_2^2\Big)Z_{k1}^S\Big)\\
&+ Z_{i1}^+\Big(-4Z_{k2}^S T_{d,22} + \sqrt{2}v_d\Big(-2|Y_{d,22}|^2 + g_2^2\Big)Z_{k1}^S\Big)\Big)\Big)
\end{aligned} \tag{186}$$



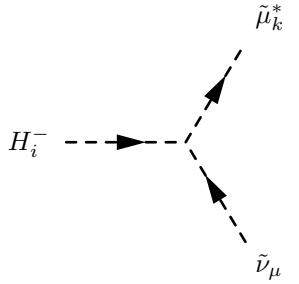
$$\frac{i}{4}\delta_{\beta\gamma}\Big(2Z^{T,*}_{j2}\Big(2T^*_{u,33}Z^B_{k1}Z^+_{i2}+Y^*_{u,33}\Big(2\mu Z^B_{k1}Z^+_{i1}+\sqrt{2}Y_{d,33}Z^B_{k2}\Big(v_dZ^+_{i2}+v_uZ^+_{i1}\Big)\Big)\Big)$$
$$+Z^{T,*}_{j1}\Big(4Z^B_{k2}\Big(\mu^*Y_{d,33}Z^+_{i2}+Z^+_{i1}T_{d,33}\Big)-\sqrt{2}Z^B_{k1}\Big(v_d\Big(-2|Y_{d,33}|^2+g_2^2\Big)Z^+_{i1}+v_u\Big(-2|Y_{u,33}|^2+g_2^2\Big)Z^+_{i2}\Big)\Big)\Big) \tag{187}$$



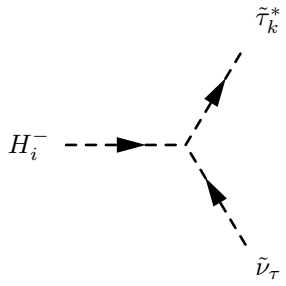
$$\frac{i}{4}\delta_{\beta\gamma}\Big(2Z^{U,*}_{j2}\Big(2T^*_{u,11}Z^D_{k1}Z^+_{i2}+Y^*_{u,11}\Big(2\mu Z^D_{k1}Z^+_{i1}+\sqrt{2}Y_{d,11}Z^D_{k2}\Big(v_dZ^+_{i2}+v_uZ^+_{i1}\Big)\Big)\Big)$$
$$+Z^{U,*}_{j1}\Big(4Z^D_{k2}\Big(\mu^*Y_{d,11}Z^+_{i2}+Z^+_{i1}T_{d,11}\Big)-\sqrt{2}Z^D_{k1}\Big(v_d\Big(-2|Y_{d,11}|^2+g_2^2\Big)Z^+_{i1}+v_u\Big(-2|Y_{u,11}|^2+g_2^2\Big)Z^+_{i2}\Big)\Big)\Big) \tag{188}$$



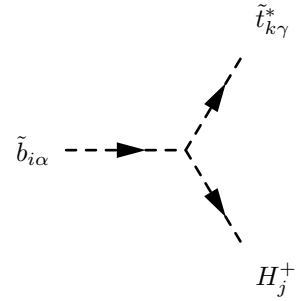
$$\frac{i}{4}\Big(4Z^E_{k2}\Big(\mu^*Y_{e,11}Z^+_{i2}+Z^+_{i1}T_{e,11}\Big)-\sqrt{2}Z^E_{k1}\Big(g_2^2v_uZ^+_{i2}+v_d\Big(-2|Y_{e,11}|^2+g_2^2\Big)Z^+_{i1}\Big)\Big) \tag{189}$$



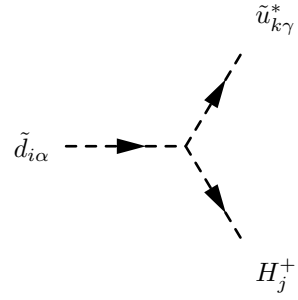
$$\frac{i}{4}\Big(4Z^{\mu}_{k2}\Big(\mu^{*}Y_{e,22}Z^{+}_{i2}+Z^{+}_{i1}T_{e,22}\Big)-\sqrt{2}Z^{\mu}_{k1}\Big(g_2^2v_uZ^{+}_{i2}+v_d\Big(-2|Y_{e,22}|^2+g_2^2\Big)Z^{+}_{i1}\Big)\Big) \tag{190}$$



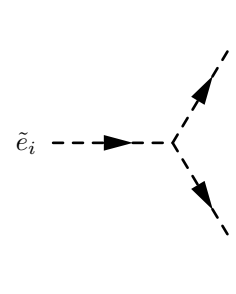
$$\frac{i}{4}\Big(Z^{+}_{i1}\Big(4Z^{\tau}_{k2}T_{e,33}-\sqrt{2}v_d\Big(-2|Y_{e,33}|^2+g_2^2\Big)Z^{\tau}_{k1}\Big)+Z^{+}_{i2}\Big(4\mu^{*}Y_{e,33}Z^{\tau}_{k2}-\sqrt{2}g_2^2v_uZ^{\tau}_{k1}\Big)\Big) \tag{191}$$



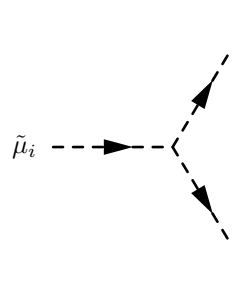
$$\begin{aligned}&-\frac{i}{4}\delta_{\alpha\gamma}\Big(-2Z^{B,*}_{i2}\Big(2T^{*}_{d,33}Z^{+}_{j1}Z^{T}_{k1}+Y^{*}_{d,33}\Big(\sqrt{2}v_uY_{u,33}Z^{+}_{j1}Z^{T}_{k2}+Z^{+}_{j2}\Big(2\mu Z^{T}_{k1}+\sqrt{2}v_dY_{u,33}Z^{T}_{k2}\Big)\Big)\Big)\\&+Z^{B,*}_{i1}\Big(Z^{+}_{j1}\Big(-4\mu^{*}Y_{u,33}Z^{T}_{k2}+\sqrt{2}v_d\Big(-2|Y_{d,33}|^2+g_2^2\Big)Z^{T}_{k1}\Big)\\&+Z^{+}_{j2}\Big(-4Z^{T}_{k2}T_{u,33}+\sqrt{2}v_u\Big(-2|Y_{u,33}|^2+g_2^2\Big)Z^{T}_{k1}\Big)\Big)\Big)\end{aligned} \tag{192}$$



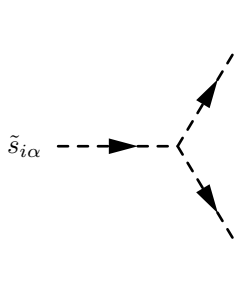
$$
\begin{aligned}
&-\frac{i}{4}\delta_{\alpha\gamma}\Big(-2Z_{i2}^{D,*}\Big(2T_{d,11}^{*}Z_{j1}^{+}Z_{k1}^{U}+Y_{d,11}^{*}\Big(\sqrt{2}v_uY_{u,11}Z_{j1}^{+}Z_{k2}^{U}+Z_{j2}^{+}\Big(2\mu Z_{k1}^{U}+\sqrt{2}v_dY_{u,11}Z_{k2}^{U}\Big)\Big)\Big)\\
&+Z_{i1}^{D,*}\Big(Z_{j1}^{+}\Big(-4\mu^{*}Y_{u,11}Z_{k2}^{U}+\sqrt{2}v_d\Big(-2|Y_{d,11}|^2+g_2^2\Big)Z_{k1}^{U}\Big)\\
&+Z_{j2}^{+}\Big(-4Z_{k2}^{U}T_{u,11}+\sqrt{2}v_u\Big(-2|Y_{u,11}|^2+g_2^2\Big)Z_{k1}^{U}\Big)\Big)\Big)
\end{aligned}
\tag{193}
$$



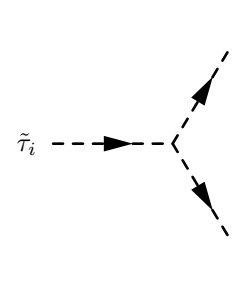
$$
\frac{i}{4}\Big(4Z_{i2}^{E,*}\Big(\mu Y_{e,11}^{*}Z_{j2}^{+}+T_{e,11}^{*}Z_{j1}^{+}\Big)-\sqrt{2}Z_{i1}^{E,*}\Big(g_2^2v_uZ_{j2}^{+}+v_d\Big(-2|Y_{e,11}|^2+g_2^2\Big)Z_{j1}^{+}\Big)\Big)
\tag{194}
$$



$$
\frac{i}{4}\Big(4Z_{i2}^{\mu,*}\Big(\mu Y_{e,22}^{*}Z_{j2}^{+}+T_{e,22}^{*}Z_{j1}^{+}\Big)-\sqrt{2}Z_{i1}^{\mu,*}\Big(g_2^2v_uZ_{j2}^{+}+v_d\Big(-2|Y_{e,22}|^2+g_2^2\Big)Z_{j1}^{+}\Big)\Big)
\tag{195}
$$

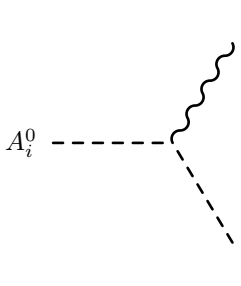


$$\frac{i}{4}\delta_{\alpha\gamma}\Big(2Z_{i2}^{S,*}\Big(2T_{d,22}^{*}Z_{k1}^{C}Z_{j1}^{+}+Y_{d,22}^{*}\Big(2\mu Z_{k1}^{C}Z_{j2}^{+}+\sqrt{2}Y_{u,22}Z_{k2}^{C}\Big(v_dZ_{j2}^{+}+v_uZ_{j1}^{+}\Big)\Big)\Big)$$
$$+Z_{i1}^{S,*}\Big(4Z_{k2}^{C}\Big(\mu^{*}Y_{u,22}Z_{j1}^{+}+Z_{j2}^{+}T_{u,22}\Big)-\sqrt{2}Z_{k1}^{C}\Big(v_d\Big(-2|Y_{d,22}|^2+g_2^2\Big)Z_{j1}^{+}+v_u\Big(-2|Y_{u,22}|^2+g_2^2\Big)Z_{j2}^{+}\Big)\Big)\Big) \tag{196}$$

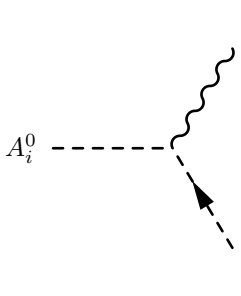


$$\frac{i}{4}\Big(4Z_{i2}^{\tau,*}\Big(\mu Y_{e,33}^{*}Z_{j2}^{+}+T_{e,33}^{*}Z_{j1}^{+}\Big)-\sqrt{2}Z_{i1}^{\tau,*}\Big(g_2^2v_uZ_{j2}^{+}+v_d\Big(-2|Y_{e,33}|^2+g_2^2\Big)Z_{j1}^{+}\Big)\Big) \tag{197}$$

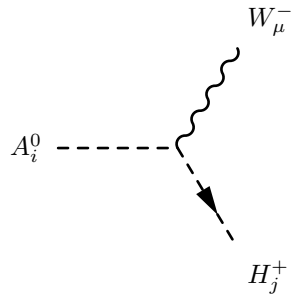
9.2 Two Scalar-One Vector Boson-Interaction



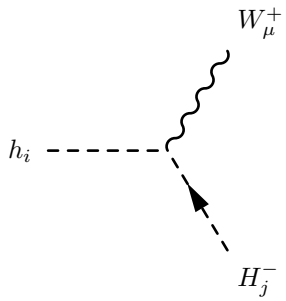
$$\frac{1}{2}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(Z_{i1}^{A}Z_{j1}^{H}-Z_{i2}^{A}Z_{j2}^{H}\Big)\Big(-p_\mu^{h_j}+p_\mu^{A_i^0}\Big) \tag{198}$$



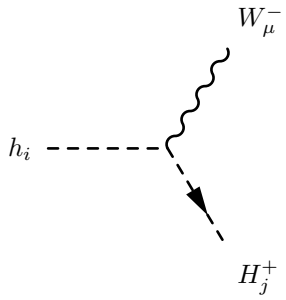
$$\frac{1}{2}g_2\Big(Z^A_{i1}Z^+_{j1} + Z^A_{i2}Z^+_{j2}\Big)\Big(-p_\mu^{H_j^-} + p_\mu^{A_i^0}\Big) \tag{199}$$



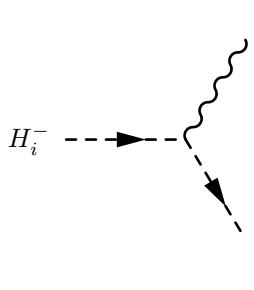
$$\frac{1}{2}g_2\Big(Z^A_{i1}Z^+_{j1} + Z^A_{i2}Z^+_{j2}\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{A_i^0}\Big) \tag{200}$$



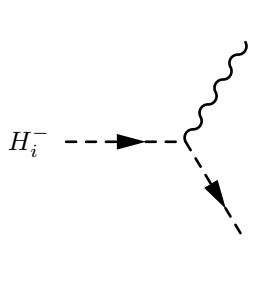
$$\frac{i}{2}g_2\Big(Z^H_{i1}Z^+_{j1} - Z^H_{i2}Z^+_{j2}\Big)\Big(-p_\mu^{H_j^-} + p_\mu^{h_i}\Big) \tag{201}$$



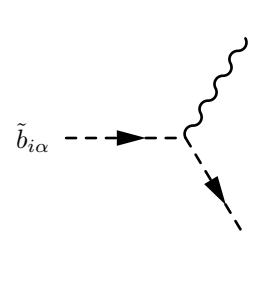
$$-\frac{i}{2}g_2\Big(Z^H_{i1}Z^+_{j1} - Z^H_{i2}Z^+_{j2}\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{h_i}\Big) \tag{202}$$



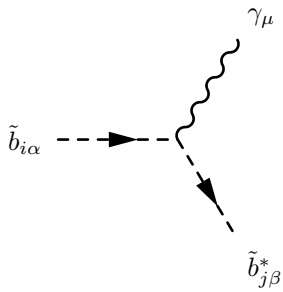
$$\frac{i}{2}\delta_{ij}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{203}$$



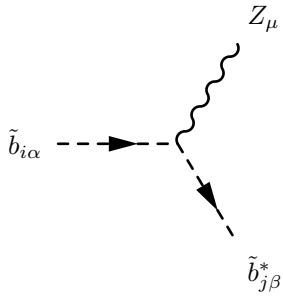
$$\frac{i}{2}\delta_{ij}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(-p_\mu^{H_j^+} + p_\mu^{H_i^-}\Big) \tag{204}$$



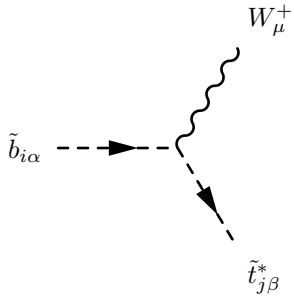
$$-\frac{i}{2}g_3\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\Big(-p_\mu^{\tilde{b}^*_{j\beta}} + p_\mu^{\tilde{b}_{i\alpha}}\Big) \tag{205}$$



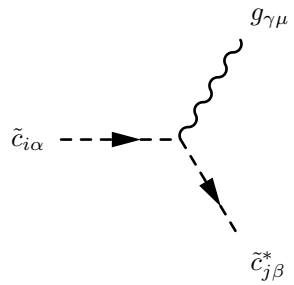
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1 Z^{B,*}_{i2}\cos\Theta_W Z^B_{j2} + Z^{B,*}_{i1}\Big(-3g_2\sin\Theta_W + g_1\cos\Theta_W\Big)Z^B_{j1}\Big)\Big(-p_\mu^{\tilde{b}^*_{j\beta}} + p_\mu^{\tilde{b}_{i\alpha}}\Big) \tag{206}$$



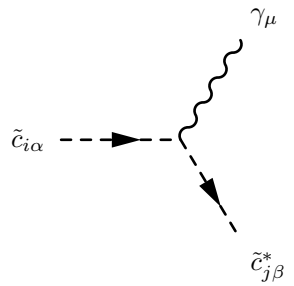
$$\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1 Z^{B,*}_{i2}\sin\Theta_W Z^B_{j2} + Z^{B,*}_{i1}\Big(3g_2\cos\Theta_W + g_1\sin\Theta_W\Big)Z^B_{j1}\Big)\Big(-p_\mu^{\tilde{b}^*_{j\beta}} + p_\mu^{\tilde{b}_{i\alpha}}\Big) \tag{207}$$



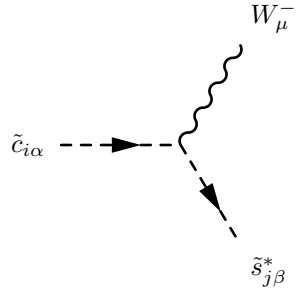
$$-i\frac{1}{\sqrt{2}}g_2 Z^{B,*}_{i1}\delta_{\alpha\beta}Z^T_{j1}\Big(-p_\mu^{\tilde{t}^*_{j\beta}} + p_\mu^{\tilde{b}_{i\alpha}}\Big) \tag{208}$$



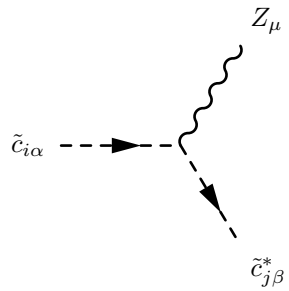
$$-\frac{i}{2}g_3\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\Big(-p_\mu^{\tilde{c}^*_{j\beta}}+p_\mu^{\tilde{c}_{i\alpha}}\Big) \tag{209}$$



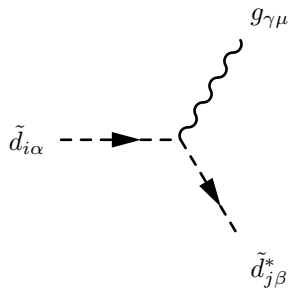
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(4g_1Z^{C,*}_{i2}\cos\Theta_W Z^C_{j2}+Z^{C,*}_{i1}\Big(3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)Z^C_{j1}\Big)\Big(-p_\mu^{\tilde{c}^*_{j\beta}}+p_\mu^{\tilde{c}_{i\alpha}}\Big) \tag{210}$$



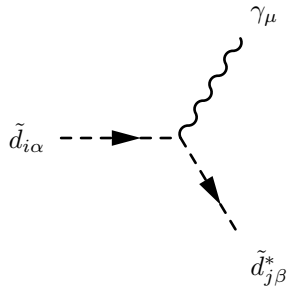
$$-i\frac{1}{\sqrt{2}}g_2Z^{C,*}_{i1}\delta_{\alpha\beta}Z^S_{j1}\Big(-p_\mu^{\tilde{s}^*_{j\beta}}+p_\mu^{\tilde{c}_{i\alpha}}\Big) \tag{211}$$



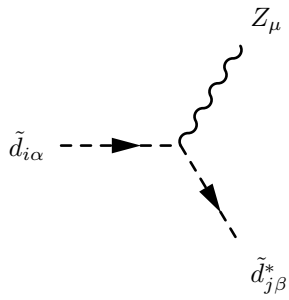
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(-4g_1 Z^{C,*}_{i2}\sin\Theta_W Z^C_{j2}+Z^{C,*}_{i1}\Big(3g_2\cos\Theta_W-g_1\sin\Theta_W\Big)Z^C_{j1}\Big)\Big(-p_\mu^{\tilde{c}^*_{j\beta}}+p_\mu^{\tilde{c}_{i\alpha}}\Big) \tag{212}$$



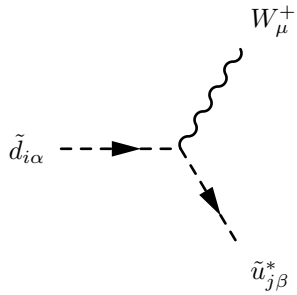
$$-\frac{i}{2}g_3\delta_{ij}\lambda^\gamma_{\beta,\alpha}\Big(-p_\mu^{\tilde{d}^*_{j\beta}}+p_\mu^{\tilde{d}_{i\alpha}}\Big) \tag{213}$$



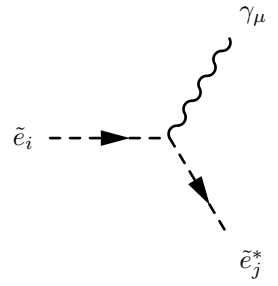
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1 Z^{D,*}_{i2}\cos\Theta_W Z^D_{j2}+Z^{D,*}_{i1}\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)Z^D_{j1}\Big)\Big(-p_\mu^{\tilde{d}^*_{j\beta}}+p_\mu^{\tilde{d}_{i\alpha}}\Big) \tag{214}$$



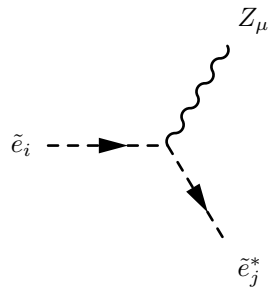
$$\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1 Z^{D,*}_{i2}\sin\Theta_W Z^D_{j2} + Z^{D,*}_{i1}\Big(3g_2\cos\Theta_W + g_1\sin\Theta_W\Big)Z^D_{j1}\Big)\Big(-p_\mu^{\tilde{d}^*_{j\beta}} + p_\mu^{\tilde{d}_{i\alpha}}\Big) \tag{215}$$



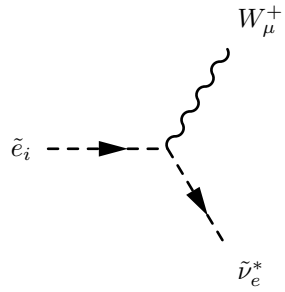
$$-i\frac{1}{\sqrt{2}}g_2 Z^{D,*}_{i1}\delta_{\alpha\beta}Z^U_{j1}\Big(-p_\mu^{\tilde{u}^*_{j\beta}} + p_\mu^{\tilde{d}_{i\alpha}}\Big) \tag{216}$$



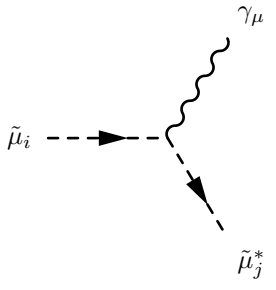
$$\frac{i}{2}\Big(2g_1 Z^{E,*}_{i2}\cos\Theta_W Z^E_{j2} + Z^{E,*}_{i1}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)Z^E_{j1}\Big)\Big(-p_\mu^{\tilde{e}^*_j} + p_\mu^{\tilde{e}_i}\Big) \tag{217}$$



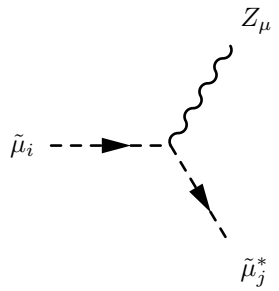
$$\frac{i}{2}\Big(- 2g_1 Z_{i2}^{E,*} \sin\Theta_W Z_{j2}^{E} + Z_{i1}^{E,*}\Big(- g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big) Z_{j1}^{E}\Big)\Big(- p_\mu^{\tilde{e}_j^*} + p_\mu^{\tilde{e}_i}\Big) \tag{218}$$



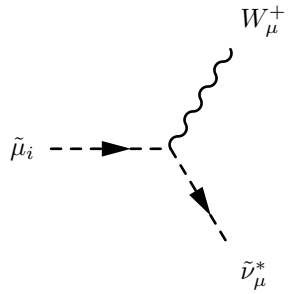
$$- i\frac{1}{\sqrt{2}} g_2 Z_{i1}^{E,*}\Big(- p_\mu^{\tilde{\nu}_e^*} + p_\mu^{\tilde{e}_i}\Big) \tag{219}$$



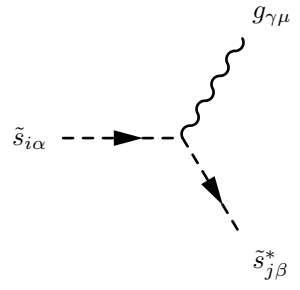
$$\frac{i}{2}\Big(2g_1 Z_{i2}^{\mu,*} \cos\Theta_W Z_{j2}^{\mu} + Z_{i1}^{\mu,*}\Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W\Big) Z_{j1}^{\mu}\Big)\Big(- p_\mu^{\tilde{\mu}_j^*} + p_\mu^{\tilde{\mu}_i}\Big) \tag{220}$$



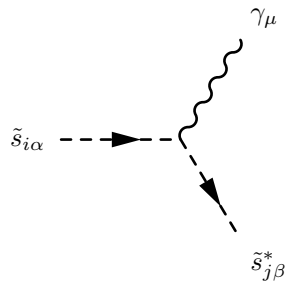
$$\frac{i}{2}\Big(- 2g_1 Z_{i2}^{\mu,*} \sin\Theta_W Z_{j2}^{\mu} + Z_{i1}^{\mu,*}\Big(- g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big) Z_{j1}^{\mu}\Big)\Big(- p_\mu^{\tilde{\mu}_j^*} + p_\mu^{\tilde{\mu}_i}\Big) \tag{221}$$



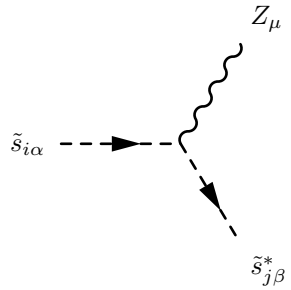
$$- i\frac{1}{\sqrt{2}} g_2 Z_{i1}^{\mu,*}\Big(- p_\mu^{\tilde{\nu}_\mu^*} + p_\mu^{\tilde{\mu}_i}\Big) \tag{222}$$



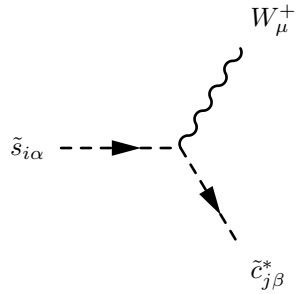
$$- \frac{i}{2} g_3 \delta_{ij} \lambda^{\gamma}_{\beta,\alpha}\Big(- p_\mu^{\tilde{s}_{j\beta}^*} + p_\mu^{\tilde{s}_{i\alpha}}\Big) \tag{223}$$



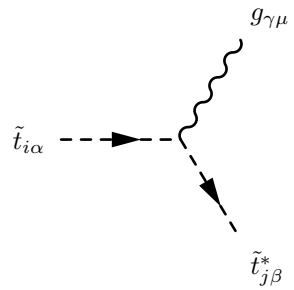
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1 Z^{S,*}_{i2}\cos\Theta_W Z^S_{j2}+Z^{S,*}_{i1}\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)Z^S_{j1}\Big)\Big(-p_\mu^{\tilde{s}^*_{j\beta}}+p_\mu^{\tilde{s}_{i\alpha}}\Big) \tag{224}$$



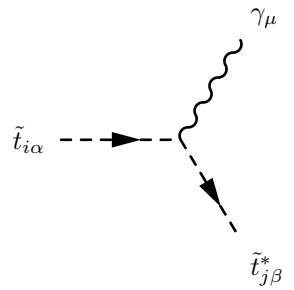
$$\frac{i}{6}\delta_{\alpha\beta}\Big(-2g_1 Z^{S,*}_{i2}\sin\Theta_W Z^S_{j2}+Z^{S,*}_{i1}\Big(3g_2\cos\Theta_W+g_1\sin\Theta_W\Big)Z^S_{j1}\Big)\Big(-p_\mu^{\tilde{s}^*_{j\beta}}+p_\mu^{\tilde{s}_{i\alpha}}\Big) \tag{225}$$



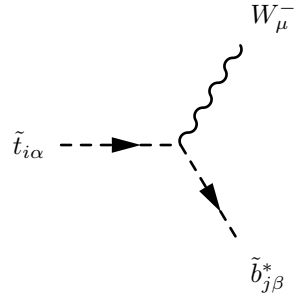
$$-i\frac{1}{\sqrt{2}}g_2 Z^{S,*}_{i1}\delta_{\alpha\beta}Z^C_{j1}\Big(-p_\mu^{\tilde{c}^*_{j\beta}}+p_\mu^{\tilde{s}_{i\alpha}}\Big) \tag{226}$$



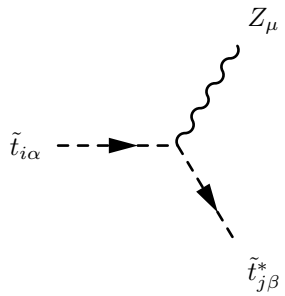
$$-\frac{i}{2}g_3\delta_{ij}\lambda^{\gamma}_{\beta,\alpha}\Big(-p_\mu^{\tilde{t}^*_{j\beta}}+p_\mu^{\tilde{t}_{i\alpha}}\Big) \tag{227}$$



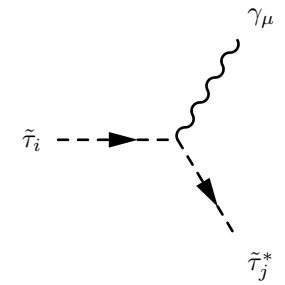
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(4g_1Z^{T,*}_{i2}\cos\Theta_W Z^T_{j2}+Z^{T,*}_{i1}\Big(3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)Z^T_{j1}\Big)\Big(-p_\mu^{\tilde{t}^*_{j\beta}}+p_\mu^{\tilde{t}_{i\alpha}}\Big) \tag{228}$$



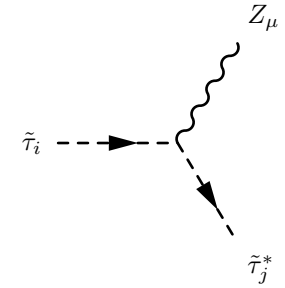
$$-i\frac{1}{\sqrt{2}}g_2Z^{T,*}_{i1}\delta_{\alpha\beta}Z^B_{j1}\Big(-p_\mu^{\tilde{b}^*_{j\beta}}+p_\mu^{\tilde{t}_{i\alpha}}\Big) \tag{229}$$



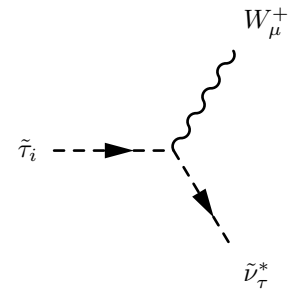
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(-4g_1 Z^{T,*}_{i2}\sin\Theta_W Z^T_{j2} + Z^{T,*}_{i1}\Big(3g_2\cos\Theta_W - g_1\sin\Theta_W\Big)Z^T_{j1}\Big)\Big(-p_\mu^{\tilde{t}^*_{j\beta}} + p_\mu^{\tilde{t}_{i\alpha}}\Big) \tag{230}$$



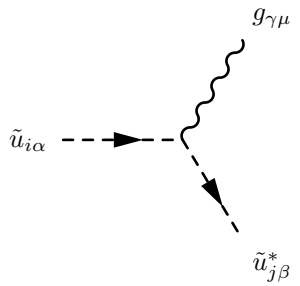
$$\frac{i}{2}\Big(2g_1 Z^{\tau,*}_{i2}\cos\Theta_W Z^\tau_{j2} + Z^{\tau,*}_{i1}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)Z^\tau_{j1}\Big)\Big(-p_\mu^{\tilde{\tau}^*_j} + p_\mu^{\tilde{\tau}_i}\Big) \tag{231}$$



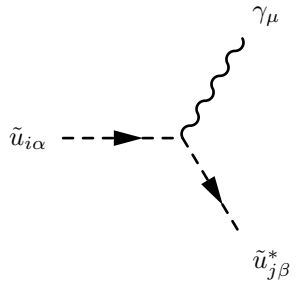
$$\frac{i}{2}\Big(-2g_1 Z^{\tau,*}_{i2}\sin\Theta_W Z^\tau_{j2} + Z^{\tau,*}_{i1}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)Z^\tau_{j1}\Big)\Big(-p_\mu^{\tilde{\tau}^*_j} + p_\mu^{\tilde{\tau}_i}\Big) \tag{232}$$



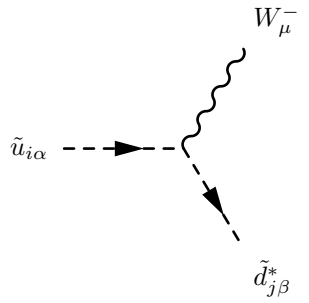
$$-i\frac{1}{\sqrt{2}}g_2 Z_{i1}^{\tau,*}\Big(-p_\mu^{\tilde{\nu}_\tau^*}+p_\mu^{\tilde{\tau}_i}\Big) \tag{233}$$



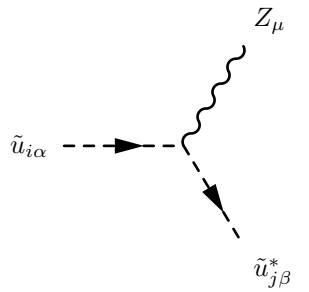
$$-\frac{i}{2}g_3\delta_{ij}\lambda_{\beta,\alpha}^{\gamma}\Big(-p_\mu^{\tilde{u}_{j\beta}^*}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{234}$$



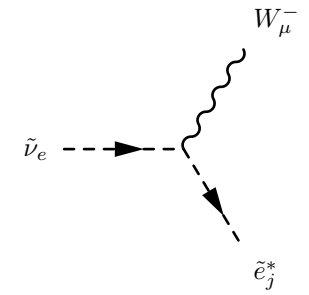
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(4g_1 Z_{i2}^{U,*}\cos\Theta_W Z_{j2}^U+Z_{i1}^{U,*}\Big(3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)Z_{j1}^U\Big)\Big(-p_\mu^{\tilde{u}_{j\beta}^*}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{235}$$



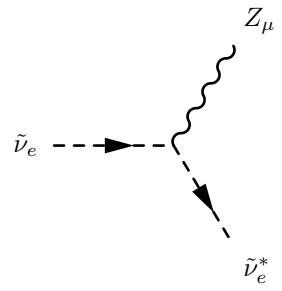
$$-i\frac{1}{\sqrt{2}}g_2 Z^{U,*}_{i1}\delta_{\alpha\beta}Z^D_{j1}\Big(-p_\mu^{\tilde{d}^*_{j\beta}}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{236}$$



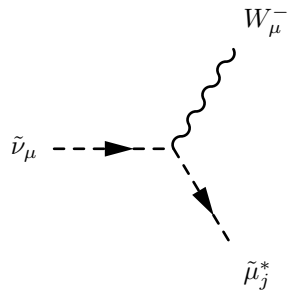
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(-4g_1 Z^{U,*}_{i2}\sin\Theta_W Z^U_{j2}+Z^{U,*}_{i1}\Big(3g_2\cos\Theta_W-g_1\sin\Theta_W\Big)Z^U_{j1}\Big)\Big(-p_\mu^{\tilde{u}^*_{j\beta}}+p_\mu^{\tilde{u}_{i\alpha}}\Big) \tag{237}$$



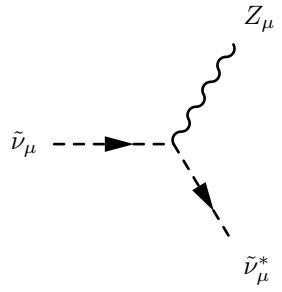
$$-i\frac{1}{\sqrt{2}}g_2 Z^E_{j1}\Big(-p_\mu^{\tilde{e}^*_j}+p_\mu^{\tilde{\nu}_e}\Big) \tag{238}$$



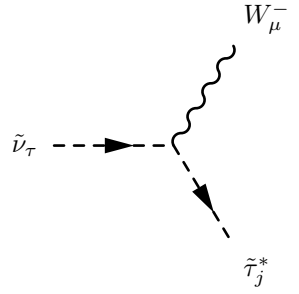
$$-\frac{i}{2}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(-p_\mu^{\tilde{\nu}_e^*}+p_\mu^{\tilde{\nu}_e}\Big) \tag{239}$$



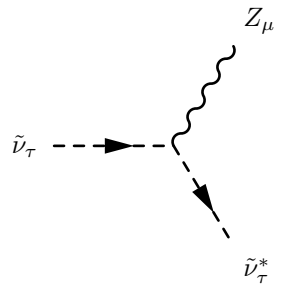
$$-i\frac{1}{\sqrt{2}}g_2 Z_{j1}^\mu\Big(-p_\mu^{\tilde{\mu}_j^*}+p_\mu^{\tilde{\nu}_\mu}\Big) \tag{240}$$



$$-\frac{i}{2}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(-p_\mu^{\tilde{\nu}_\mu^*}+p_\mu^{\tilde{\nu}_\mu}\Big) \tag{241}$$

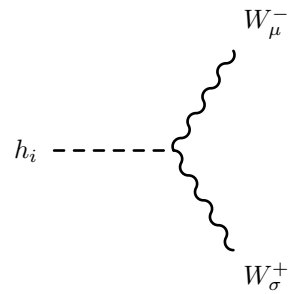


$$-i\frac{1}{\sqrt{2}}g_2 Z^{\tau}_{j1}\Big(-p_\mu^{\tilde{\tau}_j^*}+p_\mu^{\tilde{\nu}_\tau}\Big) \tag{242}$$

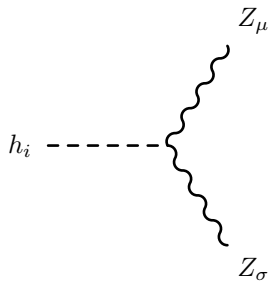


$$-\frac{i}{2}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(-p_\mu^{\tilde{\nu}_\tau^*}+p_\mu^{\tilde{\nu}_\tau}\Big) \tag{243}$$

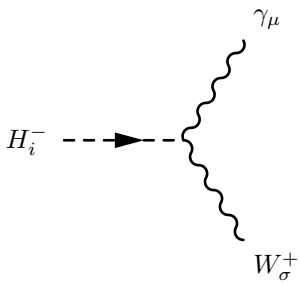
9.3 One Scalar-Two Vector Boson-Interaction



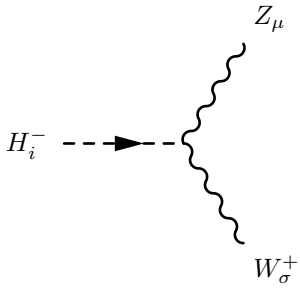
$$\frac{i}{2}g_2^2\Big(v_d Z^H_{i1}+v_u Z^H_{i2}\Big)\Big(g_{\sigma\mu}\Big) \tag{244}$$



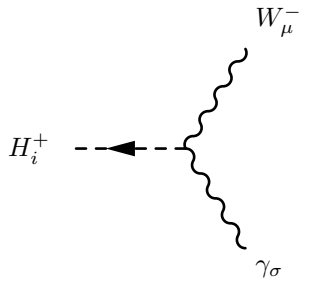
$$\frac{i}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)^2 \Big(v_d Z^H_{i1} + v_u Z^H_{i2}\Big)\Big(g_{\sigma\mu}\Big) \tag{245}$$



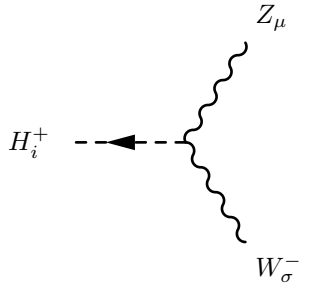
$$-\frac{i}{2} g_1 g_2 \cos\Theta_W \Big(v_d Z^+_{i1} - v_u Z^+_{i2}\Big)\Big(g_{\sigma\mu}\Big) \tag{246}$$



$$\frac{i}{2} g_1 g_2 \sin\Theta_W \Big(v_d Z^+_{i1} - v_u Z^+_{i2}\Big)\Big(g_{\sigma\mu}\Big) \tag{247}$$

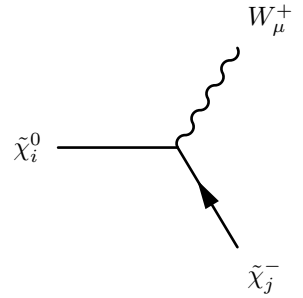


$$-\frac{i}{2}g_1 g_2 \cos\Theta_W \Big(v_d Z_{i1}^+ - v_u Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{248}$$



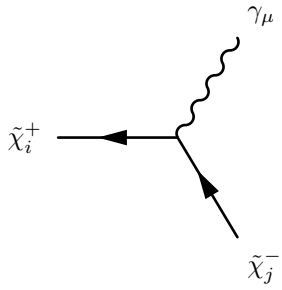
$$\frac{i}{2}g_1 g_2 \sin\Theta_W \Big(v_d Z_{i1}^+ - v_u Z_{i2}^+\Big)\Big(g_{\sigma\mu}\Big) \tag{249}$$

9.4 Two Fermion-One Vector Boson-Interaction



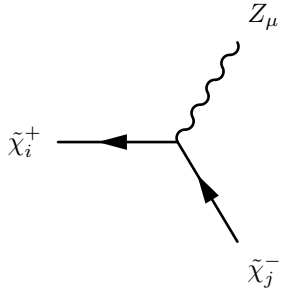
$$-\frac{i}{2}g_2\Big(2U_{j1}^* N_{i2} + \sqrt{2}U_{j2}^* N_{i3}\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{250}$$

$$+\ -\frac{i}{2}g_2\Big(2N_{i2}^* V_{j1} - \sqrt{2}N_{i4}^* V_{j2}\Big)\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{251}$$



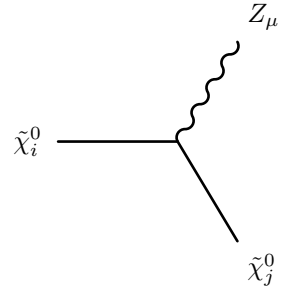
$$\frac{i}{2}\Big(2g_2U^*_{j1}\sin\Theta_W U_{i1} + U^*_{j2}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)U_{i2}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{252}$$

$$+\ \frac{i}{2}\Big(2g_2V^*_{i1}\sin\Theta_W V_{j1} + V^*_{i2}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)V_{j2}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{253}$$



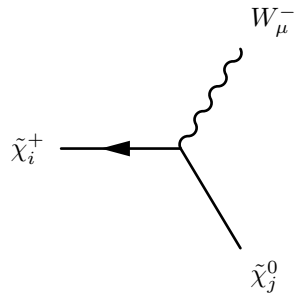
$$\frac{i}{2}\Big(2g_2U^*_{j1}\cos\Theta_W U_{i1} + U^*_{j2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)U_{i2}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{254}$$

$$+\ \frac{i}{2}\Big(2g_2V^*_{i1}\cos\Theta_W V_{j1} + V^*_{i2}\Big(-g_1\sin\Theta_W + g_2\cos\Theta_W\Big)V_{j2}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{255}$$



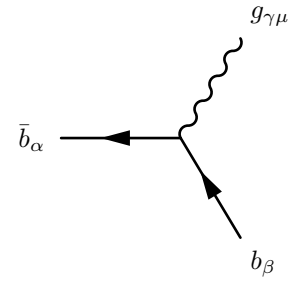
$$-\ \frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(N^*_{j3}N_{i3} - N^*_{j4}N_{i4}\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{256}$$

$$+\ \frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(N^*_{i3}N_{j3} - N^*_{i4}N_{j4}\Big)\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{257}$$



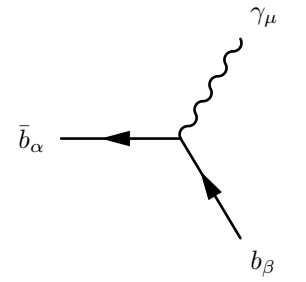
$$- \frac{i}{2} g_2 \Big(2 N_{j2}^* U_{i1} + \sqrt{2} N_{j3}^* U_{i2} \Big) \Big(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \Big) \tag{258}$$

$$+ \; - \frac{i}{2} g_2 \Big(2 V_{i1}^* N_{j2} - \sqrt{2} V_{i2}^* N_{j4} \Big) \Big(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \Big) \tag{259}$$



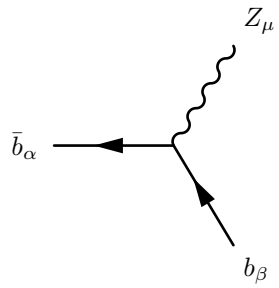
$$- \frac{i}{2} g_3 \lambda_{\alpha,\beta}^{\gamma} \Big(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \Big) \tag{260}$$

$$+ \; - \frac{i}{2} g_3 \lambda_{\alpha,\beta}^{\gamma} \Big(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \Big) \tag{261}$$



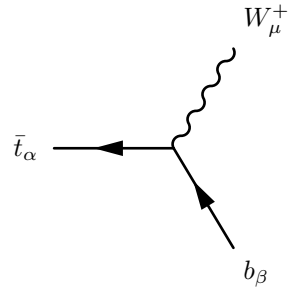
$$- \frac{i}{6} \delta_{\alpha\beta} \Big(- 3 g_2 \sin \Theta_W + g_1 \cos \Theta_W \Big) \Big(\gamma_\mu \cdot \frac{1 - \gamma_5}{2} \Big) \tag{262}$$

$$+ \; \frac{i}{3} g_1 \cos \Theta_W \delta_{\alpha\beta} \Big(\gamma_\mu \cdot \frac{1 + \gamma_5}{2} \Big) \tag{263}$$

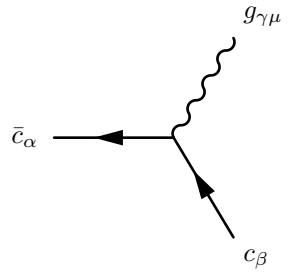


$$\frac{i}{6}\delta_{\alpha\beta}\Big(3g_2\cos\Theta_W + g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{264}$$

$$+\ -\frac{i}{3}g_1\delta_{\alpha\beta}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{265}$$

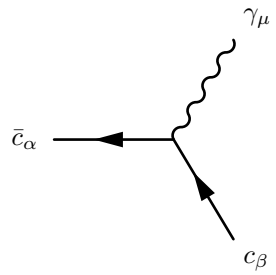


$$-\,i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{266}$$



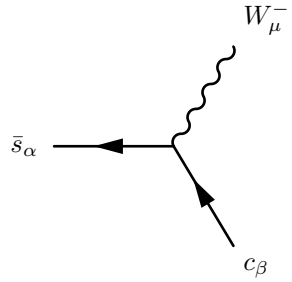
$$-\,\frac{i}{2}g_3\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{267}$$

$$+\ -\frac{i}{2}g_3\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{268}$$

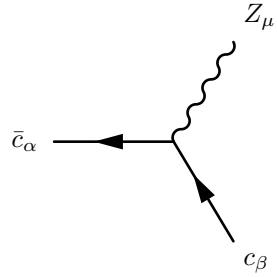


$$-\frac{i}{6}\delta_{\alpha\beta}\Big(3g_2\sin\Theta_W + g_1\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{269}$$

$$+\ -\frac{2i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{270}$$

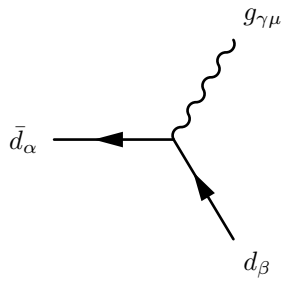


$$-\,i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{271}$$



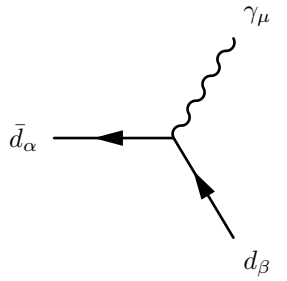
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(3g_2\cos\Theta_W - g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{272}$$

$$+\ \frac{2i}{3}g_1\delta_{\alpha\beta}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{273}$$



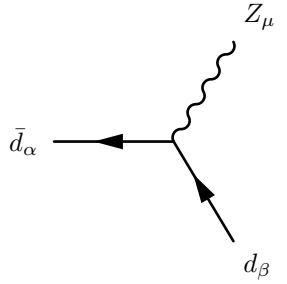
$$-\frac{i}{2}g_3\lambda^{\gamma}_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{274}$$

$$+\ -\frac{i}{2}g_3\lambda^{\gamma}_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{275}$$



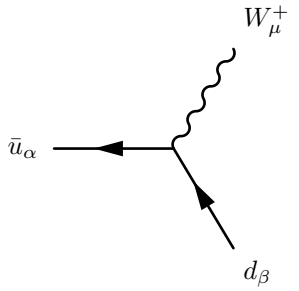
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{276}$$

$$+\ \frac{i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{277}$$

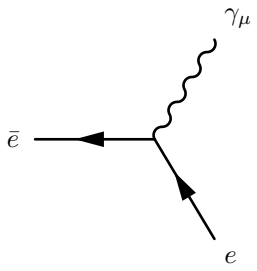


$$\frac{i}{6}\delta_{\alpha\beta}\Big(3g_2\cos\Theta_W+g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{278}$$

$$+\ -\frac{i}{3}g_1\delta_{\alpha\beta}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{279}$$

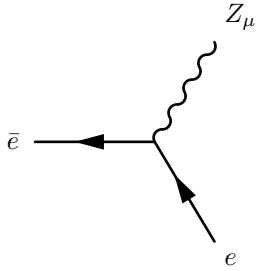


$$-\,i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{280}$$



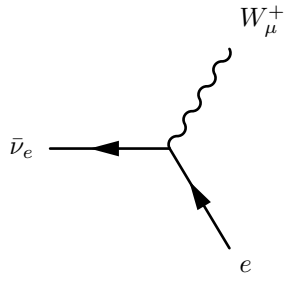
$$\frac{i}{2}\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{281}$$

$$+\;ig_1\cos\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{282}$$

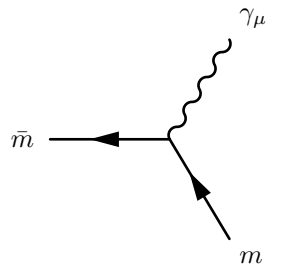


$$\frac{i}{2}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{283}$$

$$+\;-ig_1\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{284}$$

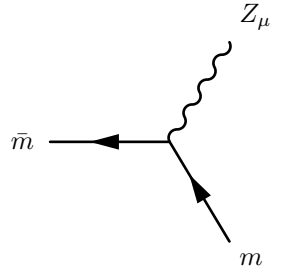


$$-i\frac{1}{\sqrt{2}}g_2\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{285}$$



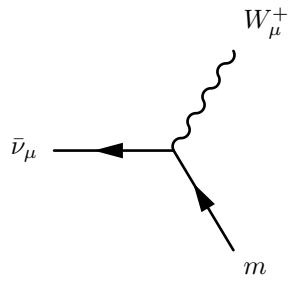
$$\frac{i}{2}\Big(g_1\cos\Theta_W+g_2\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{286}$$

$$+\ ig_1\cos\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{287}$$

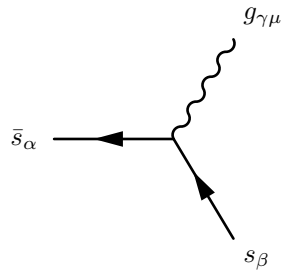


$$\frac{i}{2}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{288}$$

$$+\ -ig_1\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{289}$$

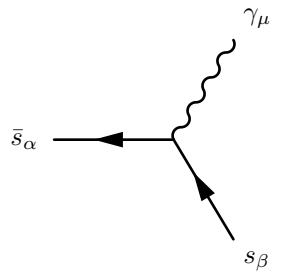


$$-\,i\frac{1}{\sqrt{2}}g_2\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{290}$$



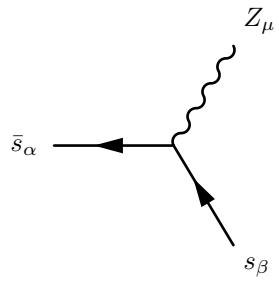
$$-\,\frac{i}{2}g_3\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{291}$$

$$+\,-\frac{i}{2}g_3\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{292}$$



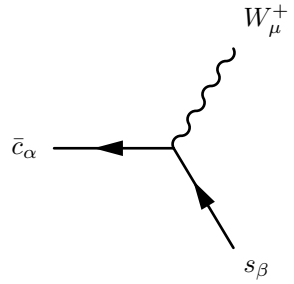
$$-\,\frac{i}{6}\delta_{\alpha\beta}\Big(-3g_2\sin\Theta_W+g_1\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{293}$$

$$+\,\frac{i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{294}$$

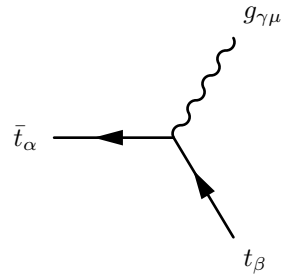


$$\frac{i}{6}\delta_{\alpha\beta}\Big(3g_2\cos\Theta_W + g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{295}$$

$$+\ -\frac{i}{3}g_1\delta_{\alpha\beta}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{296}$$

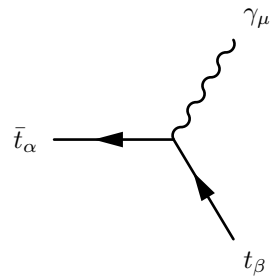


$$-\,i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{297}$$



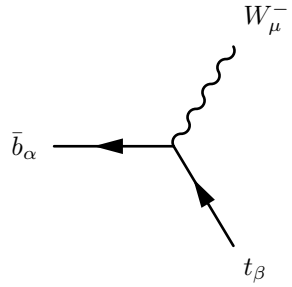
$$-\,\frac{i}{2}g_3\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{298}$$

$$+\ -\frac{i}{2}g_3\lambda^\gamma_{\alpha,\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{299}$$

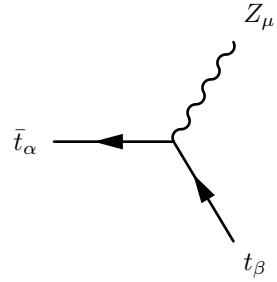


$$-\frac{i}{6}\delta_{\alpha\beta}\Big(3g_2\sin\Theta_W + g_1\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{300}$$

$$+\ -\frac{2i}{3}g_1\cos\Theta_W\delta_{\alpha\beta}\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{301}$$

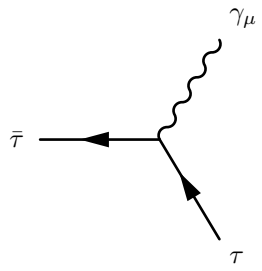


$$-\,i\frac{1}{\sqrt{2}}g_2\delta_{\alpha\beta}\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{302}$$



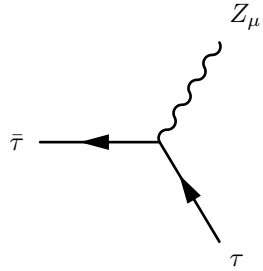
$$-\frac{i}{6}\delta_{\alpha\beta}\Big(3g_2\cos\Theta_W - g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{303}$$

$$+\ \frac{2i}{3}g_1\delta_{\alpha\beta}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{304}$$



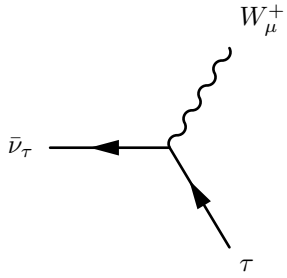
$$\frac{i}{2}\Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{305}$$

$$+\ i g_1 \cos\Theta_W \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{306}$$

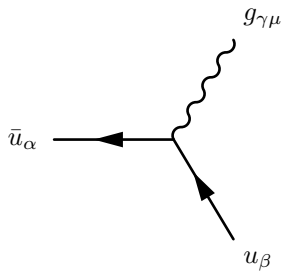


$$\frac{i}{2}\Big(-g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{307}$$

$$+\ -i g_1 \sin\Theta_W \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{308}$$

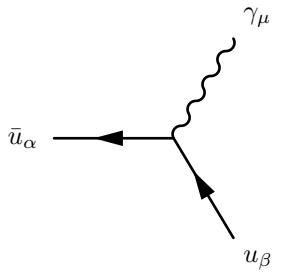


$$-\,i\frac{1}{\sqrt{2}} g_2 \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{309}$$



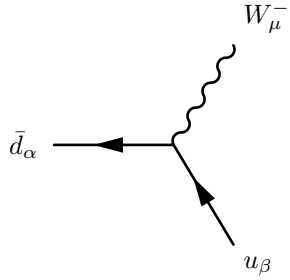
$$- \frac{i}{2} g_3 \lambda^{\gamma}_{\alpha,\beta} \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{310}$$

$$+ \; - \frac{i}{2} g_3 \lambda^{\gamma}_{\alpha,\beta} \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \Big) \tag{311}$$

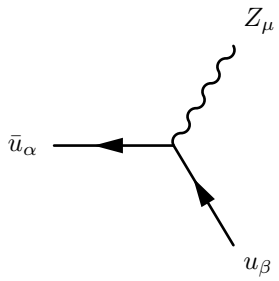


$$- \frac{i}{6} \delta_{\alpha\beta} \Big(3 g_2 \sin\Theta_W + g_1 \cos\Theta_W \Big) \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{312}$$

$$+ \; - \frac{2i}{3} g_1 \cos\Theta_W \delta_{\alpha\beta} \Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2} \Big) \tag{313}$$

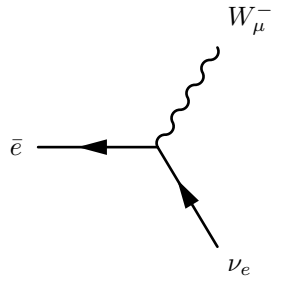


$$- i \frac{1}{\sqrt{2}} g_2 \delta_{\alpha\beta} \Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2} \Big) \tag{314}$$

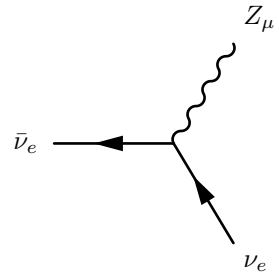


$$-\frac{i}{6}\delta_{\alpha\beta}\Big(3g_2\cos\Theta_W - g_1\sin\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{315}$$

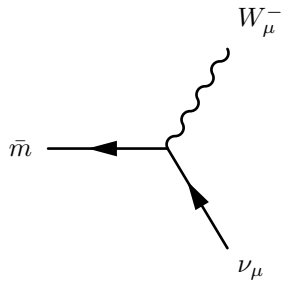
$$+\frac{2i}{3}g_1\delta_{\alpha\beta}\sin\Theta_W\Big(\gamma_\mu\cdot\frac{1+\gamma_5}{2}\Big) \tag{316}$$



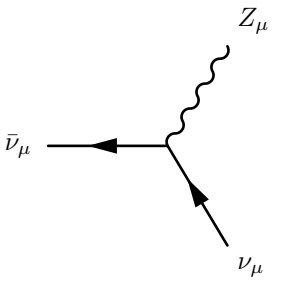
$$-i\frac{1}{\sqrt{2}}g_2\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{317}$$



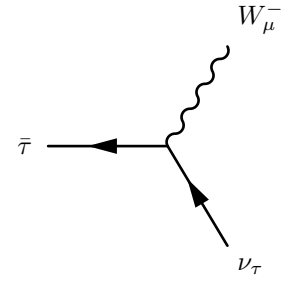
$$-\frac{i}{2}\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{318}$$



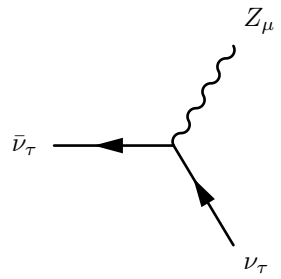
$$-i\frac{1}{\sqrt{2}}g_2\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{319}$$



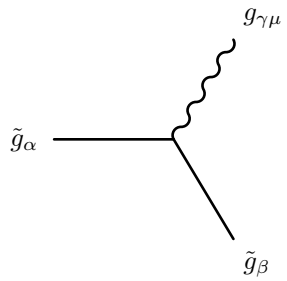
$$-\frac{i}{2}\Big(g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{320}$$



$$-i\frac{1}{\sqrt{2}}g_2\Big(\gamma_\mu\cdot\frac{1-\gamma_5}{2}\Big) \tag{321}$$



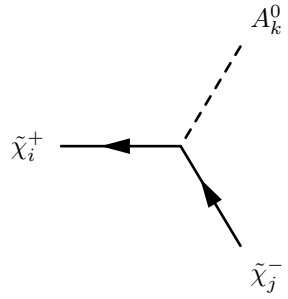
$$-\frac{i}{2}\Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W\Big)\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{322}$$



$$-g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\Big(\gamma_\mu \cdot \frac{1-\gamma_5}{2}\Big) \tag{323}$$

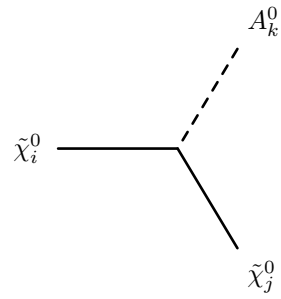
$$+\ -g_3|\phi_{\tilde{g}}|^2 f_{\alpha,\beta,\gamma}\Big(\gamma_\mu \cdot \frac{1+\gamma_5}{2}\Big) \tag{324}$$

9.5 Two Fermion-One Scalar Boson-Interaction

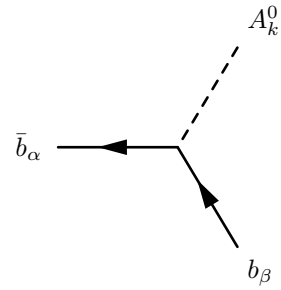


$$-\frac{1}{\sqrt{2}}g_2\Big(U_{j1}^* V_{i2}^* Z_{k2}^A + U_{j2}^* V_{i1}^* Z_{k1}^A\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{325}$$

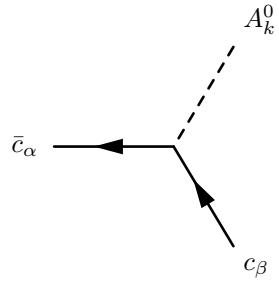
$$+\ \frac{1}{\sqrt{2}}g_2\Big(U_{i1}V_{j2}Z^A_{k2}+U_{i2}V_{j1}Z^A_{k1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{326}$$



$$\frac{1}{2}\Big(N^*_{i3}\Big(g_1N^*_{j1}-g_2N^*_{j2}\Big)Z^A_{k1}-g_2N^*_{i2}N^*_{j3}Z^A_{k1}-g_1N^*_{i4}N^*_{j1}Z^A_{k2}+g_2N^*_{i4}N^*_{j2}Z^A_{k2}$$
$$+\,g_2N^*_{i2}N^*_{j4}Z^A_{k2}+g_1N^*_{i1}\Big(N^*_{j3}Z^A_{k1}-N^*_{j4}Z^A_{k2}\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{327}$$
$$+\ \frac{1}{2}\Big(-Z^A_{k1}\Big(\Big(g_1N_{i1}-g_2N_{i2}\Big)N_{j3}+N_{i3}\Big(g_1N_{j1}-g_2N_{j2}\Big)\Big)$$
$$-\,Z^A_{k2}\Big(\Big(-g_1N_{i1}+g_2N_{i2}\Big)N_{j4}+N_{i4}\Big(-g_1N_{j1}+g_2N_{j2}\Big)\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{328}$$

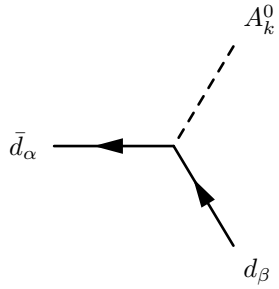


$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{d,33}Z^A_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{329}$$
$$+\ -\frac{1}{\sqrt{2}}Y^*_{d,33}\delta_{\alpha\beta}Z^A_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{330}$$



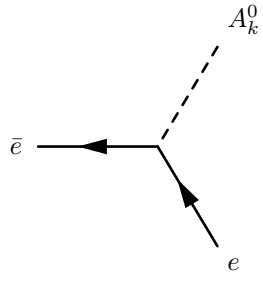
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{u,22}Z^A_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{331}$$

$$+\ -\frac{1}{\sqrt{2}}Y^*_{u,22}\delta_{\alpha\beta}Z^A_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{332}$$



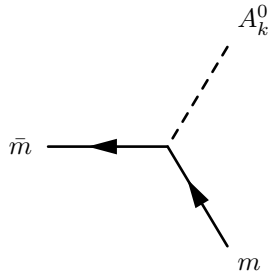
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{d,11}Z^A_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{333}$$

$$+\ -\frac{1}{\sqrt{2}}Y^*_{d,11}\delta_{\alpha\beta}Z^A_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{334}$$



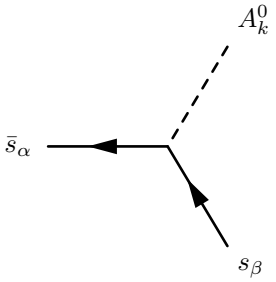
$$\frac{1}{\sqrt{2}}Y_{e,11}Z^A_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{335}$$

$$+ \; -\frac{1}{\sqrt{2}} Y^*_{e,11} Z^A_{k1} \Big(\frac{1+\gamma_5}{2} \Big) \tag{336}$$



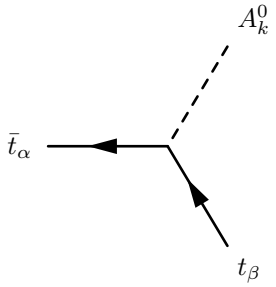
$$\frac{1}{\sqrt{2}} Y_{e,22} Z^A_{k1} \Big(\frac{1-\gamma_5}{2} \Big) \tag{337}$$

$$+ \; -\frac{1}{\sqrt{2}} Y^*_{e,22} Z^A_{k1} \Big(\frac{1+\gamma_5}{2} \Big) \tag{338}$$



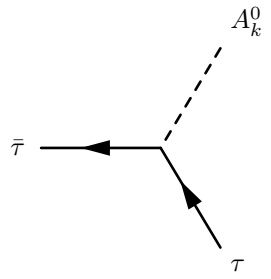
$$\frac{1}{\sqrt{2}} \delta_{\alpha\beta} Y_{d,22} Z^A_{k1} \Big(\frac{1-\gamma_5}{2} \Big) \tag{339}$$

$$+ \; -\frac{1}{\sqrt{2}} Y^*_{d,22} \delta_{\alpha\beta} Z^A_{k1} \Big(\frac{1+\gamma_5}{2} \Big) \tag{340}$$



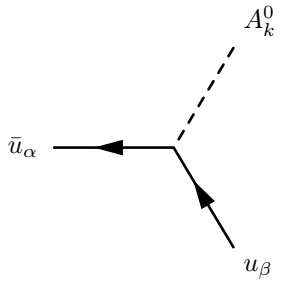
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{u,33}Z^A_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{341}$$

$$+\ -\frac{1}{\sqrt{2}}Y^*_{u,33}\delta_{\alpha\beta}Z^A_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{342}$$



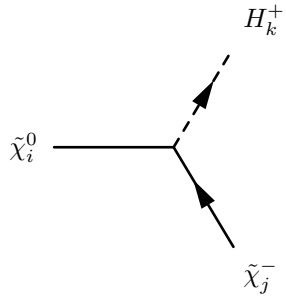
$$\frac{1}{\sqrt{2}}Y_{e,33}Z^A_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{343}$$

$$+\ -\frac{1}{\sqrt{2}}Y^*_{e,33}Z^A_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{344}$$



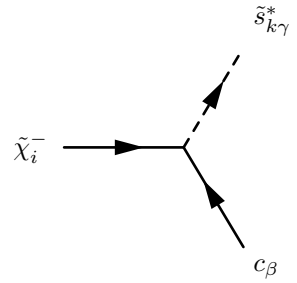
$$\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{u,11}Z^A_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{345}$$

$$+\ -\frac{1}{\sqrt{2}}Y^*_{u,11}\delta_{\alpha\beta}Z^A_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{346}$$



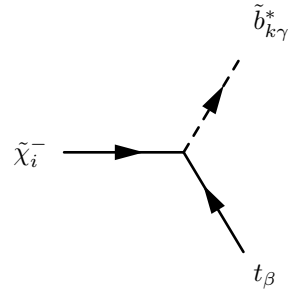
$$\frac{i}{2}\Big(- 2g_2 U^*_{j1} N^*_{i3} + \sqrt{2} U^*_{j2}\Big(g_1 N^*_{i1} + g_2 N^*_{i2}\Big)\Big) Z^+_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{347}$$

$$+ -\frac{i}{2}\Big(2g_2 V_{j1} N_{i4} + \sqrt{2} V_{j2}\Big(g_1 N_{i1} + g_2 N_{i2}\Big)\Big) Z^+_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{348}$$



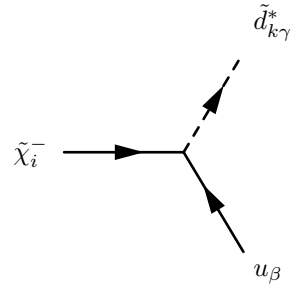
$$i\delta_{\beta\gamma}\Big(- g_2 U^*_{i1} Z^S_{k1} + U^*_{i2} Y_{d,22} Z^S_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{349}$$

$$+\ iY^*_{u,22}\delta_{\beta\gamma} V_{i2} Z^S_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{350}$$



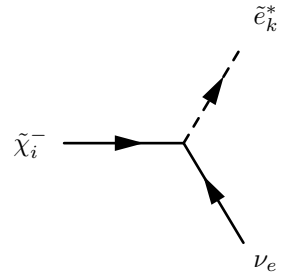
$$i\delta_{\beta\gamma}\Big(- g_2 U^*_{i1} Z^B_{k1} + U^*_{i2} Y_{d,33} Z^B_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{351}$$

$$+\ iY^*_{u,33}\delta_{\beta\gamma} V_{i2} Z^B_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{352}$$

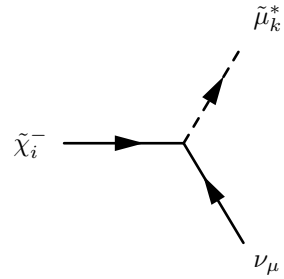


$$i\delta_{\beta\gamma}\Big(- g_2 U^*_{i1} Z^D_{k1} + U^*_{i2} Y_{d,11} Z^D_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{353}$$

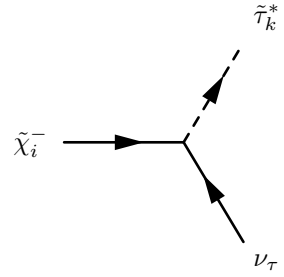
$$+\ iY^*_{u,11}\delta_{\beta\gamma} V_{i2} Z^D_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{354}$$



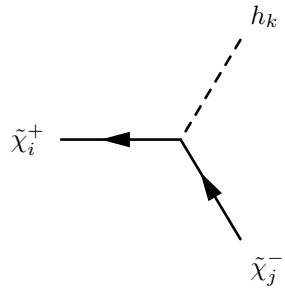
$$i\Big(- g_2 U^*_{i1} Z^E_{k1} + U^*_{i2} Y_{e,11} Z^E_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{355}$$



$$i\Big(- g_2 U^*_{i1} Z^\mu_{k1} + U^*_{i2} Y_{e,22} Z^\mu_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{356}$$

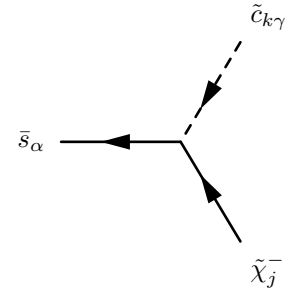


$$i\Big(- g_2 U^*_{i1} Z^\tau_{k1} + U^*_{i2} Y_{e,33} Z^\tau_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{357}$$



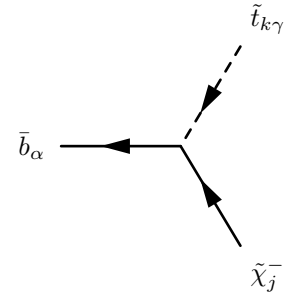
$$- i\frac{1}{\sqrt{2}}g_2\Big(U_{j1}^* V_{i2}^* Z_{k2}^H + U_{j2}^* V_{i1}^* Z_{k1}^H\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{358}$$

$$+ -i\frac{1}{\sqrt{2}}g_2\Big(U_{i1} V_{j2} Z_{k2}^H + U_{i2} V_{j1} Z_{k1}^H\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{359}$$



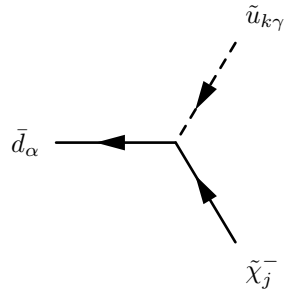
$$iU_{j2}^* Z_{k1}^{C,*}\delta_{\alpha\gamma} Y_{d,22}\Big(\frac{1-\gamma_5}{2}\Big) \tag{360}$$

$$+ i\delta_{\alpha\gamma}\Big(- g_2 Z_{k1}^{C,*} V_{j1} + Y_{u,22}^* Z_{k2}^{C,*} V_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{361}$$



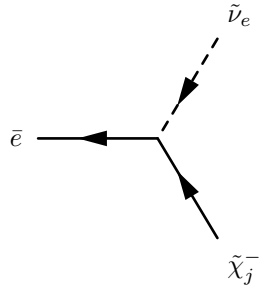
$$iU_{j2}^* Z_{k1}^{T,*}\delta_{\alpha\gamma} Y_{d,33}\Big(\frac{1-\gamma_5}{2}\Big) \tag{362}$$

$$+\ i\delta_{\alpha\gamma}\Big(-g_2 Z^{T,*}_{k1}V_{j1} + Y^*_{u,33}Z^{T,*}_{k2}V_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{363}$$



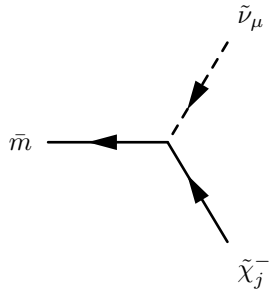
$$iU^*_{j2}Z^{U,*}_{k1}\delta_{\alpha\gamma}Y_{d,11}\Big(\frac{1-\gamma_5}{2}\Big) \tag{364}$$

$$+\ i\delta_{\alpha\gamma}\Big(-g_2 Z^{U,*}_{k1}V_{j1} + Y^*_{u,11}Z^{U,*}_{k2}V_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{365}$$



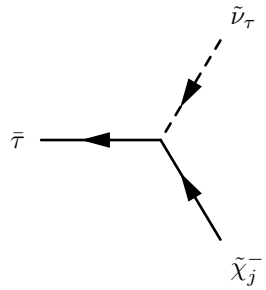
$$iU^*_{j2}Y_{e,11}\Big(\frac{1-\gamma_5}{2}\Big) \tag{366}$$

$$+\ -ig_2 V_{j1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{367}$$



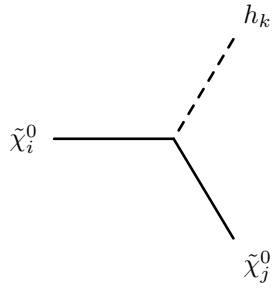
$$iU^*_{j2}Y_{e,22}\Big(\frac{1-\gamma_5}{2}\Big) \tag{368}$$

$$+\ -ig_2V_{j1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{369}$$



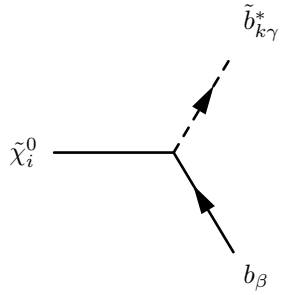
$$iU^*_{j2}Y_{e,33}\Big(\frac{1-\gamma_5}{2}\Big) \tag{370}$$

$$+\ -ig_2V_{j1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{371}$$



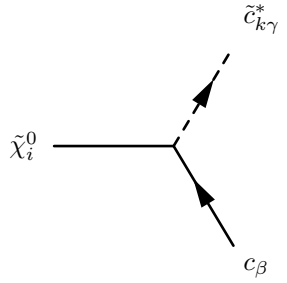
$$\frac{i}{2}\Big(N^*_{i3}\Big(g_1N^*_{j1}-g_2N^*_{j2}\Big)Z^H_{k1}-g_2N^*_{i2}N^*_{j3}Z^H_{k1}-g_1N^*_{i4}N^*_{j1}Z^H_{k2}+g_2N^*_{i4}N^*_{j2}Z^H_{k2}$$
$$+\ g_2N^*_{i2}N^*_{j4}Z^H_{k2}+g_1N^*_{i1}\Big(N^*_{j3}Z^H_{k1}-N^*_{j4}Z^H_{k2}\Big)\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{372}$$

$$+\ \frac{i}{2}\Big(Z^H_{k1}\Big(\Big(g_1N_{i1}-g_2N_{i2}\Big)N_{j3}+N_{i3}\Big(g_1N_{j1}-g_2N_{j2}\Big)\Big)$$
$$+\ Z^H_{k2}\Big(\Big(-g_1N_{i1}+g_2N_{i2}\Big)N_{j4}+N_{i4}\Big(-g_1N_{j1}+g_2N_{j2}\Big)\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{373}$$



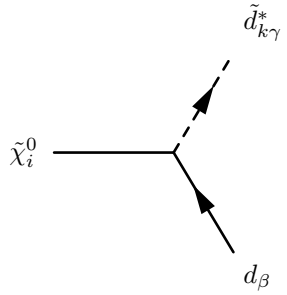
$$-\frac{i}{6}\delta_{\beta\gamma}\Big(-3\sqrt{2}g_2N^*_{i2}Z^B_{k1}+6N^*_{i3}Y_{d,33}Z^B_{k2}+\sqrt{2}g_1N^*_{i1}Z^B_{k1}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{374}$$

$$+\ -\frac{i}{3}\delta_{\beta\gamma}\Big(3Y^*_{d,33}Z^B_{k1}N_{i3}+\sqrt{2}g_1Z^B_{k2}N_{i1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{375}$$



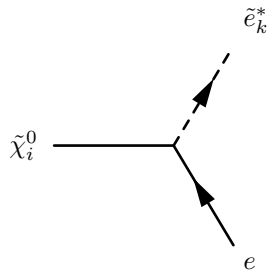
$$-\frac{i}{6}\delta_{\beta\gamma}\Big(3\sqrt{2}g_2N^*_{i2}Z^C_{k1}+6N^*_{i4}Y_{u,22}Z^C_{k2}+\sqrt{2}g_1N^*_{i1}Z^C_{k1}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{376}$$

$$+\ \frac{i}{3}\delta_{\beta\gamma}\Big(2\sqrt{2}g_1Z^C_{k2}N_{i1}-3Y^*_{u,22}Z^C_{k1}N_{i4}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{377}$$



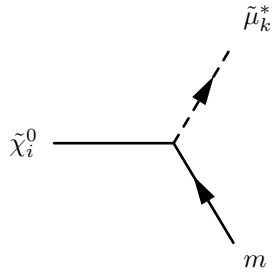
$$-\frac{i}{6}\delta_{\beta\gamma}\Big(-3\sqrt{2}g_2N^*_{i2}Z^D_{k1}+6N^*_{i3}Y_{d,11}Z^D_{k2}+\sqrt{2}g_1N^*_{i1}Z^D_{k1}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{378}$$

$$+\ -\frac{i}{3}\delta_{\beta\gamma}\Big(3Y^*_{d,11}Z^D_{k1}N_{i3}+\sqrt{2}g_1Z^D_{k2}N_{i1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{379}$$



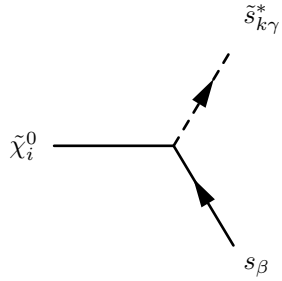
$$i\Big(\frac{1}{\sqrt{2}}g_1 N_{i1}^* Z_{k1}^E + \frac{1}{\sqrt{2}}g_2 N_{i2}^* Z_{k1}^E - N_{i3}^* Y_{e,11} Z_{k2}^E\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{380}$$

$$+\ i\Big(-\sqrt{2}g_1 Z_{k2}^E N_{i1} - Y_{e,11}^* Z_{k1}^E N_{i3}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{381}$$



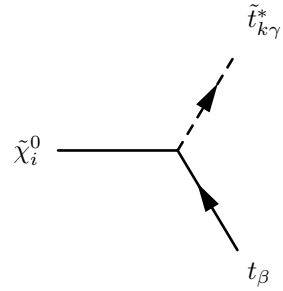
$$i\Big(\frac{1}{\sqrt{2}}g_1 N_{i1}^* Z_{k1}^\mu + \frac{1}{\sqrt{2}}g_2 N_{i2}^* Z_{k1}^\mu - N_{i3}^* Y_{e,22} Z_{k2}^\mu\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{382}$$

$$+\ i\Big(-\sqrt{2}g_1 Z_{k2}^\mu N_{i1} - Y_{e,22}^* Z_{k1}^\mu N_{i3}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{383}$$



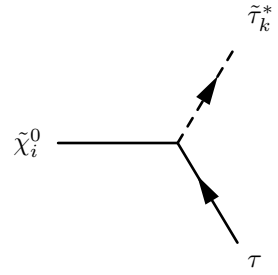
$$-\frac{i}{6}\delta_{\beta\gamma}\Big(-3\sqrt{2}g_2 N_{i2}^* Z_{k1}^S + 6N_{i3}^* Y_{d,22} Z_{k2}^S + \sqrt{2}g_1 N_{i1}^* Z_{k1}^S\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{384}$$

$$+ \; -\frac{i}{3}\delta_{\beta\gamma}\Big(3Y^*_{d,22}N_{i3}Z^S_{k1} + \sqrt{2}g_1 N_{i1}Z^S_{k2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{385}$$



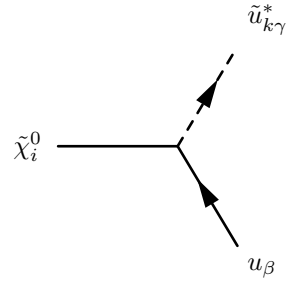
$$-\frac{i}{6}\delta_{\beta\gamma}\Big(3\sqrt{2}g_2 N^*_{i2}Z^T_{k1} + 6N^*_{i4}Y_{u,33}Z^T_{k2} + \sqrt{2}g_1 N^*_{i1}Z^T_{k1}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{386}$$

$$+\frac{i}{3}\delta_{\beta\gamma}\Big(2\sqrt{2}g_1 N_{i1}Z^T_{k2} - 3Y^*_{u,33}N_{i4}Z^T_{k1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{387}$$



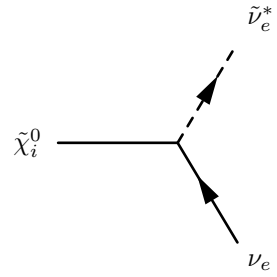
$$i\Big(\frac{1}{\sqrt{2}}g_1 N^*_{i1}Z^\tau_{k1} + \frac{1}{\sqrt{2}}g_2 N^*_{i2}Z^\tau_{k1} - N^*_{i3}Y_{e,33}Z^\tau_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{388}$$

$$+\; i\Big(-\sqrt{2}g_1 N_{i1}Z^\tau_{k2} - Y^*_{e,33}N_{i3}Z^\tau_{k1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{389}$$

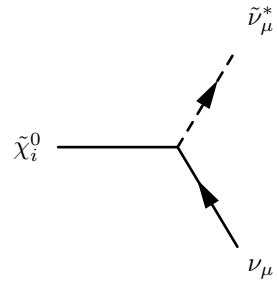


$$- \frac{i}{6}\delta_{\beta\gamma}\Big(3\sqrt{2}g_2 N^*_{i2} Z^U_{k1} + 6 N^*_{i4} Y_{u,11} Z^U_{k2} + \sqrt{2} g_1 N^*_{i1} Z^U_{k1}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{390}$$

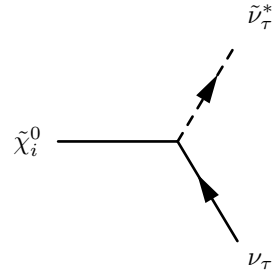
$$+ \frac{i}{3}\delta_{\beta\gamma}\Big(2\sqrt{2}g_1 N_{i1} Z^U_{k2} - 3 Y^*_{u,11} N_{i4} Z^U_{k1}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{391}$$



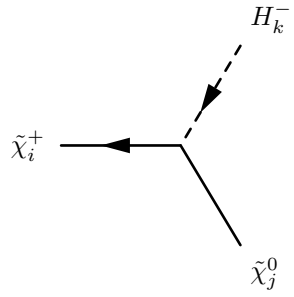
$$i\frac{1}{\sqrt{2}}\Big(g_1 N^*_{i1} - g_2 N^*_{i2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{392}$$



$$i\frac{1}{\sqrt{2}}\Big(g_1 N^*_{i1} - g_2 N^*_{i2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{393}$$

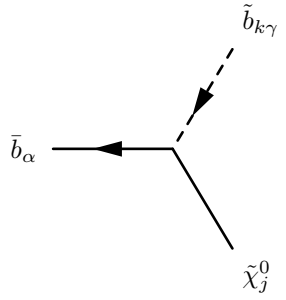


$$i\frac{1}{\sqrt{2}}\Big(g_1 N_{i1}^* - g_2 N_{i2}^*\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{394}$$



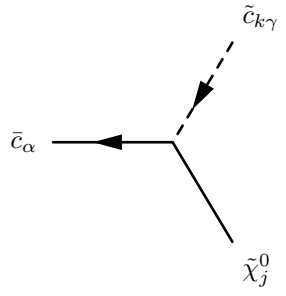
$$-\frac{i}{2}\Big(2g_2 V_{i1}^* N_{j4}^* + \sqrt{2}V_{i2}^*\Big(g_1 N_{j1}^* + g_2 N_{j2}^*\Big)\Big)Z_{k2}^+\Big(\frac{1-\gamma_5}{2}\Big) \tag{395}$$

$$+\frac{i}{2}\Big(-2g_2 U_{i1} N_{j3} + \sqrt{2}U_{i2}\Big(g_1 N_{j1} + g_2 N_{j2}\Big)\Big)Z_{k1}^+\Big(\frac{1+\gamma_5}{2}\Big) \tag{396}$$



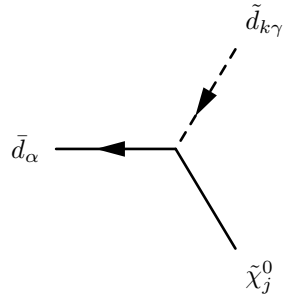
$$-\frac{i}{3}\delta_{\alpha\gamma}\Big(3Z_{k1}^{B,*}N_{j3}^* Y_{d,33} + \sqrt{2}g_1 Z_{k2}^{B,*}N_{j1}^*\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{397}$$

$$+\ -\frac{i}{6}\delta_{\alpha\gamma}\Big(6Y_{d,33}^* Z_{k2}^{B,*}N_{j3} + \sqrt{2}Z_{k1}^{B,*}\Big(-3g_2 N_{j2} + g_1 N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{398}$$



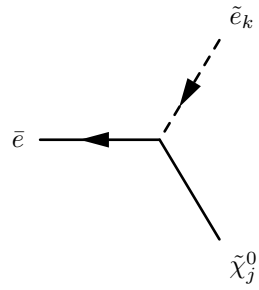
$$\frac{i}{3}\delta_{\alpha\gamma}\Big(2\sqrt{2}g_1 Z^{C,*}_{k2}N^*_{j1} - 3Z^{C,*}_{k1}N^*_{j4}Y_{u,22}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{399}$$

$$+\ -\frac{i}{6}\delta_{\alpha\gamma}\Big(6Y^*_{u,22}Z^{C,*}_{k2}N_{j4} + \sqrt{2}Z^{C,*}_{k1}\Big(3g_2N_{j2} + g_1N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{400}$$



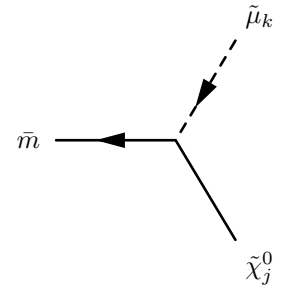
$$-\frac{i}{3}\delta_{\alpha\gamma}\Big(3Z^{D,*}_{k1}N^*_{j3}Y_{d,11} + \sqrt{2}g_1Z^{D,*}_{k2}N^*_{j1}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{401}$$

$$+\ -\frac{i}{6}\delta_{\alpha\gamma}\Big(6Y^*_{d,11}Z^{D,*}_{k2}N_{j3} + \sqrt{2}Z^{D,*}_{k1}\Big(-3g_2N_{j2} + g_1N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{402}$$



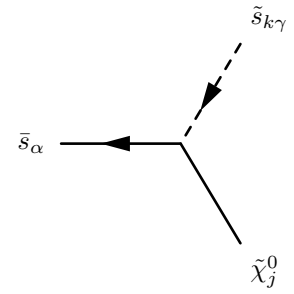
$$i\Big(-\sqrt{2}g_1Z^{E,*}_{k2}N^*_{j1} - Z^{E,*}_{k1}N^*_{j3}Y_{e,11}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{403}$$

$$+\ i\Big(\frac{1}{\sqrt{2}}Z^{E,*}_{k1}\Big(g_1N_{j1} + g_2N_{j2}\Big) - Y^*_{e,11}Z^{E,*}_{k2}N_{j3}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{404}$$



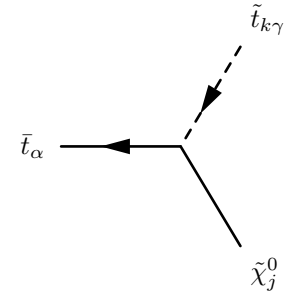
$$i\Big(-\sqrt{2}g_1 Z^{\mu,*}_{k2} N^*_{j1} - Z^{\mu,*}_{k1} N^*_{j3} Y_{e,22}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{405}$$

$$+\ i\Big(\frac{1}{\sqrt{2}} Z^{\mu,*}_{k1}\Big(g_1 N_{j1} + g_2 N_{j2}\Big) - Y^*_{e,22} Z^{\mu,*}_{k2} N_{j3}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{406}$$



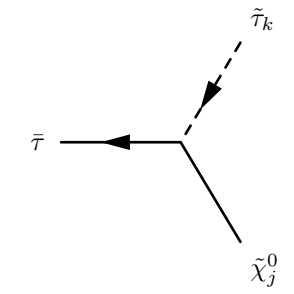
$$-\frac{i}{3}\delta_{\alpha\gamma}\Big(3N^*_{j3} Z^{S,*}_{k1} Y_{d,22} + \sqrt{2}g_1 N^*_{j1} Z^{S,*}_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{407}$$

$$+\ -\frac{i}{6}\delta_{\alpha\gamma}\Big(6Y^*_{d,22} Z^{S,*}_{k2} N_{j3} + \sqrt{2} Z^{S,*}_{k1}\Big(-3g_2 N_{j2} + g_1 N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{408}$$



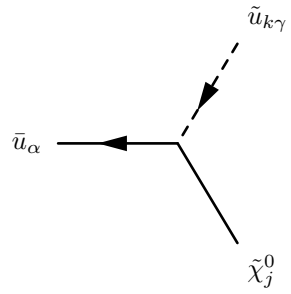
$$\frac{i}{3}\delta_{\alpha\gamma}\Big(2\sqrt{2}g_1 N^*_{j1} Z^{T,*}_{k2} - 3N^*_{j4} Z^{T,*}_{k1} Y_{u,33}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{409}$$

$$+\ -\frac{i}{6}\delta_{\alpha\gamma}\Big(6Y^*_{u,33} Z^{T,*}_{k2} N_{j4} + \sqrt{2} Z^{T,*}_{k1}\Big(3g_2 N_{j2} + g_1 N_{j1}\Big)\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{410}$$



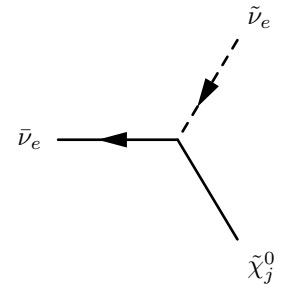
$$i\Big(- N^*_{j3} Z^{\tau,*}_{k1} Y_{e,33} - \sqrt{2} g_1 N^*_{j1} Z^{\tau,*}_{k2} \Big) \Big(\frac{1 - \gamma_5}{2} \Big) \tag{411}$$

$$+ \; i\Big(\frac{1}{\sqrt{2}} Z^{\tau,*}_{k1} \Big(g_1 N_{j1} + g_2 N_{j2} \Big) - Y^*_{e,33} Z^{\tau,*}_{k2} N_{j3} \Big) \Big(\frac{1 + \gamma_5}{2} \Big) \tag{412}$$



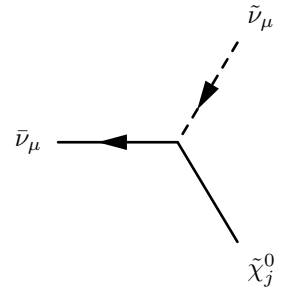
$$\frac{i}{3} \delta_{\alpha\gamma} \Big(2\sqrt{2} g_1 N^*_{j1} Z^{U,*}_{k2} - 3 N^*_{j4} Z^{U,*}_{k1} Y_{u,11} \Big) \Big(\frac{1 - \gamma_5}{2} \Big) \tag{413}$$

$$+ \; - \frac{i}{6} \delta_{\alpha\gamma} \Big(6 Y^*_{u,11} Z^{U,*}_{k2} N_{j4} + \sqrt{2} Z^{U,*}_{k1} \Big(3 g_2 N_{j2} + g_1 N_{j1} \Big) \Big) \Big(\frac{1 + \gamma_5}{2} \Big) \tag{414}$$



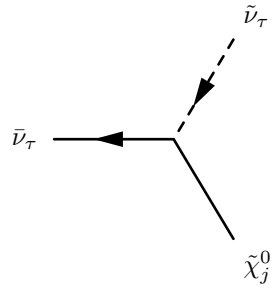
(415)

$$+ \; i \frac{1}{\sqrt{2}} \Big(g_1 N_{j1} - g_2 N_{j2} \Big) \Big(\frac{1 + \gamma_5}{2} \Big) \tag{416}$$



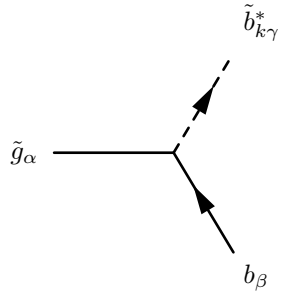
(417)

$$+\ i\frac{1}{\sqrt{2}}\Big(g_1 N_{j1} - g_2 N_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{418}$$



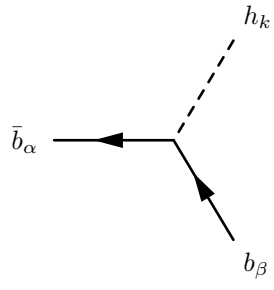
(419)

$$+\ i\frac{1}{\sqrt{2}}\Big(g_1 N_{j1} - g_2 N_{j2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{420}$$



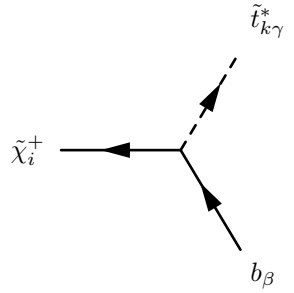
$$-\ i\frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda^{\alpha}_{\gamma,\beta} Z^B_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{421}$$

$$+\ i\frac{1}{\sqrt{2}} g_3 \phi^*_{\tilde{g}} \lambda^{\alpha}_{\gamma,\beta} Z^B_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{422}$$



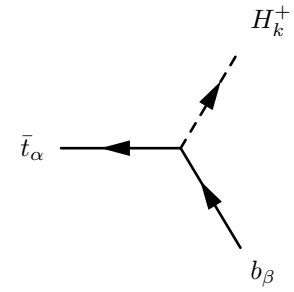
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{d,33}Z^{H}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{423}$$

$$+ \; -i\frac{1}{\sqrt{2}}Y^{*}_{d,33}\delta_{\alpha\beta}Z^{H}_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{424}$$



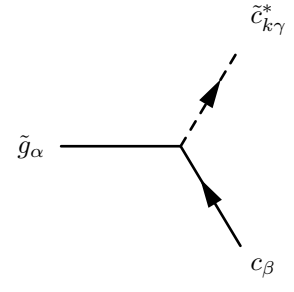
$$i\delta_{\beta\gamma}\Big(-g_2V^{*}_{i1}Z^{T}_{k1}+V^{*}_{i2}Y_{u,33}Z^{T}_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{425}$$

$$+ \; iY^{*}_{d,33}\delta_{\beta\gamma}U_{i2}Z^{T}_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{426}$$



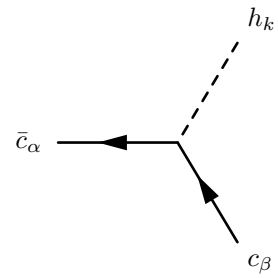
$$i\delta_{\alpha\beta}Y_{u,33}Z^{+}_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{427}$$

$$+ \; iY^{*}_{d,33}\delta_{\alpha\beta}Z^{+}_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{428}$$



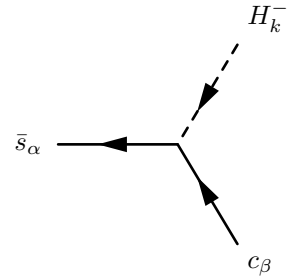
$$- i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\lambda^{\alpha}_{\gamma,\beta}Z^{C}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{429}$$

$$+ i\frac{1}{\sqrt{2}}g_3\phi^{*}_{\tilde{g}}\lambda^{\alpha}_{\gamma,\beta}Z^{C}_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{430}$$



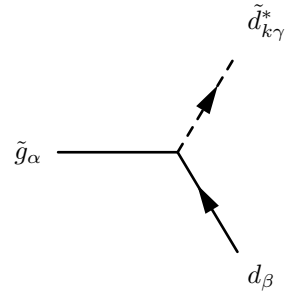
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{u,22}Z^{H}_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{431}$$

$$+ -i\frac{1}{\sqrt{2}}Y^{*}_{u,22}\delta_{\alpha\beta}Z^{H}_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{432}$$



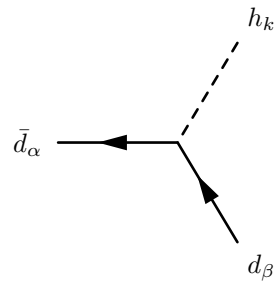
$$i\delta_{\alpha\beta}Y_{d,22}Z^{+}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{433}$$

$$+ iY^{*}_{u,22}\delta_{\alpha\beta}Z^{+}_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{434}$$



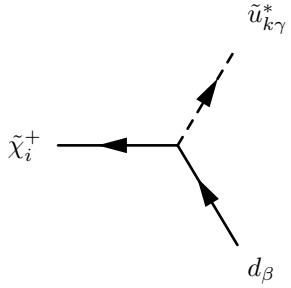
$$- i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\lambda^{\alpha}_{\gamma,\beta}Z^D_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{435}$$

$$+ i\frac{1}{\sqrt{2}}g_3\phi^*_{\tilde{g}}\lambda^{\alpha}_{\gamma,\beta}Z^D_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{436}$$



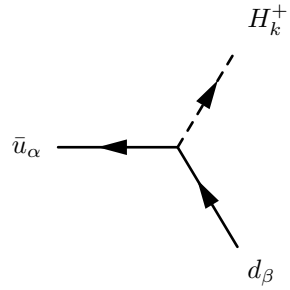
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{d,11}Z^H_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{437}$$

$$+ -i\frac{1}{\sqrt{2}}Y^*_{d,11}\delta_{\alpha\beta}Z^H_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{438}$$



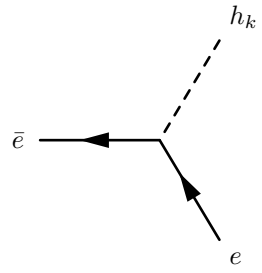
$$i\delta_{\beta\gamma}\Big(-g_2V^*_{i1}Z^U_{k1} + V^*_{i2}Y_{u,11}Z^U_{k2}\Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{439}$$

$$+ iY^*_{d,11}\delta_{\beta\gamma}U_{i2}Z^U_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{440}$$



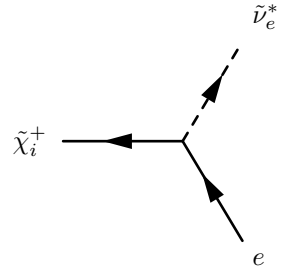
$$i\delta_{\alpha\beta}Y_{u,11}Z^{+}_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{441}$$

$$+\ iY^{*}_{d,11}\delta_{\alpha\beta}Z^{+}_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{442}$$



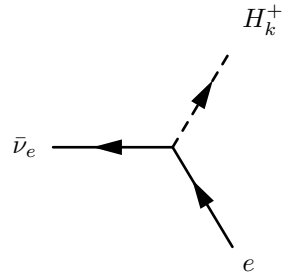
$$-\ i\frac{1}{\sqrt{2}}Y_{e,11}Z^{H}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{443}$$

$$+\ -i\frac{1}{\sqrt{2}}Y^{*}_{e,11}Z^{H}_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{444}$$



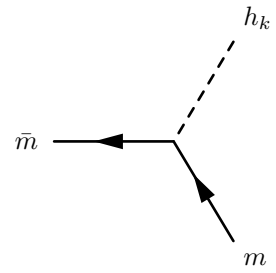
$$-\ ig_2V^{*}_{i1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{445}$$

$$+\ iY^{*}_{e,11}U_{i2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{446}$$



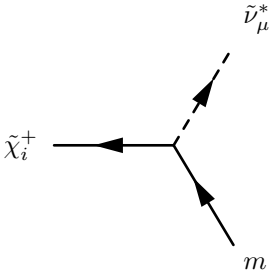
$$(447)$$

$$+\ iY^*_{e,11}Z^+_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{448}$$



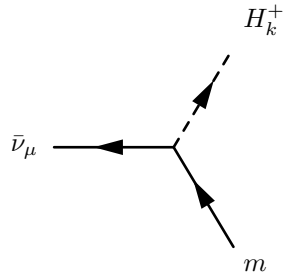
$$-\ i\frac{1}{\sqrt{2}}Y_{e,22}Z^H_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{449}$$

$$+\ -i\frac{1}{\sqrt{2}}Y^*_{e,22}Z^H_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{450}$$

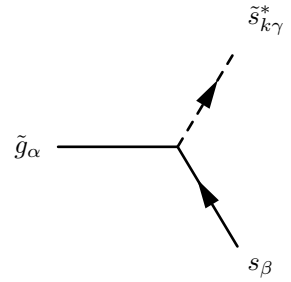


$$-\ ig_2V^*_{i1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{451}$$

$$+\ iY^*_{e,22}U_{i2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{452}$$

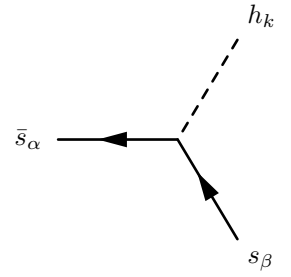


$$+\ iY^*_{e,22}Z^+_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{454}$$



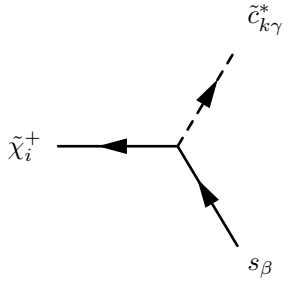
$$-\ i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}\lambda^\alpha_{\gamma,\beta}Z^S_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{455}$$

$$+\ i\frac{1}{\sqrt{2}}g_3\phi^*_{\tilde{g}}\lambda^\alpha_{\gamma,\beta}Z^S_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{456}$$



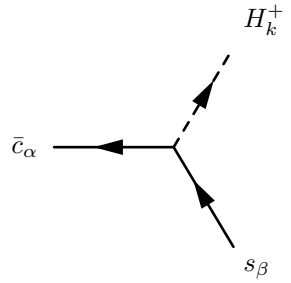
$$-\ i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{d,22}Z^H_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{457}$$

$$+\ -i\frac{1}{\sqrt{2}}Y^*_{d,22}\delta_{\alpha\beta}Z^H_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{458}$$



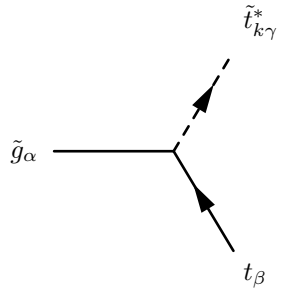
$$i\delta_{\beta\gamma}\Big(- g_2 V_{i1}^* Z_{k1}^C + V_{i2}^* Y_{u,22} Z_{k2}^C \Big)\Big(\frac{1-\gamma_5}{2}\Big) \tag{459}$$

$$+\ iY_{d,22}^* \delta_{\beta\gamma} U_{i2} Z_{k1}^C \Big(\frac{1+\gamma_5}{2}\Big) \tag{460}$$



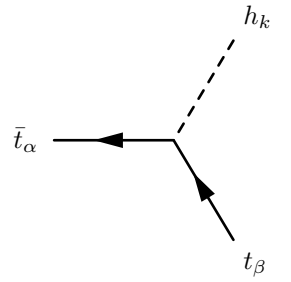
$$i\delta_{\alpha\beta} Y_{u,22} Z_{k2}^+ \Big(\frac{1-\gamma_5}{2}\Big) \tag{461}$$

$$+\ iY_{d,22}^* \delta_{\alpha\beta} Z_{k1}^+ \Big(\frac{1+\gamma_5}{2}\Big) \tag{462}$$



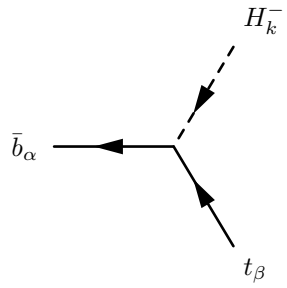
$$-\ i\frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\gamma,\beta}^{\alpha} Z_{k1}^T \Big(\frac{1-\gamma_5}{2}\Big) \tag{463}$$

$$+\ i\frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^{\alpha} Z_{k2}^T \Big(\frac{1+\gamma_5}{2}\Big) \tag{464}$$



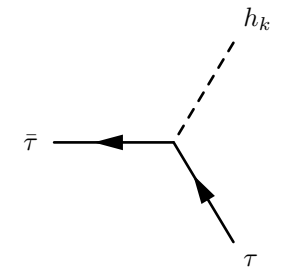
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{u,33}Z^H_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{465}$$

$$+ -i\frac{1}{\sqrt{2}}Y^*_{u,33}\delta_{\alpha\beta}Z^H_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{466}$$



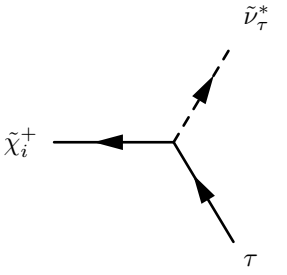
$$i\delta_{\alpha\beta}Y_{d,33}Z^+_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{467}$$

$$+ iY^*_{u,33}\delta_{\alpha\beta}Z^+_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{468}$$



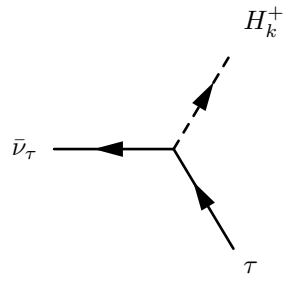
$$- i\frac{1}{\sqrt{2}}Y_{e,33}Z^H_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{469}$$

$$+ -i\frac{1}{\sqrt{2}}Y^*_{e,33}Z^H_{k1}\Big(\frac{1+\gamma_5}{2}\Big) \tag{470}$$



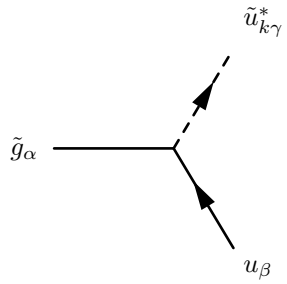
$$- ig_2 V_{i1}^* \Big(\frac{1-\gamma_5}{2}\Big) \tag{471}$$

$$+ iY_{e,33}^* U_{i2} \Big(\frac{1+\gamma_5}{2}\Big) \tag{472}$$



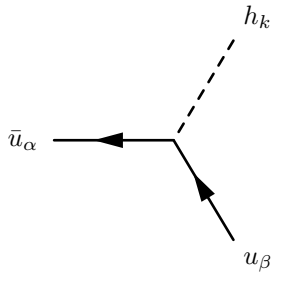
(473)

$$+ iY_{e,33}^* Z_{k1}^+ \Big(\frac{1+\gamma_5}{2}\Big) \tag{474}$$



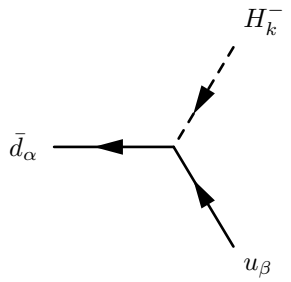
$$- i\frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}} \lambda_{\gamma,\beta}^{\alpha} Z_{k1}^U \Big(\frac{1-\gamma_5}{2}\Big) \tag{475}$$

$$+ i\frac{1}{\sqrt{2}} g_3 \phi_{\tilde{g}}^* \lambda_{\gamma,\beta}^{\alpha} Z_{k2}^U \Big(\frac{1+\gamma_5}{2}\Big) \tag{476}$$



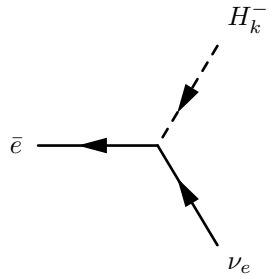
$$- i\frac{1}{\sqrt{2}}\delta_{\alpha\beta}Y_{u,11}Z^{H}_{k2}\Big(\frac{1-\gamma_5}{2}\Big) \tag{477}$$

$$+ -i\frac{1}{\sqrt{2}}Y^{*}_{u,11}\delta_{\alpha\beta}Z^{H}_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{478}$$

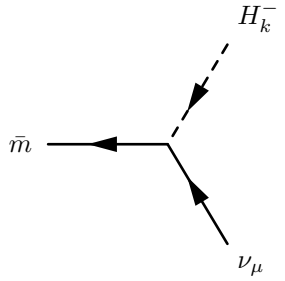


$$i\delta_{\alpha\beta}Y_{d,11}Z^{+}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{479}$$

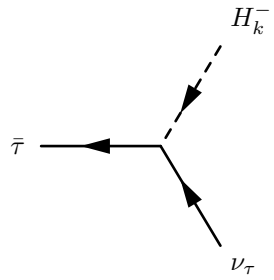
$$+ iY^{*}_{u,11}\delta_{\alpha\beta}Z^{+}_{k2}\Big(\frac{1+\gamma_5}{2}\Big) \tag{480}$$



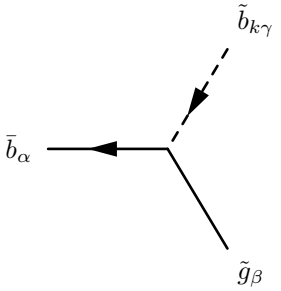
$$iY_{e,11}Z^{+}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{481}$$



$$iY_{e,22}Z^{+}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{482}$$

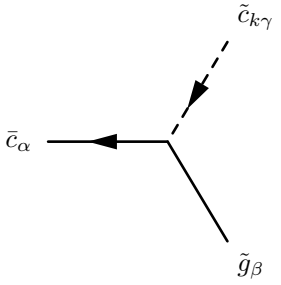


$$iY_{e,33}Z^{+}_{k1}\Big(\frac{1-\gamma_5}{2}\Big) \tag{483}$$



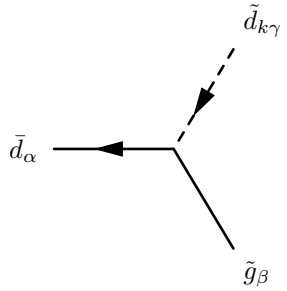
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}Z^{B,*}_{k2}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{484}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^{*}_{\tilde{g}}Z^{B,*}_{k1}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1+\gamma_5}{2}\Big) \tag{485}$$



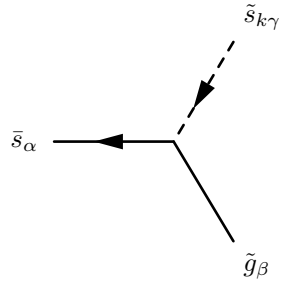
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}Z^{C,*}_{k2}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{486}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^*_{\tilde{g}}Z^{C,*}_{k1}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1+\gamma_5}{2}\Big) \tag{487}$$



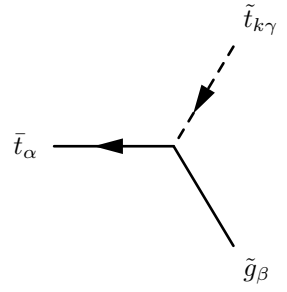
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}Z^{D,*}_{k2}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{488}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^*_{\tilde{g}}Z^{D,*}_{k1}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1+\gamma_5}{2}\Big) \tag{489}$$



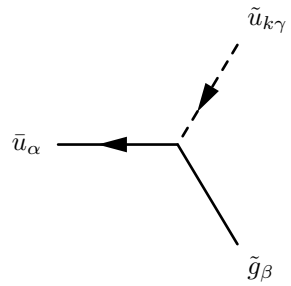
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}Z^{S,*}_{k2}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{490}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^*_{\tilde{g}}Z^{S,*}_{k1}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1+\gamma_5}{2}\Big) \tag{491}$$



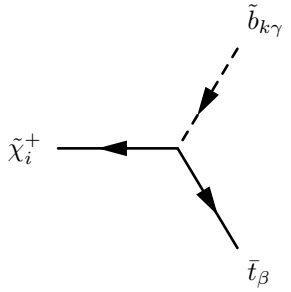
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}Z^{T,*}_{k2}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{492}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^*_{\tilde{g}}Z^{T,*}_{k1}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1+\gamma_5}{2}\Big) \tag{493}$$



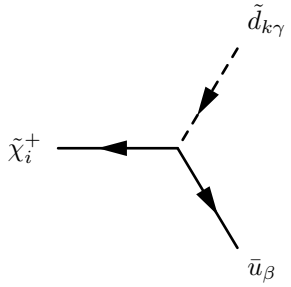
$$i\frac{1}{\sqrt{2}}g_3\phi_{\tilde{g}}Z^{U,*}_{k2}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1-\gamma_5}{2}\Big) \tag{494}$$

$$+\ -i\frac{1}{\sqrt{2}}g_3\phi^*_{\tilde{g}}Z^{U,*}_{k1}\lambda^{\beta}_{\alpha,\gamma}\Big(\frac{1+\gamma_5}{2}\Big) \tag{495}$$



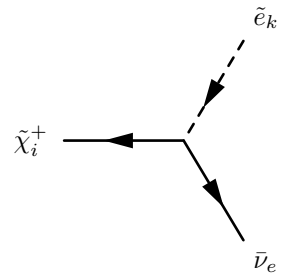
$$iV^*_{i2}Z^{B,*}_{k1}\delta_{\beta\gamma}Y_{u,33}\Big(\frac{1-\gamma_5}{2}\Big) \tag{496}$$

$$+\ i\delta_{\beta\gamma}\Big(-g_2Z^{B,*}_{k1}U_{i1}+Y^*_{d,33}Z^{B,*}_{k2}U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{497}$$



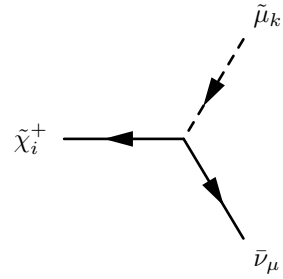
$$iV_{i2}^{*}Z_{k1}^{D,*}\delta_{\beta\gamma}Y_{u,11}\Big(\frac{1-\gamma_5}{2}\Big) \tag{498}$$

$$+\ i\delta_{\beta\gamma}\Big(-g_2Z_{k1}^{D,*}U_{i1}+Y_{d,11}^{*}Z_{k2}^{D,*}U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{499}$$



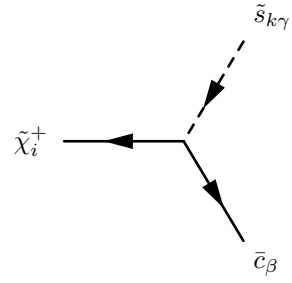
(500)

$$+\ i\Big(-g_2Z_{k1}^{E,*}U_{i1}+Y_{e,11}^{*}Z_{k2}^{E,*}U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{501}$$



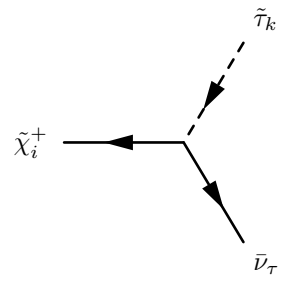
(502)

$$+\ i\Big(-g_2Z_{k1}^{\mu,*}U_{i1}+Y_{e,22}^{*}Z_{k2}^{\mu,*}U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{503}$$



$$iV_{i2}^{*}Z_{k1}^{S,*}\delta_{\beta\gamma}Y_{u,22}\Big(\frac{1-\gamma_5}{2}\Big) \tag{504}$$

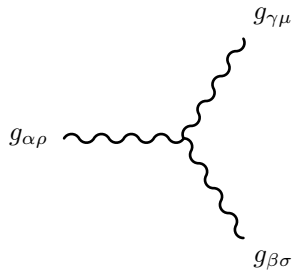
$$+\ i\delta_{\beta\gamma}\Big(-g_2Z_{k1}^{S,*}U_{i1}+Y_{d,22}^{*}Z_{k2}^{S,*}U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{505}$$



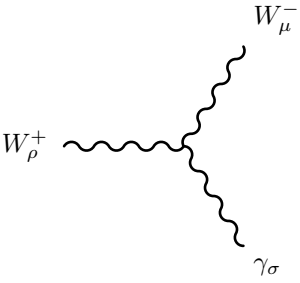
(506)

$$+\ i\Big(-g_2Z_{k1}^{\tau,*}U_{i1}+Y_{e,33}^{*}Z_{k2}^{\tau,*}U_{i2}\Big)\Big(\frac{1+\gamma_5}{2}\Big) \tag{507}$$

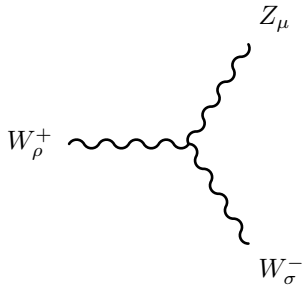
9.6 Three Vector Boson-Interaction



$$g_3f_{\alpha,\beta,\gamma}\Big(g_{\rho\mu}\Big(-p_\sigma^{g_{\gamma\mu}}+p_\sigma^{g_{\alpha\rho}}\Big)+g_{\rho\sigma}\Big(-p_\mu^{g_{\alpha\rho}}+p_\mu^{g_{\beta\sigma}}\Big)+g_{\sigma\mu}\Big(-p_\rho^{g_{\beta\sigma}}+p_\rho^{g_{\gamma\mu}}\Big)\Big) \tag{508}$$

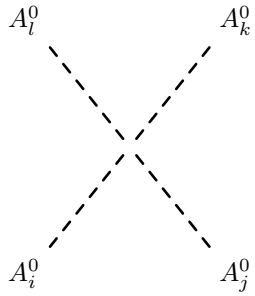


$$ig_2 \sin\Theta_W \Big(g_{\rho\mu} \Big(- p_\sigma^{W_\mu^-} + p_\sigma^{W_\rho^+} \Big) + g_{\rho\sigma} \Big(- p_\mu^{W_\rho^+} + p_\mu^{\gamma_\sigma} \Big) + g_{\sigma\mu} \Big(- p_\rho^{\gamma_\sigma} + p_\rho^{W_\mu^-} \Big) \Big) \tag{509}$$

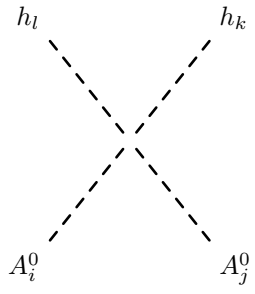


$$- ig_2 \cos\Theta_W \Big(g_{\rho\mu} \Big(- p_\sigma^{Z_\mu} + p_\sigma^{W_\rho^+} \Big) + g_{\rho\sigma} \Big(- p_\mu^{W_\rho^+} + p_\mu^{W_\sigma^-} \Big) + g_{\sigma\mu} \Big(- p_\rho^{W_\sigma^-} + p_\rho^{Z_\mu} \Big) \Big) \tag{510}$$

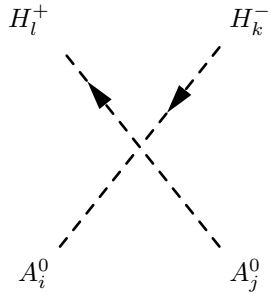
9.7 Four Scalar-Interaction



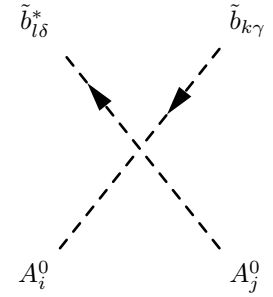
$$\begin{aligned} &\frac{i}{4} \Big(g_1^2 + g_2^2 \Big) \Big(Z_{i2}^A \Big(Z_{j1}^A \Big(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \Big) + Z_{j2}^A \Big(- 3 Z_{k2}^A Z_{l2}^A + Z_{k1}^A Z_{l1}^A \Big) \Big) \\ &+ Z_{i1}^A \Big(Z_{j1}^A \Big(- 3 Z_{k1}^A Z_{l1}^A + Z_{k2}^A Z_{l2}^A \Big) + Z_{j2}^A \Big(Z_{k1}^A Z_{l2}^A + Z_{k2}^A Z_{l1}^A \Big) \Big) \Big) \end{aligned} \tag{511}$$



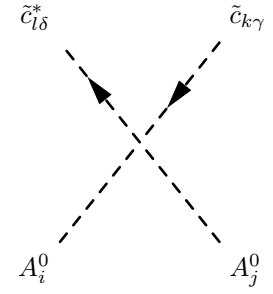
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\Big)\Big(Z_{k1}^H Z_{l1}^H - Z_{k2}^H Z_{l2}^H\Big) \tag{512}$$



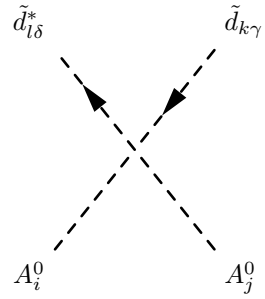
$$\begin{aligned}&\frac{i}{4}\Big(Z_{i1}^A\Big(g_2^2 Z_{j2}^A\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) - Z_{j1}^A\Big(\Big(g_1^2+g_2^2\Big)Z_{k1}^+ Z_{l1}^+ + \Big(-g_1^2+g_2^2\Big)Z_{k2}^+ Z_{l2}^+\Big)\Big)\\&+ Z_{i2}^A\Big(g_2^2 Z_{j1}^A\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) + Z_{j2}^A\Big(-\Big(g_1^2+g_2^2\Big)Z_{k2}^+ Z_{l2}^+ + \Big(-g_2^2+g_1^2\Big)Z_{k1}^+ Z_{l1}^+\Big)\Big)\Big)\end{aligned} \tag{513}$$



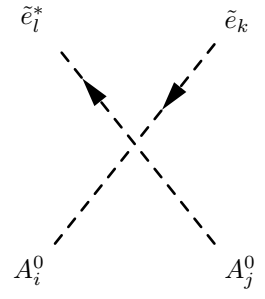
$$\begin{aligned}&\frac{i}{12}\delta_{\gamma\delta}\Big(Z_{k1}^{B,*}\Big(\Big(-12|Y_{d,33}|^2+3g_2^2+g_1^2\Big)Z_{i1}^A Z_{j1}^A - \Big(3g_2^2+g_1^2\Big)Z_{i2}^A Z_{j2}^A\Big)Z_{l1}^B\\&+2Z_{k2}^{B,*}\Big(\Big(-6|Y_{d,33}|^2+g_1^2\Big)Z_{i1}^A Z_{j1}^A - g_1^2 Z_{i2}^A Z_{j2}^A\Big)Z_{l2}^B\Big)\end{aligned} \tag{514}$$



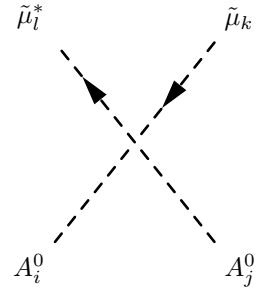
$$\frac{i}{12}\delta_{\gamma\delta}\Big(Z^{C,*}_{k1}\Big(-\Big(12|Y_{u,22}|^2-3g_2^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}+\Big(-3g_2^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}\Big)Z^C_{l1}$$
$$-4Z^{C,*}_{k2}\Big(-\Big(-3|Y_{u,22}|^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}+g_1^2Z^A_{i1}Z^A_{j1}\Big)Z^C_{l2}\Big) \tag{515}$$



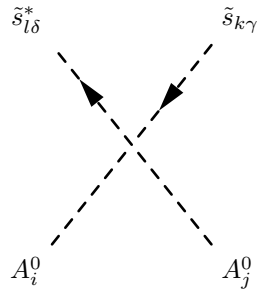
$$\frac{i}{12}\delta_{\gamma\delta}\Big(Z^{D,*}_{k1}\Big(\Big(-12|Y_{d,11}|^2+3g_2^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}-\Big(3g_2^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}\Big)Z^D_{l1}$$
$$+2Z^{D,*}_{k2}\Big(\Big(-6|Y_{d,11}|^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}-g_1^2Z^A_{i2}Z^A_{j2}\Big)Z^D_{l2}\Big) \tag{516}$$



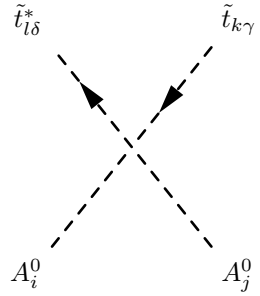
$$\frac{i}{4}\Big(Z^{E,*}_{k1}\Big(\Big(-4|Y_{e,11}|^2-g_1^2+g_2^2\Big)Z^A_{i1}Z^A_{j1}+\Big(-g_2^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}\Big)Z^E_{l1}$$
$$+2Z^{E,*}_{k2}\Big(\Big(-2|Y_{e,11}|^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}-g_1^2Z^A_{i2}Z^A_{j2}\Big)Z^E_{l2}\Big) \tag{517}$$



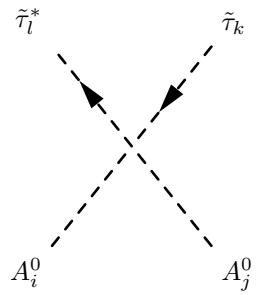
$$\frac{i}{4}\Big(Z^{\mu,*}_{k1}\Big(\Big(-4|Y_{e,22}|^2-g_1^2+g_2^2\Big)Z^A_{i1}Z^A_{j1}+\Big(-g_2^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}\Big)Z^\mu_{l1}$$
$$+2Z^{\mu,*}_{k2}\Big(\Big(-2|Y_{e,22}|^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}-g_1^2Z^A_{i2}Z^A_{j2}\Big)Z^\mu_{l2}\Big) \tag{518}$$



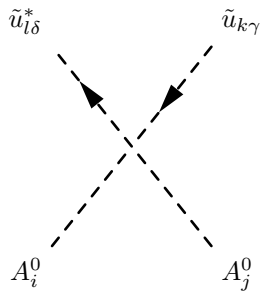
$$\frac{i}{12}\delta_{\gamma\delta}\Big(Z^{S,*}_{k1}\Big(\Big(-12|Y_{d,22}|^2+3g_2^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}-\Big(3g_2^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}\Big)Z^S_{l1}$$
$$+2Z^{S,*}_{k2}\Big(\Big(-6|Y_{d,22}|^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}-g_1^2Z^A_{i2}Z^A_{j2}\Big)Z^S_{l2}\Big) \tag{519}$$



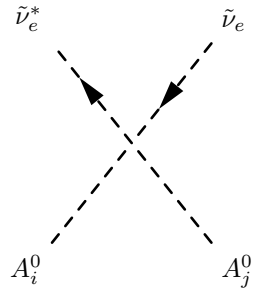
$$\frac{i}{12}\delta_{\gamma\delta}\Big(Z^{T,*}_{k1}\Big(-\Big(12|Y_{u,33}|^2-3g_2^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}+\Big(-3g_2^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}\Big)Z^T_{l1}$$
$$-4Z^{T,*}_{k2}\Big(-\Big(-3|Y_{u,33}|^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}+g_1^2Z^A_{i1}Z^A_{j1}\Big)Z^T_{l2}\Big) \tag{520}$$



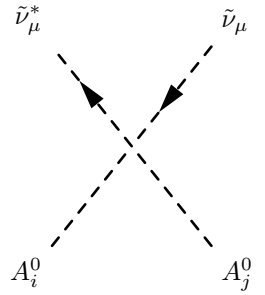
$$\frac{i}{4}\Big(Z^{\tau,*}_{k1}\Big(\Big(-4|Y_{e,33}|^2-g_1^2+g_2^2\Big)Z^A_{i1}Z^A_{j1}+\Big(-g_2^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}\Big)Z^\tau_{l1}$$
$$+2Z^{\tau,*}_{k2}\Big(\Big(-2|Y_{e,33}|^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}-g_1^2Z^A_{i2}Z^A_{j2}\Big)Z^\tau_{l2}\Big) \tag{521}$$



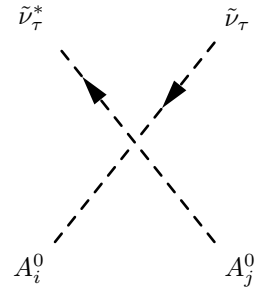
$$\frac{i}{12}\delta_{\gamma\delta}\Big(Z^{U,*}_{k1}\Big(-\Big(12|Y_{u,11}|^2-3g_2^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}+\Big(-3g_2^2+g_1^2\Big)Z^A_{i1}Z^A_{j1}\Big)Z^U_{l1}$$
$$-4Z^{U,*}_{k2}\Big(-\Big(-3|Y_{u,11}|^2+g_1^2\Big)Z^A_{i2}Z^A_{j2}+g_1^2Z^A_{i1}Z^A_{j1}\Big)Z^U_{l2}\Big) \tag{522}$$



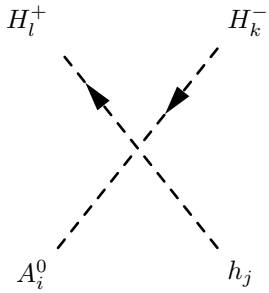
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z^A_{i1}Z^A_{j1}-Z^A_{i2}Z^A_{j2}\Big) \tag{523}$$



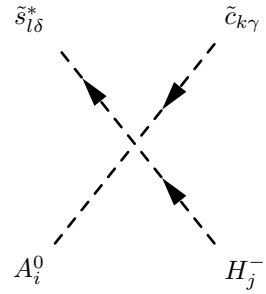
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\Big) \tag{524}$$



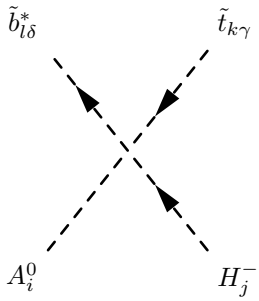
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i1}^A Z_{j1}^A - Z_{i2}^A Z_{j2}^A\Big) \tag{525}$$



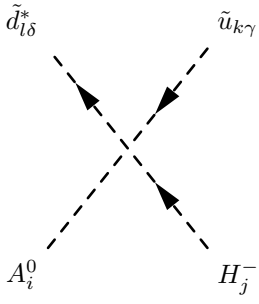
$$\frac{1}{4}g_2^2\Big(Z_{i1}^A Z_{j2}^H + Z_{i2}^A Z_{j1}^H\Big)\Big(-Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) \tag{526}$$



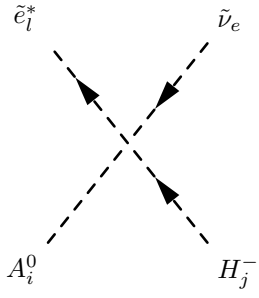
$$\begin{aligned}&-\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\Big(Z_{k1}^{C,*}\Big(\Big(-2|Y_{d,22}|^2+g_2^2\Big)Z_{i1}^A Z_{j1}^+ - \Big(-2|Y_{u,22}|^2+g_2^2\Big)Z_{i2}^A Z_{j2}^+\Big)Z_{l1}^S \\ &+2Y_{u,22}^* Z_{k2}^{C,*} Y_{d,22}\Big(Z_{i1}^A Z_{j2}^+ - Z_{i2}^A Z_{j1}^+\Big)Z_{l2}^S\Big)\end{aligned} \tag{527}$$



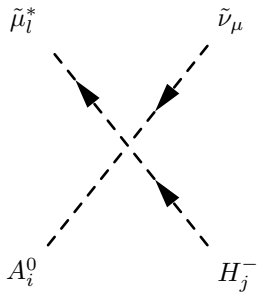
$$
\begin{aligned}
&-\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\Big(2Y^*_{u,33}Z^{T,*}_{k2}Y_{d,33}Z^B_{l2}\Big(Z^A_{i1}Z^+_{j2}-Z^A_{i2}Z^+_{j1}\Big)\\
&+Z^{T,*}_{k1}Z^B_{l1}\Big(\Big(-2|Y_{d,33}|^2+g_2^2\Big)Z^A_{i1}Z^+_{j1}-\Big(-2|Y_{u,33}|^2+g_2^2\Big)Z^A_{i2}Z^+_{j2}\Big)\Big)
\end{aligned}
\tag{528}
$$



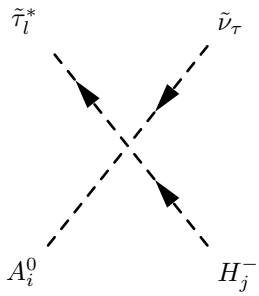
$$
\begin{aligned}
&-\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\Big(2Y^*_{u,11}Z^{U,*}_{k2}Y_{d,11}Z^D_{l2}\Big(Z^A_{i1}Z^+_{j2}-Z^A_{i2}Z^+_{j1}\Big)\\
&+Z^{U,*}_{k1}Z^D_{l1}\Big(\Big(-2|Y_{d,11}|^2+g_2^2\Big)Z^A_{i1}Z^+_{j1}-\Big(-2|Y_{u,11}|^2+g_2^2\Big)Z^A_{i2}Z^+_{j2}\Big)\Big)
\end{aligned}
\tag{529}
$$



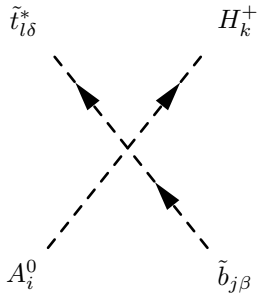
$$
-\frac{1}{2}\frac{1}{\sqrt{2}}Z^E_{l1}\Big(\Big(-2|Y_{e,11}|^2+g_2^2\Big)Z^A_{i1}Z^+_{j1}-g_2^2Z^A_{i2}Z^+_{j2}\Big)
\tag{530}
$$



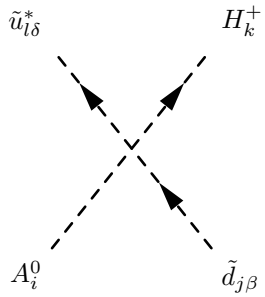
$$-\frac{1}{2}\frac{1}{\sqrt{2}}Z_{l1}^{\mu}\Big(\Big(-2|Y_{e,22}|^2+g_2^2\Big)Z_{i1}^{A}Z_{j1}^{+}-g_2^2Z_{i2}^{A}Z_{j2}^{+}\Big) \tag{531}$$



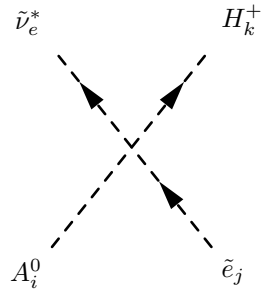
$$-\frac{1}{2}\frac{1}{\sqrt{2}}\Big(\Big(-2|Y_{e,33}|^2+g_2^2\Big)Z_{i1}^{A}Z_{j1}^{+}-g_2^2Z_{i2}^{A}Z_{j2}^{+}\Big)Z_{l1}^{\tau} \tag{532}$$



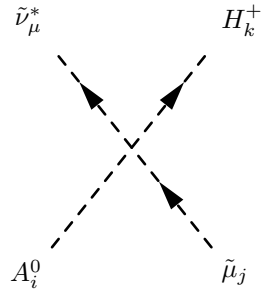
$$\begin{aligned}&\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(Z_{j1}^{B,*}\Big(\Big(-2|Y_{d,33}|^2+g_2^2\Big)Z_{i1}^{A}Z_{k1}^{+}-\Big(-2|Y_{u,33}|^2+g_2^2\Big)Z_{i2}^{A}Z_{k2}^{+}\Big)Z_{l1}^{T}\\&+2Y_{d,33}^{*}Z_{j2}^{B,*}Y_{u,33}\Big(Z_{i1}^{A}Z_{k2}^{+}-Z_{i2}^{A}Z_{k1}^{+}\Big)Z_{l2}^{T}\Big)\end{aligned} \tag{533}$$



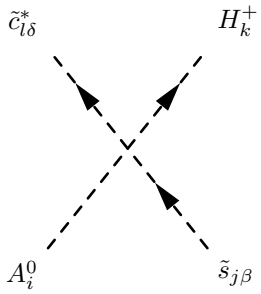
$$\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(Z^{D,*}_{j1}\Big(\Big(-2|Y_{d,11}|^2+g_2^2\Big)Z^A_{i1}Z^+_{k1}-\Big(-2|Y_{u,11}|^2+g_2^2\Big)Z^A_{i2}Z^+_{k2}\Big)Z^U_{l1}$$
$$+2Y^*_{d,11}Z^{D,*}_{j2}Y_{u,11}\Big(Z^A_{i1}Z^+_{k2}-Z^A_{i2}Z^+_{k1}\Big)Z^U_{l2}\Big) \tag{534}$$



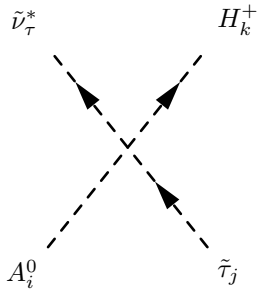
$$\frac{1}{2}\frac{1}{\sqrt{2}}Z^{E,*}_{j1}\Big(\Big(-2|Y_{e,11}|^2+g_2^2\Big)Z^A_{i1}Z^+_{k1}-g_2^2Z^A_{i2}Z^+_{k2}\Big) \tag{535}$$



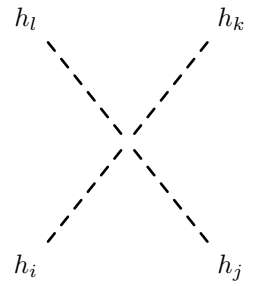
$$\frac{1}{2}\frac{1}{\sqrt{2}}Z^{\mu,*}_{j1}\Big(\Big(-2|Y_{e,22}|^2+g_2^2\Big)Z^A_{i1}Z^+_{k1}-g_2^2Z^A_{i2}Z^+_{k2}\Big) \tag{536}$$



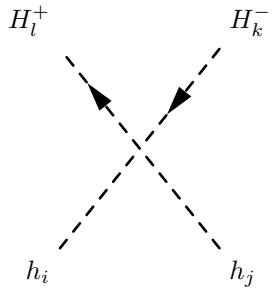
$$-\frac{1}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(2Y^*_{d,22}Z^{S,*}_{j2}Y_{u,22}Z^C_{l2}\Big(-Z^A_{i1}Z^+_{k2}+Z^A_{i2}Z^+_{k1}\Big)$$
$$+Z^{S,*}_{j1}Z^C_{l1}\Big(-\Big(-2|Y_{d,22}|^2+g_2^2\Big)Z^A_{i1}Z^+_{k1}+\Big(-2|Y_{u,22}|^2+g_2^2\Big)Z^A_{i2}Z^+_{k2}\Big)\Big) \tag{537}$$



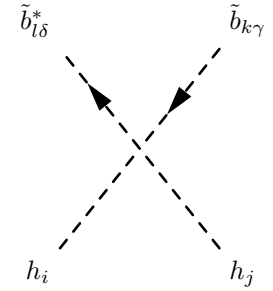
$$\frac{1}{2}\frac{1}{\sqrt{2}}Z^{\tau,*}_{j1}\Big(\Big(-2|Y_{e,33}|^2+g_2^2\Big)Z^A_{i1}Z^+_{k1}-g_2^2Z^A_{i2}Z^+_{k2}\Big) \tag{538}$$



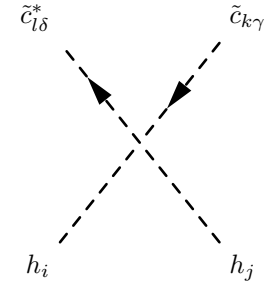
$$\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z^H_{i2}\Big(Z^H_{j1}\Big(Z^H_{k1}Z^H_{l2}+Z^H_{k2}Z^H_{l1}\Big)+Z^H_{j2}\Big(-3Z^H_{k2}Z^H_{l2}+Z^H_{k1}Z^H_{l1}\Big)\Big)$$
$$+Z^H_{i1}\Big(Z^H_{j1}\Big(-3Z^H_{k1}Z^H_{l1}+Z^H_{k2}Z^H_{l2}\Big)+Z^H_{j2}\Big(Z^H_{k1}Z^H_{l2}+Z^H_{k2}Z^H_{l1}\Big)\Big)\Big) \tag{539}$$



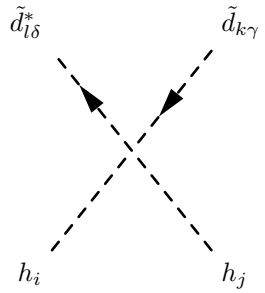
$$\frac{i}{4}\Big(- Z_{i1}^H\Big(g_2^2 Z_{j2}^H\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) + Z_{j1}^H\Big(\Big(g_1^2 + g_2^2\Big) Z_{k1}^+ Z_{l1}^+ + \Big(- g_1^2 + g_2^2\Big) Z_{k2}^+ Z_{l2}^+\Big)\Big)$$
$$+ Z_{i2}^H\Big(- g_2^2 Z_{j1}^H\Big(Z_{k1}^+ Z_{l2}^+ + Z_{k2}^+ Z_{l1}^+\Big) + Z_{j2}^H\Big(- \Big(g_1^2 + g_2^2\Big) Z_{k2}^+ Z_{l2}^+ + \Big(- g_2^2 + g_1^2\Big) Z_{k1}^+ Z_{l1}^+\Big)\Big)\Big) \tag{540}$$



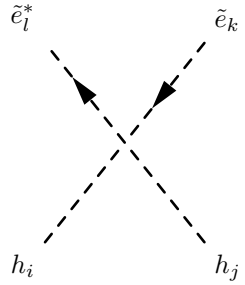
$$\frac{i}{12}\delta_{\gamma\delta}\Big(2 Z_{k2}^{B,*} Z_{l2}^B\Big(\Big(- 6|Y_{d,33}|^2 + g_1^2\Big) Z_{i1}^H Z_{j1}^H - g_1^2 Z_{i2}^H Z_{j2}^H\Big)$$
$$+ Z_{k1}^{B,*} Z_{l1}^B\Big(\Big(- 12|Y_{d,33}|^2 + 3g_2^2 + g_1^2\Big) Z_{i1}^H Z_{j1}^H - \Big(3g_2^2 + g_1^2\Big) Z_{i2}^H Z_{j2}^H\Big)\Big) \tag{541}$$



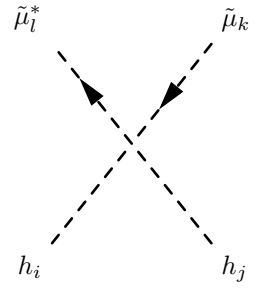
$$\frac{i}{12}\delta_{\gamma\delta}\Big(- 4 Z_{k2}^{C,*} Z_{l2}^C\Big(- \Big(- 3|Y_{u,22}|^2 + g_1^2\Big) Z_{i2}^H Z_{j2}^H + g_1^2 Z_{i1}^H Z_{j1}^H\Big)$$
$$+ Z_{k1}^{C,*} Z_{l1}^C\Big(- \Big(12|Y_{u,22}|^2 - 3g_2^2 + g_1^2\Big) Z_{i2}^H Z_{j2}^H + \Big(- 3g_2^2 + g_1^2\Big) Z_{i1}^H Z_{j1}^H\Big)\Big) \tag{542}$$



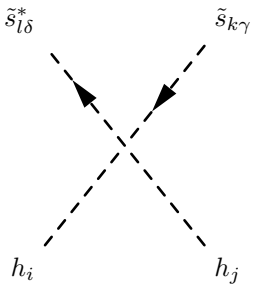
$$\frac{i}{12}\delta_{\gamma\delta}\Big(2Z^{D,*}_{k2}Z^{D}_{l2}\Big(\Big(-6|Y_{d,11}|^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}-g_1^2Z^H_{i2}Z^H_{j2}\Big) \\ +Z^{D,*}_{k1}Z^{D}_{l1}\Big(\Big(-12|Y_{d,11}|^2+3g_2^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}-\Big(3g_2^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}\Big)\Big) \tag{543}$$



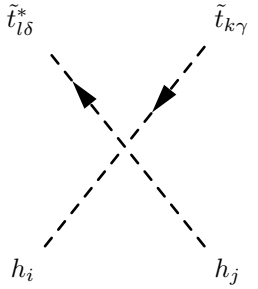
$$\frac{i}{4}\Big(2Z^{E,*}_{k2}Z^{E}_{l2}\Big(\Big(-2|Y_{e,11}|^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}-g_1^2Z^H_{i2}Z^H_{j2}\Big) \\ +Z^{E,*}_{k1}Z^{E}_{l1}\Big(\Big(-4|Y_{e,11}|^2-g_1^2+g_2^2\Big)Z^H_{i1}Z^H_{j1}+\Big(-g_2^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}\Big)\Big) \tag{544}$$



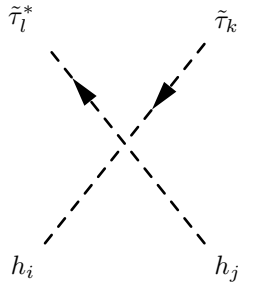
$$\frac{i}{4}\Big(Z^{\mu,*}_{k1}\Big(\Big(-4|Y_{e,22}|^2-g_1^2+g_2^2\Big)Z^H_{i1}Z^H_{j1}+\Big(-g_2^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}\Big)Z^{\mu}_{l1} \\ +2Z^{\mu,*}_{k2}\Big(\Big(-2|Y_{e,22}|^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}-g_1^2Z^H_{i2}Z^H_{j2}\Big)Z^{\mu}_{l2}\Big) \tag{545}$$



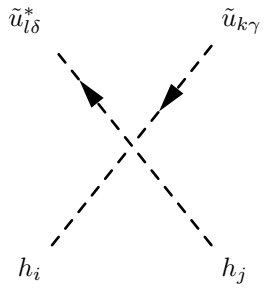
$$\frac{i}{12}\delta_{\gamma\delta}\Big(Z^{S,*}_{k1}\Big(\Big(-12|Y_{d,22}|^2+3g_2^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}-\Big(3g_2^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}\Big)Z^S_{l1}$$
$$+2Z^{S,*}_{k2}\Big(\Big(-6|Y_{d,22}|^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}-g_1^2Z^H_{i2}Z^H_{j2}\Big)Z^S_{l2}\Big) \tag{546}$$



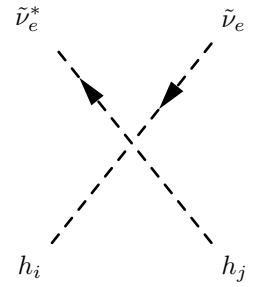
$$\frac{i}{12}\delta_{\gamma\delta}\Big(Z^{T,*}_{k1}\Big(-\Big(12|Y_{u,33}|^2-3g_2^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}+\Big(-3g_2^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}\Big)Z^T_{l1}$$
$$-4Z^{T,*}_{k2}\Big(-\Big(-3|Y_{u,33}|^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}+g_1^2Z^H_{i1}Z^H_{j1}\Big)Z^T_{l2}\Big) \tag{547}$$



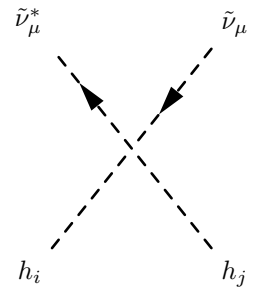
$$\frac{i}{4}\Big(Z^{\tau,*}_{k1}\Big(\Big(-4|Y_{e,33}|^2-g_1^2+g_2^2\Big)Z^H_{i1}Z^H_{j1}+\Big(-g_2^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}\Big)Z^\tau_{l1}$$
$$+2Z^{\tau,*}_{k2}\Big(\Big(-2|Y_{e,33}|^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}-g_1^2Z^H_{i2}Z^H_{j2}\Big)Z^\tau_{l2}\Big) \tag{548}$$



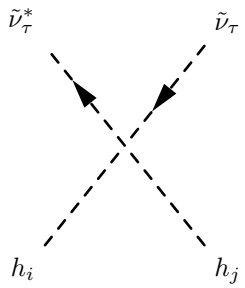
$$\frac{i}{12}\delta_{\gamma\delta}\Big(Z^{U,*}_{k1}\Big(-\Big(12|Y_{u,11}|^2-3g_2^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}+\Big(-3g_2^2+g_1^2\Big)Z^H_{i1}Z^H_{j1}\Big)Z^U_{l1}$$
$$-4Z^{U,*}_{k2}\Big(-\Big(-3|Y_{u,11}|^2+g_1^2\Big)Z^H_{i2}Z^H_{j2}+g_1^2Z^H_{i1}Z^H_{j1}\Big)Z^U_{l2}\Big) \tag{549}$$



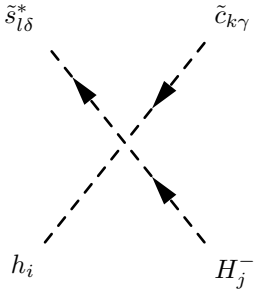
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z^H_{i1}Z^H_{j1}-Z^H_{i2}Z^H_{j2}\Big) \tag{550}$$



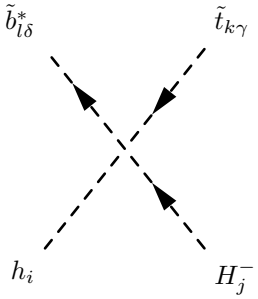
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z^H_{i1}Z^H_{j1}-Z^H_{i2}Z^H_{j2}\Big) \tag{551}$$



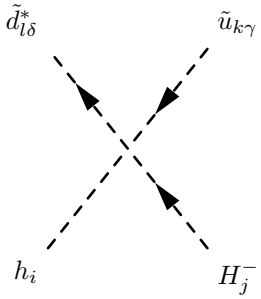
$$-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(Z_{i1}^H Z_{j1}^H - Z_{i2}^H Z_{j2}^H\Big) \tag{552}$$



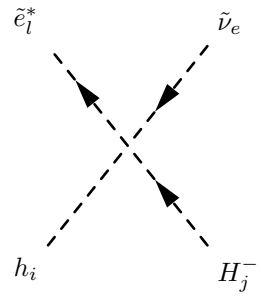
$$\begin{aligned}&\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\Big(-Z_{k1}^{C,*}\Big(\Big(-2|Y_{d,22}|^2+g_2^2\Big)Z_{i1}^H Z_{j1}^+ + \Big(-2|Y_{u,22}|^2+g_2^2\Big)Z_{i2}^H Z_{j2}^+\Big)Z_{l1}^S \\ &+2Y_{u,22}^* Z_{k2}^{C,*} Y_{d,22}\Big(Z_{i1}^H Z_{j2}^+ + Z_{i2}^H Z_{j1}^+\Big)Z_{l2}^S\Big)\end{aligned} \tag{553}$$



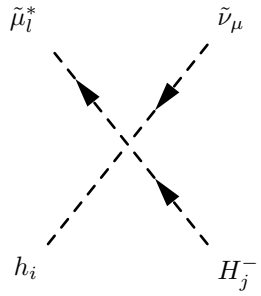
$$\begin{aligned}&\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\Big(2Y_{u,33}^* Z_{k2}^{T,*} Y_{d,33} Z_{l2}^B\Big(Z_{i1}^H Z_{j2}^+ + Z_{i2}^H Z_{j1}^+\Big) \\ &-Z_{k1}^{T,*} Z_{l1}^B\Big(\Big(-2|Y_{d,33}|^2+g_2^2\Big)Z_{i1}^H Z_{j1}^+ + \Big(-2|Y_{u,33}|^2+g_2^2\Big)Z_{i2}^H Z_{j2}^+\Big)\Big)\end{aligned} \tag{554}$$



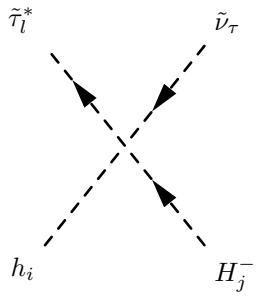
$$\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\gamma\delta}\Big(2Y^*_{u,11}Z^{U,*}_{k2}Y_{d,11}Z^D_{l2}\Big(Z^H_{i1}Z^+_{j2}+Z^H_{i2}Z^+_{j1}\Big)$$
$$-Z^{U,*}_{k1}Z^D_{l1}\Big(\Big(-2|Y_{d,11}|^2+g_2^2\Big)Z^H_{i1}Z^+_{j1}+\Big(-2|Y_{u,11}|^2+g_2^2\Big)Z^H_{i2}Z^+_{j2}\Big)\Big) \tag{555}$$



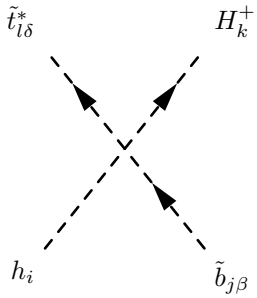
$$-\frac{i}{2}\frac{1}{\sqrt{2}}Z^E_{l1}\Big(\Big(-2|Y_{e,11}|^2+g_2^2\Big)Z^H_{i1}Z^+_{j1}+g_2^2Z^H_{i2}Z^+_{j2}\Big) \tag{556}$$



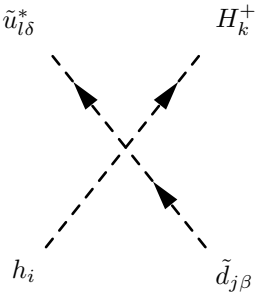
$$-\frac{i}{2}\frac{1}{\sqrt{2}}Z^\mu_{l1}\Big(\Big(-2|Y_{e,22}|^2+g_2^2\Big)Z^H_{i1}Z^+_{j1}+g_2^2Z^H_{i2}Z^+_{j2}\Big) \tag{557}$$



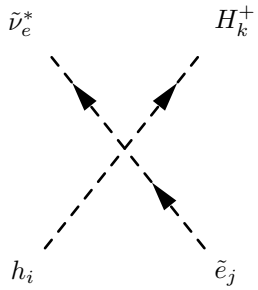
$$-\frac{i}{2}\frac{1}{\sqrt{2}}\Big(\Big(-2|Y_{e,33}|^2+g_2^2\Big)Z_{i1}^H Z_{j1}^+ + g_2^2 Z_{i2}^H Z_{j2}^+\Big)Z_{l1}^\tau \tag{558}$$



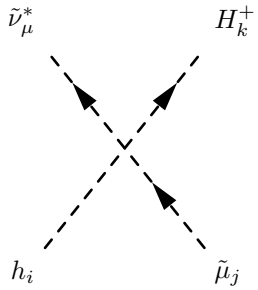
$$\begin{aligned}&\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(-Z_{j1}^{B,*}\Big(\Big(-2|Y_{d,33}|^2+g_2^2\Big)Z_{i1}^H Z_{k1}^+ + \Big(-2|Y_{u,33}|^2+g_2^2\Big)Z_{i2}^H Z_{k2}^+\Big)Z_{l1}^T\\&+2Y_{d,33}^* Z_{j2}^{B,*} Y_{u,33}\Big(Z_{i1}^H Z_{k2}^+ + Z_{i2}^H Z_{k1}^+\Big)Z_{l2}^T\Big)\end{aligned} \tag{559}$$



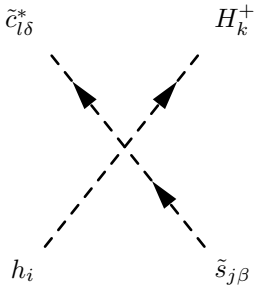
$$\begin{aligned}&\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(-Z_{j1}^{D,*}\Big(\Big(-2|Y_{d,11}|^2+g_2^2\Big)Z_{i1}^H Z_{k1}^+ + \Big(-2|Y_{u,11}|^2+g_2^2\Big)Z_{i2}^H Z_{k2}^+\Big)Z_{l1}^U\\&+2Y_{d,11}^* Z_{j2}^{D,*} Y_{u,11}\Big(Z_{i1}^H Z_{k2}^+ + Z_{i2}^H Z_{k1}^+\Big)Z_{l2}^U\Big)\end{aligned} \tag{560}$$



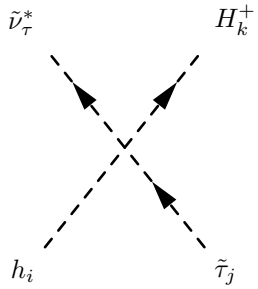
$$-\frac{i}{2}\frac{1}{\sqrt{2}}Z_{j1}^{E,*}\Big(\Big(-2|Y_{e,11}|^2+g_2^2\Big)Z_{i1}^H Z_{k1}^+ + g_2^2 Z_{i2}^H Z_{k2}^+\Big) \tag{561}$$



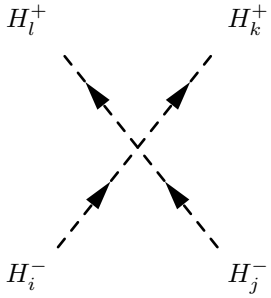
$$-\frac{i}{2}\frac{1}{\sqrt{2}}Z_{j1}^{\mu,*}\Big(\Big(-2|Y_{e,22}|^2+g_2^2\Big)Z_{i1}^H Z_{k1}^+ + g_2^2 Z_{i2}^H Z_{k2}^+\Big) \tag{562}$$



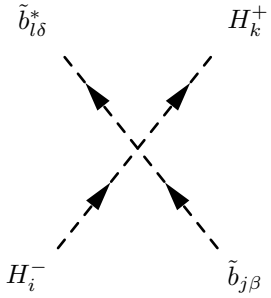
$$\begin{aligned}&\frac{i}{2}\frac{1}{\sqrt{2}}\delta_{\beta\delta}\Big(2Y_{d,22}^* Z_{j2}^{S,*} Y_{u,22} Z_{l2}^C\Big(Z_{i1}^H Z_{k2}^+ + Z_{i2}^H Z_{k1}^+\Big)\\&- Z_{j1}^{S,*} Z_{l1}^C\Big(\Big(-2|Y_{d,22}|^2+g_2^2\Big)Z_{i1}^H Z_{k1}^+ + \Big(-2|Y_{u,22}|^2+g_2^2\Big)Z_{i2}^H Z_{k2}^+\Big)\Big)\end{aligned} \tag{563}$$



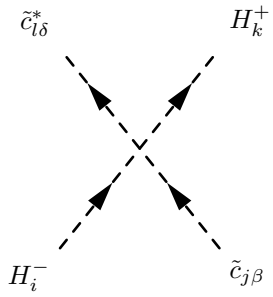
$$-\frac{i}{2}\frac{1}{\sqrt{2}}Z_{j1}^{\tau,*}\Big(\Big(-2|Y_{e,33}|^2+g_2^2\Big)Z_{i1}^H Z_{k1}^+ + g_2^2 Z_{i2}^H Z_{k2}^+\Big) \tag{564}$$



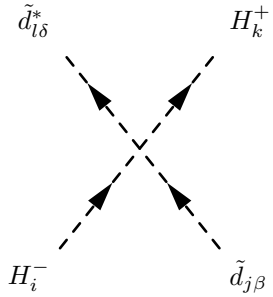
$$\begin{aligned}&-\frac{i}{4}\Big(g_1^2+g_2^2\Big)\Big(-Z_{i2}^+\Big(-2Z_{j2}^+Z_{k2}^+Z_{l2}^+ + Z_{j1}^+\Big(Z_{k1}^+Z_{l2}^+ + Z_{k2}^+Z_{l1}^+\Big)\Big)\\&+Z_{i1}^+\Big(2Z_{j1}^+Z_{k1}^+Z_{l1}^+ - Z_{j2}^+\Big(Z_{k1}^+Z_{l2}^+ + Z_{k2}^+Z_{l1}^+\Big)\Big)\Big)\end{aligned} \tag{565}$$



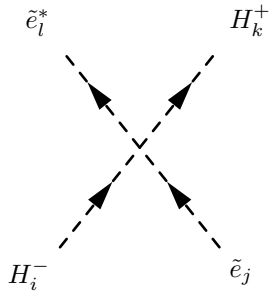
$$\begin{aligned}&\frac{i}{12}\delta_{\beta\delta}\Big(2Z_{j2}^{B,*}Z_{l2}^B\Big(\Big(-6|Y_{d,33}|^2+g_1^2\Big)Z_{i1}^+Z_{k1}^+ - g_1^2Z_{i2}^+Z_{k2}^+\Big)\\&+Z_{j1}^{B,*}Z_{l1}^B\Big(-\Big(12|Y_{u,33}|^2-3g_2^2+g_1^2\Big)Z_{i2}^+Z_{k2}^+ + \Big(-3g_2^2+g_1^2\Big)Z_{i1}^+Z_{k1}^+\Big)\Big)\end{aligned} \tag{566}$$



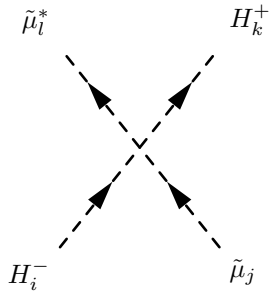
$$\frac{i}{12}\delta_{\beta\delta}\Big(Z^{C,*}_{j1}Z^{C}_{l1}\Big(\Big(-12|Y_{d,22}|^2+3g_2^2+g_1^2\Big)Z^+_{i1}Z^+_{k1}-\Big(3g_2^2+g_1^2\Big)Z^+_{i2}Z^+_{k2}\Big)$$
$$-4Z^{C,*}_{j2}Z^{C}_{l2}\Big(-\Big(-3|Y_{u,22}|^2+g_1^2\Big)Z^+_{i2}Z^+_{k2}+g_1^2Z^+_{i1}Z^+_{k1}\Big)\Big) \tag{567}$$



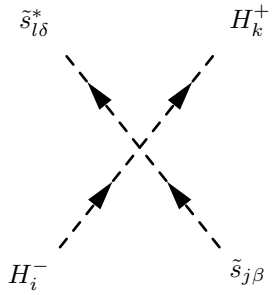
$$\frac{i}{12}\delta_{\beta\delta}\Big(2Z^{D,*}_{j2}Z^{D}_{l2}\Big(\Big(-6|Y_{d,11}|^2+g_1^2\Big)Z^+_{i1}Z^+_{k1}-g_1^2Z^+_{i2}Z^+_{k2}\Big)$$
$$+Z^{D,*}_{j1}Z^{D}_{l1}\Big(-\Big(12|Y_{u,11}|^2-3g_2^2+g_1^2\Big)Z^+_{i2}Z^+_{k2}+\Big(-3g_2^2+g_1^2\Big)Z^+_{i1}Z^+_{k1}\Big)\Big) \tag{568}$$



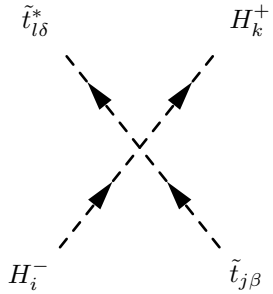
$$\frac{i}{4}\Big(-\Big(g_1^2+g_2^2\Big)Z^{E,*}_{j1}Z^{E}_{l1}\Big(Z^+_{i1}Z^+_{k1}-Z^+_{i2}Z^+_{k2}\Big)$$
$$+2Z^{E,*}_{j2}Z^{E}_{l2}\Big(\Big(-2|Y_{e,11}|^2+g_1^2\Big)Z^+_{i1}Z^+_{k1}-g_1^2Z^+_{i2}Z^+_{k2}\Big)\Big) \tag{569}$$



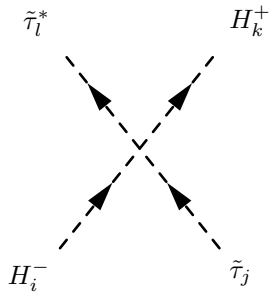
$$\frac{i}{4}\Big(-\Big(g_1^2+g_2^2\Big)Z_{j1}^{\mu,*}Z_{l1}^{\mu}\Big(Z_{i1}^{+}Z_{k1}^{+}-Z_{i2}^{+}Z_{k2}^{+}\Big) \\ +2Z_{j2}^{\mu,*}Z_{l2}^{\mu}\Big(\Big(-2|Y_{e,22}|^2+g_1^2\Big)Z_{i1}^{+}Z_{k1}^{+}-g_1^2Z_{i2}^{+}Z_{k2}^{+}\Big)\Big) \tag{570}$$



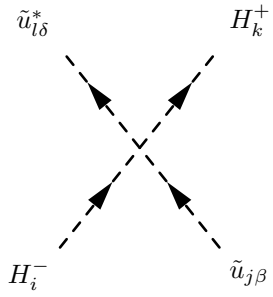
$$\frac{i}{12}\delta_{\beta\delta}\Big(Z_{j1}^{S,*}\Big(-\Big(12|Y_{u,22}|^2-3g_2^2+g_1^2\Big)Z_{i2}^{+}Z_{k2}^{+}+\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{+}Z_{k1}^{+}\Big)Z_{l1}^{S} \\ +2Z_{j2}^{S,*}\Big(\Big(-6|Y_{d,22}|^2+g_1^2\Big)Z_{i1}^{+}Z_{k1}^{+}-g_1^2Z_{i2}^{+}Z_{k2}^{+}\Big)Z_{l2}^{S}\Big) \tag{571}$$



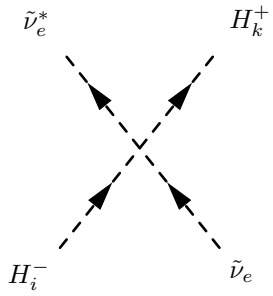
$$\frac{i}{12}\delta_{\beta\delta}\Big(Z_{j1}^{T,*}\Big(\Big(-12|Y_{d,33}|^2+3g_2^2+g_1^2\Big)Z_{i1}^{+}Z_{k1}^{+}-\Big(3g_2^2+g_1^2\Big)Z_{i2}^{+}Z_{k2}^{+}\Big)Z_{l1}^{T} \\ -4Z_{j2}^{T,*}\Big(-\Big(-3|Y_{u,33}|^2+g_1^2\Big)Z_{i2}^{+}Z_{k2}^{+}+g_1^2Z_{i1}^{+}Z_{k1}^{+}\Big)Z_{l2}^{T}\Big) \tag{572}$$



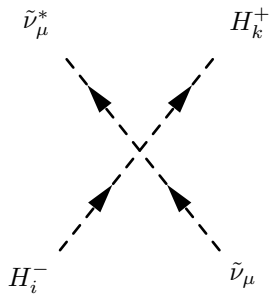
$$\frac{i}{4}\Big(-\Big(g_1^2+g_2^2\Big)Z_{j1}^{\tau,*}\Big(Z_{i1}^+Z_{k1}^+-Z_{i2}^+Z_{k2}^+\Big)Z_{l1}^{\tau}$$
$$+2Z_{j2}^{\tau,*}\Big(\Big(-2|Y_{e,33}|^2+g_1^2\Big)Z_{i1}^+Z_{k1}^+-g_1^2Z_{i2}^+Z_{k2}^+\Big)Z_{l2}^{\tau}\Big) \tag{573}$$



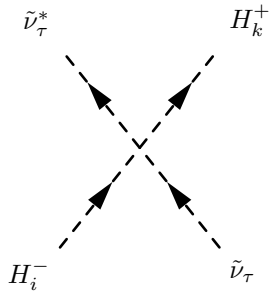
$$\frac{i}{12}\delta_{\beta\delta}\Big(Z_{j1}^{U,*}\Big(\Big(-12|Y_{d,11}|^2+3g_2^2+g_1^2\Big)Z_{i1}^+Z_{k1}^+-\Big(3g_2^2+g_1^2\Big)Z_{i2}^+Z_{k2}^+\Big)Z_{l1}^U$$
$$-4Z_{j2}^{U,*}\Big(-\Big(-3|Y_{u,11}|^2+g_1^2\Big)Z_{i2}^+Z_{k2}^++g_1^2Z_{i1}^+Z_{k1}^+\Big)Z_{l2}^U\Big) \tag{574}$$



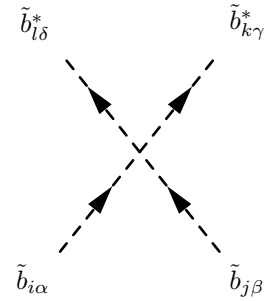
$$\frac{i}{4}\Big(\Big(-4|Y_{e,11}|^2-g_1^2+g_2^2\Big)Z_{i1}^+Z_{k1}^++\Big(-g_2^2+g_1^2\Big)Z_{i2}^+Z_{k2}^+\Big) \tag{575}$$



$$\frac{i}{4}\Big(\Big(-4|Y_{e,22}|^2-g_1^2+g_2^2\Big)Z_{i1}^+Z_{k1}^+ + \Big(-g_2^2+g_1^2\Big)Z_{i2}^+Z_{k2}^+\Big) \tag{576}$$

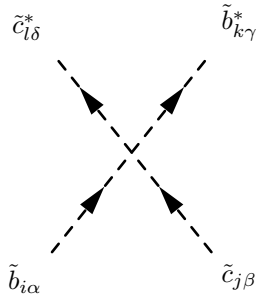


$$\frac{i}{4}\Big(\Big(-4|Y_{e,33}|^2-g_1^2+g_2^2\Big)Z_{i1}^+Z_{k1}^+ + \Big(-g_2^2+g_1^2\Big)Z_{i2}^+Z_{k2}^+\Big) \tag{577}$$

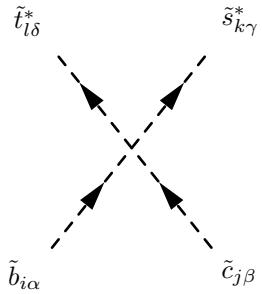


$$\begin{aligned}&\frac{i}{36}\Big(-Z_{i1}^{B,*}\Big(\Big(12g_3^2+9g_2^2+g_1^2\Big)Z_{j1}^{B,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k1}^BZ_{l1}^B\\&+2Z_{j2}^{B,*}\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(3g_3^2+g_1^2\Big)Z_{k1}^BZ_{l2}^B-9\Big(-2|Y_{d,33}|^2+g_3^2\Big)Z_{k2}^BZ_{l1}^B\Big)\\&+\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(3g_3^2+g_1^2\Big)Z_{k2}^BZ_{l1}^B-9\Big(-2|Y_{d,33}|^2+g_3^2\Big)Z_{k1}^BZ_{l2}^B\Big)\Big)\Big)\end{aligned}$$

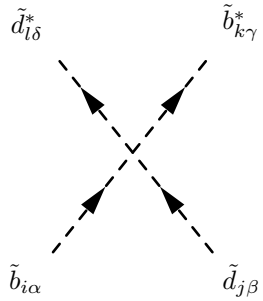
$$
\begin{aligned}
&+ 2Z_{i2}^{B,*}\Big(- 2\Big(3g_3^2 + g_1^2\Big)Z_{j2}^{B,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma} + \delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k2}^{B}Z_{l2}^{B} \\
&+ Z_{j1}^{B,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(- \Big(3g_3^2 + g_1^2\Big)Z_{k1}^{B}Z_{l2}^{B} + 9\Big(- 2|Y_{d,33}|^2 + g_3^2\Big)Z_{k2}^{B}Z_{l1}^{B}\Big) \\
&- \delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(3g_3^2 + g_1^2\Big)Z_{k2}^{B}Z_{l1}^{B} - 9\Big(- 2|Y_{d,33}|^2 + g_3^2\Big)Z_{k1}^{B}Z_{l2}^{B}\Big)\Big)\Big)\Big)
\end{aligned} \tag{578}
$$



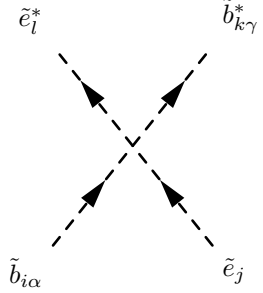
$$
\begin{aligned}
&\frac{i}{36}\Big(Z_{i1}^{B,*}Z_{k1}^{B}\Big(Z_{j1}^{C,*}\Big(- 18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma} + \Big(6g_3^2 + 9g_2^2 - g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{l1}^{C} \\
&+ 2Z_{j2}^{C,*}\Big(\Big(2g_1^2 - 3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} + 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l2}^{C}\Big) \\
&+ 2Z_{i2}^{B,*}Z_{k2}^{B}\Big(Z_{j1}^{C,*}\Big(- \Big(3g_3^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} + 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l1}^{C} \\
&+ Z_{j2}^{C,*}\Big(\Big(3g_3^2 + 4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l2}^{C}\Big)\Big)
\end{aligned} \tag{579}
$$



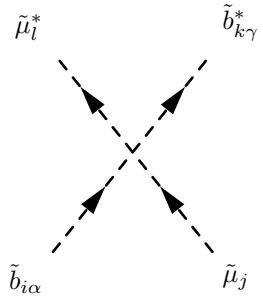
$$
- \frac{i}{2}\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(2Y_{d,33}^{*}Z_{i2}^{B,*}Z_{j1}^{C,*}Y_{d,22}Z_{k2}^{S}Z_{l1}^{T} + Z_{i1}^{B,*}Z_{k1}^{S}\Big(2Y_{u,22}^{*}Z_{j2}^{C,*}Y_{u,33}Z_{l2}^{T} + g_2^2Z_{j1}^{C,*}Z_{l1}^{T}\Big)\Big) \tag{580}
$$



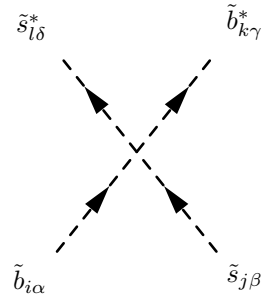
$$\frac{i}{36}\Big(- Z^{B,*}_{i1}\Big(Z^{D,*}_{j1}\Big(18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma} + \Big(- 6g_3^2 + 9g_2^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z^B_{k1}Z^D_{l1}$$
$$+ 2Z^{D,*}_{j2}\Big(18Y^*_{d,11}\delta_{\alpha\gamma}\delta_{\beta\delta}Y_{d,33}Z^B_{k2}Z^D_{l1} + \Big(\Big(3g_3^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^B_{k1}Z^D_{l2}\Big)\Big)$$
$$+ 2Z^{B,*}_{i2}\Big(Z^{D,*}_{j2}\Big(\Big(- 2g_1^2 + 3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^B_{k2}Z^D_{l2}$$
$$+ Z^{D,*}_{j1}\Big(9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}Z^B_{k2}Z^D_{l1} - \delta_{\alpha\gamma}\delta_{\beta\delta}\Big(18Y^*_{d,33}Y_{d,11}Z^B_{k1}Z^D_{l2} + \Big(3g_3^2 + g_1^2\Big)Z^B_{k2}Z^D_{l1}\Big)\Big)\Big)\Big) \tag{581}$$



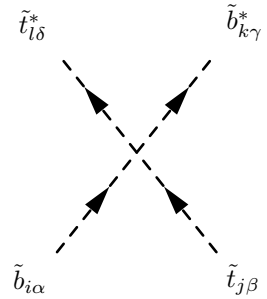
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(Z^{B,*}_{i1}\Big(- 2Z^{E,*}_{j2}\Big(6Y^*_{e,11}Y_{d,33}Z^B_{k2}Z^E_{l1} + g_1^2Z^B_{k1}Z^E_{l2}\Big) + \Big(- 3g_2^2 + g_1^2\Big)Z^{E,*}_{j1}Z^B_{k1}Z^E_{l1}\Big)$$
$$+ 2Z^{B,*}_{i2}\Big(- 2g_1^2Z^{E,*}_{j2}Z^B_{k2}Z^E_{l2} + Z^{E,*}_{j1}\Big(- 6Y^*_{d,33}Y_{e,11}Z^B_{k1}Z^E_{l2} + g_1^2Z^B_{k2}Z^E_{l1}\Big)\Big)\Big) \tag{582}$$



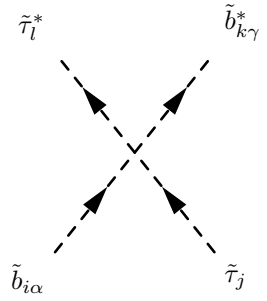
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(Z_{i1}^{B,*}\Big(-2Z_{j2}^{\mu,*}\Big(6Y_{e,22}^{*}Y_{d,33}Z_{k2}^{B}Z_{l1}^{\mu}+g_1^2Z_{k1}^{B}Z_{l2}^{\mu}\Big)+\Big(-3g_2^2+g_1^2\Big)Z_{j1}^{\mu,*}Z_{k1}^{B}Z_{l1}^{\mu}\Big)$$
$$+2Z_{i2}^{B,*}\Big(-2g_1^2Z_{j2}^{\mu,*}Z_{k2}^{B}Z_{l2}^{\mu}+Z_{j1}^{\mu,*}\Big(-6Y_{d,33}^{*}Y_{e,22}Z_{k1}^{B}Z_{l2}^{\mu}+g_1^2Z_{k2}^{B}Z_{l1}^{\mu}\Big)\Big)\Big) \tag{583}$$



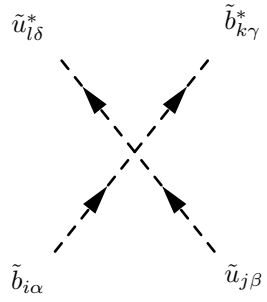
$$\frac{i}{36}\Big(-Z_{i1}^{B,*}\Big(Z_{j1}^{S,*}\Big(18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}+\Big(-6g_3^2+9g_2^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k1}^{B}Z_{l1}^{S}$$
$$+2Z_{j2}^{S,*}\Big(18Y_{d,22}^{*}\delta_{\alpha\gamma}\delta_{\beta\delta}Y_{d,33}Z_{k2}^{B}Z_{l1}^{S}+\Big(\Big(3g_3^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{k1}^{B}Z_{l2}^{S}\Big)\Big)$$
$$+2Z_{i2}^{B,*}\Big(Z_{j2}^{S,*}\Big(\Big(-2g_1^2+3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{k2}^{B}Z_{l2}^{S}$$
$$+Z_{j1}^{S,*}\Big(9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}Z_{k2}^{B}Z_{l1}^{S}-\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(18Y_{d,33}^{*}Y_{d,22}Z_{k1}^{B}Z_{l2}^{S}+\Big(3g_3^2+g_1^2\Big)Z_{k2}^{B}Z_{l1}^{S}\Big)\Big)\Big)\Big) \tag{584}$$



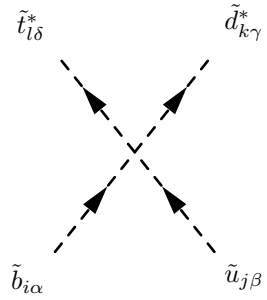
$$\frac{i}{36}\Big(-Z_{i1}^{B,*}Z_{k1}^{B}\Big(Z_{j1}^{T,*}\Big(18\Big(g_2^2+g_3^2\Big)\delta_{\alpha\delta}\delta_{\beta\gamma}+\Big(-6g_3^2-9g_2^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{l1}^{T}$$
$$+2Z_{j2}^{T,*}\Big(\Big(-2g_1^2+3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9\Big(-2|Y_{u,33}|^2+g_3^2\Big)\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l2}^{T}\Big)$$
$$+2Z_{i2}^{B,*}Z_{k2}^{B}\Big(Z_{j1}^{T,*}\Big(-\Big(3g_3^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9\Big(-2|Y_{d,33}|^2+g_3^2\Big)\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l1}^{T}$$
$$+Z_{j2}^{T,*}\Big(\Big(3g_3^2+4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l2}^{T}\Big)\Big) \tag{585}$$



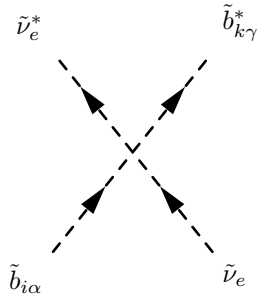
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(Z_{i1}^{B,*}\Big(-2Z_{j2}^{\tau,*}\Big(6Y_{e,33}^*Y_{d,33}Z_{k2}^BZ_{l1}^\tau+g_1^2Z_{k1}^BZ_{l2}^\tau\Big)+\Big(-3g_2^2+g_1^2\Big)Z_{j1}^{\tau,*}Z_{k1}^BZ_{l1}^\tau\Big)$$
$$+2Z_{i2}^{B,*}\Big(-2g_1^2Z_{j2}^{\tau,*}Z_{k2}^BZ_{l2}^\tau+Z_{j1}^{\tau,*}\Big(-6Y_{d,33}^*Y_{e,33}Z_{k1}^BZ_{l2}^\tau+g_1^2Z_{k2}^BZ_{l1}^\tau\Big)\Big)\Big) \tag{586}$$



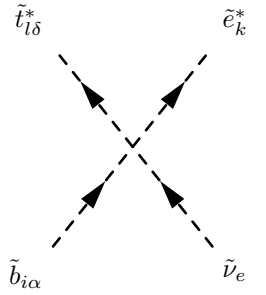
$$\frac{i}{36}\Big(Z_{i1}^{B,*}Z_{k1}^B\Big(Z_{j1}^{U,*}\Big(-18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}+\Big(6g_3^2+9g_2^2-g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{l1}^U$$
$$+2Z_{j2}^{U,*}\Big(\Big(2g_1^2-3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l2}^U\Big)$$
$$+2Z_{i2}^{B,*}Z_{k2}^B\Big(Z_{j1}^{U,*}\Big(-\Big(3g_3^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l1}^U$$
$$+Z_{j2}^{U,*}\Big(\Big(3g_3^2+4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l2}^U\Big)\Big) \tag{587}$$



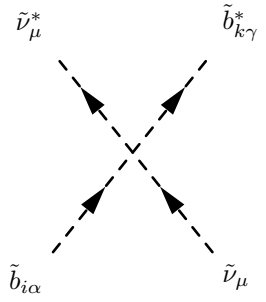
$$-\frac{i}{2}\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(2Y^{*}_{d,33}Z^{B,*}_{i2}Z^{U,*}_{j1}Y_{d,11}Z^{D}_{k2}Z^{T}_{l1}+Z^{B,*}_{i1}Z^{D}_{k1}\Big(2Y^{*}_{u,11}Z^{U,*}_{j2}Y_{u,33}Z^{T}_{l2}+g_2^2Z^{U,*}_{j1}Z^{T}_{l1}\Big)\Big) \tag{588}$$



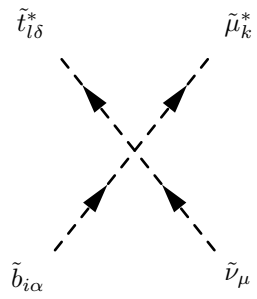
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(2g_1^2Z^{B,*}_{i2}Z^{B}_{k2}+\Big(3g_2^2+g_1^2\Big)Z^{B,*}_{i1}Z^{B}_{k1}\Big) \tag{589}$$



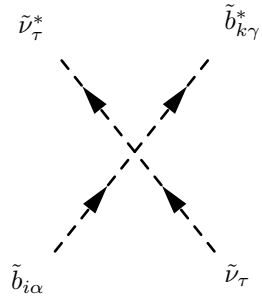
$$-\frac{i}{2}\delta_{\alpha\delta}\Big(2Y^{*}_{d,33}Z^{B,*}_{i2}Y_{e,11}Z^{E}_{k2}+g_2^2Z^{B,*}_{i1}Z^{E}_{k1}\Big)Z^{T}_{l1} \tag{590}$$



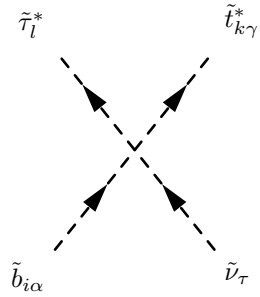
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(2g_1^2Z^{B,*}_{i2}Z^{B}_{k2}+\Big(3g_2^2+g_1^2\Big)Z^{B,*}_{i1}Z^{B}_{k1}\Big) \tag{591}$$



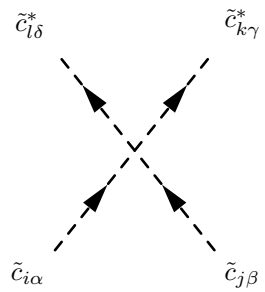
$$-\frac{i}{2}\delta_{\alpha\delta}\Big(2Y^*_{d,33}Z^{B,*}_{i2}Y_{e,22}Z^{\mu}_{k2}+g_2^2Z^{B,*}_{i1}Z^{\mu}_{k1}\Big)Z^T_{l1} \tag{592}$$



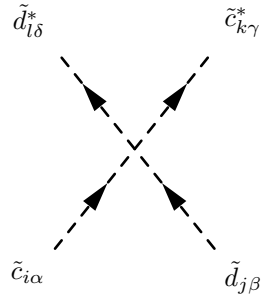
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(2g_1^2Z^{B,*}_{i2}Z^B_{k2}+\Big(3g_2^2+g_1^2\Big)Z^{B,*}_{i1}Z^B_{k1}\Big) \tag{593}$$



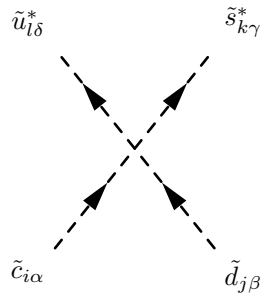
$$-\frac{i}{2}\delta_{\alpha\gamma}Z^T_{k1}\Big(2Y^*_{d,33}Z^{B,*}_{i2}Y_{e,33}Z^{\tau}_{l2}+g_2^2Z^{B,*}_{i1}Z^{\tau}_{l1}\Big) \tag{594}$$



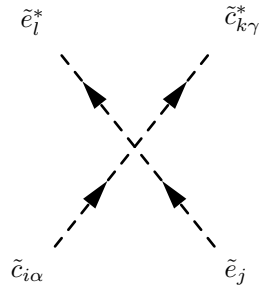
$$\begin{aligned}
&\frac{i}{36}\Big(- Z^{C,*}_{i1}\Big(\Big(12g_3^2 + 9g_2^2 + g_1^2\Big)Z^{C,*}_{j1}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma} + \delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z^C_{k1}Z^C_{l1} \\
&+ 2Z^{C,*}_{j2}\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(- 2g_1^2 + 3g_3^2\Big)Z^C_{k1}Z^C_{l2} - 9\Big(- 2|Y_{u,22}|^2 + g_3^2\Big)Z^C_{k2}Z^C_{l1}\Big) \\
&+ \delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(- 2g_1^2 + 3g_3^2\Big)Z^C_{k2}Z^C_{l1} - 9\Big(- 2|Y_{u,22}|^2 + g_3^2\Big)Z^C_{k1}Z^C_{l2}\Big)\Big)\Big) \\
&+ 2Z^{C,*}_{i2}\Big(- 2\Big(3g_3^2 + 4g_1^2\Big)Z^{C,*}_{j2}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma} + \delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z^C_{k2}Z^C_{l2} \\
&+ Z^{C,*}_{j1}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(2g_1^2 - 3g_3^2\Big)Z^C_{k1}Z^C_{l2} + 9\Big(- 2|Y_{u,22}|^2 + g_3^2\Big)Z^C_{k2}Z^C_{l1}\Big) \\
&+ \delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(2g_1^2 - 3g_3^2\Big)Z^C_{k2}Z^C_{l1} + 9\Big(- 2|Y_{u,22}|^2 + g_3^2\Big)Z^C_{k1}Z^C_{l2}\Big)\Big)\Big)\Big)
\end{aligned} \tag{595}$$



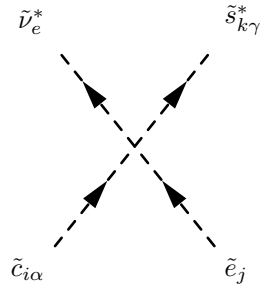
$$\begin{aligned}
&\frac{i}{36}\Big(- Z^{C,*}_{i1}Z^C_{k1}\Big(Z^{D,*}_{j1}\Big(18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma} + \Big(- 6g_3^2 - 9g_2^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z^D_{l1} \\
&+ 2Z^{D,*}_{j2}\Big(\Big(3g_3^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^D_{l2}\Big) \\
&+ 2Z^{C,*}_{i2}Z^C_{k2}\Big(Z^{D,*}_{j1}\Big(\Big(2g_1^2 - 3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} + 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^D_{l1} \\
&+ Z^{D,*}_{j2}\Big(\Big(3g_3^2 + 4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^D_{l2}\Big)\Big)
\end{aligned} \tag{596}$$



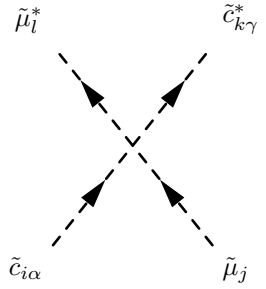
$$-\frac{i}{2}\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(2Y^*_{u,22}Z^{C,*}_{i2}Z^{D,*}_{j1}Y_{u,11}Z^S_{k1}Z^U_{l2}+Z^{C,*}_{i1}\Big(2Y^*_{d,11}Z^{D,*}_{j2}Y_{d,22}Z^S_{k2}+g_2^2Z^{D,*}_{j1}Z^S_{k1}\Big)Z^U_{l1}\Big) \tag{597}$$



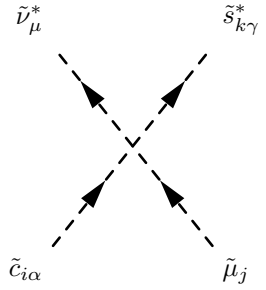
$$\begin{aligned}&\frac{i}{12}\delta_{\alpha\gamma}\Big(-4g_1^2Z^{C,*}_{i2}Z^C_{k2}\Big(-2Z^{E,*}_{j2}Z^E_{l2}+Z^{E,*}_{j1}Z^E_{l1}\Big)\\&+Z^{C,*}_{i1}Z^C_{k1}\Big(-2g_1^2Z^{E,*}_{j2}Z^E_{l2}+\Big(3g_2^2+g_1^2\Big)Z^{E,*}_{j1}Z^E_{l1}\Big)\Big)\end{aligned} \tag{598}$$



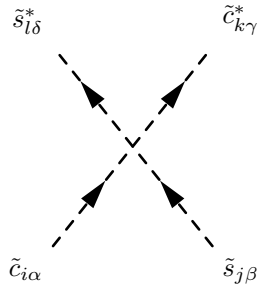
$$-\frac{i}{2}Z^{C,*}_{i1}\delta_{\alpha\gamma}\Big(2Y^*_{e,11}Z^{E,*}_{j2}Y_{d,22}Z^S_{k2}+g_2^2Z^{E,*}_{j1}Z^S_{k1}\Big) \tag{599}$$



$$\frac{i}{12}\delta_{\alpha\gamma}\Big(-4g_1^2 Z_{i2}^{C,*} Z_{k2}^{C}\Big(-2Z_{j2}^{\mu,*} Z_{l2}^{\mu} + Z_{j1}^{\mu,*} Z_{l1}^{\mu}\Big) + Z_{i1}^{C,*} Z_{k1}^{C}\Big(-2g_1^2 Z_{j2}^{\mu,*} Z_{l2}^{\mu} + \Big(3g_2^2 + g_1^2\Big) Z_{j1}^{\mu,*} Z_{l1}^{\mu}\Big)\Big) \tag{600}$$

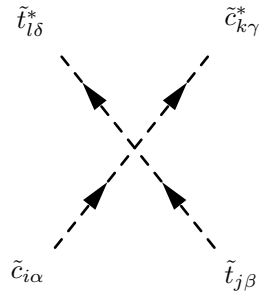


$$-\frac{i}{2} Z_{i1}^{C,*}\delta_{\alpha\gamma}\Big(2Y_{e,22}^{*} Z_{j2}^{\mu,*} Y_{d,22} Z_{k2}^{S} + g_2^2 Z_{j1}^{\mu,*} Z_{k1}^{S}\Big) \tag{601}$$

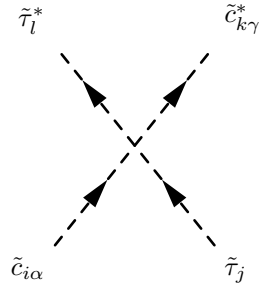


$$\frac{i}{36}\Big(-Z_{i1}^{C,*} Z_{k1}^{C}\Big(Z_{j1}^{S,*}\Big(18\Big(g_2^2 + g_3^2\Big)\delta_{\alpha\delta}\delta_{\beta\gamma} + \Big(-6g_3^2 - 9g_2^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big) Z_{l1}^{S} + 2Z_{j2}^{S,*}\Big(\Big(3g_3^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9\Big(-2|Y_{d,22}|^2 + g_3^2\Big)\delta_{\alpha\delta}\delta_{\beta\gamma}\Big) Z_{l2}^{S}\Big)$$

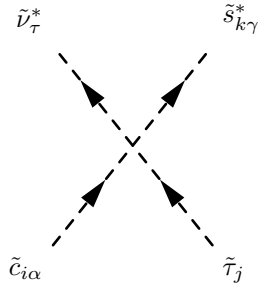
$$+ 2Z_{i2}^{C,*}Z_{k2}^{C}\Big(Z_{j1}^{S,*}\Big(\Big(2g_1^2 - 3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} + 9\Big(-2|Y_{u,22}|^2 + g_3^2\Big)\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l1}^{S}$$
$$+ Z_{j2}^{S,*}\Big(\Big(3g_3^2 + 4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{l2}^{S}\Big)\Big) \tag{602}$$



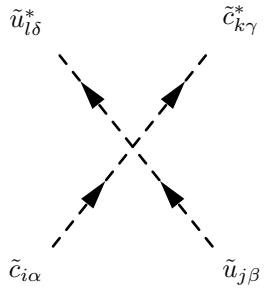
$$\frac{i}{36}\Big(-Z_{i1}^{C,*}\Big(Z_{j1}^{T,*}\Big(18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma} + \Big(-6g_3^2 + 9g_2^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k1}^{C}Z_{l1}^{T}$$
$$+ 2Z_{j2}^{T,*}\Big(18Y_{u,33}^{*}\delta_{\alpha\gamma}\delta_{\beta\delta}Y_{u,22}Z_{k2}^{C}Z_{l1}^{T} + \Big(\Big(-2g_1^2 + 3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{k1}^{C}Z_{l2}^{T}\Big)\Big)$$
$$+ 2Z_{i2}^{C,*}\Big(Z_{j2}^{T,*}\Big(\Big(3g_3^2 - 8g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{k2}^{C}Z_{l2}^{T}$$
$$+ Z_{j1}^{T,*}\Big(9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}Z_{k2}^{C}Z_{l1}^{T} + \delta_{\alpha\gamma}\delta_{\beta\delta}\Big(-18Y_{u,22}^{*}Y_{u,33}Z_{k1}^{C}Z_{l2}^{T} + \Big(2g_1^2 - 3g_3^2\Big)Z_{k2}^{C}Z_{l1}^{T}\Big)\Big)\Big)\Big)\Big) \tag{603}$$



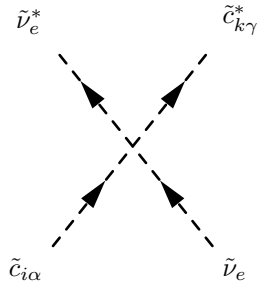
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(-4g_1^2Z_{i2}^{C,*}Z_{k2}^{C}\Big(-2Z_{j2}^{\tau,*}Z_{l2}^{\tau} + Z_{j1}^{\tau,*}Z_{l1}^{\tau}\Big)$$
$$+ Z_{i1}^{C,*}Z_{k1}^{C}\Big(-2g_1^2Z_{j2}^{\tau,*}Z_{l2}^{\tau} + \Big(3g_2^2 + g_1^2\Big)Z_{j1}^{\tau,*}Z_{l1}^{\tau}\Big)\Big) \tag{604}$$



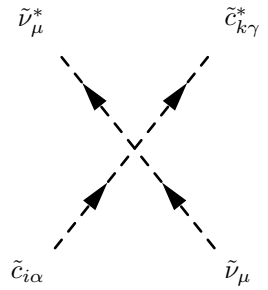
$$-\frac{i}{2}Z_{i1}^{C,*}\delta_{\alpha\gamma}\Big(2Y_{e,33}^*Z_{j2}^{\tau,*}Y_{d,22}Z_{k2}^S+g_2^2Z_{j1}^{\tau,*}Z_{k1}^S\Big) \tag{605}$$



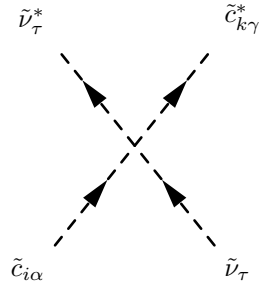
$$\begin{aligned}&\frac{i}{36}\Big(-Z_{i1}^{C,*}\Big(Z_{j1}^{U,*}\Big(18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}+\Big(-6g_3^2+9g_2^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k1}^CZ_{l1}^U\\&+2Z_{j2}^{U,*}\Big(18Y_{u,11}^*\delta_{\alpha\gamma}\delta_{\beta\delta}Y_{u,22}Z_{k2}^CZ_{l1}^U+\Big(\Big(-2g_1^2+3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{k1}^CZ_{l2}^U\Big)\Big)\\&+2Z_{i2}^{C,*}\Big(Z_{j2}^{U,*}\Big(\Big(3g_3^2-8g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{k2}^CZ_{l2}^U\\&+Z_{j1}^{U,*}\Big(9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}Z_{k2}^CZ_{l1}^U+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(-18Y_{u,22}^*Y_{u,11}Z_{k1}^CZ_{l2}^U+\Big(2g_1^2-3g_3^2\Big)Z_{k2}^CZ_{l1}^U\Big)\Big)\Big)\Big)\Big)\end{aligned} \tag{606}$$



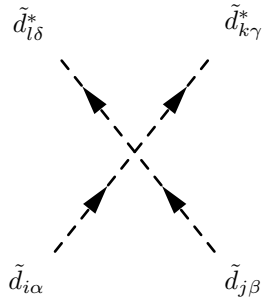
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{C,*}Z_{k1}^{C}-4g_1^2Z_{i2}^{C,*}Z_{k2}^{C}\Big) \tag{607}$$



$$\frac{i}{12}\delta_{\alpha\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{C,*}Z_{k1}^{C}-4g_1^2Z_{i2}^{C,*}Z_{k2}^{C}\Big) \tag{608}$$

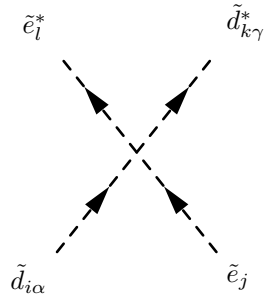


$$\frac{i}{12}\delta_{\alpha\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{C,*}Z_{k1}^{C}-4g_1^2Z_{i2}^{C,*}Z_{k2}^{C}\Big) \tag{609}$$

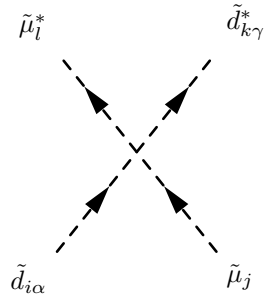


$$\frac{i}{36}\Big(-Z_{i1}^{D,*}\Big(\Big(12g_3^2+9g_2^2+g_1^2\Big)Z_{j1}^{D,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k1}^{D}Z_{l1}^{D}$$

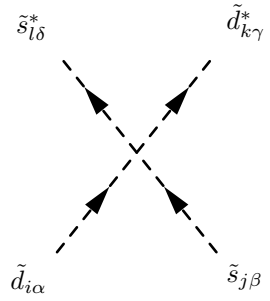
$$
\begin{aligned}
&+ 2Z_{j2}^{D,*}\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(3g_3^2+g_1^2\Big)Z_{k1}^{D}Z_{l2}^{D} - 9\Big(-2|Y_{d,11}|^2+g_3^2\Big)Z_{k2}^{D}Z_{l1}^{D}\Big)\\
&+ \delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(3g_3^2+g_1^2\Big)Z_{k2}^{D}Z_{l1}^{D} - 9\Big(-2|Y_{d,11}|^2+g_3^2\Big)Z_{k1}^{D}Z_{l2}^{D}\Big)\Big)\\
&+ 2Z_{i2}^{D,*}\Big(-2\Big(3g_3^2+g_1^2\Big)Z_{j2}^{D,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k2}^{D}Z_{l2}^{D}\\
&+ Z_{j1}^{D,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(-\Big(3g_3^2+g_1^2\Big)Z_{k1}^{D}Z_{l2}^{D} + 9\Big(-2|Y_{d,11}|^2+g_3^2\Big)Z_{k2}^{D}Z_{l1}^{D}\Big)\\
&- \delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(3g_3^2+g_1^2\Big)Z_{k2}^{D}Z_{l1}^{D} - 9\Big(-2|Y_{d,11}|^2+g_3^2\Big)Z_{k1}^{D}Z_{l2}^{D}\Big)\Big)\Big)
\end{aligned}
\tag{610}
$$



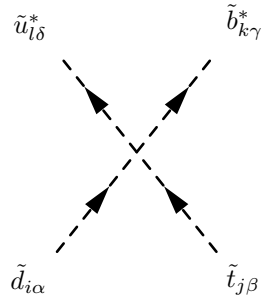
$$
\begin{aligned}
&\frac{i}{12}\delta_{\alpha\gamma}\Big(Z_{i1}^{D,*}\Big(-2Z_{j2}^{E,*}\Big(6Y_{e,11}^{*}Y_{d,11}Z_{k2}^{D}Z_{l1}^{E}+g_1^2Z_{k1}^{D}Z_{l2}^{E}\Big)+\Big(-3g_2^2+g_1^2\Big)Z_{j1}^{E,*}Z_{k1}^{D}Z_{l1}^{E}\Big)\\
&+ 2Z_{i2}^{D,*}\Big(-2g_1^2Z_{j2}^{E,*}Z_{k2}^{D}Z_{l2}^{E}+Z_{j1}^{E,*}\Big(-6Y_{d,11}^{*}Y_{e,11}Z_{k1}^{D}Z_{l2}^{E}+g_1^2Z_{k2}^{D}Z_{l1}^{E}\Big)\Big)\Big)
\end{aligned}
\tag{611}
$$



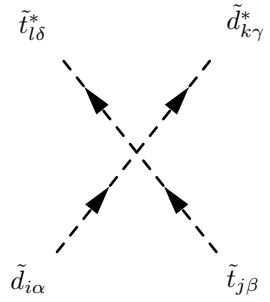
$$
\begin{aligned}
&\frac{i}{12}\delta_{\alpha\gamma}\Big(Z_{i1}^{D,*}\Big(-2Z_{j2}^{\mu,*}\Big(6Y_{e,22}^{*}Y_{d,11}Z_{k2}^{D}Z_{l1}^{\mu}+g_1^2Z_{k1}^{D}Z_{l2}^{\mu}\Big)+\Big(-3g_2^2+g_1^2\Big)Z_{j1}^{\mu,*}Z_{k1}^{D}Z_{l1}^{\mu}\Big)\\
&+ 2Z_{i2}^{D,*}\Big(-2g_1^2Z_{j2}^{\mu,*}Z_{k2}^{D}Z_{l2}^{\mu}+Z_{j1}^{\mu,*}\Big(-6Y_{d,11}^{*}Y_{e,22}Z_{k1}^{D}Z_{l2}^{\mu}+g_1^2Z_{k2}^{D}Z_{l1}^{\mu}\Big)\Big)\Big)
\end{aligned}
\tag{612}
$$



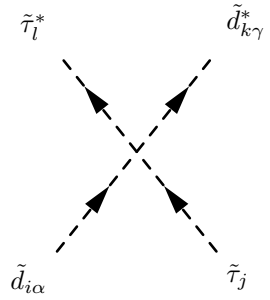
$$\frac{i}{36}\Big(- Z^{D,*}_{i1}\Big(Z^{S,*}_{j1}\Big(18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma} + \Big(- 6g_3^2 + 9g_2^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z^D_{k1}Z^S_{l1}$$
$$+ 2Z^{S,*}_{j2}\Big(18Y^*_{d,22}\delta_{\alpha\gamma}\delta_{\beta\delta}Y_{d,11}Z^D_{k2}Z^S_{l1} + \Big(\Big(3g_3^2 + g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^D_{k1}Z^S_{l2}\Big)\Big)$$
$$+ 2Z^{D,*}_{i2}\Big(Z^{S,*}_{j2}\Big(\Big(- 2g_1^2 + 3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta} - 9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^D_{k2}Z^S_{l2}$$
$$+ Z^{S,*}_{j1}\Big(9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}Z^D_{k2}Z^S_{l1} - \delta_{\alpha\gamma}\delta_{\beta\delta}\Big(18Y^*_{d,11}Y_{d,22}Z^D_{k1}Z^S_{l2} + \Big(3g_3^2 + g_1^2\Big)Z^D_{k2}Z^S_{l1}\Big)\Big)\Big)\Big) \tag{613}$$



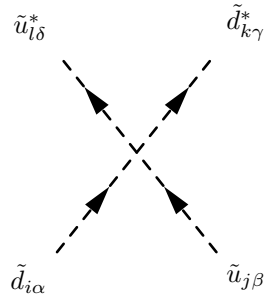
$$-\frac{i}{2}\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(2Y^*_{d,11}Z^{D,*}_{i2}Z^{T,*}_{j1}Y_{d,33}Z^B_{k2}Z^U_{l1} + Z^{D,*}_{i1}Z^B_{k1}\Big(2Y^*_{u,33}Z^{T,*}_{j2}Y_{u,11}Z^U_{l2} + g_2^2Z^{T,*}_{j1}Z^U_{l1}\Big)\Big) \tag{614}$$



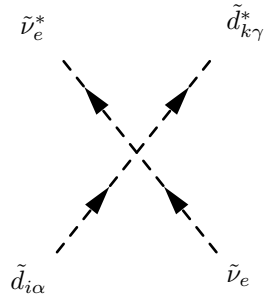
$$\frac{i}{36}\Big(Z^{D,*}_{i1}Z^{D}_{k1}\Big(Z^{T,*}_{j1}\Big(-18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}+\Big(6g_3^2+9g_2^2-g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z^{T}_{l1}$$
$$+2Z^{T,*}_{j2}\Big(\Big(2g_1^2-3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^{T}_{l2}\Big)$$
$$+2Z^{D,*}_{i2}Z^{D}_{k2}\Big(Z^{T,*}_{j1}\Big(-\Big(3g_3^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^{T}_{l1}$$
$$+Z^{T,*}_{j2}\Big(\Big(3g_3^2+4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^{T}_{l2}\Big)\Big) \tag{615}$$



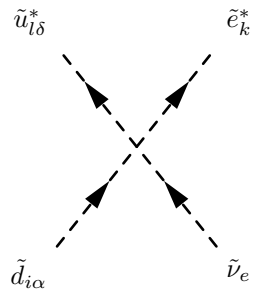
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(Z^{D,*}_{i1}\Big(-2Z^{\tau,*}_{j2}\Big(6Y^{*}_{e,33}Y_{d,11}Z^{D}_{k2}Z^{\tau}_{l1}+g_1^2Z^{D}_{k1}Z^{\tau}_{l2}\Big)+\Big(-3g_2^2+g_1^2\Big)Z^{\tau,*}_{j1}Z^{D}_{k1}Z^{\tau}_{l1}\Big)$$
$$+2Z^{D,*}_{i2}\Big(-2g_1^2Z^{\tau,*}_{j2}Z^{D}_{k2}Z^{\tau}_{l2}+Z^{\tau,*}_{j1}\Big(-6Y^{*}_{d,11}Y_{e,33}Z^{D}_{k1}Z^{\tau}_{l2}+g_1^2Z^{D}_{k2}Z^{\tau}_{l1}\Big)\Big)\Big) \tag{616}$$



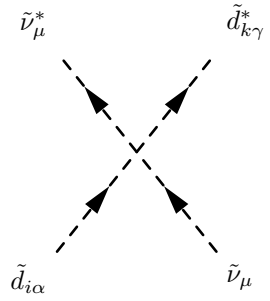
$$\frac{i}{36}\Big(-Z^{D,*}_{i1}Z^{D}_{k1}\Big(Z^{U,*}_{j1}\Big(18\Big(g_2^2+g_3^2\Big)\delta_{\alpha\delta}\delta_{\beta\gamma}+\Big(-6g_3^2-9g_2^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z^{U}_{l1}$$
$$+2Z^{U,*}_{j2}\Big(\Big(-2g_1^2+3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9\Big(-2|Y_{u,11}|^2+g_3^2\Big)\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^{U}_{l2}\Big)$$
$$+2Z^{D,*}_{i2}Z^{D}_{k2}\Big(Z^{U,*}_{j1}\Big(-\Big(3g_3^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9\Big(-2|Y_{d,11}|^2+g_3^2\Big)\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^{U}_{l1}$$
$$+Z^{U,*}_{j2}\Big(\Big(3g_3^2+4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^{U}_{l2}\Big)\Big) \tag{617}$$



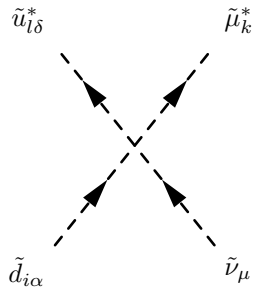
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(2g_1^2 Z_{i2}^{D,*} Z_{k2}^D + \Big(3g_2^2 + g_1^2\Big) Z_{i1}^{D,*} Z_{k1}^D\Big) \tag{618}$$



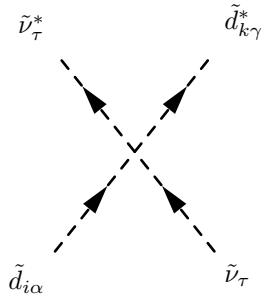
$$-\frac{i}{2}\delta_{\alpha\delta}\Big(2Y_{d,11}^* Z_{i2}^{D,*} Y_{e,11} Z_{k2}^E + g_2^2 Z_{i1}^{D,*} Z_{k1}^E\Big) Z_{l1}^U \tag{619}$$



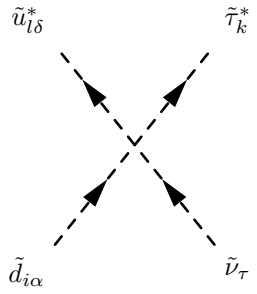
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(2g_1^2 Z_{i2}^{D,*} Z_{k2}^D + \Big(3g_2^2 + g_1^2\Big) Z_{i1}^{D,*} Z_{k1}^D\Big) \tag{620}$$



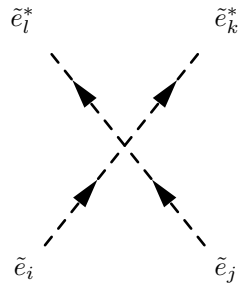
$$-\frac{i}{2}\delta_{\alpha\delta}\Big(2Y^*_{d,11}Z^{D,*}_{i2}Y_{e,22}Z^{\mu}_{k2}+g_2^2Z^{D,*}_{i1}Z^{\mu}_{k1}\Big)Z^U_{l1} \tag{621}$$



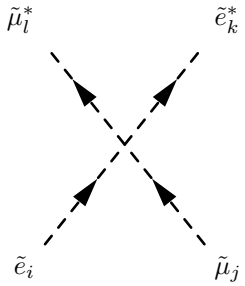
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(2g_1^2Z^{D,*}_{i2}Z^{D}_{k2}+\Big(3g_2^2+g_1^2\Big)Z^{D,*}_{i1}Z^{D}_{k1}\Big) \tag{622}$$



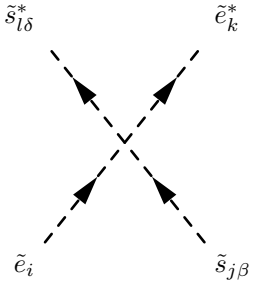
$$-\frac{i}{2}\delta_{\alpha\delta}\Big(2Y^*_{d,11}Z^{D,*}_{i2}Y_{e,33}Z^{\tau}_{k2}+g_2^2Z^{D,*}_{i1}Z^{\tau}_{k1}\Big)Z^U_{l1} \tag{623}$$



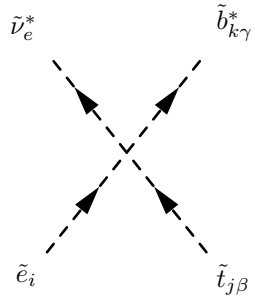
$$\frac{i}{2}\Big(Z_{i2}^{E,*}\Big(\Big(-2|Y_{e,11}|^2+g_1^2\Big)Z_{j1}^{E,*}\Big(Z_{k1}^{E}Z_{l2}^{E}+Z_{k2}^{E}Z_{l1}^{E}\Big)-4g_1^2Z_{j2}^{E,*}Z_{k2}^{E}Z_{l2}^{E}\Big)$$
$$-Z_{i1}^{E,*}\Big(-\Big(-2|Y_{e,11}|^2+g_1^2\Big)Z_{j2}^{E,*}\Big(Z_{k1}^{E}Z_{l2}^{E}+Z_{k2}^{E}Z_{l1}^{E}\Big)+\Big(g_1^2+g_2^2\Big)Z_{j1}^{E,*}Z_{k1}^{E}Z_{l1}^{E}\Big)\Big) \tag{624}$$



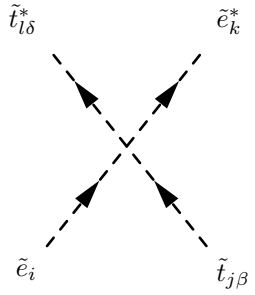
$$\frac{i}{4}\Big(-Z_{i1}^{E,*}\Big(2Z_{j2}^{\mu,*}\Big(2Y_{e,22}^{*}Y_{e,11}Z_{k2}^{E}Z_{l1}^{\mu}-g_1^2Z_{k1}^{E}Z_{l2}^{\mu}\Big)+\Big(g_1^2+g_2^2\Big)Z_{j1}^{\mu,*}Z_{k1}^{E}Z_{l1}^{\mu}\Big)$$
$$+2Z_{i2}^{E,*}\Big(-2g_1^2Z_{j2}^{\mu,*}Z_{k2}^{E}Z_{l2}^{\mu}+Z_{j1}^{\mu,*}\Big(-2Y_{e,11}^{*}Y_{e,22}Z_{k1}^{E}Z_{l2}^{\mu}+g_1^2Z_{k2}^{E}Z_{l1}^{\mu}\Big)\Big)\Big) \tag{625}$$



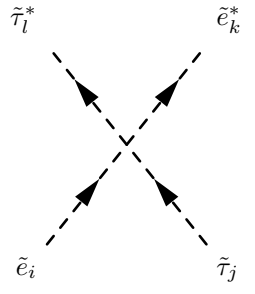
$$\frac{i}{12}\delta_{\beta\delta}\Big(Z_{i1}^{E,*}\Big(2Z_{j2}^{S,*}\Big(-6Y_{d,22}^{*}Y_{e,11}Z_{k2}^{E}Z_{l1}^{S}+g_1^2Z_{k1}^{E}Z_{l2}^{S}\Big)+\Big(-3g_2^2+g_1^2\Big)Z_{j1}^{S,*}Z_{k1}^{E}Z_{l1}^{S}\Big)$$
$$-2Z_{i2}^{E,*}\Big(2g_1^2Z_{j2}^{S,*}Z_{k2}^{E}Z_{l2}^{S}+Z_{j1}^{S,*}\Big(6Y_{e,11}^{*}Y_{d,22}Z_{k1}^{E}Z_{l2}^{S}+g_1^2Z_{k2}^{E}Z_{l1}^{S}\Big)\Big)\Big) \tag{626}$$



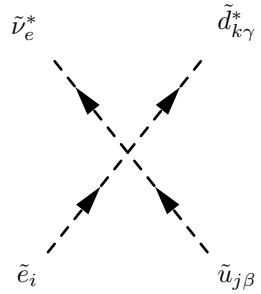
$$-\frac{i}{2}Z_{j1}^{T,*}\delta_{\beta\gamma}\Big(2Y_{e,11}^*Z_{i2}^{E,*}Y_{d,33}Z_{k2}^B+g_2^2Z_{i1}^{E,*}Z_{k1}^B\Big) \tag{627}$$



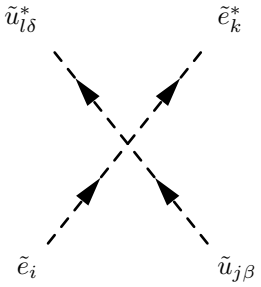
$$\begin{aligned}&\frac{i}{12}\delta_{\beta\delta}\Big(-2g_1^2Z_{i2}^{E,*}Z_{k2}^E\Big(-4Z_{j2}^{T,*}Z_{l2}^T+Z_{j1}^{T,*}Z_{l1}^T\Big)\\&+Z_{i1}^{E,*}Z_{k1}^E\Big(\Big(3g_2^2+g_1^2\Big)Z_{j1}^{T,*}Z_{l1}^T-4g_1^2Z_{j2}^{T,*}Z_{l2}^T\Big)\Big)\end{aligned} \tag{628}$$



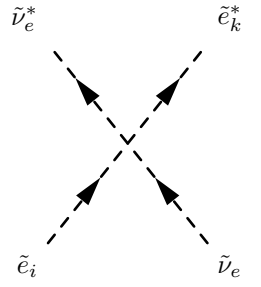
$$\begin{aligned}&\frac{i}{4}\Big(-Z_{i1}^{E,*}\Big(2Z_{j2}^{\tau,*}\Big(2Y_{e,33}^*Y_{e,11}Z_{k2}^EZ_{l1}^\tau-g_1^2Z_{k1}^EZ_{l2}^\tau\Big)+\Big(g_1^2+g_2^2\Big)Z_{j1}^{\tau,*}Z_{k1}^EZ_{l1}^\tau\Big)\\&+2Z_{i2}^{E,*}\Big(-2g_1^2Z_{j2}^{\tau,*}Z_{k2}^EZ_{l2}^\tau+Z_{j1}^{\tau,*}\Big(-2Y_{e,11}^*Y_{e,33}Z_{k1}^EZ_{l2}^\tau+g_1^2Z_{k2}^EZ_{l1}^\tau\Big)\Big)\Big)\end{aligned} \tag{629}$$



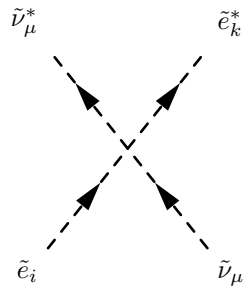
$$-\frac{i}{2}Z_{j1}^{U,*}\delta_{\beta\gamma}\Big(2Y_{e,11}^{*}Z_{i2}^{E,*}Y_{d,11}Z_{k2}^{D}+g_2^2Z_{i1}^{E,*}Z_{k1}^{D}\Big) \tag{630}$$



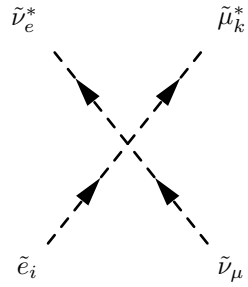
$$\begin{aligned}&\frac{i}{12}\delta_{\beta\delta}\Big(-2g_1^2Z_{i2}^{E,*}Z_{k2}^{E}\Big(-4Z_{j2}^{U,*}Z_{l2}^{U}+Z_{j1}^{U,*}Z_{l1}^{U}\Big)\\&+Z_{i1}^{E,*}Z_{k1}^{E}\Big(\Big(3g_2^2+g_1^2\Big)Z_{j1}^{U,*}Z_{l1}^{U}-4g_1^2Z_{j2}^{U,*}Z_{l2}^{U}\Big)\Big)\end{aligned} \tag{631}$$



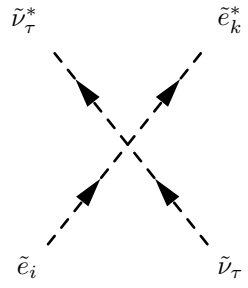
$$\frac{i}{4}\Big(2\Big(-2|Y_{e,11}|^2+g_1^2\Big)Z_{i2}^{E,*}Z_{k2}^{E}-\Big(g_1^2+g_2^2\Big)Z_{i1}^{E,*}Z_{k1}^{E}\Big) \tag{632}$$



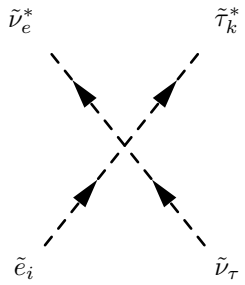
$$\frac{i}{4}\Big(2g_1^2 Z_{i2}^{E,*} Z_{k2}^E + \Big(-g_1^2 + g_2^2\Big) Z_{i1}^{E,*} Z_{k1}^E\Big) \tag{633}$$



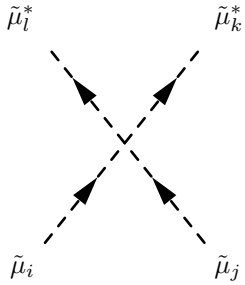
$$i\Big(-\frac{1}{2}g_2^2 Z_{i1}^{E,*} Z_{k1}^{\mu} - Y_{e,11}^* Z_{i2}^{E,*} Y_{e,22} Z_{k2}^{\mu}\Big) \tag{634}$$



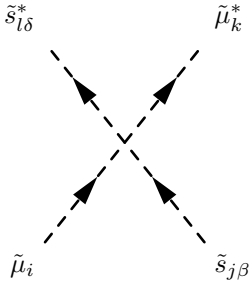
$$\frac{i}{4}\Big(2g_1^2 Z_{i2}^{E,*} Z_{k2}^E + \Big(-g_1^2 + g_2^2\Big) Z_{i1}^{E,*} Z_{k1}^E\Big) \tag{635}$$



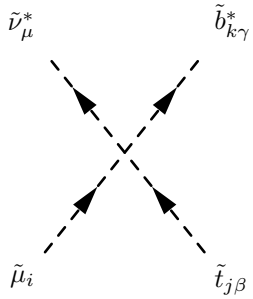
$$i\Big(-\frac{1}{2}g_2^2 Z_{i1}^{E,*} Z_{k1}^{\tau} - Y_{e,11}^* Z_{i2}^{E,*} Y_{e,33} Z_{k2}^{\tau}\Big) \tag{636}$$



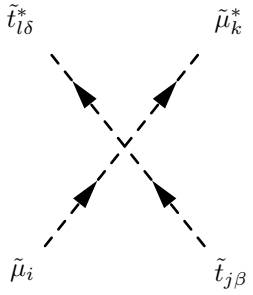
$$\begin{aligned}&\frac{i}{2}\Big(Z_{i2}^{\mu,*}\Big(\Big(-2|Y_{e,22}|^2+g_1^2\Big)Z_{j1}^{\mu,*}\Big(Z_{k1}^{\mu}Z_{l2}^{\mu}+Z_{k2}^{\mu}Z_{l1}^{\mu}\Big)-4g_1^2 Z_{j2}^{\mu,*}Z_{k2}^{\mu}Z_{l2}^{\mu}\Big)\\&-Z_{i1}^{\mu,*}\Big(-\Big(-2|Y_{e,22}|^2+g_1^2\Big)Z_{j2}^{\mu,*}\Big(Z_{k1}^{\mu}Z_{l2}^{\mu}+Z_{k2}^{\mu}Z_{l1}^{\mu}\Big)+\Big(g_1^2+g_2^2\Big)Z_{j1}^{\mu,*}Z_{k1}^{\mu}Z_{l1}^{\mu}\Big)\Big)\end{aligned} \tag{637}$$



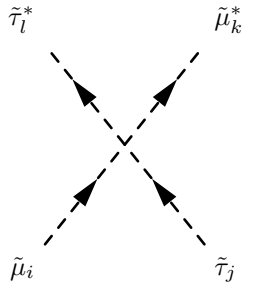
$$\begin{aligned}&\frac{i}{12}\delta_{\beta\delta}\Big(Z_{i1}^{\mu,*}\Big(2Z_{j2}^{S,*}\Big(-6Y_{d,22}^*Y_{e,22}Z_{k2}^{\mu}Z_{l1}^{S}+g_1^2Z_{k1}^{\mu}Z_{l2}^{S}\Big)+\Big(-3g_2^2+g_1^2\Big)Z_{j1}^{S,*}Z_{k1}^{\mu}Z_{l1}^{S}\Big)\\&-2Z_{i2}^{\mu,*}\Big(2g_1^2Z_{j2}^{S,*}Z_{k2}^{\mu}Z_{l2}^{S}+Z_{j1}^{S,*}\Big(6Y_{e,22}^*Y_{d,22}Z_{k1}^{\mu}Z_{l2}^{S}+g_1^2Z_{k2}^{\mu}Z_{l1}^{S}\Big)\Big)\Big)\end{aligned} \tag{638}$$



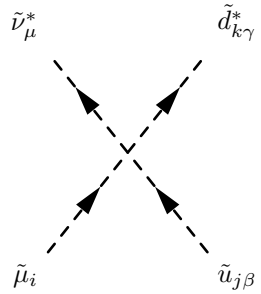
$$-\frac{i}{2}Z_{j1}^{T,*}\delta_{\beta\gamma}\Big(2Y_{e,22}^*Z_{i2}^{\mu,*}Y_{d,33}Z_{k2}^B+g_2^2Z_{i1}^{\mu,*}Z_{k1}^B\Big) \tag{639}$$



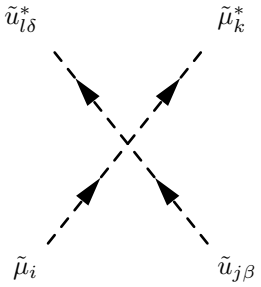
$$\begin{aligned}&\frac{i}{12}\delta_{\beta\delta}\Big(-2g_1^2Z_{i2}^{\mu,*}Z_{k2}^{\mu}\Big(-4Z_{j2}^{T,*}Z_{l2}^T+Z_{j1}^{T,*}Z_{l1}^T\Big)\\&+Z_{i1}^{\mu,*}Z_{k1}^{\mu}\Big(\Big(3g_2^2+g_1^2\Big)Z_{j1}^{T,*}Z_{l1}^T-4g_1^2Z_{j2}^{T,*}Z_{l2}^T\Big)\Big)\end{aligned} \tag{640}$$



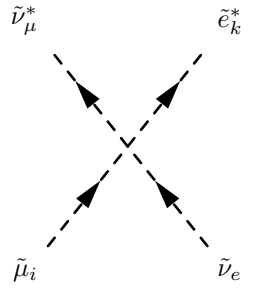
$$\begin{aligned}&\frac{i}{4}\Big(-Z_{i1}^{\mu,*}\Big(2Z_{j2}^{\tau,*}\Big(2Y_{e,33}^*Y_{e,22}Z_{k2}^{\mu}Z_{l1}^{\tau}-g_1^2Z_{k1}^{\mu}Z_{l2}^{\tau}\Big)+\Big(g_1^2+g_2^2\Big)Z_{j1}^{\tau,*}Z_{k1}^{\mu}Z_{l1}^{\tau}\Big)\\&+2Z_{i2}^{\mu,*}\Big(-2g_1^2Z_{j2}^{\tau,*}Z_{k2}^{\mu}Z_{l2}^{\tau}+Z_{j1}^{\tau,*}\Big(-2Y_{e,22}^*Y_{e,33}Z_{k1}^{\mu}Z_{l2}^{\tau}+g_1^2Z_{k2}^{\mu}Z_{l1}^{\tau}\Big)\Big)\Big)\end{aligned} \tag{641}$$



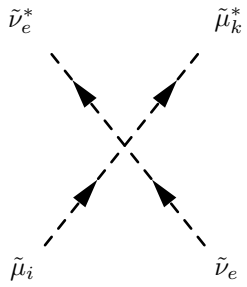
$$-\frac{i}{2}Z_{j1}^{U,*}\delta_{\beta\gamma}\Big(2Y_{e,22}^*Z_{i2}^{\mu,*}Y_{d,11}Z_{k2}^D+g_2^2Z_{i1}^{\mu,*}Z_{k1}^D\Big) \tag{642}$$



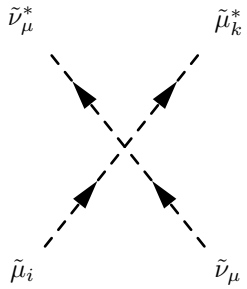
$$\begin{aligned}&\frac{i}{12}\delta_{\beta\delta}\Big(-2g_1^2Z_{i2}^{\mu,*}Z_{k2}^{\mu}\Big(-4Z_{j2}^{U,*}Z_{l2}^U+Z_{j1}^{U,*}Z_{l1}^U\Big)\\&+Z_{i1}^{\mu,*}Z_{k1}^{\mu}\Big(\Big(3g_2^2+g_1^2\Big)Z_{j1}^{U,*}Z_{l1}^U-4g_1^2Z_{j2}^{U,*}Z_{l2}^U\Big)\Big)\end{aligned} \tag{643}$$



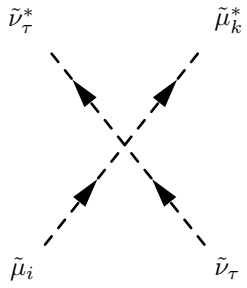
$$i\Big(-\frac{1}{2}g_2^2Z_{i1}^{\mu,*}Z_{k1}^E-Y_{e,22}^*Z_{i2}^{\mu,*}Y_{e,11}Z_{k2}^E\Big) \tag{644}$$



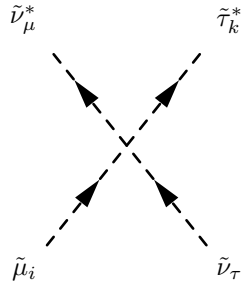
$$\frac{i}{4}\Big(2g_1^2 Z_{i2}^{\mu,*} Z_{k2}^{\mu} + \Big(-g_1^2 + g_2^2\Big) Z_{i1}^{\mu,*} Z_{k1}^{\mu}\Big) \tag{645}$$



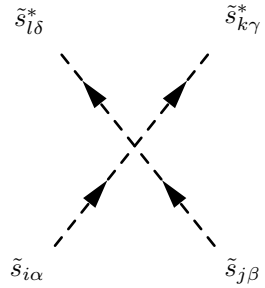
$$\frac{i}{4}\Big(2\Big(-2|Y_{e,22}|^2 + g_1^2\Big) Z_{i2}^{\mu,*} Z_{k2}^{\mu} - \Big(g_1^2 + g_2^2\Big) Z_{i1}^{\mu,*} Z_{k1}^{\mu}\Big) \tag{646}$$



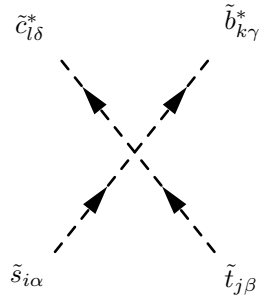
$$\frac{i}{4}\Big(2g_1^2 Z_{i2}^{\mu,*} Z_{k2}^{\mu} + \Big(-g_1^2 + g_2^2\Big) Z_{i1}^{\mu,*} Z_{k1}^{\mu}\Big) \tag{647}$$



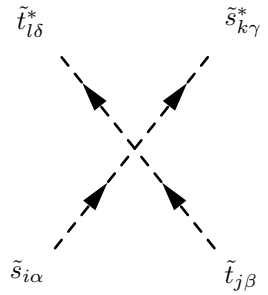
$$i\Big(-\frac{1}{2}g_2^2 Z_{i1}^{\mu,*} Z_{k1}^{\tau} - Y_{e,22}^* Z_{i2}^{\mu,*} Y_{e,33} Z_{k2}^{\tau}\Big) \tag{648}$$



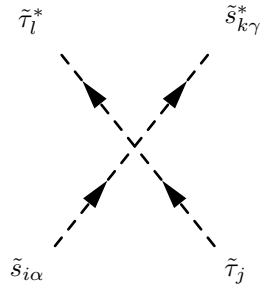
$$\begin{aligned}
&\frac{i}{36}\Big(-Z_{i1}^{S,*}\Big(\Big(12g_3^2+9g_2^2+g_1^2\Big)Z_{j1}^{S,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k1}^S Z_{l1}^S \\
&+2Z_{j2}^{S,*}\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(3g_3^2+g_1^2\Big)Z_{k1}^S Z_{l2}^S-9\Big(-2|Y_{d,22}|^2+g_3^2\Big)Z_{k2}^S Z_{l1}^S\Big) \\
&+\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(3g_3^2+g_1^2\Big)Z_{k2}^S Z_{l1}^S-9\Big(-2|Y_{d,22}|^2+g_3^2\Big)Z_{k1}^S Z_{l2}^S\Big)\Big)\Big) \\
&+2Z_{i2}^{S,*}\Big(-2\Big(3g_3^2+g_1^2\Big)Z_{j2}^{S,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k2}^S Z_{l2}^S \\
&+Z_{j1}^{S,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(-\Big(3g_3^2+g_1^2\Big)Z_{k1}^S Z_{l2}^S+9\Big(-2|Y_{d,22}|^2+g_3^2\Big)Z_{k2}^S Z_{l1}^S\Big) \\
&-\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(3g_3^2+g_1^2\Big)Z_{k2}^S Z_{l1}^S-9\Big(-2|Y_{d,22}|^2+g_3^2\Big)Z_{k1}^S Z_{l2}^S\Big)\Big)\Big)\Big)
\end{aligned} \tag{649}$$



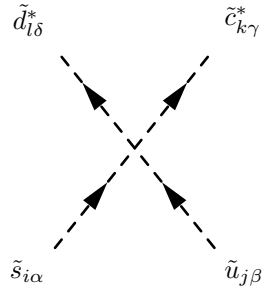
$$-\frac{i}{2}\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(2Y^*_{d,22}Z^{S,*}_{i2}Z^{T,*}_{j1}Y_{d,33}Z^B_{k2}Z^C_{l1}+Z^{S,*}_{i1}Z^B_{k1}\Big(2Y^*_{u,33}Z^{T,*}_{j2}Y_{u,22}Z^C_{l2}+g_2^2Z^{T,*}_{j1}Z^C_{l1}\Big)\Big) \tag{650}$$



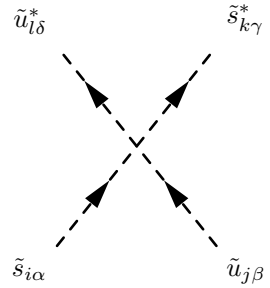
$$\begin{aligned}&\frac{i}{36}\Big(Z^{S,*}_{i1}Z^S_{k1}\Big(Z^{T,*}_{j1}\Big(-18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}+\Big(6g_3^2+9g_2^2-g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z^T_{l1}\\&+2Z^{T,*}_{j2}\Big(\Big(2g_1^2-3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^T_{l2}\Big)\\&+2Z^{S,*}_{i2}Z^S_{k2}\Big(Z^{T,*}_{j1}\Big(-\Big(3g_3^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^T_{l1}\\&+Z^{T,*}_{j2}\Big(\Big(3g_3^2+4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^T_{l2}\Big)\Big)\end{aligned} \tag{651}$$



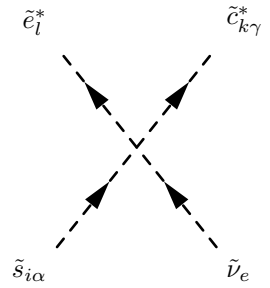
$$\begin{aligned}&\frac{i}{12}\delta_{\alpha\gamma}\Big(Z^{S,*}_{i1}\Big(-2Z^{\tau,*}_{j2}\Big(6Y^*_{e,33}Y_{d,22}Z^S_{k2}Z^\tau_{l1}+g_1^2Z^S_{k1}Z^\tau_{l2}\Big)+\Big(-3g_2^2+g_1^2\Big)Z^{\tau,*}_{j1}Z^S_{k1}Z^\tau_{l1}\Big)\\&+2Z^{S,*}_{i2}\Big(-2g_1^2Z^{\tau,*}_{j2}Z^S_{k2}Z^\tau_{l2}+Z^{\tau,*}_{j1}\Big(-6Y^*_{d,22}Y_{e,33}Z^S_{k1}Z^\tau_{l2}+g_1^2Z^S_{k2}Z^\tau_{l1}\Big)\Big)\Big)\end{aligned} \tag{652}$$



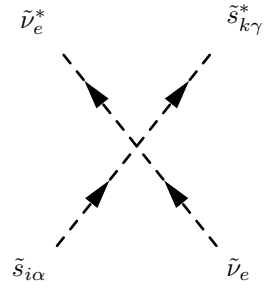
$$-\frac{i}{2}\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(2Y^*_{d,22}Z^{S,*}_{i2}Z^{U,*}_{j1}Y_{d,11}Z^C_{k1}Z^D_{l2}+Z^{S,*}_{i1}\Big(2Y^*_{u,11}Z^{U,*}_{j2}Y_{u,22}Z^C_{k2}+g_2^2Z^{U,*}_{j1}Z^C_{k1}\Big)Z^D_{l1}\Big) \tag{653}$$



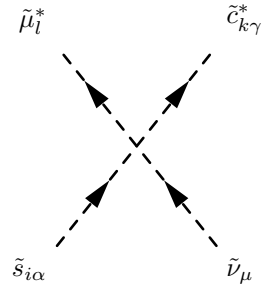
$$\begin{aligned}&\frac{i}{36}\Big(Z^{S,*}_{i1}Z^S_{k1}\Big(Z^{U,*}_{j1}\Big(-18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}+\Big(6g_3^2+9g_2^2-g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z^U_{l1}\\&+2Z^{U,*}_{j2}\Big(\Big(2g_1^2-3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^U_{l2}\Big)\\&+2Z^{S,*}_{i2}Z^S_{k2}\Big(Z^{U,*}_{j1}\Big(-\Big(3g_3^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}+9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^U_{l1}\\&+Z^{U,*}_{j2}\Big(\Big(3g_3^2+4g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z^U_{l2}\Big)\Big)\end{aligned} \tag{654}$$



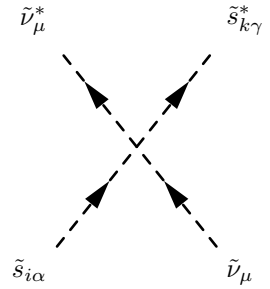
$$-\frac{i}{2}\delta_{\alpha\gamma}Z^C_{k1}\Big(2Y^*_{d,22}Z^{S,*}_{i2}Y_{e,11}Z^E_{l2}+g_2^2Z^{S,*}_{i1}Z^E_{l1}\Big) \tag{655}$$



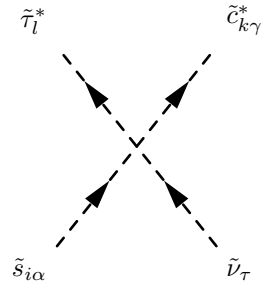
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(2g_1^2 Z_{i2}^{S,*} Z_{k2}^S + \Big(3g_2^2 + g_1^2\Big) Z_{i1}^{S,*} Z_{k1}^S\Big) \tag{656}$$



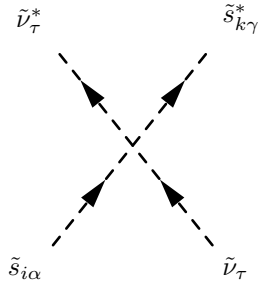
$$-\frac{i}{2}\delta_{\alpha\gamma} Z_{k1}^C \Big(2Y_{d,22}^* Z_{i2}^{S,*} Y_{e,22} Z_{l2}^\mu + g_2^2 Z_{i1}^{S,*} Z_{l1}^\mu\Big) \tag{657}$$



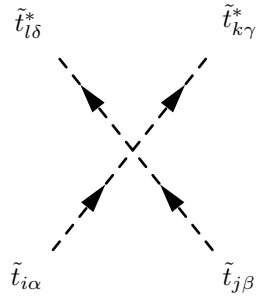
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(2g_1^2 Z_{i2}^{S,*} Z_{k2}^S + \Big(3g_2^2 + g_1^2\Big) Z_{i1}^{S,*} Z_{k1}^S\Big) \tag{658}$$



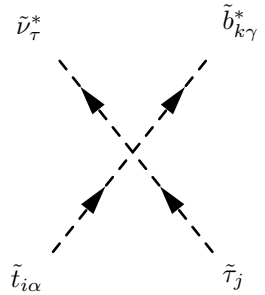
$$-\frac{i}{2}\delta_{\alpha\gamma} Z_{k1}^C \Big(2Y_{d,22}^* Z_{i2}^{S,*} Y_{e,33} Z_{l2}^\tau + g_2^2 Z_{i1}^{S,*} Z_{l1}^\tau\Big) \tag{659}$$



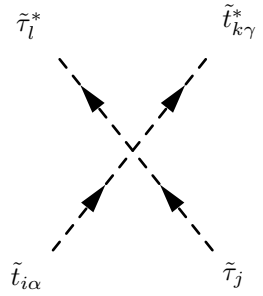
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(2g_1^2 Z_{i2}^{S,*} Z_{k2}^S + \Big(3g_2^2 + g_1^2\Big) Z_{i1}^{S,*} Z_{k1}^S\Big) \tag{660}$$



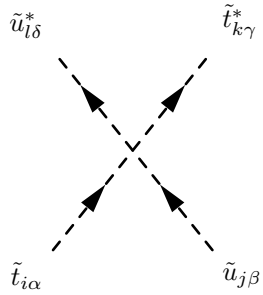
$$\begin{aligned}
&\frac{i}{36}\Big(- Z_{i1}^{T,*}\Big(\Big(12g_3^2 + 9g_2^2 + g_1^2\Big) Z_{j1}^{T,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma} + \delta_{\alpha\gamma}\delta_{\beta\delta}\Big) Z_{k1}^T Z_{l1}^T \\
&+ 2Z_{j2}^{T,*}\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(- 2g_1^2 + 3g_3^2\Big) Z_{k1}^T Z_{l2}^T - 9\Big(- 2|Y_{u,33}|^2 + g_3^2\Big) Z_{k2}^T Z_{l1}^T\Big) \\
&+ \delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(- 2g_1^2 + 3g_3^2\Big) Z_{k2}^T Z_{l1}^T - 9\Big(- 2|Y_{u,33}|^2 + g_3^2\Big) Z_{k1}^T Z_{l2}^T\Big)\Big)\Big) \\
&+ 2Z_{i2}^{T,*}\Big(- 2\Big(3g_3^2 + 4g_1^2\Big) Z_{j2}^{T,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma} + \delta_{\alpha\gamma}\delta_{\beta\delta}\Big) Z_{k2}^T Z_{l2}^T \\
&+ Z_{j1}^{T,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(2g_1^2 - 3g_3^2\Big) Z_{k1}^T Z_{l2}^T + 9\Big(- 2|Y_{u,33}|^2 + g_3^2\Big) Z_{k2}^T Z_{l1}^T\Big) \\
&+ \delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(2g_1^2 - 3g_3^2\Big) Z_{k2}^T Z_{l1}^T + 9\Big(- 2|Y_{u,33}|^2 + g_3^2\Big) Z_{k1}^T Z_{l2}^T\Big)\Big)\Big)\Big)
\end{aligned} \tag{661}$$



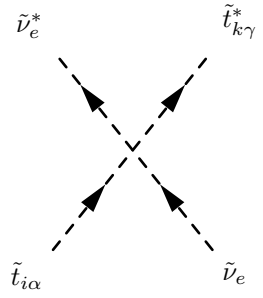
$$-\frac{i}{2}Z_{i1}^{T,*}\delta_{\alpha\gamma}\Big(2Y_{e,33}^{*}Z_{j2}^{\tau,*}Y_{d,33}Z_{k2}^{B}+g_2^2Z_{j1}^{\tau,*}Z_{k1}^{B}\Big) \tag{662}$$



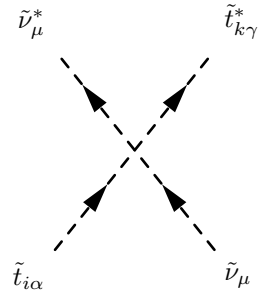
$$\begin{aligned}&\frac{i}{12}\delta_{\alpha\gamma}\Big(-4g_1^2Z_{i2}^{T,*}Z_{k2}^{T}\Big(-2Z_{j2}^{\tau,*}Z_{l2}^{\tau}+Z_{j1}^{\tau,*}Z_{l1}^{\tau}\Big)\\&+Z_{i1}^{T,*}Z_{k1}^{T}\Big(-2g_1^2Z_{j2}^{\tau,*}Z_{l2}^{\tau}+\Big(3g_2^2+g_1^2\Big)Z_{j1}^{\tau,*}Z_{l1}^{\tau}\Big)\Big)\end{aligned} \tag{663}$$



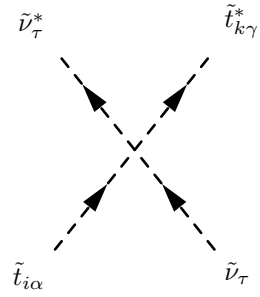
$$\begin{aligned}&\frac{i}{36}\Big(-Z_{i1}^{T,*}\Big(Z_{j1}^{U,*}\Big(18g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}+\Big(-6g_3^2+9g_2^2+g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k1}^{T}Z_{l1}^{U}\\&+2Z_{j2}^{U,*}\Big(18Y_{u,11}^{*}\delta_{\alpha\gamma}\delta_{\beta\delta}Y_{u,33}Z_{k2}^{T}Z_{l1}^{U}+\Big(\Big(-2g_1^2+3g_3^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{k1}^{T}Z_{l2}^{U}\Big)\Big)\\&+2Z_{i2}^{T,*}\Big(Z_{j2}^{U,*}\Big(\Big(3g_3^2-8g_1^2\Big)\delta_{\alpha\gamma}\delta_{\beta\delta}-9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}\Big)Z_{k2}^{T}Z_{l2}^{U}\\&+Z_{j1}^{U,*}\Big(9g_3^2\delta_{\alpha\delta}\delta_{\beta\gamma}Z_{k2}^{T}Z_{l1}^{U}+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(-18Y_{u,33}^{*}Y_{u,11}Z_{k1}^{T}Z_{l2}^{U}+\Big(2g_1^2-3g_3^2\Big)Z_{k2}^{T}Z_{l1}^{U}\Big)\Big)\Big)\Big)\Big)\end{aligned} \tag{664}$$



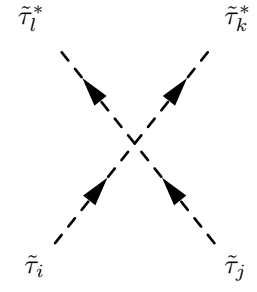
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{T,*}Z_{k1}^{T}-4g_1^2Z_{i2}^{T,*}Z_{k2}^{T}\Big) \tag{665}$$



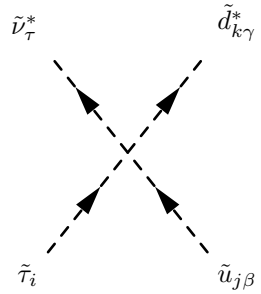
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{T,*}Z_{k1}^{T}-4g_1^2Z_{i2}^{T,*}Z_{k2}^{T}\Big) \tag{666}$$



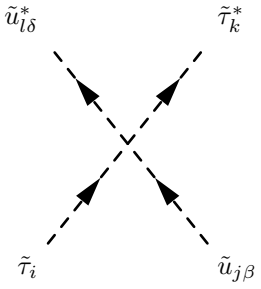
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{T,*}Z_{k1}^{T}-4g_1^2Z_{i2}^{T,*}Z_{k2}^{T}\Big) \tag{667}$$



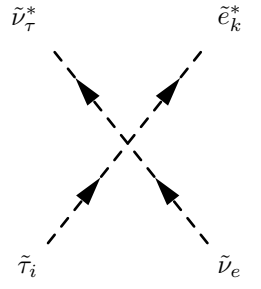
$$\begin{aligned}&\frac{i}{2}\Big(Z_{i2}^{\tau,*}\Big(\Big(-2|Y_{e,33}|^2+g_1^2\Big)Z_{j1}^{\tau,*}\Big(Z_{k1}^{\tau}Z_{l2}^{\tau}+Z_{k2}^{\tau}Z_{l1}^{\tau}\Big)-4g_1^2Z_{j2}^{\tau,*}Z_{k2}^{\tau}Z_{l2}^{\tau}\Big)\\&-Z_{i1}^{\tau,*}\Big(-\Big(-2|Y_{e,33}|^2+g_1^2\Big)Z_{j2}^{\tau,*}\Big(Z_{k1}^{\tau}Z_{l2}^{\tau}+Z_{k2}^{\tau}Z_{l1}^{\tau}\Big)+\Big(g_1^2+g_2^2\Big)Z_{j1}^{\tau,*}Z_{k1}^{\tau}Z_{l1}^{\tau}\Big)\Big)\end{aligned} \tag{668}$$



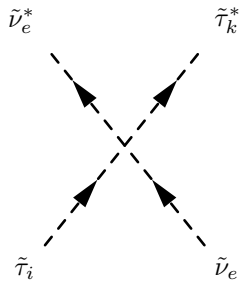
$$-\frac{i}{2}Z_{j1}^{U,*}\delta_{\beta\gamma}\Big(2Y_{e,33}^*Z_{i2}^{\tau,*}Y_{d,11}Z_{k2}^D+g_2^2Z_{i1}^{\tau,*}Z_{k1}^D\Big) \tag{669}$$



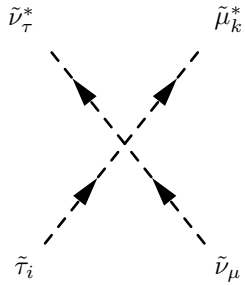
$$\begin{aligned}&\frac{i}{12}\delta_{\beta\delta}\Big(-2g_1^2Z_{i2}^{\tau,*}Z_{k2}^\tau\Big(-4Z_{j2}^{U,*}Z_{l2}^U+Z_{j1}^{U,*}Z_{l1}^U\Big)\\&+Z_{i1}^{\tau,*}Z_{k1}^\tau\Big(\Big(3g_2^2+g_1^2\Big)Z_{j1}^{U,*}Z_{l1}^U-4g_1^2Z_{j2}^{U,*}Z_{l2}^U\Big)\Big)\end{aligned} \tag{670}$$



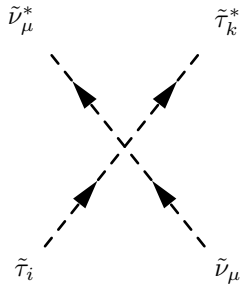
$$i\Big(-\frac{1}{2}g_2^2Z_{i1}^{\tau,*}Z_{k1}^E-Y_{e,33}^*Z_{i2}^{\tau,*}Y_{e,11}Z_{k2}^E\Big) \tag{671}$$



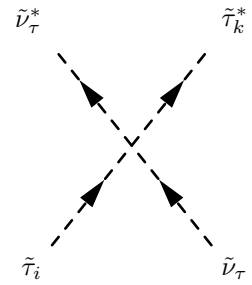
$$\frac{i}{4}\Big(2g_1^2 Z_{i2}^{\tau,*} Z_{k2}^{\tau} + \Big(-g_1^2 + g_2^2\Big) Z_{i1}^{\tau,*} Z_{k1}^{\tau}\Big) \tag{672}$$



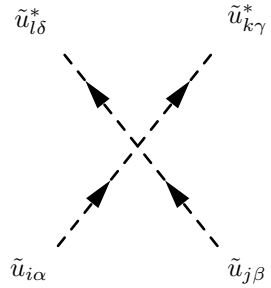
$$i\Big(-\frac{1}{2}g_2^2 Z_{i1}^{\tau,*} Z_{k1}^{\mu} - Y_{e,33}^* Z_{i2}^{\tau,*} Y_{e,22} Z_{k2}^{\mu}\Big) \tag{673}$$



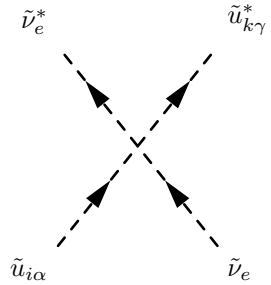
$$\frac{i}{4}\Big(2g_1^2 Z_{i2}^{\tau,*} Z_{k2}^{\tau} + \Big(-g_1^2 + g_2^2\Big) Z_{i1}^{\tau,*} Z_{k1}^{\tau}\Big) \tag{674}$$



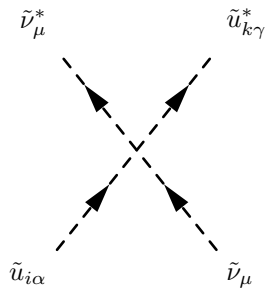
$$\frac{i}{4}\Big(2\Big(-2|Y_{e,33}|^2+g_1^2\Big)Z_{i2}^{\tau,*}Z_{k2}^{\tau}-\Big(g_1^2+g_2^2\Big)Z_{i1}^{\tau,*}Z_{k1}^{\tau}\Big) \tag{675}$$



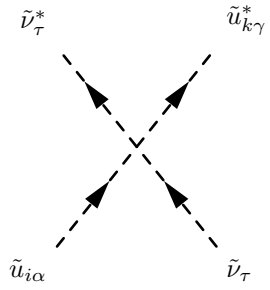
$$\begin{aligned}
&\frac{i}{36}\Big(-Z_{i1}^{U,*}\Big(\Big(12g_3^2+9g_2^2+g_1^2\Big)Z_{j1}^{U,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k1}^{U}Z_{l1}^{U}\\
&+2Z_{j2}^{U,*}\Big(\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(-2g_1^2+3g_3^2\Big)Z_{k1}^{U}Z_{l2}^{U}-9\Big(-2|Y_{u,11}|^2+g_3^2\Big)Z_{k2}^{U}Z_{l1}^{U}\Big)\\
&+\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(-2g_1^2+3g_3^2\Big)Z_{k2}^{U}Z_{l1}^{U}-9\Big(-2|Y_{u,11}|^2+g_3^2\Big)Z_{k1}^{U}Z_{l2}^{U}\Big)\Big)\Big)\\
&+2Z_{i2}^{U,*}\Big(-2\Big(3g_3^2+4g_1^2\Big)Z_{j2}^{U,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big)Z_{k2}^{U}Z_{l2}^{U}\\
&+Z_{j1}^{U,*}\Big(\delta_{\alpha\delta}\delta_{\beta\gamma}\Big(\Big(2g_1^2-3g_3^2\Big)Z_{k1}^{U}Z_{l2}^{U}+9\Big(-2|Y_{u,11}|^2+g_3^2\Big)Z_{k2}^{U}Z_{l1}^{U}\Big)\\
&+\delta_{\alpha\gamma}\delta_{\beta\delta}\Big(\Big(2g_1^2-3g_3^2\Big)Z_{k2}^{U}Z_{l1}^{U}+9\Big(-2|Y_{u,11}|^2+g_3^2\Big)Z_{k1}^{U}Z_{l2}^{U}\Big)\Big)\Big)\Big)
\end{aligned} \tag{676}$$



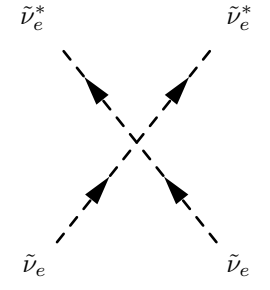
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{U,*}Z_{k1}^{U}-4g_1^2Z_{i2}^{U,*}Z_{k2}^{U}\Big) \tag{677}$$



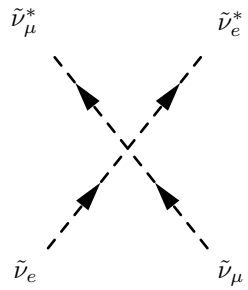
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{U,*}Z_{k1}^{U}-4g_1^2Z_{i2}^{U,*}Z_{k2}^{U}\Big) \tag{678}$$



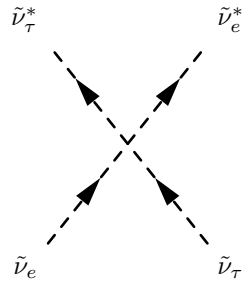
$$\frac{i}{12}\delta_{\alpha\gamma}\Big(\Big(-3g_2^2+g_1^2\Big)Z_{i1}^{U,*}Z_{k1}^{U}-4g_1^2Z_{i2}^{U,*}Z_{k2}^{U}\Big) \tag{679}$$



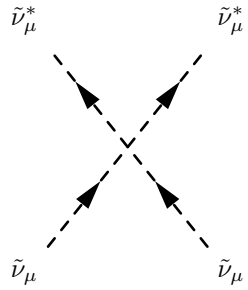
$$\frac{i}{2}\Big(-g_1^2-g_2^2\Big) \tag{680}$$



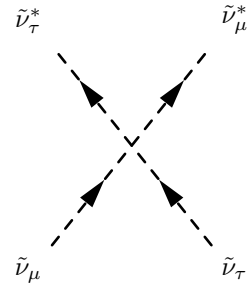
$$\frac{i}{4}\Big(-g_1^2-g_2^2\Big) \tag{681}$$



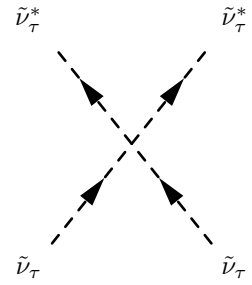
$$\frac{i}{4}\Big(-g_1^2-g_2^2\Big) \tag{682}$$



$$\frac{i}{2}\Big(-g_1^2-g_2^2\Big) \tag{683}$$

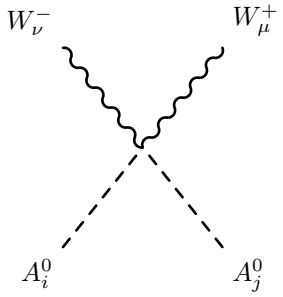


$$\frac{i}{4}\Big(- g_1^2 - g_2^2\Big) \tag{684}$$

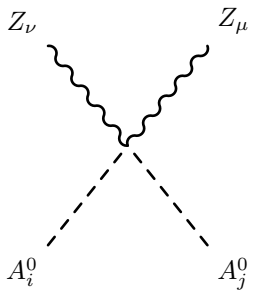


$$\frac{i}{2}\Big(- g_1^2 - g_2^2\Big) \tag{685}$$

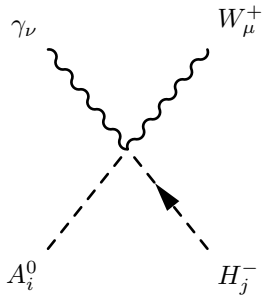
9.8 Two Scalar-Two Vector Boson-Interaction



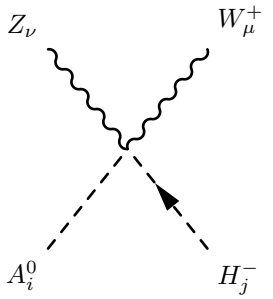
$$\Big(\frac{i}{2}g_2^2 Z_{i1}^A Z_{j1}^A + \frac{i}{2}g_2^2 Z_{i2}^A Z_{j2}^A\Big)\Big(g_{\mu\nu}\Big) \tag{686}$$



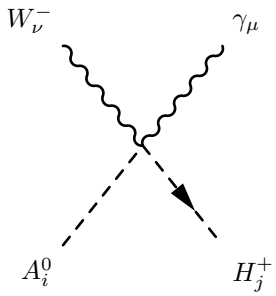
$$\Big(+ \frac{i}{2} g_2^2 \cos\Theta_W^2 Z_{i1}^A Z_{j1}^A + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i1}^A Z_{j1}^A + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z_{i1}^A Z_{j1}^A + \frac{i}{2} g_2^2 \cos\Theta_W^2 Z_{i2}^A Z_{j2}^A + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i2}^A Z_{j2}^A + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z_{i2}^A Z_{j2}^A \Big) \Big(g_{\mu\nu} \Big) \tag{687}$$



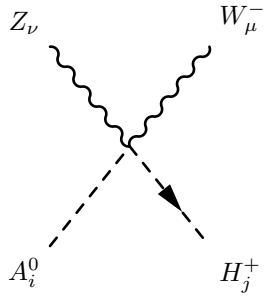
$$\Big(- \frac{1}{2} g_1 g_2 \cos\Theta_W Z_{i1}^A Z_{j1}^+ - \frac{1}{2} g_1 g_2 \cos\Theta_W Z_{i2}^A Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{688}$$



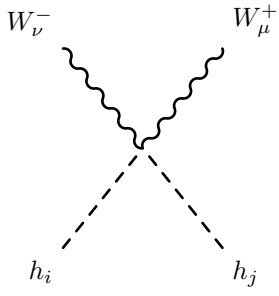
$$\Big(\frac{1}{2} g_1 g_2 \sin\Theta_W Z_{i1}^A Z_{j1}^+ + \frac{1}{2} g_1 g_2 \sin\Theta_W Z_{i2}^A Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{689}$$



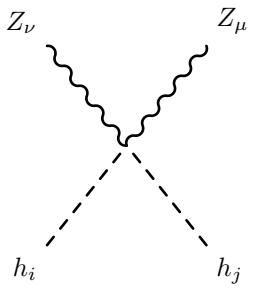
$$\Big(\frac{1}{2}g_1 g_2 \cos\Theta_W Z_{i1}^A Z_{j1}^+ + \frac{1}{2}g_1 g_2 \cos\Theta_W Z_{i2}^A Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{690}$$



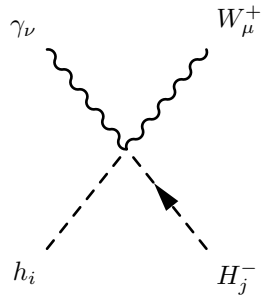
$$\Big(-\frac{1}{2}g_1 g_2 \sin\Theta_W Z_{i1}^A Z_{j1}^+ - \frac{1}{2}g_1 g_2 \sin\Theta_W Z_{i2}^A Z_{j2}^+\Big)\Big(g_{\mu\nu}\Big) \tag{691}$$



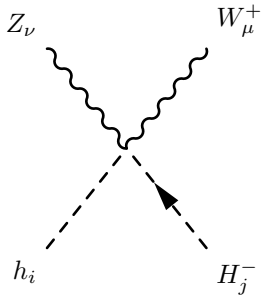
$$\Big(\frac{i}{2}g_2^2 Z_{i1}^H Z_{j1}^H + \frac{i}{2}g_2^2 Z_{i2}^H Z_{j2}^H\Big)\Big(g_{\mu\nu}\Big) \tag{692}$$



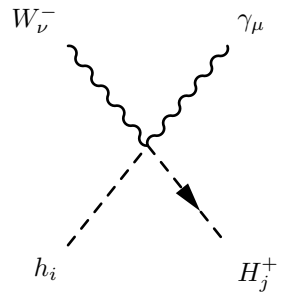
$$\Big(+ \frac{i}{2} g_2^2 \cos\Theta_W^2 Z_{i1}^H Z_{j1}^H + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i1}^H Z_{j1}^H + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z_{i1}^H Z_{j1}^H$$
$$+ \frac{i}{2} g_2^2 \cos\Theta_W^2 Z_{i2}^H Z_{j2}^H + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i2}^H Z_{j2}^H + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z_{i2}^H Z_{j2}^H \Big) \Big(g_{\mu\nu} \Big) \tag{693}$$



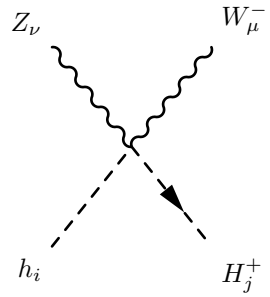
$$\Big(- \frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i2}^H Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{694}$$



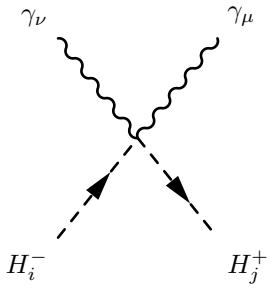
$$\Big(\frac{i}{2} g_1 g_2 \sin\Theta_W Z_{i1}^H Z_{j1}^+ - \frac{i}{2} g_1 g_2 \sin\Theta_W Z_{i2}^H Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{695}$$



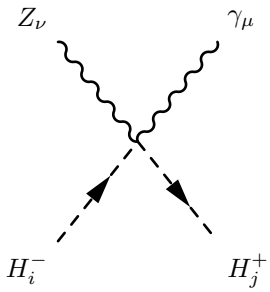
$$\Big(-\frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i1}^H Z_{j1}^+ + \frac{i}{2} g_1 g_2 \cos\Theta_W Z_{i2}^H Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{696}$$



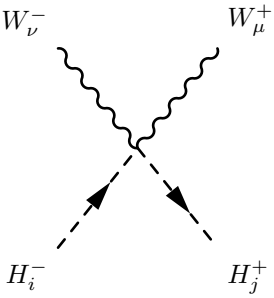
$$\Big(\frac{i}{2} g_1 g_2 \sin\Theta_W Z_{i1}^H Z_{j1}^+ - \frac{i}{2} g_1 g_2 \sin\Theta_W Z_{i2}^H Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{697}$$



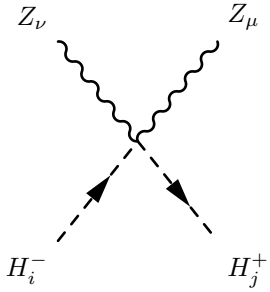
$$\begin{aligned} &\Big(+ \frac{i}{2} g_1^2 \cos\Theta_W^2 Z_{i1}^+ Z_{j1}^+ + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_2^2 \sin\Theta_W^2 Z_{i1}^+ Z_{j1}^+ \\ &+ \frac{i}{2} g_1^2 \cos\Theta_W^2 Z_{i2}^+ Z_{j2}^+ + i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{2} g_2^2 \sin\Theta_W^2 Z_{i2}^+ Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \end{aligned} \tag{698}$$



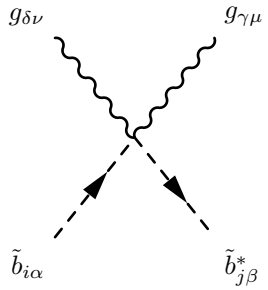
$$\Big(+ \frac{i}{2} g_1 g_2 \cos 2\Theta_W Z_{i1}^+ Z_{j1}^+ - \frac{i}{4} g_1^2 \sin 2\Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{4} g_2^2 \sin 2\Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_1 g_2 \cos 2\Theta_W Z_{i2}^+ Z_{j2}^+ - \frac{i}{4} g_1^2 \sin 2\Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{4} g_2^2 \sin 2\Theta_W Z_{i2}^+ Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{699}$$



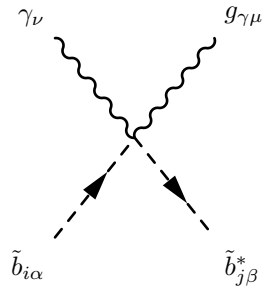
$$\Big(\frac{i}{2} g_2^2 Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_2^2 Z_{i2}^+ Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{700}$$



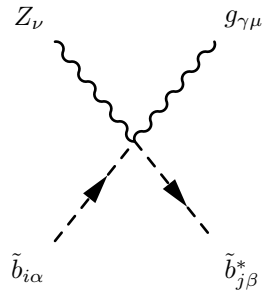
$$\Big(+ \frac{i}{2} g_2^2 \cos\Theta_W^2 Z_{i1}^+ Z_{j1}^+ - i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z_{i1}^+ Z_{j1}^+ + \frac{i}{2} g_2^2 \cos\Theta_W^2 Z_{i2}^+ Z_{j2}^+ - i g_1 g_2 \cos\Theta_W \sin\Theta_W Z_{i2}^+ Z_{j2}^+ + \frac{i}{2} g_1^2 \sin\Theta_W^2 Z_{i2}^+ Z_{j2}^+ \Big) \Big(g_{\mu\nu} \Big) \tag{701}$$



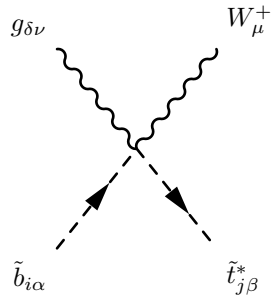
$$\Big(+ \frac{i}{4} g_3^2 Z_{i1}^{B,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j1}^{B} + \frac{i}{4} g_3^2 Z_{i1}^{B,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j1}^{B} + \frac{i}{4} g_3^2 Z_{i2}^{B,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j2}^{B}$$
$$+ \frac{i}{4} g_3^2 Z_{i2}^{B,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j2}^{B} \Big) \Big(g_{\mu\nu} \Big) \tag{702}$$



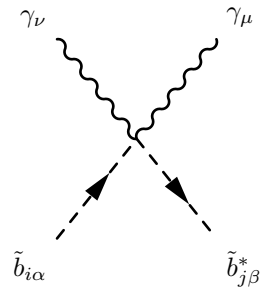
$$\Big(+ \frac{i}{6} g_1 g_3 Z_{i1}^{B,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j1}^{B} - \frac{i}{2} g_2 g_3 Z_{i1}^{B,*} \lambda_{\beta,\alpha}^{\gamma} \sin\Theta_W Z_{j1}^{B}$$
$$- \frac{i}{3} g_1 g_3 Z_{i2}^{B,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j2}^{B} \Big) \Big(g_{\mu\nu} \Big) \tag{703}$$



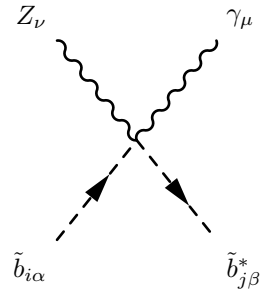
$$\Big(-\frac{i}{2} g_2 g_3 Z^{B,*}_{i1} \cos\Theta_W \lambda^{\gamma}_{\beta,\alpha} Z^B_{j1} - \frac{i}{6} g_1 g_3 Z^{B,*}_{i1} \lambda^{\gamma}_{\beta,\alpha} \sin\Theta_W Z^B_{j1} + \frac{i}{3} g_1 g_3 Z^{B,*}_{i2} \lambda^{\gamma}_{\beta,\alpha} \sin\Theta_W Z^B_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{704}$$



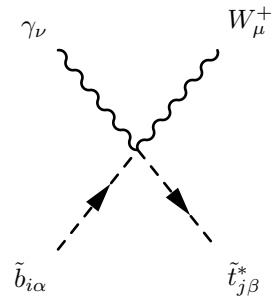
$$i \frac{1}{\sqrt{2}} g_2 g_3 Z^{B,*}_{i1} \lambda^{\delta}_{\beta,\alpha} Z^T_{j1} \Big(g_{\mu\nu} \Big) \tag{705}$$



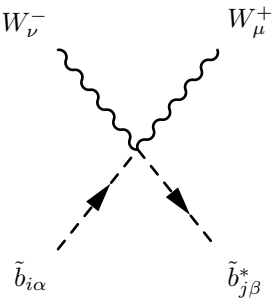
$$\Big(+ \frac{i}{18} g_1^2 Z^{B,*}_{i1} \cos^2\Theta_W \delta_{\alpha\beta} Z^B_{j1} - \frac{i}{3} g_1 g_2 Z^{B,*}_{i1} \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W Z^B_{j1} + \frac{i}{2} g_2^2 Z^{B,*}_{i1} \delta_{\alpha\beta} \sin^2\Theta_W Z^B_{j1} + \frac{2i}{9} g_1^2 Z^{B,*}_{i2} \cos^2\Theta_W \delta_{\alpha\beta} Z^B_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{706}$$



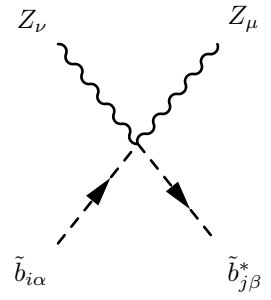
$$\Big(-\frac{i}{6} g_1 g_2 Z^{B,*}_{i1} \cos 2\Theta_W \delta_{\alpha\beta} Z^B_{j1} - \frac{i}{36} g_1^2 Z^{B,*}_{i1} \delta_{\alpha\beta} \sin 2\Theta_W Z^B_{j1} + \frac{i}{4} g_2^2 Z^{B,*}_{i1} \delta_{\alpha\beta} \sin 2\Theta_W Z^B_{j1} - \frac{i}{9} g_1^2 Z^{B,*}_{i2} \delta_{\alpha\beta} \sin 2\Theta_W Z^B_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{707}$$



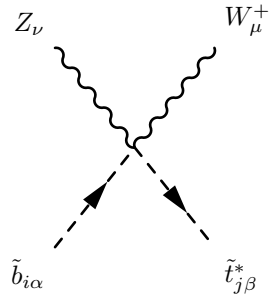
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 Z^{B,*}_{i1} \cos\Theta_W \delta_{\alpha\beta} Z^T_{j1} \Big(g_{\mu\nu} \Big) \tag{708}$$



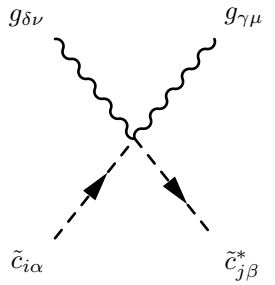
$$\frac{i}{2} g_2^2 Z^{B,*}_{i1} \delta_{\alpha\beta} Z^B_{j1} \Big(g_{\mu\nu} \Big) \tag{709}$$



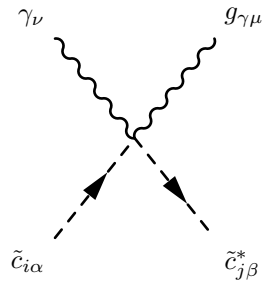
$$\Big(+ \frac{i}{2} g_2^2 Z_{i1}^{B,*} \cos\Theta_W^2 \delta_{\alpha\beta} Z_{j1}^B + \frac{i}{3} g_1 g_2 Z_{i1}^{B,*} \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W Z_{j1}^B$$
$$+ \frac{i}{18} g_1^2 Z_{i1}^{B,*} \delta_{\alpha\beta} \sin\Theta_W^2 Z_{j1}^B + \frac{2i}{9} g_1^2 Z_{i2}^{B,*} \delta_{\alpha\beta} \sin\Theta_W^2 Z_{j2}^B \Big) \Big(g_{\mu\nu} \Big) \tag{710}$$



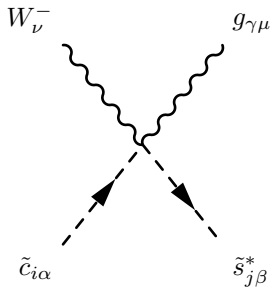
$$- \frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 Z_{i1}^{B,*} \delta_{\alpha\beta} \sin\Theta_W Z_{j1}^T \Big(g_{\mu\nu} \Big) \tag{711}$$



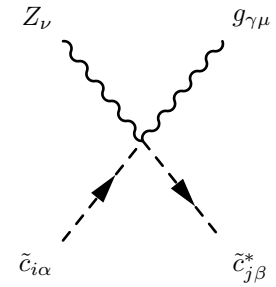
$$\Big(+ \frac{i}{4} g_3^2 Z_{i1}^{C,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j1}^C + \frac{i}{4} g_3^2 Z_{i1}^{C,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j1}^C + \frac{i}{4} g_3^2 Z_{i2}^{C,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j2}^C$$
$$+ \frac{i}{4} g_3^2 Z_{i2}^{C,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j2}^C \Big) \Big(g_{\mu\nu} \Big) \tag{712}$$



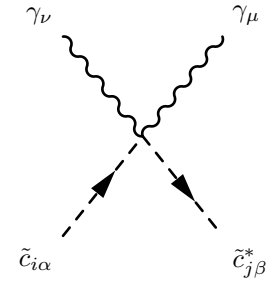
$$\Big(+ \frac{i}{6} g_1 g_3 Z_{i1}^{C,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j1}^{C} + \frac{i}{2} g_2 g_3 Z_{i1}^{C,*} \lambda_{\beta,\alpha}^{\gamma} \sin\Theta_W Z_{j1}^{C} + \frac{2i}{3} g_1 g_3 Z_{i2}^{C,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j2}^{C} \Big) \Big(g_{\mu\nu} \Big) \tag{713}$$



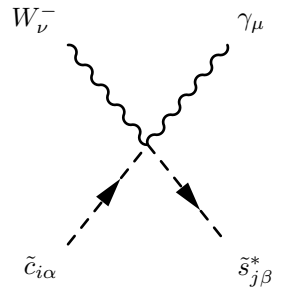
$$i \frac{1}{\sqrt{2}} g_2 g_3 Z_{i1}^{C,*} \lambda_{\beta,\alpha}^{\gamma} Z_{j1}^{S} \Big(g_{\mu\nu} \Big) \tag{714}$$



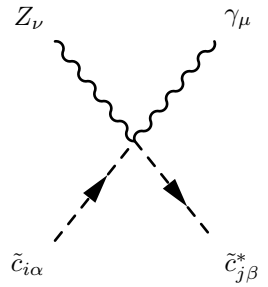
$$\Big(+ \frac{i}{2} g_2 g_3 Z_{i1}^{C,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j1}^{C} - \frac{i}{6} g_1 g_3 Z_{i1}^{C,*} \lambda_{\beta,\alpha}^{\gamma} \sin\Theta_W Z_{j1}^{C} - \frac{2i}{3} g_1 g_3 Z_{i2}^{C,*} \lambda_{\beta,\alpha}^{\gamma} \sin\Theta_W Z_{j2}^{C} \Big) \Big(g_{\mu\nu} \Big) \tag{715}$$



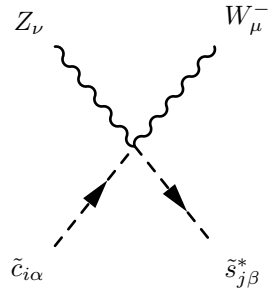
$$\Big(+ \frac{i}{18} g_1^2 Z_{i1}^{C,*} \cos\Theta_W^2 \delta_{\alpha\beta} Z_{j1}^C + \frac{i}{3} g_1 g_2 Z_{i1}^{C,*} \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W Z_{j1}^C$$
$$+ \frac{i}{2} g_2^2 Z_{i1}^{C,*} \delta_{\alpha\beta} \sin\Theta_W^2 Z_{j1}^C + \frac{8i}{9} g_1^2 Z_{i2}^{C,*} \cos\Theta_W^2 \delta_{\alpha\beta} Z_{j2}^C \Big) \Big(g_{\mu\nu} \Big) \tag{716}$$



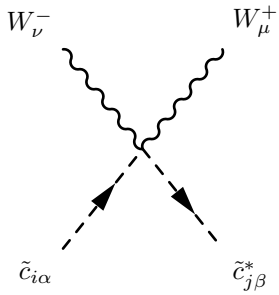
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 Z_{i1}^{C,*} \cos\Theta_W \delta_{\alpha\beta} Z_{j1}^S \Big(g_{\mu\nu} \Big) \tag{717}$$



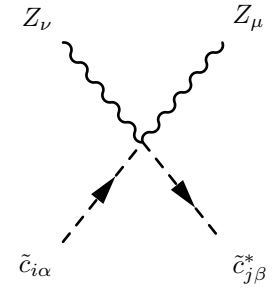
$$\Big(+ \frac{i}{6} g_1 g_2 Z_{i1}^{C,*} \cos 2\Theta_W \delta_{\alpha\beta} Z_{j1}^C - \frac{i}{36} g_1^2 Z_{i1}^{C,*} \delta_{\alpha\beta} \sin 2\Theta_W Z_{j1}^C$$
$$+ \frac{i}{4} g_2^2 Z_{i1}^{C,*} \delta_{\alpha\beta} \sin 2\Theta_W Z_{j1}^C - \frac{4i}{9} g_1^2 Z_{i2}^{C,*} \delta_{\alpha\beta} \sin 2\Theta_W Z_{j2}^C \Big) \Big(g_{\mu\nu} \Big) \tag{718}$$



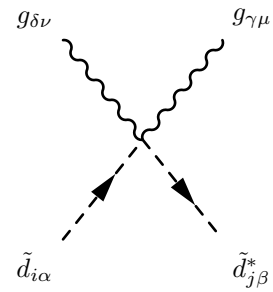
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 Z_{i1}^{C,*}\delta_{\alpha\beta}\sin\Theta_W Z_{j1}^{S}\Big(g_{\mu\nu}\Big) \tag{719}$$



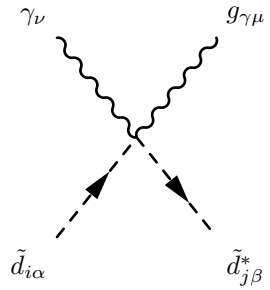
$$\frac{i}{2}g_2^2 Z_{i1}^{C,*}\delta_{\alpha\beta}Z_{j1}^{C}\Big(g_{\mu\nu}\Big) \tag{720}$$



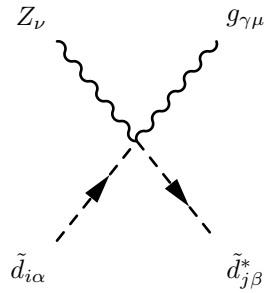
$$\begin{aligned}&\Big(+\frac{i}{2}g_2^2 Z_{i1}^{C,*}\cos\Theta_W^2\delta_{\alpha\beta}Z_{j1}^{C}-\frac{i}{3}g_1 g_2 Z_{i1}^{C,*}\cos\Theta_W\delta_{\alpha\beta}\sin\Theta_W Z_{j1}^{C}\\&+\frac{i}{18}g_1^2 Z_{i1}^{C,*}\delta_{\alpha\beta}\sin\Theta_W^2 Z_{j1}^{C}+\frac{8i}{9}g_1^2 Z_{i2}^{C,*}\delta_{\alpha\beta}\sin\Theta_W^2 Z_{j2}^{C}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{721}$$



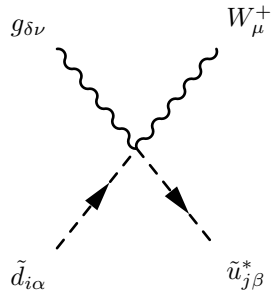
$$\Big(+ \frac{i}{4} g_3^2 Z_{i1}^{D,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j1}^{D} + \frac{i}{4} g_3^2 Z_{i1}^{D,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j1}^{D} + \frac{i}{4} g_3^2 Z_{i2}^{D,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j2}^{D}$$
$$+ \frac{i}{4} g_3^2 Z_{i2}^{D,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j2}^{D} \Big) \Big(g_{\mu\nu} \Big) \tag{722}$$



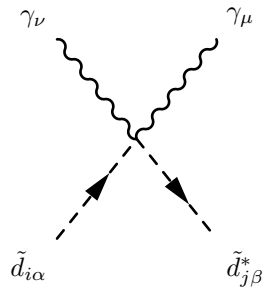
$$\Big(+ \frac{i}{6} g_1 g_3 Z_{i1}^{D,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j1}^{D} - \frac{i}{2} g_2 g_3 Z_{i1}^{D,*} \lambda_{\beta,\alpha}^{\gamma} \sin\Theta_W Z_{j1}^{D}$$
$$- \frac{i}{3} g_1 g_3 Z_{i2}^{D,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j2}^{D} \Big) \Big(g_{\mu\nu} \Big) \tag{723}$$



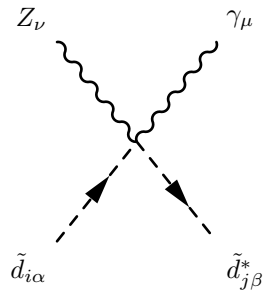
$$\Big(- \frac{i}{2} g_2 g_3 Z_{i1}^{D,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j1}^{D} - \frac{i}{6} g_1 g_3 Z_{i1}^{D,*} \lambda_{\beta,\alpha}^{\gamma} \sin\Theta_W Z_{j1}^{D}$$
$$+ \frac{i}{3} g_1 g_3 Z_{i2}^{D,*} \lambda_{\beta,\alpha}^{\gamma} \sin\Theta_W Z_{j2}^{D} \Big) \Big(g_{\mu\nu} \Big) \tag{724}$$



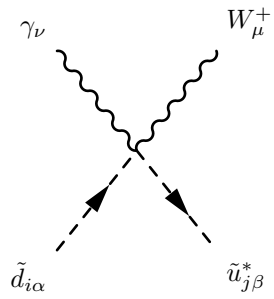
$$i\frac{1}{\sqrt{2}}g_2 g_3 Z^{D,*}_{i1}\lambda^{\delta}_{\beta,\alpha}Z^{U}_{j1}\Big(g_{\mu\nu}\Big) \tag{725}$$



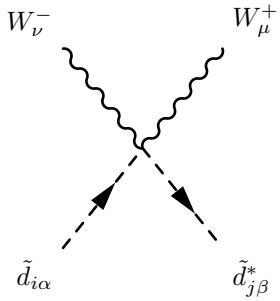
$$\begin{aligned}&\Big(+\frac{i}{18}g_1^2 Z^{D,*}_{i1}\cos\Theta_W^2\delta_{\alpha\beta}Z^D_{j1}-\frac{i}{3}g_1 g_2 Z^{D,*}_{i1}\cos\Theta_W\delta_{\alpha\beta}\sin\Theta_W Z^D_{j1}\\&+\frac{i}{2}g_2^2 Z^{D,*}_{i1}\delta_{\alpha\beta}\sin\Theta_W^2 Z^D_{j1}+\frac{2i}{9}g_1^2 Z^{D,*}_{i2}\cos\Theta_W^2\delta_{\alpha\beta}Z^D_{j2}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{726}$$



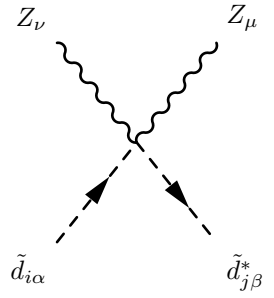
$$\begin{aligned}&\Big(-\frac{i}{6}g_1 g_2 Z^{D,*}_{i1}\cos 2\Theta_W\delta_{\alpha\beta}Z^D_{j1}-\frac{i}{36}g_1^2 Z^{D,*}_{i1}\delta_{\alpha\beta}\sin 2\Theta_W Z^D_{j1}\\&+\frac{i}{4}g_2^2 Z^{D,*}_{i1}\delta_{\alpha\beta}\sin 2\Theta_W Z^D_{j1}-\frac{i}{9}g_1^2 Z^{D,*}_{i2}\delta_{\alpha\beta}\sin 2\Theta_W Z^D_{j2}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{727}$$



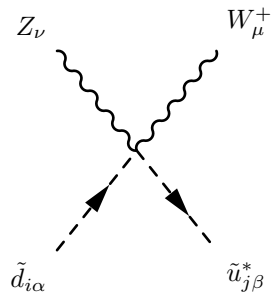
$$\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 Z^{D,*}_{i1}\cos\Theta_W \delta_{\alpha\beta} Z^U_{j1}\Big(g_{\mu\nu}\Big) \tag{728}$$



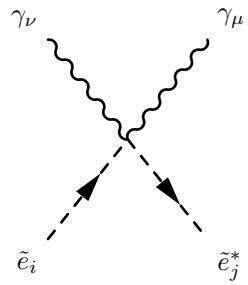
$$\frac{i}{2}g_2^2 Z^{D,*}_{i1}\delta_{\alpha\beta} Z^D_{j1}\Big(g_{\mu\nu}\Big) \tag{729}$$



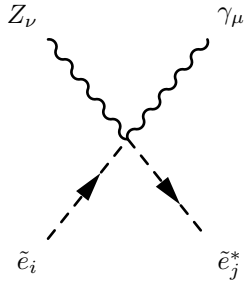
$$\begin{aligned}\Big(&+ \frac{i}{2}g_2^2 Z^{D,*}_{i1}\cos\Theta_W^2\delta_{\alpha\beta}Z^D_{j1} + \frac{i}{3}g_1 g_2 Z^{D,*}_{i1}\cos\Theta_W\delta_{\alpha\beta}\sin\Theta_W Z^D_{j1} \\ &+ \frac{i}{18}g_1^2 Z^{D,*}_{i1}\delta_{\alpha\beta}\sin\Theta_W^2 Z^D_{j1} + \frac{2i}{9}g_1^2 Z^{D,*}_{i2}\delta_{\alpha\beta}\sin\Theta_W^2 Z^D_{j2}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{730}$$



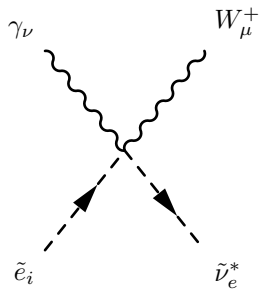
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 Z^{D,*}_{i1}\delta_{\alpha\beta}\sin\Theta_W Z^U_{j1}\Big(g_{\mu\nu}\Big) \tag{731}$$



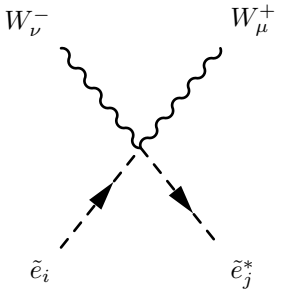
$$\begin{aligned}&\Big(+\frac{i}{2}g_1^2 Z^{E,*}_{i1}\cos\Theta_W^2 Z^E_{j1} + i g_1 g_2 Z^{E,*}_{i1}\cos\Theta_W\sin\Theta_W Z^E_{j1}\\&+\frac{i}{2}g_2^2 Z^{E,*}_{i1}\sin\Theta_W^2 Z^E_{j1} + 2i g_1^2 Z^{E,*}_{i2}\cos\Theta_W^2 Z^E_{j2}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{732}$$



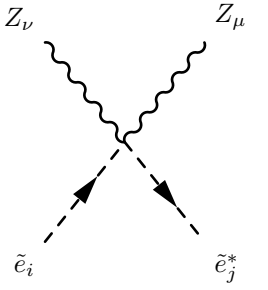
$$\begin{aligned}&\Big(+\frac{i}{2}g_1 g_2 Z^{E,*}_{i1}\cos 2\Theta_W Z^E_{j1} - \frac{i}{4}g_1^2 Z^{E,*}_{i1}\sin 2\Theta_W Z^E_{j1} + \frac{i}{4}g_2^2 Z^{E,*}_{i1}\sin 2\Theta_W Z^E_{j1}\\&- i g_1^2 Z^{E,*}_{i2}\sin 2\Theta_W Z^E_{j2}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{733}$$



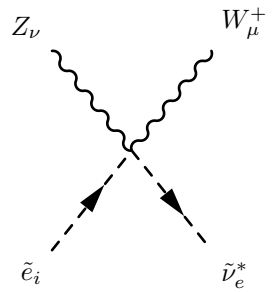
$$-i\frac{1}{\sqrt{2}}g_1 g_2 Z_{i1}^{E,*}\cos\Theta_W\Big(g_{\mu\nu}\Big) \tag{734}$$



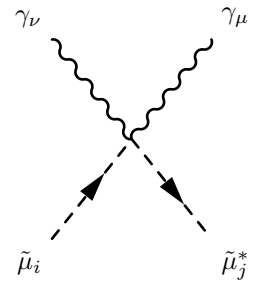
$$\frac{i}{2}g_2^2 Z_{i1}^{E,*} Z_{j1}^E\Big(g_{\mu\nu}\Big) \tag{735}$$



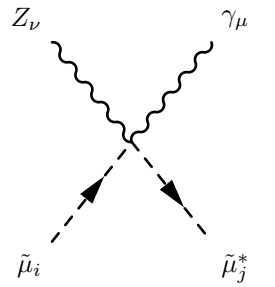
$$\begin{aligned}&\Big(+\frac{i}{2}g_2^2 Z_{i1}^{E,*}\cos\Theta_W^2 Z_{j1}^E - ig_1 g_2 Z_{i1}^{E,*}\cos\Theta_W\sin\Theta_W Z_{j1}^E\\&+\frac{i}{2}g_1^2 Z_{i1}^{E,*}\sin\Theta_W^2 Z_{j1}^E + 2ig_1^2 Z_{i2}^{E,*}\sin\Theta_W^2 Z_{j2}^E\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{736}$$



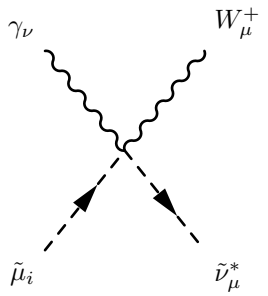
$$i\frac{1}{\sqrt{2}}g_1 g_2 Z^{E,*}_{i1}\sin\Theta_W\Big(g_{\mu\nu}\Big) \tag{737}$$



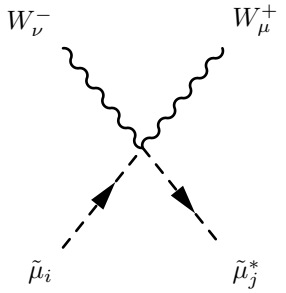
$$\begin{aligned}&\Big(+\frac{i}{2}g_1^2 Z^{\mu,*}_{i1}\cos\Theta^2_W Z^\mu_{j1} + ig_1 g_2 Z^{\mu,*}_{i1}\cos\Theta_W\sin\Theta_W Z^\mu_{j1}\\&+\frac{i}{2}g_2^2 Z^{\mu,*}_{i1}\sin\Theta^2_W Z^\mu_{j1} + 2ig_1^2 Z^{\mu,*}_{i2}\cos\Theta^2_W Z^\mu_{j2}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{738}$$



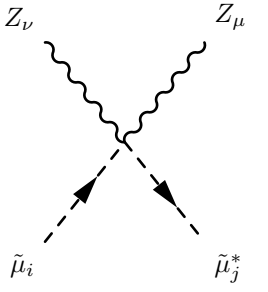
$$\begin{aligned}&\Big(+\frac{i}{2}g_1 g_2 Z^{\mu,*}_{i1}\cos 2\Theta_W Z^\mu_{j1} - \frac{i}{4}g_1^2 Z^{\mu,*}_{i1}\sin 2\Theta_W Z^\mu_{j1} + \frac{i}{4}g_2^2 Z^{\mu,*}_{i1}\sin 2\Theta_W Z^\mu_{j1}\\&- ig_1^2 Z^{\mu,*}_{i2}\sin 2\Theta_W Z^\mu_{j2}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{739}$$



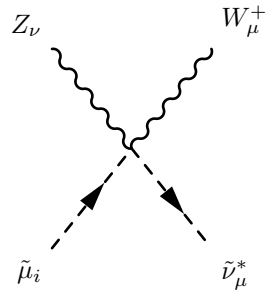
$$-i\frac{1}{\sqrt{2}}g_1 g_2 Z^{\mu,*}_{i1}\cos\Theta_W\Big(g_{\mu\nu}\Big) \tag{740}$$



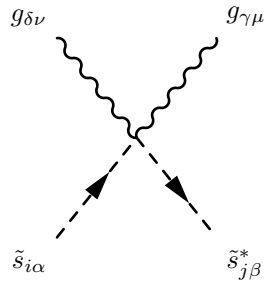
$$\frac{i}{2}g_2^2 Z^{\mu,*}_{i1} Z^{\mu}_{j1}\Big(g_{\mu\nu}\Big) \tag{741}$$



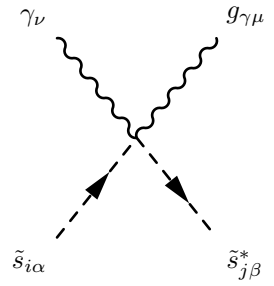
$$\begin{aligned}&\Big(+\frac{i}{2}g_2^2 Z^{\mu,*}_{i1}\cos\Theta^2_W Z^{\mu}_{j1} - ig_1 g_2 Z^{\mu,*}_{i1}\cos\Theta_W\sin\Theta_W Z^{\mu}_{j1}\\&+\frac{i}{2}g_1^2 Z^{\mu,*}_{i1}\sin\Theta^2_W Z^{\mu}_{j1} + 2ig_1^2 Z^{\mu,*}_{i2}\sin\Theta^2_W Z^{\mu}_{j2}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{742}$$



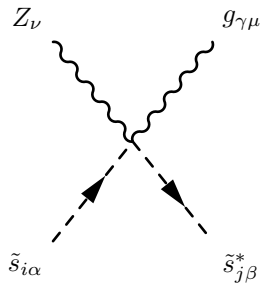
$$i\frac{1}{\sqrt{2}}g_1 g_2 Z_{i1}^{\mu,*}\sin\Theta_W\Big(g_{\mu\nu}\Big) \tag{743}$$



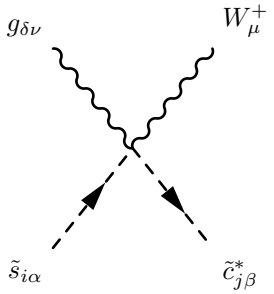
$$\Big(+\frac{i}{4}g_3^2 Z_{i1}^{S,*}\sum_{a=1}^{3}\lambda_{a,\alpha}^{\gamma}\lambda_{\beta,a}^{\delta}Z_{j1}^{S}+\frac{i}{4}g_3^2 Z_{i1}^{S,*}\sum_{a=1}^{3}\lambda_{\beta,a}^{\gamma}\lambda_{a,\alpha}^{\delta}Z_{j1}^{S}+\frac{i}{4}g_3^2 Z_{i2}^{S,*}\sum_{a=1}^{3}\lambda_{a,\alpha}^{\gamma}\lambda_{\beta,a}^{\delta}Z_{j2}^{S}$$
$$+\frac{i}{4}g_3^2 Z_{i2}^{S,*}\sum_{a=1}^{3}\lambda_{\beta,a}^{\gamma}\lambda_{a,\alpha}^{\delta}Z_{j2}^{S}\Big)\Big(g_{\mu\nu}\Big) \tag{744}$$



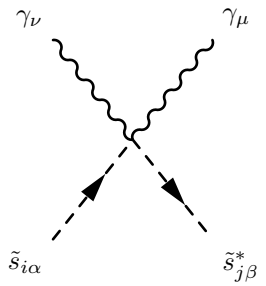
$$\Big(+\frac{i}{6}g_1 g_3 Z_{i1}^{S,*}\cos\Theta_W\lambda_{\beta,\alpha}^{\gamma}Z_{j1}^{S}-\frac{i}{2}g_2 g_3 Z_{i1}^{S,*}\lambda_{\beta,\alpha}^{\gamma}\sin\Theta_W Z_{j1}^{S}$$
$$-\frac{i}{3}g_1 g_3 Z_{i2}^{S,*}\cos\Theta_W\lambda_{\beta,\alpha}^{\gamma}Z_{j2}^{S}\Big)\Big(g_{\mu\nu}\Big) \tag{745}$$



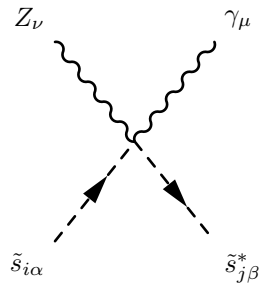
$$\Big(-\frac{i}{2} g_2 g_3 Z^{S,*}_{i1} \cos\Theta_W \lambda^{\gamma}_{\beta,\alpha} Z^S_{j1} - \frac{i}{6} g_1 g_3 Z^{S,*}_{i1} \lambda^{\gamma}_{\beta,\alpha} \sin\Theta_W Z^S_{j1} + \frac{i}{3} g_1 g_3 Z^{S,*}_{i2} \lambda^{\gamma}_{\beta,\alpha} \sin\Theta_W Z^S_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{746}$$



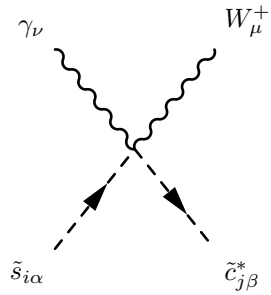
$$i \frac{1}{\sqrt{2}} g_2 g_3 Z^{S,*}_{i1} \lambda^{\delta}_{\beta,\alpha} Z^C_{j1} \Big(g_{\mu\nu} \Big) \tag{747}$$



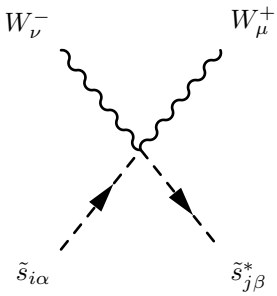
$$\Big(+ \frac{i}{18} g_1^2 Z^{S,*}_{i1} \cos^2\Theta_W \delta_{\alpha\beta} Z^S_{j1} - \frac{i}{3} g_1 g_2 Z^{S,*}_{i1} \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W Z^S_{j1} + \frac{i}{2} g_2^2 Z^{S,*}_{i1} \delta_{\alpha\beta} \sin^2\Theta_W Z^S_{j1} + \frac{2i}{9} g_1^2 Z^{S,*}_{i2} \cos^2\Theta_W \delta_{\alpha\beta} Z^S_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{748}$$



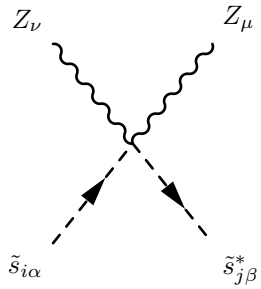
$$\Big(-\frac{i}{6} g_1 g_2 Z^{S,*}_{i1} \cos 2\Theta_W \delta_{\alpha\beta} Z^S_{j1} - \frac{i}{36} g_1^2 Z^{S,*}_{i1} \delta_{\alpha\beta} \sin 2\Theta_W Z^S_{j1} + \frac{i}{4} g_2^2 Z^{S,*}_{i1} \delta_{\alpha\beta} \sin 2\Theta_W Z^S_{j1} - \frac{i}{9} g_1^2 Z^{S,*}_{i2} \delta_{\alpha\beta} \sin 2\Theta_W Z^S_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{749}$$



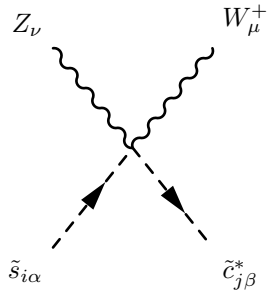
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 Z^{S,*}_{i1} \cos\Theta_W \delta_{\alpha\beta} Z^C_{j1} \Big(g_{\mu\nu} \Big) \tag{750}$$



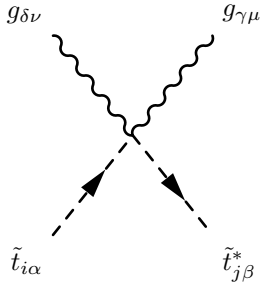
$$\frac{i}{2} g_2^2 Z^{S,*}_{i1} \delta_{\alpha\beta} Z^S_{j1} \Big(g_{\mu\nu} \Big) \tag{751}$$



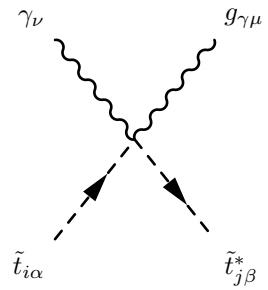
$$\Big(+ \frac{i}{2} g_2^2 Z_{i1}^{S,*} \cos\Theta_W^2 \delta_{\alpha\beta} Z_{j1}^S + \frac{i}{3} g_1 g_2 Z_{i1}^{S,*} \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W Z_{j1}^S + \frac{i}{18} g_1^2 Z_{i1}^{S,*} \delta_{\alpha\beta} \sin\Theta_W^2 Z_{j1}^S + \frac{2i}{9} g_1^2 Z_{i2}^{S,*} \delta_{\alpha\beta} \sin\Theta_W^2 Z_{j2}^S \Big) \Big(g_{\mu\nu} \Big) \tag{752}$$



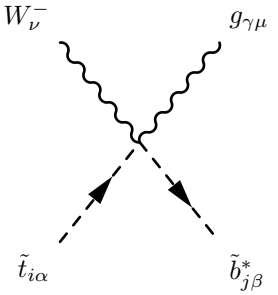
$$- \frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 Z_{i1}^{S,*} \delta_{\alpha\beta} \sin\Theta_W Z_{j1}^C \Big(g_{\mu\nu} \Big) \tag{753}$$



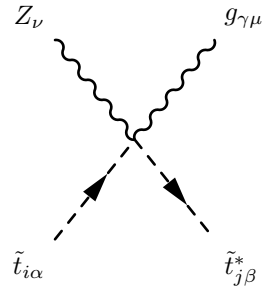
$$\Big(+ \frac{i}{4} g_3^2 Z_{i1}^{T,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j1}^T + \frac{i}{4} g_3^2 Z_{i1}^{T,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j1}^T + \frac{i}{4} g_3^2 Z_{i2}^{T,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j2}^T + \frac{i}{4} g_3^2 Z_{i2}^{T,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j2}^T \Big) \Big(g_{\mu\nu} \Big) \tag{754}$$



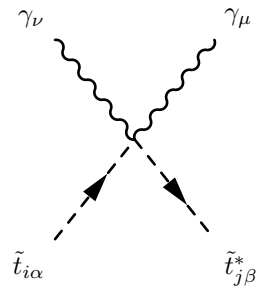
$$\Big(+ \frac{i}{6} g_1 g_3 Z^{T,*}_{i1} \cos\Theta_W \lambda^\gamma_{\beta,\alpha} Z^T_{j1} + \frac{i}{2} g_2 g_3 Z^{T,*}_{i1} \lambda^\gamma_{\beta,\alpha} \sin\Theta_W Z^T_{j1} + \frac{2i}{3} g_1 g_3 Z^{T,*}_{i2} \cos\Theta_W \lambda^\gamma_{\beta,\alpha} Z^T_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{755}$$



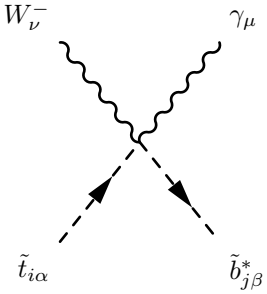
$$i \frac{1}{\sqrt{2}} g_2 g_3 Z^{T,*}_{i1} \lambda^\gamma_{\beta,\alpha} Z^B_{j1} \Big(g_{\mu\nu} \Big) \tag{756}$$



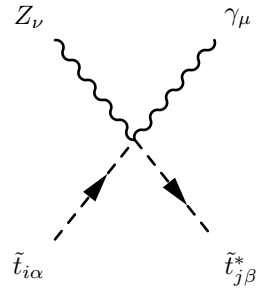
$$\Big(+ \frac{i}{2} g_2 g_3 Z^{T,*}_{i1} \cos\Theta_W \lambda^\gamma_{\beta,\alpha} Z^T_{j1} - \frac{i}{6} g_1 g_3 Z^{T,*}_{i1} \lambda^\gamma_{\beta,\alpha} \sin\Theta_W Z^T_{j1} - \frac{2i}{3} g_1 g_3 Z^{T,*}_{i2} \lambda^\gamma_{\beta,\alpha} \sin\Theta_W Z^T_{j2} \Big) \Big(g_{\mu\nu} \Big) \tag{757}$$



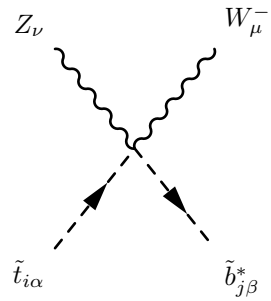
$$\Big(+ \frac{i}{18} g_1^2 Z_{i1}^{T,*} \cos\Theta_W^2 \delta_{\alpha\beta} Z_{j1}^T + \frac{i}{3} g_1 g_2 Z_{i1}^{T,*} \cos\Theta_W \delta_{\alpha\beta} \sin\Theta_W Z_{j1}^T + \frac{i}{2} g_2^2 Z_{i1}^{T,*} \delta_{\alpha\beta} \sin\Theta_W^2 Z_{j1}^T + \frac{8i}{9} g_1^2 Z_{i2}^{T,*} \cos\Theta_W^2 \delta_{\alpha\beta} Z_{j2}^T \Big) \Big(g_{\mu\nu} \Big) \tag{758}$$



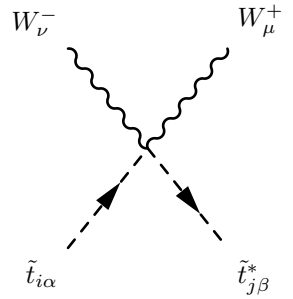
$$\frac{i}{3} \frac{1}{\sqrt{2}} g_1 g_2 Z_{i1}^{T,*} \cos\Theta_W \delta_{\alpha\beta} Z_{j1}^B \Big(g_{\mu\nu} \Big) \tag{759}$$



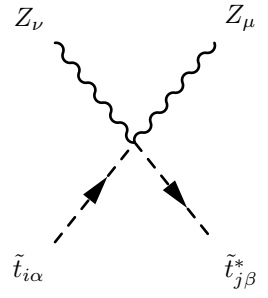
$$\Big(+ \frac{i}{6} g_1 g_2 Z_{i1}^{T,*} \cos 2\Theta_W \delta_{\alpha\beta} Z_{j1}^T - \frac{i}{36} g_1^2 Z_{i1}^{T,*} \delta_{\alpha\beta} \sin 2\Theta_W Z_{j1}^T + \frac{i}{4} g_2^2 Z_{i1}^{T,*} \delta_{\alpha\beta} \sin 2\Theta_W Z_{j1}^T - \frac{4i}{9} g_1^2 Z_{i2}^{T,*} \delta_{\alpha\beta} \sin 2\Theta_W Z_{j2}^T \Big) \Big(g_{\mu\nu} \Big) \tag{760}$$



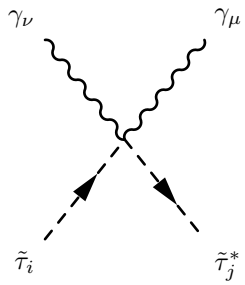
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 Z_{i1}^{T,*}\delta_{\alpha\beta}\sin\Theta_W Z_{j1}^B\Big(g_{\mu\nu}\Big) \tag{761}$$



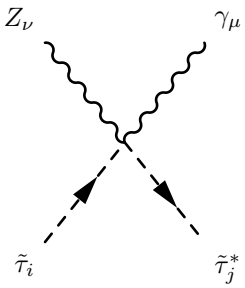
$$\frac{i}{2}g_2^2 Z_{i1}^{T,*}\delta_{\alpha\beta}Z_{j1}^T\Big(g_{\mu\nu}\Big) \tag{762}$$



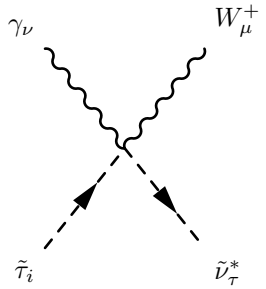
$$\begin{aligned}\Big(&+\frac{i}{2}g_2^2 Z_{i1}^{T,*}\cos\Theta_W^2\delta_{\alpha\beta}Z_{j1}^T-\frac{i}{3}g_1 g_2 Z_{i1}^{T,*}\cos\Theta_W\delta_{\alpha\beta}\sin\Theta_W Z_{j1}^T\\&+\frac{i}{18}g_1^2 Z_{i1}^{T,*}\delta_{\alpha\beta}\sin\Theta_W^2 Z_{j1}^T+\frac{8i}{9}g_1^2 Z_{i2}^{T,*}\delta_{\alpha\beta}\sin\Theta_W^2 Z_{j2}^T\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{763}$$



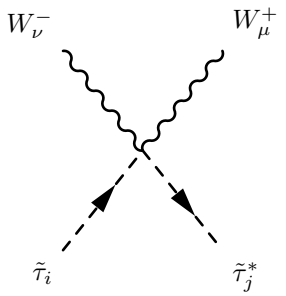
$$\Big(+ \frac{i}{2} g_1^2 Z_{i1}^{\tau,*} \cos\Theta_W^2 Z_{j1}^\tau + i g_1 g_2 Z_{i1}^{\tau,*} \cos\Theta_W \sin\Theta_W Z_{j1}^\tau + \frac{i}{2} g_2^2 Z_{i1}^{\tau,*} \sin\Theta_W^2 Z_{j1}^\tau + 2 i g_1^2 Z_{i2}^{\tau,*} \cos\Theta_W^2 Z_{j2}^\tau \Big) \Big(g_{\mu\nu} \Big) \tag{764}$$



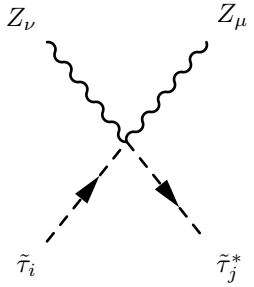
$$\Big(+ \frac{i}{2} g_1 g_2 Z_{i1}^{\tau,*} \cos 2\Theta_W Z_{j1}^\tau - \frac{i}{4} g_1^2 Z_{i1}^{\tau,*} \sin 2\Theta_W Z_{j1}^\tau + \frac{i}{4} g_2^2 Z_{i1}^{\tau,*} \sin 2\Theta_W Z_{j1}^\tau - i g_1^2 Z_{i2}^{\tau,*} \sin 2\Theta_W Z_{j2}^\tau \Big) \Big(g_{\mu\nu} \Big) \tag{765}$$



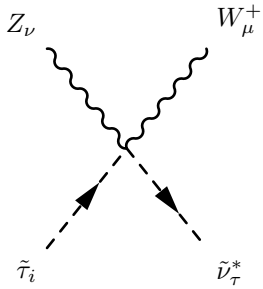
$$- i \frac{1}{\sqrt{2}} g_1 g_2 Z_{i1}^{\tau,*} \cos\Theta_W \Big(g_{\mu\nu} \Big) \tag{766}$$



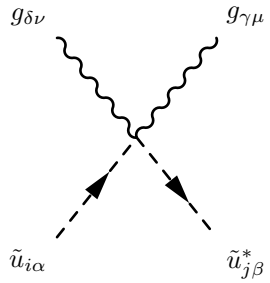
$$\frac{i}{2}g_2^2 Z_{i1}^{\tau,*} Z_{j1}^{\tau}\Big(g_{\mu\nu}\Big) \tag{767}$$



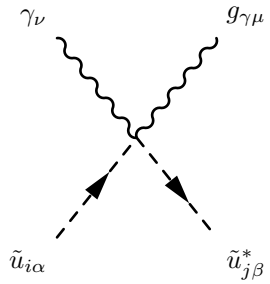
$$\begin{aligned}&\Big(+\frac{i}{2}g_2^2 Z_{i1}^{\tau,*}\cos\Theta_W^2 Z_{j1}^{\tau} - ig_1 g_2 Z_{i1}^{\tau,*}\cos\Theta_W \sin\Theta_W Z_{j1}^{\tau}\\ &+\frac{i}{2}g_1^2 Z_{i1}^{\tau,*}\sin\Theta_W^2 Z_{j1}^{\tau} + 2ig_1^2 Z_{i2}^{\tau,*}\sin\Theta_W^2 Z_{j2}^{\tau}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{768}$$



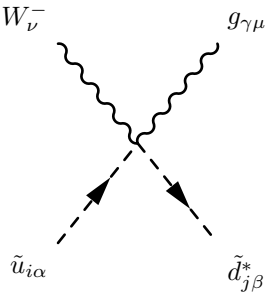
$$i\frac{1}{\sqrt{2}}g_1 g_2 Z_{i1}^{\tau,*}\sin\Theta_W\Big(g_{\mu\nu}\Big) \tag{769}$$



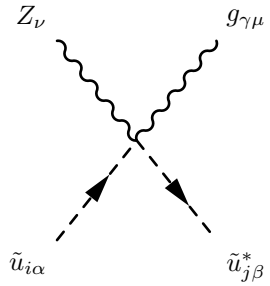
$$\Big(+ \frac{i}{4} g_3^2 Z_{i1}^{U,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j1}^{U} + \frac{i}{4} g_3^2 Z_{i1}^{U,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j1}^{U} + \frac{i}{4} g_3^2 Z_{i2}^{U,*} \sum_{a=1}^{3} \lambda_{a,\alpha}^{\gamma} \lambda_{\beta,a}^{\delta} Z_{j2}^{U}$$
$$+ \frac{i}{4} g_3^2 Z_{i2}^{U,*} \sum_{a=1}^{3} \lambda_{\beta,a}^{\gamma} \lambda_{a,\alpha}^{\delta} Z_{j2}^{U} \Big) \Big(g_{\mu\nu} \Big) \tag{770}$$



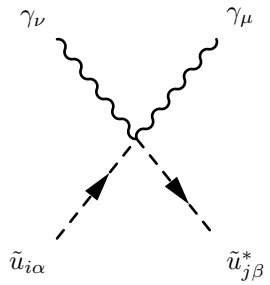
$$\Big(+ \frac{i}{6} g_1 g_3 Z_{i1}^{U,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j1}^{U} + \frac{i}{2} g_2 g_3 Z_{i1}^{U,*} \lambda_{\beta,\alpha}^{\gamma} \sin\Theta_W Z_{j1}^{U}$$
$$+ \frac{2i}{3} g_1 g_3 Z_{i2}^{U,*} \cos\Theta_W \lambda_{\beta,\alpha}^{\gamma} Z_{j2}^{U} \Big) \Big(g_{\mu\nu} \Big) \tag{771}$$



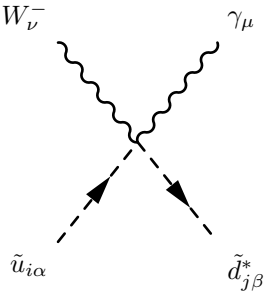
$$i\frac{1}{\sqrt{2}}g_2 g_3 Z^{U,*}_{i1}\lambda^{\gamma}_{\beta,\alpha}Z^{D}_{j1}\Big(g_{\mu\nu}\Big) \tag{772}$$



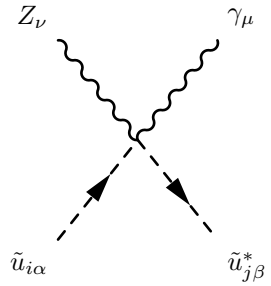
$$\Big(+\frac{i}{2}g_2 g_3 Z^{U,*}_{i1}\cos\Theta_W\lambda^{\gamma}_{\beta,\alpha}Z^{U}_{j1}-\frac{i}{6}g_1 g_3 Z^{U,*}_{i1}\lambda^{\gamma}_{\beta,\alpha}\sin\Theta_W Z^{U}_{j1}$$
$$-\frac{2i}{3}g_1 g_3 Z^{U,*}_{i2}\lambda^{\gamma}_{\beta,\alpha}\sin\Theta_W Z^{U}_{j2}\Big)\Big(g_{\mu\nu}\Big) \tag{773}$$



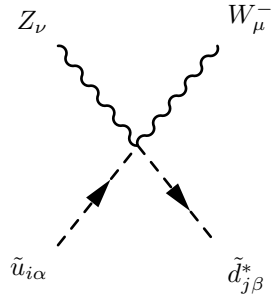
$$\Big(+\frac{i}{18}g_1^2 Z^{U,*}_{i1}\cos\Theta^2_W\delta_{\alpha\beta}Z^{U}_{j1}+\frac{i}{3}g_1 g_2 Z^{U,*}_{i1}\cos\Theta_W\delta_{\alpha\beta}\sin\Theta_W Z^{U}_{j1}$$
$$+\frac{i}{2}g_2^2 Z^{U,*}_{i1}\delta_{\alpha\beta}\sin\Theta^2_W Z^{U}_{j1}+\frac{8i}{9}g_1^2 Z^{U,*}_{i2}\cos\Theta^2_W\delta_{\alpha\beta}Z^{U}_{j2}\Big)\Big(g_{\mu\nu}\Big) \tag{774}$$



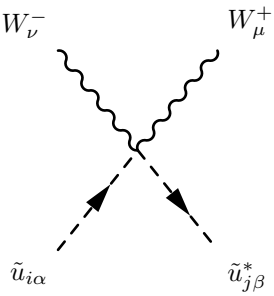
$$\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 Z_{i1}^{U,*}\cos\Theta_W \delta_{\alpha\beta} Z_{j1}^{D}\Big(g_{\mu\nu}\Big) \tag{775}$$



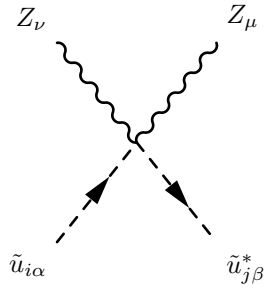
$$\begin{aligned}&\Big(+\frac{i}{6}g_1 g_2 Z_{i1}^{U,*}\cos 2\Theta_W \delta_{\alpha\beta} Z_{j1}^{U} - \frac{i}{36}g_1^2 Z_{i1}^{U,*}\delta_{\alpha\beta}\sin 2\Theta_W Z_{j1}^{U} \\ &+\frac{i}{4}g_2^2 Z_{i1}^{U,*}\delta_{\alpha\beta}\sin 2\Theta_W Z_{j1}^{U} - \frac{4i}{9}g_1^2 Z_{i2}^{U,*}\delta_{\alpha\beta}\sin 2\Theta_W Z_{j2}^{U}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{776}$$



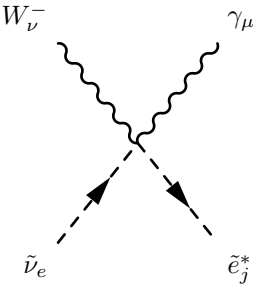
$$-\frac{i}{3}\frac{1}{\sqrt{2}}g_1 g_2 Z_{i1}^{U,*}\delta_{\alpha\beta}\sin\Theta_W Z_{j1}^{D}\Big(g_{\mu\nu}\Big) \tag{777}$$



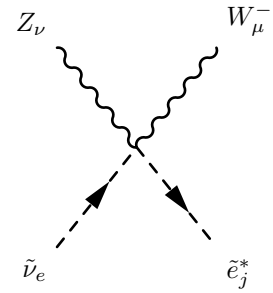
$$\frac{i}{2}g_2^2 Z_{i1}^{U,*}\delta_{\alpha\beta}Z_{j1}^{U}\Big(g_{\mu\nu}\Big) \tag{778}$$



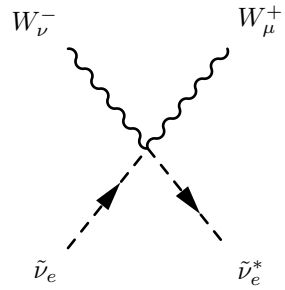
$$\begin{aligned}\Big(&+ \frac{i}{2}g_2^2 Z_{i1}^{U,*}\cos\Theta_W^2\delta_{\alpha\beta}Z_{j1}^{U} - \frac{i}{3}g_1 g_2 Z_{i1}^{U,*}\cos\Theta_W\delta_{\alpha\beta}\sin\Theta_W Z_{j1}^{U} \\ &+ \frac{i}{18}g_1^2 Z_{i1}^{U,*}\delta_{\alpha\beta}\sin\Theta_W^2 Z_{j1}^{U} + \frac{8i}{9}g_1^2 Z_{i2}^{U,*}\delta_{\alpha\beta}\sin\Theta_W^2 Z_{j2}^{U}\Big)\Big(g_{\mu\nu}\Big)\end{aligned} \tag{779}$$



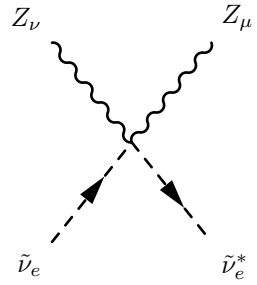
$$-i\frac{1}{\sqrt{2}}g_1 g_2\cos\Theta_W Z_{j1}^{E}\Big(g_{\mu\nu}\Big) \tag{780}$$



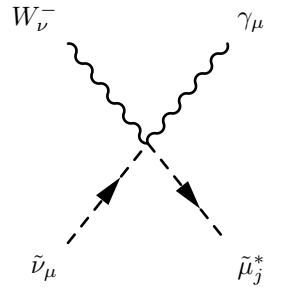
$$i\frac{1}{\sqrt{2}}g_1 g_2 \sin\Theta_W Z^E_{j1}\Big(g_{\mu\nu}\Big) \tag{781}$$



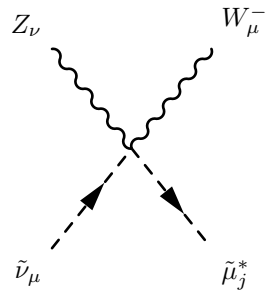
$$\frac{i}{2}g_2^2\Big(g_{\mu\nu}\Big) \tag{782}$$



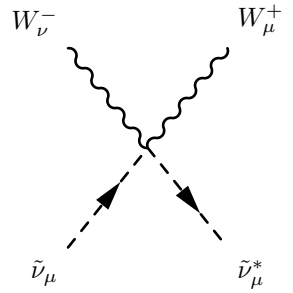
$$\Big(\frac{i}{2}g_1^2 \sin\Theta_W^2 + \frac{i}{2}g_2^2 \cos\Theta_W^2 + ig_1 g_2 \cos\Theta_W \sin\Theta_W\Big)\Big(g_{\mu\nu}\Big) \tag{783}$$



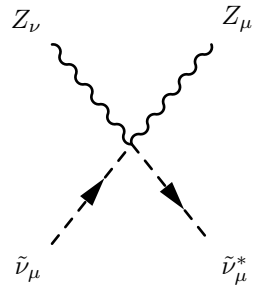
$$-i\frac{1}{\sqrt{2}}g_1 g_2 \cos\Theta_W Z^\mu_{j1}\Big(g_{\mu\nu}\Big) \tag{784}$$



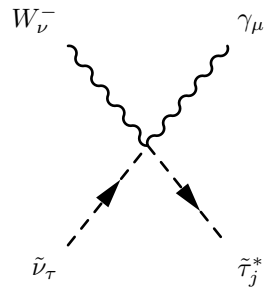
$$i\frac{1}{\sqrt{2}}g_1 g_2 \sin\Theta_W Z_{j1}^{\mu}\Big(g_{\mu\nu}\Big) \tag{785}$$



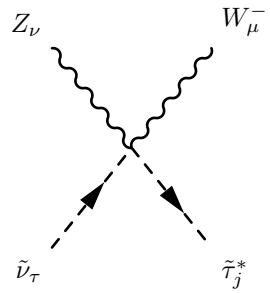
$$\frac{i}{2}g_2^2\Big(g_{\mu\nu}\Big) \tag{786}$$



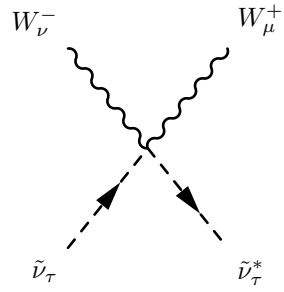
$$\Big(\frac{i}{2}g_1^2 \sin\Theta_W^2 + \frac{i}{2}g_2^2 \cos\Theta_W^2 + ig_1 g_2 \cos\Theta_W \sin\Theta_W\Big)\Big(g_{\mu\nu}\Big) \tag{787}$$



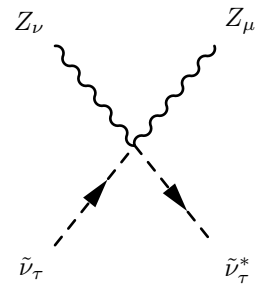
$$-i\frac{1}{\sqrt{2}}g_1 g_2 \cos\Theta_W Z_{j1}^{\tau}\Big(g_{\mu\nu}\Big) \tag{788}$$



$$i\frac{1}{\sqrt{2}}g_1 g_2 \sin\Theta_W Z_{j1}^{\tau}\Big(g_{\mu\nu}\Big) \tag{789}$$

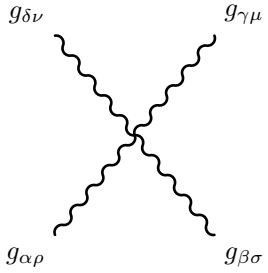


$$\frac{i}{2}g_2^2\Big(g_{\mu\nu}\Big) \tag{790}$$



$$\Big(\frac{i}{2}g_1^2\sin\Theta_W^2+\frac{i}{2}g_2^2\cos\Theta_W^2+ig_1g_2\cos\Theta_W\sin\Theta_W\Big)\Big(g_{\mu\nu}\Big) \tag{791}$$

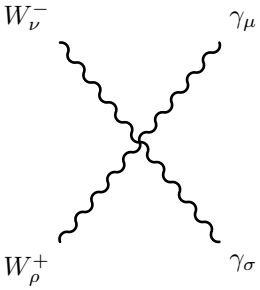
9.9 Four Vector Boson-Interaction



$$ig_3^2\Big(-\sum_{a=1}^{8}f_{\alpha,\delta,a}f_{\beta,\gamma,a}-\sum_{a=1}^{8}f_{\alpha,\gamma,a}f_{\beta,\delta,a}\Big)\Big(g_{\rho\sigma}g_{\mu\nu}\Big) \tag{792}$$

$$+\ ig_3^2\Big(-\sum_{a=1}^{8}f_{\alpha,\beta,a}f_{\gamma,\delta,a}+\sum_{a=1}^{8}f_{\alpha,\delta,a}f_{\beta,\gamma,a}\Big)\Big(g_{\rho\mu}g_{\sigma\nu}\Big) \tag{793}$$

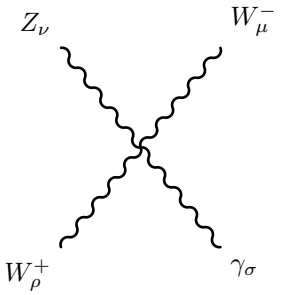
$$+\ ig_3^2\Big(\sum_{a=1}^{8}f_{\alpha,\gamma,a}f_{\beta,\delta,a}+\sum_{a=1}^{8}f_{\alpha,\beta,a}f_{\gamma,\delta,a}\Big)\Big(g_{\rho\nu}g_{\sigma\mu}\Big) \tag{794}$$



$$ig_2^2 \sin\Theta_W^2 \Big(g_{\rho\sigma} g_{\mu\nu}\Big) \tag{795}$$

$$+\ ig_2^2 \sin\Theta_W^2 \Big(g_{\rho\mu} g_{\sigma\nu}\Big) \tag{796}$$

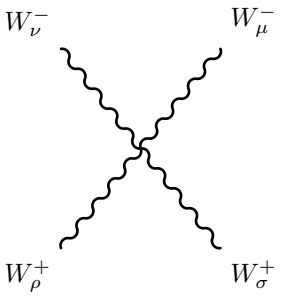
$$+\ -2ig_2^2 \sin\Theta_W^2 \Big(g_{\rho\nu} g_{\sigma\mu}\Big) \tag{797}$$



$$\frac{i}{2} g_2^2 \sin 2\Theta_W \Big(g_{\rho\sigma} g_{\mu\nu}\Big) \tag{798}$$

$$+\ -ig_2^2 \sin 2\Theta_W \Big(g_{\rho\mu} g_{\sigma\nu}\Big) \tag{799}$$

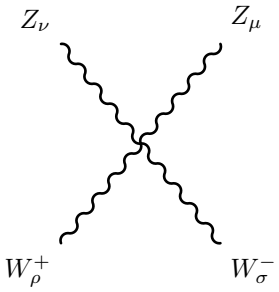
$$+\ \frac{i}{2} g_2^2 \sin 2\Theta_W \Big(g_{\rho\nu} g_{\sigma\mu}\Big) \tag{800}$$



$$2ig_2^2 \Big(g_{\rho\sigma} g_{\mu\nu}\Big) \tag{801}$$

$$+\ -ig_2^2 \Big(g_{\rho\mu} g_{\sigma\nu}\Big) \tag{802}$$

$$+\ -ig_2^2 \Big(g_{\rho\nu} g_{\sigma\mu}\Big) \tag{803}$$

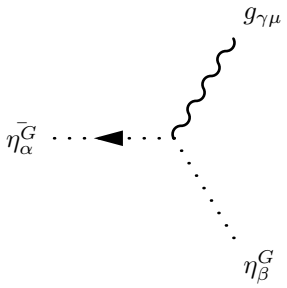


$$- 2ig_2^2 \cos\Theta_W^2 \left(g_{\rho\sigma} g_{\mu\nu}\right) \tag{804}$$

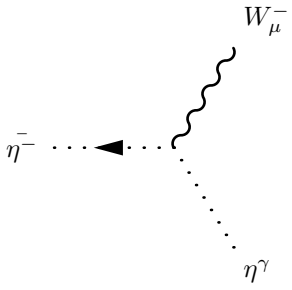
$$+ ig_2^2 \cos\Theta_W^2 \left(g_{\rho\mu} g_{\sigma\nu}\right) \tag{805}$$

$$+ ig_2^2 \cos\Theta_W^2 \left(g_{\rho\nu} g_{\sigma\mu}\right) \tag{806}$$

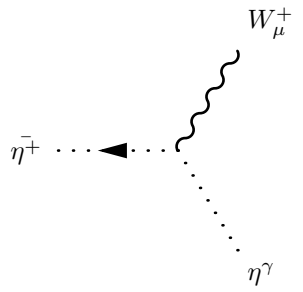
9.10 Two Ghosts-One Vector Boson-Interaction



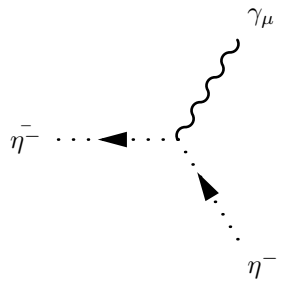
$$g_3 f_{\alpha,\beta,\gamma} \left(p_\mu^{\eta_\beta^G}\right) \tag{807}$$



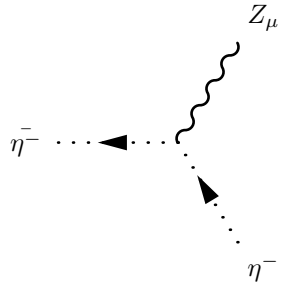
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^\gamma}\right) \tag{808}$$



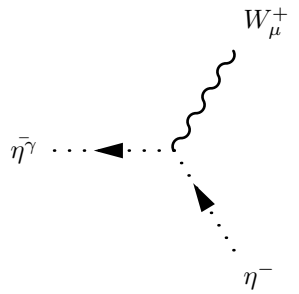
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^\gamma}\right) \tag{809}$$



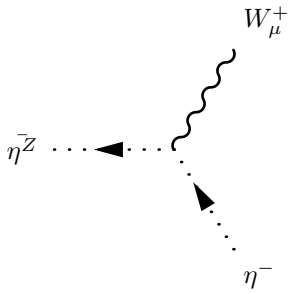
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^-}\right) \tag{810}$$



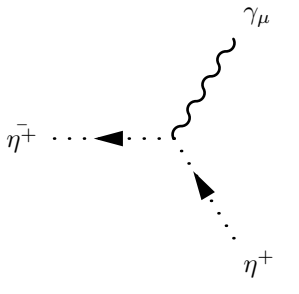
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{811}$$



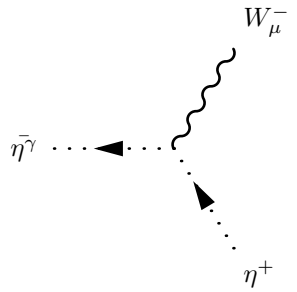
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^-}\right) \tag{812}$$



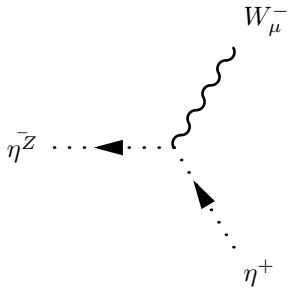
$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^-}\right) \tag{813}$$



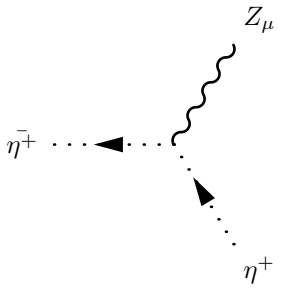
$$ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{814}$$



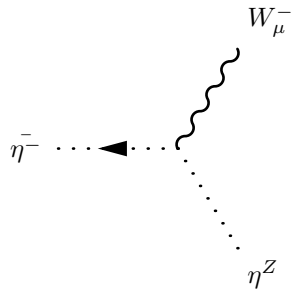
$$-ig_2 \sin\Theta_W \left(p_\mu^{\eta^+}\right) \tag{815}$$



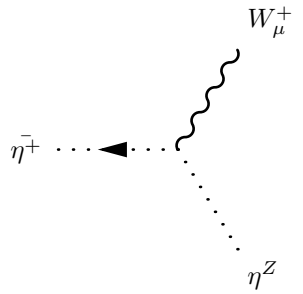
$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{816}$$



$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^+}\right) \tag{817}$$

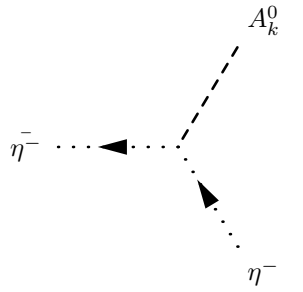


$$ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{818}$$

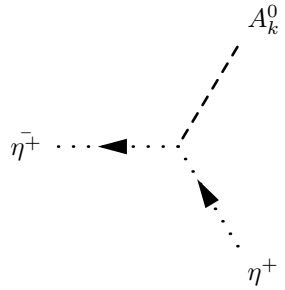


$$-ig_2 \cos\Theta_W \left(p_\mu^{\eta^Z}\right) \tag{819}$$

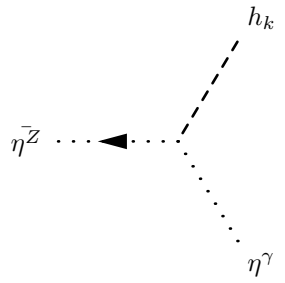
9.11 Two Ghosts-One Scalar-Interaction



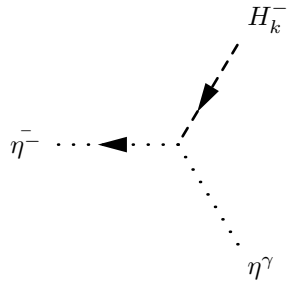
$$\frac{1}{4} g_2^2 \xi_{W^-} \left(v_d Z_{k1}^A - v_u Z_{k2}^A\right) \tag{820}$$



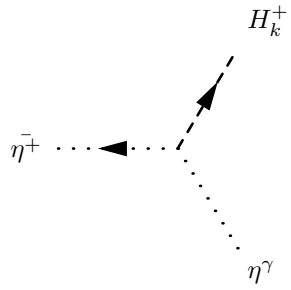
$$-\frac{1}{4}g_2^2\xi_{W^-}\Big(v_d Z_{k1}^A - v_u Z_{k2}^A\Big) \tag{821}$$



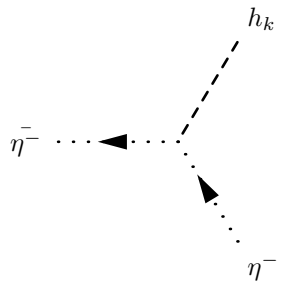
$$\frac{i}{8}\xi_Z\Big(2g_1g_2\cos 2\Theta_W + \Big(-g_2^2+g_1^2\Big)\sin 2\Theta_W\Big)\Big(v_d Z_{k1}^H + v_u Z_{k2}^H\Big) \tag{822}$$



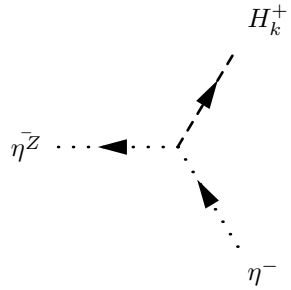
$$\frac{i}{4}g_2\xi_{W^-}\Big(g_1\cos\Theta_W + g_2\sin\Theta_W\Big)\Big(v_d Z_{k1}^+ - v_u Z_{k2}^+\Big) \tag{823}$$



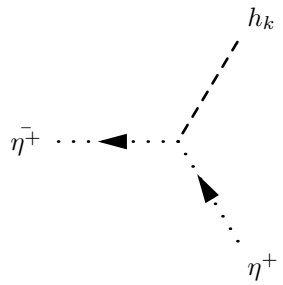
$$\frac{i}{4} g_2 \xi_{W^-} \Big(g_1 \cos\Theta_W + g_2 \sin\Theta_W \Big) \Big(v_d Z_{k1}^+ - v_u Z_{k2}^+ \Big) \tag{824}$$



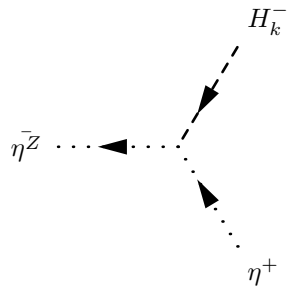
$$-\frac{i}{4} g_2^2 \xi_{W^-} \Big(v_d Z_{k1}^H + v_u Z_{k2}^H \Big) \tag{825}$$



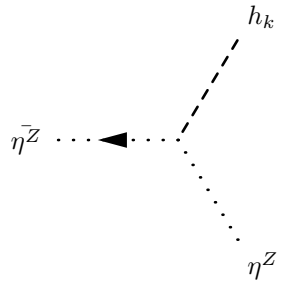
$$-\frac{i}{4} g_2 \xi_Z \Big(g_1 \sin\Theta_W + g_2 \cos\Theta_W \Big) \Big(v_d Z_{k1}^+ - v_u Z_{k2}^+ \Big) \tag{826}$$



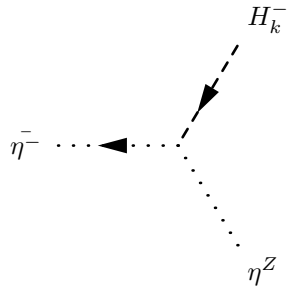
$$-\frac{i}{4}g_2^2\xi_{W^-}\Big(v_d Z_{k1}^H + v_u Z_{k2}^H\Big) \tag{827}$$



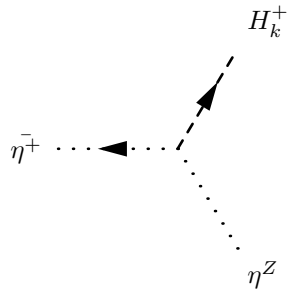
$$-\frac{i}{4}g_2\xi_Z\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)\Big(v_d Z_{k1}^+ - v_u Z_{k2}^+\Big) \tag{828}$$



$$-\frac{i}{4}\xi_Z\Big(g_1\sin\Theta_W + g_2\cos\Theta_W\Big)^2\Big(v_d Z_{k1}^H + v_u Z_{k2}^H\Big) \tag{829}$$



$$\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ_{k1}^+-v_uZ_{k2}^+\Big) \tag{830}$$



$$\frac{i}{4}g_2\xi_{W^-}\Big(-g_1\sin\Theta_W+g_2\cos\Theta_W\Big)\Big(v_dZ_{k1}^+-v_uZ_{k2}^+\Big) \tag{831}$$

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10 Clebsch-Gordan Coefficients