FeynRules Implementation of Standard Model plus DY

N. Christensen *
University of Wisconsin - Madison

July 28, 2011

Abstract

We describe the implementation of the Standard Model plus DY model using the FeynRules package.

Contents

List of Tables

*email: neil@hep.wisc.edu

1 Introduction

We describe the implementation of the Standard Model plus DY model using the FeynRules [1] package.

2 Gauge Symmetries

The gauge group of this model is

$$U1Y \times SU2L \times SU3C. \tag{1}$$

Details of these gauge groups can be found in Table 1.

Group	Abelian	Gauge Boson	Coupling Constant	Charge	Structure Constant	Symmetric Tensor	Reps	Defs
U1Y	T	B	g1	Y				
SU2L	F	Wi	gw		Eps		$FSU2L_{k,k}$	FSU2L[a$_, b$_, c$_] → -I Eps[a$, b$, c$]
SU3C	F	G	gs		f	dSUN	$T_{i,i}$	FSU3C[a$_, b$_, c$_] → -I f[a$, b$, c$]
							$FSU3C_{a,a}$	

Table 1: Details of gauge groups.

The definitions of the indices can be found in Table 2.

Index	Symbol	Range
Generation	f	1-3
Colour	i	1-3
Gluon	a	1-8
SU2W	k	1-3

Table 2: Definition of the indices.

3 Fields

In this section, we describe the field content of our model implementation.

3.1 Spin 2 Fields

In this subsection, we describe the spin 2 fields of our model. The details of the physical spin 2s can be found in Table 3.

Class	SC	I	FI	QN	Mem	M	W	PDG
TV	T				TV	MTV= 1000	WTV= 20	
TVP	F			$Q = 1$	TVP	MTVP= 1000	WTVP= 20	

Table 3: Details of physical spin 2 fields. The headers are as follows: SC = self conjugate, I = indices, FI = flavor index, QN = quantum numbers, Mem = members, M = mass, W = width, and PDG = particle data group number.

3.2 Vector Fields

In this subsection, we describe the vector fields of our model. The details of the physical vectors can be found in Table 4.

Class	SC	I	FI	QN	Mem	M	W	PDG
A	T				A	0	0	22
Z	T				Z	MZ= 91.1876	WZ= 2.4952	23
W	F			$Q = 1$	W	MW= Internal	WW= 2.085	24
G	T	a			G	0	0	21
VV	T				VV	MVV= 1000	WVV= 20	
VVP	F			$Q = 1$	VVP	MVVP= 1000	WVVP= 20	

Table 4: Details of physical vector fields. The headers are as follows: SC = self conjugate, I = indices, FI = flavor index, QN = quantum numbers, Mem = members, M = mass, W = width, and PDG = particle data group number.

The details of the unphysical vectors can be found in Table 5.

Class	SC	I	FI	QN	Mem	Definitions
Wi	T	k	k		Wi	$\mathrm{Wi}_{\mu,1} \to \frac{W_\mu + {W_\mu}^\dagger}{\sqrt{2}}$
						$\mathrm{Wi}_{\mu,2} \to -\frac{i\left(-W_\mu + {W_\mu}^\dagger\right)}{\sqrt{2}}$
						$\mathrm{Wi}_{\mu,3} \to s_w A_\mu + c_w Z_\mu$
B	T				B	$B_\mu \to c_w A_\mu - s_w Z_\mu$

Table 5: Details of unphysical vector fields. The headers are as follows: SC = self conjugate, I = indices, FI = flavor index, QN = quantum numbers, and Mem = members.

3.3 Fermion Fields

In this subsection, we describe the fermion fields of our model. The details of the physical fermions can be found in Table 6.

3.4 Scalar Fields

In this subsection, we describe the scalar fields of our model. The details of the physical scalars can be found in Table 7.

Class	SC	I	FI	QN	Mem	M	W	PDG
vl	F	f	f	$LeptonNumber = 1$				
					ve			12
					vm			14
					vt			16
l	F	f	f	$Q = -1$		Ml		
				$LeptonNumber = 1$	e	Me= 0		11
					m	MM= 0		13
					tt	MTA= 1.777		15
uq	F	f, i	f	$Q = 2/3$		Mu		
					u	MU= 0	0	2
					c	MC= 0	0	4
					t	MT= 174.3	WT= 1.50834	6
dq	F	f, i	f	$Q = -1/3$		Md		
					d	MD= 0		1
					s	MS= 0		3
					b	MB= 4.7		5

Table 6: Details of physical fermion fields. The headers are as follows: SC = self conjugate, I = indices, FI = flavor index, QN = quantum numbers, Mem = members, M = mass, W = width, and PDG = particle data group number.

Class	SC	I	FI	QN	Mem	M	W	PDG
H	T				H	MH= 120	WH= 0.00575309	25
phi	T				phi	MZ= 91.1876	Wphi	250
phi2	F			$Q = 1$	phi2	MW= Internal	Wphi2	251
SV	T				SV	MSV= 1000	WSV= 20	
SVP	F			$Q = 1$	SVP	MSVP= 1000	WSVP= 20	

Table 7: Details of physical scalar fields. The headers are as follows: SC = self conjugate, I = indices, FI = flavor index, QN = quantum numbers, Mem = members, M = mass, W = width, and PDG = particle data group number.

3.5 Ghost Fields

In this subsection, we describe the ghost fields of our model. The details of the physical ghosts can be found in Table 8. The

Class	SC	I	FI	QN	Mem	M	W	PDG
ghA	F			$GhostNumber = 1$	ghA	0		
ghZ	F			$GhostNumber = 1$	ghZ	MZ= 91.1876		
ghWp	F			$Q = 1$	ghWp	MW= Internal		
				$GhostNumber = 1$				
ghWm	F			$Q = -1$	ghWm	MW= Internal		
				$GhostNumber = 1$				
ghG	F	a		$GhostNumber = 1$	ghG	0		

Table 8: Details of physical ghost fields. The headers are as follows: SC = self conjugate, I = indices, FI = flavor index, QN = quantum numbers, Mem = members, M = mass, W = width, and PDG = particle data group number.

Class	SC	I	FI	QN	Mem	Definitions
ghWi	F	k	k		ghWi	$\mathrm{ghWi}_1 \to \frac{\mathrm{ghWm}+\mathrm{ghWp}}{\sqrt{2}}$
						$\mathrm{ghWi}_2 \to -\frac{i(\mathrm{ghWm}-\mathrm{ghWp})}{\sqrt{2}}$
						$\mathrm{ghWi}_3 \to c_w\mathrm{ghZ} + \mathrm{ghA}s_w$
ghB	F				ghB	$\mathrm{ghB} \to c_w\mathrm{ghA} - \mathrm{ghZ}s_w$

Table 9: Details of unphysical ghost fields. The headers are as follows: SC = self conjugate, I = indices, FI = flavor index, QN = quantum numbers, and Mem = members.

details of the unphysical ghosts can be found in Table 9.

4 Lagrangian

In this section, we describe the Lagrangian of our model implementation.

4.1 L_1

$$\mathrm{SV}\left(-\tfrac{1}{4}\mathrm{gSg}\left(-\partial_\nu\left[G_{\mu,a}\right]+\partial_\mu\left[G_{\nu,a}\right]+g_s f_{a,\mathrm{a2\$254},\mathrm{a3\$254}}G_{\mu,\mathrm{a2\$254}}G_{\nu,\mathrm{a3\$254}}\right)\left(-\partial_\nu\left[G_{\mu,a}\right]+\partial_\mu\left[G_{\nu,a}\right]+g_s f_{a,\mathrm{a2\$255},\mathrm{a3\$255}}G_{\mu,\mathrm{a2\$255}}G_{\nu,\mathrm{a3\$255}}\right.\right.$$

4.2 L_2

$$-\tfrac{1}{4}\mathrm{gVg}\partial_\alpha\left[\mathrm{VV}_\alpha\right]\left(-\partial_\nu\left[G_{\mu,a}\right]+\partial_\mu\left[G_{\nu,a}\right]+g_s f_{a,\mathrm{a2\$256},\mathrm{a3\$256}}G_{\mu,\mathrm{a2\$256}}G_{\nu,\mathrm{a3\$256}}\right)\left(-\partial_\nu\left[G_{\mu,a}\right]+\partial_\mu\left[G_{\nu,a}\right]+g_s f_{a,\mathrm{a2\$257},\mathrm{a3\$257}}G_{\mu,\mathrm{a2\$257}}G_{\nu,a}\right.$$
$$\left(\bar{\mathrm{dq}}_{r,i,a}.\left(\gamma_{r,s}{}^{\mu}\mathrm{gVd}_{i,j}+\mathrm{gAd}_{i,j}\gamma^{\mu}.\gamma^{5}{}_{r,s}\right).\mathrm{dq}_{s,j,a}+\bar{l}_{r,i}.\left(\gamma_{r,s}{}^{\mu}\mathrm{gVl}_{i,j}+\mathrm{gAl}_{i,j}\gamma^{\mu}.\gamma^{5}{}_{r,s}\right).l_{s,j}+\bar{\mathrm{uq}}_{r,i,a}.\left(\gamma_{r,s}{}^{\mu}\mathrm{gVu}_{i,j}+\mathrm{gAu}_{i,j}\gamma^{\mu}.\gamma^{5}{}_{r,s}\right).\mathrm{uq}_{s,j,}\right.$$

4.3 L_3

$$-\tfrac{1}{4}\mathrm{gTg}\left(\partial_\mu\left[G_{\alpha,a}\right]-\partial_\alpha\left[G_{\mu,a}\right]+g_s f_{a,\mathrm{a2\$258},\mathrm{a3\$258}}G_{\alpha,\mathrm{a3\$258}}G_{\mu,\mathrm{a2\$258}}\right)\left(\partial_\mu\left[G_{\beta,a}\right]-\partial_\beta\left[G_{\mu,a}\right]+g_s f_{a,\mathrm{a2\$259},\mathrm{a3\$259}}G_{\beta,\mathrm{a3\$259}}G_{\mu,\mathrm{a2\$259}}\right)\mathrm{TV}_{\alpha,}$$
$$i\left(\left(\mathrm{gTd}_{i,j}.\bar{\mathrm{dq}}_{\mathrm{r1},i,a}-\mathrm{gUd}_{i,j}.\bar{\mathrm{dq}}_{r,i,a}\gamma_{r,\mathrm{r1}}{}^{5}\right).\left(\partial_\nu\left[\mathrm{dq}_{s,j,a}\right]\gamma_{\mathrm{r1},s}{}^{\mu}+\partial_\mu\left[\mathrm{dq}_{s,j,a}\right]\gamma_{\mathrm{r1},s}{}^{\nu}\right)+\left(\mathrm{gTl}_{i,j}.\bar{l}_{\mathrm{r1},i}-\mathrm{gUl}_{i,j}.\bar{l}_{r,i}\gamma_{r,\mathrm{r1}}{}^{5}\right).\left(\partial_\nu\left[l_{s,j}\right]\gamma_{\mathrm{r1},s}{}^{\mu}-\right.\right.$$
$$i\left(\left(\partial_\nu\left[\bar{\mathrm{dq}}_{s,i,a}\right]\gamma_{s,\mathrm{r1}}{}^{\mu}+\partial_\mu\left[\bar{\mathrm{dq}}_{s,i,a}\right]\gamma_{s,\mathrm{r1}}{}^{\nu}\right).\left(\mathrm{gTd}_{j,i}{}^{*}.\mathrm{dq}_{\mathrm{r1},j,a}+\mathrm{gUd}_{j,i}{}^{*}.\mathrm{dq}_{r,j,a}\gamma_{\mathrm{r1},r}{}^{5}\right)+\left(\partial_\nu\left[\bar{l}_{s,i}\right]\gamma_{s,\mathrm{r1}}{}^{\mu}+\partial_\mu\left[\bar{l}_{s,i}\right]\gamma_{s,\mathrm{r1}}{}^{\nu}\right).\left(\mathrm{gTl}_{j,i}{}^{*}.\right.\right.$$

4.4 L_4

$$\mathrm{SVP}^{\dagger}\left(\mathrm{hSq}_{j,i}{}^{*}\bar{\mathrm{dq}}_{s,i,a}.\mathrm{uq}_{s,j,a}+\mathrm{hSl}_{j,i}{}^{*}\bar{l}_{s,i}.\mathrm{vl}_{s,j}+i\mathrm{hPq}_{j,i}{}^{*}\bar{\mathrm{dq}}_{r,i,a}.\mathrm{uq}_{s,j,a}\gamma_{r,s}{}^{5}+i\mathrm{hPl}_{j,i}{}^{*}\bar{l}_{r,i}.\mathrm{vl}_{s,j}\gamma_{r,s}{}^{5}\right)+$$
$$\mathrm{SVP}\left(i\bar{\mathrm{vl}}_{r,i}.l_{s,j}\gamma_{r,s}{}^{5}\mathrm{hPl}_{i,j}+i\bar{\mathrm{uq}}_{r,i,a}.\mathrm{dq}_{s,j,a}\gamma_{r,s}{}^{5}\mathrm{hPq}_{i,j}+\bar{\mathrm{vl}}_{s,i}.l_{s,j}\mathrm{hSl}_{i,j}+\bar{\mathrm{uq}}_{s,i,a}.\mathrm{dq}_{s,j,a}\mathrm{hSq}_{i,j}\right)$$

4.5 L_5

$$\mathrm{VVP}_{\mu}{}^{\dagger}\left(\mathrm{hVq}_{j,i}{}^{*}\bar{\mathrm{dq}}_{s,i,a}.\mathrm{uq}_{r,j,a}\gamma_{s,r}{}^{\mu}+\mathrm{hVl}_{j,i}{}^{*}\bar{l}_{s,i}.\mathrm{vl}_{r,j}\gamma_{s,r}{}^{\mu}+\mathrm{hAq}_{j,i}{}^{*}\bar{\mathrm{dq}}_{s,i,a}.\mathrm{uq}_{r,j,a}\gamma^{\mu}.\gamma^{5}{}_{s,r}+\mathrm{hAl}_{j,i}{}^{*}\bar{l}_{s,i}.\mathrm{vl}_{r,j}\gamma^{\mu}.\gamma^{5}{}_{s,r}\right)+$$
$$\mathrm{VVP}_{\mu}\left(\bar{\mathrm{vl}}_{s,i}.l_{r,j}\gamma_{s,r}{}^{\mu}\mathrm{hVl}_{i,j}+\bar{\mathrm{uq}}_{s,i,a}.\mathrm{dq}_{r,j,a}\gamma_{s,r}{}^{\mu}\mathrm{hVq}_{i,j}+\bar{\mathrm{vl}}_{s,i}.l_{r,j}\mathrm{hAl}_{i,j}\gamma^{\mu}.\gamma^{5}{}_{s,r}+\bar{\mathrm{uq}}_{s,i,a}.\mathrm{dq}_{r,j,a}\mathrm{hAq}_{i,j}\gamma^{\mu}.\gamma^{5}{}_{s,r}\right)$$

4.6 L_6

$$i\left(\left(\mathrm{hTl}_{i,j}.\bar{\mathrm{vl}}_{\mathrm{r1},i}-\mathrm{hUl}_{i,j}.\bar{\mathrm{vl}}_{r,i}\gamma_{r,\mathrm{r1}}{}^{5}\right).\left(\partial_\nu\left[l_{s,j}\right]\gamma_{\mathrm{r1},s}{}^{\mu}+\partial_\mu\left[l_{s,j}\right]\gamma_{\mathrm{r1},s}{}^{\nu}\right)+\left(\mathrm{hTq}_{i,j}.\bar{\mathrm{uq}}_{\mathrm{r1},i,a}-\mathrm{hUq}_{i,j}.\bar{\mathrm{uq}}_{r,i,a}\gamma_{r,\mathrm{r1}}{}^{5}\right).\left(\partial_\nu\left[\mathrm{dq}_{s,j,a}\right]\gamma_{\mathrm{r1},s}{}^{\mu}+\partial_{\mu}\right.\right.$$
$$i\left(\left(\partial_\nu\left[\bar{\mathrm{uq}}_{s,i,a}\right]\gamma_{s,\mathrm{r1}}{}^{\mu}+\partial_\mu\left[\bar{\mathrm{uq}}_{s,i,a}\right]\gamma_{s,\mathrm{r1}}{}^{\nu}\right).\left(\mathrm{hYq}_{i,j}.\mathrm{dq}_{\mathrm{r1},j,a}+\mathrm{hZq}_{i,j}.\mathrm{dq}_{r,j,a}\gamma_{\mathrm{r1},r}{}^{5}\right)+\left(\partial_\nu\left[\bar{\mathrm{vl}}_{s,i}\right]\gamma_{s,\mathrm{r1}}{}^{\mu}+\partial_\mu\left[\bar{\mathrm{vl}}_{s,i}\right]\gamma_{s,\mathrm{r1}}{}^{\nu}\right).\left(\mathrm{hYl}_{i,j}.l_{\mathrm{r1},j}\right.\right.$$
$$i\left(\left(\mathrm{hYl}_{j,i}{}^{*}.\bar{l}_{\mathrm{r1},i}-\mathrm{hZl}_{j,i}{}^{*}.\bar{l}_{r,i}\gamma_{r,\mathrm{r1}}{}^{5}\right).\left(\partial_\nu\left[\mathrm{vl}_{s,j}\right]\gamma_{\mathrm{r1},s}{}^{\mu}+\partial_\mu\left[\mathrm{vl}_{s,j}\right]\gamma_{\mathrm{r1},s}{}^{\nu}\right)+\left(\mathrm{hYq}_{j,i}{}^{*}.\bar{\mathrm{dq}}_{\mathrm{r1},i,a}-\mathrm{hZq}_{j,i}{}^{*}.\bar{\mathrm{dq}}_{r,i,a}\gamma_{r,\mathrm{r1}}{}^{5}\right).\left(\partial_\nu\left[\mathrm{uq}_{s,j,a}\right]\gamma_{\mathrm{r1},s}{}^{\right.\right.$$
$$i\left(\left(\partial_\nu\left[\bar{\mathrm{dq}}_{s,i,a}\right]\gamma_{s,\mathrm{r1}}{}^{\mu}+\partial_\mu\left[\bar{\mathrm{dq}}_{s,i,a}\right]\gamma_{s,\mathrm{r1}}{}^{\nu}\right).\left(\mathrm{hTq}_{j,i}{}^{*}.\mathrm{uq}_{\mathrm{r1},j,a}+\mathrm{hUq}_{j,i}{}^{*}.\mathrm{uq}_{r,j,a}\gamma_{\mathrm{r1},r}{}^{5}\right)+\left(\partial_\nu\left[\bar{l}_{s,i}\right]\gamma_{s,\mathrm{r1}}{}^{\mu}+\partial_\mu\left[\bar{l}_{s,i}\right]\gamma_{s,\mathrm{r1}}{}^{\nu}\right).\left(\mathrm{hTl}_{j,i}{}^{*}.\right.\right.$$

5 Parameters

In this section, we describe the parameters of our model implementation.

5.1 External Parameters

In this subsection, we describe the external parameters of our model. The details of the external parameters can be

P	C	I	V	D	PN	BN	OB	IO	Description
αEWM1	F		127.9		aEWM1	SMINPUTS		QED, -2	Inverse of the electroweak coupling constant
G_f	F		0.0000116637			SMINPUTS		QED, 2	Fermi constant
α_s	F		0.1184		aS	SMINPUTS		QCD, 2	Strong coupling constant at the Z pole.
ymc	F		0.			YUKAWA	4		Charm Yukawa mass
ymb	F		4.7			YUKAWA	5		Bottom Yukawa mass
ymt	F		174.3			YUKAWA	6		Top Yukawa mass
ymtau	F		1.777			YUKAWA	15		Tau Yukawa mass
θ_c	F		0.227736			CKMBLOCK			Cabibbo angle
gSu	F	f, f	$gSu_{1,1} \to 0.$					QED, 1	Neutral Scalar - up quark coupling constant
			$gSu_{1,2} \to 0.$						
			$gSu_{1,3} \to 0.$						
			$gSu_{2,1} \to 0.$						
			$gSu_{2,2} \to 0.$						
			$gSu_{2,3} \to 0.$						
			$gSu_{3,1} \to 0.$						
			$gSu_{3,2} \to 0.$						
			$gSu_{3,3} \to 0.$						
gPu	F	f, f	$gPu_{1,1} \to 0.$					QED, 1	Neutral Pseudoscalar - up quark coupling constant
			$gPu_{1,2} \to 0.$						
			$gPu_{1,3} \to 0.$						
			$gPu_{2,1} \to 0.$						
			$gPu_{2,2} \to 0.$						
			$gPu_{2,3} \to 0.$						
			$gPu_{3,1} \to 0.$						
			$gPu_{3,2} \to 0.$						
			$gPu_{3,3} \to 0.$						
gSd	F	f, f	$gSd_{1,1} \to 0.$					QED, 1	Neutral Scalar - down quark coupling constant
			$gSd_{1,2} \to 0.$						
			$gSd_{1,3} \to 0.$						
			$gSd_{2,1} \to 0.$						
			$gSd_{2,2} \to 0.$						
			$gSd_{2,3} \to 0.$						
			$gSd_{3,1} \to 0.$						
			$gSd_{3,2} \to 0.$						
			$gSd_{3,3} \to 0.$						

Table 10: Details of external parameters. The headers are as follows: P = parameter, C = complex, I = indices, V = value, D = definition, PN = parameter name, BN = block name, OB = order block, and IO = interaction order.

P	C	I	V	D	PN	BN	OB	IO	Description
gPd	F	f, f	$gPd_{1,1} \to 0.$ $gPd_{1,2} \to 0.$ $gPd_{1,3} \to 0.$ $gPd_{2,1} \to 0.$ $gPd_{2,2} \to 0.$ $gPd_{2,3} \to 0.$ $gPd_{3,1} \to 0.$ $gPd_{3,2} \to 0.$ $gPd_{3,3} \to 0.$					QED, 1	Neutral Pseudoscalar - down quark coupling constant
gSl	F	f, f	$gSl_{1,1} \to 0.$ $gSl_{1,2} \to 0.$ $gSl_{1,3} \to 0.$ $gSl_{2,1} \to 0.$ $gSl_{2,2} \to 0.$ $gSl_{2,3} \to 0.$ $gSl_{3,1} \to 0.$ $gSl_{3,2} \to 0.$ $gSl_{3,3} \to 0.$					QED, 1	Neutral Scalar - charged lepton coupling constant
gPl	F	f, f	$gPl_{1,1} \to 0.$ $gPl_{1,2} \to 0.$ $gPl_{1,3} \to 0.$ $gPl_{2,1} \to 0.$ $gPl_{2,2} \to 0.$ $gPl_{2,3} \to 0.$ $gPl_{3,1} \to 0.$ $gPl_{3,2} \to 0.$ $gPl_{3,3} \to 0.$					QED, 1	Neutral Pseudoscalar - charged lepton coupling constant
gSg	F		0.					QED, 1	Neutral Scalar - gluon coupling constant
gVu	F	f, f	$gVu_{1,1} \to 0.$ $gVu_{1,2} \to 0.$ $gVu_{1,3} \to 0.$ $gVu_{2,1} \to 0.$ $gVu_{2,2} \to 0.$ $gVu_{2,3} \to 0.$ $gVu_{3,1} \to 0.$ $gVu_{3,2} \to 0.$ $gVu_{3,3} \to 0.$					QED, 1	Neutral Vector - up quark coupling constant

Table 11: Details of external parameters. The headers are as follows: P = parameter, C = complex, I = indices, V = value, D = definition, PN = parameter name, BN = block name, OB = order block, and IO = interaction order.

found in Tables 10, 11, 12, 13, 14, 15, 16, 17, 18.

P	C	I	V	D	PN	BN	OB	IO	Description
gAu	F	f, f	$gAu_{1,1} \to 0.$					QED, 1	Neutral Axial vector - up quark coupling constant
			$gAu_{1,2} \to 0.$						
			$gAu_{1,3} \to 0.$						
			$gAu_{2,1} \to 0.$						
			$gAu_{2,2} \to 0.$						
			$gAu_{2,3} \to 0.$						
			$gAu_{3,1} \to 0.$						
			$gAu_{3,2} \to 0.$						
			$gAu_{3,3} \to 0.$						
gVd	F	f, f	$gVd_{1,1} \to 0.$					QED, 1	Neutral Vector - down quark coupling constant
			$gVd_{1,2} \to 0.$						
			$gVd_{1,3} \to 0.$						
			$gVd_{2,1} \to 0.$						
			$gVd_{2,2} \to 0.$						
			$gVd_{2,3} \to 0.$						
			$gVd_{3,1} \to 0.$						
			$gVd_{3,2} \to 0.$						
			$gVd_{3,3} \to 0.$						
gAd	F	f, f	$gAd_{1,1} \to 0.$					QED, 1	Neutral Axial vector - down quark coupling constant
			$gAd_{1,2} \to 0.$						
			$gAd_{1,3} \to 0.$						
			$gAd_{2,1} \to 0.$						
			$gAd_{2,2} \to 0.$						
			$gAd_{2,3} \to 0.$						
			$gAd_{3,1} \to 0.$						
			$gAd_{3,2} \to 0.$						
			$gAd_{3,3} \to 0.$						
gVl	F	f, f	$gVl_{1,1} \to 0.$					QED, 1	Neutral vector - charged lepton coupling constant
			$gVl_{1,2} \to 0.$						
			$gVl_{1,3} \to 0.$						
			$gVl_{2,1} \to 0.$						
			$gVl_{2,2} \to 0.$						
			$gVl_{2,3} \to 0.$						
			$gVl_{3,1} \to 0.$						
			$gVl_{3,2} \to 0.$						
			$gVl_{3,3} \to 0.$						

Table 12: Details of external parameters. The headers are as follows: P = parameter, C = complex, I = indices, V = value, D = definition, PN = parameter name, BN = block name, OB = order block, and IO = interaction order.

P	C	I	V	D	PN	BN	OB	IO	Description
gAl	F	f, f	$gAl_{1,1} \to 0.$					QED, 1	Neutral axial vector - charged lepton coupling constant
			$gAl_{1,2} \to 0.$						
			$gAl_{1,3} \to 0.$						
			$gAl_{2,1} \to 0.$						
			$gAl_{2,2} \to 0.$						
			$gAl_{2,3} \to 0.$						
			$gAl_{3,1} \to 0.$						
			$gAl_{3,2} \to 0.$						
			$gAl_{3,3} \to 0.$						
gVg	F		0.					QED, 1	Neutral Vector - gluon coupling constant
gTu	F	f, f	$gTu_{1,1} \to 0.$					QED, 1	Neutral Symmetric Tensor - up quark coupling constant
			$gTu_{1,2} \to 0.$						
			$gTu_{1,3} \to 0.$						
			$gTu_{2,1} \to 0.$						
			$gTu_{2,2} \to 0.$						
			$gTu_{2,3} \to 0.$						
			$gTu_{3,1} \to 0.$						
			$gTu_{3,2} \to 0.$						
			$gTu_{3,3} \to 0.$						
gUu	F	f, f	$gUu_{1,1} \to 0.$					QED, 1	Neutral axial Symmetric Tensor - up quark coupling constant
			$gUu_{1,2} \to 0.$						
			$gUu_{1,3} \to 0.$						
			$gUu_{2,1} \to 0.$						
			$gUu_{2,2} \to 0.$						
			$gUu_{2,3} \to 0.$						
			$gUu_{3,1} \to 0.$						
			$gUu_{3,2} \to 0.$						
			$gUu_{3,3} \to 0.$						
gTd	F	f, f	$gTd_{1,1} \to 0.$					QED, 1	Neutral Symmetric Tensor - down quark coupling constant
			$gTd_{1,2} \to 0.$						
			$gTd_{1,3} \to 0.$						
			$gTd_{2,1} \to 0.$						
			$gTd_{2,2} \to 0.$						
			$gTd_{2,3} \to 0.$						
			$gTd_{3,1} \to 0.$						
			$gTd_{3,2} \to 0.$						
			$gTd_{3,3} \to 0.$						

Table 13: Details of external parameters. The headers are as follows: P = parameter, C = complex, I = indices, V = value, D = definition, PN = parameter name, BN = block name, OB = order block, and IO = interaction order.

P	C	I	V	D	PN	BN	OB	IO	Description
gUd	F	f, f	$gUd_{1,1} \to 0.$ $gUd_{1,2} \to 0.$ $gUd_{1,3} \to 0.$ $gUd_{2,1} \to 0.$ $gUd_{2,2} \to 0.$ $gUd_{2,3} \to 0.$ $gUd_{3,1} \to 0.$ $gUd_{3,2} \to 0.$ $gUd_{3,3} \to 0.$					QED, 1	Neutral axial Symmetric Tensor - down quark coupling constant
gTl	F	f, f	$gTl_{1,1} \to 0.$ $gTl_{1,2} \to 0.$ $gTl_{1,3} \to 0.$ $gTl_{2,1} \to 0.$ $gTl_{2,2} \to 0.$ $gTl_{2,3} \to 0.$ $gTl_{3,1} \to 0.$ $gTl_{3,2} \to 0.$ $gTl_{3,3} \to 0.$					QED, 1	Neutral Symmetric Tensor - charged lepton coupling constant
gUl	F	f, f	$gUl_{1,1} \to 0.$ $gUl_{1,2} \to 0.$ $gUl_{1,3} \to 0.$ $gUl_{2,1} \to 0.$ $gUl_{2,2} \to 0.$ $gUl_{2,3} \to 0.$ $gUl_{3,1} \to 0.$ $gUl_{3,2} \to 0.$ $gUl_{3,3} \to 0.$					QED, 1	Neutral axial Symmetric Tensor - charged lepton coupling constant
gTg	F		0.					QED, 1	Neutral Tensor - gluon coupling constant
hSq	F	f, f	$hSq_{1,1} \to 0.$ $hSq_{1,2} \to 0.$ $hSq_{1,3} \to 0.$ $hSq_{2,1} \to 0.$ $hSq_{2,2} \to 0.$ $hSq_{2,3} \to 0.$ $hSq_{3,1} \to 0.$ $hSq_{3,2} \to 0.$ $hSq_{3,3} \to 0.$					QED, 1	Charged scalar - quark coupling constant

Table 14: Details of external parameters. The headers are as follows: P = parameter, C = complex, I = indices, V = value, D = definition, PN = parameter name, BN = block name, OB = order block, and IO = interaction order.

P	C	I	V	D	PN	BN	OB	IO	Description
hPq	F	f, f	$hPq_{1,1} \to 0.$					QED, 1	Charged pseudoscalar - quark coupling constant
			$hPq_{1,2} \to 0.$						
			$hPq_{1,3} \to 0.$						
			$hPq_{2,1} \to 0.$						
			$hPq_{2,2} \to 0.$						
			$hPq_{2,3} \to 0.$						
			$hPq_{3,1} \to 0.$						
			$hPq_{3,2} \to 0.$						
			$hPq_{3,3} \to 0.$						
hSl	F	f, f	$hSl_{1,1} \to 0.$					QED, 1	Charged scalar - lepton coupling constant
			$hSl_{1,2} \to 0.$						
			$hSl_{1,3} \to 0.$						
			$hSl_{2,1} \to 0.$						
			$hSl_{2,2} \to 0.$						
			$hSl_{2,3} \to 0.$						
			$hSl_{3,1} \to 0.$						
			$hSl_{3,2} \to 0.$						
			$hSl_{3,3} \to 0.$						
hPl	F	f, f	$hPl_{1,1} \to 0.$					QED, 1	Charged pseudoscalar - lepton coupling constant
			$hPl_{1,2} \to 0.$						
			$hPl_{1,3} \to 0.$						
			$hPl_{2,1} \to 0.$						
			$hPl_{2,2} \to 0.$						
			$hPl_{2,3} \to 0.$						
			$hPl_{3,1} \to 0.$						
			$hPl_{3,2} \to 0.$						
			$hPl_{3,3} \to 0.$						
hVq	F	f, f	$hVq_{1,1} \to 0.$					QED, 1	Charged vector - quark coupling constant
			$hVq_{1,2} \to 0.$						
			$hVq_{1,3} \to 0.$						
			$hVq_{2,1} \to 0.$						
			$hVq_{2,2} \to 0.$						
			$hVq_{2,3} \to 0.$						
			$hVq_{3,1} \to 0.$						
			$hVq_{3,2} \to 0.$						
			$hVq_{3,3} \to 0.$						

Table 15: Details of external parameters. The headers are as follows: P = parameter, C = complex, I = indices, V = value, D = definition, PN = parameter name, BN = block name, OB = order block, and IO = interaction order.

P	C	I	V	D	PN	BN	OB	IO	Description
hAq	F	f, f	$hAq_{1,1} \to 0.$					QED, 1	Charged axial vector - quark coupling constant
			$hAq_{1,2} \to 0.$						
			$hAq_{1,3} \to 0.$						
			$hAq_{2,1} \to 0.$						
			$hAq_{2,2} \to 0.$						
			$hAq_{2,3} \to 0.$						
			$hAq_{3,1} \to 0.$						
			$hAq_{3,2} \to 0.$						
			$hAq_{3,3} \to 0.$						
hVl	F	f, f	$hVl_{1,1} \to 0.$					QED, 1	Charged vector - lepton coupling constant
			$hVl_{1,2} \to 0.$						
			$hVl_{1,3} \to 0.$						
			$hVl_{2,1} \to 0.$						
			$hVl_{2,2} \to 0.$						
			$hVl_{2,3} \to 0.$						
			$hVl_{3,1} \to 0.$						
			$hVl_{3,2} \to 0.$						
			$hVl_{3,3} \to 0.$						
hAl	F	f, f	$hAl_{1,1} \to 0.$					QED, 1	Charged axial vector - lepton coupling constant
			$hAl_{1,2} \to 0.$						
			$hAl_{1,3} \to 0.$						
			$hAl_{2,1} \to 0.$						
			$hAl_{2,2} \to 0.$						
			$hAl_{2,3} \to 0.$						
			$hAl_{3,1} \to 0.$						
			$hAl_{3,2} \to 0.$						
			$hAl_{3,3} \to 0.$						
hTq	F	f, f	$hTq_{1,1} \to 0.$					QED, 1	Charged Symmetric Tensor - quark coupling constant
			$hTq_{1,2} \to 0.$						
			$hTq_{1,3} \to 0.$						
			$hTq_{2,1} \to 0.$						
			$hTq_{2,2} \to 0.$						
			$hTq_{2,3} \to 0.$						
			$hTq_{3,1} \to 0.$						
			$hTq_{3,2} \to 0.$						
			$hTq_{3,3} \to 0.$						

Table 16: Details of external parameters. The headers are as follows: P = parameter, C = complex, I = indices, V = value, D = definition, PN = parameter name, BN = block name, OB = order block, and IO = interaction order.

P	C	I	V	D	PN	BN	OB	IO	Description
hUq	F	f, f	$hUq_{1,1} \to 0.$					QED, 1	Charged axial Symmetric Tensor - quark coupling constant
			$hUq_{1,2} \to 0.$						
			$hUq_{1,3} \to 0.$						
			$hUq_{2,1} \to 0.$						
			$hUq_{2,2} \to 0.$						
			$hUq_{2,3} \to 0.$						
			$hUq_{3,1} \to 0.$						
			$hUq_{3,2} \to 0.$						
			$hUq_{3,3} \to 0.$						
hYq	F	f, f	$hYq_{1,1} \to 0.$					QED, 1	Charged Symmetric Tensor - quark coupling constant
			$hYq_{1,2} \to 0.$						
			$hYq_{1,3} \to 0.$						
			$hYq_{2,1} \to 0.$						
			$hYq_{2,2} \to 0.$						
			$hYq_{2,3} \to 0.$						
			$hYq_{3,1} \to 0.$						
			$hYq_{3,2} \to 0.$						
			$hYq_{3,3} \to 0.$						
hZq	F	f, f	$hZq_{1,1} \to 0.$					QED, 1	Charged axial Symmetric Tensor - quark coupling constant
			$hZq_{1,2} \to 0.$						
			$hZq_{1,3} \to 0.$						
			$hZq_{2,1} \to 0.$						
			$hZq_{2,2} \to 0.$						
			$hZq_{2,3} \to 0.$						
			$hZq_{3,1} \to 0.$						
			$hZq_{3,2} \to 0.$						
			$hZq_{3,3} \to 0.$						
hTl	F	f, f	$hTl_{1,1} \to 0.$					QED, 1	Charged Symmetric Tensor - lepton coupling constant
			$hTl_{1,2} \to 0.$						
			$hTl_{1,3} \to 0.$						
			$hTl_{2,1} \to 0.$						
			$hTl_{2,2} \to 0.$						
			$hTl_{2,3} \to 0.$						
			$hTl_{3,1} \to 0.$						
			$hTl_{3,2} \to 0.$						
			$hTl_{3,3} \to 0.$						

Table 17: Details of external parameters. The headers are as follows: P = parameter, C = complex, I = indices, V = value, D = definition, PN = parameter name, BN = block name, OB = order block, and IO = interaction order.

P	C	I	V	D	PN	BN	OB	IO	Description
hUl	F	f, f	$hUl_{1,1} \to 0.$					QED, 1	Charged axial Symmetric Tensor - lepton coupling constant
			$hUl_{1,2} \to 0.$						
			$hUl_{1,3} \to 0.$						
			$hUl_{2,1} \to 0.$						
			$hUl_{2,2} \to 0.$						
			$hUl_{2,3} \to 0.$						
			$hUl_{3,1} \to 0.$						
			$hUl_{3,2} \to 0.$						
			$hUl_{3,3} \to 0.$						
hYl	F	f, f	$hYl_{1,1} \to 0.$					QED, 1	Charged Symmetric Tensor - lepton coupling constant
			$hYl_{1,2} \to 0.$						
			$hYl_{1,3} \to 0.$						
			$hYl_{2,1} \to 0.$						
			$hYl_{2,2} \to 0.$						
			$hYl_{2,3} \to 0.$						
			$hYl_{3,1} \to 0.$						
			$hYl_{3,2} \to 0.$						
			$hYl_{3,3} \to 0.$						
hZl	F	f, f	$hZl_{1,1} \to 0.$					QED, 1	Charged axial Symmetric Tensor - lepton coupling constant
			$hZl_{1,2} \to 0.$						
			$hZl_{1,3} \to 0.$						
			$hZl_{2,1} \to 0.$						
			$hZl_{2,2} \to 0.$						
			$hZl_{2,3} \to 0.$						
			$hZl_{3,1} \to 0.$						
			$hZl_{3,2} \to 0.$						
			$hZl_{3,3} \to 0.$						

Table 18: Details of external parameters. The headers are as follows: P = parameter, C = complex, I = indices, V = value, D = definition, PN = parameter name, BN = block name, OB = order block, and IO = interaction order.

5.2 Internal Parameters

In this subsection, we describe the internal parameters of our model. The details of the internal parameters can be found

P	C	I	V	NV	D	PN	IO	Description
$\alpha_{\rm EW}$	F		Eq. 2	0.00781861		aEW	QED, 2	Electroweak coupling contant
M_W	F		Eq. 3	79.8244				W mass
sw2	F		Eq. 4	0.233699				Squared Sin of the Weinberg angle
e	F		Eq. 5	0.313451			QED, 1	Electric coupling constant
c_w	F		Eq. 6	0.875386				Cos of the Weinberg angle
s_w	F		Eq. 7	0.483424				Sin of the Weinberg angle
g_w	F		Eq. 8	0.648397			QED, 1	Weak coupling constant
g_1	F		Eq. 9	0.358072			QED, 1	U(1)Y coupling constant
g_s	F		Eq. 10	1.21978		G	QCD, 1	Strong coupling constant
v	F		Eq. 11	246.221			QED, -1	Higgs VEV
λ	F		Eq. 12	0.118764		lam	QED, 2	Higgs quartic coupling
μ	F		Eq. 13	84.8528				Coefficient of the quadratic piece of the Higgs potential
yl	F	f	Eq. 14	${y^l}_1 \to 0.$	${y^l}_1 \to 0$	${y^l}_1 \to$ ye	QED, 1	Lepton Yukawa coupling
				${y^l}_2 \to 0.$	${y^l}_2 \to 0$	${y^l}_2 \to$ ym		
				${y^l}_3 \to 0.0102065$		${y^l}_3 \to$ ytau		
yu	F	f	Eq. 15	${y^u}_1 \to 0.$	${y^u}_1 \to 0$	${y^u}_1 \to$ yu	QED, 1	U-quark Yukawa coupling
				${y^u}_2 \to 0.$	${y^u}_2 \to 0$	${y^u}_2 \to$ yc		
				${y^u}_3 \to 1.00112$		${y^u}_3 \to$ yt		
yd	F	f	Eq. 16	${y^d}_1 \to 0.$	${y^d}_1 \to 0$	${y^d}_1 \to$ yd	QED, 1	D-quark Yukawa coupling
				${y^d}_2 \to 0.$	${y^d}_2 \to 0$	${y^d}_2 \to$ ys		
				${y^d}_3 \to 0.0269953$		${y^d}_3 \to$ yb		
CKM	F	f, f	Eq. 17	$\mathrm{CKM}_{1,1} \to 0.97418$				CKM-Matrix
				$\mathrm{CKM}_{1,2} \to 0.225773$				
				$\mathrm{CKM}_{1,3} \to 0.$				
				$\mathrm{CKM}_{2,1} \to -0.225773$				
				$\mathrm{CKM}_{2,2} \to 0.97418$				
				$\mathrm{CKM}_{2,3} \to 0.$				
				$\mathrm{CKM}_{3,1} \to 0.$				
				$\mathrm{CKM}_{3,2} \to 0.$				
				$\mathrm{CKM}_{3,3} \to 1.$				

Table 19: Details of internal parameters. The headers are as follows: P = parameter, C = complex, I = Indices, V = value, NV = numerical value, D = definition, PN = parameter name, and IO = interaction order.

P	C	I	V	NV	D	PN	IO	Description

Table 20: Details of internal parameters. The headers are as follows: P = parameter, C = complex, I = Indices, V = value, NV = numerical value, D = definition, PN = parameter name, and IO = interaction order.

in Tables 19, 20. The values and definitions of the internal parameters will be written below.

$$\alpha_{\rm EW} = \frac{1}{\alpha{\rm EWM1}} \tag{2}$$

$$M_W = \sqrt{\frac{{\rm MZ}^2}{2} + \sqrt{\frac{{\rm MZ}^4}{4} - \frac{{\rm MZ}^2 \pi \alpha_{\rm EW}}{\sqrt{2} G_f}}} \tag{3}$$

$${\rm sw2} = 1 - \frac{{M_W}^2}{{\rm MZ}^2} \tag{4}$$

$$e = 2\sqrt{\pi}\sqrt{\alpha_{\rm EW}} \tag{5}$$

$$c_w = \sqrt{1 - {\rm sw2}} \tag{6}$$

$$s_w = \sqrt{{\rm sw2}} \tag{7}$$

$$g_w = \frac{e}{s_w} \tag{8}$$

$$g_1 = \frac{e}{c_w} \tag{9}$$

$$g_s = 2\sqrt{\pi}\sqrt{\alpha_s} \tag{10}$$

$$v = \frac{2 M_W s_w}{e} \tag{11}$$

$$\lambda = \frac{{\rm MH}^2}{2v^2} \tag{12}$$

$$\mu = \sqrt{v^2 \lambda} \tag{13}$$

$$\begin{array}{rcl} {y^l}_1 & = & 0 \\ {y^l}_2 & = & 0 \\ {y^l}_3 & = & \frac{\sqrt{2}{\rm ymtau}}{v} \end{array} \tag{14}$$

$$\begin{array}{rcl} {y^u}_1 & = & 0 \\ {y^u}_2 & = & \frac{\sqrt{2}{\rm ymc}}{v} \\ {y^u}_3 & = & \frac{\sqrt{2}{\rm ymt}}{v} \end{array} \tag{15}$$

$$\begin{array}{rcl} {y^d}_1 & = & 0 \\ {y^d}_2 & = & 0 \\ {y^d}_3 & = & \frac{\sqrt{2}{\rm ymb}}{v} \end{array} \tag{16}$$

$$\begin{array}{rcl} {\rm CKM}_{1,1} & = & {\rm Cos}\left[\theta_c\right] \\ {\rm CKM}_{1,2} & = & {\rm Sin}\left[\theta_c\right] \\ {\rm CKM}_{1,3} & = & 0 \\ {\rm CKM}_{2,1} & = & -{\rm Sin}\left[\theta_c\right] \\ {\rm CKM}_{2,2} & = & {\rm Cos}\left[\theta_c\right] \\ {\rm CKM}_{2,3} & = & 0 \\ {\rm CKM}_{3,1} & = & 0 \\ {\rm CKM}_{3,2} & = & 0 \\ {\rm CKM}_{3,3} & = & 1 \end{array} \tag{17}$$

6 Vertices

In this section, we describe the vertices of our model implementation.

6.1 V_1

$$\begin{pmatrix} G & 1 \\ G & 2 \\ \mathrm{SV} & 3 \end{pmatrix} \quad -i\mathrm{gSgp}_1{}^{\mu_2}\mathrm{p}_2{}^{\mu_1}\delta_{\mathrm{a}_1,\mathrm{a}_2} + i\mathrm{gSg}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_1,\mu_2}\mathrm{p}_1.p_2$$

$$\begin{pmatrix} \mathrm{dq} & 1 \\ \bar{\mathrm{dq}} & 2 \\ \mathrm{SV} & 3 \end{pmatrix} \quad -\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^5\mathrm{gPd}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2} + i\mathrm{gSd}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2}\delta_{\mathrm{s}_2,\mathrm{s}_1}$$

$$\begin{pmatrix} l & 1 \\ \bar{l} & 2 \\ \mathrm{SV} & 3 \end{pmatrix} \quad -\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^5\mathrm{gPl}_{\mathrm{f}_2,\mathrm{f}_1} + i\mathrm{gSl}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{s}_2,\mathrm{s}_1}$$

$$\begin{pmatrix} \mathrm{SV} & 1 \\ \mathrm{uq} & 2 \\ \bar{\mathrm{uq}} & 3 \end{pmatrix} \quad -\gamma_{\mathrm{s}_3,\mathrm{s}_2}{}^5\mathrm{gPu}_{\mathrm{f}_3,\mathrm{f}_2}\delta_{\mathrm{i}_2,\mathrm{i}_3} + i\mathrm{gSu}_{\mathrm{f}_3,\mathrm{f}_2}\delta_{\mathrm{i}_2,\mathrm{i}_3}\delta_{\mathrm{s}_3,\mathrm{s}_2}$$

6.2 V_2

$$\begin{pmatrix} G & 1 \\ G & 2 \\ \mathrm{VV} & 3 \end{pmatrix} \quad -\mathrm{gVgp}_1{}^{\mu_2}\mathrm{p}_2{}^{\mu_1}\mathrm{p}_3{}^{\mu_3}\delta_{\mathrm{a}_1,\mathrm{a}_2} + \mathrm{gVgp}_3{}^{\mu_3}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_1,\mu_2}\mathrm{p}_1.p_2$$

$$\begin{pmatrix} \mathrm{dq} & 1 \\ \bar{\mathrm{dq}} & 2 \\ \mathrm{VV} & 3 \end{pmatrix} \quad i\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3}\mathrm{gVd}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2} + i\mathrm{gAd}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2}\gamma^{\mu_3}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1}$$

$$\begin{pmatrix} l & 1 \\ \bar{l} & 2 \\ \mathrm{VV} & 3 \end{pmatrix} \quad i\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3}\mathrm{gVl}_{\mathrm{f}_2,\mathrm{f}_1} + i\mathrm{gAl}_{\mathrm{f}_2,\mathrm{f}_1}\gamma^{\mu_3}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1}$$

$$\begin{pmatrix} \mathrm{uq} & 1 \\ \bar{\mathrm{uq}} & 2 \\ \mathrm{VV} & 3 \end{pmatrix} \quad i\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3}\mathrm{gVu}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2} + i\mathrm{gAu}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2}\gamma^{\mu_3}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1}$$

6.3 V_3

$$\begin{pmatrix} G & 1 \\ G & 2 \\ \mathrm{TV} & 3 \end{pmatrix} \quad \tfrac{1}{4}i\mathrm{gTgp}_1{}^{\mu_3,2}\mathrm{p}_2{}^{\mu_3,1}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_1,\mu_2} + \tfrac{1}{4}i\mathrm{gTgp}_1{}^{\mu_3,1}\mathrm{p}_2{}^{\mu_3,2}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_1,\mu_2} - \tfrac{1}{4}i\mathrm{gTgp}_1{}^{\mu_2}\mathrm{p}_2{}^{\mu_3,2}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_1,\mu_{3,1}} - \tfrac{1}{4}i\mathrm{gTgp}_1{}^{\mu_2}\mathrm{p}_2{}^{\mu_3,1}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_1,\mu_{3,2}} - \tfrac{1}{4}i\mathrm{gTgp}_1{}^{\mu_3,2}\mathrm{p}_2{}^{\mu_1}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_2,\mu_{3,1}} - \tfrac{1}{4}i\mathrm{gTgp}_1{}^{\mu_3,1}\mathrm{p}_2{}^{\mu_1}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_2,\mu_{3,2}} + \tfrac{1}{4}i\mathrm{gTg}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_1,\mu_{3,2}}\eta_{\mu_2,\mu_{3,1}}\mathrm{p}_1.p_2 + \tfrac{1}{4}i\mathrm{gTg}\delta_{\mathrm{a}_1,\mathrm{a}_2}\eta_{\mu_1,\mu_{3,1}}\eta_{\mu_2,\mu_{3,2}}\mathrm{p}_1.p_2$$

$$\begin{pmatrix} \mathrm{dq} & 1 \\ \bar{\mathrm{dq}} & 2 \\ \mathrm{TV} & 3 \end{pmatrix} \quad -i\mathrm{gTd}_{\mathrm{f}_1,\mathrm{f}_2}{}^*\mathrm{p}_2{}^{\mu_3,2}\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3,1}\delta_{\mathrm{i}_1,\mathrm{i}_2} - i\mathrm{gTd}_{\mathrm{f}_1,\mathrm{f}_2}{}^*\mathrm{p}_2{}^{\mu_3,1}\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3,2}\delta_{\mathrm{i}_1,\mathrm{i}_2} + i\mathrm{p}_1{}^{\mu_3,2}\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3,1}\mathrm{gTd}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2} + i\mathrm{p}_1{}^{\mu_3,1}\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3,2}\mathrm{gTd}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2} - i\mathrm{gUd}_{\mathrm{f}_1,\mathrm{f}_2}{}^*\mathrm{p}_2{}^{\mu_3,2}\delta_{\mathrm{i}_1,\mathrm{i}_2}\gamma^{\mu_3,1}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1} + i\mathrm{p}_1{}^{\mu_3,2}\mathrm{gUd}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2}\gamma^{\mu_3,1}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1} - i\mathrm{gUd}_{\mathrm{f}_1,\mathrm{f}_2}{}^*\mathrm{p}_2{}^{\mu_3,1}\delta_{\mathrm{i}_1,\mathrm{i}_2}\gamma^{\mu_3,2}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1} + i\mathrm{p}_1{}^{\mu_3,1}\mathrm{gUd}_{\mathrm{f}_2,\mathrm{f}_1}\delta_{\mathrm{i}_1,\mathrm{i}_2}\gamma^{\mu_3,2}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1}$$

$$\begin{pmatrix} l & 1 \\ \bar{l} & 2 \\ \mathrm{TV} & 3 \end{pmatrix} \quad -i\mathrm{gTl}_{\mathrm{f}_1,\mathrm{f}_2}{}^*\mathrm{p}_2{}^{\mu_3,2}\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3,1} - i\mathrm{gTl}_{\mathrm{f}_1,\mathrm{f}_2}{}^*\mathrm{p}_2{}^{\mu_3,1}\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3,2} + i\mathrm{p}_1{}^{\mu_3,2}\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3,1}\mathrm{gTl}_{\mathrm{f}_2,\mathrm{f}_1} + i\mathrm{p}_1{}^{\mu_3,1}\gamma_{\mathrm{s}_2,\mathrm{s}_1}{}^{\mu_3,2}\mathrm{gTl}_{\mathrm{f}_2,\mathrm{f}_1} - i\mathrm{gUl}_{\mathrm{f}_1,\mathrm{f}_2}{}^*\mathrm{p}_2{}^{\mu_3,2}\gamma^{\mu_3,1}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1} + i\mathrm{p}_1{}^{\mu_3,2}\mathrm{gUl}_{\mathrm{f}_2,\mathrm{f}_1}\gamma^{\mu_3,1}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1} - i\mathrm{gUl}_{\mathrm{f}_1,\mathrm{f}_2}{}^*\mathrm{p}_2{}^{\mu_3,1}\gamma^{\mu_3,2}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1} + i\mathrm{p}_1{}^{\mu_3,1}\mathrm{gUl}_{\mathrm{f}_2,\mathrm{f}_1}\gamma^{\mu_3,2}.\gamma^5{}_{\mathrm{s}_2,\mathrm{s}_1}$$

$$\begin{pmatrix} \mathrm{TV} & 1 \\ \mathrm{uq} & 2 \\ \bar{\mathrm{uq}} & 3 \end{pmatrix} \quad -i\mathrm{gTu}_{\mathrm{f}_2,\mathrm{f}_3}{}^*\mathrm{p}_3{}^{\mu_1,2}\gamma_{\mathrm{s}_3,\mathrm{s}_2}{}^{\mu_1,1}\delta_{\mathrm{i}_2,\mathrm{i}_3} - i\mathrm{gTu}_{\mathrm{f}_2,\mathrm{f}_3}{}^*\mathrm{p}_3{}^{\mu_1,1}\gamma_{\mathrm{s}_3,\mathrm{s}_2}{}^{\mu_1,2}\delta_{\mathrm{i}_2,\mathrm{i}_3} + i\mathrm{p}_2{}^{\mu_1,2}\gamma_{\mathrm{s}_3,\mathrm{s}_2}{}^{\mu_1,1}\mathrm{gTu}_{\mathrm{f}_3,\mathrm{f}_2}\delta_{\mathrm{i}_2,\mathrm{i}_3} + i\mathrm{p}_2{}^{\mu_1,1}\gamma_{\mathrm{s}_3,\mathrm{s}_2}{}^{\mu_1,2}\mathrm{gTu}_{\mathrm{f}_3,\mathrm{f}_2}\delta_{\mathrm{i}_2,\mathrm{i}_3} - i\mathrm{gUu}_{\mathrm{f}_2,\mathrm{f}_3}{}^*\mathrm{p}_3{}^{\mu_1,2}\delta_{\mathrm{i}_2,\mathrm{i}_3}\gamma^{\mu_1,1}.\gamma^5{}_{\mathrm{s}_3,\mathrm{s}_2} + i\mathrm{p}_2{}^{\mu_1,2}\mathrm{gUu}_{\mathrm{f}_3,\mathrm{f}_2}\delta_{\mathrm{i}_2,\mathrm{i}_3}\gamma^{\mu_1,1}.\gamma^5{}_{\mathrm{s}_3,\mathrm{s}_2} - i\mathrm{gUu}_{\mathrm{f}_2,\mathrm{f}_3}{}^*\mathrm{p}_3{}^{\mu_1,1}\delta_{\mathrm{i}_2,\mathrm{i}_3}\gamma^{\mu_1,2}.\gamma^5{}_{\mathrm{s}_3,\mathrm{s}_2} + i\mathrm{p}_2{}^{\mu_1,1}\mathrm{gUu}_{\mathrm{f}_3,\mathrm{f}_2}\delta_{\mathrm{i}_2,\mathrm{i}_3}\gamma^{\mu_1,2}.\gamma^5{}_{\mathrm{s}_3,\mathrm{s}_2}$$

6.4 V_4

$$\begin{pmatrix} \bar{\text{dq}} & 1 \\ \text{SVP}^\dagger & 2 \\ \text{uq} & 3 \end{pmatrix} \quad -\text{hPq}_{\text{f}_3,\text{f}_1}{}^*\gamma_{\text{s}_1,\text{s}_3}{}^5\delta_{\text{i}_1,\text{i}_3} + i\text{hSq}_{\text{f}_3,\text{f}_1}{}^*\delta_{\text{i}_1,\text{i}_3}\delta_{\text{s}_1,\text{s}_3}$$

$$\begin{pmatrix} \bar{l} & 1 \\ \text{SVP}^\dagger & 2 \\ \text{vl} & 3 \end{pmatrix} \quad -\text{hPl}_{\text{f}_3,\text{f}_1}{}^*\gamma_{\text{s}_1,\text{s}_3}{}^5 + i\text{hSl}_{\text{f}_3,\text{f}_1}{}^*\delta_{\text{s}_1,\text{s}_3}$$

$$\begin{pmatrix} l & 1 \\ \text{SVP} & 2 \\ \bar{\text{vl}} & 3 \end{pmatrix} \quad -\gamma_{\text{s}_3,\text{s}_1}{}^5\text{hPl}_{\text{f}_3,\text{f}_1} + i\text{hSl}_{\text{f}_3,\text{f}_1}\delta_{\text{s}_3,\text{s}_1}$$

$$\begin{pmatrix} \text{dq} & 1 \\ \text{SVP} & 2 \\ \bar{\text{uq}} & 3 \end{pmatrix} \quad -\gamma_{\text{s}_3,\text{s}_1}{}^5\text{hPq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3} + i\text{hSq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3}\delta_{\text{s}_3,\text{s}_1}$$

6.5 V_5

$$\begin{pmatrix} l & 1 \\ \bar{\text{vl}} & 2 \\ \text{VVP} & 3 \end{pmatrix} \quad i\gamma_{\text{s}_2,\text{s}_1}{}^{\mu_3}\text{hVl}_{\text{f}_2,\text{f}_1} + i\text{hAl}_{\text{f}_2,\text{f}_1}\gamma^{\mu_3}.\gamma^5{}_{\text{s}_2,\text{s}_1}$$

$$\begin{pmatrix} \text{dq} & 1 \\ \bar{\text{uq}} & 2 \\ \text{VVP} & 3 \end{pmatrix} \quad i\gamma_{\text{s}_2,\text{s}_1}{}^{\mu_3}\text{hVq}_{\text{f}_2,\text{f}_1}\delta_{\text{i}_1,\text{i}_2} + i\text{hAq}_{\text{f}_2,\text{f}_1}\delta_{\text{i}_1,\text{i}_2}\gamma^{\mu_3}.\gamma^5{}_{\text{s}_2,\text{s}_1}$$

$$\begin{pmatrix} \bar{\text{dq}} & 1 \\ \text{uq} & 2 \\ \text{VVP}^\dagger & 3 \end{pmatrix} \quad i\text{hVq}_{\text{f}_2,\text{f}_1}{}^*\gamma_{\text{s}_1,\text{s}_2}{}^{\mu_3}\delta_{\text{i}_1,\text{i}_2} + i\text{hAq}_{\text{f}_2,\text{f}_1}{}^*\delta_{\text{i}_1,\text{i}_2}\gamma^{\mu_3}.\gamma^5{}_{\text{s}_1,\text{s}_2}$$

$$\begin{pmatrix} \bar{l} & 1 \\ \text{vl} & 2 \\ \text{VVP}^\dagger & 3 \end{pmatrix} \quad i\text{hVl}_{\text{f}_2,\text{f}_1}{}^*\gamma_{\text{s}_1,\text{s}_2}{}^{\mu_3} + i\text{hAl}_{\text{f}_2,\text{f}_1}{}^*\gamma^{\mu_3}.\gamma^5{}_{\text{s}_1,\text{s}_2}$$

6.6 V_6

$$\begin{pmatrix} l & 1 \\ \text{TVP} & 2 \\ \bar{\text{vl}} & 3 \end{pmatrix} \quad \begin{array}{l} i\text{p}_1{}^{\mu_{2,2}}\gamma_{\text{s}_3,\text{s}_1}{}^{\mu_{2,1}}\text{hTl}_{\text{f}_3,\text{f}_1} + i\text{p}_1{}^{\mu_{2,1}}\gamma_{\text{s}_3,\text{s}_1}{}^{\mu_{2,2}}\text{hTl}_{\text{f}_3,\text{f}_1} - i\text{p}_3{}^{\mu_{2,2}}\gamma_{\text{s}_3,\text{s}_1}{}^{\mu_{2,1}}\text{hYl}_{\text{f}_3,\text{f}_1} - i\text{p}_3{}^{\mu_{2,1}}\gamma_{\text{s}_3,\text{s}_1}{}^{\mu_{2,2}}\text{hYl}_{\text{f}_3,\text{f}_1} + \\ i\text{p}_1{}^{\mu_{2,2}}\text{hUl}_{\text{f}_3,\text{f}_1}\gamma^{\mu_{2,1}}.\gamma^5{}_{\text{s}_3,\text{s}_1} - i\text{p}_3{}^{\mu_{2,2}}\text{hZl}_{\text{f}_3,\text{f}_1}\gamma^{\mu_{2,1}}.\gamma^5{}_{\text{s}_3,\text{s}_1} + i\text{p}_1{}^{\mu_{2,1}}\text{hUl}_{\text{f}_3,\text{f}_1}\gamma^{\mu_{2,2}}.\gamma^5{}_{\text{s}_3,\text{s}_1} - \\ i\text{p}_3{}^{\mu_{2,1}}\text{hZl}_{\text{f}_3,\text{f}_1}\gamma^{\mu_{2,2}}.\gamma^5{}_{\text{s}_3,\text{s}_1} \end{array}$$

$$\begin{pmatrix} \text{dq} & 1 \\ \text{TVP} & 2 \\ \bar{\text{uq}} & 3 \end{pmatrix} \quad \begin{array}{l} i\text{p}_1{}^{\mu_{2,2}}\gamma_{\text{s}_3,\text{s}_1}{}^{\mu_{2,1}}\text{hTq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3} + i\text{p}_1{}^{\mu_{2,1}}\gamma_{\text{s}_3,\text{s}_1}{}^{\mu_{2,2}}\text{hTq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3} - i\text{p}_3{}^{\mu_{2,2}}\gamma_{\text{s}_3,\text{s}_1}{}^{\mu_{2,1}}\text{hYq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3} - \\ i\text{p}_3{}^{\mu_{2,1}}\gamma_{\text{s}_3,\text{s}_1}{}^{\mu_{2,2}}\text{hYq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3} + i\text{p}_1{}^{\mu_{2,2}}\text{hUq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3}\gamma^{\mu_{2,1}}.\gamma^5{}_{\text{s}_3,\text{s}_1} - i\text{p}_3{}^{\mu_{2,2}}\text{hZq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3}\gamma^{\mu_{2,1}}.\gamma^5{}_{\text{s}_3,\text{s}_1} + \\ i\text{p}_1{}^{\mu_{2,1}}\text{hUq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3}\gamma^{\mu_{2,2}}.\gamma^5{}_{\text{s}_3,\text{s}_1} - i\text{p}_3{}^{\mu_{2,1}}\text{hZq}_{\text{f}_3,\text{f}_1}\delta_{\text{i}_1,\text{i}_3}\gamma^{\mu_{2,2}}.\gamma^5{}_{\text{s}_3,\text{s}_1} \end{array}$$

$$\begin{pmatrix} \bar{\text{dq}} & 1 \\ \text{TVP}^\dagger & 2 \\ \text{uq} & 3 \end{pmatrix} \quad \begin{array}{l} -i\text{hTq}_{\text{f}_3,\text{f}_1}{}^*\text{p}_1{}^{\mu_{2,2}}\gamma_{\text{s}_1,\text{s}_3}{}^{\mu_{2,1}}\delta_{\text{i}_1,\text{i}_3} + i\text{hYq}_{\text{f}_3,\text{f}_1}{}^*\text{p}_3{}^{\mu_{2,2}}\gamma_{\text{s}_1,\text{s}_3}{}^{\mu_{2,1}}\delta_{\text{i}_1,\text{i}_3} - i\text{hTq}_{\text{f}_3,\text{f}_1}{}^*\text{p}_1{}^{\mu_{2,1}}\gamma_{\text{s}_1,\text{s}_3}{}^{\mu_{2,2}}\delta_{\text{i}_1,\text{i}_3} + \\ i\text{hYq}_{\text{f}_3,\text{f}_1}{}^*\text{p}_3{}^{\mu_{2,1}}\gamma_{\text{s}_1,\text{s}_3}{}^{\mu_{2,2}}\delta_{\text{i}_1,\text{i}_3} - i\text{hUq}_{\text{f}_3,\text{f}_1}{}^*\text{p}_1{}^{\mu_{2,2}}\delta_{\text{i}_1,\text{i}_3}\gamma^{\mu_{2,1}}.\gamma^5{}_{\text{s}_1,\text{s}_3} + i\text{hZq}_{\text{f}_3,\text{f}_1}{}^*\text{p}_3{}^{\mu_{2,2}}\delta_{\text{i}_1,\text{i}_3}\gamma^{\mu_{2,1}}.\gamma^5{}_{\text{s}_1,\text{s}_3} - \\ i\text{hUq}_{\text{f}_3,\text{f}_1}{}^*\text{p}_1{}^{\mu_{2,1}}\delta_{\text{i}_1,\text{i}_3}\gamma^{\mu_{2,2}}.\gamma^5{}_{\text{s}_1,\text{s}_3} + i\text{hZq}_{\text{f}_3,\text{f}_1}{}^*\text{p}_3{}^{\mu_{2,1}}\delta_{\text{i}_1,\text{i}_3}\gamma^{\mu_{2,2}}.\gamma^5{}_{\text{s}_1,\text{s}_3} \end{array}$$

$$\begin{pmatrix} \bar{l} & 1 \\ \text{TVP}^\dagger & 2 \\ \text{vl} & 3 \end{pmatrix} \quad \begin{array}{l} -i\text{hTl}_{\text{f}_3,\text{f}_1}{}^*\text{p}_1{}^{\mu_{2,2}}\gamma_{\text{s}_1,\text{s}_3}{}^{\mu_{2,1}} + i\text{hYl}_{\text{f}_3,\text{f}_1}{}^*\text{p}_3{}^{\mu_{2,2}}\gamma_{\text{s}_1,\text{s}_3}{}^{\mu_{2,1}} - i\text{hTl}_{\text{f}_3,\text{f}_1}{}^*\text{p}_1{}^{\mu_{2,1}}\gamma_{\text{s}_1,\text{s}_3}{}^{\mu_{2,2}} + \\ i\text{hYl}_{\text{f}_3,\text{f}_1}{}^*\text{p}_3{}^{\mu_{2,1}}\gamma_{\text{s}_1,\text{s}_3}{}^{\mu_{2,2}} - i\text{hUl}_{\text{f}_3,\text{f}_1}{}^*\text{p}_1{}^{\mu_{2,2}}\gamma^{\mu_{2,1}}.\gamma^5{}_{\text{s}_1,\text{s}_3} + i\text{hZl}_{\text{f}_3,\text{f}_1}{}^*\text{p}_3{}^{\mu_{2,2}}\gamma^{\mu_{2,1}}.\gamma^5{}_{\text{s}_1,\text{s}_3} - \\ i\text{hUl}_{\text{f}_3,\text{f}_1}{}^*\text{p}_1{}^{\mu_{2,1}}\gamma^{\mu_{2,2}}.\gamma^5{}_{\text{s}_1,\text{s}_3} + i\text{hZl}_{\text{f}_3,\text{f}_1}{}^*\text{p}_3{}^{\mu_{2,1}}\gamma^{\mu_{2,2}}.\gamma^5{}_{\text{s}_1,\text{s}_3} \end{array}$$

References

[1] N. D. Christensen and C. Duhr, arXiv:0806.4194 [hep-ph].