FeynRules Implementation of Sextet_Diquarks

C. Duhr *
IPPP, Durham

April 2, 2011

Abstract

We describe the implementation of the Sextet_Diquarks model using the FeynRules package.

Contents

List of Tables

*email: claude.duhr@durham.ac.uk

1 Introduction

We describe the implementation of the Sextet_Diquarks 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$,
SU3C	F	G	gs		f	dSUN	$T6_{u,u}$ $T_{i,i}$ $FSU3C_{a,a}$	FSU3C[a$_, b$_, c$_] → -I f[a$, b$, c

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
Sextet	u	1-6

Table 2: Definition of the indices.

3 Fields

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

3.1 Vector Fields

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

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

Table 3: 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 4.

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

3.2 Fermion Fields

In this subsection, we describe the fermion fields of our model. The details of the physical fermions can be found in Table 5.

3.3 Scalar Fields

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

3.4 Ghost Fields

In this subsection, we describe the ghost fields of our model. The details of the physical ghosts can be found in Table 7. The details of the unphysical ghosts can be found in Table 8.

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= 0.000511		11
					m	MM= 0.10566		13
					tt	MTA= 1.777		15
uq	F	f, i	f	$Q = 2/3$		Mu		
					u	MU= 0.00255	0	2
					c	MC= 1.42	0	4
					t	MT= 172	WT= 1.50834	6
dq	F	f, i	f	$Q = -1/3$		Md		
					d	MD= 0.00504		1
					s	MS= 0.101		3
					b	MB= 4.7		5

Table 5: 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
six1	F	u		$Q = 1/3$	six1	MSIX1= 500	WSIX1= 4.4108	
				$Y = 1/3$				
six2	F	u		$Q = -2/3$	six2	MSIX2= 500	WSIX2= 4.774	
				$Y = -2/3$				
six3	F	u		$Q = 4/3$	six3	MSIX3= 500	WSIX3= 4.0647	
				$Y = 4/3$				

Table 6: 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.

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 7: 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 8: Details of unphysical ghost fields. The headers are as follows: SC = self conjugate, I = indices, FI = flavor index, QN = quantum numbers, and Mem = members.

4 Lagrangian

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

4.1 L_1

$$-\frac{1}{4}\left(-\partial_\nu\left[B_\mu\right]+\partial_\mu\left[B_\nu\right]\right)^2-$$
$$\frac{1}{4}\left(-\partial_\nu\left[G_{\mu,\mathrm{a1}}\right]+\partial_\mu\left[G_{\nu,\mathrm{a1}}\right]+g_s f_{\mathrm{a1,a2,a3}}G_{\mu,\mathrm{a2}}G_{\nu,\mathrm{a3}}\right)\left(-\partial_\nu\left[G_{\mu,\mathrm{a1}}\right]+\partial_\mu\left[G_{\nu,\mathrm{a1}}\right]+g_s f_{\mathrm{a1,a4,a5}}G_{\mu,\mathrm{a4}}G_{\nu,\mathrm{a5}}\right)-$$
$$\frac{1}{4}\left(-\partial_\nu\left[\mathrm{Wi}_{\mu,\mathrm{i1}}\right]+\partial_\mu\left[\mathrm{Wi}_{\nu,\mathrm{i1}}\right]+g_w\epsilon_{\mathrm{i1,i2,i3}}\mathrm{Wi}_{\mu,\mathrm{i2}}\mathrm{Wi}_{\nu,\mathrm{i3}}\right)\left(-\partial_\nu\left[\mathrm{Wi}_{\mu,\mathrm{i1}}\right]+\partial_\mu\left[\mathrm{Wi}_{\nu,\mathrm{i1}}\right]+g_w\epsilon_{\mathrm{i1,i4,i5}}\mathrm{Wi}_{\mu,\mathrm{i4}}\mathrm{Wi}_{\nu,\mathrm{i5}}\right)$$

4.2 L_2

$$\frac{1}{2}\mu^2(H+v)^2-\frac{1}{4}(H+v)^4\lambda+\frac{e^2(H+v)^2(\mathrm{Wi}_{\mu,1}-i\mathrm{Wi}_{\mu,2})(\mathrm{Wi}_{\mu,1}+i\mathrm{Wi}_{\mu,2})}{8{s_w}^2}+$$
$$\left(\frac{e(H+v)B_\mu}{2\sqrt{2}c_w}-\frac{i\partial_\mu[H]}{\sqrt{2}}-\frac{e(H+v)\mathrm{Wi}_{\mu,3}}{2\sqrt{2}s_w}\right)\left(\frac{e(H+v)B_\mu}{2\sqrt{2}c_w}+\frac{i\partial_\mu[H]}{\sqrt{2}}-\frac{e(H+v)\mathrm{Wi}_{\mu,3}}{2\sqrt{2}s_w}\right)$$

4.3 L_3

$$i\bar{\mathrm{dq}}.\gamma^\mu.\partial_\mu[\mathrm{dq}]+i\bar{l}.\gamma^\mu.\partial_\mu[l]+i\bar{\mathrm{uq}}.\gamma^\mu.\partial_\mu[\mathrm{uq}]+i\bar{\mathrm{vl}}.\gamma^\mu.\partial_\mu[\mathrm{vl}]+\frac{eB_\mu\bar{\mathrm{dq}}.\gamma^\mu.P_-.\mathrm{dq}}{6c_w}-\frac{eB_\mu\bar{\mathrm{dq}}.\gamma^\mu.P_+.\mathrm{dq}}{3c_w}-\frac{eB_\mu\bar{l}.\gamma^\mu.P_-.l}{2c_w}-\frac{eB_\mu\bar{l}.\gamma^\mu.P_+.l}{c_w}+$$
$$\frac{eB_\mu\bar{\mathrm{uq}}.\gamma^\mu.P_-.\mathrm{uq}}{6c_w}+\frac{2eB_\mu\bar{\mathrm{uq}}.\gamma^\mu.P_+.\mathrm{uq}}{3c_w}-\frac{eB_\mu\bar{\mathrm{vl}}.\gamma^\mu.P_-.\mathrm{vl}}{2c_w}+g_s\left(\bar{\mathrm{dq}}.T^a.\gamma^\mu.\mathrm{dq}+\bar{\mathrm{uq}}.T^a.\gamma^\mu.\mathrm{uq}\right)G_{\mu,a}+$$
$$\frac{e\left(\sqrt{2}\bar{\mathrm{vl}}.\gamma^\mu.P_-.lW_\mu+\sqrt{2}\bar{\mathrm{uq}}.\mathrm{CKM}.\gamma^\mu.P_-.\mathrm{dq}W_\mu+\sqrt{2}\bar{l}.\gamma^\mu.P_-.\mathrm{vl}{W_\mu}^\dagger+\sqrt{2}\bar{\mathrm{dq}}.\mathrm{CKM}^\dagger.\gamma^\mu.P_-.\mathrm{uq}{W_\mu}^\dagger-\bar{\mathrm{dq}}.\gamma^\mu.P_-.\mathrm{dq}\mathrm{Wi}_{\mu,3}-\bar{l}.\gamma^\mu.P_-.l\mathrm{Wi}_{\mu,3}+\bar{\mathrm{uq}}.\gamma^\mu.P_-.\mathrm{uq}\mathrm{Wi}_{\mu,3}+\bar{\mathrm{vl}}.\right.}{2s_w}$$

4.4 L_4

$$-\frac{(H+v)\bar{\mathrm{dq}}_{\mathrm{s\$4761,n\$4761,i\$4761}}.\mathrm{dq}_{\mathrm{r\$4761,n\$4761,i\$4761}}P_{+\mathrm{s\$4761,r\$4761}}{y^d}_{\mathrm{n\$4761}}}{\sqrt{2}}-\frac{(H+v)\bar{\mathrm{dq}}_{\mathrm{r\$4763,n\$4762,i\$4762}}.\mathrm{dq}_{\mathrm{r\$4764,n\$4762,i\$4762}}P_{-\mathrm{r\$4763,r\$4764}}{y^d}_{\mathrm{n\$4762}}}{\sqrt{2}}-$$
$$\frac{(H+v)\bar{l}_{\mathrm{s\$4761,n\$4761}}.l_{\mathrm{r\$4761,n\$4761}}P_{+\mathrm{s\$4761,r\$4761}}{y^l}_{\mathrm{n\$4761}}}{\sqrt{2}}-\frac{(H+v)\bar{l}_{\mathrm{r\$4765,n\$4762}}.l_{\mathrm{r\$4766,n\$4762}}P_{-\mathrm{r\$4765,r\$4766}}{y^l}_{\mathrm{n\$4762}}}{\sqrt{2}}-$$
$$\frac{(H+v)\bar{\mathrm{uq}}_{\mathrm{s\$4761,n\$4761,i\$4761}}.\mathrm{uq}_{\mathrm{r\$4761,n\$4761,i\$4761}}P_{+\mathrm{s\$4761,r\$4761}}{y^u}_{\mathrm{n\$4761}}}{\sqrt{2}}-\frac{(H+v)\bar{\mathrm{uq}}_{\mathrm{r\$4767,n\$4762,i\$4762}}.\mathrm{uq}_{\mathrm{r\$4768,n\$4762,i\$4762}}P_{-\mathrm{r\$4767,r\$4768}}{y^u}_{\mathrm{n\$4762}}}{\sqrt{2}}$$

4.5 L_5

$$2\sqrt{2}\left(\bar{\mathrm{dq}}_{s,n,i}.{\mathrm{uq}_{r,m,j}}^C\mathrm{K6bar}[k,i,j]\mathrm{LUDL}_{m,n}P_{-s,r}\mathrm{six1}_k+\bar{\mathrm{dq}}_{s,n,i}.{\mathrm{uq}_{r,m,j}}^C\mathrm{K6bar}[k,i,j]\mathrm{LQQR}_{m,n}P_{+s,r}\mathrm{six1}_k\right)-$$
$$\mathrm{MSIX1}^2\mathrm{six1}_k{\mathrm{six1}_k}^\dagger+\frac{1}{2}\mathrm{LHS1}(H+v)^2\mathrm{six1}_k{\mathrm{six1}_k}^\dagger+$$
$$2\sqrt{2}\left(\mathrm{LQQR}_{m,n}{}^*{\bar{\mathrm{uq}}_{\mathrm{r\$4777},m,j}}^C.\mathrm{dq}_{\mathrm{r\$4778},n,i}\mathrm{K6}[k,i,j]P_{-\mathrm{r\$4777,r\$4778}}{\mathrm{six1}_k}^\dagger+\mathrm{LUDL}_{m,n}{}^*{\bar{\mathrm{uq}}_{\mathrm{r\$4775},m,j}}^C.\mathrm{dq}_{\mathrm{r\$4776},n,i}\mathrm{K6}[k,i,j]P_{+\mathrm{r\$4775,r\$}}\right.$$
$$\mathrm{LSS11six1}_{\mathrm{k1}}\mathrm{six1}_{\mathrm{k2}}{\mathrm{six1}_{\mathrm{k1}}}^\dagger{\mathrm{six1}_{\mathrm{k2}}}^\dagger+2\sqrt{2}\bar{\mathrm{dq}}_{s,n,i}.{\mathrm{dq}_{r,m,j}}^C\mathrm{K6bar}[k,i,j]\mathrm{LDDL}_{m,n}P_{-s,r}\mathrm{six2}_k+$$
$$2\sqrt{2}\mathrm{LDDL}_{m,n}{}^*{\bar{\mathrm{dq}}_{\mathrm{r\$4779},m,j}}^C.\mathrm{dq}_{\mathrm{r\$4780},n,i}\mathrm{K6}[k,i,j]P_{+\mathrm{r\$4779,r\$4780}}{\mathrm{six2}_k}^\dagger-\mathrm{MSIX2}^2\mathrm{six2}_k{\mathrm{six2}_k}^\dagger+\frac{1}{2}\mathrm{LHS2}(H+v)^2\mathrm{six2}_k{\mathrm{six2}_k}^\dagger+$$
$$\mathrm{LSS122six1}_{\mathrm{k2}}{\mathrm{six1}_{\mathrm{k1}}}^\dagger\mathrm{six2}_{\mathrm{k1}}{\mathrm{six2}_{\mathrm{k2}}}^\dagger+\mathrm{LSS121six1}_{\mathrm{k1}}{\mathrm{six1}_{\mathrm{k1}}}^\dagger\mathrm{six2}_{\mathrm{k2}}{\mathrm{six2}_{\mathrm{k2}}}^\dagger+\mathrm{LSS22six2}_{\mathrm{k1}}\mathrm{six2}_{\mathrm{k2}}{\mathrm{six2}_{\mathrm{k1}}}^\dagger{\mathrm{six2}_{\mathrm{k2}}}^\dagger+$$
$$2\sqrt{2}\bar{\mathrm{uq}}_{s,n,i}.{\mathrm{uq}_{r,m,j}}^C\mathrm{K6bar}[k,i,j]\mathrm{LUUL}_{m,n}P_{-s,r}\mathrm{six3}_k+$$
$$2\sqrt{2}\mathrm{LUUL}_{m,n}{}^*{\bar{\mathrm{uq}}_{\mathrm{r\$4781},m,j}}^C.\mathrm{uq}_{\mathrm{r\$4782},n,i}\mathrm{K6}[k,i,j]P_{+\mathrm{r\$4781,r\$4782}}{\mathrm{six3}_k}^\dagger-\mathrm{MSIX2}^2\mathrm{six3}_k{\mathrm{six3}_k}^\dagger+\frac{1}{2}\mathrm{LHS3}(H+v)^2\mathrm{six3}_k{\mathrm{six3}_k}^\dagger+$$
$$\mathrm{LSS132six1}_{\mathrm{k2}}{\mathrm{six1}_{\mathrm{k1}}}^\dagger\mathrm{six3}_{\mathrm{k1}}{\mathrm{six3}_{\mathrm{k2}}}^\dagger+\mathrm{LSS232six2}_{\mathrm{k2}}{\mathrm{six2}_{\mathrm{k1}}}^\dagger\mathrm{six3}_{\mathrm{k1}}{\mathrm{six3}_{\mathrm{k2}}}^\dagger+\mathrm{LSS131six1}_{\mathrm{k1}}{\mathrm{six1}_{\mathrm{k1}}}^\dagger\mathrm{six3}_{\mathrm{k2}}{\mathrm{six3}_{\mathrm{k2}}}^\dagger+$$
$$\mathrm{LSS231six2}_{\mathrm{k1}}{\mathrm{six2}_{\mathrm{k1}}}^\dagger\mathrm{six3}_{\mathrm{k2}}{\mathrm{six3}_{\mathrm{k2}}}^\dagger+\mathrm{LSS33six3}_{\mathrm{k1}}\mathrm{six3}_{\mathrm{k2}}{\mathrm{six3}_{\mathrm{k1}}}^\dagger{\mathrm{six3}_{\mathrm{k2}}}^\dagger+$$
$$\left(\partial_\mu\left[{\mathrm{six1}_k}^\dagger\right]+\frac{1}{3}ig_1B_\mu{\mathrm{six1}_k}^\dagger+ig_sG_{\mu,\mathrm{a\$4769}}{\mathrm{six1}_{\mathrm{i\$4769}}}^\dagger{\mathrm{T6}_{\mathrm{i\$4769},k}}^{\mathrm{a\$4769}}\right)\left(\partial_\mu\left[\mathrm{six1}_k\right]-\frac{1}{3}ig_1B_\mu\mathrm{six1}_k-ig_sG_{\mu,\mathrm{a\$4770}}\mathrm{six1}_{\mathrm{i\$4770}}\mathrm{T6}_{k,\mathrm{i\$4770}}\right.$$
$$\left(\partial_\mu\left[{\mathrm{six2}_k}^\dagger\right]-\frac{2}{3}ig_1B_\mu{\mathrm{six2}_k}^\dagger+ig_sG_{\mu,\mathrm{a\$4771}}{\mathrm{six2}_{\mathrm{i\$4771}}}^\dagger{\mathrm{T6}_{\mathrm{i\$4771},k}}^{\mathrm{a\$4771}}\right)\left(\partial_\mu\left[\mathrm{six2}_k\right]+\frac{2}{3}ig_1B_\mu\mathrm{six2}_k-ig_sG_{\mu,\mathrm{a\$4772}}\mathrm{six2}_{\mathrm{i\$4772}}\mathrm{T6}_{k,\mathrm{i\$4772}}\right.$$
$$\left(\partial_\mu\left[{\mathrm{six3}_k}^\dagger\right]+\frac{4}{3}ig_1B_\mu{\mathrm{six3}_k}^\dagger+ig_sG_{\mu,\mathrm{a\$4773}}{\mathrm{six3}_{\mathrm{i\$4773}}}^\dagger{\mathrm{T6}_{\mathrm{i\$4773},k}}^{\mathrm{a\$4773}}\right)\left(\partial_\mu\left[\mathrm{six3}_k\right]-\frac{4}{3}ig_1B_\mu\mathrm{six3}_k-ig_sG_{\mu,\mathrm{a\$4774}}\mathrm{six3}_{\mathrm{i\$4774}}\mathrm{T6}_{k,\mathrm{i\$4774}}\right.$$

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 found in Tables 9, 10, 11.

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.
ymdo	F		0.			YUKAWA	1		Down Yukawa mass
ymup	F		0.			YUKAWA	2		Up Yukawa mass
yms	F		0.			YUKAWA	3		Strange Yukawa mass
ymc	F		0.			YUKAWA	4		Charm Yukawa mass
ymb	F		4.7			YUKAWA	5		Bottom Yukawa mass
ymt	F		172.			YUKAWA	6		Top Yukawa mass
yme	F		0.			YUKAWA	11		Electron Yukawa mass
ymm	F		0.			YUKAWA	13		Muon Yukawa mass
ymtau	F		1.777			YUKAWA	15		Tau Yukawa mass
θ_c	F		0.227736			CKMBLOCK			Cabibbo angle
LQQRR	F	f, f	$\text{LQQRR}_{1,1} \to 0.1$ $\text{LQQRR}_{1,2} \to 0.$ $\text{LQQRR}_{1,3} \to 0.$ $\text{LQQRR}_{2,1} \to 0.$ $\text{LQQRR}_{2,2} \to 0.1$ $\text{LQQRR}_{2,3} \to 0.$ $\text{LQQRR}_{3,1} \to 0.$ $\text{LQQRR}_{3,2} \to 0.$ $\text{LQQRR}_{3,3} \to 0.1$					QCD, 1	
LQQRI	F	f, f	$\text{LQQRI}_{1,1} \to 0.$ $\text{LQQRI}_{1,2} \to 0.$ $\text{LQQRI}_{1,3} \to 0.$ $\text{LQQRI}_{2,1} \to 0.$ $\text{LQQRI}_{2,2} \to 0.$ $\text{LQQRI}_{2,3} \to 0.$ $\text{LQQRI}_{3,1} \to 0.$ $\text{LQQRI}_{3,2} \to 0.$ $\text{LQQRI}_{3,3} \to 0.$					QCD, 1	
LUDLR	F	f, f	$\text{LUDLR}_{1,1} \to 0.1$ $\text{LUDLR}_{1,2} \to 0.$ $\text{LUDLR}_{1,3} \to 0.$ $\text{LUDLR}_{2,1} \to 0.$ $\text{LUDLR}_{2,2} \to 0.1$ $\text{LUDLR}_{2,3} \to 0.$ $\text{LUDLR}_{3,1} \to 0.$ $\text{LUDLR}_{3,2} \to 0.$					QCD, 1	

Table 9: 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
			$LUDLR_{3,3} \to 0.1$						
LUDLI	F	f, f	$LUDLI_{1,1} \to 0.$					QCD, 1	
			$LUDLI_{1,2} \to 0.$						
			$LUDLI_{1,3} \to 0.$						
			$LUDLI_{2,1} \to 0.$						
			$LUDLI_{2,2} \to 0.$						
			$LUDLI_{2,3} \to 0.$						
			$LUDLI_{3,1} \to 0.$						
			$LUDLI_{3,2} \to 0.$						
			$LUDLI_{3,3} \to 0.$						
LUULR	F	f, f	$LUULR_{1,1} \to 0.1$					QCD, 1	
			$LUULR_{1,2} \to 0.$						
			$LUULR_{1,3} \to 0.$						
			$LUULR_{2,1} \to 0.$						
			$LUULR_{2,2} \to 0.1$						
			$LUULR_{2,3} \to 0.$						
			$LUULR_{3,1} \to 0.$						
			$LUULR_{3,2} \to 0.$						
			$LUULR_{3,3} \to 0.1$						
LUULI	F	f, f	$LUULI_{1,1} \to 0.$					QCD, 1	
			$LUULI_{1,2} \to 0.$						
			$LUULI_{1,3} \to 0.$						
			$LUULI_{2,1} \to 0.$						
			$LUULI_{2,2} \to 0.$						
			$LUULI_{2,3} \to 0.$						
			$LUULI_{3,1} \to 0.$						
			$LUULI_{3,2} \to 0.$						
			$LUULI_{3,3} \to 0.$						
LDDLR	F	f, f	$LDDLR_{1,1} \to 0.1$					QCD, 1	
			$LDDLR_{1,2} \to 0.$						
			$LDDLR_{1,3} \to 0.$						
			$LDDLR_{2,1} \to 0.$						
			$LDDLR_{2,2} \to 0.1$						
			$LDDLR_{2,3} \to 0.$						
			$LDDLR_{3,1} \to 0.$						
			$LDDLR_{3,2} \to 0.$						
			$LDDLR_{3,3} \to 0.1$						

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
LDDLI	F	f, f	$\text{LDDLI}_{1,1} \to 0.$					QCD, 1	
			$\text{LDDLI}_{1,2} \to 0.$						
			$\text{LDDLI}_{1,3} \to 0.$						
			$\text{LDDLI}_{2,1} \to 0.$						
			$\text{LDDLI}_{2,2} \to 0.$						
			$\text{LDDLI}_{2,3} \to 0.$						
			$\text{LDDLI}_{3,1} \to 0.$						
			$\text{LDDLI}_{3,2} \to 0.$						
			$\text{LDDLI}_{3,3} \to 0.$						
LHS1	F		0.1					QED, 2	
LHS2	F		0.1					QED, 2	
LHS3	F		0.1					QED, 2	
LSS11	F		0.1					QCD, 2	
LSS121	F		0.1					QCD, 2	
LSS122	F		0.1					QCD, 2	
LSS131	F		0.1					QCD, 2	
LSS132	F		0.1					QCD, 2	
LSS22	F		0.1					QCD, 2	
LSS231	F		0.1					QCD, 2	
LSS232	F		0.1					QCD, 2	
LSS33	F		0.1					QCD, 2	

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.

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	${y^l}_1 \to 0.$		${y^l}_1 \to$ ye	QED, 1	Lepton Yukawa coupling
				${y^l}_2 \to 0.$		${y^l}_2 \to$ ym		
				${y^l}_3 \to 0.0102065$		${y^l}_3 \to$ ytau		
yu	F	f	Eq. 15	${y^u}_1 \to 0.$		${y^u}_1 \to$ yup	QED, 1	U-quark Yukawa coupling
				${y^u}_2 \to 0.$		${y^u}_2 \to$ yc		
				${y^u}_3 \to 0.987914$		${y^u}_3 \to$ yt		
yd	F	f	Eq. 16	${y^d}_1 \to 0.$		${y^d}_1 \to$ ydo	QED, 1	D-quark Yukawa coupling
				${y^d}_2 \to 0.$		${y^d}_2 \to$ ys		
				${y^d}_3 \to 0.0269953$		${y^d}_3 \to$ yb		
CKM	F	f, f	Eq. 17	$\text{CKM}_{1,1} \to 0.97418$				CKM-Matrix
				$\text{CKM}_{1,2} \to 0.225773$				
				$\text{CKM}_{1,3} \to 0.$				
				$\text{CKM}_{2,1} \to -0.225773$				
				$\text{CKM}_{2,2} \to 0.97418$				
				$\text{CKM}_{2,3} \to 0.$				
				$\text{CKM}_{3,1} \to 0.$				
				$\text{CKM}_{3,2} \to 0.$				
				$\text{CKM}_{3,3} \to 1.$				

Table 12: 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 12, 13, 14. The values and definitions of the internal parameters will be written below.

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

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

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

P	C	I	V	NV	D	PN	IO	Description
LQQR	T	f, f	Eq. 18	$\text{LQQR}_{1,1} \to 0.1 + 0.I$			QCD, 1	
				$\text{LQQR}_{1,2} \to 0. + 0.I$				
				$\text{LQQR}_{1,3} \to 0. + 0.I$				
				$\text{LQQR}_{1,2} \to 0. + 0.I$				
				$\text{LQQR}_{2,2} \to 0.1 + 0.I$				
				$\text{LQQR}_{2,3} \to 0. + 0.I$				
				$\text{LQQR}_{1,3} \to 0. + 0.I$				
				$\text{LQQR}_{2,3} \to 0. + 0.I$				
				$\text{LQQR}_{3,3} \to 0.1 + 0.I$				
LUDL	T	f, f	Eq. 19	$\text{LUDL}_{1,1} \to 0.1 + 0.I$			QCD, 1	
				$\text{LUDL}_{1,2} \to 0. + 0.I$				
				$\text{LUDL}_{1,3} \to 0. + 0.I$				
				$\text{LUDL}_{1,2} \to 0. + 0.I$				
				$\text{LUDL}_{2,2} \to 0.1 + 0.I$				
				$\text{LUDL}_{2,3} \to 0. + 0.I$				
				$\text{LUDL}_{1,3} \to 0. + 0.I$				
				$\text{LUDL}_{2,3} \to 0. + 0.I$				
				$\text{LUDL}_{3,3} \to 0.1 + 0.I$				
LUUL	T	f, f	Eq. 20	$\text{LUUL}_{1,1} \to 0.1 + 0.I$			QCD, 1	
				$\text{LUUL}_{1,2} \to 0. + 0.I$				
				$\text{LUUL}_{1,3} \to 0. + 0.I$				
				$\text{LUUL}_{1,2} \to 0. + 0.I$				
				$\text{LUUL}_{2,2} \to 0.1 + 0.I$				
				$\text{LUUL}_{2,3} \to 0. + 0.I$				
				$\text{LUUL}_{1,3} \to 0. + 0.I$				
				$\text{LUUL}_{2,3} \to 0. + 0.I$				
				$\text{LUUL}_{3,3} \to 0.1 + 0.I$				
LDDL	T	f, f	Eq. 21	$\text{LDDL}_{1,1} \to 0.1 + 0.I$			QCD, 1	
				$\text{LDDL}_{1,2} \to 0. + 0.I$				
				$\text{LDDL}_{1,3} \to 0. + 0.I$				
				$\text{LDDL}_{1,2} \to 0. + 0.I$				
				$\text{LDDL}_{2,2} \to 0.1 + 0.I$				
				$\text{LDDL}_{2,3} \to 0. + 0.I$				

Table 13: 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
				$\text{LDDL}_{1,3} \to 0. + 0.I$				
				$\text{LDDL}_{2,3} \to 0. + 0.I$				
				$\text{LDDL}_{3,3} \to 0.1 + 0.I$				

Table 14: 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.

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

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

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

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

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

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

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

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

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

$$\begin{aligned} {y^l}_1 &= \tfrac{\sqrt{2}\mathrm{yme}}{v} \\ {y^l}_2 &= \tfrac{\sqrt{2}\mathrm{ymm}}{v} \\ {y^l}_3 &= \tfrac{\sqrt{2}\mathrm{ymtau}}{v} \end{aligned} \tag{14}$$

$$\begin{aligned} {y^u}_1 &= \tfrac{\sqrt{2}\mathrm{ymup}}{v} \\ {y^u}_2 &= \tfrac{\sqrt{2}\mathrm{ymc}}{v} \\ {y^u}_3 &= \tfrac{\sqrt{2}\mathrm{ymt}}{v} \end{aligned} \tag{15}$$

$$\begin{aligned} {y^d}_1 &= \tfrac{\sqrt{2}\mathrm{ymdo}}{v} \\ {y^d}_2 &= \tfrac{\sqrt{2}\mathrm{yms}}{v} \\ {y^d}_3 &= \tfrac{\sqrt{2}\mathrm{ymb}}{v} \end{aligned} \tag{16}$$

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

$$\mathrm{LQQR}_{i,j} = i\mathrm{LQQRI}_{i,j} + \mathrm{LQQRR}_{i,j} \tag{18}$$

$$\mathrm{LUDL}_{i,j} = i\mathrm{LUDLI}_{i,j} + \mathrm{LUDLR}_{i,j} \tag{19}$$

$$\mathrm{LUUL}_{i,j} = i\mathrm{LUULI}_{i,j} + \mathrm{LUULR}_{i,j} \tag{20}$$

$$\mathrm{LDDL}_{i,j} = i\mathrm{LDDLI}_{i,j} + \mathrm{LDDLR}_{i,j} \tag{21}$$

References

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