FeynRules Implementation of 1HDpSM_NoCKM_ggH

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Abstract

We describe the implementation of the 1HDpSM_NoCKM_ggH model using the FeynRules package.

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1 Introduction

We describe the implementation of the 1HDpSM_NoCKM_ggH 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		$Ta_{k,k}$ $FSU2L_{j,j}$ $FSU2L_{j,j}$	FSU2L[a$_, b$_, c$_] → -I Eps[a$, b$, PauliSigma[a, b, c] Ta[a,b,c] → ——— PauliSigma[a, b, c] Ta[a,b,c] → ——— FSU2L[i,j,k] :> $IEps[i, j, k]$
SU3C	F	G	gs		f	dSUN	$T_{m,m}$ $FSU3C_{a,a}$	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
Gluon	a	1-8
SU2W	j	1-3
Generation	f	1-3
Colour	m	1-3
SU2D	k	1-2

Table 2: Definition of the indices.

3 Fields

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

3.1 Scalar Fields

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

Class	SC	I	FI	QN	Mem	M	W	PDG
G0	T				G0	MZ= 91.1876	WZ= 2.4952	250
GP	F			$Q = 1$	GP	MW= Internal	WW= 2.085	251
H	T				H	MH= 125.	WH= 1	
								25
S	T				S	MS= 250.	WS= 0.407	

Table 3: 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.

The details of the unphysical scalars can be found in Table 4.

Class	SC	I	FI	QN	Mem	Definitions
Phi1	F	k	k	$Y = 1/2$	Phi1	$\text{Phi1}_1 \to -i\text{GP}$
						$\text{Phi1}_2 \to \frac{i\text{G0}+c_\alpha H+S s_\alpha+\text{vev}}{\sqrt{2}}$
SH0	T				SH0	$\text{SH0} \to \frac{c_\alpha S+\text{sev}-H s_\alpha}{\sqrt{2}}$

Table 4: Details of unphysical scalar 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. The details of the unphysical fermions can be found in Table 6.

3.3 Vector Fields

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

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 9. The details of the unphysical ghosts can be found in Table 10.

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
					mu	MMU= 0.10566		13
					ta	MTA= 1.777		15
uq	F	f, m	f	$Q = 2/3$		Mu		
					u	MU= 0.00255	0	2
					c	MC= 1.27	0	4
					t	MT= 172	WT= 1.50834	6
dq	F	f, m	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	Definitions
LL	F	k, f	k	$Y = -1/2$	LL	$\mathrm{LL}_{\mathrm{sp1,1,ff}} :\to \mathrm{Module}\left[\{\mathrm{sp2}\}, P_{-\mathrm{sp1,sp2}}\mathrm{vl}_{\mathrm{sp2,ff}}\right]$
						$\mathrm{LL}_{\mathrm{sp1,2,ff}} :\to \mathrm{Module}\left[\{\mathrm{sp2}\}, P_{-\mathrm{sp1,sp2}}l_{\mathrm{sp2,ff}}\right]$
lR	F	f	f	$Y = -1$	lR	$\mathrm{lR}_{\mathrm{sp1,ff}} :\to \mathrm{Module}\left[\{\mathrm{sp2}\}, P_{+\mathrm{sp1,sp2}}l_{\mathrm{sp2,ff}}\right]$
QL	F	k, f, m	k	$Y = 1/6$	QL	$\mathrm{QL}_{\mathrm{sp1,1,ff,cc}} :\to \mathrm{Module}\left[\{\mathrm{sp2}\}, P_{-\mathrm{sp1,sp2}}\mathrm{uq}_{\mathrm{sp2,ff,cc}}\right]$
						$\mathrm{QL}_{\mathrm{sp1,2,ff,cc}} :\to \mathrm{Module}\left[\{\mathrm{sp2,ff2}\}, V^{\mathrm{CKM}}{}_{\mathrm{ff,ff2}}P_{-\mathrm{sp1,sp2}}\mathrm{dq}_{\mathrm{sp2,ff2,cc}}\right]$
uR	F	f, m	f	$Y = 2/3$	uR	$\mathrm{uR}_{\mathrm{sp1,ff,cc}} :\to \mathrm{Module}\left[\{\mathrm{sp2}\}, P_{+\mathrm{sp1,sp2}}\mathrm{uq}_{\mathrm{sp2,ff,cc}}\right]$
dR	F	f, m	f	$Y = -1/3$	dR	$\mathrm{dR}_{\mathrm{sp1,ff,cc}} :\to \mathrm{Module}\left[\{\mathrm{sp2}\}, P_{+\mathrm{sp1,sp2}}\mathrm{dq}_{\mathrm{sp2,ff,cc}}\right]$

Table 6: Details of unphysical fermion fields. The headers are as follows: SC = self conjugate, I = indices, FI = flavor index, QN = quantum numbers, and Mem = members.

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 7: 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.

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

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

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			$GhostNumber = 1$ $Q = 1$	ghWp	MW= Internal		
ghWm	F			$GhostNumber = 1$ $Q = -1$	ghWm	MW= Internal		
ghG	F	a		$GhostNumber = 1$	ghG	0		82

Table 9: 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
ghB	F				ghB	$\mathrm{ghB} \to c_w \mathrm{ghA} - \mathrm{ghZ} s_w$
ghWi	F	j	j		ghWi	$\mathrm{ghWi}_1 \to \frac{\mathrm{ghWm} + \mathrm{ghWp}}{\sqrt{2}}$ $\mathrm{ghWi}_2 \to -\frac{i(\mathrm{ghWm} - \mathrm{ghWp})}{\sqrt{2}}$ $\mathrm{ghWi}_3 \to c_w \mathrm{ghZ} + \mathrm{ghA} s_w$

Table 10: 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 Parameters

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

4.1 External Parameters

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

P	C	I	V	D	PN	BN	OB	IO	Description
αEWM1	F		127.9		aEWM1	SMINPUTS		QED, -2	Inverse of the electroweak coupling constant
Gf	F		0.0000116639			SMINPUTS		QED, 2	Fermi constant
αS	F		0.118		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.			CKMBLOCK	1		Cabibbo angle
s_α	F		0.3		s_α				sine of the scalar mixing angle
tgβ	F		3.		tgβ				tgb = vev/sev
AA$_H$	F		0.001					HIW, 1	Effective AAH coupling
GG$_H$	F		0.001					HIG, 1	Effective GGH coupling

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.

Table 11.

4.2 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 co
M_W	F		Eq. 3	79.8247				W mass
sw2	F		Eq. 4	0.233693				Squared Sin of angle
e	F		Eq. 5	0.313451			QED, 1	Electric couplin
c_w	F		Eq. 6	0.875389				Cos of the Wei
s_w	F		Eq. 7	0.483418				Sin of the Wei
g_w	F		Eq. 8	0.648405	$g_w \to \frac{e}{s_w}$		QED, 1	Weak coupling
g_1	F		Eq. 9	0.35807	$g_1 \to \frac{e}{c_w}$		QED, 1	U(1)Y coupling
g_s	F		Eq. 10	1.21772		G	QCD, 1	Strong coupling
vev	F		Eq. 11	246.218	$\text{vev} \to \frac{2M_W s_w}{e}$		QED, -1	Higgs VEV
sev	F		Eq. 12	82.0728	$\text{sev} \to \frac{\text{vev}}{\text{tg}\beta}$		QED, -1	Singlet VEV
CKM	F	f, f	Eq. 13	${V^{\rm CKM}}_{1,1} \to 1.$ ${V^{\rm CKM}}_{1,2} \to 0.$ ${V^{\rm CKM}}_{1,3} \to 0.$ ${V^{\rm CKM}}_{2,1} \to 0.$ ${V^{\rm CKM}}_{2,2} \to 1.$ ${V^{\rm CKM}}_{2,3} \to 0.$ ${V^{\rm CKM}}_{3,1} \to 0.$ ${V^{\rm CKM}}_{3,2} \to 0.$ ${V^{\rm CKM}}_{3,3} \to 1.$	${V^{\rm CKM}}_{i,i} \to 1$ ${V^{\rm CKM}}_{i?\text{NumericQ},j?\text{NumericQ}} :\to 0/;i{=}!{=}j$			CKM-Matrix
yu	F	f, f	Eq. 14	${y^u}_{1,1} \to 0.$ ${y^u}_{1,2} \to 0.$ ${y^u}_{1,3} \to 0.$ ${y^u}_{2,1} \to 0.$ ${y^u}_{2,2} \to 0.$ ${y^u}_{2,3} \to 0.$ ${y^u}_{3,1} \to 0.$ ${y^u}_{3,2} \to 0.$ ${y^u}_{3,3} \to 0.987922$	${y^u}_{i?\text{NumericQ},j?\text{NumericQ}} :\to 0/;i{=}!{=}j$	${y^u}_{1,1} \to \text{yup}$ ${y^u}_{2,2} \to \text{yc}$ ${y^u}_{3,3} \to \text{yt}$	QED, 1	Up-type Yukaw

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.

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

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

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

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

P	C	I	V	NV	D	PN	IO	Description
yd	F	f, f	Eq. 15	${y^d}_{1,1} \to 0.$ ${y^d}_{1,2} \to 0.$ ${y^d}_{1,3} \to 0.$ ${y^d}_{2,1} \to 0.$ ${y^d}_{2,2} \to 0.$ ${y^d}_{2,3} \to 0.$ ${y^d}_{3,1} \to 0.$ ${y^d}_{3,2} \to 0.$ ${y^d}_{3,3} \to 0.0269956$	${y^d}_{i\text{?NumericQ},j\text{?NumericQ}} :\to 0/;i\text{=!=}j$	${y^d}_{1,1} \to \text{ydo}$ ${y^d}_{2,2} \to \text{ys}$ ${y^d}_{3,3} \to \text{yb}$	QED, 1	Down-type Yukawa c
yl	F	f, f	Eq. 16	${y^l}_{1,1} \to 0.$ ${y^l}_{1,2} \to 0.$ ${y^l}_{1,3} \to 0.$ ${y^l}_{2,1} \to 0.$ ${y^l}_{2,2} \to 0.$ ${y^l}_{2,3} \to 0.$ ${y^l}_{3,1} \to 0.$ ${y^l}_{3,2} \to 0.$ ${y^l}_{3,3} \to 0.0102066$	${y^l}_{i\text{?NumericQ},j\text{?NumericQ}} :\to 0/;i\text{=!=}j$	${y^l}_{1,1} \to \text{ye}$ ${y^l}_{2,2} \to \text{ym}$ ${y^l}_{3,3} \to \text{ytau}$	QED, 1	Lepton Yukawa coup
c_α	F		Eq. 17	0.953939		c_α		cosine of the scalar m angle
μ_H	F		Eq. 18	12157.7	$\mu_H \to \frac{\lambda_3 \text{sev}^2}{2} + \lambda_1 \text{vev}^2$	μ_H		Coefficient of the qua piece of the Higgs po
μ_S	F		Eq. 19	49262.8	$\mu_S \to \lambda_2 \text{sev}^2 + \frac{\lambda_3 \text{vev}^2}{2}$	μ_S		Coefficient of the qua piece of the Singlet p
λ_1	F		Eq. 20	0.163664	$\lambda_1 \to \frac{{c_\alpha}^2 \text{MH}^2 + \text{MS}^2 {s_\alpha}^2}{2\text{vev}^2}$	λ_1	QED, 2	Higgs quartic couplin
λ_2	F		Eq. 21	4.32614	$\lambda_2 \to \frac{{c_\alpha}^2 \text{MS}^2 + \text{MH}^2 {s_\alpha}^2}{2\text{sev}^2}$	λ_2	QED, 2	Singlet quartic coupl
λ_3	F		Eq. 22	0.66384	$\lambda_3 \to \frac{c_\alpha \left(-\text{MH}^2 + \text{MS}^2\right) s_\alpha}{\text{sevvev}}$	λ_3	QED, 2	Higgs-Singlet quartic coupling

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

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.

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

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

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

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

$$g_s = 2\sqrt{\pi}\sqrt{\alpha\text{S}} \tag{10}$$

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

$$\text{sev} = \frac{\text{vev}}{\text{tg}\beta} \tag{12}$$

$$\begin{aligned} V^{\text{CKM}}{}_{1,1} &= \text{Cos}\left[\theta_c\right] \\ V^{\text{CKM}}{}_{1,2} &= \text{Sin}\left[\theta_c\right] \\ V^{\text{CKM}}{}_{1,3} &= 0 \\ V^{\text{CKM}}{}_{2,1} &= -\text{Sin}\left[\theta_c\right] \\ V^{\text{CKM}}{}_{2,2} &= \text{Cos}\left[\theta_c\right] \\ V^{\text{CKM}}{}_{2,3} &= 0 \\ V^{\text{CKM}}{}_{3,1} &= 0 \\ V^{\text{CKM}}{}_{3,2} &= 0 \\ V^{\text{CKM}}{}_{3,3} &= 1 \end{aligned} \tag{13}$$

$$\begin{aligned} y^u{}_{1,1} &= \tfrac{\sqrt{2}\text{ymup}}{\text{vev}} \\ y^u{}_{2,2} &= \tfrac{\sqrt{2}\text{ymc}}{\text{vev}} \\ y^u{}_{3,3} &= \tfrac{\sqrt{2}\text{ymt}}{\text{vev}} \end{aligned} \tag{14}$$

$$\begin{aligned} y^d{}_{1,1} &= \tfrac{\sqrt{2}\text{ymdo}}{\text{vev}} \\ y^d{}_{2,2} &= \tfrac{\sqrt{2}\text{yms}}{\text{vev}} \\ y^d{}_{3,3} &= \tfrac{\sqrt{2}\text{ymb}}{\text{vev}} \end{aligned} \tag{15}$$

$$\begin{aligned} y^l{}_{1,1} &= \tfrac{\sqrt{2}\text{yme}}{\text{vev}} \\ y^l{}_{2,2} &= \tfrac{\sqrt{2}\text{ymm}}{\text{vev}} \\ y^l{}_{3,3} &= \tfrac{\sqrt{2}\text{ymtau}}{\text{vev}} \end{aligned} \tag{16}$$

$$c_\alpha = \sqrt{1 - s_\alpha{}^2} \tag{17}$$

$$\mu_H = \frac{\lambda_3 \text{sev}^2}{2} + \lambda_1 \text{vev}^2 \tag{18}$$

$$\mu_S = \lambda_2 \text{sev}^2 + \frac{\lambda_3 \text{vev}^2}{2} \tag{19}$$

$$\lambda_1 = \frac{c_\alpha{}^2 \text{MH}^2 + \text{MS}^2 s_\alpha{}^2}{2\text{vev}^2} \tag{20}$$

$$\lambda_2 = \frac{c_\alpha{}^2 \text{MS}^2 + \text{MH}^2 s_\alpha{}^2}{2\text{sev}^2} \tag{21}$$

$$\lambda_3 = \frac{c_\alpha \left(-\text{MH}^2 + \text{MS}^2\right) s_\alpha}{\text{sevvev}} \tag{22}$$

5 Vertices

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

5.1 $V_{\textbf{Gauge}}$

$$\begin{pmatrix} G & 1 \\ G & 2 \\ G & 3 \end{pmatrix} \qquad g_s f_{\mathrm{a}_1,\mathrm{a}_2,\mathrm{a}_3} \mathrm{p}_1{}^{\mu_3} \eta_{\mu_1,\mu_2} - g_s f_{\mathrm{a}_1,\mathrm{a}_2,\mathrm{a}_3} \mathrm{p}_2{}^{\mu_3} \eta_{\mu_1,\mu_2} - g_s f_{\mathrm{a}_1,\mathrm{a}_2,\mathrm{a}_3} \mathrm{p}_1{}^{\mu_2} \eta_{\mu_1,\mu_3} + g_s f_{\mathrm{a}_1,\mathrm{a}_2,\mathrm{a}_3} \mathrm{p}_3{}^{\mu_2} \eta_{\mu_1,\mu_3} + g_s f_{\mathrm{a}_1,\mathrm{a}_2,\mathrm{a}_3} \mathrm{p}_2{}^{\mu_1} \eta_{\mu_2,\mu_3} - g_s f_{\mathrm{a}_1,\mathrm{a}_2,\mathrm{a}_3} \mathrm{p}_3{}^{\mu_1} \eta_{\mu_2,\mu_3}$$

$$\begin{pmatrix} G & 1 \\ G & 2 \\ G & 3 \\ G & 4 \end{pmatrix} \qquad i{g_s}^2 f_{\mathrm{a}_1,\mathrm{a}_3,\mathrm{Gluon\$1}} f_{\mathrm{a}_2,\mathrm{a}_4,\mathrm{Gluon\$1}} \eta_{\mu_1,\mu_4} \eta_{\mu_2,\mu_3} + i{g_s}^2 f_{\mathrm{a}_1,\mathrm{a}_2,\mathrm{Gluon\$1}} f_{\mathrm{a}_3,\mathrm{a}_4,\mathrm{Gluon\$1}} \eta_{\mu_1,\mu_4} \eta_{\mu_2,\mu_3} + i{g_s}^2 f_{\mathrm{a}_1,\mathrm{a}_4,\mathrm{Gluon\$1}} f_{\mathrm{a}_2,\mathrm{a}_3,\mathrm{Gluon\$1}} \eta_{\mu_1,\mu_3} \eta_{\mu_2,\mu_4} - i{g_s}^2 f_{\mathrm{a}_1,\mathrm{a}_2,\mathrm{Gluon\$1}} f_{\mathrm{a}_3,\mathrm{a}_4,\mathrm{Gluon\$1}} \eta_{\mu_1,\mu_3} \eta_{\mu_2,\mu_4} - i{g_s}^2 f_{\mathrm{a}_1,\mathrm{a}_4,\mathrm{Gluon\$1}} f_{\mathrm{a}_2,\mathrm{a}_3,\mathrm{Gluon\$1}} \eta_{\mu_1,\mu_2} \eta_{\mu_3,\mu_4} - i{g_s}^2 f_{\mathrm{a}_1,\mathrm{a}_3,\mathrm{Gluon\$1}} f_{\mathrm{a}_2,\mathrm{a}_4,\mathrm{Gluon\$1}} \eta_{\mu_1,\mu_2} \eta_{\mu_3,\mu_4}$$

$$\begin{pmatrix} A & 1 \\ W & 2 \\ W^\dagger & 3 \end{pmatrix} \qquad -ie\mathrm{p}_1{}^{\mu_3}\eta_{\mu_1,\mu_2} + ie\mathrm{p}_2{}^{\mu_3}\eta_{\mu_1,\mu_2} + ie\mathrm{p}_1{}^{\mu_2}\eta_{\mu_1,\mu_3} - ie\mathrm{p}_3{}^{\mu_2}\eta_{\mu_1,\mu_3} - ie\mathrm{p}_2{}^{\mu_1}\eta_{\mu_2,\mu_3} + ie\mathrm{p}_3{}^{\mu_1}\eta_{\mu_2,\mu_3}$$

$$\begin{pmatrix} A & 1 \\ A & 2 \\ W & 3 \\ W^\dagger & 4 \end{pmatrix} \qquad ie^2\eta_{\mu_1,\mu_4}\eta_{\mu_2,\mu_3} + ie^2\eta_{\mu_1,\mu_3}\eta_{\mu_2,\mu_4} - 2ie^2\eta_{\mu_1,\mu_2}\eta_{\mu_3,\mu_4}$$

$$\begin{pmatrix} W & 1 \\ W^\dagger & 2 \\ Z & 3 \end{pmatrix} \qquad -\frac{ic_w e\mathrm{p}_1{}^{\mu_3}\eta_{\mu_1,\mu_2}}{s_w} + \frac{ic_w e\mathrm{p}_2{}^{\mu_3}\eta_{\mu_1,\mu_2}}{s_w} + \frac{ic_w e\mathrm{p}_1{}^{\mu_2}\eta_{\mu_1,\mu_3}}{s_w} - \frac{ic_w e\mathrm{p}_3{}^{\mu_2}\eta_{\mu_1,\mu_3}}{s_w} - \frac{ic_w e\mathrm{p}_2{}^{\mu_1}\eta_{\mu_2,\mu_3}}{s_w} + \frac{ic_w e\mathrm{p}_3{}^{\mu_1}\eta_{\mu_2,\mu_3}}{s_w}$$

$$\begin{pmatrix} W & 1 \\ W & 2 \\ W^\dagger & 3 \\ W^\dagger & 4 \end{pmatrix} \qquad -\frac{ie^2\eta_{\mu_1,\mu_4}\eta_{\mu_2,\mu_3}}{{s_w}^2} - \frac{ie^2\eta_{\mu_1,\mu_3}\eta_{\mu_2,\mu_4}}{{s_w}^2} + \frac{2ie^2\eta_{\mu_1,\mu_2}\eta_{\mu_3,\mu_4}}{{s_w}^2}$$

$$\begin{pmatrix} A & 1 \\ W & 2 \\ W^\dagger & 3 \\ Z & 4 \end{pmatrix} \qquad -\frac{2ic_w e^2\eta_{\mu_1,\mu_4}\eta_{\mu_2,\mu_3}}{s_w} + \frac{ic_w e^2\eta_{\mu_1,\mu_3}\eta_{\mu_2,\mu_4}}{s_w} + \frac{ic_w e^2\eta_{\mu_1,\mu_2}\eta_{\mu_3,\mu_4}}{s_w}$$

$$\begin{pmatrix} W & 1 \\ W^\dagger & 2 \\ Z & 3 \\ Z & 4 \end{pmatrix} \qquad \frac{i{c_w}^2 e^2\eta_{\mu_1,\mu_4}\eta_{\mu_2,\mu_3}}{{s_w}^2} + \frac{i{c_w}^2 e^2\eta_{\mu_1,\mu_3}\eta_{\mu_2,\mu_4}}{{s_w}^2} - \frac{2i{c_w}^2 e^2\eta_{\mu_1,\mu_2}\eta_{\mu_3,\mu_4}}{{s_w}^2}$$

5.2 $V_{\textbf{Higgs}}$

$$\begin{pmatrix} H & 1 \\ H & 2 \\ H & 3 \\ H & 4 \end{pmatrix} \qquad -\frac{3i{c_\alpha}^6 e^2\mathrm{MH}^2}{4{M_W}^2{s_w}^2} - \frac{3i{c_\alpha}^4 e^2\mathrm{MS}^2{s_\alpha}^2}{4{M_W}^2{s_w}^2} + \frac{3i{c_\alpha}^3 e^2\mathrm{MH}^2{s_\alpha}^3\mathrm{tg}\beta}{2{M_W}^2{s_w}^2} - \frac{3i{c_\alpha}^3 e^2\mathrm{MS}^2{s_\alpha}^3\mathrm{tg}\beta}{2{M_W}^2{s_w}^2} - \frac{3i{c_\alpha}^2 e^2\mathrm{MS}^2{s_\alpha}^4\mathrm{tg}\beta^2}{4{M_W}^2{s_w}^2} - \frac{3ie^2\mathrm{MH}^2{s_\alpha}^6\mathrm{tg}\beta^2}{4{M_W}^2{s_w}^2}$$

$$\begin{pmatrix} H & 1 \\ H & 2 \\ H & 3 \\ S & 4 \end{pmatrix} \qquad -\frac{3i{c_\alpha}^5 e^2\mathrm{MH}^2 s_\alpha}{4{M_W}^2{s_w}^2} - \frac{3i{c_\alpha}^3 e^2\mathrm{MS}^2{s_\alpha}^3}{4{M_W}^2{s_w}^2} - \frac{3i{c_\alpha}^4 e^2\mathrm{MH}^2{s_\alpha}^2\mathrm{tg}\beta}{4{M_W}^2{s_w}^2} + \frac{3i{c_\alpha}^4 e^2\mathrm{MS}^2{s_\alpha}^2\mathrm{tg}\beta}{4{M_W}^2{s_w}^2} + \frac{3i{c_\alpha}^2 e^2\mathrm{MH}^2{s_\alpha}^4\mathrm{tg}\beta}{4{M_W}^2{s_w}^2} - \frac{3i{c_\alpha}^2 e^2\mathrm{MS}^2{s_\alpha}^4\mathrm{tg}\beta}{4{M_W}^2{s_w}^2} + \frac{3i{c_\alpha}^3 e^2\mathrm{MS}^2{s_\alpha}^3\mathrm{tg}\beta^2}{4{M_W}^2{s_w}^2} + \frac{3ic_\alpha e^2\mathrm{MH}^2{s_\alpha}^5\mathrm{tg}\beta^2}{4{M_W}^2{s_w}^2}$$

$$\begin{pmatrix} H & 1 \\ H & 2 \\ S & 3 \\ S & 4 \end{pmatrix} \quad -\frac{3ic_\alpha{}^4e^2\mathrm{MH}^2s_\alpha{}^2}{4M_W{}^2s_w{}^2}-\frac{3ic_\alpha{}^2e^2\mathrm{MS}^2s_\alpha{}^4}{4M_W{}^2s_w{}^2}+\frac{ic_\alpha{}^5e^2\mathrm{MH}^2s_\alpha\mathrm{tg}\beta}{4M_W{}^2s_w{}^2}-\frac{ic_\alpha{}^5e^2\mathrm{MS}^2s_\alpha\mathrm{tg}\beta}{4M_W{}^2s_w{}^2}-\frac{ic_\alpha{}^3e^2\mathrm{MH}^2s_\alpha{}^3\mathrm{tg}\beta}{M_W{}^2s_w{}^2}+\frac{ic_\alpha{}^3e^2\mathrm{MS}^2s_\alpha{}^3\mathrm{tg}\beta}{M_W{}^2s_w{}^2}+\frac{ic_\alpha e^2\mathrm{MH}^2s_\alpha{}^5\mathrm{tg}\beta}{4M_W{}^2s_w{}^2}-\frac{ic_\alpha e^2\mathrm{MS}^2s_\alpha{}^5\mathrm{tg}\beta}{4M_W{}^2s_w{}^2}-\frac{3ic_\alpha{}^4e^2\mathrm{MS}^2s_\alpha{}^2\mathrm{tg}\beta^2}{4M_W{}^2s_w{}^2}-\frac{3ic_\alpha{}^2e^2\mathrm{MH}^2s_\alpha{}^4\mathrm{tg}\beta^2}{4M_W{}^2s_w{}^2}$$

$$\begin{pmatrix} H & 1 \\ S & 2 \\ S & 3 \\ S & 4 \end{pmatrix} \quad -\frac{3ic_\alpha{}^3e^2\mathrm{MH}^2s_\alpha{}^3}{4M_W{}^2s_w{}^2}-\frac{3ic_\alpha e^2\mathrm{MS}^2s_\alpha{}^5}{4M_W{}^2s_w{}^2}+\frac{3ic_\alpha{}^4e^2\mathrm{MH}^2s_\alpha{}^2\mathrm{tg}\beta}{4M_W{}^2s_w{}^2}-\frac{3ic_\alpha{}^4e^2\mathrm{MS}^2s_\alpha{}^2\mathrm{tg}\beta}{4M_W{}^2s_w{}^2}-\frac{3ic_\alpha{}^2e^2\mathrm{MH}^2s_\alpha{}^4\mathrm{tg}\beta}{4M_W{}^2s_w{}^2}+\frac{3ic_\alpha{}^2e^2\mathrm{MS}^2s_\alpha{}^4\mathrm{tg}\beta}{4M_W{}^2s_w{}^2}+\frac{3ic_\alpha{}^5e^2\mathrm{MS}^2s_\alpha\mathrm{tg}\beta^2}{4M_W{}^2s_w{}^2}+\frac{3ic_\alpha{}^3e^2\mathrm{MH}^2s_\alpha{}^3\mathrm{tg}\beta^2}{4M_W{}^2s_w{}^2}$$

$$\begin{pmatrix} S & 1 \\ S & 2 \\ S & 3 \\ S & 4 \end{pmatrix} \quad -\frac{3ic_\alpha{}^2e^2\mathrm{MH}^2s_\alpha{}^4}{4M_W{}^2s_w{}^2}-\frac{3ie^2\mathrm{MS}^2s_\alpha{}^6}{4M_W{}^2s_w{}^2}+\frac{3ic_\alpha{}^3e^2\mathrm{MH}^2s_\alpha{}^3\mathrm{tg}\beta}{2M_W{}^2s_w{}^2}-\frac{3ic_\alpha{}^3e^2\mathrm{MS}^2s_\alpha{}^3\mathrm{tg}\beta}{2M_W{}^2s_w{}^2}-\frac{3ic_\alpha{}^6e^2\mathrm{MS}^2\mathrm{tg}\beta^2}{4M_W{}^2s_w{}^2}-\frac{3ic_\alpha{}^4e^2\mathrm{MH}^2s_\alpha{}^2\mathrm{tg}\beta^2}{4M_W{}^2s_w{}^2}$$

$$\begin{pmatrix} H & 1 \\ H & 2 \\ H & 3 \end{pmatrix} \quad -\frac{3ic_\alpha{}^5e\mathrm{MH}^2}{2M_Ws_w}-\frac{3ic_\alpha{}^3e\mathrm{MH}^2s_\alpha{}^2}{2M_Ws_w}+\frac{3ic_\alpha{}^2e\mathrm{MH}^2s_\alpha{}^3\mathrm{tg}\beta}{2M_Ws_w}+\frac{3ie\mathrm{MH}^2s_\alpha{}^5\mathrm{tg}\beta}{2M_Ws_w}$$

$$\begin{pmatrix} H & 1 \\ H & 2 \\ S & 3 \end{pmatrix} \quad -\frac{ic_\alpha{}^4e\mathrm{MH}^2s_\alpha}{M_Ws_w}-\frac{ic_\alpha{}^4e\mathrm{MS}^2s_\alpha}{2M_Ws_w}-\frac{ic_\alpha{}^2e\mathrm{MH}^2s_\alpha{}^3}{M_Ws_w}-\frac{ic_\alpha{}^2e\mathrm{MS}^2s_\alpha{}^3}{2M_Ws_w}-\frac{ic_\alpha{}^3e\mathrm{MH}^2s_\alpha{}^2\mathrm{tg}\beta}{M_Ws_w}-\frac{ic_\alpha{}^3e\mathrm{MS}^2s_\alpha{}^2\mathrm{tg}\beta}{2M_Ws_w}-\frac{ic_\alpha e\mathrm{MH}^2s_\alpha{}^4\mathrm{tg}\beta}{M_Ws_w}-\frac{ic_\alpha e\mathrm{MS}^2s_\alpha{}^4\mathrm{tg}\beta}{2M_Ws_w}$$

$$\begin{pmatrix} H & 1 \\ S & 2 \\ S & 3 \end{pmatrix} \quad -\frac{ic_\alpha{}^3e\mathrm{MH}^2s_\alpha{}^2}{2M_Ws_w}-\frac{ic_\alpha{}^3e\mathrm{MS}^2s_\alpha{}^2}{M_Ws_w}-\frac{ic_\alpha e\mathrm{MH}^2s_\alpha{}^4}{2M_Ws_w}-\frac{ic_\alpha e\mathrm{MS}^2s_\alpha{}^4}{M_Ws_w}+\frac{ic_\alpha{}^4e\mathrm{MH}^2s_\alpha\mathrm{tg}\beta}{2M_Ws_w}+\frac{ic_\alpha{}^4e\mathrm{MS}^2s_\alpha\mathrm{tg}\beta}{M_Ws_w}+\frac{ic_\alpha{}^2e\mathrm{MH}^2s_\alpha{}^3\mathrm{tg}\beta}{2M_Ws_w}+\frac{ic_\alpha{}^2e\mathrm{MS}^2s_\alpha{}^3\mathrm{tg}\beta}{M_Ws_w}$$

$$\begin{pmatrix} S & 1 \\ S & 2 \\ S & 3 \end{pmatrix} \quad -\frac{3ic_\alpha{}^2e\mathrm{MS}^2s_\alpha{}^3}{2M_Ws_w}-\frac{3ie\mathrm{MS}^2s_\alpha{}^5}{2M_Ws_w}-\frac{3ic_\alpha{}^5e\mathrm{MS}^2\mathrm{tg}\beta}{2M_Ws_w}-\frac{3ic_\alpha{}^3e\mathrm{MS}^2s_\alpha{}^2\mathrm{tg}\beta}{2M_Ws_w}$$

$$\begin{pmatrix} H & 1 \\ H & 2 \\ W & 3 \\ W^\dagger & 4 \end{pmatrix} \quad \frac{ic_\alpha{}^2e^2\eta_{\mu_3,\mu_4}}{2s_w{}^2}$$

$$\begin{pmatrix} H & 1 \\ S & 2 \\ W & 3 \\ W^\dagger & 4 \end{pmatrix} \quad \frac{ic_\alpha e^2s_\alpha\eta_{\mu_3,\mu_4}}{2s_w{}^2}$$

$$\begin{pmatrix} S & 1 \\ S & 2 \\ W & 3 \\ W^\dagger & 4 \end{pmatrix} \quad \frac{ie^2s_\alpha{}^2\eta_{\mu_3,\mu_4}}{2s_w{}^2}$$

$$\begin{pmatrix} H & 1 \\ W & 2 \\ W^\dagger & 3 \end{pmatrix} \quad \frac{ic_\alpha eM_W\eta_{\mu_2,\mu_3}}{s_w}$$

$$\begin{pmatrix} S & 1 \\ W & 2 \\ W^\dagger & 3 \end{pmatrix} \quad \frac{ieM_Ws_\alpha\eta_{\mu_2,\mu_3}}{s_w}$$

$$\begin{pmatrix} H & 1 \\ H & 2 \\ Z & 3 \\ Z & 4 \end{pmatrix} \quad ic_\alpha{}^2e^2\eta_{\mu_3,\mu_4}+\frac{ic_\alpha{}^2c_w{}^2e^2\eta_{\mu_3,\mu_4}}{2s_w{}^2}+\frac{ic_\alpha{}^2e^2s_w{}^2\eta_{\mu_3,\mu_4}}{2c_w{}^2}$$

$$\begin{pmatrix} H & 1 \\ S & 2 \\ Z & 3 \\ Z & 4 \end{pmatrix} \qquad ic_\alpha e^2 s_\alpha \eta_{\mu_3,\mu_4} + \frac{ic_\alpha {c_w}^2 e^2 s_\alpha \eta_{\mu_3,\mu_4}}{2{s_w}^2} + \frac{ic_\alpha e^2 s_\alpha {s_w}^2 \eta_{\mu_3,\mu_4}}{2{c_w}^2}$$

$$\begin{pmatrix} S & 1 \\ S & 2 \\ Z & 3 \\ Z & 4 \end{pmatrix} \qquad ie^2 {s_\alpha}^2 \eta_{\mu_3,\mu_4} + \frac{i{c_w}^2 e^2 {s_\alpha}^2 \eta_{\mu_3,\mu_4}}{2{s_w}^2} + \frac{ie^2 {s_\alpha}^2 {s_w}^2 \eta_{\mu_3,\mu_4}}{2{c_w}^2}$$

$$\begin{pmatrix} H & 1 \\ Z & 2 \\ Z & 3 \end{pmatrix} \qquad \frac{ic_\alpha {c_w}^2 e M_W \eta_{\mu_2,\mu_3}}{s_w} + 2ic_\alpha e M_W s_w \eta_{\mu_2,\mu_3} + \frac{ic_\alpha e M_W {s_w}^3 \eta_{\mu_2,\mu_3}}{{c_w}^2}$$

$$\begin{pmatrix} S & 1 \\ Z & 2 \\ Z & 3 \end{pmatrix} \qquad \frac{i{c_w}^2 e M_W s_\alpha \eta_{\mu_2,\mu_3}}{s_w} + 2ieM_W s_\alpha s_w \eta_{\mu_2,\mu_3} + \frac{ieM_W s_\alpha {s_w}^3 \eta_{\mu_2,\mu_3}}{{c_w}^2}$$

5.3 $V_{\mathbf{Fermion}}$

$$\begin{pmatrix} \bar{\mathrm{vl}} & 1 \\ l & 2 \\ W & 3 \end{pmatrix} \qquad \frac{ie\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2}s_w}$$

$$\begin{pmatrix} \bar{\mathrm{vl}} & 1 \\ \mathrm{vl} & 2 \\ Z & 3 \end{pmatrix} \qquad \frac{ic_w e\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{2s_w} + \frac{ies_w\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{2c_w}$$

$$\begin{pmatrix} \bar{l} & 1 \\ l & 2 \\ A & 3 \end{pmatrix} \qquad -ie{\gamma_{\mathrm{s}_1,\mathrm{s}_2}}^{\mu_3}\delta_{\mathrm{f}_1,\mathrm{f}_2}$$

$$\begin{pmatrix} \bar{l} & 1 \\ \mathrm{vl} & 2 \\ W^\dagger & 3 \end{pmatrix} \qquad \frac{ie\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2}s_w}$$

$$\begin{pmatrix} \bar{l} & 1 \\ l & 2 \\ Z & 3 \end{pmatrix} \qquad -\frac{ic_w e\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{2s_w} + \frac{ies_w\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{2c_w} + \frac{ies_w\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{+\mathrm{s}_1,\mathrm{s}_2}}{c_w}$$

$$\begin{pmatrix} \bar{\mathrm{uq}} & 1 \\ \mathrm{uq} & 2 \\ A & 3 \end{pmatrix} \qquad \frac{2}{3}ie{\gamma_{\mathrm{s}_1,\mathrm{s}_2}}^{\mu_3}\delta_{\mathrm{m}_1,\mathrm{m}_2}\delta_{\mathrm{f}_1,\mathrm{f}_2}$$

$$\begin{pmatrix} \bar{\mathrm{uq}} & 1 \\ \mathrm{uq} & 2 \\ G & 3 \end{pmatrix} \qquad ig_s{\gamma_{\mathrm{s}_1,\mathrm{s}_2}}^{\mu_3}\delta_{\mathrm{f}_1,\mathrm{f}_2}{T_{\mathrm{m}_1,\mathrm{m}_2}}^{\mathrm{a}_3}$$

$$\begin{pmatrix} \bar{\mathrm{uq}} & 1 \\ \mathrm{dq} & 2 \\ W & 3 \end{pmatrix} \qquad \frac{ie{V^{\mathrm{CKM}}}_{\mathrm{f}_1,\mathrm{f}_2}\delta_{\mathrm{m}_1,\mathrm{m}_2}\gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2}s_w}$$

$$\begin{pmatrix} \bar{\mathrm{uq}} & 1 \\ \mathrm{uq} & 2 \\ Z & 3 \end{pmatrix} \qquad \frac{ic_w e\delta_{\mathrm{m}_1,\mathrm{m}_2}\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{2s_w} - \frac{ies_w\delta_{\mathrm{m}_1,\mathrm{m}_2}\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{6c_w} - \frac{2ies_w\delta_{\mathrm{m}_1,\mathrm{m}_2}\delta_{\mathrm{f}_1,\mathrm{f}_2}\gamma^{\mu_3}.P_{+\mathrm{s}_1,\mathrm{s}_2}}{3c_w}$$

$$\begin{pmatrix} \bar{\mathrm{dq}} & 1 \\ \mathrm{dq} & 2 \\ A & 3 \end{pmatrix} \qquad -\frac{1}{3} ie \gamma_{\mathrm{s}_1,\mathrm{s}_2}{}^{\mu_3} \delta_{\mathrm{m}_1,\mathrm{m}_2} \delta_{\mathrm{f}_1,\mathrm{f}_2}$$

$$\begin{pmatrix} \bar{\mathrm{dq}} & 1 \\ \mathrm{dq} & 2 \\ G & 3 \end{pmatrix} \qquad i g_s \gamma_{\mathrm{s}_1,\mathrm{s}_2}{}^{\mu_3} \delta_{\mathrm{f}_1,\mathrm{f}_2} T_{\mathrm{m}_1,\mathrm{m}_2}{}^{\mathrm{a}_3}$$

$$\begin{pmatrix} \bar{\mathrm{dq}} & 1 \\ \mathrm{uq} & 2 \\ W^\dagger & 3 \end{pmatrix} \qquad \frac{ie \left(V^{\mathrm{CKM}}\right)_{\mathrm{f}_2,\mathrm{f}_1}{}^* \delta_{\mathrm{m}_1,\mathrm{m}_2} \gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2} s_w}$$

$$\begin{pmatrix} \bar{\mathrm{dq}} & 1 \\ \mathrm{dq} & 2 \\ Z & 3 \end{pmatrix} \qquad -\frac{i c_w e \delta_{\mathrm{m}_1,\mathrm{m}_2} \delta_{\mathrm{f}_1,\mathrm{f}_2} \gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{2 s_w} - \frac{i e s_w \delta_{\mathrm{m}_1,\mathrm{m}_2} \delta_{\mathrm{f}_1,\mathrm{f}_2} \gamma^{\mu_3}.P_{-\mathrm{s}_1,\mathrm{s}_2}}{6 c_w} + \frac{i e s_w \delta_{\mathrm{m}_1,\mathrm{m}_2} \delta_{\mathrm{f}_1,\mathrm{f}_2} \gamma^{\mu_3}.P_{+\mathrm{s}_1,\mathrm{s}_2}}{3 c_w}$$

5.4 $V_{\mathbf{Yukawa}}$

$$\begin{pmatrix} \bar{\mathrm{dq}} & 1 \\ \mathrm{dq} & 2 \\ H & 3 \end{pmatrix} \qquad -\frac{i c_\alpha \left(y^d\right)_{\mathrm{f}_2,\mathrm{f}_1}{}^* \delta_{\mathrm{m}_1,\mathrm{m}_2} P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2}} - \frac{i c_\alpha \delta_{\mathrm{m}_1,\mathrm{m}_2} P_{+\mathrm{s}_1,\mathrm{s}_2} y^d{}_{\mathrm{f}_1,\mathrm{f}_2}}{\sqrt{2}}$$

$$\begin{pmatrix} \bar{\mathrm{dq}} & 1 \\ \mathrm{dq} & 2 \\ S & 3 \end{pmatrix} \qquad -\frac{i s_\alpha \left(y^d\right)_{\mathrm{f}_2,\mathrm{f}_1}{}^* \delta_{\mathrm{m}_1,\mathrm{m}_2} P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2}} - \frac{i s_\alpha \delta_{\mathrm{m}_1,\mathrm{m}_2} P_{+\mathrm{s}_1,\mathrm{s}_2} y^d{}_{\mathrm{f}_1,\mathrm{f}_2}}{\sqrt{2}}$$

$$\begin{pmatrix} \bar{l} & 1 \\ l & 2 \\ H & 3 \end{pmatrix} \qquad -\frac{i c_\alpha \left(y^l\right)_{\mathrm{f}_2,\mathrm{f}_1}{}^* P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2}} - \frac{i c_\alpha P_{+\mathrm{s}_1,\mathrm{s}_2} y^l{}_{\mathrm{f}_1,\mathrm{f}_2}}{\sqrt{2}}$$

$$\begin{pmatrix} \bar{l} & 1 \\ l & 2 \\ S & 3 \end{pmatrix} \qquad -\frac{i s_\alpha \left(y^l\right)_{\mathrm{f}_2,\mathrm{f}_1}{}^* P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2}} - \frac{i s_\alpha P_{+\mathrm{s}_1,\mathrm{s}_2} y^l{}_{\mathrm{f}_1,\mathrm{f}_2}}{\sqrt{2}}$$

$$\begin{pmatrix} \bar{\mathrm{uq}} & 1 \\ \mathrm{uq} & 2 \\ H & 3 \end{pmatrix} \qquad -\frac{i c_\alpha \left(y^u\right)_{\mathrm{f}_2,\mathrm{f}_1}{}^* \delta_{\mathrm{m}_1,\mathrm{m}_2} P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2}} - \frac{i c_\alpha \delta_{\mathrm{m}_1,\mathrm{m}_2} P_{+\mathrm{s}_1,\mathrm{s}_2} y^u{}_{\mathrm{f}_1,\mathrm{f}_2}}{\sqrt{2}}$$

$$\begin{pmatrix} \bar{\mathrm{uq}} & 1 \\ \mathrm{uq} & 2 \\ S & 3 \end{pmatrix} \qquad -\frac{i s_\alpha \left(y^u\right)_{\mathrm{f}_2,\mathrm{f}_1}{}^* \delta_{\mathrm{m}_1,\mathrm{m}_2} P_{-\mathrm{s}_1,\mathrm{s}_2}}{\sqrt{2}} - \frac{i s_\alpha \delta_{\mathrm{m}_1,\mathrm{m}_2} P_{+\mathrm{s}_1,\mathrm{s}_2} y^u{}_{\mathrm{f}_1,\mathrm{f}_2}}{\sqrt{2}}$$

5.5 $V_{\mathbf{ggH}}$

$$\begin{pmatrix} A & 1 \\ A & 2 \\ H & 3 \end{pmatrix} \qquad -i \mathrm{AA}_H c_\alpha \mathrm{p}_1{}^{\mu_2} \mathrm{p}_2{}^{\mu_1} + i \mathrm{AA}_H c_\alpha \eta_{\mu_1,\mu_2} \mathrm{p}_1.p_2$$

$$\begin{pmatrix} A & 1 \\ A & 2 \\ S & 3 \end{pmatrix} \qquad -i \mathrm{AA}_H s_\alpha \mathrm{p}_1{}^{\mu_2} \mathrm{p}_2{}^{\mu_1} + i \mathrm{AA}_H s_\alpha \eta_{\mu_1,\mu_2} \mathrm{p}_1.p_2$$

$$\begin{pmatrix} G & 1 \\ G & 2 \\ H & 3 \end{pmatrix} \qquad -i c_\alpha \mathrm{GG}_H \mathrm{p}_1{}^{\mu_2} \mathrm{p}_2{}^{\mu_1} \delta_{\mathrm{a}_1,\mathrm{a}_2} + i c_\alpha \mathrm{GG}_H \delta_{\mathrm{a}_1,\mathrm{a}_2} \eta_{\mu_1,\mu_2} \mathrm{p}_1.p_2$$

$$\begin{pmatrix} G & 1 \\ G & 2 \\ S & 3 \end{pmatrix} \qquad -i\mathrm{GG}_H s_\alpha \mathrm{p_1}^{\mu_2}\mathrm{p_2}^{\mu_1}\delta_{\mathrm{a_1},\mathrm{a_2}} + i\mathrm{GG}_H s_\alpha \delta_{\mathrm{a_1},\mathrm{a_2}}\eta_{\mu_1,\mu_2}\mathrm{p_1}.p_2$$

$$\begin{pmatrix} G & 1 \\ G & 2 \\ G & 3 \\ H & 4 \end{pmatrix} \qquad \begin{array}{l} c_\alpha \mathrm{GG}_H g_s f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_1}^{\mu_3}\eta_{\mu_1,\mu_2} - c_\alpha \mathrm{GG}_H g_s f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_2}^{\mu_3}\eta_{\mu_1,\mu_2} - c_\alpha \mathrm{GG}_H g_s f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_1}^{\mu_2}\eta_{\mu_1,\mu_3} + \\ c_\alpha \mathrm{GG}_H g_s f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_3}^{\mu_2}\eta_{\mu_1,\mu_3} + c_\alpha \mathrm{GG}_H g_s f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_2}^{\mu_1}\eta_{\mu_2,\mu_3} - c_\alpha \mathrm{GG}_H g_s f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_3}^{\mu_1}\eta_{\mu_2,\mu_3} \end{array}$$

$$\begin{pmatrix} G & 1 \\ G & 2 \\ G & 3 \\ S & 4 \end{pmatrix} \qquad \begin{array}{l} \mathrm{GG}_H g_s s_\alpha f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_1}^{\mu_3}\eta_{\mu_1,\mu_2} - \mathrm{GG}_H g_s s_\alpha f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_2}^{\mu_3}\eta_{\mu_1,\mu_2} - \mathrm{GG}_H g_s s_\alpha f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_1}^{\mu_2}\eta_{\mu_1,\mu_3} + \\ \mathrm{GG}_H g_s s_\alpha f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_3}^{\mu_2}\eta_{\mu_1,\mu_3} + \mathrm{GG}_H g_s s_\alpha f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_2}^{\mu_1}\eta_{\mu_2,\mu_3} - \mathrm{GG}_H g_s s_\alpha f_{\mathrm{a_1},\mathrm{a_2},\mathrm{a_3}}\mathrm{p_3}^{\mu_1}\eta_{\mu_2,\mu_3} \end{array}$$

$$\begin{pmatrix} G & 1 \\ G & 2 \\ G & 3 \\ G & 4 \\ H & 5 \end{pmatrix} \qquad \begin{array}{l} ic_\alpha \mathrm{GG}_H {g_s}^2 f_{\mathrm{a_1},\mathrm{a_3},\mathrm{Gluon\$1}} f_{\mathrm{a_2},\mathrm{a_4},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_4}\eta_{\mu_2,\mu_3} + \\ ic_\alpha \mathrm{GG}_H {g_s}^2 f_{\mathrm{a_1},\mathrm{a_2},\mathrm{Gluon\$1}} f_{\mathrm{a_3},\mathrm{a_4},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_4}\eta_{\mu_2,\mu_3} + \\ ic_\alpha \mathrm{GG}_H {g_s}^2 f_{\mathrm{a_1},\mathrm{a_4},\mathrm{Gluon\$1}} f_{\mathrm{a_2},\mathrm{a_3},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_3}\eta_{\mu_2,\mu_4} - \\ ic_\alpha \mathrm{GG}_H {g_s}^2 f_{\mathrm{a_1},\mathrm{a_2},\mathrm{Gluon\$1}} f_{\mathrm{a_3},\mathrm{a_4},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_3}\eta_{\mu_2,\mu_4} - \\ ic_\alpha \mathrm{GG}_H {g_s}^2 f_{\mathrm{a_1},\mathrm{a_4},\mathrm{Gluon\$1}} f_{\mathrm{a_2},\mathrm{a_3},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_2}\eta_{\mu_3,\mu_4} - \\ ic_\alpha \mathrm{GG}_H {g_s}^2 f_{\mathrm{a_1},\mathrm{a_3},\mathrm{Gluon\$1}} f_{\mathrm{a_2},\mathrm{a_4},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_2}\eta_{\mu_3,\mu_4} \end{array}$$

$$\begin{pmatrix} G & 1 \\ G & 2 \\ G & 3 \\ G & 4 \\ S & 5 \end{pmatrix} \qquad \begin{array}{l} i\mathrm{GG}_H {g_s}^2 s_\alpha f_{\mathrm{a_1},\mathrm{a_3},\mathrm{Gluon\$1}} f_{\mathrm{a_2},\mathrm{a_4},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_4}\eta_{\mu_2,\mu_3} + \\ i\mathrm{GG}_H {g_s}^2 s_\alpha f_{\mathrm{a_1},\mathrm{a_2},\mathrm{Gluon\$1}} f_{\mathrm{a_3},\mathrm{a_4},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_4}\eta_{\mu_2,\mu_3} + \\ i\mathrm{GG}_H {g_s}^2 s_\alpha f_{\mathrm{a_1},\mathrm{a_4},\mathrm{Gluon\$1}} f_{\mathrm{a_2},\mathrm{a_3},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_3}\eta_{\mu_2,\mu_4} - \\ i\mathrm{GG}_H {g_s}^2 s_\alpha f_{\mathrm{a_1},\mathrm{a_2},\mathrm{Gluon\$1}} f_{\mathrm{a_3},\mathrm{a_4},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_3}\eta_{\mu_2,\mu_4} - \\ i\mathrm{GG}_H {g_s}^2 s_\alpha f_{\mathrm{a_1},\mathrm{a_4},\mathrm{Gluon\$1}} f_{\mathrm{a_2},\mathrm{a_3},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_2}\eta_{\mu_3,\mu_4} - \\ i\mathrm{GG}_H {g_s}^2 s_\alpha f_{\mathrm{a_1},\mathrm{a_3},\mathrm{Gluon\$1}} f_{\mathrm{a_2},\mathrm{a_4},\mathrm{Gluon\$1}}\eta_{\mu_1,\mu_2}\eta_{\mu_3,\mu_4} \end{array}$$

5.6 $V_{\mathbf{Ghost}}$

$$\begin{pmatrix} \mathrm{ghG}^\dagger & 1 \\ \mathrm{ghG} & 2 \\ G & 3 \end{pmatrix} \qquad g_s f_{\mathrm{a_3},\mathrm{a_1},\mathrm{a_2}}\mathrm{p_2}^{\mu_3} + g_s f_{\mathrm{a_3},\mathrm{a_1},\mathrm{a_2}}\mathrm{p_3}^{\mu_3}$$

References

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