Oct 13, 1994 Beijing

Standard Model in Unitary Gauge and some vertices were droped

Jian-Xiong Wang

Contents

1 Mix **5**

2 Masses **5**

3 Propagtors **5**

4 Verties **6**
4.1 The Vertices of electro-weak interaction 6
4.1.1 Four Scalar Bosons Vertices 6
4.1.2 Three Scalar Bosons Vertices 6
4.1.3 Two Scalar Bosons and Two Vector Bosons Vertices 6
4.1.4 One Scalar Boson and Two Vector Bosons Vertices 6
4.1.5 Four Vector Bosons Vertices 7
4.1.6 One Scalar Boson and Two Fermions Vertices 7
4.1.7 One Vector Boson and Two Fermions Vertices 8
4.1.8 Three Vector Bosons Vertices 11
4.2 The Vertices of strong interaction 11
4.2.1 Four Vector Bosons Vertices 11
4.2.2 Two Scalar Bosons and One Vector Boson Vertices 11
4.2.3 Three Vector Bosons Vertices 11
4.2.4 One Vector Boson and Two Fermions Vertices 12

This is Standard Model in unitary gauge, include electro-weak interaction and QCD, Quark mixing terms are droped. Higgs particle couple to electron, muon, u-quark, d-quark was droped.

The following three input file of Standard Model in Unitary Gauge and some vertices were droped, Which is inputed by Jian-Xiong Wang, on Oct 13, 1994.

The following is the Feynman rules of the model

There are totally 18 particles, in which 12 are Fermions, 4 are Vector Bosons, 2 are Scalar Bosons , $g_g{}^0$ is ghost particles.

There are totally 63 vertices in this model.

The names for all the particles in FDC are listed in the following table

$name$	$name\ in\ FDC$	$mass$	$mass\ in\ FDC$	$width\ in\ FDC$	$charge$	$spin$
ν_e	nue	0	0	nue_width	0	1/2
ν_μ	$numu$	0	0	$numu_width$	0	1/2
ν_τ	nut	0	0	nut_width	0	1/2
e	ef	m_e	fme	ef_width	-1	1/2
μ	mu	m_μ	$fmmu$	mu_width	-1	1/2
τ	tau	m_τ	$fmtau$	tau_width	-1	1/2
u	qu	m_u	fmu	qu_width	2/3	1/2
c	qc	m_c	fmc	qc_width	2/3	1/2
t	qt	m_t	fmt	qt_width	2/3	1/2
d	qd	m_d	fmd	qd_width	$-1/3$	1/2
s	qs	m_s	fms	qs_width	$-1/3$	1/2
b	qb	m_b	fmb	qb_width	$-1/3$	1/2
γ	p	0	0	p_width	0	1
Z^0	z	m_{Z^0}	zm	z_width	0	1
w	w	m_w	wm	w_width	1	1
g	gs	0	0	gs_width	0	1
h	$h0$	m_h	hm	$h0_width$	0	0
g_g	gsg	0	0	gsg_width	0	0

(1)

The names for all the anti-particles in FDC are constructed as the name of the particle + b. All of them are listed in the following table

$name\ of\ particle$	$name\ of\ particle\ in\ FDC$	$name\ of\ anti-particle\ in\ FDC$
ν_e	nue	$nueb$
ν_μ	$numu$	$numub$
ν_τ	nut	$nutb$
e	ef	efb
μ	mu	mub
τ	tau	$taub$
u	qu	qub
c	qc	qcb
t	qt	qtb
d	qd	qdb
s	qs	qsb
b	qb	qbb
w	w	wb

(2)

1 Mix

The following is mix list

2 Masses

The following is mass list

$$m_{Z^0} = \frac{m_w}{\cos\theta_w}$$

$$m_{g_g{}^0} = 0$$

3 Propagtors

The following is the propagtors list.

The propgators of particle γ. is the formula as:

$$s11(p,\mu,\nu) = \frac{-g_{\mu,\nu}i}{p^2}$$

The propgators of particle Z^0, w^+. are in the same formula as:

$$s11(p,m,\mu,\nu) = \frac{\frac{p_\mu p_\nu i}{m^2} - g_{\mu,\nu}i}{p^2 - m^2}$$

The propgators of particle g^0. is the formula as:

$$s1(p,\mu,\nu) = \frac{-g_{\mu,\nu}i}{p^2}$$

The propgators of particle h^0. is the formula as:

$$s0(p,m) = \frac{i}{p^2 - m^2}$$

The propgators of the gohst particle $g_g{}^0$. is the formula as:

$$s0(p) = \frac{i}{p^2}$$

The propgators of particle ν_e, ν_μ, ν_τ. are in the same formula as:

$$sf(p) = \frac{-\hat{p}i}{p^2}$$

The propgators of particle $e^-, \mu^-, \tau^-, d, s, b, u, c, t$. are in the same formula as:

$$sf(p,m) = \frac{-\hat{p}i - im}{p^2 - m^2}$$

4 Verties

There are totally 63 vertices in this part

4.1 The Vertices of electro-weak interaction

There are 54 vertices in the section

4.1.1 Four Scalar Bosons Vertices

There are 1 vertices in the section
Vertex 1: $h^0(p_1) - h^0(p_2) - h^0(p_3) - h^0(p_4)$

$$V_1 = \frac{-3g^2 {m_h}^2 i}{4{m_w}^2}$$

4.1.2 Three Scalar Bosons Vertices

There are 1 vertices in the section
Vertex 2: $h^0(p_1) - h^0(p_2) - h^0(p_3)$

$$V_2 = \frac{-3g{m_h}^2 i}{2m_w}$$

4.1.3 Two Scalar Bosons and Two Vector Bosons Vertices

There are 2 vertices in the section
Vertex 4: $h^0(p_1) - h^0(p_2) - w_\mu^+(p_3) - w_\nu^-(p_4)$

$$V_4 = \frac{g^2 i}{2} g_{\mu,\nu}$$

Vertex 5: ${Z^0}_\mu(p_3) - {Z^0}_\nu(p_4) - h^0(p_2) - h^0(p_1)$

$$V_5 = \frac{g^2 i}{2cos^2\theta_w} g_{\mu,\nu}$$

4.1.4 One Scalar Boson and Two Vector Bosons Vertices

There are 2 vertices in the section
Vertex 6: $h^0(p_1) - w_\mu^+(p_2) - w_\nu^-(p_3)$

$$V_6 = gim_w g_{\mu,\nu}$$

Vertex 7: ${Z^0}_\mu(p_2) - {Z^0}_\nu(p_3) - h^0(p_1)$

$$V_7 = \frac{gim_w}{cos^2\theta_w} g_{\mu,\nu}$$

4.1.5 Four Vector Bosons Vertices

There are 4 vertices in the section

Vertex 8: $w_\mu^+(p_1) - w_\nu^+(p_2) - w_\alpha^-(p_3) - w_\beta^-(p_4)$

$$V_8 = g^2 i(2g_{\mu,\nu}g_{\alpha,\beta} - g_{\mu,\alpha}g_{\nu,\beta} - g_{\mu,\beta}g_{\nu,\alpha})$$

Vertex 9: $\gamma_\alpha(p_3) - \gamma_\beta(p_4) - w_\nu^-(p_2) - w_\mu^+(p_1)$

$$V_9 = sin^2\theta_w g^2 i(-2g_{\mu,\nu}g_{\alpha,\beta} + g_{\mu,\alpha}g_{\nu,\beta} + g_{\mu,\beta}g_{\nu,\alpha})$$

Vertex 10: ${Z^0}_\alpha(p_3) - \gamma_\beta(p_4) - w_\nu^-(p_2) - w_\mu^+(p_1)$

$$V_{10} = \cos\theta_w \sin\theta_w g^2 i(-2g_{\mu,\nu}g_{\alpha,\beta} + g_{\mu,\alpha}g_{\nu,\beta} + g_{\mu,\beta}g_{\nu,\alpha})$$

Vertex 11: ${Z^0}_\alpha(p_3) - {Z^0}_\beta(p_4) - w_\nu^-(p_2) - w_\mu^+(p_1)$

$$V_{11} = cos^2\theta_w g^2 i(-2g_{\mu,\nu}g_{\alpha,\beta} + g_{\mu,\alpha}g_{\nu,\beta} + g_{\mu,\beta}g_{\nu,\alpha})$$

4.1.6 One Scalar Boson and Two Fermions Vertices

There are 9 vertices in the section

Vertex 12: $e^+(p_1) - e^-(p_2) - h^0(p_3)$

$$V_{12} = \frac{m_e g i}{2m_w}$$

Vertex 13: $\mu^+(p_1) - \mu^-(p_2) - h^0(p_3)$

$$V_{13} = \frac{m_\mu g i}{2m_w}$$

Vertex 14: $\tau^+(p_1) - \tau^-(p_2) - h^0(p_3)$

$$V_{14} = \frac{m_\tau g i}{2m_w}$$

Vertex 46: $\overline{d}(p_1) - d(p_2) - h^0(p_3)$

$$V_{46} = \frac{m_d g i}{2m_w}$$

Vertex 47: $\overline{s}(p_1) - s(p_2) - h^0(p_3)$

$$V_{47} = \frac{m_s g i}{2m_w}$$

Vertex 48: $\overline{b}(p_1) - b(p_2) - h^0(p_3)$

$$V_{48} = \frac{m_b g i}{2m_w}$$

Vertex 61: $\overline{u}(p_1) - u(p_2) - h^0(p_3)$

$$V_{61} = \frac{m_u g i}{2 m_w}$$

Vertex 62: $\overline{c}(p_1) - c(p_2) - h^0(p_3)$

$$V_{62} = \frac{m_c g i}{2 m_w}$$

Vertex 63: $\overline{t}(p_1) - t(p_2) - h^0(p_3)$

$$V_{63} = \frac{m_t g i}{2 m_w}$$

4.1.7 One Vector Boson and Two Fermions Vertices

There are 33 vertices in the section

Vertex 15: $\gamma_\mu(p_3) - e^-(p_2) - e^+(p_1)$

$$V_{15} = -\sin\theta_w g i \gamma_\mu$$

Vertex 16: $\gamma_\mu(p_3) - \mu^-(p_2) - \mu^+(p_1)$

$$V_{16} = -\sin\theta_w g i \gamma_\mu$$

Vertex 17: $\gamma_\mu(p_3) - \tau^-(p_2) - \tau^+(p_1)$

$$V_{17} = -\sin\theta_w g i \gamma_\mu$$

Vertex 18: ${Z^0}_\mu(p_3) - e^-(p_2) - e^+(p_1)$

$$V_{18} = \frac{g i}{4\cos\theta_w}(-\gamma_5\gamma_\mu + 4\gamma_\mu sin^2\theta_w - \gamma_\mu)$$

Vertex 19: ${Z^0}_\mu(p_3) - \mu^-(p_2) - \mu^+(p_1)$

$$V_{19} = \frac{g i}{4\cos\theta_w}(-\gamma_5\gamma_\mu + 4\gamma_\mu sin^2\theta_w - \gamma_\mu)$$

Vertex 20: ${Z^0}_\mu(p_3) - \tau^-(p_2) - \tau^+(p_1)$

$$V_{20} = \frac{g i}{4\cos\theta_w}(-\gamma_5\gamma_\mu + 4\gamma_\mu sin^2\theta_w - \gamma_\mu)$$

Vertex 21: $\tau^+(p_1) - \nu_\tau(p_2) - w_\mu^-(p_3)$

$$V_{21} = \frac{g i}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 22: $\mu^+(p_1) - \nu_\mu(p_2) - w_\mu^-(p_3)$

$$V_{22} = \frac{g i}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 23: $e^+(p_1) - \nu_e(p_2) - w_\mu^-(p_3)$

$$V_{23} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 25: $\overline{\nu_\tau}(p_1) - \tau^-(p_2) - w_\mu^+(p_3)$

$$V_{25} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 26: $\overline{\nu_\mu}(p_1) - \mu^-(p_2) - w_\mu^+(p_3)$

$$V_{26} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 27: $\overline{\nu_e}(p_1) - e^-(p_2) - w_\mu^+(p_3)$

$$V_{27} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 28: ${Z^0}_\mu(p_3) - \nu_e(p_2) - \overline{\nu_e}(p_1)$

$$V_{28} = \frac{gi}{4\cos\theta_w}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 29: ${Z^0}_\mu(p_3) - \nu_\mu(p_2) - \overline{\nu_\mu}(p_1)$

$$V_{29} = \frac{gi}{4\cos\theta_w}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 30: ${Z^0}_\mu(p_3) - \nu_\tau(p_2) - \overline{\nu_\tau}(p_1)$

$$V_{30} = \frac{gi}{4\cos\theta_w}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 34: $\gamma_\mu(p_3) - d(p_2) - \overline{d}(p_1)$

$$V_{34} = \frac{-\sin\theta_w gi}{3}\gamma_\mu$$

Vertex 35: $\gamma_\mu(p_3) - s(p_2) - \overline{s}(p_1)$

$$V_{35} = \frac{-\sin\theta_w gi}{3}\gamma_\mu$$

Vertex 36: $\gamma_\mu(p_3) - b(p_2) - \overline{b}(p_1)$

$$V_{36} = \frac{-\sin\theta_w gi}{3}\gamma_\mu$$

Vertex 37: ${Z^0}_\mu(p_3) - d(p_2) - \overline{d}(p_1)$

$$V_{37} = \frac{gi}{12\cos\theta_w}(-3\gamma_5\gamma_\mu + 4\gamma_\mu sin^2\theta_w - 3\gamma_\mu)$$

Vertex 38: ${Z^0}_\mu(p_3) - s(p_2) - \overline{s}(p_1)$

$$V_{38} = \frac{gi}{12\cos\theta_w}(-3\gamma_5\gamma_\mu + 4\gamma_\mu sin^2\theta_w - 3\gamma_\mu)$$

Vertex 39: ${Z^0}_\mu(p_3) - b(p_2) - \overline{b}(p_1)$

$$V_{39} = \frac{gi}{12\cos\theta_w}(-3\gamma_5\gamma_\mu + 4\gamma_\mu sin^2\theta_w - 3\gamma_\mu)$$

Vertex 40: $\overline{b}(p_1) - t(p_2) - w_\mu^-(p_3)$

$$V_{40} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 41: $\overline{s}(p_1) - c(p_2) - w_\mu^-(p_3)$

$$V_{41} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 42: $\overline{d}(p_1) - u(p_2) - w_\mu^-(p_3)$

$$V_{42} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 49: $\overline{t}(p_1) - b(p_2) - w_\mu^+(p_3)$

$$V_{49} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 50: $\overline{c}(p_1) - s(p_2) - w_\mu^+(p_3)$

$$V_{50} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 51: $\overline{u}(p_1) - d(p_2) - w_\mu^+(p_3)$

$$V_{51} = \frac{gi}{2\sqrt{2}}(\gamma_5\gamma_\mu + \gamma_\mu)$$

Vertex 52: $\gamma_\mu(p_3) - u(p_2) - \overline{u}(p_1)$

$$V_{52} = \frac{2\sin\theta_w gi}{3}\gamma_\mu$$

Vertex 53: $\gamma_\mu(p_3) - c(p_2) - \overline{c}(p_1)$

$$V_{53} = \frac{2\sin\theta_w gi}{3}\gamma_\mu$$

Vertex 54: $\gamma_\mu(p_3) - t(p_2) - \overline{t}(p_1)$

$$V_{54} = \frac{2\sin\theta_w gi}{3}\gamma_\mu$$

Vertex 55: ${Z^0}_\mu(p_3) - u(p_2) - \overline{u}(p_1)$

$$V_{55} = \frac{gi}{12\cos\theta_w}(3\gamma_5\gamma_\mu + 8\gamma_\mu cos^2\theta_w - 5\gamma_\mu)$$

Vertex 56: ${Z^0}_\mu(p_3) - c(p_2) - \overline{c}(p_1)$

$$V_{56} = \frac{gi}{12\cos\theta_w}(3\gamma_5\gamma_\mu + 8\gamma_\mu cos^2\theta_w - 5\gamma_\mu)$$

Vertex 57: ${Z^0}_\mu(p_3) - t(p_2) - \overline{t}(p_1)$

$$V_{57} = \frac{gi}{12\cos\theta_w}(3\gamma_5\gamma_\mu + 8\gamma_\mu cos^2\theta_w - 5\gamma_\mu)$$

4.1.8 Three Vector Bosons Vertices

There are 2 vertices in the section
Vertex 32: $\gamma_\mu(p_3) - w^-_\alpha(p_2) - w^+_\nu(p_1)$

$$V_{32} = \sin\theta_w gi(-{p_1}_\mu g_{\nu,\alpha} + {p_1}_\alpha g_{\mu,\nu} + {p_2}_\mu g_{\nu,\alpha} - {p_2}_\nu g_{\mu,\alpha} + {p_3}_\nu g_{\mu,\alpha} - {p_3}_\alpha g_{\mu,\nu})$$

Vertex 33: ${Z^0}_\mu(p_3) - w^-_\alpha(p_2) - w^+_\nu(p_1)$

$$V_{33} = \cos\theta_w gi(-{p_1}_\mu g_{\nu,\alpha} + {p_1}_\alpha g_{\mu,\nu} + {p_2}_\mu g_{\nu,\alpha} - {p_2}_\nu g_{\mu,\alpha} + {p_3}_\nu g_{\mu,\alpha} - {p_3}_\alpha g_{\mu,\nu})$$

4.2 The Vertices of strong interaction

There are 9 vertices in the section

4.2.1 Four Vector Bosons Vertices

There are 1 vertices in the section
Vertex 3: $g^0_\mu(p_1) - g^0_\nu(p_2) - g^0_\alpha(p_3) - g^0_\beta(p_4)$

$$V_3 = {g_s}^2 i(-f_{a,b,c}f_{a,d,e}g_{\mu,\nu}g_{\alpha,\beta} + f_{a,b,c}f_{a,d,e}g_{\mu,\beta}g_{\nu,\alpha} - f_{a,b,d}f_{a,c,e}g_{\mu,\alpha}g_{\nu,\beta} + f_{a,b,d}f_{a,c,e}g_{\mu,\beta}g_{\nu,\alpha} + f_{a,b,e}f_{a,c,d}g_{\mu,\nu}g_{\alpha,\beta} - f_{a,b,e}f_{a,c,d}g_{\mu,\alpha}g_{\nu,\beta})$$

4.2.2 Two Scalar Bosons and One Vector Boson Vertices

There are 1 vertices in the section
Vertex 24: ${g_g}^0(p_1) - {g_g}^0(p_2) - g^0_\mu(p_3)$

$$V_{24} = -f_{a,b,c}g_s{p_3}_\mu$$

4.2.3 Three Vector Bosons Vertices

There are 1 vertices in the section
Vertex 31: $g^0_\nu(p_1) - g^0_\alpha(p_2) - g^0_\mu(p_3)$

$$V_{31} = f_{a,b,c}g_s({p_1}_\mu g_{\nu,\alpha} - {p_1}_\alpha g_{\mu,\nu} - {p_2}_\mu g_{\nu,\alpha} + {p_2}_\nu g_{\mu,\alpha} - {p_3}_\nu g_{\mu,\alpha} + {p_3}_\alpha g_{\mu,\nu})$$

4.2.4 One Vector Boson and Two Fermions Vertices

There are 6 vertices in the section

Vertex 43: $\overline{d}(p_1) - d(p_2) - g^0_\mu(p_3)$

$$V_{43} = \frac{T_a g_s i}{2}\gamma_\mu$$

Vertex 44: $\overline{s}(p_1) - s(p_2) - g^0_\mu(p_3)$

$$V_{44} = \frac{T_a g_s i}{2}\gamma_\mu$$

Vertex 45: $\overline{b}(p_1) - b(p_2) - g^0_\mu(p_3)$

$$V_{45} = \frac{T_a g_s i}{2}\gamma_\mu$$

Vertex 58: $\overline{u}(p_1) - u(p_2) - g^0_\mu(p_3)$

$$V_{58} = \frac{T_a g_s i}{2}\gamma_\mu$$

Vertex 59: $\overline{c}(p_1) - c(p_2) - g^0_\mu(p_3)$

$$V_{59} = \frac{T_a g_s i}{2}\gamma_\mu$$

Vertex 60: $\overline{t}(p_1) - t(p_2) - g^0_\mu(p_3)$

$$V_{60} = \frac{T_a g_s i}{2}\gamma_\mu$$