Chiral field theory of mesons and a new mechanism in EW theory

BING AN LI

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1 Introduction

A new mechanism for chiral gauge fields has been found from the study of meson physics.

How to make W and Z massive ? How to cancel

$$\frac{q_\mu q_\nu}{m^2}$$

in the propergators of W and Z ?

EW theory requires scalars.

Higgs mechanism

$$< 0|\phi|0 >= \frac{\eta}{\sqrt{2}}$$

Higgs has not been found experimentally and there are other theoretical issues.

Many attempts to modify Higgs mechanism

In 1967 Weinberg published his second sum rule(PRL **18** 507(1967))

$$m_a^2 = 2m_\rho^2$$

What is the implication ? A new chiral symmetry breaking?

How to reveal this mass relation in a field theory ?

2 Chiral field theory of mesons

Based on current algebra, in 1995 I proposed a new chiral field theory of mesons

$$\mathcal{L} = \bar{\psi}(x)(i\gamma \cdot \partial + \gamma \cdot v + \gamma \cdot a\gamma_5 - mu(x))\psi(x)$$
$$-\bar{\psi(x)}M\psi(x)$$

$$+\frac{1}{2}m_0^2(\rho_i^\mu\rho_{\mu i}+\omega^\mu\omega_\mu+a_i^\mu a_{\mu i}+f^\mu f_\mu)$$

Integrating out the quark fields, the L of physical mesons is obtained.

What is new ?

1. Constituent quark mass and current quark mass appear together. Dynamical chiral symmetry breaking

   plays dominant role

2. When $E < m_\rho$ this theory goes back to ChPT and all the 10 coefficients of ChPT are predicted

3. Meson processes with normal and abnormal parity(anomaly) are described by one L

Low energy theory of $\gamma 3\pi$ is corrected

$$A_{\gamma 3\pi}(0,0,0) = \frac{2e}{\pi^2 f_\pi^3}(1 + \frac{6c^2}{g^2}) = 12.2GeV^3$$

We can study anomaly beyond Wess-Zumino-Witten

4. Besides the pole of vector meson, a new intrinsic form form factor

$$f_{\rho\pi\pi} = 1 + \frac{q^2}{2\pi^2 f_\pi^2}\{(1 - \frac{2c}{g})^2 - 4\pi^2 c^2\}$$

is derived.

$$|F_\pi(q^2)|^2 = f_{\rho\pi\pi}^2 \frac{m_\rho^4 + q^2\Gamma_\rho^2(q^2)}{(q^2 - m_\rho^2)^2 + q^2\Gamma_\rho^2(q^2)}$$

$$< r^2 >= \frac{6}{m_\rho^2} + \frac{3}{\pi^2 f_\pi^2}\{(1 - \frac{2c}{g})^2 - 4\pi^2 c^2\}$$

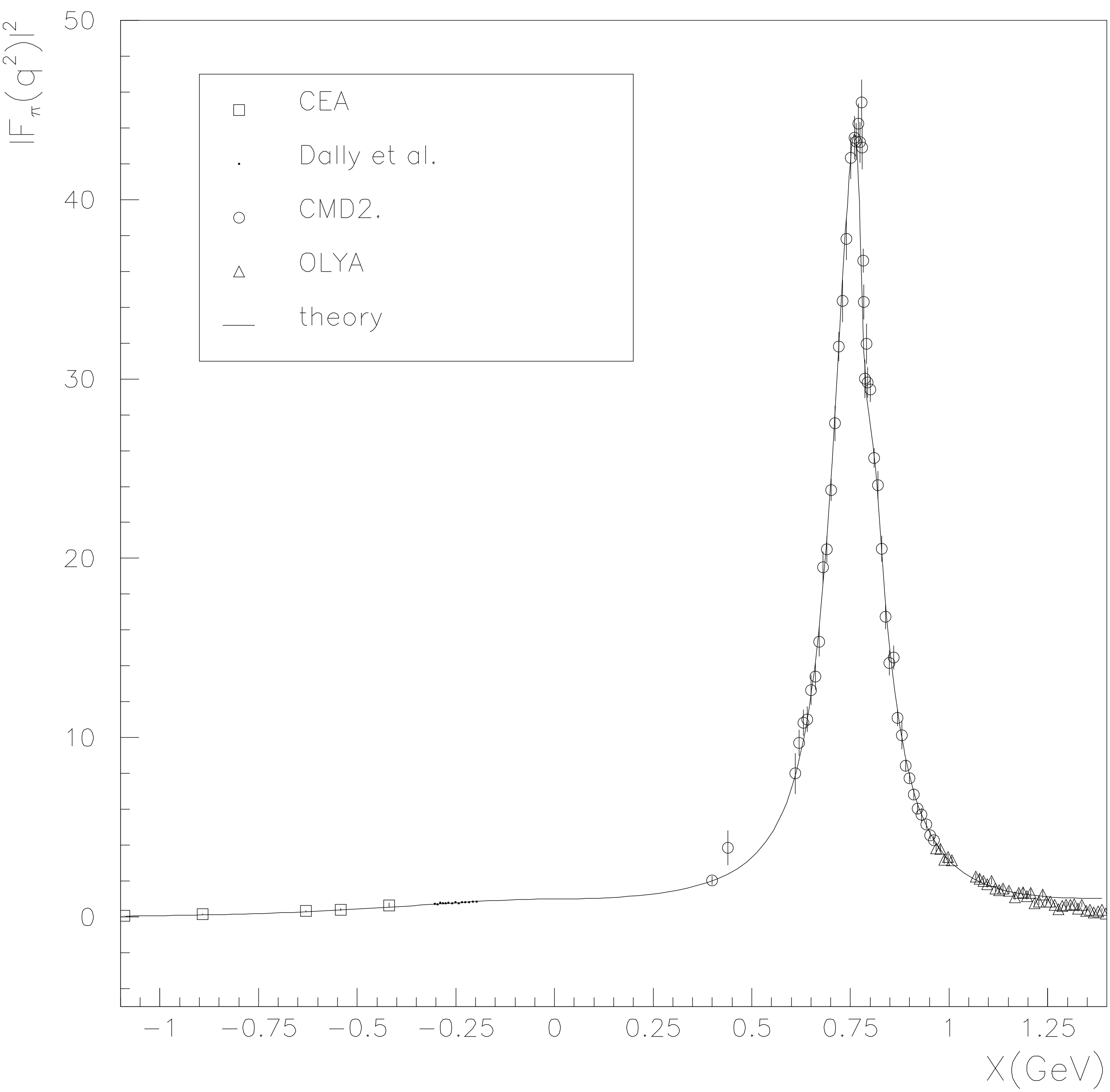
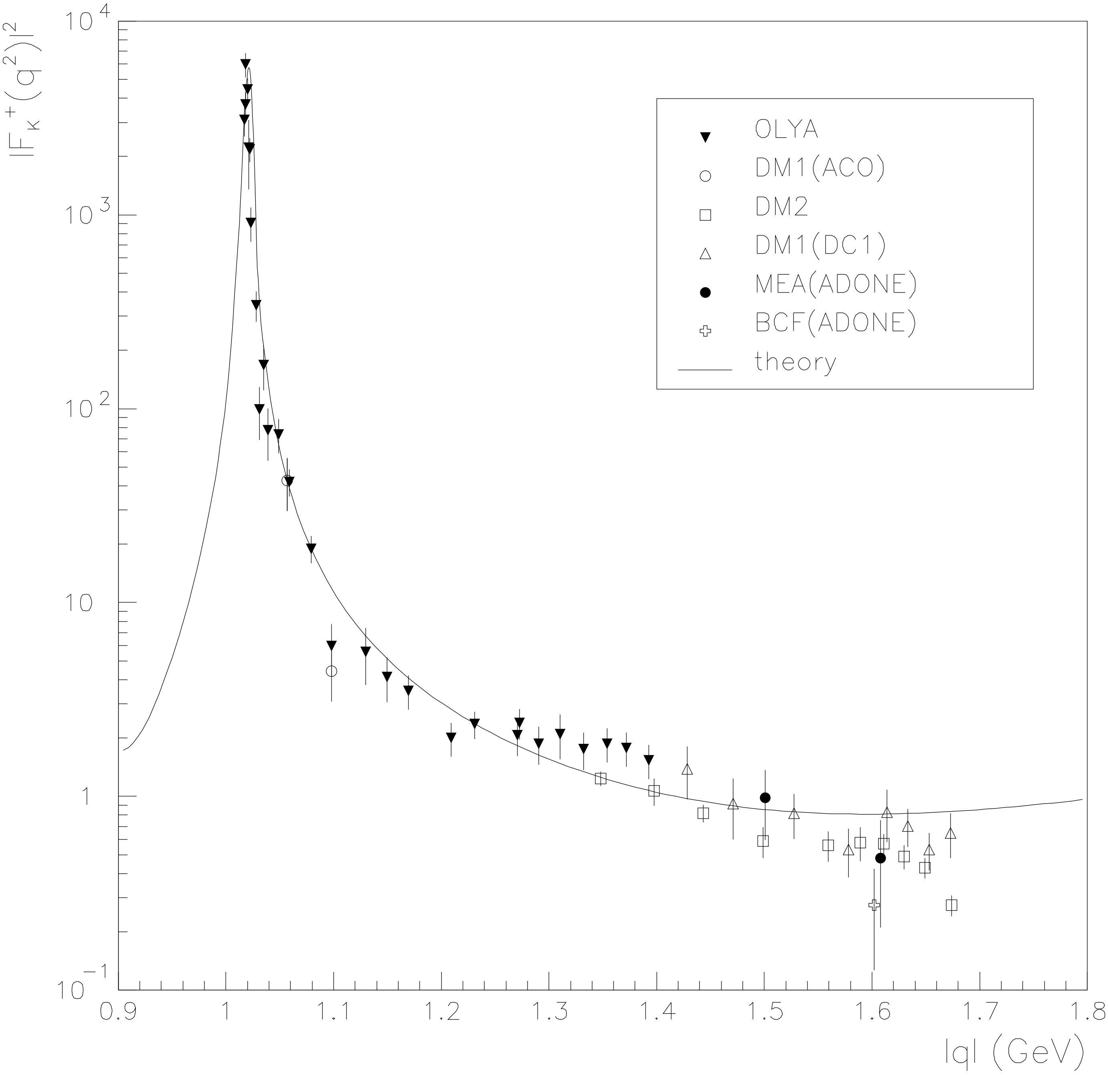

CEA
Dally et al.
CMD2.
OLYA
theory
$|F_\pi(q^2)|^2$
X(GeV)
50
40
30
20
10
0
−1
−0.75
−0.5
−0.25
0
0.25
0.5
0.75
1
1.25

FIG. 1.



$|F_K^+(q^2)|^2$
OLYA
DM1(ACO)
DM2
DM1(DC1)
MEA(ADONE)
BCF(ADONE)
theory
10^4
10^3
10^2
10
1
10^{-1}
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
|q| (GeV)

FIG. 2.

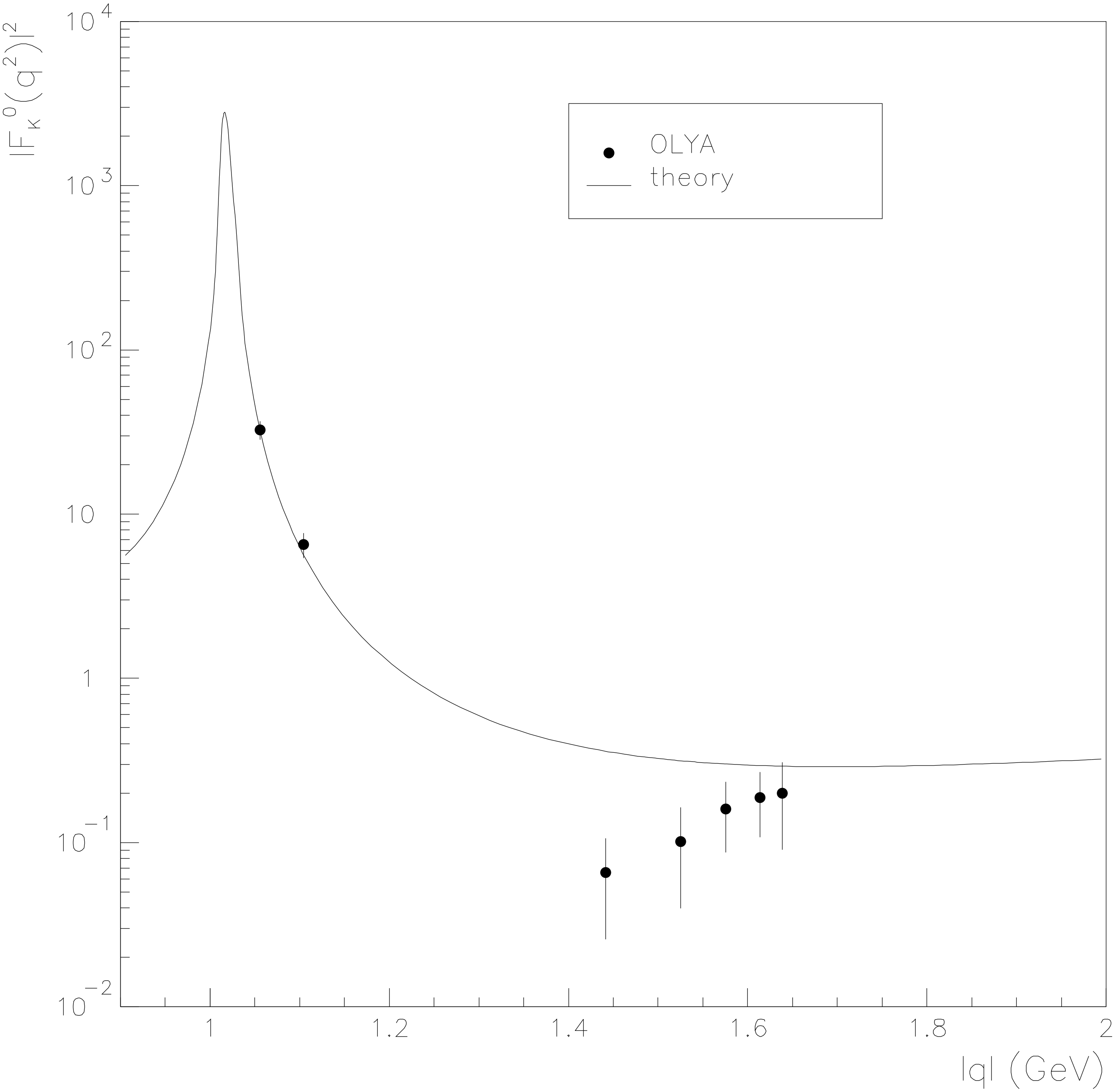


FIG. 3.

$$< r^2 >= (0.395 + 0.057) fm^2 = 0.452 fm^2$$

EXP $(0.439 \pm 0.03) fm^2$

$f_{\rho\pi\pi}$ plays essential role in decays $\rho \rightarrow \pi\pi, K^* \rightarrow K\pi, \phi \rightarrow K\bar{K}$

5. Successful in study of tricky decays $a_1 \rightarrow \rho\pi, K_1 \rightarrow K^*\pi, f_{1s} \rightarrow K^*K$.
6. $\eta' \rightarrow \eta\pi\pi$
7. Many anomalous decays
8. EM and weak decays of mesons, τ mesonic decays
9. $\pi - \pi$ and $\pi - K$ scatterings
10. In most cases there are only two parameters: f_π and a universal coupling constant g

The success of this theory exceeds all other existing models of mesons

It overcomes the shortcomings of current algebra too.

3 Meson masses and Two theorems

$$m_\pi^2 = -\frac{4}{f_\pi^2} < 0|\bar{\psi}\psi|0 > (m_u + m_d)$$

$$m_\rho^2 = 6m^2$$

$$a_\mu^i \bar{\psi}\tau_i\gamma_\mu\gamma_5\psi$$

$$(1 - \frac{1}{2\pi^2 g^2})m_a^2 = 2m_\rho^2$$

Modified Weinberg second sum rule is revealed from this chiral field theory

Why there is $(1-\frac{1}{2\pi^2 g^2})$? In Weinberg's paper(1967)

an assumption has been made "Our assumption that the currents behave like free fields"

In this theory this assumption is not true.

In the original L

$$m_a = m_\rho$$

Two dynamical chiral symmetry breaking effects are generated from this theory

At the quark level

$$\partial_\mu \bar{\psi}\gamma_\mu\gamma_5\psi = 2im\bar{\psi}\gamma_5\psi$$

$$\int d^4q e^{iqx} < 0|T\{a^i_\mu(x)a^j_\nu(0)\}|0 >= (q_\mu q_\nu - q^2 g_{\mu\nu})\Pi_1(q^2)$$

$$+q_\mu q_\nu \Pi_2(q^2) + \frac{1}{2} g_{\mu\nu} m_\rho^2$$

The nonconservation of the axial-vector current is the source of $(1 - \frac{1}{2\pi^2 g^2})$

and the additional m_ρ^2

$q_\mu q_\nu \Pi_2(q^2)$ is a gauge fixing term and means

$$\partial_\mu a_\mu^i \neq 0$$

Therefore, besides three spin-1 components a_μ^i has a spin-0 content.

THEOREM I

The mass, gauge fixing term, scalar component of a gauge field which couples to axial-vector current of massive quark are dynamically generated.

For ρ meson

$$\rho^+\bar{d}\gamma_\mu u + \rho^-\bar{u}\gamma_\mu d$$

$$\partial_\mu \bar{d}\gamma_\mu u = i(m_u - m_d)\bar{d}u$$

THEOREM II

The mass, gauge fixing term, scalar component of a charged gauge field which couples to charged vector current of massive quarks are dynamically generated.

4 Applying to EW theory

In EW theory there are axial-vector currents and charged vector currents of massive fermions

$$m_t = 175GeV$$

plays essential role.

$$\mathcal{L} = \frac{\bar{g}}{4}\{(1-\frac{8}{3}\alpha)\bar{t}\gamma_\mu t + \bar{t}\gamma_\mu\gamma_5 t\}Z^\mu$$

$$-\frac{\bar{g}}{4}\{(1-\frac{4}{3}\alpha)\bar{b}\gamma_\mu b + \bar{b}\gamma_\mu\gamma_5 b\}Z^\mu$$

$$\mathcal{L} = \frac{g}{4}\bar{\psi}\gamma_\mu(1+\gamma_5)\tau^i\psi W^{i\mu}$$

Applying the two theorems(one-loop calculation)

$$m_Z^2 = \frac{1}{2}(g^2 + g'^2)(m_t^2 + m_b^2 + ...)$$

$$TH \;\; m_Z = 91.75(1\pm 0.00189)GeV \;\; EXP \;\; 91.1867\pm 0.0021GeV$$

$$Z_\mu = Z'_\mu + \frac{1}{m_Z}\partial_\mu\phi_Z \;\; \partial_\mu Z'_\mu = 0$$

$$m_{\phi_Z} = m_t e^{\frac{m_Z^2}{m_t^2}\frac{16\pi^2}{3g^2}+1} = 3.78\times 10^{14}GeV$$

$$\Delta_{\mu\nu} = \frac{1}{q^2 - m_Z^2}\{-g_{\mu\nu} + (1+\frac{1}{2\xi_Z})\frac{q_\mu q_\nu}{q^2 - m_{\phi_Z}^2}\}$$

$$\xi_z = -\frac{m_Z^2}{2m_{\phi_Z}^2} = -1.18 \times 10^{-25}$$

$$\phi_z \; IS \; A \; GHOST \; SCALAR$$

$$m_W^2 = \frac{1}{2} g^2 m_t^2$$

$$m_W = cos\theta_W m_Z$$

$$G_F = \frac{1}{2\sqrt{2} m_t^2}$$

$$TH \;\; m_W = 80.45 GeV \;\;\; EXP \;\; 80.403 GeV$$

$$W_\mu = W'_\mu + \frac{1}{m_W} \partial_\mu \phi_W$$

$$m_{\phi_W} = m_t e^{\frac{m_W^2}{m_t^2} \frac{16\pi^2}{3g^2}} = 9.31 \times 10^{13} GeV$$

$$\Delta_{\mu\nu} = \frac{1}{q^2 - m_W^2}\{-g_{\mu\nu} + (1 + \frac{1}{2\xi_W})\frac{q_\mu q_\nu}{q^2 - m_{\phi_W}^2}\}$$

$$\xi_W = -3.73 \times 10^{-25}$$

$$L = -\frac{1}{4}F^i_{\mu\nu}F^i_{\mu\nu} - \frac{1}{4}B_{\mu\nu}B_{\mu\nu} + \bar{\psi}\{i\partial\cdot\gamma + \frac{g}{2}\tau^i A^i\cdot\gamma + \frac{1}{2}g'YB\cdot\gamma\}\psi$$
$$-m_t\bar{t}t - m_b\bar{b}b$$

will do the job.

5 Summary

1. The new mechanism in EW theory does exist

2. The new EW theory can be tested by precision measurements

3. The new heavy scalar fields have something to do with dark matter and dark energy