PROBING STRONGLY INTERACTING ELECTROWEAK
SYMMETRY BREAKING MECHANISM AT HIGH ENERGY
COLLIDERS

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Abstract

We sketch some of our recent studies on probing strongly interacting electroweak
symmetry breaking mechanism at high energy colliders such as the CERN LHC and
the future $e^+e^-$ linear collider. The study includes both model-dependent and model-
independent probes.

1 Introduction

Despite of the remarkable success that the standard model (SM) has passed all the pre-
cision tests in the LEP/SLD experiments, the electroweak symmetry breaking (EWSB)
sector in the SM is not clear yet. So far, all results of experimental searches for the
Higgs boson are negative. The recent lower bound for the Higgs boson mass obtained
from the LEP2 experiments is $m_H > 107.7 \text{ GeV}$ [1]. At present, we only know the exis-
tence of a vacuum expectation value (VEV) $v = 246 \text{ GeV}$ which breaks the electroweak
gauge symmetry, but we do not know if it is just the VEV of the elementary SM Higgs
boson. We do not even know if there is really a Higgs boson below 1 TeV. The unclear
EWSB mechanism is a big puzzle in particle physics. Since all particle masses come
from the VEV $v$, probing the EWSB mechanism concerns the understanding of the
origin of all particle masses, which is a very radical problem in physics, and is one
of the most important topics in current high energy physics. Further experimental
studies on this important problem can be done at future TeV energy colliders such as
the CERN LHC and the future $e^+e^-$ linear collider (LC).

From the theoretical point of view, there are several unsatisfactory features in
the SM Higgs sector, e.g. there are so many free parameters related to the Higgs
sector, and the Higgs sector suffers from the well-known problems of **triviality** and **unnaturalness** [2]. Usually, people take the point of view that the present SM theory is only valid up to a certain physical energy scale \( \Lambda \), and new physics beyond the SM will become important above \( \Lambda \). Possible new physics are supersymmetry (SUSY) and dynamical EWSB mechanism concerning new strong interactions, etc. So that probing the EWSB mechanism also concerns the discovery of new physics.

In the SM, the Higgs boson mass \( m_H \) is a free parameter related to the Higgs self-coupling constant \( \lambda \) which is not theoretically predictable. Experimentally, although the Higgs boson is not found, the precision electroweak data may give some hint of the Higgs boson mass.

First of all, it has been pointed out that the best fit of the SM to the LEP/SLD precision \( Z \)-pole data requires the Higgs boson mass to be \( m_H = 107^{+67}_{-45} \) GeV, and the upper bound of \( m_H \) at the 90\% C.L. is \( m_H < 220 \) GeV [3]. This implies that the Higgs boson should be light.

However, we should keep in mind that this analysis is based on the pure SM formulae. It has been shown that once new physics effects are considered, the bound may change drastically. An analysis in Ref. 4 shows that if new physics can affect the oblique correction parameter \( S \), and if \( S \) is taken as an unknown parameter rather than the SM prediction, the precision data can be well fitted by \( S = -0.20^{+0.24}_{-0.17} \), \( m_H = 300^{+690}_{-310} \) GeV, \( m_t = 172.9 \pm 4.8 \) GeV, and \( \alpha_s = 0.1221 \pm 0.0035 \). We see that the upper bound of \( m_H \) in this analysis is close to 1 TeV.

Another interesting analysis was recently given in Ref. 5. Since the Higgs boson is not found, the authors consider the possibility that there is no undiscovered particles (like the Higgs boson) below \( \Lambda \sim \) few TeV. Then, at the LEP energy, the only particles (unphysical) related to the EWSB mechanism are the would-be Goldstone bosons (GBs). The system of the GBs with electroweak interactions can be generally described by the electroweak chiral Lagrangian (EWCL) [6] which can be regarded as the low energy effective Lagrangian of the fundamental theory of EWSB (see eqs. (1)–(3) in Sec. III). It is shown that the precision \( Z \)-pole data are only sensitive to the \( O(p^2) \) terms in the EWCL, which contain two terms related to the oblique correction parameters \( S \) and \( T \). The authors showed that the precision \( Z \)-pole data can be well fitted by the EWCL with the following values of the parameters: \( S = -0.13 \pm 0.10 \), \( T = 0.13 \pm 0.11 \), \( \alpha_s(M_Z) = 0.119 \pm 0.003 \). This result means that the \( Z \)-pole precision data can be well fitted even without a Higgs boson below the scale \( \Lambda \).

Therefore, the precision \( Z \)-pole data cannot actually tell us whether there is a light Higgs boson or not.

If there is a light Higgs boson, the interactions related to it are weak and are perturbatively calculable. The light Higgs will show up as a narrow resonance. If the Higgs boson is heavy, or there is no Higgs boson below 1 TeV, the interactions related to EWSB will be strong and perturbative calculation will not work. From the experi-
mental point of view, if the Higgs boson is so heavy that its width is comparable to its mass, it will not show up as a clear resonance, and the detection is hard. Therefore, in the strongly interacting EWSB case, both nonperturbative calculation techniques and feasible ways of probing the EWSB mechanism should be developed.

The above analyses show that both the weakly interacting and strongly interacting cases should be considered for probing the EWSB mechanism. A lot of studies on searching for a light Higgs boson at high energy colliders have been made in the literature. Here we briefly present our recent studies on probing the strongly interacting EWSB mechanism which contains two kinds of studies. Sec. II is on testing specific strongly interacting EWSB models, and Sec. III is on a model-independent probe of EWSB mechanism.

2 Testing Strongly Interacting EWSB Models

Introducing elementary Higgs field is the simplest but not unique model for the EWSB mechanism. The way of completely avoiding triviality and unnaturalness is to abandon elementary scalar fields and to introduce new strong interactions causing certain fermion condensates to break the electroweak gauge symmetry. This idea is similar to those in the theory of superconductivity and chiral symmetry breaking in QCD. The simplest model realizing this idea is the original QCD-like technicolor (TC) model. However, such a simple model predicts a too large value of the $S$ parameter and is already ruled out by the LEP data. A series of improved models have been proposed to overcome the shortcomings of the simplest model, such as the Appelquist-Terning one-family model \cite{7}, topcolor-assisted technicolor models \cite{8}, etc. Topcolor-assisted technicolor theory is an attractive improvement, which combines the technicolor and the top-condensate ideas. In this theory, the TC dynamics gives rise to the masses of the $u, d, s, c,$ and $b$ quarks and a small portion of the top quark mass, while the main part of the top quark mass comes from the topcolor dynamics causing the top quark condensate, just as the constituent quarks acquiring their large dynamical masses from the QCD dynamics causing the quark condensates. In this prescription, the TC dynamics does not cause a large oblique correction parameter $T$ even the mass difference $m_t - m_b$ is so large. Improvement of this kind of model is still in progress.

Most technicolor-type models contain certain pseudo-Goldstone bosons (PGBs) including technipions in the technicolor sector and an isospin triplet top-pions. Recently, we have shown that the LEP/SLD data of $R_b$ constraints the top-pion mass to a few hundred GeV \cite{9}. These light particles characterizing the phenomenology of the model. Direct searches for PGBs have been shown to be possible but not easy.

Since the coupling between the top quark and the EWSB sector is strong due to
the large top quark mass, a feasible way of testing the strongly interacting EWSB models is to test the PGB effects in top quark productions at high energy colliders. This has been studied by several authors [10, 11]. We studied these effects in top quark productions at the LHC [12] and in $\gamma\gamma$ [13] and $e\gamma$ [14] collisions at the photon collider based on the future LC. We took three typical TC models as examples in the study, namely the Appelquist-Terning one-family model (model A) [7] which is not assisted by topcolor, the original topcolor-assisted technicolor model (model B) [8], and the multiscale topcolor-assisted technicolor model (model C) [15]. The studies include calculating the production cross sections and $t\bar{t}$ invariant mass distributions which can provide the knowledge of whether the PGB effects can be tested and whether the three kinds of models can be experimentally distinguished without relying on the details of the models.

![Feynman diagrams](image)

**Fig. 1.** Feynman diagrams for the $s$-channel pseudo-Goldstone boson contributions to the $p(\bar{p}) \rightarrow t\bar{t}$ productions: (a) the techniquark triangle loop contributions, (b) the top quark triangle loop contributions. From Ref. 10.

At the LHC, there are three kinds of PGBs contributing to the top quark pair production, namely the neutral color-octet technipion $\Pi^{0a}$ with mass around 450 GeV, the neutral color-singlet technipion $\Pi^0$ with mass around 150 GeV, and the color-singlet top-pion with mass in a few hundred GeV region. Our study in Ref. 10 shows that the $s$-channel PGB contributions are dominant. The PGBs couple to the gluons via the fermion triangle loops. For very heavy fermions (techniquarks), the triangle loop was simply evaluated by the Adler-Bell-Jackiw anomaly. For the top quark triangle loop, $m_t$ is not large enough for the validity of simply using the Adler-Bell-Jackiw anomaly, and the $m_t$-dependence of this triangle loop was taken into account in the calculation. Among the $s$-channel PGB contributions, $\Pi^{0a}$ gives the largest resonance contribution to the $t\bar{t}$ production cross section. The results in Ref. 10 show that the PGB effects in the production cross sections are large enough to be detected at the LHC. Furthermore, the obtained cross sections are quite different for the three typical models. The relative differences of the cross sections between model A and model B, model A and model C, and model B and model C are $(40-60)\%$, $(11-54)\%$, and $(11-58)\%$, respectively [12]. Considering the statistical uncertainty and the expected systematic uncertainty for measuring the $t\bar{t}$ cross section at the LHC, the three models can be experimentally distinguished at the LHC. Furthermore, the
obtained \( t \bar{t} \) invariant mass distributions characterized by the resonance peak of \( \Pi^0 \) are quite different in the three kinds of models \cite{12}, so that they are also good observables for distinguishing the three kinds of models.

Our results in Ref. 11 for \( \gamma \gamma \to t \bar{t} \) and in Ref. 12 for \( e^+ \gamma \to t \bar{b} \bar{\nu}_e \) also lead to the same conclusion that the PGB effects in the three kinds of models can be detected and they can be distinguished at the LC such as the DESY TESLA.

3 Model-Independent Probe of EWSB Mechanism

There have been various kinds of EWSB models proposed, but we do not know whether the actual EWSB mechanism in the nature looks like one of them or not. Therefore, merely probing the proposed models is not sufficient, and certain model-independent probe of the EWSB mechanism is needed to see what the nature actually looks like. Since the scale of new physics is likely to be a few TeV, electroweak physics at energy \( E \leq 1 \) TeV can be effectively described by the EWCL \cite{6}. The EWCL is a general description (including all kinds of models) which contains certain unknown coefficients whose values are determined by the underlying dynamics. Different EWSB models give rise to different sets of coefficients. The model-independent probe is to investigate through what processes and to what precision we can measure these coefficients in the experiments at future high energy colliders. From the experimental point of view, the most challenging case of probing the EWSB mechanism is that there is no light scalar resonance found below 1 TeV. We took this case as the example in a series of our investigations \cite{17}. In the EWCL, the GBs \( \pi^a \) with electroweak interactions are described in the nonlinear realization \( U = e^{i\tau^a \pi^a / f} \). Up to the \( p^4 \)-order, the EWCL reads \cite{6, 17}

\[
L_{\text{eff}} = L_G + L_S ,
\]

where \( L_G \) is the weak gauge boson kinetic energy term, and

\[
L_S = L^{(2)} + L^{(2)'} + \sum_{n=1}^{14} L_n ,
\]

with

\[
L^{(2)} = \frac{f_\pi^2}{4} \text{Tr}[(D_\mu U) \dagger (D^\mu U)], \quad L^{(2)'} = \ell_0 \left( \frac{f_\pi}{\Lambda} \right)^2 \frac{f_\pi^2}{4} \text{Tr}(T \nabla U)^2 ,
\]

\(^1\)Effective Lagrangian including a light Higgs boson has also been studied in the literature \cite{16}.
\[ \mathcal{L}_1 = \ell_1 \left( \frac{f_\pi}{\Lambda} \right)^2 \frac{gg'}{2} B_{\mu\nu} \text{Tr}(T W^{\mu\nu}), \]
\[ \mathcal{L}_2 = \ell_2 \left( \frac{f_\pi}{\Lambda} \right)^2 \frac{ig'}{2} B_{\mu\nu} \text{Tr}(T [\nu^\mu, \nu^\nu]), \]
\[ \mathcal{L}_3 = \ell_3 \left( \frac{f_\pi}{\Lambda} \right)^2 i g \text{Tr}(W_{\mu\nu} [\nu^\mu, \nu^\nu]), \quad \mathcal{L}_4 = \ell_4 \left( \frac{f_\pi}{\Lambda} \right)^2 \text{Tr}([\nu^\mu, \nu^\nu])^2, \]
\[ \mathcal{L}_5 = \ell_5 \left( \frac{f_\pi}{\Lambda} \right)^2 \text{Tr}(\nu^\nu)^2, \]
\[ \mathcal{L}_6 = \ell_6 \left( \frac{f_\pi}{\Lambda} \right)^2 \text{Tr}([\nu^\mu, \nu^\nu])\text{Tr}(T \nu^\nu)\text{Tr}(T \nu^\nu), \]
\[ \mathcal{L}_7 = \ell_7 \left( \frac{f_\pi}{\Lambda} \right)^2 \text{Tr}([\nu^\mu, \nu^\nu])\text{Tr}(T \nu^\nu)\text{Tr}(T \nu^\nu), \]
\[ \mathcal{L}_8 = \ell_8 \left( \frac{f_\pi}{\Lambda} \right)^2 \frac{g^2}{4} \text{Tr}(T W_{\mu\nu})^2, \]
\[ \mathcal{L}_9 = \ell_9 \left( \frac{f_\pi}{\Lambda} \right)^2 \frac{ig}{2} \text{Tr}(T W_{\mu\nu})\text{Tr}(T [\nu^\nu, \nu^\nu]), \]
\[ \mathcal{L}_{10} = \ell_{10} \left( \frac{f_\pi}{\Lambda} \right)^2 \frac{1}{2} \text{Tr}(T \nu^\nu)\text{Tr}(T \nu^\nu)^2, \]
\[ \mathcal{L}_{11} = \ell_{11} \left( \frac{f_\pi}{\Lambda} \right)^2 g e^{\mu\nu\rho\lambda} \text{Tr}(T \nu^\mu)\text{Tr}(\nu^\nu W_{\rho\lambda}), \]
\[ \mathcal{L}_{12} = \ell_{12} \left( \frac{f_\pi}{\Lambda} \right)^2 2g \text{Tr}(T \nu^\mu)\text{Tr}(\nu^\nu W_{\mu\nu}), \]
\[ \mathcal{L}_{13} = \ell_{13} \left( \frac{f_\pi}{\Lambda} \right)^2 \frac{gg'}{4} e^{\mu\nu\rho\lambda} B_{\mu\nu} \text{Tr}(T W_{\rho\lambda}), \]
\[ \mathcal{L}_{14} = \ell_{14} \left( \frac{f_\pi}{\Lambda} \right)^2 \frac{g^2}{8} e^{\mu\nu\rho\lambda} \text{Tr}(T W_{\mu\nu})\text{Tr}(T W_{\rho\lambda}), \]

in which \( W_{\mu\nu} \) and \( B_{\mu\nu} \) are, respectively, the field strengths of the gauge fields \( W_\mu \equiv \tau^a W_\mu^a/2 \) and \( B_\mu \), \( D_\mu U = \partial_\mu U + ig W_\mu U - ig' UB_\mu \), \( \nu_\mu \equiv (D_\mu U)^\dagger \), and \( T \equiv U \tau_3 U^\dagger \).

The coefficients \( \ell_s \) reflect the strengths of the \( \pi^a \) interactions, i.e. the EWSB mechanism. \( \ell_1, \ell_0 \) and \( \ell_8 \) are related to the oblique correction parameters \( S, T \) and \( U \), respectively; \( \ell_2, \ell_3, \ell_9 \) are related to the triple-gauge-couplings; \( \mathcal{L}_{12}, \mathcal{L}_{13} \) and \( \mathcal{L}_{14} \) are CP-violating. The task is to find out experimental processes to measure the unknown \( \ell_s \).

Note that \( \pi^a \) are not physical particles, so that they are not experimentally observable. However, due to the Higgs mechanism, the degrees of freedom of \( \pi^a \) are related to the longitudinal components of the weak bosons \( V_\mu \) (\( W_L^\pm, Z_L^0 \)) which are experimentally observable. Thus \( \ell_s \) can be measured via \( V_L^\pm \)-processes. So that we need to know the quantitative relation between the \( V_L^\pm \)-amplitude (related to the experimental data) and the GB-amplitude (reflecting the EWSB mechanism), which is the so-called
equivalence theorem (ET). ET has been studied by many authors, and the final precise formulation of the ET and its rigorous proof are given in our series of papers [18]. The precise form of the ET is

$$T[V_{\alpha_1}^a, V_{\alpha_2}^a, \cdots] = C \cdot T[-i\pi^{\alpha_1}, i\pi^{\alpha_2}, \cdots] + B,$$

where \(T[V_{\alpha_1}^a, V_{\alpha_2}^a, \cdots]\) and \(T[-i\pi^{\alpha_1}, -i\pi^{\alpha_2}, \cdots]\) are, respectively, the \(V_{\alpha}^a\)-amplitude and the \(\pi^a\)-amplitude; \(C\) is a gauge and renormalization-scheme dependent constant factor, and \(B\) is a process-dependent function of the center-of-mass energy \(E\). By taking a specially convenient renormalization scheme, the constant \(C\) can be simplified to \(C = 1\) [18]. In the EWCL theory, the \(B\)-term may not be small even when \(E \gg M_W\), and is not sensitive to the EWSB mechanism. Therefore the \(B\)-term serves as an intrinsic background when probing \(\pi^a\)-amplitude via the \(V_{\alpha}^a\)-amplitude in (4). Only when \(|B| \ll |C \cdot T[-i\pi^{\alpha_1}, -i\pi^{\alpha_2}, \cdots]|\) the probe can be sensitive.

In our papers [17], a new power counting rule for semi-quantitatively estimating the amplitudes in the EWCL theory was proposed, and with which a systematic analysis on the sensitivities of probing the EWSB mechanism via the \(V_{\alpha}^a\) processes at the LHC and the LC were given. The results are summarized in the tables in Ref. 15. The conclusion is that the coefficients \(\ell_s\) can be experimentally determined via various \(V_{\alpha}^a\) processes at various phases of the LHC and the LC (including the \(e\gamma\) collider) complementarily. Without the LC, the LHC itself is not enough for determining all the coefficients. Quantitative calculations on the determination of the quartic-\(V_{\alpha}^a\)-couplings \(\ell_4\) and \(\ell_5\) at the 1.6 TeV LC has been carried out in Ref. 17 which shows that \(\ell_4\) and \(\ell_5\) can be determined at a higher precision with polarized electron beams. Determination of custodial-symmetry-violating-term coefficients \(\ell_6\) and \(\ell_7\) via the interplay between the \(V_{\alpha}^a V_{\alpha}^a\) fusion and \(VVV\) production has been studied in Ref. 18.

Once the coefficients \(\ell_n\)s are measured at the LHC and the LC, the next problem needed to solve is to study what kind of underlying theory will give rise to this set of coefficients. Only with this theoretical study, the systematic probe of the EWSB mechanism can be complete. Such a study is difficult due to the nonperturbative nature, and there is no such kind of systematic study in the literature.

This kind of study is similar to the problem of deriving the Gasser-Leutwyler Lagrangian for low lying pseudoscalar mesons (the chiral Lagrangian) [21] from the fundamental theory of QCD. We can take the QCD case as a starting point to do this kind of investigation since the coefficients in the Gasser-Leutwyler Lagrangian have already been experimentally measured and can be compared with the theoretical results. In our recent paper, Ref. 20, we developed certain techniques to formally derive the Gasser-Leutwyler Lagrangian from the first principles of QCD without taking approximations. All the coefficients in the Gasser-Leutwyler Lagrangian up to \(O(p^4)\) are
expressed in terms of certain Green’s functions in QCD [22], which can be regarded as the QCD definitions of the Gasser-Leutwyler coefficients. The results are [22]:

\[ O(p^2): \]

\[ F_0^2 = \frac{i}{8(N_f^2 - 1)} \int d^4x \left[ \left\langle \bar{\psi}^a(0) \gamma^\mu \gamma_5 \psi^b(0) \right| \left\langle \bar{\psi}(x) \gamma_\mu \gamma_5 \psi^a(x) \right\rangle \right] \]

\[ - \frac{1}{N_f} \left\langle \left[ \bar{\psi}^a(0) \gamma^\mu \gamma_5 \psi^a(0) \right| \left\langle \bar{\psi}(x) \gamma_\mu \gamma_5 \psi^b(x) \right\rangle \right\rangle \]

\[ - \left\langle \bar{\psi}^a(0) \gamma^\mu \gamma_5 \psi^b(0) \right\rangle \left\langle \bar{\psi}(x) \gamma_\mu \gamma_5 \psi^a(x) \right\rangle \]

\[ + \frac{1}{N_f} \left\langle \bar{\psi}^a(0) \gamma^\mu \gamma_5 \psi^a(0) \right\rangle \left\langle \bar{\psi}(x) \gamma_\mu \gamma_5 \psi^b(x) \right\rangle \right] \]

\[ F_0^2 B_0 = - \frac{1}{N_f} \left\langle \bar{\psi} \psi \right\rangle. \]  

\[ (5) \]

\[ O(p^4): \]

\[ L_1 = \frac{1}{32} K_4 + \frac{1}{16} K_5 + \frac{1}{16} K_{13} - \frac{1}{32} K_{14}, \]

\[ L_2 = \frac{1}{16} (K_4 + K_6) + \frac{1}{8} K_{13} - \frac{1}{16} K_{14}, \]

\[ L_3 = \frac{1}{16} (K_3 - 2K_4 - 6K_{13} + 3K_{14}), \]

\[ L_4 = \frac{K_{12}}{16B_0}, \quad L_5 = \frac{K_{11}}{16B_0}, \quad L_6 = \frac{K_8}{16B_0^2}, \]

\[ L_7 = -\frac{K_1}{16N_f} - \frac{K_{10}}{16B_0^2} - \frac{K_{15}}{16B_0N_f}, \]

\[ L_8 = \frac{1}{16} \left[ K_1 + \frac{1}{B_0^2} K_7 - \frac{1}{B_0^2} K_9 + \frac{1}{B_0} K_{15} \right], \]

\[ L_9 = \frac{1}{8} (4K_{13} - K_{14}), \quad L_{10} = \frac{1}{2} (K_2 - K_{13}), \]

\[ H_1 = -\frac{1}{4} (K_2 + K_{13}), \]

\[ H_2 = \frac{1}{8} [-K_1 + \frac{1}{B_0^2} K_7 + \frac{1}{B_0^2} K_9 - \frac{1}{B_0} K_{15}], \]  

\[ (6) \]

where \( K_s \)s are terms with different Lorentz structures in certain Greene’s functions in QCD [22]. Both the anomaly part (from the quark functional measure) and the
normal part (from the QCD Lagrangian) give contributions to these coefficients, and the complete coefficients are given by

\[ F_0^2 = (F_0^2)^{\text{(anom)}} + (F_0^2)^{\text{(norm)}}, \]
\[ F_0^2 B_0 = (F_0^2 B_0)^{\text{(anom)}} + (F_0^2 B_0)^{\text{(norm)}}, \]
\[ L_i = L_i^{\text{(anom)}} + L_i^{\text{(norm)}}, \quad i = 1, \ldots, 10, \]
\[ H_i = H_i^{\text{(anom)}} + H_i^{\text{(norm)}}, \quad i = 1, \ldots, 10, \]

(7)

where the superscripts (anom) and (norm) denote the anomaly part and normal part contributions, respectively.

In principle, the related QCD Green’s functions can be calculated on the lattice or in certain approximations. The method in Ref. 20 can be applied to the electroweak theory to make the above desired study which is in progress.

4 Conclusions

We have briefly sketched the results in several of our recent papers concerning the probe of strongly interacting EWSB mechanism at high energy colliders such as the CERN LHC and the future \( e^+e^- \) linear collider. It contains two kinds of studies.

In the model-dependent study, we paid special attention to the effects of the PGBs which characterize the properties of different technicolor models. Without relying on the details of the technicolor models, we studied the PGB effects in \( t\bar{t} \) productions at the LHC, and in \( \gamma\gamma \) and \( e\gamma \) collisions at the \( e^+e^- \) linear collider. We showed that not only the PGB effects in certain typical improved technicolor models can be detected at these high energy colliders, but different typical technicolor models can also be experimentally distinguished by measuring the production cross sections and the \( t\bar{t} \) invariant mass distributions \[12, 13, 14\].

In the model-independent study, we have proposed and developed a systematic way of measuring the coefficients in the EWCL which reflect the EWSB mechanism, including the rigorous proof of the equivalence theorem \[15\], proposing a new power counting rule for estimating the reaction amplitudes in the EWCL theory \[17\], and a global analysis of the sensitivity of measuring the EWCL coefficients at high energy colliders \[17\]. We showed that the EWCL coefficients can be measured at the LHC and the LC, and LHC alone is not enough for this purpose.

We then studied the possibility of predicting the EWCL coefficients from the underlying theory of EWSB mechanism, which may be compared with the measured coefficients to get the knowledge of the EWSM mechanism in the nature. This kind of study is started from trying to derive the chiral Lagrangian for pseudoscalar mesons.
from QCD, and certain progress has been made in our recent paper [22]. The method can be applied to the study of the EWCL, and the study is in progress.

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