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S, T, U Parameter and Form Factor with d=6 Dimension Operator Non-Decoupling Effects of Heavy Particles in the Triple Gauge Boson (TGB) Vertices

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Abstract

As our concern lies exploring models involving physics beyond Standard model, we will discuss non-decoupling effects of the type (ii). These are expected to provide some useful constraints on the properties of new physics which might lie beyond the standard model. As far as light fermions processes are concerned, we only have to deal with non-decoupling contributions to the gauge boson two point functions the so called oblique corrections. The non-decoupling contribution of heavy particles is present in higher n-point functions of gauge boson. We have solved separately. This can be visualize oblique correction and vertex correction in the form factor for the $e^+ e^-$ collider to find out their concern through d=6 operator.

Keywords: Decoupling effects, S, T, U parameters, TGB vertices contributions.

Introduction

Any unified model of electroweak and strong interactions beyond the standard model is characterized by the existence of heavy particles of masses $M>>M_W$, M_W being the weak boson mass. Since such heavy particles are not likely to be discovered in the immediate future because of non-availability of energy it is of important to ask how their effects may be detected in low energy ($E\leq M_W$) processes of light ($m\leq M_W$) particles, such as those measured at LEP and SLC experiments, through radiative corrections. Restricting ourselves to those classes of beyond the standard modes in which the heavy particles manifest themselves only through loop effects at low energy, we divide such loop effects of heavy particles which give new physics contributions into two types:

i). Those which virtually decouple in the limit $M\rightarrow\infty$ and
ii). Those which do not decouple in the same limit.

In the type (i) the heavy mass M is dominated by a new large mass scale M_S, with $M^2=M^2+O\ (M_W^2)$. We note that the term giving M_S is $SU(2)_L\ X\ U(1)_Y$ singlet, and hence the heavy particles contributions to low-energy processes are suppressed by $\frac{1}{M_S^2}$ the so called decoupling theorem. On the other hand, in the type (ii) M has its origin in the $SU(2)_L\ X\ U(1)_Y$ breaking due to the VEV of the Higgs φ, and large M means a large coupling constant. The latter factor appearing in the numerator of amplitude cancels the suppression factor $\frac{1}{M^2}$, leading to non-decoupling effects of heavy particles.

Objective

Higher n-Point Functions of Gauge Boson

The next question to ask is whether similar non-decoupling contributions of heavy particles are present in higher n-point functions of gauge boson. The answer is known, namely, at one-loop level for n>4, the coefficient of the relevant operator O_i is suppressed by $\frac{1}{M^{n-4}}$ or more strongly since O_i has dimension $d_i\geq n$. Hence $n\approx 2,3,4$ is the only possibility to have non-decoupling effects. As such if the triple gauge boson (TGB) vertices are of relevance to use, we confine our study to only these vertices $(n\approx 2)$. Experimentally these vertices are expected to be probed in the W^+W^- production at LEP II or ensuing collider.

The inevitability of non-decoupling effects in triple gauge boson (TGB) vertices may be understood from a simple operator analysis. In a theory with spontaneous gauge symmetry breaking, quantum corrections due to heavy loops can be described in terms of gauge invariant effective operators consisting of gauge fields and the Higgs fields (φ). Gauge non-invariant effective operators in the broken phase arise when φ is replaced by the sum of its VEV v and the shifted field. To illustrate it we consider an example of the operator of dimension d=6,

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$$\phi^{\dagger}\sigma^{a}\phi\, W^{a}_{\mu\nu}B^{\mu\nu} = \upsilon^{2}W^{3}_{\mu\nu}B^{\mu\nu} \quad (1)$$

The r. h. s. of Eq. (1) expresses a broken symmetry phase. The first term $\upsilon^{2}(\vartheta_{\mu}W^{3}_{\nu} - \vartheta_{\nu}W^{3}_{\mu})B^{\mu\nu}$ contributes to the parameter S (as it describes only two point function), while the term $\upsilon^{2}(-ig\, W^{+}_{\mu}W^{-}_{\nu})\, B^{\mu\nu}$ induces a TGB coupling. We conclude that in such cases both S, T, U parameters as well as TGB contributions are to be explored in gauge boson dynamics of this kind.

Relation between S, T, U parameters and TGB vertices contributions

We illustrate this aspect by considering the Eq. (1). We have

$$\phi^{\dagger}\sigma^{a}\phi\, W^{a}_{\mu\nu}B^{\mu\nu} = \upsilon^{2}W^{3}_{\mu\nu}B^{\mu\nu}$$
$$= \upsilon^{2}\left[(\vartheta_{\mu}W^{3}_{\nu})(\vartheta^{\mu}B^{\nu}) - (\vartheta_{\nu}W^{3}_{\mu})(\vartheta^{\mu}B^{\nu}) - \ldots\ldots..\right] \quad (2)$$

Next we put W^{3}_{μ} and B_{μ} and get

$$\cong \upsilon^{2}\left[(sin\theta_{W}\ cos\theta_{W})(\vartheta_{\mu}A_{\nu}\vartheta^{\mu}A^{\nu} - \vartheta_{\mu}Z_{\nu}\vartheta^{\mu}Z^{\nu}) + cos^{2}\theta_{W}(\vartheta_{\mu}Z_{\nu}\vartheta^{\mu}A^{\nu}) - sin^{2}\theta_{W}(\vartheta_{\mu}A_{\nu}\vartheta^{\mu}Z^{\nu}) + \ldots.\right] - ig\upsilon^{2}\left[(cos\theta_{W})(W^{+}_{\mu}W^{-}_{\nu}\vartheta^{\mu}A^{\nu}) - (sin\theta_{W})(W^{+}_{\mu}W^{-}_{\nu}\vartheta^{\nu}Z^{\mu}) \cdot \ldots\ldots\ldots..\right]. \quad (3)$$

We note that the first term (coefficient) of Eq. (3) contributes to the S parameter as per our definition, where

$$\alpha S \cong 4\, e^{2}\left[\Pi'_{33}(0) - \Pi'_{3Q}(0)\right]$$

As defined by Peskin and Takeuchi, with $d_{effective}$=6.
The second term of Eq. (3) induces a TGB coupling $W^{+}_{\mu}W^{-}_{\nu}\vartheta^{\mu}A^{\nu}$, $W^{+}_{\mu}W^{-}_{\nu}\vartheta^{\nu}Z^{\mu}$.

This shows that both the parameters S and TGB contribution are present in the term Eq. (1).

Conclusion

We have able to explain through explicit ally calculation and find out oblique S, T, U parameters and Vertex TGB form factors are related through the type (ii) contribution. The coefficient of higher dimensions (d>4) operator is inversely proportional d=6 operator which will give $\frac{1}{M^{2}_{singlet}}$ term are the most important ones for this case and two and three point functions are expected to be mutually related.

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