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Search Forward-Backward Asymmetry Due to the New Z' Gauge Boson in e^+e^- Collision

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ABSTRACT

The Forward-Backward (FB) asymmetry is studied in the framework of the several models containing new Z' gauge boson in e^+e^- collision. It is shown that this physical observable is sensitive to these models. The results of this analysis can be used in the search of new physics at coming LHC experiments.

Keywords: ???

1. INTRODUCTION

Various extensions of the Standard Model (SM), such as Sequential, E6 and Minimal 3-3-1 Model etc., are predicted the existence of an extra heavy neutral gauge boson. The Z' gauge boson is characterized by a mass, width and its couplings to the fermions and bosons which are model dependent [1-3].

In the extensions of the Standard Model (SM) such as E6 and Left-Right (LR) Symmetric models, the Z' coupling constants can be represented as a function of the mixing angles θ_6 and α_{LR} , respectively. The $U(1)_\psi$ and $U(1)_\chi$ groups are described by their hypercharges of the E6 fundamental representation 27 [4]. From their linear combination, their hypercharges can be written as follows:

$$Q'(\alpha) = Q_\psi \cos\alpha + Q_\chi \sin\alpha \\ Q''(\alpha) = Q_\psi \sin\alpha - Q_\chi \cos\alpha \qquad (1)$$

where α is mixing angle to the E6 gauge group [5].

In the minimal 3-3-1 model has gauge group $SU(3)_C \otimes SU(3)_L \otimes U(1)_N$ which is include new fermions, scalars and gauge bosons [3]. To obtain minimal version in 3-3-1 model, we combined the $SU(2)_L$ doublet left handed leptons components [6]. The axial and vector coupling constants are the same for leptons in minimal model, whereas they are different for quarks. Especially, t and b quarks differ from another quarks. Direct search constraints on Z' boson come from high energy experiments. The CDF experiment searches for resonance Z' production and its decay to e^+e^- to put limits on the mass of Z' with Standard couplings at 95% C.L. [7-11].

This work is organized as follows: In the section 2, a brief of the theoretical framework is presented. Also, we present calculation for forward-backward asymmetry due to the Z' boson in e+e− collider at CLIC energies. Discussions are given in section 3.

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2. THEORETICAL FRAMEWORK

The interaction Lagrangian between the Z' gauge boson and SM fermions can be written as follows [12]:

$$L = \frac{1}{2} g_{Z'} \bar{f}\gamma^{\mu}[c_L(1-\gamma_5) + c_R(1+\gamma_5)] f Z'_{\mu} \quad (2)$$

where $g_{z'}$ is the gauge coupling, c_L and c_R are the left and right handed fermion couplings. f, indicate the final fermion state in the $e^+e^- \rightarrow f\bar{f}$ reaction. They can be defined as a vector and axial couplings for fermions, via

$c_L = (c_V^f + c_A^f)/4, \qquad c_R = (c_V^f - c_A^f)/4,$

respectively. All parameters appearing in the Lagrangian are constrained by the gauge and Lorentz invariance.

Direct searches to the new gauge bosons are fullfilled at hadron colliders, since these give access to the highest energies. In order to search for high-mass dilepton resonances, the Z' boson would be produced by quark-antiquark annihilation and decay to an electron-positron pair or a pair of opposite-charged muons.

Indirect searches the new gauge bosons are performed at electron-positron colliders, since these give access to high-precision measurements of the properties of the Standard Model Z boson.

The constraint depend on Z' mass and its mixing with the Z. Lower limit to the mass of the Z' boson is obtained from LEP and it was found that it should be heavier than a few hundred GeV for typical model parameters. The ILC will extend this reach up to 5 to 10 TeV depending on the model, since it will offer measurements of additional properties of the Z' boson.

In this work, we are looking for deviations from the SM-like predictions of the forward-backward asymmetry (A_{FB}). The differential cross section for the production of a pair of fermions (ff) is given as follows:

$$\frac{d\sigma}{dz} = \frac{N_F s}{32\pi} \sum_{ij} P_{ij}^{ss} \left[B_{ij}(1+z^2) + 2C_{ij} z \right] \quad (3)$$

where $z = \cos\theta$, the scattering angle in the center of mass frame(CM) and N_F is color factor and

$$P_{ij}^{ss} = \frac{\left(s - M_i^2\right)\left(s - M_j^2\right) + \left(\Gamma_i M_i\right)\left(\Gamma_j M_j\right)}{\left[\left(s - M_i^2\right)^2 + \left(\Gamma_i M_i\right)^2\right]\left[\left(s - M_j^2\right)^2 + \left(\Gamma_j M_j\right)^2\right]}$$

(4)

where $M_i(\Gamma_i)$ is the mass width of the i-th gauge boson

$$B_{ij} \equiv (v_i v_j + a_i a_j)_f (v_i v_j + a_i a_j)_e$$
$$C_{ij} \equiv (v_i a_j + a_i v_j)_f (v_i a_j + a_i v_j)_e \quad (5)$$

Using to the couplings normalized as

$$L = \sum_i \left[\bar{f}\gamma_{\mu}(v_{if} - a_{if}\gamma_5) f + \bar{e}\gamma_{\mu}(v_{ie} - a_{ie}\gamma_5) e \right] Z_i^{\mu}$$

(6)

The forward-backward asymmetry is determined as follows:

$$A_{FB} = \frac{\left(\int_0^1 dz \frac{d\sigma}{dzds} - \int_{-1}^0 dz \frac{d\sigma}{dzds} \right)}{\left(\int_0^1 dz \frac{d\sigma}{dzds} + \int_{-1}^0 dz \frac{d\sigma}{dzds} \right)} \quad (7)$$

Obviously, due to the Z' boson Exchange diagram, the interference term can give considerable contribution to the forward-backward asymmetry.

Table1: Coupling constants values for different models.

	c_V^e	c_A^e	c_V^f	c_A^f
Sequential	0.08	-1	-0.08	-1
E6	0	0.506	0	0.506
3-3-1 Minimal	0.068	-0.023	0.068	-0.023
3-3-1 RH	-0.027	0.347	-0.027	0.347

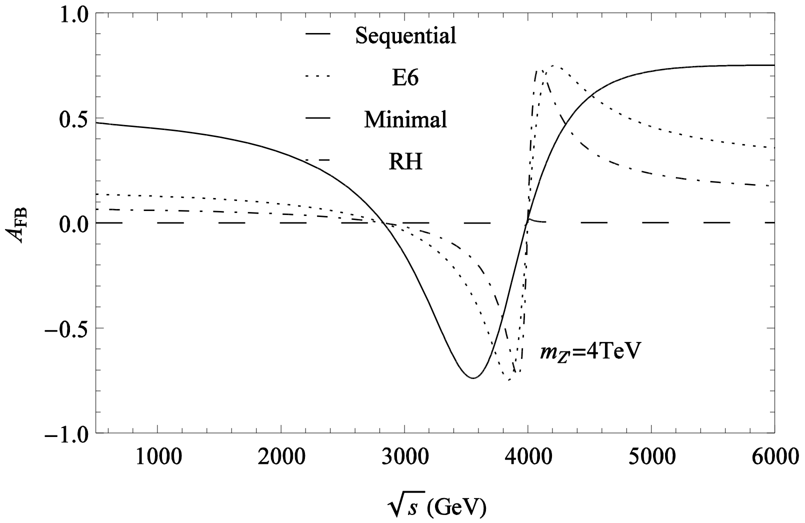

Figure 1. The dependence of the forward-backward asymmetry (A_{FB}) versus $\sqrt{s}$ center of mass (CM) energy for the $e^+e^- \to f\bar{f}$ reaction.

3. DISCUSSION

The Forward-Backward (FB) asymmetry is studied in the framework of the several models containing extra new gauge boson *Z′* in e^+e^- collision.

In Figure 1, we presented to the dependence of the forward-backward asymmetry at the center of the mass (CM) energy of the initial states. From Figure 1, it follows that the forward-backward asymmetry is the most sensitive for the $e^+e^- \to f\bar{f}$ reaction. It is obviously that there is differences in asymmetry around the mass of the *Z′* boson for different models. The measurement of asymmetry can play very useful role in the discrimination of models and for choosing "right" model.

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