A POSSIBLE EXPLANATION OF THE L3 $l^+l^-\gamma\gamma$ EVENTS

CHONG-XING YUE[a,b] AND GONG-RU LU[a,b,c]

[a]Department of Physics, Henan Normal University
Xinxiang, Henan, 453002, P.R. China*

[b]The Fundamental and Applied Science Research Institute of Henan
Zhengzhou, Henan, 450052, P.R. China

[c]The Institute of Theoretical Physics, Academia Sinica
P.O. BOX 2735, Beijing 100080, P.R. China

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In this note we attempt to explain the L3 $l^+l^-\gamma\gamma$ events in technicolor models. We find that the four L3 events are in reasonable agreement with the signature characterized by the process of $Z \to \rho^0 P^0 \to l^+l^- P^0(\gamma\gamma)$.

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The L3 collaboration has recently reported four $l^+l^-\gamma\gamma$ events (there are three events with $l = \mu$ and one with $l = e$) with $M_{\gamma\gamma} = 60$ GeV [1] which could not be explained by Standard Model processes. If we assume that the events are not due to bremsstrahlung, they would imply a kind of new physics [2]. In this letter we assume that the new particle with the mass of about 60 GeV is neutral pseudo Goldstone boson (PGB), which arise from technicolor models [3] and consider the various possibilities to explain the four L3 events.

Several groups [4, 5] have studied radiative corrections to electroweak observables in the context of technicolor models. In particular, Ref. [5] argued that the Peskin–Takeuchi electroweak parameter S is positive and sizable in contradiction to the preliminary experimental data which are small and negative. However, Ref. [6] has shown that the pseudo Goldstone bosons (PGB's) contribution to parameter S can be negative in a class of technicolor models. This negative contribution can be large enough to cancel the

* Mailing address

positive technihadron contribution. This shows that electroweak precision tests alone cannot be used to rule out technicolor. Therefore, direct search for particles associated with technicolor (PGB's and vector mesons) are still required to test technicolor. For simplicity we consider QCD-like technicolor model; its gauge group is $\mathrm{SU}(N_T)$. At energy scale Λ_{TC}, the technicolor interactions become strong and chiral flavor symmetry $\mathrm{SU}(N_f)_\mathrm{L} \times \mathrm{SU}(N_f)_\mathrm{R}$ is dynamically broken down to $\mathrm{SU}(N_f)_V$ by two technifermion condensate, and consequently a large number of PGB's and vector mesons would be produced. In general, the technicolor models contain neutral spin-one vector mesons and neutral PGB's which carry neither electric charge nor color. The neutral vector meson can interact with gauge boson and PGB. The neutral particle P^0 could be produced *via* the reaction $e^+e^- \to Z \to AP^0$ (A is a gauge boson) [7]. So, the possibilities for technicolor to explain the four L3 events are channel (a), $e^+e^- \to Z \to AP^0 \to l^+l^-P^0(\gamma\gamma)$, and channel (b), $e^+e^- \to Z \to \rho^0 P^0 \to l^+l^-P^0(\gamma\gamma)$, where P^0 is pseudo Goldstone boson and ρ^0 is virtual vector meson which arises from technicolor models.

The neutral isospin singlet PGB can couple to gluons. Its main decay mode is into two gluons. So the pseudoscalar particle P^0 should be color-singlet isospin triplet neutral PGB [8]. At the mass scale (say around 60 GeV) we consider the decays $P^0 \to Z\gamma$, $P^0 \to ZZ$ are forbidden due to the large Z mass. The $\gamma\gamma$ decay of P^0 is dominant. The "true" technicolor model might contain technifermions, and therefore PGB's which have no couplings to quarks or leptons, or which couple only indirectly through their weak charge [7]. In this case, the branching ratio for $P^0 \to \gamma\gamma$ is $\mathrm{BR}(P^0 \to \gamma\gamma) \approx 1$.

First we consider the channel (a). Its Feynman diagrams are depicted in Fig. 1.

(i) If we take $A = Z^*$ (Fig.1a), Z^* is a virtual gauge boson. We can predict the branching ratio of Z^* decays to fermion pairs and $\gamma\gamma$ as [2]

$$e^+e^-\gamma\gamma : \mu^+\mu^-\gamma\gamma : \nu\nu\gamma\gamma \approx 1 : 1 : 6\,, \tag{1}$$

which is apparently inconsistent with the experimental data. This case should be ruled out.

(ii) If we take $A = \gamma^*$ (Fig. 1b), three-photon events should be observed at LEP *via* the process of Fig. 1c, but no such events have been reported. This gives the constraint:

$$\mathrm{BR}(Z \to P^0\gamma)\mathrm{BR}(P^0 \to \gamma\gamma) < 10^{-7}\,. \tag{2}$$

Since $\mathrm{BR}(P^0 \to \gamma\gamma) \approx 1$, the $\mathrm{BR}(Z \to P^0\gamma)$ is very small. We can ignore the contribution of photon and this agrees with the result of

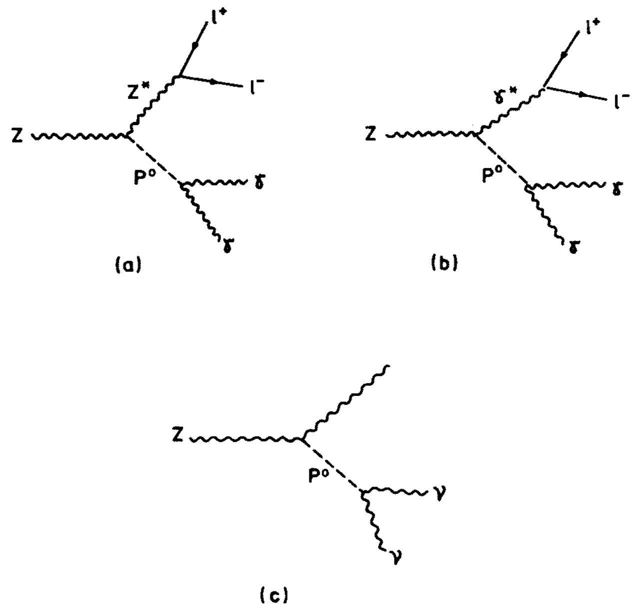

Fig. 1.

Ref. [9]. From Ref. [10] the mass of vector meson is

$$m_\rho = 885\left[\frac{4}{N_T}\right]^{1/2}\left[\frac{4}{N_d}\right]^{1/2}\ \text{GeV}\,. \tag{3}$$

Since ρ^0 is a colorless isotriplet neutral virtual particle, it is reasonable to assume the channel (b) (as shown in Fig. 2) to occur. Following scaled up version of QCD, we write $ZP^0\rho^0$ coupling as in Refs [10] and [11].

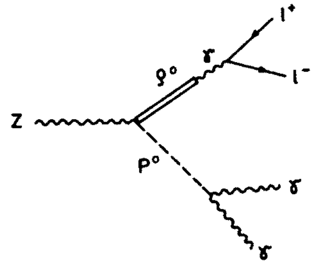

Fig. 2.

$$g_{ZP^0\rho^0} = 2g_\rho\sqrt{\frac{3}{N_T}} \times \mathrm{Tr}\{x_a[x_b,\, x_c]\}\,, \tag{4}$$

where x_a is the gauge generator of particle Z, x_b is the chiral generator of the neutral pseudoscalar P^0 and x_c is the generator of ρ^0 corresponding to the vector meson. g_ρ is the coupling constant of the $\rho\pi\pi$ coupling in QCD and $\frac{g_\rho^2}{4\pi} = 2.98$. $2\{x_a[x_b,\, x_c]\} = \frac{1}{\sqrt{N_d}}$. Thus

$$g_{ZP^0\rho^0} = g_\rho \times \sqrt{\frac{3}{N_d N_T}}\,. \tag{5}$$

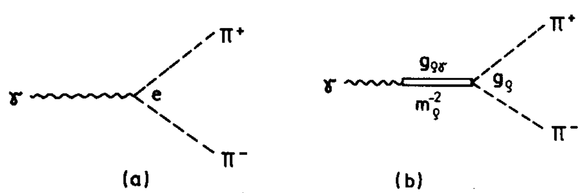

Fig. 3.

The coupling of a photon to $\pi^+\pi^-$ is proportional to a kinematic factor times e (Fig. 3a). The same kinematic factor characterizes the $\rho^0\pi^+\pi^-$ coupling (Fig. 3b), and vector-meson dominance of the low K^2 behavior of Fig. 3 requires

$$e = \frac{g_{\rho\gamma}g_\rho}{m_\rho^2}\,, \quad g_{\rho\gamma} = \frac{em_\rho^2}{g_\rho}\,. \tag{6}$$

Since the coupling of a photon to l^+l^- is proportional to a kinematic factor times e, we can write the $\rho^0 l^+l^-$ coupling [12] as

$$g_{\rho^0 l^+l^-} \approx \frac{e^2 m_\rho}{g_\rho}\,. \tag{7}$$

In the standard model we can write ZZ^*H, $Z^*l^+l^-$ coupling as follows:

$$g_{ZZ^*H} = \frac{em_Z}{2\sin\theta_W\cos\theta_W}\,, \tag{8}$$

$$g_{Z^*l^+l^-} = e(V_f - a_f\gamma_5)\,, \tag{9}$$

$$V_f = \frac{I_3^f - 2Q_f\sin^2\theta_W}{\sin\theta_W\cos\theta_W}\,,$$

$$a_f = \frac{I_3^f}{2\sin\theta_W\cos\theta_W}\,, \tag{10}$$

$$R = \frac{\Gamma[Z \to \rho^0 P^0 \to e^+e^- P^0(\gamma\gamma)]}{\Gamma[Z \to Z^* H \to e^+e^-\gamma\gamma]} \approx \frac{g^2_{Z\rho^0 P^0}}{g^2_{ZZ^*H}} \times \frac{e^2 m_\rho m_Z}{g^2_\rho (V_f^2 + a_f^2)}$$
$$= \frac{24 \sin^4\theta_W \cos^4\theta_W}{N_d N_T (1 - 2\sin^2\theta_W + 2\sin^4\theta_W)} \times \frac{m_\rho}{m_Z} \approx 0.7\,. \quad (11)$$

In the above estimation we take $\sin^2\theta_W = 0.227$, $m_Z = 91.175$ GeV, $N_d = N_T = 4$. In the standard model, the branching fraction for $Z \to Z^*H \to e^+e^-\gamma\gamma$ is 8.4×10^{-7} for $m_H = 60$ GeV [13]. The order of the branching fraction for $Z \to \rho^0 P^0 \to e^+e^- P^0(\gamma\gamma)$ is

$$\mathrm{BR}[Z \to \rho^0 P^0 \to e^+e^- P^0(\gamma\gamma)] = 5.9 \times 10^{-7}\,. \quad (12)$$

Most recent limit of L3 events (Z^0 statistics doubled, but no new $l^+l^-\gamma\gamma$ events):

$$\mathrm{BR}^{\mathrm{exp}}(Z \to e^+e^-\gamma\gamma) \approx 4 \times 10^{-7}\,. \quad (13)$$

We see that the branching ratio Eq. (12) is basically in agreement with the experimental result.

We have investigated several possibilities to explain the four L3 $\gamma\gamma l^+l^-$ events in technicolor models. We find that existing four L3 events are basically in agreement with the signatures characterized by the process of $Z \to P^0\rho^0 \to P^0(\gamma\gamma)l^+l^-$. The channel (a), $Z \to \gamma^* P^0 \to l^+l^- P^0(\gamma\gamma)$, has been ruled out because of its tiny branching ratio. But we should realize that several assumptions have been involved in our analysis and we have poor understanding of them. Furthermore, other problems — such as where are the anomalous $\gamma\gamma\tau^+$, $\gamma\gamma q\bar{q}$ events — remain open questions. If the L3 events are really the signal of new physics, we believe that this discussion will provide useful information for testing technicolor theories.

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