New Limits on the Color-Octet Technirho Mass from its Decay to Dijets

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Abstract

Recently has been shown that the physical (mass eigenstate) color-octet technirho does not couple to two gluons. In this letter we study how this result affects the presently accepted limits for the color-octet technirho mass obtained from the study of dijets production at the Tevatron. First we show that data from Tevatron Run 1b can not exclude any mass range. Finally, we obtain limits for the Tevatron Run II.

I. INTRODUCTION

It is commonly believed that colliders such as the Tevatron (Run II) and the LHC may discover phenomena beyond the Standard Model and reveal the mechanism of electroweak symmetry breaking. Many people believe that this new physics will be described by some sort of super-symmetric extension of the Standard Model. Nevertheless, other logical possibilities still exist and must be considered. One of these alternatives is dynamical electroweak symmetry breaking [1]. Its best known realization, the naïve QCD-like Technicolor idea, has been severely challenged by precision measurement from LEP; however models incorporating ideas such as Walking Technicolor or Top-color assisted Technicolor can evade these
difficulties. In this letter we deal with some features which are present in many non-minimal Technicolor models.

A very interesting prediction of this kind of models is the existence of color-nonsinglets resonances. Of special interest is the color octet isosinglet vector resonance called technirho. Its phenomenology has been studied by many authors \cite{2,3} and experimental limits on its mass has been established at the Tevatron \cite{4,5}. However, Zerwekh and Rosenfeld \cite{6} have shown that the traditional description of the color-octet technirho interactions can be considered incomplete. They propose a complete and explicitly gauge invariant model for the color-octet technirho interactions. An important consequence of their model is that a physical technirho does not couple to two gluons. In this letter we investigate how this result modifies the existing limit on the technirho mass coming from its decay to dijets.

The letter is organized as follow. In Section II we present the methodology we use in our calculation. Section III is devoted to the presentation of our results. Finally, in Section IV we summarize our main conclusions.

II. METHODOLOGY

Because the physical technirho does not couple to two gluons, its only contribution to dijets production is through its decay to a quark-anti-quark pair. The technirho-quarks interaction is described by the lagrangian

\[
\mathcal{L}_{\text{int}} = -g \tan \alpha \bar{\psi} \gamma^\mu \rho^a_\mu \frac{\lambda^a}{2} \psi
\]  

where \( g \) is the QCD coupling constant and \( \alpha \) is the technirho-gluon mixing angle with its value given by the formula:

\[
\sin \alpha = \frac{g}{\sqrt{2\pi}} \frac{1}{\sqrt{2.91 \times 3/N_{tc}}}
\]

where \( N_{tc} \) is the number of technicolors. In this letter we take the usual value \( N_{tc} = 4 \).
We wrote a FORTRAN code in order to convolute the partonic amplitudes with the partonic distribution functions CTEQ2L \[7\]. In order to compare our results with experimental data, the following kinematical cuts were implemented \[5\]:

\[ |\eta| < 2.0 \text{ GeV for both jets} \]  

(3) and

\[ |\cos \theta^*| = \left| \tanh \left( \frac{(\eta_1 - \eta_2)}{2} \right) \right| < \frac{2}{3} \]  

(4)

where $\eta$ is the pseudo-rapidity.

In our calculation we used the one loop expression for the running QCD coupling $\alpha_{QCD}(Q^2)$ with $\Lambda_{QCD} = 200 \text{ MeV}$, a renormalization scale given by $Q^2 = \hat{s}$ and five light quark flavors. We also assume that the technirho decay into two technipions is closed.

III. RESULTS

Table \[1\] shows the technirho total width, for different values of the technirho mass, and the signal cross section for a $p\bar{p}$ collider running at a center of mass energy given by $\sqrt{s} = 1800 \text{ GeV}$.

In figure 1 we compare our result (continuous line) with the prediction obtained using the traditional description of the gluon-technirho mixing (dashed line) and with the 95% C.L. upper limit obtained by CDF Collaboration \[3\] for a luminosity of 106 $\text{pb}^{-1}$ (black triangles). An extrapolation of the experimental upper limit for a luminosity of 2000 $\text{pb}^{-1}$ (Tevatron Run II) can be obtained from the previous one by scaling inversely with the square root of the luminosity \[8\], and it is also plotted in the same figure (white triangles).

Notice that our result is significantly smaller than the prediction of the traditional approach. In fact, according to our result, the CDF data cannot exclude any technirho mass range, which is in contradiction with the accepted limits: $260 < M_{\rho_T} < 470 \text{ GeV}$.

\[ \hat{s} \] is the partonic center of mass energy and in our case corresponds to the dijets invariant mass.
On the other hand, two mass intervals can be excluded at the Tevatron Run II: $260 < M_{\rho_T^8} < 475$ GeV and $600 < M_{\rho_T^8} < 775$ GeV, but an important intermediate mass interval is still allowed. Again, our result is in contradiction with the limits expected by the traditional approach: $220 < M_{\rho_T^8} < 820$ GeV.

IV. CONCLUSIONS

In this letter we have studied the limits of the color-octet technirho through its decay to dijets in the context of a recently proposed complete model for the technirho interactions. Our results are significantly different from what is expected in the framework of the traditional approach to the technirho-gluon mixing. We show, for example, that the data from the Tevatron Run Ib can not exclude any technirho mass range. On the other hand, the Tevatron Run II can exclude masses in the range $260 < M_{\rho_T^8} < 475$ GeV and $600 < M_{\rho_T^8} < 775$ GeV

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TABLE I. Technirho total width and cross section for the process $p\bar{p} \rightarrow \rho_{TS} \rightarrow \text{dijets}$ at $\sqrt{s} = 1800$ GeV

| $M_{\rho_{TS}}$ (GeV) | $\Gamma_{\rho_{TS}}$ (GeV) | $\sigma$ (pb) | $M_{\rho_{TS}}$ (GeV) | $\Gamma_{\rho_{TS}}$ (GeV) | $\sigma$ (pb) |
|------------------------|--------------------------|-------------|------------------------|--------------------------|-------------|
| 200                    | 2.50                     | 264         | 600                    | 8.92                     | 1.26        |
| 300                    | 3.75                     | 55.0        | 700                    | 10.45                    | 0.420       |
| 400                    | 5.67                     | 13.2        | 800                    | 11.96                    | 0.142       |
| 500                    | 7.36                     | 3.92        | 900                    | 13.47                    | 0.0501      |
Figure Captions

Figure 1: Our prediction for the signal cross section (continuous line), the CDF upper limits for a luminosity of 106 pb$^{-1}$ (black triangles) and its extrapolation for a luminosity of 2000 pb$^{-1}$ (white triangles). Also shown is the cross section predicted by the traditional approach (dashed line)
