DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY

DESY 85-010
February 1985

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F. Cornet

Deutsches Elektronen-Synchrotron DESY, Hamburg
and
Dept. de Física Téorica, Univ. Autónoma de Barcelona, Bellaterra, Spain

ISSN 0418-9833

NOTKESTRASSE 85 · 2 HAMBURG 52

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F. Cornet
Deutsches Elektronen-Synchrotron, DESY
Hamburg, GERMANY
and
Departament de Física Teòrica
Universitat Autònoma de Barcelona
BELLATERRA (Barcelona), SPAIN

ABSTRACT: We study the interpretation of the CERN monojet and e jet + missing energy events in terms of a new triplet of color octet vector bosons, $\vec{W}_8$. We show that they should also appear in photon-jet final states that will provide a clear signature on the existence of the $\vec{W}_8$.

The discovery of the $W^{\pm}$, Z at CERN$^{1)}$ have represented an impressive advance in the experimental test of the standard model. However, the appearence of some unexpected events in the same experiments where the $W^{\pm}$, Z have been discovered$^{2)}$ suggests that new physics might also be present. In this sense, models where the $W^{\pm}$, Z are composite particles offer an atractive scenario where these strange events could arise in a simple way. In these models, the SU(2)×U(1) theory of electroweak interactions is nothing but an effective theory describing an interaction remnant of the hypercolor force that bounds the constituents to form a $W^{\pm}$ or a Z. Until now, however, the problems encountered when building a realistic composite model have been insourmountable. For this reason, the study of the phenomenological implications of the idea of compositeness, without relying on any especific model, is of great interest.

In this note we discuss the recent paper of Gounaris and Nicolaidis$^{3)}$ where an interpretation of the CERN monojet and e jet+missing energy events is proposed in terms of the production of a new colored vector boson ($\vec{W}_8$). This particle appears naturally in models where the constituents of the $W^{\pm}$, Z carry color. In particular, if we assume that the constituents are color triplets$^{4)}$, they can be bounded in color singlet states, corresponding to the usual weak bosons, or in a color octet state corresponding to the new colored weak boson. In the absence of color and electromagnetic interactions the $W^{\pm}$, Z and $\vec{W}_8$ are expected to be degenerate in mass, but color forces split the masses causing the octet to be more massive than the singlet. Using a nonrelativistic potential model one obtains that the mass of the $\vec{W}_8$ is roughly given by$^{5,6)}$

$$M(\vec{W}_8) = M(\vec{W}) + \frac{3}{2}\alpha_s\Lambda_h , \qquad (1)$$

where α_s is the strong coupling constant and Λ_h is the scale of the hypercolor interaction. Using $\alpha_s \sim 0.1$ and $\Lambda_h \sim 0.5\text{-}1$ TeV$^{6)}$ one finds

$$M(\vec{W}_8) = 150 - 230 \text{ GeV}. \qquad (2)$$

In order to reproduce the low energy neutral-current phenomenology we assume a global SU(2) symmetry broken by a γ-W^3 mixing (analogous to the γ-ρ° mixing that appears in hadronic phenomenology) described by the lagrangian[8,9,10]

$$L_{\gamma W^3} = -\frac{1}{2}\lambda F_{\mu\nu} W^3_{\mu\nu} \,, \qquad (3)$$

where $F_{\mu\nu}$ ($W^3_{\mu\nu}$) is the photon (W^3) field and λ is a mixing parameter that has to be determined. Using Q^2-duality[11] and assuming that the mass of the first excited state of the $\vec{W}$ is much larger than the mass of the $\vec{W}$ ($M_{\vec{W}'} >> M_{\vec{W}}$), so that one can safely take into account only the $\vec{W}$ contribution, the mass and coupling contant of the neutral vector boson to fermion pairs are shifted according to

$$M_Z = \frac{M_W}{1-\lambda^2} \qquad (4)$$

and

$$g_3 = \frac{g}{\sqrt{1-\lambda^2}} \qquad (5)$$

which are exactly the same expressions as those of the standard model if we take

$$\lambda = \sin\theta_W \qquad (6)$$

It is interesting to note that, due to the fact that the W_8^3-γ and W_8^3-g mixings are forbidden by color conservation and the assumed global SU(2) symmetry, respectively, the $\vec{W}_8$ are degenerate in mass.

The main couplings of the $\vec{W}_8$ will be to $q\bar{q}$ pairs and to $\vec{W}g$. Following Gounaris and Nicolaidis[3] we shall take for the lagrangians describing these couplings

$$L_1 = -g_8 \vec{W}^{\alpha}_{\mu} \vec{J}^{\mu}_{\alpha} \qquad (7)$$

$$L_2 = -g_B \vec{W}_\mu \vec{W}^{\alpha}_{\nu} G^{\mu\nu}_{\alpha} - g'_B \varepsilon_{\mu\nu\lambda\sigma} \vec{W}^{\mu} \vec{W}^{\nu}_{\alpha} G^{\lambda\sigma\alpha} \,, \qquad (8)$$

where $\alpha=1,\ldots,8$ is the color index and the quark current $\vec{J}^{\mu}_{\alpha}$ is given by

$$\vec{J}^{\mu}_{\alpha} = a\, \bar{q}_L \frac{\vec{\tau}}{2} \frac{\lambda_\alpha}{2} \gamma^\mu q_L \,, \qquad (9)$$

where a is a model dependent constant of order 1. For definitness we will take in all our numerical calculations $a=\sqrt{6}$[3,6].

There is also a coupling $\vec{W}_8\vec{W}_8 g$, but it will be ignored because it is not relevant for present energy phenomenology.

We can now interpret the CERN monojet and e jet+missing energy events in terms of $\vec{W}_8$ production by $q\bar{q}$ collisions through the chains

$$\begin{aligned} q\bar{q} &\to W_8^3 \to Zg \to \nu\bar{\nu}g \\ q\bar{q} &\to W_8^\pm \to W^\pm g \to e^\pm \nu g, \end{aligned} \qquad (10)$$

respectively (Fig. 1a). The total cross sections for these processes are given by

$$\sigma_a = \frac{1}{9}\int_0^1 d\tau \int_\tau^1 \frac{dx}{x}\left[q_i(x)\, q_j(\tau/x) + (i \leftrightarrow j)\right] \sigma_a^0(\tau s) \,, \qquad (11)$$

where $q_i(x)$ is the distribution function of quarks i in the proton (we have taken the same distribution function for quark i in the proton as for antiquark i in the antiproton), σ_a^0 are the cross sections at the parton level and $\tau = \frac{\hat{s}}{s}$ is the ratio between the squared C.M. energy of the colliding quarks to the squared C.M. energy of the colliding protons. In our calculation we have used the distribution functions given by Glück, Hoffmann and Reya[12], that are valid until very high energies and take into account scaling violation effects.

The evolution of the cross-sections is straightforward using eqs. (7), (8) and (11). The results obtained for $\sqrt{s} \simeq 540$ GeV are

$$\begin{aligned} \sigma(p\bar{p} \to W_8^\mp X \to W^\pm g + X \to e^\pm \nu g + X) &\simeq 1.9\times 10^{-2}\ \text{nb} \\ \sigma(p\bar{p} \to W_8^3 + X \to Zg + X \to \nu\bar{\nu} + X) &\simeq 1.0\times 10^{-2}\ \text{nb} \,, \end{aligned} \qquad (2)$$

where the kinematical cuts applied by UA1 and UA2[2] in their analyses of the data have been considered. We have taken $M_8 \simeq 160$ GeV for the mass of the $\vec{W}_8$, as suggested by the data[13], and $g^2=g_8^2=g_B^2+4g_H'^2$, where g is the standard model weak coupling constant ($g\simeq0.65$), because the hypercolor structure of $\vec{W}$ and $\vec{W}_8$ (in the absence of color forces) are the same. Since the integrated luminosity is ~200 nb^{-1} (including both experiments), the expected number of events are

$$\begin{aligned} \#\ \text{events}\ (e^{\pm}\ \text{jet}\ \not{E}_T) &= 3\text{-}4 \\ \#\ \text{events}\ (\text{jet}\ \not{E}_T) &= 2\ , \end{aligned} \tag{13}$$

where $\not{E}_T$ stands for transverse missing energy. It is interesting to note that the dependence of the cross sections (12) on the applied kinematical cuts is very small. So, a release of these cuts would not modify the obtained number of events.

When comparing eq. (13) with the experimental data one sees that the order of magnitude of the expected number of events is in good agreement with the data, although the prediction of a number of $e^{\pm}$ jet+missing energy events larger than the number of monojet events does not seen to be fulfilled by the data. The accumulated statistics, however, is very poor to stress a definite conclusion on this subject. In order to allow for a comparison with the data from the new collider run we have evaluated the cross-section for processes (10) at $\sqrt{s}$=630 GeV,

$$\begin{aligned} \sigma(p\bar{p}\to W_8^{\pm}+X\to W^{\pm}g+X\to e^{\pm}\nu g+X) &\simeq 2.4\times10^{-2}\text{nb} \\ \sigma(p\bar{p}\to W_8{}^3+X\to Zg+X\to\nu\bar{\nu}g+X) &\simeq 1.6\times10^{-2}\ \text{nb} \end{aligned} \tag{14}$$

and, also, we have plotted the gluon angular distribution in the $p\bar{p}$ center of mass system (Fig. 2) for the monojet events.

Further tests of this scenario can be provided by the study of photon-jet final states in $p\bar{p}$ collisions. Indeed, when applying the W_3-γ mixing mechanism to eq. (8) one obtains, in addition to the already discussed W_8^3Zg vertex, a $W_8^3\gamma g$ interaction given by

$$L_3 = -g_B\lambda A_\mu W_\nu^{3\alpha}G_\alpha^{\mu\nu}-g_B\lambda\varepsilon_{\mu\nu\lambda\sigma}A^\mu W_\alpha^{3\nu}G^{\lambda\sigma\alpha}\ , \tag{15}$$

where A_μ is the photon field. Thus, we can calculate the cross-section for the process $p\bar{p}\to W_8^3+X\to\gamma g+X$ (Fig. 1b) without introducing any new free parameter. The results turn out to be

$$\begin{aligned} \sigma(p\bar{p}\to W_8^3+X\to\gamma g+X) &= 1\times10^{-2}\ \text{nb}\quad \text{for}\quad \sqrt{s}=540\ \text{GeV} \\ \sigma(p\bar{p}\to W_8^3+X\to\gamma g+X) &= 1.4\times10^{-2}\ \text{nb}\quad \text{for}\quad \sqrt{s}=630\ \text{GeV.} \end{aligned} \tag{16}$$

So, the expected number of photon-jet events is roughly the same as the expected number of monojet events. It must be noted that this is a consequence of the assumed global SU(2) symmetry and its breaking mechanism through a W_3-γ mixing, and, thus, it will be a common fact to all the models where the weak interaction is considered as a residual interaction and the monojet events are interpreted as $\nu\bar{\nu}$+jet final states, with the $\nu\bar{\nu}$ being the decay product of a Z. The W_8^3 production, however, can be tested using the angular distribution of the γ-jet events, which is predicted to be proportional to $(1-\cos^2\theta)$ in the $p\bar{p}$ center of mass system.

In conclusion, the recently discovered CERN monojet and e jet+missing energy events can be considered as a preliminary indication of the existence of new particles, $\vec{W}_8$, that arise in a natural way in a large class of composite models. The low accumulated statistics, however, does not allow to stress any definite conclusion and further tests are needed. This can be achieved by studying the photon-jet events, which are predicted to appear in roughly the same number as the monojet events and would provide a clear W_8^3 signature.

The author is grateful to R.D. Peccei and K. Hagiwara for many useful discussions and to A. Bramon for critical reading of the manuscript. The author also aknowledges the kind hospitality extended to him by the DESY Theory Group.

FIGURE CAPTIONS

Fig. 1.- Feynman diagrams for

a) $p\bar{p}\rightarrow W_8^{\pm}(W_8^3)+X\rightarrow W^{\pm}(Z)g+X\rightarrow e^{\pm}\nu(\nu\bar{\nu})g+X$

b) $p\bar{p}\rightarrow W_8^3+X\rightarrow\gamma g+X$

Fig. 2.- Gluon angular distribution in the $p\bar{p}$ center of mass system for the monojet events.

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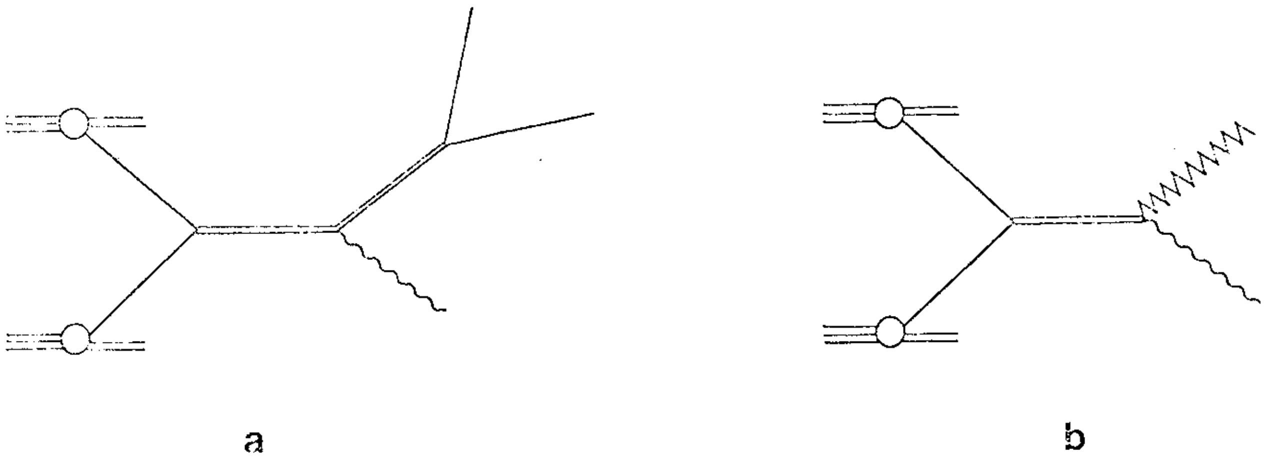

Fig.1

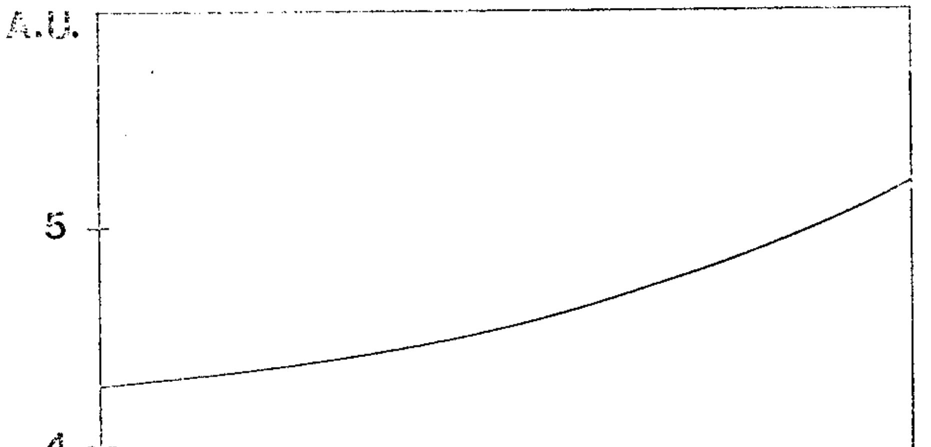

Fig.2