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Search for Technicolor Particles in W+2jet with b-tag Channel at CDF *

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Abstract. We present a preliminary result from a search for walking technicolor particles using leptonically decayed W plus two jets with at least one b-tag using $109 \pm 7\,\mathrm{pb}^{-1}$ of data taken by the Collider Detector at Fermilab (CDF). We search for technipion mass peaks in the invariant mass distribution of the two jet system and technirho mass peaks in the invariant mass distribution of W+2jet system. We do not see any significant excess in our search sample, and set 95 % confidence level upper limits on the production cross section and exclude a region of the π_T mass v.s. ρ_T mass plane.

INTRODUCTION

A recent walking technicolor(TC) model expects color singlet technirho (ρ_T) production in high energy $p\bar{p}$ collisions [1,2]. At the Tevatron energy a W boson and a technipion (π_T) decay mode of a ρ_T has the largest cross section times branching ratio when masses of the π_T and the ρ_T are around $90\,\mathrm{GeV/c^2}$ and $180\,\mathrm{GeV/c^2}$ respectively. At this mass combination, the cross section is approximately 12 pb ($\rho_T^\pm \to W^\pm \pi_T^0$) and 5 pb ($\rho_T^0 \to W^\pm \pi_T^\mp$). Here, we report a search for $\rho_T^\pm \to W^\pm \pi_T^0$ and $\rho_T^0 \to W^\pm \pi_T^\mp$ decay modes with leptonically (e or μ) decayed W's. The coupling of the π_T to fermions depends on the fermion masses and it is stronger for the larger fermion mass. Hence, the π_T would mostly decay to $b\bar{b}$ or $b\bar{c}$. The final states we search are: $\rho_T^\pm \to W\pi_T^0 \to e\nu b\bar{b}, \mu\nu b\bar{b}$ and $\rho_T^0 \to W\pi_T^\pm \to e\nu b\bar{c}, \mu\nu b\bar{c}$ as shown in Figure 1. For these final states, we use b-quark tagging to reduce the W+2jet backgrounds significantly. Following in this paper, we describe; event selection, signal Monte Carlo and efficiencies, background, mass distributions, topological and mass cuts, and finally our preliminary result.

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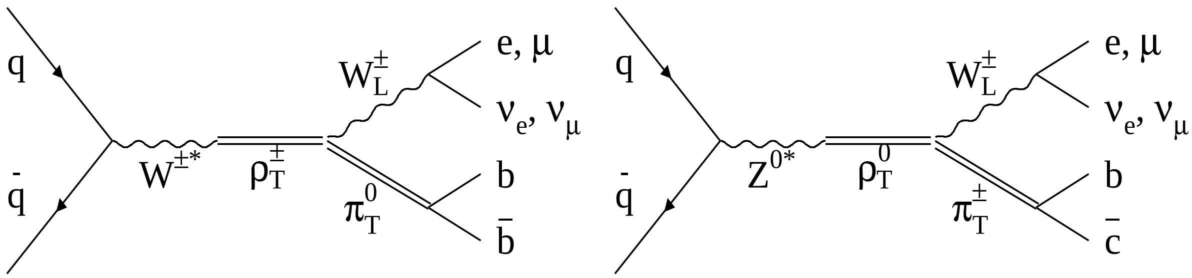

Figure 1 : Technirho production diagrams in $p\bar{p}$ collision decaying to W + Technipion.

I EVENT SELECTION

The W+2jet sample for this analysis is a subset of a sample of high-$P_{\rm T}$ inclusive lepton events which contain either an isolated electron with $E_{\rm T} > 20$ GeV or an isolated muon with $P_{\rm T} > 20$ GeV/c in the central region (pseudo-rapidity $|\eta| <1.0$). Events that contain a second same flavor lepton of opposite charge are removed as Z boson candidates if the reconstructed ee or $\mu\mu$ invariant mass is between 75 and 105 GeV/c^2. An inclusive W boson sample is selected by further requiring missing transverse energy, $\not{E}_T > 20$ GeV and that the lepton be isolated from any jet activity. A W+2jet sample is selected by further requiring exactly two jets with $E_{\rm T} > 15$ GeV. Jets are defined using a cone algorithm with $\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2} = 0.4$. In order to separate TC from the large W+2jet background, we require that at least one of the jets be identified as a b jet candidate. Identification of b jets is done by reconstructing secondary vertices from b-quark decay using the Silicon Vertex Detector (SVX b-tagging). The SVX b-tagging algorithms are described in Ref. [3]. The number of selected events is 42, while the expected number of background events is 31.6 as shown in Table 1.

II SIGNAL MONTE CARLO AND EFFICIENCIES

Using PYTHIA 6.1 [4], we generate ρ_T^0 and $\rho_T^\pm$ at $\sqrt{s} = 1.8\,\mathrm{TeV}$ $p\bar{p}$ collisions. The selected signatures are the followings: $q\bar{q} \to W^{*\pm} \to \rho_T^\pm \to W^\pm\pi_T^0$ ($\pi_T^0 \to b\,\bar{b}$:100 %) and $q\bar{q} \to Z^{0*}, \gamma^* \to \rho_T^0 \to W^\pm\pi_T^\mp$ ($\pi_T^\pm \to b\,\bar{c}, c\,\bar{b}$:95 % and $\pi_T^\pm \to c\,\bar{s}, s\,\bar{c}$:5 %) forcing W to decay either $e\nu$ or $\mu\nu$. Input parameters of the technicolor events in PYTHIA are all default values described in the TC model [2]. We generate 10k events for each π_T,ρ_T mass combination. These events are passed through the detector simulation. We choose about fifty mass combinations whose cross section is more than 5 pb. The acceptance and efficiencies are estimated using these Monte Carlo signal event samples. The result is shown in Figure 2.

W + 2 jet at least 1 b-tag Background

CDF Preliminary

Source	Distribution	N_{event} (109 pb^{-1})
Mistag	DATA (W + 2 jet)	5.1±2.0
Wbb Wcc	Herwig	9.4±2.5
Z+h.f.	VECBOS	1.4±0.5
Wc	Herwig	4.6±1.5
WW,WZ,Z$\tau\tau$	PYTHIA	1.5±0.5
non-W	DATA($\not{E}_T$,Iso method)	2.1±1.3
$t\bar{t}$	Herwig(σ=7.5 pb)	5.1±1.9
single top	Herwig(W* and Wg)	2.4±0.8
TOTAL		31.6±4.3

Table 1 : Expected number of background events in W+2jet with b-tag selection.

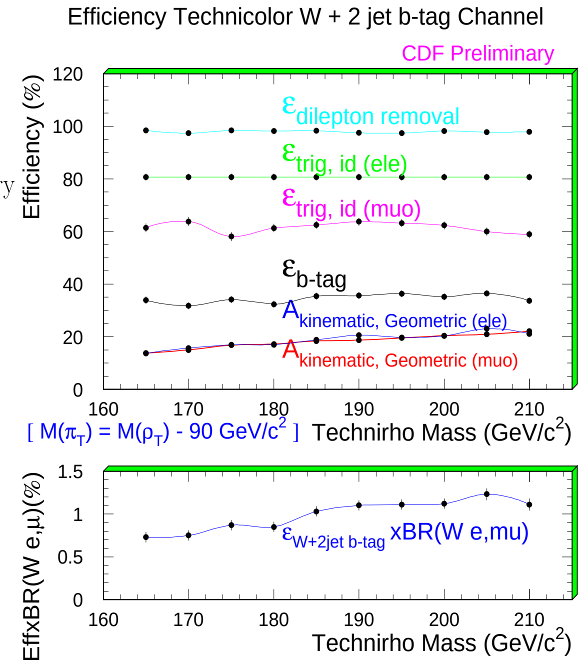

Figure 2 : Acceptances, efficiencies of each cut, and total efficiencies of W+2jet with b-tag selection including BR($W \to e\nu, \mu\nu$).

III DIJET MASS AND W+2JET MASS DISTRIBUTIONS

We reconstruct the invariant mass of the dijet system, M(jj) which would correspond to the technipion mass, and the invariant mass of the W+2jet system, M(Wjj) which would correspond to the technirho mass. A signal would appear as a narrow peak in the two mass distributions. To reconstruct M(Wjj), we need the P_z information of the neutrino. Since we only measure the missing E_T information, in order to obtain the P_z information we use the W mass constraint in a lepton-neutrino system and take the smaller P_z of the two solutions. If there is no solution for the P_z, we take the real part of the solution of the quadratic equation. Figure 3 and Figure 4 show the M(jj) and M(Wjj) distributions respectively. The upper plots show the technicolor Monte Carlo signal at M(π_T)=90 GeV/c^2 and M(ρ_T)=180 GeV/c^2 together with the background. The number of events for the signal and background are normalized to the expected number of events for 109 pb^{-1}. The bottom plots show the CDF data and the background.

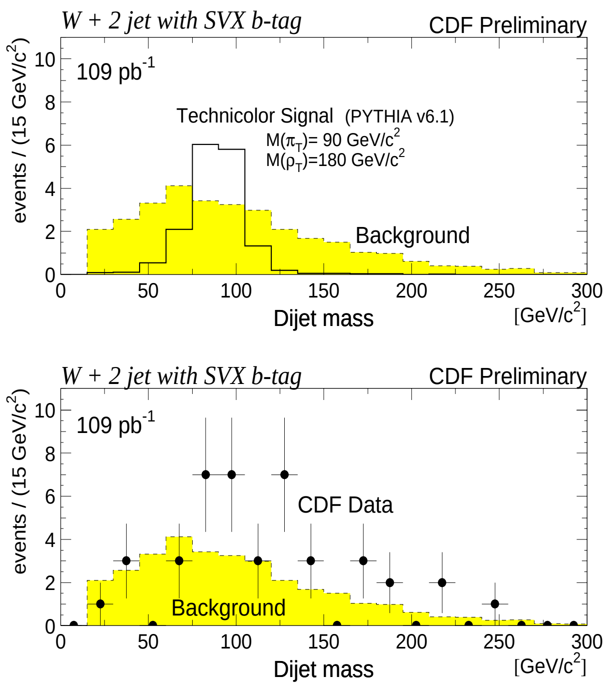

Figure 3 : The invariant mass of the dijet system for the W+2jet sample with b-tag.

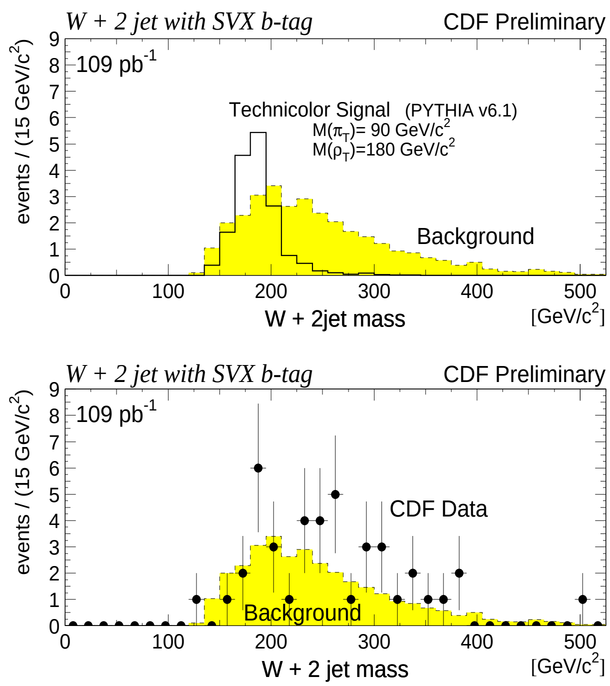

Figure 4 : The invariant mass of the W+2jet system for the W+2jet sample with b-tag.

IV TOPOLOGY AND MASS WINDOW CUTS

The topology cuts are placed on the ϕ angle between two jets, $\Delta\phi(jj)$, and the P_T of the dijet system, $P_T(jj)$ [5]. Our TC signal search region has a characteristic which is $\mathrm{M}(\pi_T) + \mathrm{M}(W) \simeq \mathrm{M}(\rho_T)$. In this case, technipions are produced nearly at rest, and consequently the $\Delta\phi(jj)$ is more back-to-back than the background and $P_T(jj)$ is smaller. Figure 5 shows the $\Delta\phi(jj)$ and $P_T(jj)$ distributions at $\mathrm{M}(\pi_T) = 90\,\mathrm{GeV/c^2}$, $\mathrm{M}(\rho_T) = 180\,\mathrm{GeV/c^2}$. In order to obtain optimum cut values, we apply the $\Delta\phi(jj)$ and the $P_T(jj)$ topology cuts simultaneously and maximize the $S/\sqrt{B}$ (signal over square-root of the background) values. We obtain different optimum topology cut values for each of the mass combinations. These cuts are very effective. The $S/\sqrt{B}$ is increased by typically 60%.

The final criteria to select a TC signal is to apply mass window cuts on the selected event sample. We require that $\mathrm{M}(jj)$ and $\mathrm{M}(Wjj)$ be within $\pm\ 3\sigma$ of the mean values. The mean values and σ are obtained from the signal Monte Carlo for each mass combination considered.

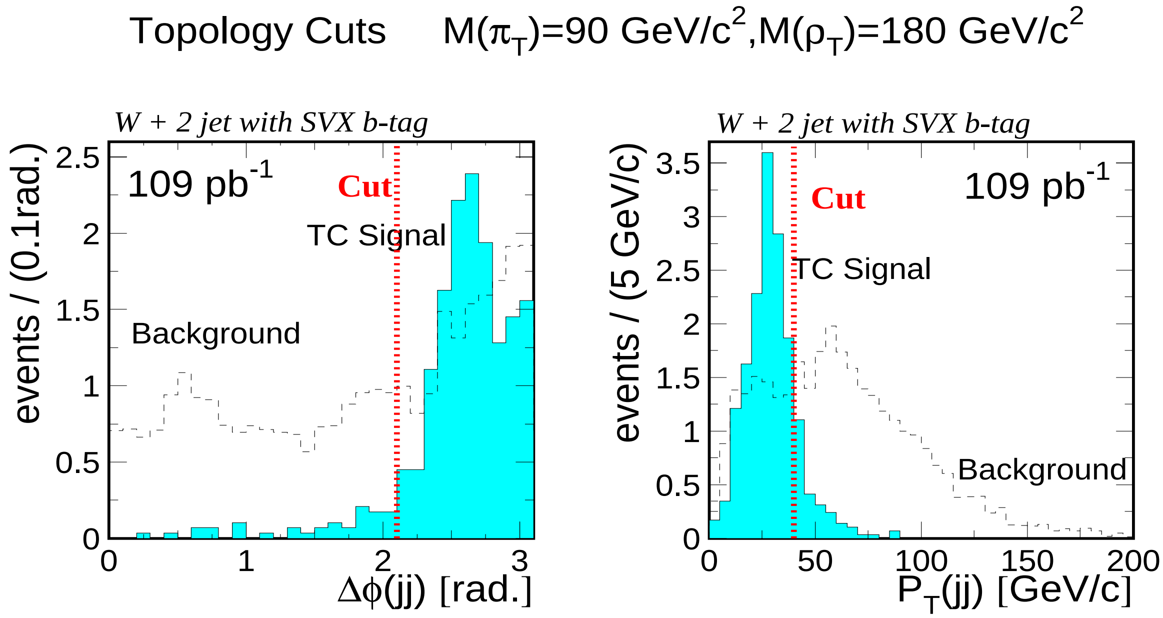

Figure 5 : The $\Delta\phi(jj)$ and $P_T(jj)$ distributions of the TC signal and the background for the W+2jet sample with b-tag. The dotted vertical lines show the optimum topological cut values for this particular mass combination.

V PRELIMINARY RESULTS

Table 2 summarizes our result. We do not see any significant excess in our search sample. As a consequence, we set 95 % C.L. upper limits on the production cross section taking into account a 26% systematic uncertainty on the signal efficiency, and we exclude some region in the M(π_T) and M(ρ_T) plane. Figure 6 shows the excluded region by this analysis as well as the expected theoretical cross section contours.

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⋆ Number of events & Cross Section Limits

CDF Preliminary

M_{π_T}, M_{ρ_T}	σ	$N^{allcuts}_{Signal}$	$N^{allcuts}_{B.G.}$	DATA	95 % C.L. limits	
	$\rho_T^{\pm} \to W+\pi_T^0$ $\rho_T^0 \to W+\pi_T^{\pm}$	(109 pb^{-1})	(109 pb^{-1})		$N_{95\,\%limit}$	$\sigma_{95\,\%limit}$
80,165	4.2 pb	2.7	4.1±0.6	5	8.1	12.6 pb
80,170	4.1 pb	2.9	5.4±0.7	5	7.2	10.4 pb
80,175	3.1 pb	2.1	7.6±1.0	9	10.4	15.6 pb
85,170	15.4 pb	11.1	3.8±0.5	5	8.3	11.5 pb
85,175	7.5 pb	4.9	5.5±0.8	5	7.2	11.0 pb
85,180	5.1 pb	3.7	6.5±0.9	7	8.8	12.1 pb
90,175	12.9 pb	10.3	4.2±0.6	5	8.0	10.0 pb
90,180	17.6 pb	13.3	5.7±0.8	5	7.1	9.4pb
90,185	8.4 pb	6.9	7.2±1.0	7	8.4	10.3 pb
95,180	10.7 pb	10.8	5.6±0.8	6	8.3	8.3 pb
95,185	14.2 pb	13.7	6.4±0.9	6	7.8	8.1 pb
95,190	13.8 pb	12.1	7.5±1.0	8	9.3	10.6 pb
100,190	12.0 pb	12.1	6.5±0.9	6	7.7	7.7 pb
100,195	12.0 pb	10.9	7.1±1.0	8	9.6	10.5 pb
100,200	10.9 pb	10.0	9.7±1.3	14	15.1	16.4 pb
105,195	10.1 pb	10.4	6.6±0.9	6	7.6	7.3 pb
105,200	10.4 pb	10.7	7.4±1.0	8	9.3	9.1 pb
105,205	9.3 pb	8.8	8.8±1.2	12	13.3	14.1 pb
110,200	8.4 pb	9.1	7.5±1.0	8	9.2	8.4 pb
110,205	8.9 pb	9.5	8.2±1.1	10	11.2	10.4 pb
110,210	8.1 pb	8.6	9.8±1.3	13	13.6	12.8 pb
115,205	7.2 pb	8.9	8.2±1.1	8	8.8	7.2 pb
115,210	7.7 pb	8.5	8.4±1.2	10	11.0	9.9 pb
115,215	7.2 pb	7.6	9.0±1.2	10	10.5	9.9 pb

Table 2 : Expected number of signal and background events for 109 pb^{-1} after all cuts, number of remaining data events, and 95% C.L. upper limits of the TC signal.

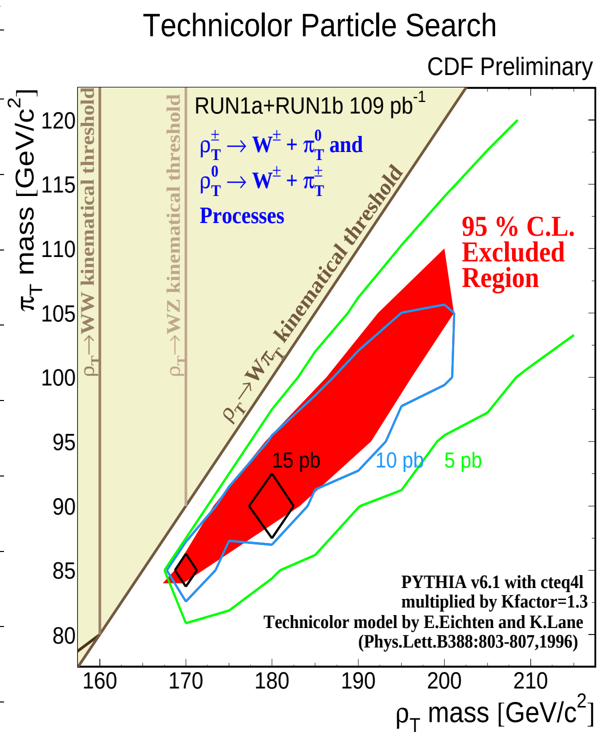

Figure 6 : 95% excluded region in the $M(\pi_T)$,$M(\rho_T)$ plane. Production cross section contour plot is shown on the same plane.

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