SEARCH FOR SECOND AND THIRD GENERATION LEPTOQUARKS AT CDF

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We report the results of a search for second and third generation leptoquarks using 88 pb^{-1} of data recorded by the Collider Detector at Fermilab. Color triplet technipions, which play the role of scalar leptoquarks, are investigated due to their potential production in decays of strongly coupled color octet technirhos. Events with a signature of two heavy flavor jets and missing energy may indicate the decay of a second (third) generation leptoquark to a charm (bottom) quark and a neutrino. As the data is found to be consistent with Standard Model expectations, mass limits are determined.

1. Introduction

The associations between quarks and leptons exemplified by the cancelation of triangle anomalies preserving the renormalizability of the Standard Model provide inviting hints at potential, fundamental connections. Theories incorporating leptoquarks furnish a mechanism whereby quarks and leptons can couple directly through a Yukawa interaction of strength λ.[1,2,3] The results of various experiments indicate that the leptoquark interactions should conserve baryon and lepton number and that the leptoquarks should couple to fermions of the same generation in order to suppress flavor changing neutral currents.[4]

At the Tevatron, the principal mechanisms for pair production of leptoquarks are $q\bar{q}$ annihilation and gluon fusion through either direct coupling to the gluon ("continuum") or a technicolor resonance state. A signature of two heavy flavor jets, missing transverse energy ($\not{E}_T$), and the absence of leptons is utilized at CDF to search for pair produced second and third generation leptoquarks decaying to $c\bar{c}\nu\bar{\nu}$ and $b\bar{b}\nu\bar{\nu}$, respectively.[5] Events are required to have two or three jets with $E_T \geq 15$ GeV, $\not{E}_T \geq 40$ GeV, jets well separated in ϕ from both the direction of $\not{E}_T$ and from each other, and no leptons. Heavy flavor jets are identified through a jet probability algorithm.[6]

2. Continuum Leptoquarks

The pair production cross section for scalar leptoquarks is parameter free and known to next-to-leading order.[7] Vector leptoquark interactions include the model dependent couplings κ_G and λ_G.[8] Yang-Mills type coupling ($\kappa_G = \lambda_G = 0$) and
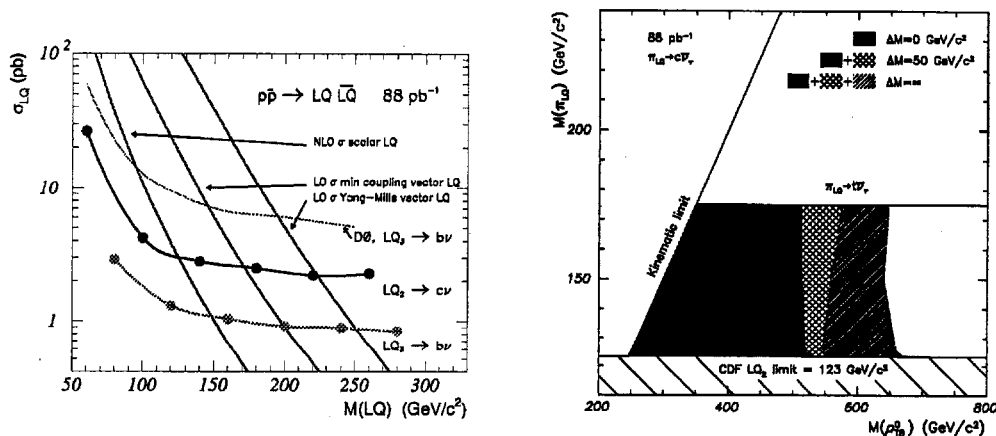
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Fig. 1. Left plot: 95% CL cross section limit on $LQ_2 \to \nu_\mu c$ and on $LQ_3 \to \nu_\tau b$ together with the expected theoretical cross sections for scalar and two types of vector LQs. Right plot: The 95% CL limit for the process $\rho_{T8} \to \pi_{LQ}\bar{\pi}_{LQ}$ in which $\pi_{LQ} \to c\bar{\nu}_\tau$.

minimal coupling ($\kappa_G = 1$ and $\lambda_G = 0$) are investigated. At present only leading order processes have been calculated for vector leptoquark pair production.[8]

The 95% CL limits for continuum leptoquark production cross sections are determined and compared to the corresponding theoretical cross sections.[7,8] The results are shown in the left plot of Figure 1. In the case of second generation leptoquarks, scalar leptoquarks with $M < 123$ GeV/c^2, minimally coupled vector leptoquarks with $M < 171$ GeV/c^2, and Yang-Mills vector leptoquarks with $M < 222$ GeV/c^2 are excluded. For third generation leptoquarks, scalar leptoquarks with $M < 148$ GeV/c^2, minimally coupled vector leptoquarks with $M < 199$ GeV/c^2, and Yang-Mills vector leptoquarks with $M < 250$ GeV/c^2 are excluded.

3. Leptoquarks from Technicolor

Enhancement of leptoquark pair production may occur through the decay of technicolor resonance states.[2,3] Color octet technirhos, ρ_{T8}, with the same quantum numbers as the gluon are possible, allowing for s-channel coupling. The color triplet and octet technipions, denoted by π_{LQ} and π_{T8}, couple in a Higgs-like fashion to quarks and leptons with the π_{LQ} identified as a scalar leptoquark. The leading-order cross section is sensitive to $\Delta M = M(\pi_{T8}) - M(\pi_{LQ})$, $\Delta M = 50$ GeV/c^2 expected.[3]

The 95% CL exclusion regions in the $M(\rho_{T8}) - M(\pi_{LQ})$ plane for $\Delta M = 0$, 50 GeV/c^2, and ∞ are shown as shaded areas in the right plot of Figure 1 and the left plot of Figure 2. The kinematically forbidden region is given by $M(\rho_{T8}) < 2M(\pi_{LQ})$. In the right plot of Figure 1, the decay of the leptoquark to $c\bar{\nu}_\tau$ is
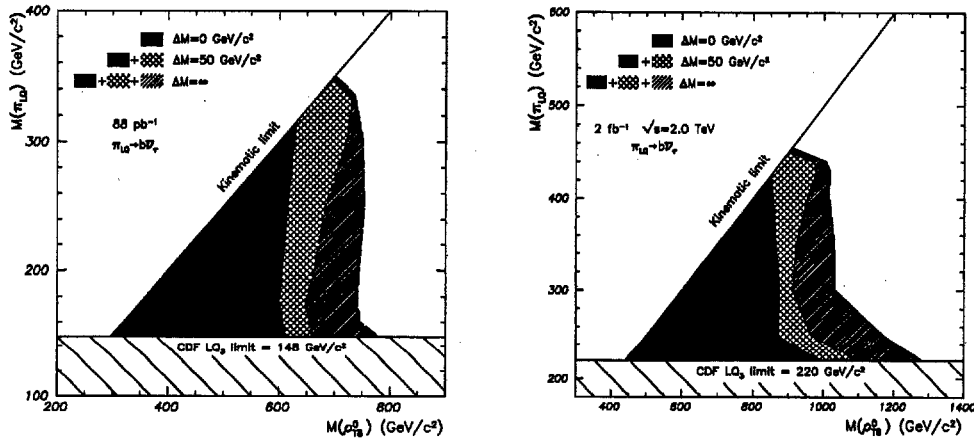
Fig. 2. Left plot: The 95% CL limit for the process $\rho_{T8} \to \pi_{LQ}\bar{\pi}_{LQ}$ in which $\pi_{LQ} \to b\bar{\nu}_\tau$. Right plot: Run II projection for the third generation continuum and resonantly produced leptoquarks.

limited by the top quark mass, above which the leptoquark will decay preferentially to $t\bar{\nu}_\tau$. When $\Delta M = 0$, $M(\rho_{T8}) < 510$ GeV/c^2 for the second generation and $M(\rho_{T8}) < 600$ GeV/c^2 for the third generation are excluded at 95% CL.

4. Run II Projections

The anticipated start of the Tevatron's Run II in March 2001 will provide fertile ground for further searches of new phenomena. With a significantly improved detector, an increase in the center of mass energy to 2.0 TeV, and a projected integrated luminosity of 2 fb^{-1} by 2003, the sensitivity to continuum produced third generation leptoquarks extends to $M < 220$ GeV/c^2. For the leptoquarks produced from technirho decays, the Run II 95% CL exclusion region is shown in the right plot of Figure 2. The sensitivity to ρ_{T8} extends to approximately 1 TeV.

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