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SEARCHES FOR LARGE EXTRA DIMENSIONS AND TECHNICOLOR AT THE TEVATRON[a]

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I present the status of searches for large extra spacetime dimensions and technicolor at the Fermilab Tevatron. I emphasize recent D0 limits on graviton-mediated exchange processes, and CDF searches for new $b\bar{b}$ resonances and third-generation leptoquarks.

1 Introduction

The hierarchy problem—the large difference between the electroweak and Planck scales—is a source of persistent difficulty for the Standard Model, and has inspired much theoretical activity over the past three decades. The main difficulty is presented by fundamental scalars, such as the SM Higgs boson. These particles receive quadratic self-energy corrections that tend to generate masses at the GUT scale or higher unless the bare scalar masses and self-couplings are fine-tuned. The most popular solution to this problem at present, supersymmetry, introduces a new spacetime symmetry whose resulting interactions cancel the divergences. In this paper I consider two alternative scenarios: large extra dimensions and technicolor. In the former case, the hierarchy problem is resolved by eliminating the hierarchy; the apparent weakness of gravity results from a geometrical suppression of the flux lines by a factor proportional to the volume of the compactified extra dimensions. In technicolor theories, the problem is resolved by eliminating fundamental scalars; Higgs bosons appear in the low-energy limit of a theory with fundamental fermions interacting via new strong interactions. I report here on searches for large extra dimensions and technicolor at the Fermilab Tevatron, using the approximately 100 pb^{-1} of $\bar{p}p$ data collected at $\sqrt{s} = 1.8$ TeV by CDF and D0 from 1992-96.

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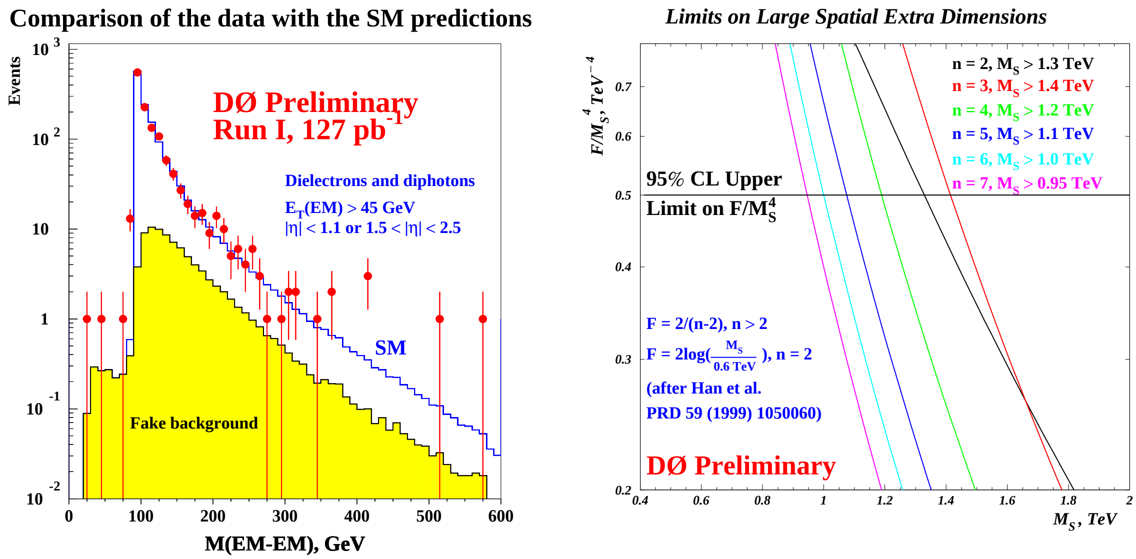

Figure 1: Limits on large extra dimensions from the dielectron and diphoton searches at D0.

2 Large Extra Dimensions

The idea that spacetime contains extra compact dimensions dates back to Kaluza and Klein in the 1920's, and has been a fixture of string theories since the 1970's. It has enjoyed new popularity among experimentalists since Arkani-Hamed, Dimopoulos, and Dvali[1] developed a model in which the extra dimensions could be large enough to have phenomenological consequences. Much recent literature has been devoted to developing such models further.[2] These models are characterized by Kaluza-Klein towers of massive gravitons whose interactions with Standard Model particles can modify SM $2 \to 2$ processes such as Drell-Yan and diphoton production, and can also lead to new missing energy signatures resulting from gravition emission. In the Drell-Yan and diphoton channels, the signature is an enhancement of the production rate at large invariant mass M, and a modification to the scattering angle $\cos\theta^*$ of the final-state lepton or photon pair.

D0 has recently carried out a search in the dielectron and diphoton channels, fitting 127 pb^{-1} of data to 2-dimensional templates in M and $\cos\theta^*$.[3] No deviations from the SM predictions are observed, leading to the limits shown in Figure 1. The limits are expressed in terms of the parameter $\mathcal{F}/M_S^4$, where M_S is the Planck scale in the extra dimensions (the scale at which gravity becomes strong), and $\mathcal{F}$ is a dimensionless parameter related to the number of extra dimensions. Values of M_S in the $\sim$1-few TeV range are preferred theoretically in order to solve the hierarchy problem. D0 finds $\mathcal{F}/M_S^4 > 0.5$ TeV^{-4} at the 95% C.L. This result translates into limits on M_S between 1.4 and 0.95 TeV for values of n between 2 and 7. Searches at CDF in the Drell-Yan, diphoton, and missing-energy channels are in progress.

3 Technicolor Searches

3.1 Searches for new Particles Decaying to $b\bar{b}$

Many technicolor models contain new resonances that decay to $b\bar{b}$. Among these are models of topcolor-assisted technicolor,[4] in which the third generation plays a special role in electroweak symmetry breaking. Initially, there is an $SU(3)_{1,2}\times SU(3)_3$ symmetry, where the first SU(3) couples to the first and second generations and the other couples to the third generation. This symmetry is broken to color SU(3). In addition, a U(1) symmetry is introduced to keep the b quark light. These added symmetries introduce two particles that can decay to $b\bar{b}$. The $\mathrm{SU}(3)_3$ gives rise to a broad color-octet topgluon that can decay to $b\bar{b}$, while the U(1) produces a narrow color-singlet Z'. New $b\bar{b}$ resonances can also appear in models with a color-octet technirho,[5] a SM-like Z',[6] or in some SUSY models with vector gluonium.[7] CDF has searched for new particles decaying to $b\bar{b}$ in 87 pb^{-1} of jet data.[8] Events are required to contain two jets with secondary vertices characteristic of b-decay. The data are consistent with QCD predictions, with no evidence for a mass peak from a new resonance. This search excludes at the 95% C.L. topgluons of width $\Gamma = 0.3M$ in the mass range $280 < M < 670$ GeV, of width $\Gamma = 0.5M$ in the range $340 < M < 640$ GeV, and of width $\Gamma = 0.7M$ in the range $375 < M < 560$ GeV. A narrow color octet technirho is excluded in the mass range $350 < M < 440$ GeV. Cross-section limits can also be placed on other narrow resonances, defined as those particles with a width less than the detector resolution of 10%, though present data do not permit mass exclusions.

3.2 Search for Third-Generation Leptoquarks via Technirho Decays

Many theories of extended technicolor (ETC)[9] contain a complete family of technifermions consisting of color triplet techniquarks and color singlet technileptons. Among the combinations of these technifermions is a color octet technirho that can decay into a pair of color triplet technipions. The technipions have the quantum numbers of a leptoquark. As ETC theories contain Higgs-like couplings between the technifermions and ordinary quarks and leptons, the technipions are expected to behave like third-generation leptoquarks if the mass of the technipion exceeds m_{top}. If the mass of the technipion is less than m_{top}, mixing with second-generation leptoquarks is also possible. Production cross sections are dependent upon the mass difference between the color octet and color triplet technipions, with $\Delta M \sim 50$ GeV expected.

CDF has previously searched for a third-generation leptoquark decaying to $b\tau$, excluding technirhos below 465 GeV at the 95% C.L.[10] A new CDF analysis[11] extends the search to final states in which $\pi_{LQ} \to b\nu_\tau$ or $c\nu_\tau$. The signature is at least one flavor-tagged jet plus missing transverse energy. Using the same data set employed in CDF's recent search[12] for scalar top and scalar bottom quarks, CDF obtains the limits shown in Figure 2.

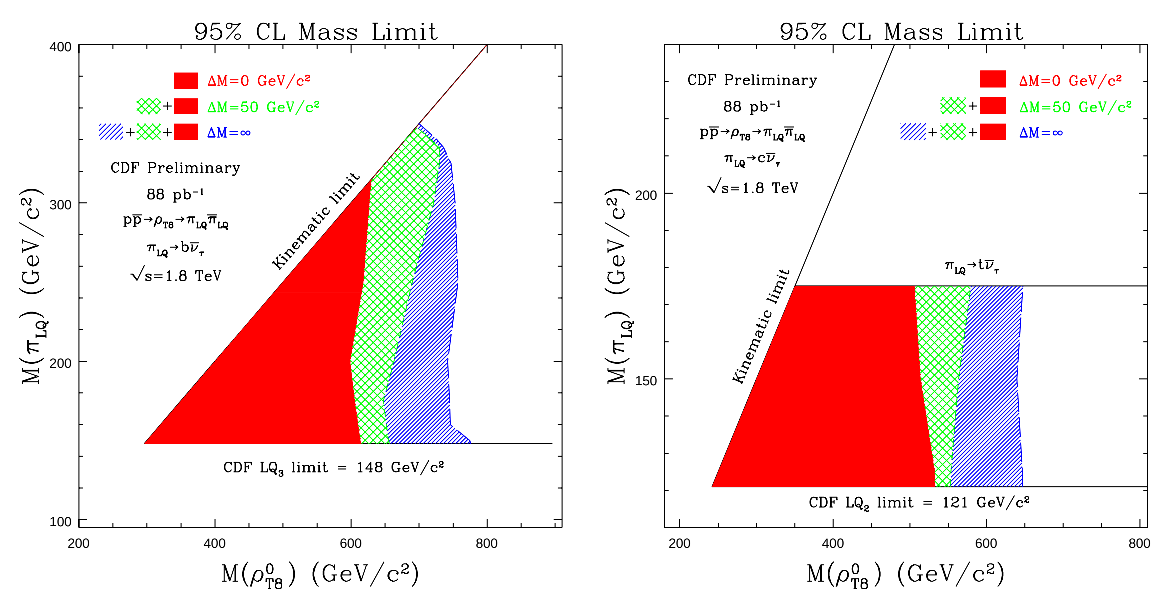

Figure 2: Limits on π_{LQ} production via color-octet technirho decays. Exclusion regions are shown for several values of the mass difference ΔM between the color octet and color triplet technipions.

4 Conclusions

The Tevatron collider experiments continue to place limits on new physics, including large extra spacetime dimensions and technicolor. Further results from the 1992-96 data set are expected before the start of the next collider run in the spring of 2001. Both CDF and D0 are completing major detector upgrades that, when combined with the expected factor-of-20 increase in the integrated luminosity, will greatly increase the sensitivity to physics beyond the Standard Model.

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