Search for New Phenomena at the Tevatron

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Recent results from searches for new particles by the DØ and CDF collaborations are described. The entire data set for the running of the Fermilab Tevatron collider at $\sqrt{s} = 1.8$ TeV is used corresponding to an integrated luminosity of approximately 110 pb^{-1}. Searches for supersymmetric particles, techniparticles, leptoquarks and magnetic monopoles are presented.

1 Introduction

The Tevatron at Fermilab is a $\bar{p}p$ collider with a center of mass energy of 1.8 TeV. As such, it produces the highest energy particle collisions of any accelerator available and offers an excellent laboratory for new particle searches. The DØ [1] and CDF [2] experiments have searched for many types of new particles and have found one (the top quark). This paper discusses a limited selection of these searches — those which are the most recent results. For information on all of DØ and CDF searches see their respective web sites [3].

The first section of this paper will describe the search for supersymmetric particles. The second will describe the search for techniparticles, the next, first generation vector-leptoquarks, and the last will describe the search for magnetic monopoles. The data used in these analyses was collected in the period 1992–96. The integrated luminosity of the two experiments is approximately 110–120 pb^{-1}.

2 Supersymmetry Searches

Supersymmetry (SUSY) models introduce a new symmetry to the Standard Model (SM) and predict that for every SM particle there will be a supersymmetric partner (sparticle) with identical gauge quantum numbers and spins that differ by 1/2.

Motivated by the observation of an unusual $ee + \gamma\gamma + \not\!\!E_T$ event CDF has carried out a search [4] for gauge mediated SUSY by looking for inclusive $\gamma\gamma + X$ signatures with $E_T^\gamma > 25$ GeV and X is any possible final state, in a sub-sample of the data with an integrated luminosity of 85 pb^{-1}. The results of this search are given in Table 1 and show no indication of any excess $\gamma\gamma + X$ production.

This search is then optimized to search for a minimal gauge mediated symmetry breaking model [5,6] in the $\gamma\gamma + \not\!\!E_T$ channel where the signature is produced via the decay of the lightest neutralino to a photon and a goldstino, $\tilde{N}_1 \rightarrow \gamma\tilde{G}$. The rate of this process depends on three parameters; sign(μ) of the Higgs mass, $\tan\beta$ the ratio of the vacuum expectation values of the Higgs doublets, and M_2 – the mass of the SU(2)gaugino at the electro-weak scale. The cuts applied are $E_T^\gamma > 12$ GeV and $\not\!\!E_T > 35$ GeV. Limits on this model are then placed as a function of sign(μ), $\tan\beta$, and M_2 and are plotted in Fig. 1. A significant region of the parameter space is ruled out by this measurement.

Table 1: CDF inclusive $\gamma\gamma + X$ search ($E_T^\gamma > 25$ GeV.)

Signature	Obs.	Pred.
$\not\!\!E_T > 25$ GeV	2	0.5 ± 0.1
$N_{\rm j} \geq 3$, $E_T > 10$ GeV, $\mid\eta\mid<2.$	0	1.7 ± 1.5
central e or μ, $E_T^l > 25$ GeV	1	0.1 ± 0.1
central τ, $E_T^\tau > 25$ GeV	0	0.3 ± 0.3
b-tag, $E_T^b > 25$ GeV	0	0.1 ± 0.1
central γ, $E_T^{\gamma,3} > 25$ GeV	0	0.01 ± 0.01

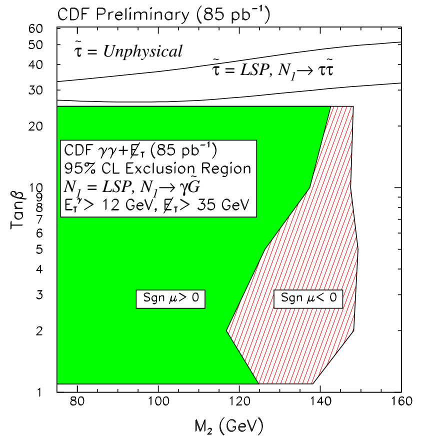

Figure 1: CDF: The range of model parameters excluded at the 95% confidence level by this measurement.

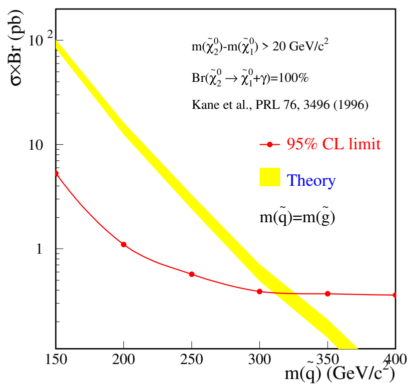

Figure 2: DØ preliminary 95% upper confidence limit on $\sigma(\bar{p}p \rightarrow \tilde{q}/\tilde{g} \rightarrow \tilde{\chi}_2^0)\times B(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 + \gamma)$ assuming equal squark and gluino masses.

DØ has carried out a search for SUSY in the $\not\!\!E_T + \gamma + \geq 2$ jets channel which is also motivated by the theoretical interest in the unusual $ee + \gamma\gamma + \not\!\!E_T$ CDF event. The data sample is selected by requiring that the photon satisfies $E_T^\gamma > 20$ GeV and $\mid\eta_\gamma\mid< 1.1$, $1.5 \mid\eta_\gamma\mid< 2.5$, the jets $E_T^{j1,2} > 20$ GeV and $\mid\eta_{\rm j}\mid< 2.0$. In addition each event is required to have $\not\!\!E_T > 45$ GeV and that the sum of the E_T of all the photons and jets in the event, $\sum E_T > 220$ GeV. The resulting data sample is five events with an expected background of 8.1 ± 5.8 events.

Since no significant excess of events is observed, limits are placed on the masses of squarks ($\tilde{q}$) and gluinos ($\tilde{g}$) for three different scenarios[7]: If $m_{\tilde{q}} = m_{\tilde{g}}$

then $m_{\tilde{q}} > 311$ GeV/c^2 is allowed at the 95% confidence limits (see Fig 2), if $m_{\tilde{q}} \gg m_{\tilde{g}} = 1$ TeV/c^2 then $m_{\tilde{q}} > 233$ GeV/c^2 is allowed, and $m_{\tilde{g}} \gg m_{\tilde{q}} = 1$ TeV/c^2 then $m_{\tilde{g}} > 219$ GeV/c^2 is allowed

3 Search for Technicolor

Technicolor [8], a strong interaction of fermions and gauge bosons at the scale $\Lambda_{\rm TC} \sim 1$ TeV, is a theory that leads to the dynamical breaking of the electro-weak symmetry without the existence of elementary scalar bosons (Higgs bosons) and is based on the similar phenomena of chiral symmetry breakdown in QCD. The masses of quarks, leptons, and the Goldstone "technipions" are produced by embedding technicolor, ordinary color, and flavor symmetries in a larger gauge group called extended technicolor (ETC), the symmetry of which is broken at $\mathcal{O}(100$ TeV). This model predicts a rich spectrum of techniparticles with masses in the range of 100 to 100 GeV/c^2, within the reach of the Tevatron.

CDF has carried out a search for techniomega production in the process $\bar{p}p \to \omega_T \to \gamma\pi_T \to \gamma b\bar{b}$. The data is selected by requiring a photon with $E_T^\gamma > 25$ GeV, at least two jets with $E_T^j > 30$ GeV, and a b–tag in the SVX detector associated with one of the jets. The data sample consists of 200 events with an expected background of 132 ± 42 events. If techniomega exists they would appear as resonances in both the spectrum of the mass of the two jets, $m(b,\text{jet})$, and the mass difference between the mass of the γ and the two jets, $m(b,\text{jet},\gamma)$,and the dijet mass: $m(b,\text{jet},\gamma) - m(b,\text{jet})$ (see Fig 3). No evidence for any resonances is found and 95% CL limits are placed on the production cross section of the techniomega. The limits are then compared to the theoretical calculation [9] to produce a 95% exclusion region in the technirho, techniomega mass plane (Fig. 4).

4 Vector Leptoquarks

Both CDF [10] and DØ [11] have carried out searches for first generation scalar leptoquarks. DØ has extended this search to place limits on vector leptoquark production via the $2e + 2j$, $e + \nu + 2j$, and $2\nu + 2j$ channels. If a Yang-Mills coupling is assumed, the 95% CL limits on the leptoquark mass are 340 GeV/c^2 for $\beta = 1$, 329 GeV/c^2 for $\beta = 0.5$, and 200 GeV/c^2 for $\beta = 0$.

5 Magnetic Monopoles

DØ has performed a search [12] for Dirac monopoles which are expected to couple to photons with a coupling strength which should be at least three orders

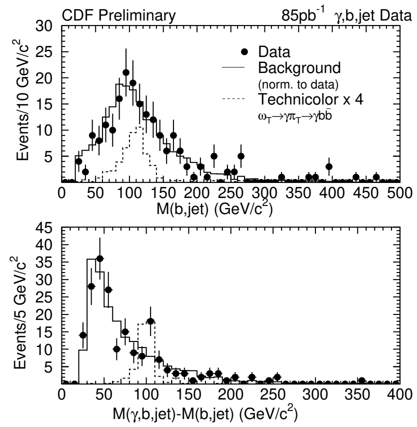

Figure 3: CDF Preliminary: Plot of $m(b, \mathrm{jet})$ and $m(b, \mathrm{jet}, \gamma) - m(b, \mathrm{jet})$ for both the data and theoretical predictions.

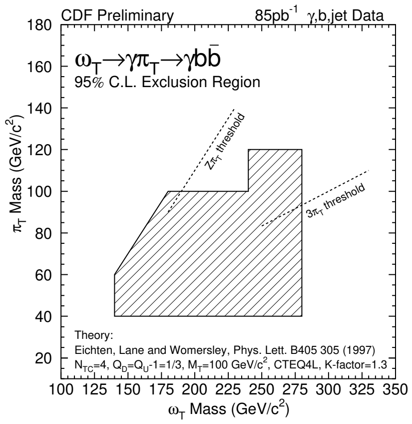

Figure 4: The 95% exclusion region for the process $\bar{p}p \to \omega_T \to \gamma\pi_T \to \gamma b\bar{b}$.

of magnitude larger than the coupling of photons to the electric charge. Therefore, monopoles if they existed, would give rise to photon-photon rescattering. The contribution to the di-photon cross section at $\bar{p}p$ colliders was recently calculated [13] assuming point-like monopoles allowing limits to be set on the monopole mass.

The data selection was applied to a data sample with an integrated luminosity of 70 pb^{-1} and required at least two photons with $E_T^\gamma > 40$ GeV and $|\eta_\gamma| < 1.1$, missing transverse energy, $\not\!\!E_T < 25$ GeV, and no jets with $E_T > 15$ GeV and $|\eta| < 2.5$. In addition, the scalar sum of the E_T of the photons, S_T, is required to be greater than 250 GeV. The expected background is 0.41 ± 0.11 events and none are observed. The upper 95% CL on the production cross section is 83 fb which results in limits on the monopole mass of 610 GeV/c^2 for a monopole spin of 0, 870 GeV/c^2 for spin 1/2, and 1580 GeV/c^2 for spin 1.

6 Conclusions

CDF and DØ have carried out searches for many new particles a few of which are presented here. Neither experiment has found any evidence for new particle production. In the future both experiments expect to collect 2 fb^{-1} of data at $\sqrt{s} = 2$ TeV by the year 2002 at the upgraded Tevatron. This data sample should allow significant exploration of the region where SUSY and other exotic particles are predicted to exist in current models.

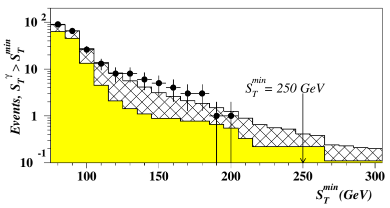

Figure 5: DØ Data and expected background as a function of $S_T^{\rm min}$. Points are the data, the hatched region corresponds to the Drell-Yan background and the solid region shows the QCD background.

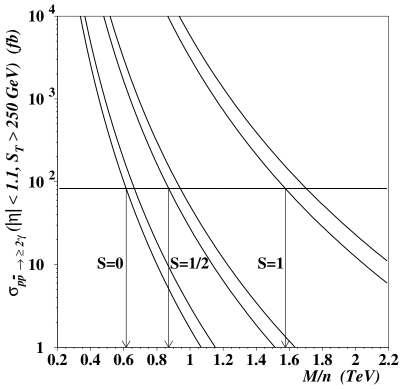

Figure 6: The curved bands show the DØ upper and lower bounds on the predicted cross sections for monopole production. The horizontal line shows the 95% CL cross section limit.

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