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# Search for New Particles in CDF

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# SEARCH FOR NEW PARTICLES IN CDF

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## ABSTRACT

Preliminary results on searches for new particles beyond the Standard Model are presented. The data were taken by the CDF collaboration at the Fermilab $\bar{p}p$ collider at a center of mass energy of 1.8 TeV. Limits on the masses of the gluino and squark in a minimal supersymmetric theory are given. The 90% confidence level asymptotic lower mass limits on each are 150 GeV/$c^2$ . A special data run was taken to search for the diffractively produced sextet quark state $\eta_6$. An $\eta_6$ with a mass larger than 20 GeV/$c^2$ is excluded at the 95% confidence level. Limits are also set on the pair-production of massive stable charged particles. Unit-charged particles belonging to spin 1/2 color triplets with masses between 50 and 139 GeV/$c^2$ are ruled out at the 95% confidence level as are charge 2/3 particles with masses between 50 and 116 GeV/$c^2$ and charge 4/3 particles with masses between 50 and 140 GeV/$c^2$ .

## 1. Introduction

The operation of colliding beam accelerators at high energies and high luminosities has allowed the search for new phenomena which go beyond the scope of the Standard Model. Here we describe three such searches undertaken by the Collider Detector at Fermilab (CDF) which studied $\bar{p}p$ collisions at a center of mass energy of 1.8 TeV and accumulated 4.4 $pb^{-1}$ of data during the 1988-89 run. We discuss searches for supersymmetric particles, the $\eta_6$ particle, and massive charged stable particles. Additional searches will be reported elsewhere at this conference.

## 2. Search for Supersymmetric Particles

Supersymmetry (SUSY) is a theory linking fermions and bosons in such a way that each of the familiar fundamental particles has a supersymmetric partner. In particular the SUSY partners of the quark, gluon, and photon are the squark ($\tilde{q}$), gluino ($\tilde{g}$), and photino ($\tilde{\gamma}$). In the minimal theory considered here, the six squark

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masses are taken to be degenerate and the photino is assumed to be the lightest SUSY particle. In addition, R-parity is considered conserved so that the SUSY particles are pair-produced and the photino is stable. The decay modes we searched for were for the case of $m_{\tilde{q}} > m_{\tilde{g}}$ : $\tilde{q} \longrightarrow q + \tilde{g}$ and $\tilde{g} \longrightarrow q + \bar{q} + \tilde{\gamma}$ and for the case of $m_{\tilde{g}} > m_{\tilde{q}}$ : $\tilde{g} \longrightarrow \bar{q} + \tilde{q}$ and $\tilde{q} \longrightarrow q + \tilde{\gamma}$. Since the photino does not deposit any energy in the detector, the experimental signal we looked for was the presence of at least two jets with a transverse energy greater than 15 GeV and missing transverse energy greater than 40 GeV. The 97 events observed are consistent with the expected background of $86 \pm 14 \pm 12$ events from W and Z decays and $4 \pm 4$ events from QCD. To derive mass limits, more stringent cuts were applied. For the case of $m_{\tilde{g}} > m_{\tilde{q}}$ the missing $E_t$ cut was raised to 100 GeV. Three events were observed compared to an expected background of $1.3 \pm 1.3$ events. For the case of $m_{\tilde{q}} > m_{\tilde{g}}$ two additional jets with $E_t > 15$ GeV were required. Two events passed these cuts compared to an estimated background of $1.3 \pm 1.3$ events. Figure 1 shows the mass region excluded at the 90% C.L. The discontinuity at $m_{\tilde{q}} = m_{\tilde{g}}$ is due to different acceptances for the two sets of cuts used. The asymptotic 90% C.L. mass limits are $m_{\tilde{q}} > 150$ GeV/c$^2$ ($m_{\tilde{g}} < 400$ GeV/c$^2$ ) and $m_{\tilde{g}} > 150$ GeV/c$^2$ (all $m_{\tilde{q}}$). Possible cascade decays were not taken into account and could lower the mass limits by an estimated 30 GeV/c$^2$ .

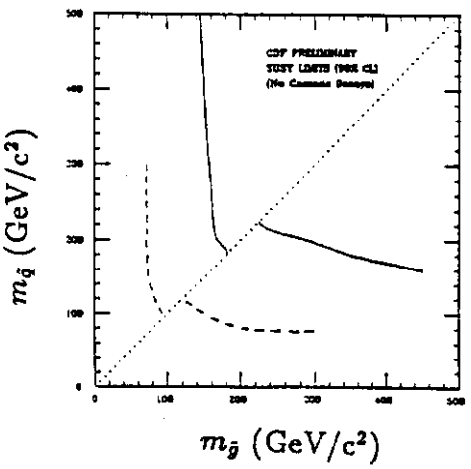


Fig. 1. The 90% C.L. excluded region in the $(m_{\tilde{g}}, m_{\tilde{q}})$ plane. Previous CDF results are indicated by the dashed lines.

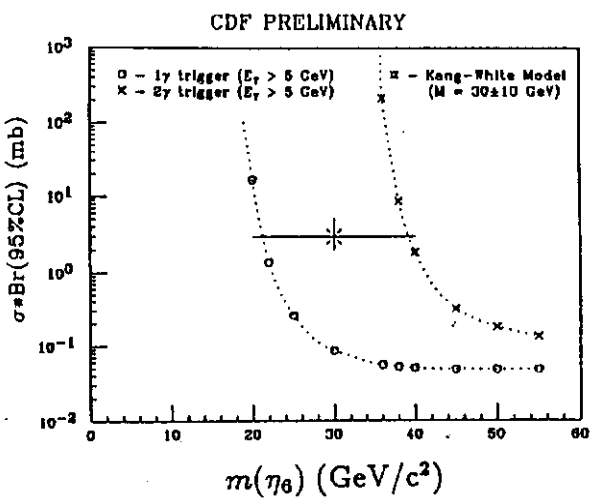


Fig. 2. The 95% C.L. $\sigma \cdot$ Br limit as a function of the mass of the $\eta_6$. Also shown is the theoretical prediction.

## 3. Search for $\eta_6$

The $\eta_6$ particle is a sextet quark state proposed[1] to explain the Mini-Centauro and Geminion[2] cosmic ray events as well as the large real to imaginary ratio of the forward elastic scattering amplitude observed by UA4.[3] The $\eta_6$ is predicted[1] to have a mass of $30 \pm 10$ GeV/c$^2$ , to be produced diffractively with a large cross section, and to have a large branching ratio into two photons.

The data for this search comes from a special run with an integrated luminosity of 70 $mb^{-1}$ which had only the occurrence of a beam-beam crossing as a trigger requirement. The diffractive production and subsequent decay of the $\eta_6$ into two photons would result in two photons at large rapidity on one side of the detector and no energy deposition on the other and therefore would not satisfy any of the conventional triggers. The presence of at least one electromagnetic cluster with a minimum energy deposition in the calorimeter of 5 GeV and a ratio of hadronic energy to electromagnetic energy of less than 0.1 were required. Five events pass these cuts. However, in each case the electromagnetic cluster has a pseudorapidity of less than 2.0 and therefore is not diffractively produced. Based on no events observed, the 95% C.L. upper limit for the $\sigma \cdot$ Br is shown in Fig. 2 for the case where one photon is detected and the case where both decay photons are detected. Also shown is the theoretical prediction.[1] The production of such an $\eta_6$ with a mass above 20 GeV/c$^2$ is excluded at the 95% C.L. provided the cross section is at least of the order of several mb.

## 4. Search for Heavy Stable Particles

Heavy stable particles are possible features of many theories which go beyond the Standard Model. We have searched for massive charged particles which have a sufficiently long lifetime ($\tau > 10^{-8}$ sec.) to enable them to penetrate the detector before decaying. The hadron calorimeter was equipped with TDC's which enabled us to determine relative arrival times in the calorimeter with a resolution of 1.6 ns. The high $p_t$ muon sample derived from 3.54 $pb^{-1}$ of integrated luminosity was examined for particles with $p_t > 25$ GeV/c and a pattern of TDC time and energy deposition consistent with that expected from massive charged particles. One event survived the cuts. The estimated background is $2.3 \pm 1.3$ events.

Monte Carlo simulations were used to derive the detection efficiency for the pair-production of stable, unit-charged particles. At least one of the two particles was required to pass all cuts imposed on the data sample.

The Poisson statistics on the number of observed events were folded together with the systematic errors. This produced the 95% C.L. upper cross section limit shown in Fig. 3 along with the theoretical cross section of Ellis[4] for the production of spin 1/2 color triplets. Masses between 50 and 139 GeV/c$^2$ are ruled out at the 95% C.L. Particles with masses less than about 50 GeV/c$^2$ cannot be reliably detected. Other theoretical cross sections were also considered including those for color sextets,

octets, and decuplets with resulting lower mass limits of 224, 227, and 290 GeV/$c^2$ respectively. In the case of spin 0 color triplets[5] we are able to exclude the mass range between 50 and 85 GeV/$c^2$ . We also used a similar method to search for the pair-production of charge 2/3 and 4/3 objects. The charge refers to final "dressed" charge of the particle. One event survived the cuts for the charge 2/3 sample and 2 events for the charge 4/3 sample. Both are consistent with the estimated backgrounds of $0.8 \pm 0.8$ and $1.5 \pm 1.1$ respectively. Masses between 50 and 116 GeV/$c^2$ are ruled out at the 95% C.L. for the charge 2/3 case and masses between 50 and 140 GeV/$c^2$ for the charge 4/3 case. If one accounts for the production of neutral as well as charged particles, these limits would be lowered by about 20 GeV/$c^2$ .

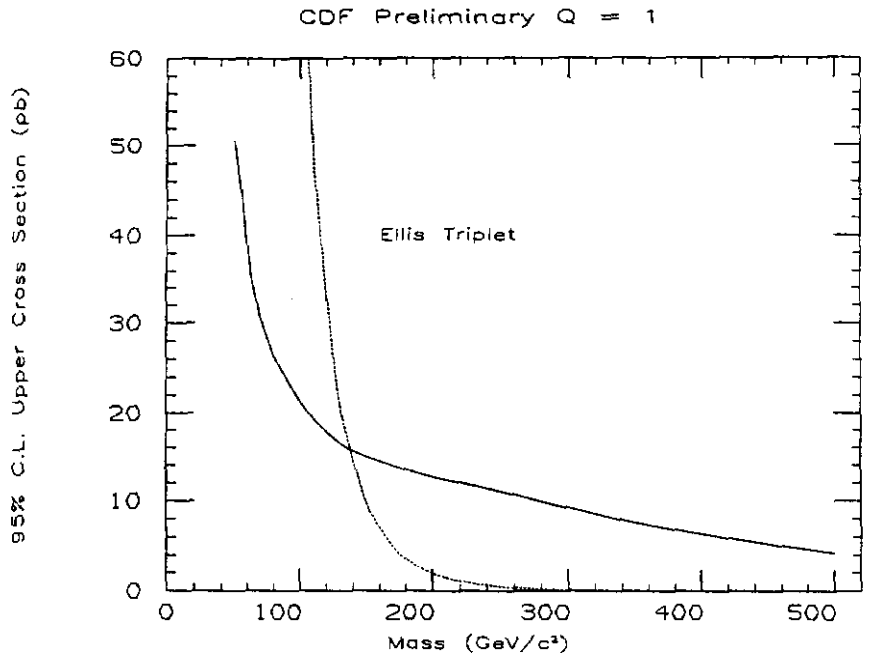


Fig. 3. The 95% confidence level upper cross section limit for the pair-production of unit-charged stable particles as a function of mass. Also shown is the theoretical cross section[4] for the production of spin 1/2 color triplets.

## References


1. K. Kang and A. White, *Phys. Rev.* **D42** (1990) 835.
2. S. Hasegawa, *ICR-Report No.* **151-87-5**, 1987 (unpublished).
   Chacaltaya and Pamir Collaboration, *ICR-Report No.* **232-91-1**, 1991 (unpublished).
3. Bernard et al. ,*Phys. Lett.* **B198** (1987) 583.
4. R. K. Ellis, *FERMILAB-Pub-* **91/30-T**, 1991 and private communication.
5. M. Drees and X. Tata, *Phys. Lett.* **B252** (1990) 695 and private communication.