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Searches at the Tevatron

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Abstract. The CDF and DØ collider experiments at Fermilab have searched for evidence of physics beyond the Standard Model of particle physics. We report on the results of searches for extra heavy gauge bosons, quark-lepton compositeness, leptoquarks, and magnetic monopoles in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. No evidence of new signals were found, therefore we derive limits on the model parameters.

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INTRODUCTION

The Standard Model of particles and interactions has been an extremely successful theory for describing high-energy physics data. However, although its predictions have been verified to great accuracy, it leaves many fundamental questions unanswered. Among these are why there are three generations of quarks and leptons and why their masses are what they are, why gravity seems to be so much weaker than the other forces, and whether all the forces can be unified into one single fundamental interaction. Many models predicting new physics beyond the Standard Model have been proposed. These models predict new signatures that can potentially be detected at high-energy colliders like the Tevatron. These searches can be challenging: the production cross-sections tend to be small and the SM backgrounds very large. Processes involving jets are usually overwhelmed by the background from QCD, so lepton final states are used even though the rates are often suppressed.

These results are based on up to 400 pb^{-1} of data delivered to the CDF and DØ experiments at Fermilab between 2002 and 2004. All limits quoted are at the 95% confidence level.

NEW CHARGED HEAVY VECTOR BOSON

The W' is an additional charged heavy vector boson that appears in theories based on extending the gauge group of the Standard Model. For example left-right symmetric models[1, 2] feature new gauge bosons including a heavy, right-handed W'. CDF performed a search using 200 pb^{-1} of data for a W' decaying to an electron-neutrino pair where the neutrino is assumed to be light and does not decay inside the detector volume. Events were selected which contained an isolated electron with $p_T > 25$ GeV and missing transverse energy $\not{E}_T > 25$ GeV. The backgrounds to W' production are from

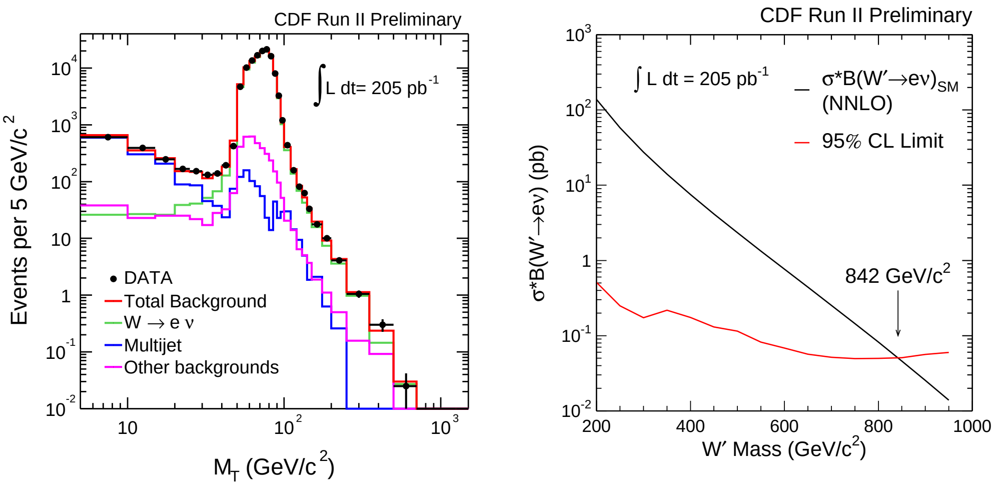

FIGURE 1. *(left)* Transverse mass distribution from selected W' sample, *(right)* 95% confidence limit on the W' cross-section, assuming the Standard Model coupling

real W decays, sources producing real electrons such as $Z/\gamma \rightarrow ee$, $t\bar{t} \rightarrow eX$, and QCD multijet events where a jet is misidentified as an electron and the jet energy is mismeasured to create significant $\not{E}_T$. The data show no evidence of an excess of events over the predicted background, which leads to a limit on the W' mass of $M_{W'} > 842$ GeV (Figure 1).

QUARK-LEPTON COMPOSITENESS

The Standard Model predicts neither the masses nor the number of families of quarks and leptons, which suggests there may be a more fundamental basis. In one scenario quarks, leptons and heavy bosons are formed from constituents called preons interacting through a new gauge interaction called metacolour[3]. Below the characteristic energy scale Λ the interaction binds the preons into composite states such as quarks and leptons. The experimental signature is highly model dependent, but exhibits itself as a deviation from the SM cross-section for dilepton production through the Drell-Yan process at high invariant masses. These deviations are highly model dependent. DØ studied 400 pb^{-1} of data in the dimuon channel. Selected events were required to have two isolated muons with $p_T > 50$ GeV. No deviations from the Standard Model prediction were found (Figure 2), so lower limits on the compositeness scale were set, ranging from $\Lambda = 4.2$ TeV to $\Lambda = 9.8$ TeV depending on the model.

LEPTOQUARKS

Several extensions of the Standard Model contain particles which possess colour, electric charge and both lepton and quark quantum numbers, and which decay into a lepton and a quark[4]. At the Tevatron leptoquarks would be produced predominantly through

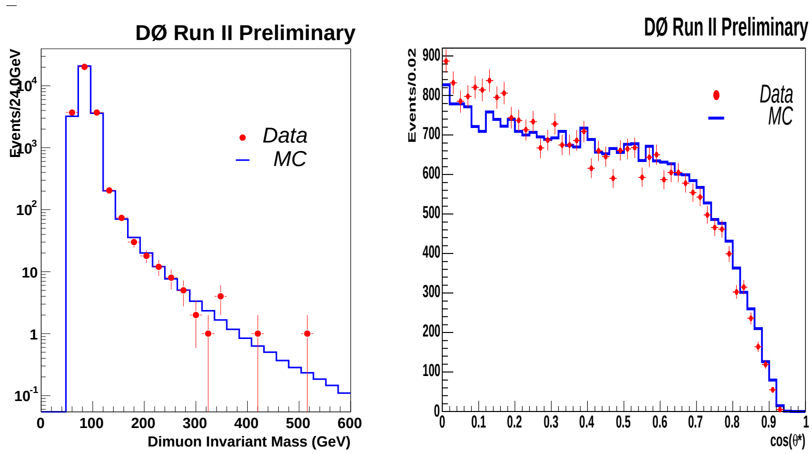

FIGURE 2. Dimuon invariant mass and cosine of scattering angle distributions from the DØ compositeness search

$q\bar{q}$ annihilation and gluon fusion, and decay to either a charged lepton and a quark (with branching fraction β), or a neutrino and a quark. DØ and CDF have searched for first generation scalar leptoquarks in the $\ell q \ell q$ and $\ell q \nu q$ channels. These have an experimental signature of two jets and either two charged leptons, or one charged lepton and missing transverse energy respectively. Additionally, CDF has included results from the $\nu j \nu j$ channel, which cannot distinguish between the different generations and has an experimental signature of two jets and missing transverse energy. No excesses over the Standard Model predictions were found. The mass limits set depend on the branching ratio β. For $\beta = 1$ first generation limits are $M > 230$ GeV (CDF) and $M > 256$ GeV (DØ), and the second generation limit is $M > 224$ GeV (CDF). First generation limits as a function of β from DØ are shown in Figure 3.

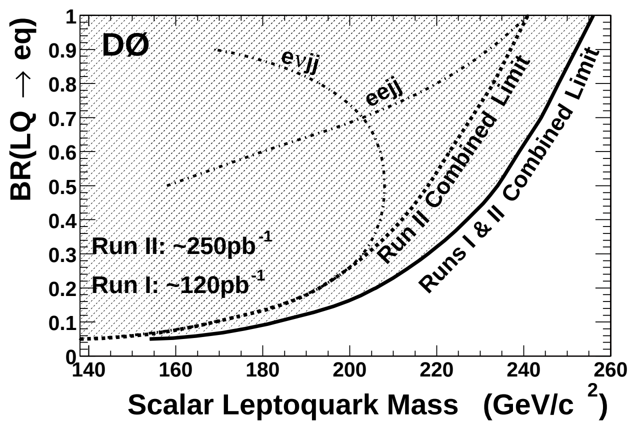

FIGURE 3. DØ first generation leptoquark exclusion region

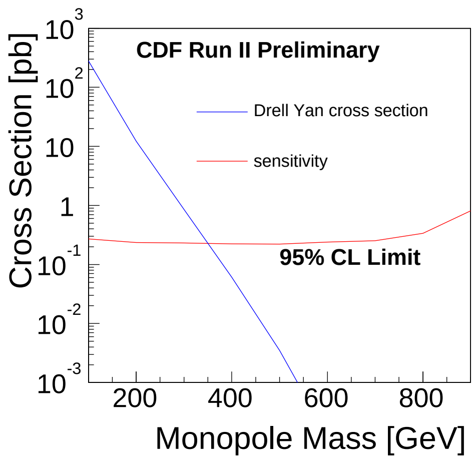

FIGURE 4. 95% confidence limit on the Dirac monopole cross-section, assuming Drell-Yan production

MAGNETIC MONOPOLES

A Dirac magnetic monopole[5] is a particle with no electric charge, no hadronic interactions and whose magnetic charge satisfies the quantization condition $g \approx 68.5 \cdot n \cdot e$. CDF conducted a search for Dirac monopoles. These have a unique signature in a detector like CDF: they are accelerated down the solenoidal magnetic in the tracking region field rather than bending in the transverse plane. Additionally, the very large magnetic charge of the monopole causes huge amounts of ionization, so CDF was able to use a very efficient dedicated trigger requiring large light pulses in the Time-Of-Flight detector scintillator bar. This trigger collected 25 pb^{-1} of data which were reconstructed with a special tracking algorithm. The unique path of the monopole means that the background is negligible. No events were found, which gives a mass limit of $M > 350$ GeV, assuming the monopoles are produced by a Drell-Yan like process (Figure 4).

SUMMARY

The CDF and DØ collaborations have analyzed data from up to 400 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. No deviations from the predictions of the Standard Model have been found, and limits have been set on the parameters of charged heavy gauge bosons, quark-lepton compositeness, leptoquarks, and magnetic monopoles.

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