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New Particle Searches at the Tevatron (I)

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NEW PARTICLE SEARCHES AT THE TEVATRON (I) [1]

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Abstract

Searches for new particles in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV are ongoing at the Fermilab Tevatron collider using the CDF and DØ detectors. Current results from searches for heavy charged vector bosons and fourth generation quarks as well as for Supersymmetric partners of Standard Model quarks and gluons are presented.

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Introduction

This paper, and the one that follows, describe the current status of searches for new phenomena in data taken in Run 1 of the Fermilab Tevatron Collider using the DØ [1] and CDF [2] detectors. In this paper, results from searches for heavy charged vector bosons and fourth generation quarks as well as for Supersymmetric partners of Standard Model quarks and gluons are presented. No evidence for such particles is found. Regions excluded by these searches are described herein.

Search for W'

New heavy charged vector bosons W' are predicted by many extensions of the Standard Model. W' from left-right symmetric models [3], which restore left-right symmetry at high energy, have right-handed couplings and are referred to as W_R. These new W-like particles are expected to manifest themselves in ways which depend on how they decay. In an analysis recently published in PRL [5], DØ looked for evidence of these particles via their decay to an electron (or positron) and a possibly massive neutrino. The massive neutrino (N) is expected to decay to a lepton and a W boson or virtual W' which then produces two or more quark jets some fraction of the time depending on the vector boson mixing. The topology of the final state depends on the N mass (M_N).

For a light N, the leading electron (from the W' decay) may be the only particle in the final state which is clearly resolved. In this case, a new state would be indicated by a distinctive Jacobian peak at $(M_{W'}^2 - M_N^2)/2M_{W'}$ in the leading electron transverse momentum (p_T^e) spectrum. This method, referred to as the *peak search*, is independent of whether the neutrino decays or interacts in the detector.

The event sample was collected by triggering the detector on a single electromagnetic (EM) cluster. Offline, events are selected by requiring an electron with $p_T^e > 55\ GeV/c$ within a pseudorapidity range $|\eta_e| < 1.1$. Strict electron quality criteria are also imposed to reduce the background from QCD multijet events where a jet is misidentified as an electron. Remaining QCD background is modeled using QCD multijet collider data. The other source of background, high-p_T W and Z production, is predicted using a computer simulation based on theoretical expectations of vector boson production combined with a simple detector simulation. No evidence of a Jacobian peak is found and excellent agreement between the measured spectra and the expected background is observed.

If the N is heavy, the final state decay products of both the W' and the N are distinct, so for this case, a counting experiment is performed, choosing events with 2 electrons and 2 or more jets. The trigger requirement for the $eejj$ search was two EM clusters with $E_T^e > 20\ GeV/c$. Offline, $E_T^e > 25\ GeV$ is required for both e's and two jets and all decay products are required to be within $|\eta| < 2.5$. The invariant mass of electron pairs is required to be inconsistent

with Z boson decay. Two events are observed in the final candidate sample, consistent with the expected background of 3.08 ± 0.78 arising mostly from QCD multijet production and Drell-Yan production of lepton pairs with additional jets.

Using 79 pb^{-1} of Run 1a and Run 1b DØ data, 95% CL limits from the peak search and the $eejj$ counting search are shown in Figure 1. In the counting search, two curves are shown for the cases of no mixing and maximal mixing between the new right-handed boson (W_R) and the left-handed couterpart, the Standard Model W boson.

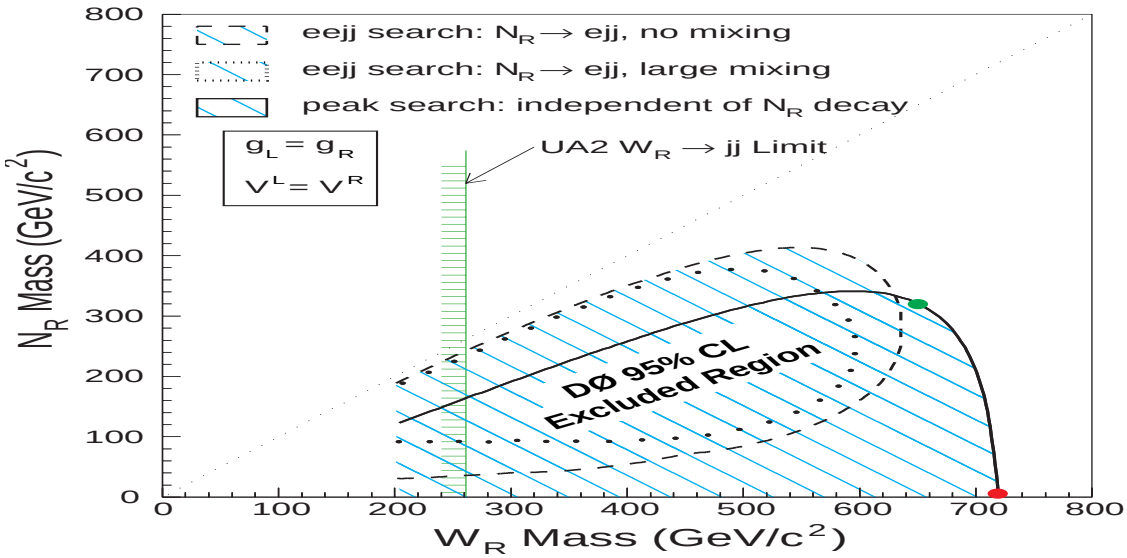

Figure 1: Excluded regions of W_R mass at the 95% CL assuming $g_R = g_L$ and $V^R = V^L$ from the eejj and peak searches.

In the limit as the neutrino mass approaches zero, the more general DØ result (a lower limit on $M_{W'}$ of 720 GeV/c^2) can be compared with that published by CDF [4]. Using 19.7 pb^-1 of Run 1a data, CDF set a lower limit of 652 GeV/c^2 on the mass of a new heavy charged boson which decays to an electron and a light non-interacting neutrino.

Search for Fourth Generation Quarks

DØ has searched for a fourth generation quark called the b'. For the model explored, the mass of the b' is lighter than both the top (t) quark and the t' (the isospin partner of the b'), so decay to t or t' is kinematically forbidden. Specific search channels are those FCNC (flavor changing neutral current) decays where one or both b' decay to a b quark and a photon and the other decays to a b-quark and a gluon. Such FCNC decays are favored if the charged current (CC) decay to a charm quark is Cabibbo suppressed because the generation number need change by two in this mode.

At the Tevatron Collider, such particles are expected to be produced in pairs with the same cross section for a given mass as the top quark. A counting analysis is performed in two specific final state channels using approximately 84.5 pb^{-1} of DØ data.

In the first channel, one b' decays to a photon and a jet and the other decays to a b-quark and a gluon. In the offline analysis, the photon must have $E_T > 20\ GeV$ and $|\eta| < 1.1$ and three jets must have $E_T > 15\ GeV$ and $|\eta| < 2.0$. At least one of the jets is identified as a b quark jet with a μ-tag. In addition to these object requirements, a sliding cut on the scalar transverse energy sum of the photon and jets is applied to maximize the significance of the signal over the background. In the second search channel, both b''s decay to a photon ($E_T > 20\ GeV, |\eta| < 2.0$) and a jet ($E_T > 15\ GeV, |\eta| < 2.5$). Additionally, the scalar sum of the transverse energy of the photons and jets is required to be $> 75\ GeV$.

For both cases, the number of events seen is consistent with the expected background, mostly from direct photon plus jet production and QCD multijet production, where one or two jets are misidentified as a photon. Less significant sources of background are vector boson production in association with a photon or jets.

Combining the results in each of the search channels with production cross sections predicted theoretically by Laenen *et al.*[6], upper limits on the branching ratio of a b' decaying to these final states is shown in Figure 2 a) and b) at the 95% CL. The vertical line indicates where the b' decay channel to $Z + b$ opens up. That channel is expected to dominate at higher b' masses. The horizontal line indicates the theoretically expected branching fraction to the relevant analysis search channel below this mass. The dashed lines indicate the upper and lower limit of uncertainty in the theoretical cross section.

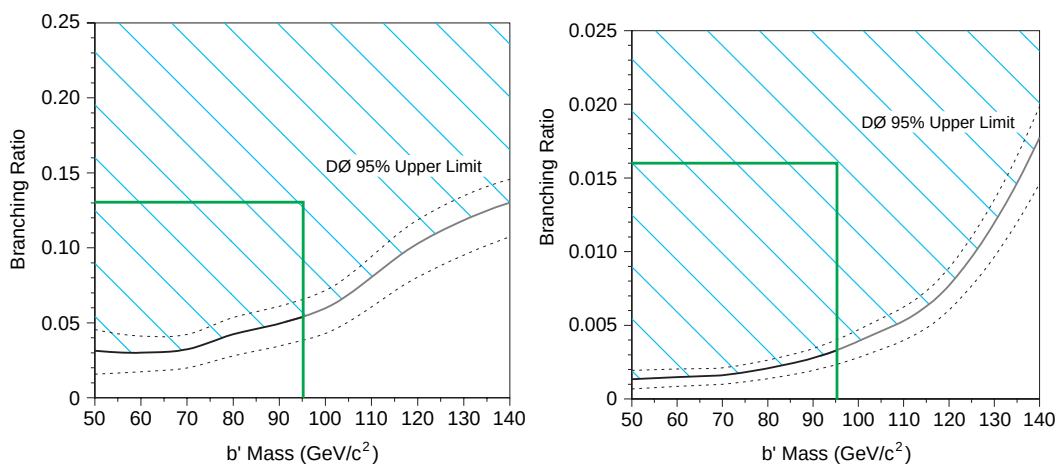

Figure 2: Upper limit at the 95% CL on the branching ratio for b' decaying to a) a photon and 3 jets where at least one jet is tagged as a b-quark with a muon, and b) for b' decaying to 2 photons and 2 jets.

Search for Supersymmetry

Supersymmetry is a symmetry which associates fermions with corresponding bosons and vice versa. Supersymmetric (SUSY) extensions of the Standard Model (SM) predict distinct superpartners for each of the SM particles. The Minimal Supersymmetric Standard Model (MSSM) incorporates the minimal number of new particles and interactions. Some particles predicted by such models are are within the reach of the Tevatron so both the DØ and CDF

collaborations have looked for evidence of SUSY production. Two of these searches are briefly described in the following subsections. Both groups assumed a supergravity constrained MSSM where R-parity is conserved and the lightest neutralino is the lightest supersymmetric particle (LSP).

Supersymmetric Quarks and Gluons

If the masses of squarks and gluinos are low enough, they will be pair produced at the Tevatron and their cascade decays would ultimately lead to jets, leptons and high ($\not\!\!E_T$) from the LSP escaping the detector. Both CDF and DØ have looked for evidence of such particles via their cascade decays to jets and high $\not\!\!E_T$.

Shown in Figure 3 is the updated lower limit on squark verses gluino masses at the 95% CL using 13.5 pb^{-1} of DØ data. This result combines the earlier published result [7] requiring 3 jets with $E_T > 15\ GeV$ and $\not\!\!E_T > 75\ GeV$ with a new analysis requiring 4 jets with $E_T > 20\ GeV$ and $\not\!\!E_T > 65\ GeV$. Also shown are results previously published by other experiments [9].

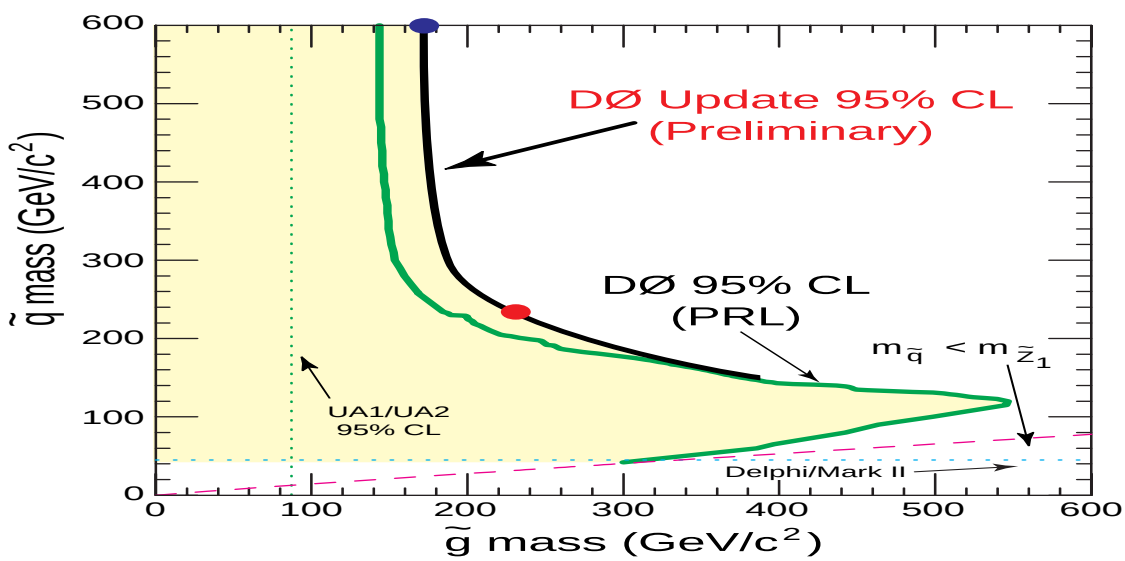

Figure 3: Regions in squark mass verses gluino mass phase space below the the solid black line are excluded by DØ at the 95% CL.

DØ finds a lower limit on the gluino mass of 173 GeV/c^2 and a lower limit of 229 GeV/c^2 for equal squark and gluino masses. Comparable results are found by CDF [8], where the corresponding upper limits are 160 and 220 GeV/c^2, respectively.

STOP - Light Supersymmetric Top Quarks

If the $\tilde{t}$ is kinematically accessible, it is expected to be produced in pairs at the Tevatron. DØ has searched [10] for the decay of the $\tilde{t}$ via its decay to $c + LSP$ under the assumption that the $\tilde{t}$ decay to other superpartners is kinematically unattainable. In this case, the signal is 2 acollinear jets and high $\not\!\!E_T$. Event selection criteria include at least 2 jets with $E_T > 30\ GeV$ and a total $\not\!\!E_T > 40\ GeV$. Using 13.5 pb^{-1} of DØ data, after all selection cuts, the three

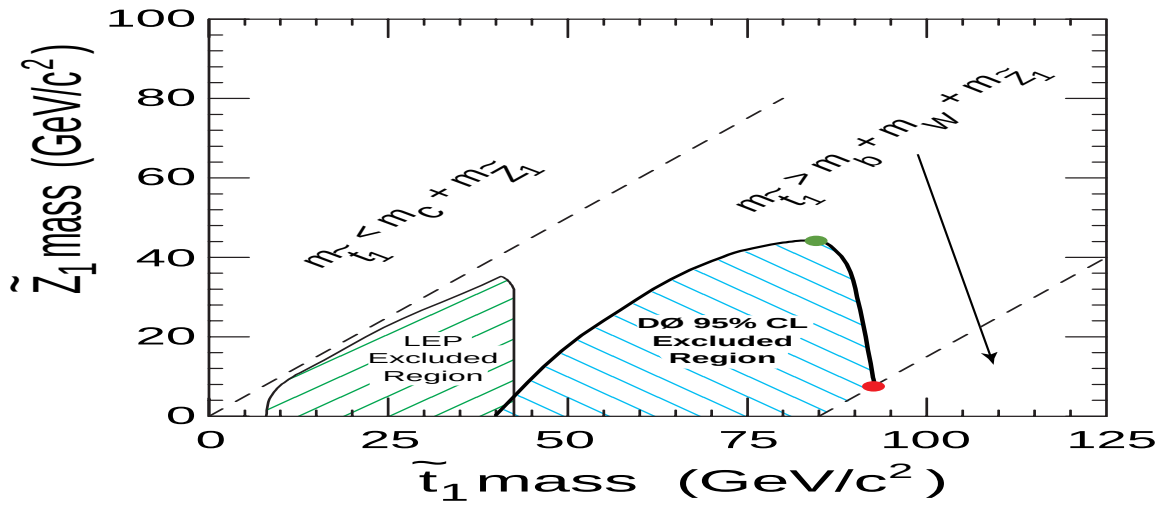

Figure 4: The DØ 95% Confidence Level exclusion contour. Also shown is the result from the OPAL experiment at LEP [11].

signal events are found to be consistent with the number of background events expected from heavy boson decays. The region of LSP mass verses $\tilde{t}$ mass excluded at the 95% CL by the current analysis is shown in Figure 4 along with the complementary region excluded by the OPAL experiment at LEP1 [11].

Conclusions

The DØ and CDF collaborations have searched for new physics beyond the Standard Model. New limits on such particles have been determined for new charged vector bosons, fourth generation quarks and supersymmetric partners of quarks and gluons, including the $\tilde{t}$ squark.

References

[1] DØ collaboration, S.Abachi *et al.*, Nucl.Instrum.Methods Phys. Res., Sect. A **338**, 185(1994).

[2] CDF Collaboration, F.Abe *et al.*, Nucl.Instrum.Methods Phys. Res., Sect. A **271**, 387(1988).

[3] see, for example R.N.Mohapatra, *Unification and Supersymmetry* (Springer, New York 1992).

[4] CDF Collaboration, F.Abe *et al.*, PRL **74**, 2900 (1995).

[5] DØ collaboration, S.Abachi *et al.*, PRL **76**, 3271 (1996).

[6] E.Laenen, J.Smith, and W.vanNeerven, Phys.Lett.B**321**, 254(1994).

[7] DØ collaboration, S.Abachi *et al.*, PRL **75**, 618(1995),

[8] J.Hauser, in Proceedings of the 10th Topical Workshop on Proton-Antiproton Collider Physics, Fermilab, May 1995.

[9] DELPHI Collaboration, P.Abreu *et al.*, Phys.Lett.B **247**, 148(1990); Mark II Collaboration, T.Barklow *et al.*, Phys.Rev.Lett. **64**, 2984(1990); UA1 Collaboration, C.Albajar *et al.*, Phys.Lett.B **198**, 261(1987); UA2 Collaboration, J.Alitti *et al.*, Phys.Lett.B **235**, 363(1990).

[10] DØ collaboration, S.Abachi *et al.*, PRL **76**, 2222(1996).

[11] OPAL Collaboration, R.Akers *et al.*, Phys.Lett.B **337**, 207(1994).