CDF/PUB/EXOTIC/PUBLIC/4166
May 7, 1997

W', Z', LEPTOQUARKS AND BUMP HUNTING AT THE TEVATRON

Juan A. Valls
Rutgers, The State University of New Jersey
Dept. of Physics and Astronomy, Piscataway, NJ, USA

Representing the CDF and DØ Collaborations

Abstract

This paper summarizes recent results on non-SUSY searches at the Fermilab Tevatron $p\bar{p}$ collider. All the analysis are based on the complete data samples recorded by both the CDF and DØ collaborations during the 1992-1995 running period (Run I), and correspond to $\sim 100\ pb^{-1}$. Searches for new neutral heavy vector bosons, leptoquarks, dijet mass resonances, and associated production of new heavy scalars together with vector bosons show no evidence for new physics. Consequently, the results have been interpreted in terms of 95% confidence level limits on production cross sections and new particle masses.

Presented at "QCD and High Energy Interactions, XXXII Rencontres de Moriond", Les Arcs, France, March 22-29, 1997.

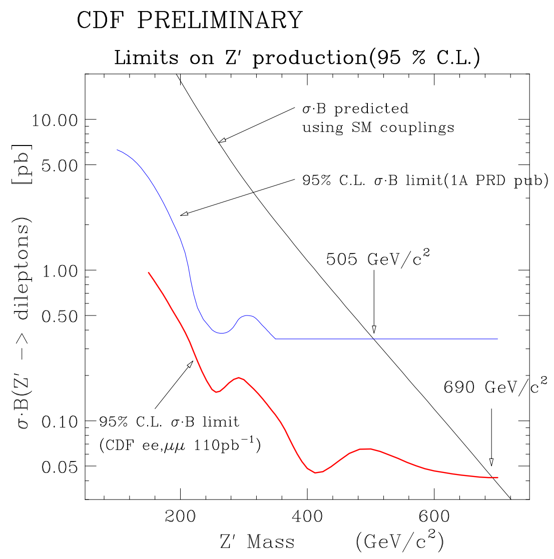

Figure 1: *CDF upper limits on* $\sigma\times BR(Z' \to e^+e^-, \mu^+\mu^-)$ *compared to the theoretical predictions of a reference* Z' *model with SM Z couplings.*

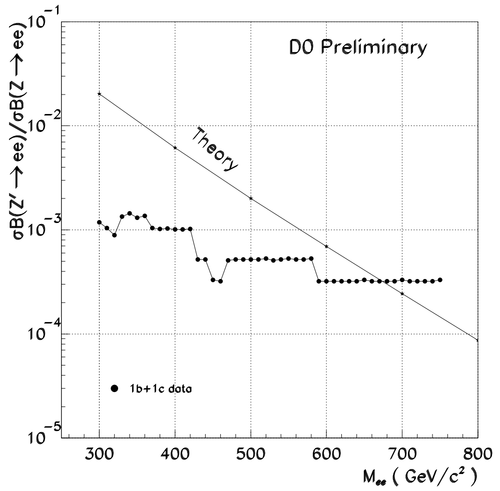

Figure 2: *DØ upper limits on* $\sigma\times BR(Z')$ $/\sigma \times BR(Z)$ *where* $Z', Z \to e^+e^-$. *The theory corresponds to a reference* Z' *model with SM Z couplings.*

1 Neutral Heavy Vector Boson Searches

The experimental observation of heavy neutral Z' bosons would provide dramatic evidence for physics beyond the Standard Model (SM). These particles are predicted in many extensions of the SM such as grand unified theories and left-right symmetric models. These models specify the strengths of the couplings of such bosons to quarks and leptons but make no mass predictions. Both the CDF and DØ collaborations have updated their previous limits[1)] for the mass of such particles including the complete Run I data. CDF analyzes both the $Z' \to e^+e^-$ and $\mu^+\mu^-$ channels[2)] while DØ considers only the e^+e^- channel. No experimental evidence of deviations in the invariant mass distributions of high p_T leptons are observed. The spectrums are consistent with the expectation from Z-boson and Drell-Yan production. CDF excludes at the 95% C.L. Z' bosons with $M < 690$ GeV/c^2 for a reference model with same Z' couplings as the SM Z. The CDF limit is shown in Figure 1 for all Run I data corresponding to 110 pb^{-1} together with the previous Run IA results based on 20 pb^{-1}. DØ sets a comparable limit of $M < 670$ GeV/c^2 for 105 pb^{-1} of Run I data as shown in Figure 2.

CDF has also compared the experimental limits with specific models and excludes Z' bosons with $M <$ 590, 620, 595, 565, 630 and 600 GeV/c^2 for Z_ψ, Z_η, Z_χ, Z_I, Z_{LR} and Z_{ALRM}, respectively, assuming the Z' decays only into known SM fermions.

2 Leptoquark Searches

Color-triplet bosons with couplings to both quarks and leptons are commonly known as leptoquarks (LQ). They appear in several SM extensions which join the quark and lepton sectors at a more fundamental level. LQ masses and coupling strenghts are severely constrained by experimental bounds of rare processes and flavour changing neutral currents. However, light LQ's with masses accesible at Tevatron are still a possibility under certain assumptions like lepton and baryon conservation numbers,

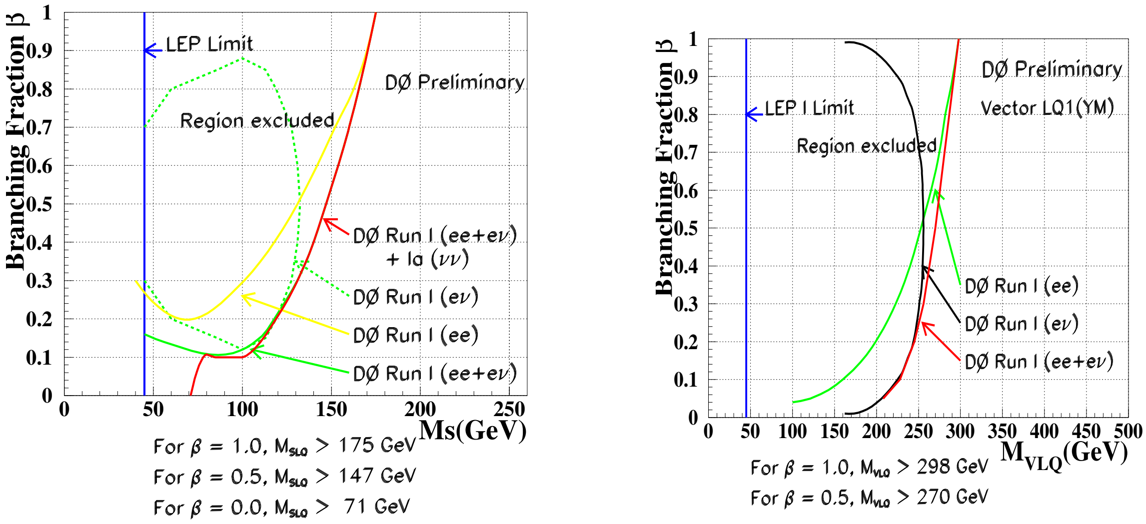

Figure 3: *DØ first generation scalar (left) and vector (right) LQ's excluded parameter space (β, M_{LQ}) for different final state topologies ($eejj$, $e\nu jj$ and $\nu\nu jj$). Results are shown for the complete Run I dataset.*

chiral couplings and single generational production. At Tevatron, LQ's are pair produced through the strong interaction, and they have been searched in all possible decay channels.

For first generation scalar LQ's DØ has updated their previous published results[3)] with the inclusion of all channels $eejj$, $e\nu jj$ and $\nu\nu jj$, and the complete dataset for Run I. They extend the exclusion parameter space (β, M_{LQ}) to lower values of β, where $\beta = BR(LQ \to lq)$ and $1 - \beta = BR(LQ \to \nu q)$. Figure 3 shows the recent DØ 95% C.L. upper limit results for scalar and vector LQ's. The results shown are obtained with the leading order (LO) cross-section of Blümlein *et al.*[4)] and exclude at 95% C.L. first generation scalar LQ with $M < 175$ (147) GeV/c^2 and vector LQ with $M < 298$ (270) GeV/c^2 for $\beta = 1$ (0.5). When using the more recent next-to-leading order (NLO) calculations from Krämer *et al.*[5)] the limit for scalar LQ increases to $M < 191$ GeV/c^2 for $\beta = 1$. Present CDF results of first generation LQ's are based on a dataset corresponding to 4 pb^{-1} from the 88-89 Tevatron run[6)]. First generation LQ's with $M < 113$ (80) GeV/c^2 for $\beta = 1$ (0.5) are excluded at 95% C.L.

Both CDF and DØ have obtained new results on second generation LQ's from the Run I data. DØ updates its published results from Run IA[7)] by analyzing additional 94.4 pb^{-1} from Run IB. The new results, based on the $\mu\mu jj$ channel, exclude second generation scalar LQ's with $M < 167$ GeV/c^2 for $\beta = 1$ when using the old LO calculations, and are shown in Figure 4. The limit increases up to $M < 185$ GeV/c^2 when using the NLO predictions. CDF results based on 110 pb^{-1} set stringent limits on second generation LQ masses. At the 95% C.L. $M < 197$ GeV/c^2 for $\beta = 1$ are excluded when using the NLO theoretical calculations.

For the first time, both experiments have also searched for third generation LQ's. CDF uses events with a $\tau\tau jj$ final state and looks for $Q = \frac{4}{3}$ and $Q = \frac{2}{3}$ LQ's[8)]. Third generation scalar LQ's with $M < 99$ GeV/c^2 for $\beta = 1$ are excluded at the 95% C.L. using LO calculations. Again, when the NLO predictions are used, the limits increase up to $M < 110$ GeV/c^2. For vector LQ's, the limits are $M < 170$ GeV/c^2 and $M < 225$ GeV/c^2 ($\beta = 1$) for $\kappa = 0$ and $\kappa = 1$ respectively, where κ is the

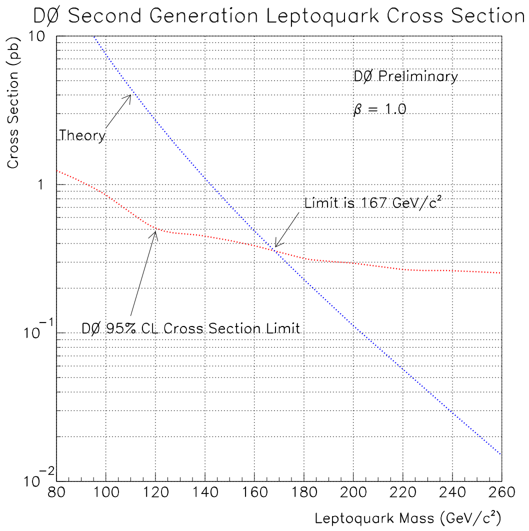

Figure 4: *95% C.L. DØ cross section upper limits for second generation scalar LQ's as a function of M_{LQ}.*

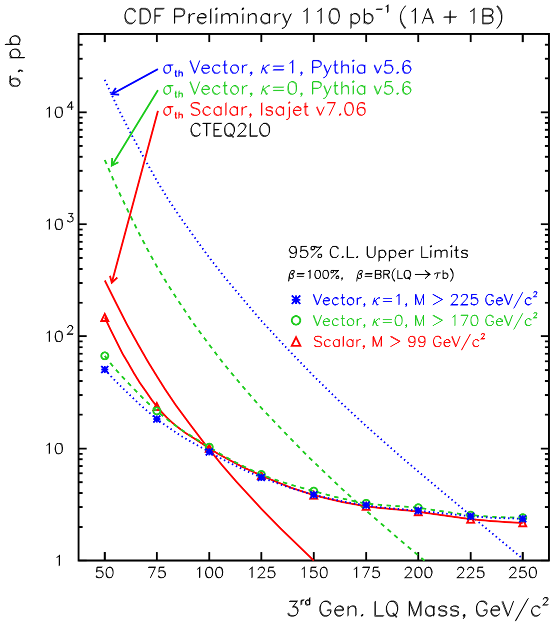

Figure 5: *95% C.L. CDF cross section upper limits for third generation scalar and vector LQ's as a function of M_{LQ}.*

"anomalous chromomagnetic moment". CDF results for third generation scalar and vector LQ's are shown in Figure 5. DØ has searched for third generation LQ's using events with a $\nu\nu jj$ final state where at least one jet is b-tagged. They exclude third generation scalar LQ's with $M < 80$ GeV/c^2 for $\beta = 0$ at 95% C.L. using LO calculations.

3 Bump Searches in Invariant Mass Distributions

Many theories predict the existence of new particles produced either single or in association with a vector boson and which decay to dijets. These particles would be observed as bumps in the dijet invariant mass spectrum. Covered here are the CDF updated results[9)] and DØ results[10)] on new particles decaying into dijets, and the results from both collaborations on the search for associated production of heavy neutral scalars with vector bosons.

3.1 Search for New Particles Decaying into Dijets

Many extensions of the SM predict new particles which decay to two jets and would be observed as resonances in the dijet mass spectrum. This is the case of models which contain axigluons, excited quarks, color octet technirhos, heavy vector bosons (W', Z'), and E_6 diquarks. Both collaborations use a sample of single jet triggers to select a clean dijet sample. The dijet invariant mass distribution is then calculated and compared to the QCD predictions. No significant deviation is observed in the dijet spectrums. In the absence of evidence for resonance production, the data curves are fit to theoretical resonance predictions and background shapes. At the 95% C.L. CDF excludes axigluons in

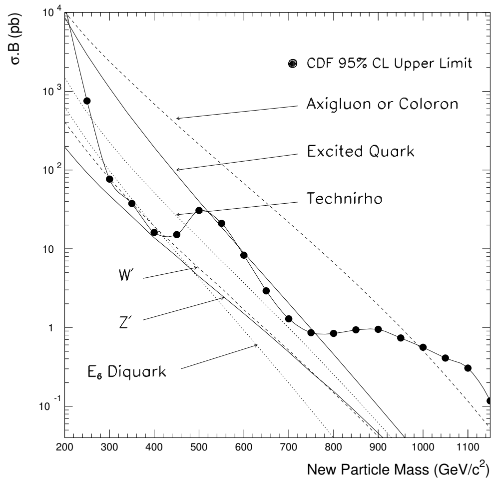

Figure 6: *Upper limit on the cross setion times branching ratio for new particles decaying to dijets (points) compared to several theoretical predictions.*

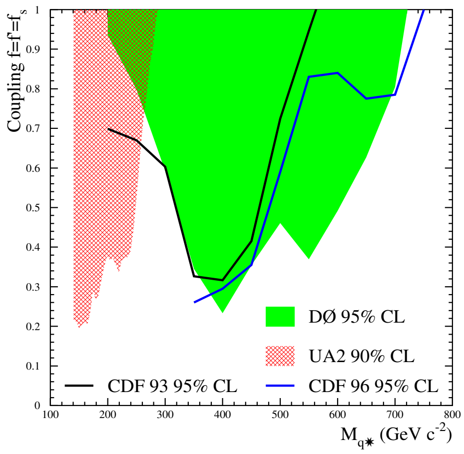

Figure 7: *Region of the coupling vs. mass plane excluded by both CDF and DØ experiments for excited quark production.*

the mass range $200 < M_A < 980$ GeV/c^2, color octet technirhos (ρ_T) in the range $260 < M_{\rho_T} < 470$ GeV/c^2, hadronic W' decays in the range $300 < M_{W'} < 420$ GeV/c^2, E_6 diquarks in the range $290 < M_{E_6} < 420$ GeV/c^2 and excited quarks in the mass ranges $200 < M_{q^\star} < 520$ GeV/c^2 and $580 < M_{q^\star} < 760$ GeV/c^2. DØ excludes excited quarks in the range $200 < M_{q^\star} < 720$ GeV/c^2. These results are shown in Figures 6 and 7 for the case of SM couplings ($f = f' = f_s = 1$) and in the coupling vs. mass plane, respectively.

3.2 Search for Neutral Heavy Scalars Produced in Association with a Vector Boson

Associated production of a vector boson with a neutral scalar represent the main observable mechanism of the SM Higgs boson at Tevatron energies. The same type of reaction are also predicted in the MSSM as well as in recent technicolor models, introduced as alternative scenarios for electroweak symmetry breaking. Two different strategies to search for such processes are followed by both collaborations using the complete Run I data. DØ analyzes a lepton + jets topology to search $W + X^0 \rightarrow l \not\!\!E_T b\bar{b}$ events while CDF searches in a multijet sample for $W + X^0 \rightarrow jjb\bar{b}$ processes. The multijet channel has the advantage of larger branching ratios and better detection efficiencies, but suffers from a large irreducible QCD background. CDF fits the observed invariant mass distribution of b-tagged dijets with different background sources and the signal. The results are shown in Figure 8 for different Higgs masses. DØ also performs a simple counting experiment. The results are shown in Figure 9 where a sensitivity between 20 and 10 pb^{-1} is reached in the region of large masses.

4 Summary

Results from recent non-SUSY searches at the Fermilab Tevatron have been shown. The data corresponds to the complete Run I dataset of ~ 100 pb^{-1}. Null results from both the CDF and DØ collaborations indicate the necessity of larger data samples to increase the sensitivity of the searches

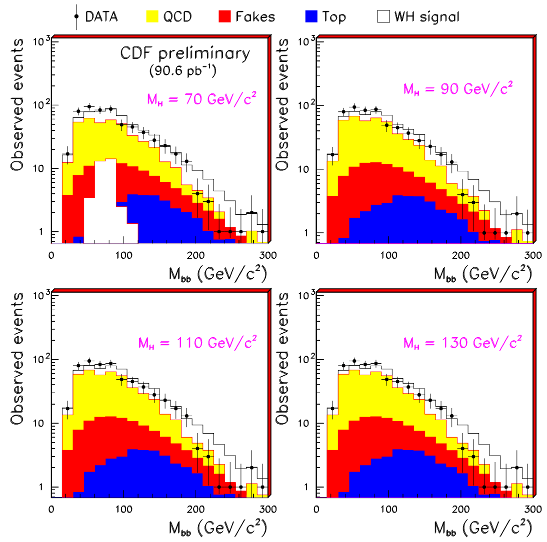

Figure 8: *Invariant mass distributions of b-tagged dijets compared with the predictions of the fit. The results are shown for M_H=70, 90, 110 and 130 GeV/c^2.*

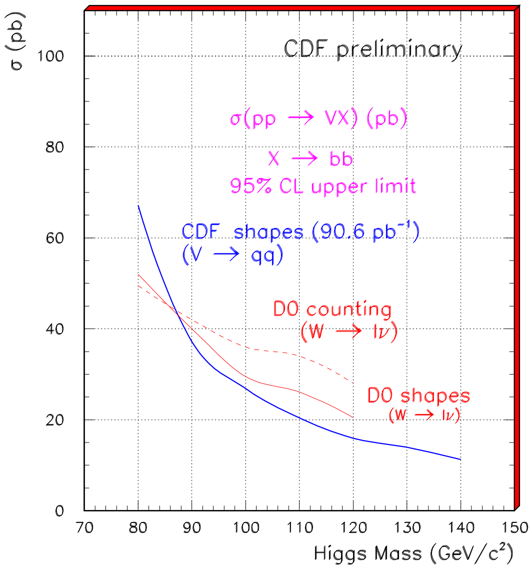

Figure 9: *95% C.L. upper limit on $\sigma(VH^0)\times BR(H^0 \rightarrow b\bar{b})$ as a function of the Higgs mass for CDF and DØ.*

reported. The expected integrated luminosity for the next Tevatron run, a factor 20 higher, will substantially increase the explored range of new physics and enhance the discovery potential of the experiments.

References

[1] F. Abe *et al.* Phys. Rev. **D51**, 949 (1995).
S. Abachi *et al.* Phys. Lett. **B385**, 471 (1996).

[2] F. Abe *et al.* Fermilab/PUB-97/122-E (submitted to Phys. Rev. Lett.).

[3] S. Abachi *et al.* Phys. Rev. Lett. **72**, 965 (1994).
G. Wang, Fermilab CONF-96/389-E (to be published in the proceedings of DPF-96).

[4] J. Blümlein, E. Boos and A. Kryukov, DESY 96-174 (hep-ph/9610408).

[5] M. Krämer *et al.*, CERN-TH/97-67 (hep-ph/9704322).

[6] F. Abe *et al.* Phys. Rev. **D48**, 3939 (1993).

[7] S. Abachi *et al.* Phys. Rev. Lett. **75**, 3618 (1995).

[8] F. Abe *et al.* Phys. Rev. Lett. **78**, 2906 (1997).

[9] F. Abe *et al.* Phys. Rev. **D55**, 5263 (1997).

[10] I. Bertram for the DØ Collaboration, Fermilab-Conf-96/389-E (1996).