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FERMILAB-Conf-95/155-E
CDF

Search for New Phenomena in CDF – I: Z', W' and Leptoquarks

Seongwan Park
For the CDF Collaboration

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

July 1995

Published Proceedings for the *10th Topical Workshop on Proton-Antiproton Collider Physics*, Fermilab, Batavia, Illinois, May 9-13, 1995

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

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CDF/PUB/EXOTIC/PUBLIC/3199
June 16, 1995
V1.0
Pbar-P '95

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S. Park

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Seongwan Park*

Fermi National Accelerator Laboratory

P.O.Box 500, Batavia

Illinois 60510, USA

Abstract

We present the latest results of CDF searches for Z', W' and leptoquarks. Using about $70\,\mathrm{pb}^{-1}$ data from 1992–95 CDF runs, we have searched for $Z' \to l^+l^-$, $W' \to WZ$ and pairs of second generation scalar leptoquark, $\mathcal{S}_2$. We find no evidence for these new particles, and set new mass limits at 95% CL. We exclude $M_{Z'} < 650\,\mathrm{GeV}/c^2$, $205 < M_W' < 400\,\mathrm{GeV}/c^2$, and $M_{\mathcal{S}_2} < 180\,\mathrm{GeV}/c^2$ for $\beta = 1$ and $M_{\mathcal{S}_2} < 141\,\mathrm{GeV}/c^2$ for $\beta = 0.5$. Two interesting strange events are also shown.

OVERVIEW

The standard model agrees with all experimental data very well. However, despite this great success, it has been believed that the standard model is not the final theory because it fails to unify all known forces, contains too many arbitrary unknown parameters, and has too many artificial features. To deal with these problems, many extensions to the standard model have been suggested, and theories beyond the standard model made.

The new particles, Z', W' and leptoquak, whose searches are reviewed here are predicted from those extensions, and explorable at the Fermilab Tevatron energy. We present the

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*Representing the CDF Collaboration.

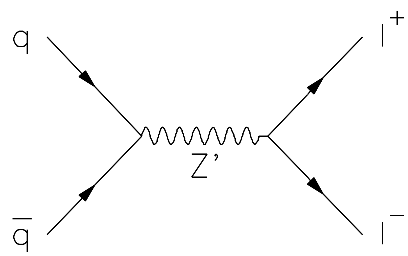

FIG. 1. Feynman diagram for Z' production in $p\bar{p}$ collisions.

latest results from the searches of these particles done by the Collider Detector at Fermilab (CDF). The possible dijet decay modes for Z' and W' are not covered here, but in the next talk, "Search for New Phenomena in CDF — II."

All searches presented here use approximately 70 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV which is the sum of about 20 pb^{-1} from 1992–93 CDF run and 50 pb^{-1} from the ongoing current run.

SEARCH FOR $Z' \rightarrow L^+L^-$

A new gauge boson Z' is predicted by most extensions to the standard model, and its couplings are very similar to Z. We search for Z' decaying to two leptons, either $\mu^+\mu^-$ or e^+e^-.

We require two electrons with $E_T > 25\,\mathrm{GeV}$ or two muons with $p_T > 20\,\mathrm{GeV}$, and look for Z' peaks in the dilepton invariant mass distributions shown in Fig. 2 over the only appreciable background from Drell-Yan $\gamma, Z \rightarrow l^+l^-$.

For dimuon decay mode, cosmic rays are additional backgrounds and removed by back-to-back angle cut and calorimeter TDC timing cut. For dielectron mode, QCD dijets misidentified as electrons are additional backgrounds, and the source of worse resolution of Z mass peak for dielectron as shown in Fig. 2.

We find no evidence of signals after subtracting backgrounds (e.g., Fig. 3 for dielectron), and get upper limits on the cross-section times branching ratio assuming 0 observation

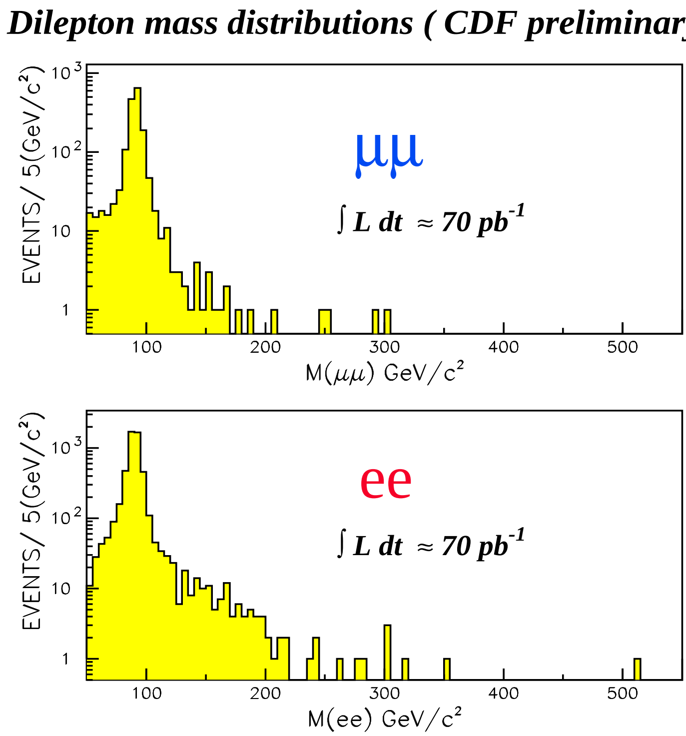

FIG. 2. Dilepton invariant mass distributions for Z' search.

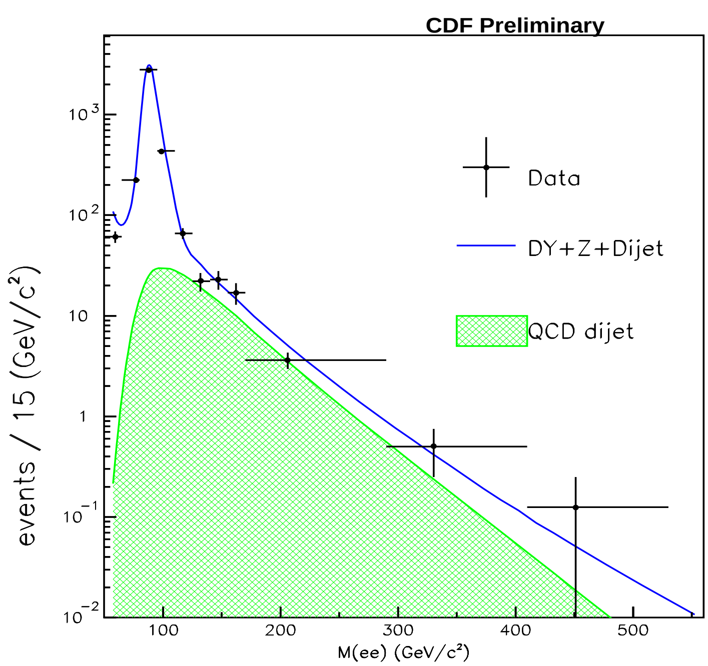

FIG. 3. Dielectron invariant mass distribution for Z' search.

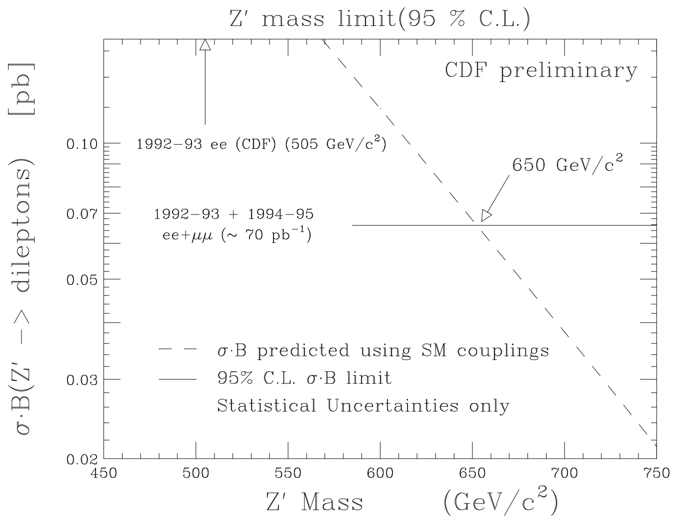

FIG. 4. Limit on $Z' \to l^+l^-$ cross-section vs mass.

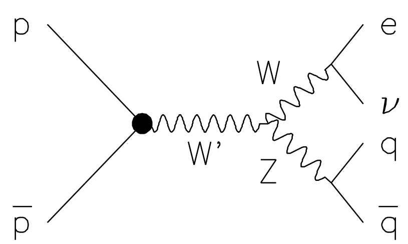

FIG. 5. Feynman diagram for W' production in $p\bar{p}$ collisions and decay to WZ.

and including only statistical uncertainties as shown in Fig. 4. Theoretical prediction is calculated with the standard model couplings and MRSD′ structure function. We exclude at 95% CL $M_{Z'} < 650\,\mathrm{GeV}/c^2$. The previous published Z' mass limit by CDF is $505\,\mathrm{GeV}/c^2$ [1].

SEARCH FOR $W' \to WZ$

A new gauge boson W' is predicted by most extensions to the standard model. In left-right symmetric models, a W' is a right-handed W boson, and decays to $e_R\nu_R$. This W' was the subject of the previous published search [2] and $M_{W'} < 652\,\mathrm{GeV}/c^2$ is excluded.

In left-handed models, a W' is a heavy version of the standard W boson, and predom-

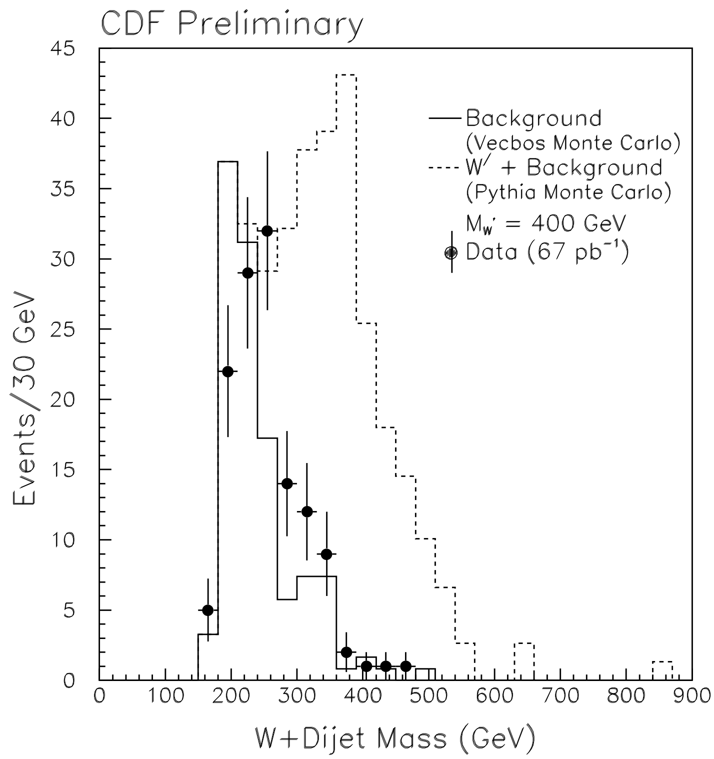

FIG. 6. W+dijet mass spectra for the data, background and W' Monte Carlo.

inantly decays to WZ if $M_{W'}$ is greater than the $M_W + M_Z$ threshold [3]. Here we present the search for $W' \to WZ$. As shown in Fig. 5, we look for the decay mode $W \to e\nu$ and $Z \to jj$ which gives the signature of a high E_T electron, high $\not{E}_T$ and 2 high E_T jets.

We require an electron with $E_T > 30\,\mathrm{GeV}$, $\not{E}_T > 30\,\mathrm{GeV}$, and two jets with $E_T > 50\,\mathrm{GeV}$ and $E_T > 20\,\mathrm{GeV}$. We look for signals over W+dijet background. Fig. 6 shows W+dijet mass spectra for the data, background and W' Monte Carlo events. There is no evidence of the production.

To calculate 95% CL upper limit of the cross-section times branching ratio, we use "binned maximum likelihood method" with the assumption of 0 background. Only statistical errors are included. The assumption makes the estimate very conservative, and the result will be much improved with the proper background subtraction in future. From Fig. 7, we exclude the mass range $205 < M_W' < 400\,\mathrm{GeV}/c^2$ for a heavy W' decaying to WZ.

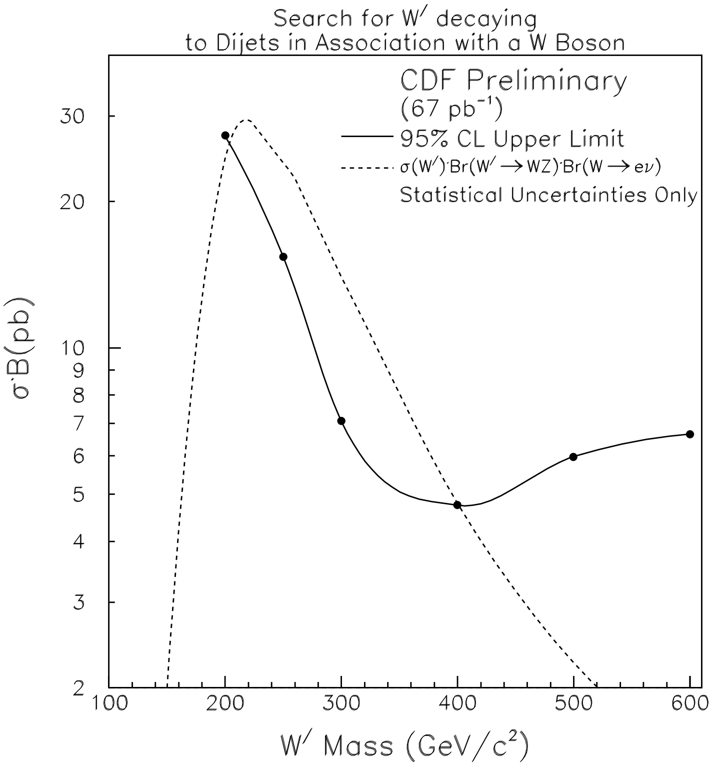

FIG. 7. 95% CL upper limit of $\sigma \cdot Br(W' \to WZ) \cdot Br(W \to e\nu)$ vs $M_{W'}$.

SEARCH FOR SECOND GENERATION LEPTOQUARKS

Leptoquarks are hypothetical color-triplet bosons carrying both color and lepton quantum numbers. Each generation of leptoquark couples to a quark-lepton pair of the corresponding generation. We search for pair production of second generation scalar leptoquarks, $\mathcal{S}_2$, each of which decays to a muon and a quark with branching ratio β. Thus, we look for the signature of two high p_T muons and two high E_T jets.

We require two muons with $p_T > 20\,\mathrm{GeV}/c$ and two jets with $E_T > 20\,\mathrm{GeV}$. We remove Z+dijet events by rejecting events with $75 < M_{\mu\mu} < 105\,\mathrm{GeV}/c^2$. Fig. 8 shows the dimuon invariant mass distributions of the data.

After the cuts, 4 candidates are left, and consistent with the estimated background 4.8 ± 1.3. The backgrounds consist of Drell-Yan+dijet, $t\bar{t}$, $Z \to \tau^+\tau^-$, fake muons, $b\bar{b}$ and WW. To derive 95% CL upper limit of the cross-section times β^2, we use a number of observed events for a mass point which is counted within a 3 σ region of reconstructed leptoquark

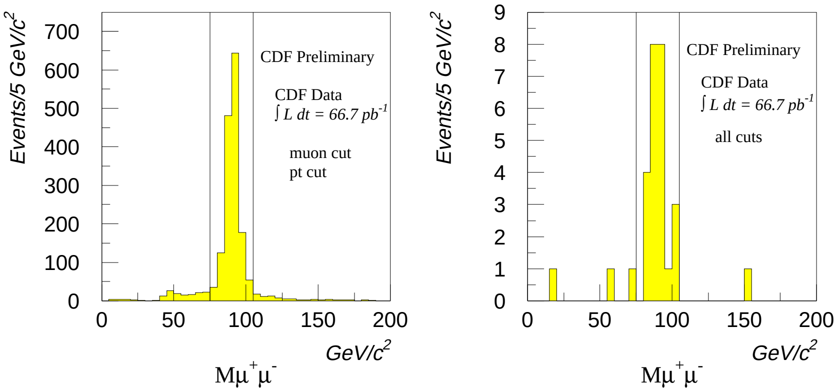

FIG. 8. Dimuon invariant mass distributions. Vertical lines indicate Z mass window. Left: Muon identification, p_T and opposite charge cuts are applied. Right: Two jet and angle cuts are applied as well as the cuts for top one.

mass resolution. We assume that the background is conservatively 0. Theorectical prediction is obtained from ISAJET with CTEQ2pM structure function.

Fig. 9 shows the upper limits vs leptoquark mass for different theoretical consideration, and branching ratio limits vs mass.

We exclude $M_{\mathcal{S}_2} < 180\,\mathrm{GeV}/c^2$ for $\beta = 1$, and $M_{\mathcal{S}_2} < 141\,\mathrm{GeV}/c^2$ for $\beta = 0.5$. The previous published mass limits of second generation leptoquark by CDF are 131 and 96 GeV/c^2 for $\beta = 1$ and 0.5, respectively [4].

ZOO EVENTS

Here we show two very interesting strange events recently recorded by CDF. The first event (Fig. 10) includes 2 electrons with $E_T = 36, 59\,\mathrm{GeV}$ and $M_{ee} = 165\,\mathrm{GeV}/c^2$, 2 photons with $E_T = 30, 38\,\mathrm{GeV}$, and $\not{E}_T = 53\,\mathrm{GeV}$. The second event (Fig. 11) includes 2 electrons with $E_T = 182, 23\,\mathrm{GeV}$, a muon with $p_T = 27\,\mathrm{GeV}$, a jet with $E_T = 83\,\mathrm{GeV}$, and $\not{E}_T = 106\,\mathrm{GeV}$.

We can speculate the origin of these events in many ways, but clearly their cross-sections from the standard model are too small to be observed. Whether these are mere statistical fluctuations or some new phenomena will be determined with more data from the ongoing CDF run.

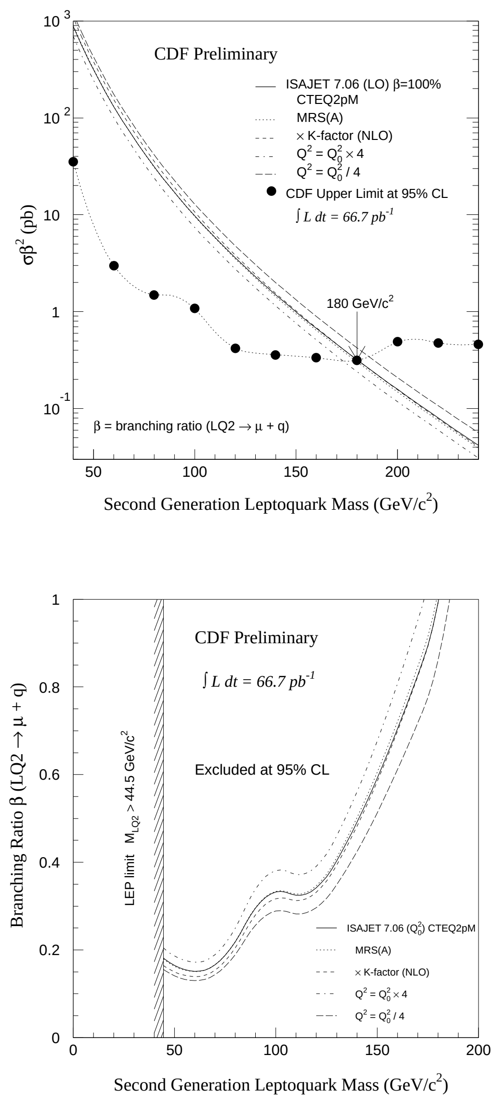

FIG. 9. 95% CL upper limits of $\sigma \cdot \beta^2$ vs mass, and 95% CL limits of branching ratio vs mass.

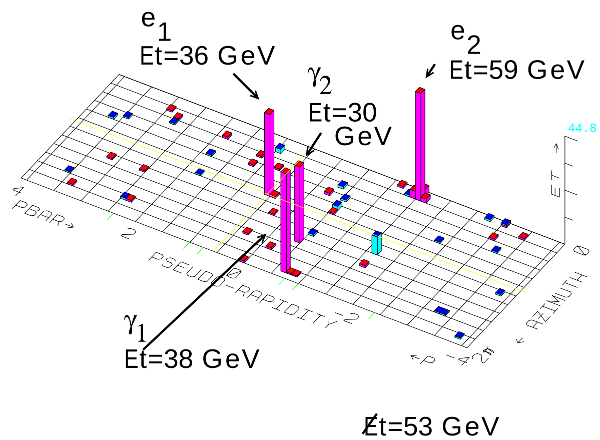

FIG. 10. A zoo event (run 68739 / event 257646) with 2 electrons, 2 photons and large $\not{E}_T$.

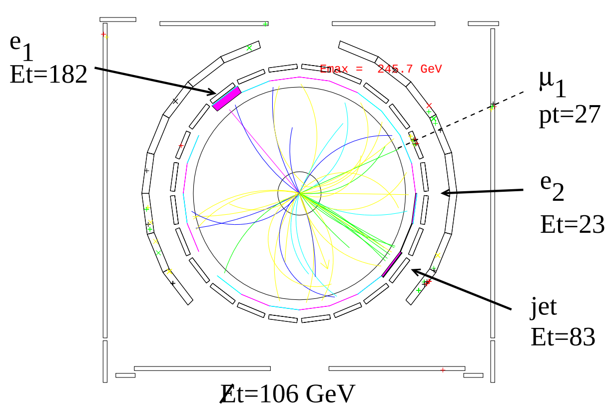

FIG. 11. A zoo event (run 67581 / event 129896) with trilepton, a jet and large $\not{E}_T$.

CONCLUSION

We search for new particles predicted by extensions to the standard models with the increasing luminosity delivered to CDF at the Tevatron energy. Although we find no evidence for those new particles, we set the most stringent limits on their masses. With more data from the ongoing CDF run and searches for more modes of the new particles ($Z' \rightarrow WW$, first and third generation scalar leptoquarks, and vector leptoquarks), we hold optimistic expectation that we will be able to find new physics beyond the standard model.

REFERENCES

[1] F. Abe, et al., Phys. Rev. D **51**, 3 (1995).

[2] F. Abe, et al., Phys. Rev. Lett. **74** (1995).

[3] G. Altarelli, et al., Z. Phys. C45, 109 (1989).

[4] F. Abe, et al., to be published in Phys. Rev. Lett..