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Final Report
Collider Physics

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submitted by

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1 Introduction

This report summarizes the work done on Grant # DE-FG03-95ER40916 over the period April 1, 1995 through March 31, 1999. Detailed progress reports have been submitted for the years through March 31, 1998. The primary project during this period was the DØ experiment at Fermilab and is discussed first. The last year of the period was an extension to complete the study of laser induced fluorescence in neon. This work is discussed in the section "Detector R&D".

2 The DØ Experiment at Fermilab

The group's primary work during this period was as a member of the DØ experiment at Fermilab. Participation included software development, data collection shifts, data processing shifts, trigger development, physics analysis and upgrade work.

2.1 DØ Physics

The group's primary responsibility was the search for supersymmetry via the the associated production of the lightest chargino, $\tilde{\chi}_1^\pm$, and the second lightest neutralino, $\tilde{\chi}_2^0$, via a trilepton + missing Et signature. The Run 1a analysis was done in collaboration with the U.T. Arlington group and published in PRL in 1995. The Run IIb,c result was published in PRL in 1998.

In an effort to increase sensitivity, a second search was initiated for $\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm$ production that required two leptons + missing Et. For the associated $\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ production, it includes $\tilde{\chi}_1^\pm$ to jets and $\tilde{\chi}_2^0$ to leptons, and two-out-of-three of the trilepton signature. Therefore, the sensitivity is increased at a cost of higher background. This analysis is now complete, and will be published as the PhD thesis for student Taylor Goss pending completion of his thesis defense.

Early in this period, the group also completed a search for second generation leptoquarks that was published in PRL in 1995. The group has also made contributions to later leptoquark analyses.

2.2 DØ Personnel / Service Activities

Members of the group during at least a portion of the period included Emeritus Professor Russ Huson, Associate Professor James White, Post Doctoral Research Associate Doug Norman and graduate students Taylor Goss and Djoko Wirjawan. Areas of major contributions have included electronics commissioning, Level 1 and 2 triggering, electron and tau ID, TRD operation and physics analysis, and software development for Run II. Our primary physics contribution has been the search for supersymmetry through the tri- and di-lepton signatures of chargino-neutralino production, though members of our group also carried out searches for leptoquarks. We also participated in numerous workshops concerning the future of HEP and Fermilab. A list of personnel and major contributions is summarized below.

- **Professor F. Russel Huson** formed and led the group as PI through 1996 when he retired.
- **Assistant Professor James White** was Co-PI of the group and led the DØ effort beginning 1990. Major contributions included initiation of and leadership in the supersymmetry di- and tri-lepton search analyses, participation in shift work during data collection, and participation in numerous studies (TeV-2000, Snowmass, and NLC workshops) concerning the DØ upgrade and other issues related to the future of high energy physics.
- **Research Associate Doug Norman** became a member of the group in Spring 1994 and was stationed at Fermilab through January 1999. His thesis - "A Search for First Generation Scalar Leptoquarks at $\sqrt{s} = 1.8$ TeV with the DØ Detector" - led to the first DØ physics paper. In addition to working closely with our students, he finished analysis of a search for second generation leptoquarks, optimized low E_t electron ID, optimized low E_t lepton triggers (needed for the group's physics analyses as well as others) and developed software for electron ID using the transition radiation detector for Run 1b. He also worked data collection shifts, played a leadership role in the supersymmetry searches, and contributed strongly to the upgrade. His primary upgrade work was on vertex triggering and vertex tracking software written in C++.
- **Student Djoko Wirjawan** was stationed at Fermilab to participate in the DØ experiment beginning September 1993. Major contributions included Level-2 trigger development, development of an H-Matrix technique to identify tau leptons, participation in

detector shift work during the data run, and participation in data processing shift work. His PhD work was completed in 1997 with a thesis titled "Search for Supersymmetry via $\tilde{\chi}_1^\pm, \tilde{\chi}_2^0 \rightarrow$ trileptons", Portions of this work were published in PRL.

- **Student Taylor Goss** was stationed at Fermilab beginning January 1994. Before that, he worked on our SSC detector program while finishing classes. Major contributions included Level-2 software development, participation in the running and development of the Transition Radiation Detector (monitoring, calibration, software development and detector shift work during the data run). His PhD analysis, "Search for supersymmetry via $\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^\pm, \tilde{\chi}_2^0 \rightarrow$ dileptons", was essentially completed in summer 1999. He is now preparing for his final exam.

3 Detector R&D

In addition to the DØ project, our group maintained a detector R&D program that began as part of the effort to build fast, radiation-resistant calorimetry for the SSC. After the termination of the SSC, we began a project in collaboration with an atomic physics group to study methods to detect radiation using fluorescent imaging of ionized and excited atoms. Several techniques were investigated theoretically and an approach that could potentially be used in a dark matter search was published in 1997 ("Spectroscopic Particle Detection: A New Technique to Search for WIMPS", J.T. White, E.S. Fry and Th. Walther, Proceedings, 14th International Conference on the Application of Accelerators in Research and Industry, Nov. 6-9, 1996, Denton, Texas, CAARI'96. published in AIP Conference proceedings 392, 1997) Several other techniques were investigated and the primary experimental effort was to investigate fluorescence of excited atoms along tracks in gaseous neon.

Personnel working on Detector R&D within our HEP group included Associate Professor James White (PI), post-doc Kiki Hosea, and graduate students David Brookes, Patrick Riggs and Ben Cain. Funding for Kiki Hosea and PhD student David Brookes have been obtained through the state of Texas (Advanced Research Program) and through two interdisciplinary research programs sponsored by our university. K. Hosea was funded through spring 1999, and D. Brooks is funded through summer 1997, after which he was funded by this DOE grant. Patrick Riggs and Ben Cain both worked on MS degrees and were funded through teaching assistantships. Undergraduate students who worked on the project include Erin

Rericha, Eric Mayes, Shawn Vinyard, Jack McClure and Jeff Hillhouse.

The investigation of tracking in neon resulted in the PhD thesis "A study of Laser Induced Fluorescence in Neon as a Potential Particle Tracking Mechanism" by student David Brookes in 1999. A subsection of this work resulted in the MS thesis "Measurement of ION Diffusion in He, N and Ar" by student Ben Cain in 1998. The expertise gained from this effort also lead to the development of two argon-based approaches to dark matter detection. Our group is now developing these ideas with the goal being to build a large scale dark matter detector in the near future.

4 Publications

The following is a fairly complete list of publications produced during the grant period.

1. "Search for Top Squark Pair Production in the Dielectron Channel" Phys. Rev. D 57, 589 (1998)
2. "Search for the Trilepton Signature from Associated Gaugino Pair Production. Phys. Rev. Letters 80 1591 (1998)
3. "Measurement of the Top Quark Mass Using Dilepton Events" Phys. Rev. Letters 80 2063 (1998)
4. "Measurement of Dijet Angular Distributions and Search for Quark Compositeness" Phys. Rev. Letters 80 666 (1998)
5. "Experimental Search for Chargino and Neutralino Production in Supersymmetry Models with a Light Gravitino" Phys. Rev. Letters 80 442 (1998)
6. "Determination of the Mass of the W Boson Using the D0 Detector at the Tevatron" Phys. Rev. D 58 12002 (1998)
7. "Zgamma Production in pbarp Collisions at $\sqrt{s}=1.8$ TeV and Limits on Anomalous ZZgamma and Zgammagamma Couplings" Phys. Rev. D 57 3817 (1998)
8. "Search for First Generation Scalar Leptoquark Pairs in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 80 2051 (1998)

9. "A Measurement of the W Boson Mass" Phys. Rev. Letters 80 3000 (1998)
10. "Direct Measurement of Top Quark Mass at D0" Phys. Rev. D 58 052001 (1998)
11. "Search for the Decay $b \rightarrow s \mu \mu$ " Physics Lett. B423, 419 (1998)
12. "Measurement of the Shape of the Transverse Momentum Distribution of W Bosons Produced in pbarp Collisions at $\sqrt{s}=1.8$ TeV" Physics Rev. Lett. 80 5498 (1998)
13. "Limits on WWgamma and WWZ Couplings from W Boson Pair Production" Phys. Rev D58, Rapid Communications 051101 (1998)
14. "Search for Charge 1/3 Third Generation Leptoquarks in pbarp Collisions at $\sqrt{s}=1.8$ TeV" Phys. Rev Lett. 81 38 (1998)
15. "Limits on Anomalous WWg and WWZ Couplings" Phys. Rev. D Rapid Communications D58 31102 (1998)
16. "Search for Heavy Pointlike Dirac Monopoles" Phys. Rev. Lett. 81 524 (1998)
17. "The D0 Detector at TeV33" preprint , FERMILAB PUB-98-124-E, hep-ex/9804011, D0note 3410.
18. "Combined Limits on First Generation Leptoquarks from the CDF and D0 Experiments" preprint only; CDF-D0 combined , FERMILAB PUB-98/312-E, hep-ex/9810015.
19. "Small Angle J/Psi Production in ppbar Collisions at $\sqrt{s}=1.8$ TeV" Phys. Rev Lett. xx ppp (1998), FERMILAB PUB-98/237-E, hep-ex/9807029.
20. "Search for Squarks and Gluinos in Single-Photon Events with Jets and Large Missing Transverse Energy in ppbar Collision at $\sqrt{s}=1.8$ TeV" Phys. Rev. Lett. xx ppp (1998), FERMILAB PUB-98/243-E, hep-ex/9808010.
21. "Probing Hard Color-Singlet Exchange in pbarp Collisions at $\sqrt{s}=630$ GeV and 1800 GeV" Phys. Lett. xx ppp (1998), FERMILAB PUB-98/285-E, hep-ex/9809016.
22. "The Dijet Mass Spectrum and a Search for Quark Compositeness in pbarp Collisions at $\sqrt{s}=1.8$ TeV" Phys. Rev Lett. xx ppp (1998), FERMILAB PUB-98/220-E, hep-ex/9807014.

23. "The Inclusive Jet Cross Section in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Lett. xx ppp (1998), FERMILAB PUB-98/207-E, hep-ex/9807018.
24. "Measurement of the Top Quark Pair Production Cross Section in $p\bar{p}$ Collisions using Multijet Final States" Phys. Rev. Dxx ppp (1998), FERMILAB PUB-98/130-E, hep-ex/9808034.
25. "Search for a Fourth Generation $-1/3$ Quark via Flavor Changing Neutral Current Decay" Phys. Rev. Letters 78 3818 (1997), FERMILAB-PUB-96/430-E, hep-ex/9611021
26. "Search for Diphoton Events with Large Missing Transverse Energy in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 78 2070 (1997), FERMILAB-PUB-96/446-E, hep-ex/9612011
27. "Limits on Anomalous $WW\gamma$ Couplings from $p\bar{p} \rightarrow W \gamma + X$ Events at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Lett. 78, 3634 (1997), FERMILAB-PUB-96/434-E, hep-ex/9612002
28. "Study of the $ZZ\gamma$ and $Z\gamma\gamma$ Couplings in $Z(\nu\nu)\gamma$ Production" Phys. Rev. Letters 78, 3640 (1997)
29. "Direct Measurement of the Top Quark Mass" Phys. Rev. Letters 79 1197 (1997)
30. "Studies of Gauge Boson Pair Production and Trilinear Couplings" Phys. Rev. D56, 6742 (1997)
31. "Measurement of the Top Quark Pair Production Cross Section in $p\bar{p}$ Collisions" Phys. Rev. Letters 79 1203 (1997)
32. "Limits on WWZ and $WW\gamma$ couplings from $p\bar{p} \rightarrow e^+ \nu_e j j X$ events at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 79 1441 (1997)
33. "Search for Scalar Leptoquark Pairs Decaying to Electrons and Jets in $p\bar{p}$ Collisions" Phys. Rev. Letters 79 4327 (1997)
34. "Color Coherent Radiation in Multijet Events from $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Lett. B vv pppp (1997), FERMILAB PUB-97/201-E, hep-ex/9706012,

35. "Spectroscopic Particle Detection: A New Technique to Search for WIMPS", J.T. White, E.S. Fry and Th. Walther, refereed paper, Proceedings, 14th International Conference on the Application of Accelerators in Research and Industry, Nov. 6-9, 1996, Denton, Texas, CAARI'96. published in AIP Conference proceedings 392, 1997
36. "Search for New Particles at the Tevatron", J.T. White, for the CDF and D0 collaborations, Beyond the Standard Model V, 5th conference, Balholm, Norway, April-May 1997, published in AIP Conference proceedings 415, 1997
37. "Jet Production via Strongly-Interacting Color-Singlet Exchange in pbarp Collisions" Phys. Rev. Lett. 76 734 (1996)
38. "The Azimuthal Decorrelation of Jets Widely Separated in Rapidity" Phys. Rev. Letters 77, 595 (1996)
39. "Search for Anomalous WW and WZ Production in pbarp Collisions at $\sqrt{s}=1.8$ TeV" Phys. Rev. Letters 77 (1996) 3303 (1996).
40. "J/Psi Production in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Physics Letters B370, 239 (1996).
41. "Measurement of the W Boson Mass" Phys. Rev. Letters 77, 3309 (1996).
42. "Search for Additional Neutral Gauge Bosons" Phys. Lett. B 385, 471 (1996)
43. "The Isolated Photon Cross Section in the Central and Forward Rapidity Region in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Accepted by Phys. Rev. Letters, FERMILAB-PUB-96/072-E
44. "Search for High Mass Top Quark Production in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 74 2422 (1995)
45. "Inclusive mu and b-Quark Production Cross Sections in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 74 3548 (1995)
46. "Observation of the Top Quark" Phys. Rev. Letters 74 2632 (1995)
47. "Limits on the ZZgamma and Zgammagamma Couplings in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 75 1028 (1995)

48. "Search for W Boson Pair Production in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 75 1023 (1995)
49. "Search for Squarks and Gluinos at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 75 618 (1995)
50. "Transverse Energy Distributions within Jets in pbarp Collisions at 1.8 TeV" Phys. Letters B357 500 (1995)
51. "A Study of the Strong Coupling Constant Using W - Jets Processes" Phys. Rev. Letters 75 3226 (1995)
52. "Second Generation Leptoquark Search in pbarp Collisions at 1.8 TeV" Phys. Rev. Letters 75 3618 (1995)
53. "Measurement of the WWgamma Gauge Boson Coupling in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 75 1034 (1995)
54. "W and Z Boson Production in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Phys. Rev. Letters 75 1456 (1995)
55. "Top Quark Search with the D0 1992-1993 Data Sample" Phys. Rev. D52 4877 (1995)
56. "Jet Production via Strongly-Interacting Color-Singlet Exchange in pbarp Collisions" Phys. Rev. Lett. 76 734 (1996)
57. "Search for Heavy W Bosons in 1.8 TeV pbarp Collisions" Phys. Letters B358 405 (1995)
58. "Glass-Liquid Scintillating Fibers for Calorimetry", M. Gui, F.R. Huson, J.T. White, D. Suson, Submitted to Nuclear Instruments and Methods, Accepted July 1995.
59. "Search for Wino1 Zino2 via Trilepton Final States in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Submitted to Phys. Rev. Letters , FERMILAB-PUB-95/385-E
60. "Studies of Topological Distributions of Inclusive Three- and Four- Jet Events in pbarp Collisions at $\sqrt{s} = 1800$ GeV with the D0 Detector" Submitted to Phys. Rev. D , FERMILAB-PUB-95/296-E

61. "Search for Right-Handed W Bosons and Heavy W' in pbarp Collisions at $\sqrt{s} = 1.8$ TeV" Submitted to Phys. Rev. Letters , FERMILAB PUB-95/412-E
62. "Search for Light Top Squarks in pbarp Collisions at 1.8 TeV" Submitted to Phys. Rev. Letters , FERMILAB-PUB-95/380-E