Task A: High Energy Physics Program
Experiment and Theory
Progress Report Covering the Period
From July 1, 1991 to June 30, 1992
and
Task B: High Energy Physics Program
Numerical Simulation
of
Quantum Field Theories
Progress Report Covering the Period
From July 1, 1991 to June 30, 1992

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Progress Report Covering the Period From July 1, 1991 to June 30, 1992

to the

U.S. Department of Energy

from

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INDEX

I. Project Abstract 1

A. Experimental Program 1

B. Particle Theory Program 2

II. Highlights of Activities During the Past Year 3

III. Personnel During the Past Five Years 4

IV. Experimental Program 6

A. Fixed Target Experiments 8

1. Brookhaven National Laboratory–Experiment 771

$K^+K^o\pi^-$ Production and the Study of the D(1285), E/iota(1420) and a

Resonance at 1510 MeV, With π^-, K^- and $\bar{p}$ Beams at 8 GeV/c. 8

2. Di Hadron Production in pN Interactions at 800 GeV - E711 11

B. Collider Experiments 12

1. E740 Fermilab $\bar{p}p$ Collider Experiment $D\emptyset$ 12

2. CERN LEP - ALEPH 18

3. SSC Experiments SDC and EMPACT 23

C. Computing, Networking and VAX Upgrade 24

D. SSC Preparation, Detector Development and Detector Construction 27

E. Absorption of CAD System Geometries into GEANT for SSC 32

V. Particle Theory Program 34

1. An order α_s calculation of hadronic ZZ production, J. Ohnemus and J. F. Owens, Phys. Rev. **D43**, 3626 (1991). 35
2. Update of the Effect of Cascade Decays on the Tevatron Gluino and Squark Mass Bounds, H. Baer, X. Tata and J. Woodside, Physical Review **D44**, 207 (1991). 35
3. Phenomenology of Light Top Squarks at the Fermilab Tevatron Collider, H. Baer, M. Drees, R. Godbole, J. Gunion and X. Tata, Physical Review **D44**, 725 (1991). 35
4. An order α_s calculation of hadronic W^-W^+ production, J. Ohnemus, Phys. Rev. **D44**, 1403 (1991). 35
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9. An order α_s calculation of hadronic $W^{\pm}Z$ production, J. Ohnemus, Phys. Rev. **D44**, 3477 (1991). 37
10. Multilepton Signals from Supersymmetry at Supercolliders, H. Baer, X. Tata and J. Woodside, Phys. Rev. **D45**, 142-160 (1992). 37
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12. Latest Software, Hardware Serve High Energy Phenomenology, H. Baer and W. F. Long, feature article in *Computers in Physics* magazine, p. 24-32, January 1992. 38

13. Observability of $\gamma\gamma$ Decays of Higgs Bosons from Supersymmetry at Hadron Supercolliders, H. Baer, M. Bisset, C. Kao, and X. Tata, FSU-HEP-911104 (Phys. Rev. D- in press). 38

14. Electroweak Vector Boson Production in High Energy ep Collisions, U. Baur, J.A. M. Vermaseren, and D. Zeppenfeld, Nucl. Phys. **B375**, 31 (1992). 38

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16. Parton Distribution Functions of Hadrons, J. F. Owens and Wu-Ki Tung, to appear in Ann. Rev. Nucl. Part. Sci. 39

17. An order α_s Monte Carlo calculation of hadronic double photon production, B. Bailey, J. Ohnemus, and J. F. Owens, to be published in Phys. Rev. **D**. 40

18. Production of a Pseudoscalar Higgs with a Z Boson from Gluon Fusion, Chung Kao, submitted to Phys. Rev. D. 40

19. Searching for the CP-Odd Higgs Boson of the Minimal Supersymmetric Model at Hadron Supercolliders, J. F. Gunion, H. E. Haber, and C. Kao, submitted to Phys. Rev. D. 40

20. Supercollider Signals from Gluino and Squark Decays to Higgs Bosons, H. Baer, M. Bisset, X. Tata, and J. Woodside, FSU-HEP-920224 (Phys. Rev. D- in press). 40

21. Snagging the Top Quark with a Neural Net, H. Baer, D. Dzialo-Karatas and G. Giudice, FSU-HEP-911130 (submitted to Phys. Rev. D). 41

22. The Search for Higgs Bosons of Minimal Supersymmetry: Impact of Supersymmetric Decay Modes, H. Baer, M. Bisset, C. Kao, and X. Tata, FSU-HEP-920630 (submitted to Phys. Rev. D). 41

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28. The Search for Supersymmetry, H. Baer, proceedings of Beyond the Standard Model 3, Ottawa, Canada, June, 1992. 42

VI. Ongoing and Proposed Projects 43

1. Continued Study of Hard Scattering Processes 43
2. Parton Distributions 43
3. New Particle Searches 44

VII. Task B - Progress Report 45

Appendix I - List of Publications

TASK A – Progress Report

I. Project Abstract

In this document the High Energy Physics group reviews its accomplishments and progress during the past year, and presents plans for continuing research during the next several years.

A. Experimental Program

During the last year the effort of the experimental group has been concentrated on the CERN, ALEPH and FERMILAB $D\emptyset$ collider experiments and completion of two fixed target experiments.

The BNL fixed target experiment 771 took the world's largest sample of D(1285) and E/iota(1420) events, using pion, kaon and antiproton beams. We have observed the following resonances:

0^{-+} [1280] with π^-, K^- and $\bar{p}$ beams, 1^{++} [1280] with π^- and $\bar{p}$ beams, 0^{-+} [1420] with $\pi^-, K^-, \bar{p}$ beams, 0^{-+} [1470] with π^- and $K^-, \bar{p}$ beams, 1^{+-} [1415] with π^- and K^- beams.

The Fermilab fixed target experiment E711, di-hadron production in pN interactions at 800 GeV, completed data reduction and the analysis. The atomic weight dependence, when parameterized as $\sigma(A) = \sigma_0 A^{\alpha}$, yielded a value of $\alpha = 1.043 \pm 0.011 \pm .012$ independent of the two particle mass (up to 14 GeV/c^2) and charge state. The cross section per nucleon and angular distributions was also measured as a function of two particle mass and agrees very well with QCD calculations that were fitted to ISR and EMC data.

The D$\emptyset$ Fermilab Collider Experiment E740 began its first data taking run in April, 1992 after commissioning parts of the detector with cosmic rays during the past year. The FSU group has participated in many phases of D$\emptyset$, so far including machining calorimeter pieces, assembling calorimeter modules, testing and calibrating calorimeter modules in a testbeam, writing and debugging software for monte carlo event generation, developing software for trigger filtering and physics analysis and graphics displays. Now we are taking shifts during the data runs. We have recently taken on the responsibility of the TRD operation with Saclay and are working on calibration and monitoring of the TRD detector.

We hope to reap exciting physics results from the current run, which should accumulate an integrated luminosity of about 20 pb^{-1}. The discovery of the top quark is the primary goal. Studies of W and Z bosons will enable us to make a precise test of the standard model. The first W and Z candidates are already being analyzed. The FSU group is involved in direct photon tests of QCD as well as searches for SUSY particles. It should be an exicting year for D$\emptyset$ and FSU!

The CERN collider experiment ALEPH at LEP is presently taking more data. The Z mass and width, the couplings to the upper and lower components of the hadronic isospin doublet, forward-backward asymmetries of hadronic events, and measurements of the fragmentation process have been made. FSU is in charge of the on-line VAXstation system for which we have contributed a substantial amount of hardware. We are responsible for the software and now have a system to display the detector and individual events in three dimensions. The simulation of the detector is a crucial component and we have coded large parts in vector mode to allow us to analyze large quantities of Monte-Carlo events. Substantial effort is being made in the analysis of these events.

The effort of detector development for the SSC has substantially increased with particular emphasis on scintillators, both in fibers and plates. A close collaboration with industry has resulted in new scintillators that are at least an order of magnitude more radiation resistant than what existed several years ago. Most of the effort is now concentrated on the calorimetry of the SDC.

Many papers were published on completed fixed target experiments, ALEPH and even some on *DØ*. Results of the above mentioned experiments, as well as SSC detector development results, were also reported at various conferences.

B. Particle Theory Program

The high energy theory group has had an active and productive year with thirteen papers published in journals, five accepted, four submitted, and six published in or submitted to conference proceedings. The subjects covered a variety of topics in the areas of strong and electroweak physics. Last fall Ulrich Baur joined our group as an Assistant Scholar/Scientist, filling the position previously held by Howie Baer before he became an Assistant Professor. Chung Kao joined our group at the same time, replacing Jim Ohnemus in a postdoctoral research associate position.

Work has continued on higher order QCD calculations using the Monte Carlo technique developed previously. This year results for WW, ZZ, WZ, and $\gamma\gamma$ production have been published. A method for incorporating parton showering in such calculations was developed and applied to W production. Versions of these programs have been supplied to various experimental groups and we are working with them in order to compare the theoretical predictions with new data. Work is continuing also on parton distribution phenomenology and a review article has been submitted to Annual Reviews of Nuclear and Particle Science.

Many topics in collider phenomenology have been investigated including signatures of supersymmetric particles, methods for studying triple gauge boson couplings, and Higgs phenomenology at the SSC. A detailed list of topics and current papers is given later in this report.

II. Highlights of Activities During the Past Year:

- J. Owens became our department chairman in August 1991 for the next three years.
- V. Hagopian accepted the directorship of Graduate Studies starting August 1991 for the next few years.
- U. Baur joined us in September 1991 as Research Scientist, a position vacated by Baer.
- C. Kao joined us in September 1991 to replace J. Ohnemus who took a Post-Doc position at the University of Durham.
- S. Hagopian is co-chairman on Fermilab's Users Facility Advisory Committee.
- J.E. Lannutti is now on the URA Board of Fermilab, External Visiting Committee.
- J.E. Lannutti and D. Duke continue to serve as Director and Associate Director of the Supercomputer Computations Research Institute.
- V. Hagopian serves on the executive committee of the Southern Association of High Energy Physics (SAHEP).
- V. Hagopian is the institutional representative on the SSC-SDC Institutional Board.
- J. Owens was a co-convenor for a session at the 1991 DPF conference in Vancouver B.C.
- S. Hagopian was granted graduate faculty status by the Physics Department, i.e., she can now officially direct Ph. D. dissertations.
- J. Owens helped organize and presented three lectures at a summer school held at Mackinac Island, Michigan.
- K. Johnson and V. Hagopian convened the second conference on Radiation Tolerant Scintillators and Fibers (RADDAM92) held in FSU from April 28 to May 2, 1992.
- Faculty full time at HEP laboratories: H. Wahl - Fermilab, May - December 1992; J. Womersley - Fermilab, May - August 1992 and January - August 1993; D. Levinthal - CERN, May 1992 - August 1993.

III. Personnel During the Past Five Years

At the middle of 1988 the High Energy Physics group included 14 Ph.D. physicists, 9 of whom were funded by the University. In June 1992 the group had 15 Ph.D. physicists, 9 of whom are funded by the University. One new faculty position was added in August 1989 (Prof. W. John Womersley) and another new faculty joined in August 1990 (Prof. H. Baer). We expect to add another experimental Research Associate by October 1992 to be funded 50% by TNRLC and 50% DOE and another theory research associate by July 1992 to be funded more than 50% by TNRLC.

The table below gives the names of Ph.D. physicists who are part of the high energy physics grant during the last five years. The table also lists the title, the period and the funding source.

	1988	1989	1990	1991	1992	Funding
THEORETICAL:						
H. Baer (RS)	--------	--------	----->			DOE
H. Baer (Fac)			--	--------	--->	FSU
U. Baur (RS)				---	--->	DOE
D.W. Duke (Fac)	------->	To SCRI	....	....	...>	FSU
J.D. Kimel (Fac)	--------	--------	-------->			FSU
C. Kao (RA)				---	--->	DOE
J. Ohnemus (RA)	------	--------	--------	---->		DOE
J.F. Owens (Fac)	--------	--------	--------	--------	--->	FSU
EXPERIMENTAL:						
W. Dharmaratna (RA-FNAL)			--------	--------	--->	DOE
J.H. Goldman (RS)	--------	--------	--------	--------	--->	DOE
S. Hagopian (SP)	--------	--------	--------	--------	--->	FSU
V. Hagopian (Fac)	--------	--------	--------	--------	--->	FSU
M. Ikeda (RA-CERN)		----	--------	--------	--->	DOE
K. Johnson (CRS)	--------	--------	--------	--------	--->	FSU
J. Lannutti (Fac)	--------	--------	--------	--------	--->	FSU
D. Levinthal (Fac)	--------	--------	--------	--------	--->	FSU
H. Piekarz (RS-FNAL)	--------	--------	--------	--------	--->	DOE
G. Stimpfl (RA-CERN)		---	---->			DOE
J. Streets (RA)	--------	--->				DOE
H. Wahl (Fac)	--------	--------	--------	--------	--->	FSU
W. J. Womersley (Fac)		---	--------	--------	--->	FSU

Fac - Faculty; RA - Research Associate; SP - Staff Physicist;
CRS - Computer Research Specialist; RS - Research Scientist;
Note: The University considers SP and RS as faculty.

Florida State University supports the High Energy Physics group with manpower as well as capital and expense funds. During the academic year the faculty is totally paid by the University and our teaching load averages one course per semester, with occasional time off for full time research.

In addition, the University has assigned to our program three full-time research personnel funded entirely by FSU funds. They are:

1) Dr. Sharon Hagopian (Staff Physicist) who devotes 100% of her time to our experimental program.

2) Dr. Kurtis Johnson (Computer Research Specialist) who also devotes 100% of his time to the experimental program.

3) Mr. Maurizio Bertoldi (Engineer), who is our mechanical engineer and devotes 100% of his time to our experimental research program.

By the use of DOE funds, the group employs 5 full time persons:

4) Mr. James Thomaston (Engineer) is our electronics engineer.

5) Mrs. Lupe Howell, Computer Software Scientist.

6) Mr. Ke Hu, Engineer funded by SSC subsystem work and TNRLC.

7) Mrs. Sherry Rybak (Grant Specialist II).

8) Mrs. Kathy Mork (Administrative Secretary).

In addition, during the past several years, the equivalent of one full time machinist, paid by FSU funds, worked building equipment components for our experimental program.

Not shown above, but of course, of significance to the research progress are the graduate students trained in the group. The number of graduate students varies, as new ones join the group and others graduate. During this progress report year two students completed their dissertations and graduated with the Ph.D. degree. They are:

1) Lee Sawyer.

2) Herman White.

At present we have 11 graduate students and 4 undergraduate students working in our research program.

IV. EXPERIMENTAL PROGRAM

Summary of the Experimental Program:

Here we present our program of experimental high energy particle physics. We review our program, present our current on-going activities and our plans for the foreseeable future.

The past year completed the transition from fixed target to collider experiments. From 1985 through 1988, the major effort of the group was directed towards two fixed target experiments. The first at Fermilab: the study of two high momentum transfer particles. In this experiment one of our members was the spokesman and FSU contributed over 75% of the effort. The second experiment was at BNL, where we studied the D(1285) and E/iota(1420) regions. During the past year two invited talks were given on this experiment.

Starting in 1987, we increased substantially our participation in two major collider experiments, namely $D\emptyset$ at FNAL and ALEPH at CERN. We view the SSC as an important future direction of our group and considerable effort has also expanded towards this objective. We have worked on a variety of detector problems for the SSC and five of our members have joined the SDC.

The presentation of the experimental part is divided into two main sections: fixed target experiments and collider experiments.

Under the fixed target section, we describe our concluding efforts of the fixed target experiments, namely:

- BNL E771 – Study of the D(1285) and E/iota(1420) in $\pi^- p, K^- p$, and $\bar{p}p$ Interactions at 8 GeV/c .
- FNAL E711 – Di-Hadron Production in pN Interactions at 800 GeV.

Under the collider physics experimental program, we describe the extensive efforts of our group on two experiments, namely:

- $D\emptyset$ at FNAL
- ALEPH at LEP in CERN.

Also discussed are our varied efforts for the SSC, focusing on the SSC-SDC effort.

During the past seven years, the experimental group has benefited from access to supercomputers (CRAY-YMP and the connection machine) as a result of the establishment of the Supercomputer

Computational Research Institute (SCRI) at FSU. Our very close working relationship with the scientists at SCRI has enhanced the programs of both groups. SCRI now has six experimental high energy physics Research Scientists. Below we list their names and other pertinent information:

Name	Starting date	Experiments
M. Corden	3/88	CERN ALEPH and SSC
C. Georgiopoulos	12/84	CERN ALEPH
S. Linn	9/85	FNAL *DØ*
S. Youssef	12/86	FNAL *DØ* and SSC
D. Xiao	1/91	SSC and *DØ*
S. Wasserbaech	9/91	SSC and ALEPH

We expect to continue our very close working relationship in the forseeable future.

After each experiment, we will list the names of all the Ph.D. physicists that have worked on the experiment during the past year.

A. Fixed Target Experiments

1. Brookhaven National Laboratory experiment 771.

$K^+K^0\pi^-$ Production and the Study of the D(1285), E/ι(1420) and a Resonance at 1510 MeV With π^-, K^- and $\bar{p}$ Beams at 8 GeV/c.

(V. Hagopian, J.H. Goldman)

This experiment obtained data over a period of four years from 1983 to 1987. The original motivation was the study of the E(1420) region with at least 10 times the statistics of any previous experiment. The expectation was to decide between the two conflicting claims of the spin, parity and C-parity of this object. The two claims were 0^{-+} which did not fit the standard SU3 multiplet classification and 1^{++} which had a place in the spin 1 multiplet. The interest in the (0^{-+}) state is due to the fact that this resonance is a glueball candidate. Details of this experiment is given in previous progress reports.

The table below shows the resonances we observed. A * means a well determined resonance.

Beam	J^{PC}	Resonance	Mass		
π^-	0^{-+}	1270*	1420*	1470	
	1^{++}	1290*	1430		1510*
	1^{+-}		1400		
$\bar{p}$	0^{-+}	1290*	1430*		
	1^{++}	1270*	1400		
K^-	0^{-+}	1280	1390	1480	
	1^{++}		1410		
	1^{+-}		1430*		

Our analysis concluded the following:

1. The D(1285) is mostly 1^{++} but there is also a non-negligible 0^{-+} resonance at about the same mass. This fact was confirmed by another experiment studying the decay mode $\eta\pi\pi$.
2. The E/ι(1420) region is very complex. This experiment has identified two (0^{-+}) waves, one (1^{++}) wave, one (1^{+-}) wave. Not all of these resonances can be $q\bar{q}$ states.

3. The peak at 1512 MeV and width 35 Mev has spin parity of 1^{++}.
4. A search for the reported U(3100) $\rightarrow p\bar{\Lambda}\pi$'s failed to confirm previously reported (statistically not too significant) peaks.

BNL experiment 771, was proposed by BNL, FSU and Southeastern Mass. Univ. (now University of Massachusetts). After approval was granted, Univ. of Indiana also joined the collaboration. FSU made a large commitment to this experiment, providing about 25% of the manpower. Besides the usual effort during the data taking part, we at FSU built all the light guides of the TOF counters and helped in the final assembly of the unit. The TOF was put in the BNL-MPS in 1985, before the second round of data taking. Without this unit, it would have been pointless to take any K^- data, as the protons in the final particles would have completely dominated the trigger, with no hope of separating the K^+. FSU took complete responsibility in the reduction and analysis of both the 1983 and 1987 $\bar{p}$ data. We also reduced and analysed the 1985 and 1986 K^- data. In addition we also reduced the 1987 K^- data and the analysis of this part of the data was performed by a UM Dartmouth graduate student. One important result that we (FSU) were able to extract, was the relative cross sections, for the D(1285) and E/ι(1420). Even though it was known that D and E/ι had either small or zero production cross sections with a K^- beam, there was no good way of comparing these values with π^- beam results. Since the equipment, the trigger elements, the reconstruction programs and the beam momenta were the same for the K^- and π^- data, we were able to compute relative cross sections and determined that the production of the D and E/ι by K^- beam is down at least one order of magnitude. This is a puzzle, as quark exchange diagrams predict approximately equal production cross sections.

Another result that came out of the $\bar{p}$ portion of our data, is the upper limit of U(3100) $\rightarrow p\bar{\Lambda}\pi$'s. This object had been observed with very poor statistics at CERN and Serpukov. We were unable to confirm their observations!

The last three publications at the end of this section list the papers that appeared during the past year. FSU personnel have given 12 invited talks on this experiment, two by V. Hagopian in the past year. The first an invited talk at the 1991 APS-SESAP meeting in Durham NC. and the second a seminar at Tohoku University in Sendai, Japan in May 1992.

This experiment has been a very productive one. Three of our graduate students have obtained Ph.D. degrees based on the data, two of them now working at Fermilab. This experiment showed that the naive picture of the Particle Data Group for the 1420 MeV mass range is incomplete and at least one of the two (0^{-+}) states and the 1^{+-} states cannot be $q_{-}\bar{q}$ but either glueballs or hybrids. We will eventually publish all of the results as time permits.

So far 18 papers and conference proceedings have been published from this experiment. The last three during the past year are listed below.

1) Search for the U(3.1) $\rightarrow \overline{\Lambda} p\pi$'s From $\bar{p}p$ Interactions at 8 Gev/c. Proceedings of the Rheinfels Workshop 1990, Hadron Mass Spectrum, St. Goar, Germany, 3-6 September 1990. Nuclear Physics B, Vol. 21, pp 174-178, (1991).

2) Partial Wave Analysis of $K\bar{K}\pi$ From $\bar{p}p$ Interactions at 8 Gev/c. Proceedings of the Rheinfels Workshop 1990, Hadron Mass Spectrum, St. Goar, Germany, 3-6 September 1990. Nuclear Physics B, Vol. 21, pp 142-148, (1991).

3) Preliminary Partial-Wave Analysis of $K^{+}\bar{K}^{o}\pi$ System Produced in 8 Gev/c $K^{-}p$ Interactions. Proceedings of the Rheinfels Workshop, 1990 Hadron Mass Spectrum, St. Goar, Germany, 3-6 September 1990. Nuclear Physics B, Vol. 21, pp 11-15, (1991).

2. Di Hadron Production in pN Interactions at 800 GeV - E711

(V. Hagopian, D. Levinthal, plus one graduate student)

The objective of this experiment was to acquire and analyze a data sample to measure the parton-parton scattering cross section. This was done by studying massive dihadron (up to 14 GeV) production. The two leading hadrons can be used to give approximate measurements of each scattered parton and thereby give the energies and final state directions. The initial state directions are assumed to be collinear with the beam axis. The data-taking finished in February 1988. The data reduction and Monte Carlo simulations were done on supercomputers at FSU. Details of this experiment are given in previous progress reports.

The atomic weight dependence of the scattering cross section when parameterized as $\sigma(A) = \sigma_o A^\alpha$ yielded a value of $\alpha = 1.043 \pm .011 \pm .012$ independent of mass or charge state. The average fraction of the jet momentum carried by high p_T leading hadrons with the QCD parton model predictions. The reaction studied was $p + N \rightarrow h_1 + h_2 + X$ where h_1 and h_2 are the leading particles of the two jets produced at high p_T. The distributions agree well with the QCD parton model predictions for single independent proton-nucleon scattering and independent fragmentation process.

The angular distribution of the di-hadrons relative to the beam direction, at fixed dihadron mass, is closely related to the parton-parton scattering angle. Analysis of the data has shown that, when it is parametrized to the form:

$$\frac{d\sigma}{d\cos\theta} = \sigma_o \left(\frac{1}{(1-\cos\theta)^a} + \frac{1}{(1+\cos\theta)^a} \right)$$

the data yields a value of a = 2.91 ± 0.12 for the opposite sign charge state and a value of 2.85 ± 0.14 for the same sign charge states. The value reported by CCOR for the $\pi^o\pi^o$ final state was a = $2.97 \pm .05$. The QCD Monte Carlo discussed before, yields slightly flatter distributions with a corresponding value of a = 2.74 for the CCOR analysis and a = 2.73 for the opposite sign and a = 2.77 for the same sign charged particles.

One FSU student (K. Streets) completed her Ph.D. dissertation in 1989 and is now a post-doc for University of Maryland working on $D\emptyset$ at Fermilab. A second FSU student (G. Boca) completed in 1990 and now has a staff position at University of Pavia. Another student, who was resident at FSU, has also received her Ph.D. in 1991 from University of Michigan. The last FSU student (H. White) graduated in August 1991, and is now at Fermilab.

B. Collider Experiments

Since 1984 physicists of the Florida State University have been participating in two collider experiments; DØ at the Fermilab Tevatron and ALEPH at the LEP collider at CERN. During the past year we contributed substantially in data reduction and analysis of ALEPH and in testbeam work and software development and preparation and commissioning of the DØ detector, which has finally begun its first collider run. Last year several graduate students worked on the collider experiments and the first student has received his Ph.D on ALEPH. Two FSU graduate students are working on DØ for their theses. FSU has made significant commitments and contributions to both of these experiments and we expect them to dominate our experimental program through the early 1990's.

1. E740 Fermilab $\bar{p}p$ Collider Experiment DØ

(W. Dharmaratna, S. Hagopian, V. Hagopian, H. Piekarz, H. Wahl, J. Womersley and five graduate students)

This year has seen the first collider data taken by DØ , an event which all of DØ , including the FSU group, has been working hard to witness. The commissioning of parts of the detector with cosmic rays has been going on for over a year; it intensified when the completed DØ detector was rolled into the collision hall in March and so-called "collider commissioning" began in mid-April. The first beam-beam collisions were seen in DØ at the end of April and the first good three day collider run, where W candidates were detected, was at the end of May. It is a time of great excitement and also of hard work for DØ . The collider running will be at relatively low luminosity until mid-July, when full-intensity and minimally interrupted running will begin. The slow start-up has actually been rather helpful to DØ in its work to break in a new detector, with new hardware, new software, and a learning curve for the experimenters. At our first collaboration meeting after the run began, on June 10-12, we were very pleased to see the first sets of data already processed through reconstruction and analysis. The first physics results are now beginning to emerge (together, of course, with some problems in shaking down the detector.) It will, however, take a concentrated effort to keep up with the flow of data as it intensifies and press onward to real physics results. This initial run ('Run Ia') is expected to last until December 1992 and accumulate an integrated luminosity of $\approx$20 pb^{-1}; a second run from March to December 1993 ('Run Ib') should add an additional $\approx$80 pb^{-1}.

Being a general-purpose detector, DØ is capable of covering a wide range of physics topics. Our highest priority for the first run of the experiment is a search for the top quark at masses higher than those so far ruled out by the CDF experiment. We hope this will be the year of not only the first DØ collider data, but also that of the "top discovery" by DØ . In the first run, we expect to be sensitive to top quark masses up to about 120 GeV. The top quark is one of the last missing pieces of the Standard Model of particle interactions, which has been enormously successful in describing almost all observed high energy phenomena. Increasing effort is focused on precision tests of its predictions. For run Ia (assuming an integrated luminosity of 20 pb^{-1} and 50% efficiency), DØ is expected to observe about 2000 $Z^{\circ} \rightarrow e^{+}e^{-}$, about 20,000 $W \rightarrow e\nu$, with comparable numbers for the decays into muons. A precision measurement of the W and Z mass ratio will determine $\sin^2\theta_w$ to an accuracy of 0.0005; if the top quark mass is known, this will be a precise test of the standard model. Studies of asymmetry in W production and decay may yield information about the existence of new heavy gauge bosons not included in the standard model. Other studies will include tests of QCD by measuring jet production, production of high energy photons in association with jets, and studies of very high p_T jets (which test the point-like nature of quarks and gluons). In addition, there is also great interest in direct searches for new gauge bosons, Higgs bosons, heavy leptons, supersymmetric particles, higher generations of quarks, technicolor, signs of a quark-gluon plasma, and any other new unexpected objects.

The DØ detector was designed later than CDF and incorporates lessons learned at earlier collider detectors (UA1 and UA2). Its uranium-liquid-argon calorimeter provides very nearly hermetic coverage down to small polar angles ($\eta \approx 5$), with rather uniform response and good hadronic and electromagnetic energy resolution over the whole region of coverage. The superior hadronic resolution and the near equality of electron and hadron response will allow good precision in the jet energy measurement, a feature which will be crucial in identifying hadronic decays of W's and Z's. The hermeticity and large depth results in good missing energy measurement capability, which is essential in searches for new phenomena such as supersymmetry. The muon detector is far superior to that of CDF because of a thicker absorber and two layers of proportional drift tubes outside the absorber/magnet. The acceptance for high-p_T muons is also much larger and the kaon decay background and pion punch through are less than for CDF.

These advantages should allow DØ to be very competitive with CDF in searches for the top quark, as well as in exploratory surveys of the TeVatron energy regime, and in performing precision tests of the Standard Model.

During the past year, six Ph.D.'s from the FSU High Energy group, two SCRI Ph.D's, one programmer, eight students and three part-time technical support personnel participated in DØ . Two of the Ph.D.s (W. Dharmaratna and H. Piekarz) are stationed full-time at Fermilab. Two FSU graduate students, Bob Madden and Mark Goforth moved to Fermilab in January 1992. They will remain there through the first DØ run and do their theses based on data to be taken during the present run.. Mark is working on a search for gluinos by studying events with three or more jets and missing E_T, originating from gluino cascade decays. Bob is studying events where a direct photon is produced together with two jets, which enables precise tests of QCD.

Test and Calibration Beam Activities

The FSU commitment to the test beam program at Fermilab continued to the end of data taking (late 1991) and analysis (which is now being completed). Horst Wahl, John Womersley and four graduate students (Mark Goforth, Bob Madden, James Richardson and Jin Xu) spent the summer of 1991 at Fermilab, working on software for the transporter, modifications to the DØ online analysis program EXAMINE, and on the development of procedures to test the cabling and mapping of calorimeter cells to electronics channels. They worked with Henryk Piekarz on the testing and installation of trigger and TOF counters. All seven took shifts during the summer on the Testbeam run. In addition, Ramon Avellaneda, an FSU graduate, worked part-time on DØ Testbeam activities.

Testbeam Data Analysis

Using the FSUHEP VAX Cluster, John Womersley has been running a Monte Carlo simulation of the 1990 calorimeter testbeam, using the latest version of the GEANT Monte Carlo program (v. 3.14). This work is being carried out in conjunction with Marcel Demarteau at Fermilab. It has been found that using this new version of the Monte Carlo, plus very low cut offs for tracking particles, gives good detailed agreement with the data, though events take a long time to generate (typically 50 events per day on a 3-MIP VAXstation). Pion showers were generated, for determination of their resolution and shower shapes (which now agree well with data) and of shower leakage to correct the measured e/π response ratio. About four VAXstations (typically two with 3 MIPs and two with 7.6 MIPs) were used for this effort.

During 1991-2 John Womersley coordinated the writing of a NIM paper from the data taken at the test beam in 1990 (End Calorimeter modules). This includes descriptions of electron and hadron energy response and resolution in the ECEM + EC1H calorimeter system, position resolution, muon response, and rate dependence studies. Dharma wrote the section on response to muons for the paper including the e/μ ratio as well as the results from uniformity studies. This paper was submitted to NIM in June, 1992, and is a Fermilab preprint.

Dharma completed the Load 2 muon (15 GeV) data analysis. This included understanding the FH/EM response discrepancy and comparison with the Monte Carlo predictions. It was found that after all known corrections the ratio of the mean response between the FH and EM(FH/EM) are 1.05 ± 0.03 and 1.07 ± 0.05 for Monte Carlo and data respectively. Also the individual layer response agree very well with that of the MC.

The η scan data from the Load 2 run was analyzed by Dharma in detail (with projected tracking) in order to understand an unexpected η dependance. The data taken from $\eta = 0$ to -1.0 indicates about 2.5% variation. The data taken from $\eta = 0$ to 1.0 also indicates similar behaviour. Some of the dips and peaks seen in the η dependence is found to be due to the variation in gains. The over all η dependence is understood, at least partially. By using the optimized weighting (on individual layers) for 100 GeV electrons, instead of the weighting for MIP which neglects the significance of the e/mip ratio, the η dependence is found to be within 0.5% for all η except for the central tower at $\eta = 0.05$, which is about 1.5% lower. This dip and the disagreement with the Monte Carlo remains to be understood.

Work by Dharma and Chip Stewart on the CCEM crack data analysis is also in progress. DST's and Ntuples have been made from all data files (more than 250 files). The effect of the "key notches" which coincide with cracks is being studied in detail.

Other Software

The FSU group contributed to the software effort in DØ in areas of Monte Carlo programs, off-line reconstruction programs and graphics as well as to testbeam data software and analysis mentioned above.

John Womersley worked with Wyatt Merritt on tuning the parameters of the DØ GEANT Monte Carlo. Following our upgrade to GEANT version 3.14, it was necessary to redetermine the smearing applied to showers in the mixture geometry, and the attenuation of EM energy used to get the e/π ratio correct. He also investigated the alternative hadronic shower algorithm NUCRIN which is available in this version of GEANT. Our usual choice, GHEISHA, was found to give superior results, so no change is foreseen here. A DØ note describing this work was written.

During the summer of 1991 FSU contributed to the generation of simulated physics Monte Carlo events on our VAX cluster; supplying background events (two jet "QCD events"). FSU generated 12,000 events and processed them through DØ RECO to make DST files. We also ran 1,500 Beauty events through DØ GEANT for the Triggerfest held in January, 1992 at LBL. For electron ID studies in cooperation with Norman Graf (Fermilab), FSU generated 151,000 single electron Monte Carlo events on our VAX cluster at various rapidities and energies.

Dharma has worked on generating a new shower library. This includes making few corrections and some modifications to the existing shower library codes. The data generation, 15K events (GEANT 3.14), is in progress.

H. Piekarz worked on Level 1 and Level 2 trigger study regarding the direct photon detection and analysis. He also made Level 1 and Level 2 studies of trigger rates and filtering for two-jet superhard scattering processes including direct photons with very large transverse momenta.

Lupe Howell developed a new program, PXBUILD, which allows the user to interactively build an RCP file for making event displays. This was released to DØ LIBRARY in September, 1991.

Sharon Hagopian and Nobu Oshima (Fermilab) continued work on the DØ event display to make it useful for physics analysis as well as for ONLINE event monitoring and OFFLINE alogorithm development. Over 14 documentation files were written to help the DØ experimenters make use of the various graphics packages developed over the last few years.

Lupe Howell modified many DØ graphics routines to make them compatible with UNIX so that they would work on Silicon Graphics workstations. She has made the DØ Event display work on the FSU Silicon Graphics workstation and is doing further improvements to make use of its special fast 3-D rotations.

John Womersley, Saul Youssef (SCRI) and Peter Dragovitsch (SCRI) developed a package called OCTAGON which absorbs CAD system defined geometries into GEANT. Among many tests, they have absorbing a PWC stand defined in autocad into the GEANT representation of the TB90 test calorimeter. While making various improvements to the package, they plan to use it to add some of the more difficult details of the DØ detector into D0GEANT.

Transition Radiation Detector

In March 1992, FSU joined the TRD group. We agreed to work with Saclay in the maintenance, operation and running of the Transition Radiation Detector built by Saclay. We will also assist in the calibration and software analysis of the TRD. Members of our group have spent a large fraction of their time interacting with members of the Saclay group, to help ensure a smooth transfer of knowhow and responsibilities. Henryk Piekarz took an active role in the preparation and commissioning of the TRD gas system, and has taken responsibility for its operation and maintenance. Assisted by members of our group (mainly the two resident students, with contributions from other group members), he is also looking after the read-out electronics of the TRD.

Current Activities

Two of our faculty members (Horst Wahl and John Womersley) are spending the summer of 1992 at Fermilab together with three FSU summer students (in addition to the two resident FSU students). Besides taking shifts during the collider data-taking, with special emphasis on the TRD and the rest of the central tracking detector, the students are doing calibration and commissioning and maintenance work on the TRD, as well as help with the analysis of testbeam data. The advanced students continue Monte Carlo studies connected with their thesis topics and are beginning analysis of real data and comparison with the monte carlos. John Womersley has created a first version of a direct photon analysis package, and tests on the first 10 nb^{-1} of collider data agree well with expected cross sections for photon and isolated π^0 production.

2. ALEPH

(D. Levinthal and M. Ikeda)

The last year has seen ALEPH continue its analysis of data from electroproduced Z°s and prepare for the final two large data taking periods at these energies. A silicon strip vertex detector was installed during 1991 yielding much improved track and vertex resolutions. The 1991 run provided ALEPH with more than 300K hadronic Z° decays, for a total sample of half a million. The 1992 run, which started in April, has the potential to increase the statistics to more than a million events by the end of the year. ALEPH has now produced more than 50 physics publications[1]. In step with this program the FSU group has similarly continued its physics work and made arrangements for an increased presence at CERN.

The contingent of the FSU group from the physics department has focussed on detailed comparisons of data and rigorous standard model calculations, and the physics of charmed meson production at LEP. The standard model analysis [2] has been updated to conform as closely as possible to the more standard types of analysis done in ALEPH. This simplifies the comparisons of data samples as there are fewer differences in the cuts. In addition, refinements in the Monte Carlo corrections have been made and runs with ten times greater statistics have been finished to gain greater control of systematic effects. With the processing of the 1991 data sample finally finished and the use of the beam depolarizing resonances to determine the absolute beam energy to 5 MeV, the detailed analysis of the 500,000 Z° decays taken in 1990 and 1991 will be completed in the next two weeks. With the increased data sample and the W mass measurements now available, these data should yield top quark mass determinations with errors of around 30 GeV. We are currently studying what limits on minimal supersymmetry can be made through the use of the generalized additions to the vacuum expectation value self energy corrections *a la* Peskin and Takeuchi [3].

In August 1991 we published our results on charm physics based on 189,000 events taken in 1989 and 1990. With the addition of 289,000 hadronic events recorded in 1991, we are now able to update last year's results.

The main source of systematic error in last year's result on charm fragmentation and production rate was the uncertainty in the b/c ratio. This value was estimated to be 0.95 ± 0.10 and was determined from the Monte Carlo simulations. In order to decrease the systematic error, an additional discriminator of b events was necessary. This discriminator, Xnn, was obtained using an artificial neural network from 9 variables characterizing the event topology. Only the variables associated to the opposite hemisphere of the D* candidate were used. Thus there is no correlation between Xnn and Xe. From the two-dimensional fit in the (Xe,Xnn) plane we obtain ($c \rightarrow$ D*)BR(D* $\rightarrow K\pi\pi$) = (6.5 ± 0.5 ± 0.2)* 10⁻3 < Xe > = .495 ± .010 ± .001 which are in good agreement with our previous results but with lower statistical and systematic errors and b/c = 0.87 ± 0.15 ± 0.01 in good agreement with our original Monte Carlo estimate.

This year we have also improved our estimate of Pv, the probability for producing a charm vector meson. Using the increased statistics and the new CLEO branching ratio for $D^* \rightarrow D^o\pi$, we obtain Pv = 0.49 ± 0.04 ± 0.05 A new charm signal, $D^+ \rightarrow K^+\pi^+\pi^-$, has also been used to estimate Pv. The preliminary result we obtain is Pv = 0.59 ± 0.08 where the error includes the statistical error and errors from branching ratios but does not include the systematic errors from the D^+ selection. We are currently investigating the effect P-wave charmed states on Pv.

The service effort for the collaboration by the Physics department personnel, Ikeda and Levinthal, has included running shifts and sharing in the organization and operation of the large VAX workstation cluster, ALWS, with the CERN group. In order to participate to the fullest extent during the last two runs, D. Levinthal has just finished one year of a double teaching load. This will allow him to remain in residence at CERN for the entire 1992/1993 academic year and the two surrounding summers. Thus with the forseen replacement of M. Ikeda, who will be taking another position later this summer, the FSU Physics department will be able to have two full time scientists at CERN for the bulk of these data taking periods.

The hardware efforts of the FSU group continue to center on the offline computing facilities at CERN used by the ALEPH entire group. The large VAX workstation cluster, ALWS, has been reconfigured to include an FDDI backbone. Since the inclusion of this isolating element in the network, the stability of the cluster has improved dramatically, maintaining continuous up times in excess of 3 months at a stretch, in spite of being the largest example of such a cluster known. The lack of disk space and high speed file servers which can take advantage of the CERN groups purchase of the FDDI hardware continues to plague us, as DOE has continued to refuse any requests for funds no matter how trivial in comparison with its lavish support of the Wisconsin group. As usual we repeat our request for support of the facility which produces the overwhelming majority of the ALEPH results. The ALWS cluster has been selected to receive 2 of the new DEC ALPHA workstations for β site testing this fall. One will be configured to run VMS, the other the new OSI standard version of UNIX (OSF). These two stations will be evaluated for use in large group environments and as the replacements of choice for the current system of file servers. As the presence of DEC equipment in the HEP community is so pervasive and the entire future of DEC appears to be tied to these machines, this β test is likely to have resounding impact on the future of HEP computing.

In addition, with our increased presence at CERN, we anticipate working with the group investigating the use of a high resolution straw tube chamber to replace the current ITC. Many of the new materials and design ideas have been provided by FSU personnel, M. Bertoldi in particular. Much of the research into material and construction techniques can be more easily researched from the United States. With the time zone overlap that the Eastern U.S. has with Europe, Florida State is in a unique position within the ALEPH collaboration for investigating novel solutions of American origin. The first large prototype of the straw chamber will be built this summer as we believe we now have a construction technique for 2 meter long straws. It will consist of 72 channels and will be run in the test beam this fall.

Since 1990 the D* group has been extensively using a software package, SANDY, developed by Y. Maumary (Heidelberg) and maintained jointly by Y. Maumary, P. Colas (Saclay), and M. Ikeda (Florida State). The SANDY package reduces the standard data set to a smaller set called nano-DSTs and performs a number of time-consuming algorithms at production time. The advantages of SANDY as compared to the standard ALEPH analysis package (ALPHA) is speed and compactness. The increase in speed depends on the analysis program; for example, in our charm meson programs we have found a factor of 10 increase in speed. The compactness allows the complete 1990-1991 data set to be stored on a private workstation disk. The reduction in size also allows Monte Carlo events to be stored on the ALEPH data disks and thus they are easily available to VAX users.

This year the package has been expanded and other heavy flavour groups and the QCD group are now taking advantage of the speed and simplicity of the nano-DST. SANDY is currently available on a number of VAX and IBM machines among many collaborators including IN2P3 (the central computing center for French institutes), Saclay, Heidelberg, and Cineca (Italy). Recently the package has been ported to the ALEPH DECstation cluster and has been found to work perfectly.

Currently the nano-DSTs are produced on the ALEPH VAX cluster usually after each major reprocessing. In the near future there will be discussions on whether the nano-DST production should be incorporated in the ALEPH-standard production programs.

Corden, Georgiopoulos, and Wasserbaech, as members of SCRI, (DE-FC05-85ER250000) are in close collaboration with the Department of Physics at FSU. While the travel expenses, salaries for these three collaborators and the commonly used CERN budget code are covered by the SCRI contract, the FSU share of the detector maintenance (computer maintenance contract on ALWS, etc), hardware upgrades and responsibilities are covered by this contract, making a clean division of financial responsibilities. Their community service includes direct involvement in running the experiment, software projects to improve and automate the handling and network transfer of data to offline facilities, and generation of Monte Carlo events for general use by the collaboration. They share with the Barcelona group the responsibility for the operation and maintenance of the ALEPH Event Reconstruction Facility (also known as "FALCON"[4,5]. This data processing system is dedicated to the quasi-online, parallel reconstruction of the data recorded by ALEPH, and the distribution of the Data Summary Tapes to the offline computing facilities for physics analysis. It is a medium size (20 nodes) local area VAX-cluster, closely coupled to the online cluster via a set of dual-ported disks to which the raw data are written. The dual porting provides access to the raw data for reconstruction within minutes of data taking. Within hours, fully reconstructed event files ready for physics analysis are delivered to the offline computing facilities. The success of the FALCON system has resulted in; (1) the rapid availability of reconstructed output facilitating the timely publication of physics results; (2) the sophisticated monitoring of the detector during data taking; and (3) the capability to reprocess raw data with updated constants at more than 20,000 hadronic Z's a day. Corden and Georgiopoulos each spend a quarter of their time during the running period as FALCON managers at CERN. (The Barcelona group is responsible for the other half of the running period). This service provides the collaboration with an uninterrupted flow of reconstructed data (DST's) to the offline facilities for physics analysis.

SCRI's expertise in the use of supercomputers has given ALEPH the opportunity to exploit the CRAYs at CERN and FSU to the fullest. Software has been developed on the CRAYs for detector simulation, DST analysis, data conversion, and even for a fileserver for the FALCON facility, all of which exploit the Cray's strong points of vector processing and fast I/O capability. The fileserving capabilities of the CRAY were fully realized, during December 1991 when all of the data accumulated during the 1991 period were reprocessed. More than 300 Gigabytes of data were delivered in less than 20 days to and from FALCON using the CRAY as a fileserver. As a consequence of our efforts, the CRAY is now used by the collaboration as heavily as any other offline facility at CERN (for example the IBM 3090 and the ALWS VAXstation cluster).

With ever-growing data samples, progressively larger numbers of simulated events will be required for acceptance calculations and comparison with real data. Our work on the Monte Carlo simulation, which is envisaged to continue for the lifetime of the experiment, includes the planned upgrade to centre of mass energies above the threshold for pair production of W gauge bosons (LEP II). Detailed simulations will be needed. In 1991, 55,000 $Z^\circ \rightarrow q\bar{q}$ and more than 200,000 $Z^\circ \rightarrow \tau^+ \tau^-$ events were generated on the CRAY Y-MP at FSU, which are currently used by the collaboration.

Physics analysis will continue in the coming years. The areas of interest of the group in the exploration of charm and beauty physics with final states containing ϕ's, K^0's and π^0's, the search for new particles, and the measurement of the lifetime of the τ lepton will become more central with the installation of the micro vertex detector.

dE/dx information from the TPC is used to discriminate between charged kaons and pions, thus improving the signal to background ratio for ϕ identification in the K^+K^- spectrum. Consequently the $D_s^\pm \rightarrow \phi\,\pi^\pm$ [6] signal can be extracted with reduced background. This search will be exploited for B meson decay channels such as $B_s \rightarrow J/\psi\ \phi$ and $B_s \rightarrow D_s^+\ D_s^-$ as more data become available. The CTool package developed by S. Youssef of SCRI is used to study the channels $D_s^\pm \rightarrow \phi\,\pi^\pm\,\pi^0$ and $D_s^\pm \rightarrow K^0\,\pi^\pm$. This package allows a clustering algorithm to be optimized for any chosen physics criterion: for example, one can optimize the identification of neutrals in a calorimeter based on a specific signal. Studies of other multiple ϕ systems are also under way but are currently hampered by limited statistics.

The SCRI group has participated in a search for the production of leptoquarks, which are predicted in a variety of theoretical schemes beyond the Standard Model. An event generator was written to simulate the production and decay of leptoquarks according to the model of Schaille and Zervas, and an analysis strategy was devised for efficient signal isolation. From the ALEPH data, the production of first and second generation leptoquarks can be excluded over a mass range between 5 and 44 GeV/c^2 at the 95% confidence level[7]. This significantly extends the upper bound set by the TRISTAN collaboration.

Through the work of Steve Wasserbaech the SCRI group is currently involved in the measurement of the lifetime of the τ lepton. A new technique has been developed, whereby the τ lifetime measurement can be extracted from events where both τ leptons decay into a single charged particle. In this method, the mean τ decay length is computed by measuring the correlation between the impact parameters and the azimuthal angle between the two charged tracks. The advantages of this method compared to the classical impact parameter methods are; reduced model dependence, smaller systematic error, and there is no need to determine the τ direction to estimate the sign of the impact parameter. Using this technique as well as the more traditional ones, ALEPH obtained a lifetime (τ_τ) of 286 $\pm$ 14 fs[8]. This measurement is slightly lower than the world average, and yields a ratio of G_τ/G_μ of 1.006 $\pm$ 0.031, consistent with $\mu - \tau$ universality, where G_τ and G_μ are the Fermi coupling constants of the τ and μ to the charged weak current. This result is based on data taken up to 1990; using the 1991 data with the silicon vertex detector, a considerably improved measurement should be possible.

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3. SSC Experiments SDC and EMPACT

(V. Hagopian, K. Johnson, H. Wahl, W.J. Womersley)

During the past year considerable effort was expended for the R&D and proposal writing of SSC experiments. One member of our group (W.J.W.) contributed to the EMPACT proposal while the others worked with SDC. Since most of our effort was on tracking and calorimeter sub-systems, we will discuss the progress in the technical part presented in Section D of the Progress Report.

C. Computing, Networking and VAX Upgrades

The High Energy Physics group had a dedicated VAX-11/780 from 1981 through 1989. This computer served as the boot node for a 10 node Local Area VAX Cluster (LAVC) from 1987 through 1989. The cluster satellite nodes (7 VAXstation 2000's, 1 VAXstation 3200, and one MicroVAX II (now at Fermilab)) provided additional CPU power, but eventually we saturated the capacities of both the boot node to run the cluster and the CPU power in the entire cluster.

At the end of 1988, the U.S. D.O.E. and Florida State University agreed to contribute $150,000 each to upgrade our computing facility. The D.O.E share was funded over three years, starting in 1989. After extensively evaluating several systems, it was decided to purchase a Local Area VAX Cluster (LAVC) initially based on VAX 3000 series CPU's. The upgraded system initially had the computing power (for floating point calculations) of approximately 70 VAX-11/780's, and over 18 GB of hard disk storage.

During the following years we continually upgraded the system, by trading obsolete units for faster and better ones and by purchasing additional newer units. Sometimes the savings of one year's maintenance cost was enough to enable us to upgrade to a faster model. For example, we had eleven VAXstation 3200's, each with a yearly maintenance cost of about $1500. For $2045 each we exchanged VAXstation 3200's for VAXstation 3100-76's with a one year warranty and three times the CPU speed. We also added two Exabyte 8200 8 mm cartridge tape drives, to ease disk backup operations and data transfer between institutions. This past year we upgraded the 8 mm tape units to dual density Exabyte 8500 drives, and purchased a third such drive for use at Fermilab, all required both to maintain compatibility with the DØ experiment and to keep up with the higher density disk drives we have purchased and intend to purchase in the near future (2 GB disk drives are now coming onto the market).

The new VAX system has many advantages over our previous configuration. The dual boot nodes provide hardware redundancy, so that the cluster can continue to run should one of the system's boot nodes or one of the two "system" disks fail. Each of the "CPU batch engine" VAXstations has a minimum of 1 GB of local disk storage, so that we can run I/O intensive jobs without saturating either the Ethernet itself or the Ethernet controller cards on each CPU. We run many jobs in "parallel" mode on these "CPU" engines.

Since the time of the initial upgrade, The Florida State University has provided over $100,000 in additional funds for computer upgrades. Among other things, this has allowed us to purchase a

16 MB color graphics VAXstation 3520 workstation in 1990, and this year to replace it with a 16 MB color VAXstation 4000-M60. This past year seven of our 8 MB VAXstation 3200's were traded in for VAXstation 3100-76's with 16 MB of memory, and also three VAXstation 2000's were also traded in for VAXstation 3100-76's. Later in the year we purchased three of the newer VAXstation 4000-M60 machines (monochromatic). We also added six one Gbyte hard disks and, this past year, four 1.4 Gbyte hard disks and some networking equipment.

We now have a total of eight VAX computers at CERN for the ALEPH experiment, six at FNAL for the DØ experiment, and one at FNAL for the SDC experiment. There are also 4 GB of hard disk at CERN and 2 GB of hard disk at FNAL.

The lifetime of these computers is relatively short. There is obvious need for continual equipment upgrades, or else the system will soon become obsolete. Furthermore, the demands on computing power from the collider experiments and also for phenomenological calculations continue to grow at a very fast pace.

Comparison of Batch CPU's: 1989, now, mid-of-1992 (FSU computers and disks at Fermilab and CERN are not in the totals.).

Current configuration: 175 VAX-11/780 equiv. + 23 GB "data base" disks
24 GB total disks

dual	VAX 3400	Dual Boot nodes for LAVC
4	VAX 3200	Batch Engine for I/O intensive jobs and 6250 tape drives and old 1 Gbyte disks.
6	VAX 3100-30	Interactive workstations
2	VAX 2000	Interactive workstations
3	VAX 4000-M60	Interactive graphics workstation
1	VAX 4000-M60	Interactive color graphics workstation
1	VAX 3100-38	Interactive workstation
9	VAX 3100-76	Batch engines & interactive workstations
1	VAX 3100-76	Batch engine & color graphics workstation
1	VAX 3100-76	Batch & interactive workstation, Task B
1	VAX 4000-VLC	Batch & interactive workstations, Physics Dept.
5	SABRE disks	5.3 gigabytes (data base + "user" disks)
12	WREN VII disks	12.5 gigabytes (data base disks)
4	WREN VIII disks	6.2 gigabytes (data base disks)

The computing facilities at our disposal are as follows: (CPU in terms of VAX 11/780. Batch CPU is total available for batch processing). The quantity now is the system as it exists now. Some of the CPU's are for practical purposes not available for batch processing (the VAXstation 2000's are too slow)

Computer	CPU (MIPS)	Qnty 1989	Batch 1989	Qnty Now	Batch Now
VAX 3100-30	2.75	8	22	6	16.5
VAX 3100-38	3.8	1	4	1	3.8
VAX 3100-76	7.75			11	85.3
VAX 3200	2.75	11	30	4	11
VAX 3400	2.5	2	5	2	5
VAX 3520	2.75*2	1	6		
VAX 4000-M60	12.0			4	48
VAX 4000-VLC	6.0			1	6
VAX 2000	0.75	5	None	2	None
TOTAL BATCH POWER			67		175

Examples of LAVC use over the past year:

(a) Monte Carlo event generation for ALEPH

(b) Analysis of reduced data (Data summary files) for ALEPH

(c) Monte Carlo event generation for DØ

(d) Monte Carlo event generation by the phenomenological theory group

(e) Other phenomenological calculations by the theory group

(f) Monte Carlo calculations by the Lattice Gauge theory group (Task B).

(g) Monte Carlo event generation for FermiLab Experiment 711

(h) Analysis of reduced data (Data summary files) for FermiLab E-711.

Often two or even three of the above jobs are running simultaneously, on different groups of nodes in the cluster.

At present we have the following equipment at Fermilab: a VAXstation 2000, two VAXstation 3100-30's, one VAX 3200 and two VAXstation 3100-76's each with a one Gigabyte disk, all for the DØ experiment. At CERN we have one VAXstation 3540, one VAXstation 3100-76, and one VAXstation 3100-38 with a Gbyte disk. The newer units are not only faster, they also have twice the physical memory (16MB), which is increasingly becoming necessary for the collider jobs. A second major component of the cluster is disk space. Disks have gone down in price since 1989, from about \$8,000 per GByte to \$1,800 per Gbyte, and the price is still falling. Our disk capacity for data processing has increasing to 23 GB, with another 7 GB to 8 GB planned in the near future. The cluster also has 3 laser printers, 3 nine track tape drives and two Exabyte 8 mm tape drives. We need to retain some of the Q-BUS VAXstation 3200's for the 9-track tape drives and for our five oldest 1 GB SMD hard disk drives! We just recently removed the Exabyte 8 mm tape drives from the Q-BUS and put them onto the SCSI BUS.

Recently, with some complicated funding, we purchased our first true color real-time 3-D graphics machine, a Silicon Graphics Inc. Crimson/ELAN computer, which has very fast graphics capabilities, rather impressive Floating point CPU speed, and comes with the Unix operating system. We already have started making use of this system, and once all the libraries are installed we expect to use it rather heavily for our collider experiments. We have already measured this unit at 8.1 MFLOPS, which is to be compared to our VAXstation 4000 Model 60's which we have measured at 2.4 MFLOPS. So for our mix of problems the Crimson is 3.4 faster than our previously fastest computer. The computer was purchased with a 1.6 GB disk, so that we would have room to mount/generate data from/for the collider experiments. We intend to add an 8 mm tape unit and another GB disk in the near future.

As a computing engine, the Crimson is most suitable for non-parallelizable problems. We of course expect to make heavy use of the graphics capabilities:

1,000,000 vectors/second

225,000 triangles/second

100,000 polygons/second

for the Fermilab DØ and SSC SDC experiments, as well as for the SciAn project from SCRI and for color CAD programs.

D. SSC Preparation, Detector Development and Detector Construction

(V. Hagopian, K. Johnson; two starting graduate students Daryl Davis and Michelle Shepard; three engineers and three undergrad students)

Up until two years ago our detector development laboratory concentrated on building, testing and quality control of fixed target experiments and the FNAL DØ detector. For DØ we built over 3,500 parts for the calorimeter which is now being used to take data. We also built a thickness measuring device for the uranium plates of the DØ calorimeter. This device used a IBM PC to move a sonic thickness measuring sensor over an area of about 3 meters x 2 meters. During the past two years most of the emphasis has been on SSC detectors. Nine FSU high energy physicists are now members of the SDC collaboration, of which four are from SCRI. Two other FSU physicist were members of other SSC experimental proposals, but their continuation with GEM is not definite. We have also started to design and build the prototype for the tracking upgrade of ALEPH at CERN using straw tubes. Funding for the SSC detector development has been augmented by SSCL funds and TNRLC grants.

Our detector development effort is housed in three laboratory rooms in the Physics building of our university. In addition we use the facilities of the material science group to aluminize the ends of fibers and the 3 MeV electron accelerator facility to irradiate plastic scintillators and wave length shifting fibers. The physics department shop facilities are also used extensively, where the numerical control milling machine is used to cut, polish and groove plates. During the past decade we have collected specialized tools and electronics, that now form the core of our detector development and prototyping laboratory. Most of the equipment was purchased using Physics Department funds. We now have a modest amount of equipment for the design, prototyping and testing of various components. The hardware includes:

1. MicroVAX II with CAMAC interface and software. This equipment is now at Fermilab and was used in the test beam of the hanging file calorimeter. We will use this equipment again at Fermilab during the next running period for the test beam.
2. Macintosh II with CAMAC interface and software.
3. Two CAMAC crates with about ten CAMAC boards, including TDC, ADC, etc.
4. Two NIM crates and about 15 NIM units.
5. Lecroy and Bertan high voltage power supplies.
6. Four oscilloscopes, including one 500MHz digital sampling oscilloscope.
7. Spectrophotometer connected to a Macintosh computer.
8. Two IBM PC compatible units for data collection.
9. 2.5 meter long black box to measure scintillating and WLS fiber attenuation length and light yield. Excitation is by means of 30 KVolt X-ray source, UV light or blue scintillator light.
10. CAD/CAM system for PC board layout.
11. Phototubes, bases, scintillators, etc.
12. Cosmic ray telescope to measure fluor decay times and efficiencies.

Most of our effort has been for the SSC SDC experiment. At present we have two physicists, three engineers, two beginning graduate students and three undergraduate physics students working on various aspects of this program. The SSC SDC experiment has by now made many technological decisions and several more need to done within the next year. The calorimeter for this detector has chosen the technology of scintillating plates and wave length shifting (WLS) fibers. Both scintiilators and fibers suffer radiation damage and our group has measured this damage for over 50 different scintillators and fibers. By August of 1992, the calorimeter group will decide on the scintillator and fiber types for the central barrel of the calorimeter, where radiation levels are low but non-negligible. For the end caps the choice must be done in about one year; where, as of now, no candidate scintillator exists. It is imperative that we continue our close work with industry to come out with better scintillators and fibers. In December 1991 the SDC calorimeter management identified our group for several of these efforts. This work is shared with Fermilab, Argonne National Laboratory, University of Michigan and Louisiana State University. We have tested scintillators and WLS fibers from BICRON, KURARAY and POLYHITECH Corporations. We at FSU held the second International workshop on Radiation Tolerant Scintillators and Detectors (RADDAM92) during April 28 to May 2, 1992. The first one RADDAM90 was held at FSU in March of 1990. The plan is to hold the third conference in Portugal in late 1993. Proceedings of the first conference was published by us and the proceeding of the second workshop will be published by the journal Radiation Physics and Chemistry.

The High Energy Physics group at Florida State University has taken a very active roll in the preparation of the design of the SDC detector. Our expertise is in the precise measurement of light yield and radiation damage of plastic scintillators and fibers and all its associated components. In addition several members of our group also contribute substantially to the effort of computer simulations. Initially our group concentrated its efforts on the calorimeter and tracking sub-systems. When the tracking group decided to build a straw tube tracker, we reprogrammed our efforts totally on the calorimeter sub-system only. Now fibers for tracking are back in discussion and we may yet be asked to help.

Florida State University has had an active program to study radiation damage to plastic scintillator for the past four years. FSU contributed to the first demonstrations of the exceptional radiation hardness of 3-HF based fibers, the use of silicone based glue adhesive, the first systematic damage investigation of a complete EM module and has been testing commercial products on a ongoing basis. We have also been providing radiation damage facilities and testing on an informal basis to all SSC related groups - at last count these included FNAL, Texas A&M, Rockefeller, Duke, Bicron, Kuraray, CEBAF and Soviet Union (at no charge).

This cooperative atmosphere has contributed, for example, to the rapid progress of Jim White's capillary studies and Bicron's program to create rad-hard fluors and plastic bases, as well as the long-term aging tests led by Nikos Giokaris of Rockefeller and Carl Zorn of CEBAF.

The list of projects to which we are contributing includes:

1. Ongoing damage surveys of any commercial product of interest (bulk scintillator, fibers, adhesives, etc.)
2. Close collaborative testing of Kuraray's and Bicron's new developments (including recently, for example, the new claddings)
3. Studies of optimal tile/fiber light coupling geometries, machining practice and glues
4. Electromagnetic module radiation damage tests at Beijing
5. Long-term ageing tests of both bulk scintillator and fibers
6. We have provided DAQ, PM's and manpower to the test beam run at FNAL.
7. Measuring several wave shifting fibers for efficiency and radiation damage, including BCF91, BCF91A, Y7, Y11 and very recently the fast WLS fiber from BICRON TYPE G2.

During the summer of 1991 we had two students at FNAL assembling the hanging file calorimeter units, the test beam modules and also some help to the Argonne Calorimetry test module effort. We have so far cut and grooved 22 plates for a new electromagnetic module that has been sent to Beijing. We have diamond cut and grooved plates for the first test tower of the Argonne Unit. Our shops also have cut, polished and grooved 300 plates for the second tower of the Argonne calorimeter unit. Just recently we diamond cut and grooved 50 plates of a new BICRON co-polymer scintillator for testing at Argonne National Laboratory.

During the next year we expect to contribute substantially to the development of the calorimetry. Our work will not be limited to radiation damage tests but includes investigations on the groove shapes, machining operations and optimization of light collection, as well as continued development and selection of the best tile/fiber combination. We will also contribute to the design and building of modules. We were recently asked to evaluate the new green extended Hamamatsu 1.5 inch phototubes, (R580-17).

The major task of this R&D is to work with industry and possibly others to produce the brightest scintillating plate-fiber combination, which is the most radiation damage resistant.

1. For irradiation damage, we will continue to work with BICRON and others in testing radiation damage of scintillator-fiber systems which in geometry is very close to the final design. BICRON will continue to send or sell us samples that are more radiation hard. By now BICRON has produced a simple polystyrene based scintillator (BC499-27), which is 25% brighter than Kuraray SCSN81 and almost as radiation hard. The difference is due to the final fluor where the BICRON scintillator has emission spectra about 30 nm shorter in wavelength. The major effort will be in producing scintillators and fibers with longer wavelengths, to get the spectrum away from the transmission damage region. We will continue to measure the irradiation damage to all samples using our 3 MeV electron accelerator. This work will continue in collaboration with Argonne National Laboratory (contact: Jimmy Proudfoot) as well as with Fermilab physicists.

2. Testing grooves for scintillators. In the past we have cut grooves in scintillators that have produced more light as well as less variation from unit to unit. Our design produced 70% more light than the previous designs. We will continue this effort, as well as, the R&D of groove cutting at the highest speed possible. At this time this speed is only 15 cm/min and seems to be the limit in groove cutting speed. We will test new ideas to increase this rate without the scintillator-fiber sustaining damage. We performed a proof of principle test of multi-grooves versus one grove and reduced the irradiation damage (up to 10 Mrad) by a factor of two. We will continue that investigation, using even finer wave shifting fibers.

3. Wave shifting fibers and coupling to clear fibers. So far we have used the BICRON BCF91A for all testing and calorimeter modules. There is damage in both the fiber and the cladding. It is known that amongst clear fibers, silica (glass) fibers have the least irradiation damage. We will experiment in the coupling of these fibers to the wave shifting fibers. In addition, we will work with industry to improve the brightness of the wave shifting fibers as well as the irradiation hardness. So far an improvement of a factor of 40% has already occurred, but we do not believe that this brightness is the limit. We have already started to investigate the mirroring of the end of a fiber with either silver or aluminum. We will continue this effort.

4. SDC Community Effort. In the past we have contributed to this effort in the form of providing manpower for assembly and beam testing of modules at laboratories. We have also cut and polished scintillators and grooved them for both the Fermilab and Argonne modules. We also irradiate various components for other SDC users, including those groups working in the forward calorimeter, where radiation levels are much higher. We will continue all this type of service.

Every member of this collaboration has been with this R&D effort for over two years with the exception of two first year graduate students who joined us this summer. Our research group has developed precision measuring techniques for both irradiation levels and light output reduction due to radiation damage. For radiation damage we use the FSU 3 MeV electron accelerator that can give controlled amount of minimum ionizing particles to damage scintillators and fibers. We have also constructed light output measuring devices which are controlled by PC computers. The excitations are by 30 KeV X-rays, UV light, and blue scintillator light. Results are checked against cosmic muons using digital oscilloscope and digital electronics (both QVT and CAMAC). In the past we damaged and measured individual components. Starting several months ago, all our work is directed towards the systems of scintillators and fibers nested inside each other. Very good summaries of our work is given in the four paper presented at the RADDAM92 conference and appended to this progress report.

E. Absorption of CAD System Geometries into GEANT for SSC

(J. Womersley)

I have been working for the last two years on the problem of interfacing computer-aided modelling systems ("CAD systems") with physics simulation programs (usually the CERN Monte Carlo program GEANT). The aim is to avoid the need to tediously re-create a detector model in GEANT after one has already been designed, albeit on a different computer system, for engineering purposes. This has been recognized as desirable for many years but is a complex task because there are many incompatible CAD formats, none using the GEANT hierarchical tree, and often supporting shapes that GEANT does not.

The first effort in this direction at FSU was funded by the SSC Lab (SSC-PC-030, 1990) for the addition of a particle tracking capability within the I-DEAS solid modeller system; this proved very useful in designing the shapes of the calorimeters for the EMPACT/TEXAS SSC proposal.

Building on this experience with CAD systems, work has been done over the last year in conjunction with two SCRI physicists (Youssef and Dragovitsch) to develop OCTAGON, a translator from a common ascii CAD interchange format (DXF) to GEANT FORTRAN input. It is not intended to solve the general translation problem but rather as a way of getting small, odd-shaped parts of a detector, which can be sketched quickly on the CAD system, incorporated into the GEANT model. It deals with shapes — whether they are GEANT supported volumes or not —

by breaking them recursively into smaller units and thus building a so-called "octree" in which the shape is built up of small bricks. A first release version of the program was completed in May 1992, and is available through the FreeHEP software library. We are investigating its use to model add-shaped cable bundles in the Monte Carlo simulation of DØ.

In March 1992 the program was presented at CERN at the GEANT User's Meeting and a copy is being beta-tested by the Computer Aided Detector Design Group there. We aim to coordinate future developments with this group.

V. Particle Theory Program

During this past year the high energy theory group has consisted of two tenured or tenure-track faculty members (Baer and Owens), one Research Scientist (Baur), one Research Associate (Ohnemus and then Kao), and two graduate students funded by this contract (Bailey and Chen). Uli Baur came to our group from the University of Wisconsin, Madison, to fill the Research Scientist position vacated by Howie Baer when he became an Assistant Professor. Jim Ohnemus finished three years with us as a Research Associate and took a similar position with the high energy group at the University of Durham in England. He has been replaced by Chung Kao who joined us in September 1991.

There has been extensive participation in conferences and workshops during the past year. Owens served as a co-chairman of two parallel sessions on QCD (one for fixed target and one for collider results) at the DPF '91 conference in Vancouver, B.C. and Baer presented two talks there, as well. Baer also presented talks at the U-C Davis Workshop on Higgs Physics, at the DØ New Phenomena Workshop in Arlington, Texas, at the SSC Symposium at the University of Wisconsin, Madison, and at the meeting "Supersymmetry: Beyond the Standard Model III" held at Carleton University in Ottawa. Both Baur and Owens presented talks at the Moriond Conference in March and Chung presented a paper at the SSC Symposium at the University of Wisconsin, Madison. Numerous colloquia and seminars were also presented at ANL, FNAL, Durham, University of Wisconsin, Madison, University of Munich, DESY, Technical University, Aachen, University of Illinois, Urbana-Champaign, and the SSC Laboratory (Baur), FSU, FNAL, University of Alabama, University of Texas, Austin (Baer), FSU and the University of Texas, Austin (Kao).

The CTEQ Collaboration consists of a group of theorists and experimentalists who are partially supported by the Texas National Laboratory Research Commission with the goal of furthering the quantitative comparison of theory and data for standard model processes. This year the group sponsored a summer school on quantitative QCD analysis. Approximately 30 hours of lectures along with informal discussions took place over an eight day period. As a member of the collaboration Owens participated in the planning and running of the school and presented three lectures on higher order QCD calculations. The school was attended by 82 advanced graduate students and post-docs. Five attendees were from FSU - Madden and Goforth (graduate students working on DØ), Bailey and Chen (theory graduate students) and Kao (theory post-doc).

The following is a list of journal articles and conference reports which were published, accepted, or submitted during the past year. Following each is the abstract or a brief description of the paper.

1. An order α_s calculation of hadronic ZZ production, J. Ohnemus and J. F. Owens, Phys. Rev. **D43**, 3626 (1991).

   An order α_s calculation of $p\overset{(-)}{p} \rightarrow ZZ + X$ is presented. Results are given for the total cross section and differential distributions for Tevatron, LHC, and SSC energies. The calculation utilizes a combination of analytic and Monte Carlo integration methods which makes it easy to calculate a variety of observables and to impose experimental cuts.

2. Update of the Effect of Cascade Decays on the Tevatron Gluino and Squark Mass Bounds, H. Baer, X. Tata and J. Woodside, Physical Review **D44**, 207 (1991).

   The CDF mass bounds on squarks and gluinos are obtained using simplistic assumptions. We use the event generator SUSYSM, developed at FSU, to evaluate cross-sections for missing energy events from gluinos and squarks, in the framework of the MSSM. The gluino mass bound can be as much as 30 GeV below CDF claims, while the squark mass bound is typically reduced by $10 - 15$ GeV. We show how these constraints on the MSSM parameter space compare to those from LEP data.

3. Phenomenology of Light Top Squarks at the Fermilab Tevatron Collider, H. Baer, M. Drees, R. Godbole, J. Gunion and X. Tata, Physical Review **D44**, 725 (1991).

   The renormalization group equations of the MSSM predict that one of the super-partners of the top-quark can be much lighter than the other squarks. We assume this to be true, and examine how this assumption would lead to modifications of top-quark physics at the Tevatron collider, and we also evaluate rates for missing energy events from top-squarks.

4. An order α_s calculation of hadronic W^-W^+ production, J. Ohnemus, Phys. Rev. **D44**, 1403 (1991).

   An order α_s calculation of $p\overset{(-)}{p} \rightarrow W^-W^+ + X$ is presented. Results are given for the total cross section and differential distributions for Tevatron, LHC, and SSC energies. The calculation utilizes a combination of analytic and Monte Carlo integration methods which makes it easy to calculate a variety of observables and to impose experimental cuts.

5. A Complete $O(\alpha_s)$ Event Generator for $p\bar{p} \rightarrow W \rightarrow e\nu X$ with Parton Showering, H. Baer and M. H. Reno, Phys. Rev. **D44**, R3375 (1991).

We have found a way to evaluate W production to $O(\alpha_s)$, while including parton showers from initial and final state quark and gluon lines of the Feynman diagrams. We avoid previous problems of negative weights and double counting parton emissions. Predictions for $W+n$-jet rates agree well with matrix element approaches, while the W p_T-distribution agrees well with the best previous theoretical estimates. A single program can yield all this information in the form of an event generator, and can be interfaced with hadronisation and detector simulation programs.

6. A Comparative Study of the Benefits of Jet Tagging in Heavy Higgs Production at the SSC, V. Barger, K. Cheung, T. Han, J. Ohnemus, and D. Zeppenfeld, Phys. Rev. **D44**, 1426 (1991).

$H \rightarrow ZZ \rightarrow 4$ charged leptons is of order 40 events per year at standard SSC luminosity and the QCD background is of comparable size. By tagging a single forward jet of energy $E_j > 1$ TeV and rapidity $2 < |\eta_j| < 5$ from the $qq \rightarrow qqZZ$ process, the QCD background can be essentially eliminated, with 12 signal events per year remaining, which amounts to 70% of the $qq \rightarrow qqZZ$ rate. The complete experimental separation of the vector boson scattering subprocess is thereby possible.

7. An updated set of parton distribution functions, J. F. Owens, Phys. Lett. **B266** 126, 1991.

A new parametrization of parton distributions is presented which is designed to update the older Duke-Owens Set 1 parametrization. The distributions result from fits which are based on new data from deep-inelastic lepton-nucleon scattering, dilepton production, and direct photon plus jet production. Some slight modifications have been made to the form of the parametrizations in order to extend the range of validity in both x and Q^2. The results are presented in a format which will allow an easy upgrade for routines based on the old parametrizations.

8. Event Structure in Photon plus Two-Jet Final States, S. Keller and J. F. Owens, Phys. Lett. **B269**, 445 (1991).

Direct photons can be used as a probe of the hard scattering mechanism in high-p_T multi-jet final states. For final states containing a photon and two jets, three classes of events can be distinguished according to whether the photon has the highest, second highest, or lowest energy as compared to the two jets. By comparing Dalitz plot structures as well as angular distributions for each of these different types of events, it is possible to distinguish the contributions from specific classes of Feynman graphs. In particular, it is possible to isolate a sample of events dominated by the bremsstrahlung production mechanism. The cross section for such events is sufficiently large to make this measurement practical in the forthcoming collider run as the Tevatron.

9. An order α_s calculation of hadronic $W^{\pm}Z$ production, J. Ohnemus, Phys. Rev. **D44**, 3477 (1991).

An order α_s calculation of $p\overset{(-)}{p} \to W^{\pm}Z + X$ is presented. Results are given for the total cross section and differential distributions for Tevatron, LHC, and SSC energies. The calculation utilizes a combination of analytic and Monte Carlo integration methods which makes it easy to calculate a variety of observables and to impose experimental cuts.

10. Multilepton Signals from Supersymmetry at Supercolliders, H. Baer, X. Tata and J. Woodside, Phys. Rev. **D45**, 142-160 (1992).

We have developed a new event generator SUSYSM to simulate the production of squarks and gluinos at hadron supercolliders including all the cascade decays as given by the minimal supersymmetric model. The simulation incorporates final state hadronization and fragmentation effects for the decays of heavy flavors. We have used this to compute the rates for $\not{E}_T$ events, same-sign dilepton events, $n_l = 3$, 4, and 5 isolated lepton events and single or double $Z^0 + \not{E}_T$ events from squark and gluino production at the LHC and the SSC for cuts inspired by the SDC Collaboration. We have identified and estimated several backgrounds to the various event topologies and shown that it should be possible to extract signals in several channels both at the LHC and SSC. We have shown that after accumulating one year's worth of design luminosity, it should be possible to identify a gluino with mass up to 2 TeV at the SSC, while the corresponding reach of the LHC is 1.2 – 1.7 TeV, depending on the luminosity.

11. W and Z Production at $p\bar{p}$ Colliders: Parton Showers Merged with $O(\alpha_s)$ Monte Carlo Approach, H. Baer, M. H. Reno, Phys. Rev. **D45**, 1503-1511 (1992).

We construct event generators for $p\bar{p} \to W^+X \to e^+\nu X$ and $p\bar{p} \to Z^0X \to e^+e^-X$ including complete $O(\alpha_s)$ corrections, and interface with initial and final state parton showers. Problems with negative weights and double counting multiple parton emissions are averted.

We calculate the $q_T(W)$ spectrum at both $\sqrt{s} = 0.63$ TeV and $\sqrt{s} = 1.8$ TeV, and compare with data and other theoretical predictions. We also present cross-sections for the various W or Z plus multi-jet event topologies and compare with matrix element results. We show several distributions associated with W+multi-jet events and find the jet rapidity distributions can be used to test the validity of our approach.

12. Latest Software, Hardware Serve High Energy Phenomenology, H. Baer and W. F. Long, feature article in *Computers in Physics* magazine, p. 24-32, January 1992.

We review for the general physics audience the usage of computers in High Energy phenomenology. We discuss software available for typical calculational problems, and also discuss current status and future trends in hardware relevant to particle physics.

13. Observability of $\gamma\gamma$ Decays of Higgs Bosons from Supersymmetry at Hadron Supercolliders, H. Baer, M. Bisset, C. Kao, and X. Tata, FSU-HEP-911104 (Phys. Rev. D- in press).

Motivated by the recent discovery that radiative corrections can cause the mass of the lightest scalar Higgs boson, H_l, of the minimal supersymmetric model (MSSM) to be in the intermediate mass range, we assess the prospects for discovering the MSSM Higgs bosons via their $\gamma\gamma$ decay modes at the SSC and at the LHC. We find that if the charged Higgs boson is not too light, it is possible to discover at least one of the Higgs bosons via this mode within a few years of operation of the SSC, provided the detector has the resolution to identify a Standard Model Higgs boson in the intermediate mass range via its $\gamma\gamma$ decay. Similar conclusions hold at the LHC provided the luminosity is higher by a factor of about 4. In the case where m_{H^+}, and hence, m_{H_p} is somewhat smaller than 200 GeV, we find there are regions of parameter space where all three Higgs bosons are in the intermediate mass range, and none of them lead to an observable signal. Thus, new strategies may be needed to identify the Higgs bosons of the MSSM.

14. Electroweak Vector Boson Production in High Energy ep Collisions, U. Baur, J.A.M. Vermaseren, and D. Zeppenfeld, Nucl. Phys. **B375**, 31 (1992).

We present the results of a comprehensive study of W and Z production in high energy ep collisions. The processes $ep \to eW^{\pm}X$, $ep \to \nu W^{-}X$, $ep \to eZX$ and $ep \to \nu ZX$ are investigated. The region of small momentum transfer in eW and eZ production, with a fermion exchanged in the u-channel, is treated using the photon structure function approach, and carefully matched to the deep inelastic region. Low momentum photon exchange contributions to νW and eZ production, where the proton either stays intact or is transformed into a nucleon resonance, are calculated using form factors and structure functions fitted directly to experimental data. These processes will be the source of rare but spectacular events. Total cross sections for W and Z production at HERA and at an ep collider in the LEP tunnel (LEP/LHC), and detailed results for the characteristics of eW, νW, eZ and νZ events are presented. In $ep \to eWX$, eZX the uncertainties of the quark densities in the proton and photon allow the total cross section predictions to vary by $\pm 40\%$ at HERA and $\pm 15\%$ at LEP/LHC.

15. Probing the $WW\gamma$ Vertex in $e^{\pm}p \to \nu\gamma X$, U. Baur and M. A. Doncheski, FSU-HEP-920225, MAD/PH/692, preprint, February 1992, to appear in Phys. Rev. **D**.

We study the prospects of testing the $WW\gamma$ vertex in $e^{-}p \to \nu\gamma X$ and $e^{+}p \to \nu\gamma X$ at HERA and LEP/LHC. Destructive interference effects between the Standard Model and the anomalous contributions to the amplitude severely limit the sensitivity of both processes to non-standard $WW\gamma$ couplings. Sensitivity limits for the anomalous $WW\gamma$ couplings κ and λ at HERA and LEP/LHC are derived, taking into account experimental cuts and uncertainties, and the form factor behaviour of nonstandard couplings. These limits are found to be significantly weaker than those which can be expected from other collider processes within the next few years. At HERA, they are comparable to bounds obtained from S-matrix unitarity.

16. Parton Distribution Functions of Hadrons, J. F. Owens and Wu-Ki Tung, to appear in Ann. Rev. Nucl. Part. Sci.

The QCD analysis of parton distribution functions in hadrons is reviewed. Elements of perturbative QCD which form the basis of this analysis and recent developments on the various physical processes which contribute most significantly to the global analysis are summarized. The theoretical, experimental, and phenomenological issues and uncertainties involved in a comprehensive study of parton distributions needed for contemporary precision QCD applications and high energy predictions are discussed in some detail. The status of currently available distribution sets and their proper use are examined. Finally, a list of yet-to-be finished tasks and critical challenges in this key area of high energy physics is presented.

17. An order α_s Monte Carlo calculation of hadronic double photon production, B. Bailey, J. Ohnemus, and J. F. Owens, to be published in Phys. Rev. **D**.

An order α_s calculation of hadronic double photon production is presented. The results are compared with data from both colliding beam and fixed target experiments. The calculation utilizes a combination of analytic and Monte Carlo integration methods which make it easy to calculate a variety of observables and impose experimental cuts.

18. Production of a Pseudoscalar Higgs with a Z Boson from Gluon Fusion, Chung Kao, submitted to Phys. Rev. D.

The minimal supersymmetric model is adopted to study the production of a pseudoscalar Higgs boson (A) in association with a Z gauge boson from gluon fusion ($gg \to ZA$) at future hadron supercolliders. Its production rate is determined and compared to that of the associated production of the Standard Model Higgs boson (H_{SM}) with a Z boson from quark-antiquark annihilation ($q\bar{q} \to ZH_{SM}$) and gluon fusion ($gg \to ZH_{SM}$). Some promising decay modes are suggested for detection.

19. Searching for the CP-Odd Higgs Boson of the Minimal Supersymmetric Model at Hadron Supercolliders, J. F. Gunion, H. E. Haber, and C. Kao, submitted to Phys. Rev. D.

The CP-odd Higgs boson, A^0, of a non-minimal Higgs model possesses no tree-level couplings to vector boson pairs. As a result, many of the techniques employed to search for the Standard Model Higgs boson at the SSC and LHC are not likely to be useful in searches for the A^0. This paper focuses on the phenomenology of A^0 production and decay in the minimal supersymmetric model (MSSM). We evaluate a comprehensive set of branching ratios for the A^0 (which includes all two-body tree-level and one-loop decays into nonsupersymmetric final states), including the effects of leading log radiative corrections. The one-loop decay $A^0 \to ZZ$ leads to the "gold-plated" signature $ZZ \to l^+l^-l^+l^-$ and provides an observable signature for A^0 production at the SSC and LHC only over a very narrow region of parameter space. More promising signatures for the A^0 are discussed.

20. Supercollider Signals from Gluino and Squark Decays to Higgs Bosons, H. Baer, M. Bisset, X. Tata, and J. Woodside, FSU-HEP-920224 (Phys. Rev. D- in press).

If the mass of the charged Higgs boson of the minimal supersymmetric model (MSSM) is smaller than about 150 GeV, the branching fraction for heavy gluinos and left-handed squarks to cascade decay to the heavier Higgs bosons H_h, H_p and $H^{\pm}$ of the MSSM may be as large as $50-60\%$ for values of SUSY parameters consistent with experimental data. These decays, which have been assumed to be kinematically inaccessible in earlier analyses, can potentially lead to significant modification of the cross section for $\not{E}_T$, same-sign dilepton and multilepton events from squarks and gluinos. We find that the $\not{E}_T$, same-sign dilepton and trilepton production rates are relatively insensitive to low values of m_{H^+}, so that these remain viable signals for the identification of gluinos and squarks at the SSC or the LHC. Finally, our exploratory study shows that substantial production of H_h and H_p ($H^{\pm}$) in gluino and squark pair events can lead to $\not{E}_T$ events with anomalously large numbers of b-quarks (τ-leptons). There also exist small regions of parameter space where the H_l and H_h may be identifiable via the presence of $\gamma\gamma$ in $\not{E}_T$ events.

21. Snagging the Top Quark with a Neural Net, H. Baer, D. Dzialo-Karatas and G. Giudice, FSU-HEP-911130 (submitted to Phys. Rev. D).

    The search for the top quark at $p\bar{p}$ colliders in the one-lepton plus jets channel is plagued by an irremovable background from W-boson plus multi-jet production. In this letter, we show how the top quark signal can be distinguished from background in the distribution of neural network output. By making a cut on the network output, we maximize the ratio of signal to background in a final event sample, and compare our results with those obtained by making kinematical cuts on the data sample. We also demonstrate the robustness of the neural network method by training the neural network on signal events of one top mass and testing upon another.

22. The Search for Higgs Bosons of Minimal Supersymmetry: Impact of Supersymmetric Decay Modes, H. Baer, M. Bisset, C. Kao, and X. Tata, FSU-HEP-920630 (submitted to Phys. Rev. D).

    We explore the consequences of Higgs boson decays to super-particles, and prospects for detection at hadron colliders.

23. Supersymmetry at Supercolliders, H. Baer, proceedings of DPF91 Conference, Vancouver, August, 1991, p. 472.

    A review of how supersymmetric particles would manifest themselves in experiments at hadron supercolliders.

24. $O(\alpha_s)$ Monte Carlo for W Production with Parton Showering, H. Baer, proceedings of DPF91 Conference, Vancouver, August, 1991, p. 705.

A summary of work done in merging parton showers with higher order QCD Monte Carlo for vector boson production.

25. W- and Z-Boson Production at ep Colliders, U. Baur, FSU-HEP-920427, preprint, April 1992, to appear in the Proceedings of the XXVIIth Recontres de Moriond "QCD and High Energy Hadronic Interactions", Les Arcs, Savoie, France, March 22 – 28, 1992.

We briefly summarize the results of a comprehensive study of W and Z production in high energy ep collisions. The processes $ep \to eW^{\pm}X$, $ep \to \nu W^{-}X$, $ep \to eZX$ and $ep \to \nu ZX$ are investigated. The region of small momentum transfer in eW and eZ production, with a fermion exchanged in the u-channel, is treated using the photon structure function approach, and carefully matched to the deep inelastic region. Low momentum photon exchange contributions to νW and eZ production, where the proton either stays intact or is transformed into a nucleon resonance, are calculated using form factors and structure functions fitted directly to experimental data.

26. An order α_s Monte Carlo calculation of hadronic double photon production, J. F. Owens, to appear in the Proceedings of the XXVIIth Recontres de Moriond "QCD and High Energy Hadronic Interactions", Les Arcs, Savoie, France, March 22 – 28, 1992.

An order α_s calculation of hadronic double photon production is presented. The results are compared with data from both colliding beam and fixed target experiments. The calculation utilizes a combination of analytic and Monte Carlo integration methods which make it easy to calculate a variety of observables and impose experimental cuts.

27. $O(\alpha_s)$ Monte Carlo for W Production with Parton Showering, H. Baer, proceedings of the Monte Carlo 91 Conference, Amsterdam, April, 1991.

A summary of work done in merging parton showers with higher order QCD Monte Carlo for vector boson production.

28. The Search for Supersymmetry, H. Baer, proceedings of Beyond the Standard Model 3, Ottawa, Canada, June, 1992.

A review of how supersymmetric particles would manifest themselves in experiments at hadron supercolliders.

Ongoing and Proposed Projects

1. Continued study of hard scattering processes.

Work is continuing on a variety of next-to-leading-logarithm calculations for various hard scattering processes. Bailey, Ohnemus, and Owens have completed a next-to-leading-logarithm Monte Carlo program for two photon production which has been used to compare predictions with data from the WA-70, UA-2, and CDF Collaborations. The agreement with the first two experiments is good, while the predictions for the higher energy data from CDF lie below the data. We are continuing to work with members of the CDF Photon group in order to understand this. Also, predictions from our earlier next-to-leading-logarithm direct photon program for the angular distribution of the produced photon+jet system are somewhat flatter than the CDF data. Finally, data on direct photon production from UA-1, UA-2, and CDF all show that the predictions tend to fall below the data at the low p_T end of the range covered by the data. We are investigating various explanations for these discrepancies such as a larger bremsstrahlung component or modifications of the parton distributions. In conjunction with this Bailey and Owens are using data from Z decays with final states containing a photon to try to learn how good are the approximations used in various direct photon calculations to describe the bremsstrahlung component. When looked at in this way, the Z decay data provide a pure bremsstrahlung sample.

The DØ detector at Fermilab has started to take data and members of the FSU group are interested in studying direct photon production. We are providing programs which are being used to design triggers for various processes such as the production of photon plus two jet final states. Later, we will provide programs to generate predictions for these processes, as well.

Baer, Chen and Reno plan further investigations into the merging of parton showers with higher order QCD Monte Carlo programs. In particular, they are looking at general rules for such mergers, which ought to be applicable to all processes, and to all orders in perturbation theory. They plan specific application of such techniques to $e^+e^- \rightarrow jets$.

2. Parton distributions.

The global analysis of parton distributions has been an ongoing project here since the late 70's. As new data are obtained and new calculations performed it is important to review and update the existing parton distributions. The advent of new two-loop calculations for deep inelastic scattering represents an important theoretical advance. New understanding of the reasons for inconsistencies between high statistics deep inelastic scattering data has opened the way for improving previous fits. New data extending the measurements of F_2 to lower values of x are also having an impact. Accordingly, the process of refining the parton distribution fits will continue. In the near term, one goal will be to efficiently incorporate a direct photon program into our fitting package so as to be able to use a larger sample of direct photon data in the fits than has been done previously.

3. New Particle Searches.

Another area in which members of the group have been active is the search for new particles. Baer is carrying out detailed computations of supersymmetric signals and standard model backgrounds for the Tevatron, SSC and LHC. These calculations implement the ISASUSY event generator developed at FSU to simulate gluino and squark events in accord with the Minimal Supersymmetric Standard Model. Further improvements in ISASUSY should take place in 1992-1993. CDF and D0 are currently using this simulation package in their SUSY analysis. Also under the topic of supersymmetry, Baer and Kao will further their investigations of the possibility of observing the various Higgs bosons of supersymmetry at hadron supercolliders. Work in these areas will continue, driven to some extent by the results of the collider experiments currently taking data. In short, we intend to maintain a high level of activity in the area of collider phenomenology.

Task B – Progress Report 1991/1992

The multicanonical Monte Carlo (MC) algorithm [5] has stood up to the promises anticipated by last year's progress report. A concise up-to-date review is given in [12]. Precisely speaking we did not propose a new algorithm, but the suggestion is to simulate a new statistical ensemble, the "multicanonical". This notation was first used in [7] and in more details developed in [15,16] and [12]. Once the ensemble is defined, one may invent algorithms to simulate it. Up to now only fairly straightforward Metropolis type algorithms were used to simulate approximations of the strict multicanonical ensemble (defined in [12]). A number of improvements towards better algorithms seem to be possible. So far we have gained practical experience in multicanonical simulations of first order phase transitions [7,10,11,13,14,17,20] and for spin glass systems [15,16,19].

Originally our work started with first order phase transitions, and the multicanonical method seems now to be well recognized in this field. At the Jülich workshop "*Dynamics of First Order Phase Transitions*" six talks reported results relying on multicanonical simulations, additionally the method was mentioned in several other talks, including the one by Binder. Besides our group two more collaboration reported multicanonical simulations. Großman, Trappenberg and Wiese from the HLRZ Jülich did an exploratory study of the $L_t = 2$ SU(3) deconfining phase transition. Borgs and Kappler (FU–Berlin) used the method to perform an investigation of the "Equal weight versus equal height" problem, which plays some role in the finite size scaling (FSS) theory of first order transitions. Both collaborations agreed that the multicanonical method works and enables hitherto impossible calculations. In our own work we have continued FSS scaling studies of 2d Potts models. The 10-state model was our first applicational target [7]. In case of the 7-state model [10] we provided evidence that surface tension estimates in the previous literature (Potvin and Rebbi; Kajantie et. al.) are off by an order of magnitude. Reference [10] contains also a very preliminary estimate of the $L_t = 2$ SU(3) surface tension. To clarify questions about the asymptotic FSS theory, we have recently turned to the 20-state model [20]. Besides studying Potts models, we employed a multimagnetic variant of the method to estimate the order–order surface tension of Ising models. Exact 2d results are reproduced with high precision [11,14]. In 3d a new estimate of the surface tension amplitude is provided [13,17]. This quantity is of physical interest as it allows comparison with experimental results from fluids which populate the Ising model universality class. The largest improvement factor which we obtained, as compared to standard canonical simulations, is about 10^{60} for one of the relevant 3d Ising model data points.

More recent are applications of the multicanonical method to systems with conflicting constraint, a line which has now also been pursued by Marinari and Parisi. In our work we studied the 2d Edwards-Anderson Ising spin glass [15,16] and found greatly improved ergodicity times. Similarly, remarkable improvements are reported in the Marinari–Parisi paper. We also intend to publish exploratory results for the physically more interesting 3d Edwards-Anderson Ising spin glass [19]. More generally, the multicanonical ensemble opens new horizons for simulations of the large class of systems which have to cope with conflicting constraints. Likely our method is going to replace simulated annealing, a method which stands out because of its generality.

In other developments, we have published our seminal paper [8] on multi-histograms techniques, applied to FSS investigations [1,2] of the SU(3) pure gauge theory. Reference [3,4] cover relevant aspect concerning the statistical analysis of such MC data. A pilot study [9] was carried out for the deconfining phase transition in full QCD with four flavors. In view of our recent progress, multi-histogram methods seem now to be obsolete. In future, simulations of the multicanonical ensemble should be carried out for these systems and, if the teraflop project [6] gets funded, these methods will also become relevant in this context.

Our project to simulate 4d SU(2) pure lattice gauge theory, the simplest asymptotically free theory in four dimension, on a Regge skeleton to include quantum gravity, has made progress. A paper on the theoretical parts, as well as reporting exploratory MC data is in preparation [18].

Task B – Summary of Proposed Future Work

It seems to be fair to say that the multicanonical method has been a relevant breakthrough. This statement has thoroughly been demonstrated for first order phase transitions, but likely the range of relevant applications is much wider. Over the next year we intend to concentrate on exploring further the potential of the multicanonical ensemble [12].

Rather straightforward applications are first order phase transitions in QCD and other gauge theories. In particular, we plan to clarify some old questions concerning the U(1) phase transition. A recent multi-histogram study of this system (Wuppertal preprint by Bhanot et al.) encountered severe problems as no overlap of the histograms could be achieved for $L = 16$.

Less straightforward is the questions of better algorithms for multicanonical simulations. We will explore several directions. A notable one is the possibility of a replica-cluster algorithm. Presumably a number of groups will now embark on such projects. Additional interest has certainly been stimulated by the Marinari–Parisi paper. Still, we think that our group is substantially ahead in some of the key questions.

Our spin glass simulations [15,16] came up with promising results. Directly along this line we intend to perform a larger scale simulation of the 3d Edwards-Anderson Ising model, which should lead far beyond our exploratory results [19]. It has remained controversial whether Parisi's mean field picture provides the appropriate ground state picture for this model, or whether a droplet model can be applied. Worse, due to recent work by Bhanot, is seems now even be controversial whether the model has a finite temperature phase transition or not. Previous MC simulations have remained fairly inconclusive due to the famous "supercritical" slowing down. Likely we are able to overcome this problem, and to reach physically interesting conclusions. Concerning other spin glass problems, Binder and Reger (Mainz University) have expressed interest in collaborations. After we have clarified the algorithmic problems, it seems to be a good idea to involve such well-known spin glass experts.

Beyond spin glasses, there is a tremendously large class of systems for which previous simulations suffered from similar problems of conflicting constraints. These systems include neural networks, protein folding, optimization problems like the travelling salesman, and many other issues. Due to manpower, it is clear that we will not be able to make relevant contributions in all these fields. However, initial demonstrations may be feasible. Neural networks are of direct interest to high energy physics, for instance in connection with the SSC. Therefore, we feel that DOE should at least provide funds to pursue one or two of these direction in more details. This is only possible, if the present task B budget becomes substantially expanded, as explained in the subsequent budgetary notes.

1991 - 1992 Publications

Task A

A. Papers Published

1. An Updated Set of Parton Distribution Parametrizations, J.F. Owens, *Physics Letters* **B266**, 126 (1991).
2. Event Structure in Photon Plus Two-Jet Final States, S. Keller and J.F. Owens, *Physics Letters* **B269**, 445 (1991).
3. Latest Software, Hardware Serve High-Energy Phenomenology, H. Baer and W.F. Long, *Computers in Physics* **V6**, 24 (1992).
4. W and Z Production at $p\bar{p}$ Colliders: Parton Showers Merged with $O(\alpha_s)$ Monte Carlo Approach, H. Baer and M.H. Reno, *Physical Review* **D45**, 1503 (1992).
5. Multi-lepton Signals from Supersymmetry at Hadron Supercolliders, H. Baer, X. Tata, J. Woodside, *Physical Review* **D45**, 142 (1992).
6. Update of the Effect of Cascade Decays on the Fermilab Tevatron Gluino and Squark Mass Bounds, H. Baer, X. Tata, J. Woodside, *Physical Review* **D44**, 207 (1991).
7. Phenomenology of Light Top Squarks at the Fermilab Tevatron, H. Baer, M. Dress, R. Godbole, J. Gunion, X. Tata, *Physical Review* **D44**, 725 (1991).
8. Complete $O(\alpha_s)$ Event Generator for $p\bar{p} \to W^+X \to e^+\nu X$ with Parton Showering, H. Baer, M. Reno, *Physical Review* **D44**, R3375 (1991).
9. Order (α_s) Calculation of Hadronic W^-W^+ Production, J. Ohnemus, *Physical Review* **D44**, 1403 (1991).
10. Comparative Study of the Benefits of Forward Jet Tagging in Heavy-Higgs-Boson Production at the Superconducting Super Collider, V. Barger, K. Cheung, T. Han, J. Ohnemus, D. Zeppenfeld, *Physical Review* **D44**, 1426 (1991).
11. Order (α_s) Calculation of Hadronic $W^{\pm}Z$ Production, J. Ohnemus, *Physical Review* **D44**, 3477 (1991).
12. Neutralino and Chargino Production in Association with Gluinos and Squarks, H. Baer, D. Dzialo-Karatas, X. Tata, *Proceedings of the Large Hadron Collider Workshop*, Eds. Jarlskog and Rein, p. 654, CERN Report 90-10, (1991).
13. Searching for the Higgs in ep Collisions at LEP/LHC, G. Grindhammer, D. Haidt, J. Ohnemus, J. Vermaseren, D. Zeppenfeld, *Proceedings of the Large Hadron Collider Workshop*, Eds. Jarlskog and Rein, p. 967, CERN Report 90-10, (1991).
14. Electroweak Vector Boson Production in High Energy ep Collisions, U. Baur, J. Vermaseren, D. Zeppenfeld, *Nuclear Physics* **B375**, 3 (1992).
15. Supersymmetry at Supercolliders, H. Baer, Proceedings of the 1991 DPF Meeting in Vancouver, Eds. Axen, Bryman and Comyn; p. 472, World Scientific Press (1992).
16. An $O(\alpha_s)$ Monte Carlo for W Production with Parton Showering, H. Baer, Proceedings of the 1991 DPF Meeting in Vancouver, Eds. Axen, Bryman and Comyn; p. 705, World

Scientific Press (1992). Also in *Proceedings of MC91*, Detector and Event Simulation in HEP, Eds. K. Bos ans van Eijk, p. 490, NIKHEF, (1991).

17. An Order α_s Calculation of Hadronic ZZ Production, J. Ohnemus and J. F. Owens, Phys. Rev. **D43**, 3626 (1991).

18. Improved Measurements of Electroweak Parameters From Z Decays into Fermion Pairs, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Zeitschrift für physik* **C53**, 1 (1992).

19. Electroweak Parameters of the Z^o Resonance and the Standard Model, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B276**, 247 (1992).

20. Measurement of the Charged Particle Multiplicity Distribution in Hadronic Z Decays, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B273**, 181 (1991).

21. Search for the Neutral Higgs Bosons of the MSSM and Other Two-Doublet models, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B265**, 475 (1991).

22. Production and Decay of Charmed Mesons at the Z Resonance, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B266**, 218 (1991).

23. Measurement of the Polarization of τ Leptons Produced in Z Decays, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B265**, 430 (1991).

24. Search for a New Weakly Interacting Particle, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B262**, 139 (1991).

25. Charged Particle Pair Production Associated with a Lepton Pair in Z Decays. Indication of an Excess in the Tau Channel, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B263**, 112 (1991).

26. Measurement of the Forward-Backward Asymmetry in $Z \longrightarrow b\bar{b}$ and $Z \longrightarrow c\bar{c}$, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B263**, 325 (1991).

27. Measurement of Isolated Photon Production in Hadronic Z Decays, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B264**, 476 (1991).

28. Measurement of the Tau Lepton Lifetime, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Physics Letters* **B279**, 411 (1992).

29. A Study of Bose-Einstein Correlations in e^+e^- Annihilation at 91 GeV, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). *Zeitschrift für Physik C* **54**, 75 (1992).

30. Search for the U(3.1) $\rightarrow \bar{\Lambda} p \pi$'s From $\bar{p}p$ Interactions at 8 GeV/c, A Boehnlein, D. Boehnlein, J.H. Goldman, V. Hagopian and P. Rulon 3, *Nuclear Physics* **B21**, 174 (1991).

31. Partial Wave Analysis of $K\bar{K}\pi$ from $\bar{p}p \rightarrow K^+\bar{K}^0\pi^- X$ at 8 GeV/c, A Boehnlein, D. Boehnlein, J.H. Goldman, V. Hagopian and P. Rulon 3, *Nuclear Physics* **B21**, 142 (1991).

32. Preliminary Partial-Wave Analysis of the $K^+K^o{}_s\pi^-$ System Produced in 8 GeV/c K^-p Interactions, A. Boehnlein, D. Boehnlein, J. Goldman, V. Hagopian, P. Rulon 3, *Nuclear Physics* **B21**, 11 (1991).

33. EMPACT: A Detector for High-p_T Physics at the SSC, J. Womersley, *Nuclear Physics* **A23**, 24 (1991).

34. Radiation Damage Tests of New Scintillating Fibers and Plates, M. Bertoldi, M. Goforth, V. Hagopian, K. Hu, K.F. Johnson, P. Rulon 3, J. Thomaston, H. Wahl, H. Whitaker, J. Xu, C.A. Young, *Proceedings of 1990 Symposium on Detector Research and Development for the SSC*, Fort Worth, Eds. Dombeck, Kelly and Yost, p.674, World Scientific Press (1991).

35. Effect of Radiation-Induced Discoloration of the Cladding on Liquid Scintillating Fibers, V. Hagopian, K. Hu, K.F. Johnson, J. Thomaston, H. Whitaker, *et al*, *Proceedings of 1990 Symposium on Detector Research and Development for the SSC*, Fort Worth, Eds. Dombeck, Kelly and Yost, p.677, World Scientific Press (1991).

36. Design of Readout Electronics for a Scintillating Plate Calorimeter, V. Hagopian, K.F. Johnson, *et al*, *Proceedings of 1990 Symposium on Detector Research and Development for the SSC*, Fort Worth, Eds. Dombeck, Kelly and Yost, p.438, World Scientific Press (1991).

37. Radiation Damage Tests of a Scintillating Fiber Calorimeter, K.F. Johnson, *et al*, *Proceedings of 1990 Symposium on Detector Research and Development for the SSC*, Fort Worth, Eds. Dombeck, Kelly and Yost, p.672, World Scientific Press (1991).

38. A Measurement of e/π For a Fast Liquid Argon Calorimeter, V. Hagopian, J. Womersley, *et al*, *Proceedings of 1990 Symposium on Detector Research and Development for the SSC*, Fort Worth, Eds. Dombeck, Kelly and Yost, p.354, World Scientific Press (1991).

39. Using Octrees to Implement CAD System Objects into GEANT, P. Dragovitsch, S. Youssef, J. Womersley, *Proceedings of MC'91*, Detector and Event Simulation in HEP, Eds. K. Bos ans van Eijk, p. 423, NIKHEF, (1991).

40. Graphics and Interactive Data Handling in *DØ*, S. Hagopian, *Proceedings of the 14th Workshop of the INFN Eloisatron Project*, Data Structures for Particle Physics Experiments, Eds. Brun, Kunz and Palazzi, p. 194, World Scientific Press (1991).

41. Scintillators for Calorimetry, M. Bertoldi, V. Hagopian, E. Hernandez, K. Hu, C. Immer, K.F. Johnson and J. Thomaston; Proceedings of the 1991 DPF Meeting in Vancouver, Eds. Axen, Bryman and Comyn; p. 1164, World Scientific Press (1992).

B. Accepted for Publication

1. Parton Distribution Functions of Hadrons, J.F. Owens and W.K. Tung, to be published in *Annual Reviews of Nuclear and Particle Science*.

2. Observability of $\gamma\gamma$ Decays of Higgs Bosons from Supersymmetry at Hadron Supercolliders, H. Baer, C. Kao, M. Bisset, X. Tata, *Physical Review D - in press.*

3. Supercollider Signals from Gluino and Squark Decays to Higgs Bosons, H. Baer, M. Bisset, X. Tata, J. Woodside, *Physical Review D - in press.*

4. Probing the WWγ Vertex in $e^{\pm}p \to \nu\gamma X$, U. Baur and M.A. Doncheski, FSU-HEP-920225, 1992. *Physical Review D - in press.*

5. Radiation Resistant Scintillating Fibers, M. Bertoldi, M. Goforth, V. Hagopian, K. Hu, K.F. Johnson, P. Rulon 3, J. Thomaston, H. Wahl, H. Whitaker, J. Xu, C.A. Young, to appear in the proceedings of the Snowmass DPF Summer Study on High Energy Physics, (1990).

6. Direct Photon Production, J.F. Owens and Jianwei Qiu, to appear in the proceedings of the Snowmass DPF Summer Study on High Energy Physics, (1990).

7. The Performance and Physics Potential of the D-Zero Detector Operating at the SSC, W. Guryn, N. Graf, T. Murphy, J. Womersley, J. Ohnemus, M. Fortner, D. Hedin, to appear in the proceedings of the Snowmass DPF Summer Study on High Energy Physics, (1990).

8. Supersymmetry: Current Status and Future Prospects, H. Baer, A. White, N. Amos, R. Barnett, A. Beretvas, G. Bhattacharya, K. De, D. Dzialo-Karatas, L. Roszkowski, M. Takashima, X. Tata, J. Woodside, P. Yamin, to appear in the proceedings of the Snowmass DPF Summer Study on High Energy Physics, (1990).

9. Event Structure in Photon plus Two-Jet Final States, S. Keller and J. F. Owens, to appear in the proceedings of the Snowmass DPF Summer Study on High Energy Physics, (1990).

10. Heavy Flavor Production and Top Quark Search at Hadron Colliders, H. Baer, to appear in the proceedings of the Workshop on High Energy Physics Phenomenology, Clacutta, India, January 1991.

11. New Particle search and Structure Functions: Group Report, H. Baer, to appear in the proceedings of the Workshop on High Energy Physics Phenomenology-II, Clacutta, India, January 2-15th, 1991.

12. W - and Z -Boson Production at ep Colliders, U. Baur, to appear in the proceedings of the XXVIIth Recontres de Moriord "QCD and High Energy Hadronic Interactions", Les Arcs, Savoie, France, March 22-28 1992.

13. Single Tile-Fiber Unit of SDC Calorimeter, V. Hagopian, E. Bartosz, M. Bertoldi, E. Hernandez, K. Hu, C. Immer, K.F. Johnson, J. Thomaston and H. Whitaker; to be published in Proceeding of the International Conference on Radiation Tolerant Scintillators and Detectors, Florida State University (1992) to appear in periodical Radiation Physics and Chemistry.

14. Machining of Scintillator Tiles for the SDC Calorimeter, M. Bertoldi, E. Bartosz, C. Davis, V. Hagopian, E. Hernandez, K. Hu, C. Immer, and J. Thomaston; to be published in Proceeding of the International Conference on Radiation Tolerant Scintillators and Detectors, Florida State University (1992) to appear in periodical Radiation Physics and Chemistry.

15. Fiber Sputtering and Painting, E. Hernandez, E. Bartosz, M. Bertoldi, V. Hagopian, K. Hu, C. Immer, K.F. Johnson, J. Thomaston and H. Whitaker; to be published in Proceeding of the International Conference on Radiation Tolerant Scintillators and Detectors, Florida State University (1992) to appear in periodical Radiation Physics and Chemistry.

16. Pre-Radiation Enviromental Effects on Radiation Damage of Scintillator Bases, H. L. Whitaker and K.F. Johnson;to be published in Proceeding of the International Conference on Radiation Tolerant Scintillators and Detectors, Florida State University (1992) to appear in periodical Radiation Physics and Chemistry.

17. An Order α_s Monte Carlo Calculation of Hadronic Double Photon Production, B. Bailey, J. Ohnemus, and J. F. Owens, to appear in Phys. Rev. **D**.

18. Comparison of PWA Results of $K^+K^o{}_s\pi^-$ Final States Produced in 8 GeV/c K^-p, π^-p and $\bar{p}p$ Interactions, J.H. Goldman, V. Hagopian, P. Rulon 3, A. Boehnlein, D. Boehnlein, *et al*, proceedings of 4th International Conference on Hadron Spectroscopy.

C. Papers Submitted for Publication

1. An Investigation into Intermittency, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). CERN-PPE/91-121, submitted to *Zeitschrift für Physik C*.

2. Evidence for the Triple-Gluon Vertex from Measurements of the QCD Colour Factors in Z Decay into 4 Jets, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). CERN-PPE/92-31, submitted to *Physics Letters B*.

3. Measurement of the Absolute Luminosity with the ALEPH Detector, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). CERN-PPE/91-129, submitted to *Zeitschrift für Physik C*.

4. Measurement of α_s in Hadronic Z Decays Using All-Orders Resummed Predictions, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). CERN-PPE/92-33, submitted to *Physics Letters B.*

5. Measurement of Tau Branching Ratios, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). CERN-PPE/91-186, submitted to *Zeitschrift für Physik C.*

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7. Searches for New Particles in Z Decays Using the ALEPH Detector, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). CERN-PPE/91-149, submitted to *Physics Reports.*

8. Observation of the Semileptonic Decays of Bs and Lambda(b) Hadrons at LEP, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, *et al* (ALEPH Collaboration - 380 authors). CERN-PPE/91-149, submitted to *Physics Letters B.*

9. Production of a Pseudoscalar Higgs with a Z Boson from Gluon Fusion, C. Kao, FSU-HEP-911205, submitted to *Physical Review D*

10. Radiation Damage Tests on a Scintillating Fiber Calorimeter, K. Johnson, D. Hertzog, S. Hughes, P. Reimer, R. Tayloe, submitted to *Nuclear Instruments and Methods.*

11. Searching for the CP-Odd Higgs Boson of the Minimal Supersymmetric Model at Hadron Supercolliders, C. Kao, H. Haber, J. Gunion, FSU-HEP-911222, submitted to *Physical Review D.*

12. Snagging the Top Quark with a Neural Net, H. Baer, D.D. Karatas, G. Giudice, FSU-HEP-911130, submitted to *Physical Review D.*

13. Beam Tests of the *DØ* Uranium Liquid Argon End Calorimeters, J. Womersley, S. Hagopian, H. Wahl, R. Madden, H. Piekarz, J. Xu, S. Linn, W. Dharmaratna, S. Youssef, R. Avellaneda, M. Goforth, *et al* (The *DØ* Collaboration - 217 Authors), submitted to *Nuclear Instruments and Methods in Physics Research.*

14. Evidence for Two-Baryon Strangeness -1 States in Reactions $K^- d \rightarrow \pi^- X$ and $K^-\ {}^3He \rightarrow \pi^+ n X$ at 870 MeV/c, H. Piekarz, submitted to *Physical Review D.*

15. The Search for Higgs Bosons of Minimal Supersymmetry: Impact of Supersymmetric Decay Modes, H. Baer, M. Bisset, C. Kao, and X. Tata, FSU-HEP-920630, submitted to *Physical Review D.*

16. Single Quark Polarization in Quantum Chromodynamics Subprocesses, W.G.D. Dharmaratna and Gary R. Goldstein, submitted to *Physical Review D.*

D. Ph.D. Dissertations

1 A Study of Angular Dependence in Parton-Parton Scattering from Massive Hadron Pair Production Herman B. White (1991).

2 A Study of the Charge Assymetry in Hadronic Events Produced in Electron-Positron Collisions at Z Resonance. H. Lee Sawyer, Jr. (1991).

1990 - 1991 Publications

(Task A)

A. Papers Published

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2. Summary of Workshop on Radiation Hardness of Plastic Scintillators, K. Johnson, Proceedings of the Workshop on Radiation Hardness of Plastic Scintillators, FSU 1990, Ed. K. Johnson, 127-130, Florida State University (1991).
3. Average Fraction of Jet Momentum Carried by High P(T) Hadrons. With G. Boca, D. Levinthal, F. Lopez, C. Georgiopoulos, H. Goldman, S. Hagopian, V. Hagopian, K.F. Johnson, J. Streets, K. Streets, H.B. White (Florida State Univ.), M. Crisler, A. Lathrop, S. Pordes (Fermilab), M. Cummings, H.R. Gustafson (Michigan Univ.), *Z. Phys.* **C49**, 543 (1991).
4. CAD Tools for Detector Design, J. Womersley, proceedings of the International Industrial Symposium on the Supercollider, Miami Beach, Florida (1990).
5. Atomic-Weight Dependence of the Production of Hadron Pairs by 800-GeV/c Protons on Nuclear Targets, K. Streets, G. Boca, C. Georgiopoulos, J.H. Goldman, S. Hagopian, V. Hagopian, K.F. Johnson, D.M. Kaplan, D. Levinthal, F. Lopez, H.L. Sawyer, J. Streets, H.B. White, C. Young, et al, *Phys. Rev. Lett.* **66**, **(7)**, 864 (1991).
6. Production of High P_t Jets in Hadron-Nucleus Collisions, S. Hagopian, et al, *Phys. Rev.* **D42**, 1385 (1990).
7. Photoproduction of an Isovector $\rho\pi$ State at 1775 MeV, *Phys. Rev.*, **D43**, 2787 (1991).
8. New Tools for the Simulation and Design of Calorimeters, W.J. Womersley *Nuc. Instr. and Methods* **A289**, 475 (1990).
9. Absorbing CAD System Geometries into GEANT, J. Womersley, et al, *Nucl Instr and Meth* **A289**, 475 (1990).
10. Heavy Flavour Production in Z Decays, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, et al (ALEPH Collaboration - 380 authors). *Phys. Lett.* **B244**, 551 (1990).
11. Search for Neutralino Production in Z Decays, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, et al (ALEPH Collaboration - 380 authors). *Phys. Lett.* **B244**, 541 (1990).
12. Search for a Very Light Higgs Boson in Z Decays, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, et al (ALEPH Collaboration - 380 authors). *Phys. Lett.* **B245**, 289 (1990).
13. Searches for the Standard Higgs Boson, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, et al (ALEPH Collaboration - 380 authors). *Phys. Lett.* **B246**, 306 (1990).
14. Measurement of the Electroweak Parameters From Z Decays Into Fermion Pairs, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, et al (ALEPH Collaboration - 380 authors). *Zeitschrift für Physik* **C48**, 365 (1990).
15. Search for Excited Neutrinos in Z Decay, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, et al (ALEPH Collaboration - 380 authors). *Phys. Lett.*, **B250**, 172 (1990).
16. Measurement of the Strong Coupling Constant ALPHA-S from Global Event Shape Variables of Hadronic Z Decays, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, et al (ALEPH Collaboration - 380 authors) *Phys. Lett.* **B255**, 623 (1991).

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18. Measurement of the B Hadron Lifetime, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, et al (ALEPH Collaboration - 380 authors). *Phys. Lett.* **B257**, 492 (1991).

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20. Measurement of Charge Asymmetry in Hadronic Z Decays, M. Ikeda, J. Lannutti, D. Levinthal, L. Sawyer, et al (ALEPH Collaboration - 380 authors). *Phys. Lett.* **B259**, 377 (1991).

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23. Constraints on Supersymmetric Particles from the LEP data on Z^o Decay Properties, H. Baer. M. Drees and X. Tata, Phys. Rev. **D41**, 3414 (1990).

24. Detecting very massive top quarks at the Tevatron, H. Baer, V. Barger, J. Ohnemus, and R. J. N. Phillips, Phys. Rev. **D42**, 54 (1990).

25. A Next-to-Leading-Logarithm Calculation of Direct Photon Production, by H. Baer, J. Ohnemus, and J. F. Owens, Phys. Rev. **D42**, 61 (1990).

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28. Gluino and Squark Production in Association with Gauginos at Hadron Supercolliders, H. Baer, D. Dzialo-Karatas and X. Tata Physical Rev. **D42**, 2259 (1990).

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30. An order α_s calculation of hadronic ZZ production, J. Ohnemus and J. F. Owens, Phys. Rev. **D43**, 3626 (1991).

31. Report of the Collider Physics (New Particles) working Group, H. Baer with J. Freeman *et al.*, in the proceedings of Physics at Fermilab in the 1990's Breckenridge, Colorado (1989) p. 224.

32. Fixed Target Electroweak and Hard Scattering Physics, J. F. Owens (with the Fixed Target Electroweak and Hard Scattering Group), in the proceedings of Physics at Fermilab in the 1990's, Breckenridge, Colorado (1989) p. 358.

33. A Next-to-Leading-Logarithm Monte Carlo Calculation for Direct Photon Production, J. F. Owens, in the proceedings of the DPF90 Conference, Houston, Texas (1990) p. 559.

34. Supersymmetry at e^+e^- and $p\bar{p}$ Colliders, H. Baer, in the proceedings of the DPF90 Conference, Houston, Texas (1990) p. 919; also in the proceedings of the Lake Louise Winter Institute, (1990) p. 323.

35. Next-to-Leading-Logarithm Calculations of Direct Photon Production, J. F. Owens, in the proceedings of the Workshop on Hadron Structure Functions and Parton Distributions, Fermilab (1990) p. 264.

B. Workshop Proceedings

1. Workshop on Radiation Hardness of Plastic Scintillators, March 1990 held at FSU. Ed. K. Johnson 131. Published by Florida State University (1991).

1989 - 1990 Publications

(Task A)

A. Papers Published .

1. Hadron and Electron Response of Uranium/Liquid Argon Calorimeter Modules for the *DØ* Detector, S. Hagopian, S. Linn, H. Piekarz, H. Wahl, W. Womersley, S. Youssef, *et al.*, Nuclear Instruments and Methods **A280**, 36 (1989).
2. **A** Dependence of Highly Inelastic p-nucleus Collisions, S. Hagopian, *et al.*, Phys. Rev. **D41**, 1371 (1990).
3. Radiation Damage Studies in Plastic Scintillators with a 2.5 MeV Electron Beam, K. Johnson, V. Hagopian, J. Thomaston, H. Wahl, *et al.*, Nuclear Instruments and Methods, **A281**, 500 (1989).
4. New Tools for the Simulation and Design of Calorimeters, W. J. Womersley, Nuclear Instruments and Methods, **A289**, 475 (1990).
5. High Dose Calorimetry with Scintillating Fibers, K.F. Johnson *et al.*, IEEE Transactions on Nuclear Science, **37**, 500 (1990).
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7. Search for Excited Leptons in Z^0 Decays, M. Corden, C. Georgiopoulos, J.H. Goldman, M. Ikeda, J. Lannutti, D. Levinthal, M. Mermikides, L. Sawyer, G. Stimpfl, *et al.*, Phys. Lett. **B236**, 501 (1990).
8. A Precise Determination of the Number of Families with Light Neutrinos and of the Z Boson Partial Widths, M. Corden, C. Georgiopoulos, H. Goldman, M. Ikeda, J. Lannutti, D. Levinthal, M. Mermikides, L. Sawyer, G. Stimpfl, *et al.*, Phys. Lett. **B235**, 399 (1990).
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10. Properties of Hadronic Events in e^+e^- Annihilation at $\sqrt{s} = 91$ GeV, M. Corden, C. Georgiopoulos, H. Goldman, M. Ikeda, J. Lannutti, D. Levinthal, M. Mermikides, L. Sawyer, *et al.*, Phys. Lett. **B234**, 204 (1990).
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12. Search for the Neutral Higgs Boson for Z^o Decay, M. Corden, C. Georgiopoulos, H. Goldman, M. Ikeda, J. Lannutti, D. Levinthal, M. Mermikides, L. Sawyer, *et al.*, Phys. Lett. **236**, 233 (1990).
13. The Gluon Content of the Nucleon Probed with Real and Virtual Photons, P. Aurenche, R. Baier, M. Fontannaz, J. F. Owens, and M. Werlen, Phys. Rev. **D38**, 3275 (1989).
14. WW Signatures From Top Quarks at the Tevatron, H. Baer, V. Barger, and R.J.N. Phillips, Phys. Rev. **D39**, 2809 (1989).
15. Search for Top Quark Decays to Real W Bosons at the Tevatron Collider, H. Baer, V. Barger, and R.J.N. Phillips, Phys. Rev. **D39**, 3310 (1989).

16. A Next-to-Leading-Logarithm Calculation of Jet Photoproduction, H. Baer, J. Ohnemus, and J.F. Owens, Phys. Rev. **D40**, 2844 (1989).

17. Perturbative QCD Calculations of Weak Boson Production in Association with Jets at Hadron Colliders, V. Barger, T. Han, J. Ohnemus, and D. Zeppenfeld, Phys. Rev. **D40**, 2888 (1989).

18. Expectations for Two- and Three-jet Events at HERA, H. Baer, J. Ohnemus, and J.F. Owens, Z. Phys. **C42**, 657 (1989).

19. Dileptons from Chargino and Stop Production at the Tevatron, H. Baer, V. Barger, R.J.N. Phillips, and X. Tata, Phys. Lett. **B220**, 303 (1989).

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25. Some Recent Developments in the Determination of Parton Distributions, J. F. Owens, Proceedings of the St. Croix Advanced Research Workshop on QCD Hard Hadronic Processes, ed. by B. Cox, (Plenum, New York) 279 (1989).

26. Higher Order Calculations for Hard Scattering Processes, J.F. Owens, Proceedings of the 1988 DPF Conference, U. Conn., Storrs, Connecticut, 570 (1989).

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32. New Particle Signals at the SSC and at an Upgraded Tevatron Collider, H. Baer, *et al.*, High Energy Physics in the 1990's, Snowmass, (1988).

33. The Search for Very Heavy Top and the Fourth Generation, H. Baer, Proceedings of the Beyond the Standard Model Conference, Ames, Iowa, (1988).

34. Signals for Supersymmetry at Current $\bar{p}p$ Colliders, H. Baer, Proceedings of the Moriond Meeting on Hadronic Interactions, (1989).

35. Effect of Cascade Decays on Gluino and Squark Signals from the Tevatron, H. Baer, *et al.*, Proceedings of the International Europhysics Conference, Madrid, Spain (1989).

B. Ph.D. Dissertations

1. Experimental Determination of the Average Fraction of Jet Momentum Carried by the Leading Hadrons Produced at Large Transverse Momenta, Gianluigi Boca.
2. Study of the $K^+\overline{K}^o\pi^-$ System Produced in the Reaction $\overline{p}p \to K^+\overline{K}^o\pi^- + X$ at 8 GeV/c, Amber S. Boehnlein.
3. $K^+\overline{K}^o\pi^-$ Production in K^-p Interactions at 8 GeV/c, David J. Boehnlein.

1988 - 1989 Publications
(Task A)

A. Papers Published .

1. Light Meson Spectroscopy, The D (1285) [f_1(1285)] and E/iota (1420) [f_1(1420), η (1440)], A. Boehnlein. D. Boehnlein, J.H. Goldman, V. Hagopian, D. Reeves, *et al.*, Proceedings of the Conference - Production and Decay of Light Mesons, Paris (1988), Ed P. Fleury, p. 74, World Scientific Press, Singapore (1989).

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13. Higgs Boson Production via Z, W Bosons and Toponium in the E_6 Superstring Model, K. Whisnant *et al* , Int. J. Mod. Phys. **A3**, 1907 (1988).

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Papers Published .

1. Two-Photon Backgrounds for the Intermediate Mass Higgs Boson, H. Baer and J.F. Owens, Phys. Lett. B **205**, 377 (1988).
2. Top-Quark Signatures at the Fermilab Tevatron Collider, H. Baer, *et al.*, Phys. Rev. D **37**, 3152 (1988).
3. Use of Z Lepton Asymmetry to Determine Mixing Between Z Boson and Z' Boson of E_6 Superstring Theory, K. Whisnant, *et al.*, Phys. Rev. D **36**, 979 (1987).
4. Heavy-Z-Boson Decays to Two Bosons in E_6 Superstring Models, K. Whisnant, *et al.*, Phys. Rev. D **36**, 3429 (1987).
5. Superstrings: A Group Report, K. Whisnant, *et al.*, Int. J. of Mod. Phys. A **2**, 1097 (1987).
6. Gauge Boson Mass Shifts for Extended Higgs Sectors, S. R. Moore , K. Whisnant, and B.L. Young, Phys. Rev. D **37**, 179 (1988).
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1991 - 1992 Publications
(TASK B)

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2) R. Villanova, N. Alves and B. Berg, jDensity of States and Finite Size Scaling Investigations, Nucl. Phys. B (Proc. Suppl.) 20 (1991) 665-668.
3) B. Berg, jMonte Carlo Calculation of Confidence Levels for Realistic Least Square Fitting, Comp. Phys. Commun. 69 (1991) 65-75.
4) B. Berg, jDouble Jackknife Bias Corrected Estimators, Comp. Phys. Commun. 69 (1992) 7-15.
5) B. Berg and T. Neuhaus, jMulticanonical Algorithms for First Order Phase Transitions, Phys. Lett. B 267 (1991) 249-253.
6) S. Aoki et al. (The QCD Teraflop collaborations), jPhysics Goals of the QCD Teraflop Project, Int. J. Mod. Phys. C2 (1991) 829-947.
7) B. Berg and T. Neuhaus, jThe Multicanonical Ensemble: A New Approach to Simulate First-Order Phase Transitions, Phys. Rev. Lett. 68 (1992) 9-12.
8) N. Alves, B. Berg and S. Sanielevici, jSpectral Density Study of the SU(3) the Deconfining Phase Transition, Nucl. Phys. B 376 (1992) 218-252.
9) N. Alves, B. Berg, D. Duke, A. Irbaek and S. Sanielevici, jSpectral Density Analysis of the Chiral Transition in $n_f = 4$ Finite Temperature QCD, Phys. Lett. B 280 (1992) 261-266.

2. Papers Accepted for Publication:

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11) U. Hansmann, B. Berg and T. Neuhaus, jMultimagnetical Simulations, Talk given by U. Hansmann, to appear in the Proceedings of the Workshop "Recent Developments in Computer Simulation Studies in Condensed Matter Physics", (Athens GA, USA, February 16-21, 1992).
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1. Papers Published:

1) B. Berg and C. Vohwinkel, *Non-Abelian Gauge Theory: Mass Spectrum and Deconfining Temperature I*, Annal. Phys. (NY) 204 (1990) 351-400.
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3) N. Alves, B. Berg and S. Sanielevici, *Binder Energy Cumulant for SU(3) Lattice Gauge Theory*, Phys. Lett. B241 (1990) 557-560.
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9) C. Vohwinkel, ¡Analytical Progress towards the Mass Spectrum and Deconfining Temperature in SU(3) Gauge Theory, Phys. Rev. Lett. 63 (1989) 2544-2547

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