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Progress Report Covering the Five Year Period From August 1, 1984 to May 31, 1989 With Special Emphasis for the period of August 1, 1988 to May 31, 1989

to the

U.S. Department of Energy

from

PARTICLE PHYSICS GROUP
PHYSICS DEPARTMENT
THE FLORIDA STATE UNIVERSITY
TALLAHASSEE, FLORIDA 32306-3016

EXPERIMENTAL PHYSICISTS:

J.H. Goldman, Associate Research Scientist
S. Hagopian, Staff Physicist
V. Hagopian, Professor
K. Johnson, Comp. Research Specialist
J.E. Lannutti, Professor
D. Levinthal, Assistant Professor
H. Piekarz, Assistant Research Scientist
J. Streets, Research Associate (Resigned 5/26/89)
H.D. Wahl, Associate Professor

THEORETICAL PHYSICISTS:

H. Baer, Assistant Research Scientist
D.W. Duke, Associate Professor
J.D. Kimel, Associate Professor
J. Ohnemus, Research Associate
J.F. Owens, Professor

THEORETICAL PHYSICIST TASK B:
B. Berg, Professor

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Appendix I - List of Publications

I. Project Abstract

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

A. Experimental Program

During the last few years the effort of the experimental group has been divided approximately equally between fixed target physics and preparations for future collider 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 produced about 9,000 E/iota(1420) and about 5,000 D(1285) events with the pion beam. The original interest in this experiment was the possibility that the iota is a glueball. The spin-parity-C parity of the D(1285) has been determined to be 1^{++} with a non-negligible peak in the 0^{-+} wave. The complex system at 1420 MeV is primarily 0^{-+} with important contributions from 1^{++} and 1^{-+}. Production of the D(1285) and E/iota(1420) by antiproton beam is also substantial, with the D being 1^{++} and the E/iota primarily being 0^{-+}. The K^- beam data do not show D and E/iota production and the cross section upper limits are an order of magnitude smaller than the corresponding ones produced by the pion beam. The new peak at 1512 MeV has been determined to be 1^{++}. Analyses of the kaon and antiproton beam data are continuing.

Data reduction and most of the analysis have been completed for the Fermilab fixed target experiment E711, which was designed to measure di-hadron production in pN interactions at 800 GeV. This is the first experiment that used the FSU supercomputer to both reduce the data and perform the Monte Carlo simulations. The atomic weight dependence, when parameterized as $\sigma(A) = \sigma_o A^\alpha$, 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 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 first two papers on this data were submitted for publication. Analysis of the angular distributions is continuing.

The FSU group has made a major commitment to the Fermilab collider experiment, *D∅*-E740. *D∅* should excel at a wide range of physics - from heavy states (bottom and top) to W-Z measurements to searches for new particles. *D∅* will be more hermetic, have better hadronic energy resolution and better muon discrimination that CDF and complement the data taken by CDF. The FSU manpower for this experiment has been steadily increasing as our fixed target effort has wound down. In the past we headed the coordination of the test and calibration facility at Fermilab and are still heavily involved in this effort. Our shops built more that 3,500 components of the central calorimeter. We also built the quality control equipment that measures the uranium plate thickness and templates for the position of notches. The on-line and off-line graphics programs are being developed under our direction. Members of our group wrote vast quantities of software for the development and analysis of various components of the detector and helped install the Monte Carlo program GEANT on the supercomputer and develop a vectorized version of it. We expect to reap good physics results from $D\emptyset$ in the coming few years.

The CERN collider experiment ALEPH at LEP is scheduled to take data this year. The initial goals include the determination of 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. The manpower for this program is slowly increasing and we expect to have as many as three full time persons at CERN during the next data taking period. FSU is in charge of the on-line VAX station cluster system for which we have contributed a substantial amount of hardware. We are responsible for the software of this system and now have a system to display in three dimensions the detector and individual events. The simulation of the detector is a crucial component and we have coded large parts in vector mode to allow the analysis of large quantities of Monte-Carlo events. We are gearing to analyse large amounts of data on our computer system and get some of the earliest results from ALEPH.

Many papers were published on completed fixed target experiments performed at Fermilab. Results of the above mentioned fixed target experiments, as well as several other completed ones, were also reported at various conferences.

B. Theory Program

During the past five years the main emphasis of the theory group has been in the area of strong and electroweak phenomenology with an emphasis on hard scattering processes. With the recent creation of the Supercomputer Computations Research Institute, some work has also been done in the area of numerical simulations of condensed matter spin models and techniques for implementing numerical simulations on supercomputers.

Calculations of hard scattering processes require knowledge of the appropriate input parton distributions. We maintain a file of current deep inelastic scattering data and update fits of parton distributions periodically. A set of parameterizations of these results has been published and is widely used in comparisons with a variety of data. These have been continually refined as new data become available. We have also continued to seek ways of improving our knowledge of the gluon distribution. A recent analysis used both direct photon and deep inelastic scattering data in a joint fit using next-to-leading-logarithm expressions for the hard scattering processes. The results were more sensitive to the gluon distribution than if deep inelastic data alone had been used.

A new method for using Monte Carlo methods to perform next-to-leading-logarithm calculations has been developed and applied to symmetric di-hadron production and jet photoproduction. The method is currently being applied to direct photon production where we will be able to calculate observables involving photon-jet or photon-particle correlations. It is expected that these programs will yield new and more precise determinations of the nucleon gluon distribution as new data become available.

Many topics in collider phenomenology have been investigated including signatures of super-symmetric particles, fourth generation quarks, $E(6)$ superstring theory phenomenology, and Higgs signatures, just to name a few. Current projects include studies of strategies for $t-$quark searches at the Tevatron and CERN colliders. A detailed list of topics and current papers is given later in this report.

Two of our students recently received their Ph. D. degrees, one for a calculation of symmetric di-hadron production and the other for an analysis of a stochastic method of simulating renormalization group improved lattice gauge theory actions.

With the recent successful runs of collider and fixed target experiments at Fermilab and CERN, and with new facilities due to come on line soon, we look forward to new challenges and topics of investigation.

II. Five-Year Summary

A. Support:

The high energy physics group is now currently being supported by the U.S. Department of Energy and Florida State University. The table below summarizes the funding for the past five years. We have included contributions of the University -- which have been quite substantial. Two years ago a Task B was started for Numerical Simulations and is not included in this summary. Neither included is the Detector R & D funded by the SSC program for the building of a small scintillator lead calorimeter with 1 cm² pads. In 1989 the DOE and FSU agreed to fund (50% each) an upgrade of our VAX system. The total cost is $300,000 and FSU has given $150,000 while the DOE's share is to be funded over three years. 1989 includes the full FSU VAX upgrade share but only $50,000 for DOE.

Revised Budgets During the Past Five Years
(in thousands of Dollars)

Contract Year	1985		1986		1987		1988		1989	
	FSU	DOE	FSU	DOE	FSU	DOE	FSU	DOE	FSU	DOE
Personnel[1]	230	345	258	387	280	356	297	458	330	507
Expenses	4	275	0	228	3	208	0	203	0	196
Equipment	0	73	0	79	4	40	32	10	162	60
Indirect[2]	103	132	114	131	125	121	131	139	145	147
Sub Total	337	825	372	825	412	725	460	810	637	910
Fermilab acct.		25		25		25		25		20
TOTAL	337	850	372	850	412	750	460	835	637	930
Available[3]	337	850	372	815	412	785	460	840	637	925

(1) FSU share of personnel include 2 full time physicists, 1 full time engineer, 1 full time machinist, 50% of academic salary of faculty except Lannutti who is at 20% of full year.
(2) FSU Indirect cost calculated at on-campus rate of 44.0%
DOE Indirect cost at off-campus rate of 21.3% (85-87) & 21.0% (88-89)
(3) In 1986 DOE ordered a sequestration (Gramm-Rudman) of $35,000 to be transferred to 1987. $5,000 in 1989 was for a conference held in 1988.

B. Personnel:

At the beginning of 1985 the High Energy Physics group included 11 Ph.D. physicists, 8 of whom were paid by the University. At present, in 1989 the group includes 14 Ph.D. physicists (one person on one year leave of absence), 9 of whom are paid by the University. One new faculty position was added in 1989 and Prof. John Womersley will arrive on campus in August 1989. Also Mr. M. Ikeda, a student at University of California, Riverside has accepted a Research Associate position and will join our effort at CERN as soon as he completes his dissertation.

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

	1985	1986	1987	1988	1989	Funding
THEORETICAL:						
A. Axelrod (RA)	---------	-------->				DOE
H. Baer (RS)			---	---------	--->	DOE
D.W. Duke (Fac)	---------	---------	---------	-------->	LOA	FSU
J.D. Kimel (Fac)	---------	---------	---------	---------	--->	FSU
J. Ohnemus (RA)				------	--->	DOE
J.F. Owens (Fac)	---------	---------	---------	---------	--->	FSU
K. Whisnant (RA)	---	---------	-------->			DOE
EXPERIMENTAL:						
J.H. Goldman (RS)	---------	---------	---------	---------	--->	DOE
S. Hagopian (SP)	---------	---------	---------	---------	--->	FSU
V. Hagopian (Fac)	---------	---------	---------	---------	--->	FSU
K. Johnson (CRS)		---	---------	---------	--->	FSU
D. Kaplan (CRS)	---------	-------->				FSU
J. Lannutti (Fac)	---------	---------	---------	---------	--->	FSU
D. Levinthal (Fac)	---------	---------	---------	---------	--->	FSU
F. Lopez (RA)	---------	------->				DOE
H. Piekarz (RS)			----	---------	--->	DOE
J. Streets (RA)			-------	---------	-->*	DOE
H. Wahl (Fac)	-	---------	---------	---------	--->	FSU

Fac - Faculty; RA - Research Associate; SP - Staff Physicist;
CRS - Computer Research Specialist; RS - Research Scientist;
LOA - Leave of absence.
Note: The University considers SP and RS as faculty.
* Resigned to take a permanent position at FNAL.

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 is one course, with occasional time off for full time research.

In addition, the University has assigned to our program three full-time research personnel paid 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 II), 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 3 full time persons:

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

5) Mrs. Sherry Beasley (Grant Specialist II).

6) 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 program, are the graduate students trained in the group. The number of graduate students varies as new ones join the group and others graduate. During the past year four students completed their Ph.D. dissertations. They are:

1) Lewis Bergmann
2) David Boehnlein
3) Steve Black
4) Kathy Turner Streets

At present we have another 9 graduate students working with our group. From time to time we also employ undergraduate students who help us in various aspects of our research program.

III. Highlights of Activities During the Past Several Years:

During the past five years the experimental group increased by two new faculty members, both of which are new positions. In addition, during this period we had two promotions from associate professor to professor (J. Owens and J.D. Kimel) and two from assistant professor to associate professor with tenure (D. Levinthal and D.W. Duke). Also several years ago the Physics department added two new faculty members specializing in lattice gauge theory and their support is now a new DOE Task B.

- W.J. Womersley, now at Fermilab, employed by University of Florida, will join our faculty in August 1989 as an assistant professor.
- J. Streets (Research Assoc.) resigned effective 5/89 and accepted a permanent position at Fermilab.
- M. Ikeda from University of California, Riverside, recently accepted a Research Associate position to be based at CERN and work on ALEPH.
- D. Levinthal was granted an academic year (1989-1990) sabbatical and will be at CERN working on ALEPH.
- D. Levinthal continues to receive the fifth year of a five year Presidential Young Investigator Award at $62,500 per year.
- D. Levinthal is in the second year of a two year Sloan Fellowship with a $25,000 grant.
- S. Hagopian serves on Fermilab's Users Facility Advisory Committee.
- J.E. Lannutti continues to serve on HEPAP.
- J.E. Lannutti continues to serve on the URA Board and is chairman of the Physics 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).
- H. Wahl received a $55,000 grant from DOE-SSC for R&D of a small scintillator element calorimeter.
- J. F. Owens served for three years on the URA Site Visiting Committee which evaluates the operation of Fermilab.

- K. Whisnant resigned his Research Associate position to take a faculty position at Iowa State University.
- J. Ohnemus joined the theory group as a Research Associate.
- H. Baer joined the theory group as an Assistant Research Scientist.
- D.W. Duke and J.F. Owens, served as co-organizers for a conference entitled "Advances in Lattice Gauge Theory", held at FSU in 1985. They also served as co-editors of the proceedings.
- J.F. Owens served on the international organizing committee of a NATO Advanced Research Workshop on QCD Hard Hadronic Processes held in St. Croix in 1987.
- J.F. Owens served as co-organizer of a lattice higgs workshop held at FSU in 1988. He also served as a co-editor of the proceedings.
- H. Wahl served on the international organizing committee of the Second Workshop on Calorimetry held in Alabama in 1989.
- During the past several years, members of the high energy group participated in many workshops and conferences and gave numerous talks.

IV. EXPERIMENTAL PROGRAM

Summary of the Experimental Program:

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

The past five years has been a period of slow transition from fixed target to collider experiments. We completed the analysis and published papers on several fixed target experiments that took data in the first half of the 1980's. From 1985 through 1988, the major effort of the group was directed towards two fixed target experiments. The first, at Fermilab, entailed the study of the production of high transverse momentum particle pairs. 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. For this experiment, FSU initially contributed 25% of the effort. Our share of this experiment has slowly increased to the present level of about 50% of the effort.

Starting with 1987, we increased substantially our participation in two major collider experiments, namely *DØ* at FNAL and ALEPH at CERN. Also, we view the SSC as an important future direction of our group and considerable effort has been expended towards this objective. Our group provided the prime motivation in getting the State of Florida to submit an SSC siting (near Jacksonville, Florida) proposal. Since then we have worked on a variety of detector problems for the SSC and several of our members have joined the liquid argon/uranium large detector (son of *DØ*) proposal effort. At this time the group has decided to be part of one major collider detector, rather than dividing our effort on two or more experiments at the SSC.

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 extensive efforts in the two fixed target experiments, which were the main thrust of our program, 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.

Also briefly described is an AGS experiment where the spokesman is a member of our group:

- BNL E820 – Search for Strangeness -1 Dibaryon Resonances.

For completeness, we review briefly the following completed fixed target experiments, where data were obtained before 1986, but some of the analysis and several of the papers appeared in this review period:

- FNAL E580 – A Study of $K^oK^o, \Lambda\overline{\Lambda}, K^oK^on\pi, K^o\Lambda n\pi$, etc Production in π^- p Interactions at 200 GeV.
- FNAL E557/623 – High Transverse Momentum Jets.
- FNAL E623 – A Study of $\phi\phi, \phi K^+K^-$, etc Final States in pN Interactions at 400 GeV.
- BNL E673 - K^-p and $\overline{p}p \rightarrow K^+X^-$ Interactions using the BNL MPS.
- SLAC BC 67, 72/73 – π^+p and γp Interactions Using the SLAC Hybrid Bubble chamber.

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

- *DØ* at FNAL
- ALEPH at CERN.

Also discussed are our varied efforts for the SSC, focusing on the detector development work.

During the past five years, the experimental group has benefited from the acquisition of CDC supercomputers (205 and ETA10) and the establishment of the Supercomputer Computational Research Institute (SCRI). Our very close working relationship with the scientists at SCRI has enhanced the programs of both groups. SCRI has hired five 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
C. Georgiopoulos	12/84	FNAL E711 and CERN ALEPH
S. Linn	9/85	FNAL *DØ* and SSC
M. Mermikides	12/88	CERN ALEPH
S. Youssef	12/86	FNAL *DØ* and SSC

The primary focus of the SCRI group is the vectorization of GEANT and other simulation programs. We expect to continue our very close working relationship for the forseeable future.

A. Fixed Target Experiments

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.

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 goal 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 SU_3 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. But the more data we obtained, the more evident it became that the system is very complex.

So far 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/iota (1420) region is very complex with one prominent wave 0^{-+} and possibly two more resonances with $J^{PC} = 1^{++}$ and 1^{+-}.
3. The newly observed peak at 1512 MeV with a width of 35 Mev has spin parity of 1^{++}.
4. The mass distribution of $K\overline{K}\pi$ produced with a K^- beam is very different from the one produced by a π^- beam. The D and E/iota peaks are missing and the production cross sections are at least an order of magnitude smaller than those measured using the π^- beam data.

Below is the table that list the chronology of the data taking and the number of events obtained:

Year	$\pi^-p \rightarrow K^+K^o_s\pi^-n$	$K^-p \rightarrow K^+K^o_s\pi^-X$	$\bar{p}p \rightarrow K^+K^o_s\pi^-X$
1985	210 x 10^9 flux 14,000 events		30 x 10^9 flux 12,000 events
1985	310 x 10^9 flux 13,000 events	5.5 x 10^9 flux 900 events	
1986	430 x 10^9 flux 26,000 events	5.8 x 10^9 flux 1000 events	
1987		30 x 10^9 flux 8000 events	45 x 10^9 flux 10,000 events

The analysis of the π^- beam data is essentially complete. The results were published in Physical Review Letters and all that remains is a final article that we are writing for the Physical Review. The K^- data of 1985 and 1986 have been reduced and the analysis is now complete. This data sample was utilized in the dissertation of one of our Ph.D. students. Even though the K^- data has no D or E/iota peaks, we analyzed it anyhow and performed a phase shift analysis to determine the partial waves that contribute to the reaction. The plots at the end of this section show the data produced by the K^- beam. The data reduction of the 1987 got delayed because BNL decommissioned their CDC7600 computer and replaced it with an IBM3090. Converting the computer programs to the new IBM3090 was a massive undertaking of three persons working full time for 9 months!!! Now the data reduction is almost complete and preliminary results from the $\bar{p}$ data are also shown at the end of this section. The D(1285) and E/iota(1420) peaks are clearly seen and we have begun the phase shift analysis. Another one of our students will use the $\bar{p}$ beam data for her Ph.D. dissertation. The major difference between the 1983 and 1987 $\bar{p}$ data was that, for the later run we built a time-of-flight (TOF) counter which was needed to separate the fast K^+ from the proton, (the π^+ was eliminated by the high pressure Cherenkov counter). This TOF was also used for the K^- beam data.

BNL experiment 771, was proposed by BNL, FSU and Southeastern Mass. University. After approval was granted, the University of Indiana also joined the collaboration. FSU made a large commitment to this experiment, providing about 25% of the manpower during the data acquisition. Besides the usual effort during the data taking part, we at FSU built all the light guides of the TOF counter and helped in the final assembly of the unit. The TOF was put in the BNL-MPS in 1985, just before the start of 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 out the K^+. The TOF also was the crucial difference between the 1983 and 1987 $\bar{p}$ data, where the non-$K^+K_s^o\pi^-$ background was reduced to essentially zero. FSU took complete responsibility for 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 will be performed by a SMU graduate student. One important result that we were able to get, was the relative cross sections for the D(1285) and E/iota(1420) by π^- and K^- beams. Even though it was known that D and E/iota 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. The production of the D and E/iota by a K^- beam compared to a π^- 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

$$U(3100) \rightarrow p\overline{\Lambda}(n\pi); n \geq 1$$

This object had been observed with very poor statistics at CERN and Serpukov. We were unable to confirm their observations!

The list of the publications on the next page gives all the published results of this experiment with the last five being during the past year. Paper 11 is the written version of a talk given by V. Hagopian and number 14 is the write-up of a the talk given by our student, Amber Cope Boehnlein. FSU personnel have given four invited talks on this experiment, including one at the BNL user group annual meeting in 1987.

In the near future we intend to complete the data analysis of the $\bar{p}$ data. This will be the dissertation of our student Amber Cope Boehnlein. A paper on the relative production cross sections of the D and E/iota by K^- and π^- beams will also be written. The K^- beam data of 1987 will be added to the 1985 and 1986 K^- beam data and a complete phase shift analysis will be done. We expect to analyse the K^- and $\bar{p}$ beam data by the phase shift analysis programs developed for the π^- data. We expect both objectives to be substantially completed during 1990.

This experiment will end our commitment to the BNL program.

Publication List of BNL 771 Experiment

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12. Partial Wave Analysis of the $K^+K_s^o\pi^-$ System. Phys. Rev. Letters, Vol. 61, p. 1557 (1988).
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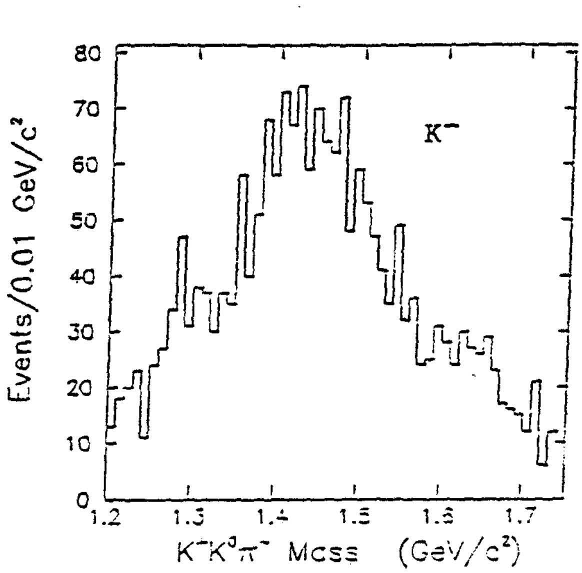
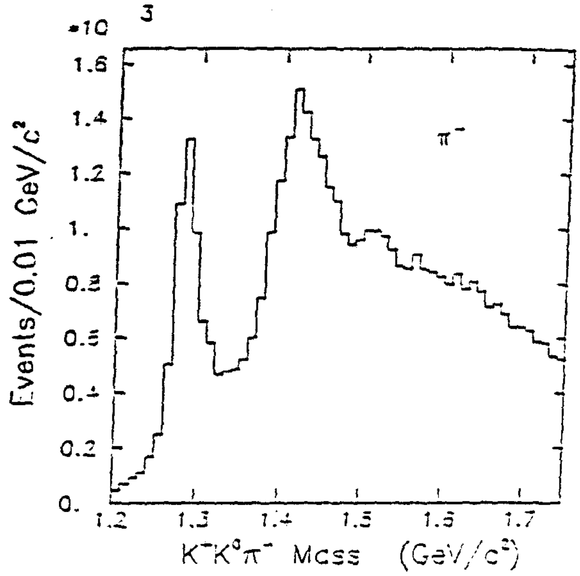
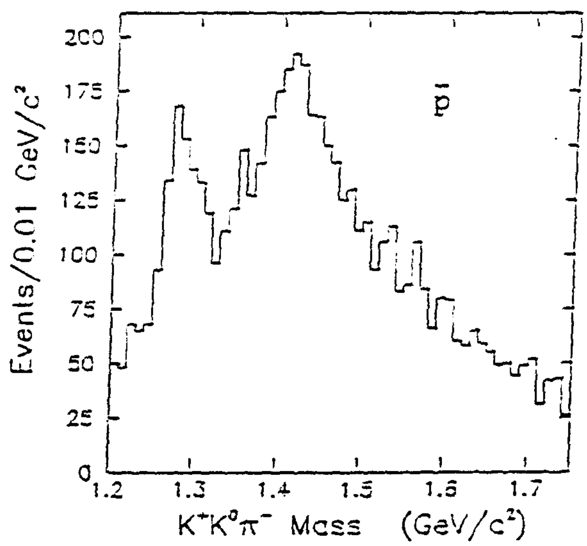
15. Mass Dependent Fits of the Partial Wave Analysis of the $K^+K_s^o\pi^-$ System. Proceedings of the BNL Workshop on Glueballs, Hybrids and Exotic Hadrons, Aug. 1988. Ed. S. Chung, AIP Conf Proceedings, No. 185, p. 363 (1989).







$K^+ K_S^o \pi^-$ Mass for the Reactions

$K^- p \rightarrow K^+ K_S^o \pi^- X$

$\pi^- p \rightarrow K^+ K_S^o \pi^- n$

$\bar{p} p \rightarrow K^+ K_S^o \pi^- X$

Figure 1

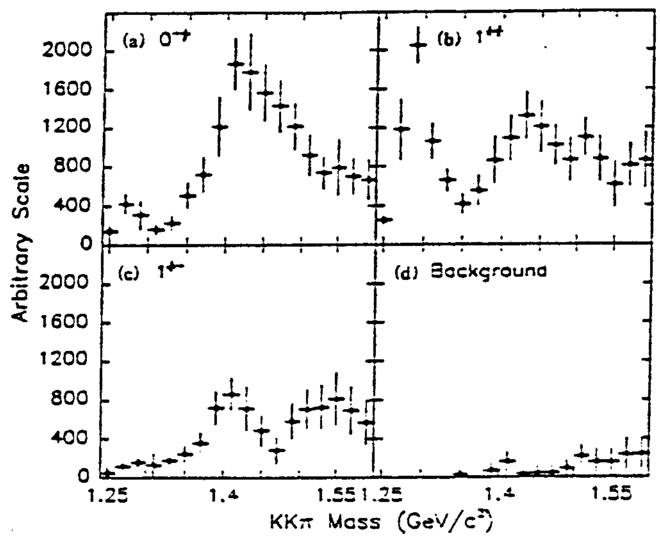


FIG. 2. Major spin-parity components of the $K^+\bar{K}^0\pi^-$ system for $0.0 \leq -t < 1.0$ GeV$^2/c^2$. Scale as in Fig. 1(b). (a) $0^{-+}(a_0)$ and (K^*), (b) $1^{++}(a_0)$ and (K^*), (c) $1^{+-}(K^*)$, and (d) background.

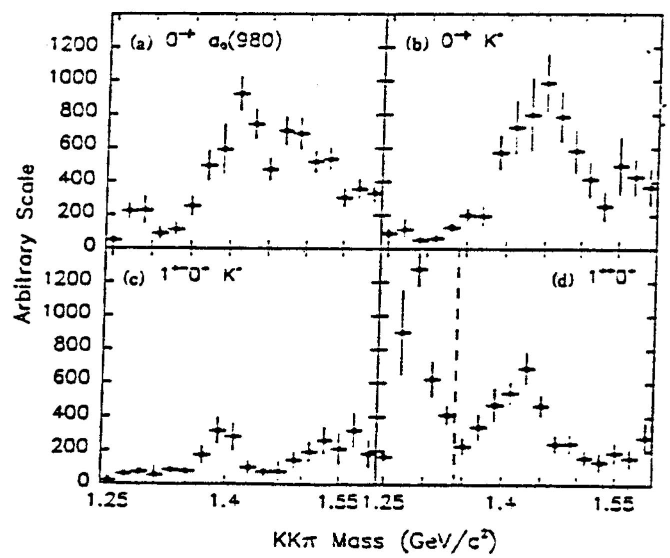


FIG. 3. Spin-parity components of the $K^+\bar{K}^0\pi^-$ system for $0.0 \leq -t < 1.0$ GeV$^2/c^2$. Scale as in Fig. 1(b). (a) $0^{-+}(a_0)$, (b) $0^{-+}(K^*)$, (c) $1^{+-}0^+(K^*)$, (d) $1^{++}0^+(a_0)$ for $M(K^+\bar{K}^0\pi^-) < 1.34$ GeV/c^2 and $1^{++}0^+(K^*)$ for $M(K^+\bar{K}^0\pi^-) > 1.34$ GeV/c^2 (the dashed line indicates the division).

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

The past year has seen the completion of FNAL Experiment 711. The objective of this experiment was to acquire and analyze a data sample which could measure the parton-parton scattering cross section. This can be done by studying the production of pairs of hadrons, each of which has a large transverse momentum. The two leading hadrons can provide 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 mid-February 1988. The reduction of the data was done on the CYBER 205 and ETA-10 supercomputers at FSU during the months of May and June, 1988. The final data summary files were finished by July, 1988. The acceptance and efficiency calculations were done by Monte Carlo simulation of the experiment. The simulated events were also generated on the FSU supercomputers. Preliminary results were presented by our graduate student K. Streets at the D.P.F. meeting at Storrs, Connecticut in September, 1988.

Since the presentation at the D.P.F. meeting the final corrections were applied to the data based on the full simulation. 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. Figure 1 shows the data from the three charge states and Figure 2 shows a comparison of the other experiments with the results from E711.

We extracted a cross section per nucleon using a value of α of 1.0 as our measurement was very close to this value. We also updated the CCOR QCD Monte Carlo to use new structure and fragmentation functions from fitting the recently published EMC data and including the expected scaling violations in the fragmentation process. The definition of Q^2 was chosen to optimize the agreement with the CCOR $\pi^o\pi^o$ results. The CCOR data, the E711 data and the results of this calculation are shown in Figure 3.

Since nuclear effects are small, we can also measure the angular distribution of the di-hadrons relative to the beam direction. This distribution, at fixed di-hadron mass, is closely related to the parton-parton scattering angle. The question of observing charge state dependence, due to differing matrix element contributions (same type quark states leading to same charge hadron states, versus different type quarks leading to +− charge states), naturally arises. The distributions for two values of mass are shown in Figure 4. Preliminary analysis of the data has shown that, when it is parameterized by 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 $a = 3.18 \pm 0.12$ for the opposite sign charge state and $a = 3.42 \pm 0.15$ 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.

These results have been written up as three articles and the first two have been submitted for publication. One student, K. Streets, has finished her Ph.D. dissertation and is interviewing for post doctoral positions. Another FSU student (H. White) is working on finishing the analysis. The third student (G. Boca) is writing his dissertation and already has a position with the University of Pavia in Italy.

E711 was primarily an FSU experiment, with nine physicists and five graduate students. From other institutions the participation was a total of four physicists and one graduate student (Fermilab, University of Michigan and University of California, Davis). For this experiment we built five wire chamber modules (2 PWC and 3 drift) each with four planes where most of the parts were machined in the FSU shops. We also built all the phototube bases, acquired the phototubes, helped in the construction and calibration of the calorimeter, designed and built various electronics. We wrote all of the software, from on-line monitoring, to reconstruction to data analysis, including Monte Carlo simulation. All of the data reduction and analysis was done at FSU. E711 was a major undertaking and we are happy that the results are excellent and worth the effort. We expect to report on this experiment at upcoming conferences.

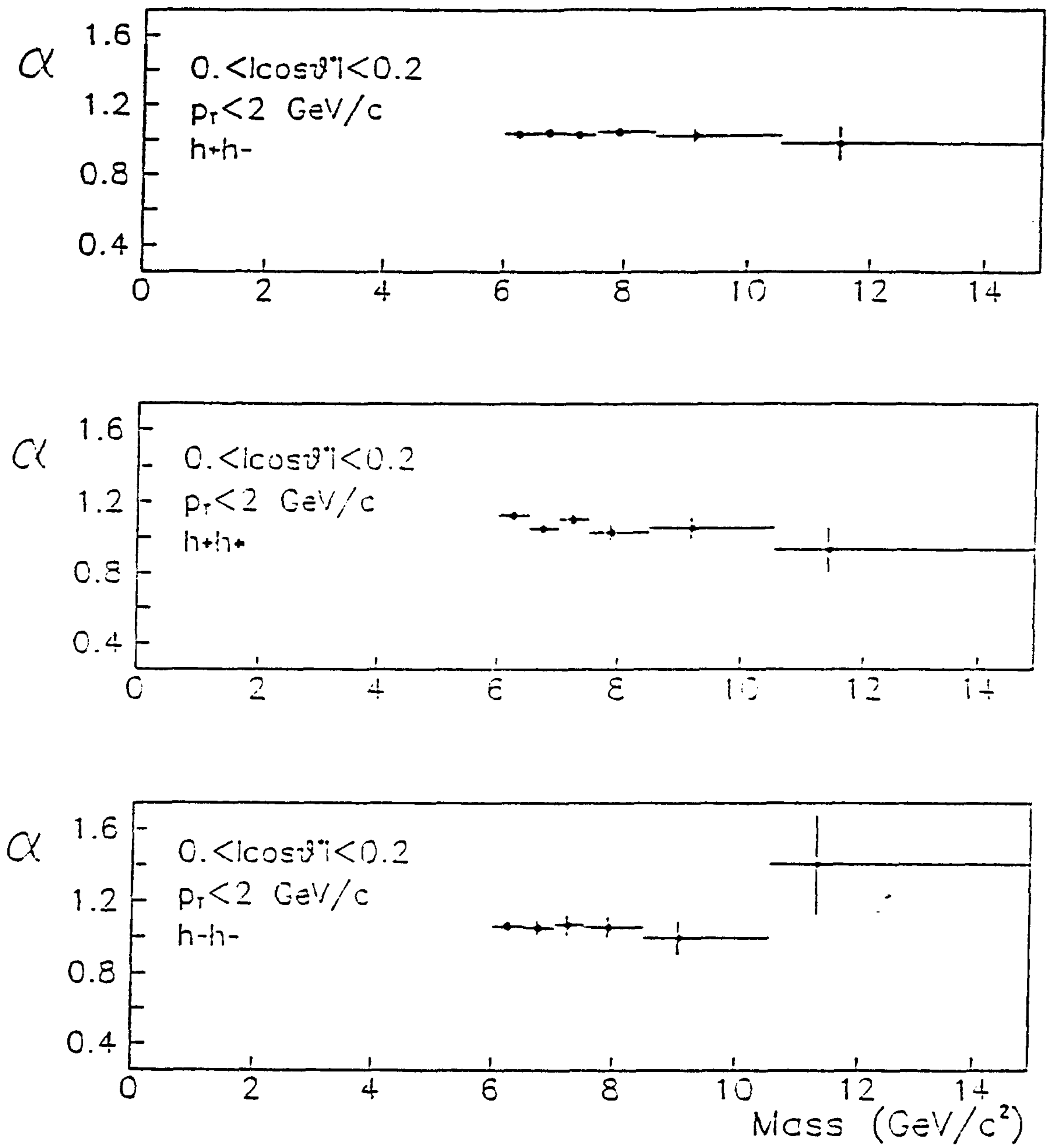


Fig. 1. Values of α, the power of the nuclear cross section (σ) term ($\sigma = \sigma_o A^\alpha$) versus di-hadron mass, where A is the atomic weight. The three diagrams are for +-, ++, and -- charge states.

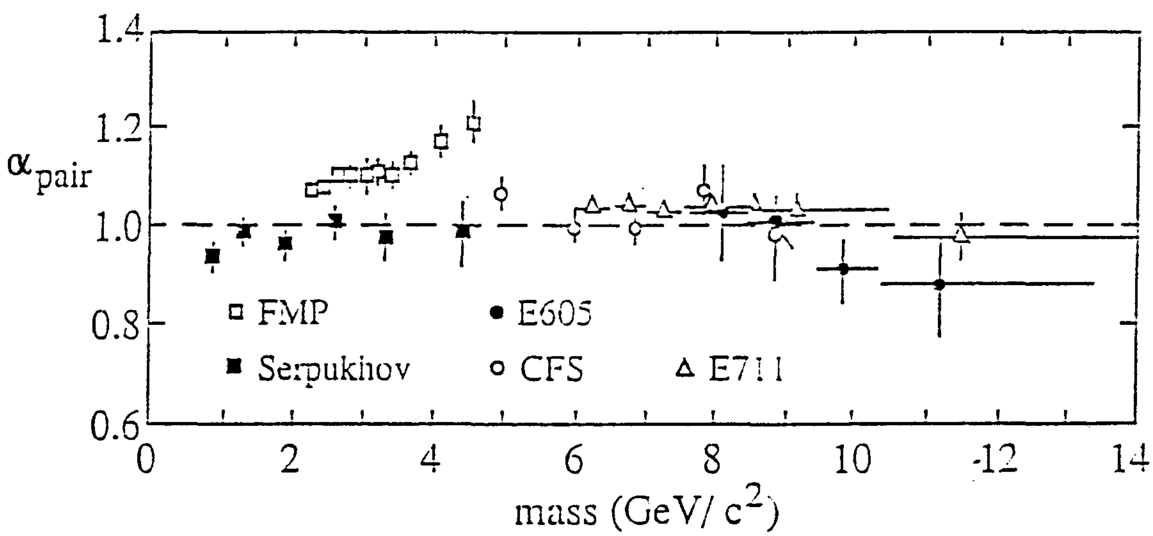


Fig. 2. Comparison of α from this and other experiments.

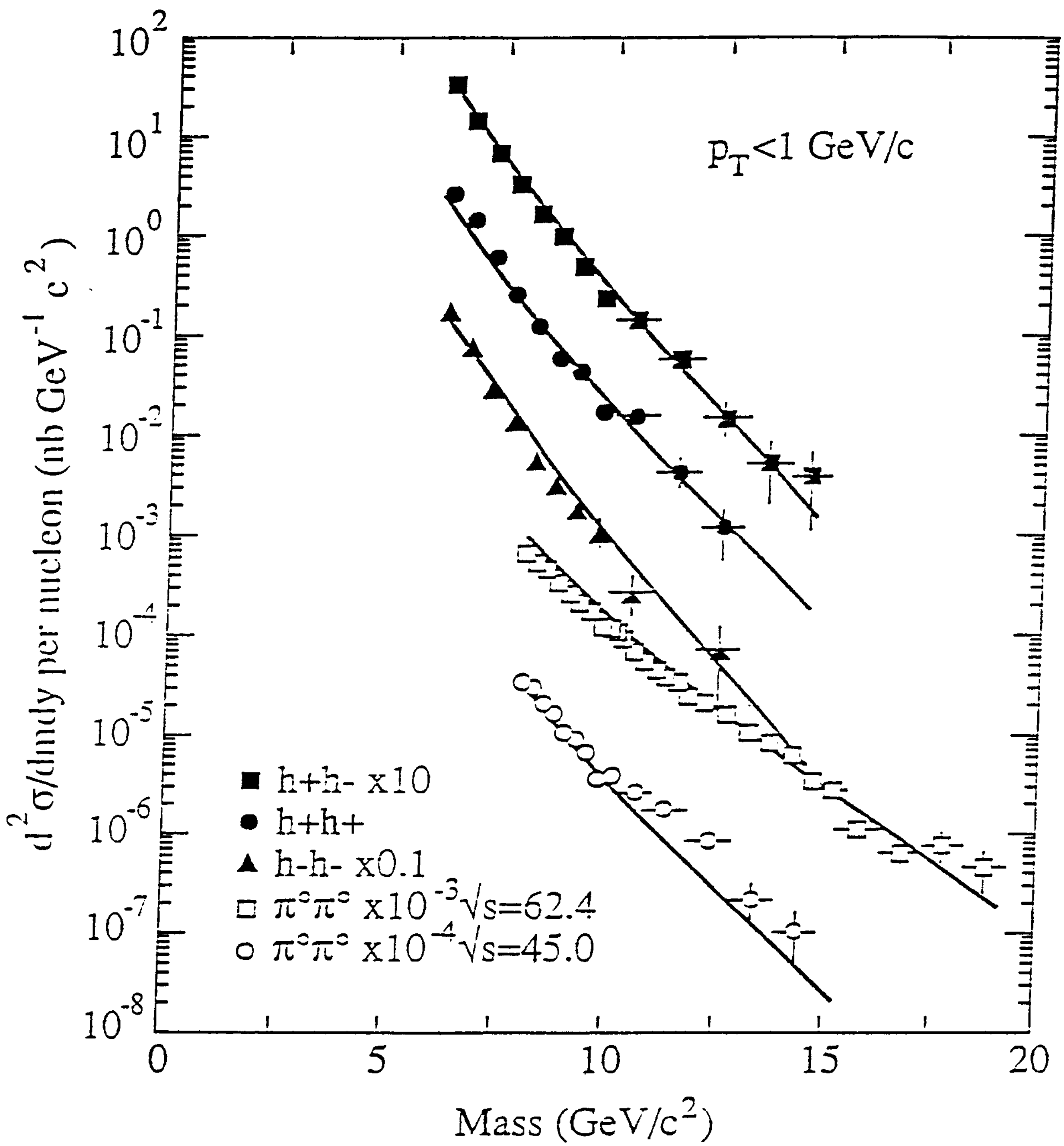


Fig. 3. Differential cross section versus di-hadron mass. Open circles and squares are CCOR data. The curves are QCD calculations.

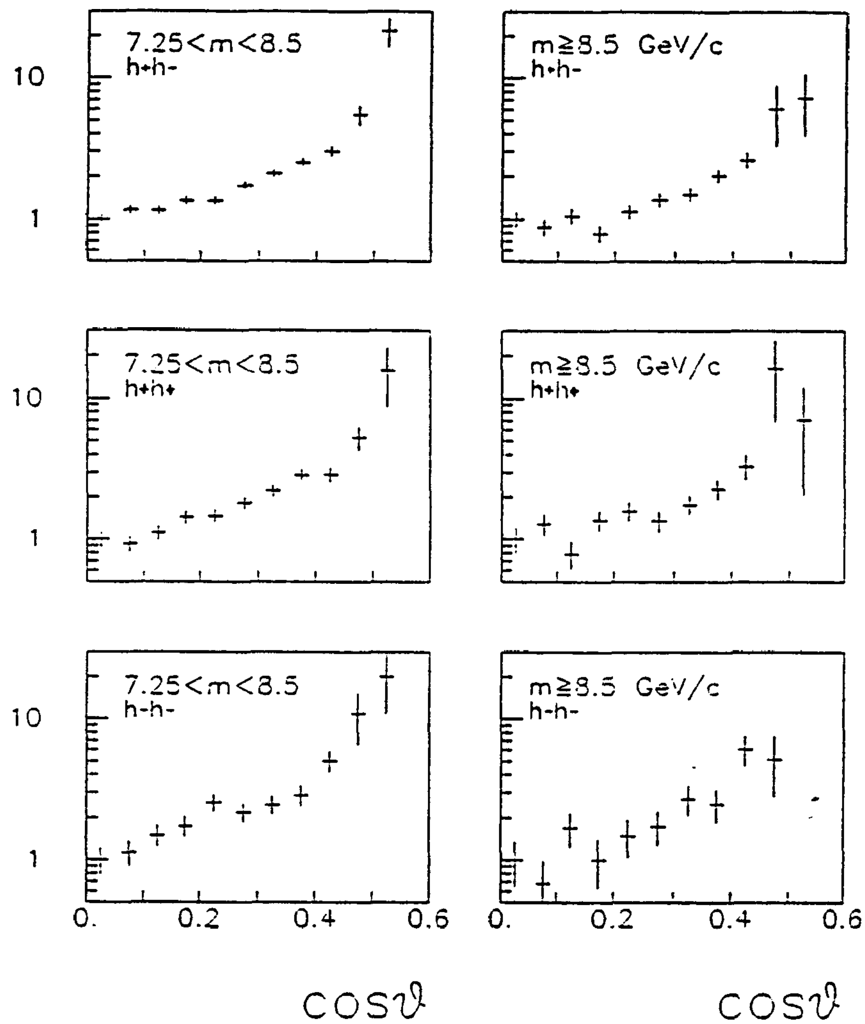


Fig. 4. Angular distributions for various mass and charge states.

3. EXPERIMENT AGS820

SEARCH FOR STRANGENESS -1 DIBARYON RESONANCE USING REACTION $K^- +^3 He \rightarrow \pi^+ + n + X$

FSU-BNL-Houston-INS-MIT-Ohio-Osaka-Texas A&M [1]

(Note: The proposal for this experiment with H. Piekarz as spokesman was submitted and approved before he joined our group.)

The BNL experiment AGS820 has run successfully in January/February 1989 for about 600 hours during the AGS slow extraction period.

The aim of this experiment was to search for the bag model predicted strangeness -1 dibaryon resonance of 2.1 GeV/c^2 mass, spin 0 and orbital- parity LP=-1 using the reaction:

$$K^- +^3 He \rightarrow \pi^+ + n + X$$

The above reaction was studied using the missing mass, two-arm magnetic spectrometer at the LESBII beam line of the AGS. The kaon beam momentum was chosen at 870 MeV/c and the scattering angle 20 degrees in order to enhance the production of the p-wave resonant states. The liquid ^3He target located between the two arms of the spectrometer was surrounded by the scintillation hodoscope to provide a Λ particle trigger. The production of the Λ particle is not possible in the examined reaction with the exception of the dibaryon decay or two step rescattering process inside the target nucleus ($K^- + p \rightarrow \Lambda + \pi^o$ followed by $\pi^o + p \rightarrow n + \pi^+$). The probability of such a process is expected to be small and may be comparable to that of a dibaryon production itself.

The quasi-free formation of the Σ particle and two neutrons was expected to be the most strongly populated reaction channel giving a strong maximum some 20 MeV/c^2 above the sigma-n threshold mass (2.13 GeV/c^2) for the reactions studied at 20 degree scattering angle. In addition to that, some flat kaon decay background should also be observed.

If no dibaryon state is produced, the missing mass spectrum would be characterized by two maxima: one at about 2.07 GeV/c^2 due to $\Lambda - n - n$ events from the rescattering process and a second one at about 2.15 GeV/c^2 due to $\Sigma - n - n$ events from quasi-free sigma production. The second maximum would strongly dominate the missing mass spectrum. Taking into account that both 2.07 GeV/c^2 and 2.15 GeV/c^2 maxima are broad (>30 MeV/c^2) the resonance may only be observed if its mass value is close to that predicted in the bag model (about 2.1 GeV/c^2) so the overlap with the background maxima is minimal.

The preliminary analysis (see figure on next page)of the missing mass spectra from the examined reaction indicates that indeed the best fit to data may be obtained with assumption of three maxima, two of them correspond to expected $\Lambda - n - n$ and $\Sigma - n - n$ channels while the third one is at about 2.1 GeV/c^2. The $\Sigma - n - n$ channel strongly dominates the spectrum while the cross-sections for both the $\Lambda - n - n$ and 2.1GeV/c^2 maxima are in the range of 10-15 microbarn/strd being in good agreement with previously observed [2] strangeness-1 "dibaryon" states (2.128 GeV/c^2 and 2.144 GeV/c^2) in the interaction of K^- mesons with deuterium target nuclei.

In Table 1, a comparison is presented of the bag model predicted strangeness -1 dibaryon states with dibaryon-candidate maxima observed, in reactions of 870 MeV/c^2 K^- mesons on deuterium and helium targets.

TABLE 1

DIBARYON [REF.3]			OBSERVED MAXIMUM		
STRUCTURE	SPIN	MASS[GeV/c2]	SPIN	MASS[GeV/c^2]	REF.
{Q6}1	3S1	2.17	3S1	2.13 ± 0.01	[2]
{Q4}x{Q2}	3PJ	2.16	3PJ	2.14 ± 0.02	[2]
{Q4}x{Q2}	1P1	2.09	1P1	2.10 ± ?	

Although the pattern of the observed maxima fits that for the predicted dibaryon states, the measured spectra will be analyzed from the point of view of both the systematic errors and backgrounds.

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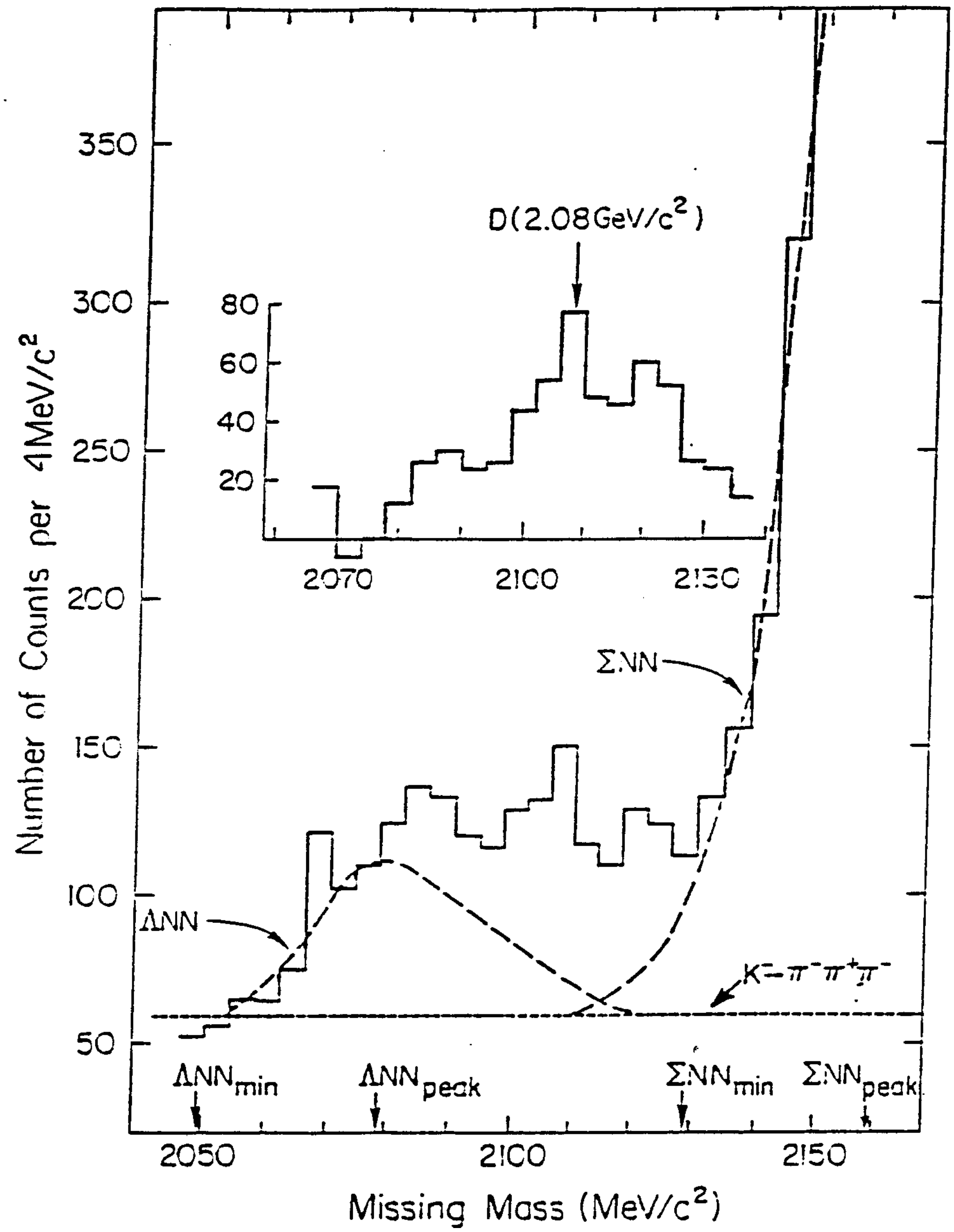

Fig. 1 Missing mass spectrum observed in reaction $K^- + 3He \rightarrow \pi^+ + n + X$. The dashed lines represent the expected backgrounds. The inset spectrum results from the subtraction of the backgrounds and shows a possible new maximum at 2.08 GeV/c^2.

B. Collider Experiments

In 1984 physicists of the Florida State University joined two collider experiments; the DØ experiment at Fermilab and the ALEPH experiment at the LEP collider at CERN. During the past year we increased the manpower on the collider experiments and contributed substantially in hardware acquisition, construction of equipment and software development. With our fixed target experiments slowly winding down (only two experiments are still in analysis mode), the effort on the collider experiments will continue to increase. Last year several graduate students worked on the collider experiments and the first student is now working on his Ph.D. dissertation. 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

The physics of DØ is very exciting and covers a wide range of topics. Even though the Standard Model has been enormously successful, the theoretical literature has focused on the necessity of augmenting it in some way. The experiment is expected to observe about 3000 Z^o decaying into electrons and muons and also about 15,000 $W \rightarrow e\nu$. A precision measurement of the W and Z mass ratio will determine $\sin^2\theta_w$ to an accuracy of 0.0005. Studies of decay asymmetry in W production and decay may signal the existence of heavy W's and Z's. Other studies will include QED/QCD ratio tests, high p_T studies and jet production. Of course, great interest also exists in searches for gauge bosons, Higgs bosons, heavy vector bosons, heavy leptons, supersymmetric particles, heavy quarks, technicolor, signs of a quark-gluon plasma, and new unexpected objects.

The physics of DØ will complement the data now being taken by the CDF detector. The DØ detector was designed after CDF. It is more hermetic and should be able to measure complete events with fewer particles missing in dead regions. It also has better hadronic energy resolution than CDF because of its uranium-liquid argon calorimeter. 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 larger and the kaon decay background and pion punch through are less than for CDF. Although the CDF central detector is better able to measure particles with energy below 20 GeV, the ease of calibration and better resolution of the liquid-argon-uranium gives DØ better energy measurement for high-p_T electrons. While CDF is an excellent detector of low energy particles due to its central magnetic field, DØ will allow cleaner recognition of jet properties without the distortion introduced by a magnetic field. The DØ detector should excel at several types of physics including (a)semileptonic decays of heavy states (bottom and top) which require a combination of full 4π lepton identification, excellent missing p_T resolution, and good jet discrimination; (b) precision W-Z measurements requiring stable and systematic-free calorimetry; (c) measurements of high p_T single photons through the fine calorimeter segmentation; and (d) searches for a variety of new states (SUSY particles, technicolor objects, new quark generations, and heavy bosons) which require finding events with a mixture of jets, leptons and missing p_T.

During the past 5 years, our participation in DØ increased from one person to four Ph.D.'s from the FSU High Energy group, two SCRI Ph.D's, one programmer, two students and three part-time technical support personnel. In August an additional Assistant Professor, John Womersley, who is already a DØ collaborator, will be joining our group and we are recruiting a postdoc to be stationed at Fermilab, working on DØ. During this period, our group has contributed to the design and construction of DØ in both hardware and software. Our hardware responsibilities were mainly in the area of calibration, testing and quality control of the uranium calorimeter modules, and machining pieces for the modules. In software we were responsible in the areas of graphics, Monte Carlo and test beam analysis.

Early work on DØ included a track reconstruction program written by H. Goldman to help design muon proportional tubes. From May through August of 1986, H. Wahl and two FSU students worked at BNL on assembling and testing the prototype steel calorimeter module and the first full size prototype module made of depleted uranium, as well as the development of testing and quality control procedures. One of the students, E. Scime, continued working on this project, completed the impurity measurements of liquid Argon and wrote it up for his senior year research project.

One main focus of FSU's effort in DØ has been the testing and calibration of calorimeter modules in the NWA test beam at Fermilab. The test and calibration beam was the responsibility of FSU, BNL and Univ. of Rochester, with contributions from FNAL, MSU, NYU and Univ. of Florida collaborators. This included 4 senior physicists, 2 post-docs and 2 graduate students and taking over 30 shifts per week for the 7 month run from August 1987 thru mid-February, 1988. A paper based on analysis of this data has been accepted for publication by N.I.M.

FSU's contribution included working on the organization, installation, setting-up, data-taking and doing software development and analysis of the data. H. Wahl was in charge of the DØ test beam program from Feb. 1986 - May 1988. H. Piekarz has been stationed at Fermilab since June, 1987, and has worked full-time on the test beam. H. Wahl and two graduate students spent the summer of 1987 at Fermilab working on the installation of the test setup. This included work on a

Faraday cage, the cryostat, bathtub, supports for the modules, cabling for the electronics and beam line instrumentation. H. Piekarz made a special contribution in the design and implementation of the air pad system to rotate the test beam cryostat. F.S.U. took approximately 1/3 of the total number of shifts during the DØ test beam data-taking.

H.Piekarz also assumed responsibility for argon loading into the test beam cryostat and made crucial contributions to the liquid argon purity monitoring. These accurate oxygen contamination measurements gave important input to the models attempting to understand the "discharge" effect of the modules.

After the 1987-1988 test beam run, the NWA setup was modified by H. Piekarz to allow studies of how additives to liquid Argon (SF6 and allene) could help solve the discharge and current draw problem in calorimeter modules. These studies have continued during the past year. Results are encouraging and further studies will be made during the 1990 testbeam run.

FSU also made important contributions to the software effort for the test beam. S. Hagopian made special module displays and LEGO plots for the five central calorimeter EM modules, the end cap medium hadronic module and the central calorimeter fine hadronic modules. S. Youssef wrote CAMAC and PWC unpacking, tracking and display programs which were used to determine the beam position relative to the calorimeter modules. S. Linn worked on a cabling system for the five central calorimeter EM modules and incorporated this system into unscrambling routines to obtain the correspondence between read-out labels and physics variables. He also wrote matching routines to scramble the Monte Carlo data. S. Linn did Monte Carlo simulations of the test beam using the SCRI Cyber 205. S. Linn also worked on off-line analysis of the test beam data. He did studies of the uniformity of response and energy loss in the crack between two EM modules. This work was summarized in a *DØ* seminar given by S. Linn at Fermilab in May, 1988. S. Youssef is working on the MC4 vectorized Monte Carlo and has been granted time on the ETA-10 to do a high statistics simulation of the DØ test beam calorimeter. Chris Georgiopoulos and Martyn Corden are working on vectorizing GEANT, the CERN Monte Carlo program, which will be of use for many experiments including DØ.

Sharon Hagopian was in charge of the group which designed and developed the 2-D version of the DØ event display of the final detector and data, which was released in February, 1989. This contains 2-D views of each sub-detector system (VTX,TRD,CDC,CAL.,MUO) and a combined R-PHI view of VTX+TRD+CDC detectors and tracks, as well as LEGO plots. Tami Kramer worked as a FSU programmer on prototypes of the event display program with S. Hagopian from May, 1986 until May, 1987, when she was hired by DØ group at Northern Illinois University as an Assistant Research Scientist. Guadalupe Rosas, a FSU Computer Science student, has been working on the DØ display since May 1988. Also working on the DØ event display were Olivier Callot, SUNY, J. Bantly, Northern Illinois University and Mike Peters, University of Hawaii. Current work is concentrated on a 3-D view of the detector. It will use standard DI3000 calls and so is nominally "device independent", but is being initially optimized for the Evans and Sutherland terminal with 3-D rotation hardware.

FSU contributed to the calorimeter hardware effort by machining parts for central calorimeter modules. In the period July 1985 - February 1989, FSU machined 2,400 spacers and 1,300 end plates and other parts. This corresponds to over 3,300 hours of machine shop time on our numerically controlled milling machine. A part-time student was hired to work on this to assist the FSU funded machinist.

FSU built two sets of uranium plate quality control templates which were designed to measure and check the dimensions and notches of the uranium plates, as well as a computerized uranium thickness measuring table, which uses ultrasound probes. The thickness measuring unit was shipped to BNL in August, 1987. The templates are now being used by MSC in Oak Ridge and Brookhaven National Laboratory. It was used there until January, 1988 when it was sent to LBL, where it is being used to measure both uranium plates and read-out boards.

Both H. Wahl and H. Piekarz are working on the new DØ test beam setup, which is to be implemented for the next fixed target run. Planning for this has been going on for a long time, but was pursued with lower priority during of the 1987-1988 fixed target running period. H. Piekarz has organized weekly planning meetings for the new test beam facility and is now in charge of the construction and installation of the transporter and the loading system. The new transporter arrived at NWA in early March, 1989. The complete system is expected to be operational by late 1989. The next Fermilab DØ testbeam run is scheduled to begin in January, 1990. H. Wahl and two graduate students spent the summer of 1988 at Fermilab, participating in the planning of the new test beam setup, the testing of calorimeter modules, and the analysis of the previous test beam results. H. Wahl gave a report on the DØ test beam results at the $\bar{p}p$ Workshop at Fermilab in June, 1988. H. Wahl and two FSU graduate students are spending the summer of 1989 at Fermilab helping test end cap modules in a special cryostat and assisting in calorimeter module installation tests in DØ hall.

The FSU D0 group is especially interested in the physics accompanying direct photon production, which can be used in tests of QCD and as a signal for new physics such as supersymmetric particle production. (See review paper by J. Owens, Rev. Mod. Phys. 59, 465,1987). The FSU experimental group has expertise in the building and calibration of electromagnetic calorimeters and in the Monte Carlo simulation and analysis of electromagnetic showers. Direct photon production will be the thesis topic of one of our graduate students, D. Wilkinson. The first collider run for DØ is scheduled to begin in January, 1991.

2. CERN LEP - ALEPH

The past year has seen the final preparations of the ALEPH detector for the scheduled data taking this coming summer and fall. In this effort the FSU HEP Group has been involved in the mechanical installation of the Hadron Calorimeter (Hcal), the development of the online data acquisition software, the offline reconstruction and Monte Carlo simulations, and the offline interactive computing analysis system. In the upcoming year, we anticipate a "check out" run in late summer, the first data run in the fall, and a second run next spring.

Being based at FSU, it is clear that the group's effort should concentrate on software and computer related topics. In particular, our experience with supercomputers suggested an emphasis on optimizing ALEPH's use of the Cray and ETA supercomputers to which the collaboration has access. The first part of this was to get the suite of ALEPH (and CERN) software running on these machines. This was first done on the ETA-10 at FSU, thereby enabling us also to understand the 32 bit to 64 bit changes required for the Cray. For example, the memory manager BOS implicitly assumes a 32 bit architecture throughout, and an identical internal machine representation of real, integer and machine zero, which are not valid assumptions on ETA and Cray machines.

One of the essential ingredients to understand the quality of reconstruction and analysis software is a good three dimensional display of the detector and the event by event data. This allows immediate detection of errors by simply viewing simulations and their reconstruction. J. Streets has written a display program for the Silicon Graphics Iris 3020 workstation, accessible to us at FSU. It is written using the native Silicon Graphics display calls. As these are similar to the imminently available PHIG's graphics standard, we will have with a little modification, a graphics package that will be transportable to all high end graphics workstations. As Dr. Streets is leaving FSU to take a position at FNAL, we will seek a replacement to finish this task. With the upcoming run, we would like the new post doc to be resident at CERN for the next year or so.

Having established a working software environment, we then turned to rewriting the most time consuming part of the ALEPH offline software for vector pipeline computer architecture.

As ALEPH's primary tracking device is a TPC, the pattern recognition is not a major difficulty in regards to required computing capacity. In fact the data reconstruction will be done as part of the online system. The largest computing requirement will be due to the need for simulation. This is the area in which most of the group's efforts have been focused.

In e^+e^- interactions the underlying physical processes are well understood and can be simulated with great precision, considerably more reliably than in hadronic processes. Given the statistical significance of the anticipated LEP data sample, with many physical parameters measured with statistical accuracies of 10^{-3}, physics results will be limited by systematic errors. The minimization and determination of these systematic uncertainties will rely almost entirely on the precision of the experimental simulation.

The detailed simulation of the TPC (TPCSIM) has been the most time consuming part of the detector simulation. This code followed the individual electrons liberated in the gas, tracked them to the TPC end plates, determined the individual electron responses and then summed the responses. This procedure was able to reproduce the data from the TPC prototype with remarkable precision. As the TPC is intrinsically an analog device this detail is necessary for understanding the overlap and merging of the ionization from multiple tracks (particularly for K^o_s and Λ^o). There is an inherent long vector in the problem being the list of liberated electrons. By vectorizing the calculation over this list the simulation time per Z^o decay event was reduced from 30 minutes on a VAX 11/780 to 15 seconds on a single processor of the Cray XMP/48 at CERN. At this speed ALEPH can consider having large data samples ($>$ 100K events) with the full simulation. We have already generated 10K events on the ETA-10 and the "data" is being used to study the reconstruction with what had been an unreachable data sample.

To understand our data to the maximum extent, ALEPH needs a second independent simulation and one which is fast enough to generate hundreds of thousands of events overnight. This will be a particularly important part of tuning the fragmentation simulation of the event generators in order to get correct fragmentation functions and correctly simulated physics.

Over the past two years several fast simulations have been developed, always improving the level of precision. In the summer of 1988 the FSU and Wisconsin groups jointly undertook the task of writing a very fast simulation which could generate input for the reconstruction program. This would enable the simulated data sample to have all the biases introduced by the reconstruction directly, rather than trying to introduce these biases by guessed parameterizations. The division of labor was that the Wisconsin group would write the particle tracking up to the calorimeter surface by modifying a previous fast simulation, adding many improvements (including interactions in the detectors) and FSU would write a vectorized calorimetry code based on the techniques developed for the E711 simulation. At the current time the tracking code is finished and the calorimetry is undergoing its final polishing. Pieces of the calorimeter code (the electromagnetic shower part) have been moved onto the Cray with speed up factors of seven attained. Based on the current timing's we expect this code to be twice as fast as the reconstruction program when both are run on the Cray (the intended target machine) with the total taking approximately 1.5 seconds/event/processor. Both of these simulation codes (TPCSIM and FASCAL) have been described at computing summer schools and conferences.

As the FSU group was the first in ALEPH to explore the use of workstations for physics analysis we were given responsibility for the ALEPH workstation system at CERN. Over the past year the system has been designed and a large number of the components purchased and installed at CERN. The system will be a collection of VAX clusters connected by ethernet and LAN bridges to isolate the ethernet traffic. The collaboration requested that we supply the system manager so the post doc slated for the online work was moved to run the system. FSU has contributed to this common analysis system 2 VS3500 boot nodes, 2 file servers (VS 3200) and 3 disk drives (1 GB CDC Saber 1230). This equipment was bought with NSF funding. The preliminary tests and optimization of the I/O capabilities of all the devices have been conducted by FSU personnel (J.H. Goldman, D. Levinthal) as well as the bandwidth of network access to the CERN central IBM system.

The number of people in residence will rise rapidly with the upcoming run this summer, particularly M. Ikeda and the replacement of J. Streets who will be running the VAX clusters and D. Levinthal who will be on sabbatical at CERN next year. The two people that have been there have been involved in the development of the online data acquisition software (L. Sawyer) and the installation of the Hadron Calorimeter (W. Burley). We could not afford to pay the travel expenses for W. Burley. However, the Italian groups, responsible for the HCAL, were very grateful for this assistance and covered the lacking travel funds while NSF paid the base salary. This arrangement had an enormous impact on the timely completion and installation of a working system.

The online software in ALEPH is extremely complex due to the large number of readout channels and their associated microprocessors. The monitoring of these devices and logging of their operation is critical to insure high data quality. FSU has been involved with the online system group for several years, supplying equipment and effort. L. Sawyer has written the electronic logbook and the data base interface for identifying non-functioning components of the system. The logbook will also be used in the offline workstation environment to provide each physicist with an automated record for analysis, comments and data plots.

With the commissioning of LEP we enter a new phase of our involvement in ALEPH. Our efforts will be focused on the extraction of results from the collected data. We intend to migrate this concentration to reflect the statistical significance of the increasing data sample.

The first data run this fall is expected to collect between 50K and 250K events. With this data sample we will participate in the work on the Z^o line shape (mass and width), the couplings to the upper and lower components of hadronic isospin doublets (lepton P_T spectrum), forward backward asymmetries of hadronic events, and measurement of the fragmentation process.

As the FSU group is geographically isolated from the rest of the ALEPH collaboration, the subjects we work on and the division of labor must deal with the difficulty of travel and the intensity of the competition between the four LEP experiments. The optimization of the line shape study is something we have worked on over the last several years and we will continue this work through the people who will be in residence at CERN. Similarly, the coupling constant work will likely be done at CERN, given the high interest and basic nature of these measurements. The hadronic asymmetry and fragmentation studies are coupled and require a much more delicate understanding of the complicated hadronization process. The asymmetry depends on the ability to determine the quark charge from the charges of the observed hadrons, and that the summed asymmetry of the five quark flavors is non-zero. The quark charge tagging can be checked at some level by making two measurements per event and looking at the ratio of opposite to same charges for two jets events, but the reliability and optimization of the tagging method will rely heavily on the simulation.

One of the main reasons for writing the fast simulation is to be able to optimize the parameters of the hadronization process in the generating Monte Carlo. We expect to continue in this effort as data materializes and the tuning of the generators proceeds to ensure that it correctly describes our data. This fast simulation will allow us to quickly arrive at an optimized generator so that the fully detailed simulation can be run in production with some assurance that the input is correct.

This procedure will also lead to an extremely high statistics determination of the fragmentation functions at the highest value of Q^2 to date. We hope to be able to see the Q^2 violations of the fragmentation functions (Altarelli-Parisi, Owens, Utematsu) at large z (z>.8) by comparing the LEP data with the PEP data at lower energy. To date a direct verification of the scaling violations in fragmentation (visible at large z so as to be distinct from mass effects) has been unreachable (as opposed to structure functions where they are well established).

In the second run planned for early 1990 the anticipated event sample should rise to over $10^6 Z^o$. In addition ALEPH will have installed its silicon strip micro vertex detector. We expect to use this data sample to study the b-quark system. The size of the data sample will allow accurate determination of the mixing matrix parameters and $B^o\overline{B}^o$ mixing. We will continue our fragmentation studies with work on the b-quark fragmentation measurement. The large data sample and vertex detection will allow a unique insight into both the electroweak and hadronic physics of heavy quarks.

C. Completed Fixed Target Experiments

We discuss only the experiments where our contribution was substantial.

1. π^+p and γp Interactions Using the SLAC Hybrid Bubble Chamber Facility

Data were obtained in the late 1970's and early 1980's. The analysis of these data yielded many interesting physics results. During the past five years several papers were published which are listed below.

a. Study of the $\rho'(1600)$ Mass Region Using $\gamma p \to \pi^+\pi^- p$ at 20 GeV/c. The $\rho'(1600)$ was produced in this experiment and its properties were investigated. Phys. Rev. Lett. **53**, 751 (1984).

b. Triggered Bubble Chamber Study of the Reaction $\pi^+p \to \Delta^{++}\pi^o\pi^o$ at 16 GeV/c. The neutral $\pi^o\pi^o$ has no ρ (770) contamination and the s-wave was calculated. The contribution of the s-wave is substantial. Phys. Rev. D1, **32**, 1061 (1985).

c. Inclusive Photoproduction of Strange Baryons at 20 GeV. Copious amounts of strange baryons were produced and studied. Phys. Rev. D1 **32**, 2869 (1985).

d. Test of s-Channel Helicity Conservation in inelastic ρ^o Diffraction in 20 GeV Photoproduction. Phys. Rev. D1 **32**, 2288 (1985).

e. ρ and ω Production in π^+p Interactions at 15.7 GeV/c. ρ and ω interference was studied in this experiment. Phys. Rev. D1 **36**, 1961 (1987).

2. K^-p and $\bar{p}p \to K^+X^-$ Interactions Using the BNL Multi-Particle Spectrometer.

This experiment was our first MPS experiment, for which we built a K^+ detector. Most of the data reduction and analysis of the part of the data that used the K^+ detector was done at FSU. The two papers published in this five year period were:

a. Search for Narrow States with Baryon Number Zero and Strangeness -1 in $\bar{p}p \to K^+X^-$. We searched unsuccessfully for narrow states. These states are similar to baryonia, i.e. they could be four quark states. Phys. Rev. D1 **30**, 1409 (1984).

b. Measurement of Decay Parameters and Polarization in Inclusive Cascade Production from K^-p Interactions. The polarization and decay parameters were determined from a very large sample of cascade events. Nuc. Phys. **B252**, 561 (1985).

3. E580 A Study of $K^oK^o, \Lambda\bar{\Lambda}, K^oK^on\pi, \Lambda\bar{\Lambda}n\pi$ and $K^o\Lambda$ ($\bar{\Lambda}$) $n\pi$ Production in π^- p Interaction at 200 GeV/c

This "double-vee" search for resonances was approved in 1978 and ran in early 1980. For reasons out of our control, we received only one-tenth of our approved integrated beam intensity and that was at a lower energy (200 GeV instead of 300 GeV). However, even at the much lower level of statistics available, much interesting physics has been gleaned from the data and eight publications have resulted.

This experiment was performed in collaboration with physicists at Fermilab and the universities of Arizona, Notre Dame, Tufts, Vanderbilt, and Virginia Tech. A member of our group was the spokesman. The trigger for the experiment was (1) a definite number (0,1,2,...n) of charged tracks leaving the target and (2) the appearance downstream of four additional tracks, from the decays of the two V's. We recorded 1.45 x 10^6 raw triggers. Data reduction through kinematics were completed and data summary tapes (DST's) were distributed to all collaborators.

Eight papers have been published from this experiment's data out of which five were in this five year reporting period. In addition, six ten-minute talks have been given on these data. Topics included, inclusive cross sections and momentum distributions for single V and double V production and comparisons to QCD counting rules. Baryon production and decay into strange particle final states was also studied. Three students, J. Piper from F.S.U., S. Mikocki from V.P.I., and R. Joyner from Notre Dame, have received Ph.D.'s from this experiment.

E-580 has officially ended. It has been a productive experiment in terms of bread-and-butter physics, but could have produced much more significant results, especially on charm production, if it had received the requested luminosity instead of 1/10 the amount.

The papers published in this reporting period are:

a. $K^{*\pm}$ (892) Production in π^-N Interactions at 200 GeV. Phys. Lett. **152B**, 428 (1985).

b. Forward $K_s^oK_s^o$ Production in 200 GeV π^-N Interactions. Phys. Rev. D1 **30**, 877 (1985).

c. Baryon Production and Decay Into Strange Particle Final States in 200 GeV π^-N Interactions. Phys. Rev. D1, **30**, 872 (1984).

d. Inclusive Strange Particle Production in Single-Vee Events in 200 GeV π^-N Interactions. Phys. Rev. D1 **34**, 42 (1986).

e. Diffractive Productions of $\pi^-\pi^-\pi^+$ by 200 GeV π^-N Interactions. Phys. Rev. D1, **39**, 1865 (1989).

4. E557/672 - High Transverse Momentum Jets

E557/672 is an experiment to study "jets" using wide angle calorimeter triggers. Data was taken in 1984 with the following triggers: dimuons, global, single particle, high multiplicity and collimated beam jet. Targets used include Be, Al, Cu, Pb and liquid hydrogen. Some minimum bias (interacting beam trigger) data were taken for cross-section normalization and low p_T physics. Over 2 x 10^6 triggers were recorded. Our contribution to this experiment was during setting up, data taking and reduction. Two students from Indiana University have received Ph.D.'s from this experiment. Analysis done on the measurement of the A-dependence of high-E_T events and jet production, has resulted in a Phys. Rev. article. Theoretical predictions for the A dependence for hard scattering give α near 1, since it should be proportional to the number of constituents within the nucleus. Corrections due to the structure of the nucleus, Fermi motion and jet rescattering increased the predicted value to 1.1 or 1.2. This experiment is the most direct measurement of the A dependence of a hard-scattering cross section at that time. The value of α for the production of jetlike events approached 1.1 $\pm$ 0.1 for the E557 data, in agreement with these predictions.

Paper Published:

Measurement of the Nuclear Enhancement in high-E_t and Jet Event Production, Phys. Rev. D1 **35**, 2736 (1987).

5. E623 - A Study of $\phi\phi, \phi K^+K^-, \phi\pi^\pm, \phi K^\pm, K^*, K^*\overline{K}^*$ and ϕK^* Final States in 400 GeV/c pN Interactions

$\phi\phi$ spectroscopy is a good way to search for high mass states, since the experimental backgrounds are reduced due to the narrowness of the ϕ state, and the uncorrelated production of the $\phi\phi$'s in hadronic interactions is inhibited by the O.Z.I. rule. Also, of course, $\phi\phi$ states must have I = 0.

A test was done in April 1981, consisting of 20,000 triggers of the type pN $\rightarrow K^+K^-K^+K^-X$ where X had a forward charge multiplicity of less than 6. A trigger processor selected low mass (in the bend plane) K^+K^- pairs and was extensively debugged during this test run. For the four-week data run in May-June 1982, modifications were made to the Fast Trigger Processor which improved the trigger purity by an order of magnitude. We upgraded the hardware rate capabilities by replacing the spark chambers with drift chambers. With these upgrades, the average flux that could be handled was increased to 3 x 10^6 / spill, a factor of 5 improvement over the test run.

We collected 3 x 10^6 $\phi\phi$ triggers (4 x 10^6 total triggers, adding in the $\phi KK, \phi$ and monitor triggers). After the completion of the data collection, it was decided to write a completely new pattern recognition (track reconstruction) program for the VAX computer (now called "FLOWERS", written by Harvey Goldman at Florida State University). The "FLOWERS" program was checked on Monte Carlo generated events (where multiple coulomb scattering, measured chamber inefficiencies and resolutions, etc., were taken into account) and found to be efficient (90% probability of reconstructing a track whose momentum is < 25 GeV/c) and measured good mass resolution (FWHM of the ϕ being ~ 8 MeV/c^2). The data was processed on VAX-11/780 computers available to the collaboration at FSU, Tufts and Vanderbilt (50% at FSU and 25% each at Tufts and Vanderbilt). All of the post-pattern recognition processing, to be described next, was performed on the VAX-11/780 at FSU.

The final phase of the data-reducing process was to identify the track as π's, K's, or protons (where possible) using the information from the 30-cell Cerenkov counter downstream of the bending magnet (π threshold at 5.7 GeV/c and $K^{\pm}$ threshold at 21 GeV/c. The data reduction was completed and data summary tapes distributed to collaborators by March 1984.

The data sample contains 18,000 single ϕ events, 1,200 ϕK^+K- events, and 300 $\phi\phi$ events. At FSU we have concentrated our efforts on studying the $\phi\phi$, and ϕKK channels while Tufts and FNAL are concentrating on the $\phi\pi, \phi\pi\pi$, etc. events. Virginia Tech is concentrating on the $\phi K\pi$ final state, and Vanderbilt University is concentrating on $K^+, \overline{K}^*, K^*\overline{K}^*$, etc.

We have published four papers on this experiment, all during the past five years. In addition, talks have been presented at the 1985 Spring APS meeting (BF-6: Study of the Reaction $pN \rightarrow K^*\overline{K}^o\pi X$ at 400 GeV/c) and at the XVI International Symposium on Multiparticle Dynamics, Kiryat Anavim, Israel, June 1985 (Recent results on $\phi\phi$, ϕKK, and $\phi\pi\pi$ from 400 GeV/c pN interactions). Four graduate students received their Ph.D.'s from work on this experiment (one from FSU). The first paper published described the observation of the Cabibbo suppressed decay $D^{\pm} \rightarrow \phi\pi^{\pm}$ (Physics Letters 152B, 428 (March 1985). Chris Georgiopoulos presently at FSU (SCRI) wrote his Ph.D. dissertation on this topic and graduated from Tufts in 1985.

Forest Davenport received his Ph.D. degree from FSU, writing his dissertation on the study of the $\phi\phi$ final state. He obtained a value of 0.84 ± 0.27 μb for the total inclusive $\phi\phi$ cross section at 400 GeV/c. He also obtained a 99.7% upper limit on the cross section $\sigma(pN \rightarrow \eta_c + X) < 3.75\mu b$. This is about a factor of four higher than the prediction from the gluon fusion model of Einhorn and Ellis using the gluon distribution functions of Duke and Owens. Nevertheless, this is the closest that data has come to the predicted cross section curve. A paper was published (Phys. Rev. D **33**, 2519, (May 1986)) summarizing his results.

In both the ϕK^+K^- and the $\phi\pi^+\pi^-$ final states, a narrow resonance is observed at 2.14 GeV/c. The relative branching ratio is unusually large: $B(M \rightarrow \phi K^+K^-)/B(M \rightarrow \phi\pi^+\pi^-) = 0.49 \pm 0.16$. This leads to the suspicion that we may be seeing a "glueball" state rather than an ordinary $q\bar{q}$ meson. A paper has been published (Phys. Rev. Letters **56**, 1639 (April 1986)) reporting these results.

In the $\phi K^{\pm}\pi^{\mp}$ state we observed K^{o*} (2060) decays. Across section times branching ratio of 400 $\pm$ 100 nb was measured. Sergio Torres has received his Ph.D. from Virginia Tech, writing his dissertation on the study of this final state. We have published a paper describing these results (Phys. Rev. D, **34** 707 (Aug. 1986).

D. Miscellaneous Projects

1. GEANT on Vector Computer

The FSU HEP and SCRI (Supercomputer Computations Research Institute) groups have for the past several years been jointly working on several projects to make use of vector supercomputers (e.g. the ETA-10 at FSU and the CRAY XMP 48 at CERN) for experimental HEP analysis. This joint project has been extremely successful and will certainly continue for the forseeable future.

The FNAL E711 data has been analysed using the CYBER 205 and ETA 10 supercomputers at FSU. The processing program makes use of vector algorithms described in several published papers we have published (Nulc. Inst and Methods A **249**, 451 (Sept 1986), Nucl. Inst. and Methods A **261**, 493 (1987), Asilomar Conference on High Energy Computing, Computer Physics Communications (1987)) to reconstruct and then fit the charged particle trajectories through the E711 drift chamber spectrometer. Without the speed of the vector algorithm on the supercomputers (over 200 events reconstructed in the time that a VAX-11/780 could reconstruct one event) we would never have been able to process all of the 500 raw data tapes (corresponding to about 3 x 10^7 triggers).

Work has also been progressing on vectorizing Monte Carlo programs for use on diverse supercomputers. A very fast vectorized Monte Carlo calorimeter shower algorithm was written for E711, to allow us to calculate the experimental acceptances versus various parameters, fiducial volume cuts, etc.. This developmental work has been carried over to the Monte Carlo shower generation for the LEP ALEPH experiment where it is now being employed on the CRAY XMP 48 computer at CERN as well as on the FSU supercomputers.

Work has also been progressing on vectorizing the CERN GEANT Monte Carlo program, with speed-ups ranging from a factor of three to a factor of ten depending upon the physics interaction being studied. The CERN DD division is committed to support the vectorized version of this code. During February of this year, 10,000 full blown GEANT Monte Carlo events were generated for the LEP ALEPH experiment on the FSU ETA-10 and delivered to CERN. This represents and order of magnitude improvement over what had been done up until that time.

The SCRI High Energy Physicists organized a three day school at FSU on Vectorization for Experimental High Energy Physics (June 1988). This meeting was attended by approximately sixty physicists. David Levinthal gave one of the talks, describing the successes with vectorization for the analysis of Fermilab experiment 711.

2. COMPUTING, NETWORKING and VAX UPGRADE

The High Energy Physics group has a dedicated VAX-11/780 which was ordered in 1980 and delivered in 1981. In 1985, with the help of SCRI, the disk units were upgraded from 380 megabytes to 1400 megabytes and the CPU memory was also doubled. This computer today serves as the boot node for a 10 node Local Area VAX Cluster (LAVC). The cluster satellite nodes (seven VAXstation 2000's, one VAXstation 3200, and one MicroVAX II) provide additional CPU power, but at this point we have saturated the capacities of both the boot node (VAX 11/780) to run the cluster and the CPU power in the entire cluster. With the two collider experiments (ALEPH at CERN and D0 at Fermilab) coming on line, with ALEPH taking data this fall, our needs for computing power and disk storage will increase dramatically. The computational needs of the theory group have also risen rapidly as they use the system to simulate collider experiments (both present and future) as well as perform phenomenological calculations.

At the end of 1988, U.S. DOE and Florida State University agreed to contribute $ 150,000 each to upgrade our aging VAX 11/780. (The DOE share is funded over three years, starting in 1989). After evaluating various systems, including the VAX 6000 series, it was decided to purchase a cluster system that will have the CPU power of about 60 VAX 11/780's and over 12 GByte of disk space. To overcome the problem of saturated networking, 11 VAX 3200 were ordered each to have its own 1 GByte disk. In addition, we have ordered 8 PVAXes for individual use and the Dual VAX 3400 as the boot node. Below we will compare the various computers:

I. Comparison of various VAX computers (I/O speeds are in Megabytes/sec, and CPU speeds are relative to the VAX-11/780):

Computer	CPU speed	BUS	BUS speed	controller speeds disk	Ethernet	Disk I/O's per second
VAX-11/780	1	UNIBUS	1.4	0.34	0.11	25
VAX 3100	3	SCSI	0.4			
VAX 3200	3	Q-BUS	3.3	0.80	0.20	30
VAX 3400	2.5	Q-BUS	3.3	0.80	0.20	30
		DSSI	4.0		0.20	30

II. The present system consists of the following components:

1) One (1) VAX 11/780 with 1400 MByte of disk

2) Six (6) VAX 2000 Interactive Workstations, 1 for Task B.

3) One (1) VAX 3200 Purchased by non-DOE funds by D. Levinthal

4) One (1) MicroVAX II

III. Proposed new LAVC configuration:

a)	dual	VAX 3400	(dual boot nodes for LAVC)
b)	11	VAX 3200	(Batch Engine for I/O intensive jobs)
c)	8	VAX 3100	(interactive workstations)
d)	5	VAX 2000	(interactive workstations)
e)	2	VAX 2000	(interactive workstations, task B)
f)	1	VAX 3100	(interactive workstations, Physics Dept.)
g)	12	SABRE disks	(12.7 gigabytes) (data base disks)

a) Dual boot nodes, each has two 400 megabyte disks, a "system" disk and a "Products" disk (CERN library DI-3000, etc). Each disk has its own controller, thus doubling disk I/O bandwidth.

b) Batch engine, with "data base" 1 GByte disks (2 to 4 gigabytes per CPU eventually). One of the VAX 3200's will have the "user" disk (an extra 1 gigabyte CDC SABRE disk).

c) User 3 Mips Workstations, each has a local 105 megabyte disk.

d) User 1 Mips Workstations, each has a local 70 megabyte disk.

g) Each 1.06 GB disk to be installed on a VAX 3200.

IV. Details of the VAX 3400:

a) the Ethernet controller sits on the 13 MB/sec (same speed as BI-BUS) CVAX memory bus.

b) the two "system" disk controllers sit on the 4 MB/sec DSSI Bus.

c) Other peripherals sit on the 3.3 MB/sec Q-BUS

V. Advantages of the new system:

a) The CPU power driving the "system" + "products" + "user" disks is 8 Mips, 8 times better than the present VAX-11/780 based system.

b) The I/O rate to "system" + "products" + "user" disk is 90 I/O requests per second. This is 3.6 times better than the present system limit of 25.

c) The I/O rate to "system" + "products" + "user" disk through Ethernet is 240 I/O requests/sec, 5.3 times better than the present limitation of 45 I/O's /sec. In most cases this is not an issue, since the bottleneck is still (b)

d) Jobs accessing local disks can transfer data at 0.8 MBytes/sec/disk. Jobs running on the CPU's with "data base" disks (the VAX 3200's) could each read or write each of the 1

GByte disks simultaneously in about 20 minutes (I/O time only). By reading two disks simultaneously, the I/O rate can be raised to 1.1 MBytes/sec/CPU.

V. Examples of LAVC use:

a) A collider experiment can expect to run for 10^7 sec/year and collect data at the rate of one event per second. Running at 50% efficiency yields 0.5 x 10^7 events/year. After reconstruction and some filtering (e.g. to remove obvious beam-gas interactions) one expects a data base of about 0.25 x 10^7 events. The goal is to go through this data base at the rate of 50 events/sec/CPU, then it would take 7 CPU hours to analyse. Using 10 CPU's in parallel one could analyse the entire data base in about 45 minutes (real time). What about the I/O? The event size can be expected to be of order 2000 bytes, so the data base is 5 gigabytes. Put onto 10 one gigabyte disks, each accessed at 0.8 MB/sec, the data base can be read in about 10 min. The event data base files can be constructed so that each physical record is of order 30000 bytes (we did that for E-711), then 0.8 MB/sec is also 27 I/O requests/sec, near the limit that the individual disks can provide (but 50 events/sec is only about 10^5 bytes, so there will be no real strain on the I/O capabilities of the local disks).

b) Further filtering on the data base in example (a) (trigger selection, event topology, the presence of electrons, muons, etc.) might reduce the data base by another factor of five. By placing the data base onto all the local disks, 50 MB/disk, and run parallel batch jobs on 20 CPU's, at the analysis rate of 50 events/sec/CPU, one goes through the entire data base in under 10 minutes. An I/O rate near 0.8 MB/sec would require only about 1.5 minutes to read the data base. Since typically these types of jobs are run many times, it is important that they run as fast as possible in real time.

c) Monte Carlo jobs are very common these days, in both the experimental and theoretical groups. Monte Carlo jobs basically require a large infinite amount of CPU, so presumably the more CPU power you have the better you can do. The HEP LAVC isn't meant to be competitive with doing calculations on a supercomputer. Nevertheless it is important to note that a 60 Mips cluster represents (roughly, these numbers never translate in precisely defined terms) over 10 MegaFLOPS, which is quite respectable, even by today's standards.

VI. Other Computing and Networking

In addition to the VAX Cluster, the group has a MicroVAX II and a Macintosh (the latter funded by FSU) dedicated to on-line data gathering by CAMAC crates. We have acquired, over the years, key CAMAC units and use these systems for detector development and prototyping.

The campus has several computers that are also used by the high energy physics group. The campus computers are CDC CYBER 850, ETA CYBER 205 and ETA 10. We used the supercomputers for data reduction of FNAL E711 experiment and Monte Carlo generation of events for the E711 experiment. We are also using the supercomputers for GEANT Monte Carlo to simulate both CERN LEP ALEPH and FNAL D0 experiments. The campus computers are also used by the theorists to perform unique computations, such as those using SCHOONSCHIP.

Two years ago, worldwide networking was achieved through the efforts of SCRI and that now connects us to FERMILAB via a 56 Kbaud optical fiber line and then to CERN. The connection between Fermilab and CERN was paid for by FSU-SCRI. The connection to HEPNET has been crucial for our program development of D0 and ALEPH experiments.

3. SSC Preparation, Detector Development and Detector Construction

In the past the detector development concentrated for the fixed target experiments at Fermilab and BNL. Now that data taking of those experiments is over, our efforts concentrate in building FNAL *DØ* collider parts (over 3500 parts built) and in developing and prototyping unique parts for collider detectors with the future emphasis being on the SSC calorimetry. Over the years we have collected specialized tools and electronics that is now our detector development and prototyping laboratory. We now have a modest amount of hardware for the design, prototyping and testing of various equipment. The hardware includes:

1. MicroVAX II with CAMAC interface and software
2. Macintosh II with CAMAC interface and software
3. CAMAC crate with about ten CAMAC boards, including ADC, TDC, scalers, etc
4. Two NIM crates and about 15 NIM units, including discriminators, coincidence units, scalers, etc.
5. Lecroy high voltage power supply.
6. High speed oscilloscope.

7. Spectrophotometer.
8. Phototubes, bases, shields, some scintillators, etc.
9. CAD/CAM system for PC board layout.

We have a clean room where some of our development work takes place. The detector development program has enabled us, not only to build parts for experiments, but also train graduate students in fast electronics. In the past we constructed a uranium thickness measuring machine that uses ultrasonic waves to measure the thickness. This unit, that is driven by an IBM PC, is now at LBL measuring the uranium plates for the FNAL D0 calorimeter. During the past we also completed the design of the front-end electronics preamplifiers for the E711 drift chambers that has high gain and stability. Our machine shop has one numerical control milling machine and a second one on order to be delivered in October 1989. We have a CAD/CAM system that loads the program to the numerical control milling machine directly. This unit was used extensively to build the $D\emptyset$ parts.

During the past five years, the high energy physics group has expended considerable effort in support of the SSC. This effort has been quite diverse, from phenomenological calculations, to participation of workshops, political support, detector development, preparing a State of Florida proposal, etc. During the past five years several papers were written and some published in various proceedings. In March 1989, several members of our group participated in the second Workshop of SSC Calorimetry, and contributed to the design of the liquid argon, very small scintillator pad type and Zeus type scintillator/uranium calorimeter workgroups. Our group also started research efforts on the radiation damage of plastic scintillators and FITCAL, the small scintillator pad calorimeter modules.

Another continuing effort is the construction of a high pressure 16 plane drift chamber that will measure cosmic rays to an accuracy of 15 microns. This high resolution drift chamber will also give our new students the experience of working with high speed electronics and complex detectors. Details of these efforts are described below.

a. Fiber Tower Calorimeter (FITCAL)

The aim of this project is the design and construction of a prototype for an electromagnetic calorimeter which could serve as the first section of a total absorption calorimeter for the SSC. The absorber material is lead (or a suitable alloy), scintillator is used as the sensitive medium, and wavelength-shifting fibers serve to bring the signal out to a photodetector (e.g. a multi-anode photomultiplier). This is an attempt to combine the attractive features of the spaghetti-calorimeter with those of a conventional scintillator sandwich calorimeter with read-out by wavelength shifting bars.

Very good hermeticity is achievable by using the absorber as mechanical support for the scintillator and the fibers. A compact block ($\sim$ 8 x 8 x 30 cm^3) of absorber is made with fine slots containing small ($\sim$ 1 x 1 cm^2) tiles of scintillator and fine (diameter $\sim$ 1.5 mm) holes along the length of the block. The light is collected by fibers (e.g. polystyrene, doped with wavelength shifter), which are embedded in the long holes and which go through holes in the center of the scintillator tiles. The relative amounts of lead and scintillator (volume ratio lead: scintillator $\sim$ 4 : 1) are chosen such as to give compensation, i.e. equal response for electromagnetic and hadronic showers. A proposal submitted to DOE-SSC was funded.

FSU has taken responsibility for the mechanical design and construction and the calibration system; the University of Florida group will supply the scintillators and fibers, and the Oak Ridge group will do response calculations.

Since approval and funding of the proposal, we have spent appreciable effort on identifying a lead alloy which satisfies the requirements of high lead content, good mechanical strength, and suitability for the manufacturing process envisaged, and we have tried to find a manufacturing method which lends itself to mass production. The original idea had been to cast the blocks, with slots for scintillator tiles and holes for the fibers. After unsuccessful attempts to do this ourselves in our shop, we tried to find companies experienced in lead casting that would be interested in studying the feasibility. It turned out that casting such an object is very difficult, due to the smallness of the slots and holes and the stringent requirements on mechanical tolerances. Therefore we devised a method whereby the block is subdivided in layers, which are then assembled into a block, held together by pegs (dowels), also made of the same alloy. This appears to be a viable technique, and so far one company has expressed interest in manufacturing the layers and assembling them to a block. The technique used for making the layers is "fine blanking", which allows high precision, very good reproducibility, and fast (and therefore low cost) production. The drawback is the high tooling cost ($\sim$ 30 k$ for every species of layer). This is acceptable if the number of different species of pieces is small, but the cost becomes prohibitive if (as required for projective geometry) every layer were different. Therefore we continue our attempts to find appropriate expertise in industry.

In order to allow construction of the prototype, we are now machining the layers in our shop, and are developing a fixture for assembly. Machining these parts on a milling machine is clearly not the technique that one would choose for a large scale detector, but we are reluctant to spend money on tooling for a prototype before the other problems are better understood (e.g. light-coupling, light yield, uniformity,..).

In parallel with mechanical studies, we are also thinking about ways to calibrate and monitor this device; one possible ingredient would be to have a sheet of scintillator covering the entrance face of the calorimeter, with the fibers optically coupled to this sheet. Exciting scintillation light in this scintillator with, e.g., a movable X-ray source would allow one to measure and monitor the fiber-to-fiber variations.

b. Detector Development; Radiation Damage

The Florida State University/University of Florida collaboration for the study of radiation damage to plastic scintillator began in November 1988 has met with substantial success. We have demonstrated the utility of our high intensity 3 MeV electron accelerator for systematic radiation damage inquiries, studied the effects of composition and temperature on radiation hardness and found a highly radiation resistant 3-hydroxyflavone (3-HF) doped polystyrene fiber. We have submitted a paper to Nuclear Instruments and Methods, which details measurements on a plastic scintillating fiber that is radiation resistant to 10 megarads (the first such known plastic scintillator). We have also presented our results to the Workshop on Calorimetry for the Superconducting Super Collider at Tuscaloosa, Alabama (March 13 - 17, 1989).

Our highest priority is to continue and expand the scintillating fiber investigation. We would like to find the upper limit of radiation resistance of the 3-HF fiber and test other possible candidates for radiation resistance such as SCSN81+Y7 as well as "conventional" fibers like SCSN38 and BCF-10.

Next is an investigation into the limits of conventional plastic scintillator using bulk (1 cm. thick) scintillator. The purpose is to find methods of reducing damage, accelerating recovery and raising the final level of recovery. We wish to clarify the role of gas environment and temperature since there are contradictory reports in the literature. We intend to irradiate SCSN38, SCSN81 (polystyrene based) and BC408 (PVT based) in Argon, O_2 and air environments.

There is some question as to whether irradiation by neutrons produces the same kind or amount of damage as electromagnetic irradiation. To address this question we intend to expose samples to an intense neutron flux, perhaps at Brookhaven National Laboratory, typical of what we expect in an SSC detector, and measure the damage, rate of recovery, etc.

Another measure for the equivalence of damage done by heavy particles such as neutrons and photons is the number of scissions or polymer chain breaks per rad. We are planning to irradiate various portions of a bar of polystyrene which has very uniform chain length to different doses and subsequently measure the breakage as a function of dose or neutron fluence.

c. High Pressure Chamber

To explore an options in high resolution tracking, we have undertaken the construction of a cosmic ray tracking system to assist in the development of position sensitive devices. The cosmic ray telescope will consist of two stacks of 24 planes of 1 ft^2 drift chambers with a capability to run these chambers at up to 4 atmospheres of gas pressure. This will theoretically produce a track resolution of $15\mu m$ at the point where a test device would be introduced (between the two stacks).

The printed circuit board has been cut and etched and half of the aluminum cores fabricated. The high pressure gas boxes are designed and fabrication has commenced. Since the material is almost entirely surplus, the net cost to date has been $\sim$ \$5,000. The electronics and cables have been acquired through bartering.

Since his return from CERN, W. Burley has taken charge of the construction and we anticipate the completion of the mechanical assembly by August. The plane wiring will be done under D. Levinthal's supervision upon his return from CERN next year. The immediate use of the device will be to study gas mixtures for vertex tracking systems with an eye toward use at the SSC.

V. Particle Theory Program

In this section the activities over the last five years of the high energy theory component of Task A will be reviewed. This has been a period of change for us as the creation of the Supercomputer Computations Research Institute made possible new techniques and areas of investigation. As a result of changing research interests, the makeup of the group has changed somewhat over this same period. At the beginning of the five year review period the theory group consisted of three tenured or tenure earning faculty members (Duke, Kimel, and Owens), one visiting professor (Devoto), and two students (Bergmann and Black). Shortly thereafter, Devoto returned to Italy to accept a permanent university position there and we added a Research Associate (Axelrod) to the group. With the creation of SCRI in 1984, Duke became the Associate Director for Research and shifted his research interests to numerical simulations. Simultaneously, Kimel began a collaboration with Y. L. Wang, a condensed matter theorist in the Physics Department. They have been simulating various spin models on the FSU supercomputers. In 1986 a second Research Associate position was created in order to partially rebuild our strength in the area of collider physics. This position was filled by K. Whisnant, who specializes in electroweak phenomenology. He subsequently took a faculty position at Iowa State in 1988. This Research Associate position is currently filled by J. Ohnemus, who has been with us since March, 1988. Also, in 1987 we upgraded the original Research Associate position to a Research Scientist position which is now held by H. Baer. This year our two graduate students (Bergmann and Black) received their Ph. D.'s.

After all of the above changes, the theory group currently consists of one tenured professor (Owens), one Research Scientist (Baer), and one Research Associate (Ohnemus), all working in the area of collider physics and one tenured professor (Kimel) working on condensed matter model simulations. In addition, three first-year graduate students will be starting to work with us this summer.

At this point it would be appropriate to review some of the highlights of the group's recent research accomplishments. During the four year period 1984-1988, members of the group published thirty-five high energy physics papers, nine papers on numerical simulations of various spin systems, and contributed to the editing of the proceedings of two conferences. During the 1988-1989 progress report period, members of the group have published six papers, have fifteen in press, and have submitted four more. A summary of the topics covered is given below, organized by year. The relevant publication citations are given in the Task A publication list, and selected abstracts are included there, as well. For the 1988-1989 reporting period a somewhat more detailed summary of the projects completed or still in progress is presented.

1984-1985

- Nine papers in high energy phenomenology and one in numerical simulations published.

- Q^2-Dependent parametrizations of pion and nucleon parton distributions. These have served as standards of the field for comparisons with data for large momentum transfer processes. (Duke, Owens)

- Participation in the 1984 Snowmass SSC summer study with contributions to various working groups concerned with hard scattering and structure functions. (Owens)

- A calculation of the fourth order non-singlet longitudinal structure function in QCD. (Duke, Kimel)

- Review articles on determinations of α_s and tables of integrals for Feynman diagrams. (Duke, Devoto)

- A study of renormalization flow of SU(3) lattice gauge actions. (Duke)

1985-1986

- Six papers in high energy phenomenology and two in numerical simulations published.

- Conference presentations reviewing the determination of parton-parton scattering angular distributions and the status of photon structure function measurements and calculations. (Owens)

• A study of dinucleon decay and of the degenerate state formalism applied to deep inelastic scattering. (Axelrod)

• A study of extra gauge bosons and fermions expected in E_6 superstring theories. (Whisnant)

• Numerical simulations of finite-size scaling for the three-dimensional Ising model and of fractals and interpolating dimensions. (Duke)

• Participation in the organization of a lattice gauge theory conference and the editing of the proceedings. (Duke, Owens)

1986-1987

• Nine papers in high energy phenomenology and four in numerical simulations published.

• A review article on large momentum transfer production of direct photons, jets, and particles. (Owens)

• Further studies of topics in E_6 superstring theories. (Whisnant)

• Studies of solar neutrino oscillations, charmless B decays, and a source for monojet events. (Whisnant)

• Numerical simulations of the three-dimesional Ising model, the two-dimensional Blume-Capel model, and the partition functions of the Z(2) and Z(8) lattice gauge theories in four dimensions. (Duke, Kimel)

1987-1988

• Eleven papers in high energy phenomenology and two in numerical simulations published.

• Continued studies of the phenomenology E_6 superstring theories. (Whisnant)

• Studies of vector boson production in supersymmetric QCD and possible supersymmetric effects in QED. (Axelrod)

- A study of top-quark signatures at the Tevatron. (Baer)

- A study of two-photon backgrounds for the intermediate mass Higgs boson. (Baer, Owens)

- Numerical studies of the three-dimensional Ising model and the spin-1 Blume-Emery-Griffiths model. (Kimel)

- Participation in the organization of a lattice Higgs conference and the editing of the proceedings. (Owens)

1988-1989

We now turn to a detailed description of the various projects which members of the group have worked on during the past year. As in previous years, the work falls into three main categories: phenomenology of hard scattering processes including higher order calculations, phenomenology of the standard model and other theories with specific applications to collider physics, and numerical simulations of various spin models and gauge theories. The past year has been a fruitful one, with six papers published, fifteen in press, and four submitted. In addition, two students received their Ph. D. degrees this semester. Three first year students will begin working with the group this summer.

One of the limitations concerning detailed tests of QCD in hard scattering processes has been the fact that leading-logarithm calculations have large uncertainties in their overall normalization due to the fact that the renormalization and factorization scales are not specified in such calculations. In the kinematic regions accessible to experiment, sub-leading terms can have a significant impact on the theoretical predictions. For this reason, calculations performed in the next-to-leading-logarithm approximation are needed. Conventional analytic calculations have been performed for a number of single particle or single jet observables. However, it is not always possible to tailor these to conform to the needs of the experimentalists as regards various cuts, jet definitions, etc. Therefore, we have sought a method which would have a greater degree of flexibility as to the inclusion of such effects and which could easily be applied to new observables. Our solution is based on performing the required phase space integrals using a mixture of analytic and Monte Carlo techniques. The regions of phase space containing soft and/or collinear divergences are separated off using theoretical soft and collinear cutoffs. The integrations in these regions are performed using dimensional regularization in n-dimensional phase space. The integrations in these regions are done analytically. Monte Carlo techniques are used for the remainder of the phase space. For scattering subprocesses involving final states with two or three partons, one ends up with a "two pass" Monte Carlo integration program. Both the two-body and three-body contributions depend on the theoretical cutoffs used to separate the regions containing the divergent contributions. However, at the histogramming stage the cutoff dependences cancel when a suitable inclusive observable is calculated. This approach is very flexible and one can quickly modify the program to accommodate various cuts, jet definitions, or new types of observables. One particular strength of this approach is that one can easily perform correlation calculations involving two jets or particles, an area which has not been studied previously using next-to-leading-order calculations. We have applied this technique to a study of jet photoproduction processes which should be measured by E-683 during the 1990 fixed target running period at Fermilab. The technique has also been applied to the production of massive dihadron pairs proceeding via non-singlet fragmentation. We are in the process of writing programs to apply the method to the study of direct photon production and photon-jet correlations. Two papers have been written to date and their titles and abstracts are given below as items 1 and 2.

Also in the area of high-p_T phenomenology, a joint analysis of direct photon production and deep-inelastic lepton-nucleon scattering using next-to-leading-logarithm expressions, has recently been completed. The main result is that it is possible to simultaneoulsy describe both types of data using a common gluon description. More information concerning the gluon distribution is obtained than if either data type alone were to be used. The abstract is included below as item 3.

With the *ep* machine, HERA, it will become possible to study photoproduction processes at center-of-mass energies in the range of several hundred GeV. As part of our program for studying processes involving real photons, we have investigated the production of two- and three-jet final states at HERA. This work is in press and the abstract is listed below as item 4.

Many of the papers written this year involve testing the standard model or its extensions at hadron or lepton colliders. Signature for fourth-generation quarks are discussed in item

5, while the production and detection of top quarks are discussed in items 5, 9, 11, and 12. Heavy vector boson production is discussed in items 6 and 7. Supersymmetry phenomenology has also been an active area with work reported in items 10, 13, 14, and 15.

Members of the group have participated in a number of workshops, conferences, and schools. Recent developments in the measurement of parton distributions are described in item 16 and some aspects of the higher order calculation work are presented in item 17. Three lectures on applications of QCD to hard scattering processes are described in item 18. Contributions to the Snowmass working group on new particles discussed in items 19 and 21, while items 20 and 22 report work on the top and fourth-generation quarks and supersymmetry.

Two theory students received their Ph.D. degrees this semester. The work of L. Bergmann on a next-to-leading-logarithm calculation is discussed in item 2, while the lattice gauge study of S. Black is discussed in item 23.

Recent work on simulating the three-dimensional antiferromagnetic Blume-Capel model by Kimel and Wang is discussed in item 24.

1. A next-to-leading-logarithm calculation of jet photoproduction, by H. Baer, J. Ohnemus, and J. F. Owens, submitted to Phys. Rev. D.

   A Monte Carlo program containing both leading-logarithm and next-to-leading-logarithm contributions has been developed and used to study the photoproduction of large-transverse-momentum hadronic jets. Predictions are presented and discussed for a variety of observables including single jet invariant cross sections, dijet cross sections, and angular distributions. For some observables the inclusion of the next-to-leading-logarithm terms dramatically lessens the dependency on the choice of the renormalization and factorization scales entering the calculation, thereby increasing the precision of the predictions. The flexibility of the Monte Carlo technique allows predictions for additional observables to be generated easily.

2. Next-to-leading-logarithm QCD calculation of symmetric dihadron production, L. J. Bergmann and J. F. Owens, submitted to Phys. Rev. D.

A technique is presented for using a Monte Carlo method to perform phase space integrations used in calculating the next-to-leading-logarithm QCD contribution to symmetric dihadron production. This method is shown to be relatively simple, straightforward, and sufficiently flexible so as to be applicable to a broad range of next-to-leading-logarithm calculations.

3. 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. D, in press.

A common fit is performed to lepton-hadron deep-inelastic-scattering and large-p_T direct photon cross sections, using complete beyind leading logarithm QCD expressions. For direct photon cross sections, theoretical uncertainties coming from the renormalization and factorization schemes are removed by applying the principal of minimal sensitivity. We find that the direct photon data, especially from the recent fixed target expeiments, strongly constrain the gluon distribution function, whereas the deep-inelastic data determine the quark distribution functions and constrain the value of $\Lambda_{\overline{MS}}$. Our analysis is a successful test of perturbative QCD which provides a coherent and quantitative description of two very different reactions.

4. Expectations for two- and three-jet events at HERA, by H. Baer, J. Ohnemus, and J. F. Owens, Z. Phys. C, in press.

We calculate cross-sections for two- and three-jet events in $e^- p$ collisions at $\sqrt{s} =$ 314 GeV. We include contributions from point-like photon interactions, as well as contributions from when the photon is resolved into constituent quarks and gluons. It is shown that measurements of the angular distribution of the dijet system in two-jet events as a function of the dijet mass will assist in the separation of these two components. Aside from being a direct test of QCD photoproduction subprocesses, measurement of these events will yield information on the hadronic structure of the photon.

5. Signatures for fourth-generation quarks and a heavy top quark at the Superconducting Super Collider, by H. Baer, V. Barger, H. Goldberg, and J. Ohnemus, Phys. Rev. **D38**, 3467 (1988).

We examine methods for detection of new heavy quarks at the Superconducting Super Collider where the heavy quark could be either one of a fourth generation of quarks (a, v), or a very massive ($\sim$ 150 GeV) top quark. The signals can be classified according to number of leptons in the final state. Requiring the presence of a single fast isolated lepton along with ≥ 4 jets and $\not{p}_T$ allows one to separate the a, v, or t signal from backgrounds. Heavy-quark pairs are produced with sufficient hemispheric separation to allow the direction of one of the quarks to be tagged by the transverse momentum of the isolated high-p_T lepton. A distinct enhancement is then observed at the heavy-quark mass in the cluster mass spectrum of all jets moving opposite to the lepton. A fourth-generation quark should also be visible in the two isolated lepton channel, and its mass resolvable. Additional signals from multilepton events would then also be present, though these channels may not yield a heavy-quark mass determination.

6. Spin correlation effects in the hadroproduction and decay of very heavy top quark pairs, by V. Barger, J. Ohnemus, and R. J. N. Phillips, Int. J. Mod. Phys. **A4**, 617 (1989).

Density matrix techniques in the helicity basis allow us to write down explicitly the squared matrix elements for tree-level hadroproduction and weak decay of very heavy top quark pairs, that decay before hadronization. This treatment includes the full effects of quark spin correlation. We illustrate the effects of spin correlation on physical distributions in $p\bar{p}$ dilepton events, $p\bar{p} \to t\bar{t}X,\ t \to b\bar{\ell}\nu,\ \bar{t} \to \bar{b}\ell\bar{\nu}$, for the case $m_t = 120$ GeV at $\sqrt{s} = 2$ TeV, the energy of the Tevatron collider. The effects of spin correlation are quantitatively small compared to calculations that ignore them, giving corrections of order 10% or less in the physical distributions studied.

7. Large p_T weak boson production at the Tevatron, by V. Barger, T. Han, J. Ohnemus, and D. Zeppenfeld, Phys. Rev. Lett. **62**, 1971 (1989).

Perturbative QCD calculations of the processes $p\bar{p} \to W^{\pm}, Z + n$ jets $(n = 1, 2, 3)$ with $W \to e\nu$ and $Z \to e\bar{e}$ decays are presented for comparison with forthcoming Tevatron data at $\sqrt{s} = 1.8$ TeV. The W, Z + 2-jet results are compared with the corresponding $p\bar{p} \to WW, WZ$, and ZZ electroweak cross sections.

8. Hadronic W-decays at HERA, H. Baer, J. Ohnemus, and D. Zeppenfeld, Z. Phys. C, in press.

   ep collisions at HERA will produce real W's with a cross section of almost 1 pb. We discuss to what extent the hadronic decays of these W's will be visible above the QCD background. Using optimal cuts to enhance the hadronic W signal, a clear W peak should be visible after several years of running at HERA.

9. WW Signatures From Top Quarks at the Tevatron, H. Baer, V. Barger, and R. J. N. Phillips, Phys. Rev. D, in press.

   We examine signals from top quarks if $m_t \simeq m_b + M_W$. In this case $t\bar{t}$ events resemble W-pair events and at the Tevatron collider one ought to see lepton plus 2 jet events and dilepton events above background.

10. Dileptons From Chargino and Stop Production at the Tevatron, H. Baer, V. Barger, R. J. N. Phillips, and X. Tata, Phys. Lett. B, in press.

    Isolated dilepton events are taken to be a sure signal for top, but many other new physics processes can also yield dileptons. We compare dilepton signals from $t\bar{t}$ with dileptons from two supersymmety mechanisms, fourth generation leptons and W-pair production.

11. Top Quark Detection via W+n Jet Measurements, H. Baer, V. Barger, R J. N. .Phillips, Phys. Lett. B, in press.

    The first place one might find evidence for top quarks is in inclusive "W" events. Top quarks may show up in the $M_T(e,\nu)$ distribution, or via enhancements in expected rates for W+n-jet events compared to total W events, or via enhancement in expected W+n-jet events to Z+n-jet events.

12. Search for Top Quark Decays to Real W Bosons at the Tevatron Collider, H. Baer, V. Barger, and R. J. N. Phillips, Phys. Rev. D, in press.

We look for optimal cuts to elicit top quark signal from background when $m_t > M_W$. We find that the Tevatron collider can probe up to $m_t \simeq 180$ GeV in the one-lepton channel, and throughout the entire theoretical range of $m_t < 200$ GeV in the dilepton channel, after 100 pb^{-1} of data has been collected. We show ways to measure the t-quark mass.

13. Searching for supersymmetry at e^+e^- supercolliders, A. Bartl, H. Baer, D. Karatas, W. Majerotto, and X. Tata, Int. J. Mod. Phys. A, in press

    We calculate production cross-sections for all sfermions and gauginos at e^+e^- colliders with TeV energy. Decay schemes for such heavy sparticles are vastly different from those considered in previous calculations. We compute the cascade decays available to sleptons and sneutrinos, as well as gauginos, and discuss signatures for very heavy supersymmetric particles produced at e^+e^- supercolliders.

14. Effect of Cascade Decays on the Tevatron Gluino and Squark Mass Bounds, H. Baer, X. Tata, and J. Woodside, submitted to Phys. Rev. Lett.

    Squarks and gluinos are predicted by supergravity models to decay through a cascade of gauginos. The effect of the cascade lowers quoted CDF mass limits by 3-30 GeV for the gluino and typically 10 GeV for the squark.

15. Gluino Cascade Decay Signatures at the Tevatron Collider, H. Baer, X. Tata, and J. Woodside, submitted to Phys. Rev. D.

    Squark and gluino cascade decays yield new signatures for supersymmetry. These include 5-jet+missing p_T events (which allow the highest value of gluino mass to be probed), single lepton signatures, and isolated dileptons. In particular, isolated same sign dileptons provide a clean SUSY signature with virtually no standard model background.

16. 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.

Recent data relevant for determining parton distributions are discussed. Particular attention is paid to the question of how to improve our knowledge of the gluon distribution. The role of photon-jet and photon-hadron correlation data is discussed in conjunction with a new technique for performing next-to-leading order two-particle inclusive calculations.

17. Higher order calculations for hard hadronic processes, J. F. Owens, proceedings of the 1988 DPF Conference, U. Conn., Storrs, Connecticut.

    In order to improve the precision of predictions for hard scattering processes, it is necessary to go beyond the leading-logarithm approximation. A technique has been developed for performing such calculations using Monte Carlo integration techniques. The method is easily tailored to different observables and experimental situations.

18. Applications of QCD to hard hadronic processes, J. F. Owens, proceedings of the Third Lake Louise Winter Institute.

    In these lectures I review the formalism used to obtain perturbative predictions for hard hadronic processes using quantum chromodynamics. In the process of reviewing the various types of calculations, I point out the major sources of theoretical uncertainty and what steps are being taken to improve the precision of the predictions.

19. Searching for 100-300 GeV Gluinos at the Tevatron and SSC, H. Baer, X. Tata, and J. Woodside), to be published in proceedings of Snowmass '88.

    Report of work done at Snowmass 1988. We began work on an event generator incorporating complete cascade decays of gluinos. We also looked at the missing energy signal from associated gluino-photino production at the SSC.

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

    This paper is a report of recent work on top quark and fourth generation quark signals at the Tevatron and SSC.

21. New Particle Signals at the SSC and at an Upgraded Tevatron Collider, H. Baer, with R.M. Barnett et. al., to be published in the proceedings of Snowmass '88.

This report provides an overview of all work done in the New Particles group at Snowmass.

22. Supersymmetry at Current Hadron Colliders, H. Baer, to be published in Proceedings of Moriond Meeting on Hadronic Interactions-1989.

This paper is a review of signals expected from supersymmetric particles at proton-antiproton colliders. Squark and gluino pair production, and vector boson decay to gauginos are covered.

23. Stochastic implementation of improved actions for gauge theories on a lattice, S. Black, Ph.D. Dissertation.

We investigate the use of a random or stochastic process to perform the Monte Carlo simulations of improved actions for pure SU(2) gauge theory formulated on a lattice. The improved actions studied are extensions of Wilson's simple plaquette action to include six-link plaquettes. The stochastic or "noisy" method involves computing additional terms in the action such that they have the correct values on the average. We devise two schemes for achieving this and compare them to the Metropolis method, where the additional terms are computed exactly. We find that the noisy methods produce independent configurations more rapidly than the Metropolis method. The greatest improvement is found to be by roughly a factor of two. The results, however, are sensitive to the values of the coefficients of the additional terms in the action. Our study indicates that for more complex actions a noisy method will be sufficiently superior to an exact method such as the Metropolis algorithm. This means that current lattice sizes and computer resources can be used to measure observables much closer to the continuum limit.

24. Three-dimensional antiferromagnetic Blume-Capel model, J. D. Kimel and Y. L. Wang.

We have investigated, using Monte Carlo simulations on the FSU Cyber 205 supercomputer, the three-dimensional antiferromagnetic Blume-Capel model. The main new result is the discovery of a fourth-order phase transition, suggested by the mean-field approximation but until now not verified by a realistic simulation. Considerable effort has been spent locating the fourth-order critical point the determining the critical indices. A paper describing these results is in preparation.

Ongoing and Proposed Projects

1. Continued study of hard scattering processes involving photons.

Our program to study processes involving real photons is continuing and has produced some interesting and useful results in the last year. During the forthcoming year, members of the group will continue to work with the E-683 collaboration at Fermilab with respect to their fixed target experiment to measure jet photoproduction using calorimetric techniques similar to those used in E-609 with a hadron beam. The construction of a similar next-to-leading-logarithm program for studying direct photon production by hadronic beams is progressing well and a preliminary version is now running and undergoing tests. Our intention is to use this program to study both the direct photon invariant cross section as well as photon-jet correlation observables. Such photon-jet data already exist from the AFS collaboration at the ISR. The basic idea is twofold – one needs to work with next-to-leading-logarithm expressions in order to reduce the uncertainties due to the factorization and renormalization scale choices and the use of joint photon-jet observables allows one to have greater control of the underlying hard-scattering kinematics, thereby increasing the amount of information extracted from the data. Our intention is to further refine the knowledge concerning the nucleon gluon distribution by utilizing these additional observables. In addition, new data should be forthcoming from fixed target experiments at Fermilab (E-705 and 706) which have the capability of measuring photon-jet or photon-hadron correlations. CDF is also producing data on direct photon production which should compliment the fixed target results as the relevant x-range for the parton distributions shifts to smaller values as the energy is increased at fixed transverse momentum. On a somewhat longer timescale, D0 will also produce data on direct photon production. This process is expected to be the dissertation topic for one of the graduate students in our experimental group.

In a related area, we expect to continue refining parton distributions extracted from deep-inelastic scattering data. Presently, the situation is somewhat confused as the two experiments with the highest statistics disagree with each other as to the shape and normalization of the structure functions. As new data become available they will be included in our data base and incorporated into our fits. This has been an ongoing project since the Duke-Owens Set 1 and Set 2 distributions were published in 1984. Joint analyses of direct photon and deep-inelastic scattering data have already yielded interesting results (see item 3 above) and we shall continue to pursue this approach. Further refinement of our knowledge of parton distributions will have an impact on extrapolations used for SSC predictions, as well as certain types of data available from the Tevatron colliding beam experiments. Note that at $\sqrt{s} = 1.8$ TeV and $p_T = 9$ GeV, the relevant x range is in the vicinity of $x = .01$ with $Q^2 = 100$ GeV^2, a region which has not been accesible to deep-inelastic experiments. In future years this type of analysis will be extended by data from HERA which can be expected to extend the available x and Q^2 ranges.

2. Collider Physics.

With the increased data samples coming from both Fermilab and CERN, and with new facilities coming on line in the next several years, we can anticipate a continued need for and interest in calculations of various processes relating to the standard model and its extensions. For example, the search for the t-quark at hadron colliders relies on identifying unique signatures of the production and decay processes which will allow the presence of the t-quark to be identified amidst all of the other competing standard model reactions. Work in this particular area has been done here in the last year, and will continue.

Another area in which members of the group have been active is new particle searches, such as supersymmetric particles, additional gauge bosons, or fourth-generation quarks. 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.

3. Numerical simulations of spin models.

J.D. Kimel, in collaboration with Physics Department materials science theorist Y.L. Wang, is investigating fourth-order phase transitions which may occur in certain antiferromagnetic materials under stress, with transverse field applied, with dilution, and in other physical systems. A mean-field approximation has found a fourth-order critical point in some models. Our recent work on the three-dimensional Blume-Capel model has verified the existence of the fourth-order critical point but with results which are quantitatively quite different from those of the mean-field approximation. We plan next to study the antiferromagnetic Blume-Emory-Griffiths model, which can be applied to many physical systems. One expects a fourth-order line to appear in the three-dimensional case, since a fourth-order point has been found in the antiferromagnetic Blume-Capel model. This study will be the final work of a series of simulations of Ising-like models.

1988 - 1989 Publications

(Task A)

Note: This publication period is only for 10 months (August 1, 1988 - May 31, 1988) due to the advanced submission date of the progress report for external review.

A. <u>Papers Published</u> .

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).
2. Partial Wave Analysis of the $K^+\overline{K}^0\pi^-$ System, A. Boehnlein, D. Boehnlein, J.H. Goldman, V. Hagopian, D. Reeves, *et al.*, Phys. Rev. Lett. **61**, 1557 (1988).
3. Partial Wave Analysis of the $K^+\overline{K}^0\pi^-$ System Produced in the Reaction $\pi^-p \rightarrow K^+\overline{K}^0\pi^-n$ AT 8 GeV/c, A . Boehnlein, D. Boehnlein, J.H. Goldman, V. Hagopian, D. Reeves, *et al.*, Proceedings of the Third Conference on the Intersections Between Particle and Nuclear Physics, Maine 1988. Ed. G. Bunce, AIP Conference Proceedings **176**, p. 759 (1989).
4. Preliminary Results of $\overline{p}p$ at 8 GeV/c. Proceedings of the BNL Workshop on Glueballs, Hybrids and Exotic Hadrons, Aug. 1988. Ed. S. Chung, AIP Conference Proceeding No. 185, p. 446 (1989).
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6. Diffractive Productions of $\pi^-\pi^-\pi^+$ by 200 GeV/c π^- N Interactions, J.R. Albright, J.H. Goldman, S.L. Hagopian, J.E. Lannutti, *et al.*, Phys. Rev. D **39**, 1865 (1989).
7. Signatures for Fourth Generation Quarks and a Heavy Top-Quark at the SSC, H. Baer, J. Ohnemus, *et al.*, Phys. Rev. **D. 38**, 3467 (1988).
8. Spin correlation effects in the hadroproduction and decay of very heavy top quark pairs, by J. Ohnemus, *et al*, Int. J. Mod. Phys. **A4**, 617 (1989).
9. Large p_T Weak Boson Production at the Fermilab Tevatron, J. Ohnemus *et al*, Phys. Rev. Lett. **62**, 1971 (1989).
10. Applications of QCD to Hard Hadronic Processes, J. F. Owens, Proceedings of the Third Lake Louise Institute, (1988) ed. by B. A. Campbell, A. N. Kamal, F. C. Khanna, and M. K. Sundaresan World Scientific, Singapore, p. 1. (1989).
11. On the Model Dependence of the Chargino Mass Bound from the CERN Collider Data, H. Baer *et al*, Phys. Rev. **D38**, 1485 (1989).
12. 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).
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).

B. Papers Accepted for Publication

1. Hadron and Electron Response of Uranium/Liquid Argon Calorimeter Modules for the *D∅* Detector, S. Hagopian, S. Linn, H. Piekarz, H. Wahl, S. Youssef, *et al*, Nuclear Instruments and Methods.
2. Hadronic W-decays at HERA, H. Baer, J. Ohnemus, and D. Zeppenfeld, Z. Phys. **C**.
3. Expectations for two- and three-jet events at HERA, H. Baer, J. Ohnemus, and J. F. Owens, Z. Phys. **C**.
4. Signals for Supersymmetry at Current $\bar{p}p$ Colliders, H. Baer and X. Tata. Proceedings of the Moriond Conference on Hadronic Interactions, Les Arcs, France (1989).
5. WW Signatures From Top Quarks at the Tevatron, H. Baer, V. Barger, and R. J. N. Phillips, Phys. Rev. **D**.
6. Top Quark Detection via W+n Jet Measurements, H. Baer, V. Barger, and R. J. N. Phillips, Phys. Lett. **B**.
7. Search for Top Quark Decays to Real W Bosons at the Tevatron Collider, H. Baer, V. Barger, and R. J. N. Phillips, Phys. Rev. **D**.
8. 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. **D**.
9. Searching for Supersymmetry at e^+e^- Supercolliders, A. Bartl, H. Baer, D. Karatas, W. Majerotto, and X. Tata, Int. J. Mod. Phys. **A**.
10. Searching for 100-300 GeV Gluinos at the Tevatron and SSC, H. Baer, X. Tata, and J. Woodside, proceedings of the 1988 Snowmass summer study.
11. The Search for Very Heavy Top and the Fourth Generation, H. Baer, Proceedings of the Beyond the Standard Model Conference, Ames, Iowa (1988).
12. New Particle Signals at the SSC and at an Upgraded Tevatron Collider, H. Baer (with R.M. Barnett et. al.), proceedings of the 1988 Snowmass summer study.
13. Supersymmetry at Current Hadron Colliders, H. Baer, Proceedings of the Moriond Meeting on Hadronic Interactions-1989.
14. 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, 1989), in press.
15. Higher Order Calculations for Hard Scattering Processes, J. F. Owens, proceedings of the 1988 DPF Conference, U. Conn., Storrs, Connecticut.

C. Papers Submitted for Publication

1. Effect of Cascade Decays on the Tevatron Gluino and Squark Mass Bounds, H. Baer, X. Tata, and J. Woodside, submitted to Phys. Rev. Letters.
2. Gluino Cascade Decay Signatures at the Tevatron Collider, H. Baer, X. Tata, and J. Woodside, submitted to Phys. Rev. **D**.
3. A next-to-leading-logarithm calculation of jet photoproduction, by H. Baer, J. Ohnemus, and J. F. Owens, FSU-HEP-890301, submitted to Phys. Rev. **D**.
4. Next-to-Leading-Logarithm QCD Calculation of Symmetric Dihadron Production, L. J. Bergmann and J. F. Owens, submitted to Phys. Rev. **D**.

5. Atomic Weight Dependence of the Production of Hadron Pairs from 800 GeV/c Protons on Nuclear Targets, K. Streets, G. Boca, C. Georgiopoulos, J.H. Goldman, S. Hagopian, V. Hagopian, K.F. Johnson, D. Kaplan, D. Levinthal, F. Lopez, H.L. Sawyer, J. Streets, H. White, C. Young *et al*, submitted to Phys. Rev. Lett.
6. The Cross Section for Massive Hadron Pair Production by 800 GeV/c Protons on Nuclear Targets, D. Levinthal, K. Streets, G. Boca, J.H. Goldman, K.F. Johnson, H.L. Sawyer, J. Streets, H.B. White, *et al*, submitted to Phys. Rev. Lett.
7. Radiation Damage Studies in Plastic Scintillators with a 2.5 MeV Electron Accelerator, K.F. Johnson, V. Hagopian, J. Thomaston, H. Wahl *et al*, submitted to Nucl. Inst. and Methods.

D. Ph.D. Dissertations

1. Next-to-Leading-Log QCD Calculation of Symmetric Dihadron Production, L.J. Bergmann.
2. Stochastic Implementation of Improved Actions for Gauge Theories on a Lattice, S.C. Black.
3. $K^+\overline{K}^o\pi^-$ Production in K^-p Interactions at 8 GeV/c, D.J. Boehnlein.
4. The Atomic Weight Dependence and Mass Cross Sections of Massive Hadron Pair Production in Proton-Nucleus Collisions at 800 GeV/c, K.R.T. Streets.

1987 - 1988 Publications
(Task A)

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).
7. Signatures for a New Supersymmetric Left-Right Gauge Model From Superstrings, K. Whisnant, *et al.*, Int. J. of Mod. Phys. A **2**, 1199 (1987).
8. Discovery Limits of New Gauge Bosons of $Sp_L(6)$xU(1), K. Whisnant, *et al.*, Int. J. of Mod. Phys. A **2**, 1327 (1987).
9. Production and Decays of Extra Gauge Bosons in a Left-Right E_6 Superstring Model, K. Whisnant, *et al.*, Int. J. of Mod. Phys. A **3**, 879 (1988).
10. Broken Supersymmetry and the Divergence of the Perturbation Series in QED, Alan Axelrod, Phys. Lett. B **196**, 365 (1987)
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13. Phase Diagrams of the Spin-1 Ising Blume-Emery-Griffiths Model: Monte Carlo Simulations, Y.L. Wang, F. Lee and J.D. Kimel, Phys. Rev. B **36**, 8945 (1987).
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15. Rho and Omega Production in π^+p Interactions at 15.7 GeV/c, P.M. Barlow, R.K. Clark, R.N. Diamond, V. Hagopian, J.E. Lannutti, C.M. Spencer, *et al.*, Phys. Rev. D **36**, 1961 (1987).
16. A Vectorized Track Finding and Fitting Algorithm in Experimental High Energy Physics Using a Cyber-205, C.H. Georgiopoulos, J.H. Goldman, *et al.*, Nuclear Instruments and Methods in Physics Research **A261**, 493 (1987).
17. Experimental HEP Supercomputing at FSU, D. Levinthal, J.H. Goldman, *et al.*, Comp. Phys. Comm. **45**,137 (1987).
18. The Use of SA/SD Methods in *D∅* Software Development, S . Hagopian, S. Linn, *et al.*, Comp. Phys. Comm. **45**, 245 (1987).

1986 - 1987 Publications
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2. B-Meson Decays Without Charmed Particles in the Final State, Jun-chen Su, K. Whisnant and Bing-lin Young, Phys. Rev. D **34**, 1376 (1986).
3. Model of New Scalar Bosons as the Source of One-Jet Events at the $p\bar{p}$ Collider, Ernest Ma and K. Whisnant, Z. Phys. C **32**, 85 (1986).
4. Level Crossings in Solar Neutrino Oscillations, V. Barger, R.J.N. Phillips and K. Whisnant, Phys. Rev. D **34**, 980 (1986).
5. Neutral Meson-Antimeson Mixing for a Heavy Isosinglet Quark Constituent, V. Barger, R.J.N. Phillips and K. Whisnant, Phys. Rev. Lett. **57**, 48 (1986).
6. Production, Decays and Forward-Backward Asymmetries of Extra Gauge Bosons in E_6, V. Barger, N.G. Deshpande, J.L. Rosner and K. Whisnant, Phys. Rev. D **35**, 2893 (1987).
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9. Signature for Extra Gauge Bosons of E_6 at the SSC: Their Production, Decays and Asymmetries, V. Barger, N.G. Deshpande, J.L. Rosner and K. Whisnant, Snowmass Summer Study on the Physics of the SSC, 1986.
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11. Monte Carlo Study of the Antiferromagnetic Two-Dimensional Blume-Capel Model ,J.D. Kimel, S. Black, P. Carter, and Y.-L. Wang, Phys. Rev. B **35**, 3347(1987).
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18. A Non-Numerical Method for Track Finding in Experimental High Energy Physics Using Vector Computers, Nuc. Inst. and Meth., **A249**, C. Georgiopoulos,J.H. Goldman, M. Hodous, and D. Levinthal, 451, (1986).

19. Production of Hadrons and Leptons at High p_t and Pairs at High Mass, Quarks, Strings, Dark Matter and all the Rest, D. Kaplan. Proceedings of the 7th Vanderbilt High Energy Physics Conference, World Scientific Press, ed. R. Panvini, and T. Weiler, (1987).

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4. Spin and Parity Analysis of $K\overline{K}\pi$ System in the D and E/iota Regions. Phys. Rev. Lett. **55**, 779 (1985).
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PUBLICATIONS

1) 1988-1989
   a) Published
   b) Accepted
   c) Submitted

Reprints removed.

2) Selected front pages of publications 1985-1988

1988 - 1989 Publications

(Task A)

Note: This publication period is only for 10 months (August 1, 1988 - May 31, 1988) due to the advanced submission date of the progress report for external review.

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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4. Preliminary Results of $\overline{p}p$ at 8 GeV/c. Proceedings of the BNL Workshop on Glueballs, Hybrids and Exotic Hadrons, Aug. 1988. Ed. S. Chung, AIP Conference Proceeding No. 185, p. 446 (1989).
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12. 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).
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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2. Hadronic W-decays at HERA, H. Baer, J. Ohnemus, and D. Zeppenfeld, Z. Phys. **C**.
3. Expectations for two- and three-jet events at HERA, H. Baer, J. Ohnemus, and J. F. Owens, Z. Phys. **C**.
4. Signals for Supersymmetry at Current $\bar{p}p$ Colliders, H. Baer and X. Tata. Proceedings of the Moriond Conference on Hadronic Interactions, Les Arcs, France (1989).
5. WW Signatures From Top Quarks at the Tevatron, H. Baer, V. Barger, and R. J. N. Phillips, Phys. Rev. **D**.
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12. New Particle Signals at the SSC and at an Upgraded Tevatron Collider, H. Baer (with R.M. Barnett et. al.), proceedings of the 1988 Snowmass summer study.
13. Supersymmetry at Current Hadron Colliders, H. Baer, Proceedings of the Moriond Meeting on Hadronic Interactions-1989.
14. 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, 1989), in press.
15. Higher Order Calculations for Hard Scattering Processes, J. F. Owens, proceedings of the 1988 DPF Conference, U. Conn., Storrs, Connecticut.

C. Papers Submitted for Publication

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2. Gluino Cascade Decay Signatures at the Tevatron Collider, H. Baer, X. Tata, and J. Woodside, submitted to Phys. Rev. **D**.
3. A next-to-leading-logarithm calculation of jet photoproduction, by H. Baer, J. Ohnemus, and J. F. Owens, FSU-HEP-890301, submitted to Phys. Rev. **D**.
4. Next-to-Leading-Logarithm QCD Calculation of Symmetric Dihadron Production, L. J. Bergmann and J. F. Owens, submitted to Phys. Rev. **D**.

5. Atomic Weight Dependence of the Production of Hadron Pairs from 800 GeV/c Protons on Nuclear Targets, K. Streets, G. Boca, C. Georgiopoulos, J.H. Goldman, S. Hagopian, V. Hagopian, K.F. Johnson, D. Kaplan, D. Levinthal, F. Lopez, H.L. Sawyer, J. Streets, H. White, C. Young *et al*, submitted to Phys. Rev. Lett.

6. The Cross Section for Massive Hadron Pair Production by 800 GeV/c Protons on Nuclear Targets, D. Levinthal, K. Streets, G. Boca, J.H. Goldman, K.F. Johnson, H.L. Sawyer, J. Streets, H.B. White, *et al*, submitted to Phys. Rev. Lett.

7. Radiation Damage Studies in Plastic Scintillators with a 2.5 MeV Electron Accelerator, K.F. Johnson, V. Hagopian, J. Thomaston, H. Wahl *et al*, submitted to Nucl. Inst. and Methods.

D. Ph.D. Dissertations

1. Next-to-Leading-Log QCD Calculation of Symmetric Dihadron Production, L.J. Bergmann.
2. Stochastic Implementation of Improved Actions for Gauge Theories on a Lattice, S.C. Black.
3. $K^+\overline{K}^o\pi^-$ Production in K^-p Interactions at 8 GeV/c, D.J. Boehnlein.
4. The Atomic Weight Dependence and Mass Cross Sections of Massive Hadron Pair Production in Proton-Nucleus Collisions at 800 GeV/c, K.R.T. Streets.

1987 - 1988 Publications
(Task A)

Papers Published .

1. Two-Photon Backgrounds for the Intermediate Mass Higgs Boson, H. Baer and J.F. Owens, Phys. Lett. B **205**, 377 (1988).
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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).
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8. Discovery Limits of New Gauge Bosons of $Sp_L(6)$xU(1), K. Whisnant, *et al.*, Int. J. of Mod. Phys. A **2**, 1327 (1987).
9. Production and Decays of Extra Gauge Bosons in a Left-Right E_6 Superstring Model, K. Whisnant, *et al.*, Int. J. of Mod. Phys. A **3**, 879 (1988).
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17. Experimental HEP Supercomputing at FSU, D. Levinthal, J.H. Goldman, *et al.*, Comp. Phys. Comm. **45**,137 (1987).
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5. Neutral Meson-Antimeson Mixing for a Heavy Isosinglet Quark Constituent, V. Barger, R.J.N. Phillips and K. Whisnant, Phys. Rev. Lett. **57**, 48 (1986).
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18. A Non-Numerical Method for Track Finding in Experimental High Energy Physics Using Vector Computers, Nuc. Inst. and Meth., **A249**, C. Georgiopoulos,J.H. Goldman, M. Hodous, and D. Levinthal, 451, (1986).

19. Production of Hadrons and Leptons at High p_t and Pairs at High Mass, Quarks, Strings, Dark Matter and all the Rest, D. Kaplan. Proceedings of the 7th Vanderbilt High Energy Physics Conference, World Scientific Press, ed. R. Panvini, and T. Weiler, (1987).

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21. Fractals and Interpolating Dimensions, G. Bhanot, D. Duke, and R. Salvador, Phys. Lett. **165B**, 355 (1985).

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5. Forward $K^o_sK^o_s$ Production in 200 GeV/c π^-N Interactions. Phys. Rev. D **30**, 877 (1985).
6. Baryon Production and Decay into Strange Particle Final States in 200 GeV/c π^-N Interactions Phys. Rev. D **30**, 872 (1984).
7. Study of the ρ' (1600) Mass Region using $\gamma p \rightarrow \pi^+\pi^-p$ at 20 GeV. Phys. Rev. Lett. **53**, 751 (1984.)
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21. On the Unification of the Law of Motion, L. Halpern, Foundations of Physics, 14, 1011 (1984).

VITAE

HOWARD A. BAER
DENNIS W. DUKE
JOEL HARVEY GOLDMAN
SHARON L. HAGOPIAN
VASKEN HAGOPIAN
KURTIS F. JOHNSON
J. DANIEL KIMEL
JOSEPH E. LANNUTTI
DAVID LEVINTHAL
JAMES OHNEMUS
JOSEPH FRANCIS OWENS, III
HENRYK PIEKARZ
HORST D. WAHL
WILLIAM JOHN WOMERSLEY

HOWARD A. BAER

VITA

Address Department of Physics
Florida State University
Tallahassee, Fl. 32306
BITNET Address: BAER@FSU
DECNET Address: 7479::BAER

Phone 904-644-3289

Marital Status Single

Date of Birth [redacted]

Citizenship United States

Education

1981-1984 Ph.D., University of Wisconsin, Physics
1980-1981 M.Sc., University of Wisconsin, Physics
1975-1979 B.Sc., University of Wisconsin, Physics, Mathematics (with honors)

Research and Teaching Positions

1987 - Present, Assistant Research Scientist in Particle Theory, Florida State University, Tallahassee
1985-1987, Postdoctoral Appointee in Particle Theory, Argonne National Laboratory
1984-1985, Paid Scientific Associate in Particle Theory, CERN, Geneva, Switzerland
1981-1984, Research Assistant in Particle Theory, University of Wisconsin - Madison
1980-1981, Teaching Assistant in General Physics, University of Wisconsin-Madison
1979-1980, Teaching Assistant in Physics, University of Maryland-College Park

PUBLICATIONS

1. Decays of Weak Vector Bosons and t-Quarks into Doubly Charged Higgs Scalars (with V. Barger, W.Y. Keung and R.J.N. Phillips), Phys. Rev . **D26**, 218 (1982).
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REFERENCES

Professor V. Barger
Department of Physics
University of Wisconsin
Madison, Wisconsin 53706 USA

Dr. E.L. Berger
High Energy Physics Division
Argonne National Laboratory
Argonne, Illinois 60439 USA

Dr. J. Ellis
CERN, Theory Division
CH-1211 Geneve 23
Switzerland

Professor H. Goldberg
Department of Physics
Northeastern University
Boston, Massachusetts, 02115 USA

Dr. R.J.N. Phillips
Theory Group, Head
Rutherford Appleton Laboratory
Chilton, Didcot, Oxon
England

GRADUATE STUDENTS SUPERVISED

Debra Karatas (Argonne, IIT) Ph.D. May 1989

COMMUNITY SERVICE

Member of Speakers Bureau for Union of Concerned Scientists and Tallahassee Peace Coalition.

Nuclear Issues Chairperson- Big Bend Sierra Club

CURRICULUM VITÆ

Dennis W. Duke

University Address

Department of Physics
473 SCL
Florida State University
Tallahassee, FL 32306
(904) 644-1010

Home Address

813 Voncile Avenue
Tallahassee, FL 32306
(904) 385-3929

Date of Birth [redacted]

Education

B.S., Vanderbilt University, 1970
D.Phil., Iowa State University, 1974

Experience

1984-present, Associate Director for Research, Supercomputer Computations Research Institute, The Florida State University

1986–present, Associate Professor, Department of Physics, The Florida State University

1984–1986, Assistant Professor, Department of Physics, The Florida State University

1979–1984, Visiting Assistant Professor, Department of Physics, The Florida State University

1978–1979, Research Associate, Theory Division, Rutherford Laboratory, England

1976–1978, Research Associate, Theory Department, Fermi National Accelerator Laboratory

1974–1976, Research Associate, University of Rochester

1970–1974, NSF Traineeship, Iowa State University

Research Interests

Theoretical High Energy Physics
Computational Physics

PUBLICATIONS & ARTICLES

(* indicates articles published in refereed journals)

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JOEL HARVEY GOLDMAN

VITA

Place of Birth [redacted]

Date of Birth [redacted]

Citizenship USA

Marital Status Single

Education
1966, B.S., Mathematics, MIT
1967, M.S., Physics, University of Minnesota
1972, Ph.D., University of Maryland

Experience
1972-1975, Associate Research Physicist at New York University
1975-1977, Assistant Physicist, Physics Department, Brookhaven National Laboratory
1977-1978, Associate Physicist, Physics Department, Brookhaven National Laboratory
1979, Consultant to Florida State University on Experiment 673 at Brookhaven National Laoratory
1979, Associate Physicist, Physics Department, Brookhaven National Laboratory
1979-1981, Research Assistant Professor, Physics Department, Florida State University
1981-1983, Assistant Research Scientist, Physics Department, Florida State University
1983-present, Associate Research Scientist, Physics Department, Florida State University

Organizations
The American Physical Society
Brookhaven National Laboratory Users Group
Fermi National Accelerator Users Group

PUBLICATIONS

Papers

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4. K^-P Elastic Differential Cross Sections Between 1.4 and 1.9 GeV/c. With K. Abe, B.A. Barnett, A.T. Laasanen and P.H. Steinberg, University of Maryland; and G.J. Marmer, D.R. Moffett and E.F. Parker, Argonne National Laboratory. Presented at the Purdue University Baryon Resonances Conference (1973), and published in *Baryon Resonances–* 73 (pp. 305-310). Edited by E.C. Fowler, Purdue University Press, West Lafayette, Indiana (1973).
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11. Study of K^* (1780) in the Reaction $K^-p \rightarrow K^-pi^+N$ at 6 GeV/c. With S.U. Chung, A. Etkin, V. Flamino, K.J. Foley, J. Kopp, W.A. Love, D.N. Michael, T.W. Morris, S. Ozaki, E.D. Platner, S.D. Protopopescu, A.C. Saulys, C.D. Wheeler and E.H. Willen, Brookhaven National Laboratory; J.R. Bensinger and S.M. Jacobs, Brandeis University; S.J. Lindenbaum, B.N.L. and C.C.N.Y.; I.J. Kim and M.A. Kramer, C.C.N.Y.; J. Button-Shafer, S. Dhar and R. Lichti, University of Massachusetts; and W. Selove, University of Pennsylvania. *Physical Review Letters* 40, 355 (1978).

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SHARON L. HAGOPIAN

VITA

Place of Birth	[redacted]
Date of Birth	[redacted]
Citizenship	USA
Marital Status	Married, one child
Education	1963, A.B., Vassar College 1965, M.S., University of Pennsylvania 1970, Ph.D., University of Pennsylvania
Experience	June-August 1963, Research Specialist, Brookhaven National Laboratory September 1963-May 1964, Graduate Teaching Assistant, University of Pennsylvania June 1964-August 1965, Graduate Research Assistant, University of Pennsylvania September 1965-August 1966, Research Specialist, Lawrence Radiation Laboratory September 1966-August 1967, Graduate Research Assistant, University of Pennsylvania September 1967-May 1970, National Science Foundation Trainee June 1970-November 1975, Research Associate, The Florida State University November 1975-present, Staff Physicist, The Florida State University

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VASKEN HAGOPIAN

VITA

Place of Birth [redacted]

Date of Birth [redacted]

Citizenship USA

Marital Status Married, one child

Education
1963, Ph.D., University of Pennsylvania
Major - Physics

Experience
1954-1958, Part-time High School Physics Teacher
September 1958-June 1963, Research Assistant, Department of Physics, University of Pennsylvania
July 1963-August 1965, Research Associate, Department of Physics, University of Pennsylvania
September 1965-August 1966, Visiting Assistant Professor, University of California, Berkeley, California
September 1965-December 1969, Assistant Professor of Physics, University of Pennsylvania
1967-1969, (1/2-time basis), Head Physicist of Bubble Chamber Program at Princeton- Pennsylvania Accelerator, Princeton University, Princeton, New Jersey
1969-1975, Associate Professor of Physics, Florida State University
1975-present, Professor of Physics, Florida State University
1985-present, Faculty Associate, Supercomputer Computations Research Institute

Special Summer Appointments
Where either salary or expenses paid by institution, not counting institutions where normally employed.
1964, Guest Physicist, Brookhaven National Laboratory
1966, Physicist, Lawrence Berkeley Laboratory
1968, Physicist, Princeton-Pennsylvania Accelerator
1973-1974, 1976, 1978-1981, Research Collaborator or Visiting Physicist, Department of Physics, Brookhaven National Laboratory

Guess Appointments (worked on experiments at various times)
1964-present, Brookhaven National Laboratory
1965-1966, Lawrence Berkeley Laboratory
1966-1969, Princeton-Pennsylvania Accelerator
1966-1970, Argonne National Laboratory
1971-1984, Stanford Linear Accelerator Center
1976-present, Fermi National Accelerator Center

Organizations
American Physical Society
Particle and Fields, A.P.S.
Sigma Xi
Brookhaven National Laboratory User Group
Stanford Linear Accelerator User Group
Fermi National Accelerator User Group
SSC User Group

Conferences
March 28-30, 1973, Co-Chairman of International Conference on $\pi^-\pi$ Scattering and Associated Topics

Principal Investigator
1973-1974, National Science Foundation Grant GP-37090 for International Conference on $\pi^-\pi$ Scattering

Co-Investigator
1970-present, Department of Energy Grant DE-AS05-ER03509A017 for High Energy Physics

PUBLICATIONS

Papers

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67. Partial Wave Analysis of the $K^+K^0\pi^-$ System Produced in the Reaction $\pi^-p \rightarrow K^+K^0\pi^-n$ at 8 GeV/c. Proceedings of the Third Conference on the Interaction Between Particle and Nuclear Physics. Maine, May 1988. To be published.

68. Preliminary Results of $\bar{p}p$ at 8 GeV/c. Proceedings of the BNL Workshop on Glueballs, Hybrids and Exotic Hadrons, Aug. 1988. To be published.

69. Mass Dependent Fits of the Partial Wave Analysis of the $K^+K^0\pi^-$ System. Proceedings of the BNL Workshop on Glueballs, Hybrids and Exotic Hadrons, Aug. 1988. To be published.

70. Atomic Weight Dependence of the Production of Hadron Pairs from 800 GeV/c Protons on Nuclear Targets. Submitted to Phys. Rev. Letters (1989).

Kurtis F. Johnson

VITA

Place of Birth [redacted]

Date of Birth [redacted]

Citizenship U.S. citizen

Marital Status Married, two children

Education

1987, Ph.D., University of Chicago, Physics
1978, M.S., University of Chicago, Physics
1975, Diplomphysiker degree, University of Heidelberg, Heidelberg, West Germany

Experience

January 1987-present, Computer Research Specialist, The Florida State University

Construction of 7500 channels of pre-amplifier electronics for the FNAL experiment E711 drift chamber system:

- overall responsibility for the project; supervison of the technicians
- prototyping pre-amp electronics
- vendor selection
- installation, testing, trouble shooting

Overall responsibility for the construction of a fifth drift chamber station and refurbishing of four older drift chambers for FNAL experiment E711.

August 1986-January 1987, Postdoctoral Research Associate, The Florida State University, Tallahassee, Florida

September 1978-July 1986, Research Assistant in particle physics Enrico Fermi Institute, The University of Chicago

Construction of 4000 channel drift chamber system for a dimuon experiment at FNAL:

- construction and testing of prototype chambers
- design and construction of interface logic for chamber readout
- coordination of wire chamber assembly
- precision installation and survey of chambers in experimental areas
- installation of electronics and cabling
- design and installation of the chamber gas mixing system (to mix Argon and ethane in a precise 50:50 ratio)

Data taking:

- prototyping phototube/base combinations to find highly linear PM/base set for use in calorimeter
- novel detector development: built and tested a calorimeter segment using dibromoethane as shower medium; built a liquid Helium neutron detector for use in an ultra-cold neutron EDN experiment (development was cut short by lack of funds)

1971 - 1975 Research Assistant, Institute for Hochenergiephysik, University of Heidelberg.

800 MeV/c K p bubble chamber experiment:

- scanning; later supervision of scanners
- creation of pattern recognition software for analysis of bubble chamber exposures using a PDP-10 controlled Precision Encoding and Pattern Recognition device (PEPR)

Computer Experience

Assembly language data acquisition software and device drivers in PDP-10 and PDP11 assemblers.
Designed and built digital interface for PDP-11.
Assembly language CAMAC drivers.
Large scale FORTRAN monte carlo simulations of high energy physics experiments and analysis of same.
Extensive experience in coding on CYBER main frames

PUBLICATIONS

Papers

1. Atomic-,mass dependence of the transverse momentum distribution of massive muon pairs form 225 GeV/c π^- nucleus collisions, *Phys. Rev. Lett.* **53**, 32 (1984).
2. Atomic-weight dependence of muon pair production in 225 GeV/c π^- nucleus interactions, *Phys. Rev. Let* **D25**, 2000 (1982).
3. A fast and powerful system to measure difficult bubble chamber events, NIM 116, 17 (1974).
4. Production of massive muon pairs in π^- nucleus collisions, *Phys. Let Rev.* **55**, 1555 (1985).
5. Atomic Weight Dependence of the Production of Hadron Paris from 800 GeV/c Protons on Nucler Targets, With D. Levinthal, K. Streets, G. Boca, C. Georgiopoulos, J. H. Goldman, S. Hagopian, V. Hagopian, D. Kaplan, F. Lopez, H.L. Sawyer, J. Streets, H.B. White, M. Criler, A. Lathrop, S. Pordes, J. Volk, M. Cummings, H.R. Gustafson, and C. Young. *Submitted Physical Review Letters*, (1989).
6. The Cross Section for Massive Hadron Pair Production by 800 GeV/c Protons on Nuclear Targets, With D. Levinthal, K. Streets, G. Boca, C. Georgiopoulos, J.H. Goldman, F. Lopez, H.L. Sawyer, J. Streets, H.B. White, M. Crisler, A. Lathrop, S. Prodes, M. Cummings, and H.R. Gustafson. *Submitted Physical Review Letters*, (1989).
7. Radiation Damage Studies in Plastic Scintillators with a 2.5 MeV Electron Beam. *Submitted to Nuclear Instruments and Letters*, (1989).

JOSEPH E. LANNUTTI

University Address	High Energy Particle Physics 513 Keen Building Florida State University Tallahassee, FL 32306-3016 (904) 644-1492
Home Address	1501 Crestview Ave. Tallahassee, FL 32303 (904) 224-1655

Place of Birth	[redacted]
Date of Birth	[redacted]
Citizenship	USA
Marital Status	Married
Education	1950, B.S., Pennsylvania State College, Physics 1953, M.S., University of Pennsylvania, Physics 1957, Ph.D., University of California, Physics

Experience

June 1943-July 1944, Pennsylvania Railroad Company, Office of the Master Mechanics

July 1944-July 1946, U.S. Army, 28th Infantry Division, European Theater

August 1946-September 1947, Pennsylvania Railroad Company, Administrative Assistant, Office of the Chief of Motive Power

December 1949-September 1950, Research Assistant, Pennsylvania State University, in X-ray Laboratory with Dr. Ray Pepinsky

September 1952-September 1953, Research Assistant and Teaching Assistant, University of Pennsylvania, in β-ray Spectroscopy Lab with Dr. Sherman Frankel

September 1953-September 1954, Theoretical Physicist designing guided missle autonavigation systems, North American Aviation, Inc., Downey, California

January 1954-September 1957, Research Assistant, University of California Radiation Laboratory with Dr. Gerson Goldhaber and Dr. Emilio Segre

September 1957-1963, Assistant Professor, The Florida State University

September 1958-present, Initiator and Principal Investigator, High Energy Particle Physics, The Florida State University (approximate total FY88 budget–$1M)

September 1963-1965, Associate Professor, The Florida State University

September 1965-present, Professor, The Florida State University

October 1982–September 1984, Initiator and Co-director, FAMU/FSU College for Engineering

January 1984–present, Associate Vice President for Academic Affairs

October 1984–present, Initial organizer and Director, Supercomputer Computations Research Institute, The Florida State University (approximate total FY89 budget–$16M)

Organizations

American Physical Society
Sigma Xi
Sigma Pi Sigma
Users Groups at Fermi National Accelerator Laboratory, Brookhaven National Accelerator Laboratory, Stanford Linear Accelerator Center, and Center for Nuclear Research for Europe in Geneva

Users Executive Committee, Fermi National Accelerator Laboratory (past member)

Southeastern University Research Association, Board of Trustees (past member)

University Research Association, Board of Trustees, Chairman of Physics Committee

Oak Ridge Associated Universities, Board of Directors and former Chairman of Council

High Energy Physics Advisory Panel, U.S. Department of Energy

Field of Research Interest

Elementary Particle Physics and Use of Supercomputers in Science

More than 100 abstracts and publications.

Papers

1. Method for Alignment of Stripped Nuclear Emulsions. With Goldsack and Goldhaber. University of California, *UCRL-* **2928** (March 1955).
2. Measurements on K-particles From the Bevatron. With Chupp, Goldsack, G. Goldhaber, S. Goldhaber, Smith and Webb. *Physical Review* **99**, 335 (1955).
3. K-meson Mass From a K-hydrogen Scattering Event. With G. Goldhaber, S. Goldhaber, Chupp and Johnson. *Physical Review* 99, 1042 (1955).
4. Mean Lifetime of Positive K-mesons. With Iloff, Chupp. G. Goldhaber, S. Goldhaber, Pevsner and Ritson. *Physical Review* **99**, 1917 (1955).
5. Interactions and Decay of Positive K-particles in Flight. With Chupp, G. Goldhaber, S. Goldhaber, Iloff, Pevsner and Ritson. Proceedings of Pisa. Conference 1955, *Nuovo Cimento* 4 Supplement, 361 (1956).
6. Mean Lifetime of Negative K-mesons. With Iloff, G. Goldhaber, Gilbert, Violet, White, Fournet, Pevsner, Ritson and Widgoff. *Physical Review* 102, 917 (1956).
7. Study of the Interaction of Positive K-mesons. With G. Goldhaber, S. Goldhaber and Chupp. *Physical Review* 109, 2121 (1958).
8. Scattering of K^+ Mesons in Emulsion. With Igo, Ravenhall, Tiemann, Chupp, G. Goldhaber and S. Goldhaber. *Physical Review* 109, 2133 (1958).
9. Evidence for the Reaction $\bar{p} + p \rightarrow \Sigma + \Lambda$. With Button, Eberhard, Lynch, Kalbfleisch, Maglic and Stevenson. *Physical Review* Letters 4, 530 (1960).
10. Double Scattering of Antiprotons in Hydrogen. With Lynch, Maglic, Stevenson and Xuong. *Proceedings of the 1960 Annual International Conference on High Energy Physics* at Rochester, 159 (August 25, 1960).
11. Antiproton Experiments in a Hydrogen Bubble Chamber. With Button, Eberhard, Kalbfleisch, Limentani, Lynch, Maglic, Stevenson and Xoung. *Proceedings of the 1960 Annual International Conference on High Energy Physics* at Rochester, 164 (August 25, 1960).
12. The Reaction $\bar{p} + p \rightarrow \bar{\Lambda} + \Lambda$. With Button, Eberhard, Kalbfleisch, Lynch, Maglic, Stevenson and Xuong. *Ibid*, 481.
13. The Reaction $p + p \rightarrow \bar{\Lambda} + \Lambda$. Button, Eberhard, Kalbfleisch, Lynch, Maglic, Stevenson and Xuong. *Physical Review* **121**, 1788 (1961).
14. Two-meson Annihilations of 1.16 BeV/c Antiprotons in Hydrogen. With Lynch, Eberhard, Kalbfleisch, Maglic, Shafer, Stevenson and Xuong. *Physical Review* 131, 1287 (1963).
15. Final State Enhancement at 1920 MeV in $\pi^- p$ Inelastic Scattering. With Gutay, Csonka, Moravcsik and Scadron. *Physics Letters* **16** 343 (1965).
16. Exchange Mechanisms for the Reactions $\pi^- p \rightarrow \rho^0 n$ and $\pi^- p \rightarrow \rho^- p$ at 2.0 GeV/c. With Gutay and Tuli. *Nuovo Cimento* **39**, 38 (1961).
17. Negative Pion-Proton Elastic Scattering at 2.26 GeV/c. With Reynolds, Brucker, Harrison, Harms, Kimel and Albright. *Physics Letters* **24B**, 311 (1967).
18. Analysis of the Decay of ρ^- Mesons Produced in $\pi^- p$ Interactions at 2.26 GeV/c. With Reynolds, Albright, Bradley, Brucker, Harms, Harrison, Sims and Wieckowicz. Nucl. Phys. B6, 633 (1968).

19. $\pi^- p$ Elastic Scattering at 2.26 GeV/c. With Reynolds, Kimel, Albright, Bradley, Brucker, Harrison, Harms, Sims and Wieckowicz. *Physical Review* **173**, 1403 (1968).
20. $\Lambda\pi\pi$ Structure from 1600 to 1740 MeV. With Bartley, Chu, Dowd, Greene, Schnepps, Sims, Albright, Brucker, Reynolds, Meer, Mueller, Schneeberger and Wolf. *Physical Review Letters* 21, 1111 (1968).
21. Partial Wave Analysis of the Sequential Reaction $K^- N \rightarrow Y^*$ (1385) $\pi \rightarrow \Lambda\pi\pi$. With Sims, Albright, Brucker, Dockery, O'Neall, Reynolds, Bartley, Dowd, Greene, Schnepps, Meer, Mueller, Schneeberger and Wolf. *Physical Review Letters* 21, 1413 (1968).
22. Study of Resonant Structure in the $\pi^- \eta$ System from the Reaction $\pi^- p \rightarrow \pi^- p\eta$ at 2.26 GeV/c. With Wieckowicz, Reynolds, Albright, Brucker, Harms, Harrison and Sims. *Physics Letters* 28B, 199 (1968).
23. T = 2 Pion-Pion Scattering. With Albright, Bradley, Brucker, Harms, Harrison, Hunter, Reynolds, Sims and Wieckowicz. *Nuovo Cimento* **60A**, 1 (1 March 1969).
24. Single Pion Production in $\pi^- p$ Interaction at 2.26 GeV/c. With Reynolds, Kimel, Albright, Bradley, Brucker, Harrison, Harms, Sims and Wieckowicz. *Physical Review* 184, 1424 (1969).
25. A Study of the I=0 Enhancement in the 1.07 GeV Mass Region. With Reynolds, Huwe, Albright, Bradley, Brucker, Harms, Harrison, Sims, Wieckowicz, Marquit, Oppenheimer and Schultz. *Nuclear Physics* B21, 77 (1970).
26. A Study of the I=1 Reaction $K^- n \rightarrow \Sigma^\pm \pi^\pm \pi^-$ from 1585 to 1735 MeV. With Brucker, Harrison, Sims, Albright, Chandler and Reynolds. *1970 Conference Report on Hyperon Resonances*, Duke University, p. 155 (April 1970).
27. A Study of the Non-Impulse Events in the Reactions $K^- d \rightarrow \Lambda\pi p$ and $\Lambda\pi\pi N$ at 670-925 MeV/c. With Sims, O'Neall, Albright and Brucker. *Physical Review* **D3**, 1162 (1971).
28. Observation of a 7π Enhancement at 3.01 GeV. With Yost, Morris, Albright and Brucker. *Physical Review* **D3**, 642 (1971).
29. Asymmetry Properties of Longitudinal Momentum Distributions for the Reaction $\pi^+ p \rightarrow p8\pi$ at 11 GeV/c. With Yost, Morris and Albright. *Physical Review* **D6**, 3051 (1972).
30. $K^- d$ Elastic Scattering at 727 MeV/c. With Wieckowicz and Albright. *Nuclear Physics* **B61**, 274 (1973).
31. Mass Dependence of the Momentum Transfer Distribution in $\pi^+ p \rightarrow p8\pi$ at 11.0 GeV/c. With Yost, Morris and Albright. *Physical Review* **D10**, 1 (1974).
32. Topological Cross Sections and Multiplicity Momenta for $\pi^- p$ Interactions at 250 GeV/c. With S. Hagopian, Albright, Hays, Bogert, Hanft, Harris, Kahn, Huson, Pascaud and Smart. *Proceedings of Div. of Particle and Fields*, Seattle, Washington (August 1975).
33. Search for Charm in 250 GeV/c $\pi^- p$ Interactions. With Harris, Bogert, Hanft, Kahn, Huson, Pascaud, Smart, Albright, S. Hagopian and Hays. *Proceedings of D.P.F.*, Seattle, Washington (August 1975).
34. Neutral Strange Particle Production in $\pi^- p$ Interactions at 250 GeV/c. With Bogert, Hanft, Harris, Huson, Kahn, Pasaud, Smart, Albright, S. Hagopian and Hays. *Proceedings of of D.P.F.*, Seattle, Washington (August 1975).
35. Reaction $\pi^+ d \rightarrow \pi^+ \pi^+ \pi^- d$ at 15 GeV/c. With Home, S. Hagopian, V. Hagopian, Pewitt, Wilkins, Wind and Bensinger. *Physical Review* **D11**, 996 (1975).

36. Duality and Low Mass $K\overline{K}$ Resonances. With S. Hagopian, Albright, V. Hagopian and Wilkins. *Proceedings of D.P.F. Meeting*, Seattle, Washington, p. 277, *Am. Inst. of Phys.* (1975).

37. Search for Charmed Mesons and Baryons. S. Hagopian, Wilkins, Wind, V. Hagopian, Albright, Pewitt, Horne and Bensinger. *Physical Review* **36**, 296 (1976).

38. Resonances in the K_sK_s System. With Wilkins, Albright, S. Hagopian and V. Hagopian. *Physical Review* **D13**, 1831 (1976).

39. Longitudinal-Phase-Space Analysis of $\pi^+n \rightarrow \pi^+\pi^-p$ at 15 GeV/c. With Richey, S. Hagopian, Kimel, V. Hagopian, Wind, Horne, Pewitt, Bensinger and Cohn. *Physical Review* **D15**, 3155 (1977).

40. Reaction $K^-n \rightarrow \Lambda^0\pi^-$ from 1550 to 1650 MeV. With Morris, Albright, Colleraine and Kimel. *Physical Review* **D17**, 55 (1978).

41. Inclusive Production of Neutral Strange Particles in 250 GeV/c π^-p Interactions. With Harris, Bogert, Hanft, Huson, Kahn, Pascaud, Smart, Albright, S. Hagopian and Hays. *Physical Review* **D16**, 2098 (1977).

42. Two Particle Correlations Involving Neutral Strange Particles. With Harris, Bogert, Hanft, Huson, Kahn, Smart, Biswas, Bishop, Cason, Kenney, Shephard, Albright, S. Hagopian and Hays. *Physical Review* **D17**, (1978).

43. Many-Pion Production in π^+d Reactions at 15 GeV/c. With Gluch, S. Hagopian, Horne, Jenkins, Williams, Wind, Cohn, Bugg, Condo, Handler and Hart. *Physical Review* **D20**, 2113 (1979).

44. Neutral Three Pion $(\pi^+\pi^-\pi^0)$ Resonance Production in 15 GeV/c π^+d Collisions. With S. Hagopian, Bugg, Condo, Handler, Hart and Cohn. *Physical Review* **D21** 623 (1980).

45. Investigations of Higher Mass Even-G States from 15 GeV/c π^+d Collisions. With Bugg, Condo, Handler, Hart, Cohn, S. Hagopian and Wind. *Physical Review* **D21**, 1744 (1980).

46. 250 GeV/c π^-p Multiplicity Distributions and the Two Component Model. *Physical Review* **D23**, 20 (1981).

47. The Lead Glass Columns: A Large Shower Detector at the SLAC Hybrid Facility. With Brau, Butler, Bugg, Carroll, Cautis, Cohn, Condo, Dado, Davenport, Diamond, Erickson, Field, Fortney, Franek, Gearhart, Glanzman, Goldberg, Goshaw, V. Hagopian, Handler, Hargis, Hart, Huang, Kelsey, Lucas, Moffeit, Maruyama, Paolunek, Rafatian, Robertson, Rogers, Sugahara, Takahashi, Tether, Walker, Yamaguchi and Yamamoto. *Nucl. Inst. and Methods* **196**, 403-413 (1982).

48. Inclusive π^0 Production in 250 GeV/c π^-p Interactions. With Diamond, S. Hagopian and Hays. *Physical Review* **D25**, 41 (1982).

49. Lifetimes of Charmed Particles Produced in a 20 GeV γp Experiment. With Abe, Bacon, Ballam, Berny, Bevan, Bingham, Brau, Brick, Bugg, Butler, Cameron, Carroll, Cautis, Chima, Cohn, Colley, Condo, Dado, Diamond, Dornan, Erickson, Fieguth, Field, Fortney, Franek, Fujiwara, Gearhart, Goldberg, Gopal, Goshaw, Hafen, V. Hagopian, Hall, Hancock, Handler, Hargis, Hart, Haridas, Hasegawa, Hayashino, Huang, Hulsizer, Isaacson, Jobes, Kalmus, Kelsey, Kent, Kitagaki, Lang, Levy, Lucas, Mann, Maruyama, MacDermott, Merenyi, Milburn, Milstene, Moffeit, Murray, Napier, Noguchi, Ochiai, Neale, Palounek, Pless, Rabin, Rankin, Robertson, Rogers, Ronat, Rudnicka, Sato, Schnepps, Shank, Shapiro, Sinclair, Sugahara, Suzuki, Takahashi, Tamai, Tanaka, Tether, Wald, Walker, Widgoff, Wilkins, Wolbers, Woods, Wu, Yamaguchi, Yamamoto, Yamashita, Yekutieli, Yoshimura, Yost and Yuta. *Physical Review Letters* **48**, 1526-1529 (1982).

50. Searching for the Higgs at Tevatron II. With Donoghue, Haridas, Glass and Williams. *Physics Opportunities for the Fixed Target Tevatron*, eds. G. Kane and N. Gelfand, Fermilab, p.9 (1981).

51. Lifetimes of Charmed Particles Produced in a 20 GeV γp Experiment. With Abe, et al. SLAC-PUB-2870 (January 1982).

52. Charm Photoproduction Cross Section at 20 GeV. With Abe, et al. SLAC-PUB-3114 (April 1983). *Physical Review Letters* **51**, 156 (1983).

53. Resonance Production in Diffractive $\pi^-N \rightarrow K_s^oK_s^o\pi^-N'$ at 200 GeV/c. With Chen, Jenkins, Johnson, Lai, LeBritton, Lin, Pifer, Fenker, Green, Albright, Diamond, Goldman, Hagopian, Piper, et al. *Physical Review* **D28**, 2304 (1983).

54. Diffraction and Resonance Production in $\pi^-N \rightarrow V^oV^oX$ at 200 GeV/c. With Ficenec, et al. Proceedings of the 14th International Symposium on Multiparticle Dynamics at Lake Tahoe (June 22-27, 1983).

55. Total Inelastic Pion Multiplicity Distribution in 250 GeV/c π^-p Interactions. With Diamond, Hayes and Hagopian. *Physical Review* **D29**, 368 (1984).

56. Observation of the $\pi^+\pi^-$ Decay of the ρ' (1600) in γ-Proton Interactions at 19 GeV. With 98 co-authors. Proceeding of the Experimental Meson Spectroscopy-1983 New York Conference. Ed. S. Lindenbaum. *American Institute of Physics*, p. 169 (1984).

57. Latest Results from the Charm Photoproduction Experiment. With 98 co-authors. Proceeding of the Experimental Meson Spectroscopy-1983 New York Conference. Ed. S. Lindenbaum. *American Institute of Physics*, p. 419 (1984).

58. Diffractive Production of $K_s^oK_s^o\pi^+\pi^-\pi^-$ in π^-N Interactions at 200 GeV/c. With Chang, et al. *Physical Review* **D29**, 1888 (1984).

59. Charm Photoproduction at 20 GeV. With 94 co-authors. *Physical Review* **D30**, 1-21 (1984).

60. Baryon Production and Decay into Strange Particles Final States in 200 GeV/c q-N Interactions. With C. Chang, T. Davis, R. Diamond, K. Johnson, T. Chen, E. Jenkins, K. Lai, J. LeBritton, H. Fenker, D. Green, J. Albright, J. Goldman, S. Hagopian, J. Piper, A. Napier, J. Marraffino, J. Waters and M. Webster. *Physical Review* **D30**, 872 (1984)

61. Forward $K_s^oK_s^o$ Production in 200 GeV/c π^-N Interactions. With C. Chang, T. Davis, R. Diamond, K. Johnson, T. Chen, E. Jenkins, K. Lai, J. LeBritton, H. Fenker, D. Green, J. Albright, J. Goldman, S. Hagopian, J. Piper, A. Napier, J. Marraffino, J. Waters and M. Webster. *Physical Review* **D30**, 877 (1984)

62. Rho and Omega Production in π^+p Interactions at 15.7 GeV/c. With M. Ferguson, T. Glanzman, A. T. Goshaw, P. Lucas, N. Morgan, W. Robertson, W.D. Walker, P.M. Barlow, R.K. Clark, R.N. Diamond, V. Hagopian, C.M. Spencer, W. Bugg, G. Condo, T. Handler, E. Hart, A. Rogers, H.O. Cohn, I.J. Kim, C.R Sun, and R. Gearhart. *Physical Review D* **36**, 1961 (1987).

63. A Triggered Bubble Chamber Study of the Reaction π^+p $\rightarrow \Delta^{++}\pi^o\pi^o$ at 16 GeV/c. With R.K. Clark, P.M. Barlow, R.N. Diamond, V. Hagopian, C.M. Spencer, M. Ferguson, T. Glanzman, A.T. Goshaw, P. Lucas, N. Morgan, W. Robertson, W.D. Walker, W. Bugg, G. Condo, T. Handler, E. Hart, A. Rogers, H.O. Cohn, I.J. Kim, C.R. Sun, and R. Gearhart. *Physical Review* **D32**, 1061 (1985).

64. Inclusive Strange-Particle Production in Sigle-Vee Events in 200 GeV/c π^- N Interactions, Phys. Rev. D. 34, 42 (1986).

65. Rho and Omega Production in π^+ p Interactions at 15.7 GeV/c, P.M. Barlow, R.K. Clark, R.N. Diamond, V. Hagopian, J.E. Lannutti, C.M. Spencer, et al., Phys. Rev. D 36, 1961 (1987).

66. Mass Dependent Fits of the Partial Wave Analysis of the $K^+K^o\pi^-$ System. Proceedings of the BNL Workshop on Glueballs, Hybrids and Exotic Hadrons, Aug. 1988. Ed. S. Chung, AIP Conference Proceeding No. 185, p. 363 (1989).

DAVID LEVINTHAL

VITA

Date of Birth	[redacted]
Citizenship	USA
Marital Status	Single
Education	1976, B.A., Physics, University of California at Berkeley 1980, M.A., M.Ph., Ph.D., Columbia University, (Advisor: L.M. Lederman)
Professional Experience	1980-1983, Research Associate at Fermi National Accelerator Laboratory, Batavia, Illinois 1983-1988, Assistant Professor of Physics, The Florida State University 1988-present, Associate Professor of Physics, The Florida State University
Experimental Experience	CCOR - Collaboration at Intersecting Storage Ring at C.E.R.N. approximately two years of running. Group Leaders, L. DiLella/L. Camilleri. (Ph.D. Experiment). CCFR - Collaboration at Fermi National Accelerator Laboratory, 23-week data-taking in 1982. Group Leader, M. Shaevitz. Main responsibilities: Lab E detector and fast electronics. Wonder Building Monte Carlo. Wonder Building track reconstruction. Wonder Building software libraries. Prototyping E- 652 drift chambers. E711 - Collaboration at Fermilab; Group Leader, D. Levinthal. Test data run 1985, Main data run June 1987 - February 1988. ALEPH - Collaboration at C.E.R.N.; Group leader, J. Steinberger. FSU spokesman and member of Steering Committee, D. Levinthal. Reponsibilities: fast simulation, optimization of codes for supercomputers, off-line analysis computer system, on-line system (contributed manpower and equipment). 1982-1984, Directors Computer Advisory Committee at Fermilab. 1984-1986, Elected member of Fermilab User Executive Committee.

AWARDS

1. U.S. Department of Energy Outstanding Junior Investigator $45,000 per year 1984 - present and continuing.
2. FSU COFRS Summer Salary (partial) 1984 years (1985 - 1989)
3. U.S. Presidential Young Investigator award $62,500 per year for 5 years (1985 - 1989)
4. LeCroy, Inc. Equipment Grant $25,565 (1985)
5. PACER Fellowship (Funded by Control Data Corporation) $25,000 per year for two years (1986 - 1988)
6. SLOAN Foundation Fellow $12,500 per year for two years (1987-1989)
7. FSU COFRS Summer Salary (partial) 1987
8. Digital Equipment Corporation (DEC) External Research Grant $500,000 (1987)

Invited Seminars and Colloquia at following institutions:

1. CERN, Switzerland.
2. FERMILAB, Illinois.
3. Columbia University.
4. Rutgers University.
5. California Institute of Technology.
6. University of Michigan.
7. University of Washington.
8. SLAC, Stanford, California.
9. Florida State University.
10. Asilomar Conference on High Energy Computing.
11. Goddard Space Center, Washington, D.C.
12. Johns Hopkins University.
13. CERN Summer School on Computing, Troja, Portugal.
14. Ecole Polytechnique, Paris, France.

PUBLICATIONS

1. A System of Cylindrical Drift Chambers in a Superconducting Solenoid. With A.L.S. Angelis, B.J. Blumenfeld, L.Camilleri, T.J. Chapin, R.L. Cool, H. Cunitz, C. del Papa, L. di Lella, Z. Dimcovski, F. Doughty, R. Harfield, R.J. Hollebeek, L.M. Lederman, L.Lyons, C.J. Onions, N, Phinney, B.G. Pope, S.H. Pordes, A.F. Rothenberg, A.M. Segar, J. Singh-Sidhu, W. Sippach, A.M. Smith, M.J. Tannenbaum, R.A. Vidal, J.S. Wallace-Hadrill, T.O. White, and H. Wind. *Nuclear Instruments and Methods* **97**, 427 (1978).
2. A Measurement of Inclusive π^0 Production at Large P_T from PP Collisions at the CERN ISR. With A.L.S. Angelis, B.J. Blumenfeld, L. Camilleri, T.J. Chapin, R.L. Cool, C. del Papa, L. di Lella, Z. Dimcovski, R.J. Hollebeek, L.M. Lederman, J.T. Linnemann, L. Lyons, N. Phinney, B. G. Pope, S.H. Pordes, A.F. Rothenberg, A.M. Segar, J. Singh-Sidhu, A.M. Smith , M.J. Tannenbaum, R.A. Vidal, J. Wallace-Hadrill, T.O. White, and J.M. Yelton. *Physics Letters* **79B**, 505 - 520 (1978).
3. Results on Correlations and Jets in High Transverse Momentum PP Collisions at the CERN ISR. With A.L.S. Angelis, B.J. Blumenfeld, L. Camilleri, T.J. Chapin, R.L. Cool, C. Del Papa, L. di Lella, Z. Dimcovski, R.J. Hollebeek, L.M. Lederman, J.T. Linnemann, L. Lyons, N.Phinney, B.G. Pope, S.H. Pordes, A.F. Rothenberg, A.M. Segar, J. Singh-Sidhu, A.M. Smith, M.J. Tannenbaum, R.A. Vidal, J. Wallace-Hadrill, T.O. White, and J.M. Yelton. *Physics Scripta* **19**, 116 - 147 (1979).
4. A Measurement of the Production of Massive e^+e^- Pairs in Proton Proton Collisions at $\sqrt{s}$ = 62.4 GeV. With A.L.S. Angelis, H.J. Besch, B.J. Blumenfeld, L. Camilleri, T.J. Chapin, R.L. Cool, C. del Papa, L. di Lella, Z. Dimcovski, R.J. Hollebeek, L.M. Lederman, J.T. Linnemann, C.B. Newman, N. Phinney, B.G. Pope, S.H. Pordes, A.F. Rothenberg, R.W. Rusack, A.M. Segar, J. Singh- Sidhu, A.M. Smith, M.J. Tannenbaum, R.A. Vidal, J. Wallace- Hadrill, J.M. Yelton, and K.K. Young. *Physics Letters* **87B**, 398 - 412 (1979).
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6. A Measurement of the Transverse Momenta of Partons and of Jets Fragmentation as a Function of $\sqrt{s}$ in PP Collisions. With A.L.S. Angelis, H.J. Besch, B.J. Blumenfeld, L. Camilleri, T.J Chain, R.L. Cool, C. del Papa, L. di Lella, Z. Dimcovski, R.J. Hollebeek, L.M. Lederman, J.T. Linnemann, C.B. Newman, N. Phinncy, B.G. Pope, S.H. Pordes, A.F. Rothenberg, R.W. Rusack, A.M Segar, J. Singh-Sidhu, A.M. Smith, M.J. Tannenbaum, R.A. Vidal, J. Wallace-Hadrill, J.M. Yelton, and K.K. Young. *Physics Letters* **97B**, 163 - 168 (1980).
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15. Supercomputing in Experimental H.E.P. D. Levinthal. *Proceedings of the CERN Summer School of Computing*, Troja, Portugal (1987)

J. DANIEL KIMEL

VITA

Place of Birth	[redacted]
Date of Birth	[redacted]
Citizenship	USA
Marital Status	Married, four children
Education	1959, B.S., University of North Carolina 1960, M.S., University of Wisconsin 1966, Ph.D., University of Wisconsin
Experience	June-September 1958 and June-September 1959, Junior Physicist, Diamond Ordinance Fuse Laboratories, Washington, D.C. 1959-1960, Woodrow Wilson Fellow, University of Wisconsin 1960-1963, National Science Foundation Fellow, University of Wisconsin 1963-1965, Research Assistant, University of Wisconsin February-August 1966, Research Associate, University of Wisconsin September 1966-September 1967, Research Associate, The Florida State University September 1967-September 1973, Assistant Professor, The Florida State University September 1973-August 1988, Associate Professor, The Florida State University August 1988-Present, Professor, The Florida State University
Organizations	American Physical Society Sigma Xi Phi Beta Kappa
Field of Research Interest	Computational physics, theoretical studies of elementary particle properties and interactions.

PUBLICATIONS

Papers

1. Negative Pion-Proton Elastic Scattering at 2.26 GeV/c. With B. Reynolds, J. Albright, E.B. Brucker, C. Harrison, B. Harms and J.E. Lannutti. *Physics Letters* **24B**, 311 (1967).
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17. Pulsed UV Nitrogen Laser: Its Intensity and Line Width. With P. Richter and G.C. Moulton. *Applied Optics* **15**, 1117 (1976).
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25. A New Calculation of the Order-g^4 QCD Corrections to the Longitudinal Structure Function. With A. Devoto, D.W. Duke and G.A. Sowell. *Physics Letters* **138B**, 418 (1984).

26. Analytic Calculation of the Fourth Order Quantum-chromodynamic Contribution to the Nonsinglet Quark Longitudinal Structure Function. With A. Devoto, D.W. Duke and G.A. Sowell. *Physical Review* **D30**, 541 (1984).

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Software

1. Analysis and Graphics Package, published in Selected Software from the Conference on Computers in Physics Instruction, North Carolina State University (1989).

JOSEPH FRANCIS OWENS, III

VITA

Place of Birth	[redacted]
Date of Birth	[redacted]
Citizenship	USA
Marital Status	Married, two children
Education	1968, B.S., Worcester Polytechnic Institute 1973, Ph.D., Tufts University
Experience	September 1973-August 1976, Research Associate, Case Western Reserve University August 1976-May 1979, Research Associate, The Florida State University May-September 1979, Staff Physicist, The Florida State University September 1979-September 1980, Research Assistant Professor, The Florida State University September 1980-August 1982, Assistant Professor, The Florida State University September 1982-August 1985, Associate Professor, The Florida State University September 1985-present, Full Professor, The Florida State University.
Referee Reports	Reviewed numerous manuscripts for the Physical Review, Physical Review Letters, and other journals. Reviewed various DOE and NSF research proposals.
Conference	March 1981, Co-chaired a conference on Perturbative Quantum Chromodynamics held at The Florida State University. April 1985, Co-chaired a conference on Advances in Lattice Gauge Theory held at The Florida State University October 1987, served as a member of the international organizing Committee for a Nato Advanced Research Workshop on QCD Hard Hadronic Processes, held in St. Croix, U.S. Virgin Islands. May 1988, Served as a member of the organizing committee for the Lattice Higgs Workshop held at The Florida State University.
DOE Review Board	1982-1984, Served on a panel which reviewed applications for funding under the Department of Energy's Outstanding Junior Investigator program.
URA Visiting Committee	1984-1986, Served on the URA Visiting Committee which reviewed the operation of the Fermi National Accelerator Laboratory.
Field of Research	Theoretical High Energy Physics
Organizations	American Physical Society
Honors and Awards	Pi Mu Epsilon, a national mathematics honor society 1979 Outstanding Junior Investigator from the Department of Energy 1981 COFRS Award, The Florida State University 1982 Developing Scholar Award, The Florda State University 1984 Elected to Membership in Sigma Xi, a national scientific research society 1986 COFRS Award, The Florida State University.

PUBLICATIONS

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22. Detailed Quantum Chromodynamic Predictions for High-p_T Processes. With E. Reya and M. Gluck. *Physical Review* **D18**, 1501 (1978).
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31. Charm Photoproduction with Linearly Polarized Photons. With D.W. Duke. *Physical Review Letters* **44**, 1173 (1980).
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34. Momentum Distributions for J/ψ Photoproduction. With D.W. Duke. *Physical Letters* **96B**, 184 (1980).
35. Higher Order Corrections for J/ψ Photoproduction. In the proceedings of the XXth International Conference on High Energy Physics, *High Energy Physics - 1980*, ed. by L. Durand and L.G. Pondrom (AIP, New York, 1981) p.284.
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39. Inelastic J/ψ Photoproduction with Linearly Polarized Photons. With D.W. Duke. *AIP Conference Proceedings* **74**, ed. with D.W. Duke (AIP, New York, 1981) p. 416.

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42. Models for J/ψ Photoproduction. In the *Proceedings of the Moriond Workshop on New Flavors*, ed. by J. Tran Thanh Van and L. Montenet (Editions Frontieres, France, 1982) p. 62.

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46. Direct Analysis of Scaling Violations in Large Q^2 Deep Inelastic Neutrino and Muon Scattering. With A. Devoto, D.W. Duke and R.G. Roberts. *Physical Review* **D27**, 508 (1983).

47. Compact U(1) in (2+1)D: The Finite Lattice Hamiltonian Approach. With A.C. Irving and C.J. Hamer. *Physical Review* **D 28**, 2059 (1983).

48. Determining Λ in Deep Inelastic Scattering. In the proceedings of the XVIIIth Rencontre de Moriond, *Gluons and Heavy Flavors*, ed. by J. Tran Thanh Van (Editions Frontieres, France, 1983) p. 267.

49. Q^2 Dependent Parametrizations of Parton Distribution Functions. With D.W. Duke. *Physical Review* **D30**, 49 (1984).

50. Q^2 Dependent Parametrizations of Pion Parton Distribution Functions. *Physical Review* **D30**, 943 (1984).

51. Multi-jet Final States: Exact Results and the Leading Pole Approximation. With R.K. Ellis. *Proceedings of the 1984 Summer Study on the Design and Utilization of the SSC*, ed. by R. Donaldson and J.G. Morfin (Fermilab, Batavia, 1984) p. 207.

52. Considerations for the Process $pp \to W\gamma + X$ at the SSC. With S. Matsuda. *Proceedings of the 1984 Summer Study on the Design and Utilization of the SSC*, ed. by R. Donaldson and J.G. Morfin (Fermilab, Batavia, 1984) p. 216.

53. High-p_T Photon Production and Compositeness at the SSC. With T. Ferbel, M. Dine and I Bars. *Proceedings of the 1984 Summer Study on the Design and Utilization of the SSC*, ed. by R. Donaldson and J.G. Morfin (Fermilab, Batavia, 1984) p. 218.

54. Structure Functions at the SSC. With J. Morfin. *Proceedings of the 1984 Summer Study on the Design and Utilization of the SSC*, ed. by R. Donaldson and J.G. Morfin (Fermilab, Batavia, 1984) p. 243.

55. Interpreting Measurements of Parton-Parton Scattering Angular Distributions. In the proceedings of the XXth Rencontre de Moriond, *QCD and Beyond*, ed. by J. Tran Thanh Van (Editions Frontieres, France, 1985) p. 151.

56. A Survey of Topics in Two-Photon Physics. In the proceedings of the XVIth International Symposium on Multiparticle Dynamics, *Multiparticle Dynamics 1985*, ed. by J. Grunhaus (Editions Frontieres, France, 1986)p. 725.

57. Large Momentum Transfer Production of Direct Photons, Jets, and Particles. *Reviews of Modern Physics* **59**, 465 (1987).

58. Some Recent Developments in the Determination of Parton Distributions, J.F. Owens, FSU-HEP-871209, to be published in the proceedings of the Advanced Research Workshop QCD Hard Hadronics Processes.

59. Two Photon Backgrounds for the Intermediate Mass Higgs Boson. With H. Baer. *Physics Letters* **B205**, 377 (1988).

60. Applications of QCD to Large Momentum Transfer Processes. Proceedings of the 3rd Lake Louise Winter Institute, *Quantum Chromodynamics: Theory and Experiment*, ed. by B.A. Campbell, A.N. Kamal, F.C. Khanna, and M.K. Sundaresan (World Scientific, Singapore, 1988)p. 1.

61. Higher Order Calculations for Hard Scattering Processes. To be published in the proceedings of the 1988 annual meeting of the Division of Paricles and Fields of the American Physical Society, Storrs, Connecticut.

62. Expectations for Two- and Three-Jet Events at HERA. With H. Baer and J. Ohnemus. To be published in *Z. Phys. C*.

63. The Gluon Content of the Proton Probed With Real and Virtual Photons. With P. Aurenche, R. Vaier, M. Fontannaz, and M. Werlen, submitted to *Phys. Rev. D*.

64. A Next-to-Leading-Logarithm QCD Calculation of Symmetric Dihadron Production. With L. Bergmann, in preparation.

65. A Next-to-Leading-Logarithm Calculation of Jet Photoproduction. With H. Baer and J. Ohnemus, in preparation.

Thesis Topic

1. A Phenomenological Analysis of Charged Pi Nucleon and Pi Delta Photoproduction at High Energies. Dr. Gary R. Goldstein was my Thesis Advisor.

Invited Lectures

1. I gave an invited series of five lectures on Applications of Quantum Chromodynamics at the University of Notre Dame. At the same time, I provided theoretical assistance to the high energy experimental group there (February 1980).
2. I spent four weeks at the University of California, Riverside, where I gave a series of eight lectures on Perturbative Quantum Chromodynamics (May 1982).
3. I gave a set of three lectures at the University of Toronto on High-p_T Photoproduction, Direct Photon Production, and the Photon Structure Function (March 1984).
4. I gave two seminars at the University of Maryland on Scaling Violations in Deep Inelastic Scattering and on Direct Photon Production (May 1984).
5. I gave a set of three lectures on applications of QCD to large momentum transfer processes at the 1988 Labe Winter Institute (March 1988).
6. I gave a set of four lectures on applications of QCD to large momentum transfer processes at the Oak Ridge National Laboratory (October 1988).

Henryk Piekarz

VITA

Place of Birth	[redacted]
Date of Birth	[redacted]
Citizenship	Poland - U.S. Residency since Nov. 1983
Marital Status	Married, two children
Education	Master of Science, University of Warsaw, 1963 Philosophical Doctor Degree, Institute of Nuclear Research Polish Academy of Sciences, Warsaw, 1969 Habilitated Doctor Degree, Institute for Nuclear Research Polish Academy of Science, Warsaw 1975
Experience	9/1967 - 5/1981 - Institute for Nuclear Research, High Energy Phisics Dept. Hoza 69, 00681 Warsaw, Poland Adiunkt (since 1976) 6/1981 - 8/1983 - Physics Department Medium Energy Group University of Houston Houston, TX 77004 Research Associated 9/1983 - 5/1987 - Physics Dept. High Energy Group Brandeis University Waltham, Mass. 02254 Research Associate 6/1987 - present - Physics Dept. High Energy Group The Florida State University Tallahassee, Fl. 32306 Assistant Research Scientist
Scientific Visits	1/1968 - 12/1968 - Joint Institute For Nuclear Research Dubna, USSR Visiting Physicist 2/1969 -10/1970 - CERN, Geneva, Switzerland Research Associate 2/1974 - 12/1976 - Institut de Physique des Particles et de Physique Nucleaire, France Scientifique Associate 1/1977 - 6/1977 - CERN, 1211 Geneva, Switzerland Scientifique Associate 10/1979 - 5/1981 - Physics Dept. Medium Energy Group Brookhaven National Laboratory Visiting Physicist

PUBLICATIONS

<u>Papers</u>

I. TENARY FISSION

1. The presision method of measurement of the thickness and homogeniy of fine layers and thin folis. With M. Dakowski, H. Piekarz, M. Sowinski and J. Chwaszczewska. *Institute of NUclear Research, Report* 446/IA/II, Warsaw (1983).
2. On the possibility of 235U(n, alpha) 232Th reaction fo slow neutrinos. With M. Sowinski, M. Dakowski and M. Sowinski. *Phys.Lett.* **6**, 321 (1963)
3. A method of target preparation by electro-spraying directly on semiconductor detectors. With M. Dakowski, H. Piekarz and M. Sowinski. *Institute of Nuclear Research*, Report no 595/IA, Warsaw (1965)
4. Observation of fission events in mica sandwiches. With E. Cieslak, M. Dakowski, H. Piekarz, J. Piekarz, M. Sowinski and J. Zakrzewski. *Nucl.Instr.&Meth.* **39**, 224 (1966)
5. Preliminary results on high-energy nuclear fission by means of mica detectors. With R. Brandt, F. Carbonara, E. Cieslak, M. Dakowski, I. Jarstorff, H. Piekarz, J. Piekarz, W. Riezler, R. Riminillo, E. Sassi, M. Sowinski and J.Zakrzewski. *VI Int. Conf. on Corpuscular Photography, Florence*, 443 (1966).
6. On the spin assignment of neutron resonances in 149Sm using (n,alpha) reaction. With M. Dakowski, T. Krogulski, E. Piasecki, H. Piekarz and M. Sowinski. *Nucl.Phys.* **A97**, 187 (1967)
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8. Energy distribution of long-range alpha particles emitted during thermal neutron fission of 235U. With M. Sowinski, J. Chwaszczewska, M. Dakowski, A. Gadomski, T.Krogulski, E. Piasecki and H. Piekarz. *Acta Physica Polonica* **33**, 819 (1968).
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10. Some experiences in the use of semiconductor detectors for fission studies in high-energy proton beam at CERN. With R. Brandt, T. Krogulski, E. Piasecki, H. Piekarz, M. Sowinski, J. Chwaszczewska, M. Moszynski. *Nukleonica* **13**, 845 (1968).
11. Correlated emission of light nuclei and neutrons in 235U and 252Cf fission. With J. Blocki, J. Chwaszczewska, M. Dakowski, T. Krogulski, E. Piasecki, H. Piekarz, J.Tys. *Int. Conf. Physics and Chemistry of Fission*, Vienna, **115** (1969).
12. Investigation of prompt neutrons accompanying spontaneous ternary fission of 252Cf. With H. Piekarz, J. Blocki, T. Krogulski and E. Piasecki, *Nucl.Phys.* **A146**, 273 (1970).
13. The study of nuclear fission induced by high-energy protons. With R. Brandt, F. Carbonara, E. Cieslak, H. Piekarz, J. Piekarz and J. Zakrzewski *CERN Report* NP772 (1971) and *Revue de Physique*, Tom7, **423** (1972).

II. HYPERNUCLEI AND EXOTIC ATOMS

14. Observation of antiprotonic atoms. With A. Bamberger, U. Lynen, H. Piekarz, J. Piekarz, B. Povh, H.G. Ritter, G. Backenstoss, T. Bunaciu, J. Egger, W.D. Hamilton and H.Koch. *Phys.Lett.*,**33B**,233 (1970).

15. Observation of gamma-rays from the excited states of hypernuclei. With A. Bamberger, M.A. Faessler, U. Lynen, H. Piekarz, J. Piekarz, J. Pniewski, B. Povh, H.G. Ritter and V. Soergel, *Phys.Lett.* **36B**, 412 (1971).

16. Low energy separated beam for stopped K mesons and antiprotons. With A. Bamberger, A. Colombo, I. Egger, U. Lynen, G. Petrucci, H. Piekarz, B. Povh, H.G. Ritter, G. Sepp and V.Soergel, *CERN Report* NO-72-2

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23. Further investigation of the gamma transitions in light hypernuclei. With M. Bedjidian, F. Desxroix, I.Y. Grossiord, A. Guichard, M. Gusakow, M. Jacquin, M.J. Kudla, H. Piekarz, J. Piekarz, J.R. Pizzi and J.Pniewski, *7th Int. Conf. on High Energy Physics and Nuclear Structure*, Zurich (1977)

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25. The K19 beam for stopped K- mesons. With M. Bedjidian, F. Descroix, J.Y. Grossiord, A. Guichard, M. Gusakow, M. Jacquin, M.J. Kudla, H. Piekarz, J. Piekarz, J.R. Pizzi and J. Pniewski, *CERN Report* EP 77-14 (1977)

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28. Observation of levels in Carbon 13, Nitrgen 14 and Oxygen 18 hypernuclei. With M. May, H. Piekarz, R.E. Chrien, S. Chen, D. Maurizio, H. Palevsky, R. Sutter, Y. Xu, P. Barnes, B. Bassaleck, N.J. Collela, R. Eisenstein, R. Grace, P. Pile, F. Takeutchi, W. Wharton, M. Deutsch, J. Piekarz, S.Bart, R. Hackenburg, B. Mayer, L. Pinsky, R. Cester and R.L. Stearns, *Phys.Rev.Lett.* **47**, 1106 (1981)

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30. Hypernuclear gamma spectroscopy. *Proc. Int. Conf. on Hypernuclear and Kaon Physics, Heidelberg*, June 20-24 (1982)

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III.EXOTICS (DIBARYONS,GLUEBALLS, etc.)

32. Search for dibaryons of strangeness -1. Int.Symp. on Kaon and Hypernuclear Physics, *Nucl.Phys.* **A450**, 85c (1986)

33. Search for strange dibaryons in reaction K-d-¿lambda-p-Pi at 870MeV/c, *Proc. Int. Symp. on Hypernuclear Physics*, Tokyo (1986)

34. Strange dibaryons, Proc. of the 11th IUPAP Conf. on Few Body Systems in Particle and Nuclear Physics, 291,Tokyo and Sendai (1986)

35. Evidence for Iota(1460) production in Pi-P interactions at 21.4 GeV/c. With M. Rath, J .M. Bishop, N.N. Biswas, N.M. Cason, V.P. Kinney, J. Piekarz, R.C.Ruchti, W.D. Shepard, J.R. Bensinger, M.R. Fortner, L.E.Kirsch, H.Piekarz, R. Poster, P. Zogrofou, A. Etkin,K.J.Foley, R.S. Longacre, W.A. Love,T.W. Morris, E.D. Platner A.C. Saulys, S.J. Lindenbaum, *Phys.ReV.Lett* **61** (1988)

36. The K0sK0sPi0 system produced in Pi-P interactions at 22 GeV/c. With M. Rath, J.M. Bishop, N.N. Biswas, N.M. Cason, V.P. Kinney, J. Piekarz, R.C. Ruchti, W.D. Shepard, J.R. Bensinger, M.R. Fortner, L.E. Kirsch, H. Piekarz, R. Poster, P. Zogrofou, A. Etkin, K.J. Foley, R.S. Longacre, W.A. Love, T.W. Morris, E.D. Platner, A.C. Saulys, S.J. Lindenbaum, Submitted to *Phys.ReV* (1989)

IV. HIGH ENERGY

37. An Electromagnetic Calorimeter for the small angle regions of the collider detector at Fermilab. With G. Brandenburg,D.Brown, R. Carey, M. Eaton, A. Feldman, E. Kerns, J. Oliver, E. Sadowski, R. Schwitters, M. Shapiro, R.St. Denis, J. Bensinger, C. Blocker, M. Contreras, L. Demortier, P. Kesten, L. Kirsch, H. Piekarz, L. Spencer, S. Tarem *Nucl.Instr.&Meth.* **A262** (1988)

38. Transverse momentum distrubution of charged particles produced in pbar-p interactions at s1/2=630 and 1800 GeV. With F.Abe et al (CDF Collaboration), *Phys.ReV.Lett* **61**, 1819 (1988)

39. Measurement of the inclusive jet cross-section in pbar-p collisions at s1/2=1.8TeV. With F.Abe et al (CDF Collaboration), *Phys.ReV.Lett* **62**, 613 (1989)

40. Limits on the masses of super- symmetric particles from 1.8 TeV pbar-p collisions. With F.Abe et al (CDF Collaboration), submitted to *Phys.ReV.Lett* (1989)

41. A measurement of W boson production in 1.8 TeV pbar-p collisions. With F.Abe et al (CDF Collaboration) submitted to *Phys.ReV.Lett* (1989)

42. Hadron and electron response of uranium/liquid argon calorimeter modules for D0 detector. With Abolins et al (D0 Collaboration), submitted to *Nucl.Instr.&Meth.* and *Proc. of 7th Topical Workshop on Proton- Antiproton Collider Physics*, Fermilab, Batavia, Ill 60510 (1989)

CURRICULUM VITAE

JAMES OHNEMUS

Office:
Department of Physics
Florida State University
Tallahassee, Florida 32306
(904) 644-6830
Bitnet: ohnemus@fsu

Home:
2001 Old St. Augustine Road
Apt. D-207
Tallahassee, Florida 32301
(904) 878-1845
Decnet: 7479::ohnemus

EDUCATION:

Ph.D., Physics, Minor in Mathematics, University of Wisconsin-Madison, December 1987.

B.S., Engineering Physics (with Honors), University of Illinois at Urbana-Champaign, May 1980.

RESEARCH EXPERIENCE:

Postdoctoral Research Associate, High Energy Theory Group, Florida State University, Tallahassee, Florida, April 1988 to present. Conducted research on problems in collider physics phenomenology; research is described in separate enclosure.

Postdoctoral Research Associate, Institute for Elementary Particle Physics Research, University of Wisconsin-Madison, October 1987 to April 1988. Conducted research on problems in proton-antiproton collider physics phenomenology.

Research Assistant, Institute for Elementary Particle Physics Research, University of Wisconsin-Madison, May 1983 to October 1987. Investigated heavy lepton production at hadron colliders for Ph.D. thesis (advisor Prof. Vernon Barger).

Research Assistant, High Energy Physics Group, University of Wisconsin-Madison, Summer 1982. Developed software and analyzed data from an experiment at Fermi National Accelerator Laboratory.

Research Assistant, Columbia University Nevis Laboratory, Irvington, New York, Summer 1980. Developed software for a bubble chamber experiment.

TEACHING EXPERIENCE:

Teaching Assistant, University of Wisconsin-Madison, September 1981 to May 1983. Taught laboratory and discussion sections of introductory physics.

Teaching Assistant, Columbia University, New York City, September 1980 to May 1981. Taught laboratory sections of introductory physics.

PUBLICATIONS IN REFEREED JOURNALS:

"A next-to-leading-logarithm Calculation of Jet Photoproduction",
(with H. Baer and J. F. Owens).
Florida State University report FSU-HEP-890502 (1989).

"Perturbative QCD Calculations of Weak Boson Production in Association with Jets at Hadron Colliders",
(with V. Barger, T. Han, and D. Zeppenfeld).
Florida State University report FSU-HEP-890420 (1989).

"Hadronic W-Decays at HERA",
(with H. Baer and D. Zeppenfeld).
To be published in *Zeitschrift für Physik* C.

"Large p_T Weak Boson Production at the Tevatron",
(with V. Barger, T. Han, and D. Zeppenfeld).
Published in *Physical Review Letters* **62**, 1971 (1989).

"Expectations for Two- and Three-Jet Events at HERA",
(with H. Baer and J. F. Owens).
To be published in *Zeitschrift für Physik* C.

"Signatures for Fourth-Generation Quarks and a Heavy Top Quark at the Superconducting Super Collider",
(with H. Baer, V. Barger, and H. Goldberg).
Published in *Physical Review* **D38**, 3467 (1988).

"Spin Correlation Effects in the Hadroproduction and Decay of Very Heavy Top Quark Pairs",
(with V. Barger and R. J. N. Phillips).
Published in *International Journal of Modern Physics* **A4**, 617 (1989).

"The Intermediate-Mass Higgs Boson and the Fourth Generation",
(with E. W. N. Glover and S. S. D. Willenbrock).
Published in *Physics Letters* **B206**, 696 (1988).

"Higgs Boson Decay to One Real and One Virtual W Boson",
(with E. W. N. Glover and S. S. D. Willenbrock).
Published in *Physical Review* **D37**, 3193 (1988).

"Heavy Leptons at Hadron Supercolliders",
(with V. Barger and T. Han).
Published in *Physical Review* **D37**, 1174 (1988).

"Helicity Projection Techniques for Evaluating Cross Sections of Heavy Fermion Production and Decay Via W Bosons",
(with V. Barger and R.J.N. Phillips).
Published in *Physical Review* **D35**, 166 (1987).

"The Missing p_T Plus Jets Signal for Heavy Leptons in $p\bar{p}$ Collisions",
(with V. Barger and R.J.N. Phillips).
Published in *Physical Review* **D35**, 158 (1987).

"Jets in W, Z Production from QCD Showers",
(with V. Barger, T. Gottschalk, and R.J.N. Phillips).
Published in *Physical Review* **D32**, 2950 (1985).

"Testing Spinless-Boson-Parent Models for Anomalous $\ell^+\ell^-\gamma$ Events",
(with H. Baer and K. Hagiwara).
Published in *Physical Review* **D32**, 11 (1985).

CONFERENCES AND WORKSHOPS ATTENDED:

Beyond the Standard Model, Iowa State University, Ames, Iowa, November 1988.

Workshop on "From Colliders to Super Colliders", University of Wisconsin–Madison, May 1987.

Workshop on "Physics Simulations at High Energy", University of Wisconsin–Madison, May 1986.

New Particles 1985, University of Wisconsin–Madison, May 1985.

VIIth European Symposium on Antiproton Interactions, University of Durham, July 1984.

CITIZENSHIP:

United States of America.

HORST D. WAHL

VITA

Place of Birth	[redacted]
Date of Birth	[redacted]
Citizenship	Austria
Marital Status	Married, two children

Education

June 1969: Ph.D. Graduation (with honors). University of Vienna

1966 to 1969: work on PhD thesis (Spin-Parity analysis of $K\pi\pi$ system)

Jul. to Nov. 1965: Summer student at CERN

from 1964: work in high energy physics group of Phys. Dept.

1959 to 1969: Studies at University of Vienna; (in between: 1963 to 1964 Service in Austrian Army)

Research Work

Sept. 1988 to present: Studies on development of detectors for the Superconducting Super Collider (radiation hardness, calorimetry).

Dec. 1985 to present: Assoc. Professor at FSU. Participation in D0 experiment at Fermilab Tevatron collider; responsible for coordination of testbeam activities (February 86 to May 88).

May 1979 to Nov. 1985: Research Physicist at the Institute for High Energy Physics of the Austrian Academy of Sciences; leader of the Vienna group in experiment UA1 at the CERN proton-antiproton collider; responsible for read-out electronics of electromagnetic calorimeter, and for calibration measurements in testbeam. (Goal and main success of this experiment: observation of vector bosons W and Z, jet physics.

Sept. 1974 to April 1979: Staff member at CERN, continue work in experiment R407/408 (analysis), and preparation and data taking of experiment R416 at the CERN-ISR (Spokesman of this experiment) (high transverse momentum reactions, and charm search)

Sept. 1974 to Aug. 1976: Visiting Assoc. Professor at SUNY at Stony Brook, NY.

Participation in design, construction, test and installation of detectors for experiment E494 at FNAL (high transverse momentum dihadron production).

Participation in analysis of bubble chamber experiments (study of multiparticle reactions)

Jan. 1973 to Aug. 1974: Staff Member at CERN. Work in various bubble chamber experiments; (hadron spectroscopy, production mechanism, multiparticle reactions) from summer 1973: participate in experiment R407/408 at the ISR. (study of high transverse momentum phenomena, double poweron exchange , multiple reactions)

Jan. 1971 to Dec. 1972: Fellow at CERN, Geneva, Switzerland;

1968 to 1970: Research Assistant at Institute for High Energy Physics of Austrian Academy of Sciences, Vienna

Honors and Awards

1987: COFRS Award, Florida State University

Nov. 1986: Wilhelm Exner Medal of the "Österreichischer Gewerbeverein" (Austrian Association for the Advancement of Industry and Technology)

May 1986: Erwin Schrödinger Prize of the Austrian Academy of Sciences

Service

Member of ISR Committee (1980 - 1984)

Organizations

Austrian Physical Society
American Physical Society

Referee Reports

Reviewed various papers for Physics Letters

PUBLICATIONS

Papers

1. J. Bartsch et al.: Observation of a ($K\pi\pi$) Resonance Near 1800 MeV; *Phys. Lett.* **22** (1966) 357-360.
2. M. Aderholz et al.: K^-p Elastic Scattering at 10 GeV/c; *Phys. Lett.* **24B** (1967) 234-437.
3. J. Bartsch et al.: Ξ^-, Ω^- and Antibaryon Production in 10 GeV/c K^-p Interactions; *Nucl. Phys.* **B4** (1968) 326-334.
4. M. Aderholz et al.: Lambda Production in 10 GeV/c Interactions; *Nucl. Phys.* **B5** (1968) 606-618.
5. J. Bartsch et al.: Analysis of the K*(1320) and L-meson Produced in 10 GeV/c K^-p Interactions; *Nucl. Phys.* **B8** (1968) 9-30.
6. J. Bartsch et al.: A Study of the Reaction $K^-p \rightarrow p\overline{K^0}\pi^-$ with the Veneziano Model; *Nucl. Phys.* **B20** (1970) 63-76.
7. J. Bartsch et al.: Application of the Veneziano Model with Pion and Pomeron Exchange to the Reaction $K^-p \rightarrow nK^-\pi^+$ at 10 GeV/c; *Nucl. Phys.* **B23** (1970) 1-18.
8. J. Bartsch et al.: Evidence that the L-meson has Decay Modes Other Than $K^*(1420)\pi$: *Phys. Lett.* **33B** (1970) 186-188.
9. J. Bartsch et al.: A Dual Diffractive Model for the Q^- and L-mesons; *Nucl. Phys.* **B24** (1970) 221-230.
10. J. Bartsch et al.: K^-p Elastic Scattering at 10 GeV/c; *Nucl. Phys.* **B29** (1971) 398-404.
11. J.V. Beaupre et al.: Experimental Characteristics of the Charge Exchange K^0 Producing Reactions in K^+p and K^-p Interactions; *Nucl. Phys.* **B30** (1971) 381-397.
12. J.V. Beaupre et al.: Diffraction Dissociation and Processes Involving Charge, Strangeness and Exotic Exchanges in Four-body Final States of K^-p Reactions at 10 GeV/c; *Nucl. Phys.* **B35** (1971) 61-78.
13. J.V. Beaupre et al.: Limiting Properties in Inclusive π^+p Reactions at 8 and 16 GeV/c with Exotic and Non-exotic Particle Combinations; *Phys. Lett.* **37B** (1971) 432-434.
14. J. Bartsch et al.: Study of Lambda Production in 10 GeV/c K^-p Interactions; *Nucl. Phys.* **B40** (1972) 103-124.
15. J. Bartsch et al.: How Well Does an LPS Analysis Separate Production Mechanisms in π^+p Interactions at 8 and 16 GeV/c? *Nucl. Phys.* **B46** (1972) 1-20.
16. J. Bartsch et al.: Study of the Exchange Mechanisms in the ρ Production Reactions $\pi^\pm p \rightarrow \rho N$ at 16 GeV/c; *Nucl. Phys.* **B46** (1972) 46-60.
17. K. Boesebeck et al.: Central Emission of Pions and Search for a Symmetry System; *Nucl. Phys.* **B46** (1972) 371-380.
18. J.V. Beaupre et al.: Interference Between (P, f^0,...) and (ρ^0, B^0,...) Exchanges in Pion Diffraction Dissociation at 16 GeV/c; *Phys. Lett.* **41B** (1972) 393-396.
19. J.V. Beaupre et al.: Violation of Both s- and t- Channel Helicity Conservation From an LPS Analysis of Diffraction Dissociation in $\pi \rightarrow \pi\pi\pi p$; *Nucl. Phys.* **B49** (1972) 441-457.
20. K. Boesebeck et al.: Three- and Four-Pion Correlations in High-Multiplicity πp Interactions; *Nucl. Phys.* **B52** (1973) 189-202.
21. P. Bosetti et al.: Inclusive Single-Particle Distributions in $\pi^\pm p$ Reactions at 8 and 16 GeV/c; *Nucl. Phys.* **B54** (1973) 141-160.
22. H. *Grässler* et al.: Quantum Number Transfer in K^-p Interactions; *Nucl. Phys.* **B59** (1973) 333-347.
23. P. Bosetti et al.: Study of Momentum Distributions of Particles Produced in K^-p Interactions at 10 and 16 GeV/c; *Nucl.Phys.* **B60** (1973) 307-314.
24. M. Deutschmann et al.: Ω^- Production in K^-p Interactions; *Nucl. Phys.* **B61** (1973) 102-115.
25. P. Bosetti et al.: Study of the Forward Peak in π^+p Reactions at 8, 16 and 23 GeV/c and Comparison with ISR Results; *Nucl. Phys.* **B62** (1973) 1-12.
26. P. Bosetti et al.: Charge Exchange and Charge Distributions in K^-p Interactions at 10 and 16 GeV/c; *Nucl. Phys.* **B62** (1973) 46-60.
27. J.V. Beaupre et al.: Inclusive Δ^{++} Production and a Test of the Triple Regge Limit; *Nucl. Phys.* **B67** (1973) 413-424.
28. H. Wahl: Limiting Trends Visible at Lower Energies (invited talk) in Proc. of the IInd Int. Conference on Elementary Particle Physics, Aix-en-Provence, 1973); *Journal de Physique* **34** suppl.C1 (1973) 373 - 378.
29. P. Bosetti et al.: Slopes and Breaks of Transverse-Momentum-Squared Distributions in 16 GeV/c π^-p interactions; *Nucl. Phys.* **B68** (1974) 29-43.
30. M. Deutschmann et al.: Transverse Spectra in $\pi^\pm$ and K^-p Interactions Between 8 and 16 GeV/c; *Nucl. Phys.* **B70** (1974) 189-204.
31. M. Deutschmann et al.: The "True" Multiplicity Distribution in K^-p Interactions and the Two-Component Model; *Nucl. Phys.* **B70** (1974) 237-256.
32. E.L. Berger et al.: Multiplicity Cross Sections for 100 GeV/c π^-p Interactions; *Nucl. Phys.* **B77** (1974) 365-374.
33. G. Otter et al.: Partial Wave Analysis of the 3π System Produced in the Reaction $\pi^+p \rightarrow (\pi^+p\pi^+\pi^+\pi^-)p$ at 8,16 and 23 GeV/c; *Nucl. Phys.* **B80** (1974) 1-11.
34. P.A. Baker et al.: Approach to Scaling in Proton Fragmentation Studied in the Reactions $K^+p \rightarrow \pi^\pm X$ and $K^-p \rightarrow \pi^\pm$X; *Nucl. Phys.* **B89** (1975) 189-200.
35. R.Cottrell et al.:Measurement of Large Transverse Momentum Positive Particles Produced at Medium Angles at $\sqrt{s}$=52.5 GeV/c; *Phys. Lett.* **55B** (1975) 341-344.
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37. J.Hanlon et al.: Inclusive Reactions p + n $\rightarrow$ p + X and π^+ + n $\rightarrow$ p + X at 100 GeV/c; *Phys. Rev. Lett.* **37** (1976) 967-970.
38. T.Kafka et al.: One-, Two-, and Three-Particle Distributions in pp Collisions at 205 GeV/c; *Phys. Rev.* **D16** (1977) 1261-1293.
39. R.D.Kephart et al.: Measurement of the Dihadron Mass Continuum in p-Be Collisions and a Search for Narrow Resonances; *Phys.Rev.Lett.* **39** (1977) 1440-1443.

40. R.L.McCarthy et al.: Nucleon-Number Dependence of the Production Cross Sections for Massive Dihadron States; *Phys. Rev. Lett.* **40** (1978) 213-216.

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43. M.Della Negra et al.: Observation of Jet Structure in High P_T Events at the ISR and the Importance of Parton Transverse Momentum; *Nucl. Phys.* **B127** (1977) 1-42.

44. H.Wahl: Density, Charge and Transverse Momentum Correlations of Particles in Non-Diffractive p-p Collisions at $\sqrt{s}$=52.5 GeV/c; in *Proc. 19th Int. Conf. High Energy Physics*, Tokyo 1978, pp 72-74.

45. D.Drijard et al.: Double Pomeron Exchange in the Reaction pp $\rightarrow$ pp$\pi^+\pi^-$ at ISR energies; *Nucl. Phys.* **B143** (1978) 61-80.

46. D.Drijard et al.: Observation of Charmed D Meson Production in pp Collisions; *Phys. Lett.* **81B** (1979) 250-254.

47. D.Drijard et al.: Charmed Baryon Production at the CERN Intersecting Storage Rings; *Phys. Lett.* **85B** (1979) 452-457.

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49. D.Drijard et al.: Quantum Number Effects in Events with a Charged Particle of Large Transverse Momentum, (I) Leading Particles in Single and Diquark Jets; *Nucl. Phys.* **B156** (1979) 309-327.

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51. D.Drijard et al.: Production of Vector and Tensor Mesons in Proton-Proton Collisions at $\sqrt{s}$=52.5 GeV; Zeits. *Phys.* **C9** (1981) 293-303.

52. D.Drijard et al.: Further Investigation of Beauty Baryon Production at the ISR; *Phys. Lett.* **108B** (1981) 361-366.

53. D.Drijard et al.: Neutral Strange Particle Particle Production in Proton-Proton Collisions at $\sqrt{s}$=63 GeV; *Zeits. Phys.* **C12** (1982) 217-224.

54. D.Drijard et al.: A Measurement of the Inclusive Cross Section of Charged Pions at Very High Transverse Momenta; *Nucl. Phys.* **B208** (1982) 1-11.

55. G.Arnison et al.: Some Observations on the First Events Seen at the CERN Proton-Antiproton Collider; *Phys. Lett.* **107B** (1981) 320-324.

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58. G.Arnison et al.: Small Angle Elastic Scattering at the CERN Proton Antiproton Collider, *Phys. Lett.* **121B** (1983) 77-82.

59. G.Arnison et al.: Experimental Observation of Isolated Large Transverse Energy Electrons with Associated Missing Energy at $\sqrt{s}$=540 GeV; *Phys. Lett.* **122B** (1983) 103-116.

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61. G.Arnison et al.: Charged Particle Multiplicity Distributions in Proton-Antiproton Collisions at 540 GeV Centre of Mass Energy; *Phys. Lett.* **123B** (1983) 108-114.

62. G.Arnison et al.: Observation of Jets in High Transverse Energy Events at the CERN Proton-Antiproton Collider; *Phys. Lett.* **123B** (1983) 115-122.

63. H.D.Wahl: Recent Results from the $\bar{p}p$ Collider, Lectures at the XXII. Int. Universitätswochen für Kernphysik, Schladming 1983, *Acta Physica Austriaca Suppl.* XXV (1983) 399-487.

64. G.Arnison et al.: Experimental Observation of Lepton Pairs of Invariant Mass Around 95 GeV/c^2 at the CERN SPS Collider; *Phys. Lett.* **126B** (1983) 398-410.

65. G.Arnison et al.: Elastic and Total Cross Section Measurement at the Proton-Antiproton Collider; *Phys. Lett.* **128B** (1983) 336-342.

66. G.Arnison et al.: Further Evidence for Charged Intermediate Vector Bosons at the SPS Collider; *Phys. Lett.* **129B** (1983) 273-282.

67. G.Arnison et al.: Hadronic Jet Production at the CERN Proton-Antiproton Collider; *Phys. Lett.* **132B** (1983) 214-222.

68. G.Arnison et al.: Jet Fragmentation Into Charged Particles at the CERN Proton-Antiproton Collider; *Phys. Lett.* **132B** (1983) 223-229.

69. G.Arnison et al.: Observation of the Muonic Decay of the Charged Intermediate Vector Boson; *Phys. Lett.* **134B** (1984) 469-476.

70. G.Arnison et al.: Search for Massive $e\nu\gamma$ and $\mu\nu\gamma$ Final States at the CERN SPS Collider, *Phys. Lett.* **135B** (1984) 250-254.

71. G.Arnison et al.: Angular Distributions and Structure Functions From Two-Jet Events at the CERN *Sp$\bar{p}$S* Collider; *Phys. Lett.* **136B** (1984) 294-300.

72. G.Arnison et al.:Experimental Observation of Events With Large Missing Energy Accompanied by a Jet or a Photon(s) in $p\bar{p}$ collisions at $\sqrt{s}$=540 GeV, *Phys. Lett.* **139B** (1984), 115-125.

73. G.Arnison et al.:$D^{*\pm}$ Production in Jets at the CERN SPS Collider, *Phys. Lett.* **147B** (1984) 222-226.

74. G.Arnison et al.: Observation of Muonic Z^o Decay at the $\bar{p}p$ Collider, *Phys. Lett.* **147B** (1984) 241-248.

75. G.Arnison et al.:Associate Production of an Isolated, Large-Transverse-Momentum Lepton (Electron or Muon), and Two Jets at the CERN $\bar{p}p$ Collider, *Phys. Lett.* **147B** (1984) 493-508.

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77. H.D.Wahl: Review of Weak Boson Production in Antiproton-Proton Collisions (invited talk), in Proc. 15th Int. Sympos. on Multiparticle Dynamics, Lund 1984, edited by G. Gustafson and C. Peterson, pp. 410-422.

78. G. Arnison et al., Intermediate Mass Dimuon Events at the CERN $p\bar{p}$ collider at $\sqrt{s}$ = 540 GeV, *Phys. Lett.* **155B**(1985) 442-456

79. G. Arnison et al.; Comparison of Three-jet and Two-jet Cross Sections in $p\bar{p}$ collisions at the CERN SPS collider, *Phys. Lett.* **158B** (1985) 494-504.

80. G. Arnison et al., W Production Properties at the CERN SPS Collider, *Nuovo Cimento Lett.* **44** (1985) 1-16.

81. C. Cochet et al., The Central Electromagnetic Calorimeter of UA1, *Nucl.Instr.and Methods* **A243** (1986) 45-57.

82. G. Arnison et al., Recent Results on Intermediate Vector Boson Properties at the CERN Supersynchrotron collider, *Phys. Lett.* **166B** (1986) 484-490.

83. G. Arnison et al., Measurement of the Inclusive Jet Cross Section at the CERN $p\bar{p}$ Collider, *Phys. Lett.* **172B** (1986) 461-466.

84. G. Arnison et al., Angular Distributions for High-mass Jet Pairs and a Limit on the Energy Scale of Compositeness for Quarks from the CERN $p\bar{p}$ Collider, *Phys. Lett.* **177B** (1986) 244-250.

85. G. Arnison et al., Analysis of the Fragmentation Properties of Quark and Gluon Jets at the CERN SPS $p\bar{p}$ Collider, *Nucl. Physics* **B276** (1986) 253-271.

86. C. Albajar et al., Events with Large Missing Transverse Energy at the CERN Collider: I. W$\rightarrow \tau\nu$ decay and test of $\tau - \mu - e$ universality at $Q^2 = m_W^2$. *Phys. Lett.* **185B** (1986) 23-240.

87. C. Albajar et al., Events with Large Missing Transverse Energy at the CERN Collider: II. Search for the decays of $W^{\pm}$ into heavy leptons and of Z^0 into non-interacting particles, *Phys. Lett.* **185B** (1986) 241-248.

88. C. Albajar et al.; Beauty Production at the CERN Proton-antiproton Collider, *Phys. Lett.* **186B** (1986) 237-246.

89. C. Albajar et al.; Search for B^0 - $\overline{B}^0$ Oscillations at the CERN Proton- Antiproton Collider, *Phys. Lett.* **186B** (1986) 247-254.

90. M. Albrow et al.; A Uranium Scintillator Calorimeter with Plastic-fibre Readout, *Nuclear Instruments and Methods* **A256** (1987) 23-37.

91. C. Albajar et al.; Production of W's with Large Transverse Momenum at the CERN Proton-Antiproton Collider, *Phys. Lett.* **193B** (1987) 389-398.

92. C. Albajar et al.; Analysis of the Highest Transverse Energy Events Seen in the UA1 Detector at the $Sp\bar{p}S$ Collider, *Zeits. F. Physik* **C36** (1987) 33-43.

93. H.D. Wahl; R & D Issues in Calorimetry for the SSC, in proceedings of the *2nd ORAU Workshop on the SSC,* Atlanta, May 1988.

94. M. Abolins et al.; Hadron and Electron Response of Uranium/Liquid Argon Calorimeter Modules for the *D0* Detector, submitted to *Nuclear Instruments and Methods.*

William John Womersley

VITA

Place of Birth [redacted]

Date of Birth [redacted]

Citizenship British

Marital Status Single

Education

1983, Corpus Christi College, Cambridge University, Cambridge CB2 1RH, England
B.A. in Natural Sciences — subjects studied:
Part IA: physics, chemestry, mathematics, crystaline materials,
Part IA: physics, mathematics, Part II:physics
Part IB: physics, mathematics, PartII: physics
1981, Awarded College Foundation Scholarship on the basis of Part IA examination results.
1983, Awarded B.A. (Natural Scinces), 1st class honors.
1987, B.A. transformed to M.A. degree (no academic requirement).
September 1983 - October 1986, Corpus Christi College, Oxford University.
Oxford OX1 4JF, England
D. Phil. in experimental high energy physics;
member of EMC collaboration at CERN.
Thesis completed in October 1986, supervisor:
January 1987, Viva examination passed and thesis accepted.

Experience

November 1986 - July 1989, Postdoctoral Research Associate, University of Florida, Gainesville, FL 32611, U.S.A. Working full-time at Fermilab, Batavia, IL. on *D0* and E733 collaborations.
August 1989 - present, Assistant Professor, Florida State University

List of Publications

Thesis

— A Study of Forward Hadron Production in Deep Inelastic Muon-Nucleus Scattering, Oxford, 1986 (copies available from the Nuclear Physics Laboratory, University of Oxford)

Publications with the European Muon Collaboration

— J. Ashman *et al.*, Exclusive ρ^0 and ϕ Production in Deep Inelastic Muon Scattering, Z. Phys. C **39** (1988) 170

— J. Ashman *et al.*, Measurement of the Ratios of Deep Inelastic Muon-nucleus Cross Sections on various Nuclei compared to Deuterium, Physics Letters **B202** (1988) 603

— J. Ashman *et al.*, A Measurement of the Spin Asymmetry and the Structure Function g_1 in Deep Inelastic Muon-Proton Scattering, Physics Letters B **206** (1988) 364

— J. Ashman *et al.*, An Investigation of the Spin Structure of the Proton in Deep Inelastic Scattering of Polarised Muons on Polarised Protons, submitted to Nuclear Physics B.

Publications with Fermilab Experiment 733

— W.J. Womersley *et al.*, Hadron Showers in a Low-Density Fine-Grained Flash Chamber Calorimeter, Nucl. Instr. & Meth. **A267** (1988) 49

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— D0 Calorimeter Group (M. Abolins *et al.*), Hadron and Electron Response of Uranium / Liquid Argon Calorimeter Modules for the D0 Detector, FNAL-PUB-89/38 and BNL-42336, submitted to Nucl. Instr. & Meth.