Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

**HIGH ENERGY PHYSICS DIVISION
SEMIANNUAL REPORT OF RESEARCH ACTIVITIES**

January 1, 1994 - June 30, 1994

Prepared from information gathered and edited by
the Committee for Publications and Information:

Members:

R. Wagner
P. Schoessow
R. Talaga

September 1994

MASTER *do*
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Contents

I	Experimental Research Program	2
I.A	Experiments Taking Data	2
I.A.1	Medium Energy Polarization Program	2
I.A.2	Polarized Proton Physics at Fermilab	3
I.A.3	Collider Detector at Fermilab	3
I.A.4	Non-Accelerator Physics at Soudan	14
I.A.5	ZEUS Detector at HERA	18
I.A.6	BNL Partial Snake Experiment	31
I.B	Experiments in Planning or Construction Phase	33
I.B.1	STAR Detector for RHIC	33
I.B.2	Long Baseline Neutrino Oscillation Experiment	35
I.B.3	ATLAS Detector Research & Development	37
I.C	Experiments in Closeout Phase	45
I.C.1	SDC Detector Research & Development	45
II	Theoretical Physics Program	47
II.A	Theory	47
II.A.1	Strong Interaction Asymmetries in the Production of B Mesons	47
II.A.2	The Dilepton-Production Cross Section in Principal-Value Resummation	47
II.A.3	The Paradigm of Pseudodual Chiral Models	48
II.A.4	Sum Rules and Factorization in Compton Processes	49
II.A.5	Higher-Order Lipatov Kernels	50
II.A.6	Inclusive Heavy Quark Production at Hadron Collider Energies	50
II.A.7	Finite Temperature QED	51
II.A.8	Decay and Production of Heavy Quarkonium	51
II.A.9	Lattice Measurement of Matrix Elements for Decays of Heavy Quarkonium	51
II.B	Computational Physics	52
III	Accelerator Research & Development Program	54
III.A	Argonne Wakefield Accelerator Program	54
III.A.1	Accelerator R & D	54

III.A.2 Commissioning Approval	54
III.A.3 AWA Facility Status	54
III.A.4 AWA Experiment Preparations	55
III.A.5 Workshop on Advanced Accelerator Concepts	55
III.B High Resolution Profile Monitor Development	55
IV Divisional Support Facilities	57
IV.A Mechanical Support Group	57
IV.B Electronics Support Group	58
IV.C Computer Support Group	59
V Publications	60
VI Colloquia and Conference Talks	67
VII High Energy Physics Community Activities	70
VIII High Energy Physics Division Research Personnel	72

Abstract

This report describes the research conducted in the High Energy Physics Division of Argonne National Laboratory during the period of January 1, 1994 - June 30, 1994. Topics covered here include experimental and theoretical particle physics, advanced accelerator physics, detector development, and experimental facilities research. Lists of division publications and colloquia are included.

I EXPERIMENTAL RESEARCH PROGRAM

I.A EXPERIMENTS TAKING DATA

I.A.1 Medium Energy Polarization Program

One of the primary goals of the medium energy polarization program is to understand the origin of the energy dependent structure observed near 2.1 GeV beam kinetic energy in pp elastic scattering and in other reactions. Data for this program have previously been collected in March and April, 1992 and in November and December, 1993 at the CEA Saclay Laboratory Saturne II accelerator in France.

A third set of pp elastic scattering data was obtained in May and June, 1994, using a polarized N-type proton beam and a polarized N-type proton target. The goal for this data was twofold: to check the previous measurements, recently published in Phys. Lett. **B320** (1994) 206, and to extend the measurements to higher energies. The published data appear consistent with predictions of E. Lomon based on a cloudy bag model. These predictions suggest further structure in spin observables near 2.55 GeV; hence, the motivation for scattering measurements in this beam energy region. The new data were taken at seven energies in the range of the published results: 1.98, 2.04, 2.12, 2.16, 2.18, 2.22, and 2.24 GeV; and at five higher energies: 2.40, 2.50, 2.57, 2.60, and 2.65 GeV. ANL personnel were heavily involved in operating the new data acquisition system and the ANL multiwire proportional chamber, adding electronics for new polarimeter counters, operating the polarized target, and testing a new NMR system for the target. Special emphasis by ANL physicists was devoted to the study of possible systematic effects such as beam motion, intensity variations, differences in acceptance, etc.

Work on offline analysis of the past Saclay pp data has begun. Existing programs from Saclay were modified to run on the Sun workstation at Argonne, and some additions and improvements made. Preliminary results for the 2.04 GeV data from the November/December 1993 run agreed well with the published 2.04 GeV measurements. Much more work remains to be done to better monitor the apparatus performance and the effects of various possible sources of systematic uncertainties. All the November/December, 1993 and May/June, 1994 results will be analyzed at ANL as part of a Ph.D. thesis for C. Allgower.

A paper on the design of a new type polarized antiproton beam for intermediate energies was completed and submitted to *Nuclear Instruments and Methods*. This new design requires antiprotons from a secondary beam and does not need dedicated running of an accelerator or storage ring. The intensity has been estimated to be about 2×10^{-4} polarized antiprotons per incident antiproton, with a polarization of ~ 0.2 for the momentum range 0.5-2.5 GeV/c. Such a beam would be quite useful for spin observable measurements in $\bar{p}p$ elastic and charge exchange scattering at a kaon factory, or perhaps at Brookhaven after planned upgrades are completed.

(H. Spinka)

I.A.2 Polarized Proton Physics at Fermilab

We have no new results during the period January-June, 1994, but describe the ongoing analyses of E-704.

Single-Spin Asymmetries and High p_T Inclusive π^0 Cross Sections These data were collected using the Fermilab 200 GeV/c polarized proton and antiproton beams incident on a hydrogen target. The measured asymmetries are consistent with a value of zero within the uncertainties for the kinematic regions, $-0.15 < x_F < 0.15$ and $1 < p_T < 4.5$ GeV/c. These data confirm perturbative QCD expectations and indicate that the higher-twist contribution to the single-spin asymmetry may not be as large as previously expected. Data analyses are almost final.

Direct Photon Production These data were collected simultaneously with the above π^0 data. The results will be compared with predictions of perturbative QCD higher-twist contribution.

Drell-Yan Production We are making an attempt to identify Drell-Yan production in the same data. To date this seems to be a feasible task.

Inclusive Λ Production We also are continuing with the analysis of data in the interactions $p^\uparrow p \rightarrow \Lambda^\uparrow X$ and $\bar{p}^\uparrow p \rightarrow \pi^\pm X$.

(A. Yokosawa)

I.A.3 Collider Detector at Fermilab

a. Physics Results

The dominant physics activity of the CDF collaboration, demanding attention from essentially the entire collaboration, continued to be the top quark. The particular searches causing the excitement require at least one energetic lepton (electron or muon) along with missing transverse energy to signal the presence of at least one W in the event. The dilepton search requires in addition a second energetic lepton and at least 2 jets. Two events passing these requirements are found. The tag searches start by requiring, in addition to the first lepton, at least 3 jets. There are 52 such events. One of the jets in the selected events is required to be tagged as coming from a b quark decay. Two types of tags are used. The soft lepton tag requires that a jet be associated with a muon or electron of at least 2 GeV/c. The vertex tag search requires that a jet contain a detached vertex as reconstructed in the silicon vertex detector (SVX). There are ten out of the 52 events with at least one jet tagged. The ten tagged events contain 6 jets tagged by SVX tags and 7 jets tagged with soft leptons. The overall statistical significance of the top signal is calculated as the probability that the background, accounting systematic errors and correlations, would fluctuate to produce the tagged events. This gives 0.28% or 2.8σ . The evidence for top is not strong enough to be called a discovery.

One of the events identified in the dilepton search has both a soft lepton tag and a vertex tag. Seven of the ten tagged events are used for a constrained kinematic fit for the top mass. A value for the top mass of 174 ± 17 GeV/c² has been determined. This agrees well with electroweak radiative correction calculations based on LEP measurements at the Z pole, the polarized asymmetry measurement by SLD, W mass measurements, and neutrino neutral current measurements. The

predictions range from 162 to 177 GeV/c², depending on which data are included. Measurement uncertainties of the data used give a mass uncertainty of about ± 12 GeV/c² in the prediction and the variation with assumed Higgs mass contributes ± 18 GeV/c².

The CDF top searches as described were documented in a *Physical Review* paper. This paper has been approved by the collaboration, submitted and accepted for publication. Steve Kuhlmann served on the review committee for these searches and the paper. Support for the top signal is provided by a kinematic analysis of lepton plus jet events without b tagging. This result has been approved for conference presentations.

Bob Wagner, Jimmy Proudfoot, Theresa Fuess, and Larry Nodulman have been active in electroweak physics. Larry, along with Kevin Einsweiler (LBL), is convening the electroweak physics group. Work on calibration issues for the central electromagnetic calorimeter is particularly relevant to the W mass measurement. The calibration, which includes time variation and an improvement to the calorimeter response map as well as individual tower gains, has been completed and installed. Larry is serving on David Salzberg's thesis committee at the University of Chicago; David's thesis is on the W mass measurement using electrons. The preliminary muon result was approved during this period. When combined with the already available preliminary electron result, the combined W mass measurement becomes 80.38 ± 0.23 GeV/c². This is in good agreement with previous measurements and with other precision electroweak measurements, except the SLAC asymmetry measurement. Now that the tracking code and calibrations have finally settled down and momenta are reproducible, standard false curvature corrections for track momenta have also been determined. The W mass analysis should be completed for publication in the late fall. There is strong participation in the W mass analysis from the University of Illinois and Lawrence Berkeley Laboratory as well as Chicago and Argonne.

Bob Wagner, along with CDF colleagues from UCLA, University of Illinois and Tufts University, is studying photons associated with W and Z production in run 1a data. Nonstandard coupling of the photon to the W would produce an excess of events at high transverse energy. Such couplings could arise if the W were composite. The shape as well as the normalization of the photon E_T distributions can be used to limit nonstandard couplings. In the standard mode, the CP-conserving couplings κ and λ are 1 and 0, respectively. The magnetic dipole moment of the W is proportional to $(1 + \kappa + \lambda)$ and the electric quadrupole moment of the W is proportional to $(\kappa - \lambda)$. Preliminary limits for the W are illustrated in Figure 1 and compared to D0 and older measurements. Here $\Delta\kappa$ is $\kappa - 1$. Limits for similarly defined nonstandard Z couplings are illustrated in Figure 2. Letters describing these results are nearing submission. Theresa Fuess is working with Chris Wendt from the University of Wisconsin on similar nonstandard couplings for WW and WZ production. One of the signatures for the diboson production process is a leptonically decaying W or Z at high p_T opposite a jet pair coming from another W or Z . Nonstandard couplings would populate the high p_T region. Very few event candidates of this type are found and the preliminary limits shown in Figure 3 have been derived.

Karen Byrum and Barry Wicklund are continuing to study various aspects of b quark physics using the inclusive electron data sample. Colleagues from the University of Pennsylvania and Johns Hopkins University have joined in deriving b physics from this sample, which was also used for calibration. Studies of self tagging techniques are continuing. Cross section results for b production are being derived from both the inclusive electrons and electrons in association with D mesons. The charged and neutral b lifetime difference can be determined by the rates for different charmed mesons associated with electron decays. A preliminary result on that is forthcoming.

Figure 1: Limits on the CP-conserving coupling parameters $\Delta\kappa$ and λ from the CDF and D0 studies of $W\gamma$ events are essentially identical and a considerable improvement over previous studies.

Figure 2: The 68% (inner) and 95% (outer) confidence level contours for the CP-conserving $ZZ\gamma$ transition moments from $Z\gamma$ event studies.

Figure 3: Limits on the CP-conserving combinations of coupling parameters $\Delta\kappa$ and λ from the CDF absence of WW and WZ events at high p_T .

Steve Kuhlmann continues his active interest in QCD physics including membership in CTEQ. Bob Blair continues to organize the photon group. The inclusive photon analysis has been completed for the run 1a dataset. Using the preradiator analysis and calibrating with known π^0 and photon samples (Figure 4), the systematic errors decrease by about a factor of 2. The result is shown in Figure 5. The letter on inclusive photon production has been submitted to *Physical Review Letters*.

b. Experimental Apparatus Improvement

The focus of our activity is to maintain the viability of the existing detectors supported by our group for the increased luminosity and changed bunch structure for run 2. Run 2 will begin perhaps in 1998, after both the main injector installation is completed and the various detector upgrades to both CDF and D0 are completed. CDF upgrades include the new scintillator plug calorimeters, a new 2-dimensional silicon vertex detector, and new front end electronics to deal with the bunch spacing of 128ns. D0 is putting in, among other upgrades, magnetic tracking.

Studies of strip chamber noise for development of front ends for Run 2 are continuing using a RABBIT system set up with a spare strip chamber in an RF box at Argonne. The FIG group at Fermilab, and Marcus Hohlmann and Theresa Fuess have shown that the VME readout scheme for multibunch front ends will increase the level of noise in the shower max signals. A noise generator is used to simulate the digital traffic. The current front end scheme takes advantage of a long gate (1 μ s) to reduce the noise. The 128ns bunch spacing leads to a desire to speed up the charge integration so that the pulses are spread over fewer cycles.

Although the signals are not quite differential, we have shown a 30% noise reduction using a prototype faster amplifier which receives differentially and acts as a current source output. The circuit diagram for the amplifier is shown in Figure 6. Using test pulses it was shown (Figure 7) that the amplifier integrates properly. We need further improvement to shorten the signal acquisition time while reducing the noise. The amplifiers used now would need about 8 crossings to integrate strip pulse height.

We also will become involved as consumers of the new fast tracker, XFT, to make sure that the strip chamber track match trigger functionality is retained. So far this is being designed for muons at the University of Illinois and for the calorimeter towers at the University of Chicago. The matching can be completed at level 1 of the upgraded trigger scheme.

The multibunch running will mean that the higher luminosities with the main injector do not imply higher detector occupancies than we are currently seeing. We are studying the effects of the current high luminosities in excess of $1.5 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$ in terms of current draw for chambers and aging. Some reduction of gain for preradiators is possible but unless the noise situation improves for the strip chamber, lower gain will imply loss of function for low energy showers. Additional data samples of 500 – 1000pb $^{-1}$ are expected from run 2.

c. Summary of Active Data Acquisition

In general, the CDF detectors have worked well for data taking in run 1b. The new silicon vertex detector, in particular, is performing well. The data are essentially good enough to use for physics, just not voluminous. The new DAQ system is now operational and performing well. The new level 2 trigger processors have not yet been installed. The disappointing collider performance during this period, with luminosity accumulating at half the rate of run 1a (8 pb $^{-1}$ in 6 months),

CDF Preliminary

Figure 4: The η and π^0 signals used to define a photon signal and (inset) the $\rho^\pm$ signal used to define a π^0 standard signal.

Figure 5: The photon cross section versus E_T as (data-theory)/theory. Note the low E_T excess and the small systematic uncertainty.

Figure 6: Prototype of a differential charge integrating preamplifier for the CDF shower max detector using high speed, large bandwidth components.

Figure 7: Response of the prototype shower max detector amplifier (top trace) to a rectangular test pulse (bottom trace; 10mV, 200ns) using $Z_t = 1 \text{ k}\Omega$, $C_F = 15 \text{ pF}$, $R_F = 30 \text{ k}\Omega$.

was later traced to a displaced and rotated low beta quadrupole magnet. This was also responsible for the 3mm horizontal displacement of the beam and the extremely skewed longitudinal vertex distribution, Figure 8.

We have been promised a recorded integrated luminosity of about 150 pb^{-1} . Since the quadrupole has now been moved back to its nominal position, and the run has been scheduled to continue to at least September, 1995; this goal is possible. Despite the paucity of data so far, offline reconstruction has only kept up with the high priority 10% subset of events so that calibration studies for run 1b data, which need the inclusive electron sample, have been postponed.

The central EM calorimeter otherwise is in good shape. The new source calibration at the beginning of run 1b has been tuned up in detail. Some of the gain loss noted during run 1a has been recovered and so far the gains seem fairly stable. Strip, crack, and preradiator chambers have no new problems and are performing well. Karen Byrum, working with the Michigan group, got the new front end cards and shower max strip chamber trigger hardware operational. It gives improved electron and photon selection as advertised. Figure 9 shows the good correspondence between the trigger threshold and the shower max wire pulse height as read out. Figure 10 shows the trigger rate as a function of the track match width. The overall efficiency for electrons is shown in Figure 11. Spare cards are now available and the electronics is working reliably.

Larry Nodulman is continuing to develop and support online data monitoring. Bob Wagner reinlisted as a member of a pool of about 15 shift leaders or "Scientific Coordinators" who help lead data taking. Jimmy Proudfoot and Theresa Fuess completed their cycles as scientific coordinators and Bob Blair has signed up for the next, current cycle. Marcus Hohlmann has served his term as a DAQ expert or "ace" and is helping to support fast offline monitoring of data quality.

d. Planning Activities

Members of the Argonne CDF group participated in the preparation of an expression of interest (EOI) for a further round of detector upgrades aimed at a run 3. As specified in the call

Figure 8: The longitudinal vertex distribution in centimeters for minimum bias events during skewed running of run 1b.

Figure 9: Efficiency as a function of shower max wire pulse height. We use a threshold of 3500 counts, about 6.5 GeV. The inclusive electron calorimeter energy threshold is 8 GeV.

Figure 10: Level 2 and level 3 trigger cross sections as a function of the matching width used for the projected level 2 track. We use a window of $\pm 3\text{cm}$ to achieve a rate reduction of $\times 0.5$.

Figure 11: Efficiency as a function of transverse energy using a sample of conversion electrons. At 8 GeV the shower max match requirement is 86% efficient.

for EOIs, a further increase of about a factor of two in instantaneous luminosity to about 8×10^{31} peak is expected, with conditions otherwise similar to run 2. Topics in b quark physics are expected to be important. How such a run would be related in time to the LHC turn-on is unclear. The Fermilab director has expressed displeasure at the results of the call for EOIs, and indeed, the long term schedule is rather unclear. The rather aggressive schedule calling for letters of intent next January will be delayed.

Other options for larger increases in instantaneous luminosity involving antiproton rings in the main injector tunnel are being studied, and we are considering what detector measures would be appropriate in such schemes. The function of the shower max strip chamber would likely be lost and a new fast preradiator system would be needed to keep the calorimeter viable for electrons and photons. The unpredictability of the Fermilab long range schedule makes planning difficult.

Some members of the Argonne CDF group are expected to participate only through run 2, moving on to ATLAS involvement. Others would likely want to remain with a Tevatron collider b physics experiment whether or not it evolves directly from CDF.

(L. Nodulman)

I.A.4 Non-Accelerator Physics at Soudan

a. Physics Results

The Soudan collaboration continued to focus most of its analysis effort on the measurement of the ν_μ/ν_e ratio from atmospheric neutrino interactions in Soudan 2. Preliminary results from the first 1.0 fiducial kton-year exposure were presented at the 1993 summer conferences (described in the last Semiannual Report). The main task during the first half of 1994 was a major upgrade of the Monte Carlo simulation of the experiment. This included improvements in the neutrino event generator, more accurate representation of the detector geometry, the use of actual detector parameters from the experiment database, and improved simulations of drifting and electronics. A large sample of new Monte Carlo events will be analyzed in parallel with contained events from the third half kiloton year data sample. Monte Carlo neutrino events will be processed by the same software as Soudan 2 data events, and will be mixed with data events for the final physicist scan of the contained event sample.

Analysis of contained event data from the third half kiloton year of Soudan 2 exposure continued during the first half of 1994. New data (from the fourth half kiloton year sample) are also being examined as they become available from the detector, and the characterization of neutrino interaction and nucleon decay candidate events has begun. Because the event selection and characterization procedures had evolved somewhat during the analysis of the first kiloton year exposure, the first half of that data sample has been reanalyzed with the same programs and scan rules used for the second half. Related analysis projects include work to isolate partially contained events (e.g. high energy neutrino interactions) and to characterize the non-quasi-elastic neutrino events (which are not currently used for the flavor ratio analysis).

Although identification of contained events (neutrino interactions and nucleon decay) continue to be a major task of the data analysis effort, the Soudan 2 detector also allows some interesting studies of cosmic ray physics. The search for astrophysical point sources of high energy cosmic rays using anisotropies in the flux of underground muons is the subject of a paper which

is being prepared for publication by Soudan collaborators at Oxford and Minnesota. A whole sky intensity map was made using 14 million muon tracks recorded by Soudan 2 between January, 1989 and February, 1993. This map is being used to search for evidence of steady point sources of cosmic rays, with a particular emphasis on the gamma ray sources identified by the Compton Gamma Ray Observatory. The construction of this map and the significance of regions with muon flux higher than the expected isotropic background is the subject of Graham Giller's Oxford Ph.D. thesis, which was completed in April, 1994.

Other ongoing cosmic ray analyses include the study of primary cosmic ray composition using multiple muon events, with and without coincidence data from surface detectors which observe the parent air showers directly. Above a few TeV/nucleon, heavy nuclei produce more muons at Soudan 2 depth than do light nuclei of the same total energy, making the underground muon multiplicity distribution sensitive to primary composition. The Soudan 2 surface array can be used to estimate the energy of each primary cosmic ray, making the analysis more sensitive to energy dependent effects. Figure 12 shows the results from the Soudan 2 surface-underground coincidence experiment compared to various models of primary cosmic ray composition. The shower size S_R is the number of air shower particles at the surface-array elevation, and can be used to obtain the energy of an air shower for a given primary nucleus. The Soudan data favor a light nuclear composition at high energy, or at least do not show any significant increase in primary mass in the 100 to 5000 TeV energy range.

b. Experimental Apparatus Improvement

A major adjustment was made to all Soudan 2 readout-plane anode high voltages in January, 1994. This change was made to optimize the dE/dx resolution and used information obtained during the previous month by running the readout planes at a series of voltages. On average, the anode high voltages were reduced by 25V, which significantly reduces the rate of noise hits and ensures operation in the proportional gas-gain region.

Following the completion of the 963-ton Soudan 2 detector in 1993, a major upgrade of early detector modules was begun in January, 1994. Sixty four of the oldest 5-ton modules in the southwest and southeast quadrants were removed to repair gas leaks or to improve the uniformity of wireplane response using new alignment techniques. Repairs were completed on 24 of these modules during the first half of 1994. Sixteen halfwalls were partially disassembled to gain access to the 64 modules; ten of these halfwalls were back in operation by the end of June. (A halfwall is a subassembly of eight 5-ton modules, stacked four across and two high.) In addition, anode high voltage splitter hardware was installed on all halfwalls so that pairs of wireplanes are no longer required to operate at the same high voltage.

Other installation activities included deploying new active shield proportional tubes which cover small holes and cracks along the edges of the floor panels and commissioning, during June, three new ceiling panels of single-layer HPW proportional tubes (salvaged from the Harvard-Purdue-Wisconsin nucleon decay experiment). These tubes are oriented orthogonal to the double-layer panels of the original active shield, to provide both improved efficiency and additional position information for cosmic ray muon tracks in the vicinity of the detector. In addition, the field wires of all HPW tubes were raised from ground potential to 500V in order to shorten the maximum charge collection time and to improve the time resolution. The three new panels, together with three panels previously installed, provide three-layer shield coverage immediately above the main detector. Two more panels of HPW tubes are needed to complete the three-layer coverage of the

Figure 12: Average observed muon multiplicity in Soudan 2 as a function of the reconstructed shower size S_R at the surface array. The range of S_R shown corresponds to total primary energies of 30 - 5000 TeV for protons and 100 - 10,000 TeV for iron nuclei. The curves labelled PP, MD, CMC, and Linsley show expected muon multiplicities for four realistic composition models. The Linsley model is the only one with a predominantly light nuclear composition at high energy. The curves labelled Fe, He, and H are for ad hoc compositions consisting of pure iron, helium, and hydrogen nuclei.

ceiling.

Argonne physicists and engineers continued to make substantial contributions to the installation and operation of the detector. Major activities included the study of detector and electronics performance, and coordination of the detector upgrade project. Electronics work focused on the identification and repair of analog-to-digital converters with anomalous responses. Argonne physicists are also continuing the development of software to make use of the dE/dx information from the detector.

c. Summary of Active Data Acquisition

The Soudan 2 detector is operated for physics data primarily during night and weekend periods when installation or maintenance work is not in progress, and the underground laboratory is unoccupied. The anode-cathode edge trigger, which was devised for neutrino interactions and nucleon decay, has high efficiency for cosmic-ray muon tracks as well. All data are processed at Soudan through track reconstruction programs, and the analysis results are recorded on 8mm magnetic tape cassettes for distribution to the collaborating institutions.

The Soudan 2 experiment continued routine data acquisition for contained events (neutrinos and nucleon decay) and cosmic ray muons during the first half of 1994. Although data from the 40m² surface array are generally recorded in coincidence with Soudan 2 to measure the energies of some of the cosmic ray air showers which produce underground muon events, the surface array was shut down for most of the period in order to upgrade its data acquisition electronics. It was brought back into operation at the end of June. Data from a wide-angle air Cerenkov air-shower detector were also recorded in coincidence with Soudan 2 on clear moonless nights.

The Soudan 2 detector itself recorded data for 135 days of livetime, giving a duty cycle of 75%. This brought the total Soudan 2 exposure to 4.2 years, or 1.9 fiducial kiloton years useful for nucleon decay and atmospheric neutrino physics.

d. Planned Activities

The Soudan 2 module upgrade is proceeding somewhat slower than expected because a number of modules have developed gas leaks while being moved to gain access to other modules. On the other hand, an unanticipated benefit of the southwest quadrant upgrade has been a significant decrease in gas usage, saving several thousand dollars per year in gas costs. Upgrade of the south half of the detector should be complete during the spring of 1995. The upgrade of the newer north half of the detector is expected to proceed much faster, and should be complete by the end of 1995.

At the completion of the 5-ton module construction in 1992, extra bandolier was fabricated for three additional modules. Bandolier is the subassembly of Hytrel drift tubes, Mylar insulation, and copper strips which provide the drift-tube voltage gradients. It has been decided to use the extra bandolier, along with shorter pieces left over at the end of module construction, to completely rebuild five modules at Argonne. These modules have always drifted poorly, apparently due to faulty or contaminated drift tubes. The modules will be shipped to Argonne during the fall of 1994 and will be returned to Soudan in the spring of 1995. Only the corrugated steel sheets will be saved; all other module components will be replaced.

(D. Ayres)

Figure 13: Feynman diagrams for photoproduction showing examples of (a) a direct and (b) a resolved process.

I.A.5 ZEUS Detector at HERA

a. Physics Results

Four papers were published or submitted for publication in this period. The analyses were based on the 25 nb^{-1} of data collected in 1992.

A search was made for both direct and resolved processes in hard photoproduction using events with two jets in the final state. Typical Feynman diagrams for these processes are shown in Figure 13. In the direct process of Figure 13a, the photon couples directly to a quark pair so that all of its energy enters into the hard interaction. In contrast, in the resolved process of Figure 13b, a parton constituent of the photon scatters with a parton from the proton. The photon remnant continues along the photon direction. Such events will show significant energy in the rear calorimeter of ZEUS in addition to the two jets from the hard interaction.

The data sample of about 20,000 events spanning the c-m energy range $130 < W < 250$ GeV was used to search for jets using a cone of unit radius in $\eta - \phi$ space; 1850 jets were found with a transverse energy, $E_T > 5$ GeV. The E_T and η distributions are shown in Figure 14 and are compared to simulations containing both direct and resolved contributions. The latter dominates the cross section in this regime of the kinematics.

Conservation of energy and momentum leads to the following expressions for the Bjorken x of the partons entering to the hard collisions:

$$x_p = \frac{\Sigma(E + p_z)_{\text{jet}}}{2E_{\text{proton}}} \quad (1)$$

$$x_\gamma = \frac{\Sigma(E - p_z)_{\text{jet}}}{\Sigma(E - p_z)_{\text{total}}} \quad (2)$$

The sum in the denominator runs over all calorimeter cells.

After applying the selections $|\eta_{\text{jet1}} - \eta_{\text{jet2}}| < 1.5$ and $|\phi_{\text{jet1}} - \phi_{\text{jet2}}| > 120^\circ$, 193 events remained. The x_p and x_γ distributions for these events are shown in Figure 15. The mean x_p value is 0.014; a region where the parton densities in the proton are well known. The x_γ distribution shows two clear regions: the peak near one coming from the direct process and the events with lower x_γ values being examples of resolved photon interactions. The corresponding cross sections are $9.4 \pm 2.7 \pm 2.7 \text{ nb}$ (direct) and $21.1 \pm 5.2 \pm 5.7 \text{ nb}$ (resolved).

Figure 14: Inclusive jet distributions for (a) the transverse energy of jets, (b) pseudorapidity of the jets, η^{jet} . The relative contributions of the direct and resolved processes as predicted by Monte Carlo simulation are also shown.

Figure 15: The (a) x_p and, (b) x_γ distributions for events with two or more jets after final selection. The Monte Carlo distributions are the result of the fit to the data shown in (b).

A detailed paper describing the measurement of the total and partial cross sections for photoproduction was submitted to *Zeitschrift für Physik C*. The energy distributions in the different calorimeter regions were fitted to the different contributions that make up the total cross section. The results are $\sigma_{\text{tot}} = 143 \pm 7 \mu\text{b}$, $\sigma_{\text{el}} = 18 \pm 7 \mu\text{b}$, $\sigma_{\text{diff}} = 33 \pm 8 \mu\text{b}$, and $\sigma_{\text{non-diff}} = 91 \pm 11 \mu\text{b}$. The values for the elastic vector meson production and the total cross section are compared to previous measurements in Figure 16.

The observation of Deep Inelastic Scattering (DIS) events with a large rapidity gap between the final state proton remnants and other hadronic activity in the event has created much interest. This work was described in the previous semi-annual report. The initial observations have been followed up with two studies: the first reports the observation of jets in these events and the second compares the energy flows in the normal DIS sample with those observed in the rapidity gap, diffractive events.

The distribution in η_{max} , the pseudorapidity of the most forward energy deposit above 400 MeV in the calorimeter, is shown in Figure 17. The full histogram is the prediction of a standard DIS Monte Carlo simulation. The excess for $\eta_{\text{max}} < 1.5$ is the signal for the diffractive events. They are reasonably simulated by the POMPYT Monte Carlo program using a hard pomeron structure function varying like $x(1-x)$ as shown in the dashed histogram. POMPYT uses Regge theory to describe the pomeron flux from the proton and then treats the pomeron as a particle made up of partons. Both hard and soft ($[1-x]^5$) structure functions can be chosen. A second simulation is based on the model of Nikolaev and Zakharov (NZ). In this model the pomeron is represented by two gluons which interact with a $q\bar{q}$ pair coming from fluctuations in the photon.

Although the total c-m energy, W , is large for these events, the mass of the hadronic system, M , is limited as can be seen in Figure 18. The two event samples with the η_{max} selection at 1.5 populate different regions of the $W - M$ plane. Fits to the data distributions using POMPYT give a mean fraction of the proton momentum carried by the pomeron of 3.2×10^{-3} with a maximum value of 2×10^{-2} . These values are well within the selection of 5×10^{-2} usually imposed in studies of hadronic collisions when selecting diffractive events.

Figure 19 shows various distributions in the $\gamma^* - p$ c-m system. The transverse energy in the events is low but extends above 10 GeV. The single (double) shaded area corresponds to events where one (two) jet(s) is(are) found in the event. The black area shows the E_T values of the few events with three jets. The two jet events are back to back in azimuth as is seen in Figure 19b and the E_T distribution of the jets extends as high as 8 GeV. Both the hard POMPYT and the NZ model give a reasonable representation of the data. The jets are usually manifest as seen in the Lego plots and jet profiles in η and ϕ of Figure 20. In the $\Delta\eta$ distribution of Figure 20c, the normal events, shown as the open circles, have energy at positive $\Delta\eta$ — towards the proton remnant.

A more detailed study of this effect is illustrated in the energy flow plots of Figure 21. These plots show, for different Q^2 selections, the energy weighted pseudorapidity difference distributions for normal and diffractive events. The $\Delta\eta = 0$ value is that expected for a simple quark-parton model. The proton remnant is at positive $\Delta\eta$. As previously reported, the normal events show a shift in the energy flow towards the proton remnant coming from QCD radiation which populates the region between the recoil quark and the proton remnant. The diffractive events, however, do not show such an effect; consistent with reduced QCD radiation in these processes. This effect is particularly clear in the Breit frame distributions of Figure 22. The current fragmentation region is at negative η^* . The full histogram was generated with the hard pomeron structure function and the dashed histogram with the soft parametrization. The latter is clearly ruled out by the data as

Figure 16: (a) The total photoproduction cross section as a function of the γp center of momentum energy, $W_{\gamma p}$. The curves are the predictions from various parametrizations. (b) The elastic vector meson production cross section ($\gamma p \rightarrow V p$) as a function of $W_{\gamma p}$.

Figure 17: The distribution of the pseudorapidity, $\eta_{\max}$, of the most forward energy deposit in the calorimeter above 400 MeV. The solid circles are the ZEUS data points, the full histogram is the DIS Monte Carlo, and the dashed histogram is the POMPYT Monte Carlo with a hard structure function.

Figure 18: Hadronic mass, M versus the total c-m energy, W .

Figure 19: $\gamma^* - p$ c-m system distributions: (a) the $\gamma^* - p$ transverse energy, E_T^* , (b) the jet-jet azimuthal separation, (c) the transverse energy of the jet, $E_T^* \text{jet}$.

Figure 20: Example Lego plots (transverse energy deposition in $\eta - \phi$ space) for (a) a large rapidity gap event with one hadronic jet and, (b) a two jet large rapidity gap event. (c),(d) The transverse energy weighted profiles for jets with $\eta_{\text{jet}} < 0$ with $\eta_{\text{max}} < 1.5$ (filled circles) and with $\eta_{\text{max}} > 1.5$ (open circles).

Figure 21: The energy weighted rapidity difference, $\frac{1}{N} \frac{dE}{d\Delta\eta}$, in five bins of Q^2 . The open circles are the non-rapidity gap events ($\eta_{\max} > 1.5$). The solid circles are the rapidity gap events. The histogram is a DIS Monte Carlo.

Figure 22: The energy weighted rapidity in the Breit frame for 5 values of Q^2 . The open circles are the non-rapidity gap events and the solid circles are the rapidity gap events.

the energy it predicts at positive η^* , which comes from the pomeron remnant, is too large.

b. HERA and ZEUS operations

The 1994 data taking started in this period with HERA operating with 184 bunches. The proton beam current was higher than in 1993 and was up to one third of the design value with lifetimes of tens of hours being achieved. However, the serious problem of a short lifetime for the electron beam at high currents persisted. This is thought to be connected with positively charged particles coming from the vacuum pumps and being trapped by the potential well of the electron beam. It seems likely that all of the electron ring vacuum pumps will need to be replaced before stable high-luminosity $e^- - p$ collisions can be produced. In the mean time, the decision was reached to switch to e^+ operation for at least the remainder of the 1994 operations period.

The ZEUS detector was equipped with a number of new devices, notably the small angle rear tracker consisting of crossed scintillator strips and the new wire chamber rear tracking detector. In addition, the full shower max detector was installed in the rear calorimeter. These three devices will much improve the capability to precisely reconstruct events with electrons and hadrons in the rear direction. An improved version of the forward neutron calorimeter was installed in the HERA tunnel. The final version of the calorimeter and the required modifications to the HERA beam pipe will be implemented in the 1994-1995 shutdown. More detector planes were added to the forward proton spectrometer so good data will be available this run in which the forward proton is measured. Implementation of the read out of the forward tracking system and the transition radiation detectors was planned for the 1994 operation, but some problems with the flash ADC system are yet to be resolved.

The high backgrounds associated with the short electron lifetime lowered the data taking efficiency at the start of the operation. The system had become more stable at the end of the period so that one can expect good detector operation when the $e^+ - p$ HERA operation starts.

c. Apparatus Development

The High Resolution Calorimeter of ZEUS has outstanding energy resolution for jets and gives good measurements of the recoil electron in DIS when it is isolated but the limited number of readout channels that is characteristic of scintillator based calorimeters makes it difficult to measure individual particles within jets. To overcome this problem, the Rear Calorimeter (RCAL) of ZEUS has been equipped with a set of $3 \times 3\text{cm}^2$ silicon pads placed near the maximum of the electromagnetic showers in the EMC section of the calorimeter. This device is called the Hadron-Electron Separator (HES). An essentially identical system is planned for the Forward Calorimeter. It is natural, therefore, to consider a similar augmentation of the Barrel Calorimeter.

The HES is used to provide a finer segmentation and precision in the location of electromagnetic showers than is allowed by the $10 \times 20\text{cm}^2$ ($5 \times 20\text{cm}^2$) size of the RCAL (FCAL) scintillator towers and is particularly important when more than one particle is incident on the same tower. The DIS events at very low x have both the scattered electron and the hadron jet in the RCAL so identification of the electron in the presence of both hadrons and electromagnetic showers from the jet fragmentation is aided by the HES.

Other physics processes have been studied to understand the case for the HES; notably heavy quark production where the challenge is to identify electrons coming from semi-leptonic decay of b and c quarks in which the electrons are accompanied by other particles making up a jet.

Figure 23: Barrel calorimeter module end view.

The conclusion of such studies was that the HES provided an important additional discriminator against background and was needed in order to isolate a clean sample of such events.

A HES consisting of silicon pads does a good job but is prohibitively expensive since the surface area of the BCAL is equal to the sum of those of the RCAL and FCAL. We have pursued a simpler and cheaper option for a BCAL HES that uses a set of wires along z , the e-p beam direction and pads in θ . Such a system is used with the CDF detector. The OSU group has studied an alternative technology that uses scintillator fibers in z and has no θ segmentation.

In constructing the BCAL modules of ZEUS, an aluminum box was located after three uranium plates as shown in the end view of a module of Figure 23. This box, which is 24cm wide is divided into four compartments separated by longitudinal ribs to support the compressive force that holds the module together. Access to the compartments is from the rear end. Any BHES must fit in this 1.6cm high box. The small tubes shown in the base of the ribs were provided as water cooling channels.

The lower part of Figure 23 shows the cross section of the aluminum extrusions that form the proportional chamber skis. Eight cells are provided in each ski giving 32 per module and 1024 for the whole BCAL. The wire spacing is 6.8mm and they extend the full 2.77m module length. The active area of a cell is 5.8mm in ϕ by 5.5mm in radial depth giving a total gas volume per ski of 650ml. The top of the U-channel extrusion combs is closed with a segmented printed circuit board

with 1.7cm etched copper strips facing the wires. These 160 cathode pads produce an induced signal and provide a z coordinate. This segmentation is comparable to the 2cm Molière radius of the calorimeter structure. The HES samples the shower after $4X_0$.

The ribs of the combs ensure electrostatic stability for the wires that typically operate at 1250V and minimize any problem coming from Compton electrons spiraling around the wire. However, the ribs both in the skis and between them as well as the module to module gaps mean that 20% of the azimuth is not instrumented. This will mainly effect single muons as typical electromagnetic showers spread over several cells. The total material in the skis is about $0.1X_0$.

The A/CO₂ gas used is supplied through a manifold at the end of each ski. Within a ski all cells are connected in series and the printed circuit board is gas sealed to the ribs. The feed and return lines from each ski will be manifolded together at the rear of the BCAL. It is likely that the 10% A/90% CO₂ gas used by the ZEUS Backing Calorimeter can also be used for the BHES.

The signals from each cathode pad are brought through the printed circuit board to a surface mount preamplifier that shapes the signal and drives a microstrip line extending to the end of the ski. Each ski currently uses five boards. For a production design it would be preferable to use a single full length multi-layer board that incorporates the connections to the end. This option is under investigation.

At the ends of the skis, the pad signals are multiplexed to form partial barrel hoops as a single readout. The number of signals is $5120/N$, where N is the number of modules that are multiplexed together. The summer cards and the drivers for the 160 strips in a given ski are mounted at the end of each module. Both the wire and pad signals are transmitted through twisted pair cables to the bulkhead on the back beam of the BCAL modules.

Both wire and pad preamplifiers are based on simple and cheap current amplifiers with positive feedback to increase the dynamic range and improve the linearity. The current gain of the amplifiers is about 200 and the dispersion is typically $< 5\%$. The dynamic range is 200 with $\sim 1\%$ non-linearity. The power dissipation in the on-ski electronics is 10W per module; the driver cards located at the module ends dissipate 20W per module.

In addition to the twisted pair signal cables and the gas lines, each module needs one high voltage cable, five RG174 charge injection cables and two wires to carry $\pm 5V$. The electronics which has been designed to read out the BHES signals is built in a 9U VME format. The signals from wires and pads are received differentially on the cards from the ribbon twisted pair. Each card can accomodate 16 wire or pad signals and provides common mode rejection. A shaping filter and gain of 10 is provided for each signal.

The shaped and amplified pad/wire signals are digitized by 8 bit Harris HI1175 flash encoders clocking at the frequency of the HERA clock. A 6 bit programmable delay allows the flash encoder clock to be delayed from the HERA clock with 2ns resolution. The delay is set by the contents of a register written from VME. The 8 bit data from the 16 flash encoders is written to dual port memories which emulate fifos, the depth of the fifo being determined by the contents of another register written from VME.

In the event of a first level trigger accept, the next N words appearing at the outputs of the fifo emulators are written to fifos. Again N is the content of a register written from VME. This logic allows the system to acquire data after the latency of the first level accept, and to acquire the number of data words required for the offline algorithm. Logic is included to preclude writing

data to the fifos if an abort is received from the fast clear. The content of the 16 fifos is available asynchronously to VME for data acquisition.

In order to investigate the installation problems and to study possible effects of the BHES on the operation of the calorimeter itself, the four first prototype modules were mounted in Module #26 of the BCAL. The installation was done from the rear since the front end of the BCAL EMC is covered by the frustum. Most of the rear is covered by a trellis that carries the cables from the tracking chambers, but the three modules at the bottom and two at the top can be accessed. Although, for the test installation no rotation was needed, in order to install the complete set of BCAL HES skis the BCAL/spokeplate assembly must be rotated by 180°. This was foreseen and included in the original design.

The skis are light enough that they could be hand carried inside the open clam shells and slotted into the aluminum box provided. To access the ends of the box requires removing a small cover plate. Replacement plates fit around the HES skis. For the prototype installation, aluminum tape was used to light tight module and measurements of the DU current before and after the installation verified that the module remained light tight, throughout. The installation took about two hours. The production skis will have a simple rectangular cross section as they emerge from the module to alleviate this problem.

Each ski had a thermometer mounted near the forward end to measure the temperature rise caused by the 10W heat dissipation of the pad preamplifiers. The heat source is at the inside radius and so next to a DU plate rather than to scintillator tiles. The measured temperature rise was 2°C with a time constant of about an hour. No effect was seen on the DU current.

Since it is known that N₂ gas increases the light output of SCSN-38 scintillator, the final check was to measure any effect on the scintillator light output from A/CO₂ that could be introduced into the BCAL module by a gas leak. The gas inside the module was sampled by the ZEUS gas analyser and the uranium current measured as gas was flown through the chambers. Although A and CO₂ were sensed in the module at a level of 10ppm no effect on the DU current was measured. To make a more sensitive check both N₂ gas and A/CO₂ were introduced directly into the BCAL prototype module at Argonne. Indeed, N₂ increased the DU signal at the 5-10% level but, A/CO₂ had no effect even at very high flow rates of gas directly into the BHES box. The conclusion from these tests is that the BHES has no direct adverse effect on the calorimeter operation.

A second set of skis was built and mounted in the prototype BCAL module that was placed in the AGS test beam at BNL. Measurements were made with electrons and pions between 1 and 6 GeV. Only the wire readout was implemented for this first test. Scintillation counters placed after a piece of aluminum, used to simulate the coil, were used as a presampler test. The data are currently under analysis.

(M. Derrick)

I.A.6 BNL Partial Snake Experiment

The partial snake experiment at the AGS, E880, had a very successful first run with polarized beam in April, 1994. There was a large Argonne effort in setting up and running the internal polarimeter. After being shut down for about six years the polarized ion source came to life again giving us about 2×10^9 polarized protons per pulse (pppp) in the AGS at the beginning of the run

and increasing steadily up to 6×10^9 pppp. The 200 MeV polarimeter measured a polarization of 80%. In the Booster, we observed the effect of both imperfection resonances ($G \times \gamma = 3, 4$) and both resonances were as predicted weak. $G\gamma = 3$ needed no correction and $G\gamma = 4$ caused about 5% depolarization without correction. We extracted from the Booster before the intrinsic resonance but could see its effect when we lowered the tune in the Booster. In the AGS we measured full polarization below the first intrinsic resonance both with and without the 5% Snake. However, as expected, the Snake induced full spin flip at every integer value of $G\gamma$. Without the Snake we did not observe any polarization surviving above the first intrinsic $G\gamma = n\nu_y$. With the 5% Snake we were able to observe polarization up to $G\gamma = 22.5$ losing polarization only at intrinsic resonances. We did not go higher in energy because the low analyzing power of the internal polarimeter at these higher energies and the low polarization from the losses at the intrinsic resonances made the measurements quite lengthy. The result is that we did not lose any polarization from imperfection resonances — the partial Snake works!

For the next run, now scheduled for December, 1994, we need to concentrate on reaching the full machine energy (25 GeV) which means we need to fully understand the polarimeter and also do something about the losses from the intrinsic resonances.

(D. Underwood)

I.B EXPERIMENTS IN PLANNING OR CONSTRUCTION PHASE

I.B.1 STAR Detector for RHIC

a. STAR Calorimeter

The RHIC/STAR R&D at Argonne during the period from January to June, 1994 concentrated on the design of support rings and the estimation of thermal effects for the STAR electromagnetic calorimeter (EMC). An engineering model for an EMC module was also designed and work on designing and prototyping trigger electronics was performed.

The STAR magnet will consist of a series of conventional coils in a solenoidal configuration, separated by the EMC support rings. The rings will be supported from the magnet flux return bars or backleg steel bars, and in turn the rings will support the full EMC weight of ~ 180 tons. In close connection with the magnet engineers at Brookhaven, a number of conceptual designs have been studied for these rings. Considerations such as space available, installation and alignment scenarios, tolerances, etc. have been discussed with the magnet and other subsystem groups of STAR. This work is documented in a recent STAR note (#154). Work is continuing on a preliminary ring design. Drawings for the center ring have been made at Argonne and are being considered by Brookhaven engineers. The goal is to have final designs for all nine rings at the time of the final design review for the magnet iron in May or June, 1994.

Another major effort has been the study of thermal effects on the EMC design. The lack of a chiller for magnet cooling water in early STAR operation could conceivably lead to average magnet temperatures of $\sim 115^\circ$ F in summer, while the detector construction could occur at $\sim 65^\circ$ F in winter. This is a 50° F temperature variation, which might lead to high stresses in EMC supports or modules. These effects were studied with finite element computer models. A variety of related heat flow estimates and measurements of high temperature effects on EMC optical components have also been performed. Most of this work is now complete, and various requirements can be stated for some of the thermal effects. A STAR note describing these calculations and measurements is almost completed.

An engineering model and associated test fixture have been designed for an EMC module. The purpose will be to check various stress and deflection calculations based on finite element computer models. Tests will also be conducted on the rail system planned for installing the modules. The drawings have been completed, and some parts are ordered for the engineering model. It is hoped to complete the model by the end of this fiscal year.

Another activity at Argonne was making a conceptual design and doing some simple prototyping of the trigger for the EMC. A number of calculations were made over several months to determine how much of the trigger should be analog and how much digital. Prototypes were then constructed of a multilayer XILINX digital summer and a fast analog current summer with good common mode rejection. Timing tests on the digital summer showed that the clock frequency and total pipeline time were quite feasible for the proposed trigger. The digital test involved summing 8 words of 16 bits in 3 layers of two-word sums. The real trigger would have nine layers. The worst case time for the 3 layers was 45 ns; so 9 layers would take 405 ns. This summing is pipelined; therefore, there is no problem with the 110 ns bunch crossing time. The analog sums were done with a new kind of video amplifier, the MAX435. This amplifier has good common mode rejection for noise suppression and the outputs can be wire "ORed" to make sums of a number of channels. A STAR note is being prepared which will describe the proposed method, the calculations, and the

tests of the prototypes.

b. RHIC Spin Physics Program

During the period January-June, 1994, we carried out several simulation studies in order to understand the acceptance of STAR, the expected event rates, and the backgrounds for several reactions of interest.

i. Single Jet Production

We can study gluon-gluon scattering up to $p_T = 20$ GeV/c and then gluon-quark scattering above ~ 20 GeV/c. By measuring the asymmetry, A_{LL} , in single jet production in the region $10 < p_T < 20$ GeV/c, we can determine the gluon polarization $\Delta G/G$, where $\Delta G(x) \equiv G^+(x) - G^-(x)$ is the helicity distribution of the gluon.

With the STAR detector, the electromagnetic component of jets can be measured in the EM calorimeter, and the charged component determined using the TPC. Monte Carlo studies of the rates, acceptances, and resolutions were made using the ISAJET program with EHLQ1 structure functions and the GEANT detector simulation package.

ii. Direct Photon Production

Prompt photons are produced through the $q\bar{q}$ annihilation process and the $q - g$ Compton process, $qg \rightarrow \gamma q$. The Compton interaction is the dominant one in pp interactions since there are no valence antiquarks in the proton. The asymmetry, A_{LL} , in direct- γ production is directly proportional to $\Delta G(x)$.

Monte Carlo simulations of the Compton interaction were performed using PYTHIA 5.6 and JETSET 7.3. The hard processes $q + q \rightarrow q + q$, $g + q \rightarrow g + q$, and $g + g \rightarrow g + g$ were considered as a background to the direct gamma production.

To select direct gamma events the following trigger and cuts were applied:

- At least one EM calorimeter tower with $E_T > 10$ GeV
- Isolation cut — A matrix of 3×3 towers centered on the maximum E_T but excluding this tower should not have an energy deposit > 0.5 GeV.
- No charged track associated with the tower with maximum E_T .
- $E(\text{hadrons})/E(\text{max. tower}) < 15\%$ (using EMC + TPC).

A simulation with a large number of events showed signal/noise = 7.6 ± 0.8 .

iii. $W^\pm$ and Z Production at 500 GeV

The following production cross sections for W and Z bosons in pp interactions at $\sqrt{s} = 500$ GeV were estimated using PYTHIA V5.3/V5.6:

$$\sigma \cdot \text{Br} (pp \rightarrow W^+ + X \rightarrow e^+ + \nu_e + X) = 120 \text{ pb} \quad (3)$$

$$\sigma \cdot \text{Br} (pp \rightarrow W^- + X \rightarrow e^- + \bar{\nu}_e + X) = 43 \text{ pb} \quad (4)$$

$$\sigma \cdot \text{Br} (pp \rightarrow Z^0 + X \rightarrow e^+ e^- + X) = 10 \text{ pb} \quad (5)$$

The STAR detector with electromagnetic calorimeters is especially suited to experiments measuring W and Z boson production properties due to its large acceptance for electrons produced by high mass particle decays. The estimated event rates for an integrated luminosity of 800 pb^{-1} were $W^+ = 68,000$ events, $W^- = 15,000$ events, and $Z^0 = 3840$ events.

Simulation studies were made with the Lund set of routines PYTHIA V5.6/JETSET V7.3 on the detection of hard $e^\pm$ from $W^\pm$ and Z^0 decays, and also on the backgrounds arising from π^0 Dalitz decay and high p_T charged hadrons mis-identified as electrons

The $W^\pm$ background from $Z \rightarrow e^+e^-$ decay in which one decay lepton is not detected is unrejectable, in principle. For an integrated luminosity of 800 pb^{-1} , the expected number of events with a missing electron, but detected positron within the fiducial acceptance is expected to be about 1700, with an equal number of events with missing positron, but detected electron. Thus, the background to W^+ from one-legged Z decays will be about 2.7%, but about 12.4% for W^- .

The background to W production from π^0 Dalitz decay ($\pi^0 \rightarrow \gamma + e^+e^-$) was studied by assuming at least one Dalitz decay electron has $p_T^e > p_T^{e_{\text{cut}}}$. Taking into account, the application of other criteria to W event selection (demanding isolation, rejecting pairs of close $e^\pm$ distinguishable in the tracking system and using the Shower Maximum Detector(SMD) signal), the background from π^0 Dalitz decays is found to be negligible.

The contamination of the W sample by high p_T charged hadrons mis-identified as electrons is expected to be the most serious source of background. Our ability to extract W signals depends on the detector capability to distinguish hadrons from electrons. The first stage simulations were performed by i) matching the momentum measured in the STAR tracking system to the energy deposited in the EMC, ii) applying the isolation cut, and iii) applying the rejection power of the SMD. With a reasonable $p_T^{e_{\text{cut}}}$ of about 20 GeV/c, the ratio of all charged background to genuine W events becomes about 10%.

(A. Yokosawa)

I.B.2 Long Baseline Neutrino Oscillation Experiment

The Soudan collaboration has been working with Fermilab since 1990 in formulating a possible long baseline neutrino oscillation experiment from Fermilab's Main Injector to Soudan 2. The purpose of the experiment would be to search for $\nu_\mu \rightarrow \nu_\tau$ (or $\nu_\mu \rightarrow \nu_e$) oscillations in the region of parameter space suggested by the atmospheric neutrino deficit. After our first presentation was made to the Fermilab Program Advisory Committee in November, 1993, there were several questions about systematic uncertainties on the neutral current to charged current ratio (R_{nc}/cc). These were addressed in a presentation to the Fermilab PAC in March, 1994.

In December 1993, Fermilab issued a public call for proposals for long baseline neutrino oscillation experiments. The 822 collaboration responded with a supplement to its existing proposal with an Expression of Interest (EOI) to build an additional 16 kTon iron plate calorimeter. This was one of 3 EOI's received by Fermilab in May, 1994. In June of 1994 the Fermilab PAC reviewed these EOI's and recommended a joint Short Baseline/Long Baseline neutrino oscillation program at Fermilab, acknowledged several advantages of the Soudan site, and proposed an ambitious schedule and budget for this program. The Argonne part of the Soudan collaboration has taken the lead role in promoting this experiment. The 822 collaboration includes the Soudan collaboration (Argonne, Minnesota, Tufts, Oxford and Rutherford) and several Fermilab physicists.

In the March, 1994 update to the 822 proposal, the collaboration studied in detail possible systematic uncertainties. A long baseline experiment can interpret a change in the neutral current to charged current ratio in two separated detectors as evidence for neutrino oscillations. Our collaboration proposed having one detector located at Fermilab, and using for the other detector the Soudan 2 which is 730 km away. In order to judge the feasibility of a larger detector, we carried these Monte Carlo studies well beyond the statistical precision attainable with the Soudan 2 detector. A straightforward study of systematic errors uses the ratio

$$T \equiv \frac{N_{cc}}{N_{total}} \quad (6)$$

instead of R_{nc}/cc , where N_{total} includes apparent neutral current events, charged current events, and events which can not be reliably separated. The result of the study is shown in Table 1. The largest systematic uncertainty identified is from reconstruction uncertainties that differ in the near and far detectors due to the different geometries of cracks and edges. Two other effects deserve comment. Uncertainties in the charm cross section near threshold contribute to an uncertainty in the expected value of the charged current cross section. Also there is uncertainty in the relative flux of ν_e 's, whose interactions will not be distinguishable from neutral current events. Both of these systematics are greatly reduced by the comparison of T in the near and far detectors. If limited by systematic uncertainties alone, oscillations could be detected down to the 1% level.

Contribution	dT	dP_e	dP_τ	$\sin^2 2\theta$	
				$\nu_\mu \rightarrow \nu_e$	$\nu_\mu \rightarrow \nu_\tau$
Statistics	0.0100	0.0195	0.0526	0.0507	0.1368
MisID-energy cut	0.00010	0.00013	0.00035		
MisID- Δ (Acceptance)	0.00002	0.00003	0.00008		
MisID-reconstruction fail		0.00225	0.00608		
Length cut		0.00050	0.00135		
ν_e	0.00167	0.00220	0.00594		
Charm	0.00077	0.00099	0.00268		
Energy spectrum-PBEAM	0.00009	0.00009	0.00025		
M_A	0.00020	0.00026	0.00070		
Q^2 cutoff	0.00030	0.00039	0.00105		
Total Systematics		0.00336	0.00928	0.00874	0.02413
Statistics and Systematics		0.0198	0.0534	0.0515	0.1388

Table 1: Summary of statistical and systematic uncertainties

This study strengthened our belief that a larger detector would be useful for a long baseline neutrino beam. The 822 collaboration was one of 3 that proposed 15-20 kTon detectors at large distances from Fermilab. Taking advantage of the infrastructure at the existing Soudan laboratory, as well as the operating the 1 kTon fine-grained Soudan 2 detector, the Soudan EOI described additional tests for neutrino oscillations that could be performed with a large new detector.

Meanwhile, a site specific engineering study on the costs and technical feasibility of creating a neutrino beam aimed at Soudan 2 has been updated and improved by the Fermilab Facilities

Engineering Services Section. A study of a beam solely for the short baseline experiment was also done for comparison. For the joint beam, a region of highly fractured rock which had been found in test bores was avoided by redesigning the beam optics. The short baseline beam was estimated at \$23.4M. The cost estimate of the joint beam was lowered from \$45.7M, to \$35.2M. The bottom of the near detector hall now sits 150 feet below grade.

The Fermilab PAC reacted with enthusiasm. *"The Committee (PAC) was impressed with the detector design and simulation studies, and with the ultimate reach in $\sin^2 2\theta$ and Δm^2 of a 15-20 kTon fine-grained iron sampling calorimeter...The PAC further recommended a staging option that would take advantage of early running with the existing Soudan detector. The Committee endorses the concepts presented in these EOI's and looks forward to receiving a single LOI by January 1995."*

The Soudan collaboration is working to join with proponents of other EOI's in a large collaboration which can meet the PAC schedule for a proposal by June, 1995. We are also working with Fermilab on the beam design and engineering studies needed for a Conceptual Design Report on that timescale. We envisage a submitting a detailed funding request (schedule 44) to the DOE for the beamline by January of 1997 and Congressional authorization and funding in FY1998. Such a beam would be ready for an initial run in the year 2000. In the meantime, the collaboration will undertake extensive detector R&D and prototyping for the large calorimeter.

(M. Goodman)

I.B.3 ATLAS Detector Research & Development

a. Overview of ANL LHC Related R&D Programs

Following the cancellation of the SSC, many of the physicists at Argonne involved in the SDC collaboration have considered the physics opportunities presented by the Large Hadron Collider, to be constructed at CERN in the next decade. These deliberations have included extensive discussions with many US university staff as well as with several of the subsystem leaders from both of the major LHC collaborations. As a result of these, in January of this year, a group within the division has sought to identify collaborators within the US to pursue collaboration on the ATLAS experiment for the LHC. We have, at present, identified 4 US university groups wishing to collaborate with us and to make use of ANL facilities: a group at the University of Chicago led by Prof. J. Pilcher; a group at the University of Illinois led by Prof. S. Errede; a group at Harvard University led by Prof. M. Franklin, and a group at Brandeis University led by Prof. C. Blocker.

The areas of collaboration sought by us are on the hadron scintillator-tile calorimeter and the associated trigger electronics. The calorimeter is a scintillator/iron sampling calorimeter in which the sampling geometry is rather novel [Figure 24]. However, in all other respects it has many similarities both to some early mechanical designs we developed for the SDC endcap calorimeter, and to the readout that was being developed for the scintillator tiles in the barrel electromagnetic calorimeter for the SDC. As a group, we are, therefore, rather well positioned to contribute immediately to the ongoing design efforts at CERN. Our work in these two areas, as well as tests carried out on the scintillator readout during this six month period, are described in more detail below. In the near future these areas will also require substantial simulation studies for optimization of the detector's performance and for comparison to beam test data. We intend to build up our capabilities in this area both from the point of view of component optimization and towards performing physics simulations to participate in the development of the physics goals of the experiment.

Figure 24: The principle of the proposed hadron calorimeter. Each tile is read out by two fibers and the coupling of fibers to groups of tiles defines the radial segmentation.

In the long term, we anticipate that approximately one third of the barrel hadron calorimeter will be constructed by this US collaboration. At ANL, our ultimate intent is to provide a nucleus for the eventual construction responsibilities much in the spirit of the ZEUS collaboration, whereby module components and submodules will be produced at the collaborating institutions in the US with coordination, final assembly and shipping being handled by ANL staff. The actual division of effort among the present intended collaborating US institutions is still in the process of being discussed and will be developed in the course of time.

The ATLAS Computing group has shown considerable interest in the work of the PASS collaboration, which has been developing a database approach to data storage and access for SSC/LHC experiments and potentially other large, data-intensive scientific projects. The ATLAS collaboration and people interested in computing for the LHC, in general, are just now beginning to investigate the object oriented approaches to data management that PASS has pioneered. Argonne and the rest of PASS has begun working with the new Moose (RD41) collaboration at LHC on these topics.

b. Barrel Hadron Calorimeter Design

As part of our initial efforts to familiarize ourselves with the ATLAS calorimeter mechanical design, we undertook a thorough examination of their concept as it stood in January of this year. As a first step, six finite element calculations were carried out using different levels of approximation for the calorimeter structure to compute deflections and stresses within it and the tie bolts used at that time to compress the stack. The details of these calculations are documented in an internal ATLAS note (TILECAL-NO-013). Our conclusion is that, in the original CERN design concept in which 22 tie bolts running the full 6 meter length of the central barrel are used to compress the stack, the combined stress on the bolts from compression, bending and tensile load is acceptable if high strength steel is used. The engineers at ANL, however, felt that the safety margins were unacceptably low and, therefore, proposed a variant on the CERN design in which the 6 meter structure is comprised of six independent submodules. For this design [Figure 25,26] the combined stress would be more than a factor of 10 below the yield values of conventional steel. In the ANL design, the submodules are held by 44 straps of approximately $25 \times 3\text{mm}^2$. The simple increase in load bearing area immediately alleviates the stress problem. In addition, these straps run through only the steel structure and, therefore, in this design there is no requirement for holes in the scintillator for mechanical support structures. We, therefore, also proposed to run the tubes for radioactive source calibration in the same region and thereby remove entirely the need for holes in the scintillator tiles. This analysis and design was proposed to the ATLAS group in April and the ensuing discussion resulted in a series of questions to be answered by the next meeting (held in June). These concerned the precision with which all boundaries and slots could be cut; the mechanism by which the straps would be tensioned and fastened; a review of the stresses in the straps; the resolution of a concern that the welding used to attach spacer plates to the full length master plates would result in unacceptable distortion; and, finally, a conceptual fabrication and assembly scheme with an associated cost estimate.

These issues were studied in the period from May to June and most questions were answered to an acceptable level. By the close of the June meeting, the concept of using rigid submodules of approximately 1m in length which are then assembled into the full length barrel module was unanimously adopted as the baseline for the calorimeter. The outstanding questions concerning the Argonne implementation of this concept still lay with issues on welding (both straps and spacers), tolerances and cost. Several tests currently in progress by the group will determine the viability of

Figure 25: Schematic assembly of a 6 meter long barrel module.

our concept to meet the ATLAS specifications. The first of these is a test of the strap welding with the strap under tension and the stack under compression, using a fixture designed and fabricated in collaboration with the University of Chicago. The second is the fabrication of a 25cm deep stack to test many of the details of the fabrication approach we are proposing. This test piece will be directly compared to an analogous test module being constructed at CERN using their preferred approach of gluing the steel structure together. Finally, we are proposing to build a 1m prototype stack in FY95.

c. Scintillator Readout Design Tests

In this period the Argonne group has carried out several types of measurements on the ATLAS readout scheme both to better understand its operation and in response to requests from the ATLAS hadron calorimeter group. Essentially all of these measurements have used the collimated ruthenium source developed for testing the fiber readout of tiles for the SDC. Our first concern was the uniformity of the injection molded ATLAS tile. We, therefore, compared the response from the ATLAS tile with that from a similar tile machined from commercial cast scintillator plate and also studied the effect of the edge geometry and masking on the uniformity. These data are shown in Figure 27, where the difference in quality between injection molded and cast scintillator is all too evident. These results have been documented in an internal ATLAS note [TILECAL-NO-010]. A test tile using a concave edge against which to locate the readout fiber was also tested and shown to have poorer response than a straight perpendicular cut. We conclude that a simple perpendicular machined edge results in a more uniform response than that obtained from the original ATLAS concept in which the readout fiber fits into a groove molded directly into the tile. After several groups in Europe duplicated this result it was finally accepted by the hadron calorimeter group

Figure 26: Sketch of a 1m module, split so as to show the strap positions.

Figure 27: A comparison of the tile uniformity for cast and injection molded scintillator tiles relative to the best uniformity achieved for an injection molded tile using a perpendicular edge and optimised masking.

and is now the baseline concept.

While carrying out these tests we observed what was thought to be Cerenkov light when the source passed over the readout fibers. Therefore, at the request of the CERN group we carried out a systematic study of fibers, provided by them, containing differing amounts of UV quenching additives. The response for a typical set of fibers is shown in Figure 28 for the case of the readout fiber being scanned directly by the ruthenium source. We also measured the coupling of each fiber to a standard scintillator tile to allow an estimate of the relative importance of any Cerenkov light. In total 14 fibers from two manufacturers were tested and we concluded that three of the fibers obtained from Bicron Corporation showed promising characteristics.

In addition to the above tests, two other studies on the optics and calibration system are in progress. The first of these is an evaluation of the source calibration system to determine if our proposed modification to the ATLAS concept will yield acceptable precision. We are also embarking on a program of mapping the tile response over the full tile surface area for several sizes of tile. These data too have important ramifications for the ATLAS calibration concept as early data indicate a significant non-uniformity in tile response in the immediate vicinity of the hole through which the source tube passes. In addition, they may be relevant to accurate modeling of the calorimeter response measured in the CERN testbeams and we hope to combine all of these results with the testbeam data to be taken this summer.

d. Second Level Trigger

Considerable interest has been expressed within the Argonne group and by our US collaborators to participate in the trigger hardware design and development. In this reporting period the bulk of the work has been targeted at fact finding and, to this end, we have participated in several ATLAS trigger meetings. In the near future we anticipate establishment of the necessary Monte Carlo codes, which will then allow a more active contribution to the trigger design. At present, the particular Argonne interest tends towards issues associated with the hadron calorimeter (jet and missing energy triggers at Level 2). However, this does not preclude us from eventually contributing in other areas.

(J. Proudfoot)

Figure 28: Cerenkov light response of four fibers with differing levels of UV quenching agent.

I.C EXPERIMENTS IN CLOSEOUT PHASE

I.C.1 SDC Detector Research & Development

a. SDC Barrel Calorimeter Design

Work on the SDC Barrel EM Calorimeter during this period was confined to closeout activities and is described in the section covering the Mechanical Support Group work.

b. SDC Data Systems R&D and the PASS project

Two HEP physicists (L. Price and E. May) who had participated in activities associated with the SDC computing working group closed out this activity based on the demise of the SSCL.

Price and May, along with a computer scientist (D. Malon) from DIS division, continued to work on the "Petabyte And Storage Solutions" (PASS) project. This R&D project is supported by the High Performance Computing and Communication (HPCC) initiative and the High Energy Physics Division at Argonne. It has the goal of studying the use of database technologies for the storage of and access to scientific data on the scale of a few petabytes (10^{15} bytes). Future HEP experiments will collect data at the rate of 1 petabyte per year; new advanced technology (both hardware and software) is required to provide the access to this quantity of data in a fast and efficient manner for a world-wide HEP environment. This work is being done in collaboration with the University of Illinois at Chicago (UIC), University of Maryland, Lawrence Berkeley Laboratory (LBL) and the SSC Laboratory. We note that although we report on PASS here together with SDC close out work, we expect funding from the DOE office of Scientific Computing to continue, so that this high performance computing work will not end with the demise of the SSC. We describe briefly some PASS activities in which ANL staff had the principal role or made important contributions.

The final draft of the "PASS Project Architectural Model" was completed and issued as a PASS report. It reports in some detail the PASS scheme to design and implement a HEP data storage and access system based on standards developed within the Object Management Group (OMG) and the Object Database Management Group (ODMG).

The results of the tests conducted last fall with the PASS prototype data access system based on ANL extensions to the UIC PTool code at ANL and SSCL on Sun workstations and servers was analyzed and written up. A talk and a paper were presented at the conference "Computing in High Energy Physics" (CHEP94). The results of tests, on the ANL/IBM SP1 parallel computer, of a distributed data access model were written up; a talk and a paper were presented at the CHEP94 conference. A total of 5 presentations were made at the CHEP94 conference by people in the PASS collaboration. Good contacts were made with groups at CERN (MOOSE, P55, DD division) concerning the transfer of the focus of the PASS work from the SSCL/SDC to the LHC program.

The I/O and data storage system associated with the ANL/IBM SP1 parallel computer were made available to PASS as early users. This consists of 8 I/O server machines connected by 32 fast FiberChannel links to the 128 node SP1 and attached via a HIPPI channel to a 220GB RAID disk system and a 6 Tbyte 3 headed DD2 tape robot. An NSL unitree data management system provides a software interface to this hierarchical storage hardware environment. We have extended the ANL version of the PASS data access model based on the UIC PTool system to work in this "state-of-the-art" I/O and storage system, both at the raw device access level to the RAID and TAPE system and at the NSL unitree level which implements an IEEE version 4 Mass Storage

model. Substantial effort was made in the configuration and debugging of both our software and the IBM hardware, requiring a great deal of interaction with ANL/MCS and IBM personnel. We have conducted tests and demonstrations on the 7GB CDF data sample with the ANL/PTool which achieves single channel access rates of 22MB/sec sustained. When the final hardware and software configuration is available this summer we will study the potential for parallel access via the 8 servers into the SP1 as query clients. Theoretically the ip based access methods should provide an aggregate performance of at least 88 MB/sec throughput.

We have started a cooperative project with a group from the Fermilab Computing Division: "High Performance Parallel Computing" HPPC and "Computing and Analysis for Physics" CAP. They have met several times with ANL and UIC to discuss the use of the ANL/UIC code system as applied to a demonstration project to study the use of a 24 node IBM SP1 and NSL unitree system for DST analysis of D0 data. A joint working group of Fermilab, UIC and ANL people performed a demonstration using 1 GB of D0 data. This was sufficiently encouraging for the Fermilab people to abandon the existing relational model for an object-oriented data model based on PTool and P4, and to prepare a "serious" test based on 40 GBytes. This work is in progress with a target date of the summer for performance tests. Ultimately, a system is envisioned which has 50-100GB of D0 DST data on disk with several terabytes in the Unitree robot system.

A presentation was prepared and was given to the DOE Office of Scientific Computing, who conducted a review of the PASS program as part of our request for continuing support.

(E. May)

II THEORETICAL PHYSICS PROGRAM

II.A THEORY

II.A.1 Strong Interaction Asymmetries in the Production of B Mesons

Interest in the possibility of studying CP noninvariance in the decays of B mesons produced in hadron collisions motivated Ed Berger to examine in some detail $B/\bar{B}$ asymmetries expected purely from strong interaction production dynamics. There are two sources: $b/\bar{b}$ quark/antiquark asymmetries predicted from interference effects in next-to-leading order quantum chromodynamic (QCD) hard scattering, and $B/\bar{B}$ meson/antimeson asymmetries produced through final state strong interactions even in the absence of $b/\bar{b}$ quark/antiquark asymmetries. The latter are referred to sometimes as "leading particle effects". Berger investigated both mechanisms during the past spring and summarized some of his results in the invited review of the theory of heavy quark production he presented at Beauty '94, the 2nd International Workshop on B Physics at Hadron Machines, Mont Saint Michel, France, in April, 1994, ANL-HEP-CP-94-26. The calculations of $b/\bar{b}$ asymmetries from interference effects in QCD hard scattering were done in collaboration with Ruibin Meng (University of Kansas) and are reported in ANL-HEP-PR-94-30. Berger and Meng provide explicit calculations of the expected magnitude and longitudinal momentum dependence of $b/\bar{b}$ quark/antiquark asymmetries in $\bar{p}p$ and π^-p reactions at fixed target and collider energies. Berger's presentation of strong interaction asymmetries motivated a great deal of discussion during the Mont Saint Michel workshop. Production asymmetries in the neutral B meson system may constitute an advantage in the search for CP asymmetries, if exploited properly. When there is a production asymmetry, A_p , a CP asymmetry proportional to A_p may be observed in transitions of neutral B mesons into a CP eigenstate, even without independent flavor tagging. To be sure, the quantity A_p itself must be measured in the same experiment in neutral B decay channels for which no CP violation can occur.

(E. Berger)

II.A.2 The Dilepton-Production Cross Section in Principal-Value Resummation

The Drell-Yan process of dilepton production in hadronic collisions via an electroweak vector boson has been an area of intense theoretical and experimental activity for the last 20 years. Theoretically, the process is a veritable "laboratory" for testing QCD, in both its perturbative and non-perturbative aspects. Early one-loop calculations had shown that the perturbative QCD (pQCD) corrections to the process are numerically large, in essence invalidating the reliability of finite-order pQCD. Arguments for resummation of *all* large perturbative corrections would be needed before one is able to compare perturbative calculations with experiment. In fact, without resummation, *any* agreement of finite-order calculations with experiment can be viewed as a mere accident, given that the apparent divergence of the series seems to persist in more recently calculated terms, as 2-loop corrections show. Furthermore, due to renormalon singularities, the series should not be considered convergent, but asymptotic at best, although the latter statement has had so far a rather vague meaning in the literature. This property suggested an equally vague connection to the QCD's non-perturbative aspect, the interface with the perturbative "asymptotic" one being determined by the phase space for a given process.

A resummation method exhibiting all these properties and called "Principal-Value Resummation" has been advanced by Harry Contopanagos and George Sterman (Stony Brook), Nucl. Phys. B419 (1994) 77. The method is quite general and applies to various hard-scattering reactions having the aforementioned problems. In a recent article (ANL-HEP-PR-94-25; ITP-SB-94-33; to be published in Nucl. Phys. B) Contopanagos and Lyndon Alvero (Stony Brook), applied this resummation method to the Drell-Yan process specifically, including all large threshold corrections. They also studied analytically and numerically the perturbative and non-perturbative aspects of the resummation for the Drell-Yan "hard part", which is the quantity calculable in pQCD, as a function of parton phase space. They recovered a *precisely defined, exponentiated* asymptotic perturbative series, in the perturbative domain of the process, as well as a higher-twist quantity in the non-perturbative one. Finally, they computed analytically and numerically the hard scattering part of the process. In contrast to finite-order calculations, the resulting cross section and its various differential distributions, are bounded functions of all kinematic variables, at large dilepton mass values. In another article, in preparation, Contopanagos and Alvero are using these results to make predictions and comparisons for the dilepton production cross section at various experimental settings, at fixed-target and collider energies and both for the physical continuum and the Z-resonance. Preliminary results show that the agreement between resummed predictions and experiment is excellent.

(H. Contopanagos)

II.A.3 The Paradigm of Pseudodual Chiral Models

Dual and Pseudodual Chiral Models (PCM) have recently become central in varied Field Theoretic and String contexts. The later type actually possess an infinite number of nonlocal conservation laws *but also* allow particle production, at variance with naive expectations—a folk theorem of integrable models, as pointed out in the construction of these laws, Phys.Rev. D49 5408 (1994), by C. Zachos and T. Curtright (Univ. of Miami). Continuing their project, the authors further explored the remarkable structure of these models [ANL-HEP-CP-94-33], and the first one reported on progress in the PASCOS '94 Conference.

The new results concern, firstly, the explicit nonlocal solution for the dualized field in the nonabelian *canonical transformation* invented, which connects the usual Chiral Model to its fully *equivalent Dual σ -Model*. The string community is gearing up only now to attack this problem, initially through free-field warm-up canonical transformations; whereas a complete, explicit, non-abelian transformation is already available for the Chiral case in print (reference above).

The second and third results are technical items to be added to the calculational toolbox of field theories of this type, possibly of use in future applications.

The second result is the observation that the PCM, with a constant torsion term in the lagrangean, in fact amounts to a delicate Wigner-Inönü contraction of the target manifold in the WZW model in which the "pion decay constant" (the radius of the target hypersphere) is taken to infinity in tandem with the WZW topological integer coupling. In consequence, the connections among the Chiral Model, the Dual Sigma Model, the Pseudodual Chiral Model and the WZW

model are summarized in the diagram:

Finally, the one-loop β -function for the PCM, first computed by Nappi, now follows virtually by inspection (to the expert) from the general analysis of renormalization of models with torsion by Braaten, Curtright, and Zachos, Nucl.Phys. **B260** 630 (1985). Introducing a (field-scale) coupling η in the relative normalization of the interaction term, the complete triviality of the metric is noted, $g_{ab} = \delta^{ab}$; the torsion $S_{abc} = \eta f_{abc} \sqrt{g}$ of the interaction term has now collapsed to a constant, merely the structure constant times the coupling, $S_{abc} = \eta f_{abc} = \eta \partial_{[a} e_{bc]}$, for torsion potential $e_{ab} = \eta f_{abc} \phi^c$. But, to one loop, BCZ have established that e_{ab} evolves by the antisymmetric part of the generalized Ricci tensor, vanishing in this case of constant torsion, so e_{ab} does not renormalize. In contrast, $M \frac{d}{dM} g_{ab} = -S_{acd} S_b{}^{cd} / 2\pi = -\eta^2 f_{acd} f_b{}^{cd} / 2\pi = -\eta^2 \delta_{ab} C / 2\pi$, where C is the quadratic adjoint index, e.g. $N - 2$ for $O(N)$. Rescaling the kinetic term to canonical normalization amounts to simply *increasing* the interaction coupling as

$$M \frac{d\eta}{dM} = \frac{3\eta}{2} \frac{C\eta^2}{2\pi} = \frac{3}{4\pi} \eta^3 C.$$

The PCM is thus anti-asymptotically free, in contrast to the Chiral Model.

(C. Zachos)

II.A.4 Sum Rules and Factorization in Compton Processes

The study of exclusive photon-hadron collisions at intermediate energy has been at the center of the research interests of Claudio Corianò and Hsiang-nan Li (Academia Sinica, Taiwan). These reactions are among the most interesting to identify the transition region of the strong interactions from their non-perturbative domain to the perturbative one. There is an unsettled controversy among the experts in this field over whether the concept of hadronic wave functions is meaningful in the description of these reactions at moderate energy. An alternative approach relies on the use of dispersion relations as a way to connect the order parameters of the QCD vacuum to the perturbative region using the concept of Local Duality. The method is best known as QCD Sum Rules. In ANL-HEP-PR-94-19 Corianò and Li have discussed the role of factorization in hadronic collisions by comparing modified factorization theorems to QCD Sum Rules. In their work they have shown that there is an overlap of predictions between the two descriptions, which can possibly clarify the behavior of elastic processes in the non-perturbative domain. Such overlap appears to be at 4 GeV^2 in simple Compton processes and is characterized by a remarkable angular dependence. The sum rule prediction is in agreement with the data.

In ANL-HEP-PR-94-18 Corianò has discussed the role of the radiative corrections to hadronic spectral densities as a way to describe the phases of $\gamma \gamma$ collisions, which are of non-perturbative origin at $4-5 \text{ GeV}^2$, and he presented new methods for the evaluation of such contributions. He has shown that the perturbative hadronic spectral densities involved in these reactions have special properties of analyticity which can be analyzed optimally by light-cone methods.

(C. Corianò)

II.A.5 Higher-Order Lipatov Kernels

Currently there is much excitement about the small- x behavior of structure functions and it seems that the "Lipatov Pomeron" may have been seen at HERA. Alan White has recently developed a new technique for constructing higher-order corrections to the Lipatov Pomeron.

The Lipatov equation was originally derived from extensive leading and next-to-leading log calculations in the Regge limit of (massive) Yang-Mills theories and is applied as an evolution equation for parton distributions at small- x . To obtain non-leading corrections to the $O(g^2)$ kernel, it appears that (very complicated) non-leading log Regge limit calculations are required.

The complete set of reggeon diagrams should determine (and be determined by) all Regge limit logs and it might be hoped that these diagrams could be constructed directly from reggeon unitarity. At first sight this looks impossible, firstly because of singular reggeon interactions due to gluon poles and secondly because of undetermined parameters in higher-order reggeon interactions. In a recent Argonne preprint ANL-HEP-PR-94-23 (to be published in Physics Letters B) White has shown that the first problem is resolved by the construction of reggeon loops via multiple discontinuities (this involves no singular interactions) and the second problem is resolved for Yang-Mills theories by the imposition of Ward identity constraints directly on reggeon amplitudes. The result is a powerful new technique for constructing reggeon diagrams (and thus higher-order Lipatov kernels) without going through very complicated underlying Feynman diagram calculations.

The method is first illustrated via a derivation of the Lipatov equation directly from reggeon diagrams. New two-two, one-three and two-four $O(g^4)$ reggeon kernels are then presented explicitly.

(A. White)

II.A.6 Inclusive Heavy Quark Production at Hadron Collider Energies

Heavy flavor production has been of interest because of the theoretical issues it raises in the theory of strong interactions and because of the discovery potential it presents, notably in studies of CP noninvariance in the bottom sector. At energies relevant for future hadron colliders, calculations of cross sections for heavy flavor production may assist in the design of experiments and in the evaluation of the merits of various options, such as the use of a supercollider in a fixed target mode. In Argonne report ANL-HEP-CP-94-26, to be published in the Proceedings of the Mont Saint Michel Workshop on B Physics at Hadron Machines, Ed Berger presents calculations valid to next-to-leading order in QCD perturbation theory for inclusive single quark differential cross sections and two-particle quark-antiquark inclusive cross sections (correlations) for $b\bar{b}$ production in high energy hadronic interactions at fixed target and collider energies. Comparisons are made with available data, and uncertainties in the theoretical results are summarized. Expectations are provided for the energies of the LHC collider and fixed target options, along with simple parametrizations of calculated cross sections. Berger also reviewed the status of current work on J/ψ production at collider energies.

(E. Berger)

II.A.7 Finite Temperature QED

The equations of state of QED and QCD at nonzero temperature are important in several astrophysical contexts. In the QED case, the equation of state was obtained by Akhiezer and Peletminskii to the third order (e^3) more than three decades ago and, since then, little progress has been made in the calculation of the higher order corrections. Great technical difficulty had discouraged various experts in the field from considering the evaluation of the e^4 correction. For phenomenological reasons it is helpful to know how big corrections to the lowest order result can be. Secondly, the calculation serves as a prototype to illustrate techniques which may be used to perform similar calculations in QCD. In QCD asymptotic freedom suggests that at high temperature and/or density hadronic matter will transform into a weakly interacting quark-gluon plasma, a novel state of matter that is currently under intense study. Rajesh Parwani(Saclay) and Claudio Corianò have developed new methods to analyze these higher order corrections and, in particular, to handle the infrared divergences at finite temperature. They have presented in two papers the evaluation of the e^4 and e^5 corrections to the equation of state of QED at high temperature (ANL-HEP-PR-94-02, ANL-HEP-PR-94-32).

(C. Corianò)

II.A.8 Decay and Production of Heavy Quarkonium

G. Bodwin, E. Braaten (Northwestern), and G.P. Lepage (Cornell) have completed a paper (ANL-HEP-PR-94-24) that describes in detail their new formalism for treating inclusive decays and production of heavy quarkonium and lays the groundwork for future calculations based on that formalism. (See the July 1, 1993–December 30, 1993 report for a detailed description of this paper.)

(G. Bodwin)

II.A.9 Lattice Measurement of Matrix Elements for Decays of Heavy Quarkonium

G. Bodwin, D. Sinclair, and S. Kim are currently involved in a project to measure on the lattice the nonperturbative operator matrix elements that appear in the Bodwin-Braaten-Lepage formalism in the decays of S-wave and P-wave charmonium and bottomonium systems. The numerical simulations are described in the Computational Physics section of this report.

One new area of investigation is the measurement of operators that appear in the order v^2 corrections to the decays of S-wave states. It is necessary to include such order v^2 corrections in the theoretical calculations in order to make a comparison, at the current level of experimental precision, with the data for the charmonium system. Because the order v^2 operators mix under renormalization with the order v^0 operators, which have much larger matrix elements, it is expected that important corrections will appear when one relates the lattice matrix elements to the continuum ($\overline{MS}$) matrix elements. A project to compute these corrections in one-loop order is underway.

(G. Bodwin)

Figure 29: Octet matrix element for h_b and χ_b decays into light hadrons from lattice calculations.

II.B COMPUTATIONAL PHYSICS

The computational physics effort is devoted to numerical simulations of lattice quantum field theories, particularly of lattice quantum chromodynamics (QCD). The lattice provides the needed ultraviolet regulation of the theory and allows numerical simulations which are the only reliable way of calculating non-perturbative results from QCD. In particular lattice QCD enables one to calculate the hadron masses and the strong interaction contributions to low energy matrix elements, and to study QCD thermodynamics. These latter studies are relevant to relativistic heavy ion collisions (RHIC), the nature of the early universe, and the interior of neutron stars. The matrix element calculations enable predictions of hadronic decay rates and the extraction of parameters of the weak and electromagnetic part of the standard model from experimentally measured decay rates.

In collaboration with G. T. Bodwin of the theory group, we have been attempting to calculate the matrix elements which describe the decays of the charmonium and upsilon states. For this we have been using gauge field configurations generated on a $16^3 \times 32$ lattice at $g^2 = 1$, neglecting the effects of light quarks. The CRAY C-90 computer at NERSC was used for the generation. The matrix elements have been calculated in the non-relativistic approximation. In this time period we have extracted 4 matrix elements for the decays of the lowest mass S- and P-wave states in the upsilon system ($\eta_b, \Upsilon, h_b, \chi_b$). Two of these enable us to check the vacuum saturation approximation which relates them to the wave function or its derivative at the origin. Our measurements show that this approximation is even better than expected. The third matrix element, which contributes to the P-wave decay, involves the exchange of a gluon, and can only be obtained from the lattice. We predict a value which is smaller than expected. Thus, it will be interesting to see the measurement that comes from future experiments. The final matrix element is a higher order correction to S-wave decay. While the value of this matrix element has been determined very accurately, we have yet to calculate the perturbative subtraction needed to compare it with experiment. We are now extending these calculations to the charmonium system.

In collaboration with J. B. Kogut and M.-P. Lombardo (University of Illinois), we have

been studying lattice QCD at finite baryon number density (nuclear matter) in the quenched approximation on a $16^3 \times 32$ lattice using the CRAY C-90 at NERSC. Here we have been trying to determine whether the chiral phase transition from nuclear matter to a quark-gluon plasma occurs at the physical value of $\mu = m_N/3$ (μ is the quark number chemical potential) or the anomalous value of $\mu = m_\pi/2$. If the first is true, the quenched model is useful for such studies, whereas, if the second is true, the quenched theory is unphysical for finite baryon number density. We have now extended our earlier calculations of the hadron spectrum and chiral condensate into the region $m_\pi/2 < \mu < m_N/3$. While there is some indication of changes which could indicate the restoration of chiral symmetry, the results are, as yet, far from decisive. We will soon be extending our work to study full QCD at both finite temperature and finite density using the CRAY T3D at PSC.

Our calculations of the spectrum of light hadrons in quenched QCD on a $32^3 \times 64$ lattice at lattice spacing $\sim 0.1\text{fm}$ have continued through this period on the Intel Touchstone Delta and Paragon computers at Caltech. We have also been using a smaller Paragon (also at Caltech) to study finite size effects using a $16^3 \times 64$ lattice. These calculations are now shedding new light on the chiral structure of the quenched theory.

The simulations of finite temperature QCD with 2 light flavors of dynamical quarks, which we had been performing as part of the HTMCGC collaboration, were completed in May with the departure of the CM-2 at PSC. We are now analysing the "data" obtained from this run. The transition from hadronic matter to a quark-gluon plasma is observed at $6/g^2 = 5.48(2)$, which on this $16^3 \times 8$ lattice, corresponds to a temperature of approximately 150 MeV. Just above this transition we find that the quark sea has roughly 25% strange quarks. Other properties of the quark-gluon plasma are being extracted from the data.

S. Kim has been involved, with S. Ohta of the Riken Institute in Japan, in setting up to perform a calculation of the spectrum of light hadrons in quenched QCD on a $48^3 \times 70$ lattice. This calculation is to be performed on the new, parallel, Fujitsu VPP-500 at Riken.

S. Kim has also collaborated with J. B. Kogut and others to study a theory with 4-fermi couplings on the lattice, and the behaviour of the chiral transition in this theory with and without a chemical potential, μ , for fermion number. With a chemical potential, the transition occurs at $\mu = \text{fermion mass}$ as expected. The scaling properties of the theory close to this transition have been determined, leading to an equation of state for the system.

(D. Sinclair, S. Kim)

III ACCELERATOR RESEARCH & DEVELOPMENT PROGRAM

III.A Argonne Wakefield Accelerator Program

III.A.1 Accelerator R & D

Things are becoming increasingly exciting in the Argonne Wakefield Accelerator (AWA) project as equipment we have been building begins to be tested in preparation for full-fledged beam commissioning. Not unexpectedly, a few glitches turned up which must be corrected. But in general, AWA apparatus is working as designed, and we anticipate exciting and rewarding times ahead.

III.A.2 Commissioning Approval

A major step for the AWA was accomplished when the DOE granted permission to initiate commissioning of the AWA facility. Approval was based upon determination that the risks as analyzed in the AWA Phase-I Safety Analysis Document (SAD) are acceptable when operated within the machine's approved Accelerator Safety Envelope, that an Accelerator Readiness Review (ARR) of appropriate scope and depth was conducted, that approved testing procedures have been developed, and that all issues from the ARR were addressed.

III.A.3 AWA Facility Status

RF: The 30 MW, 1.3 GHz rf power supply is now operational with the completion of the low level systems and installation of the complex wave guide plumbing on top of the shield vault. A number of wave guide joints were found to be defective in the course of rf tests. This was traced to an error by the manufacturer of the power splitters who installed incorrect gaskets, causing poor rf contact between flanges. This problem was corrected by substituting indium seals for the elastomer seals. There would have been an unacceptably long delay in obtaining OEM replacements.

Laser: Streak camera facilitated measurements verified synchronization of the laser pulses and rf power delivered to the AWA electron gun and accelerating cavities. The laser system is now ready for use to produce photoelectrons in the high gradient gun.

Vacuum: A very complicated leak delayed rf commissioning of the photocathode based gun for three weeks. Vacuum in the AWA is now in the low 10^{-7} Torr range (good enough to begin rf conditioning) and is steadily improving. Surface cleanup during rf conditioning can be expected.

Test Gun: The multi-celled witness gun will be shipped to a west coast fabricator for brazing very soon. Final machining of the wave guide-to-cavity coupling cell remains to be done at this time.

III.A.4 AWA Experiment Preparations

One of the first experiments to be done with the AWA is a plasma based experiment by UCLA collaborators. It is a very natural follow up to earlier experiments performed at the AATF facility at lower beam intensities. The new experiments will study wakefield effects in what is frequently referred to as the "blow out" regime. That describes the situation in which the driving electron beam is of sufficient intensity that plasma electrons are essentially displaced from the volume of the drive beam. As these electrons return they produce extremely large accelerating fields which should have desirable focusing properties.

A plasma source of appropriate density has been fabricated and is operating reliably. Beam line components, including a special focusing solenoid to create the very high drive beam density for the experiment are ready for installation in the business end of the AWA.

A spectrometer magnet is positioned in the facility as part of the initial start-up configuration. It, together with emittance measuring apparatus, will be used to diagnose the beams during commissioning.

III.A.5 Workshop on Advanced Accelerator Concepts

The AWA Group hosted the 6th Workshop on Advanced Accelerator Concepts at The Abbey on Lake Geneva, Wisconsin, June 12-18, 1994. The workshop was sponsored primarily by the DOE, with additional support from ANL and from the University of Chicago Board of Governors for ANL. Workshop attendance was by invitation only and was limited to about 140 persons. Participants included representatives from FSU countries, France, Germany, China, and Japan. Approximately 25 students were among those attending.

Two new items were introduced in the workshop arrangements: (1) high speed computer hookups for use by workshop attendees and (2) electronic publishing of workshop proceedings. It is almost certain that these will become the norm for future workshops in this series.

(J. Simpson)

III.B High Resolution Profile Monitor Development

Following the request by the SLAC Experimental Program Advisory Committee that we should make a test of our high resolution profile monitor experiment somewhere before we run on the SLAC Final Focus Test Beam (FFTB), we have been trying to develop and run such a test experiment. Since the diagnostic systems have been designed to reject low energy photons, it is desirable to operate the test in a linac with beams of more than 500 MeV. After visiting CEBAF and Bates, and talking to SLAC test beam users, we concluded that the most desirable place to run is at Bates. The 14° test beam there can provide the necessary space and beams of a wide range of energies and intensities. Unfortunately, this beam has been unavailable due to problems with the accelerator.

During this time, calculations for beam profile measurements using secondary photon emission (beamstrahlung or synchrotron radiation) have been refined and been sent to SLAC. Measuring the beamstrahlung or electron angular distribution downstream of the Interaction Point should be a completely passive and highly useful method of measuring the parameters of flat beams at SLC.

A modification of this system using foils has been considered for the FFTB, but seems to be less useful than the SLC measurement.

While waiting for beam time at Bates there has been some continuing effort on plasma lens development. Recently Rajagopalan, Cline, and Chen have proposed using a plasma lens as a sweeping magnet to remove electrons from the photon beam in a photon-photon collider. Such a plasma lens, combined with technology being tested at SLAC to develop high intensity backscattered photon beams would permit operation of a linear collider in a mode producing high luminosity $e\gamma$ or $\gamma\gamma$ collisions in addition to e^+e^- collisions. We have studied the properties of such a plasma lens and possible production methods. The plasma lens in such a collider must have very sharp boundaries or it will defocus the electron beam before it is converted to photons reducing the luminosity. The required gas density gradient is roughly a factor of 1000 in 1-2mm. We have been exploring methods of producing plasmas with sharp boundaries by means of laser pellet ablation, in which a solid hydrogen pellet is hit with an intense laser pulse, the pellet is ionized, and a supersonic expansion of the pellet material is produced. This method is very efficient, producing high density plasmas with little pumped gas.

(J. Norem)

IV DIVISIONAL SUPPORT FACILITIES

IV.A Mechanical Support Group

During this report period the efforts of the Mechanical Support Group were concentrated on two major projects: the closeout activities for the SDC detector and the continued work on the STAR EM Calorimeter. Work was also started on the Tile-Cal Hadronic Calorimeter for ATLAS in response to requests from the ATLAS collaboration. The details of these efforts are described below. Details of other work performed by the Mechanical Support Group can be found in the sections of this report devoted to those experiments.

SDC Closeout

With the receipt of funds from the SSC Laboratory, we were able to resurrect the equipment built prior to the stop work order in 1993. A contract was let to Westinghouse Science and Technology Center (WSTC) for casting the full size lead EM calorimeter. Westinghouse responsibility includes the commissioning of the furnace used for casting at Taracorp, a lead casting foundry in Granite City, Illinois, and completing the mold components. This contract also includes the necessary WSTC engineering to complete one barrel EMC casting. The additional parts that remained the responsibility of ANL were started with the goal of finishing the casting in early September. The final report of the work completed prior to the stop work order in October, 1993 was compiled and sent to the SSC Laboratory on April 1, 1994. This work was also contracted with Argonne in late 1993 as part of the SDC closeout.

STAR EM Calorimeter

Work on STAR was concentrated on the design of the support structure for the calorimeter and some of the structural analysis associated with this design. The primary responsibility for this work was transferred from the Engineering Physics Division to the High Energy Physics Division during this period. The use of EP engineers was necessitated by the work load for the HEP engineering and support staff at the end of calendar year 1993.

ATLAS Tile-Cal Hadron Calorimeter

A new task was assumed early in 1994 as a result of the formation of a US collaboration to assist in the design and construction of a hadron calorimeter for the ATLAS Detector at the LHC at CERN. The initial work was primarily a review of work already completed in Europe and some analysis of the existing design concept. In the month of June a new design concept was proposed to the ATLAS collaboration at the ATLAS week meeting.

ZEUS Experiment

During this period, final work was completed on the prototype HES upgrade to the ZEUS EM Calorimeter. Test beam studies will be conducted on this prototype in the near future. The prototype module was shipped to Brookhaven National Laboratory in preparation for these tests.

(N. Hill)

IV.B Electronics Support Group

Work continued in support of the Nucleon Decay Experiment, Soudan 2. Our involvement during the period was one primarily of construction and maintenance. We modified 48 Analog Cards, repaired 2 Anode H. V. Distribution Boxes, repaired 4 Balka Boxes, modified a Veto Shield Interface Card, and made efforts toward being able to repair the Single Board Processors in the Multibus Crates. These processors are no longer supported by the manufacturer (Intel) and the number of functional spares has declined. Miscellaneous other pieces of electronic equipment were maintained as necessary. We spent some time working on the conceptual framework for triggering and data acquisition in the Long Baseline Detector.

Our major effort with regard to support of the ZEUS calorimeter has been the development of the first level calorimeter trigger processor (CFLTP) and the trigger for the Small Angle Rear Tracker (SRTD). The Zeus calorimeter first-level trigger processor presents summary data on energy deposition in the uranium/scintillator sampling calorimeter to the global first-level trigger (GFLT). The summary data includes global and regional sums of electromagnetic and hadronic energy deposition, the number of isolated muons and isolated electrons, missing transverse energy, jet cluster information, and the likelihood of beam-gas background. The CFLTP receives data from 16 regional trigger pre-processors which digitize the calorimeter signals and perform regional energy sums and logical operations. Design and construction of these regional pre-processors is the responsibility of our collaborators from Wisconsin.

During the period, our major effort for ZEUS was to redo the design of the SRTD trigger electronics. The trigger cards as designed for this system were extremely dense, and we found that it was impossible to have them fabricated. This redesign was completed in the period and card fabrication is proceeding. The system also includes a EVB/FLT card which will be in the Rucksack and will tie the trigger cards to the GFLT and the data acquisition. The EVB/FLT cards have already been produced.

During FY 1992 and FY 1993 we built and tested electronics for the CDF trigger upgrade. This is an effort to bring the preshower radiator and shower max detector wires into the trigger at the second level to improve the efficiency for b quark physics. We hope to have a part in the upgrade to 132ns operation in the areas of data acquisition from the shower max and preshower chambers and formulation of the trigger using shower max and tracking data. During the period the study continued of shower max noise problems associated with the upgrade VME readout scheme.

In the Star detector for RHIC, we hope to have a part in the development and production of electronics for the trigger and data acquisition relating to the Electromagnetic Calorimeter. During the period we built a number of prototype circuits for analog summing for the trigger. During the period we also built several small pieces of hardware for the Wakefield Accelerator Development project, the ANL Physics Division, and the Environmental Science Division.

(J. Dawson)

IV.C Computer Support Group

The major effort of the Computer Support Group has been directed toward installation of the new Divisional Local Area Network (LAN). The group helped coordinate the efforts of the Electronics, Computing and Telecommunications Division to install a hybrid cable hub network consisting of both copper twisted-pair and fiber which should satisfy the divisions needs for the next ten years. The group also acquired and tested a Cisco router which will link the new LAN to the lab-wide network.

Other equipment upgrades included two Postscript laser printers and several X-terminals. In addition, the group continued to install vendor supplied updates as well user contributed software such as CERNLIB and WWW client software on the SGI, DEC, Macintosh and personal computer platforms. The group also set up a World Wide Web server to provide information about the division's activities.

The group wrote software for the ZEUS Small Angle Rear Tracking Detector (SRTD) trigger electronics engineered by the Electronics Support Group. The software provides diagnostics for validating the operation of the cards, as well as performing online sampling of input to the SRTD trigger for monitoring the performance of the system.

(J. Schlereth)

V PUBLICATIONS

A. Journal Publications, Conference Proceedings, Books

A Separate Higgs

J. Hewett, T. Rizzo (ANL), V. Barger (U. of WI), N. Deshpande (U. of OR)
Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders
edited by J. Hewett, A. White, and D. Zeppenfeld, 437 (1994)

Currents, Charges, and Canonical Structure of Pseudodual Chiral Models

C. Zachos (ANL) and T. Curtright (U. of Miami)
Phys. Rev. D 49, 5408 (1994)

Deep Inelastic Scattering Results from the First Year of Hera Operation

S. Magill (ANL)
Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders
edited by J. Hewett, A. White, and D. Zeppenfeld, 167 (1994)

Extended Gauge Sectors at Linear Colliders

J. Hewett (ANL)
Workshop on Physics and Experiments with Linear Colliders, World Scientific,
edited by F. Harris, S. Olsen, S. Pakvasa, and X. Tata, (1994)

Extraction of Z' Coupling Data from $Z' \rightarrow jj$ at the LHC and SSC

T. Rizzo (ANL)
Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders
edited by J. Hewett, A. White, and D. Zeppenfeld, 555 (1994)

FNAL Polarized Beams and Spin Dependence at RHIC

A. Yokosawa (ANL)
Proceedings of the International Conference (Vth Blois Workshop) on Elastic and Diffractive Scattering, World Scientific, edited by H. Fried, K. Kang, and C. Tan, 404 (1994)

High Energy Asymptotics of Perturbative Multi-Color QCD

L. Lipatov (ANL)
Proceedings of the International Conference (Vth Blois Workshop) on Elastic and Diffractive Scattering, World Scientific, edited by H. Fried, K. Kang, and C. Tan, (1994)

High Energy Behavior of σ_{tot} , ρ , and B-Asymptotic Amplitude Analysis and a QCD-Inspired Analysis

A. White (ANL), M. Block, F. Halzen, R. Margolis
Proceedings of the International Conference (Vth Blois Workshop) on Elastic and Diffractive Scattering, World Scientific, edited by H. Fried, K. Kang, and C. Tan, 205 (1994)

Matrix Elements for the Decays of S- and P-Wave Quarkonium: an Exploratory Study

G. Bodwin, S. Kim, D. Sinclair (ANL)
Nucl. Phys. B 34 (Proc. Suppl.), 434 (1994)

Measurement of the B^+ and B^0 Meson Lifetimes

R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. Wicklund, (ANL) and the CDF Collaboration
Phys. Rev. Lett. V 72, 3456 (1994)

Model Dependence of W_R Searches at the Tevatron

T. Rizzo (ANL)

Phys. Rev. D 50, 325 (1994)

Monte Carlo Event Generators for Hadron-Hadron Collisions

I. Knowles (ANL), S. Protopopescu (BNL)

Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders
edited by J. Hewett, A. White, and D. Zeppenfeld, 651, (1994)

Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders

edited by J. Hewett, A. White, and D. Zeppenfeld (1994)

Progress in SSC Higgs Physics: Report of the Higgs Working Group

R. Blair, J. Hewett, L. Rizzo (ANL), J. Gunion (Davis Inst. for HEP), S. Geer (Fermilab)
and Working Groups

Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders
edited by J. Hewett, A. White, and D. Zeppenfeld, 335, (1994)

Quenched QCD Spectrum on a $32^3 \times 64$ Lattice

S. Kim and D. Sinclair (ANL)

Nucl. Phys. B 34 (Proc. Suppl.), 347 (1994)

Report of the Subgroup on the Top Quark

L. Nodulman (ANL), C. Yuan (Michigan State), *et al.*

Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders
edited by J. Hewett, A. White, and D. Zeppenfeld, 495, (1994)

Rescattering and Energy Loss of Fast Partons in Nuclear Matter

T. Fields (ANL), M. Corcoran (Rice U.)

HEP 93 Proceedings of the International Europhysics Conference on High Energy Physics
edited by J. Carr and M. Perrottet, 535 (1994)

Search for Excited Quarks in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. Wicklund,
(ANL) and the CDF Collaboration

Phys. Rev. Lett. V72, 3004 (1994)

Search for Top Quark Decaying to a Charged Higgs Boson in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. Blair, K. Byrum, T. Fuess, S. Kuhlmann, L. Nodulman, J. Proudfoot, D. Underwood,
R. Wagner, A. Wicklund, (ANL) and the CDF Collaboration

Phys. Rev. Lett. V72, 1977 (1994)

Status of Elastic Scattering: Total Cross Sections, Real Parts and $d\sigma/dt$

A. White (ANL) K. Kang, P. Valin

Proceedings of the International Conference (Vth Blois Workshop) on Elastic
and Diffractive Scattering, World Scientific, edited by H. Fried, K. Kang, and
C. Tan, 50 (1994)

Summary of the Extensions of the Standard Model Working Group

T. Rizzo (ANL) and S. Godfrey (Carleton U.)

Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders
edited by J. Hewett, A. White, and D. Zeppenfeld, 525 (1994)

The Pomeron and QCD with Many Light Quarks

A. White (ANL)

Proceedings of the International Conference (Vth Blois Workshop) on Elastic and Diffractive Scattering, World Scientific, edited by H. Fried, K. Kang, and C. Tan, 243 (1994)

Thermodynamic q-distributions that aren't

S. Vokos, C. Zachos (ANL)

Mod. Phys. Lett. A2, 1 (1994)

Transverse Momentum Distributions for Heavy Quark Pairs

E. Berger, R. Meng (ANL)

Phys. Rev. D49, 3348 (1994)

Using $b \rightarrow s\gamma$ to Probe Top Quark Couplings

J. Hewett and T. Rizzo (ANL)

Phys. Rev. D49, 319 (1994)

Using 'Invisible' Decay Modes as Probes of Z' Couplings

J. Hewett and T. Rizzo (ANL)

Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders edited by J. Hewett, A. White, and D. Zeppenfeld, 547 (1994)

Vector Leptoquark Production at Hadron Colliders

J. Hewett, T. Rizzo (ANL), S. Pakvasa (U. of HI), H. Haber, A. Pomarol (U. of CA)

Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders edited by J. Hewett, A. White, and D. Zeppenfeld, 539 (1994)

B. Papers Submitted for Publication

Principal Value Resummation

H. Contopanagos (ANL) and G. Sterman (SUNY)

ANL-HEP-PR-94-01

Submitted to Nucl. Phys. B

The Three Loop Equation of State of QED at High Temperature

C. Coriano (ANL) and R. Parwani (Saclay)

ANL-HEP-PR-94-02

Submitted to Phys. Rev. Lett.

A Possible Method to Produce a Polarized Antiproton Beam at Intermediate Energies

H. Spinka, J. Hoffman (ANL), E. Vaandering (ANL and Valparaiso U.)

ANL-HEP-PR-94-11

Submitted to Nuclear Instruments & Methods

Observation of Direct Processes in Photoproduction at HERA

M. Derrick, D. Krakauer, S. Magill, B. Musgrave, J. Repond, S. Repond, R. Stanek,

R. Talaga, J. Thron (ANL) and the ZEUS Collaboration

ANL-HEP-PR-94-14

Accepted for publication in Phys. Lett.

Dispersive Methods and QCD Sum Rules for $\gamma\gamma$ Collisions

C. Coriano (ANL)

ANL-HEP-PR-94-18

Submitted to Nucl. Phys. B

The Transition to Perturbative QCD in Compton Scattering
C. Coriano (ANL) and H. Li (Nat'l. Chung-Cheng U.)
ANL-HEP-PR-94-19
Submitted to Nucl. Phys. B

Looking for the Logarithm in Four-Dimensional Nambu-Jona-Lasinio Models
S. Kim (ANL), A. Kocic and J. Kogut (U. of IL-Urbana)
ANL-HEP-PR-94-20
Submitted to Nucl. Phys. A

The $O(g^4)$ Lipatov Kernels
A. White (ANL)
ANL-HEP-PR-94-23
Submitted to Phys. Lett

Non-Leading Logarithms in Principal Value Resummation
L. Alvero, H. Contopanagos (ANL)
ANL-HEP-PR-94-25
Submitted to Nucl. Phys. B

Plasma Lens Formation in $e\gamma$ and $\gamma\gamma$ Colliders
J. Norem (ANL)
ANL-HEP-PR-94-36
Submitted to Nuclear Instruments and Methods

C. Papers or Abstracts Contributed to Conferences

Neutron Fluence Calculations for the SC Detector and the Results of Codes and Comparison
P. Job (ANL), T. Gabriel *et al.*
ANL-HEP-CP-94-08
Submitted to the Proc. of the 8th Int'l. Conf. on Radiation Shielding, Arlington, TX

Analysis of the High Energy Behavior of the Forward Scattering Parameters -- σ_{tot} , ρ , and B
A. White (ANL), M. Block *et al.*
ANL-HEP-CP-94-09
Proceedings of Multiparticle/93 Conference, Aspen, CO

A Multi-Level Object Store and Its Application to HEP Data Analysis
E. May, D. Lifka, D. Malon (ANL), R. Grossman, *et al.*
ANL-HEP-CP-94-29
Submitted to the Proceedings of Computing in High Energy Physics (CHEP '94)
San Francisco, CA

Parallel Query Processing for Event Store Data
D. Malon, D. Lifka, E. May (ANL), R. Grossman, *et al.*
ANL-HEP-CP-94-31
Submitted to the Proceedings of Computing in High Energy Physics (CHEP '94)
San Francisco, CA

The Paradigm of Pseudodual Chiral Models
C. Zachos (ANL), T. Curtright (U. of Miami)
ANL-HEP-CP-94-33
Submitted to Proceedings of PASCOS '94, Syracuse, NY

The PASS Project: A Progress Report

D. Lifka, E. Lusk, D. Malon, E. May, L. Price (ANL), C. Day, *et al.*

ANL-HEP-CP-94-37

Submitted to the Proceedings of Computing in High Energy Physics (CHEP '94)
San Francisco, CA

The PASS Project Architectural Model

D. Lifka, E. Lusk, D. Malon, E. May, L. Price (ANL), C. Day, *et al.*

ANL-HEP-CP-94-38

Submitted to the Proceedings of Computing in High Energy Physics (CHEP '94)
San Francisco, CA

A Tau-Charm-Factory at Argonne

J. Norem, J. Repond (ANL)

ANL-HEP-CP-94-39

Submitted to the Proceedings of the Workshop on the Future of High Sensitivity Charm
Experiments, Fermilab, Batavia, IL

A-Dependent Effects in High PT Reactions

T. Fields (ANL)

ANL-HEP-CP-94-40

Submitted to the Proceedings of the 5th Conf. on the Intersections of Particle and
Nuclear Physics, St. Petersburg, FL

D. Technical Notes

A Possible Level 0 Trigger Scheme for the STAR EMC

D. Underwood (ANL)

ANL-HEP-TR-94-04, and Star Note #180

Summary of FEA Calculations of STAR Support Rings

V. Guarino (ANL)

ANL-HEP-TR-94-10

A Tau-Charm-Factory at Argonne

E. Berger, T. Fields, D. Grosnick, J. Norem, J. Repond, P. Schoessow (ANL)

ANL-HEP-TR-94-12

Conceptual Design for the STAR Barrell Electromagnetic Calorimeter Support Rings

E. Bielick, T. Fornek, H. Spinka, D. Underwood (ANL)

ANL-HEP-TR-94-13, and Star Note #154

Beam Test of the SDC Barrel EM Calorimeter Test Module

L. Balka, V. Guarino, N. Hill, D. Jankowski, C. Keyser, T. Kirk, L. Kocenko, D. Morgan,
J. Nasiatka, E. Petereit, L. Price, J. Proudfoot, H. Spinka, D. Underwood, R. Wagner,
K. Wood

ANL-HEP-TR-94-16

Self Tagging Studies Using Semileptonic B Decays

A. Wicklund and K. Byrum

ANL-HEP-TR-94-17 and CDF/ANAL/BOTTOM/CDFR/2514

Design and Development of the SDC Barrel Electromagnetic Calorimeter

I. Ambats, L. Balka, R. Blair, D. Carbaugh, V. Guarino, N. Hill, D. Jankowski, P. Job,
C. Keyser, T. Kicmal, T. Kirk, L. Kocenko, B. Musgrave, J. Nasiatka, L. Nodulman,
E. Petereit, L. Price, J. Proudfoot, R. Stanek, R. Taylor, H-J. Trost, D. Underwood,
A. Wicklund, K. Wood

ANL-HEP-TR-94-21

Engineering Design Evaluation of Atlas Tile-Calorimeter
N. Hill, V. Guarino, J. Proudfoot, R. Stanek, L. Price, E. Petereit
ANL-HEP-TR-94-28

High Energy Physics Division Semiannual Report of Research Activities
R. Wagner, P. Moonier, P. Schoessow, R. Talaga
ANL-HEP-TR-94-34

- CDF Note 2425 Direct Photon Plus Charm Quark Production at CDF
S. Kuhlmann
- CDF Note 2430 Measurement of $W\gamma$ and $Z\gamma$ Cross Sections in the Electron and
Muon Channels with the 1992/1993 Data and Search for
Anomalous $W\gamma$ and $Z\gamma$ Couplings
R. G. Wagner, et al.
- CDF Note 2436 Expression of Interest in a Future Collider Detector at B0
R. Blair, K. Byrum, T. Fuess, S. Kuhlmann, L. Nodulman,
J. Proudfoot, R. Wagner, A. B. Wicklund, and the CDF Collaboration
- CDF Note 2448 Update on Run 1A Diphotons
R. Blair, et al.
- CDF Note 2478 Calibration of CPR Conversion Probability from $\rho^\pm \rightarrow \pi^\pm \pi^0$
Decay
S.. Kuhlmann, et al.
- CDF Note 2487 CEM Tower Calibration and Map Trim
L. Nodulman and K. Byrum
- CDF Note 2493 Preliminary Results of a Search for the Higgs and for the b'
Quark in Run 1A
R. Blair, S. Kuhlmann, et al.
- CDF Note 2501 Search For WW, WZ, ZZ Production
T. A. Fuess, et al.
- CDF Note 2514 Self Tagging Studies Using Semileptonic B Decays
A. B. Wicklund and K. Byrum
- CDF Note 2517 $J/\psi \rightarrow e^+e^-$ and $B \rightarrow \psi K$
A. B. Wicklund
- CDF Note 2575 Comparison of 1988-89 Jet-20 vs. 1992-93 Photon-16 QCD Jet
Fragmentation Probabilities $\rho(J \rightarrow \gamma)$ for the $W + \gamma$ and $Z + \gamma$
Data Samples
R. G. Wagner, et al.
- CDF Note 2594 Updated Limits on 3-Boson Couplings from WW, WZ
T. A. Fuess, et al.
- CDF Note 2598 Measurement of Charged and Neutral B Meson Lifetimes Using
Electron-Charm Events
A. B. Wicklund, et al.

- CDF Note 2605 A Precision Measurement of the Prompt Photon Cross Section in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV
R. Blair, et al.
- CDF Note 2609 A Study of Parton Distribution Functions with the Use of Photon + Jet Event Kinematics at CDF
S. Kuhlmann, et al.
- CDF Note 2620 YMON Slide File Crib Sheet
L. Nodulman
- CDF Note 2624 Calibration of CTC DE/DX
A. B. Wicklund and K. Byrum
- CDF Note 2627 The Diphoton Production Rate in $p\bar{p}$ Collisions at $\sqrt{s} = 1800$ GeV
R. Blair, et al.
- CDF Note 2630 Implementation of the Shower Max Electron Trigger in CDF
K. Byrum, J. Dawson, L. Nodulman, A. B. Wicklund, et al.
- CDF Note 2646 Wg and Zg Cross Section Results from the 1992-93 Run
R. Wagner, et al.
- CDF Note 2652 Recipe for Refitting Tracks Used by the W Mass Group
L. Nodulman, et al.
- CDF Note 2668 A Measurement of the Leading Jet h Boost and h^* Distribution in Direct Photon Plus Jet Events,
R. Blair, S. Kuhlmann, et al.
- PDK-576 Soudan 2 Experiment Quarterly Status Report, October-December 1993
D. Ayres
- PDK-581 Update to P822: Proposal for a Long-Baseline Neutrino Oscillation Experiment from Fermilab to Soudan
M. Goodman
- PDK-584 Decisions of the Rutherford Collaboration Meeting, March 22-25, 1994
D. Ayres
- PDK-585 Soudan 2 Experiment Quarterly Status Report, January-March 1994
D. Ayres
- PDK-587 Expression of Interest for a Long-Baseline Neutrino Oscillation Experiment from Fermilab to Soudan Using a 16 kT Iron Calorimeter
M. Goodman
- PDK-589 Penetration of Cosmic Ray Muons into the Earth
J. Uretsky
- ZEUS 94-042 Energy Corrections to Jets in the ZEUS Calorimeter
S. Magill
- ZEUS 94-060 Direct versus Resolved Photoproduction of Jets
G. Bodwin and J. Repond

VI COLLOQUIA AND CONFERENCE TALKS

E. Berger

"Spin Physics at the RHIC Collider"

RHIC Spin Collaboration Annual Meeting

Argonne National Laboratory (April 1994)

"B Physics at Hadron Facilities — Cross Sections, Correlations, and Asymmetries"

Second International Workshop on B Physics at Hadron Machines

Mont Saint Michel, France (April 1994)

"Summary of the Drell Subpanel Report"

High Energy Physics Division Seminar

Argonne National Laboratory (May 1994)

M. Derrick

"Physics with High Energy e-p Collisions"

Michigan State University (March 1994)

"Neutrino Physics at Argonne"

ZGS Symposium

Argonne National Laboratory (May 1994)

T. Fields

"Introduction to the 30th Anniversary ZGS Symposium"

ZGS Symposium

Argonne National Laboratory (May 1994)

"A-Dependent Effects in High p_T Reactions"

Conference on Intersections of Nuclear and High Energy Physics

St. Petersburg, Florida (June 1994)

M. Goodman

"Prospects for Long Baseline Neutrino Oscillations"

Virginia Polytechnic Institute and State University (February 1994)

University of Chicago (April 1994)

"Long Baseline Neutrino Oscillation Experiments"

High Energy Physics Seminar

University of Wisconsin (February 1994)

"Atmospheric Neutrinos"

Joint Experimental and Theoretical Seminar

Fermi National Accelerator Laboratory (April 1994)

V. Guarino

"Engineering Design Evaluation of ATLAS Tile-Calorimeter"

ATLAS Collaboration Meeting

CERN, Geneva, Switzerland (June 1994)

N. Hill

"Argonne Mechanical Design Proposal for the ATLAS Hadron Calorimeter"

ATLAS Collaboration Meeting

CERN, Geneva, Switzerland (June 1994)

S. Kim

"A Lattice QCD Calculation of Heavy Quarkonium Decay Matrix Elements"

University of Tokyo (May 1994)

Univeristy of Tsukuba, Japan (May 1994)

"Quenched QCD Spectrum Calculation"

Institute of Physical and Chemical Research (RIKEN), Japan (May 1994)

S. Kuhlmann

"Perturbative QCD Tests at LEP, HERA, TEVATRON"

The XIVth International Conference on Physics in Collision

Tallahassee, Florida (June 1994)

D. Malon

"Parallel Query Processing for Event Store Data"

Computing in High Energy Physics (CHEP'94)

San Francisco (April 1994)

Ed May

"A Demonstration of a Multi-Level Object Store and Its Application to the Analysis of HEP Data"

Computing in High Energy Physics (CHEP'94)

San Francisco (April 1994)

L. Nodulman

"Evidence for Top at CDF"

SLAC Colloquium

Stanford Linear Accelerator Center (May 1994)

"Electroweak Physics at the TeV Collider"

Conference on Radiative Corrections

Gatlinburg, Tennessee (June 1994)

J. Proudfoot

"Electroweak and QCD Results from CDF and D0"

Joint April Meeting of The American Physical Society and the American Association of Physics Teachers

Crystal City, Virginia (April 1994)

G. Ramsey

"Large t Elastic Spin Observables at RHIC"
R7 Collaboration of RHIC
University of Iowa (June 1994)

Robert Wagner

"Limits on Anomalous Gauge Boson Couplings from $W\gamma/Z\gamma$ Production at CDF"
High Energy Physics Division Seminar
Argonne National Laboratory (March 1994)

A. White

"The QCD Pomeron and Small- x Physics"
Triangle Nuclear Theory Colloquium
Duke University (March 1994)

"Higher-Order Lipatov Kernels and the QCD Pomeron"
The XVIIth Kazimierz Meeting on Elementary Particle Physics, Poland (May 1994)
Workshop on Quantum Infra-Red Physics, Paris (June 1994)

A. Yokosawa

"RHIC Spin Physics Update"
STAR Collaboration Meeting
Lawrence Berkeley Laboratory (February 1994)

"Spin Physics at RHIC Using STAR Detector"
University of Tohoku, Sandai, Japan (June 1994)

C. Zachos

"Currents and Canonical Structure of Pseudodual Chiral Models"
University of Chicago (February 1994)

"Introduction to High Energy Physics"
Science and Engineering Research Semester Seminar
Argonne National Laboratory (March 1994)

"The Paradigm of Pseudodual Chiral Model"
PASCOS '94: Particles, Strings, and Cosmology
Syracuse University (May 1994)

"High Energy Physics and the Top Quark"
Student Research Participation Seminar
Argonne National Laboratory (June 1994)

VII HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES

E. Berger

Member, Department of Energy High Energy Physics Advisory Panel (HEPAP), 1991-present

Chairman, Committee on Meetings, American Physical Society, 1994-5, Member since 1991

Member, Department of Energy Strategic Planning Team for Science and Technology, 1993-4; "Table Leader" for the Focus Area, Fundamental Research in Energy and Matter

Member, U.S. contact person, Scientific Program Committee, XXIX Rencontre de Moriond, "QCD and High Energy Hadronic Interactions", Meribel, France, March 1994

Member, Organizing Committee, Fifth Conference on the Intersections between Particle and Nuclear Physics, May 1994

Member, Advisory Committee, Workshop on Future High Sensitivity Charm Experiments (CHARM 2000), Fermilab, June 1994

Member, U.S. contact person, Scientific Program Committee, XXX Rencontre de Moriond, Meribel, France, March 1995

T. Fields

Member, URA Visiting Committee for Fermilab

Member, Organizing Committee for ZGS 30th Anniversary Symposium, May 1994

M. Goodman

Organizer, Long Baseline Working Group "N2L", "Particle and Nuclear Astrophysics and Cosmology in the Next Millennium" Workshop, Snowmass, June-July 1994

L. Price

Member, ESnet Steering Committee, 1988-present

Member, U.S./China Committee for Cooperation in High Energy Physics

P. Schoessow

Member, Local Organizing Committee, Workshop on Advanced Accelerator Concepts, June 1994

J. Simpson

Co-Chair, Workshop on Advanced Accelerator Concepts, June 1994

Member, Organizing Committee, Particle Accelerator Conference, Dallas, Texas, 1995

A. White

Co-Chairman "2nd Workshop on Small- x and Diffractive Physics at the Tevatron", Fermilab, September 1994

Member, International Advisory Committee for the VIII International Symposium on Very High-Energy Cosmic-Ray Interactions, Tokyo, Japan (July 1994)

Member, International Advisory Committee for the XXIV International Symposium On Multiparticle Dynamics, Vietri sul Mare, Italy, September 1994

VIII HIGH ENERGY PHYSICS DIVISION RESEARCH PERSONNEL

Administration

L. Price

D. Hill

Accelerator Physicists

W. Gai

J. Norem

M. Rosing

P. Schoessow

J. Simpson

Experimental Physicists

D. Ayres

M. Beddo

R. Blair

K. Byrum

D. Crane

M. Derrick

T. Fields

T. Fuess

M. Goodman

D. Grosnick

P. K. Job

T. Kirk

D. Krakauer

S. Kuhlmann

D. Lopiano

S. Magill

E. May

B. Musgrave

L. Nodulman

J. Proudfoot

J. Repond

R. Seidlein

H. Spinka

R. Stanek

R. Talaga

J. Thron

D. Underwood

R. Wagner

A. B. Wicklund

A. Yokosawa

Theoretical Physicists

E. Berger

G. Bodwin

H. Contopanagos

C. Coriano

S. Y. Kim

D. Sinclair

A. White

C. Zachos

Engineers, Computer Scientists, and Applied Scientists

E. Chojnacki

J. Dawson

V. Guarino

W. Haberichter

N. Hill

J. Nasiatka

J. Schlereth

X. Yang

Technical Support Staff

I. Ambats

L. Balka

H. Blair

D. Jankowski

T. Kasprzyk

L. Kocenko

D. Konecny

R. Rezmer

Laboratory Graduate Participants

C. Allgower

N. Barov

H. Gallagher

M. Hohlmann

H. Huang

D. Mikunas

J. Power

Visiting Physicists

W. L. Barrett (Soudan)

E. Kovacs (Theory/CDF)

J. Qui (Theory)