HIGH ENERGY PHYSICS DIVISION SEMIANNUAL REPORT OF RESEARCH ACTIVITIES

January 1, 1993 – June 30, 1993

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SEMIANNUAL REPORT OF RESEARCH ACTIVITIES***

January 1, 1993 - June 30, 1993

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December 1993

MASTER

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Abstract

This report describes the research conducted in the High Energy Physics Division of Argonne National Laboratory during the period of January 1, 1993 - June 30, 1993. 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 PROGRAM

A. Physics Results

I. Collider Detector at Fermilab

Data taking for the 92-93 collider run ("1A") was completed at the end of May with an integrated luminosity of about 22 pb^{-1} collected by CDF. The data was rapidly processed and shortly after data taking stopped at the end of May, essentially all good data had been analyzed to select top quark candidates in several decay channels. Dilepton search cuts were tightened over that from 88-89 which had an integrated luminosity of 4 pb^{-1} . The one 88-89 $e\text{-}\mu$ candidate does not pass the new selection. Three new candidates were observed. Preliminary estimates of background are greater than 3 events. However, if we assume the 3 are signal, a 95% CL lower limit of 113 GeV is set for the top quark mass. For higher mass top there is good probability of finding 2 or more jets in a dilepton event and 2 of the 3 events have such jets, with an estimated background of about 1.3 events. An inclusive analysis of W plus multijets finds that the VECBOS tree level Monte Carlo describes the data in a control region but that the 11 events in a "signal" region includes some with higher jet E_T than might be expected from VECBOS. About 5 top events would be expected in this sample for a top mass of 170 GeV. Three events with W + 3 or more jets where at least one jet has an SVX b quark tag are found with an expected background of about 1.5. Soft leptons associated with a jet are also used as a b quark tag and six W + 3 or more jet events are found in this category, with an estimated background of 2.5. Although it is premature to talk about discovery of the top quark perhaps there is a beginning of an indication of something.

One of the outstanding features of the 92-93 data is the fine performance of the silicon vertex detector. This is shown in the vertex displacement for inclusive Ψ s shown in Fig. 1. The background of about 6% is found using Ψ sidebands. The Ψ s are readily decomposed into a prompt component e.g., from χ and a long lived component which has been used to determine an inclusive Ψ event b lifetime of $1.46 \pm 0.06 \text{ ps}$. Note that b fraction is considerably lower than the assumed value in our 88-89 inclusive Ψ and Ψ' measurements of the b cross section and only part of the difference is the result of the lower p_T threshold this run. Exclusive signals with Ψ s have been isolated allowing separate lifetime measurements for B^+ and B^0 as well as the observation of $B_s \rightarrow \Psi \Phi$.

The b physics activity in the Argonne group is based on the inclusive electron sample. Figure 2 shows the $D \rightarrow K \pi$ peak seen associated with inclusive electrons. Figure 3 shows the signal to noise improvement as well as the efficiency for silicon

Fig. 1, Dimuon vertex displacement for a sample of inclusive Ψ s. The darker shaded area (6%) is the background from Ψ sidebands. The remainder clearly has a substantial prompt component as well as a component characterized by the b lifetime.

Fig. 2. $K\pi$ mass peak in association with inclusive electrons in 92-93 data.

Fig. 3. $K \pi$ mass peak in association with inclusive electrons where both tracks reconstruct in the silicon vertex detector and the intersection is on the same side of the beam spot as the b direction ($L_{xy} > 0$). The improved signal to noise and the efficiency are apparent by comparison to Fig. 2.

vertex detector reconstruction of the K and π with a track intersection on the momentum side of the beam spot ($L_{xy} > 0$). The L_{xy} distribution of a sample of $b \rightarrow e \nu D^0$ which is anti selected for D^* mass combinations is shown in Fig. 4; these events are predominantly B^+ . Figure 5 shows the L_{xy} distribution for selected $e \nu D^*$, predominantly B^0 . We hope to extract a competitively accurate lifetime ratio. The vertex information will be used to refine the b cross section measurement. Figure 6 shows the signed impact parameter fraction for inclusive electrons as a function of cut on p_T with respect to the presumed b jet. Apparently the contribution from charm is a bit larger than initially expected.

QCD study has continued with various jet studies and, in particular, the preradiator chambers, an Argonne project, have allowed a considerable extension of the direct photon production studies. The amount of material in front of the preradiator and thus the conversion probability is determined accurately by using photons from reconstructed η s and π^0 s (Fig. 7). The resulting preradiator hit rate predictions and observations are shown in Fig. 8. The resulting photon cross section is shown in Fig. 9 and is compared to old and new transverse profile method photon identification results. The diphoton spectrum (Fig 10) is also of considerable interest.

The Argonne group continues to be involved with the group measuring the mass of the W boson as well as the study of photons associated with W s and Z s. We hope to achieve an uncertainty in the W mass of less than 200 MeV. Calibration issues will be discussed in the section on running. (L. Nodulman)

2. Soudan Data Analysis

At the end of June the Soudan contained event analysis team completed the initial identification and characterization of neutrino event candidates in the second half fiducial kiloton year of Soudan 2 exposure. About 100 fully contained interactions of atmospheric neutrinos have now been identified in Soudan 2 data. Two thirds of these events are quasi-elastic scattering candidates which are used to measure the ratio of muon neutrinos to electron neutrinos. Although the statistics are still limited, the Soudan measurement of the ratio of muon to electron neutrinos continues to support the anomalously low value obtained by the IMB and Kamiokande experiments. One interpretation of these results is that the muon neutrino flux is lower owing to the oscillation of muon neutrinos into tau or electron neutrinos, which requires nonzero neutrino masses and nonconservation of lepton number. An alternative interpretation is that the electron neutrino rate appears high because of contamination by positrons from proton decay in the mode $p \rightarrow e^+ \nu \nu$.

Fig. 4. Projected displacement from the beam spot (L_{xy}) for a sample of electron and D^0 events selected not to have a D^* candidate. These are predominantly from charged B.

Fig. 5. Projected displacement from the beam spot (L_{xy}) for a sample of electron and D^0 events which are D^* candidates. These are predominantly from neutral B.

Fig. 6. Fraction of inclusive electron events where the signed impact parameter for the electron track (DVX) is larger than 200 μm versus the transverse momentum of the electron with respect to the presumed b jet (P_{trel}). The dashed curves illustrate the rates seen in the data total and for the pion fake contribution. The dotted curves are the predictions for b and c. The different shapes allow the relative contributions to be measured. The solid curves show the range for the nominal assumptions (20% efficiency for c). Clearly additional charm contribution will be needed in extracting a b cross section.

Fig. 7. Diphoton mass. The preradiator rate calibrates the material at smaller radius.

Fig. 8. Fraction of events with a preradiator hit expected for π^0 and other background, expected for photons, and observed in the data versus photon p_T .

Fig. 9. Direct photon cross section versus photon p_T for the preradiator analysis and for the transverse profile analysis used in 88-89 and repeated for 92-93 data.

Fig. 10. Integral distribution of diphoton candidates in diphoton mass.

The quantity actually measured in these experiments is the ratio of the track-like to shower-like neutrino interaction events, which is nearly equal to the ratio of muon to electron quasi-elastic neutrino interactions. The ratio R' of the observed to expected (Monte Carlo) track/shower ratios will be unity in the absence of neutrino oscillations. Table 1 compares the current preliminary Soudan 2 measurement with results from other experiments.

Table 1. Comparison of results on the atmospheric neutrino flavor ratio (the first uncertainty shown is statistical, the second systematic)

<u>Experiment</u>	<u>Exposure/(kton year)</u>	$R' = \frac{(\text{track/shower})_{\text{exp t}}}{(\text{track/shower/MC})}$
Kamiokande	4.90	$0.60^{+0.07}_{-0.06} \pm 0.05$
IMB 3	7.70	$0.54 \pm 0.02 \pm 0.07$
Frejus	1.56	$1.06 \pm 0.18 \pm 0.15$
NUSEX	0.4	0.99 ± 0.40
Preliminary Soudan 2	1.0	$0.69 \pm 0.19 \pm 0.09$

Motivated by these results, the Soudan collaboration has proposed to search directly for neutrino oscillations using a 730 km long neutrino beam from Fermilab (proposal P-822). A high intensity 20 GeV muon neutrino beam produced by the new Fermilab Main Injector would be aimed towards Soudan (at a 3.3 degree angle below the horizon). If the atmospheric neutrino result is due to oscillations, many of the muon neutrinos in the Fermilab beam will become tau or electron neutrinos on their trip to Soudan. This will decrease the fraction of interactions containing final state muons, and provide an unambiguous signal of neutrino oscillations. Figure 11 shows the route of the neutrino beam between Fermilab and Soudan.

The Soudan collaborators are proposing the construction a new detector, optimized for the higher energy of the Fermilab beam, in the unoccupied part of the Soudan underground laboratory. A detector mass as large as 8 kton could be assembled in the available space without disturbing the existing 1 kton experiment. With the recently increased design intensity of the Fermilab Main Injector, the combined 9 kton detector would record about 43,000 neutrino interactions with contained vertices during a two year run. Figure 12 shows the region of the muon-to-tau neutrino-oscillation parameter space which would be ruled out if this experiment were to obtain a negative result. Several designs for new detectors for the long

Fig. 11. Sketch of the 730 km long neutrino beamline between Fermilab and Soudan. The beam is pitched down at 3.3 deg below the horizontal at Fermilab. The 1 mrad beam divergence gives a beam radius at Soudan which is nearly equal to the 713 m detector depth.

Fig. 12. Sensitivity of the proposed Fermilab-Soudan long baseline experiment, P-822. The region above and to the right of the curve would be excluded by P-822 if the ratio of neutral to charged current neutrino events is equal to the predicted value (with no oscillations). The curve shows the 90% confidence level limit for a two year run and systematic uncertainties of 0.5%. The single point plotted at $\Delta m^2 = 10^{-2} \text{ eV}^2$ shows the most probable values of the oscillation parameters if the atmospheric neutrino ratio measured by the Kamiokande experiment is due to ν_{μ} to ν_{τ} oscillations.

baseline experiment were discussed during a meeting of the P-822 collaboration at Argonne in April.

Although contained events (neutrino interactions and nucleon decay) continue to be the major thrust of Soudan 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 continuing at Oxford and Minnesota. In addition, two Ph.D. theses submitted during the first half of 1993 made use of multiple muon events in Soudan 2 data to study the nuclear composition of cosmic ray primaries.

Multiple muon (muon bundle) events have two or more parallel muon tracks from the same cosmic ray air shower in Soudan 2. The distribution of muon multiplicities is sensitive to the nuclear composition of the primary cosmic ray particles. At Tufts University, N. Sundaralingam's thesis takes advantage of the large area of the active shield around Soudan 2 to more than double the effective area of the detector for multiple muon events. The results of his thesis, "Investigation of the relative abundance of heavy versus light nuclei in primary cosmic rays using underground muon bundles," favors a light composition around the interesting "knee" region of 1000 to 10,000 TeV primary energy. At the University of Minnesota, N. Longley's thesis, "Ultra high energy cosmic ray composition," uses data from the array of proportional tubes on the surface above Soudan 2 to obtain a measure of the energies of some of the cosmic ray showers which produce underground muons. The results of this thesis also favor a light nuclear composition in the knee region.

The March 13 issue of the New Scientist contained a news article about the atmospheric neutrino flavor ratio and its interpretation as evidence for neutrino oscillations or proton decay. The article highlighted the potential for Soudan 2 to resolve the controversy, and the proposal to test the neutrino oscillation hypothesis with the Fermilab-Soudan long baseline experiment. A news article in the April issue of the CERN Courier commemorated Argonne's completion of 5-ton module construction for Soudan 2. Finally, Soudan collaborators submitted four papers describing preliminary results on neutrino interactions and cosmic ray composition to the 23rd International Cosmic Ray Conference, to be held in July in Calgary, Canada. (D. Ayres)

3. ZEUS Detector at HERA

ZEUS Physics Analysis. In December, the collaboration submitted a paper "Initial Study of Deep Inelastic Scattering with ZEUS at HERA", to Physics Letters which was accepted for publication in this reporting period. The results were from the initial data run of $\sim 3 \text{ nb}^{-1}$ and covered the Q^2 range up to $\sim 1000.0 \text{ GeV}^2$. At the large center of mass energy $\sqrt{s} = 296 \text{ GeV}$, the events occur at low values of Bjorken x ,

extending the range studied by previous experiments by two orders of magnitude, down to $x \sim 10^{-4}$ at $Q^2 \sim 10 \text{ GeV}^2$. These data open the nuclear structure function to exploration in a new kinematic region. The precise timing provided by the calorimeter is crucial in removing beam gas background. Photoproduction background to DIS is rejected using calorimeter and luminosity monitor energy cuts. The distribution of events in the (x, Q^2) plane is shown in Fig. 13a. Lines of constant y are shown. The resolution degrades at values of $y \lesssim 0.02$. The projections of the data in x and Q^2 , shown in Fig. 13b and 13c are in satisfactory accord with the Monte Carlo simulation. Although these early data are predominantly at low values of Q^2 , overlapping the Q^2 range of previous experiments, the data extend lower in x by two orders of magnitude than previously possible. Three bins in Q^2 where the acceptance is both uniform and high and where the resolution is better than 40% in x and 25% in Q^2 , are used for the cross section measurement. The cross section values, corrected for QED radiative effects, are shown in Fig. 13d. The lines are the Born cross sections calculated from extrapolations of three parton density sets, MRSDO, MTB1 and MTB2, into this kinematic region. There is good agreement with all three parametrizations at the level of precision of the data. The inner error bars shown on the cross sections are statistical, while the outer error includes a linear addition of the estimated systematic effects, between 15% and 25%, depending on the Q^2 value. It is very encouraging that the detector, especially the calorimeter, allows DIS events to be selected with very little background.

A second publication in this reporting period, "Search for Leptoquarks with the ZEUS Detector", used the full data set of 26 mb^{-1} from the 1992 cycle. HERA permits a natural and complementary technique to searches in e^+e^- and hadron-hadron colliders in that a single leptoquark state may be produced with the rate depending directly on the lepton-quark coupling to the leptoquark (LQ) and not on other properties of the leptoquark such as additional couplings or spatial extent. The search is made in both NC and cc channels:

$$e^-p \rightarrow e^- + x \quad (1)$$

$$e^-p \rightarrow \nu_e + x \quad (2)$$

The signature is a peak in the x distribution at $x_0 = M_{LQ}^2/s$. No evidence was found for the production of leptoquarks with decay to $e^+ + \text{jet}$ or $\nu_e + \text{jet}$. For example, scalar isosinglet leptoquarks with electroweak coupling strength to $(e-u)$ states are ruled out at

Fig. 13. (a) The distribution of events in the (x, Q^2) plane. (b) The Q^2 distribution of the events. (c) The x distribution of the events. The Monte Carlo predictions, shown as the shaded histograms, are calculated from the extrapolation of the MRSD0 parametrization. (d) The measured differential Born cross sections, in the selected (x, Q^2) ranges indicated in (a), compared to the extrapolations of three parton density functions: MTB1, MTB2 and MRSD0.

the 95% confidence level for masses below 168 GeV for left-handed couplings and below 176 GeV for right-handed couplings. This is summarized in Fig. 14 which shows the 95% confidence limits of leptoquark-electron-quark coupling for the (e^-u) decay to neutral current and charged current final states. (B.Musgrave)

4. Polarized Proton Physics

Our new experimental result from the Fermilab E-704 data analysis is the analyzing power in Drell-Yan production. This work was motivated to check the prediction of a theoretical model [C. Boros et al., Phys. Rev. Lett. 70, 1751 (1993)] that interpreted our A_N data in pion production, $p^\uparrow p \rightarrow \pi x$, as revealing a mirror symmetry for π^+ and π^- with respect to x_F . These experimental results on π^+ , π^- , and π^0 with polarized-proton and -antiproton beams are regarded as evidence for the existence of orbiting valence quarks. If this view is correct, the so-called "proton spin crisis" caused by the results of polarized μp deep inelastic experiments at SLAC and CERN is eliminated. While pion production at large x_F is regarded as direct quark-antiquark fusion producing a large asymmetry, high-mass lepton-pairs produced at $x_F = 0$ are solely due to quark-antiquark annihilation. The prediction by the model is $A_N = +35\%$ in the lepton-pair mass region of 3 to 4 GeV. Our new result for the pair mass region of 2,600 to 3,250 MeV is $A_N = +(52.5 \pm 28.0)\%$. The false asymmetry with unpolarized beam is $A_N = +(9.8 \pm 25.7)\%$.

The on-going analyses of FNAL E-704 data are as follows:

- $\Delta\sigma_L(pp)$ and $\Delta\sigma_L(\bar{p}p)$, difference in total cross sections in pure spin states
- Direct-gamma collected simultaneously with π^0 data
- Detailed analysis of π^0 data
- Detailed analysis of π^0 and η production
- K production

(A. Yokosawa)

5. Spin Physics at LAMPF

The ANL-HEP experimental program at Los Alamos has concentrated on np elastic scattering spin measurements in order to derive the isospin-0 nucleon-nucleon amplitudes for beam kinetic energies between 500 and 800 MeV. Results of a number of major experiments are being finalized and written in major papers. During this period, a long article on np elastic scattering spin observables was published (T. Shima et al., Phys. Rev. D47, 29 (1993)) containing data on C_{SS} and C_{LS} in the c.m. angular range $25^\circ - 80^\circ$. The analysis of the remaining elastic scattering data from that experiment was completed,

Fig. 14. The 95% confidence upper limits on the couplings of scalar leptoquarks with zero weak isospin and fermion number $F = -2$ versus the leptoquark mass in GeV. (a) The right handed coupling limit from the NC decay mode with $b=1$, where b is the branching fraction for leptoquark decay to (1) , $b = \Gamma_{NC}/(\Gamma_{NC} + \Gamma_{CC})$; (b) Assuming $b = 1/2$, the left-handed coupling calculated from the NC data sample (dotted), from the CC data sample (dashed), and from the combined samples (solid). To obtain the limit for other branching fraction assumptions, the ordinate of the NC (CC) curve should be multiplied by $\sqrt{0.5/b}[\sqrt{0.5/(1-b)}]$. Because the limits from NC and CC are similar at larger masses, the combined left-handed coupling limit at large mass is largely independent of b .

and the writing of a paper describing the results has begun. This paper will include final values for C_{LL} , C_{SS} , and $C_{LS} = C_{SL}$ over the angular range $25^\circ - 180^\circ$ at 484, 634, and 788 MeV, as well as over a more restricted angular range at 720 MeV. An instrumentation paper describing a relative neutron beam polarimeter was published in this period (I. Supek et al., Nucl. Instrum. Meth. **A324**, 19 (1993)), and a physics article containing data on P and K_{NN} over a broad angular range and the four energies above was submitted for publication (see Fig. 15). Using these new np polarization results, plus similar data at somewhat higher energies from Saclay, revised values for the LAMPF neutron beam polarization have been derived. These new values will be described in the final paper on C_{LL} , C_{SS} , and C_{LS} . (H. Spinka)

6. Spin Physics at SATURNE

Work on the experiments at Saclay continued. A new data acquisition system, based on a SUN computer and Vx Works hardware and software, was successfully commissioned during an experimental run in April. This represents a major accomplishment for the collaboration, and it was largely due to the efforts of the ANL-HEP physicists. For example, various problems in the on-line software written at Saclay and Orsay were identified and solved by Argonne personnel permitting a significant improvement in the data acquisition rate compared to the older system. ANL-HEP physicists also wrote a number of subroutines to monitor the performance of various experimental hardware. This monitoring could not be done under the older system. In this period, improvements were also made to the polarized target magnet power supplies by Argonne technician, Tom Kasprzyk, and a physicist from Dubna. As a result, the target operation was considerably more stable, allowing improved polarizations for the ${}^6\text{LiH}$ and ${}^6\text{LiD}$ target materials.

Several other activities occurred during this period. An instrumentation article describing the Saclay experimental apparatus was published (J. Ball et al., Nucl. Instrum. Meth. **A327**, 308 (1993)). Several other papers were submitted for publication which describe the measurement of np elastic scattering spin observables at Saclay. A sample of these data for $P = A_{000n} = A_{00n0}$ and $C_{NN} = A_{00nn}$ are shown in Fig. 16. Preparations were begun to add a second Argonne multiwire proportional chamber to the Saclay experiment. Supports were designed and constructed. The ribbon cables connecting the preamplifiers on the chamber and the remote latches were prepared for shipment. The electronics were assembled and prepared for testing. Additional software for the on-line data acquisition program was written. Also, some studies were performed to understand systematic errors that may be present in pp elastic scattering spin data collected at Saclay

Fig. 15. Measurements of the np elastic scattering spin parameter K_{NN} with polarized neutron beam and a carbon rescattering polarimeter for the outgoing proton. The beam kinetic energies are 485, 635, and 788 MeV. The curves show various phase shift predictions of K_{NN} .

Fig. 16. Measurements of the np elastic scattering spin parameters $P = A_{oonn} = A_{oono}$ and $C_{NN} = A_{oonn}$ with a polarized neutron beam on a polarized proton target. The beam kinetic energies are 1000 and 1100 MeV.

near 2 GeV kinetic energy. Finally, a new graduate student joined the group; his thesis research will involve data from the Saclay experiments. (H. Spinka)

B. Experiments Taking Data

1. Soudan 2

The Soudan 2 experiment continued routine data acquisition for contained events (neutrinos and nucleon decay) and cosmic ray muons during the first half of 1993. In addition, data from the 40 m² surface array were recorded in coincidence with Soudan 2 in order to measure the energies of some of the cosmic ray air showers which produce underground muon events. The experiment recorded data for 139 days of livetime, giving a duty cycle of 77%. This brought the total Soudan 2 exposure to 3.4 years, or 1.3 fiducial kiloton years useful for nucleon decay and atmospheric neutrino physics.

The detector is operated for physics data primarily during night and weekend periods when installation 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 by track reconstruction programs and the analysis results are recorded on 8 mm magnetic tape cassettes for distribution to the collaborating institutions. (D. Ayres)

2. Collider Detector at Fermilab

Data taking continued through May and is summarized in Fig. 17. The yield of 22 pb⁻¹ was as predicted and the efficiency of slightly greater than 70% was a bit disappointing. The equivalent numbers were 4.2 pb⁻¹ and 50% in 88-89. The silicon vertex detector survived the run although the performance of the inner layer deteriorated noticeably toward the end. The muon upgrade worked well but the muon extension detectors had counting rate problems which limited our ability to use it in the trigger. There was some relief when thick sections of beam pipe and flange were replaced with thinner versions during the January break.

The central EM calorimeter was prepared for the run by going back to source calibrations; the gain of all of the phototubes were reasonably well set. There was a noticeable gain decline of about 5% on average during the course of the run, illustrated by the decline in E/p for inclusive electrons as shown in Fig. 18. The scintillator attenuation did not deteriorate more than the expected amount corresponding to the usual ~1% annual light loss and there is no sign of any non linearity which would result from deterioration of the wavelength shifter. There seems to have been some decline in PMT gain as monitored by the LED flashers. The gain change is sufficiently well characterized to get on with W mass measurement but it is quite worrisome and remains under study. The

Fig. 17. Integrated luminosity at B0 produced by the Tevatron and recorded by CDF versus time for the 92-93 run.

Fig. 18. Decline in gain of the central EM calorimeter as illustrated by the decline in E/p versus run number in a sample of inclusive electrons for $(E+p)/2 > 11$.

preradiator chambers and shower max. strip chambers performed with only occasional high voltage trips. The new gas mixing scheme and the high voltage feedback based on atmospheric pressure sensors performed well after an initial glitch as seen in Fig. 19.

(L. Nodulman)

3. ZEUS Detector at HERA

a) HERA Status

The HERA startup after the winter shutdown occurred at the beginning of April. The machine experienced a number of component reliability problems in PETRA and HERA which resulted in a slow turnon. During May problems were experienced with increased proton emittance leading to a decrease in proton beam lifetime and high background levels in both experiments. This disappeared in June without the reason being understood. Problems were also experienced with the proton bunch length.

Some luminosity running was possible by the middle of June after a shutdown to allow the H1 detector to move into its interaction region following detector repairs. Proton currents of about 4 mA and electron currents around 7 mA were typical with 30 bunch operation. It is expected that the 1993 running period will result in up to ten times the data collected in 1992.

b) ZEUS Operation

During the winter shutdown the final trigger configuration was installed. This represented a major effort on the part of the Wisconsin and Argonne groups. The trigger was commissioned in the early HERA operation and was working reliably by the time good luminosity operation began to be available in June.

During 1992 operation, the false trigger rate coming from photomultiplier (PMT) sparking in the barrel calorimeter (BCAL) was at the level of about 50 Hz, unacceptably high and certain to be a serious problem given the much higher data rates expected in 1993. A significant reduction in this sparking rate was achieved during the winter shutdown when the Argonne group retrofitted the PMTs with metal screens connecting the high voltage at the aquadag layer to the acrylic transition pieces which interface the light guide to the PMT photocathode. This was done for some 120 of the PMT sites showing the highest sparking rates and reduced the overall rate of false triggers to about 5 Hz, an acceptable rate.

The ZEUS solenoid has so far only been operated to produce a field of 1.43 Tesla because the forces on the coil were found to exceed the allowed values for operation at the design field of 1.8 Tesla. During the winter shutdown, the separation between the rear calorimeter (RCAL) and the BCAL was increased by 1 cm so as to allow operation at about 1.6 Tesla. When subsequently operating the solenoid in April, the expected

Fig. 19. Counting rate (%/channel/minimum bias event) in strips plus wires of the central strip shower max. detectors versus run number. The early glitch shows a gain change when the large scale gas mixing was started followed by a return when nominal high voltages were accordingly adjusted. Runs after the January shutdown had somewhat more noise.

increase in field could not be realized since the forces on the coil were not reduced as expected from the redistribution of the field return iron. The whole problem will be re-examined during the 1993 winter shutdown.

A major improvement to the detector capability was achieved by completing installation of the central tracker (CTD) readout and trigger electronics during the shutdown. Routine operation of the CTD was possible by the early luminosity running in June.

A further improvement to the detector, very important in view of the recent observation of events with a diffractive signature in the 1992 data, was the partial installation of the leading proton spectrometer detector stations. In its present form, the spectrometer is expected to provide useful data in the 1993 data taking cycle.

c) Barrel Calorimeter Hadron-Electron Separator (HES) R&D

The rear calorimeter is now equipped with a Si-pad hadron-electron separator at shower maximum and construction of a similar device is underway for the forward calorimeter. While this has also been suggested for the barrel calorimeter, the US-ZEUS collaboration is also considering other techniques for providing a hadron-electron separator in view of the high cost involved with the Si-pad option. The work at Argonne was motivated by the successful use of a proportional wire chamber with anode wire and orthogonal cathode strip readout in the CDF detector. During the last year, R&D was done with small chambers in the uranium environment of the ZEUS calorimeter. This was sufficiently encouraging that a full scale 3.2 m long prototype has been constructed and is now ready for testing in the barrel calorimeter prototype module at Argonne. The chamber provides readout from 32 wire and 160 cathode strips and is designed to fit inside the aluminum box which was built into each of the 32 ZEUS barrel calorimeter modules at shower maximum. This is illustrated in Fig. 20 where the top from one of the HES boxes is removed to show two of the wire chambers in place. The design of this box was driven by the assumption that a Si-Pad device would also be used in the barrel but this does not have a significant effect on the design of a wire chamber option. Also shown in Fig. 20 is an aluminium chamber profile and the two layer PC board with pads on one side and surface mounted pad pre-amplifiers on the other. It is expected that test results will be available in July.

(B. Musgrave)

Fig. 20. Two of the four PWC chambers which make up a barrel calorimeter module HES are shown in the HES Box. Also shown is one of the aluminium profiles and its top side, a PC board with the cathode pads on the underside and surface mount electronics on the top.

C. Experiments in Preparation Phase

1. Collider Detector at Fermilab

The major preparations under way for the run expected to start late this fall are the new AC coupled radiation hard silicon vertex detector and DAQ upgrades. We also hope to install the central shower max. trigger. The FASTBUS card which inputs strip chamber wire bits and track information and outputs matches has been dubbed CERES. It has been successfully attached to the trigger hardware downstream and to track information. The first set of prototype wire boards to provide the bits were put into one wedge by Dave Gerdes, now moved to Michigan from Chicago. While the bits were correctly read out, the cards themselves had several addressing problems and the amplifiers were saturating and the cards were removed. These problems were fixed on the prototypes and the cards were reinstalled. A sample threshold curve is shown in Fig. 21 - the system performed well. We are working with the Michigan group to try to get the system operational for run 1b.

Our group has become involved in the needed electronics for multibunch running which is expected to begin perhaps in 1997. In particular we are working with the PIG group at FNAL to develop a scheme to read out the strips and wires of preradiators and strip chambers and crack chambers. There is continuing work going on studying noise pickup in the strip chamber strips; the strips are most sensitive to noise pickup. The new front end will produce the trigger bits as designed for strip chamber wires and the preradiators, and a new interface to replace the CERES will be needed to use the new XFT track processor which is being developed at FNAL for multibunch running. All tracks will be presented by XFT simultaneously instead of the sequential list in the present CFT track processor system. (L. Nodulman)

2. Soudan Detector Installation

Three new halfwalls were added to the Soudan 2 detector during the first half of 1993. (A halfwall is a subassembly of eight 5-ton modules, stacked four across and two high.) This increased the operating mass from 791 to 894 tons. In addition to new halfwall construction, four of the 5-ton modules in one operating halfwall were replaced in order to improve performance. These modules are being upgraded and will be reinstalled in the detector. A number of anode high voltage splitters, which allow top and bottom modules to operate at different, optimum wireplane voltages, were installed while the detector was open for module replacement.

Run 47552

21/05/93 09.38

Fig. 21. The sum of read out pulse height in wire channels without (histogram) and with (dots) a trigger bit set. This is a sum over 16 channels in place. A reasonably sharp threshold and good efficiency are observed.

A major milestone was passed in April with the arrival of the last 5-ton module at the Soudan underground laboratory. All 227 modules constructed at Argonne and at the Rutherford Appleton Laboratory in England are now at Soudan. The completed detector will consist of 224 modules and will have a total mass of 963 tons. All but the last 16 modules were installed and operating at the end of June.

Other installation activities included the deployment of 44 new active shield proportional tube manifolds; 21 of these were operational by the end of June. The new shield tubes are part of the North wall and floor complex which is less important for contained event physics than the large ceiling, wall, and floor panels which have been in operation for several years. An additional 85 tubes will be installed to cover the few remaining holes in the active shield. During a major shield maintenance period in June the electrical connections to many shield tubes were upgraded to improve efficiency and reliability, and a high voltage plateau of all 1442 operating shield tubes was performed.

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 module assembly and installation. Electronics work focused on the identification and repair of analog-to-digital converters which showed anomalous responses during a new calibration procedure. Argonne physicists are developing software to study the dE/dx response of the detector to cosmic-ray muons. This information is needed in order to make use of track ionization measurements for particle identification in contained events. (D. Ayres)

3. STAR Calorimeter

a) Brookhaven National Laboratory E-880 Experiment

The construction of the 4.7 tesla-meter solenoid snake was completed and it was installed in the 10-foot long AGS straight section, I20. The role of the partial snake is to provide stable polarized beams with higher polarization.

The Argonne group is responsible for the design and construction of the internal polarimeter in the AGS. The polarimeter is ready for installation and testing.

b) Polarized pp Collisions by RSC

The proposal on spin physics at the RHIC collider was presented for the second time at the Brookhaven PAC meeting in February 1993. The PAC endorsed the physics addressed by the RHIC Spin Collaboration (RSC). This constitutes Phase I approval. After the first-stage approval, the Brookhaven PAC requested detailed Monte Carlo calculations for various proposed experiments on the detector of choice equipped with whatever additional supplements that we would require.

Our proposed experiments would use the STAR detector. STAR utilizes a time projection chamber to measure hadron production over a large solid angle. Other important components of STAR, for which the Argonne group is responsible, include an electromagnetic calorimeter and shower maximum detector. Due to limited funds, we plan to carry out the proposed physics in the following manner:

i) With one-half barrel calorimeter (180° ϕ coverage with $+90^\circ$ to -90°), we will detect large- p_T jet and di-jet events. In particular, in the dijet measurements we can determine $\Delta G/G = [G^+(x) - G^-(x)]/[G^+(x) + G^-(x)]$, where ΔG is the helicity distribution carried by gluon fields, at x_1 and x_2 as:

$$A_{LL} = [\Delta G(x_1)/G(x_1)] \cdot [\Delta G(x_2)/G(x_2)] \cdot \hat{a}_{LL}(gg \rightarrow gg).$$

ii) With the full barrel calorimeter and the shower maximum detector, we will measure inclusive direct- γ production at $\sqrt{s} = 200$ GeV. Direct photons are produced through the $q\bar{q}$ annihilation subprocess and q - g Compton subprocess, $qg \rightarrow \gamma q$. The Compton process is the dominant one in pp interactions. We can then determine $\Delta G/G$ using the relation

$$A_{LL} = [\Delta u(x_1)/u(x_1)] \cdot [\Delta G(x_2)/G(x_2)] \cdot \hat{a}_{LL}(qg \rightarrow \gamma g),$$

where values for $\Delta u/u$ are derived from EMC-SMC experiments.

We also propose to measure the parity-violating asymmetry in W and Z production at 500 GeV.

For W^+ production:

$$A_L^{PV} = \frac{\Delta u(x_1) \bar{d}(x_2) - \Delta \bar{d}(x_1) u(x_2)}{u(x_1) \bar{d}(x_2) + \bar{d}(x_1) u(x_2)} \hat{a}_L$$

From this measurement, we will extract the sea-quark spin distribution and test standard-model couplings.

iii) With the full barrel and an endcap calorimeter, we propose to measure direct- γ production and use the measurement of the "away-side" jet to determine the spin-dependent gluon structure function with respect to x .

We also propose to measure the Drell-Yan process (at 200 GeV c.m. energy) to study the sea-quark helicity distribution and the quark transversity distribution in polarized protons. (A. Yokosawa)

D. SSC Detector Research and Development

1. Overview of ANL SSC Related R&D Programs

Work on components of the SDC detector increased in pace during the first half of 1993. The largest efforts were directed toward the calorimeter and especially work on the barrel electromagnetic calorimeter (EMC) for which Argonne has the lead. The rate of work was abruptly lowered following the House vote to stop work on the SSC on June 17, but there was little impact during this reporting period.

For the barrel EMC absorber, final design details were completed for the full size prototype wedges. Virtually all of the frame for the first absorber casting was fabricated and about half of the work was done on the second frame. Large pieces of the mold were imminently expected from the Westinghouse Science and Technology Center to allow test fitting of frame and mold components. Several test castings were made, including some which modeled the largest plates of the full size casting. This exercise was repeated as some difficulties were uncovered and in order to explore the effect of variations in procedure. These activities brought the group almost to the point of being ready to cast the first full size absorber if funding had continued from SSCL.

Also working toward the prototype modules and the shared instrumentation by ANL and FNAL, Argonne group members worked with FNAL to develop fiber routing strategies on a mockup of a calorimeter wedge.

New in this period were two activities concerned with the newly discovered high neutron fluxes in the SDC detector. Predictions of the fluxes were made throughout the detector through simulations with the CALOR code system. This activity was carried out in collaboration with ORNL, University of Tennessee, LANL, and SSCL. A portion of the activity was focused on achieving agreement between three different codes used for these calculations, so that the results could be considered reliable. Second, arrangements were made to measure the effect of neutron irradiation on scintillator similar to that which what will be used in the calorimeter, using a TRIGA type research reactor at Western Washington University. Much effort has been expended to assure accuracy of dosimetry, in contrast to some other measurements.

Work was begun on planning for the procedures of "final assembly" of the calorimeters before they are integrated into the overall detector. Argonne has the lead in this task for the SDC calorimeter group. Although any final assembly activity is many

years off, it is necessary to do some of that planning in parallel with calorimeter design to ensure that the task can eventually be carried out successfully.

Argonne continued to play a strong role in design of computing and data systems for the SDC. In addition to participating in task forces of the SDC computing subgroup, Argonne leads the PASS collaboration which is developing software for data storage and access for the multiples of 10^{15} bytes of data expected per year when SDC runs. PASS is preparing to test the Mark 1 prototype of its system on platforms at the SSC Laboratory (single processors with hierarchical storage) and ANL (massively parallel system with hierarchical storage).
(L. Price)

2. SDC Calorimeter Engineering Design

a) Overview

The key focus of the work carried out from January 1st through June 30th, 1993 has been completion of final design details of the module structure and fabrication of frames to cast two full scale prototype calorimeter wedges. As part of this effort, a full review of the design was held on March 1-2 by the Argonne and Westinghouse Science and Technology collaboration. This identified only a few outstanding technical issues. All have since been resolved. Some final design changes prevented us from meeting our intended (optimistic) schedule. Nonetheless, as of June 30th the first of the four frames needed was 95% complete and the remaining three were in various stages of assembly. A photograph of this first frame assembled and laid out to check the fabrication accuracy is shown in Fig. 22. Figure 23 shows the deviation from nominal of the position of the stainless steel bulkheads (used to support the lead along the length) for the first two frames. These have met most of our dimensional tolerances which are typically 0.020" on absolute position of structural elements and flatness.

Several subtasks were carried out within the design program and are described in some detail below. These covered areas which are as diverse as neutron damage, mechanical testing of lead plates and support frames, final assembly, and facility design.

b) Mechanical Design Tests

In 1992 a test mold was fabricated for casting a representative set of the longest plates in the calorimeter. This mold was used five times in the first half of 1993 to test the many features of the prototype design. We evaluated three lead alloys of calcium and tin, chosen to give increasing modulus, and two mold release preparations (one of which, a silicon based agent, failed completely). Mechanical features of the frame which were tested included the endplate lead connections, the angled bulkhead tabs, and the stainless

Fig. 22. The stainless steel frame for the first full scale prototype in the final stages of assembly.

SLOT DISTANCE FROM THE END

DIFFERENCE FROM NOMINAL

Figure 23. Fabricated position, relative to design, of slots in the front plate used to locate the stainless steel bulkheads for the first and second prototype frames.

steel reinforcement tubes which were added to the design due to a concern that the safety margin was inadequate. The critical measurements made on these castings were the plate deflections within the structure (Fig. 24). These are significantly higher than originally calculated using finite element modeling of the structure. As a cross-check following these measurements, the plates were cut from the structure and deflections measured for two end connection types (fixed and simply supported). These are shown in Fig. 25 for one of the plates tested. As was expected, the deflections are about four times larger for a simply supported plate. However, there is a clear increase in deflection with time. This was completely unexpected. A series of time-extended tensile tests on cast lead bars confirmed this conclusion and showed that the effective Young's Modulus of lead is a function of time under load (Fig. 26). Using the asymptotic value we repeated the finite element analysis of deflections on our ten tower mechanical model casting using a longitudinal load equivalent to that resulting from gravity in the full scale model. The measured and computed endplate deflections as a function of height were then found to be in good agreement (Fig. 27). The earlier test castings had been marred by problems varying from complete failure of the mold release to distortion and separation of the lead plates from the bulkheads. The fifth, and final, casting in this period incorporated essentially all of the features of the current module design and was an unqualified success.

c) Optical System Tests

The Argonne group has developed one of two alternative layouts to route fibers from the scintillator tiles along the surface of the wedge to the phototubes. These are to be evaluated by an SDC review panel in the fall, and a single concept will be chosen.

Following the results of the mechanical tests described in the previous section, it was determined that the lead plates would sag onto the surface of the scintillator tiles in a portion of the calorimeter. We are, therefore, studying the effect of bending and compression on scintillator light output. To date, the principal variations seen in response are attributable to gain change in the photomultiplier tubes.

d) Neutron Irradiation

During this half year, we initiated a collaboration with physicists at Washington State University to carry out neutron irradiation studies at the TRIGA reactor there. The initial work included a study of shielding configurations to minimize the gamma ray dose in the region of the beam tube in which our tests will be carried out. The observed dose is reasonably well described by EGS calculations with the exception of that at large

MAX. DISPLACEMENTS

PLATE # 6

Fig. 24. Plate distortion as a function of position for plates in one of the "high η " test castings.

BOW IN PLATES

MEASURED RELATIVE TO ONE END

Fig. 25. Single plate deflection as a function of end connection for a typical plate and for that plate measured in the high η test casting.

Fig. 26. Young's modulus as a function of time under load for a Ca-Sn lead alloy.

ENDPLATE DEFLECTIONS 10-TOWER CASTING

Fig. 27. Measured and computed endplate deflection as a function of position. The finite element calculation uses the asymptotic value for the Young's modulus of lead from Fig. 26.

thickness of lead absorber. Here there is an indication of photon backgrounds coming from the reactor shielding. While studying this issue, we obtained and installed code to unfold neutron spectra from activation foil data. This code is now running at both ANL and WSU. Much of the experimental work at the reactor will be carried out by a summer student. With most of the shielding and experimental setup issues addressed, we anticipate an extensive series of tests to be carried out in July and August.

e) Final Assembly

With a view to extended involvement in the engineering areas associated with the SDC, we have undertaken a role in the "final assembly" task. At this stage of the detector construction, this is a planning exercise to determine building facilities required, facility utilization, assembly sequence, and time required. Detector integration issues are also being addressed. A typical integration issue was a change in the design of the coil supports needed to optimize the available space in the gap between barrel and endcap calorimeters through which all of the readout from the central tracking detector must pass. These coil supports required a stiffening gusset, which in turn forced a reduction in fiducial volume of the electromagnetic calorimeter. An orthogonal type of question pertained to scheduling and facilities in the event that the construction schedule is increased in time to reflect a lower funding profile. The specific outcome of this exercise had significant impact on the facilities required to carry out the assembly. In particular, this scenario would allow assembly in the underground hall, thereby removing the need for the heavy load path.

f) Prototype Module Fabrication

As of June 30, 1993, the frame for the first prototype was 95% complete and should be finished in early July. The second frame is 50% complete; the remaining two frames are in the early phase of fabrication having most parts made but little assembled. The mold, in which the frame is inserted for casting, is being procured by the Westinghouse Science and Technology Center in Pittsburgh. This is considerably behind schedule on a few key items. The mold base and a first set of aluminum inserts are presently at WSTC and have been checked against specification. These will be shipped to Argonne in early July to enable us to begin fit and tolerance checks with the frame.

g) Calibration and Test

In parallel to the main engineering effort, members of the group carried out studies on calorimeter calibration issues. These fall in three areas. The first is scintillator tile calibration using radioactive sources where we used the two 10 tower prototypes fabricated in 1991 to study the intrinsic precision achievable using the source tubes embedded in the lead absorber plates. In addition, we have studied the possibility of using sources traveling along the edges of tiles as we see definite design advantages in this configuration (Fig. 28). These measurements have been given to Virgil Barnes at Purdue University who is modeling source calibration to quantify the reliability of the energy sharing function needed to give a single tile calibration. These data will be reviewed by the SDC calorimeter group later this year. The second area of involvement is in the design of a cosmic ray test stand to be used for the two full scale prototypes. Initial work on trigger scintillators, tracking, and supports has been carried out. Finally, the SDC anticipates using a test beam in the MP9 area at Fermilab to beam test the prototypes. The Argonne group is fortunate in having the unique expertise of Dave Underwood, who has contributed significantly to the design of the beam optics and magnet layout for this new beamline.

h) Assembly and Test Room Operations

In Building 366, the former ZEUS assembly room is used for small scale assembly and test operations for the SDC electromagnetic calorimeter design and construction effort. In it, at present are

- 1) A mechanical test model on which stress and strain measurements are made;
- 2) A mechanical test casting, used to test the design concept for the longest span of lead plate;
- 3) Fixtures and gauges to test gravitational load deflections on individual lead and scintillator plates; and
- 4) Tools and fixtures to fabricate source tube and reinforcement tubes for the full scale prototypes which are presently under construction.

Operations carried out in the area include assembly and disassembly of the molds and frames used for the casting. The principal hazards associated with the project are lead handling and methyl chloride used in an aerosol spray for the application of a graphite mold-release agent. All lead handling is carried out either at the foundry (at present Tarracorp in southern Illinois) or in this area. Lead handling operations include mold

Fig. 28. Signal response as a function of position for a Cs^{137} scan along the edge of a test stack of steel and scintillator tiles.

cleanup and flashing removal which pose a minimal level of risk as the lead is removed in sheets and large pieces. This scrap lead is returned to the foundry and recycled. One operation (cleanup of lead plates within the casting) does have the potential to produce airborne lead particles and for this operation air-purifying respirators are worn. These are also used at the foundry where lead vapor is present. All personnel involved in this area of the project have had the appropriate lead handling training and in addition were given special advise by Gary Meyers from Industrial Hygiene.

Application of the mold release (a painting operation) has been carried out in Building 362 in well ventilated areas for the small scale tests. A second area has been prepared to carry out this application of mold release on the full scale mold. This room has several windows to allow external monitoring of the work in progress and we will use a two man crew for this operation. For the prototype, we are engaged in discussions with Industrial Hygiene on our proposed plan of operation. The application of mold release will be carried out in an externally ventilated (and air-conditioned) enclosure in the 366 area. Initially, personnel will wear Tyvek suits and use self contained breathing apparatus. Air quality will be monitored by Industrial Hygiene and following completion of the first pair of absorber structures the safety procedures will be reviewed. We are aware of the health hazard associated with the use of Tyvek suits, which we feel is potentially more serious than any of the other hazards in the area, and are in the process of reviewing the exact work plan for the area. The necessary equipment is in the process of being procured. Our initial plan is being reviewed to reflect the outcome of the above discussions and will be re-submitted for approval to the HEP Division Safety Committee in the near future (well in advance of the start of anticipated operation in August this year).

(J. Proudfoot)

3. Simulation Studies for the SDC Detector

The evaluation of neutron and photon background for the SDC detector and electron identification studies for the barrel electromagnetic calorimeter were the major simulation activities during this period.

The high energy and high luminosity of SSC cause radiation damage problems for the detectors. Almost all the radiation to the SDC detector comes from the 20 TeV on 20 TeV pp collisions. The design luminosity corresponds to 10^8 collisions per second. This luminosity is maintained for 10^7 seconds for each year. The simulation group at Argonne (P.K. Job, R.E. Blair, and L.E. Price) in collaboration with the Oak Ridge, Los Alamos and SSC Laboratories carried out detailed calculations on neutron and photon background at various locations of the detector and on the shielding requirements. Since the different

national labs have expertise on the different aspects of the problem, extensive benchmarking of the particle transport codes CALOR89, GCALOR, LAHET, MARS and FLUKA was carried out on a simple iron-concrete shielding configuration. After properly tuning up the new GCALOR package the agreement between the codes is excellent.

At ANL we used ISAJET in combination with CALOR89 to evaluate the total neutron fluences per year at various locations in the SDC detector. In CALOR89 the low energy neutron fluence is precisely estimated by MORSE. The low energy neutrons are important because they can produce radioactive nuclides in large quantities. We modified the MORSE code to estimate the low energy gamma fluence from the (n,γ) reaction. The low energy photons were of concern because of the background they can cause in the muon chambers. Figures 29a and 29b give the average axial and radial neutron fluences in the SDC detector, and Figs. 29c and 29d give neutron and gamma spectra at a typical location in the detector.

We examined the effectiveness of graphite at reducing albedo neutrons at the front face of the forward calorimeter. The study was done varying the graphite thickness in the front face of the forward calorimeter. The results show that although 50 cm of graphite could cut down the albedo neutrons by an order of magnitude, the albedo energy is cut down only by a factor of two.

The effect of the iron bulkheads upon the electromagnetic calorimeter response was evaluated using the EGS4 code. The bulkheads are 0.5 mm steel plates for structural strength between the towers of the electromagnetic calorimeter in the incident beam direction. The Loss of light and the worsening of the electromagnetic resolution was evaluated as a function of the thickness of the bulkhead and the point of incidence of the electrons. It was concluded that a 0.50 mm bulkhead (the design thickness) will cause a light loss of 10% and corresponds to worsening of EM resolution by only 2-3% in the event the electron is incident directly on the bulkhead.

Work is in progress on defining electron and photon selection criteria in the barrel. This is a prelude to background studies to determine at what level jets produce background for 'poorly identified' electrons and 'well identified' photons. A follow on study is planned to see how the tracking material degrades the baseline efficiency. For this purpose we modified the EGS4 user code extensively to study a 9 tower EM calorimeter with inner magnetic coil and structural plates. electrons, photons and π^0 s at energies 10, 50 and 100 GeV are being simulated with EGS4. Thirty six parameters per event relevant to incident particles are saved on the PAW ntuple files including leakage

Fig. 29. Average axial neutron fluence and the neutron spectra in the SDC detector.

from each of the towers. The angle of incidence is smeared along the axis defined by the colliding beam. These ntuple files are being analyzed. (P. K. Job & R. Blair)

4. SDC Data Systems R&D

Two HEP physicists (Larry Price and Ed May) continued to participate in meetings and workshops associated with the SDC computing working group and various task forces.

Principal goals of this effort are the design and prototyping of the offline computing environment and the data access and storage systems for the SDC experiment.

Two physicists (Price and May), a computer scientist (Dave Malon) from EIS division and a scientific programmer/analyst (Dave Lifka) continued to work on the "Petabyte And Storage Solutions" (PASS) project. This is a HPCC and HEP supported R&D project to study the use of database technologies for the storage of and access to scientific data on the scale of a few petabytes (10^{15} bytes). The SDC experiment 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 lab (LBL) and the SSC Laboratory.

We have extended the user interface built for the SIGgraph demo last summer. We have done an implementation of the PASS QTool concept to provide a unified single user interface for queries and displays to each of the three database technologies PASS has studied: relational, object-oriented and object-manager. These are Motif based systems and provide: schema browsers, query editors, results browsers, query-by-forms (with translators to SQL and C++) and an interface to the Fermilab Ntuple viewer HistoScope.

A new version of the PTool/VTool using 64bit pointer technology from UIC was debugged and loaded with CDF J/psi data using the new object-oriented data model designed during the previous reporting period. It will be used as the basis of the ANL/UIC part of the Mark 1 trials to be done at the SSCL during the summer of 1993. The hardware platform at the SSCL will include a Sun Sparc server, a SGI server, 10 GB of shared disk and a dual ported DD2 tape drive capable of reading and writing data at 10MB/sec onto a 25GB cartridge media. Thus substantial planning work has been done to move from the Mark 0 scale (100MB to 1000MB data stores) to the Mark 1 scale (1GB to 25GB). Testing has been done at the SSCL.

Considerable effort has been devoted to the design and prototyping of parallelized versions of the database and data store systems by PASS, focused in particular at applying to the second part of the Mark 1 trials. ANL has focused on the integration of the ANL MCS developed P4 parallel programming tool set with the UIC PTool/VTool object manager. An HPCC funded R&D facility has been sited at the ANL MCS division.

The installation of an advanced IBM parallel computer has begun. The SP1 and a network attached I/O system consists of file servers, a 220 GB RAID disk store and a 6 TB DD2 tape robot system. This is a ideal facility for the second phase of the PASS Mark 1 trials of a data system built on a IEEE Mass Storage model and using PASS design software for testing at the scale of 100GB to 1TB. PASS obtained early access to a 32 node SP1 which has 32 GB of local disk. The single processor version of the PTool/VTool based CDF database has been ported to the IBM RS6000 based environment. Early versions of the parallel data access database have been successfully implemented and run on the SP1.

Active study of how to use the hierarchical storage has begun, so that it can be used for the evaluation of the PASS Mark 1 data access and database system can be made when the hardware installation is complete in the fall of 1993.

An invited talk and paper entitled "Requirements for a System to Analyze HEP Events Using Database Computing" was presented at the 12th IEEE Symposium on Mass Storage Systems.

ANL hosted a PASS collaboration meeting during March, 1993. (E. May)

II. THEORETICAL PROGRAM

A. Computational Physics

The computational physics effort is devoted to numerical simulations of quantum field theories defined on discrete lattices. Foremost among the lattice field theories we (Don Sinclair and Se-Yong Kim) have been studying is lattice quantum chromodynamics (QCD), in which QCD is defined on a discrete spacetime lattice which supplies the needed ultraviolet regulation of the theory and facilitates numerical simulations. Such lattice QCD simulations are aimed at measuring such non-perturbative phenomena as hadron masses and the strong interaction contributions to low energy matrix elements, and at studying QCD at high temperatures and/or baryon number density. These latter studies are relevant to relativistic heavy ion collisions, the nature of the early universe, and the interior of neutron stars. We have also used lattice methods to study the electrodynamics of a compact scalar field to understand better the non-perturbative interplay between Higgs fields and vector gauge fields. Such studies were directed to better understanding the Higgs sector of the standard model. Work is also underway on studying theories with 4-fermion interactions on the lattice.

We have been using the Intel Touchstone Delta computer at Caltech to estimate the spectrum of low mass hadrons in the quenched (valence quark) approximation to lattice QCD. We are currently extending our calculations of the hadron mass spectrum of quenched QCD on a $32^3 \times 64$ lattice with a new set of parameters. Since this lattice is still too small to accomodate 140MeV pions with a lattice spacing, a , small enough to achieve scaling and restoration of continuum lattice symmetries, something must be sacrificed. In our earlier simulations we demanded a lattice spacing, a , small enough to achieve scaling and symmetry restoration ($a \sim 0.05\text{fm}$), leaving us with a rather small spatial box (length $\sim 1.6\text{ fm}$). This restricted us to pions with masses $>\sim 300\text{MeV}$. In the current simulations we have increased our lattice spacing to $\sim 0.1\text{fm}$. At this value, we are at the edge of the scaling regime, but continuum flavor symmetry is sacrificed. However, the larger spatial box (length $\sim 3.2\text{fm}$) could accomodate pions of near their physical mass (because of our limited resources on the Delta we restrict ourselves to pion masses $>\sim 200\text{MeV}$). Some preliminary results on pion masses are shown in Fig. 30.

In collaboration with John Kogut (University of Illinois) and his collaborators we have studied the electrodynamics of a compact scalar field using the CRAY C-90 at NERSC. The monopole loop excitations of such a theory gave hope that it might possess a non-trivial phase structure. If so then this would have indicated that the Higgs sector of

Fig. 30. Pion effective mass plots from our simulations on a $32^3 \times 64$ lattice.
a) At $\beta=6$ (preliminary).
b) At $\beta=6.5$.

the standard model might have non-trivial non-perturbative behavior once the effect of gauge fields was taken into account. Early studies of this theory had indicated that it did indeed have 2 phases and that part of the phase boundary was second order. What we found, however, from the scaling behavior of the specific heat, was that the theory was logarithmically trivial (similar behavior to that of a ϕ^4 theory.).

We have also been involved with John Kogut and Maria-Paola Lombardo (University of Illinois) in an attempt to study the behavior of lattice QCD at a finite chemical potential for baryon number, within the quenched approximation. Here, by looking at the hadron spectrum in addition to other order parameters we hope to sort out the confusion that has arisen from earlier attempts to study this domain. So far we have noted the expected result for small chemical potential, i.e. that $\langle \bar{\psi}\psi \rangle$ and the meson spectrum remain unchanged, while the baryon mass is effectively reduced by 3μ where μ is the chemical potential. We are now making measurements in the intermediate chemical potential regime which should clarify the situation.

As part of the multi-institutional HTMCGC collaboration we have been extending our simulations of the thermodynamics of lattice QCD on a $16^3 \times 8$ lattice to a lower quark mass ($m_q/T = 0.05$ down from $m_q/T = 0.1$), closer to the true u and d quark masses for temperatures, T , of interest. Here we are trying to determine the position and nature of the transition from hadronic matter to a quark-gluon plasma, and to measure those properties of the plasma which might help distinguish it from the hadronic matter phase if it is produced in heavy ion collisions. For these simulations we are using the Connection Machine (CM-2) at PSC. We use the hybrid molecular dynamics simulation method which allows for the inclusion of light dynamical quarks.

In collaboration with Geoffrey Bodwin of the theory group we are attempting to calculate certain matrix elements which describe the decays of the charmonium and upilon states on the lattice. For this we are using the $16^3 \times 32$ configurations at $g^2=1$ which have been generated for our finite baryon number density calculations. So far we have calculated charmonium masses as a way of choosing the correct input values of the charmed quark mass and calculating the values of the charmonium wave function at the origin which are needed to calculate these matrix elements.

One of us (S.Kim) has recently started a project with J.B.Kogut to study the Nambu-Jona Lasinio model (a fermion model with 4-fermi couplings) on the lattice in 3 and 4 dimensions. This was motivated on by our earlier studies of QED on the lattice, where we discovered that it had non-trivial behaviour due largely to induced 4-fermi couplings. This is the latest in our studies aimed at discovering what field theories in

addition to QCD are non-trivial. This is important for finding candidate "grand-unified" theories.

Finally we have been involved in the formation of a group which seeks to combine the expertise of computer scientists with those of lattice gauge theorists to work on problems in our field. To fund this we have submitted a proposal for NSF/HPCC support.

(D. Sinclair)

B. Monte Carlo Event Generation

An almost essential tool for the interpretation and analysis of experimental data is a Monte Carlo event generator. Such a program is HERWIG, which, by employing perturbative QCD and phenomenological models when necessary, attempts a complete description of high energy particle interactions. Working with members of the E683 collaboration at FNAL, Ian Knowles has developed new subroutines to complete HERWIG's representation of photon-hadron collisions. This work has subsequently been successfully applied to describe data. Also, at the request of the SLD collaboration at SLAC, Knowles has re-written HERWIG's e^+e^- subroutines for hadronic production to take full account of the effects of particle masses, to include the option of Z' production, and to allow for arbitrarily polarized lepton beams. His work is continuing with new program options being developed for simulation of deep inelastic scattering, Higgs production, Drell-Yan production and anomalous gauge boson couplings; it also aims for a complete rationalization of the program's treatment of electroweak interactions.

(I. Knowles)

C. Lattice Formulation of Chiral Gauge Theories

For some time, Geoffrey Bodwin and Eve Kovacs (Fermilab) have been studying the problem of formulating gauge theories containing chiral fermions on the lattice. This problem is of practical importance, as it is central to any numerical simulation of the standard electroweak theory. At a more fundamental level, the existence of a nonperturbative (e.g. lattice) ultraviolet regulator for chiral gauge theories is a crucial issue in assessing the consistency of such theories.

A serious difficulty in transcribing continuum field theories to the lattice is that the simplest transcription yields not only the fermions in the original theory, but also unintended "doubler" fermions, some of which have a handedness opposite to that of the original continuum fermions. One way to eliminate the effects of the doublers is to give them a Wilson mass, which tends to infinity as the lattice spacing is removed.

Unfortunately, the Wilson mass breaks the chiral gauge symmetry, thereby endangering the renormalizability and unitarity of the theory. Such breaking of the chiral gauge symmetry seems to be unavoidable; according to various no-go theorems it is an inevitable consequence of the elimination of the doublers.

In previous work, Bodwin and Kovacs have argued that violations of the chiral gauge symmetry have the form of local renormalization counterterms and that they can, therefore, be removed by the inclusion of such counterterms in the original theory. Bodwin and Kovacs have proposed two methods for implementing a large class of the required counterterms "automatically", i.e., without recourse to tuning of the counterterm coefficients. Their method restores an exact chiral gauge symmetry to the even-parity part of the effective gauge-field action. In the absence of multi-loop corrections, all of the violations of the gauge symmetry in the odd-parity contributions to the effective action correspond to the Adler-Bell-Jackiw anomaly and cancel when one includes a suitable complement of physical fermions. It had been hoped that, in the presence of multi-loop corrections, the violations of chiral symmetry could be removed by tuning the coefficients of just two counterterms. This is the case at the two-loop level. Unfortunately, it appears that all of the gauge-variant counterterms allowed by the lattice cubic symmetry are generated by higher multiloop corrections.

Recently, Bodwin and Kovacs have proposed a way out of this dilemma. One can subdivide the gauge-field lattice into a finer mesh on which the Dirac fields reside. In the limit in which the Dirac-field lattice spacing goes to zero before the gauge-field lattice spacing, the chiral gauge symmetry of the odd-parity part of the effective action becomes exact. Since the even-parity part of the effective action is rendered exactly gauge-invariant by the original Bodwin-Kovacs prescription, it does not require this limiting procedure. One can show that the odd-parity part of the effective action is finite in the limit of zero Dirac lattice spacing (for nonzero gauge-field lattice spacing). Thus, it may be possible to compute that limit to a high degree of accuracy in a practical numerical simulation by extrapolation from a finite Dirac lattice spacing. (G. Bodwin)

D. Longitudinal Structure Function at Intermediate x and the Gluon Density

Ed Berger and Ruibin Meng continued work, described in prior semi-annual reports, aimed toward the determination of new sets of parton densities of the nucleon from global fits to a large body of hard-scattering data. Focusing on aspects of data not considered by others, they have determined sets of parton densities having significant and interesting differences from those of other published sets. As Berger and Meng explain in Phys. Lett. B304 (1993) 318, these differences, particularly in the region of

intermediate Bjorken x , could be explored further with data on the longitudinal structure function F_L from experiments at DESY's ep collider HERA. The new parton densities have been distributed widely in the high energy community and are included as part of the latest release of the CERN database compilation PDFLIB, a library of all available parton density functions. It would be desirable to maintain this effort in the future, to incorporate new data as they appear, for example from the ZEUS and H1 experiments, but it appears doubtful that it will be possible to do so. (R. Meng)

E. Lattice Measurement of Matrix Elements for Decay and Production of P -Wave Quarkonia

In 1992, Geoffrey Bodwin, Eric Braaten (Northwestern), and Peter Lepage (Cornell) formulated a method treating the decays of P -wave quarkonia rigorously in perturbative QCD. In this approach, the decay rates and production cross sections are each expressed as a sum of two terms: one corresponding to a subprocess in which the heavy $Q\bar{Q}$ are in a color-singlet P -wave, and the other corresponds to a subprocess in which the $Q\bar{Q}$ are in a color-octet S -wave. Each term factors into a hard parton-level subprocess, which can be calculated in perturbative QCD, and a nonperturbative matrix element. In the case of charmonium χ states, a phenomenological analysis determines the decay matrix elements to a precision of about 40%; the production matrix elements are known from B-meson decays to charmonium with less precision.

Bodwin, Don Sinclair, and SeYong Kim have begun a project to measure the nonperturbative matrix elements in a lattice simulation. In the case of the decay matrix elements, the measurement will provide an important check of the consistency of the phenomenological approach, the lattice method, and the underlying heavy-quark formalism. In the case of the production matrix elements, the lattice measurement should yield more precise values than does the B-meson-decay phenomenology and, consequently, could have important implications for calculations of the rates of χ_c production at hadron colliders. The measurements will make use of the lattice version of the nonrelativistic heavy-quark effective field theory formulated by Lepage and collaborators. The simulation will be carried out using existing quenched gauge-field configurations at $\beta = 6.0$ on a $16^3 \times 32$ lattice. Preliminary measurements of the S -wave and P -wave spin-singlet propagators have been carried out, and the results are consistent with expectations. (G. Bodwin)

F. Transverse Momentum Distributions for Heavy Quark Pairs

The distribution in the transverse momentum $q_{\perp}$ of a heavy quark pair, $Q\bar{Q}$ produced in hadron-hadron interactions is of interest for elucidating the underlying quantum chromodynamics (QCD) mechanisms, and its understanding is important in studies of $B - \bar{B}$ mixing and CP violation at hadronic facilities. In contrast to the case of pairs of heavy quarks produced in e^+e^- annihilation, $Q\bar{Q}$ pairs created in hadron hadron collisions are often not in a back-to-back configuration (even in a plane transverse to the beam direction). The net transverse momentum of the pair measures the imbalance between the transverse momenta of the $\bar{Q}$ and the Q . In report ANL-HEP-PR-93-57, Ed Berger and Ruibin Meng examine the quantitative description of the expected imbalance in QCD perturbation theory. Predictions for the region of large $q_{\perp}$ are based on exact order α_s^3 QCD perturbation theory. For the regions of small and modest $q_{\perp}$, they employ an all-orders resummation of leading logarithmic contributions associated with the emission of soft gluons from the initial-state partons that participate in the hard scattering process. In their paper, they present explicit results for $b\bar{b}$ pair production at the Fermilab Tevatron collider and for $c\bar{c}$ pair production at fixed target energies. An example of their results is presented in Fig. 31. Their calculation addresses a question of current interest and practical importance for heavy quark tagging at hadron facilities: if a Q is tagged with a given transverse momentum, what distribution in transverse momentum should one expect to observe for the associated $\bar{Q}$? (R. Meng)

G. The Mass of the Heavy Axion η_6

If electroweak dynamical symmetry breaking is due to a chiral condensate of color sextet quarks, there is a remnant low mass scalar particle, the η_6 , which at first sight is a conventional Peccei-Quinn axion. The η_6 can indeed be responsible for strong CP conservation in the color triplet quark sector, but it differs from a Peccei-Quinn axion in that it receives additional contributions to its mass from electroweak scale color instantons. In a contribution [ANL-HEP-CP-93-56] to the XVIth International Symposium on Lepton-Photon Interactions, Alan White discusses how dynamics analogous to "walking technicolor" provide an enhancement of the sextet chiral condensate by orders of magnitude compared to the electroweak chiral scale. This enhancement compensates for the exponential suppression of electroweak scale color instantons and as a result the η_6 axion can naturally acquire an electroweak scale mass. This implies the η_6 may be "the axion" and could also be a candidate for a new massive particle decaying into photon pairs---a few such two photon events have been observed in at least one experiment at LEP. (A. White)

Fig. 31. Distribution in the square of the $b\bar{b}$ pair transverse momentum as calculated by Berger and Meng. At large $q_{\perp}^2 > 50 \text{ GeV}^2$ they use fixed order α_s^3 perturbative QCD. For small $q_{\perp}^2$ they employ a technique for all orders resummation of leading logarithmic contributions associated with initial-state soft gluon radiation.

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

JoAnne Hewett and Tom Rizzo [ANL-HEP-PR-93-37] have constrained possible anomalous couplings of the top-quark to on-shell photons and gluons using recent results on both inclusive and exclusive radiative B decays. The CLEO collaboration has observed the exclusive decay $B \rightarrow K^* \gamma$ with a branching fraction of $(4.5 \pm 1.5 \pm 0.9) \times 10^{-5}$, and has placed an upper limit on the inclusive quark-level process $b \rightarrow s\gamma$ of $B(b \rightarrow s\gamma) < 5.4 \times 10^{-4}$ at 95% C.L. Using a conservative estimate of the ratio of exclusive to inclusive decay rates, the observation of the exclusive process implies the lower bound $B(b \rightarrow s\gamma) > 0.65 \times 10^{-4}$ at 95% C.L. If the t-quark possesses large anomalous couplings, then the resulting prediction of the rate for $b \rightarrow s\gamma$ would conflict with experiment. Hewett and Rizzo find that this process can lead to reasonable bounds on both the anomalous electric and magnetic dipole moments of the top-quark. For a value of the top-quark mass, m_t , of 150 GeV the anomalous magnetic dipole moment is restricted to lie in the range $(-2.6 \text{ to } 3.4) \times 10^{-16}$ e-cm, and the anomalous electric dipole moment is constrained to be $< 5.1 \times 10^{-16}$ e-cm. Essentially no limits are obtained on the corresponding chromoelectric and chromomagnetic moments, which enter the expression for the decay rate only through operator mixing. (J. Hewett)

I. q-Black-Body Thermodynamics

The excitations of various systems, such as nonlinear masers, interacting-magnon cavities, etc., are often modeled through q-oscillators, ultimately traceable to unpublished work of Heisenberg. In ANL-HEP-CP-93-39, Stamatis Vokos (Univ. of Washington) and Cosmas Zachos argue that determination of the black-body energy distribution in such systems cannot serve to distinguish q-excitations from plain oscillators. To counter fragmentation of opinion on the subject, they provide discussion, context, and exigently needed references.

Bosonic q-oscillators are bosons (they commute with each other). Consequently, free collections of them are described by the conventional Bose-Einstein distribution. However, *interactions*, which are naturally systematized by the q-oscillator formalism, suggest q-dependent partition functions and distributions should somehow interpolate between the Fermi and the Bose-Einstein distributions. Unfortunately, an easy, but specious, way to readily produce q-dependent density distribution functions is via Einstein's celebrated method of balancing the equilibrium absorption and emission rates from a black-body wall of a cavity without any direct reference to the hamiltonian of the gas of q-modes in the cavity. A *naive* application of this technique would appear to yield q-dependent distributions for free modes, which, however, are mere bosons.

Unfortunately, such misinterpretations have found their way into print many times. Nevertheless, this paradox has been resolved by correct taking of thermal averages, by Vokos and Zachos (in April 1992; subsequently, they appreciated that this paradox had also been resolved correctly by two groups, but also, incorrectly, by a surprising number of other authors). Of course, the conventional Planck-Bose-Einstein distribution ensues: In a cavity, emission and absorption rates may grow or shrink---and even diverge. They nevertheless balance to yield the Planck distribution.

A novel observation is that the minimum value of the frequency for which the absorption/emission rate of quasi-modes involved converges suggests an inverse maximal cavity size $1/\omega_c$, below which q-oscillators are not a good description of the system in question, at a given temperature; alternately, a maximum (quasi-Hagedorn) temperature for a given frequency. Depending on the physics problem addressed, it may also indicate a singularity of the coordinate description employed. (C. Zachos)

J. Elastic Scattering Phenomenology

Alan White, Kyungsik Kang (Brown), and Pierre Valin (McGill) have carried out a comprehensive comparison of a range of "Standard" and "non-Standard" theoretical models of high-energy elastic scattering with the latest set of experimental data. The results are contained in a paper entitled "The Status of Elastic Scattering", submitted to the Vth Blois Workshop on Elastic and Diffractive Scattering. With the new low value of the real part from UA4/2 and the increased total cross-section from CDF, there is now nothing very striking in the data and, perhaps unfortunately, little to discriminate between models.

In another paper submitted to the same meeting and co-authored with Martin Block (Northwestern), Francis Halzen (Wisconsin) and Bernie Margolis (McGill), the new experimental data is also included in a previous asymptotic amplitude analysis by Block and White and in a comparison with experiment of a "QCD-inspired" eikonal model developed by Block, Halzen and Margolis. (A. White)

K. Constraints on New Physics From Tevatron Dijet Data

The CDF Collaboration, using data from their 1988-89 run, has recently announced limits on the production cross-section as a function of mass for a narrow resonance in the dijet channel assuming various possible width-to-mass ratios for this resonance in the range 0.01-0.1. This is just the range anticipated for a rather large class of exotic objects which are predicted to exist in extended electroweak models. T. Rizzo has examined [ANL-HEP-PR-93-08, submitted to Phys. Rev. D] the implications of these

constraints on a number of scenarios involving Z' 's, W' 's, and fundamental spin-0 diquarks which can occur in E_6 models. The new limits obtained by this analysis were found to complement those arising from searches in the electron and/or muon channels. In the Z' case, most models were found to predict cross-sections below the CDF bounds so that no new limits were obtained. Exceptions to this general result were the Z' of the Foot-Hernandez Model, which was now excluded in the 260-600 GeV mass window; the Z' of the Left-Right-Symmetric Model (LRM), now excluded in the 480-560 GeV window; and the Georgi et al. Ununified Model for small values of the parameter s_ϕ . The resulting bounds on W' 's were found to be somewhat more significant due to the generally larger production cross-sections for these particles. For example, the W' of the LRM with $g_R/g_L = 1$ was now excluded in the 250-625 GeV mass window; the corresponding lower limit from the combined e and μ data is only 520 GeV. In the case of E_6 fundamental diquarks, no new limits were obtained *assuming* that the Yukawa coupling of this object to valence quarks was of electromagnetic strength or less.

(T. Rizzo)

L. Analytic Multi-Regge Theory and the Pomeron in QCD

Alan White has circulated Part II of an extensive article on the Pomeron in QCD. The 180-page article [ANL-HEP-PR-93-16] is entitled "Analytic Multi-Regge Theory and the Pomeron in QCD : II. Gauge Theory Analysis" and will be published in the review section of the Journal of Modern Physics A. Part I (J. Mod. Phys. A11, 1859 (1991)) was a comprehensive development of the general formalism of Analytic Multi-Regge Theory based on the analyticity properties of many-particle amplitudes.

The review aspect of Part II covers known results on the Regge behavior of vector bosons and fermions in spontaneously-broken gauge theories and the organization and extrapolation of these results into a full reggeon diagram description of the high-energy behavior of such theories. The aim of the original development of Part II is to extract the high-energy behavior of QCD (that is the Pomeron) via an infrared analysis of the reggeon diagrams describing the corresponding spontaneously-broken theory, as the symmetry-breaking is systematically restored. A key part of the analysis is the role played by massless quark infra-red anomalies in producing confinement in reggeon diagrams. Confinement can be understood as associated with the development of a reggeon-condensate at the stage when the full SU(3) gauge symmetry is partially restored to SU(2). This condensate is identified with the Pomeron condensate of the Super-Critical theory described in Part I. As a result contact is made between the Critical and Super-Critical Pomeron theories described in Part I and the Pomeron in QCD. (A. White)

M. Tests of a Model of Universality Violation

The universality of the strong and electroweak interactions is one of the hallmarks of the Standard Model (SM), and, although well established for the first two generations, a small universality violation (UV) in the couplings of the third generation remains a possibility. Li and Ma, motivated by the τ lifetime problem, have proposed an extended electroweak model in which UV's for the third generation only are realized in a natural manner. The deviations of the predictions of their model from those of the SM can be parameterized in terms of only two quantities, p and ε . In a recent paper [ANL-HEP-PR-93-20, submitted to Phys. Rev. D], Tom Rizzo compared in detail the predictions of the Li and Ma model with the data from LEP and the SLC; the CDF W mass measurement; and a fit to all τ mass, lifetime, and leptonic branching fraction data. This analysis incorporated SM radiative corrections, in a generalization of the Peskin-Takeuchi oblique correction parameterization. By combining all data except τ lifetime data, the 95% CL limit on ε was found to be 0.009 (assuming a top quark mass of 150 GeV) for all values of $0 \leq p \leq 1$. This implies that the τ lifetime itself cannot exceed its SM prediction by more than 1.8% in this model. The latest fit to all of the τ data has resulted in the determination $\varepsilon = 0.0076 \pm 0.0066$, which agrees with the radiative corrections analysis of the Li and Ma model but yields an inferior upper bound. The constraints on the p and ε parameters were then used to obtain predictions for the properties of the new gauge bosons, W' and Z' , expected in this model. It was found that these particles are most likely to be too massive to be directly produced at the Tevatron, while large event rates at the SSC are possible depending on the size of ε . (T. Rizzo)

N. Bounds on Anomalous Gauge Boson Couplings from $b \rightarrow s\gamma$

One of the important tests of the gauge theory nature of the Standard Model (SM) is to probe the trilinear couplings between the gauge bosons. So far, the only direct constraints arise from the measurements of the $W\gamma$ production cross section by the UA2 Collaboration. Indirect limits are, however, obtainable from considering finite loop-order processes which occur at low energies and are cut-off independent. Tom Rizzo [ANL-HEP-93-19, submitted to Phys. Lett. B] has used the recently reported results from the CLEO Collaboration on the branching fraction for the radiative decay, $b \rightarrow s\gamma$ to obtain limits on the two CP conserving $WW\gamma$ trilinear coupling parameters, κ and λ , whose values are fixed in the SM. The theoretical analysis of the decay included next-to-leading order operator coefficient evolution as well as QCD bremsstrahlung and appropriate phase space corrections. When these results were combined with those from UA2,

employing the bound on the top quark mass from the CDF analysis and the ratio of exclusive to inclusive radiative B decays as determined from lattice studies, it was shown that the remaining allowed region in the $\kappa - \lambda$ parameter plane was rather small in comparison to that allowed by the UA2 analysis alone and contained the SM prediction. Individual bounds on κ and λ separately were shown to be even more restrictive. This is the first time that a cut-off independent low energy measurement has been used successfully to constrain the anomalous gauge boson couplings. Further improvements in the CLEO measurements and an analysis by CDF similar to that performed by UA2 are expected to reduce the allowed region further. (T. Rizzo)

O. Extraction of Coupling Information from $Z' \rightarrow jj$

If a new neutral gauge boson, Z' , were discovered at the SSC or LHC, its various couplings should be determined in order to discover its origin within a specific extended electroweak model (EEM). Quite generally, this is a rather difficult task and a large number of techniques to extract the Z' couplings have been suggested during the past three years. All of these have some serious limitations. In a recent paper [ANL-HEP-PR-93-18, submitted to Phys. Rev. D], Tom Rizzo, building upon the analysis of the ATLAS Collaboration, has suggested that for some EEMs the $Z' \rightarrow jj$ mode may be observable above QCD backgrounds with sufficient statistics to provide information on the Z' 's coupling to quark pairs. The first step in this procedure is to make strong cuts on the transverse momenta p_t s and rapidities (η s) of the two jets: $p_t > 0.2M_{Z'}$ and $-1 \leq \eta_{j_1 j_2} < 1$. Secondly, it is assumed that the mass and approximate width of the Z' has been determined from the leptonic data so that only dijets with invariant mass in the range $0.7M_{Z'} < M_{jj} < 1.5M_{Z'}$ can be readily selected. Since Z' 's are rather narrow objects, the dijet excess will most likely occur in the signal region $0.9M_{Z'} < M_{jj} < 1.1M_{Z'}$ and all events outside this range are then treated as background and fit to a scaled polynomial of degree 7 (which gives the best $\chi^2/d.o.f.$). Third, the fit to the background is extrapolated into the signal regime and subtracted leaving a possible Z' peak which is then fitted to either a Gaussian or Breit-Wigner distribution and integrated. Fourth, the number of excess dijet events remaining after background subtraction is scaled to the number of dilepton events in the discovery channel to form the ratio R .

The ratio R is insensitive to both luminosity and parton distribution uncertainties and is easily calculable for any EEM. For a Z' of mass 1 TeV produced at the SSC, this analysis yielded a value of $R = 34.9 \pm 4.0$, with a model prediction of 30.5. When this is translated into a bound on the quantity $\kappa = g_R / g_L$ the 'data' yielded a 3σ allowed range

of $0.83 < \kappa < 1.11$ when $\kappa = 1$ was used as input in the simulation. Similarly, for a Z' with SM-like couplings, one obtains $R = 20.4 \pm 2.2$ with a value of 18.9 predicted by the model. In both cases an integrated luminosity of 10 fb^{-1} was assumed. However, for many other models, this integrated luminosity was found to be insufficient to extract a value of R with reasonable errors since many Z' 's have rather weak couplings. In a contribution to the Argonne Collider Workshop [ANL-HEP-CP-93-50], the expectations for the success of this technique at both the SSC and LHC for Z' 's of various masses arising from several distinct classes of models is discussed. For some models, it was shown that extraction of coupling information from $Z' \rightarrow jj$ was possible for Z' masses in excess of 2 TeV, provided integrated luminosities in excess of 30 fb^{-1} were available.
(T. Rizzo)

P. Energy Flow Measurement in Semi-Inclusive Deeply Inelastic Scattering at HERA

Preliminary experimental results from HERA have demonstrated its potential in measuring quark and gluon distributions, as well as testing QCD. In previous published work (Nucl. Phys. B371 (1992) 79), Ruibin Meng has shown how measuring the angular distribution of hadronic energy flow (with respect to the scattered electron's direction) provides yet another probe of QCD, analogous to the Drell-Yan process. This measurement is distinguished by small systematic errors and its allowance for parity violating contributions to be separated from parity conserving ones in the same experiment. It helps determine gluon distributions since gluonic contributions influence the hadronic energy flow distributions significantly. Presently, Meng is extending his predictions for the energy flow measurement from the large transverse momentum (q_T) region to the small (q_T) region, by resumming the leading and the next-to-leading order large logarithms to all orders in perturbation theory. This extension should provide a first test of the Sudakov formalism for the small (q_T) region in deep inelastic scattering. It could also help in the experimental investigation of the new kinematic frontier in Q^2 two orders of magnitude above the reach of present deep inelastic scattering experiments, where no appreciable large (q_T) event rates would be available.
(R. Meng)

III. ACCELERATOR RESEARCH AND DEVELOPMENT

A. Argonne Wakefield Accelerator R&D

Most of the Accelerator R&D effort during this reporting period was devoted toward construction of the AWA rf power supply and to safety related items. Notable points are listed here.

1. RF Power Supply Construction

Following the bankruptcy of the rf power supply vendor late last fall, the group recovered as much of its equipment as was possible from the closed plant and proceeded to complete the supply at Argonne. Many of the missing and unordered components had relatively long procurement times. Missing and/or incorrect electrical drawings also complicated the construction process, and most of the recovered printed circuit boards required re-work. Nevertheless, the modulator is now nearly complete and has been successfully tested using a dummy load. The last major item yet to be received is the tank in which the klystron and its step-up transformer are to be mounted. Provided the scheduled delivery date holds, full power rf tests of the supply will start in the fall. Low power components of the rf system are now being assembled and tested. They are expected to be operational by the time they are required.

A low conductivity water (LCW) system was constructed to cool the klystron and its magnet. This system has been installed, commissioned, and is ready to be plumbed.

Recovery from this unfortunate bankruptcy is now almost complete and has been done in considerably less time than some observers had feared.

2. Laser Pulse Shaper Tests

Shaping of the 2 ps long, 2 cm diameter laser pulse before it impinges upon the photocathode in the rf electron gun is an important feature of the AWA design. This is done by a special device developed by the group, which consists of a set of precision ground cylindrical steel sleeves. The end of each cylindrical shell is polished and coated with a multi-layered dielectric reflector. Computer controlled stepping motors position the sleeves with respect to each other. The reflection of light incident on the ends of the sleeves is therefore delayed according to the relative position of the sleeve from which it is reflected.

Time resolved measurements, using a streak camera, of the reflected AWA laser pulses confirm the performance of this technique. Figure 32 shows a mountain range plot made from a streak camera image of a single 2 ps long laser pulse after it has been reflected from the pulse shaper. The curvature of the pulse is clearly visible. This data was acquired and processed by the AWA control computer.

3. Safety Related Activity

The Preliminary Safety Analysis Document (PSAD) for the AWA has undergone major revisions in anticipation of an Operational Readiness Review. A Conduct of Operations document will soon be completed.

A radiation protection system has been installed in the AWA shield vault. A great deal of effort went into the design of and component selections for this system to insure reliable and effective operations.

4. Planning and Scheduling

Responding to the concerns of a DOE review, a comprehensive critical path analysis was generated for the AWA project. This CPM schedule is periodically updated to reflect the status of the project and its plans. It is anticipated that this exercise will be useful for the efficient and timely completion of the AWA, and useful in communicating to outside reviewers the state of the project.

(J. Simpson/P. Schoessow)

B. High Resolution Profile Monitor Development

The next generation of linear colliders, (250 + 250 GeV), will require beam spot sizes of 0.003 to 0.1 microns, and this is roughly 1-3 orders of magnitude smaller than the demonstrated resolution of any size or profile measurement system. We are developing a system, using nonimaging gamma ray optics, which should have better spatial and temporal resolution than any existing or proposed system, and be able to measure the parameters of both single beams and beam-beam collisions.

The CCD camera/image intensifier unit, to be used in tests of this technique at the Argonne APS and SLAC linacs, was completed and operated. Single photon signals were used to establish that the camera resolution was roughly 25 microns. The radiation sensitivity of the camera was measured by operation in the 20 MeV linac in the Chemistry building.

Fig. 32. Streak camera measurement of curved laser wavefront produced by the AWA wavefront shaper.

A number of shielding calculations have been done with the aim of reducing backgrounds during the expected operation at zero degrees in the SLAC Final Focus Test Beam. Muons and shower secondaries should be the largest source of backgrounds, and these should be reduced by the use of slit collimators with openings of a few microns. The effective acceptance of such a collimator pair for slit scattering is very small, since scattered energy through the first collimator is less than 0.001 of the transmitted flux, with almost two orders of magnitude further reduction in scattered energy due to the second collimator.

The eventual use of this technique at a linear collider has been studied. The optical resolution of such a system using beamstrahlung, radiation produced by electrons in the intense (roughly 1000 T) fields of colliding bunches, could be about 0.005 microns. In this mode, the method would require no hardware in the detector region of the linear collider and should be roughly compatible with present designs for beam dumps.

(J. Norem)

IV. EXPERIMENTAL FACILITIES RESEARCH

A. Mechanical Support

The mechanical support group continued to support the following division activities during this period. The major portion of the groups work has been concentrated on the SDC detector.

SDC

See SDC report section.

CDF

No mechanical support effort on CDF during this report period.

ZEUS

Some mechanical support effort during this period was devoted to the construction of prototype HES wire chambers for the ZEUS barrel calorimeter. This work was confined primarily to fabrication of the chamber components and mechanical assembly.

PDK

Mechanical support efforts were confined primarily to the fabrication of wire plane components to complete the modules that are not yet installed in the detector.

Wakefield

The Mechanical Support Group contribution to the Wakefield program during this period consisted of assistance in the assembly of the R.F. and safety interlock systems. Some engineering effort contributed to klystron shielding, see Fig. 1, and heat transfer calculations for cooling the accelerating column. (N. Hill)

B. Electronic Support

Work continued in support of the Nucleon Decay Experiment, Soudan 2. Our involvement during the period was one primarily of construction and maintenance. We produced 64 Front/Back Splitter Boards, produced 16 Front/Back H.V. Feeder Boards, upgraded 9 Anode HV Distribution Boxes, and produced 75 Tufts Veto-Shield Preamp Boards. Miscellaneous other pieces of electronic equipment were maintained as

necessary, and an effort was made to implement a new diagnostic program for compactor cards. As the course of events with regard to Fermilab P822 (the long baseline neutrino oscillation search) becomes clearer we would hope that there would be areas of development which we could undertake.

Our major effort with regard to the support of the ZEUS calorimeter has been the development of the first level calorimeter trigger processor (CFLTP). 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 perform final modifications and checkout of the cards which implement the global algorithms, install these cards in the CFLTP at DESY, and execute diagnostics on the global algorithms. This was a period of intense effort, and this work concluded our development and construction efforts for the CFLTP. This hardware is currently executing the global algorithms satisfactorily for physics data acquisition at DESY.

Other construction and maintenance work for ZEUS which was completed during the period was production of 4 and upgrading of 2 Output Cards, upgrading of 4 Input Cards, modification for Wisconsin of 1 Communications Card and one Adder Support Module, production of 1 Input Emulator Module for test purposes at DESY, and production and delivery to DESY of 2 Phototube Discharge Noise Units.

A proposal has been submitted to the directorate to add a Small Angle Rear Tracker to the Zeus detector. We expect to be responsible for the trigger electronics and a section of the data acquisition electronics for this device, and have begun electronic development of the requisite hardware. During the period, we built a prototype of the SRTD trigger electronics. This hardware was shipped to DESY and installed in the RCAL section of ZEUS. This trigger was then tested with diagnostic software created at ANL and integrated into the GFLT. The prototype SRTD trigger is currently running and is capable of participating in the first level trigger. Test results from this prototype equipment are being used in design of the production trigger.

A proposal was made by ANL that a shower max chamber for the barrel calorimeter be developed using proportional wires and strips to be implemented instead of the silicon Barrel Hadron Electron Separator (BHES) which had previously been proposed. This would naturally be cost advantageous, but the impact on physics needs to be understood. Prototype development on this hardware has proceeded during the period and data acquisition is currently under way from sections of test chambers and from a full size chamber installed in the prototype BCAL module. Tests include data from cosmics, iron and cadmium, effects of the DU activity in the calorimeter module, and effects of heat produced in the chamber on the scintillator.

During FY 1992 and FY 1993 we have 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 Level 2 trigger to improve the efficiency for B physics. We are responsible for the digital aspects of the work and our collaborators from Fermilab, the University of Chicago, and the University of Michigan are responsible for the analog electronics. Four FASTBUS CES/CPR cards were produced and tested. We continue to interact in the installation of this trigger hardware.

During the period we have produced a number of specialized electronic systems for studying the noise problems which will be involved in the CDF upgrade which will allow operation with the 132 nanosecond crossing period. We expect to have a significant part in this upgrade in the areas of data acquisition from the shower max and preshower chambers and formulation of the trigger using shower max and tracking data.

We have begun development of hardware for the first level calorimeter trigger for the STAR detector at RHIC. We expect to be responsible for this trigger and the interface to the data acquisition from the calorimeter. A CAMAC ADC Test Module was produced implementing a gated integrator with fast clear and 10 bit FADC for use in data acquisition from the calorimeter. Software for the design of Xilinx 4000 Series Field Programmable Gate Arrays (FPGA's) was installed and a number of macro's were developed to be used in implementing the STAR trigger algorithms. We are currently developing the procedures to be used in downloading the configuration files to the Xilinx FPGA's in the VME environment. Various other hardware was produced to support current development efforts for STAR. This included a 4-Channel Clearing Integrator NIM Module, an E-880 Gate Module, a CAMAC Stepping Motor Control Module, and 35 Phototube Bases.

In support of the Bremsstrahlung Beam Profile Monitor development effort under way in HEP we produced the data acquisition hardware and were involved in the integration of this hardware into the monitor system. The data acquisition hardware

consists a CAMAC Camera Controller Module and a CCD Camera Box. This electronics has been tested and is ready for data acquisition during a test run in a test beam at SLAC or at the APS at ANL. During FY 1994 we will be building electronics to support concurrent data acquisition from a seismometer operated in conjunction with the profile monitor.

During the period we also built several small pieces of hardware for the Wakefield Accelerator Development project and ordered parts for 10 more of the Zero Deadtime Discriminator NIM Module which we had developed for the ANL Physics Division.

(J. Dawson)

C. Computer Support

During the past half year computing support was provided to the following areas and activities:

- A vaxstation model 4000/90 was installed for Soudan 2 as part of the HEP Vaxcluster.
- The PASS Sun Sparcstations 1 and 2 were upgraded to the current OS level. Audio and video equipment was acquired for these workstations. Desktop video teleconferencing software was acquired and tested for packet based audio and video over the ANL lan and the ESnet internet.
- A 1.8 GB disk was acquired for SDC and installed on the SGI workstation network.
- The AFS network file system was made available to the SUN and SGI workstations. The node sun2.hep.anl.gov is serving as a local cache manager. This provides a very flexible and high performance wide-area extension to the traditional unix network file system.
- A small number of xterminals, IBM pc's and Apple mac's were attached to the HEP lan.
- The "Data Reduction Committee" was reactivated to review the computing needs and requirements of the major users within the HEP division. A short term acquisition strategy was recommended to meet the immediate needs. Future meetings will focus on a longer term strategy with regard to support for VMS, UNIX, PC's and local Lan planning.
- A joint service project was initiated with ECT division to review the existing HEP lan and make specific recommendation for upgrading the 362 lan cable plant and the interface between the HEP lan and the ANL backbone lan.

- Continuing support was provided for maintenance and system administration for the division's central VAX cluster, the SGI Unix network, the AppleTalk Macs, and pathworks PC's. Continued support for maintenance and operation of the conference-room based video teleconferencing sytem was provided. (E. May)

V. PUBLICATIONS

A. Journal Publications, Conference Proceedings, Books

A Search for Magnetic Monopoles with the Soudan 2 Detector

J. Thron, I. Ambats, D. Ayres, L. Balka, W. Barrett, T. Brock, W. Dawson, T. Fields, M. Goodman, N. Hill, J. Hoftiezer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth, H. Trost (ANL), & Soudan 2 Collaboration
Phys. Rev. D**46**, p. 4822, (1992)

Anomalous Nuclear Enhancements in Hard pA Collisions at Fermilab Energies

T. Fields (ANL) & E609 Collaboration
Nuclear Physics A, **544**, p. C565, (1992)

Chiral Symmetry Breaking in Gauge Theories from Reggeon Diagram Analysis

A. White (ANL)
Proceedings of the Int'l. Workshop on Electroweak Symmetry, World Scientific, edited by W. Bardién, (1992)

Composition Studies Based on Coincident Air Shower Array and Underground Muon Data

T. Fields (ANL), W. DasGupta and K. Ruddick (U. of Minnesota)
Phys. Rev. C**45**, p. 1459, (1992)

Construction of $\Delta m^2 - \sin^2 2\theta$ Plots

M. Goodman (ANL) and R. Snyder (Oberlin College)
Proceedings of the Workshop on Long-Baseline Neutrino Oscillation, Fermilab, edited by M. Goodman, p. 491, (1992)

Contributions to the W-Boson Anomalous Moments in the Two-Higgs-Doublet Model at Collider Energies

T. Rizzo (ANL)
Phys. Rev. D**46**, p. 3894, (1992)

Dijet Angular Distribution in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

L. Nodulman & CDF Collaboration
Phys. Rev. Lett. **69**, p. 2896, (1992)

Dilepton Signatures at TeV e^+e^- and e^-e^- Collisions

T. Rizzo (ANL)
Phys. Rev. D**46**, p. 910, (1992)

Experimental Results with the Fermilab Polarized Beams

A. Yokosawa (ANL)
Polarization Dynamics in Nuclear and Particle Physics, World Scientific, (1992)

Experimental Study of Neutrino Absorption on Carbon

D. Krakauer, R. Talaga (ANL); R. Allen, H. Chen R. Hausmann, W. Lee, X. Lu, H. Mahler, and K. Wang (U. of California); T. Bowles, R. Burman, R. Carlini, D. Cochran, P. Doe, J. Frank, E. Piasetzky, M. Potter, V. Sandberg (LANL)
Phys. Rev. C**45**, p. 2450, (1992)

Implications of Bottom Quark Cross Section Data at Hadron Collider Energies

E. Berger, R. Meng (ANL), W.-K. Tung (IIT)
Phys. Rev. D46, p. 1895, (1992)

Inclusive $J/\psi, \psi(2S)$, and b-Quark Production in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

L. Nodulman (ANL) & CDF Collaboration
Phys. Rev. Lett. 69, p. 3704, (1992)

Limit on Flavor-Changing Neutral Currents from a Measurement of Neutrino-Electron Elastic Scattering

D. Krakauer, R.L. Talaga (ANL), R. Allen, H. Chen, R. Hausmann, W. Lee, X. Lu, H. Mahler, and K. Wang (U. of California); T. Bowles, R. Burman, R. Carlini, D. Cochran, P. Doe, J. Frank, M. Potter, V. Sandberg (LANL); E. Piasetzky (Tel Aviv U.)
Phys. Rev. C45, p. 975, (1992)

Limit on Rare Decay $W^\pm \rightarrow \gamma\pi^\pm$ in pp Collisions at $\sqrt{s} = 1.8$ TeV

L. Nodulman (ANL) & CDF Collaboration
Phys. Rev. Lett. 69, p. 2160, (1992)

Limits on the Production of Massive Stable Charged Particles

L. Nodulman (ANL) & CDF Collaboration
Phys. Rev. D46, p. R1889, (1992)

Measurement of Atmospheric Neutrino Composition with the Imb-3 Detector

D. Sinclair (ANL)
Phys. Rev. Lett., 66, p. 2561, (1992)

Measurement of the Production and Muonic Decay Rate of W and Z Bosons in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. Blair, S. Kuhlmann, W. Li, L. Nodulman, J. Proudfoot, D. Underwood, R. Wagner, A. Wicklund (ANL) & CDF Collaboration
Phys. Rev. Lett. 69, p. 28, (1992)

NP Elastic Spin-Transfer Measurements at 485 and 635 MeV

H. Spinka (ANL); M. McNaughton, K. Koch, I. Supek, N. Tanaka (LANL); K. McNaughton, P. Riley, D. Ambrose, J. Johnson, A. Smith (U. Texas at Austin); G. Glass, J. Hiebert, L. Northcliffe, A. Simon (Texas A&M); D. Adams (Rice U.); R. Ransome, D. Clayton (Rutgers U.); R. Jeppesen (U. of Montana); C. Tripard (Washington State U.)
Phys. Rev. D46, p. 47, (1992)

New Probes for Extended Gauge Structures at HERA

T. Rizzo (ANL)
Phys. Rev. D46, p. 3751, (1992)

Observation of Hard Scattering in Photoproduction at HERA

M. Derrick (ANL) & ZEUS Collaboration
Phys. Lett. B 297, p. 404, (1992)

P-Wave Charmonium Production in B-Meson Decays

G. Bodwin, L. Braaten (ANL), T. Yuan (Northwestern U.), G. Lepage (Cornell)
Phys. Rev. D46, p. 3703, (1992)

Phenomenology of R-parity Breaking in E₆ Models

T. Rizzo (ANL)
Phys. Rev. D 46, p. 5102, (1992)

Prospects for Long Baseline Neutrino Oscillation Experiments

M. Goodman (ANL) & Soudan 2 Collaboration
Proceedings of the Workshop Long-Baseline Neutrino Oscillation,
Fermilab, edited by M. Goodman, p. 53, (1992)

QCD Thermodynamics with Eight Staggered Quark Flavors on a $16^3 \times 6$ Lattice

S. Kim (ANL), S. Ohta (Riken)
Phys. Rev. D 46, p. 3607, (1992)

Realization of Large Systems - A Summary Talk

M. Derrick (ANL)
Proceedings of the Second International Conference on Calorimetry in High Energy Physics,
World Scientific, edited by A. Ereditato (1992)

Resolving the Unitary Gauge Puzzle of Thermal Phase Transitions

P. Arnold, S. Vokos (ANL/HEP), E. Braaten (Northwestern Univ)
Phys. Rev. D 46, p. 3576, (1992)

Rigorous QCD Predictions for Decays of P-Wave Quarkonia

G. Bodwin (ANL), E. Bratten (Northwestern U.), G. Lepage (Cornell)
Phys. Rev. D 46, p. 1914, (1992)

Search for AGN ν 's with the Soudan 2 detector

I. Ambats, D. Ayres, L. Balka, W. Barrett, T. Brock, W. Dawson, T. Fields, M. Goodman,
N. Hill, J. Hoftiezer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth, J. Thron,
H. Trost (ANL), & Soudan 2 Collaboration
High Energy Neutrino Astrophysics, World Scientific, edited by V. Stenger, et al.,
p. 243, (1992)

Search for Squarks and Gluinos from $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

L. Nodulman (ANL) & CDF Collaboration
Phys. Rev. Lett. 69, p. 3439, (1992)

Signals from Cosmic Ray Sources, Some Statistical Issues

M. Goodman (ANL)
Research Directions for the Decade, Snowmass 1990, World Scientific,
edited by E. Berger, (1992)

Status of Search for Atmospheric Neutrino Oscillations with the Soudan 2 Detector

D. Roback (ANL and U. of Minnesota) & Soudan 2 Collaboration
Proceedings of the Workshop on Long-Baseline Neutrino Oscillation, Fermilab,
edited by M. Goodman, p. 171, (1992)

Thermodynamics of Lattice QCD with 2 Light Dynamical (staggered) Quark Flavours on a $16^3 \times 8$ Lattice

D. Sinclair (ANL), S. Gottlieb, A. Krasnitz (Indiana U.), U. Heller, A. Kennedy (Florida State U.), J. Kogut (U. of IL), W. Liu (Thinking Machines Corp.), R. Renken (U. of Central Florida), R. Sugar (U. of CA, Santa Barbara), D. Toussaint (U. of Arizona), and K. Wang (U. of South Wales-Australia)

Proceedings of LATTICE '91, edited by S. Brodsky, et al, (1992)

Two Scalar Doubles Models with Softly Broken Symmetries

I. Knowles (ANL), C. Froggatt, R. Moorhouse (U. of Glasgow)

Nucl. Phys B 386, p. 63, (1992)

^2H (p,n)2p Spin Transfer from 305 to 788 MeV

H. Spinka (ANL); M. McNaughton, I. Supek (LANL); K. McNaughton, K. Johnson, P. Riley, D. Ambrose, A. Smith (U. Texas at Austin); G. Glass, J. Hiebert, L. Northcliffe, A. Simon (Texas A&M); D. Mercer (U. of Colorado), D. Adams (Rice U.); R. Jeppesen (U. of Montana); G. Tripard (Washington State U.)

Phys. Rev. C 45, p. 2564, (1992)

B. Papers Submitted for Publication and ANL Reports

Thermodynamics of Lattice, QCD with Two Light Quarks on a $16^3 \times 8$ Lattice

D. Sinclair (ANL); S. Gottlieb, A. Krasnitz (Indiana U.); U. Heller, A. Kennedy (Florida State); J. Kogut (U. of IL); R. Renken (U. of Central Florida); R. Sugar (U. of California); D. Toussaint (U. of Arizona); K. Wang (U. of New South Wales)

ANL-HEP-PR-92-57

Submitted to Phys. Rev. D

The Production of Z' Associated with Photons or Jets as a Probe of New Gauge Boson Couplings

T. Rizzo (ANL)

ANL-HEP-PR-92-58

Submitted to Phys. Rev. D

Supersymmetric Renormalisation Group Fixed Points and Third Generation Fermion Mass Predictions

I. Knowles (ANL), C. Froggatt, R. Moorhouse (U. of Glasgow)

ANL-HEP-PR-92-62

Submitted to Phys. Lett. B

Bremsstrahlung Contributions to Hadronic $W^\pm\gamma$ and $Z\gamma$ Production

J. Ohnemus (ANL), W. Stirling (U. of Durham)

ANL-HEP-PR-92-73

Submitted to Phys. Lett. B

Proton-Proton Elastic Spin Observables at Large t

G. Ramsey (ANL), D. Sivers (Portland Phys. Institute)

ANL-HEP-PR-92-75

Submitted to Phys. Rev. D

Nuclear Rescattering Effects in Massive Dihadron Production

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

ANL-HEP-PR-92-76

Submitted to Phys. Rev. Lett.

Lepton Number Violating Radiative W Decay in Models with R-parity Violation

T. Rizzo (ANL)

ANL-HEP-PR-92-81

Submitted to Phys. Rev. D

Implications of τ Decays into Strange Scalar Axial Vector Mesons

H. Lipkin (ANL)

ANL-HEP-PR-92-87

Submitted to Phys. Lett. B

Supersymmetry and the Nonlocal Yangian Deformation Symmetry

C. Zachos (ANL), T. Curtright (U. of Miami)

ANL-HEP-PR-92-89

Submitted to Symmetries in Science VI: From the Rotation Group to Quantum Algebras, Plenum Press

Probing the Weak Boson Sector in $Z\gamma$ Production at Hadron Colliders

E. Berger (ANL/HEP, U. Bauer (Florida State U.)

ANL-HEP-PR-92-91

Submitted to Phys. Rev.

Final State Interaction of Longitudinal Vector Bosons

E. Berger (ANL), J-L. Basdevant (Inst. de Phys.), D. Dicus (U. of Texas),

C. Kao (Florida State), S. Willenbrock (FNAL)

ANL-HEP-PR-92-93

Submitted to Phys. Lett. B

A Measurement of $\sigma_{\text{tot}}(\gamma p)$ at $\sqrt{s} = 210$ GeV

B. Musgrave (ANL) & ZEUS Collaboration

ANL-HEP-PR-92-96

Submitted to Phys. Rev. Lett.

The Mechanical Universe and a "Dialogue" Lab in a Community College

J. Uretsky (ANL)

ANL-HEP-PR-92-98

Submitted to Am. Journal of Phys.

A Separate Higgs?

T. Rizzo, J. Hewett (ANL), H. Deshpande, V. Barger (U. of Wisconsin)

ANL-HEP-PR-92-102

Submitted to Phys. Rev. Lett.

Apparatus for the Measurement of Spin Dependent Observables in np and pp Elastic and Quasielastic Scattering

M. Beddo, D. Grosnick, T. Kasprzyk, D. Lopiano, H. Spinka (ANL)

& Saclay Collaboration

ANL-HEP-PR-92-104

Submitted to Nuclear Instruments and Methods

Angular Dependence of Analyzing Power in np Elastic Scattering Between 0.312 and 1.10 GeV

D. Lopiano, H. Spinka (ANL) & Saclay Collaboration

ANL-HEP-PR-92-106

Submitted to Nucl. Phys. B

Angular Dependence of the Beam and Target Analyzing Powers A_{0000} and A_{0001} in np Elastic Scattering Between 0.477 and 0.940 GeV

D. Lopiano, H. Spinka (ANL) & Saclay Collaboration

ANL-HEP-PR-92-105

Submitted to Nucl. Phys. B

Angular Dependence of the Spin Correlation Parameter A_{0011} in np Elastic Scattering Between 0.8 and 1.1 GeV

D. Lopiano, H. Spinka (ANL) & Saclay Collaboration

ANL-HEP-TR-92-107

Submitted to Nucl. Phys. B

Can $b \rightarrow s\gamma$ Close the Supersymmetric Higgs Production Window?

J. Hewett (ANL)

ANL-HEP-PR-92-110

Submitted to Phys. Rev. Letter

C. Papers or Abstracts Contributed to Conferences

Symmetry of Wavefunctions in Quantum Algebras and Supersymmetry

C. Zachos (ANL)

ANL-HEP-CP-92-53

Submitted to XXist Int'l Conference on Differential Geometric Methods in Theoretical Physics,

Argonne's New Wakefield Test Facility

J. Simpson (ANL)

ANL-HEP-CP-92-54

Submitted to the XVth International Conference on High Energy Accelerators, Hamburg, Germany, July 20-24, 1992,

The Argonne Wakefield Accelerator (AWA) Laser System and Its Associated Optics

W. Gai, R. Konecny, J. Power (ANL)

ANL-HEP-CP-92-55

Submitted to the XVth International Conference on High Energy Accelerators, Hamburg, Germany, July 20-24, 1992,

Argonne Wakefield Accelerator Update '92

M. Rosing, L. Balka, E. Chojnacki, W. Gai, C. Ho, R. Konecny, J. Power, P. Schoessow,
J. Simpson (ANL)

ANL-HEP-CP-92-65

Submitted to the 1992 Linear Accelerator Conference, Ottawa, Canada, August 23-29,
1992

A High Resolution, Single Bunch, Beam Profile Monitor

J. Norem (ANL)

ANL-HEP-CP-92-72

Submitted to the Conference on Advanced Accelerator Concepts, June 15-20, 1992

Constraints on the Gluon Density from Bottom Quark and Prompt Photon Production

E. Berger, R. Meng (ANL), J. Qiu (Iowa State)

ANL-HEP-CP-92-79

Submitted to the Proceedings of the 26th Int'l. Conference on High Energy Physics
August 5-12, 1992

The SDC Central Calorimeter

J. Proudfoot (ANL) & SDC Collaboration

ANL-HEP-CP-92-80

Submitted to the Proceedings of the 3rd Int'l. Conference on Calorimetry in High Energy
Physics, September 29 - October 2, 1992

Results from the Soudan 2 Detector

J. Thron, I. Ambats, D. Ayres, L. Balka, W. Barrett, T. Brock, W. Dawson, T. Fields,
M. Goodman, N. Hill, J. Hoftiezer, D. Jankowski, F. Lopez, E. May, L. Price,

J. Schlereth, (ANL), & Soudan 2 Collaboration

ANL-HEP-CP-92-85

Submitted to the Proceedings of the 26th Int'l. Conference on High Energy Physics
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Hadron Spectrum of Quenched QCD on a $32^3 \times 64$ Lattice

S. Kim, S. Sinclair (ANL)

ANL-HEP-CP-92-92

Submitted to the Proceedings of LATTICE '92, September 15-19, 1992

Some Fiber-Tile Optical Studies for SDC Electromagnetic Calorimeter

D. Underwood (ANL)

ANL-HEP-CP-92-94

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Physics, September 29 - October 2, 1992

The Electromagnetic Calorimeter for the STAR Experiment at RHIC

D. Underwood (ANL)

ANL-HEP-CP-92-95

Submitted to the Proceedings of the 3rd Int'l. Conference on Calorimetry in High Energy
Physics, September 29 - October 2, 1992

A Streamlined Method for Chiral Fermions on the Lattice

G. Bodwin (ANL) and E. Kovacs (FNAL)

ANL-HEP-CP-92-103

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The Gluon Density

E. Berger and R. Meng (ANL)

ANL-HEP-CP-92-108

Submitted to the Proceedings of the 7th Meeting of the American Physical Society, Division of Particles and Fields, Fermilab, November 10-14, 1992

Rigorous QCD Predictions for Decays of P-Wave Quarkonia

G. Bodwin (ANL), E. Braaten (Northwestern U.), G Lepage (Cornell)

ANL-HEP-CP-92-109

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QCD with 2 Light Quark Flavours: Thermodynamics on a $16^3 \times 8$ Lattice and Glueballs and Topological Charge on a $16^3 \times 32$ Lattice

S. Kim, D. Sinclair (ANL); K. Bitar, R. Edwards, U. Heller, A. Kennedy (Florida State); S. Gottlieb, A. Krasnitz (Indiana U.); J. Kogut (U. of IL); W. Liu (Thinking Machines); M. Ogilvie (Washington U.); R. Renken (U. of Central Florida); R. Sugar (U. of California); M. Teper (U. of Oxford); D. Toussaint (U. of Arizona); K. Wang (U. of South Wales, Australia)

ANL-HEP-CP-92-113

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The η_6 and Massive Photon Pairs at LEP

A. White and I. Knowles (ANL), K. Kang (Brown U.)

ANL-HEP-CP-92-117

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Heavy Fermion Mass Predictions and Renormalization Group Equations

I. Knowles (ANL), C. Froggatt and R. Moorhouse (Glasgow Univ)

ANL-HEP-CP-92-120

Submitted to the Proceedings of the 7th Meeting of the American Physical Society, Division of Particles and Fields, Fermilab, November 10-14, 1992

Nuclear Rescattering Effects in $pA \rightarrow$ Dihadrons

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

ANL-HEP-CP-92-121

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Interactions of Atmospheric ν_μ and ν_e Observed in Soudan 2

M. Goodman (ANL) & Soudan 2 Collaboration

ANL-HEP-CP-92-124

Submitted to the Proceedings of the 7th Meeting of the American Physical Society,
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Constraints on the Charged Higgs Sector from B Physics

J. Hewett (ANL)

ANL-HEP-CP-92-125

Submitted to the Proceedings of the 7th Meeting of the American Physical Society,
Division of Particles and Fields, Fermilab, November 10-14, 1992

Signals for Virtual Leptoquark Exchange at Colliders

J. Hewett (ANL) and M. Doncheski (U. of Wisconsin)

ANL-HEP-CP-92-126

Submitted to the Proceedings of the 7th Meeting of the American Physical Society,
Division of Particles and Fields, Fermilab, November 10-14, 1992

Quenched Hadron Spectrum of QCD

S. Kim (ANL)

ANL-HEP-CP-92-127

Submitted to the Proceedings of the 7th Meeting of the American Physical Society,
Division of Particles and Fields, Fermilab, November 10-14, 1992

D. Technical Notes

High Energy Physics Division Semiannual Report of Research Activities ; January 1, 1992 - June 30, 1992

P. Moonier, P. Schoessow, R. Talaga, R. Wagner (ANL)

ANL-HEP-TR-92-50

Noise Events in the Contained Event Sample of Soudan 2

A. Lopez, M. Goodman (ANL) & Soudan 2 Collaboration

ANL-HEP-TR-92-61

Estimates of Rates and Errors for Measurements of Direct- γ and Direct- γ + Jet Production by Polarized Protons at RHIC

M. Beddo, H. Spinka, D. Underwood (ANL)

ANL-HEP-TR-92-59, Star Note #77

Response to Concerns of the EM Review Committee

N. Hill, V. Guarino, J. Nasiatka (ANL)

ANL-HEP-TR-92-67, SDC-92-00299

Calibration of the Fermilab E-704 Polarized Target

D. Hill (ANL)

ANL-HEP-TR-92-68

A High Current, Short Pulse Electron Source for Wakefield Accelerators

C. Ho (ANL)

ANL-HEP-TR-92-74

The Prospects for Polarized Target Materials with Pure Carbon Background

D. Hill (ANL)

ANL-HEP-TR-92-88

Effect of Pb and Air Absorber Thickness on ^{137}Cs Signal

D. Jankowski, D. Lopiano, R. Stanek (ANL)

ANL-HEP-TR-92-97, SDC-92-350

Calibration of the LAMPF E-960 Polarized Target

D. Hill (ANL)

ANL-HEP-TR-92-111

Estimates of the Neutron Fluence for the SDC Detector

P. Job, L. Price (ANL), T. Handler (U. of Tennessee), and T. Gabriel (ORNL)

ANL-HEP-TR-92-112

Measurement of Radiation Dose Using Radiochromic Film

D. Jankowski, J. Proudfoot (ANL)

ANL-HEP-TR-92-114, SDC-92-373

Final Report on Cost Estimate of Forward Superconducting Air Core Toroid

T. Fields (ANL)

ANL-HEP-TR-92-122, SDC-92-384

Nucleon Spin Structure Studies with Polarized Proton and Antiproton Beams

H. Spinka (ANL) & P-863 Collaboration

ANL-HEP-TR-92-128

AGN-20	Camac Module Voltage-Optic and Optic-Voltage Converter
E. Chojnacki (ANL)
AGN-21	Low-Power, High Resolution, Stepping-Motor-Driver Phase Shifters
E. Chojnacki (ANL)
AGN-22	Results from the SSC Liner Run
P. Schoessow (ANL)
AGN-23	A String of Beads Pulse Monitor
J. Simpson (ANL)
CDF-1941	Measurement of $\sigma_{\text{BR}}(W + \gamma)$ and $\sigma_{\text{BR}}(Z + \gamma)$ in the Electron and Muon Channels in $\sqrt{s} = 1.8 \text{ TeV}$ $\bar{p} - p$ Collisions
R. Wagner (CDF Collaborators)
CDF-1954	Drell-Yan Backgrounds for Inclusive Electrons
A. B. Wicklund, F. Ukegawa
CDF-1963	Inclusive Photon Cross Section 1992
S. Kuhlmann

- CDF 1971 Inclusive Jet Cross Section from 1992-93 Data Set
S. Kuhlmann
- CDF-2046 First Pass Data Derived CEM Map
L. Nodulman, K. Byrum
- CDF-2059 The Inclusive Electron Binary Files for the 1992/93 Run
K. Byrum, A. B. Wicklund
- CDF-2069 Digital Electronics for the Inclusion of Shower Max and Preshower Wire
J. Dawson, K. Byrum, W. Haberichter
- CDF-2070 The Diphoton Rate in the '92-'93 Data Sample (A First Look)
R. Blair
- CDF-2074 A Study of Events Containing a Photon and Two Jets
P. Maas, R. Blair, S. Kuhlmann
- CDF-2079 Identification of Conversion Electrons in the Inclusive Electron Sample
F. Ukegawa, A. B. Wicklund
- CDF-2080 Separation of QCD Prompt-Photon and π Production in the Conversion
Electron Sample
F. Ukegawa, A. B. Wicklund
- CDF-2081 Lateral Shower size for Hadrons
F. Ukegawa, A. B. Wicklund
- CDF-2082 E/P Systematics from the W-Electron Sample
K. Byrum, A. B. Wicklund
- CDF-2115 A First Look at 1992-93 Minimum Bias Data
M. Hohlmann
- CDF 2119 Detector Counting Rates in the 92-93 Run
L. Nodulman
- CDF-2132 Studies of QCD Backgrounds in the Electron/Muon $W+\gamma/Z+\gamma$ Data
R. Wagner
- CDF-2143 Preliminary Measurement of $\sigma \cdot \text{BR}(W+\gamma)$ and $\sigma \cdot \text{BR}(Z+\gamma)$ in the Electron and
Muon Channels with the 1992/1993 Data
R. Wagner
- PDK-523 Quarterly Activity Report April - June 1992
D. Ayres (ANL)
- PDK-535 Decisions of the Tower Collaboration Meeting, October 3-6, 1992
D. Ayres (ANL)

- PDK-537 Quarterly Activity Report July - September 1992
D. Ayres (ANL)
- PDK-544 Soudan 2 Experiment Quarterly Status Report October - December 1992
D. Ayres (ANL)
- WF-168 Self Consistent Theory of Charged Particle Motion and Radiation
M. Rosing (ANL)
- WF-169 Computer Modeling of Cherenkov Wakefield Accelerator Structures
P. Schoessow (ANL)
- WF-170 Generic Solution for Two Region Cylindrical Geometry
M. Rosing (ANL)

VI. COLLOQUIA AND CONFERENCE TALKS

R. Blair

"CDF Diphotons - Implications for SSC Diphoton Measurements"
ANL Conference on Future Collider Physics (June 1993)

G. Bodwin

"A Lattice Method for Chiral Fermions"
Washington University, St. Louis, MO (April 1993)

M. Derrick

"The HERA Physics Program"
ASA, Washington, D.C. (April 1993)

T. Fields

"Cosmic Rays"
L. Bollinger 70th Birthday: ANL Symposium, Argonne National Laboratory
April 1993)

M. Goodman

"Prospects for Long Baseline Neutrino Oscillations Experiments"
University of Minnesota (February 1993)

"Are There Atmospheric Neutrino Oscillations?"
TRIUMF Laboratory, Vancouver, Canada (April 1993)

"Results from Soudan 2"
Baton Rouge Atmospheric Neutrino Workshop (May 1993)

J. Hewett

"Studies of Extended Gauge Sectors at Linear Colliders"
Workshop on Physics and Experimentation with Linear e^+e^- Colliders, Waikola,
Hawaii (April 1993)

" $b \rightarrow s\gamma$ in the Standard Model and Extended Higgs Scenarios"
BNL, Upton, NY (March 1993)

"b $\rightarrow$ sy Confronts the Standard Model and Beyond"

SLAC, U of C-Davis (March 1993)

Syracuse University (April 1993)

Cornell University (April 1993)

U. of Hawaii (April 1993)

"The Search for Top: A Status Report"

Colloquium at the U of C-Davis, Davis, CA (March 1993)

P. K. Job

"CALOR89, Benchmarking and Applications"

Workshop on Simulation of the Accelerator Radiation Environment,
Santa Fe, NM (February 1993)

"Report on the Simulating Accelerator Radiation Environment Workshop"

High Energy Physics Lunch Seminar, ANL (February 1993)

"CALOR89 Predictions for the ongoing File Experiment"

MC93 Conference, Tallahassee, FL (February 1993)

S. Kim

"Quenched QCD Spectrum Calculation on the Touchstone Delta"

Norfolk, VA (April 1993)

"On the Lattice QCD Calculation"

Seoul, Korea (May 1993)

T. Kirk

"Status of SDC"

Underground Technology Advisory Panel, SSC Laboratory (January 1993)

"Managing the SDC Project"

SSSCL Senior Scientists, SSC Laboratory (January 1993)

"SDC Experiment"

Japanese Ambassador to U.S. T. Okubo, SSC Laboratory (May 1993)

"SDC Experiment"

Mexican Science Board, Mexico City, Mexico (May 1993)

"Status of SDC"

Collider Physics Workshop at Argonne National Laboratory (June 1993)

"Science Experiments at SSC"

Summer Science Teacher's Institute, SSC Laboratory (June 1993)

S. Kuhlmann

"QCD Studies at CDF"
Dallas CTBQ Meeting (January 1993)

"Direct Photon Studies at CDF"
MSU CTBQ Meeting (May 1993)

S. Magill

"ZEUS Results from the First Year--DIS Cross Section and Hadronic Final States"
HERA Workshop, Durham, England (March 1993)

"Deep Inelastic Scattering Results from the First Year of HERA Operation"
Argonne Workshop on Physics at Current Accelerators (June 1993)

E. May

"Requirements for a System to Analyze HEP Data using Database Technology"
IEEE 12th Symposium on MASS Storage Systems, Monterey, CA (April 1993)

R. Meng

"Bottom quark Production at Hadronic Colliders"
Snowmass 93, Colorado (June 1993)
Madison, Wisconsin (April 1993)

L. Nodulman

Adventures in CDF Run 1A"
HEP, Argonne National Laboratory (February 1993)

"Recent Results from CDF"
Fermilab Users Meeting (June 1993)

J. Repond

"ZEUS Results from the First Year of Data Taking"
Aspen Winter Conference (January 1993)
Argonne National Laboratory (January 1993)

T. Rizzo

"Gauge Model Extensions Working Group Summary Report"
Workshop on Physics at Current Accelerators and the Supercollider, Argonne
National Laboratory (June 1993)

"Inverse Neutrinoless Double- β Decay at the NLC"

Workshop on Physics and Experiments with Linear e^+e^- Colliders, Waikoloa, Hawaii (April 1993)

H. Spinka

"Neutron-Proton elastic Scattering at LAMPF"

Valparaiso University, Valparaiso, IN (January 1993)

"pp Inclusive Direct-Photon Production at RHIC"

Los Alamos National Laboratory, Los Alamos, NM (January 1993)

"Measurement of Spin Effects at RHIC"

Indiana University, Bloomington, IN (February 1993)

"The Electromagnetic Calorimeter for STAR"

LBL, Livermore, CA (February 1993)

"Experiments to Measure the Gluon Spin Distribution"

BNL, Upton, NY (March 1993)

A. White

"QCD with Sextet Quark, Electroweak Symmetry Breaking and the η_6 "

Brown University, Providence, RI (April 1993)

"The Pomeron and QCD with Many Light Quarks"

International Conference (Vth Blois Workshop) on Elastic and Diffractive Scattering, Brown University, Providence, RI (June 1993)

A. Yokosawa

"FNAL Polarized Beams and Spin Dependence at RHIC"

BLOIS Workshop on Elastic and Diffractive Scattering, Brown University, Providence, RI (June 1993)

C. Zachos

"Supersymmetry and the Yangian Deformation Symmetry"

Los Alamos (January 1993)

University of Freiburg (February 1993)

"Overview of Particle Physics"

Science and Engineering Research Semester Seminar, Argonne National
Laboratory (February 1993)

"Symmetry Group Representations"

Loyola University, Chicago, IL (April 1993)

"Thermodynamic q -Distributions that Aren't"

Second Colloquium Quantum Groups, Prague, The Czech Republic (June 1993)

VII. HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES

E. Berger

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

Member, Committee on Meetings, American Physical Society, 1991 - Appointed by the President of the APS to propose guidelines and rules for the organization and operation of all meetings of the APS and its subunits.

Member, U.S. Contact person, Scientific Program Committee, XXVIII Rencontre de Moriond, "QCD and High Energy Hadronic Interactions", Les Arcs, France, March, 1993.

Member, Organizing Committee, Workshop on Transverse Polarization in Deep Inelastic Lepton Scattering, University of Geneva, March, 1993.

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

T. Kirk

Served as member of the Executive Committee, APS Division of Particles & Fields

Served as Vice-President of IISCC

Consultant to Massachusetts General Hospital Medical Physics Advisory Committee

Consultant to NSF on LIGO Project Review

L. Nodulman

Cochair, Top Subgroup Argonne Workshop on SSC and Accelerator Physics

Reviewer, IEEE NSS Symposium, November 1993

Committee to Possibly Review HEP Gordon Conference

A. White

Organizing Committee, SSC Symposium, Madison, March 1993

Co-chair, Workshop on Physics at Current Accelerators and the SSC, June 1993

International Advisory Committee, International Conference on Elastic and Diffractive Scattering, Brown University, June 1993.

Co-chair, XXIII International Symposium on Multiparticle Dynamics, Aspen, CO, September 1993

C. Zachos

Organizer, Workshop on Physics at Current Accelerators and the Supercollider, ANL (June 1993)

VIII. HIGH ENERGY PHYSICS RESEARCH PERSONNEL

Administration

L. Price	P. Moonier
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Accelerator Physicists

W. Gai	M. Rosing
C. Ho	P. Schoessow
J. Norem	J. Simpson

Experimental Physicists

D. Ayres	E. May
M. Beddo	B. Musgrave
R. Blair	L. Nodulman
K. Byrum	J. Proudfoot
M. Derrick	J. Repond
T. Fields	H. Spinka
M. Goodman	R. Stanek
D. Grosnick	R. Talaga
P. Job	J. Thron
T. Kirk	D. Underwood
D. Krakauer	R. Wagner
S. Kuhlmann	A. B. Wicklund
D. Lopiano	A. Yokosawa
S. Magill	

Theoretical Physicists

E. Berger	R. Meng
G. Bodwin	T. Rizzo
J. Hewett	D. Sinclair
S. Y. Kim	A. White
I. Knowles	C. Zachos

Engineers, Computer Scientists and Applied Scientists

E. Chojnacki	N. Hill
J. Dawson	J. Nasiatka
A. Derlicki	J. Schlereth
V. Guarino	X. Yang
D. Hill	

Technical Support Staff

I. Ambats	D. Jankowski
L. Balka	T. Kasprzyk
H. Blair	R. Konecny
A. Derlicki	D. Lifka
W. Haberichter	R. Rezmer

Laboratory Graduate Participants

C. Allgower	J. Power
M. Hohlmann	

END

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