HIGH ENERGY PHYSICS DIVISION SEMIANNUAL REPORT OF RESEARCH ACTIVITIES

July 1, 1996 – December 31, 1996

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

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December 1997

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I. EXPERIMENTAL RESEARCH PROGRAM

I.A. EXPERIMENTS WITH DATA

I.A.1 Medium Energy Physics Program

The medium energy physics program in the past has concentrated on the study of nucleon-nucleon elastic scattering spin effects. The goal of these measurements, plus results from other groups, is the determination of the scattering amplitudes. Such amplitudes are crucial for understanding the strong interaction at intermediate energies, nucleon scattering from nuclei, and the interpretation of certain electron scattering experiments at Jefferson Lab (CEBAF) and elsewhere.

Analysis of a large amount of pp elastic scattering data collected in 1992 -- 1995 from Saclay continued during this period. The spin observables $P = A_N = A_{\text{ono}} = A_{\text{oon}}$ and $C_{NN} = A_{NN} = A_{\text{oon}}$ were measured for $\theta_{c.m.} \sim 60 - 90^\circ$ at over 30 beam kinetic energies between 1800 and 2800 MeV. These data will form the basis for a Ph.D. thesis by Chris Allgower, supported by Argonne. Difficulties with optimizing the method to obtain the physics parameters were solved in this period. The data at each energy consists of yields measured with four different beam and two different target spin states. These eight yields at each angle and energy can be expressed in terms of two spin observables, the four unknown beam polarizations, the spin-averaged yield, and a ratio of efficiencies between the two target spin state run periods. Extensive studies of beam polarizations with beam polarimeter data and with a dedicated set of measurements provided three relationships among the four beam polarization magnitudes. Thus, five unknown quantities remain for the eight yields at each angle and energy. Two relations among the yields, due to the operation of the polarized ion source, were previously known. During this period, two additional relations among the yields were found. Hence, it was concluded that there was no way to solve for all five unknown quantities in general.

As a result, two methods with different assumptions were adopted to solve for the spin observables. One method assumed the beam polarization was known, while the other assumed the ratio of detection efficiencies between the two target spin states was independent of angle. An interaction between the two methods allowed both a determination of the beam polarization and a test of the variation with angle of the ratio of efficiencies. Previous studies had eliminated most cases with hardware problems that caused changes in efficiency. However, a few

additional problems with hardware performance were discovered. The offending data were studied to understand the source of efficiency changes, and then were eliminated. It is now believed that the derived results will be free from sizable systematic errors.

Figure 1A shows data at a beam kinetic energy of 2180 MeV. The two spin observables are $A_{\text{oono}} = A_{\text{oonn}}$ and A_{oonn} , and the ratio of efficiencies is C_0 . In this case, the results were consistent without further changes, and they agree well with the independent analysis at Saclay (open circles). On the other hand, Fig. 1B shows similar data at 2230 MeV. Significant differences are observed in C_0 for $\theta_{\text{c.m.}} \sim 57 - 69^\circ$. This change of efficiency with angle was traced to problems with wire chamber gas mixtures, when the gas system was turned off. Experimenters noted the problem some time later. The c.m. angles with the gas problem were eliminated from the analysis and final results derived.

After analysis by these methods at most energies, two Argonne physicists visited collaborators at Saclay, where an independent analysis was performed. In general, there was excellent agreement of the two sets of results. Differences for a couple data sets were discussed and resolved. Also, there was discussion on three papers to be written at Saclay and four to be written at Argonne. Work on the Argonne papers has begun.

Preparations for runs on Brookhaven experiments E913/914 with the Crystal Ball detector continued. The physics goal will be to study hadron spectroscopy via π^-p and K^-p reactions into all neutral final states. Polarization effects will be studied using self-analyzing decays of Λ^0 and Σ^0 hyperons. Several iterations on the design for the Crystal Ball support were made, and a final design adopted. This is shown in Fig. 2. Arizona State University agreed to machine some of the parts and send them to Brookhaven. Argonne, Abilene Christian University, and a commercial machine shop in Abilene, Texas machined and/or paid for all remaining parts. The support was assembled late in this period and the Crystal Ball installed without significant problems. The engineering, designing, drafting, and supervision during installation were primarily the responsibility of Argonne personnel, and most of the cost of construction was paid by the DOE/NP budget at Argonne. Brookhaven engineers and technicians contributed significantly with the installation.

During the early part of this period, a professor and undergraduate student supported by Argonne, an Argonne physicist, and three physicists from Valparaiso University collaborated on simulations of experiments E913/914. Tests were performed of the event generator and reconstruction software. A program was written to display single events in preparation for upcoming runs. Studies of various kaon beam reactions were performed to examine cuts for

rejection of backgrounds. Also, a number of Monte Carlo and Gent calculations were made to estimate the effects of neutrons in the Crystal Ball detectors. A note was begun describing the results of these calculations.

Two new proposals were submitted to the Brookhaven Program Advisory Committee for experiments with the Crystal Ball. One was a search for a glueball candidate in $\bar{p}p \rightarrow \text{neutrals}$ reactions (E924). There was evidence for such a glueball state from measurements with the Crystal Barrel at LEAR. This experiment was approved, but could only be run once the Crystal Ball is moved to a different beamline with higher energies. The second proposal is to measure the rate of the $K^+ \rightarrow \pi^0 e^+ \nu_e$ (K_{e3}) decays to better than 1%. This experiment would yield an improved determination of the V_{us} CKM matrix element, and a significantly better test of the unitarity of the CKM matrix. A departure from unitarity would be evidence for new physics beyond the Standard Model. This experiment (E927) was also approved. Additional hardware would be required for both experiments.

(H. Spinka)

Fig. 1. Plot of the spin observables A_{oono} and A_{oonn} and the ratio of efficiencies C_0 for the two target states as a function of c.m. angle. The filled squares correspond to the analysis method where the beam polarization was assumed to be known, and the open circles to the independent analysis at Saclay. A) Beam kinetic energy of 2180 MeV, showing C_0 consistent with a constant, and giving good agreement between the spin observables derived from the two analyses. B) Beam kinetic energy of 2230 MeV. Problems with the wire chamber gas led to the observed behavior of C_0 for $\theta_{c.m.} \sim 57 - 69^\circ$.

Fig. 2. Drawing of the Crystal Ball support designed and partially constructed at Argonne. The existing structure around the Crystal Ball is indicated by dot-dashed lines. The distance from the floor to the center of the Crystal Ball is 1.98 m. The support allows the upper hemisphere of the Crystal Ball to be raised and lowered with an electric motor for access to the center of the Ball. Limit switches and some electrical wiring were installed by a member of the Argonne technical staff.

I.A.2 Polarized Proton Physics at FNAL

A paper on "Spin Transfer in Inclusive Λ Production by Transversely Polarized Protons" appeared in Phys. Rev. Lett. D_{NN} reaches large positive values of about 30% at high x_F and $p_T \sim 1.0$ GeV/c as shown in Figure 1. This result indicates a large spin transfer from the incident polarized proton to the outgoing Λ .

(A. Yokosawa)

I.A.3. Collider Detector at Fermilab

a. QCD Physics

Steve Kuhlmann published in PRL the paper on high p_T jets and the gluon distribution. This gluon variation became the most popular explanation for the CDF high p_T jet excess. Bob Blair and Steve Kuhlmann guided three direct photon analyses to the stage where they can be shown in public. The first was the photon cross section in the plug detector, which was finished by Takashi Ino from Tsukuba University. The second was the photon cross section at $\sqrt{s}=630$ GeV, which Steve analyzed using the same method as run Ia. The third is the diphoton cross section from the complete Run I sample, analyzed by Takeshi Takano also from Tsukuba. The latter two analyses are expected to be published.

b. Top Physics

Tom LeCompte carried out the first studies on the CKM matrix element V_{tb} , using the observed number and distribution of b-quark tags in the t - $\bar{t}$ candidate sample. Assuming a unitary CKM matrix, this analysis gave $|V_{tb}|=0.97\pm 0.15(\text{stat.})\pm 0.07(\text{syst.})$. In addition, LeCompte carried out a search for FCNC top decays, searching for prompt photon decays in the same sample (e.g. $t \rightarrow c + \gamma$, $u + \gamma$); the 95% c.l. limits are $B(t \rightarrow q + \gamma) < 0.032$. A parallel search for FCNC decays $t \rightarrow q + Z$, with the signature $Z \rightarrow e + e^-$, yields a 95% c.l. limit of 0.33.

c. W Mass Analysis

Several studies were carried out on the electron response calibrations for the run 1B data. First, the individual central calorimeter phototube responses (two tubes in each of 477 towers) were measured as a function of time, using the large inclusive electron sample and the measured E/p response. The average tube gain is observed to drop by about 4% over the 18 month duration of Run Ib, consistent with the long term aging effects measured over the history of the central detector. The response map of the calorimeter was also optimized as a function of local

shower position in each calorimeter wedge. This calibration yields the relative response of the central calorimeter to electrons as a function of time, tower number, and local coordinate.

The absolute calibration of the calorimeter energy scale is set by matching the observed E/p distribution for W -electrons with that expected for internal and external bremsstrahlung. The E/p distributions were modeled using several independent Monte Carlos. Larry Nodulman developed an EGS4 model to describe radiation in the detector material, while Barry Wicklund used a parametric Monte Carlo. These and other studies gave consistent predictions for the relation between the peak position, $E/p \sim 1$, and the E/p tails ($E/p > 1.4$) caused by bremsstrahlung.

To check the absolute amount of external material, conversion electrons were used to map the material in units of X_0 , similar to the analysis done for Run Ia. The statistics in Run Ib are high enough that we can use the wires in the CTC wire chambers as a known radiator to calibrate the absolute rates. As an example, Figure 1 shows the distribution of conversion electrons seen as a function of the wire number in the first CTC superlayer. This analysis is a cross check on the E/p analysis described above.

In addition, backgrounds from non- W sources in the electron channel were studied (e.g., conversion electrons with mismeasured E_t , QCD jets faking electrons, etc.), as well as backgrounds involving real W 's with photon radiation followed by photon conversion in the detector material ("tridents"). These studies are important for the E/p calibration, since these backgrounds tend to contribute preferentially to the E/p tails and hence distort the true E/p bremsstrahlung spectrum.

d. Triboson Couplings

The focus of the $W\gamma/Z\gamma$ analysis during this period was on improving the photon conversion pair analysis to more efficiently identify electron-positron pairs from very high E_T conversion photons. The small curvature of the tracks from these conversions results in frequent difficulty tracing the tracks to a common vertex. The problem was greatly reduced by fitting the tracks to a conversion point. The program which was part of the standard CDF analysis package still had to be modified and tuned in order to handle the fitting of these high E_T conversions.

A second major project begun was development of a method to correct the missing transverse energy calculation. This effort grew out of a study of $W\gamma$ event candidates having very high E_T electrons. These events typically have jets accompanying the electron in the event. Moreover, it was observed that the missing transverse energy vector usually was pointing into or directly away from one jet. This in turn was due to our use of the simplest missing E_T calculation which just sums calorimeter tower energies with equal weight and assigns the

negative of the imbalance as the missing E_T . The more correct way of handling the calculation is to separately add the transverse components of the corrected electron, photon, and jet energies plus the p_T of beam constrained muons to arrive at the corrected clustered energy. Transverse energy deposits less than 10 GeV are treated as unclustered energy. The energy of towers associated with clusters is replaced in the calorimeter sum by an average underlying event energy (~ 30 MeV). The resultant is summed as in the *naïve* missing E_T calculation. This “unclustered” energy is then separately corrected and added to the corrected clustered energy to arrive at the overall summed transverse energy. The negative of this vector is then taken to be the corrected missing transverse energy. The development of the algorithm to do this correction was begun during the last months of the year.

(R. Wagner)

Fig. 1 Distribution of conversion electrons seen as a function of the wire number in the first CTC superlayer.

e. B Physics

Karen Byrum and Barry Wicklund established the trigger efficiency parametrization for inclusive electrons used in many analyses for studies of B semileptonic decays. The electron trigger used in Run Ia imposes resolution-smeared cuts on electron calorimeter energy, track momentum, and hadronic calorimeter leakage, which then modulate the steeply falling spectrum of electrons from B decay. The efficiency is obtained by comparing different threshold triggers in Et and Pt, and by using electrons found in events selected on other trigger requirements (e.g., muon triggers.)

Tom LeCompte analysed the data taken in Run Ic at $\sqrt{s}=630$ and 1800 GeV. The analysis is based on inclusive muons measured in the CDF silicon vertex detector. The decay length distribution from the muon (plus other charged particle track(s)) is used to separate B decays from prompt backgrounds and charm production. Figure 2 shows the ratio of the inclusive b cross section at the two energies, together with the predicted ratio based on NLO QCD. Note that many experimental systematics cancel in the measured ratio, since the same detector biases enter into both measurements; likewise many theoretical uncertainties are expected to drop out in the ratio. The CDF cross sections measured in Run 0, without the use of the vertex detector, were systematically higher than NLO QCD predictions available in 1991, whereas it appeared that the UA1 results were closer to the predictions at $\sqrt{s}=630$. With the vertex detector information, the CDF cross sections in run I are systematically lower than in Run 0. The predicted cross sections, with more modern SF's, are also lower. The result is that both CDF and UA1 cross sections are higher than current NLO QCD by factors of two-to-three, but the $\sqrt{s}$ dependence is consistent with theory.

Barry Wicklund and collaborators at U. Penn. completed analysis of the B^0 and B^+ lifetimes using the large (~ 7000 signal events) sample of semileptonic B decays. Figure 3 shows the decay proper time distribution for B^+ (top) and B^0 (bottom) decays; the two are separated, with some cross-talk, using the observed decays to neutral and charged D^0 and D^{*+} mesons. Figure 4 shows the measured ratio of charged and neutral B lifetimes for all experiments. The two CDF results, one from exclusive J/ψ decays and the other the semileptonic analysis, are the single most accurate results available. The lifetime ratio is expected to be much closer to unity than that for charmed mesons (D^+ and D^0); the lifetime ratio is predicted to be around 1.05, consistent with the combined result in Figure 4.

Fig. 2 Theoretical predictions using *MRSA'* parton distribution functions on the ratio of *b* quark cross sections (integrated above a minimum P_T) at 630 GeV to 1800 GeV. The solid line is for choice of scale μ_0 and a *b* mass of 4.75 GeV; the dashed lines show the theoretical variation with scale and *b* mass. The data point is this measurement. Uncertainties are combined statistical and systematic.

Fig. 3 Decay time distribution for B^+ (top) and B^0 .

Fig. 4 The measured ratio of charged and neutral B lifetimes for all experiments.

f. TeV-33 Studies

Snowmass '96 brought a flurry of activity concerning Tev33 and the Higgs study. Shinhong Kim and Steve Kuhlmann updated the Higgs search with more realistic kinematic cuts, and presented a 5-sigma discovery limit vs luminosity plot. With 30 Fb^{-1} a Higgs boson of mass less than 125 GeV should be observable at the Tevatron in the WH associated production mode,

assuming a 20-30% improvement in dijet mass resolution. This has led to the beginning of a concerted effort to improve the dijet mass resolution, led by Steve and a team of students and faculty from Pisa.

(B. Wicklund)

I.A.4 Non-Accelerator Physics at Soudan

a. Physics Results

During the second half of 1996 Soudan physicists continued the analysis effort on the identification and characterization of atmospheric neutrino interaction events from the second and third kt-year of Soudan 2 data. Results from the first 1.5 kt-year on the ν_μ / ν_e "flavor" ratio for atmospheric neutrinos were published in Physics Letters. The quantity R is the ratio of the measured flavor ratio to that predicted by Monte Carlo simulations. $R \neq 1$ has previously been interpreted as evidence for neutrino oscillations.

A number of other studies of cosmic rays bore fruition during this time period. These include a measurement of the neutrino induced horizontal muon flux, a measurement of the shadow of the moon in cosmic rays which produce muons, and the use of multiple muons for cosmic ray chemical composition studies.

Deep underground experiments, such as Soudan 2, indirectly study the composition of cosmic rays by comparing observations of multiple muon event rates to expectations derived through Monte Carlo simulations using various trial composition models as input. A multiple muon event is one in which two or more nearly parallel, time-coincident muon tracks are observed in the detector. These muons are decay products of mesons which are generated in the hadronic core of the atmospheric cascade. At high energies, massive primaries generate more high energy muons per event than proton primaries of the same total energy. This is because the initial parent meson (predominantly pion) particle multiplicities are larger from the more massive primary, and the atmosphere is more favorable to pion decay versus interaction early in the cascade development. In addition, the point of first interaction of the heavy primary is likely to be higher in the atmosphere than for the proton primary due to the larger cross-section of the heavy nucleus-air interactions.

Events with high muon multiplicity require the ability to separate tracks bunched tightly together, as well as to distinguish tracks obscured by showers in multiple muon events in which a large bremsstrahlung has occurred. The high resolution of Soudan 2 is particularly suited to this type of study since a typical track will leave hundreds of reconstructed pulses along its path. Fig. 1 shows three views of a 14-muon event as recorded in the detector. The resolution of a space

point along a muon track detected in Soudan 2 is ~ 1 cm. The angular resolution of a typical muon track is $< 1^\circ$.

- The Monte Carlo simulation used in this analysis consists of three stages:
- A 3-dimensional simulation of the atmospheric cascade;
- A 3-dimensional simulation of the propagation of the muons through the rock overburden;
- A simulation of the detector.

The cascade simulation uses the HEMAS cascade code for controlling the overall structure of the cascade development. This code injects a nucleus of a requested energy, mass, azimuth and zenith angle into the atmosphere. It then tracks this particle and any secondaries produced along the path of the cascade development until they either interact, decay, drop below some user defined energy threshold, or reach the atmospheric sampling height. The HEMAS cascade code is built so that the hadronic interaction code is fully modular. We have used the program SIBYLL for generating hadronic interactions. SIBYLL is based on the dual parton model with minijet production superimposed. The nucleus-air interaction simulation was done with NUCLIB which includes appropriate corrections for the different nuclear targets present in air. To determine the absolute single and multiple muon rates in the detector, the composition and thickness of the rock overburden is required, as well as a simulation of the passage of the muons through the rock. A digitized map from the US Geological Survey was used to determine the depth of rock around the Soudan site. To determine the rock density of the overburden, a fit to "world survey" muon data was performed using a large body of muon data. The effective rock density was determined in 337 angular bins. The GEANT Detector Description Simulation package developed by CERN was used to propagate muons underground. Finally, the detector was simulated using a simplified model which compares well against a more realistic simulation of the response of the tracking calorimeter modules and their readout electronics.

The energy and mass of the primary cosmic rays cannot be determined on an event-by-event basis through indirect experimental methods such as underground muon rates because of large fluctuations in the atmospheric development of a cosmic ray cascade. Instead, the experimental approach is to assume a model of primary composition at the top of the atmosphere as a function of mass and energy, and to use the Monte Carlo simulation to predict from the assumed composition the muon rate underground. For simplicity, primary composition models generally divide primary cosmic rays into five mass groups centered around the principal nuclei H, He, CNO, Ne-S, and Fe. To narrow the field of possible test composition models, we have defined three composition models which satisfy the following criteria:

- The model is theoretically motivated by an astrophysical model;
- The model fits the available satellite and balloon direct measurement data in the low energy region (< 1000 TeV/nucleus) in which this data is available;
- The model normalizes to the air-shower determined all-particle spectrum in the knee energy region.

We then define three test composition models: “New Source P,” “Heavy,” and “New Source Fe.” The New Source_P model, motivated by the model of Fichtel and Linsley assumes that a new source consisting entirely of protons predominates at energies around the knee. There is excellent agreement between the low-energy component of the Monte Carlo with the direct measurement data.

The results of this analysis are shown in Fig. 2. This figure shows the ratio of simulated multiple muon event rates to observed event rates for each of the three test composition models. Fig. 3 shows the primary energy range to which each multiplicity is sensitive. We note that 90% of the high multiplicity (≥ 6) events come from a fairly well defined region of the energy spectrum which is $8 \times 10^5 - 1.3 \times 10^7$ GeV / nucleus. This is the energy region just below and around the knee of the energy spectrum. From a comparison of event rates, we conclude that the high multiplicity events offer a statistically significant test of composition of cosmic rays in this part of the all-particle spectrum.

The agreement of the measured and simulated event rates of each test composition model is tabulated in Table I. $\chi^2 / \text{d.o.f.}$ in each case is calculated by comparing the absolute event rates of the simulated and measured data for the seven multiplicities 6 through 12 which span the primary energy region of interest around the knee of the all-particle spectrum. The data event rates used in this calculation include statistical and systematic errors, while the simulated event rates include statistical errors only. Of the three trial composition models considered here, the New Source_P simulated event rates clearly give the best agreement with the data in the knee energy region of the all-particle spectrum.

The observed absolute single muon rate agrees with the Monte Carlo rates obtained with all three composition models to within 5%. $\sim 85\%$ of single muon events come from a region of the spectrum in which the composition is known from direct measurements; therefore the agreement of the single muon observed and Monte Carlo rates shows that the Monte Carlo is successful at simulating muon events at low energy.

Fig. 1. A 14 muon event in the Soudan 2 detector. The figure shows three different view of the same event. All axes are labeled in centimeters.

Fig. 2. Ratio of simulated to data absolute event rates as a function of event multiplicity. The ratio errors are calculated using the systematic and statistical errors of the Data rates, and statistical errors only of the Monte Carlo rates.

Fig. 3. Distributions of Monte Carlo multiple muon events as a function of primary energy. The distributions have been normalized to the total live time of the analysis.

Table I. Calculated values of χ^2 , χ^2 per degree of freedom (d.o.f.), and confidence level for each of the test composition models. See text for further discussion.

Composition Model	χ^2	d.o.f.	$\chi^2 / \text{d.o.f.}$	C.L. (%)
New Source_P	8.7	7	1.2	28
Heavy	103	7	15	2.1×10^{-17}
New Source_Fe	236	7	34	3.0×10^{-45}

b. Experimental Apparatus, Operation and Maintenance

Argonne physicists continued to make substantial contributions to the maintenance and operation of the detector. Major activities included ongoing improvements of detector and electronics performance, and coordination of the module upgrade project. Argonne physicists also continued the development of software to make use of dE/dx information from the detector.

c. Planning Activities

In response to a report from the SAGENAP panel (Scientific Assessment Group for the Evaluation of Non-Accelerator Physics), the Soudan 2 collaboration prepared a letter detailing the important physics contributions uniquely addressed by the Soudan 2 experiment. A physics steering committee has been formed to coordinate the analysis efforts through the collaboration, with five members; one from each major group. A new spokesman, Tony Mann from Tufts University, has been elected.

(M. Goodman)

I.A.5 ZEUS Detector at HERA

a. Physics Results

Five papers were published in this period and three more manuscripts were submitted for publication.

Deep inelastic charged-current reactions have been studied in e^+p and e^-p collisions at a center-of-mass energy of about 300 GeV in the kinematics region $Q^2 > 200 \text{ GeV}^2$ and $x > 0.006$. The integral cross sections for $Q^2 > 200 \text{ GeV}^2$ are found to be

$$\sigma_{e^+p \rightarrow \bar{\nu}X} = 30.3^{+5.5}_{-4.2} {}^{+1.6}_{-2.6} \text{ pb and } \sigma_{e^-p \rightarrow \nu X} = 54.7^{+15.9}_{-9.8} {}^{+2.8}_{-3.4} \text{ pb}$$

in reasonable agreement with Standard Model predictions of 32.3 pb and 65.8 pb, respectively. The differential cross sections for both e^+p and e^-p as function of Q^2 are shown in Figure 1.

Fig. 1. Differential charged current cross section versus Q^2 for both e^+p and e^-p collisions. The ratio of cross sections is shown in the lower graph. The lines indicate the Standard Model predictions based on the MRSA parton densities.

The measurements are compared to the predictions based on the Standard Model and the MRSA parton densities. No significant deviations from the predictions are observed. The Q^2 dependence of the cross section is largely determined by the propagator term involving the W -boson mass, M_W . A fit with M_W as free parameter, applied simultaneously to the e^+p and e^-p cross sections, yields

$$M_W = 79^{+8}_{-7} \text{ [stat]}^{+4}_{-4} \text{ [syst]} \text{ GeV}$$

in agreement with direct measurements at $p\bar{p}$ colliders.

A new reconstruction method for neutral current deep inelastic scattering events has allowed a significant improvement in the resolution of the kinematics variables and an extension of the kinematics region covered by the experiment. At $Q^2 < 35 \text{ GeV}^2$ the range in x now spans $6.3 \cdot 10^{-5} < x < 0.08$ providing overlap with measurements from fixed target experiments. At values of Q^2 above 1000 GeV^2 , the x range extends to 0.5. Systematic errors below 5% have been achieved for most of the kinematics region. As seen in Figure 2, the structure function $F_2(x, Q^2)$ rises as x decreases; the rise becomes more pronounced as Q^2 increases. The behavior of $F_2(x, Q^2)$ is well described over the whole kinematics range by next-to-leading order perturbative QCD as implemented in the DGLAP evolution equations.

The installation of a forward neutron calorimeter some 100 meters downstream of the interaction point in the proton direction allowed for the detection of energetic forward neutrons in deep inelastic scattering (DIS) events. The neutrons are detected at very small detection angles, $\theta \leq 0.75 \text{ mrad}$, and at high $x_L \equiv E_n / E_p$, $x_L > 0.3$. Within the present statistics, leading neutron production appears to occur at a constant fraction of deep inelastic scattering, independent of x_{BJ} and Q^2 . Furthermore, the neutron energy spectrum shows no variation of its mean or width with x_{BJ} and Q^2 . Neutrons with energy $E_n > 400 \text{ GeV}$ and $|t| < 0.5 \text{ GeV}^2$ account for a substantial fraction, of the order of 10%, of DIS events.

The production of ϕ mesons in the reaction $e^+p \rightarrow e^+\phi p$, for $7 < Q^2 < 25 \text{ GeV}^2$ and for virtual photon-proton centre of mass energies W in the range 42-134 GeV, has been studied. When compared to lower energy data at similar Q^2 , the results show that the $\gamma^* p \rightarrow \phi p$ cross section rises strongly with W , see Figure 3. This behavior is similar to that found for the $\gamma^* p \rightarrow \rho p$ cross section. This strong dependence cannot be explained by production through soft pomeron exchange. It is, however, consistent with perturbative QCD expectations, where it reflects the rise of the gluon momentum density in the proton at small x . The ratio of $\sigma(\phi) / \sigma(p)$,

which has been determined to be 0.065 ± 0.013 in photoproduction at a mean W of 70 GeV, is measured to be 0.18 ± 0.03 at a mean Q^2 of 12.3 GeV^2 and a mean W of 100 GeV and is thus approaching at large Q^2 the value of $2/9$ predicted from the quark charges of the vector mesons and a flavor independent production mechanism.

Fig. 2. Structure function F_2 as a function of x for fixed values of Q^2 . The solid dots correspond to data from ZEUS. The “ISR” (open squares) and “SVX” (open triangles) data show ZEUS results obtained from events with hard initial state radiation and a shifted vertex, respectively. The results (open circles) from NMC are also shown. The solid lines indicate the QCD NLO fit to the data.

Fig. 3. The $\gamma^* p \rightarrow \phi p$ cross section as a function of W for several values of Q^2 . The low energy data come from fixed target experiments.

The dijet angular cross section $d\sigma / d|\cos\theta^*|$, where θ^* is the jet scattering angle in the dijet center of mass system, has been measured for $ep \rightarrow 2$ or more jets with transverse energies $E_T^{\text{jet}} \geq 6$ GeV, dijet mass $M_{jj} > 23$ GeV, and average pseudorapidity $|\eta| < 0.5$, in the range $0.25 < y < 0.8$ and for virtualities of the exchanged photon less than 4 GeV². The cross section has been measured for resolved ($x_\gamma^{\text{OBS}} < 0.75$) and direct ($x_\gamma^{\text{OBS}} > 0.75$) processes separately. The variable x_γ^{OBS} is the fraction of the photon energy contributing to the production of the two highest E_T^{jet} jets. It is defined as

$$x_\gamma^{\text{OBS}} = \frac{E_T^{\text{jet1}} e^{-\eta^{\text{jet1}}} + E_T^{\text{jet2}} e^{-\eta^{\text{jet2}}}}{2E_\gamma},$$

where E_γ is the initial photon energy. The dependence of $d\sigma / d|\cos\theta^*|$ on $|\cos\theta^*|$ reflects the different spins of the quark and gluon propagators and the relative contributions of the underlying subprocesses in resolved and direct photoproduction, see Figure 4. In LO QCD the cross section rises faster with increasing $|\cos\theta^*|$ for resolved photoproduction, where processes involving spin-1 gluon exchange dominate, than for direct photoproduction, where processes involving spin-1/2 quarks exchange dominate. These aspects are preserved in NLO QCD calculations. The $|\cos\theta^*|$ dependence of the measured cross sections is in good agreement with these theoretical predictions and thus confirms fundamental aspects of QCD.

ZEUS 1994

Fig. 4. $d\sigma / d|\cos\theta^*|$ normalized to one at $\cos\theta^*=0$ resolved (black dots and direct (open circles)) photoproduction. In a), the data are compared to LO and NLO QCD predictions, in b), the same data is compared to the PYTHIA and HERWIG distributions.

b. HERA and ZEUS Operations

Overall the 1996 run period was a great success for both HERA and ZEUS. HERA delivered an integrated luminosity of 17 pb^{-1} and ZEUS logged 11.1 pb^{-1} on tape, see Figure 5. During this run period HERA delivered a record luminosity of 400 nb^{-1} in one day and ZEUS collected 1.023 pb^{-1} in one single week.

Fig. 5. Integrated luminosity as a function of the date for the 1996 run.

ZEUS improved from 60% to 65% its on-tape efficiency. This improvement was made possible due to several factors:

1. New third-level-trigger system with more bandwidth and more reliable and faster transitions.
2. New calorimeter run control.
3. New computer for the general second-level-trigger.
4. Improved voice alarm system.

5. New central-tracking-detector high voltage program.

(J. Repond)

I.A.6 BNL AGS "Partial Snake Magnet" Experiments

There are two kinds of depolarizing resonances, imperfection and intrinsic, to overcome. In the past, we succeeded in eliminating imperfection resonances by using a partial snake magnet. Intrinsic spin resonance is caused by the vertical betatron oscillation, and the resonance condition of $G\gamma = kP \pm \nu_z$, where k is an integer, P is the number of super periods, G is the anomalous gyromagnetic factor, for proton it is 1.7923, and ν_z is the vertical betatron tune. To accelerate polarized protons to the RHIC injection energy of 23 GeV, we will encounter 7 intrinsic resonances: $G\gamma = \nu_z, 24 - \nu_z, 12 + \nu_z, 36 - \nu_z, 24 + \nu_z, 48 - \nu_z, 36 + \nu_z$ in the AGS. Therefore, a novel scheme of overcoming intrinsic resonance with the emittance preserved is required. The feasibility of crossing the intrinsic resonances by exciting a coherent betatron oscillation with an AC dipole field was extensively studied. Major work was done by an Argonne graduate student. The particle's dynamic tracking and spin tracking with AGS parameters were carried out. Test results with an AGS unpolarized beam are in good agreement with the calculations.

(D. Underwood, A. Yokosawa)

I.B EXPERIMENTS IN PLANNING OR CONSTRUCTION

I.B.1 Polarized-Beam Experiments for a RHIC Polarimeter

As charged by the BNL management in 1995, a group called RHIC polarization Measurement Working Group was formed. After a number of studies and discussions, we concluded that the best candidate is an inclusive pion polarimeter, as demonstrated in the Fermilab E-704 experiment ($x_F = 0.8, p_T = 1.0$ GeV/c) at 200 GeV/c. However, the asymmetry in pion production at the injection energy of 23 GeV/c is not well understood. Therefore, it became urgent to make such a measurement at 23 GeV/c.

Several people from Argonne began working on a proposal, and quickly formed a collaboration consisting of ANL - BNL - IHEP(Protvino) - ITEP(Moscow) - Indiana - Kyoto - - Tokyo - UCLA - Iowa (One of co-spokesmen from Argonne).

We propose to measure asymmetries in the inclusive reactions, $p^\uparrow p \rightarrow \pi^\pm \text{ anything}, p^\uparrow C \rightarrow \pi^\pm \text{ anything}$ at 23 GeV/c. The goal of these measurements is to obtain basic information in order to design a polarimeter for the RHIC polarized beams.

At RHIC we plan to measure the polarization of the RHIC beams from 23 GeV (at injection) to 250 GeV. Polarimeters, used at lower energies, utilize pp elastic scattering to analyze the beam polarization. The analyzing power for this reaction becomes too small to be useful much above 23 GeV/c.

We started from scratch initially searching for a suitable experimental area. Our experience with E-704 was extremely useful in writing the proposal. This proposal was presented at the fall meeting of the BNL HEP-NP PAC. In October 1996, we received approval with top priority; Tom Kirk wrote "my personal thanks for a very well-constructed and well-presented proposal, and that is of vital importance to the future of the RHIC Spin Program." Since the E-925 approval, various plans were discussed among the collaborators.

The Argonne group assumed major responsibilities in setting up experiments by utilizing a number of scintillator hodoscopes from E-704 together with electronics. The UCLA group provided a luminosity monitor and trigger counters, BNL provided an analyzing magnet, a Cerenkov counter, and a proper experimental area etc., ANL and IHEP worked on data acquisition software, RIKEN-Kyoto-Tokyo worked on the pp elastic channel to determine the incident beam polarization.

(A. Yokosawa, D. Underwood)

I.B.2 STAR Detector for RHIC

The solenoidal tracker at RHIC (STAR) will search for signatures of quark-gluon plasma (QGP) formation and investigate the behavior of strongly interacting matter at high energy density. The emphasis will be the correlation of many observables on an event-by-event basis. In the absence of definitive signatures for the QGP, it is imperative that such correlations be used to identify special events and possible signatures. This requires a flexible detection system that can simultaneously measure many experimental observables. Also RHIC is the best place to do the spin physics, because of the energy and parton-parton luminosity.

The physics goals dictate the design of this experiment. The detector is a 4π detector with solenoidal field much like other collider detectors. The central tracker is a TPC, 4-meter long and 4-meters in diameter. The magnet is a 0.5T conventional magnet. The electromagnetic calorimeter (EMC) will be inside the magnet coils, for better sensitivity to low energy electrons and gammas.

Argonne led the STAR EMC project in the areas of optics, shower maximum detector prototypes and electronics development, mechanical engineering of supports, triggering, and simulations for additional physics processes. ANL with Wayne State is helping to optimize the

design, and passed a conceptual design review for continued funding to finalize the design and production details.

(A. Yokosawa, D. Underwood)

I.B.3 MINOS--Main Injector Neutrino Oscillation Search

The MINOS experiment will search for neutrino oscillations in regions of $\sin^2(2\theta)$ and Δm^2 parameter space which previous accelerator experiments have not been able to reach. If oscillations are found, MINOS will measure the parameters and determine the oscillation mode. The experiment requires the construction of a high intensity neutrino beam, produced by Fermilab's new Main Injector accelerator, the excavation of experimental halls at Fermilab and 730 km away at Soudan, Minnesota, and the construction of magnetized iron tracking calorimeter detectors at Fermilab and Soudan. The 10 kiloton "far" detector at Soudan will be an 8-m diameter, 50-m long assembly of 4-cm thick steel planes which alternate with planes of active detector elements. The "near" detector at Fermilab will be as similar as possible to the far detector, but will be much less massive owing to the higher neutrino flux. The presence of oscillations will be signaled by an unexpected difference in the rates and/or characteristics of neutrino interaction events in the two detectors.

During the last half of 1996 the MINOS collaboration continued its development program to optimize the design of the experiment. The main parameters of the experiment and detectors must be decided by early FY 1998 in order to be ready for the first neutrino beam in 2001. The specific goals of this work were to optimize the designs of the active detector technology, the fabrication technique for the steel detector planes, the neutrino beam configuration, and the halls for the near and far detectors. Important accomplishments during the last half of 1996 include:

1. Completion of the collaboration-standard Monte Carlo simulation package for the experiment, GMINOS. This software generates Monte Carlo neutrino events in MINOS near and far detectors instrumented with various steel and active detector options, and is now being used to study the effect of design parameters on the sensitivity to oscillations.

2. Development of alternative active detector technologies. The MINOS group at Argonne is developing aluminum proportional tube (APT) detectors, as described later in this report. Other MINOS collaborators are working on liquid and plastic scintillator detectors. The collaboration decided to stop work on resistive plate counters (RPC's) in October 1996. The new Detector R&D Advisory Committee, which was established to guide the collaboration's R&D work, held its first meetings in August and December 1996.

3. Electronics design. Work continued on the design of the electronics systems which will be needed to read out the near and far detectors. Several different architectures are being discussed, but detailed design work cannot begin until an active detector technology is chosen. Most of this effort was concentrated in the U.K. since no MINOS R&D funds have been available to support electronics engineering in the U.S. The Argonne electronics group did, however, begin planning for the readout system which would be needed for the test beam exposure of a prototype APT calorimeter in 1997.

4. Development of steel plane fabrication techniques. In October 1996 the collaboration decided to adopt the steel plane design developed by the Livermore group, in which each 4 cm thick plane is assembled from two 2-cm thick layers. Each 8-m diameter octagonal layer is made up of 2-m wide strips, with the strips in the two layers oriented at right angles to each other and plug welded together. Work at Argonne on an alternative fabrication technique, described in the previous Semiannual Report, has been completed.

5. Planning for excavation at Soudan. Excavation of the new underground experimental hall for the MINOS far detector at Soudan is scheduled to begin in the spring of 1998. Many tasks must be completed before this time: State and Federal environmental regulations must be satisfied, cavern dimensions must be decided, and a plan for funding the excavation and outfitting contracts must be agreed to. Work on the Environmental Assessment Worksheet has now started at the University of Minnesota. An outside contractor, Charles Nelson Associates (CNA) mine consultant engineers, has started to work with MINOS physicists and engineers to develop a detailed plan and cost estimate for the excavation.

6. Planning for detector installation. Installation of the 10 kT far detector places important requirements on the new underground hall at Soudan (e.g. space required for assembling the 8-m diameter planes of steel and detectors). The manpower needed for this labor intensive task is a major part of the cost of the experiment. A working group of physicists and engineers, including several Argonne participants, has been formed to work out detailed plans and cost estimates for the installation process.

7. Development of emulsion detector design. The collaboration began a study of the sensitivity of a hybrid emulsion detector which was suggested by K. Niwa of Nagoya University for possible use at Soudan. If $\nu_\mu \rightarrow \nu_\tau$ oscillations occur, this detector would be able to identify tau lepton decays with high efficiency and low background. If it works as well as predicted, a few hundred tons of detector could perform a ν_τ appearance experiment which would be more sensitive to oscillations than the 10 kT MINOS far detector. The emulsion detector would consist of alternating layers of 1-mm thick steel plates and 1-mm thick plastic sheets with 50 μm emulsion layers on both sides. Planes of track chambers (perhaps APT's) spaced every 10 cm within the emulsion detector would be used for triggering and event

localization. These chambers identify the emulsion module where a neutrino interaction takes place and provide a starting point for the emulsion scanning. Individual emulsion modules could be removed and scanned as soon as candidate events are identified.

(D. Ayres)

I.B.4 ATLAS Detector Research and Development

a. Overview of ANL LHC Related R&D Programs

The second half of 1996 was an exceptionally busy and productive period for the ATLAS groups in the division participating in the second level trigger and TileCal calorimeter subsystems. In the trigger subsystem processors and software for use in trigger architecture tests to be conducted in early 1997 were prepared and tested. The Tile Calorimeter subsystem met two major milestones: The barrel prototype module was exposed to high energy beams at a CERN test beam in August and September; and in December the Tile Calorimeter Technical Design Report was submitted to the LHCC. In addition to these two achievements, the US groups in ATLAS submitted an updated proposal to DOE and NSF, and in the TileCal subsystem began construction of a prototype extended barrel module to be built entirely here in the US and carried out extensive structural analysis, both in support of the TDR and to firm up the support and assembly concepts of the tile and liquid argon calorimeter systems.

(J. Proudfoot)

C. DETECTOR DEVELOPMENT

I.C.1 CDF Detector and DAQ Electronics Development

a. Upgraded Shower Max Readout Electronics

J. Dawson, working with K. Byrum, could not come up with a quiet enough preamp for use with shower max as demonstrated in with our test setup.

b. CDF Central Tracking Chamber Replacement

V. Guarino, with L. Nodulman, developed a FEA model for the endplate of the new CDF tracker (COT), and negotiated a project to provide insertion tooling for putting wire planes and field sheets into the tracker.

T. LeCompte participated in a review and redesign of forward muon coverage and became CDF project manager for muon upgrades.

I.C.2 ZEUS Detector Upgrade (Barrel Pre-Sampler)

During this period, the HERA winter shutdown schedule was revised, resulting in a very short (8-week) shutdown period in which the ZEUS detector was accessible. This schedule precluded installation of the entire 32-module BPRES detector, so a revised installation of 6 modules was planned. In this way, some experience could be gained by operating part of the BPRES before the final installation. Six modules were seen as the best trade-off between installation time and usefulness of the anticipated data. Full containment of a jet (typically 4-5 modules wide in the barrel region) was used as the criteria.

Procurement of most of the parts needed for mechanical construction of all 32 BPRES modules was completed during this time period. Delivery of the cassette end pieces (from DESY) occurred in November, and 6 cassettes were completed by the end of the year. All of the scintillator tiles were rough cut at ANL and the sequence of edge finishing (at PSU) and fiber groove machining (at OSU) was begun at the beginning of this time period and essentially completed by the end of the year. All parts for the PMT housings were received, the end plates being machined at DESY and delivered to ANL. PMTs were ordered through Wisconsin, and enough arrived at DESY in time to be tested and used for the 6-module installation. Fiber splicing was completed at FNAL during this period. All of the spliced fibers were to be tested at Andrews University. This testing consisted of measuring the light output at the end of the clear fiber from an LED positioned at the WLS end. Individual fibers were then paired according to their measured signals in order to reduce effects from splice non-uniformity. The following plots

show the distribution of unpaired fibers from the third group to be tested and the distribution after pairing. The effect of the systematic pairing of fibers reduces the spread

Fig. 1 Distribution of unpaired and paired fibers.

in the distribution from about 16% to 2%. By the end of the year, enough fibers were tested and paired to complete the 6 modules needed for installation. A study performed by an ANL undergraduate summer student resulted in fixing the design for the LED calibration system. Fibers and acrylic (for mixing bars) were ordered for the entire BPPE. This system was not installed on the first 6 modules at the time of construction, however, before the permanent installation in the winter of 1997-1998, the LED system will be installed in these modules. Electronics construction has begun at Kyungpook University (Korea) for the analog cards and at Iowa for the digital cards.

The 6 modules for the winter 1996-1997 shutdown installation were completed at ANL and sent to DESY in December 1996. This included 6 PMT housings, parts necessary for the installation, and enough PMTs and bases for the readout. The electronics (enough for 6 BPPE modules) was already at DESY and was intended to be installed in spare slots of existing ZEUS components. The HV supply for the PMTs was to be provided by spare channels on the Barrel Calorimeter (BCAL).

(S. Magill)

I.C.3 STAR Electromagnetic Calorimeter and Related Topics

Most of the activity in this period was directed toward preparation for the Conceptual Design Review of the STAR EMC and toward design of the supports of the EMC. The Conceptual Design Review for the STAR EMC took place at BNL in December. It was run by

RHIC using outside reviewers. The review was very successful in presenting the physics case, and the basic design. There were a number of items that need action before construction begins.

For the Conceptual design review, we documented work done at ANL on the following topics: Physics motivation for having the Calorimeter in STAR, and for the particular design features such as number of towers; and use of shower max detector. The EMC will enable STAR to do both triggering and measurements for two different kinds of QCD studies, search for the quark-gluon plasma in Heavy ion collisions, and spin structure of the nucleon in high energy pp spin-polarized collisions.

Some changes to the design of the EMC were made in the preceding months to improve the performance in high multiplicity AuAu collisions. The increase in number of towers from 1200 to 4800 will be particularly useful for finding individual pi-zeros as compared to a general flux of photons from pi-zero, and also for counting occupied towers as a major help in finding a disordered chiral condensate, which would presumably affect the energy and multiplicity of particles in some area of the phase space. The shower-maximum detector design was also modified to work better in a high multiplicity environment. The strips of 0.5 in eta length were broken up into pieces of 0.1 in eta to reduce occupancy.

Module size tolerances, as influenced by deflections in the modules and support system both during installation and when the modules are in final position.

- Integration drawings, showing the EMC characteristics and location of supports, numbers of optical fibers, location of phototubes, etc.
- Integration of Shower max cables and optical fibers into the space around the EMC modules, and through the spaces between coils of the STAR magnet.

Tests of the loss of optical fiber output over time for fibers which were bent, bent as they will be inside scintillator tiles and in the modules. We documented that one brand of fibers decayed on all time scales from minutes to 4 years, while another brand appeared to be stable. The overall plan for calibration, including comparison of many methods, and cost effectiveness of a few. Development and testing of prototype preamplifiers to be used on the Shower-Max. detector to amplify very small signals so that the electrical noise from the STAR magnet coils would not interfere with them.

(D. Underwood)

I.C.4 ATLAS Calorimeter Development

a. Hadron TileCal Calorimeter Mechanical Design

The mechanical design work focused on two areas in this period: Beginning construction of the extended barrel prototype to be completed in Spring 1997; and structural analysis of the tile calorimeter and its connections and the effect of the supports of the liquid argon cryostat. The general schedule for the production of the prototype is shown in Figure 1 and work has begun on submodule construction; girder construction; module assembly base design and integration. In addition, the group contributed extensively to the writing of the Technical Design Report:-providing the chapter writer/editor for the mechanics chapter, one of the two general editors and substantial assistance to the editor responsible for the optics chapter.

Fig. 1. Extended barrel module 0 assembly - construction schedule

1. Extended Barrel Submodule Construction

Eight standard submodules, one special submodule and one ITC submodule are required to construct the extended barrel prototype module. Of these, 4 standard submodules and one special submodule were stacked at Argonne in October and November. This was the first time in which the semi-automatic glue delivery system was used for stacking and although some minor problems were encountered the outcome was generally successful and the time required approximately the same as obtained for manual application but with much less effort. In addition, a new facility was used at Argonne to clean plates prior to gluing. This was a

commercial plate cleaner using hot water and an environmentally-friendly cleaning agent. Although the procedure worked reasonably well (despite some problems with residue) it was still time-consuming due to a mismatch in size and capacity. This is one area in which additional work is required prior to production. Following the completion of these modules, the fixture was shipped to the University of Illinois where the remaining 4 standard submodules were stacked, with assistance from ANL staff for the first of these.

As part of the prototype construction effort, Argonne also procured 5mm raw sheet and stamped an additional 600 master plates. This allowed us to establish that a US vendor could meet the TileCal steel specification and to obtain a reasonable cost basis for production. It also allowed us to demonstrate that the die could be re-installed in a press and still meet our tight tolerances. As a byproduct, we discovered that the task of surface preparation was an area which might benefit from further cost optimization (the price increased relative to the first run).

All modules required some cleanout to remove glue from the scintillator slots. This is also a labor intensive procedure and some minor changes to the gluing technique and to the volume of glue required may prove desirable for production. All submodules were coated with a corrosion prevention agent (CORTEC) and subsequently found to be tacky indicating that either some minor changes in the technique or a different agent might be preferred for production modules. Neither of these two issues are considered major and improvements are already being studied within the collaboration.

2. Extended Barrel Girder Construction

The detailed design of the support girder upon which submodules are mounted to form modules was an area of extensive discussion in this period. The main disagreements concerned tolerances. However, there were some areas of disagreement in the design itself between the engineering staff at Argonne with those at CERN, in particular as they relate to the module envelope. These were eventually resolved "in spirit" and we released the procurement in late December (about 6 weeks behind schedule). Our present best evaluation of this envelope, using the Argonne specific design, is shown in Figure 2. This in fact shows that as designed we do not fall within a 0.5 mm envelope and further work and discussion will continue in 1997.

Fig. 2. Module assembly - tolerance envelope

3. Extended Barrel Module Assembly Preparations

The construction of the module assembly base to be used for the construction of the prototype module is the responsibility of the University of Texas at Arlington. The base must integrate fully with the girder (designed at Argonne) and the actual assembly will be carried out at Argonne and we have therefore collaborated closely with this group on the design of the system. As with the girder itself, the design of the assembly base was finalized later than scheduled with the actual fabrication being begun by UTA in late December. We expect to receive it at Argonne for installation towards the end of January.

(N. Hill and J. Proudfoot)

b. Structural Analysis

Over the last six months 3-dimensional finite element analysis was used to examine the forces between modules of the extended barrel and to begin to understand the design of the extended barrel support saddle. The additional loads from the endcap Liquid Argon calorimeter

have not been included for this initial study. In this analysis a complete extended barrel was examined, however, only half of the extended barrel was actually modeled by applying symmetric boundary conditions at the six o' clock position. The following additional assumptions were made.

1. There was no contact across the top of the extended barrel at the 12 o' clock position.
2. The modules were connected by a bearing force at the front plate and a bearing and radial force at the outer radius.
3. The extended barrel was supported only at $z=0$ and $z=2.6$ from modules 22 through 27.

The distribution of the bearing forces at the inner and outer radius are shown in Figure 3, where they are compared to a 2-dimensional static analysis performed at CERN. The maximum compressive force at the inner radius is 141 metric tons. The connection at the outer radius is initially in tension but becomes compression at the area in which the extended barrel is supported. The maximum tensile force at the outer radius occurs below the area of support and is 96 metric tons. The results of this analysis and a 2-dimensional static analysis performed at CERN were very similar.

This initial analysis was then extended to establish the general features of the required support saddle. The model conditions and assumptions are listed below.

1. Support saddle modeled using plate elements.
2. Support modeled using thick plate elements.
3. Radial connection between support and extended barrel at each module using six 25 mm bolts.
4. Shear connection between support and extended barrel at the 27th module.
5. Each support is restrained in only the vertical direction by the rail.

Fig. 3. Inner and outer radius forces obtained from finite element analysis, compared with those of a 2-dimensional static calculation.

The connection between the extended barrel and the support saddle consists of the shear connection at the bottom of the saddle and six bolts which could only carry radial forces along the length of each saddle for a total of 24 bolts. Nine different cases were examined in which the thickness of the saddle, its width, location along the length of the extended barrel and the height of the rail support were all varied as indicated schematically in Figure 4: The thickness of the saddle support was varied from 25-75 mm; the separation between the support on the same saddle from 147-294 mm; the location of the first support on the saddle from the inner edge to the outer edge of the first saddle; the distance between supports from approximately 150-235 cm; and the vertical location of the support relative to the rail by approximately 40 cm. In addition, to verify that the lateral load on the rail was small, one case was run in which the supports were restrained from lateral movement. For this coarse approximation of the support saddle geometry, the maximum stresses in the saddle itself range from 70-120N/mm for the nine cases considered.

EXTENDED BARREL "DONUT" CONCEPT

Fig. 4. Saddle parameters varied in finite element analysis of supports.

Figure 5 shows the variation of the bearing force at the inner radius for the nine cases. The pattern of forces does not change significantly as the parameters of the support saddle are varied. A similar conclusion is obtained for the load distribution at the outer radius as well as for the radial loads. However, it should be noted that the forces shown are total forces which are summed along the length of the modules. When the variation of these forces along the length of the module are examined, significant differences arise.

Fig. 5. Inner radius bearing loads from 3-dimensional finite element analysis of the calorimeter support structure for nine support cases as described in the text.

Our preliminary conclusions are that the support should be as wide as possible and that the saddle plates should have a thickness of 50 mm. There is no indication of any significant transverse load being applied to the ATLAS main rail system. The placement of the saddle, however, can strongly affect the localized forces in the calorimeter structure and requires further study using a more accurate model of the EB and Liquid Argon support. With the demonstrated agreement between the static model used at CERN and the FEA calculations, we are now equipped with the tools to optimize the design of the supports.

Finally, the 3-dimensional model with the support saddle was used to calculate the deflection envelope of the EB. Figure 6 shows the vertical and horizontal deflection of the EB which displays an 'egg-shelling' deflection pattern. The maximum vertical deflection at the top

of the barrel was -2.9 mm. There was no significant dependence on the design of the support saddle observed within the range of the investigated parameters.

(V. Guarino)

Fig. 6. Horizontal and vertical displacements of extended barrel calorimeter structure from finite element calculations.

c. CERN Test Beam Program

The second half of 1996 again saw intense activity at the testbeam at CERN where data were taken with the first barrel module designed to real ATLAS specifications. Barrel Module 0, as it is known, was sandwiched between a top and bottom layer of the 1-meter prototype modules on the 85-ton capacity scanning table. The module was equipped with fast sampling electronics known as the FERMI readout system, and hydraulic and pneumatic source drive systems. Data were taken with a variety of beam particles and energies under a program designed to thoroughly understand the performance of this new device.

The scanning table was a major piece of equipment costing in excess of \$100K for construction alone. Argonne contributed the design and construction of the electro-mechanical part of the scanning table. Before the start of the testbeam program, Argonne physicists installed electrical and safety components for the motors as well as the electronics for local and remote operation. Our efforts culminated in a system which provided a fast, precision and reliable manipulator in z , q , and f .

Once the scanning table was in place, the loading of the 1m-prototypes and barrel Module 0 was done. Calibration of the detector was done in place and included the standard laser system and both of the ^{137}Cs drive systems. A beam's-eye view of the setup is shown in Figure 7.

Data on Module 0 is currently being analyzed. The FERMI readout system functioned well, although errors in calibration procedures have forced us to invent non-standard analysis techniques to reconstruct the energy from the 40 charge samples obtained in each of the approximately forty PMTs. Seen in Figure 8 are the charge samples for one event for each of the phototubes of one side of the module. The event is a 180 GeV pion shower, and the signal is clearly seen in seven cells which contain the shower.

(R. Stanek)

Fig. 7. Setup of the Barrel Module 0 in the testbeam at CERN. Seen are two of the prototype 1m-modules resting on top of the 6m long barrel module.

Fig. 8. The FERMI readout for the ODD side of Module 0 for each of the 23 phototubes. Data are for 180 GeV pions incident at $h = 0.45$.

I.C.5. ATLAS Trigger Development

a. The ATLAS Level 2 Supervisor and Region-of-Interest Builder

There exists within the Level 2 Trigger community an effort (The Demonstrator Project) to implement in hardware subsets of the actual trigger architecture envisioned for ATLAS, and in fact there are currently three different architectures being discussed. Our objective has been to

provide supervisor support for these three architectures with prototype hardware, striving to make our design general enough that it supports all three architectures. Clearly, in a project with a time dimension like ATLAS, there is a danger in freezing technology choices too early. However, our feeling has been that a prototype hardware realization effort at this time is useful in leading to the judicious choice of architecture for the Level 2 Trigger and in providing insight into the bottlenecks and other problems to be encountered in the final design.

The prototype hardware we are developing consists of the input and output routers, PCI mezzanine cards (PMC), bus structures, and miscellaneous support hardware. We have produced PMC cards which basically satisfy the requirements of the supervisor support for The Demonstrator Project, and in fact for ATLAS itself. Figure 1 shows one of these PMC cards. These PMC cards utilize the AMCC 5933 chip to manage the PCI port, and transfer data using the asynchronous mode utilizing the on-chip fifo. Data rates as high as 65 MB/sec have been routinely achieved operating the PMC cards with a Motorola 604 Processor using a 100 MHz PowerPC running under OS-9000, and data transfers seem quite robust.

Fig. 1. A photograph of one of the PMC cards fabricated for the ATLAS Level 2 Trigger demonstrators.

A very simplified flowchart of the polling loop for an individual ROI processor in the system described above is shown in Figure 2. A similar flowchart for the steward processor appears in Figure 3. Using transfer rates measured at CERN for the CES RIO2 processor for the PCI access and the VME transfers and estimates based on algorithm benchmarks done on other processors we conclude that a small system of four or five processors should be able to manage

Fig. 2. Flowchart of processing done by one ROI processor in the ATLAS T2 supervisor.

the level 2 system at the required rate. These estimates, which do not include contention on the VME bus nor overheads associated with switching between transfer tasks and computing, lead to overall times for a single steward system of 8 microseconds per event for the steward and 8 microseconds for each ROI CPU to process an event.

(R. Blair and J. W. Dawson)

Fig. 3. Flowchart of processing done by the steward processor in the ATLAS T2 supervisor.

I.C.6 MINOS Detector Development

During the last half of 1996 MINOS R&D work at Argonne was focused almost entirely on studies of the Aluminum Proportional Tube (APT) active detector technology option. The APT design has evolved from the Limited Streamer Tube (LST) technology, which was chosen as the reference detector for the MINOS Proposal because of the very favorable experience with large scale LST systems in the hadron calorimeters of LEP detectors and the MACRO detector. LST's for these experiments have been mass produced at factories in Italy, Dubna, Beijing and Houston. The experience of these experiments gives confidence in the fabrication cost estimates, large scale performance, and long term stability of very large LST detector systems.

During the past year MINOS collaborators at Argonne, Beijing, Dubna and Tufts have adapted the reference detector technology to the special requirements of MINOS, leading to the current APT design. This evolution from LST's to APT's has been driven by two requirements:

1. Good electromagnetic energy resolution requires uniform gas gain, which is limited mainly by the dimensional uniformity of the LST comb extrusions. Dimensional uniformity is easier to maintain with commercially extruded aluminum than with the original PVC comb material.
2. The desire for MINOS to use nonflammable gas mandates that the chambers be operated in proportional mode instead of limited streamer mode, because LST's with aluminum extrusions (cathodes) produce afterpulsing in gases with low isobutane content.

Other design changes involve the details of detector construction, specifically the change from 8 cell to 16 cell chambers to reduce manufacturing cost, and the packaging of seven APT chambers into 1.15 meter wide modules to reduce installation costs. These changes preserve the advantages of the original design, with the possible exception of the good calorimeter response, which might be worse for proportional mode operation than for limited streamer mode. Test beam studies of a prototype APT calorimeter will be conducted at Fermilab during 1997 to resolve this question. This calorimeter will require the construction of 150 1-meter long APT chambers.

Figure 1 shows a sketch of an APT chamber. The chamber consists of a 16-channel aluminum comb extrusion, up to 8 m long, enclosed in a gas-tight extruded PVC sleeve. Each of the 16 open-faced channels in the comb extrusion is 9 mm by 9 mm with 1 mm walls, and contains a 50 μ m gold-plated tungsten anode wire under 250 g tension. The wires are soldered to pads at the ends of the channels and are constrained by injection molded supports every 50 cm to maintain the wire positions within the tubes. Injection molded end caps seal the gas enclosure and provide feedthroughs for gas, signal, and high voltage connections. Groups of seven chambers are laminated between plastic sheets to form modules which are easy to install. Cathode strip planes are constructed from doubled-sided copper-clad glass polyester sheets which are scored on one side to form planes of 2 cm wide strips. Each 8-m diameter detector plane is assembled from seven APT modules, which are attached to the steel plane at the edges and around the central coil hole. Strip planes are glued to each APT chamber plane after it is attached to the steel. Electronics cards are mounted around the top edges of the steel planes (all readouts and gas connections are made at the upper end of each chamber), with the signals interconnected by optical fibers.

By the end of 1996 the Argonne group had found commercial suppliers of APT chamber components: aluminum comb extrusions, PVC gas sheaths, and injection molded plastic end

caps, wire termination boards, and wire supports. Argonne engineers and physicists worked closely with three local industries to develop satisfactory designs and specifications for the components. Prototype chambers built from these components were being studied with cosmic rays and radioactive sources at the end of the year.

(D. Ayres)

Aluminum Proportional Tubes

II. THEORETICAL PHYSICS PROGRAM

II.A THEORY

II.A.1 All-Orders Calculation of the Inclusive Cross Sections for the Production of Top Quarks

In conventional perturbative calculations carried out at fixed-order within the context of quantum chromodynamics (QCD), the size of the next-to-leading order term in the cross section can exceed that of the leading order term when the invariant mass produced in the hard-scattering reaction is a significant fraction of the total energy available. The origin of the large threshold enhancement may be traced to large logarithmic contributions associated with initial-state soft-gluon radiation in the hard-scattering subprocess. To obtain more reliable theoretical estimates of cross sections in such situations, the effects of gluon radiation must be reevaluated through a procedure known as soft-gluon resummation to all orders in the QCD running coupling strength. Edmond Berger and Harry Contopanagos developed an original formulation of resummation that they term "perturbative resummation". They used this procedure to carry out a complete calculation of soft-gluon resummation for top quark production. In *Physical Review D* **54**, 3085 (1996), they present a thorough exposition of their method and provide predictions of the physical cross section for inclusive $t\bar{t}$ production as a function of top mass in proton-antiproton reactions at center-of-mass energies 1.8 and 2.0 TeV.

The quantitative reliability of the theoretical calculations of the cross section for top quark production is an important issue. The top is so heavy that one might imagine that production mechanisms beyond standard QCD could play a role. After all-orders resummation, the top quark cross section calculated by Berger and Contopanagos at 1.8 TeV exceeds the next-to-leading order value by 9%, with an estimated overall theoretical uncertainty of 10%. Although the cross section measured by the CDF collaboration is somewhat high, the comparison with the Berger-Contopanagos prediction shows no evidence yet for non-standard contributions.

Ed Berger presented their work on perturbative resummation and discussed the differences between their method and that of Catani *et al.* in invited talks at the 1996 Snowmass summer study; the 28th International Conference on High Energy Physics, Warsaw; DPF '96; and the 1996 CTEQ Symposium. Summaries appear in the following papers that Berger and Contopanagos wrote during this reporting period: ANL-HEP-CP-96-76 (DPF '96 proceedings), ANL-HEP-CP-96-83 (Warsaw proceedings), and ANL-HEP-CP-96-95 (Snowmass proceedings).

The Berger-Contopanagos method can be applied to other problems of substantial current interest. For example, as discussed in ANL-HEP-CP-96-95, they estimate that all-orders resummation accounts for 20% of the excess in cross section above the next-to-leading order

value observed by the CDF collaboration in the production of hadronic jets at large transverse momentum.

(E. L. Berger and H. Contopanagos)

II.A.2 Isolated Prompt Photon Production—Breakdown of Factorization

Edmond Berger, Xiaofeng Guo, and Jianwei Qiu (Iowa State University) completed a major paper of the theory and phenomenology of isolated prompt photon production in hadronic final states of electron-positron annihilation, published in *Physical Review D* **54**, 5470 (1996). They derive complete analytic expressions for the *isolated* prompt photon production cross sections in e^+e^- annihilation reactions through one-loop order in QCD perturbation theory. This is the first time such a calculation has been done. Isolation is an unfortunate but apparently unavoidable restriction imposed in experiments to reduce backgrounds from, e.g., $\pi^0 \rightarrow \gamma\gamma$. The measured cross section is not inclusive, and the usual factorization theorems that apply to inclusive reactions need not apply for isolated cross sections. Factorization is the statement that a physical cross section can be factored as a convolution of an infrared-finite short-distance partonic hard-part times a universal long-distance parton-to-photon fragmentation function. Although not proven, the validity of factorization has been assumed in all existing phenomenological calculations of isolated prompt photon production in hadron-hadron as well as e^+e^- annihilation reactions. A proper theoretical treatment of the cross section for isolated photons requires careful consideration of the origins and cancellation of both infrared and collinear singularities in QCD perturbation theory that underlie the factorization theorems. In a theoretical calculation, isolation of the photon restricts the final-state phase space accessible to accompanying final-state quarks and gluons. In their paper, Berger, Guo, and Qiu demonstrate that this phase space restriction inevitably breaks the perfect cancellation of infrared singularities between real gluon emission and virtual gluon exchange diagrams that is required to yield finite partonic cross sections in each perturbative order. This breakdown of conventional factorization limits the region of $x_\gamma = 2E_\gamma/\sqrt{s}$ in which quark-to-photon fragmentation functions may be extracted reliably from electron-positron reaction data. It also limits the extent to which CDF and D0 collider data on prompt photon production can be described quantitatively at the present time. Berger was invited to speak about this research at DPF '96 (the written version appears in Argonne report ANL-HEP-CP-96-77), and Xiaofeng Guo spoke about the work at PANIC '96 (ANL-HEP-CP-96-53).

(E. L. Berger)

II.A.3 Prompt Photon Plus Associated Heavy Flavor at Next-To-Leading Order in QCD

Although most of their published work was completed prior to the start of this reporting period, Edmond Berger and Lionel Gordon continued their investigations of the production of a prompt photon in association with charm, $p + \bar{p} \rightarrow \gamma + c + X$. Their analysis of the two-particle inclusive cross section is done at next-to-leading order in perturbative QCD. They show that the

study of the two-particle inclusive distribution, with specification of the momentum variables of both the final prompt photon and the final heavy quark, tests correlations inherent in the QCD matrix elements and provides a means for measuring the charm quark density in the nucleon. Lionel Gordon spoke about this work at DPF '96 (the written version appears in Argonne report ANL-HEP-CP-96-64), and Berger spoke at the 28th International Conference on High Energy Physics, Warsaw (ANL-HEP-CP-96-84).

(E. L. Berger and L. Gordon)

II.B COMPUTATIONAL PHYSICS

The computational physics effort is devoted to numerical simulations of lattice quantum field theories, primarily lattice quantum chromodynamics (QCD). Use of a finite lattice reduces the field theory to one with a finite number of degrees of freedom, allowing numerical simulations. The finite lattice spacing provides the needed ultraviolet regularization of the theory. For QCD, such lattice methods provide the only reliable way of calculating non-perturbative results. This enables one to calculate the basic properties of hadrons such as their masses and decay rates. In addition it enables one to determine the properties of hot and/or dense nuclear matter, which is not only relevant to neutron stars and the early universe, but is also expected to be relevant to relativistic heavy ion collisions, such as will be observed at RHIC.

We have continued our work on studying the difference between the effective (screening) masses of flavour singlet and flavour triplet mesons at finite temperatures in lattice QCD with dynamical quarks. Here we have discovered that the flavour singlet $s(f_0)$ and flavour triplet $d(a_0)$ masses appear to remain distinct across the transition from hadronic matter to a quark-gluon plasma due to the disconnected contribution to the s propagator, and are relating this to instantons. We are now generating configurations at a new coupling (and thus temperature) within the transition region, to clarify these preliminary results. If true, this means that the $U(1)_{axial}$ symmetry is not restored as this deconfinement transition is crossed.

Last fiscal year we had started a project to study lattice QCD with a chiral 4-fermion interaction. While such an interaction is irrelevant and should not change the continuum physics, it has the effect of rendering the Dirac operator non-singular and thus allows us to work at zero quark mass which is impossible for the standard action. A corollary is that it requires much less computer time to work at the physical u and d quark masses with this new action. We have performed some preliminary simulations at zero temperature and zero quark mass on a small lattice ($8^3 \times 24$), and measured the p and s propagators, and masses. As shown in Figure 1, we find that the pion mass is zero as expected. We have now started to extend the finite temperature simulations we performed last year on a small ($8^3 \times 4$) lattice to a somewhat larger lattice ($12^2 \times 24 \times 4$) to perform the required finite size analysis and make quantitative studies of the deconfinement phase transition.

Finally we have commenced a project to improve the lattice QCD action with staggered fermions to attempt to reduce the flavour symmetry violations at finite lattice spacing. In this we are attempting to improve on the action suggested by the MILC collaboration. Other attempts at improving the staggered fermion actions, while having some nice properties, had yielded no significant reduction in flavour symmetry violations.

The above computations were performed on the CRAY C-90 at NERSC, and on divisional workstations.

Fig. 1. The pion propagator on an $8^3 \times 24$ lattice. The fit is to a massless lattice boson propagator.

(D. K. Sinclair and J.-F. Lagaë)

III. ACCELERATOR RESEARCH AND DEVELOPMENT

III.A ARGONNE WAKEFIELD ACCELERATOR PROGRAM

III.A.1 Wakefield Measurements at the AWA

During this period we continued our initial collinear dielectric structure wakefield experiments and our characterization of the wakefield measurement system. Tuning both drive and witness beams through the test section is proving to be more challenging than originally anticipated; nevertheless steady progress was made and a number of wakefield device measurements were performed. Figure 1 shows a 15 GHz dielectric structure wakefield as mapped at the AWA. While measured gradients are still relatively low (6 MeV/m) this is due to limitations of the present beamline design in terms of the maximum drive charge transmitted through the test section. It is of interest to note that the peak accelerating gradients currently obtained in dielectric structures exceed those of the previous AATF experiments by a factor of 10.

Fig. 1. Measured 15 GHz dielectric structure wakefield

III.A.2 Experiments and New Ideas

a. Witness Gun Tests

In addition to the wakefield measurement program, work continued on characterization of the witness gun. Both eminence (quad scan) and bunch length measurements (aerogel Cherenkov radiator and streak camera) were performed, with the results found to be in good agreement with design simulations. Typical witness beam parameters are normalized transverse eminence = 3.4 mm mr and bunch length 10 ps at 3.9 MeV and 0.1 nC/pulse.

b. TTF Gun and Linac

Efforts during this period were concentrated on obtaining reliable bunch length and eminence measurements and on preliminary bunch compression experiments. At the end of this reporting period the ANL phase of the program was completed and the equipment moved to its permanent location at Fermilab.

c. Plasma Wakefield

Most of the efforts in this area were concentrated on optimizing drive beam propagation through the plasma cell. A quartz plate was installed in the cell for bunch length measurements. Transported drive beam intensities have been increased to 24 nC at a 20 ps bunch length.

III.A.3 AWA Hardware Upgrades

Software development continued for the new frame grabber (Imaging Technology 150/40). The unit can now acquire video images on triggers generated by the Linac. This unit is now used as the standard imaging system for the AWA.

A number of the beamline trim and quad power supplies were fitted with a new bipolar power supply system developed at ANL. A Burr-Brown line driver chip is used to control both the magnet current and polarity, eliminating the need for mechanical polarity reversing switches. Magnets outfitted with these supplies can also be degaussed under computer control without the need for operator intervention.

(P. Schoessow)

III.B HIGH RESOLUTION PROFILE MONITOR DEVELOPMENT

III.B.1 Development of a Beam Monitor at SLAC

We had a run or about 4 hours on August 8, The immediate goal of the tests was to use a 20 m wire at IP1 to demonstrate the alignment and motion of the collimators at the micron level to measure statistically limited resolutions. The first three hours were used to realign the beam and collimators to the new position of the beam which had moved since the previous run in eight months earlier, and the beam had been moved 500 microns from that time. After realignment of the collimators we had time to close the slit and make one initial set of scans. The result of this scan is shown in figure 1 below.

Fig. 1. Profile measurements compared to calculated distribution from a 14 micron slit extrapolated to wire target position.

The average of all data taken, shown in Figure 2, shows that there was considerable background in the signal, due to the location of the detectors in the beam dump area. These detectors were shielded Pb locally and the optical path was designed to be insensitive to particles traveling parallel to the beam.

This background was measured as a function of slit opening to prove that spurious signal was not associated with the beam through the collimators or the scattering from the collimator surfaces. This is shown in the following figure. On the other hand the signal itself seemed large enough to do precision single bunch measurements.

Fig.2. Average of all data taken, mostly with large slit opening, plotted against channel number

Fig. 3. Background amplitude as a function of slit opening in microns.

III.B.2 Design of a High Energy e^+e^- Collider for the VLHC Tunnel

As a result of discussions at the Snowmass meeting there seemed to be some interest in the design of a large lepton collider that would fit in the tunnel of the VLHC, then being designed at Fermilab. Following some initial discussion a paper was then written with Eberhard Keil of CERN, who had independently been working on the problem. The machine would have a diameter of ~100 miles and many unique features.

The magnetic field required to guide the electrons would be only a 80 G, and the injection field would be only 10 - 20 G. These fields are so low that the earth's field would form a significant perturbation. Various methods of shielding the magnets from the earth's field were considered, however the magnet yoke itself might provide a significant source of shielding. To evaluate this a small prototype magnet yoke was constructed by ANL-ASD, and measurements were made of the vertical field component as a probe was inserted into the yoke gap. The yoke was composed of 0.025" laminations separated by 25" plastic spacers, dimensions appropriate to the desired low field magnet. The results are shown in the figure.

Fig. 1. The shielding effect of a magnet yoke on the external magnetic field.

Because of the large diameter, and low production of photodesorbed gas, it seems desirable to try concentrate vacuum pumping at discrete locations as much as possible. This could be done if the vacuum chamber had a slot to allow the majority of the synchrotron radiation fan into an antechamber, where pumping could be concentrated at intervals of about

100 m. The antechamber would require minimal pumping provided by Non-Evaporable Getter material and would also probably require some cooling.

Cooling the ring could be done by circulating water into the rock, possibly by burying a heat exchanger coil in the rock. Assuming 100 MW of synchrotron power distributed over 500 km, or 200 W/m, the power density is low enough so that the expense and environmental problems associated with cooling towers on the surface could be avoided.

Some of the parameters of the machine are shown in the Table:

Circumference /m	531000
Total synch power /MW	100
Beam aperture Ax: Ay /mm	62: 40
Beam beam tune shift xx: xy	0.03: 0.03

Work on this design is continuing.

(J. Norem)

IV. DIVISIONAL COMPUTING ACTIVITIES

IV.A HIGH PERFORMANCE COMPUTING: THE PASS PROJECT

Two physicists (L. Price and E. May) and a computer scientist (D. Malon) from DIS division 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). Future HEP experiments will collect data at the rate of 1 petabyte per year; new advanced technology (both hardware and software) is required to provide the access to this quantity of data in a fast and efficient manner for a world-wide HEP environment. This work is being done in collaboration with the University of Illinois at Chicago (UIC), University of Maryland, and Lawrence Berkeley lab (LBL). I describe briefly some PASS activities in which ANL staff had the principal role or made important contributions.

This is the last reporting interval for the PASS Project which is now completed. During this interval we worked in the following areas: a) completed the PASS project and wrote a summary/close-out report. "The PASS Project: A Close-out Report," D. M. Malon, E. N. May, L. E. Price (ANL), D. R. Quarrie (LBNL), Grossman (UIC), 1996 unpublished ANL report; and b) worked on some aspects of the Atlas Computing Technical Proposal preparation.

We continue to collaborate with the CERN RD45 group on the project "A Persistent Object Manage for HEP". We did some initial investigations of Java front ends to database systems. We collaborated with CERN L3 group to test and evaluate the "virtual room" video conference software system being developed for CMS and Atlas. This uses point-to-point bridging to improve the transatlantic bandwidth limitations of standard MBONE based conferencing.

A proposal, "Data Access and Analysis of Massive Datasets for High-Energy and Nuclear Physics," prepared by D. Olson, G. Odyneic, I. Sakremda, J. Marx, J. Siegrist, I. Hinchliffe, R. Jacobsen, D. Quarrie, W. Johnston, B. Tierney, N. Johnston, S. Lau, K. Campbell, A. Shoshani, D. Rotem, W. Barber, H. Simon (LBNL), E. May, D. Malon (ANL), B. Gibbard (BNL), G. Riccardi, L. Dennis (FSU), H. Huang (UCLA), S. Sorensen (Univ. Tennessee), and S. Kumar (Yale), was submitted to DOE Grand Challenge Applications, 1996, unpublished.

(Ed May)

V. 1996 PUBLICATIONS

V.A JOURNAL PUBLICATIONS, CONFERENCE PROCEEDINGS, BOOKS

“Associated Production of Charm and A Hard Photon”

B. Bailey, E. L. Berger, and L. Gordon

Published in ‘96 QCD and High Energy Hadronic Interactions, Proceedings of the XXXI Rencontres de Moriond on QCD and High Energy Hadronic Interactions, edited by J. Tran Thanh Van (Editions Frontieres, Paris, 1996)
p. 195

“Dijet Angular Distribution in Direct and Resolved Photoproduction at HERA”

ZEUS Collaboration, M. Derrick, *et al.*

Phys. Lett. B384, 401 (1996)

“Flavor-Singlet g_A from Lattice QCD”

J. -F. Lagae, *et al.*

Phys. Rev. Lett. 75, 2096 (1996)

“Measurement of the Branching Fraction $B(B_u^+ \rightarrow J/\psi \pi^+)$ and Search for $B_c^+ \rightarrow J/\psi \pi^+$ ”

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

Phys. Rev. Lett. 77, 5176 (1996)

“Measurement of the Dijet Angular Distributions by the Collider Detector at Fermilab”

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

Phys. Rev. Lett. 77, 5336 (1996)

“Measurement of Elastic ω Photoproduction at HERA”

ZEUS Collaboration, M. Derrick, *et al.*

Z. Phys. C73, 73 (1996)

“Measurement of the F_2 Structure Function in Deep Inelastic e^+p Scattering Using 1994 Data from the ZEUS Detector at HERA”

ZEUS Collaboration, M. Derrick, *et al.*

Phys. C72, 399 (1996)

- “Measurement of the $\gamma + D^{*\pm}$ Cross Section in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV”
 R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner,
 A. Wicklund (ANL) and the CDF Collaboration
 Phys. Rev. Lett. 77, 5005 (1996)
- “Observation of Events with an Energetic Forward Neutron in Deep Inelastic Scattering”
 ZEUS Collaboration, M. Derrick, *et al.*
 Phys. Lett. B384, 388 (1996)
- “Prompt Photon Plus Heavy Quark Production at Colliders”
 B. Bailey, E. L. Berger, L. E. Gordon
 Phys. Rev. D 54, 1896 (1996)
- “Ratios of Bottom Meson Branching Fractions Involving J/ψ Mesons and Determination of b
 Quark Fragmentation Fractions”
 R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. Wicklund
 (ANL) and the CDF Collaboration
 Phys. Rev. D54, 6596 (1996)
- “Study of Charged Current ep Interactions at $Q^2 > 200 \text{ GeV}^2$ with the ZEUS Detector at HERA”
 ZEUS Collaboration, M. Derrick, *et al.*
 Z. Phys. C72, 47 (1996)
- “Supersymmetric Analysis and Predictions Based on the CDF $ee\gamma\gamma + \text{Missing Energy Event}$ ”
 S. Mrenna, *et al.*
 Phys. Rev. Lett. 76, 3498 (1996)
- “The Perturbative Resummed Series for Top Production”
 E. L. Berger and H. Contopanagos
 Published in ‘96 QCD and High Energy Hadronic Interactions, Proceedings of
 the XXXI Rencontres de Moriond on QCD and High Energy Hadronic
 Interactions, edited by J. Tran Thanh Van (Editions Frontieres, Paris, 1996) p. 33
- “Unitarity Boundary for Deep Inelastic Structure Functions”
 E. M. Levin, *et al.*
 Phys. Lett. 388 (1), 188 (1996)

V.B PAPERS SUBMITTED FOR PUBLICATION

“An Inverse Cherenkov Accelerator Using A Dielectric Channeled Waveguide”

W. Gai, J. Simpson

Submitted to Phys. Rev. Lett.

“Azimuthal Dependence of Forward-Jet Production in DIS in the High-Energy Limit”

M. Wusthoff, *et al.*

Accepted for publication in Z. Phys. C

“Constraints on ΔG from Prompt Photon Plus Jet Production at HERA - $\overline{N}$ ”

L. E. Gordon

To appear in Phys. Lett.

“Discovering a Light Mass Higgs Boson at the Tevatron Collider”

S. Mrenna

Submitted to Perspectives in Higgs Physics II

“Effects of QCD Resummation on Distributions of Top-Antitop Quark Pairs Produced at the Tevatron”

S. Mrenna, and C. -P. Yuan

Submitted to Phys. Rev. D

“Integrable Symplectic Trilinear Interaction Terms for Matrix Membranes”

T. Curtright, D. Fairlie, and C. Zachos

Submitted to Phys. Lett B

“Isolated Photons at Hadron Colliders at $O(\alpha\alpha_s^2)$ (I): Spin Averaged Case”

L. E. Gordon

To appear in Nucl. Phys. B

“Isolated Photons at Hadron Colliders at $O(\alpha\alpha_s^2)$ (II): Spin Dependent Case”

L. E. Gordon

To appear in Nucl. Phys. B

“Large Rapidity Gap Events in Deep Inelastic Scattering”

M. Wusthoff

Submitted to Phys. Rev. D

“Low Energy Supersymmetry with a Neutralino LSP and the CDF $ee\gamma\gamma$ and Missing E_T Event”

S. Mrenna, *et al.*

Submitted to Phys. Rev. D

“NLO Conformal Symmetry in the Regge Limit of QCD”

A. White, M. Wusthoff, *et al.*

Submitted to Nucl. Phys. B

“Numerical Simulations of Intense Charged Particle Beam Propagation in a Dielectric Wakefield Accelerator”

Wei Gai, J. Simpson, A. D. Kanareykin, and A. L. Kustov

Submitted to Phys. Rev. E

“Penguins, Trees and Final State Interactions in B Decays in Broken SU(3)”

H. J. Lipkin

Submitted to Phys. Lett. B

“Probing Nucleon Spin Structure”

G. P. Ramsey

Submitted to Progress in Particle and Nuclear Physics

Erratum: “Rigorous QCD Analysis of Inclusive Annihilation and Production of Heavy Quarkonium”

G. T. Bodwin, E. Braaten, and G. Peter Lepage

Submitted to Phys. Rev. D

“SPYTHIA, A Supersymmetric Extension of PYTHIA 5.7”

S. Mrenna

Submitted to Comput. Phys. Commun.

“Sudakov Factorization and Resummation”

H. Contopanagos, E. Laenen, and G. Sterman

Submitted to Nucl. Phys. B

“Thermodynamics of Lattice QCD with Two Light Quark Flavours on a $16^3 \times 8$ Lattice II”

D. K. Sinclair, *et al.*

Submitted to Phys. Rev. D

V.C PAPERS OR ABSTRACTS CONTRIBUTED TO CONFERENCES

“A Theoretical Overview on Single Hard Diffraction”

M. Wusthoff

Presented at the “XI Topical Workshop on Proton, Antiproton Collider Physics” Abano Terme, Italy, May 26 - June 1, 1996
ANL-HEP-CP-96-81

“Detectors for the MINOS Long-Baseline Neutrino Oscillation Experiment”

D. S. Ayres

Presented at the “5th International Conference on Advanced Tech. and Particle Physics,” Como, Italy, October 7 - November 1996
ANL-HEP-CP-97-43

“Diboson Production at the Tevatron”

L. J. Nodulman, The CDF Collaboration

Presented at the “28th International Conference on High Energy Physics” (ICHEP ‘96), Warsaw, Poland, July 25 - 31, 1996
ANL-HEP-CP-96-80

“Direct Photons at CDF”

L. Nodulman, The CDF Collaboration

Conference paper for the “28th International Conference on High Energy Physics,” (ICHEP ‘96), Warsaw, Poland, July 25 - 31, 1996

“Electroweak Physics at CDF”

L. Nodulman, The CDF Collaboration

Conference paper for the “28th International Conference on High Energy Physics,” (ICHEP ‘96), Warsaw, Poland, July 25 - 31, 1996

“Improvement of Signal Significance in $WH \rightarrow l + \nu + b + \bar{b}$ Search at TeV33”

S. Kim, S. Kuhlmann and W. M. Yao

Presented at the 1996 DPF/DPB Summer Study, “New Directions for High Energy Physics” (Snowmass ‘96), Snowmass, CO, June 25 - July 12, 1996

“Isolated Prompt Photon Cross Sections”

E. L. Berger, Xiaofeng Guo, and Jianwei Qiu

Invited paper presented at the “1996 Meeting of the Division of Particles and Fields of the American Physical Society” (DPF ‘96), Minneapolis, MN, August 10-15, 1996
ANL-HEP-CP-96-77

“Isolated Prompt Photon Production at HERA”

L. Gordon and W. Vogelsang

Presented at “The International Workshop on Deep Inelastic Scattering & Related Phenomena,” Rome, Italy, April 15-19, 1996

ANL-HEP-CP-96-50

“Measurement of the Ratio of b-Quark Production Cross Sections at $\sqrt{s} = 630$ GeV and $\sqrt{s} = 1800$ GeV”

T. LeCompte, J. Lewis, S. Tkaczyk, The CDF Collaboration

Presented at the “28th International Conference on High Energy Physics” (ICHEP ‘96), July 25 - 31, 1996, Warsaw University, Warsaw, Poland

“Performance of the Argonne Wakefield Accelerator Facility and Initial Experimental Results”

W. Gai, M. Conde, G. Cox, R. Konecny, J. Power, P. Schoessow, J. Simpson, N. Barov

Presented at the “XVIII International Linac Conference”

Geneva, Switzerland, August 26 - 30, 1996

ANL-HEP-CP-96-68

“Measurements of the Argonne Wakefield Accelerator’s Low Charge, 4 MeV RF Photocathode Witness Beam”

P. Schoessow, J. Power, M. Conde, W. Gai, R. Konecny, and J. Simpson (ANL),
E. Chojnacki (Cornell)

Presented at the Advanced Accelerator Concepts Workshop

Granlibakken Conference Center, Tahoe City, CA, October 12-18, 1996

ANL-HEP-CP-98-26

“Measurement of the Ratio of b-Quark Production Cross Sections at $\sqrt{s} = 630$ GeV and $\sqrt{s} = 1800$ GeV”

T. LeCompte, J. Lewis, S. Tkaczyk, The CDF Collaboration

Presented at the “28th International Conference on High Energy Physics”

(ICHEP ‘96) Warsaw, Poland, July 25 - 31, 1996

“Production of Charm with a Photon at Proton-Antiproton Colliders”

B. Bailey, E. L. Berger, and L. Gordon

Presented at the “1996 Meeting of the Division of Particles and Fields of the

American Physical Society” (DPF ‘96), Minneapolis, MN, August 10 - 15, 1996

ANL-HEP-CP-96-64

“Prompt Photon Plus Charm Production at Next-to-Leading Order in QCD”

B. Bailey, E. L. Berger, and L. Gordon

Presented at the “28th International Conference on High Energy Physics,”
Warsaw, Poland, July 25-31, 1996
ANL-HEP-CP-96-84

“QCD Subgroup on Diffractive and Forward Physics”

A. White, *et al.*

Presented at the 1996 DPF/DPB Summer Study, “New Directions for High
Energy Physics” (Snowmass ‘96), Snowmass, CO, June 25 - July 12, 1996
ANL-HEP-CP-97-40

“Report of Spin Physics Subgroup”

E. L. Berger, *et al.*

Presented at the 1996 DPF/DPB Summer Study, “New Directions for High
Energy Physics” (Snowmass ‘96), Snowmass, CO, June 25 - July 12, 1996
ANL-HEP-CP-97-72

“Report of the Supersymmetry Theory Subgroup”

S. Mrenna, *et al.*

Presented at the 1996 DPF/DPB Summer Study, “New Directions for High
Energy Physics” (Snowmass ‘96), Snowmass, CO, June 25 - July 12, 1996
ANL-HEP-CP-97-29

“Sea Quark Matrix Elements and Flavor Singlet Spectroscopy on the Lattice”

J. -F. Lagae

Presented at the “2nd International Conference on Quark Confinement and
the Hadron Spectrum II,” Como, Italy, June 26-29, 1996
ANL-HEP-CP-96-85

“Signals of Dynamical Supersymmetry Breaking in a Hidden Sector”

B. Dobrescic and S. Mrenna

Presented at the 1996 DPF/DPB Summer Study, “New Directions for High
Energy Physics” (Snowmass ‘96), Snowmass, CO, June 25 - July 12, 1996
ANL-HEP-CP-98-22

“Structure Function Subgroup Summary”

A. R. White, *et al.*

Presented at the 1996 DPF/DPB Summer Study, “New Directions for High
Energy Physics” (Snowmass ‘96), Snowmass, CO, June 25 - July 12, 1996
ANL-HEP-CP-98-23

“Tests of QCD at HERA: Determination of the Gluon Density”

J. Repond

Presented at the “1996 Meeting of the Division of Particles and Fields of the American Physical Society” (DPF ‘96) Minneapolis, MN, August 10-15, 1996
ANL-HEP-CP-96-93

“The Hard Gluon Component of the QCD Pomeron”

A. White

Invited paper for the “Third AUP Workshop on Quantum Chromodynamics: Collisions, Confinement & Chaos,” Paris, France, June 3-8, 1996
ANL-HEP-CP-96-74

“The MINOS Long-Baseline Experiment at Fermilab”

D. S. Ayres

Presented at the Fourth KEK Topical Conference on “Flavor Physics,”
KEK, Japan, October 29-31, 1996
ANL-HEP-CP-97-80

“Theoretical Aspects of Top Quark Production at Hadron Colliders”

E. L. Berger and H. Contopanagos

Presented at the “28th International Conference on High Energy Physics,”
Warsaw, Poland, July 25 - 31, 1996
ANL-HEP-CP-96-83

“Top Quark Physics: Future Measurements”

E. L. Berger, *et al.*

Presented at the 1996 DPF/DPB Summer Study, “New Directions for High Energy Physics” (Snowmass ‘96), Snowmass, CO, June 25 - July 12, 1996
ANL-HEP-CP-97-18

“Total Cross Section for Top Quark Production”

E. L. Berger and H. Contopanagos

Presented at the “1996 Meeting of the Division of Particles and Fields of the American Physical Society” (DPF ‘96), Minneapolis, MN, August 10-15, 1996
ANL-HEP-CP-96-76

V.D TECHNICAL REPORTS AND NOTES

“Data Access and Analysis of Massive Datasets for High-Energy and Nuclear Physics”

E. May and D. Malon (ANL), B. Gibbard (BNL), G. Riccardi, L. Dennis (FSU),
H. Huang (UCLA), S. Sorensen (U.Tenn), S. Kumar (Yale), D. Olson, *et al.*

A proposal submitted to DOE Grand Challenge Applications, unpublished (1996)

Note: “Polarized RHIC Bunch Arrangement”

D. Underwood

ANL-HEP-TR-96-73

and AGS/RHIC/SN N0. 035 (August 1996)

CDF Note 3746 “Direct Photons at CDF”

L. Nodulman for the CDF Collaboration

CDF Note 3762 “Technical Design Report for the CDF Calorimeter and Shower Maximum
Detector Front End Electronics”

A. Byon-Wagner, *et al.*

CDF Note 3764 “An Experimental Evaluation of the CDF ee $\gamma\gamma$ + MET Event”
B. Blair

CDF Note 3779 “What Do We Really Measure With Top Decays?”
T. LeCompte

CDF Note 3786 “Measurement of B^- and $\overline{B}^0$ Lifetimes Using Semileptonic Decays”
A. B. Wicklund, F. Ukegawa, and N. S. Lochyer

CDF Note 3798 “W and Z Plus Multiple Photon Events”
R. Wagner and K. Lannon

CDF Note 3813 “Common Limit Calculations on Top FCNC Decays”
T. LeCompte, R. Roser, and R. Cox

CDF Note 3850 Update to CDF Note 3456: “Search for Cousins of the eeggmet Event in the
Diphoton Channel”
R. Blair, J. Berryhill, *et al.*

CDF Note 3853 “Diboson Production at the Tevatron”
L. Nodulman for CDF and DO

- CDF Note 3860 "Studies on The Central Strip Chambers"
K. Byrum, G. Drake, and L. Nodulman
- CDF Note 3896 "A Further Tweak to CEM Response for Incidence Angle"
L. Nodulman, W. Sakamoto, and J. Wahl
- CDF Note 3904 "Improvement of Signal Significance in $WH \rightarrow l + \nu + b + \bar{b}$ Search at TeV33"
S. Kim, S. Kuhlmann, and W.M. Yao
- CDF Note 3958 "Simulation Studies of the Showermax QIE"
K. Byrum and G. Drake
- CDF Note 3973 "An EGS Study of E/p Issues"
L. Nodulman
- CDF Note 4011 "The $\mu - \tau$ and $e - \tau$ Decay of Top Quark Pairs Produced in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV"
R. Blair, K. Byrum, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. Wicklund (ANL) and the CDF Collaboration
- NuMI-L-198 "A Proposal for a Laminated Pie Mechanical Construction of a Toroidal Magnet for the Far Detector for the MINOS Experiment"
June 5, 1996 Addendum, August 20, 1996
N. Hill
- NuMI-L-202 Minutes of the August 1996 MINOS Institutional Board
D. Ayres
- NuMI-L-203 Minutes of the MINOS Executive Committee Meeting of August 23, 1996
M. Goodman
- NuMI-L-204 Transparencies from the August 1996 MINOS Meeting
D. Ayres
- NuMI-L-205 Minutes of the August 27th Technical Board from the MINOS Meeting
August 1996, D. Ayres
- NuMI-L-206 Minutes of the MINOS Collaboration Meeting, August 1996
D. Ayres

- NuMI-L-209 Field Computation for a Neutrino Detector Magnet: the Effect of Small Gaps in Large Bodies, September 1996
L. Turner
- NuMI-L-211 Interim DRAC Report, September 1996
L. Price
- NuMI-L-216 The MINOS Long-Baseline Neutrino Oscillation Experiment,
The 1996 DPF Meeting in Minneapolis, October 1996
J. Thron
- NuMI-L-217 Minutes of the MINOS Executive Committee at Fermilab, October 1996
M. Goodman
- NuMI-L-218 Transparencies from the October 1996 MINOS Meeting
D. Ayres
- NuMI-L-219 Minutes of the October Technical Board from the MINOS Meeting, October 1996
D. Ayres
- NuMI-L-220 Minutes of the MINOS Collaboration Meeting, October 1996
D. Ayres
- NuMI-L-227 The MINOS Long-Baseline Experiment at Fermilab,
contributed to the KEK Workshop, October 1996
D. Ayres
- NuMI-L-229 MINOS Physics Goals and Experimental Requirements, December 1996
S. Wojcicki
- NuMI-L-233 Transparencies from the December 1996 MINOS Meeting
D. Ayres
- NuMI-L-234 Minutes of the December 1996 MINOS Meeting at Fermilab
D. Ayres
- NuMI-L-235 D. Ayres, Minutes of the December 1996 MINOS ExCom Meeting
D. Ayres
- NuMI-L-236 Minutes of the December 1996 MINOS Institutional Board Meeting
D. Ayres

- NuMI-L-237 Minutes of the December 1996 Det. R&D Committee Meeting
D. Ayres
- NuMI-L-238 Minutes of the December 1996 Tech. Board Meeting
D. Ayres
- NuMI-L-240 Detectors for the MINOS Long-Baseline Neutrino Oscillation Experiment,
December 1996
D. Ayres
- NuMI-L-241 Interim DRAC Report, December 1996
L. Price
- PDK-644 Background Corrections for the CEV Analysis, October 1996
R. Seidlein
- PDK-645 Guidelines for Event Reconstruction, November 1996
R. Seidlein, P. Litchfield
- PDK-647 Soudan 2 Experiment Quarterly Status Report, July - September 1996
D. Ayres
- PDK-648 Soudan 2 Collaboration Response to Comments in the SAGENAP Report,
July 25, 1996, D. Ayres
- PDK-649 Decisions of the Soudan 2 Collaboration Meeting at Ely, MN,
October 12-14, 1996
D. Ayres
- PDK-652 Measuring Procedures for Multi-Tracks Contained Events, July 1996
W. Leeson
- PDK-654 Monte Carlo Background Study, October 1996
M. Goodman, R. Seidlein
- PDK-657 Minutes of the CEV Meeting, December 1996, University of Minnesota,
Minneapolis, MN
R. Seidlein

- PDK-658 12/96 Contained Event Analysis Jobs, December 1996
M. Goodman, P. Litchfield
- PDK-660 Soudan 2 Experiment Quarterly Status Report, October - December 1996
D. Ayres
- STAR 35 Note on Polarized RHIC Bunch Arrangement
D. Underwood
- STAR 244 Charmonium Production in STAR
T. J. Lecompte
- STAR 251 Direct Photons in Au Au Collisions: The Case for the Shower Max Detector
T. J. LeCompte
- STAR 264 Measuring the Spin Structure of the Proton with the STAR Detector at RHIC
T. J. LeCompte

VI. COLLOQUIA AND CONFERENCE TALKS

D. S. Ayres

“Detectors for the MINOS Long Baseline Neutrino Oscillation Experiment”

Presented at the “5th International Conference on Advanced Technology and Particle Physics,” Como, Italy, October 7-11, 1996.

“The MINOS Long Baseline Experiment at Fermilab”

Presented at the “4th KEK Topical Conference on *Flavor Physics*,” Tsukuba, Japan, October 29-31, 1996.

E. L. Berger

“Threshold Resummation for Heavy Quark Production at Hadron Colliders”

Invited talk presented at the “1996 CTEQ Symposium on Confronting QCD with Experiment,” Fermi National Accelerator Laboratory, Batavia, IL, November 9, 1996.

“Isolated Prompt Photon Cross Sections”

Invited talk presented at the “1996 Meeting of the Division of Particles and Fields of the American Physical Society” (DPF ‘96), Minneapolis, MN, August 13, 1996.

“Total Cross Section for Top Quark Production”

Invited talk presented at the “1996 Meeting of the Division of Particles and Fields of the American Physical Society” (DPF ‘96), Minneapolis, MN, August 12, 1996.

“Theoretical Aspects of Top Quark Production at Hadron Colliders”

Invited talk presented at the “28th International Conference on High Energy Physics,” Warsaw, Poland, July 26, 1996.

“Prompt Photon plus Charm Production at Next-to-Leading Order in QCD”

Invited talk presented at the “28th International Conference on High Energy Physics,” Warsaw, Poland, July 25, 1996.

“Perturbative Resummation and the Calculation of Top Quark Production Cross Section in Hadron Collisions”

Presented at the 1996 Snowmass Conference, “New Directions in High Energy Physics” (Snowmass ‘96), Snowmass, CO, July 9, 1996.

G. T. Bodwin

“Quarkonium Decay Matrix Elements from Lattice QCD”

Presented at the “Theory Institute on QCD-Based Studies of Hadron Spectroscopy and Interactions,” ANL Physics Division, Argonne, IL, July 23, 1996.

M. Derrick

“Physics in Collision”

Presented at the “Mexico City Diffractive Phenomena,” Mexico City, Mexico, June 1996.

“Review of Diffractive Phenomena”

Presented at the “International Symposium on Multiparticle Dynamics,” September 1996, Faro, Portugal.

W. Gai

“100 GHz Dielectric Traveling Wave Structures for 5- TEV Colliders”

Presented at the 1996 Snowmass Conference, “New Directions for High Energy Physics” (Snowmass ‘96), Snowmass, CO, June 25 - July 12, 1996.

“Inverse Cherenkov Acceleration Using Dielectric Channeled Waveguide”

Presented at the 1996 Snowmass Conference, “New Directions for High Energy Physics” (Snowmass ‘96), Snowmass, CO, June 25 - July 12, 1996.

“Performance of the Argonne Wakefield Accelerator Facility and Initial Experimental Results”

Presented at the “XVIII International Linac Conference,” Geneva, Switzerland
August 26-30, 1996.

M. C. Goodman

“The Atmospheric Neutrino Hint”

Talk presented at the “Physics Colloquium,” Illinois Institute of Technology (IIT),
October, 1996.

“Search for Neutrino Oscillation”

Talk presented at the “Physics Colloquium,” University of Illinois Chicago (UIC)
November 20, 1996.

L. E. Gordon

“Production of Charm with a Photon $p\bar{p}$ Colliders”

Talk presented at the “1996 Meeting of the Division of Particles and Fields of the American Physical Society” (DPF ‘96), Minneapolis, MN, August 10-15, 1996.

J. -F. Lagae

“Sea Quark Matrix Elements and Flavor Singlet Spectroscopy on the Lattice”

Talk presented at the “Second International Conference on Quark Confinement and the Hadron Spectrum,” Como, Italy, June 26-29, 1996.

G. Ramsey

“Polarized Parton Distributions: Theory and Experiment”

Invited talk presented at the “Circum-Pan-Pacific Workshop on High Energy Spin Physics,” Kobe University, Japan, October 2-4, 1996.

“Nucleon Spin Distributions from Recent SMC and SLAC Data”

Presented at the “12th International Symposium on High Energy Spin Physics,” Amsterdam, The Netherlands, September 10-14, 1996.

“X-Dependent Polarized Parton Distributions from Recent SMC and SLAC Data”

Presented at the “12th International Symposium on High Energy Spin Physics,” Amsterdam, The Netherlands, September 10-14, 1996.

J. Repond

“Dijets and Gluons”

Presented at the 1996 DPF/DPB Summer Study, “New Directions for High Energy Physics” (Snowmass ‘96), Snowmass, CO, July 1996.

“Tests of QCD at HERA”

Plenary talk presented at the “1996 Meeting of the Division of Particles and Fields of the American Physical Society” (DPF ‘96), Minneapolis, MN, August 10-15, 1996.

“Determination of the Gluon Density at HERA”

Presented at the “3rd Workshop on Small-x and Diffractive Physics,” Argonne, IL, September 1996.

J. Thron

Status Report of the MINOS "Long Baseline Neutrino Oscillation Experiment"

Talk presented at the "1996 Meeting of the Division of Particles and Fields of the American Physical Society" (DPF '96), Minneapolis, MN, August 10-16, 1996.

A. R. White

"The Hard Gluon Component of the QCD Pomeron"

Invited talk presented at the "3rd Workshop on Small-x and Diffractive Physics," Argonne, IL, September 22-29, 1996.

C. Zachos

"String Duality"

Talk presented at the Argonne "High Energy Physics Lunch Seminar," Argonne, IL, August 20, 1996.

VII. HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES

D. S. Ayres

Deputy Spokesperson of the MINOS Collaboration.

E. L. Berger

Member, High Energy and Nuclear Physics Advisory Committee, Brookhaven National Laboratory, Upton, NY, 1995-98.

Member, Past-Chairman, Committee on Meetings, American Physical Society, 1991-96.
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, International Advisory Committee, Seventh International Conference on Hadron Spectroscopy, Brookhaven National Laboratory, Upton, NY, August 24-30, 1997.

Member, International Advisory Committee, Symposium: Twenty Beautiful Years of Bottom Physics, Illinois Institute of Technology, Chicago, IL, June 29 - July 2, 1997.

Organizing Committee, Sixth Conference on the Intersections Between Particle and Nuclear Physics, May 1997.

Member, Scientific Program Committee, XXXII Rencontres de Moriond, "QCD and High Energy Hadronic Interactions," Les Arcs, France, March 1997.

Member, Argonne National Laboratory Director's Review Committee, Individual Investigator Laboratory Directed Research and Development Program, Argonne, IL, 1994-96.

Member, International Advisory Committee, Snowmass Summer Study, Division of Particles and Fields of the American Physical Society, Snowmass, CO, June-July 1996.

E. May

Member of staff, Esnet Steering Committee.

L. Price

Chair, Esnet Steering Committee.

J. Repond

Chairman, Local Organizing Committee for the 5th International Workshop on
Deep Inelastic Scattering.

A. R. White

Organizer and Co-Chair, 3rd Workshop on Small-x and Diffractive Physics, Argonne, IL,
September 22-29, 1996.

Member, International Advisory Committee, IXth International Symposium on Very High-
Energy Cosmic-Ray Interactions, Karlsruhe, Germany, August 19-23, 1996.

C. Zachos

Member, Editorial Board, Journal of Physics A: Mathematical and General, (UK).

VIII.

HIGH ENERGY PHYSICS DIVISION RESEARCH PERSONNEL

Administration

L. Price

D. Hill

Accelerator Physicists

W. Gai

P. Schoessow

J. Norem

J. Simpson

Experimental Physicists

D. Ayres

L. Nodulman

R. Blair

J. Proudfoot

K. Byrum

J. Repond

M. Derrick

H. Spinka

T. Fields

R. Stanek

M. Goodman

R. Talaga

D. Krakauer

J. Thron

S. Kuhlmann

D. Underwood

T. LeCompte

R. Wagner

S. Magill

A. Wicklund

E. May

A. Yokosawa

B. Musgrave

Theoretical Physicists

E. Berger

D. Sinclair

G. Bodwin

A. White

L. Gordon

M. Wusthoff

J. F. Lagae

C. Zachos

S. Mrenna

Engineers, Computer Scientists, and Applied Scientists

J. Dawson

J. Schlereth

W. Haberichter

X. Yang

N. Hill

Technical Support Staff

I. Ambats
R. Blair
G. Cox
D. Jankowski
T. Kasprzyk
C. Keyser

L. Kocenko
R. Konecny
E. Petereit
R. Rezmer
R. Taylor
K. Wood

Laboratory Graduate Participants

C. Allgower
N. Barov
A. Hardman
J. Power

D. Mikunas
H. Zhang

Visiting Scientists

M. Conde (AWA)
X. Li (AWA)

H. Lipkin (Theory)
G. Ramsey (Theory)
J. Uretsky (Theory)

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