Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

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

July 1, 1994 - December 31, 1994

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

Members:

R. Wagner
P. Schoessow
R. Talaga

April 1995
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *at*

MASTER

DISCLAIMER

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

DISCLAIMER

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

Contents

I	Experimental Research Program	2
I.A	Experiments with Data	2
I.A.1	Medium Energy Polarization Program	2
I.A.2	Polarized Proton Physics at Fermilab	4
I.A.3	Collider Detector at Fermilab	4
I.A.4	Non-Accelerator Physics at Soudan	10
I.A.5	ZEUS Detector at HERA	13
I.A.6	BNL Partial Snake Experiment	20
I.B	Experiments in Planning or Construction Phase	22
I.B.1	STAR Detector for RHIC	22
I.B.2	MINOS—Main Injector Neutrino Oscillation Search	22
I.B.3	ATLAS Detector Research & Development	26
I.C	Detector Development	27
I.C.1	CDF Detector and DAQ Electronics Development	27
I.C.2	ZEUS Barrel Hadron Electron Separator	30
I.C.3	STAR Calorimeter Development	30
I.C.4	ATLAS Hadron Calorimeter and Trigger Development	34
I.C.5	Electronics Support Group	41
II	Theoretical Physics Program	43
II.A	Theory	43
II.A.1	Lattice Measurement of Matrix Elements for Decays of Heavy Quarkonium	43
II.A.2	Higher-order Lipatov Kernels and Small- x Physics	43
II.A.3	New Strong Interactions Above the Electroweak Scale	44
II.A.4	Canonical Dual Transformations in Field Theory	44
II.A.5	Isolated and Inclusive Prompt Photon Production in Electron-Positron An- nihilation.	45
II.A.6	Strong Interaction Asymmetries in the Production of B Mesons	45
II.A.7	Principal Value Resummation	45
II.A.8	Parametrization of the Ambiguous Large Higgs Mass Effects	47
II.A.9	Isolated Direct Photon Production at HERA	48

II.A.10 Aspects of Four-Jet Production in Polarized Proton-Proton Collisions	48
II.A.11 Polarization and Elastic pp Scattering	49
II.A.12 Cosmic Correlations	49
II.A.13 Penetration of Muons into the Earth	50
II.B Computational Physics	50
III Accelerator Research & Development Program	53
III.A Argonne Wakefield Accelerator Program	53
III.A.1 AWA Facility Status	53
III.A.2 Experiments and New Ideas	54
III.B High Resolution Profile Monitor Development	54
IV Divisional Computing Activities	57
IV.A High Performance Computing: The PASS Project	57
V Publications	59
VI Colloquia and Conference Talks	68
VII High Energy Physics Community Activities	71
VIII High Energy Physics Division Research Personnel	72

Abstract

This report describes the research conducted in the High Energy Physics Division of Argonne National Laboratory during the period of July 1, 1994 - December 31, 1994. Topics covered here include experimental and theoretical particle physics, advanced accelerator physics, detector development, and experimental facilities research. Lists of division publications and colloquia are included.

I EXPERIMENTAL RESEARCH PROGRAM

I.A EXPERIMENTS WITH DATA

I.A.1 Medium Energy Polarization Program

The medium energy polarization program has studied spin effects in proton+proton (pp) and neutron+proton (np) scattering for many years. One of the goals has been to measure the isospin-0 and -1 nucleon-nucleon elastic scattering amplitudes. These amplitudes are important for understanding the strong interaction at intermediate energies and nucleon scattering from nuclei. Another goal has been to investigate energy-dependent structure seen in various nucleon-nucleon spin observables and other reactions. One possible explanation for the structure is 6-quark states, which have been predicted by various QCD models. Measurements for this second goal have occurred recently near a beam kinetic energy of 2.1 GeV at the CEA Saclay Laboratory, Saturne II accelerator, in France.

Proton-proton elastic scattering spin observable data (A_{oono} and A_{oonn}) near 2.1 GeV were collected in March and April, 1992; November and December, 1993; and May and June, 1994. Considerable work on the off-line analysis of these experiments occurred during the second half of 1994. Essentially all of the data from the two most recent run periods were analyzed at Argonne. Studies of systematic effects suggested problems in the determination of the beam polarization and the track reconstruction efficiency. During a collaboration meeting in December, 1994, these results were compared to the results of an independent analysis performed at Saclay, and indicated a good agreement. Figure 1 shows the comparison of the spin observable $A_{\text{oonn}} \equiv C_{\text{NN}}$ at one energy during the three run periods. The data all correspond to the same analyzing power for the beam polarimeter.

Further work by ANL physicists suggested a procedure to solve several of the problems uncovered in the past several months, such as the reconstruction efficiency and an incorrect beam intensity measurement. This procedure will involve an extra step in the present data analysis method, and will be implemented early next year. Additional changes to the software will also be made to more effectively use the beam polarimeter information and the scattering event data from an unpolarized target. All the data will be reanalyzed after these changes.

Another run period has been approved for April, 1995. Measurements will occur near 0.8 GeV to calibrate the target polarization, at a few energies near 2.1 GeV to check previously measured points, and at several energies above 2.3 GeV. The model presented by E. Lomon of MIT suggests that additional energy-dependent structure, a sharp drop in A_{oonn} (90°), should be seen near 2.55 GeV. The upcoming higher-energy measurements will search for such structure. All the November/December 1993 and May/June 1994 results, plus perhaps the April 1992 or April 1995 data, will be analyzed at ANL as part of a Ph.D. thesis for C. Allgower.

(H. Spinka)

2040 MeV A_{oonn} vs Theta CM

(Comparison of Three Running Periods)

Figure 1: Comparison of the pp spin observable $A_{oonn} \equiv C_{NN}$ at a beam kinetic energy of 2.04 GeV for three different run periods. The analyzing power for the beam polarimeter was taken from the April 1992 data. The data are preliminary.

I.A.2 Polarized Proton Physics at Fermilab

We are completing a paper on "Single-Spin Asymmetries and Invariant Cross Sections of the High Transverse-Momentum Inclusive π^0 Production in 200 GeV/c pp and $\bar{p}p$ Interactions". The measured asymmetries are consistent with a value of zero within the uncertainties for the kinematic regions, $-0.15 < x_F < 0.15$ and $1 < p_T < 4.5$ GeV/c. These data indicate that perturbative QCD expectations seem confirmed and the higher-twist contribution to the single-spin asymmetry in π^0 production at $x_F = 0$ is not large.

Our recent paper on "Measurement of Single Spin Asymmetry for Direct Photon Production in pp Collisions at 200 GeV/c" has been accepted for publication in *Physics Letters*. The results are consistent with perturbative QCD predictions within the experimental uncertainties.

Our paper on "Measurement of the Double-Spin Asymmetry A_{LL} for Inclusive Multi-Photon Production with 200 GeV/c Polarized Proton Beam and Polarized Proton Target" has been published in *Physics Letters*. The A_{LL} values were found to be consistent with zero and were compared with theoretical predictions of gluon polarization. The results put restrictions on the size of $\Delta G/G$ in the region of $0.05 < x < 0.35$.

We are preparing a paper on "Measurement of Spin Observables in Inclusive Λ and K_S^0 Production with a 200 GeV Polarized Proton Beam". The spin observables analyzing power, A_N , polarization, P , and depolarization, D_{NN} in inclusive Λ production were measured in the kinematic range of $0.2 < x_F < 1.0$ and $0.1 < p_T < 1.5$ GeV/c and the analyzing power for inclusive K_S^0 in the kinematic range of $0.1 < x_F < 0.7$ and $0.1 < p_T < 1.0$ GeV/c. The results obtained in this work show that at these energies spin effects are substantial and that the current picture of spin effects in hadronic interactions is much more complex than naively thought.

(A. Yokosawa)

I.A.3 Collider Detector at Fermilab

a. Physics Results

The top quark continued to hold the attention of the collaboration as the data sample increase became significant and confidence developed in dealing with the replaced silicon vertex detector. Conclusions will come later.

Bob Wagner, Jimmy Proudfoot, Theresa Fuess and Larry Nodulman continue to be active in electroweak physics. Larry, along with Kevin Einsweiler (LBL), is convening the electroweak physics group. Larry served on David Salzberg's thesis committee at the University of Chicago. David's thesis is the run 1a W mass measurement using electrons. An extensive article as well as a letter on the electron and muon combined W mass measurement have been prepared and are going through the CDF collaboration approval process. The combined W mass measurement gives 80.41 ± 0.18 GeV/c², in good agreement with previous measurements and with other precision electroweak measurements as shown in Figure 2. There has been strong participation in the W mass analysis from the University of Illinois and LBL as well as Chicago and Argonne.

Bob Wagner, along with CDF colleagues from UCLA, University of Illinois and Tufts, is studying photons associated with W and Z production in 1a data. Nonstandard coupling of the photon to the W would produce an excess of events at high transverse energy. Such couplings

Measurements of W mass

Figure 2: On the left, inferred values of the W mass from LEP precision electroweak measurements, the SLAC polarization asymmetry and neutrino measurements are compared on the right with direct measurements at colliders. The average of direct measurements assumes that all share 85 MeV of common systematic uncertainty.

$B^-/\bar{B}^0$ Lifetime ratio

Figure 3: Measurements of the ratio of lifetimes for the charged and neutral B mesons.

could arise if the W were composite. The shape as well as the normalization of the photon E_T distributions can be used to derive limits on nonstandard couplings. In the standard mode, the CP conserving couplings κ and λ are 1 and 0 respectively. The magnetic moment of the W is proportional to $(2 + \kappa + \lambda)$ and the quadrupole moment of the W is proportional to $(\kappa - \lambda)$. Letters describing experimental constraints on these couplings and similarly defined couplings for $Z\gamma$ have been submitted and accepted for publication. Theresa Fuess is working with Chris Wendt from Wisconsin on similar nonstandard couplings for WW and WZ production. Only one event is found in 1a data which could be a leptonic W or Z decay at high p_T opposite a jet pair which could come from another W or Z . A letter describing the coupling implications of the absence of such events is going through the CDF collaboration approval process.

Karen Byrum and Barry Wicklund are continuing to study various aspects of b physics using the inclusive electron data sample. Colleagues from the University of Pennsylvania and Johns Hopkins have joined in deriving b physics analyses from this sample, which was also used for calibration. Studies of self tagging techniques are continuing. Cross section results for b production are being derived from both the inclusive electrons and electrons in association with D mesons. The charged and neutral b lifetime difference can be determined by the branching fraction to different charmed mesons associated with electron decays. A preliminary result using sign correlations of D and D^* candidates with electrons is comparable to the direct study of ψK and to LEP analyses as shown in Figure 3.

Steve Kuhlmann continues his active participation in QCD physics including membership in CTEQ. Bob Blair continues to organize the photon group. The photon and diphoton data raise the issue that intrinsic k_T may be needed to describe the data and the implications of this are being pursued. A letter on inclusive photon production has been published.

b. Summary of Active Data Acquisition

In general, the CDF detectors have worked well for data taking in run 1b. The new silicon vertex detector in particular is performing well, although the effects of radiation are much larger than was expected. The data are essentially usable for physics analyses, and since the displaced and rotated low beta quadrupole magnet was realigned luminosity of $1 - 1.5 \times 10^{31} \text{cm}^{-2}\text{s}^{-1}$ has been typical; almost 40pb^{-1} of data has been collected in this period, see Figure 4.

Offline reconstruction has kept up with the high priority 10% subset of events and is catching up with reconstructing the bulk of the data including the inclusive electron sample. A further low priority dataset is not yet being processed.

The central EM calorimeter is in good shape. The new source calibration performed at the beginning of run 1b has been tuned up in detail. The gain loss noted during 1a has not proved to be proportional to luminosity. The 1b behavior shown in Figure 5 shows similar trends. Strip, crack and preradiator chambers have no new problems and continue to perform well at high luminosity. The new shower max trigger has proved to be reliable and effective.

Larry Nodulman is continuing to develop and support online data monitoring. Bob Wagner completed his terms as a member of a pool of about 15 shift leaders or "Scientific Coordinators" who help lead data taking. Bob Blair is a current shift leader. Marcus Hohlmann continues to support fast offline monitoring of data quality.

c. CDF Planning Activities

Members of the Argonne CDF group participated in the preparation of an expression of interest (EOI) for a further round of detector upgrades aimed at a run 3. This process has been declared moot by Fermilab. The long term accelerator options under study include options for antiproton storage rings in the main injector tunnel which could greatly increase luminosity. The lab anticipates eventually having EOIs on b -physics specific collider programs, and a series of workshops has begun to see if there is some niche of high p_T physics which would make sense at the Tevatron collider after the LHC program is going. Members of our group are interested in both options. One or the other may evolve out of what is now CDF.

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

(L. Nodulman)

Run IB Integrated Luminosity July 94 - Jan. 9

Figure 4: Cumulative integrated luminosity for CDF for the period. The shaded region is on tape. The salutary effect or rotating the low beta quad and the shutdown associated with lack of liquid nitrogen are obvious.

Figure 5: Average tower gain of the central EM calorimeter for each physical arch.

Figure 6: Schematic representation of a Soudan 2 wireplane pulse. The parameters that describe the pulse shape include: length above threshold, integrated pulse height, microstructure peak, FWHM, and rise time.

I.A.4 Non-Accelerator Physics at Soudan

a. Physics Results

By the end of 1994 Soudan physicists had nearly completed the upgrade of the Monte Carlo simulation software which is needed to continue the analysis of Soudan 2 neutrino data. Our first physics priority continues to be the measurement of the ν_μ/ν_e ratio from atmospheric neutrino interactions in Soudan 2. This included improvements in the neutrino event generator, a more accurate representation of the detector geometry, the use of actual detector parameters from the experiment database, and improved simulations of drifting and electronics. The fidelity of the new simulation of the detector response was checked against Soudan 2 cosmic ray data. The pulse shape parameters used in this analysis are defined in Figure 6. The excellent agreement between data and the Monte Carlo simulation is shown in Figure 7.

A large sample of new Monte Carlo events will be analyzed in parallel with contained events from the second kiloton-year data sample. Monte Carlo neutrino events will be processed by the same software as Soudan 2 data events, and will be mixed with data events for the final physicist scan of the contained event sample. At the end of the year the new software needed to begin the final event classification of the second kiloton-year data sample was nearly ready for use. This large data sample will more than double the size of the Soudan 2 atmospheric neutrino event sample. The new data have already been completely processed up to this final event-characterization stage.

Soudan 2 data are also being used for a number of ongoing cosmic-ray physics analyses,

All dip angles.

Figure 7: Comparison of simulated and actual pulse shape parameter distributions from the Soudan 2 detector. See Figure 6 for definitions of the parameters.

which will be the subjects of several graduate student Ph.D. theses. These include the use of underground muon tracks to search for astrophysical point sources and for large-scale anisotropies of cosmic rays. The collaboration also continued the study of primary cosmic ray composition using multiple muon events, with and without coincidence data from surface detectors which observe the parent air showers directly.

b. Experimental Apparatus Improvement

The upgrade of Soudan 2 calorimeter modules continued throughout 1994. During the first half of the year 64 of the worst-performing modules were removed from the South half of the detector to improve wireplane gain uniformity and to repair leaks. During the past six months two more modules were removed and the six worst modules were shipped back to the Argonne module factory for complete rebuilding (only the corrugated steel sheets will be saved). Another 27 modules were repaired at Soudan. Four more of the detector halfwalls, which had been disassembled earlier, were brought back into operation during the six-month period. (A halfwall is a subassembly of eight 5-ton modules, stacked four across and two high.) In addition, anode high voltage splitter hardware was installed on nearly all remaining halfwalls, so that each individual wireplane may be operated at its own optimum high voltage. At the end of the year, all but two halfwalls were back in operation, bringing the total operating mass to 894 tons.

The six worst Soudan 2 modules were shipped to Argonne during the fall of 1994. One module was cut open and partially unstacked to repair a drift high voltage fault, and two of the others have now been completely rebuilt. All module components except the corrugated steel were replaced. The last three modules will be rebuilt and returned to Soudan during the spring of 1995.

Other installation activities included the deployment of 47 new active shield proportional tubes, covering small gaps between floor panels. Preparations for the installation of shield tubes which will cover the last remaining cracks in coverage were also well under way at the end of the year. These cracks constitute only a few percent of the total solid angle coverage provided by the active shield, but require special short tubes which are quite labor intensive to build and install.

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

c. Summary of Active Data Acquisition

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

The Soudan 2 experiment continued routine data acquisition for contained events (neutrinos and nucleon decay) and cosmic ray muons during the last half of 1994. In addition, data from the 40m² surface array were recorded in coincidence with Soudan 2 in order to measure the energies of some of the cosmic ray air showers which produce underground muon events. Data from a wide-angle air Čerenkov air-shower detector were also recorded in coincidence with Soudan 2 on clear,

moonless nights.

The Soudan 2 detector itself recorded data for 152 days of livetime, giving an all-time record high duty cycle of 82%. This brought the total Soudan 2 exposure to 4.6 years, providing a total exposure of 2.1 fiducial kiloton-years useful for nucleon decay and atmospheric neutrino physics.

d. Planned Activities

Upgrade of the South half of the detector is expected to be completed during the spring of 1995. Repair of modules in the newer North half of the detector is less urgent, particularly since the two worst modules have already been removed for repair at Argonne. After the six rebuilt modules are returned from the Argonne module factory in the spring of 1995, the full 963 ton calorimeter will be brought back into operation during the summer.

Preparations have already begun for the next major upgrade to the Soudan 2 experiment. The Oxford group is preparing an array of proportional tubes which will be installed immediately above the upper layer of Soudan 2 calorimeter modules. This array will make use of tubes built originally for the Tasso detector at CERN. It will provide enhanced protection from cosmic ray muons which might enter the calorimeter undetected through cracks between modules and halfwalls. Such protection is already provided by the cavern-liner active shield which has been in operation for many years. While the original shield is still thought to provide completely adequate coverage, crack-penetrating muons are potentially such a serious background for neutrino and nucleon decay events that the redundancy provided by the new "crack filler" array is very important, if only to confirm the effectiveness of the original shield. The installation of the new crack-filler active shield panel is expected to begin during the summer of 1995.

(D. Ayres)

I.A.5 ZEUS Detector at HERA

a. Physics Results

Five papers were published or submitted for publication in this period. All of the results are based on the 550 nb^{-1} of data taken by ZEUS in 1993; which is about a factor of twenty more than the 1992 data set. The measurement of the proton structure function F_2 , shown in Figure 8, confirms the strong rise for lower x_{Bj} values first observed with the earlier data. Parton density distributions that assume a gluon distribution that is independent of x_{Bj} are ruled out by these data. The ZEUS results are in good agreement with those of the H1 collaboration and show a smooth variation in Q^2 from the fixed target data as seen in Figure 9. These F_2 values were analysed to give a direct measure of the gluon density. Three techniques were used. The first, due to Prytz, assumes that the GLAP evolution equations are dominated by the gluon splitting terms and relates the slope of F_2 at a given value of x_{Bj} to the gluon density at $2x_{Bj}$. The second method, suggested by Ellis, Kunszt and Levin, uses both the values of F_2 and their logarithmic slopes at a given value of x_{Bj} . Finally, a global fit was made to the ZEUS data and some NMC results using the functional forms of Roberts, Martin and Stirling. The results for $Q^2 = 20 \text{ GeV}^2$ are shown in Figure 10. The solid line is the result of the global fit with the uncertainty given by the shaded area. The dotted lines show two recent parametrizations by the Durham group: the lower one (MRSD'_0) has a constant gluon density and the upper (MRSD'_-) the $1/x_{Bj}^{0.5}$ power law dependence suggested by the BKFL pomeron. Our global fit gives a value of 0.35 rather than 0.5

ZEUS 1993

Figure 8: ZEUS measurements of F_2 compared to lower energy values from the NMC collaboration.

for this exponent. Two new studies of jet production in photoproduction reactions were reported in this period. The inclusive jet cross sections in the transverse energy range $8 \text{ GeV} < E_T < 41 \text{ GeV}$ and pseudo-rapidities between $-1 < \eta < 2$ were measured using a cone algorithm with unit radius to define the jets. The center of mass energies span the range from 130 GeV to 270 GeV. The results are shown in Figures 11 and 12. The statistical errors are shown as the inner bars; the outer bars include the systematic errors. The shaded area shows the uncertainties coming from the absolute energy scale. The lines are the results of calculations including both the direct (dotted) plus resolved photon interactions. The resolved photon component is clearly required. These data probe the photon structure function down to $x_\gamma = 0.01$ and, at the present level of precision, do not distinguish the various parametrizations of the photon structure. The second study reports the observation of jets in diffractive photoproduction. Diffractive events are chosen on the basis of there being a gap in pseudorapidity between the HERA proton direction and the most forward particle observed in the detector. For this analysis a particle is taken as a calorimeter cluster with more than 400 MeV of energy. The distribution in η_{max} is shown in Figure 13a. The diffractive events are the shoulder extending from $\eta_{\text{max}} = 1.5$ to negative values. The dashed histogram, which is based on the PYTHIA Monte Carlo simulation, represents the bulk of the data. The full histogram, which results from a simulation of the diffractive events using the POMPYT program, shows that these events extend beyond the $\eta_{\text{max}} = 1.5$ cut off. POMPYT assumes that the diffractive reaction proceeds by the interaction of the photon with a constituent of the pomeron. A hard pomeron structure function of the $x(1-x)$ form was used. The distributions in the $\gamma - p$ mass (W) are typically peaked 200 GeV as seen in Figure 13b, whereas the mass of the diffractively produced state (M_x) of Figure 13c is an order of magnitude lower. A search for jet activity in the diffractive sample using the cone algorithm yielded a number of events with clear jet activity. For event $E_T > 5 \text{ GeV}$, 91.4% of the events had no jets, 6.5% had one jet and 2.0% had two jets. One two-jet event is shown in Figure 14. The energy flow about the jet axis for these events has the same shape as for the inclusive jet sample. A measurement of x_γ for the diffractive events shows

Figure 9: The Q^2 variation of F_2 for different x_{Bj} values measured by the ZEUS, H1, E665, and NMC collaborations compared to the MRSD'_0 and MRSD'_- parametrizations.

ZEUS 1993

Figure 10: The gluon momentum density as a function of x_{Bj} at $Q^2 = 20 \text{ GeV}^2$ as determined from ZEUS data using the Prytz and EKL methods. The inner error bars are the statistical errors; the outer bars include the systematic effects. The solid line is the GLAP NLO fit with the shaded area indicating the associated error. The two MRS parametrizations are shown as the dotted lines.

that they are predominantly produced by direct coupling of the photon rather than by the resolved process. This is well understood given the kinematics and the event selection criteria.

b. HERA and ZEUS operations

Following the HERA switch to positron operation both the intensity and stability of the stored electron beam improved so that by the end of the running period more than 6 pb^{-1} of luminosity had been delivered of which ZEUS logged more than 3 pb^{-1} . This is a factor of six higher than the 1993 data set.

c. Apparatus Development

A paper describing the ZEUS first level calorimeter trigger, a joint project of the Wisconsin and ANL groups was submitted to NIM. Based on the experience of the 1993 data taking it appears that the design goals have been met. In 1994, the isolated electron and isolated muon triggers that depend on the Argonne Trigger Processor were implemented. The first level trigger for the Small-Angle Rear Tracking Detector (SRTD) was completed in this period and will be installed for the 1995 ZEUS data taking. The SRTD is a crossed hodoscope of 272 scintillator finger counters located around the beam pipe just in front of the rear calorimeter. The trigger provides better than 1ns timing, has a programmable threshold that can be set as low as 0.3 mip, and has extensive on-line and off-line monitoring capability.

Figure 11: Measured differential $e-p$ cross section for jet production integrated over E_T for three E_T thresholds. The shaded bands indicate the uncertainty coming from the jet energy scale. The results of the PYTHIA simulation for two different photon structure functions are shown as the lines. Also indicated is the contribution from the direct process alone.

ZEUS 1993

Figure 12: The E_T variation of the jet cross section for two different η selections compared to several parametrizations of the photon structure function. The direct contribution is also indicated.

ZEUS 1993

Figure 13: a) The distribution of $\eta_{\max}$, the most forward particle, for the photoproduction sample with $E_T > 5$ GeV with the predictions of PYTHIA and POMPYT. b) The distribution in total c-m energy W for all events and for those with $\eta_{\max} < 1.5$. The POMPYT simulations are shown as the histograms. c) The mass of the hadronic system M_x for events with $\eta_{\max} < 1.5$ compared to the POMPYT simulations.

Figure 14: Display of a two jet event in diffractive hard photoproduction.

Discussion of R & D on the Barrel Hadron Electron Separator (BHES) is found in Section I.C which covers detector development within the division.

(M. Derrick)

I.A.6 BNL Partial Snake Experiment

In December, 1994 as part of the BNL partial snake experiment (E880), polarized protons were accelerated in the AGS to the highest energy ever achieved by means of acceleration. Only E704 at Fermilab has had higher energy polarized beams, and it used a different method. The effect of the "Siberian snake" at 5% strength is illustrated in figure 15. Beam polarization is preserved as imperfection resonances are crossed with the snake on. Partial depolarization is seen to occur due to the noted intrinsic depolarizing resonances. Argonne has played a major rôle in this work for more than two years. We were responsible for the polarimeter, which was used to guide the machine studies. Argonne also developed the detectors, DAQ system, and online analysis. Much of the offline analysis is being performed by an Argonne-Indiana University graduate student. This student was also responsible for much of the accelerator calculations and studies.

(D. Underwood)

Figure 15: Measured value of vertical beam polarization at $G\gamma = n + \frac{1}{2}$ up to $G\gamma = 22.5$. Partial depolarization is due to the noted intrinsic spin resonances.

I.B EXPERIMENTS IN PLANNING OR CONSTRUCTION PHASE

I.B.1 STAR Detector for RHIC

Our major effort during this period was concentrated on the presenting the case for an electromagnetic calorimeter for the STAR experiment as one of the RHIC "additional upgrade" projects. Studies were made regarding the measurement of the gluon distribution in pp interactions and gluon shadowing in pA interactions. Simulation studies were conducted in jet and photon identification. The results were presented during the BNL PAC meeting where the construction of the STAR EMC was regarded as a very high priority project.

Extensive simulation studies are being carried out for R5 (the approved RHIC spin physics program): direct-photon, jets, and W, Z production. The two large Monte Carlo efforts during this period were a study of jet finding in $A-A$ collisions by Shesternanov, an ANL visitor from Protvino, and a study by Beddo, an ANL visitor from Johns Hopkins university, of the adequacy of the proposed shower maximum detector for direct photon events which will enable structure function studies. Additionally, there was some more work on the background under the W decaying via the electron-neutrino channel with electron detection provided by the EM calorimeter. The statistics on detected Z s as a function of rapidity were also studied.

The jet finding studies showed good efficiency for 30 GeV jets for A up to iron in $A-A$. The study focused on two-jet events because jet quenching by the quark-gluon plasma may be found by comparing one jet in an event with the balancing jet in the same event. The jet finding algorithm can potentially find fake jets in the high density of particles in an $A-A$ collision. This was found to be less than 10% for single jets (typically concentrated around 10 GeV or less), and less than 1% for two-jet events.

The direct photon studies were done for both $p-A$ and pp . The gluon structure function in heavy nuclei may be modified in a way similar to the quark distribution in the EMC effect. This must be measured in order to understand the colliding photon fluxes in $A-A$. Part of the spin of the proton is not carried by valence quarks and may be carried by gluons. This will be measured in collisions of polarized proton beams producing direct photon plus jet.

(D. Underwood, A. Yokosawa)

I.B.2 MINOS—Main Injector Neutrino Oscillation Search

The Soudan group, which previously had been working on a proposal for a Fermilab neutrino oscillation experiment (P822) using Soudan 2, has joined a new collaboration to build a large new detector in the Soudan mine to study neutrino oscillations. The collaboration includes Argonne, Boston College, Caltech, Columbia, Fermilab, Houston, Indiana, ITEP, Lebedev, Livermore, Minnesota, Oak Ridge, Oxford, Rutherford, Stanford, Sussex, Texas A&M, Tufts, and Western Washington. The MINOS Collaboration proposes to conduct a search for $\nu_\mu \rightarrow \nu_\tau$ and $\nu_\mu \rightarrow \nu_e$ oscillations using a new ν_μ beam from the Fermilab Main Injector with energies well above τ production threshold. Oscillations will be detected by the comparison of signals in a 'near' detector at Fermilab and a 'far' detector situated 730 km away. The experiment will require self-consistency among several tests for oscillations to build a compelling case for any discovery. A new 10 kton detector will be built at Soudan to allow the exploration of oscillation parameters down to $\Delta m^2 \approx 0.002 \text{ eV}^2$

and $\sin^2 2\theta \approx 0.01$. In addition the existing, much finer grained but smaller, Soudan 2 detector will provide an independent check of any potential signal with $\sin^2 2\theta$ larger than ≈ 0.1 . The MINOS proposal has been presented to the Fermilab PAC and received strong support from the committee.

Atmospheric neutrino data suggest that oscillations occur with $L/E_\nu \approx 100$ km/GeV. A ν_τ appearance experiment requires a neutrino beam energy well above τ production threshold. The Main Injector can produce high flux neutrino beams with $E_\nu \approx 10$ GeV, suggesting a distance similar to the 730 km between Fermilab and Soudan. Independent of the atmospheric neutrino anomaly, the neutrino energy and baseline of the MINOS experiment represent a good compromise between sensitivity to both low Δm^2 (long L) and small $\sin^2 2\theta$ (high statistics, short L).

The MINOS proposal describes a 10 kton reference detector which can be built using well understood technology. It will be build in a new hall at the Soudan mine, adjacent to the existing hall containing the Soudan 2 detector. The detector is designed to obtain measurements of muon momentum by range and/or curvature in magnetized steel, and to provide calorimetric measurements of hadronic and electromagnetic energy. Monte Carlo calculations performed to date give us confidence that this detector will reach the design goals of the experiment. We shall continue both detector R&D and simulation with the expectation of further improving the physics capabilities and reducing costs.

The reference detector is a 36-m long, 8-m diameter sandwich of 4-cm thick octagonal steel plates separated by 2-cm gaps containing the active detectors. A total of 600 such planes constitute the mass of 10 kton. A coil running through a central hole will produce a toroidal magnetic field of ~ 1.5 Tesla. Figure 16 shows a schematic view of the detector.

The active detector elements will be 1-cm thick, 1-cm pitch limited streamer tubes. Both the wires and 2-cm pitch cathode strips perpendicular to the wires will be read out. The active detector area will be $32,000$ m^2 with 480,000 readout channels. The electronics will utilize on-chamber chips to amplify, digitize and store information from the limited streamer tubes, and to form triggers locally. The near detector will be closely similar to the far detector, with the same granularity and detector technology.

The experiment relies on multiple tests for neutrino oscillations, carried out with both wide-band and narrow-band beams. The results of these tests can be used to measure $\sin^2 2\theta$ and Δm^2 and determine the oscillation mode ($\nu_\mu \rightarrow \nu_\tau$, $\nu_\mu \rightarrow \nu_e$ or a mixture of the two). Consistency between the results of the tests will be necessary before any discovery could be claimed. The experiment is therefore well protected against spurious effects and a positive result would be very convincing. Figure 17 shows the sensitivity of the experiment for two years of running, using 90% confidence limits for tests for $\nu_\mu \rightarrow \nu_\tau$.

Our present schedule is to have one third of the MINOS far detector operational when the NuMI beam turns on in 2000, and the rest of the detector completed by the end of 2001. In order to achieve this, the new cavern excavation will start at Soudan in the autumn of 1996, and far-detector construction will begin in mid-1998. The estimated cost for a 10 kT detector is \$56M. The cost estimate for the MINOS detector scales with far detector mass M as: $\text{Cost (M\$)} = 15.5 + 4.1 \times M(\text{kton})$.

(M. Goodman)

MINOS (Main Injector Neutrino Oscillation Search)
Far (Labyrinth) Detector

Figure 16: Overview of the far detector for MINOS.

Figure 17: MINOS two year 90% CL limit curves for $\nu_\mu \rightarrow \nu_\tau$ oscillations. Curve "A" is for the $\frac{cc}{total}$ test. Curve "B" is for the near/far rate comparison and is dominated by 4% systematic error. Curve "C" comes from the total energy measurement. The dashed curve shows measured limits from the CDHS experiment, and the dot-dashed curve shows FNAL E-531 limits. The diamond is the Kamiokande best-fit point.

I.B.3 ATLAS Detector Research & Development

a. Overview of ANL LHC Related R&D Programs

In the second half of 1994, the involvement of Argonne in the ATLAS experiment has been consolidated. The US groups involved in the hadron file calorimeter design effort (presently Argonne, Univ. of Chicago, Univ. of Illinois, Michigan State University, Univ. of Texas at Arlington) have formed a US "TileCal" collaboration with L. Price (ANL) and J. Pilcher (Univ. of Chicago) as co-spokespersons. In October 1994, the scope of work proposed by the TileCal collaboration was reviewed and endorsed by a subcommittee formed by the US ATLAS collaboration. Argonne has established itself as one of the principal centers for further development of the mechanical design. In addition, we completed a study of scintillator tile uniformity, have contributed to the fall test beam program and associated data analysis, and have made some progress towards identifying an area of the level 2 trigger system which we may be able to adopt as a whole. In addition, we contributed directly to the ATLAS Technical Proposal, which was submitted in December to the CERN LHCC, in the areas of mechanical design, optical component performance, and overall editing. An extensive discussion of R & D on the ATLAS TileCal calorimeter and on trigger electronics development is found in section I.C which covers detector development.

(J. Proudfoot)

Figure 18: Time dependence of the amplified CES chamber wire signal as predicted by SPICE.

I.C DETECTOR DEVELOPMENT

I.C.1 CDF Detector and DAQ Electronics Development

a. Upgraded Shower Max Readout Electronics

CDF has selected the "QIE" autoranging flash ADC system developed for SDC and KTeV for the run 2 front end electronics. A modified version will be developed for the shower max readout. The amplification scheme developed by Marcus Hohlmann will be adapted to the QIE and modified to reduce power consumption. SPICE simulations (Figure 18) reproduce the time development of the chamber wire signal as seen in Figure 19. Separately housed front end cards will receive, amplify and digitize the wire chamber signals, multiplexing the output sent to DAQ electronics in VME and to the trigger, as shown in Figure 20. Argonne will have specific engineering responsibility for these cards through the QIEs and Fermilab will engineer the multiplexing. We are pursuing the option of preamplifying the preradiator and crack chamber signals locally on the front of the wedge. The plan for shower max front ends went through a review and the overall scheme was approved; we look forward to the availability of QIE chips and test boards so we can test a reasonable overall prototype.

b. CDF Tracking Upgrade

Bob Wagner worked with the Duke group in CDF to prepare a proposal for a straw tube

Figure 19: Time dependence of the amplified CES chamber wire signal as observed. The top trace is $1\mu\text{s}$ per division, the bottom trace 200 ns per division.

Figure 20: Data path for wire chamber readout: preamplifiers: separate boxes on the back of the wedge will contain preamplifiers and digitizers which send data to VME readout cards.

Figure 21: Detail-A shows the support structure of the proposed intermediate straw tracker. The bundle end stand is used for both alignment and for transferring the tension load from the support cylinder to the G-10 endplate. Detail-B shows the support scheme within the length of the chamber where precision aligned shim rings are contained within the support cylinder. All support components except the end flange would be of carbon fiber construction to produce a small total radiation length for the chamber.

option for intermediate tracking for run 2. The tracker proposed would contain two superlayers: one axial and one stereo. The overall active length along the beam direction would be 170 cm and would extend from a radius of 17.6 cm to 27.1 cm. The axial superlayer is located as the outer of the two superlayers and consists of twelve layers of straw tubes embedded in a hexagonal structure. The stereo superlayer contains eight layers of straw tubes with a stereo angle of $\sim 4^\circ$. The geometry of the stereo layer is rather complicated to visualize, but was designed have the minimum radius at the midpoint of the chamber along the beam. This is effectively accomplished by rotating each straw about a radial line at the chamber midpoint. This geometry along with the desire to minimize the radiation length presented to particles traversing the chamber and to achieve a $50\mu\text{m}$ tolerance for straw and wire placement requires careful engineering of the support structure for the chamber. Argonne's rôle in the proposal was to provide the design and engineering calculations for this support structure. Figure 21 shows a schematic diagram of the details for the support structure that we designed to meet the required structural requirements. Shim rings spaced along the length of the chamber would provide for the accurate placement of the straw tube bundles. These shim rings would be precisely glued into a carbon fiber support cylinder whose main purpose is to carry the tension load from the sense wires in the chamber. Bundle end support stands at either end of the chamber are used to position the bundles in a way similar to that of the shim rings. They also transfer the wire tension to the G-10 end flange that provides the global support structure for the chamber.

In December an internal CDF review opted for a more expensive and more powerful fiber option for intermediate tracking as well as a 5th layer of double sided silicon. As the luminosity is now anticipated to be increased from 10^{32} to $2 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ after about two years of run 2, CDF has also requested to put in a replacement for the central tracking chamber at that later date, perhaps 2002. Straw and open geometry options are being considered and the Argonne CDF group is interested in assisting on the design of the support for the straw tracker replacement option. The much larger volume as compared to the intermediate tracker presents a more challenging problem for support and alignment of the straw bundles.

(L. Nodulman, R. Wagner)

I.C.2 ZEUS Barrel Hadron Electron Separator

The data taken at the AGS test beam with the wire chamber shower max detector called the Barrel Hadron Electron Separator (BHES) installed in the prototype BCAL module that was described in the previous report has been analysed and the results documented in a NIM paper. The BHES consists of a set of proportional wires parallel to the beam axis with cathode pads to measure the perpendicular coordinate. The measured position resolution for isolated electromagnetic showers, shown in Figure 22, is about a factor of three better than that from the calorimeter alone, in both coordinates. Separation of electrons from pions is also significantly improved. Two cuts are used. The first is the multiplicity of hits in both wires and pads; the second is the pulse height sum of five wires centered on the incident particle. Figure 23 shows typical distributions of these quantities for 3 GeV incident pions and electrons. An aluminum block 1X₀ thick was placed in front of the module to simulate the ZEUS magnet coil. This was followed by a scintillation counter to act as a presampler (PRE). The pulse height distribution in this counter is shown in Figure 24. The e/π separations for 90% electron efficiency for the BCAL and BHES are shown in Figure 25 and for the BCAL and PRE in Figure 26 as a function of energy.

(M. Derrick)

I.C.3 STAR Calorimeter Development

Argonne had a major involvement in the BNL test beam run in July with a prototype calorimeter for the STAR experiment at Brookhaven. This test was very successful (although highly stressful for all involved). The measured calorimeter resolution was $16\%/\sqrt{E}$, which agrees with that from calculations. The uniformity of response was very good; non-uniformities not being seen in the online analysis. Offline analysis is continuing. The response was linear with electrons from 0.5 to 8.0 GeV, the highest energy available in the beam. Two technologies of shower-maximum detector were also tested inside the calorimeter. One of the purposes of this test run was to find the response to low energy charged pions in what is nominally an electromagnetic calorimeter. This is needed to make corrections to the total neutral (photon) energy in measurements in $A - A$ collisions. We obtained this data, and additionally found that depth segmentation of the calorimeter provided about a factor of 4 rejection of charged pion energy deposition compared to electron energy deposition.

Figure 22: Position resolutions for isolated electromagnetic showers measured with the BHES compared to the values determined from the calorimeter.

Figure 23: a) Number of wires showing charge above $Q_{\min}$ for 3 GeV electrons. b) Number of wires showing charge above $Q_{\min}$ for 3 GeV pions. c) Total charge on five wires centered around the incident particle for 3 GeV electrons and pions.

Figure 24: PRE sampler pulse height for 3 GeV electrons and pions.

Figure 25: Pion contamination for 90% electron acceptance as a function of momentum for the CAL, the BHES, and the combination.

Figure 26: Pion contamination for 75% electron acceptance as a function of momentum for the PRE, the CAL, and the combination.

The proposed shower maximum detector is very similar that in the CDF central E-M calorimeter. It would be at a depth of 5 radiation lengths in the calorimeter, and would provide fine spatial resolution to resolve individual photons from π^0 s and η s which are the primary background for the direct gamma signal. Studies with the Hijing event generator showed that the occupancy of the detector was only a factor of 2 more in p -Au collisions than in pp collisions. The occupancy in p -Au at $\sqrt{S} = 200$ GeV/nucleon is similar to the occupancy in pp at 1800 GeV. Early in the study numerous errors in the Hijing event generator were found by comparing it with Isajet.

(D. Underwood)

I.C.4 ATLAS Hadron Calorimeter and Trigger Development

a. Hadron Calorimeter Mechanical Design

In June 1994, the Argonne group presented an alternative module design concept to the ATLAS TileCal collaboration. This followed the adoption of the Argonne proposal to move to a submodule concept for module fabrication. The detailed Argonne proposal was based on submodules approximately 1m in length constructed of master and spacer plates held together using welded straps through the structure. The CERN/Barcelona groups in the meantime had developed a new approach based on submodules approximately 30cm in length, with plates bonded together using an epoxy adhesive. The ATLAS TileCal group decided to adopt this latter approach as the baseline design concept, primarily due to a perception that it would be cheaper, use less skilled labor, and would be more accessible to small institutions. However, much of the design work done at Argonne on stacking and on the master plate design was carried over into the bonded stack

EXTENDED BARREL MODULE

Figure 27: Calorimeter master plate layout for present design. The keys at the inner and outer radii have been taken directly from the ANL design work done in the first half of 1994.

concept. Figure 27 shows the present design for the master plate. The keys at the inner and outer radii are directly taken from the design work done at Argonne, in which we demonstrated their usefulness in realizing the desired submodule tolerances. A further outcome of this meeting was that the Argonne group agreed to carry out tests of gluing, a re-design of the support girder, evaluation of master plate manufacturing costs, and an analysis of transportation costs for a variety of models for submodule and module assembly locations.

i. Plate Bonding Tests

A variety of bond strength tests have been carried out at Argonne (ANL-HEP-TR-94-86). These have included tests of the epoxy resin used for the initial tests at CERN (Araldite AY 103 with HY 991 hardener), the epoxy resin used in recent years in the Division for several projects (Hysol 9430), the use of glass microspheres to maintain glue line thickness, and a variety of surface preparations and cure temperatures. The required shear strength for the bond has been estimated to be 2 N/mm^2 with the assumption that half of the plate surface area is bonded. We have determined that any of the above bonds can meet this specification. A typical set of bond shear strength measurements is shown in Table 1, where the glue line has been maintained using glass

Sample	Load (lbs)	Stress (N/mm ²)
1	975	6.71
2	1050	7.23
3	1025	7.06
4	1075	7.40
5	1125	7.75
6	975	6.71
7	1000	6.89
8	1025	7.06
9	1050	7.23
10	1000	6.89

Table 1: Lap shear test of araldite AY 103(10g) and HY 991 (4g). A glue line thickness of 50 microns has been maintained using glass microspheres

microspheres to ensure a thickness of approximately 50 μm . These data indicate that we have a factor of 4 safety margin for shear strength. The time for the bond to develop maximum shear strength has also been shown to be approximately 12 hours. This is sufficient to meet the projected submodule production rate of one every two days.

ii. Argonne Girder Design

A cost estimate in the US of the support girder design as shown at the beginning of 1994 indicated it to be prohibitively expensive. The Argonne group therefore agreed to undertake the task of redesigning this structure to minimize its cost. The support girder has three primary functions: the support of the calorimeter modules, the structure within which the calorimeter readout photomultipliers and front end electronics are contained, and the shielding of the readout PMTs and electronics from the solenoidal and toroidal fields surrounding them. Argonne engineers were of the opinion that the original design had centered too much on the location of the readout elements and shielding and had incorrectly incorporated the support function. This had lead to a structure which, according to US manufacturers, required a significant amount of high precision machining. Argonne chose to develop a design in which a commercially available steel tube formed the principal support function, low tolerance steel plates added to the structure provide magnetic shielding, and the precision location of the electronics is achieved locally at the fiber bundle rather than globally along the length of the structure. This design is shown schematically in Figure 28. It is documented in an internal ATLAS note (ATLAS TileCal-NO-035) and was presented to the TileCal collaboration in November, 1992. A decision on this design is to be made in early 1995.

iii. Plate Manufacturing

A key component in the cost of the TileCal hadron calorimeter is the procurement cost of the master and spacer plates with the high precision tolerances as required for submodule assembly and a minimal intermodule azimuthal gap of 1mm. Argonne undertook an evaluation of the stamping process for plate manufacturing in comparison to the laser cutting process used in Europe for test module plate production. This study indicated that the cost of the stamping die would be approximately \$45,000 for either the master plates or for each of the 11 spacer plates. Stamping is, therefore, not considered economical for spacer plate fabrication and we are now considering

EXTENDED BARREL MODULE

Figure 28: Argonne girder design (schematic), developed in order to minimize the amount of plate machining (and, therefore, cost) required to realize the design specifications. Submodules are mounted to the girder front plate using the key ways. The circular holes on each side of the girder are for the PMT and fiber readout. Access holes (for installation) are cut in the top of the girder. These are covered in the final assembly by a steel plate to provide magnetic shielding.

the option of stack machining or laser cutting for their fabrication. However, it does appear that stamping is the preferred method for fabrication of the master plates from the viewpoint of both cost and the required cutting precision.

iv. Transportation Study

The calorimeter fabrication and assembly is presently planned to be carried out using 7 locations for submodule fabrication and 3 locations for module assembly (one extended barrel in the US, one in Spain and one in Eastern Europe). Procurement of some of the other major items (e.g. steel plate, the support girder) may also occur in more than one location and must be shipped to fabrication and assembly points. Transportation costs may, therefore, become a significant component of the total construction cost and a study was carried out using various models to estimate and bound the magnitude of these costs.

As the various scenarios for construction of the TileCal Hadron Calorimeter become more realistic we have been conveying this information to an outside integrated transportation expert. One of the major components of these particular scenarios included shipping all of the steel from Europe to the US for punching, and then returning 2/3 of the finished plates to Europe. Our study indicated that this would result in an unacceptably high transportation cost and resulted in a modification of the production plan to one in which the plates are punched or cut independently at locations closer to the assembly location. This alone could result in a reduction in cost of several hundreds of thousands of dollars. As the construction and procurement plans become more clearly defined, it is our intention to continue to use this type of analysis to assist in the decision process regarding procurement and logistics for Tile-Cal components.

(N. Hill, J. Proudfoot)

b. Scintillator Readout Design Tests

In the summer and fall of 1994, the response uniformity was measured at Argonne for several prototypes of the scintillator tiles to be used in the readout of the hadron calorimeter. Various tile characteristics were studied (tile geometry, readout edge preparation, wrapping paper and masking patterns). The response was mapped over the entire surface of the tile and data analyzed to characterize the overall uniformity. The data were documented in an internal report (ATLAS-TILECAL-NO-027). With the addition of a rather simple mask near each of the readout fibers, good uniformity was obtained (a non-uniformity of 6.5% rms over 90% of the tile surface). This is considered to be sufficient to preclude tile response non-uniformity from significantly degrading the calorimeter energy resolution. The Argonne group was particularly concerned that the 6mm holes in the tiles, which are required by the source calibration system, would seriously compromise the response of the tile over a large fraction of its surface area. The tile response map as a function of position is shown in Figure 29 for a tile masked to optimize uniformity (the grid points are 0.5cm x 1.0cm). The locations of the holes are (0,-4.5) and (0,4.5). As can be seen from the response map, these holes have a relatively minor affect on the tile response. They essentially only contribute as a dead area of radius approximately 1cm.

(J. Proudfoot)

Figure 29: A tile uniformity map. Note that the holes in the scintillator, located at (0,-4.5) and (0,4.5), which are required for the source calibration scheme have a minimal effect on the tile response.

c. Test Beam Program

Argonne has participated fully in the TileCal test beam program since the spring of 1994. In the latter half of this year there was an important run involving a combined test of the hadron calorimeter prototypes with an electromagnetic calorimeter prototype. Several members of the Argonne group contributed to the setup and data taking periods of this test. Following this we have been carrying out data analysis of the standalone data taken in June and July of this year. Data from the combined test only became available at the end of the year and is now being studied.

i. Response to muons at 90 and 11 degrees.

The TileCal calorimeter design requires that the primary calibration be obtained using radioactive sources. To evaluate the precision with which this calibration was achieved, the hadron calorimeter was exposed with the tile and absorber plates at normal incidence to the beam rather than at a small angle as is intended in the actual design. This allows the tile response to be mapped out using muons at normal incidence and, in particular, it allows one to study the response in the gaps between scintillators.

Figure 30 shows the response in the gaps near the tile edges. Shown in the figure is the total calorimeter response by the linear addition of all energy signals. The bottom figure is simply normalized to one at the central value. Tile 10 has an intermediate size and the response seen is typical of most tiles. The large increase at the gaps between modules 2 and 3 and between modules 3 and 4 are caused by the edge effects of the injection molded scintillator, and by scintillation light induced in the fibers themselves. A close inspection of the response shows that, in fact, the

Figure 30: The response of scintillators to orthogonally incident muons for Tile 10. Muons scanned from about the center of module 2 to about the center of module 4. Etot is the arithmetic sum of all scintillator signals. Scintillators in Module 3 have an improved light collection edge.

nonuniformity at the cracks mainly arises from tiles in modules 2 and 4. Module 3 has the edges machined flat and we can see a moderate improvement in the tile uniformity across the face of the tiles in module 3.

The absolute response to muons as a function of depth segment has also been studied, in this case for muons at 11 degrees incidence to the scintillator edges. Although good uniformity (approx. 6%) was observed along the length of the calorimeter, systematic changes in response were observed as a function of calorimeter depth readout. These were as large as a 20% shift in the true energy scale and are somewhat in contradiction with the data taken at normal incidence (analysed by the Barcelona group). This analysis will be repeated once new calorimeter readout calibrations have been incorporated into the data and further studies will be carried out to understand this result.

(J. Proudfoot, R. Stanek)

d. Level 2 Supervisor

The US Group will be responsible for the design, development, and production of the Level 2 Supervisor for the Atlas Level 2 Trigger. This Supervisor performs the essential tasks of

managing and coordinating the Level 2 Trigger hardware in conjunction with the other features of the architecture.

On a Level 1 Accept the Level 2 Supervisor receives from Level 1 the relevant information regarding the event, including the RoI (Region of Interest) identification. Since Level 2 operates only on information from the regions of interest, the Supervisor must allocate the specific Local Processors for the event, and must oversee the passing of this information from the Level 2 Buffers to the Local Processors. During Local Processing the salient features of the event are extracted, and the Supervisor must monitor status information, including timeouts or errors, as well as completion of local processing. At the conclusion of local processing the Supervisor must allocate global processor resources to the event and oversee the passing of the extracted feature information to the global processor. At the conclusion of Level 2 global processing, a Level 2 Accept or Reject is generated by the global processor, and forwarded to the Supervisor. The Supervisor must take appropriate action, including reallocation of resources, and, in the case of a Level 2 Accept, this action must include passing of all the event information from the Level 2 Buffers to Level 3 for further processing.

We expect that the US Group will pursue efforts on several fronts to achieve the objective of providing the Level 2 Supervisor for the Atlas Detector. It will be essential to model and simulate the trigger in conjunction with important physics processes, and understand the latencies and other important characteristics. This will be a matter of first importance and will require resources of the group for several years. A second effort which will be pursued simultaneously will involve development of prototype hardware for the Atlas test beam, installation and operation of the equipment in the Atlas Test Beam, and interpretation of results. This work will be done in conjunction with coworkers involved in other aspects of Level 2 Trigger development, primarily from CERN and Rutherford. We expect that this work will extend over several years. The third effort will be devoted to design, development, and realization of the actual hardware for the Atlas Detector. Because this work must rely on prior efforts and because we hope to take advantage of improvements which will become available over the coming years, this work will not begin for several years; and then will have a protracted period of design, modeling, prototyping, and development.

(J. Dawson)

e. Simulation Studies

Our eventual goal is to establish a strong simulation effort at Argonne in support of both our calorimeter and trigger design tasks. The ATLAS (ATRECON/DICE) simulation codes have been installed on the SGI platform in the division in preparation for this work to begin in 1995.

I.C.5 Electronics Support Group

Work continued in support of the Nucleon Decay Experiment, Soudan 2. Our involvement during the period was one primarily of construction and maintenance. We modified 30 Analog Cards, repaired 4 Anode H. V. Distribution Boxes, repaired 6 8086 Multibus processor cards, repaired one Balka Box, produced 6 Smart Fuse cards, and produced 5 Twelve Volt Imbalance Detectors. Miscellaneous other pieces of electronic equipment were maintained as necessary.

We spent some time working on the conceptual framework for triggering and data acquisition in the Long Baseline Detector. We participated in the development of the electronic conceptual

design for the Proposal. We built a number of limited streamer chambers and investigated their performance as a function of several parameters. One interesting limited streamer chamber was built using hytel for the body material.

Our major effort with regard to support of the ZEUS calorimeter has been the development of the first level calorimeter trigger processor (CFLTP) and the trigger for the Small Angle Rear Tracker (SRTD). During the period, our major effort for ZEUS was to produce the trigger electronics for the SRTD. These cards have four fast TDC's which clear on every HERA cycle and send to the Global First Level Trigger four 6-bit words giving the time of the first coincident hit in each of the four sectors on every crossing. Altogether, there are 272 fast high impedance amplifiers, 544 fast discriminators, and a large amount of logic, all of which must run inside the detector adjacent to the Rear Calorimeter. The system also includes a EVB/FLT card which is located in the Rucksack and ties the trigger cards to the GFLT and the data acquisition. The EVB/FLT cards have already been produced. A Subsector card also is located in the Rucksack to give the GFLT position information on the hit which stopped the TDC in each sector.

During FY 1992 and FY 1993 we have built and tested electronics for the CDF trigger upgrade. This is an effort to bring the preshower radiator and shower max detector wires into the trigger at second level to improve the efficiency for B physics. We hope to have a significant part in the upgrade to 132ns operation in the areas of data acquisition from the shower max and preshower chambers and in formulation of the trigger using shower max and tracking data. To this end, during the last half of 1994, the study of noise problems continued.

(J. Dawson)

II THEORETICAL PHYSICS PROGRAM

II.A THEORY

II.A.1 Lattice Measurement of Matrix Elements for Decays of Heavy Quarkonium

Geoff Bodwin, Don Sinclair and Seyong Kim are continuing work on a project to measure on the lattice the nonperturbative operator matrix elements that appear in the Bodwin-Braaten-Lepage formalism in the decays of S-wave and P-wave charmonium and bottomonium systems. The numerical simulations are described in the Computational Physics section of this report. Preliminary results from this work were presented by Sinclair at the Lattice '94 conference and are summarized in ANL-HEP-CP-94-91.

One part of this effort is aimed at the analytic calculation of the one-loop corrections to the relations between the lattice-regulated operator matrix elements and the continuum-regulated ($\overline{MS}$) operator matrix elements. The lattice-regulated matrix elements are, of course, the ones that are measured in the numerical simulations, while the continuum-regulated matrix elements are the ones that interface with the standard, parton-level perturbative-QCD calculations in the factorized expressions for the quarkonium decay rates. So far, this analytic work has focussed on the operators that appear in the order v^2 contributions to the decays of S-wave states. Calculations of the largest corrections for the order v^2 operators, which involve mixing with the order v^0 operators, have now been completed. Work on the remaining corrections for the S-wave operators is underway, and calculations for the P-wave color-octet and color-singlet operators will be started soon.

(G. Bodwin)

II.A.2 Higher-order Lipatov Kernels and Small- x Physics

The BFKL equation describes the small- x evolution of parton distributions and was originally derived from Regge limit leading log calculations. The BFKL Pomeron - $F_2(x, q^2) \sim x^{1-\alpha_0} \sim x^{-\frac{1}{2}}$ may have been seen at HERA. $(\alpha_0 - 1)$ is the leading eigenvalue of $K^{(2)}$ the leading-order "Lipatov Kernel". Alan White and Claudio Corianò have developed a new technique (Phys. Letts. B334, 87 (1994), ANL-HEP-CP-94-79), combining gauge invariance with abstract Regge theory, to obtain corrections to the BFKL equation from general higher-order Lipatov kernels.

In a general kernel t -channel nonsense states produce transverse momentum diagrams via unitarity. Gauge invariance provides Ward identity and infra-red finiteness constraints which determine diagram weights, fixing uniquely the scale-invariant (no evolution of α_s) part of the kernel. In the $\mathcal{O}(g^4)$ kernel the four-particle nonsense states combine with the $(K^{(2)})^2$ to give the complete $K^{(4)}$. Parton evolution requires only the forward kernel. Corianò and White have given an explicit evaluation (ANL-HEP-PR-94-84) of the forward kernel and shown that it decomposes into two distinct terms. The first term is simply a logarithmic "renormalization" of the $\mathcal{O}(g^2)$ kernel. The second term is completely new and has many interesting properties. It is separately infra-red finite and its eigenvalues satisfy the holomorphic factorization property necessary for conformal invariance of the (non-forward) kernel. This term should be insensitive to scale ambiguities. It gives a reduction $\sim 65\alpha_s^2/\pi^2$ in the power growth of parton distributions at small- x .

(C. Corianò, A. White)

II.A.3 New Strong Interactions Above the Electroweak Scale

For some time Alan White has promoted the virtues of a new color sextet quark sector. In a paper presented at the International Symposium on Very High Energy Cosmic Rays (ANL-HEP-CP-94-46) he describes i) theoretical virtues within QCD - mainly for the Pomeron, ii) remaining problems of the Standard Model that may be solved - including electroweak symmetry-breaking, Strong CP conservation, and electroweak scale CP violation, iii) the radical change in the strong interaction above the electroweak scale due to the sextet sector - multiple W s and Z s, and new, semi-stable, very massive baryons, will be commonly produced, iv) a variety of observed high-energy cosmic ray effects that might be explained by the new interactions - the accumulation of such effects suggests the famous "knee" in the induced spectrum may be a new strong interaction threshold and v) related phenomena that might be seen at the Fermilab Tevatron - some of which could be confused with top production.

(A. White)

II.A.4 Canonical Dual Transformations in Field Theory

As was evidenced productively by bosonization techniques in the last twenty years, (and hinted at by dual supersymmetric Yang-Mills theories popular this past year), transforming a local field theory nonlocally to an *equivalent* but very different-looking local field theory provides efficient handles for better understanding the behavior of such a system: many of its properties would have been obscure in the original formulation. A canonical transformation is one which preserves Poisson Brackets (commutators and anti-commutators), and thus the functional measure and the over-all quantum behavior of a model. The unique extant nonabelian dual canonical transformation which connects two local bosonic $2d$ field theories to each other has been invented by Tom Curtright (Univ. of Miami) and Cosmas Zachos, in Phys.Rev. **D49** (1994) 5408, and [ANL-HEP-CP-94-33]/hep-th/9407044. This transformation is already serving as the standard guiding prototype in general T-duality (a symmetry relating physical properties in big spacetime radii with quantities at small radii) string-vacuum-related searches by Alvarez-Gaumé and others (Phys.Lett. **B336** (1994) 183, and hep-th/9410237); it is also being generalized to a recondite geometrical problem of Cartan bundle duality by O. Alvarez (Univ. of Miami), [in preparation].

Nevertheless, there is *no* general theory of such transformations at hand, and (nonsystematic) progress in the field is still predicated on the availability of such nontrivial examples. In collaboration with T. Uematsu (Univ. of Kyoto), Cosmas Zachos is searching for further such examples of equivalent pairs of field theories, has established a number of general exclusion rules which specify theories that *cannot* be canonically equivalent to other local ones, as suggested by analyses in the literature. The canonical transformation of fermions to fermions had not been investigated until these theorists posited an *Ansatz* for the generating functional of a canonical transformation of the supersymmetric version of the above-mentioned models. For the first time, this informed *Ansatz* (whose supersymmetry invariance has not yet been fully proved but nevertheless appears compelling) sheds considerable light on the canonical transformation of fermions to fermions, which involves a chiral rotation reflecting duality, in marked contrast to the bosonization of fermions. These results are in the process of being written up.

(C. Zachos)

II.A.5 Isolated and Inclusive Prompt Photon Production in Electron-Positron Annihilation.

Edmond Berger (ANL), Jianwei Qiu (Iowa State), and Xiaofeng Guo (Iowa State) have been engaged in a comprehensive analysis of the inclusive and isolated production of hard photons at collider energies. In Argonne report ANL-HEP-PR-94-74, they provide complete analytic expressions for the inclusive and isolated prompt photon production cross sections in e^+e^- annihilation reactions through one-loop order in quantum chromodynamic (QCD) perturbation theory. They report on their explicit computation of direct photon production contributions through first order in the electromagnetic strength α_{em} and the quark-to-photon and gluon-to-photon fragmentation contributions through first order in the strong coupling in α_s . Berger *et al.* present a detailed treatment of the collinear and infrared singularities that arise in the isolated and inclusive cases. For the isolated case, they derive the functional dependences of the cross section on the isolation cone size δ and isolation energy parameter ϵ . They display the full angular dependence of the cross sections, separated into transverse ($1 + \cos^2 \theta_\gamma$) and longitudinal ($\sin^2 \theta_\gamma$) components, where θ_γ specifies the direction of the photon with respect to the e^+e^- collision axis. The analytic understanding they have developed on the infrared singularity structure in the production of isolated prompt photons in e^+e^- annihilation will lead to improved theoretical calculations of prompt photon yields at hadron colliders. In the paper, Berger *et al.* discuss tests of perturbative QCD predictions as well as the extraction of fragmentation functions from e^+e^- data at LEP, SLC, and elsewhere, and their use in computations of prompt photon production in hadron-hadron and lepton-hadron collisions.

(E. Berger)

II.A.6 Strong Interaction Asymmetries in the Production of B Mesons

Edmond Berger (ANL) and Ruibin Meng (University of Kansas) have continued their examination of $B\bar{B}$ asymmetries expected purely from strong interaction production dynamics. As they reported in the prior Semi-Annual Report (January-June, 1994), forward/backward charge asymmetries, i.e., b quark $\bar{b}$ antiquark flavor asymmetries, are generated from interference effects in next-to-leading order in quantum chromodynamic perturbation theory. Proper understanding of this phenomenon is important for a full assessment of the potential for CP violation studies in the B system at hadron machines. An example of their results is presented in Figure 31 appropriate at fixed-target energies. Ed Berger presented these results as well as other aspects of his research on heavy quark production in an invited plenary review talk at the Second International Workshop on Heavy Quark Physics, University of Virginia, October 5-10, 1994. His paper will be published in the proceedings of the meeting.

(E. Berger)

II.A.7 Principal Value Resummation

Harry Contopanagos and Lyndon Alvero (Stony Brook) have finished and published a paper in which they apply Principal Value Resummation (PVR) to predict dilepton-production cross sections in the setting of various fixed-target experiments, and compare with data ("The Dilepton Production Cross Section in Principal Value Resummation", ANL-HEP-PR-94-59 (Nov. 1994),

Figure 31: Calculation by Ed Berger and Ruibin Meng of the predicted $b\bar{b}$ flavor asymmetry in $\pi^- N$ reactions at 515 GeV. In the forward direction, the $\bar{b}$ cross section is expected to be greater than the b cross section.

Nucl. Phys. B, to be published). They give predictions for the invariant-mass differential cross section, mass-rapidity differential cross section and K-factor, using various parton distributions. The cross sections have been evaluated in the DIS scheme and the parton distributions used are both, purely DIS fits (DFLM) and the more recent global fits (MRSD' , CTEQ2D) that are obtained by fits to all experimental data, including Drell-Yan (for which a one-loop calculation for the cross section was input). The results of the comparisons are as follows: (1) For antiproton beams (NA3, E537), PVR is in good agreement with the data. If DFLM parton sets are used, PVR predictions give the best fit to the data, while with global parton fits the 2-loop cross sections give the best fit; but PVR cross sections overshoot the data by 7% – 3% (decreasing with dilepton mass), easily within uncertainties. (2) For proton beams (E605, E772), PVR is in fairly good agreement with the data when DIS-fitted parton sets are used, but overshoots the data by 40% – 20% when globally fitted parton sets are employed. In the latter case, the one-loop cross sections (or, in some cases the two-loop cross sections) give excellent fits. This is hardly surprising, since one-loop cross sections were used as input to produce the global fits in the first place.

In light of these issues we can conclude that PVR has successfully tamed the large threshold corrections existing in dilepton production, to all orders in perturbation theory. The sensitivity of the predictions to the parton sets used, as well as the difference between (1) and (2) above suggests that the major difference between DFLM and MRSD' , CTEQ2D is in the sea-quark parametrization. The reasons for the disagreement in (2) may be one (or a combination) of the following. (i) The global parton sets have used a 1-loop hard part as an input, to simulate experiments other than DIS, for their fits. Therefore there is an obvious bias (and double-counting) when one uses these sets to obtain the PVR predictions. On the other hand, these fits use the best DIS data to date, so it would be useful if a modification of these parton sets became available, where all

inputs except DIS data were switched off. Repeating the PVR calculation with these modified parton sets would give the most proper predictions. (ii) It could be that, even with the modified parton sets, PVR predictions in (2) would still overshoot the data. This would be an indication for existence of a certain amount of physical higher twist, whose effect could be significant at low values of the dilepton mass. Parametrization of this effect using PVR is straightforward and has recently appeared in the literature. (iii) Resummation of non-Sudakov constant terms is not well understood at present, and some assumptions for those terms were made in our predictions. Also, non-singular terms in the finite-order cross section, were *assumed* to be small. This assumption is correct in view of the existing one- and two-loop calculations (where the effects of the finite terms give 7% – 3% negative contributions), but higher-order calculations producing “accidental” large regular terms is a logical possibility.

In another publication (in preparation) Contopanagos, Eric Laenen (CERN) and George Sterman (Stony Brook), derived the resummation formula using a simplified method, compared with past approaches. They only used refactorization of soft-gluon phase space, Renormalization-Group invariance and Lorentz boost invariance, eliminating the need for extra inputs used in the past such as gauge-invariance and homogeneity arguments. They also derived the resummation formula in the $\overline{MS}$ -scheme, for completeness and future reference.

Finally, Contopanagos is preparing a series of papers for applying PVR on top-quark production at the Tevatron. The dominant production mechanism, calculated to one loop, and a resummation of this calculation, depending on undetermined infrared (IR) cutoffs, already exist in the literature. The latter is unfortunately very sensitive to these cutoffs, which were furthermore chosen quite large (10% and 25% of the top mass, for the quark-antiquark and gluon partonic channels, respectively). PVR, which is independent of IR cutoffs, will be ideal in either corroborating the existing predictions in an unambiguous way, or possibly producing larger cross sections, in better agreement with the CDF data. Preliminary results show that PVR predicts larger partonic cross sections than the previously published, throughout the phase space, with high peaks near the top production threshold. It is worth noting that the existing calculation, by imposing an IR cutoff, can only approach the threshold up to a certain point, while the remaining contributions are neglected. It remains to be seen what numerical effect these encouraging differences will have on the physical cross section.

(H. Contopanagos)

II.A.8 Parametrization of the Ambiguous Large Higgs Mass Effects

The properties of a very heavy Higgs particle has been the subject of intense research in the last 18 years. The heavy-Higgs theory is examined as an effective model probing an underlying more fundamental structure at high energies. In this sense the Higgs functions as an ultraviolet regulator and by taking its mass to be infinitely large ($m \rightarrow \infty$) the particle itself is removed and one may study the cutoff sensitivity. However, the heavy-Higgs theory is not well defined. The scalar sector of the standard model may be described in terms of the linear or the non-linear σ model depending on whether we take $m \rightarrow \infty$ at the lagrangian level or at the end of the calculations, respectively. At low energies, while at the one-loop level the radiative corrections are uniquely defined, at the two-loop level the correspondence between the two descriptions ceases to exist. At high energies it is missing even at the one-loop level. In this sense the results for the various physical results are ambiguous.

In ANL-HEP-PR-94-83, Sissy Kyriazidou has suggested that the ambiguity is due to the way of performing the renormalization of the Higgs mass which in the past was specified as the physical mass of the Higgs particle. This definition, however, loses its significance as soon as the mass becomes infinite and correspondingly the particle itself ceases to have a meaning as a physical object. In this sense the Higgs mass renormalization remains unspecified. The question addressed in this work is whether it may be redefined in a way to remove the inconsistency between the two representations in the large Higgs mass limit. While it turns out that this is not possible, it is shown that the Higgs mass renormalization can be used to parametrize the ambiguity. Thus the appearance of its contributions precisely designates the effects that are not uniquely defined. This is illustrated by computing such contributions in the longitudinal WW scattering.

(S. Kyriazidou)

II.A.9 Isolated Direct Photon Production at HERA

In a paper to be published in Phys. Rev. D, Lionel Gordon and Werner Vogelsang (Rutherford), have examined the effects of isolation on prompt photon production rates at the HERA $e - p$ collider. They provide the first fully consistent study performed completely in next-to-leading order QCD. They study particularly whether the cross section will be useful for obtaining information on the gluon content of the photon. The cross-section turns out to be hardly sensitive to the gluon distribution of the photon in the kinematically accessible range, but it depends significantly on the quark content of the photon in some regions of the kinematic variables. It is also shown that the present knowledge of the proton's parton distributions, in particular its gluon distribution, has to be improved in order to determine the photonic structure functions in this process.

(L. Gordon)

II.A.10 Aspects of Four-Jet Production in Polarized Proton-Proton Collisions

The prospects for a comprehensive program of polarized proton-proton collisions at collider energies at RHIC, using the STAR and PHENIX detectors, has motivated a large number of theoretical studies examining the spin-dependence of many standard model processes and their sensitivity to polarized parton distributions. Extending previous studies of 2- and 3-jet production, in ANL-HEP-PR-94-58 Scott Fraser (Sonoma State), Sean Fraser (Sonoma State), and Rick Robinett (on sabbatical leave at Argonne from Penn State) examined the intrinsic spin-dependence of the dominant $gg \rightarrow gggg$ subprocess contribution to 4-jet production in polarized pp collisions. Using the exact $2 \rightarrow 4$ helicity amplitudes, it was found that the partonic level, longitudinal spin-spin asymmetry $\hat{a}_{LL}$, is almost maximally large ($a_{LL} \approx 0.8 - 0.9$) in the kinematic regions probed in experiments detecting four isolated jets so that this process has a large 'analyzing power'; work on the evaluation of the spin asymmetries for the complete set of $2 \rightarrow 4$ subprocesses continues. Such events may then provide another qualitative or semi-quantitative test of the spin structure of QCD at RHIC.

(R. Robinett)

II.A.11 Polarization and Elastic pp Scattering

Elastic scattering of polarized protons on polarized sources has been of interest for over 20 years. Mysteries still remain regarding the oscillations of elastic cross sections and the double spin asymmetry A_{NN} at 90° c.m. At smaller angles and fixed t , Regge theory predicts an asymptotically vanishing polarization asymmetry. However, measured polarization asymmetries indicate that this may not be the case. This result is directly related to helicity non-conserving effects on the hadronic level. Furthermore, the applicability of perturbative calculations to elastic pp processes in these kinematic regions has been in question.

A detailed study of elastic pp amplitudes has been made by Gordon Ramsey and Dennis Sivers. In a recent Argonne preprint ANL-HEP-PR-94-69 (to be published in Physical Review D), Ramsey and Sivers report their investigation of these questions in a number of kinematic regions. They found that there is a possible connection between the oscillations in the elastic cross sections and the asymmetry A_{NN} at 90° c.m. and that there are probably two different non-perturbative mechanisms responsible for these oscillations, which interfere with the perturbatively calculated "Quark Interchange" diagrams. Analysis of the polarization observables in the hard scattering region: $m_p^2 \ll -t \ll s$ reveals that there is a specific non-zero behavior of the polarization asymmetry which can be predicted for a large range of $-t$ values, and whose form is able to reproduce existing polarization data.

Recently, there has been interest in performing polarized elastic scattering pp experiments at Fermilab and RHIC at BNL. Ramsey has outlined how the proposed experiments can test the hypotheses mentioned above in Argonne preprint ANL-HEP-PR-94-77 and in the conference report ANL-HEP-CP-94-66 (to be published in the proceedings of the XIth International Conference on High Energy Spin Physics, Bloomington, Indiana).

There is much to learn from these experiments, regarding the mechanisms which contribute to elastic polarized processes and the non-perturbative effects associated with helicity non-conservation on the hadronic level.

(G. Ramsey)

II.A.12 Cosmic Correlations

Jack Uretsky has made a proposal (PDK 608) for a novel kind of cosmic ray experiment. No funding is required and data are already available. It is proposed to search for correlations relating primary cosmic rays of very different energies, observed by detectors that are geographically widely separated. "Widely separated" in this context, means that the detectors are unlikely to see secondaries from the same atmospheric collision of a secondary. One example of a possible detector pair consists of Soudan II and an array at Notre Dame. Soudan II detects muons at a depth of about 2 km (water equivalent). The Notre Dame array detects extensive air-showers. Most of the vertical underground muons detected at Soudan II come from primaries in the 1-3 TeV range. Extensive air shower arrays, on the other hand, are sensitive to primaries with energies of the order of 100 TeV. The condition that the two detectors be sensitive to different energy primaries is accordingly well satisfied. The distance between the Soudan mine and Notre Dame is approximately 400 km. Lines of sight tangent to the earth's surface from the two detectors intersect at a height of about 15 km above the earth's surface. Assuming that most primary interactions occur below about 50

km above the earth's surface, the overlap in view from the two detectors is less than about $1/20$ sr. Given that the secondaries from a high-energy primary interaction are highly collimated in solid angle, the two detectors satisfy the criterion of being "widely separated". Detection of correlations would provide evidence of coherent transport of charged particles within the galaxy, or of magnetic anomalies in regions within the solar system.

(J. Uretsky)

II.A.13 Penetration of Muons into the Earth

The propagation of high energy muons through the earth can be described by an integro-differential equation, the form of which has been known since the 1930's. Jack Uretsky has found (PDK 569, submitted to Phys. Rev. D) a new solution of the equation that starts from a simple, and long known, "continuous" approximation that can be corrected systematically. The corrections are expressed in the form of an infinite series of modes; each mode being characterized by an inverse power of the muon energy. The correction terms describe multiple scattering from lower to higher modes, the higher the mode then the larger the number of scatterings. The form of solution accordingly has the structure of a random walk. The continuous approximation, aided by the two lowest order correction terms, is compared with data from the Soudan I experiment. The input is the primary cosmic ray flux, believed to be known to about 10% uncertainty. The calculations agree with the data to better than 50% precision over a range of about 5 orders of magnitude. Lack of precise knowledge of the density of the rock overburden in the vicinity of the Soudan mine appears to be the major source of uncertainty in the comparison with experiment.

(J. Uretsky)

II.B COMPUTATIONAL PHYSICS

The computational physics effort is devoted to numerical simulations of lattice quantum field theories, primarily of lattice quantum chromodynamics (QCD). The lattice provides the needed ultraviolet regulation of the theory and allows numerical simulations which are the only reliable way of calculating non-perturbative results from QCD. This enables one to investigate the behavior of hadronic/nuclear matter at finite temperature and finite baryon number density, and, in particular, to study the transition to a quark-gluon plasma. These calculations have relevance to the physics of the early universe, to neutron stars, and to relativistic heavy ion collisions (RHIC). In addition, lattice QCD enables us to calculate basic properties of hadrons, such as their masses and decay rates.

In collaboration with J.B.Kogut (University of Illinois) and M.-P. Lombardo (Julich), we have been studying lattice QCD at finite baryon number density (nuclear matter). This has now been extended to finite temperature as well, using the CRAY C-90's at NERSC and PSC. Our early studies of this finite temperature/finite density system have not yielded any surprises. These simulations have been performed in the quenched approximation, which neglects physics which might well be important in the finite baryon number density regime. We are, therefore, setting up to perform simulations of full QCD at finite temperature and small baryon number density. Our early studies of the complex Langevin method which we will use for these simulations, have encountered the instabilities which caused others to abandon this method. We have devised methods to avoid

these instabilities, at least for the pure gauge sector, and are porting this code to the CRAY T3D at PSC for more extensive studies.

For some time we have been involved in a project aimed at calculating the matrix elements which describe the decays of charmonium and bottomonium into light hadrons, in collaboration with G.T.Bodwin of the theory group. We had previously calculated the matrix elements describing the decays of S- and P- wave bottomonium. Since then we have been calculating the "renormalizations" required to relate these lattice matrix elements to their continuum counterparts. The S-wave renormalizations have been completed and the P-wave calculations are underway. Since the lattice spacings on the $6/g^2 = 6.0$ lattices we used for bottomonium are too small to be used for a non-relativistic treatment of charmonium, we are currently generating coarser lattices with $6/g^2 = 5.7$ (roughly twice the lattice spacing for $6/g^2 = 6.0$). These will be used to repeat the calculation for charmonium, where there is adequate data to check our predictions. This work is being performed on the CRAY C-90 at NERSC and on our Silicon Graphics Indigo work station.

We have been engaged for some time in calculating the spectrum of light hadrons in quenched QCD on $32^3 \times 64$ and $16^3 \times 64$ lattices at a lattice spacing of $\sim 0.1\text{fm}$. These simulations have been performed on the ITEL Touchstone Delta and the Intel Paragons at CCSF. The lattice quark masses used were $\sim 20\text{ MeV}$, $\sim 10\text{ MeV}$ and $\sim 5\text{ MeV}$ (to get the correct pion mass would require a quark mass in the 1-2 MeV range). For the lowest 2 quark masses, considerable finite size effects were seen. We therefore performed simulations on $24^3 \times 64$ lattices, obtaining results consistent with those of the $32^3 \times 64$ lattices, indicating that finite size effects on the pion mass are negligible for spatial boxes larger than 24^3 ($\sim (2.4\text{fm})^3$). Comparing these pion masses with the PCAC predictions, we found the first clear evidence for the logarithmic violations of PCAC, predicted from chiral perturbation theory for quenched QCD, actually exist (see Figure 32). This is important since the quenched approximation is widely used in lattice QCD. Measurements of the way in which it departs from full QCD, indicate how far we can trust the predictions of quenched QCD.

S.Kim completed work on the Gross-Neveu model at non-zero chemical potential with J.B.Kogut(Illinois) and S.Hands(Swansea) during this period. Here they were able to study the restoration of chiral symmetry for a sufficiently large chemical potential, both by direct simulation and by summing the perturbation series for large numbers of flavors. It is hoped that such model calculations will help our understanding of QCD at non-zero baryon number density.

(D. K. Sinclair, S. Kim)

Figure 32: Plot of m_{π}^2/m_q against m_{π_2} for quenched QCD at $g=1$. PCAC would predict a constant value. The curve is fit to the form predicted by quenched chiral perturbation theory.

III ACCELERATOR RESEARCH & DEVELOPMENT PROGRAM

III.A Argonne Wakefield Accelerator Program

During this reporting period the AWA wakefield accelerator activities moved from a construction phase into the initial phase of beam associated experiments. The program had overcome the problems it faced due to the bankruptcy of the rf power supply vendor in late 1992.

III.A.1 AWA Facility Status

a. Drive Linac Commissioning

Towards the end of October, 1994, we performed the first laser induced beam tests of the AWA drive gun and linac. Within minutes of turning on the rf and laser systems, the AWA was producing stable 10 nC beam pulses. Already, this placed the AWA in the category of being one of the most intense laser driven, photocathode based electron sources in operation. A few more hours of tuning resulted in 20 nC beam pulses, a value consistent with that expected from published values for the quantum efficiency of the copper cathode we were using.

Based upon recently published information, we decided to replace the copper cathode with one made of magnesium, anticipating a gain in quantum efficiency of between 10 and 20. Indeed, when we resumed tests we quickly obtained beam charges in excess of 100 nC per "pulse". However, experiments showed that the intensity of the beam was highly nonlinear with respect to the laser pulse energy incident on the photocathode. Such a phenomenon had been observed by other photocathode based gun developers, and although the exact mechanism is not understood at this time, the operating conditions under which it occurs is frequently called the "explosive emission regime".

Reducing the laser energy density on the photocathode to values below that of the explosive regime resulted in quantum efficiencies of only twice that of copper. We do not presently understand these values, but with additional experiments over the next few months we anticipate doing so.

We want it to be clear that all our measurements to date are very encouraging regarding emittance (small values are good and we measure values about half those predicted by simulations), pulse length (about that predicted), and charge (already up to 40-50% of design with no evidence that there is any limitation other than quantum efficiency).

b. Witness Beam System

Progress on building the low current witness gun and beam system has been somewhat slower than desired, mostly due to distractions in getting the rf system completed and in developing some of the more complicated beam line designs. A several week delay was also caused by a mishap during shipment of rf cavity cells to the company that does the vacuum brazing. One of the cells was damaged beyond repair and it was necessary for us to have a new one machined at ANL. Those problems are now in the past, and progress in fabricating the gun system should accelerate.

The new beam line system design is very flexible and convenient. It will provide relatively simple control of the displacement and angle of the witness beam relative to the drive beam, a

feature important for coupled wake tube experiments.

III.A.2 Experiments and New Ideas

a. Plasma Based Experiments

The UCLA plasma cell and associated equipment was moved into the drive beam for a few days of preliminary tests to check out some new diagnostic devices. Although some of the optical transition radiation (OTR) based diagnostics has not yet functioned as planned, "auto acceleration" of the single pulse beam was observed. This effect occurs when the tail-end of a beam pulse is accelerated by the wake of the head-end part to energies higher than that of the initial beam. Analysis of the data is now proceeding.

b. Dielectric Based Experiments

Several single beam experiments are designed and will be done prior to having the witness beam system in place. The basis for these experiments is to confirm experimentally the large predicted rf power flow and to test coupling device designs. It should also be possible to test dielectric loaded lines for breakdown problems, albeit for short lengths due to the relatively low energy (< 20 MeV) of Phase-I of the AWA.

c. New Ideas

In addition to acceleration concepts based on dielectric loaded guides and on plasma, we consider other "advanced schemes". Recently, this has included that of using direct laser excitation of modes in both cylindrical and planar geometries using dielectric boundaries. The possibility of macroscopic tests, using extremely high frequency rf waves for excitation, is being contemplated.

(J. Simpson)

III.B High Resolution Profile Monitor Development

We have recently completed a test run of the high resolution profile monitor hardware at the MIT/Bates linac using an 800 MeV electron beam. The electrons were used to produce a beam of bremsstrahlung photons, which was collimated down to a height of $25\text{ }\mu\text{m}$. The profile of this beam was then measured, along with detection efficiencies and backgrounds for the apparatus. The overall setup is shown in Figure 33

The experiment was set up in a specially built extension of the 14° line beyond the normal beam dump. The final exit window of the vacuum pipe and a scintillation screen were used as a bremsstrahlung target 0.0019 radiation lengths thick. About 6 m downstream of the bremsstrahlung source, a narrow beam was produced by a slit of two precision ground tungsten blocks separated with $25\text{ }\mu\text{m}$ aluminum shims. The collimators were mounted downstream on precision optical mounts, 1.4 m apart and about 4 m downstream of the tungsten block slit. Photons were detected using a 4 radiation length tungsten converter to produce electron, positron pairs from photons, followed by 10 cm of air to produce Čerenkov light from the pairs. A periscope with mirror optics relayed the image produced at the converter to the image intensified camera. The computer which controlled the experiment was located in a nearby experimental hall.

Figure 33: The test setup at the MIT/Bates linac for the high resolution profile monitor.

The experiment was able to measure the profile of the γ beam in steps of $8 \mu\text{m}$ by moving the first, single sided collimator through the beam while recording the intensity of detected photons, (Figure 34). In addition, by orienting the axis of the camera perpendicular to the photon beam it was possible to measure the transverse dimensions of the effective photon source at the converter and backgrounds from all sources, (Figure 35). Most of the background seemed to be coming from the primary collimator.

The next step is to try the technique at SLAC. We are now constructing optics and vacuum chambers for collimators in the dump line of the Final Focus Test Beam. These chambers will incorporate apparatus to insert and retract the collimators as well as control the position to about $0.1 \mu\text{m}$. In this test it should be possible to measure beams with a resolution of 30 nm .

(J. Norem)

Figure 34: Photon beam intensity profile

Figure 35: Photon beam transverse dimensions

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 Laboratory (LBL). I describe briefly some PASS activities in which ANL staff had the principle rôle or made important contributions.

The PASS architecture model makes extensive use of the OMG CORBA protocols; we have obtained the IBM version of these (DSOM) and have begun testing and developing "toy" codes to check the features and to determine how much of the PASS model can be developed in the DSOM environment. We had a three day workshop with the LBL people to formulate a "persistence" strategy for PASS data objects and query services within the OMG Corba protocol framework.

We have continued development of the ANL version on the PTool code system for use and testing on the ANL IBM SP-1 facility. The code was revised to provide a more unified interface to the wide variety of storage schemes and with an eye toward making it more consistent with an OMG Corba API. We have performed a series of client-server type performance studies with our standard physics query to the 7 GB CDF data store used in the Mark 1 test at SSCL to explore the rather wide variety of network and storage devices on the ANL IBM SP-1. The best performance is achieved when using our own server codes, rather than relying on I/O services provided by the Unitree storage server, which is limited to IP over the slow ethernet. Two theoretical analysis reports were completed: "Object Cluster Trade-offs for Data Mining Queries" and "Notes on Stripping Persistent Data Segments on the SP System".

We have continued our cooperative project with the Fermilab computing division group "High Performance Parallel Computing" HPPC and "Computing and Analysis for Physics" CAP meeting at Fermilab with ANL and UIC approximately once a week during the summer and fall of 1994. A design consistent with the requirements of the D0/CAP data store was completed; coding, testing and debugging were begun. The design was a client-server system based on a modified version of the UIC PTool using the ANL P4 communications package running on the ip network over the TB2 switch in a 24 node SP-1 at Fermilab. The Fermilab CLUBS group will do the interface to the Unitree hierarchical storage system. In addition, we have run a test of the ANL version of PTool on the CAPs system, with the CDF data stored in the CLUBS Unitree storage system and observed a throughput of 0.52 MB/sec. The limitation appears to be in the IBM tape robot system, for which there is very little user level optimization available.

We expect the PASS system to work in both a local and wide-area network environments. To this end we have continued to be a test site of fiber channel and ATM advanced networks. The PASS IBM workstation was upgraded with a new fiber channel interface and new driver software, and is now considerably more reliable. An ATM interface was installed in the PASS Sun workstation. New video-teleconferencing equipment was installed and tested on the Sun workstation. A number

of successful workstation video teleconference tests were completed with CERN and Fermilab. A WWW server was established on the Sun workstation to provide access to PASS documentation and information.

(E. May)

V PUBLICATIONS

A. Journal Publications, Conference Proceedings, Books

A Multi-Level Object Store and Its Application to HEP Data Analysis

E. May, D. Lifka, D. Malon (ANL) *et al.*

Proceedings of Computing in High Energy Physics '94, LBL, edited by S. Loken, 236 (1994)

A Tau-Charm Factory at Argonne

J. Norem and J. Repond (ANL)

Proceedings of the CHARM2000 Workshop, Batavia, IL, edited by D. Kaplan, S. Kwan, 135 (1994)

Analysis of the High Energy Behavior of the Forward Scattering Parameters -- σ_{tot} , ρ , and B

A. White (ANL), M.M. Block, *et al.*

Proceedings of Multiparticle/93 Conference, Aspen, CO, edited by M.M. Block and A.R. White, 373 (1994)

Automatic Scanning and Measuring Using POLLY

T. Fields (ANL)

Bubbles 40, Nucl. Phys B (Proc. Suppl.) 36, 521 (1994)

Bubble Chamber Measurements of Cascade Times in Mesic Atoms

T. Fields (ANL)

Bubbles 40, Nucl. Phys B (Proc. Suppl.) 36, 523 (1994)

Comparison of Energy Flows in Deep Inelastic Scattering Events with and without a Large Rapidity Gap

M. Derrick, D. Krakauer, S. Magill, B. Musgrave, J. Repond, J. Schlereth, R. Stanek, R. Talaga, J. Thron (ANL) and the ZEUS Collaboration
Phys. Lett B 338, 483 (1994)

Elastic Spin Observables and Proton Wave Function Normalization at Large t''

G. Ramsey (ANL)

Proceedings of the V Int'l. Wkshp. in High Energy Spin Physics, Protvino, Russia, 161 (1994)

Evidence for Top Quark in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV

R. Blair, K. Byrum, T. Fuess, S. Kuhlmann, L. Nodulman, J. Proudfoot, R. Wagner, A. Wicklund (ANL) and the CDF Collaboration
Phys. Rev. Lett, V73, p 225 (1994)

Experiments to Measure the Gluon Helicity Distribution in Protons

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

Proceedings on Future Directions in Particle and Nuclear Physics at Multi-GeV Hadron Beam Facilities, Brookhaven, Upton, NY, edited by D.F. Geesaman, 223 (1994)

Giant Chambers

M. Derrick (ANL)

Bubbles 40, Nucl. Phys B (Proc. Suppl.) 36, 177 (1994)

Looking for the Logarithms in Four-Dimensional Nambu-Jona-Lasinio Models

S. Kim (ANL), A. Kocic and J. Kogut (U. of IL-Urbana)
Nucl. Phys. B 429, 407 (1994)

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

G.T. Bodwin, S. Kim, and D.K. Sinclair (ANL)

Nucl. Phys. B (Proc. Suppl.) 34, 432 (1994)

Measurement of Drell-Yan Electron and Muon Pair Differential Cross Sections in $\bar{p}p$ Collisions at

$\sqrt{s} = 1.8$ TeV

R. Blair, K. Byrum, T. Fuess, S. Kuhlmann, W. Li, L. Nodulman, J. Proudfoot,

D. Underwood, R. Wagner, A. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. D, V49, 1 (1994)

Measurement of Small Angle Antiproton-Proton Elastic Scattering at $\sqrt{s} = 546$ and 1800 GeV

R. Blair, K. Byrum, T. Fuess, S. Kuhlmann, W. Li, L. Nodulman, J. Proudfoot,

D. Underwood, R. Wagner, A. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. D, V50, 5518 (1994)

Measurement of Total and Partial Photon Proton Cross Sections at 180 GeV Center of Mass Energy

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

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

Zeitschrift fur Physik C63, 391 (1994)

Measurement of the B meson and b Quark Cross Sections at $\sqrt{s} = 1.8$ TeV Using the Exclusive

Decay $B^0 \rightarrow J/\psi K(892)^0$

R. Blair, K. Byrum, T. Fuess, S. Kuhlmann, W. Li, L. Nodulman, J. Proudfoot,

D. Underwood, R. Wagner, A. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. D V50, 4252 (1994)

Measurement of the Longitudinal Spin-Dependent Neutron-Proton Total Cross-Section Difference

$\Delta\sigma_L$ (np) between 500 and 800 MeV

M. Beddo, D. Grosnick, D. Hill, D. Lopiano, H. Spinka, R. Stanek, D. Underwood,

A. Yokosawa (ANL) *et al.*

Phys. Rev. D 50, 104 (1994)

Observation of Jet Production in Deep Inelastic Scattering with a Large Rapidity Gap at HERA

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

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

Phys. Lett B 332, 228 (1994)

Parallel Query Processing for Event Store Data

D. Malon, D. Lifka, E. May (ANL) *et al.*

Proceedings of Computing in High Energy Physics '94, LBL, edited by S. Loken, 239 (1994)

Precision Measurement of the Prompt Photon Cross Section in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV

R. Blair, K. Byrum, D. Crane, T. Fuess, S. Kuhlmann, L. Nodulman, J. Proudfoot,

R. Wagner, A. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. Lett., v73, 2662 (1994)

Rescattering and Energy Loss of Fast Partons in Nuclear Matter

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

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

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

R. Blair, K. Byrum, D. Crane, T. Fuess, S. Kuhlmann, L. Nodulman, J. Proudfoot,

R. Wagner, A. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. Lett., V73, 2667 (1994)

The $O(g^4)$ Lipatov Kernels

A. White (ANL)

Phys Lett B 334, 87 (1994)

The PASS Project: A Progress Report

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

Proceedings of Computing in High Energy Physics '94, LBL, edited by S. Loken, 229 (1994)

The PASS Project Architectural Model

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

Proceedings of Computing in High Energy Physics '94, LBL, edited by S. Loken, 233 (1994)

The Three Loop Equation of State of QED at High Temperature

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

Phys. Rev. Lett. 73, 2398 (1994)

W Boson + Jet Angular Distribution in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

R. Blair, K. Byrum, D. Crane, T. Fuess, S. Kuhlmann, L. Nodulman, J. Proudfoot,

R. Wagner, A. Wicklund (ANL) and the CDF Collaboration

Phys. Rev. Lett., v73, 2296 (1994)

B. Papers Submitted for Publication and ANL Reports

Ultra High Energy Cosmic Ray Composition from Surface Air Shower and Underground Muon Measurements at Soudan 2

I. Ambats, D. Ayres, L. Balka, W. Barrett, J. Dawson, T. Fields, M. Goodman, N. Hill,

J. Hofteizer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth, J. Thron,

J. Uretsky (ANL) and the Soudan 2 Collaboration

ANL-HEP-PR-94-45

Submitted to Phys. Rev. D

The Phases and Triviality of Scalar Quantum Electrodynamics

S. Kim (ANL), *et al.*

ANL-HEP-PR-94-47

Submitted to Phys. Rev. D

The Atmospheric Neutrino Anomaly in Soudan 2

M. Goodman, I. Ambats, D. Ayres, L. Balka, W. Barrett, J. Dawson, T. Fields, N. Hill,

J. Hofteizer, D. Jankowski, F. Lopez, E. May, L. Price, J. Schlereth, J. Thron,

J. Uretsky (ANL) and the Soudan 2 Collaboration

ANL-HEP-PR-94-56

Submitted to Nucl. Phys. B Proceedings Supplements Section

The Dilepton-Production Cross Section in Principal Value Resummation

H. Contopanagos (ANL) and L. Alvero (SUNY)

ANL-HEP-PR-94-59

Submitted to Nucl. Phys. B

Preservation of Proton Polarization by a Partial Siberian Snake

H. Huang, M. Beddo, D. Grosnick, D. Lopiano, H. Spinka, D. Underwood,

A. Yokosawa (ANL) *et al.*

ANL-HEP-PR-94-64

Submitted to Phys. Rev. Lett

A Scheme for Radiative CP Violation

W.-Y. Keung, D. Chang (ANL)

ANL-HEP-PR-94-65

Submitted to Phys. Rev. Lett.

NN Scattering Amplitudes from 90° C.M. into the Landshoff Region

G. Ramsey (ANL) and D. Sivers (Portland Phys. Inst.)

ANL-HEP-PR-94-69

Submitted to Phys. Rev. D

A New Parametrization of the Ambiguous Large Higgs-Mass Effects

S. Kyriazidou (ANL)

ANL-HEP-PR-94-83

Submitted to Phys. Lett. B

The Spectrum of the $O(g^4)$ Scale-Invariant Lipatov Kernel

C. Coriano and A. White (ANL)

ANL-HEP-PR-94-84

Submitted to Phys. Rev. Lett.

Beam Profile Measurements Using Nonimaging Gamma Optics

J. Norem, J. Dawson, W. Haberichter, R. Lam, L. Reed, X-F Yang (ANL) and

J. Spender (Stanford)

ANL-HEP-PR-94-93

Submitted to Nucl. Instru. and Methods

The ZEUS Calorimeter First Level Trigger

J. Dawson, D. Krakauer, J. Schlereth, R. Talaga, (ANL) *et al.*

ANL-HEP-PR-94-96

Submitted to Nucl. Instru. and Methods

Observation of Hard Scattering in Photoproduction Events with a Large Rapidity Gap at HERA

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

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

ANL-HEP-PR-94-97

Submitted to Phys. Rev. Lett.

A Search for Excited Fermions in Electron-Proton Collisions at HERA

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

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

ANL-HEP-PR-94-98

Submitted to Zeitschrift fur Physik

Inclusive Jet Differential Cross Sections in Photoproduction at HERA

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

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

ANL-HEP-PR-94-99

Submitted to Phys. Rev. Lett.

Extraction of the Gluon Density of the Proton at Small x

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

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

ANL-HEP-PR-94-100

Submitted to Phys. Rev. Lett.

Measurement of the Proton Structure Function F_2 from the 1993 HERA Data
M. Derrick, D. Krakauer, S. Magill, B. Musgrave, J. Repond, J. Schlereth, R. Stanek,
R. Talaga, J. Thron (ANL) and the ZEUS Collaboration
ANL-HEP-PR-94-101
Submitted to Zeitschrift fur Physik

C. Papers or Abstracts Contributed to Conferences

New Shower Maximum Trigger for Electrons and Photons at CDF
K. Byrum, J. Dawson, L. Nodulman, A. Wicklund (ANL), *et al.*
ANL-HEP-CP-94-43
Submitted to DPF '94

New Strong Interactions above the Electroweak Scale
A. White (ANL)
ANL-HEP-CP-94-46
To appear in the 8th International Symposium on Very High Energy Cosmic Ray
Interactions, Tokyo, Japan

Higher-Order Lipatov Kernels and the QCD Pomeron
A. White (ANL)
ANL-HEP-CP-94-49
To appear in the Proceedings of the XVII Kazimierz Meeting on Elementary Particle Physics,
in Kazimierz, Poland

Electroweak Physics from the Tevatron
L. Nodulman (ANL)
ANL-HEP-CP-94-51
To appear in the Proceedings of the Tennessee International Symposium on
Radiative Corrections: Status and Outlook, Gatlinburg, Tennessee

The Free Energy of Hot QED at Three and a Half Loops
C. Coriano (ANL), R. Parwani, (Saclay)
ANL-HEP-CP-94-52
To appear in Proceedings of the Workshop of Quantum Infrared Physics, Paris, France

Principal-Value Resummation for Dilepton Production
H. Contopanagos (ANL), L. Alvero, G. Sterman, (SUNY)
ANL-HEP-CP-94-53
Submitted to DPF '94

A Possible Method to Produce a Polarized Antiproton Beam at Intermediate Energies
H. Spinka, E. Vannndering, J. Hofmann (ANL)
ANL-HEP-CP-94-62
Submitted to Proceedings of SPIN '94, Indiana Univ., Bloomington, IN

Measurements of $\Delta\sigma_L$ (pp) and $\Delta\sigma_L$ ($\bar{p}p$) at 200 GeV/c
D. Grosnick (ANL)
ANL-HEP-CP-94-63
Submitted to Proceedings of SPIN '94, Indiana Univ., Bloomington, IN

Polarization and N-N Elastic Scattering Amplitudes
G. Ramsey (ANL)
ANL-HEP-CP-94-66
Submitted to Proceedings of SPIN '94, Indiana Univ., Bloomington, IN

Proton-Proton Interactions Using the RHIC Polarized Collider

A. Yokosawa (ANL)

ANL-HEP-CP-94-68

Submitted to Proceedings of XII Int'l. Seminar on High Energy Physics Problems
JINR, Dubna, Russia

Sea and Gluon Spin Structure Function Measurements at RHIC

A. Yokosawa

ANL-HEP-CP-94-70

Submitted to Proceedings of SPIN '94, Indiana Univ., Bloomington, IN

Electroweak Boson Pair Production in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV

T. Fuess (ANL)

ANL-HEP-CP-94-71

Submitted to DPF '94

Neutrino Oscillation Experiments with Atmospheric Neutrinos

M. Goodman (ANL) and T. Gaisser (Univ. of Delaware)

ANL-HEP-CP-94-72

Submitted to Snowmass '94 - Particle and Nuclear Astrophysics and Cosmology in the
Next Millennium

A Review of High Energy Polarimetry, With a View Toward RHIC

D. Underwood (ANL)

ANL-HEP-CP-94-75

Submitted to Proceedings of SPIN '94, Indiana Univ., Bloomington, IN

New Results in Nucleon-Nucleon Scattering at Intermediate Energies

H. Spinka (ANL)

ANL-HEP-CP-94-76

Submitted to Proceedings of SPIN '94, Indiana Univ., Bloomington, IN

Using Spin to Probe Hadronic Structure

G. Ramsey (ANL)

ANL-HEP-PR-94-77

Submitted to Particle World

The STAR EM Calorimeter Design and Small Prototype Test Results

D. Underwood (ANL) for the STAR EMC Collaboration

ANL-HEP-CP-94-78

Submitted to the Proceedings of the V Int'l. Conference on Calorimetry in High Energy
Physics, Brookhaven National Laboratory, Upton, NY

Scale-Invariant Lipatov Kernels from t-Channel Unitarity

C. Coriano and A. White (ANL)

ANL-HEP-CP-94-79

Submitted to the Proceedings of the XXIV Int'l. Symposium on Multiparticle Dynamics,
Vietri sul Mare, Italy

The High Energy Behavior of the Forward Scattering Parameters-- σ_{tot} , ρ , and B

A. White (ANL), *et al.*

ANL-HEP-CP-94-81

Submitted to the Proceedings of the XXIV Int'l. Symposium on Multiparticle Dynamics,
Vietri sul Mare, Italy

Long-Baseline Neutrino Oscillation Experiments

D. Crane and M. Goodman (ANL)

ANL-HEP-CP-94-82

Submitted to Snowmass '94 - Particle and Nuclear Astrophysics and Cosmology in the Next Millennium

Test of a ZEUS BCAL Module Including Presampler and Shower Max Detector in a Low Energy Beam

D. Mikunas (ANL)

ANL-HEP-CP-94-85

Submitted to the Proceedings of the V Int'l. Conference on Calorimetry in High Energy Physics, Brookhaven National Laboratory, Upton, NY

Decays Rates for S- and P-Wave Bottomonium

G. Bodwin, S. Kim, and D. Sinclair (ANL)

ANL-HEP-CP-94-91

Submitted to the Proceedings of LATTICE'94, Bielefeld, Germany

Lattice QCD Calculation Using VPP500

S. Kim (ANL) and S. Ohta (RIKEN)

ANL-HEP-CP-94-92

Submitted to the Proceedings of LATTICE'94, Bielefeld, Germany

D. Technical Notes

Thermal Effects on the STAR Electromagnetic Calorimeter

T. Fornek, V. Guarino, H. Spinka, and D. Underwood (ANL)

ANL-HEP-TR-94-42 and Star Note 177

Argonne Mechanical Design Proposal for the ATLAS Hadron Calorimeter

N. Hill (ANL)

ANL-HEP-TR-94-48

Unbinned Maximum Likelihood Fit for the CP Conserving Couplings for W+ Photon Production at CDF

R. Wagner (ANL) and K. Lannon (St. Norbert College)

ANL-HEP-TR-94-57

High Energy Physics Division Semiannual Report of Research Activities (January 1-June 30, 1994)

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

ANL-HEP-TR-94-60

Tests of Adhesives Used for Plate Bonding for Atlas Tile-Cal Hadron Calorimeter

N. Hill and L. Kocenko (ANL)

ANL-HEP-TR-94-86

Support Girder Design for the Atlas Hadron Calorimeter

N. Hill, V. Guarino, E. Petereit

ANL-HEP-TR-94-87

AGN-29

Simulation of AWA Modulators PFN Regulation

J. Simpson

AGN-30

OTR Basics

M. Conde

CDF-2922

PTW Skew in the W Mass Analysis

L. Nodulman (ANL), *et al.*

- CDF-2905 WW,WZ in Leptons Plus Jets Mode, Continued
T. Fuess, C.Wendt
- CDF-2899 Determination of CDF Inner Detector Materials Using Conversion
Electrons
A. Wicklund
- CDF-2822 Charmonium Production, b Quark and B Meson Production and $\bar{b}$
Correlations at CDF"
K. Byrum, and the CDF Collaboration
- CDF-2806 Easy Access Tool for Ymon Slide Files
L. Nodulman
- CDF-2800 Perturbative QCD Tests from the LEP, HERA, and Tevatron Colliders
S. Kuhlmann
- CDF-2795 Shower Maximum Trigger for Electrons and Photons at CDF
K. Byrum, J. Dawson, L. Nodulman, A. Wicklund (ANL), *et al.*
- CDF-2772 Form Factor Scales for 1992-93 $W\gamma/Z\gamma$ Analyses
R. Wagner (ANL), *et al.*
- CDF-2758 Electroweak Physics at the Tevatron Collider
L. Nodulman, and the CDF Collaboration
- CDF-2757 Electroweak Boson Pair Production in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV
T. Fuess, and the CDF Collaboration
- CDF-2752 Electron Based Curvature Corrections for W Mass Tracking
L. Nodulman
- CDF-2740 New Shower Maximum Trigger for Electrons and Photons at CDF
K. Byrum, J. Dawson, L. Nodulman, A. Wicklund, and the CDF
Collaboration
- CDF-2627 The Diphoton Production Rate in $\bar{p}p$ Collisions at $\sqrt{s} = 1800$ GeV
R. Blair, and the CDF Collaboration
- NuMI-1 Bibliography of notes before 1994 related to NuMI projects
G. Koizumi and M. Goodman
- NuMI-L-8 Expression of interest for a long-baseline neutrino oscillation
experiment from Fermilab to Soudan using a 16 kT iron calorimeter
(PDK-587, May 16, 1994)
M. Goodman, *et al*
- NuMI-L-12 List of transparencies from the long baseline neutrino and atmospheric
neutrino sessions at Snowmass
M. Goodman
- NuMI-L-17 Unofficial notes on the Long Baseline Collaboration meeting at Fermilab
(PDK-599, August 12-13, 1994)
D. Ayres

NuMI-B-27	Long Baseline Neutrino Beam Calculations (30 September 1994) B. Blair, M. Goodman, and P. Job
NuMI-L-30	List of transparencies from the 1-2 October 1994 Long Baseline Collaboration Meeting at Fermilab M. Goodman
NuMI-L-32	Unofficial notes on the Long Baseline Collaboration Meeting at Fermilab, October 1-2, 1994 D. Ayres
NuMI-B-35	Studies of Decay Pipe Radius and Length for the NuMI Neutrino Beam D. Crane
NuMI-B-38	Minutes of the Beam Meeting of 10/28/94 (and a primer on Horn Design from Alan Ball) M. Goodman
NuMI-L-48	Unofficial Notes on the Long Baseline Collaboration Meeting at Fermilab, December 3-4, 1994 D. Ayres
PDK-593	Soudan 2 Experiment Quarterly Status Report D. Ayres
PDK-598	Summary of the CEV Meeting R. Seidlein
PDK-603	Soudan 2 Experiment Quarterly Status Report (July-September 1994) D. Ayres
PDK-604	Decisions of Argonne Collaboration Meeting D. Ayres
PDK-606	Summary File for the CEV Analysis R. Seidlein
PDK-608	Cosmic Correlations J. Uretsky
PDK-610	Soudan 2 Experiment Quarterly Status Report (October - December 1994) D. Ayres
WF-174	Externally Powered Dielectric Loaded Wave Guides as Accelerating Structures J. Simpson
WF-176	Numerical Simulations of Intense Charged Particle Beam Propagation in a Dielectric Wake Field Accelerator W. Gai
ZEUS 94-051	An Electron Energy Correction Method: A Preliminary Implementation and Its Effect on the F2 Measurement D. Krakauer <i>et al.</i>
ZEUS 94-130	Calorimeter Calibration Triggers in the ZEUS Luminosity Run J. F. Zhou and D. Krakauer
ZEUS 94-137	Direct Measurement of the Gluon Density of the Proton at Large x J. Repond

VI COLLOQUIA AND CONFERENCE TALKS

E. Berger

"Dynamics of Bottom Quark Production"

Theoretical Physics Seminar

Physics Department

Iowa State University, Ames (1994)

"Bottom Quark Physics — Cross Sections, Correlations, and Asymmetries"

Second International Workshop on Heavy Quark Physics (HQ'94)

University of Virginia, Charlottesville (October 1994)

R. Blair

"The Diphoton Production Rate in $\bar{p}p$ Collisions at $\sqrt{s} = 1800$ GeV"

8th Meeting of the DPF of APS

University of New Mexico, Albuquerque (August 1994)

K. Byrum

"Charmonium Production, b Quark and B Meson Production and $\bar{b}$ Correlations at CDF"

27th International Conference on High Energy Physics

Glasgow, Scotland (July 1994)

D. Crane

"Long Baseline Neutrino Oscillations"

Fermi National Acceleratory Laboratory, Batavia, Illinois (1994)

M. Derrick

"Physics with High Energy Electron-Proton Colliding Beams"

Freiburg University, Freiburg, Germany (1994)

Physics Colloquium, Argonne National Laboratory, Argonne (1994)

T. Fields

"Parton Scattering in Nuclear Matter"

Fermi National Acceleratory Laboratory, Batavia, Illinois (1994)

T. Fuess

"Electroweak Boson Pair Production in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV"

8th Meeting of the DPF of APS

University of New Mexico, Albuquerque (August 1994)

M. Goodman

"Neutrino Oscillations"

Snowmass Meeting on Particle and Nuclear Astrophysics
Snowmass, Colorado (1994)

"The Atmospheric Neutrino Oscillation Hint"

Physics Department Colloquium
Rutgers University, Piscataway, New Jersey (1994)

"Prospects for Long Baseline Neutrino Oscillation Experiments"

Physics Department Colloquium
Rutgers University, Piscataway, New Jersey (1994)

D. Grosnick

"Measurements of $\Delta\sigma_L(pp)$ and $\Delta\sigma_L(\bar{p}p)$ at 200 GeV/c"

SPIN '94, Indiana University, Bloomington (September 1994)
Los Alamos National Laboratory, Los Alamos, New Mexico (1994)

L. Nodulman

"Report on the Radiative Correction Conference / Tevatron Electroweak Physics"

High Energy Physics Division Seminar
Argonne National Laboratory (1994)

J. Norem

"Report on the Sausalito $\mu - \mu$ Collider Conference"

High Energy Physics Division Seminar
Argonne National Laboratory (1994)

J. Repond

"A Tau-Charm Factory at Argonne"

Workshop on the Tau-Charm Factory in the Era of *B*-Factories and CESR, Stanford Linear Accelerator Center, Palo Alto, California (August 1994)
Physics Division Seminar, Argonne National Laboratory, Argonne, Illinois (1994)
Physics Department Seminar, University of Iowa, Iowa City (1994)
Physics Department Seminar, University of Illinois, Chicago (1994)
Town Meeting on Nuclear Physics, Argonne National Laboratory, Argonne, Illinois (1994)

H. Spinka

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

SPIN '94 Conference
Indiana University, Bloomington (September 1994)

"Dibaryons — A Status Report"

Seminar at Indiana University Cyclotron Facility, Bloomington (1994)

"New Results in Nucleon-Nucleon Scattering at Intermediate Energies"

SPIN '94 Conference
Indiana University, Bloomington (September 1994)

A. White

"Higher-Order Lipatov Kernels"

Summer Institute on QCD, Gran Sasso, Italy (1994)

XXIVth International Symposium on Multiparticle Dynamics, Vietri sul Mare, Italy
(September 1994)

2nd Workshop on Small- x and Diffractive Physics at the Tevatron, Fermilab,
Batavia, Illinois (September 1994)

"The QCD Pomeron and Small- x Physics"

Theory Seminar, Northwestern University, Evanston, Illinois (1994)

Joint Experimental/Theoretical Physics Seminar, Fermilab, Batavia, Illinois (1994)

A. Yokosawa

"Proton-Proton Interactions Using the RHIC Polarized Collider"

XIIth International Seminar on High Energy Problems
Dubna, Russia (September 1994)

"Sea and Gluon Spin Structure Function Measurements at RHIC"

SPIN '94 Conference

Indiana University, Bloomington (September 1994)

C. Zachos

"Bosonization without Fermions"

Osaka University, Osaka, Japan (1994)

"Canonical and Non-canonical Transformations in Field Theory"

FIHS, Kyoto University, Kyoto Japan (1994)

"The Paradigm of Pseudodual Chiral Models and Duality"

Yukawa Institute for Theoretical Physics, Kyoto, Japan (1994)

VII HIGH ENERGY PHYSICS COMMUNITY ACTIVITIES

E. Berger

Chairman, Committee on Meetings, American Physical Society (1994)

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

Member, APS Division of Particles and Fields Working Group on "Structural Issues" (1994)

Member, U.S. contact person, Scientific Program Committee, XXX Rencontre de Moriond, "QCD and High Energy Hadronic Interactions", Les Arcs, France, to be held in March 1995

Member, Local Organizing Committee, 10th Topical Workshop on Proton-Antiproton Collider Physics, Fermilab, to be held in May 1995

Member, American Physical Society Task Force on Meetings (1994)

Chairman, Argonne National Laboratory Director's Review Committee for Individual Investigator Laboratory Directed Research and Development Program (1994-1995)

E. May

Technical Group Member of the DOE "Remote Conferencing Working Group" (1994)

L. Nodulman

Member, Ph. D. Thesis Committee for David Saltzberg, University of Chicago (1994)

J. Simpson

Co-Chair, Organizing Committee for the 6th Workshop on Advanced Accelerator Concepts (1994)

Member, Program Committee for the 1995 PAC Meeting

Member, American Physical Society Division of Particle Beams Fellowship Committee (1994)

A. White

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

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

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

C. Zachos

Member, Editorial Board of the Journal of Physics A: Mathematical and General Physics

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

E. May

R. Blair

B. Musgrave

K. Byrum

L. Nodulman

D. Crane

J. Proudfoot

M. Derrick

J. Repond

T. Fields

R. Seidlein

T. Fuess

H. Spinka

M. Goodman

R. Stanek

D. Grosnick

R. Talaga

T. Kirk

J. Thron

D. Krakauer

D. Underwood

S. Kuhlmann

R. Wagner

D. Lopiano

A. B. Wicklund

S. Magill

A. Yokosawa

Theoretical Physicists

E. Berger

S.-Y. Kim

G. Bodwin

D. Sinclair

H. Contopanagos

A. White

C. Coriano

C. Zachos

L. Gordon

Engineers, Computer Scientists, and Applied Scientists

E. Chojnacki

N. Hill

J. Dawson

J. Nasiatka

V. Guarino

J. Schlereth

W. Haberichter

X. Yang

Technical Support Staff

I. Ambats

T. Kasprzyk

L. Balka

L. Kocenko

H. Blair

D. Konecny

G. Cox

R. Rezmer

D. Jankowski

Laboratory Graduate Participants

C. Allgower

H. Huang

N. Barov

D. Mikunas

H. Gallagher

J. Power

M. Hohlmann

H. Zhang

Visiting Physicists

D. Chang(Theory)

R. Robinett(Theory)

M. Conde(AWA)

M. Samuel(Theory)

A. Davidenko(STAR)

K. Shestermanov(STAR)

X. Guo(Theory)

J. Uretsky(Theory/Soudan)

G. Ramsey(Theory)